UNDERSTANDING THE NATIONAL ELECTRICAL CODE®

2023 GUIDE

ARTICLES 90 - 480

RESIDENTIAL

COMMERCIAL

INDUSTRIAL

A COMPREHENSIVE STUDY OF EMERGING ELECTRICAL SOLUTIONS

Michael Hamilton

THE ULTIMATE GUIDE TO ELECTRICAL SAFETY AND COMPLIANCE

TABLE OF CONTENTS

About This Textbook xv

Additional Products to Help You Learn xviii

How to Use the *National Electrical Code* 1

Article 90—Introduction to the *National Electrical Code* 7

90.1 Purpose of the *NEC* 7
90.2 Scope of the *NEC* 8
90.3 *Code Arrangement* 11
90.4 Enforcement 12
90.5 Mandatory Requirements and Explanatory Material 13
90.7 Examination of Equipment for Product Safety 14

Article 90—Practice Questions 15

CHAPTER 1—GENERAL RULES 19

Article 100—Definitions 21

100 Definitions 21

Article 110—Requirements for Electrical Installations 65

Part I. General Requirements 65

110.1 Scope 65
110.2 Approval of Conductors and Equipment 65
110.3 Use and Product Listing (Certification) of Equipment 66
110.4 Voltage Rating of Electrical Equipment 66
110.5 Conductor Material 66
110.6 Conductor Sizes 67
110.7 Wiring Integrity 67
110.8 Suitable Wiring Methods 67
110.9 Interrupting Rating (Overcurrent Protective Devices) 68
110.10 *Equipment Short-Circuit Current Rating* 68
110.11 Deteriorating Agents 69
110.12 *Mechanical Execution of Work* 70
110.13 *Mounting and Cooling of Equipment* 72
110.14 *Conductor Termination and Splicing* 72
110.15 *High-Leg Conductor Identification* 79
110.16 *Arc Flash Hazard Warning* 80
110.21 *Markings* 81
110.22 *Identification of Disconnecting Means* 82
110.24 *Available Fault Current* 83
110.25 Lockable Disconnecting Means 83

Part II. 1,000V, Nominal, or Less 84

110.26 Spaces About Electrical Equipment 84
110.28 Enclosure Types 92

Chapter 1—Practice Questions 95

CHAPTER 2—WIRING AND PROTECTION 101

Article 200—Use and Identification of Grounded Conductors 103

200.1 Scope 104
200.2 General 104
200.4 Neutral Conductor 104
200.6 Identification of Grounded Conductors 105
200.7 Use of White or Gray Color 107
200.9 Means of Identification of Terminals 108
200.10 Identification of Terminals 108

Article 210—Branch Circuits 109

Part I. General Provisions 109

210.1 Scope 109
210.3 Other Articles 110
210.4 Multiwire Branch Circuits 110
210.5 Identification for Branch Circuits 112
210.7 Multiple Branch Circuits 114
210.8 GFCI Protection 114
210.11 Branch Circuits Required 121
210.12 Arc-Fault Circuit-Interrupter Protection 123

Part II. Branch-Circuit Ratings 124

210.18 Branch-Circuit Rating 124
210.19 Conductor Sizing 125
210.20 Overcurrent Protection 128
210.21 Receptacle Rating 129
210.23 Permissible Loads, Multiple-Outlet Branch Circuits 130

Part III. Required Outlets 130

210.50 Receptacle Outlets 130
210.52 Dwelling Unit Receptacle Outlet Requirements 131
210.60 Receptacles in Guest Rooms, Guest Suites, Dormitory Units, and Similar Occupancies 138
210.63 Equipment Requiring Servicing 139

Article 215 Table of Contents

210.65 Meeting Rooms 140
210.70 Lighting Outlet Requirements 141

Article 215—Feeders 145
215.1 Scope 145
215.2 Conductor Sizing 145
215.3 Overcurrent Protection Sizing 150
215.10 Ground-Fault Protection of Equipment 151
215.12 Conductor Identification 151

Article 220—Branch-Circuit, Feeder, and Service Load Calculations 153
Part I. General 153
220.1 Scope 153
220.3 Application of Other Articles 153
220.5 Calculations 154
220.11 Floor Area 154
Part II. Branch-Circuit Load Calculations 155
220.12 Lighting Load for Non-Dwelling Occupancies 155
220.14 Other Loads—Occupancies 156
220.18 Motor-Operated Loads 160
Part III. Feeder and Service Calculations 160
220.42 General Lighting Demand Factors 160
220.43 Show-Window and Track Lighting Loads, Commercial 161
220.44 Receptacle Load, Other Than Dwelling Units 162
220.50 Motor Type Loads 162
220.51 Fixed Electric Space-Heating Load 162
220.52 Small-Appliance and Laundry Loads, Dwelling 162
220.53 Appliance Load, Dwelling 163
220.54 Clothes Dryer Demand Load, Dwelling 164
220.55 Cooking Appliances in Dwelling Units 165
220.56 Kitchen Equipment Load, Commercial 167
220.60 Noncoincident Loads 168
220.61 Neutral Load 168
Part IV. Optional Calculations for Computing Feeder and Service Loads 170
220.82 Optional Load Calculations, Dwellings 170
220.84 Optional Load Calculations, Multifamily 171
220.85 Optional Load Calculations, Two Dwelling Units 172
220.87 Determining Existing Loads 172

Article 225—Outside Branch Circuits and Feeders 175
Part I. General 175
225.1 Scope 175
225.6 Minimum Conductor Size and Support 175
225.16 Attachment of Overhead Conductors 176
225.17 Masts as Supports 176
225.18 Clearance for Overhead Conductors 177
225.19 Clearances from Buildings 178
225.22 Raceways on Exterior Surfaces of Buildings or Other Structures 179
225.26 Trees for Conductor Support 179
225.27 Raceway Seals 180
Part II. Buildings or Other Structures Supplied by a Feeder 180
225.30 Number of Supplies 180
225.31 Disconnecting Means 181
225.32 Disconnecting Means Location 181
225.33 Maximum Number of Disconnects 181
225.34 Grouping of Disconnects 182
225.37 Identification of Multiple Supplies 182
225.39 Rating of Disconnecting Means 182

Article 230—Services 183
Part I. General 183
230.1 Scope 183
230.2 Number of Services 183
230.3 Not to Pass Through a Building 185
230.6 Conductors Considered Outside a Building 185
230.7 Service Conductors Separate from Other Conductors 185
230.8 Raceway Seals 186
230.9 Clearances on Buildings 186
230.10 Vegetation as Support 187
Part II. Overhead Service Conductors 187
230.23 Overhead Service Conductor Size and Rating 187
230.24 Vertical Clearance for Overhead Service Conductors 188
230.26 Point of Attachment 189
230.27 Means of Attachment 189
230.28 Service Masts as Support 189
Part III. Underground Service Conductors 190
230.30 Installation 190
230.31 Underground Service Conductor Size and Rating 190
230.32 Protection Against Damage 190
Part IV. Service-Entrance Conductors 191
230.40 Number of Service-Entrance Conductor Sets 191
230.42 Conductor Sizing 191
230.43 Wiring Methods 195
230.46 Spliced Conductors 195
230.50 Protection Against Physical Damage 196
230.51 Cable Supports 197
230.53 Raceways to Drain 197
230.54 Overhead Service Locations 197
230.56 High-Leg Conductor Identification 198
Part V. Service Disconnect—General 199
230.62 Service Equipment—Enclosed or Guarded 199
230.66 Marking for Service Disconnect 199
230.67 Surge Protection 199

Part VI. Service Disconnect—Disconnecting Means 200
230.70 Service Disconnect Requirements 200
230.71 Number of Service Disconnects 201
230.72 Grouping of Disconnects 202
230.76 Manually or Power Operated 202
230.79 Rating of Disconnect 202
230.82 Connected on Supply Side of the Service Disconnect 203
230.85 Emergency Disconnects 204

Part VI. Service Disconnect Overcurrent Protection 204
230.90 Overload Protection—Where Required 204
230.91 Location 205
230.95 Ground-Fault Protection of Equipment 206

Article 240—Overcurrent Protection 207

Part I. General 208
240.1 Scope 208
240.2 Definitions 208
240.3 Other Articles (Overcurrent Protection of Equipment) 209
240.4 Overcurrent Protection of Conductors 209
240.5 Protection of Flexible Cords, Flexible Cables, and Fixture Wires 213
240.6 Standard Ampere Ratings 213
240.10 Supplementary Overcurrent Protection 214
240.13 Ground-Fault Protection of Equipment 214
240.15 *Phase Conductor Overcurrent Device* 215

Part II. Location 215
240.21 Location in Circuit 215
240.24 *Location of Overcurrent Protective Devices at Premises* 221

Part III. Enclosures 223
240.33 *Vertical Position* 223

Part IV. Disconnecting and Guarding 223
240.40 *Disconnecting Means for Fuses* 223

Part V. Plug Fuses, Fuseholders, and Adapters 224
240.51 *Edison-Base Fuses* 224

Part VI. Cartridge Fuses and Fuseholders 224
240.60 General 224
240.67 *Arc Energy Reduction—Fuses* 225

Part VII. Circuit Breakers 226
240.81 *Indicating* 226
240.83 Markings 226
240.85 Applications 227
240.86 Series Ratings 228
240.87 *Arc Energy Reduction—Circuit Breakers* 228
240.88 *Reconditioned Equipment* 229

Article 242—Overvoltage Protection 231

Part I. General 232
242.1 Scope 232

Part II. Surge Protective Devices (SPDs), 1,000V or Less 232
242.6 Uses Not Permitted 232
242.8 Listing 232
242.10 Short-Circuit Current Rating 233
242.12 Type 1 SPDs—Line Side of Service Disconnect 233
242.14 Type 2 SPDs—Feeder Circuits 233
242.20 Number Required 234
242.24 Routing of Surge Protection Device Conductors 234

Article 250—Grounding and Bonding 235

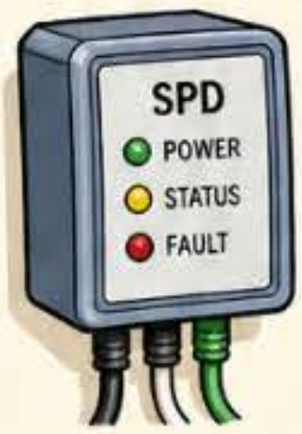
Part I. General 235
250.1 Scope 235
250.4 Performance Requirements for Grounding and Bonding 236
250.6 Objectionable Current 242
250.8 Connection of Grounding and Bonding Connectors 246
250.10 Protection of Ground Clamps and Fittings 246
250.12 Clean Surfaces 246

Part II. System Grounding and Bonding 247
250.20 Systems Required to be Grounded 247
250.21 Ungrounded Systems 248
250.24 Grounding 248
250.25 Grounding for Supply Side of the Service Disconnect 252
250.28 *Main Bonding Jumper and System Bonding Jumper* 253
250.30 *Separately Derived Systems* 254
250.32 *Buildings Supplied by a Feeder* 263
250.34 *Generators—Portable and Vehicle- or Trailer-Mounted* 265
250.36 *High-Impedance Grounded Systems* 266

Part III. Grounding Electrode System and Grounding Electrode Conductor 267
250.50 *Grounding Electrode System* 267
250.52 *Grounding Electrode Types* 267
250.53 *Grounding Electrode Installation Requirements* 270
250.54 *Auxiliary Grounding Electrodes* 275
250.58 *Common Grounding Electrode* 276
250.62 *Grounding Electrode Conductor* 277
250.64 *Grounding Electrode Conductor Installation* 277
250.66 *Sizing Grounding Electrode Conductor* 281
250.68 *Grounding Electrode Conductor and Bonding Jumper Connection to Grounding Electrodes* 282
250.70 *Grounding Electrode Conductor Termination Fittings* 284

Part IV. Enclosure, Raceway, and Service Cable Connections 285
250.80 *Service Raceways and Enclosures* 285
250.86 *Other Enclosures* 285

Part V. Bonding for Fault Current 285
250.90 General 285
250.92 *Bonding Equipment Containing Service Conductors* 285
250.94 *Bonding Communications Systems* 288
250.96 *Bonding Other Enclosures* 289
250.97 *Bonding Metal Parts Containing 277V and 480V Circuits* 290



DEFINITIONS | From Michael Hamilton Publications

Article 300 | Table of Contents

250.98 Bonding Loosely Jointed Metal Raceways....291
250.102 Neutral Conductor, Bonding Conductors, and Bonding Jumpers....291
250.104 Bonding of Piping Systems and Exposed Structural Metal....293
250.106 Lightning Protection Systems....297

Part VI. Equipment Grounding and Equipment Grounding Conductors....298
250.109 Metal Enclosures....298
250.114 Equipment Connected by Cord and Plug....298
250.118 Types of Equipment Grounding Conductors....299
250.119 Identification of Equipment Grounding Conductors....303
250.120 Equipment Grounding Conductor Installation....304
250.121 Restricted Use of Equipment Grounding Conductors....304
250.122 Sizing Equipment Grounding Conductors....304

Part VII. Methods of Equipment Grounding Conductor Connections....308
250.134 Equipment Connected by Permanent Wiring Methods....308
250.136 Equipment Secured to Grounded Metal Supports....309
250.138 Cord-and-Plug-Connected....309
250.140 Frames of Ranges, Ovens, and Clothes Dryers....309
250.142 Neutral Conductor for Effective Ground-Fault Current Path....310
250.146 Connecting Receptacle Grounding Terminal to an Equipment Grounding Conductor....311
250.148 Continuity and Attachment of Equipment Grounding Conductors in Boxes....314

Chapter 2—Practice Questions....317

CHAPTER 3—WIRING METHODS AND MATERIALS....323

Article 300—General Requirements for Wiring Methods and Materials....327
Part I. General Requirements....327
300.1 Scope....327
300.3 Conductors....328
300.4 Protection Against Physical Damage....331
300.5 Underground Installations....334
300.6 Protection Against Corrosion and Deterioration....338
300.7 Raceways Exposed to Different Temperatures....339
300.9 Raceways in Wet Locations Above Grade....340
300.10 Electrical Continuity....340
300.11 Securing and Supporting....341
300.12 Mechanical Continuity....342
300.13 Mechanical and Electrical Continuity of Conductors—Splices and Pigtails....343
300.14 Length of Free Conductors....344
300.15 Boxes or Fittings....345
300.17 Number and Size of Conductors in a Raceway....347
300.18 Inserting Conductors in Raceways....349
300.19 Supporting Conductors in Vertical Raceways....350
300.20 Induced Alternating Currents in Ferrous Metal Parts....350
300.21 Spread of Fire or Products of Combustion....352
300.22 Wiring in Ducts and Plenum Spaces....353
300.23 Panels Designed to Allow Access....355
300.25 Exit Enclosures (Stair Towers)....355

Article 310—Conductors for General Wiring....357
Part I. General....357
310.1 Scope....357
310.3 Conductors....357
Part II. Construction Specifications....358
310.4 Conductor Construction and Application....358
310.6 Conductor Identification....361
Part III. Installation....361
310.10 Uses Permitted....361
310.12 Single-Phase Dwelling Services and Feeders....364
310.14 Ampacities for Conductors Rated 0 V to 2,000 V....367
310.15 Ampacity Tables....368
310.16 Ampacities of Insulated Conductors in Raceways, Cables, or Buried....375

Article 312—Cabinets....377
Part I. Scope and Installation....377
312.1 Scope....377
312.2 Damp or Wet Locations....377
312.3 Position in Walls....378
312.4 Repairing Gaps in Noncombustible Surfaces....378
312.5 Enclosures....378
312.6 Deflection of Conductors....380
312.8 Overcurrent Device Enclosures....380
Part II. Construction Specifications....382
312.10 Material....382

Article 314—Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures....383
Part I. Scope and General....383
314.1 Scope....383
314.3 Nonmetallic Boxes....383
314.4 Metal Boxes....384
Part II. Installation....384
314.15 Damp or Wet Locations....384
314.16 Sizing Outlet Boxes....384
314.17 Conductors That Enter Boxes or Conduit Bodies....392
314.20 Flush-Mounted Box Installations....393
314.21 Repairing Noncombustible Surfaces....393
314.22 Surface Extensions....394
314.23 Support of Boxes....394

314.25 Covers and Canopies ... 397
314.27 Outlet Box Requirements ... 398
314.28 Sizing Pull and Junction Boxes ... 399
314.29 Wiring to be Accessible ... 403
314.30 Handhole Enclosures ... 403

Article 320—Armored Cable (Type AC) ... 405
Part I. General ... 405
320.1 Scope ... 405
320.2 Definition ... 405
320.6 Listing Requirements ... 406
Part II. Installation ... 406
320.10 Uses Permitted ... 406
320.12 Uses Not Permitted ... 406
320.15 Exposed Work ... 406
320.17 Through or Parallel to Framing Members ... 406
320.23 In Accessible Attics or Roof Spaces ... 407
320.24 Bending Radius ... 407
320.30 Securing and Supporting ... 408
320.40 Boxes and Fittings ... 409
320.80 Conductor Ampacity ... 409
Part III. Construction Specifications ... 410
320.100 Construction ... 410
320.108 Equipment Grounding Conductor ... 410

Article 330—Metal-Clad Cable (Type MC) ... 411
Part I. General ... 411
330.1 Scope ... 411
330.2 Definition ... 411
330.6 Listing Requirements ... 412
Part II. Installation ... 412
330.10 Uses Permitted ... 412
330.12 Uses Not Permitted ... 413
330.15 Exposed Work ... 413
330.17 Through or Parallel to Framing Members ... 413
330.23 In Accessible Attics or Roof Spaces ... 413
330.24 Bending Radius ... 414
330.30 Securing and Supporting ... 414
330.80 Conductor Ampacities ... 416
Part III. Construction Specifications ... 417
330.108 Equipment Grounding Conductor ... 417

Article 334—Nonmetallic-Sheathed Cable (Type NM) ... 419
Part I. General ... 419
334.1 Scope ... 419
334.2 Definition ... 419
334.6 Listing Requirements ... 419
Part II. Installation ... 420
334.10 Uses Permitted ... 420
334.12 Uses Not Permitted ... 420
334.15 Exposed Work ... 421
334.17 Through or Parallel to Framing Members ... 422
334.23 Accessible Attics and Roof Spaces ... 423
334.24 Bending Radius ... 423
334.30 Securing and Supporting ... 424
334.40 Boxes and Fittings ... 424
334.80 Conductor Ampacity ... 425
Part III. Construction Specifications ... 426
334.108 Equipment Grounding Conductor ... 426

Article 336—Power and Control Tray Cable (Type TC) ... 427
Part I. General ... 427
336.1 Scope ... 427
336.2 Definition ... 427
336.6 Listing Requirements ... 427
Part II. Installation ... 427
336.10 Uses Permitted ... 427
336.12 Uses Not Permitted ... 428
336.24 Bending Radius ... 428

Article 338—Service-Entrance Cable (Types SE and USE) ... 429
Part I. General ... 429
338.1 Scope ... 429
338.2 Definitions ... 429
338.6 Listing Requirements ... 430
Part II. Installation ... 430
338.10 Uses Permitted ... 430
338.12 Uses Not Permitted ... 431
338.24 Bending Radius ... 431

Article 340—Underground Feeder and Branch-Circuit Cable (Type UF) ... 433
Part I. General ... 433
340.1 Scope ... 433
340.2 Definition ... 433
340.6 Listing Requirements ... 433
Part II. Installation ... 433
340.10 Uses Permitted ... 433
340.12 Uses Not Permitted ... 434
340.24 Bends ... 434
340.80 Ampacity ... 434
Part III. Construction Specifications ... 434
340.108 Equipment Grounding Conductor ... 434
340.112 Insulation ... 434

Article 342 | Table of Contents

Article 342—Intermediate Metal Conduit (Type IMC)

Part I. General 435
342.1 Scope 435
342.2 Definition 435
342.6 Listing Requirements 436
Part II. Installation 436
342.10 Uses Permitted 436
342.14 Dissimilar Metals 436
342.20 Trade Size 436
342.22 Number of Conductors 436
342.24 Bends 436
342.26 Number of Bends (360°) 436
342.28 Reaming 436
342.30 Securing and Supporting 437
342.42 Couplings and Connectors 438
342.46 Bushings 438
342.60 Equipment Grounding Conductor 439

Article 344—Rigid Metal Conduit (Type RMC)

Part I. General 441
344.1 Scope 441
344.2 Definition 441
344.6 Listing Requirements 442
Part II. Installation 442
344.10 Uses Permitted 442
344.14 Dissimilar Metals 442
344.20 Trade Size 442
344.22 Number of Conductors 442
344.24 Bends 443
344.26 Number of Bends (360°) 443
344.28 Reaming 443
344.30 Securing and Supporting 443
344.42 Couplings and Connectors 445
344.46 Bushings 446
344.60 Equipment Grounding Conductor 446

Article 348—Flexible Metal Conduit (Type FMC)

Part I. General 447
348.1 Scope 447
348.2 Definition 447
348.6 Listing Requirements 447
Part II. Installation 447
348.10 Uses Permitted 447
348.12 Uses Not Permitted 447
348.20 Trade Size 448
348.22 Number of Conductors 448
348.24 Bends 449
348.26 Number of Bends (360°) 449
348.28 Trimming 449
348.30 Securing and Supporting 449
348.60 Equipment Grounding and Bonding Conductors 450

Article 350—Liquidtight Flexible Metal Conduit (Type LFMC)

Part I. General 451
350.1 Scope 451
350.2 Definition 451
350.6 Listing Requirements 451
Part II. Installation 452
350.10 Uses Permitted 452
350.12 Uses Not Permitted 452
350.20 Trade Size 452
350.22 Number of Conductors 452
350.24 Bends 453
350.26 Number of Bends (360°) 453
350.28 Trimming 453
350.30 Securing and Supporting 453
350.60 Equipment Grounding and Bonding Conductors 454

Article 352—Rigid Polyvinyl Chloride Conduit (Type PVC)

Part I. General 457
352.1 Scope 457
352.2 Definition 457
Part II. Installation 457
352.10 Uses Permitted 457
352.12 Uses Not Permitted 458
352.20 Trade Size 459
352.22 Number of Conductors 459
352.24 Bends 460
352.26 Number of Bends (360°) 460
352.28 Trimming 460
352.30 Securing and Supporting 460
352.44 Expansion Fittings 461
352.46 Bushings 462
352.48 Joints 462
352.60 Equipment Grounding Conductor 462

Article 356—Liquidtight Flexible Nonmetallic Conduit (Type LFNC)

Part I. General 465
356.1 Scope 465
356.2 Definition 465
356.6 Listing Requirements 465
Part II. Installation 465
356.10 Uses Permitted 465
356.12 Uses Not Permitted 466

TABLE OF CONTENTS

356.20 Trade Size ... 466
356.22 Number of Conductors ... 466
356.24 Bends ... 467
356.26 Number of Bends (360°) ... 467
356.30 Securing and Supporting ... 467
356.42 Fittings ... 467
356.60 Equipment Grounding Conductor ... 468

Article 358—Electrical Metallic Tubing (Type EMT) ... 469
Part I. General ... 469
358.1 Scope ... 469
358.2 Definition ... 469
358.6 Listing Requirements ... 470
Part II. Installation ... 470
358.10 Uses Permitted ... 470
358.12 Uses Not Permitted ... 470
358.20 Trade Size ... 471
358.22 Number of Conductors ... 471
358.24 Bends ... 471
358.26 Number of Bends (360°) ... 471
358.28 Reaming ... 471
358.30 Securing and Supporting ... 472
358.42 Couplings and Connectors ... 473
358.60 Equipment Grounding Conductor ... 473

Article 362—Electrical Nonmetallic Tubing (Type ENT) ... 475
Part I. General ... 475
362.1 Scope ... 475
362.2 Definition ... 475
362.6 Listing ... 475
Part II. Installation ... 475
362.10 Uses Permitted ... 475
362.12 Uses Not Permitted ... 477
362.20 Trade Sizes ... 477
362.22 Number of Conductors ... 477
362.24 Bends ... 478
362.26 Number of Bends (360°) ... 478
362.28 Trimming ... 478
362.30 Securing and Supporting ... 478
362.46 Bushings ... 479
362.48 Joints ... 479
362.60 Equipment Grounding Conductor ... 479

Article 376—Metal Wireways ... 481
Part I. General ... 481
376.1 Scope ... 481
376.2 Definition ... 481
Part II. Installation ... 482
376.10 Uses Permitted ... 482
376.12 Uses Not Permitted ... 482
376.20 Conductors Connected in Parallel ... 482
376.22 Number of Conductors and Ampacity ... 482
376.23 Wireway Sizing ... 484
376.30 Supports ... 485
376.56 Splices, Taps, and Power Distribution Blocks ... 485
Part III. Construction Specifications ... 486
376.100 Construction ... 486

Article 380—Multioutlet Assemblies ... 487
Part I. General ... 487
380.1 Scope ... 487
Part II. Installation ... 487
380.10 Uses Permitted ... 487
380.12 Uses Not Permitted ... 487
380.76 Through Partitions ... 487

Article 386—Surface Metal Raceways ... 489
Part I. General ... 489
386.1 Scope ... 489
386.2 Definition ... 489
386.6 Listing Requirements ... 490
Part II. Installation ... 490
386.10 Uses Permitted ... 490
386.12 Uses Not Permitted ... 490
386.21 Size of Conductors ... 490
386.22 Number of Conductors ... 490
386.30 Securing and Supporting ... 491
386.56 Splices and Taps ... 491
386.60 Equipment Grounding Conductor ... 491
386.70 Separate Compartments ... 491

Article 392—Cable Trays ... 493
Part I. General ... 493
392.1 Scope ... 493
392.2 Definition ... 493
Part II. Installation ... 493
392.10 Uses Permitted ... 493
392.12 Uses Not Permitted ... 495
392.18 Cable Tray Installations ... 495
392.20 Cable and Conductor Installation ... 496
392.30 Securing and Supporting ... 496
392.44 Expansion Splice Plates ... 496
392.46 Bushed Conduit and Tubing ... 496
392.56 Cable Splices ... 496
392.60 Equipment Grounding Conductor ... 497

Chapter 3—Practice Questions ... 499

DEFINITIONS | From Michael Hamilton Publications

Article 400 | Table of Contents

CHAPTER 4—EQUIPMENT FOR GENERAL USE 505

Article 400—Flexible Cords and Flexible Cables 507
400.1 Scope 507
400.3 Suitability 507
400.4 Types of Flexible Cords and Flexible Cables 508
400.5 Ampacity of Flexible Cords and Flexible Cables 508
400.10 Uses Permitted 508
400.12 Uses Not Permitted 509
400.14 Pull at Joints and Terminals 510
400.17 Protection from Damage 510

Article 402—Fixture Wires 513
402.1 Scope 513
402.2 Other Articles 513
402.3 Types 513
402.5 Ampacity of Fixture Wires 513
402.6 Minimum Size 513
402.7 Raceway Size 514
402.8 Neutral Conductor 514
402.10 Uses Permitted 514
402.12 Uses Not Permitted 515

Article 404—Switches 517
Part I. Installation 517
404.1 Scope 517
404.2 Switch Connections 517
404.3 Switch Enclosures 519
404.4 Damp or Wet Locations 519
404.7 Indicating 520
404.8 Accessibility and Grouping 521
404.9 General-Use Snap Switches, Dimmers, and Control Switches 523
404.10 Mounting of Snap Switches, Dimmers, and Control Switches 524
404.12 Grounding of Enclosures 525
404.14 Rating and Use of Snap Switches 525
Part II. Construction Specifications 525
404.20 Switch Marking 525
404.22 Electronic Control Switches 526

Article 406—Receptacles, Attachment Plugs, and Cord Connectors 527
406.1 Scope 527
406.2 Definitions 527
406.3 Receptacle Rating and Type 527
406.4 General Installation Requirements 528
406.5 Receptacle Mounting 531
406.6 Receptacle Faceplates 533
406.7 Attachment Plugs and Flanged Surface Devices 534
406.9 Receptacles in Damp or Wet Locations 534
406.11 Connecting Receptacle Grounding Terminal to Equipment Grounding Conductor 537
406.12 Tamper-Resistant Receptacles 537

Article 408—Switchboards and Panelboards 539
Part I. General 539
408.1 Scope 539
408.3 Arrangement of Busbars and Conductors 539
408.4 Field Identification 540
408.5 Clearance for Conductors Entering Bus Enclosures 541
408.6 Short-Circuit Current Rating 542
408.7 Unused Openings 542
408.8 Reconditioning of Equipment 542
Part II. Switchboards and Switchgear 542
408.18 Clearances 542
Part III. Panelboards 543
408.36 Overcurrent Protection 543
408.37 Panelboards in Damp or Wet Locations 543
408.40 Equipment Grounding Conductor 543
408.41 Neutral Conductor Terminations 544
408.43 Panelboard Orientation 544

Article 410—Luminaires, Lampholders, and Lamps 545
Part I. General 545
410.1 Scope 545
410.2 Definitions 546
410.6 Listing Required 546
410.7 Reconditioned Equipment 546
Part II. Luminaire Locations 546
410.10 Luminaires in Specific Locations 546
410.16 Luminaires in Clothes Closets 548
Part III. Luminaire Outlet Boxes and Covers 549
410.22 Outlet Boxes to be Covered 549
410.24 Connection of Electric-Discharge and LED Luminaires 549
Part IV. Luminaire Supports 550
410.30 Supports 550
410.36 Means of Support 551
Part V. Grounding (Bonding) 552
410.44 Equipment Grounding Conductor 552
410.46 Equipment Grounding Conductor Attachment 552
Part VI. Wiring of Luminaires 552
410.62 Cord-Connected Luminaires 552
Part X. Special Provisions for Flush and Recessed Luminaires 553
410.115 Temperature 553
410.116 Clearance and Installation 553
410.118 Access to Other Boxes 554

TABLE OF CONTENTS

Part XII. Electric-Discharge Lighting 554
410.130 General 554

Part XIV. Track Lighting 554
410.151 Installation 554
410.154 Fastening 555

Part XV. Special Provisions for Horticultural Lighting Equipment 555
410.170 General 555
410.172 Listing 555
410.174 Installation and Use 555
410.176 Locations Not Permitted 555
410.178 Flexible Cord 555
410.180 Fittings and Connectors 555
410.182 Grounding 556
410.184 Ground-Fault Circuit-Interrupter Protection 556
410.186 Support 556

Article 411—Low-Voltage Lighting 557
411.1 Scope 557
411.3 Low-Voltage Lighting Systems 557
411.4 Listing Required 557
411.5 Specific Location Requirements 558

Article 422—Appliances 559
Part I. General 559
422.1 Scope 559
422.3 Other Articles 559
422.5 GFCI Protection 559
422.6 Listing Required 561

Part II. Branch-Circuit Requirements 561
422.10 Branch Circuits 561
422.11 Overcurrent Protection 561
422.12 Central Heating Equipment 561
422.13 Storage Water Heaters 561
422.15 Central Vacuums 562
422.16 Flexible Cords 563
422.18 Support of Ceiling-Suspended (Paddle) Fans 565
422.19 Space for Conductors 565
422.20 Outlet Boxes to be Covered 565

Part III. Disconnecting Means 565
422.30 Disconnection—General 565
422.31 Permanently Connected Appliance Disconnects 565
422.33 Disconnection of Cord-and-Plug-Connected or Attachment Fitting-Connected Appliances 566

Article 424—Fixed Electric Space-Heating Equipment 567
Part I. General 567
424.1 Scope 567
424.3 Other Articles 567
424.4 Branch Circuits 567

Part III. Electric Space-Heating Equipment 568
424.19 Disconnecting Means 568

Part V. Electric Space-Heating Cables 569
424.44 Electric Heating Gables in Concrete or Masonry Floors 569

Part VI. Duct Heaters 569
424.65 Location of Disconnecting Means for Electric Duct Heater Controllers 569

Article 430—Motors, Motor Circuits, and Controllers 571
Part I. General 571
430.1 Scope 571
430.2 Definitions 572
430.6 Table FLC versus Motor Nameplate Current Rating 572
430.14 Location of Motors 573
430.17 Highest Rated Motor 573

Part II. Conductor Size 574
430.22 Single Motor Conductor Size 574
430.24 Several Motors—Conductor Size 576

Part III. Motor and Branch-Circuit Overload Protection 576
430.31 Overload 576
430.32 Overload Sizing for Continuous-Duty Motors 577

Part IV. Branch-Circuit Short-Circuit and Ground-Fault Protection 579
430.51 General 579
430.52 Branch-Circuit Short-Circuit and Ground-Fault Protection 580
430.55 Combined Overcurrent Protective Device 581

Part V. Feeder Short-Circuit and Ground-Fault Protection 582
430.62 Motor Feeder Protection 582

Part VI. Motor Control Circuits 584
430.72 Overcurrent Protection for Control Circuits 584
430.75 Disconnect for Control Circuits 584

Part VII. Motor Controllers 584
430.83 Motor Controller Horsepower Rating 584

Part IX. Disconnecting Means 585
430.102 Disconnect Location 585
430.107 Readily Accessible 586
430.109 Type of Disconnecting Means 586

Part X. Adjustable-Speed Drive Systems 586
430.120 General 586
430.122 Conductor Sizing 586
430.124 Overload Protection 588
430.128 Disconnecting Means 588
430.130 Branch-Circuit Short-Circuit and Ground-Fault Protection 588

Part XIV. Tables 588

Article 440 | Table of Contents

Article 440—Air-Conditioning and Refrigeration Equipment 591

Part I. General 591

440.1 Scope 591
440.2 Definitions 591
440.3 Other Articles 591
440.4 Marking on Hermetic Refrigerant Motor-compressors and Equipment 592
440.9 Grounding and Bonding 593

Part II. Disconnecting Means 593

440.14 Location 593

Part III. Overcurrent Protection 594

440.21 General 594
440.22 Short-Circuit and Ground-Fault Overcurrent Device Size 594

Part IV. Conductor Sizing 595

440.33 Motor-compressors(s) With or Without Additional Motor Loads 595

Article 445—Generators 599

445.1 Scope 599
445.6 Listing 599
445.11 Marking 599
445.13 Ampacity of Conductors 600
445.18 Disconnecting Means and Emergency Shutdown 600

Article 450—Transformers 603

450.1 Scope 603
450.3 Overcurrent Protection 603
450.9 Ventilation 604
450.10 Grounding and Bonding 604
450.13 Transformer Accessibility 605
450.14 Disconnecting Means 605

Article 480—Storage Batteries 607

480.1 Scope 607
480.2 Definitions 607
480.4 Battery and Cell Terminations 608
480.5 Wiring and Equipment Supplied from Batteries 609
480.7 Direct-Current Disconnect Methods 609
480.8 Insulation of Batteries 609
480.9 Battery Support Systems 609
480.10 Battery Locations 610
480.12 Battery Interconnections 610
480.13 Ground-Fault Detection 610

Chapter 4—Practice Questions 611

Final Exam A—Straight Order 617

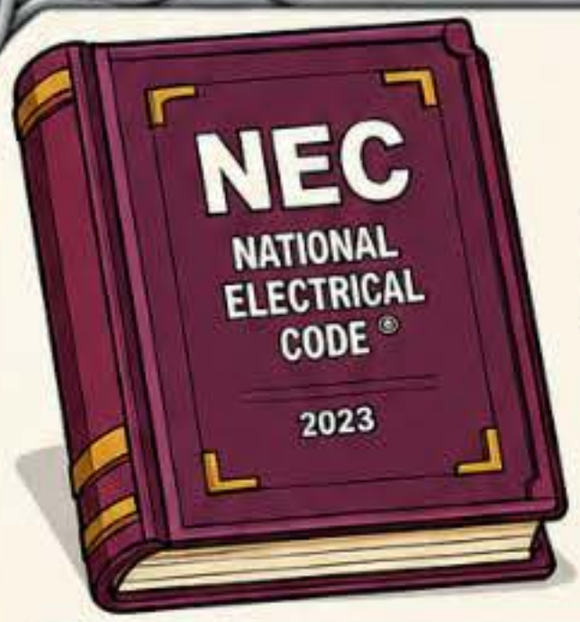
Final Exam B—Random Order 627

INDEX 637

About the Author 645

About the Illustrator 646

About the Michael Hamilton Team 647



HOW TO USE THE *NATIONAL ELECTRICAL CODE*

The original *NEC* document was developed in 1897 as a result of the united efforts of various insurance, electrical, architectural, and other cooperative interests. The National Fire Protection Association (NFPA) has sponsored the *National Electrical Code* since 1911.

The purpose of the *Code* is the practical safeguarding of persons and property from hazards arising from the use of electricity. It isn't intended as a design specification or an instruction manual for untrained persons. It is, in fact, a standard that contains the minimum requirements for an electrical installation that's essentially free from hazard. Learning to understand and use the *Code* is critical to you working safely; whether you're training to become an electrician, or are already an electrician, electrical contractor, inspector, engineer, designer, or instructor.

The *NEC* was written for qualified persons; those who understand electrical terms, theory, safety procedures, and electrical trade practices. Learning to use the *Code* is a lengthy process and can be frustrating if you don't approach it the right way. First, you'll need to understand electrical theory and if you don't have theory as a background when you get into the *NEC*, you're going to struggle. Take one step back if necessary and learn electrical theory. You must also understand the concepts and terms in the *Code* and know grammar and punctuation in order to understand the complex structure of the rules and their intended purpose(s). The *NEC* is written in a formal outline which many of us haven't seen or used since high school or college so it's important for you to pay particular attention to this format. *Our goal for the next few pages is to give you some guidelines and suggestions on using your Code book to help you understand that standard, and assist you in what you're trying to accomplish and, ultimately, your personal success as an electrical professional!*

Language Considerations for the *NEC*

Terms and Concepts

The *NEC* contains many technical terms, and it's crucial for *Code* users to understand their meanings and applications. If you don't understand a term used in a rule, it will be impossible to properly apply the *NEC* requirement. Article 100 defines those that are used generally in two or more articles throughout the *Code*; for example, the term "Dwelling Unit" is found in many articles. If you don't know the *NEC* definition for a "dwelling unit" you can't properly identify its *Code* requirements. Another example worth mentioning is the term "*Outlet.*" *For many people it has always meant a receptacle—not so in the NEC!*

Many Code articles use terms unique to that specific article, and the definitions of those terms only apply to that given article. Definitions for them are usually found in the beginning of the article. For example, Section 250.2 contains the definitions of terms that only apply to Article 250—Grounding and Bonding. Whether definitions are unique to a specific article, or apply throughout the NEC, is indicated at the beginning of the definitions (xxx.2) section of the article. For example, Article 690 contains definitions (in 690.2) that apply ONLY to that article while Article 705 introduces definitions (in 705.2) that apply throughout the entire *Code.*

Small Words, Grammar, and Punctuation

Technical words aren't the only ones that require close attention. Even simple words can make a big difference to the application of a rule. Is there a comma? Does it use "or," "and," "other than," "greater than," or "smaller than"? The word "or" can imply alternate choices for wiring methods. A word like "or" gives us choices while the word "and" can mean an additional requirement must be met.

An example of the important role small words play in the *NEC* is found in 110.26(C)(2), where it says *equipment containing overcurrent, switching, "or" control devices that are 1,200A or more "and" over 6 ft wide require a means of egress at each end of the working space. In this section, the word "or" clarifies that equipment containing any of the three types of devices listed must follow this rule. The word "and" clarifies that 110.26(C)(2) only applies if the equipment is both 1,200A or more and over 6 ft wide.*

Author's Commentary: *Mastering the Code takes patience, practice, and a solid plan. Build a foundation in electrical theory, pay attention to definitions, and don't overlook small words—they can change everything. Use your Code book actively, not passively. Highlight, tab, and take notes as you learn. The more you engage with it, the more confident and capable you'll become as an electrical professional.*

— Michael Hamilton

NEC Style and Layout | How to Use the *National Electrical Code*

Choosing the right grammar and punctuation is vital when creating the meaning behind each rule. A small change in where the comma appears can completely alter how a rule must be appiled. For example, suppose a main bonding jumper is allowed to be either a wire, bus, screw, or any other suitable conductor. If the comma between "bus" and "screw" is taken out, then only a bus screw would be acceptable. That single comma drastically changes how the rule is enforced.

Slang Terms or Technical Jargon

Trade professionals across different regions often use local slang that isn't common everywhere. This can lead to misunderstandings if it isn't clear what a term means. Before using a slang expression, look it up so that you know exactly what it means.

For example, "pigtail" can refer to two different things. One meaning describes the short conductor used to connect a device to a splice. The other meaning is a short rubber-covered light socket with factory-attached conductors. The word "splice" and the word "tap" are other terms that can have more than one meaning.

Consistency is essential. If the same term is used to mean different things in different places, confusion is inevitable. That's why the definitions in the *Code* are written so everyone, no matter where they work, has the same understanding.

NEC Style and Layout

To get the most from the *Code*, it helps to understand its organization and writing style. The *2023 National Electrical Code* is arranged using twelve major components.

1. Table of Contents
2. Chapters—Chapters 1 through 9 *(major sections)*
3. Articles—Chapter subdivisions that address specific topics
4. *Parts—Divisions used to organize article subject matter*
5. *Sections—Divisions used to organize section subject matter*
6. *Tables and Figures—Show the mandatory requirements of a rule*
7. *Exceptions—Alternatives to the main rule*
8. *Informational Notes—Extra material that explains a rule (not a requirement)*
9. *Tables—Referenced in the NEC*
10. *Annexes—Additional explanatory information like tables and references (not requirements)*
11. *Index*
12. *Changes to the Code from the previous edition*

1. Table of Contents. The Table of Contents shows how the code is organized, including chapters, articles, parts, and page numbers. It is an excellent resource and should be used regularly to see how all the *NEC* components relate to one another. When trying to find the rules for a specific situation, trained *Code* users often start at the Table of Contents to quickly locate the relevant *NEC* rule.

2. Chapters. The *Code* is divided into nine chapters, each split into articles. The articles are grouped into four general categories: General Requirements (Chapters 1 through 4), Specific Requirements (Chapters 5 through 7), Communications Systems (Chapter 8), and Tables (Chapter 9).

- Chapter 1—General
- Chapter 2—Wiring and Protection
- Chapter 3—Wiring Methods and Materials
- Chapter 4—Equipment for General Use
- Chapter 5—Special Occupancies
- Chapter 6—Special Equipment
- Chapter 7—Special Conditions
- Chapter 8—Communications Systems (Telephone, Data, Satellite, Cable TV, and Broadband)
- Chapter 9—Tables—*Conductor and Raceway Specifications*

3. Articles. *The NEC includes about 140 articles, each covering a specific subject area. It begins with Article 90, which explains the purpose of the Code, how it is organized, and how the Code works. It also explains how the Code is enforced and provides mandatory and permissive rules, as well as explanatory material. Article 90 gives guidance on enforcement, interpretation, examination of equipment for safety, wiring planning, and information about measurement unit formats. Examples of articles you will find in the NEC include:*

- *Article 110—Requirements for Electrical Installations*
- *Article 250—Grounding and Bonding*
- *Article 300—General Requirements for Wiring Methods and Materials*
- *Article 430—Motors, Motor Circuits, and Motor Controllers*
- *Article 500—Hazardous (Classified) Locations*
- *Article 680—Swimming Pools, Fountains, and Similar Installations*
- *Article 725—Remote-Control, Signaling, and Power-Limited Circuits*
- *Article 800—General Requirements for Communications Systems*

DEFINITIONS | From Michael Hamilton Publications

4. Parts. Extensive items are split into parts. This is because *Code* articles aren't included in section numbers. To indicate where a part belongs, we prepend the word "part" before the *NEC* rule. For instance, Table 110.34(A) lists working space requirements for electrical equipment. If we aren't precise, we might think it applies to every installation. Part III, Table 110.34(A) actually covers basic working space for electrical equipment in installations containing more than 1,000 volts, nominal. The table requirements for installations of 1,000 volts, nominal, or less are in Table 110.26(A)(1), which appears in *Part II—1,000 volts, nominal*, or less.

5. Sections. Each *NEC* rule is placed in a "*Code Section.*" A *Code* section may be divided into subdivisions; the first level subdivision is in parentheses like (A), (B), and so forth. Level-two subdivisions use numbers in parentheses like (1), (2), etc., and level-three subdivisions use lowercase letters such as (a), (b), and so on.

For example, the rule for all receptacles in a dwelling unit bathroom calls out GFCI protection in Section 210.8(A)(1) in Chapter 2, Article 210, Section 8, first-level subdivision (A), and second-level subdivision (1).

Author's Commentary:
According to the 2023 NEC Style Manual, first- and second-level subdivisions always have titles. Titles for third-level subdivisions may be included or omitted.

— Michael Hamilton

Many in the industry incorrectly use the term "Article" when referring to a Code section. For example, they say "Article 210.8," when they should say "Section 210.8." Section numbers in this textbook are shown with the word "Section," unless they appear at the beginning of a sentence. For example, 210.8(A) is shown as simply 210.8(A).

6. Tables and Figures. *Many NEC requirements are presented in tables, which are lists of Code rules arranged in a systematic manner. The table titles are extremely important; you must read them carefully to understand the contents, applications, and limitations of each entry. Notes are often provided in or below the table; be sure to read them as they may be part of the requirement. For example, Note 1 in Table 300.5 explains how to measure the cover when burying cables and raceways, and Note 5 explains what to do if solid rock is encountered.*

7. Exceptions. *Exceptions are NEC requirements or permissions that offer an alternative way to meet a rule. There are two kinds of exceptions—mandatory and permissive. When a rule lists several exceptions, those exceptions with mandatory requirements are listed before the permissive exceptions.*

Mandatory Exceptions. A mandatory exception uses the words "shall" or "shall not." The word "shall" in an exception means that if you're using the exception, you're required to do it in a specific way. The phrase "shall not" means it isn't permitted.

Permissive Exceptions. A permissive exception uses words such as "shall be permitted," which means it's acceptable (but not mandatory) to do it in this way.

8. Informational Notes. An Informational Note contains explaantory material intended to clarify a rule or give assistance, but it isn't a *Code* requirement.

9. Tables. Chapter 9 consists of tables applicable as referenced in the *NEC*. They're used to calculate raceway sizing, conductor fill, the radius of raceway bends, and conductor voltage drop.

10. Informative Annexes. Annexes aren't a part of the *Code* requirements and are included for informational purposes only.

Annex A. *Product Safety Standards*
Annex B. *Application Information for Ampacity Calculation*
Annex C. *Raceway Fill Tables for Conductors and Fixture Wires of the Same Size*
Annex D. *Examples*
Annex E. *Types of Construction*
Annex F. *Critical Operations Power Systems (COPS)*
Annex G. *Supervisory Control and Data Acquisition (SCADA)*
Annex H. *Administration and Enforcement*
Annex I. *Recommended Tightening Torques*
Annex J. *ADA Standards for Accessible Design*

11. Index. *The index at the back of the NEC is helpful in locating a specific rule using pertinent keywords to assist in your search.*

12. Changes to the Code. *Changes in the NEC are indicated as follows:*

- *Rules that were changed since the previous edition are identified by shading the revised text.*
- *New rules aren't shaded like a change; instead they have a shaded "N" in the margin to the left of the section number.*
- *Relocated rules are treated like new rules with a shaded "N" in the left margin by the section number.*
- *Deleted rules are indicated by a bullet symbol " • " located in the left margin where the rule was in the previous edition. Unllke older editions the bullet symbol is used when one or more complete paragraphs have been deleted. There's no indication used where a word, group of words, or a sentence was deleted.*
- *Δ Δ represents text deletions and figure/table revisions.*

How to Locate a Specific Requirement | How to Use the *National Electrical Code*

How to Locate a Specific Requirement

The method you use to find what you're looking for in the *Code* book changes based on your comfort with the *NEC*. Specialists generally know the requirements so thoroughly that they can quickly go to the exact rule. Less experienced people might need the Table of Contents to find the section that covers their topic. Meanwhile, the average user should employ all the resources in the Table of Contents, the Index, and the search function in electronic versions of the *Code*.

Let's work through a simple example: What *NEC* rule specifies the maximum number of disconnects allowed for a service?

Using the Table of Contents. If you're an experienced *Code* user, you might start with the Table of Contents. You'll find Article 230 under "Services," and this article is broken into multiple parts (eight parts to be precise). *With that knowledge, you can go straight to the Table of Contents, open the Service Equipment Disconnecting Means requirements in Part VI, and review them.*

> ***Author's Commentary:***
>
> *The number "70" before all page numbers in this standard exists because the NEC's NFPA Standard Number 70.*
>
> ***— Michael Hamilton***

Using the Index. *If you prefer the Index (which lists topics in alphabetical order), look up the term "service disconnect," and you'll see there is no direct entry. If you try "disconnecting means," then "services," you'll discover the Index directs you to Article 230, Part VI. Since the NEC doesn't give a page number in the Index, you'll need to consult the Table of Contents to identify the section, or flip through the Code to find it. Article 230, Part VI will take you right to the information you need.*

Many people complain that the NEC only confuses them by using terms in circles. Once you gain experience with its layout you'll understand the words, terms, principles, and practices, and it will become much easier to comprehend—and far more useful than you first thought.

With enough exposure to the Code, you'll notice that certain terms appear in specific places. The word "solar," for example, will immediately lead experienced users to Article 690—Solar Photovoltaic (PV) Systems. The word "marine" suggests Article 555. Occasionally one article will send you to another for a particular requirement; in that case, it will say (for example), "in accordance with 230.xx." Don't view those situations as a "circle," but as a roadmap guiding you to the exact location of what you need.

Customizing Your *Code* Book

One way to increase your comfort level with your *Code* book is to customize it to meet your needs. You can do this by highlighting and underlining important *NEC* requirements. Preprinted adhesive tabs are also excellent aids to quickly find important articles and sections that are regularly referenced. However, understand that if you're using your *Code* book to prepare for an exam, some exam centers don't allow markings of any type. For more information about tabs for your *Code* book, visit the publisher's website.

Highlighting. *As you read through or find answers to your questions, be sure to highlight those requirements in the NEC that are the most important or relevant to you. For one color, like yellow, use it for general interest and a different one for important requirements you want to find quickly. Be sure to highlight terms in the Index and the Table of Contents as you use them.*

Underlining. *Underline or circle key words and phrases in the Code with a red or blue pen (not a lead pencil) using a short ruler or other straightedge to keep lines straight and neat. This is a very handy way to make important requirements stand out. A short ruler or other straightedge also comes in handy for locating the correct information in a table.*

Interpretations

Industry professionals often enjoy the challenge of discussing, and at times debating, the Code's requirements. These types of discussions are important to the process of better understanding the NEC requirements and their applications. However, if you decide you're going to participate in one of these discussions, don't speak without having the actual Code book in your hand. The professional way of discussing a requirement is by referring to a specific section rather than talking in vague generalities. This will help everyone involved clearly understand the point and become better educated. In fact, you may become so well educated about the NEC that you might even decide to participate in the change process and help to make it even better!

Become Involved in the *NEC* Process

The actual process of changing the Code takes about two years and involves hundreds of individuals trying to make the NEC as current and accurate as possible. As you advance in your studies and understanding of the Code, you might begin to find it very interesting, enjoy it more, and realize that you can also be a part of the process.

How to Use the *National Electrical Code* | Become Involved in the *NEC* Process

You don't have to just sit back and wait for others to take the lead—you can help shape the *NEC* by taking an active role. In the 2023 edition, there were 3,730 Public Inputs and 1,930 comments. Each year, hundreds of proposals and fresh articles are reviewed so the *NEC* stays current with new technologies and continues to guide us toward a safer, more dependable electrical future.

Here's how the process unfolds:

STEP 1—Public Input Stage

Public Input. The revision cycle kicks off when the *NEC* publishes a Public Input (PI) notice inviting anyone interested to submit ideas for a new code requirement or for updating an existing committee-approved draft standard. After the submission period closes, the committee holds a *First Draft Meeting* to respond to every *Public Input*.

First Draft Meeting. At the First Draft (FD) Meeting, the *Technical Committee reviews all Public Inputs and decides how to proceed. They may use the input to create Initial Revisions to the standard. The First Draft includes the meeting's initial majority agreement. However, the Technical Committee's final position must be determined through a vote, as described below.*

Committee Ballot on First Draft. *The First Draft becomes ballotable at the First Draft Meeting. To be approved in this stage, a revision must earn support from at least two-thirds of the Technical Committee.*

First Draft Report Posted. *All revisions that pass the ballot are compiled into the First Draft Report and posted on the NFPA website. This report documents the Input Stage and is available for public review and comment. The public may also examine the report to decide whether to submit comments on the First Draft.*

STEP 2—Public Comment Stage

Public Comment. *Once the First Draft Report is released, a Public Comment period begins. Anyone may submit a Public Comment on the First Draft. When the comment window closes, the Technical Committee holds their Second Draft Meeting.*

Second Draft Meeting. *After the comment period ends, if any comments were received or if the committee added proposed revisions, a Second Draft Meeting is held. At this meeting, the Technical Committee reviews the First Draft and may make additional changes to the draft Standard. The committee considers all input and the Technical Committee provides responses to every Public Comment. These actions yield the Second Draft.*

Committee Ballot on Second Draft. The Second Revisions developed at the Second Draft Meeting are ballotable. For the draft to move forward in the Second Draft, it must be approved by at least two-thirds of the Technical Committee.

Second Draft Report Posted. All revisions that pass ballot are compiled and published in the Second Draft Report on the NFPA website. This report serves as a record of the Comment Stage and is made available for public review.

Once published, the public can review the *Second Draft Report* and decide whether to *file a Notice of Intent to Make a Motion (NITMAM)* for additional consideration.

STEP 3—NFPA Technical Meeting (Tech Session)

After the Public Input and Public Comment stages are complete, *there's a chance for open discussion and debate at the NFPA Technical Meeting. These meetings take place during the NFPA Conference & Expo®. Attendees may propose changes to the resulting final Standard based on the recommendations published in the Second Draft.*

STEP 4—Council Appeals and Issuance of Standard

Issuance of Standards. *When the Standards Council meets to issue an NFPA standard, related appeals may also be considered. Appeals are an important part of assuring that all NFPA rules are followed and that the process remains open and fair throughout standards development. The Standards Council reviews appeals based on written records and by conducting live hearings during which all interested parties can participate. Appeals are decided on the full record of the process, as well as on written submissions and formal statements.*

After reviewing all appeals related to a standard, the Standards Council, if appropriate, proceeds to issue the Standard as an official NFPA Standard. The decision of the Standards Council is the final word for the NFPA Board of Directors. The new NFPA standard becomes effective 20 days after the Standards Council acts to approve it.

Author's Commentary:

Your input truly matters. Together, we keep the NEC current, practical, and aligned with real-world needs.

— Michael Hamilton

Become Involved in the *NEC* Process

How to Use the *National Electrical Code*

Temporary Interim Amendment—(TIA)

At times, the *NEC* must respond quickly to new situations. An editorial correction that alters how the *Code* is applied in electrical work can unintentionally create a safety risk. Or perhaps, a previously rare event occurs in the field and introduces a hazard that requires immediate attention because it can't wait for the normal *Code* development cycle and the next edition of the standard.

When circumstances demand a fast solution, a TIA, or "Temporary Interim Amendment," may be issued for review and consideration.

The NFPA processes TIAs as, "proposed revisions that have not yet gone through the entire standards development process. *They are interim measures used only between editions of a standard. A TIA is automatically sent out for public review by the proponent of the next standard edition; such as the Standards Council, and is then subjected to all of the steps in the standards development procedure."*

Author's Commentary:

You can submit proposals, feedback, and TIAs for consideration online at the NFPA website.

Go to nfpa.org. From the homepage, select "*Codes & Standards*," then find "*Standards Development*," and click on "*How the Process Works*."

If you believe something in the *Code* should be updated, this is how you can take part in the process and help shape the next edition.

— Michael Hamilton

ARTICLE 90 INTRODUCTION TO THE *NATIONAL ELECTRICAL CODE*

Introduction to Article 90—Introduction to the *National Electrical Code*

Article 90 begins by making it clear that the *National Electrical Code (NEC,* or *Code)* is not meant to be a design document or an installation manual. Its role is limited and well defined: it provides practical safeguards for people and property from the dangers that can arise when electrical energy is misused. This is not to say installations will be inefficient, inconvenient, or unable to handle future needs; rather, the emphasis is on safety. Because the *Code* covers so many topics in detail, it is essential to study it thoroughly. Understanding how to locate the rules that apply to an installation is invaluable. Rules can appear in many different articles, and sometimes even in a simple note. Not every provision will be needed for every job, so it is important to know where to look once you have studied the material.

Article 90 then explains the scope and structure of the *NEC*. It strikes a balance between giving the reader a clear overview and providing enough essential information to understand the *Code* rules.

Most electrical work requires a solid understanding of the first four chapters of the *NEC* (which apply generally) and a working knowledge of Chapter 9 tables. Together, these parts clarify the rules in Articles 5, 6, and 7 and lay the groundwork for the rest of the *Code*. After that, most installations call for special spaces, special equipment, or special conditions, and the rules in the early chapters direct you to the right chapters.

Chapter 8 details the requirements for communication systems—such as radio and television gear, satellite receivers, antenna systems, twisted-pair wiring, and coaxial cables. *Communications systems are not covered by the general requirements of Chapters 1 through 4 or by the special requirements in Chapters 5 through 7, unless those chapters specifically point to a rule in earlier chapters.*

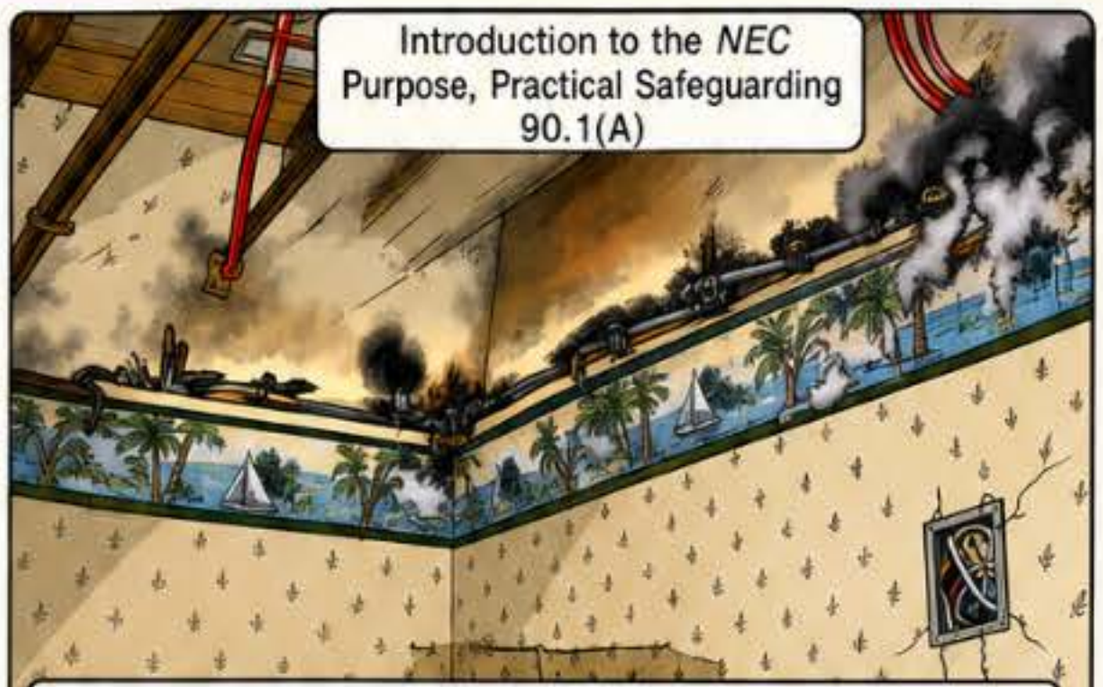
90.1 Purpose of the *NEC*

Scan this QR code to watch a video of Michael Hamilton explaining this topic; it's a sample from the videos that go with this textbook.

www.MichaelHamilton.com/23UN1videos

(A) Practical Safeguarding. The intent of the *National Electrical Code* is to ensure electrical *systems are installed in ways that protect people and property by reducing the hazards posed by the use of electricity. The NEC is not a design specification standard nor is it an instruction manual for the untrained and unqualified.*

Figure 90–1



The purpose of the *NEC* is to provide practical safeguarding of persons and property from hazards arising from the use of electricity. This *Code* is not intended as a design specification or as an instruction manual for untrained persons.

Figure 90–1

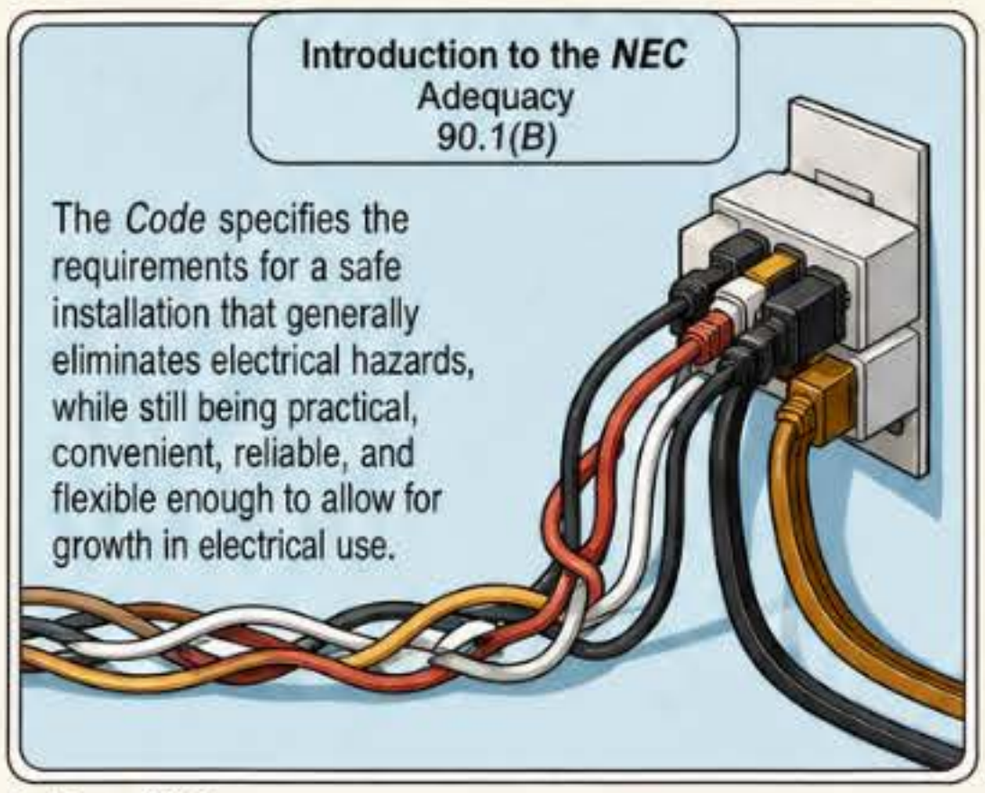
90.2 | Introduction to the *National Electrical Code*

Author's Commentary:

- The *Code* establishes standards for individuals who possess training and expertise in electrical theory, system design, construction practices, and the installation and operation of electrical equipment.

(B) Adequacy. The *NEC* outlines the criteria that are required for a safe electrical installation. If an installation follows the *Code*, it is generally free from electrical hazards.

These requirements ensure electrical installations are practical, easy to use, capable of reliable service, and suitable for future expansion. ▶ **Figure 90–2**

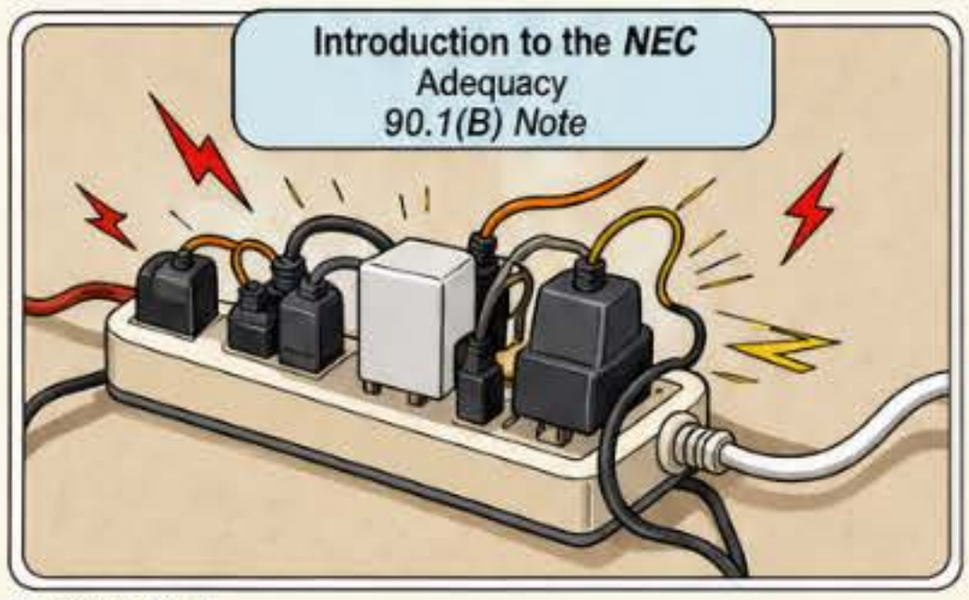


▶ **Figure 90–2**

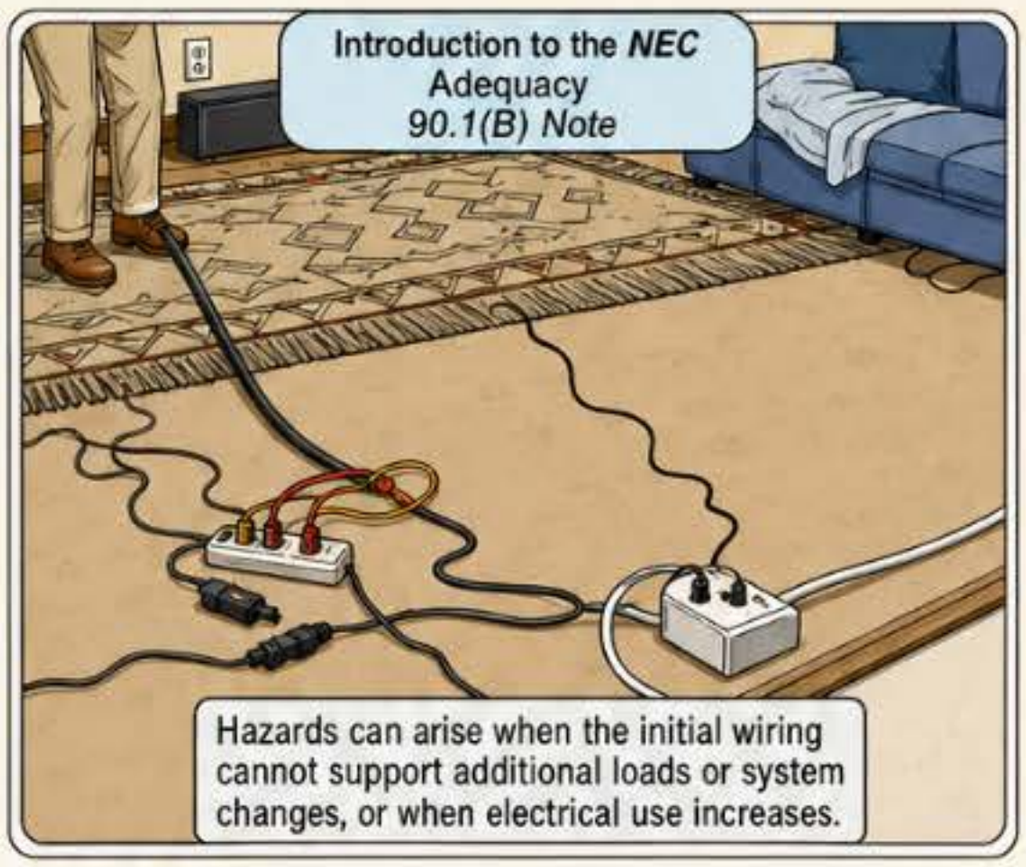
Author's Commentary:

- *Managing electrical energy, maintaining equipment, supplying power, and being ready for future loads fall outside the scope of the Code.*

Note: *Problems can arise because the original wiring was not sized to handle increases in electrical demand, so wiring systems may become overloaded.* ▶ **Figure 90–3**



▶ *Figure 90–3*



▶ **Figure 90–3**

Author's Commentary:

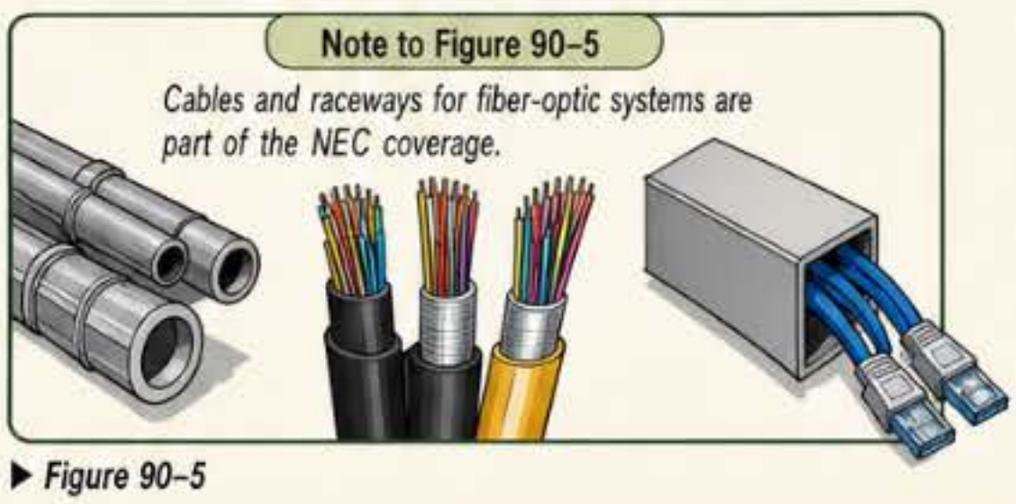
The *NEC* does not demand that electrical systems be designed or installed for future loads. Still, designers (usually electrical engineers) often try to incorporate a margin of safety (called *Code compliance*) and also consider what customers may need both today and *tomorrow. To meet these needs, electrical systems are frequently planned and built to exceed the minimum criteria set by the NEC.*

(C) Relation to International Standards. The requirements of the *Code* reflect the fundamental safety principles outlined in the International Electrotechnical Commission (IEC) Standard.

Note: IEC 60364-1, Section 131, lists core safety principles: *protection from electric shock, protection against thermal effects, protection against overcurrent, protection from fault currents, and protection from overvoltage. Each possible hazard is addressed by the Code's requirements.* ▶ **Figure 90–4**

90.2 Scope of the *NEC*

(A) What is Covered by the *NEC*. The *NEC* covers how *to install and remove electrical conductors, equipment, and raceways; handles signaling and communication conductors and equipment; and includes fiber-optic cables and raceways as listed below:* ▶ **Figure 90–5**



▶ *Figure 90–5*

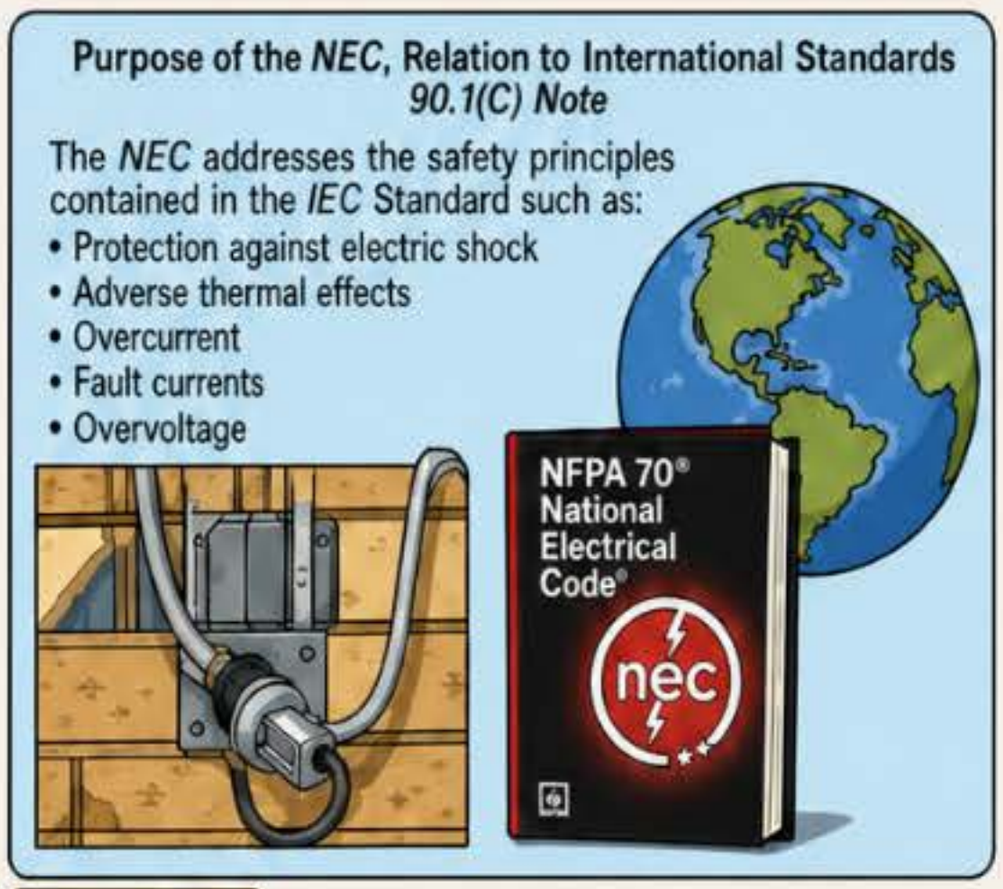


Figure 90–4

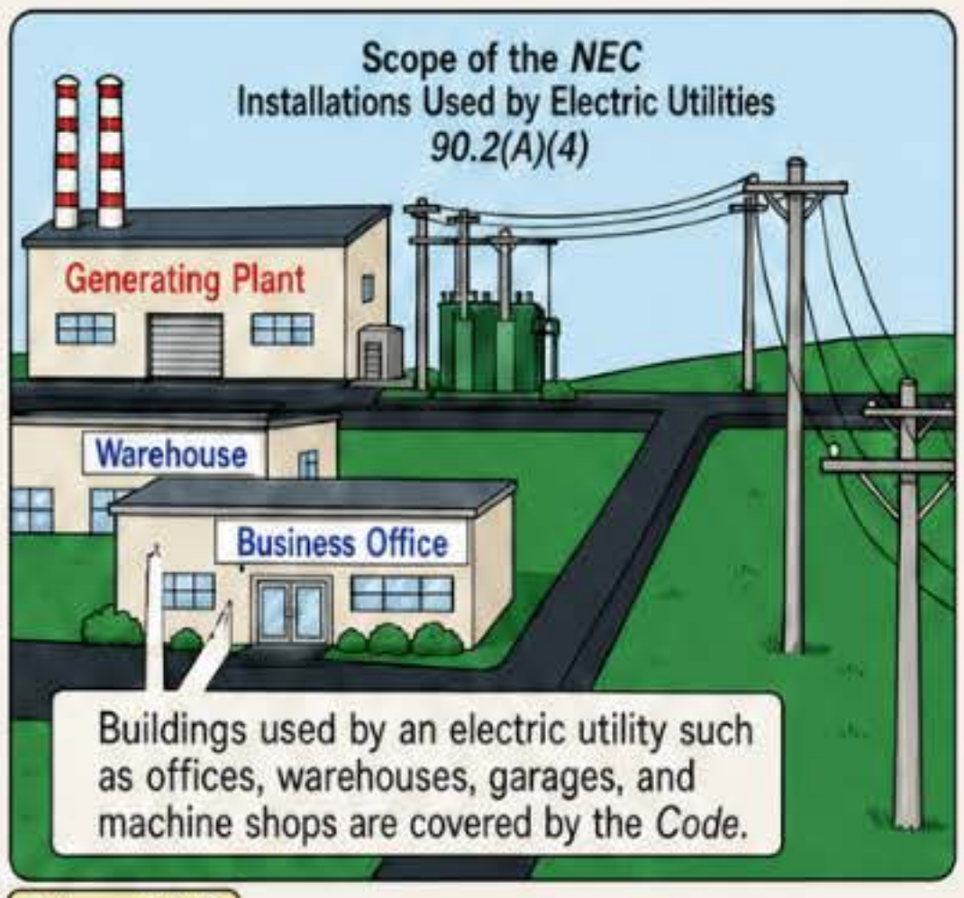


Figure 90–6

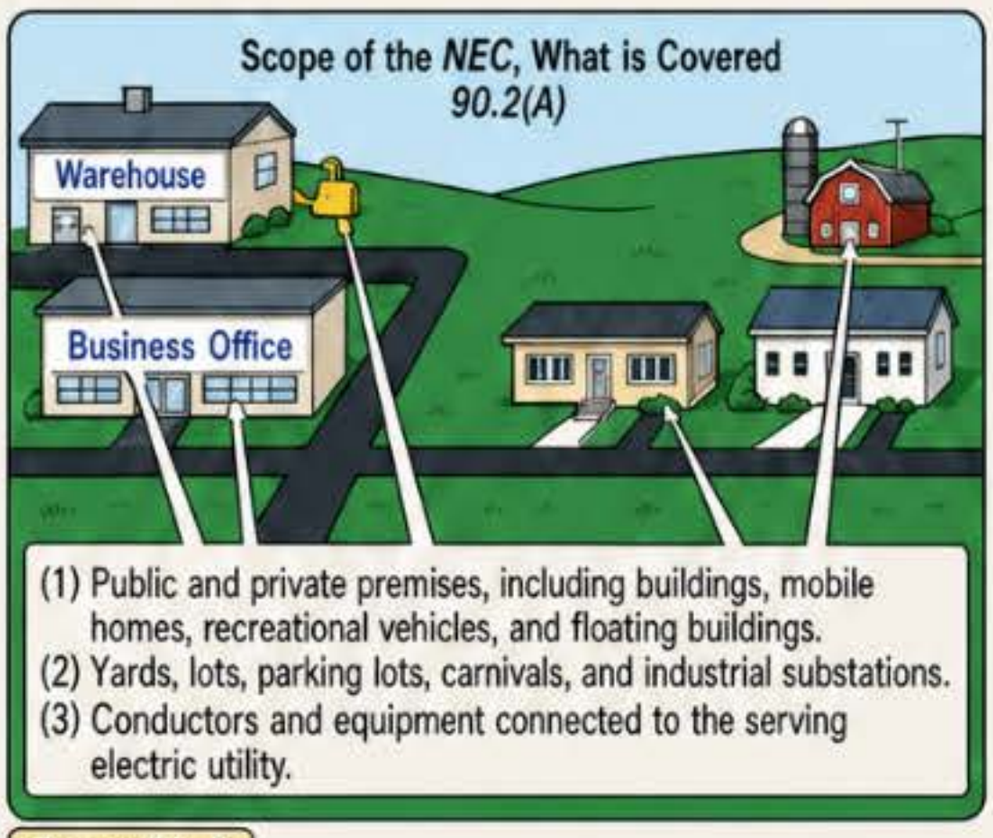


Figure 90–5

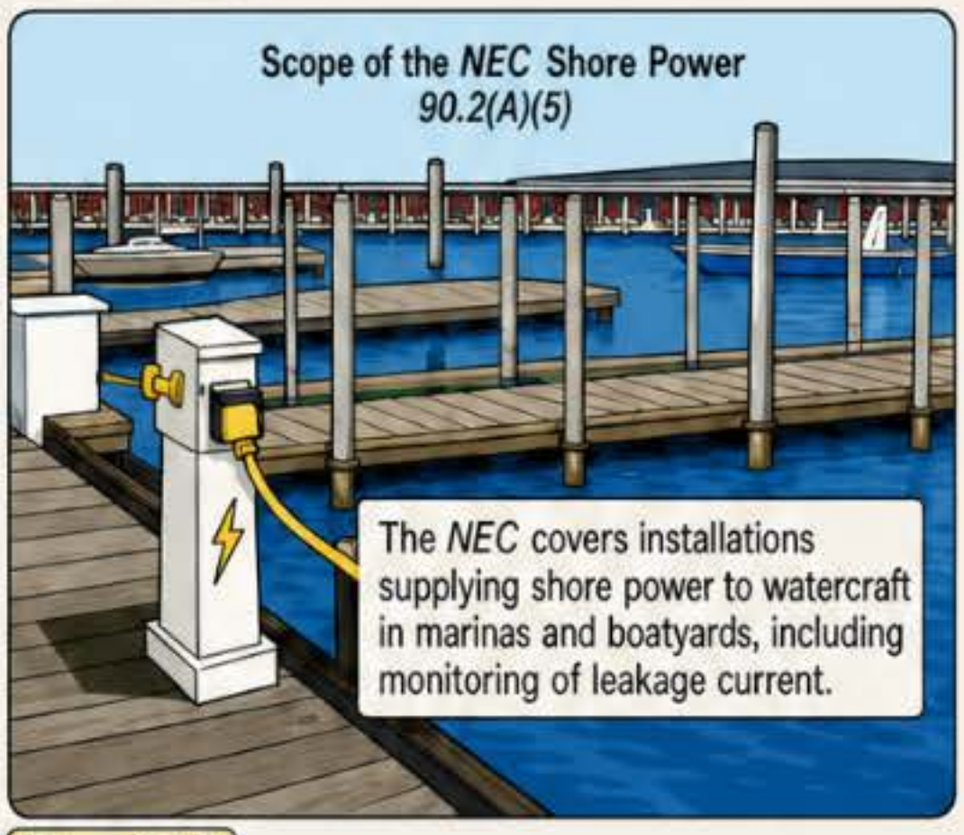


Figure 90–7

(1) Public and private premises including buildings, mobile homes, recreational vehicles, and floating buildings.

(2) Yards, lots, parking lots, carnivals, and industrial substations.

(3) Conductors and equipment connected to the serving electric utility.

(4) Installations used by a serving electric utility such as office buildings, warehouses, garages, machine shops, recreational buildings, and other electric utility buildings that are not an integral part of a utility's generating plant, substation, or control center. ▸ Figure 90–6

(5) Installations supplying shore power to watercraft in marinas and boatyards, including monitoring of leakage current. ▸ Figure 90–7

Author's Commentary:

- The new item in Article 90's scope, 90.2(A)(5), now includes the power cable between the pedestal and the boat in the scope of the *NEC*. However, there are no specific rules in Article 555 covering that power-supply cord.
- The text in 555.35(B) requires leakage detection equipment to sense leakage current from boats and apply it to the load side of the supplying receptacle.

(6) Installations used to export electric power from vehicles to premises wiring or for bidirectional current flow. ▸ Figure 90–8

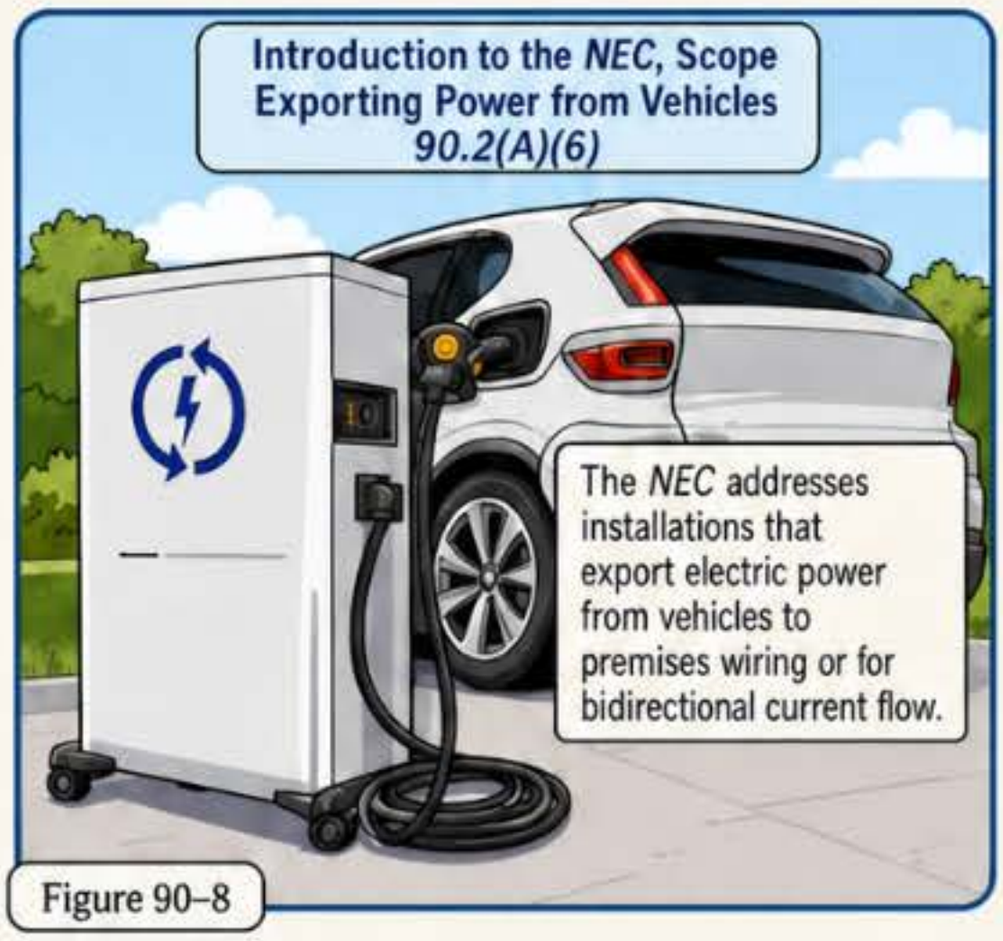


Figure 90–8

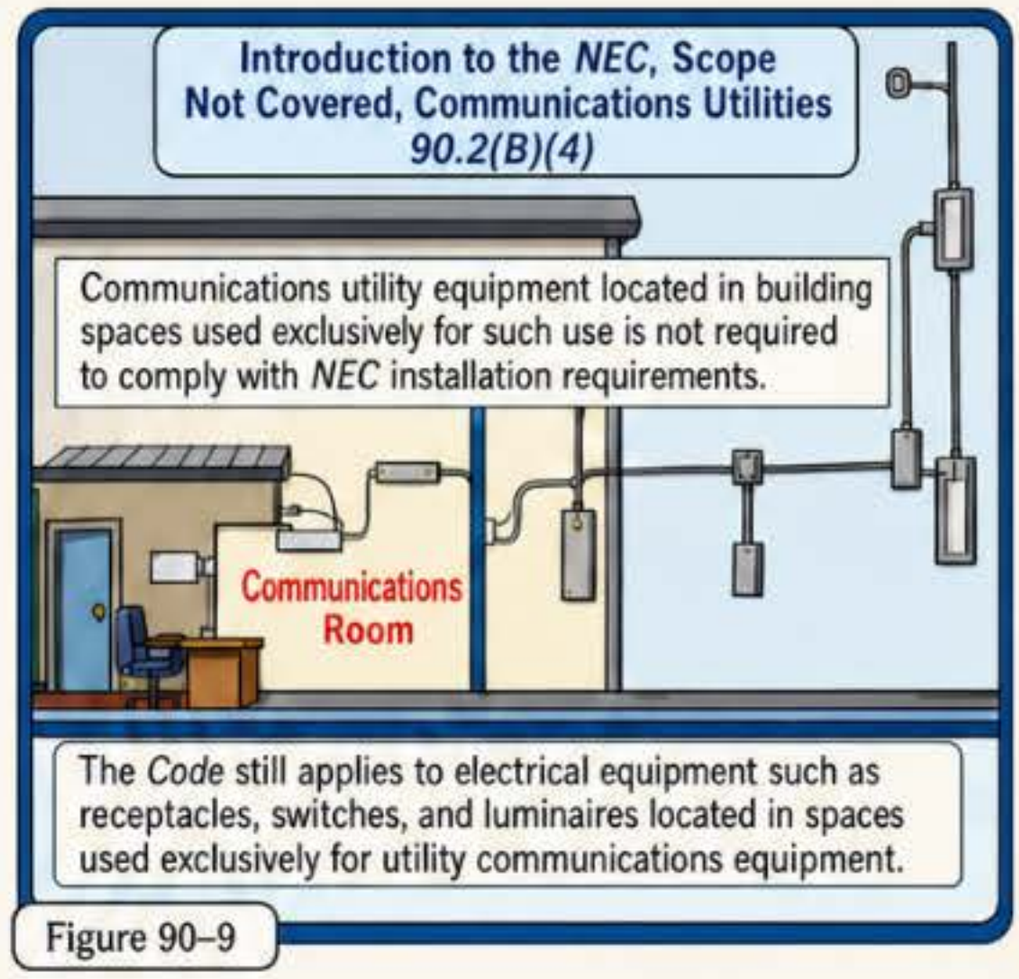


Figure 90–9

Author's Commentary:

- Electric vehicle battery power can serve as backup energy or an *alternative source to feed premise wiring during an outage. Details of this application can be found in Article 625.*

— Michael Hamilton

(B) What is not Covered by the *NEC*. The *Code* does not apply to installations of electrical or communications systems for:

(1) Transportation Vehicles. The *NEC* excludes installations in ships and watercraft other than floating structures, plus automobiles and vehicles other than mobile homes and recreational units.

(2) Mining Equipment. The *Code* does not govern installations in underground mines, nor the electrical systems of self-propelled mobile mining machinery and their on-board power cables.

(3) Railways. The *NEC* does not apply to railway power, *signaling, energy storage, or communications wiring.*

(4) Communications Utilities. The *Code* does not regulate installations under the sole control of communications *utilities in building spaces used exclusively for such equipment or located outdoors.* ▸ Figures 90–9

(5) Electric Utilities. The *NEC does not apply to electrical* installations under the *exclusive control of a serving electric utility where such installs cover:*

a. *Drops of service or service laterals and the metering connected to them, or* ▸ *Figure 90–11*

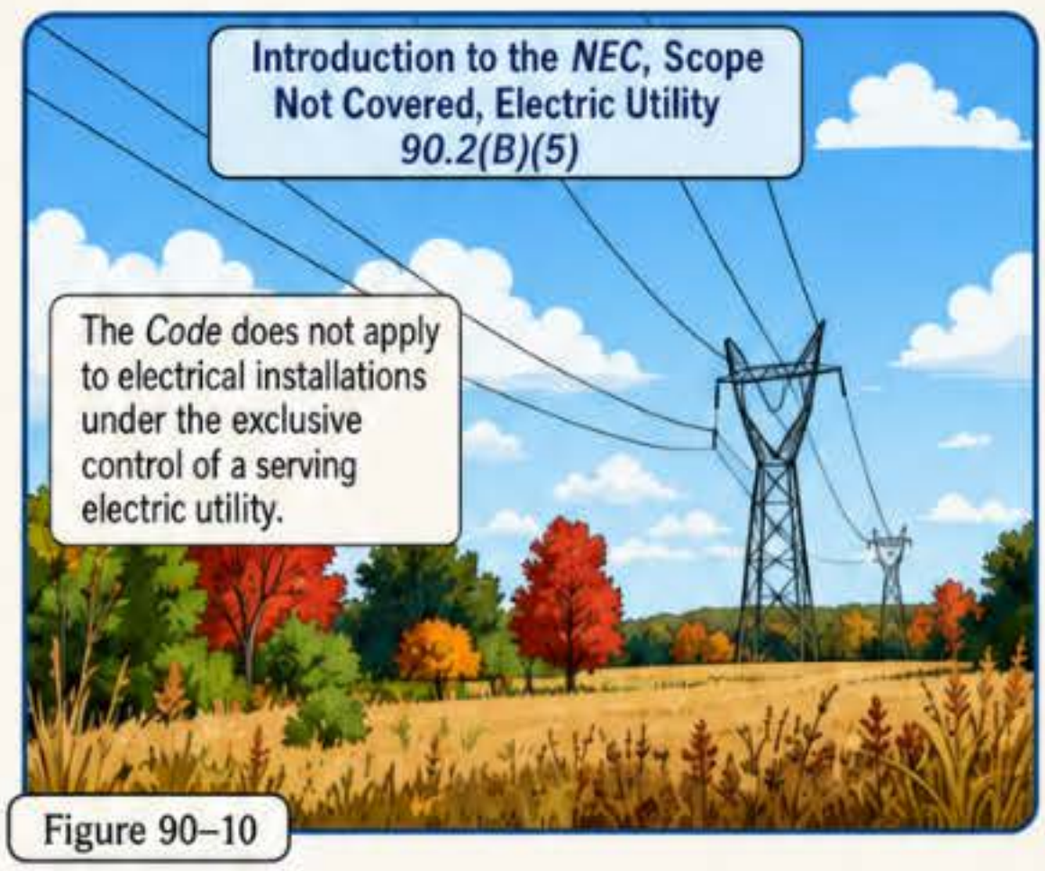


Figure 90–10

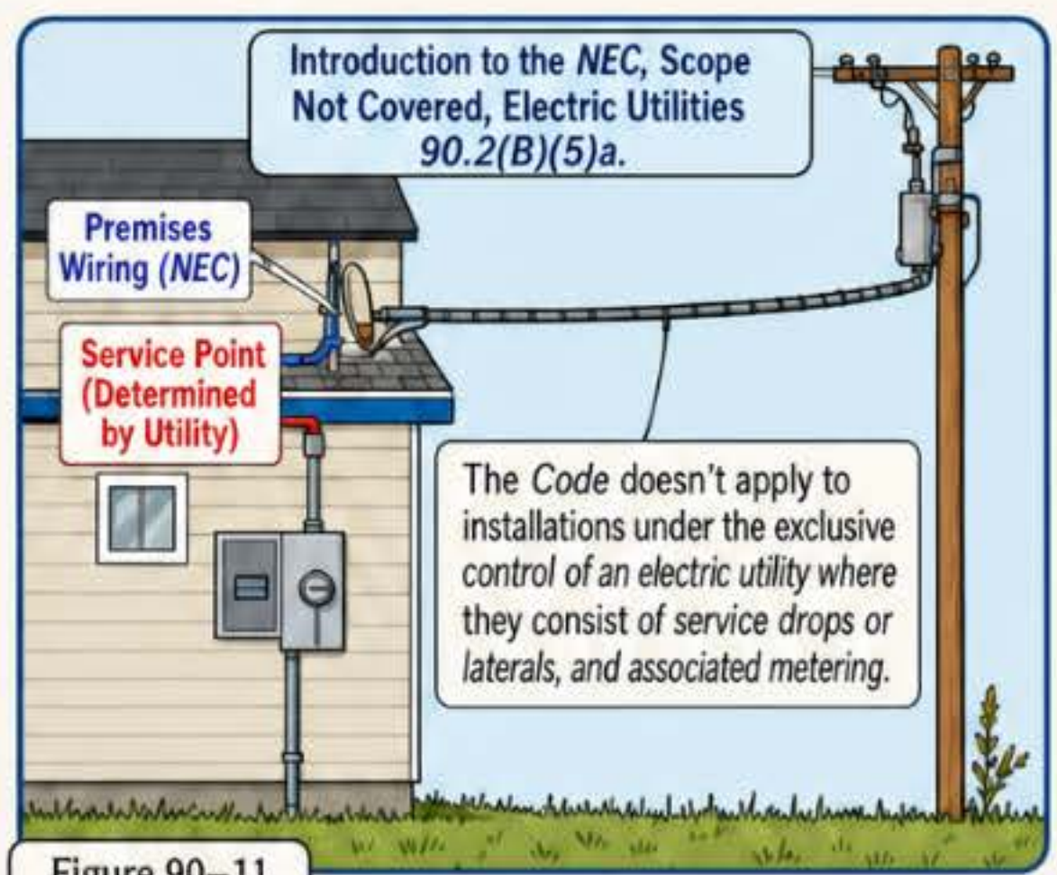


Figure 90–11

Introduction to the *National Electrical Code®* | 90.3

b. If a utility owns or leases property for communications, metering, power generation, controls, transformation, transmission, storage, or the delivery of electrical energy, the *NEC* does not apply. ▶ **Figure 90–12**

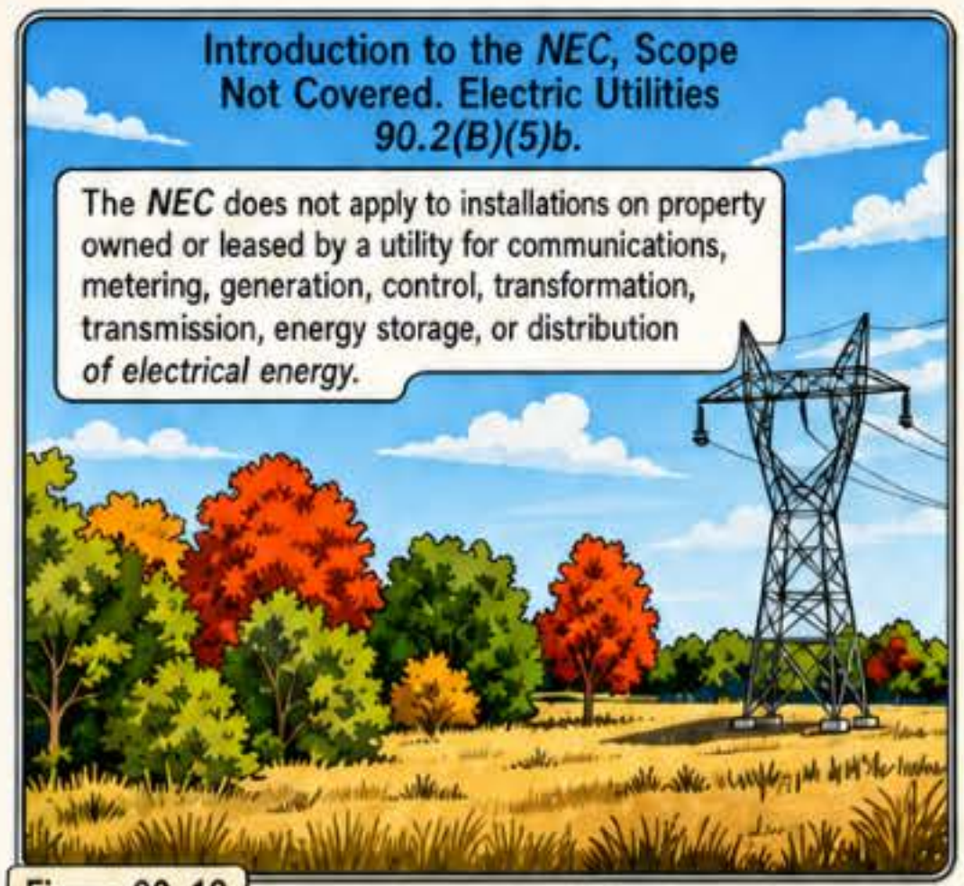


Figure 90–12

c. Installations situated within legally recognized easements or rights-of-way are outside the *NEC*. ▶ *Figure 90–13*

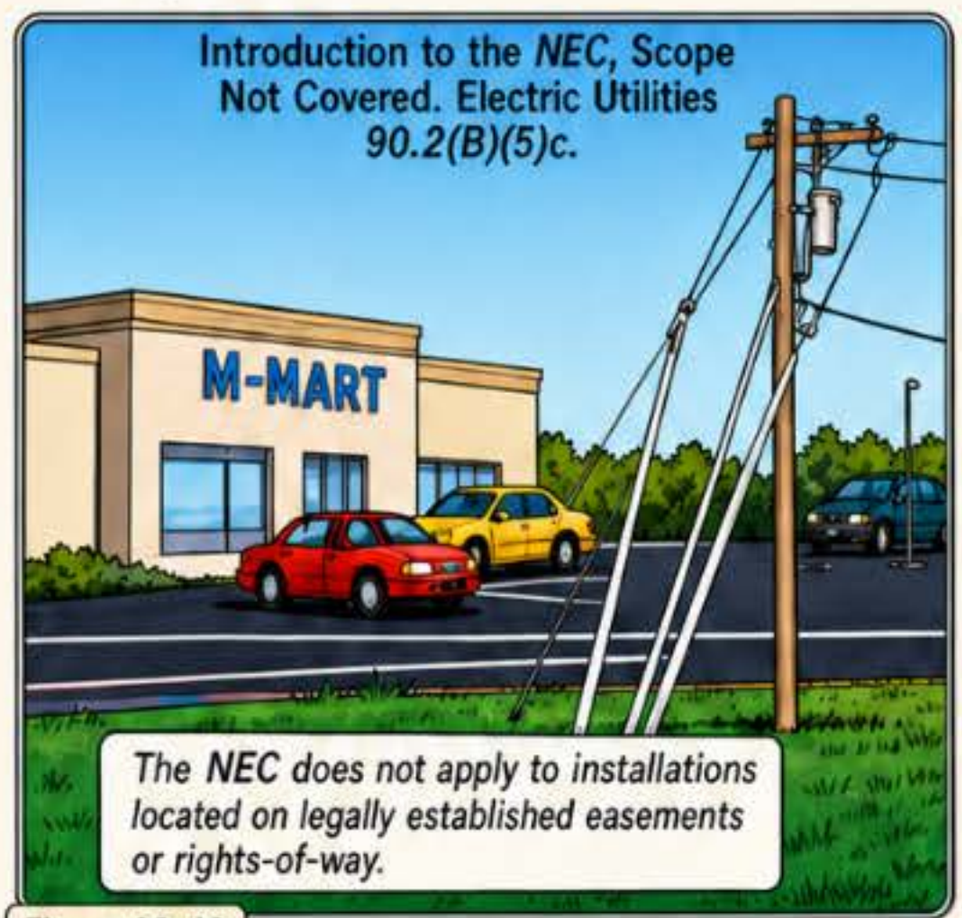


Figure 90–13

90.3 Code Arrangement

General Requirements. *The Code is arranged into an introduction and nine chapters, followed by informative annexes. Chapters 1, 2, 3, and 4 are general in nature.* ▶ *Figure 90–14*

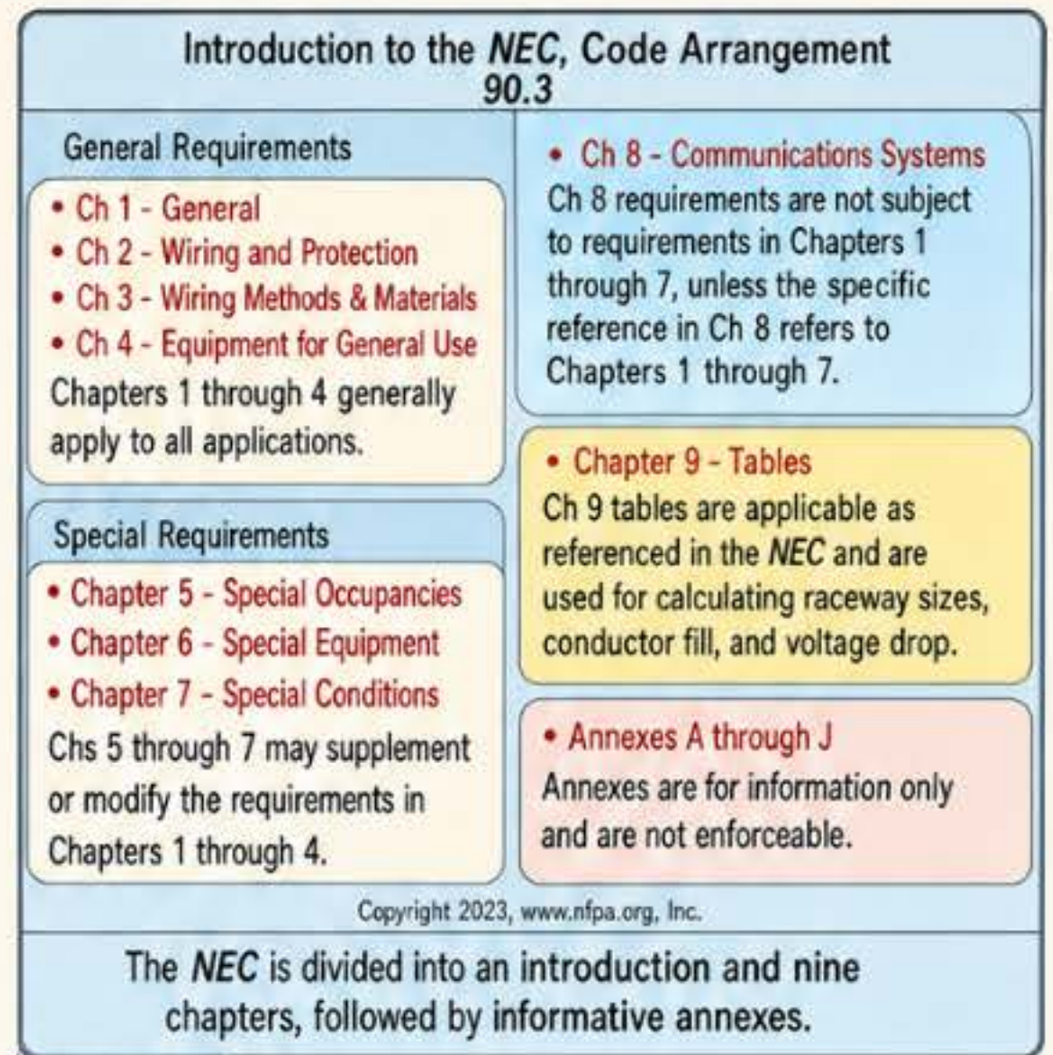


Figure 90–14

The requirements in Chapters 5, 6, and 7 apply to special occupancies, special equipment, or other special conditions, which may add to or change the provisions found in Chapters 1 through 7; but not Chapter 8.

Chapter 8 contains the rules for communications systems (twisted wire, antennas, and coaxial cable) that are not covered by the general provisions in Chapters 1 through 4, or the special requirements of Chapters 5 through 7, unless a specific reference in Chapter 8 points to a rule in Chapters 1 through 7.

Chapter 9 consists of tables that are referenced in the NEC. These tables are used to determine raceway sizes, conductor fill, bending radius for raceways, and conductor voltage drop.

Annexes are not part of the enforceable requirements of the Code but are included for informational purposes. The Code contains these annexes:

- Annex A. Product Safety Standards
- Annex B. Application Information for Ampacity Calculation
- Annex C. Raceway Fill Tables for Conductors and Fixture Wires of the Same Size
- Annex D. Examples
- Annex E. Types of Construction
- Annex F. Critical Operations Power Systems (COPS)
- Annex G. Supervisory Control and Data Acquisition (SCADA)
- Annex H. Administration and Enforcement
- Annex I. Recommended Tightening Torques
- Annex J. ADA Standards for Accessible Design

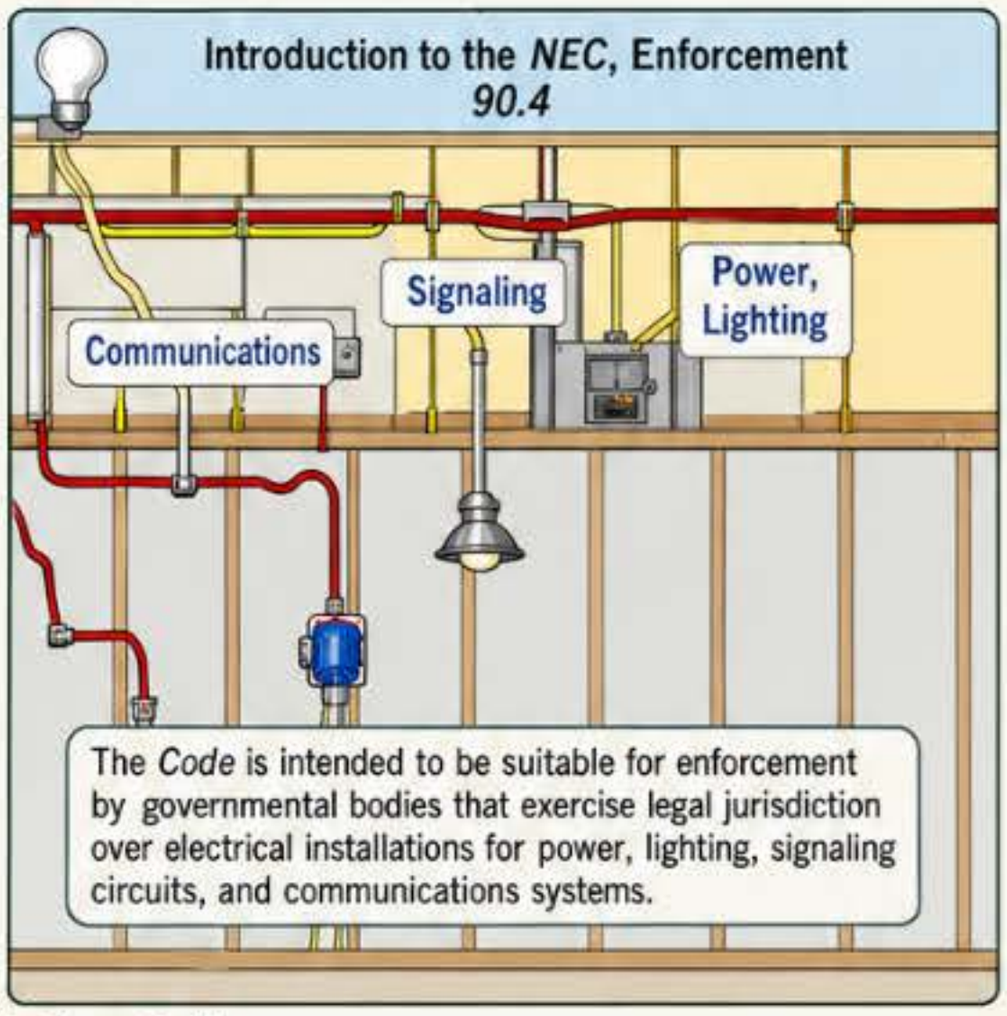
90.4 | Introduction to the *National Electrical Code*

90.4 Enforcement

Scan this QR code to watch a video of Michael Hamilton explaining this topic; it's an excerpt from the lessons that accompany this textbook.

The *NEC* is designed so government entities with legal authority can enforce electrical installation requirements for power, lighting, signaling, and communications systems.

▶ Figure 90–15



▶ Figure 90–15

Signaling circuits include:

- Article 725. Remote-Control, Signaling, and Power-Limited Circuits
- Article 760. Fire Alarm Systems
- Article 770. Optical Fiber Cables

Communications systems which include:

- Article 810. Radio and Television Equipment (Satellite Antenna)
- Article 820. Community Antenna Television and Radio Distribution Systems (Coaxial Cable)

Author's Commentary:

- *Once adopted (in whole or in part, or amended), the National Electrical Code becomes the statutory law for the jurisdiction adopting it and is thereby treated as a legal document.*

— Michael Hamilton

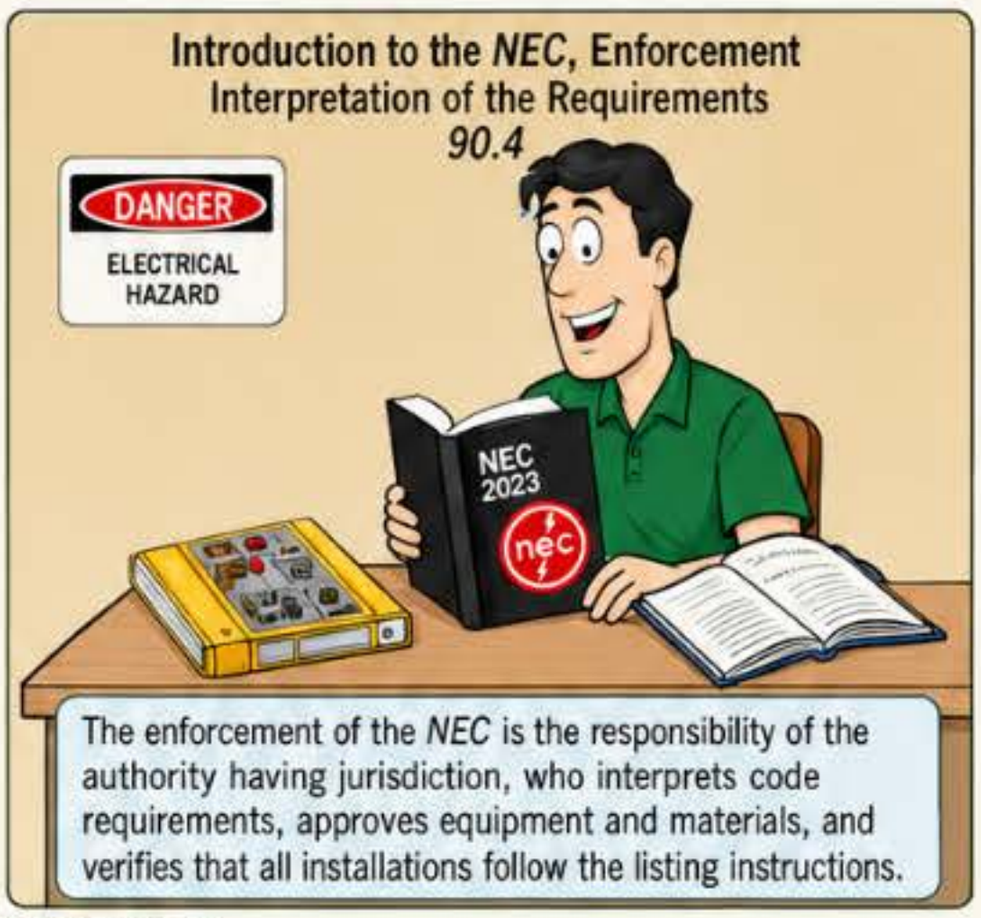
Enforcement. Enforcement of the *NEC* is the duty of the authority having jurisdiction. This official or organization is responsible for interpreting code requirements, approving equipment and materials, and ensuring that installations comply with all applicable code provisions and listing instructions.

▶ Figure 90–16

Author's Commentary:

- The term "authority having jurisdiction" is defined in *Article* 100 as the organization, agency, or person responsible for approving equipment, materials, an installation, or a procedure. See sections 90.4 and 90.7 for additional information.

— Michael Hamilton



▶ Figure 90–16

Author's Commentary:

- The word "approved" in Article 100 means acceptable to the authority having jurisdiction; this is usually the electrical inspector.

— Michael Hamilton

Interpretation. The authority having jurisdiction is responsible for interpreting the *NEC*.

Author's Commentary:

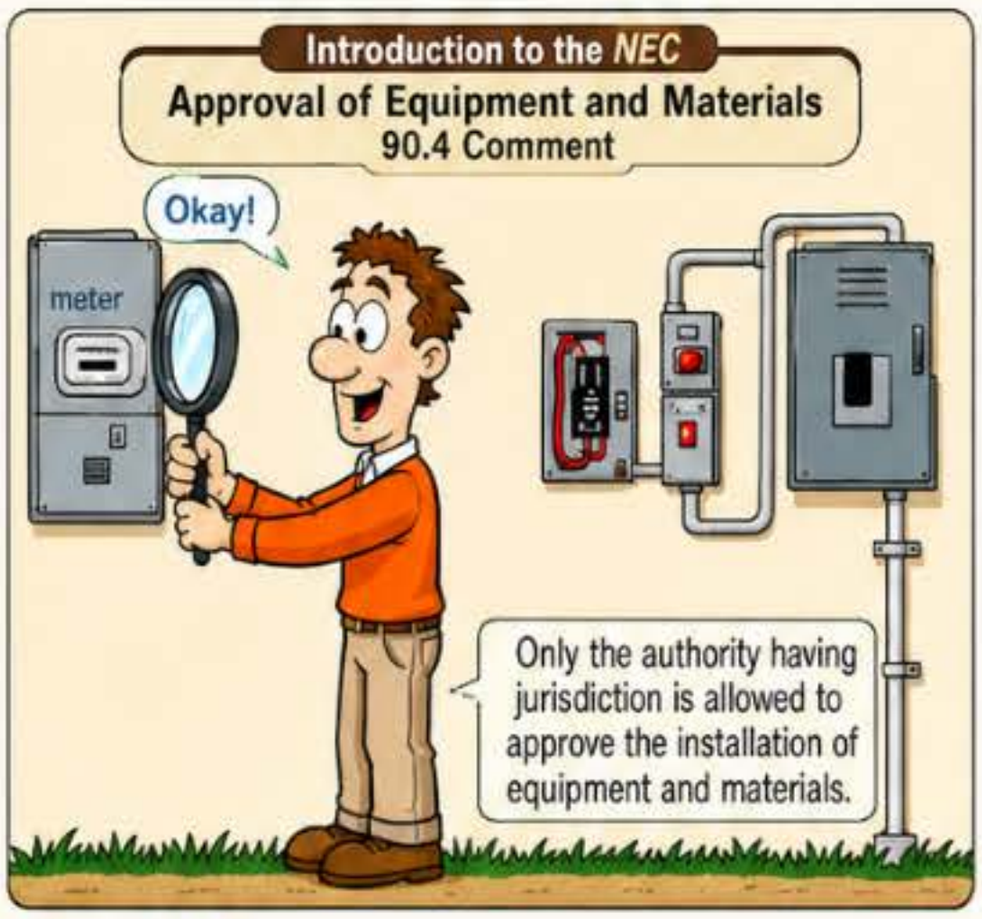
- *Interpretations issued by the authority having jurisdiction must be grounded in a specific code requirement. If an installation is rejected, the basis must be a particular NEC rule that was not met.*

The goal of working with the AHJ is to perform quality work and understand what the Code requires (not what you think it requires). This helps you make the right choices when inevitable disagreements arise.

— Michael Hamilton

DEFINITIONS | From Michael Hamilton Publications

Approval of Equipment and Materials. Only the authority having jurisdiction has the power to authorize the installation of equipment and the use of materials. ▸ **Figure 90–17**



▸ **Figure 90–17**

Author's Commentary:

Typically, the AHJ will authorize equipment that has been evaluated by a product testing organization such as Underwriters Laboratories, Inc. (UL). The NEC does not demand that all equipment be listed, but many state and local authorities not only have jurisdiction over this subject but also refer to Articles 90.7, 110.2, and 110.3 and the definitions for "Approved," "Identified," "Labeled," and "Listed" in Article 100.

Per the Code, the authority having jurisdiction determines whether to approve equipment. That means the AHJ may refuse an installation of identified equipment and might also reject listed equipment when it does not meet their standards. Because our highly safety-conscious society keeps raising the bar, it is becoming tougher to get approval for equipment that is not listed.

— Michael Hamilton

Approval of Alternate Means. With special permission, the authority having jurisdiction can accept alternative methods when those methods *provide equivalent safety and are properly* maintained.

Author's Commentary:

"Special permission" is the written consent of the AHJ as provided in Article 100.

— Michael Hamilton

Waiver of Product Requirements. *If the Code requires products, materials, or constructions that are not available when needed, the authority having jurisdiction may permit a waiver.*

NEC is adopted, and the authority having jurisdiction may allow items that were acceptable under the earlier *Code* to keep being used.

Author's Commentary:

In some cases it takes years for testing labs to develop product standards for new *NEC* requirements. Then it may take manufacturers time to design, build, and sell those new products.

— Michael Hamilton

90.5 Mandatory Requirements and Explanatory Material

(A) Mandatory Requirements. The words "shall" or "shall not" show a mandatory requirement.

Author's Commentary:

For simplicity in reading this book, we will use "must" when "shall" appears and "must not" in place of "shall not."

— Michael Hamilton

(B) Permissive Requirements. When the *Code* uses "shall be permitted," it means the action is allowed but not required. Permissive rules are often listed with exceptions to the general rule.

Author's Commentary:

To make reading easier, the phrase "shall be permitted" (as found in the NEC) is replaced with "is permitted" or "are permitted" throughout this book.

— Michael Hamilton

(C) Explanatory Material. References to other standards or information in a *Code* rule appear as "Informational Notes." These notes are provided only for information and do not enforce any *NEC* requirement.

For example, Informational Note No. 3 in 210.19(A)(1) recommends that the voltage drop in a circuit not exceed 3 percent. *This is a recommendation—not a rule that must be followed.*

Author's Commentary:

For convenience and easier reading, "Informational Notes" will simply be called "Note" in this text.

— Michael Hamilton

CAUTION

Side notes and other commentary in this book are provided for educational purposes only. Since these notes are not mandated by the *Code*, we will refer to them as "Table Notes."

(D) Informative Annexes. Appendix material found in the back of the *Code* consists of useful reference information only and carries no mandatory requirements of the *Code*.

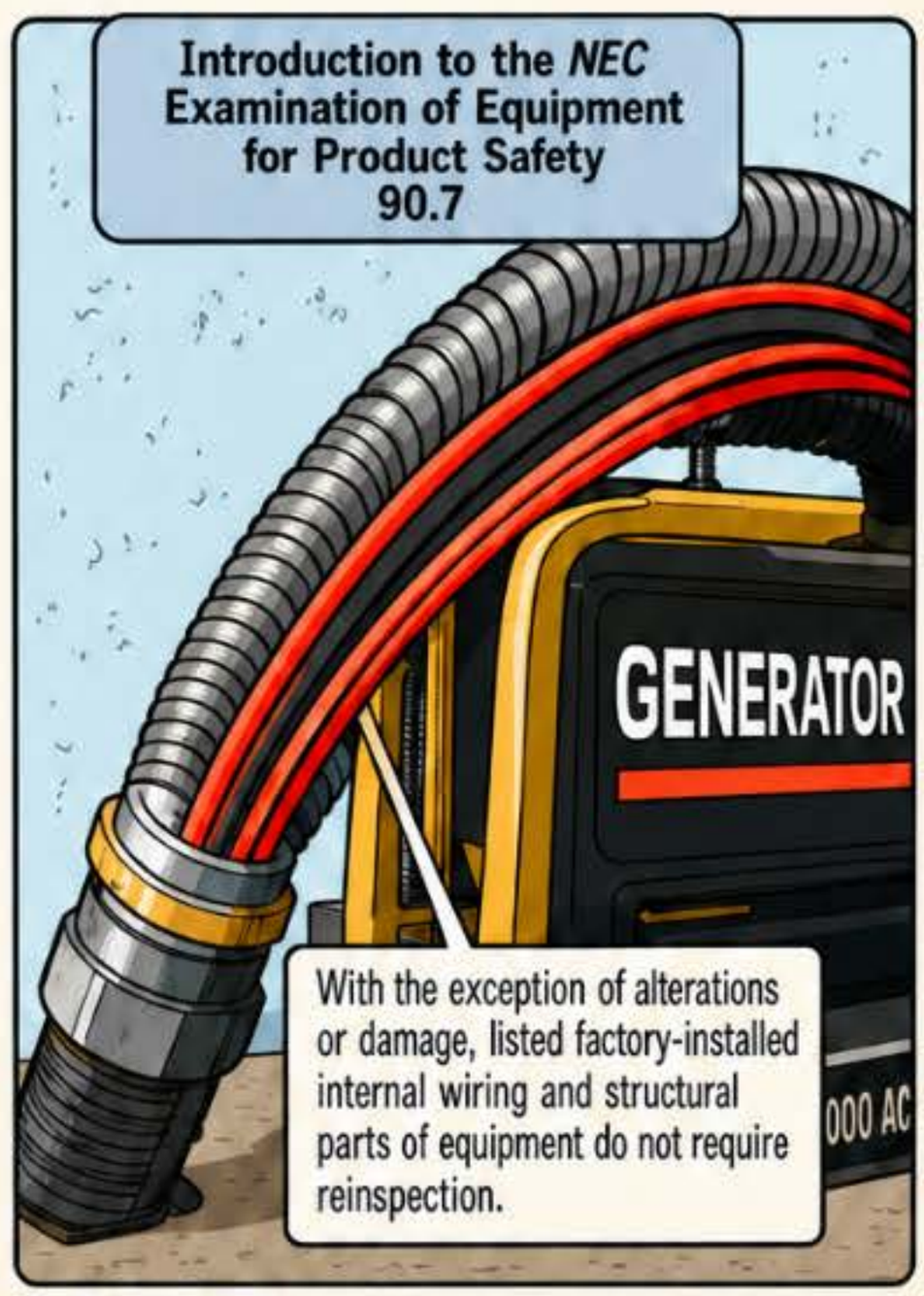
90.7 Examination of Equipment for Product Safety

To ensure compliance with the *Code*, for approval, and to help safeguard people, equipment is usually tested by a nationally accredited laboratory following the standards listed in the *Code*.

Except for changes, damage, or listed factory-installed wiring inside equipment that has already been checked and approved by a qualified testing laboratory, equipment does not need to be inspected a second time for *Code* compliance at the time of field installation.

Note 1: The provisions of Article 300 do not apply to the integral components of *electric equipment*. See 110.3(B).

Note 2: The term "listed" is explained in Article 100 as equipment or materials that appear in a list issued by a recognized testing laboratory acceptable to the authority having jurisdiction. The listing organization must regularly review the products or materials it lists to make sure they continue to meet the appropriate standards and remain suitable for their intended use.



▶ Figure 90–18

ARTICLE 90

PRACTICE QUESTIONS

Please use the *2023 Code* book to answer the following questions.

ARTICLE 90—INTRODUCTION TO THE *NATIONAL ELECTRICAL CODE*

1. The *NEC* is ____.

(a) intended to be a design manual
(b) meant to be used as an instruction guide for untrained persons
(c) for the practical safeguarding of persons and property
(d) published by the Bureau of Standards

2. Compliance with the *Code* and proper maintenance result in an installation that is ____.

(a) essentially free from hazards
(b) not necessarily efficient or convenient
(c) not necessarily adequate for good service or future expansion
(d) all of these

3. Compliance with the provisions of the *NEC* will result in ____.

(a) good electrical service
(b) an efficient electrical system
(c) an electrical system essentially free from hazard
(d) all of these

4. The *Code* contains provisions considered necessary for safety, which will not necessarily result in ____.

(a) efficient use
(b) convenience
(c) good service or future expansion of electrical use
(d) all of these

5. Electrical hazards often occur because the initial wiring did not provide for increases in the use of electricity and therefore wiring systems become overloaded.

(a) inspection
(b) owner
(c) wiring
(d) builder

6. Hazards often occur because of ____.

(a) overloading of wiring systems by methods or usage not in conformity with the *NEC*
(b) initial wiring not providing for increases in the use of electricity
(c) manufacturing defects
(d) overloading of wiring systems by methods or usage not in conformity with the *NEC* and initial wiring not providing for increases in the use of electricity

7. Which of the following systems shall be installed and removed in accordance with the *NEC* requirements?

(a) Signaling conductors, equipment, and raceways
(b) Communications conductors, equipment, and raceways
(c) Electrical conductors, equipment, and raceways
(d) all of these

8. The *NEC* applies to the installation of ____.

(a) electrical conductors and equipment within or on public and private buildings
(b) signaling and communication conductors
(c) optical fiber cables
(d) all of these

Article 90 | Practice Questions

9. This Code covers the installation of _____ for public and private premises, including buildings, structures, mobile homes, recreational vehicles, and floating buildings.

(a) optical fiber cables
(b) electrical equipment
(c) raceways
(d) all of these

10. Installations supplying _____ power to ships and watercraft in marinas and boatyards are covered by the *NEC*.

(a) shore
(b) primary
(c) secondary
(d) auxiliary

11. Installations used to export electric power from vehicles to premises wiring or for _____ current flow are covered by the *NEC*.

(a) emergency
(b) primary
(c) bidirectional
(d) secondary

12. The *NEC* does apply to installations in _____.

(a) floating buildings
(b) mobile homes
(c) recreational vehicles
(d) all of these

13. The *NEC* does not cover electrical installations in ships, watercraft, railway rolling stock, aircraft, or automotive vehicles.

(a) True
(b) False

14. The *Code* covers underground mine installations and self-propelled mobile surface mining machinery and its attendant electrical trailing cable.

(a) True
(b) False

15. The *Code* does not cover installations under the exclusive control of an electrical utility such as _____.

(a) service drops and laterals
(b) electric utility office buildings
(c) electric utility warehouses
(d) electric utility garages

16. Installations of communications equipment that are under the exclusive control of communications utilities and located outdoors or in building spaces used exclusively for such installations _____ covered by the *NEC*.

(a) are
(b) are sometimes
(c) are not
(d) may be

17. Chapters 1 through 4 of the *NEC* apply _____.

(a) generally to all electrical installations
(b) only to special occupancies and conditions
(c) only to special equipment and material
(d) all of these

18. Chapters 5, 6, and 7 apply to special occupancies, special equipment, or other special conditions and may supplement or modify the requirements in Chapters 1 through 7.

(a) True
(b) False

19. Chapters 5, 6, and 7 of the *NEC* apply to _____.

(a) special occupancies
(b) special equipment
(c) special conditions
(d) all of these

20. Communications wiring such as telephone, antenna, and CATV wiring within a building shall not be required to comply with the installation requirements of Chapters 1 through 7, except where specifically referenced in Chapter 8.

(a) True
(b) False

21. Installations shall comply with the material located *in the NEC Annexes because they are part of the requirements of the Code.*

(a) True
(b) False

22. The _____ *has the responsibility for deciding on the approval of equipment and materials.*

(a) manufacturer
(b) authority having jurisdiction
(c) testing agency
(d) the owner of the premises

PRACTICE QUESTIONS | 90.7

23. The authority having jurisdiction is responsible for which of the following?

(a) creating interpretations of rules
(b) making decisions on equipment and materials approval
(c) applying specific requirements in the *Code* and allowing alternate methods and materials when safety is still achieved
(d) all of these

24. If the *NEC* requires new products that are not yet available when a new edition is adopted, the _____ may allow use of the products that complied with the most recent earlier edition of the *Code* adopted by that jurisdiction.

(a) electrical engineer
(b) master electrician
(c) authority having jurisdiction
(d) permit holder

25. In the *NEC*, the word "_____" indicates a mandatory requirement.

(a) shall
(b) shall not
(c) shall be permitted
(d) shall or shall not

26. When the *Code* uses "_____" it means that the identified actions are allowed but not required, and they may be options or alternative methods.

(a) shall
(b) shall not
(c) shall be permitted
(d) shall or shall not

27. Explanatory material such as references to other standards, references to related sections of the *NEC*, or information related to a *Code* rule are included in the form of Informational Notes.

(a) True
(b) False

28. Nonmandatory Informative Annexes contained in the back of the *Code* book are _____.

(a) for information only
(b) not enforceable as a requirement of the *Code*
(c) enforceable as a requirement of the *Code*
(d) for information only and not enforceable as a *requirement of the Code*

29. It is the intent of the *NEC* that factory-installed _____ wiring of listed equipment need not be inspected at the time of installation of the equipment, except to detect alterations or damage.

(a) external
(b) associated
(c) internal
(d) all of these

30. Factory-installed _____ wiring of listed equipment need not be inspected at the time of installation of the equipment, except to detect alterations or damage.

(a) external
(b) associated
(c) internal
(d) all of these

Author's Commentary:
Distinguishing between "shall" and "shall be permitted" is essential when reading the NEC. "Shall" means you must comply. "Shall be permitted" means you have permission to use an option, but it's not mandatory. This understanding helps prevent misinterpretation and supports safe, code-compliant installations.

— Michael Hamilton

Author's Commentary:
The NEC includes helpful guidance that is informative but not mandatory. Annexes, notes, and optional language provide valuable context and flexibility, but only the enforceable requirements marked by "shall" carry mandatory weight in the field.

— Michael Hamilton

Notes

CHAPTER 1 GENERAL RULES

Introduction to Chapter 1—General Rules

To work effectively with the *2023 NEC*, you need a solid grasp of the general rules, core ideas, key definitions, and essential requirements.

This chapter introduces two major elements: a list of 100 terms that clarify the vocabulary used in *Code* discussions and Article 110, which outlines the overall requirements for applying the *NEC* correctly.

Once you understand Chapter 1, portions of the *Code* that may seem confusing will be much easier to interpret. These rules provide the foundation you will rely on for clear understanding and proper application throughout the *NEC*.

- **Article 100—Definitions.** Article 100 is organized into three parts. Part I includes definitions for all terms used throughout the *Code* for systems operating at 1,000 volts or less, whether AC or DC. The definitions apply to both nominal and non-nominal systems and are not limited by the scope of this textbook. Part II lists definitions that only apply to "*Hazardous (Classified)* Locations" in Chapter 5 of the *NEC*.

  The article overall contains only terms that are used in more than one place. Everyday electrical words such as *volt, voltage drop, ampere, impedance, and resistance are not included in Article 100. If the NEC does not define a word, then a dictionary or the legal term dictionary in your jurisdiction must be used to find an acceptable meaning.*

  Definitions can be placed at the beginning of an article, throughout the article, or at the end. When a definition appears in an article, it applies to that article, and the article number is followed by ".2." *For example, definitions specific to photovoltaic (PV) systems are located in 690.2.*

- **Article 110—Requirements for Electrical Installations.** *This article outlines the general rules that apply to all electrical installations.*

Notes |

ARTICLE 100 DEFINITIONS

Introduction to Article 100—Definitions

How often have you been in a conversation with someone just trying to figure out what a word meant or how it should be interpreted? Misunderstandings like this happen all the time when people use terms differently.

That's why the definitions in the 2023 *NEC* appear right at the start of the *Code* (Article 100), before any other articles. Defining key words up front helps promote clarity and prevents confusion. Because the *NEC* exists to safeguard people and property, it's crucial that you can explain terms clearly and understand how they are used. Read through Article 100 carefully so you can use these definitions with confidence.

100 Definitions

Scope. This article provides definitions that are vital for applying this *Code*; it does not include all necessary terms from other *codes* and *standards*. In general, any word or phrase used in two or more articles is defined in Article 100.

Definitions are also found in the following:

- Part I of this article contains definitions intended for use wherever those terms appear throughout the *NEC*.
- Part III contains definitions that apply to *Hazardous (Classified) Locations*.

Accessible (as applied to equipment). Capable of being reached for operation, renewal, and inspection. **Figure 100–1**

Accessible, Readily (Readily Accessible). Capable of being reached *quickly for operation, renewal, or* inspection without needing those *to whom ready access is necessary to use tools (such as keys), climb over or under obstacles, remove barriers, or resort to portable ladders, and so forth.* **Figure 100–2**

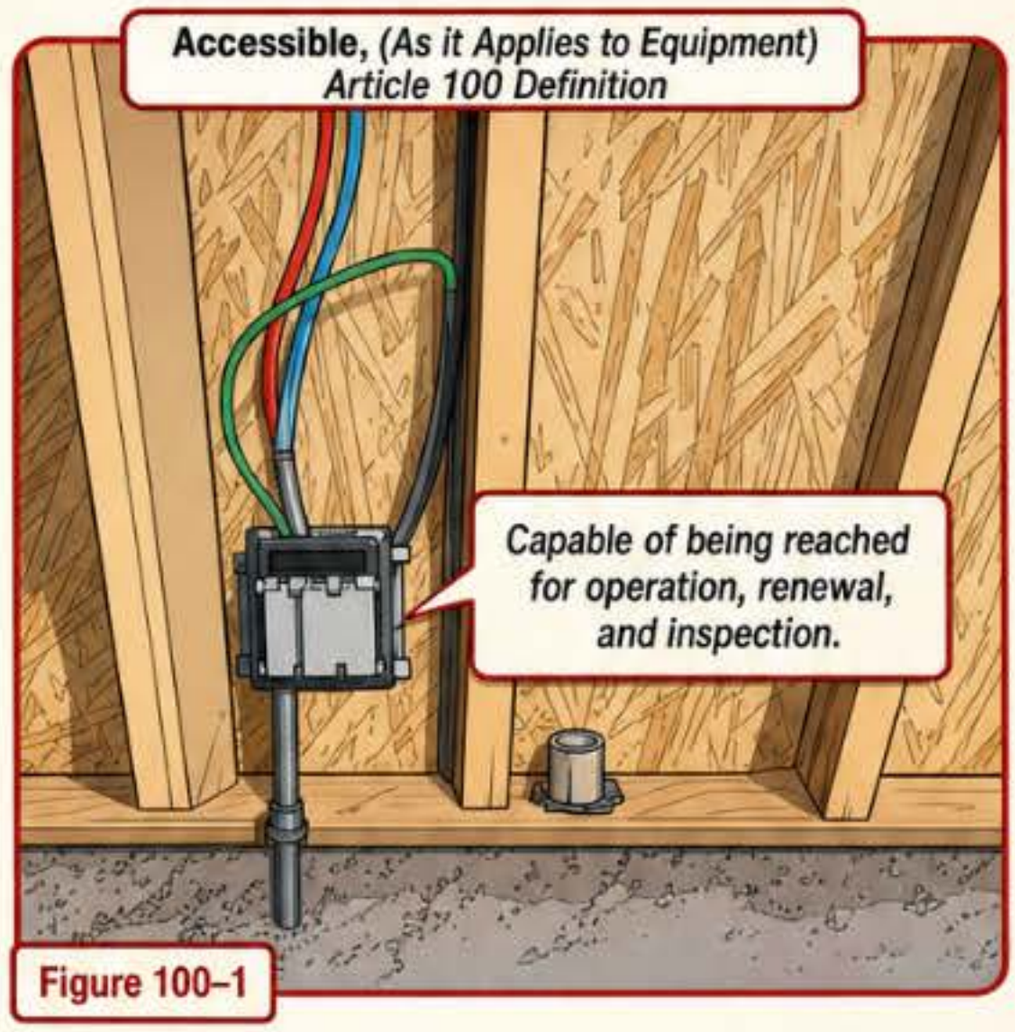


Figure 100–1

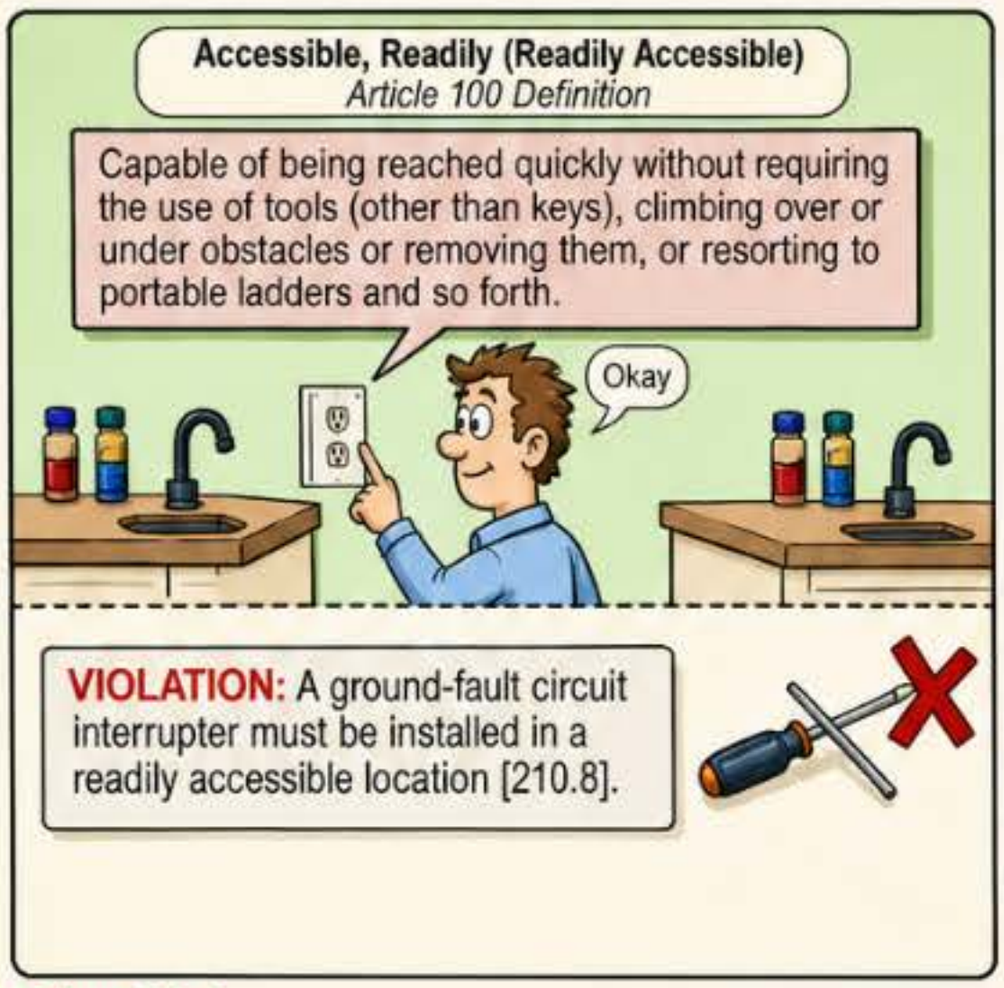
Note: The use of keys for locks on electrical equipment, *and locked doors to electrical equipment rooms and vaults, is a common practice and permitted by the NEC.* **Figure 100–3**

Adjustable-Speed Drive System. *A combination of an adjustable speed drive (with its associated motor(s)) and any other equipment associated with the two.*

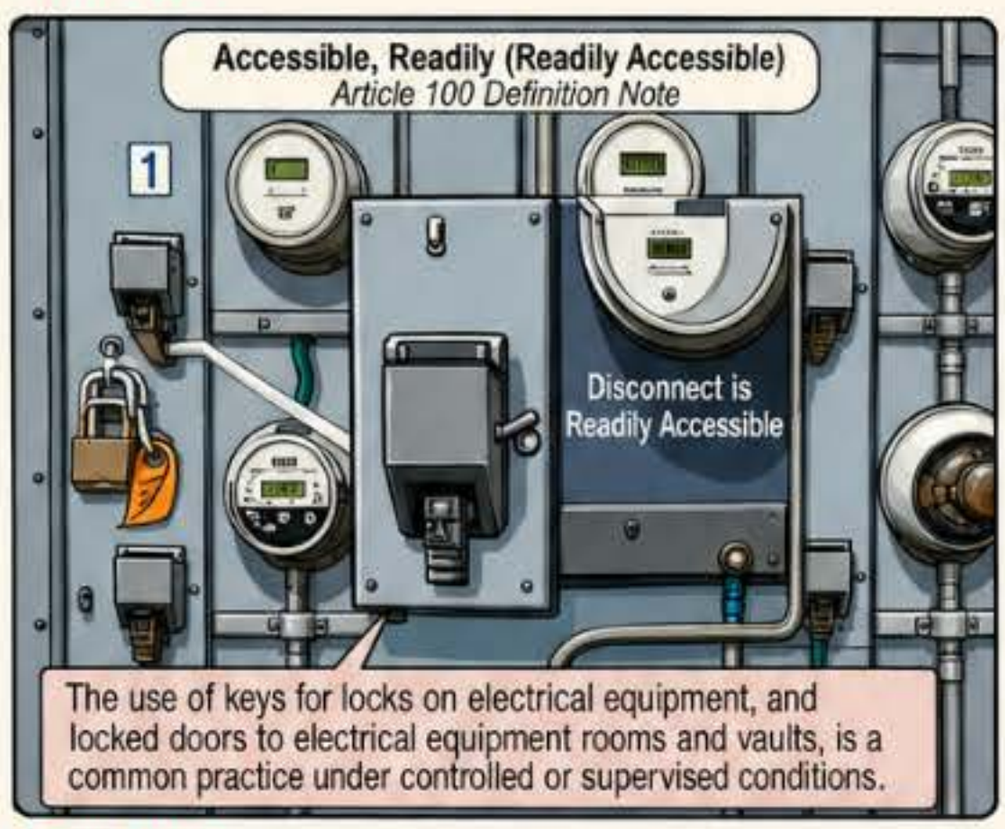
Author's Commentary:

Clear definitions are the foundation of safe electrical work. If you know exactly what a term means, you're far less likely to make a dangerous mistake.

— Michael Hamilton



▶ Figure 100–2

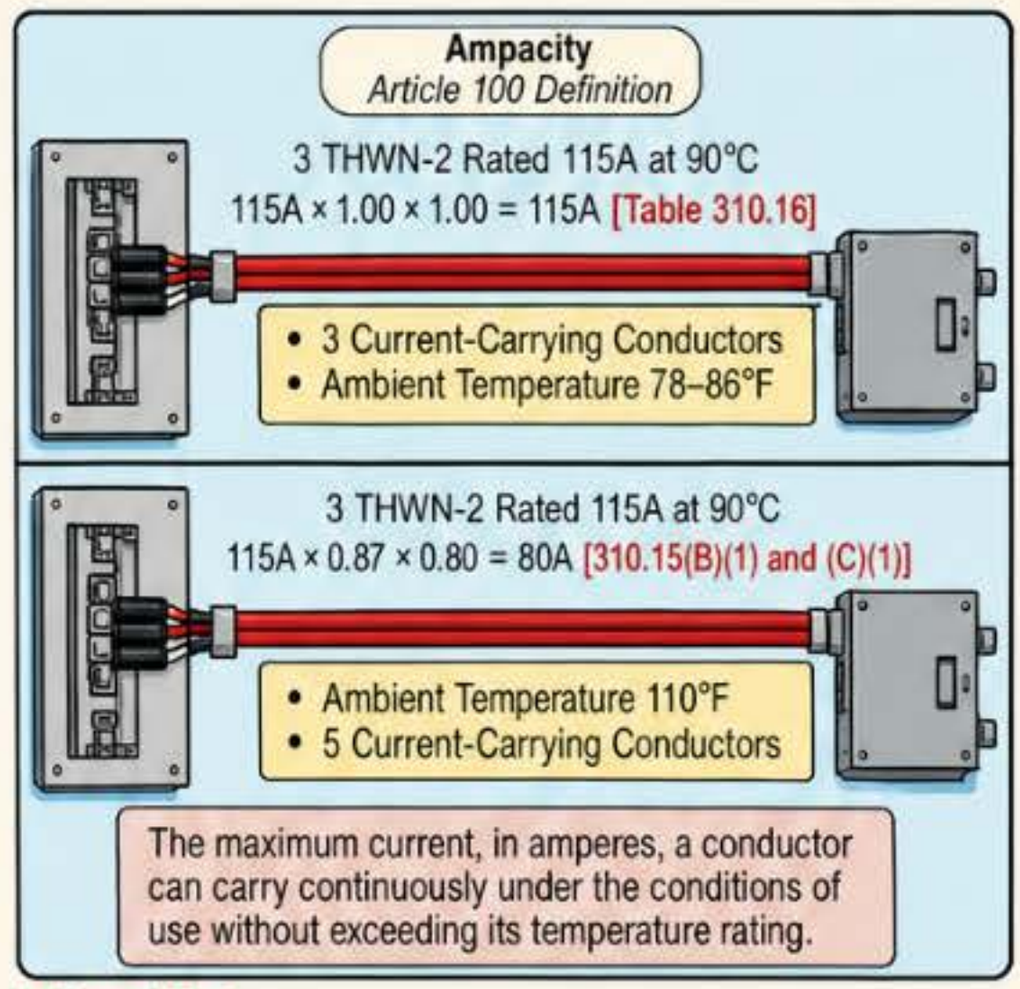


▶ Figure 100–3

Author's Commentary:

- An adjustable-speed drive is a *piece of equipment that provides* a way to adjust the speed *of an electric motor. Adjustable-speed drives are often referred to as "variable-speed drives" or "variable-frequency drives (VFDs)."*
- A *variable-frequency drive is a type of electronic adjustable-speed drive that controls the speed of an alternating-current motor by changing the frequency and voltage of the motor's power supply.*

Ampacity. The current, in amperes, a *conductor can carry continuously under its conditions of use without exceeding its temperature rating.* ▶ Figure 100–4



▶ Figure 100–4

Author's Commentary:

- See 310.10 and 310.15 for details and examples.

Appliance [Article 422]. Electrical equipment, other than industrial equipment, built in standardized sizes. Examples of appliances are ranges, ovens, cooktops, refrigerators, drinking water coolers, and beverage dispensers.

Approved. Acceptable to the authority having jurisdiction; usually the electrical inspector. ▶ Figure 100–5

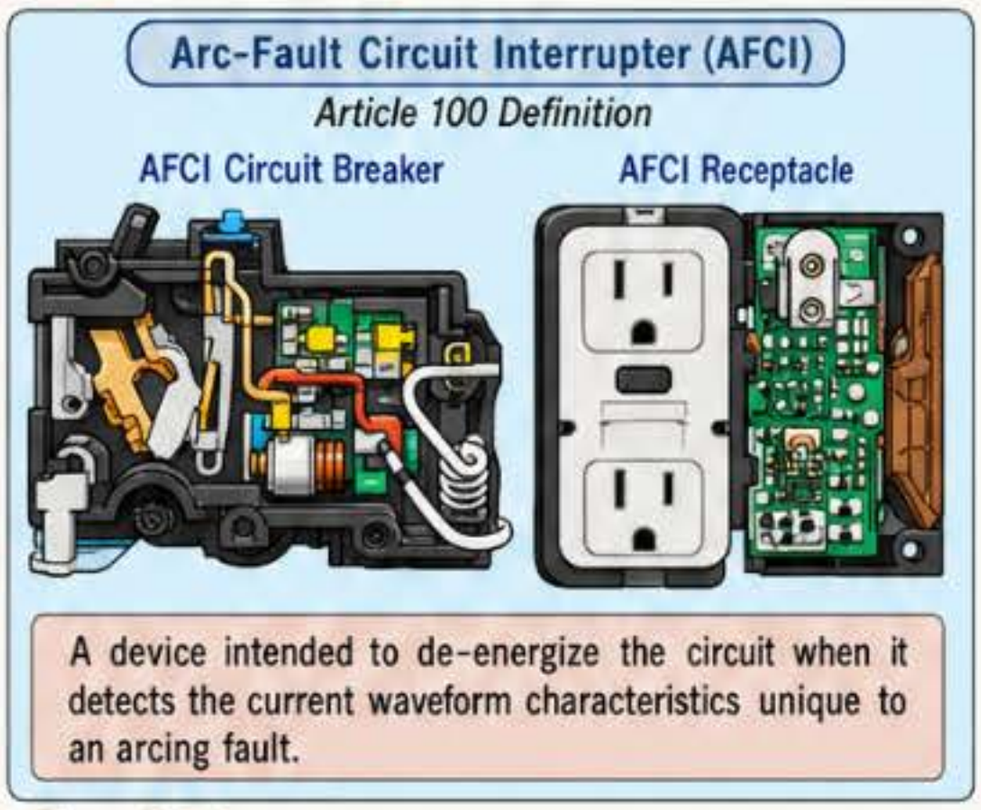
▶ Figure 100–5

DEFINITIONS | From Michael Hamilton Publications

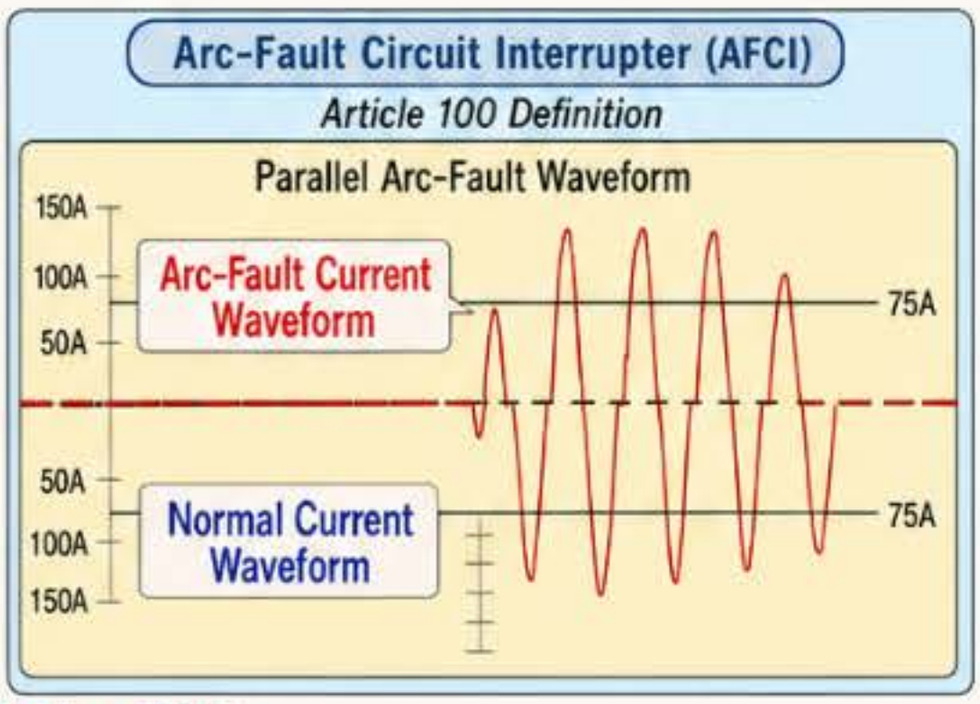
Author's Commentary:
A product listing does not mean the product is approved. However, such listings can provide a foundation for approval. See 90.4, 90.7, and 110.2 and the definitions here for "Authority Having Jurisdiction," "Identified," "Labeled," and "Listed."

— Michael Hamilton

Arc-Fault Circuit Interrupter (AFCI). A device designed to de-energize the circuit when it senses the unique current waveform characteristics produced by an arc fault. • Figure 100-6 and • Figure 100-7



▶ Figure 100-6

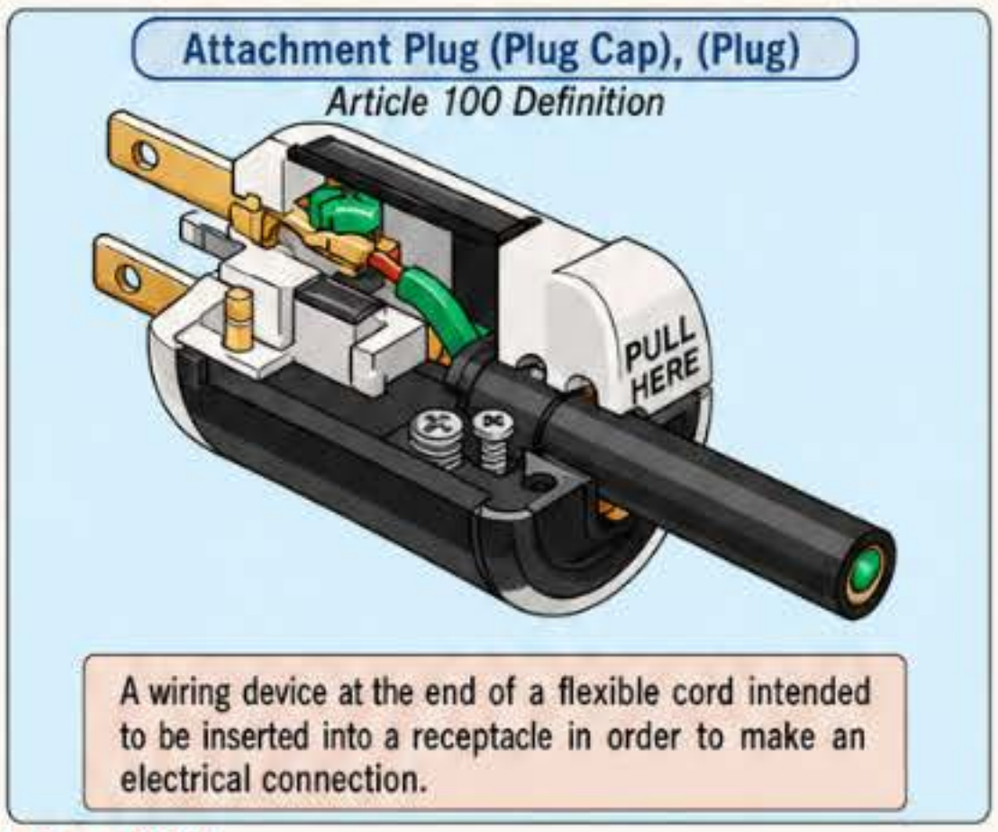


▶ Figure 100-7

Attachment Fitting. A device that, by insertion into a locking support and mounting receptacle, establishes a connection between the conductors of the attached utilization equipment and the branch-circuit conductors connected to the locking support and mounting receptacle.

Note: *An attachment fitting is different from an attachment plug, because no cord is associated with the fitting. Using a locking support together with a mounting receptacle secures the connected equipment and helps it support its weight.*

Attachment Plug (Plug Cap), (Plug). A wiring device at the end of a flexible cord intended to be inserted into a receptacle to create an electrical connection. • Figure 100-8



▶ Figure 100-8

Authority Having Jurisdiction (AHJ). The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure. See 90.4 and 90.7 for more information.

Note: *The authority having jurisdiction may be a federal, state, or local government department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor or health department, a building official, electrical inspector, or others having statutory authority. In some situations, the property owner or his or her agent assumes the role, and at government installations, the commanding officer or departmental official may be the authority having jurisdiction.*

Author's Commentary:
The authority having jurisdiction can be a federal, state, or local agency or an individual like a fire chief, building official, or electrical inspector. In certain cases, the property owner or their agent takes on this role, and at government facilities, it may be the commanding officer or a designated official.

— Michael Hamilton

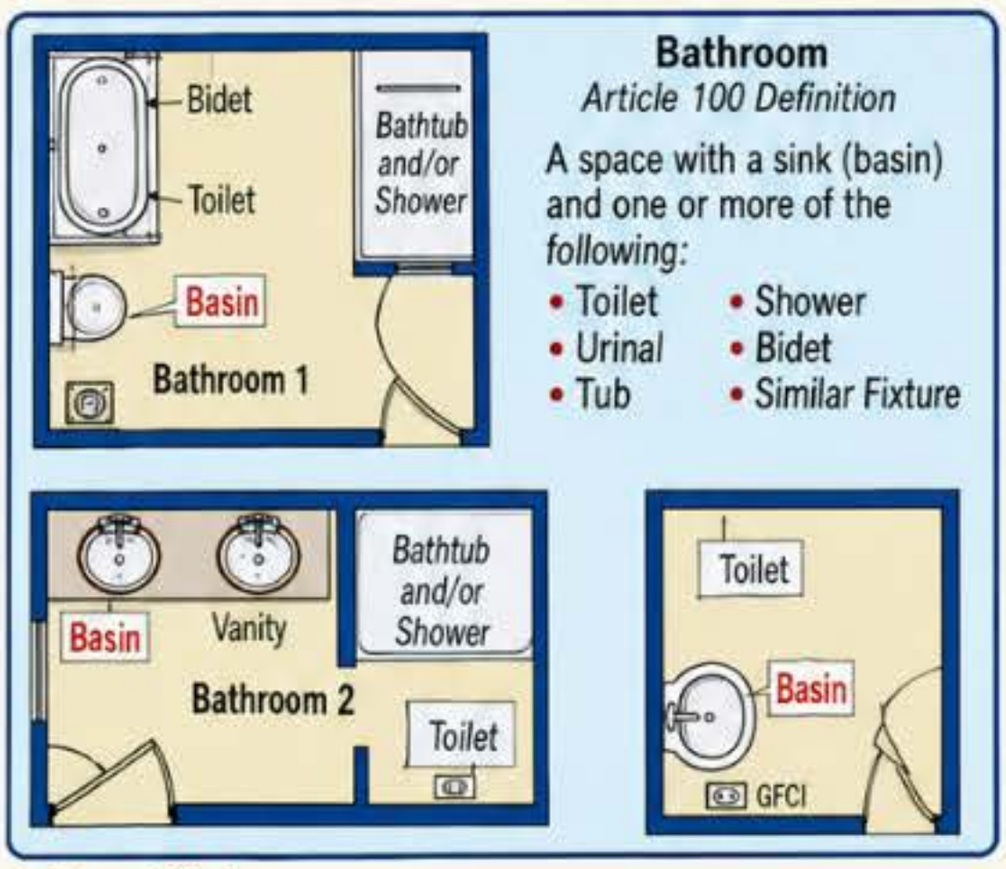
Author's Commentary:

- The individual who enforces electrical requirements is usually an electrical inspector who has legal permission to act in that role. If no federal, state, or local rules apply, the building operator (or their representative, such as an architect or engineer working for the facility owner) assumes this responsibility.
- Most people who "have authority having jurisdiction" have at least some field background in electrical work, such as training in electrical design or practical experience as a contractor or licensee. In a few cases, State rules may allow this position without electrical experience. Membership, certificates, or active participation in electrical groups like the International Association of Electrical Inspectors (IAEI) can show an individual's qualifications. Go to IAEI.org to learn more about the organization.

— Michael Hamilton

Automatic. *Operating without the need for direct human action.*

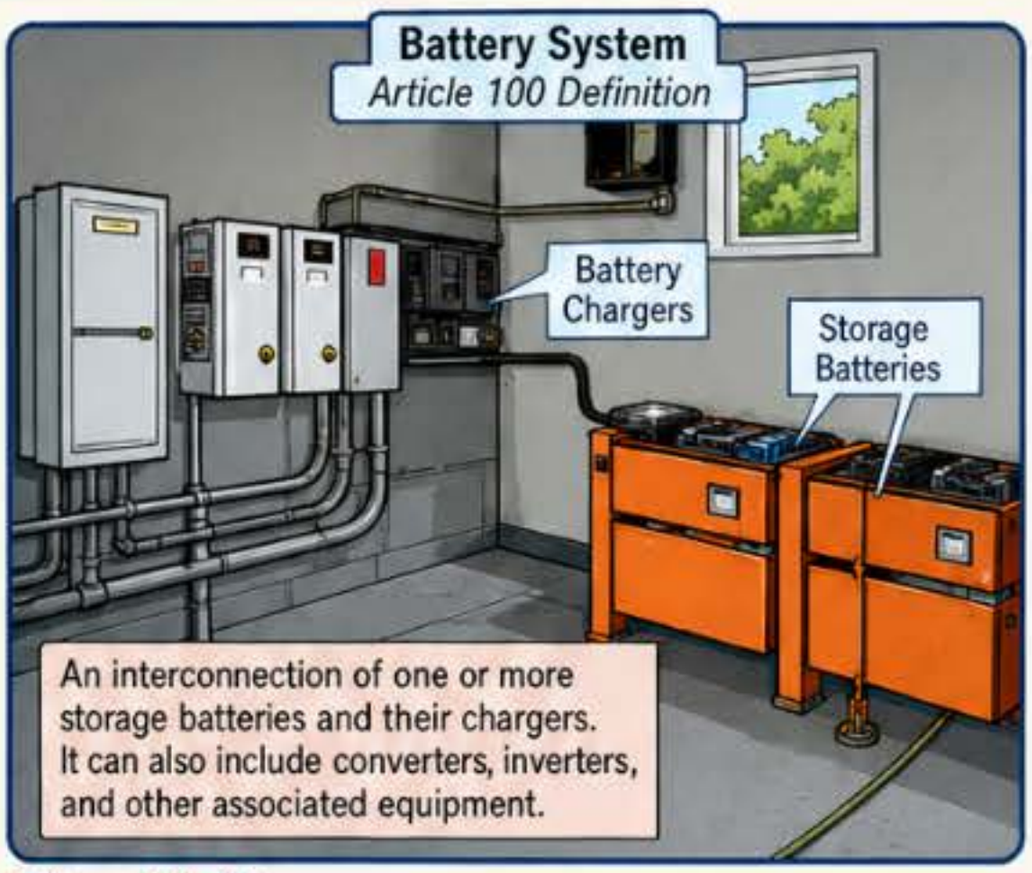
Bathroom. *A space with a sink (basin) and one or more of the following: a toilet, urinal, tub, shower, bidet, or other plumbing fixture.* • Figure 100–9



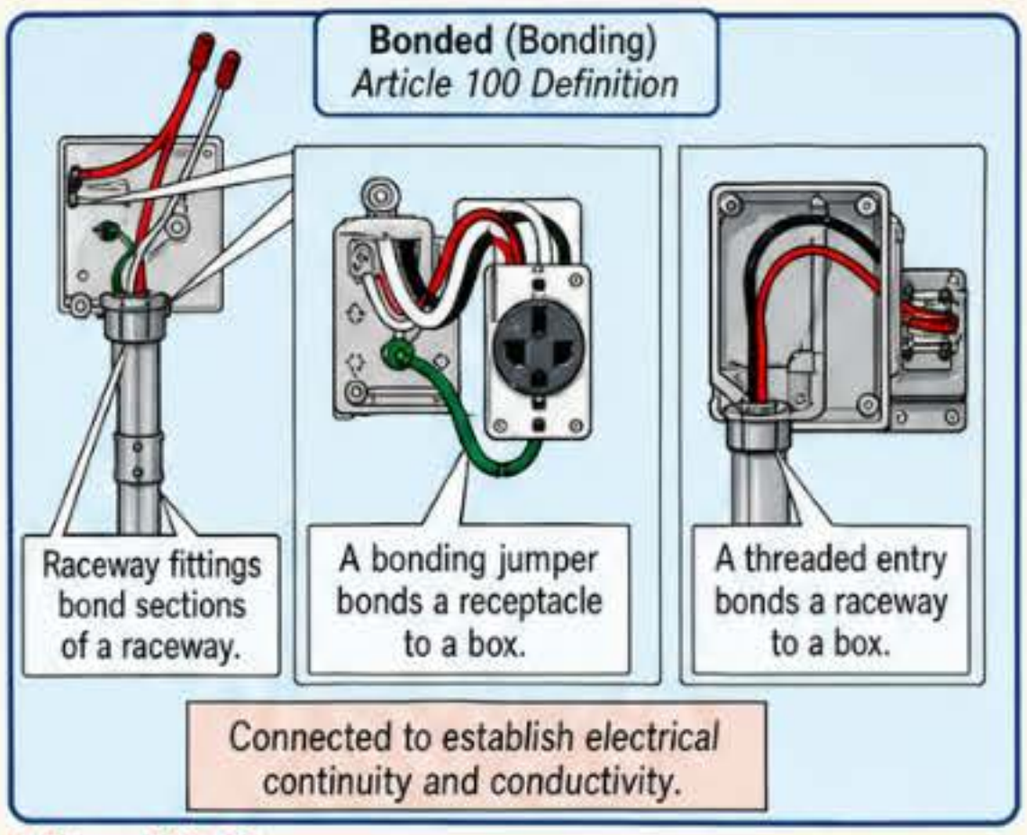
▶ Figure 100–9

Battery System. *An interconnection of one or more storage batteries and their chargers. It can also include converters, inverters, and other associated equipment.* • Figure 100–10

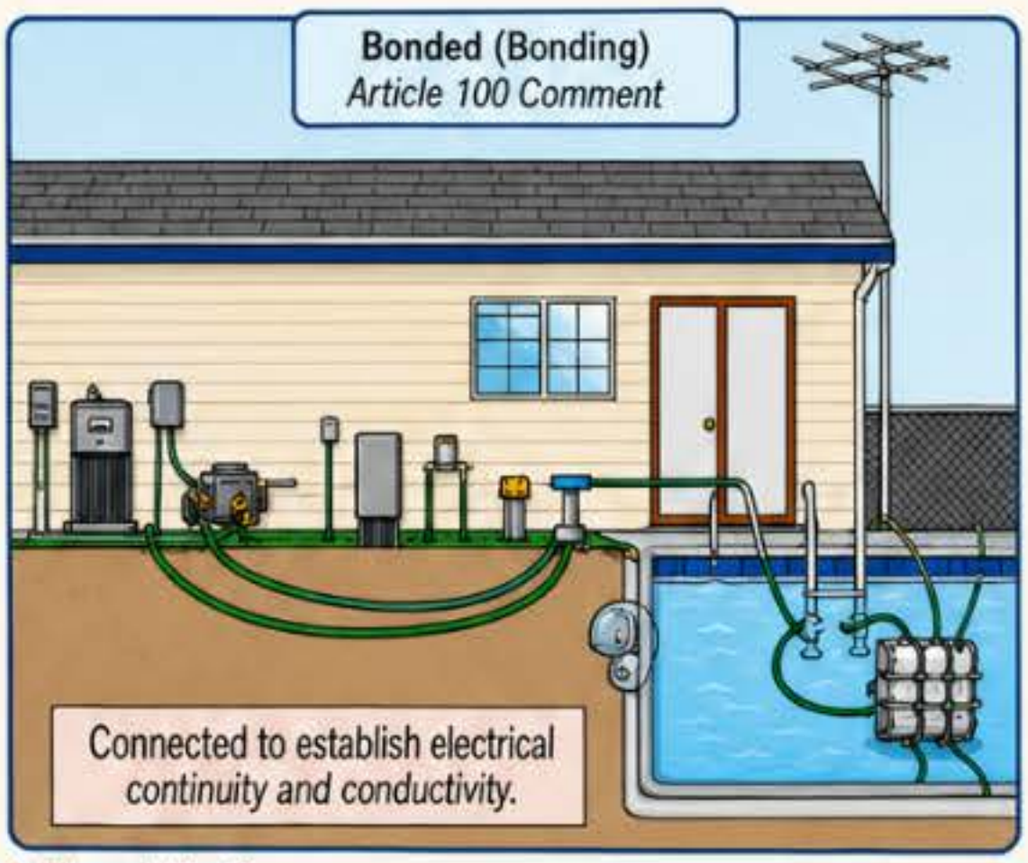
Bonded (Bonding). *Connected to establish electrical continuity and conductivity.* • Figure 100–11 *and* • Figure 100–12



▶ Figure 100–10



▶ Figure 100–11



▶ Figure 100–12

DEFINITIONS | From Michael Hamilton Publications

Bonding Conductor or Jumper. A bonding conductor creates a low-impedance path that maintains electrical continuity between metal parts of an electrical system. **Figure 100–13**

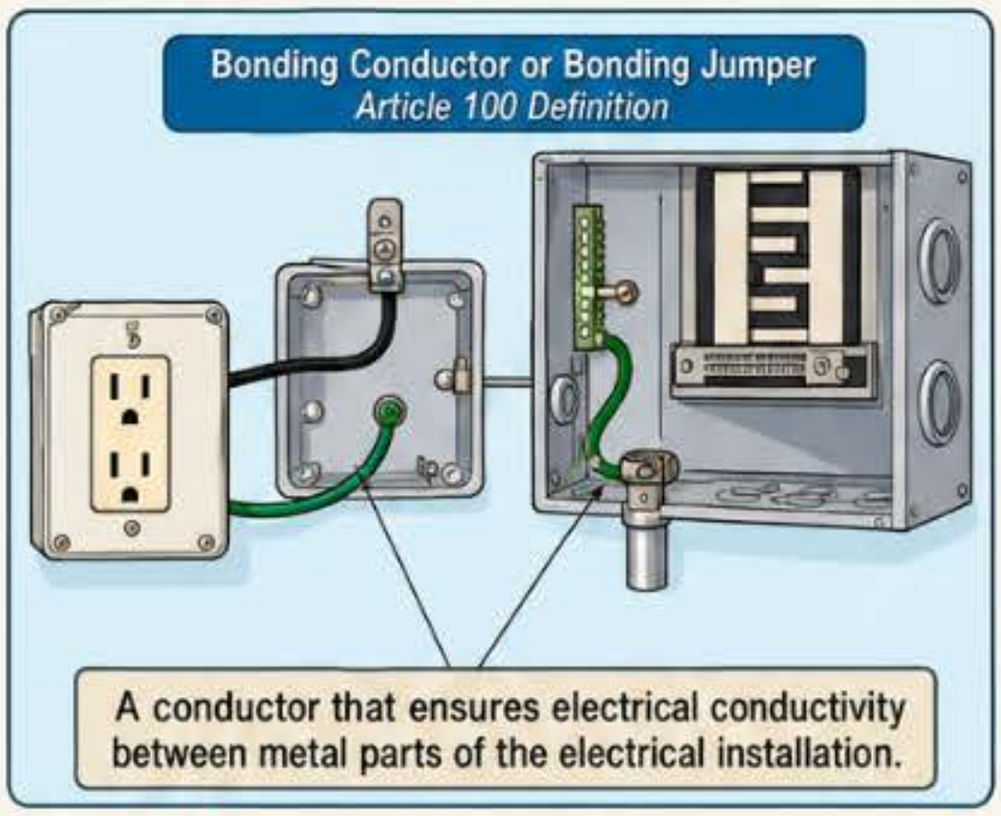


Figure 100–13

Author's Commentary:
Either "bonding conductor" or "bonding jumper" may be used as the term. They can be short or extended in length and typically provide an electrical connection between two metallic components.
— *Michael Hamilton*

Bonding Jumper, Equipment. A connection that joins two or more portions of the equipment grounding conductor. **Figure 100–14**

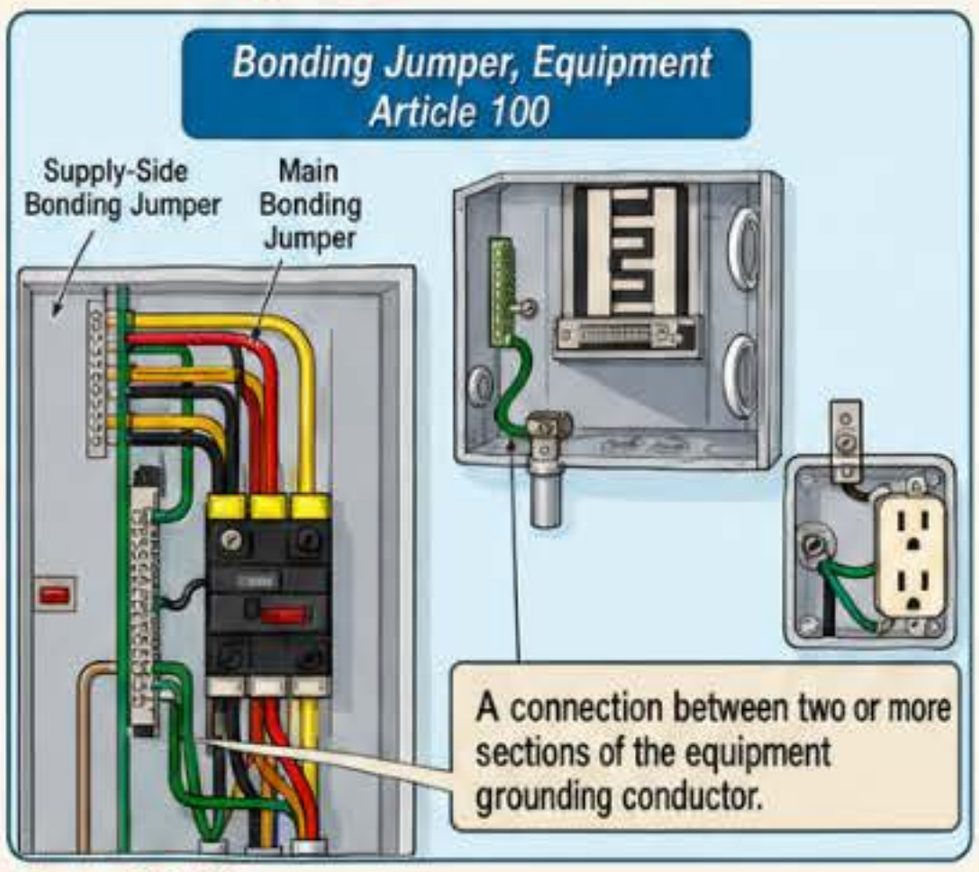


Figure 100–14

Author's Commentary:
Equipment bonding jumpers are installed where the mechanical or electrical path needed for ground-fault current could be opened or disrupted.
— *Michael Hamilton*

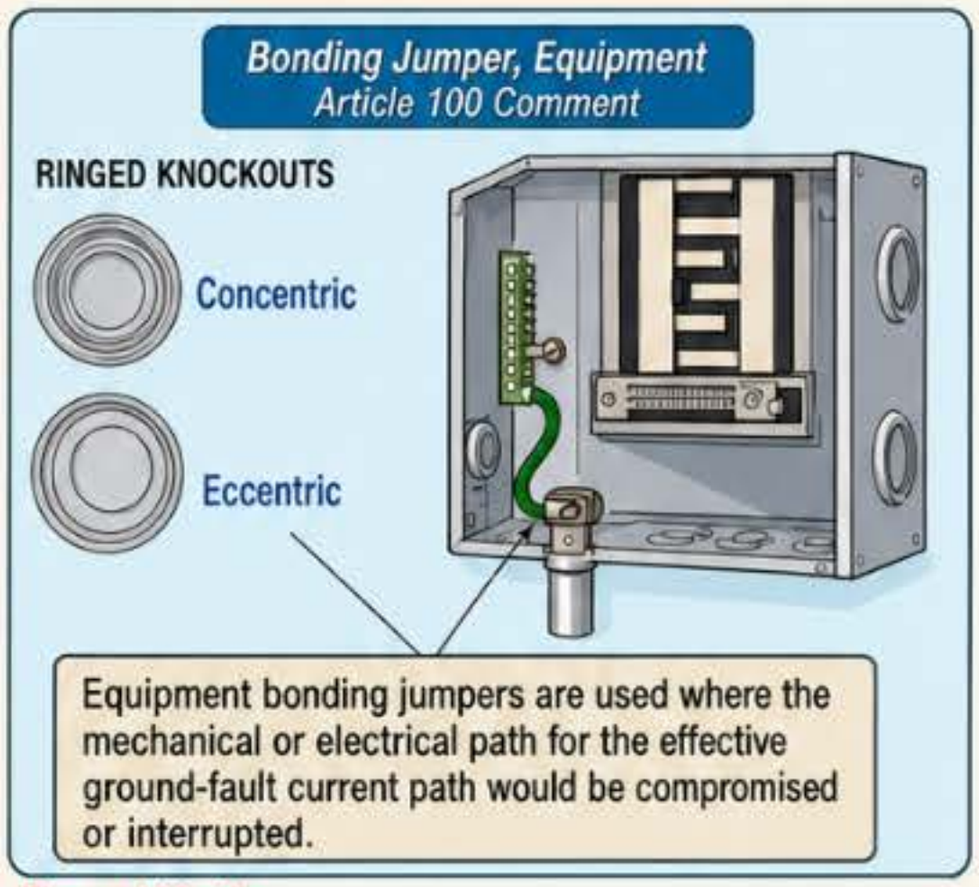


Figure 100–15

Bonding Jumper, Main. A conductor, screw, or strap used to connect the circuit equipment grounding conductor to the neutral conductor or the supply-side bonding jumper at the service equipment in accordance with 250.24(B). **Figure 100–16 and Figure 100–17**

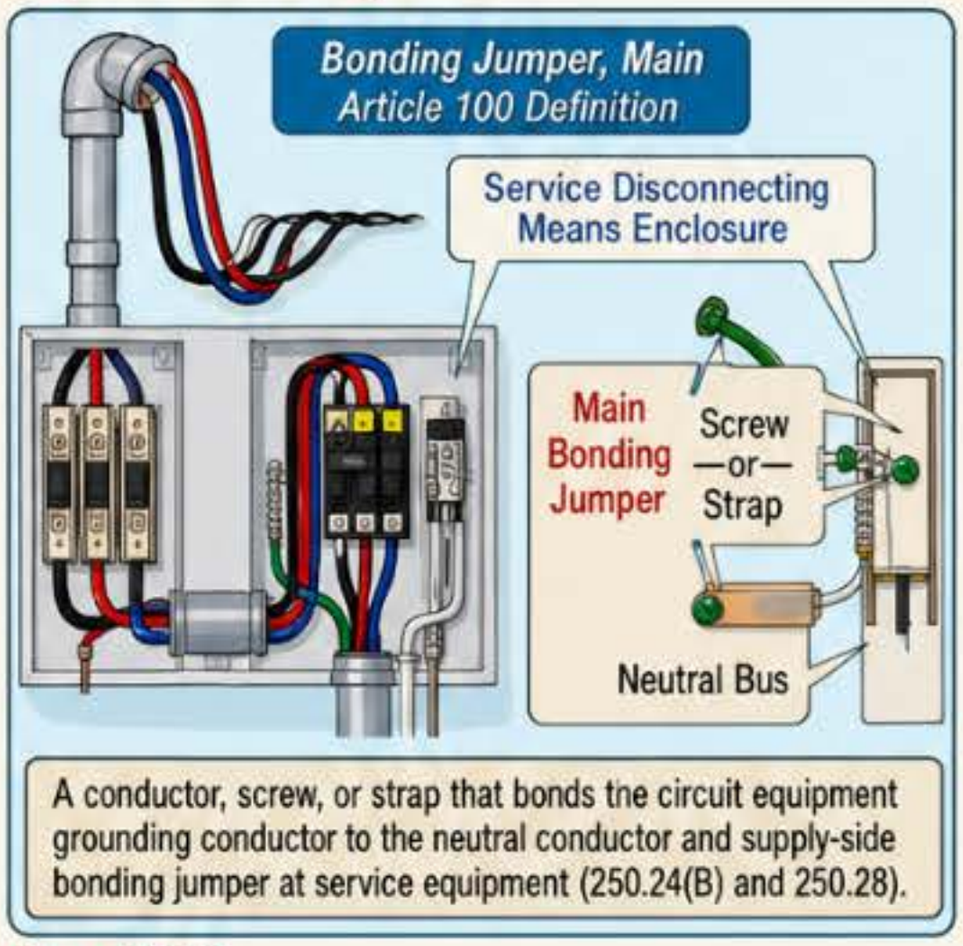


Figure 100–16

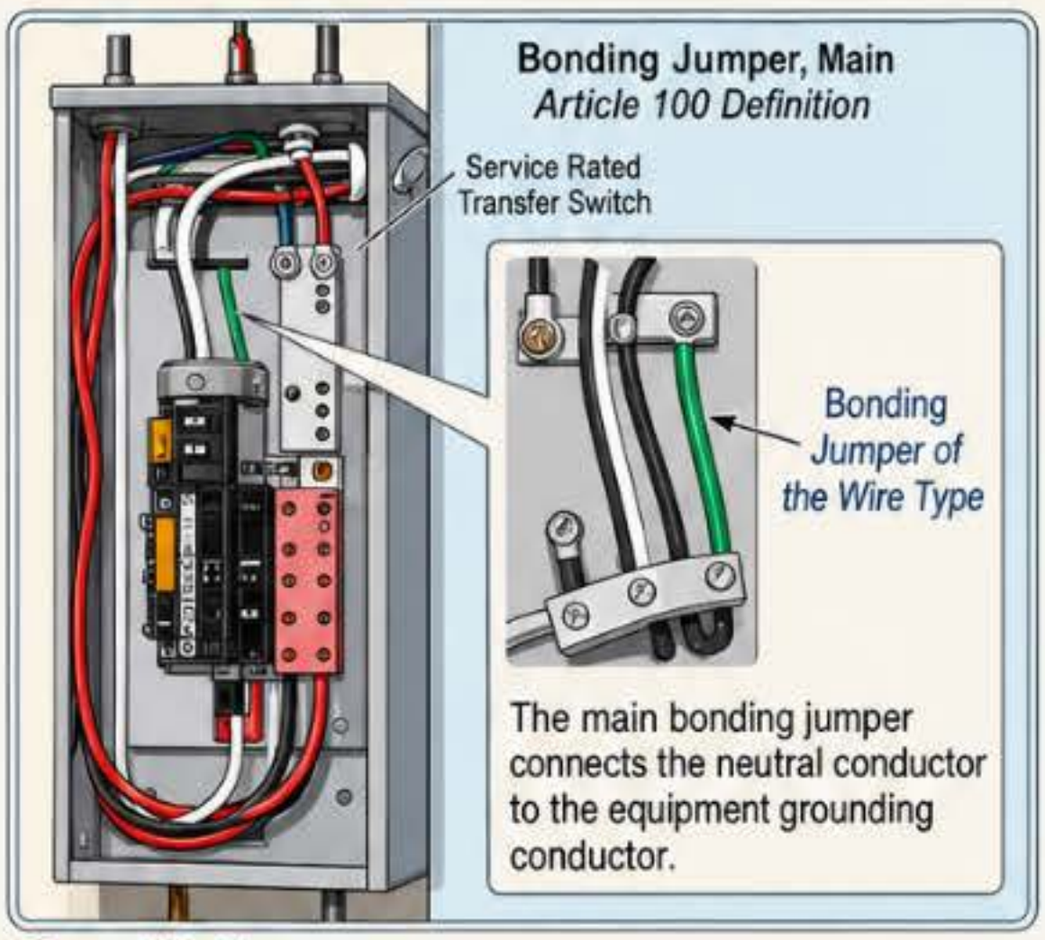


Figure 100–17

Bonding Jumper, Supply-Side. The conductor installed on the supply side of a service or separately derived system that ensures conductivity between metal parts required to be electrically connected. ▸Figure 100–18, ▸Figure 100–19, and ▸Figure 100–20

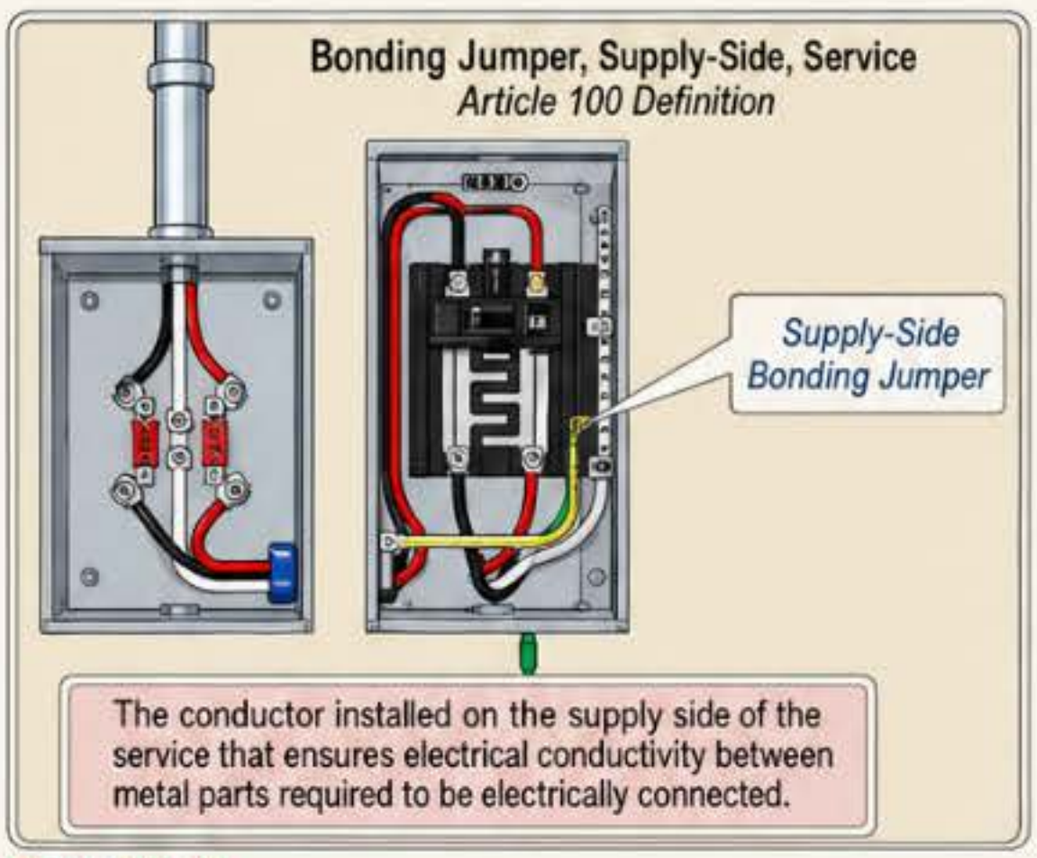


Figure 100–18

Bonding Jumper, System. The connection between the neutral conductor or grounded-phase conductor and the supply-side bonding jumper or equipment grounding conductor, or both, at a separately derived system transformer. ▸Figure 100–21

Branch Circuit. The conductors between the final overcurrent device and the receptacle outlets, lighting outlets, or other outlets as defined in this article. ▸Figure 100–22

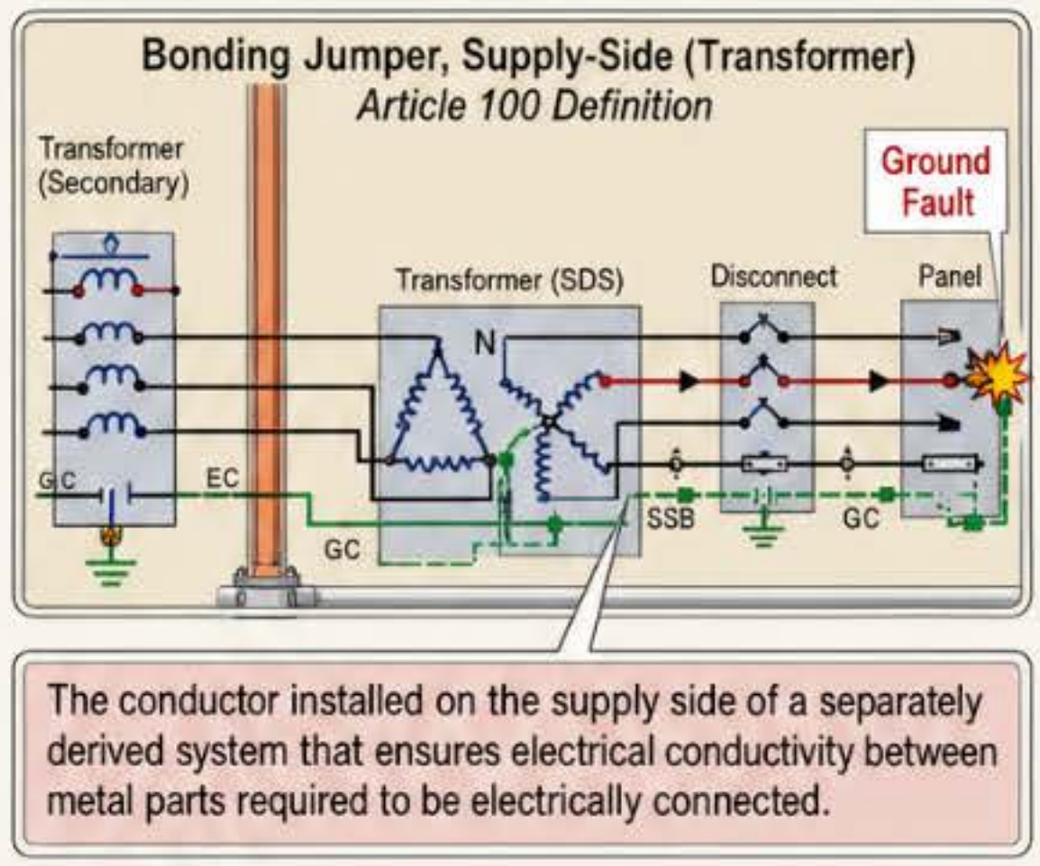


Figure 100–19

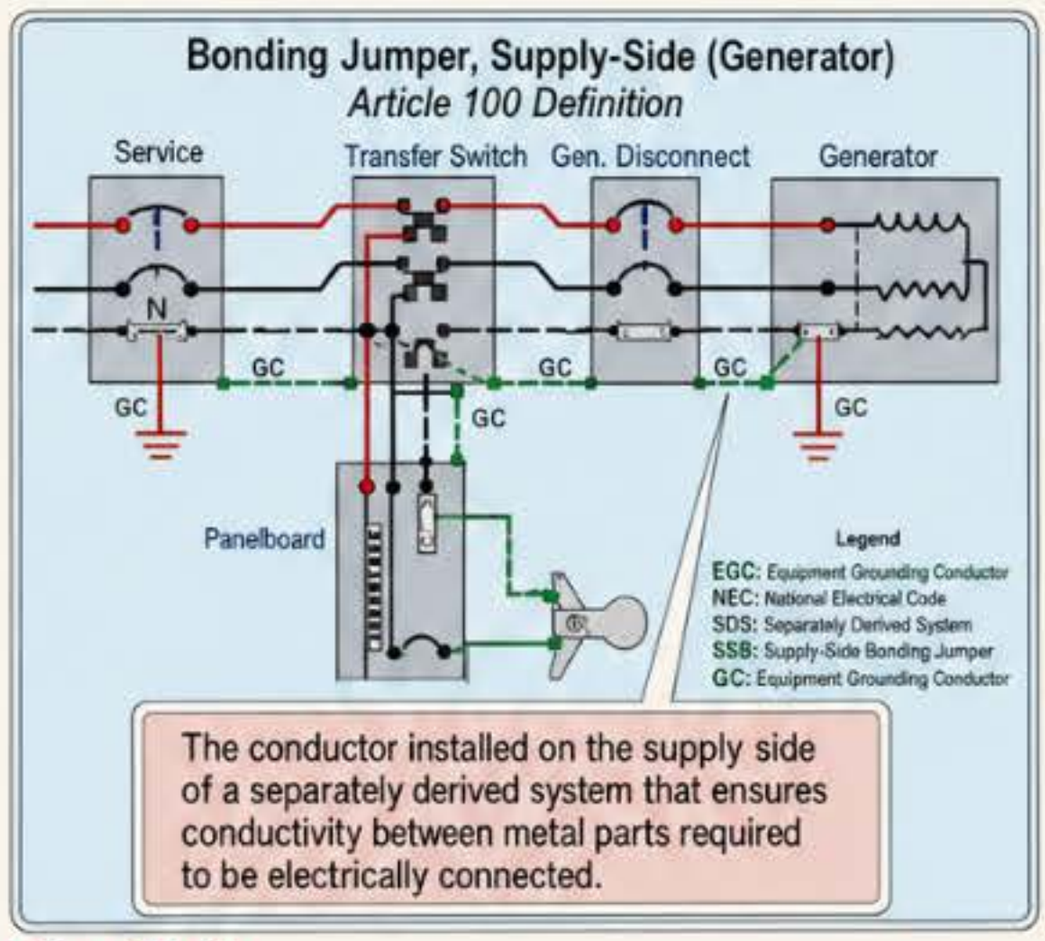


Figure 100–20

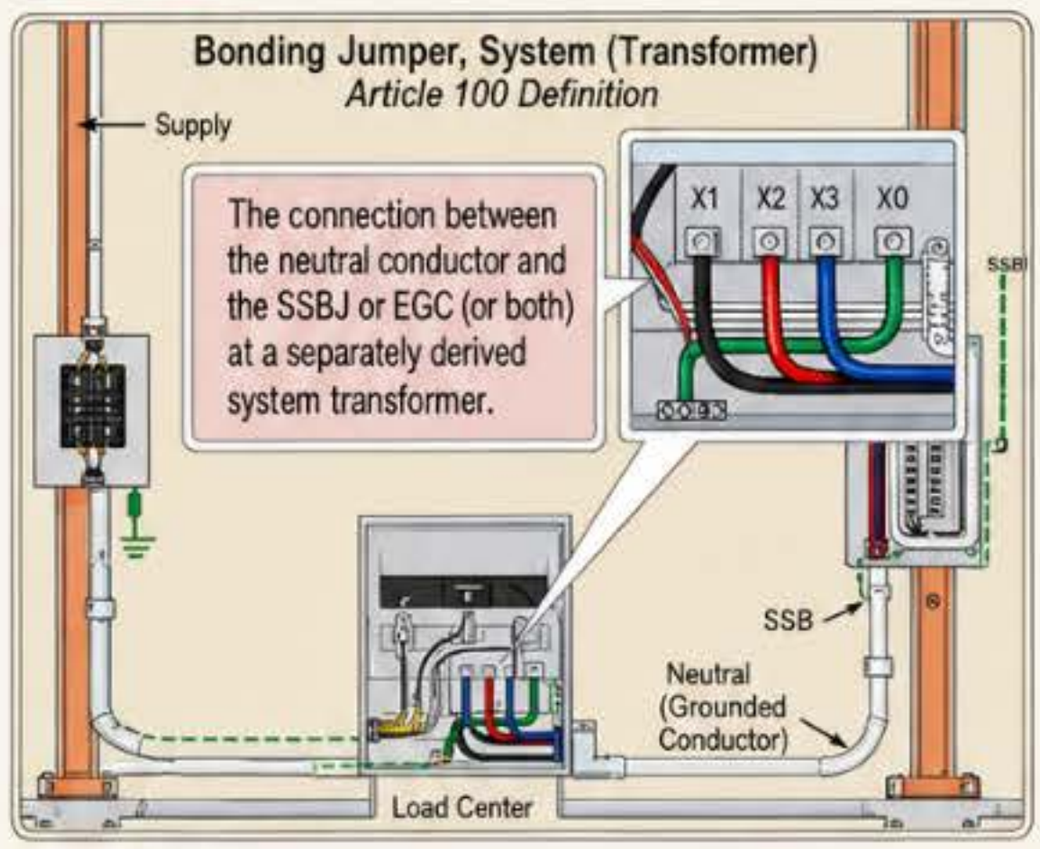
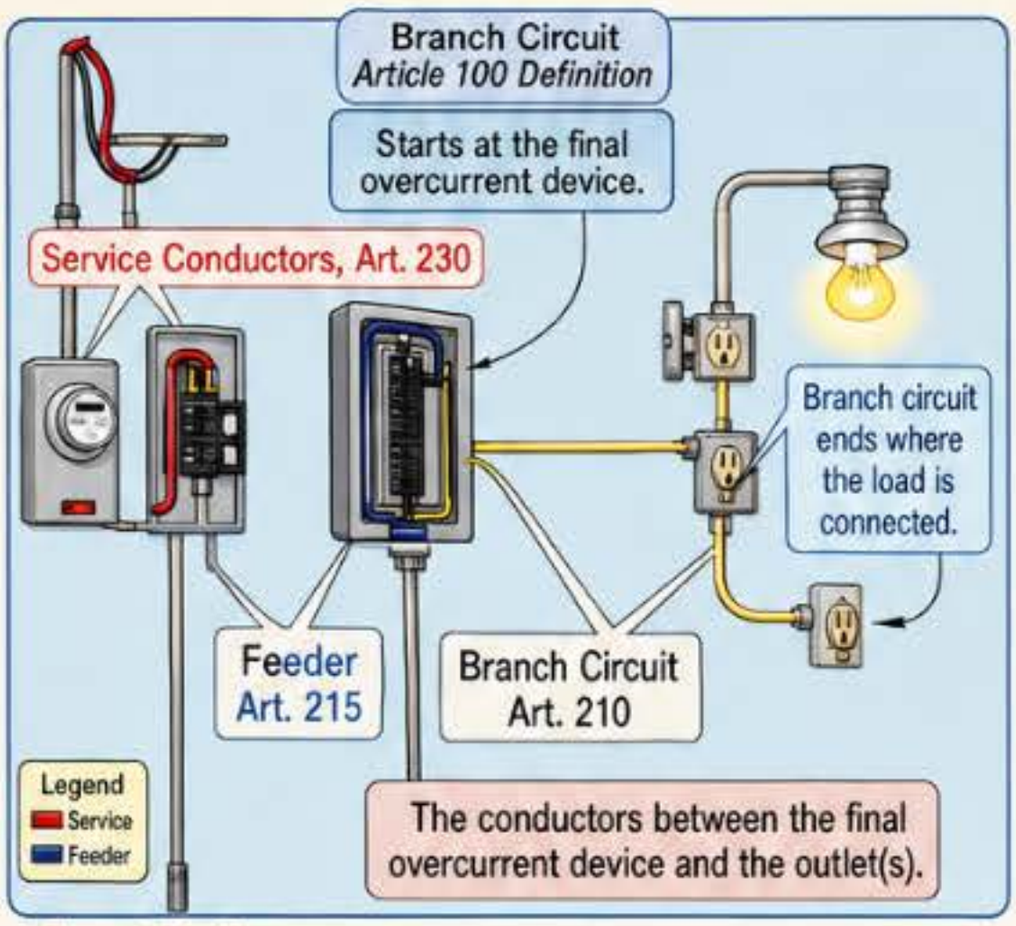


Figure 100–21

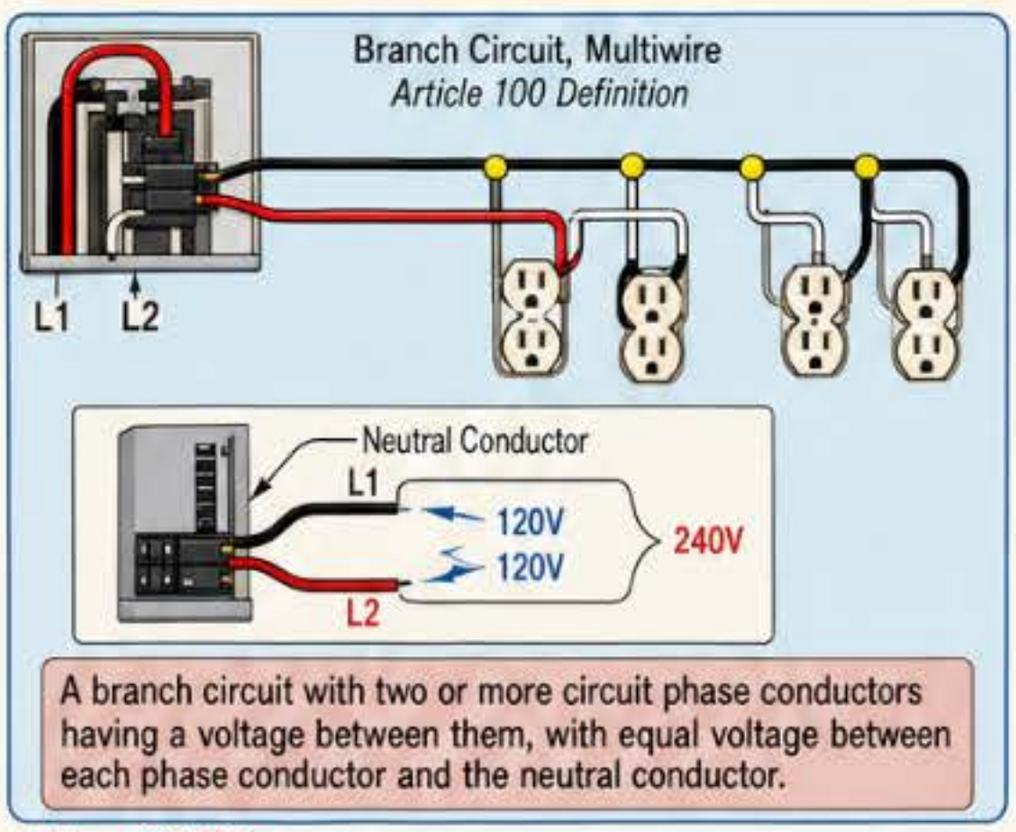
DEFINITIONS | From Michael Hamilton Publications



▲ Figure 100–22

Branch Circuit, Individual (Individual Branch Circuit). A branch circuit that only supplies one load.

Branch Circuit, Multiwire (Multiwire Branch Circuit). A branch circuit consisting of two or more circuit phase conductors with a common neutral conductor. There must be a voltage between the phase conductors and an equal difference of voltage from each phase conductor to the common neutral conductor. ▲ Figure 100–23



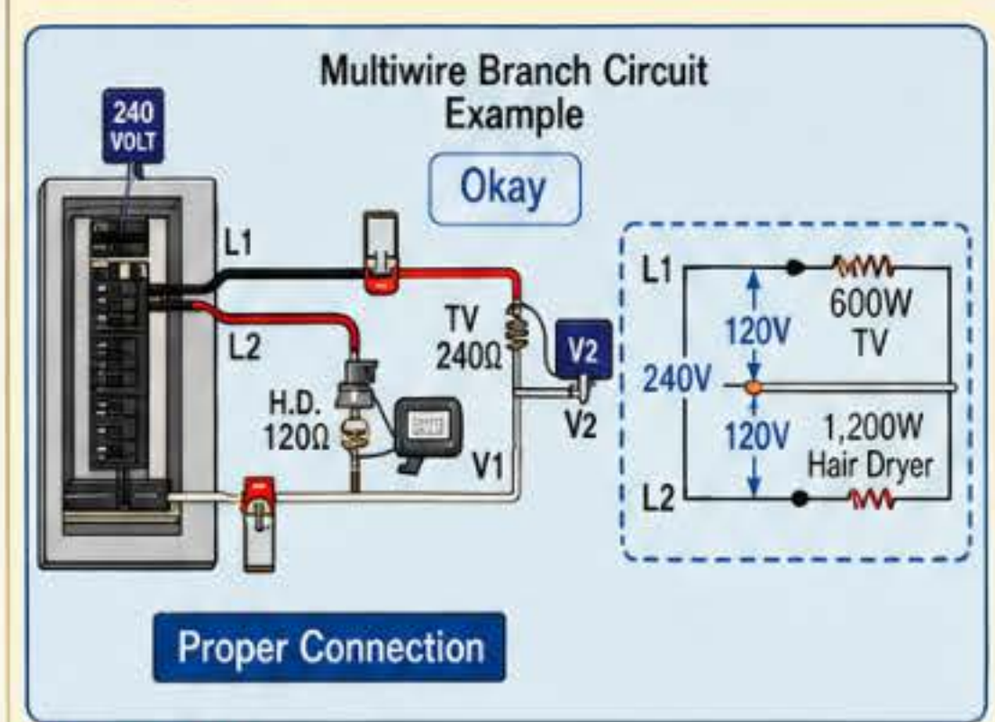
▲ Figure 100–23

Author's Commentary:
Multiwire branch circuits offer the advantage of fewer conductors within a raceway, which can result in smaller raceways, and reduced material and labor costs. In addition, multiwire branch circuits can reduce circuit voltage drop by as much as 50 percent. Because of the dangers associated with the use of multiwire branch circuits and the need for extra care, the 2023 NEC contains additional requirements to ensure a safe installation. See 210.4, 300.13(B), and 408.41 in this textbook for details.

— ***Michael Hamilton***

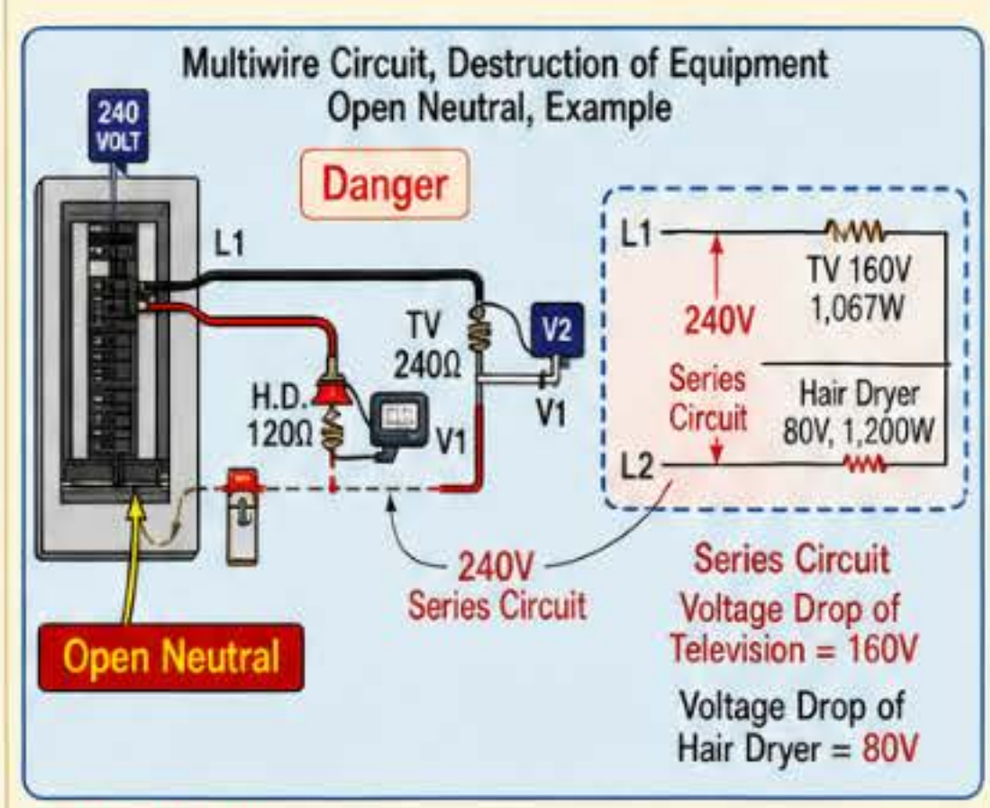
▶ Hazard of an Open Neutral

Example: *A 3-wire, single-phase, 120/240V multiwire circuit supplies a 1,200W, 120V hair dryer and a 600W, 120V television.* ▶ Figure 100–24



▲ Figure 100–24

If the neutral conductor of the multiwire circuit is interrupted, it will cause the 120V television to operate at 160V and consume 1,067W of power (instead of 600W) for only a few seconds before it burns up. ▶ Figure 100–25



▲ Figure 100–25

ARTICLE 100 — DEFINITIONS

Solution:

Step 1: Find the resistance of each appliance.

$R = E^2/P$

R of the hair dryer = 120V² / 1,200W
R of the hair dryer = 12 ohms

R of the television = 120V² / 600W
R of the television = 24 ohms

Step 2: *Find the current of the circuit.*

I = Volts / Resistance

Volts = 240V
R = 36 ohms (12 ohms + 24 ohms)

I = 240V / 36 ohms
I = 6.70A

Step 3: *Find the operating voltage for each appliance.*

Volts = I × R

I = 6.70A
R = 12 ohms for hair dryer and 24 ohms for TV

Voltage of hair dryer = 6.70A × 12 ohms
Voltage of hair dryer = 80V

Voltage of television = 6.70A × 24 ohms
Voltage of television = 160V

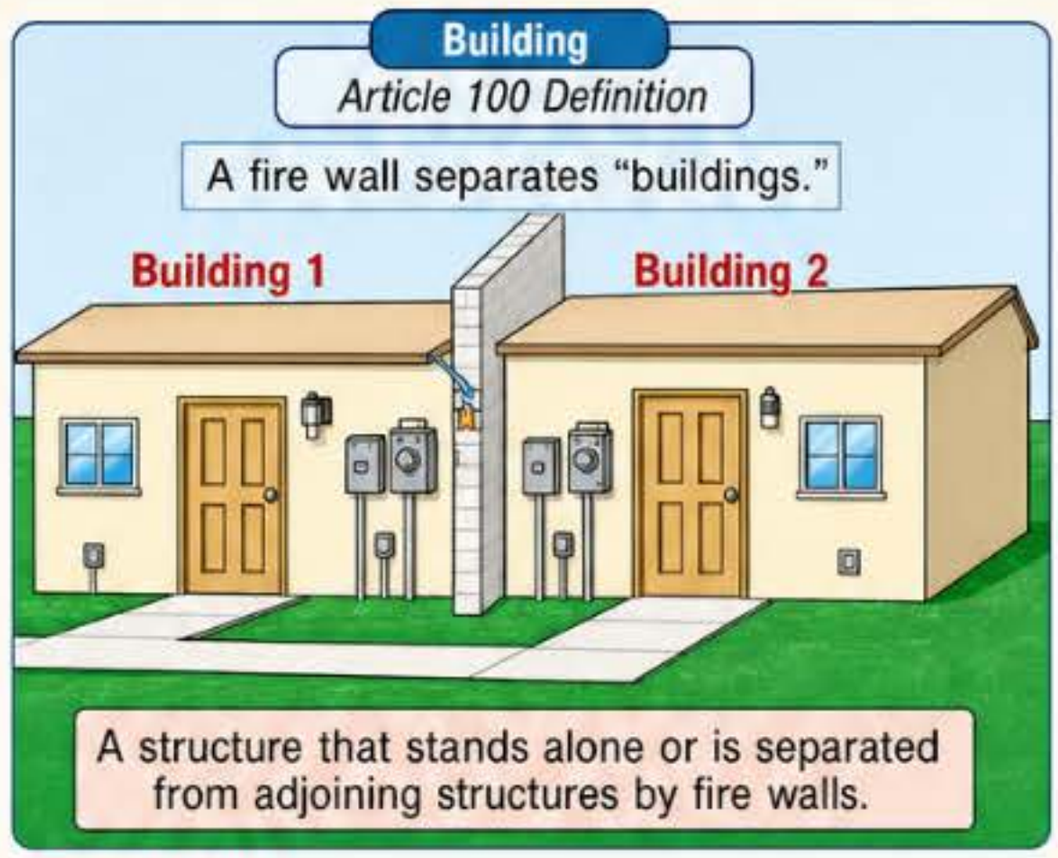
Answer: *160V*

Warning

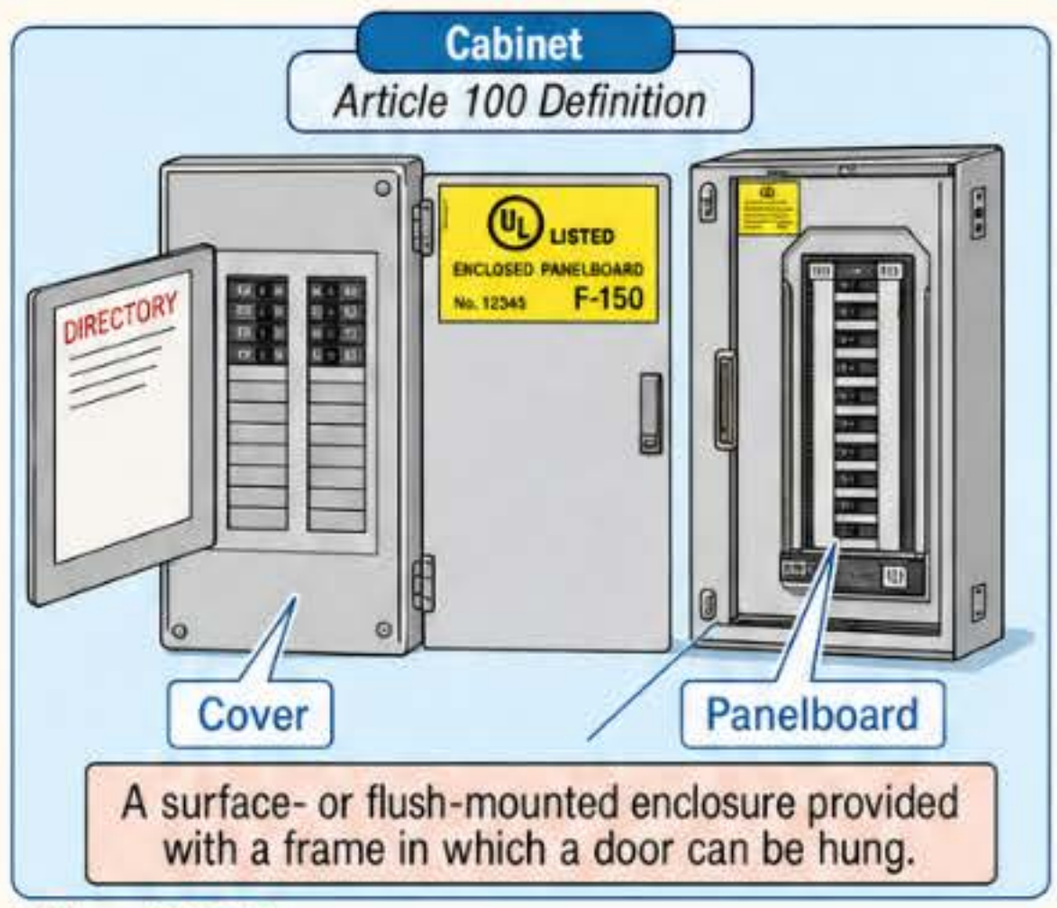
Failure to terminate the phase conductors to separate phases can cause the neutral conductor to become overloaded because the current from the phase conductors is additive and the insulation can be damaged or destroyed by excessive heat. Conductor overheating is known *to decrease the service life of insulation, which creates the potential for arcing faults and can ultimately lead to fires. It is not known just how long conductor insulation lasts, but heat does decrease its life span.*

Building. A structure that stands alone or is separated from *adjoining structures by fire walls.* ▶ *Figure 100–26*

Cabinet. *A surface-mounted or flush-mounted enclosure provided with a frame in which a door can be hung.* ▶ *Figure 100–27*



▶ **Figure 100–26**



▶ **Figure 100–27**

Author's Commentary:

➤ *Cabinets are used to enclose panelboards. See the definition of "Panelboard" in this article.*

— Michael Hamilton

Cable, Coaxial. A cylindrical assembly containing a conductor centered inside a metallic shield, separated by a dielectric material, and covered by an insulating jacket. ▶ **Figure 100–28**

Cable, Optical Fiber. An assembly of optical fibers. ▶ **Figure 100–29**

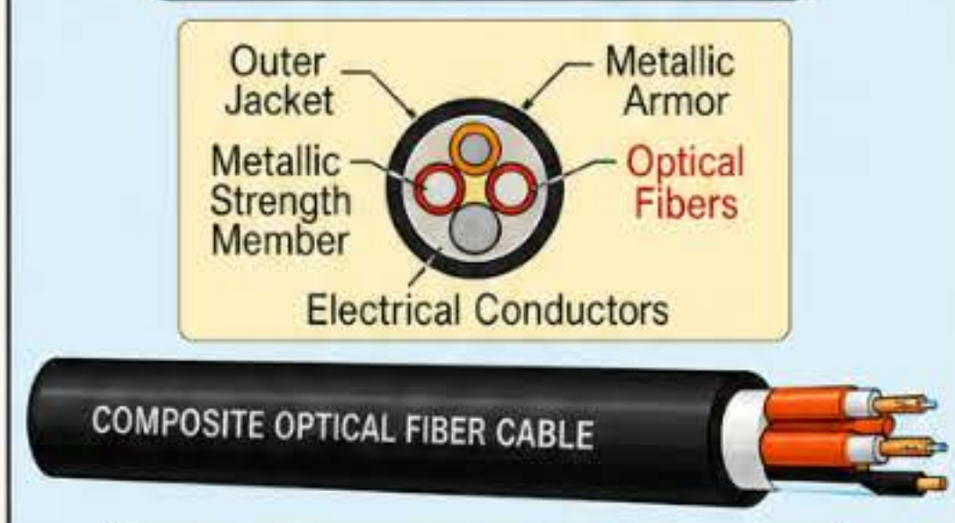
Note: *A field-assembled optical fiber cable is an assembly of one or more optical fibers within a jacket. The jacket is installed like a raceway into which the optical fibers are inserted.*

Cable, Coaxial (CATV)
Article 100 Definition

A cylindrical assembly containing a conductor centered inside a metallic shield, separated by a dielectric material, and covered by an insulating jacket.

▶ Figure 100–28

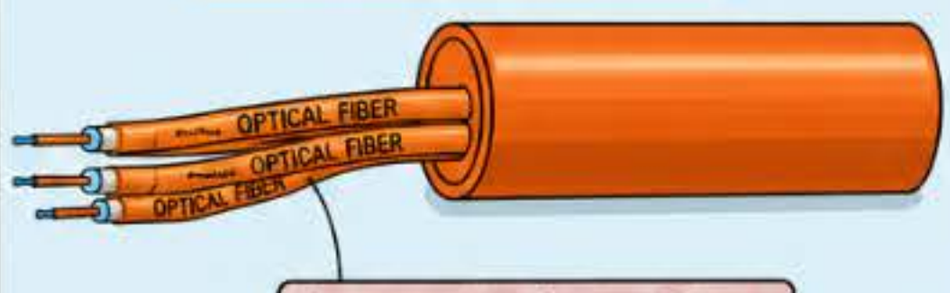
Cable, Optical Fiber, Composite
Article 100 Definition



A cable containing optical fibers and current-carrying electrical conductors.

▶ Figure 100–30

Cable, Optical Fiber
Article 100 Definition and Note

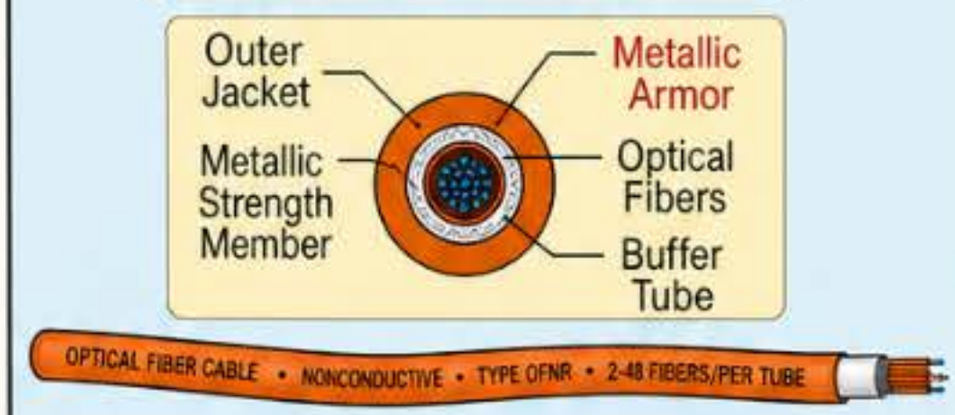


An assembly of optical fibers.

Note: A field-assembled optical fiber cable is an assembly of one or more optical fibers within a jacket. The jacket is installed like a raceway and then the optical fibers are inserted into the jacket.

▶ Figure 100–29

Cable, Optical Fiber, Conductive
Article 100 Definition



An optical fiber cable containing conductive members such as metallic strength members, metallic vapor barriers, and metallic armor or sheath.

▶ Figure 100–31

Cable, Optical Fiber, Composite. A cable containing optical fibers and current-carrying electrical conductors. ▶Figure 100–30

Author's Commentary:

Article 770 authorizes the use of composite optical fiber cables only where the optical fibers and current-carrying electrical conductors are functionally associated [770.133(A)].

— Michael Hamilton

Cable, Optical Fiber, Conductive. An optical fiber cable containing conductive members such as metallic strength members, metallic vapor barriers, or metallic armor or sheath. ▶Figure 100–31

Author's Commentary:

A cable routing assembly is typically a U-shaped trough (with or without covers) designed to hold cables. It is not a raceway.

— Michael Hamilton

Cable, Optical Fiber, Nonconductive. An optical fiber cable without any electrically conductive materials. ▶Figure 100–32

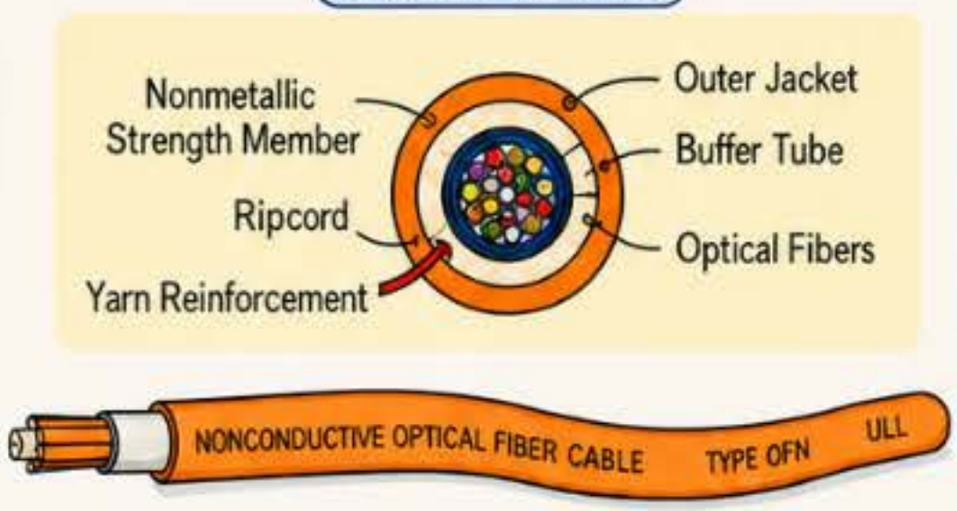
Cable Routing Assembly. A channel or structure (with fittings) that supports and routes communications wiring and cables, and optical fiber; includes Class 2, Type PLTC, and power-limited fire alarm cables in plenum, riser, and general-purpose applications. ▶Figure 100–33

Author's Commentary:

Article 770 permits composite optical fiber cables only when their optical fibers and associated electrical conductors are functionally related [770.133(A)].

— Michael Hamilton

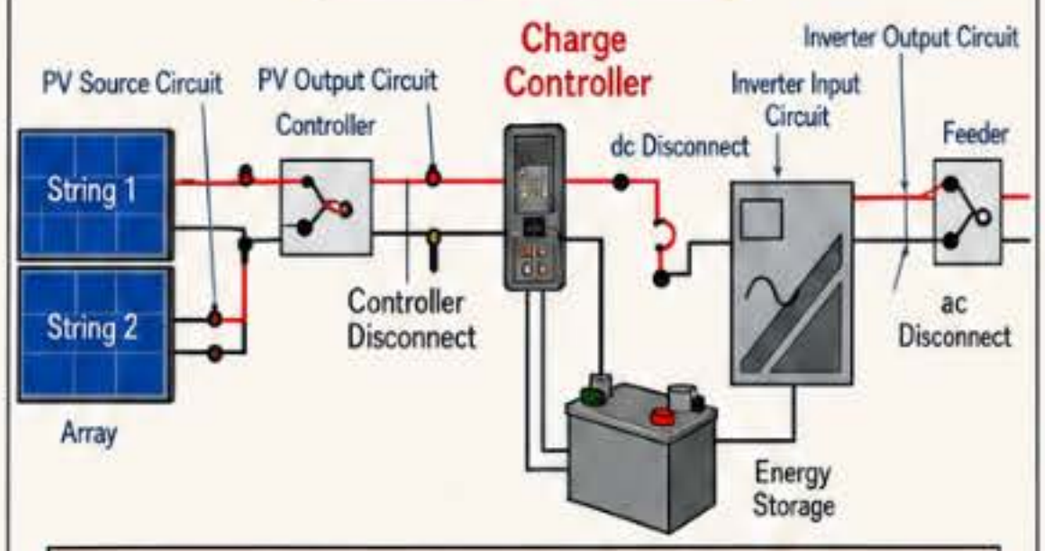
Cable, Optical Fiber, Nonconductive
Article 100 Definition



An optical fiber cable without any electrically conductive materials.

Figure 100–32

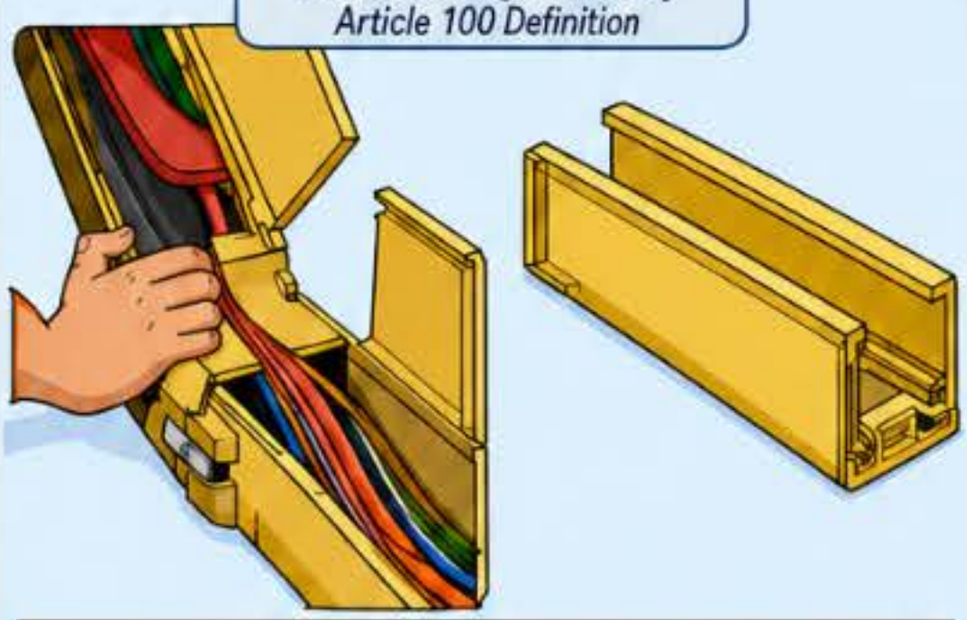
Charge Controller
Article 100 Definition



Equipment that controls dc voltage or dc current (or both) and is used to charge a battery or other energy storage device.

Figure 100–34

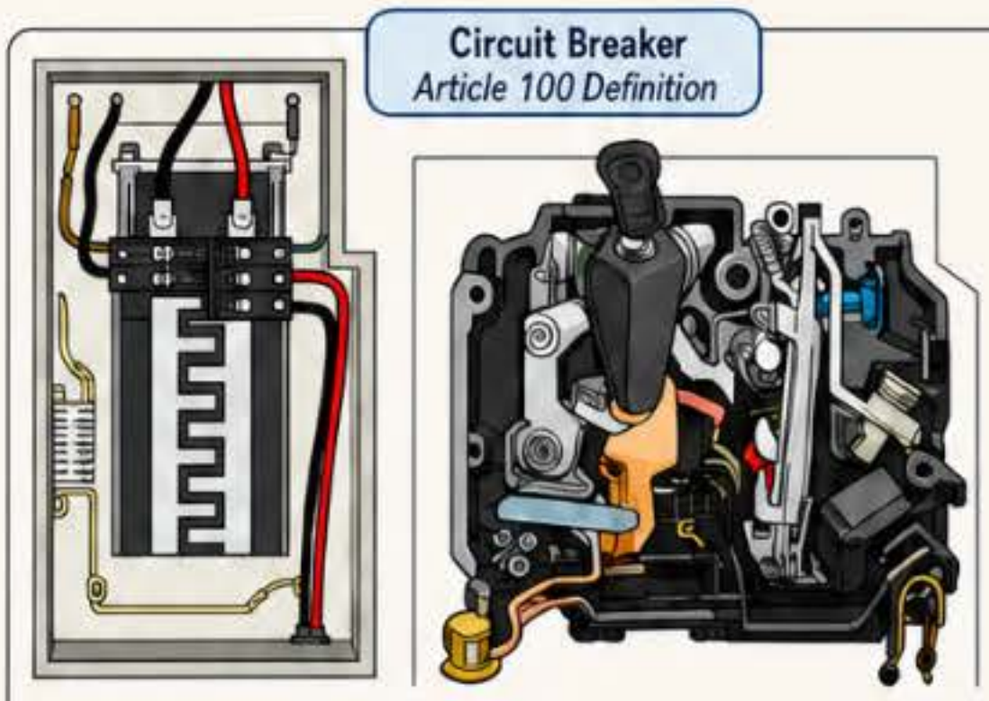
Cable Routing Assembly
Article 100 Definition



Channel or channels, with their fittings, that support and route communications wires and cables, optical fiber cables, data cables, Class 2 and Class 3 cables, Type PLTC, and Type PLFA cables in plenum, riser, and general-purpose applications.

Figure 100–33

Circuit Breaker
Article 100 Definition



A device designed to be opened and closed manually, and which opens automatically on a predetermined overcurrent without damage to itself.

Figure 100–35

Charge Controller. *Equipment that regulates direct-current voltage or current, or both. It is used to charge a battery or other energy storage device. [Figure 100–34]*

Circuit Breaker. *A device that can be opened and closed manually and also opens automatically when an overcurrent occurs without harming the device. Circuit breakers come in many configurations, such as adjustable trip (electronically controlled), instantaneous trip, motor-operated trip, and reverse time. [Figure 100–35]*

Circuit Breaker, Adjustable. *Adjustable circuit breakers let the user set the trip point to trip at different current levels (or both), within a specified range.*

Circuit Breaker, Instantaneous Trip. *Instantaneous trip circuit breakers open immediately in response to electromagnetic forces and are used as motor protection. These devices are sometimes called "motor-circuit protectors." This type of overcurrent protective device does not provide overload protection. It only protects against short-circuit and ground-fault conditions; overload protection must be provided separately.*

Author's Commentary:

- *Instantaneous trip circuit breakers do not include any intentional time delay and are sensitive to current surges, vibration, and impact. As a result, they should never be used in situations where these influences are present.*

— Michael Hamilton

Circuit Breaker, Inverse Time. This category of circuit breaker is intentionally built to postpone its tripping action when an overcurrent condition exists.

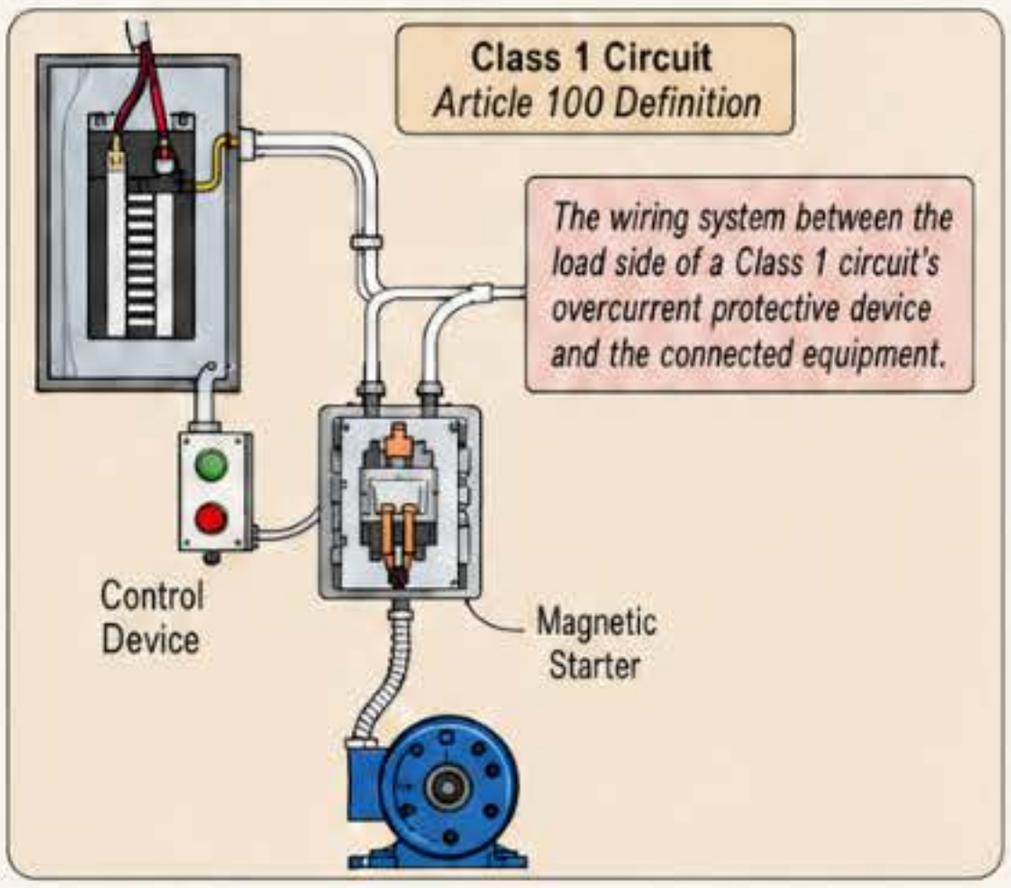
The goal is to compensate for the brief inrush of current that occurs during normal start-up of equipment such as vacuum cleaners or air conditioners, helping to avoid so-called "nuisance tripping."

Author's Commentary:

Inverse time breakers work on the idea that as the current rises, the allowable time to trip gets shorter. They provide reliable overcurrent protection during overloads, short circuits, or ground-fault situations.

— Michael Hamilton

Class 1 Circuit. The wiring system between the load side of a Class 1 circuit overcurrent protective device and the connected equipment. ▶ Figure 100–36

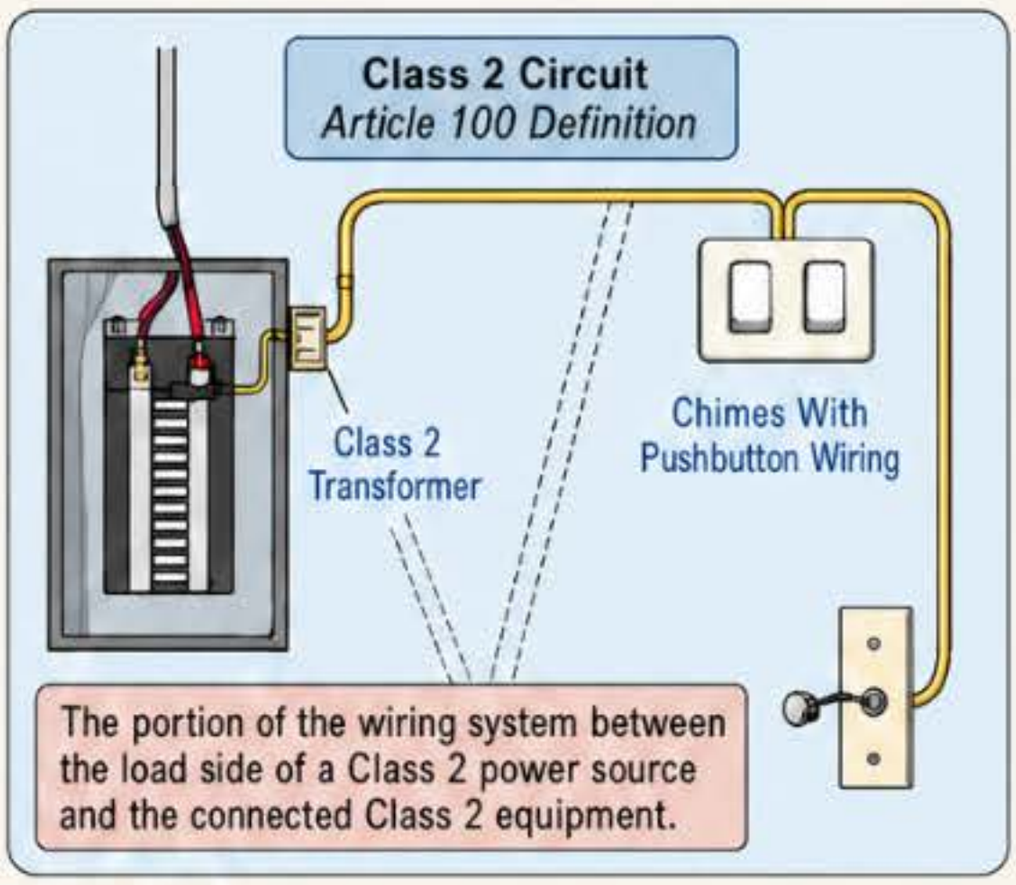


▶ Figure 100–36

Note: See 725.41 for the voltage and power limitations of Class 1 circuits.

Class 2 Circuit. The portion of the wiring system between the load side of a Class 2 power supply and the connected Class 2 equipment. ▶ Figure 100–37

Due to power supply limitations, a Class 2 circuit is treated as safe from the initiation standpoint and offers acceptable protection against electric shock.



▶ Figure 100–37

Author's Commentary:

- *Class 2 circuits are considered safe by restricting the power source to 100 VA or less at 30V or lower, and by capping the current at 5 mA for circuits over 30V [725.121(A) and Chapter 9, Table 11(A)].*
- *These circuits are commonly used for low-energy systems such as thermostats, programmable controllers, burglar alarms, and security systems. Typical wiring includes twisted-pair or coaxial cable for interconnections. Applications include local area networks (LANs), POE systems, and PLC I/O circuits [725.121(A)(3) and 725.121(A)(4)].*

— Michael Hamilton

Class 3 Circuit. The portion of the wiring system between the load side of a Class 3 power supply and the connected Class 3 equipment. ▶ Figure 100–38

Author's Commentary:

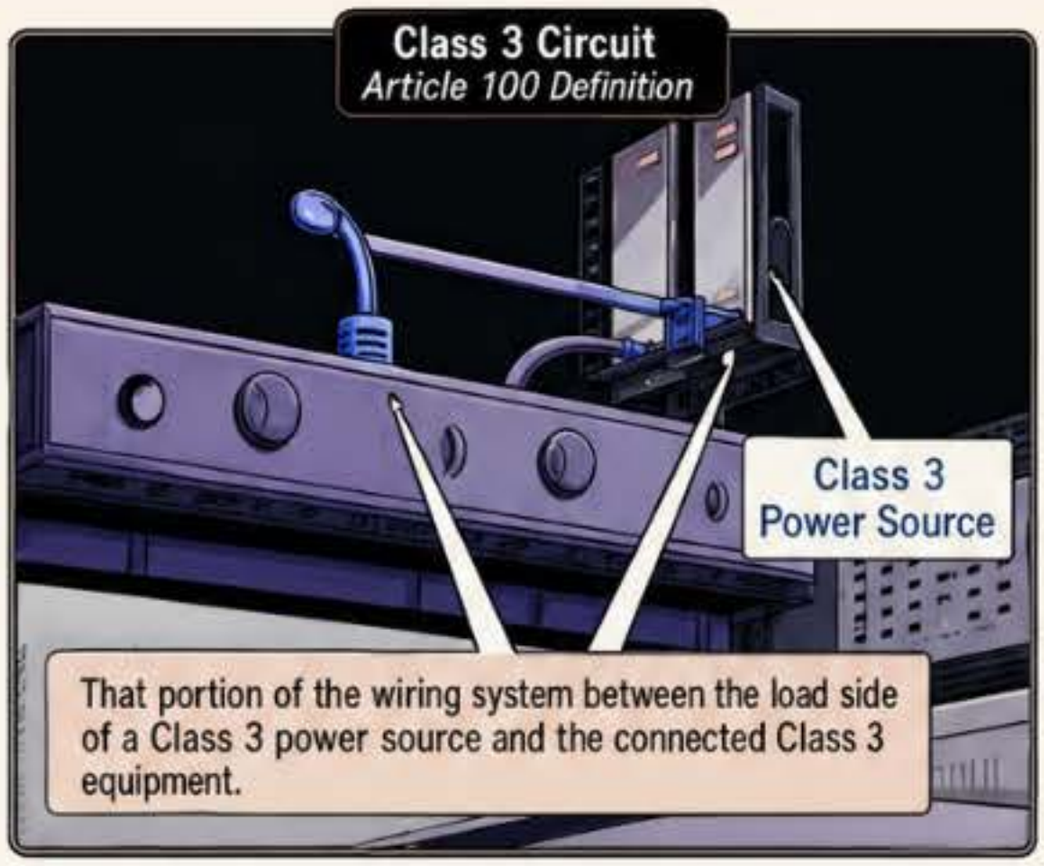
- *Class 3 circuits apply when the power demand goes beyond 30 VA but does not exceed 100 VA [Chapter 9, Table 11(A)].*

Clothes Closet. *A nonhabitable room or enclosed space intended mainly to store clothing and accessories.*
▶ Figure 100–39

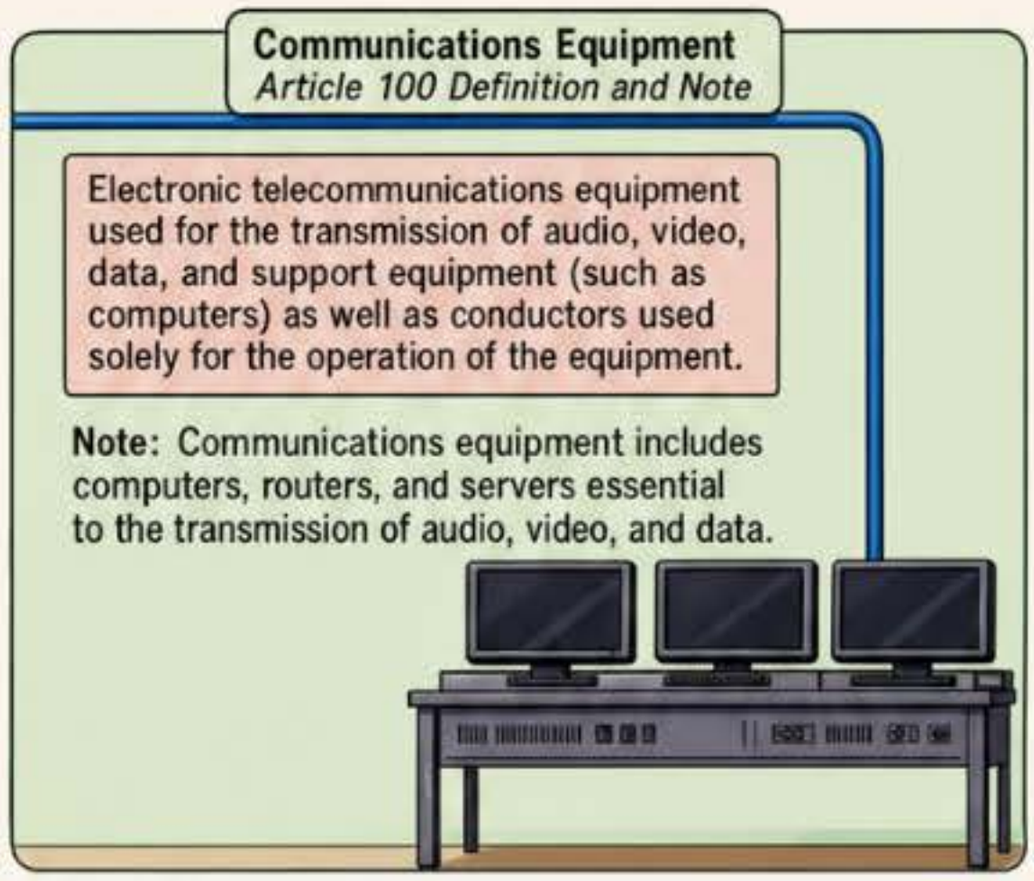
Author's Commentary:

- *The term "Clothes Closet" clarifies how overcurrent protection devices [240.24(D)] and lighting [410.16] are applied within closets used for storing garments.*

— Michael Hamilton

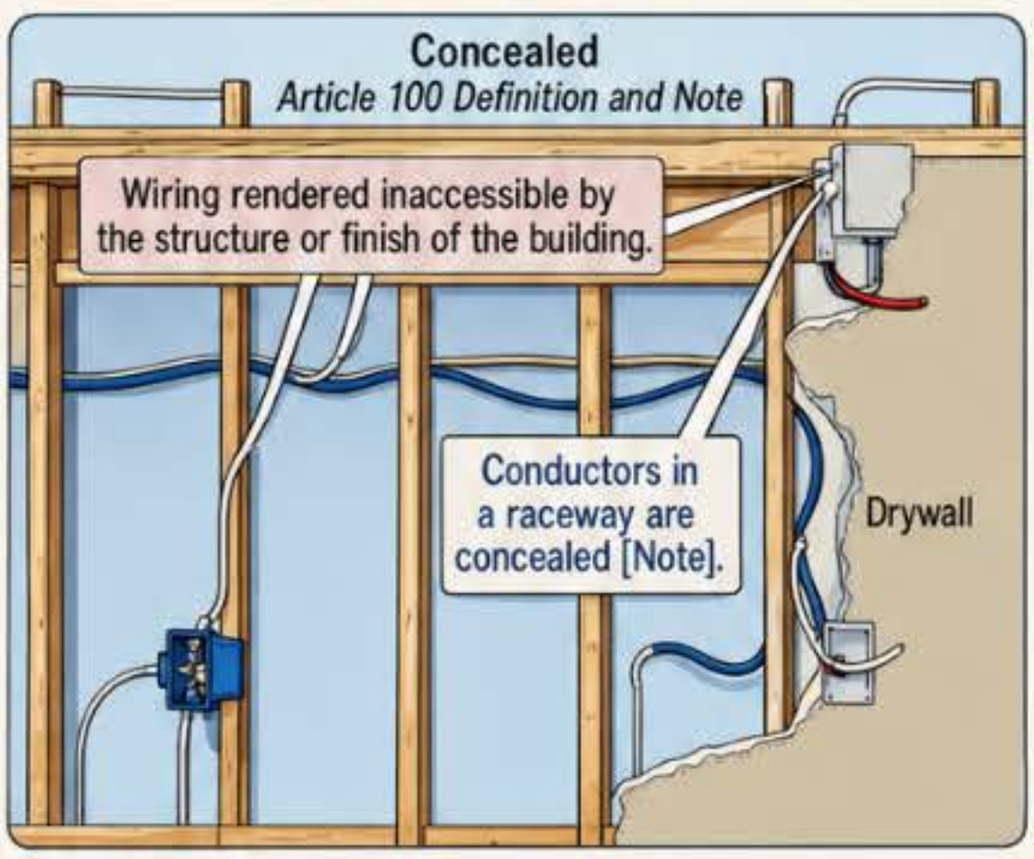


▶ Figure 100–38



▶ Figure 100–40

▶ Figure 100–39



▶ Figure 100–41

Communications Equipment. Electronic telecommunications equipment used for the transmission of audio, video, and data *including* support equipment (such as computers) and the conductors used solely for the operation of the equipment.

Note: Communications equipment includes the computers, routers, and servers essential to the transmission of audio, video, and data. ▶ Figure 100–40

Concealed. *Rendered inaccessible by the structure or finish of the building.* ▶ Figure 100–41

Note: *Conductors in a concealed raceway are considered concealed even though they may be made accessible by withdrawing them from the raceway.*

Author's Commentary:

- Wiring behind panels designed to allow access, such as removable ceiling tile and wiring in accessible attics, is not considered concealed; it is considered exposed. *See the definition of "Exposed" applied to wiring methods.*
- *Boxes are not permitted to be concealed by the finish of the building.* ▶ Figure 100–42

— Michael Hamilton

Continuous Load. *A load where the maximum current is expected to exist for 3 hours or more continuously such as in schools, office buildings, stores, or parking lot lighting.*

DEFINITIONS | From Michael Hamilton Publications

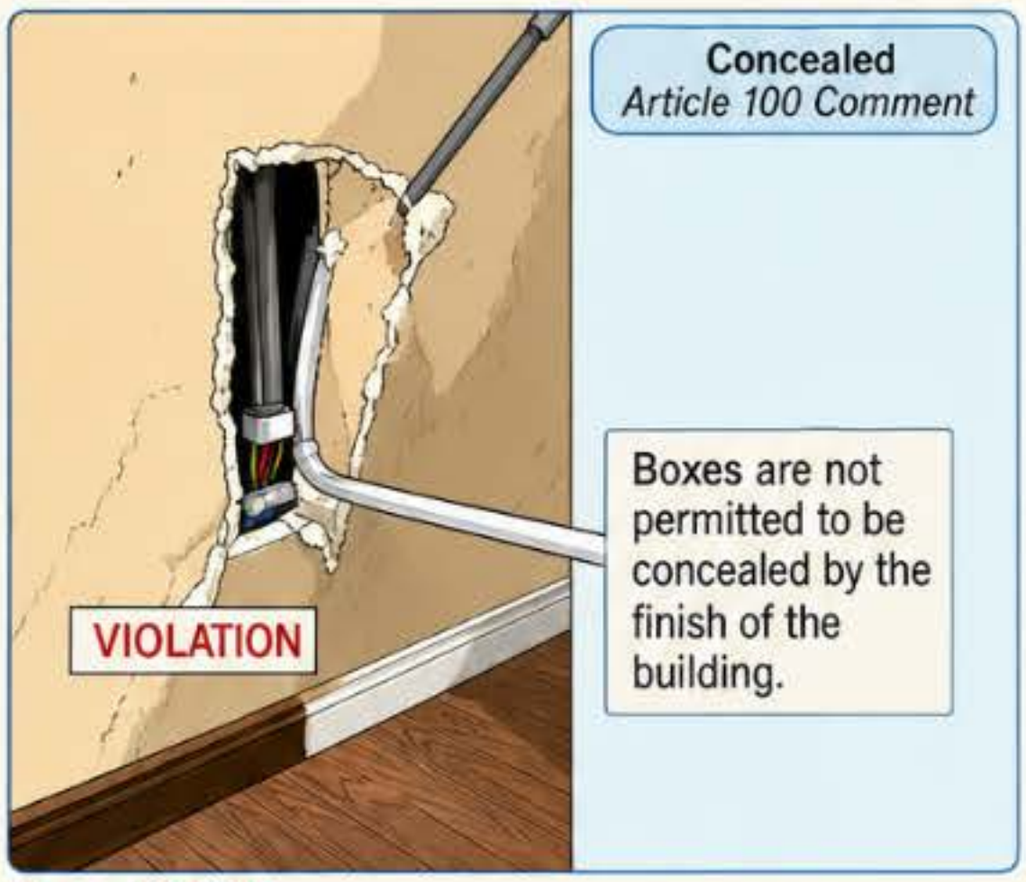


Figure 100–42

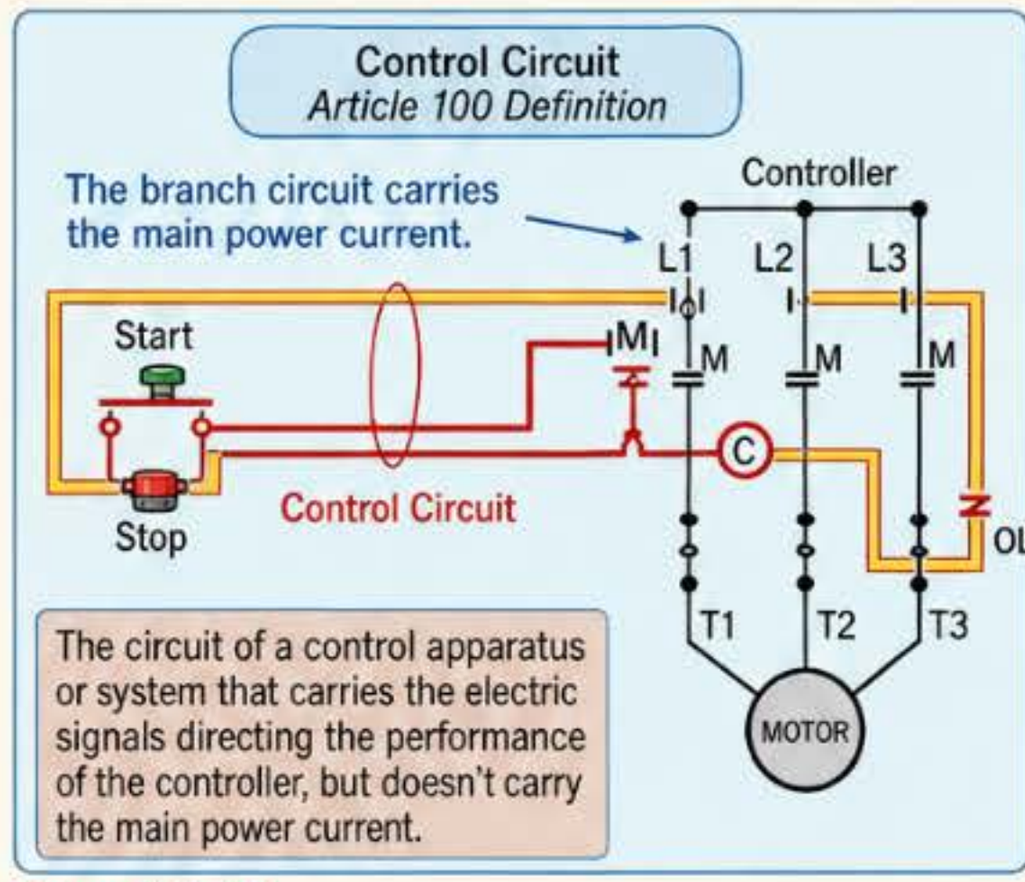


Figure 100–44

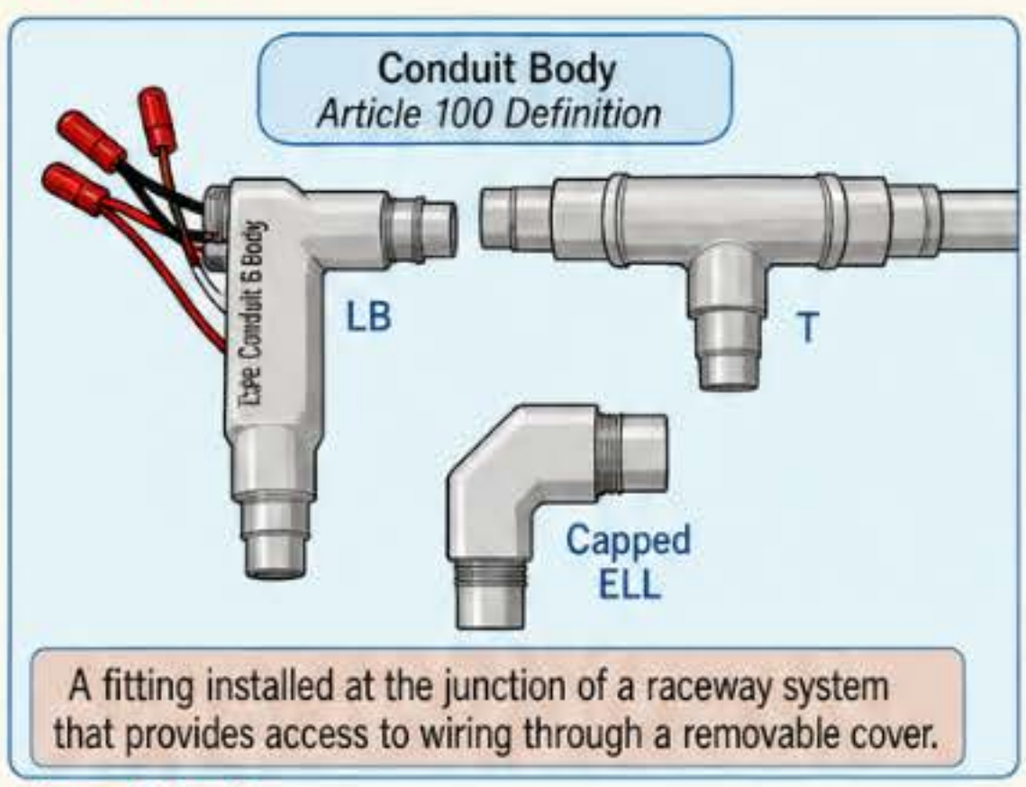


Figure 100–43

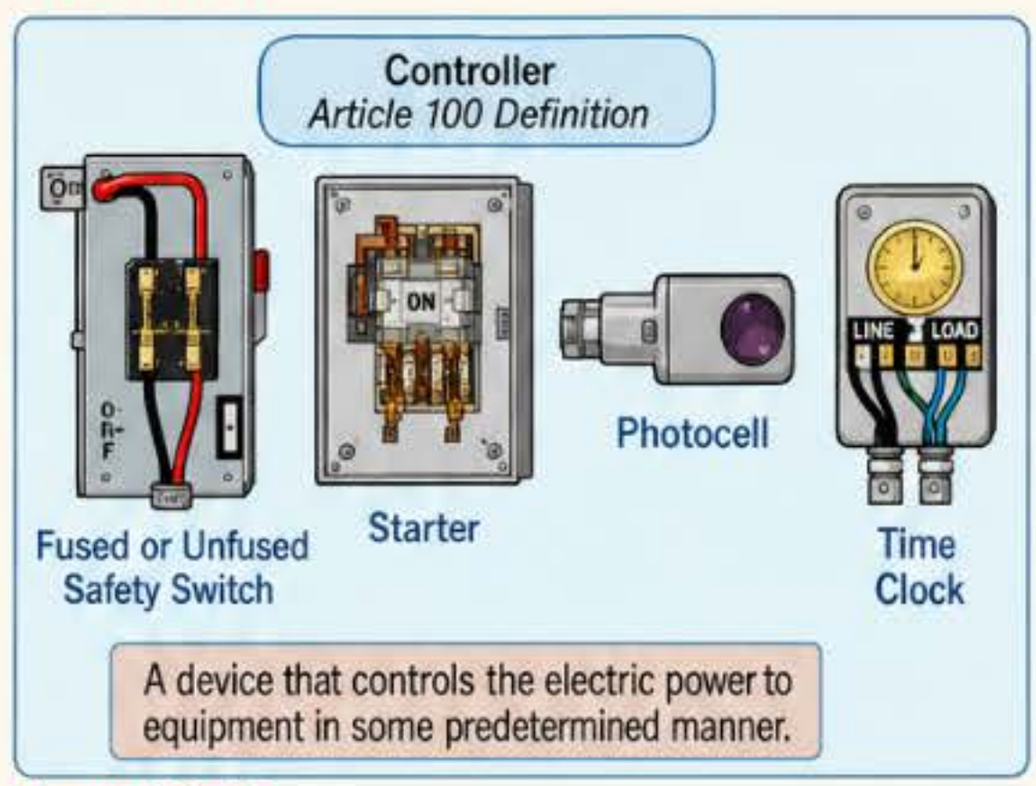


Figure 100–45

Control Circuit. The circuit of a control apparatus or system that carries the electric signals directing the performance of a controller but does not carry the main power current. ▶ *Figure 100–44*

Controller. A device that controls the electric power delivered to electrical equipment in some predetermined manner. This includes time clocks, lighting contactors, photocells, and equipment with similar functions. ▶ *Figure 100–45*

Coordination, Selective (Selective Coordination). Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices. Selective coordination includes all currents from overloads, short circuits, or ground faults. ▶ *Figure 100–46*

Author's Commentary: *These definitions form the foundation for understanding control systems, their components, and how electrical protection is coordinated to ensure safety and reliability.*
—Michael Hamilton

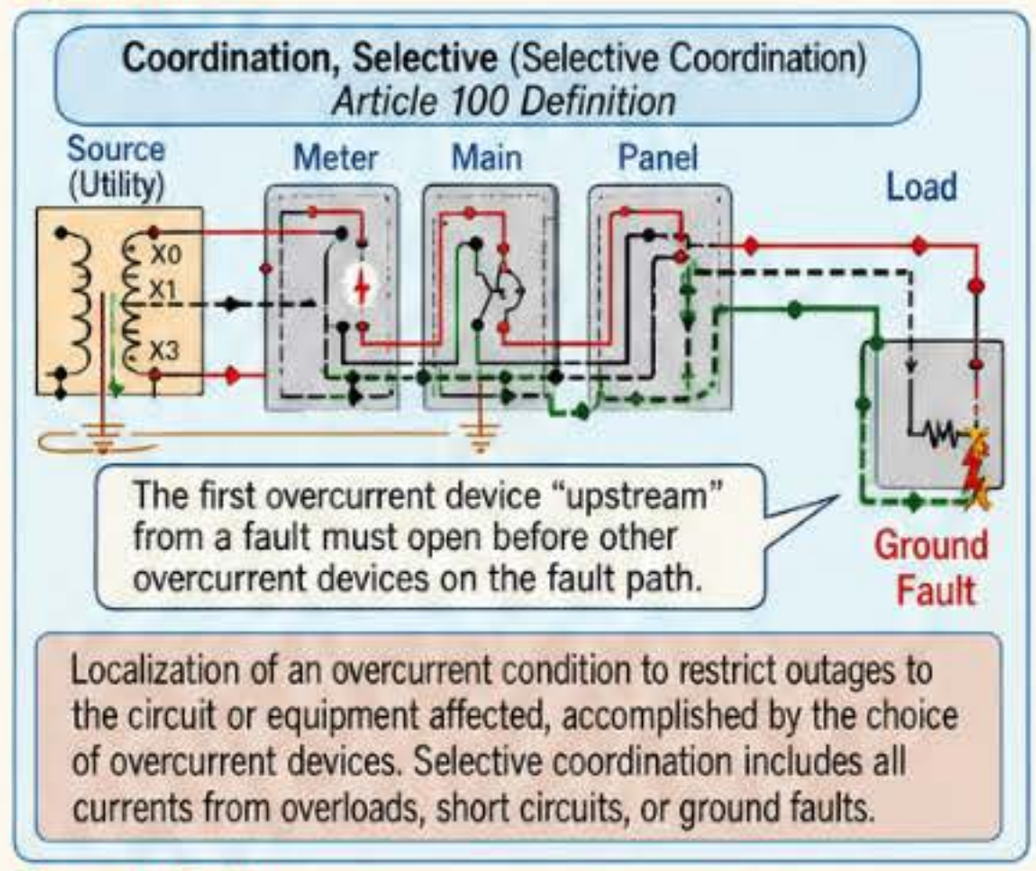


Figure 100–46

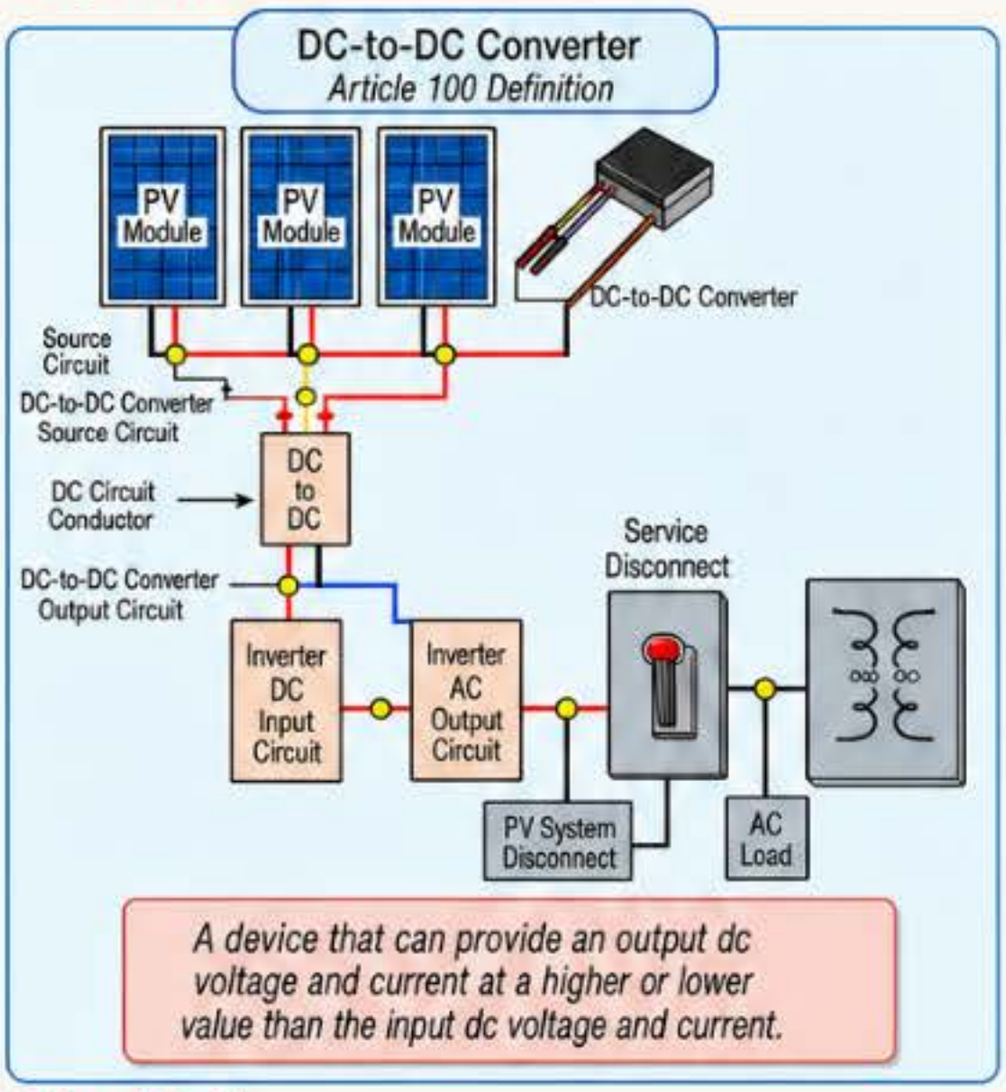
DEFINITIONS | From Michael Hamilton Publications

Author's Commentary:

- *Coordinated overcurrent protection ensures that an opening device interrupts a fault in a particular branch while letting other parts of the electrical system keep running. For example, if someone plugs a space heater into a 20A circuit in a 25A panel, selective coordination means only the 20A fuse or breaker opens during a short circuit. That device isolates the faulted branch, limiting damage and reducing downtime for the rest of the system. This is especially important in hospitals and data centers, where even brief outages in power can lead to serious consequences, including loss of life.*

— ***Michael Hamilton***

DC-to-DC Converter. A component that delivers a direct current output voltage and current that are higher or lower than its direct current input voltage and current.
▶ **Figure 100–47**



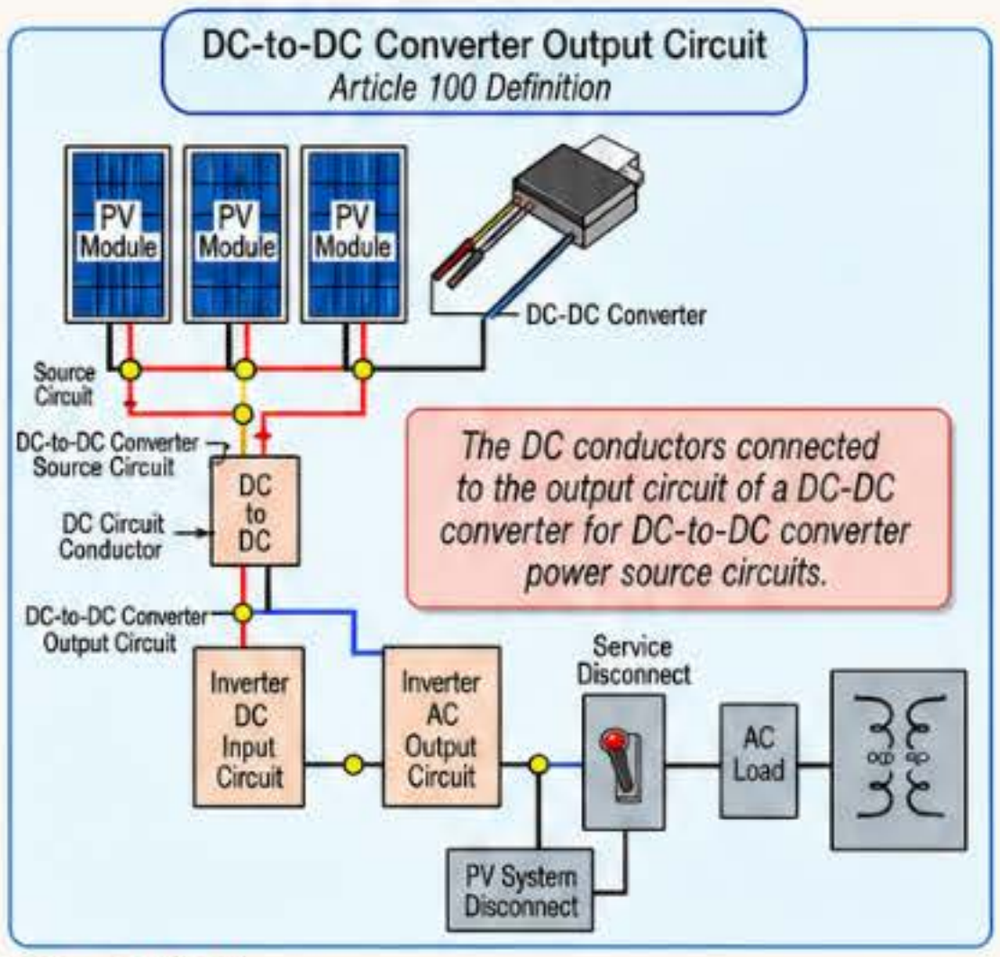
▶ **Figure 100–47**

Author's Commentary:

- *DC-to-DC converters are built to get the most usable power from individual PV modules. They reduce energy losses caused by variations among modules. Each converter connects straight to a module's frame or the PV rack.*
- *A DC-to-DC converter also lets a PV inverter maintain the best DC circuit voltage automatically, no matter how the sunlight changes or how long the wiring is. This setup helps each module perform at its peak.*

— ***Michael Hamilton***

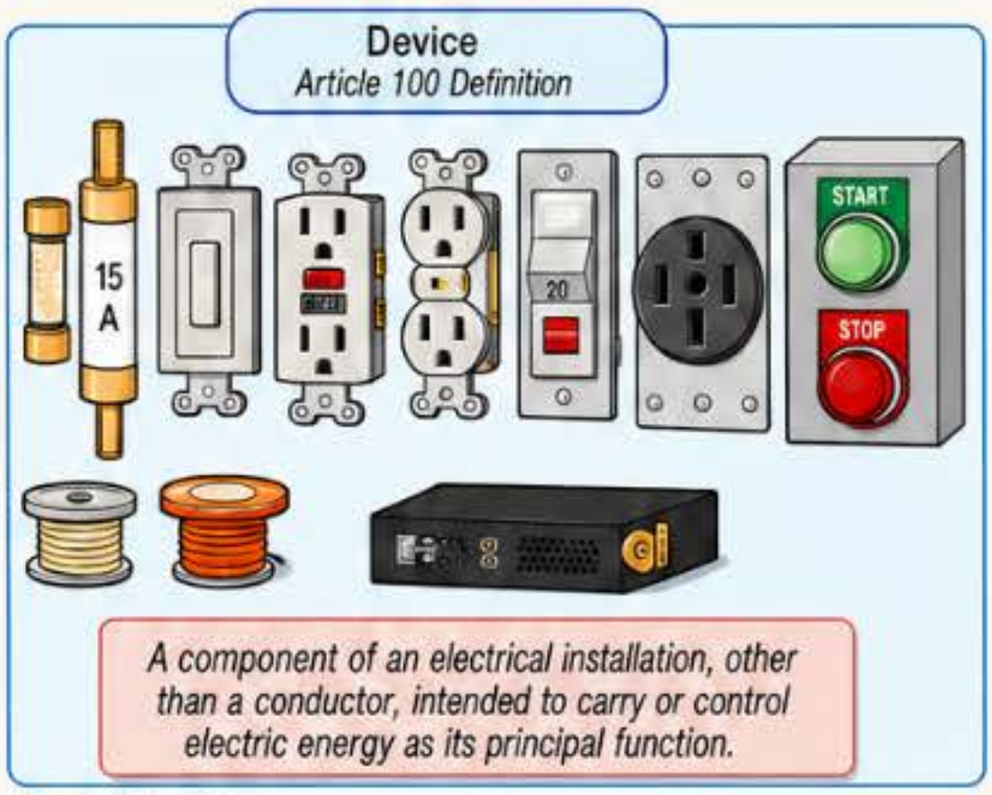
DC-to-DC Converter Output Circuit. The DC conductors that are connected to the output circuit of a DC-DC converter power source circuits. ▶ **Figure 100–48**



▶ **Figure 100–48**

Demand Factor. The ratio of the maximum demand placed on the system to its total connected load.

Device. A piece of electrical equipment, other than a conductor, that is intended to carry, control, or utilize electrical energy as its main purpose. ▶ **Figure 100–49**



▶ **Figure 100–49**

Author's Commentary:

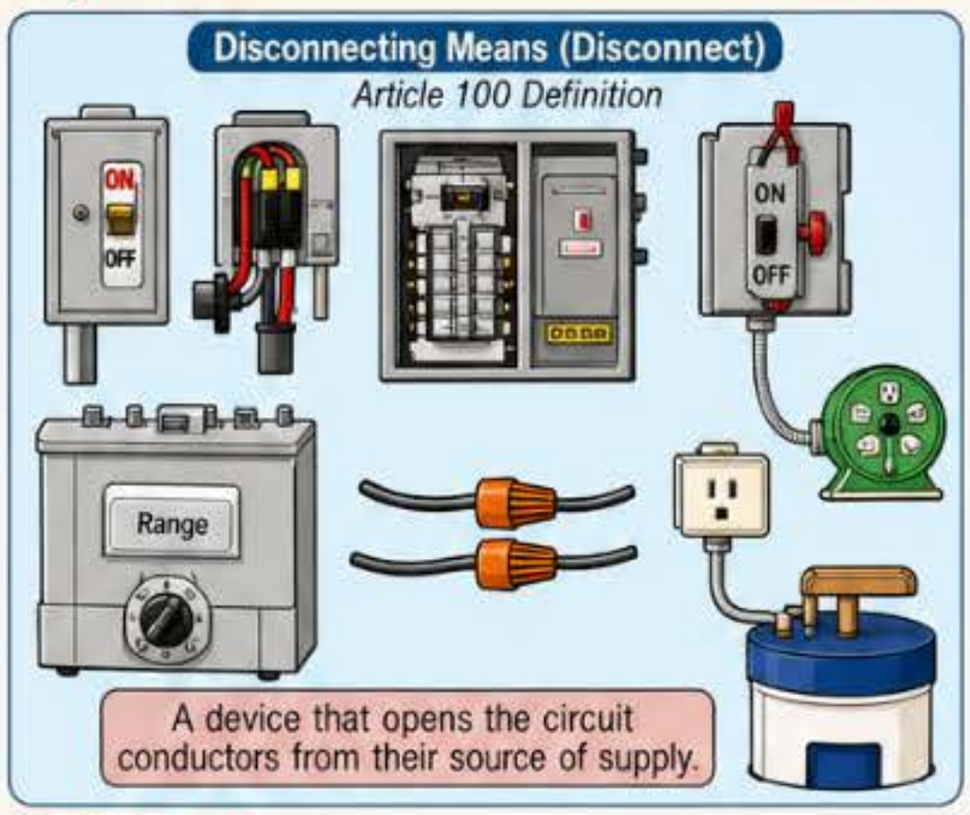
- *Devices do not use up electric energy. Examples include receptacles, switches, light fixtures, circuit breakers, fuses, timers, clocks, controllers, attachment plugs, and so forth.*

— ***Michael Hamilton***

DEFINITIONS | From Michael Hamilton Publications

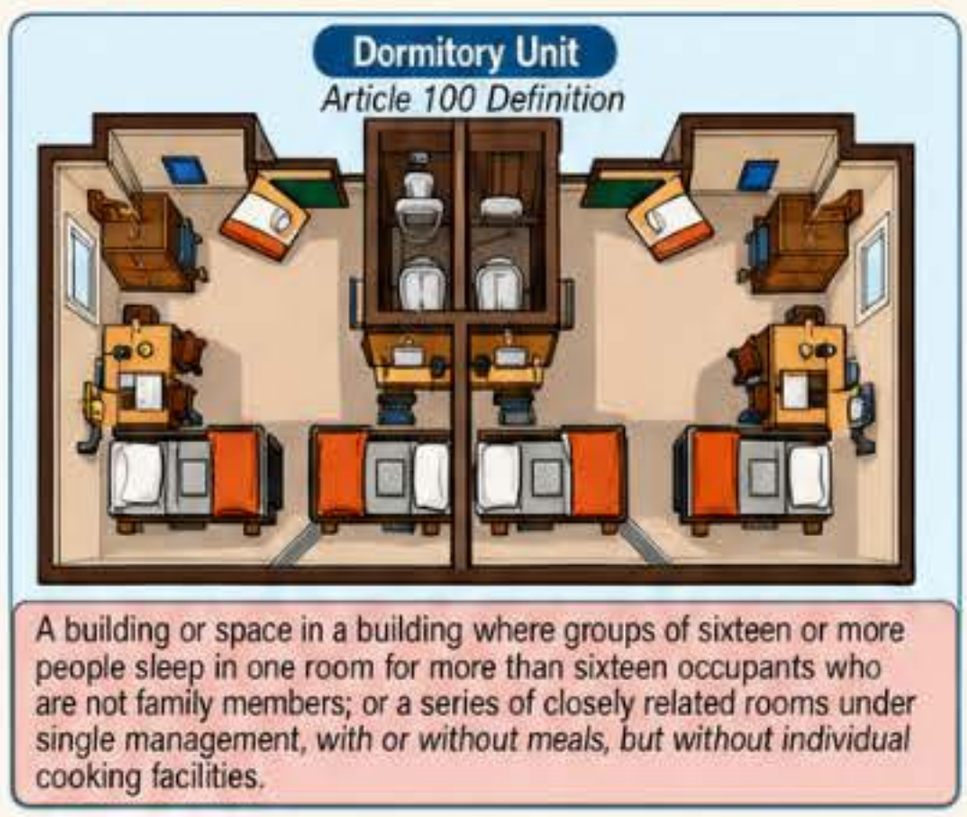
Some items—such as illuminated switches, contactors, or relays—use only tiny amounts of power yet remain classified as devices because they perform a specific control or operating function.

Disconnecting Means (Disconnect). A device that separates the circuit conductors from their power source. Typical examples include switches, attachment plugs, and circuit breakers. ▶ Figure 100–50



▶ Figure 100–50

Dormitory Unit. A building or space within a building where groups of sixteen or more people are provided sleeping accommodations in a single room for more than sixteen occupants who are not members of the same family; or a collection of closely associated rooms, under joint occupancy and single management, with or without meals, but without individual cooking facilities. ▶ Figure 100–51



▶ Figure 100–51

Duty, Continuous (Continuous Duty). Operation at a substantially constant load for an indefinite period of time.

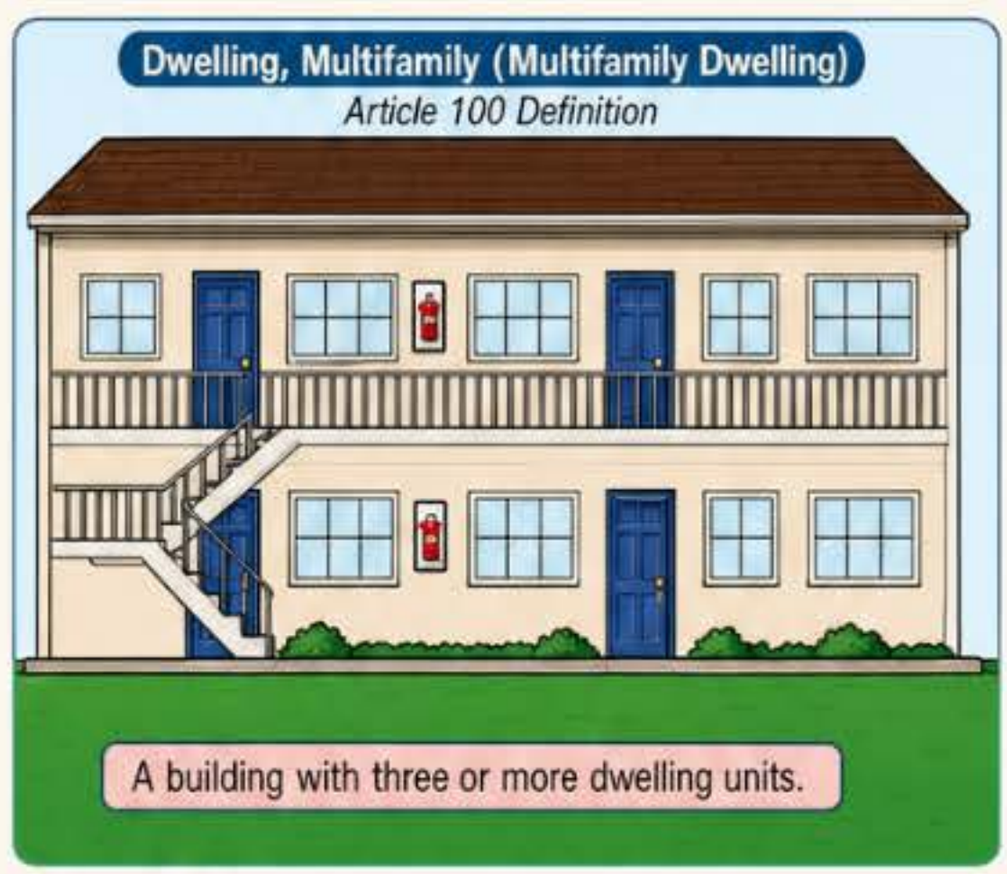
Duty, Varying (Varying Duty). Operation at loads, and for different intervals of time, which may extend widely.

Dwelling, One-Family (One-Family Dwelling). A building that contains solely one dwelling unit.

Dwelling, Two-Family (Two-Family Dwelling). A building that contains two dwelling units. ▶ Figure 100–52

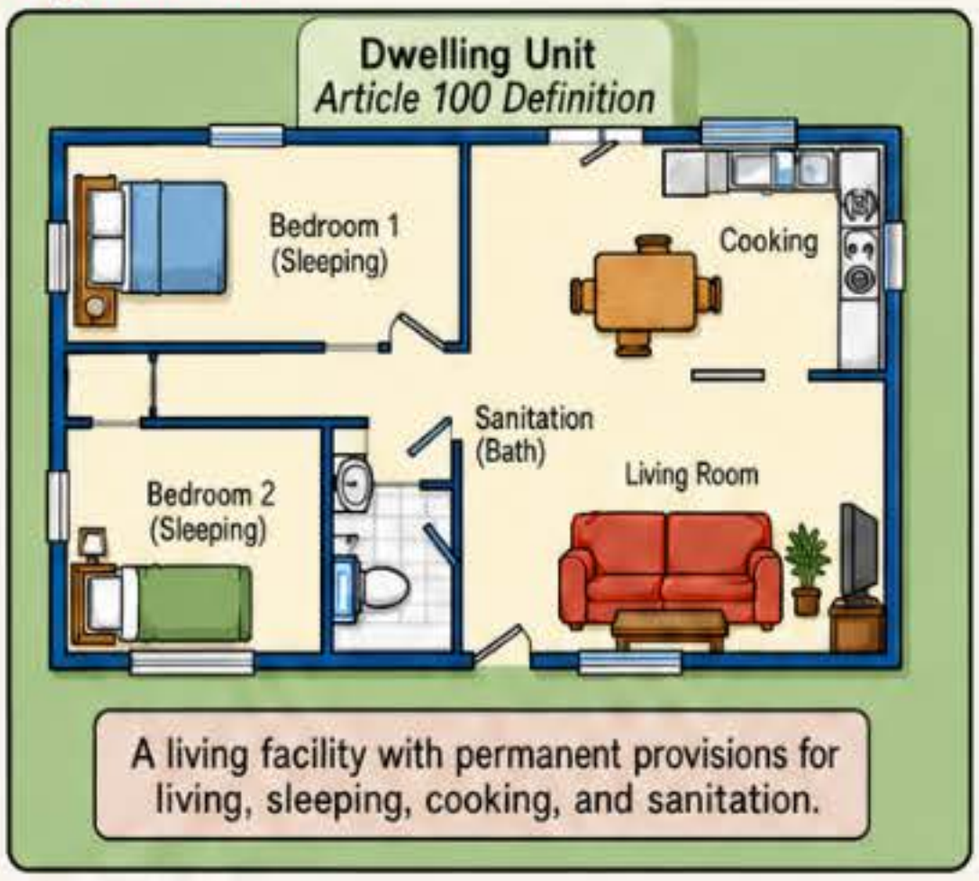
▶ Figure 100–52

Dwelling, Multifamily (Multifamily Dwelling). A building that contains three or more dwelling units. ▶ Figure 100–53



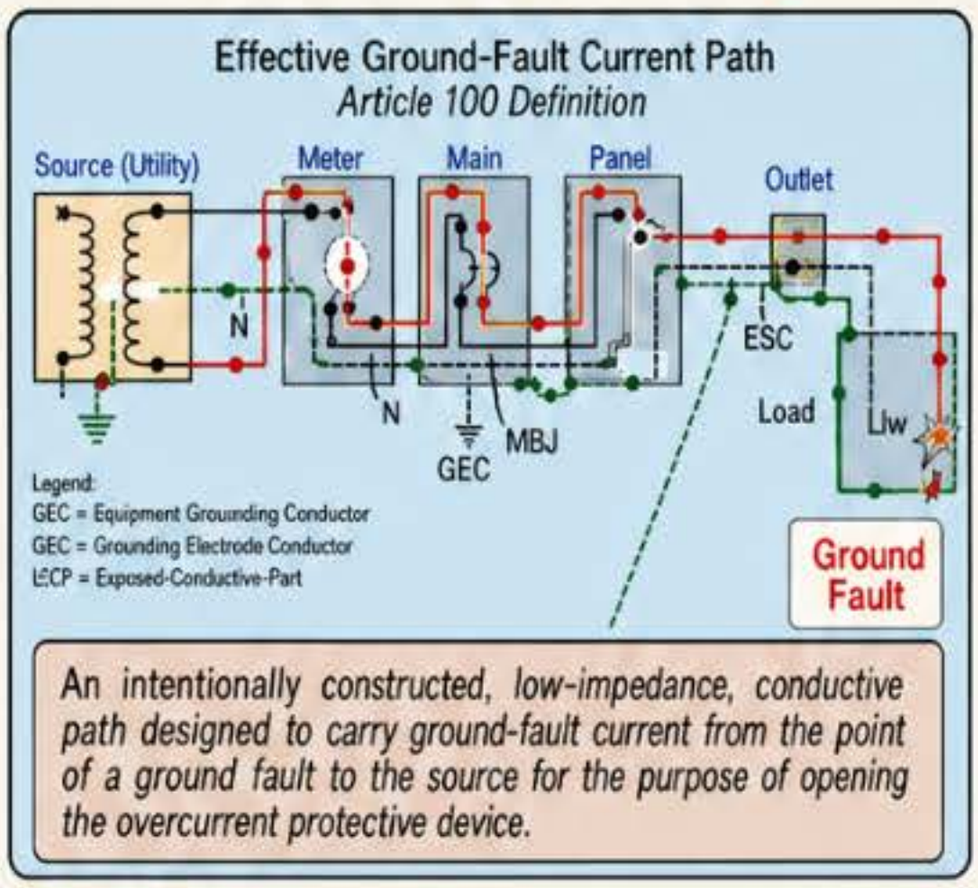
▶ Figure 100–53

Dwelling Unit. A space that offers separate, independent living accommodations with room for eating, sleeping, and ongoing household needs such as cooking and sanitation. ▶ Figure 100–54



▶ Figure 100–54

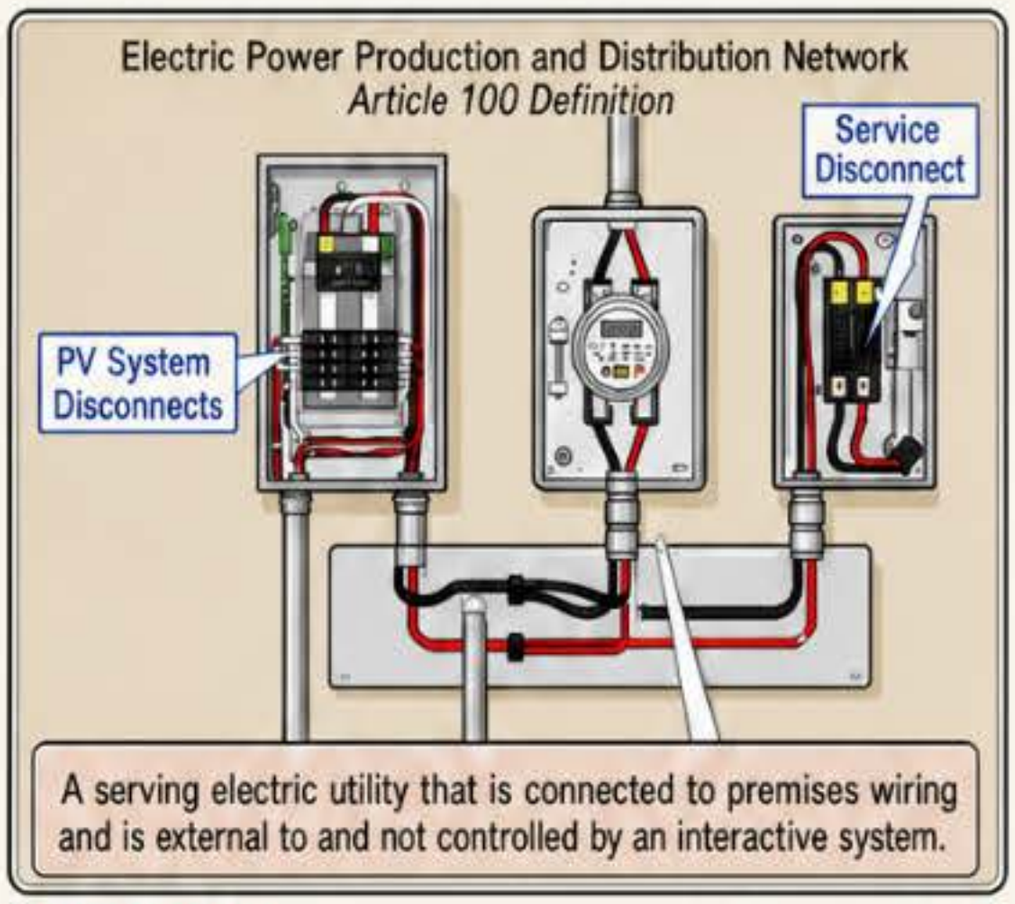
Effective Ground-Fault Current Path. An intentionally constructed low-impedance conductive path designed to carry ground-fault current from the point of a ground fault to the source for the purpose of opening the circuit overcurrent protective device. ▶ Figure 100–55



▶ Figure 100–55

Author's Commentary:
The effective ground-fault current path is intended to help remove dangerous voltage from a ground fault by opening the circuit overcurrent protective device.
— Michael Hamilton

Electric Power Production and Distribution Network. A serving electric utility that is connected to premises wiring and is not controlled by an interactive system. ▶ Figure 100–56



▶ Figure 100–56

Author's Commentary:
An interactive system is an electric power production system that operates in parallel with, and may deliver power to, the serving electric utility. An example is a PV system interactively connected in parallel to the utility by an interactive inverter.
— Michael Hamilton

Electric Sign (Article 600). A permanent, portable, or fixed, self-contained, electrically powered and/or illuminated unit that uses words or symbols to convey information or attract attention. ▶ Figure 100–57

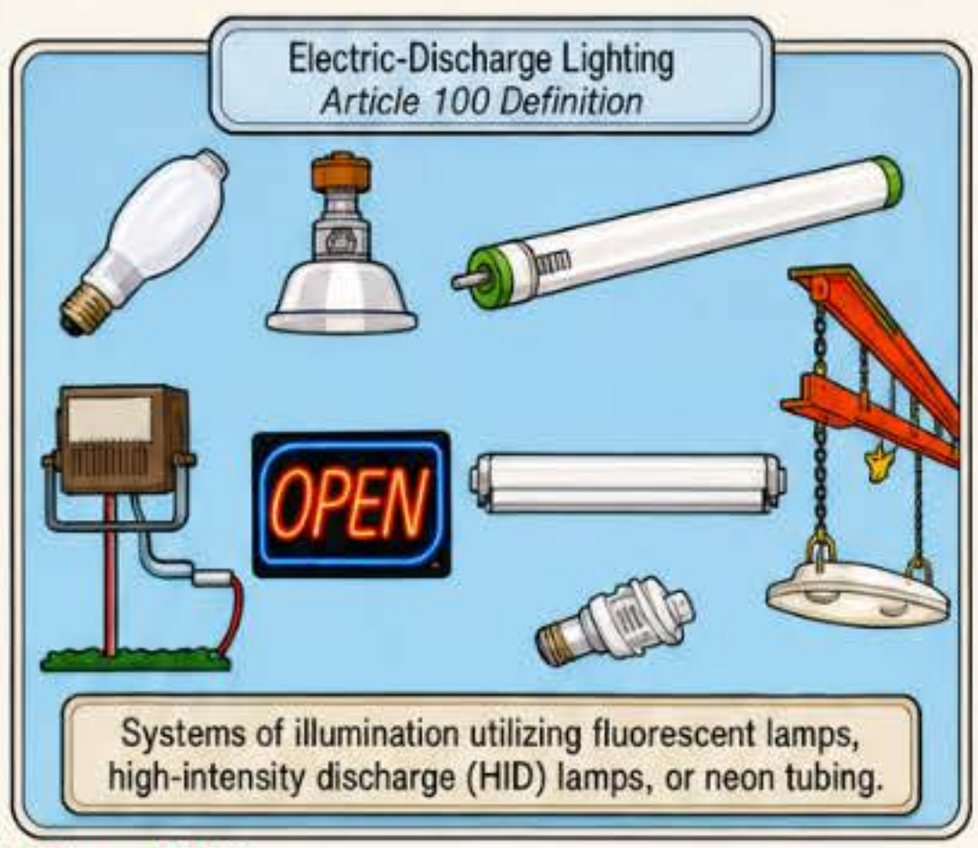
Electric-Discharge Lighting. Systems that produce illumination using fluorescent lamps, high-intensity discharge (HID) lamps, or neon tubing. ▶ Figure 100–58

Electric Vehicle. A road vehicle that is driven by an electric motor. This includes common types such as automobiles, buses, trucks, vans, neighborhood electric vehicles, and motorcycles. ▶ Figure 100–59

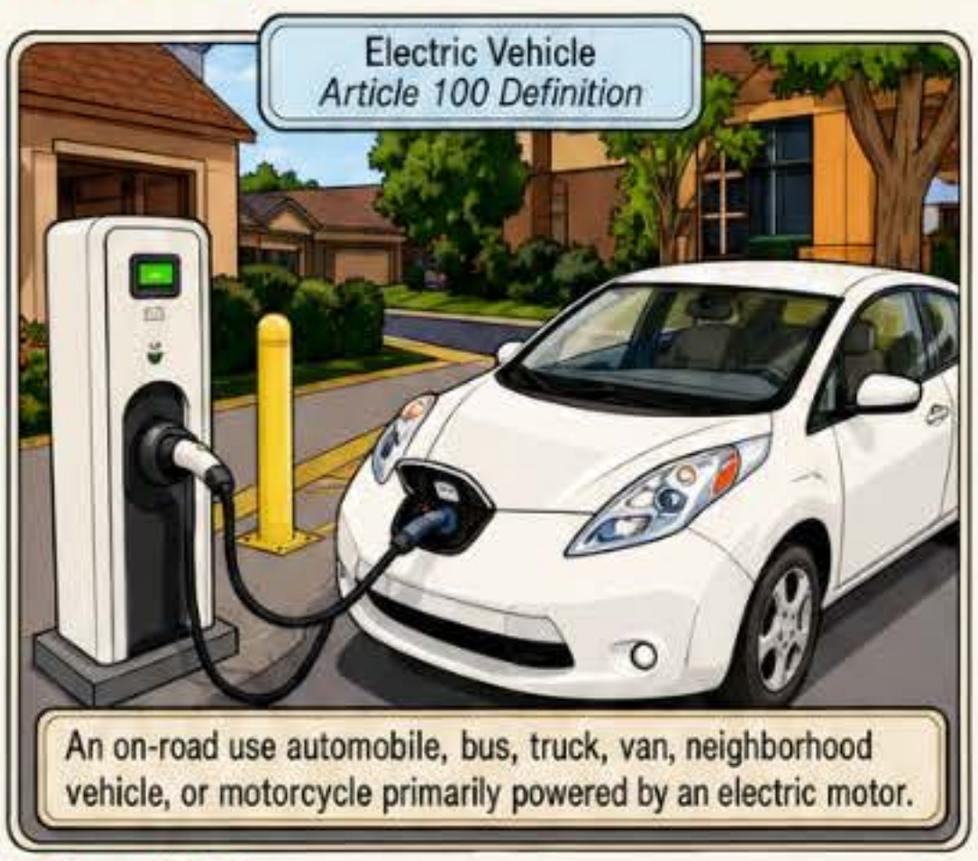
Off-road, self-propelled electric industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, and boats are not considered electric vehicles.

Author's Commentary:
The portion of plug-in hybrid type vehicles containing both an electric motor and a combustion engine that pertains to re-charging the electric motor is covered by Article 625.
— Michael Hamilton

▶ Figure 100–57



▶ Figure 100–58



▶ Figure 100–59

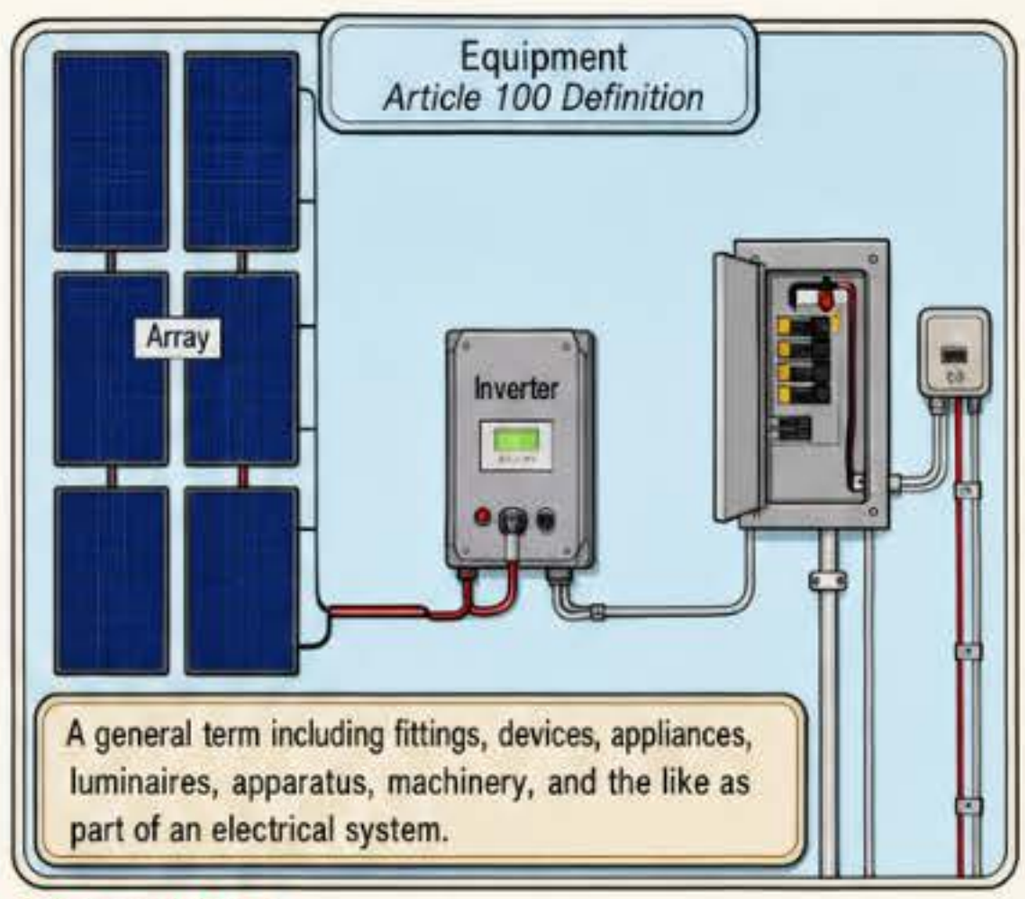
Electrical Datum Plane. A specified distance above a water level above which electrical equipment can be installed and electrical connections can be made.

> ***Author's Commentary:***
>
> This definition previously listed the specific elevations of the electrical datum plane in detail.
>
> Those detail requirements in 682.5 apply only when they are relevant to this article; other articles do not use that terminology.
>
> ***– Michael Hamilton***

Enclosed. Surrounded by a case, housing, fence, or wall(s) that prevents accidental contact with energized parts.

Energized. Electrically connected to a source of voltage.

Equipment. A general term including fittings, devices, appliances, luminaires, machinery, and similar items—either as part of an electrical installation or connected to it. ▶ Figure 100–60



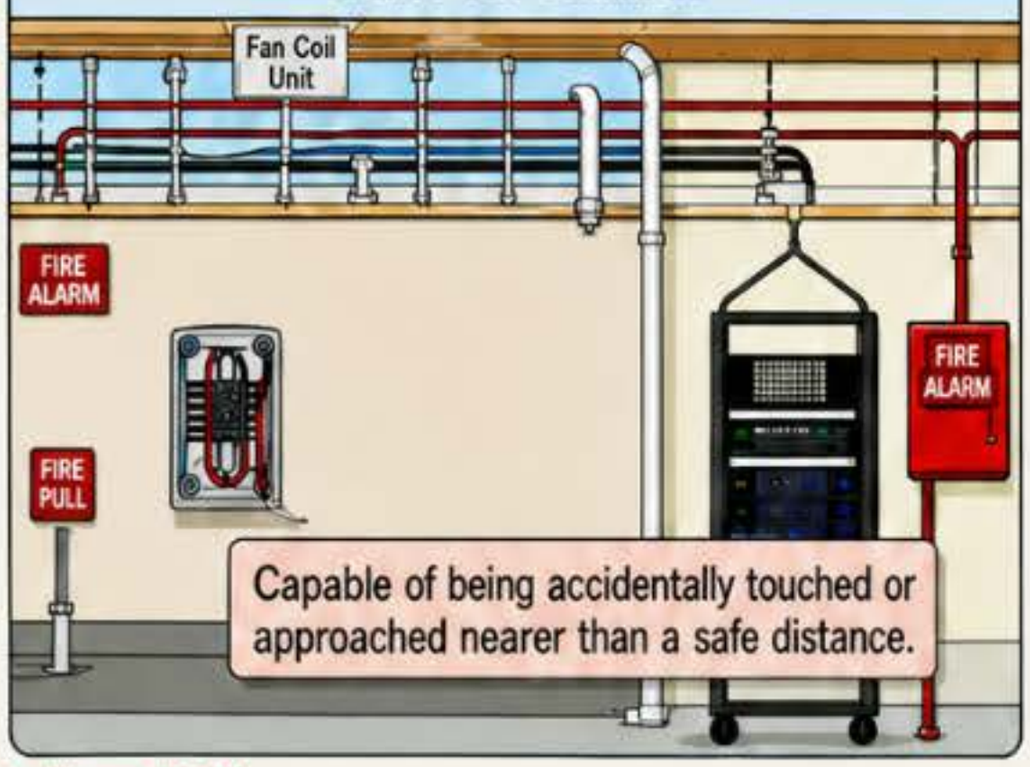
▶ Figure 100–60

Exposed (as applied to live parts). Capable of being accidentally touched or approached nearer than a safe distance. ▶ Figure 100–61

Note: This term applies to parts that are not suitably guarded, isolated, or insulated for the condition such as line-side lugs in a meter socket or panelboard.

Exposed (as applied to wiring methods). On or attached to the surface of a building, or behind panels designed to allow access. ▶ Figure 100–62

Exposed (as Applied to Live Parts)
Article 100 Definition



▶ Figure 100-61

Exposed (as Applied to Wiring Methods)
Article 100 Definition

▶ Figure 100-62

Fault Current. The current that appears at a location on a system during a short-circuit event. ▶ Figure 100-63

Note: A short circuit can occur during abnormal conditions such as a fault between circuit conductors or between a conductor and ground.

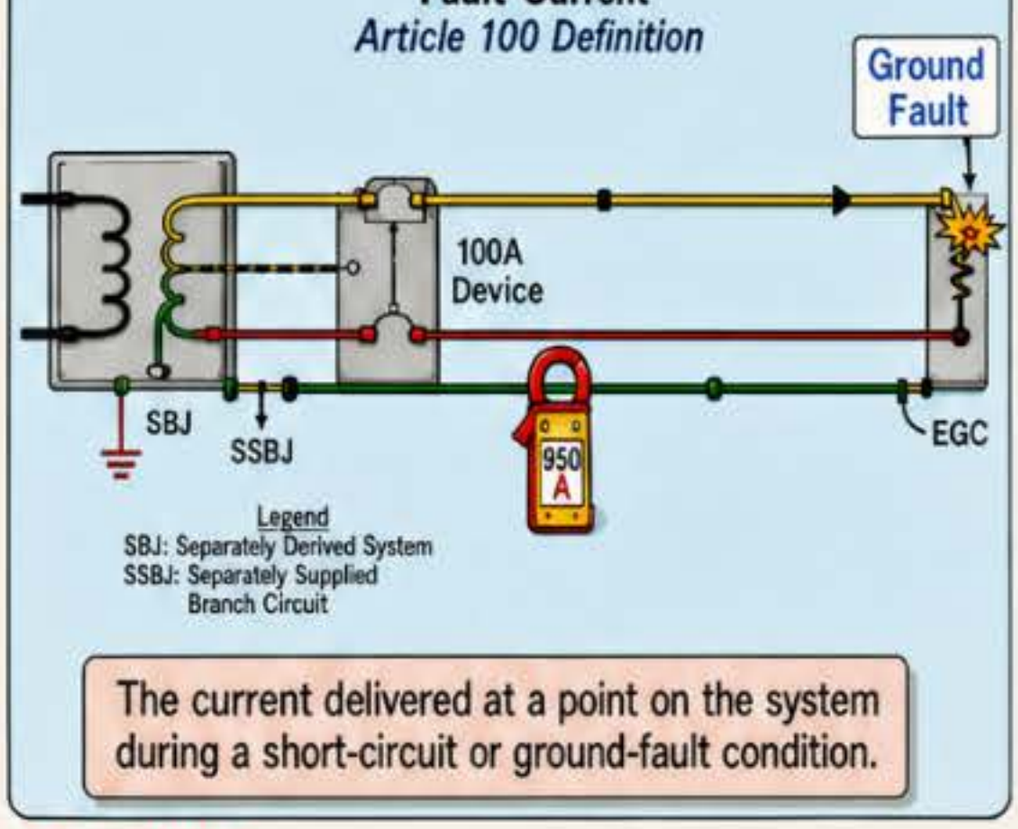
Feeder. The conductors running between the service disconnect, *a separately derived system (usually a transformer), or another supply source and the final branch-circuit overcurrent device.*
▶ Figure 100-64

Author's Commentary:

▶ *An "other power-supply source" includes solar photovoltaic (PV) systems or conductors from generators.*

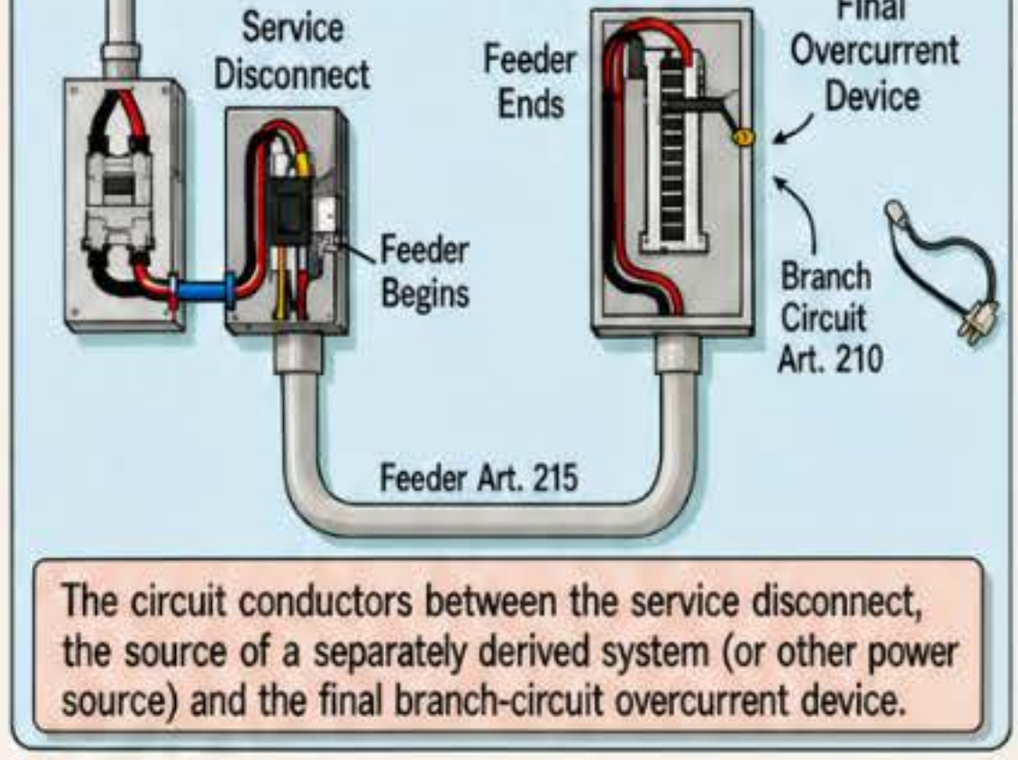
— Michael Hamilton

Fault Current
Article 100 Definition



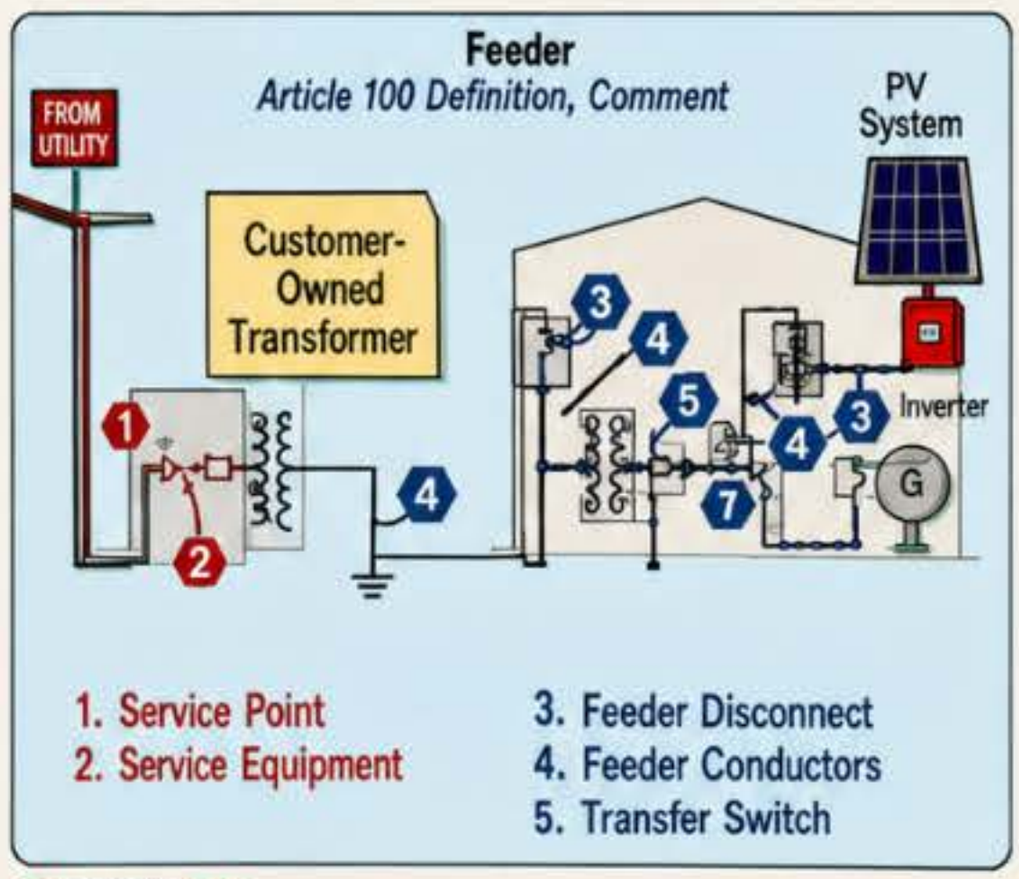
▶ Figure 100-63

Feeder
Article 100 Definition



▶ Figure 100-64

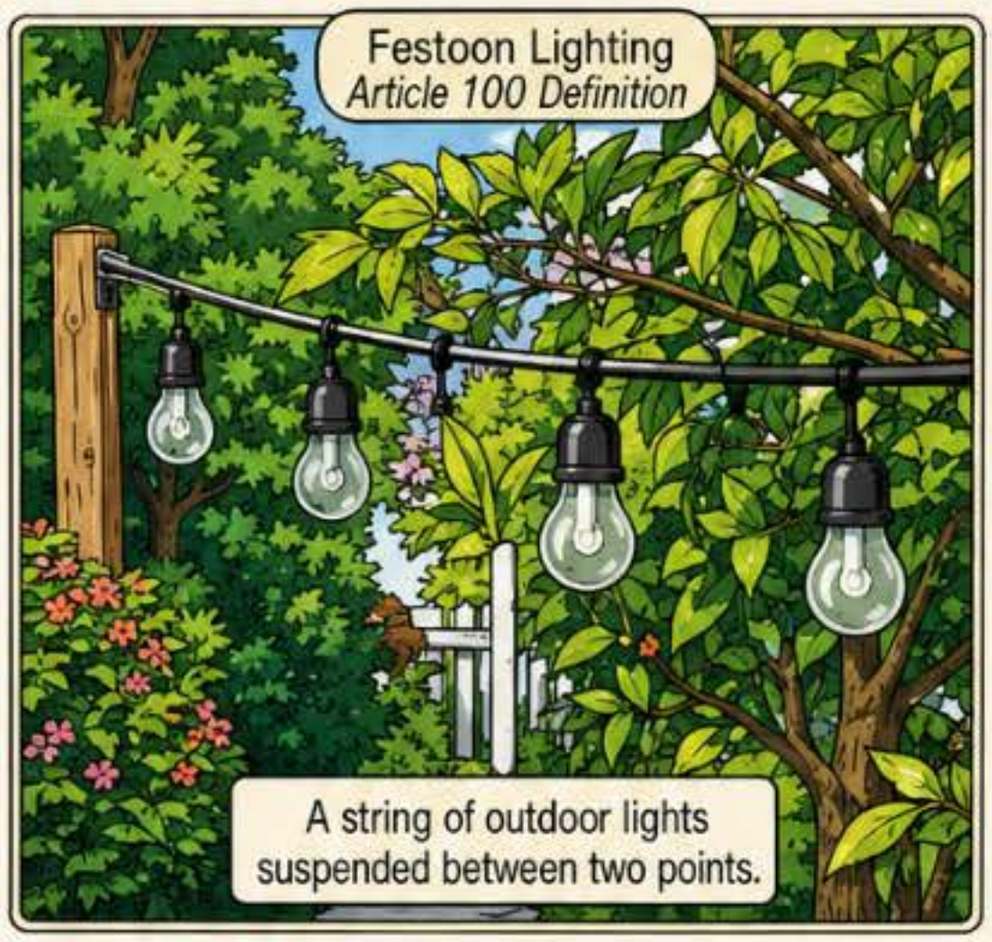
Feeder
Article 100 Definition, Comment



▶ Figure 100-65

DEFINITIONS | From Michael Hamilton Publications

Festoon Lighting. Outdoor light strings hung between two points.
▶ Figure 100–66



▶ Figure 100–66

Field Evaluation Body (FEB). An organization or part of an organization that performs field evaluations of electrical equipment and materials.

Field Labeled (as applied to evaluated products). Equipment or materials which have a label, symbol, or other identifying mark of a field evaluation body (FEB) indicating the equipment or materials were evaluated and found to comply with the requirements described in the accompanying field evaluation report.

Fitting. An accessory such as a locknut, bushing, or other part of a wiring system that is primarily intended to perform a mechanical rather than an electrical function.
▶ Figure 100–67

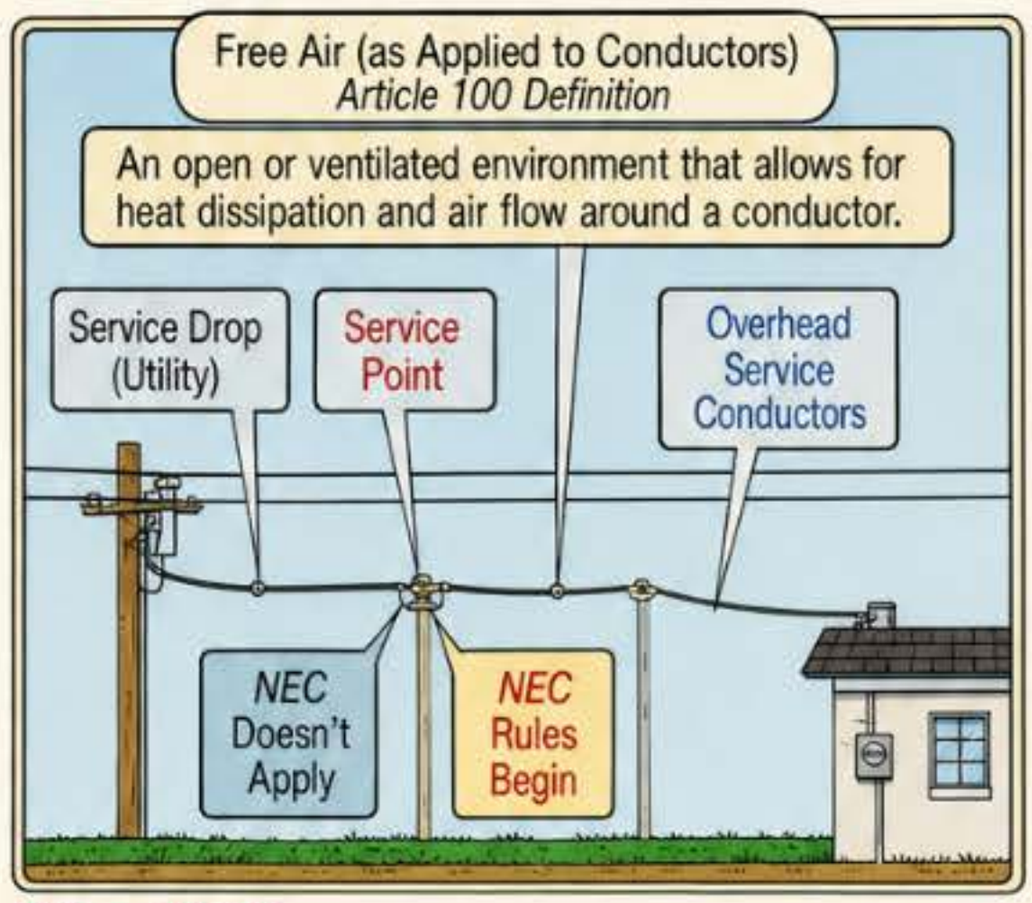
Free Air (as applied to conductors). An open or ventilated environment that allows for heat dissipation and airflow around a conductor. ▶ Figure 100–68

Garage. A building or portion of a building where self-propelled vehicles can be kept.

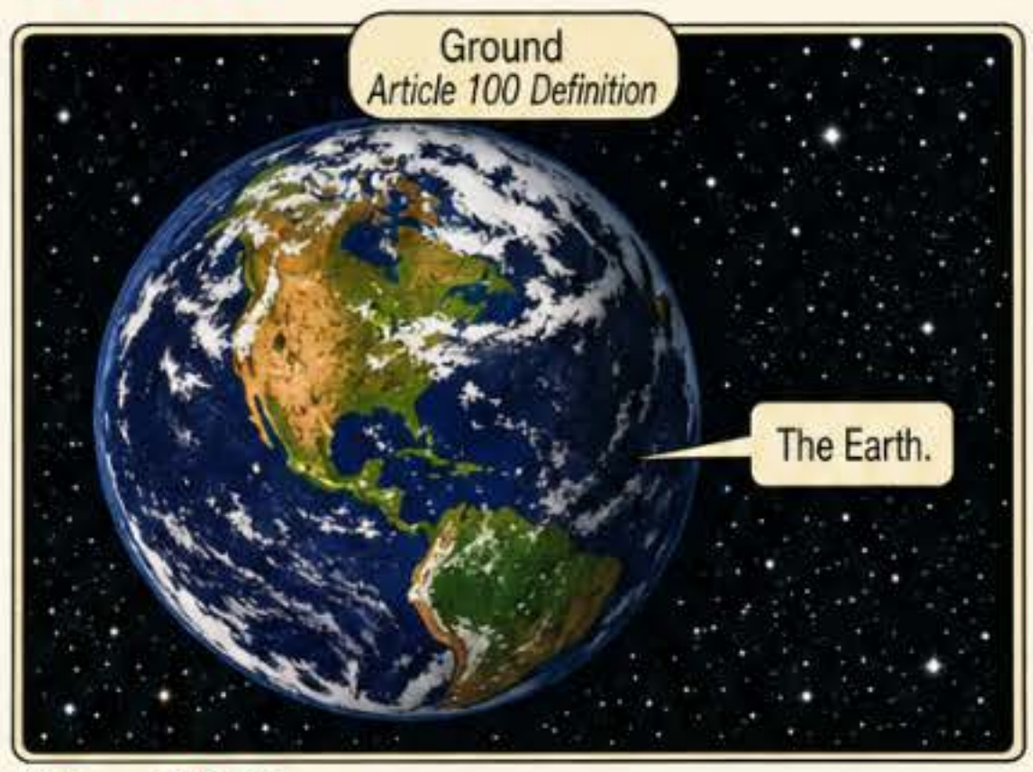
Generating Capacity, Inverter. The sum of parallel-connected inverters' maximum continuous output power at 40°C in watts or kilowatts.

Ground. The Earth. ▶ Figure 100–69

▶ Figure 100–67



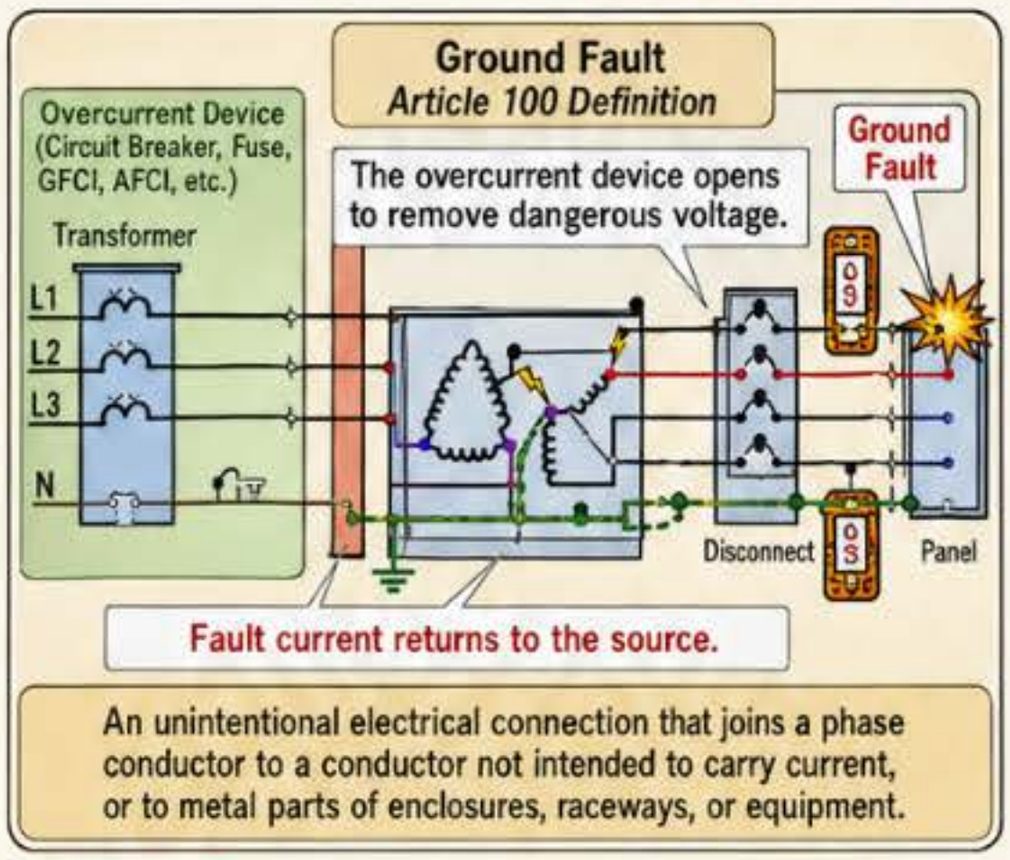
▶ Figure 100–68



▶ Figure 100–69

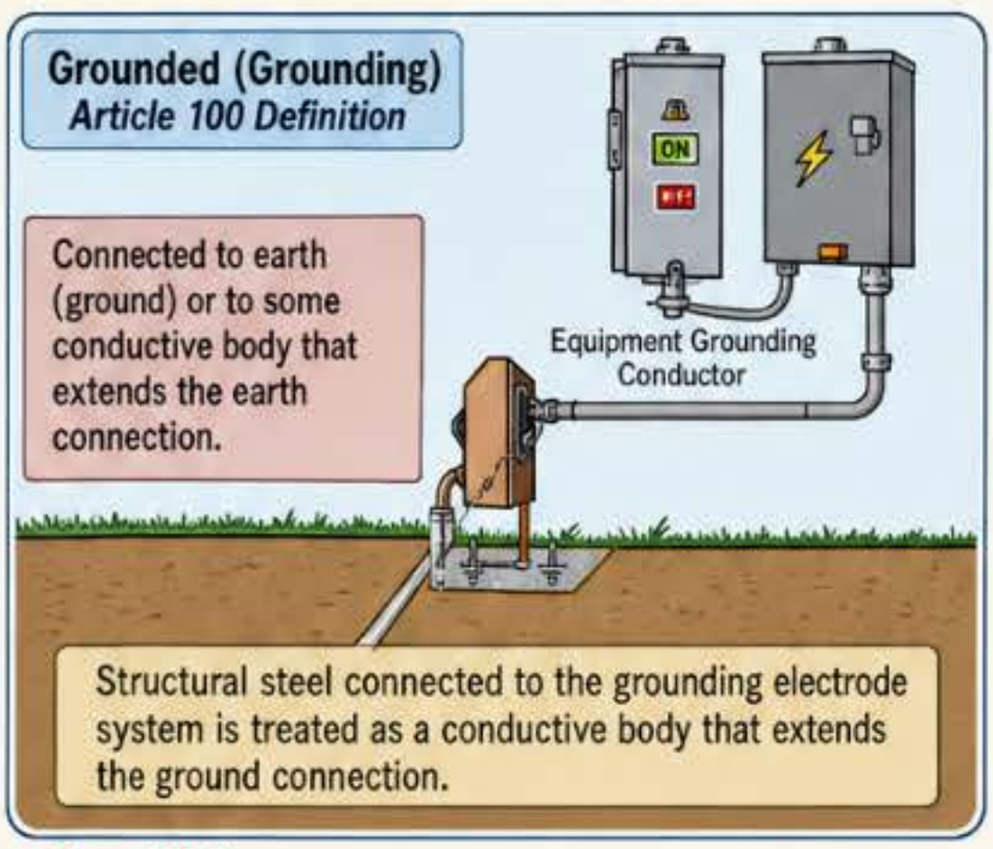
100 | DEFINITIONS

Ground Fault. An unintentional electrical connection between a phase conductor and another conductor that normally does not carry current, or between a phase conductor and metal surfaces of enclosures, raceways, or equipment. **(Article 100 Definition)**



▶ Figure 100–70

Grounded (Grounding). Connected to the Earth (ground) or to a conductive body that extends the Earth connection. **(Article 100 Definition)**



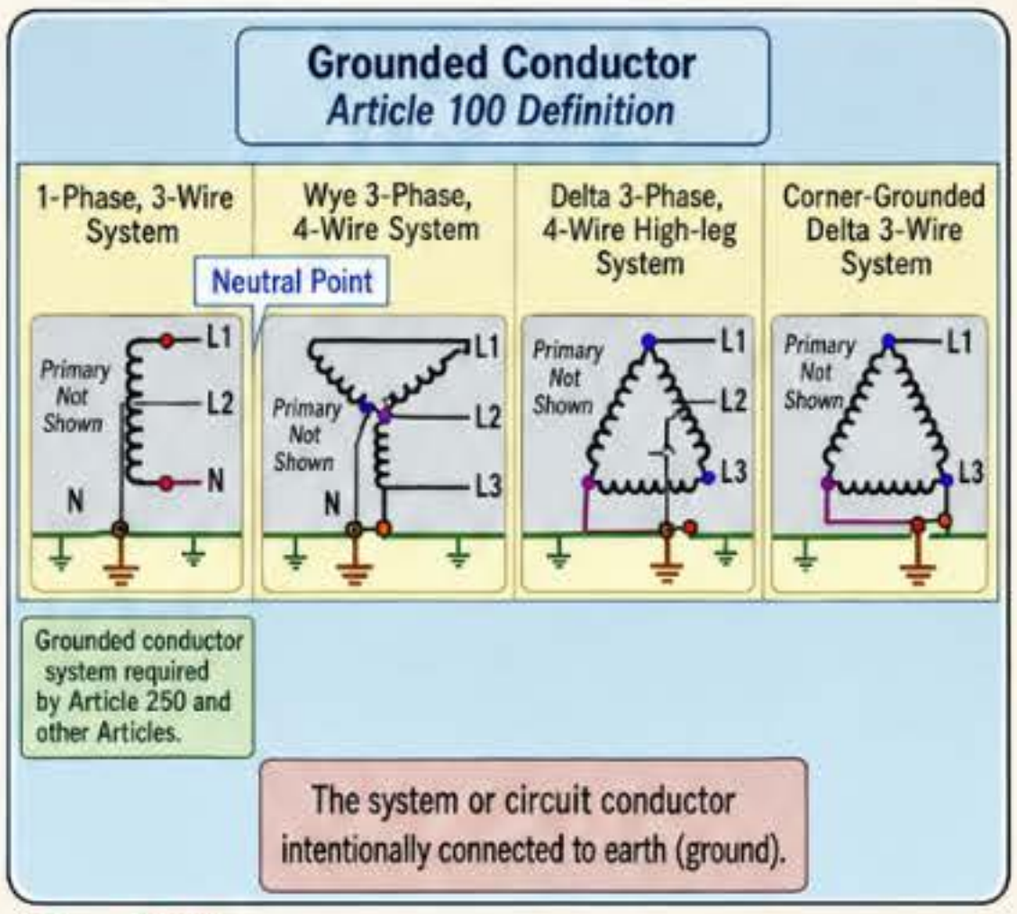
▶ Figure 100–71

Author's Commentary:

An example of a "body that extends the ground (earth) connection" is a termination to structural steel that is linked to the Earth either directly or by connection to another grounding electrode, as described in Article 250.52.

— Michael Hamilton

Grounded Conductor. The system or circuit conductor that is intentionally connected to the Earth (ground). **(Article 100 Definition)**



▶ Figure 100–72

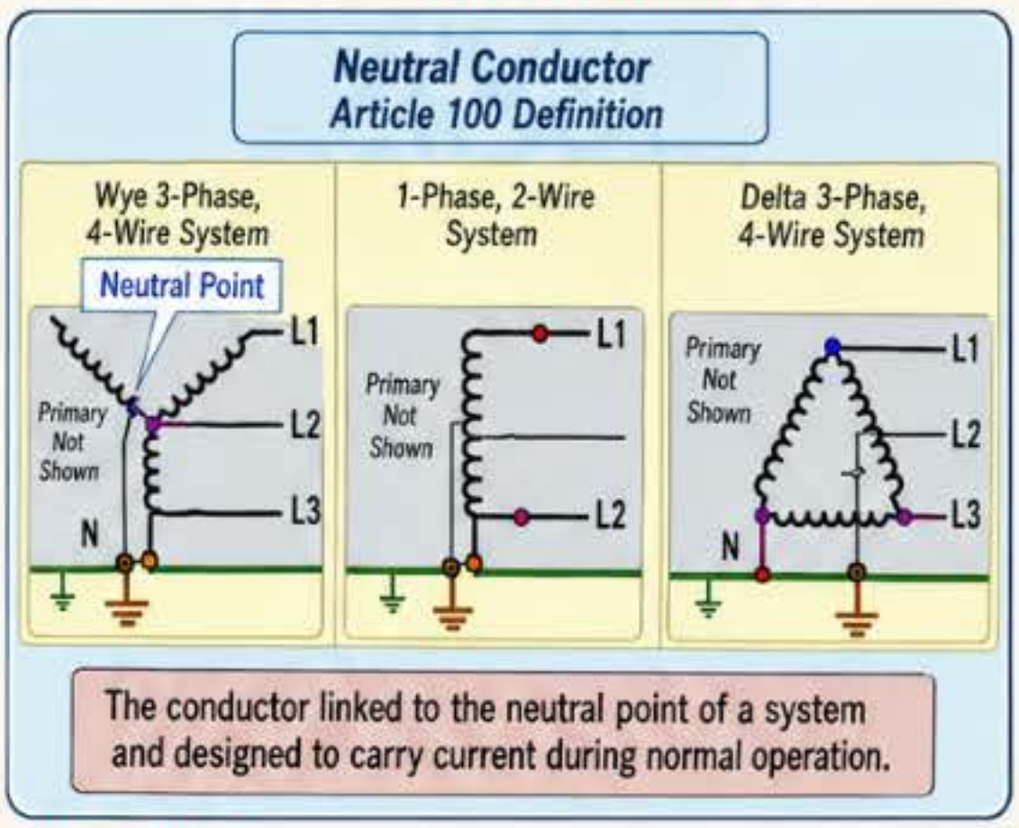
Note: Although an equipment grounding conductor is grounded, it is not classified as a grounded conductor.

Author's Commentary:

There are two categories of grounded conductors: the neutral (grounded) conductor and grounded-phase conductor. A system where the transformer secondary is bonded with the neutral point to establish a neutral is shown in Figure 100–73.

— Michael Hamilton

Neutral Conductor. *The conductor that is connected to the neutral point of a system and intended to carry current under normal operating conditions.* **(Article 100 Definition)**



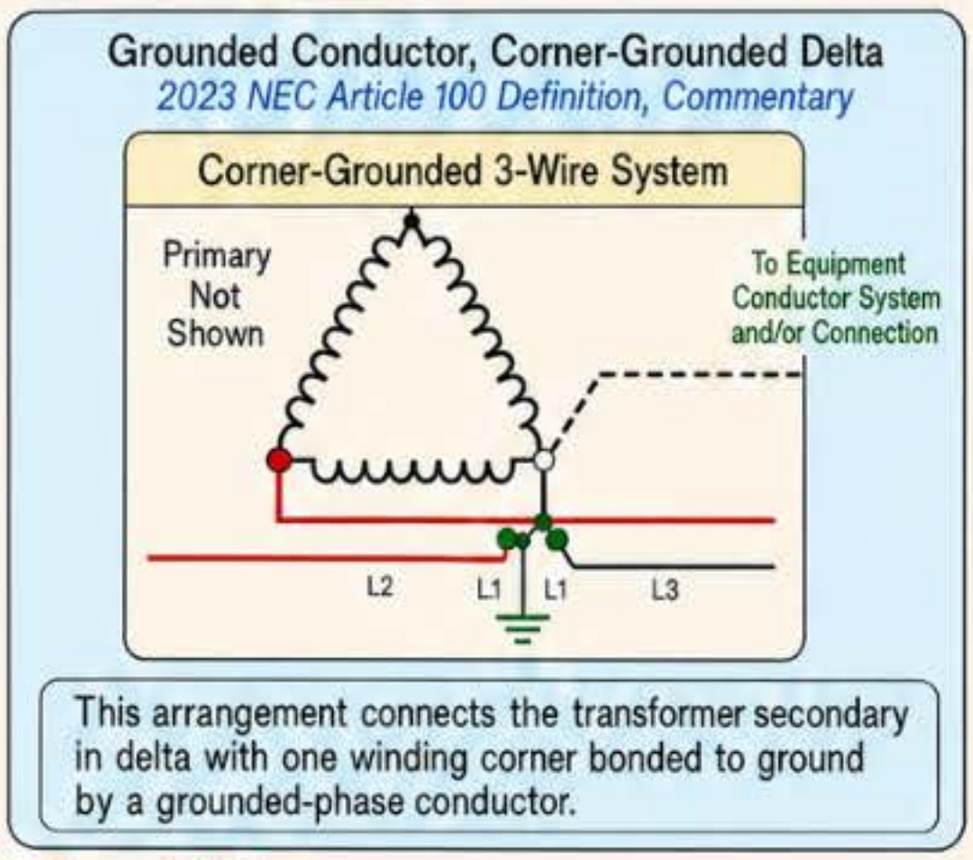
▶ Figure 100–73

DEFINITIONS | From Michael Hamilton Publications

Author's Commentary:

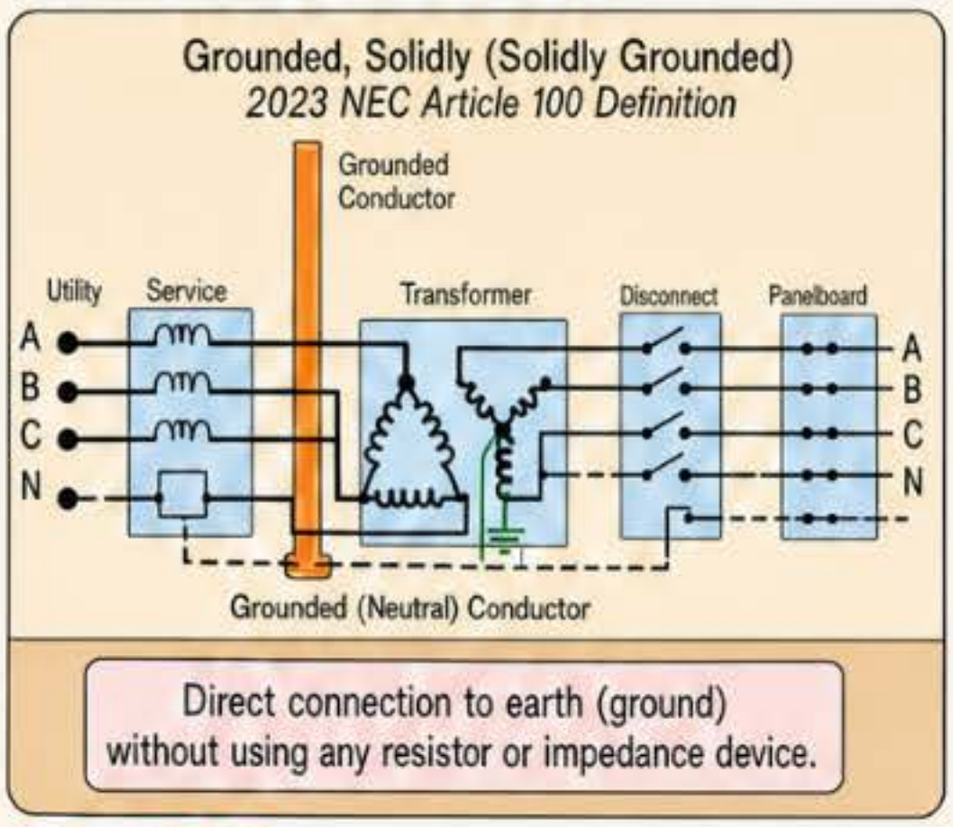
- A setup in which the transformer's secondary is connected in a delta configuration with a single corner tied to an earth ground through a grounded conductor.

  — ***Michael Hamilton***



▶ Figure 100–74

Grounded, Solidly (Solidly Grounded). Connected to ground (earth) without adding any resistor or impedance device. ▶ Figure 100–75



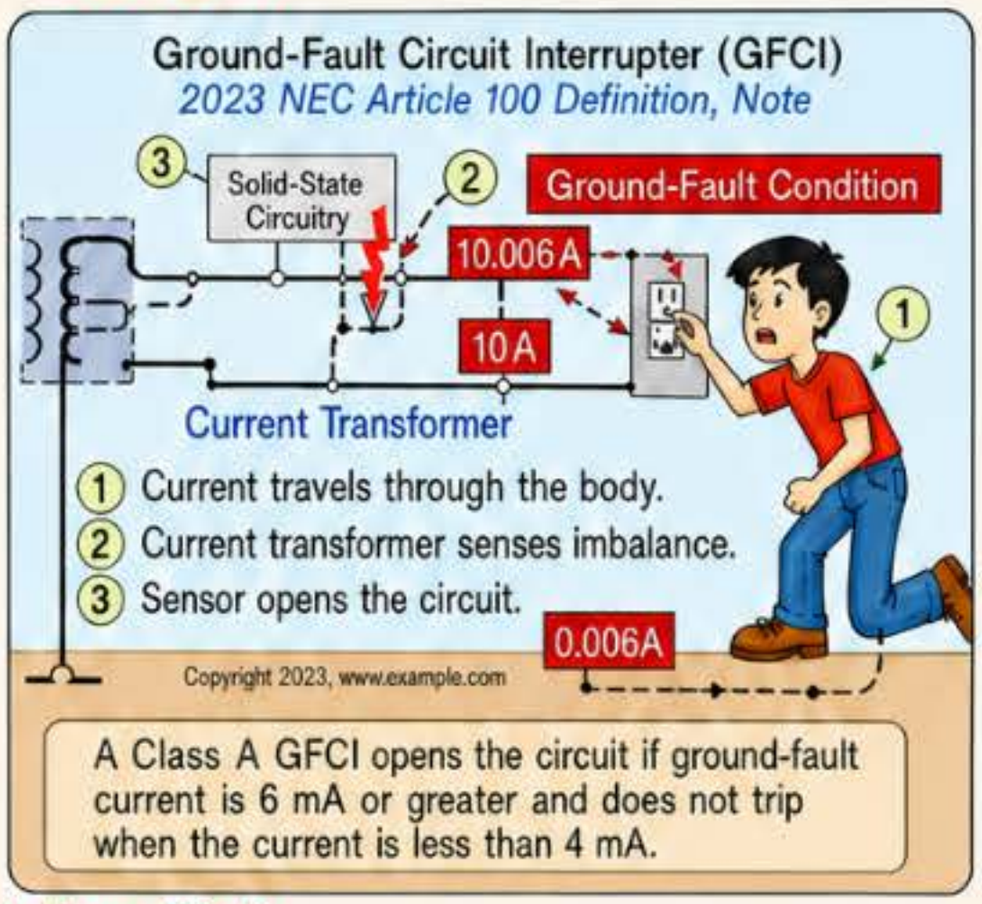
▶ Figure 100–75

Ground-Fault Circuit Interrupter (GFCI). A device intended to safeguard people by automatically removing power when ground-fault current exceeds the threshold for a "Class A" device.

▶ Figure 100–76

Note: A Class A ground-fault circuit interrupter will open the circuit if the ground-fault current is 6 mA or higher and it will not trip if the ground-fault current is less than 4 mA.

▶ Figure 100–76

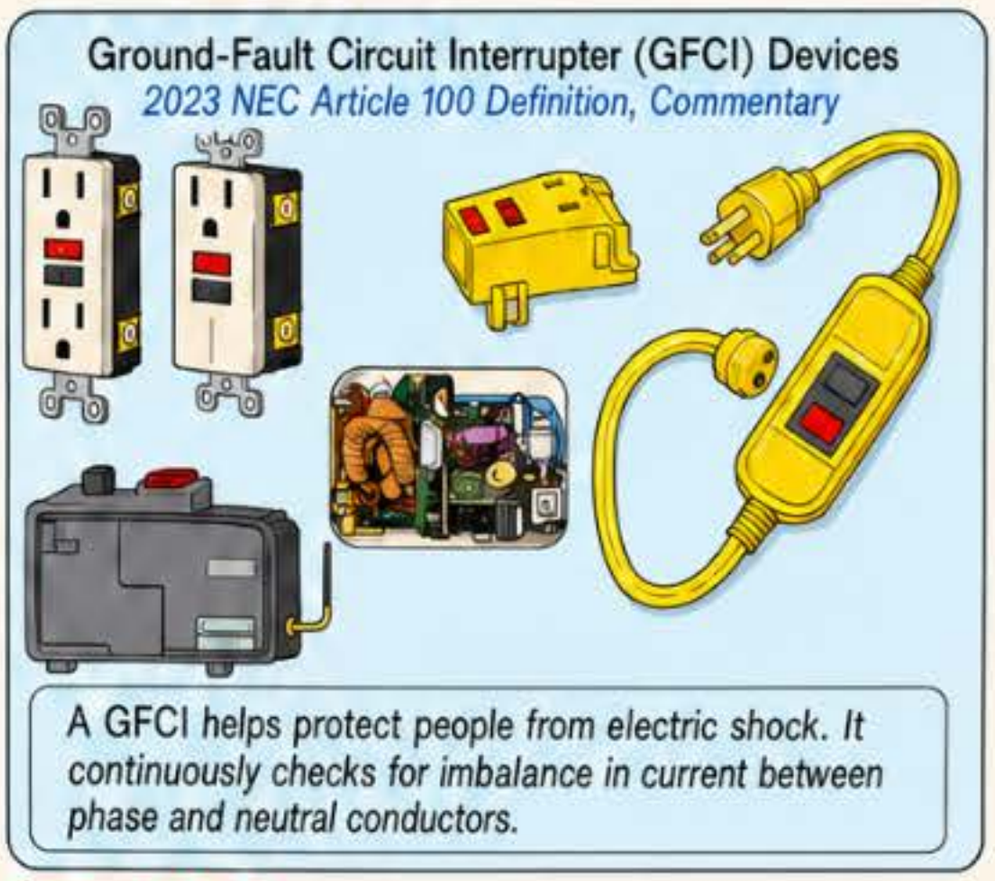


▶ Figure 100–76

Author's Commentary:

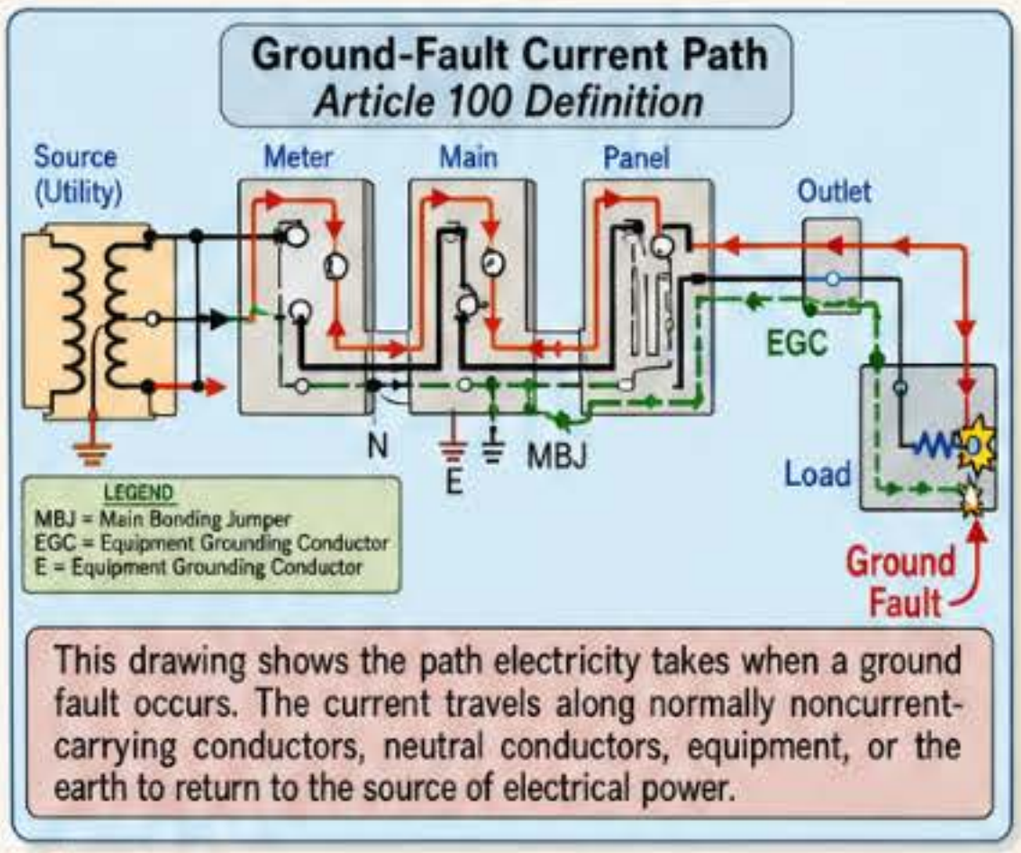
- A GFCI works on the principle of monitoring any difference between the current on the ungrounded conductors. On 120V circuits, it compares the ungrounded current in the phase to the neutral. On 240V circuits, it compares the ungrounded currents in both conductors. Receptacles, breakers, cord sets, and other protective accessories that incorporate GFCI technology are commercially available.

  — ***Michael Hamilton***



▶ Figure 100–77

Ground-Fault Current Path. It is the electrical route created when a ground fault occurs in a wiring system. The fault current flows through normally noncurrent-carrying conductors, metallic conductive parts, equipment enclosures, and the earth back to the source of electrical power. See **Figures 100–78**.



▶ Figure 100–78

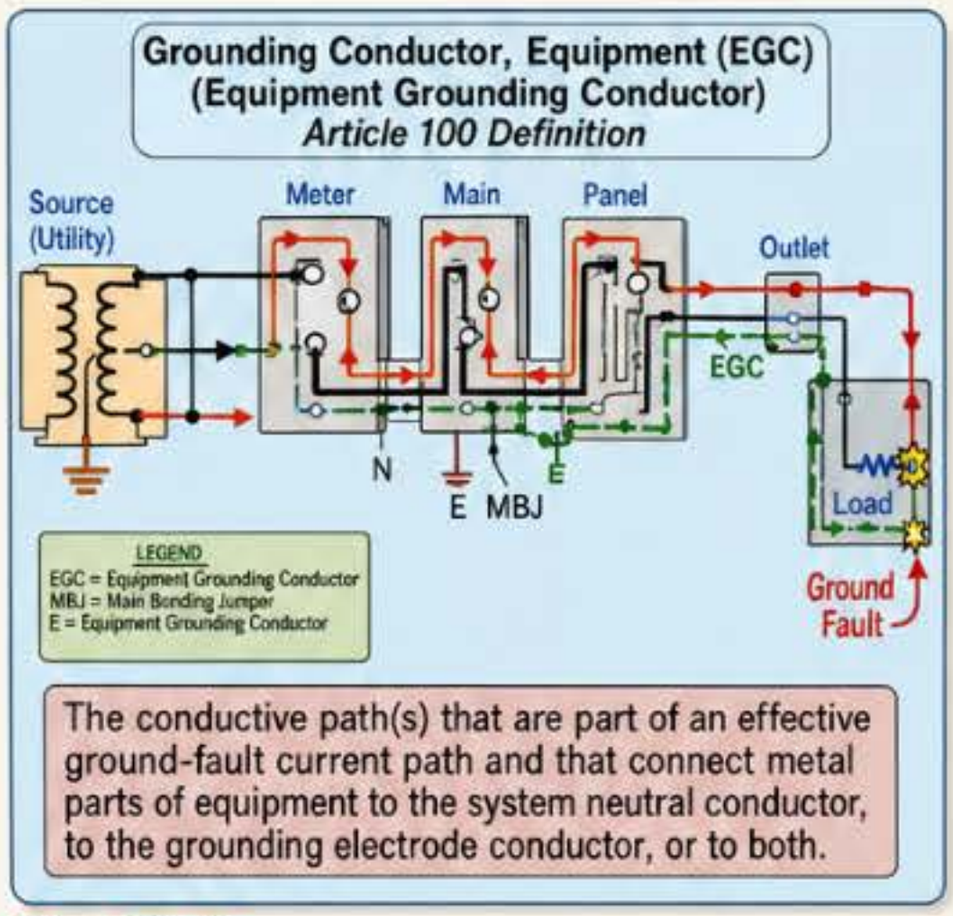
Note: Examples of ground-fault current paths include any combination of equipment grounding conductors, metallic raceways, metal cable sheaths, electrical equipment, and other electrically conductive material like metal, water, and gas piping; steel framing members; stucco mesh; metal ducting; reinforcing steel; shields of communications cables; neutral conductors; and the earth itself.

Ground-Fault Protection of Equipment. A system intended to protect equipment from damage caused by ground-fault currents by opening all ungrounded conductors of the affected circuit. This protection maintains current levels below those required to prevent conductors from damage during the operation of a supply circuit overcurrent device [215.10, 230.95, and 240.13].

Author's Commentary:
This kind of protective device is not meant to safeguard people. It works by opening the circuit when current exceeds that of a "Class A" GFCI-type device. It is generally used to protect equipment or GFPE but should never be called a GFCI.
— Michael Hamilton

Grounding Conductor, Equipment (Equipment Grounding Conductor). *The conductive path(s) used in an effective ground-fault current path that links metal parts of equipment to the system neutral conductor or to a grounded-phase conductor [250.110 through 250.126].*

▶ Figure 100–79

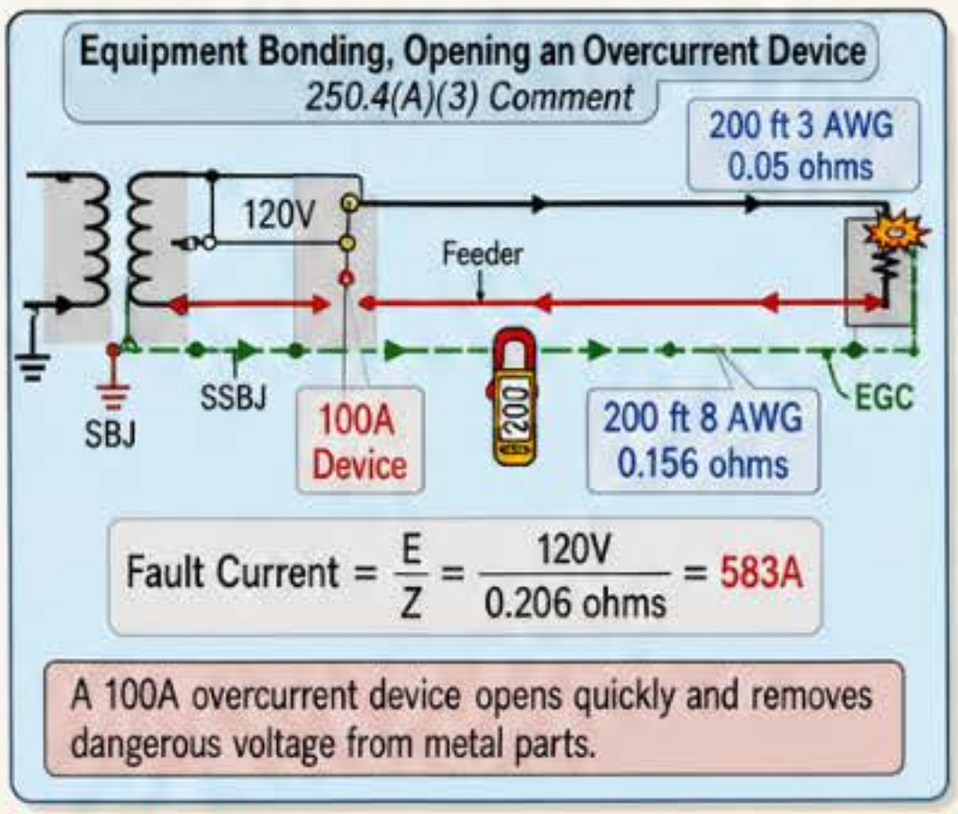


▶ Figure 100–79

Note 1: The circuit equipment grounding conductor also performs bonding.

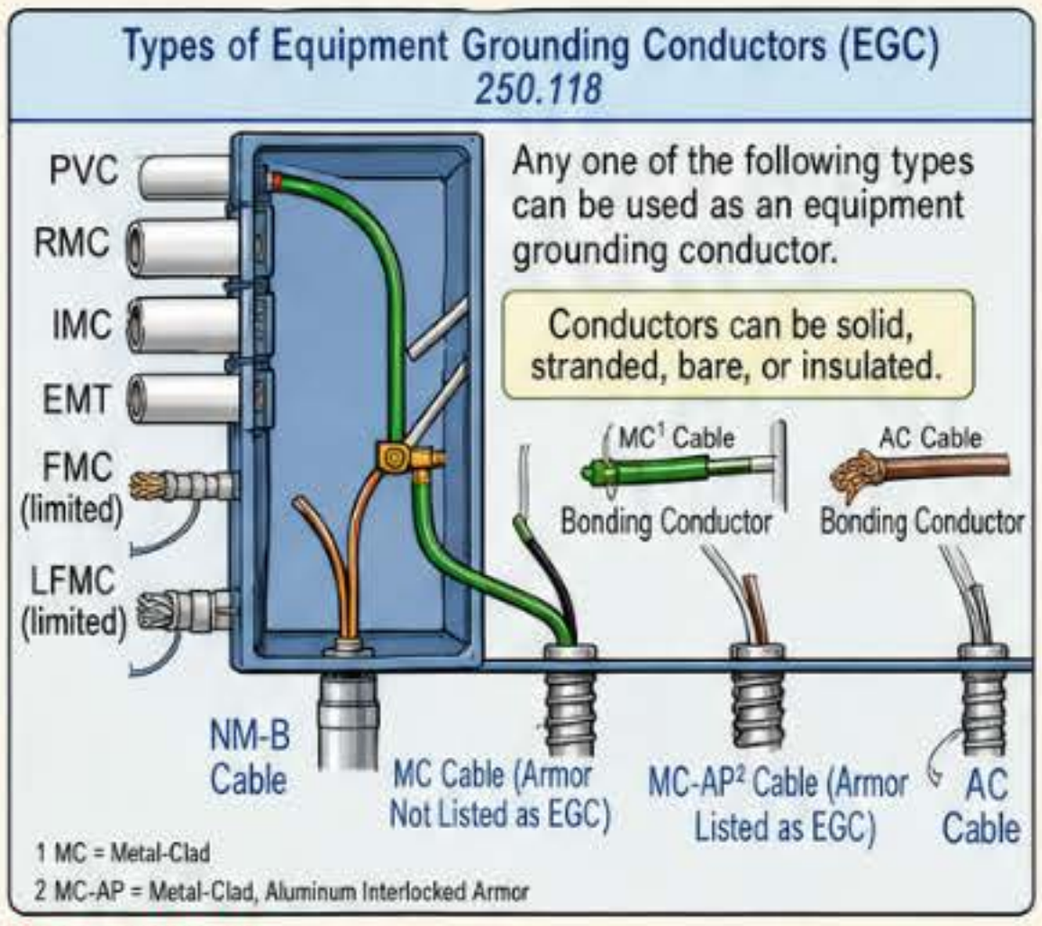
Author's Commentary:
To quickly eliminate a hazardous touch voltage on metal parts during a ground fault, the equipment grounding conductor (EGC) must connect to the system neutral conductor at the source. Since the source has very low enough impedance, the fault current will rise rapidly to a level that will trip the overcurrent device.
— Michael Hamilton

Note 2: An equipment grounding conductor can be any one or a combination of the types listed in 250.118. See **Figure 100–81**.

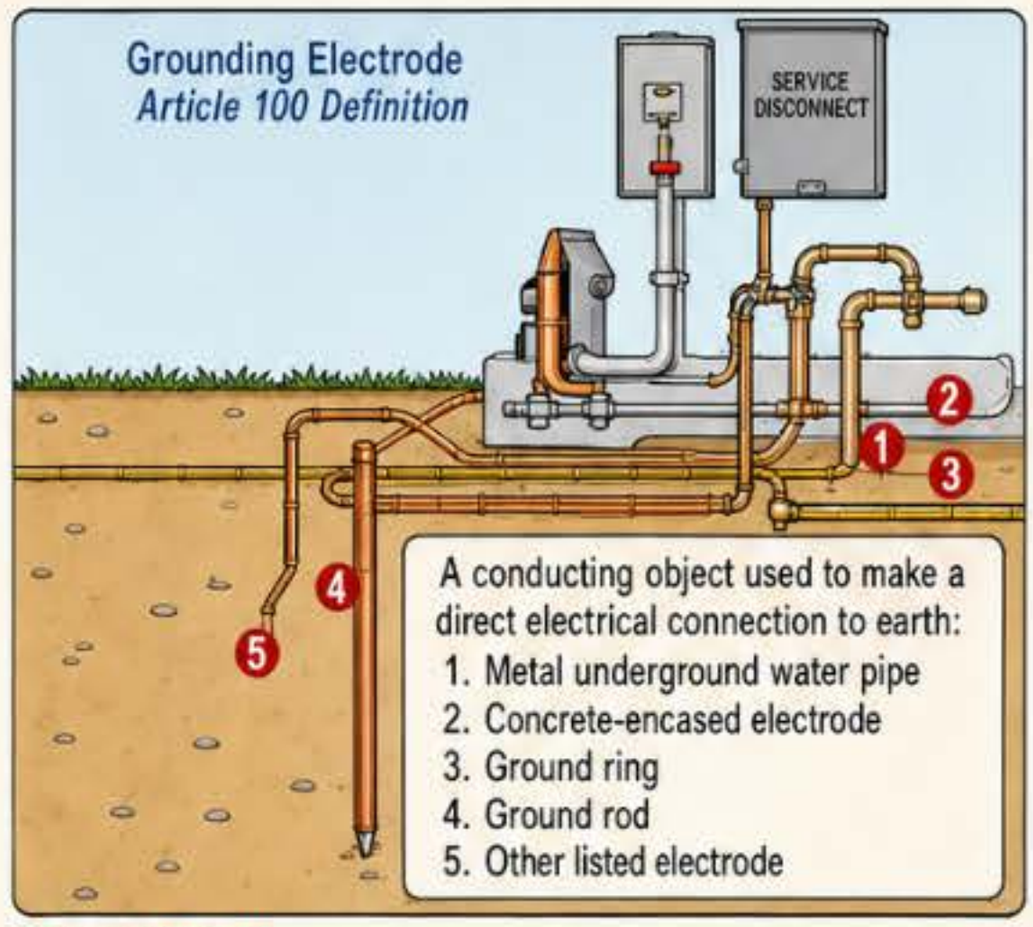


▶ Figure 100–80

Definitions



▸ Figure 100–81



▸ Figure 100–82

Author's Commentary:

Equipment grounding conductors are allowed to be formed from:

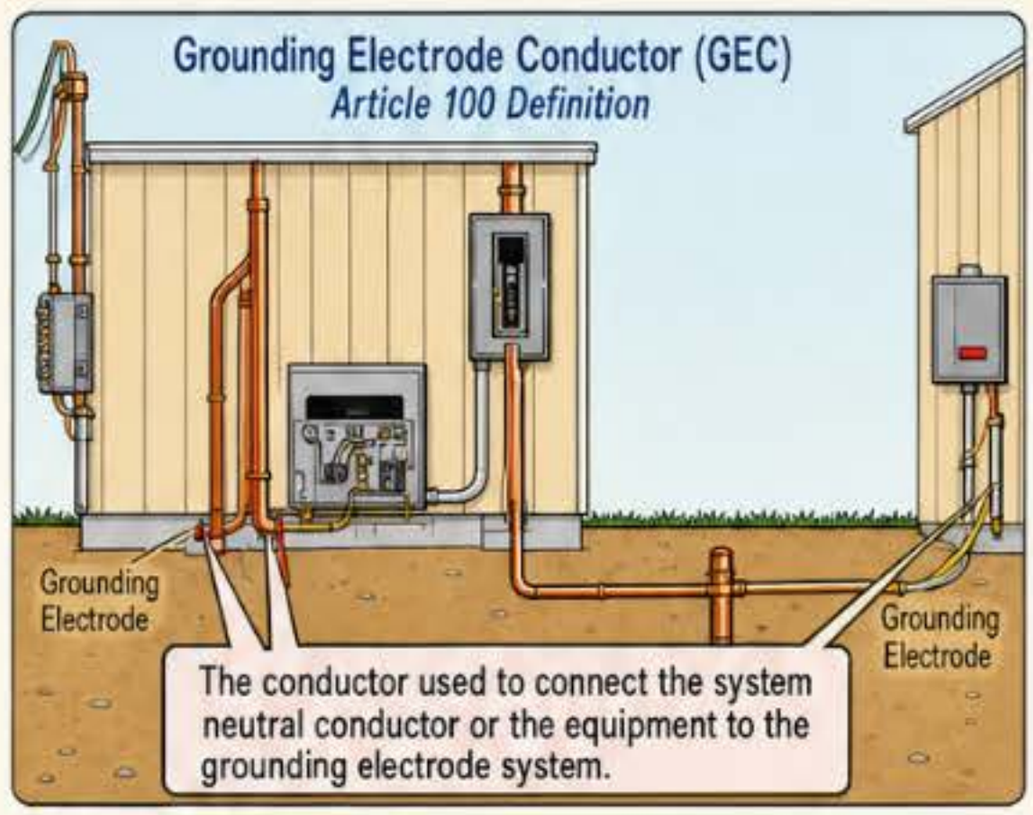
- A bare or insulated conductor
- Rigid metal conduit
- Intermediate metal conduit
- Electrical metallic tubing
- Listed flexible metal conduit as limited by 250.118(5)
- Listed liquidtight flexible metal conduit as limited by 250.118(6)
- Armored cable
- The copper metal sheath of mineral-insulated cable
- Metal-clad cable as limited by 250.118(10)
- Metal cable trays as limited by 250.118(11) and 392.60
- Electrically continuous metal raceways listed for grounding
- Surface metal raceways listed for grounding
- Metal enclosures

— Michael Hamilton

Grounding Electrode. A conducting object used to make a direct electrical connection to the Earth [250.50 through 250.70]. ▸ Figure 100–82

Grounding Electrode Conductor. The conductor used to connect the system neutral conductor or grounded-phase conductor, or the equipment, to the grounding electrode system. ▸ Figure 100–83

Guest Room. An accommodation combining living, sleeping, sanitary, and storage facilities. ▸ Figure 100–84

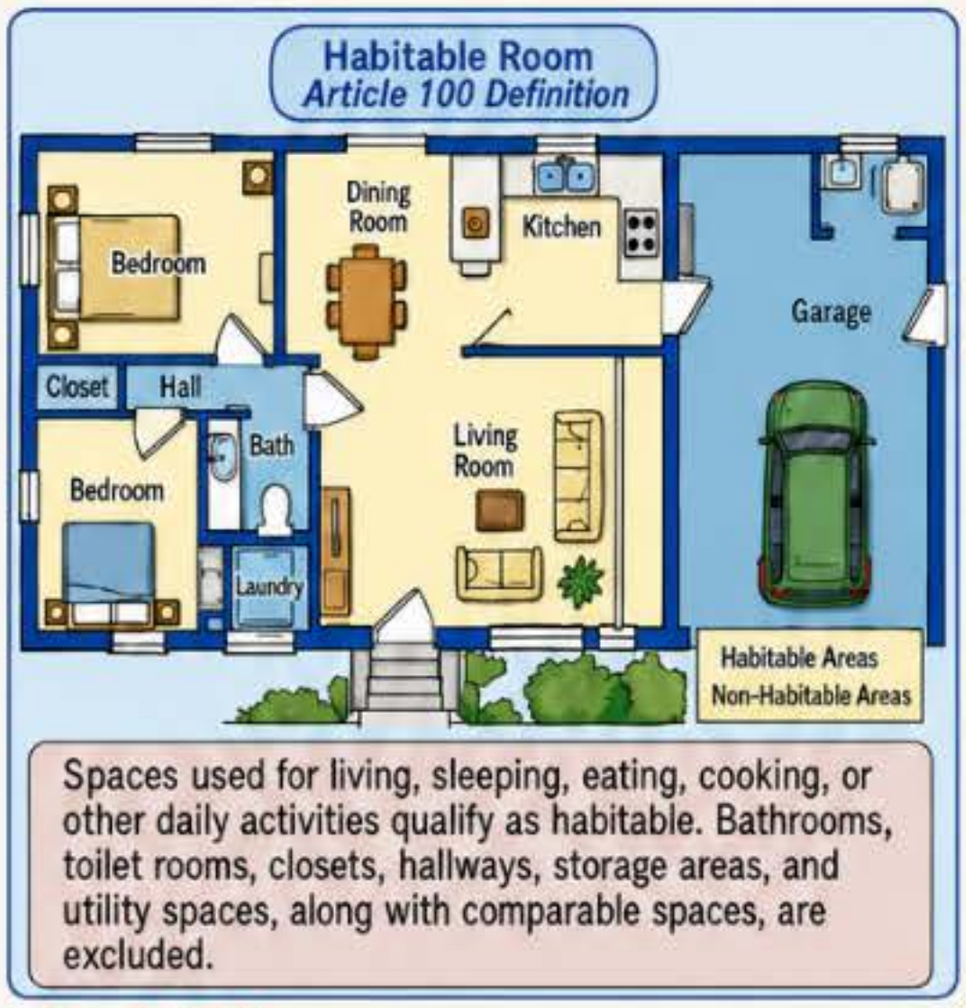


▸ Figure 100–83

▸ Figure 100–84

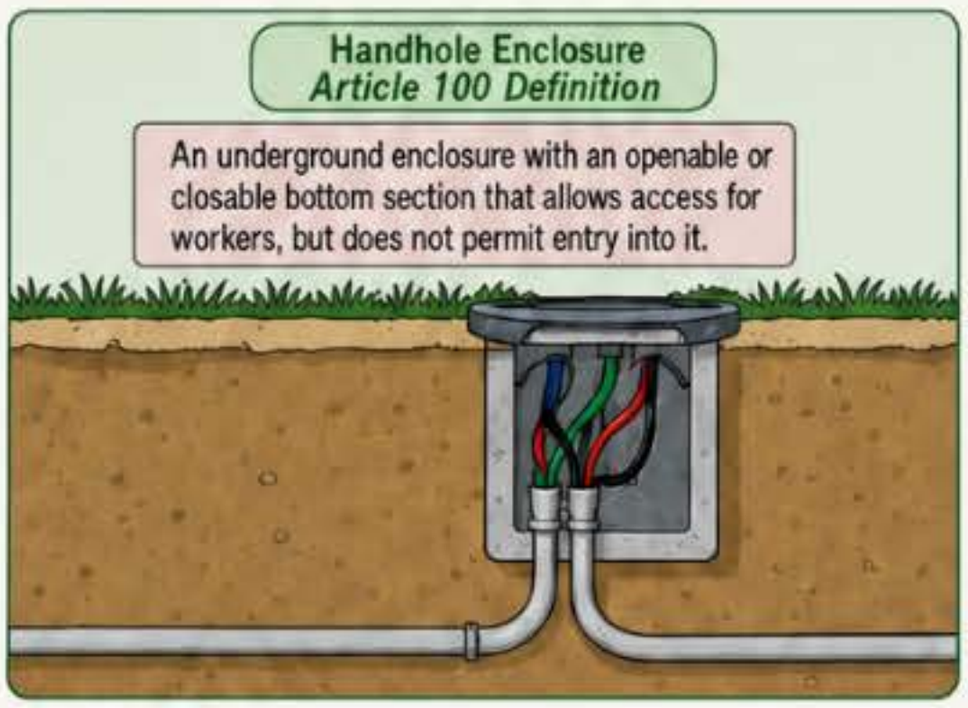
Guest Suite. A lodging area with two or more adjoining rooms—either within a single unit or separated by doors—that offers living, sleeping, sanitary, and storage facilities.

Habitable Room. A room intended for activities such as living, sleeping, eating, or cooking. Bathrooms, toilet rooms, closets, corridors, storage rooms, and utility spaces, along with similar spaces, are not included. • Figure 100–85



▶ Figure 100–85

Handhole Enclosure. An underground enclosure that has an open or closable bottom for allowing personnel entry, but not for entering the enclosure itself. • Figure 100–86



▶ Figure 100–86

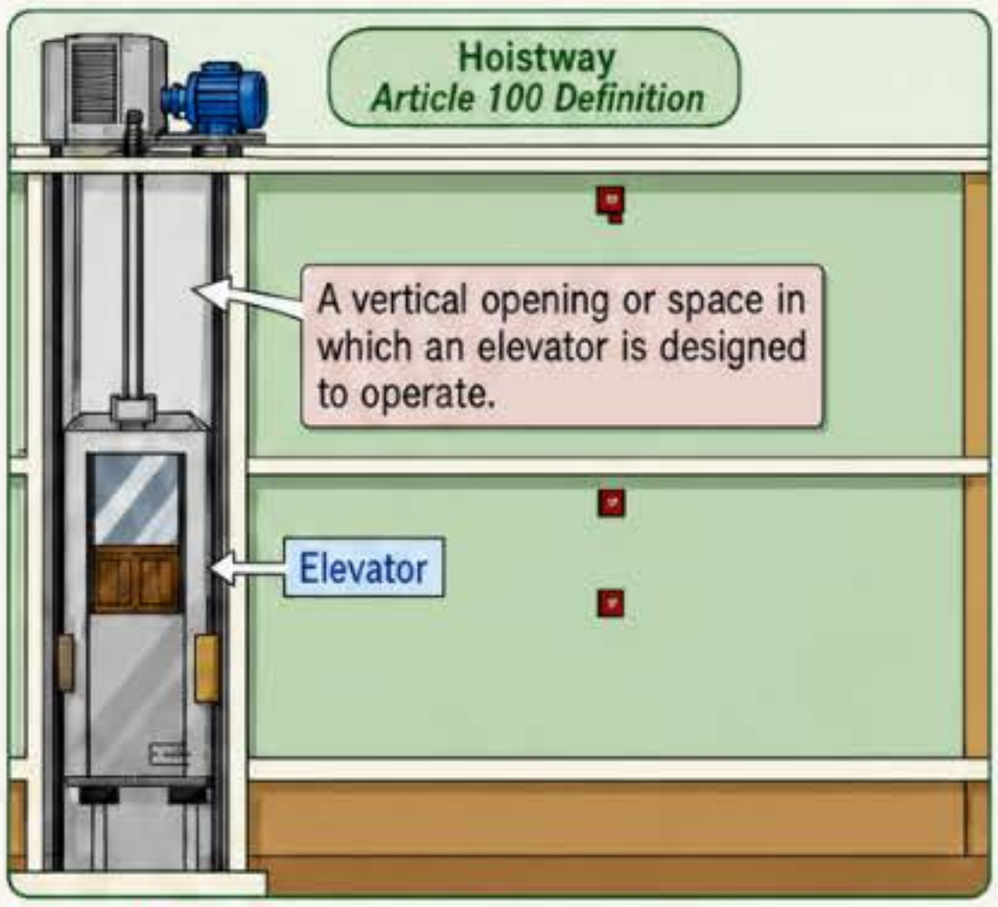
Author's Commentary:

▶ *Refer to 314.30 for the installation rules that apply to handhole enclosures.*

— Michael Hamilton

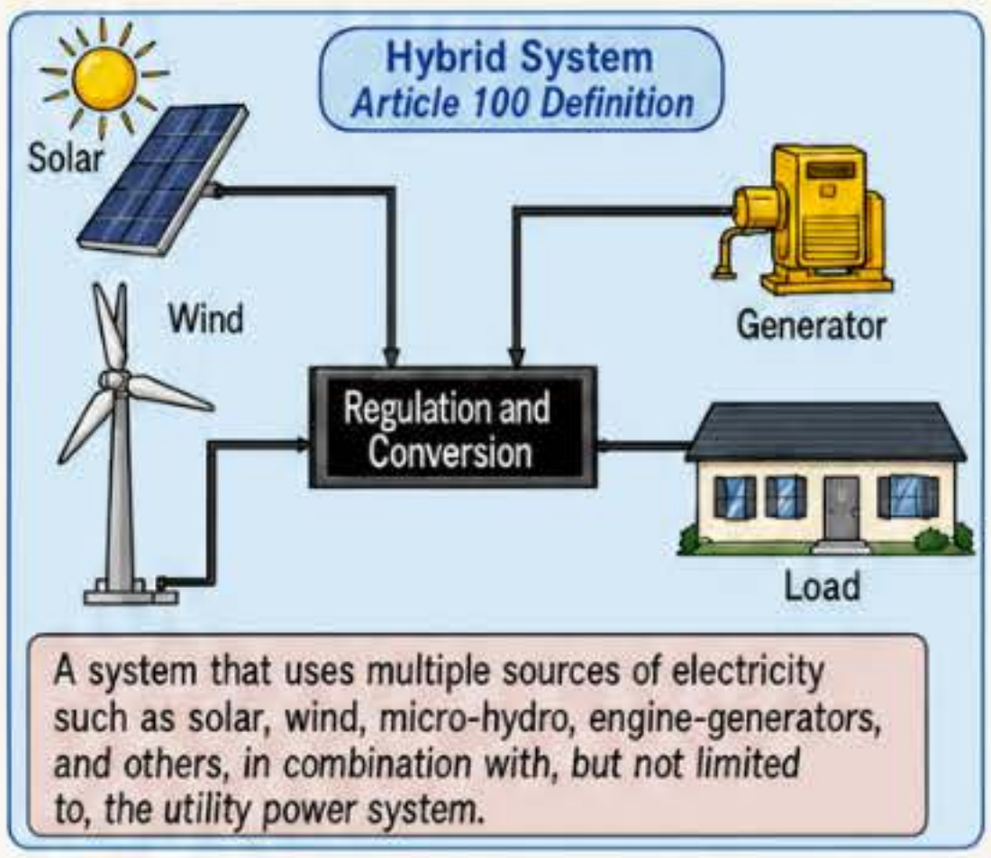
Hermetic Refrigerant Motor-Compressor. A compressor and motor contained within a single sealed housing and functioning together using refrigerant.

Hoistway. A vertical shaft or opening in which an elevator or dumbwaiter is intended to travel. • Figure 100–87



▶ Figure 100–87

Hybrid System. A setup that combines several electrical power sources—such as photovoltaic, wind, micro-hydro, engine-driven generators, and others—with, but not limited to, the electric utility power system. • Figure 100–88



▶ Figure 100–88

Identified (as applied to equipment). Recognized as appropriate for a specified purpose, function, use, environment, or application as described within a code requirement. • Figure 100–89

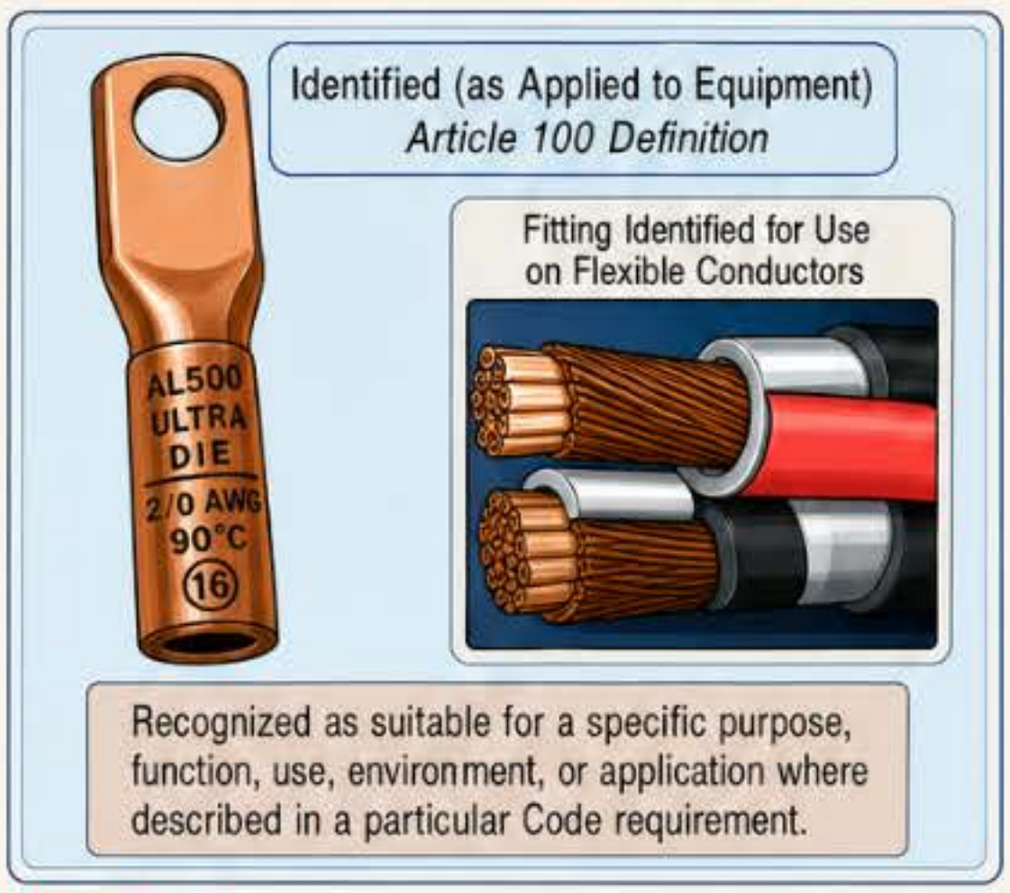


Figure 100–89

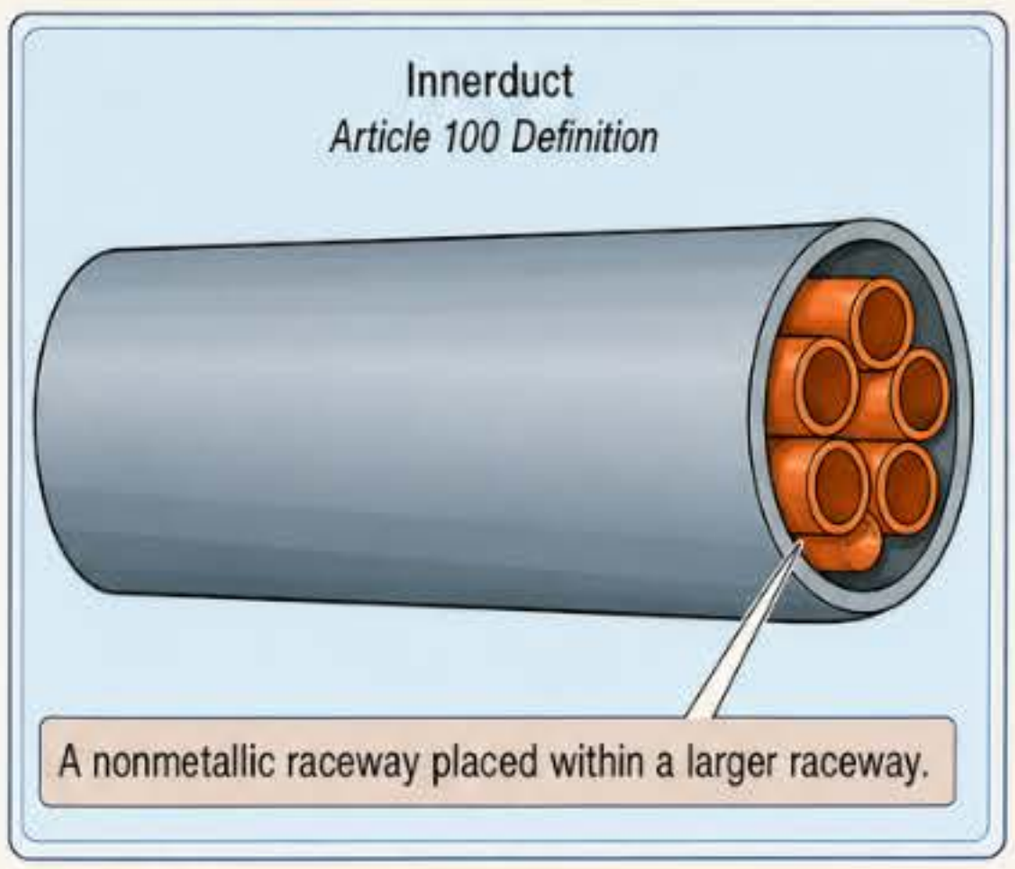


Figure 100–91

Author's Commentary:

- See 90.4, 90.7, and 110.3(A)(1) and the definitions for "Approved," "Labeled," and "Listed" in this article.

Information Technology Equipment (ITE). Equipment used for the creation and manipulation of data, voice, and video. It does not include communications equipment. Figure 100–90

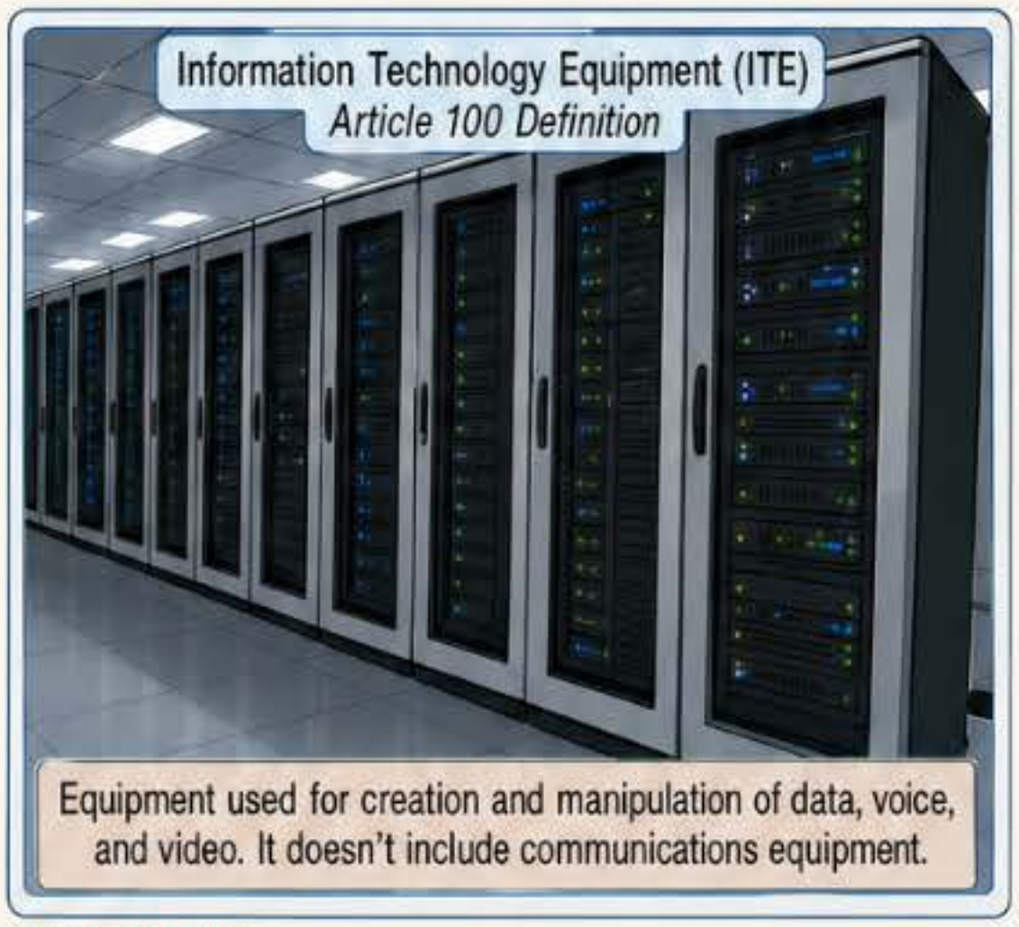


Figure 100–90

Innerduct. A nonmetallic raceway placed within a larger raceway. Figure 100–91

In Sight From (Within Sight From). Visible and not more than 50 ft away from the equipment. Figure 100–92

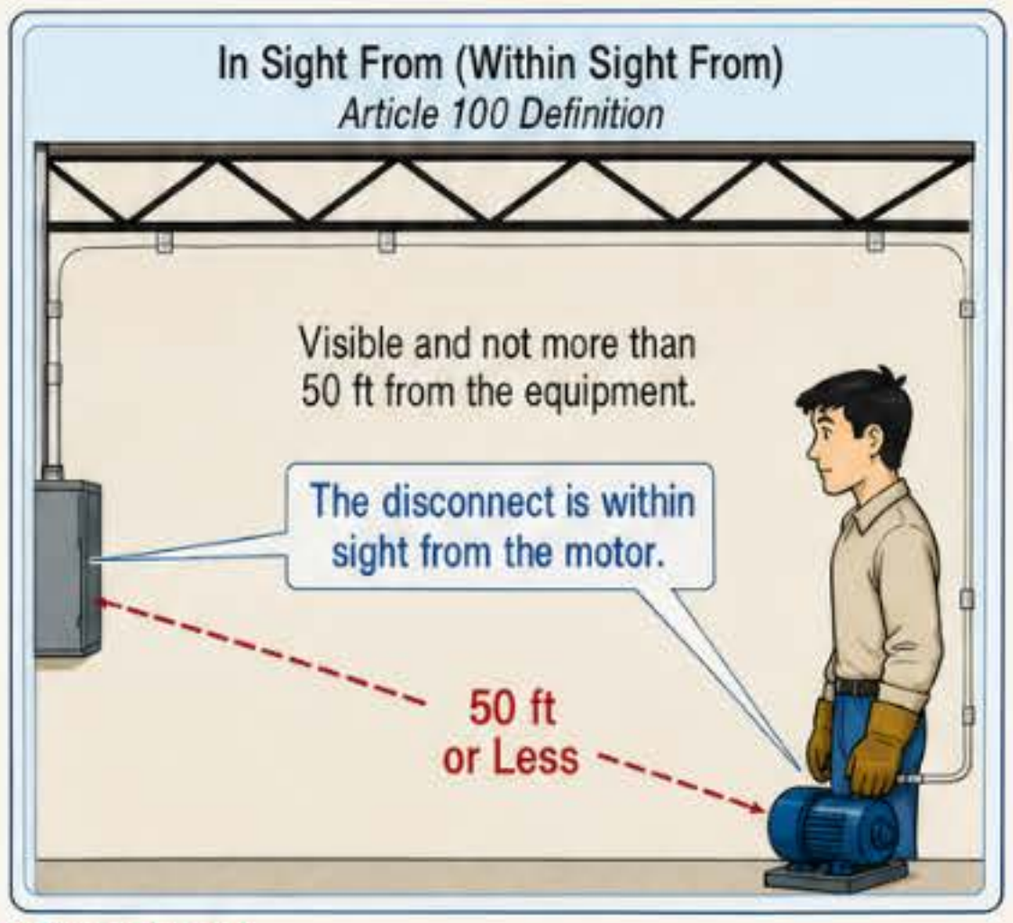


Figure 100–92

Interactive Inverter. An inverter intended to be used in parallel with a power source(s), such as the serving electric utility, to supply common loads and is capable of delivering power to the serving electric utility. Figure 100–93

Author's Commentary:

- A listed interactive inverter automatically stops exporting power upon loss of utility voltage and cannot be reconnected until the voltage has been restored. Interactive inverters can automatically or manually resume exporting power to the utility once the utility source is restored.

— *Michael Hamilton*

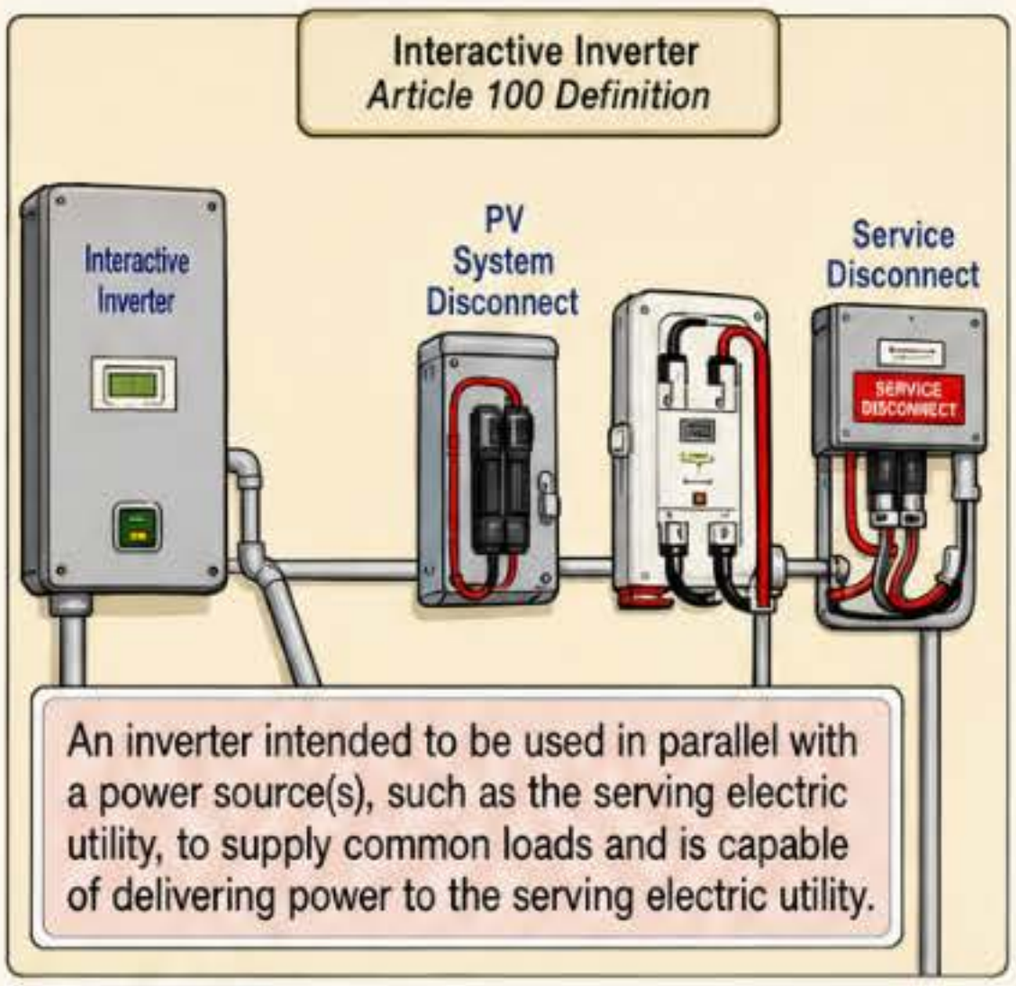


Figure 100–93

Interactive System. An electric power production system that operates in parallel with, and may deliver power to, the serving electric utility. ▶ Figure 100–94

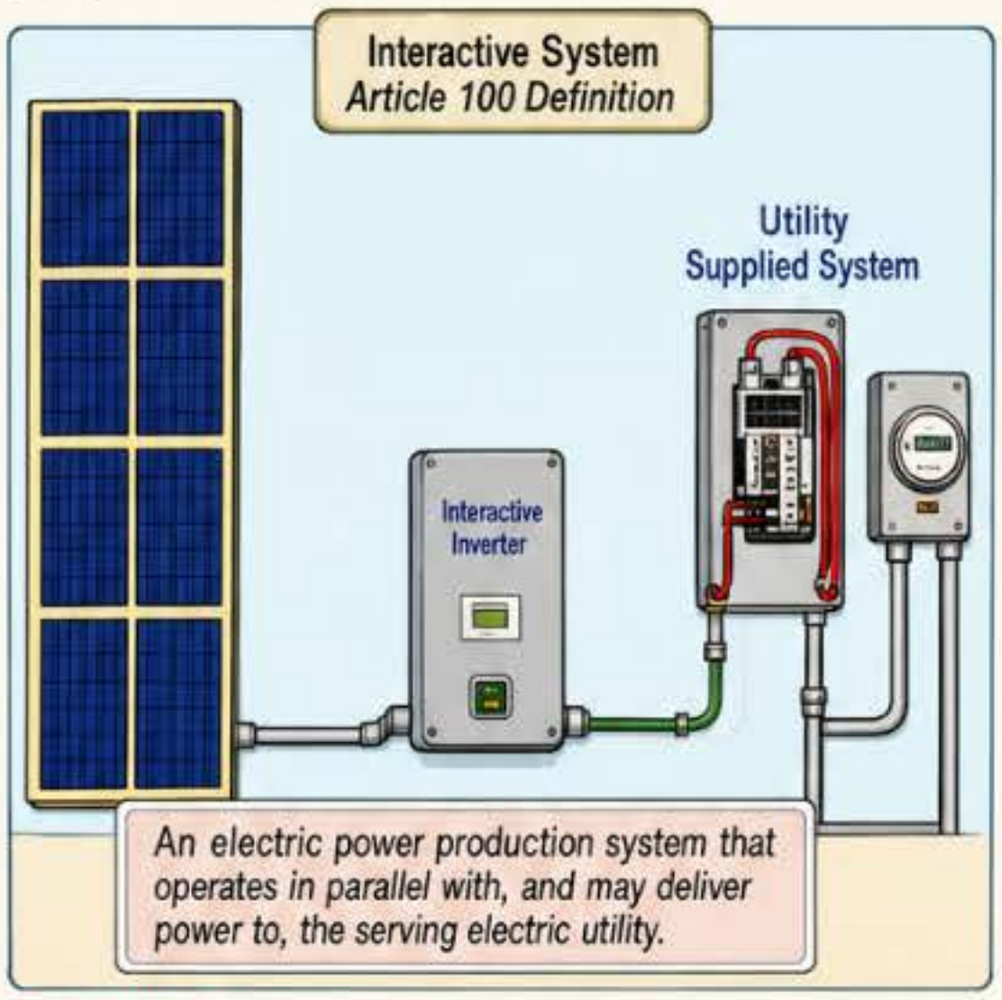


Figure 100–94

Interrupting Rating. The highest short-circuit current at rated voltage the device is identified to safely interrupt under standard test conditions.

Intersystem Bonding Termination. A device that provides a means to connect intersystem bonding conductors for communications systems (twisted wire, antennas, and coaxial cable) to the grounding electrode system, in accordance with 250.94. ▶ Figure 100–95

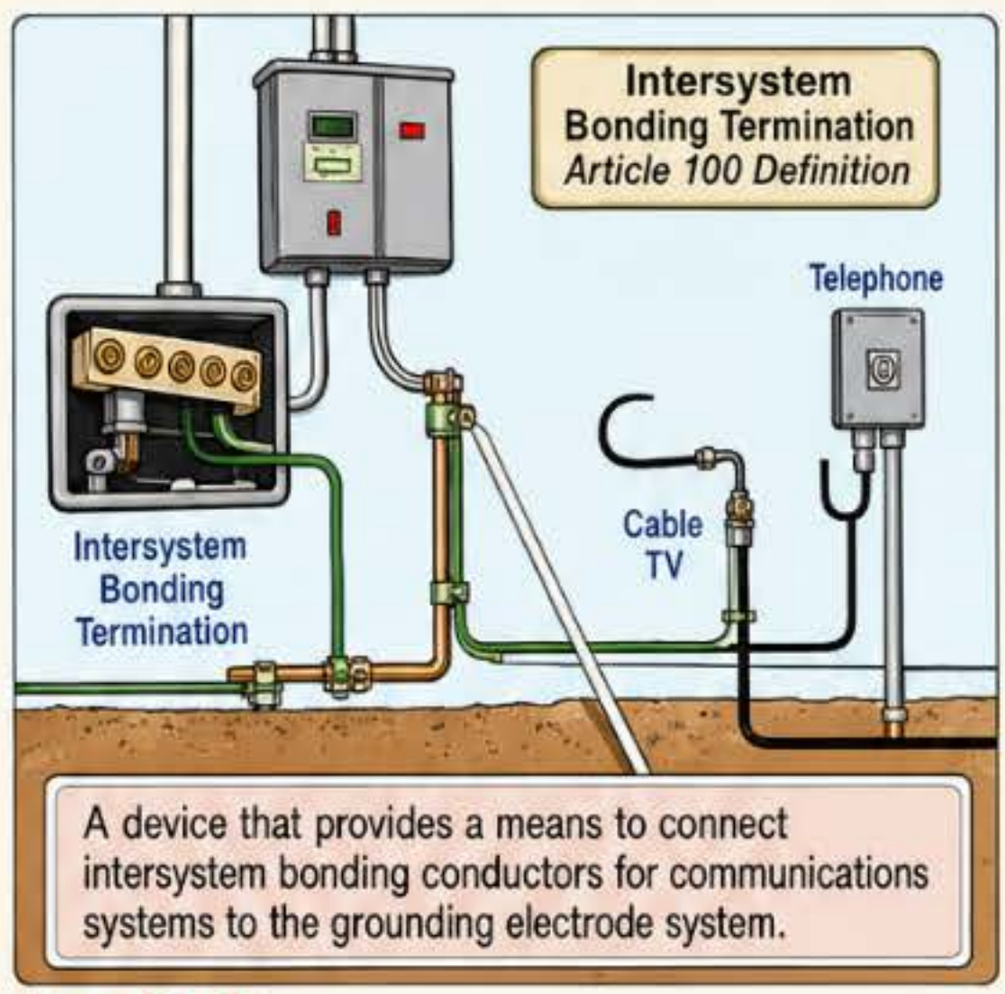


Figure 100–95

Author's Commentary:

- Overcurrent protective devices have two current ratings, "rated current" and "fault current." Rated current protects circuits under normal conditions and the rating is labeled on the handle of the circuit breaker. The fault current rating or "ampere interrupting capacity" (AIC) is the amount of current the device can safely handle during a ground fault or short circuit. Fault current ratings range up to the tens, or even hundreds, of thousands of amperes!
- For more information, see 110.9 in this textbook.

— *Michael Hamilton*

Inverter. Equipment that changes direct current to alternating current. ▶ Figure 100–96

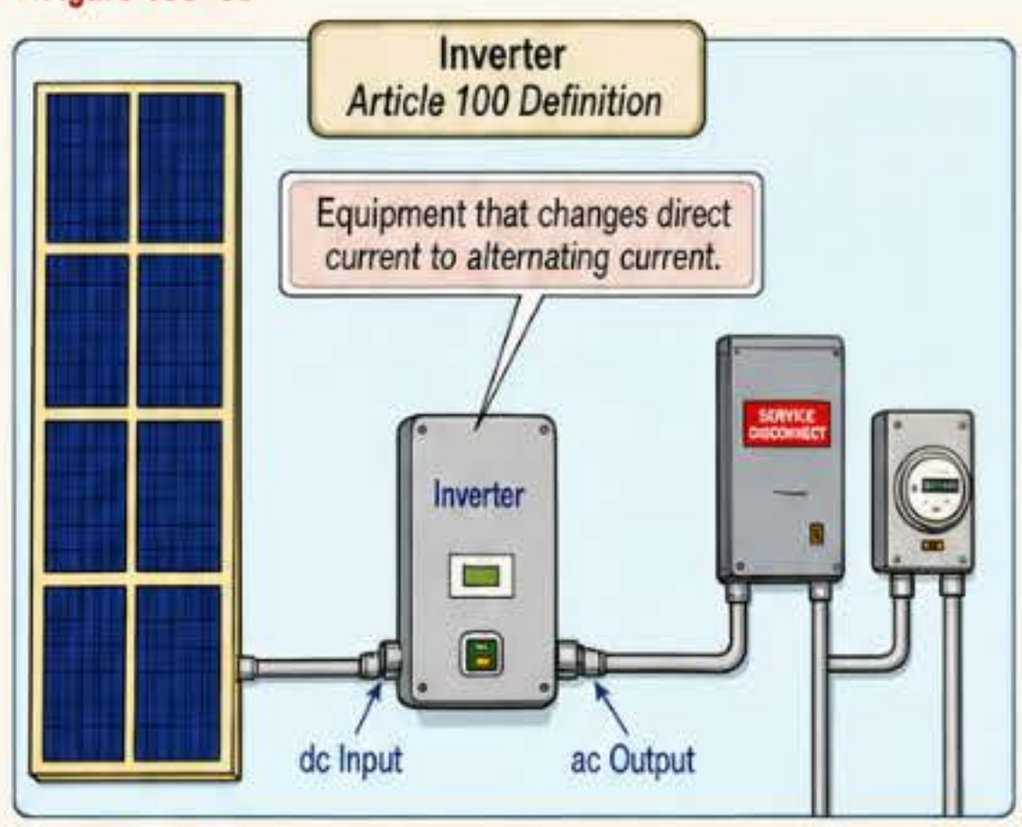
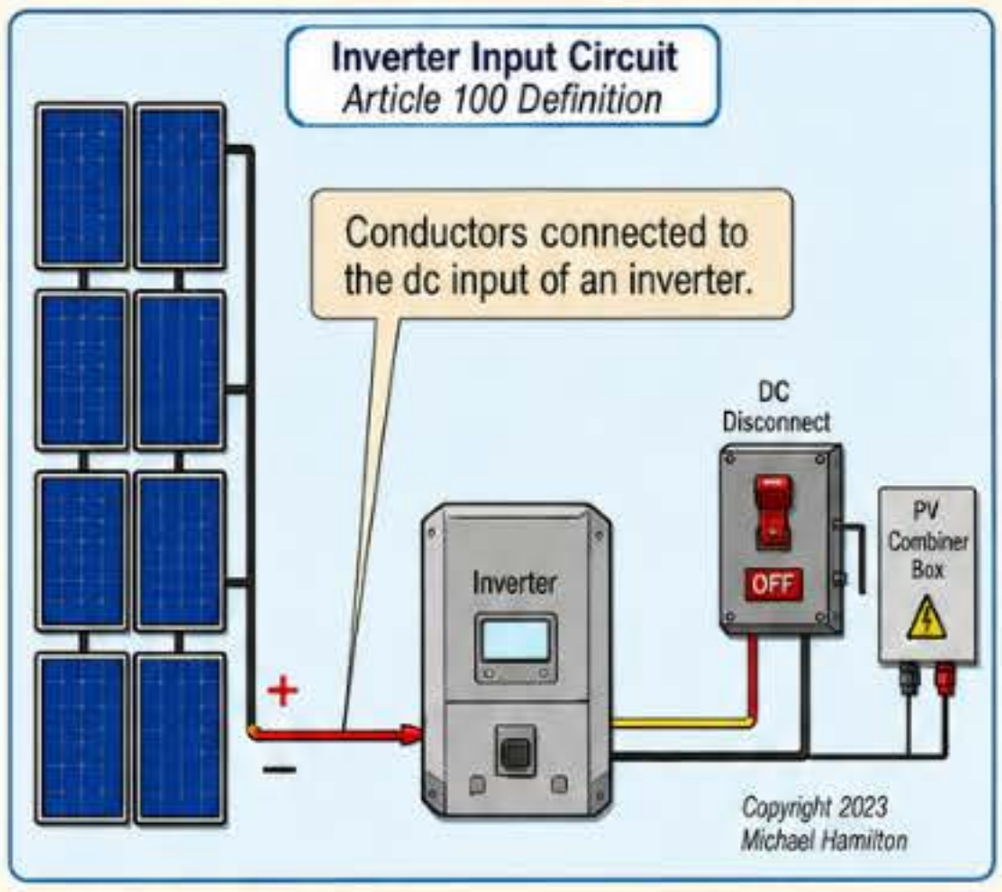


Figure 100–96

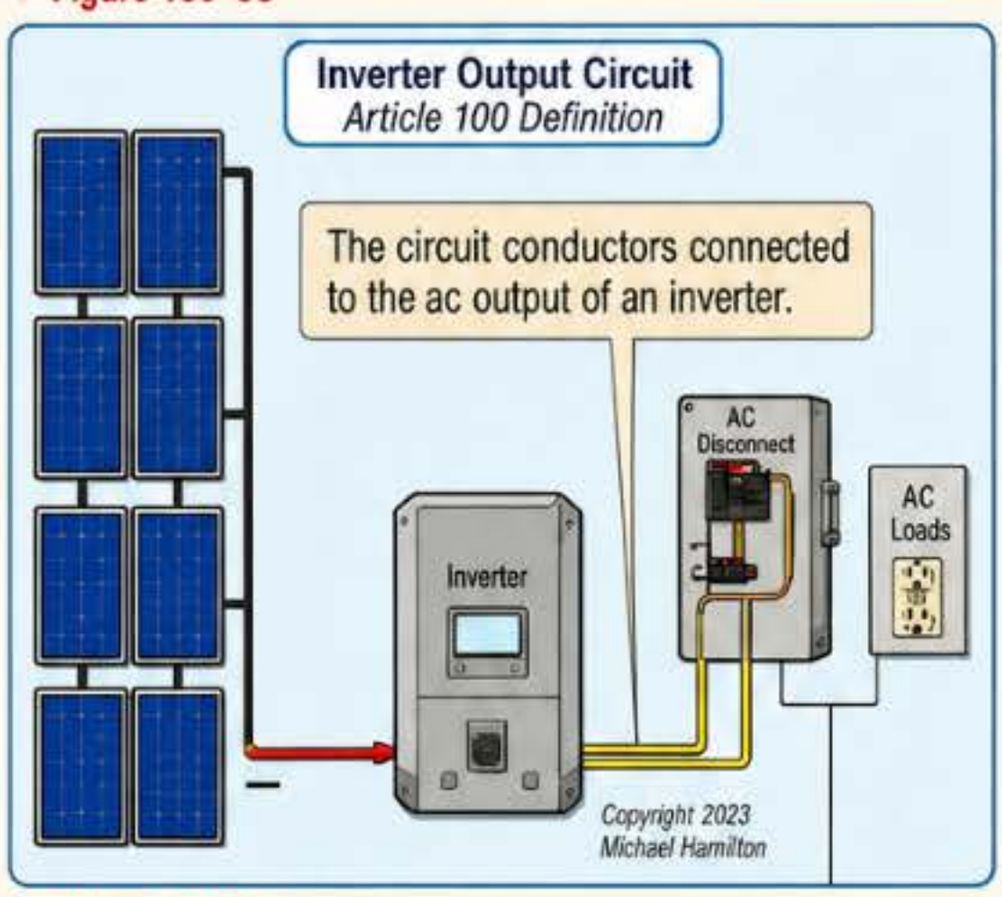
DEFINITIONS | From Michael Hamilton Publications

Inverter Input Circuit. The conductors that carry the direct-current power entering an inverter. ▶ Figure 100–97



▶ Figure 100–97

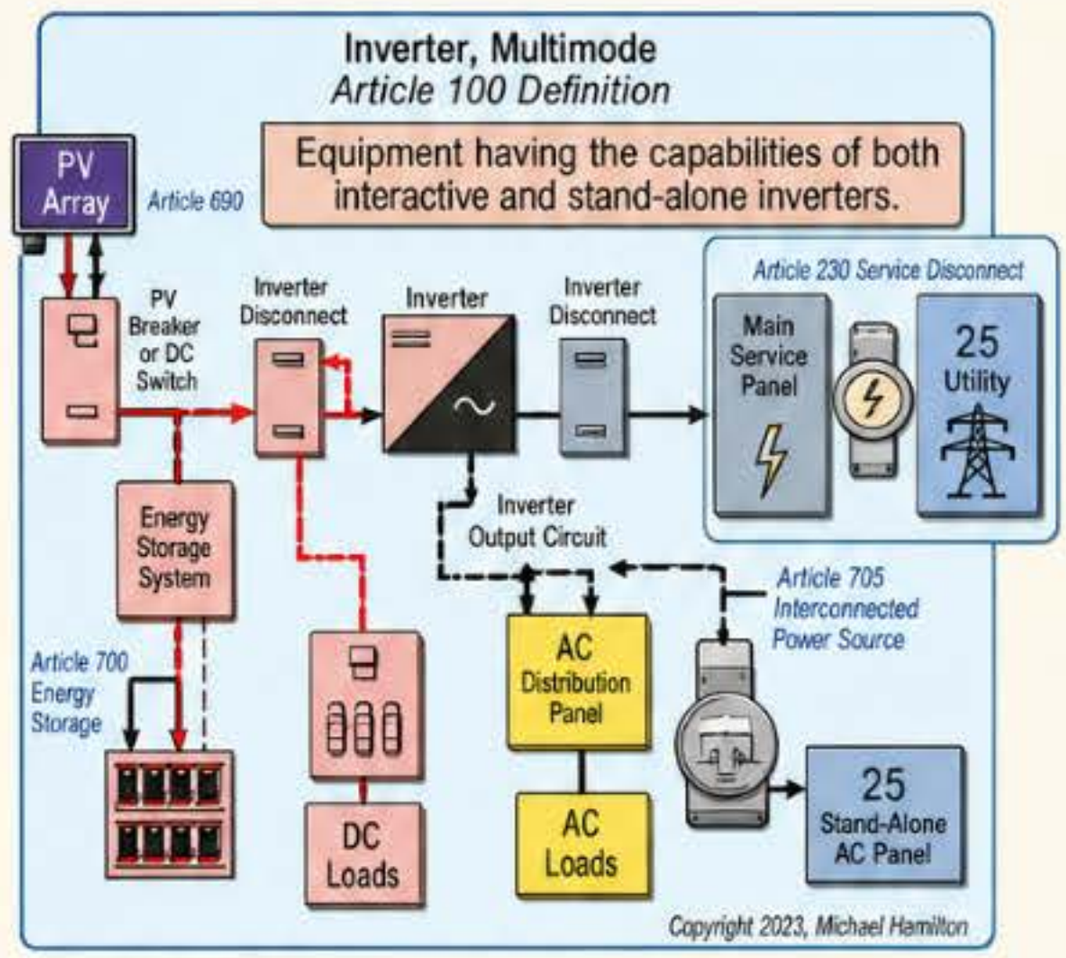
Inverter Output Circuit. The conductors that carry the alternating-current power delivered by an inverter. ▶ Figure 100–98



▶ Figure 100–98

Inverter, Multimode. Equipment that is capable of operating as both an interactive and a stand-alone inverter. ▶ Figure 100–99

Island Mode. The condition in which stand-alone power generation equipment—or a related microgrid—or both operate while completely separated from an electric power production and distribution network or from any other main power source.



▶ Figure 100–99

Isolated. Not easily reachable by people unless special tools or procedures are used to gain access.

Kitchen. A room that includes a sink and permanent fixtures for preparing and cooking food. ▶ Figure 100–100

▶ Figure 100–100

Author's Commentary:

▶ *Spaces such as employee break rooms that have a sink and a cord-and-plug-connected cooking appliance—like a microwave oven—are not classified as kitchens.*

— Michael Hamilton

Labeled. Items of equipment or materials that bear a label, symbol, or other identifying mark—such as a sticker, decal, printed tag, or a mark molded into or stamped on the product—are considered by a recognized testing laboratory to be acceptable for use by the authority having jurisdiction.
▶ Figure 100–101

▶ Figure 100–101

> ***Author's Commentary:***
> *Providing labels and listing information on equipment is typically the starting point for gaining approval from the authority that has jurisdiction over the installation.*
> ***— Michael Hamilton***

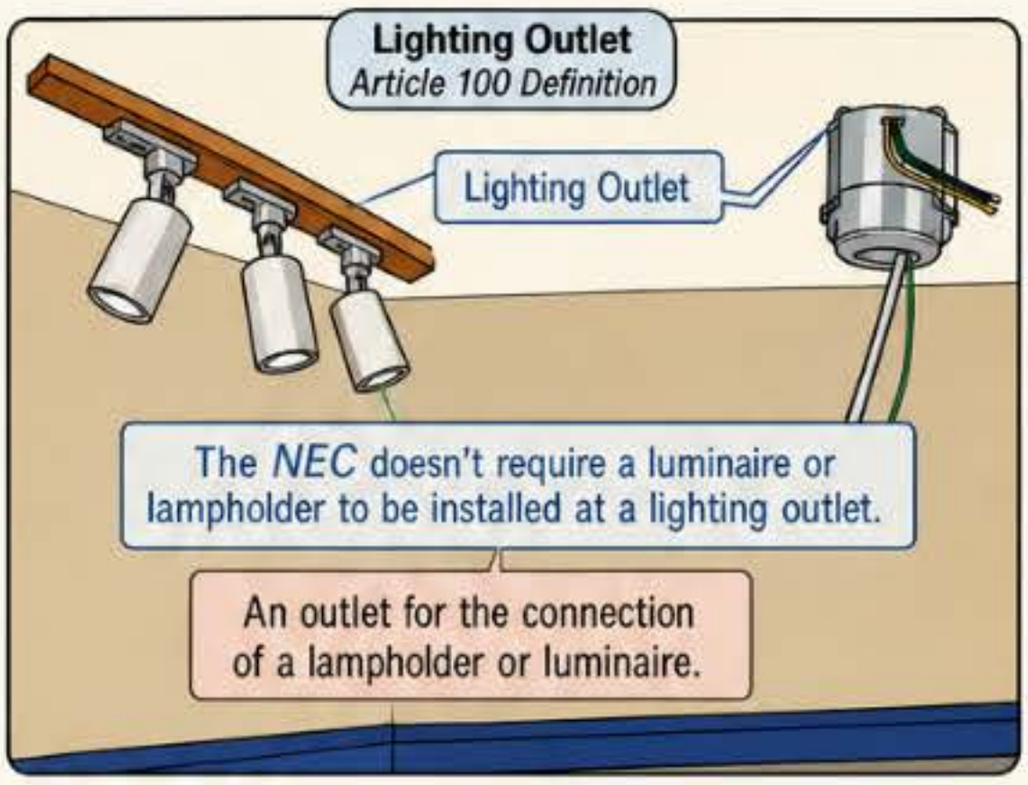
Note: If a listed product is so small or shaped—or has a surface texture—that a full label cannot be attached in a readable or lasting way, the label may be placed on the smallest individual unit container or on the packaging in which it is shipped.

Laundry Area. *A space (or one item intended for that use) that includes a laundry tray, clothes washer, or clothes dryer.*
▶ Figure 100–102

> ***Author's Commentary:***
> *A "laundry tray" refers to a fixed utility or clothes-washing sink. These sinks are usually set near the washer and dryer. By code, a laundry area includes any installation—or even a single appliance—intended for washing or drying clothes.*
> ***— Michael Hamilton***

Lighting Outlet. *A point of connection intended to supply power to a luminaire.* ▶ Figure 100–103

▶ Figure 100–102



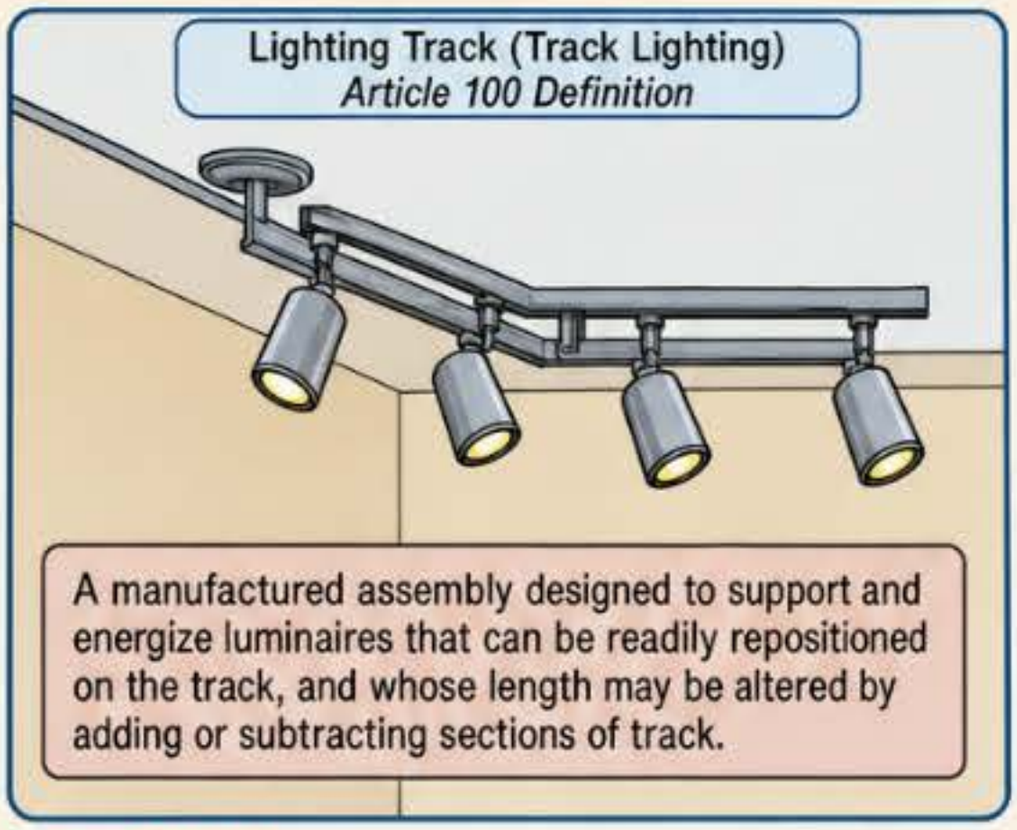
▶ Figure 100–103

Lighting Track (Track Lighting). *A manufactured assembly created to support and energize luminaires that can be easily repositioned along the track. The length of the track may be modified by adding or removing sections.* ▶ Figure 100–104

Listed. *Equipment or materials that appear in a list issued by a recognized testing laboratory and are acceptable to the authority having jurisdiction. The listing organization must inspect production periodically to verify that the equipment or material continues to meet the design standards that apply to its intended use.*

Note: Examples of nationally recognized testing laboratories (NRTLs) are Underwriters Laboratories (UL) and Canadian Standards Association (CSA). Both operate in the United States and Canada. Most electrical equipment carries the mark of one (or both) agencies. *Always check for a seal or marking, and do not accept any item showing signs of alteration or fraud.*

DEFINITIONS | From Michael Hamilton Publications



▶Figure 100–104

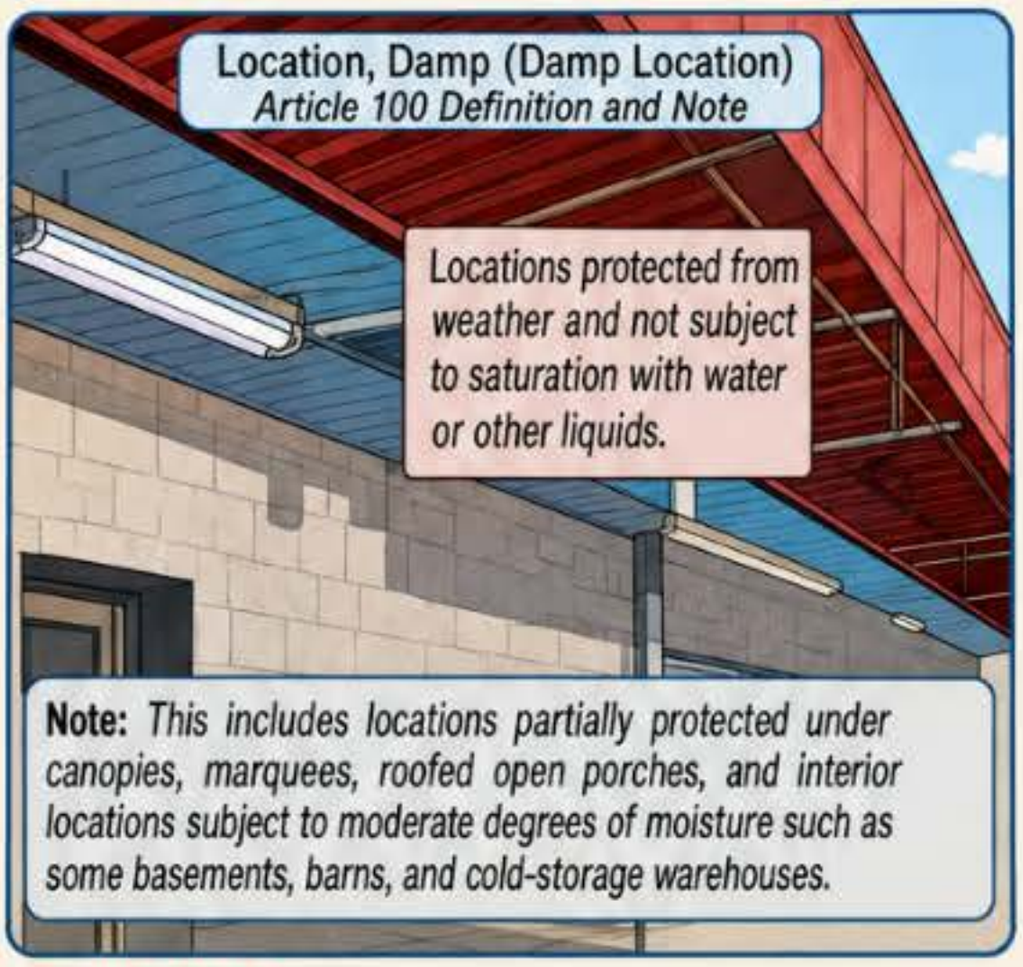
Author's Commentary:

The NEC does not require all electrical equipment to be listed, but some Code requirements do specifically call for product listing. Organizations such as OSHA are increasingly requiring listed equipment to be used when such equipment is available [90.7, 110.2, and 110.3].

— Michael Hamilton

Location, Damp (Damp Location). *Locations protected from weather and not subject to saturation with water or other liquids.*

▶Figure 100–105



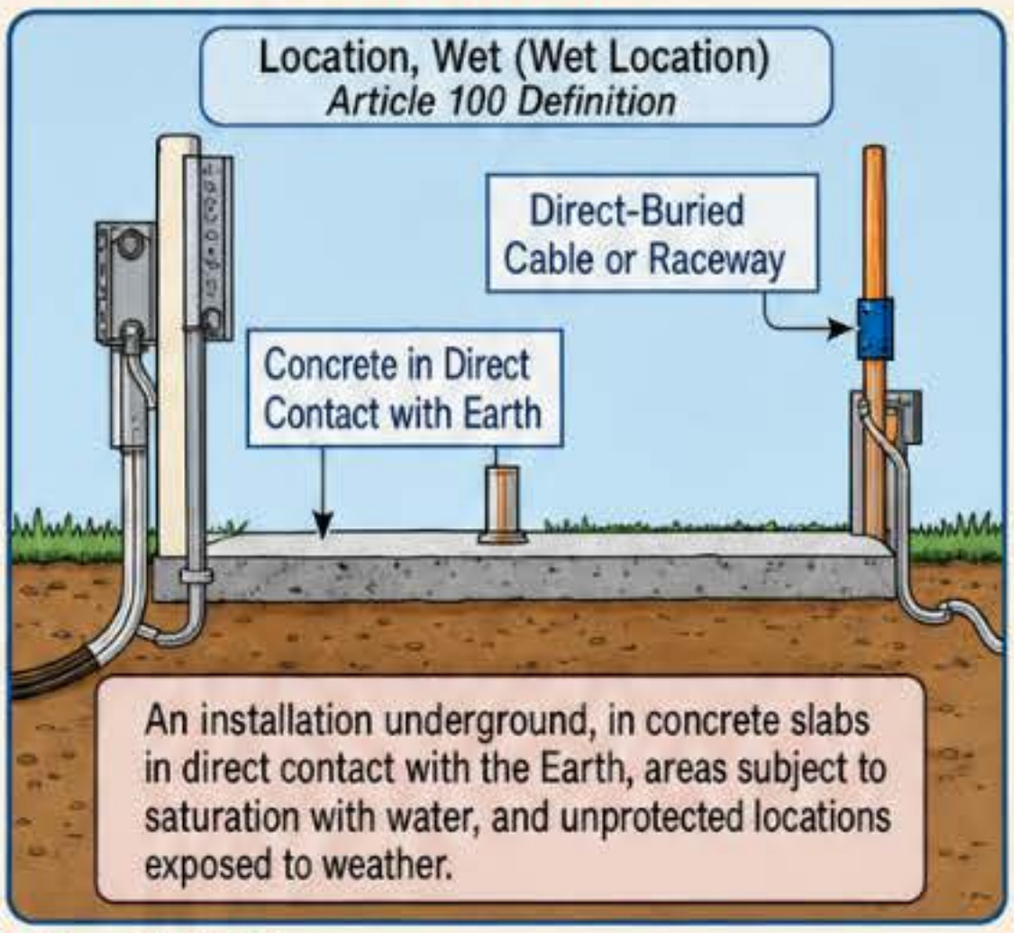
▶Figure 100–105

Note: This includes locations partially protected under canopies, marquees, roofed open porches, and interior locations subject to moderate degrees of moisture such as some basements, barns, and cold-storage warehouses.

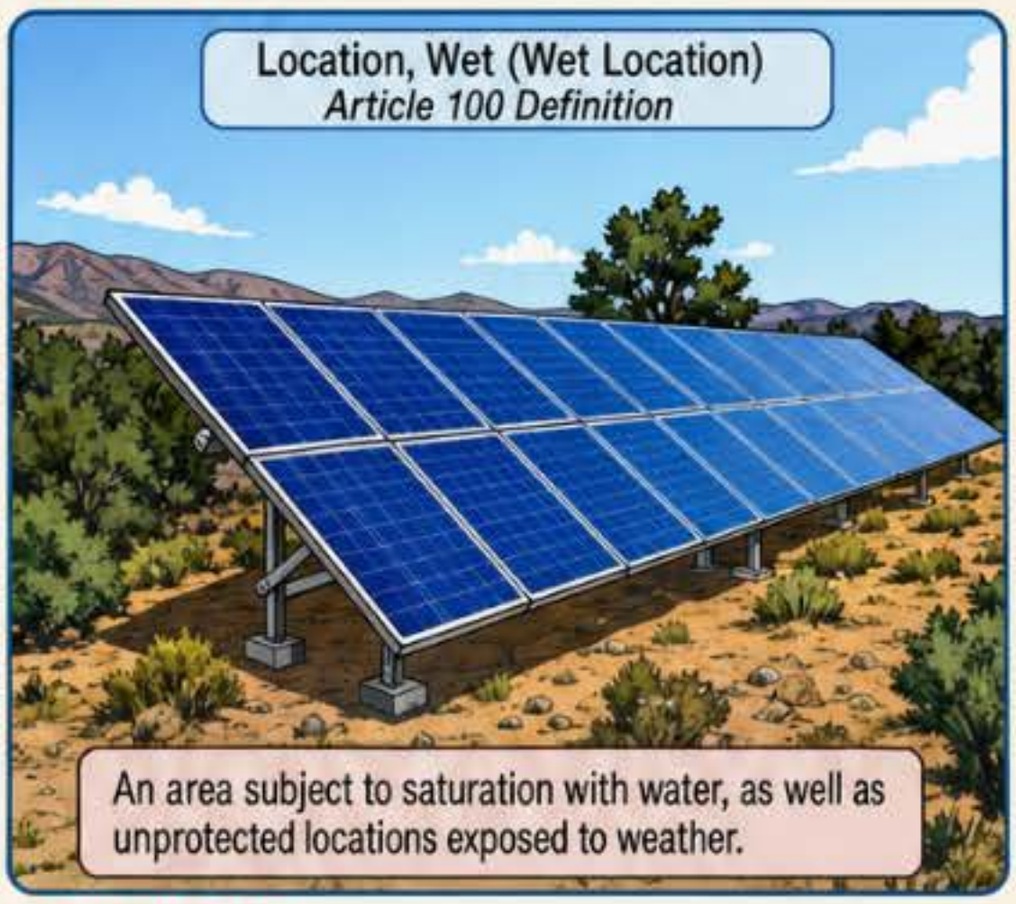
Location, Dry (Dry Location). An area not normally subjected to dampness or wetness, but which may temporarily be subjected to dampness or wetness, such as a building under construction.

Location, Wet (Wet Location). An installation underground, in concrete slabs in direct contact with the Earth, areas subject to saturation with water, and unprotected locations exposed to weather.

▶Figure 100–106 and ▶Figure 100–107



▶Figure 100–106

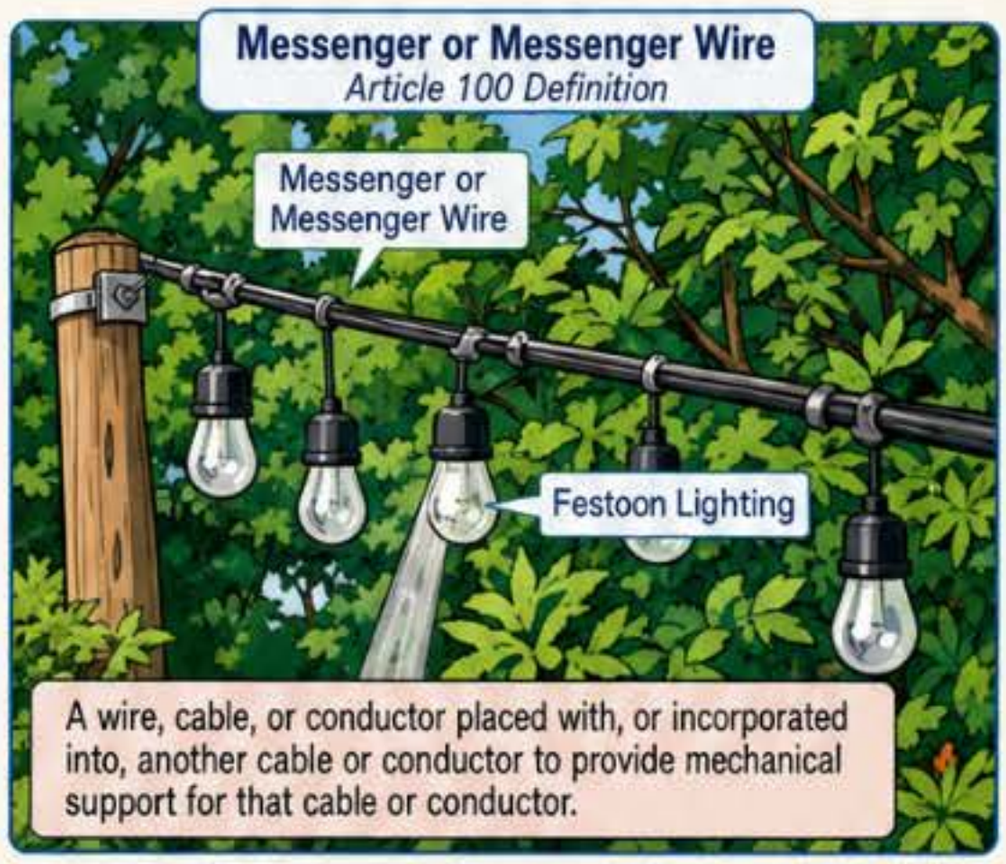


▶Figure 100–107

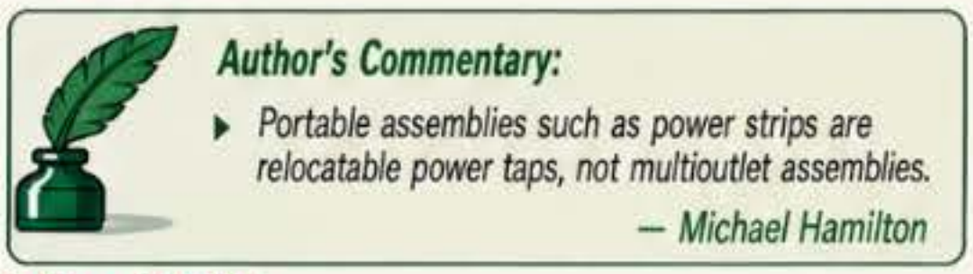
Luminaire. An assembly that provides illumination. It combines a lamp or light source with components that position the light, attach the unit to the power supply, and may also include elements that shield or distribute the light. Figure 100–108

▸ Figure 100–108

Messenger or Messenger Wire. A tension-supporting wire, cable, or conductor that is installed alongside or built into another cable or conductor to supply mechanical support for it. Figure 100–109



▸ Figure 100–109

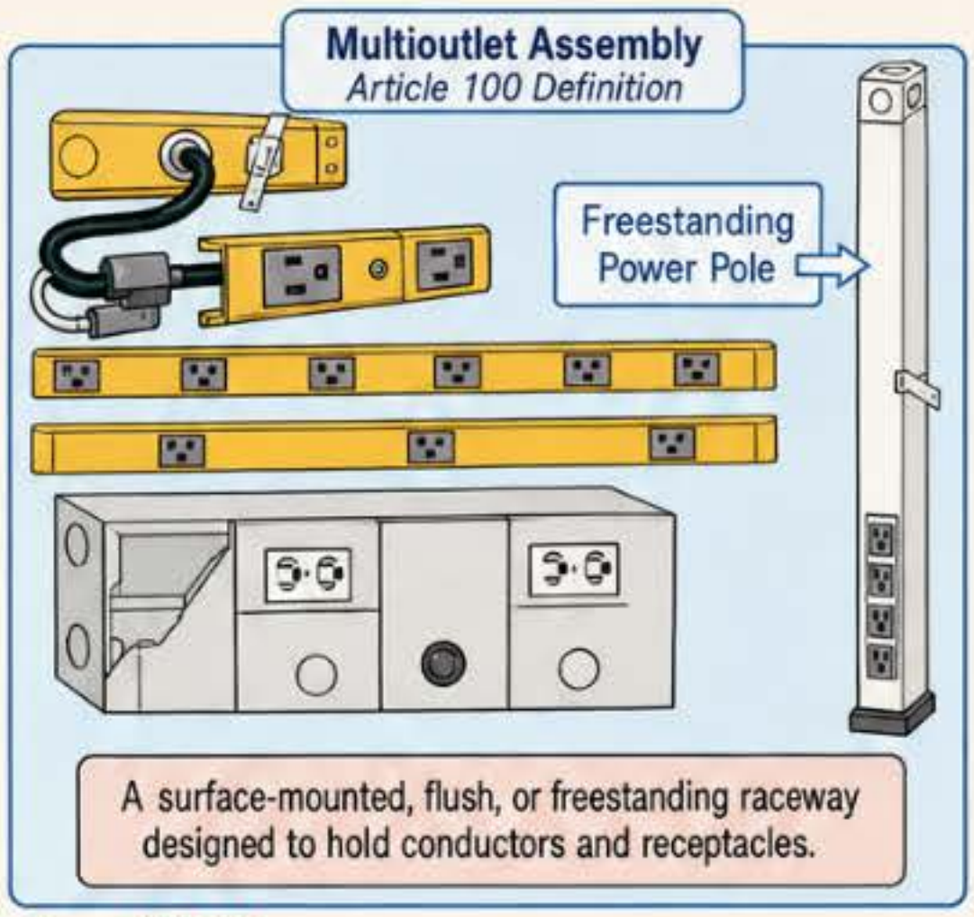


Author's Commentary:

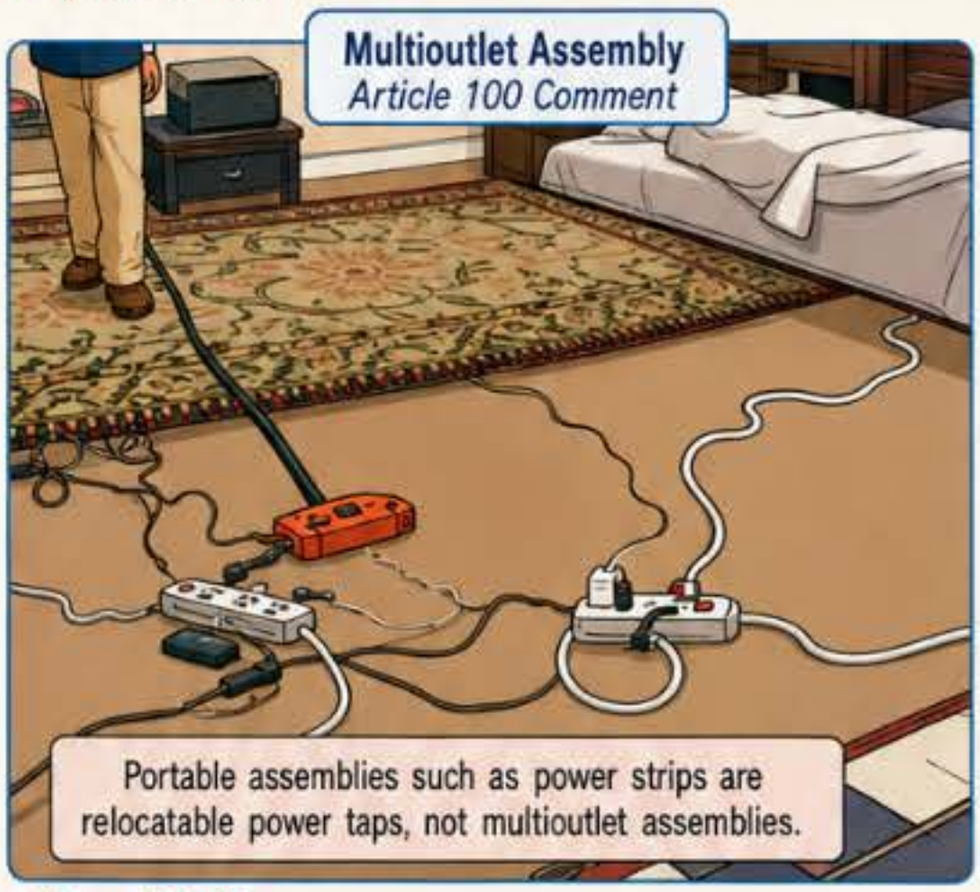
▸ *Portable assemblies such as power strips are relocatable power taps, not multioutlet assemblies.*

— Michael Hamilton

▸ Figure 100–111



▸ Figure 100–110



▸ Figure 100–111

Neutral Conductor. The conductor joined to the neutral point of a system that is meant to carry current under usual operating conditions. Figure 100–112

Neutral Point. The common junction in a 4-wire, 3-phase, wye-connected system; the midpoint in a 3-wire, single-phase system; or the midpoint of the single-phase portion in a 3-phase, delta-connected system. Figure 100–113

Nonautomatic. *Requiring human action to perform a function.* Figure 100–114

Nonlinear Load. *A load where the current waveform does not match the shape of the applied sinusoidal voltage waveform.* Figure 100–114

DEFINITIONS | From Michael Hamilton Publications

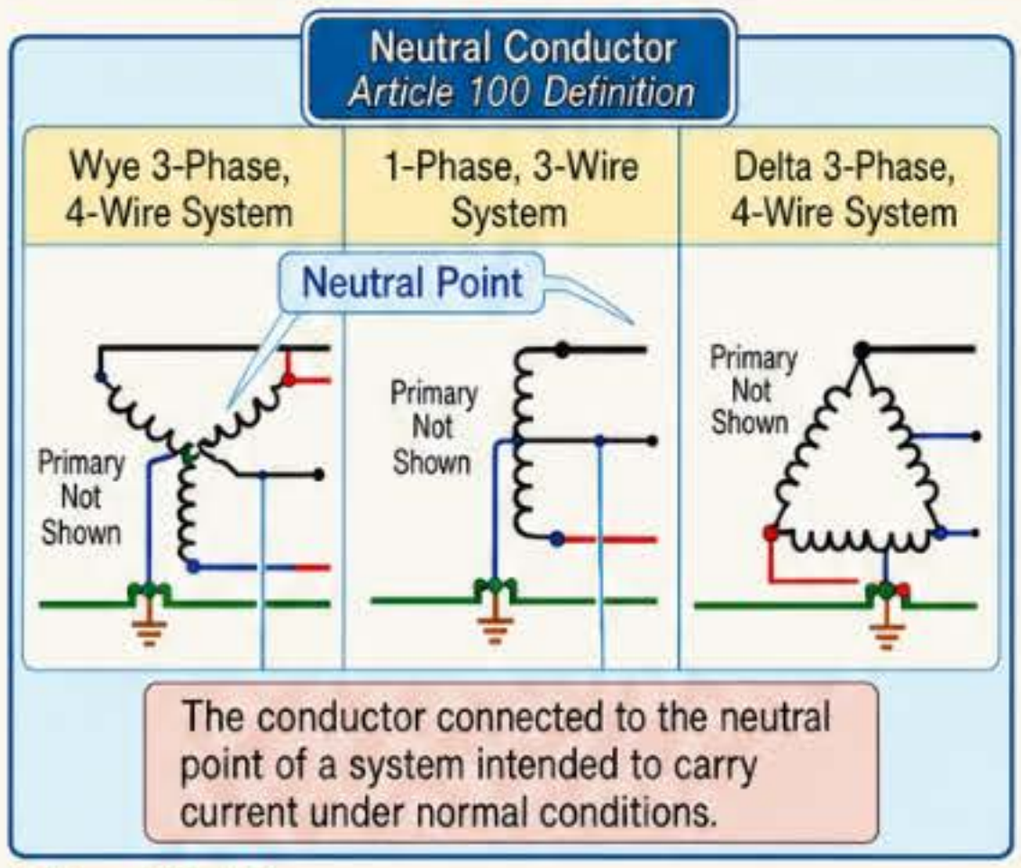


Figure 100–112

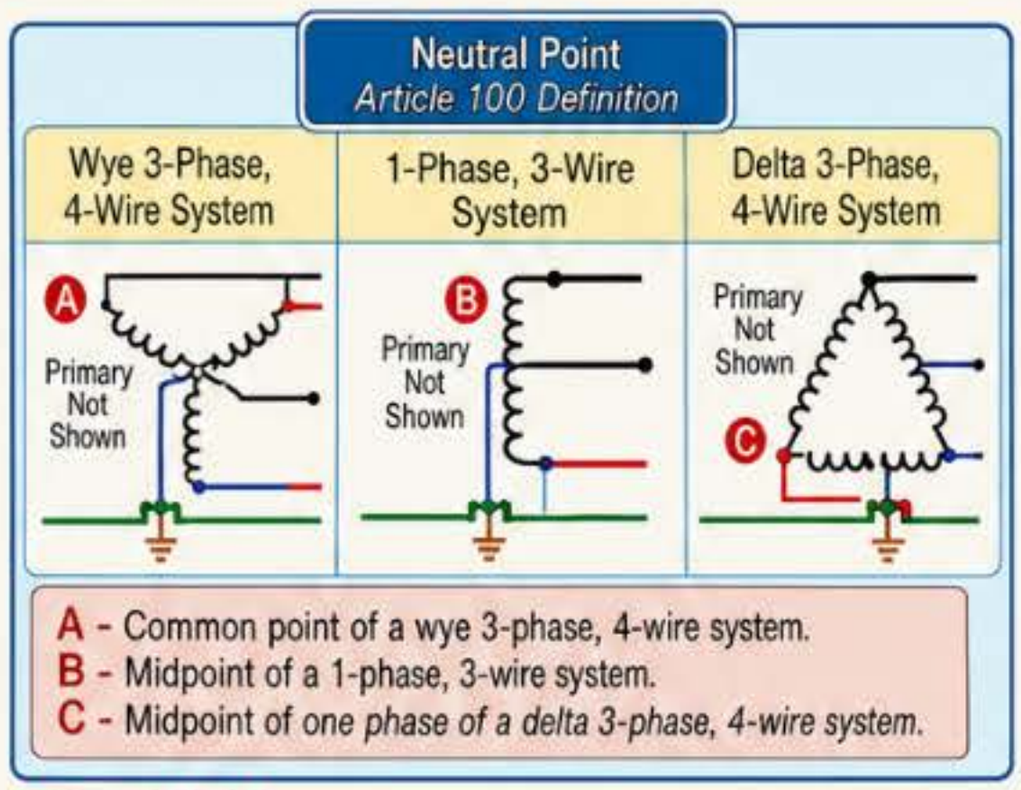


Figure 100–113

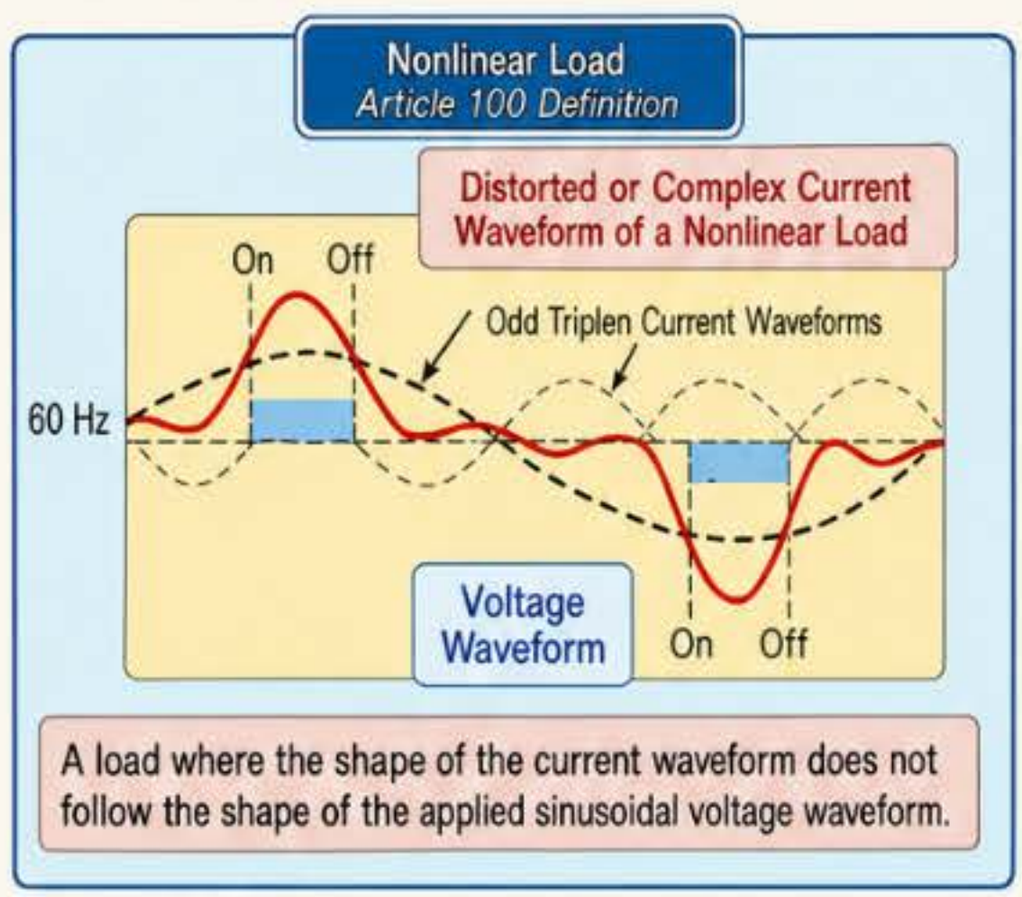


Figure 100–114

Note: Single-phase nonlinear loads include electronic equipment such as copy machines, laser printers, and electric-discharge lighting. Three-phase nonlinear loads include uninterruptible power supplies, induction motors, and electronic switching devices such as adjustable-speed drive systems. Figure 100–115

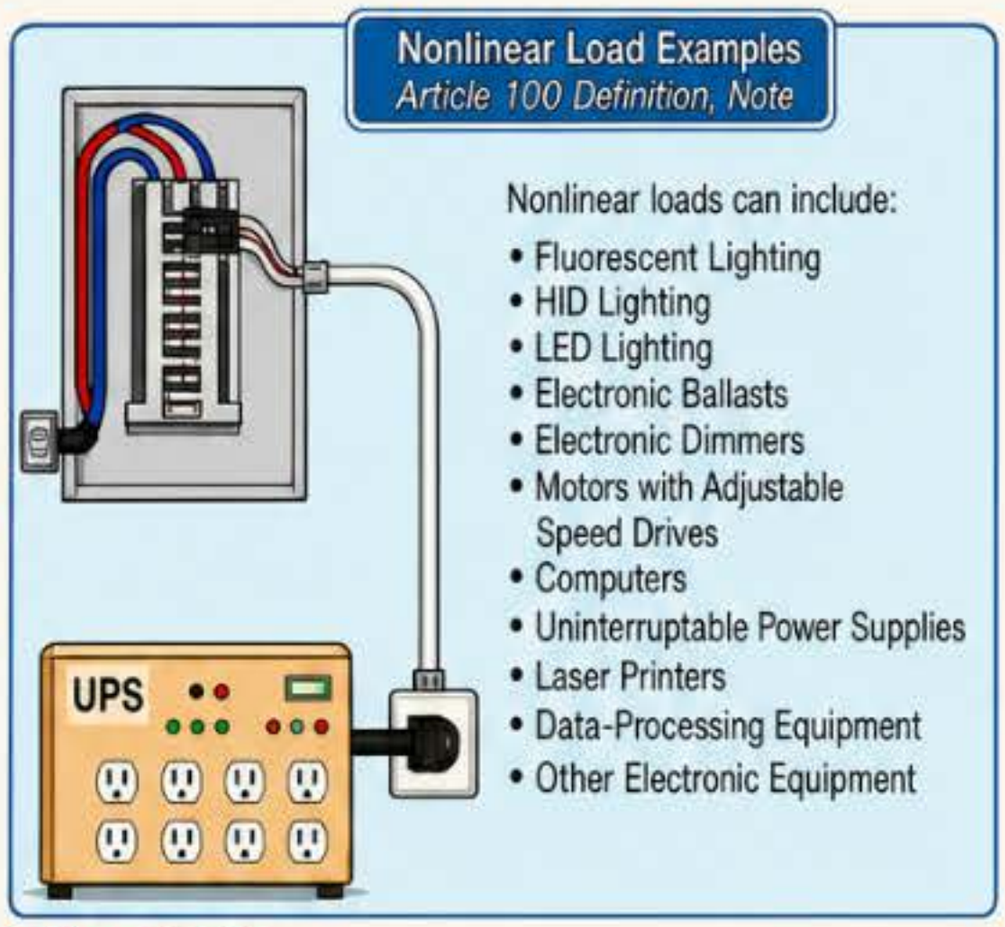


Figure 100–115

Author's Commentary:

The subject of nonlinear loads is beyond the scope of this textbook. For more in-depth information on this topic, consult the "Technical" link on the "Power Quality" page.

— Michael Hamilton

Outlet. A point in the wiring system where electricity is made available to supply utilization equipment. Figure 100–116

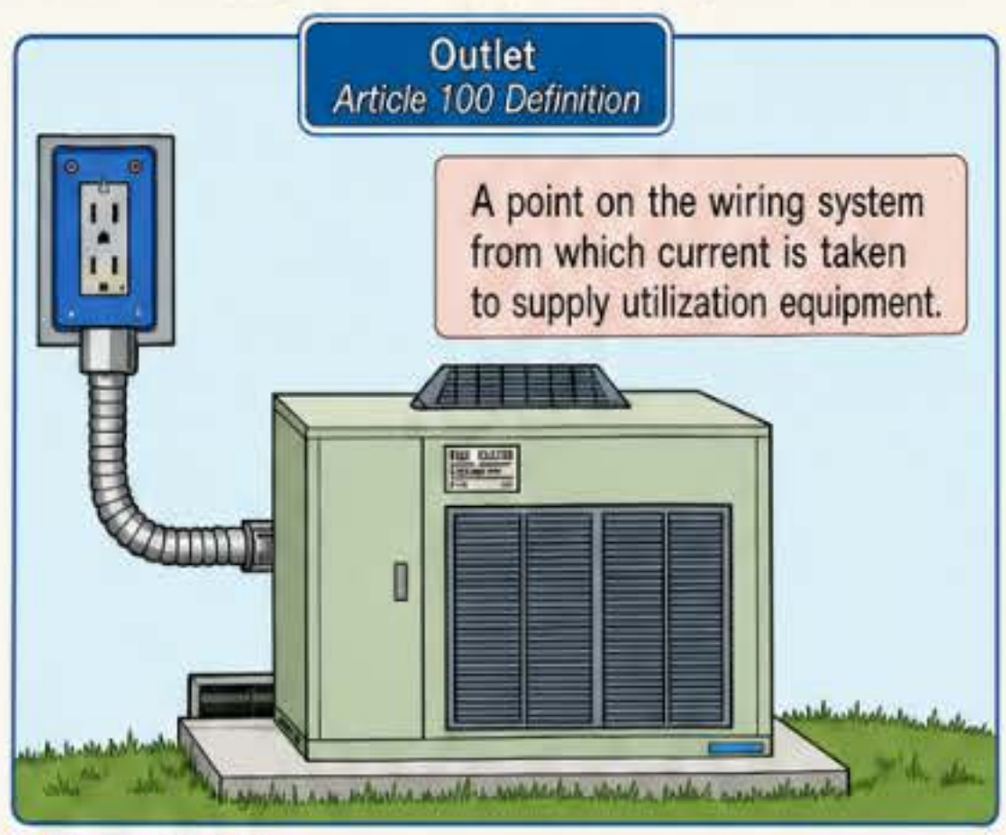
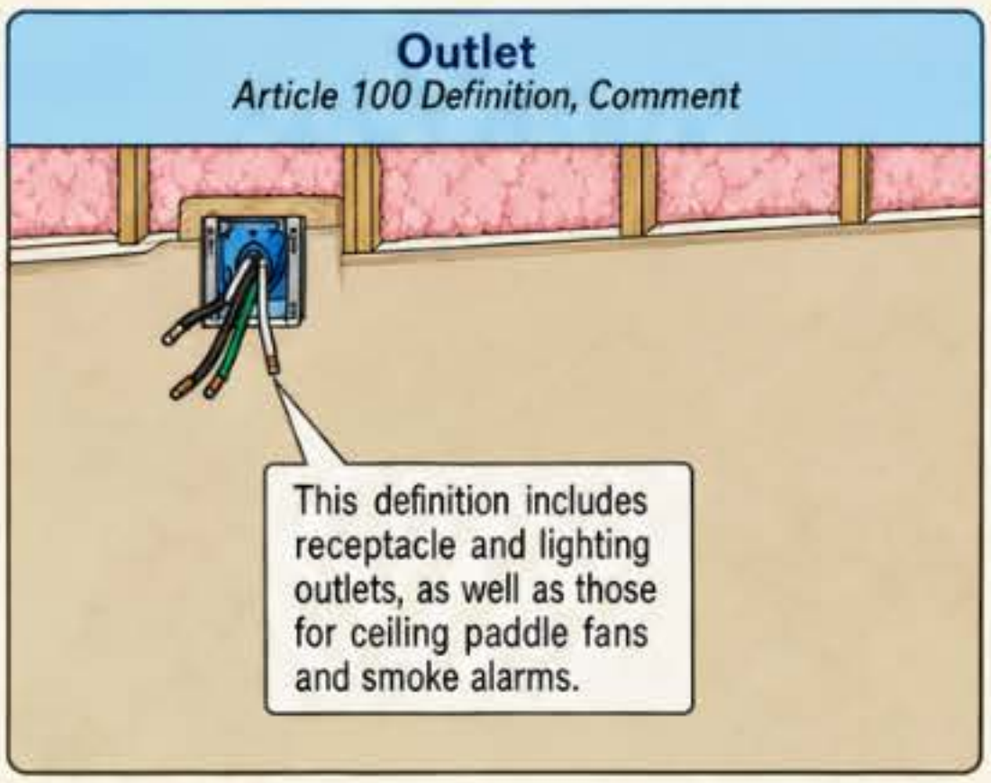


Figure 100–116

Author's Commentary:

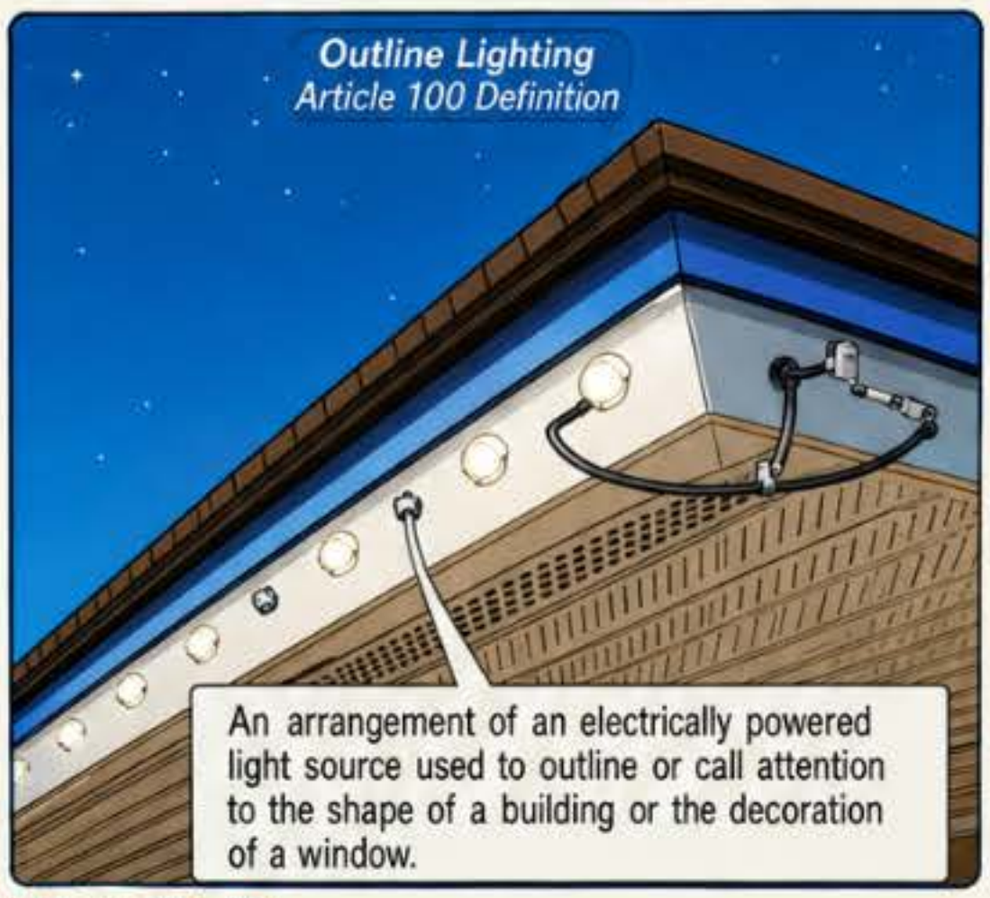
This section covers receptacle and lighting outlets, as well as equipment used for ceiling paddle fans and smoke alarms.

— ***Michael Hamilton***



▶ Figure 100–117

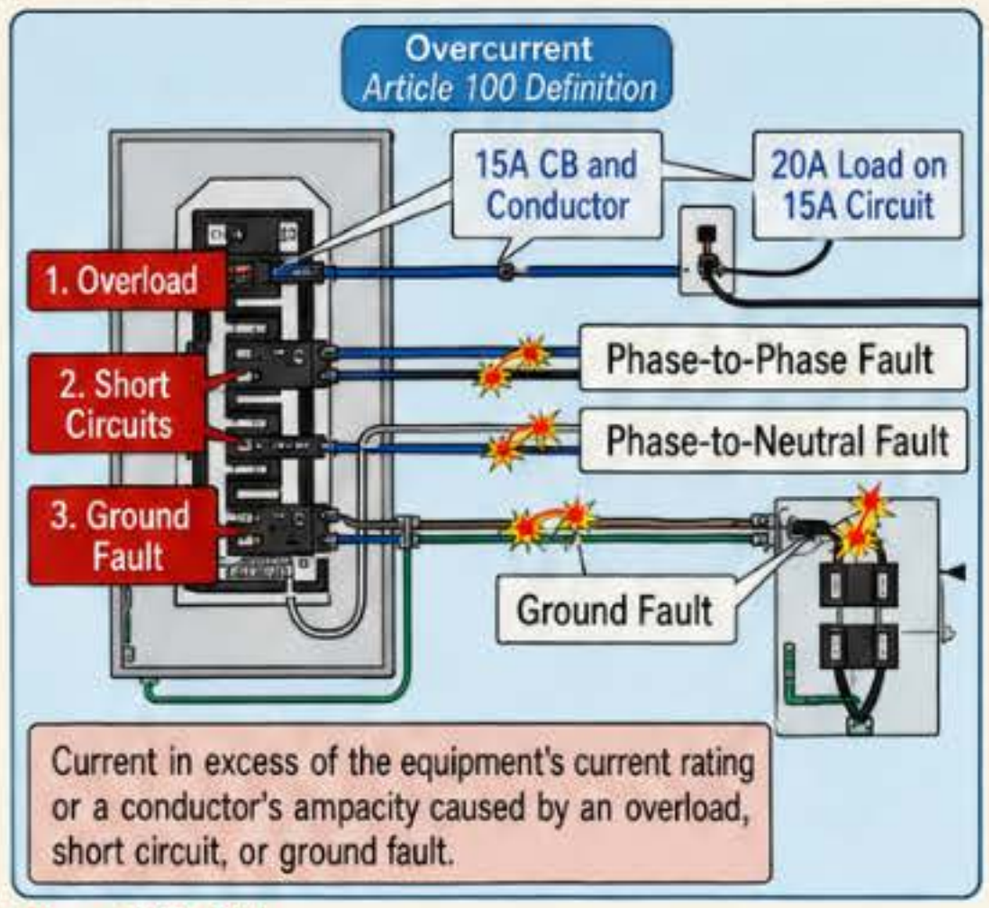
Outline Lighting. An arrangement of an electrically powered light source used to outline or call attention to building features such as the shape of a building or the decoration of a window. ▶ Figure 100–118



▶ Figure 100–118

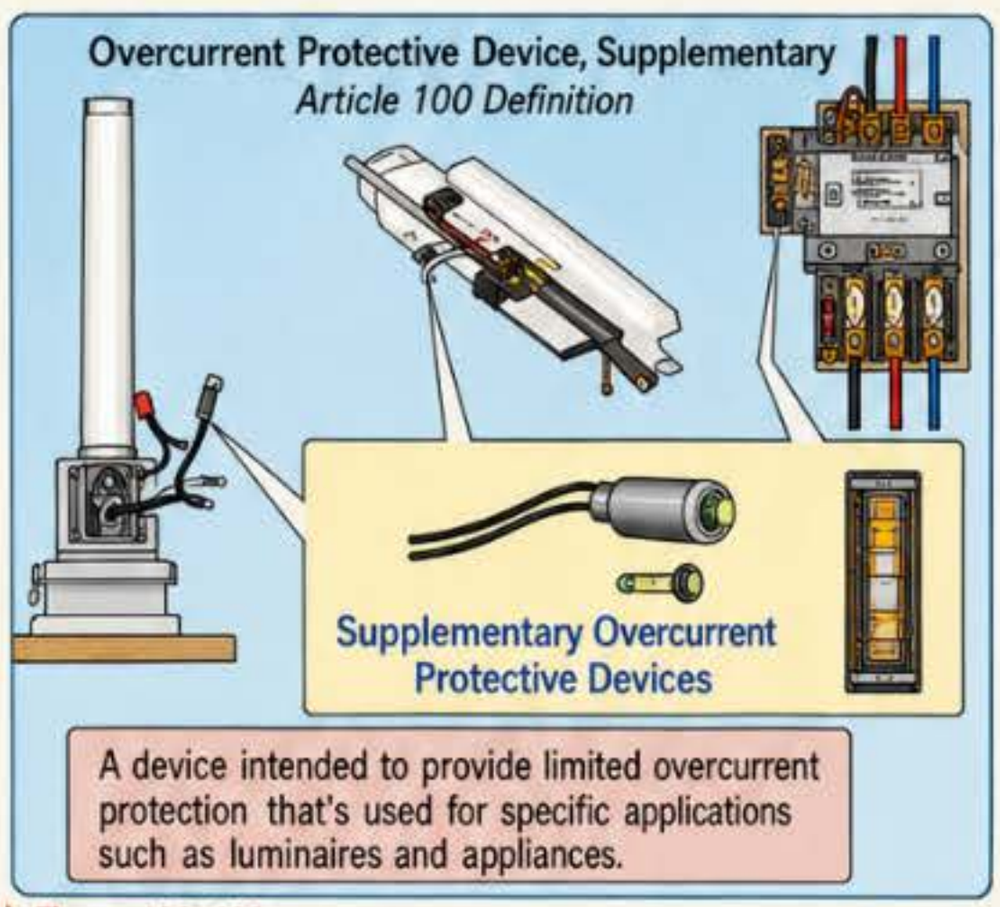
Overcurrent. Current in excess of the equipment's current rating or a conductor's ampacity caused by an overload, short circuit, or ground fault. ▶ Figure 100–119

Overcurrent Protective Device, Branch Circuit. A device capable of providing protection from an overload, short circuit, or ground fault for service, feeder, and branch circuits.



▶ Figure 100–119

Overcurrent Protective Device, Supplementary. A device intended to provide limited overcurrent protection for specific applications and utilization equipment, such as luminaires and appliances. This limited protection is in addition to the protection required and provided by the branch-circuit overcurrent protective device. ▶ Figure 100–120



▶ Figure 100–120

Overload. The operation of equipment above its current rating, or current in excess of a conductor's ampacity. If an overload condition persists long enough, the result can be equipment failure or a fire from damaging or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload. ▶ Figure 100–121

Panelboard. An assembly designed for the distribution of light, heat, or power circuits with overcurrent devices and typically placed in a cabinet. ▶ Figure 100–122

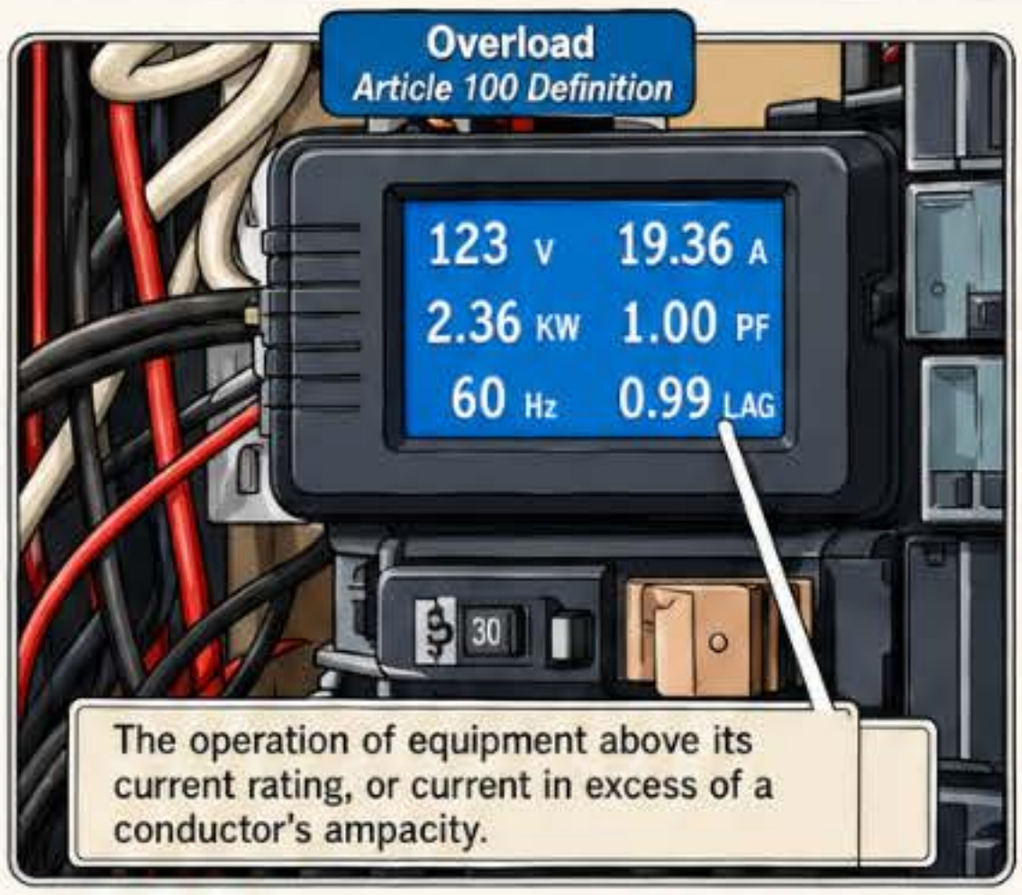


Figure 100-121

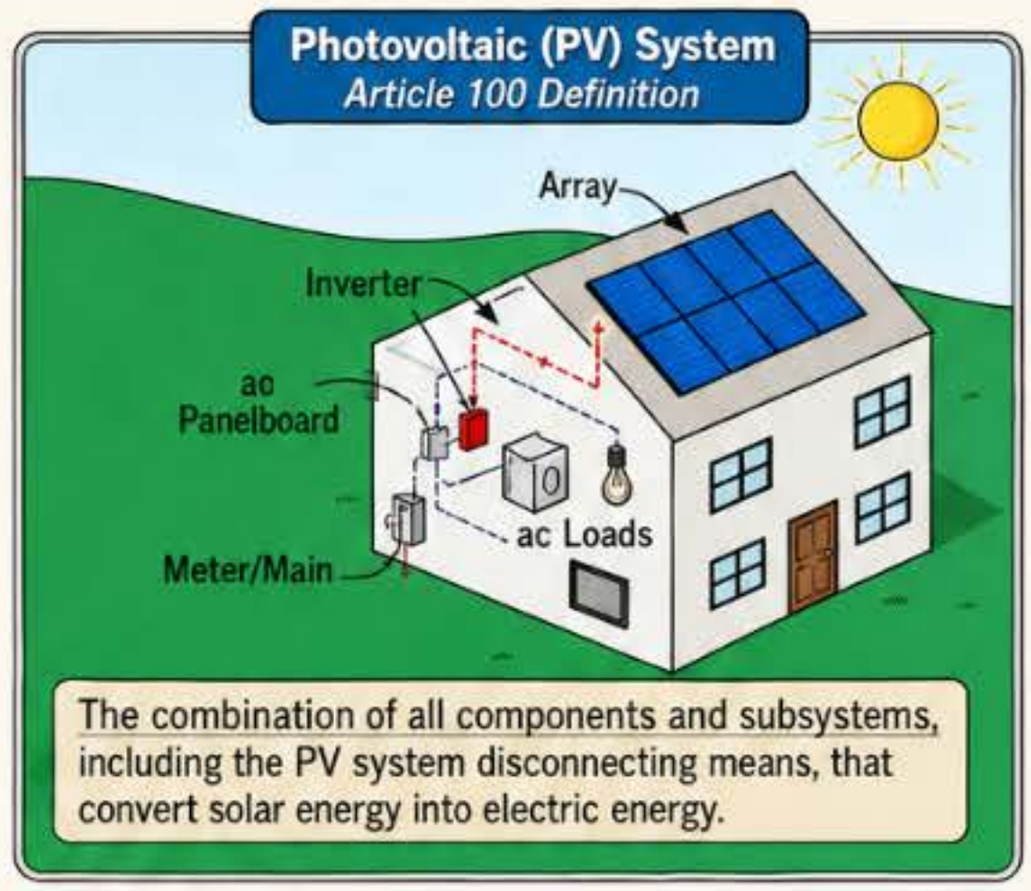


Figure 100-123

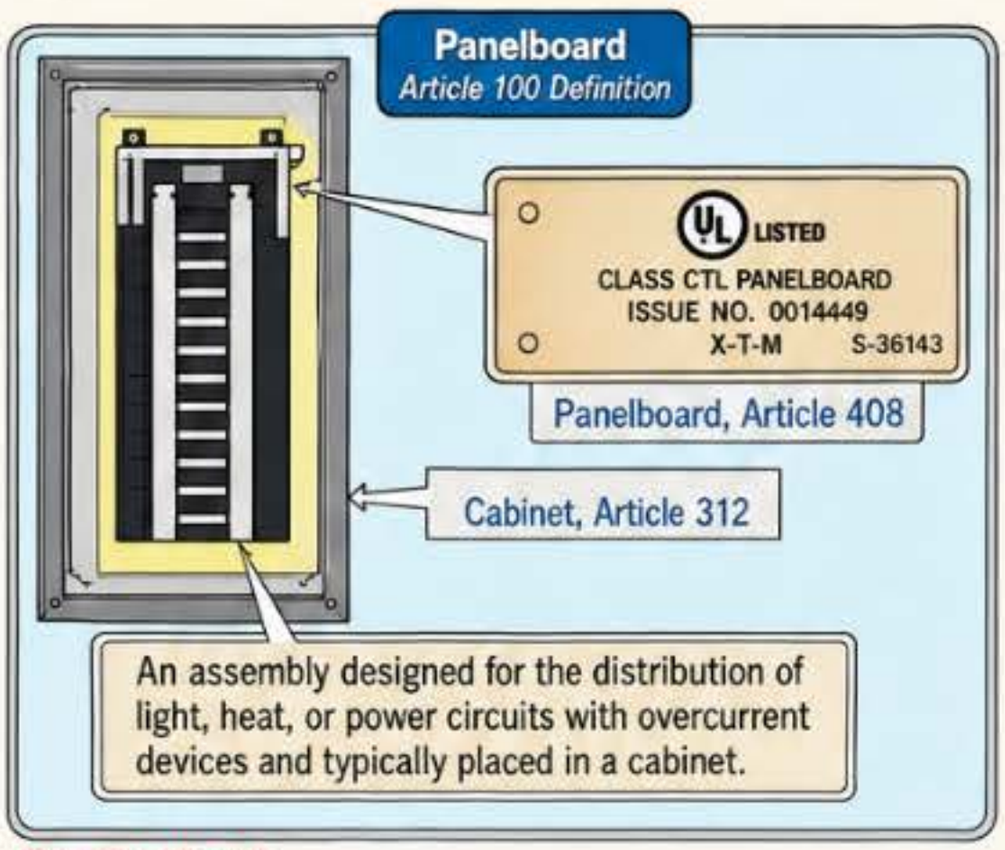


Figure 100-122

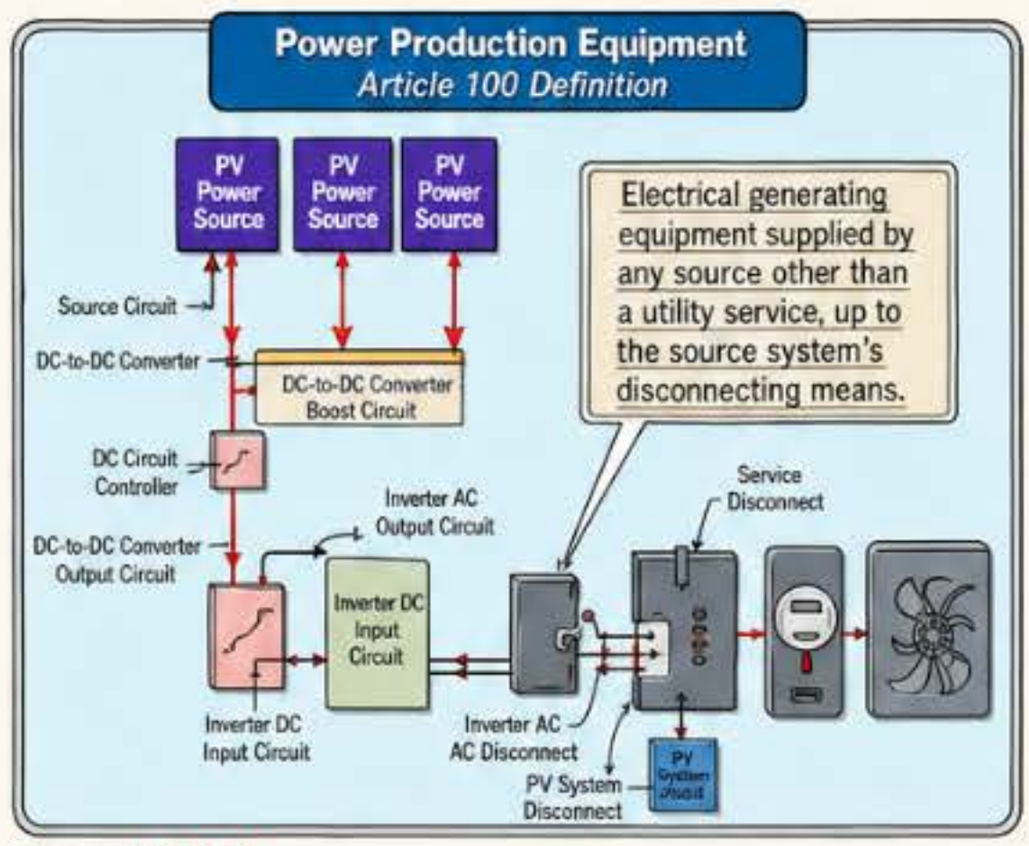


Figure 100-124

Author's Commentary:

- See the definition of "Cabinet" in this article.
- The slang term in the electrical field for a panelboard is "the guts." This is the interior of the panelboard assembly and is covered by Article 408, while the cabinet is addressed by Article 312.

— Michael Hamilton

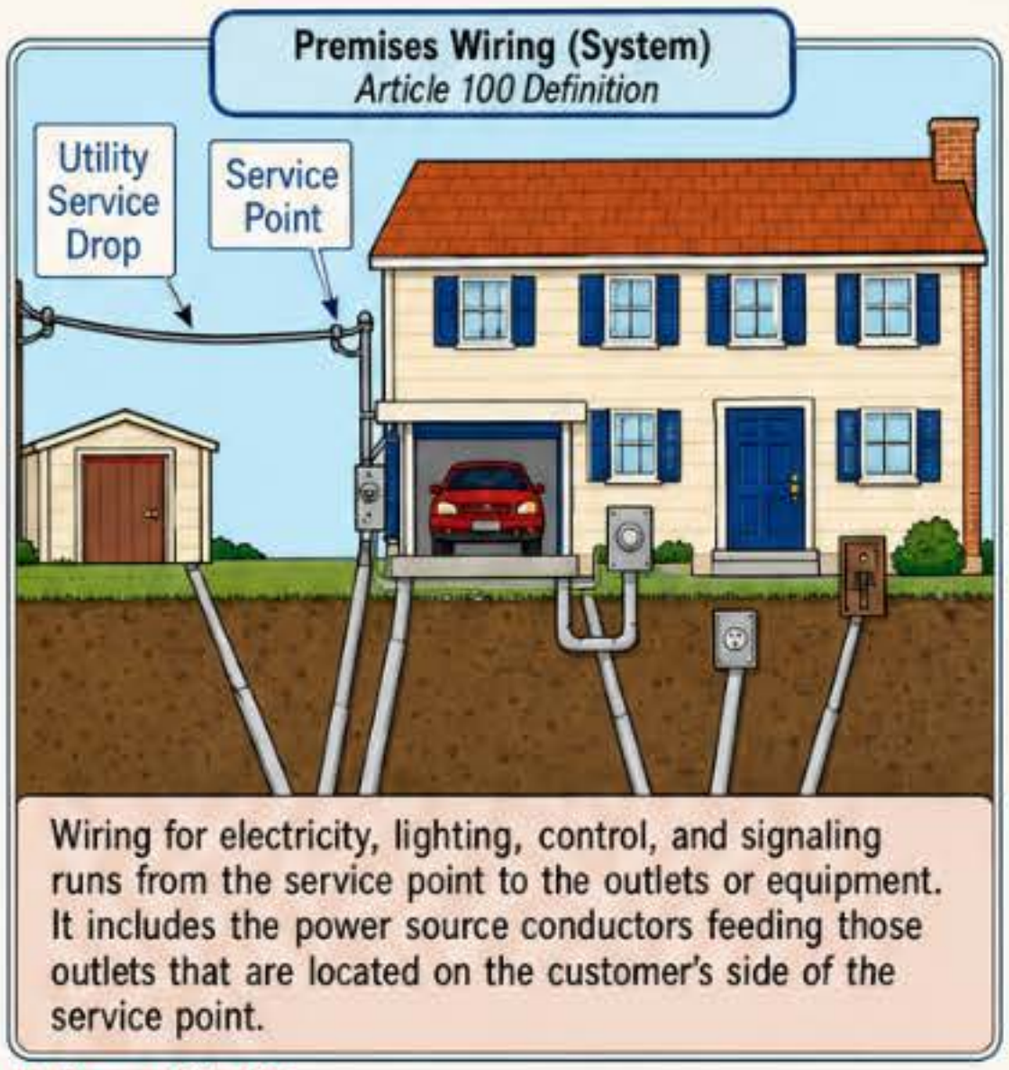
Photovoltaic (PV) System. The combination of all components and subsystems, including the PV system disconnecting means, that convert solar energy into electric energy for utilization loads. • **Figure 100-123**

Power Production Equipment. Electrical generating equipment supplied by any source other than a utility service, up to the source system's disconnecting means. • ***Figure 100-124***

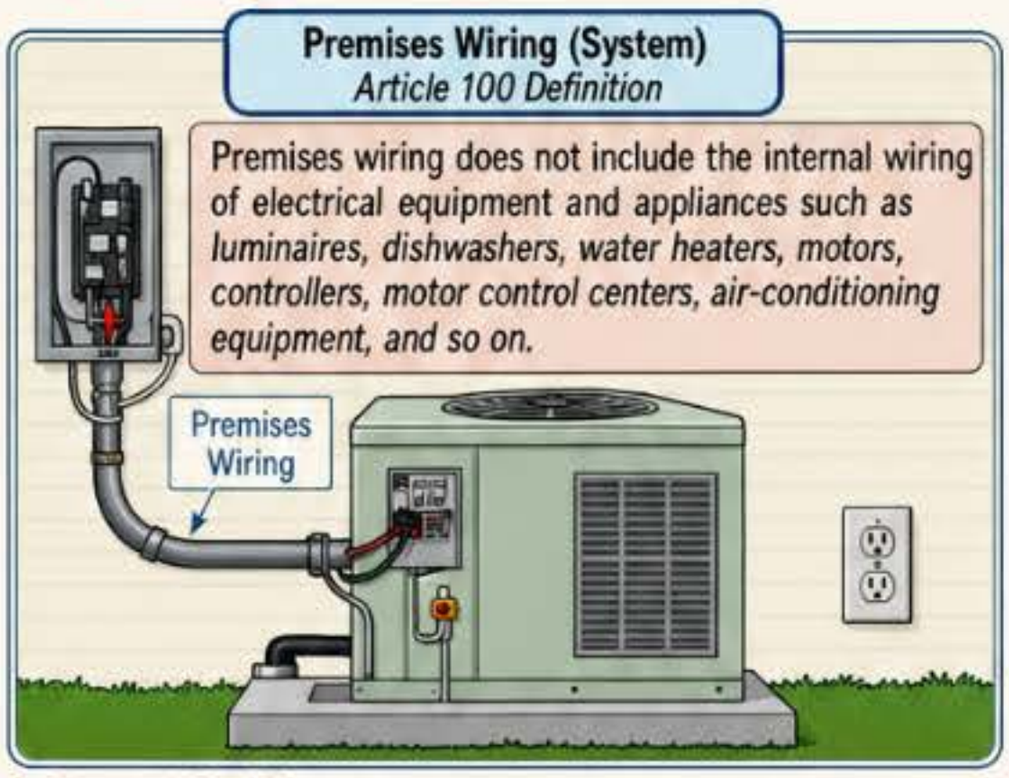
Note: Examples of power production equipment include such items as generators, solar photovoltaic systems, and fuel cell systems.

Premises Wiring. The interior and exterior wiring including power, lighting, control, and signaling circuits, and all associated hardware, fittings, and wiring devices. This includes permanently and temporarily installed wiring from the service point to the outlets. Where there is no service point, it is the wiring from and including the electric power source (such as a generator, transformer, or PV system) to the outlets. • **Figure 100-125**

Premises wiring does not include the internal wiring of electrical equipment and appliances such as luminaires, dishwashers, water heaters, motors, controllers, motor control centers, air-conditioning equipment, and so on [90.7 and 300.1(B)]. • **Figure 100-126**



▶ Figure 100–125



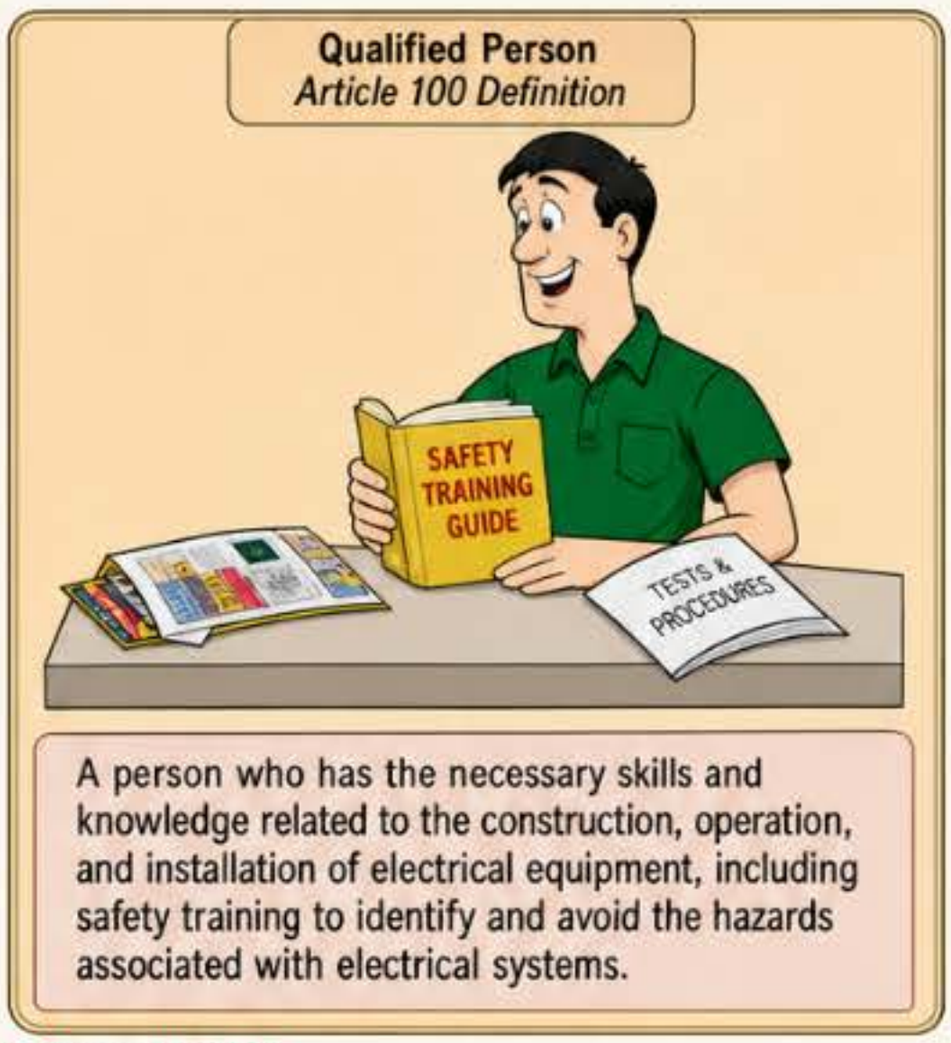
▶ Figure 100–126

Note: Electric power sources include (but are not limited to) interconnected or stand-alone batteries, photovoltaic (PV) systems, other distributed generation systems, and generators.

Prime Mover. The machine that provides mechanical power to drive a generator.

Qualified Person. *A person who has the necessary skills and knowledge related to the construction and operation of electrical equipment and its installation. This person must have completed safety training to identify and avoid the hazards involved with electrical systems.* ▶ ***Figure 100–127***

Note: *The 2023 Edition of NFPA 70E, Standard for Electrical Safety in the Workplace, explains the expectations for "qualified person" safety training in greater detail.*



▶ Figure 100–127

Author's Commentary:

- The examples of safety training listed here are not exhaustive. Training may also involve the use of special precautionary methods, personal protective equipment (PPE), insulating and shielding techniques, appropriate materials, and properly insulated tools and test instruments when working near exposed conductors or circuit components that could become energized.
- Across the United States, electricians, electrical contractors, inspectors, and engineers must complete 24 hours of *NEC* review each year as part of maintaining their licenses. This ongoing education helps ensure *everyone remains familiar with the current requirements. This mandate in itself does not make an individual automatically qualified to address the particular risks present in electrical installations.*

— Michael Hamilton

Raceway. A channel designed to support and route conductors, cables, or busbars.

Author's Commentary:

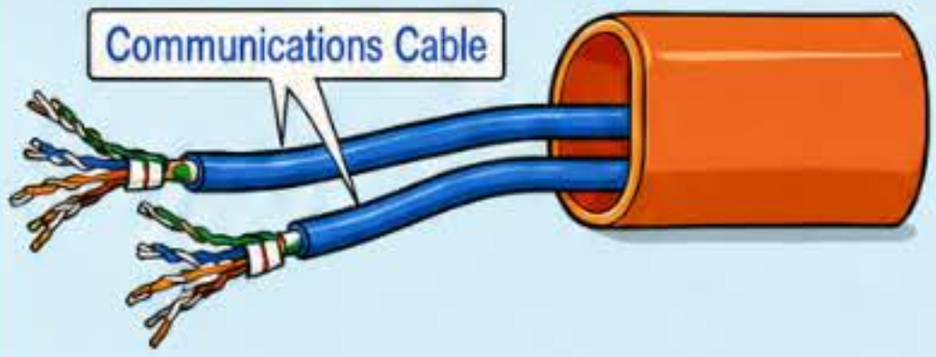
- *Cable tray systems are not raceways; they function as a support structure for cables and raceways* [392.2].

— Michael Hamilton

Raceway, Communications. *An enclosed, nonmetallic channel used to contain communication wiring and cables, including optical fiber cables. This term covers cables used with information technology and communications equipment, Class 2, Type PLTC, and power-limited fire alarm cables in plenum spaces, risers, and for general-purpose applications.* ▶ ***Figure 100–128***

Rainproof. *Constructed, protected, or treated to keep rain from interfering with proper operation under specified test conditions.*

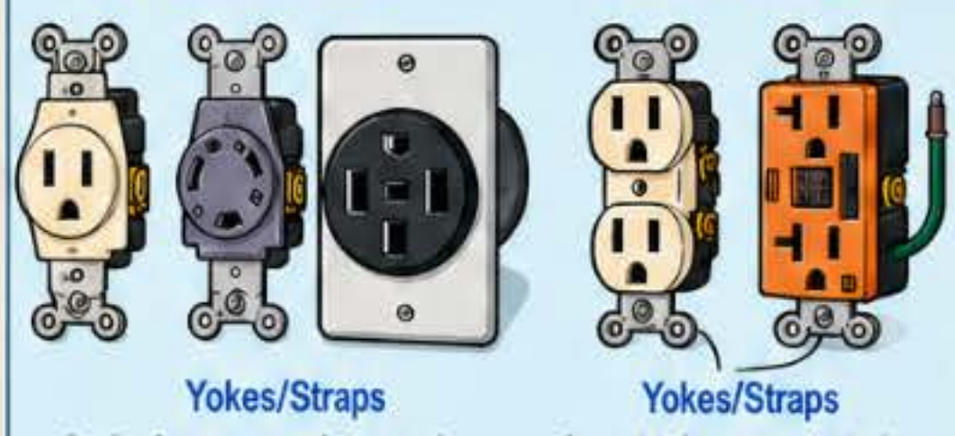
Raceway, Communications
Article 100 Definition



An enclosed nonmetallic channel designed for holding communications wires and cables, optical fiber cables, data cables, Class 2, and Type PLTC cables, and power-limited fire alarm cables in plenum spaces, risers, and general-purpose applications.

Figure 100–128

Receptacle
Article 100 Definition



A single receptacle contains one contact device on the same yoke or strap.

A multiple receptacle has more than one contact device on the same yoke.

Figure 100–130

Raintight. Constructed or protected so exposure to a beating rain will not result in the entrance of water under specified test conditions.

Receptacle. A contact device installed at an outlet for the connection of an attachment plug, or for the direct connection of equipment designed to mate with the contact device (GFCI receptacle). ▶ Figure 100–129

Author's Commentary:

A yoke (also called a "strap") is the metal mounting structure for such items as receptacles, switches, switches with pilot lights, and switch/receptacles to name a few. ▶ Figure 100–131 and ▶ Figure 100–132

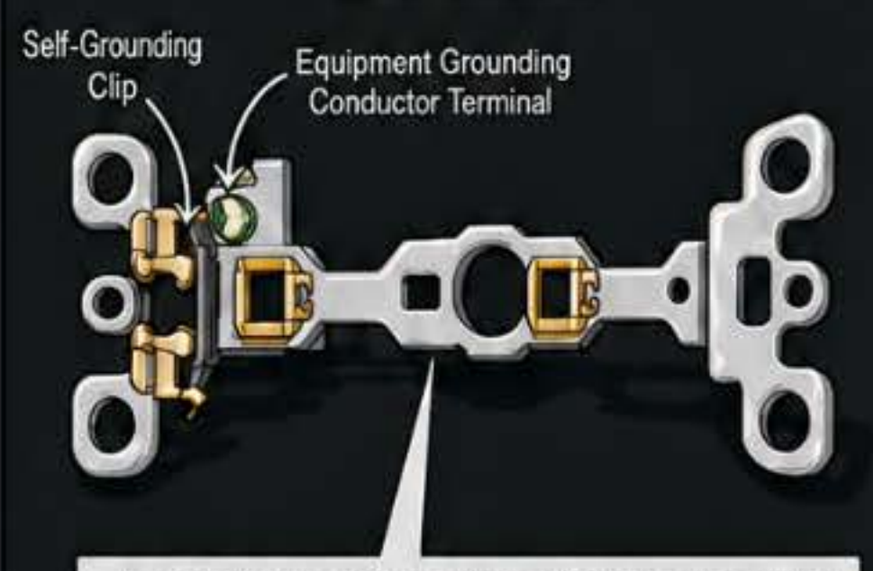
— *Michael Hamilton*

Receptacle
Article 100 Definition

A contact device installed at an outlet for the connection of an attachment plug, or for the direct connection of equipment designed to mate with the contact device.

Figure 100–129

Branch Circuits
Devices on Same Yoke (Strap)
210.7 *Comment*



A yoke (also called a "strap") is the mounting structure for a receptacle, switch, switch with pilot light, switch/receptacle, and so forth.

Figure 100–131

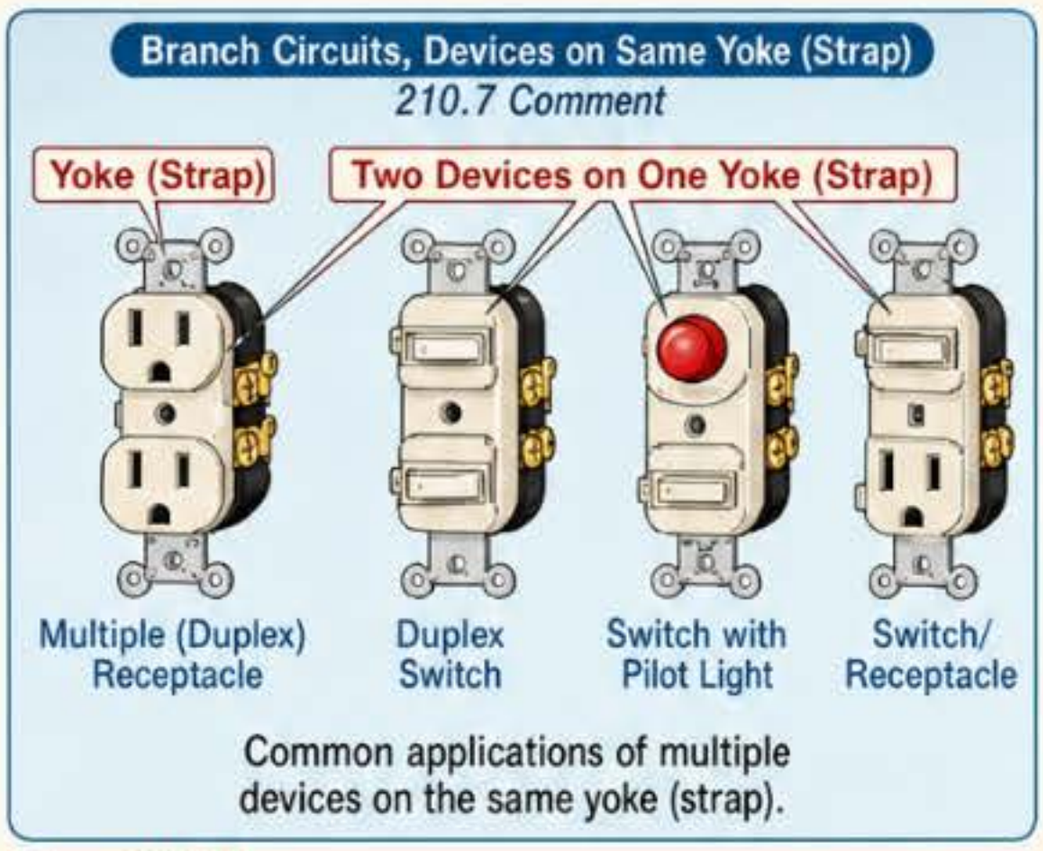
Author's Commentary:

▶ For additional information about listed locking support and mounting receptacles, visit *www.safetyquicklight.com.*

A single receptacle contains one contact device on a yoke or strap; a multiple receptacle has more than one contact device on the same yoke or strap. ▶ Figure 100–130

Note: A duplex receptacle is an example of a multiple receptacle with two receptacles on the same yoke or strap.

Receptacle Outlet. An opening in an outlet box where receptacles have been installed.

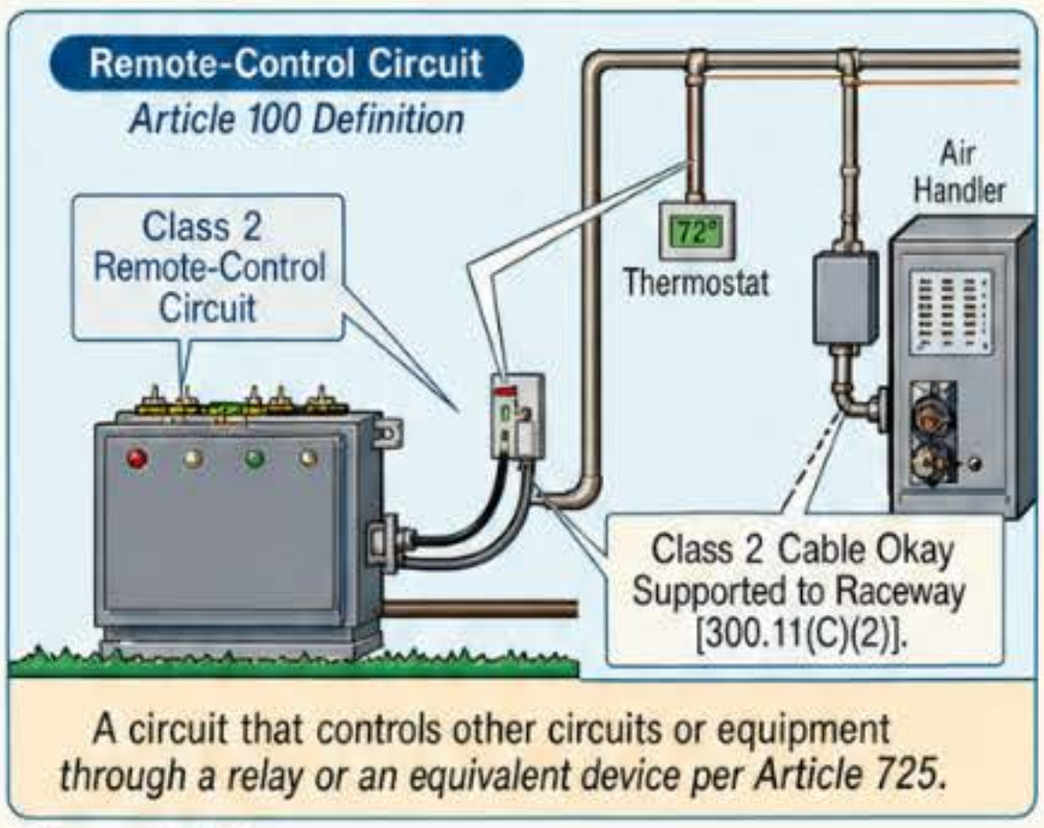


▶ Figure 100–132

Reconditioned. Electromechanical systems, equipment, apparatus, or components that are returned to serviceable condition. This process differs from ordinary servicing because the item remains within a facility, or a replacement of the listed equipment is done on a one-for-one basis.

Note: *The term reconditioned is commonly used to describe equipment that has been rebuilt, refurbished, or remanufactured.*

Remote-Control Circuit. An electrical circuit that governs another circuit through a relay or an equivalent device installed in accordance with Article 725. ▶ Figure 100–133



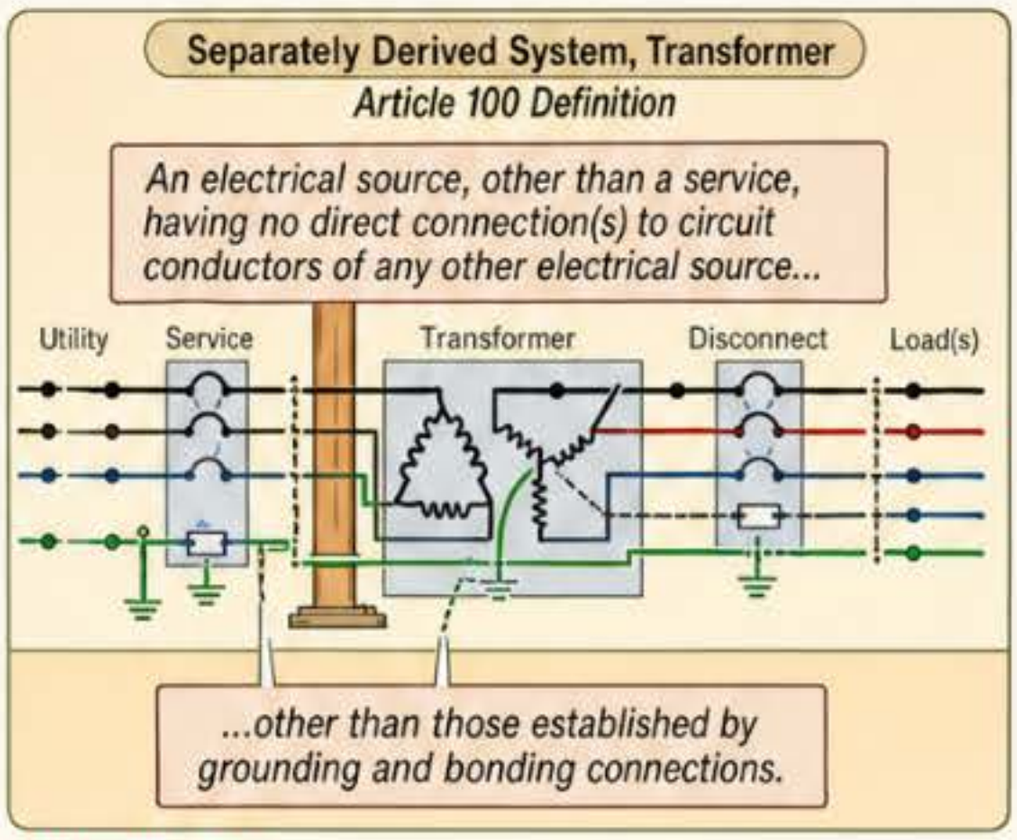
▶ Figure 100–133

Retrofit Kit. *A collection of parts used in the field to convert a utilization device to a different service.*

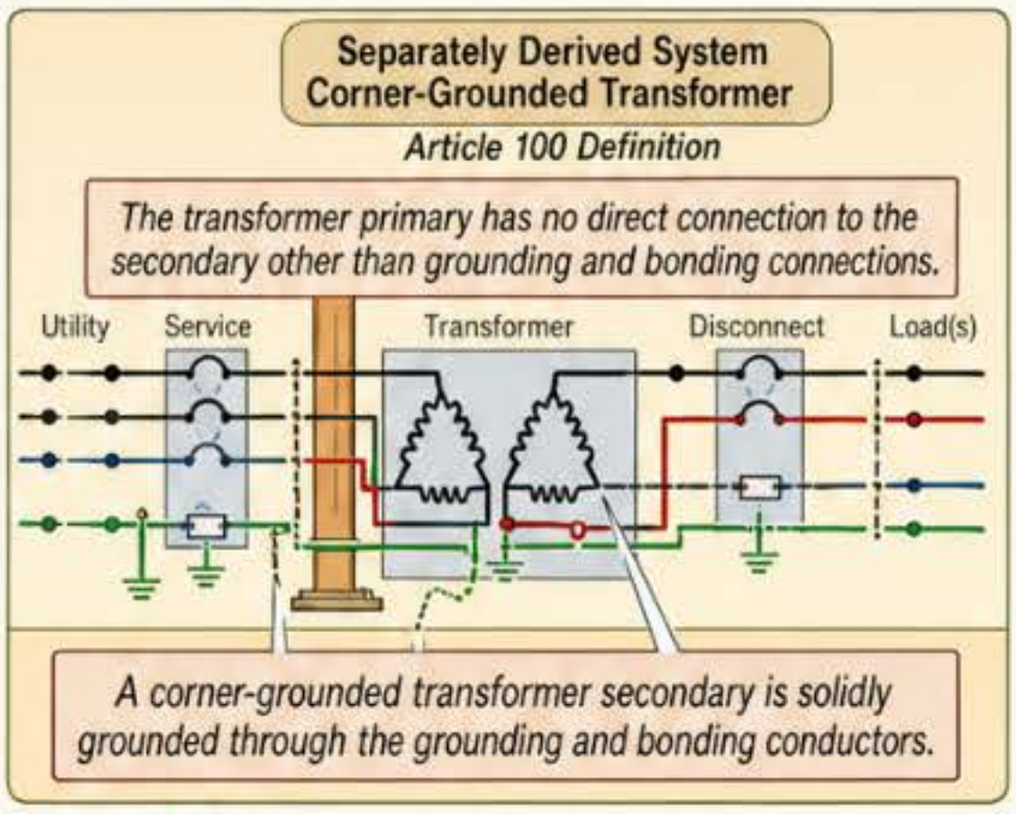
Sealable Equipment. *Equipment enclosed with a means of sealing or locking so that the interior cannot be accessed without opening the enclosure.*

Note: The equipment may or may not be operable without opening the enclosure.

Separately Derived System. An electrical source, other than a service, having no direct connection(s) to the circuit conductors of any other electrical source other than those established by grounding and bonding connections. ▶ Figure 100–134, ▶ Figure 100–135, and ▶ Figure 100–136



▶ Figure 100–134



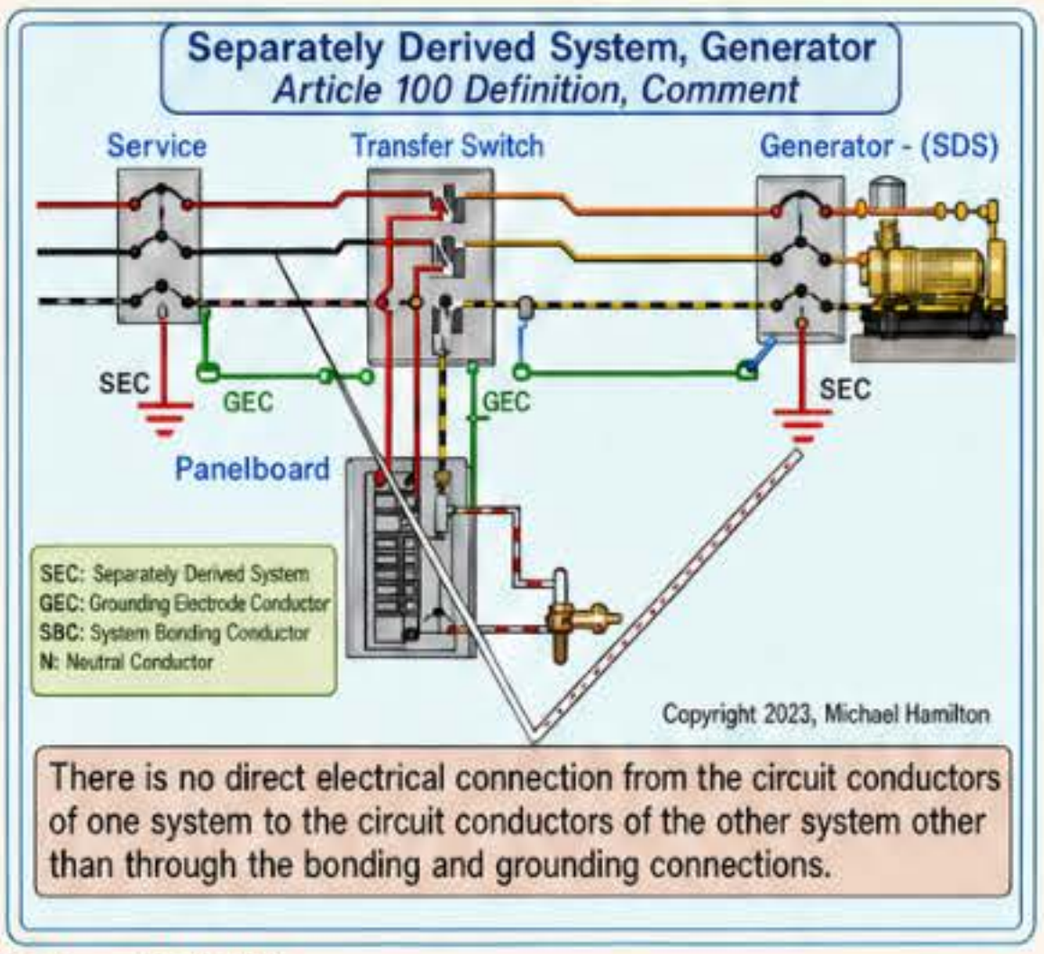
▶ Figure 100–135

Author's Commentary:

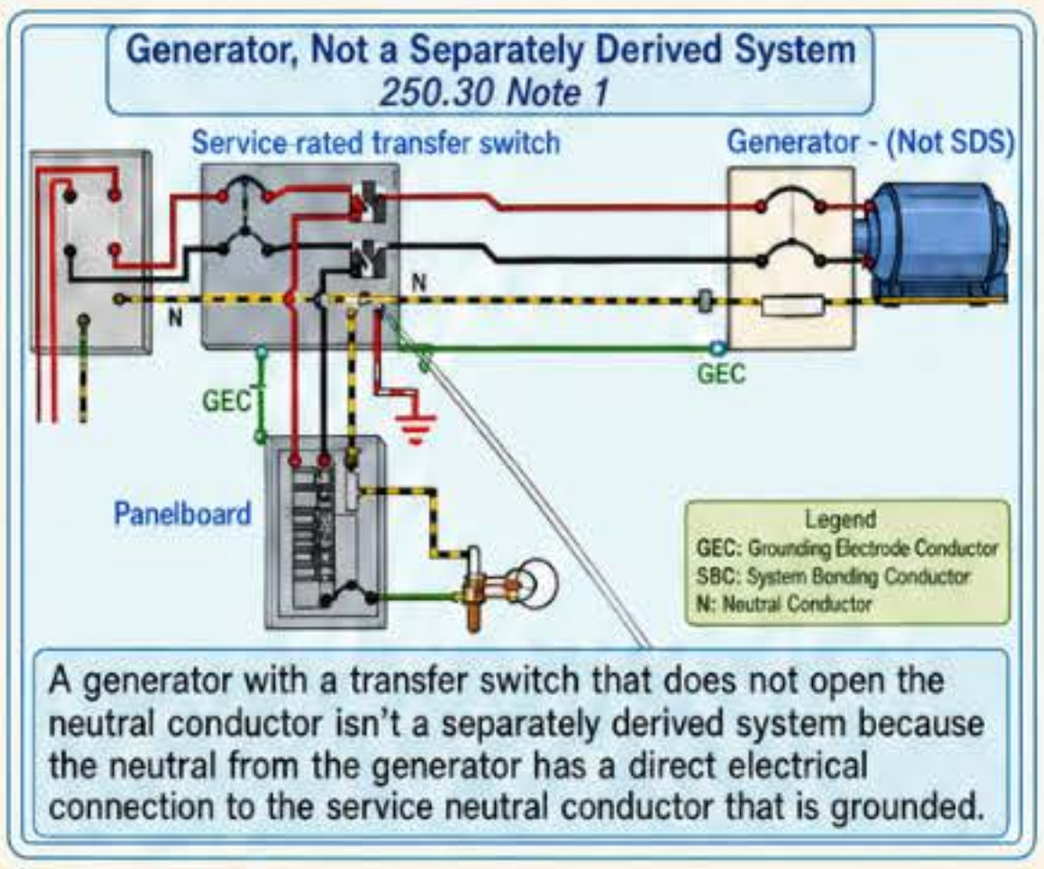
▶ *A generator is not considered a separately derived system if its neutral conductor is firmly connected to a service supplied system neutral conductor. An example is a generator equipped with a transfer switch that includes a neutral conductor that remains closed (not switched).*

— Michael Hamilton

DEFINITIONS | From Michael Hamilton Publications



▶ Figure 100–136



▶ Figure 100–137

Author's Commentary:

- *Separately derived systems are much more complex than the Code's definition suggests and understanding them requires additional study. For more information, see 250.30.*

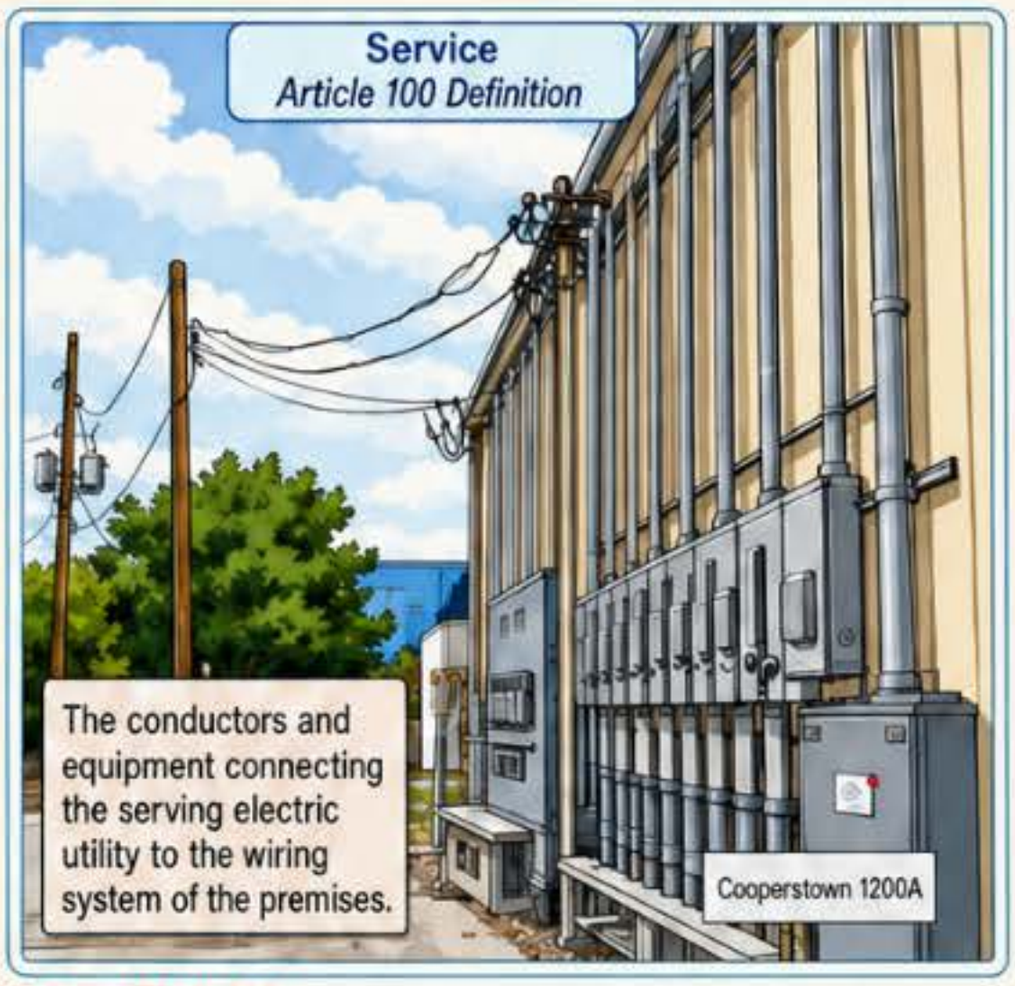
— Michael Hamilton

Service [Article 230]. *The conductors and equipment connecting the serving electric utility to the wiring system of the premises served.*

Author's Commentary:

- *A service can only be supplied by the serving electric utility and is not covered by the NEC. If power is supplied by other than the serving electric utility, the conductors and equipment are part of a feeder and covered by the Code.*

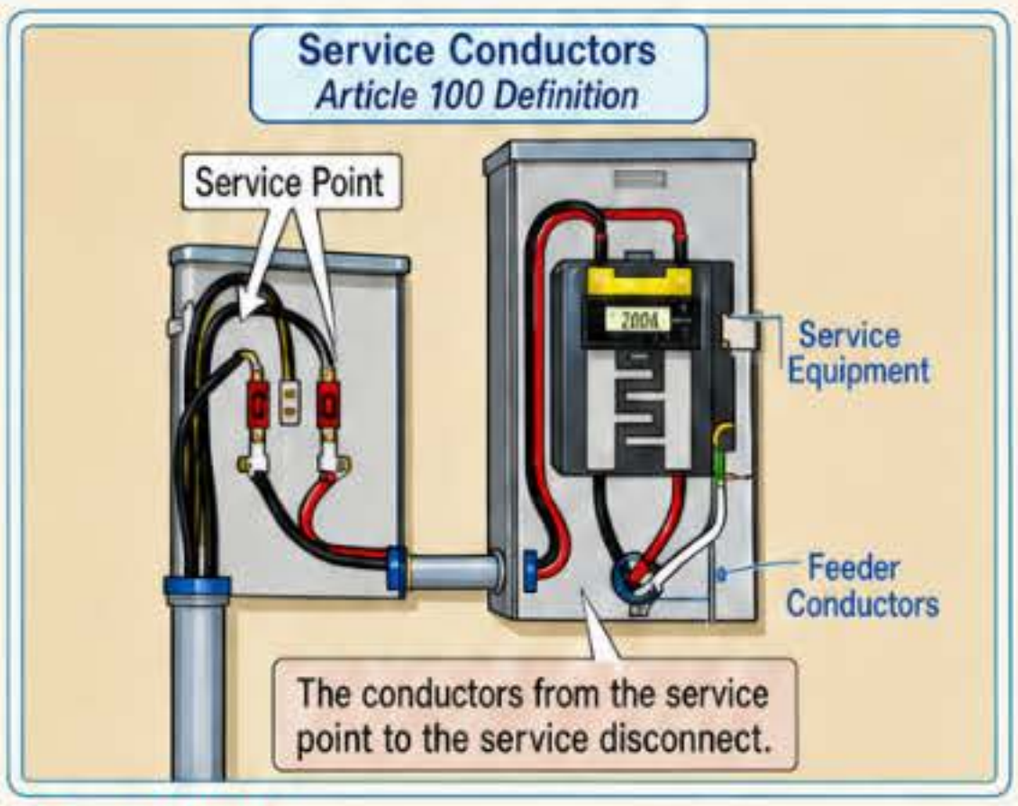
— Michael Hamilton



▶ Figure 100–138

- Conductors from UPS systems, solar PV systems, generators, or transformers are not service conductors. See the definitions of "Feeder" and "Service Conductors" in this article.

Service Conductors. The conductors from the serving electric utility service point to the service disconnect. ▶ Figure 100–139



▶ Figure 100–139

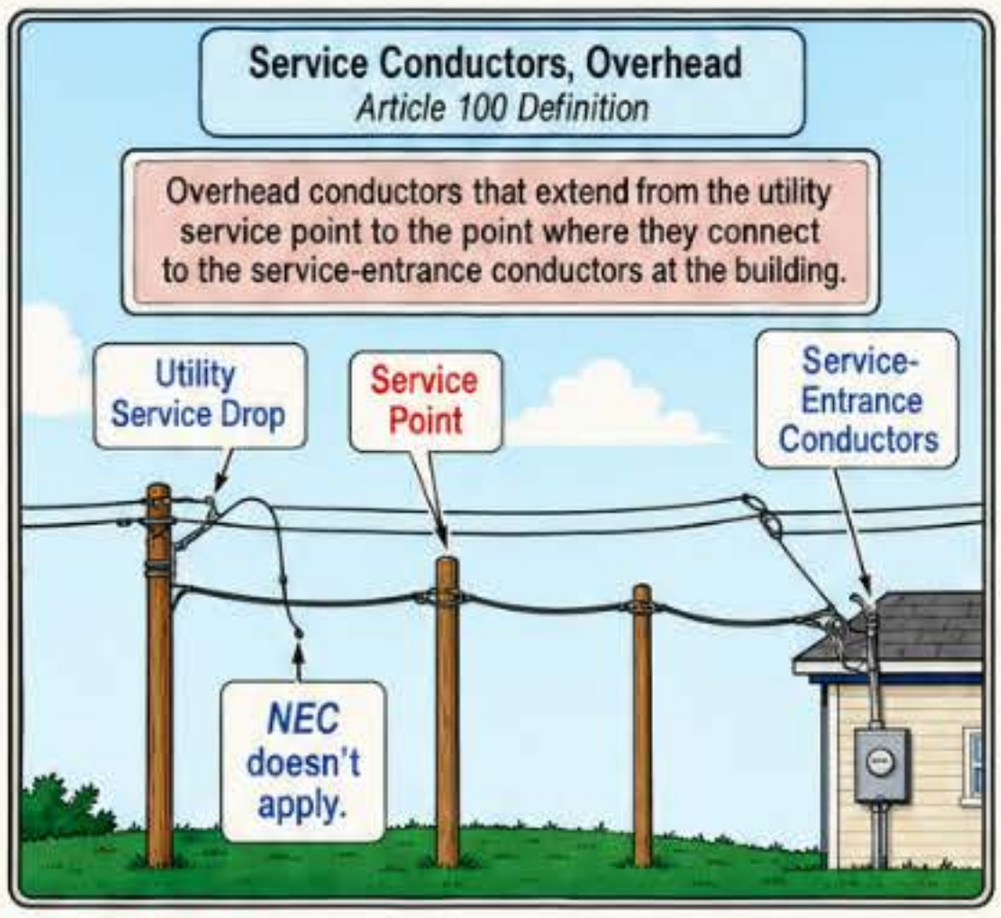
Author's Commentary:

- *Service conductors can include overhead service conductors, overhead service-entrance conductors, and underground service conductors. These conductors are not under the exclusive control of the serving electric utility, which means they are owned by the customer and are covered by the requirements in Article 230.*

— Michael Hamilton

DEFINITIONS | From Michael Hamilton Publications

Service Conductors, Overhead (Overhead Service Conductors). Overhead conductors that span from the utility's distribution point to the first connection at the service-entrance conductors where the building is supplied. ▶ Figure 100–140

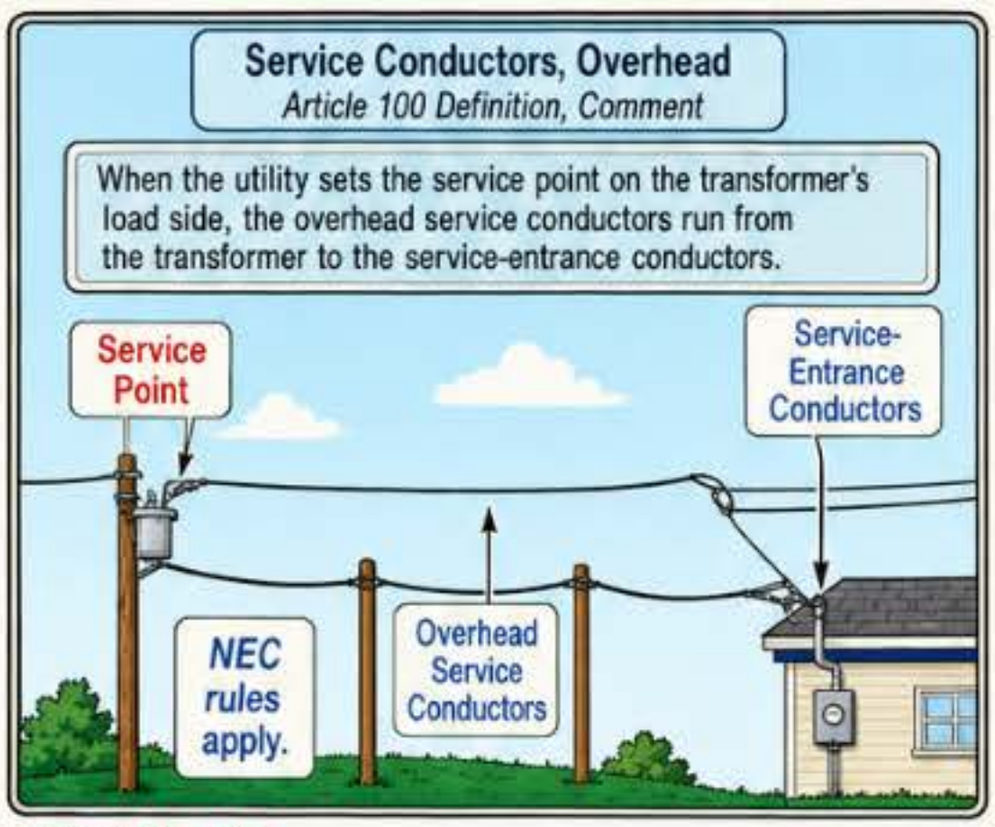


▶ Figure 100–140

Author's Commentary:

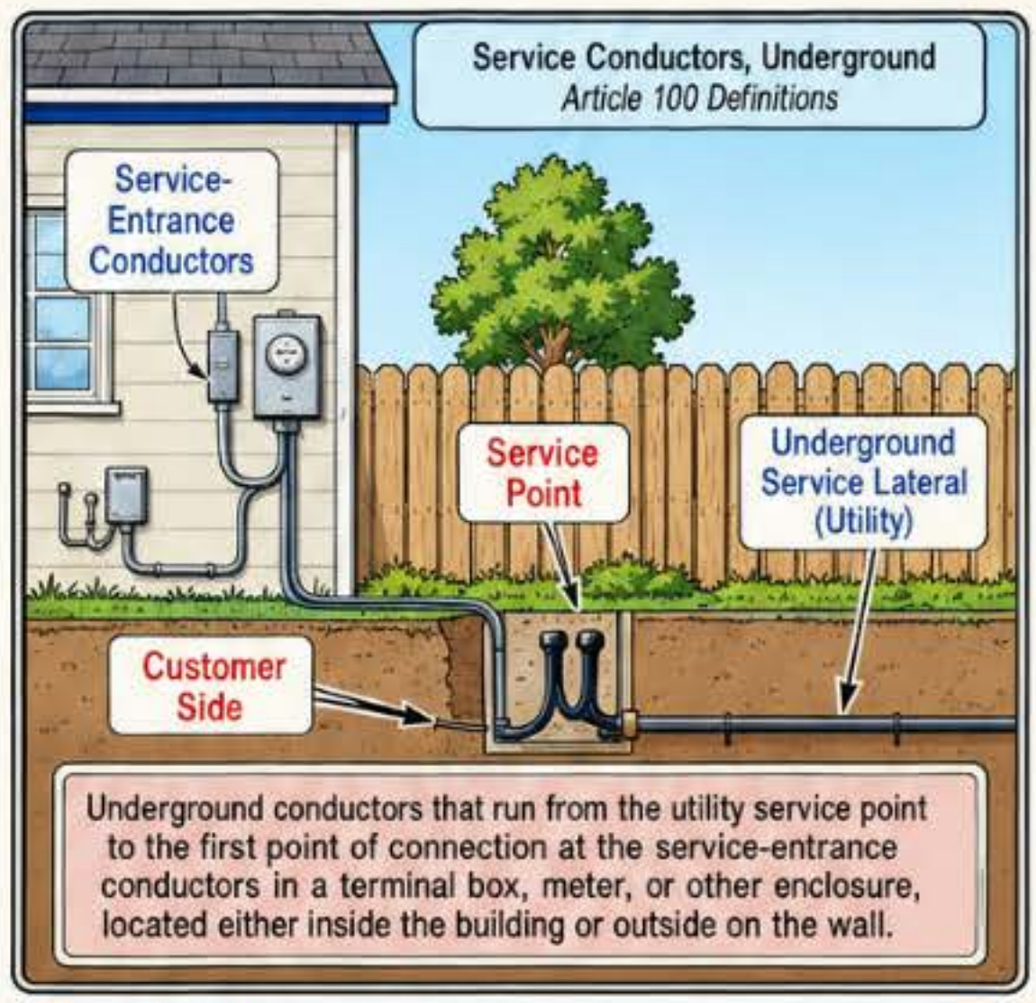
The location of the service point is usually set by the utility provider. The utility decides where the service begins at the pole side of the transformer, and the overhead wires between that point and the building are the service-entrance conductors.

— Michael Hamilton



▶ Figure 100–141

Service Conductors, Underground (Underground Service Conductors). *Underground conductors that extend from the service point to the first point of connection at the service-entrance conductors in a terminal box, meter, or other enclosure; located either inside the building or on the outside wall.* ▶ Figure 100–142



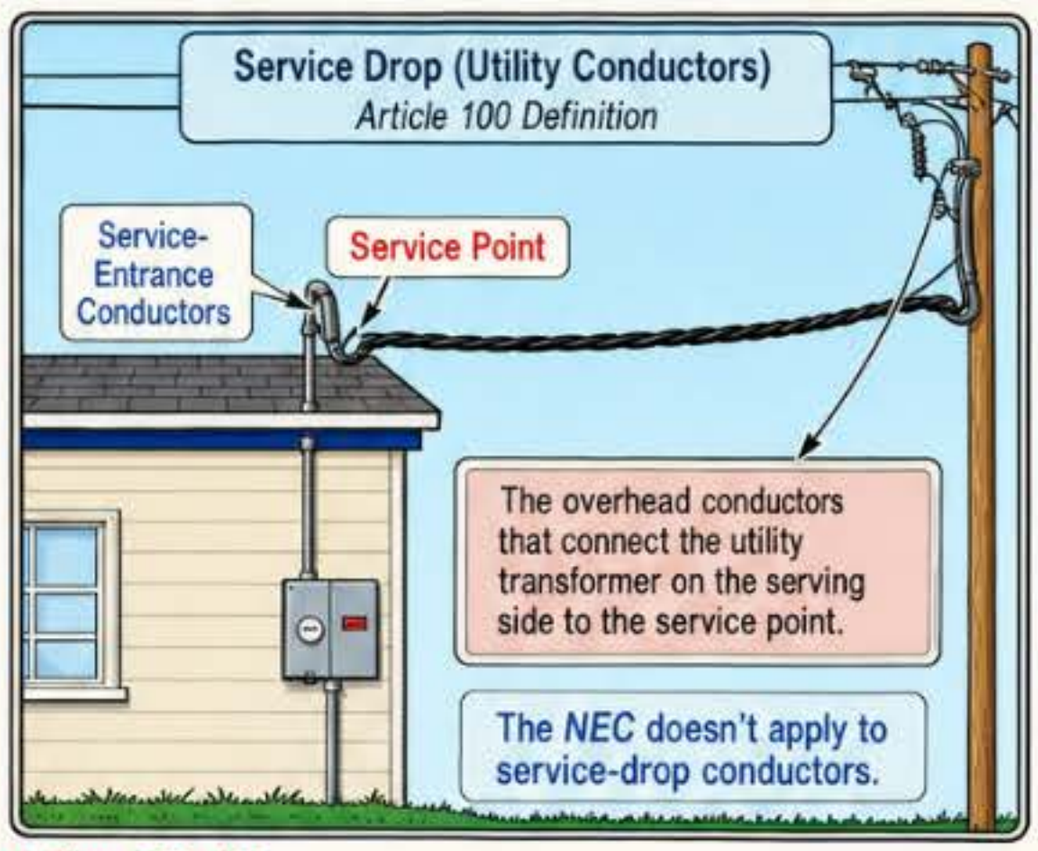
▶ Figure 100–142

Author's Commentary:

- *Service conductors are not governed by Article 230 because they fall under the exclusive control of the serving electric utility.*

Note: *When no terminal box, meter, or other enclosure exists, the point where the conductors enter the building becomes the point of connection.*

Service Drop. Overhead conductors owned by the utility that span from the electric utility to the service point. ▶ Figure 100–143



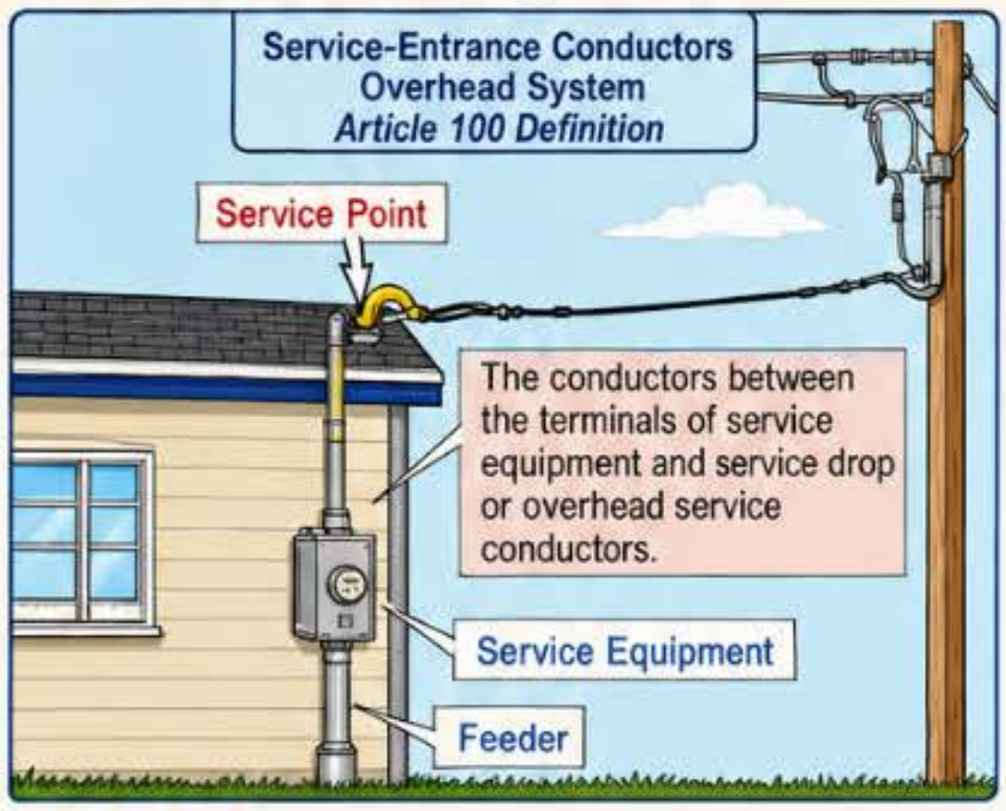
▶ Figure 100–143

Author's Commentary:

- *The NEC provisions do not govern service drops.*

— Michael Hamilton

Service-Entrance Conductors, Overhead (Overhead Service-Entrance Conductors). These conductors run from the utility terminals at the service disconnect to the service drop or to the overhead service conductors. ***Figure 100–144**



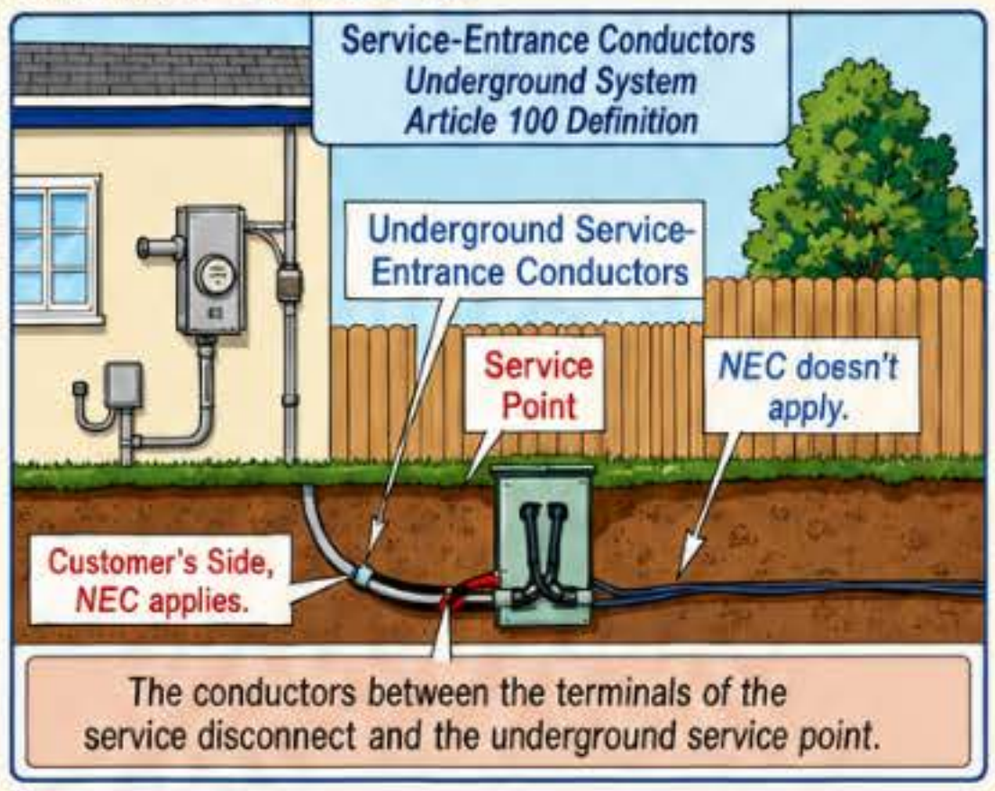
▶ Figure 100–144

Author's Commentary:

Since they are outside the exclusive control of the serving utility, overhead service-entrance *conductors must meet the requirements of Article 230.*

— Michael Hamilton

Service-Entrance Conductors, Underground (Underground Service-Entrance Conductors). These conductors extend from the terminals of the service disconnect to the underground service point. ***Figure 100–145**



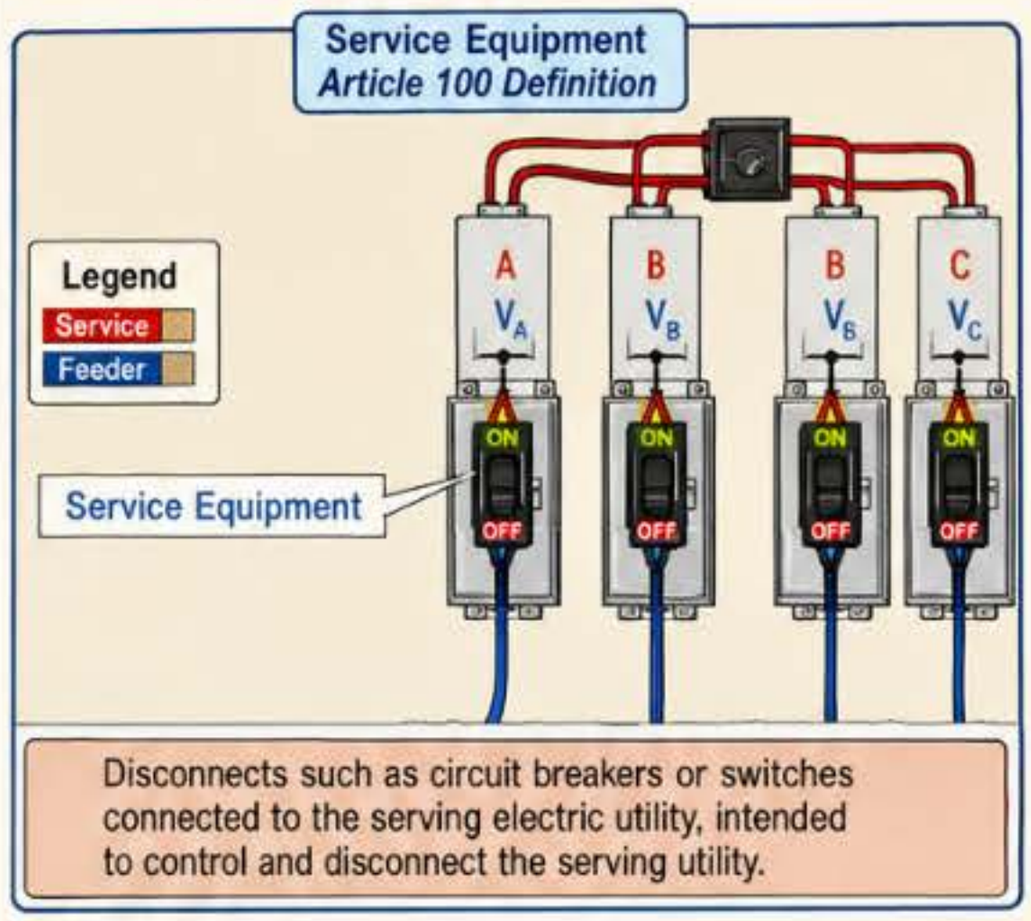
▶ Figure 100–145

Author's Commentary:

Because they lie between the service disconnect and the underground service point, these conductors are covered by NEC requirements.

— Michael Hamilton

Service Equipment (Service Disconnect). These are devices such as circuit breakers or switches that are connected to the serving electric utility and are intended to open the circuit and isolate the power feed for control and safety. ***Figure 100–146**

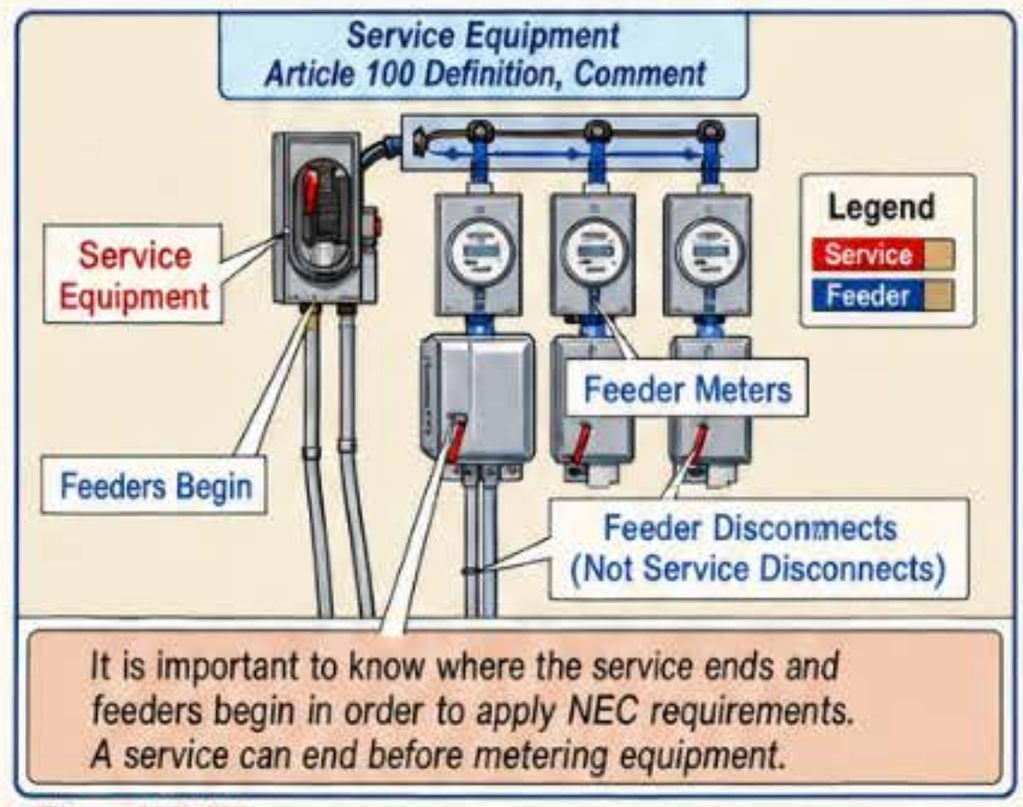


▶ Figure 100–146

Author's Commentary:

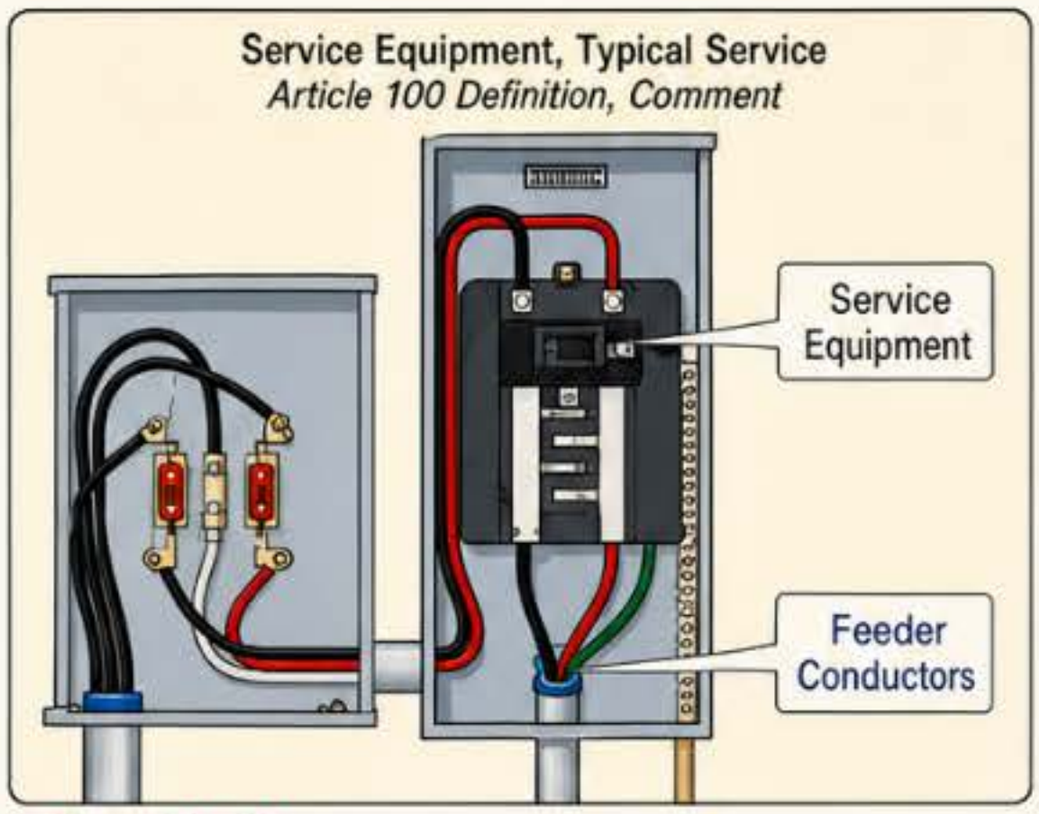
It's important to know where the service begins and where it ends so that Code rules can be applied correctly. In some situations, the service ends before the metering equipment. ▶ ***Figure 100–147*** *and* ▶ ***Figure 100–148***

— Michael Hamilton



▶ Figure 100–147

Author's Commentary:



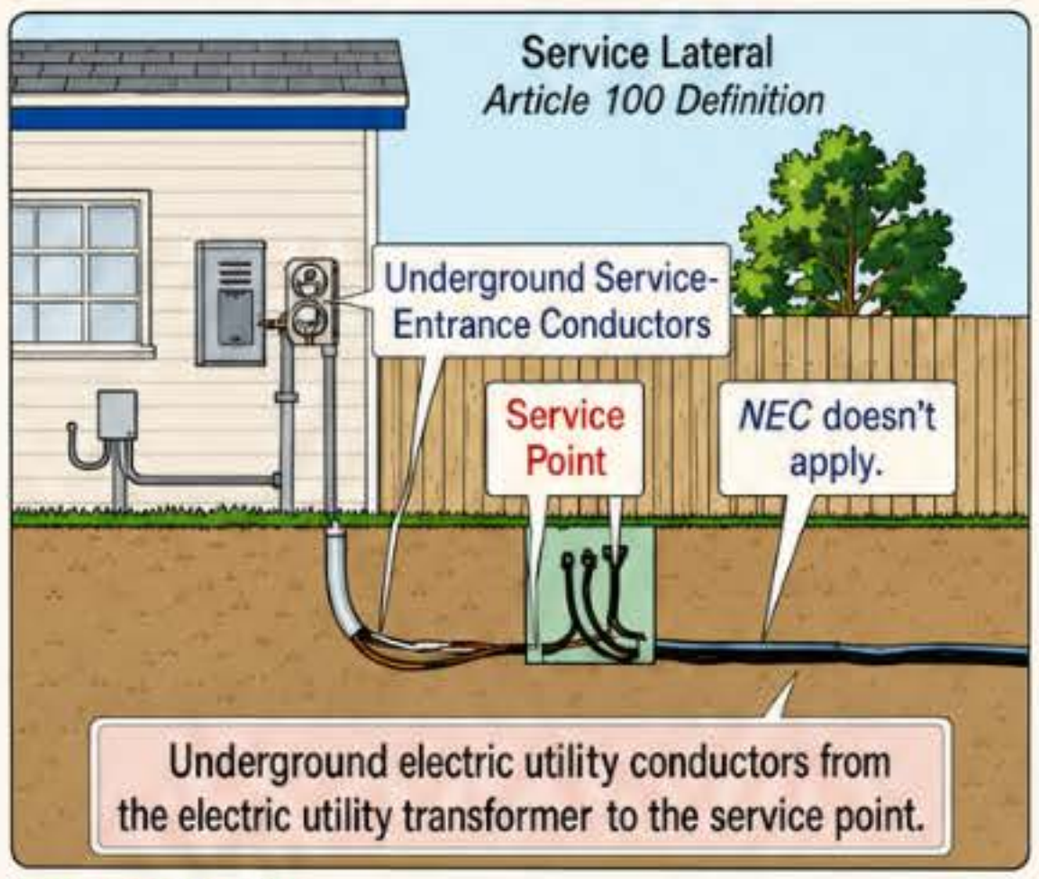
▶ Figure 100–148

Author's Commentary:

- Service equipment is commonly known as the "service disconnect" or "service main."
- Meter socket enclosures are not treated as service equipment [230.66].

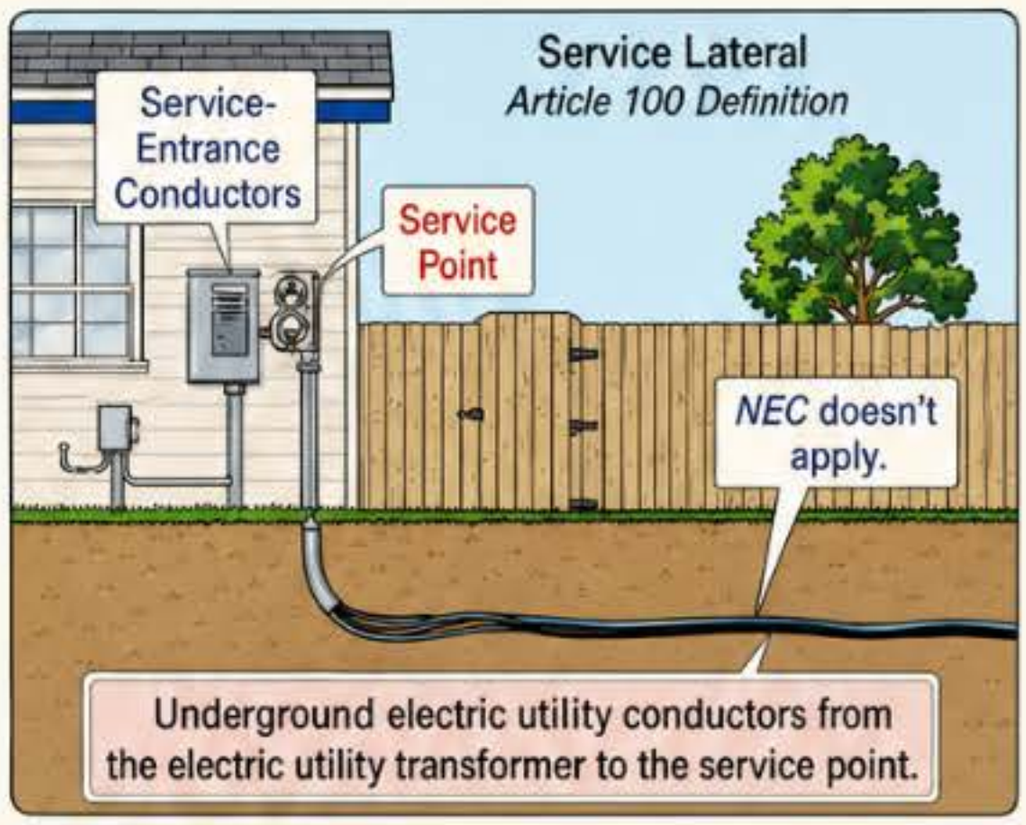
— *Michael Hamilton*

Service Lateral. Utility-owned underground conductors that run between the serving electric utility transformer and the service point. ◆ Figure 100–149 and Figure 100–150

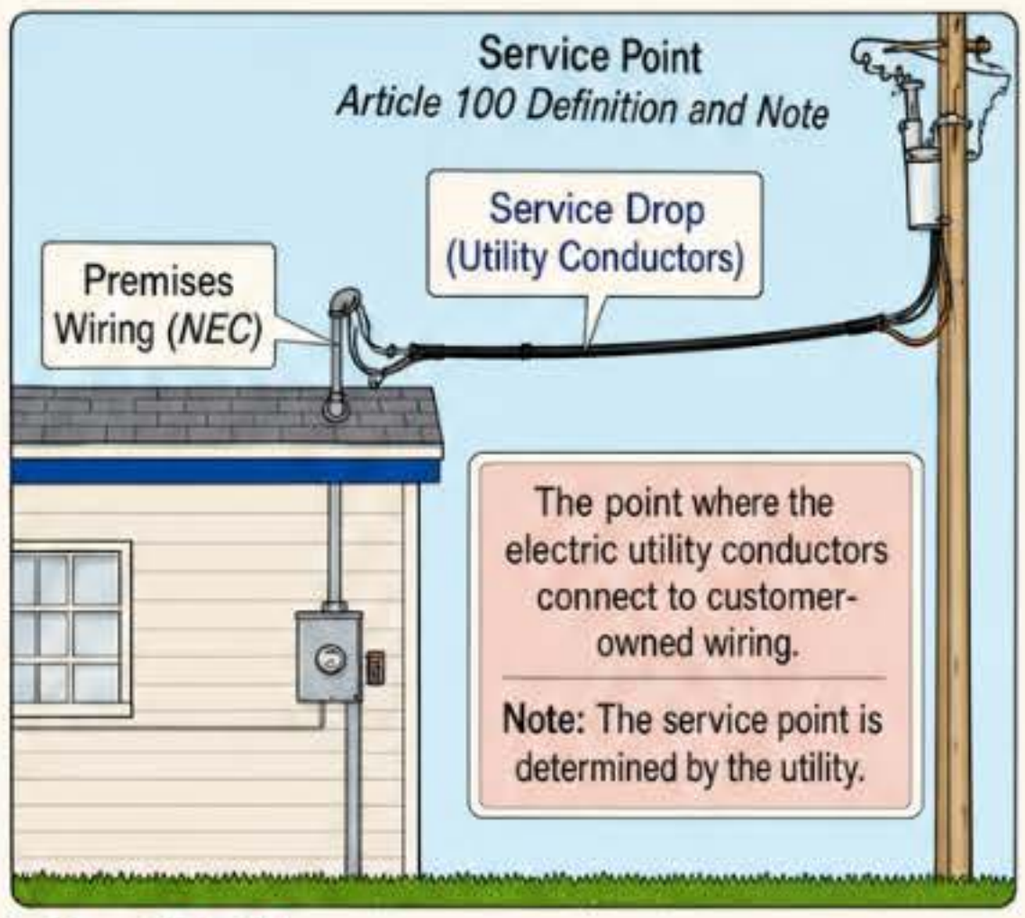


▶ Figure 100–149

Service Point. *The point where the serving electric utility conductors connect to customer-owned wiring.* ◆ Figure 100–151



▶ Figure 100–150



▶ Figure 100–151

Author's Commentary:

- The service point is normally established by the serving electric utility and may vary with the type of utility and the occupancy involved.
- For utility-owned transformers, the service point will be *located at the serving electric utility's transformer secondary terminals — at the service drop, or at the meter socket enclosure depending on where their conductors terminate.* ◆ Figure 100–152
- *For customer-owned transformers, the service point will be at the termination of the serving electric utility's conductors, usually at the utility pole.* ◆ Figure 100–153

— *Michael Hamilton*

DEFINITIONS | From Michael Hamilton Publications

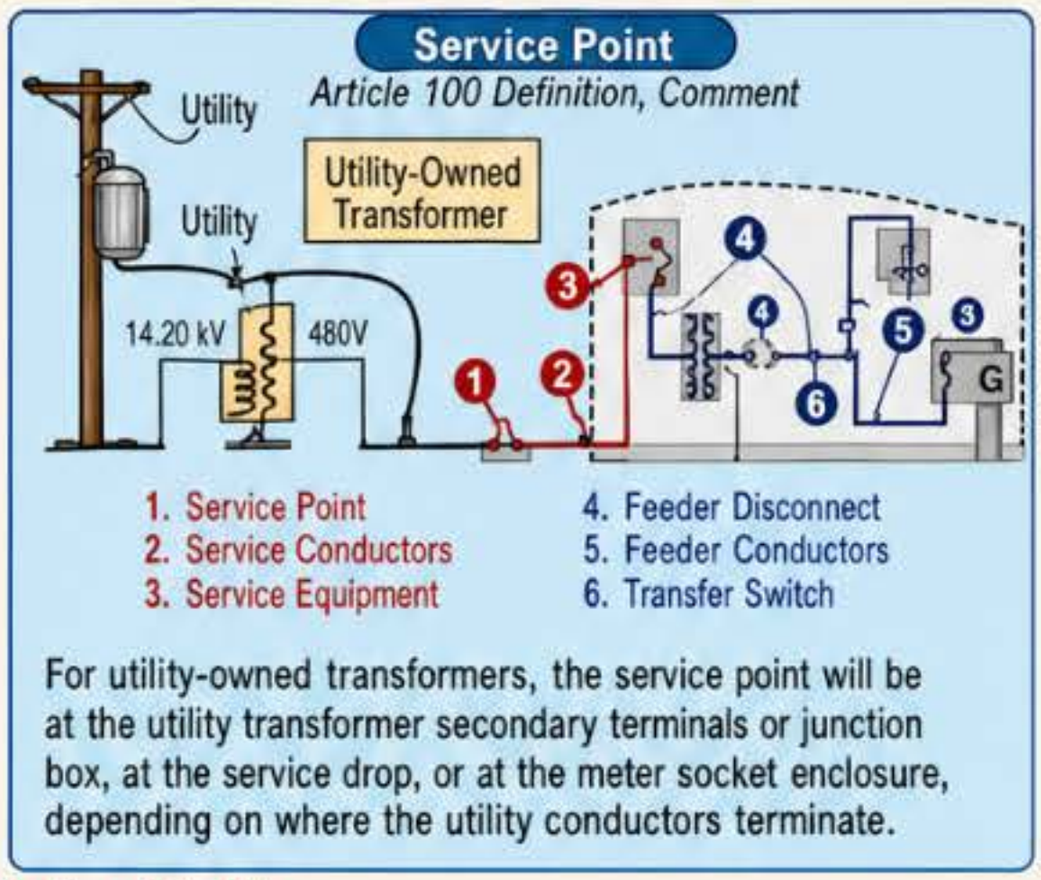


Figure 100–152

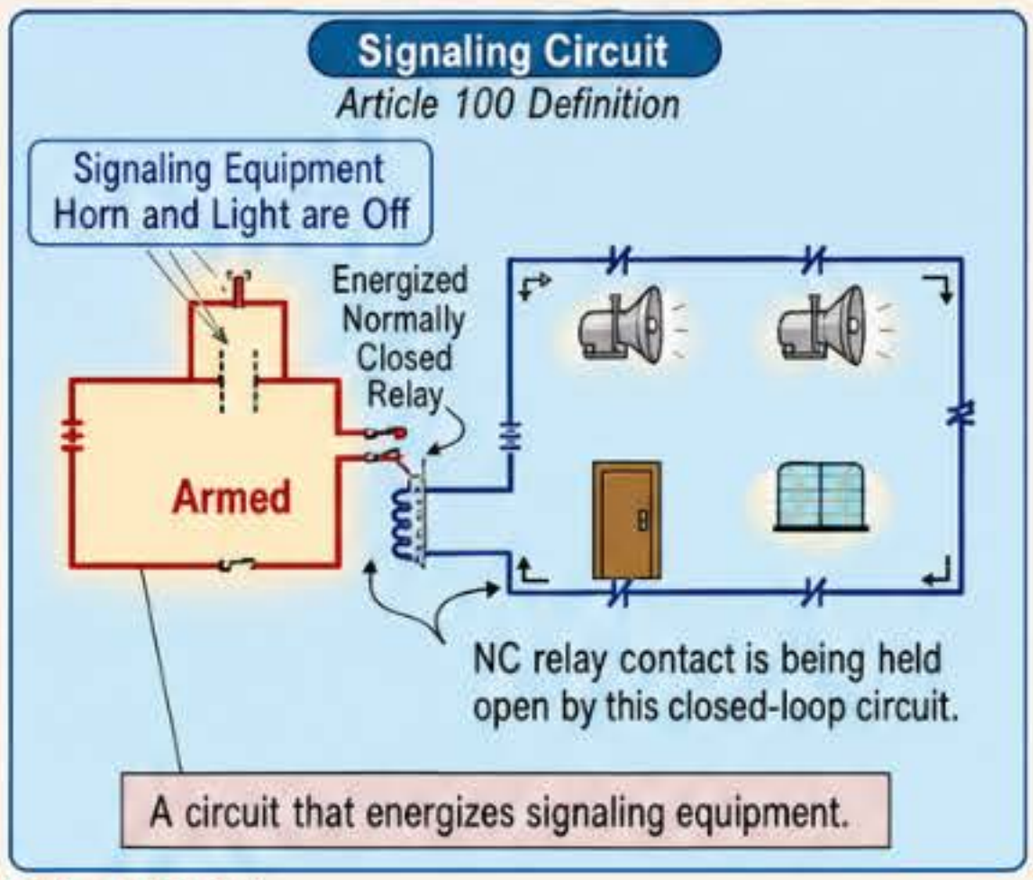


Figure 100–154

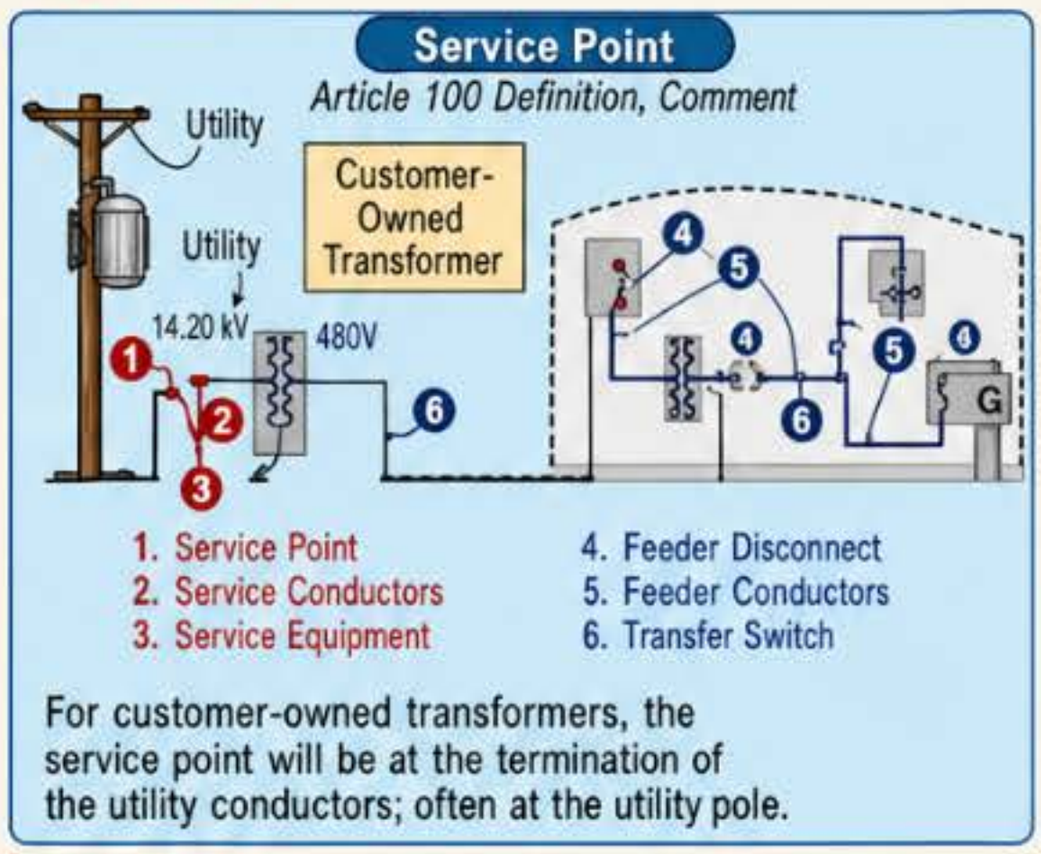


Figure 100–153

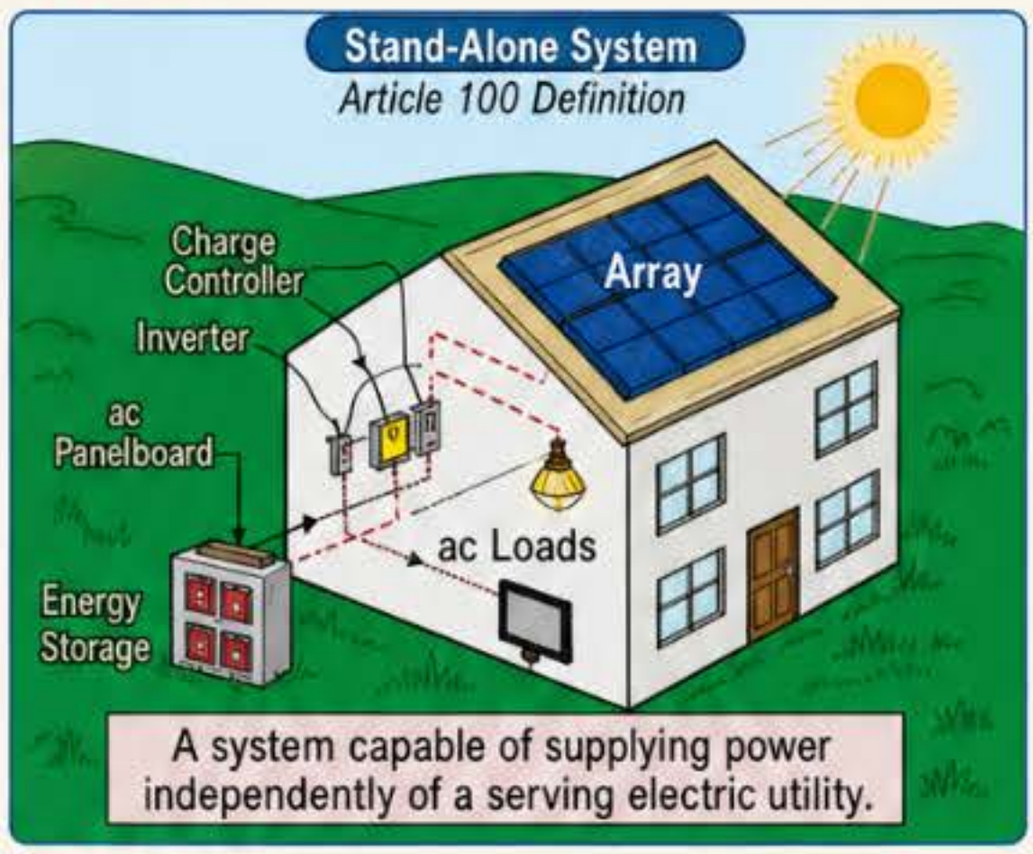


Figure 100–155

Short-Circuit Current Rating. The prospective symmetrical fault current at a nominal voltage to which electrical equipment can be connected without sustaining damage exceeding defined acceptance criteria.

Signaling Circuit [Article 725]. A circuit that energizes signaling equipment. Figure 100–154

Special Permission. Written consent from the authority having jurisdiction.

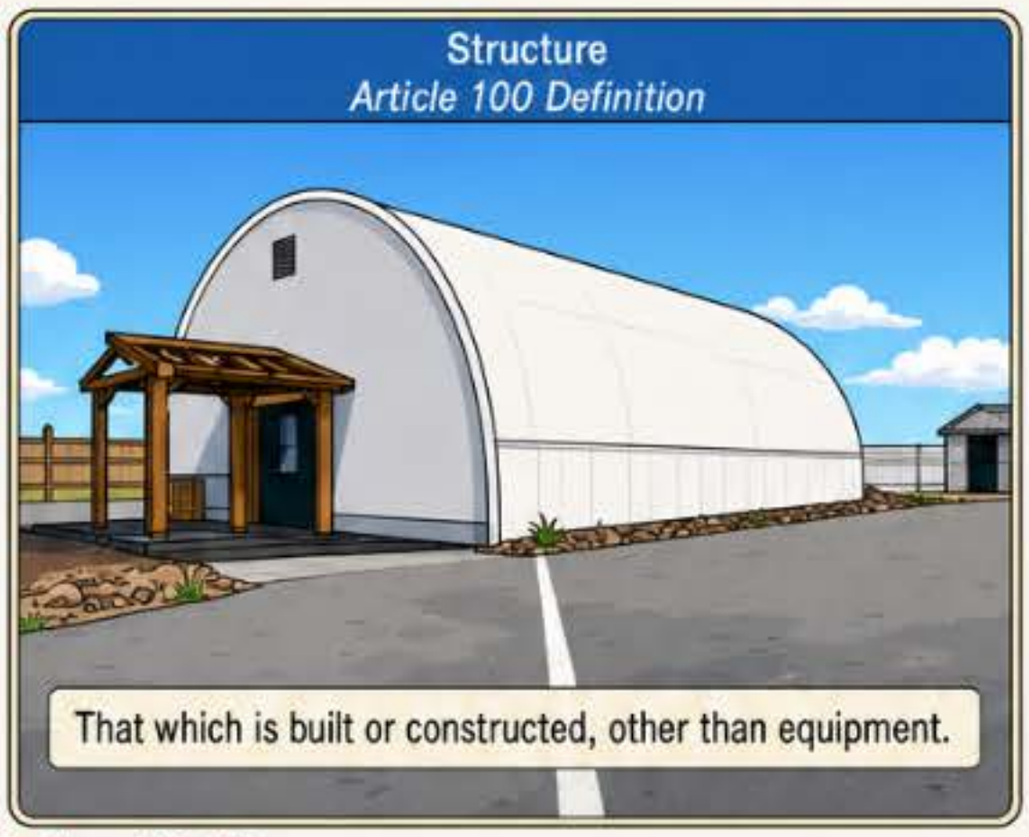
Author's Commentary:
See the definition of "Authority Having Jurisdiction."
— Michael Hamilton

Stand-Alone System. *A system capable of supplying power independently of a serving electric utility.* Figure 100–155

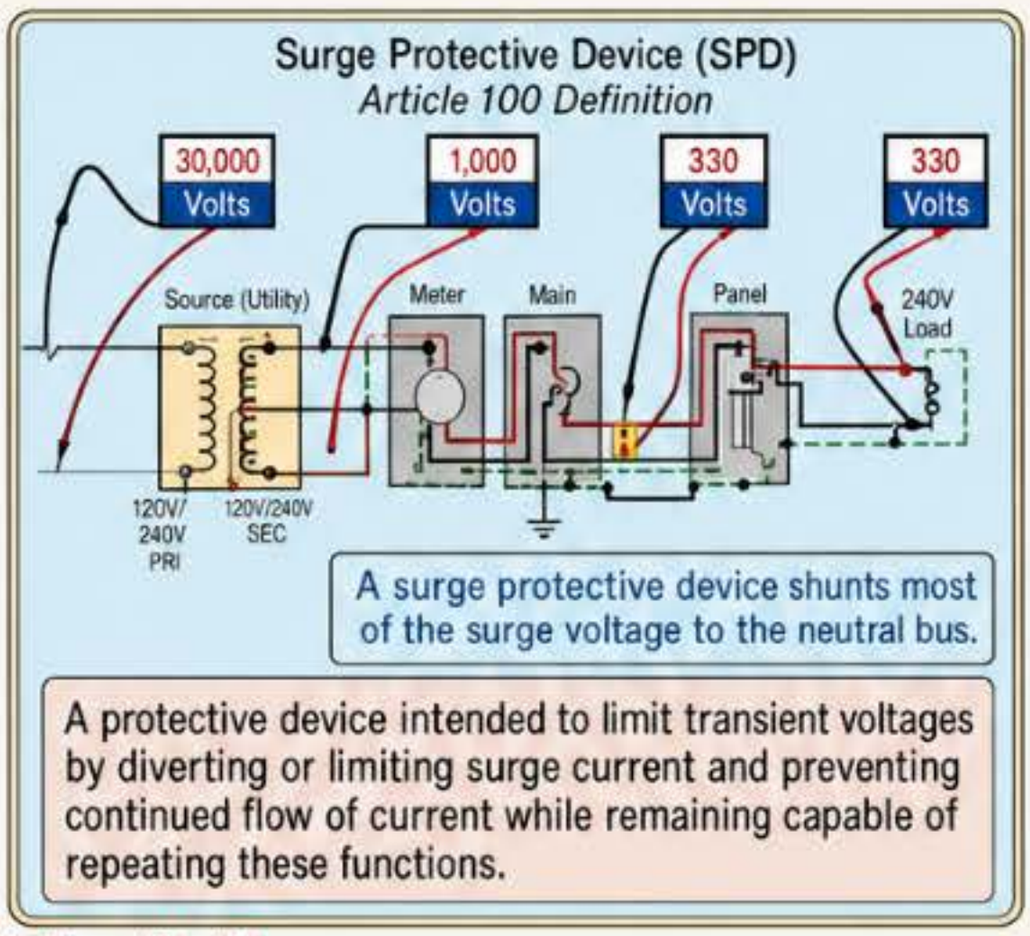
Author's Commentary:
Although stand-alone systems can operate independently of the serving electric utility, they may include a connection to the serving electric utility for use when not operating in stand-alone mode ("island mode").
— Michael Hamilton

Structure. That which is built or constructed, other than equipment. Figure 100–156

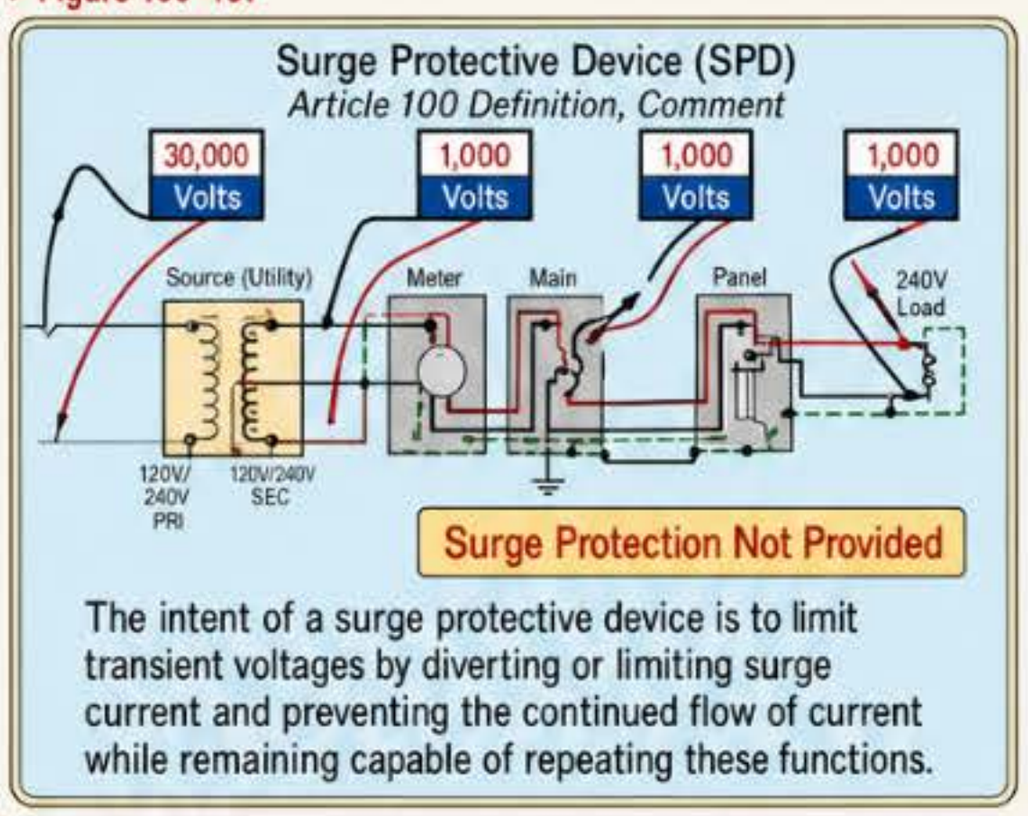
Surge-Protective Device. *A protective device intended to limit transient voltages by diverting or limiting surge current and preventing its continued flow while remaining capable of repeating these functions.* Figure 100–157 *and* Figure 100–158



▶ Figure 100–156

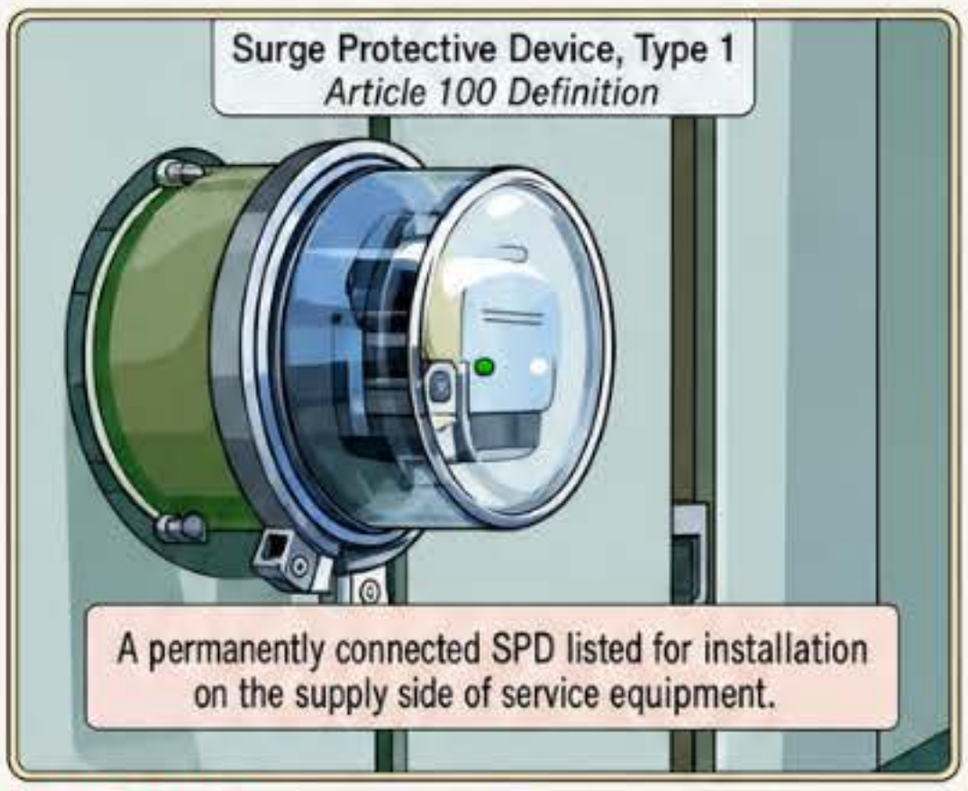


▶ Figure 100–157



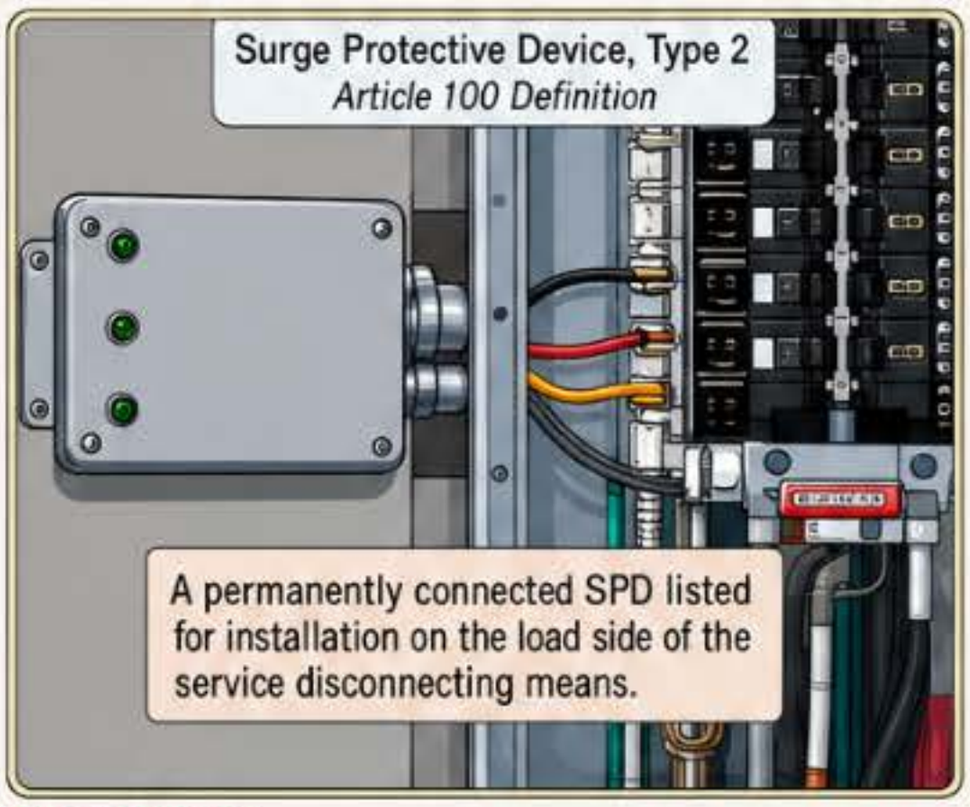
▶ Figure 100–158

Type 1. A permanently connected surge protective device listed for installation at or ahead of the service disconnect. ▶ Figure 100–159



▶ Figure 100–159

Type 2. A permanently connected surge protective device listed for installation on the load side of the service disconnect. ▶ Figure 100–160



▶ Figure 100–160

Type 3. A surge protective device listed for installation on branch circuits. ▶ Figure 100–161

Author's Commentary:

- Type 3 surge protective devices can be installed anywhere on the load side of branch-circuit overcurrent protection up to the equipment served, provided there is a conductor at least 30 feet long between the connection and the service or transformer [242.16].

— *Michael Hamilton*

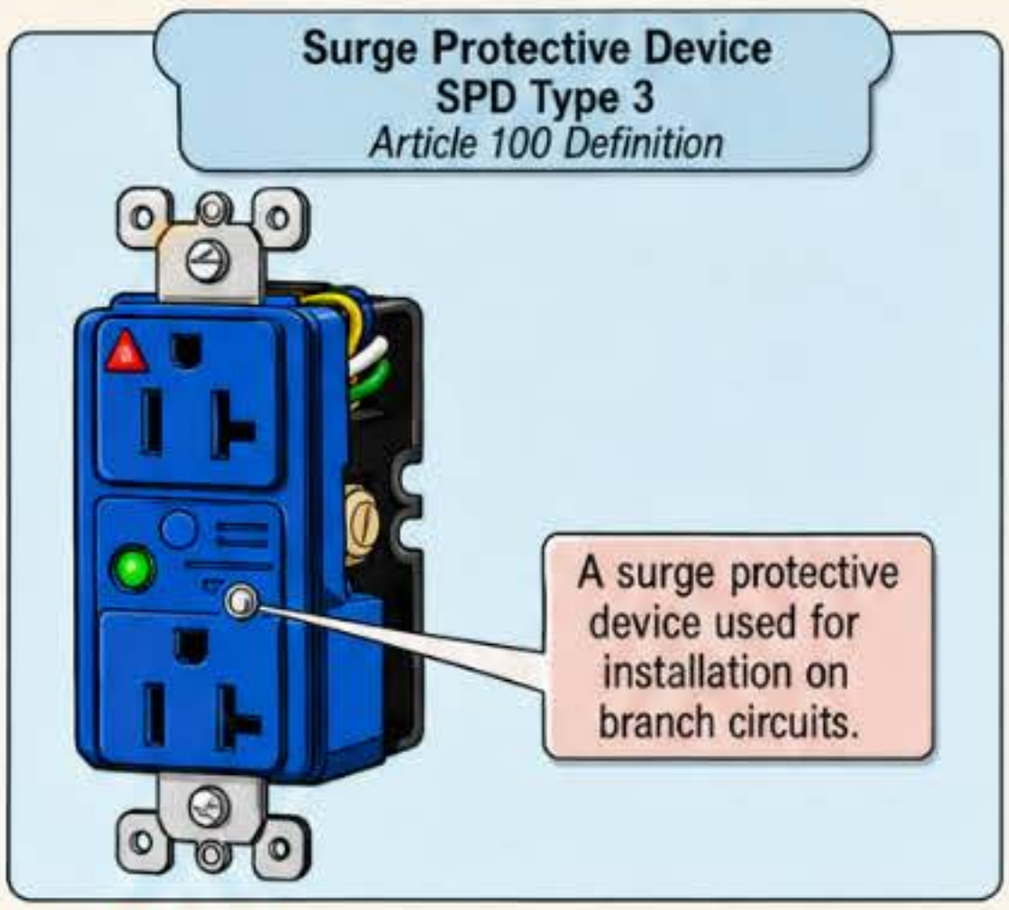


Figure 100–161

Type 4. A component surge protective device which includes those installed in receptacles and relocatable power taps (power strips).

Note: For additional information, see UL 1449, *Standard for Surge Protective Devices.*

Switch, General-Use Snap (General-Use Snap Switch). A switch constructed to be installed in a device box or a box cover.

Ungrounded System. A power-supply system not connected to earth (*ground*).

Figure 100–162

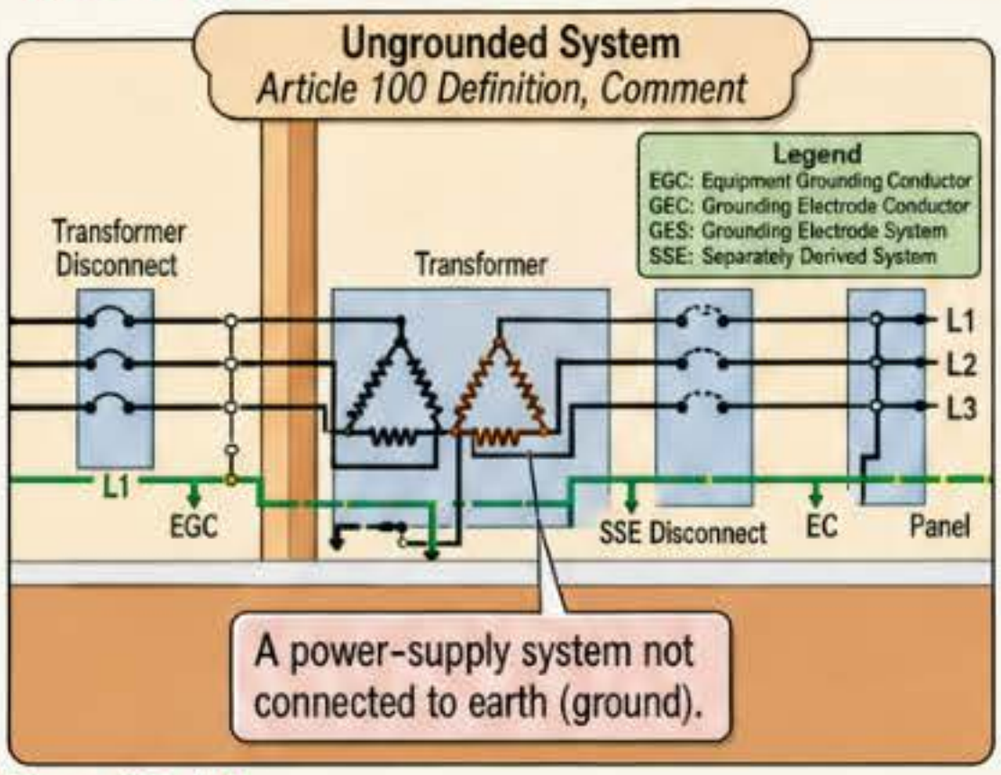


Figure 100–162

Author's Commentary:

Electrical systems may be ungrounded, but the enclosure still must be tied to Earth [250.4(B)].

— Michael Hamilton

Utilization Equipment. Equipment that uses electricity for electronic, electromechanical, chemical, heating, lighting, or other similar purposes.

Voltage of a Circuit. The root-mean-square (RMS) value that represents the greatest effective potential difference between any two conductors in the circuit.

Figure 100–163

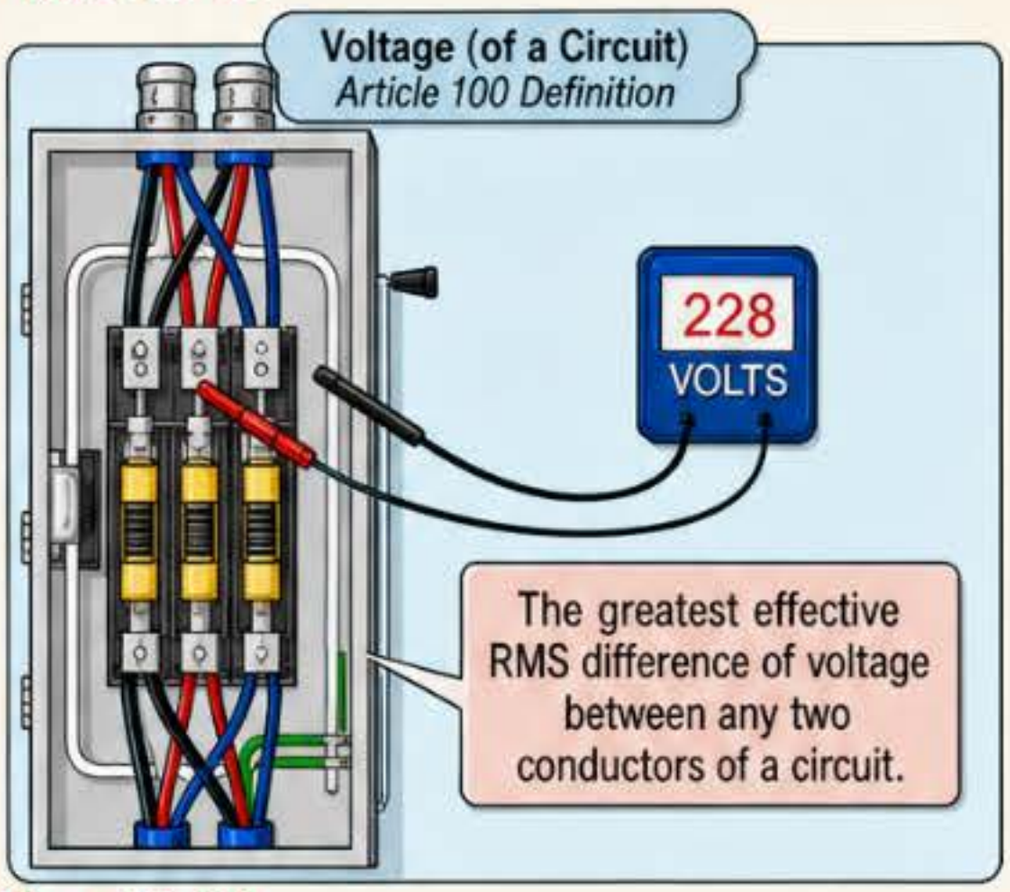


Figure 100–163

Voltage, Nominal (Nominal Voltage). A value assigned for conveniently designating voltage classes. Examples are 120/240V, 120/208V, or 277/480V [220.5(A)].

Figure 100–164

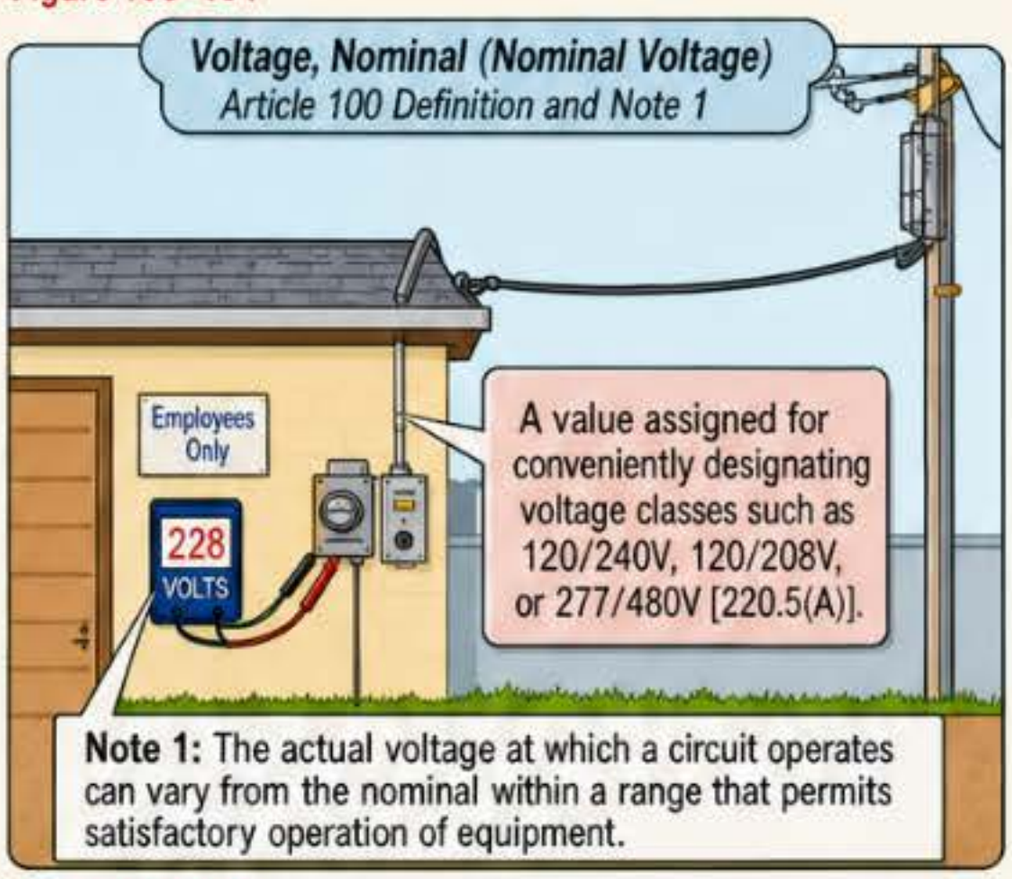


Figure 100–164

Note 1: The actual voltage at which a circuit operates can vary from the nominal within a range that allows *satisfactory operation of equipment.*

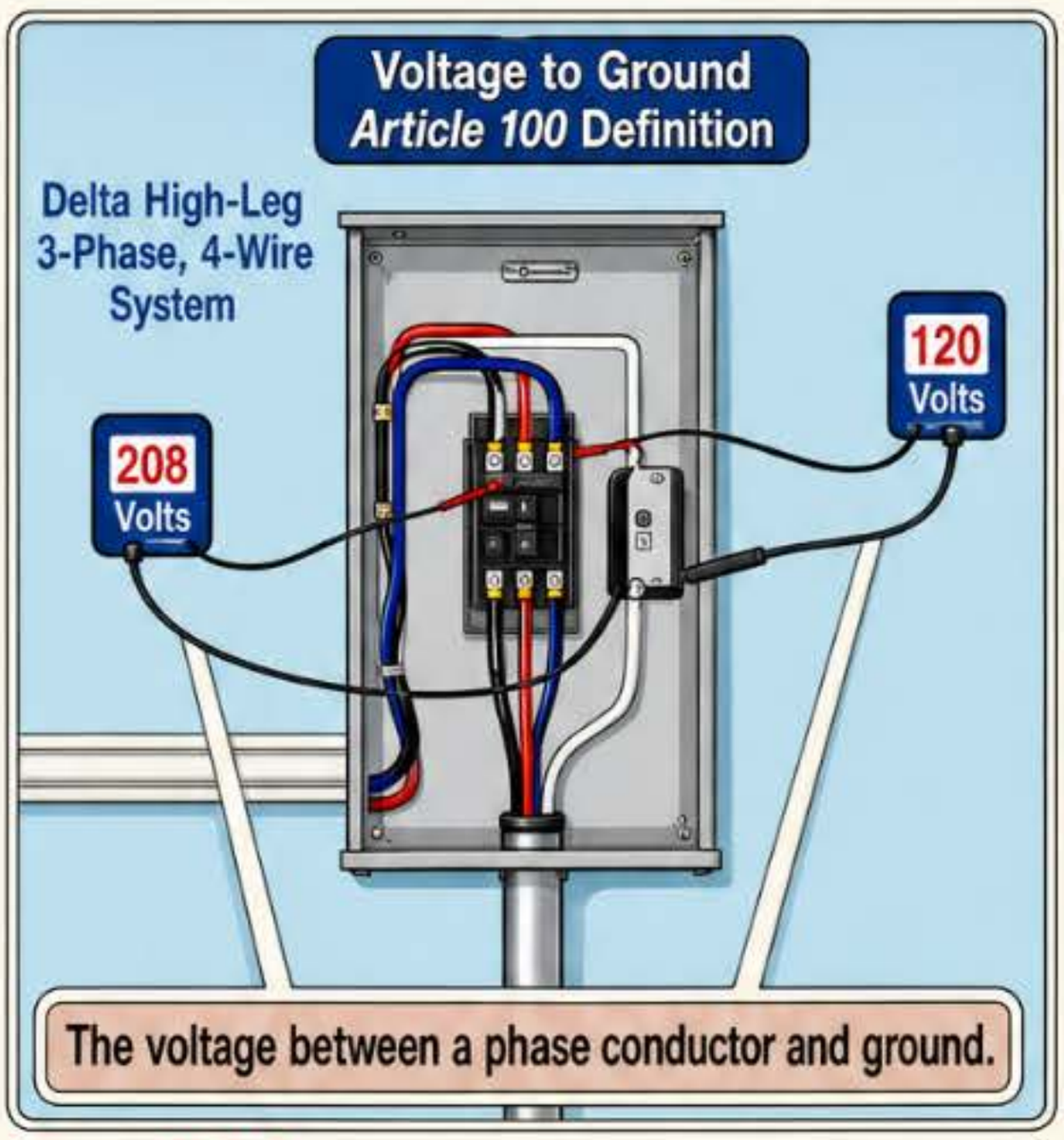
Author's Commentary:

Typical voltage designations for electrical apparatus include 115V, 120V, 208V, 230V, and 460V. The delivered power might be 240V, line-to-neutral, or any lower value, but never less than the equipment's normal nameplate rating.

– Michael Hamilton

Note 3: Some batteries are rated 48V dc nominal, even though their float (maintenance) voltage can be as high as 58V dc while charging.

Voltage to Ground. In an ungrounded system, this is the voltage measured between one phase conductor and earth/ground; most often it is the neutral conductor. ▶Figure 100–165



▶Figure 100–165

For ungrounded systems, the voltage to ground is the greatest difference in RMS voltage between any two phase conductors.

Watertight. Built so liquid will not penetrate the enclosure when tested.

Weatherproof. Constructed or protected to resist the weather without impairing proper operation.

Author's Commentary:

Article 100 now contains a new *Part III that defines terms related to hazardous (classified) locations. A number of those terms are new to the Code, while others were moved from Chapter 5 into this new section.*

– Michael Hamilton

ARTICLE 110 REQUIREMENTS FOR ELECTRICAL INSTALLATIONS

Introduction to Article 110—Requirements for Electrical Installations

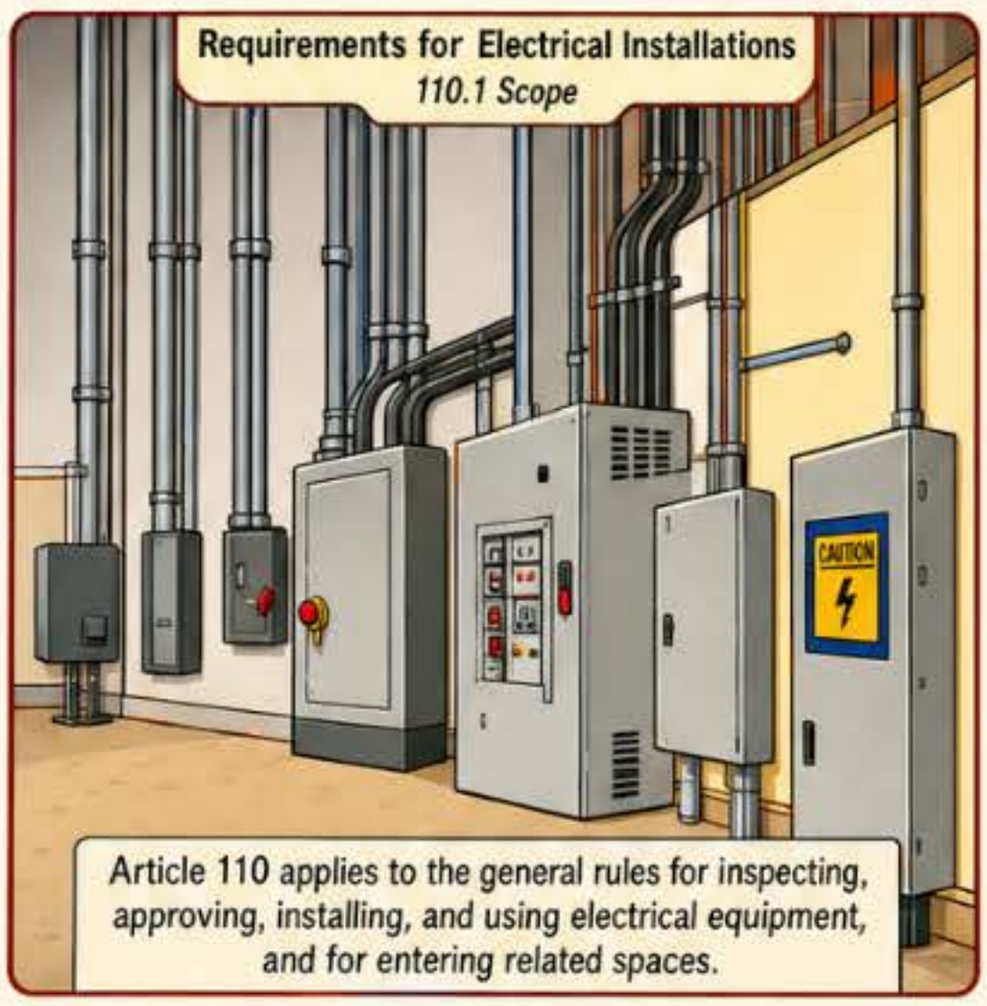
Article 110 lays the groundwork for how the rest of the *NEC* is carried out. Grasping this article fully is essential because it provides the base for much of the *Code*. As you read and master Article 110, you are setting the stage for correct and compliant application of the *NEC*. The purpose of the *National Electrical Code* is to promote a safe installation, and this article places special emphasis on investments of time, effort, and resources to ensure that installations are suitable for the installer and for those who maintain and operate them.

Part I. General Requirements

110.1 Scope

This section describes the overall requirements for inspecting, approving, installing, and using electrical equipment, and for accessing spaces associated with electrical installations.

▶ Figure 110-1



▶ Figure 110-1

Author's Commentary:

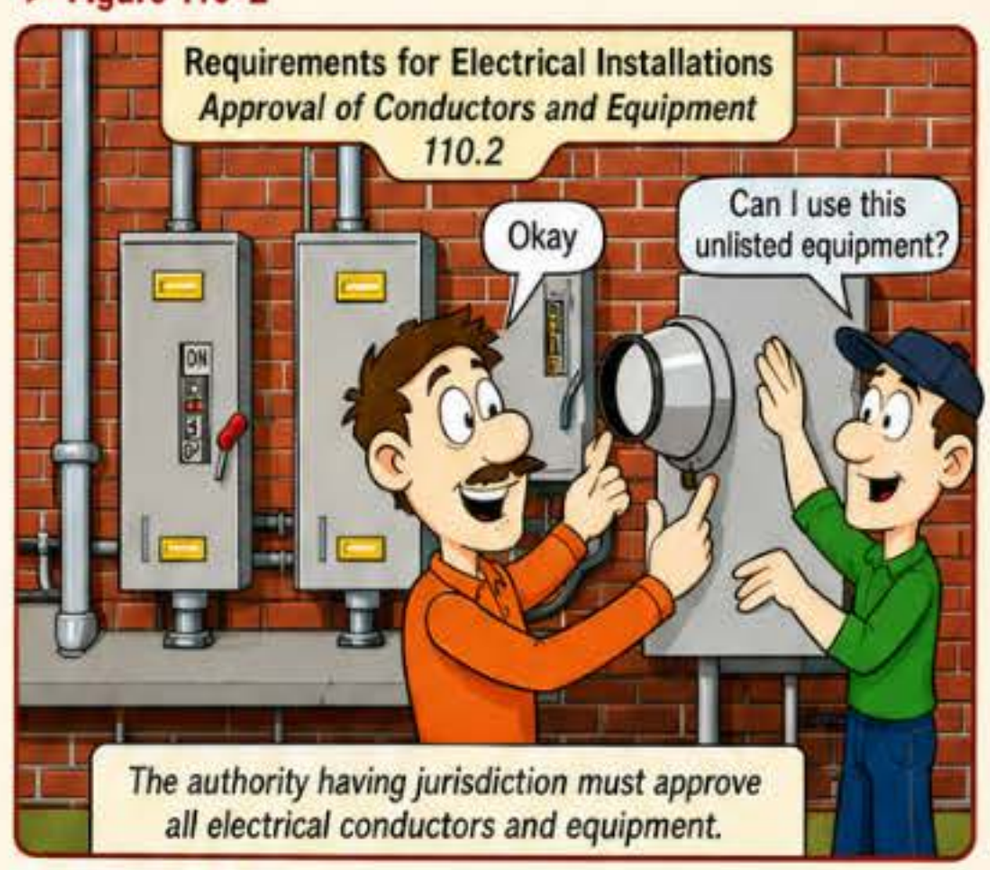
People with disabilities may need a variety of provisions, such as specific mounting heights for switches and receptacles, and clearances that allow objects like wall sconces to project from a wall.

— Michael Hamilton

110.2 Approval of Conductors and Equipment

The organization responsible for enforcing electrical codes must sign off on the conductors and equipment.

▶ Figure 110-2



▶ Figure 110-2

Note: Consult Annex J for details on accessibility design for people with disabilities (*ADA*).

Author's Commentary:

To build a solid understanding of product approval, carefully study 90.4, 90.7, and 110.3 along with the definitions of "Approved," "Identified," "Labeled," and "Listed" in Article 100.

— Michael Hamilton

110.3 Use and Product Listing (Certification) of Equipment

(A) Guidelines for Approval. Authorities having jurisdiction must approve equipment. When doing so, they must take into account the following:

(1) Suitability for installation and use in accordance with the *NEC*

Note 1: Equipment can be new, reconditioned, refurbished, or remanufactured.

Note 2: Suitability of equipment can be determined by a product description, or by other information that shows the product is appropriate for its intended purpose, the environment in which it will be used, or any application. Special conditions of use or other limitations may be indicated on the equipment, in the product instructions, or in the information provided by the manufacturer through a private marking or labeling system. Suitability of equipment can be shown through listing or labeling.

(2) Mechanical strength and durability

(3) Wire-bending and connection space

(4) Electrical insulation

(5) Heating effects under all conditions of use

(6) Arcing effects

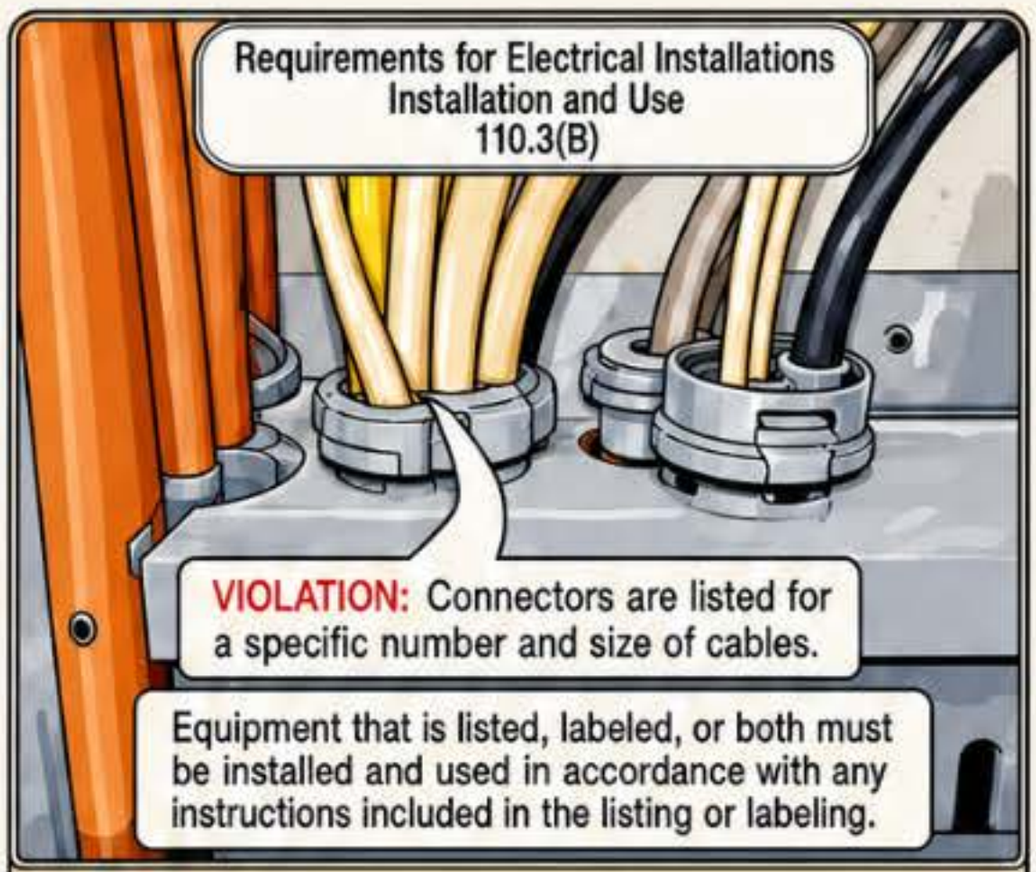
(7) Classification by type, size, voltage, current capacity, and specific use

(8) Other factors that affect the practical safety of people who are using or may contact the equipment

(B) Installation and Use. Equipment that is listed, labeled, or both must be installed and used according to the included instructions for installation and use. Figure 110-3

(C) Product Listing. Product testing, evaluation, and listing must be performed by a qualified testing laboratory that evaluates products to standards that ensure effective safety and compliance with the *NEC*.

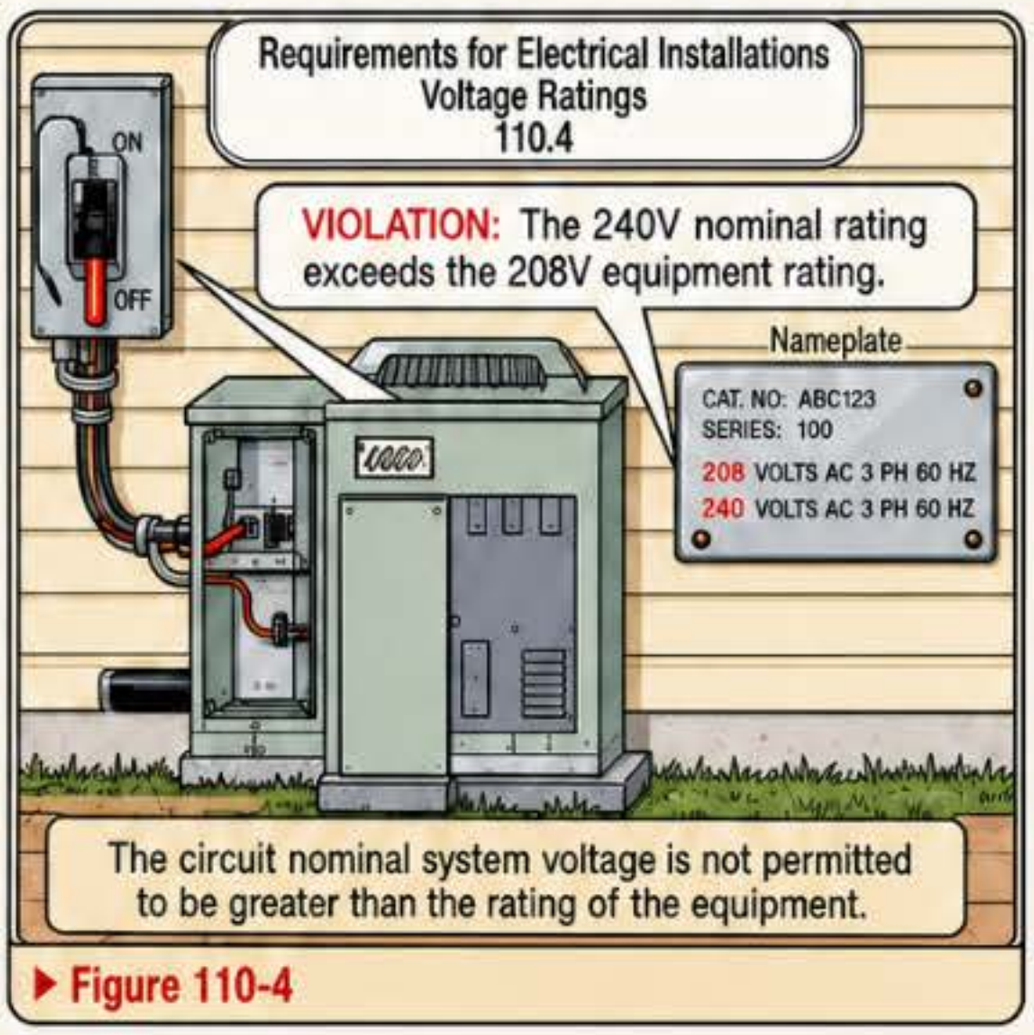
Note: OSHA recognizes qualified electrical testing laboratories that certify products as meeting recognized electrical standards.



▶ Figure 110-3

110.4 Voltage Rating of Electrical Equipment

The circuit nominal system voltage is not permitted to be greater than the rating of the equipment. Figure 110-4



▶ Figure 110-4

110.5 Conductor Material

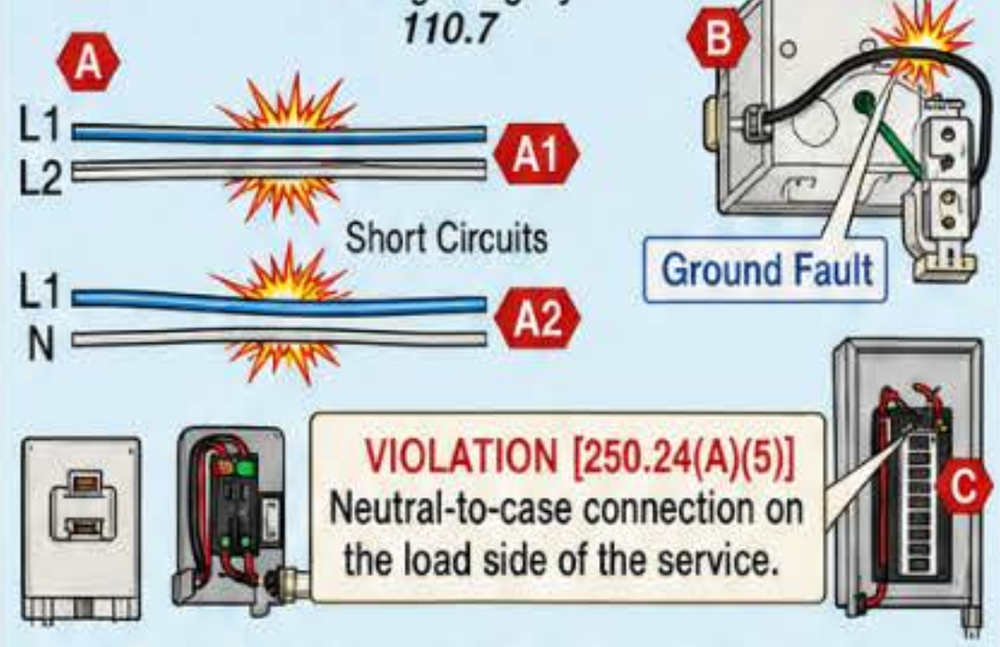
Conductors must be copper, aluminum, or copper-clad aluminum unless otherwise provided in this *Code*; and when the conductor material is not specified in a rule, the sizes given in the *NEC* are based on a copper conductor. Figure 110-5

Requirements for Electrical Installations, Conductor Material
110.5

Conductors must be copper, aluminum, or copper-clad aluminum unless stated otherwise in the *NEC*. When conductor material is not specified, the *Code* rule is based on copper.

▶ Figure 110-5

Requirements for Electrical Installations
Wiring Integrity
110.7



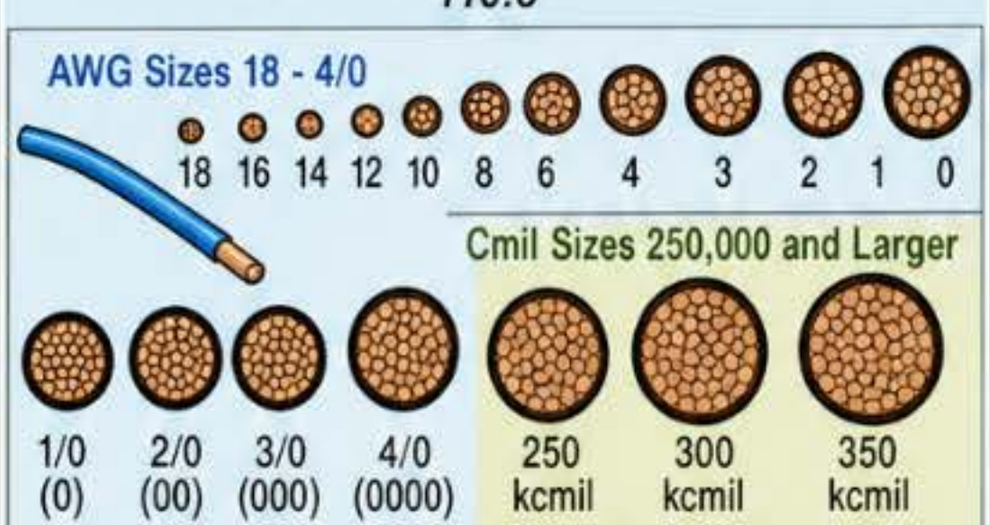
Electrical installations must be free from short circuits, ground faults, or any connections to conductive metal parts unless required or permitted by the *Code*.

▶ Figure 110-7

110.6 Conductor Sizes

Conductor sizes are expressed in American Wire Gage (AWG) or circular mils (cmil). ▶ Figure 110-6

Requirements for Electrical Installations, Conductor Sizes
110.6



Conductors 18 through 4/0 are American Wire Gauge (AWG).

Conductors 250 and larger are circular mils (for example 250,000 cmil or 250 kcmil).

▶ Figure 110-6

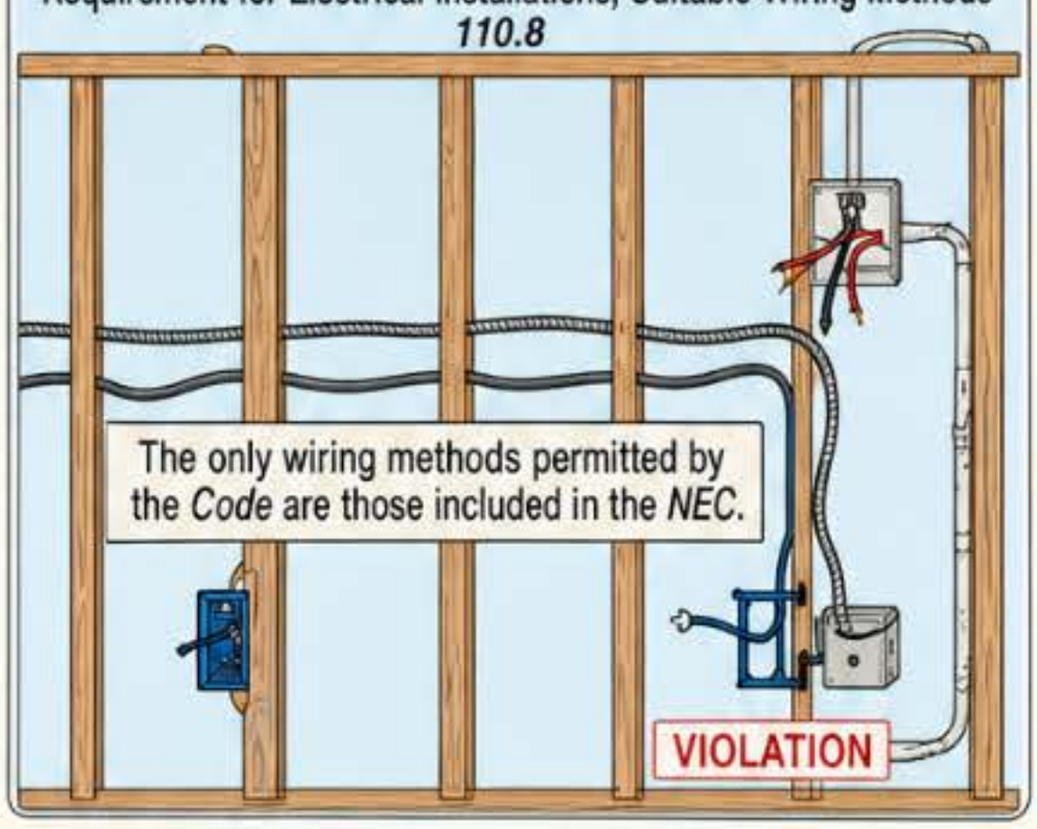
110.7 Wiring Integrity

Electrical installations must be free from short circuits, ground faults, or any connections to conductive metal parts unless required or permitted by the *Code*. ▶ Figure 110-7

110.8 Suitable Wiring Methods

The only wiring methods permitted by the *NEC* are those included in the *Code*. ▶ Figure 110-8

Requirement for Electrical Installations, Suitable Wiring Methods
110.8



▶ Figure 110-8

Author's Commentary:

Study Chapter 3 for power and lighting wiring methods; Chapter 7 for signaling, remote-control, and power-limited circuit wiring methods; and Chapter 8 for communications circuits wiring methods.

— Michael Hamilton

110.9 Requirements for Electrical Installations

110.9 Interrupting Rating (Overcurrent Protective Devices)

Every overcurrent protective device—such as circuit breakers and fuses—must be able to safely interrupt a fault current. Its interrupting rating (AIC) has to be equal to or greater than the fault current that can be delivered at the line terminals of the equipment.

See Figure 110-9.

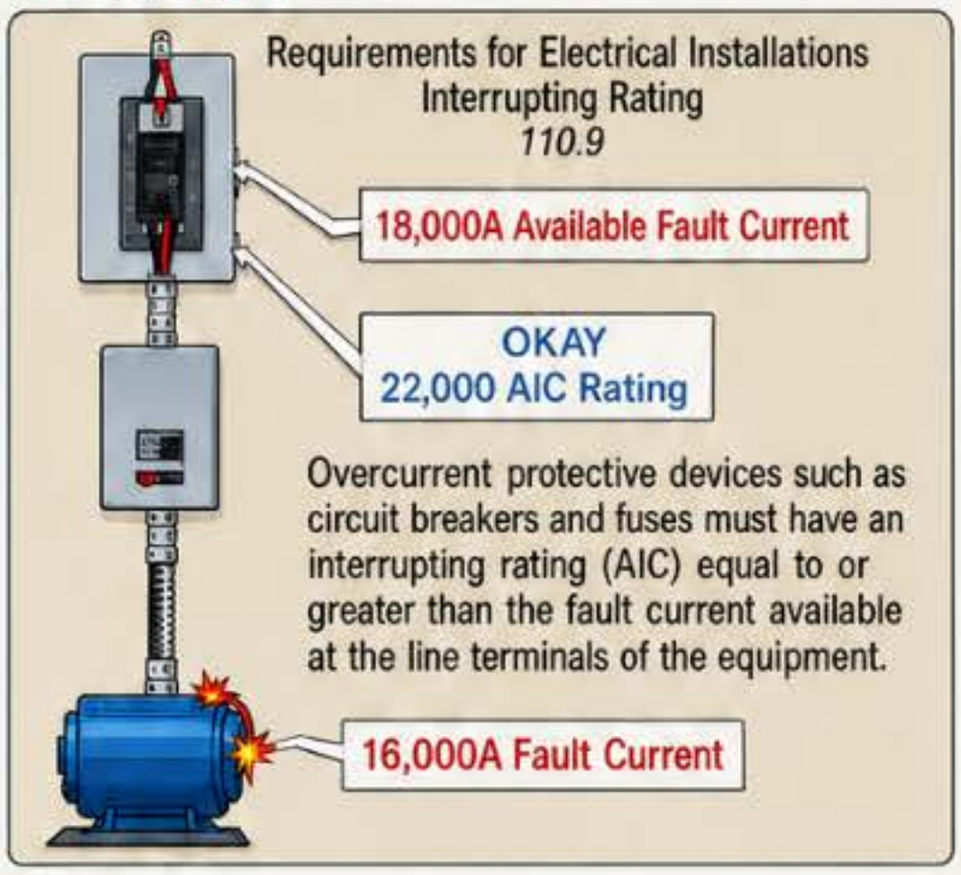


Figure 110-9

Author's Commentary:

- *Article 100 defines "interrupting rating" as the highest short-circuit current, at the rated voltage, that a device can safely open under specified test conditions.*
- *Interrupting ratings are also called "Ampere Interrupting Rating" (AIR) or "Ampere Interrupting Capacity" (AIC).*
- *If not otherwise marked, the ampere Interrupting rating for circuit breakers is 5,000A [240.83(C)], and for fuses it is 10,000A [240.60(C)(3)].* See Figure 110-10.

— Michael Hamilton

110.10 Equipment Short-Circuit Current Rating

Electrical equipment must be marked with a short-circuit current rating that indicates it can safely open due to a short circuit or ground fault without causing extensive damage to the equipment.

The regulations listed below apply when this requirement is present. See Figures 110-11 and 110-12.

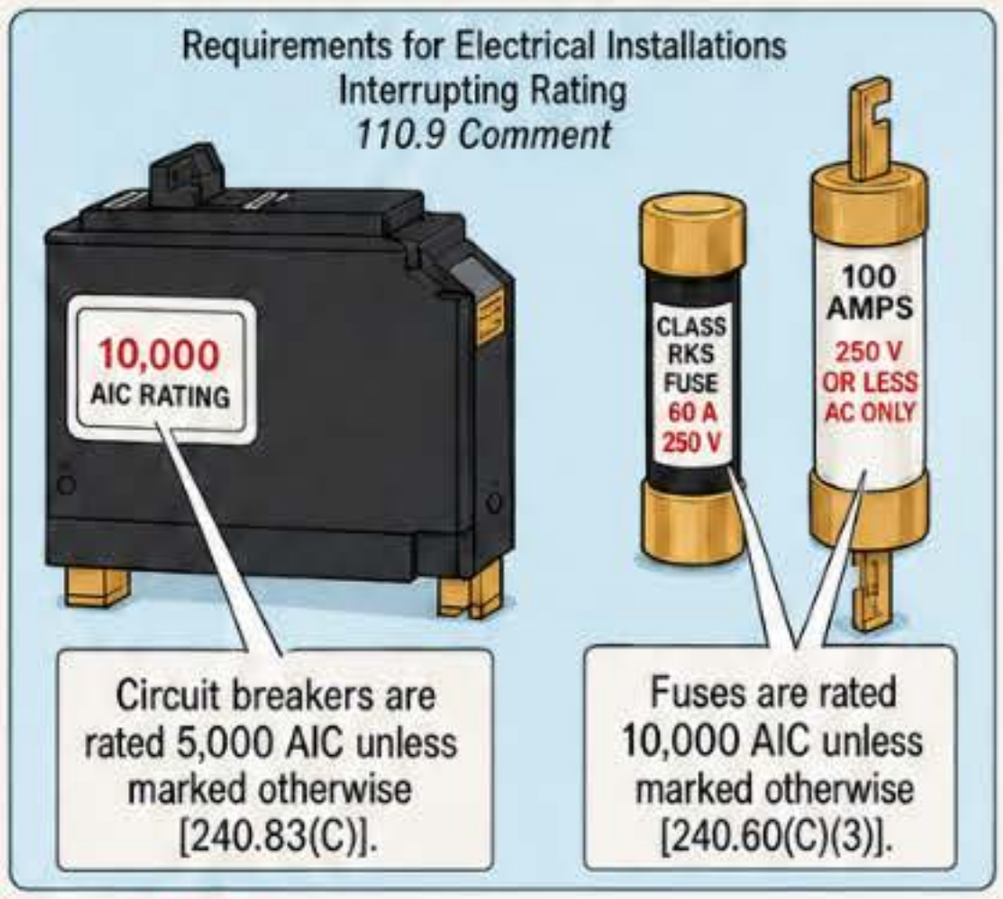


Figure 110-10

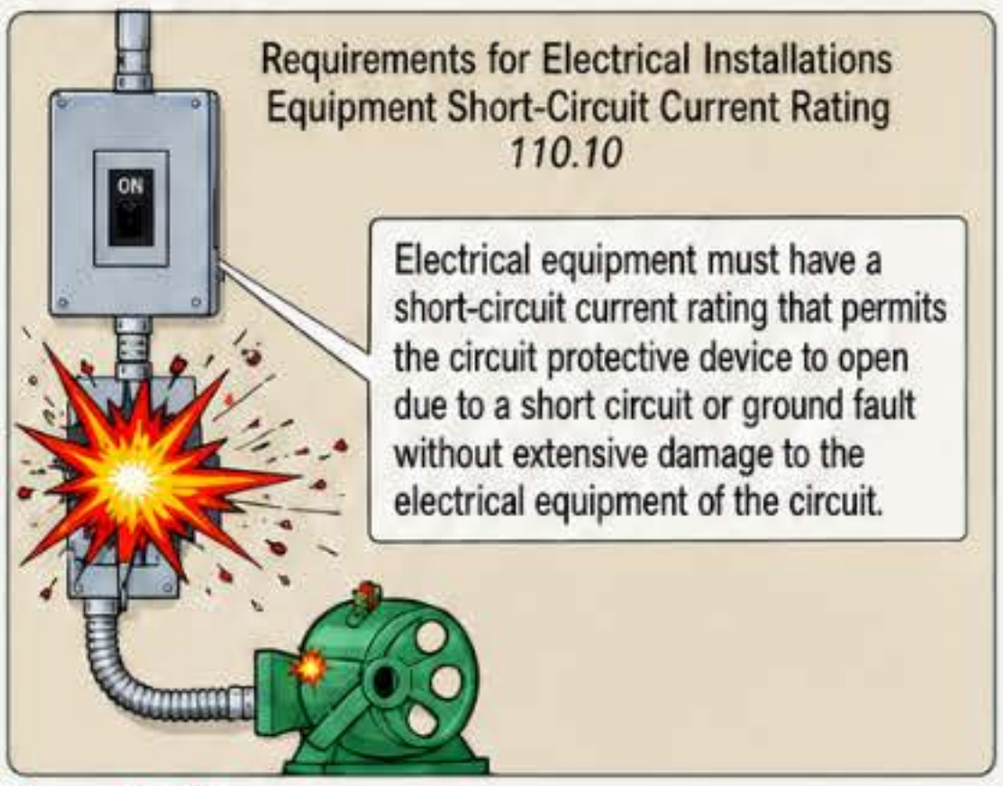


Figure 110-11

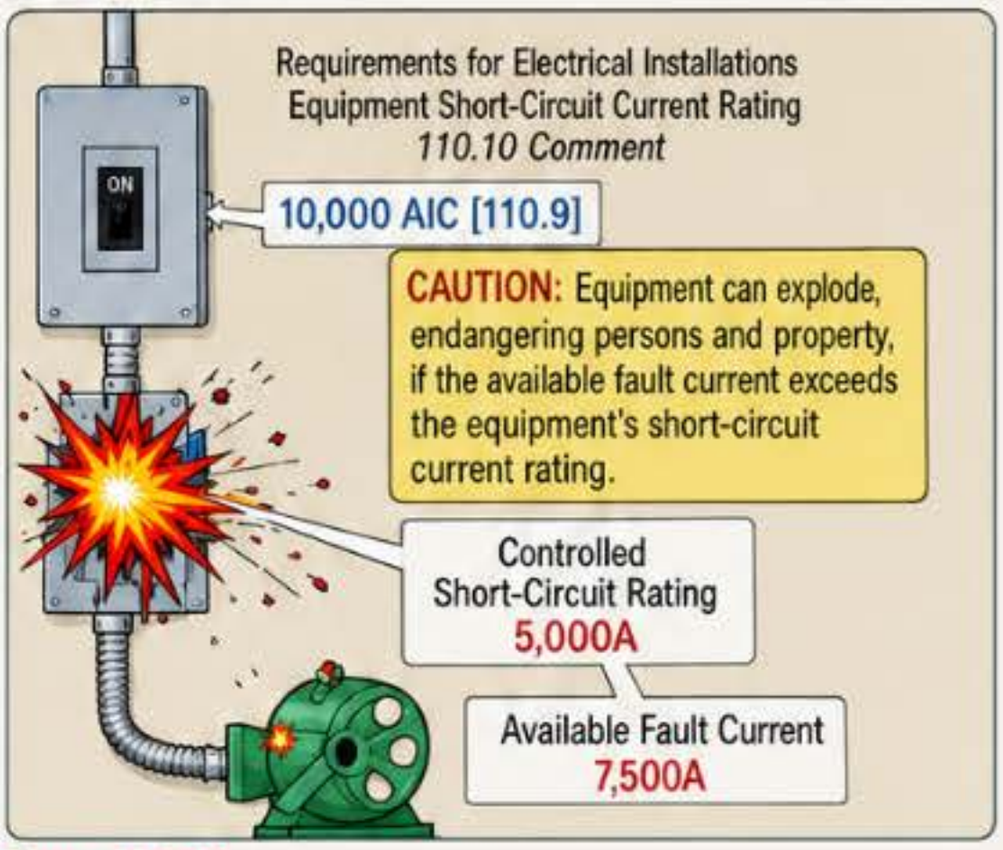


Figure 110-12

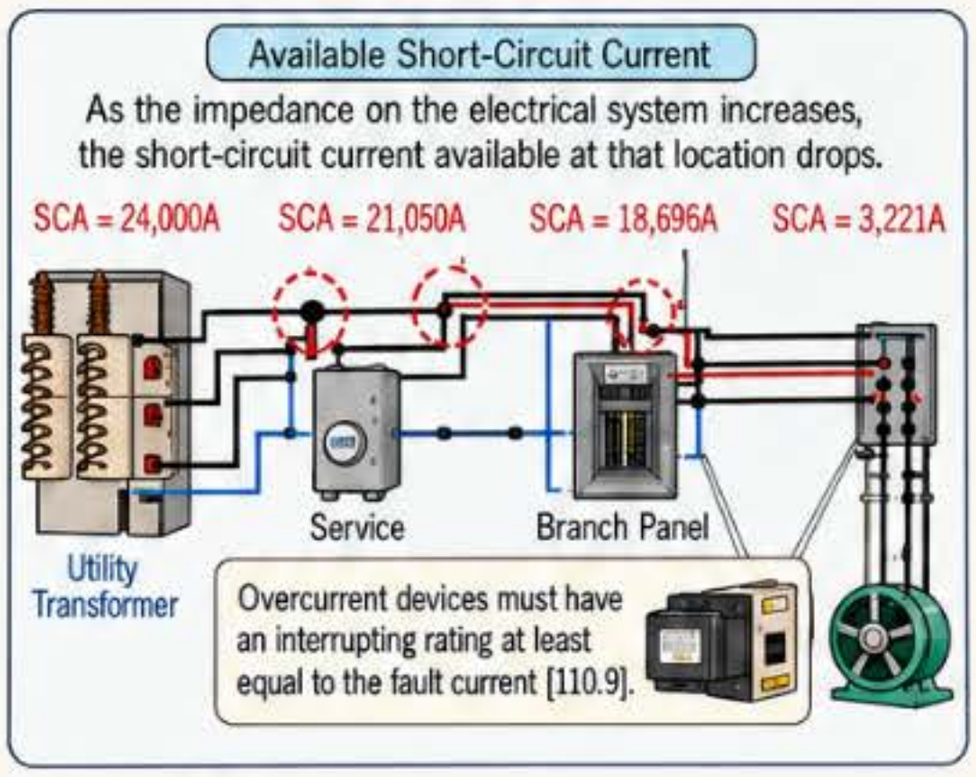
Available Short-Circuit Current

Sections 110.9 and 110.10 use related terminology, which can make the meaning a bit tricky. Read carefully to avoid mixing up "interrupting rating" with "short-circuit rating."

Available short-circuit current is the current, in amperes, that would be present at a specific point in an electrical system. This value is determined at the secondary terminals of the serving utility's transformer, as calculated by the utility engineer. Once the utility installs its equipment at the customer side and the service conductors are connected, the panelboards and other devices throughout the facility are linked through many connections supplied by the utility.

Beginning at the transformer secondary terminals, the available short-circuit current decreases at every downstream connection point in the electrical system.

At any location, the available short-circuit current depends on the impedance of the circuit serving that point. As the circuit impedance gets larger, the available short-circuit current becomes smaller. ▶ Figure 110–13

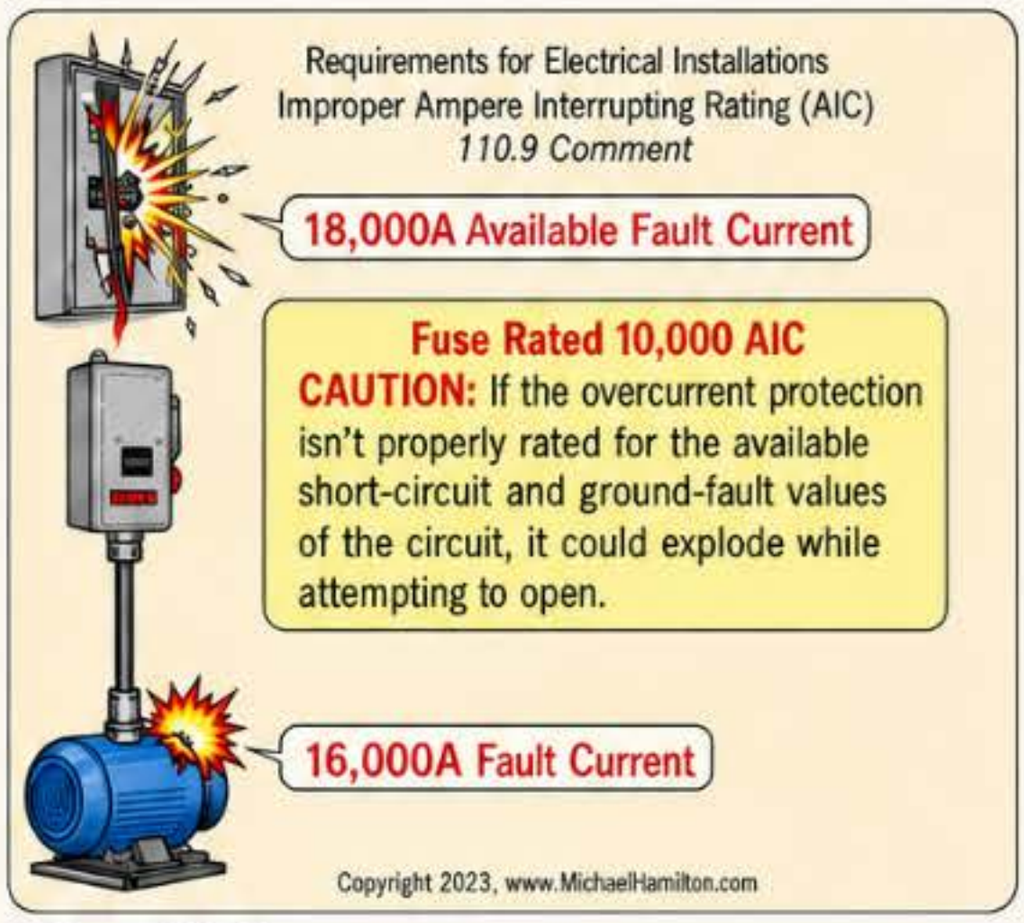


▶ Figure 110–13

Factors that affect the available short-circuit current at the serving electric utility transformers include the system voltage, the transformer kVA rating, and the impedance. *Properties that influence the circuit impedance include the conductor material (copper vs. aluminum), the conductor size, conductor length, the cable type (metallic vs. nonmetallic), the ambient temperature, and the motor loads.*

Caution

Extremely high levels of current from short circuits or ground faults create severe thermal and magnetic forces. If an overcurrent protective device is unable to quickly clear the fault current at the available fault level, it can explode and scatter hot metal parts that may cause serious injury or death, along with extensive damage to electrical components and the entire system. ▶ Figure 110–14



▶ Figure 110–14

110.11 Deteriorating Agents

Electrical equipment and conductors must be appropriate for the environmental conditions in which they are installed and used. In addition to considering corrosive gases, fumes, vapors, liquids, and other substances in the atmosphere, also account for how those conditions may affect both the wiring system and the equipment. ▶ Figure 110–15

Note 1: Raceways, cable trays, cablebus, cable armor, junction boxes, cable sheathing, cabinets, enclosures, couplings, fittings, supports, and mounting hardware must be suitable for the environment they are installed in; see 300.6. ▶ Figure 110–16

Note 2: Certain cleaning and lubricating materials include chemicals that can damage plastic components.

Note 3: *For enclosure type designations, refer to Table 110.28 for the NEC 2023 enclosure-type classifications.*

Note 4: *For minimum flood protection requirements, see the International Building Code (IBC) and the International Residential Code (IRC).*

110.12 | Requirements for Electrical Installations

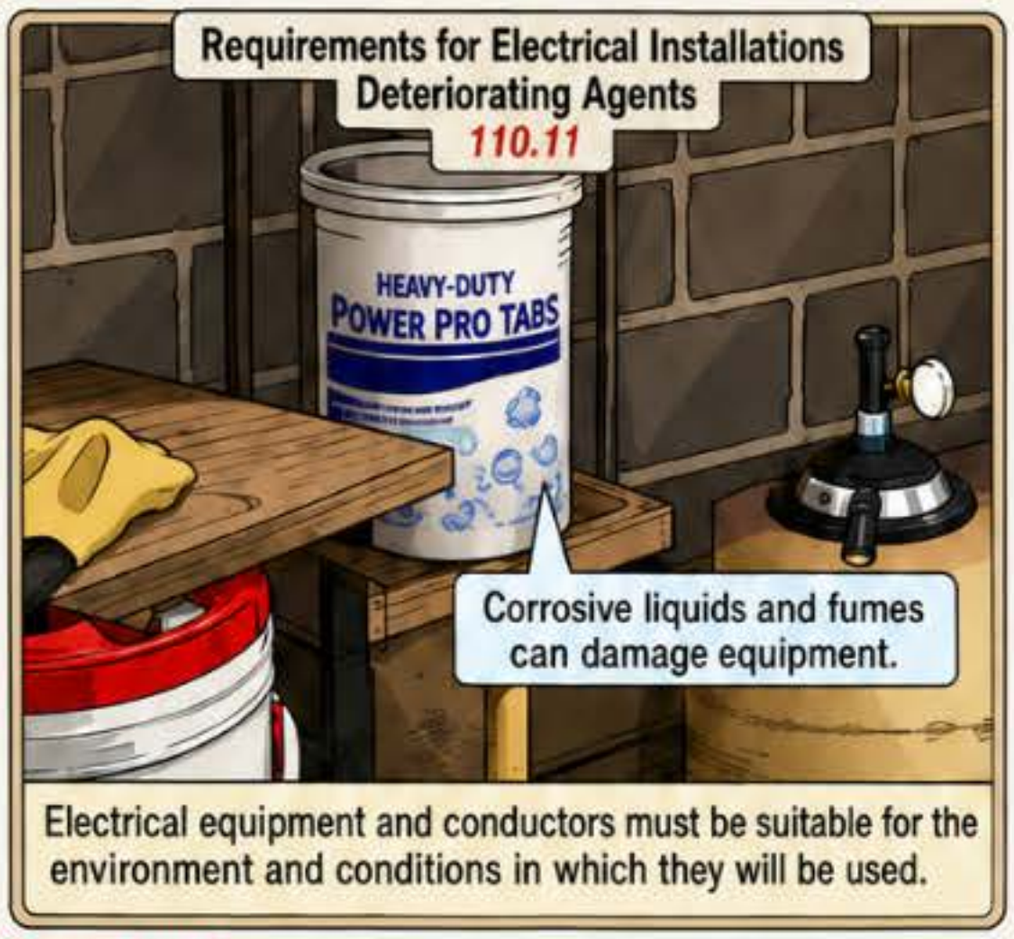


Figure 110-15

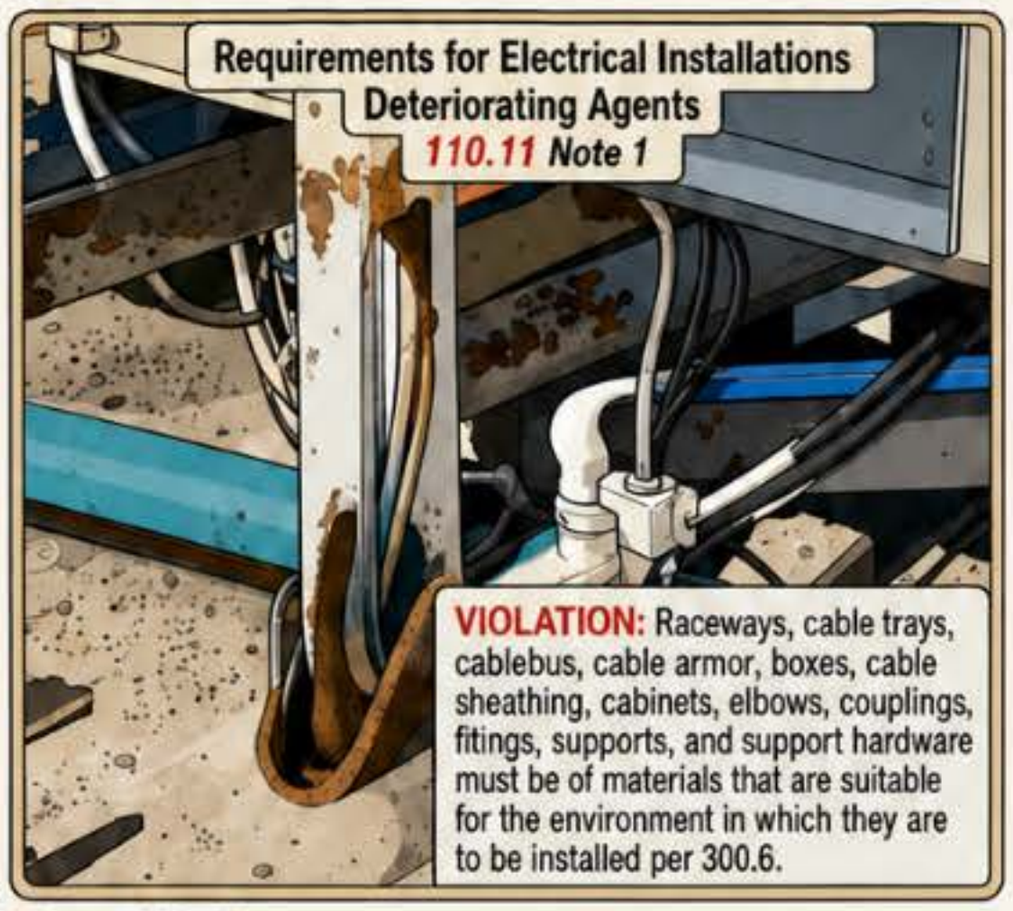


Figure 110-16

110.12 Mechanical Execution of Work

Electrical equipment must be installed in a neat and workmanlike manner. ▶ Figure 110-17

Author's Commentary:

- *This rule is likely one of the most broad-reaching requirements in the Code, and applying it often comes down to professional judgment made by the authority having jurisdiction.*

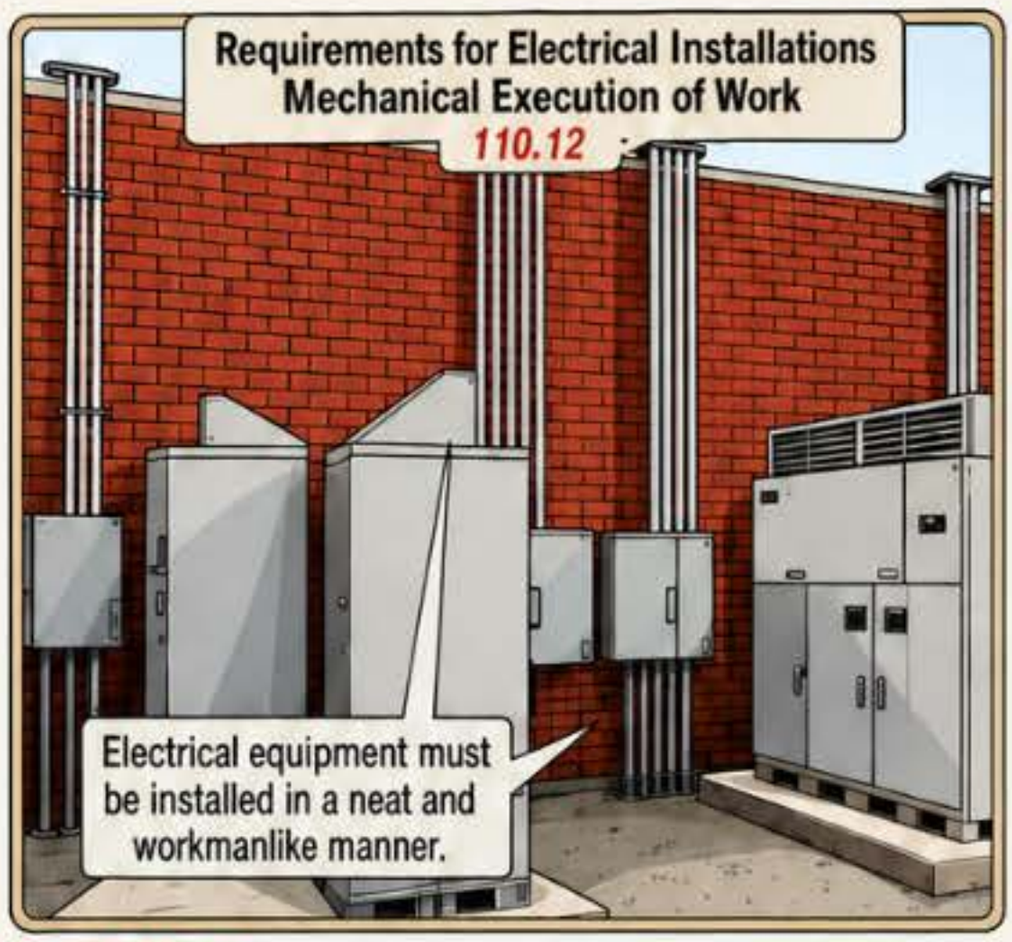


Figure 110-17

Author's Commentary:

- *The National Electrical Contractors Association (NECA) developed a set of National Electrical Installation Standards (NEIS)® that serve as the industry's primary reference for electrical installation practices. These standards set a benchmark (baseline) for both quality and workmanship in the installation of electrical equipment and systems. They describe what it means to install equipment in a "neat and workmanlike manner" and outline how to achieve it.*

  To learn more about these standards, visit www.NECA-NEIS.org.

(A) Unused Openings. Any openings that are not in use must be closed with fittings that offer protection equal to the wall that surrounds the equipment. ▶ Figure 110-18

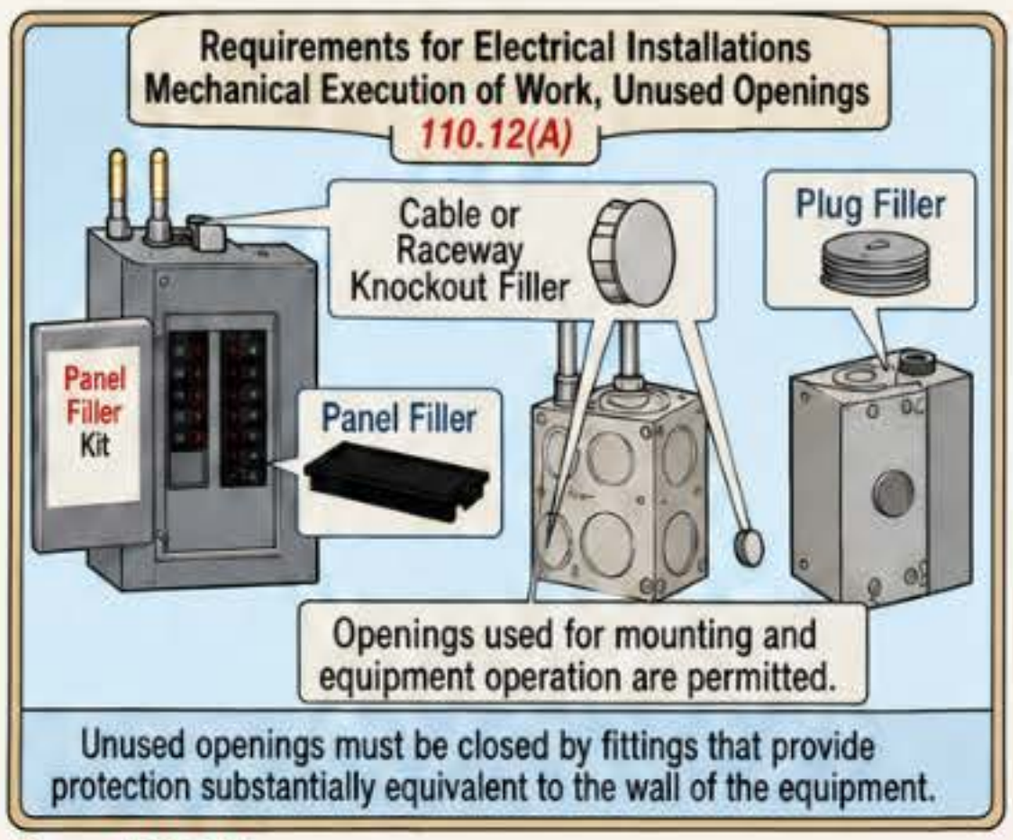


Figure 110-18

Requirements for Electrical Installations 110.12

(B) Integrity of Electrical Equipment. Internal components of electrical equipment must be free from damage and must not be polluted or contaminated by outside material. This includes paint, plaster, cleaning agents, and similar substances. See **Figure 110–19.**

Requirements for Electrical Installations, Mechanical Execution of Work, Integrity of Electrical Equipment *110.12(B)*

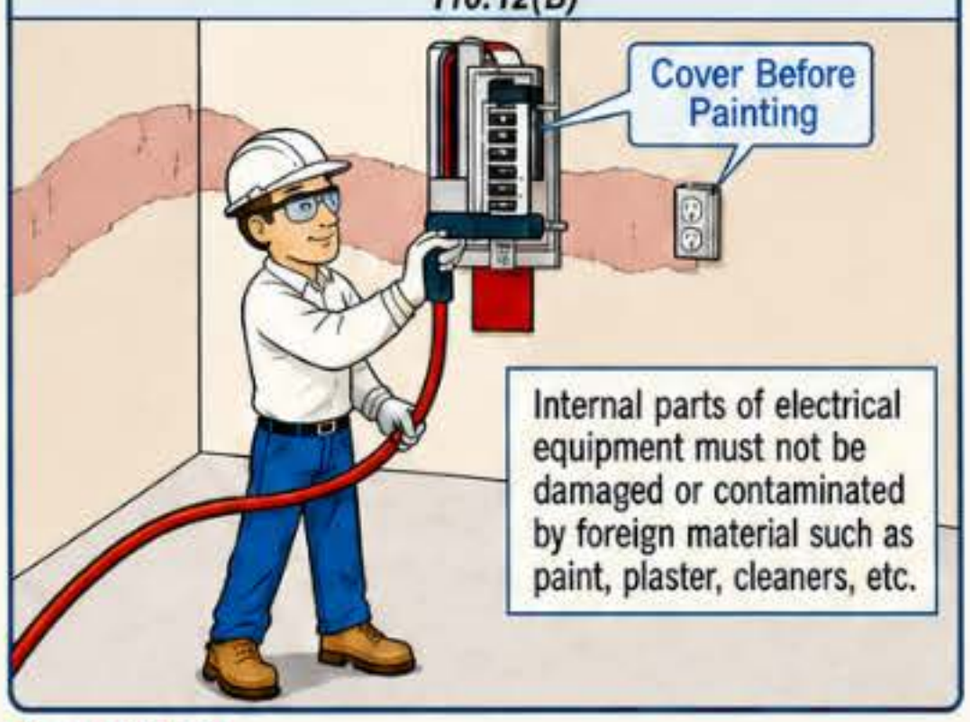


Figure 110–19

Author's Commentary:

▶ *Take precautions to prevent contamination of the interior of panelboards and receptacles during construction. Keep equipment properly masked and protected before sheetrock, painting, or other trade work begins to prevent accidental contamination or damage.*

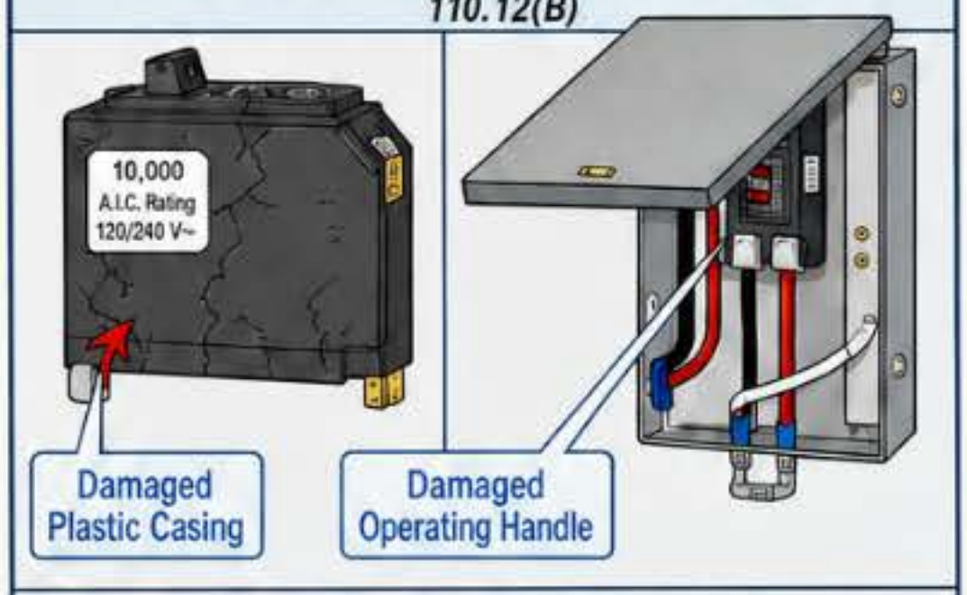
— Michael Hamilton

Requirements for Electrical Installations, Mechanical Execution of Work, Integrity of Electrical Equipment *110.12(B) Comment*

Figure 110–20

Electrical equipment that is broken, bent, cut, or has suffered corrosion or chemical attack—and items that are deteriorated or overheated—are not allowed in an installation. See **Figure 110–21.**

Requirements for Electrical Installations, Mechanical Execution of Work, Integrity of Electrical Equipment *110.12(B)*



Defective or damaged electrical components can weaken the safety and reliability of equipment. Weak or compromised equipment must not be installed.

Figure 110–21

Author's Commentary:

▶ *Damaged parts include cracked insulators, arc shields that are not in position, overheated fuse clips, and damaged or missing switch handles or circuit-breaker handles.*

— Michael Hamilton

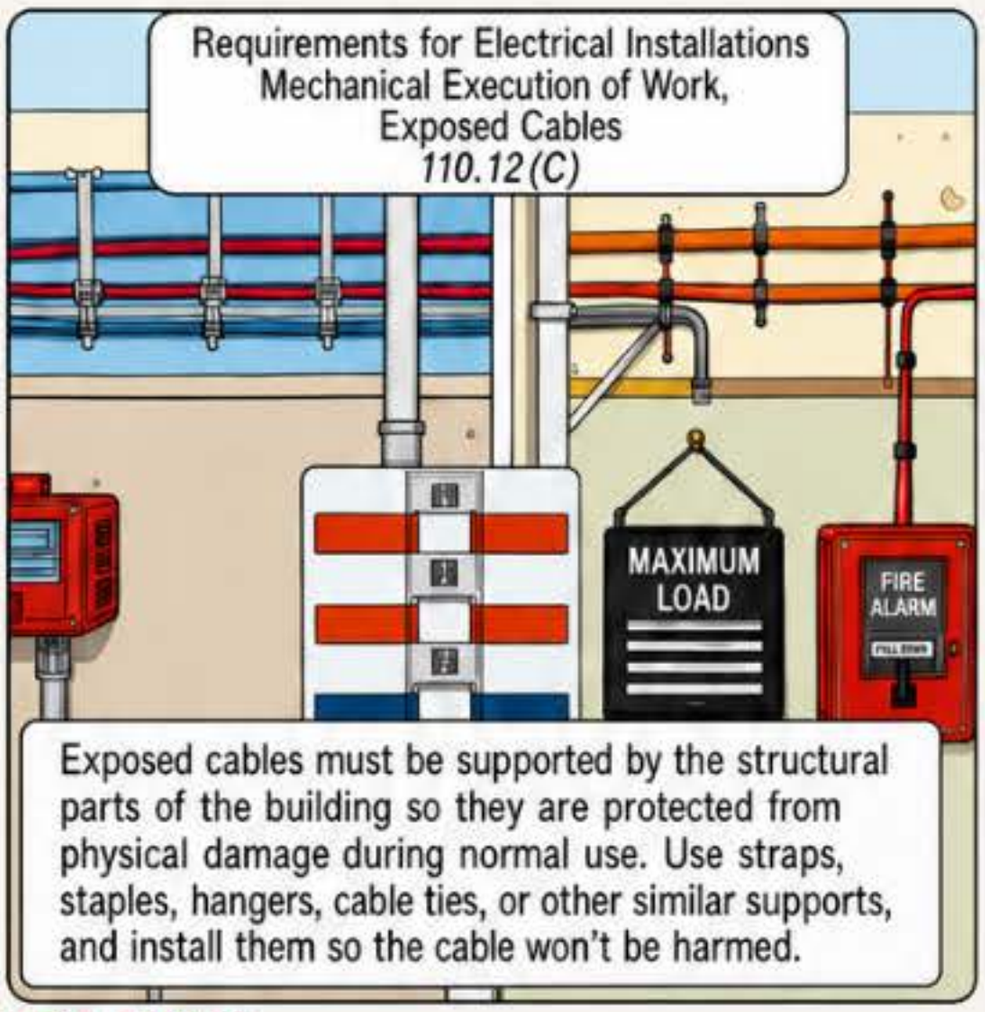
(C) Cables and Conductors. Cables and conductors must be installed carefully and in a workmanlike manner. See **Figure 110–22.**

Requirements for Electrical Installations, Mechanical Execution of Work, Cables and Conductors *110.12(C)*

Figure 110–22

110.13 | Requirements for Electrical Installations

Exposed cables must be supported by the structural parts of the building so they are protected from physical damage during normal use. Use straps, staples, hangers, cable ties, or other listed supports, and install them so the cable itself won't be harmed. ▶Figure 110–23



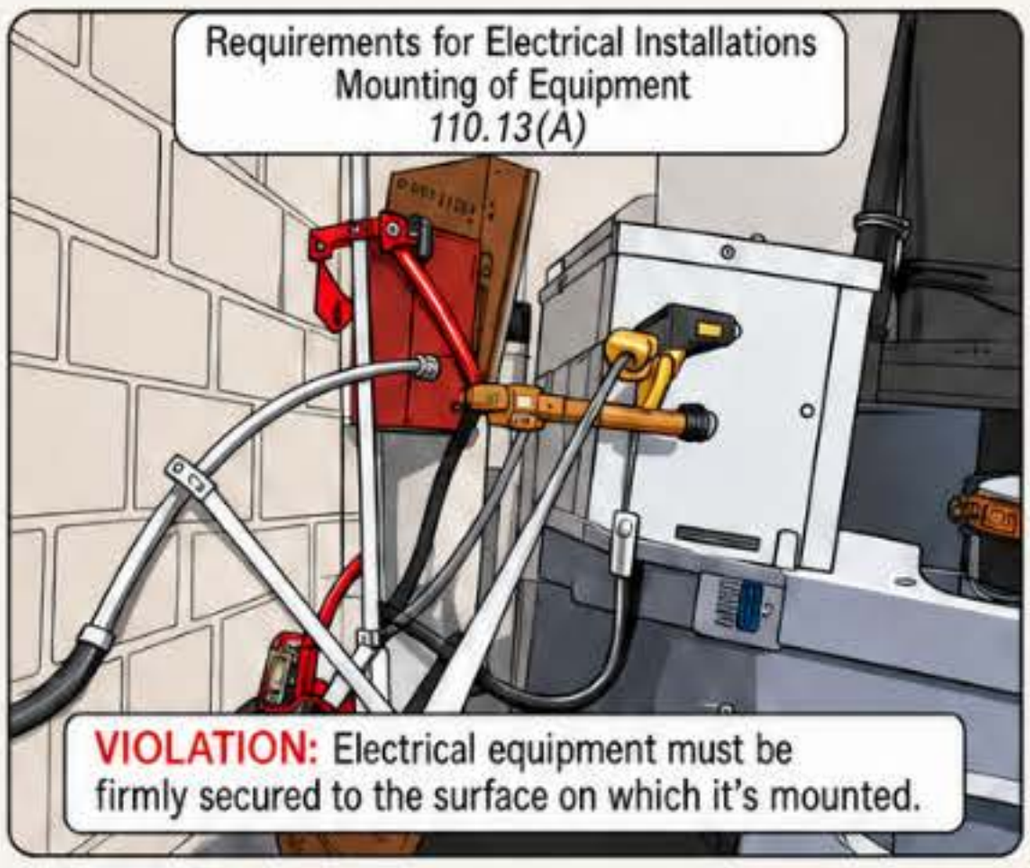
▶Figure 110–23

Note 1: Industry practices are described in ANSI/NECA/FOA 301, *Standard for Installing and Testing Fiber Optic Cables*, and other ANSI-approved installation standards.

Note 3: Paint, plaster, cleaners, abrasives, corrosive residues, or other contaminants may cause hidden changes in fiber optic cable performance.

110.13 Mounting and Cooling of Equipment

(A) Mounting. Electrical equipment must be firmly secured to the surface on which it is mounted. ▶Figure 110–24

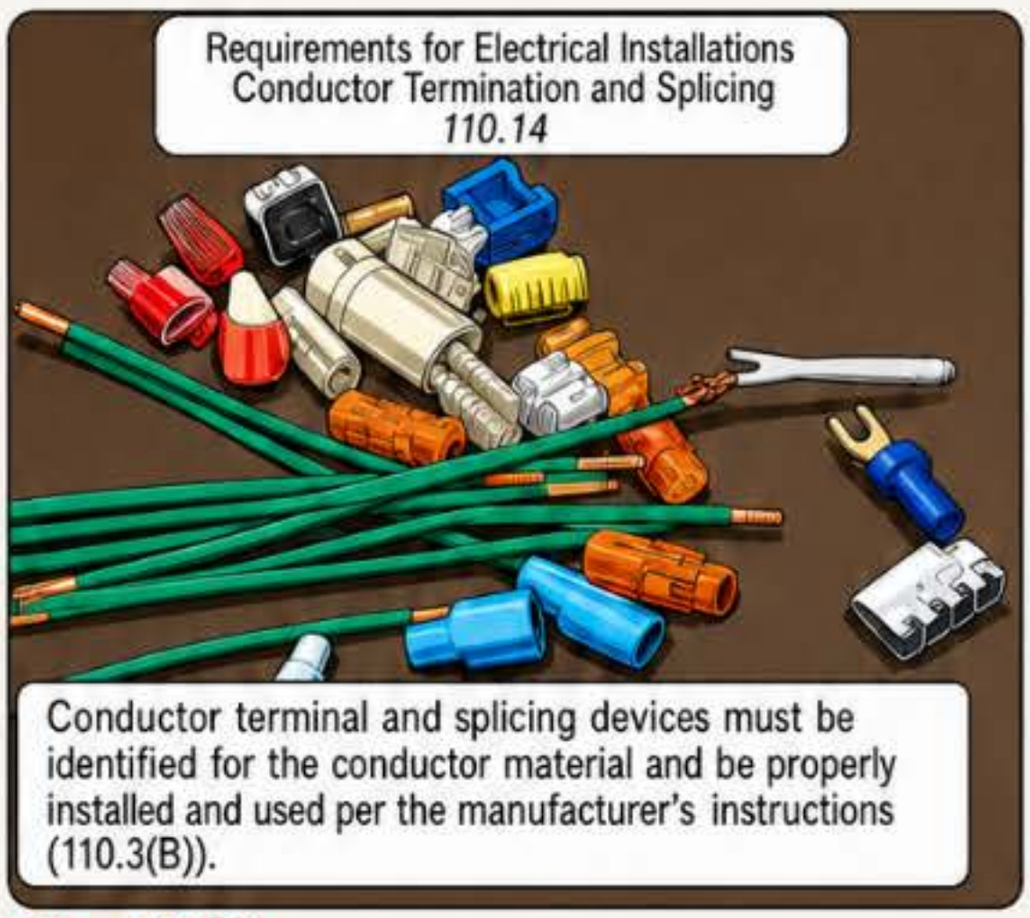


▶Figure 110–24

110.14 Conductor Termination and Splicing

Scan this QR code for a video from Michael Hamilton explaining this topic; it's a sample from the videos that accompany this textbook.

Conductor terminal and splicing devices must be identified for the conductor material and must be properly installed in accordance with the manufacturer's instructions (110.3(B)). ▶Figure 110–25



▶Figure 110–25

Author's Commentary:

- *Conductor terminals suitable for aluminum wire only will be marked "AL." Those acceptable for copper wire only will be marked "CU." Terminals for both copper and aluminum wire will be marked "CU-AL" or "AL-CU." For 6 AWG and smaller, the markings may appear on the container or on an information sheet inside. A "75" or "75°C means a 75°C rated terminal, and a "90" or "90°C means a 90°C rated terminal. If a terminal has no marking, it can be used only with copper conductors."* — ***Michael Hamilton***

Connectors and terminals for conductors more finely stranded than Class B and Class C must be identified for the use of finely stranded conductors. ▶Figure 110–27

Requirements for Electrical Installations

110.14

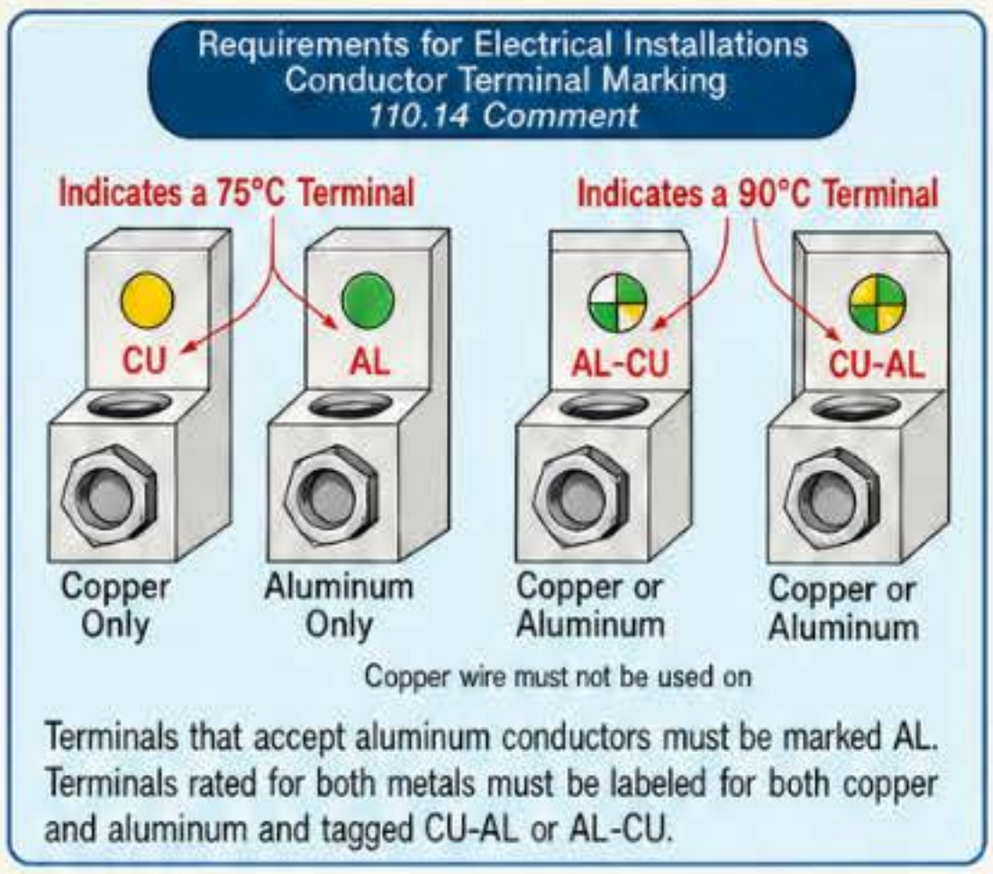


Figure 110–26

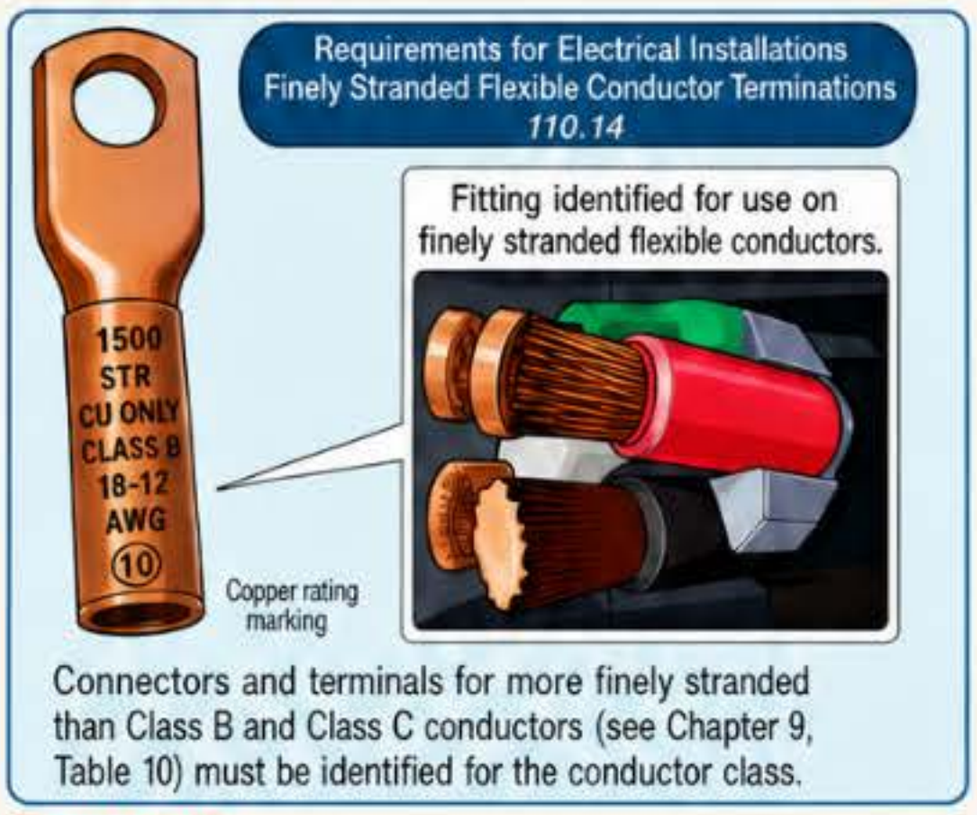


Figure 110–27

Author's Commentary:

- *Per Article 100, "identified" means the equipment is suitably marked so a specific purpose, role, surroundings, labeling, or other approved criteria by the authority having jurisdiction are recognized.*
- *Conductor terminations must follow the manufacturer's installation instructions required by 110.3(B). For instance, if the instructions say "Suitable for 18–12 AWG Stranded," then only stranded conductors can be used with the terminator. If they read "Suitable for 18–12 AWG Solid," then only solid conductors are allowed, and if they state "Suitable for 18–12 AWG," then either solid or stranded conductors may be used with the device.*

— *Michael Hamilton*

Copper and Aluminum Mixed. Copper and aluminum conductors (dissimilar metals) are not permitted to contact each other in a device unless the device is listed and identified for this purpose.

Author's Commentary:

- *A few termination products are approved for both aluminum and copper conductors. However, when that's the case, the product or its terminal is clearly identified. Copper and aluminum should not touch one another in terminations because they corrode together through galvanic action, which raises contact resistance at the splice. Higher resistance can cause the splice to overheat and may start a fire.*

— *Michael Hamilton*

(A) Conductor Terminations. Conductor terminals must make a secure connection without harming the conductors.

Terminals are only listed for single-conductor use unless marked otherwise. If a terminal is listed for more than one conductor, it must be identified for that purpose either in the equipment instructions or on the terminal itself.

Figure 110–28

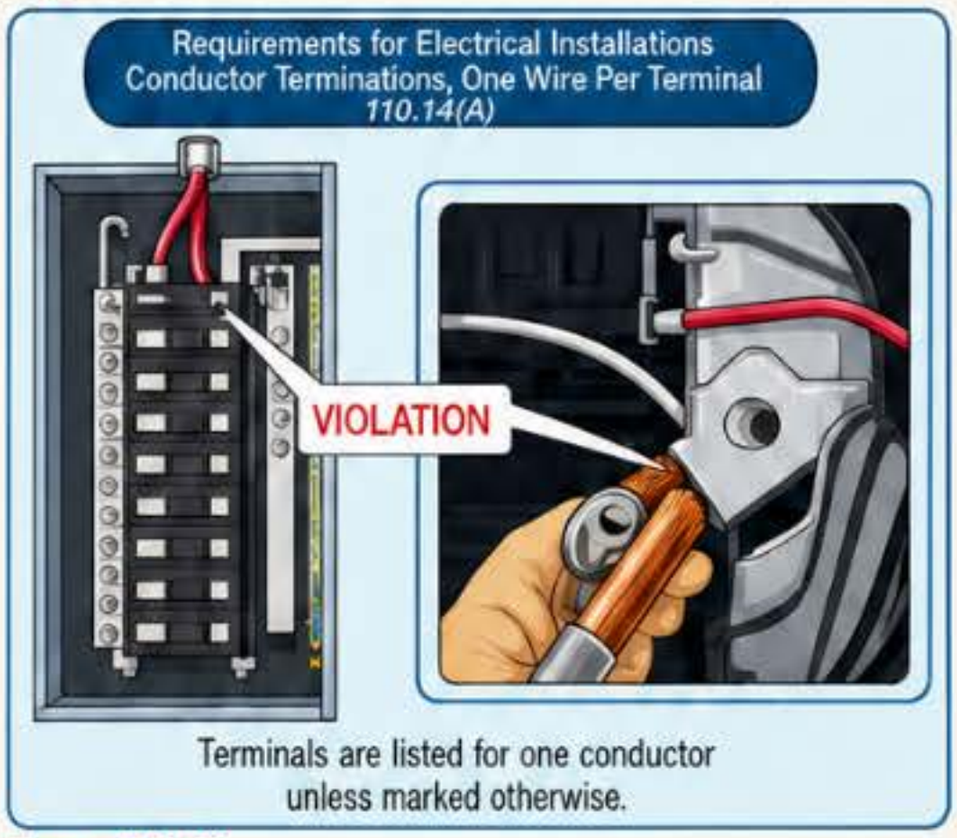


Figure 110–28

Author's Commentary:

- *Split-bolt connectors are commonly rated for either two conductors or three conductors, although some are listed for three. However, a frequent industry practice is using a split-bolt connector to terminate as many conductors as possible, even though this goes against NEC requirements.*

— *Michael Hamilton*

Figure 110–29

110.14 | Requirements for Electrical Installations

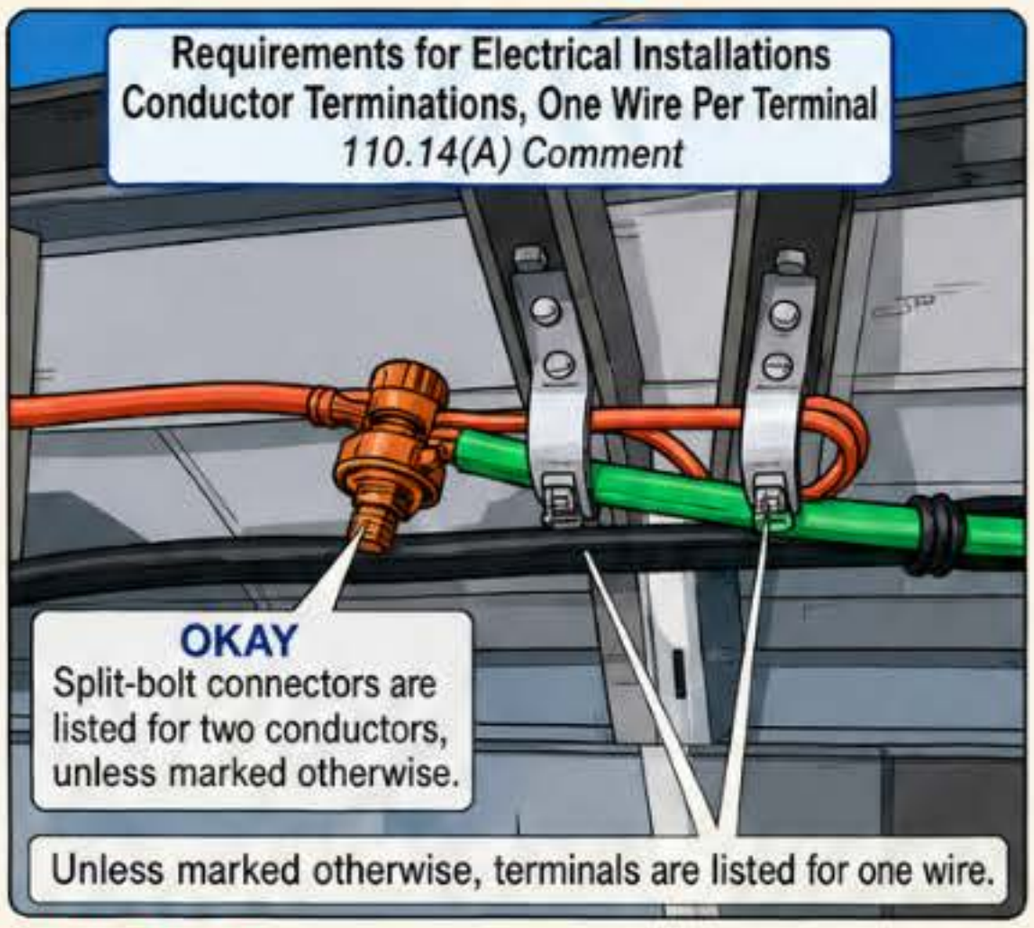


Figure 110–29

(B) Conductor Splices. Conductors must be spliced by a splicing device that is identified for the purpose. • Figure 110–30

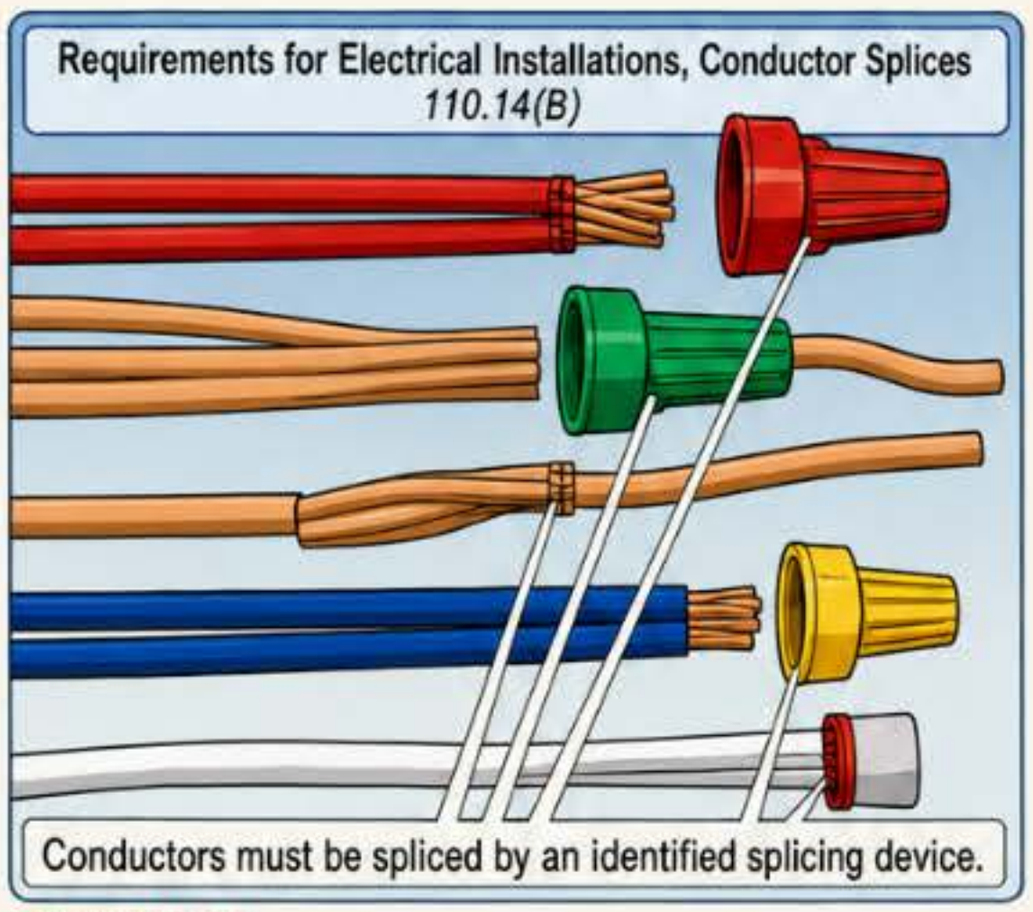


Figure 110–30

Unused circuit conductors are not required to be removed. However, to prevent an electrical hazard, the free ends of the conductors must be insulated to prevent the exposed end(s) from touching energized parts. This requirement can be met by using an *insulated* twist-on or push-on wire connector. • Figure 110–31

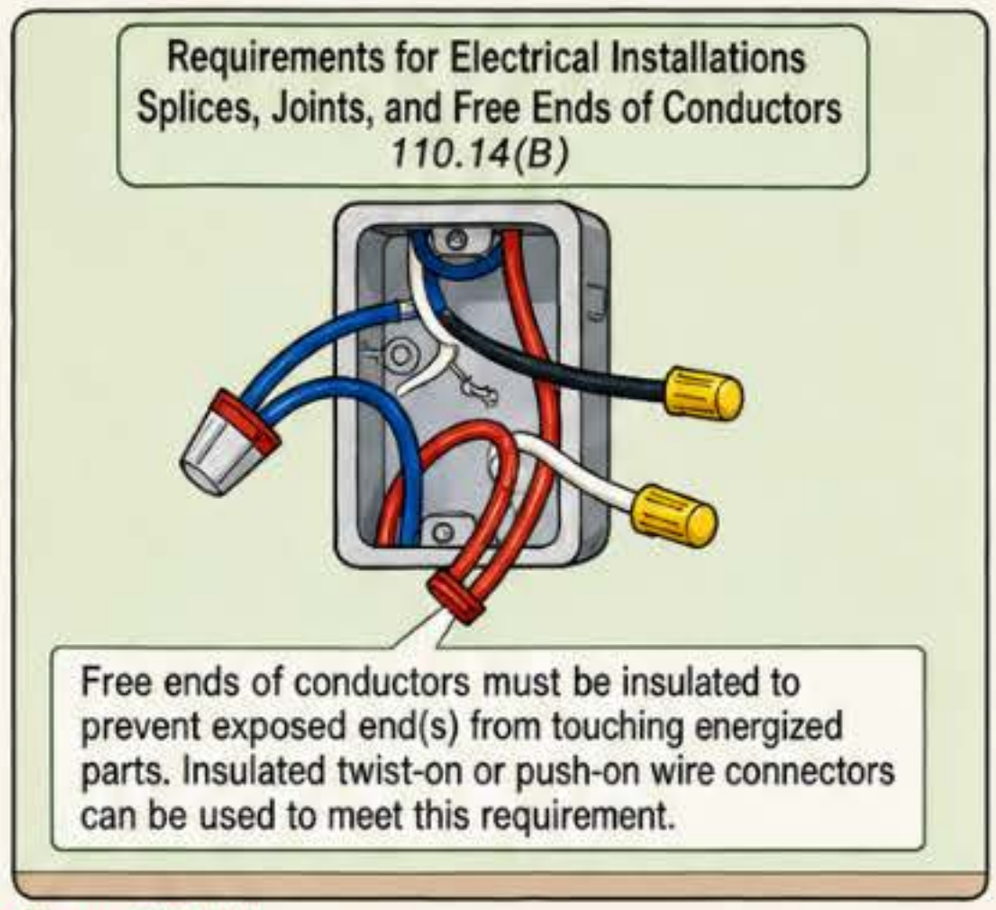


Figure 110–31

- Pre-twisting conductors before applying twist-on wire connectors has been a very common practice in the field for years. The question (and subsequent debate) has always been, "Is pre-twisting required?" The *NEC* does not require that practice and, in fact, ideal® made a statement about their Wing-Nut® twist-on connectors which said, "Pre-twisting is acceptable, but not required." Always follow the manufacturer's instructions and there will be no question [110.3(B)].
- Reusing twist-on connectors seems to be another point of contention in the field. Should they be reused? Some say that they just never seem quite the same once they have been used, while others say they reuse them all the time. Defer to the manufacturer's instructions; ideal® and 3M® both indicate in their information that it is perfectly fine to reuse their twist-on connectors. • Figure 110–32

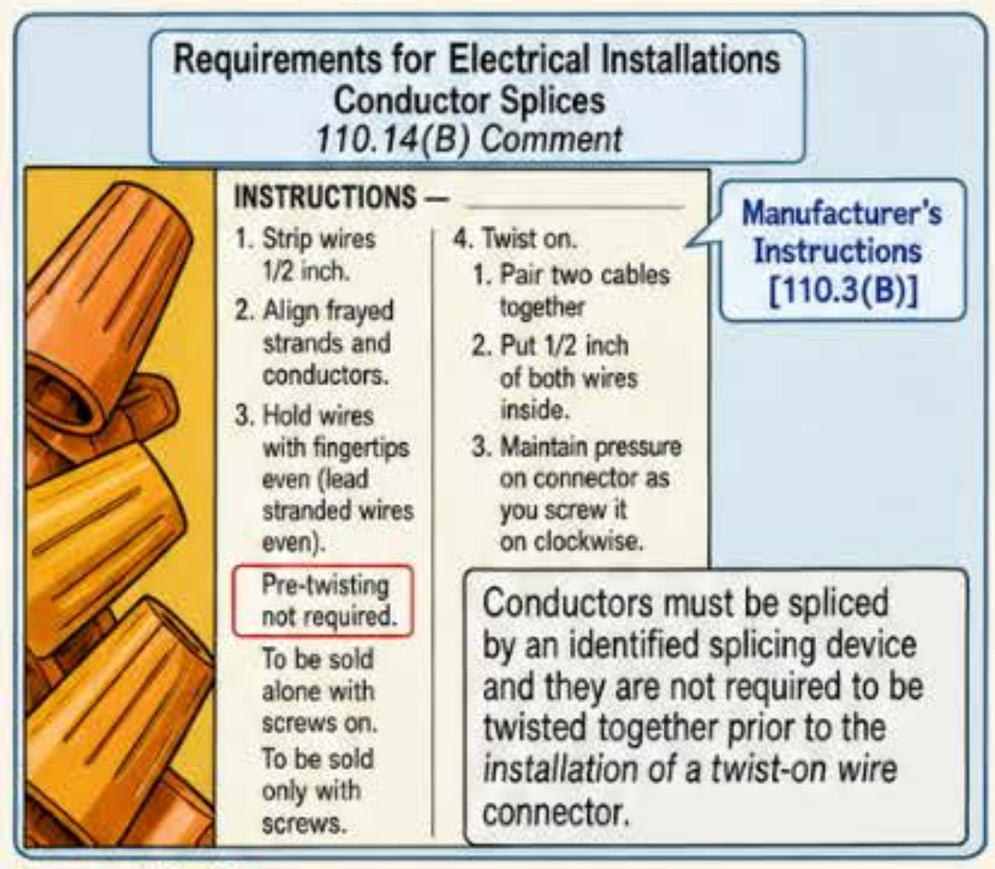


Figure 110–32

Author's Commentary:

Per Article 100, "Energized" refers to anything that is electrically connected to a source of voltage.

— Michael Hamilton

Requirements for Electrical Installations | 110.14

Underground Splices, Single Conductors. Direct-burial underground single conductors may be spliced only with a device that is identified for that purpose, in accordance with 300.5(E) and 300.15(G). ▶ Figure 110-33

Requirements for Electrical Installations
Underground Splices, Single Conductors
110.14(B)

Single Type UF or USE conductors can be spliced underground with a device listed for direct burial.

▶ Figure 110-33

Underground Splices; Multiconductor Cable. Each individual conductor of a multiconductor UF or USE cable can be spliced underground using a listed splice kit that fully surrounds the conductors and the cable jacket.

Author's Commentary:

Faulty connections are a major source of equipment mishaps and fires. Loose or poorly made terminations, or ignoring the manufacturer's instructions, create unreliable links. Excess heat, arcing, and breakdown are common results. Good workmanship, following specs carefully, and using the right torque help ensure dependable terminations and reduce the risk of electrical failures.

— Michael Hamilton

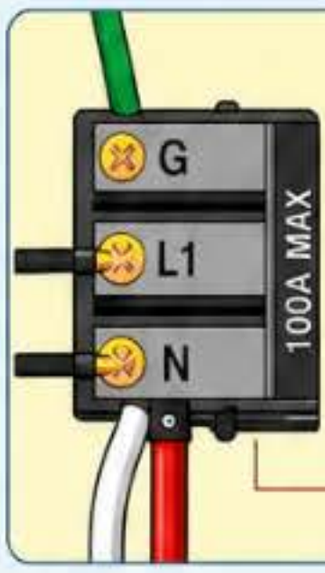
(C) *Conductor Size to Terminal Temperature Rating.* *Size conductors in accordance with 110.14(C)(1) and (2).*

(1) Equipment Terminals. *Unless the equipment is listed and marked otherwise, use conductor sizes that align with (a) or (b) below:*

(a) Equipment Rated 100A or Less

(2) Insulation Temperature. *When the conductor's insulation temperature rating exceeds 60°C, the conductor must be sized based on the ampacity values found in the 60°C temperature column of Table 310.16.* ▶ Figure 110-34

Requirements for Electrical Installations, Conductor Sizing
Equipment Rated 100A or Less
110.14(C)(1)(a)(2)



50A Device With 60°C Terminals
Size Conductors Using
Table 310.16 60°C Column
Minimum Conductor Size
Permitted is 6 AWG

6 AWG With Insulation Rated
90°C is Permitted

6 THWN-2 Okay

Conductors with an insulation temperature rating above 60°C are allowed, but the conductor must be sized by the ampacities in the 60°C temperature column of Table 310.16.

▶ Figure 110-34

▶ Example

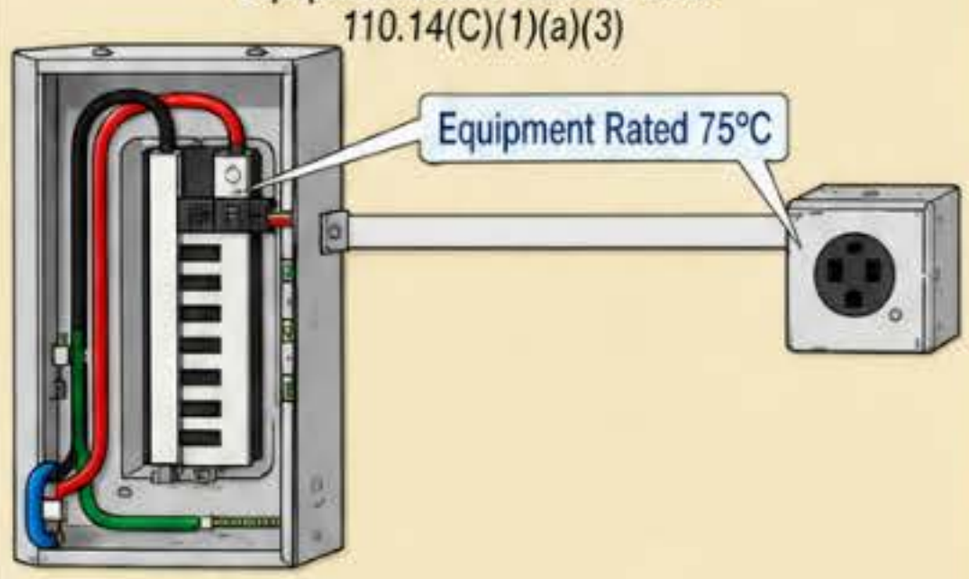
Question: *According to Table 310.16, what size THWN-2 conductor is required for a circuit rated 50A?*

(a) 10 AWG (b) 8 AWG (c) 6 AWG (d) 4 AWG

Answer: *(c) 6 AWG rated 55A at 60°C [110.14(C)(1)(a)(2) and Table 310.16]*

(3) *Terminal Rating 75°C.* Conductors connected to terminals rated 75°C must be sized using ampacity values from the 75°C temperature column of Table 310.16. ▶ Figure 110-35

Requirements for Electrical Installations, Conductor Sizing
Equipment Rated 100A or Less
110.14(C)(1)(a)(3)



Conductors terminating on equipment rated 75°C must be sized based on ampacities in the 75°C temperature column of Table 310.16.

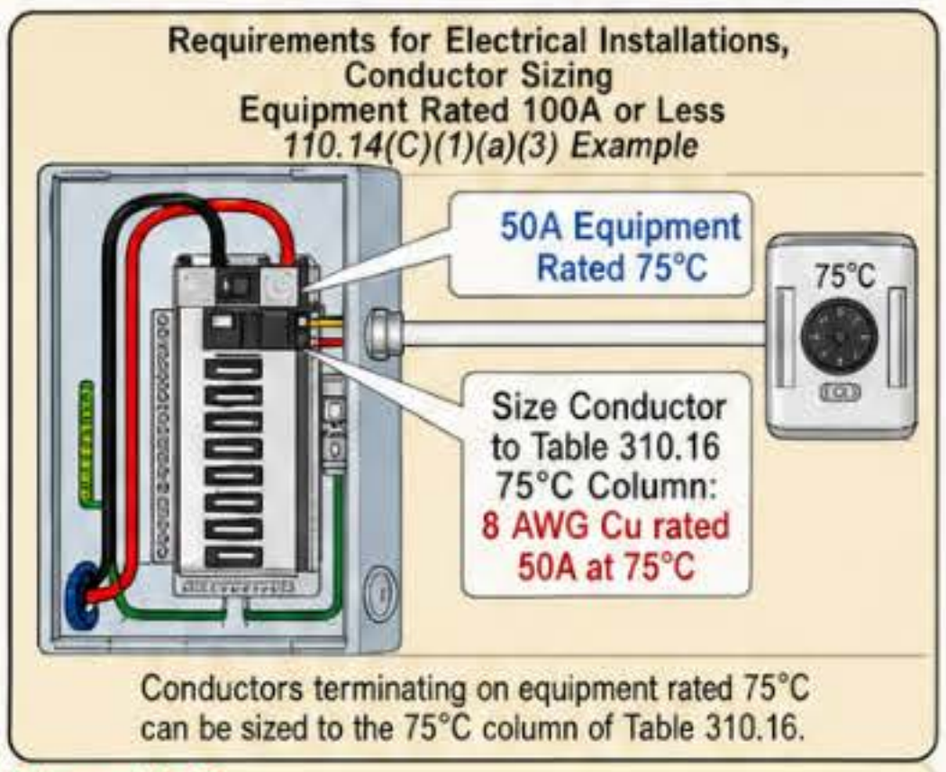
▶ Figure 110-35

110.14 Requirements for Electrical Installations

▶ **Example**

Question: *Refer to Table 310.16. What size THHN conductor is required for a 50A branch circuit when the equipment is intended for use at 75°C?*

(a) 10 AWG (b) 8 AWG (c) 6 AWG (d) 4 AWG



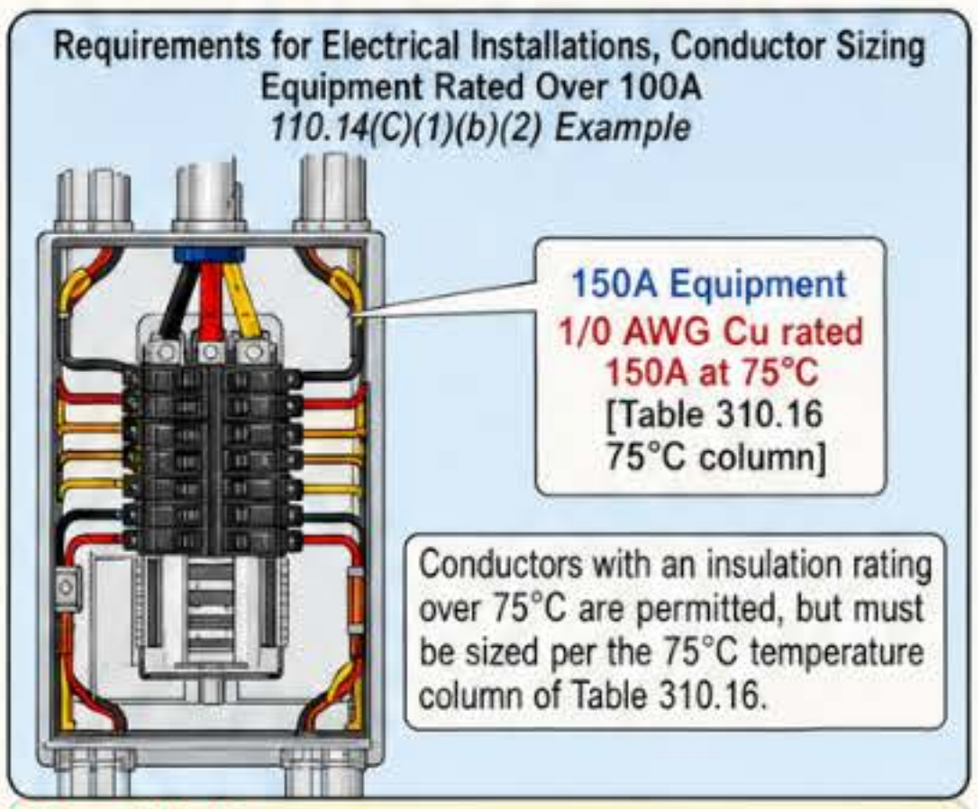
▶ Figure 110–36

Answer: *(b) 8 AWG rated for 50A at 75°C [110.14(C)(1)(a)(3) and Table 310.16]*

▶ **Example**

Question: *Refer to Table 310.16. What size THHN conductor is needed to supply a 150A feeder?* ▶ Figure 110–38

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

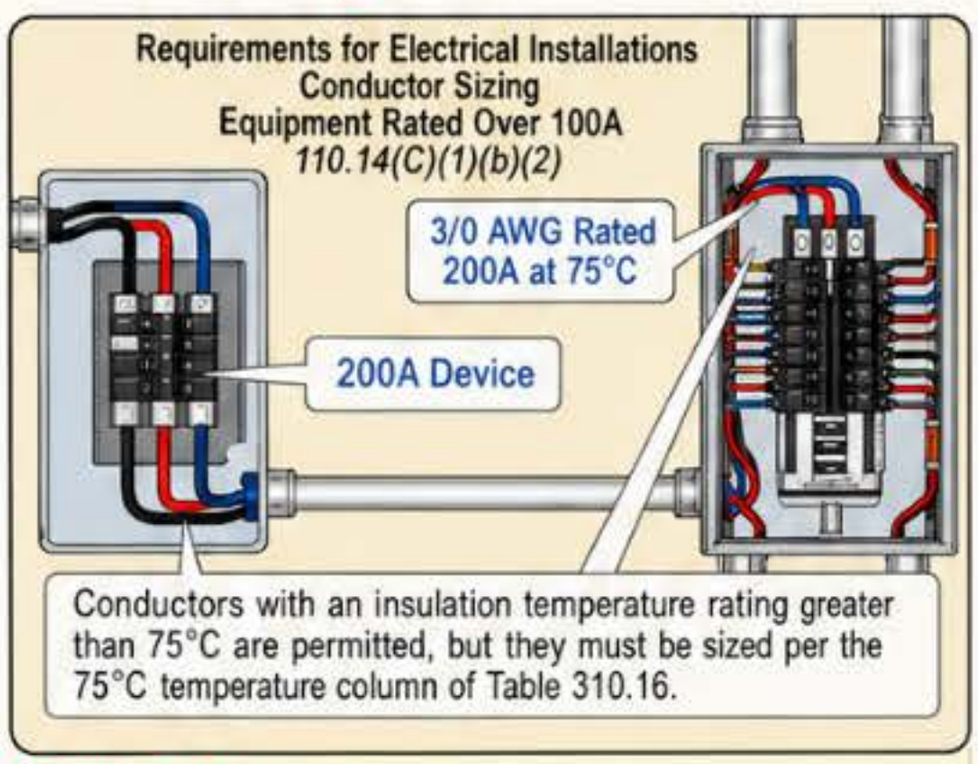


▶ Figure 110–38

Answer: *(a) 1/0 AWG rated for 150A at 75°C [110.14(C)(1)(b)(2) and Table 310.16]*

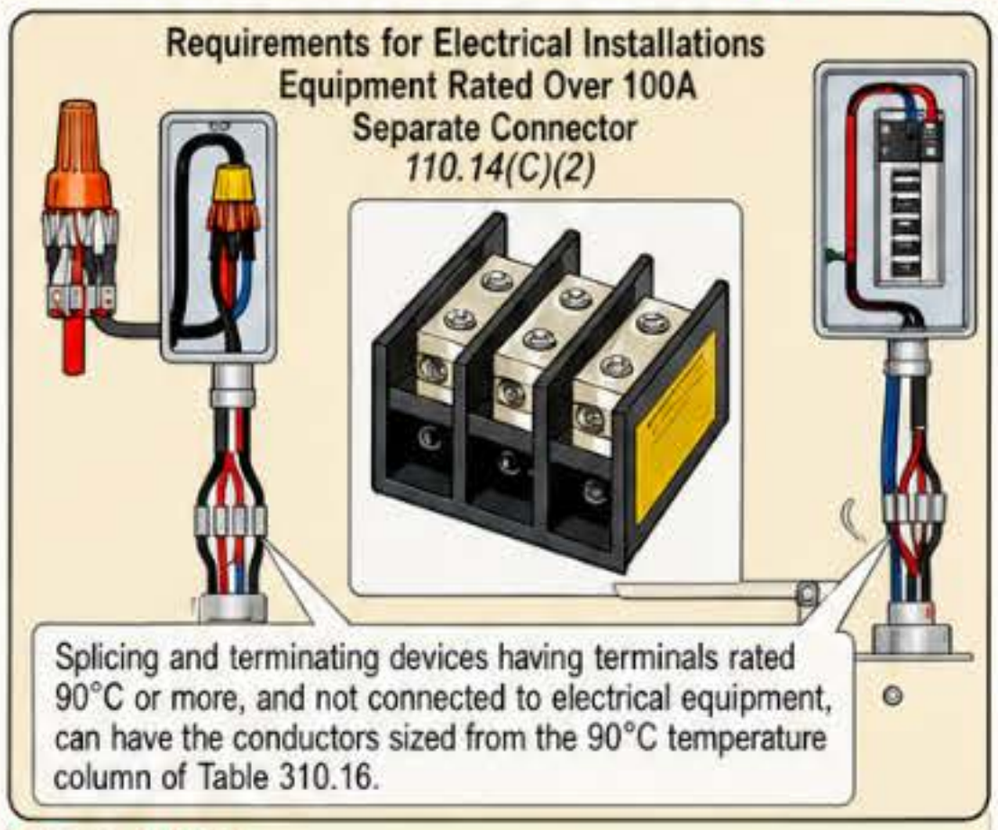
(b) Equipment Rated Over 100A

(2) Conductors with an insulation temperature rating greater than 75°C are permitted, but the conductor must be sized in accordance with the ampacities in the 75°C temperature column of Table 310.16. ▶ Figure 110–37



▶ Figure 110–37

(2) Separate Connector. Splicing and terminating devices with terminals rated 90°C and not connected to electrical equipment can have the conductors sized in accordance with the ampacities in the 90°C temperature column of Table 310.16. ▶ Figure 110–39



▶ Figure 110–39

Author's Commentary:
When conductor insulation is rated above the standard 75°C, the NEC permits you to select conductor sizes from the 75°C column of Table 310.16 for most equipment terminations. However, when using separate splicing or terminating connectors with 90°C-rated terminals that are not mounted on equipment, you may use the 90°C column of Table 310.16. Always match the rules to the situation.

— Michael Hamilton

REQUIREMENTS FOR ELECTRICAL INSTALLATIONS 110.14

▶ Example 1

Question: *Based on Table 310.16, what size aluminum conductor may be used to interconnect busbars guarded by a 200A overcurrent protective device when all terminals are rated 90°C?*

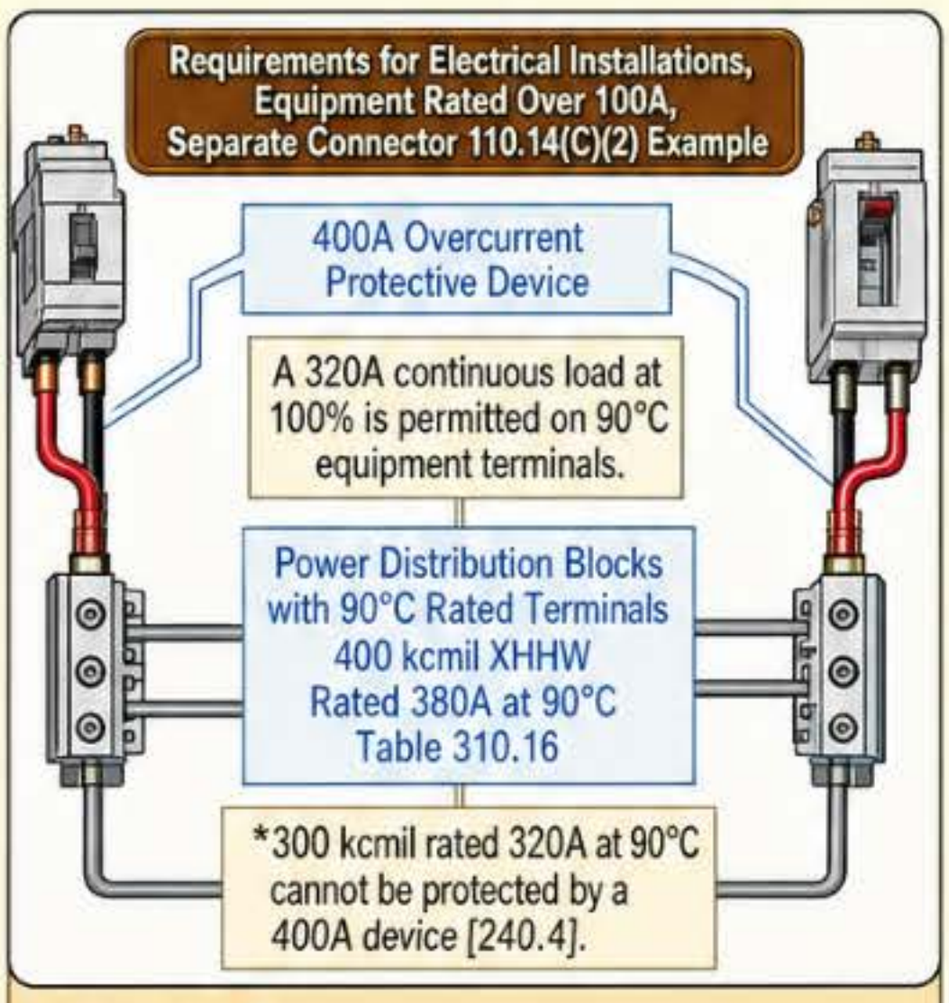
(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

Answer: *(d) 4/0 AWG aluminum rated 205A at 90°C [Table 310.16]*

▶ Example 2

Question: *What size XHHW copper conductor can be used to interconnect 90°C rated power distribution blocks protected by a 400A overcurrent protective device serving a 320A continuous load?*

(a) 250 kcmil (b) 300 kcmil (c) 350 kcmil (d) 400 kcmil



▶ Figure 110-40

Author's Commentary: *Although 350 kcmil is rated 350A at 90°C, it is not allowed in this example because it cannot be protected by the 400A overcurrent device [240.4].*

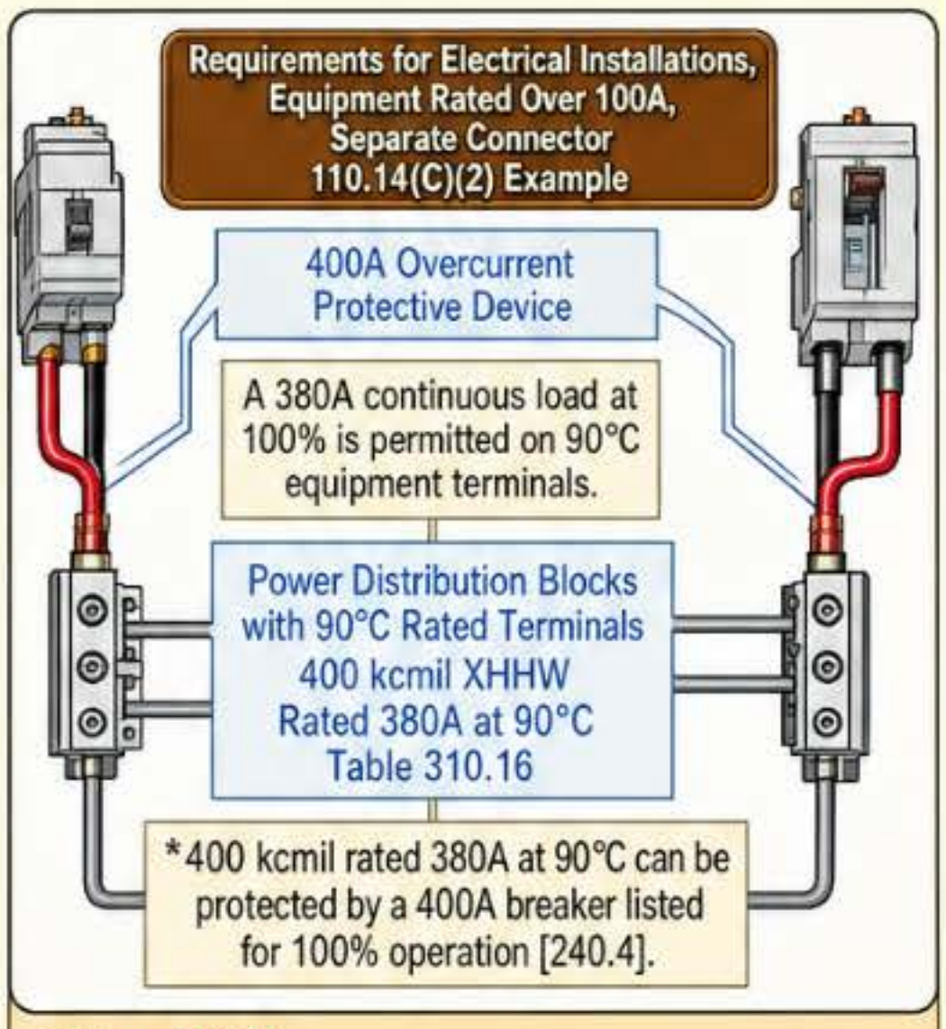
Answer: *(d) 400 kcmil rated 380A at 90°C [Table 310.16]*

— Michael Hamilton

▶ Example 3

Question: *What size XHHW copper conductor can be used to interconnect 90°C rated power distribution blocks protected by a 400A overcurrent protective device serving a 375A continuous load?*

(a) 250 kcmil (b) 300 kcmil (c) 350 kcmil (d) 400 kcmil



▶ Figure 110-41

Author's Commentary: *The 400 kcmil conductor is rated 380A at 90°C, which matches the 400A overcurrent device listed for continuous duty at 100% [240.4].*

Answer: *(d) 400 kcmil rated 380A at 90°C [Table 310.16]*

— Michael Hamilton

Table 310.16 Ampacities of Insulated Conductors

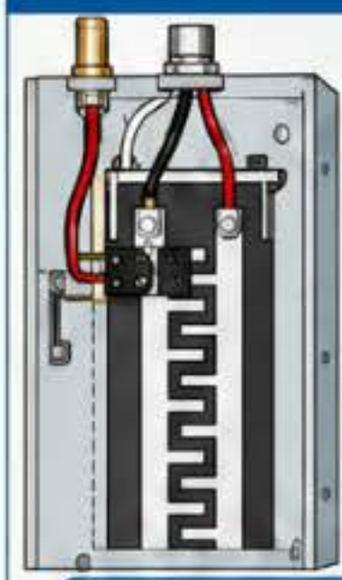
Based on Not More Than Three Current-Carrying Conductors and Ambient Temperature of 30°C (86°F)

Size AWG kcmil	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	Size AWG kcmil
	TW UF	RHW THHW THW THWN XHHW USE	RHH RHW-2 THHN THHW THW-2 THWN-2 USE-2 XHHW XHHW-2	TW UF	THW THWN XHHW	THHN THW-2 THWN-2 THHW XHHW XHHW-2	
	Copper			Aluminum/Copper-Clad Aluminum			
14	15	20	25	14	15	20	25	14
12	20	25	30	12	15	20	25	12
10	30	35	40	10	25	30	35	10
8	40	50	55	8	35	40	45	8
6	55	65	75	6	40	50	55	6
4	70	85	95	4	55	65	75	4
3	85	100	115	3	65	75	85	3
2	95	115	130	2	75	90	100	2
1	110	130	145	1	85	100	115	1
1/0	125	150	170	1/0	100	120	135	1/0
2/0	145	175	195	2/0	115	135	150	2/0
3/0	165	200	225	3/0	130	155	175	3/0
4/0	195	230	260	4/0	150	180	205	4/0
250	215	255	290	250	170	205	230	250
300	240	285	320	300	195	230	260	300
350	260	310	350	350	210	250	280	350
400	280	335	380	400	225	270	305	400
500	320	380	430	500	260	310	350	500

(D) Terminal Connection Torque

Tightening torque values for terminal connections must be provided in the equipment or installation instructions. An approved means (a torque tool) should be used to reach the specified torque. See **Figure 110–42** and **Figure 110–43.**

Requirements for Electrical Installations
Terminal Connection Torque
110.14(D)

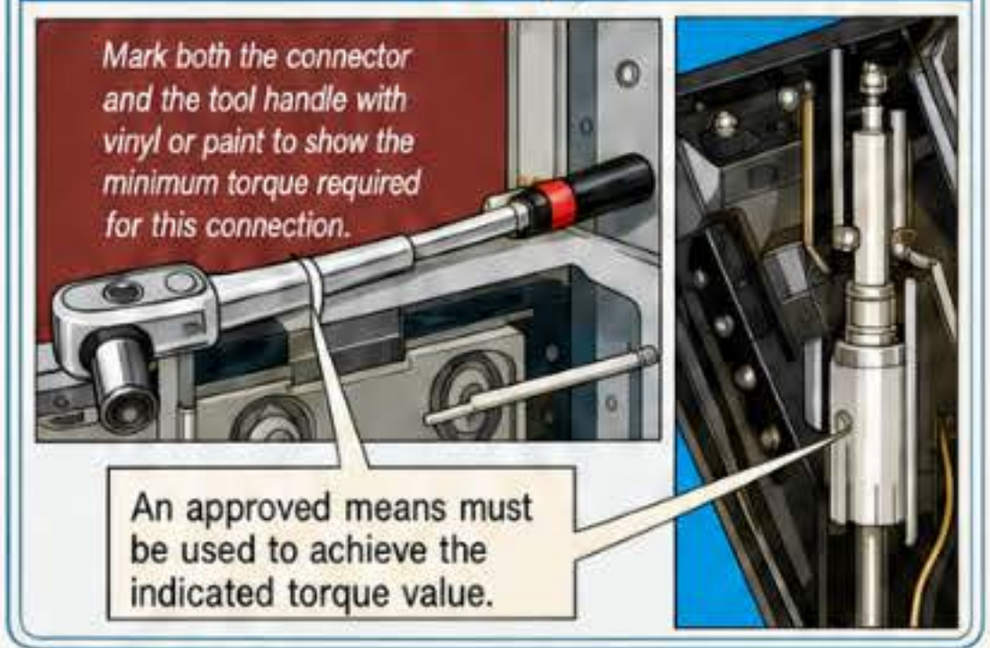


TORQUE WIRE PRESSURE SCREW(S) AS FOLLOWS:			
WIRE SIZE/ AWG or kcmil	NEUTRAL & GROUND BAR LB-IN	GROUND LUG (TAIL) & GROUND WIRE LB-IN	PANEL LUGS (A & B) & MAIN TERMINAL LUG LB-IN
#14–10	20	—	—
#8	23	—	—
#6–2/0	35	60	60
#3–4/0	—	60	60
#250–300	—	—	—

Tightening torque values for terminal connections must be as indicated on equipment or installation instructions. An approved means must be used to achieve the indicated torque value.

▶ **Figure 110–42**

Requirements for Electrical Installations
Terminal Connection Torque
110.14(D)



▶ **Figure 110–43**

Author's Commentary:

▶ *All conductors must end in devices whose terminals have been tightened to the manufacturer's published torque values found in the instructions that come with the equipment. Overheating, terminal damage, or arcing can result from inadequate tightening. Conversely, overtightening can harm threads and reduce clamping ability. Loose connections may increase heat, raise the risk of arcing, and even cause short circuits or equipment failure.*

— Michael Hamilton

Ignoring these torque requirements can cause serious hazards such as fires or equipment failure, including arc flash incidents. Using the wrong torque also violates 110.3(B), which requires all equipment to be installed in accordance with its listing or labeling instructions.

Note 1: Valid ways to achieve the required torque include using properly calibrated torquing tools or devices like shear bolt or breakaway-style connectors that have clear visual cues showing correct torque.

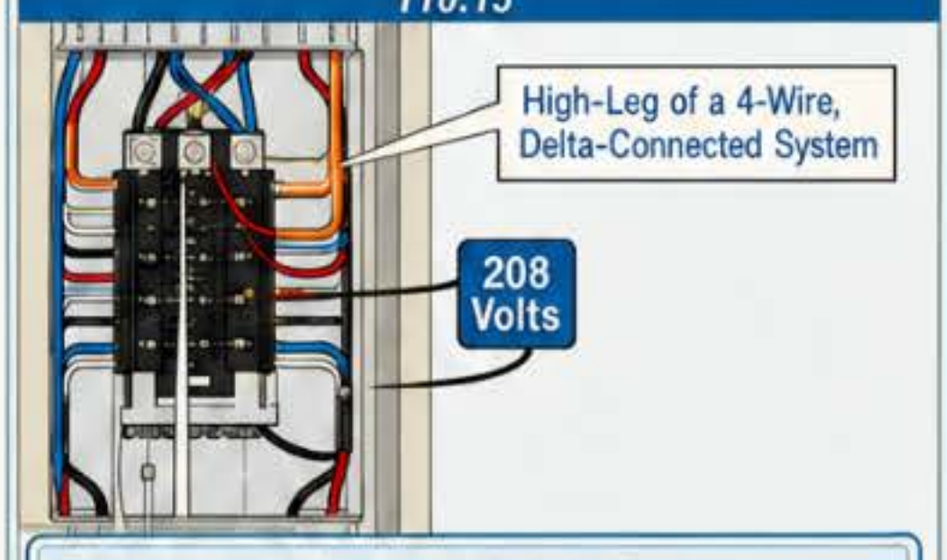
Note 2: Contact the manufacturer if the numeric torque spec is missing on the equipment or if the installation instructions do not provide the value. Annex J of UL Standard 486A–486B, *Standard for Safety-Wire Connectors, provides torque values in the absence of the manufacturer's recommendations.*

Note 3: Additional information about *torquing threaded* connections and terminations can be found in Section 8.11 of NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance, 2023 edition.*

110.15 High-Leg Conductor Identification

In a 4-wire, delta-connected, three-phase system (where the midpoint of one phase winding of the secondary is grounded) the conductor with the resulting 208V to ground (high-leg) must be durably and permanently marked by an outer finish (insulation) that is orange or some other effective means. Such identification must be placed at each point where a connection is made if the neutral conductor is present [230.56]. See **Figure 110–44.**

Requirements for Electrical Installations
High-Leg Conductor Identification
110.15



The high-leg conductor must be identified by an orange color, or other effective means, at each point in the system where a connection is made, and the neutral conductor is present.

▶ **Figure 110–44**

110.16 | Requirements for Electrical Installations

Author's Commentary:

This high-leg conductor is sometimes called *the "wild leg" or "stinger leg."*

— Michael Hamilton

110.16 Arc Flash Hazard Warning

Scan this QR code for a video of Michael explaining this topic; it's a sample from the videos that accompany this textbook.

(A) Arc Flash Hazard Warning Label. In locations other than dwelling units, switchboards, switchgear, panelboards, industrial control panels, meter socket enclosures, and motor control centers must be marked to warn qualified personnel about the arc flash hazards that result from a short circuit or ground fault. The label must be permanently attached, have the required durability to resist the envivonment involved [110.21(B)], and be easy for qualified workers to see during any examination, adjustment, servicing, or maintenance of the equipment. Figure 110–45

Requirements for Electrical Installations
Arc-Flash Hazard Warning Labels,
Other Than Dwellings [110.16(A)]

Switchboards, switchgear, panelboards, industrial control panels, meter socket enclosures, and motor control centers must be marked to alert qualified workers about arc-flash hazards.

Figure 110–45

Author's Commentary:

- *Under Article 100, a "Qualified Person" is defined as someone who has the training and knowledge required to safely build and operate electrical equipment and its installations. This individual must be able to recognize risks and avoid dangers connected to electrical systems.*
- *NFPA 70E, Standard for Electrical Safety in the Workplace, gives details on safety training expectations for a "qualified person."*

— Michael Hamilton

- Examples of this safety training include (but are not limited to) instruction in the use of special precaution methods, personal protective equipment (PPE), insulating and shielding materials, and the use of insulated tools and test equipment when working on or near exposed conductors or circuit parts that can become energized.
- In many parts of the United States, electricians, electrical contractors, electrical inspectors, and electrical engineers must complete from 6 to 24 hours of *NEC* review each year as a requirement to maintain licensing. This does not necessarily make one qualified to deal with the specific hazards involved with electrical systems.
- This rule is intended to warn qualified persons who work on energized electrical systems that an arc flash hazard exists and that the level of danger is present. They will then be able to select the necessary personal protective equipment (PPE) in accordance with industry accepted safe work practice standards. Figure 110–46

Requirements for Electrical Installations
Arc-Flash Hazard Warning
[110.16(A) Comment]

This rule is intended to alert qualified personnel who work on energized systems that an arc flash hazard may be present so they can choose the proper personal protective equipment (PPE) in accordance with industry accepted safe work practices.

Figure 110–46

(B) Service Disconnect. In addition to the requirements in 110.16(A), a service disconnect rated 1,200A or higher on equipment installed at a facility must have a field-applied label containing the following information and be durable enough to withstand the environment: Figure 110–47

(1) Nominal system voltage

(2) Available fault current at the line side of the service overcurrent protective device

(3) Clearing time of the service overcurrent protective device

(4) Date the label was installed

REQUIREMENTS FOR ELECTRICAL INSTALLATIONS

Requirements for Electrical Installations
Arc-Flash Hazard Warning Label, Service Disconnect
110.16(B)

In addition to the requirements in 110.16(A), a service disconnect rated 1,200A or more must have a label that contains the nominal system voltage, available fault current, clearing time of the service overcurrent protection, and date the label was installed.

▶ **Figure 110–47**

Author's Commentary:

Figuring the available fault current on the line side of equipment terminals requires you to know the available fault current (supplied by the utility), the type of conductor material, the conductor length, and the wiring method used to install those conductors. With this information, you can utilize an app or computer software to calculate the available fault current at the line terminals.

— Michael Hamilton

Example: *Arc flash labels are not required if a service disconnect fault current label is applied in accordance with NFPA 70E, Standard for Electrical Safety in the Workplace, 2023 edition. See Note 3 and* ***Figure 110–48****.*

Requirements for Electrical Installations, Arc-Flash Hazard Warning Labels, Service Equipment 1,200A or More
110.16(B) Ex

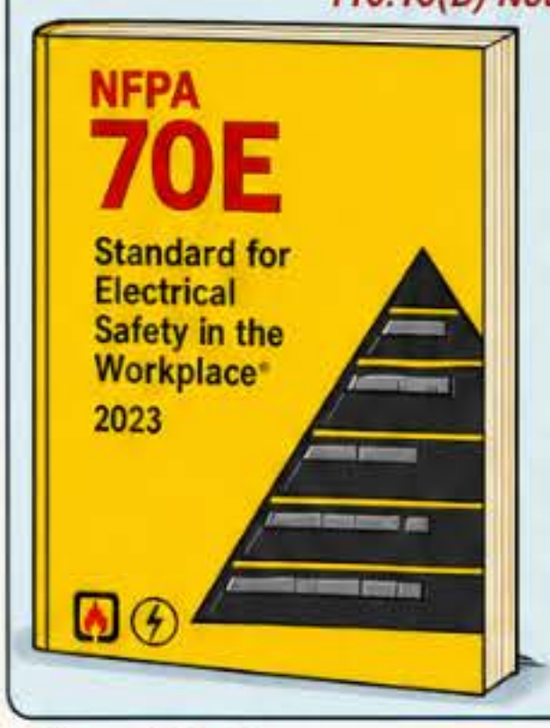
Service equipment labels required by 110.16(B) are not required if an arc flash label complying with NFPA 70E is applied.

▶ **Figure 110–48**

Note 1: NFPA 70E, *Standard for Electrical Safety in the Workplace*, provides guidance in determining the severity of potential exposure, planning safe work practices, arc flash labeling, and selecting personal protective equipment.

Figure 110–49

Requirements for Electrical Installations
Arc-Flash Hazard Warning Labels, Service Equipment
110.16(B) Note 1



NFPA 70E, *Standard for Electrical Safety in the Workplace*, provides guidance in determining the severity of potential exposures, planning safe work practices, arc flash labeling, and selecting *personal protective equipment.*

▶ **Figure 110–49**

Note 3: NFPA 70E, *Standard for Electrical Safety in the Workplace provides specific criteria for developing arc flash labels such as nominal system voltage, incident energy levels, arc flash boundaries, and selecting personal protective equipment.*

Author's Commentary:

The information required by 110.16(B)(1), (2), and (3) is necessary to determine the incident energy and arc flash boundary distance by using an app or computer software to ensure the label complies with NFPA 70E to increase safety during future work on service equipment.

— Michael Hamilton

110.21 Markings

(A) Equipment Markings

(1) General. *The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product can be identified must be placed on all electrical equipment. Other markings indicating voltage, current, wattage, or other ratings must be provided as specified elsewhere in this* ***Code****. The marking or label must be of sufficient durability to withstand the environment involved.*

110.22 | Requirements for Electrical Installations

(2) Reconditioned Equipment

Equipment that has been reconditioned must carry a name, trademark, or other identification of the organization that performed the reconditioning or that can be held accountable for the work, together with the date the reconditioning was completed.

The reconditioned equipment must be clearly identified as "reconditioned," and any previous listing mark must be removed. Acceptance of reconditioned equipment cannot be based solely on the product's original listing.

Example: *In industrial facilities where preventive maintenance and oversight are part of a scheduled program, service markings required by 110.21(A)(2) are not necessary for equipment that has been reconditioned by the owner or operator within the scope of a regular equipment maintenance program.*

Note 1: Industry standards are available that address the application of reconditioned and rebuilt equipment.

Note 2: The phrase "reconditioned" may be exchanged with terms such as "rebuilt," "refurbished," or "remanufactured."

Note 3: The original listing mark may include the certification mark, but it must not appear on the entire equipment.

(B) Field-Applied Hazard Markings. When caution, warning, or danger labels are required, the labels must comply with the following criteria:

(1) The markings must warn of the hazards using effective words, colors, symbols, or a combination of the three. ▶Figure 110–50

Requirements for Electrical Installations
Field-Applied Hazard Markings
110.21(B)(1)

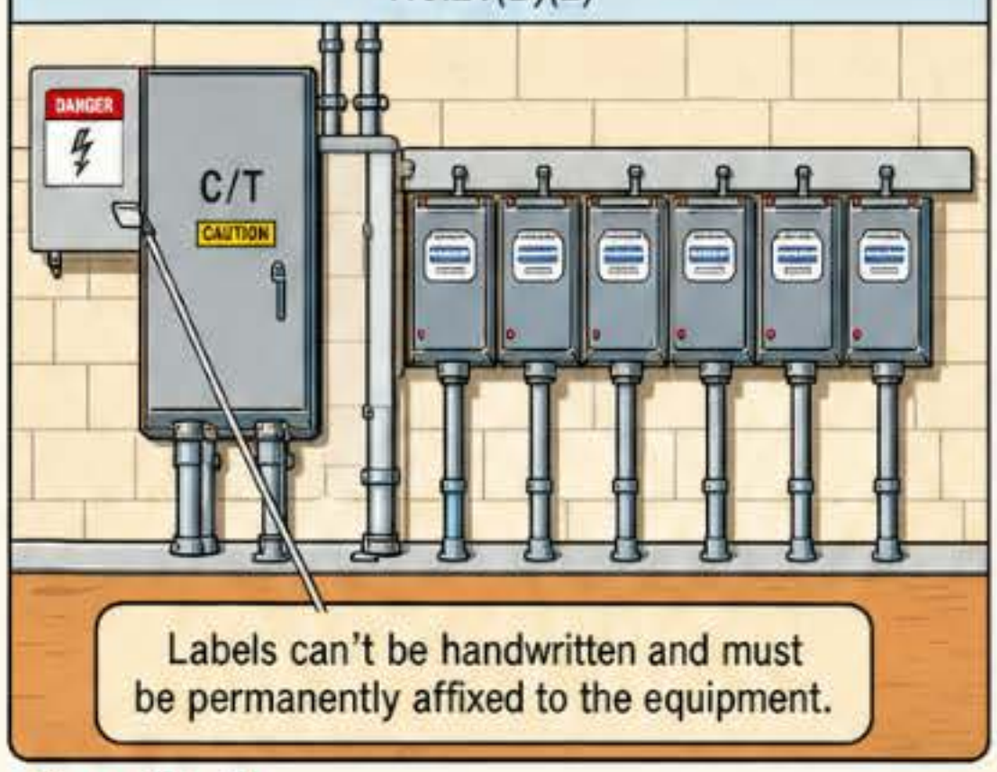
The markings must warn of the hazards using effective words, colors, symbols, or a combination of words, colors, and symbols.

▶Figure 110–50

Note: ANSI Z535.4, *Product Safety Signs and Labels, provides guidelines for the design and durability of signs and labels.*

(2) The label cannot be handwritten and must be permanently affixed to the equipment. ▶Figure 110–51

Requirements for Electrical Installations
Field-Applied Hazard Markings, Label Requirements
110.21(B)(2)



▶Figure 110–51

Example: *Labels containing information likely to change can be handwritten, provided the writing is clear and legible.*

(3) The marking must be strong enough to withstand the environment involved.

110.22 Identification of Disconnecting Means

(A) General. Each disconnecting means must be clearly marked to show its purpose, unless its location and use are obvious within one- or two-family dwellings. The label must identify the circuit source that supplies the disconnecting means. The marking must withstand the environmental conditions involved. ▶Figure 110–52

Author's Commentary:

▶ *See 408.4 for additional requirements for labeling on switchboards and panelboards.*

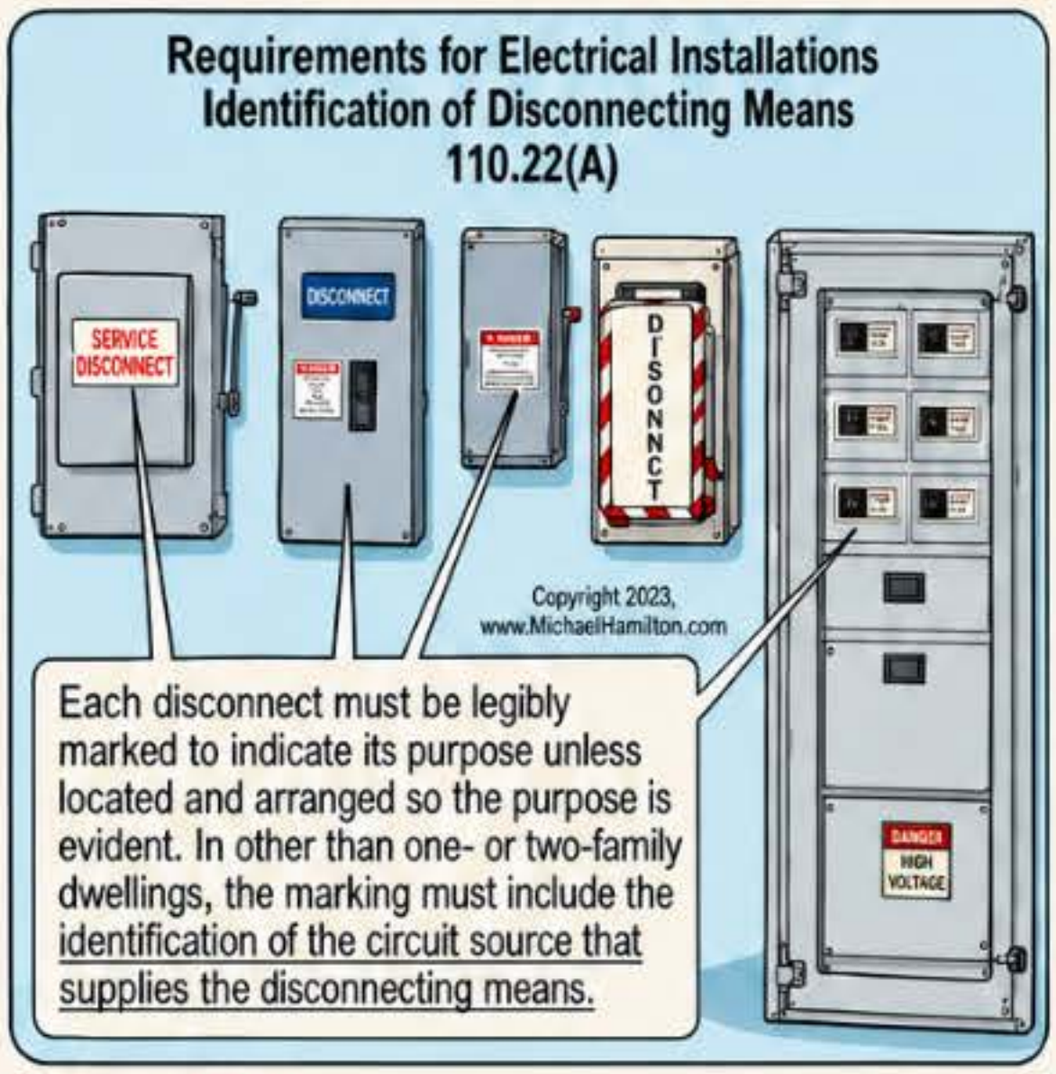
— Michael Hamilton

(C) Tested Series Combination Systems. *Tested assemblies that are listed for series-rated applications must be permanently labeled to indicate the equipment has been applied with a series combination in accordance with 240.86(B), to remain affixed, and to have sufficient durability to endure the environmental conditions in accordance with 110.21(B).*

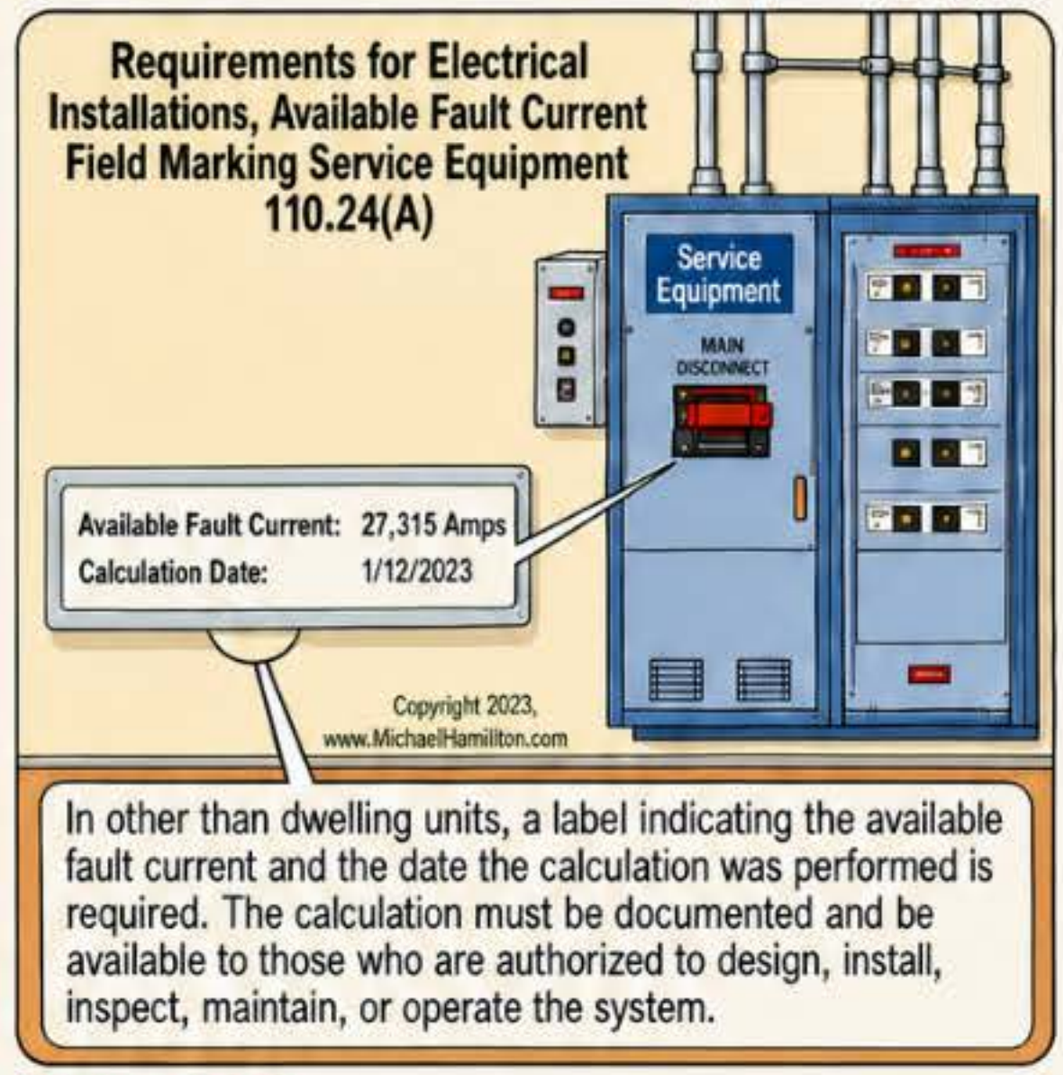
▶Figure 110–52

REQUIREMENTS FOR ELECTRICAL INSTALLATIONS

110.25



▲ Figure 110-52



▲ Figure 110-53

CAUTION—SERIES COMBINATION SYSTEM RATED ____ AMPERES. IDENTIFIED REPLACEMENT COMPONENTS REQUIRED

110.24 Available Fault Current

(A) Field Marking. In other than dwelling units, service disconnects must be field marked with the available fault current on the line side of the service disconnect, the date the fault current calculation was performed, and the marking must be of sufficient durability to withstand the environment present.

The available fault current calculation must be documented and available to those who are authorized to design, install, inspect, maintain, or operate the system. ▶ Figure 110-53

Note 1: *The available fault current markings required by this section are related to the short-circuit current and interrupting ratings of equipment required by 110.9 and 110.10. They are not intended to be used for arc flash analysis. Arc-flash hazard information is available in NFPA 70E, Standard for Electrical Safety in the Workplace.*

Note 2: *Values of available fault current for use in determining short-circuit current and interrupting ratings of service equipment are available from electric utilities in published or other forms.*

(B) Modifications. When modifications to the electrical installation affect the available fault current at the service disconnect, the available fault current must be recalculated to ensure the short-circuit current ratings at the service disconnect is sufficient for the available fault current. The required field marking(s) in 110.24(A) must be adjusted to reflect the new level of available fault current.

Author's Commentary:

- *It is common for electrical systems to be modified to accommodate growth. When the capacity of the system increases, equipment is installed to increase efficiency or alternative energy systems are added to the existing installation. These factors can all influence the available fault current if the utility transformer is changed. This increase in available fault current could end up exceeding the short-circuit current ratings of equipment in violation of 110.9 and 110.10.*

Ex: Field markings required in 110.24(A) and 110.24(B) are not required for industrial installations where conditions of maintenance and supervision ensure that only qualified persons service the equipment.

110.25 Lockable Disconnecting Means

If the *Code* requires a disconnect to be lockable in the open position, the provisions for locking must remain in place whether the lock is installed or not. ▶ Figure 110-54

▶ Figure 110–54

Part II. 1,000V, Nominal, or Less

110.26 Spaces About Electrical Equipment

Scan this QR code for a video of Michael Hamilton explaining this topic—it's a sample from the videos that accompany this textbook.

For the purposes of safe operation and maintenance of equipment, access and working space must be provided around all electrical equipment. ▶ Figure 110–55

▶ Figure 110–55

Author's Commentary:

- The clearances around electrical equipment (width, depth, and height) define the space workers need for protection [110.26(A)] and the open area required to reach, enter, and safeguard the equipment [110.26(E)].

— Michael Hamilton

(A) Working Space. Equipment that may require inspection, adjustment, servicing, or upkeep while energized must have the working space provided in accordance with 110.26(A)(1), (2), (3), and (4).

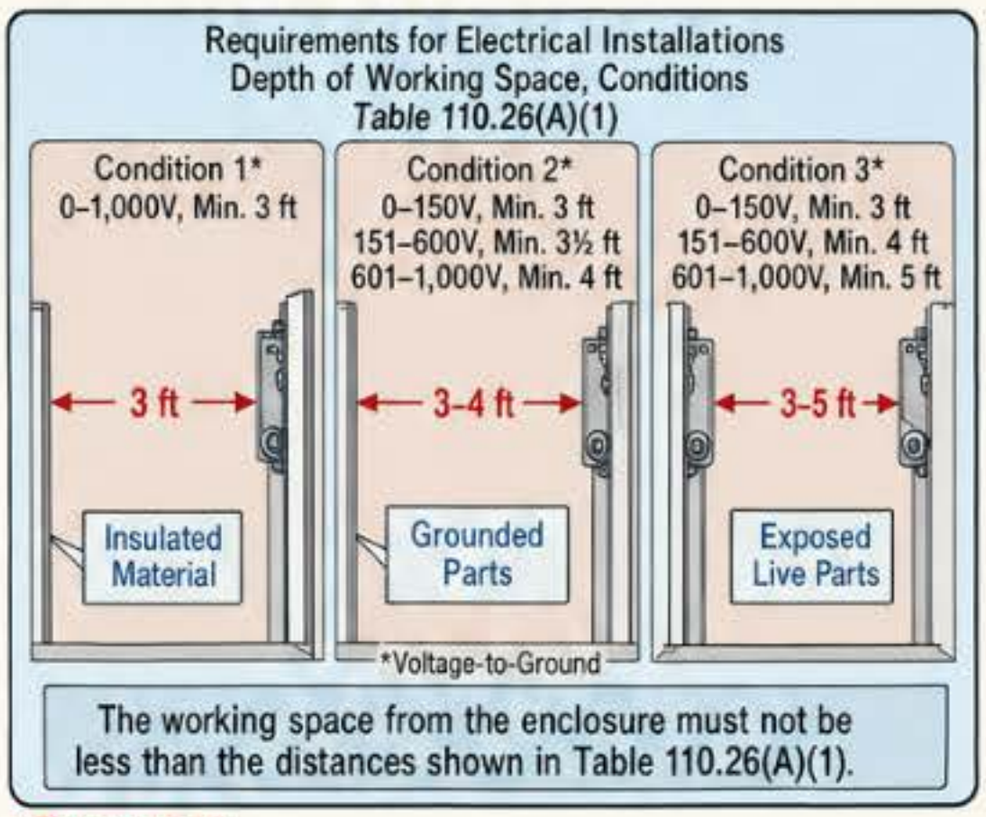
Author's Commentary:

- The phrase "while energized" is at the heart of much debate. Always verify with the authority having jurisdiction to determine whether the equipment they believe needs a clear working space falls under this requirement.

— Michael Hamilton

Note: NFPA 70E, *Standard for Electrical Safety in the Workplace*, offers direction on how to evaluate the *seriousness of possible exposure, plan safe work practices—including establishing an electrically safe work condition—perform arc flash labeling, and choose appropriate personal protective gear.*

(1) Depth of Working Space. The depth of the work area, measured from the enclosure front, cannot be less than the distances listed in Table 110.26(A)(1), which vary depending on voltage and the type of working condition. ▶ Figure 110–56

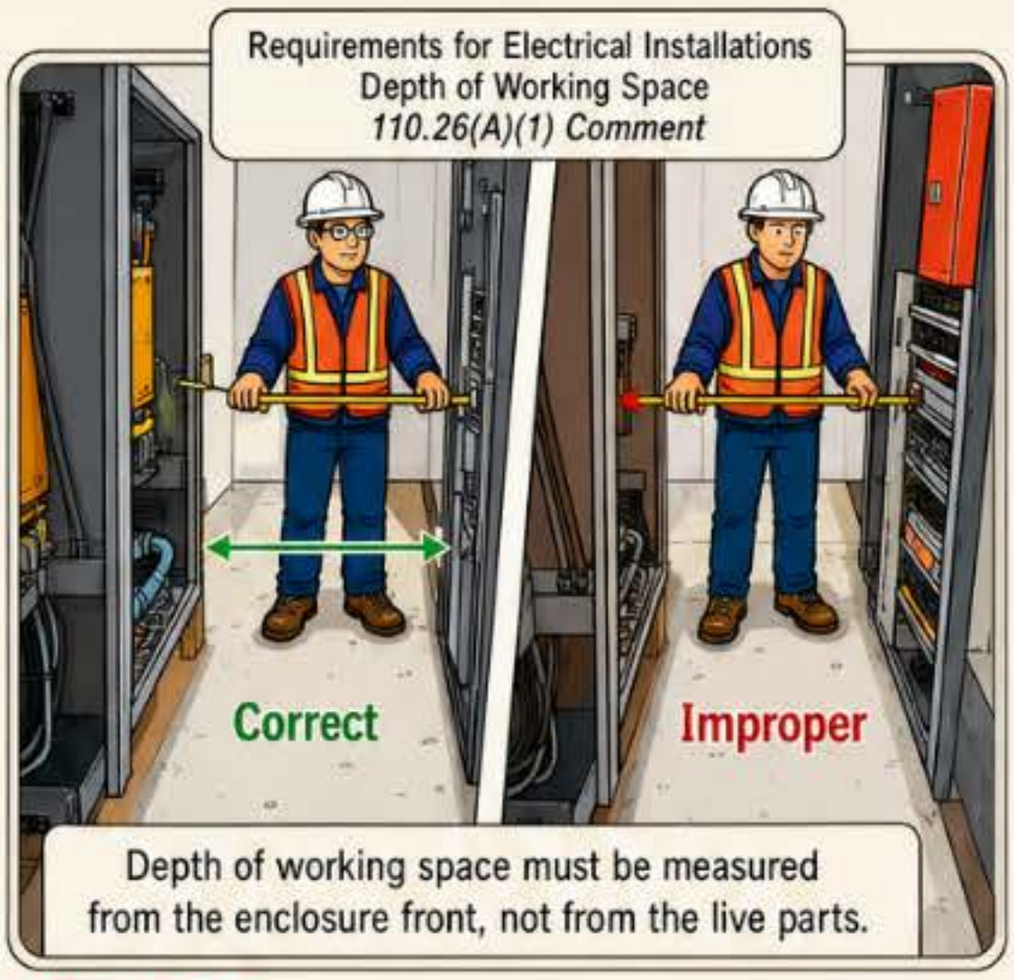


▶ Figure 110–56

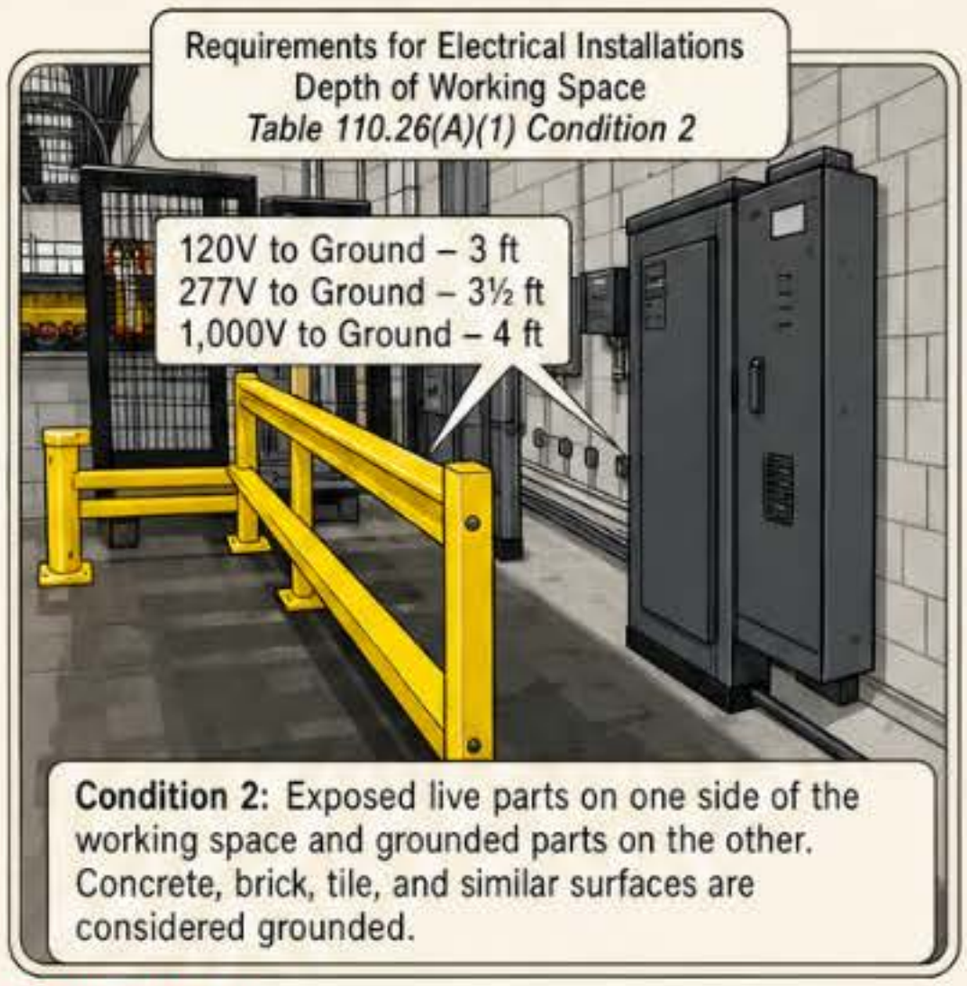
Author's Commentary:

- Depth of working space is measured from the front face of the enclosure, *not from live parts inside.*

— Michael Hamilton



▶ Figure 110-57

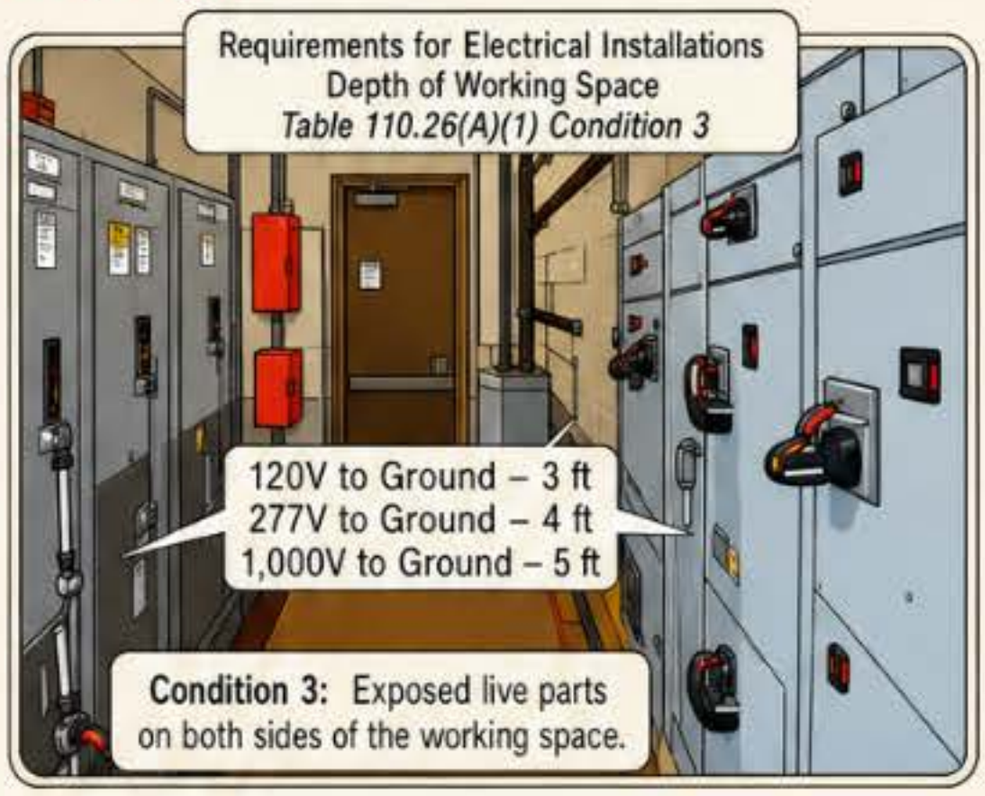


▶ Figure 110-59

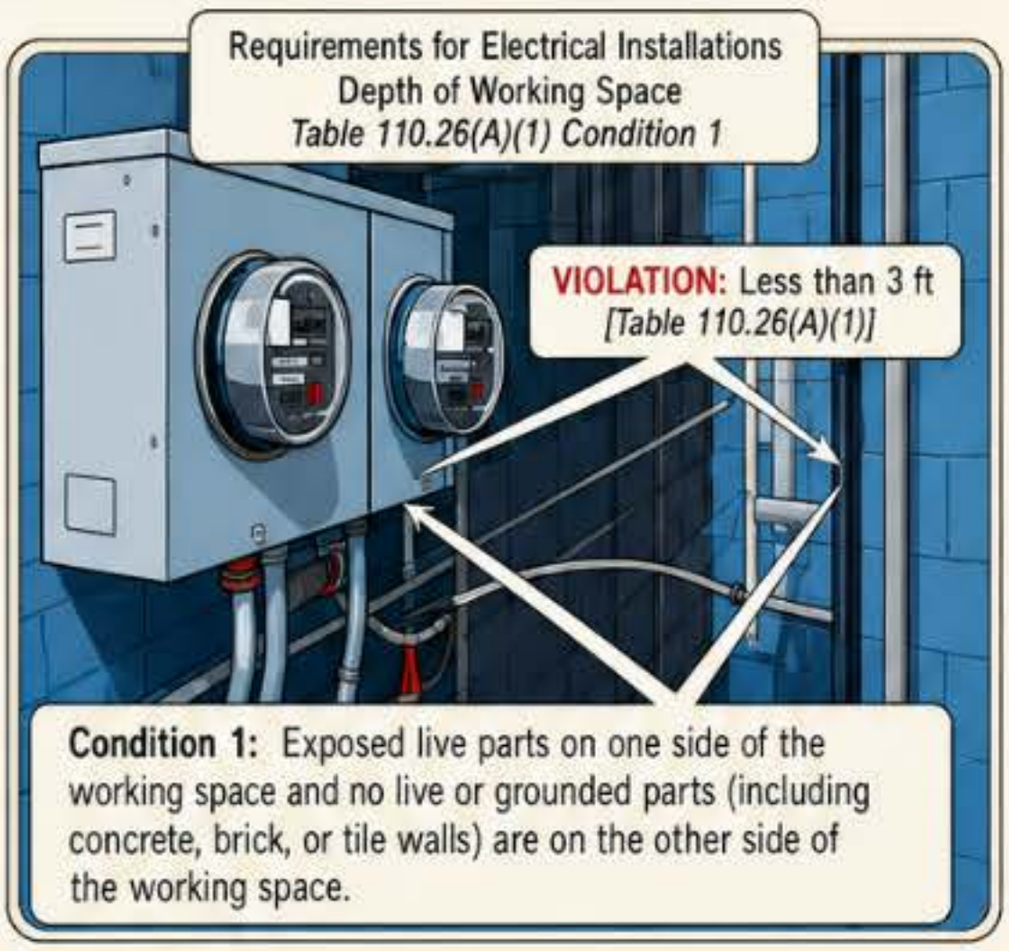
Table 110.26(A)(1) Working Space

Voltage-to-Ground	Condition 1	Condition 2	Condition 3
0–150V	3 ft	3 ft	3 ft
151–600V	3 ft	3½ ft	4 ft
601–1,000V	3 ft	4 ft	5 ft

▶ Figure 110-58, ▶ Figure 110-59, *and* ▶ Figure 110-60



▶ Figure 110-60



▶ Figure 110-58

Author's Commentary:

When a working space is a platform, its dimensions must be sized to meet the working space requirements. ▶ Figure 110-61

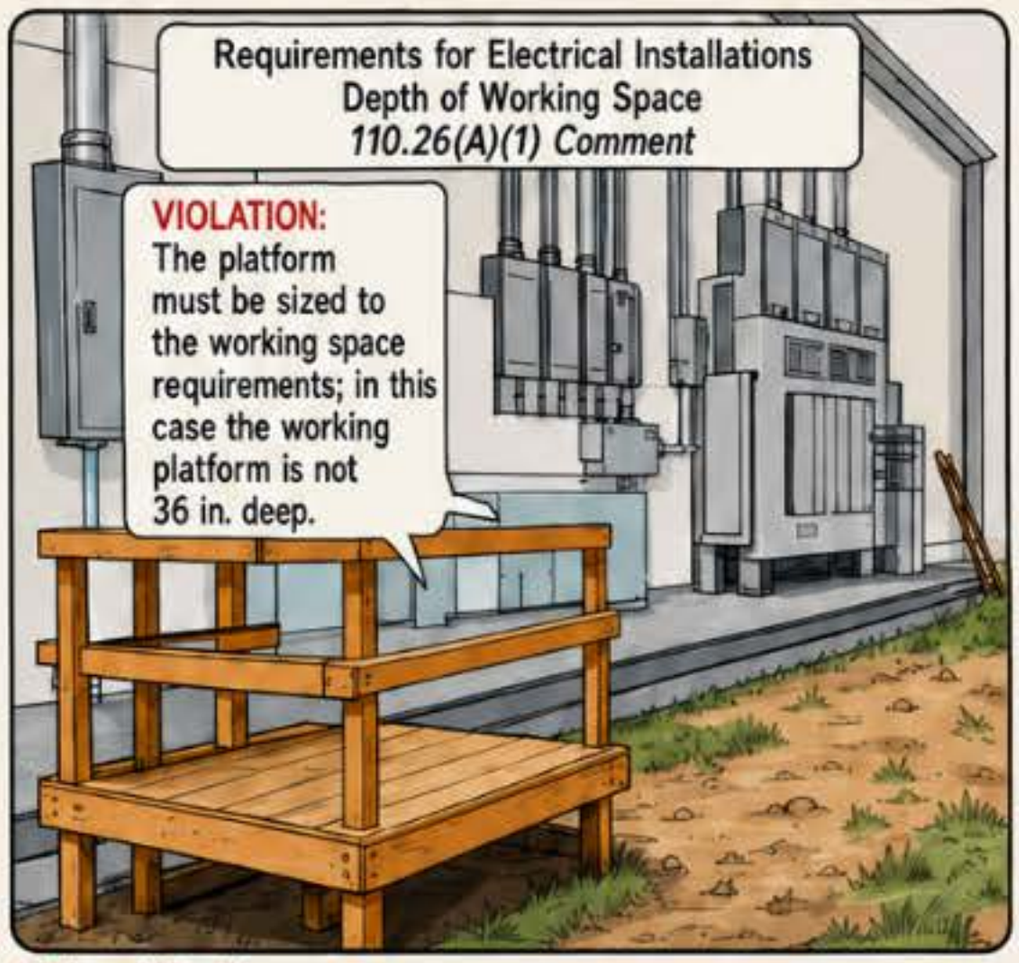
— Michael Hamilton

(a) Rear and Sides of Dead-Front Equipment. A working space is not required at the back or on the sides of dead-front equipment when all connections and parts are either fixed in place, adjustable, or serviceable from the front. ▶ Figure 110-62

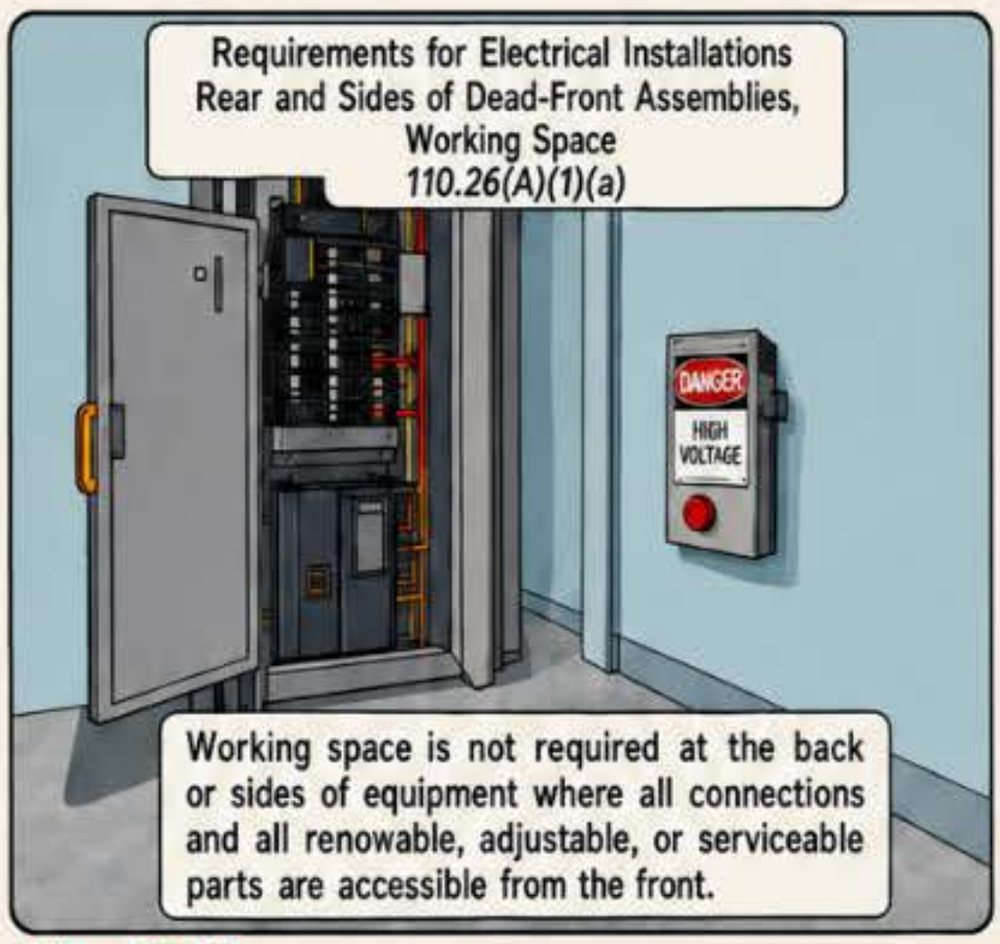
Author's Commentary:

Equipment that requires rear or side access for making field connections must be marked by the manufacturer on the front of the equipment. See 408.18(C).

— Michael Hamilton



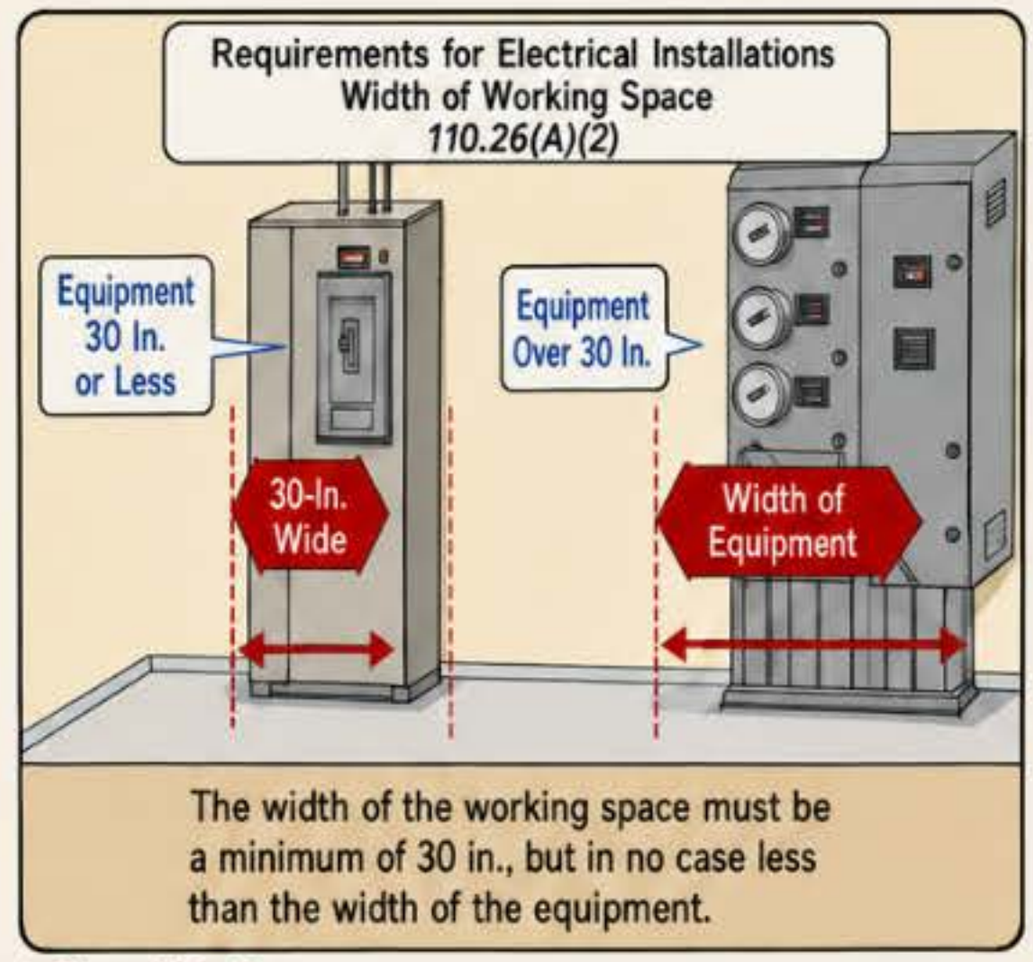
▸ Figure 110-61



▸ Figure 110-62

(c) Existing Buildings. If electrical equipment is being replaced, Condition 2 working space is permitted between dead-front switchboards, switchgear, panelboards, or motor control centers located across the aisle from each other where conditions of maintenance and supervision ensure that written procedures have been adopted to prohibit equipment on both sides of the aisle from being open at the same time, and only authorized, qualified persons will service the installation.

(2) Width of Working Space. *The width of the working space must be a minimum of 30 in., but in no case less than the width of the equipment.* ▸ Figure 110-63

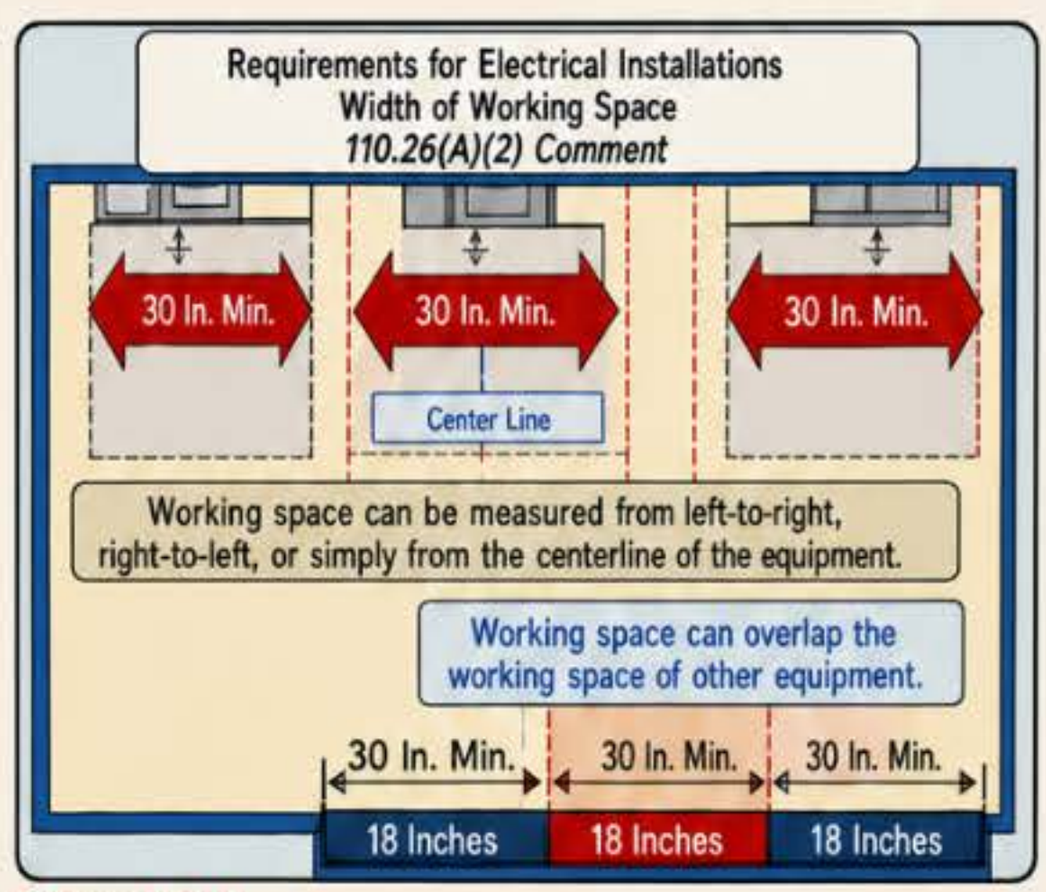


▸ Figure 110-63

Author's Commentary:

Measure the working space from left to right, from right to left, or center it on the equipment. Measurement can overlap the space allocated for neighboring electrical equipment.

— Michael Hamilton

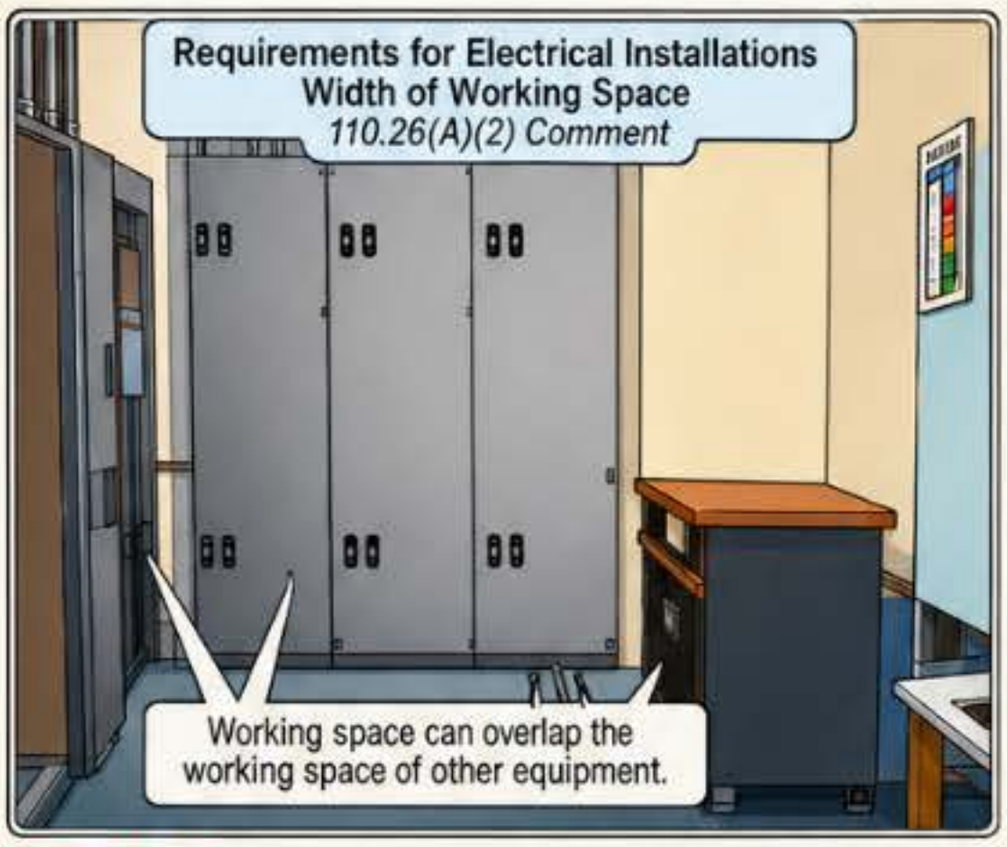


▸ Figure 110-64

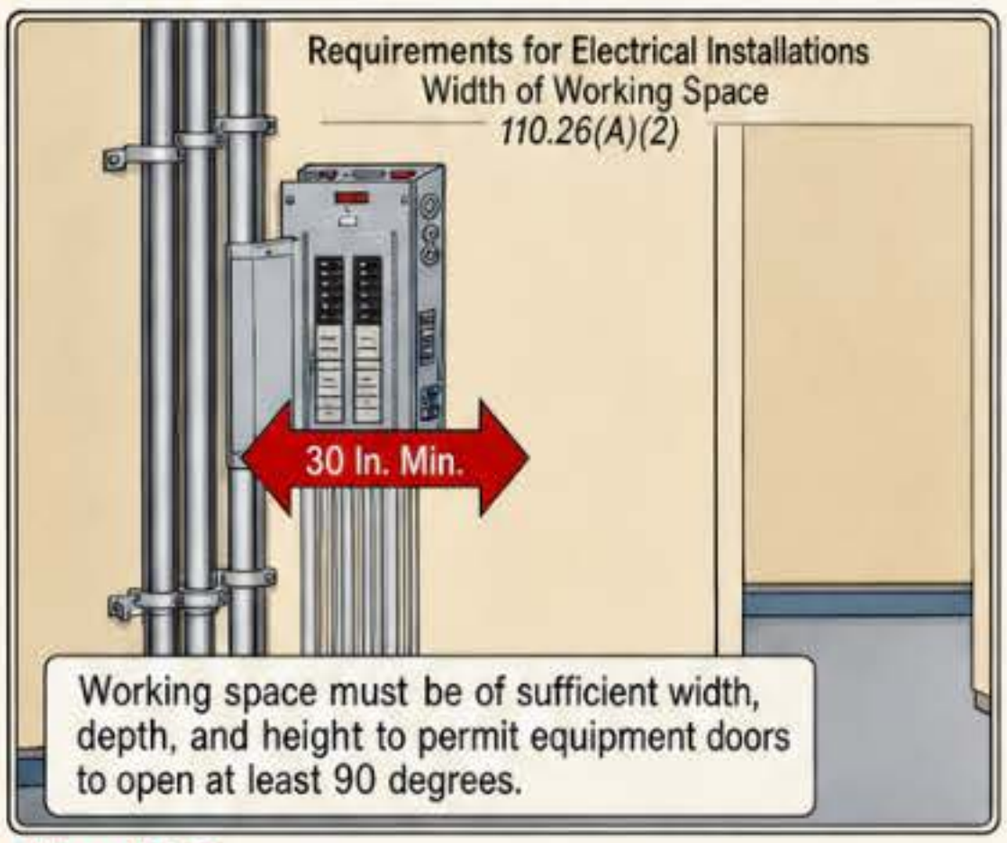
The working space must be of sufficient width, depth, and height to permit equipment doors to open at least 90 degrees. ▸ Figure 110-66

(3) Height of Working Space. *The height of the working space must be clear and extend from the grade, floor, or platform to a height of 6½ ft or the height of the equipment.* ▸ Figure 110-67

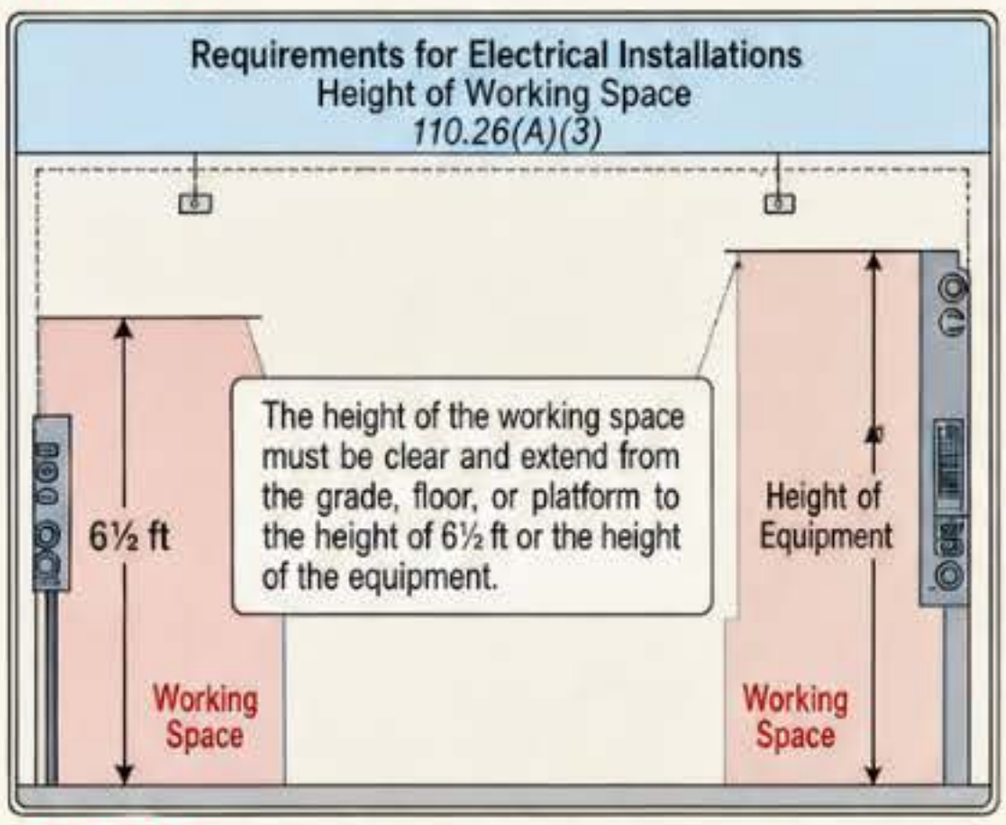
REQUIREMENTS FOR ELECTRICAL INSTALLATIONS



▶Figure 110-65



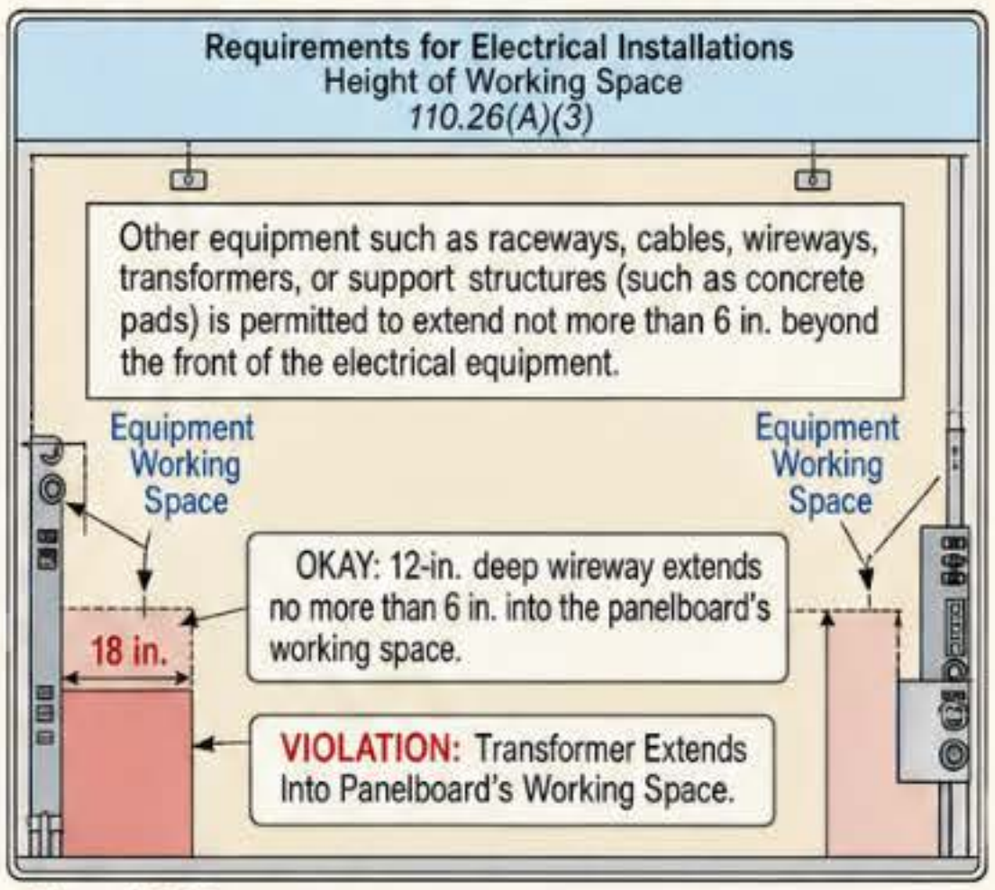
▶Figure 110-66



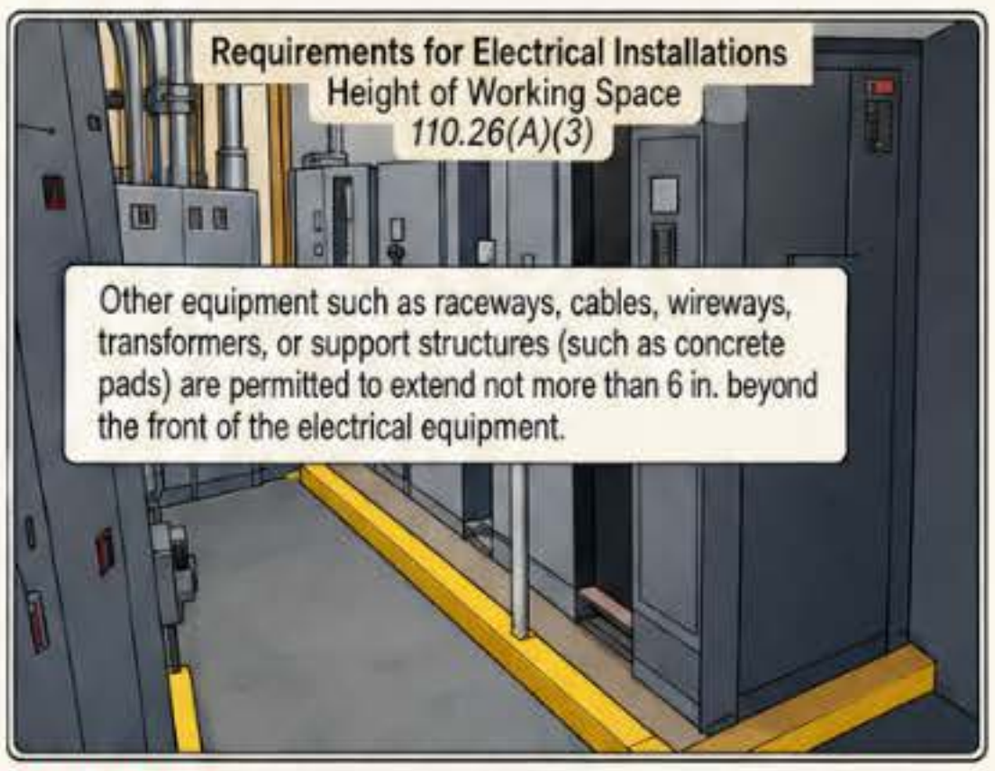
▶Figure 110-67

Other equipment such as raceways, cables, wireways, transformers, or support structures (such as concrete pads) are permitted to extend not more than 6 in. beyond the front of the electrical equipment.

▶Figure 110-68 and ▶Figure 110-69



▶Figure 110-68



▶Figure 110-69

Ex 2: The minimum height of working space does not apply to a service disconnect or panelboards rated 200A or less located in an existing dwelling unit.

Ex 3: Meters are permitted in the working space.

(4) Limited Access. Where equipment *is likely to require examination, adjustment, servicing, or maintenance while energized is located above a suspended ceiling or crawl space, all the following conditions apply:*

Author's Commentary:
The working space rules keep electrical equipment safe to operate and service. Think of the clearances as the 'personal space' every panel needs.
— Michael Hamilton

(1) Equipment mounted overhead from a suspended ceiling must be reachable through an opening at least 22 in. by 22 in. Equipment installed below a raised floor must have an access opening no smaller than 22 in. by 30 in.

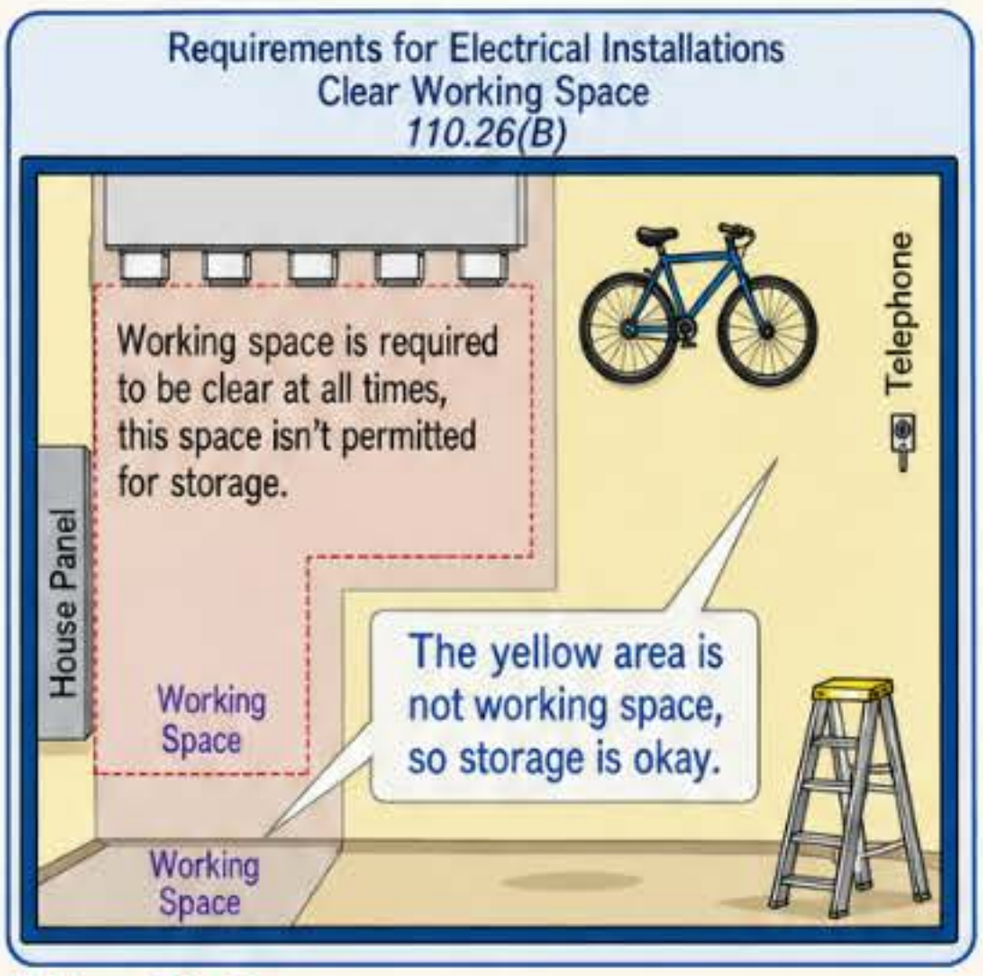
(2) The clear height in front of equipment must be at least 30 in., but in no case less than the equipment width.

(3) Doors providing access to the work area must be capable of opening at least 90 degrees.

(4) The space directly in front of electrical equipment must satisfy Table 110.26(A)(1). Horizontal projecting structural members are permitted in this zone.

(B) Clear Working Space. Whenever this section calls for a clear working area, that space cannot be used for storage.

▶ **Figure 110–70**



▶ **Figure 110–70**

CAUTION

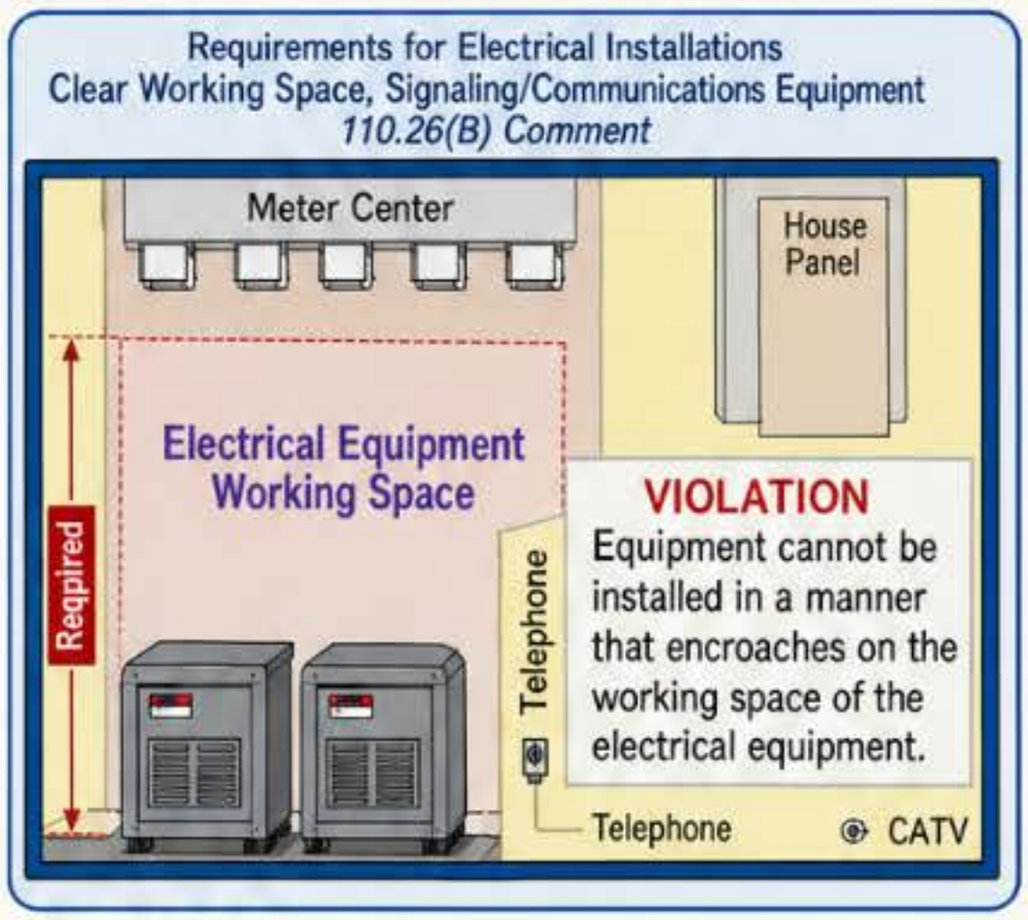
Live electrical components can be extremely hazardous. It's unacceptable to expose energized parts by storing items such as appliances, bicycles, boxes, crates, or other obstructions in the work zone.

Whether in a passageway or an open area, the working space (if required) must be kept clear and protected.

Author's Commentary:

- In a corridor, the walkway must be safeguarded from being occupied by people. When using a passage for electrical equipment, be mindful of fire protection. During an emergency, several people may need to evacuate and move through the area.
- Signaling and communication hardware is allowed in a manner that does not intrude on the working clearance of the electrical equipment.

— Michael Hamilton



▶ **Figure 110–71**

(C) Access to and Egress from Working Space

(1) **Minimum Required.** Each entrance must be large enough to allow entry to and exit from the work area.

Author's Commentary:

- *Verify that the authority having jurisdiction accepts "large enough." Building codes establish minimum sizes for doors and pass-throughs for personnel.*

— Michael Hamilton

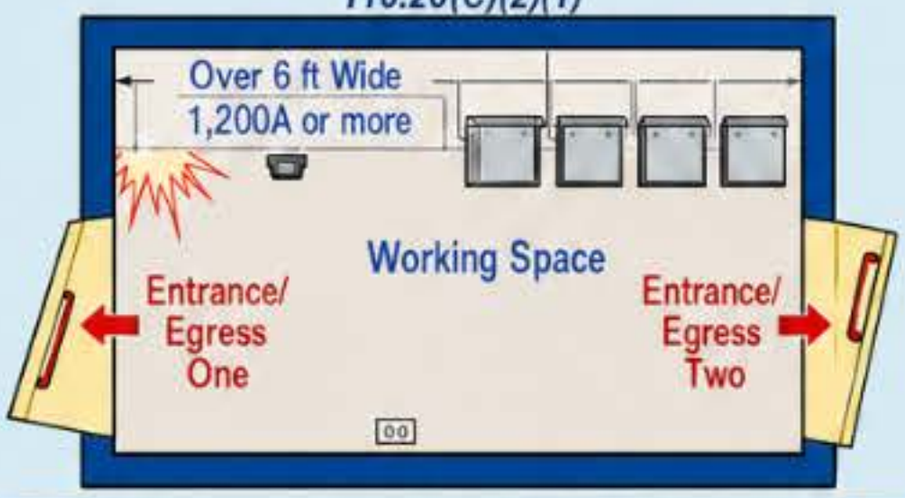
(2) **Large Equipment.** *For large installations containing overcurrent devices, switching equipment, or control devices, there must be an entry and exit to the required work area that is at least 24 in. wide and 6½ ft high. This requirement applies if either of the following exists:*

(1) *The equipment is 6 ft or wider and rated at 1,200 amperes or more.*

▶ **Figure 110–72**

Requirements for Electrical Installations

Requirements for Electrical Installations
Access to and Egress from Working Space, Large Equipment
110.26(C)(2)(1)

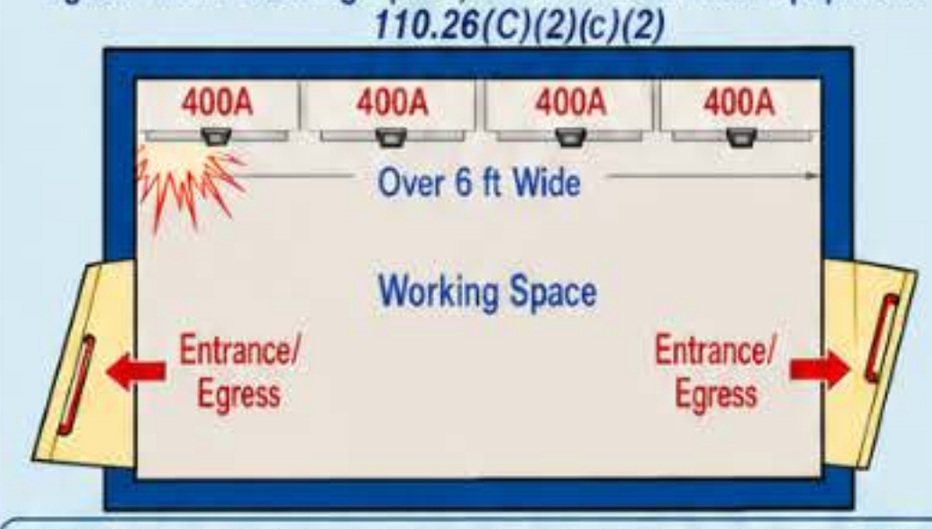


Equipment containing overcurrent devices or switching devices 1,200A or more and over 6 ft wide requires an entrance for the required working space not less than 24 in. wide and 6½ ft high at each end of the working space.

▸ Figure 110-72

(2) Where the service disconnecting means installed in accordance with 230.71 has a combined rating of 1,200A or more and is over 6 ft wide ▸ Figure 110-73

Requirements for Electrical Installations, Access to and Egress from Working Space, Combined Service Equipment
110.26(C)(2)(c)(2)



Service disconnecting means with a combined rating of 1,200A or more and over 6 ft wide requires an entrance to and egress from the required working space not less than 24 in. wide and 6½ ft high at each end of the working space.

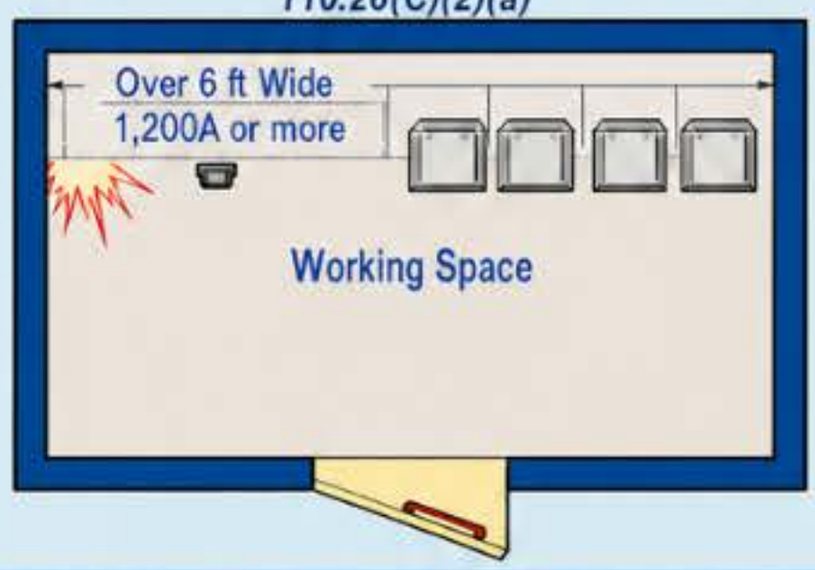
▸ Figure 110-73

Open equipment doors must not impede the entry to or egress from the working space.

A single entrance for access to and egress from the required working space is permitted where either of the following conditions are met:

(a) Unobstructed Egress. Where the location permits a continuous and unobstructed way of egress travel. ▸ Figure 110-74

Requirements for Electrical Installations, Entrance to and Egress from Working Space, Unobstructed Egress
110.26(C)(2)(a)

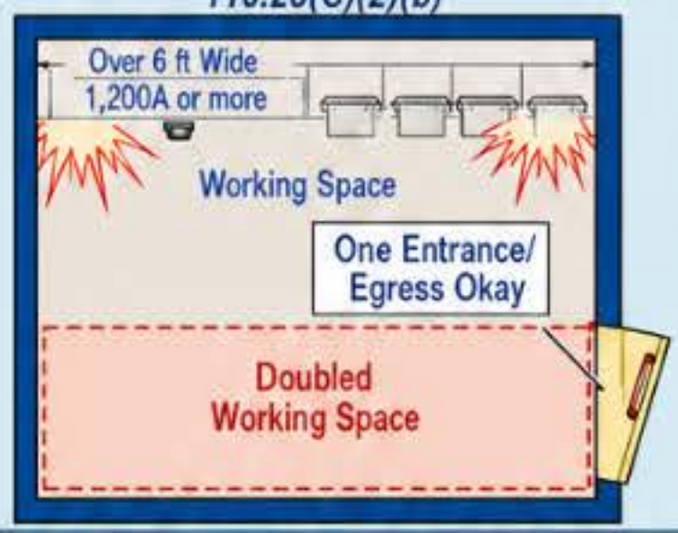


A single entrance is permitted where the location allows a continuous and unobstructed way of egress travel.

▸ Figure 110-74

(b) Double Working Space. Where the required working space depth is doubled and the equipment is located so the edge of the entrance is no closer than the required working space distance. ▸ Figure 110-75

Requirements for Electrical Installations, Entrances to and Egress from Working Space, Large Equipment, Double Working Space
110.26(C)(2)(b)



One entrance/egress is permitted where the required working space is doubled, and equipment is located so the edge of the entrance is no closer than the required working space distance.

▸ Figure 110-75

(3) Fire Exit Hardware on Personnel Doors. Where equipment rated 800A or more contains overcurrent, switching, or control devices is installed and there is a personnel door(s) intended for entrance to and egress from the working space less than 25 ft from the nearest edge of the working space, the door(s) are required to open in the direction of egress and be equipped with listed panic or listed fire exit hardware. ▸ Figure 110-76

Author's Commentary: *Keep door swings in mind when planning entrances. An open door must never block the required access or exit path.*
— Michael Hamilton

Author's Commentary: *Outward-swinging doors with listed panic or fire exit hardware help ensure that personnel can leave quickly and safely in an emergency.*
— Michael Hamilton

Key Takeaway: *Entrances must provide clear, unobstructed access and egress to the working space as required by the equipment size and configuration.*

Michael Hamilton, page 89

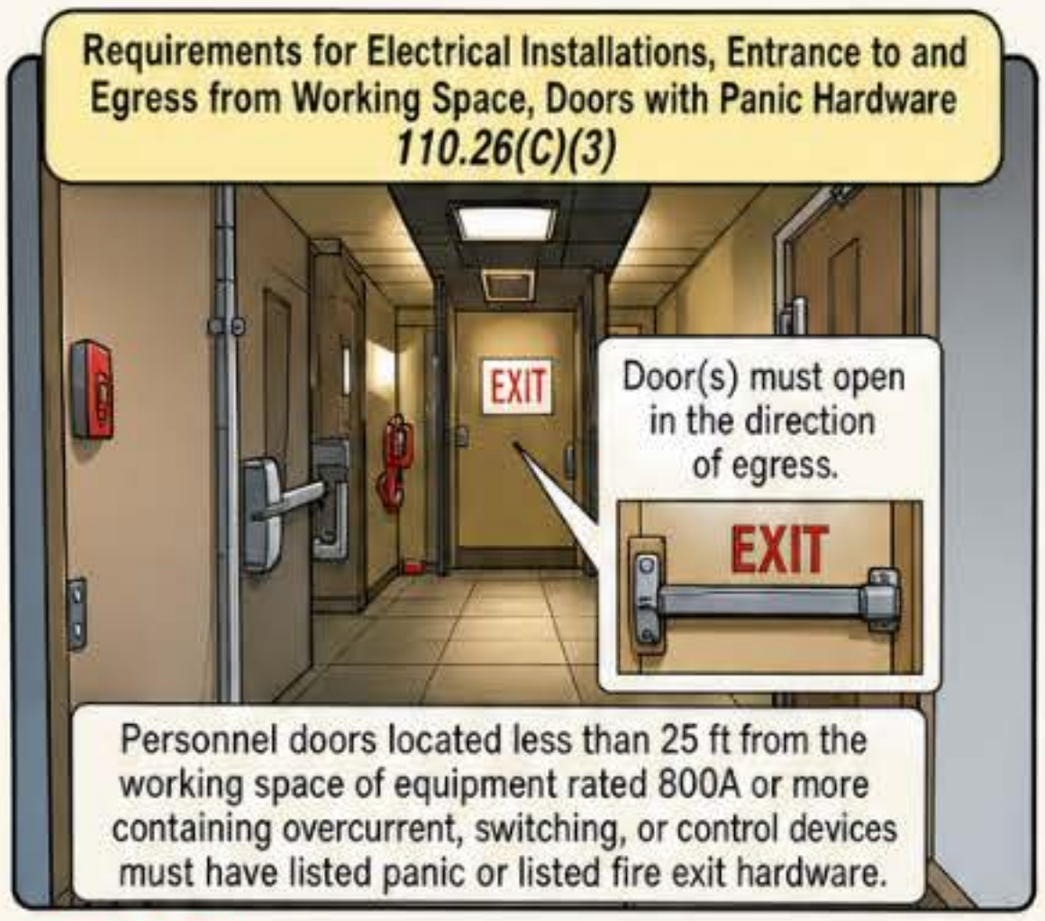


Figure 110-76

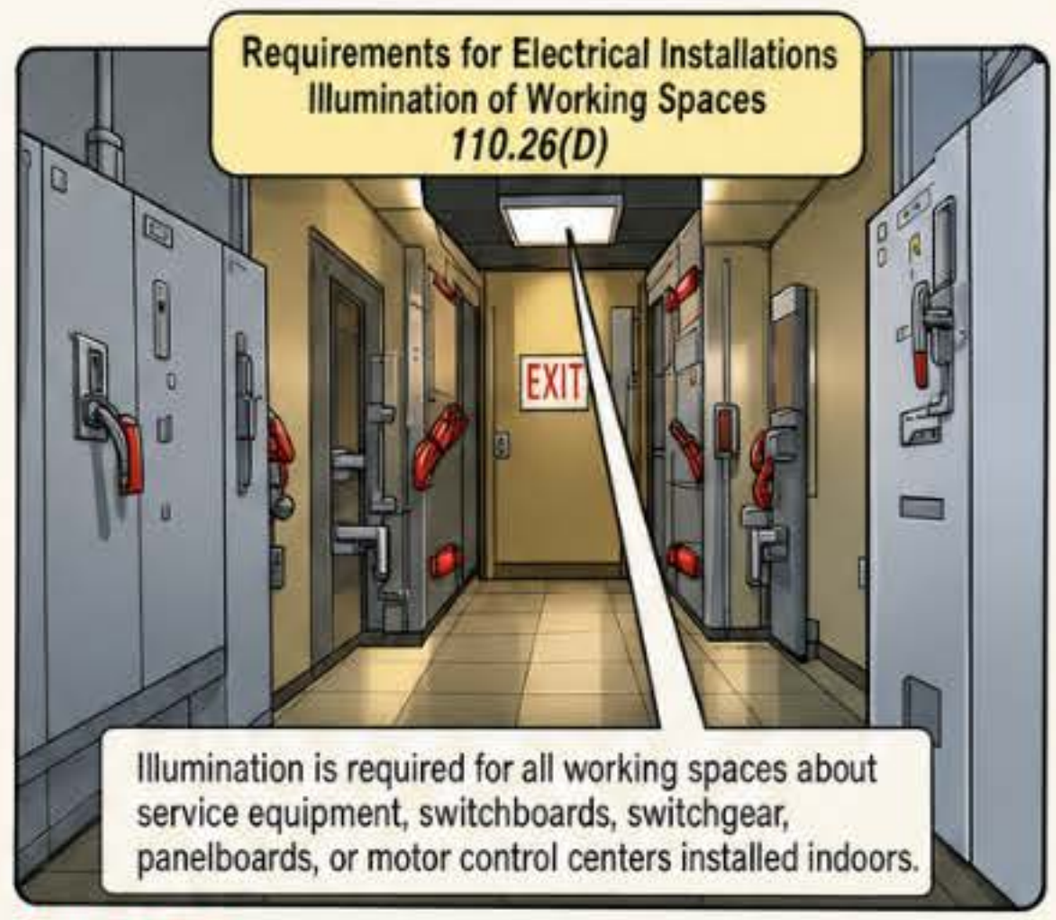


Figure 110-77

Author's Commentary:

- History has shown that electricians who suffer burns on their hands in electrical arc flash or arc blast events often cannot open doors equipped with knobs that must be turned or doors that must be pulled open.
- Since this requirement is in the *NEC*, electrical contractors are responsible for ensuring panic hardware is installed where required. Some are offended at being held liable for *non-electrical responsibilities, but this rule is designed to save the lives of electricians. For this and other reasons, many construction professionals routinely hold "pre-construction" or "pre-con" meetings to review potential opportunities for miscommunication—before the work begins.*

— Michael Hamilton

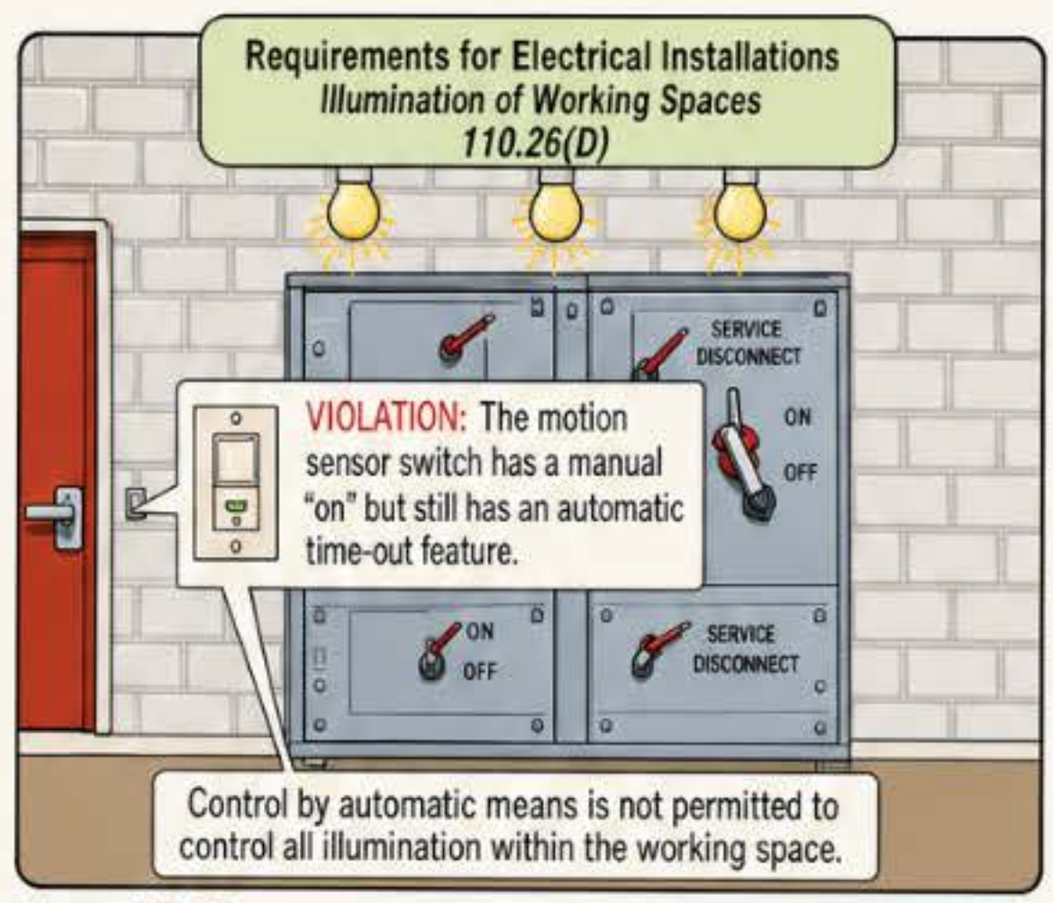


Figure 110-78

(D) Illumination. Illumination is required for all working spaces about service equipment, switchboards, switchgear, panelboards, or motor control centers installed indoors. Control by automatic means is not permitted to control all illumination within the working space. ▸Figure 110-77 and ▸Figure 110-78

Additional lighting outlets are not required where the working space is illuminated by an adjacent light source, or as permitted by 210.70(A)(1) Ex 1 for switched receptacles.

Author's Commentary:

The Code does not identify the minimum foot-candles required to provide proper illumination even though it is essential in electrical equipment rooms for the safety of those qualified to work on such equipment.

— Michael Hamilton

(E) Dedicated Electrical Equipment Space. Switchboards and panelboards must have dedicated equipment space and be protected from damage that could result from condensation, leaks, breaks in the foreign systems, and vehicular traffic as follows:

(1) Indoors. Switchboards and panelboards installed indoors must comply with the following:

(a) Equipment Space. The footprint space (width and depth of the equipment) extending from the floor to a height of 6 ft above the equipment or to the structural ceiling, whichever is lower, must be dedicated for electrical equipment. ▸Figure 110-79

No piping, ducts, or other equipment foreign to the electrical system *can be installed in this dedicated electrical equipment space.* ▸Figure 110-80

Requirements for Electrical Installations, Dedicated Electrical Equipment Space, Indoor Switchboard/Panelboard
110.26(E)(1)(a)

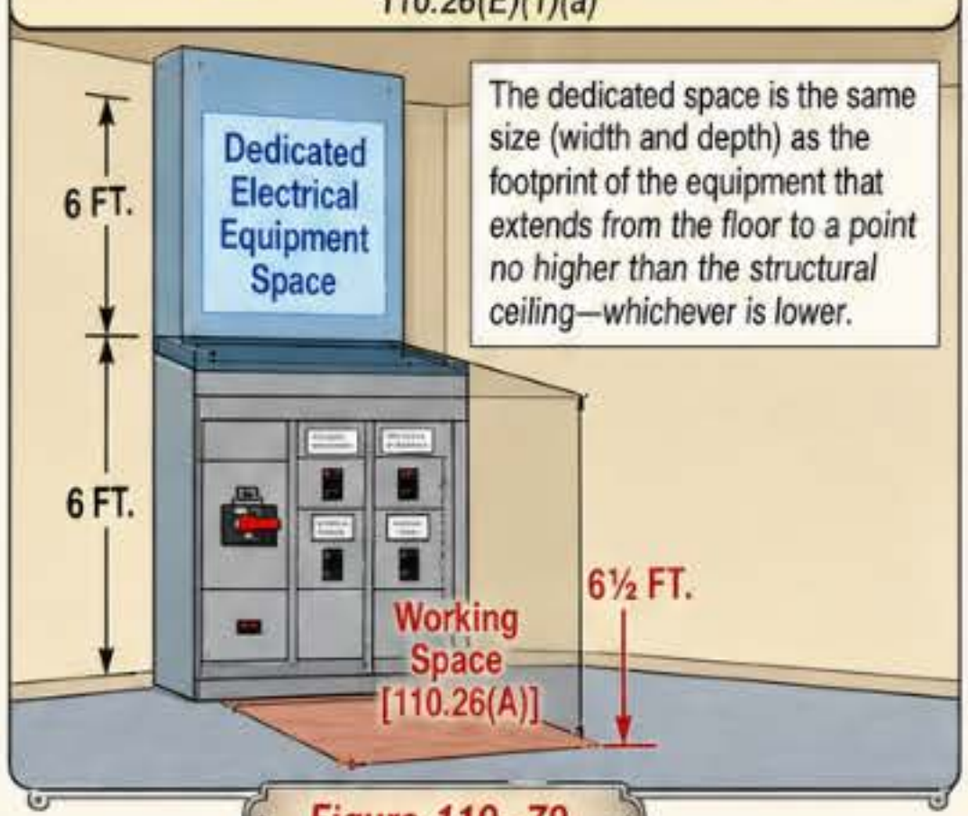


Figure 110–79

Requiments for Electrical Installations Dedicated Electrical Space, Indoors
110.26(E)(1)(a) Comment

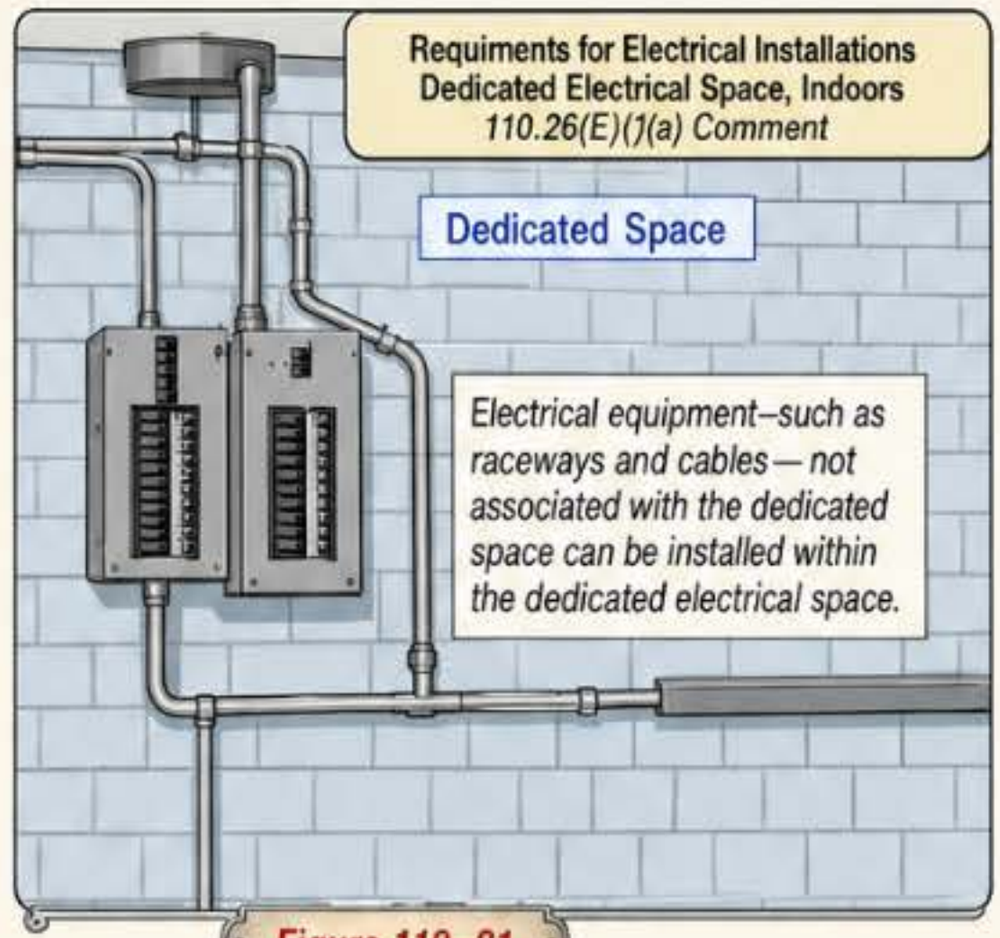


Figure 110–81

Requirements for Electrical Installations Dedicated Electrical Equipment Space, Indoors
110.26(E)(1)(a)

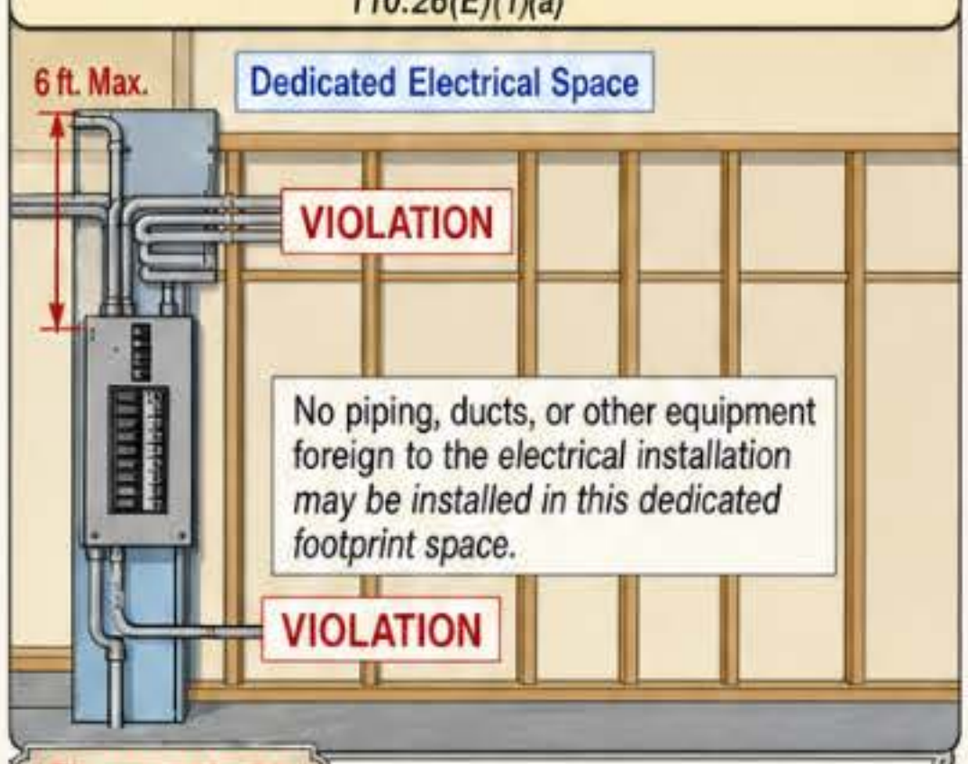


Figure 110–80

Requirements for Electrical Installations Dedicated Electrical Space Indoors, Foreign Systems
110.26(E)(1)(b)

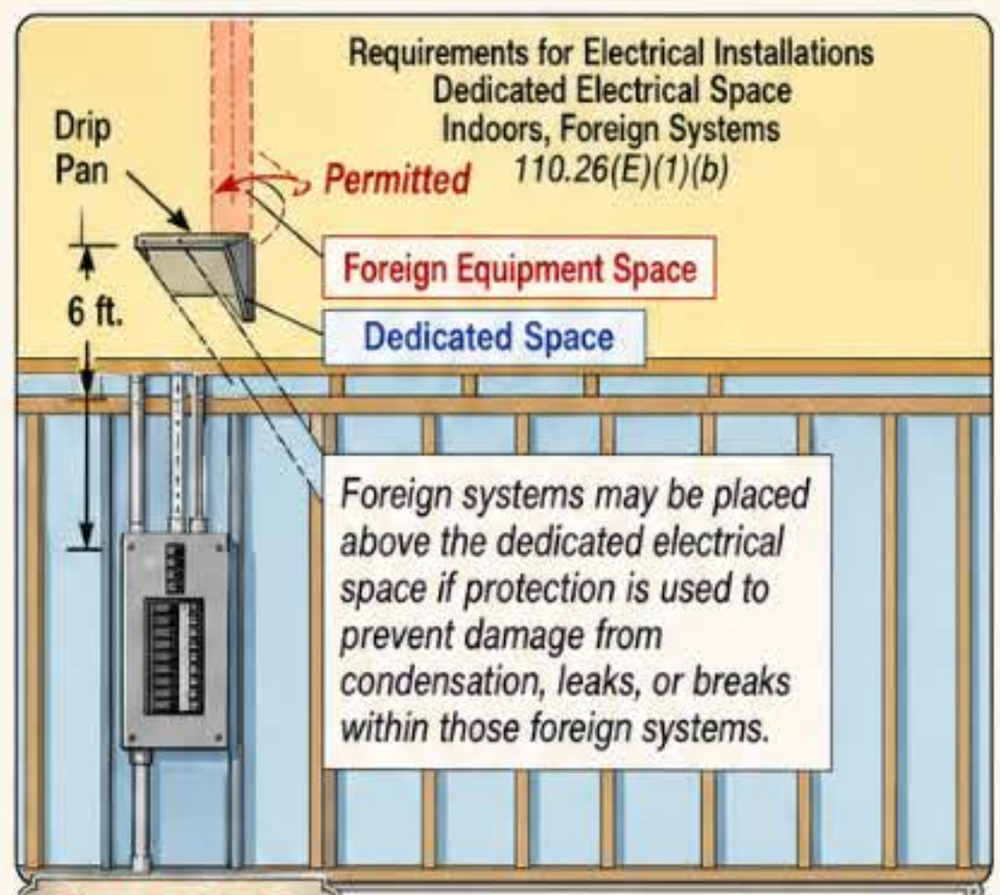


Figure 110–82

Author's Commentary:

- *Electrical equipment like raceways and cables that are not part of the dedicated space can be installed in the dedicated space.* ▸*Figure 110–81*

Ex: Suspended ceilings with removable panels can be inside the dedicated space [110.26(E)(1)(a)].

(b) Foreign Systems. *Foreign systems may be located above the dedicated space when installed protection is used to prevent damage to electrical equipment from condensation, leaks, or breaks in the foreign system.*
This protective method can be as simple as a drip pan. ▸*Figure 110–82*

(c) Sprinkler Protection. *Sprinkler piping is not allowed within the dedicated space, but the NEC does not prohibit sprinklers from spraying water on electrical equipment.*

(d) Suspended Ceilings. *A dropped, suspended, or similar ceiling is not considered a structural ceiling.* ▸*Figure 110–83*

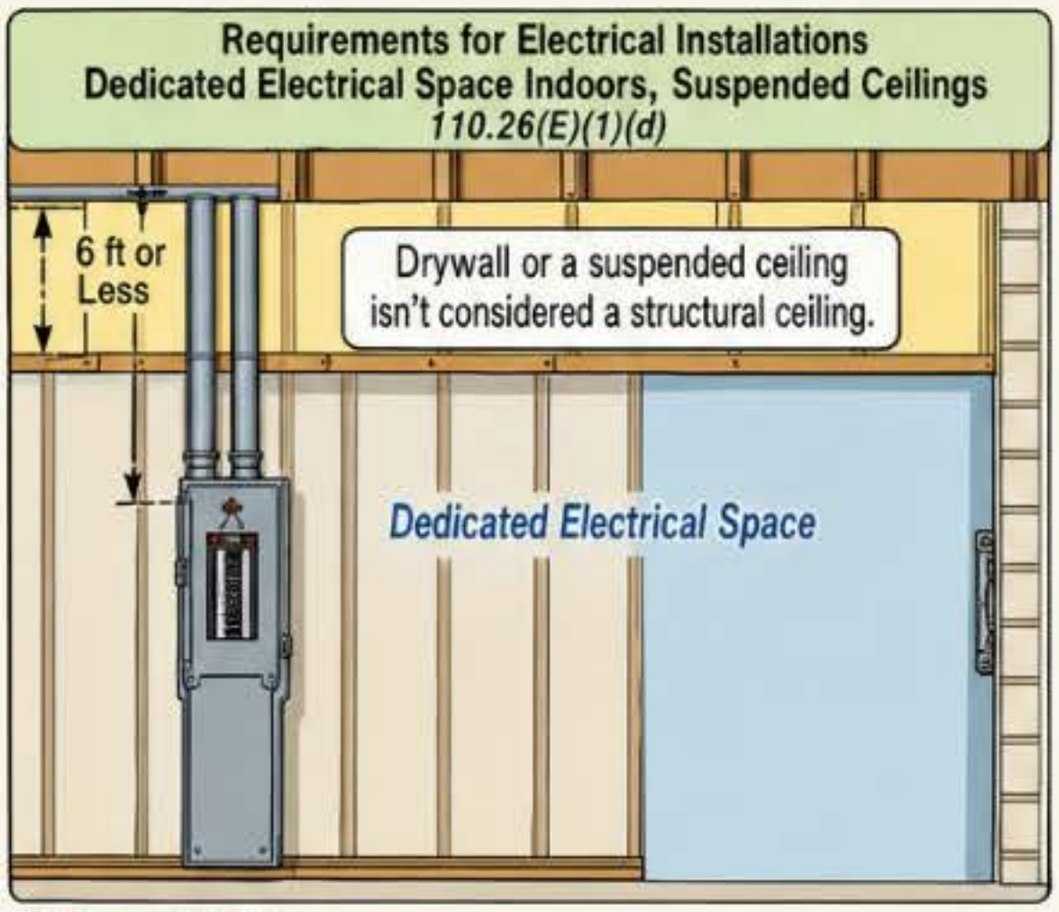
(2) Outdoor. *Outdoors, switchboards and panelboards must comply with the following:*

(a) Installation Requirements.

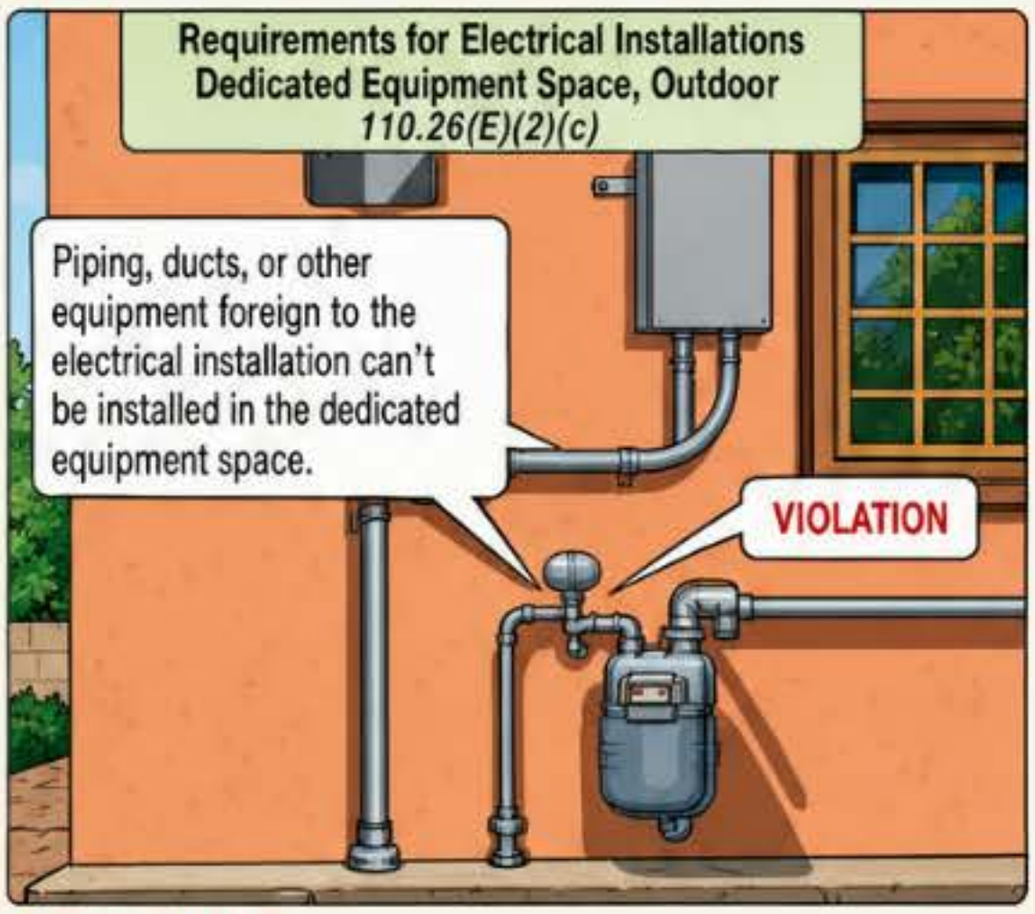
(1) *Installed in identified enclosures.*

(2) *Protected from accidental contact by unauthorized personnel or by vehicular traffic.* ▸*Figure 110–84*

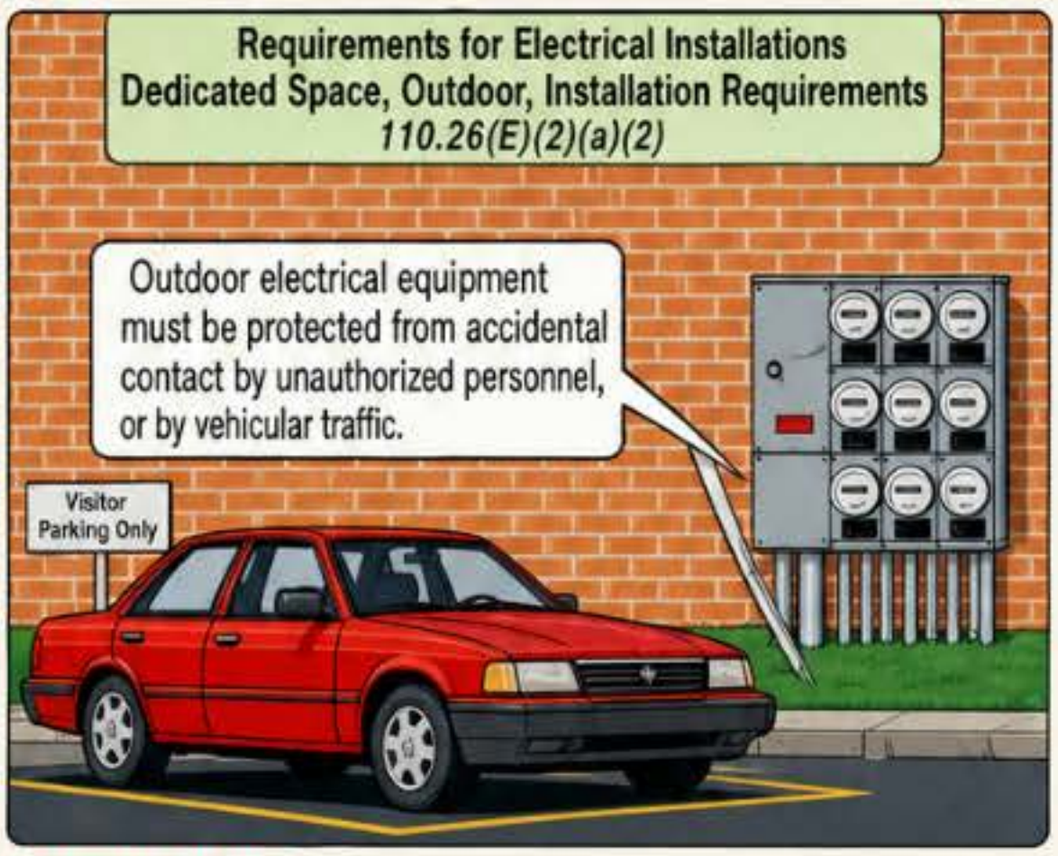
110.28 | Requirements for Electrical Installations



▲ Figure 110–83



▲ Figure 110–85



▲ Figure 110–84

▲ Figure 110–86

(3) Protected from accidental spillage or leakage from piping systems

(b) Working Space. The working clearance space includes the zone described in 110.26(A). Architectural appurtenances or other equipment are not permitted within this zone.

(c) Dedicated Equipment Space Outdoors. The footprint space (width and depth of the equipment) of the outdoor dedicated space extending from grade to a height of 6 ft above the equipment must be dedicated for electrical installations. No piping, ducts, or other equipment foreign to the electrical installation can be installed in this dedicated space. ▶ Figure 110–85

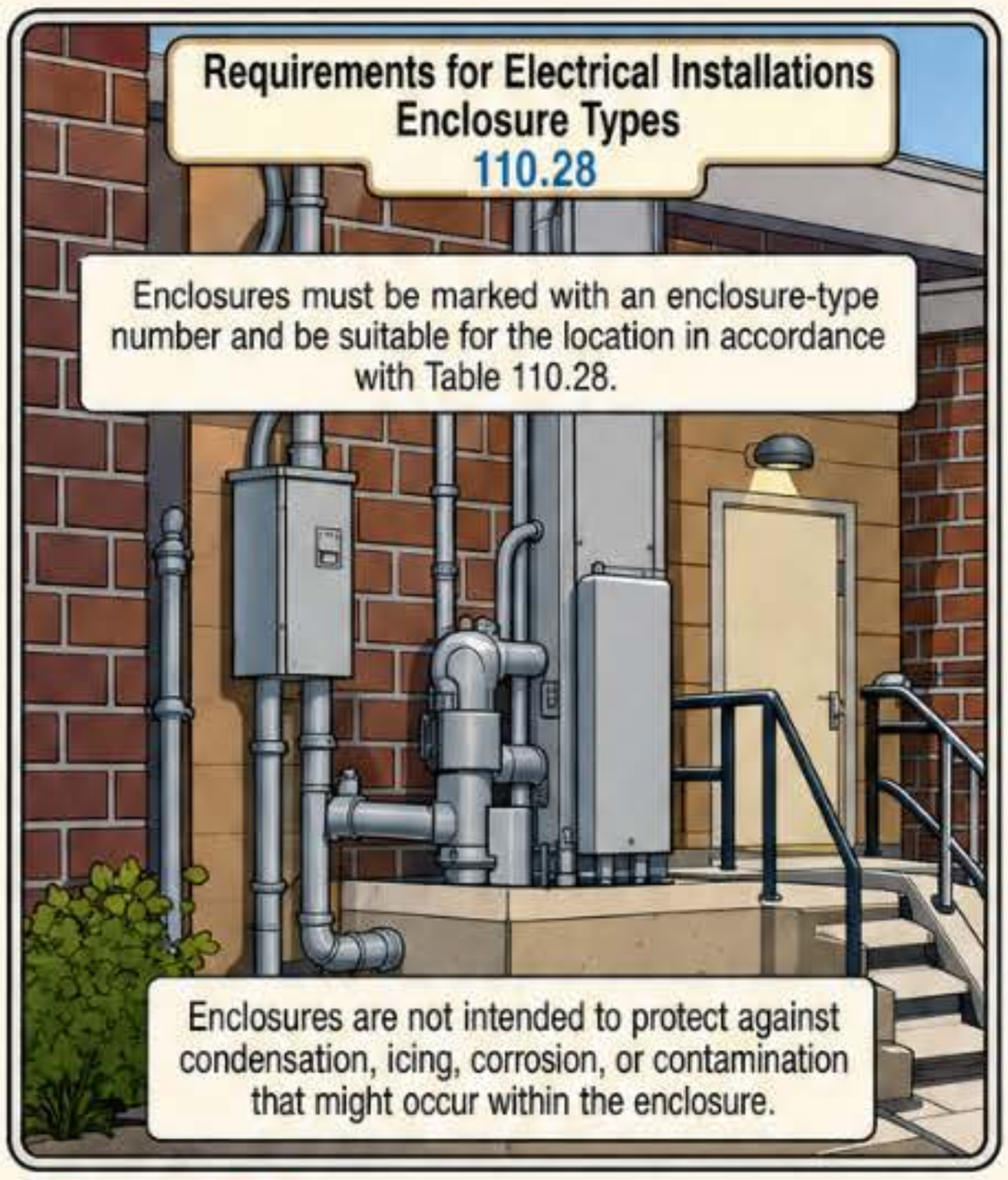
(f) Locked Electrical Equipment Rooms or Enclosures. Rooms or enclosures containing electrical equipment controlled by a lock are *considered accessible to qualified persons.* ▶ Figure 110–86

110.28 Enclosure Types

Enclosures must be marked with an enclosure-type number and be suitable for the location in accordance with Table 110.28. They are not intended to protect against condensation, icing, corrosion, or contamination that might occur within the enclosure or that enters via a raceway or unsealed openings. ▶ Figure 110–87

Note 1: Raintight enclosures include Types 3, 3S, 3SX, 3X, 4, 4X, 6, and 6P; rainproof enclosures are Types 3R and 3RX; watertight enclosures are Types 4, 4X, 6, and 6P; driptight enclosures are Types 2, 5, 12, 12K, and 13; and dusttight enclosures are Types 3, 3S, 3SX, 3X, 4, 4X, 5, 6, 6P, 12, 12K, and 13.

REQUIREMENTS FOR ELECTRICAL INSTALLATIONS | 110.28



▲ Figure 110-87

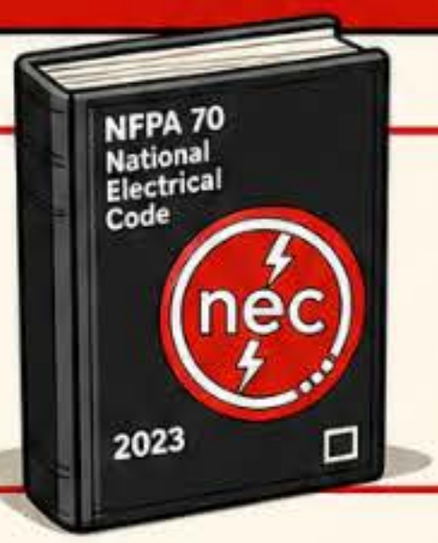
Note 3: Dusttight enclosures are suitable for use in hazardous locations in accordance with 502.10(B)(4), 503.10(A)(2), and 506.15(C)(9).

Note 4: Dusttight enclosures are suitable for use in unclassified locations and in Class II, Division 2; Class III; and Zone 22 hazardous (classified) locations.

Notes

CHAPTER 1

PRACTICE QUESTIONS



Please use the 2023 *Code* book to answer the following questions.

CHAPTER 1—GENERAL RULES

1. Part III of Article 100 contains definitions which are applicable to _____.
   (a) Solar (PV) Systems
   (b) Hazardous (Classified) Locations
   (c) Electrical Systems Over 1,000V
   (d) Healthcare Facilities

2. By definition, an attachment fitting is different from an attachment plug because no _____ is associated with the fitting.
   (a) cable
   (b) fixture wire
   (c) cord
   (d) wiring compartment

3. A battery system includes storage batteries and battery chargers, and can include inverters, converters, and associated electrical equipment.
   (a) True
   (b) False

4. A branch circuit that supplies only one utilization equipment is a(n) _____ branch circuit.
   (a) individual
   (b) general-purpose
   (c) isolated
   (d) special-purpose

5. A multitwire branch circuit consists of _____.
   (a) two or more ungrounded conductors that have a voltage between them
   (b) a grounded conductor that has equal voltage between it and each ungrounded conductor of the circuit
   (c) a grounded conductor connected to the neutral or grounded conductor of the system
   (d) all of these

6. Composite optical fiber cables contain optical fibers and _____.
   (a) strength members
   (b) vapor barriers
   (c) current-carrying electrical conductors
   (d) recycled plastic

7. Due to its power limitations, a Class 2 circuit considers safety from a fire initiation standpoint and provides acceptable protection from electric shock.
   (a) True
   (b) False

8. The _____ of any system is the ratio of the maximum demand of a system, or part of a system, to the total connected load of a system.
   (a) load
   (b) demand factor
   (c) minimum load
   (d) calculated factor

DEFINITIONS | From Michael Hamilton Publications

9. Systems of illumination utilizing fluorescent lamps, high-intensity discharge (HID) lamps, or neon tubing are all types of _____.

(a) Area Lighting
(b) Flood Lighting
(c) Security Lighting
(d) Electric Discharge Lighting

10. An effective ground-fault current path is an intentionally constructed, low-impedance electrically conductive path designed and intended to carry current during a ground-fault condition from the point of a ground fault on a wiring system to _____.

(a) ground
(b) earth
(c) the electrical supply source
(d) the grounding electrode

11. Surrounded by a case, housing, fence, or wall(s) that prevents persons from accidentally contacting energized parts is called "_____."

(a) guarded
(b) covered
(c) protection
(d) enclosed

12. Equipment or materials to which has been attached a(n) _____ of an FEB indicating the equipment or materials were evaluated and found to comply with requirements as described in an accompanying field evaluation report is known as "field labeled (as applied to evaluated products)."

(a) symbol
(b) label
(c) other identifying mark
(d) any of these

13. "Generating capacity, inverter" is defined as the sum of parallel-connected inverter maximum continuous output power at 40°C in _____.

(a) amps or kVA
(b) volts or kV
(c) watts or kW
(d) a 24 hour period

Author's Commentary: *Know these definitions well. They describe essential terms used throughout the code and are key to answering many questions correctly.*

— Michael Hamilton

14. Examples of ground-fault current paths include any combination of conductive materials including _____.

(a) equipment grounding conductors
(b) metallic raceways
(c) metal water and gas piping
(d) all of these

15. Connected (connecting) to ground or to a conductive body that extends the ground connection is called "_____."

(a) equipment grounding
(b) bonded
(c) grounded
(d) all of these

16. The installed conductive path(s) that is part of a ground-fault current path and connects normally noncurrent-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both, is known as a(n) "_____ conductor."

(a) grounding electrode
(b) grounding
(c) equipment grounding
(d) neutral

17. A conducting object through which a direct connection to earth is established is a "_____."

(a) bonding conductor
(b) grounding conductor
(c) grounding electrode
(d) grounded conductor

18. A conductor used to connect the system grounded conductor, or the equipment to a grounding electrode or to a point on the grounding electrode system, is called the "_____ conductor."

(a) main grounding
(b) common main
(c) equipment grounding
(d) grounding electrode

19. A "_____" is an accommodation that combines living, sleeping, sanitary, and storage facilities within a compartment.

(a) guest room
(b) guest suite
(c) dwelling unit
(d) single-family dwelling

Author's Commentary: *Understanding grounding components and related terms is fundamental to safe system design and code compliance.*

— Michael Hamilton

20. A hoistway is any _____ in which an elevator or dumbwaiter is designed to operate.

(a) hatchway or well hole
(b) vertical opening or space
(c) shaftway
(d) all of these

21. A hybrid system is comprised of multiple power sources, such as _____, but not the utility power system.

(a) photovoltaic
(b) wind
(c) micro-hydro generators
(d) all of these

22. Information and technology equipment and systems are used for creation and manipulation of _____.

(a) data
(b) voice
(c) video
(d) all of these

23. "Within sight from" means visible and not more than _____ ft distant from the equipment.

(a) 10
(b) 20
(c) 25
(d) 50

24. The conductors connected to the direct-current input of an inverter for PV systems form the _____.

(a) branch circuit
(b) feeder
(c) inverter input circuit
(d) inverter output circuit

Author's Commentary:
The DC conductors entering the inverter are considered the inverter input circuit.
— *Michael Hamilton*

25. The term "Luminaire" means a single individual lampholder by itself.

(a) True
(b) False

26. A wire that is run along with integral to a cable or conductor to provide mechanical support for the cable or conductor is a _____.

(a) tension wire
(b) messenger wire
(c) guy wire
(d) strain relief wire

27. "Nonautomatic" is defined as requiring _____ to perform a function.

(a) protection from damage
(b) human intervention
(c) mechanical linkage
(d) all of these

28. An overload is the same as a short circuit or ground fault.

(a) True
(b) False

29. NFPA 70E, *Standard for Electrical Safety in the Workplace*, provides information to help determine the electrical safety training requirements expected of a qualified person.

(a) True
(b) False

30. Any electrical circuit that controls any other circuit through a relay or an equivalent device is called a "_____."

(a) primary circuit
(b) remote-control circuit
(c) signal circuit
(d) controller

31. A "service drop" is defined as the overhead conductors between the utility electric supply system and the _____.

(a) service equipment
(b) service point
(c) grounding electrode
(d) equipment grounding conductor

32. The "_____" is the necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuse(s) and their accessories, connected to the load end of service conductors, and intended to constitute the main control and cutoff of the supply.

(a) service equipment
(b) service
(c) service disconnect
(d) service overcurrent device

33. The underground conductors between the utility electric supply system and the service point are known as the "_____."

(a) utility service
(b) service lateral
(c) service drop
(d) main service conductors

Chapter 1 | Practice Questions

34. A permanently connected surge-protective device (SPD) intended for installation on the load side of the service disconnect overcurrent device, including SPDs located at the branch panel, is a "Type _____ SPD."

(a) 1
(b) 2
(c) 3
(d) 4

35. In judging equipment for approval, considerations such as _____ shall be evaluated.

(a) mechanical strength
(b) wire-bending space
(c) arcing effects
(d) all of these

36. Listed or labeled equipment shall be installed and used in accordance with any instructions included in the listing or labeling.

(a) True
(b) False

37. All _____ shall be covered with an insulation equivalent to that of the conductors or with an identified insulating device.

(a) splices
(b) joints
(c) free ends of conductors
(d) all of these

38. Separately installed pressure connectors shall be used with conductors at the _____ not exceeding the ampacity at the listed and identified temperature rating of the connector.

(a) voltages
(b) temperatures
(c) listings
(d) ampacities

39. NFPA *70E, Standard for Electrical Safety in the Workplace,* provides guidance, such as determining severity of potential exposure, planning safe work practices, *arc-flash labeling, and selecting* _____.

(a) personal protective equipment
(b) coordinated overcurrent protective devices
(c) emergency egress plans
(d) fire suppression systems

40. As applied to electrical equipment, the term reconditioned may be interchangeable with the term(s) "_____."

(a) rebuilt
(b) refurbished
(c) remanufactured
(d) any of these

41. Each disconnecting means shall be legibly marked to indicate its purpose unless located and arranged so _____.

(a) that it can be locked out and tagged
(b) it is not readily accessible
(c) the purpose is evident
(d) that it operates at less than 300 volts-to-ground

42. The *NEC* requires tested series-rated installations of circuit breakers or fuses to be legibly marked in the field to indicate the equipment has been applied with a series combination rating.

(a) True
(b) False

43. _____ at other than dwelling units shall be legibly field marked with the available fault current, include the date the fault-current calculation was performed, and be of sufficient durability to withstand the environment involved.

(a) Service equipment
(b) Sub panels
(c) Motor control centers
(d) all of these

44. The required working space for access to live parts of equipment operating at 300 volts-to-ground, where there are exposed live parts on one side and grounded parts on the other side, is _____.

(a) 3 ft
(b) 3½ ft
(c) 4 ft
(d) 4½ ft

45. The minimum working space on a circuit for equipment operating at 750 *volts-to-ground, with exposed live parts on one side and grounded parts on the other side of the* working space, is _____.

(a) 1 ft
(b) 3 ft
(c) 4 ft
(d) 6 ft

PRACTICE QUESTIONS | From Michael Hamilton Publications 110.28

46. What is the minimum vertical clearance that must be maintained above electrical equipment, such as switchboards, panelboards, or motor control centers rated at 1,000 volts, nominal, or less, when service, operation, adjustments, servicing, or ordinary maintenance may be performed while the equipment is energized?

The required height is at least 6½ ft (2.0 m) or the equipment height—whichever is greater— except for service equipment and panelboards in existing dwellings where the limit is 200 A or less.

(a) True
(b) False

47. A working space must not be used for which purpose?

(a) storage
(b) raceways
(c) lighting
(d) accessibility

48. For large equipment that includes service disconnecting means installed in accordance with 230.71, when the combined ampere rating equals _____ amperes or more and the working space is not less than 24 in. (610 mm) wide and 6½ ft (2.0 m) high at each end, there is one entrance to and one exit from the required working space.

(a) 800A
(b) 1000A
(c) 1200A
(d) 2000A

49. Switchboards, switchgear, panelboards, and motor control centers must be set in dedicated spaces and guarded against damage. The clearance for outdoor installations within the zone described in _____ must also be maintained.

(a) 110.26(A)
(b) 110.26(B)
(c) 110.26(C)
(d) 110.26(D)

50. Electrical equipment rooms or enclosures that house electrical apparatus with a lock(s) controlling access must be considered _____ to qualified persons.

(a) readily accessible
(b) accessible
(c) available
(d) secured

Author's Commentary:

Clearances and working spaces are about safety and access. Maintain adequate height, keep spaces free of storage, and secure equipment from damage and unauthorized access.

— Michael Hamilton

Notes

CHAPTER 2

WIRING AND PROTECTION

INTRODUCTION TO CHAPTER 2—WIRING AND PROTECTION

Chapter 2 lays out the fundamental requirements for wiring and sizing of services, feeders, and branch circuits, as well as the necessary safeguards against overcurrent conditions in conductors and equipment. These rules govern the planning and bonding of electrical systems. The provisions here apply to all electrical setups addressed by the 2023 NEC®—except as amended in Chapters 5, 6, and 7 [90.3].

Communications systems [Chapter 8]—such as twisted-pair cables, antennas, and coaxial lines—fall outside the scope of the general rules in Chapters 1 through 4, or the specialized requirements in Chapters 5 through 7. For details on such systems, see Chapter 8 or refer back to Chapters 1 through 7 [90.3].

As you progress through Chapter 2, keep in mind that its primary focus is correct conductor sizing and protection of circuits. Every section in this chapter addresses what is needed to achieve a safe installation.

- **Article 200—Use and Identification of Neutral and Grounded-Phase Conductors.** This article sets the rules for how to use and identify the grounded conductor, which is neutral in most situations.
- **Article 210—Branch Circuits.** Article 210 explains requirements for branch circuits, including conductor sizing, identification, AFCI and GFCI protection, and the acceptance and placement of lighting outlets.
- **Article 215—Feeders.** This article outlines the rules for installing feeders and determining their ampacity.
- **Article 220—Branch-Circuit, Feeder, and Service Calculations.** Article 220 gives the methods for figuring conductor sizes for branch circuits, feeders, and services. It also offers guidance on how to determine required numbers of branch circuits and receptacles.
- **Article 225—Outside Feeders.** This article addresses wiring methods located outdoors (above ground and underground). It includes feeders run on or between structures, poles, and other supports that may exist on the premises or used to feed the premises.
- **Article 230—Services.** Article 230 describes installation requirements for service conductors and equipment. It is important to know where the service begins and ends when applying Article 230.
- **Article 240—Overcurrent Protection.** This article presents the requirements for both overcurrent and overvoltage protection. Overcurrent protection for conductors and equipment is intended to open the circuit if current reaches a level that could cause overheating or damage to insulation.
- **Article 242—Overvoltage Protection.** Part I of this article covers general installation and connection requirements for surge protective devices (SPDs) that are permanently installed on the line side and load side of service disconnects. Part II covers SPDs that are permanently installed on systems rated 1,000 volts or less. Part III addresses surge arresters used on systems over 1,000 volts that fall outside the scope of this book.

- **Article 250—Grounding and Bonding.** Article 250 covers the grounding requirements for providing a path to the Earth to reduce overvoltage from lightning, and the bonding requirements for the low-impedance fault current path necessary to facilitate the operation of overcurrent protective devices in the event of a ground fault.

ARTICLE

200 USE AND IDENTIFICATION OF GROUNDED CONDUCTORS

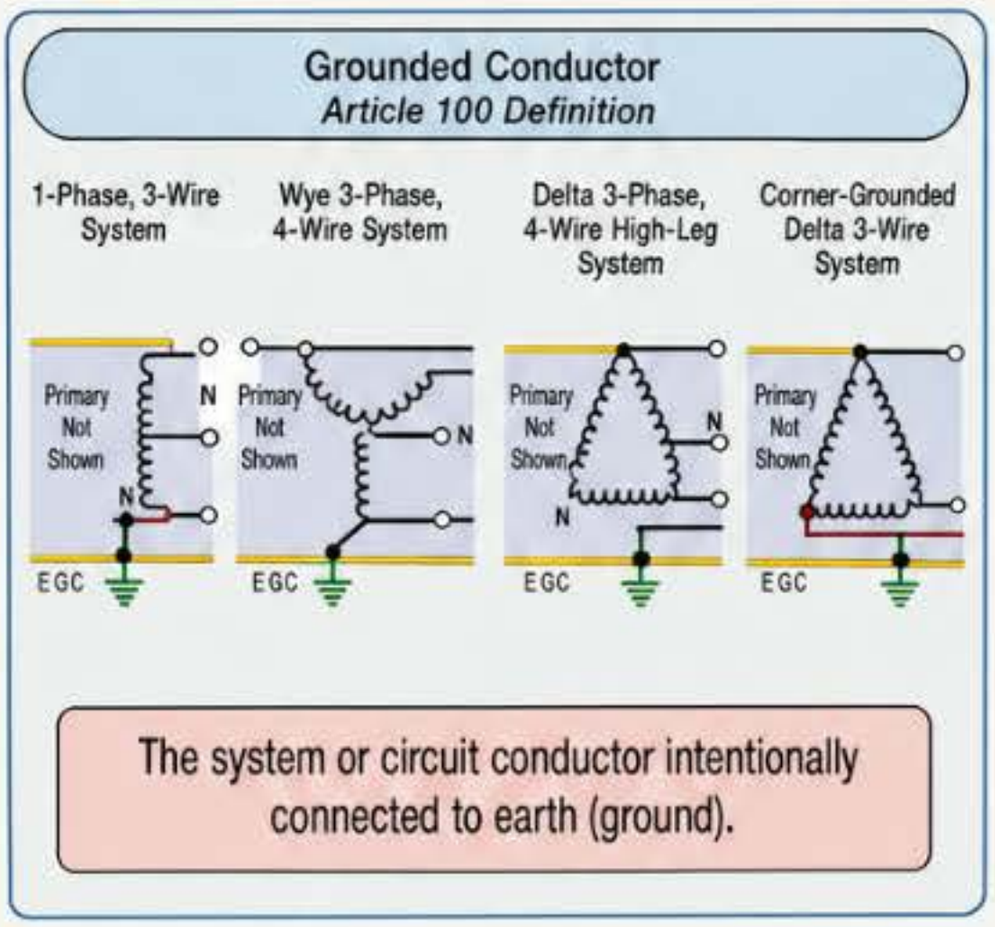
Introduction to Article 200—Use and Identification of Grounded Conductors

This article establishes the rules for recognizing grounded conductors and their terminations. There are two categories of grounded conductors: neutral conductors and grounded-phase conductors.

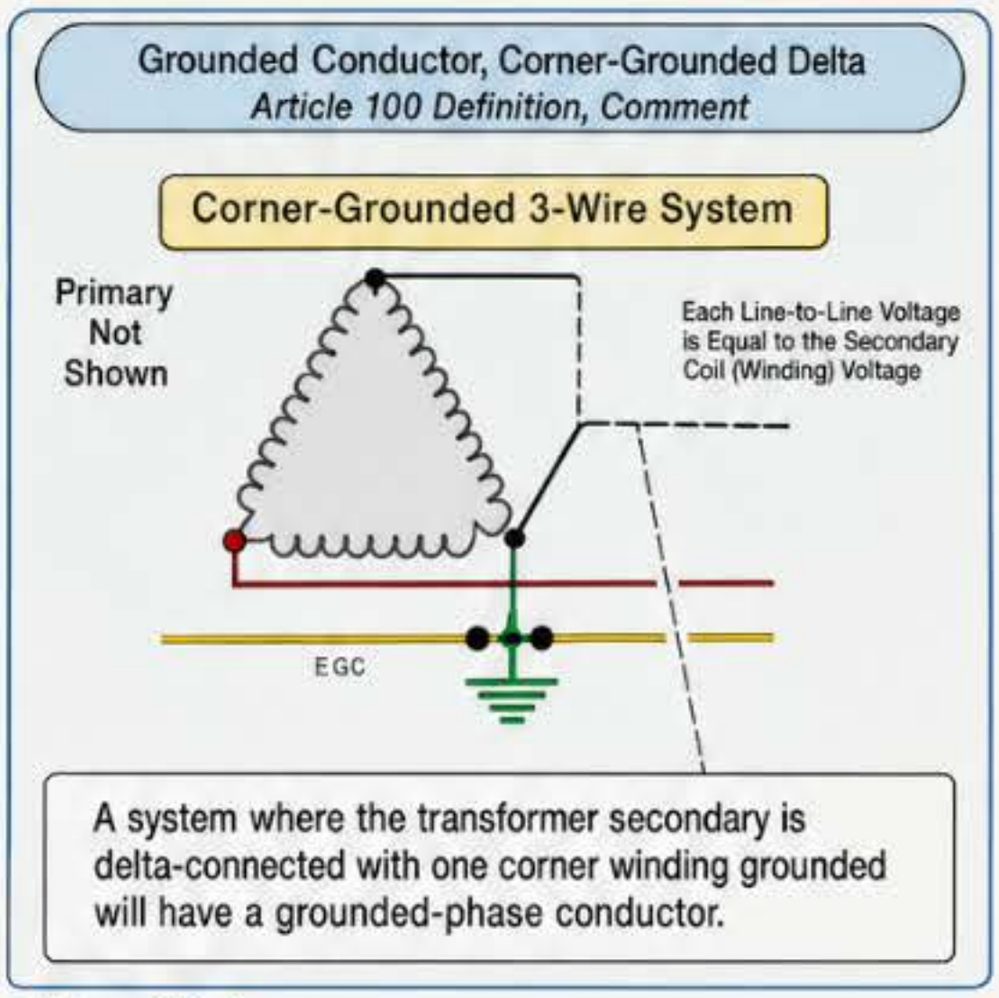
In systems where the transformer secondary winding is wye-connected and the neutral point is solidly connected to earth, the identified neutral conductor is the grounded conductor. ► Figure 200–1

In systems where the transformer secondary is delta-connected with a single point of the winding bonded to earth, a grounded-phase conductor is present. ► Figure 200–2

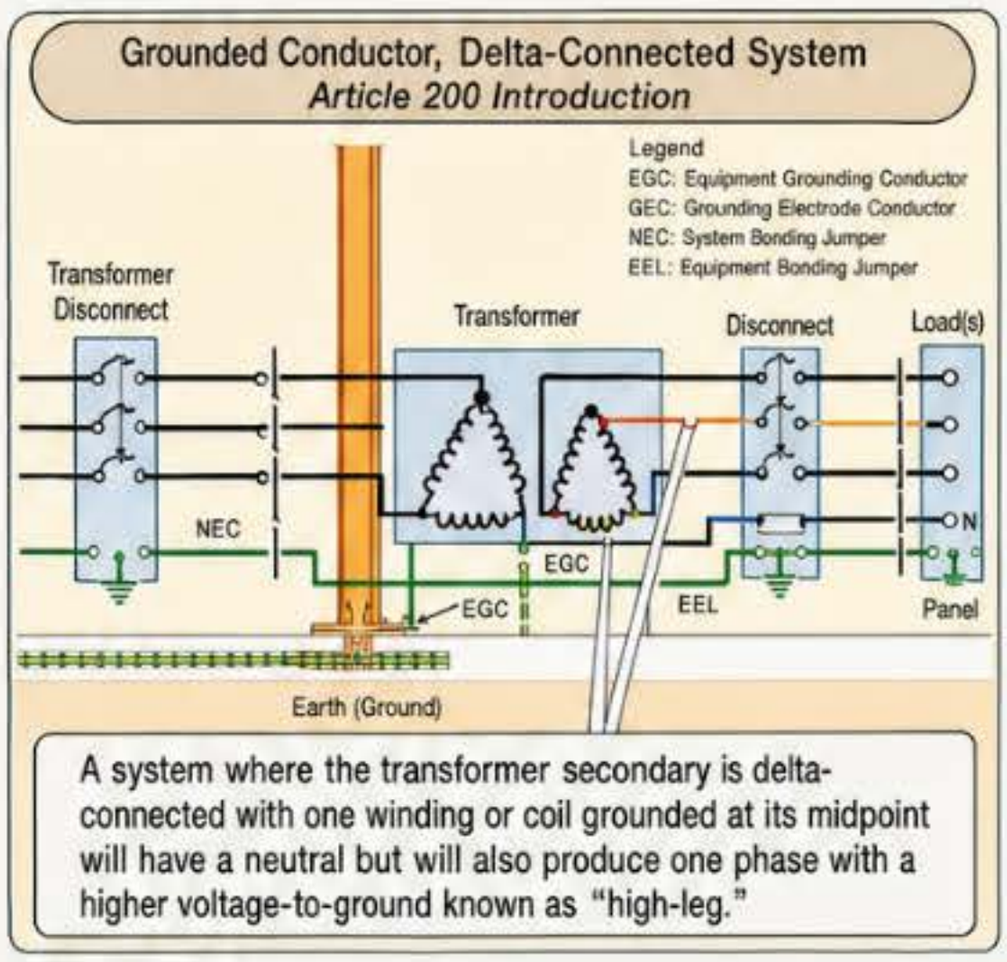
In systems where the transformer secondary is delta-connected and the midpoint of a winding or coil is grounded, the identified neutral conductor may also be used. Such systems operate at an elevated voltage to ground known as "high-leg." ► Figure 200–3



► Figure 200–1



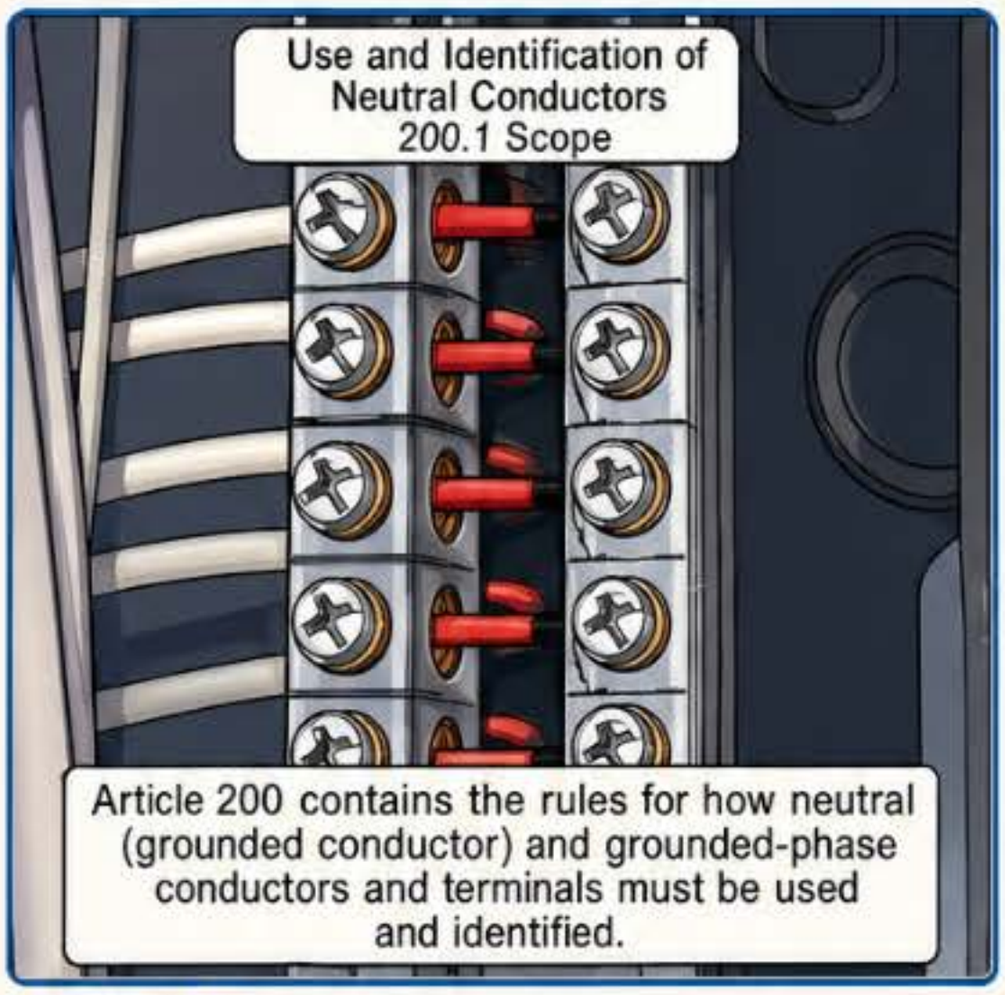
► Figure 200–2



► Figure 200–3

200.1 Scope

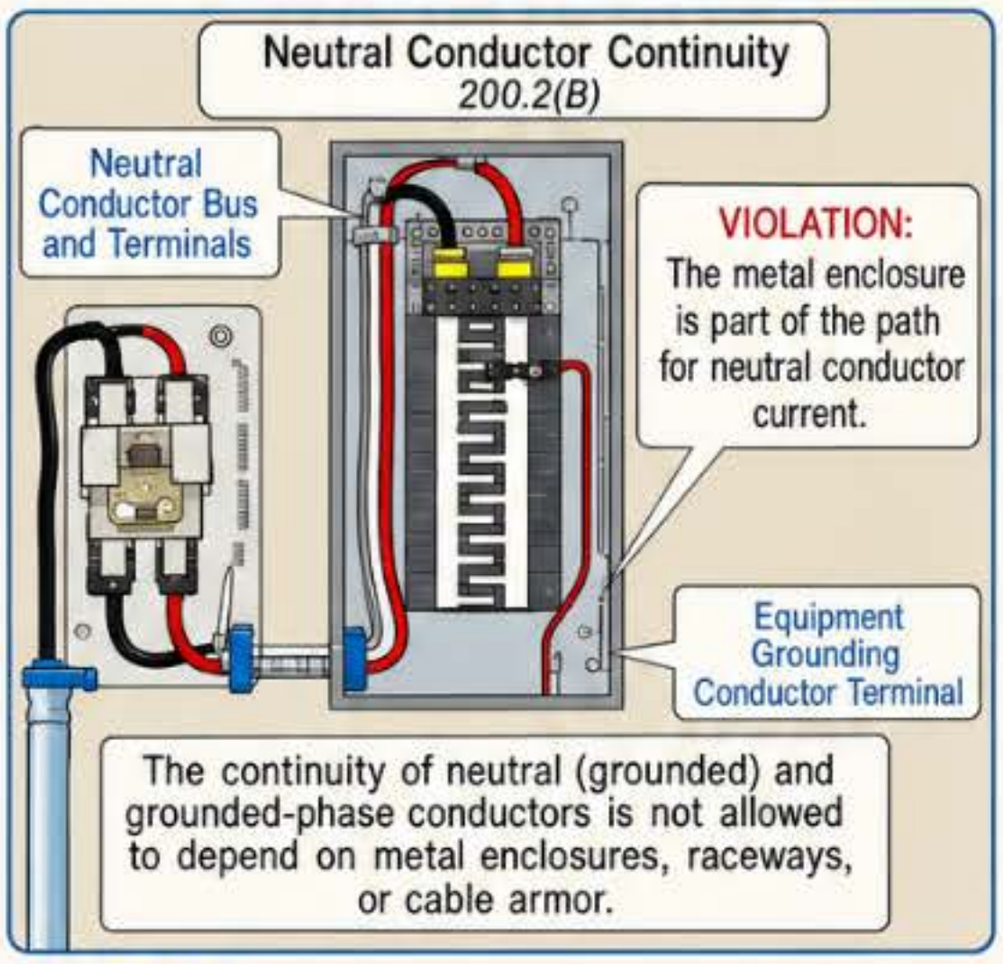
Article 200 contains the rules for how neutral (grounded conductor) and grounded-phase conductors and terminals must be used and identified. ▶ Figure 200-4



▶ Figure 200-4

200.2 General

(B) Continuity. The continuity of neutral (grounded) and grounded-phase conductors is not allowed to depend on metal enclosures, raceways, or cable armor. ▶ Figure 200-5



▶ Figure 200-5

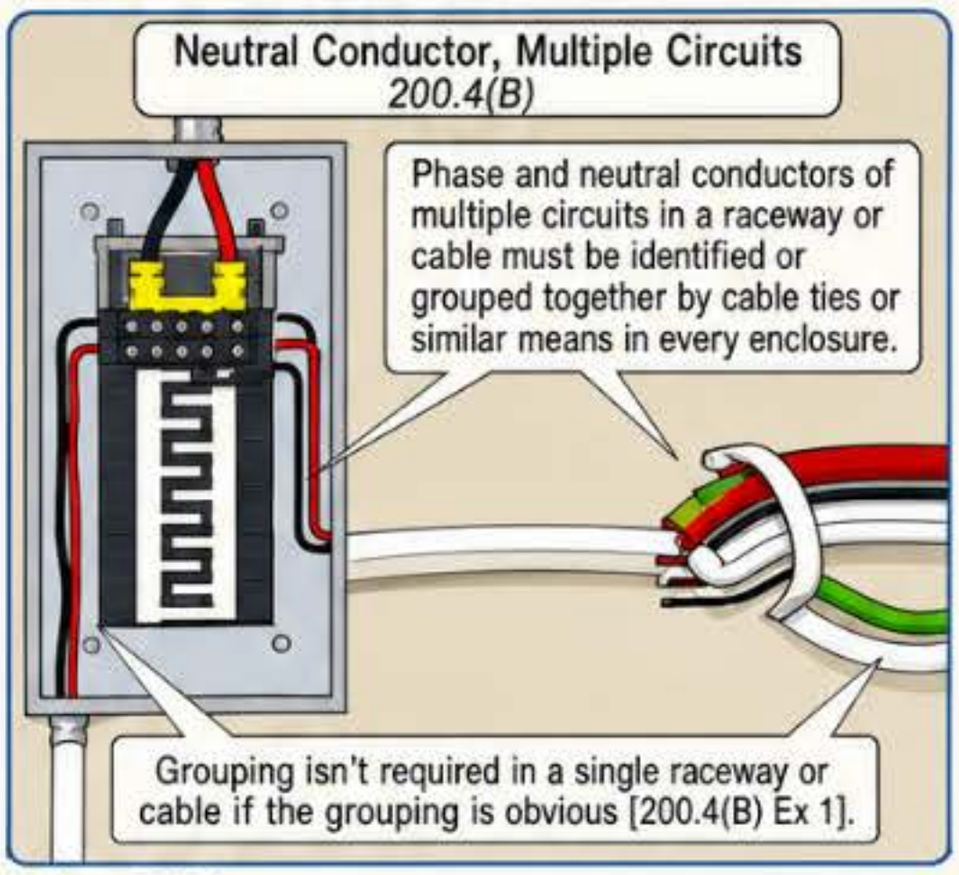
200.4 Neutral Conductor

Neutral conductors must comply with (A) and (B).

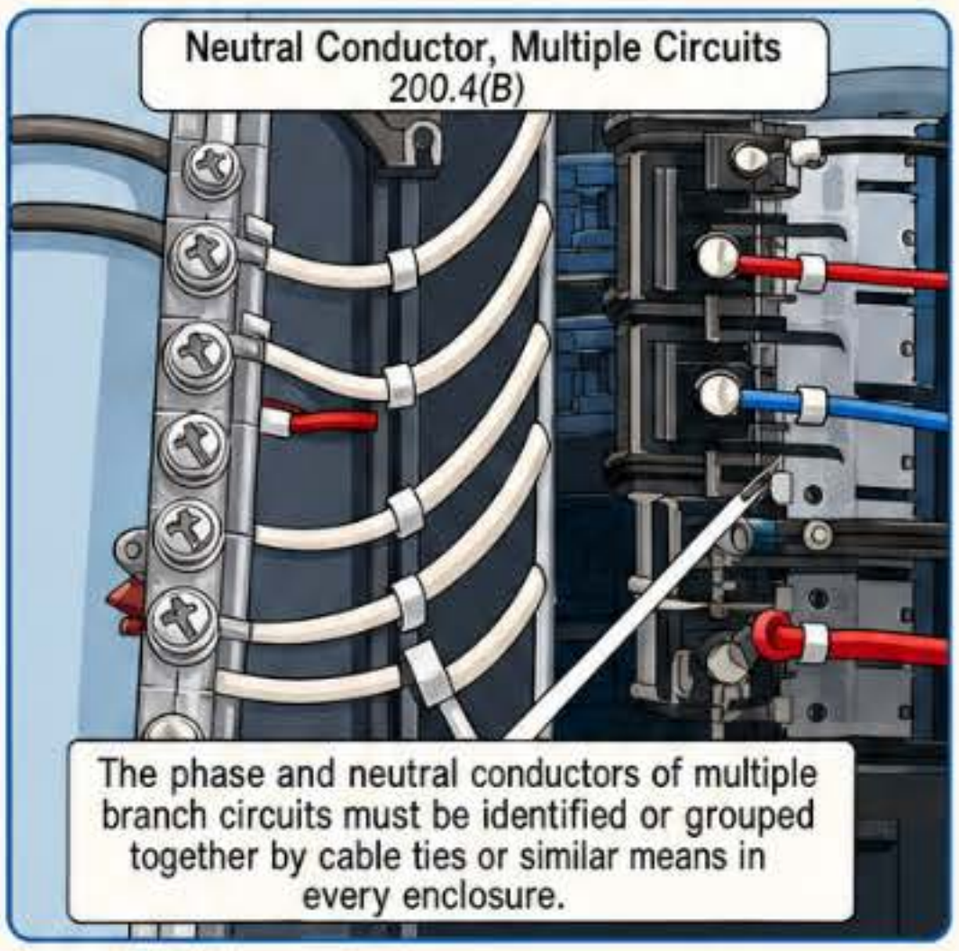
(A) Installation. A single neutral conductor cannot be used for more than one branch circuit or multiwire branch circuit.

(B) Multiple Circuits. The circuit conductors of each branch circuit must be identified or grouped together by cable ties or similar means in every enclosure.

▶ Figure 200-6 ▶ Figure 200-7



▶ Figure 200-6



▶ Figure 200-7

Ex 1: Grouping is not required where the circuit conductors are contained in a single raceway or cable unique to that circuit making the grouping obvious.

200.6 Identification of Grounded Conductors

Ex 2: *Combining conductors inside an enclosure or raceway is not required, provided the conductors pass through a box or conduit body without any splices or terminations.*

Author's Commentary:

Bundling together related conductors with cable ties, wire wraps, or similar means at the point where they originate makes it easier to visually track all the branch-circuit conductors in that bundle. This practice helps ensure the intended grounded (conductor) is paired with the correct phase conductor at splices and termination points, especially in circuits that share a neutral conductor.

— Michael Hamilton

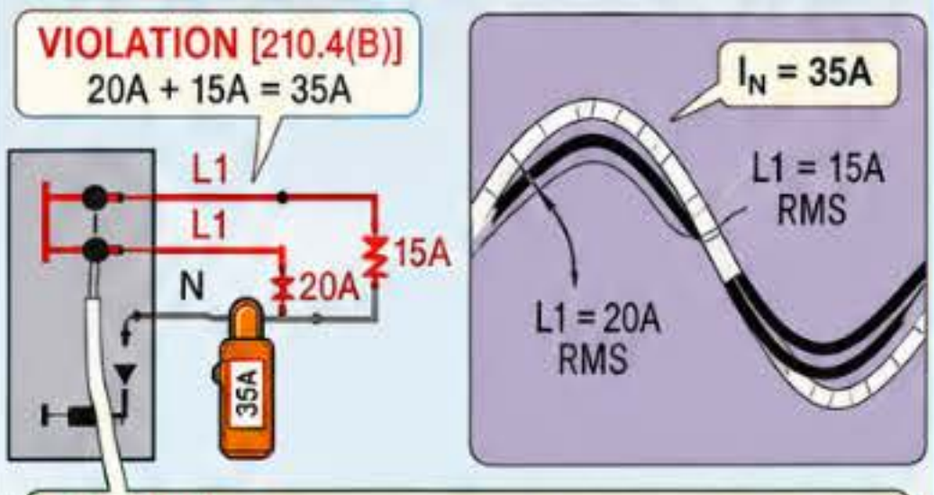
CAUTION

If the current-carrying conductors in a multiwire circuit are not terminated to different phases or line conductors, the grounded (neutral) conductor will carry added current and can become unbalanced or overloaded. This increased neutral current may exceed the neutral conductor's ampacity and can damage the insulation, creating a fire hazard.

See Figure 200-8.

210.4(D) Comment

Miswired Multiwire Circuit, Overload on Neutral



CAUTION: *If the current-carrying conductors of a multiwire circuit are not connected to different phases or line conductors, the neutral conductor will not cancel the phase currents. This lack of cancellation causes a dangerous overload on the neutral conductor.*

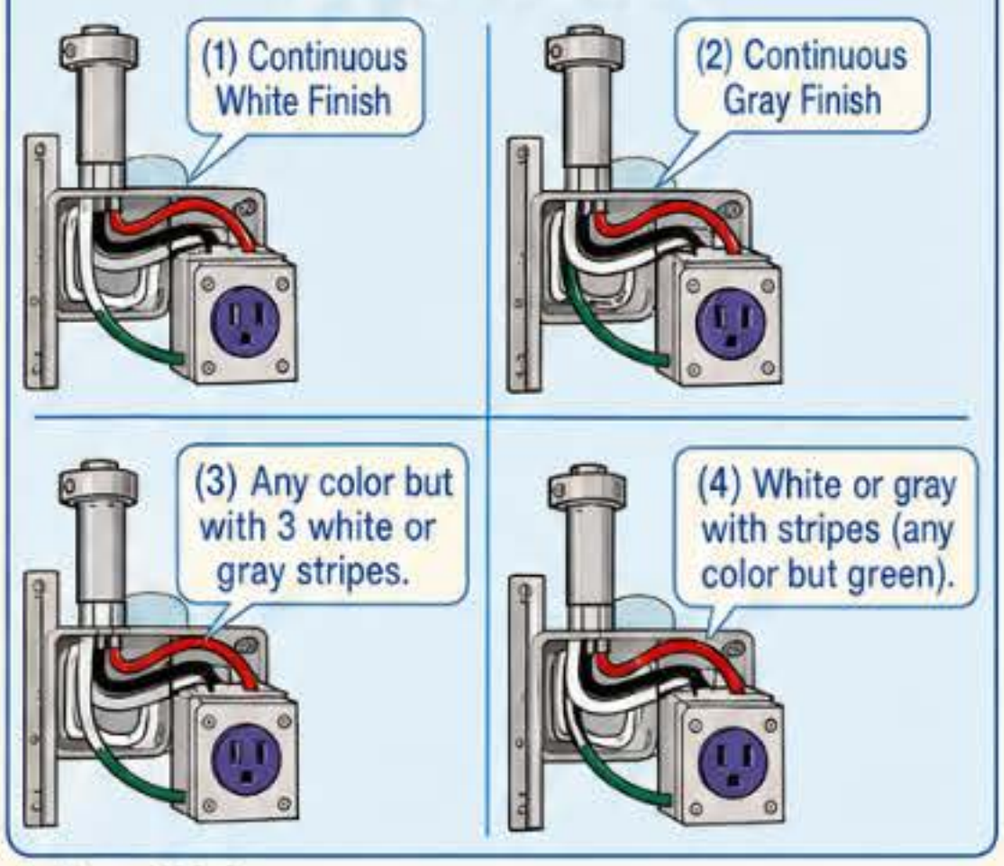
▲ Figure 200-8

200.6 Identification of Grounded Conductors

(A) 6 AWG or Smaller. Neutral and grounded (neutral) conductors 6 AWG and smaller must be identified by one of the methods listed below. *See Figure 200-9.*

200.6(A)

Neutral Conductors, Identification Size 6 AWG and Smaller



▲ Figure 200-9

(1) Insulated conductors with a continuous white outer covering.

(2) Insulated conductors with a continuous gray outer covering.

(3) Insulated conductors with three continuous white or gray stripes running the entire length on a base color other than green.

(4) Insulated conductors whose outer covering is white or gray and is marked with stripes of another color *(except green)* to indicate the source of manufacture.

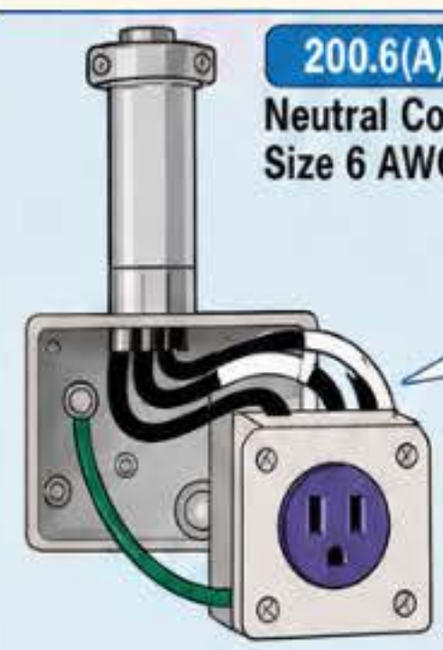
Author's Commentary:

White tape, paint, or other identification methods are not allowed for neutral and grounded (neutral) conductors that are 6 AWG and smaller.

— Michael Hamilton

200.6(A) Comment

Neutral Conductor, Identification Size 6 AWG and Smaller

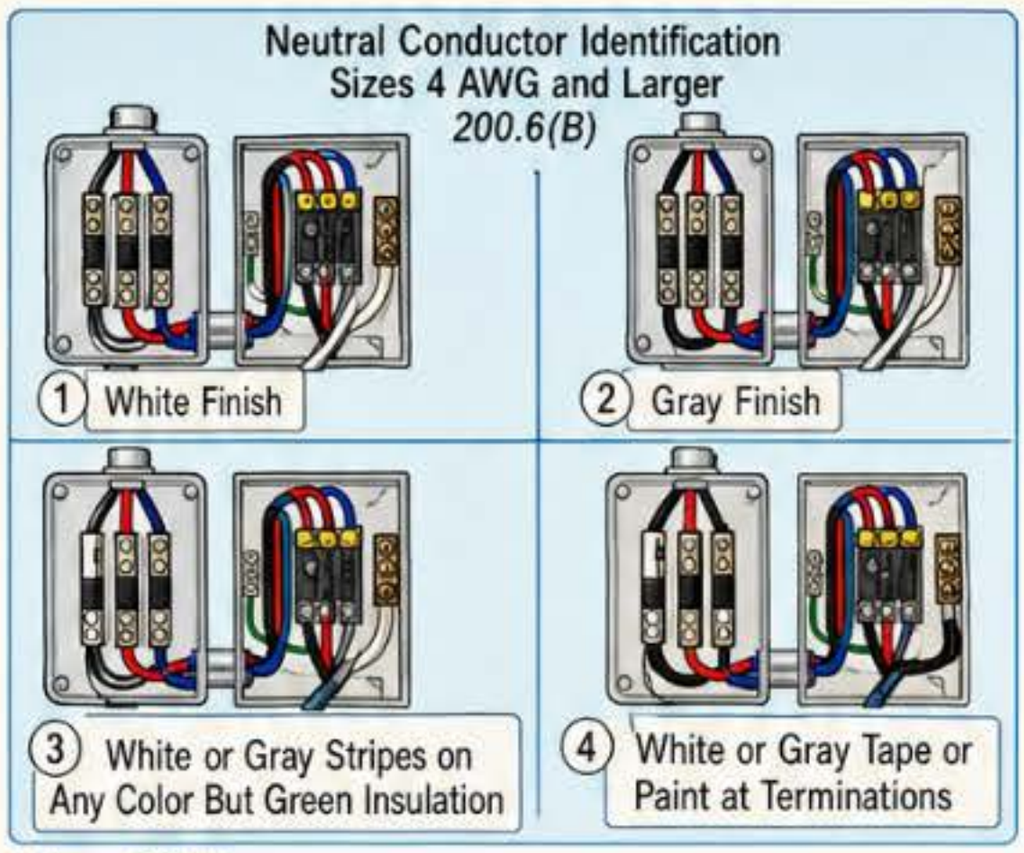


VIOLATION: Marking with white tape, paint, or any other identification method is not permitted for neutral and grounded (neutral) conductors 6 AWG and smaller.

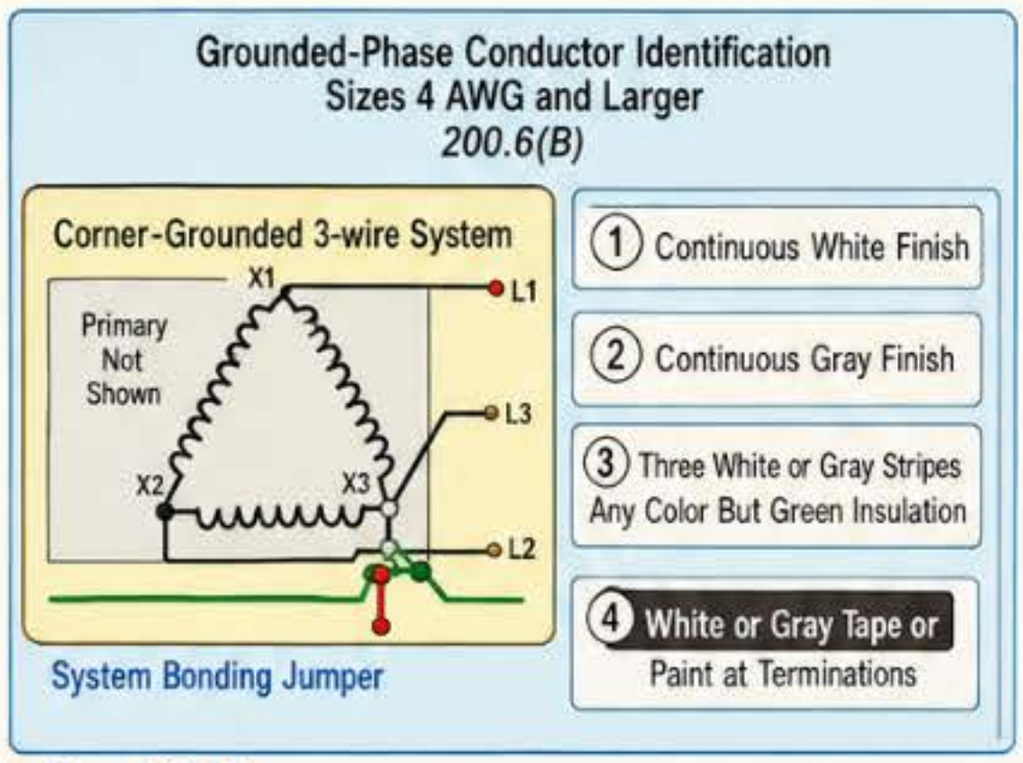
▲ Figure 200-10

200.6 | Use and Identification of Grounded Conductors

(B) 4 AWG or Larger. Neutral and grounded-phase conductors that are 4 AWG or bigger must be identified by one of the methods shown below. → Figure 200–11 and Figure 200–12



▲ Figure 200–11



▲ Figure 200–12

(1) A continuous white outer finish along their entire length.

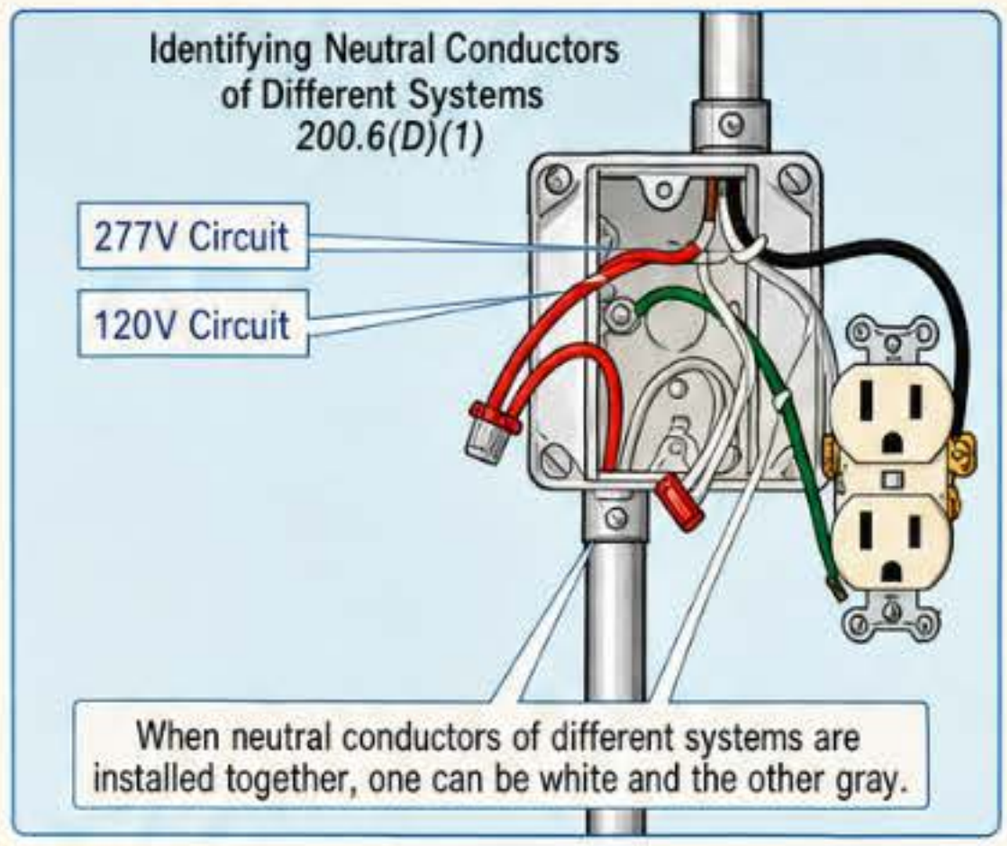
(2) A continuous gray outer finish along their entire length.

(3) Three continuous white or gray stripes along their length.

(4) White or gray tape or markings at the terminations.

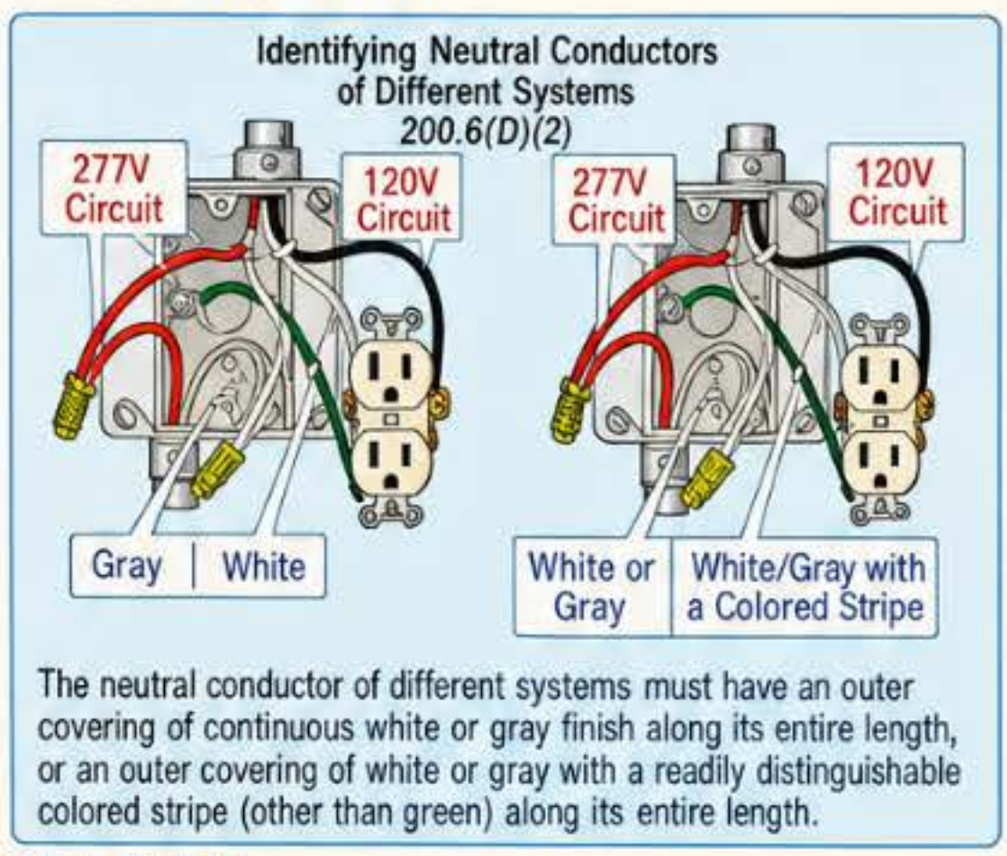
(D) Neutral Conductors of Different Systems. When neutral conductors of different voltage systems are installed in the same raceway, cable, or enclosure each system neutral conductor must be individually identified by:

(1) A continuous white or gray outer finish along its entire length. → Figure 200–13



▲ Figure 200–13

(2) The neutral conductor of the other system must have a different outer covering of continuous white or gray outer finish along its entire length, or an outer covering of white or gray with a readily distinguishable color stripe (other than green) along its entire length. → Figure 200–14



▲ Figure 200–14

(3) Other identification allowed by 200.6(A) or 200.6(B) that will distinguish each system's neutral conductor. → Figure 200–15

Author's Commentary:

Properly identifying neutral (grounded) conductors is essential for safety and troubleshooting. The NEC provides multiple clear options so electricians can consistently distinguish neutrals in multi-system environments.

— Michael Hamilton

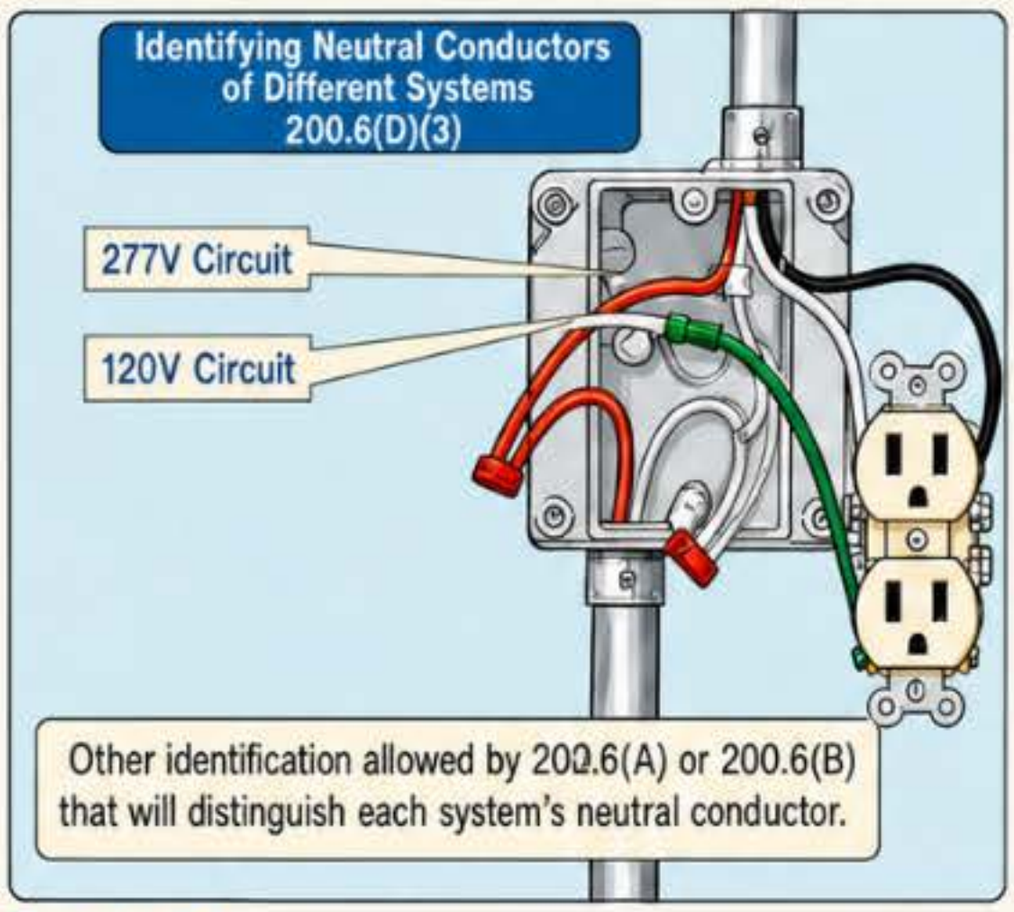


Figure 200–15

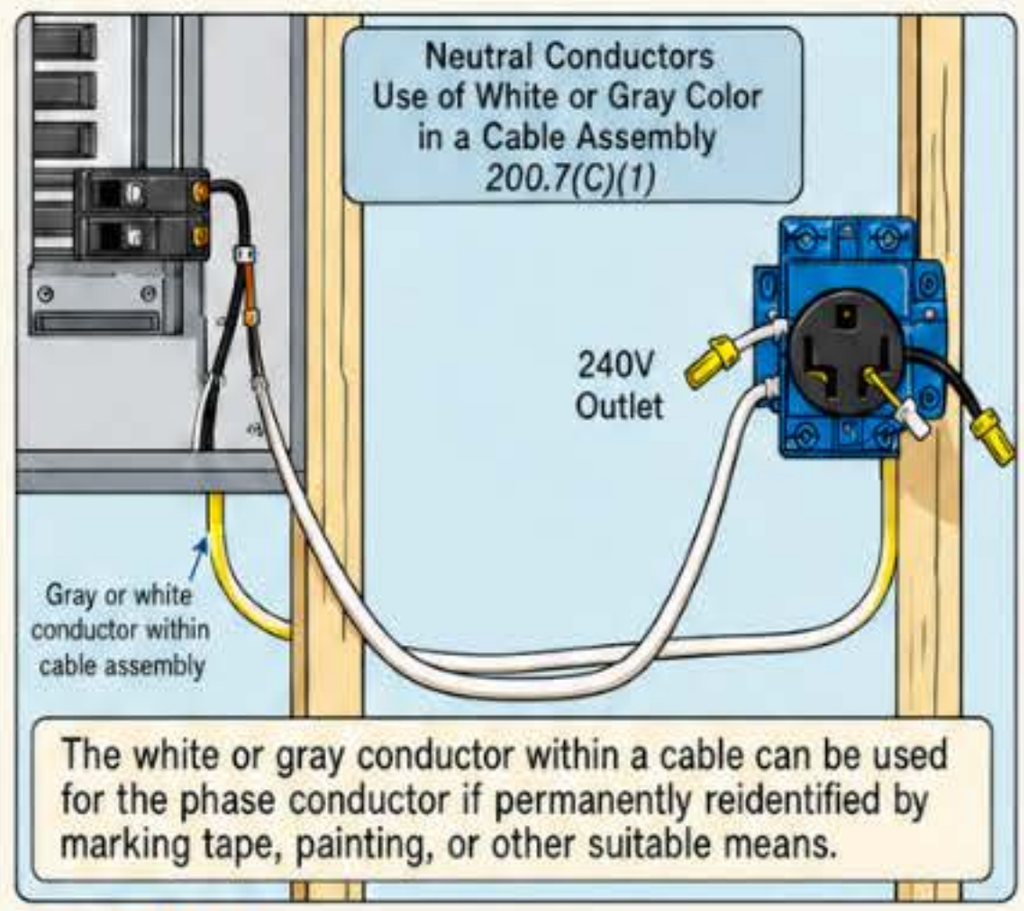


Figure 200–16

Author's Commentary:

The method used to uniquely identify the neutral conductors of different voltage systems should remain consistent throughout the premises.

— Michael Hamilton

(E) Neutral Conductors in Multiconductor Cables. Insulated neutral conductor(s) sized 6 AWG and smaller in multiconductor cables must be identified by a continuous white or gray outer finish, or by three continuous white or gray stripes. *Conductors in multiconductor cables sized 4 AWG or larger can have the neutral conductor identified in accordance with 200.6(B).*

Ex 1: *Neutral conductors within multiconductor cables are permitted to be reidentified at their terminations at the time of installation by a distinctive white or gray marking.*

200.7 Use of White or Gray Color

(A) General. Insulated conductors identified with white or gray markings can only be used for the neutral or grounded-phase conductor except as permitted in 200.7(C).

(C) Circuits of 50V or More, Reidentification. *A conductor with white or gray insulation used as a phase conductor is permitted as follows:*

(1) Cable Assembly. *The white or gray conductor within a cable can be used for the phase conductor if the white conductor is permanently reidentified as a phase conductor by marking tape, painting, or other effective means where the conductor is visible. Identification must encircle the insulation and must be of a color other than white, or green.* ▸ *Figure 200–16*

The white or gray conductor within a cable can be used to supply power to switches if the conductor is reidentified *as a phase conductor by marking tape, painting, or other effective means where the conductor is visible.* ▸ *Figure 200–17* and ▸ *Figure 200–18*

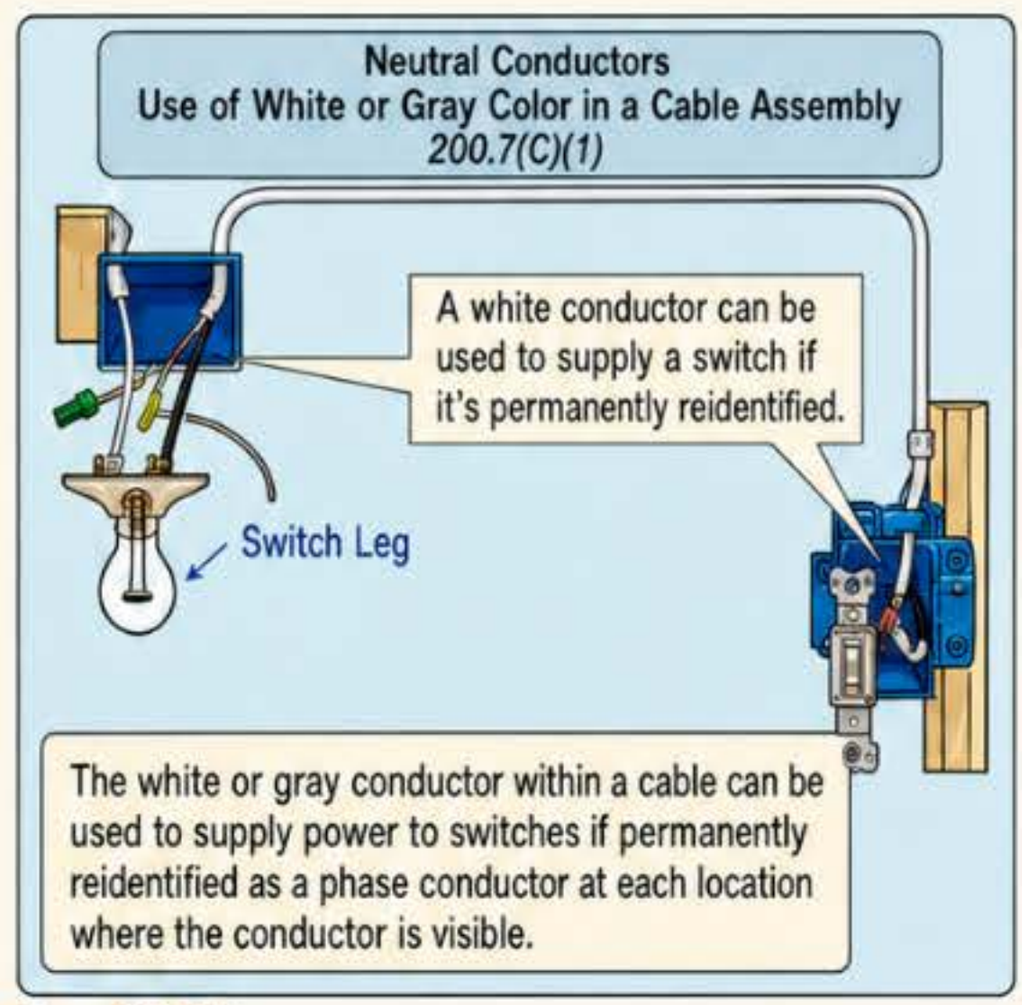


Figure 200–17

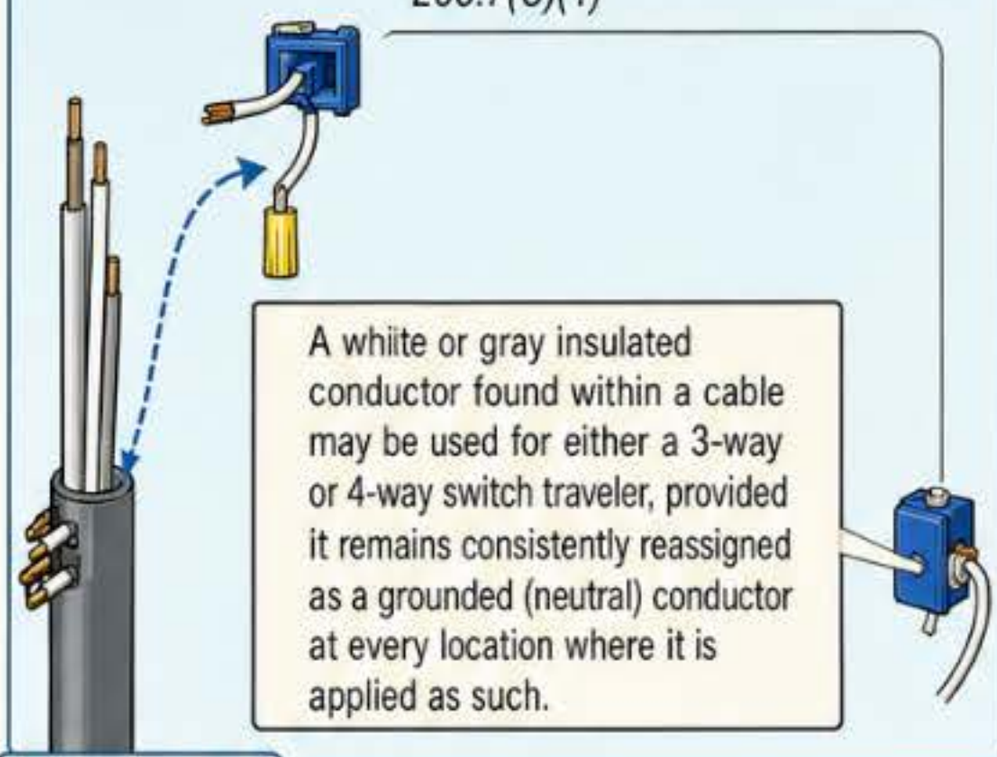
Author's Commentary:

The NEC does not permit the use of white or gray conductor insulation for phase conductors within a raceway, even if they are permanently reidentified.

— Michael Hamilton

200.9 | Use and Identification of Grounded Conductors

Neutral Conductors
Use of White or Gray in a Cable Assembly
200.7(C)(1)



A white or gray insulated conductor found within a cable may be used for either a 3-way or 4-way switch traveler, provided it remains consistently reassigned as a grounded (neutral) conductor at every location where it is applied as such.

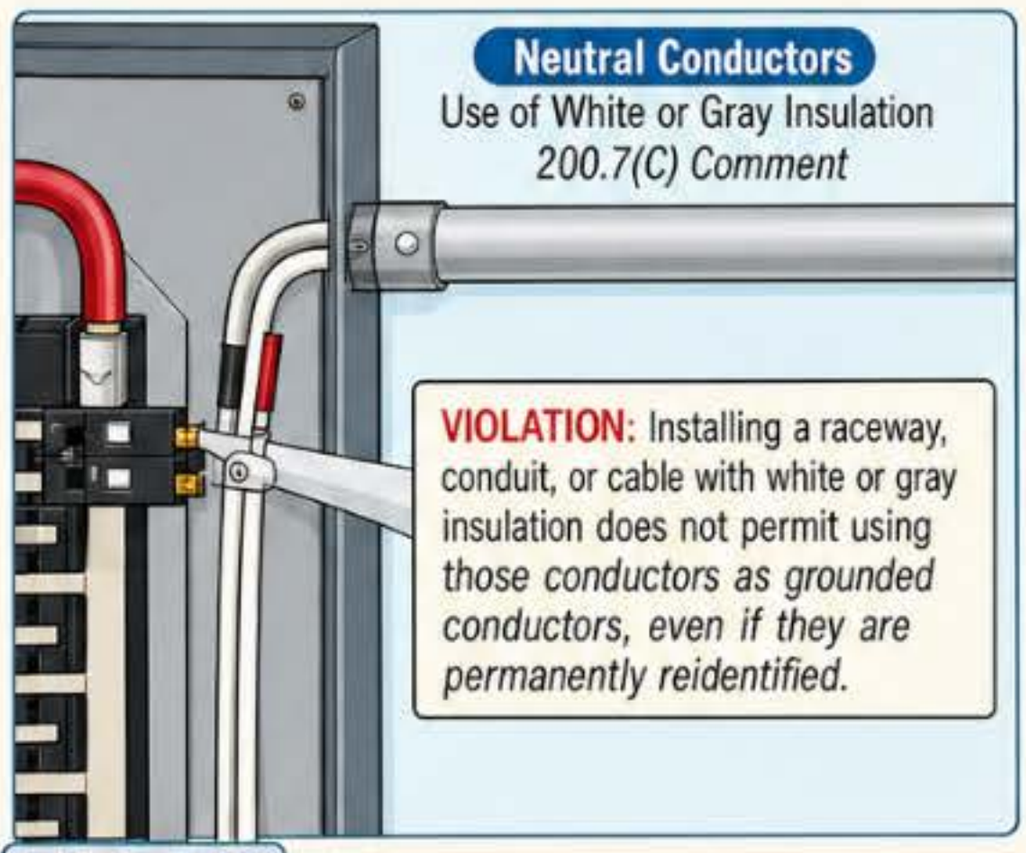
Figure 200–18

Neutral Conductors
Means of Identification of Terminals
200.9

For equipment or appliances that use polarized connections, the terminal intended for the neutral conductor must be permanently identified by its white or silver appearance. This identification must be of a readily different and distinguishable color from any other terminals.

Figure 200–20

Neutral Conductors
Use of White or Gray Insulation
200.7(C) Comment



VIOLATION: Installing a raceway, conduit, or cable with white or gray insulation does not permit using *those conductors as grounded conductors, even if they are permanently reidentified.*

Figure 200–19

200.10 Identification of Terminals

(B) Receptacles. Receptacles must have the neutral terminal identified by:

(1) A metal terminal or metal coating terminal that is substantially white or silver in color or marked by the word "white" or the letter "W."

(2) If the terminal is not visible, the conductor entrance hole must be marked with the word "white" or the letter "W."

(C) Screw Shell. The neutral terminal of a luminaire must be connected to the screw shell [410.90].

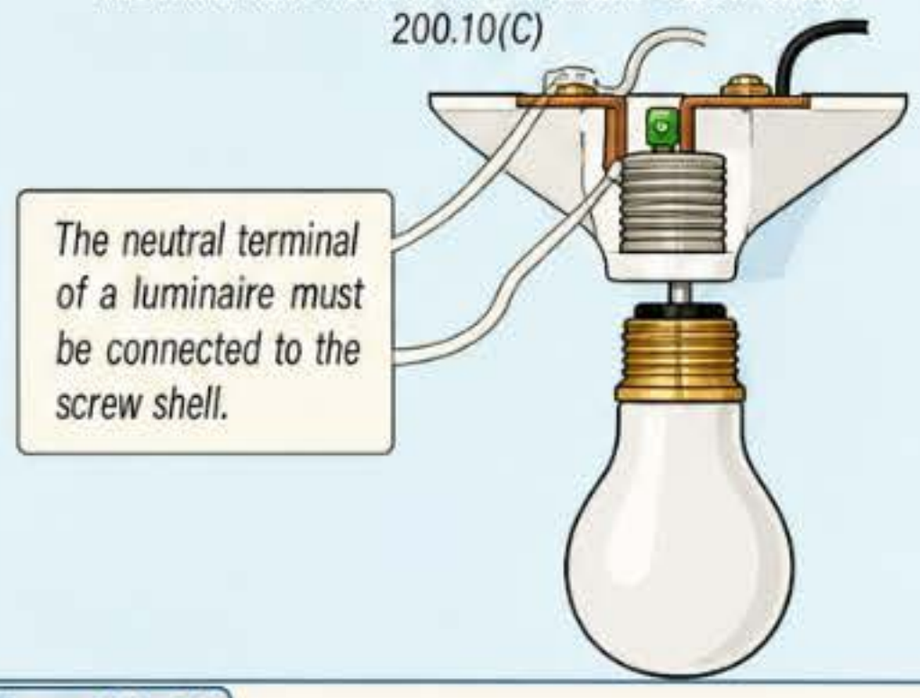
Figure 200–21

200.9 Means of Identification of Terminals

For devices and appliances that use polarized connections, the terminals meant for the neutral conductor must be clearly identified. These terminals must appear substantially white or silver. Any other terminals must use a color that is easily distinguishable from the neutral terminal's color.

Figure 200–20

Neutral Conductors
Identification of Terminals Luminaire Screw-Shells
200.10(C)



The neutral terminal of a luminaire must be connected to the screw shell.

Figure 200–21

ARTICLE 210 BRANCH CIRCUITS

Introduction to Article 210—Branch Circuits

This article covers the requirements for branch circuits, including how conductors are sized and identified, protection by GFCI and AFCI, and the rules for receptacles and lighting outlets.

The material is organized into three parts:

- **Part I.** General Provisions
- **Part II.** Branch-Circuit Ratings
- **Part III.** Required Outlets

Table 210.3 lists branch circuits intended for specific uses. The rules in this article apply to equipment specifically named here and also provide any additional requirements in Article 210 that are needed for those branch circuits. *It is important to become familiar with all of the information in this table.*

Part I. General Provisions

210.1 Scope

Article 210 sets out the general rules for branch circuits. These rules cover conductor sizing, overcurrent protection, identification, GFCI and AFCI protection, and requirements for *receptacle outlets and lighting outlets.*

Author's Commentary:

Article 100 defines a "branch circuit" as the conductors that run between the final overcurrent protective device and the receptacle outlets, lighting outlets, or other outlets.

— Michael Hamilton

Figures 210-1

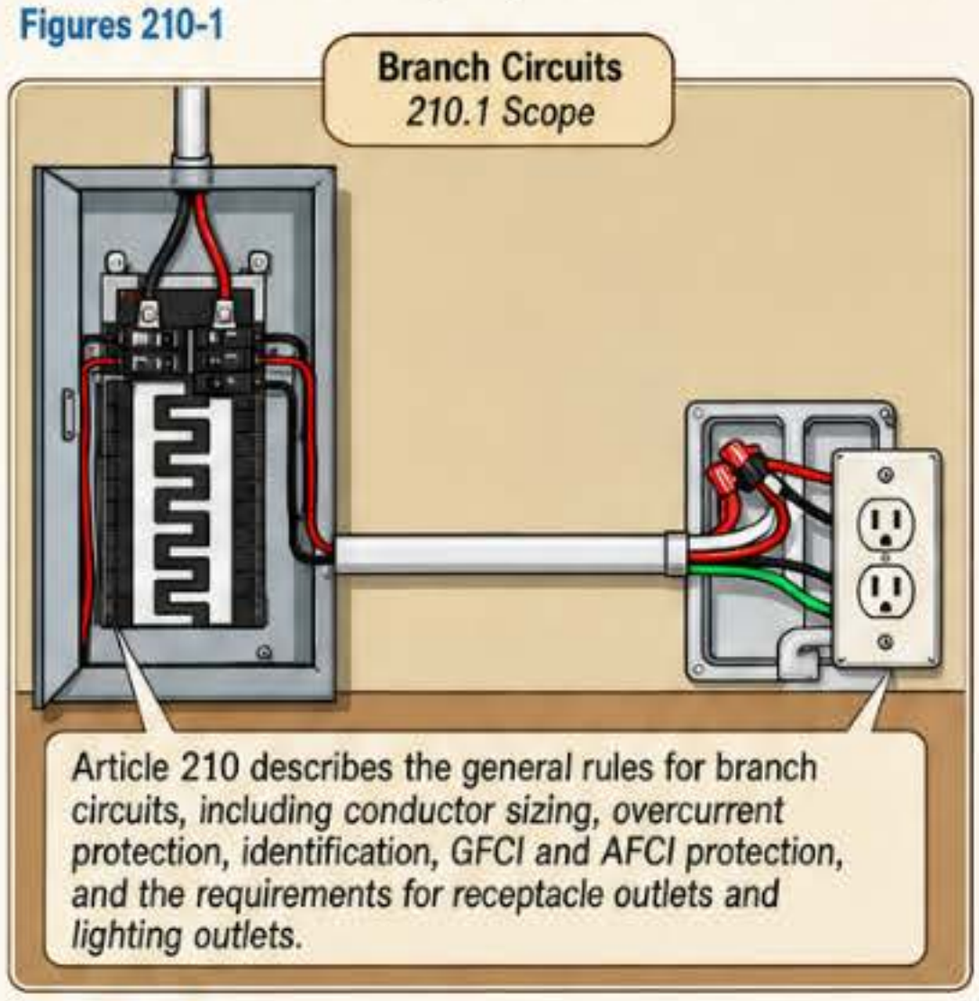


Figure 210-1

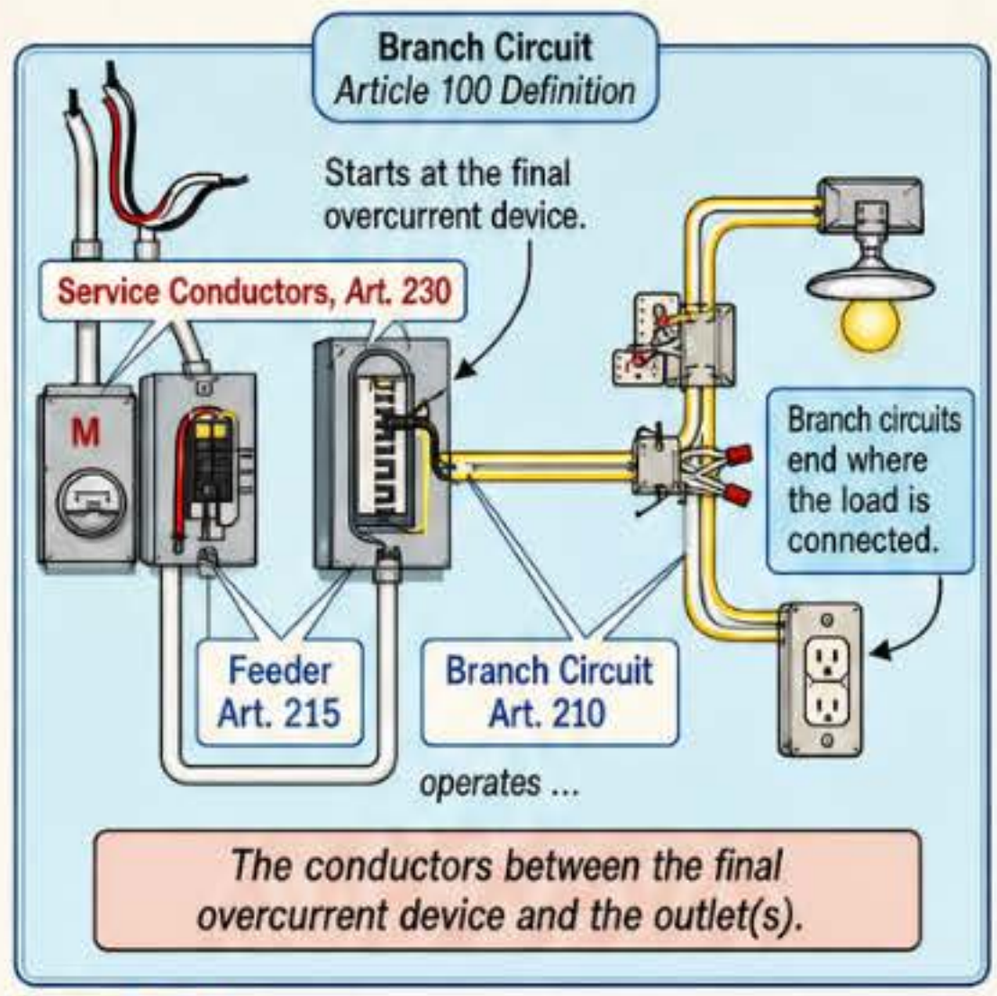


Figure 210-2

Key Terms

Branch circuit. *The conductors running from the final overcurrent protective device to receptacle outlets, lighting outlets, or to other outlet points.*

Final overcurrent protective device. *The last device in the circuit that opens the circuit when an overcurrent condition occurs.*

210.3 Other Articles

Table 210.3 provides citations for specific equipment allowances for branch circuits that modify or add to those found in Article 210.

210.4 Multiwire Branch Circuits

Scan this QR code to watch a video where Michael Hamilton explains the subject. It's a clip from the instructional videos that accompany this textbook.

(A) General. All conductors within a multiwire branch circuit must originate at the same panelboard. Figure 210–3

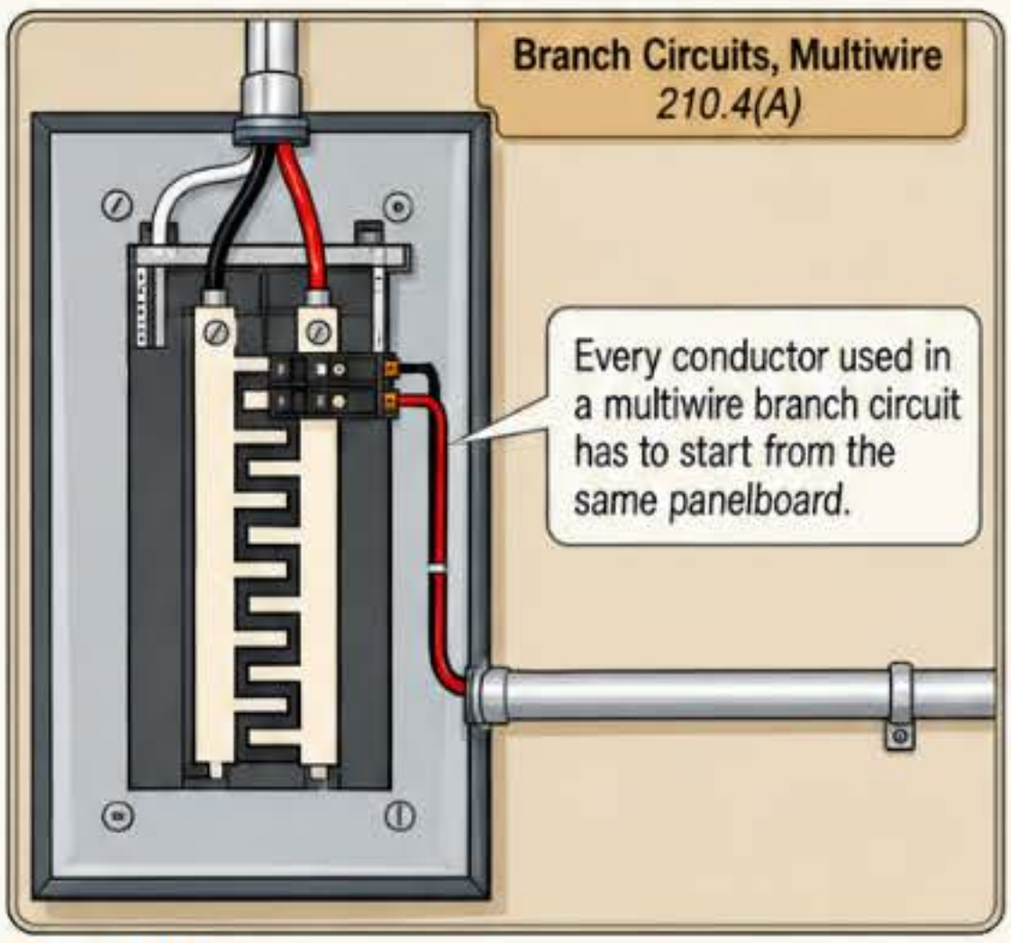


Figure 210–3

Author's Commentary:

According to Article 100, a "Multiwire Branch Circuit" is a circuit made up of two or more ungrounded (circuit phase) conductors *that share one neutral conductor. This arrangement works because the currents in the phase conductors oppose each other, creating a voltage difference between each phase conductor and the common neutral conductor.* Figure 210–4

All circuit conductors (including the neutral and equipment grounding conductors) must be installed together in the same raceway, cable, trench, cord, or cable tray. Exception: As allowed by 300.3(B)(1) through (4).

Note 2: See 300.13(B) for the requirements addressing the *continuity of the neutral conductor on multiwire branch circuits.*

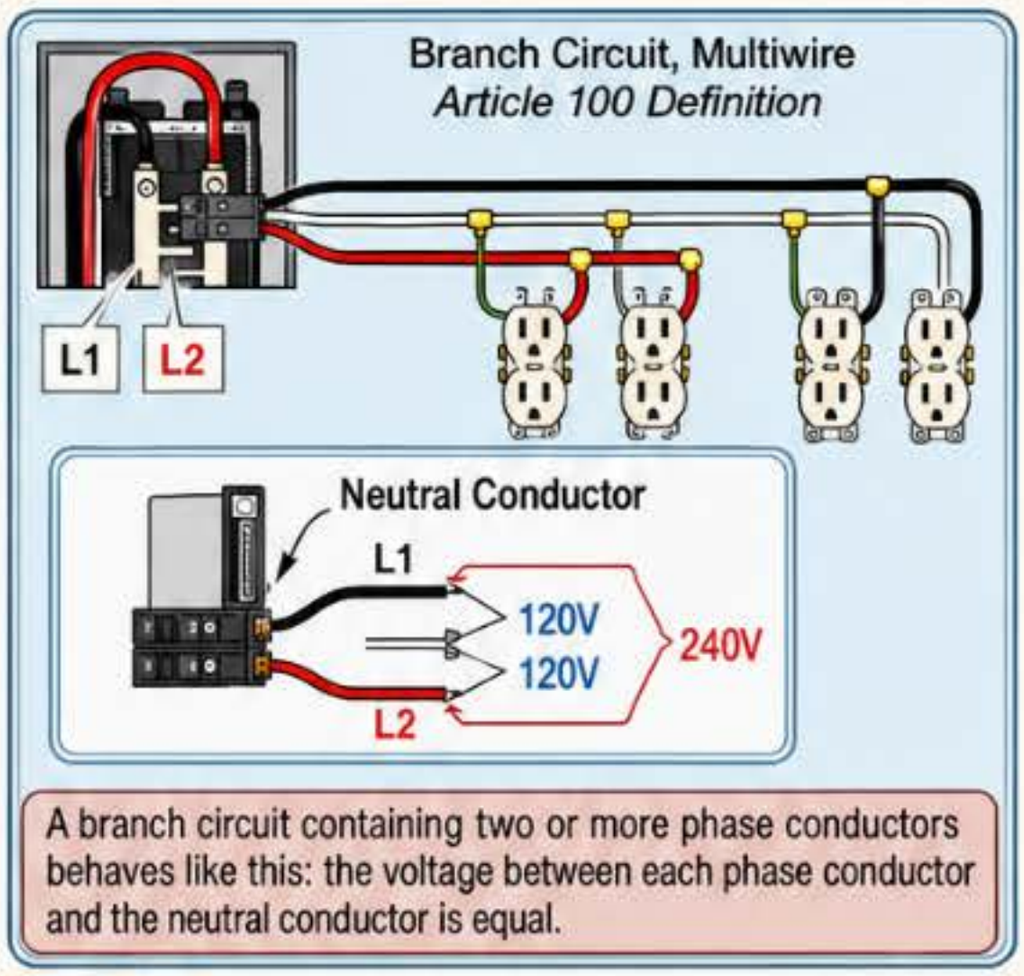


Figure 210–4

(B) Disconnecting Means. Every multiwire branch circuit must include a means that opens all ungrounded conductors at the originating point of the circuit. Figure 210–5

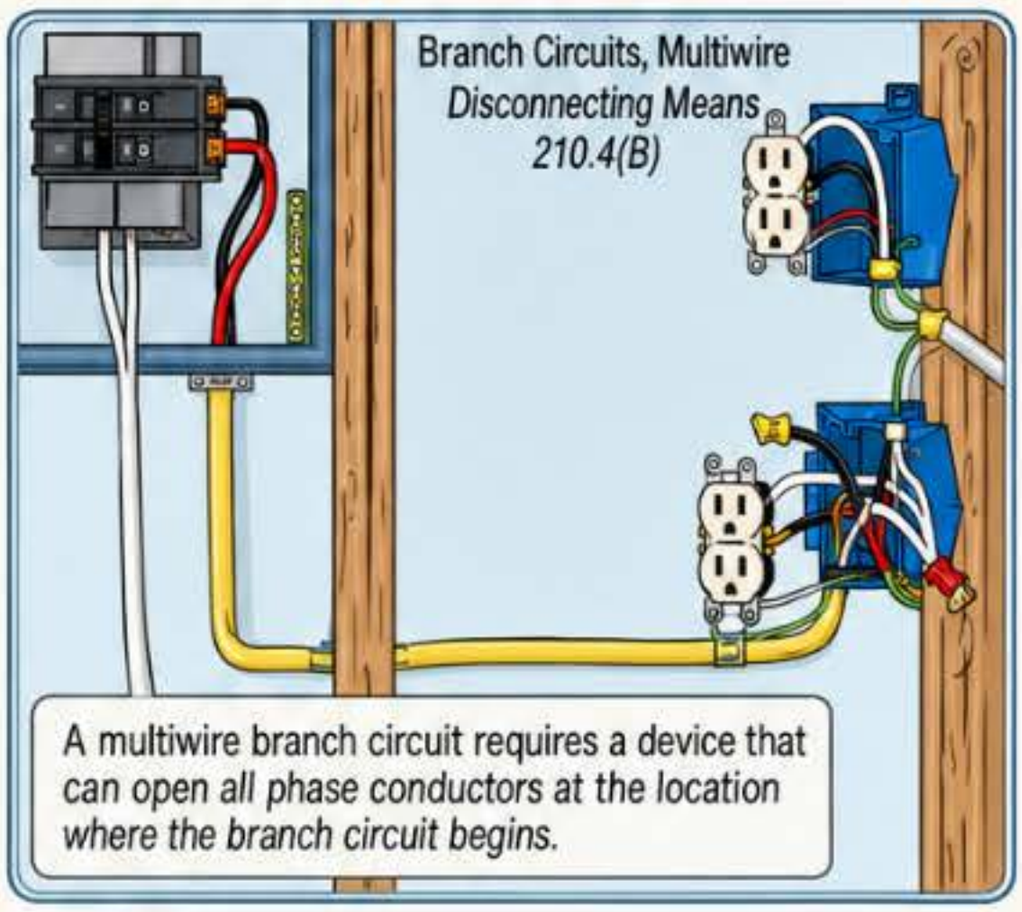


Figure 210–5

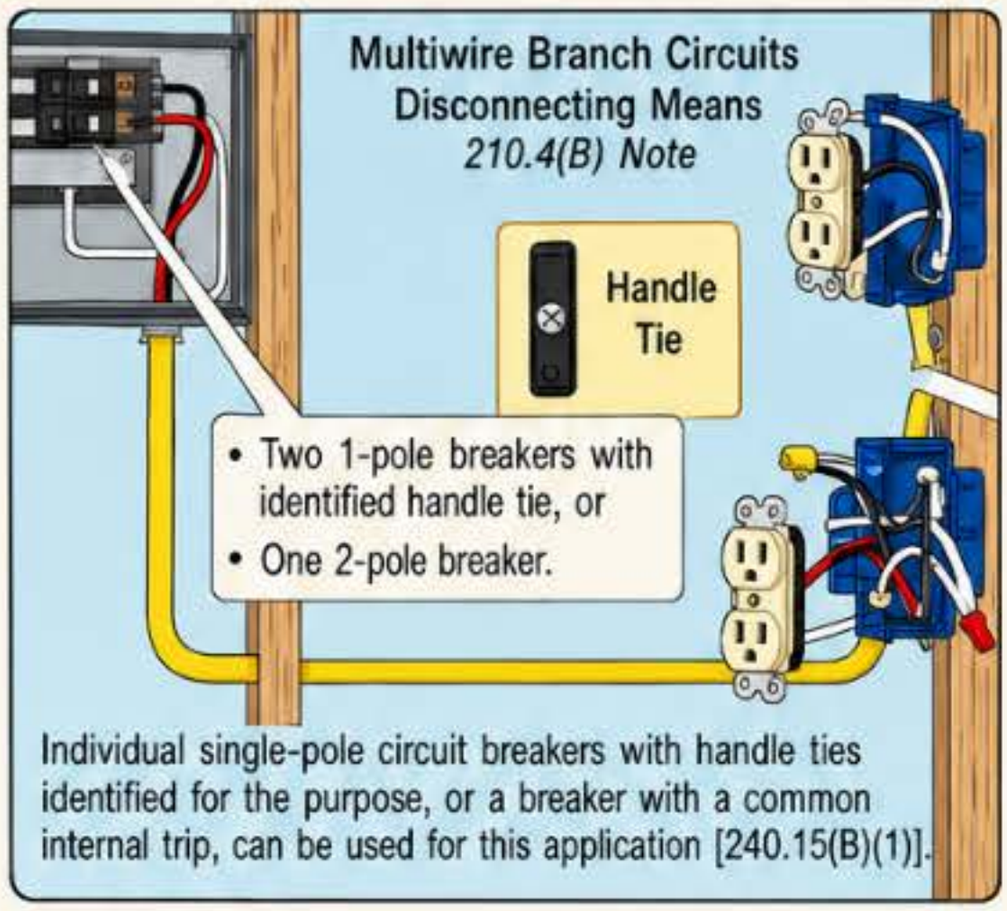
Note: Single-pole circuit breakers equipped with handle ties are considered to provide the required means, as do common trip triplex breakers used for this purpose [240.15(B)(1)]. Figure 210–6

Caution

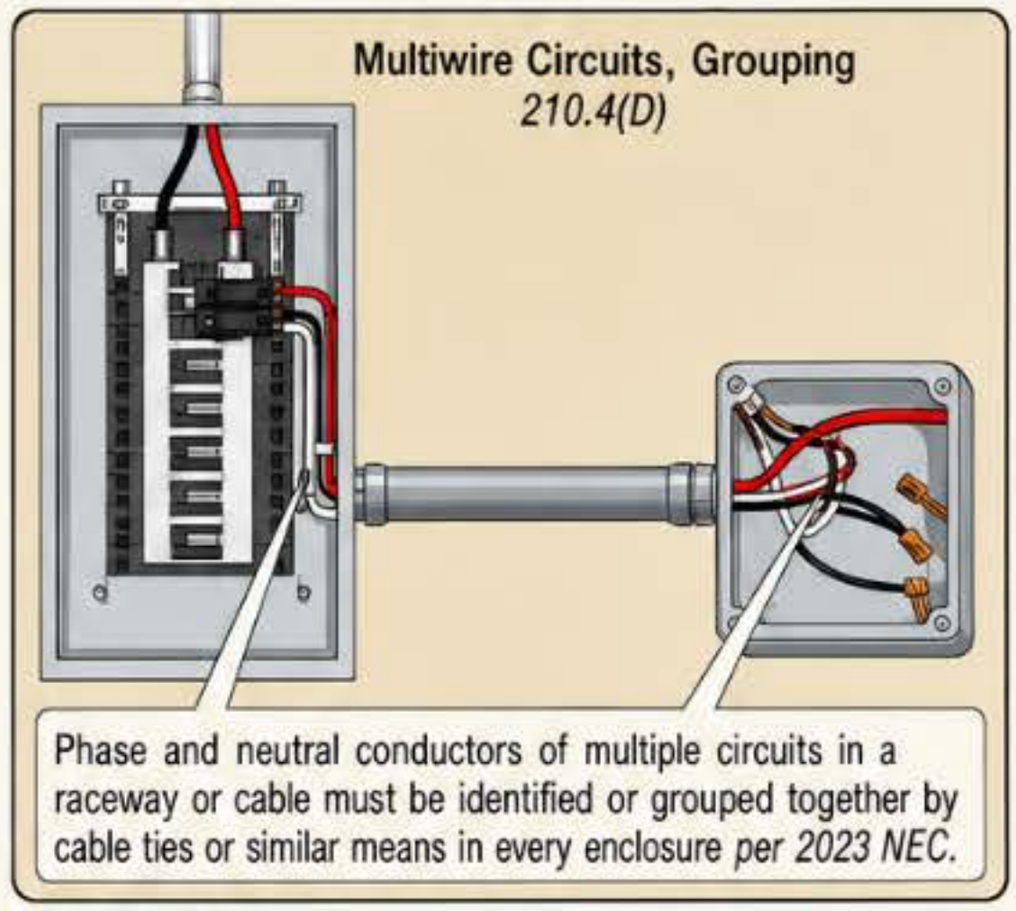
This rule is designed to protect people who might be working on what they believe is a de-energized circuit that is actually still energized.

BRANCH CIRCUITS

210.4



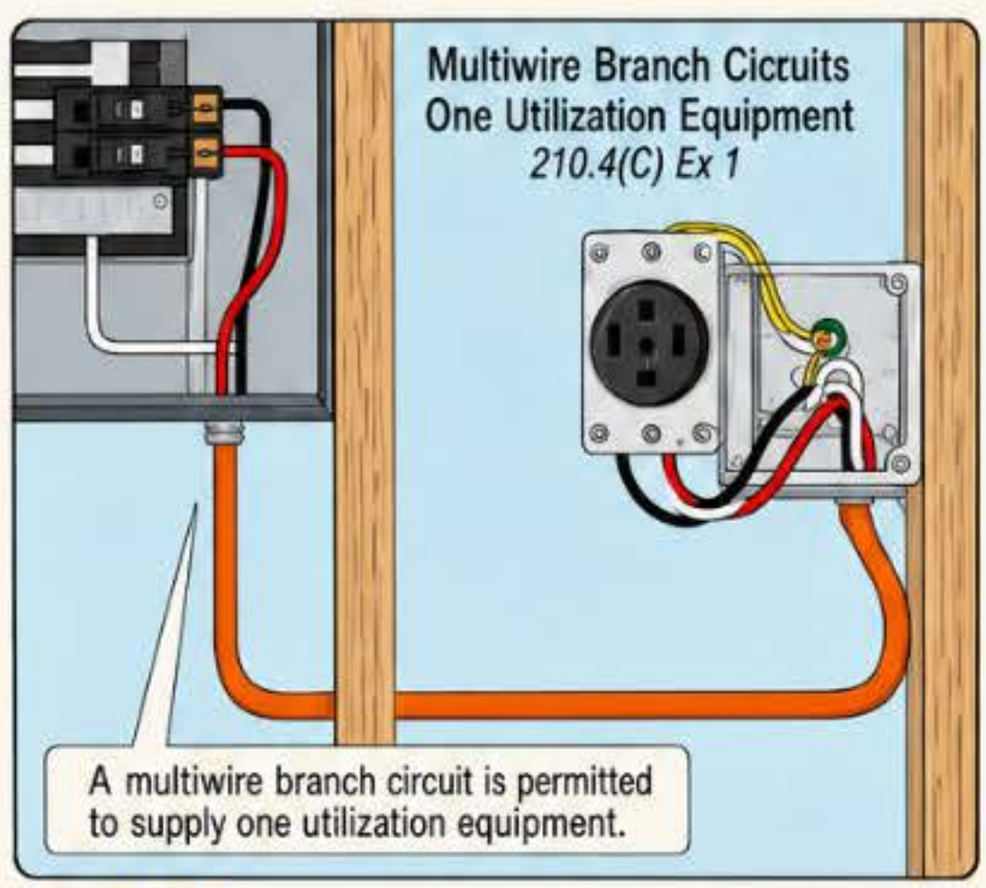
▸ Figure 210–6



▸ Figure 210–8

(C) Line-to-Neutral Loads. Multiwire branch circuits must supply only line-to-neutral loads.

Ex 1: A multiwire branch circuit can supply an individual piece of line-to-neutral utilization equipment such as a range or dryer. ▸ Figure 210–7



▸ Figure 210–7

Ex 2: A multiwire branch circuit can supply both line-to-neutral and line-to-line loads if the circuit is protected by a device such as a multipole circuit breaker with a common internal trip that opens all phase conductors of the multiwire branch circuit simultaneously under a fault condition.

(D) Grouping. Phase and neutral conductors of a multiwire branch circuit must be identified or grouped together by cable ties or similar means in every enclosure in accordance with 2023 *NEC*. ▸ Figure 210–8

Author's Commentary:

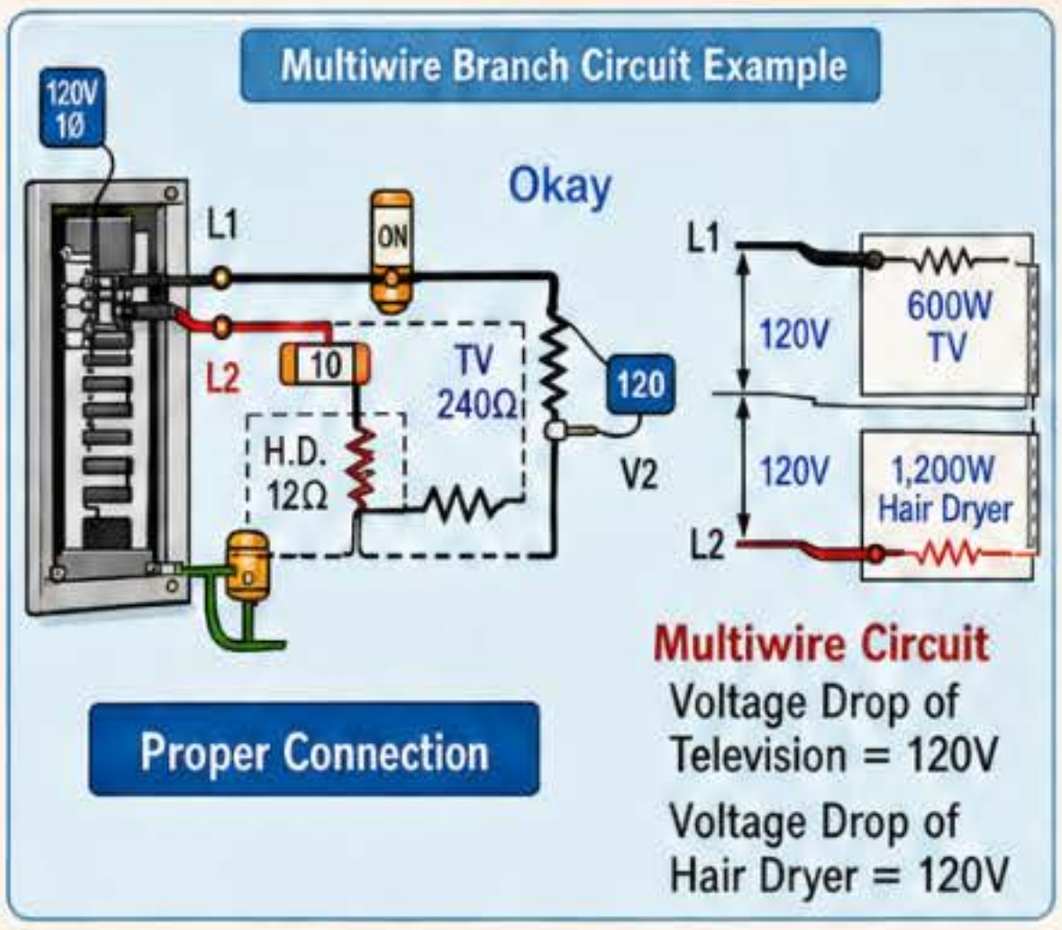
- *Grouping is not required where the circuit conductors are contained in a single raceway or cable unique to that circuit making the grouping obvious [2023 NEC Ex 1].*
- *If the conductors pass through a box or conduit body without any splices or terminations, then grouping is not required [2023 NEC Ex 2].*
- *Grouping all associated conductors of a multiwire branch circuit together by cable ties or other means at the point of origin makes it easier to visually identify the conductors of each multiwire branch circuit. The grouping assists in ensuring the correct neutral is paired with the intended circuit conductors at junction points, and in correctly connecting multiwire branch-circuit conductors to circuit breakers. If proper care is not exercised when making these connections, two circuit conductors can be accidentally connected to the same phase or line.*

— Michael Hamilton

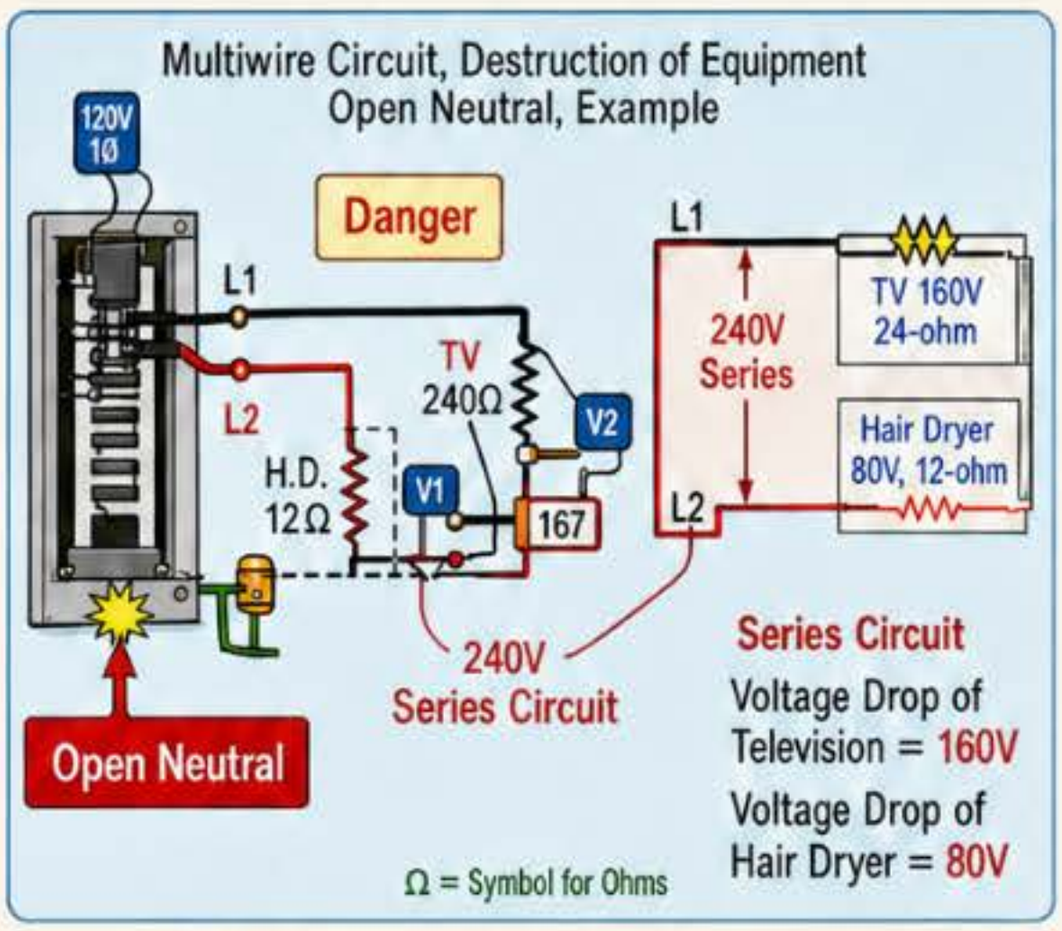
CAUTION

If the phase conductors of a multiwire branch circuit are not terminated to different phases or lines, the currents on the neutral conductor from the phase conductors will be additive and will not cancel. This increased current may exceed the rating of the neutral conductor which in turn might damage the insulation and create a fire or other hazard.

▸ Figure 210–9 and ▸ Figure 210–10



▲ Figure 210-9



▲ Figure 210-10

210.5 Identification for Branch Circuits

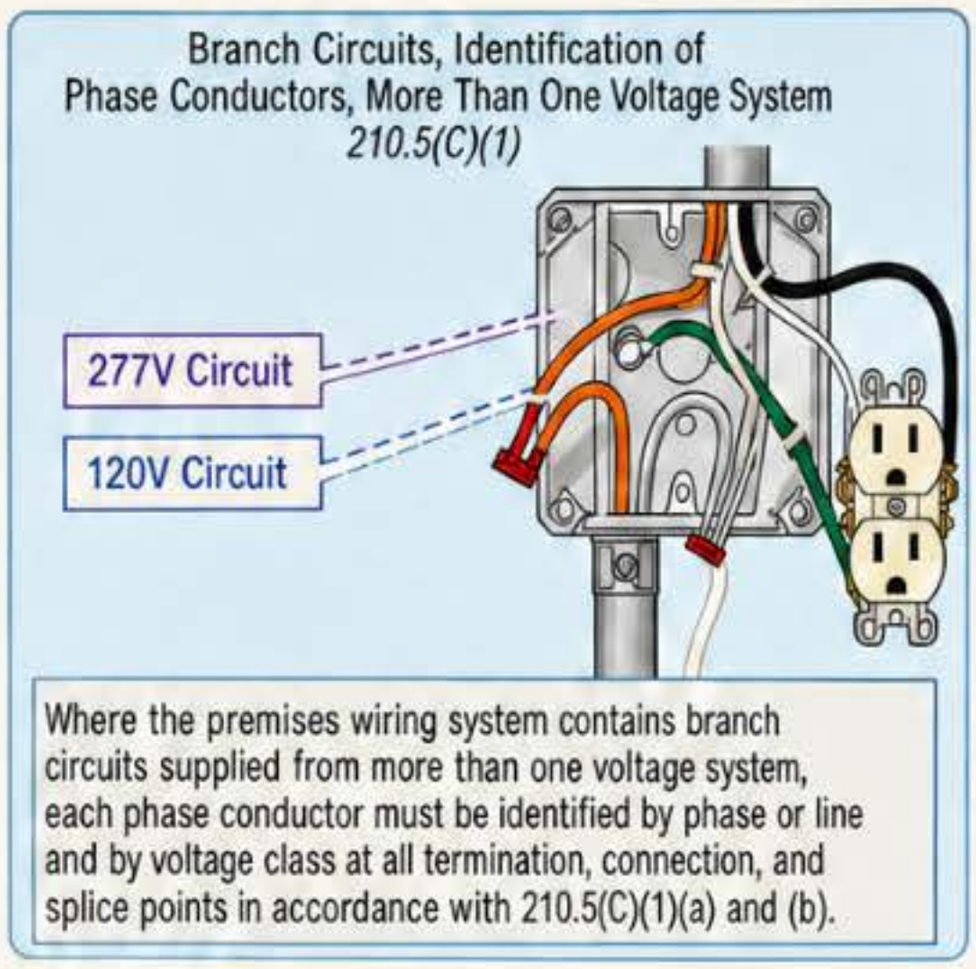
(A) Neutral Conductor. The branch-circuit neutral conductor must be identified in accordance with 200.6.

(B) Equipment Grounding Conductor. Equipment grounding conductors may be bare, covered, or insulated. Insulated equipment grounding conductors for 4 AWG and smaller must have a continuous outer finish either green or green with one or more yellow stripes [250.119].

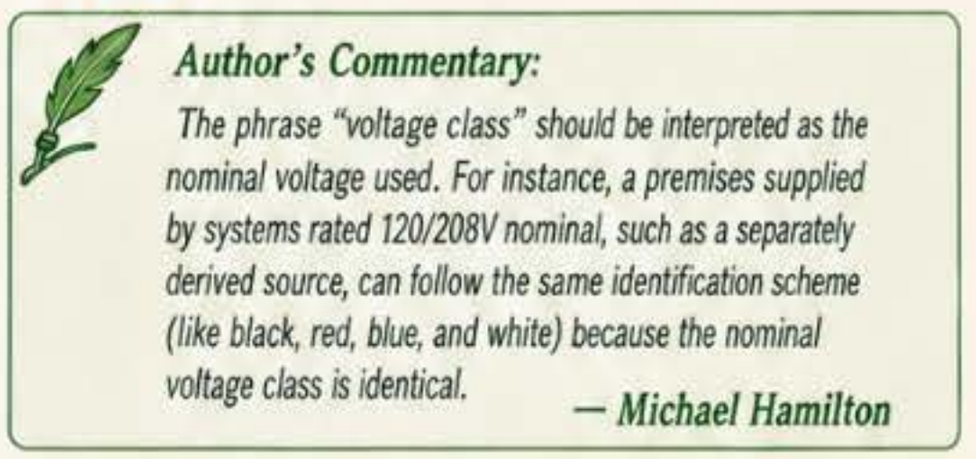
Insulated equipment grounding conductors 4 AWG and larger can be permanently identified with green marking at the time of installation where accessible [250.119(A)].

(C) Identification of Phase Conductors. Circuit phase conductors must be identified as follows:

(1) More Than One Voltage Distribution System. Where premises wiring is supplied from more than one nominal voltage system, the phase conductors of branch circuits must be identified by phase or line and by voltage class at all termination, connection, and splice points in accordance with 210.5(C)(1)(a) and (b). Different systems within the premises with the same system voltage class can use the same method of identification. → Figure 210-11



▲ Figure 210-11



Author's Commentary:

The phrase "voltage class" should be interpreted as the nominal voltage used. For instance, a premises supplied by systems rated 120/208V nominal, such as a separately derived source, can follow the same identification scheme (like black, red, blue, and white) because the nominal voltage class is identical.

— Michael Hamilton

(a) Means of Identification. Identification of the phase conductors can be by color coding, marking tape, tagging, or other methods approved by the authority having jurisdiction. → Figure 210-12

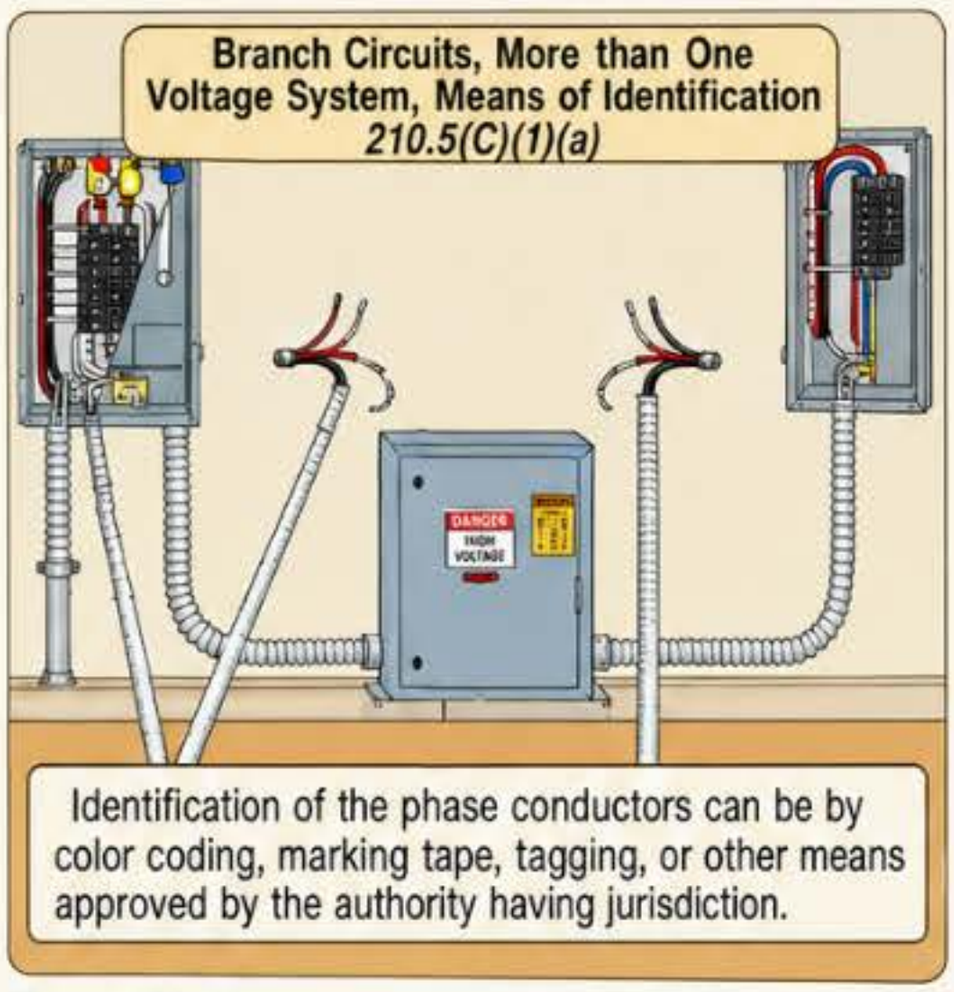


Figure 210-12

(b) Posting of Identification. The method of identification must be readily available or permanently posted at each branch-circuit panelboard, not be handwritten, and be sufficiently durable to withstand the environment involved. Figure 210-13

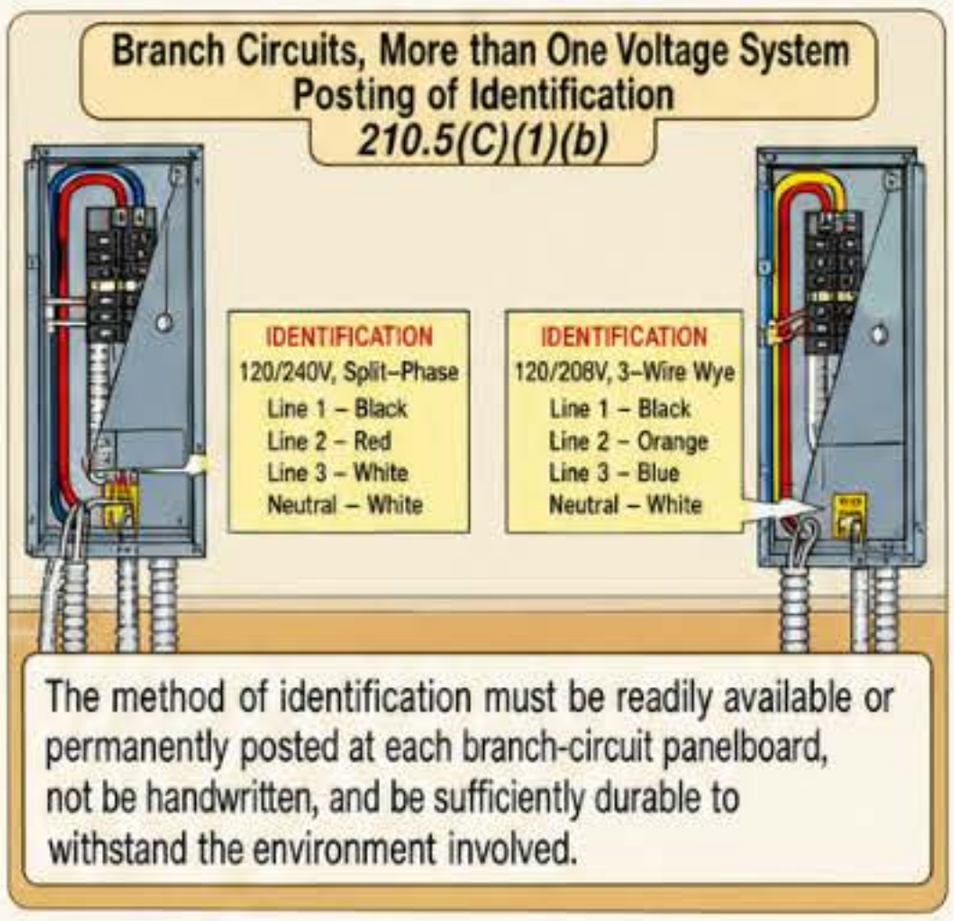


Figure 210-13

Ex: Where a different voltage system is added to an existing installation, branch-circuit identification is only required for the new one. Each voltage system distribution equipment must have a label with the words "other unidentified systems exist on the premises." Figure 210-14

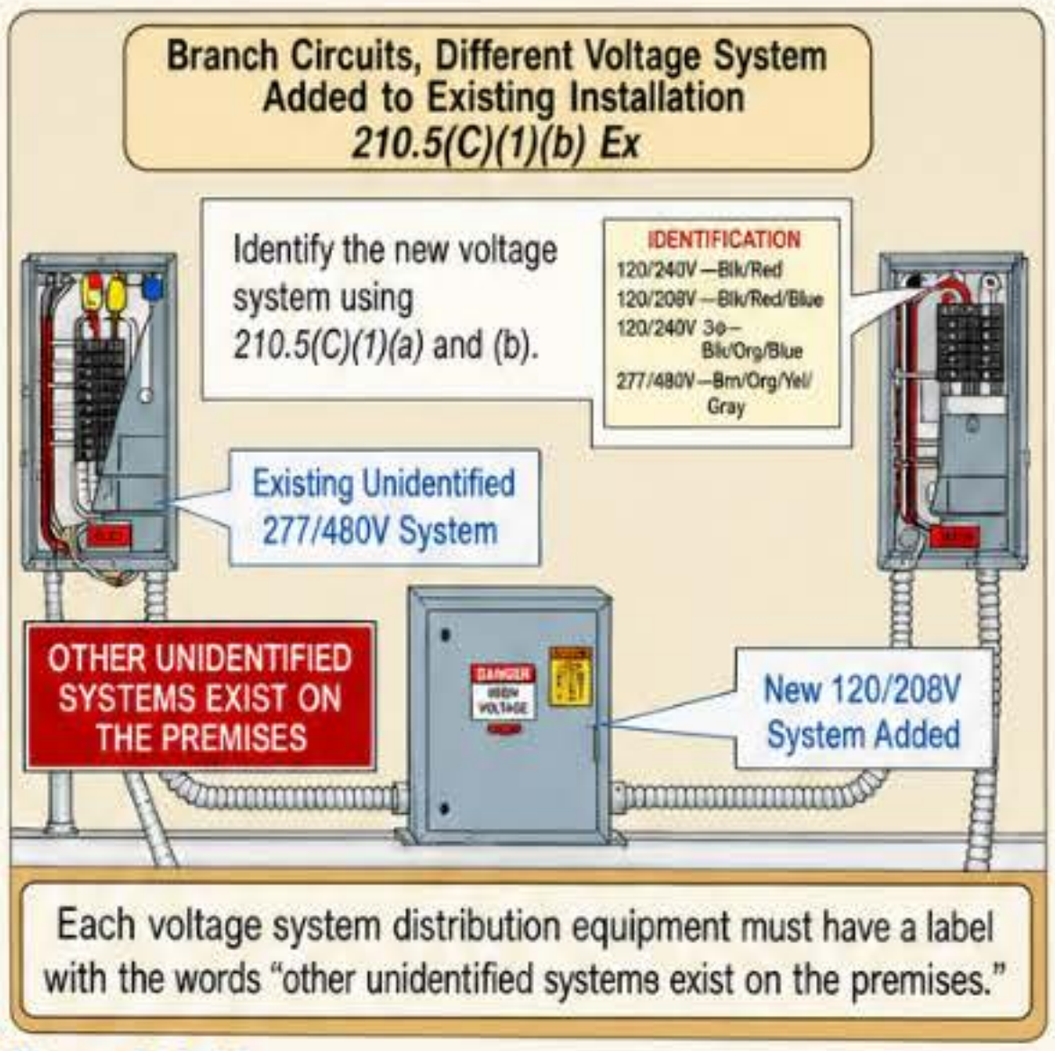


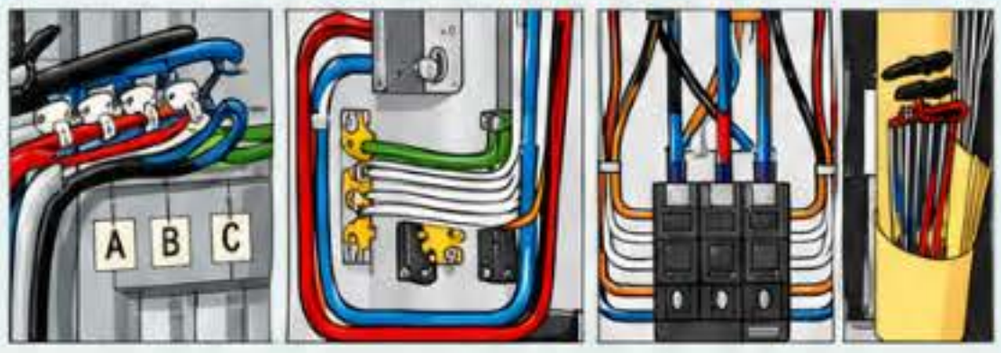
Figure 210-14

Author's Commentary:

- *When a premises has more than one voltage system supplying branch circuits, the phase conductors must be identified by phase and system. This can be done by permanently posting an identification legend that describes the method used, such as color-coded marking tape or color-coded insulation.*
- *Although the 2023 NEC does not require a specific color code for phase conductors, electricians often use the following systems:*
  - *120/240V, single-phase—black, red, and white*
  - *120/208V, three-phase—black, red, blue, and white*
  - *120/240V, three-phase (high-leg)—black, orange, blue, and white*
  - *277/480V, three-phase—brown, orange, yellow, and gray; or, brown, purple, yellow, and gray*
- *Whichever color scheme is used, it is important for it to remain consistent wherever phase conductors are terminated or accessible throughout the entire premises. This is especially important when identifying different system voltages and neutrals.*

— Michael Hamilton

Common Phase Conductor Identification Methods
210.5, 215.12, and 310.6(C) Comment



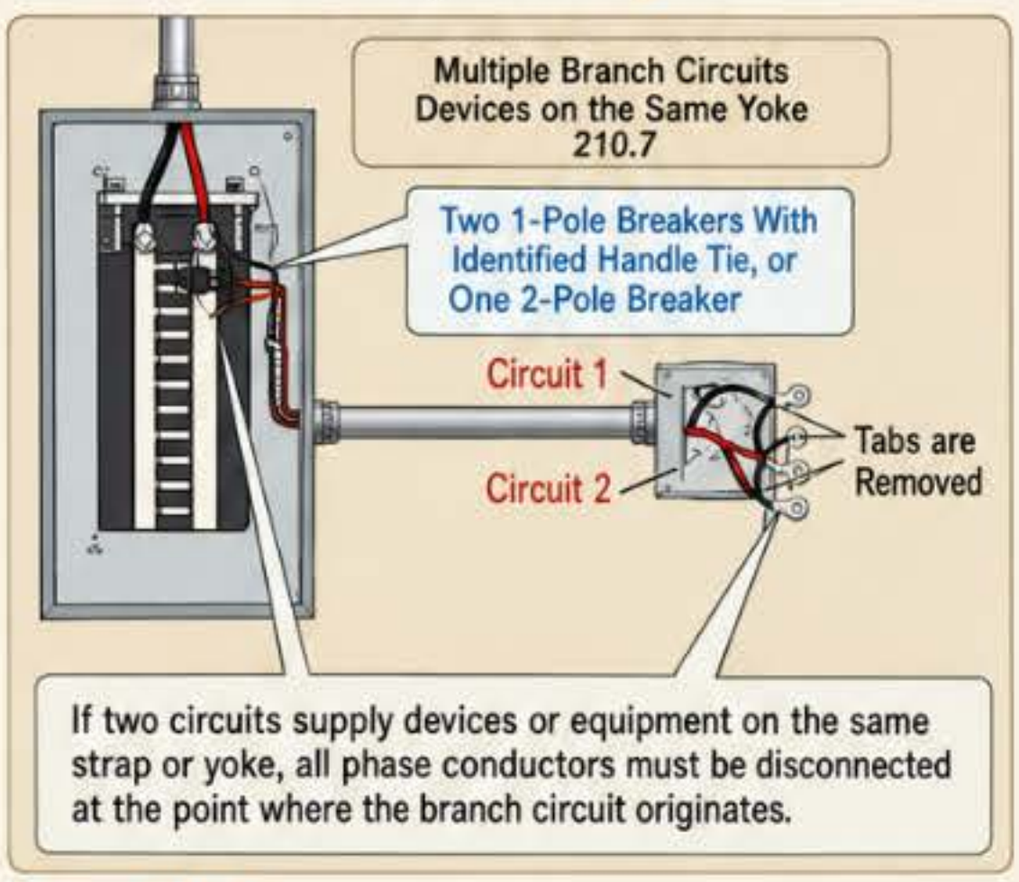
The *NEC* does not demand a specific color scheme for phase conductors, and electricians commonly use various color combinations to distinguish them. Typical color set options include the following for power and lighting conductor identification:

- 120/240V, single-phase—black, red, and white
- 120/208V, three-phase—black, red, blue, and white
- 120/240V, three-phase (high leg)—black, orange, blue, and white
- 277/480V, three-phase—brown, orange, yellow, and gray; or brown, purple, yellow, and gray

▶ Figure 210-15

210.7 Multiple Branch Circuits

If two circuits supplying devices or equipment are on the same strap or yoke, all phase conductors must be disconnected at the point where the branch circuit originates. ▶ Figure 210-16



▶ Figure 210-16

Author's Commentary:

▶ *Individual single-pole circuit breakers with handle ties identified for the purpose, or a circuit breaker with a common internal trip, can be used for this application [240.15(B)(1)].*

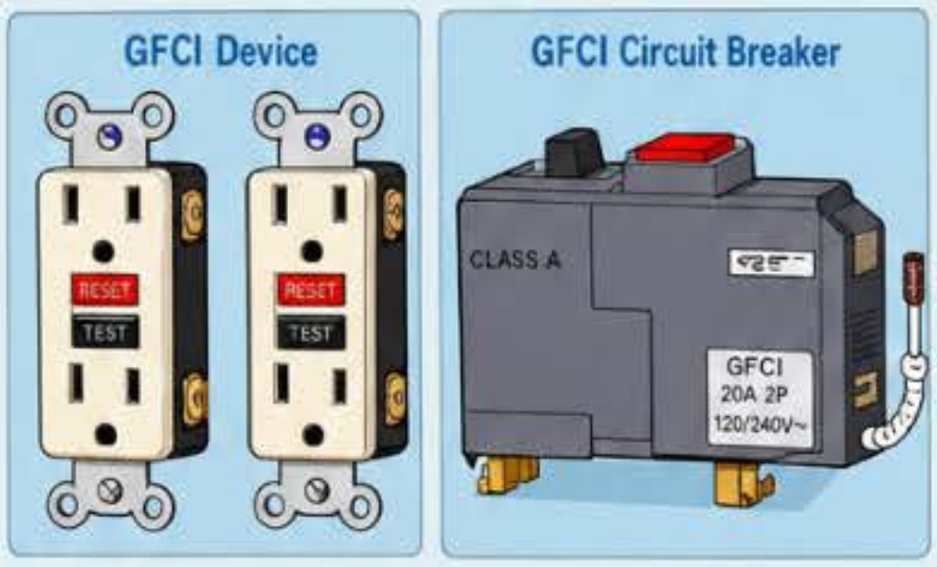
— Michael Hamilton

210.8 GFCI Protection

Ground-fault circuit interruption protection, located in a readily accessible location, must be provided in accordance with 210.8(A) through (F).

▶ Figure 210-17

Branch Circuits, GFCI Protection
210.8



GFCI protection must be provided as required in 210.8(A) through (F). The GFCI must be installed in a readily accessible location.

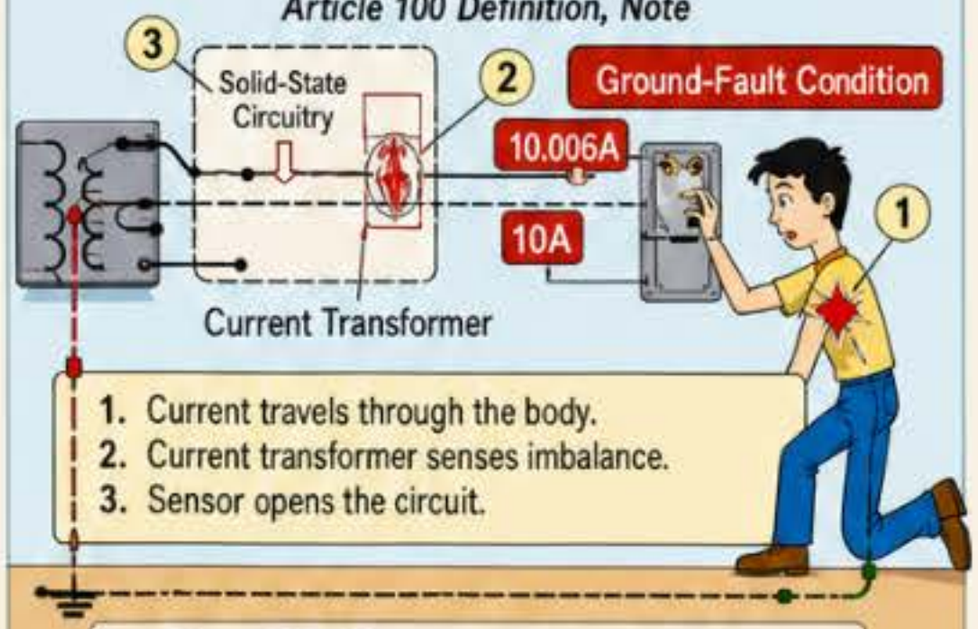
▶ Figure 210-17

Author's Commentary:

▶ *According to Article 100, a "Ground-Fault Circuit Interrupter" (GFCI) is a device intended to protect people by de-energizing a circuit when a current imbalance is of 6 mA or higher and does not do so when the current to ground is less than 4 mA.* ▶ Figure 210-18

— Michael Hamilton

Ground-Fault Circuit Interrupter (GFCI)
Article 100 Definition, Note



A "Class A" GFCI opens the circuit when the ground-fault current is 6 mA or higher and does not do so when the ground-fault is less than 4 mA.

▶ Figure 210-18

Branch Circuits | 210.8

Author's Commentary:

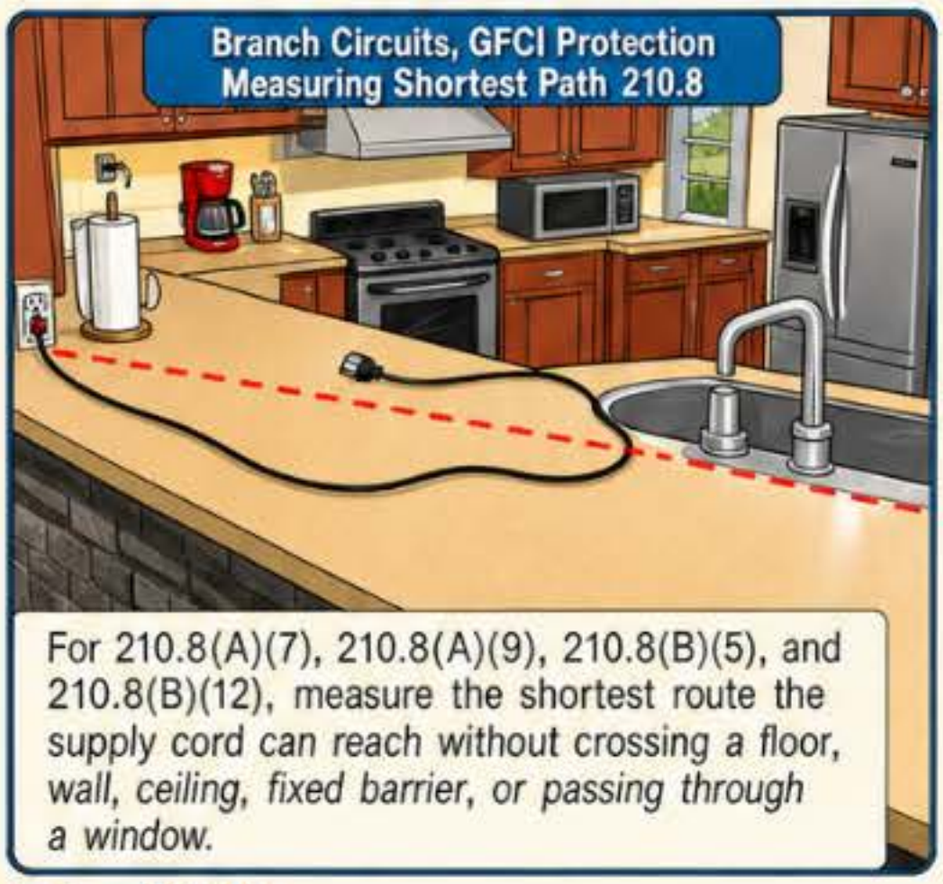
- The GFCI circuit breaker offers ground-fault protection right from the breaker, so every device on that circuit is protected. A GFCI receptacle only guards the outlets it serves and its own load-side terminals, while also providing downstream protection for any other receptacle(s) connected to the circuit.
- Per Article 100, "Readily Accessible" means within reach without needing to climb over or get past objects, or without using portable ladders.

Note 2: See 422.5 for GFCI requirements for specific *equipment such as automotive vacuum machines, drinking water coolers, high-pressure spray washing machines, tire inflation machines provided for public use, and vending machines.*

Note 3: See 555.9 for GFCI *requirements for boat hoists.*

Note 4: *Additional GFCI requirements for specific circuits and equipment are contained in Chapters 4, 5, and 6.*

For the application of 210.8(A)(7), 210.8(A)(9), 210.8(B)(5), and 210.8(B)(12), measure the **shortest path** *an appliance's supply cord can reach without piercing a floor, wall, ceiling, fixed barrier, or passing through a window.* ▶ *Figure 210–19*

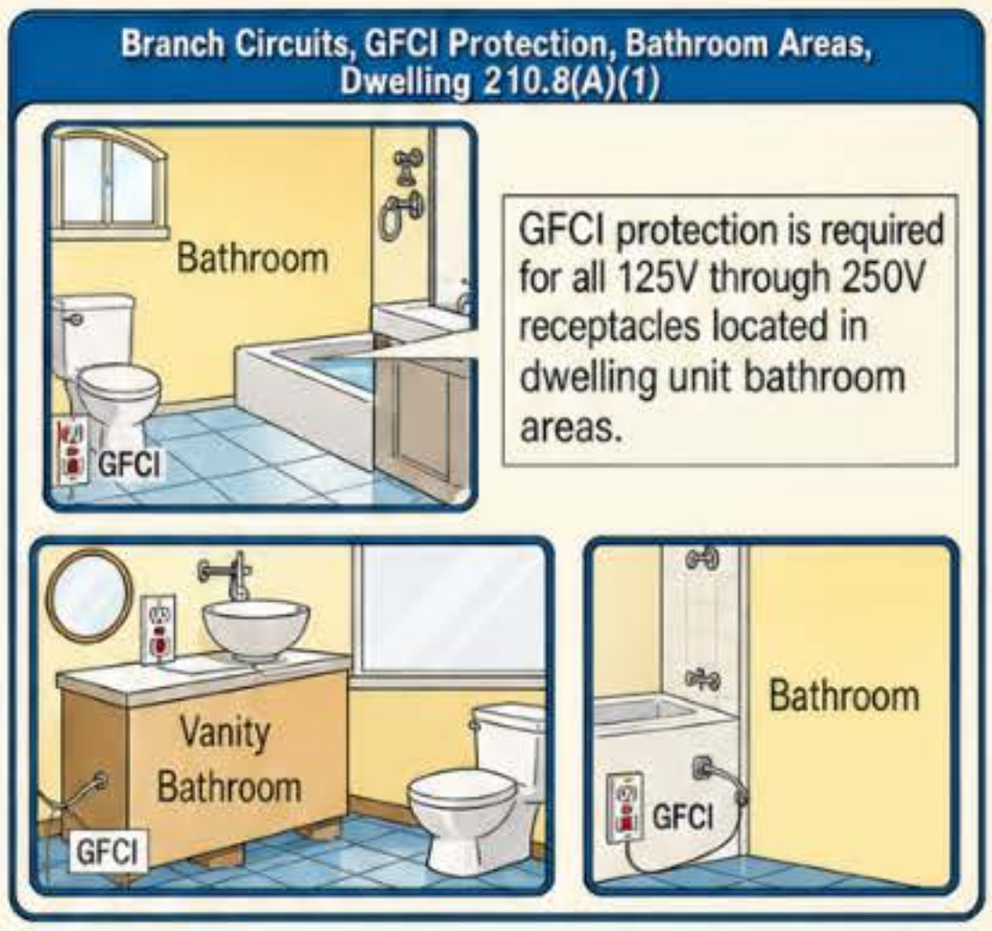


▶ Figure 210–19

(A) Dwelling Units. All 125V through 250V receptacles installed in the following dwelling unit locations must have GFCI protection.

(1) Bathroom Areas. GFCI protection *is required for all receptacles located in dwelling unit bathroom areas.*

▶ Figure 210–20

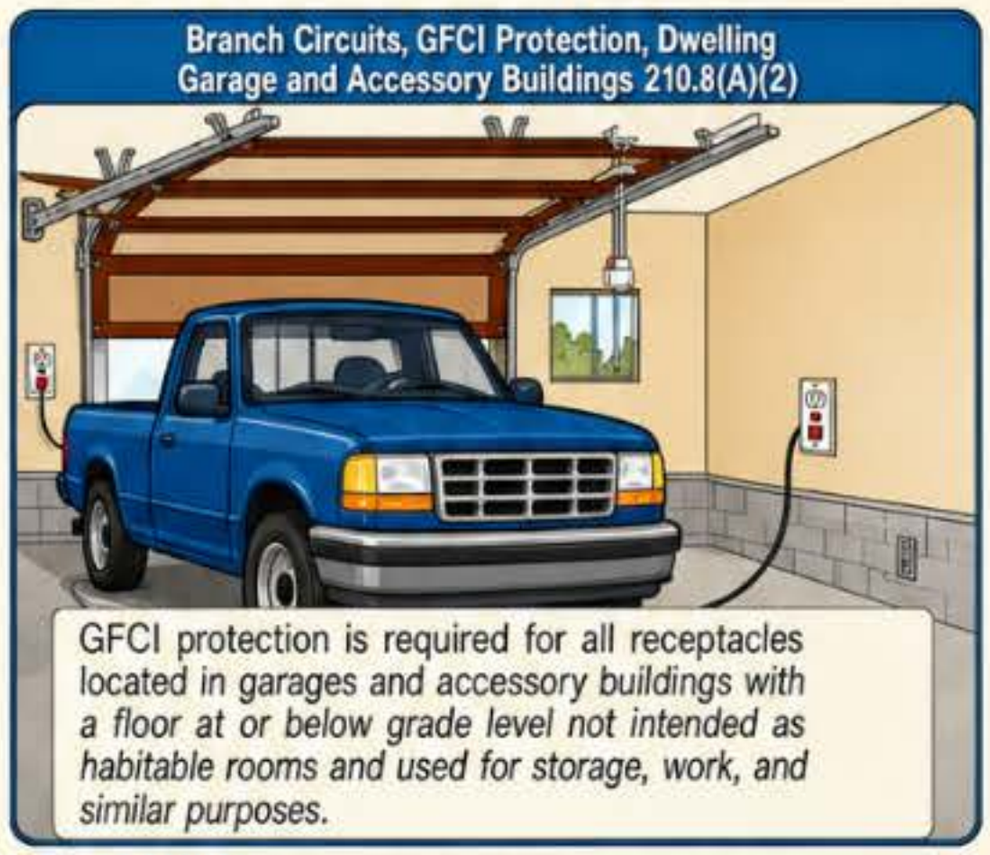


▶ Figure 210–20

Author's Commentary:

- Article 100 describes a "Bathroom Area" as a space that includes a toilet and one or more of the following: a urinal, tub, shower, bidet, or other similar plumbing fixture.

(2) Garages and Accessory Buildings. GFCI protection is required for all receptacles located in garages and accessory *buildings that have a floor level at or below grade and that are not intended as habitable rooms and are not used for storage, work, or similar purposes.* ▶ *Figure 210–21*



▶ Figure 210–21

(3) Outdoors. GFCI protection is required *for all receptacles located outdoors at dwelling units, including receptacles under the eaves of roofs.*

▶ Figure 210–22

210.8 | Branch Circuits

▸ Figure 210–22

Ex: *GFCI protection is not required for a receptacle dedicated to fixed electric snow-melting equipment if the receptacle is not readily accessible and ground-fault protection of equipment is provided as required by 426.28 and 427.22.*

▸ Figure 210–23

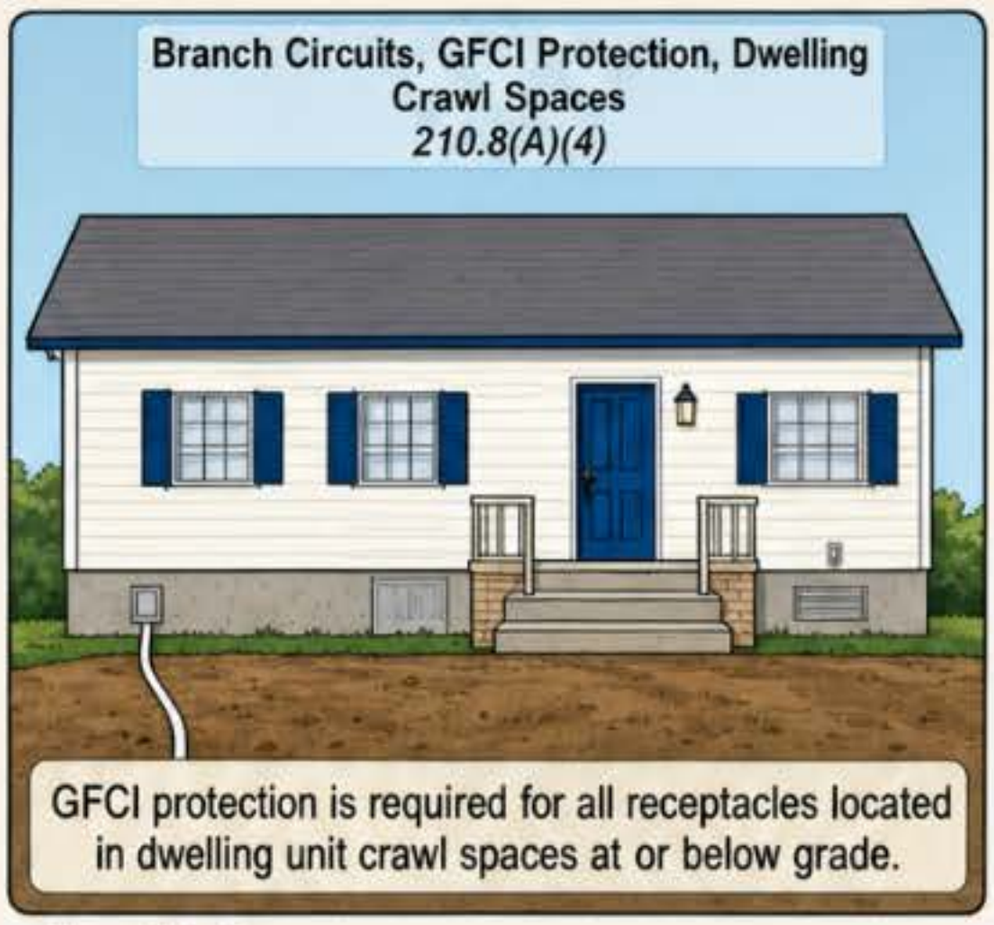
▸ Figure 210–23

(4) Crawl Spaces. GFCI protection is required for all receptacles located in dwelling unit crawl spaces at or below grade.

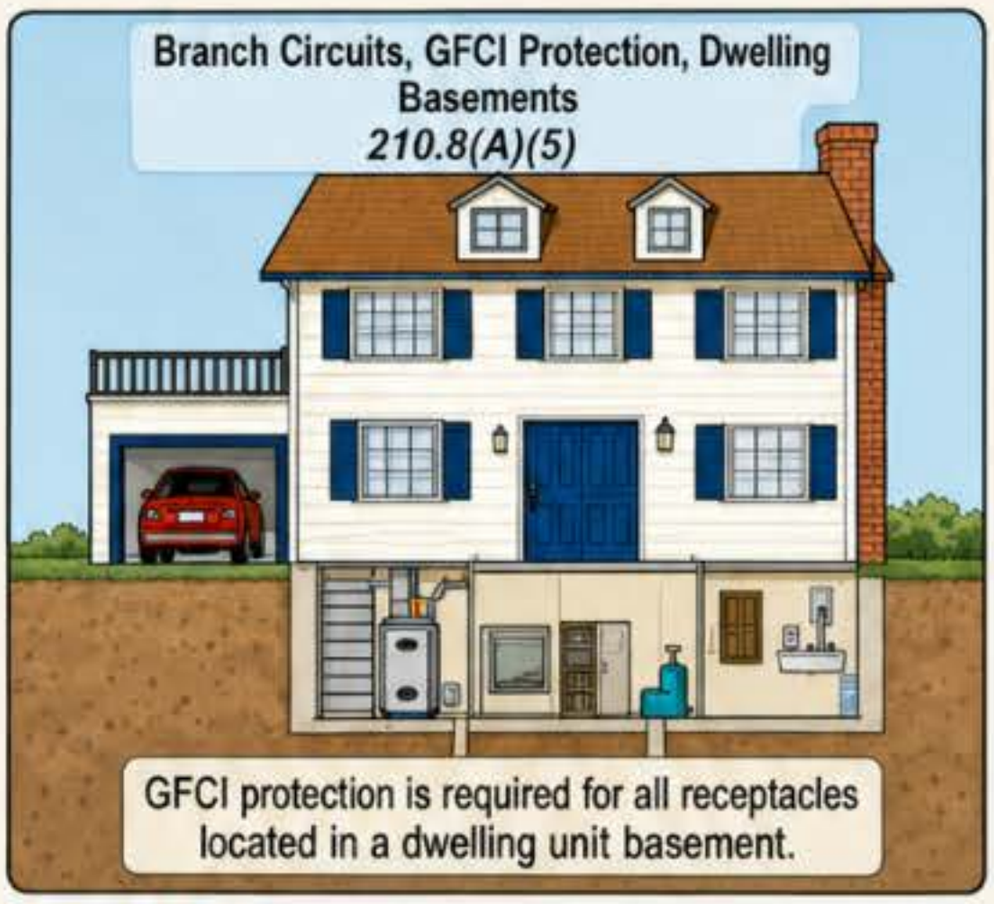
▸ Figure 210–24

(5) Basements. GFCI protection is required for all receptacles located in finished and unfinished areas of dwelling unit basements.

▸ Figure 210–25



▸ Figure 210–24



▸ Figure 210–25

Ex: *A receptacle supplying only a permanently installed fire or burglar alarm system is not required to have ground-fault circuit-interrupter protection.*

(6) Kitchen Countertops. GFCI protection is required for all receptacles that serve kitchen countertop surfaces.

▸ Figure 210–26

Author's Commentary:

- *Receptacles installed below a countertop for appliances such as trash compactors or garbage disposals do not require GFCI protection unless they are within 6 ft (1.8 m) from the upper inside edge of the bowl of a sink (210.8(A)(7)).*

— *Michael Hamilton*

Branch Circuits, GFCI Protection, Dwelling, Kitchens
210.8(A)(6)

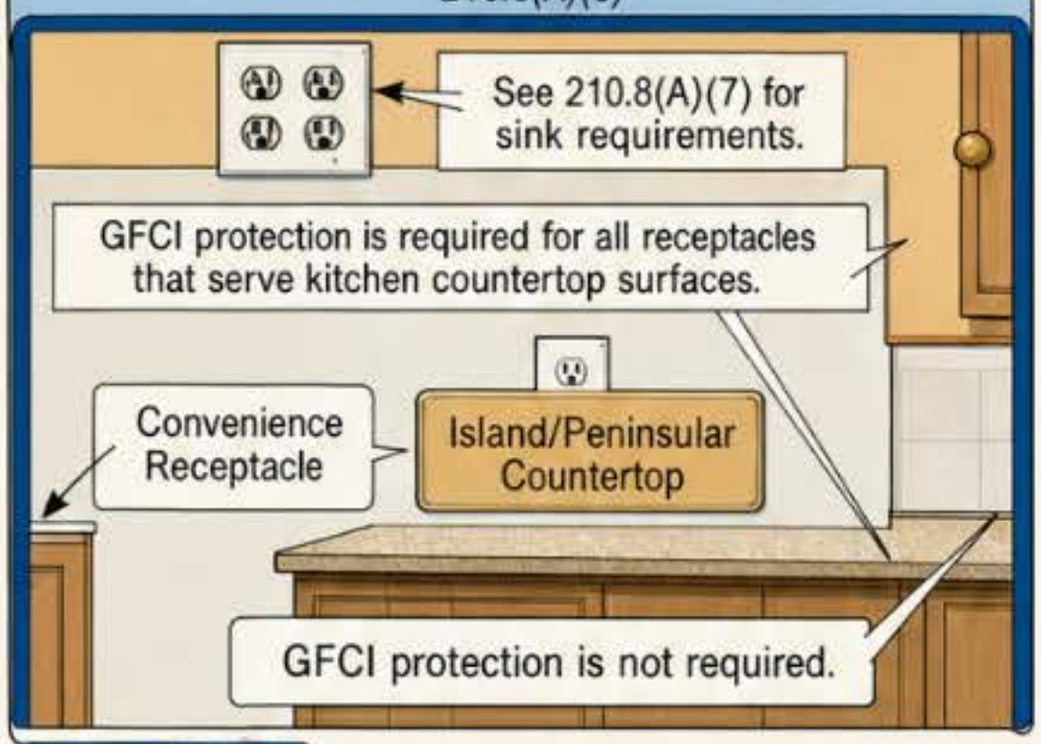


Figure 210–26

Branch Circuits, GFCI Protection, Sinks, Dwelling
210.8(A)(7)

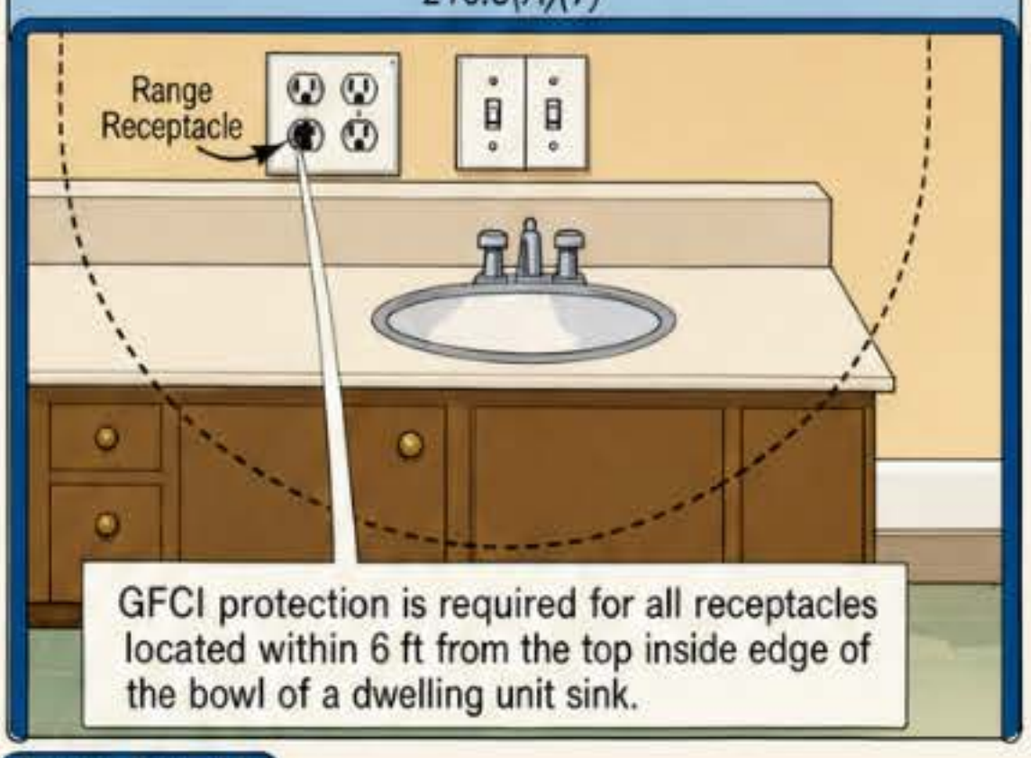


Figure 210–28

- GFCI protection is not required for a refrigerator receptacle outlet unless it is located within 6 ft from the top inside edge of the bowl of a kitchen sink [210.8(A)(7)].
- Figure 210–27

Branch Circuits, GFCI Protection, Kitchens, Dwelling
210.8(A)(6) Comment

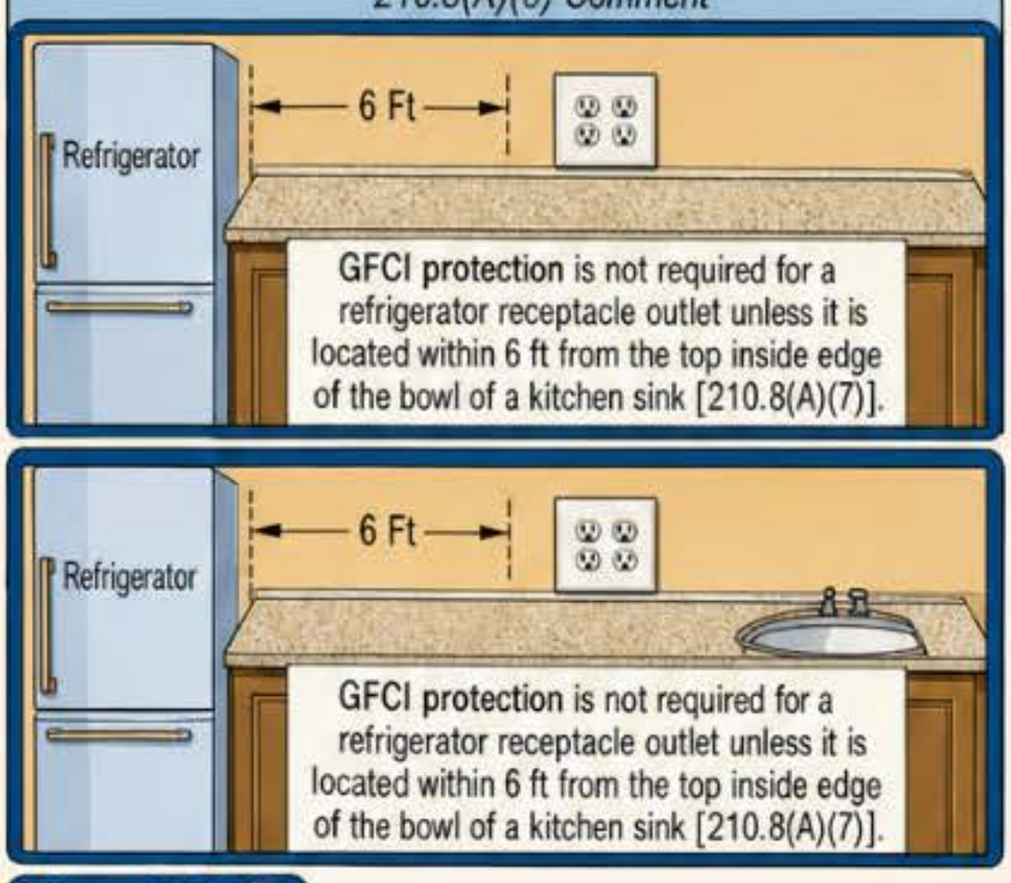


Figure 210–27

Author's Commentary:

- *Outlets supplying dishwashers require GFCI protection [210.8(D)].*

— Michael Hamilton

(7) Boathouses. *GFCI protection is required for all receptacles located in a dwelling unit boathouse.* Figure 210–29

Branch Circuits, GFCI Protection, Dwelling Boathouses
210.8(A)(8)

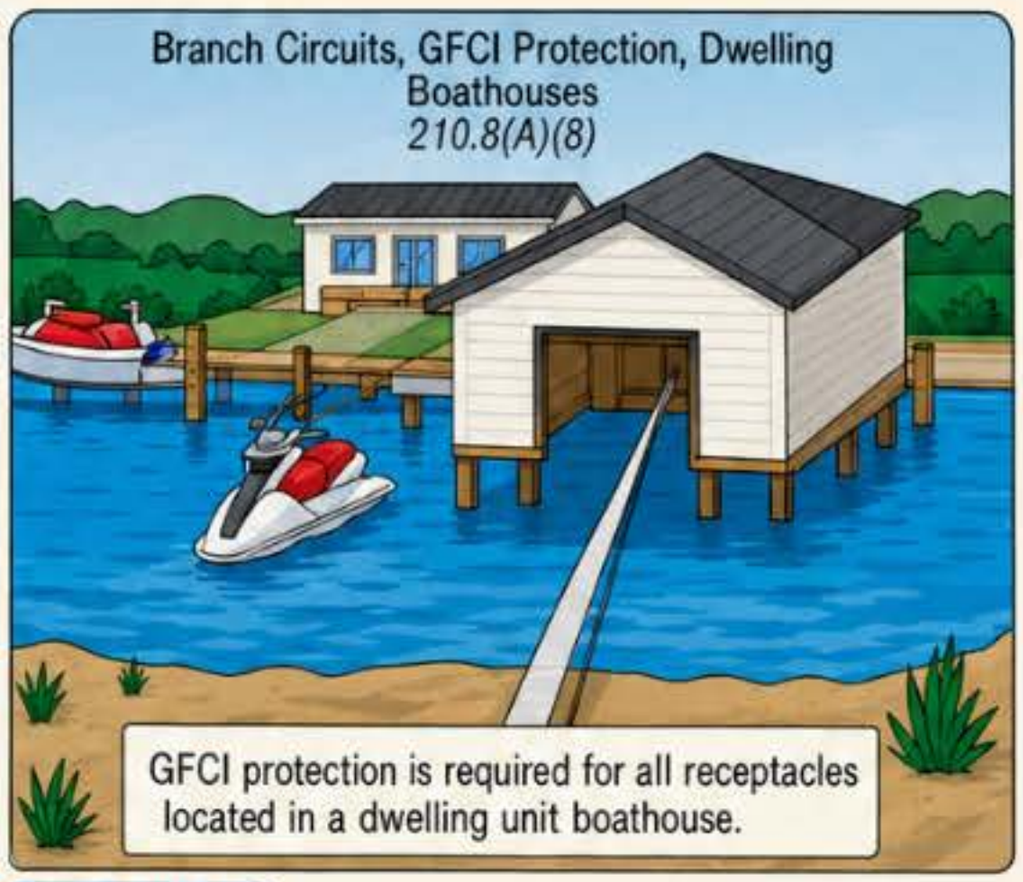


Figure 210–29

Author's Commentary:

- *The Code does not require a receptacle to be installed in a boathouse; however, if one is installed, it must be GFCI protected.*

— Michael Hamilton

(9) Bathtubs or Shower Stalls. GFCI protection is required for receptacles located within 6 ft of the outside edge of a bathtub or shower stall not installed within a bathroom as defined in Article 100. Figure 210–30

(10) Laundry Areas. *GFCI protection is required for all receptacles installed in the laundry area of a dwelling unit.* Figure 210–31

210.8 | Branch Circuits

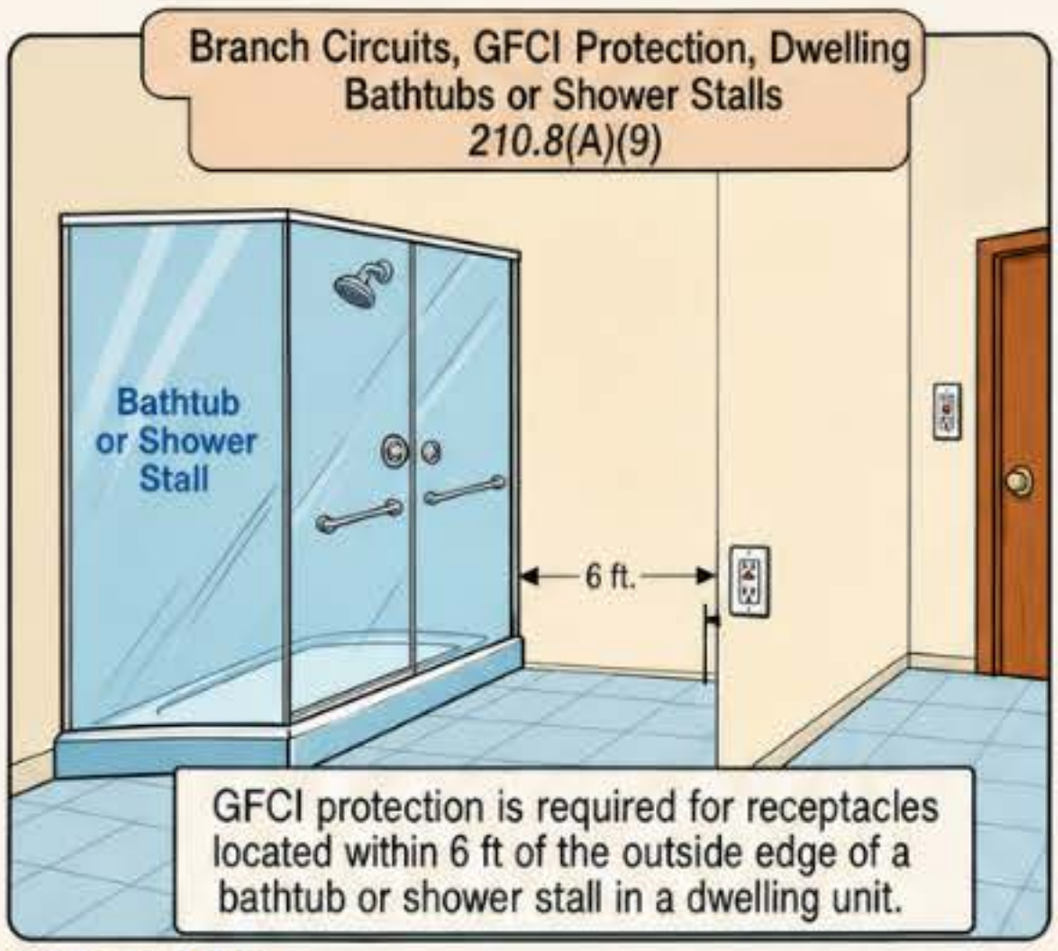


Figure 210–30

Figure 210–32

Figure 210–31

(11) Damp and Wet Locations Indoors. *GFCI protection must be provided for all receptacles installed in interior locations that are damp or wet.*

(B) Other Than Dwellings. *GFCI protection is required for all 125V through 250V receptacles supplied by single-phase branch circuits rated 150V or less to ground, 50A or less, and for all receptacles supplied by three-phase branch circuits rated 150V or less to ground, 100A or less, in indoor locations.*

(1) Bathroom Areas. *GFCI protection is required for all receptacles located in bathroom areas.* Figure 210–32

Author's Commentary:

A "Bathroom Area" as defined in Article 100 includes any space that contains a basin and one or more of these: a water closet, urinal, tub, shower, bidet, or other similar plumbing fixture.

— Michael Hamilton

(2) Kitchens. *GFCI protection is required for all receptacles located in kitchens or in areas with a sink, and also for permanent provisions for either food preparation or cooking.* Figure 210–33

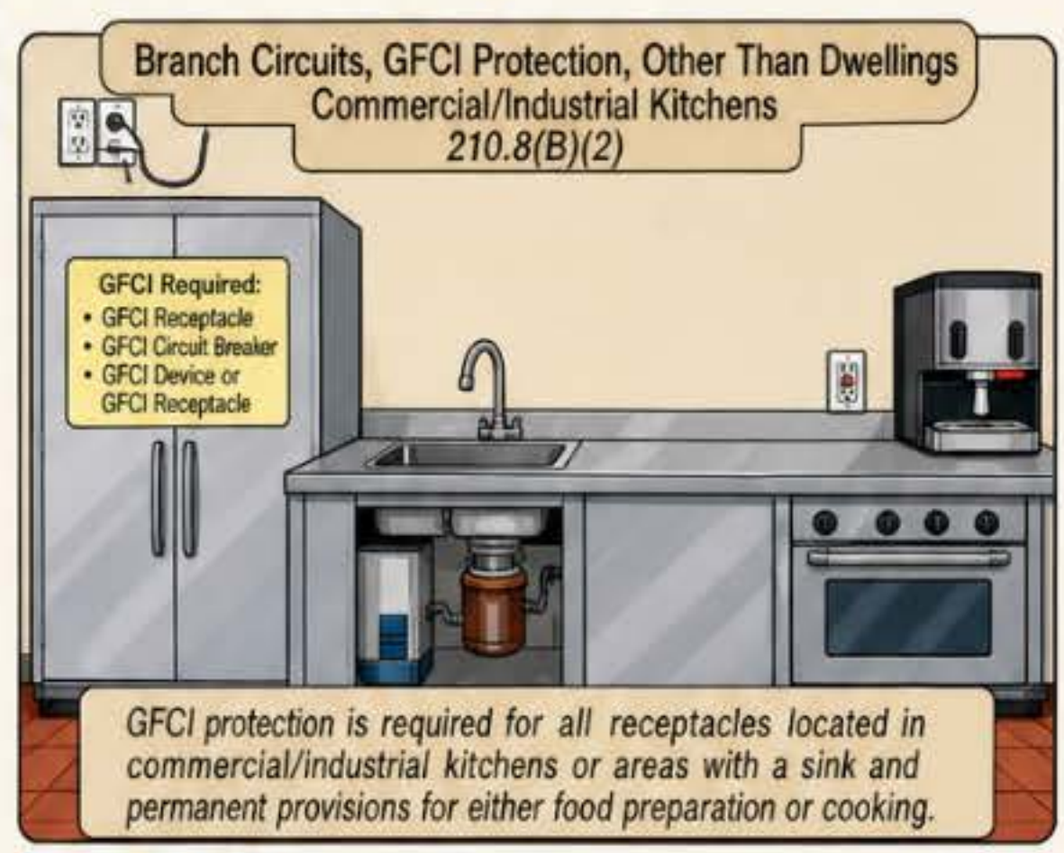
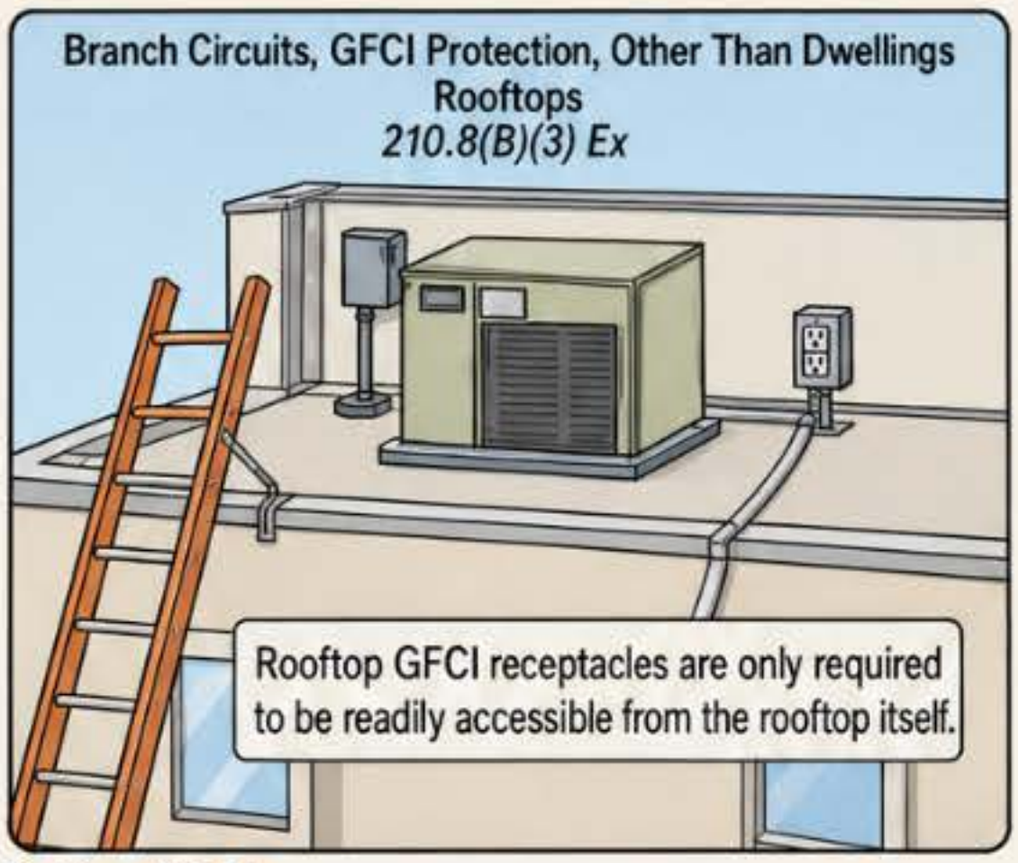
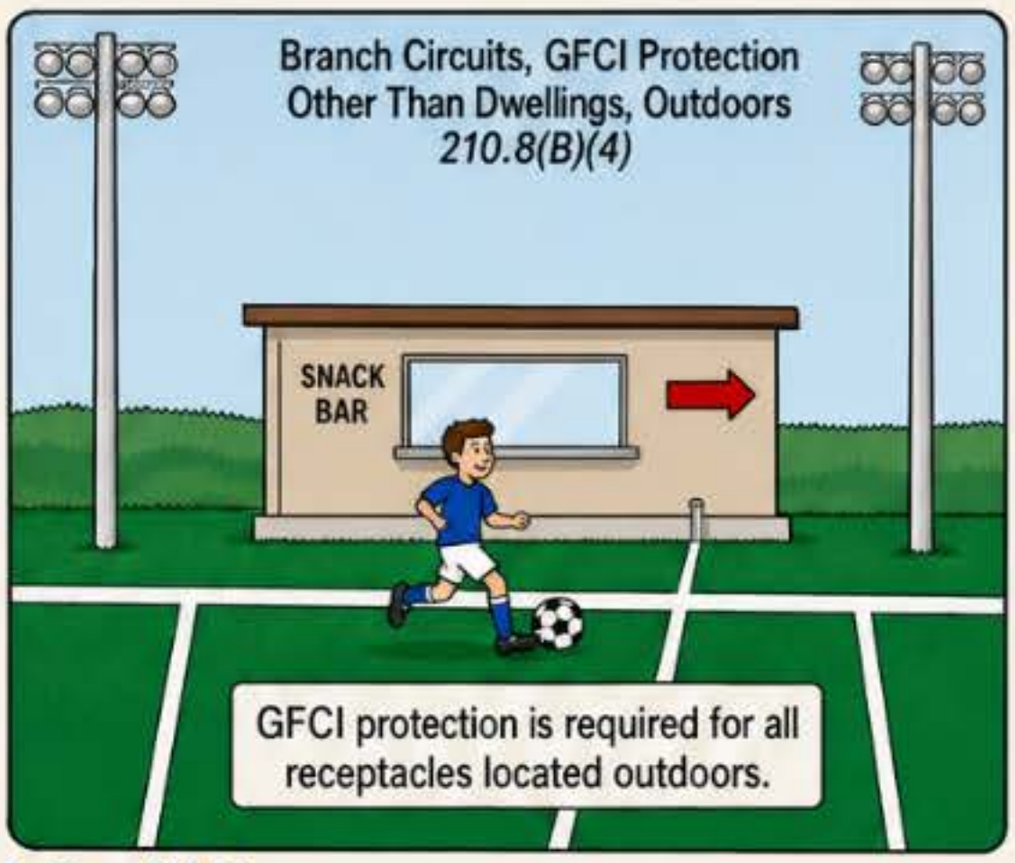


Figure 210–33

(3) Rooftops. *GFCI protection is required for all receptacles installed on rooftops.* Figure 210–34



▶ Figure 210-34

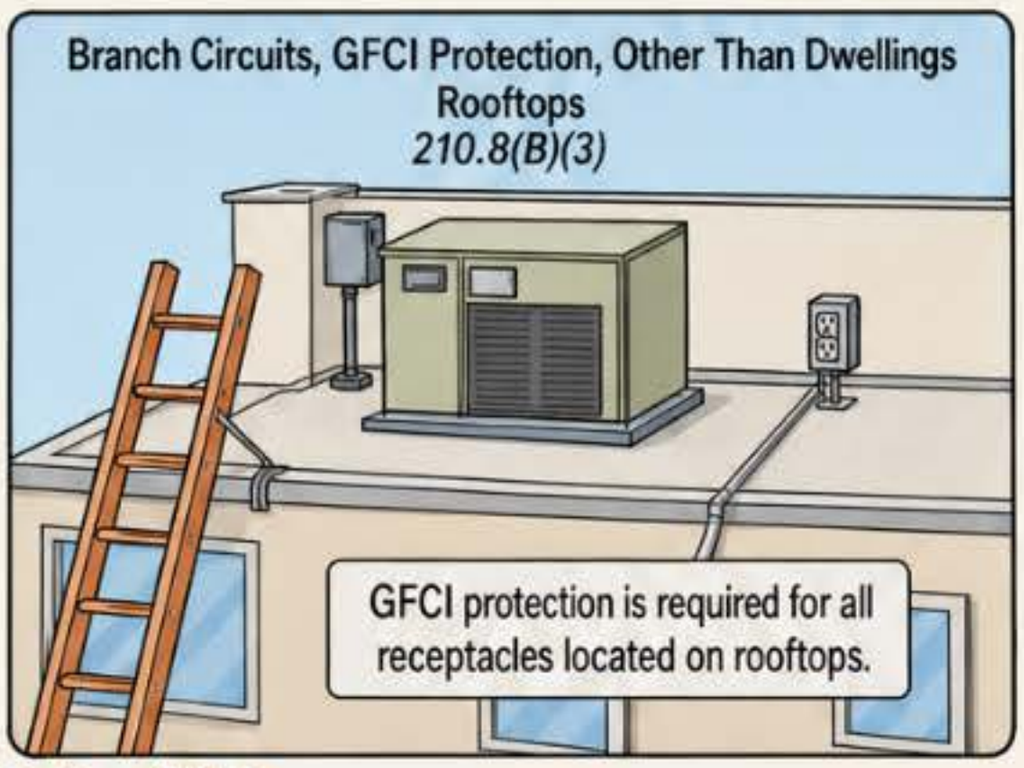


▶ Figure 210-36

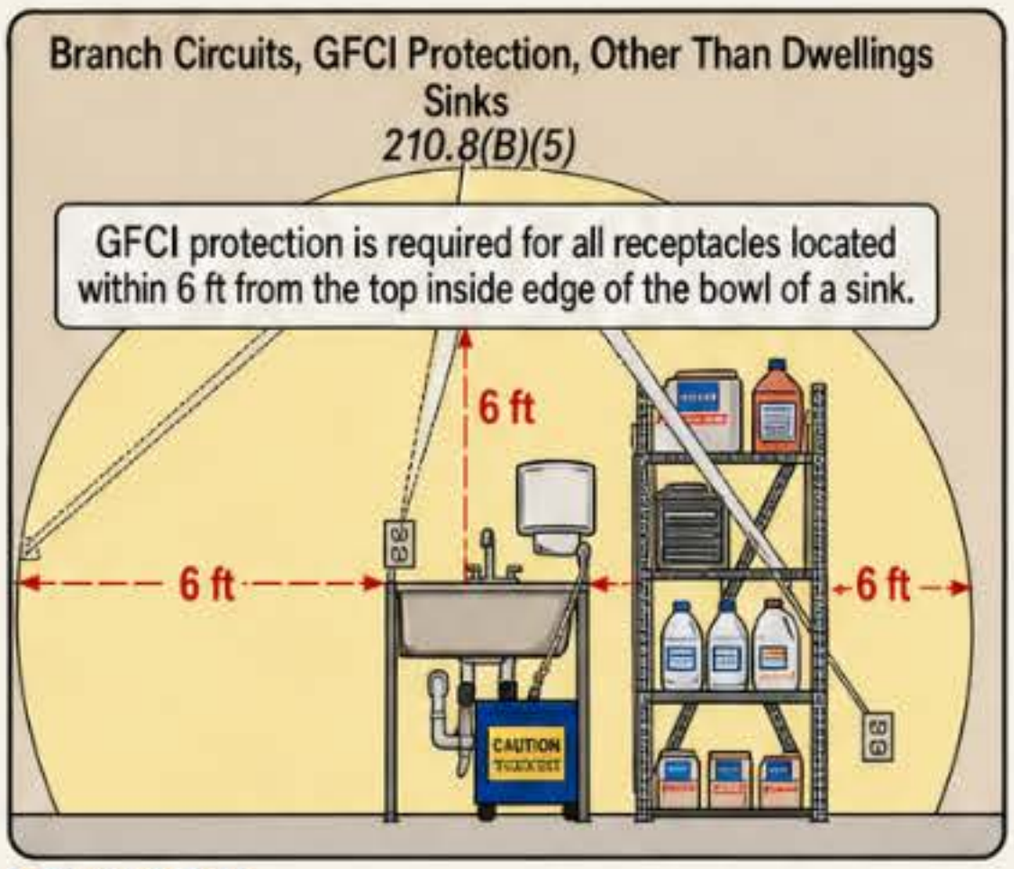
Author's Commentary:

▶ Exception: Rooftop GFCI receptacles need to be readily accessible only from the rooftop itself.

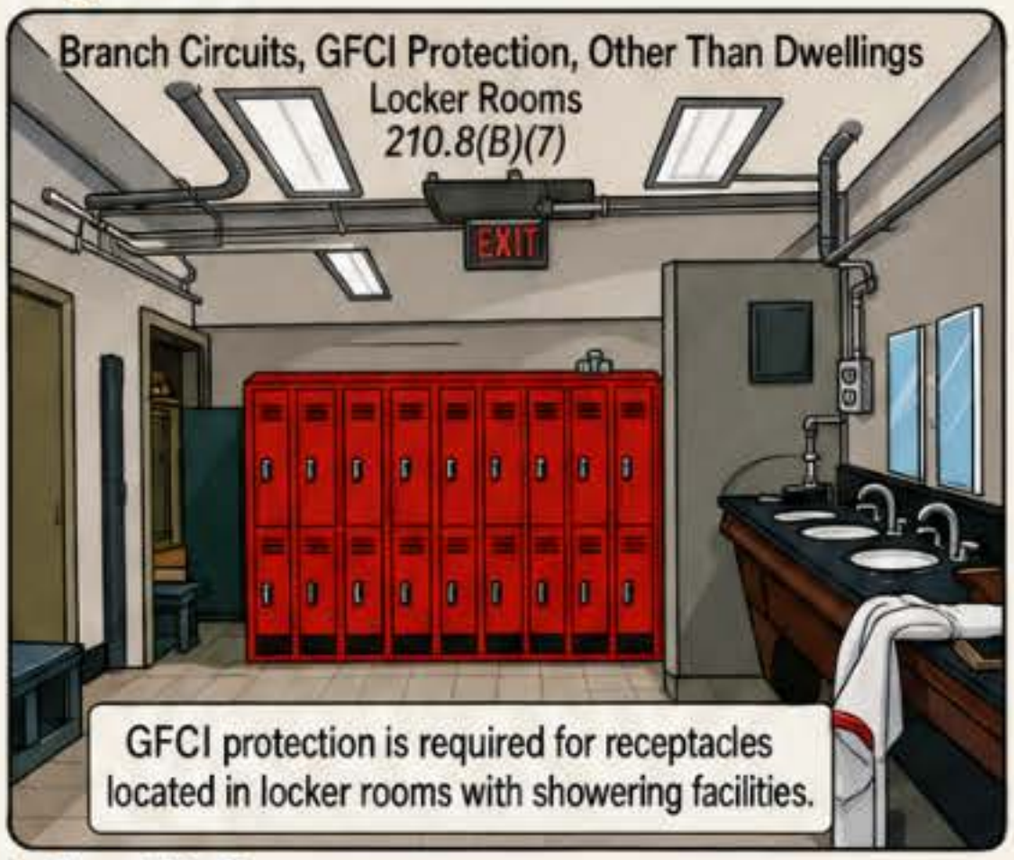
— Michael Hamilton



▶ Figure 210-35



▶ Figure 210-37



▶ Figure 210-38

(4) Outdoors. GFCI protection is required for all receptacles located outdoors. ▶ Figure 210-36

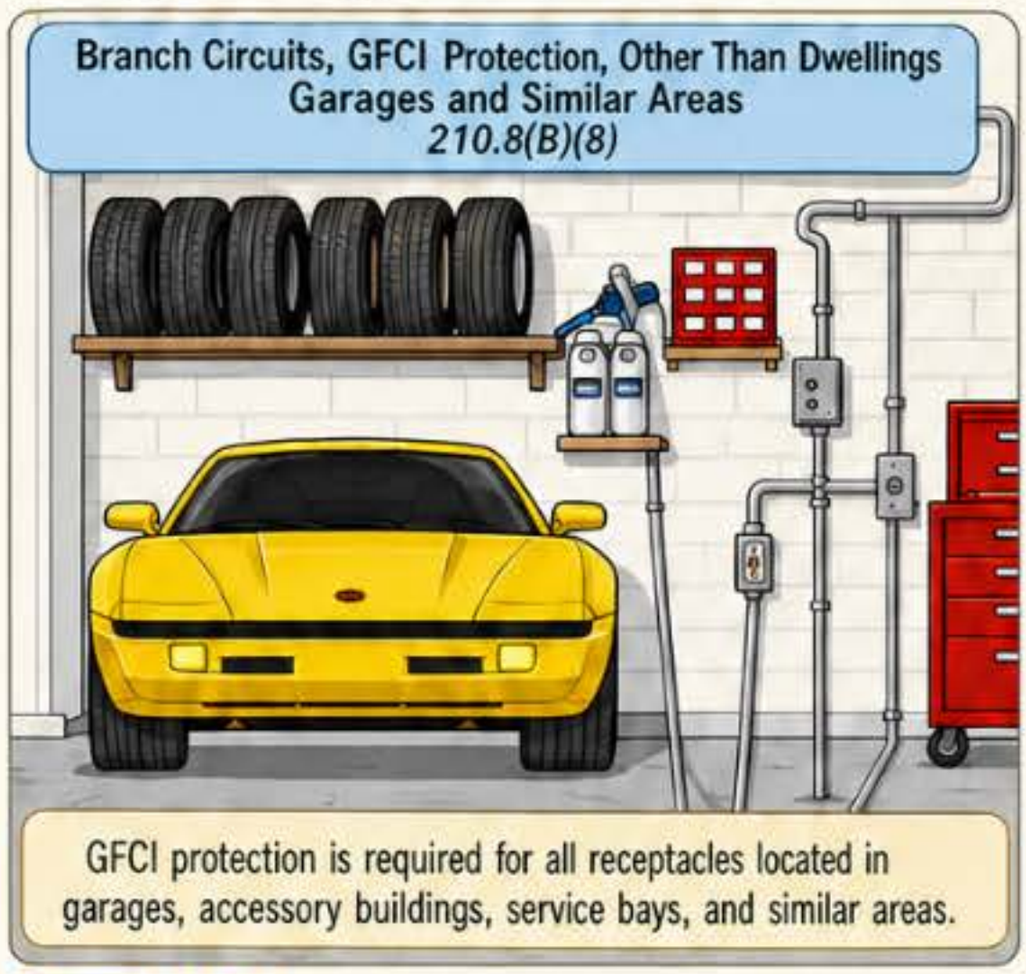
(5) Sinks. GFCI protection is required for all receptacles located within 6 ft from the top inside edge of the bowl of a sink. ▶ Figure 210-37

(6) Indoor Damp and Wet Locations. GFCI protection is required for all receptacles located in indoor damp and wet locations.

(7) Locker Rooms, GFCI protection is required for receptacles located in locker rooms with showering facilities. ▶ Figure 210-38

210.8 BRANCH CIRCUITS

(8) Garages and Similar Areas. Ground-fault circuit-interrupter (GFCI) protection must be provided for every receptacle found in garages, buildings accessory to dwellings, service bays, and comparable locations.



▶ Figure 210-39

(9) Crawl Spaces. GFCI protection is required for all receptacles located in crawl spaces at or below grade level.

Author's Commentary:

According to Article 100, a "*garage*" is a *structure or portion of a structure that is intended to house one or more self-propelled vehicles. Garages can serve many purposes, including use, storage, repair, display, or demonstration.*

— Michael Hamilton

(10) Unfinished Areas of Basements. GFCI protection is required for all receptacles located in unfinished basement spaces.

(11) Laundry Areas. GFCI protection is required for all receptacles located in laundry areas.

(12) Bathtubs and Shower Stalls. GFCI protection is required for all receptacles installed within 6 ft of the outside edge of a bathtub or shower stall when a bathroom as defined in Article 100 does not already have that receptacle protection.

(C) Crawl Space Lighting Outlets. GFCI protection is required for 120V lighting outlets in crawl spaces.

Author's Commentary:

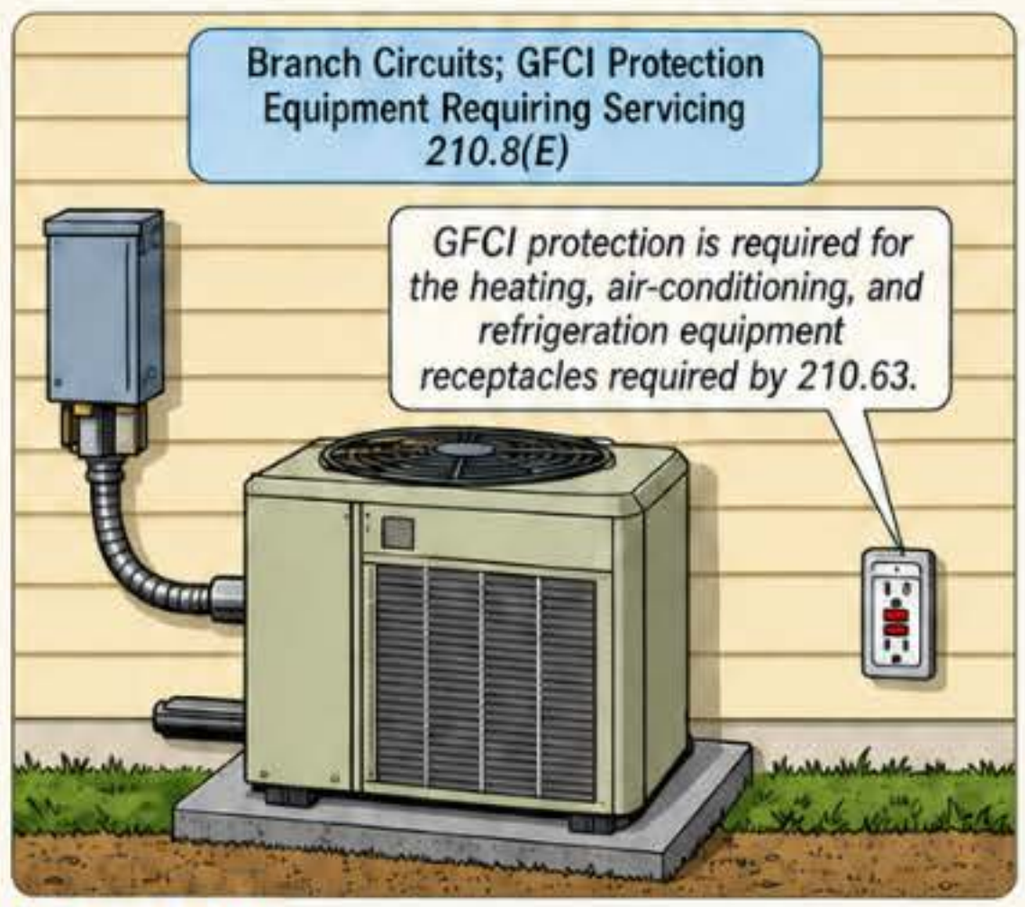
- A lighting outlet isn't required for a dwelling unit crawl space unless that space is used for storage or hosts equipment that needs servicing [210.7(A)(3)].

— Michael Hamilton

(D) Specific Appliances. Unless GFCI protection is provided in accordance with 422.5(B)(3) through (B)(5), outlets supplying appliances listed in 422.5(A) must have GFCI protection in accordance with 422.5(B)(1) or (B)(2).

Where the appliance is a vending machine specified in 422.5(A)(5) and GFCI protection is not provided in accordance with 422.5(B)(3) or (B)(4), the branch circuit supplying the vending machine must have GFCI protection in accordance with 422.5(B)(1) or (B)(2).

(E) Equipment Requiring Servicing. GFCI protection is required for the heating, air-conditioning, and refrigeration equipment receptacles that require servicing [210.63(A)].



▶ Figure 210-40

(F) Outdoor Dwelling Unit Outlets. GFCI protection is required for all outdoor outlets serving dwelling units, except those for snow-melting *equipment covered in* 210.8(A)(3) Ex.

Ex: *GFCI protection is not required on lighting outlets other than those covered in 210.8(C).*

▶ Figure 210-41

210.11 Branch Circuits Required

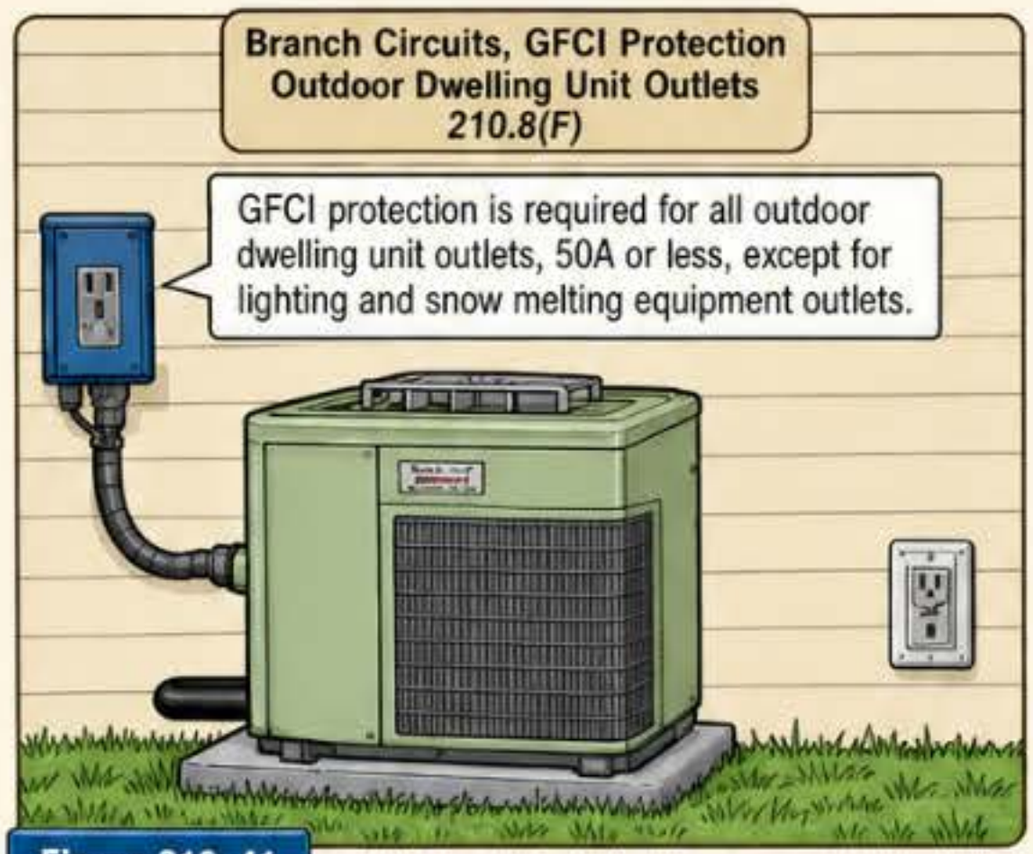


Figure 210–41

Solution:

Step 1: *Determine the total VA load.*

VA = 2,400 sq ft × 3 VA per sq ft (Table 220.12)
VA = 7,200 VA

Step 2: *Determine the amperes.*

I = Volt-Amperes/Volts
I = 7,200VA/120V
I = 60A

Step 3: *Determine the number of circuits.*

Number of 15A Circuits = 60A/15A
Number of 15A Circuits = Four
Number of 20A Circuits = 60A/20A
Number of 20A Circuits = Three

Answer: *(c) Four 15A or three 20A, 120V circuits.*

210.11 Branch Circuits Required

(A) Number of Branch Circuits. The number of branch circuits required is determined by dividing the total calculated load in amperes by the ampere rating of the circuit.

▶ Example

Question: *How many 15A or 20A, 120V circuits are required for the general lighting and general-use receptacles for a dwelling having a floor area of 2,400 ft², exclusive of an unfinished cellar not adaptable for future use (Example D1(a) in Annex D)?* ▶ Figure 210–42

(a) Two 15A or one 20A, 120V circuits.
(b) Three 15A or two 20A, 120V circuits.
(c) Four 15A or three 20A, 120V circuits.
(d) Five 15A or four 20A, 120V circuits.

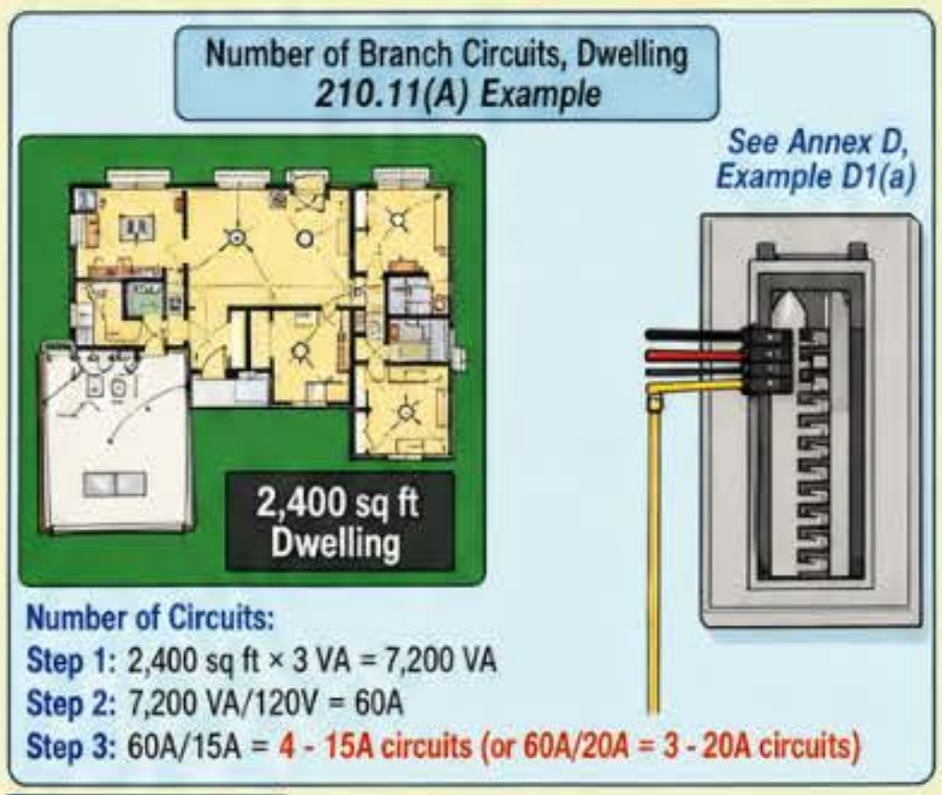
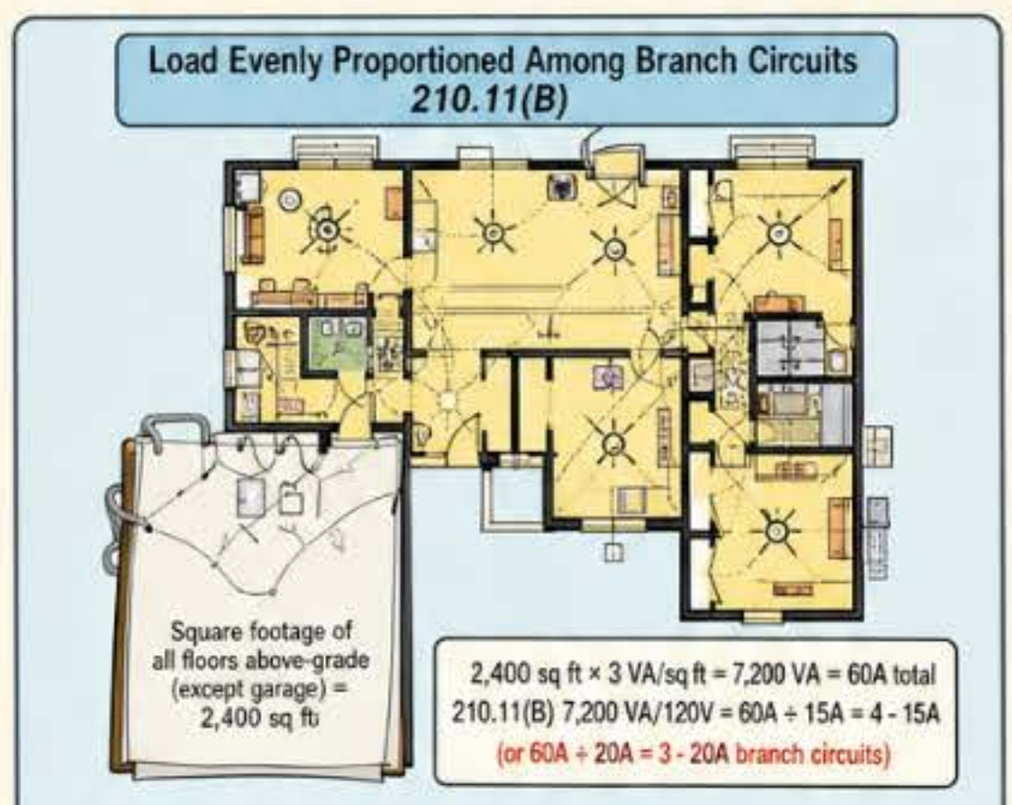


Figure 210–42

(B) Load Evenly Proportioned Among Branch Circuits. If the load is calculated on volt-amperes/square foot, the wiring system must serve the calculated load. The load must be evenly proportioned among the branch circuits within the panelboard. ▶ Figure 210–43



If the load is calculated on the basis of VA per square foot, the wiring system must be provided to serve the calculated load, with the loads evenly apportioned among multioutlet branch circuits within the panelboard.

Figure 210–43

(C) Dwelling Unit

(1) Small-Appliance Circuits. At least two 20A, 120V branch circuits are required to supply receptacle outlets in a dwelling unit kitchen, dining room, breakfast room, pantry, or similar dining area as required by 210.52(B). ▶ *Figure 210–44*

210.11 | Branch Circuits

Small-Appliance Branch Circuits, Dwelling
210.11(C)(1)

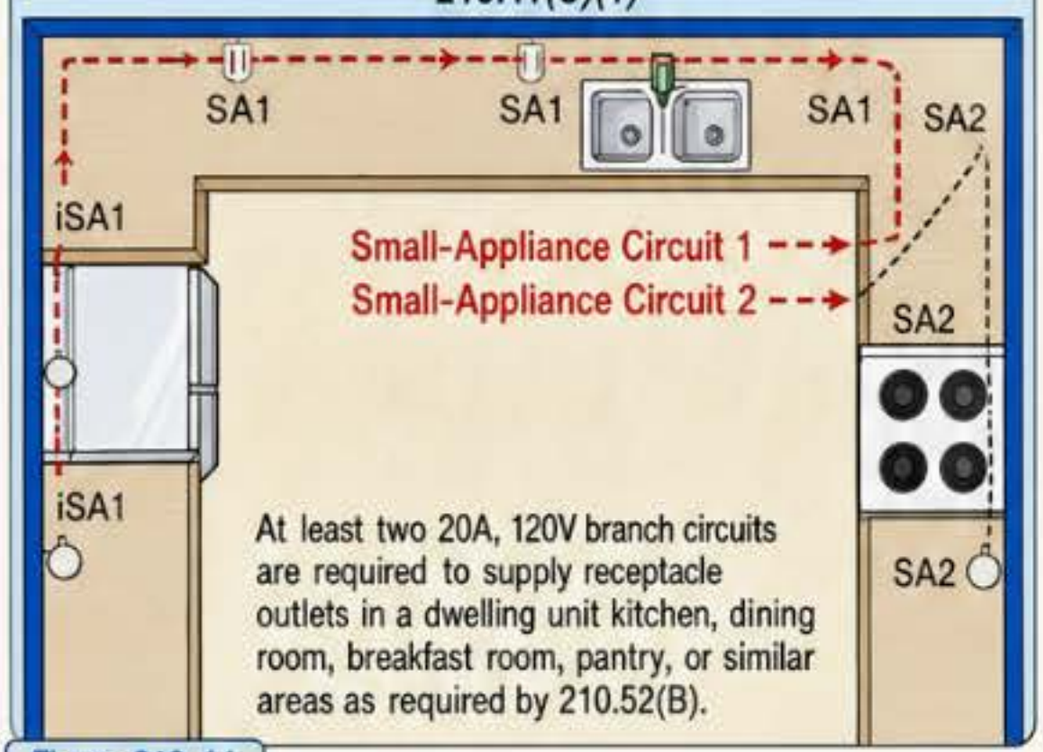


Figure 210-44

> **Author's Commentary:**
> The two 20A small-appliance branch circuits can be supplied by one 3-wire multiwire circuit or by two separate 120V circuits [210.4(A)].
>
> — *Michael Hamilton*

(2) Laundry Area Circuit. At least one 20A, 120V branch circuit is required to supply receptacle outlet(s) in the laundry area as required by 210.52(F). *This circuit is not permitted to supply lighting outlets or receptacle outlets in other rooms.* Figure 210-45

Laundry Area Branch Circuit, Dwelling
210.11(C)(2)

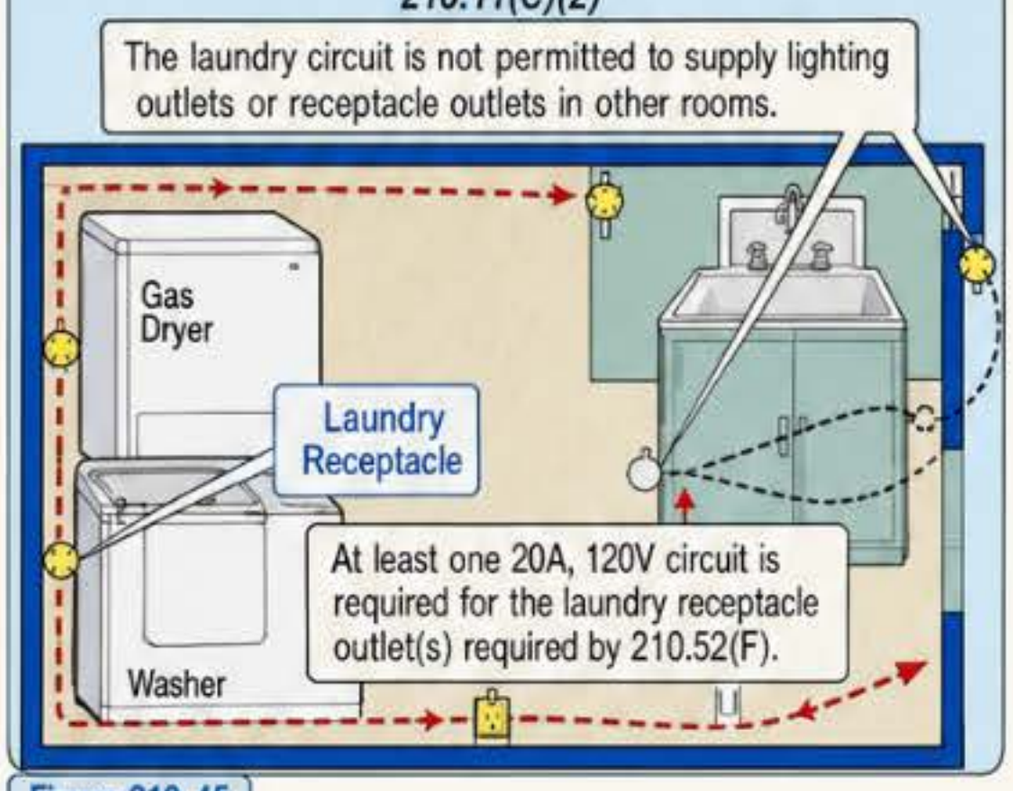


Figure 210-45

> **Author's Commentary:**
> *The laundry receptacle circuit can supply more than one receptacle outlet in the laundry area.*
>
> — *Michael Hamilton*

- The laundry receptacle circuit is required even if the laundry appliance is a 30A, 240V combination washer/dryer. Figure 210-46

Laundry Area Branch Circuit, Dwelling
210.11(C)(2) Comment

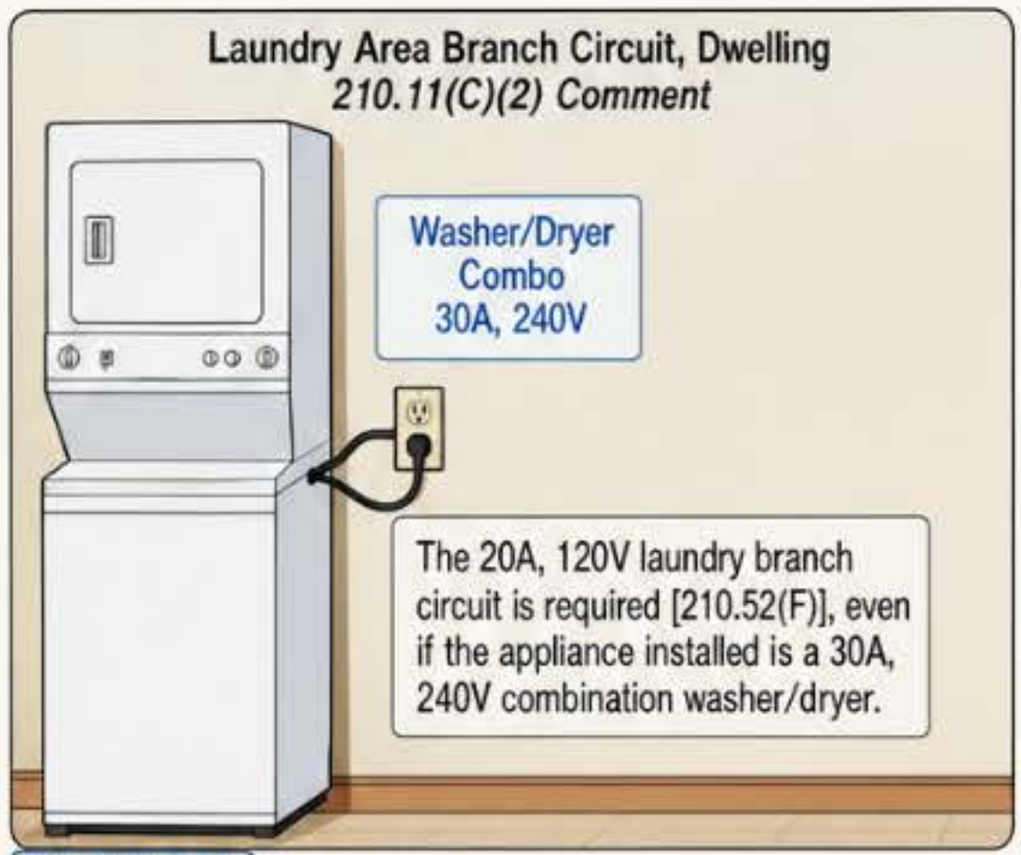


Figure 210-46

(3) Bathroom Area Circuit. At least one 20A, 120V branch circuit is required to supply the receptacle outlet(s) in the bathroom(s) as required by 210.52(D), and any countertop and similar work surface *receptacle outlets. This circuit is not permitted to supply lighting outlets or receptacle outlets in other rooms.* Figure 210-47

Bathroom Area Branch Circuit, Dwelling
210.11(C)(3)

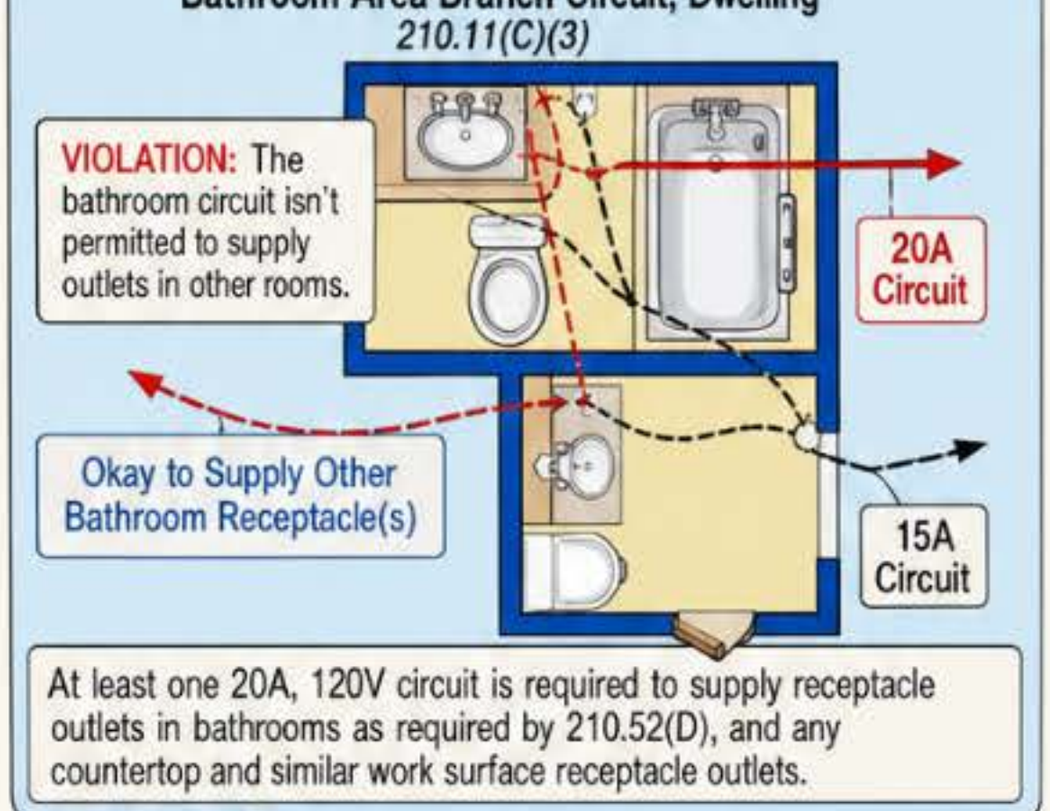


Figure 210-47

Ex: *A single 20A, 120V branch circuit can supply all the outlets in a single bathroom area.* Figure 210-48

BRANCH CIRCUITS | 210.12

Bathroom Area Branch Circuit, Dwelling
210.11(C)(3) Ex

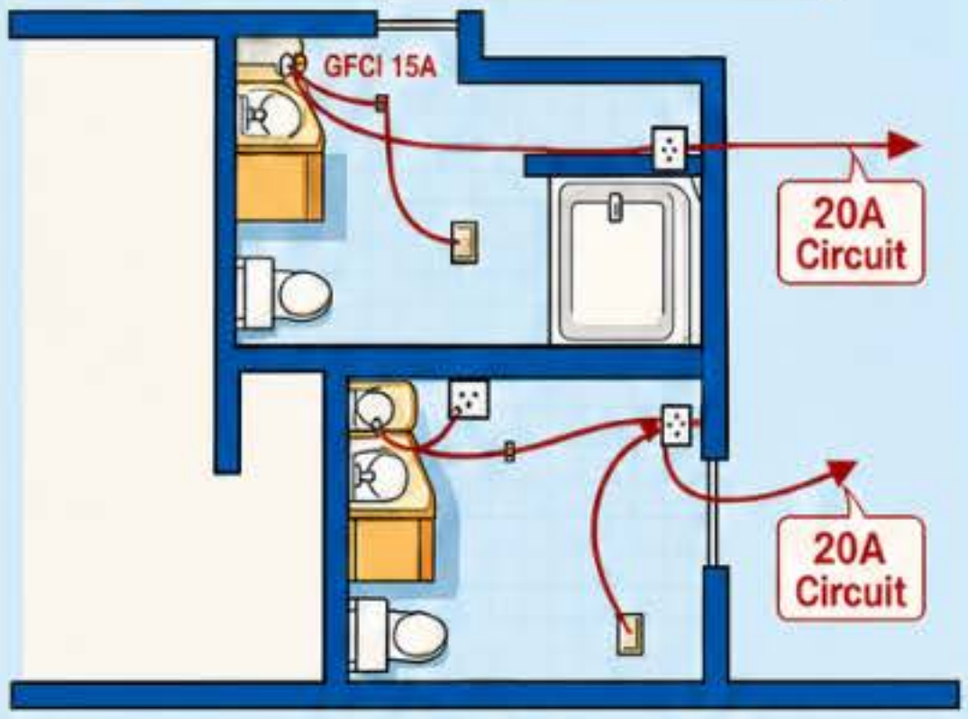
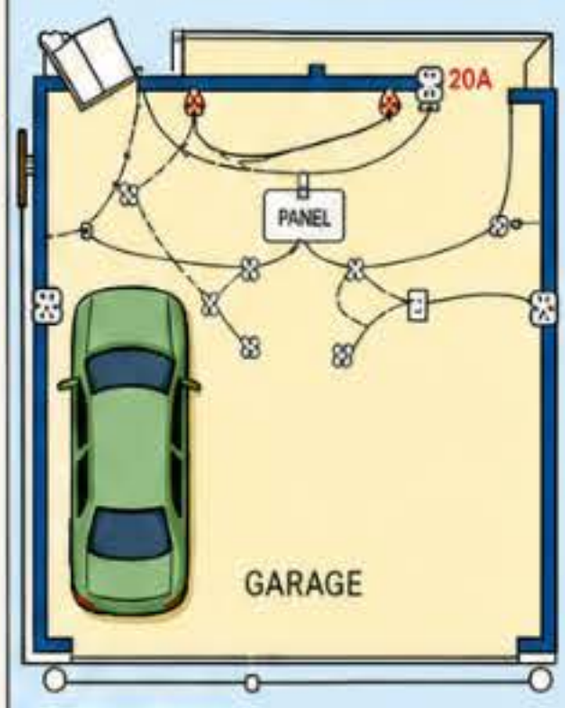


Figure 210–48 A single 20A, 120V branch circuit can supply all outlets in a single bathroom.

Garage Branch Circuit, Dwelling
Outdoor Receptacle
210.11(C)(4) Ex

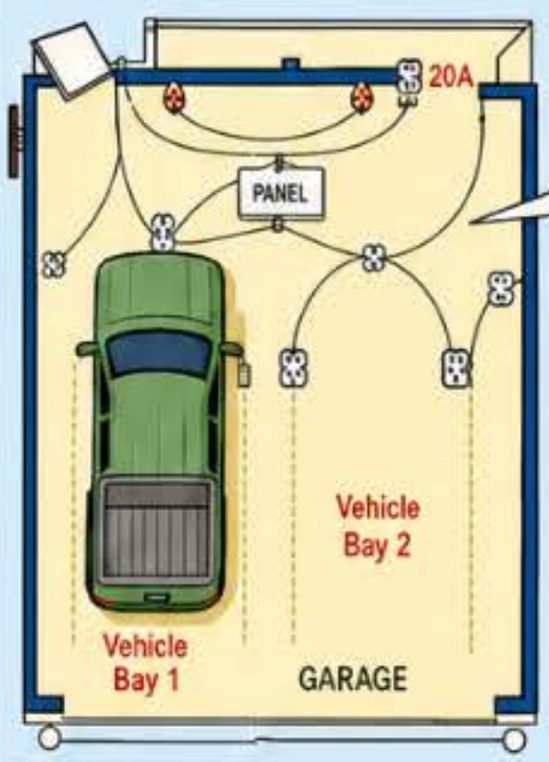


Outdoor receptacle outlets can be supplied by the 20A, 120V garage receptacle circuit.

Figure 210–50

(4) Garage Circuits. In garages with electric power, at least one 20A, 120V branch circuit must be installed to supply the receptacle outlet(s) required by 210.52(G)(1). Figure 210–49

Garage Branch Circuit, Dwelling
210.11(C)(4)



In garages with electric power, at least one 20A, 120V branch circuit must be installed to supply receptacle outlet(s) required by 210.52(G)(1).

Figure 210–49

The required 20A, 120V garage receptacle branch circuit is not permitted to supply lighting outlets or receptacle outlets in other area.

Ex: Outdoor receptacle outlets are permitted to be supplied by the 20A, 120V garage receptacle circuit. Figure 210–50

210.12 Arc-Fault Circuit-Interrupter Protection

Arc-fault circuit-interrupter protection, located in a readily accessible location, must be provided in accordance with 210.12(A), (B), (C), and (D).

(A) Dwelling Units. AFCI protection is required for all 15A or 20A, 120V branch circuits supplying outlets in dwelling unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas. Figure 210–51

Branch Circuits, AFCI Protection, Dwellings
210.12(A)

15A and 20A, 120V branch circuits supplying outlets or devices in the following locations require AFCI protection:

- Bedrooms
- Closets
- Dens
- Dining Rooms
- Family Rooms
- Hallways
- Kitchens
- Laundry Areas
- Libraries
- Living Rooms
- Parlors
- Rec Rooms
- Sunrooms
- Similar Areas

Figure 210–51

210.18 | Branch Circuits

Author's Commentary:

- *AFCI protection is not necessary for receptacles installed in bathrooms, garages, or outdoors.*

— Michael Hamilton

(B) Dormitory Units. AFCI protection must be provided for all 15A or 20A, 120V branch circuits that supply outlets in *dormitory unit bedrooms, living rooms, hallways, closets, bathrooms, or analogous spaces.* Figure 210–52

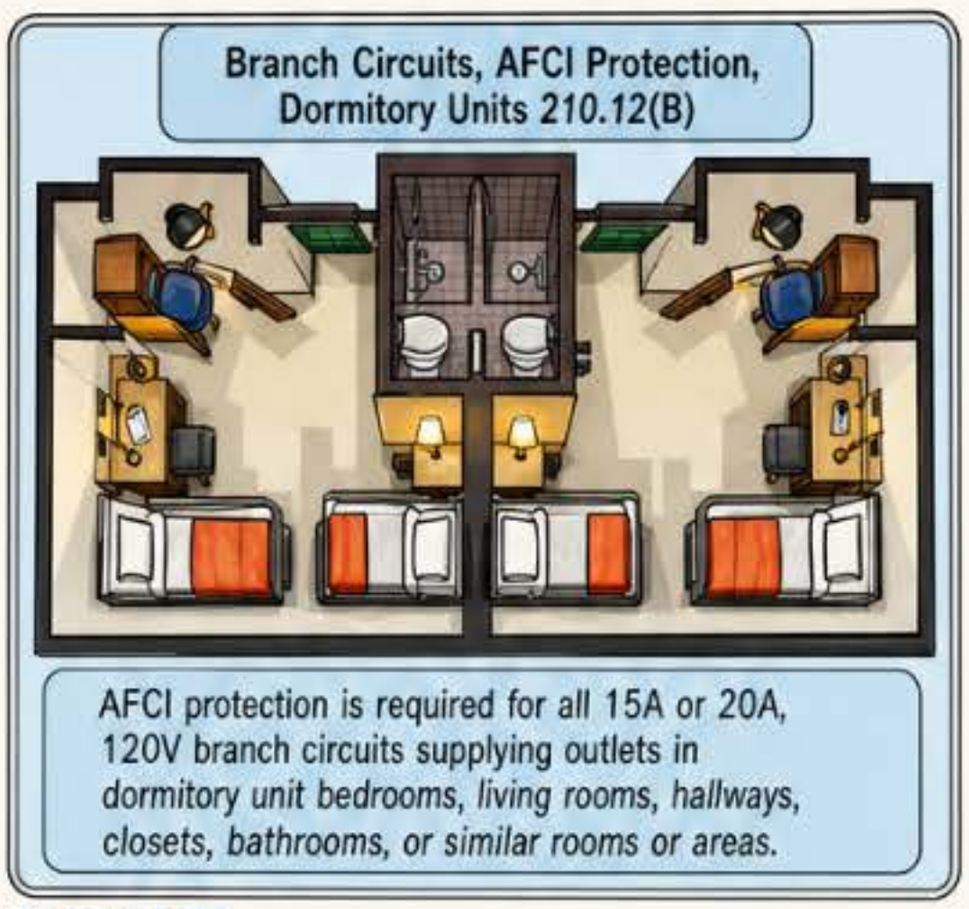


Figure 210–52

(C) Guest Rooms and Guest Suites. AFCI protection is *required for all 15A and 20A, 120V branch circuits supplying outlets in guest rooms and guest suites of hotels and motels.* Figure 210–53

Figure 210–53

(D) Branch Circuit Extensions or Modifications—Dwelling Units, Dormitory Units, Guest Rooms, and Guest Suites. Where 15A or 20A, 120V branch-circuit wiring is modified, replaced, or extended in any of the areas specified in 210.12(A), (B), or (C), the wiring must be AFCI protected.

Ex: AFCI protection is not required for extension wiring that is less than 6 ft in length (raceway or cable) if no outlets or devices, other than splicing devices, are added. This measurement does not include the conductors inside an enclosure, cabinet, or junction box.

Part II. Branch-Circuit Ratings

210.18 Branch-Circuit Rating

The rating of a branch circuit is determined by the rating of the branch-circuit overcurrent protective device, *not by the ampacity rating of the conductor.* Figure 210–54

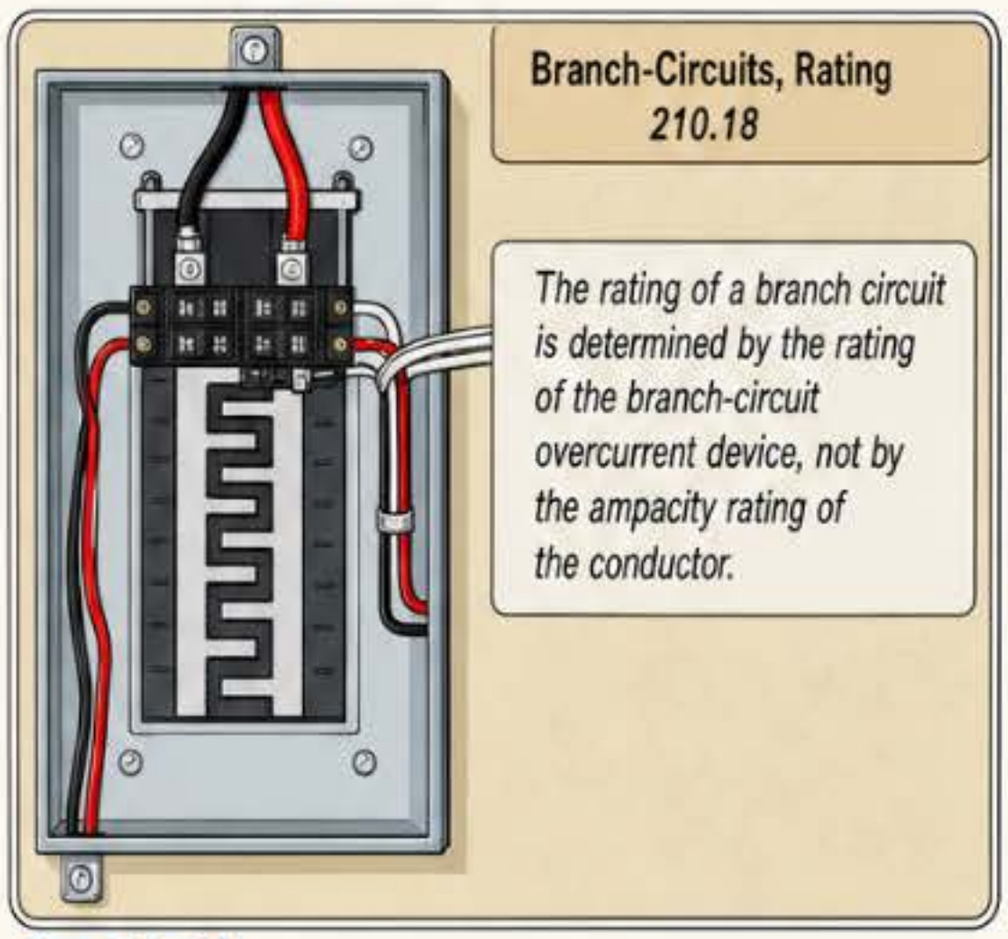


Figure 210–54

Author's Commentary:

- *A 10 THHN rated 30A at 60°C, when protected by a 20A circuit breaker, is considered a 20A rated circuit.*

— Michael Hamilton

BRANCH CIRCUITS | 210.19

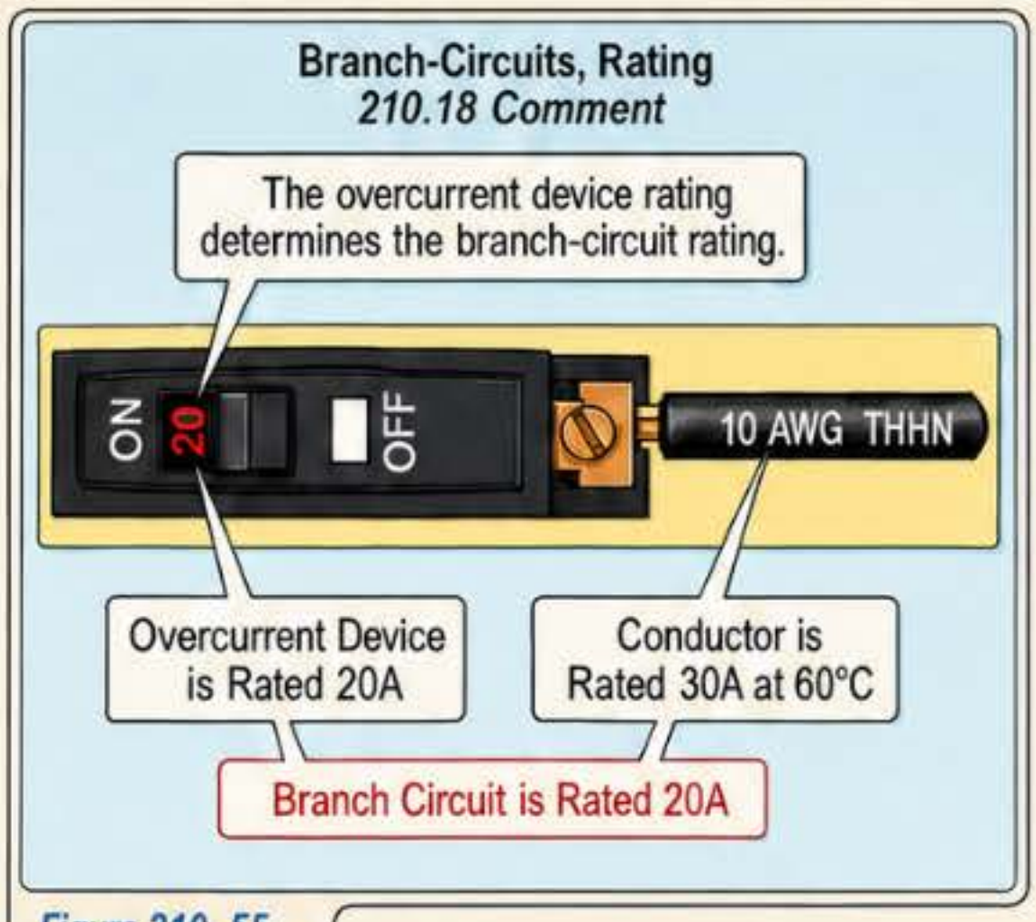


Figure 210–55

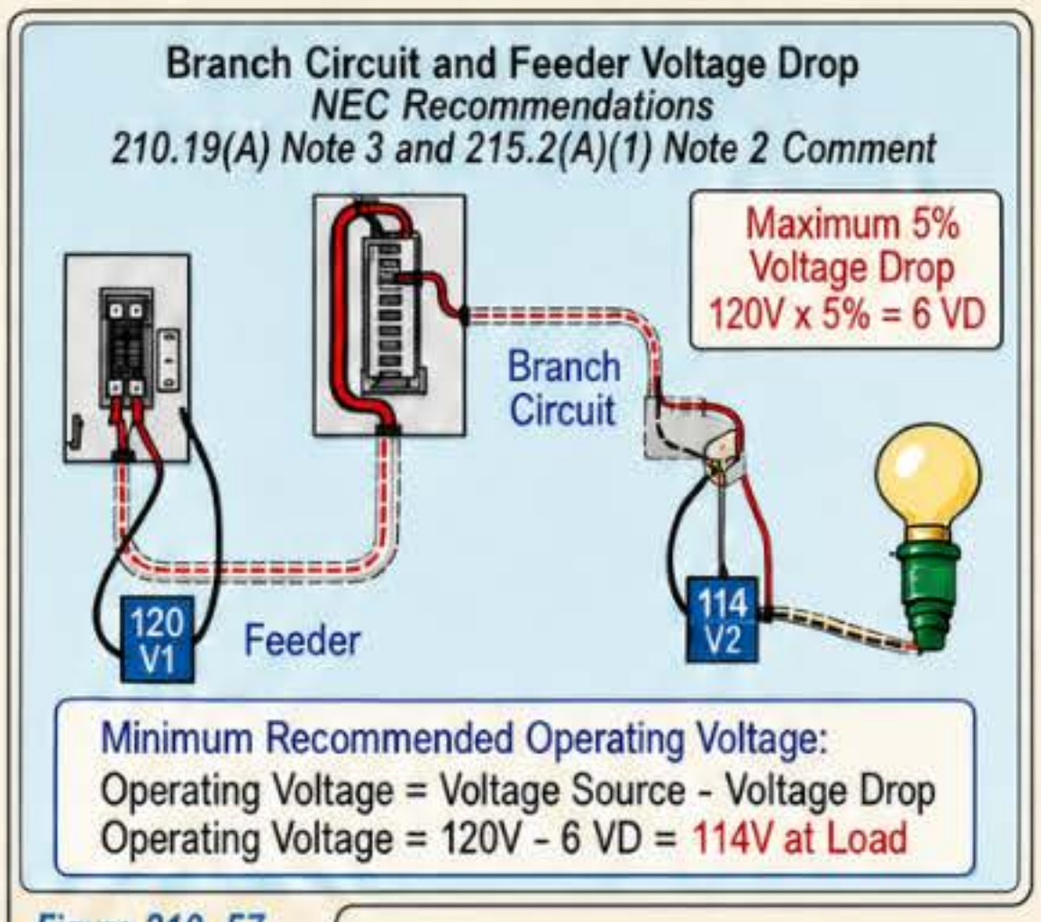


Figure 210–57

210.19 Conductor Sizing

(A) Branch Circuits

Note 3: To promote reliable operation of electrical equipment, branch-circuit conductors should be sized to prevent a voltage drop that exceeds 3 percent. In addition, the total voltage drop on both feeders and branch circuits must not be greater than 5 percent [215.2(A)(1)]. *Figure 210–56* and *Figure 210–57*

Author's Commentary:

- *Size conductors to keep voltage drop percentages within the limits recommended by NEC Information Note. This is not a code requirement since the Informational Notes are advisory only and not enforceable [90.5(C)].*
- *See 695.7 for requirements related to voltage drop on pump installations.*

— Michael Hamilton

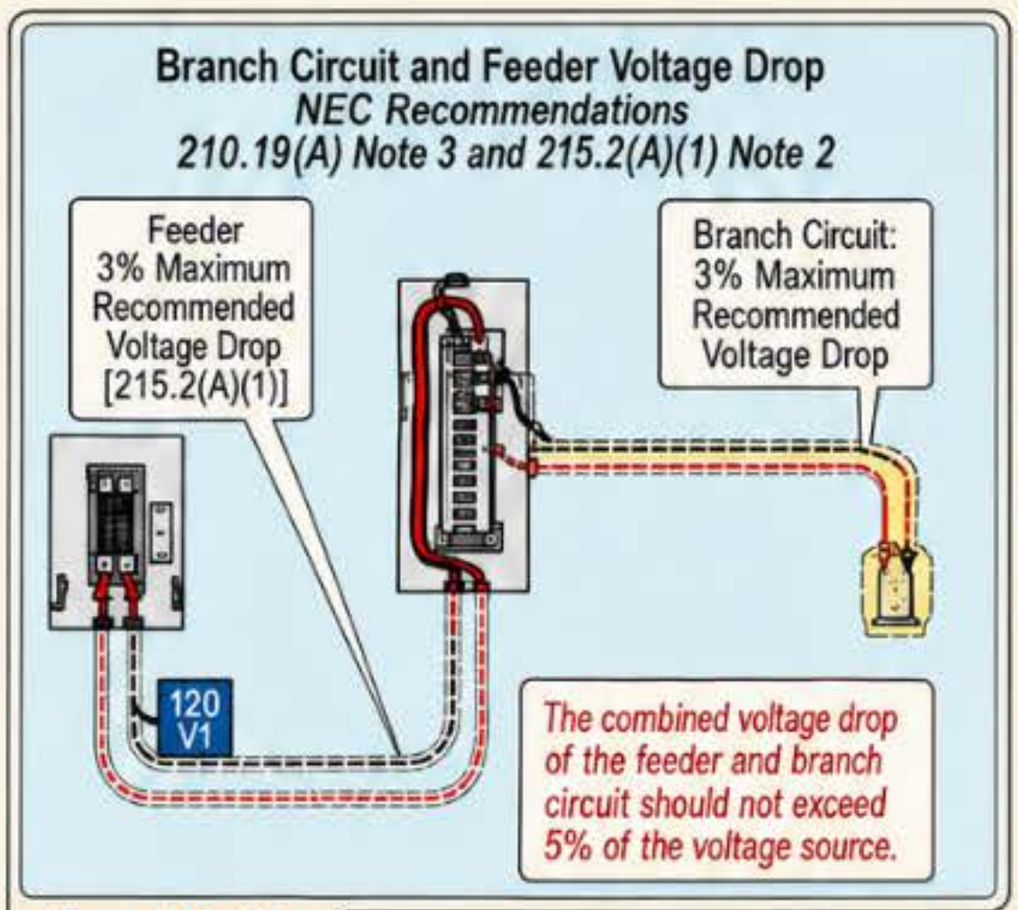


Figure 210–56

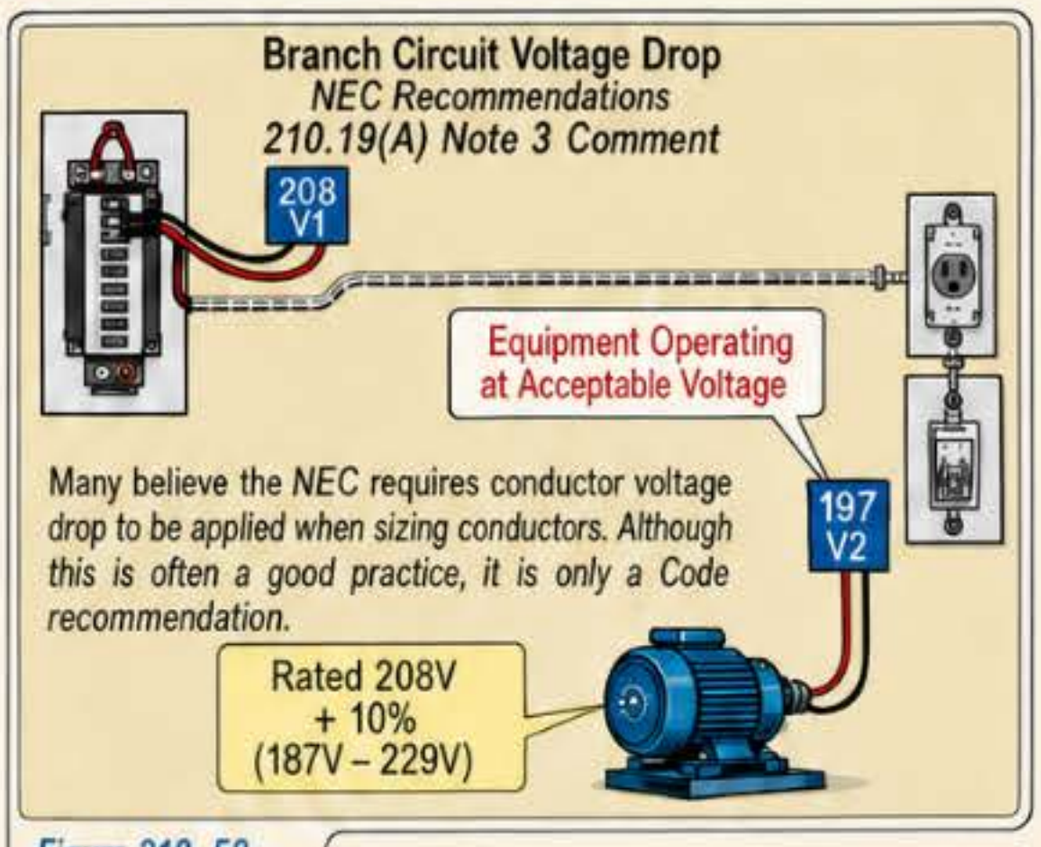
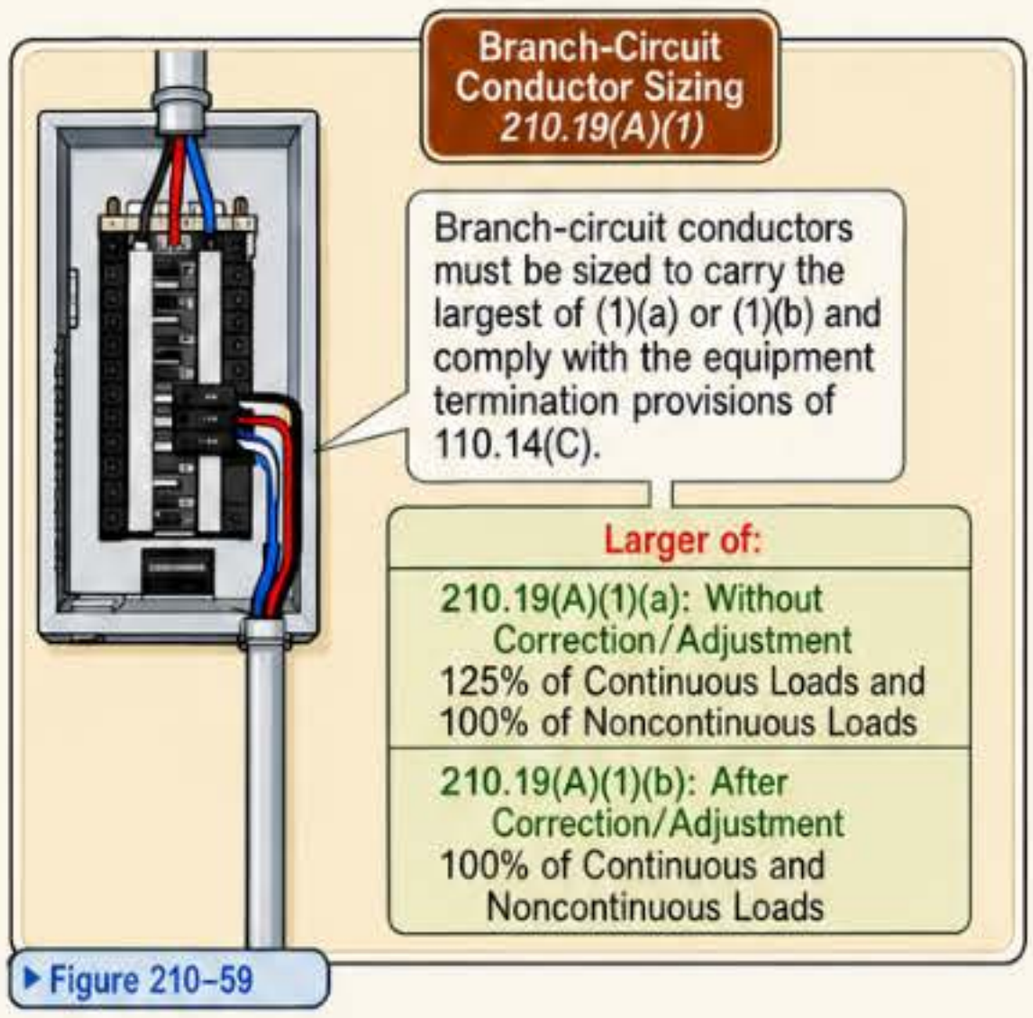


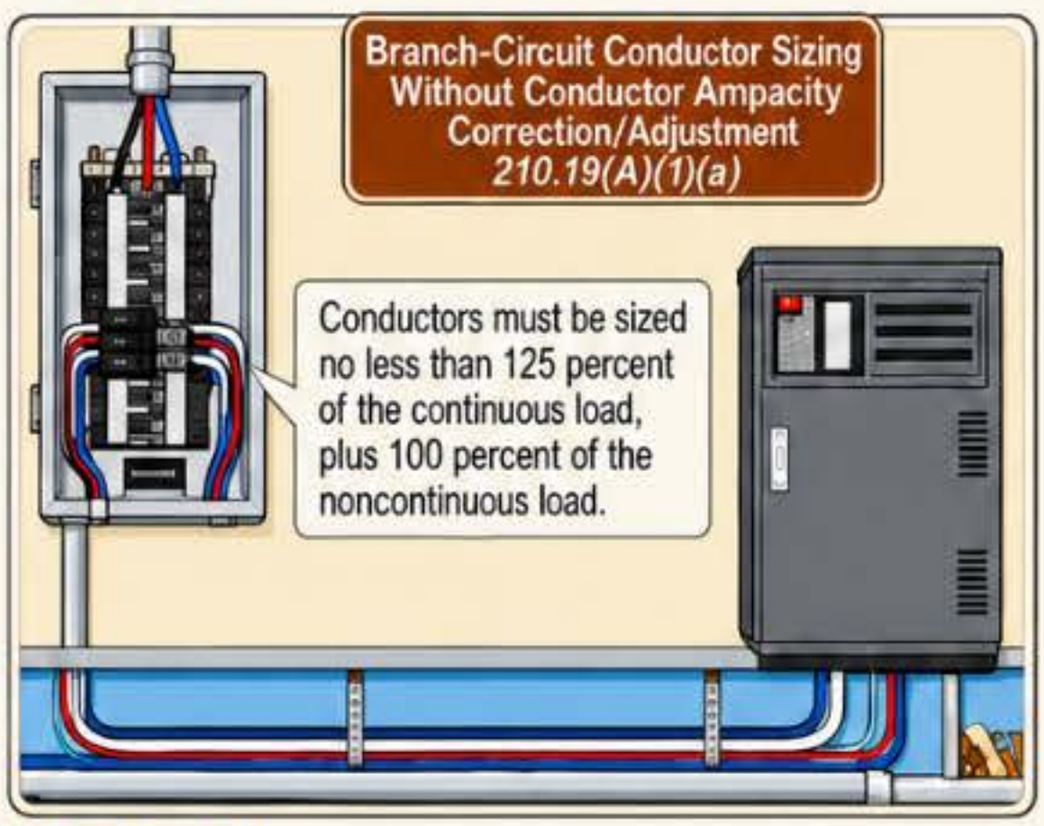
Figure 210–58

(1) General. Branch-circuit conductors mmust be sized to carry at least the largest of the calculations contained in (a) or (b) and comply with the equipment termination provisions of 110.14(C). *Figure 210–59*



▶ Figure 210–59

(a) Without Conductor Ampacity Adjustment and/or Correction. Branch-circuit conductors must have an ampacity of not less than 125 percent of the continuous loads, plus 100 percent of the noncontinuous loads in accordance with 310.14; based on the terminal temperature rating ampacities in Table 310.16 [110.14(C)(1)]. ▶ Figure 210–60



▶ Figure 210–60

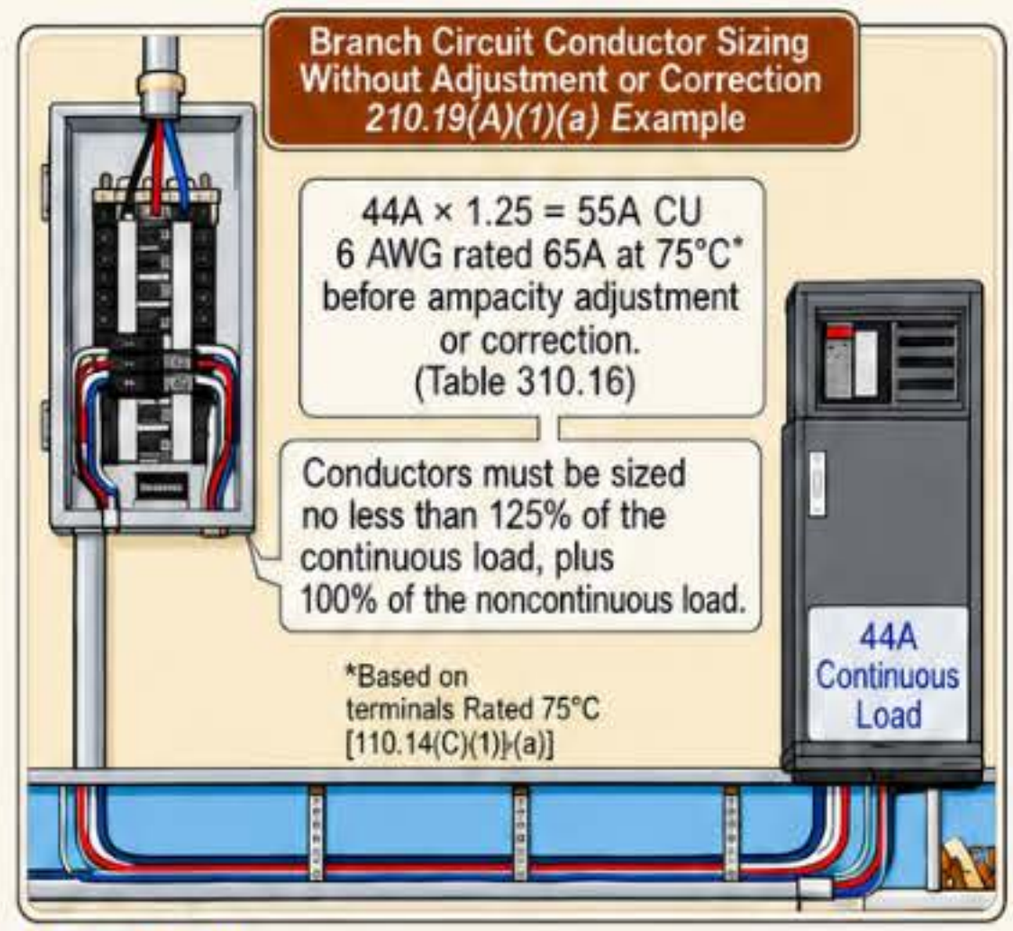
▶ Example 1

Question: *What size conductors rated 90°C are required for a circuit supplying a 44A continuous load where the equipment terminals are rated 75°C?* ▶ Figure 210–61

(a) 8 AWG (b) 6 AWG (c) 4 AWG (d) 3 AWG

Solution:

Step 1. *Conductor Ampacity. The conductor must have an ampacity of at least 55A (44A × 125%).*



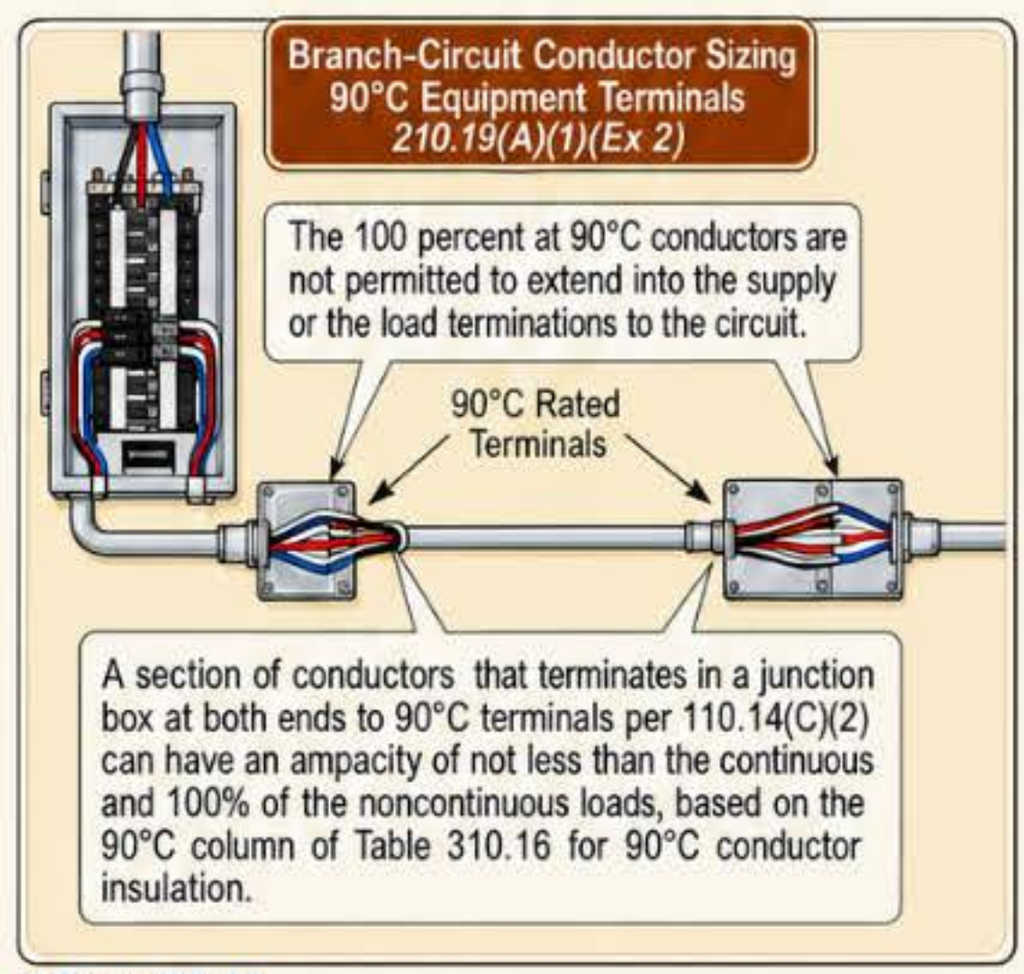
▶ Figure 210–61

Step 2: *Size conductors in accordance with 110.14(C)(1)(a)(3) and Table 310.16.*

6 AWG is rated 65A and is suitable to be used (Table 310.16, 75°C column).

Answer: *(b) 6 AWG*

Ex 2: *A section of conductors that terminates in a junction box at both ends to 90°C terminals in accordance with 110.14(C)(2) can have an ampacity of not less than 100 percent of the continuous and 100 percent of the noncontinuous loads based on the 90°C column of Table 310.16 for 90°C conductor insulation. The 100 percent at 90°C conductors are not permitted to extend into the supply or the load terminations to the circuit.* ▶ Figure 210–62



▶ Figure 210–62

BRANCH CIRCUITS 210.19

▶ Example

Question: *What size conductors rated 90°C are required between terminals rated 90°C for a circuit supplying a 44A continuous load?*

(a) 10 AWG (b) 8 AWG (c) 6 AWG (d) 4 AWG

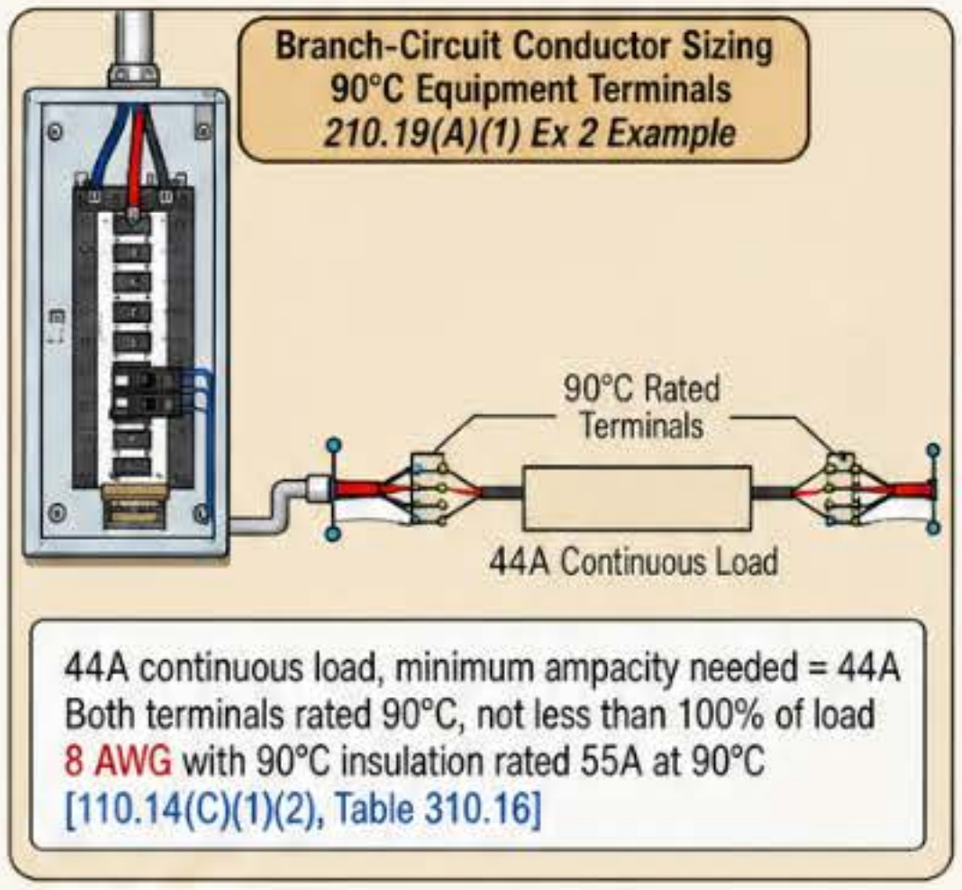


Figure 210-53

Solution:

Step 1: *Conductor Ampacity. The conductor between the power distribution blocks must have an ampacity of at least 44A.*

Step 2: *Size conductors in accordance with 110.14(C)(2) and Table 310.16.*

When terminals at each end of a conductor have different terminal temperature ratings, use the lower temperature rating when sizing conductors from Table 310.16. In this case the terminals are both rated 90°C, so the conductors are selected in accordance with the 90°C column of Table 310.16. Based on the 44A load at 100 percent, 8 AWG is rated 55A and is suitable to be used between the two 90°C rated terminals.

Answer: *(b) 8 AWG*

(b) After Conductor Ampacity Adjustment and Correction. Branch-circuit conductors must be sized to carry not less than 100 percent of the continuous load, plus 100 percent of the noncontinuous load after conductor ampacity adjustment and/or correction in accordance with Table 310.15(B)(1) and Table 310.15(C)(1). Figure 210-64

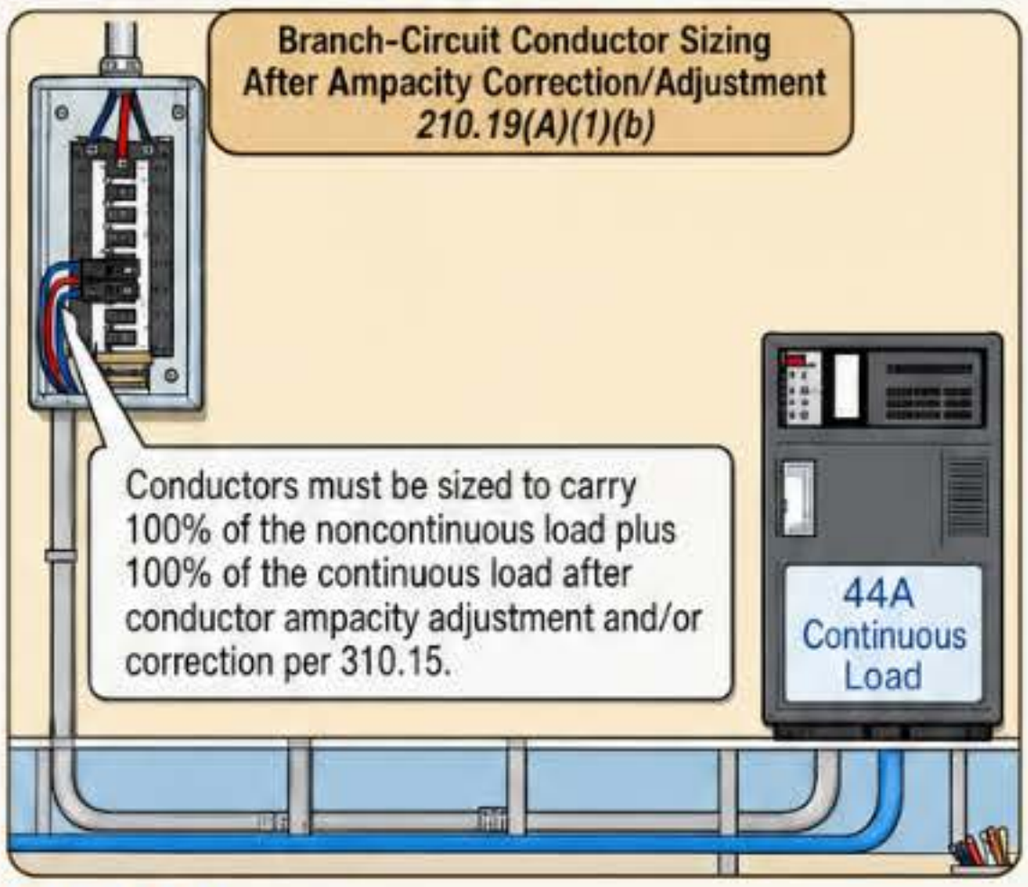


Figure 210-64

▶ Example

Question: *What size conductors rated 90°C are required for a circuit containing four current-carrying conductors supplying a 44A continuous load in an ambient temperature of 100°F where the equipment terminals are rated 75°C?* Figure 210-65

(a) 10 AWG (b) 8 AWG (c) 6 AWG (d) 4 AWG

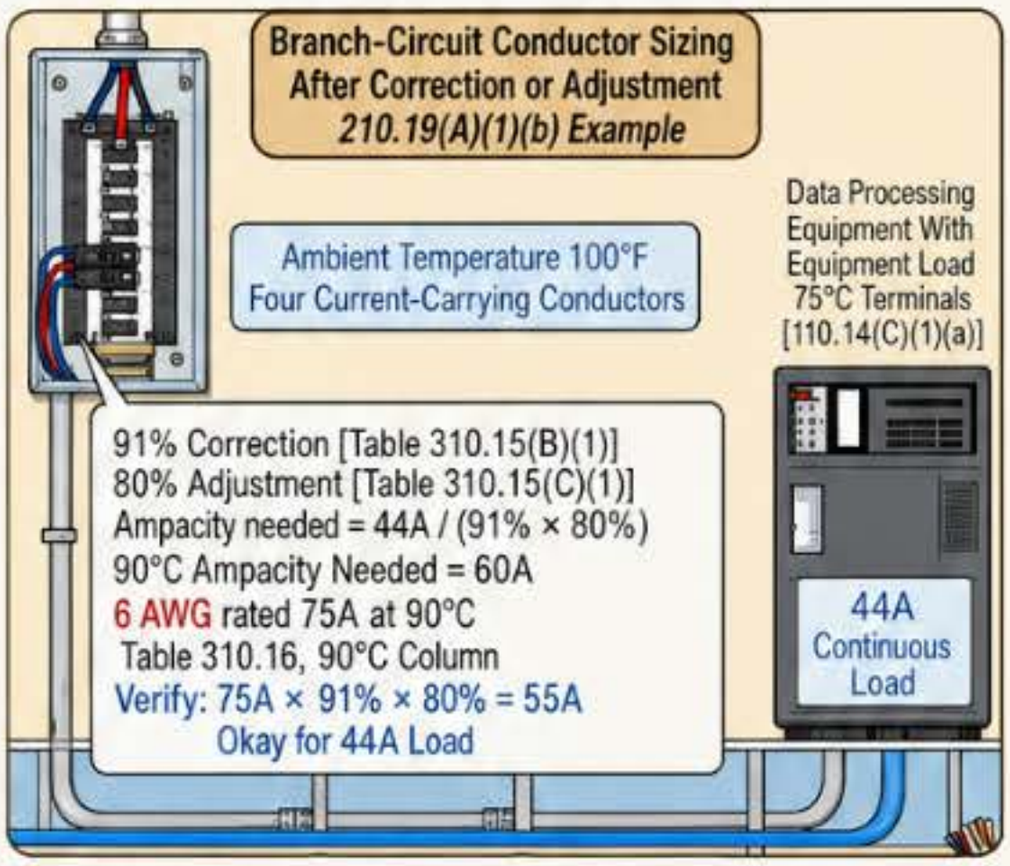


Figure 210-65

Solution:

Step 1: *The circuit conductors must have an ampacity of not less than 44A after conductor ampacity temperature correction [Table 310.15(B)(1)] and adjustment [Table 310.15(C)(1)], based on the conductor insulation rating of 90°C [110.14(C)(1)(a)]. One way to find the conductor size is to determine the conductor ampacity required to supply a 44A load at 100% after correction and adjustment.*

Conductor Ampacity at 90°C = Actual Load/ (Correction × Adjustment)

Actual Load = 44A

Correction [Table 310.15(B)(1)] = 91% (100°F with 90°C Conductor)

Adjustment [Table 310.15(C)(1)] = 80% (four current-carrying conductors)

Conductor Ampacity at 90°C Column = 44A/(91% × 80%)
Conductor Ampacity at 90°C Column = 44A/73%
Conductor Ampacity at 90°C Column = 60A

Step 2: *Select the conductors from the 90°C column of Table 310.16.*

6 AWG is suitable because it has an ampacity of 75A at 90°C before any correction and adjustment. In addition, 6 AWG is the minimum conductor size allowed according to 210.19(A)(1)(a).

Step 3: *Verify that the ampacity of 6 AWG after correction and adjustment is capable of carrying 100 percent of the 44A continuous load at 90°C.*

Conductor Ampacity after Correction and Adjustment = Conductor Ampacity × Correction × Adjustment

*Conductor Ampacity at 90°C = 75A**
*(*Note: 75A is from Step 2.)*
Correction = 91%
Adjustment = 80%
Conductor Ampacity after Correction and Adjustment = 75A × 91% × 80%
Conductor Ampacity after Correction and Adjustment = 55A

6 AWG has an ampere rating of 55A which is more than enough for the 44A continuous load.

Step 4: *Verify that the ampacity of 6 AWG at 75°C without correction and adjustment is capable of carrying 125 percent of the 44A continuous load in accordance with 210.19(A)(1)(a).*

Conductor Ampacity at 125% = 44A × 125%
Conductor Ampacity at 125% = 55A
According to Table 310.16, 6 AWG is suitable because it is rated 65A at 75°C. ▶ *Figure 210–66*

Author's Commentary:

Branch-circuit conductors cannot be sized less than determined using 210.19(A)(1)(a). In this scenario, based on the conditions specified in this example, 6 AWG is the minimum permitted size.

— Michael Hamilton

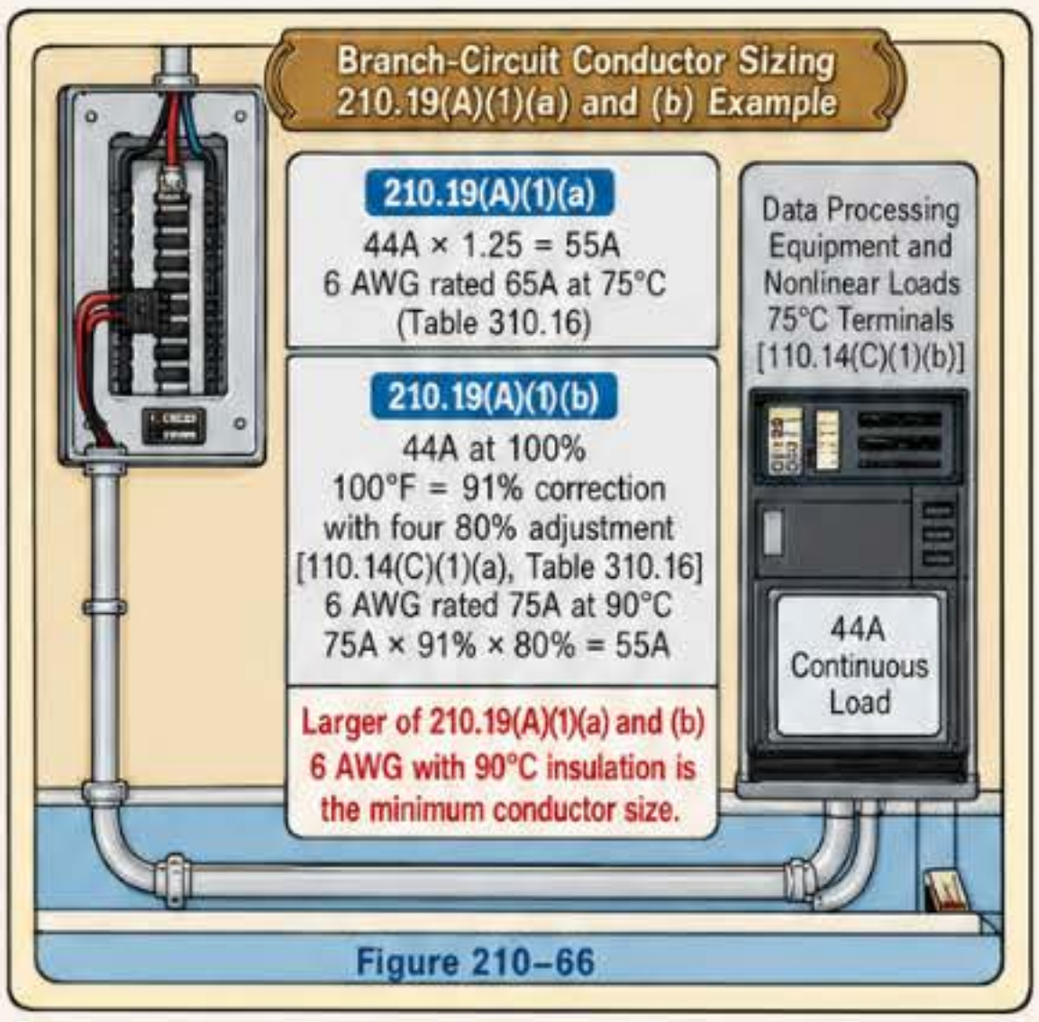


Figure 210–66

The conductor cannot be sized less than the load at 100 percent based on the 75°C terminals specified in the question (50°C when not specified [110.14(C)]). In this case, the minimum conductor size for 44A circuit conduction using the 75°C column of Table 310.16 is 8 AWG; but, since 210.19(A)(1)(a) only permits a minimum of 6 AWG, the 8 AWG cannot be used.

Answer: *(c) 6 AWG*

210.20 Overcurrent Protection

Branch-circuit conductors and equipment must be protected by overcurrent protective devices with a rating or setting that complies with 210.20(A) through (D).

(A) Continuous and Noncontinuous Loads. Branch-circuit overcurrent devices must have a rating of not less than 125 percent of the continuous loads, plus 100 percent of the noncontinuous loads. ▶ *Figure 210–67*

210.21 RECEPTACLE RATING

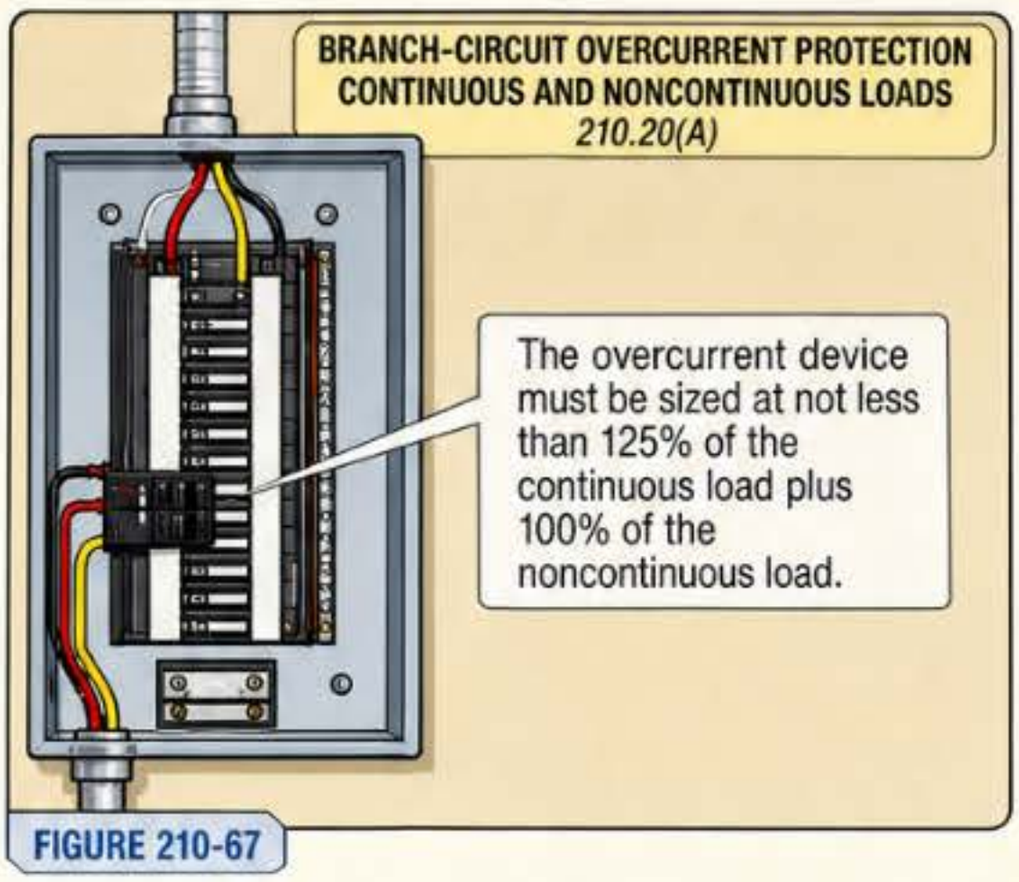


FIGURE 210-67

▶ EXAMPLE

Question: *What size circuit breaker is required for a branch circuit that has a 44A continuous load?* **Figure 210-68**

(a) 20A *(b) 30A* *(c) 50A* *(d) 60A*

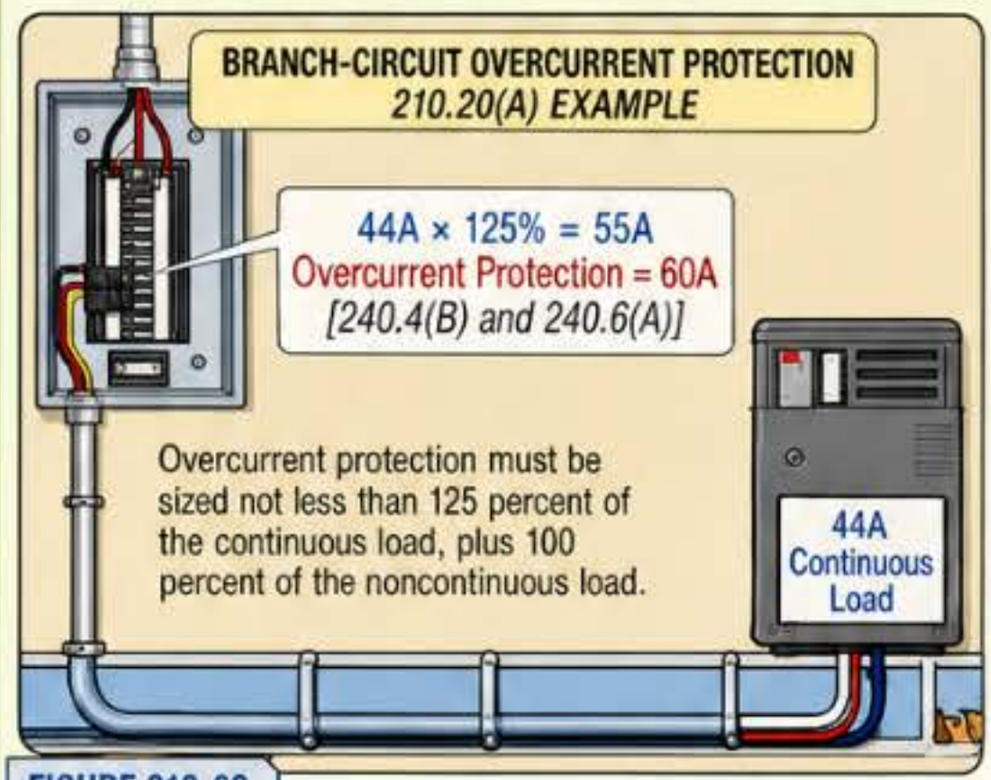


FIGURE 210-68

Solution:

Protection Rating = 44A × 125%

Protection Rating = 55A; the next size up is permitted [240.4(B)]: 60A per 240.6(A).

Answer: *(d) 60A*

210.21 RECEPTACLE RATING

(B) Receptacles—Rating and Load Capacity

(1) Single Receptacle. A single receptacle must have an ampere rating of not less than the rating of the circuit overcurrent protective device. **Figure 210-69**

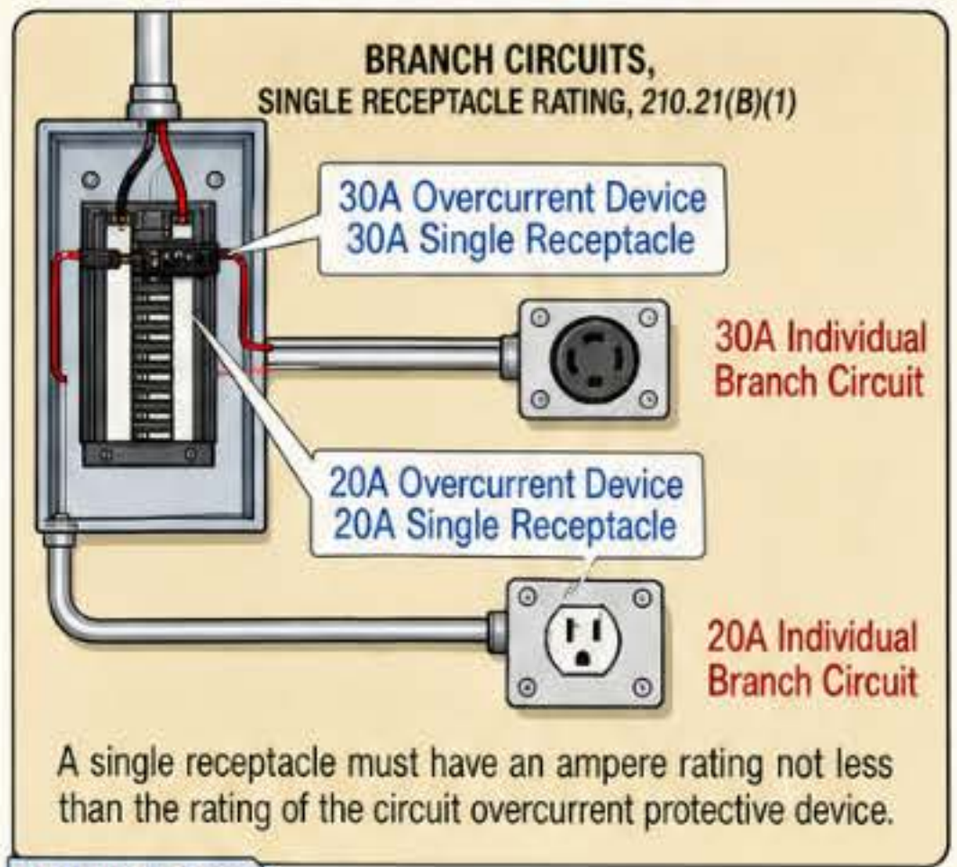


FIGURE 210-69

Note: A single receptacle has only one contact device on its yoke [Article 100]; a duplex receptacle is not a single receptacle since it has two receptacles on the yoke.

(3) Multiple Receptacles. Where multiple receptacles are connected to a branch circuit, their ampere ratings must be in accordance with Table 210.21(B)(3).

AUTHOR'S COMMENTARY:

▶ *Table 210.21(B)(3) allows both 15A and 20A receptacles on a 20A multioutlet circuit.*

— Michael Hamilton

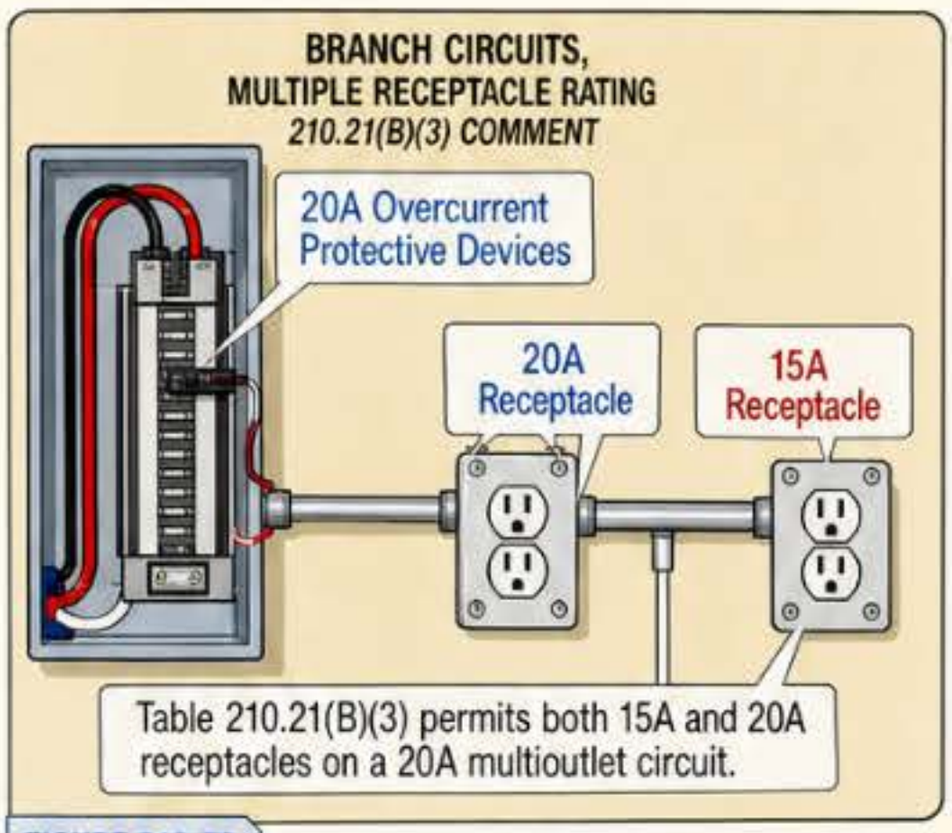
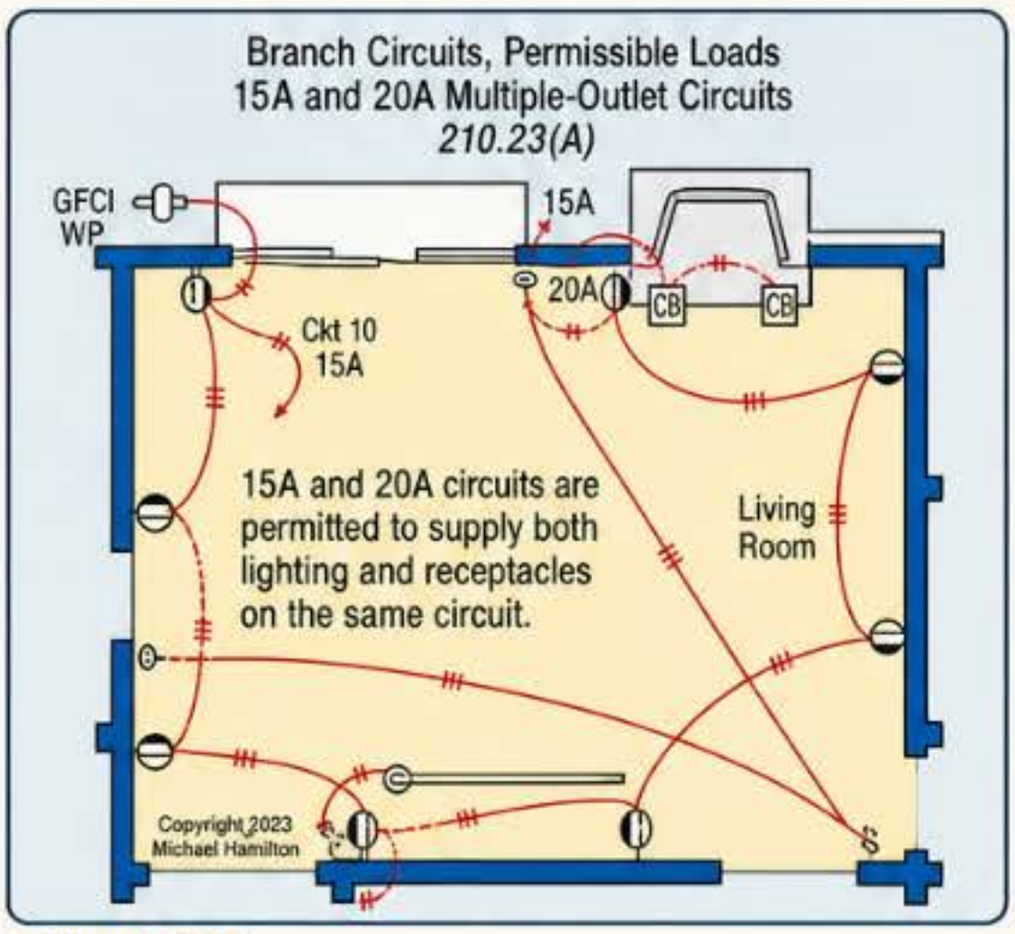


FIGURE 210-70

Table 210.21(B)(3) Receptacle Ratings	
Circuit Rating	**Receptacle Rating**
15A	15A
20A	15A or 20A
30A	30A
40A	40A or 50A
50A	50A

210.23 Permissible Loads, Multiple-Outlet Branch Circuits

(A) 15A and 20A Branch Circuits. A 15A or 20A branch circuit can supply lighting, equipment, or any combination of both. ▶ Figure 210–71



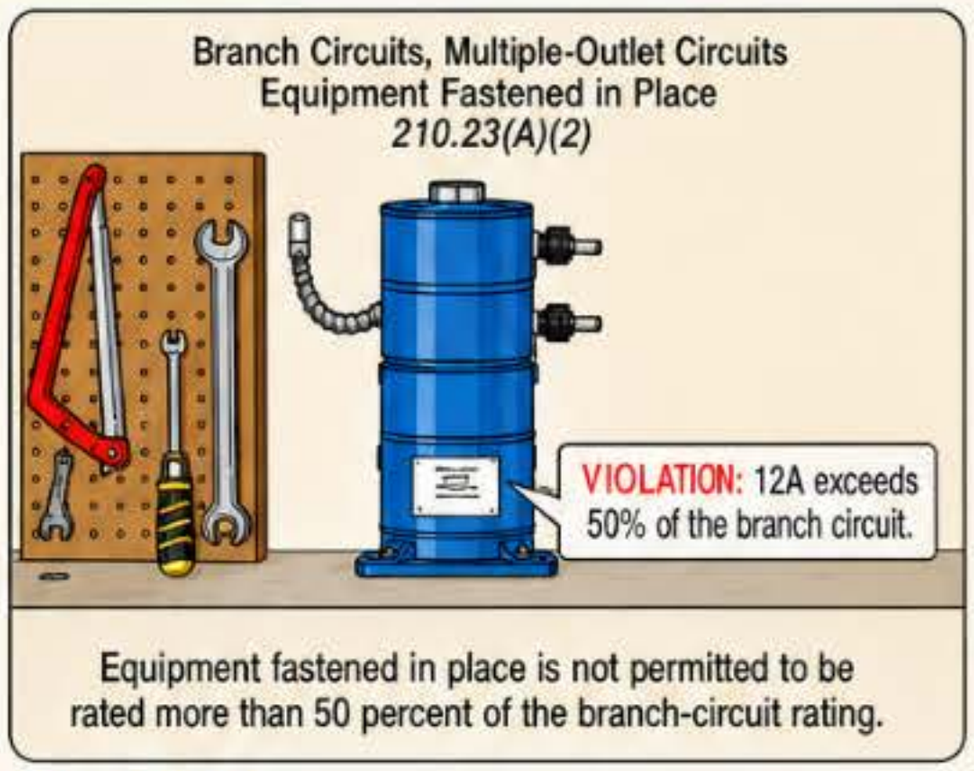
▶ Figure 210–71

(1) Cord-and-Plug Equipment. Cord-and-plug-connected equipment is not permitted to be rated more than 80 percent of the branch-circuit ampere rating.

(2) Equipment Fastened in Place. Equipment fastened in place is not permitted to be rated more than 50 percent of the branch-circuit rating that supplies more than one outlet. ▶ Figure 210–72

Author's Commentary: *When a circuit feeds more than one outlet, any permanently installed equipment must be limited to half the circuit's capacity. For portable or cord-connected loads, stay within eight-tenths of the circuit rating.*

— Michael Hamilton

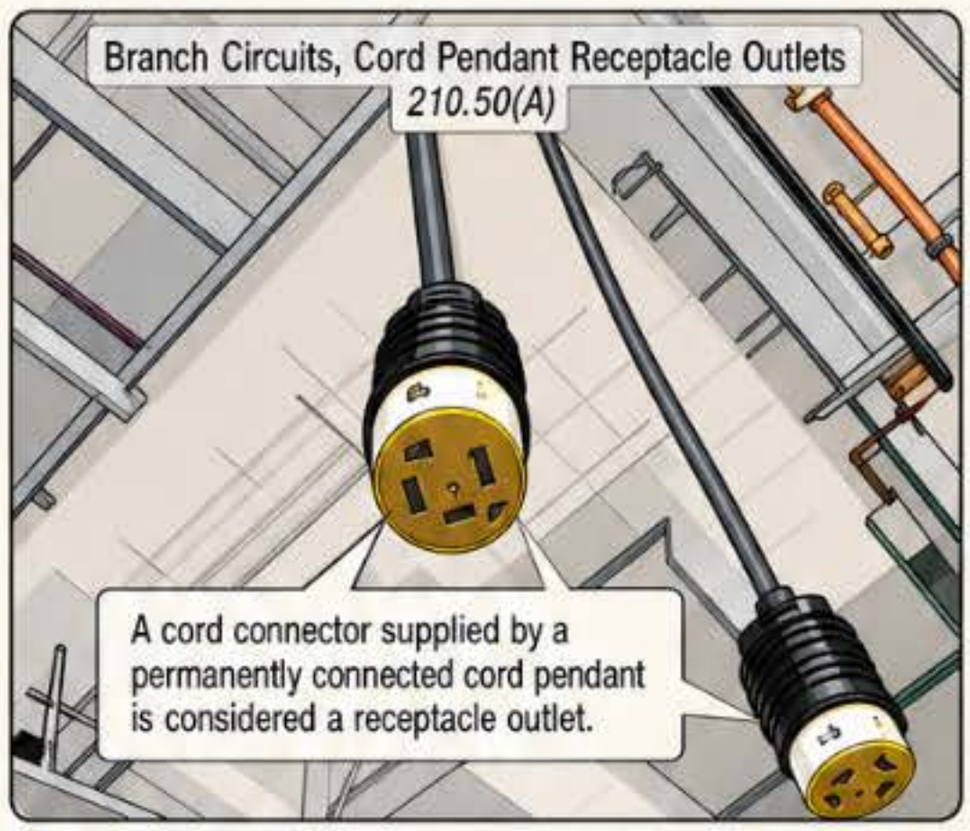


▶ Figure 210–72

Part III. Required Outlets

210.50 Receptacle Outlets

(A) Cord Pendants. A cord connector supplied by a permanently connected cord pendant is considered a receptacle outlet. ▶ Figure 210–73



▶ Figure 210–73

(C) Appliance Receptacle Outlets. Receptacle outlets in dwelling units for specific appliances such as washing machines, dryers, ranges, garage door openers, or refrigerators must be within 6 ft of the intended location of the appliance unless this distance is modified elsewhere in the *Code*. ▶ Figure 210–74

Author's Commentary: *Keep appliance receptacles within six feet so the cord can easily reach the unit. The Code allows other distances when additional rules elsewhere permit a different requirement.*

— Michael Hamilton

Branch Circuits, Dwelling
Appliance Receptacle Outlet Location
210.50(C)

Receptacle outlets intended for a specific appliance, such as a washing machine, dryer, range, or refrigerator must be within 6 ft of the appliances' intended location.

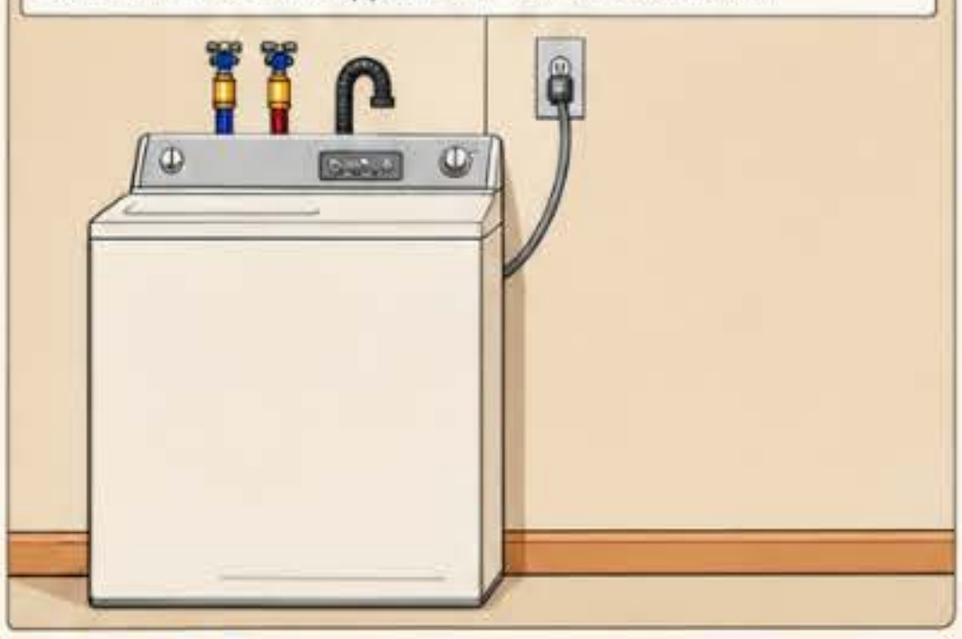


Figure 210-74

Branch Circuits, Receptacle Outlet Spacing, Dwelling
210.52(A)(1)

A receptacle outlet must be installed so no point along the floor line of any wall is more than 6 ft, measured horizontally along the floor line, from a receptacle outlet.

Figure 210-75

210.52 Dwelling Unit Receptacle Outlet Requirements

This section provides the requirements for 15A and 20A, 125V receptacle outlets in dwelling units, and are in addition to those for any receptacle that is:

(1) Part of a luminaire or appliance,

(2) Controlled by a listed wall-mounted control device in accordance with 210.70(A)(1) Ex 1

(3) Located within cabinets or cupboards, or

(4) Located more than 5½ ft above the floor.

(A) General Requirements. A receptacle outlet must be installed in every kitchen, family room, dining room, living room, sunroom, parlor, library, den, bedroom, recreation room, and similar room or area in accordance with (1), (2), (3), and (4).

(1) Receptacle Outlet Spacing. A receptacle outlet must be installed so no point along the floor line of any wall is more than 6 ft, measured horizontally along the floor line, from a receptacle outlet. Figure 210-75

Author's Commentary:

This rule exists to ensure that there are sufficient general-purpose receptacles conveniently distributed throughout the space, reducing dependence on extension cords.

— Michael Hamilton

(2) Definition of a Wall Space. The wall space for receptacle outlet placement includes the following:

(1) Any wall space 2 ft or more in width that is unbroken along the floor line by doorways, fireplaces, and fixed cabinets without countertops or work surfaces. Figure 210-76 and Figure 210-77

Branch Circuits, Receptacle Outlet Spacing, Dwelling
Definition of a Wall Space
210.52(A)(2)(1)

Any wall space 2 ft or more in width that is unbroken along the floor line by doorways, fireplaces, and fixed cabinets without countertops or work surfaces.

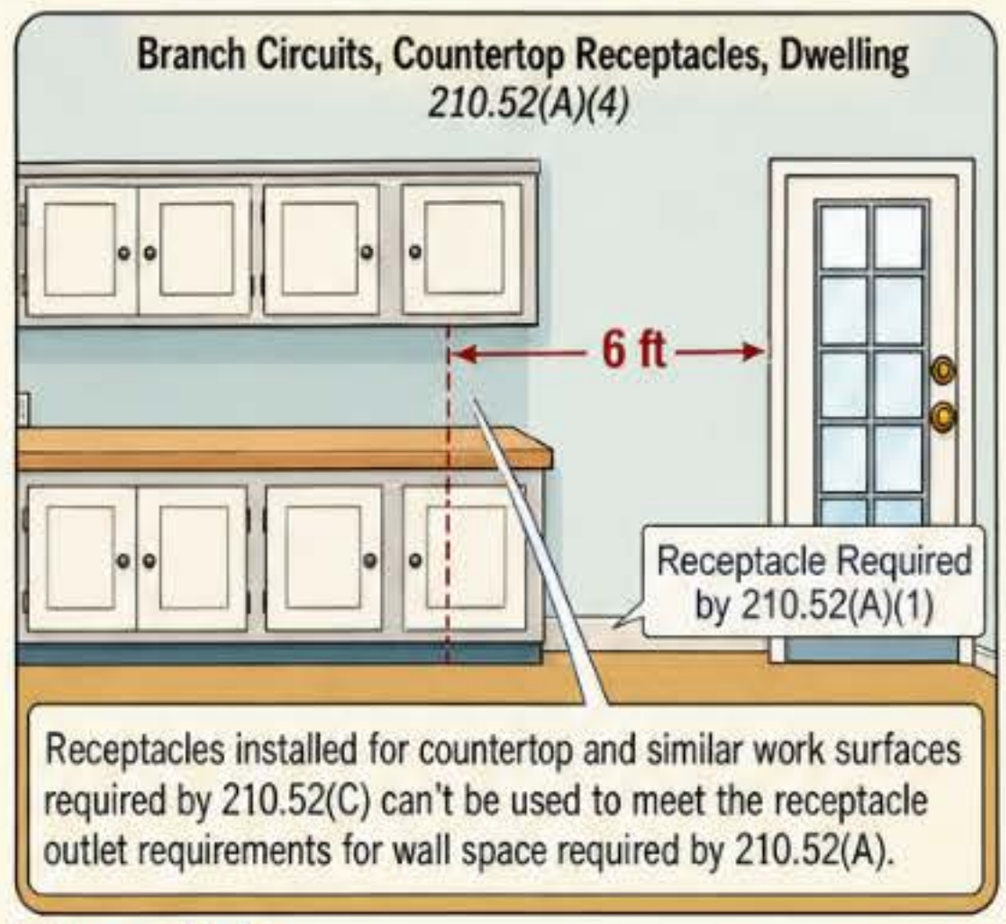
Figure 210-76

(2) The space occupied by fixed panels.

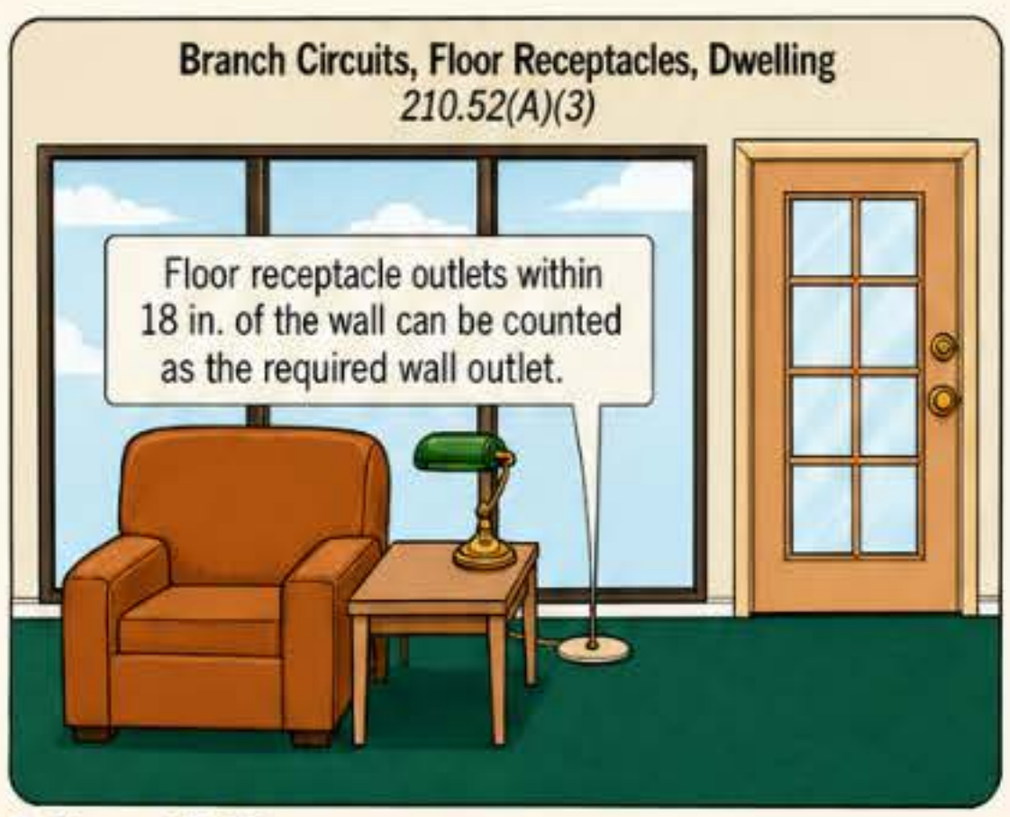
(3) The space occupied by fixed room dividers such as railings.

(3) Floor Receptacles. Floor receptacle outlets located within 18 in. of the wall can be counted as the required wall outlet. Figure 210-78

▶ Figure 210–77



▶ Figure 210–79



▶ Figure 210–78

Author's Commentary:

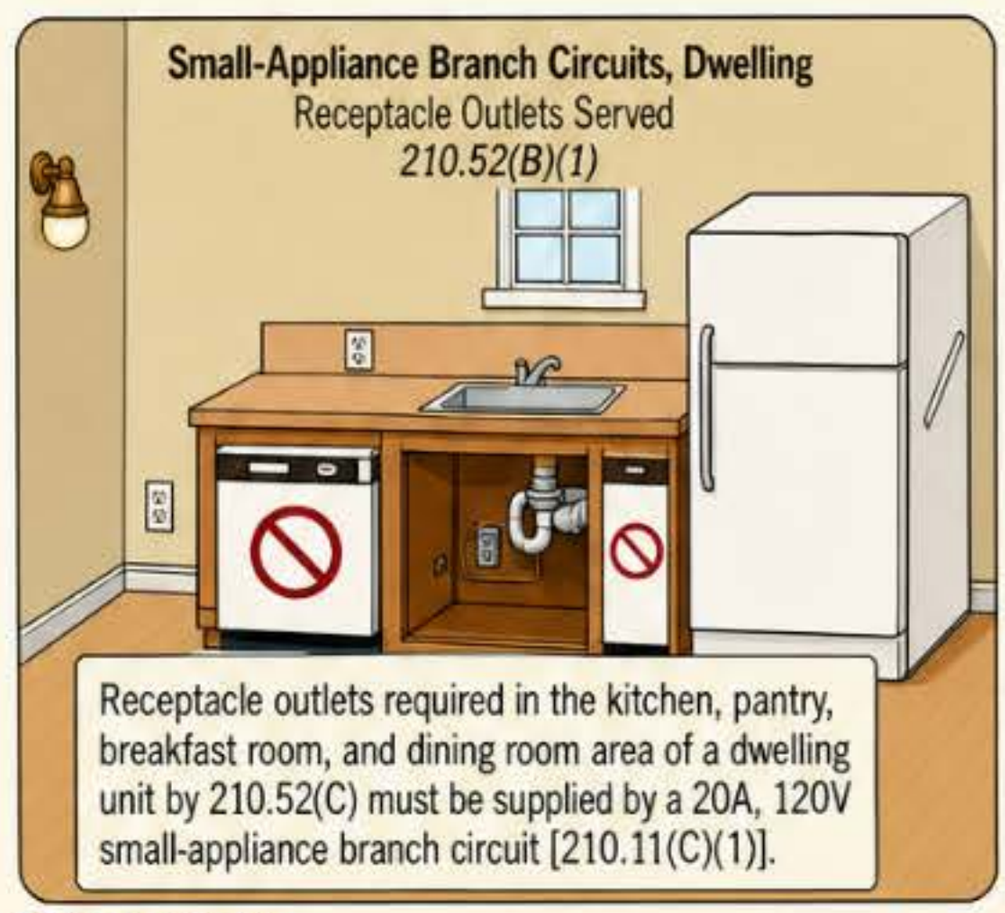
- Spaces such as fixed panels in walls [210.52(A)(2)(2)] or fixed room dividers [210.52(A)(2)(3)] may be a railing or be constructed of glass, in which case installing a typical receptacle outlet is impractical. Since these fixed panels or room dividers are still considered a wall space, a floor receptacle located within 18 in. can be used for the required receptacle(s).

—Michael Hamilton

(4) Countertop Receptacles. Receptacle outlets installed for countertop and similar work surfaces required by 210.52(C) cannot be used to meet the receptacle outlet rules for wall space outlined in 210.52(A). ▶ Figure 210–79

(B) Small-Appliance Circuits

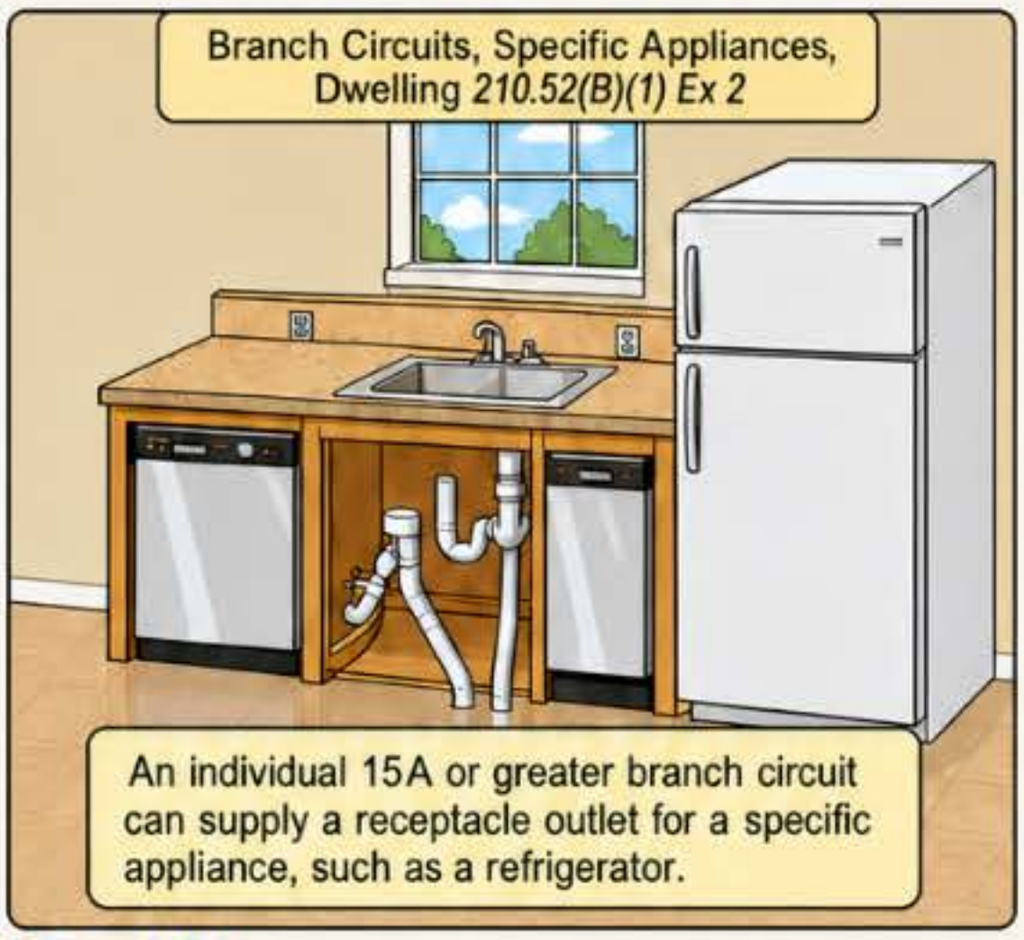
(1) Receptacle Outlets. Receptacle outlets required in the kitchen, pantry, breakfast room, and dining room area of a dwelling unit by 210.52(C) must be supplied by a 20A, 120V small-appliance branch circuit [210.11(C)(1)]. ▶ Figure 210–80



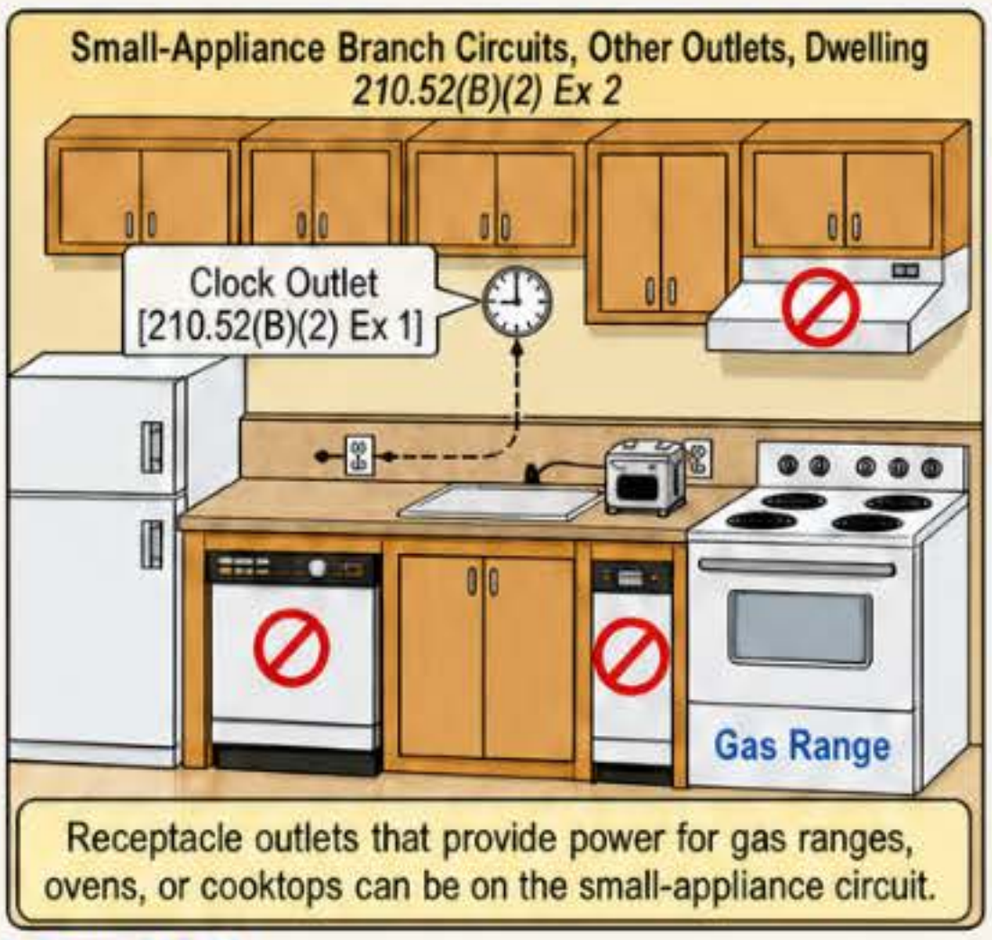
▶ Figure 210–80

Ex 2: An individual 15A or larger branch circuit can supply a receptacle outlet for a specific appliance such as a refrigerator. Figure 210–81

BRANCH CIRCUITS | 210.52

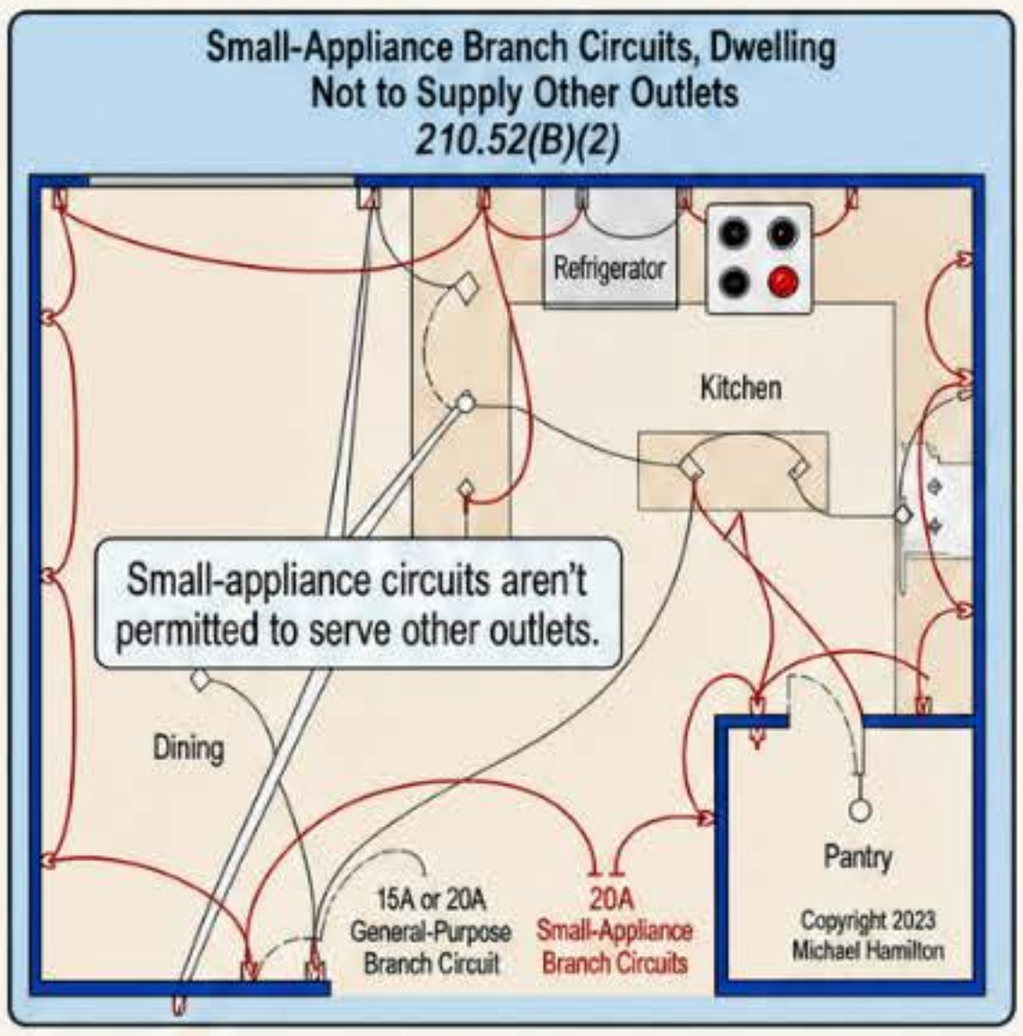


▶ Figure 210-81



▶ Figure 210-83

(2) Not Supply Other Outlets. The 20A, 120V small-appliance circuit is not permitted to supply lighting outlets or receptacle outlets outside the kitchen, pantry, breakfast room, or dining room area. Figure 210-82



▶ Figure 210-82

Ex 2: *A receptacle outlet for a gas-fired range, oven, or countertop mounted cooking unit is permitted on the 20A, 120V small-appliance circuit.* Figure 210-83

Author's Commentary:

A range hood, or over-the-range microwave listed as a range hood that is flexible cord-and-plug-connected, must be supplied by an individual branch circuit [422.16(B)(4)(3)]. When only a range hood is installed and "hard-wired," it is not permitted to be supplied by the small-appliance branch circuit(s). It is usually fed from a nearby lighting circuit instead.

— Michael Hamilton

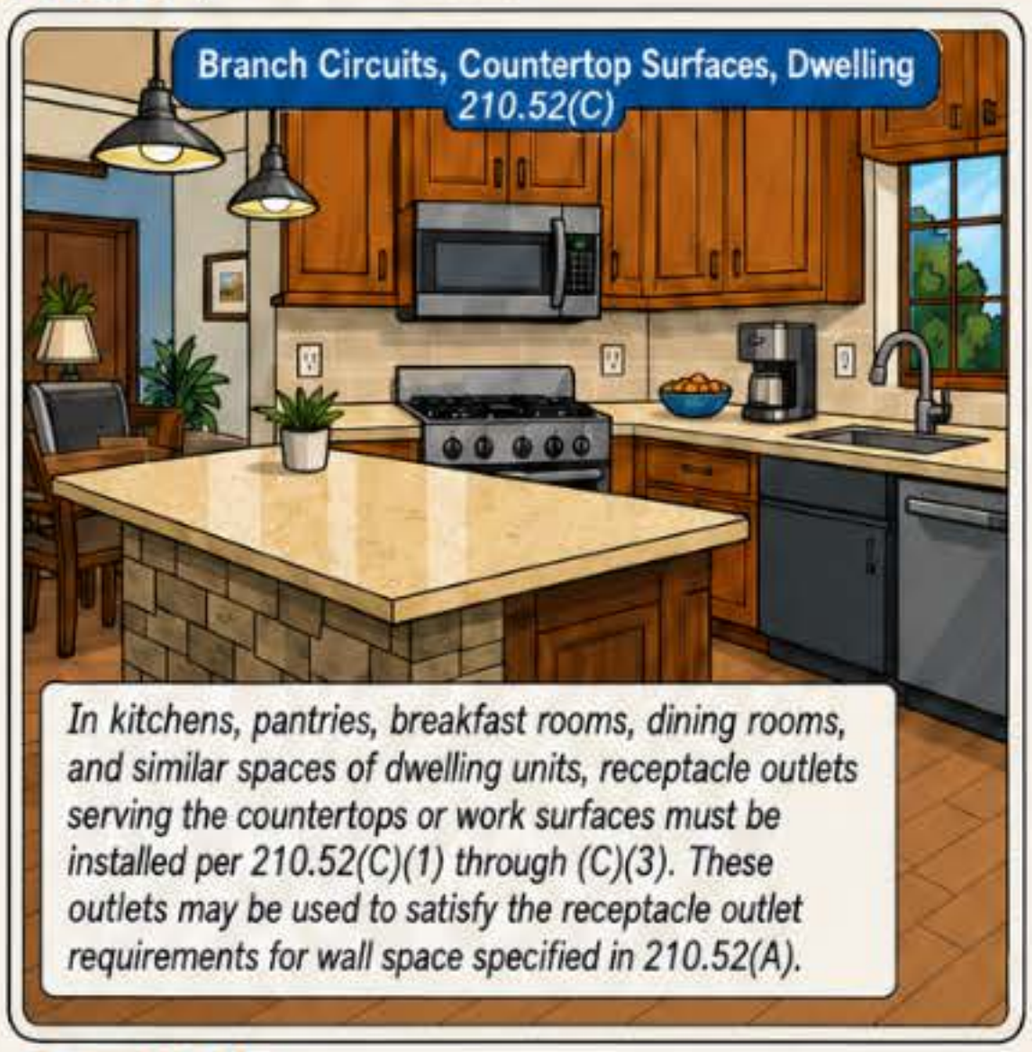
(3) Kitchen Receptacle Requirements. Receptacles installed in *a kitchen to serve countertop surfaces must be supplied by no fewer than two small-appliance branch circuits; either or both of which can supply receptacle outlets in the same kitchen and in other rooms specified in 210.52(B)(1).*

(C) Countertops and Work Surfaces. In kitchens, pantries, breakfast *rooms, dining rooms, and similar areas of dwelling units, receptacle outlets for countertop and work surfaces that are 12 in. or wider must be installed in accordance with 210.52(C)(1) through (C)(3) and are not permitted to be used to meet the receptacle outlets for wall space required by 210.52(A).* Figure 210-84

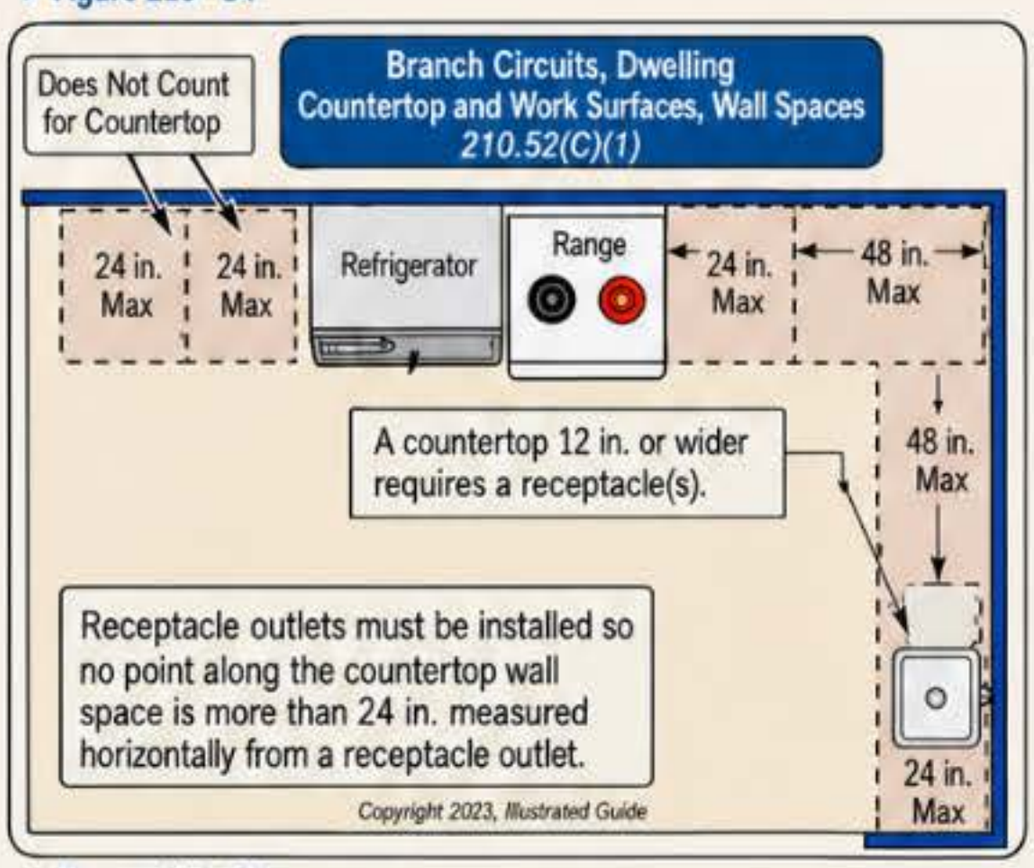
Where multioutlet assemblies are used, each 12 in. of multioutlet assembly containing two or more receptacles are considered to be one receptacle outlet.

(1) Wall Spaces. *Receptacle outlets. A receptacle outlet must be installed so no point along the countertop wall space is more than 2 ft, measured horizontally, from a receptacle outlet.* Figure 210-85

210.52 | Branch Circuits



▶ Figure 210–84

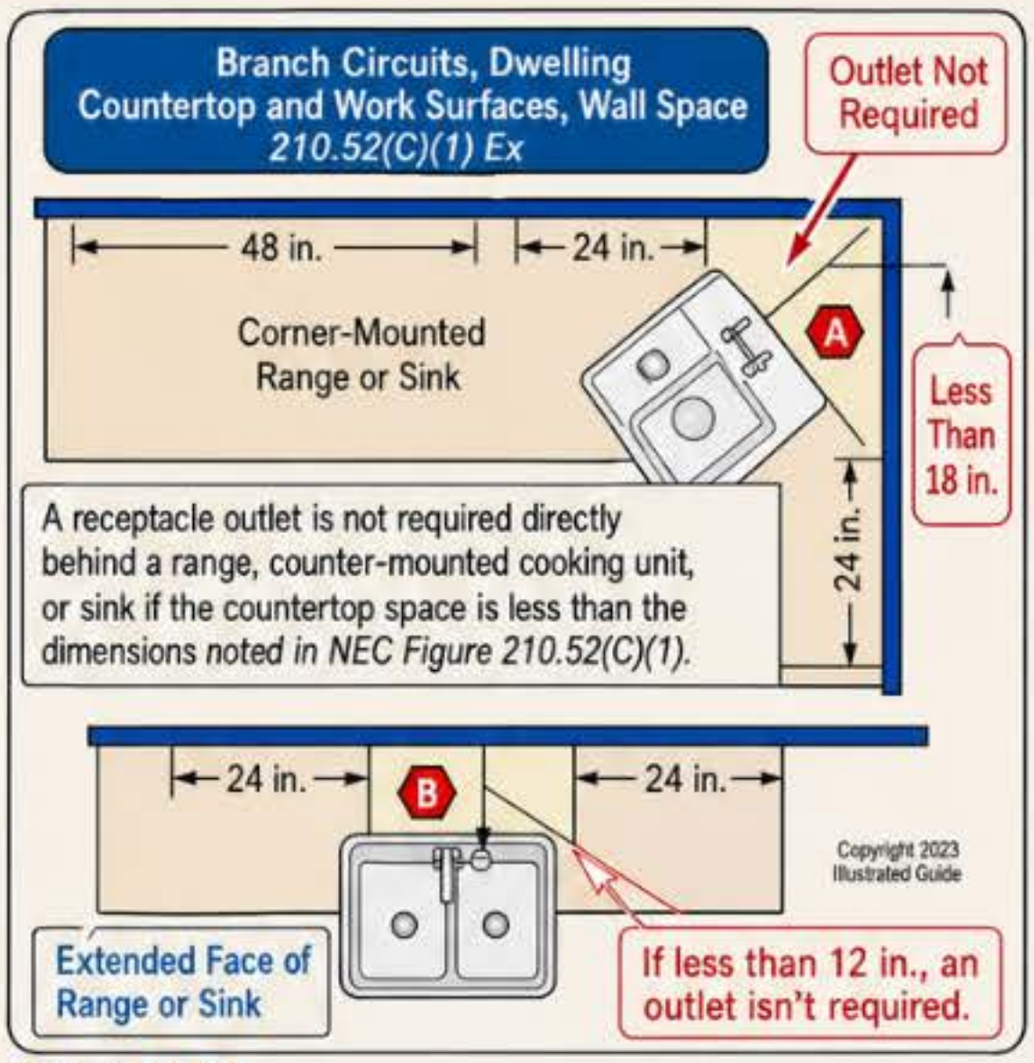


▶ Figure 210–85

Ex: A receptacle outlet is not required directly behind a range, counter-mounted cooking unit, or sink in accordance with Figure 210.52(C)(1) in the NEC.
▶ Figure 210–86

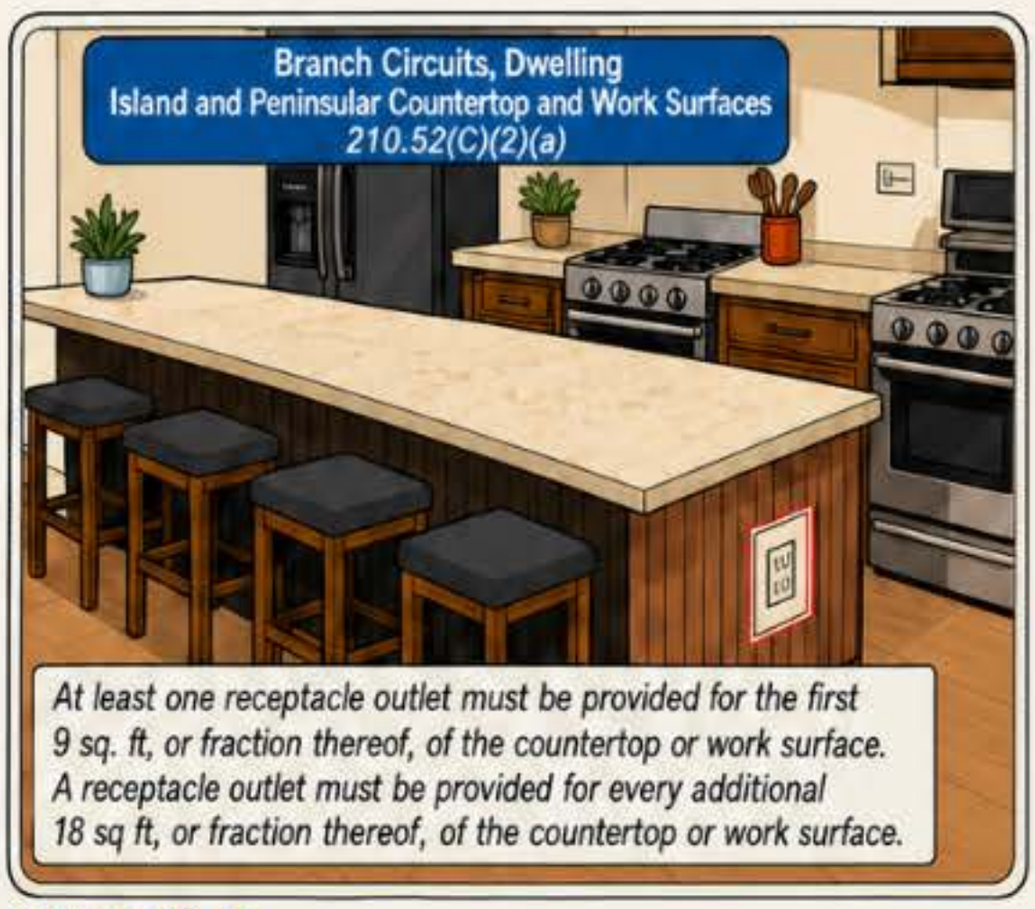
Author's Commentary:
If the countertop space behind a range or sink exceeds the dimensions shown in Figure 210.52(C)(1) or the Code section, a GFCI-protected receptacle must be installed in that area. This GFCI protection is essential for all practical appliances. If sufficient space cannot be provided for any appliance, it will be more difficult to install later.
— Michael Hamilton

(2) Island and Peninsular Countertops and Work Surfaces. *Receptacle outlets must be installed in accordance with the following:*



▶ Figure 210–86

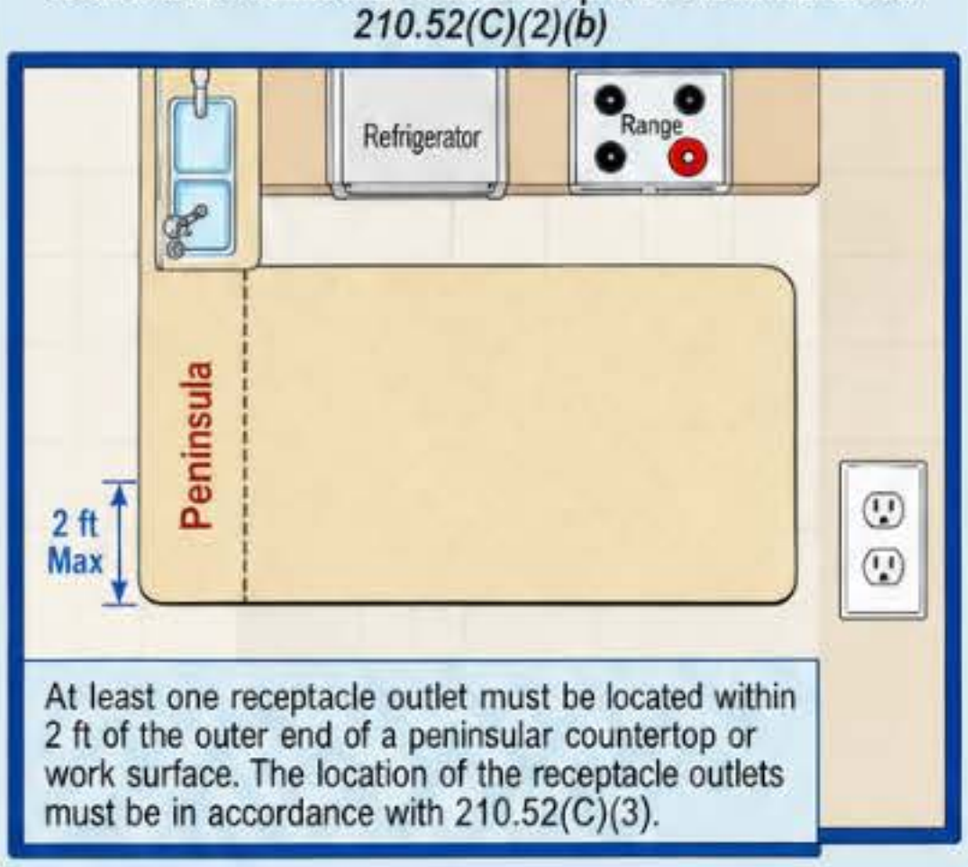
(a) At least one receptacle outlet must be provided for the first 9 sq ft, or fraction thereof, of the countertop or work surface. A receptacle outlet must be provided for every additional 18 sq ft, or fraction thereof, of the countertop or work surface.
▶ Figure 210–87



▶ Figure 210–87

(b) At least one receptacle outlet must be located within 2 ft of the outer end of a peninsular countertop or work surface. *Additional required receptacle outlets are permitted to be located as determined by the installer, designer, or building owner. The location of the receptacle outlets must be in accordance with 210.52(C)(3).* ▶ Figure 210–88

Branch Circuits, Dwelling,
Island and Peninsular Countertop and Work Surfaces
210.52(C)(2)(b)



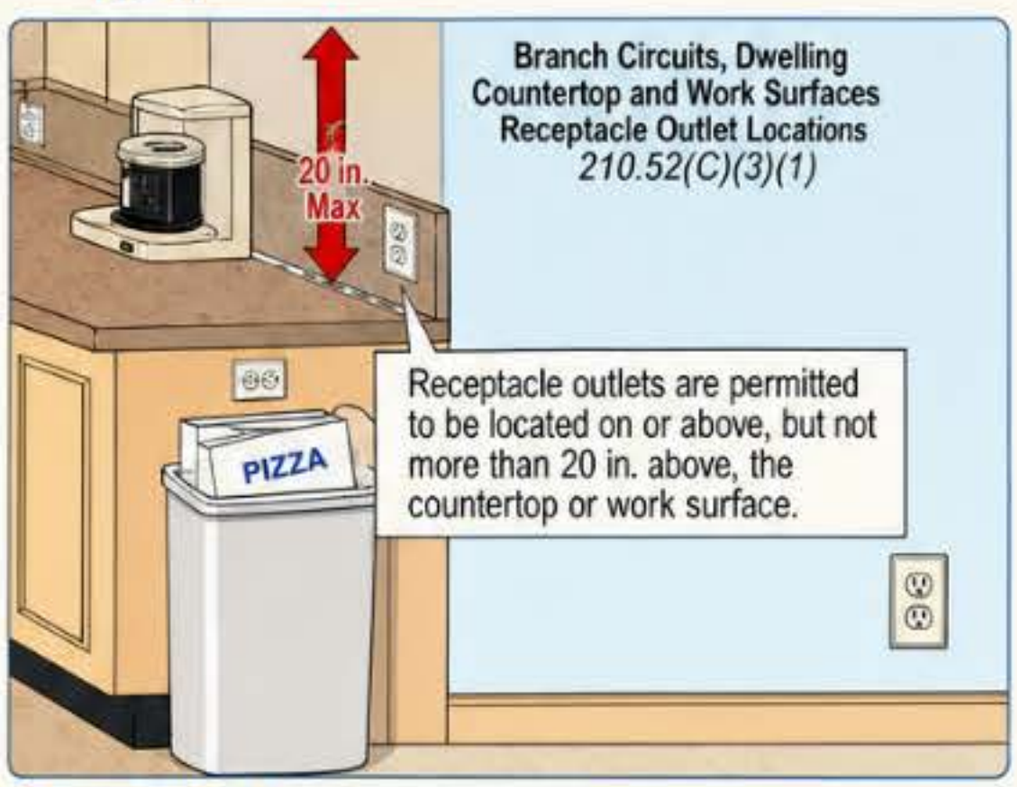
▸ Figure 210–88

A peninsular countertop must be measured from the connected perpendicular wall.

(3) Receptacle outlets must be installed in one or more of the following locations:

(1) Receptacle outlets are permitted to be located on or above, but not more than 20 in. above, the countertop or work surface. ▸ Figure 210–89

Branch Circuits, Dwelling
Countertop and Work Surfaces
Receptacle Outlet Locations
210.52(C)(3)(1)



▸ Figure 210–89

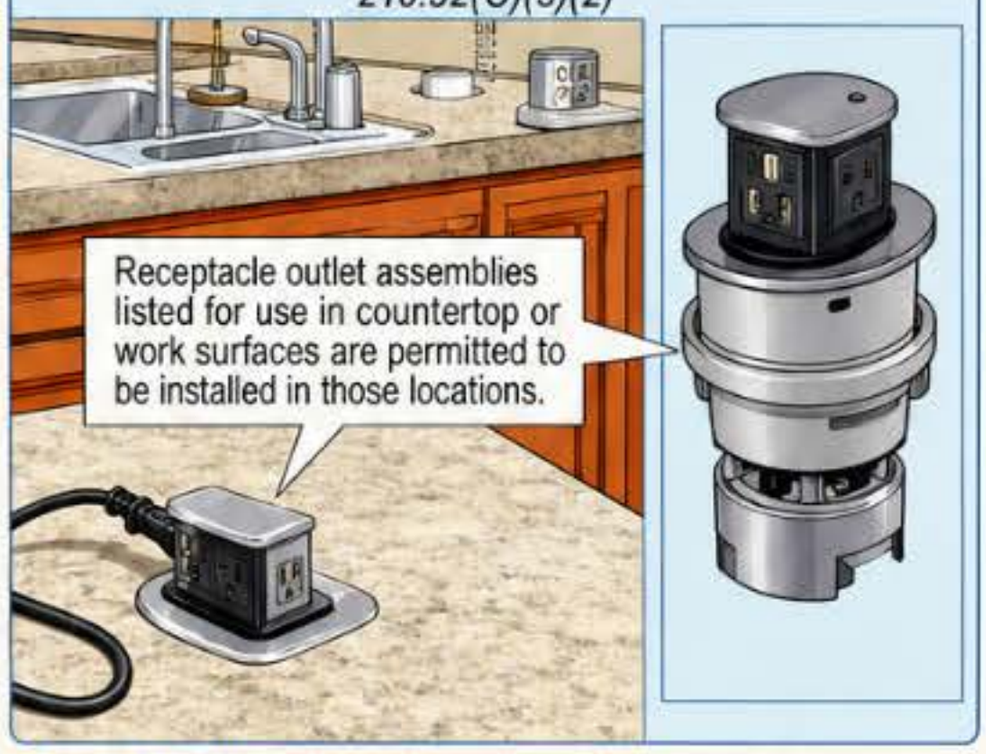
Author's Commentary:

This rule gives you flexibility in placing receptacle outlets for an overhead cabinet, while still requiring the outlets used for countertops and work areas to be located below the cabinets. By doing this, no outlet can be more than 20 inches above the countertop or work surface.

— Michael Hamilton

(2) In countertop or work surfaces: Receptacle outlet assemblies listed for use in countertop or work surfaces are permitted to be installed in those locations. ▸ Figure 210–90

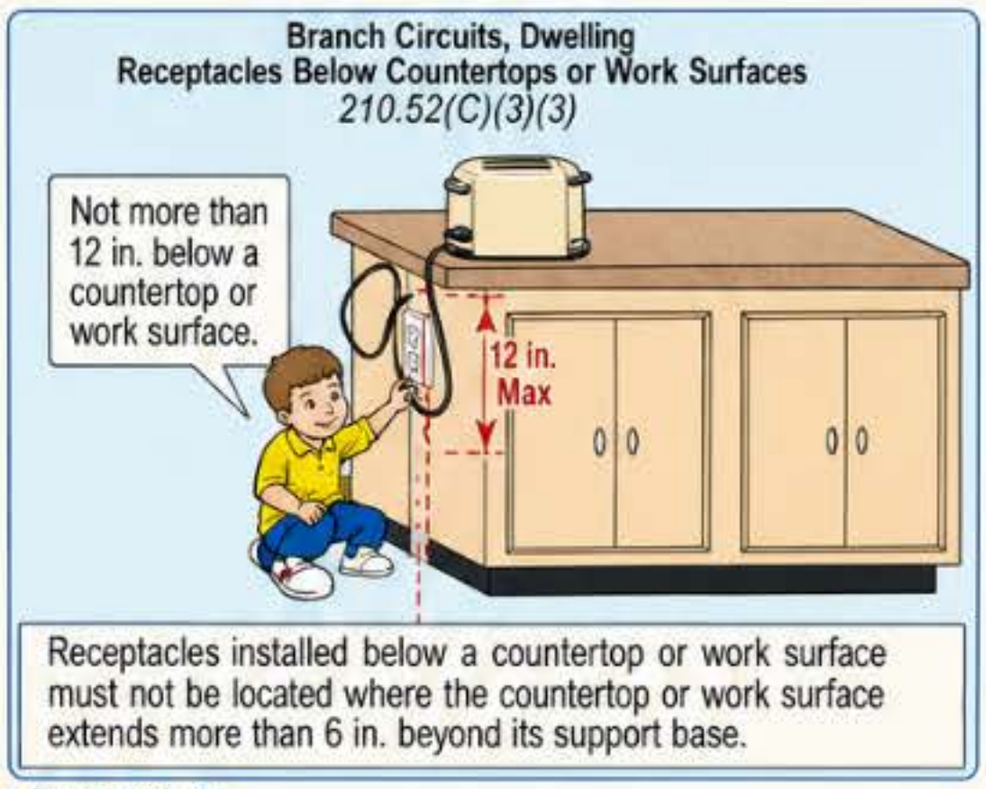
Branch Circuits, Dwelling
Receptacles in Countertops or Work Surfaces
210.52(C)(3)(2)



▸ Figure 210–90

(3) Below countertop or work surfaces: Receptacles must not be located more than 12 in. below the countertop or work surface. Those installed below a countertop or work surface must not be located where the countertop or work surface extends more than 6 in. beyond its support base. ▸ Figure 210–91

Branch Circuits, Dwelling
Receptacles Below Countertops or Work Surfaces
210.52(C)(3)(3)



▸ Figure 210–91

Receptacle outlets rendered not readily accessible by appliances fastened in place, situated in an appliance garage, behind sinks, ranges, or cooktops [210.52(C)(1)(b) Ex], or powering appliances that occupy assigned spaces do not count as the required countertop surface receptacle outlets.

210.52 | Branch Circuits

Author's Commentary:

▶ *An "Appliance Garage" is a concealed storage space built into a countertop so an appliance can be kept out of sight when not being used. Receptacle outlets installed within an appliance garage do not count as a required countertop receptacle outlet.*

— Michael Hamilton

Note 1: *See 406.5(E) and 406.5(G) for placing receptacles in countertops, 406.5(F) and 406.5(G) for placing receptacles in work surfaces, and 380.10 for installing multiple assemblies.*

(D) Bathroom Area Receptacle Outlets. A receptacle outlet rated 15A or 20A, 125V must be installed *within* 3 ft of the outside edge of each bathroom area basin.

The outlet must be located on a wall or partition that *adjoins the basin countertop surface, or it may be on the side or face of the basin cabinet. In no case can that receptacle be positioned more than 12 in. below the upper edge of the basin or basin countertop.*

Branch Circuits, Bathroom Area Receptacle Outlets, Dwelling *210.52(D)*

At least one 15A or 20A, 125V receptacle outlet must be installed within 3 ft of the outside edge of each basin. In no case can this receptacle be installed more than 12 in. below the top of the basin or basin countertop.

Figure 210–92

Author's Commentary:

▶ *One receptacle outlet can serve two basins if it is located within 3 ft of the outside edge of each basin.*

— Michael Hamilton

Receptacle outlet assemblies listed for use in countertops *are permitted to be installed in the basin countertop surface.*

(E) Outdoor Receptacle Outlets. *Outdoor receptacle outlets must comply with the following:*

Branch Circuits, Bathroom Area Receptacle Outlets, Dwelling *210.52(D) Comment*

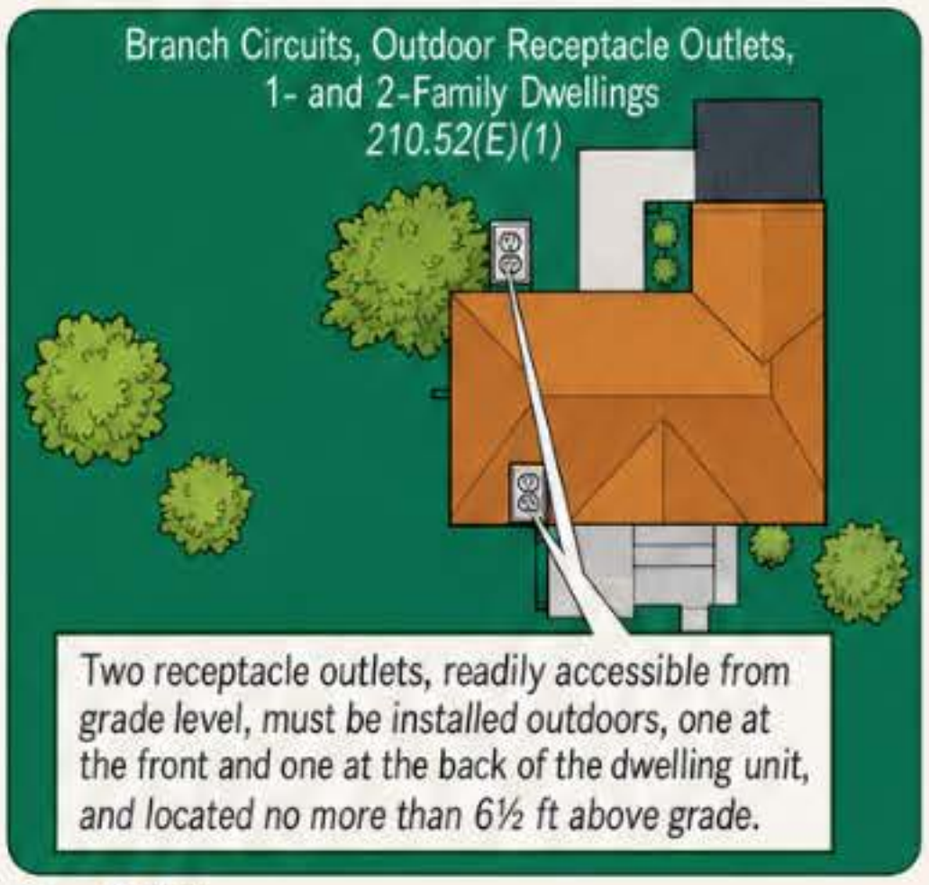
One receptacle can serve both basins if it is located within 3 ft of the outside edge of each basin.

Figure 210–93

(1) One- and Two-Family Dwellings. Two outdoor, readily accessible from grade, *receptacle outlets must be installed: one at the front and one at the back of each dwelling unit. They cannot be located more than 6½ ft above grade.*

Figure 210–94

Branch Circuits, Outdoor Receptacle Outlets, 1- and 2-Family Dwellings *210.52(E)(1)*



Two receptacle outlets, readily accessible from grade level, must be installed outdoors, one at the front and one at the back of the dwelling unit, and located no more than 6½ ft above grade.

Figure 210–94

(2) Multifamily Dwelling. *Each dwelling unit of a multifamily dwelling with grade level entry must have at least one outdoor receptacle outlet, readily accessible from grade, and located not more than 6½ ft above grade.*

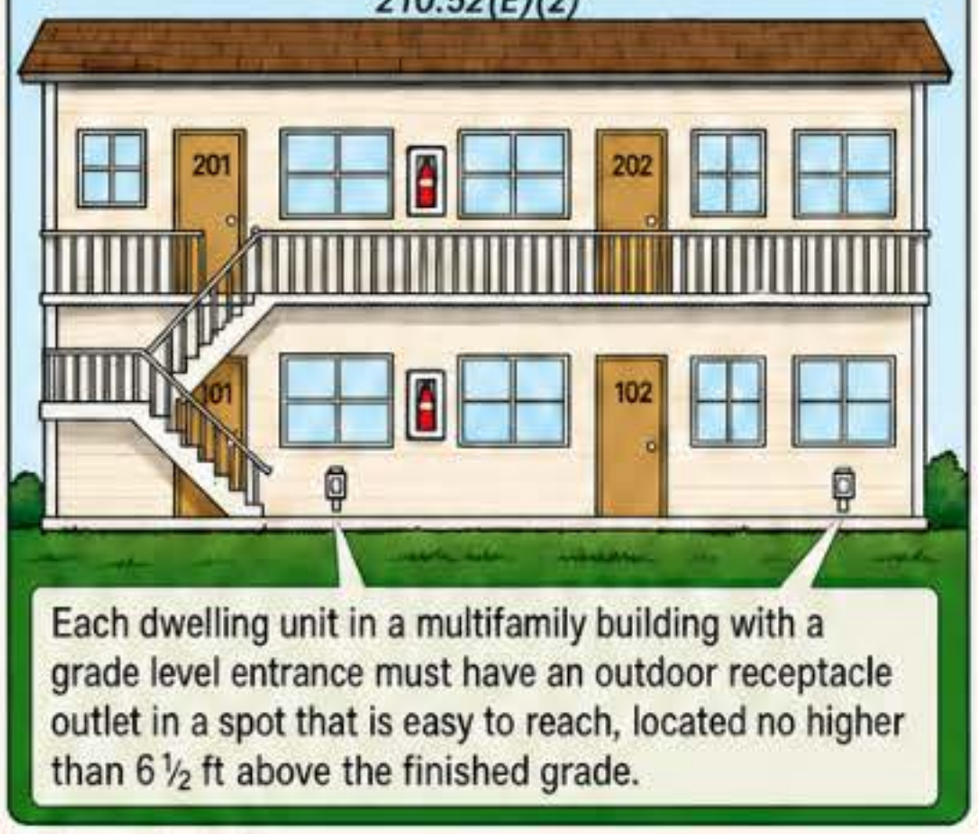
Figure 210–95

(3) Balconies, Decks, and Porches. *At least one receptacle outlet must be installed not more than 6½ ft above any balcony, deck, or porch surface that is within 4 in. horizontally of the dwelling unit.*

Figure 210–96

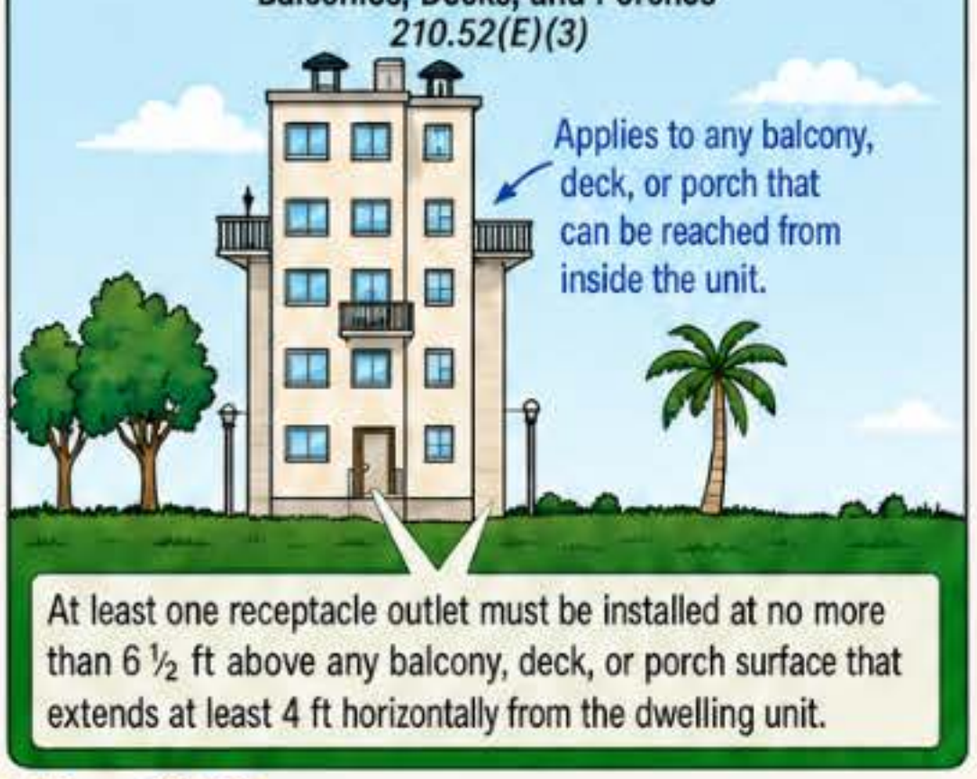
BRANCH CIRCUITS | 210.52

Branch Circuits, Outdoor Receptacle Outlets Multifamily Dwelling
210.52(E)(2)



▶ Figure 210–95

Branch Circuits, Outdoor Receptacle Outlets, Dwelling Balconies, Decks, and Porches
210.52(E)(3)



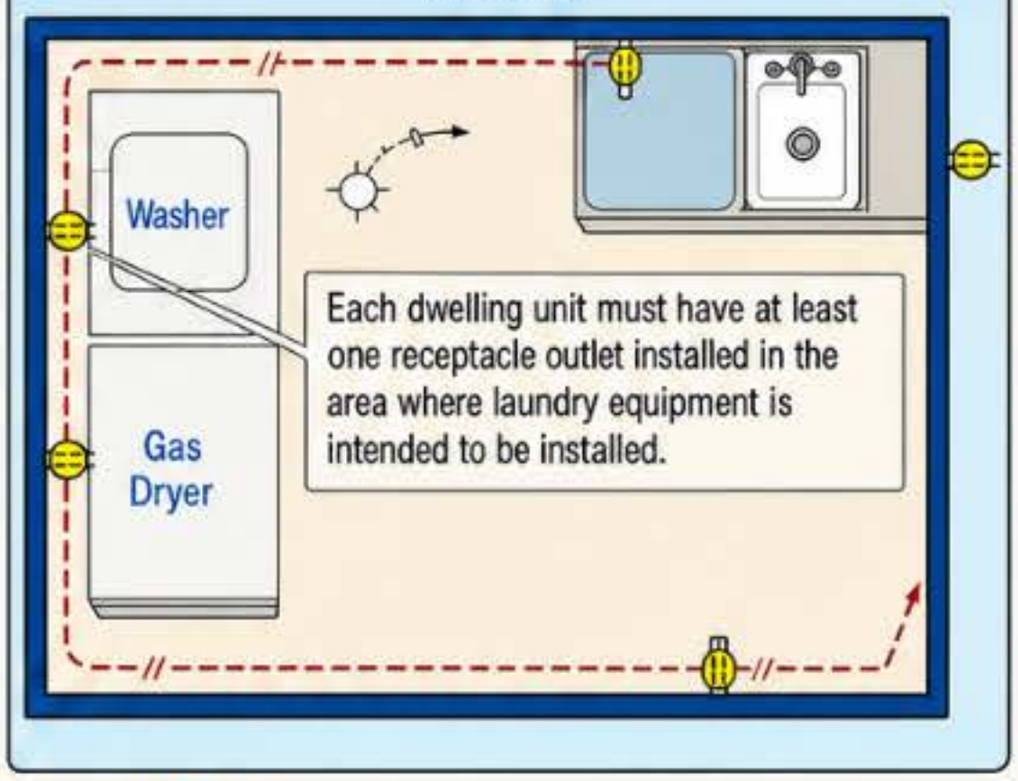
▶ Figure 210–96

(F) Laundry Area Receptacle Outlet. Each dwelling unit must have at least one receptacle outlet installed in the area where laundry equipment is intended to be installed. ▶ Figure 210–97

Example 1: A laundry receptacle outlet is not required in a dwelling unit located in a multifamily building when the necessary laundry facilities are available to all occupants.

> ***Author's Commentary:***
> *A laundry space may be designed so that a receptacle outlet is unnecessary if no laundry equipment will be used.*
> *— Michael Hamilton*

Branch Circuits, Dwelling Laundry Area Receptacle Outlet
210.52(F)

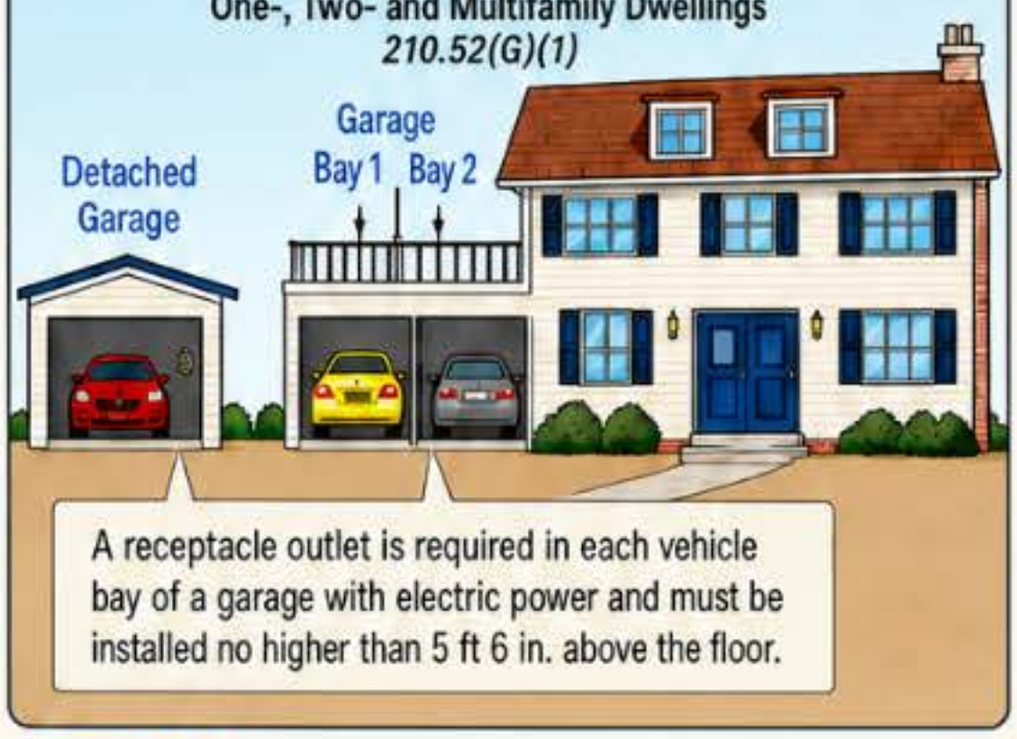


▶ Figure 210–97

(G) Garage, Basement, and Accessory Building Receptacle Outlet. For a one- or two-family dwelling, and multifamily dwellings, at least one receptacle outlet must be installed in accordance with (1) through (3).

(1) Garages. A receptacle outlet is required in each vehicle bay of a garage with electric power and must be installed no higher than 5 ft 6 in. above the floor. ▶ Figure 210–98

Branch Circuits, Garage Receptacle Outlets One-, Two- and Multifamily Dwellings
210.52(G)(1)



▶ Figure 210–98

Example 2: A receptacle outlet is not required in a garage area that is not attached to an individual dwelling unit in a multifamily dwelling.

(2) Accessory Buildings. *A receptacle outlet is required in each accessory structure that has electric power.* ▶ Figure 210–99

210.60 | Branch Circuits

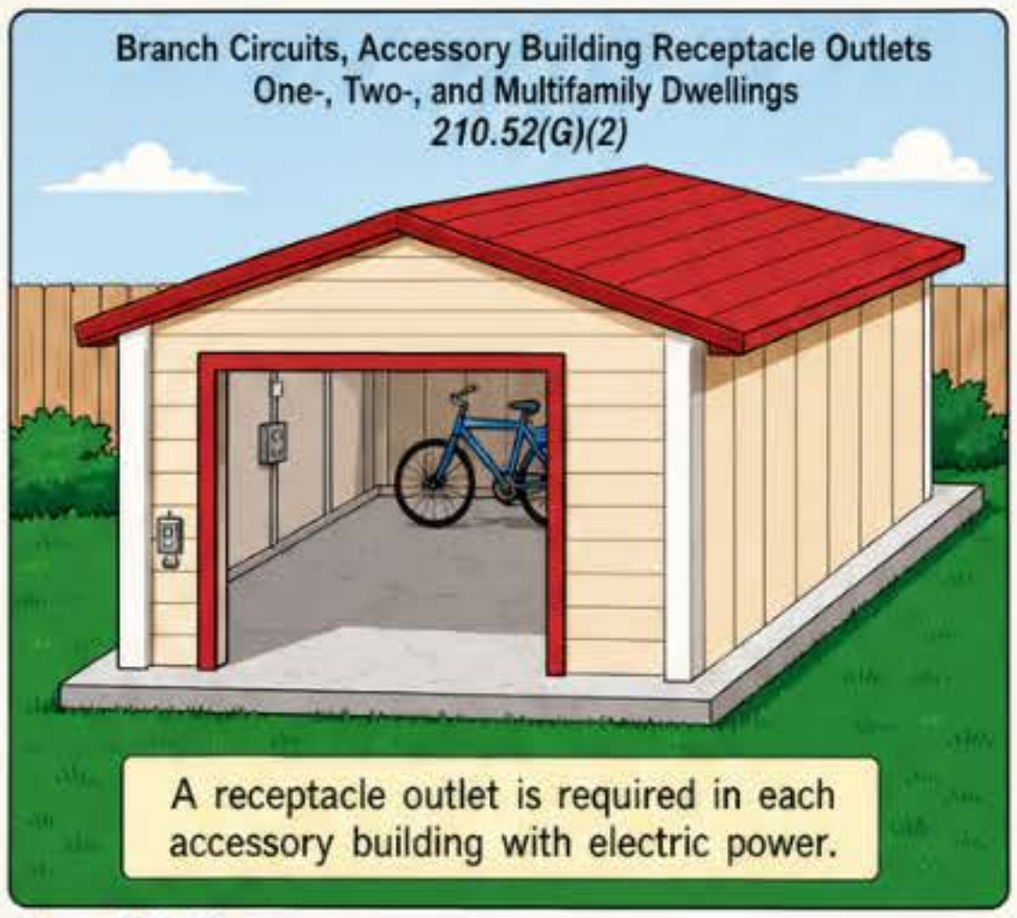


Figure 210–99

(3) Basements. Every unfinished area of a basement must include a receptacle outlet. ▶ Figure 210–100

Figure 210–100

(H) Hallway Receptacle Outlets. *Install at least one receptacle outlet in every hallway that is 10 ft or longer in length, measured along the centerline of the hallway without passing through a doorway.* ▶ Figure 210–101

Author's Commentary:
These rules ensure that every space where people may spend time has convenient access to electricity. Provide outlets in all unfinished basement areas, long hallways, spacious foyers, accessory buildings, and guest areas so occupants can safely and easily plug in their equipment.
— Michael Hamilton

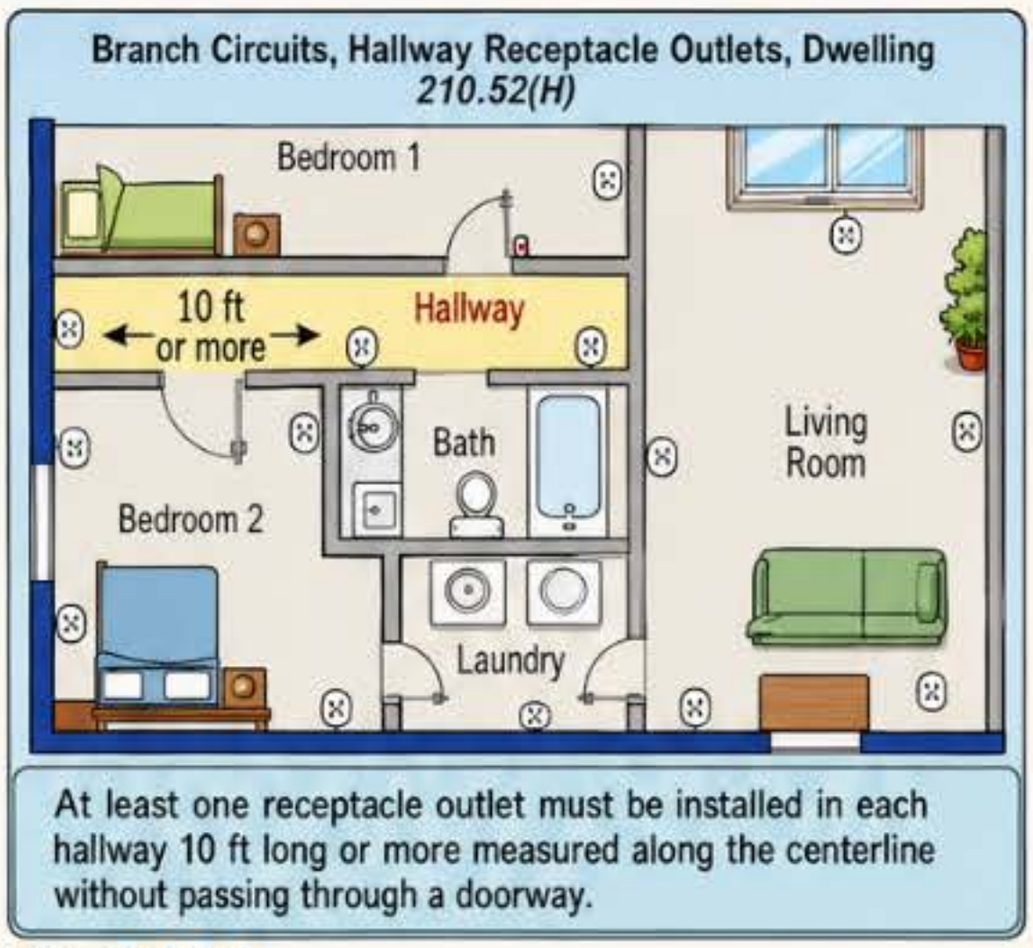


Figure 210–101

(I) Foyer Receptacle Outlets. Rooms or spaces with more than 60 sq ft of floor area must have a receptacle outlet on any wall section at least 3 ft wide that is not interrupted by doorways, windows that start at the floor, or openings of similar type. ▶ Figure 210–102

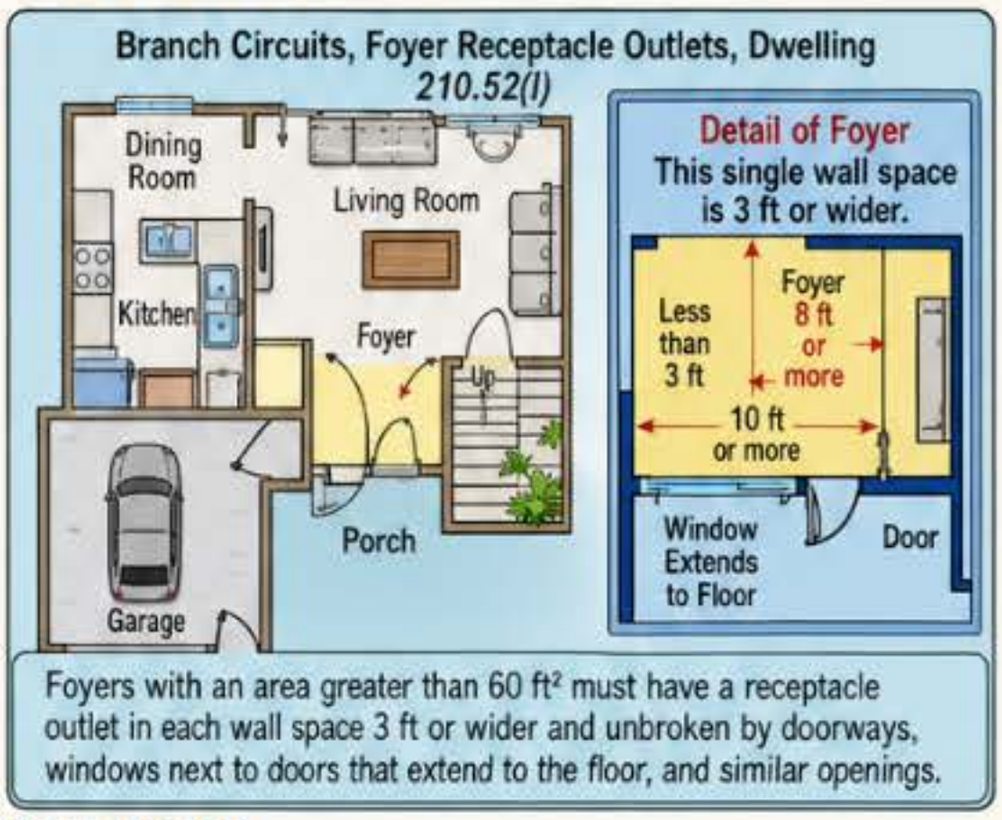


Figure 210–102

210.60 Receptacles in Guest Rooms, Guest Suites, Dormitory Units, and Similar Occupancies

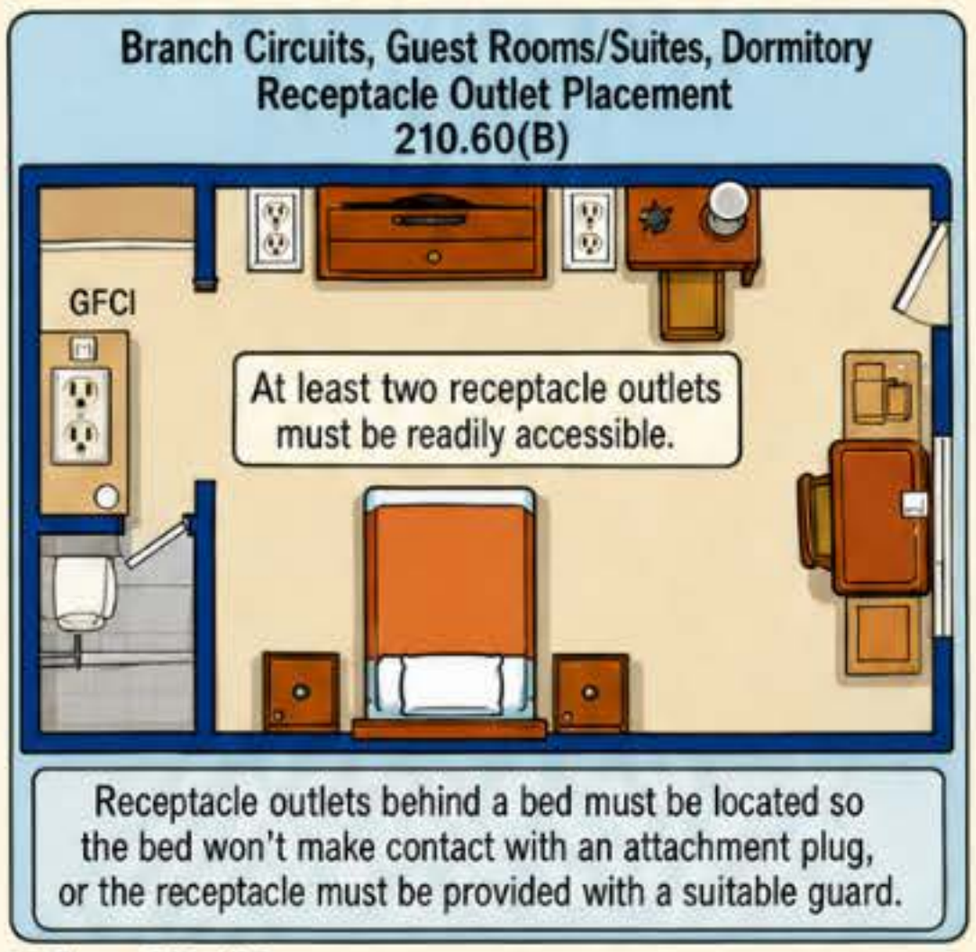
(A) General Requirements. *Guest rooms or guest suites in hotels, motels, and sleeping rooms in dormitory units and similar occupancies must have receptacle outlets installed in accordance with the requirements for a dwelling unit as described in 210.52(A) and 210.52(D).*

DEFINITIONS | From Michael Hamilton Publications

Guest rooms that include permanent cooking facilities must have receptacle outlets installed in accordance with the dwelling unit requirements of 210.52.

(B) Receptacle Outlet Placement. The amount of receptacle outlets needed for guest rooms, guest suites, and dormitories is not less than what is required in 210.52(A) for dwelling units. For external power connections to appliances like irons, computers, fridges, or other items, receptacle outlets cannot be located beside any piece of permanent furniture such as a bed, unless at least two outlets are readily usable.

Outlets behind a bed must be positioned so the bed doesn't block access to the attachment plug, or a suitable guard must be supplied. ▶ Figure 210–103



▶ Figure 210–103

Author's Commentary:

▶ *The minimum number of receptacles is determined by 210.52, but their placement in a guest room or suite is based on the location of permanent furniture and for convenience.*

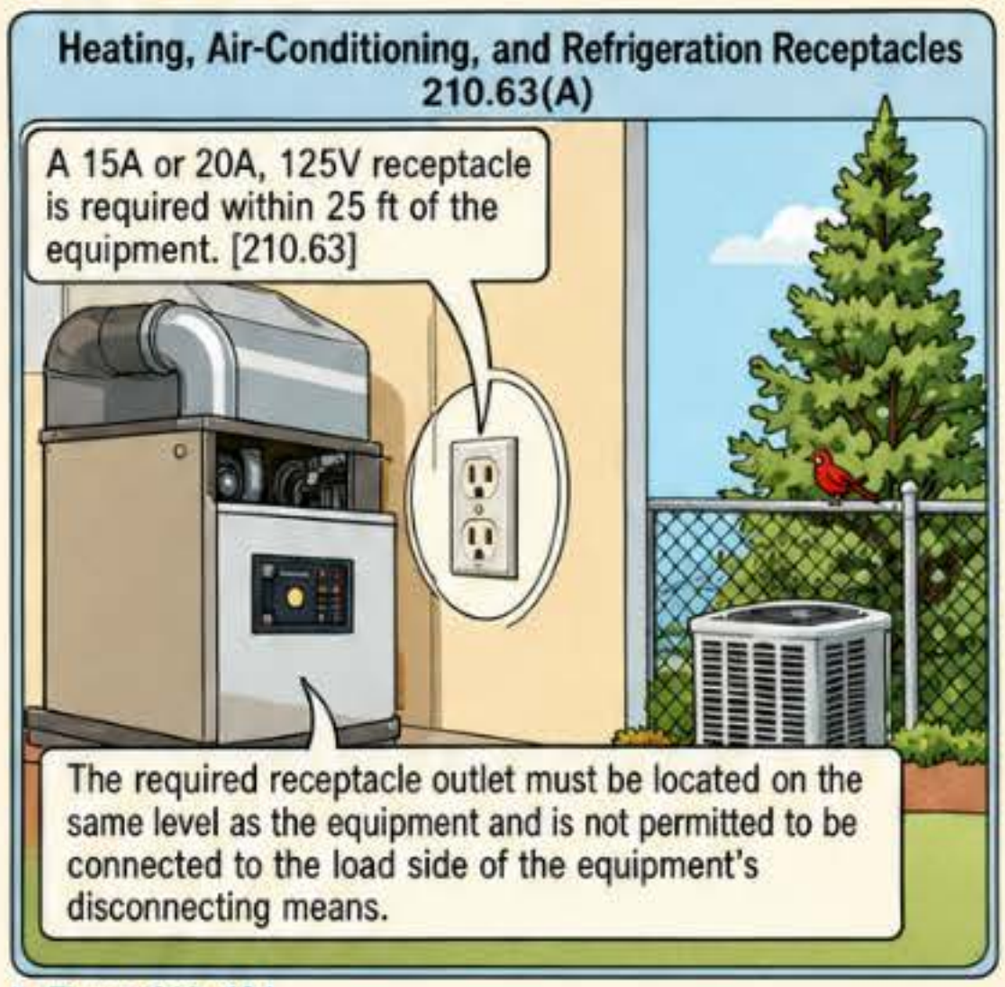
— Michael Hamilton

210.63 Equipment Requiring Servicing

A 15A or 20A, 125V, single-phase receptacle outlet must be installed at an accessible location within **25 ft** of equipment in accordance with the following:

(A) Heating, Air-Conditioning, and Refrigeration Equipment. The required receptacle outlet must be located on the same level as the heating, air-conditioning, and refrigeration equipment and is not permitted to be connected to the load side of the equipment's disconnecting means.

▶ Figure 210–104



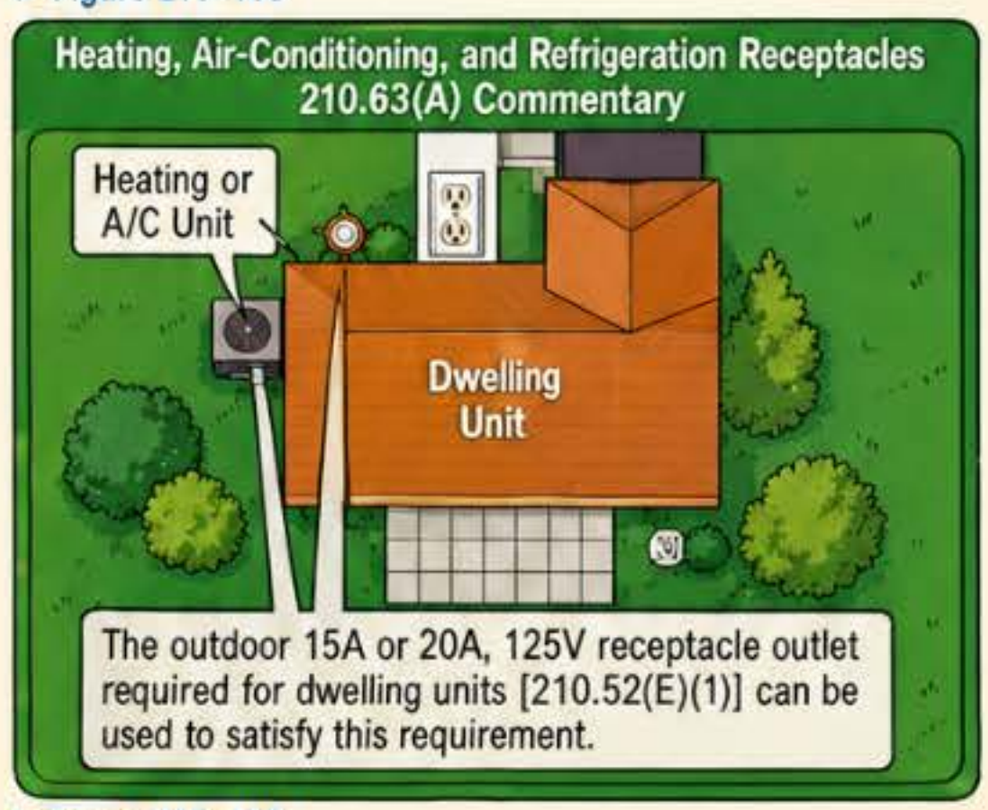
▶ Figure 210–104

Author's Commentary:

▶ *These equipment service receptacles must be GFCI protected even if the equipment is installed in areas not typically requiring such protection. [210.8(E)]*

The outdoor 15A or 20A, 125V receptacle outlet required for dwelling units [210.52(E)(1)] can be used to satisfy this requirement.

▶ Figure 210–105



▶ Figure 210–105

(B) Other Electrical Equipment. In settings other than one- and two-family residences, any receptacle outlet must be installed as described below:

(1) Indoor Service Equipment. Install a 15A or 20A, 125V, single-phase receptacle outlet within easy reach of the indoor equipment, no higher than 25 ft from the service equipment. Figure 210–106

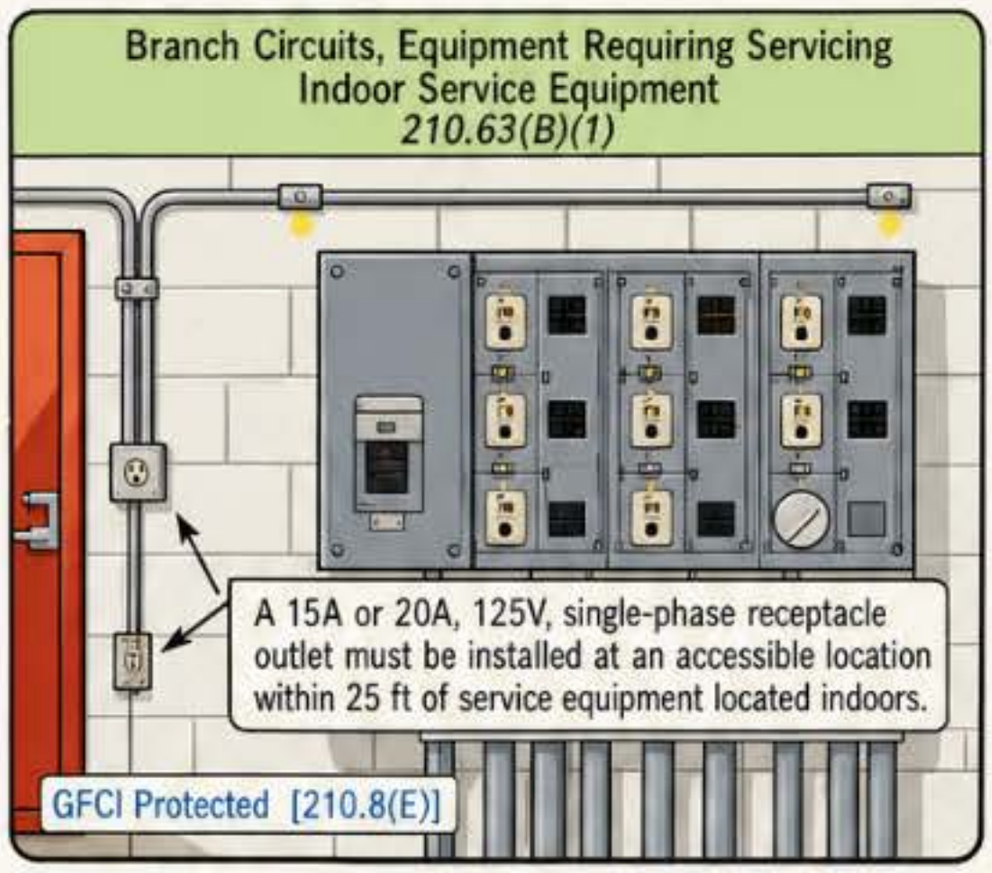


Figure 210–106

(2) Indoor Switchboards, Switchgear, Panelboards, and Motor Control Centers. A 15A or 20A, 125V, single-phase receptacle outlet must be installed at an accessible location within the same room or area as switchboards, switchgear, panelboards, and motor control centers [110.26(E)] and cannot be connected to the load side of the equipment disconnecting means.

Author's Commentary:
A receptacle outlet is not needed for ventilation equipment because it does not contain heating, air-conditioning, or refrigeration components.
— Michael Hamilton

Example: *A receptacle outlet is not required at one- and two-family dwellings for servicing evaporative coolers.*

210.65 Meeting Rooms

(A) General. Meeting rooms no larger than 1,000 sq ft must have receptacle outlets for 15A or 20A, 125V in accordance with 210.65(B). Figure 210–107

When a room (or space) includes a movable partition, its overall size must be determined with the partition(s) in the position that creates the smallest meeting area.

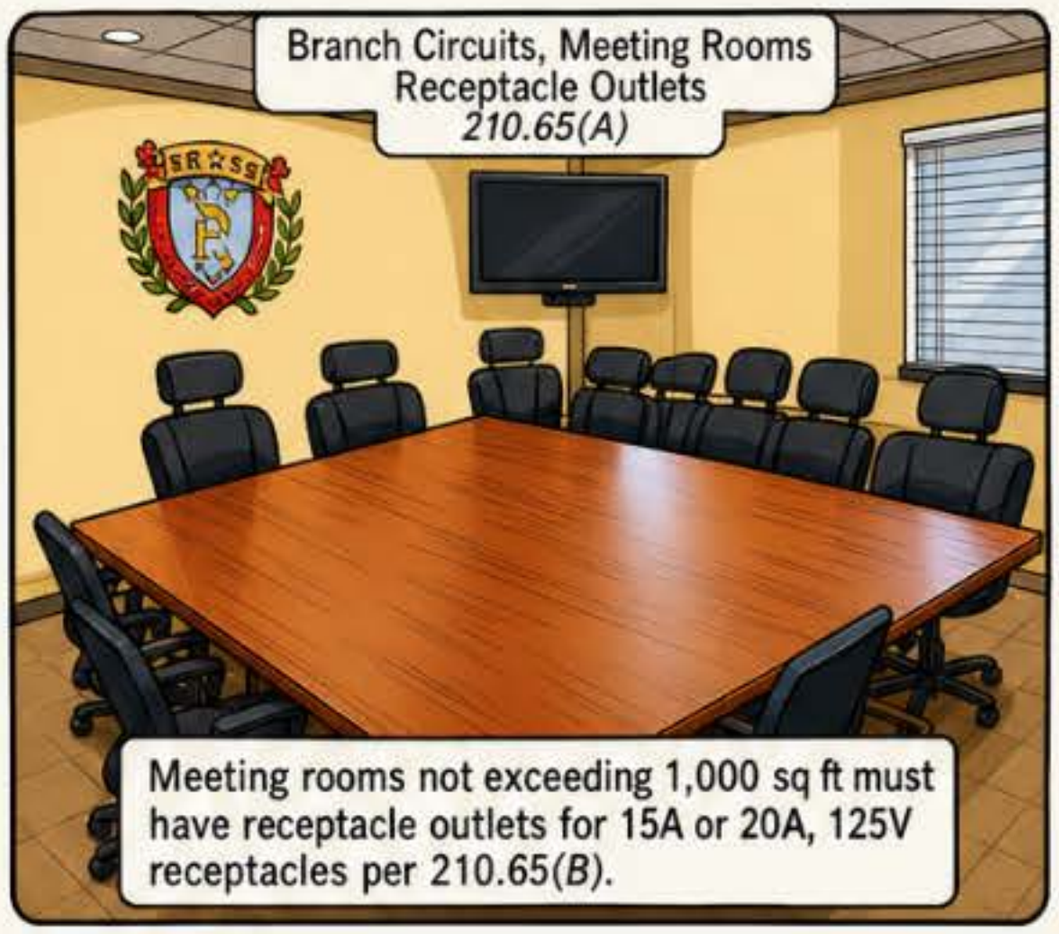


Figure 210–107

Note 1: Meeting rooms are typically created for the convening of seated occupants for conferences, deliberations, or similar purposes where portable electronic devices like computers, projectors, or similar equipment are likely to be used. Figure 210–108

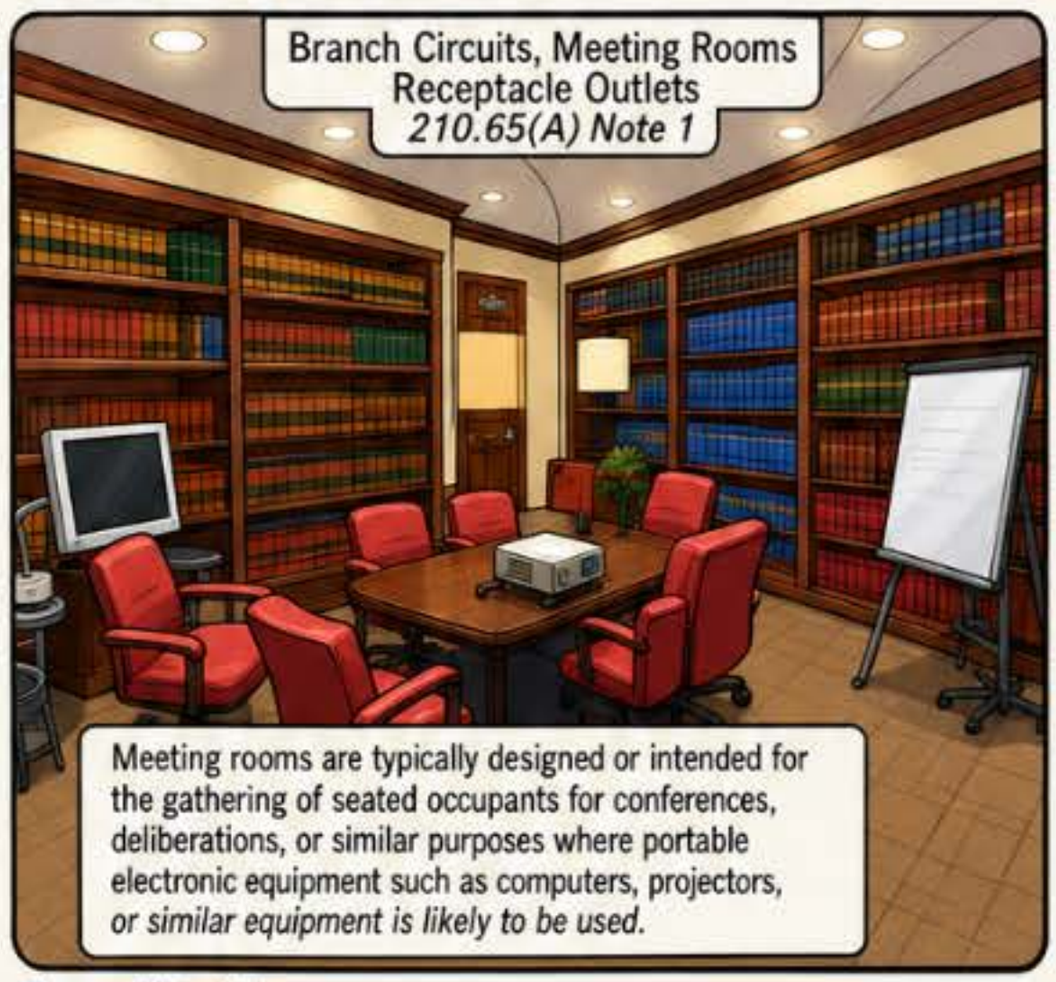


Figure 210–108

Note 2: *Examples of rooms that do not qualify as meeting rooms under 210.65 include auditoriums, school classrooms, and coffee shops.* Figure 210–109

(B) Number of Receptacle Outlets Required. *The total number of receptacle outlets—including floor outlets and receptacle outlets in fixed furniture—must not be less than the number determined in (1) and (2).*

DEFINITIONS | From Michael Hamilton Publications

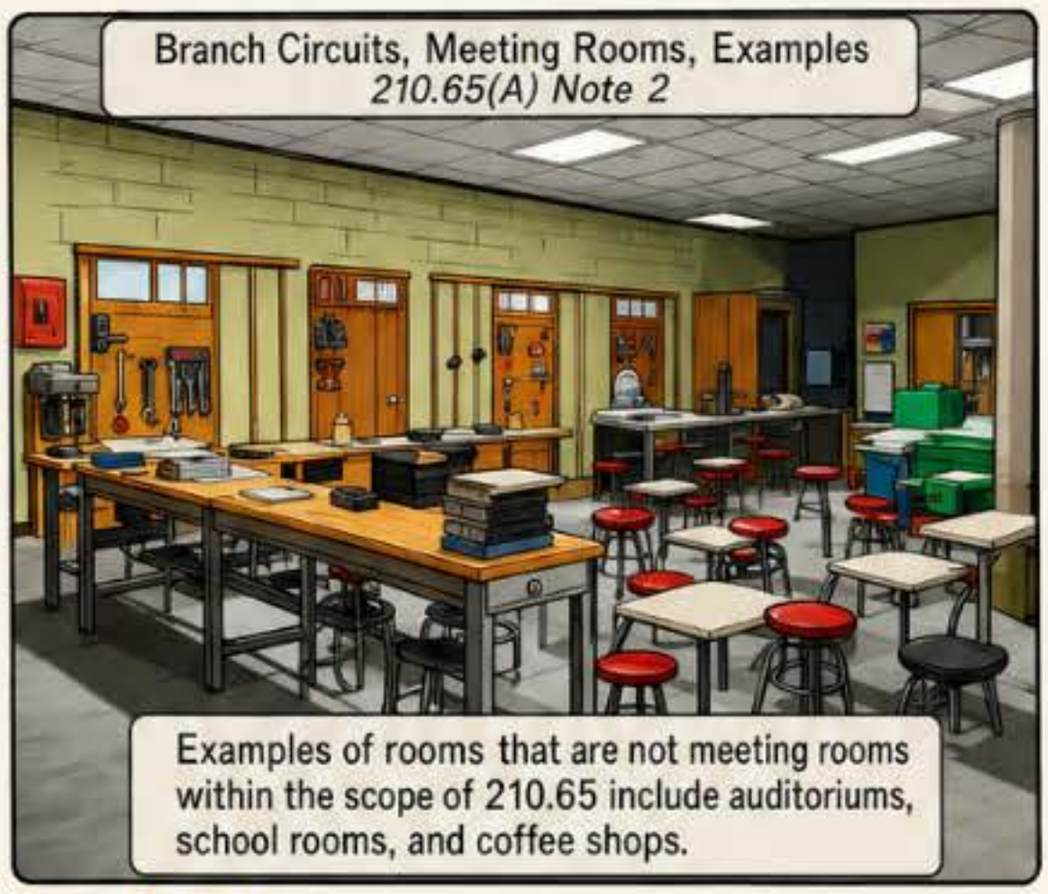


Figure 210–109

(1) The required number of receptacle outlets must be determined in accordance with 210.52(A)(1) through (A)(4). Their location can be determined by the installer, designer, or building owner. Figure 210–110

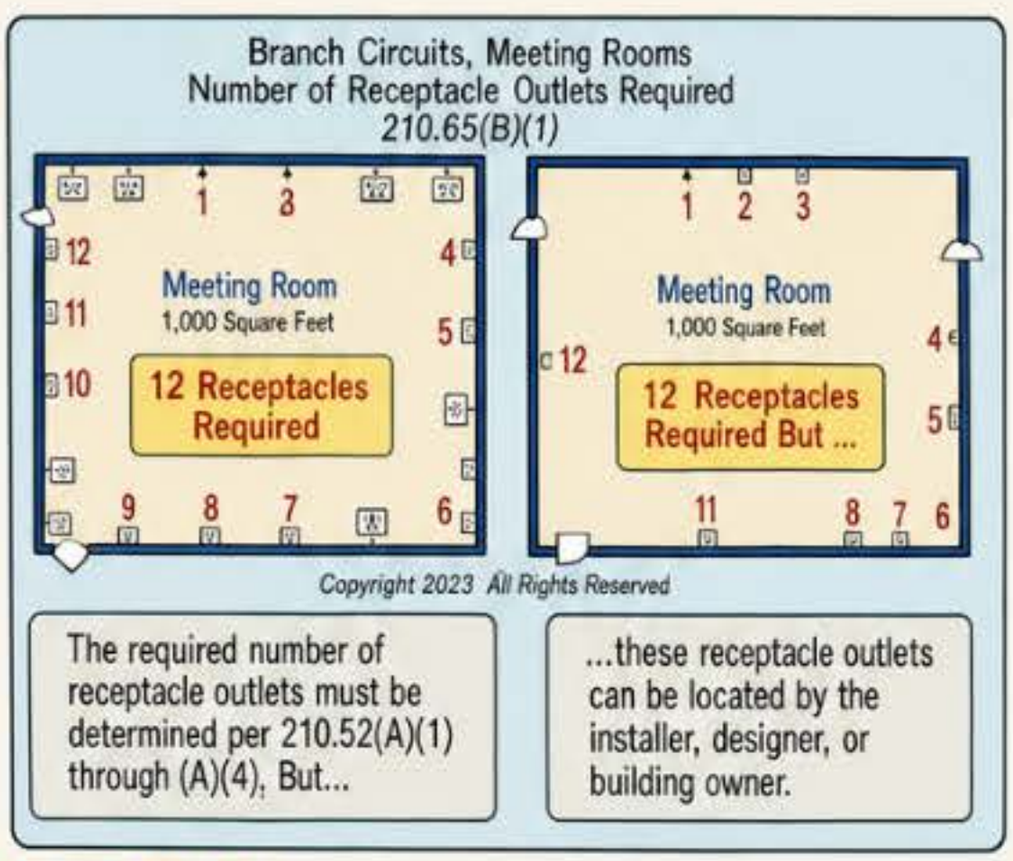


Figure 210–110

(2) A meeting room with any floor dimension 12 ft or greater in any direction and has a floor area of at least 215 sq ft must have at least one *floor receptacle outlet* or *floor outlet* to serve a *receptacle(s) located not less than 6 ft from any fixed wall for each 215 sq ft or major portion of floor space.* Figure 210–111

Note 1: See 314.27(B) for floor boxes used for receptacles located in the floor.

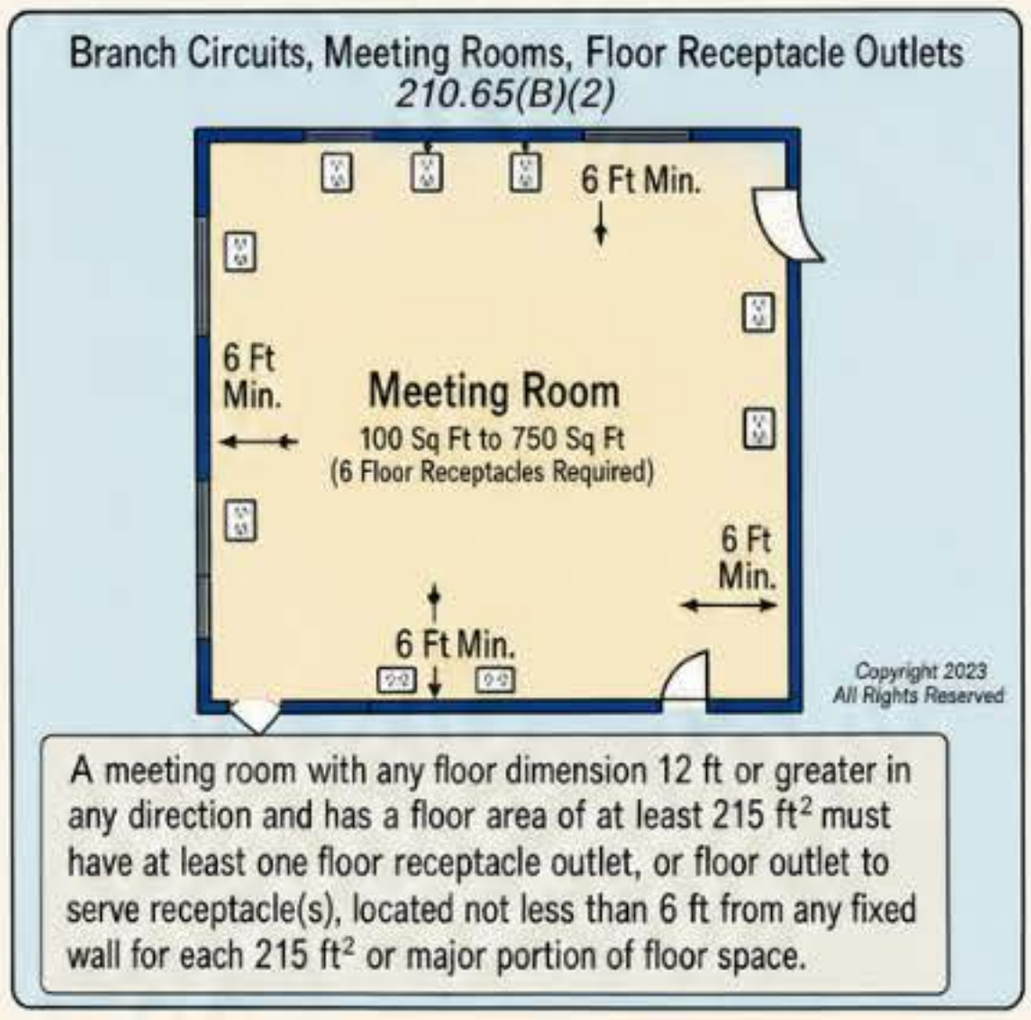


Figure 210–111

210.70 Lighting Outlet Requirements

(A) Dwelling Unit Lighting Outlets. Lighting outlets must be installed in:

(1) Habitable Rooms. At least one lighting outlet controlled by a listed wall-mounted control device must be installed in every habitable room, kitchen, and bathroom area of a dwelling unit. The wall-mounted control device must be located on a wall near an entrance to the room. Figure 210–112

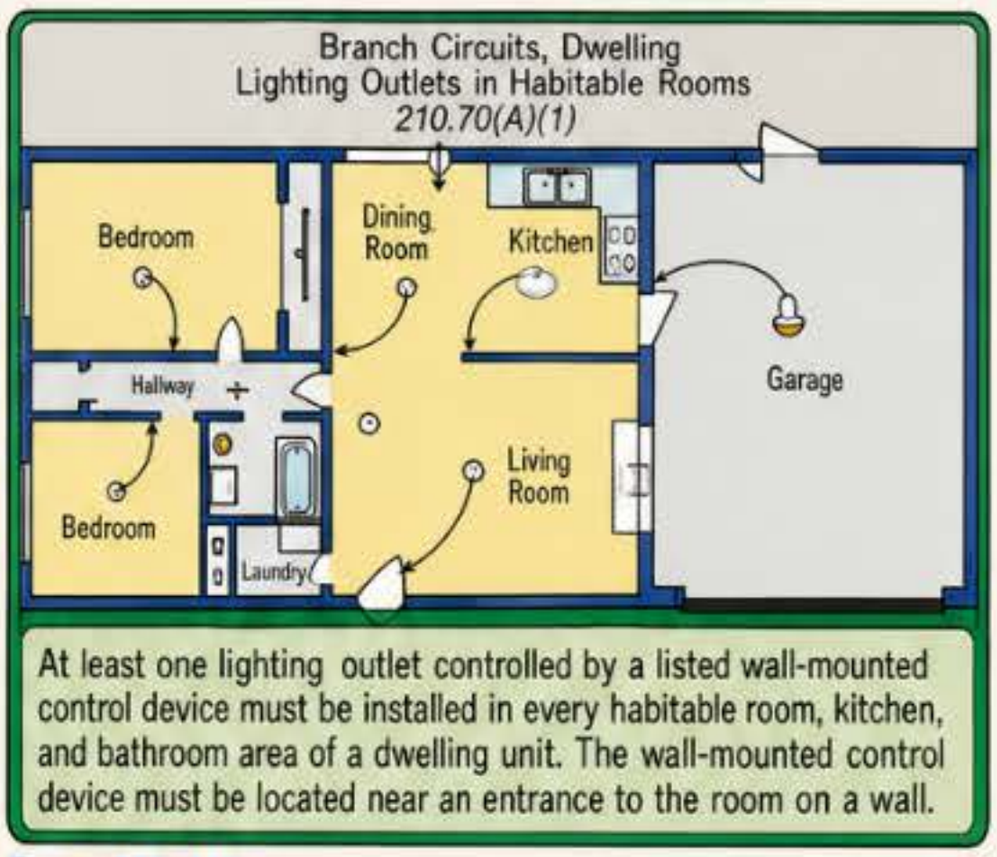


Figure 210–112

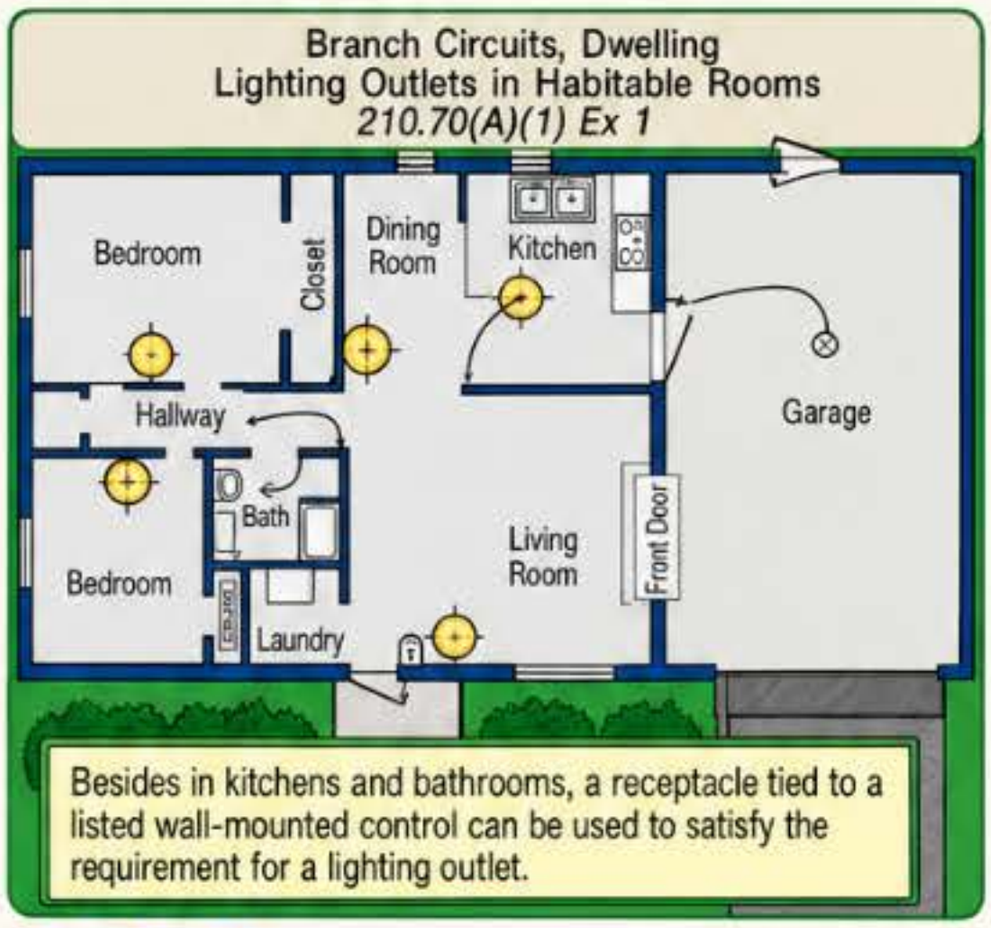
210.70 | Branch Circuits

Author's Commentary:

- Refer to the meaning of "Lighting Outlet" in Article 100.
- Refer to the meaning of "Habitable Room" in Article 100.

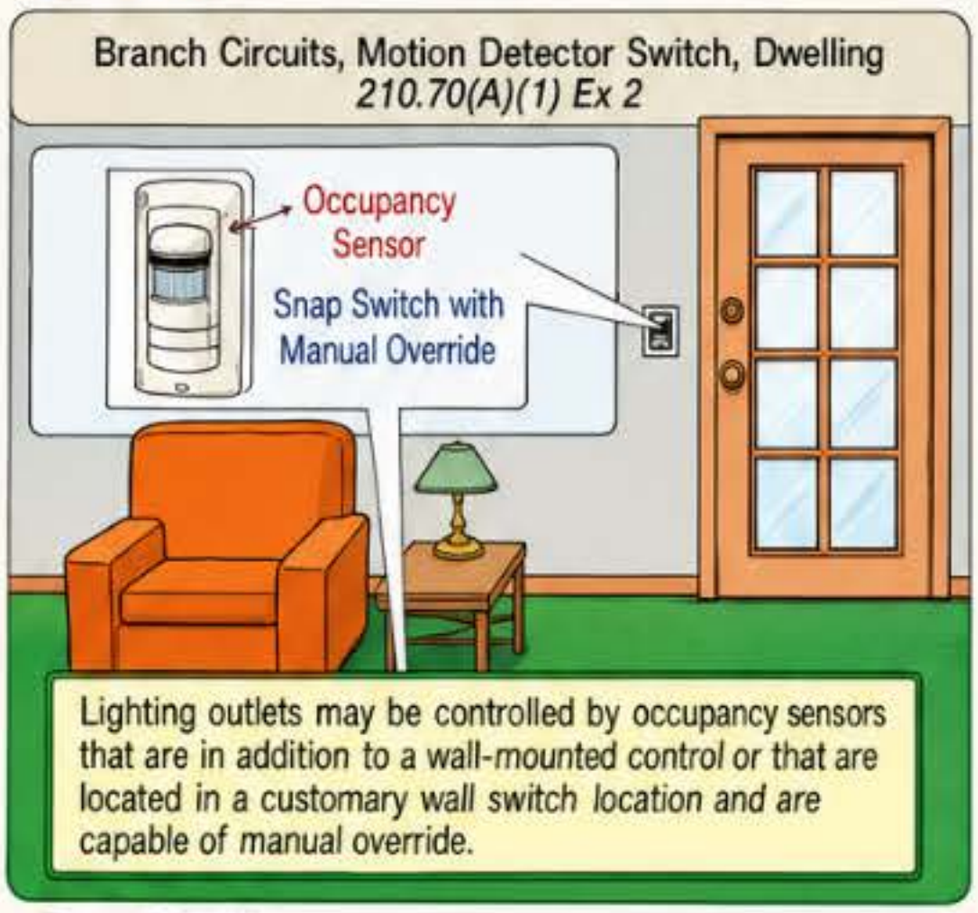
— Michael Hamilton

Ex 1: *Besides in kitchens and bathrooms, a receptacle controlled by an approved wall-mounted control device can serve in place of a lighting outlet.* Figure 210-113



▶ Figure 210-113

Ex 2: *Lighting outlets can be controlled by occupancy sensors that are in addition to a wall-mounted control device or are placed in a customary wall switch location and are capable of manual override.* Figure 210-114

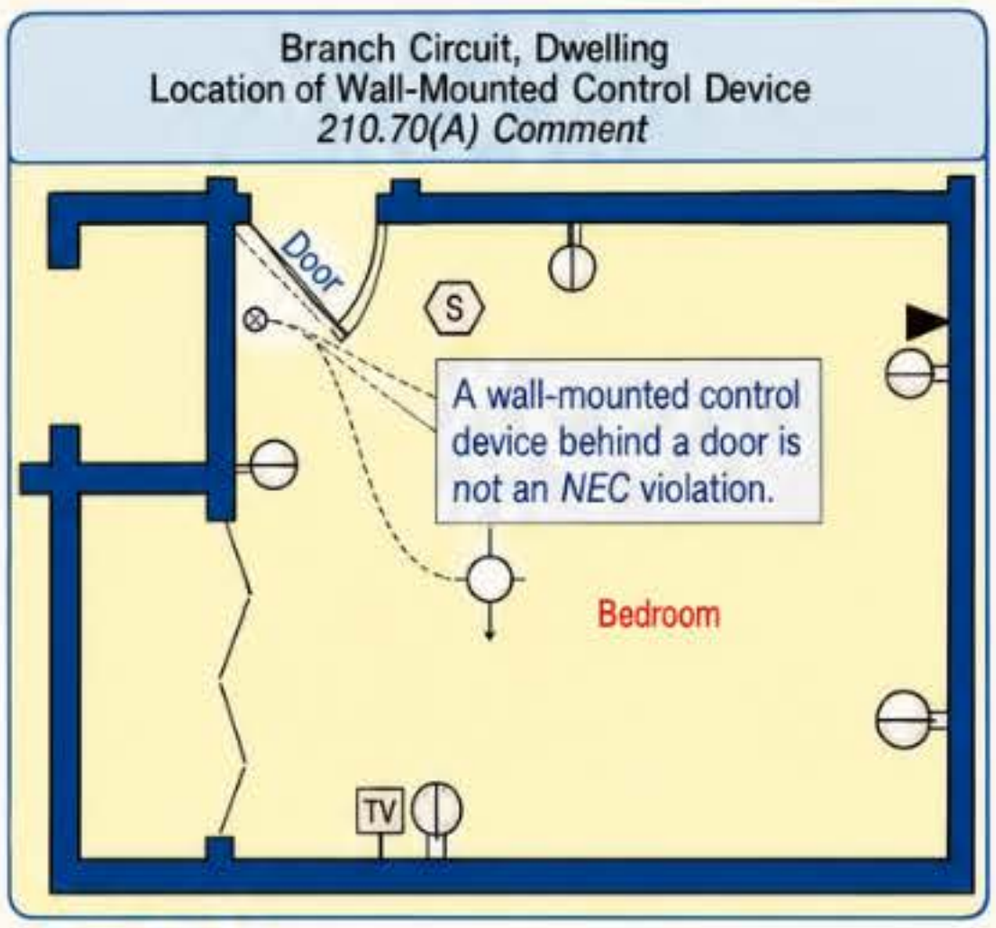


▶ Figure 210-114

Author's Commentary:

The *Code* identifies where a lighting outlet must be placed, though it does not dictate the position of the wall-mounted control device. Typically, you wouldn't want the switch located behind a door or in other hard-to-reach spots, but the *NEC* doesn't require the switch to face a specific side of the door. When in doubt as to the best location for a switch, consult the plans or ask the customer.

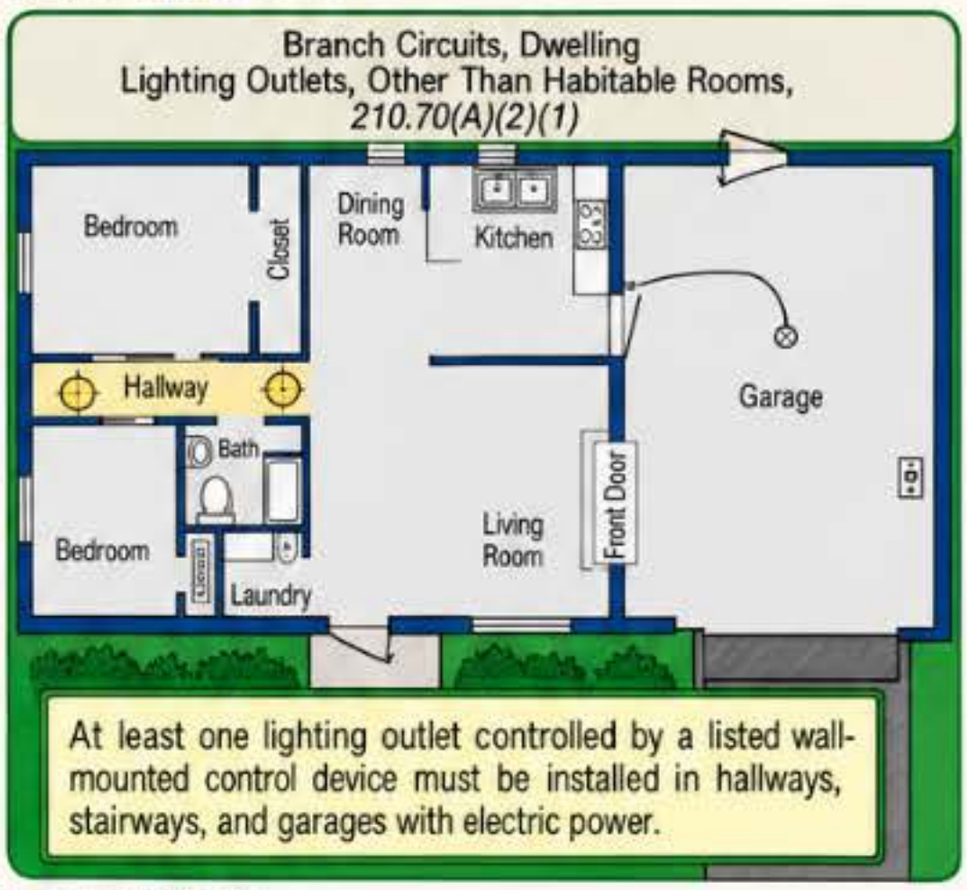
— Michael Hamilton



▶ Figure 210-115

(2) Other Than Habitable Rooms

(1) Hallways, Stairways, and Garages. At least one lighting outlet controlled by a listed wall-mounted control device must be installed in hallways, stairways, and garages with electric power. Figure 210-116



▶ Figure 210-116

(2) Exterior Entrances. Homes that include an attached or detached garage with electricity must have at least one outdoor outlet controlled by a listed, wall-mounted control device. That outlet must supply light at outdoor entry points or exit paths with grade-level access.

If the garage door is not intended for outdoor entry or exit, this requirement does not apply. See **Figure 210–117**.

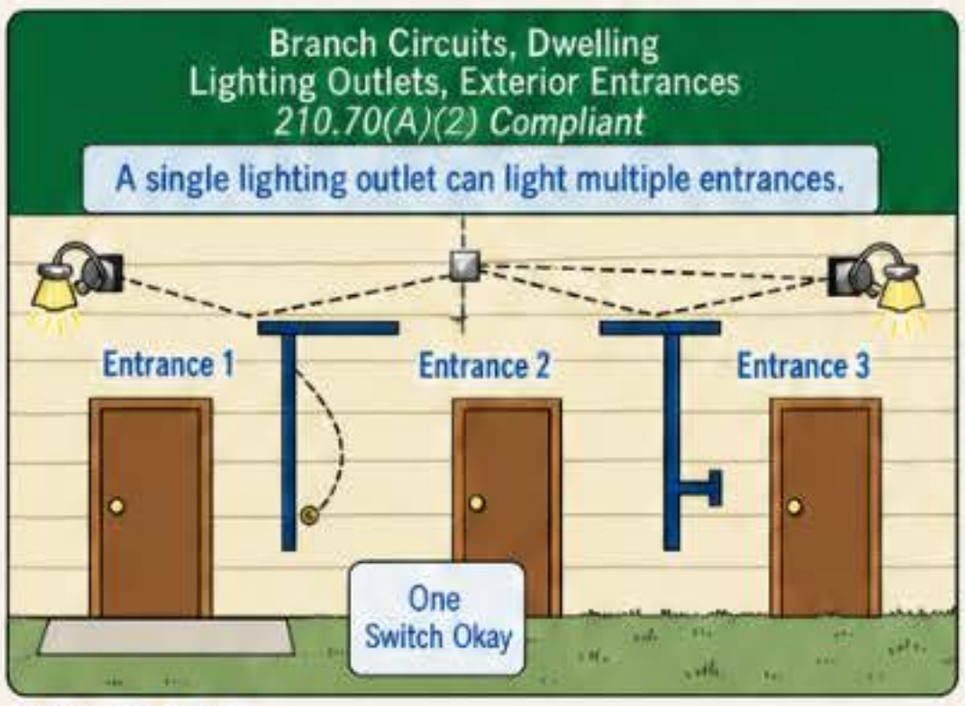
Branch Circuits, Dwelling
Lighting Outlets, Exterior Entrances
210.70(A)(2)

For homes with attached garages, and for detached garages that have power, at least one outdoor outlet must be controlled by a listed, wall-mounted control device. This outlet must provide lighting for outside entrances or exit ways with access at grade level.

▶ **Figure 210–117**

Author's Commentary:
One exterior lighting outlet can illuminate more than one entry or exit located at ground level. See Figure 210–118.
— Michael Hamilton

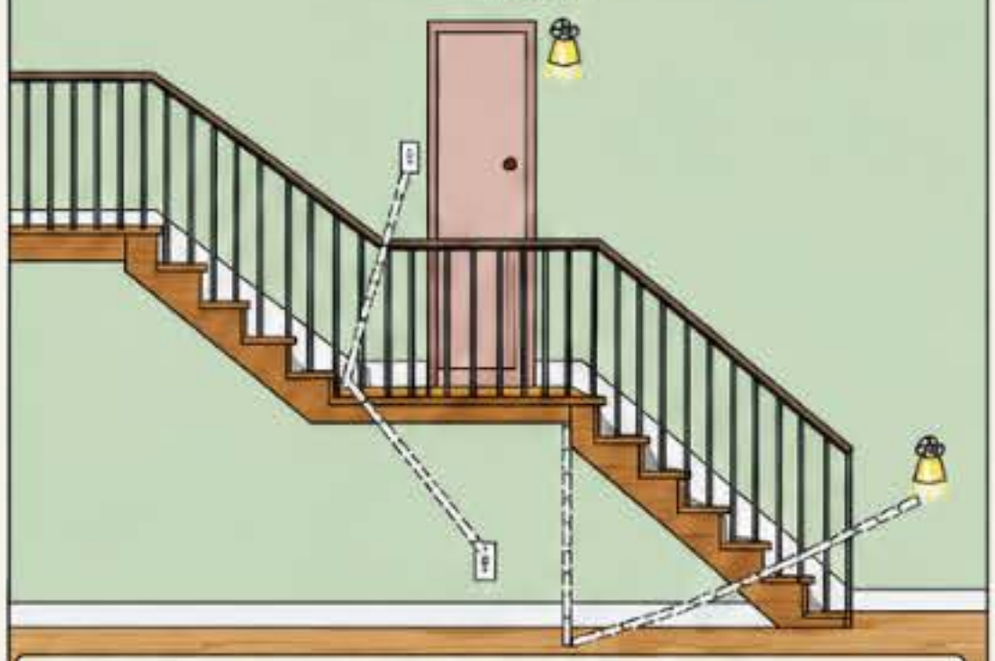
Branch Circuits, Dwelling
Lighting Outlets, Exterior Entrances
210.70(A)(2) Compliant



▶ **Figure 210–118**

(3) Stairway. When a stairway includes six or more risers, a listed wall-mounted control device must be installed for the stairway lighting at every floor landing. Each landing level must also include an entryway. **Figure 210–119**.

Branch Circuits, Dwelling
Lighting Outlets, Stairway, Wall-Mounted Control Devices
210.70(A)(2)(3)

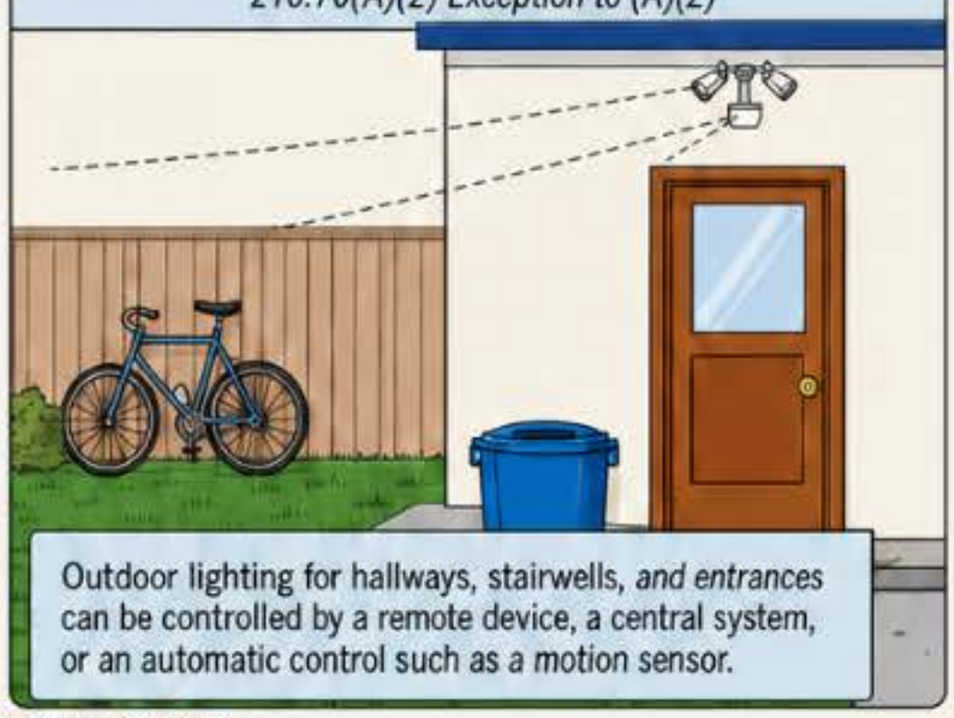


Where lighting is installed in interior stairways with six or more risers, a listed wall-mounted control device must be installed at each floor level and at each landing. Each level must have an entryway.

Figure 210–119

Examples (1), (2), and (3): Lighting outlets for hallways, stairwells, and outdoor entrance points can be operated by a remote-control device, a central control system, or an automatic control device. See **Figure 210–120**.

Branch Circuits, Dwelling
Lighting Outlets, Alternative Switching
210.70(A)(2) Exception to (A)(2)



Outdoor lighting for hallways, stairwells, *and entrances* can be controlled by a remote device, a central system, or an automatic control such as a motion sensor.

▶ **Figure 210–120**

(4) Dimmer Control. In stairways where 210.70(A)(2)(3) applies, the lighting outlets must be controlled by a listed, wall-mounted control device that supports full-range dimming at each switch location per 210.70(A)(2)(3).

(B) Guest Rooms or Guest Suites. Every habitable *room and bath area in a guest room or guest suite in a hotel, motel, or similar lodging must have at least one lighting outlet controlled by a listed, wall-mounted control.*

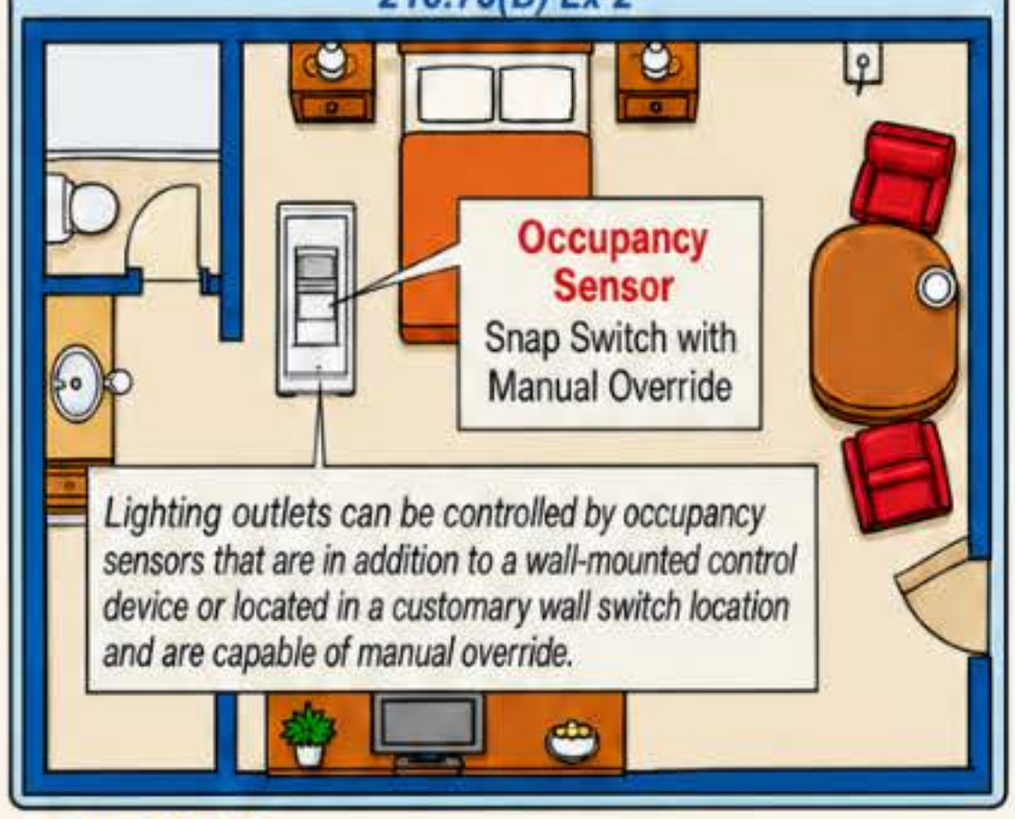
Example: In addition to bath and kitchen spaces, a receptacle controlled by a listed, wall-mounted control is allowed. Figure 210–121.

Branch Circuits, Guest Rooms or Guest Suites Wall-Mounted Control Device
210.70(B) Ex 1

▶ Figure 210–121

> ***Author's Commentary:***
> *Example 2 explains that occupancy sensor controlled lighting outlets may be used in addition to, or instead of, a manual wall switch or switch that overrides automatically.*
>
> ***— Michael Hamilton***

Branch Circuits, Guest Rooms or Guest Suites Occupancy Sensors
210.70(B) Ex 2

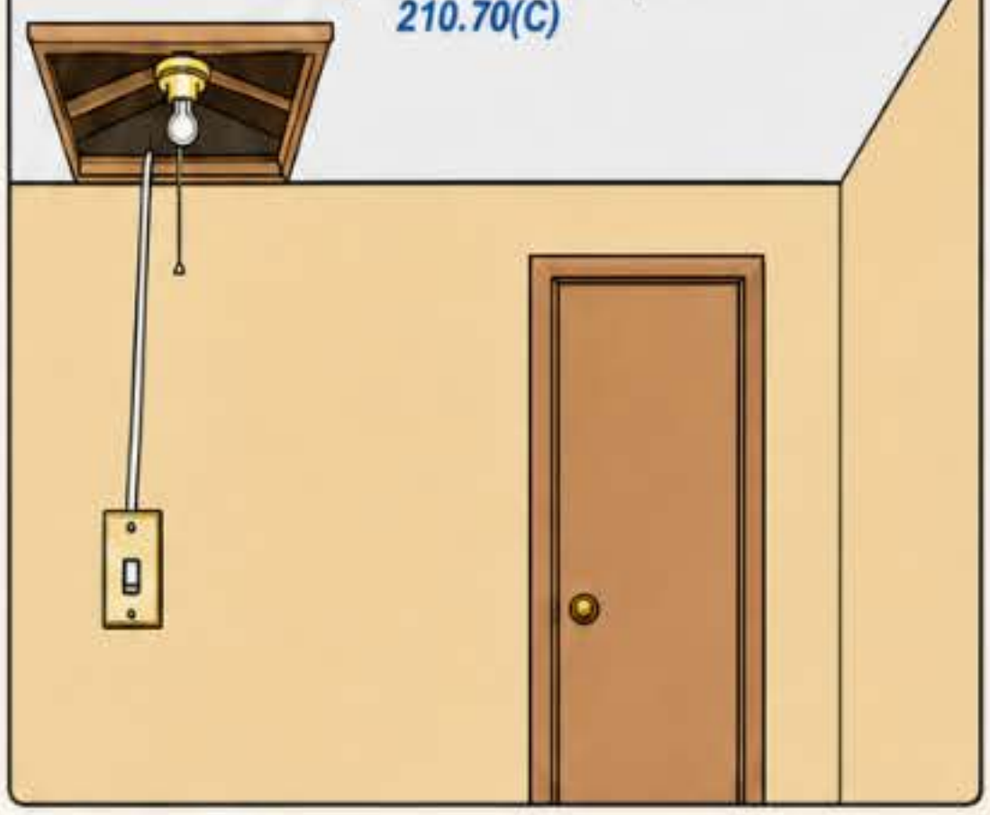


▶ Figure 210–122

> ***Author's Commentary:***
> *Two different methods are shown in Example 2. Both use occupancy sensors and allow the user to override the control manually.*
>
> ***— Michael Hamilton***

(C) Lighting Outlets, Storage and Equipment Spaces. At least one lighting outlet that contains a switch or is controlled by a wall switch or listed wall-mounted control device must be installed in attics, underfloor spaces, utility rooms, and basements used for storage or containing equipment that requires servicing. ▶ Figure 210–123

Branch Circuits, Lighting Outlets, All Occupancies, Storage and Equipment Spaces
210.70(C)



▶ Figure 210–123

> ***Author's Commentary:***
> *This example illustrates a single switched lighting outlet in a utility or storage area that includes equipment needing service access.*
>
> ***— Michael Hamilton***

The switch or wall-mounted control device must be located at the usual point of entrance to these spaces. The lighting outlet must be located at each entry that permits access to the attic and underfloor space, utility room, or basement.

Where a lighting outlet is installed for equipment requiring service, it must be installed at or near that equipment.

> ***Author's Commentary:***
> *The control device goes where you normally enter the space. Every access point to the area must have a lighting outlet.*
>
> ***— Michael Hamilton***

> ***Code Connection:***
> *These requirements ensure adequate lighting is available in storage and equipment spaces to promote safe access and proper servicing, as required by* ***NEC 2023 Section 210.70(C).***

ARTICLE 215 FEEDERS

Introduction to Article 215—Feeders

Article 215 establishes the requirements for installing and evaluating the ampacity of feeders. The rules for feeders are comparable in many respects to those for branch circuits. However, in some cases feeders follow rules that are more similar to service conductors. It is important to understand the differences among these three types of circuits so that you can apply the *Code* correctly.

Feeders are the conductors that run between the service disconnect, a separately derived system, or another supply source, and the final branch-circuit overcurrent protective device. Conductors on the supply side of the final overcurrent protective device—which also power the circuit and final branch-circuit conductors—may be considered part of Article 210 (Part I, *Branch Circuits*) or Article 100 (Definitions).

Service conductors begin at the service point and terminate at the service disconnect [Article 100 (2023 Definitions)]. If no utility service is present, and the electric supply is provided by an on-site source such as a generator or other power source, then the conductors from that source to the service disconnect are treated as service conductors.

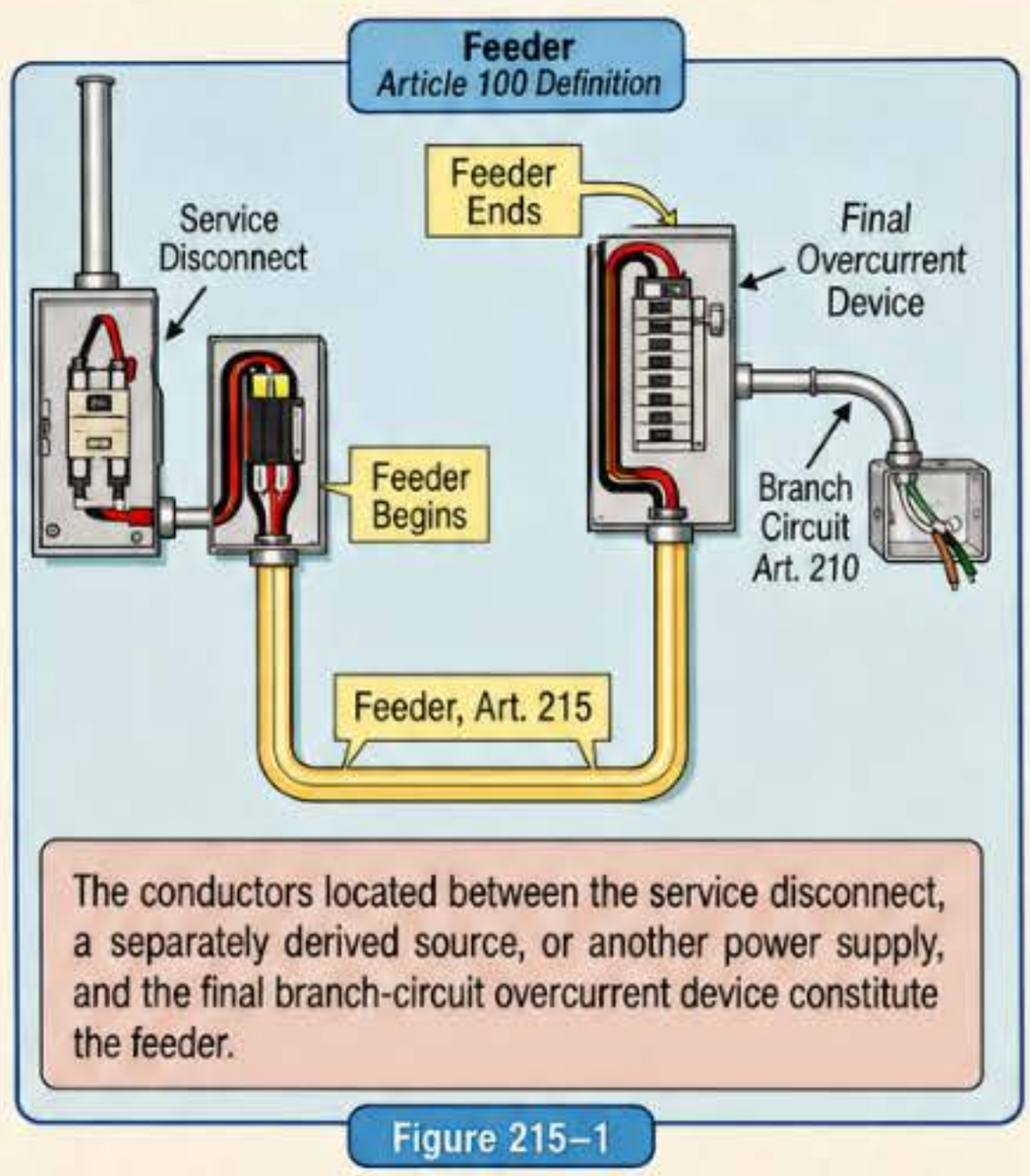


Figure 215–1

It can be confusing to distinguish among feeder, branch-circuit, and service conductors, which is why it is essential to review each installation carefully using the definitions in Article 100 to ensure compliance with the correct *NEC* rules.

215.1 Scope

Article 215 covers the installation, sizing of conductors, and protection against overcurrent for feeder conductors. ▶ Figure 215–2

Author's Commentary:

▶ *Article 100 defines "feeders" as the conductors that run between the service disconnect, a separately derived system, or another source of electrical power and the final branch-circuit overcurrent device.* ▶ *Figure 215–3*

215.2 Conductor Sizing

(A) Feeders—Sizing

(1) General. Feeder conductors must be sized to handle at least the largest of the calculated loads in (a) or (b) and must satisfy the equipment termination requirements of *110.14(C)*. ▶ *Figure 215–4*

Branch Circuits

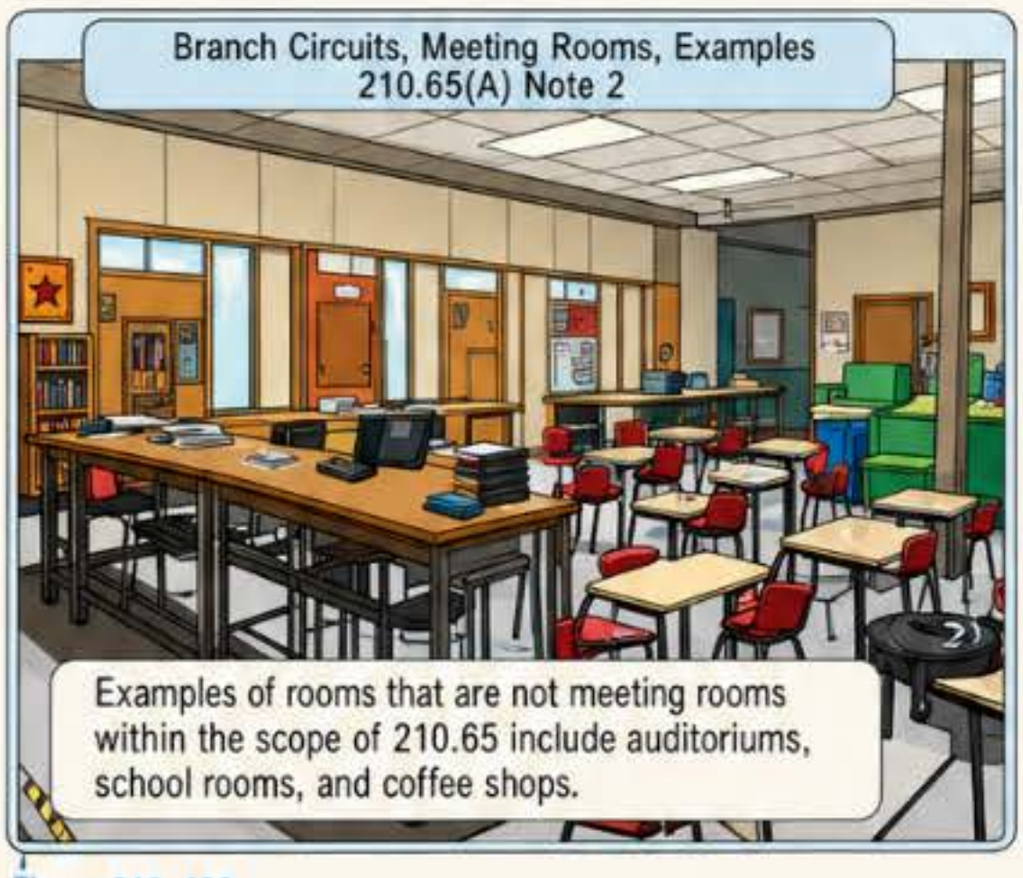


Figure 210–109

(1) The required number of receptacle outlets must be determined in accordance with 210.52(A)(1) through (A)(4). Their location can be determined by the installer, designer, or building owner. ▶ Figure 210–110

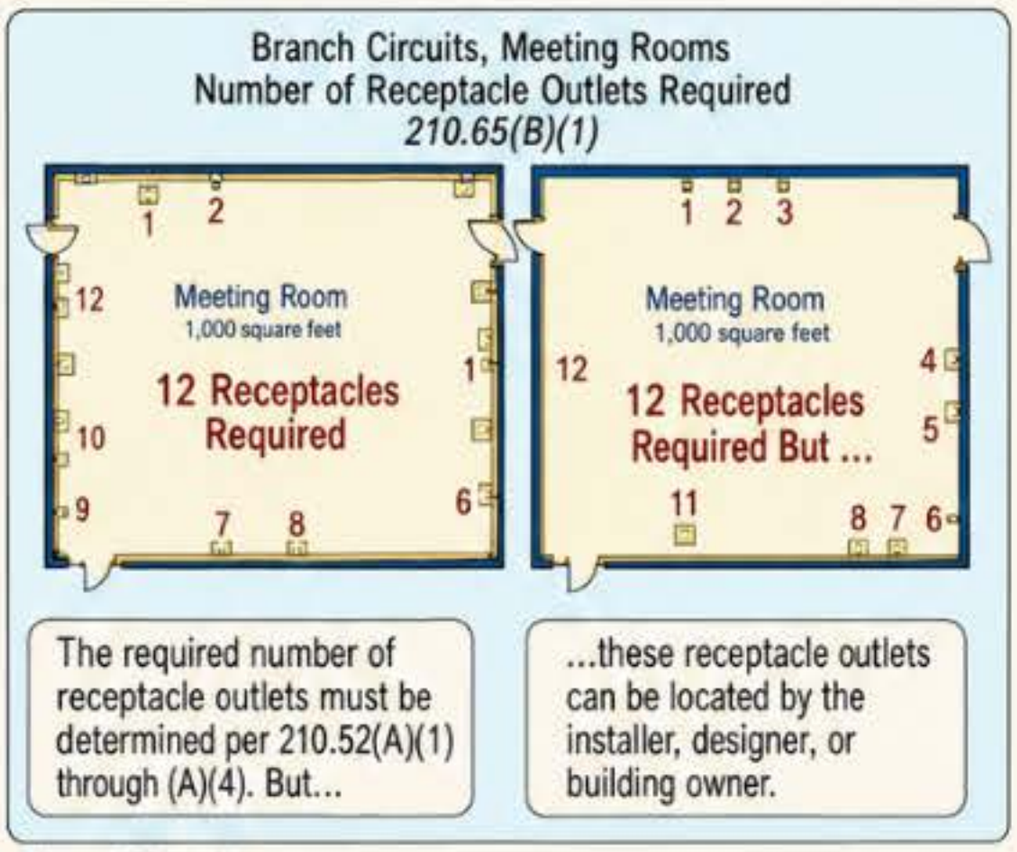


Figure 210–110

(2) A meeting room with any floor dimension 12 ft or greater in any direction and has a floor area of at least 215 sq ft must have at least one floor receptacle outlet or floor outlet to serve a receptacle(s) *located not less than 6 ft from any fixed wall for each 215 sq ft or major portion of floor space.* ▶ Figure 210–111

Note 1: *See 314.27(B) for floor boxes used for receptacles located in the floor.*

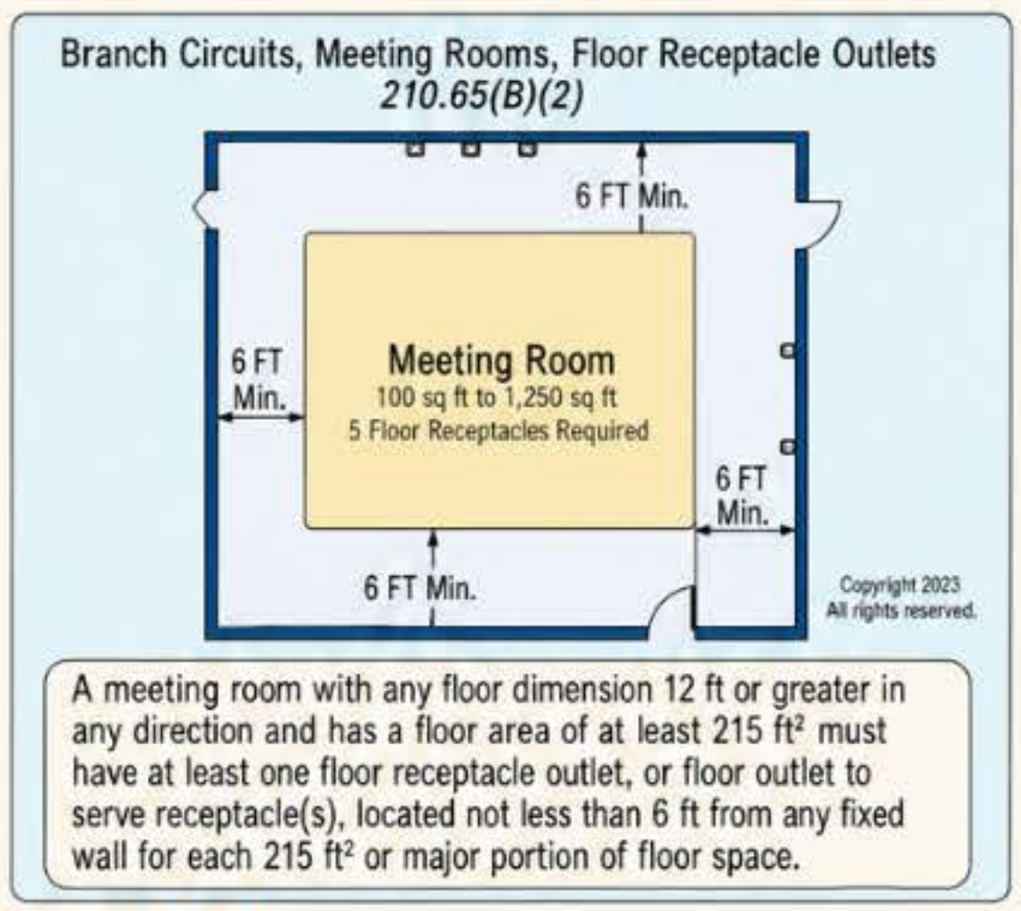


Figure 210–111

210.70 Lighting Outlet Requirements

(A) Dwelling Unit Lighting Outlets. Lighting outlets must be installed in:

(1) Habitable Rooms. At least one lighting outlet controlled by a listed wall-mounted control device must be installed in every habitable room, kitchen, and bathroom area of a dwelling unit. The wall-mounted control device must be located on a wall near an entrance to the room. ▶ Figure 210–112

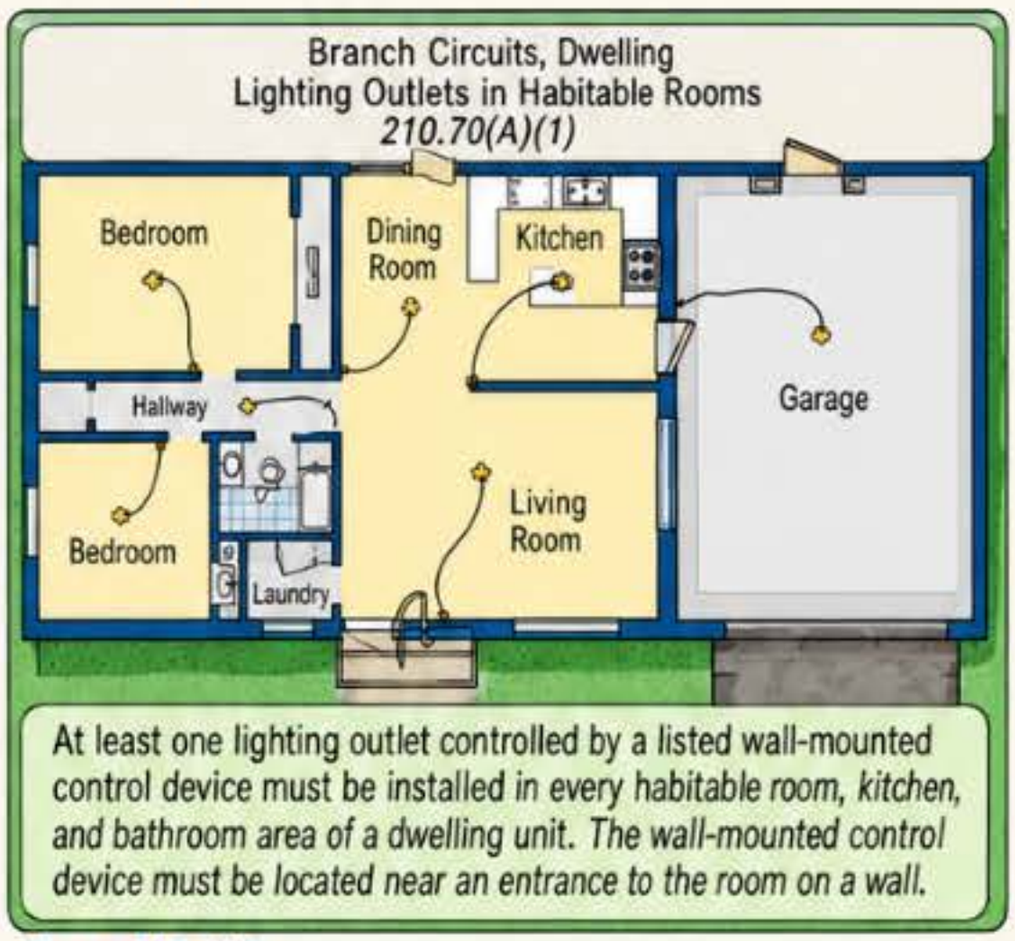


Figure 210–112

210.70 | Branch Circuits

Author's Commentary:

- *Consult the definition of "Lighting Outlet" in Article 100.*
- *Consult the definition of "Habitable Room" in Article 100.*

Ex 1: *Besides kitchens and bathrooms, a receptacle regulated by a listed wall-mounted control device may serve as a lighting outlet.*
— Michael Hamilton

Branch Circuits, Dwelling
Lighting Outlets in Habitable Rooms
210.70(A)(1) Ex 1

Besides kitchens and bathrooms, a receptacle regulated by a listed wall-mounted control device may be used as a lighting outlet.

▶ Figure 210-113

Ex 2: *Lighting outlets can be controlled by occupancy sensors that are in addition to a wall-mounted control device or located in a customary wall switch location and are capable of manual override.*
— Michael Hamilton

Branch Circuits, Motion Detector Switch, Dwelling
210.70(A)(1) Ex 2

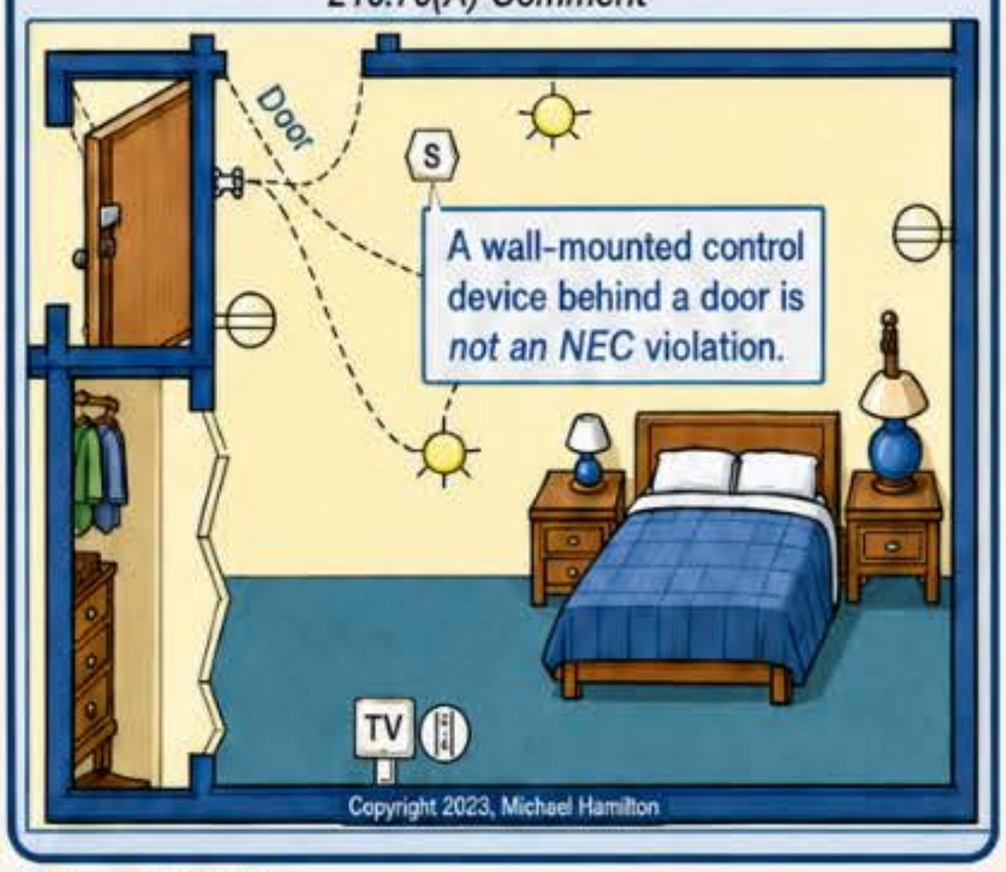
Lighting outlets may be controlled by occupancy sensors that are in addition to a wall-mounted control device or located in a customary wall switch position and that can be manually overridden.

▶ Figure 210-114

Author's Commentary:

The Code indicates where the lighting outlet must be located, but it does not require the wall-mounted control device to be in that same location. Normally, you would not want a switch tucked behind a door or in another awkward spot, but the NEC does not force you to move the switch to match the door's swing. If the light switch ends up in an odd place, consult the job plans or ask the customer.
— Michael Hamilton

Branch Circuit, Dwelling
Location of Wall-Mounted Control Device
210.70(A) Comment

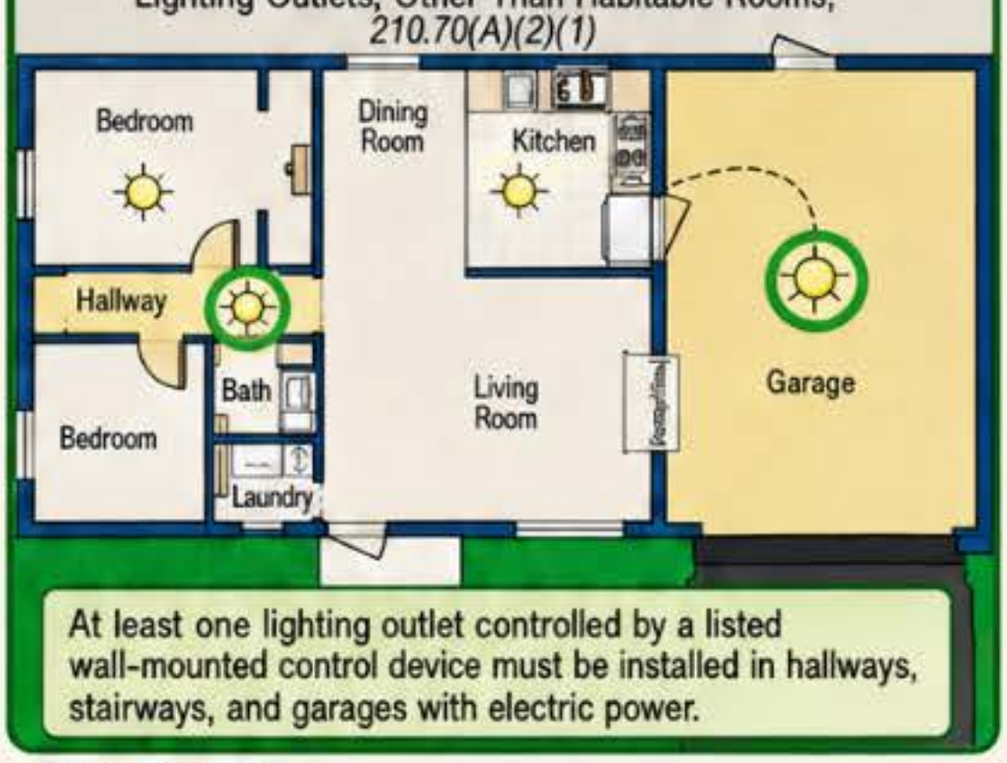


▶ Figure 210-115

(2) Other Than Habitable Rooms

(1) Hallways, Stairways, and Garages. *At least one lighting outlet controlled by a listed wall-mounted control device must be installed in hallways, stairways, and garages with electric power.*
— Michael Hamilton

Branch Circuits, Dwelling
Lighting Outlets, Other Than Habitable Rooms,
210.70(A)(2)(1)



At least one lighting outlet controlled by a listed wall-mounted control device must be installed in hallways, stairways, and garages with electric power.

▶ Figure 210-116

Solution:

Step 1: *Look up conductor ampacity at 90°C terminations to handle 100 percent of a 320A continuous load. When terminals are identified to operate continuously at each end of a conductor set rated 90°C, the ampacity adjustment for 90°C terminations can be applied to the 90°C column in Table 310.16 (215.2(A)(1)(a) Ex 2). A 320A load is rated 320A at 90°C.*

Step 2: *Since the conductors are safeguarded by a 400A circuit breaker, size the conductors using the 320A at 90°C value shown to be protected by a 400A circuit breaker. A 400 kcmil conductor rated 326A at 90°C is the minimum size permitted (240.4(B)).*

Answer: *(c) 400 kcmil*

Ex 3: *Neutral conductors must have an ampacity of not less than 100 percent of the continuous and noncontinuous loads.*

▶ Example

Question: *What size neutral conductor rated 90°C is required for a 200A continuous neutral load if the terminals are rated 75°C?* Figure 215-10

(a) 3/0 AWG (b) 4/0 AWG (c) 250 kcmil (d) 300 kcmil

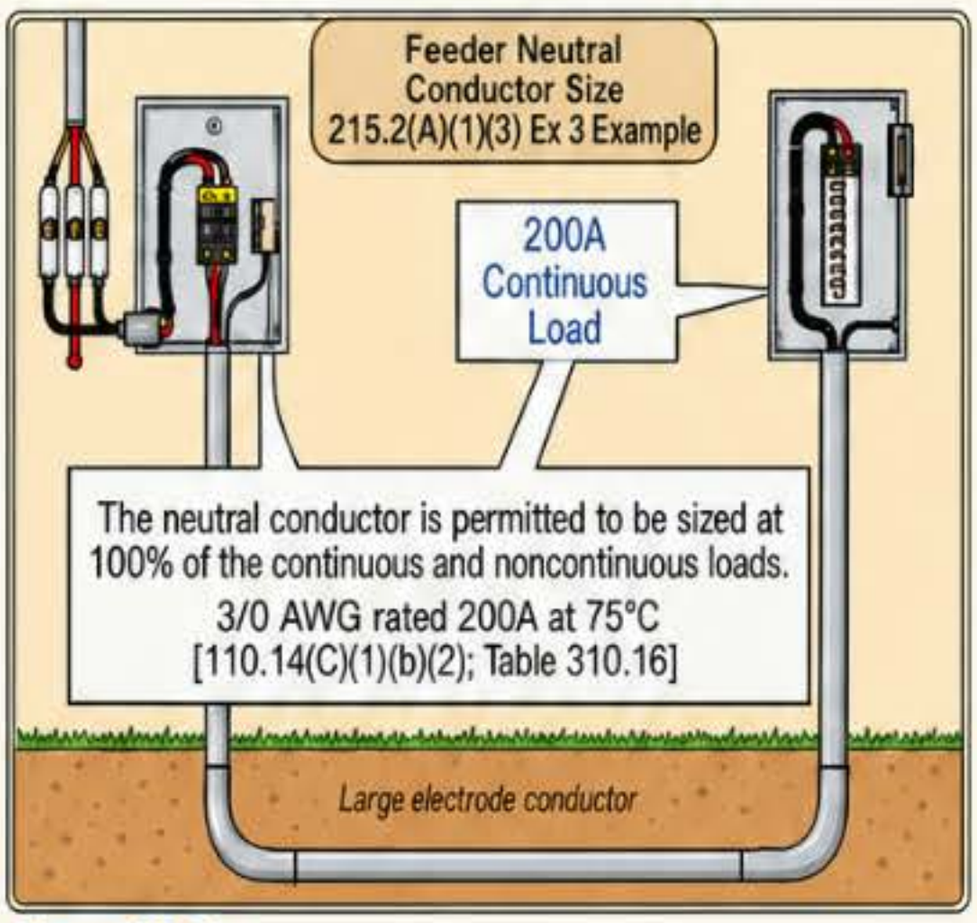


Figure 215-10

Solution:

Step 1: *Size the neutral conductor to carry the 200A continuous load at 100 percent.*

Step 2: *Size the conductors in accordance with 110.14(C)(1)(b)(2) and Table 310.16.*

3/0 has an ampacity of 200A (Table 310.16, 75°C column).

Answer: *(a) 3/0 AWG [110.14(C)(1)(b)]*

(b) With Conductor Ampacity Adjustment and Correction. Conductors must be sized to carry not less than 100 percent of the continuous load, plus 100 percent of the noncontinuous load after applying the conductor ampacity adjustment and/or correction in accordance with 310.14.

➤ Figure 215-11

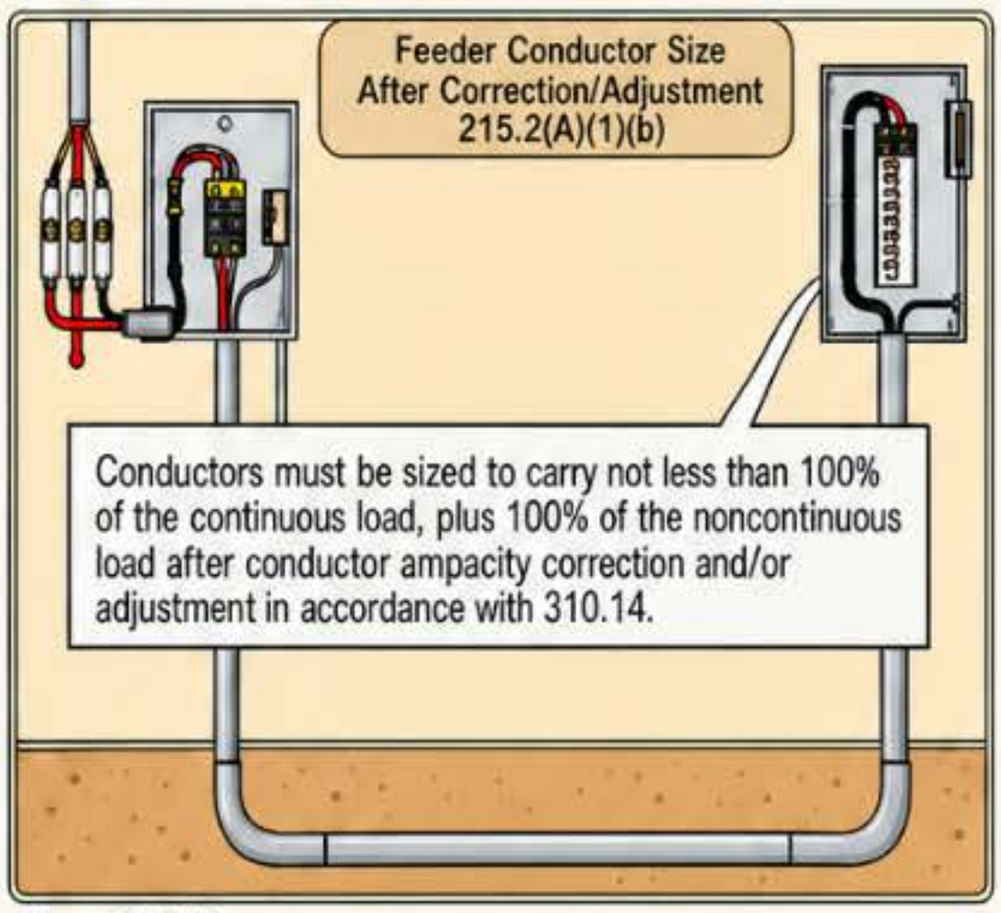


Figure 215-11

▶ Example 1

Question: *What size conductors rated 90°C are required for a feeder combining four current-carrying conductors supplying a 180A continuous load in an ambient temperature of 90°C where the equipment terminals are rated 75°C?* Figure 215-12

(a) 4/0 AWG (b) 300 kcmil (c) 500 kcmil (d) 600 kcmil

Author's Commentary:

According to 215.2(A)(1), the feeder conductor size is determined by the larger of 215.2(A)(1)(a) and (b).

— Michael Hamilton

Feeders | 215.2

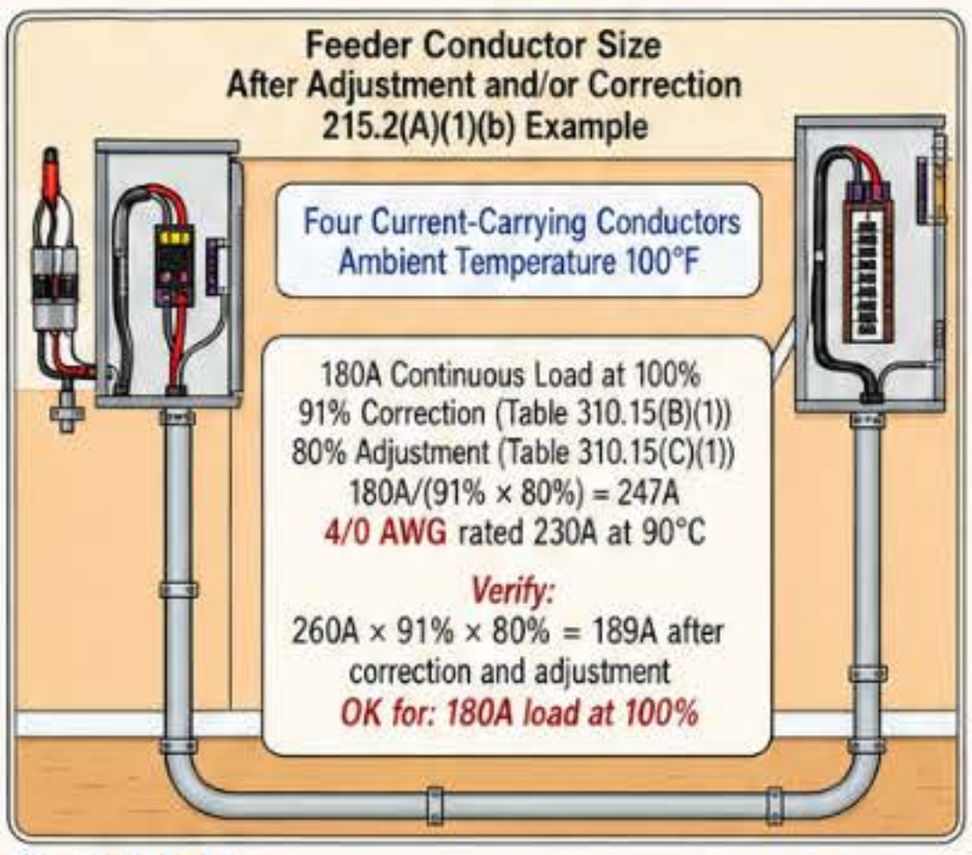


Figure 215–12

Solution:

Step 1: *The current-carrying conductors must be sized for an ampacity of not less than 180 amperes after all applicable temperature corrections (Table 310.15(B)(1)) and adjustment (Table 310.15(C)(1)) are applied. This is based on the conductor's insulation rating of 90°C. One way to size the conductors is to first determine the required ampacity by applying a 180A continuous load at 100% after both correction and adjustment.*

Conductor Ampacity at 90°C – Continuous Load at 100% (Correction + Adjustment)

Continuous Load – 180A

Correction (Table 310.15(B)(1)) – 91% (100°F, with 90°C conductor)

Adjustment (Table 310.15(C)(1)) – 80% (four current-carrying conductors)

Conductor Ampacity at 90°C Column = 180A/(91% × 80%)

Conductor Ampacity at 90°C Column = 180A/73%

Conductor Ampacity at 90°C Column = 247A

Step 2: *Select the conductors from the 90°C column of Table 310.15 (in 310.16(A)(2)).*

4/0 AWG is suitable because it has an ampacity of 260A at 90°C before any correction and adjustment.

Step 3: *Verify that the ampacity of 4/0 AWG after correction and adjustment is capable of carrying 180 percent of the 180A continuous load at 90°C.*

Conductor Ampacity after Correction and Adjustment = Conductor Ampacity × Correction × Adjustment

Conductor Ampacity at 90°C = 260A (Note: 260A is from Step 2.)*

Correction = 91%

Adjustment = 80%

Conductor Ampacity after Correction and Adjustment = 260A × 91% × 80%

Conductor Ampacity after Correction and Adjustment = 189A

4/0 with 90°C insulation has an ampacity rating of 189A which is more than enough for the 180A continuous load.

Step 4: *Verify that the ampacity of 4/0 AWG at 75°C without correction and adjustment is capable of carrying the 180A continuous load at 125 percent in accordance with 215.2(A)(1)(a).*

Conductor Ampacity at 125% = 180A × 125%

Conductor Ampacity at 125% = 225A

4/0 AWG is suitable because it is rated 230A at 75°C (Table 310.15).

Answer: *(a) 4/0 AWG*

▶ Example 2

Question: *What size conductors rated 90°C are required for a feeder connecting four current-carrying conductors supplying a 320A continuous load in an ambient temperature of 100°F where the equipment terminals are rated 75°C?* * **Figure 215–13**

(a) 300 kcmil (b) 400 kcmil (c) 500 kcmil (d) 600 kcmil

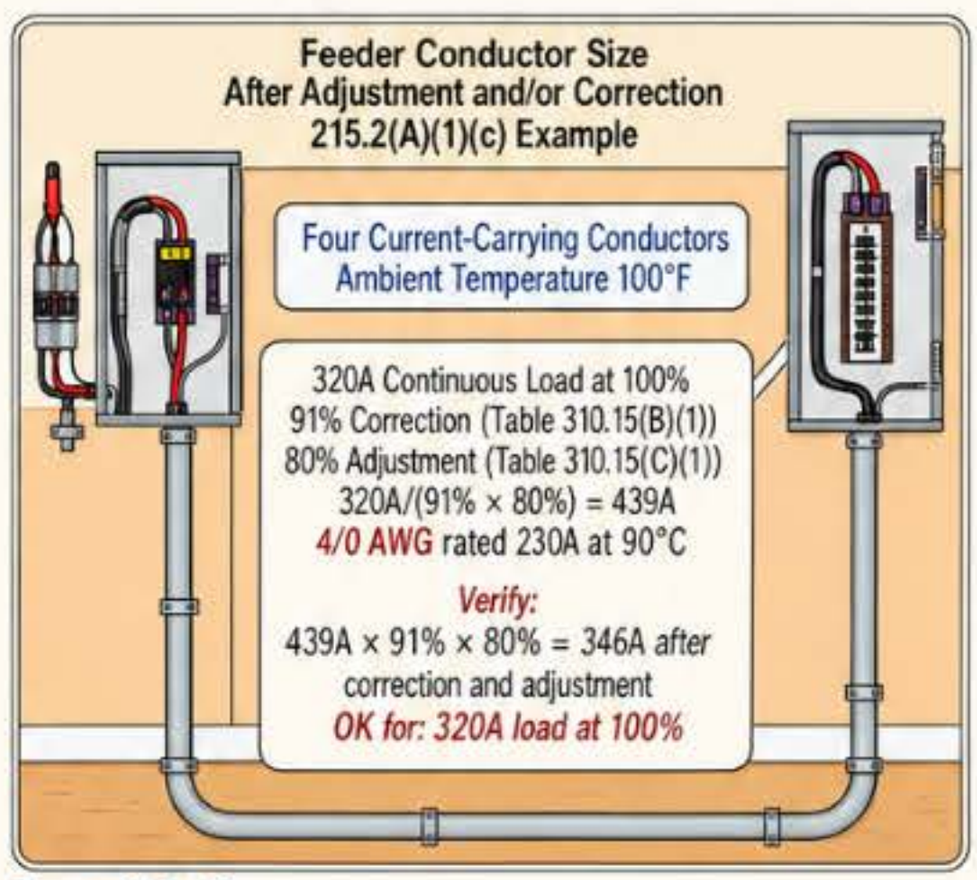


Figure 215–13

Solution:

Step 1: *The current-carrying conductors must have an ampacity of not less than 320A after all applicable temperature correction (Table 310.15(B)(1)) and adjustment (Table 310.15(C)(1)), based on the conductor's insulation rating of 90°C. One way to size the conductors is to determine the conductor ampacity needed to carry a 320A continuous load at 100% after correction and adjustment.*

• • •

Conductor Ampacity at 90°C = Continuous Load at 100%/ (Correction × Adjustment)

Continuous Load = 320A

Correction [Table 310.15(B)(1)] = 91% (100°F with 90°C Conductor)

Adjustment [Table 310.15(C)(1)] = 80% (four current-carrying conductors)

Conductor Ampacity at 90°C Column = 320A/(91% × 80%)
Conductor Ampacity at 90°C Column = 320A/73%
Conductor Ampacity at 90°C Column = 438A

Step 2: *Select the conductor from the 90°C column of Table 310.16.*

600 kcmil is suitable because it has an ampacity of 475A at 90°C before any correction and adjustment.

Step 3: *Verify that the ampacity of 600 kcmil after correction and adjustment is capable of carrying 100 percent of the 320A continuous load at 90°C.*

Conductor Ampacity after Correction and Adjustment = Conductor Ampacity × Correction × Adjustment

*Conductor Ampacity at 90°C = 475A**
*(*Note: 475A is from Step 2.)*
Correction = 91%
Adjustment = 80%

Conductor Ampacity after Correction and Adjustment = 475A × 91% × 80%
Conductor Ampacity after Correction and Adjustment = 346A

600 kcmil has an ampere rating of 346A which is more than enough for the 320A continuous load.

Step 4: *Verify that the ampacity of 600 kcmil at 75°C without correction and adjustment is capable of carrying the 320A continuous load at 125 percent in accordance with 215.2(A)(1)(a).*

Conductor Ampacity at 125% = 320A × 125%
Conductor Ampacity at 125% = 400A

600 kcmil is suitable because it is rated 420A at 75°C [Table 310.16].

Answer: *(d) 600 kcmil*

Author's Commentary: *To help electrical equipment operate efficiently, feeder conductors should be sized to avoid excessive voltage drop from exceeding 3 percent. In addition, the total voltage drop on both feeders and branch circuits should not exceed 5 percent.*

— Michael Hamilton

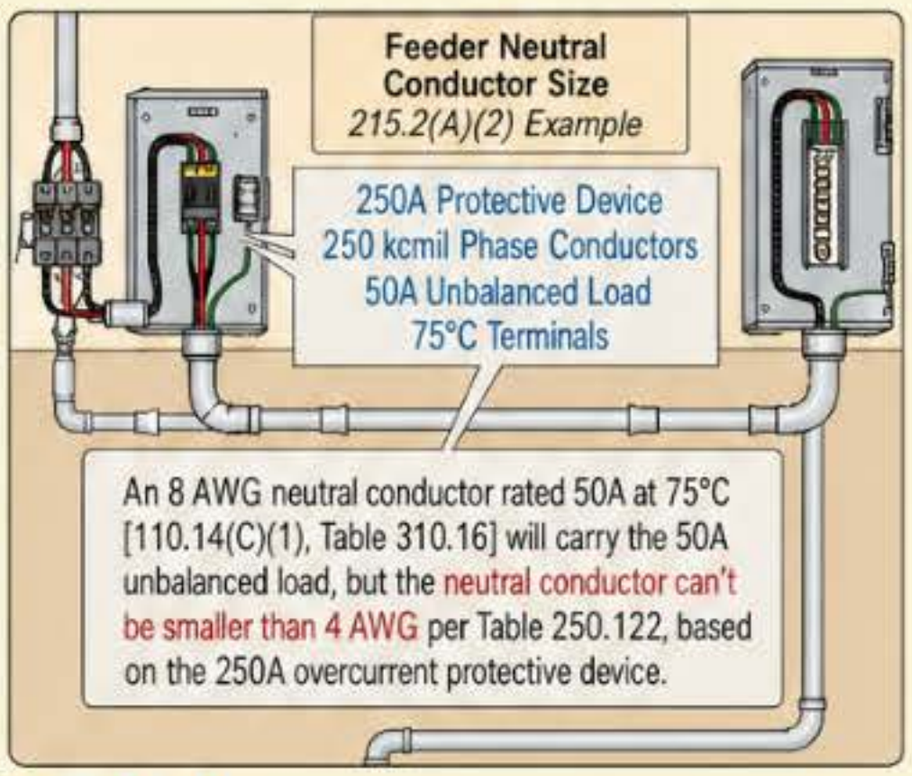
Note 3: See 210.19(A) Note 3 for voltage drop for branch circuits.

(2) Neutral Conductor Size. The neutral conductor must be sized to carry the maximum unbalanced load in accordance with 220.61 and is not permitted to be smaller than contained in 250.122, based on the rating of the feeder overcurrent protective device.

▶ Example

Question: *What size neutral conductor is required for a feeder consisting of 250 kcmil phase conductors and one neutral conductor protected by a 250A overcurrent protective device, where the unbalanced load is 50A with 75°C terminals?* ▶ **Figure 215–14**

(a) 8 AWG (b) 6 AWG (c) 4 AWG (d) 2 AWG



▶ **Figure 215–14**

Solution:

Section 220.61 and Table 310.16 permit an 8 AWG neutral conductor rated 50A at 75°C [110.14(C)(1) and Table 310.16] to carry the 50A unbalanced load, but the neutral conductor is not permitted to be smaller than 4 AWG [Table 250.122], based on the 250A overcurrent protective device.

Answer: *(c) 4 AWG*

215.3 Overcurrent Protection Sizing

Feeder overcurrent protective devices must have a rating of not less than 125 percent of the continuous loads, plus 100 percent of the noncontinuous loads.

Author's Commentary: *For feeder OCPDs, size them to at least 125 percent of the continuous load, and add 100 percent of any noncontinuous loads.*

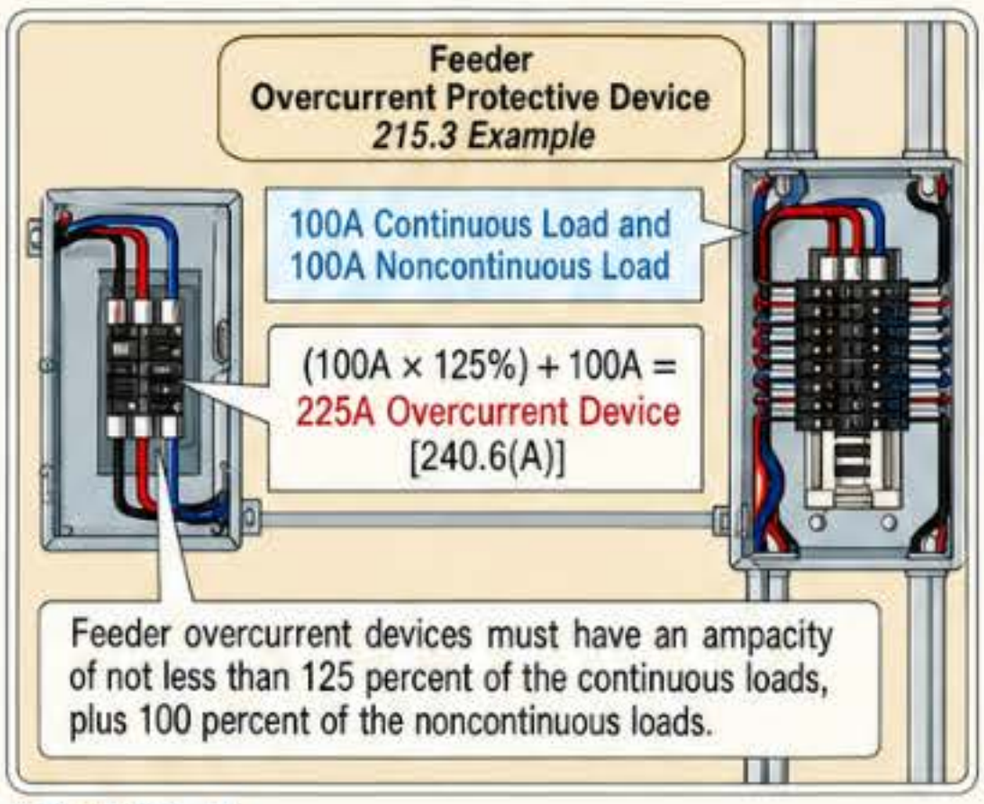
— Michael Hamilton

DEFINITIONS | From Michael Hamilton Publications

▶ Example

Question: *How much overcurrent protection is required for a 100A continuous load and a 100A noncontinuous load?* ▸ Figure 215–15

(a) 200A *(b) 225A* *(c) 250A* *(d) 300A*



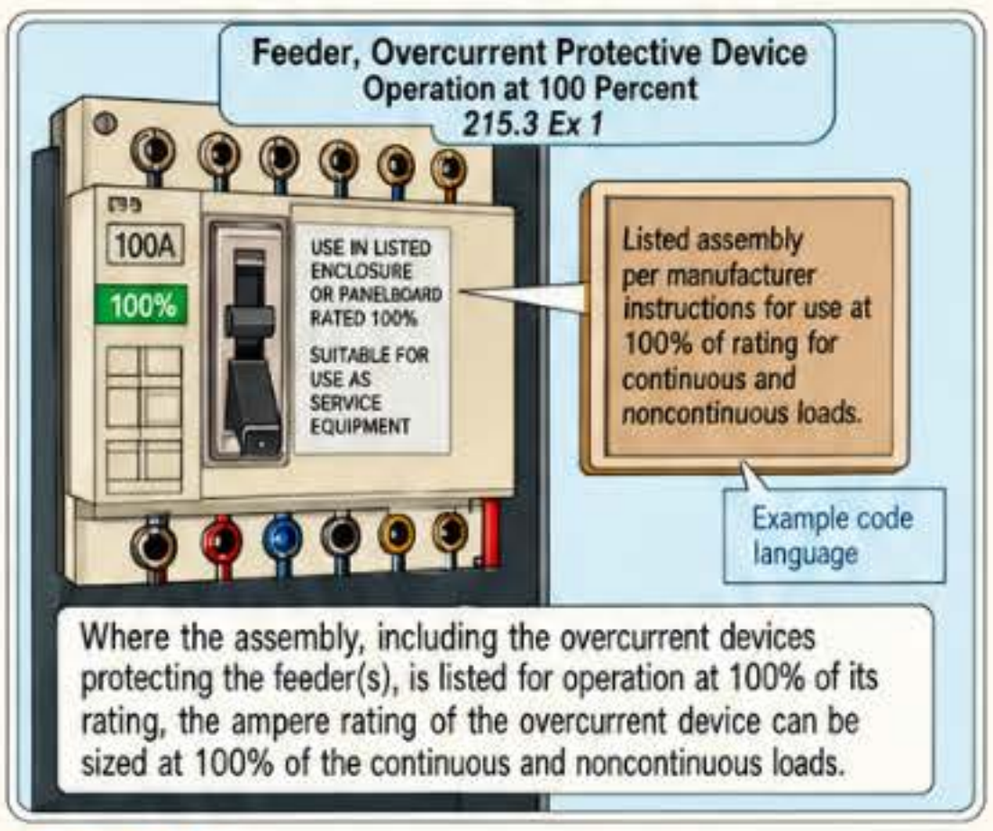
▲ Figure 215–15

Solution:

100A Continuous Load × 125% + 100A Noncontinuous Load = 225A [240.6(A)]

Answer: *(b) 225A*

Ex 1: *Where the assembly, including the overcurrent devices protecting the feeder(s), is listed for operation at 100 percent of its rating, the ampere rating of the overcurrent device can be sized at 100 percent of the continuous and noncontinuous loads.* ▸ Figure 215–16



▲ Figure 215–16

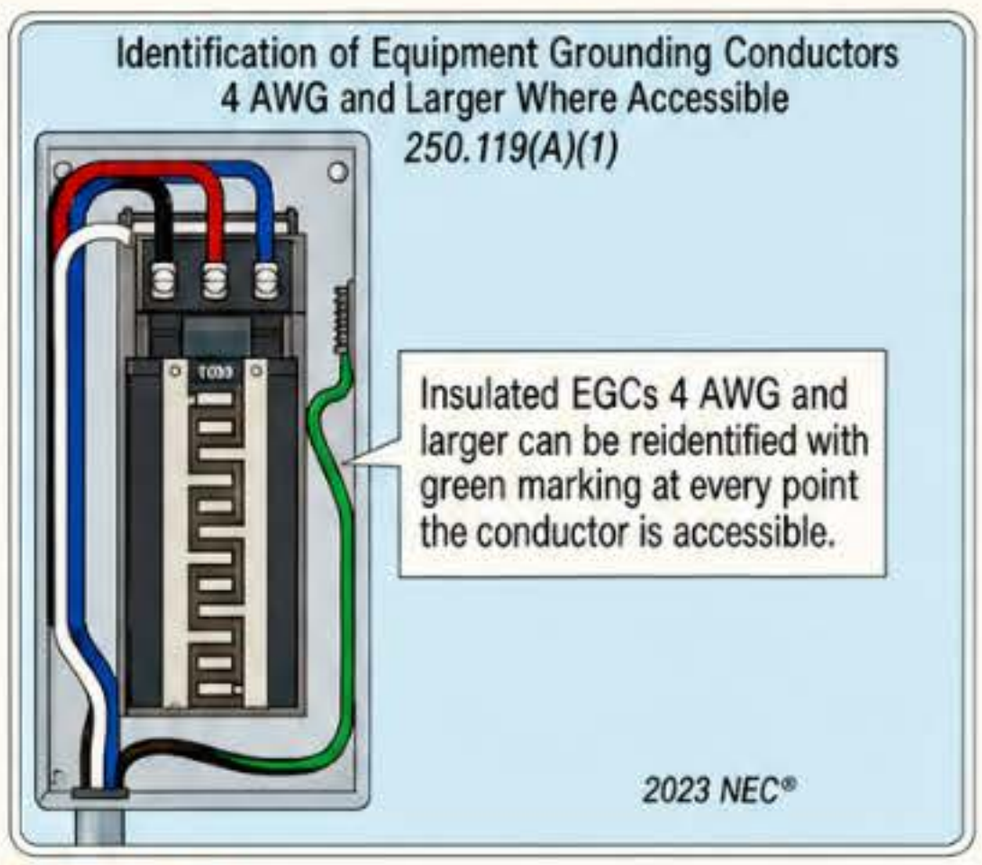
215.10 Ground-Fault Protection of Equipment

Each feeder disconnect rated 1,000A or more supplied by a 4-wire, three-phase, 277/480V wye-connected system must be provided with ground-fault protection of equipment in accordance with 230.95 and 240.13.

215.12 Conductor Identification

(A) Neutral Conductor. The feeder neutral conductor must be identified in accordance with 200.6.

(B) Equipment Grounding Conductor. Equipment grounding conductors can be bare, covered, or insulated. Insulated equipment grounding conductors 6 AWG and smaller must have a continuous outer finish either green or green with one or more yellow stripes [250.119]. ▸ Figure 215–17



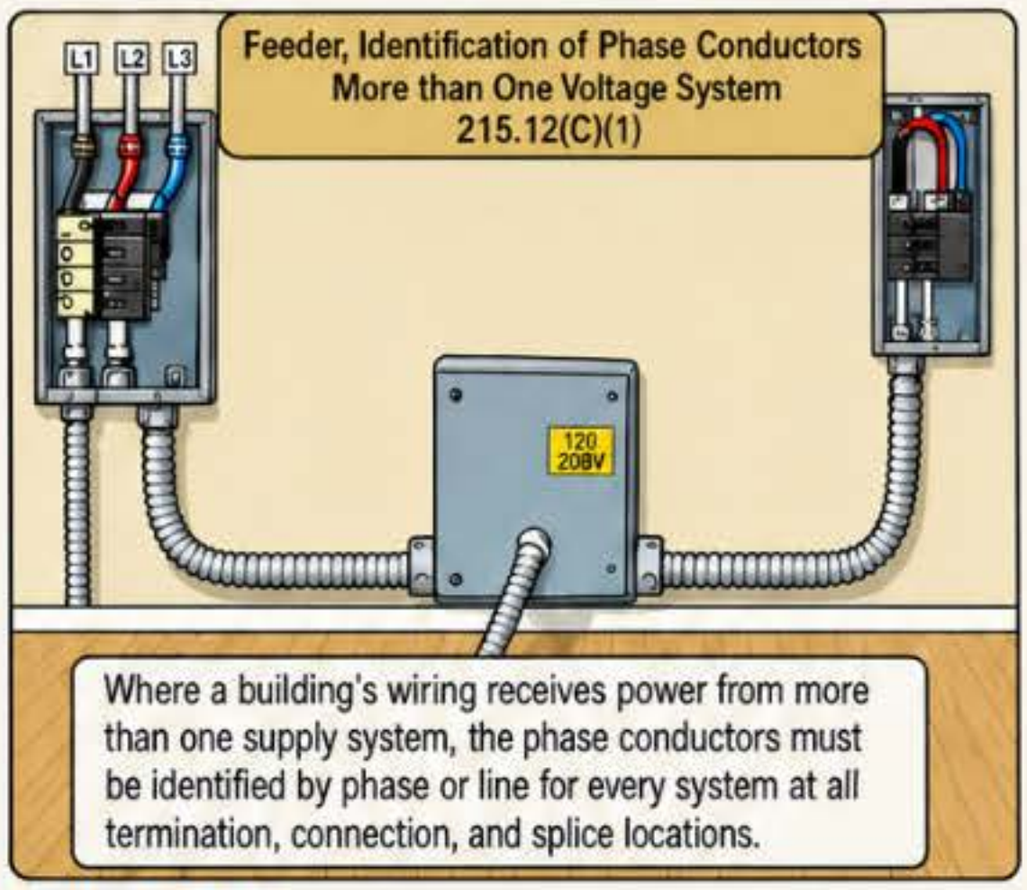
▲ Figure 215–17

Insulated equipment grounding conductors 4 AWG and larger can be permanently reidentified with green marking at the time of installation where accessible [250.119(A)].

(C) Identification of Phase Conductors. Circuit phase conductors must be identified as follows:

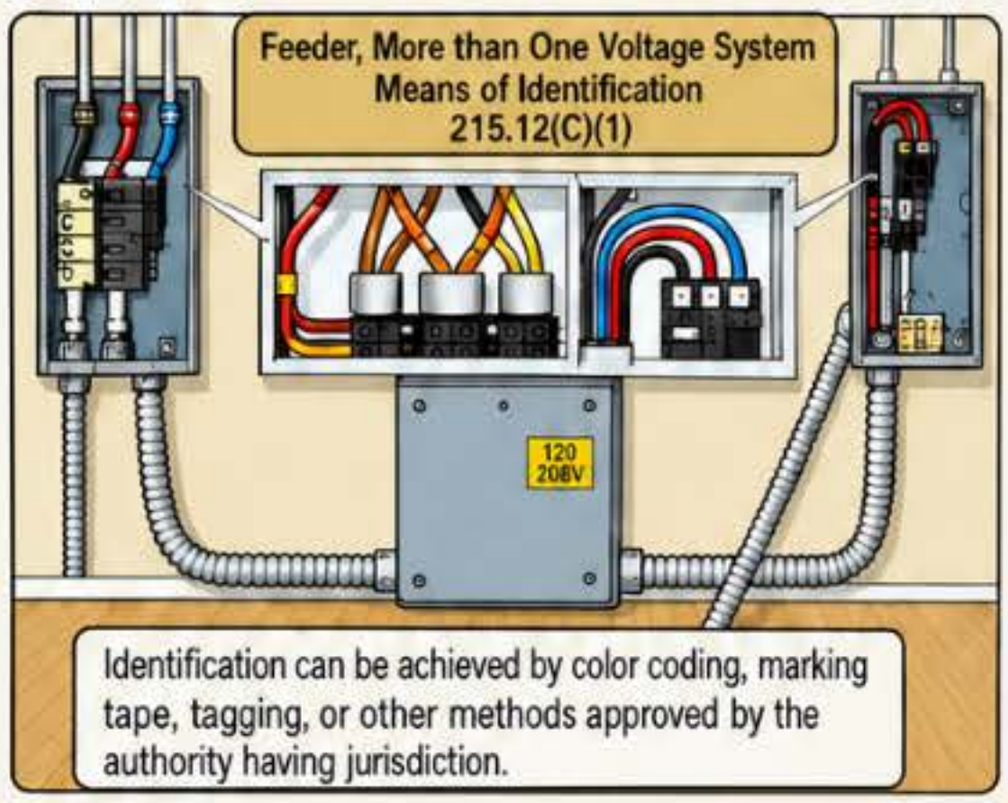
(1) More Than One Voltage Distribution System. Where premises wiring is supplied from more than one power-supply system, phase conductors must be identified by phase or line and by system at all termination, connection, and splice points as follows: ▸ Figure 215–18

215.12 | Feeders



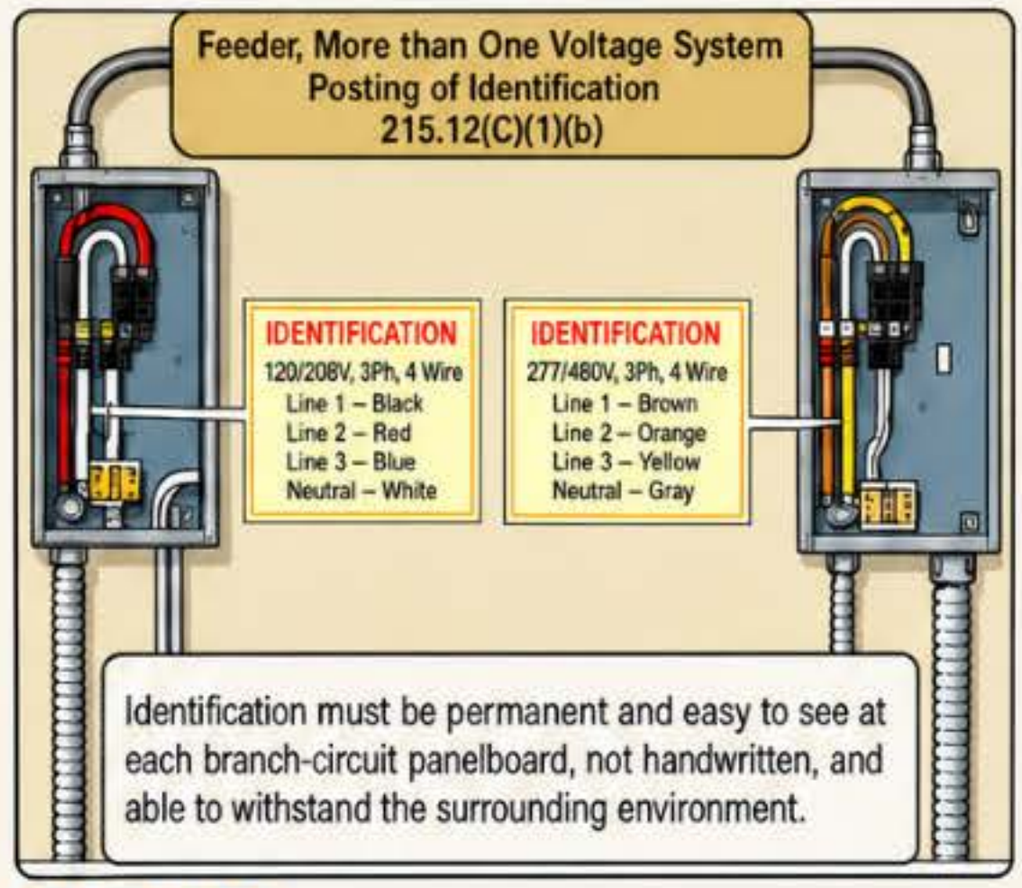
▶ Figure 215–18

(a) Means of Identification. The phase conductors must be identified using color coding, marking tape, tagging, or other approved methods by the authority having jurisdiction. Figure 215–19



▶ Figure 215–19

(b) Posting of Identification. The identification method must be permanently available or permanently posted at each branch-circuit panelboard, not handwritten, and be durable enough to handle the environment involved. Figure 215–20

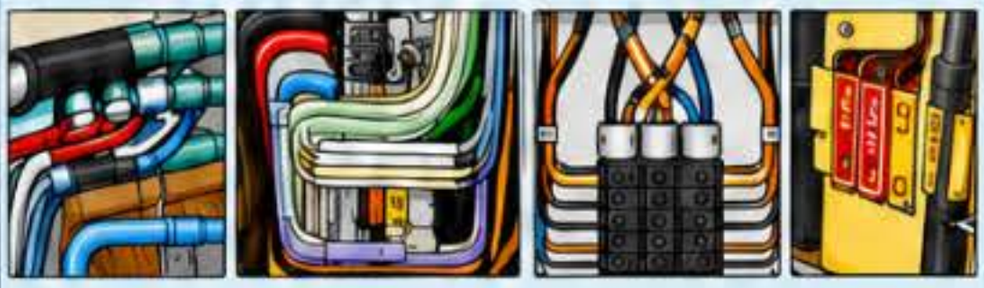


▶ Figure 215–20

▶ While the *NEC* does not require a specific color code for phase conductors, electricians commonly use the following system: Figure 215–21

- 120/240V, *single-phase—black, red, and white*
- 120/208V, *three-phase—black, red, blue, and white*
- 120/240V, *three-phase—black, orange, blue, and white*
- 277/480V, *three-phase—brown, orange, yellow, and gray; or, brown, purple, yellow, and gray*

Common Phase Conductor Identification Methods
210.5, 215.12, and 310.6(C) Comment



Although the *NEC* does not mandate a specific color code for phase conductors, electricians often use the following for power and lighting circuit identification:

- 120/240V, *single-phase—black, red, and white*
- 120/208V, *three-phase—black, red, blue, and white*
- 120/240V, *three-phase—black, orange, blue, and white*
- 277/480V, *three-phase—brown, orange, yellow, and gray; or, brown, purple, yellow, and gray*

▶ Figure 215–21

Author's Commentary:
Whenever a property is served by more than one voltage system at a branch-circuit panelboard, the phase conductors have to be identified by the phase and system. This can be done by posting a clear identification legend that explains the method used—such as color-coded marking tape or color-coded insulation.

— Michael Hamilton

Author's Commentary:
Whichever color system you choose, consistency is essential. Make sure phase conductors are identified the same way at every termination or connection point. This is especially important when determining different system voltages and identifying the neutral conductor.

— Michael Hamilton

ARTICLE 220 BRANCH-CIRCUIT, FEEDER, AND SERVICE LOAD CALCULATIONS

Introduction to Article 220—Branch-Circuit, Feeder, and Service Load Calculations

This article is dedicated to determining demand loads (including all applicable demand factors) in order to size branch circuits [210.19(A)(1)], feeders [215.2(A)(1)], and service conductors [230.42(A)].

Part I presents the structure of Article 220 and includes a summary table that shows where other types of load calculations can be found within the *NEC*. Part II outlines the requirements for branch-circuit calculations and for each specific type of branch circuit. Part III explains the rules for feeder and service conductor calculations using what is commonly known as the "Standard Method of Calculation." Part IV offers optional calculation approaches that can be used instead of the standard methods provided in Parts II through III—if your installation meets certain conditions—the "Farm Load Calculations" are addressed in Part V of this article.

In some cases, the *Code* provides an optional method (Part IV) for feeder and service calculations in addition to the standard method (Part III); however, this option does not apply to every scenario. In fact, using the optional method usually leads to a smaller feeder or service, but before applying it, read the instructions carefully to confirm that the method fits your situation. As you study Article 220, review the illustrations that accompany it to better grasp the requirements. Also, be sure to examine the examples in Annex D of the *NEC* to gain more practice with these types of calculations. The *Code* acknowledges that not all demand for power will occur at the same instant and allows for loads with varying demand factors to be included together in a single calculation.

Part I. General

220.1 Scope

This article establishes the requirements for calculating demand loads for branch circuits, feeders, and services.
•*Figure 220-1*

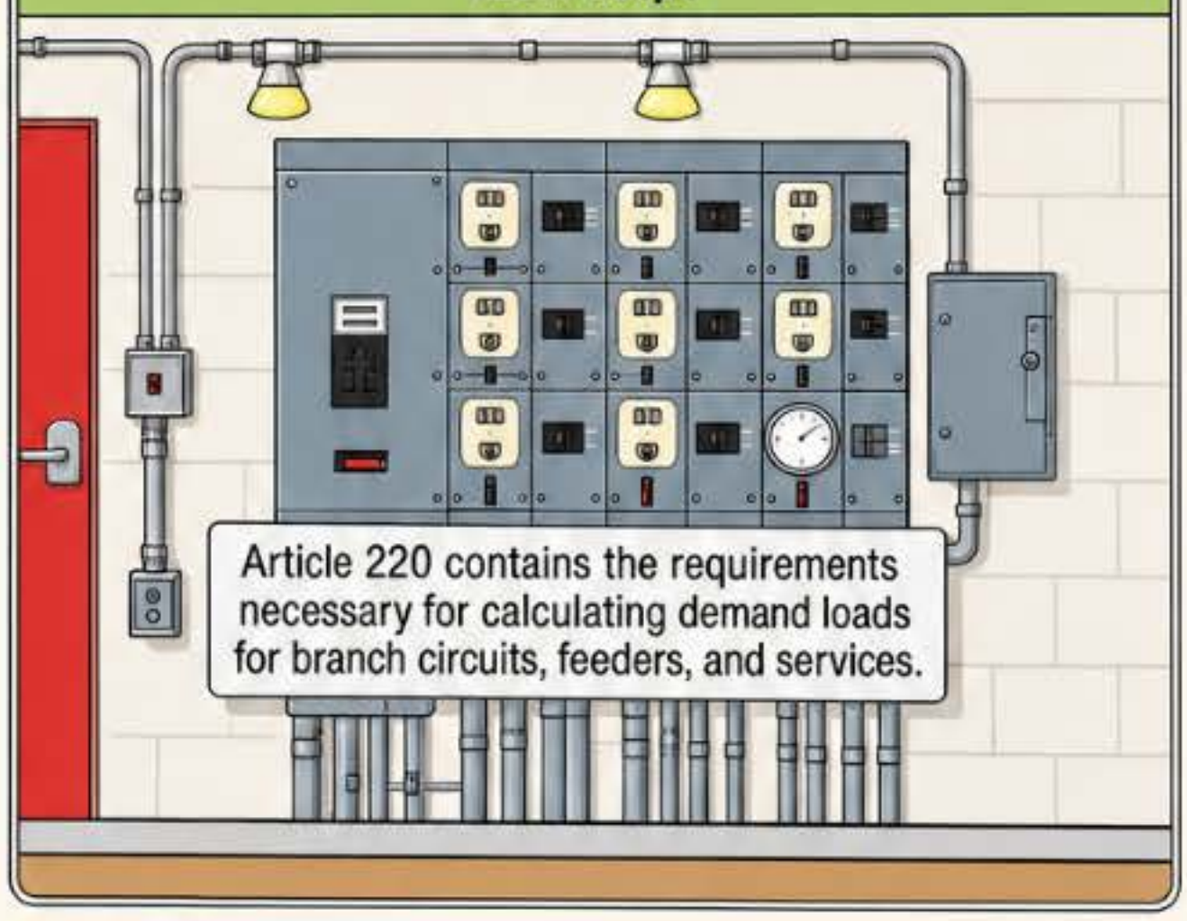
Note 2: *See NEC Figure 220.1 for information on the organization of Article 220.*
•*Figure 220-2*

220.3 Application of Other Articles

Table 220.3 lists references for branch-circuit calculations for specific equipment in *Chapter 4 of the NEC*.

- Air-Conditioning and Refrigeration Equipment; 440.6, 440.21, 440.22, 440.31, 440.32, and 440.62
- Fixed Electric Space-Heating Equipment; 424.3(B)
- Motors; 430.6(A), 430.22, 430.24, 430.52, and 430.62
- Hermetic Refrigeration; 440.6 and Part IV of Article 440

Branch-Circuit, Feeder, and Service Load Calculations
220.1 Scope



•*Figure 220-1*

220.5 Branch-Circuit, Feeder, and Service Load Calculations

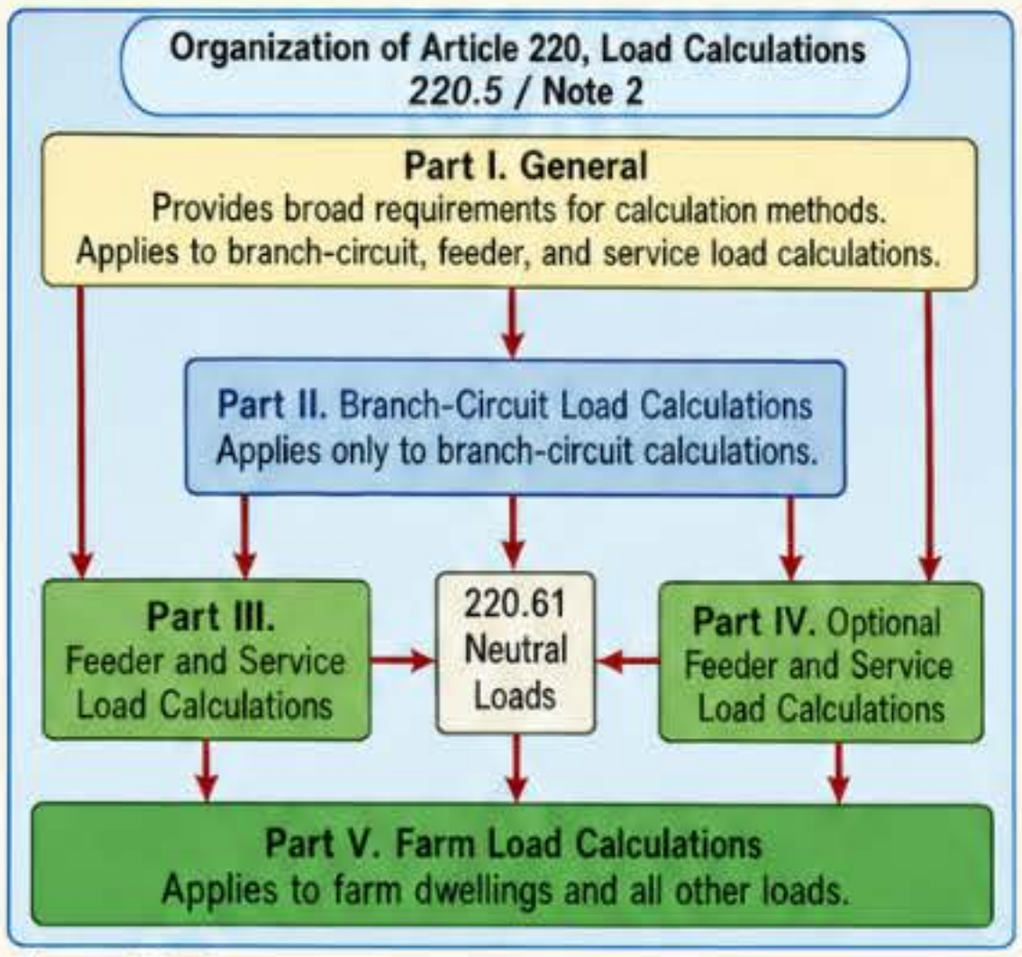


Figure 220-2

220.5 Calculations

(A) Voltage Used for Calculations. Unless otherwise specified, branch-circuit, feeder, and service loads must be calculated on nominal system voltages such as 120V, 120/240V, 120/208V, 240V, 277/480V, or 480V. Figure 220-3

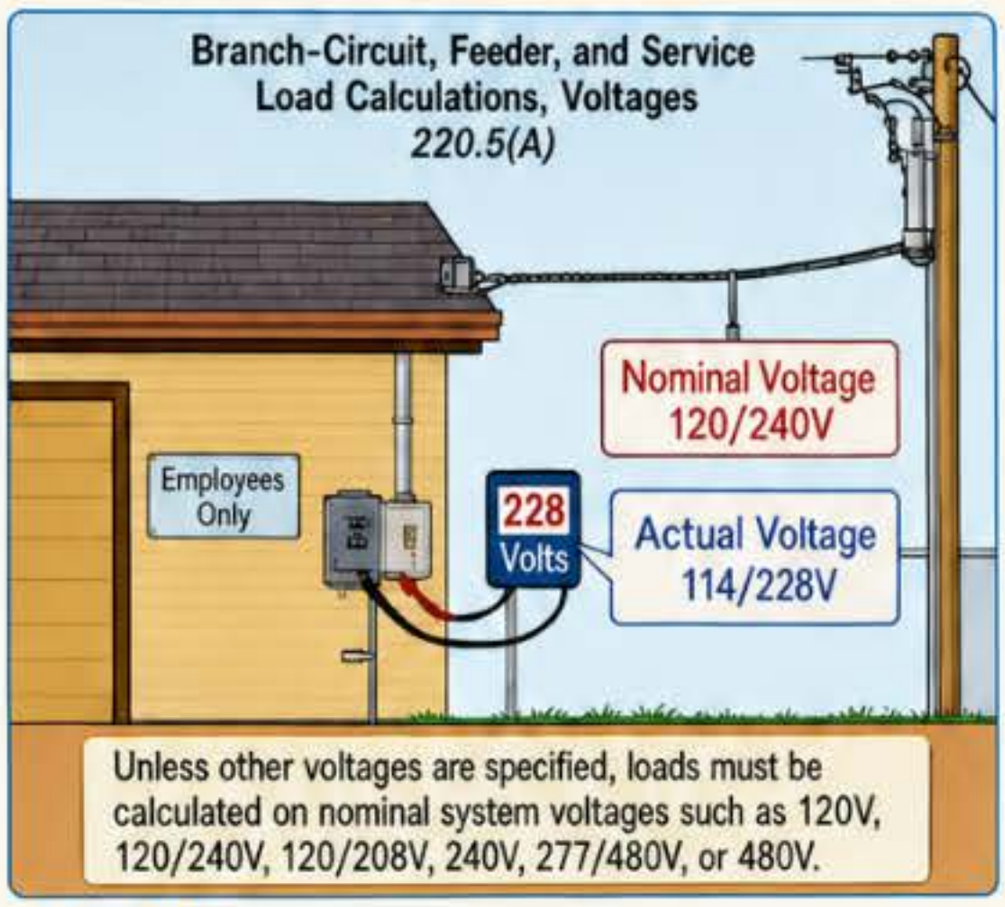


Figure 220-3

Author's Commentary:

Per Article 100, "Nominal System Voltage" is treated as a notional value assigned to a circuit for convenient identification. The actual circuit voltage within a circuit may span a range that allows satisfactory operation of equipment from a factory.

— *Michael Hamilton*

(B) Rounding Fractions of Amperes. Calculations resulting in a fraction of an ampere can be rounded to the nearest whole number. Figure 220-4

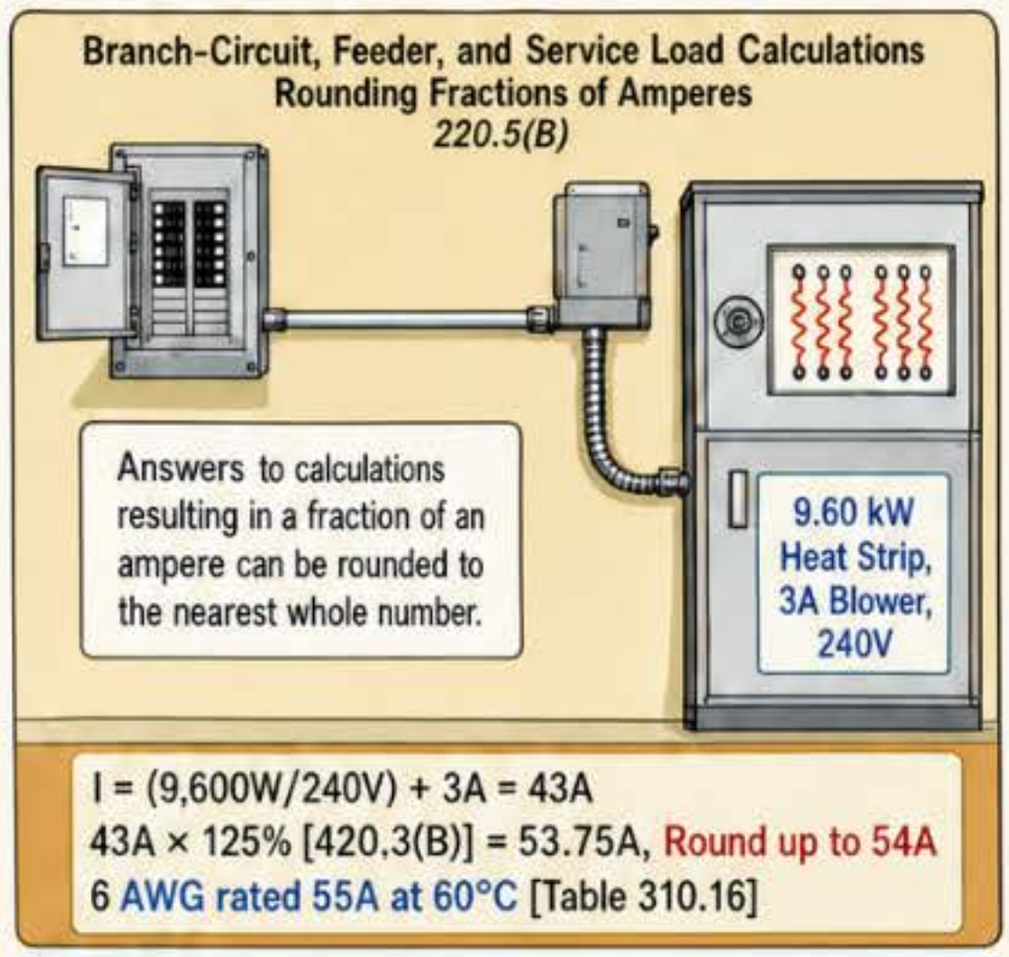


Figure 220-4

220.11 Floor Area

The floor area is calculated from the outside dimensions of the building, dwelling unit, or other area involved. Figure 220-5

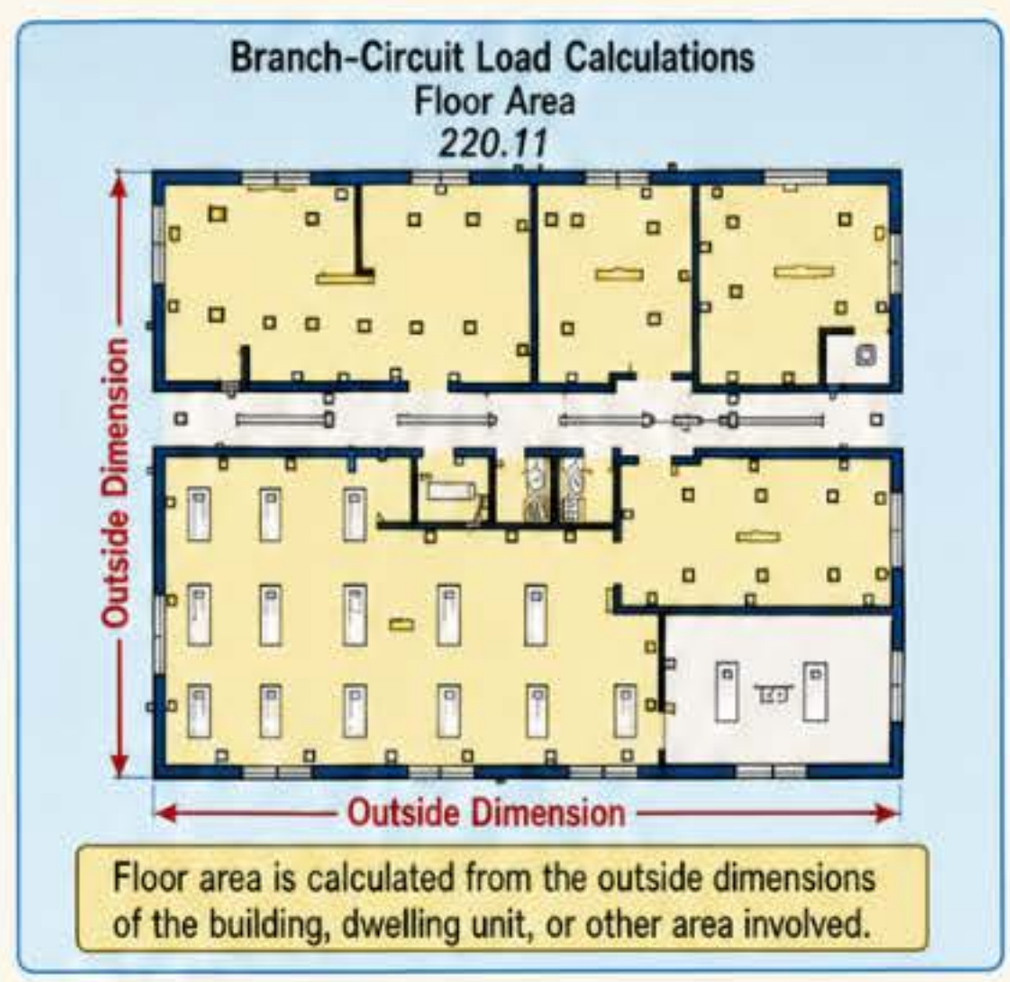
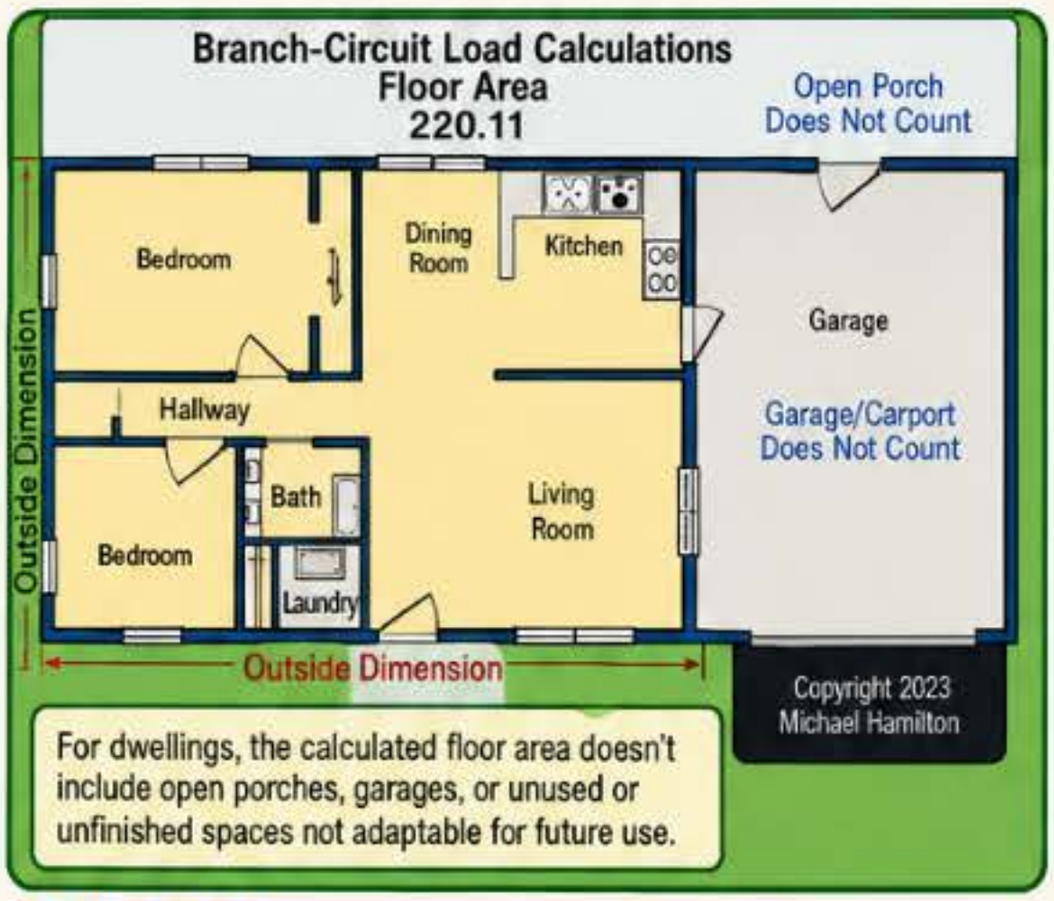


Figure 220-5

For dwelling units, the calculated floor area does not include open porches, garages, or unused or unfinished spaces not suitable for future use. Figure 220-6

220.12 BRANCH-CIRCUIT, FEEDER, AND SERVICE LOAD CALCULATIONS (2023)

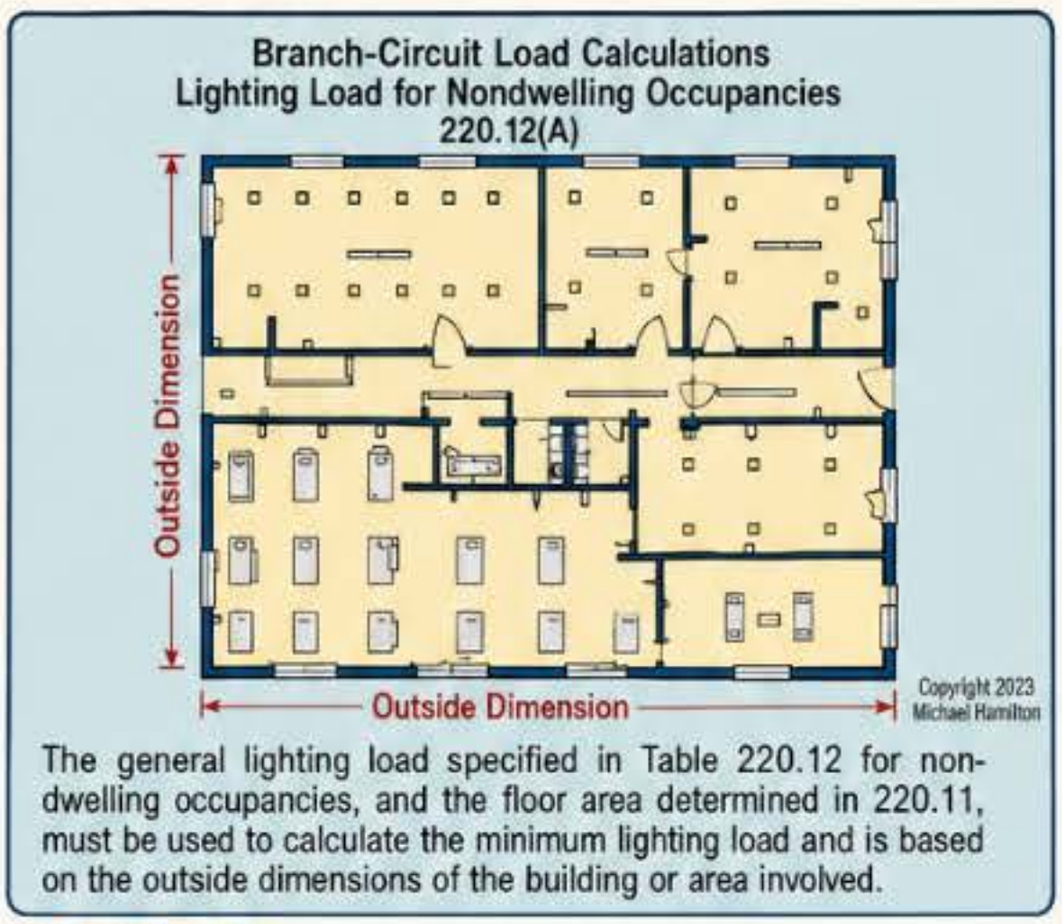


▶ Figure 220–6

Part II. Branch-Circuit Load Calculations

220.12 Lighting Load for Non-Dwelling Occupancies

(A) General. The general lighting load specified in Table 220.12 for nondwelling occupancies, and the floor area determined in accordance with 220.11, must be used to calculate the minimum lighting load. ▶ Figure 220–7



▶ Figure 220–7

(B) Energy Code. Where the building is designed and constructed to comply with an energy code adopted by the local authority, the lighting load can be calculated using the unit values specified in the energy code where the following conditions are met:

(1) A power monitoring system is installed that will provide continuous information regarding the total general lighting load of the building.

(2) The power monitoring system will be set with alarm values to alert the building owner or manager if the lighting load exceeds the values set by the energy code. Automatic means to act to reduce the connected load is permitted.

(3) The demand factors specified in 220.42 are not applied to the general lighting load.

(4) The continuous load multiplier of 125 percent must be applied.

Table 220.12 General Lighting Loads by Non-Dwelling Occupancy

Type of Occupancy	VA/ft²
Automotive facilities	1.50
Convention centers	1.40
Courthouses	1.40
Dormitories	1.50
Exercise centers	1.40
Fire stations	1.30
Gymnasiums [a]	1.70
Type of Occupancy	VA/ft²
Health care clinics	1.60
Hospitals	1.60
Hotels and motels, including apartment houses without provisions for cooking by tenants [b]	1.70
Libraries	1.50
Manufacturing facilities [c]	2.20
Motion picture theaters	1.60
Museums	1.60
Offices [d]	1.30
Parking garages [e]	0.30
Penitentiaries	1.20
Performing arts theaters	1.50
Police stations	1.30
Post offices	1.60
Religious facilities	2.20

220.14 Branch-Circuit, Feeder, and Service Load Calculations

Table 220.12 General Lighting Loads by Non-Dwelling Occupancy (continued)

Occupancy Type	Watts per ft^2
Restaurants	1.50
Retail [g,h]	1.90
Schools/universities	3.00
Sports arenas	3.00
Town halls	1.40
Transportation occupancies	1.20
Warehouses	1.20
Workshops	1.70

Note: *The 125 percent multiplier for a continuous load as specified in 210.20(A) is factored in when using the unit loads in this table to determine the minimum lighting load for a given occupant load.*

[a] *Armories and auditoriums are treated as gymnasium-type occupancies.*

[b] *Lodge rooms are similar to hotels and motels.*

[c] *Industrial commercial loft buildings are considered manufacturing-type occupancies.*

[d] *Banks are office-type occupancies.*

[e] *Garages—commercial (storage) are considered parking garage occupancies.*

[f] *Clubs are considered restaurant occupancies.*

[g] *Barber shops and beauty parlors are considered retail occupancies.*

[h] *Stores are considered retail occupancies.*

220.14 Other Loads—Occupancies

(D) Luminaires. The branch-circuit VA load for luminaires must be computed from the highest VA rating of the luminaires that are used.

(F) Sign Outlet. Every commercial occupancy that people can walk into must have at least one 20A sign outlet [600.5(A)], which must be on a minimum branch circuit load of 1,200 VA or the actual VA if larger. Figure 220-8

(G) Show Windows. The branch-circuit VA load for show-window lighting must be calculated in accordance with (1) or (2):

(1) 180 VA *for each show-window lighting outlet in accordance with 220.14(L), or*

(2) *200 VA for each linear foot of show window [220.43].*

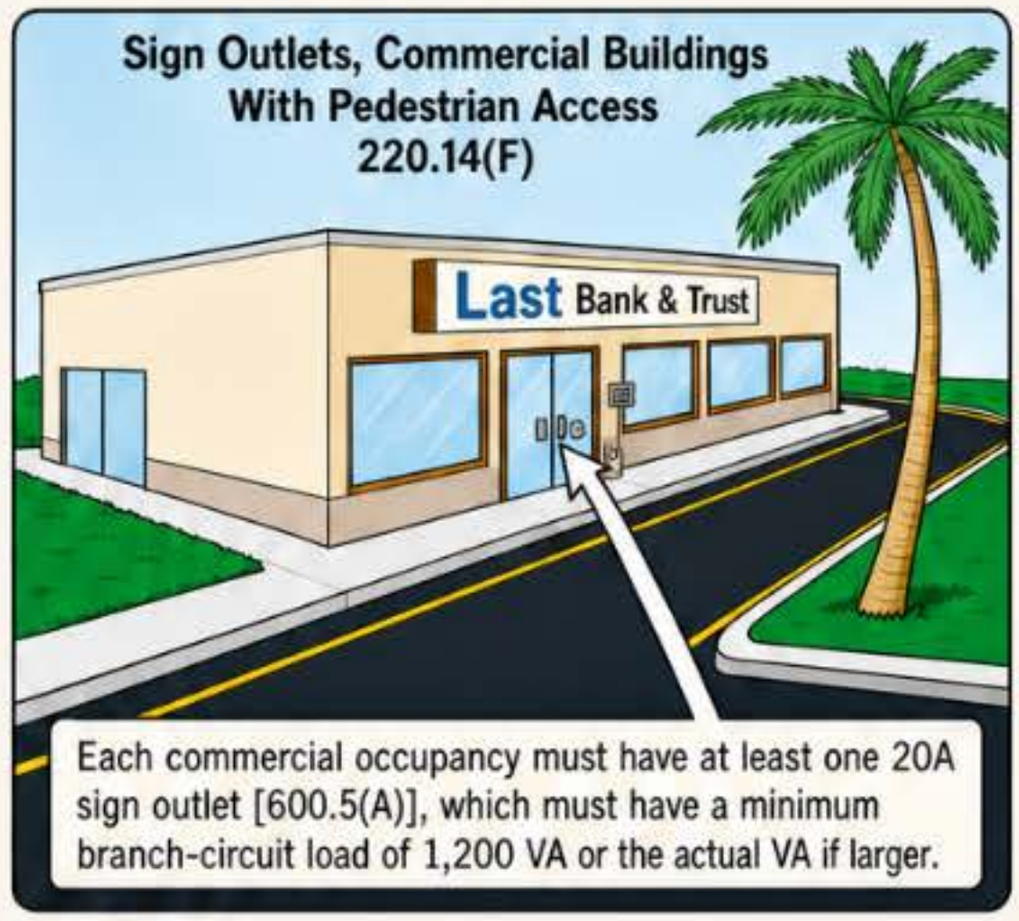
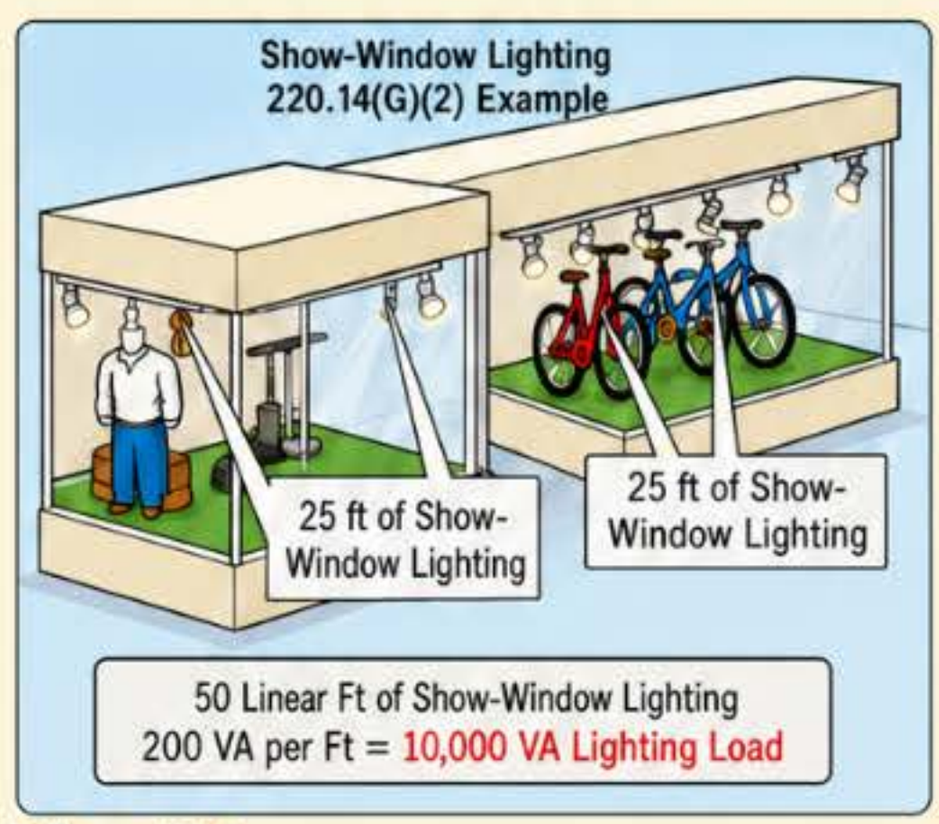


Figure 220-8

▶ Example

Question: *What is the calculated load for 50 linear feet of show window?* Figure 220-9

(a) 5,000 VA (b) 10,000 VA (c) 15,000 VA (d) 20,000 VA



▶ Figure 220-9

Solution:

50 Linear ft of Show Window × 200 VA per Linear ft = 10,000 VA

Answer: *(b) 10,000 VA*

(H) Fixed Multioutlet Assemblies. *Fixed multioutlet assemblies in commercial occupancies must be calculated in accordance with (1) or (2).* Figure 220-10

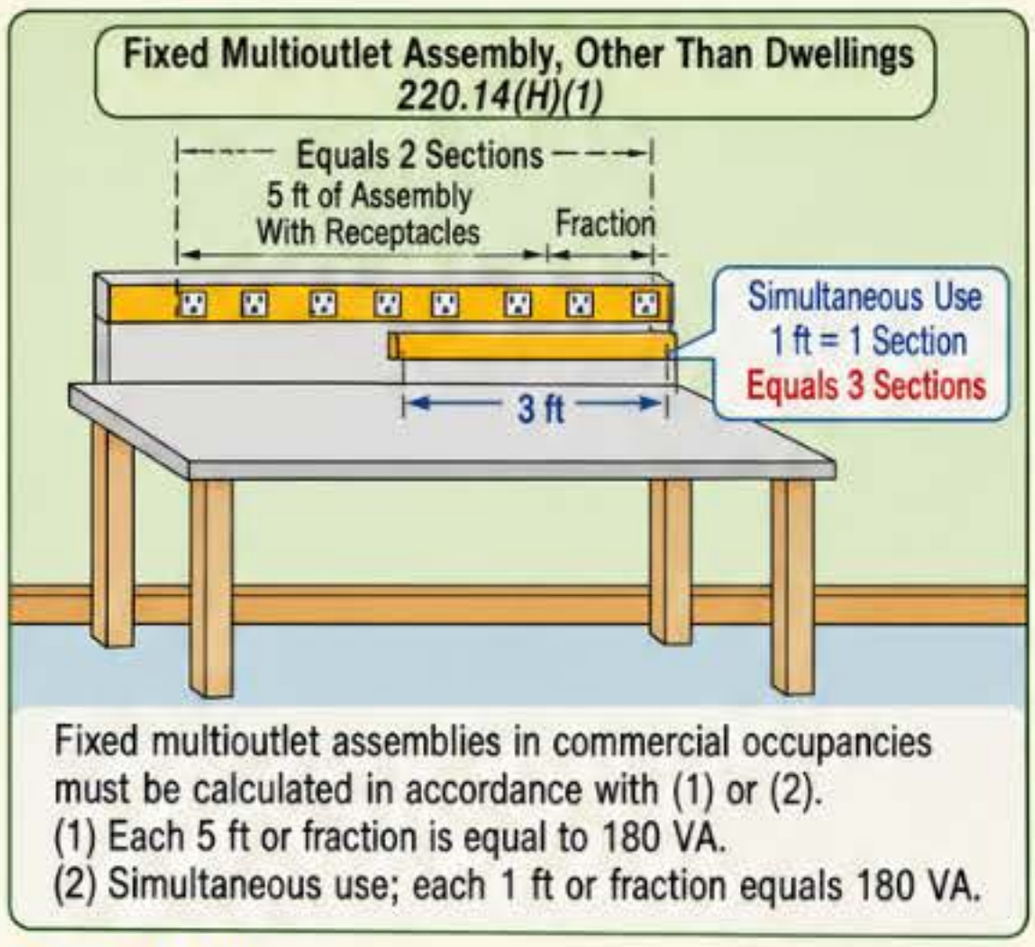


Figure 220-10

(1) If appliances are unlikely to be used simultaneously, each 5 ft (or fraction of 5 ft) of multioutlet assembly is considered 180 VA. Figure 220-11

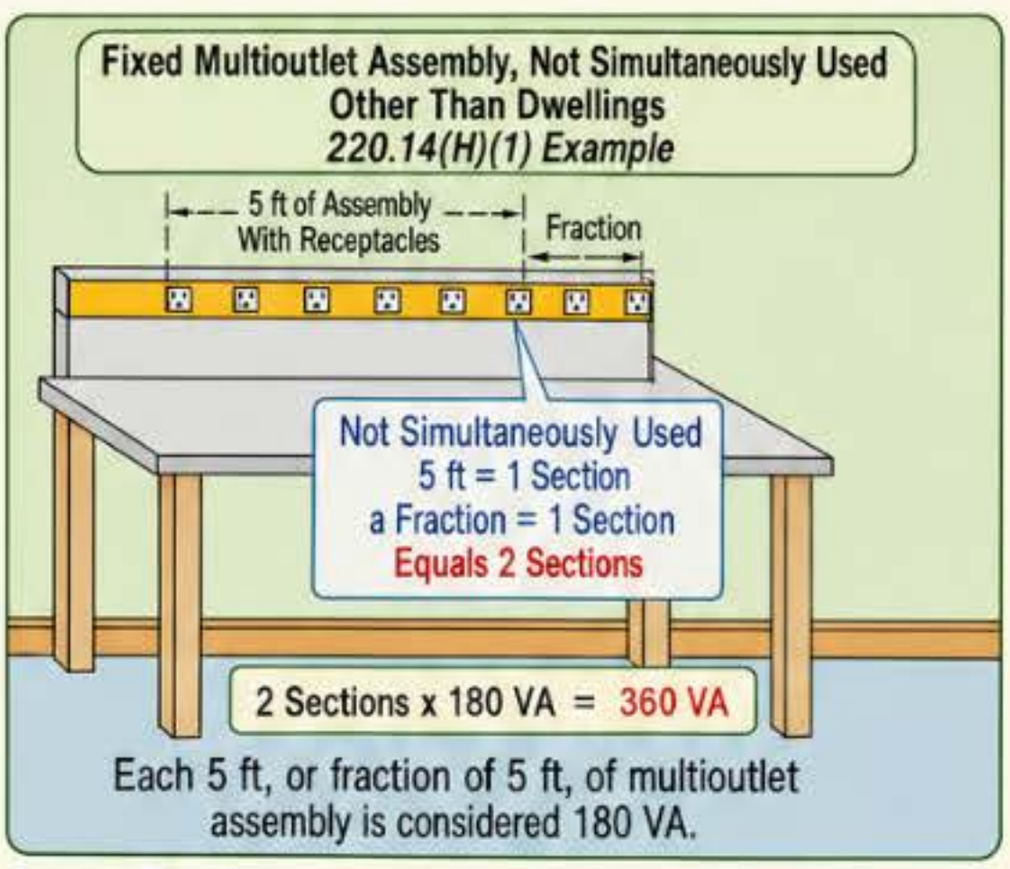


Figure 220-11

(2) If appliances are likely to be used simultaneously, each 1 ft (or fraction of a ft) of multioutlet assembly is considered 180 VA. Figure 220-12

Author's Commentary:

- See the definition of "Multioutlet Assembly" in Article 100.
- The feeder or service calculated load for fixed multioutlet assemblies can be calculated in accordance with the demand factors contained in 220.44.

— Michael Hamilton

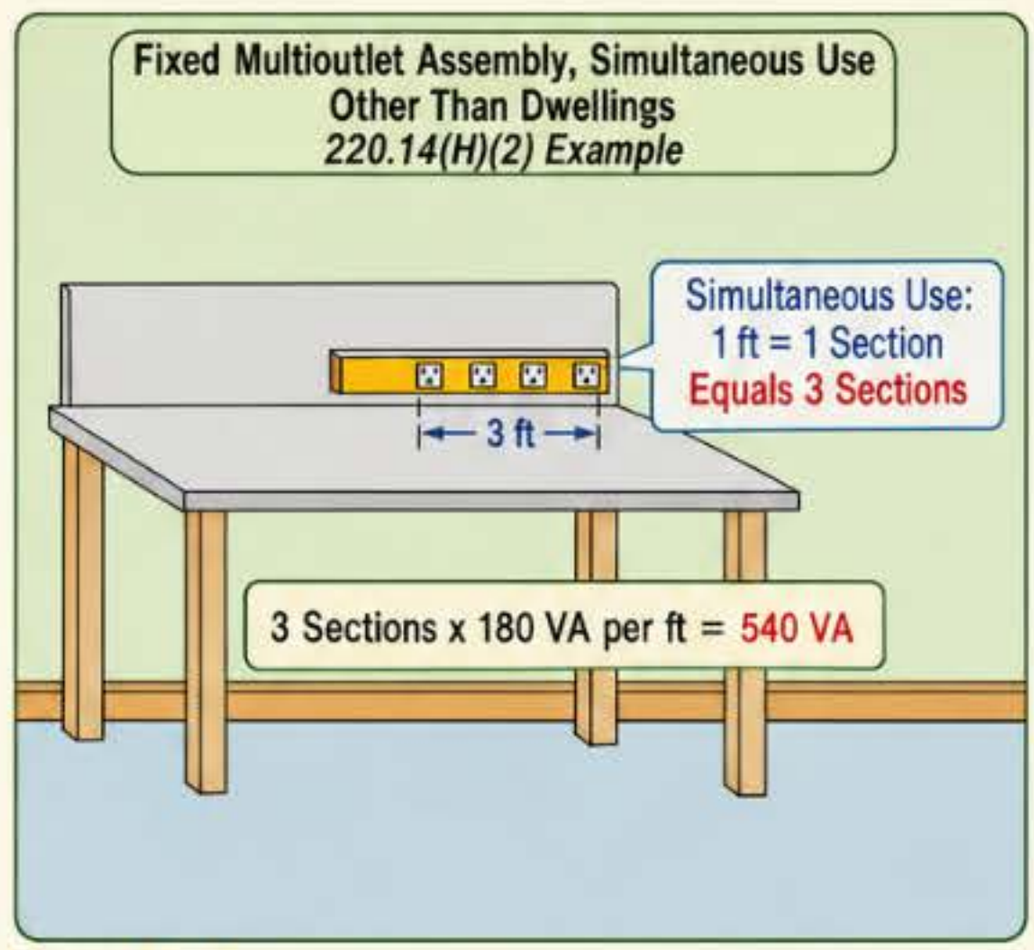


Figure 220-12

(I) Commercial Receptacle Outlets. In commercial occupancies, each 15A or 20A, 125V general-use receptacle outlet is considered 180 VA per mounting strap for each, except as covered in 210.14(J) and (K). Figure 220-13

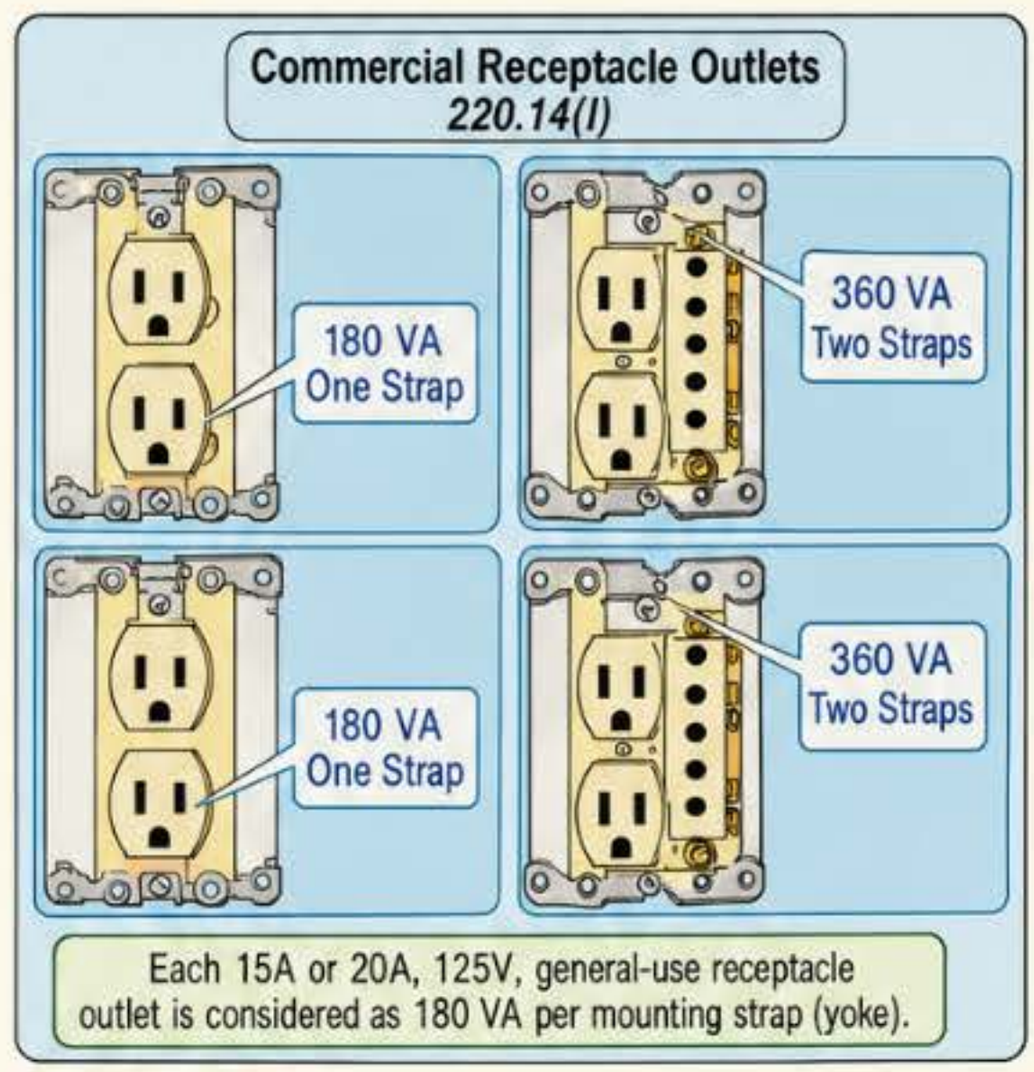


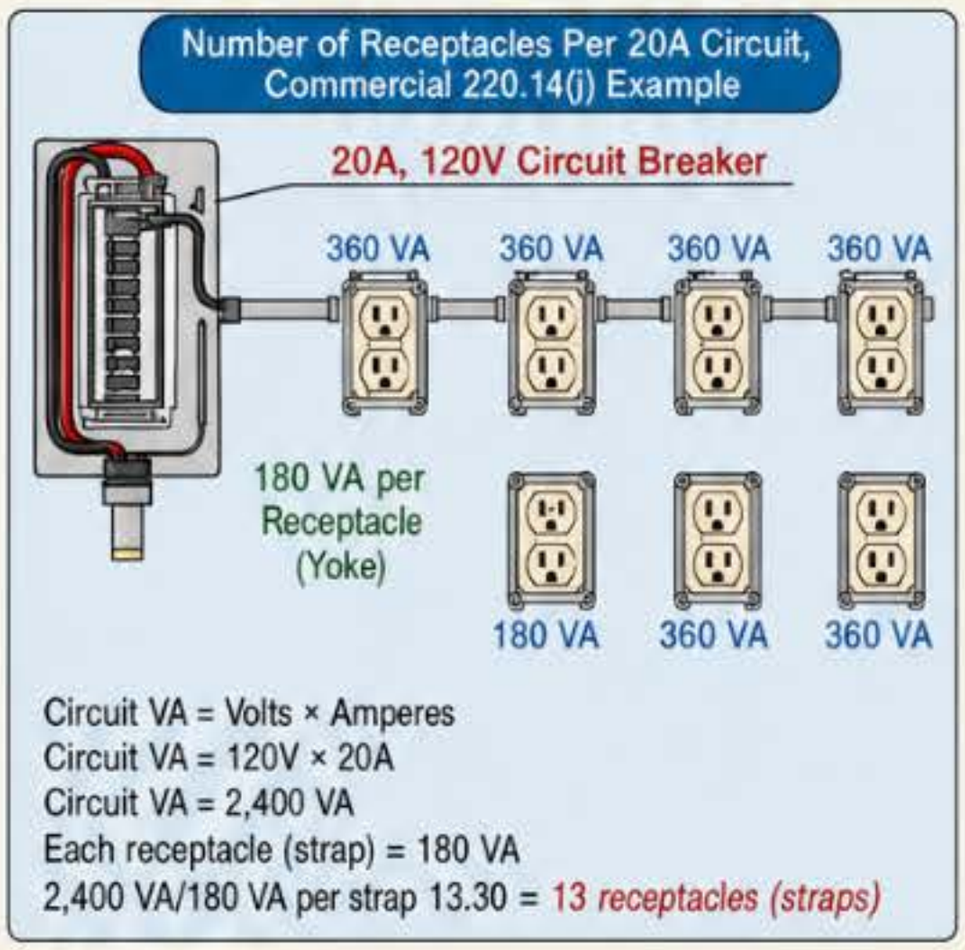
Figure 220-13

220.14 | Branch-Circuit, Feeder, and Service Load Calculations

▶ Example

Question: *What is the largest number of 15A or 20A, 125V receptacles (straps) allowed on a 20A, 120V general-purpose branch circuit in a commercial space?* **Figure 220-14**

(a) 10 receptacles (straps) *(b) 11 receptacles (straps)*
(c) 12 receptacles (straps) *(d) 13 receptacles (straps)*



▶ **Figure 220-14**

Solution:

Circuit VA = Volts × Amperes
Circuit VA = 120V × 20A
Circuit VA = 2,400 VA

Number of Receptacles (Straps) = 2,400 VA/180 VA
Number of Receptacles (Straps) = 13 receptacles (straps)

Answer: *(d) 13 receptacles (straps)*

Author's Commentary:

- *General-purpose receptacles are not considered a continuous load according to the NEC Handbook published by the NFPA.*

— Michael Hamilton

(J) Dwelling Units. In one- and two-family, and multifamily dwellings, the lighting and receptacle outlets specified in 220.14(J)(1), (J)(2), and (J)(3) are included in the 3 VA per sq ft unit load in Table 220.12. No additional load calculations are required for such outlets. The minimum lighting load must be determined using the 3 VA per sq ft unit load and the floor area as determined in 220.11. **Figure 220-15**

▶ **Figure 220-15**

(1) General-use receptacle outlets rated 20A or less, including receptacles connected to the bathroom or garage circuits in accordance with 210.11(C)(3) and 210.11(C)(4).

(2) Receptacle outlets specified in 210.52(E) and (G) for outdoors, garages, and basements.

(3) Lighting outlets specified in 210.70.

Author's Commentary:

- *There is no VA load for 15A and 20A, 125V general-use receptacle outlets because the loads for these devices are part of the "3 VA per sq foot for general lighting" contained in 220.14(J) for dwelling units.*
- *The Code does not limit the number of receptacle outlets on a general-purpose branch circuit in a dwelling unit. See the NEC Handbook for more information.*

— Michael Hamilton

▶ Example

Question: *What is the largest number of 15A or 20A, 125V receptacles permitted on a 15A or 20A, 120V general-purpose circuit in a dwelling unit?*

(a) 10 receptacles *(b) 11 receptacles*
(c) 12 receptacles *(d) There is no limit*

Answer: *(d) There is no limit*

Branch-Circuit, Feeder, and Service Load Calculations 220.14

Author's Commentary:
The total number of receptacles allowed on general-purpose branch circuits in dwelling units isn't unlimited. The Code requires a minimum count or the circuits feeding general-purpose receptacle outlets and lighting outlets [210.11(A)]. Also, the loads connected to those circuits must be evenly distributed among all the circuits [210.11(B)].

— Michael Hamilton

(K) Office Buildings. *To determine the load for receptacle outlets in office buildings, use the larger of the two methods shown below in (1) or (2).*

(1) *The first 180 VA of receptacle outlets per receptacle yoke [220.14(K)], after applying the demand factors given here.*

(2) *A base of 1 VA per square foot*

▶ Office General Receptacle—Example

Question: *Find the general receptacle load for an 18,000 square foot office area with 160 receptacle yokes, each with one hundred forty 15A, 125V receptacles. See Figure 220-16.*

(a) 18,200 VA (b) 19,400 VA (c) 20,100 VA (d) 22,200 VA

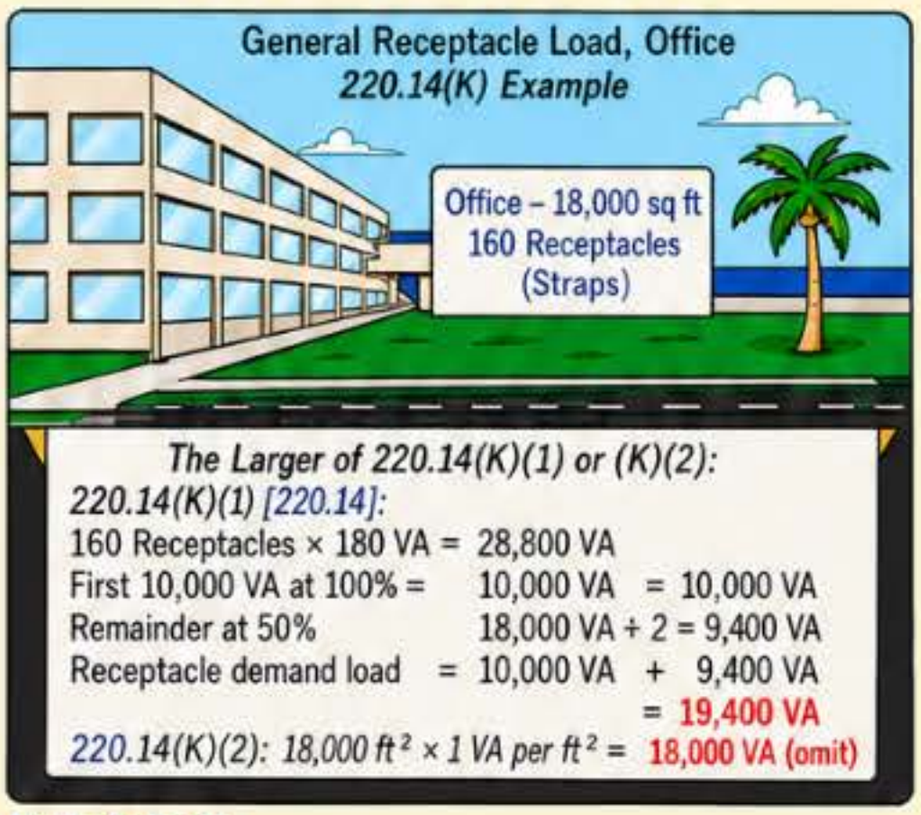


Figure 220-16

Solution:

160 Receptacles × 180 VA = 28,600 VA
First 10,000 VA at 100% = 10,000 VA × 100% = 10,000 VA
Remainder at 50% = 18,600 VA × 50% = 9,400 VA
Receptacle Calculated Load = 19,400 VA

[220.14(K)(2)
18,000 × 1 VA per sq ft = 18,000 VA (omit)]

Answer: *(b) 19,400 VA*
[220.14(K)(1) and 220.14(K)(1)].

▶ Office General Lighting and Receptacle—Example

Question: *What is the lighting and receptacle demand load for an 18,000 sq ft office space with one hundred forty 15A, 125V receptacles? See Figure 220-17.*

(a) 41,400 VA (b) 51,000 VA (c) 68,200 VA (d) 70,000 VA

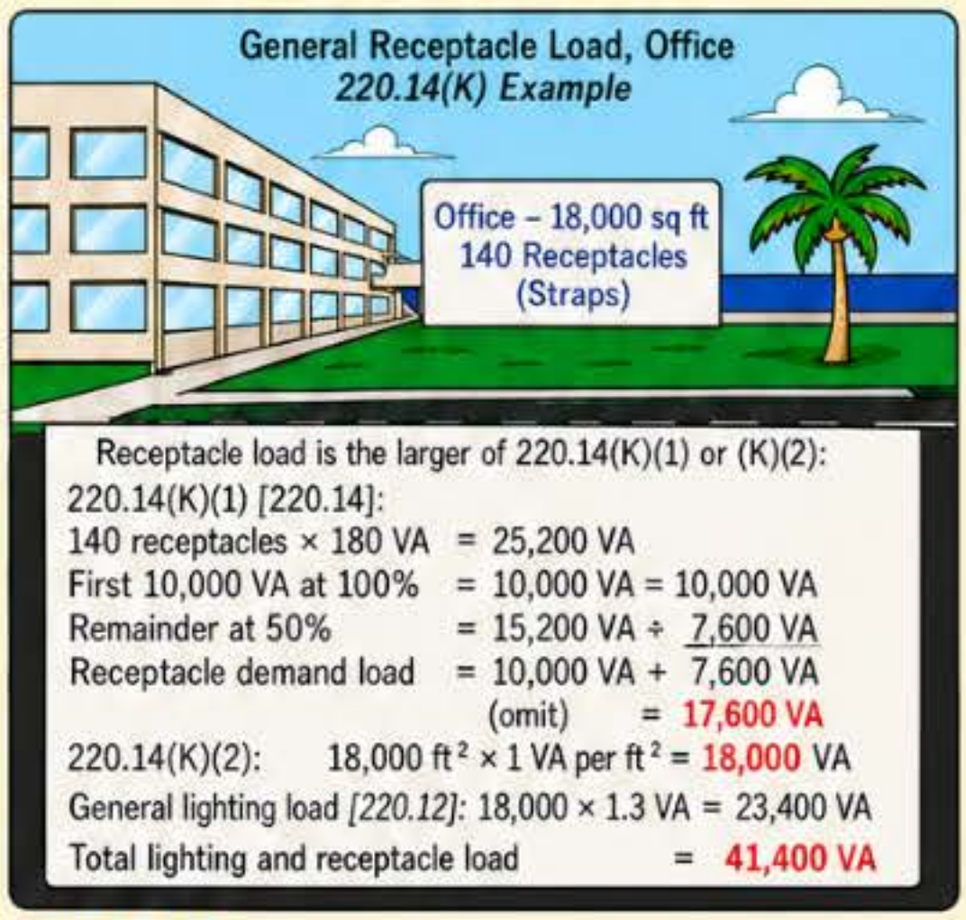


Figure 220-17

Solution:

Step 1: *Determine the general lighting load [220.12].*

18,000 sq ft × 1.30 VA = 23,400 VA

Step 2: *Determine the receptacle calculated load [220.14].*

Based on Actual Number of Receptacles:

140 Receptacles × 180 VA = 25,200 VA
First 10,000 VA at 100% = = 10,000 VA × 100% = 10,000 VA
Remainder at 50% = = 18,600 VA × 50% = 9,400 VA
Receptacle Calculated Load = 19,400 VA
(omit)

Based on the NEC [220.14(K)(2)]:
18,000 × 1 VA per sq ft = 18,000 VA

Step 3: *Determine the total demand load.*

General Lighting	*23,400 VA*
Receptacles	*+ 19,400 VA*
Total	*41,400 VA*

Answer: *(a) 41,400 VA*
[220.12, 220.42, 220.14(K)(1), and 220.14(K)(1)]

(L) Other Outlets. *180 VA for each receptacle and lighting outlet not covered in (A) through (K).*

(M) Hotel and Motel Occupancies. For guest rooms or suites in hotels and motels, the lighting and receptacle outlets specified in 220.14(M)(1), (M)(2), and (M)(3) are part of the minimum 1.70 VA per square foot unit load in Table 220.12. No extra load calculations are necessary for these outlets. The minimum lighting load is established using the 1.70 VA per square foot unit load and the floor area as stated in 220.11. Figure 220-18

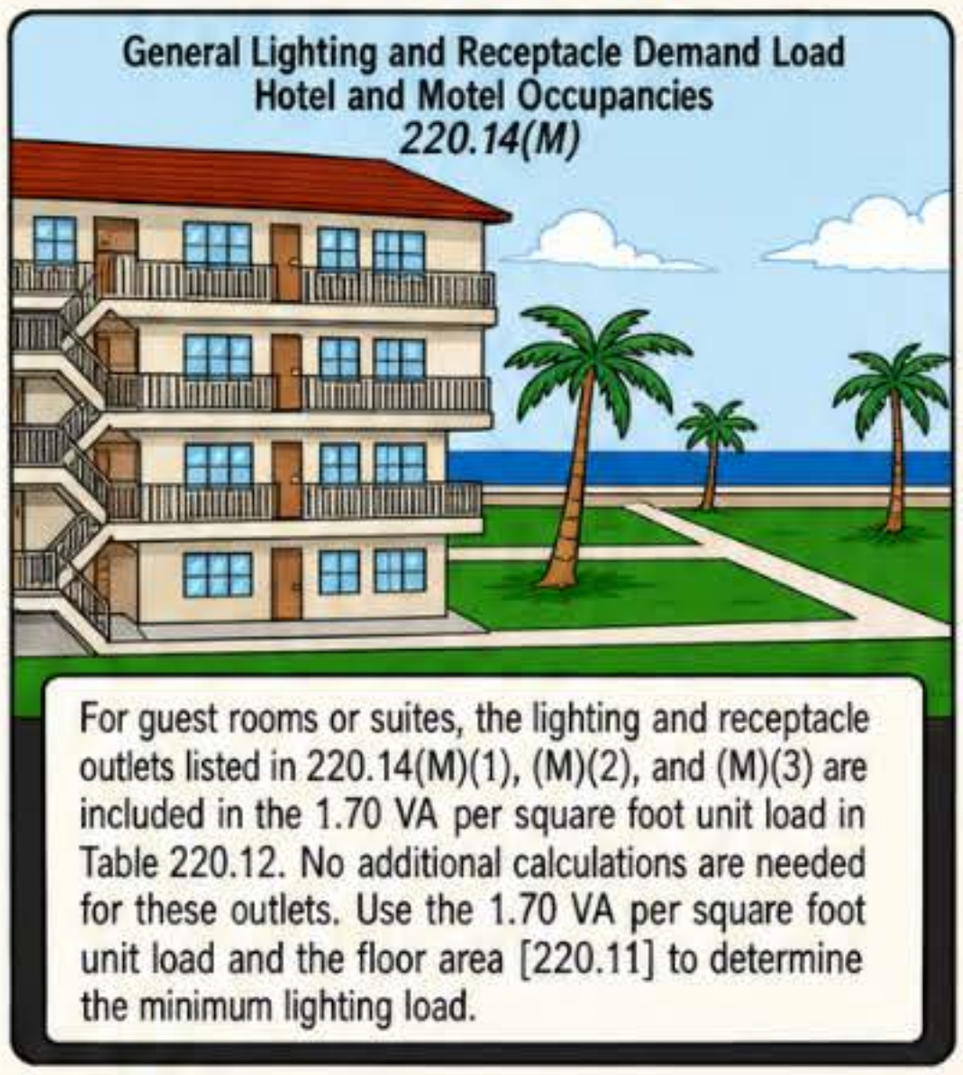


Figure 220-18

(1) General-use receptacle outlets rated 20A or less, including receptacles connected to bathroom or garage circuits, in accordance with 210.11(C)(3) and 210.11(C)(4).
(2) Receptacle outlets specified in 210.52(E)(3) for balconies, decks, and porches.
(3) Lighting outlets specified in 210.70.

220.18 Motor-Operated Loads

(A) Motor-Operated Loads. When a circuit powers only a motor, the conductor and overcurrent protection must be sized following Article 430. Where a circuit supplies only air-conditioning equipment, Article 440 applies.

Author's Commentary:

- *For motor circuits, see 430.22 for branch-circuit conductor sizing, 430.32 for overload sizing, and 430.52(C) for short-circuit and ground-fault protection sizing in this textbook.*
- *For air-conditioning circuits, see 440.4(B) in this textbook for conductor sizing and overcurrent protection.*

— Michael Hamilton

(B) Inductive and LED Lighting Loads. Branch circuits that supply inductive and LED driver lighting loads must be sized to the ampere rating of the luminaire, not to the wattage of the lamps. Figure 220-19

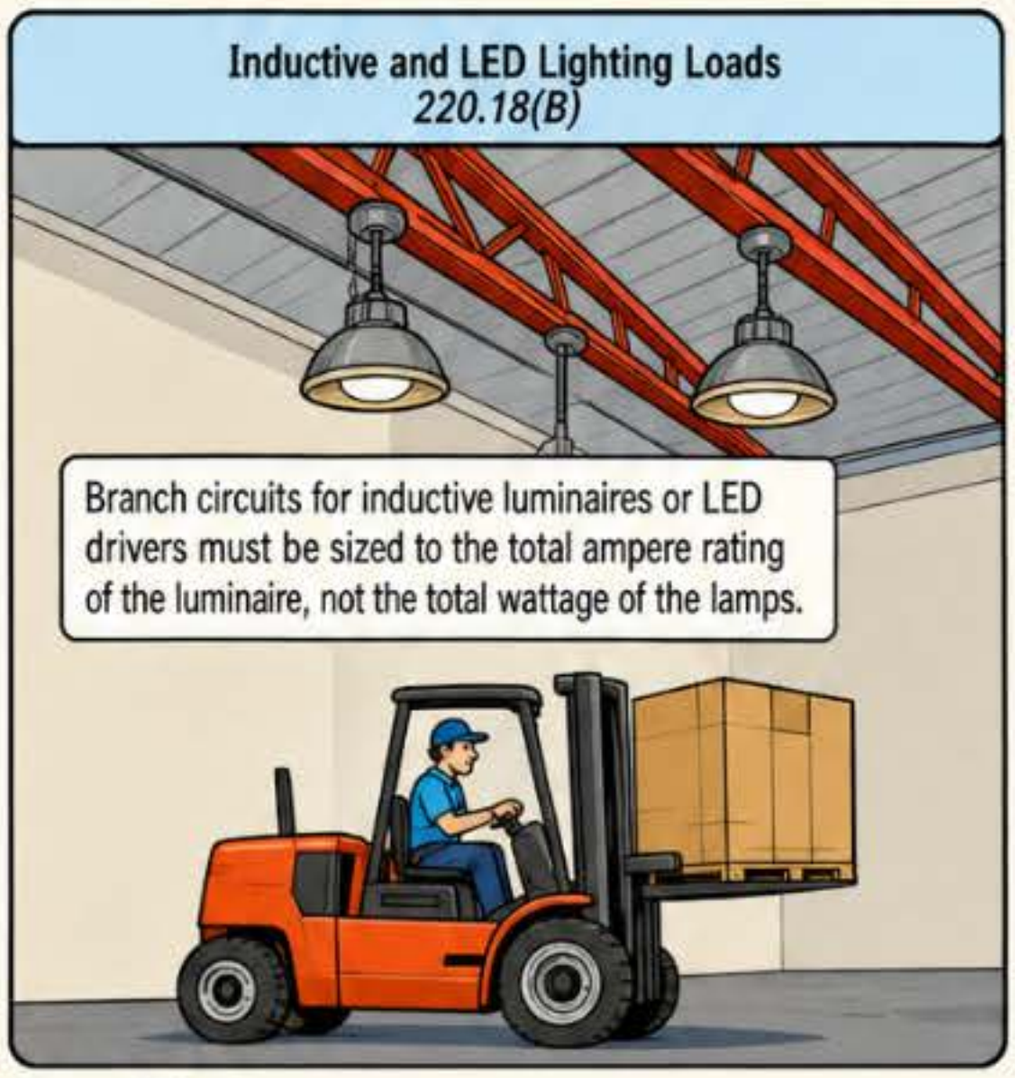


Figure 220-19

Part III. Feeder and Service Calculations

220.42 General Lighting Demand Factors

The *Code* allows that not all luminaires will be on at the same time and provides the following demand factors to be applied to the general lighting load as determined in accordance with Table 220.42.

Author's Commentary:

- *For dwelling units, the demand factors of Table 220.42 apply to the two small-appliance circuits of 1,500 VA each [220.52(A)] and a laundry circuit of 1,500 VA [220.52(B)], which are included as part of the general lighting load calculation, along with the required lighting and general-use receptacle load of 3 VA per square foot [220.14(J)].*

— Michael Hamilton

Branch-Circuit, Feeder, and Service Load Calculations

Table 220.42 General Lighting Demand Factors

Type of Occupancy	Lighting VA Load	Demand Factor
Dwelling units	First 3,000 VA 3,001 VA to 120,000 VA Remainder over 120,000 VA	100% 35% 25%
Hotels/motels/ apartment houses without provision for cooking*	First 20,000 VA 20,001 VA to 100,000 VA Remainder over 100,000 VA	60% 50% 35%
Warehouses (storage)	First 12,500 VA Remainder over 12,500 VA	100% 50%
Others	Total VA	100%

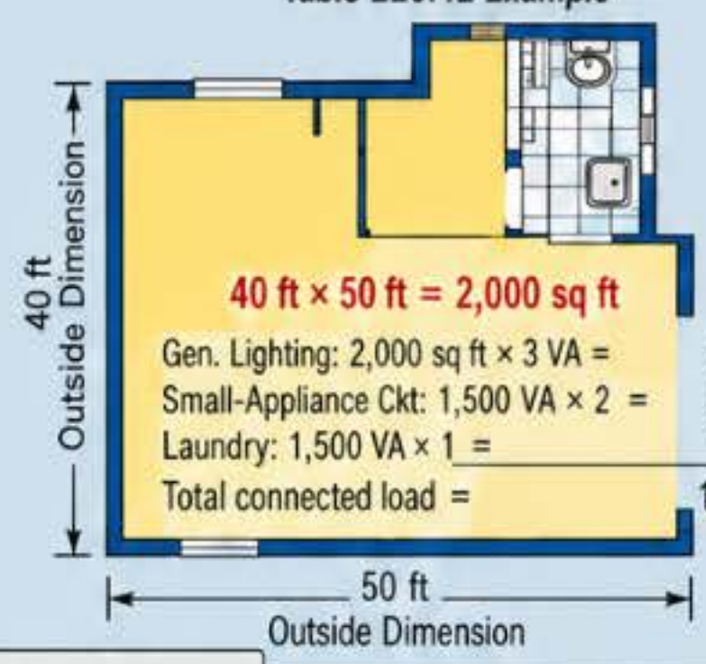
** The demand factors of this table do not apply to the calculated load of feeders or services supplying areas in hotels and motels where the entire lighting is likely to be used at one time, such as in ballrooms or dining rooms.*

▶ Example

Question: *What is the general lighting and receptacle load, after demand factors, for a 40 ft × 50 ft dwelling unit?* *(Figure 220–20)*

(a) 4,500 VA (b) 5,625 VA (c) 5,825 VA (d) 6,225 VA

General Lighting and Receptacle Demand Load
Table 220.42 Example



Garage, carport, or spaces not adaptable for future use Do NOT Count.	10,500 VA Total Connected Load −3,000 VA × 100% = 3,000 VA 7,500 VA × 35% = +2,625 VA **Demand Load = 5,625 VA**

▶ Figure 220–20

Solution:

General Lighting and Receptacles = 40 ft × 50 ft
General Lighting and Receptacles = 2,000 sq ft × 3 VA per sq ft
General Lighting and Receptacles = 6,000 VA

General Lighting and Receptacles =		*6,000 VA*
Small-Appliance Circuit [210.52(A)] =	*1,500 VA × 2 circuits =*	*3,000 VA*
Laundry Circuit [210.52(B)] =	*1,500 VA × 1 circuit =*	*+1,500 VA*
Total General Lighting =		*10,500 VA*
First 3,000 VA at 100%	*3,000 VA × 100% =*	*3,000 VA*
Next 7,500 VA at 35%	*7,500 VA × 35% =*	*+2,625 VA*
General Lighting and General-Use Receptacles Calculated Load =		*5,625 VA*

Note: *Remember to subtract 3,000 VA from 120,000 VA when using Table 220.42 since the 35% only applies to the 3,001 VA to 120,000 VA range.*

Answer: *(b) 5,625 VA*

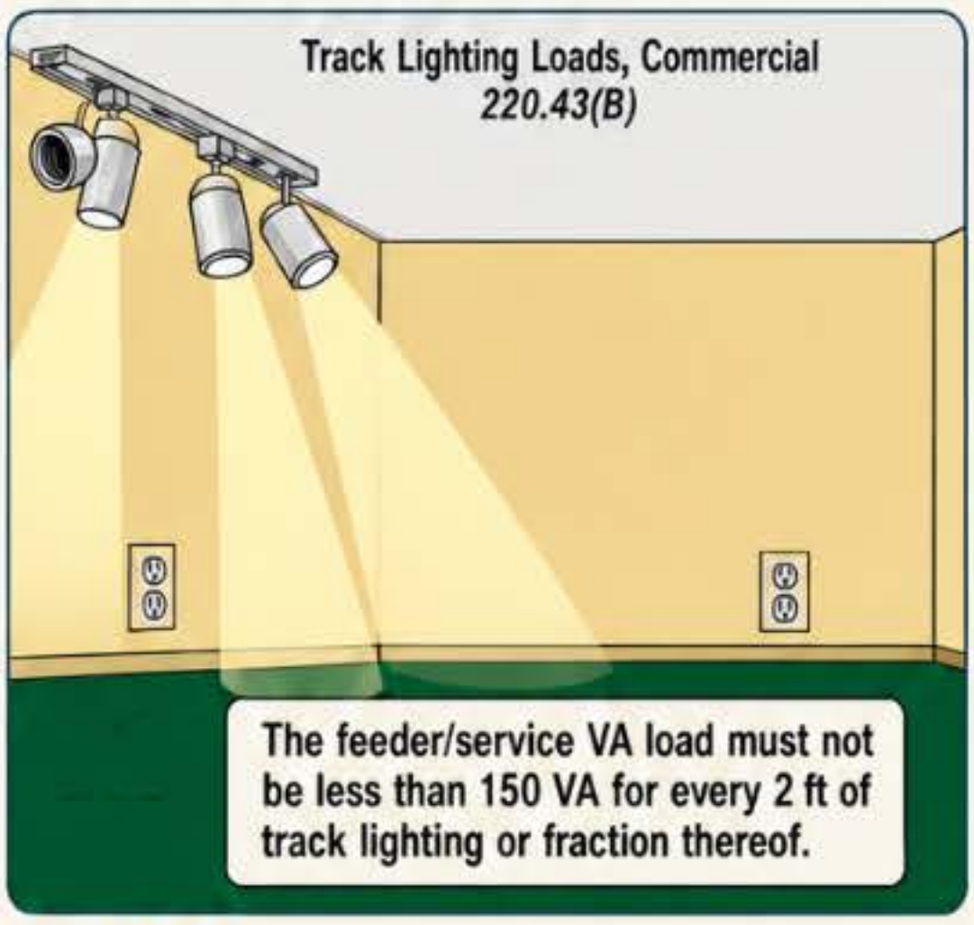
220.43 Show-Window and Track Lighting Loads, Commercial

(A) Show Windows. The load for show-window lighting cannot be less than 200 VA per linear foot.

(B) Track Lighting. The load for track lighting cannot be less than 150 VA for every 2 ft of track lighting or fraction of that length.

▶ Figure 220–21 and ▶ Figure 220–22

Track Lighting Loads, Commercial
220.43(B)



▶ Figure 220–21

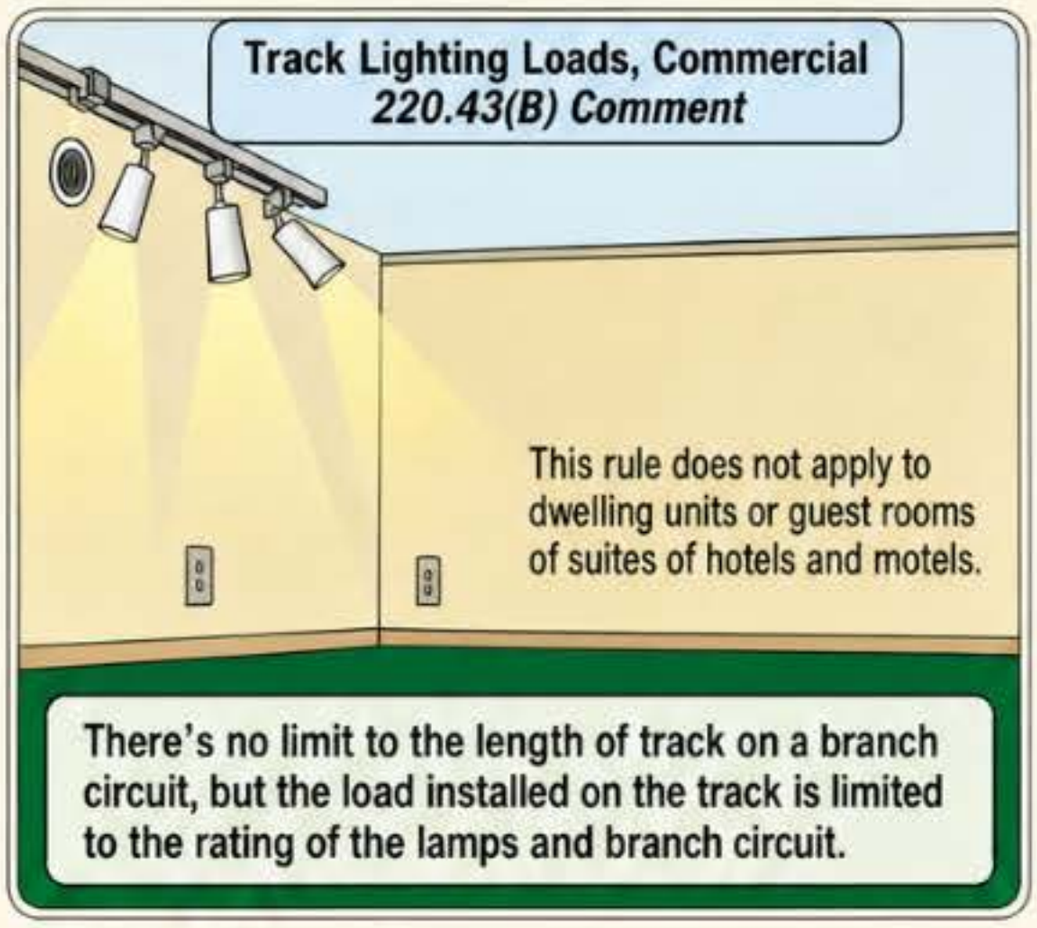


Figure 220–22

220.44 Receptacle Load, Other Than Dwelling Units

The load for general-purpose receptacle outlets [220.14(I)] and fixed multioutlet assemblies [220.14(H)] is determined by:

- Adding the receptacle and fixed multioutlet assembly VA load to the general lighting load [Table 220.12] and adjusting this VA value by the demand factors contained in Table 220.42, or
- Applying a 50 percent demand factor to that portion of the receptacle and fixed multioutlet receptacle loads that exceed 10 kVA.

Example

Question: *What is the demand load for one hundred fifty general-purpose receptacles and 100 ft of fixed multioutlet assembly in a commercial occupancy? The appliances powered by the multioutlet assembly are not used simultaneously.* ▶ *Figure 220–23*

(a) 18,200 VA (b) 19,400 VA (c) 20,100 VA (d) 20,300 VA

Solution:

Step 1: *Determine the total connected load.*

Receptacle Load = 150 receptacles × 180 VA
Receptacle Load = 27,000 VA [220.14(I)]

Multioutlet Load = 100 ft/5 ft
Multioutlet Load = 20 sections × 180 VA
Multioutlet Load = 3,600 VA [220.14(H)]

Step 2: *Apply the Table 220.44 demand factors.*

Total Connected Load =	*30,600 VA*	
First 10,000 VA at 100% =	*10,000 VA × 100% =*	*10,000 VA*
Remainder at 50% =	*20,600 VA × 50% =*	*10,300 VA*
Receptacle Calculated Load =		*20,300 VA*

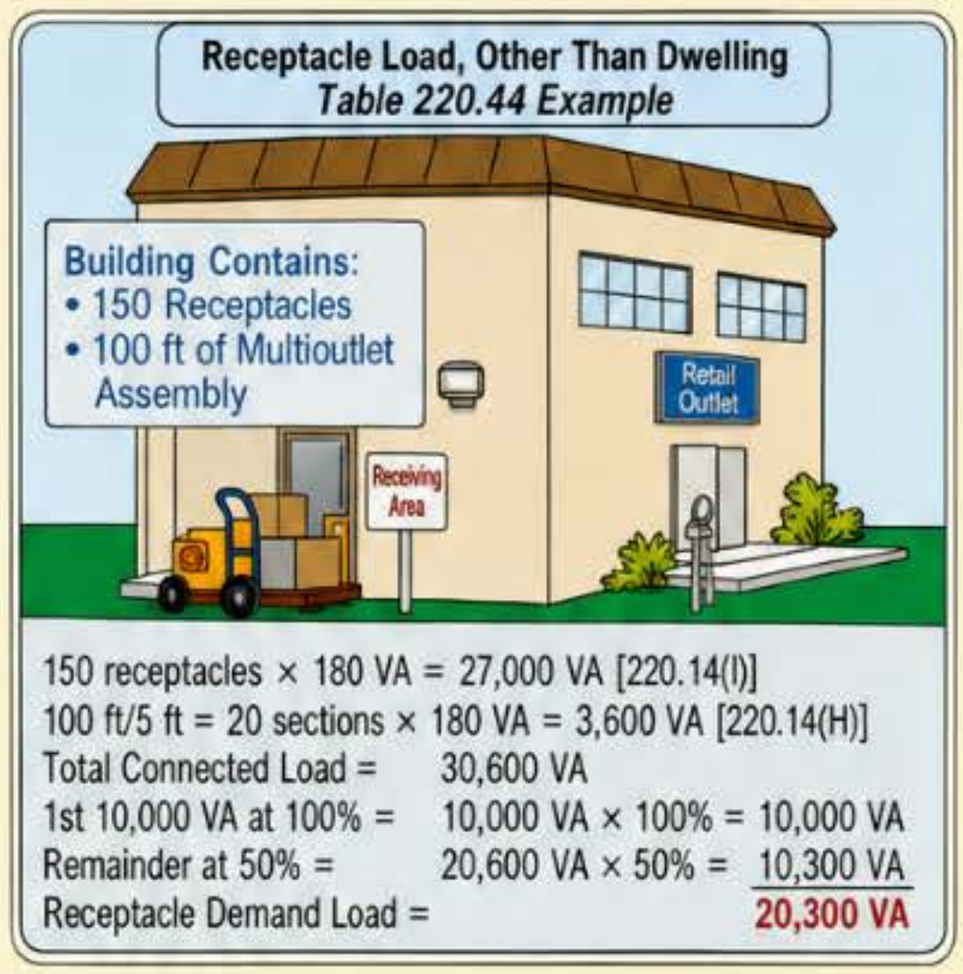


Figure 220–23

Answer: *(d) 20,300 VA*

220.50 Motor Type Loads

The feeder conductor for motor loads is calculated in accordance with 430.24.

220.51 Fixed Electric Space-Heating Load

The feeder/service load for fixed electric space-heating equipment must be calculated at 100 percent of the total connected load.

220.52 Small-Appliance and Laundry Loads, Dwelling

(A) Small-Appliance Circuit Load. The load for each 20A small-appliance circuit covered by 210.11(C)(1) is 1,500 VA. This load can be subjected to the general lighting demand factors contained in Table 220.42. ▶ *Figure 220–24*

(B) Laundry Circuit Load. The load for each 20A laundry circuit covered by 210.11(C)(2) is 1,500 VA. This load can be subjected to the general lighting demand factors contained in Table 220.42.

Branch-Circuit, Feeder, and Service Load Calculations

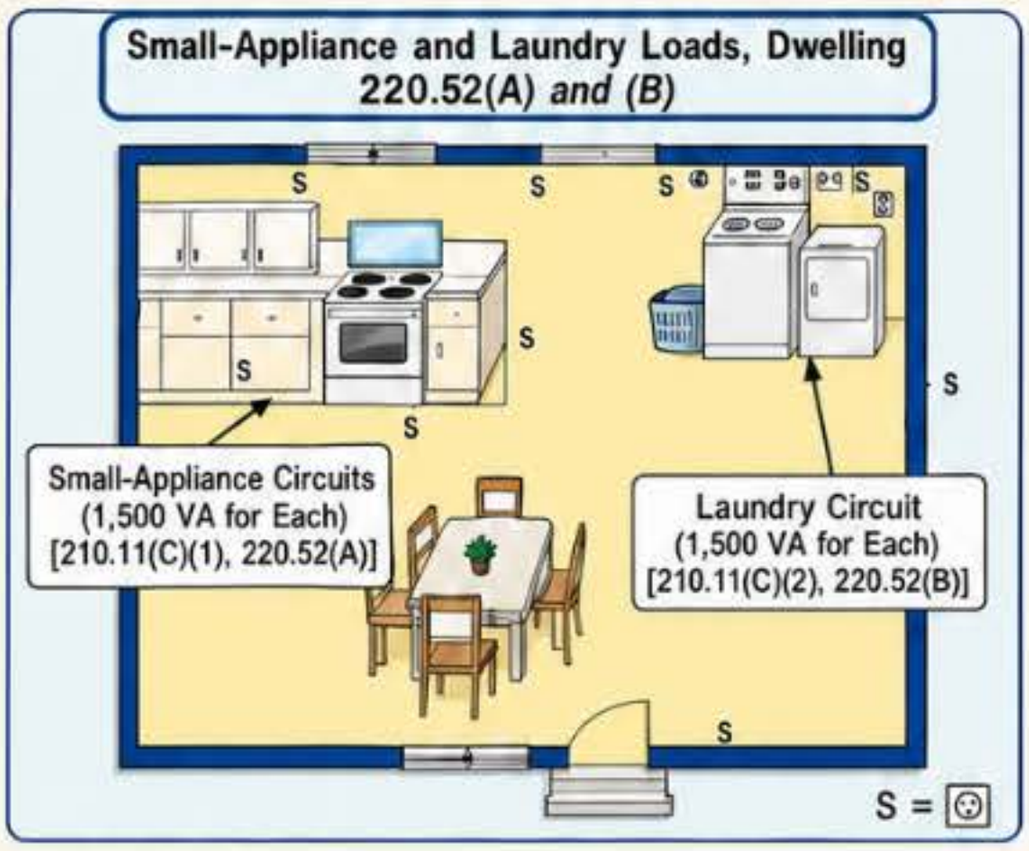


Figure 220-24

The VA requirements for small-appliance and laundry branch circuits are influenced by the demand factors listed in Table 220.42.

220.53 Appliance Load, Dwelling

A demand factor of 75 percent can be applied to the total connected load of four or more appliances rated 1/4 hp or greater, or 500W or higher, when they are fastened in place. *Figure 220-25*

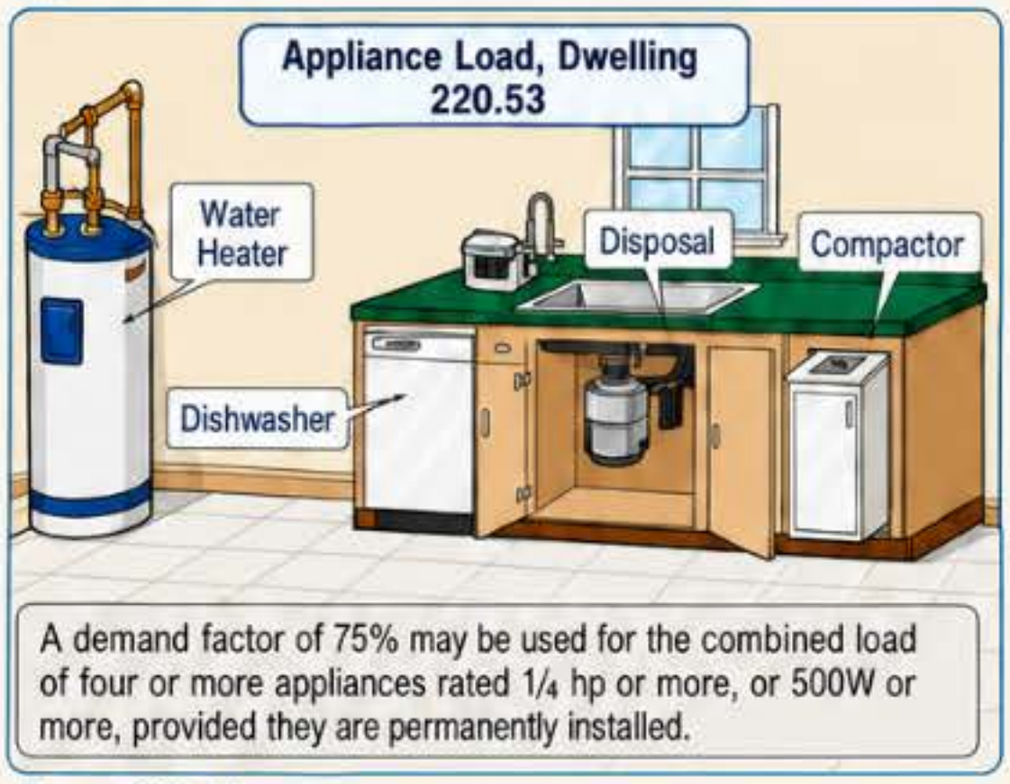


Figure 220-25

This demand factor does not apply to:

1. Household electric cooking equipment that is fastened in place [220.55]
2. Clothes dryers [220.54]
3. Space-heating equipment [220.51]
4. Air-conditioning equipment [220.50]

▶ Example 1

Question: *What is the demand load for a dwelling unit that contains a 1,000 VA waste disposal, a 1,500 VA dishwasher, and a 4,500 VA water heater?* ***Figure 220-26***

(a) 6,000 VA (b) 7,000 VA (c) 8,000 VA (d) 9,000 VA

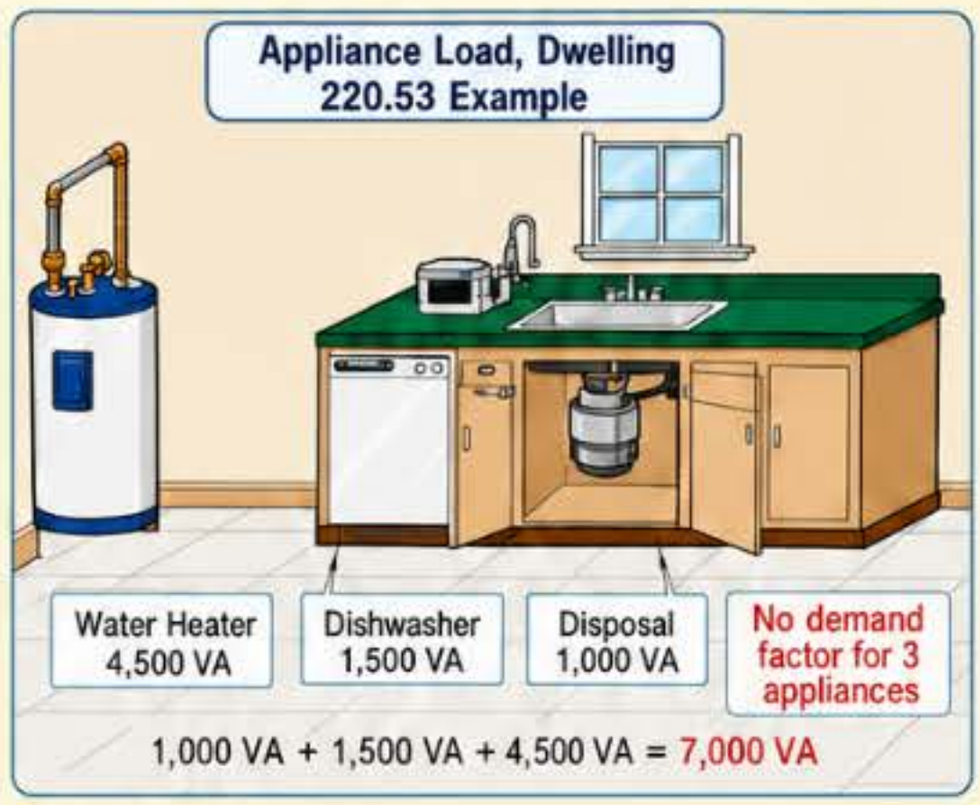


Figure 220-26

Solution:
1,000 VA + 1,500 VA + 4,500 VA = 7,000 VA

Answer: *(b) 7,000 VA*

▶ Example 2

Question: *What is the demand load for a 12-unit multifamily dwelling if each unit contains a 1,000 VA waste disposal, a 1,500 VA dishwasher, and a 4,500 VA water heater?* ***Figure 220-27***

(a) 63,000 VA (b) 71,000 VA (c) 82,000 VA (d) 93,000 VA

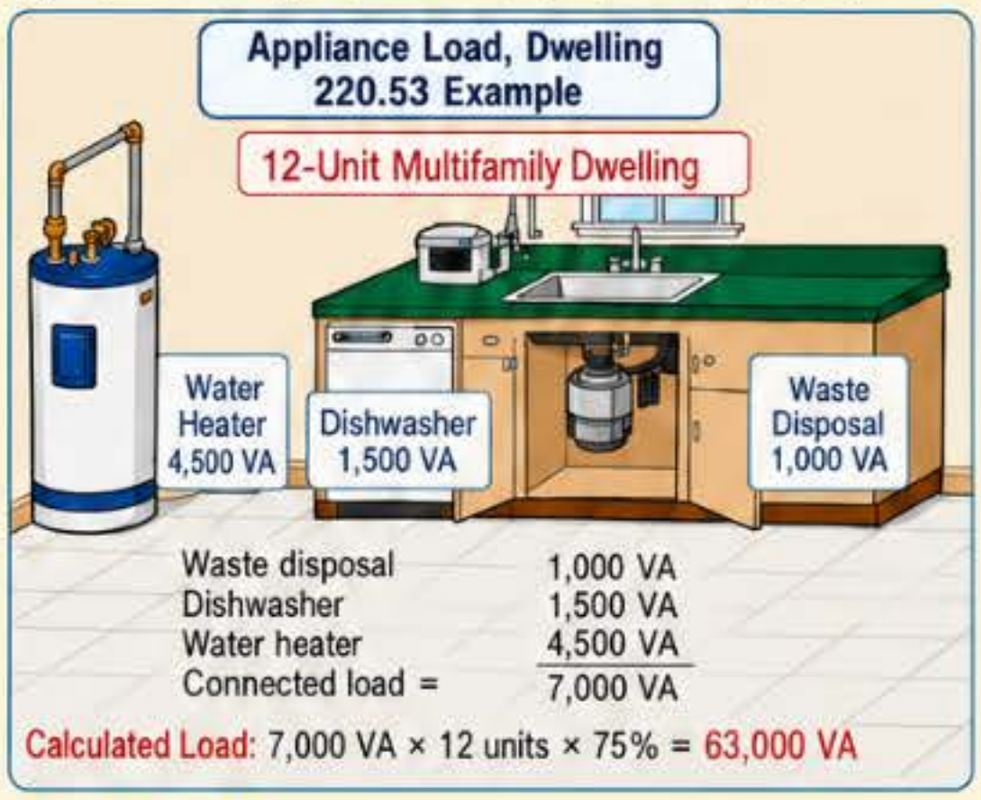


Figure 220-27

• • •

220.54 | Branch-Circuit, Feeder, and Service Load Calculations

Solution:

*Calculated Load = (1,000 VA + 1,500 VA + 4,500 VA) × 12 units × 75%**

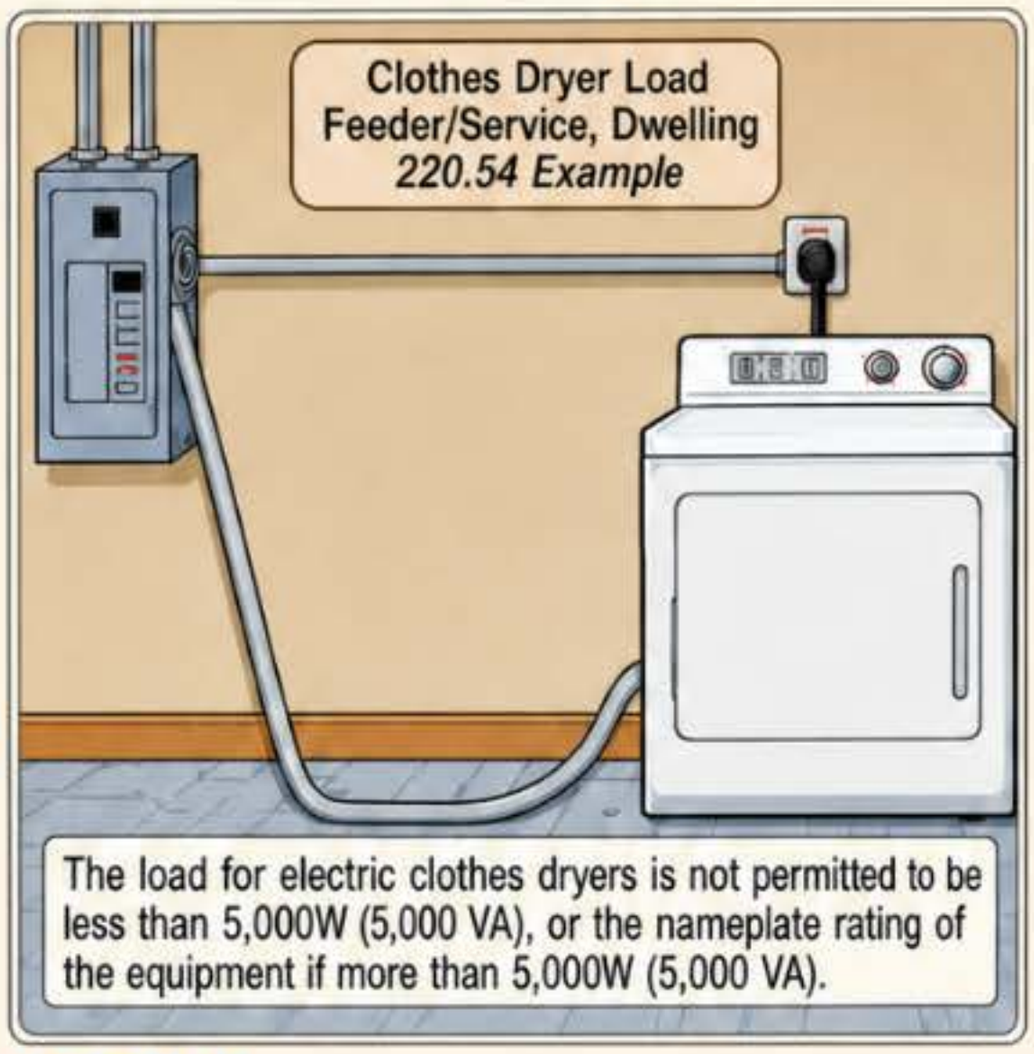
Calculated Load = 63,000 VA

**Each dwelling unit has only three appliances, but the feeder/service supplies a total of 36 appliances (12 units × 3 appliances).*

Answer: *(a) 63,000 VA*

220.54 Clothes Dryer Demand Load, Dwelling

The service/feeder load for electric clothes dryers must not be less than 5,000W (5,000 VA), or the nameplate rating of the equipment if more than 5,000W (5,000 VA). Kilovolt-amperes (kVA) is the same as kilowatts (kW), and volt-amperes (VA) is the same as watts (W) for load calculations in this section. ▶ Figure 220–28



▶ Figure 220–28

When a building contains five or more dryers, the demand factors contained in Table 220.54 can be applied to the total connected dryer load.

Table 220.54 Dwelling Unit Dryer Demand Factors

Number of Dryers	Demand Factor (Percent)
1–4	100%
5	85%
6	75%
7	65%
8	60%
9	55%
10	50%
11	47%
12–23	47% minus 1% for each dryer exceeding 11
24–42	35% minus 0.50% for each dryer exceeding 23
43 and over	25%

▶ Example

Question: *What is the service demand load for a 10-unit multifamily building that contains a 4 kW clothes dryer in each unit?* ▶ Figure 220–29

(a) 16 kW (b) 21 kW (c) 25 kW (d) 29 kW

▶ Figure 220–29

Solution:

Table 220.54 Demand Factor for 10 units = 50%

Calculated Load = 10 units × 5,000W × 50%

Calculated Load = 25,000W or 25 kW

Answer: *(c) 25 kW*

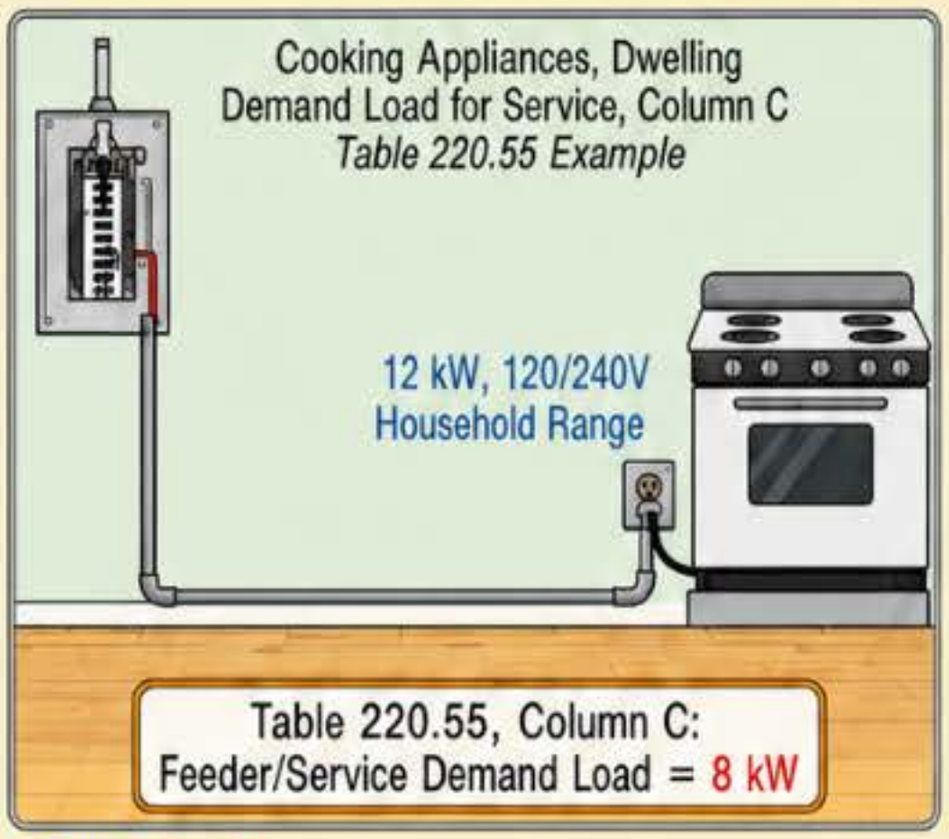
220.55 Cooking Appliances in Dwelling Units

Household cooking appliances rated above 1.75 kW can supply the feeder or service demand load. That demand is determined using the factors listed in Table 220.55.

▶ Example

Question: *What service demand load applies to one 12 kW, 120/240V cooking appliance?* ▶ Figure 220–30

(a) 6 kW (b) 8 kW (c) 10 kW (d) 12 kW



▶ Figure 220–30

Answer: *(b) 8 kW [Table 220.55, Column C]*

Table 220.55 Note 1: *For groups that are individually rated above 12 kW, the maximum demand in Column C must be increased by five percent for each added kilowatt, or major part, whose rating causes the total for that group to exceed 12 kW.*

▶ Example

Question: *What demand applies to three 15.60 kW ranges?*

(a) 16.80 kW (b) 21 kW (c) 25 kW (d) 29 kW

Solution:

Step 1: *Look up the base demand for three units in Table 220.55, Column C: 14 kW.*

Step 2: *Each range is 15.60 kW, or 3.60 kW above 12 kW. The Column C demand must be increased by 5% for each 3.60 kW (or major fraction) that pushes the rating past 12 kW.*

Step 3: *Increase the Column C value 14 kW by 20%.*

14 kW × 1.20 = 16.80 kW

Answer: *(a) 16.80 kW*

Table 220.55 Note 2: For groups rated more than 8.75 kW, but not above 27 kW, and for different ratings, find the total by adding the factors for all ratings in all ranges to get the total connected load (using 12 kW for any range rated under 12 kW) and then dividing that sum by the number of ranges. The maximum demand in Column C must then be increased five *percent for each extra kilowatt, or major fraction thereof, by which the average value exceeds 12 kW.*

▶ Example

Question: *What service demand applies to three ranges totaling 9 kW and three ranges totaling 14 kW?*

(a) 16 kW (b) 21 kW (c) 22 kW (d) 23 kW

Solution:

Step 1: *Find the total connected load.*

9 kW (minimum 12 kW)	*3 ranges × 12 kW =*	*36 kW*
14 kW	*3 ranges × 14 kW =*	*+42 kW*
Total Connected Load =		*78 kW*

Step 2: *Average the range ratings.*

78 kW / 6 units = 13 kW average rating

Step 3: *Demand from Table 220.55 Column C.*

6 ranges = 21 kW

Step 4: *Since the average (13 kW) is above 12 kW, increase the Column C demand (21 kW) by 5%.*

Calculated Load = 21 kW × 105%

Calculated Load = 22.05 kW, round to 22 kW

Answer: *(c) 22 kW*

Table 220.55 Note 3: *For groups from 1¾ kW through 8¾ kW, use the method in Column C. You may add together the ratings of all cooking appliances rated above 1¾ kW but not more than 8¾ kW, then apply the demand factors given for Column A or Column B for the number of appliances. If the rating of appliances includes both Column A and Column B, the demand factors for each column can be used for that column, and the results combined.*

220.55 | Branch-Circuit, Feeder, and Service Load Calculations

▶ Example

Question: *What is the service demand load for one 6 kW cooktop and two 3 kW ovens?* ▶ Figure 220-31

(a) 6.80 kW (b) 7.10 kW (c) 8.20 kW (d) 9.30 kW

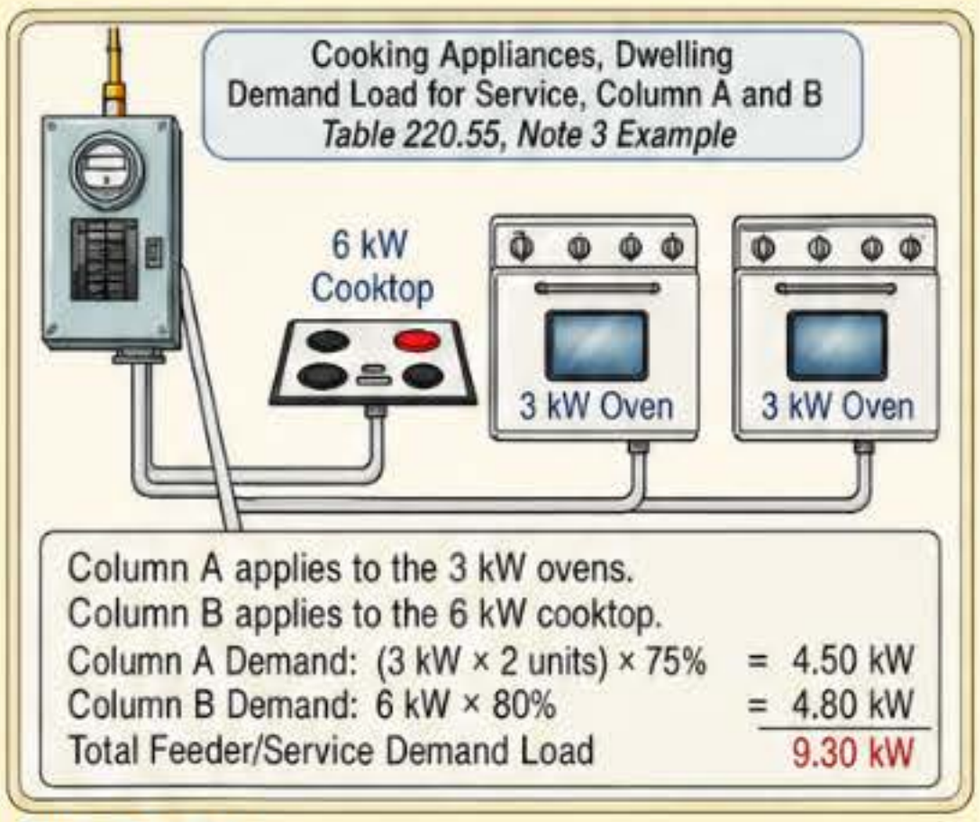


Figure 220-31

Solution:

Column A applies to the 3 kW ovens.
Column B applies to the 6 kW cooktop.

Column A Demand = (3 kW × 2 ovens) × 75%
Column A Demand = 6 kW × 75%
Column A Demand = 4.50 kW
Column B Demand = 6 kW × 80%
Column B Demand = 4.80 kW

Service Demand Load = 4.50 kW + 4.80 kW
Service Demand Load = 9.30 kW

Answer: *(d) 9.30 kW*

Table 220.55 Note 4: It is permissible to calculate the branch-circuit load for one range in accordance with Table 220.55.

▶ Example

Question: *What is the branch-circuit demand load in amperes for a single 12 kW range connected on a 120/240V circuit?* ▶ Figure 220-32

(a) 25A (b) 27A (c) 31A (d) 33A

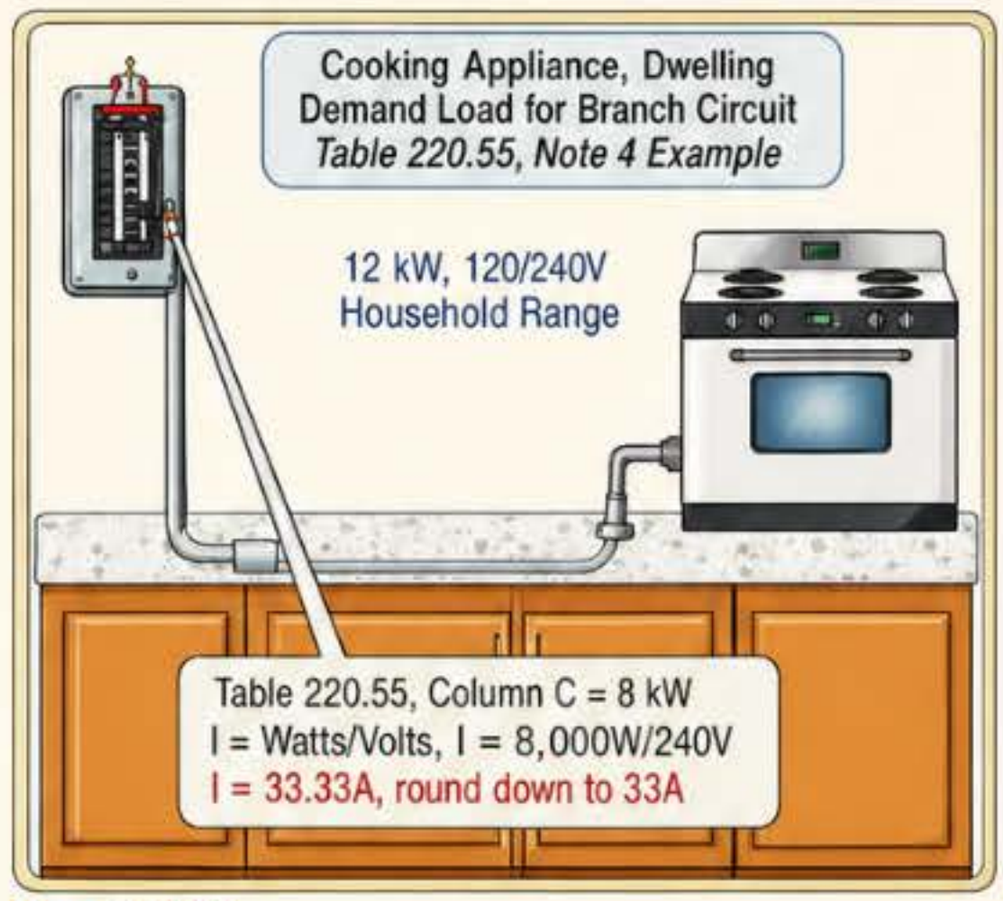


Figure 220-32

Solution:

Column C Calculated Load = 8 kW
*Branch-Circuit Load in Amperes = **I = P/E***

P = 8,000W

Volts = 240V

I = 8,000W/240V
I = 33.33A; round down to 33A

Answer: *(d) 33A*

Table 220.55 Note 4: The branch-circuit load for one wall-mounted oven or one counter-mounted cooking unit must be the nameplate rating of the appliance.

▶ Example

Question: *What size branch-circuit conductors are required for a 6 kW wall-mounted oven connected on a 120/240V circuit?* ▶ Figure 220-33

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG

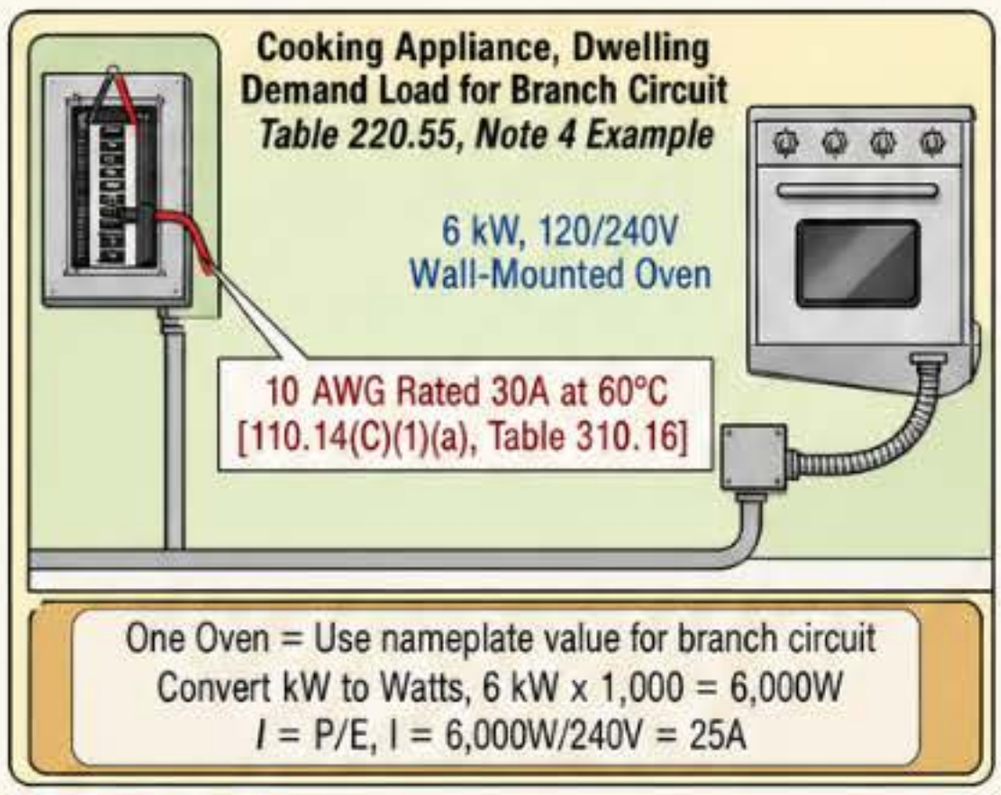
Solution:

Determine the branch-circuit load in amperes.

I = P/E
I = 6,000W/240V
I = 25A

Use 10 AWG conductors rated 30A at 60°C {110.14(C)(1) and Table 310.16}.

Answer: *(b) 10 AWG*



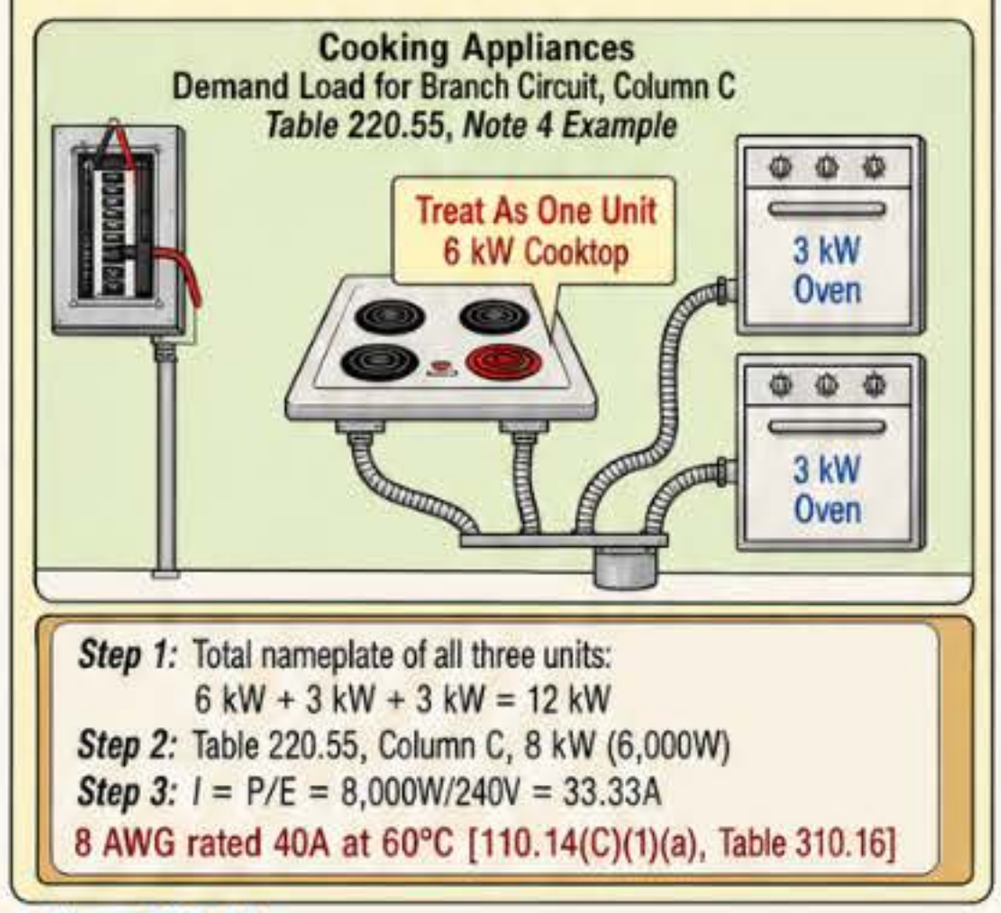
▶ Figure 220–33

Table 220.55 Note 4: The branch-circuit load for one counter-mounted cooking unit and up to two wall-mounted ovens is determined by adding the nameplate ratings together and treating that value as a single range.

▶ Example

Question: *What size branch-circuit conductors are required for one 6 kW counter-mounted cooking unit and two 3 kW wall-mounted ovens connected on a 120/240V circuit?* ▶ *Figure 220–34*

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG



▶ Figure 220–34

Solution:

Step 1: *Determine the total connected load.*

Total Connected Load = 6 kW + 3 kW + 3 kW
Total Connected Load = 12 kW

Step 2: *Determine the calculated kW load as a single 12 kW range.*

Table 220.55, Column C = 8 kW

Step 3: *Determine the branch-circuit load in amperes.*

I = P/E
P = 8,000W
Volts = 240V

I = 8,000W/240V
I = 33.33A

Use 8 AWG conductors rated 40A at 60°C [110.14(C)(1)(a) and Table 310.16].

Answer: *(c) 8 AWG*

220.56 Kitchen Equipment Load, Commercial

Table 220.56 can be used to calculate the demand load for thermostat-controlled or intermittently used commercial kitchen equipment such as electric cooking equipment, dishwasher booster heaters, water heaters, and other similar kitchen loads. The kitchen equipment feeder/service calculated load must not be less than the sum of the two largest kitchen equipment loads.

Table 220.56 demand factors do not apply to space-heating, ventilating, or air-conditioning equipment.

▶ Example

Question: *What is the service demand load for one 15 kW water heater, one 15 kW booster water heater, one 3 kW oven, and one 2 kW deep fryer in a commercial kitchen?* ▶ *Figure 220–35*

(a) 20 kW (b) 30 kW (c) 40 kW (d) 50 kW

Solution:

Step 1: *Determine the total connected load.*

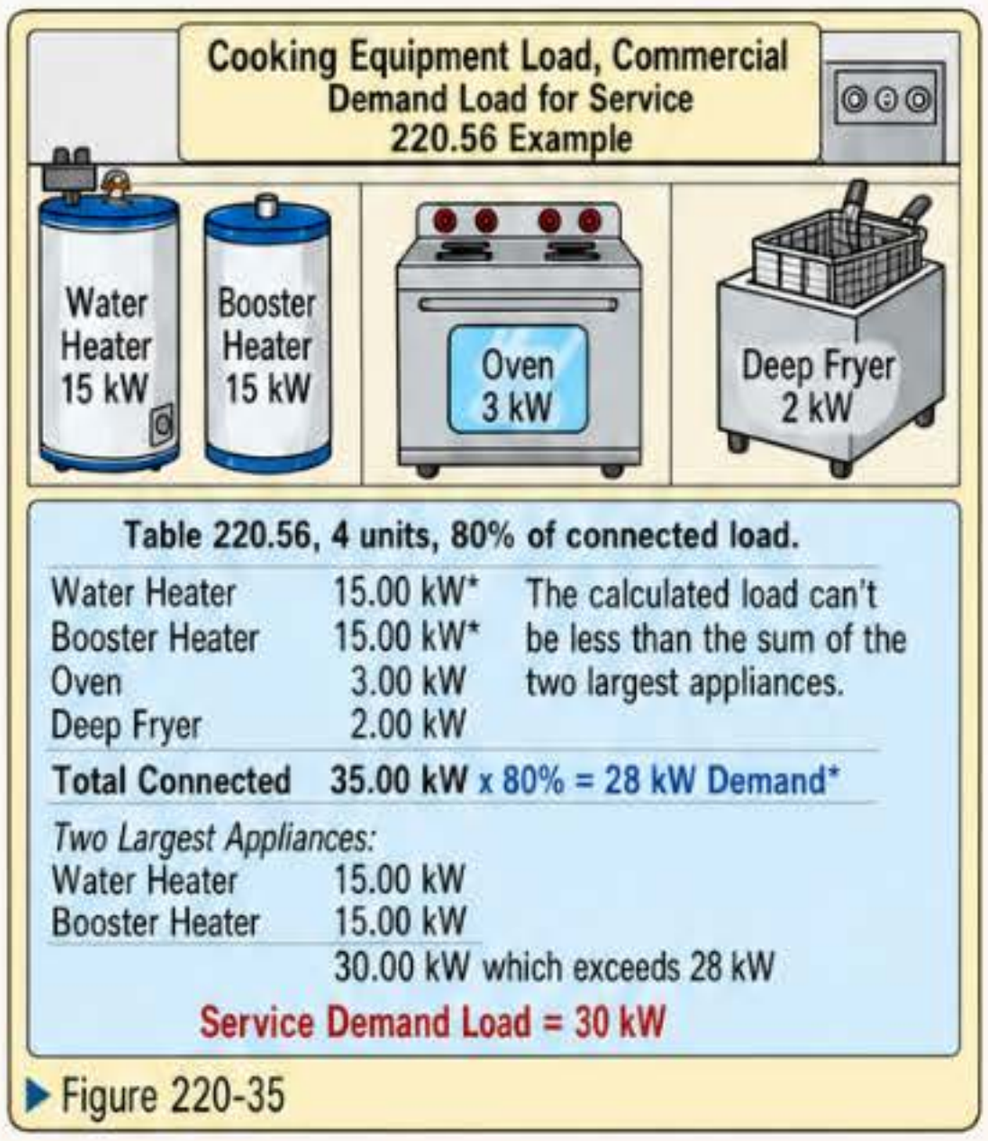
Total Connected Load = 15 kW + 15 kW + 3 kW + 2 kW
Total Connected Load = 35 kW

Step 2: *Determine the feeder/service calculated load.*

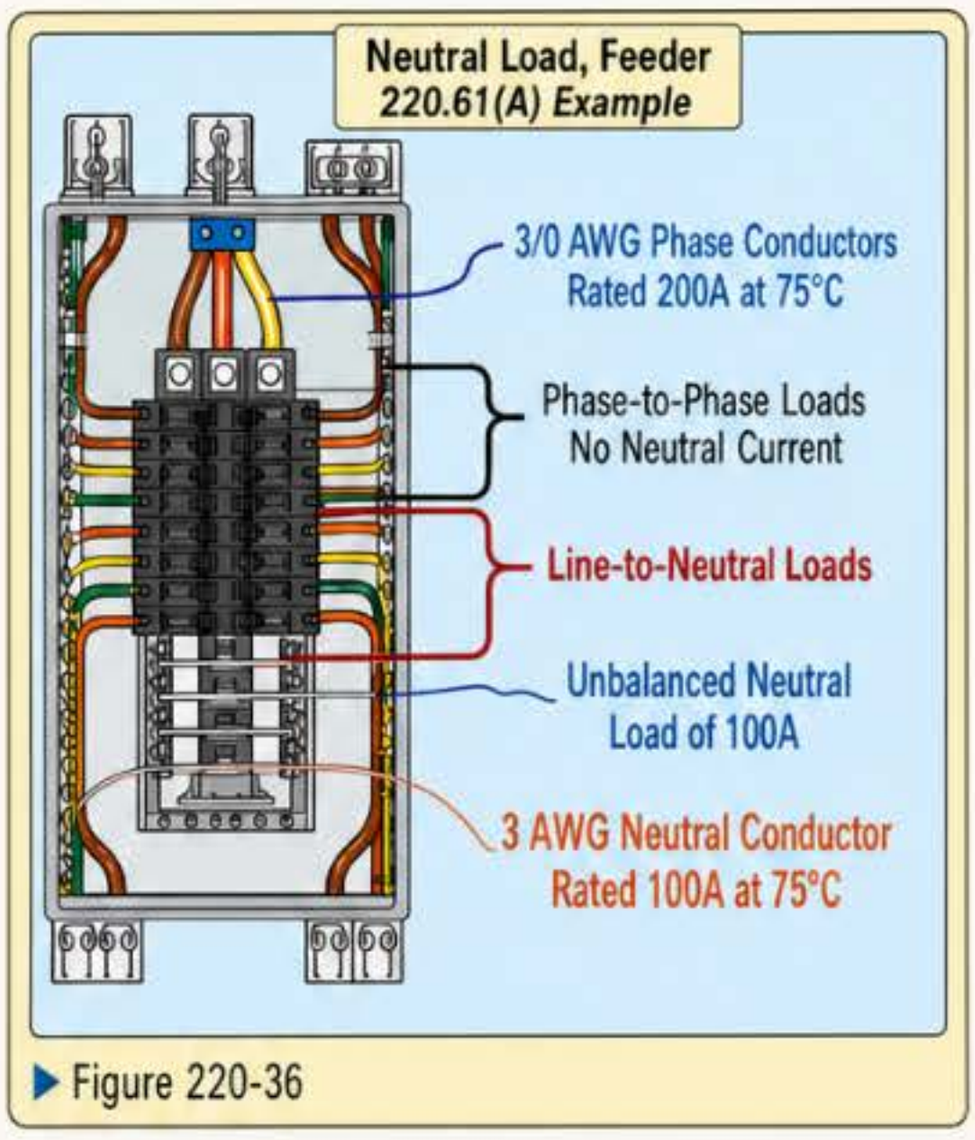
Feeder/Service Calculated Load = 35 kW × 80%
Feeder/Service Calculated Load = 28 kW

Check the size of the two largest appliances. The 15 kW water heater + the 15 kW booster heater is 30 kW. The feeder/service calculated load is 30 kW because it cannot be less than the sum of the two largest appliances.

Answer: *(b) 30 kW*



▶ Figure 220-35



▶ Figure 220-36

220.60 Noncoincident Loads

When two or more loads are unlikely to operate at the same time, only the largest load is used for load calculations.

220.61 Neutral Load

(A) Basic Calculation. The neutral load for feeders or services is based on the maximum calculated load between the neutral conductor and any one phase conductor.

Line-to-line loads do not place any load on the neutral conductor; therefore they are not included in the calculation.

▶ Example

Question: *What is the minimum neutral conductor size for a 200A feeder which has 100A of line-to-line loads with a maximum unbalanced neutral load of 100A?* ▶ *Figure 220-36*

(a) 3 AWG (b) 2 AWG (c) 1 AWG (d) 1/0 AWG

Solution:

200A Total Load − 100A Line-to-Line Loads = 100A Neutral Load

Use a 3 AWG conductor rated 100A at 75°C [110.14(C)(1) and Table 310.16].

Answer: *(a) 3 AWG*

(B) Permitted Reductions

(1) Cooking and Dryer Neutral Load, Dwelling

Cooking Load. The feeder/service neutral load for household electric ranges, wall-mounted ovens, or counter-mounted cooking units can be calculated at 70 percent of the cooking equipment demand load as determined in accordance with Table 220.55.

▶ Example

Question: *What is the minimum neutral load for nine 12 kW household ranges?*

(a) 14.80 kW (b) 16.80 kW (c) 18.40 kW (d) 20.50 kW

Solution:

Step 1: *Determine the Column C value for 9 ranges.*

Table 220.55, Column C = 24 kW for 9 ranges

Step 2: *Determine the neutral load.*

Neutral Load = 24 kW × 70%

Neutral Load = 16.80 kW

Answer: *(b) 16.80 kW*

Dryer Load. The feeder/service neutral load for household electric dryers can be calculated at 70 percent of the dryer calculated load as determined in accordance with Table 220.54.

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▶ Example

Question: *A 10-unit multifamily building has a 5 kW electric clothes dryer in each unit. What is the minimum neutral load for these dryers?*

(a) 14.80 kW (b) 16.80 kW (c) 17.50 kW (d) 20.50 kW

Solution:

Step 1: *Find the total connected load of all the dryers.*

Table 220.54 = 10 units × 5 kW × 50%

Table 220.54 = 25 kW

Step 2: *Calculate the neutral load.*

Neutral Load = 25 kW × 70%

Neutral Load = 17.50 kW

Answer: *(c) 17.50 kW*

(2) Over 200A Neutral Reduction. The feeder/service calculated neutral load for a 3-wire, single-phase or 4-wire, three-phase system can be calculated at 70 percent for that portion of the unbalanced load over 200A.

Author's Commentary:

In addition to the 70 percent demand factor contained in 220.61(B)(1), a further demand factor of 70 percent can be applied to that portion of the unbalanced load in excess of 200A. See Annex D, Example D4(a) Multifamily Dwelling.

— Michael Hamilton

▶ Example

Question: *What is the feeder/service neutral calculated load for the following?* ▶ Figure 220–37

- *500A of line-to-line loads*
- *100A of household ranges*
- *50A of household dryers*
- *350A of line-to-neutral loads*

(a) 351A (b) 361A (c) 379A (d) 391A

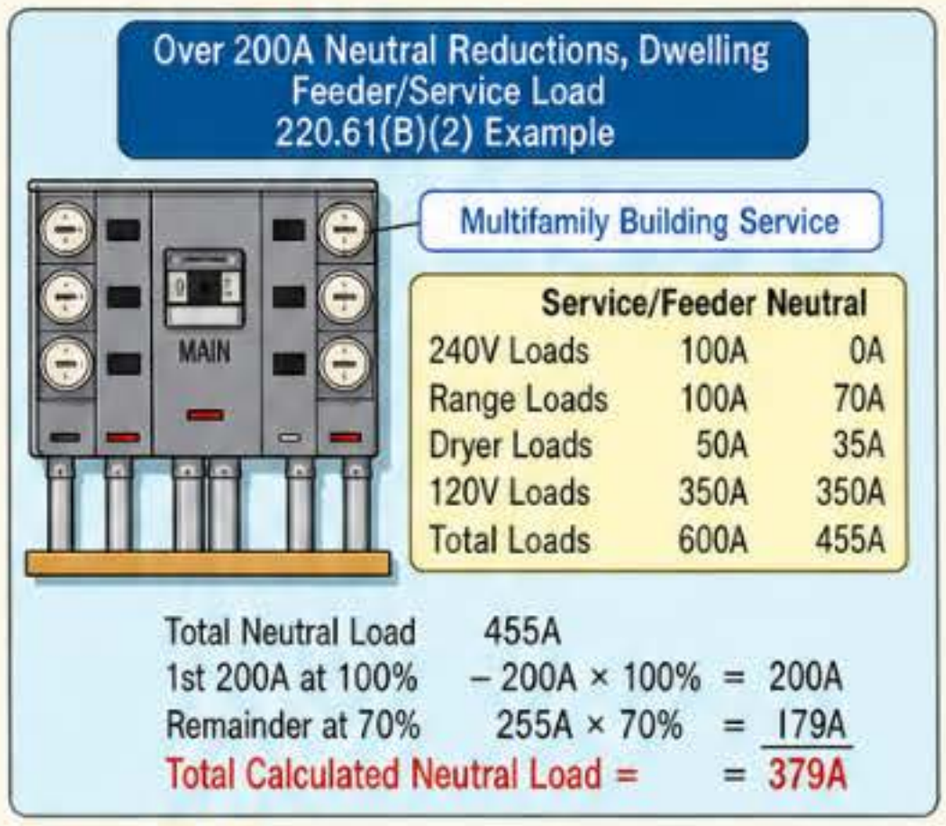
Solution:

Step 1: *Determine the neutral load after applying a 70 percent adjustment in accordance with 220.61(B)(1).*

Line-to-Line 500A	*(500A × 0)*	*0A*
Ranges 100A	*(100A × 70%)*	*70A*
Dryers 50A	*(50A × 70%)*	*35A*
Line-to-Neutral		*+ 350A*
Total Load =		*455A*

Step 2: *Determine the neutral load after applying a 70 percent demand factor for that portion of the unbalanced load in excess of 200A [220.61(B)(2)].*

Total Neutral Load =	*455A*	
First 200A at 100%	*– 200A × 100% =*	*200A*
Remainder at 70%	*255A × 70% =*	*+179A*
Total Calculated Neutral Load =		*379A*

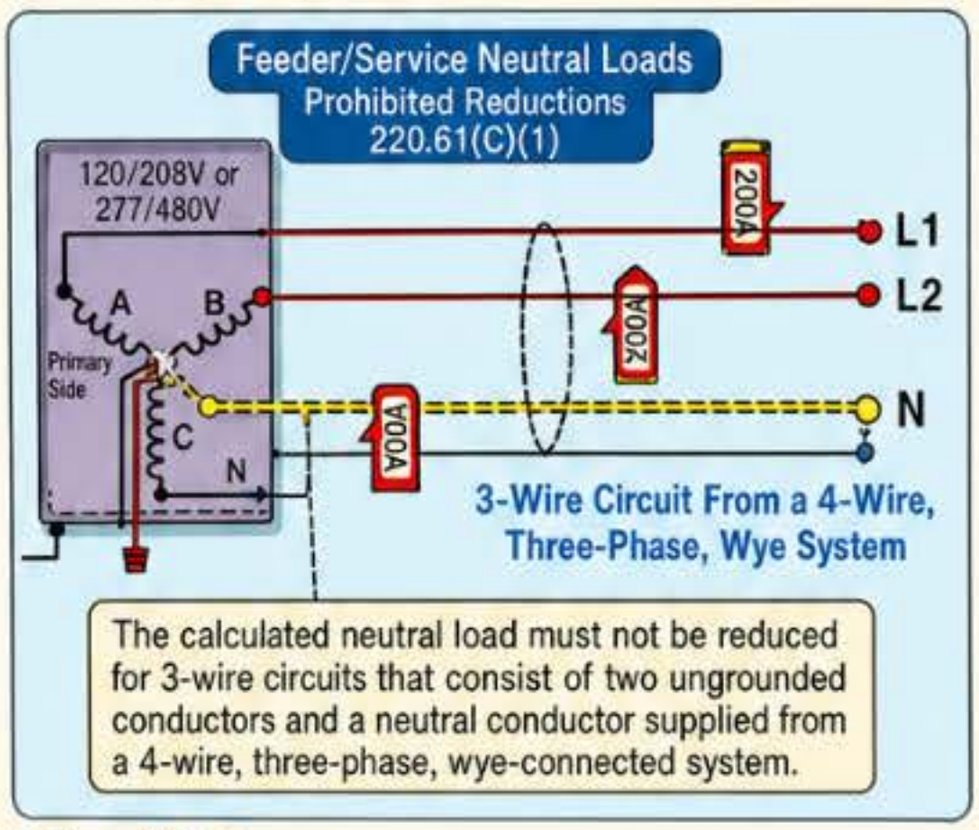


▶ Figure 220–37

Answer: *(c) 379A*

(C) Prohibited Reductions. No reduction of the neutral conductor calculated feeder/service load is permitted for the following:

(1) 3-Wire Circuits from 4-Wire, Wye-Connected Systems. This is because the neutral load on the 3-wire circuit will carry approximately the same amount of line-to-neutral current as the phase conductors [310.15(E)(3)]. ▶ Figure 220–38



▶ Figure 220–38

220.82 | Branch-Circuit, Feeder, and Service Load Calculations

(2) Nonlinear Loads. The neutral conductor in the feeder or service is allowed to be sized without considering nonlinear loads supplied from a 4-wire, three-phase, wye-connected system.

▶ Example

Question: *What is the feeder or service neutral calculated load for the following?*

- *500A of line-to-line loads*
- *200A of line-to-neutral linear loads*
- *200A of line-to-neutral nonlinear loads*

(a) 200A (b) 300A (c) 400A (d) 450A

Solution:

Nonlinear Line-to-Neutral Loads	*200A*
Linear Line-to-Neutral Loads	*+200A*
Total Neutral Calculated Loads	*400A*

Answer: *(c) 400A*

Part IV. Optional Calculations for Computing Feeder and Service Loads

220.82 Optional Load Calculations, Dwellings

(A) Feeder/Service Load. If the load for a dwelling unit is not less than 100A, the service load can be calculated by adding the calculated loads from 220.82(B) and (C).

The neutral load must be determined in accordance with 220.61.

(B) General Loads. The demand load must not be less than 100 percent of the first 10 kVA, plus 40 percent of the remaining kVA for the following loads:

(1) General Lighting. The general lighting load is based on 3 VA per sq ft for general lighting and general-use receptacles.

(2) Small-Appliance and Laundry Circuits. Add 1,500 VA for each 20A small-appliance circuit required by 210.11(C)(1)(a) with a minimum of two circuits per dwelling unit, and 1,500 VA for each 20A laundry circuit required by 210.11(C)(2).

(3) Appliances. The nameplate rating of the following appliances:

a. Appliances fastened in place, permanently connected, or located to be on a specific circuit

b. Ranges, wall-mounted ovens, and counter-mounted cooking units

c. Clothes dryers

d. Water heaters

(4) Motor VA. The VA nameplate rating of motors not part of an appliance.

(C) Air-Conditioning and Heating Equipment. The larger of (1) through (6):

(1) Air-Conditioning Equipment. 100 percent of the air-conditioning nameplate rating(s).

(2) Heat-Pump Compressor without Supplemental Heating. 100 percent of the heat-pump nameplate rating.

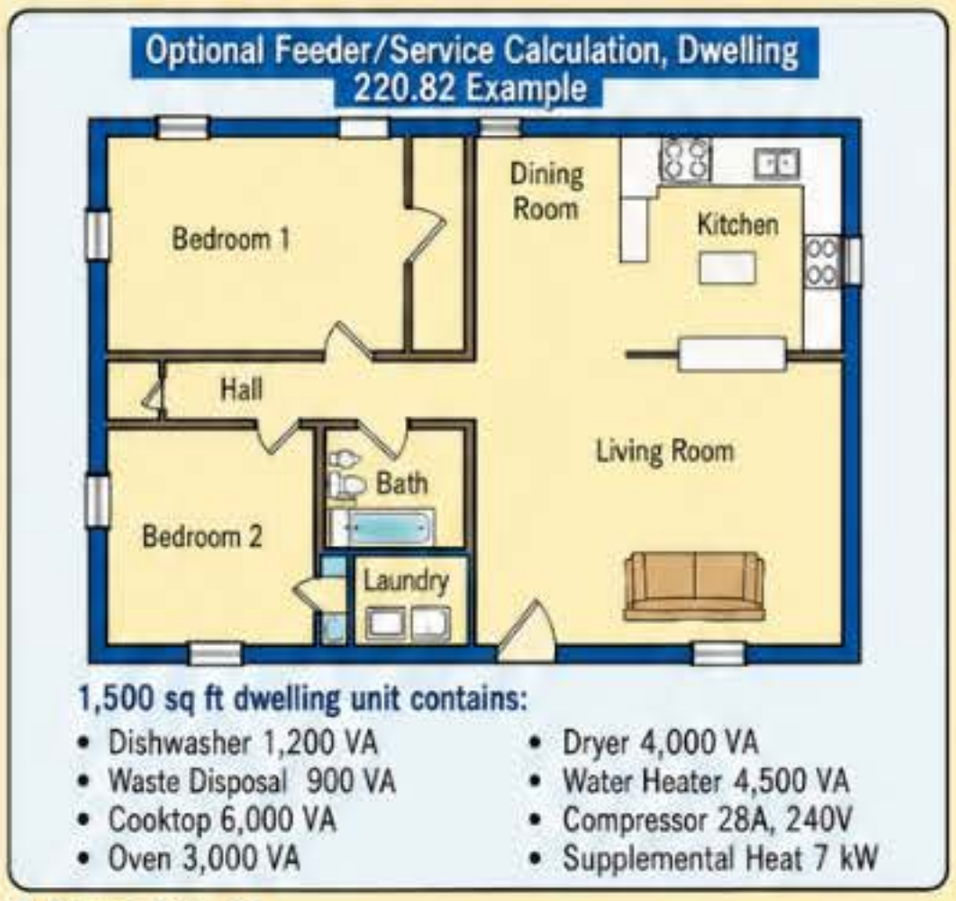
(3) Heat-Pump Compressor and Supplemental Heating. 100 percent of the nameplate rating of the heat pump and 65 percent of the supplemental electric heating.

(4) Space-Heating Units (Three Units and Fewer). 65 percent of the space-heating nameplate rating(s).

(5) Space-Heating Units (Four or More Units). 40 percent of the space-heating nameplate rating(s).

▶ Example

Question: *Using the optional calculation method, what size service is required for a 1,500 sq ft dwelling unit that contains the following loads?* ▼ Figure 220–39



▼ Figure 220–39

- *Dishwasher, 1,200 VA*
- *Waste Disposal, 900 VA*
- *Cooktop, 6,000 VA*
- *Oven, 3,000 VA*
- *Dryer, 4,000 VA*

BRANCH-CIRCUIT, FEEDER, AND SERVICE LOAD CALCULATIONS 220.84

- *Water heater, 4,500 VA*
- *Heat-pump compressor rated 28A at 240V, with supplemental electric heat having a rating of 7 kW.*

(a) 100A (b) 110A (c) 125A (d) 150A

SOLUTION:

STEP 1: *Determine the total feeder/service calculated load.*

(1) Lighting, receptacles, and appliance calculated load

Small-Appliance	1,500 VA × 2 =	3,000 VA
Laundry	1,500 VA × 1 =	1,500 VA
General Lighting	1,500 sq ft × 3 VA/sq ft =	4,500 VA
Dishwasher	1,200 VA × 1 =	1,200 VA
Waste Disposal	900 VA × 1 =	900 VA
Cooktop	6,000 VA × 1 =	6,000 VA
Oven	3,000 VA × 1 =	3,000 VA
Dryer	4,000 VA × 1 =	4,000 VA
Water Heater	4,500 VA × 1 =	4,500 VA-
Calculated Load =		28,600 VA
First 10,000 VA at 100%	10,000 VA × 100% =	10,000 VA
Remainder at 40%	18,600 VA × 40% =	7,440 VA
220.82(B) Demand Load		17,440 VA

(2) Largest of Air-Conditioning or Heat [220.82(C)]

Heat Pump Compressor at 100% 240V × 28A =	6,720 VA
Supplemental Heat at 65% = 7,000 VA × 65% =	4,550 VA
220.82(C) Demand Load	11,270 VA

Total Demand Load [220.82(B) and (C)] = 17,440 VA + 11,270 VA
Total Demand Load [220.82(B) and (C)] = 28,710 VA

STEP 2: *Determine the service size in amperes.*

I = Volt-Amperes/Volts
I = 28,710 VA/240V
I = 120A, 125A Service [240.6(A)]

ANSWER: *(c) 125A*

220.84 OPTIONAL LOAD CALCULATIONS, MULTIFAMILY

(A) Feeder or Service Load. The feeder/service calculated load for a building with three or more dwelling units equipped with electric cooking equipment, and either electric space heating or air-conditioning, can be in accordance with the demand factors of Table 220.84, based on the number of dwelling units.

The feeder/service neutral calculated load must be determined in accordance with 220.61.

(C) Connected Loads. The demand factors of Table 220.84 include the following:

(1) 3 VA per sq ft for general lighting and general-use receptacles.

(2) 1,500 VA for each 20A small-appliance circuit required by 210.11(C)(1)(a) with a minimum of two circuits per dwelling unit, and 1,500 VA for each 20A laundry circuit required by 210.11(C)(2).

AUTHOR'S COMMENTARY:

A laundry circuit is not required in an individual unit of a multifamily dwelling if common laundry facilities are provided [210.52(F) Ex 1].

— Michael Hamilton

(3) Appliances. The nameplate rating of the following:

a. Appliances fastened in place, permanently connected, or located to be on a specific circuit

b. Ranges, wall-mounted ovens, and counter-mounted cooking units

c. Clothes dryers

d. Water heaters

(4) The nameplate rating of all motors not part of an appliance.

(5) The larger of the air-conditioning load at 100% or fixed electric space-heating load at 100%.

▶ EXAMPLE

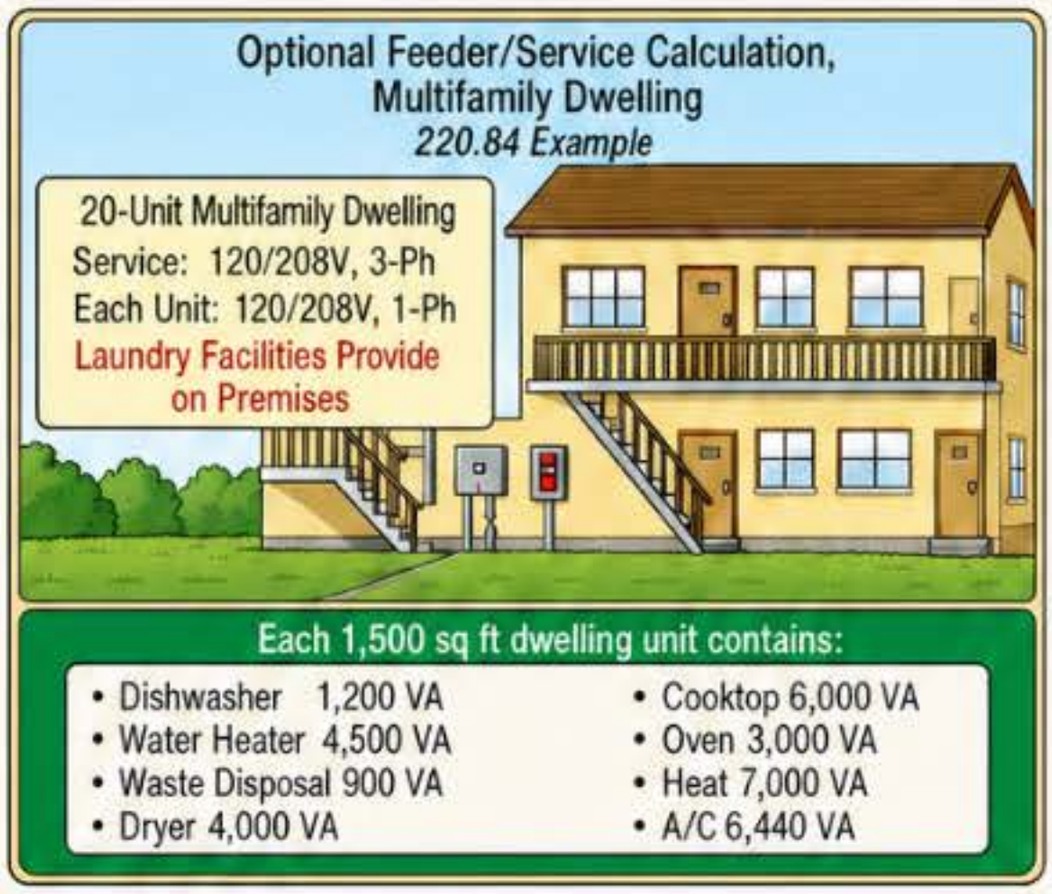
QUESTION: *What size 4-wire, three-phase, 120/208V service is required for a multifamily building with twenty 1,500 sq ft dwelling units, where each unit contains the following loads?* ▶ *Figure 220–40*

- *Dishwasher, 1,200 VA*
- *Water Heater, 4,500 VA*
- *Waste Disposal, 900 VA*
- *Dryer, 4,000 VA*
- *Cooktop, 6,000 VA*
- *Oven, 3,000 VA*
- *Heat, 7,000 VA*
- *Air-Conditioning, 6,440 VA*

(a) 400A (b) 600A (c) 800A (d) 1,000A

•••

220.85 | Branch-Circuit, Feeder, and Service Load Calculations



▶ Figure 220–40

Solution:

Step 1: *Determine the connected load for one dwelling unit.*

General Lighting	*1,500 sq ft × 3 VA =*	*4,500 VA*
Small-Appliance	*1,500VA × 2 =*	*3,000 VA*
Laundry	*1,500 VA × 1 =*	*1,500 VA*
Dishwasher	*1,200 VA × 1 =*	*1,200 VA*
Water Heater	*4,500 VA × 1 =*	*4,500 VA*
Garbage Disposal	*900 VA × 1 =*	*900 VA*
Dryer	*4,000 VA × 1 =*	*4,000 VA*
Cooktop	*6,000 VA × 1 =*	*6,000 VA*
Oven	*3,000 VA × 1 =*	*3,000 VA*
Air-Conditioning	*6,440 VA*	*(omit)*
Heat	*7,000 VA × 1 =*	*+ 7,000 VA*
Total Dwelling Unit Load =		*35,600 VA*

Step 2: *Determine the calculated load for the multifamily building.*

Demand Load = Calculated Load × Demand Factor

Demand Factor for 20 units = 38% [Table 220.84]

Demand Load = 35,600 VA × 20 × 38%

Demand Load = 270,560 VA

Step 3: *Determine the feeder/service size.*

I = VA/(E × √3)

I = 270,560 VA/(208V × 1.732)

I = 751A

Service = 800A [240.6(A)]

Service Conductors if Paralleled in Two Raceways = 751A/2 conductors

Service Conductors if Paralleled in Two Raceways = 376A per raceway

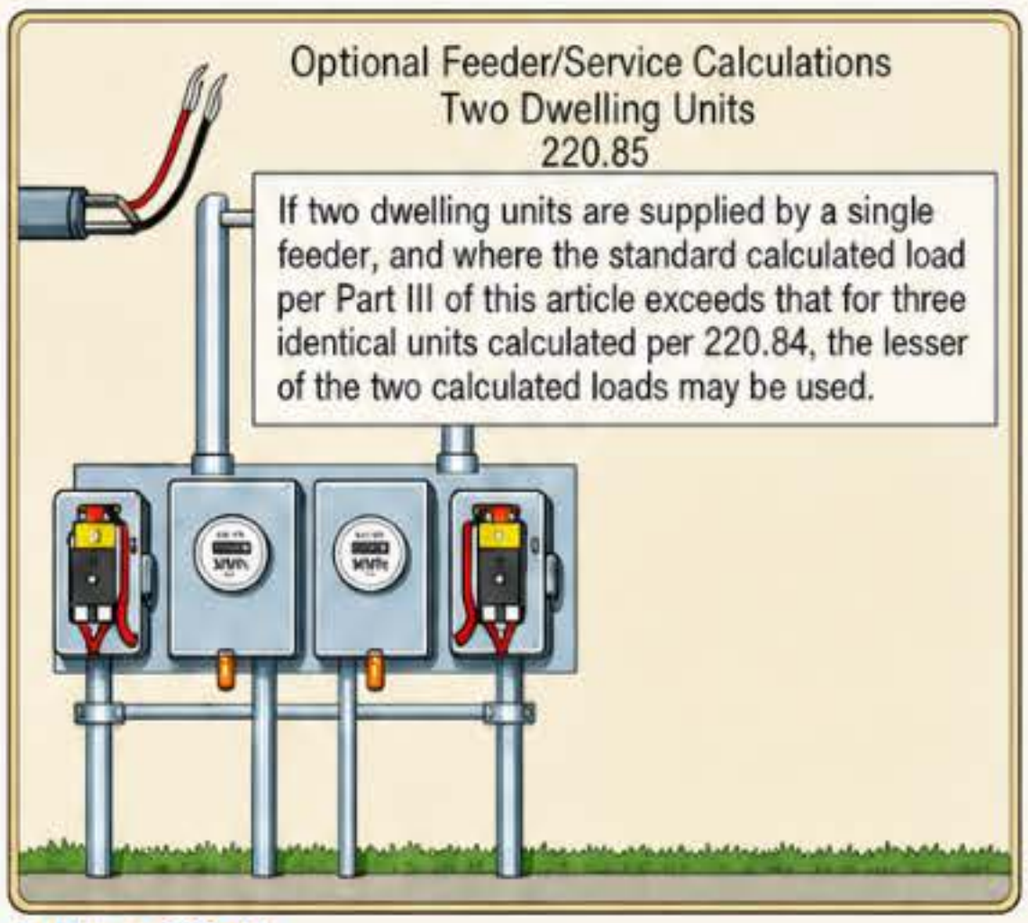
Conductor = 500 kcmil rated 380A at 75°C × 2

Conductor = 760A [240.4(B) and Table 310.16]

Answer: *(c) 800A*

220.85 Optional Load Calculations, Two Dwelling Units

If two dwelling units are supplied by a single feeder, and where the standard calculated load in accordance with Part III of this article exceeds that for three identical units calculated in accordance with 220.84, the lesser of the two calculated loads may be used. ▶ Figure 220-41



▶ Figure 220-41

220.87 Determining Existing Loads

The calculation of a feeder or service load for an existing dwelling unit must be in accordance with all the following:

(1) The maximum demand data for a 1-year period.
Ex: The highest average kW for a 15-minute period over a period of 30 days. ▶ Figure 220-42

(2) The maximum demand at 125 percent plus the new load does *not exceed the ampacity of the feeder or rating of the service.*

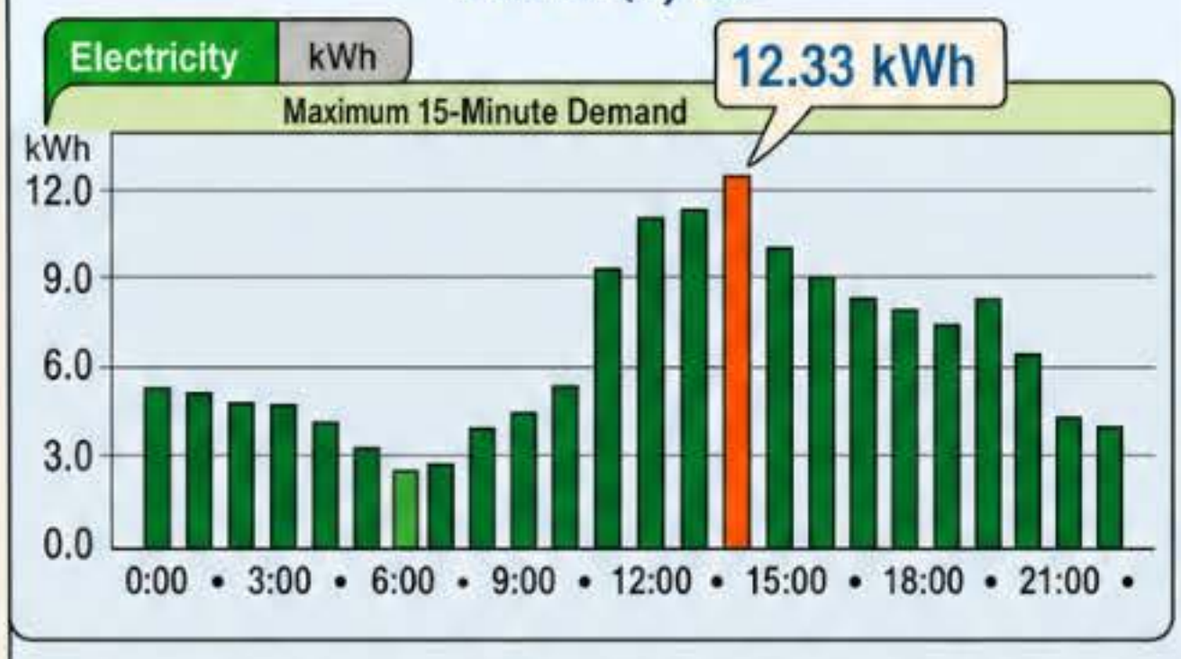
(3) The feeder has overcurrent protection in accordance with 240.4, *and the service has overload protection in accordance with 230.90.*

Author's Commentary: *These optional calculation methods allow more accurate sizing for services supplying multiple dwellings. Always compare both options and use the smaller calculated value.*

— Michael Hamilton

Service and Feeder Load Calculations
Determining Existing Loads

220.87(1) Ex



The maximum demand data for one year or the average power demand for a 15-minute period over a minimum of 30 days can be used to size the electric power source.

Figure 220-42

Author's Commentary:

This calculation method is not permitted if the feeder or service has any renewable energy system such as solar photovoltaic or wind electric systems or uses any form of peak load shaving.

— Michael Hamilton

Notes |

ARTICLE 225

OUTSIDE BRANCH CIRCUITS AND FEEDERS

Introduction to Article 225—Outside Branch Circuits and Feeders

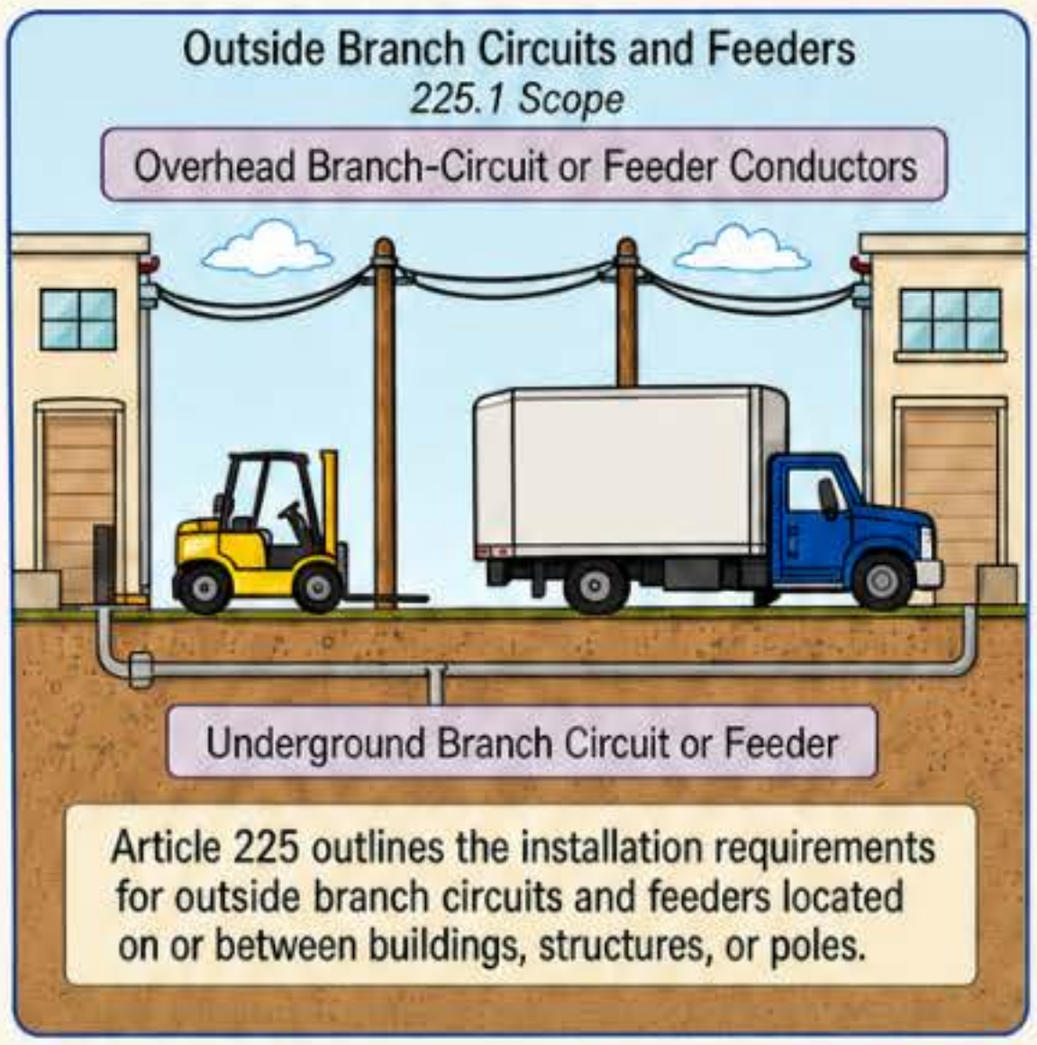
This article addresses the rules for installing equipment, including overhead and underground branch-circuit and feeder conductors located outdoors or between buildings, poles, and other structures on the premises. Outdoor conductors may be used for many purposes, such as area lighting, supplying power for outdoor equipment, or providing a dedicated source to other buildings or structures. It's important to remember that the power feeding a building is not always a service conductor but may be a feeder or branch-circuit conductor originating at a different building. Never assume that the incoming conductors to a building are service conductors until you have positively identified the point of service.

Section I of Article 225 establishes limits on the total number of feeders and branch circuits a building may have and sets out the requirements governing their disconnects. Those requirements cover disconnect rating, construction properties, labeling, the location of the disconnect, and how multiple disconnects must be grouped.

Part I. General

225.1 Scope

Article 225 outlines the installation requirements for outside branch circuits and feeders located on or between buildings, structures, or poles. ▶ Figure 225-1



▶ Figure 225-1

Author's Commentary:

Review the following terms as they are defined in Article 100:

- "Branch Circuit"
- "Building"
- "Feeder"
- "Structure"

— Michael Hamilton

225.6 Minimum Conductor Size and Support

(A) Overhead Spans

(1) Conductor Size. Conductors 10 AWG and larger are permitted for overhead spans up to 50 ft long. For spans over 50 ft, the minimum conductor size is 8 AWG, unless the conductor is supported by a messenger wire. ▶ Figure 225-2

(B) Festoon Lighting. Overhead conductors used for festoon lighting must not be smaller than 12 AWG and must be supported by messenger wire (with strain insulators) whenever the spans go beyond 40 ft in length. ▶ Figure 225-3

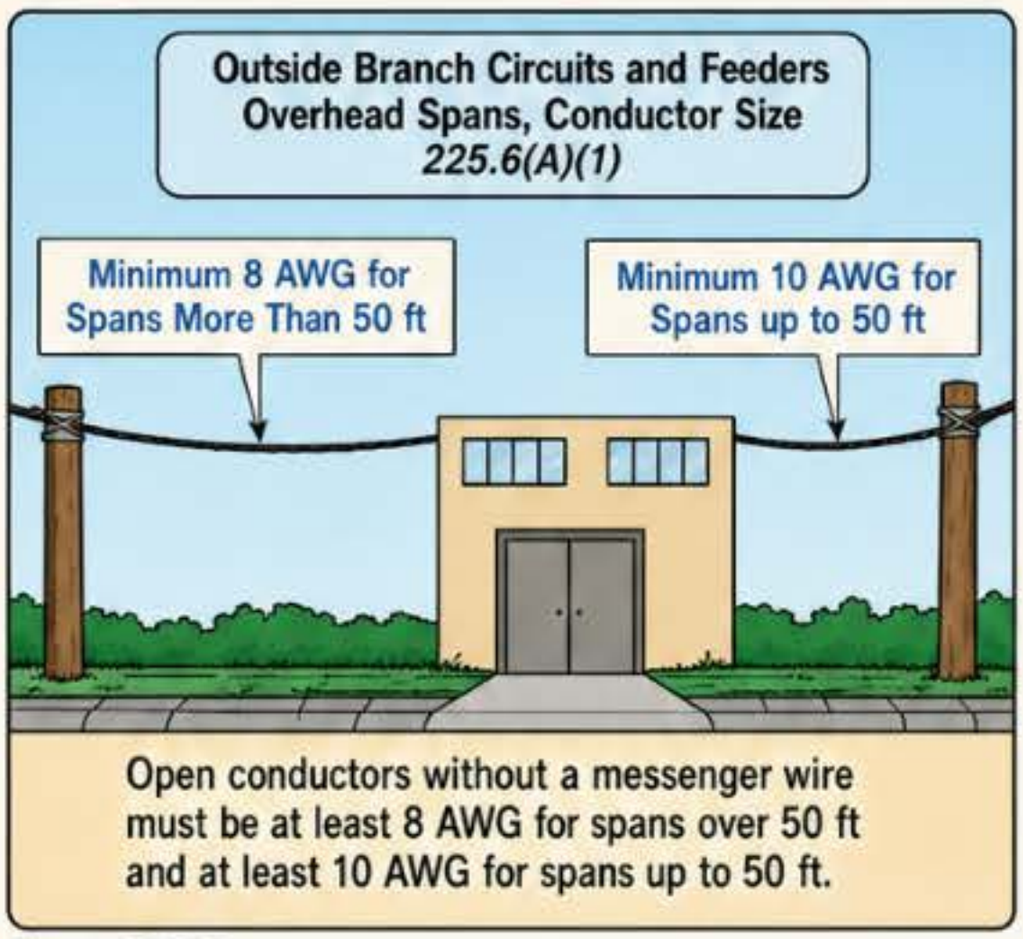


Figure 225-2

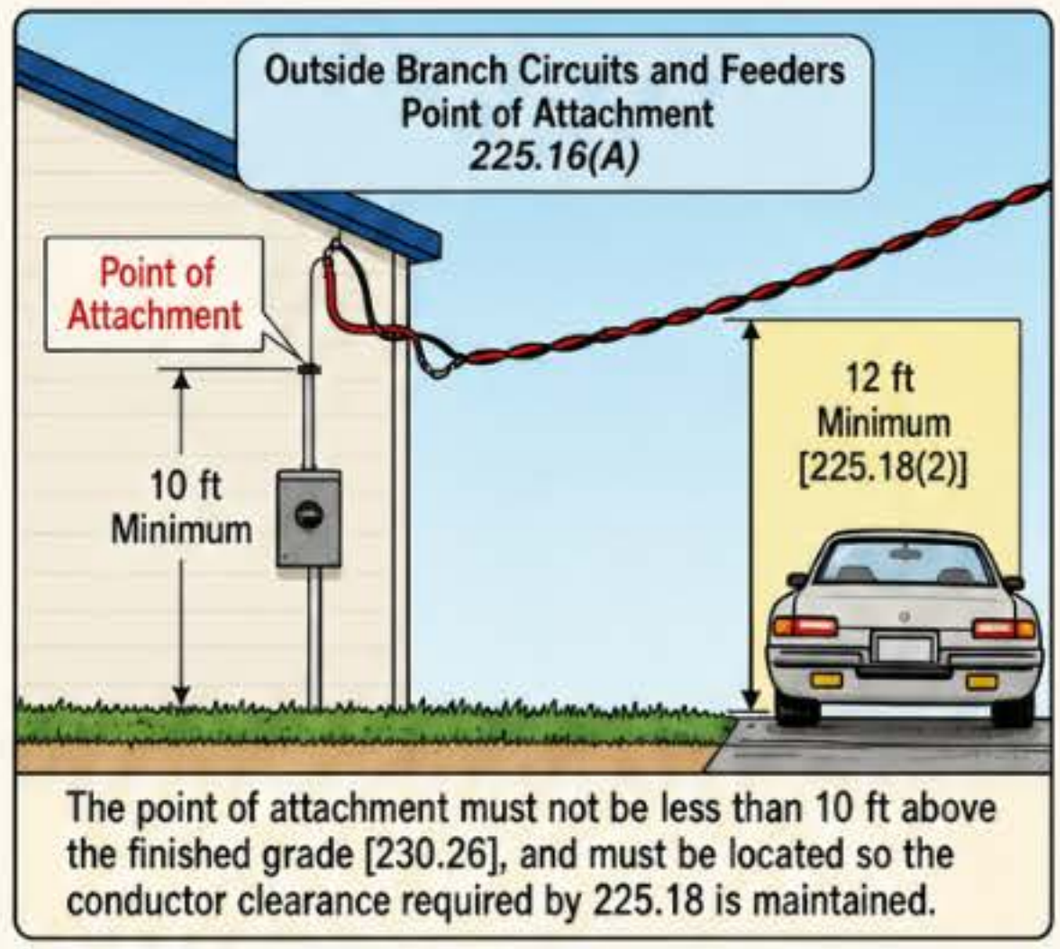


Figure 225-4

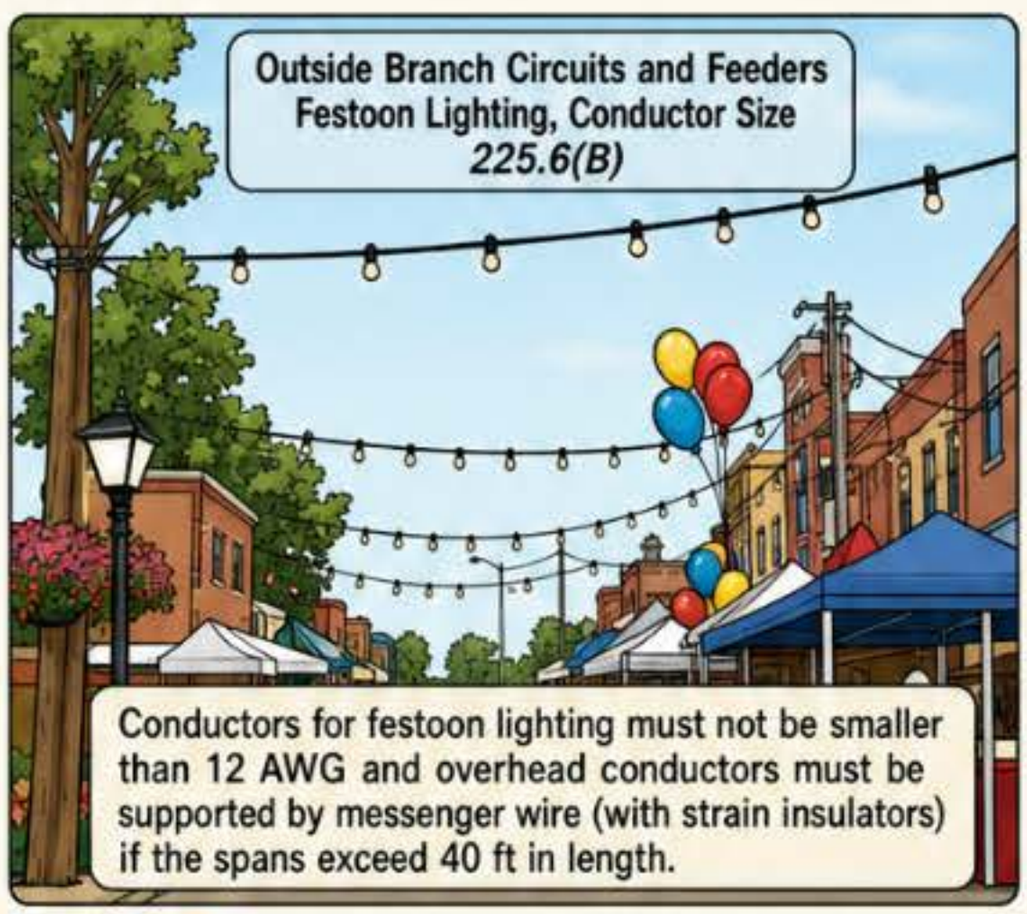


Figure 225-3

Author's Commentary:

According to Article 100 "Festoon Lighting" is a string of outdoor lights suspended between two points. Festoon lighting is commonly used at carnivals, circuses, fairs, Christmas tree lots [525.20(C)], and as temporary lighting at construction sites [590.4(F)].

— Michael Hamilton

225.16 Attachment of Overhead Conductors

(A) Point of Attachment. The point of attachment for overhead conductors must not be less than 10 ft above the finished grade [230.26]. ▸ *Figure 225-4*

Author's Commentary:

The point of attachment must also be located so the minimum conductor clearances required by 225.18 can be maintained.

— Michael Hamilton

Caution

Conductors might need to have the point of attachment raised so the overhead conductors will comply with the clearances from building openings and other building areas required by 225.19.

(B) Means of Attachment to Buildings. Open conductors must be attached to fittings identified for use with conductors or to noncombustible, nonabsorbent insulators securely attached to the building [230.27].

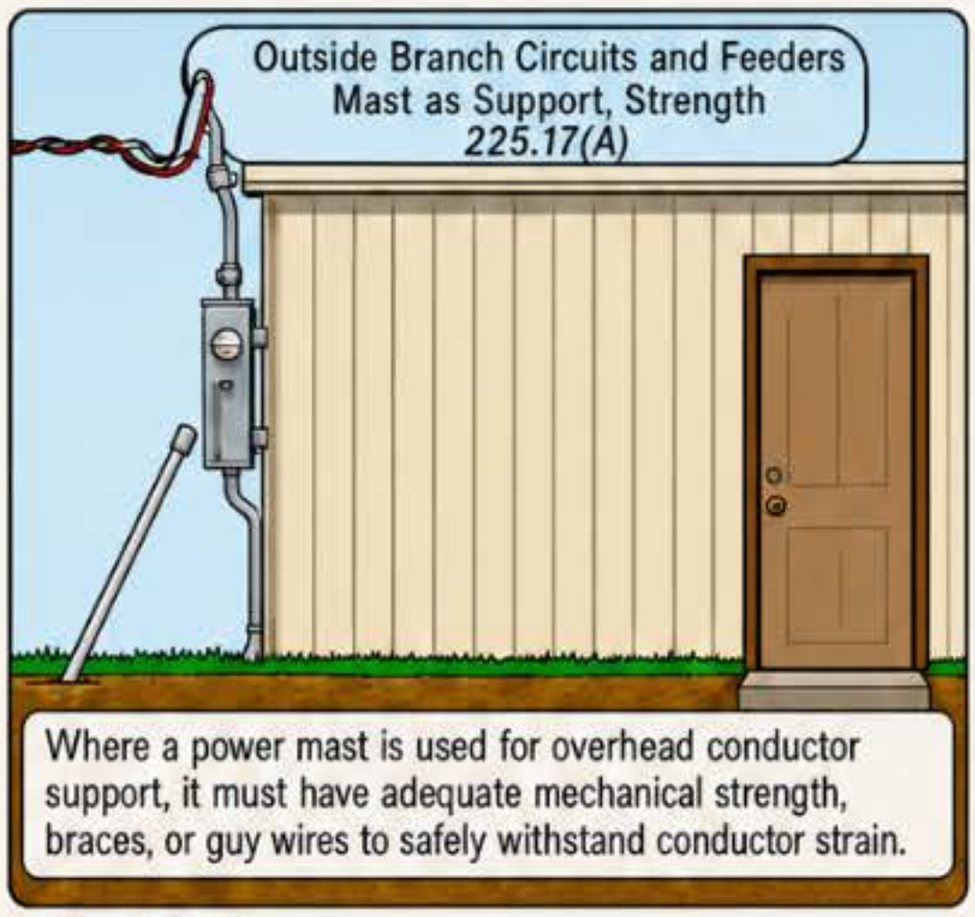
225.17 Masts as Supports

Masts for the support of overhead conductors must be installed as follows:

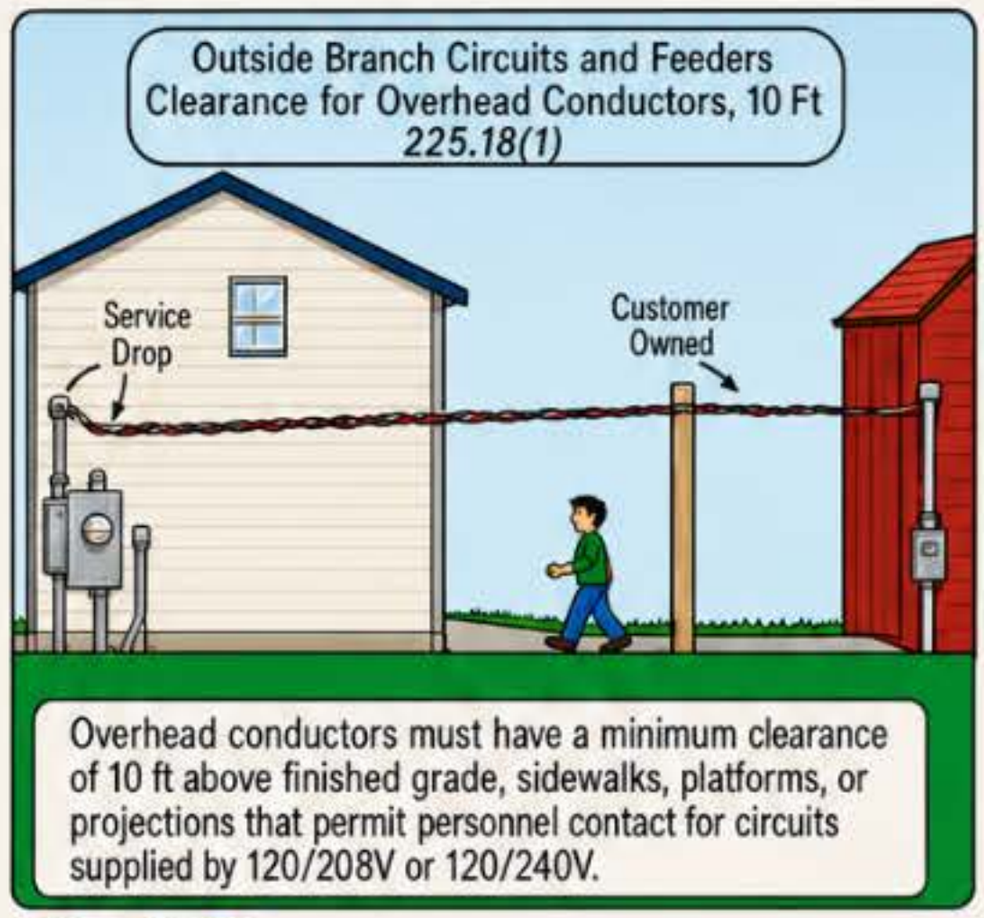
(A) Strength. The mast must have adequate mechanical strength, braces, or guy wires to safely withstand the strain caused by the conductors. ▸ *Figure 225-5*

(B) Attachment. Overhead conductors cannot be attached to a mast *where the conductor attachment is located between a weatherhead and a coupling located above the last point of securement to the building, or where the coupling is located above the roof.* ▸ *Figure 225-6*

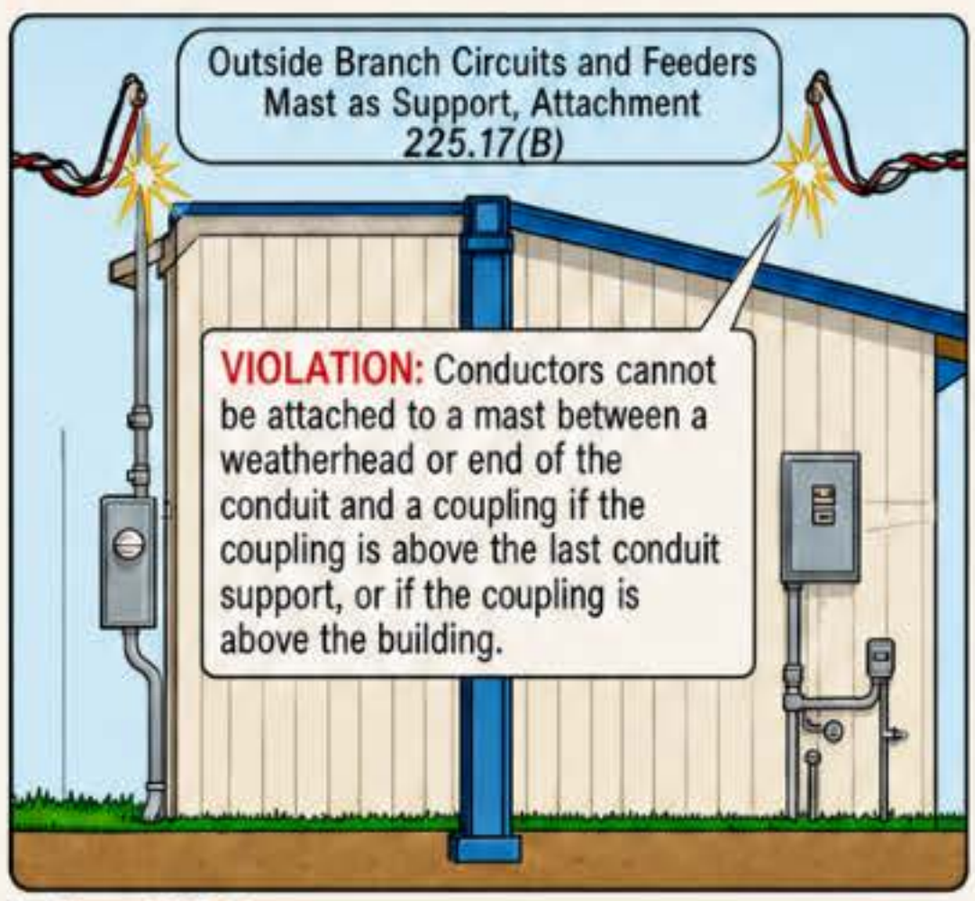
225.18 Clearance for Overhead Conductors



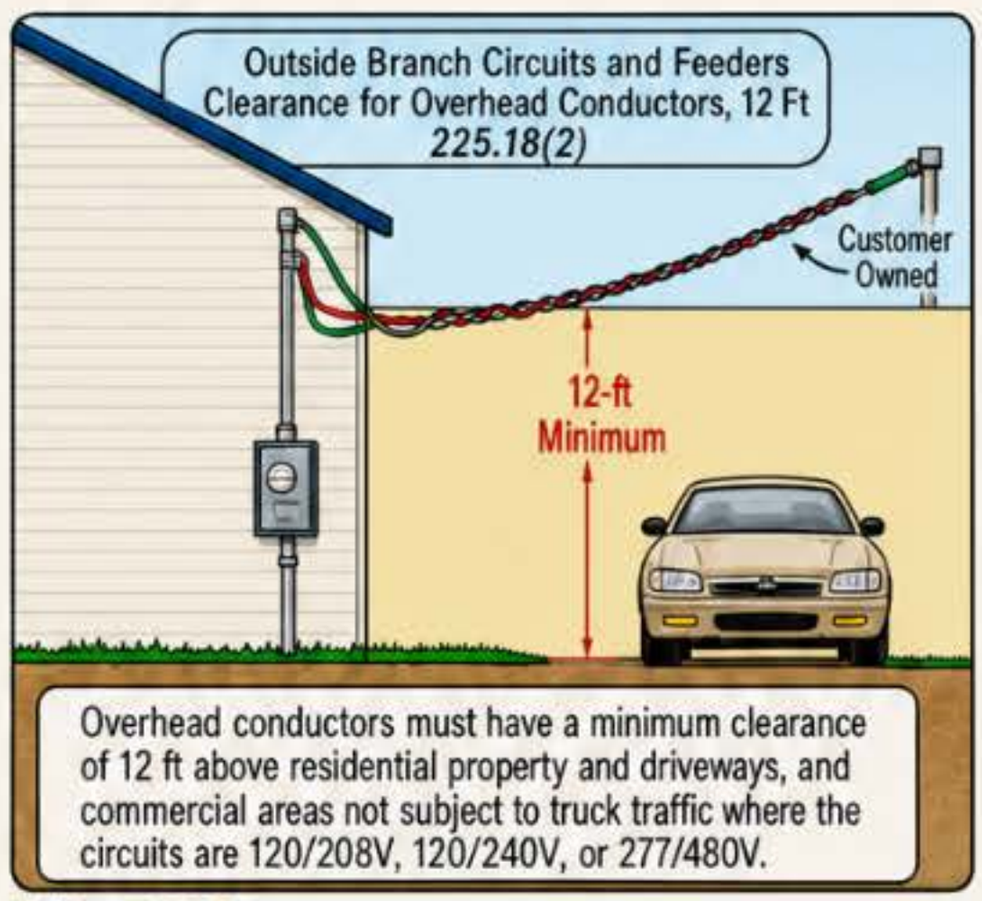
▶ Figure 225-5



▶ Figure 225-7



▶ Figure 225-6



▶ Figure 225-8

225.18 Clearance for Overhead Conductors

Overhead conductor spans must maintain vertical clearances of:

1. *At least 10 ft above finished surfaces, sidewalks, platforms, or projections where people can reach for circuits supplied at 120/208V or 120/240V.* ▶ Figure 225-7
2. *At least 12 ft above residential property, driveways, and commercial zones not open to truck traffic for circuits supplied at 120/208V, 120/240V, or 277/480V.* ▶ Figure 225-8
3. *At least 15 ft above residential property and driveways, and commercial zones not subject to truck traffic for circuits supplied by systems operating at more than 300V to ground.* ▶ Figure 225-9
4. *Spans crossing public streets, alleys, roads, parking areas that allow vehicle crossing, driveways, and other nonresidential lots, plus farmland or land used for cultivation, grazing, forestry, and orchards must be at least 18 ft.* ▶ Figure 225-9

Author's Commentary:

Overhead conductors placed above swimming pools, spas, hot tubs, diving facilities, observation decks, towers, or similar structures need to satisfy the clearance rules set out in 680.9.

— Michael Hamilton

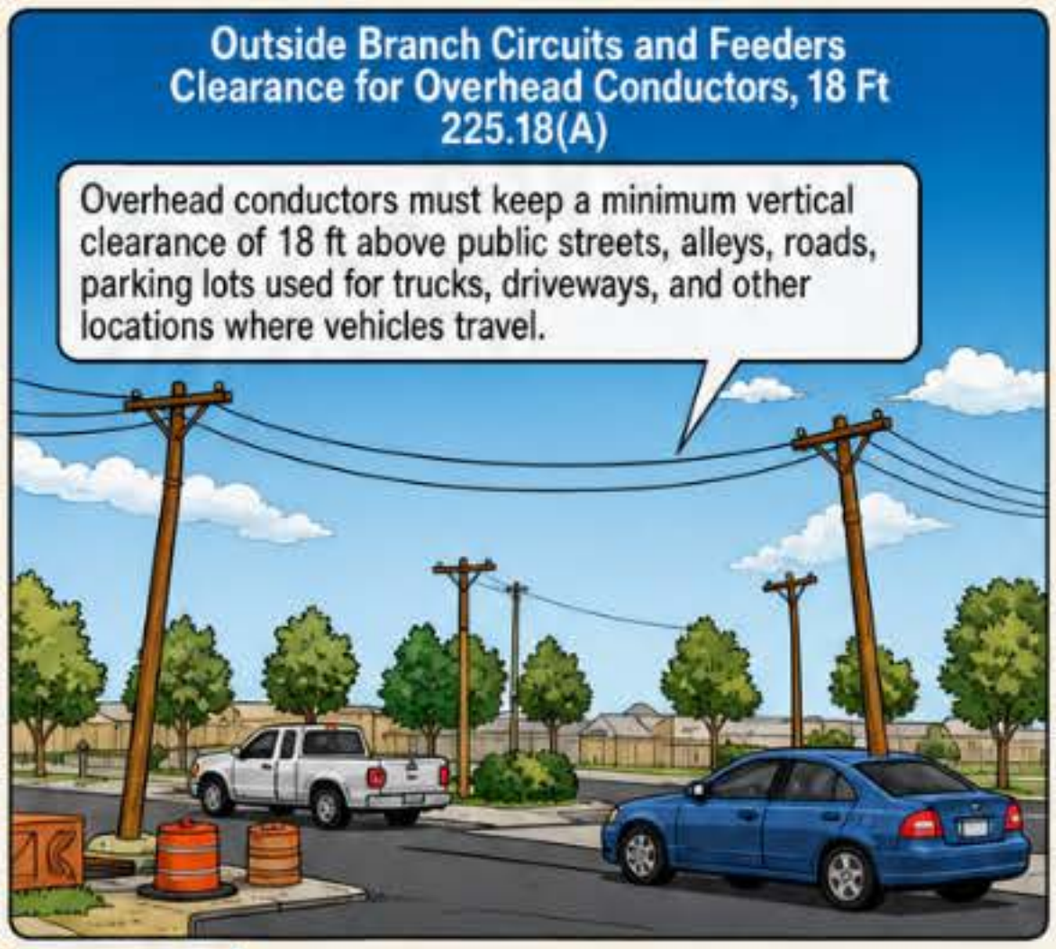


Figure 225-9

225.19 Clearances from Buildings

Overhead spans of conductors must comply with 225.19(A), (B), (C), and (D).

(A) Above Roofs. Overhead conductors must maintain a vertical clearance of at least 8 ft 6 in. above the surface of a roof and must be maintained for a distance of at least 3 ft from the edge of the roof. *Figure 225-10*

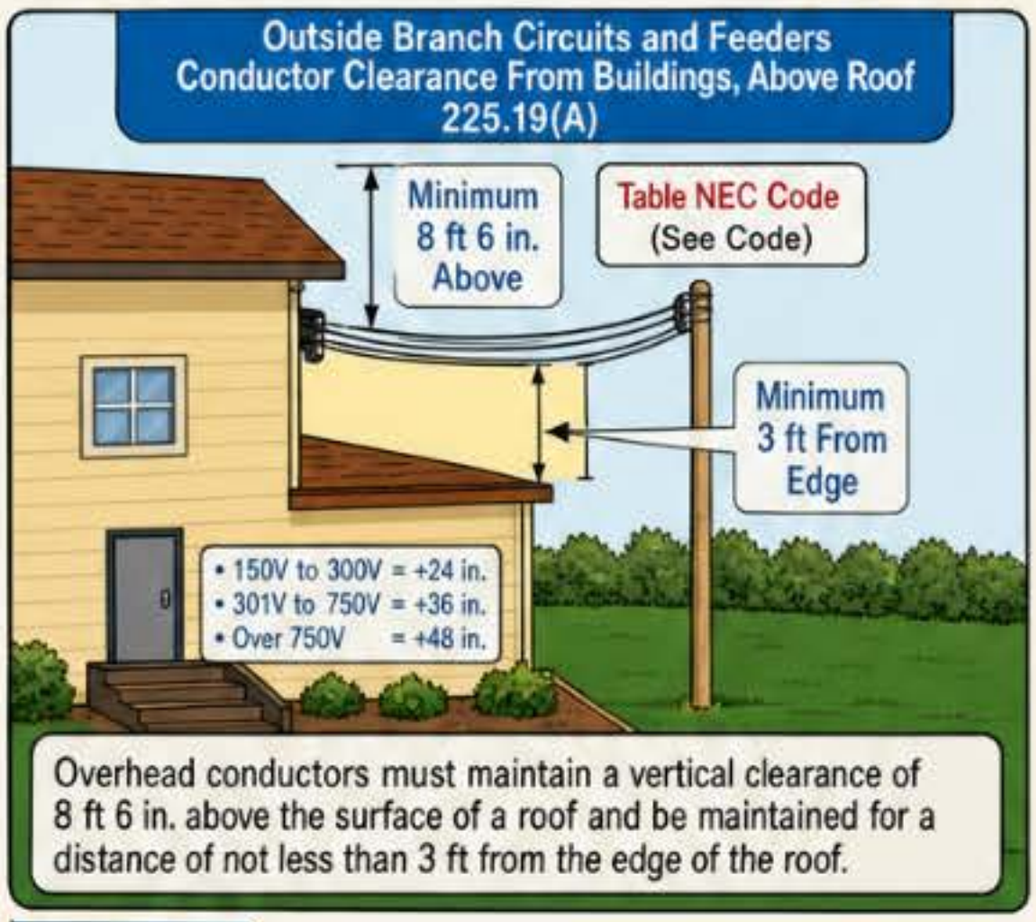


Figure 225-10

Ex 2: *The overhead conductor clearances from the roof can be reduced to 3 ft if the slope of the roof meets or exceeds 4 in. of vertical rise for every 12 in. of horizontal run.*

Ex 3: *For 120/208V or 120/240V circuits, the conductor clearance over the roof overhang can be reduced to 18 in. if no more than 6 ft of conductor passes over no more than 4 ft of roof.* Figure 225-11

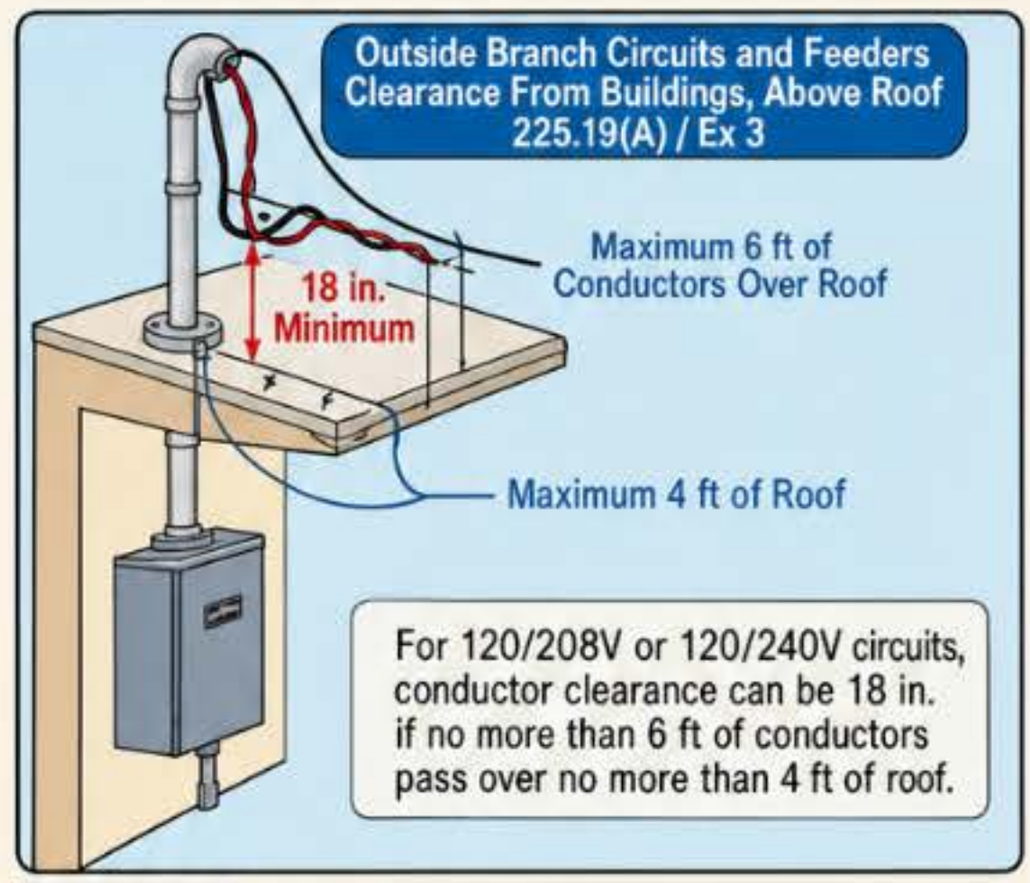


Figure 225-11

Ex 4: *The 3-ft clearance from the roof edge does not apply when the point of attachment is on the side of the building below the roof.* Figure 225-12

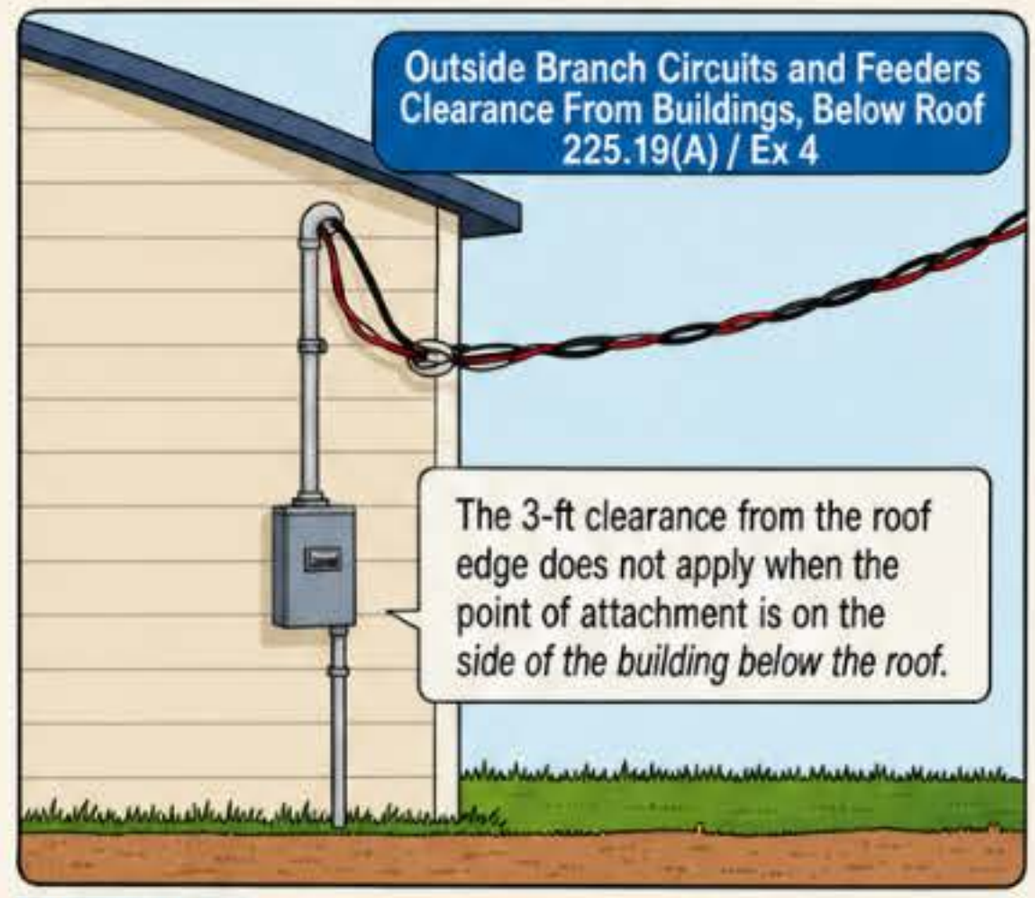


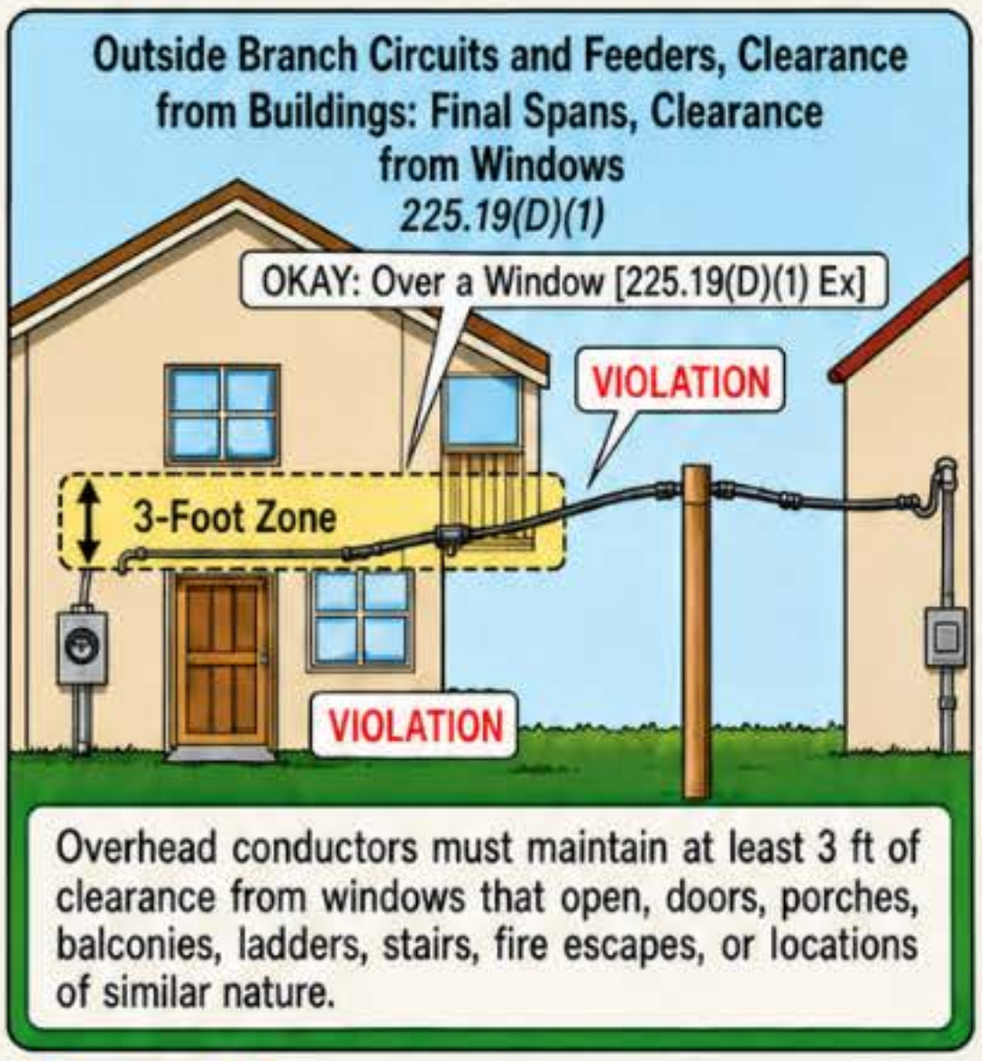
Figure 225-12

(B) From Other Structures. Overhead conductors must maintain a clearance of at least 3 ft from signs, chimneys, radio and television antennas, tanks, and other nonbuilding structures.

(D) Final Span Clearance

Outside Branch Circuits and Feeders | 225.26

(1) Clearance from Windows. Conductors installed above window openings, doors, porches, balconies, ladders, stairs, fire escapes, or similar areas must keep a minimum vertical clearance of 3 ft from any window that can open. ▶ Figure 225–13

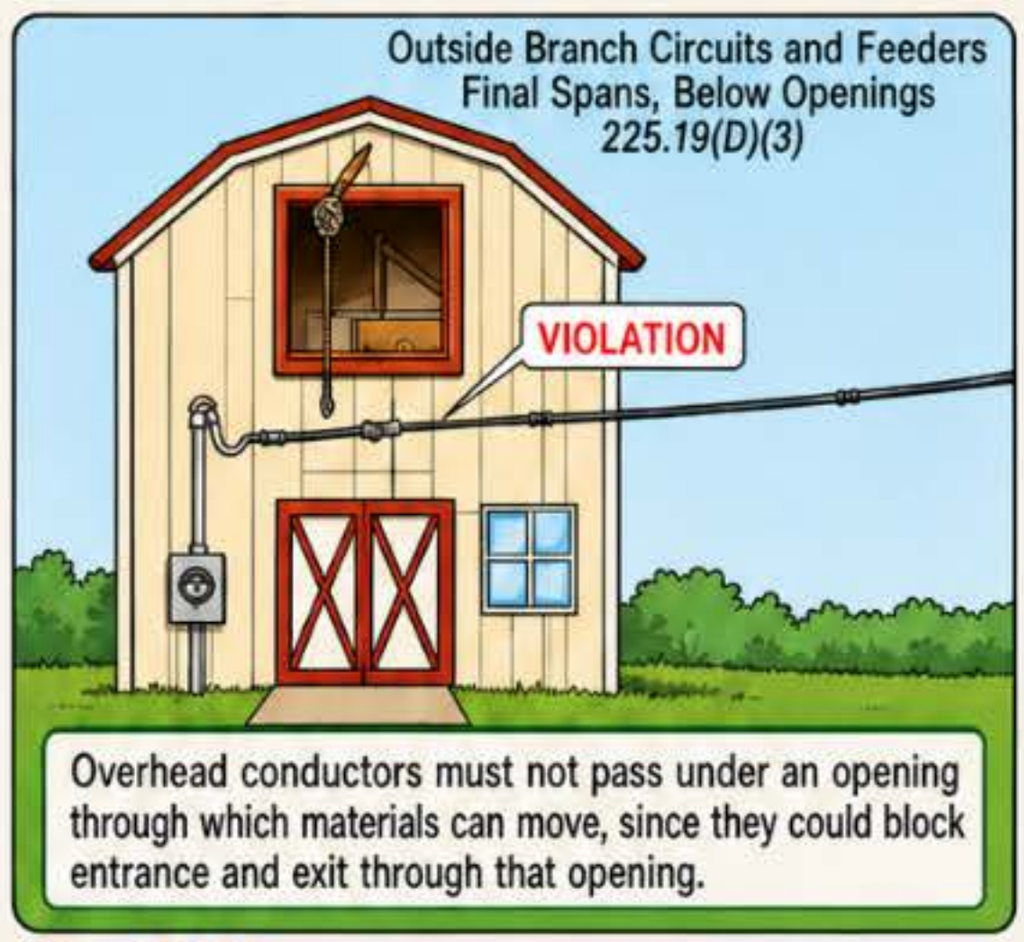


▶ Figure 225–13

Ex: If an overhead conductor is placed above a window, it does not need to be exactly 3 ft away from the window itself.

(2) Vertical Clearance. Above platforms, projections, or surfaces where people can contact the conductor as described in 225.18, the minimum vertical clearance must be 10 ft. This measurement is taken straight *up* from the *walking/working surface to the lowest point of the conductor.*

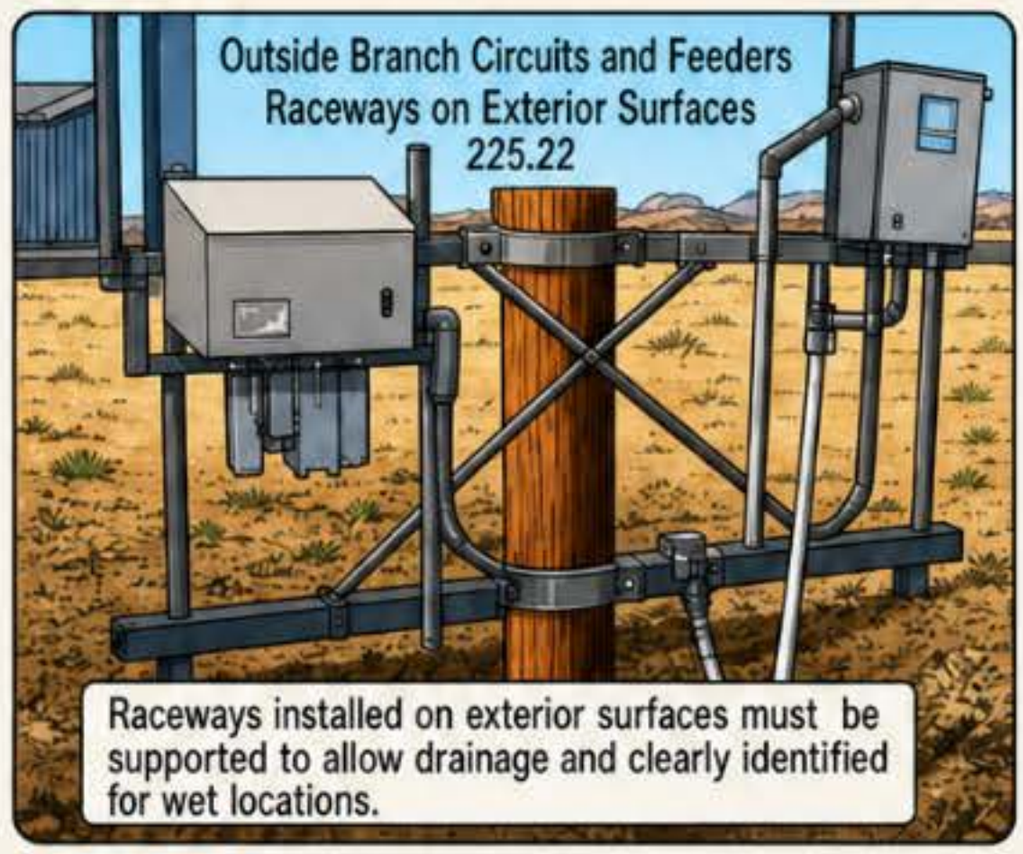
(3) Below Openings. Conductors are not permitted beneath openings through which materials may pass unless these openings *are not located where material would normally be transported into the space.*



▶ Figure 225–14

225.22 Raceways on Exterior Surfaces of Buildings or Other Structures

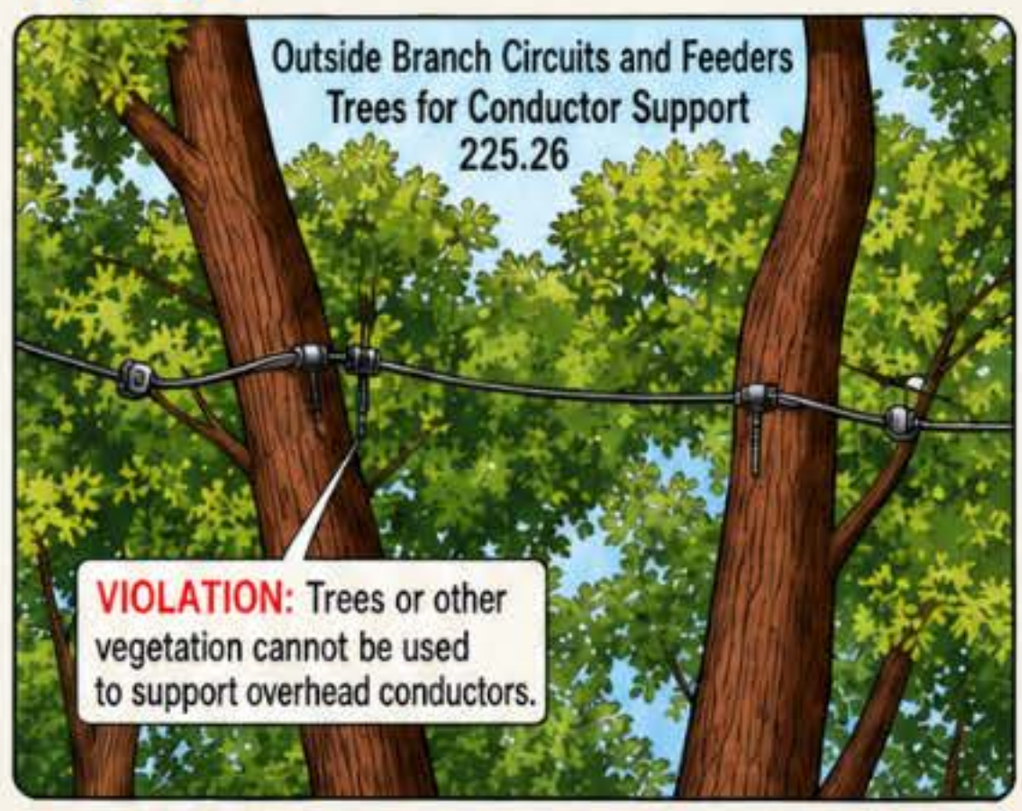
Raceways that run along the outside of a building or other structure must be secured, drained, and identified for use in wet environments. ▶ Figure 225–15



▶ Figure 225–15

225.26 Trees for Conductor Support

Trees and other vegetation are not allowed to be used as support points for overhead conductors. ▶ Figure 225–16



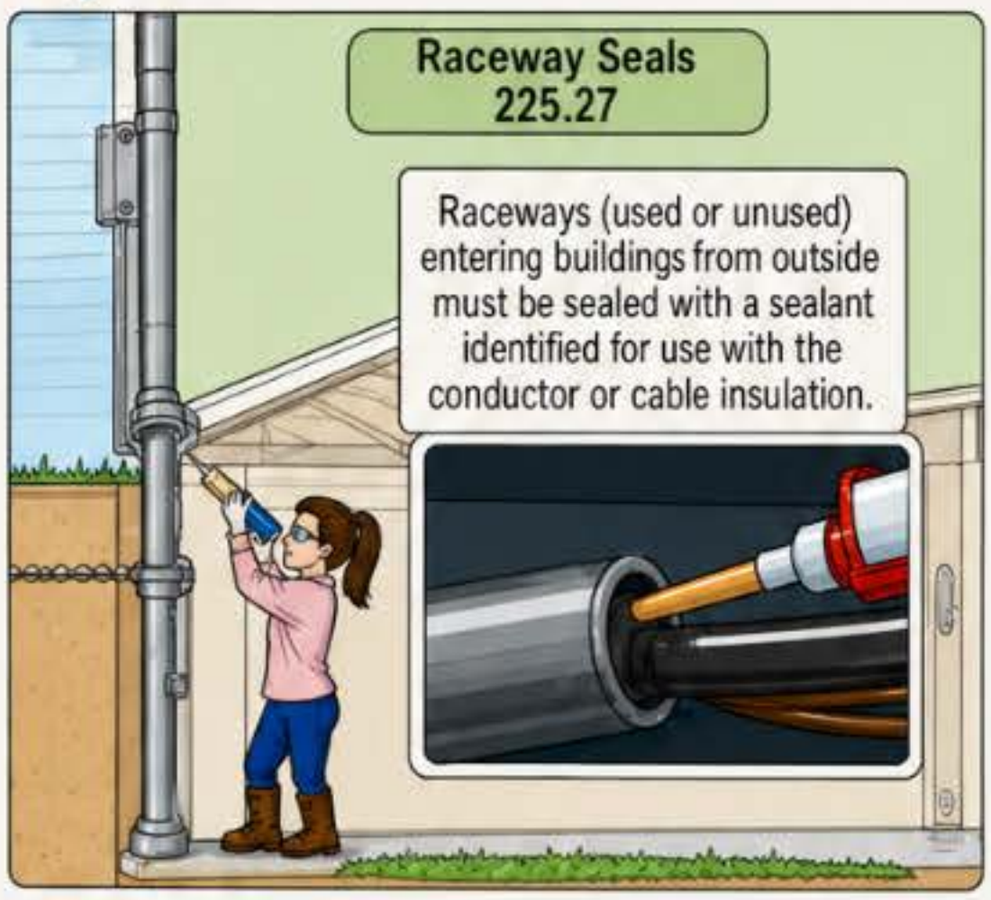
▶ Figure 225–16

225.27 | Outside Branch Circuits and Feeders

Author's Commentary:
Overhead conductors supported for service entrance [230.10] and temporary wiring [590.4(J)] cannot be installed using vegetation as support.
— *Michael Hamilton*

225.27 Raceway Seals

Any raceway—whether in use or not—entering a structure from outdoors must be closed at the entry point with a seal identified for use with the conductor or cable insulation. ▶ Figure 225–17



▶ Figure 225–17

Part II. Buildings or Other Structures Supplied by a Feeder

225.30 Number of Supplies

A building can only be supplied by a single feeder unless otherwise permitted in 225.30(A) through (E). ▶ Figure 225–18

(A) Special Conditions. Additional feeders are permitted to supply:

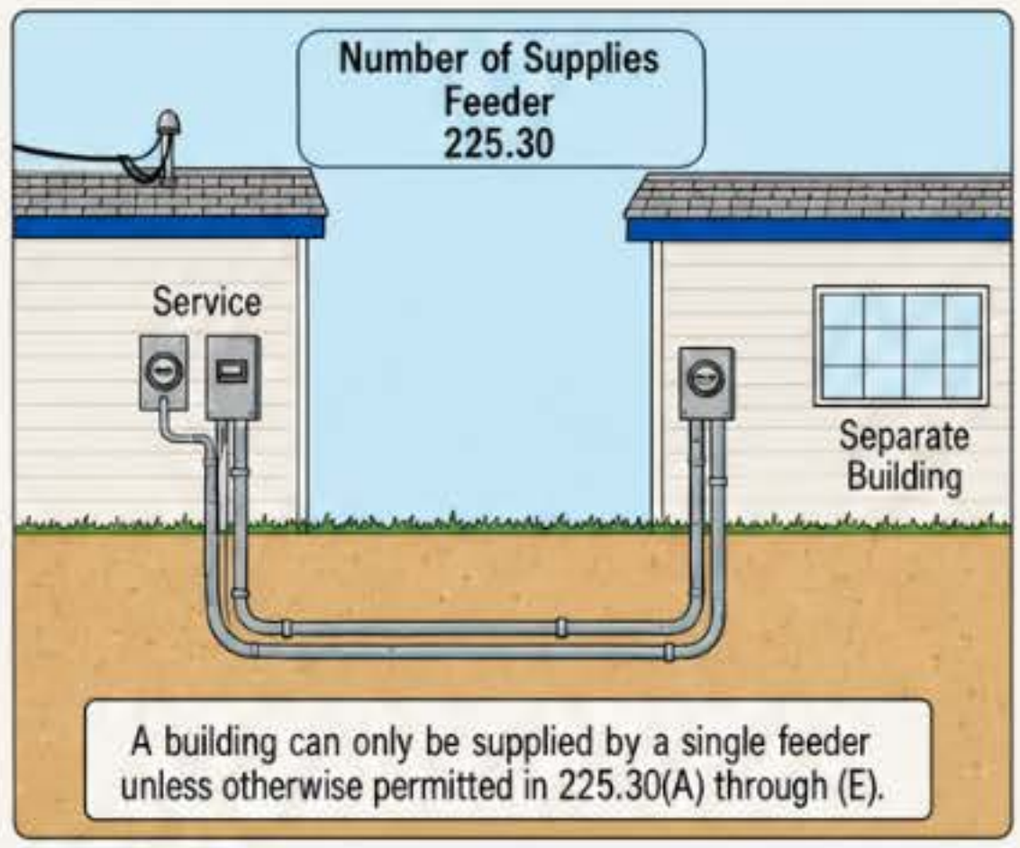
(1) Fire pumps.

(2) Emergency systems.

(3) Legally required standby systems.

(4) Optional standby systems.

(5) Parallel power production sources.



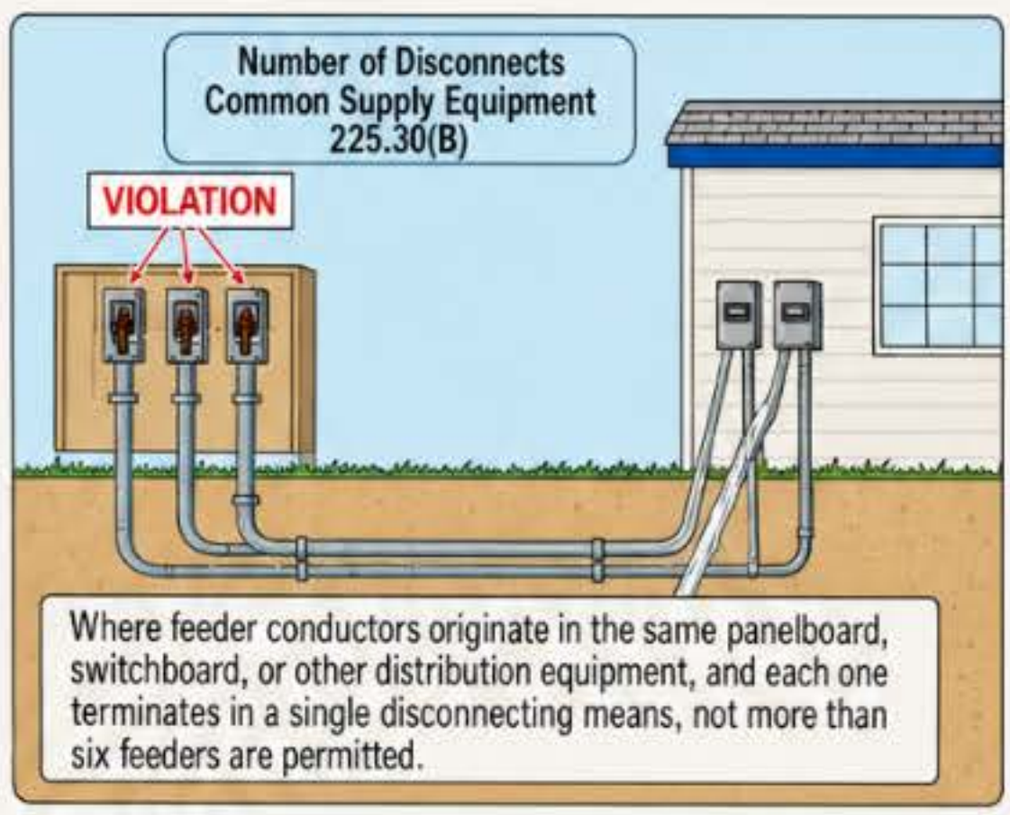
▶ Figure 225–18

(6) Systems designed for connection to multiple sources of supply for the purpose of enhanced reliability.

(7) Electric vehicle charging systems listed, labeled, and identified for more than a single branch circuit or feeder.

(8) Docking facilities and piers.

(B) Common Supply Equipment. Where feeder conductors originate in the same panelboard, switchboard, or other distribution equipment, and each one terminates in a single disconnecting means, not more than six feeders are permitted. ▶ Figure 225–19



▶ Figure 225–19

Where more than one feeder is installed, all feeder disconnects supplying the building must be grouped in the same location. Each *disconnect must be marked to indicate the load served.*

(C) Special Occupancies. Authorities having jurisdiction may permit extra feeders and other allowances for:

(1) Buildings that have several tenants and where no room is available to place supply equipment that can be reached by every tenant, or

(2) A structure so large that two or more sources are needed.

(D) Capacity Requirements. More equipment is allowed for a building when its calculated demand loads are above 2,000 A.

(E) Different Characteristics. Extra supplies are permitted for systems that operate at different voltages, frequencies, or other attributes; for example, to keep outdoor lighting circuits separate in several locations.

(F) Documented Switching Procedures. Additional equipment is allowed where safe switching steps are written, posted, and kept up to date so that circuits can be disconnected reliably.

225.31 Disconnecting Means

A disconnect is required for all feeder conductors that enter a building. ▶ Figure 225–20

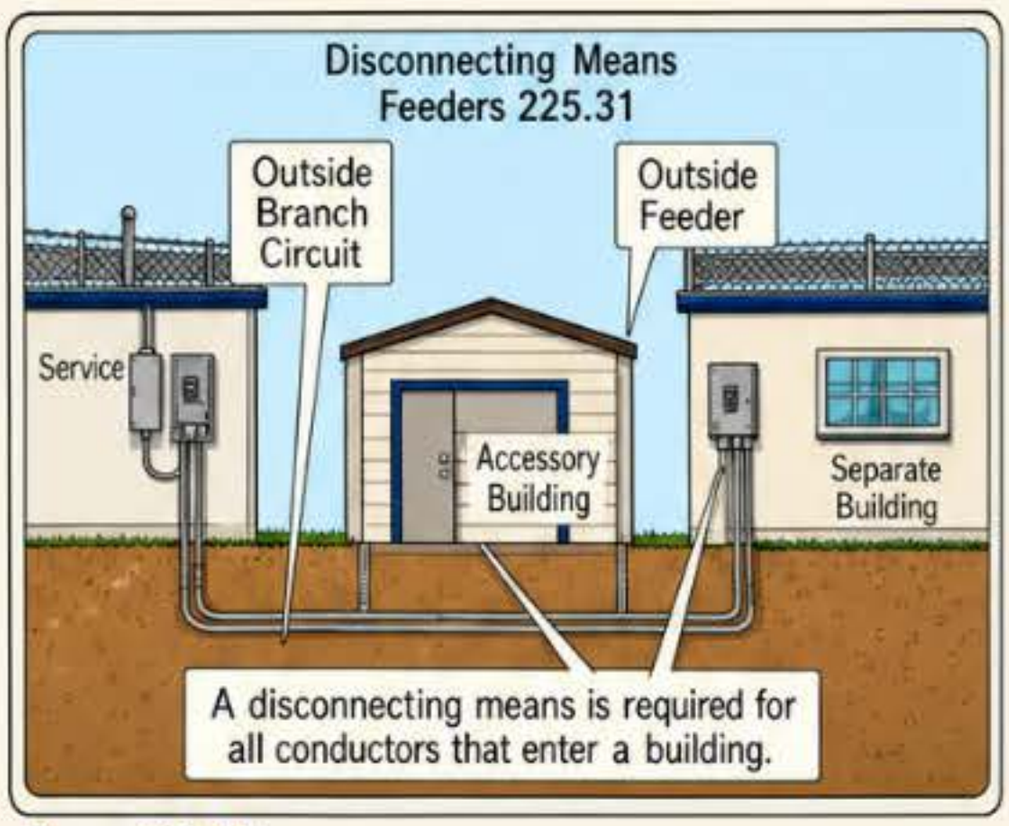


Figure 225–20

225.32 Disconnecting Means Location

The feeder disconnect must be placed where it is easy to reach, either outdoors or indoors, and as close as practical to the point where the conductors enter. ▶ Figure 225–21

Conductors are considered outside a building when they are encased or installed under not less than 2 in. of concrete or brick [230.6]. ▶ Figure 225–22

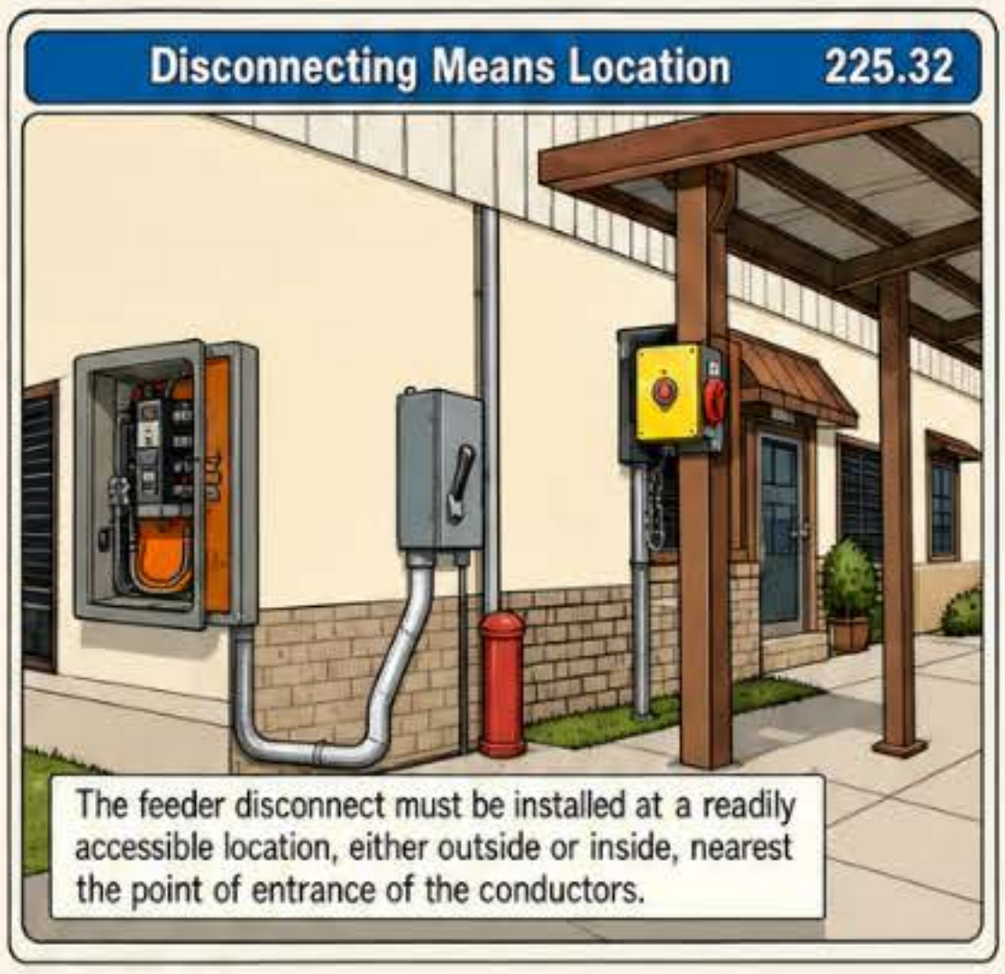


Figure 225–21

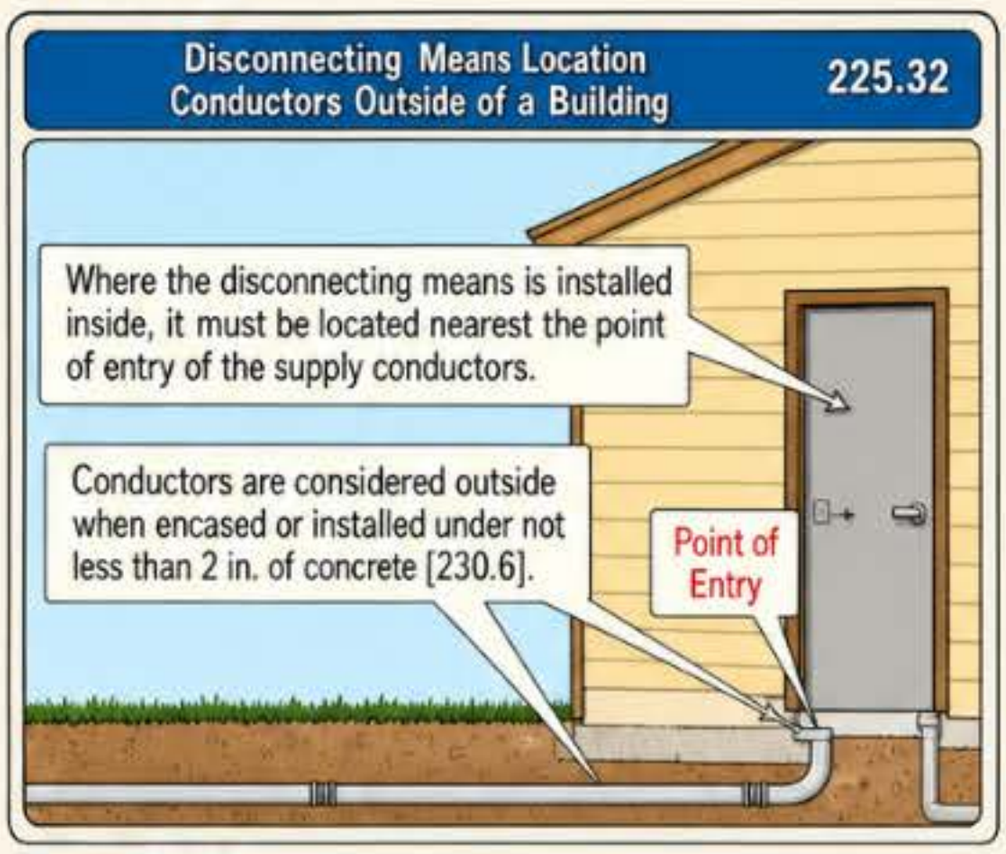
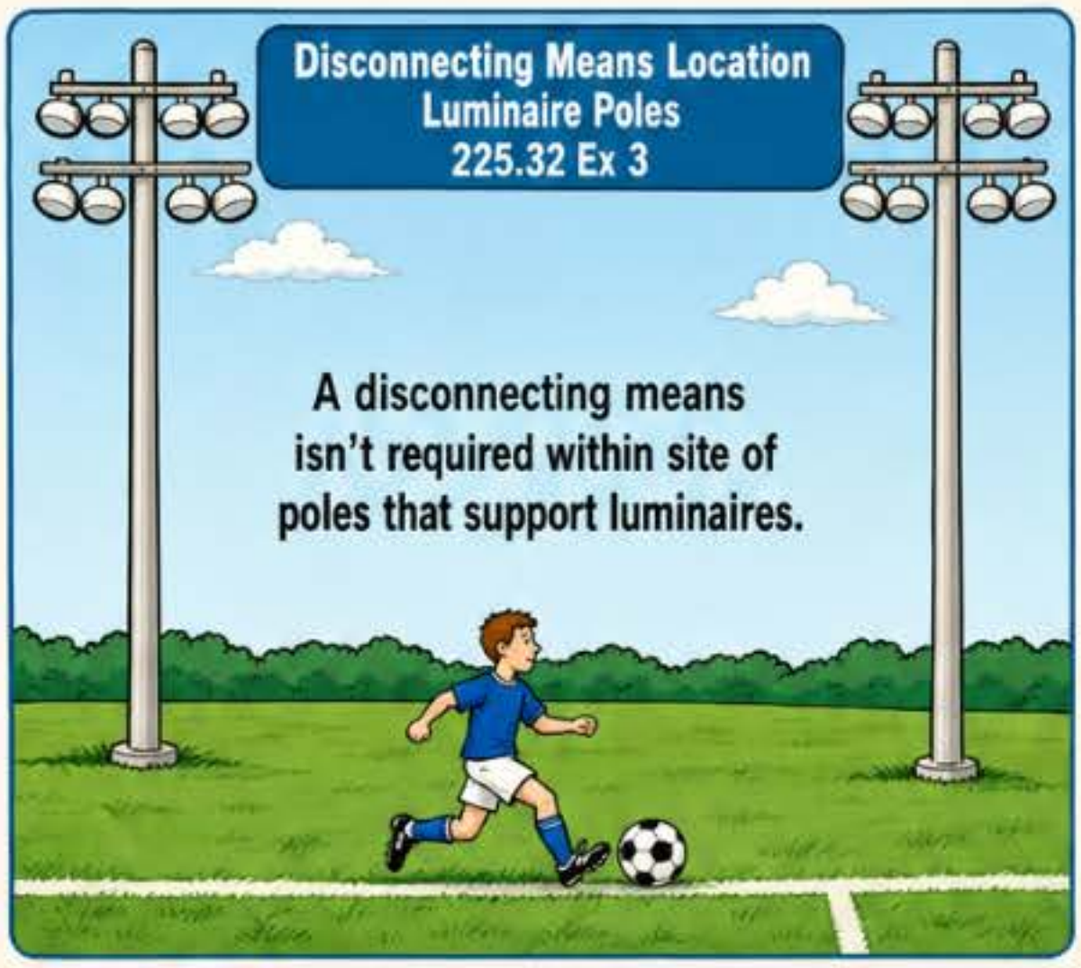


Figure 225–22

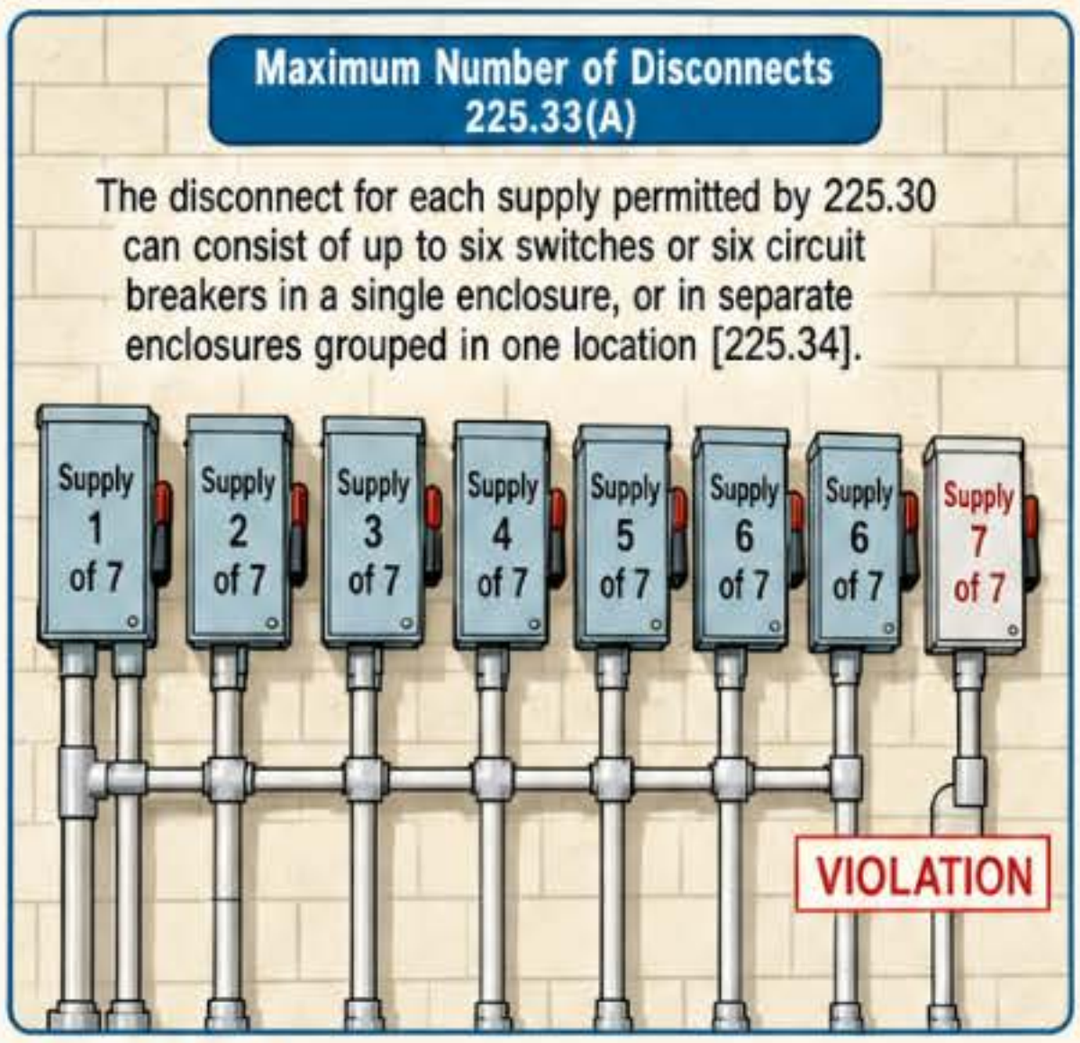
Ex 3: *A disconnect is not required for poles that support luminaires.* ▶ Figure 225–23

225.33 Maximum Number of Disconnects

(A) General. For each supply allowed by 225.30, the disconnecting means can include up to six switches or circuit breakers in a single enclosure, or they can be in separate enclosures grouped in one location [225.34]. ▶ Figure 225–24



▶ Figure 225–23



▶ Figure 225–24

225.34 Grouping of Disconnects

(A) General. The building disconnects must be grouped in one location and marked to indicate the loads they serve [110.22].

(B) Additional Disconnects. To minimize the possibility of accidental interruption of critical power systems, the disconnect for a fire pump or for standby power must be located remotely from the normal power disconnect.

225.37 Identification of Multiple Supplies

If a building is fed by more than one supply, a permanent plaque or directory must be installed at each feeder disconnect location denoting all other feeders supplying that building, and the area served by each.

225.39 Rating of Disconnecting Means

A single disconnect for a building must have an ampere rating of not less than the calculated load as determined by Article 220. If the disconnect consists of more than one switch or circuit breaker, the combined ratings of the circuit breakers are not permitted to be less than the calculated load as determined by Article 220. In addition, the disconnect is not permitted to be rated less than:

(A) One-Circuit Installation. For installations to supply only limited loads of a single branch circuit, the branch-circuit disconnecting means must have a rating of not less than 15A.

(B) Two-Circuit Installation. For installations consisting of two 2-wire branch circuits, the feeder disconnect must have a rating of not less than 30A.

(C) One-Family Dwelling. For a one-family dwelling, the feeder disconnect must have a rating of not less than 100A, 3-wire.

(D) Other Installations. For all other installations, the feeder or branch-circuit disconnect must have a rating of not less than 60A.

ARTICLE 230 SERVICES

Introduction to Article 230—Services

This article describes the rules for installing service conductors and the devices that disconnect them. Because service conductors are different from other wiring methods, the requirements in this article do not always match the rules for other conductors. A service conductor might pass through the inside of a building or route outside. When it is outdoors—as opposed to being "inside" a building—many readers may be unsure which rules apply. Article 230 can help you decide when service conductors are considered to be outside. Article 230 includes seven major parts:

- Part I. General
- Part II. Overhead Service Conductors
- Part III. Underground Service Conductors
- Part IV. Service-Entrance Conductors
- Part V. Service Disconnect
- Part VI. Disconnecting Means
- Part VII. Overcurrent Protection

Part I. General

230.1 Scope

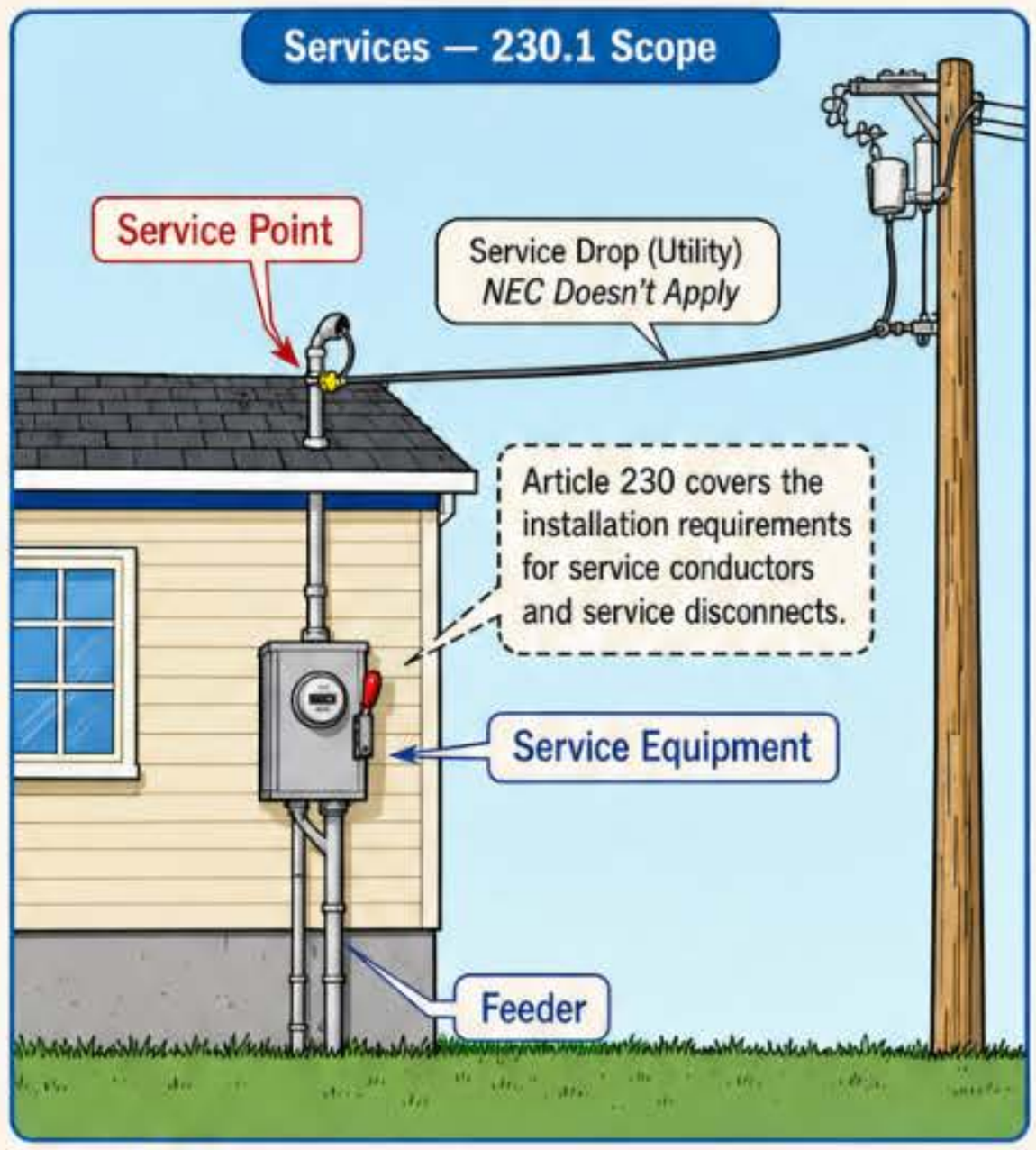
Article 230 explains how to install service conductors and service disconnects. ▶ Figure 230–1

Author's Commentary:

The "service point," as defined in Article 100, marks the beginning of the electrical system for a building and identifies where the utility and the *NEC* requirements meet.

Learning Articles 100 through 230 about service disconnects and conductors is *essential for understanding* Article 230.

— Michael Hamilton



▶ Figure 230–1

230.2 Number of Services

A building may have only one service drop or service lateral unless allowed by one of the exceptions in (A) through (D). ▶ Figure 230–3 and ▶ Figure 230–4

230.2 | Services

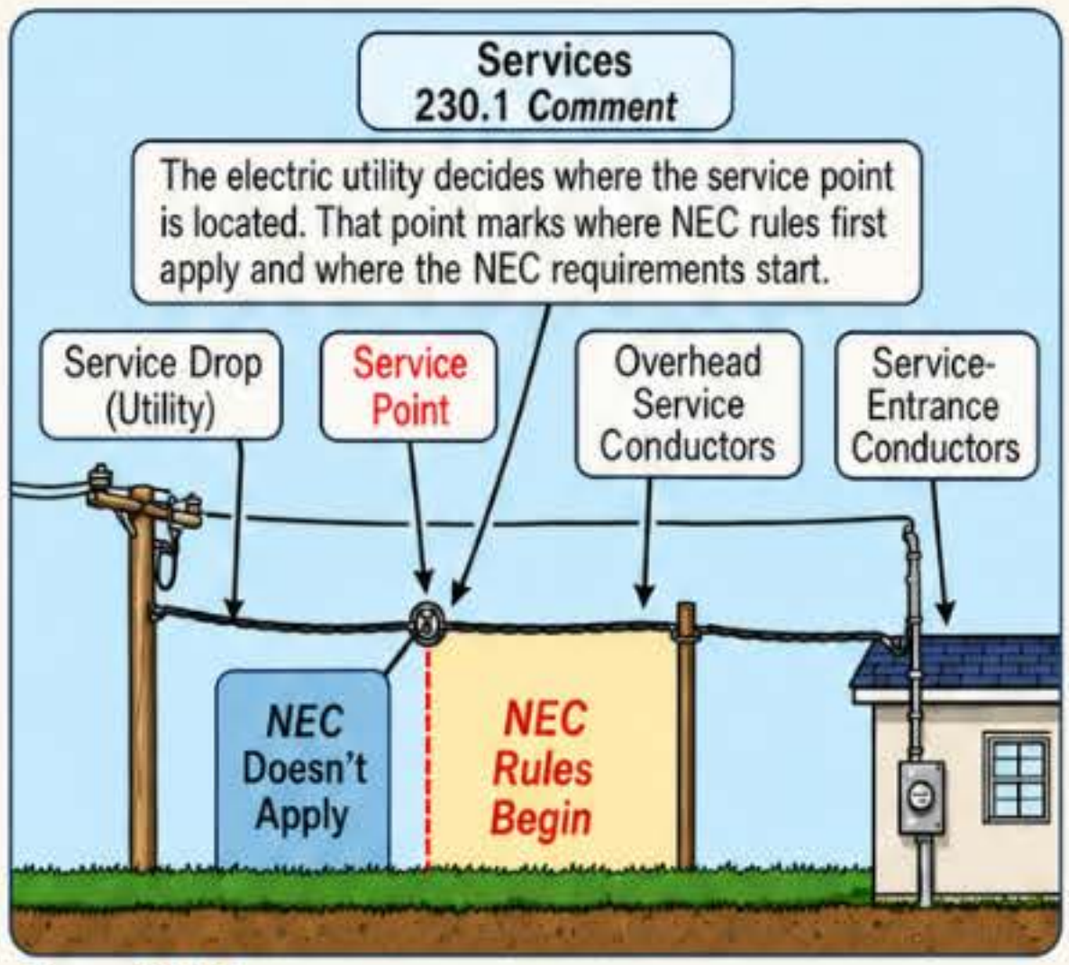


Figure 230-2

To apply 230.40 Ex 2, underground sets of conductors sized 1/0 AWG or larger that run to the same location and connect to the same point at a building or structure must not be connected together at their supply end (but may join together at the load end) if they are considered to be supplying one service.

Author's Commentary:

Many different combinations may qualify as one service drop or service lateral. When necessary, a drop or lateral may be divided and joined to several service disconnects. When multiple services operate in parallel using several sets of conductors, they are still treated as one service. See 230.40 and Exceptions 1 through 6.

— Michael Hamilton

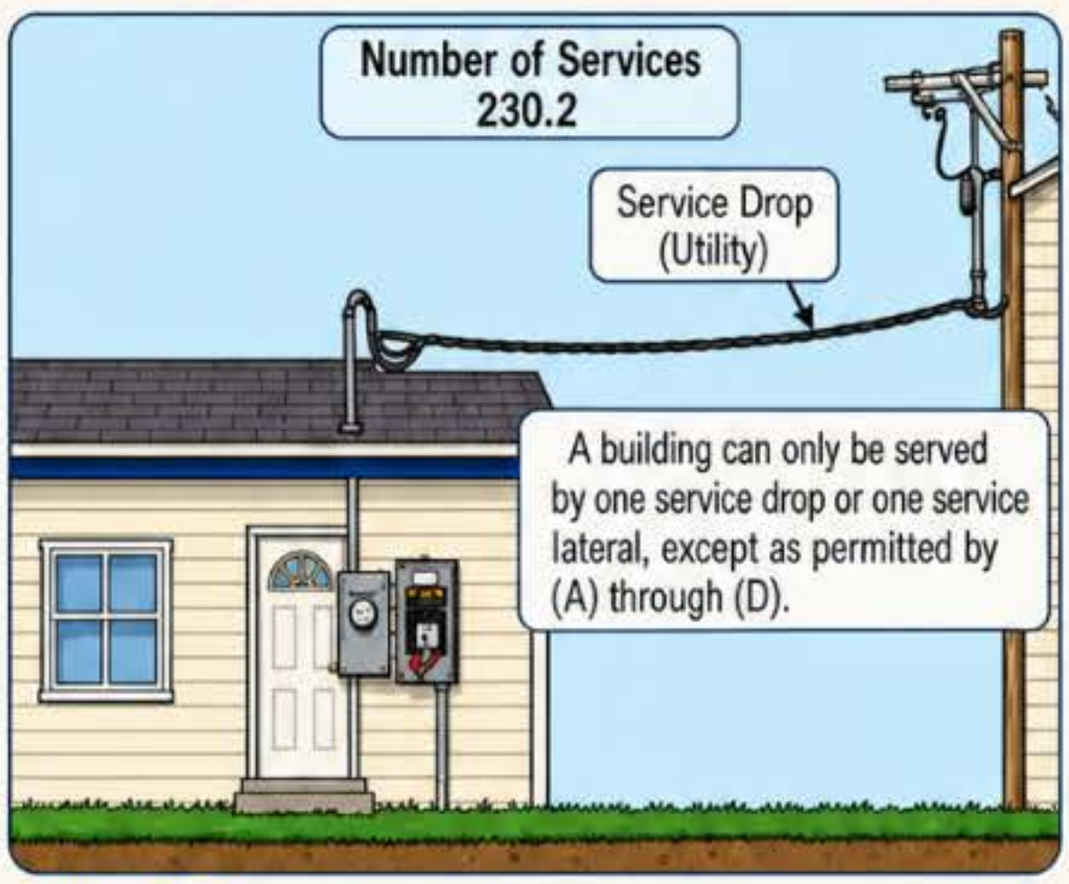


Figure 230-3

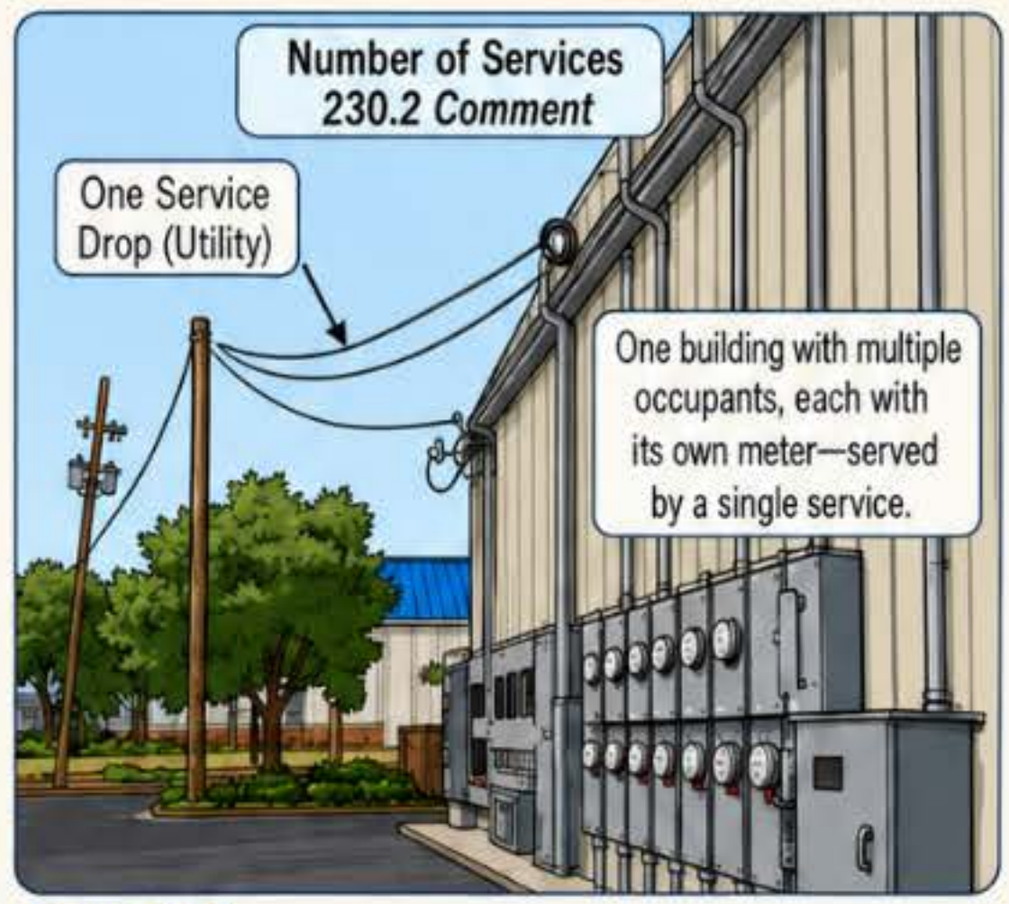


Figure 230-5

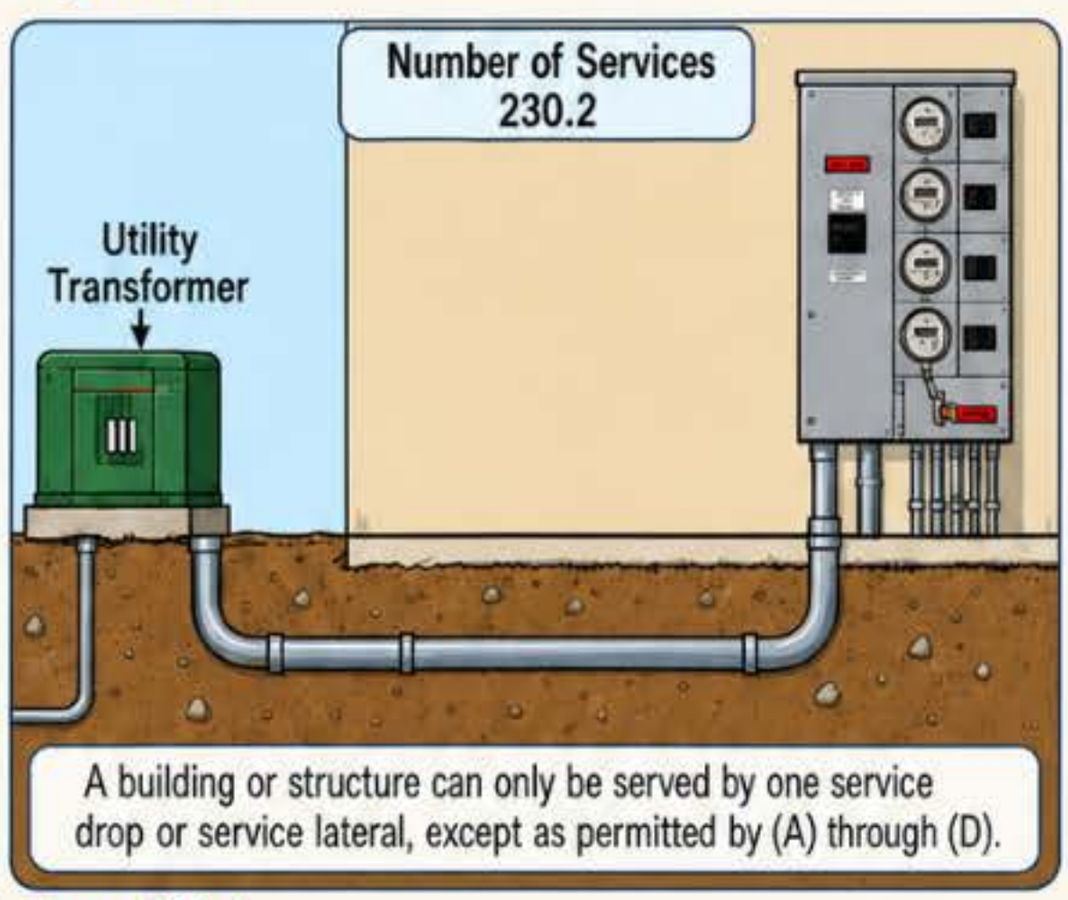


Figure 230-4

(A) Special Conditions. Additional services are allowed for the following:

(1) Fire pumps.

(2) Emergency systems.

(3) Legally required standby systems.

(4) Optional standby power.

(5) Parallel power production sources.

(6) Systems designed to connect to multiple sources of supply for improved reliability.

(B) Special Occupancies. With the proper permission, extra services are permitted for:

(1) Multi-occupancy buildings when no space is available for supply equipment that all occupants can reach, or

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(2) A building so large that two or more supplies are necessary.

(C) Capacity Requirements. Additional services are permitted:

(1) When the capacity requirements go beyond 2,000A, or

(2) When the load requirements of a single-phase installation go beyond that utility's service capacity, or

(3) By special permission.

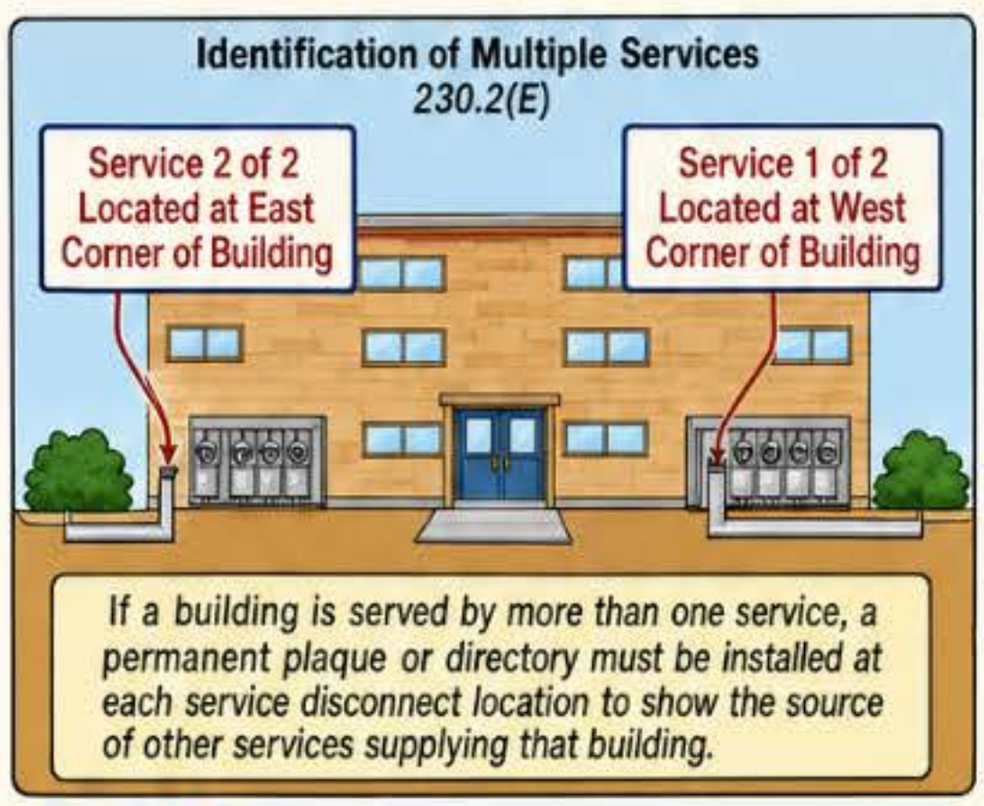
Author's Commentary:

The term "Special Permission" as used in Article 100 means the written approval issued by the authority responsible for enforcing jurisdiction.

— Michael Hamilton

(D) Different Characteristics. Additional services are allowed for installations that operate at different voltages, frequencies, or phases, or that serve distinct kinds of loads such as different electrical uses or rate schedules.

(E) Identification of Multiple Services. If a building receives more than one service, a permanent plaque or directory must be installed at each service disconnect location indicating where other services feeding that building originate. ▸ Figure 230-6



▸ Figure 230-6

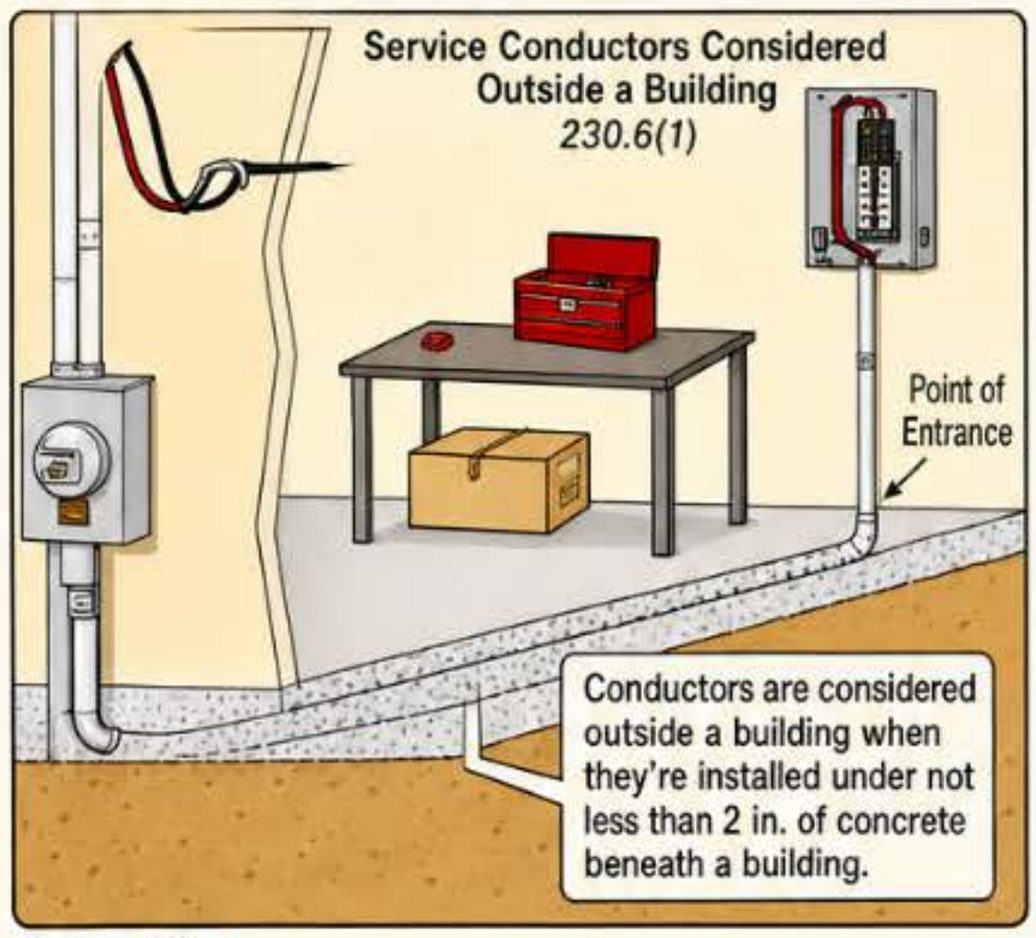
230.3 Not to Pass Through a Building

Service conductors may not run through the interior of a building to supply another building.

230.6 Conductors Considered Outside a Building

Conductors are considered to be outside a building when they are:

(1) Installed in not less than 2 inches of concrete under a building. ▸ Figure 230-7

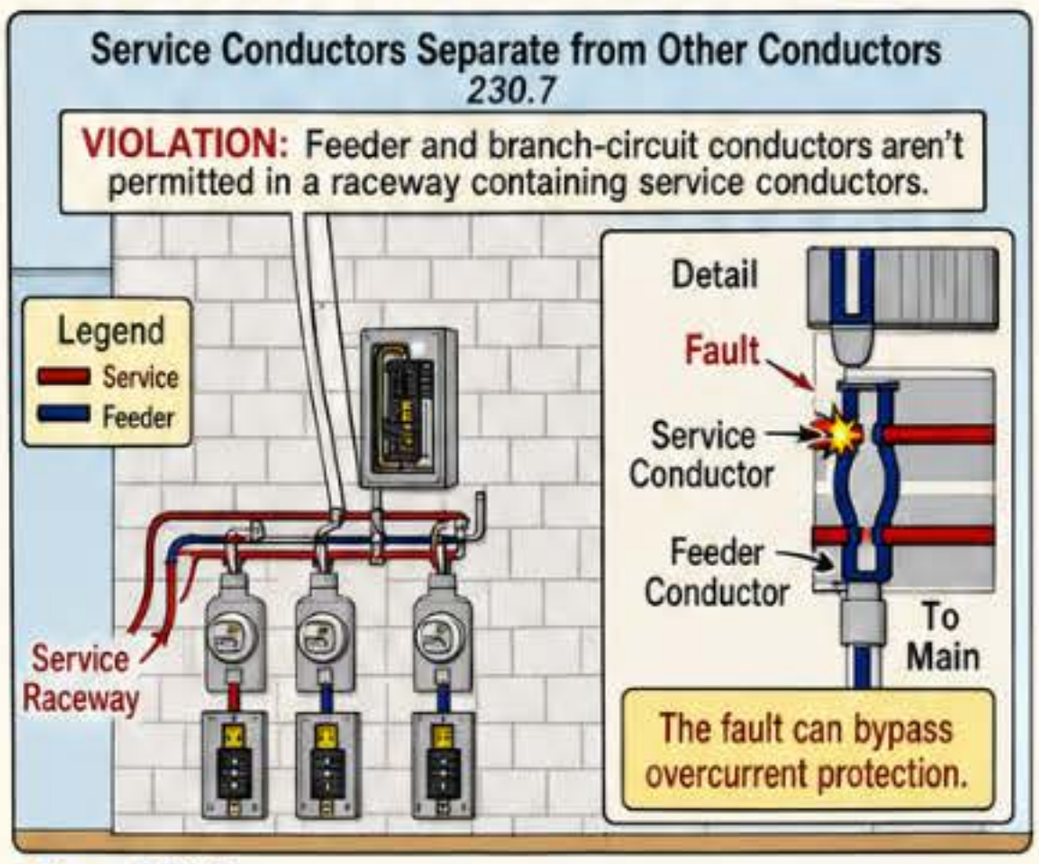


▸ Figure 230-7

(2) Within a building in a raceway encased in not less than 2 in. of concrete or brick.

230.7 Service Conductors Separate from Other Conductors

Feeder and branch-circuit conductors are not permitted to be installed in a raceway containing service conductors. ▸ Figure 230-8



▸ Figure 230-8

Ex 1: *Grounding electrode conductors or supply-side bonding jumpers can be run in a service raceway that contains service conductors.*

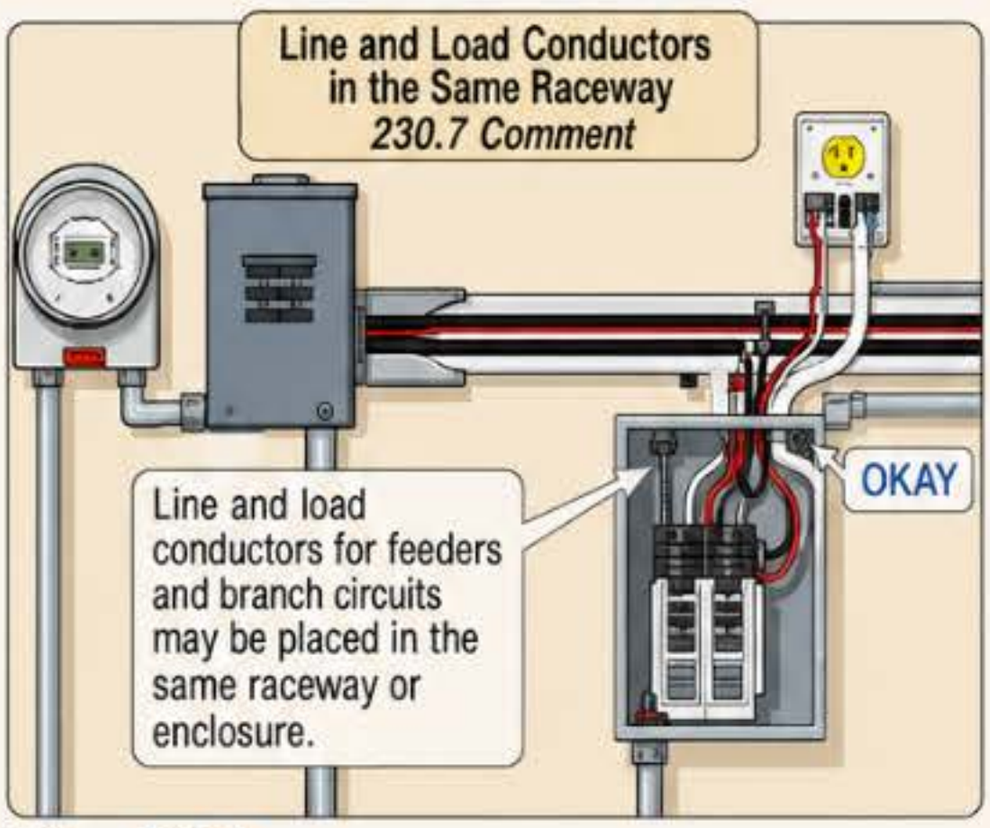
Warning

Overcurrent protection for feeder or branch-circuit conductors cannot be mixed, bypassed, or faulted, or create a condition that allows service conductors to be combined with feeder or branch-circuit conductors in the same raceway. The same is true if a fault occurs between service and feeder or branch-circuit conductors.

Author's Commentary:

- *This rule does not permit mixing service, feeder, or branch-circuit conductors in a shared service disconnect enclosure.*

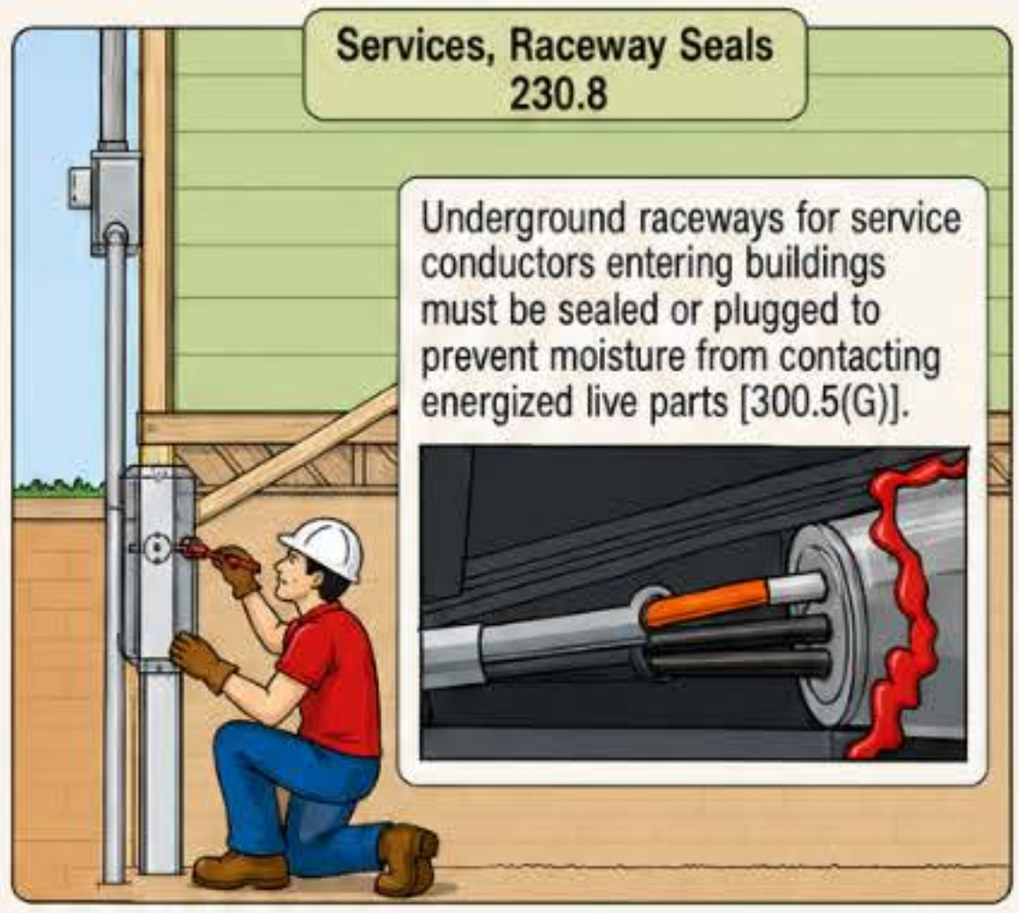
— Michael Hamilton



▸ Figure 230–9

230.8 Raceway Seals

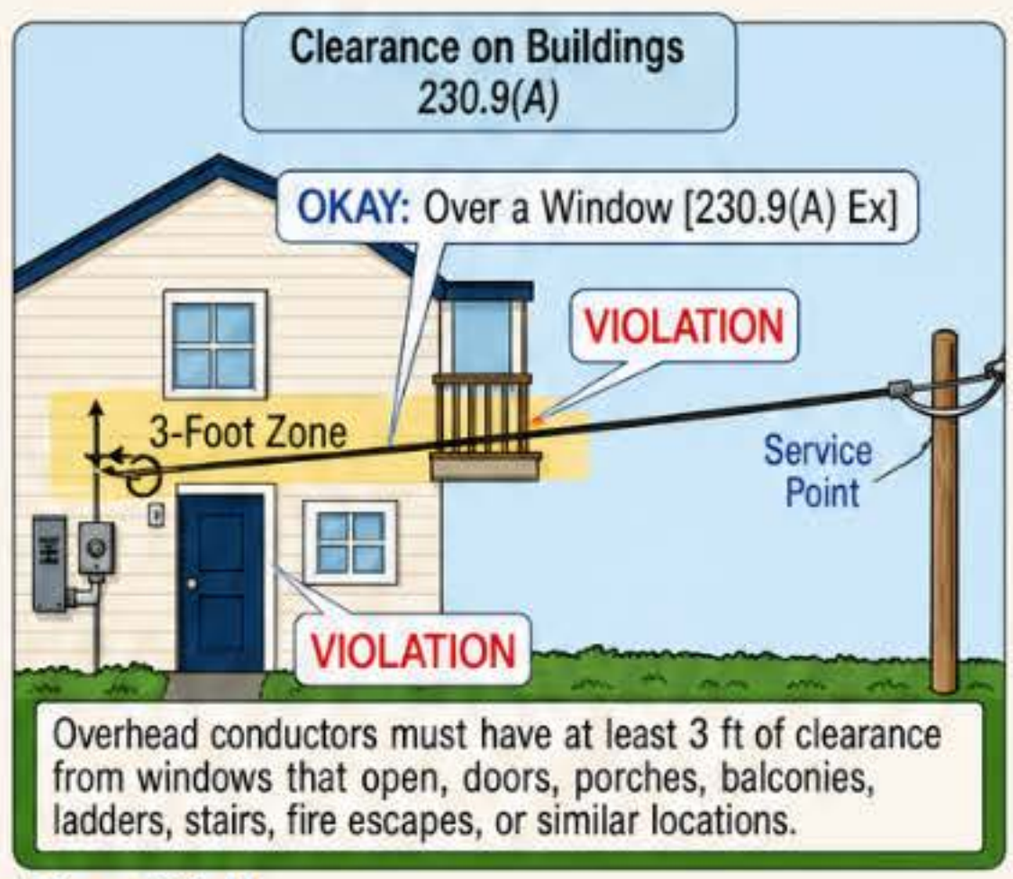
Underground raceways for service conductors entering buildings must be sealed or plugged to keep moisture from contacting energized live parts [300.5(G)]. Sealing materials must be listed for use with the conductor or cable insulation. ▸ Figure 230–10



▸ Figure 230–10

230.9 Clearances on Buildings

(A) Clearance. Overhead service conductors must maintain a clearance of 3 ft from windows that open, doors, porches, balconies, ladders, stairs, fire escapes, or similar locations. ▸ Figure 230–11



▸ Figure 230–11

(B) Vertical Clearance. *Overhead service conductors within 3 ft measured horizontally of platforms, projections, or surfaces allowing access for personnel must have a vertical clearance of no less than 10 ft above those platforms, projections, or surfaces [230.24(B)].*

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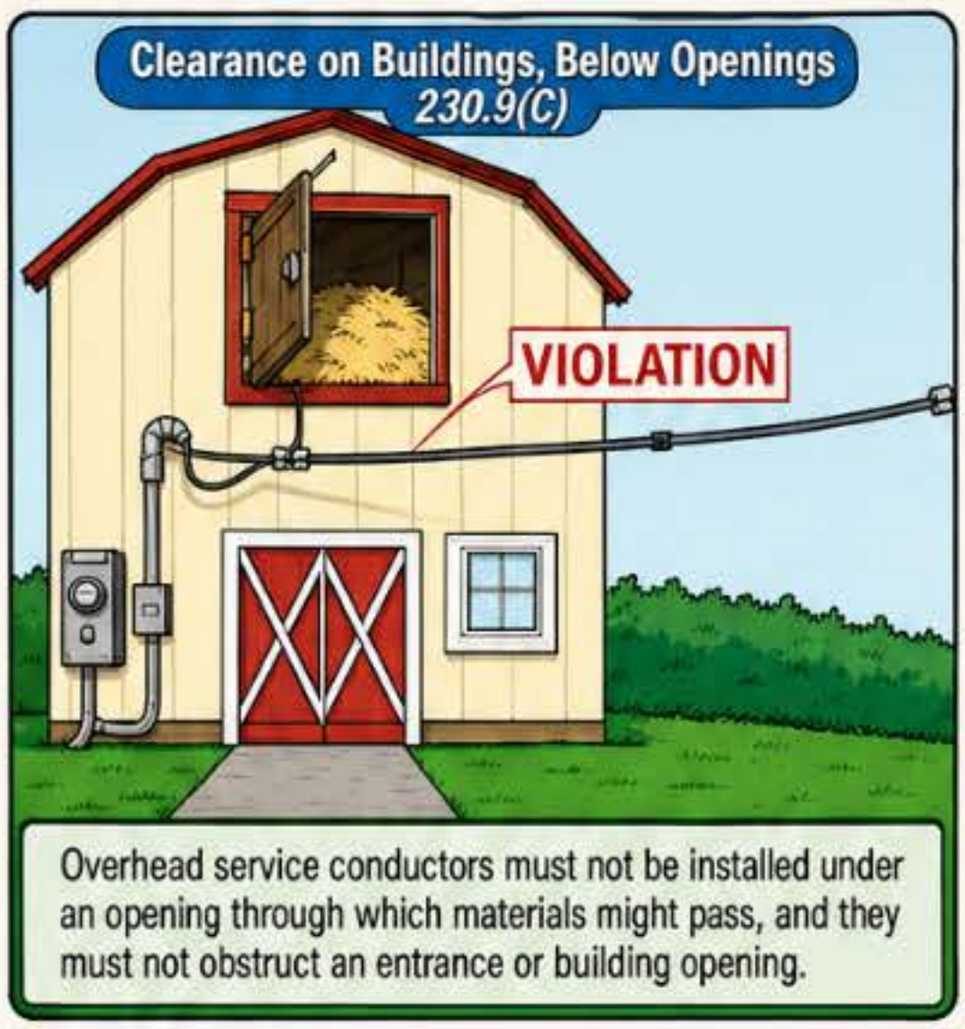
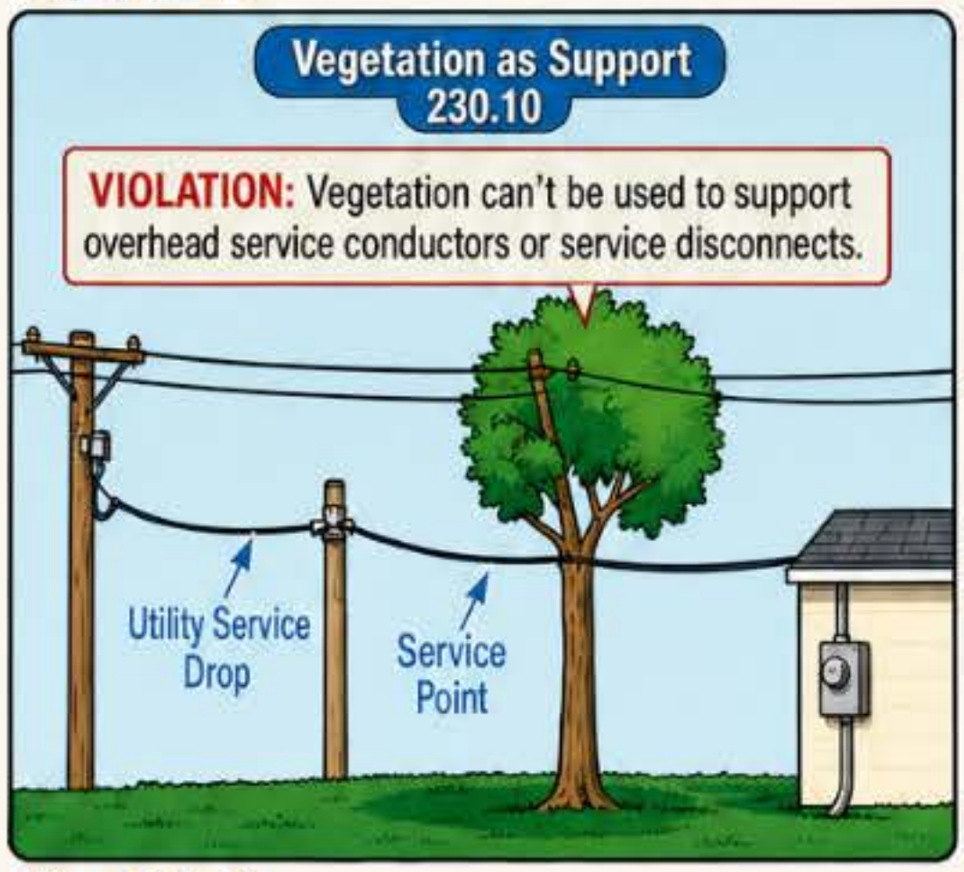
(C) Below Openings. Service conductors cannot be installed under an opening through which materials might pass, and they are not permitted to be installed where they will obstruct entrance to building openings. • Figure 230–12



▸ Figure 230–12

230.10 Vegetation as Support

Trees or other vegetation must not be used for the support of overhead service conductor spans or service disconnects. ▸ Figure 230–13

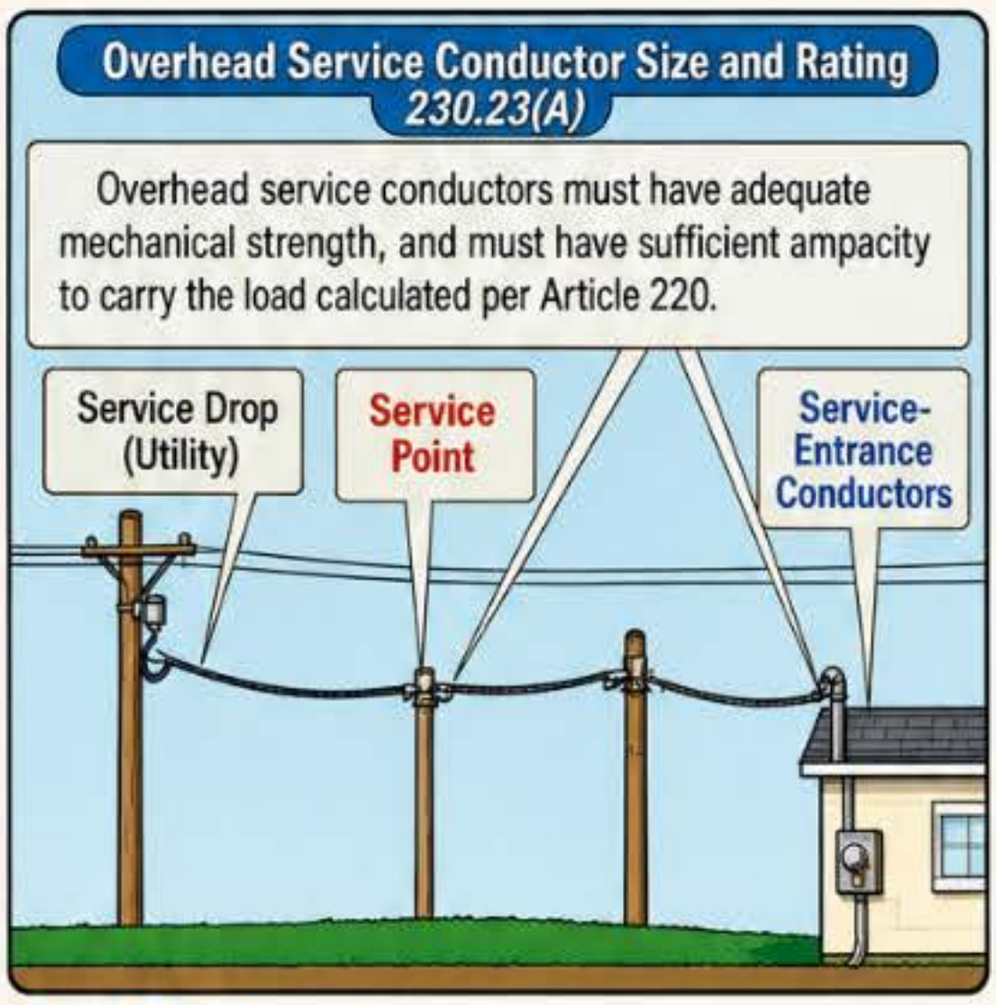


▸ Figure 230–13

Part II. Overhead Service Conductors

230.23 Overhead Service Conductor Size and Rating

(A) General. Overhead service conductors must have adequate mechanical strength and enough ampacity to carry the load as calculated in accordance with Article 220. • Figure 230–14



▸ Figure 230–14

(B) Phase Conductor Size. Overhead service conductors cannot be smaller than 8 AWG copper or 6 AWG aluminum.

Ex: Overhead service conductors can be as small as 12 AWG for limited-load installations.

(C) Neutral Conductor Size. The neutral conductor for overhead service conductors must be sized to carry the maximum unbalanced load in accordance with 220.61 and must be sized no smaller than required by 250.24(C).

Warning

The service neutral conductor size must not be smaller than that required by 250.24(C) to ensure it has sufficiently low impedance and current-carrying capacity to safely carry fault current in order to facilitate the operation of the over-current protective device [250.4(A)(5)].

230.24 | Services

▶ Example

Question: *What size neutral conductor is needed for a building that has a 400A service supplied by 500 kcmil conductors if the highest continuous load is no more than 100A?*

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

Solution:

From Table 310.16, a 3 AWG conductor rated 100A at 75°C [110.14(C)(1)(a)(1)] is adequate for any 100A or lower neutral current. However, the service neutral cannot be smaller than 1/0 AWG per Table 250.102(C)(1), which is based on the area of the 500 kcmil service conductors [250.24(C)].

Answer: *(a) 1/0 AWG*

230.24 Vertical Clearance for Overhead Service Conductors

Overhead service conductor spans must maintain vertical clearances as follows:

(A) Above Roofs. Stay at least 8 ft above a rooftop, or a distance of 3 ft above anything that is within 3 ft of the roof edge.

Ex 2: *If the roof's pitch is 4 in. per foot or steeper, reduce the clearance for each 12 in. horizontally: 120/208V or 120/240V conductors can be lowered 3 ft, while 277/480V conductors can be lowered 2 ft.*

Ex 3: *If no more than six service conductors cross less than 4 ft above any roof point, 120/208V or 120/240V over-roof clearances may be lowered to 18 in.* ▶ Figure 230–15

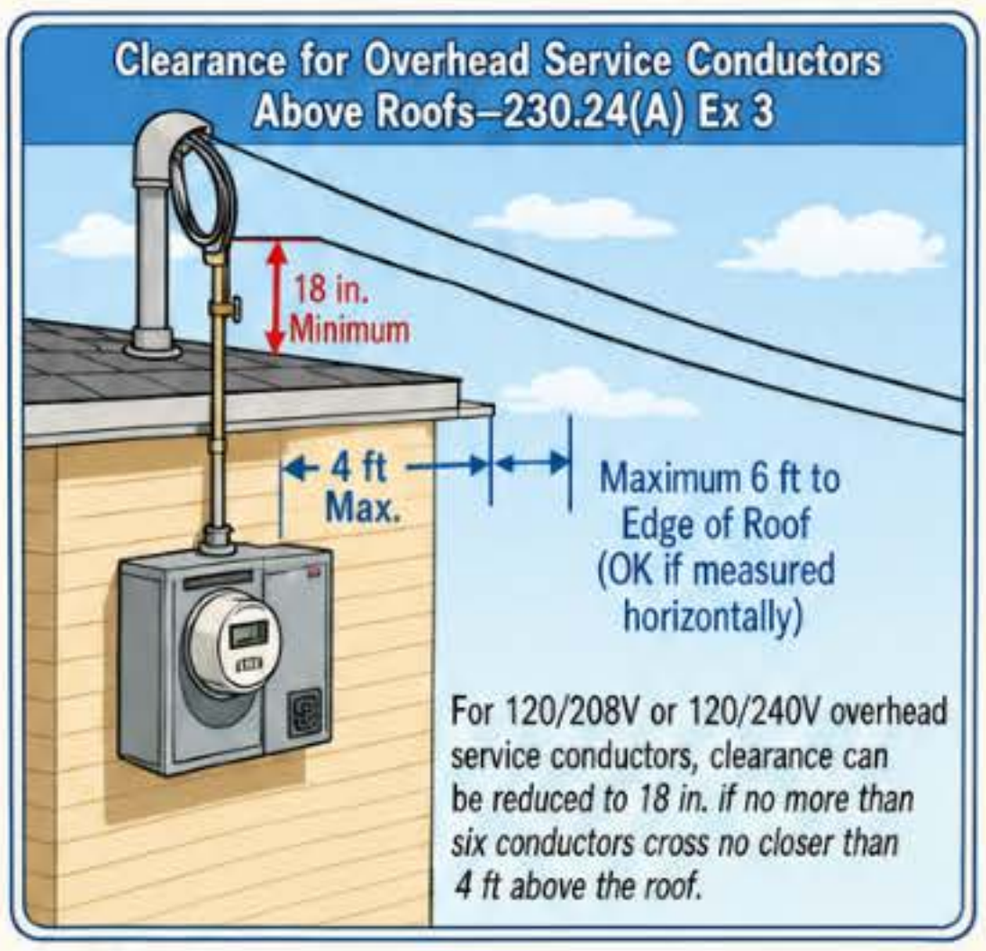


Figure 230–15

Ex 4: The 3-ft vertical clearance for overhead service conductors that extends from the roof does not apply when the point of attachment is on the side of the building below the roof.

Ex 5: *If the voltage between conductors does not exceed 300V and the roof area is protected or isolated, the clearance may be reduced to 3 ft.*

(B) Vertical Clearance for Overhead Service Conductors. All overhead service conductor spans must preserve the following vertical clearances: ▶ Figure 230–16

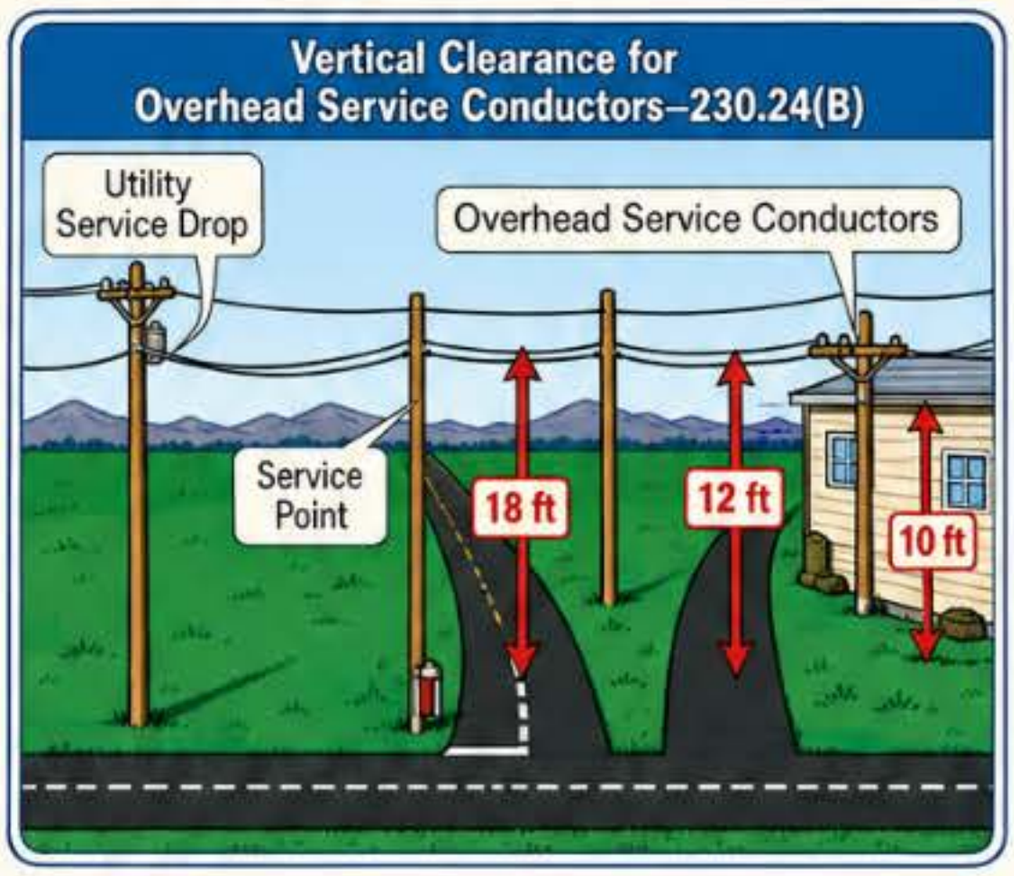


Figure 230–16

(1) 10 ft above finished ground level, sidewalks, platforms, or projections that allow contact for 120/208V or 120/240V circuits.

(2) *12 ft above residential property and driveways, and commercial areas that are not open to truck traffic for 120/208V, 120/240V, or 277/480V circuits.*

(3) *15 ft above residential property and driveways, and commercial areas that are not open to truck traffic for systems with a phase-to-phase voltage greater than 300V to ground.*

(4) *18 ft above public streets, alleys, roads, parking areas open to trucks, driveways on properties other than residences, and other regions that vehicles such as those used for crops, livestock, lumber, forests, or orchards may traverse.*

Author's Commentary:

The Department of Transportation (DOT) commonly uses rights-of-way in rural regions for slow-moving or tall farm equipment to keep roadways clear.

— Michael Hamilton

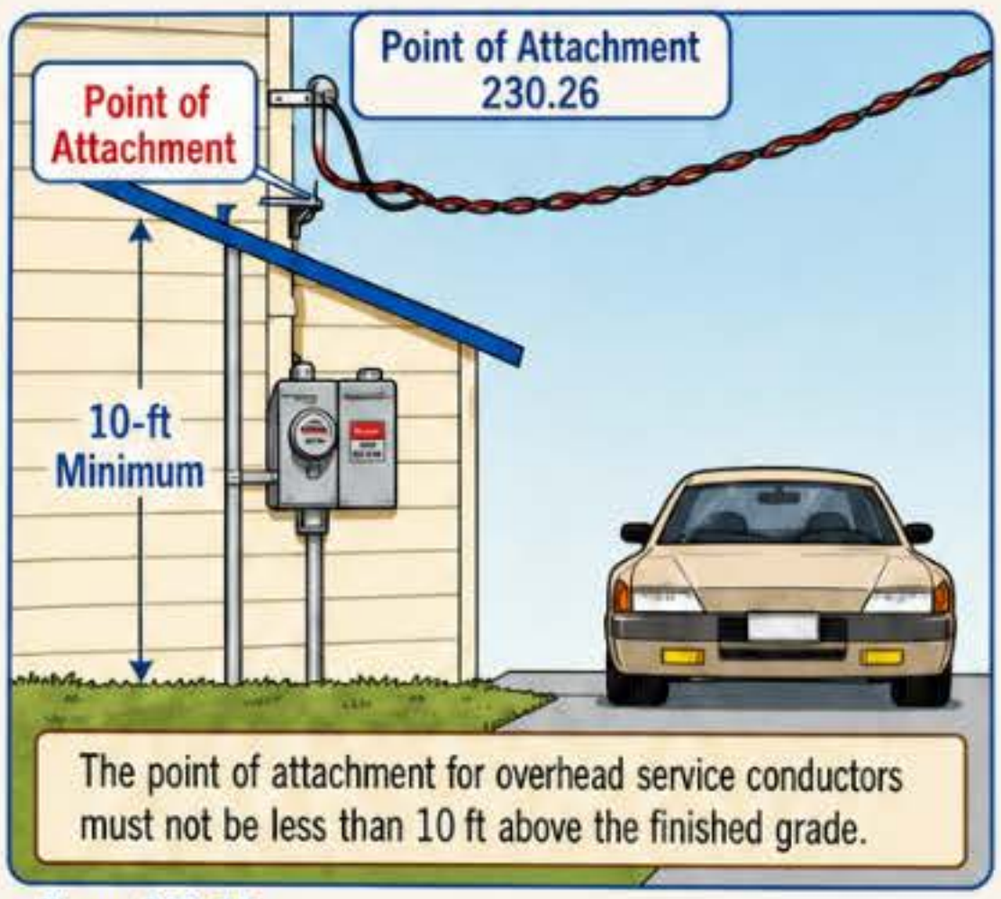
DEFINITIONS | From Michael Hamilton Publications

(5) 24 ft 6 in. over tracks of railroads.

(D) Swimming Pools. Where service conductors run over swimming pools, the serving electric utility has exclusive control. Pools, outdoor spas, hot tubs, diving structures, observation stands, towers, and platforms must be installed to meet the clearance requirements of 680.9.

230.26 Point of Attachment

The point of attachment for overhead service conductors is limited to no less than 10 ft above the finished grade and must be positioned where the minimum clearances specified by 230.9 and 230.24 can be maintained. • Figure 230–17



• Figure 230–17

CAUTION

The point of attachment for conductors might need to be raised so that overhead service conductors comply with the clearance requirements from buildings in sections 230.9 and from other locations in section 230.24.

— Michael Hamilton

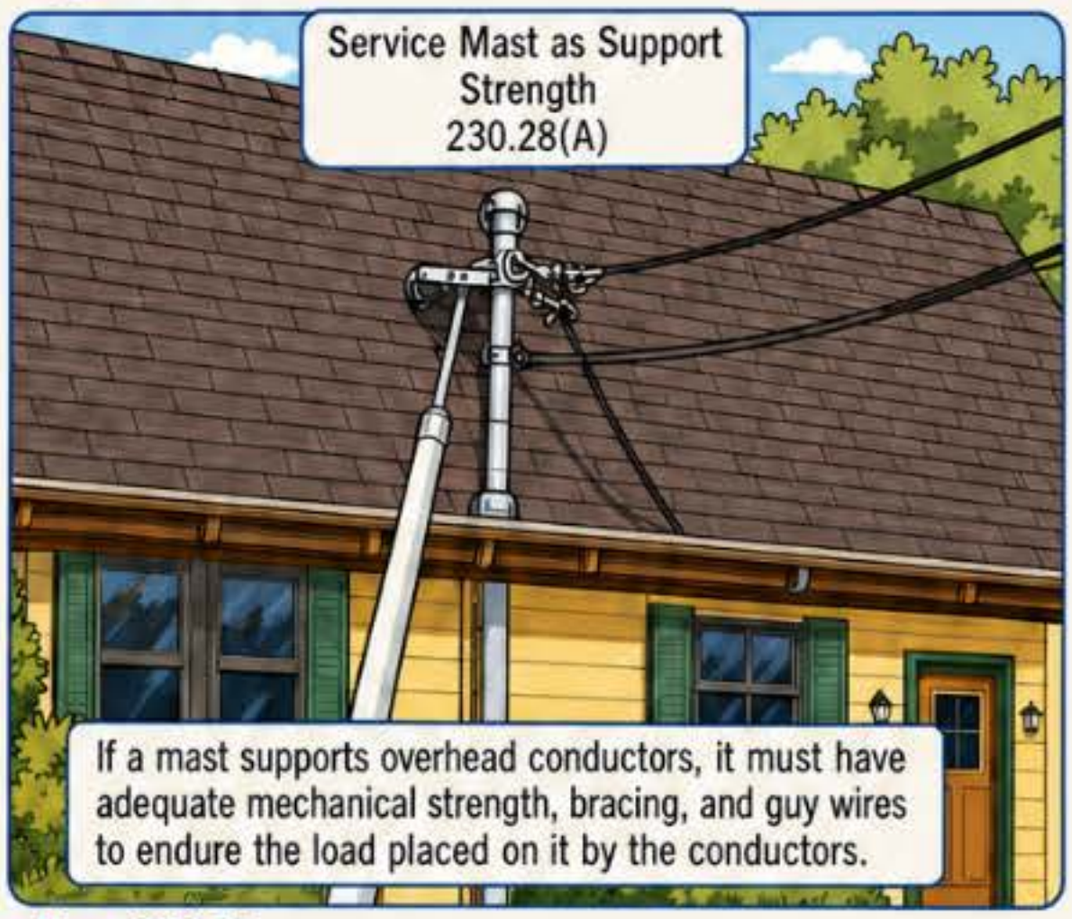
230.27 Means of Attachment

Open conductors must be fastened to fittings approved for service conductors or to noncombustible, nonabsorbent insulators that are securely fixed to the building.

230.28 Service Masts as Support

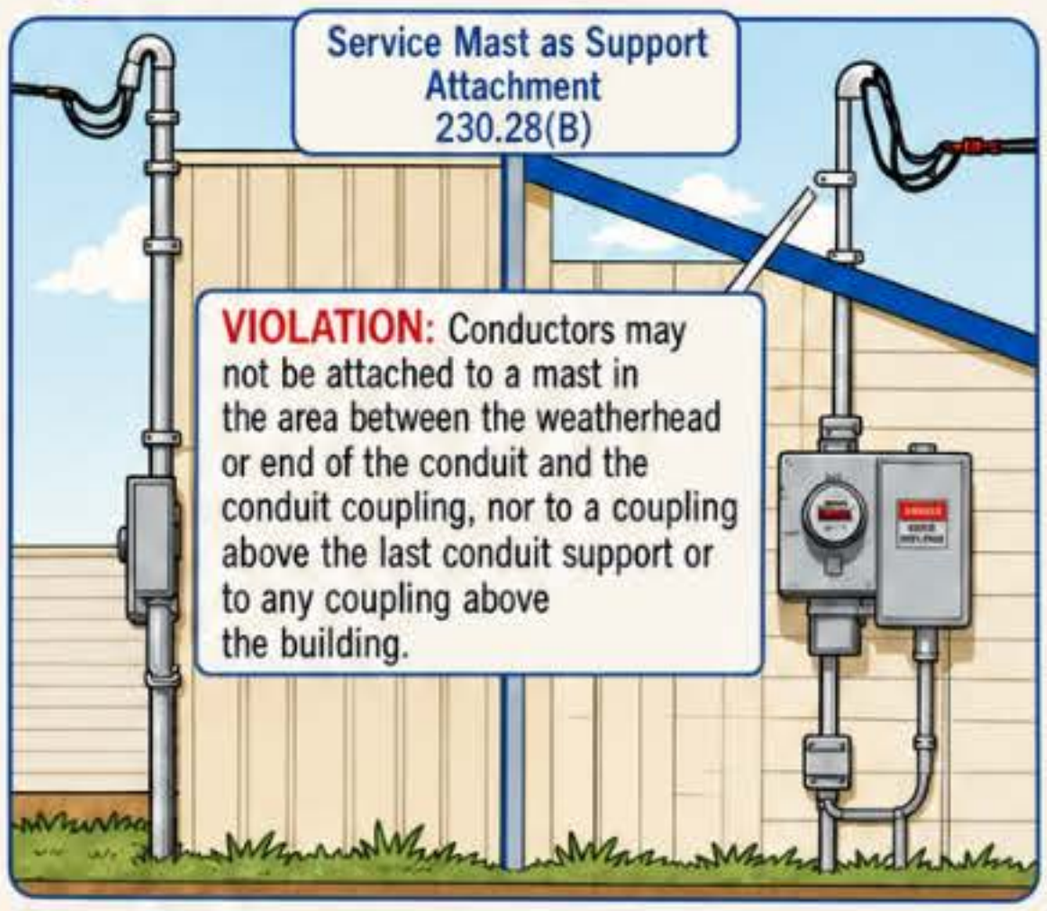
Masts used to support overhead service conductors or service drops have to be installed in accordance with (A) and (B).

(A) Strength. When a mast supports overhead conductors, it must have adequate mechanical strength, bracing, and guy wires to withstand the tension placed on it by the conductors. • Figure 230–18



• Figure 230–18

(B) Attachment. Conductors may not be attached to a mast located between a weatherhead or end of the conduit and the coupling of that conduit, and a coupling positioned above the last conduit support, or any coupling above the building. • Figure 230–19



• Figure 230–19

Author's Commentary:

Municipal codes or utility company rules may mandate that a minimum trade size 2 rigid metal conduit be used for the service mast. In addition, many electrical utilities publish their own requirements for the installation of service masts.

— Michael Hamilton

Part III. Underground Service Conductors

230.30 Installation

(B) Wiring Methods. The only wiring methods authorized for use with service conductors are the following:

(1) Type RMC.

(2) Type IMC.

(3) Type NUCC.

(4) Type HDPE conduit.

(5) Type PVC conduit.

(6) Type RTRC.

(7) Type IGSC cable.

(8) Type USE conductors or cables.

(9) Type MV or Type MC cable identified for direct burial applications.

(10) Type MI cable that is suitably protected against physical damage and corrosion.

230.31 Underground Service Conductor Size and Rating

(A) General. Underground service conductors must have sufficient ampacity to carry the load as calculated in accordance with Article 220. See Figure 230–20.

(B) Phase Conductor Size. Underground service conductors must be no smaller than 8 AWG copper or 6 AWG aluminum or copper-clad aluminum.

Ex: Underground service conductors can be as small as 12 AWG for limited-load installations.

(C) Neutral Conductor Size. The neutral conductor must be sized to carry the maximum unbalanced load in accordance with 220.61 and must not be smaller than required by 250.24(C).

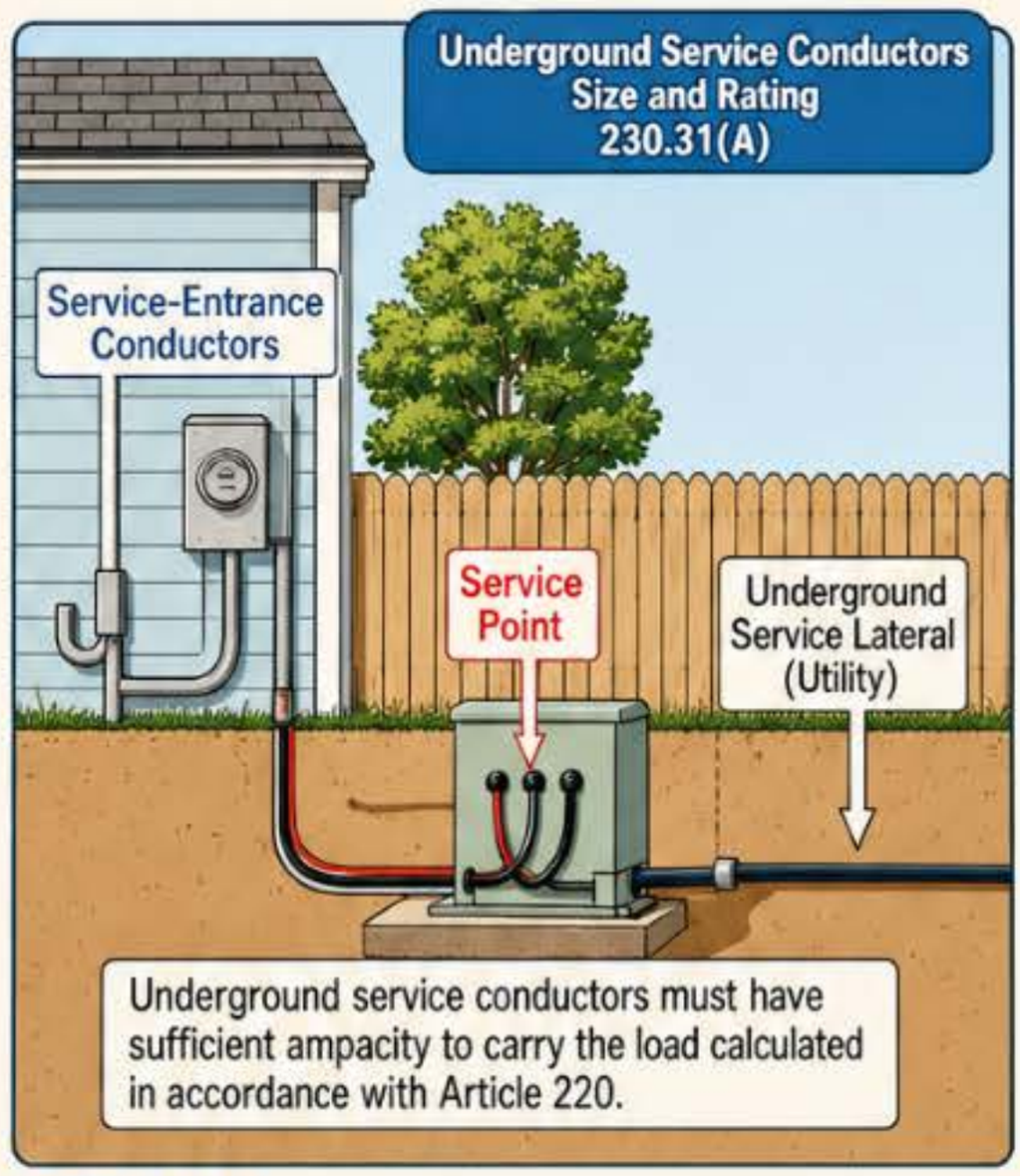


Figure 230–20

Example

Question: *What size neutral conductor is required for a structure with a 400A service supplied with 500 kcmil conductors if the maximum line-to-neutral load is no more than 100A?*

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

Solution:

According to Table 310.16, a 3 AWG conductor rated 100A at 75°C [110.14(C)(1)(b)(1)] can carry 100A of neutral current. However, the service neutral conductor must not be smaller than 1/0 AWG according to Table 250.102(C)(1), based on the size/area of the 500 kcmil service conductors [250.24(C)].

Answer: *(a) 1/0 AWG*

230.32 Protection Against Damage

Underground service conductors must be installed in accordance with 300.5 and the minimum cover must be in accordance with Table 300.5. See Figure 230–21.

Part IV. Service-Entrance Conductors

Figure 230–21

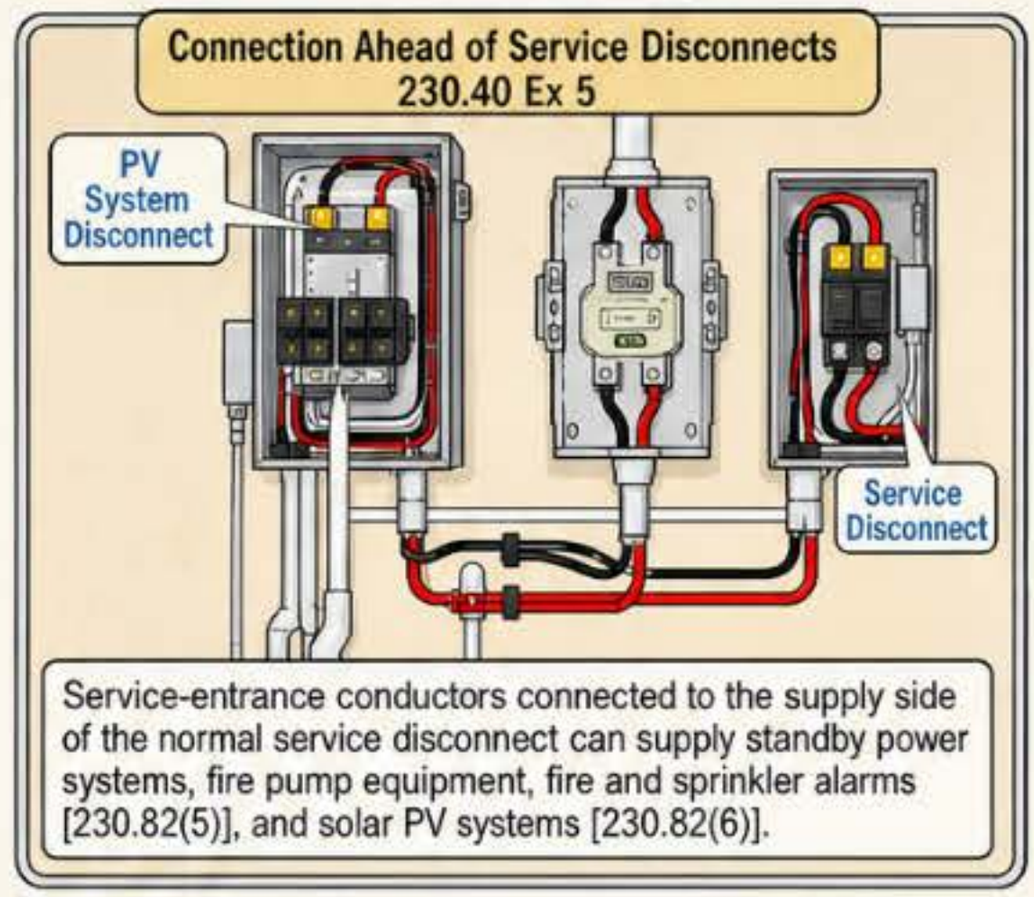


Figure 230–22

Part IV. Service-Entrance Conductors

230.40 Number of Service-Entrance Conductor Sets

Each service drop, service lateral, or set of underground or overhead service conductors can supply one set of service-entrance conductors.

Example 2: *Up to six service disconnects can be supplied by just two to six service conductors [230.71(B)].*

Author's Commentary:
When multiple underground conductors (1/0 AWG or larger) or long raceways terminate together at the same point and are connected on the supply end, but not on the load end, they are considered to supply only a single service [230.2].
— Michael Hamilton

Example 5: *One set of service-entrance conductors connected to the supply side of the normal service disconnect can provide standby power systems, fire pump equipment, fire and sprinkler alarms [230.82(5)], and solar PV systems [230.82(6)].*

230.42 Conductor Sizing

(A) General. Conductors must be sized to carry not less than the largest of the calculations contained in 230.42(A)(1) or (2).

Conductor ampacity must be determined in accordance with 310.14 and the conductors must be sized to the terminal temperature rating in accordance with 110.14(C)(1).

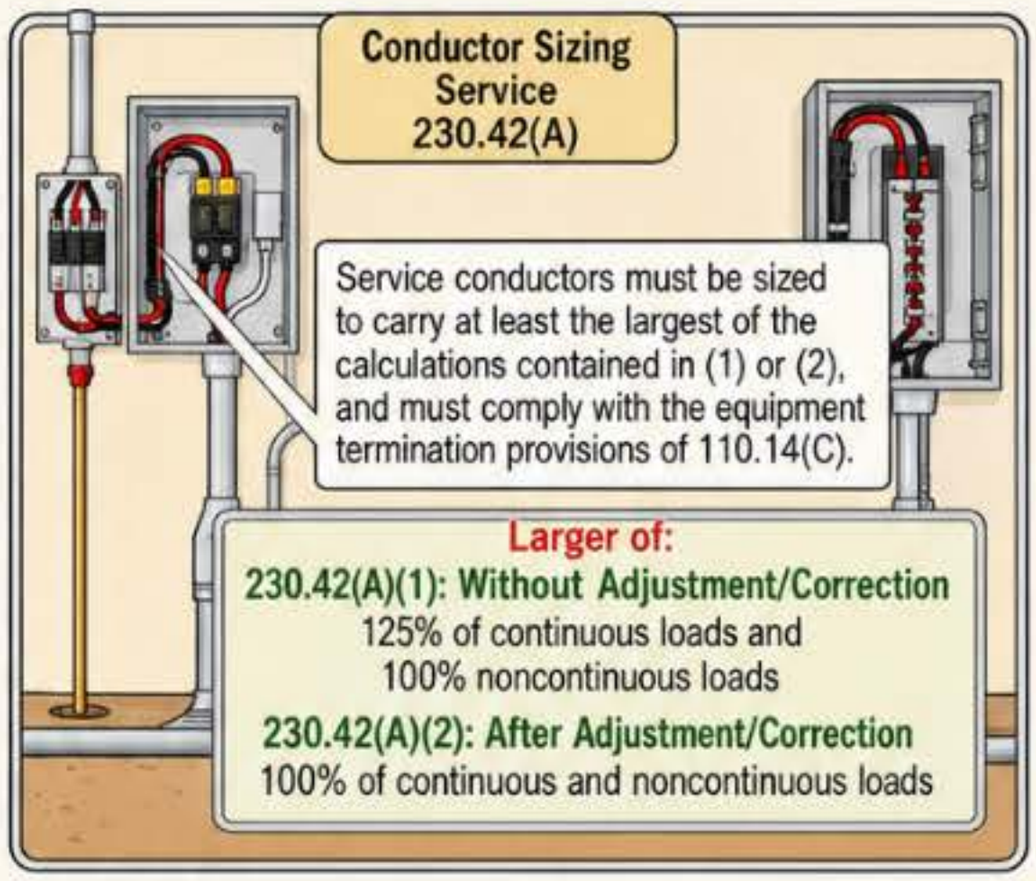


Figure 230–23

(1) Without Conductor Ampacity Adjustment and/or Correction. Conductors must be sized to carry 125 percent of the continuous loads, plus 100 percent of the noncontinuous loads, based on the terminal temperature rating ampacities contained in Table 310.16 [110.14(C)(1)].

Figure 230–24

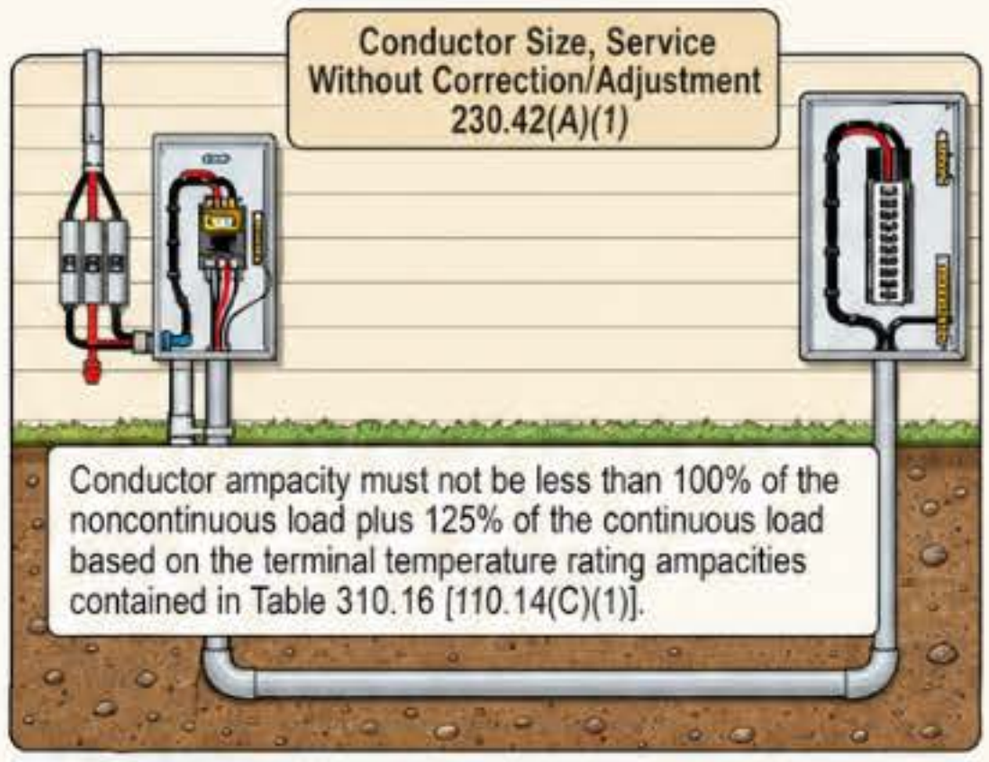


Figure 230-24

▶ Example 1

Question: *What size conductors rated 90°C are required for a service supplying a 180A continuous load where the equipment terminals are rated 75°C?* ▶Figure 230-25

(a) 3/0 AWG (b) 4/0 AWG (c) 300 kcmil (d) 350 kcmil

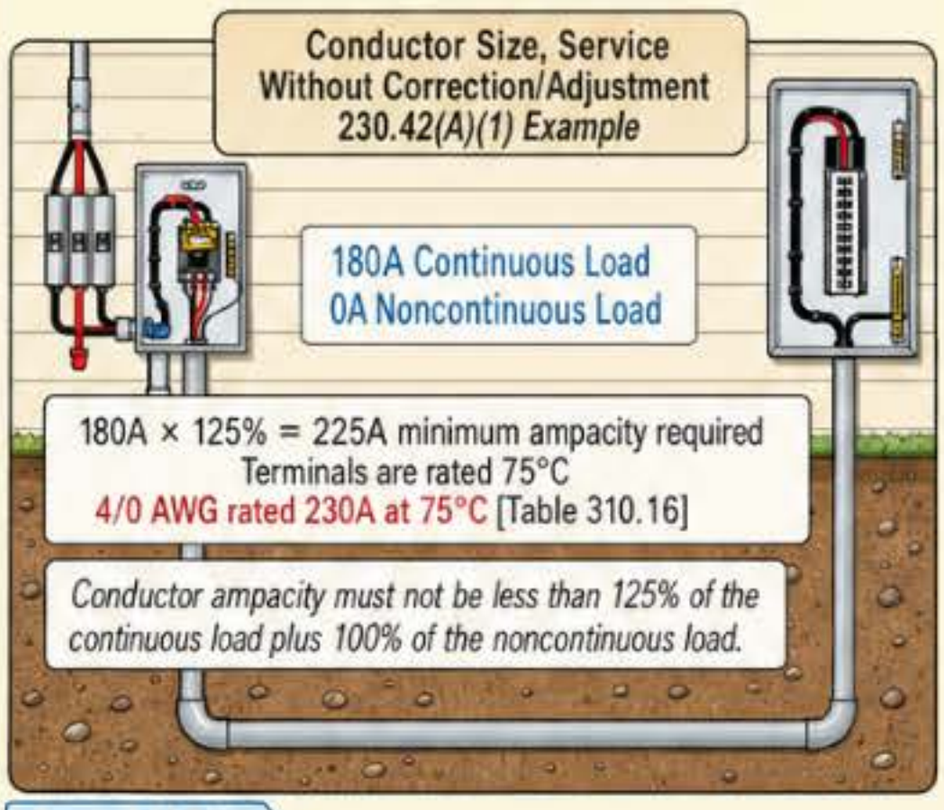


Figure 230-25

Solution:

Step 1: *Conductor Ampacity. The conductors must have an ampacity of at least 225A (180A × 125%).*

Step 2: *Size the conductors in accordance with 110.14(C)(1)(b)(2) and Table 310.16.*

According to the 75°C column of Table 310.16, 4/0 AWG is rated 230A and is therefore suitable to be used.

Answer: *(b) 4/0 AWG*

▶ Example 2

Question: *What size conductors rated 90°C are required for a service supplying a 320A continuous load where the equipment terminals are 75°C?* ▶Figure 230-26

(a) 300 kcmil (b) 400 kcmil (c) 500 kcmil (d) 600 kcmil

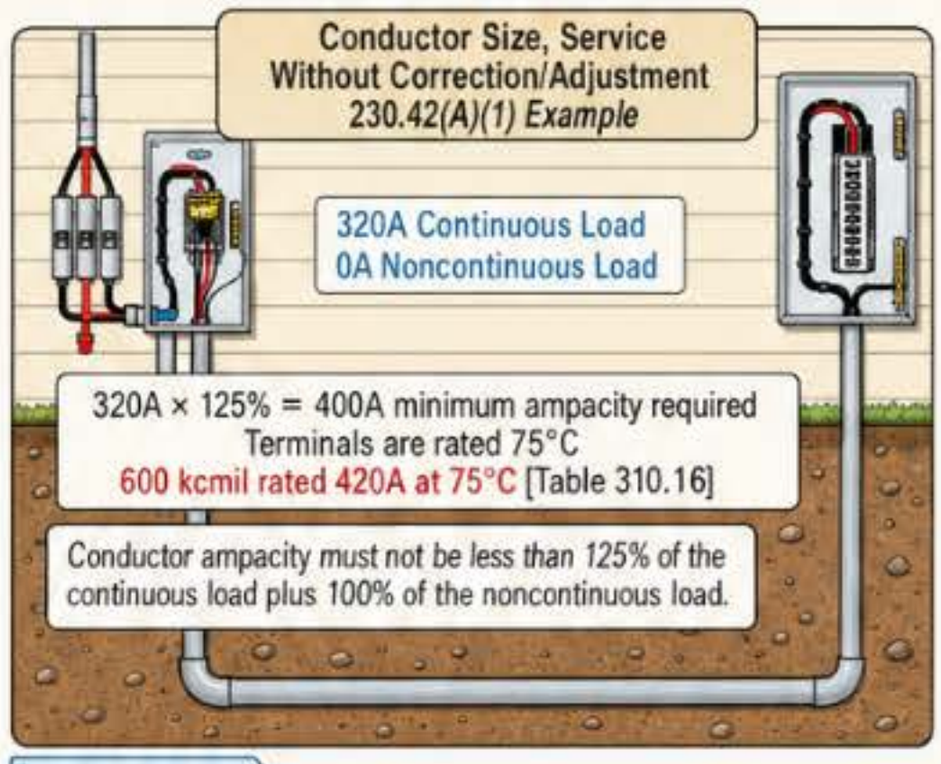


Figure 230-26

Solution:

Step 1: *Conductor Ampacity. The conductors from the panelboard to the distribution block must have an ampacity of at least 400A (320A × 125%).*

Step 2: *Size the conductors in accordance with 110.14(C)(1)(b)(2) and Table 310.16.*

According to the 75°C column of Table 310.16, 600 kcmil is rated 420A and is therefore suitable to be used.

Answer: *(d) 600 kcmil*

Author's Commentary:

Example 1: *Neutral conductors must have an ampacity of not less than 100 percent of the continuous and noncontinuous loads.*

— Michael Hamilton

▶ Example

Question: *What size neutral conductor rated 90°C is required for a 200A continuous neutral load if the terminals are rated 75°C?* ▶Figure 230-27

(a) 3/0 AWG (b) 4/0 AWG (c) 250 kcmil (d) 300 kcmil

Solution:

Step 1: *The neutral conductor is sized to the 200A continuous load (100 percent).*

Author's Commentary:

Example: *The neutral conductor must have an ampacity equal to 100 percent of the continuous load.*

— Michael Hamilton

DEFINITIONS | From Michael Hamilton Publications

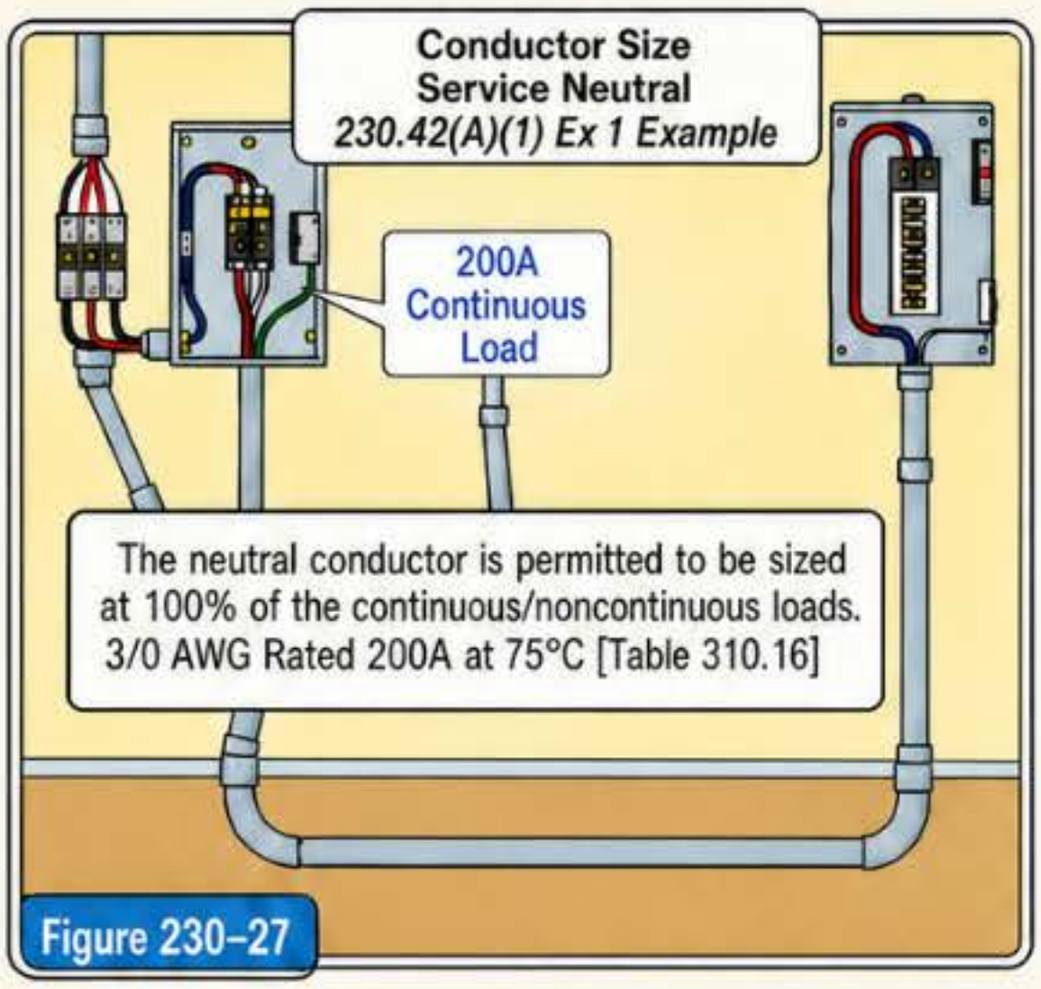


Figure 230–27

Step 2: *Size conductors in accordance with 110.14(C)(1)(b)(2) and Table 310.16.*

According to the 75°C column of Table 310.16, 3/0 AWG has an ampacity of 200A.

Answer: *(a) 3/0 AWG [110.14(C)(1)(b)(2) and Table 310.16]*

(2) With Conductor Ampacity Adjustment and Correction. *Conductors must be sized to carry not less than 100 percent of the continuous load, plus 100 percent of the noncontinuous load after conductor ampacity adjustment and/or correction in accordance with 310.14.*

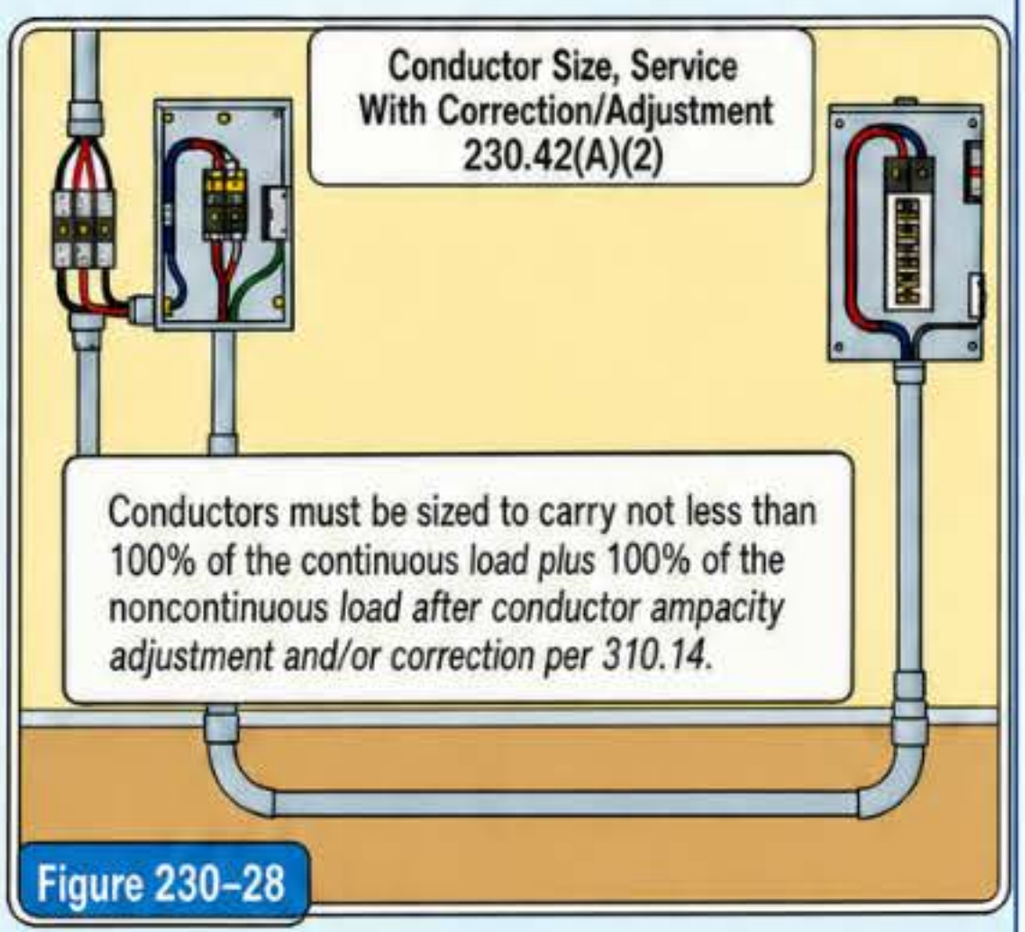


Figure 230–28

▶ Example 1

Question: *What size conductors rated 90°C are required for a service containing four current-carrying conductors supplying a 180A continuous load in an ambient temperature of 100°F where the equipment terminals are rated 75°C?* ***Figure 230–29***

(a) 4/0 AWG (b) 300 kcmil (c) 500 kcmil (d) 600 kcmil

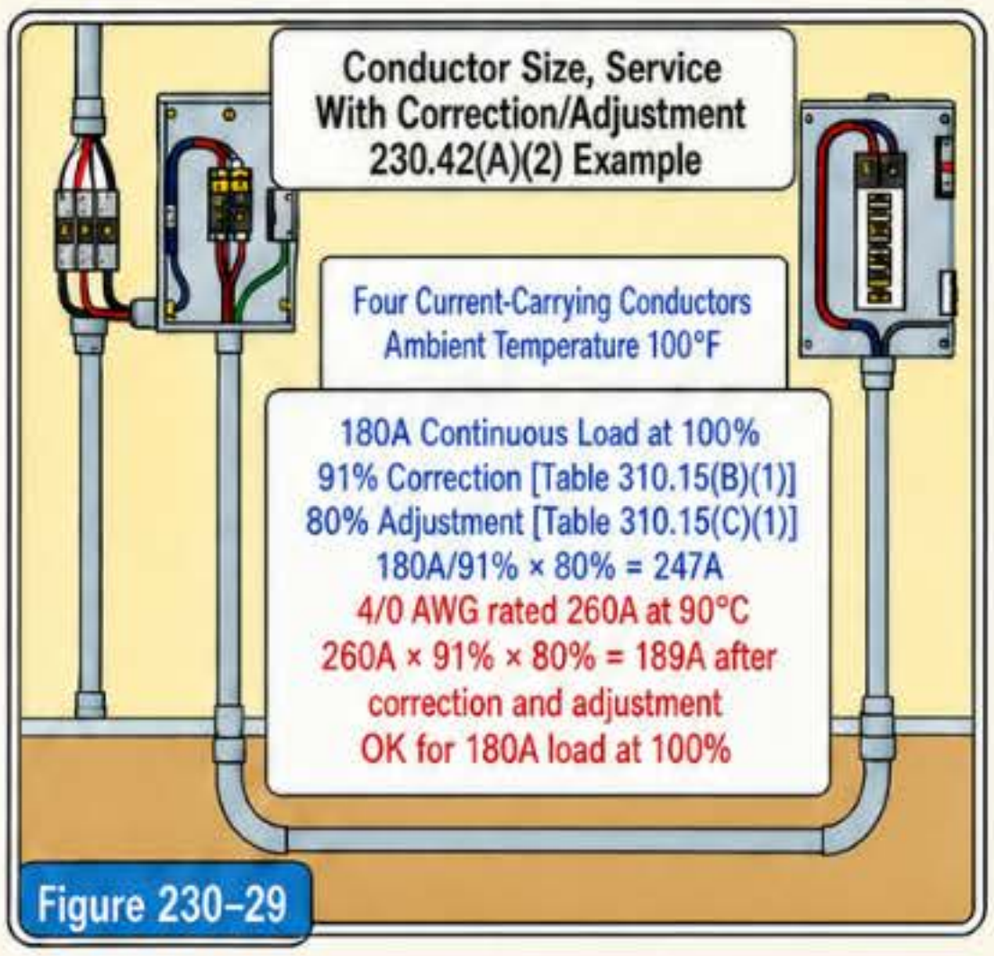


Figure 230–29

Solution:

Step 1: *The conductors must have an ampacity of not less than 180A after conductor ampacity temperature correction [Table 310.15(B)(1)] and adjustment [Table 310.15(C)(1)] based on the conductor insulation rating of 90°C. One way to find the conductor size is to determine the conductor ampacity required to supply a 180A continuous load at 100 percent after correction and adjustment.*

Conductor Ampacity at 90°C = Continuous Load at 100% (Correction × Adjustment)

Continuous Load = 180A

Correction [Table 310.15(B)(1)] = 91% (100°F with 90°C Conductor)

Adjustment [Table 310.15(C)(1)] = 80% (four current-carrying conductors)

Minimum Conductor Ampacity Needed from the 90°C Column = 180A/(91% × 80%)

Minimum Conductor Ampacity Needed from the 90°C Column = 180A/(91% × 80%) = 247A

DEFINITIONS | From Michael Hamilton Publications

Step 2: *Pick the conductor listed in the 90°C column of Table 310.16 [X](1)(2).*

4/0 AWG works because it has an ampacity of 260A at 90°C prior to any correction or adjustment.

Step 3: *Confirm its ampacity after applying all required corrections and adjustments can carry 100 percent of the 180A continuous load at 90°C.*

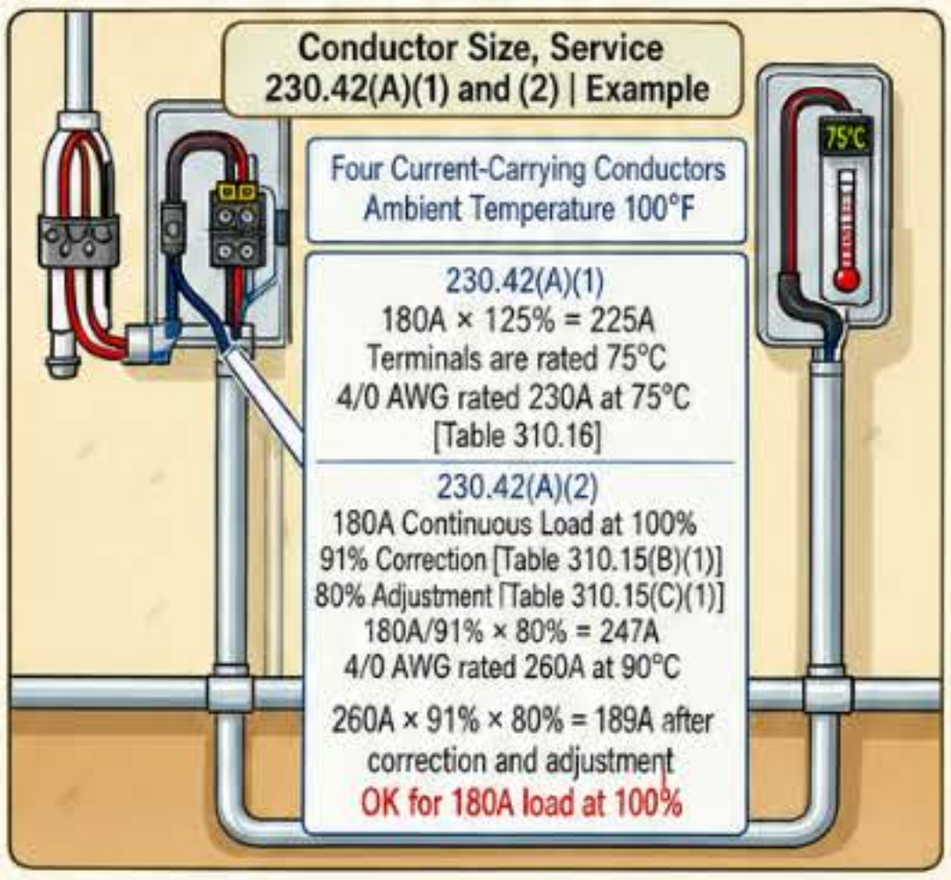
Conductor Ampacity after Correction and Adjustment = Conductor Ampacity × Correction × Adjustment

Conductor Ampacity at 90°C = 260A
Correction = 91%
Adjustment = 80%

Conductor Ampacity after Correction and Adjustment = 260A × 91% × 80%
Conductor Ampacity after Correction and Adjustment = 189A

4/0 AWG with 90°C insulation has an ampere rating of 189A which is more than enough for the 180A continuous load.

Step 4: *Confirm that the ampacity of 4/0 AWG at 75°C without correction and adjustment can handle the 180A continuous load at 125 percent in accordance with 230.42(A)(1).* ▶ **Figure 230–30**



▶ **Figure 230–30**

Conductor Ampacity Needed = Continuous load at 125%
Conductor Ampacity Needed = 180A × 125%
Conductor Ampacity Needed = 225A

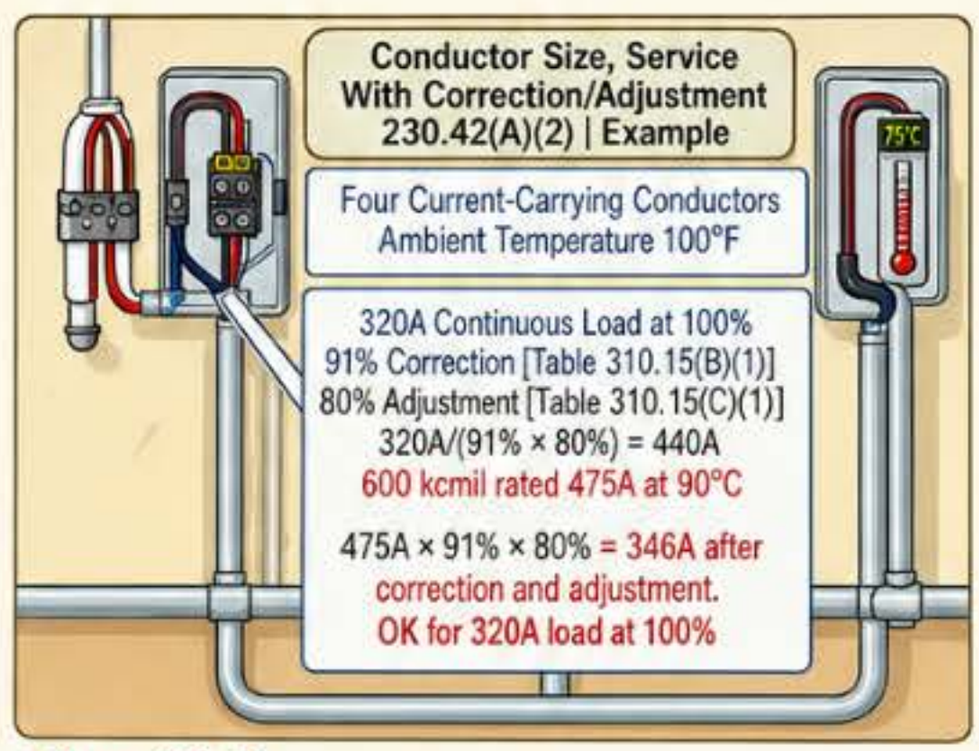
According to Table 310.16, 4/0 AWG is suitable because it is rated 230A at 75°C.

Answer: *(a) 4/0 AWG*

▶ Example 2

Question: *What size conductors rated 90°C are required for a service containing four current-carrying conductors supplying a 320A continuous load in an ambient temperature of 100°F where the equipment terminals are rated 75°C?* ▶ **Figure 230–31**

(a) 300 kcmil (b) 400 kcmil (c) 500 kcmil (d) 600 kcmil



▶ **Figure 230–31**

Solution:

Step 1: *The conductors must have an ampacity of not less than 320A after conductor ampacity temperature correction [Table 310.15(B)(1)] and adjustment [Table 310.15(C)(1)], based on the conductor insulation rating of 90°C. One way to find the conductor size is to determine the conductor ampacity required to supply a 320A continuous load at 100 percent after correction and adjustment.*

Conductor Ampacity at 90°C = Continuous Load at 100% / (Correction × Adjustment)

Continuous Load = 320A
Correction [Table 310.15(B)(1)] = 91% (100°F with 90°C Conductor)
Adjustment [Table 310.15(C)(1)] = 80% (four current-carrying conductors)

Minimum Conductor Ampacity Needed from the 90°C Column = 320A/(91% × 80%)
Minimum Conductor Ampacity Needed from the 90°C Column = 320A/73%
Minimum Conductor Ampacity Needed from the 90°C Column = 438A

Step 2: *Pick the conductor from the 90°C column of Table 310.16.*

600 kcmil is suitable because it has an ampacity of 475A at 90°C before any correction and adjustment.

Step 3: *Confirm that the ampacity of 600 kcmil, after applying correction and adjustment factors, can support 100 percent of the 320A continuous load at 90°C.*

Conductor Ampacity after Correction and Adjustment = Conductor Ampacity × Correction × Adjustment

Conductor Ampacity at 90°C = 475A
Correction = 91%
Adjustment = 80%

Conductor Ampacity after Correction and Adjustment = 475A × 91% × 80%
Conductor Ampacity after Correction and Adjustment = 346A

600 kcmil has an ampere rating of 346A which is greater than enough for the 320A continuous load.

Step 4: *Verify that the ampacity of 600 kcmil at 75°C without correction and adjustment can carry the 320A continuous load at 125 percent in accordance with 230.42(A)(1).*

Conductor Ampacity Needed = Continuous load at 125%
Conductor Ampacity Needed = 320A × 125%
Conductor Ampacity Needed = 400A

According to Table 310.16, 600 kcmil is suitable because it is rated 420A at 75°C.

Answer: *(a) 600 kcmil*

(C) Neutral Conductor Size. The service neutral conductor must be sized to carry the maximum unbalanced load in accordance with 220.61 and must not be smaller than required by 250.24(C).

Warning

In no case can the service neutral conductor size be smaller than required by 250.24(C) to ensure it has sufficiently low impedance and *current-carrying capacity to safely carry fault current in order to facilitate the operation of the overcurrent protective device.*

230.43 Wiring Methods

Service-entrance conductors can be installed with any of the following wiring methods:

(1) Open wiring on insulators.

(3) Rigid metal conduit (RMC).

(4) Intermediate metal conduit (IMC).

(5) Electrical metallic tubing (EMT).

(6) Electrical nonmetallic tubing (ENT).

(7) Service-entrance cables.

(8) Wireways.

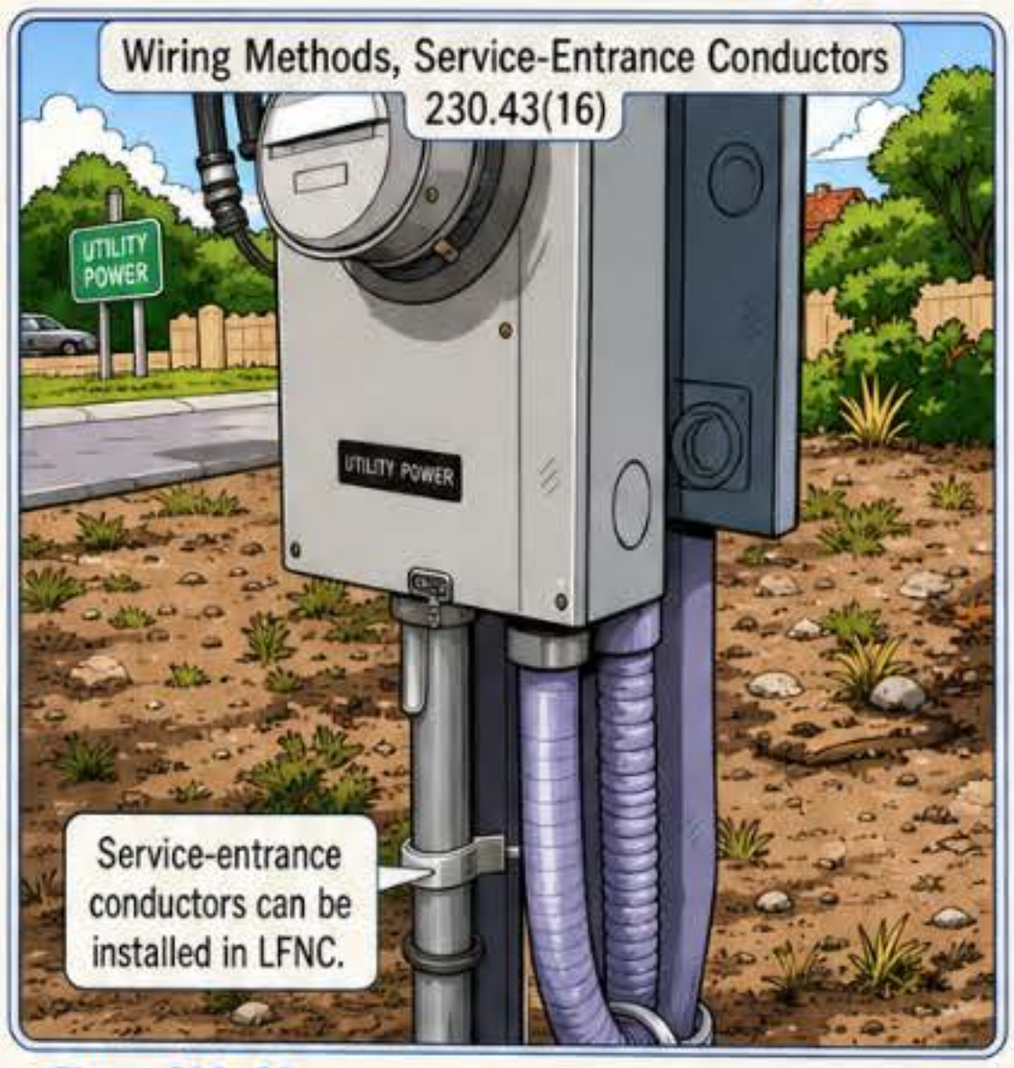
(11) PVC conduit.

(13) Type MC cable.

(15) Flexible metal conduit (FMC) or liquidtight flexible metal conduit (LFMC) in lengths not longer than 6 ft.

(16) Liquidtight flexible nonmetallic conduit (LFNC).

▶ Figure 230–32



▶ Figure 230–32

(17) High-density polyethylene conduit (HDPE).

(18) Nonmetallic underground conduit with conductors (NUCC).

(19) Reinforced thermosetting resin conduit (RTRC).

(20) Type TC-ER cable.

230.46 Spliced Conductors

Service-entrance conductors can be spliced or tapped in accordance with 110.14, 300.5(E), 300.13, and 300.15.

Pressure connectors and devices for splices and taps must be listed. Power distribution blocks installed on service conductors must be listed and marked "suitable for use on the line side of the service equipment" or equivalent.

▶ Figure 230–33

230.50 | Services

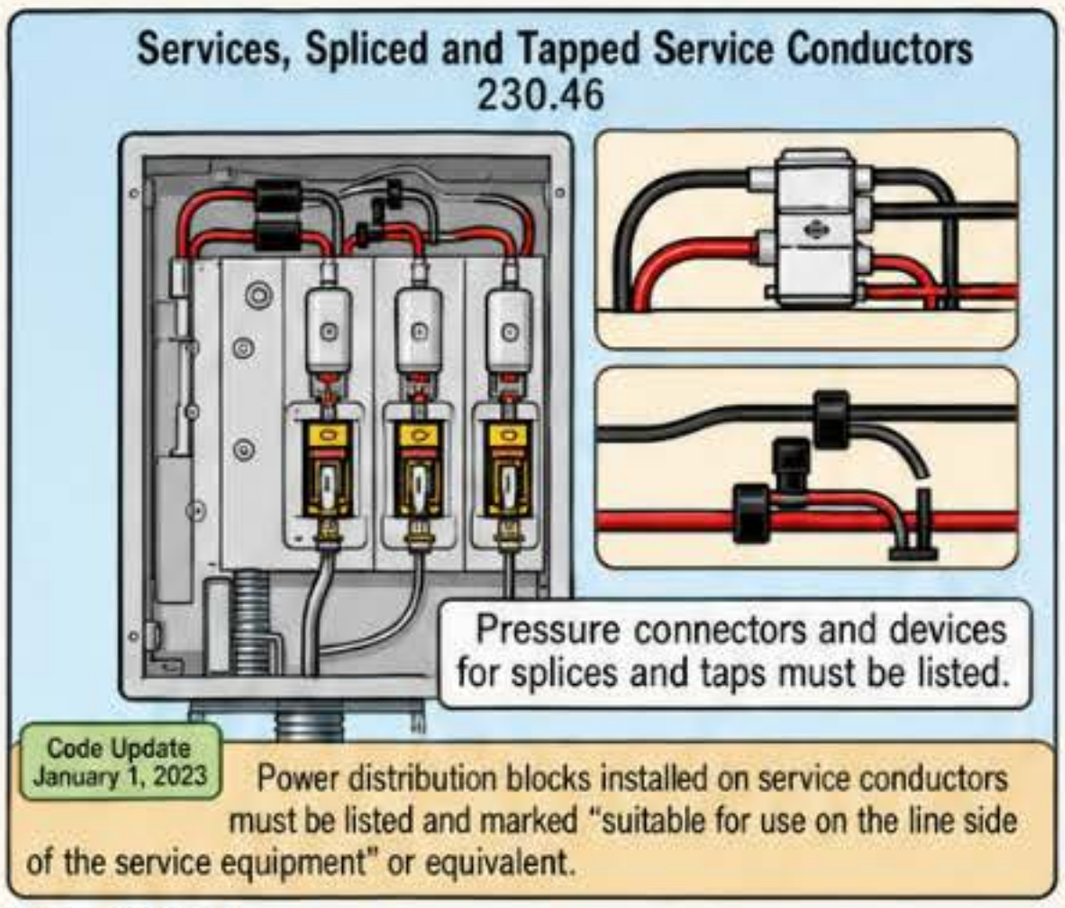


Figure 230–33

Note: Effective January 1, 2023, pressure connectors and devices for splices and taps installed on service conductors must be marked "suitable for use on the line side of the service equipment" or equivalent.

230.50 Protection Against Physical Damage

(A) Underground Service-Entrance Conductors. Underground service-entrance conductors must be protected against physical damage in accordance with 230.5. Figure 230–34

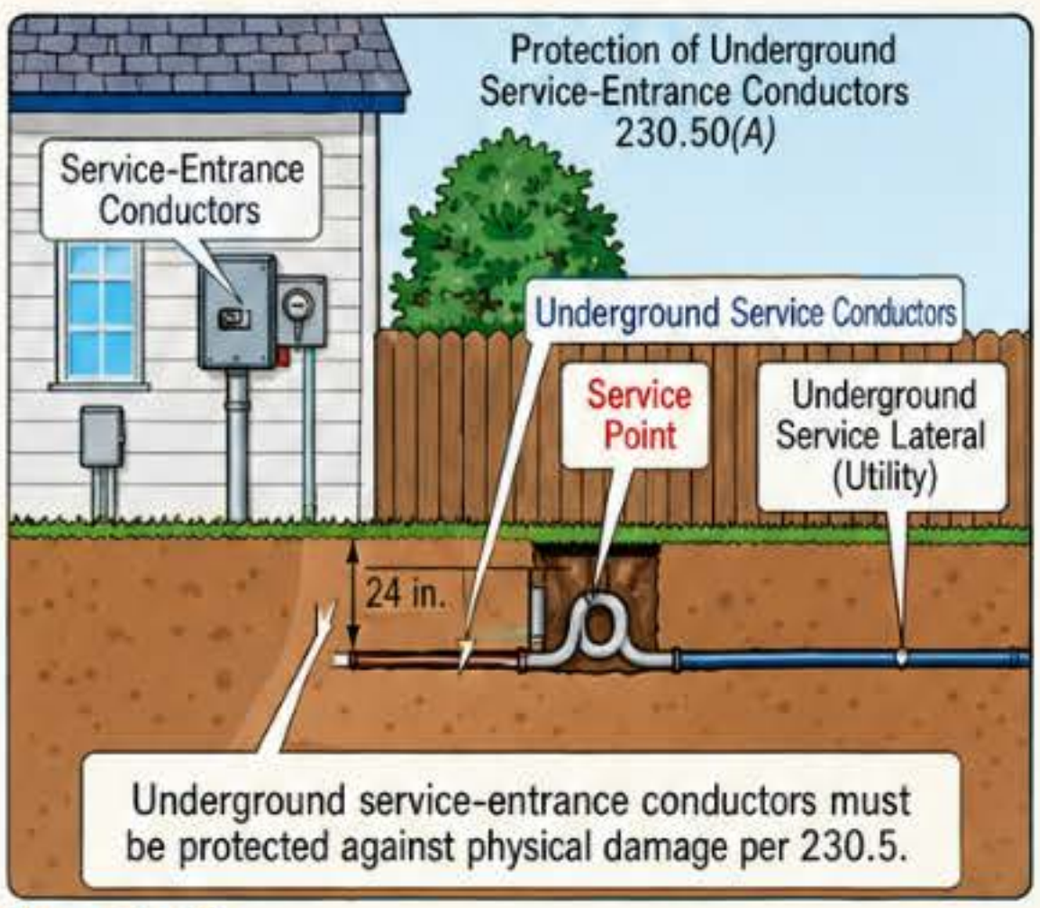


Figure 230–34

(B) Service-Entrance Cables Subject to Physical Damage.

(1) Service-Entrance Cables. Service-entrance cables that are subject to physical damage must be protected by any of the following: • Figure 230–35

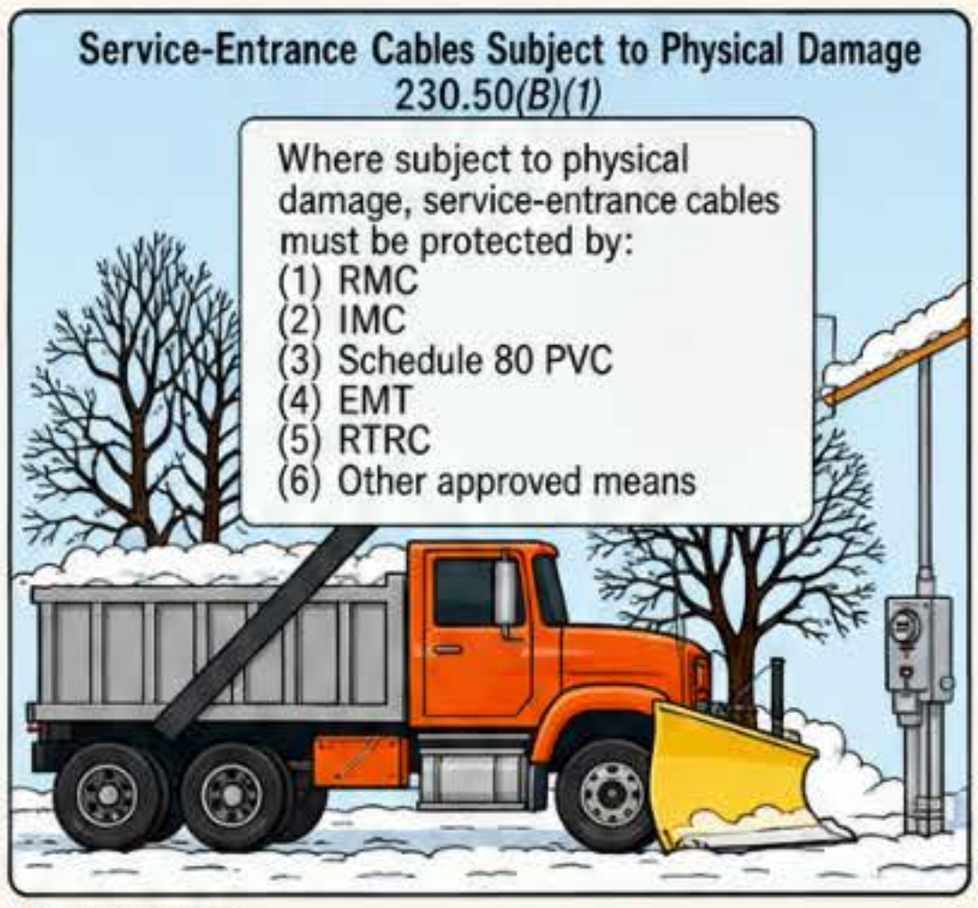


Figure 230–35

(1) Rigid metal conduit (RMC).

(2) Intermediate metal conduit (IMC).

(3) Schedule 80 PVC conduit.

Author's Commentary:

If the authority having jurisdiction determines the raceway is not subject to physical damage, Schedule 40 PVC conduit can be used. • Figure 230–36

— Michael Hamilton

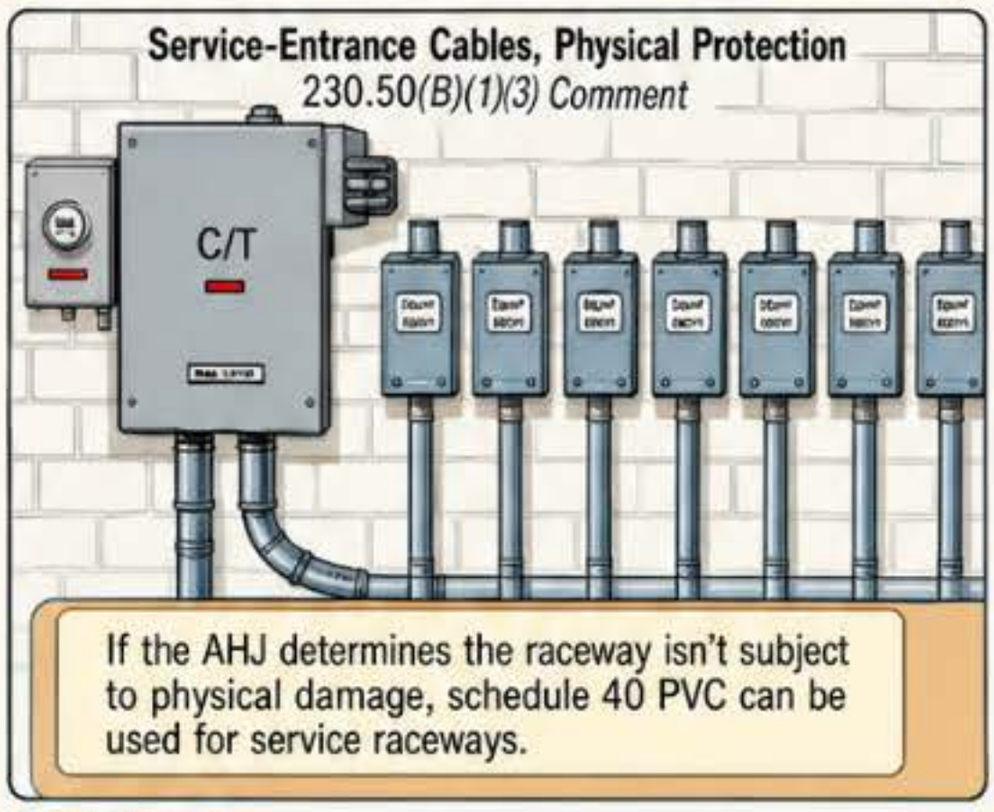


Figure 230–36

(4) Electrical metallic tubing (EMT).

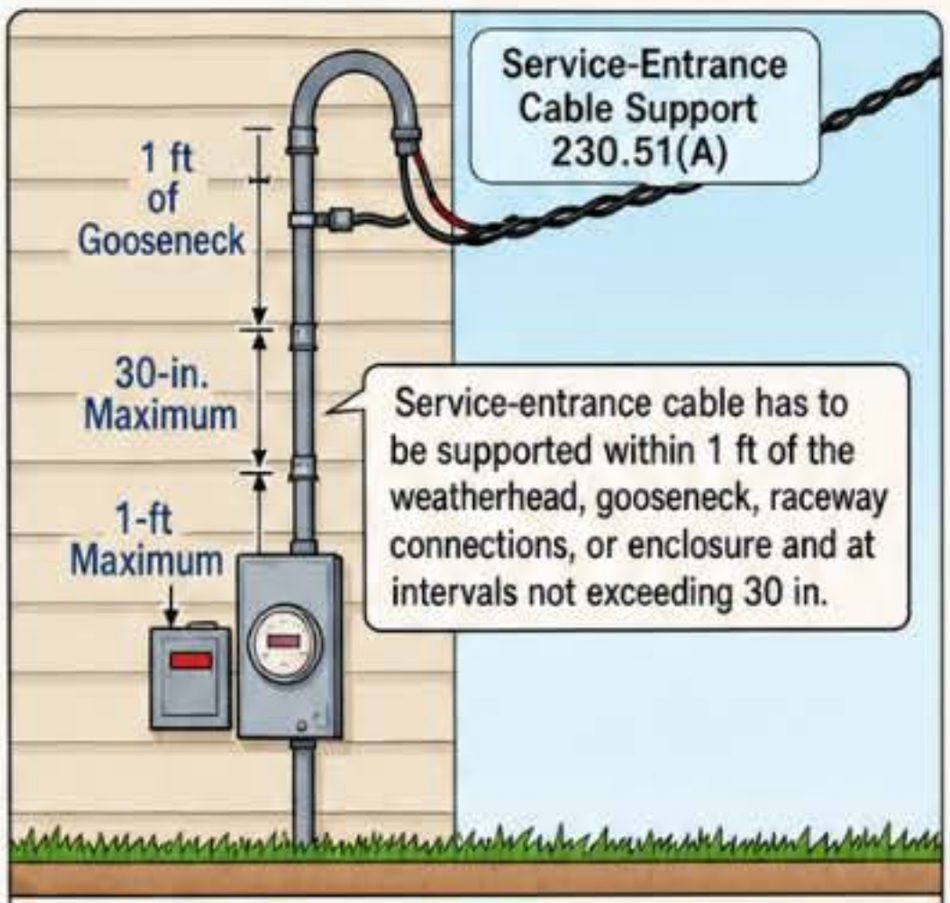
(5) Reinforced thermosetting resin conduit (RTRC), Type XW [355.10(F) Note].

(6) Other methods that the authority having jurisdiction accepts.

(2) Other Than Service-Entrance Cable. Open conductors and cables other than service-entrance cable must not be used within 10 ft of the ground or they must be protected from physical harm.

230.51 Cable Supports

(A) Service-Entrance Cable Supports. Service-entrance cable has to be held within 1 ft of the weatherhead, gooseneck, raceway fittings, or enclosure. Supports may not be spaced more than 30 in. apart.



▶ Figure 230–37

230.53 Raceways to Drain

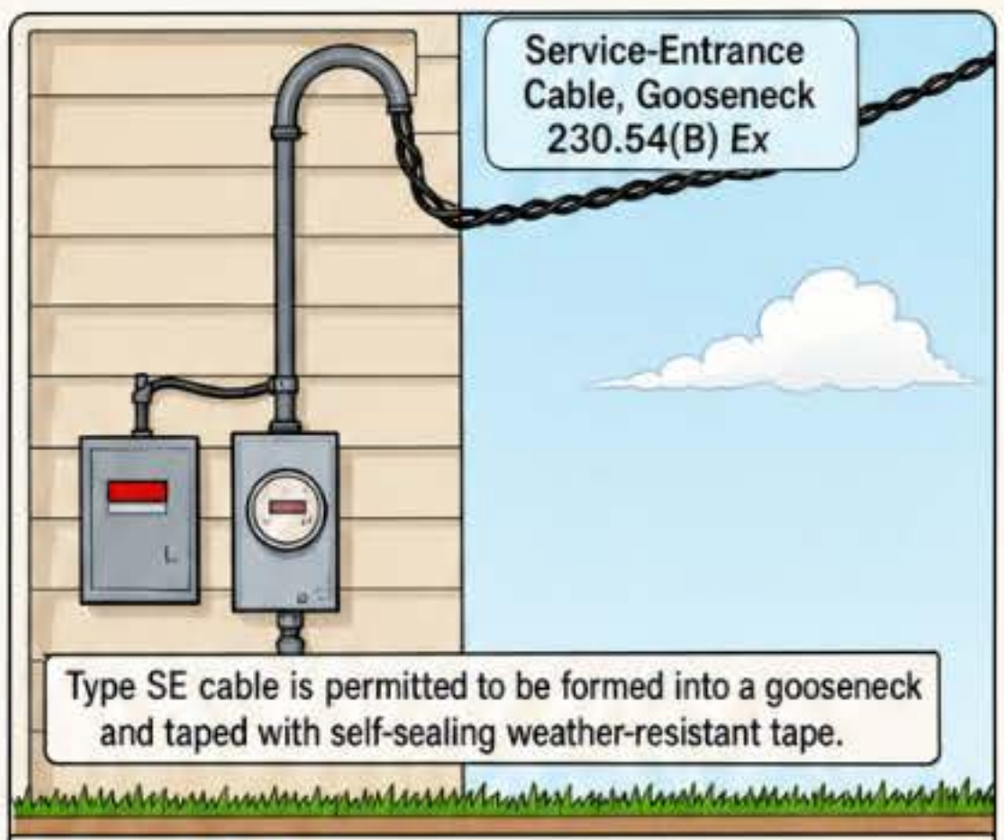
Where subject to weather, raceways that contain service-entrance conductors must be identified for intended use in wet environments and installed to allow drainage. Raceways built into masonry must also be arranged to drain.

230.54 Overhead Service Locations

(A) Service Head. Conductor raceways used for service drops or overhead service must have a weatherhead listed for wet locations.

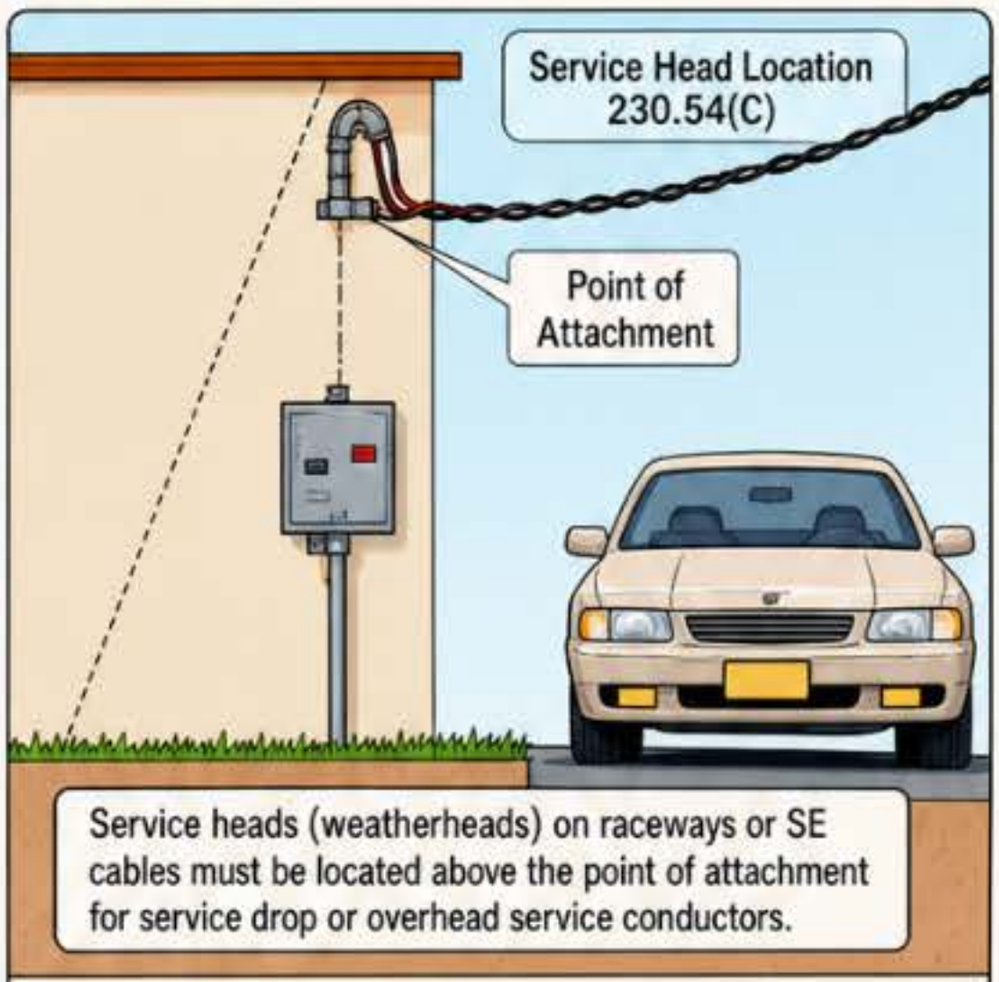
(B) Service-Entrance Cable. Service-entrance cables must be fitted with a weatherhead listed for wet locations.

Ex: Type SE cable is permitted to be formed in a gooseneck and taped with a self-sealing weather-resistant tape.
▶ Figure 230–38



▶ Figure 230–38

(C) Above the Point of Attachment. Service heads on raceways or service-entrance cables must be located above the point of attachment [230.26] for service-drop or overhead service conductors.
▶ Figure 230–39



▶ Figure 230–39

Ex: If it is impractical to locate the service head above the point of attachment, it must be placed within 2 ft of the point.

(D) Secured. *Service-entrance cables must be securely in place.*

(E) Opposite Polarity Through Separately Bushed Holes. *Service heads must have separate openings bushing and phase conductors must be in distinct holes.*

230.56 Services

(F) Drip Loops. Drip loop conductors must be connected to the service-drop or overhead service conductors below the service head or termination of the service-entrance cable sheath. Figure 230-40

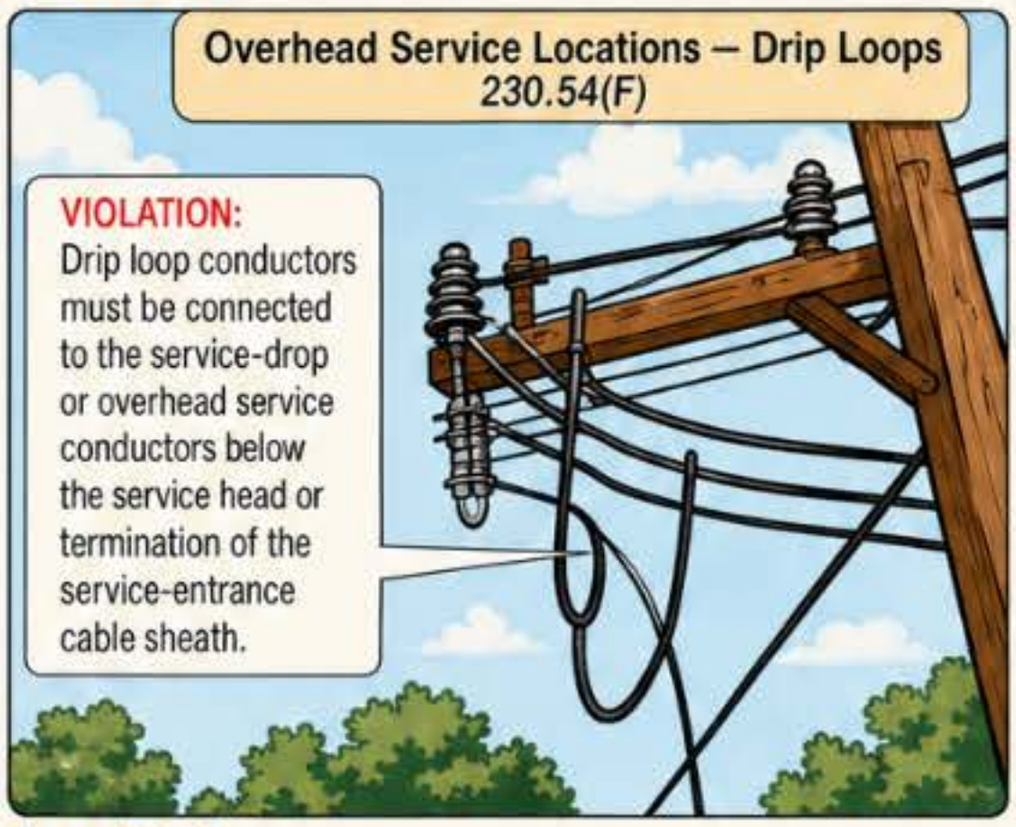


Figure 230-40

(G) Arranged so Water Will Not Enter. Service-entrance and overhead service conductors must be arranged to prevent water from entering the service disconnect.

230.56 High-Leg Conductor Identification

On a 4-wire, delta-connected, three-phase high-leg system, the conductor with the higher phase voltage-to-ground (208V) must be durably and permanently marked by an outer finish that is orange in color or by other effective means. Such identification must be placed at each point on the system where both a connection is made and the neutral conductor is present [110.15]. Figure 230-41

Author's Commentary:

- *The high-leg conductor is also called the "Wild Leg" or "Stinger Leg."*
- *Since 1975, panelboards supplied by a 4-wire, delta-connected, three-phase system must have the high-leg (208V) conductor terminate to the "B" (center) phase of a panelboard [408.3(E)]. For many years, high-leg marking of larger conductors was usually done with orange phasing tape, but individual conductors are now manufactured with orange insulation in almost all sizes.*

— Michael Hamilton

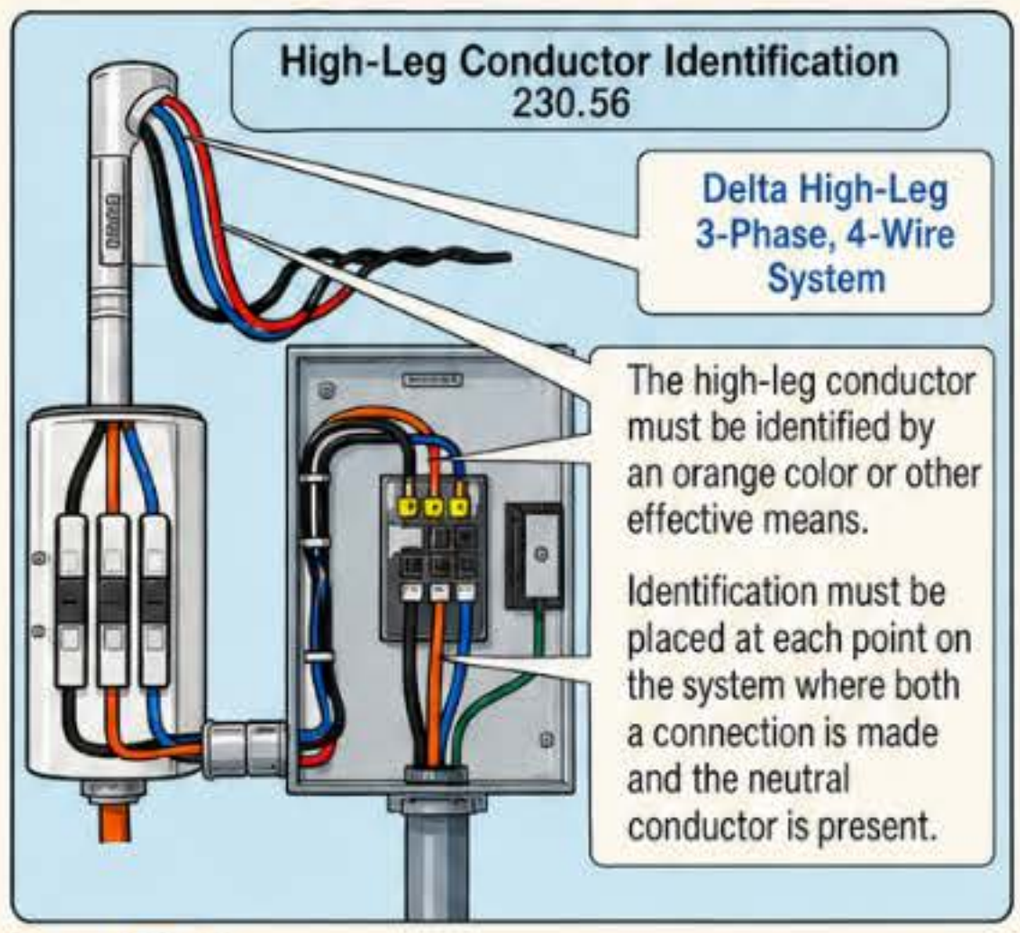


Figure 230-41

- The ANSI standard for meter equipment requires the high-leg conductor (208V to neutral) to terminate on the "C" (right) phase of the meter socket enclosure. This is because the demand meter needs 120V which comes from the "B" phase. Hopefully, the electric utility lineman is not colorblind and does not inadvertently cross the "orange" high-leg (208V) conductor with the red (120V) service conductor at the weatherhead. It has happened before... Figure 230-42

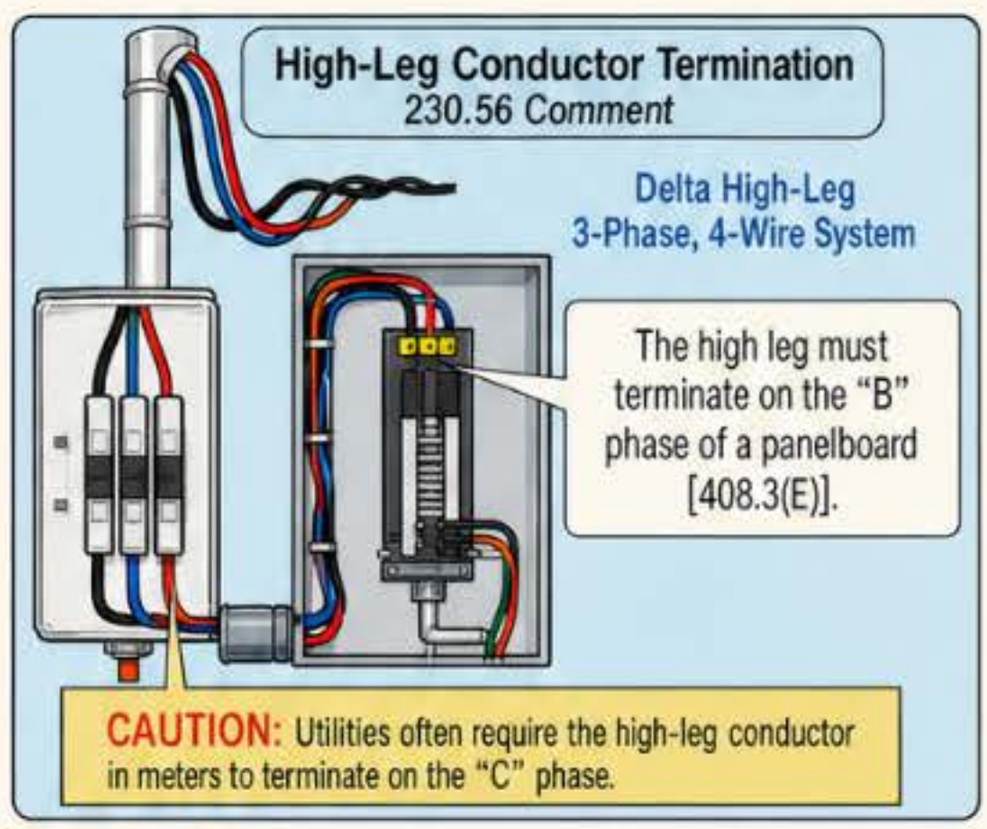


Figure 230-42

Part V. Service Disconnect—General

230.62 Service Equipment—Enclosed or Guarded

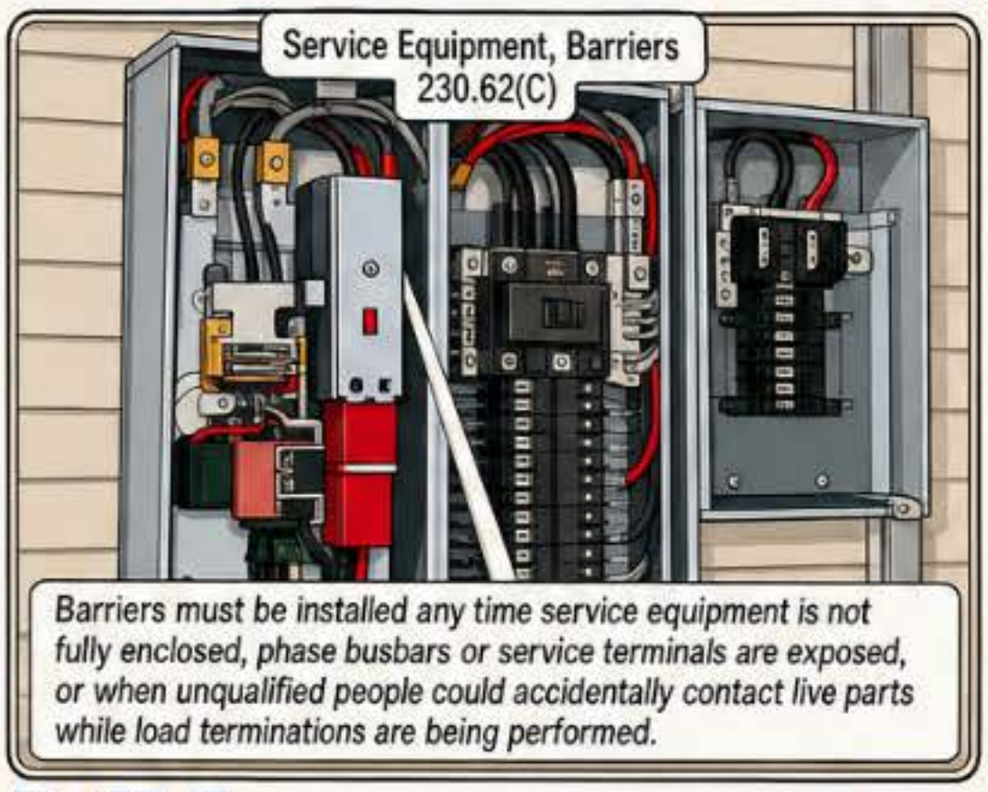
Parts that carry current in service equipment must be either fully enclosed as described in 230.62(A) or protected by guarding as described in 230.62(B).

(A) Enclosed. Current-carrying parts must be completely inside an enclosure so they cannot be touched accidentally or must be protected to meet the guarding requirements of 230.62(B).

(B) Guarded. Components that are not fully enclosed shall be mounted on a switchboard, panelboard, or control board and shielded in accordance with 110.18 and 110.27. Where devices qualify under 110.27(A)(1) and (A)(2), this includes locking or sealing doors that give access to the energized parts.

(C) Barriers. Barriers must be placed where service equipment is not completely enclosed, phase conductors or service terminals are exposed, or where unqualified personnel or maintenance workers could come into contact with live parts while load termination work is being done.

Author's Commentary:
Think of barriers as physical shields. They must be in position any time there is a risk of someone brushing against energized components.
— *Michael Hamilton*



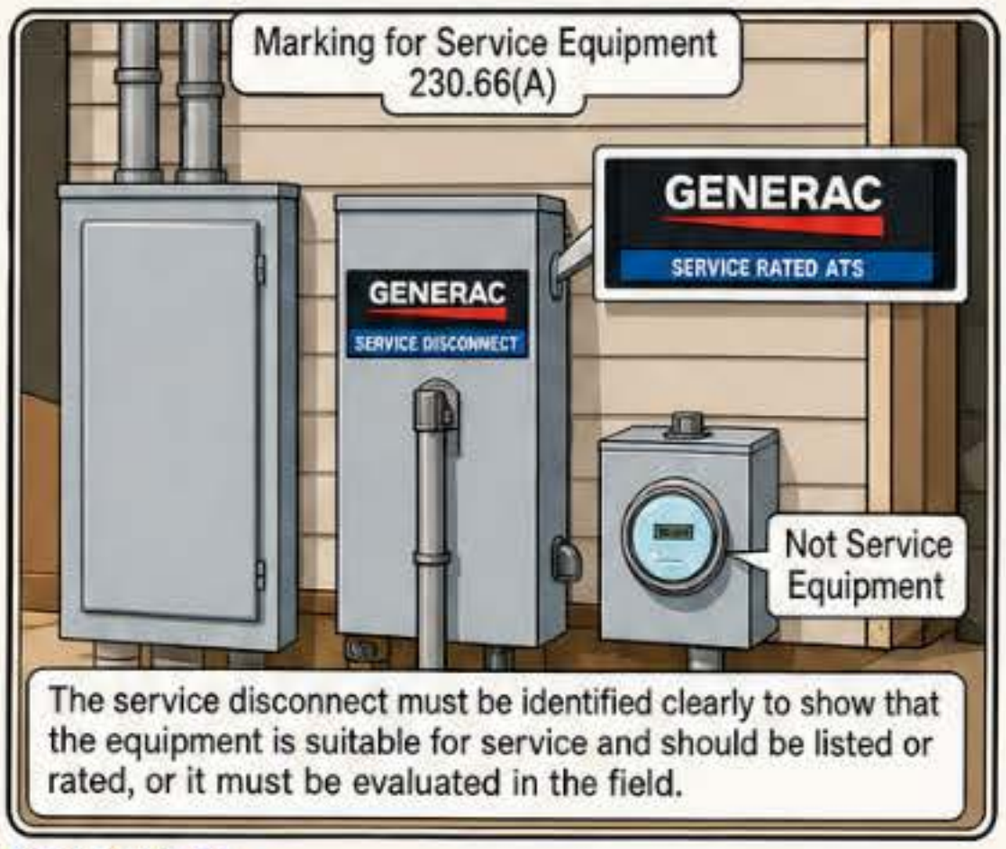
Barriers must be installed any time service equipment is not fully enclosed, phase busbars or service terminals are exposed, or when unqualified people could accidentally contact live parts while load terminations are being performed.

Figure 230–43

230.66 Marking for Service Disconnect

(A) General. The service disconnect must be clearly marked to show that the equipment is suitable for use as service equipment and must be listed or field evaluated. Figure 230–44

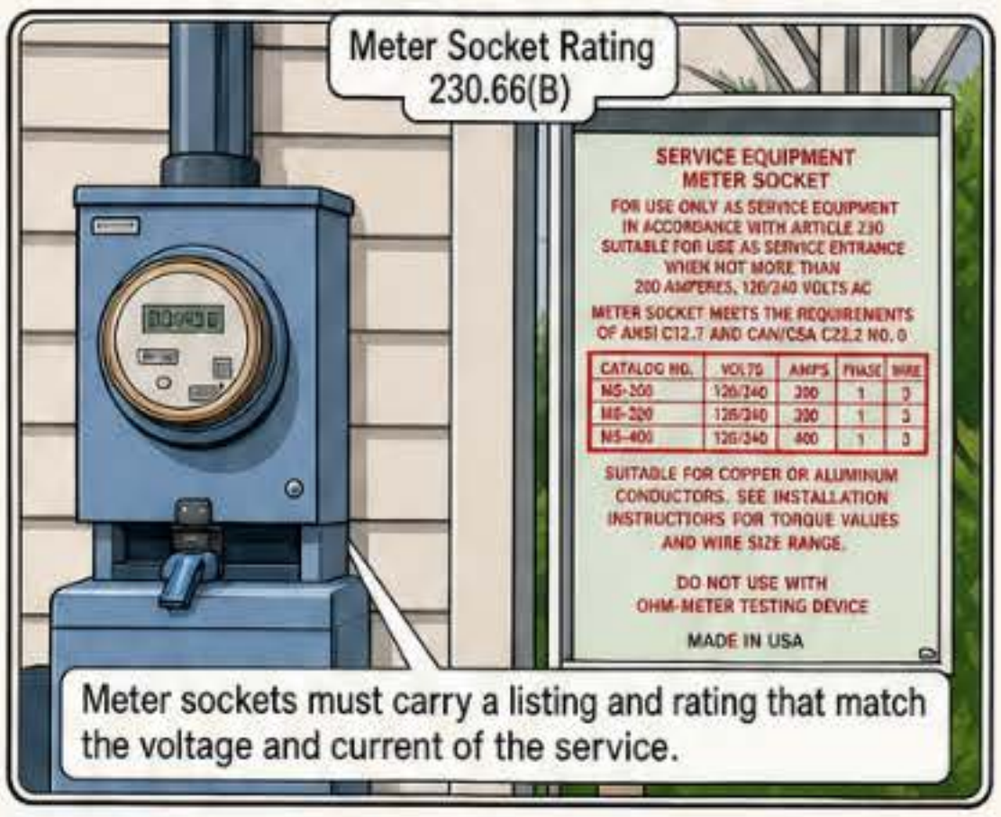
Author's Commentary:
Good labeling prevents confusion in an emergency. A clear mark identifies what is safe to work on and what is not.
— *Michael Hamilton*



The service disconnect must be identified clearly to show that the equipment is suitable for service and should be listed or rated, or it must be evaluated in the field.

Figure 230–44

(B) Meter Sockets. Meter sockets must be listed and rated for both the voltage and current they will carry. Figure 230–45



Meter sockets must carry a listing and rating that match the voltage and current of the service.

Figure 230–45

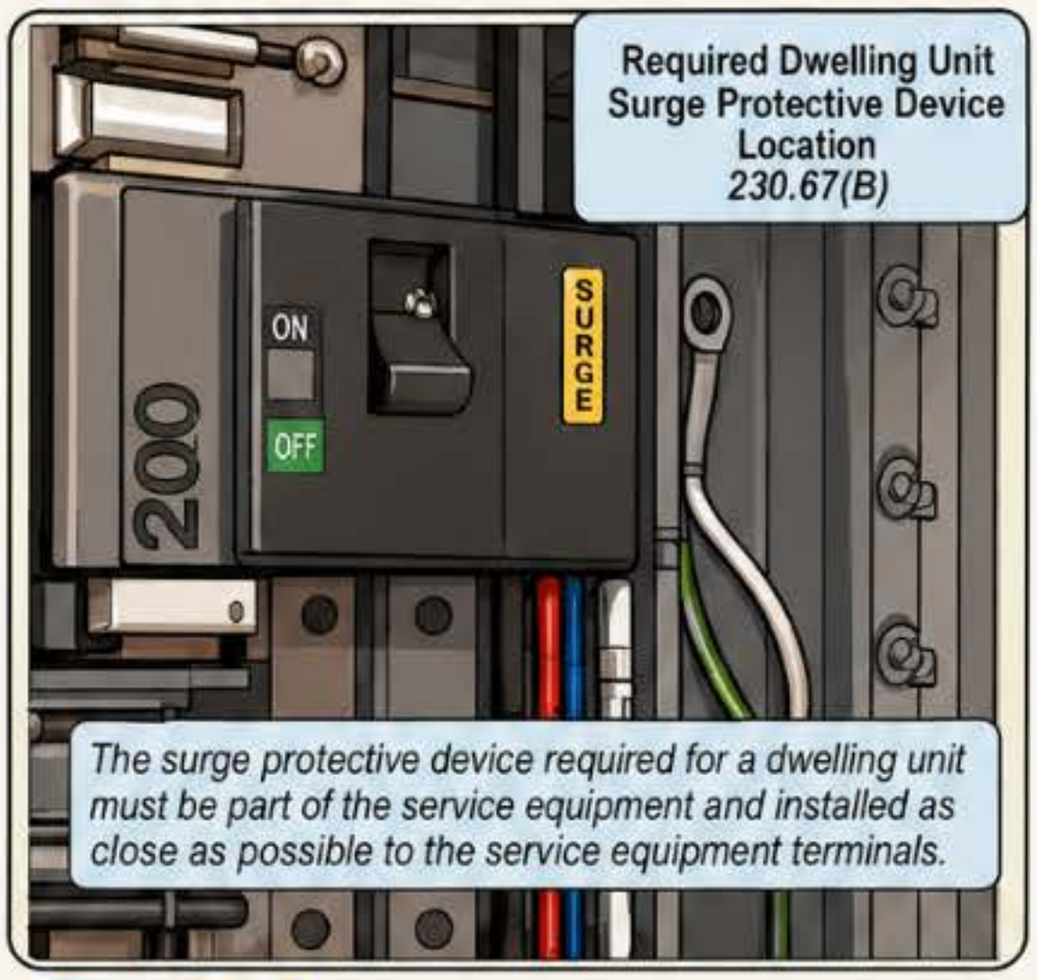
230.67 Surge Protection

(A) Surge Protective Device. Every service supplying a building or other structure must include a surge protective device.

(B) Location. The surge protective device must be an integral part of the service disconnect or installed immediately adjacent to it. Figure 230–46

Author's Commentary:
A surge protective device guards the entire structure from damaging voltage spikes coming from the outside.
— *Michael Hamilton*

230.70 | Services



▶ Figure 230-46

Ex: *The surge protective device is permitted to be in the downstream panelboard.*

Author's Commentary:

- *One example of this exception is when an exterior meter feeds an interior panel. The SPD may be installed within the interior panel using this exception.*
- *See Parts I and II of Article 242 for the installation requirements that apply to SPDs.*

— Michael Hamilton

(C) Type. The surge protective device must be a Type 1 or Type 2 SPD.

(D) Replacement. When service equipment is replaced, *surge protection is required to be installed.*

Part VI. Service Disconnect—Disconnecting Means

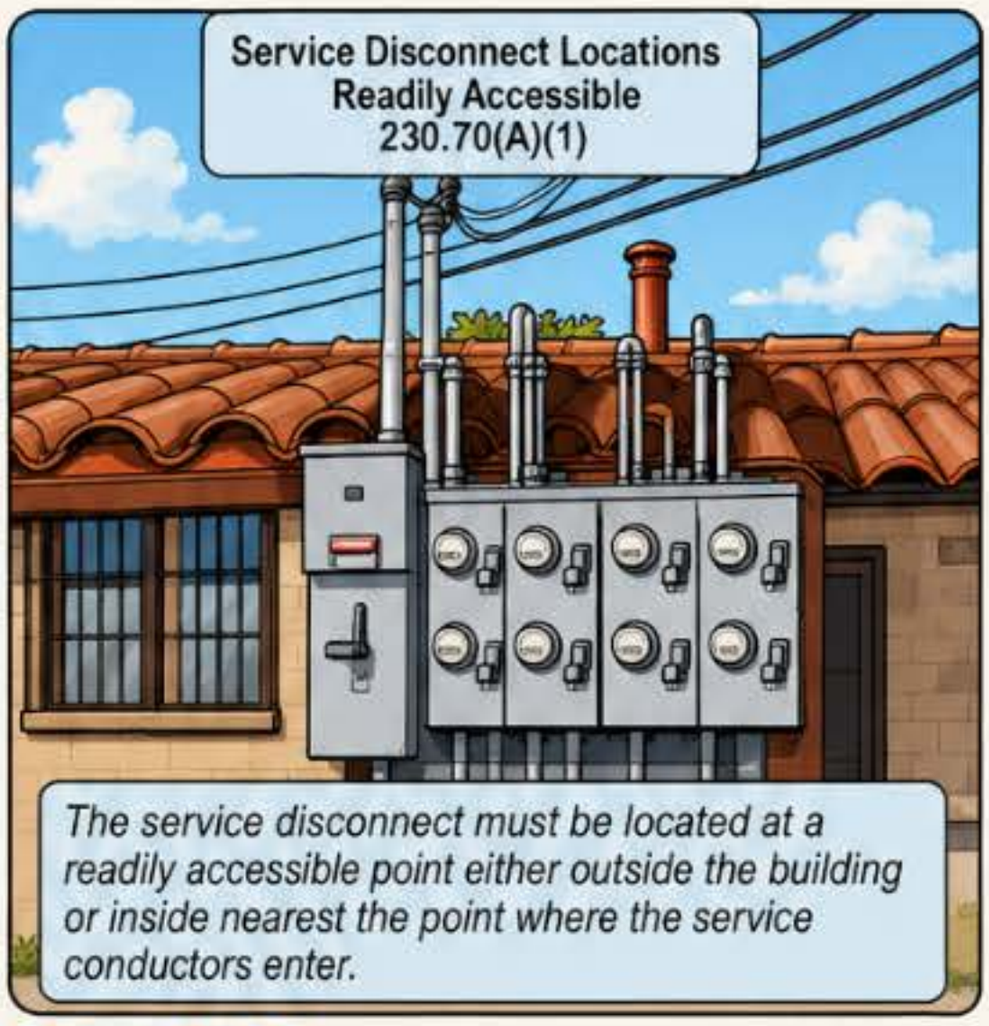
230.70 Service Disconnect Requirements

The service *disconnect must open all phase conductors.*

(A) Location.

(1) Readily Accessible. *The service disconnect must be located at a readily accessible point either outside the building or inside nearest the point of conductor entry.*

▶ Figure 230-47

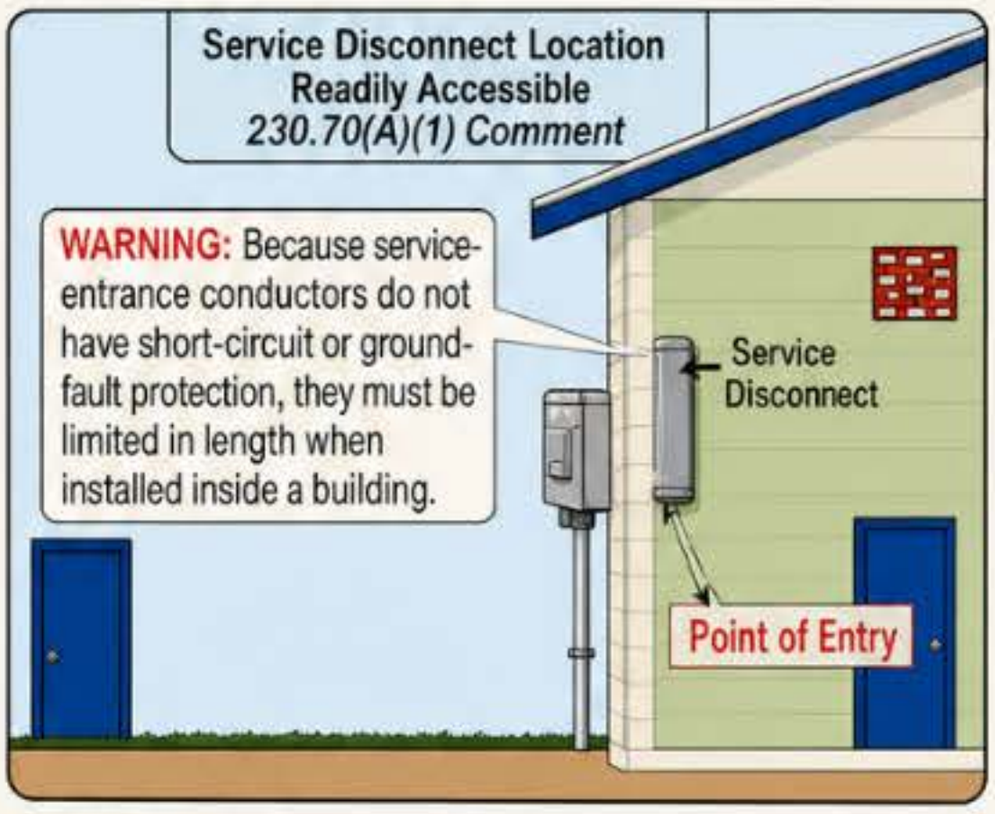


▶ Figure 230-47

Warning

Because service-entrance conductors do not have short-circuit or ground-fault protection, they must be limited in length when installed inside a building. Some local jurisdictions have a maximum allowable length based on their specific requirements.

▶ Figure 230-48



▶ Figure 230-48

(2) Bathroom Areas. *Service disconnects are not permitted to be installed in a bathroom area.*

▶ Figure 230-49

Services | 230.71

Figure 230-49

(3) Remote Control. A remote-control device (such as a pushbutton for a shunt-trip breaker) used to activate the service disconnect cannot serve as the service disconnect. The service disconnecting means, not the remote-control device, must be located at a readily accessible location either outside the building or, if inside, near the point of entrance of the service conductors as required by 230.70(A)(1). ▶ Figure 230-50

Figure 230-50

Author's Commentary:

▶ *The service disconnect must be a manually operated switch, or a power-operated switch or circuit breaker that can be operated manually [230.76]. The remote-control device is not allowed to serve as the service disconnect.*

— Michael Hamilton

(B) Disconnect Identification. Every service disconnect must be permanently labeled so it's clear that it serves as the service disconnect.

▶ Figure 230-51

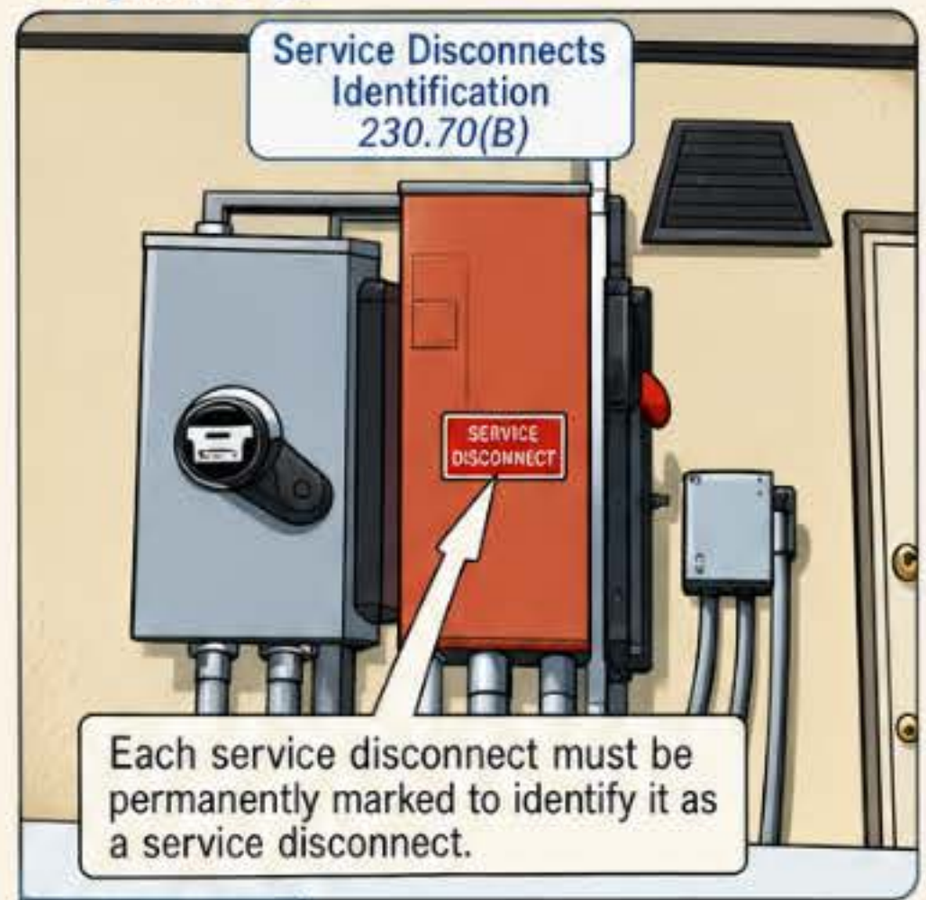


Figure 230-51

230.71 Number of Service Disconnects

Scan this QR code for a video by Michael Hamilton explaining this topic; it's a sample from the videos that accompany this textbook. www.MichaelHamilton.com/2023NECvideos

Every service is permitted one disconnecting means except as allowed in 230.71(B).

(B) Two to Six Service Disconnecting Means. Up to six service disconnects are permitted for each service allowed by 230.2, or for each set of service-entrance conductors permitted by 230.40 Ex 1, 3, 4, or 5.

The two-to-six service disconnecting means must be any combination of the following:

(1) Separate enclosures with a main service disconnect in each enclosure

(2) Panelboards with a main service disconnect in each panelboard

(3) Switchboard(s) where there's only one service disconnect in each separate vertical section having barriers between each vertical section

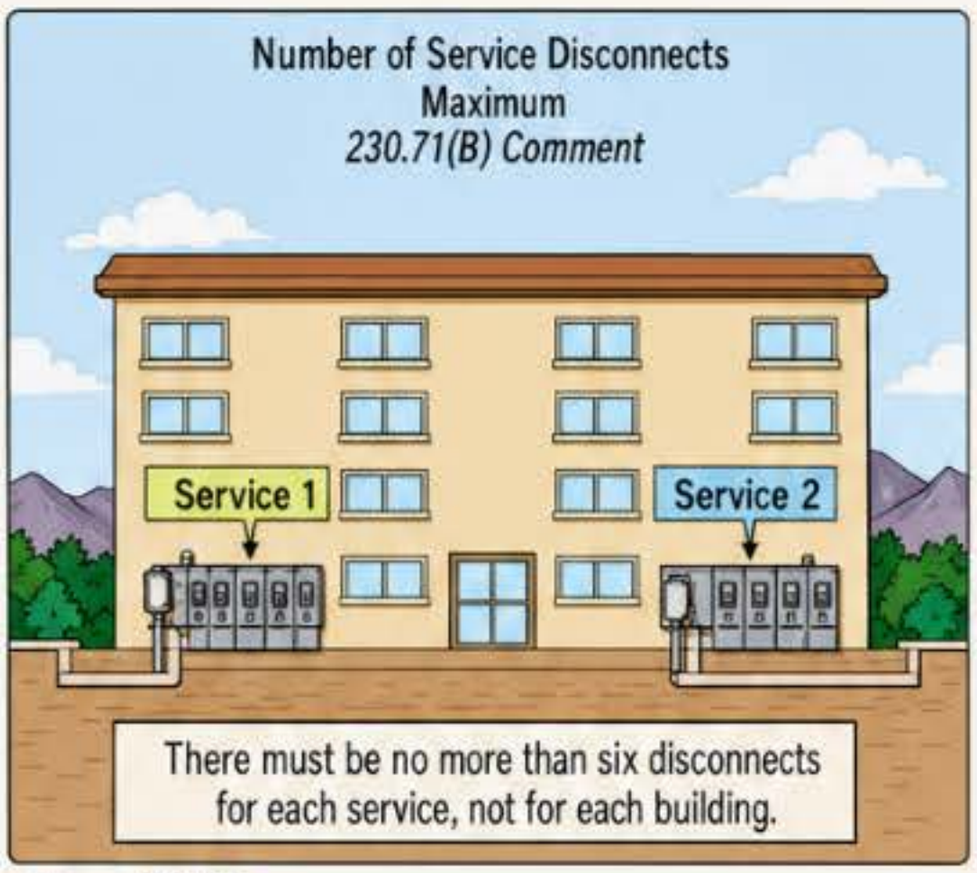
(4) Service disconnects in switchgear or metering centers where each disconnect is in a separate compartment

Note 2: Examples of separate enclosures with main service disconnecting means in each enclosure include (but are not limited to) motor control centers, fused disconnects, circuit breaker enclosures, and transfer switches that are suitable for use as service equipment.

CAUTION

The rule requires six disconnects for each service, not for each building. If one building has two services, then it must have a total of 12 service disconnects (six disconnects for each service).

▸ Figure 230–52



▸ Figure 230–52

230.72 Grouping of Disconnects

(A) Two to Six Disconnects. The service disconnects for each service must be grouped and marked to indicate the load served.

(B) Additional Service Disconnecting Means. To minimize the possibility of simultaneous interruption of power, the disconnect for fire pumps [Article 695], emergency systems [Article 700], legally required standby systems [Article 701], or optional standby systems [Article 702] *must be located remote from the service disconnect(s) for normal service.*

Author's Commentary:

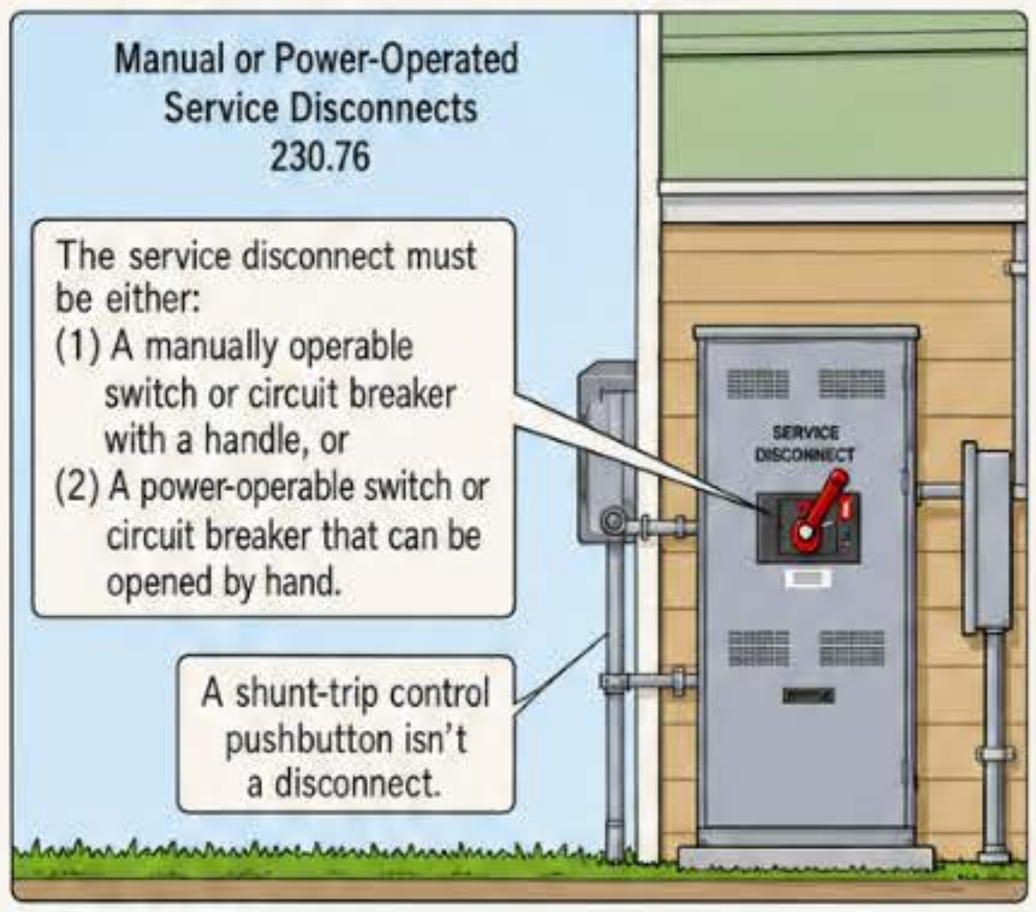
Because emergency systems are just as important as fire pumps and standby systems, they need to have the same safety precautions to prevent unintended interuption of the supply of electricity.

— Michael Hamilton

▸ The authority having jurisdiction is responsible for determining what a sufficiently remote distance is for an additional service disconnect.

230.76 Manually or Power Operated

The service disconnect can consist of: ▸ Figure 230–53



▸ Figure 230–53

(1) A manually operable switch or circuit breaker equipped with a handle.

(2) A power-operated switch or circuit breaker provided it can be opened by hand in the event of a power supply failure.

Author's Commentary:

A shunt-trip button does not qualify as a service disconnect because it does not meet any of the above requirements.

— Michael Hamilton

230.79 Rating of Disconnect

The service disconnect for a building must have an ampere rating of not less than the calculated load according to Article 220 and in no case can it be less than:

(A) One-Circuit Installation. *For installations consisting of a single branch circuit, the disconnect must have a rating of not less than 15A.*

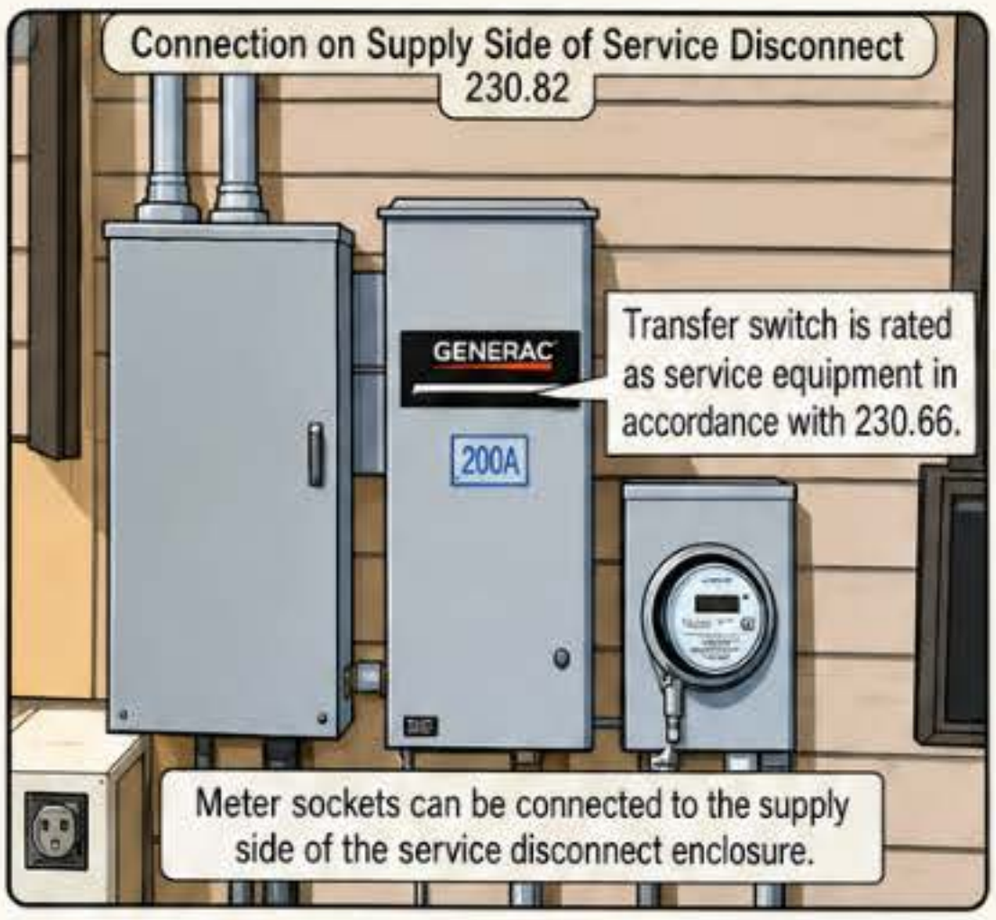
(B) Two-Circuit Installation. *For installations consisting of two 2-wire branch circuits, the disconnect must have a rating of not less than 30A.*

(C) One-Family Dwelling. *For a one-family dwelling, the disconnect must have a rating of not less than 100A, 3-wire.*

(D) Other Installations. For all other installations, the disconnect must be rated no less than 60 amperes.

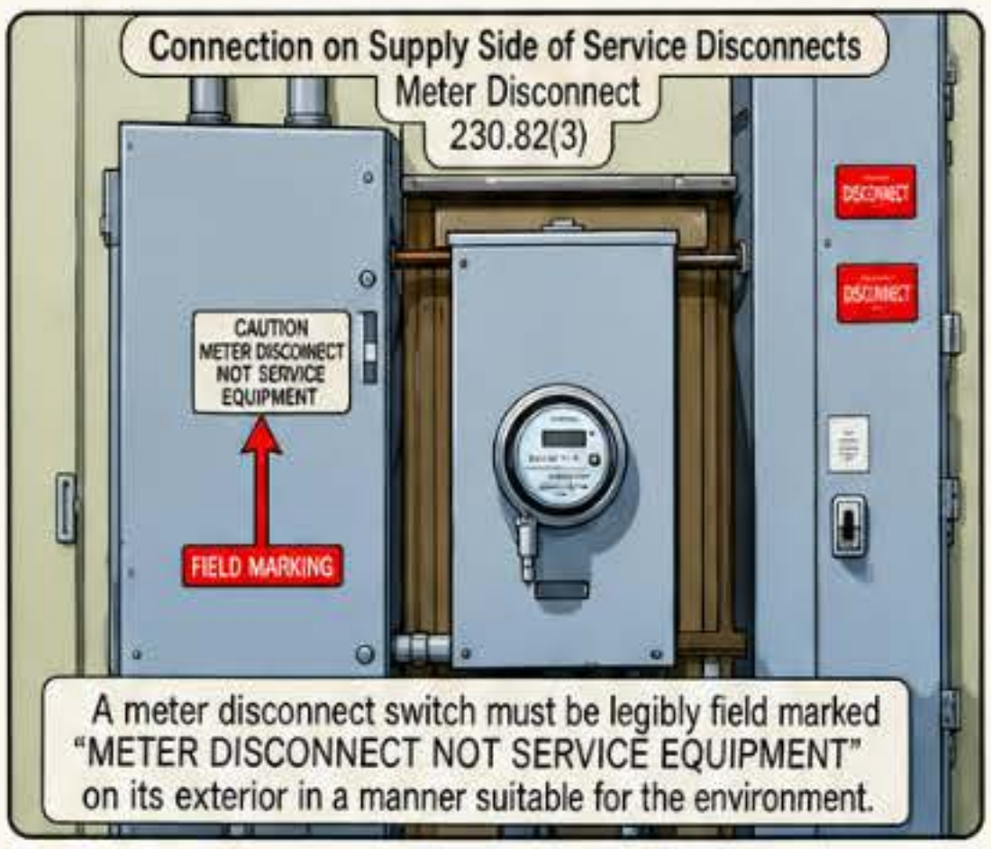
230.82 Connected on Supply Side of the Service Disconnect

Only the following electrical equipment is permitted to be connected to the supply side of the service disconnect. ▶Figure 230–54



▶Figure 230–54

(3) Meter disconnect switches are permitted to be connected to the supply side of the service disconnect. They must be legibly field marked on the exterior in a manner suitable for the environment as follows: **METER DISCONNECT NOT SERVICE EQUIPMENT** ▶Figure 230–55



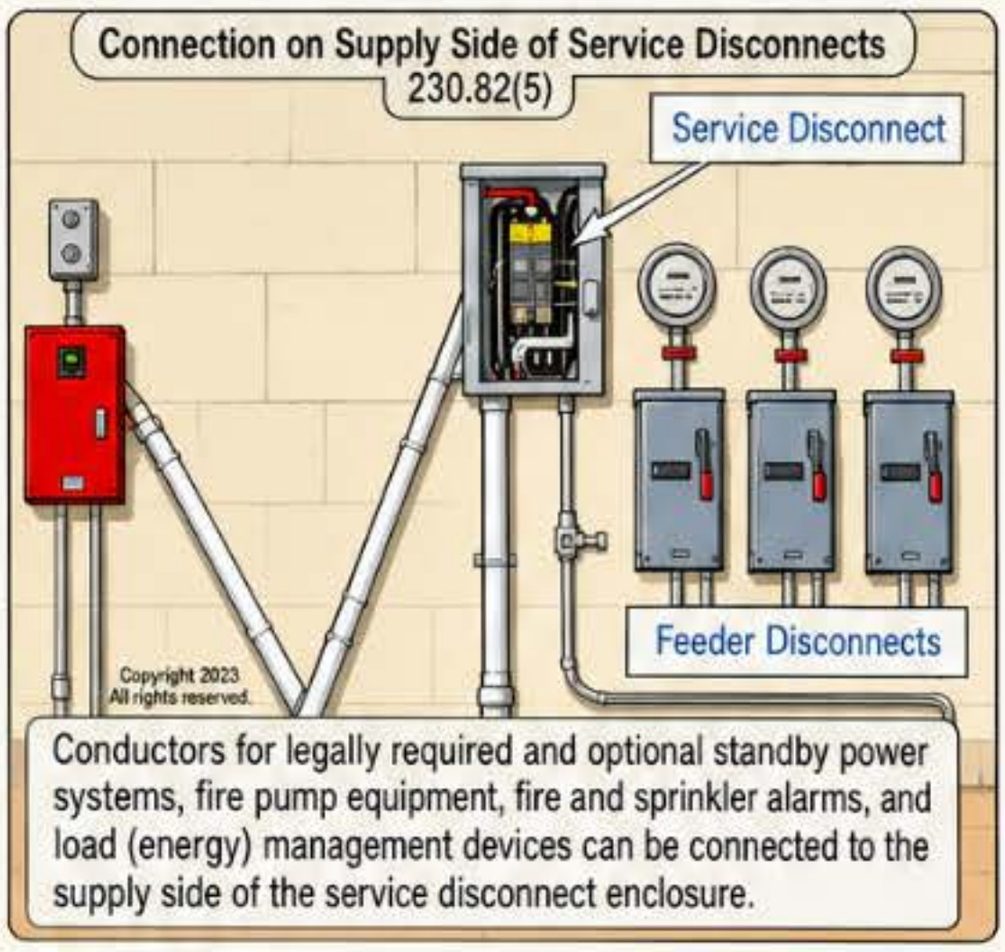
▶Figure 230–55

Author's Commentary:

Some electric utilities require a disconnect switch ahead of the meter enclosure for 277/480V services for the purpose of enhancing safety for the serving electric utility's personnel when they install or remove a meter socket.

— Michael Hamilton

(5) Conductors for legally required and optional standby power systems, fire pump equipment, fire and sprinkler alarms, and load (energy) management devices can be connected to the supply side of the service disconnect enclosure. ▶Figure 230–56



▶Figure 230–56

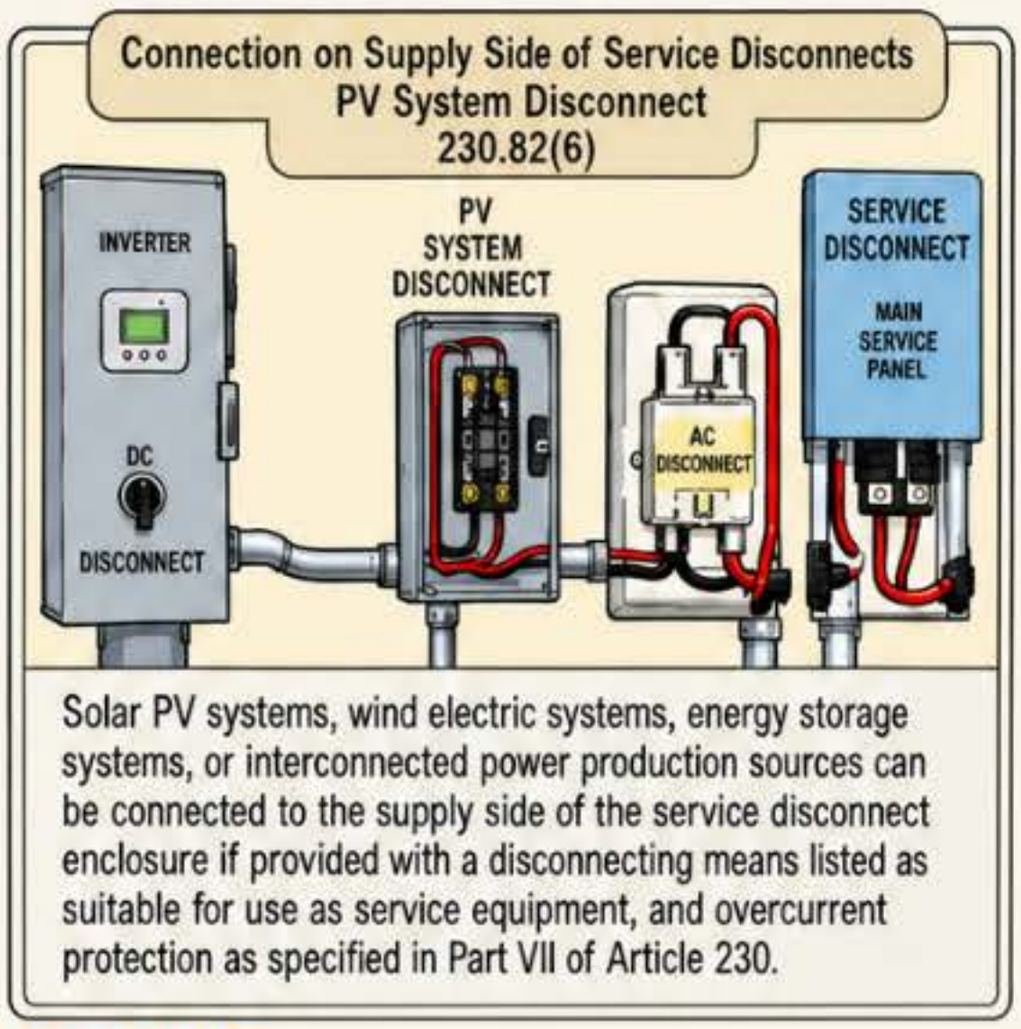
(6) Solar PV systems, wind electric systems, energy storage systems, or interconnected power production sources can be connected to the supply side of the service disconnect enclosure if provided with a disconnecting means listed as suitable for use as service equipment and overcurrent protection as specified in Part VII of Article 230. ▶Figure 230–57

(10) Emergency disconnects in accordance with 230.85.

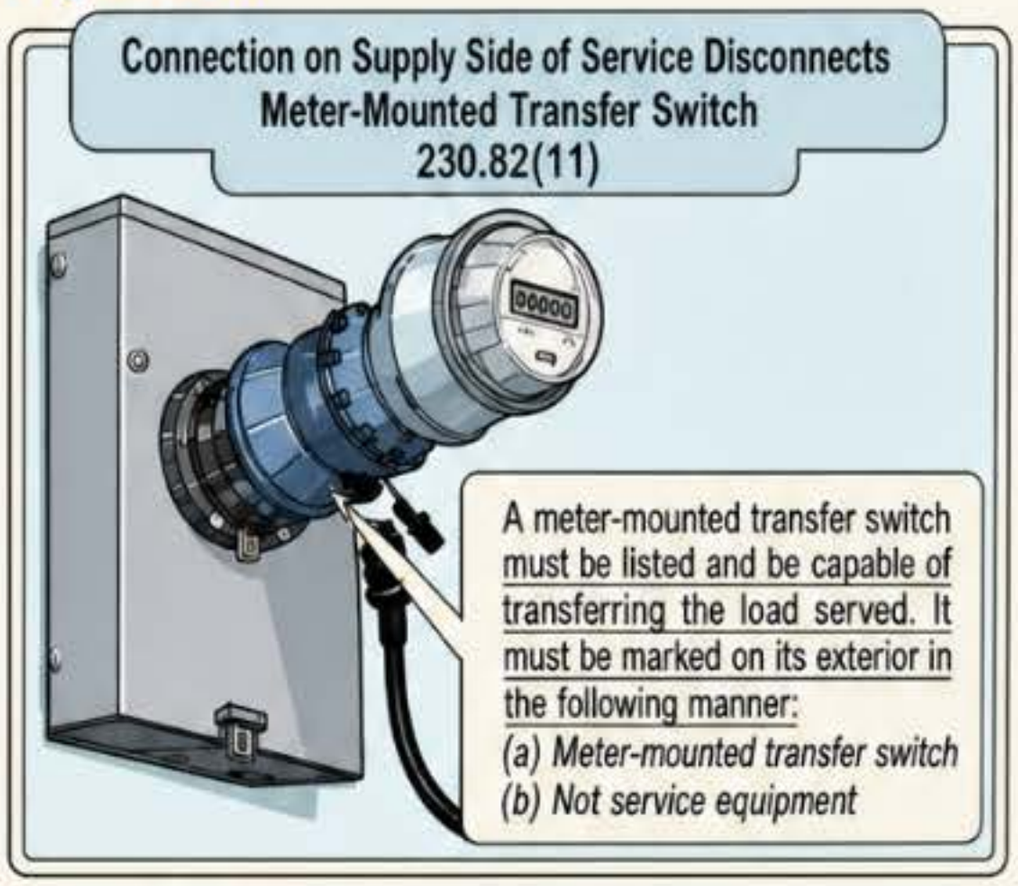
(11) Meter-mounted transfer switches that have a short-circuit current rating equal to or greater than the available fault current. A meter-mounted transfer switch must be listed and be capable of transferring the load served. A meter-mounted transfer switch must be marked on its exterior the following manner: ▶Figure 230–58

(a) Meter-mounted transfer switch

(b) Not service equipment



▶ Figure 230–57



▶ Figure 230–58

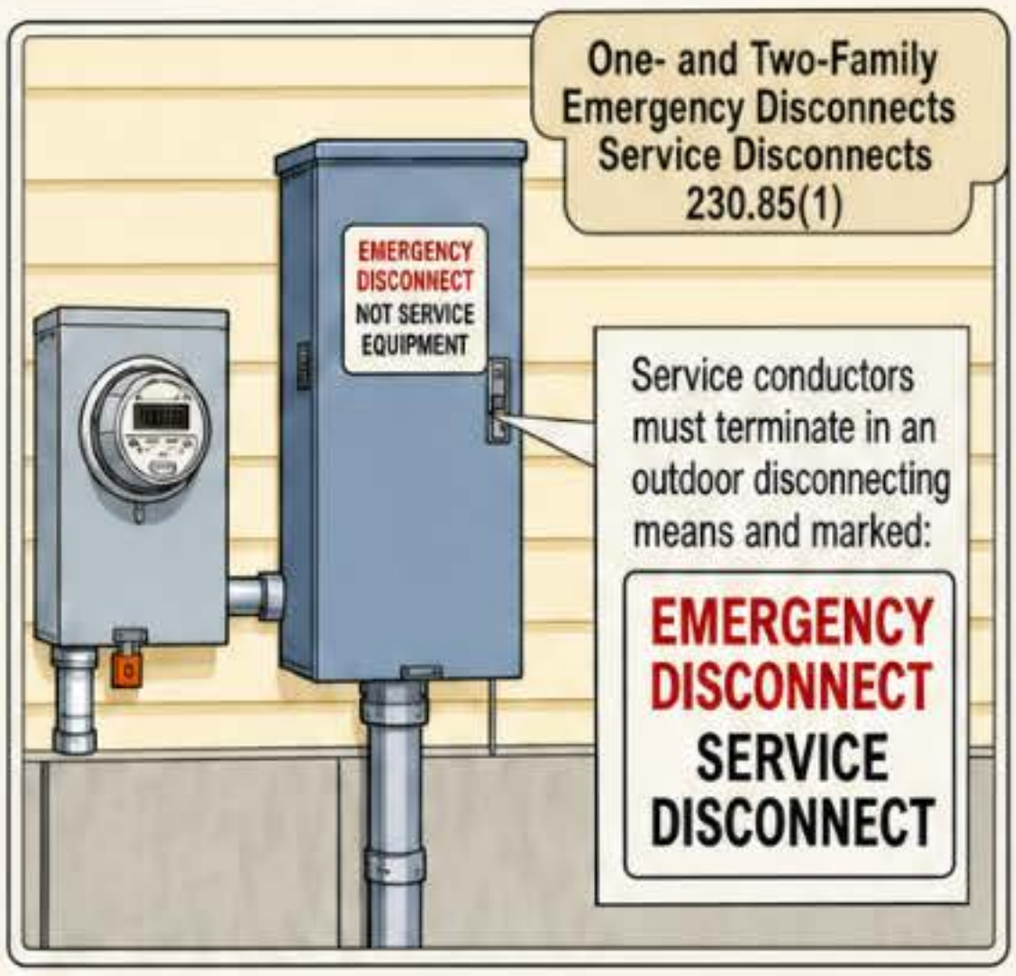
230.85 Emergency Disconnects

Scan this QR code for a video of Michael Hamilton explaining this topic; it's a sample from the videos that accompany this textbook.

For one- and two-family dwelling units, all service conductors must terminate in a disconnecting means having a short-circuit current rating equal to or greater than the available fault current and installed in a readily accessible outdoor location. If more than one disconnect is provided, they must be grouped. Each disconnect must be one of the following:

(1) *Service disconnects marked:* **EMERGENCY DISCONNECT, SERVICE DISCONNECT** ▶ Figure 230–59

(2) Meter disconnects installed accordance with 230.82(3) must be marked: **EMERGENCY DISCONNECT, METER DISCONNECT, NOT SERVICE EQUIPMENT**



▶ Figure 230–59

(3) *Other listed disconnect switches or circuit breakers on the load side of the meter and supply side of each service disconnect marked:* **EMERGENCY DISCONNECT, NOT SERVICE EQUIPMENT**

Markings must be permanently affixed and be sufficiently durable to withstand the environment involved in accordance with *110.21(B)*.

Part VII. Service Disconnect Overcurrent Protection

230.90 Overload Protection—Where Required

Each service phase conductor must have overload protection. ▶ Figure 230–60

(A) Overcurrent Protective Device Rating. *The rating of the overcurrent protective device must not be greater than the ampacity of the service phase conductors.* ▶ Figure 230–61

Ex 2: If the ampacity of the phase conductors does not correspond with the standard rating of overcurrent protective devices as listed in 240.6(A), the next higher overcurrent protective device can be used if it does not exceed 800A [240.4(B)]. ▶ Figure 230–62

Ex 3: The combined ratings of two to six service disconnects can exceed the ampacity of the service conductors provided the calculated load, in accordance with Article 220, does not exceed the ampacity of the service conductors. ▶ Figure 230–63

Overload Protection, Where Required
230.90

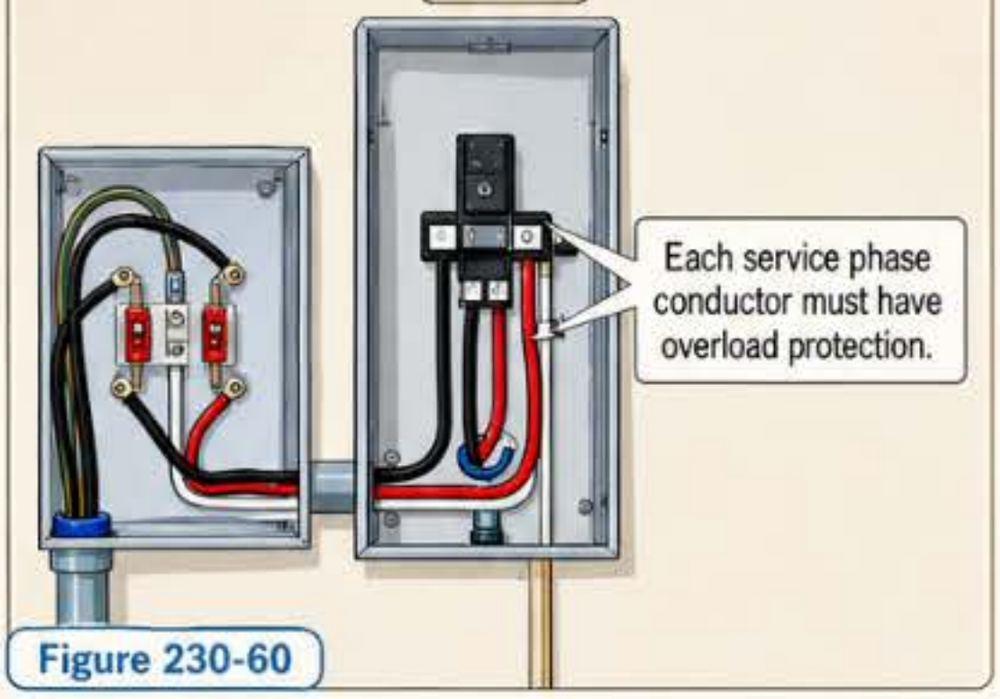


Figure 230-60

Overcurrent Protective Device Rating, Services
230.90(A) Ex 3

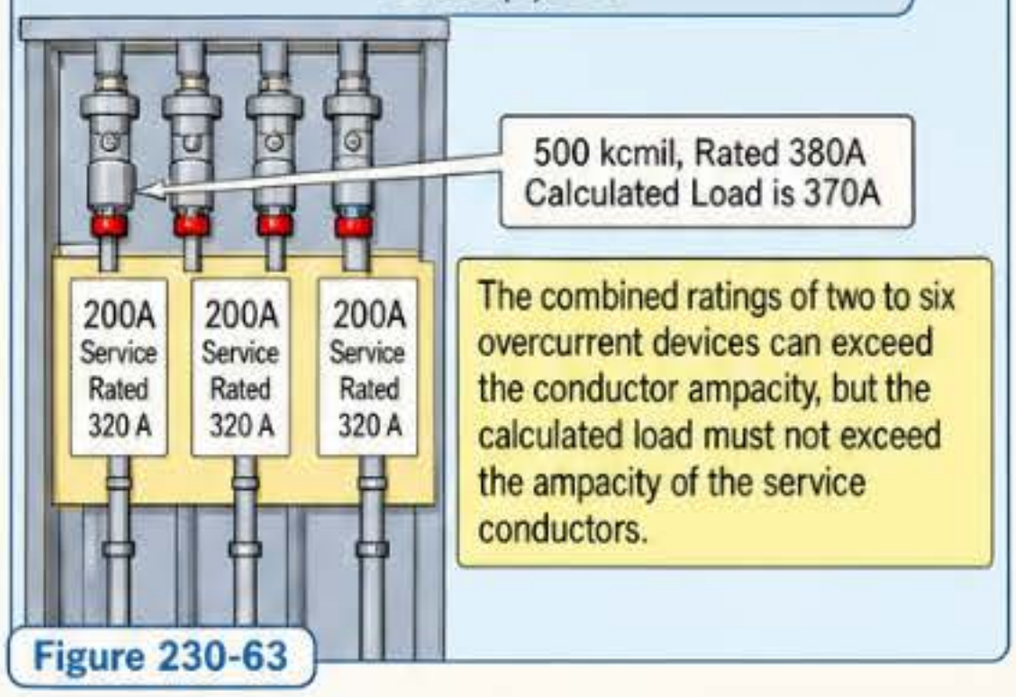


Figure 230-63

Overcurrent Protective Device Rating
230.90(A)

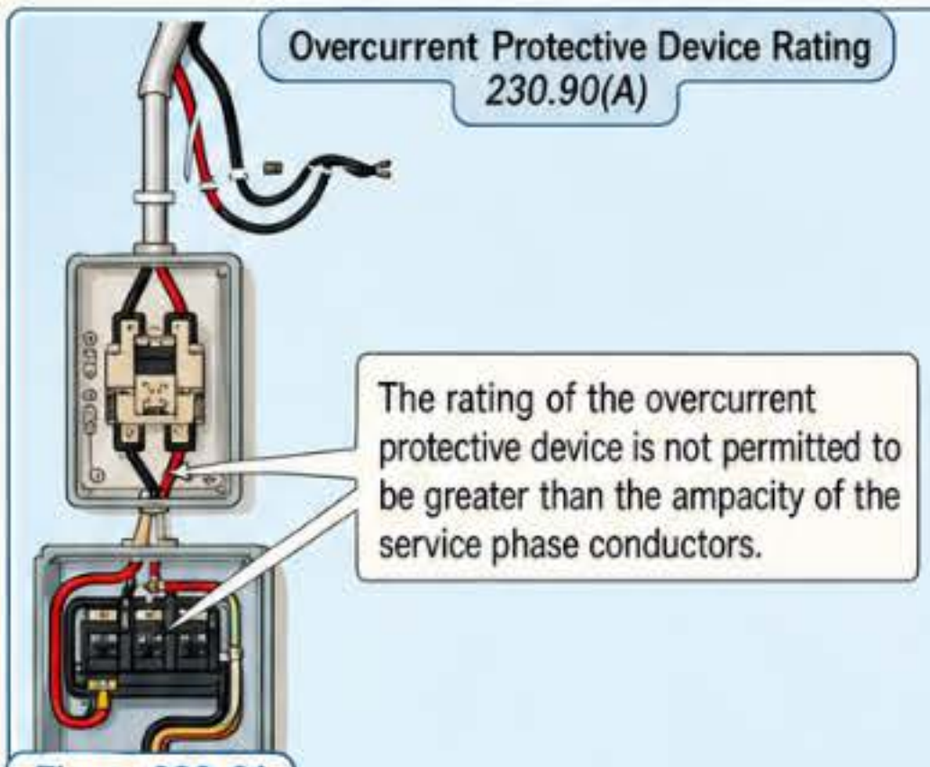


Figure 230-61

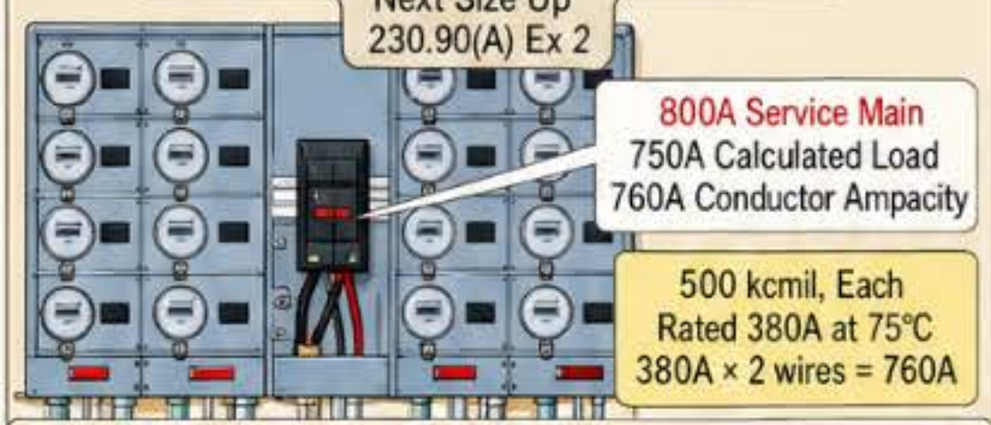
Ex 5: Overload protection for 120/240V, 3-wire, single-phase dwelling services is permitted in accordance with the requirements 310.12.

230.91 Location

The service overcurrent device must be an integral part of the service disconnecting means or be located immediately adjacent to the service disconnecting means. Where fuses are used as the service overcurrent device, the disconnecting means must be located ahead of the supply side of the fuses.

Figure 230-64

Overcurrent Protective Device Rating, Services
Next Size Up
230.90(A) Ex 2



Where the ampacity of the phase conductors doesn't correspond with the standard rating of the overcurrent device [240.6(A)], the next higher overcurrent device can be used if it doesn't exceed 800A [240.4(B)].

Figure 230-62

Location of Overcurrent Protection Device, Fuses
230.91

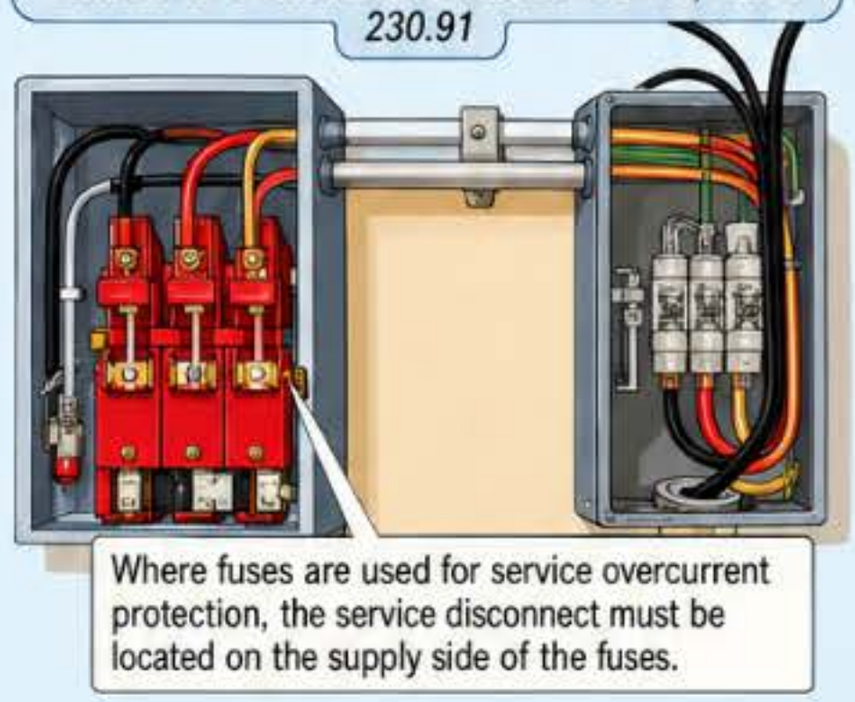


Figure 230-64

Author's Commentary:

These examples highlight key rules for service overcurrent protection. Each service phase needs its own overload protection when required (230.90). You may combine the ratings of two to six devices, but the calculated load can't exceed the conductor ampacity (230.90(A) Ex 3). Device ratings cannot be larger than the service conductor ampacity (230.90(A)). In some cases, the next larger standard rating can be used if it doesn't exceed 800A (230.90(A) Ex 2). The service overcurrent device must be an integral part of or immediately next to the service disconnect; if fuses are used, the disconnect must be ahead of the fuse line side (230.91). Many 120/240V, 3-wire dwelling services can use overload protection per 310.12 (Ex 5).

— Michael Hamilton

230.95 Services

230.95 | Services

230.95 Ground-Fault Protection of Equipment

Ground-fault protection of equipment is required for 277/480V service disconnects rated 1,000A or more. The rating of the service disconect is based on the rating of the largest fuse that can be installed or the circuit breaker's highest continuous current trip setting.

ARTICLE 240 OVERCURRENT PROTECTION

Introduction to Article 240—Overcurrent Protection

This article establishes the requirements for overcurrent protection and covers how to choose and install the protective devices—usually circuit breakers or fuses. Overcurrent exists when the current going through equipment or a conductor rises above the safe continuous rating due to an overload, a short circuit, or a ground fault [Article 100]. Figure 240–1

- ***Overload:*** An overload occurs when equipment or conductors carry current beyond their rated continuous capacity [Article 100]. This condition is not a short circuit or a ground fault. *Example:* when multiple 12.50 A (1,500 W) hair dryers are plugged into a single 20 A branch circuit.
- ***Short Circuit:*** A short circuit is an unintentional connection between two normally current-carrying conductors of a circuit, whether line-to-line or line-to-neutral.
- ***Ground Fault:*** A ground fault is an unintentional electrical connection between a phase conductor and either the noncurrent-carrying conductors, metal enclosures, metal raceways, metal equipment, or the earth [Article 100]. If a ground fault happens, dangerous voltage may appear on metal parts until the protective device opens and clears the fault.

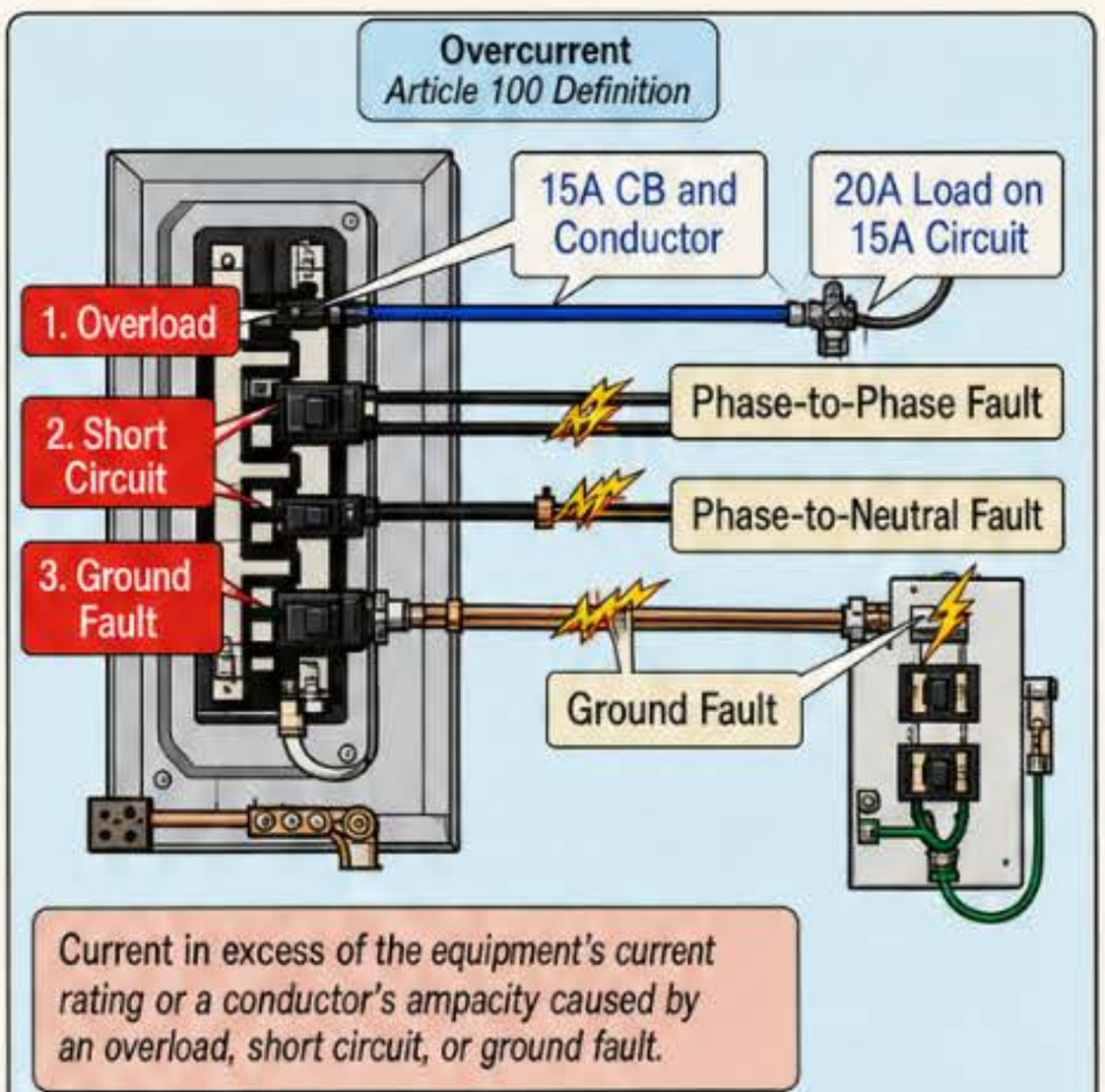


Figure 240–1

Overcurrent protective devices are intended to protect conductors and equipment. Selecting the proper overcurrent protection for a specific circuit can be more involved than it first appears. The general principle for overcurrent protection is that conductors must be protected in line with their ampacities at the point where they receive their supply [240.4 and 240.21]. The asterisked notes next to the small conductor sizes in Table 310.16 refer to a cross-reference leading you to 240.4(D). That part sets the general rule for small conductors, which restricts the rating of overcurrent devices protecting small conductors. Especially in safety-critical situations, there can be exceptions that make the rules deviate from what seems to be "break" those rules. Table 240.4(G) lists cases in the *Code* that allow changes to the basic rules of 240.4(D). Several rules allow tap conductors (with many lower ampacity values than the device that protects them) to be used in certain situations [240.21(B)].

Author's Commentary:

The tripping response of an overcurrent protective device during an overload follows a "time-curve." In simple terms, the higher the overcurrent, the faster the device opens the circuit. Because of this behavior, conductors with lower ampacities than the protective device can sometimes interrupt higher currents. However, if the overcurrent is only slightly above the device's rating, the trip may be too slow. In that situation the overcurrent could last long enough to cause damage, but your protective device might not trip. So, an overcurrent condition is safe only when it is brief and of short duration.

— *Michael Hamilton*

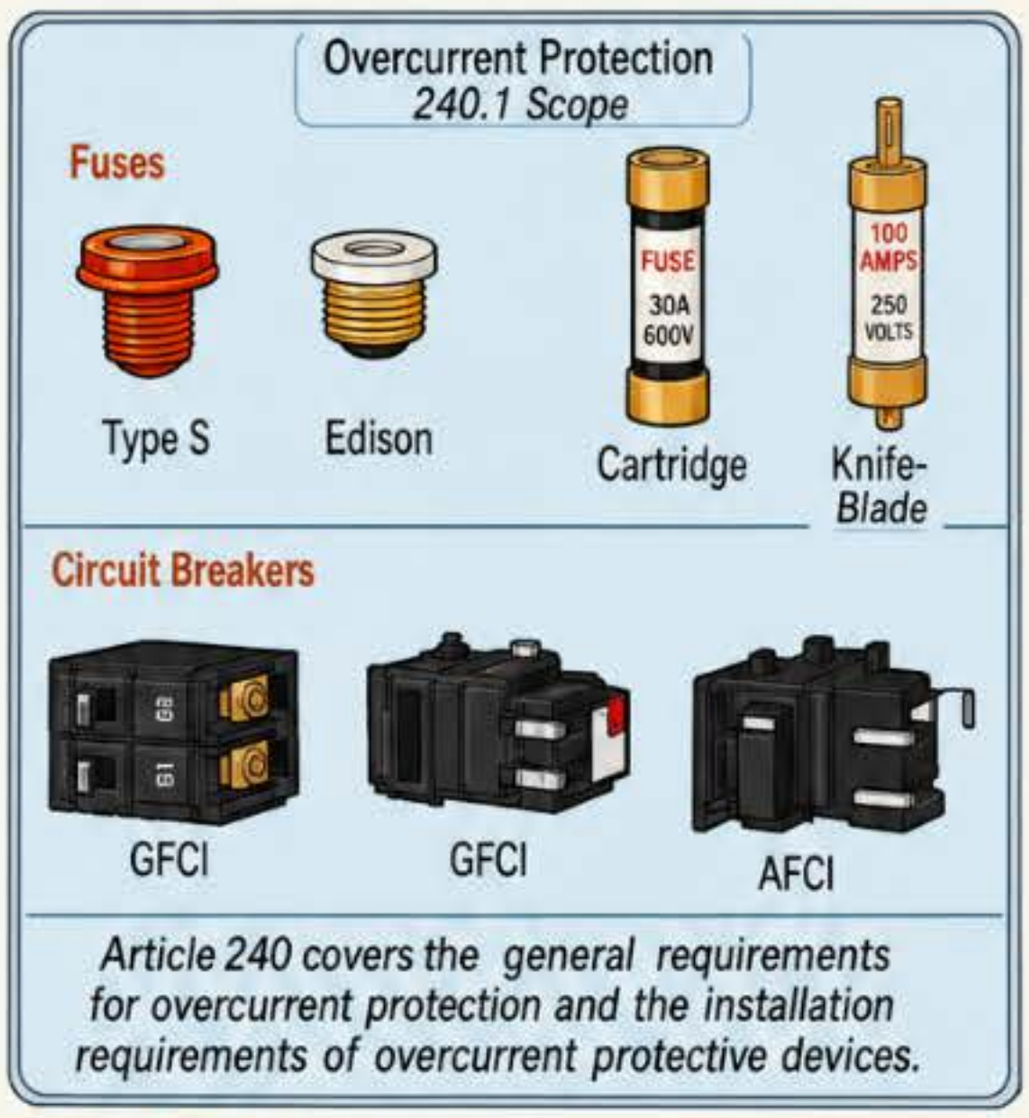
240.1 | Overcurrent Protection

Equipment used to provide overcurrent protection must be able to open a circuit when an overcurrent occurs and must have an interrupting rating high enough to safely clear the available fault current at that location [110.9]. Be sure to select an overcurrent protective device with sufficient rating for the prospective fault current at the point of installation.

Part I. General

240.1 Scope

Article 240 sets forth the general rules for overcurrent protection and specifies the installation requirements for overcurrent protective devices. ▶ Figure 240–2



▶ Figure 240–2

Author's Commentary:

▶ An overcurrent is a current that goes beyond the equipment rating or the current-carrying ability of a conductor because of overload, short circuit, or ground fault [Article 100].

— Michael Hamilton

Note: *Overcurrent protective equipment opens the circuit when current reaches a level that could cause overheating or dangerous temperature rise (overheating) in conductors. These devices must have an interrupting rating adequate to clear the maximum available fault current at the line-side terminals of the equipment [110.9]. Electrical equipment must have a short-circuit current rating that allows it to safely withstand the forces of overcurrent events without suffering extensive damage to electrical parts [110.10].*

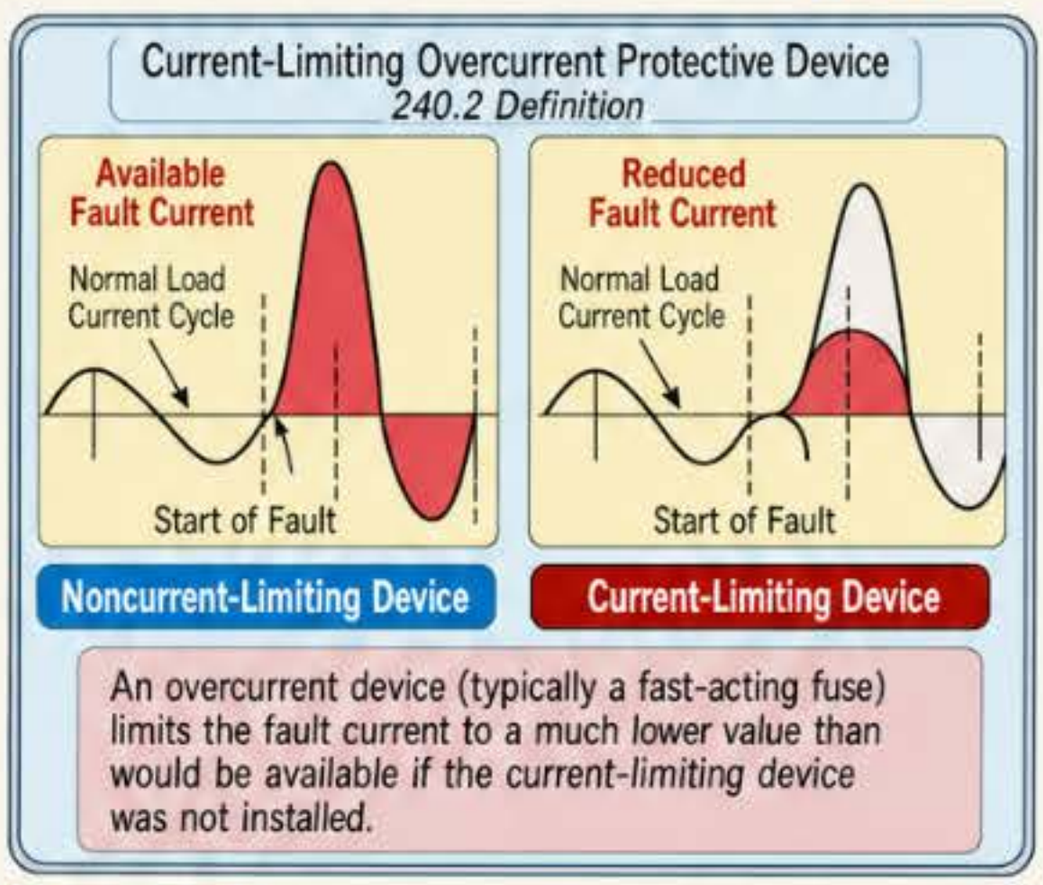
Author's Commentary:

▶ It is important to recognize that a major concern is that a fault or other overcurrent may happen even in the best electrical systems. Your responsibility is to make sure overcurrent protective devices can respond safely, with minimal risk of damage. Proper selection of these devices is a crucial part of that responsibility.

— Michael Hamilton

240.2 Definitions

Current-Limiting Overcurrent Protective Device. A fast-acting *fuse designed to limit let-through current so that the current allowed to flow during a fault is substantially less than the maximum current that would be available if the current-limiting device was not used. See 240.40 and 240.60(B).* ▶ Figure 240–3



▶ Figure 240–3

Author's Commentary:

▶ *A current-limiting fuse is intended for use in circuits where short-circuit events may occur. When the overcurrent is within its limiting range, the link inside the fuse melts quickly—less than one quarter of a cycle—and the fuse opens a short circuit in less than half a cycle. This behavior restricts the energy let through by the fuse.*

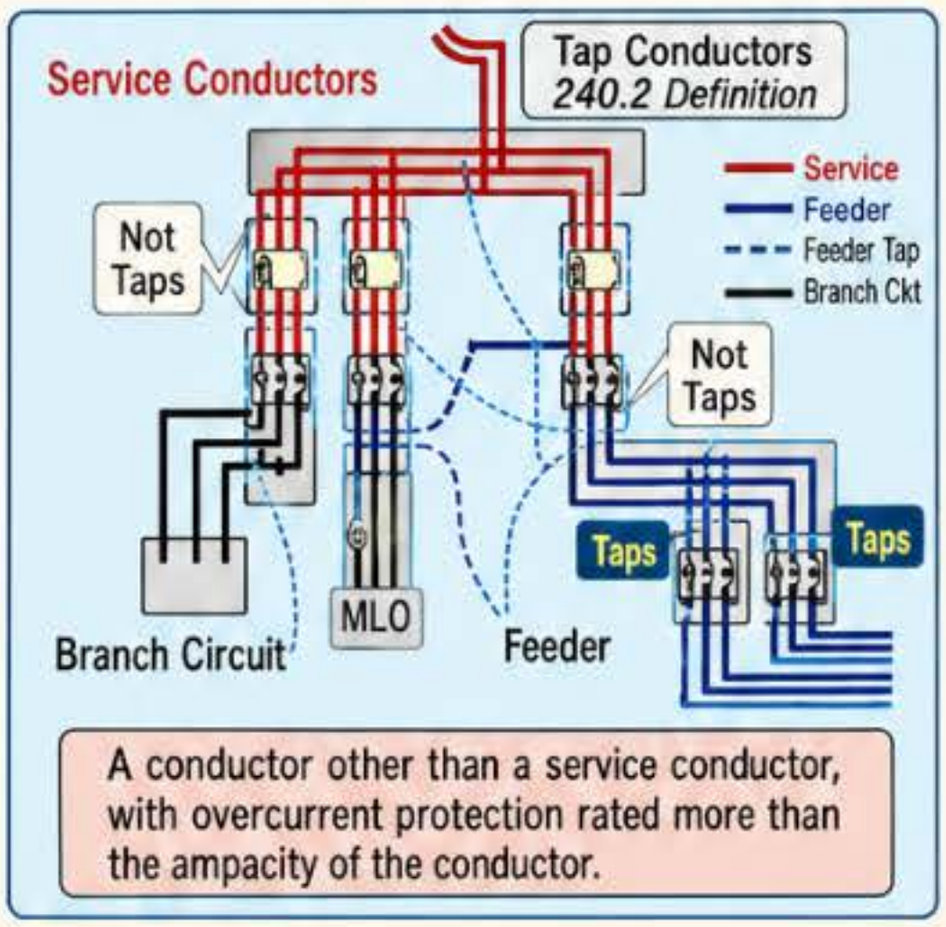
— Michael Hamilton

An instantaneous peak let-through current is the amount of current that passes to a value noticeably below what would occur in the same circuit if the protective device were replaced by a solid conductor of equal impedance. If the available short-circuit current is higher than the equipment's or conductor's short-circuit current rating, thermal stress and magnetic force can create damaging stress on the equipment circuit conductors and the grounding conductors (as well as the circuit equipment grounding conductors) due to excessive vaporization. To reduce the issue of too much fault current, only these two solutions are available:

- Install equipment with a higher ampere interrupting capacity (AIC) rating, or
- Guard circuit components with a current-limiting overcurrent protective device—such as a fast-acting fuse—which can reduce the let-through energy.

A breaker or a fuse restricts how much current can flow, so it is not a current-limiting device. A thermal-magnetic circuit breaker typically clears a fault current in less than three to five cycles when a short circuit or ground fault of 20 times its rating occurs. A standard fuse will clear the same fault in less than one cycle, and a current-limiting fuse in less than half of a cycle.

Tap Conductors. A conductor other than a service conductor, with overcurrent protection rated more than the ampacity of the conductor. See 240.21(A) and 240.21(B) for details. ▶ Figure 240–4



▶ Figure 240–4

240.3 Other Articles (Overcurrent Protection of Equipment)

The following equipment and their conductors must be protected against overcurrent in accordance with the article for that type of equipment:

Table 240.3–Other Articles

Equipment	Article	Section
Air-Conditioning and Refrigeration Equipment	440	440.22
Appliances	422	All
Audio Circuits	640	640.9
Branch Circuits	210	210.20
Class 1, 2, and 3 Circuits	725	All
Feeder Conductors	215	215.3
Flexible Cords	240	240.5(B)(1)
Fire Alarms	760	All
Fire Pumps	695	All
Fixed Electric Space-Heating Equipment	424	424.22
Fixture Wire	240	240.5(B)(2)
Panelboards	408	408.36
Service Conductors	230	230.90(A)
Transformers	450	450.3

240.4 Overcurrent Protection of Conductors

Except as permitted by (A) through (G), conductors must be protected against overcurrent in accordance with their ampacity after ampacity correction and adjustment as specified in 310.14. ▶ Figure 240–5

240.4 | OVERCURRENT PROTECTION

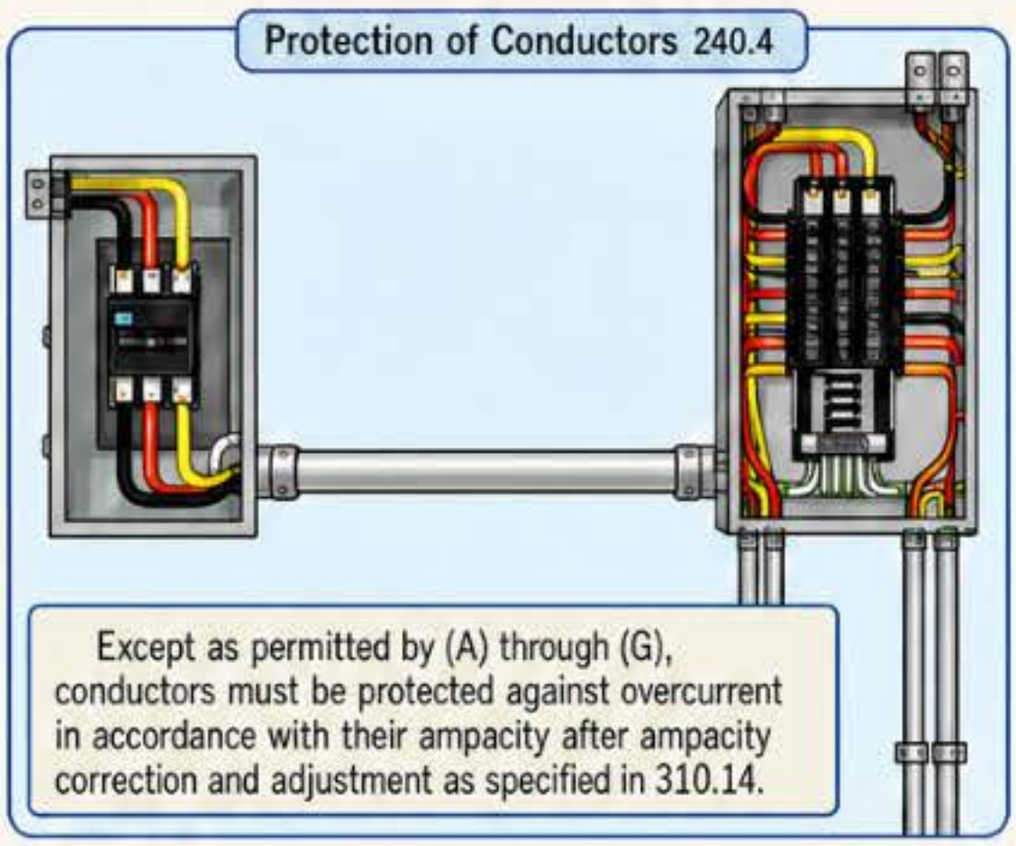


Figure 240–5

Author's Commentary:

- *Table 310.16 defines conductor ampacities based on up to three current-carrying conductors routed in a raceway within ambient temperatures of 86°F (or 30°C) up to 2,000 feet. When more than three current-carrying conductors or different ambient conditions are involved, the ampacities from Table 310.16 must be adjusted in accordance with 310.15(B) and then (if needed) further modified per 310.15(C).*
- *Safeguarding conductors against excessive current is essential for safety and reliable operation. Skipping proper overcurrent protection puts people and property at serious risk.*

— Michael Hamilton

(A) Power Loss Hazard. While conductor overload protection is not required, a short-circuit protective device is needed at any point where interrupting the circuit could create a safety risk, such as in equipment handling *electromechanical loads* or fire pump circuits.

(B) Overcurrent Protection Devices Rated 800A or Less. *The next-higher standard rating of overcurrent protective device (but not exceeding the phase conductor ampacity) may be used when all of the following apply:*

(1) The conductors are not part of a branch circuit supplying more than receptacle or cord-and-plug-connected loads.

(2) After applying ambient temperature correction [310.15(B)], conductor bundling adjustment [Table 310.15(C)(1)], and any other applicable adjustments [Table 310.15(C)(1)], the conductor ampacity is at least equal to the device rating of a fuse or circuit breaker in 240.6(A).

(3) The next-higher standard overcurrent protective device rating [240.6(A)] does not exceed 800A.

▶ Example

Question: *According to Table 310.16, what is the maximum size overcurrent protective device that can be used to protect 500 kcmil conductors where each conductor has an ampacity of 380A at 75°C?* ▶ **Figure 240–6**

(a) 300A (b) 350A (c) 400A (d) 500A

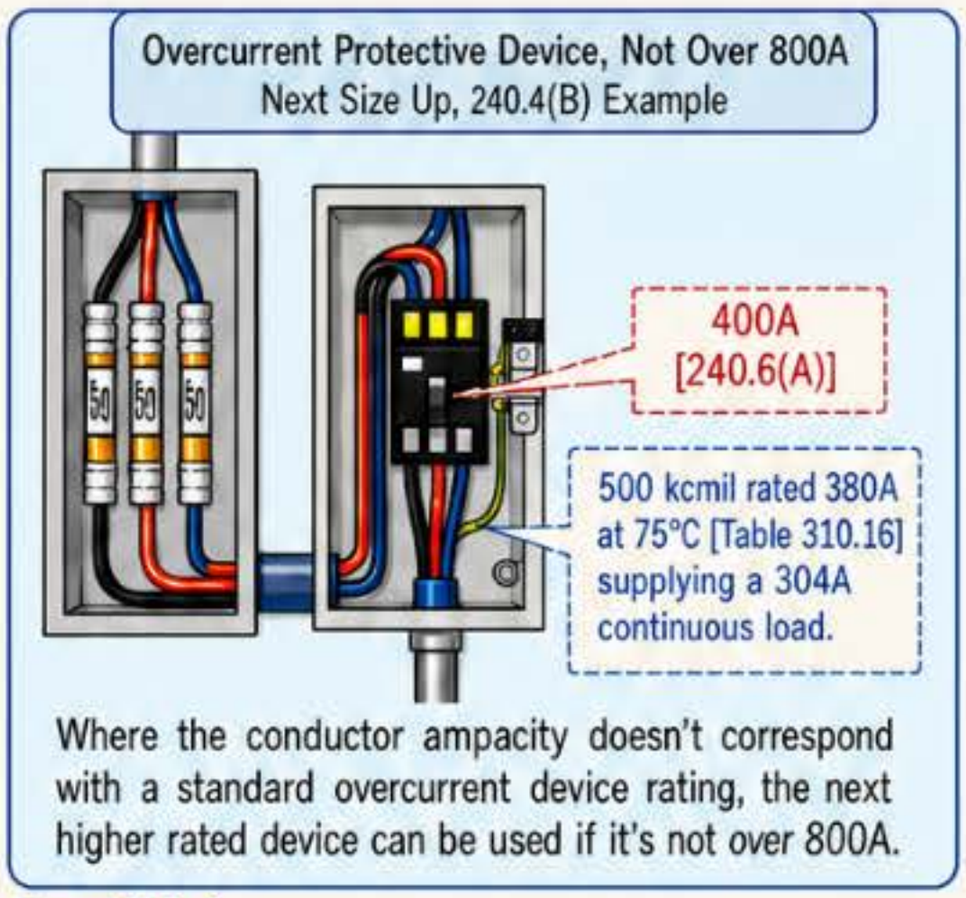


Figure 240–6

(C) Overcurrent Protective Devices Rated Over 800A. If the *circuit's overcurrent protective device is rated above 800A, the conductor ampacity—after applying ambient temperature correction [310.15(B)(1)], conductor bundling adjustment [Table 310.15(C)(1)], or both—must be at least the rating of the protective device or the value specified in 240.6, whichever is greater.*

▶ Example

Question: *What is the minimum size of conductor, arranged in three sets and protected by a 1,200A overcurrent protective device?* ▶ **Figure 240–7**

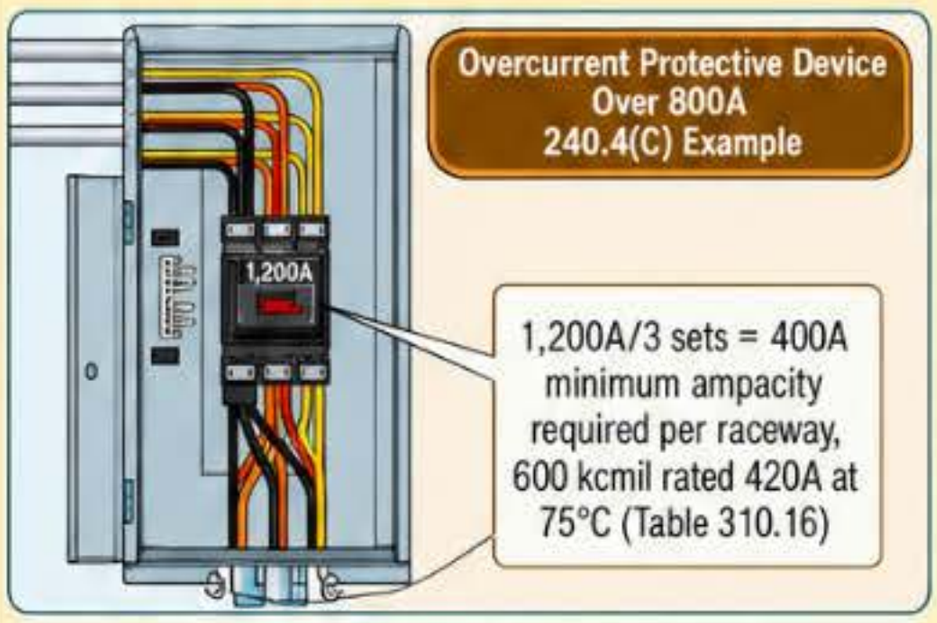
(a) 400 kcmil (b) 500 kcmil (c) 600 kcmil (d) 750 kcmil

Solution:

The combined ampacity of the three parallel conductors must be greater than or equal to 1,200A [240.4(C)]. The individual conductor ampacity within the parallel set must be at least equal to or greater than 400A [1,200A/3 conductors].

Conductor size = 600 kcmil per conductor for three conductors per phase rated 420A at 75°C [110.14(C)(1) and Table 310.16]

Total Conductor Ampacity = 420A × 3 conductors
Total Conductor Ampacity = 1,260A

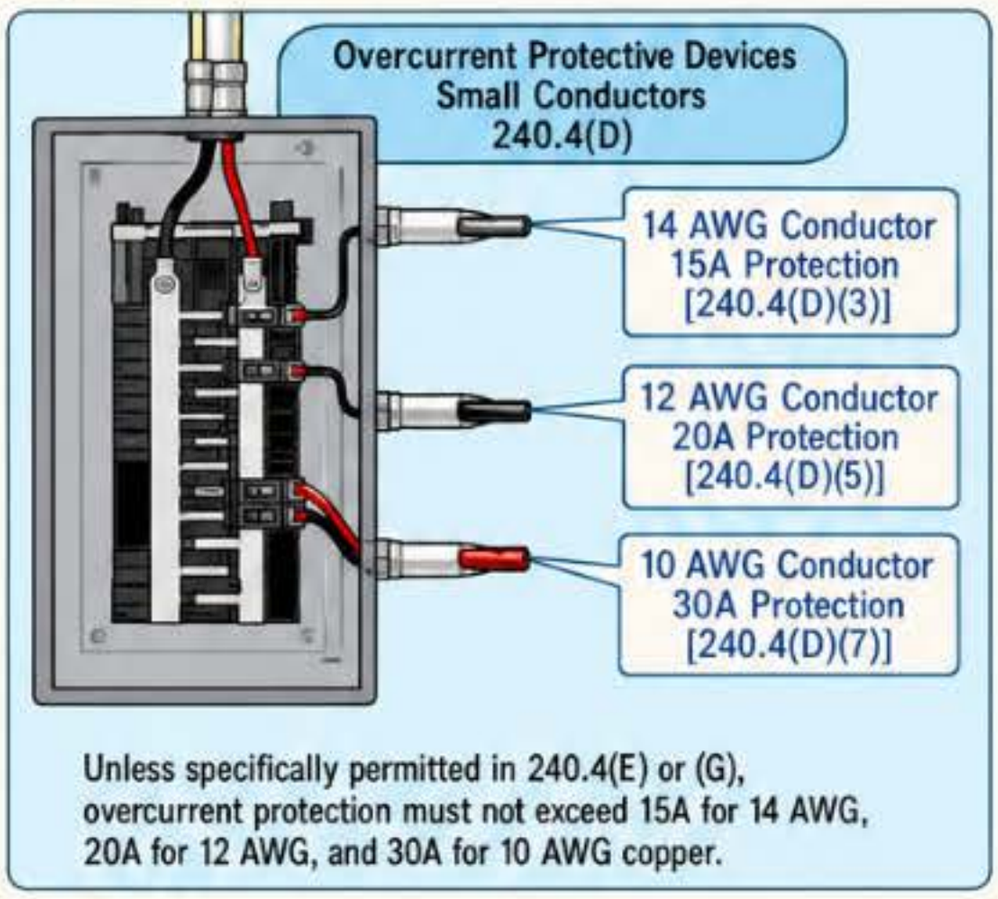


If the circuit's overcurrent device exceeds 800A, the conductor must have an ampacity no less than the overcurrent device rating.

▶ Figure 240–7

Answer: *(c) 600 kcmil*

(D) Small Conductors. Unless specifically permitted in 240.4(E) or (G), overcurrent protection is not permitted to exceed the following: ▶Figure 240–8



▶ Figure 240–8

(1) 18 AWG Copper—7A.

(2) 16 AWG Copper—10A.

(3) 14 AWG Copper—15A.

(4) 12 AWG Aluminum and Copper-Clad Aluminum—15A.

(5) 12 AWG Copper—20A.

(6) 10 AWG Aluminum and Copper-Clad Aluminum—25A.

(7) 10 AWG Copper—30A.

(E) Tap Conductors. Tap conductors must have overcurrent protection in accordance with the following:

(1) Household Ranges, Cooking Appliances, and Other Loads [210.19(A)(3) and (4)].

(2) Fixture Wire [240.5(B)(2)].

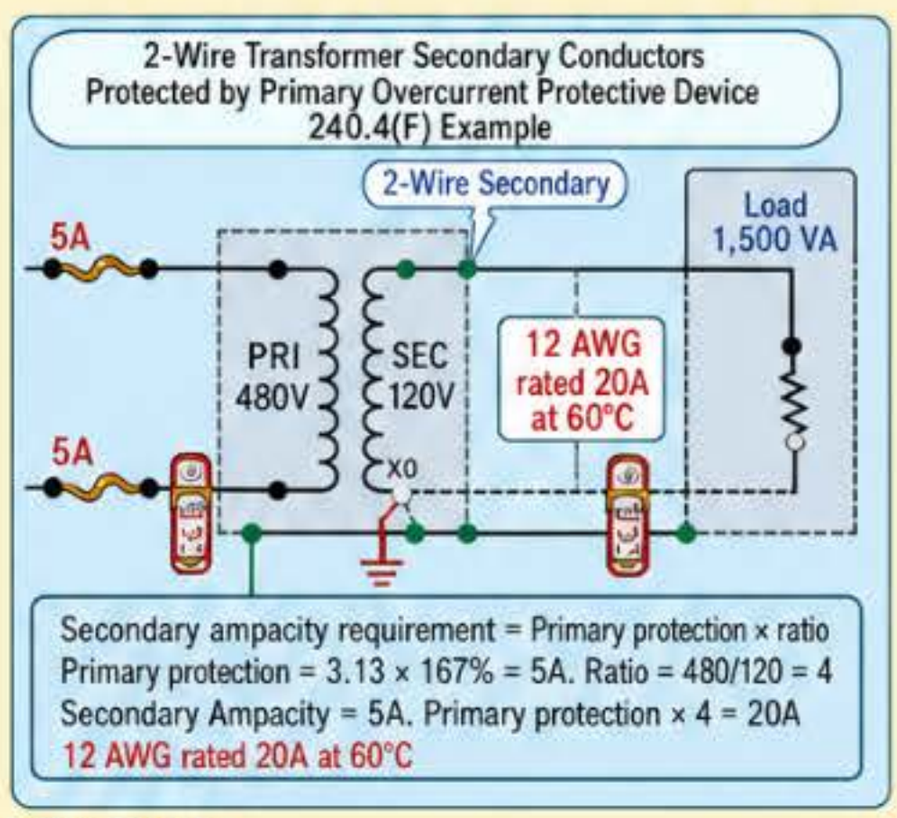
(3) Location in Circuit [240.21].

(F) Transformer Secondary Conductors. For a 2-wire, single-voltage system and delta-delta, 3-wire systems, the primary overcurrent protective device sized in accordance with 450.3(B) is considered suitable to protect the secondary conductors, provided it does not exceed the value determined by multiplying the secondary conductor ampacity by the secondary-to-primary transformer voltage ratio.

▶ Example

Question: *What is the minimum size secondary conductor required for a single-phase, 1.50 kVA, 480V to 120V transformer that is protected with a 5A fuse?* ▶Figure 240–9

(a) 18 AWG (b) 16 AWG (c) 14 AWG (d) 12 AWG



▶ Figure 240–9

Solution:

Step 1: *Determine the primary current.*

VA/E
VA = 1,500 VA
E = 480V

Primary Current = 1,500 VA/480V
Primary Current ≈ 3.13A

Step 2: *Determine the primary overcurrent protective device size [450.3(B)].*

Primary Overcurrent Protection = 3.13A × 167%
Primary Overcurrent Protection = 5.23A or a 5A Fuse

Step 3: *Determine the primary-to-secondary transformer winding voltage ratio.*

Winding Voltage Ratio = Primary Volts/Secondary Volts
Winding Voltage Ratio = 480V/120V
Winding Voltage Ratio = 4 to 1

Step 4: *Determine the secondary conductor minimum ampacity.*

Secondary Ampacity = Primary Overcurrent Protection × Ratio
Secondary Ampacity = Primary of 5A × Winding Voltage Ratio of 4
Secondary Ampacity = 20A

Use a 12 AWG conductor rated 20A at 60°C [110.14(C)(1)(a)(2) and Table 310.16].

Answer: *(d) 12 AWG*

(G) Overcurrent Protection for Specific Applications. Overcurrent protection for specific equipment and conductors can comply with the requirements referenced in *Table 240.4(G)*.

Author's Commentary:
The information in Table 240.4(G) lists the overcurrent protection rules for certain situations—like air conditioners and motors. Depending on the device, you may need to follow a different part of Article 440 or Article 430.
— Michael Hamilton

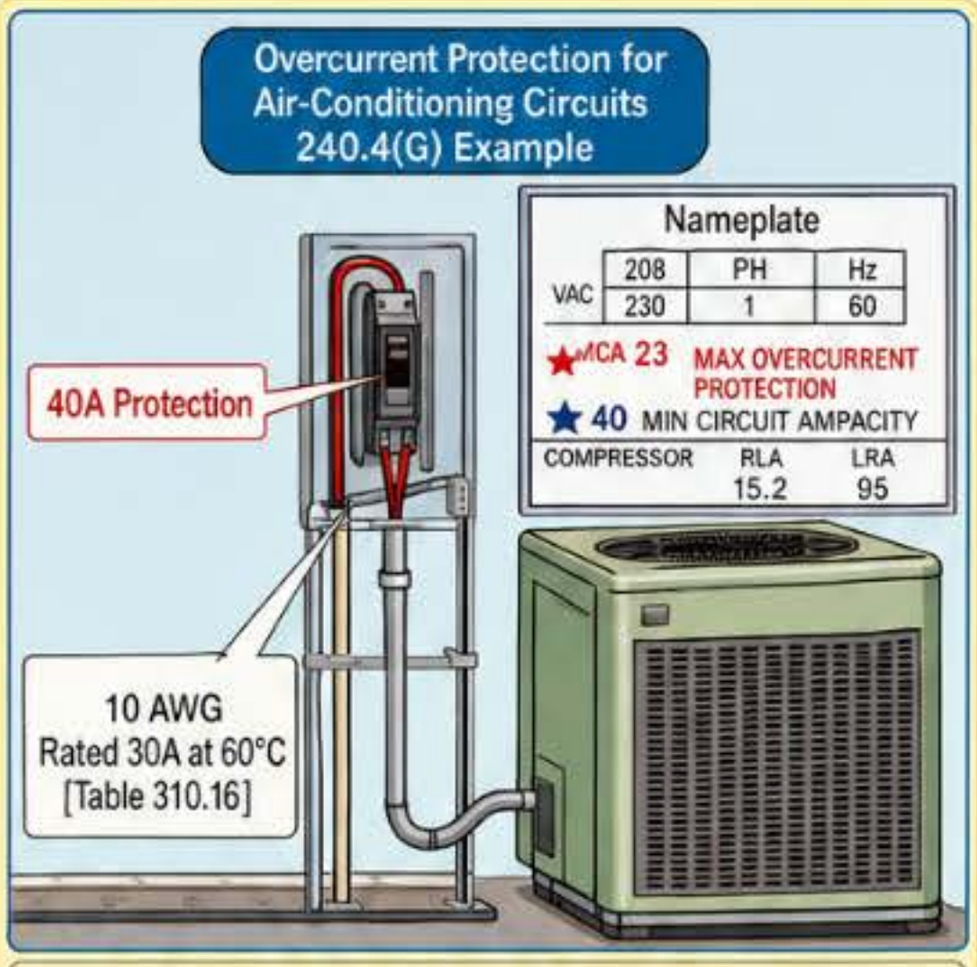
▶ Air Conditioner Example

Question: *What size branch-circuit conductor and overcurrent protective device are required for an air conditioner when the nameplate indicates the minimum circuit ampacity is 23A and the maximum overcurrent protection is 40A?* ▶ Figure 240–10

(a) 10 AWG, 20A OCPD *(b) 10 AWG, 30A OCPD*
(c) 10 AWG, 40A OCPD *(d) 10 AWG, 50A OCPD*

Solution:

The nameplate values for listed air-conditioning and refrigeration equipment are used to size the branch-circuit conductors and short-circuit overcurrent protective device [440.4(A)]. No calculation is required.



Air-conditioning and refrigeration equipment must be protected against overcurrent per 440.4(B).

▶ Figure 240–10

Conductor: *The air conditioner branch-circuit conductor is sized to the nameplate minimum circuit ampacity of 23A. A 10 AWG conductor is suitable since it has an ampacity of 30A at 60°C [110.14(C)(1) and Table 310.16].*

Protection: *The air conditioner branch-circuit short-circuit protection is sized to the nameplate maximum value of 40A.*

A 40A circuit breaker is permitted to protect a 10 AWG conductor rated 30A at 60°C in accordance with 110.14(C)(1)(a)(2), 240.4(G) and 440.4(A).

Answer: *(c) 10 AWG, 40A*

▶ Motor Example

Question: *What size branch-circuit conductor and overcurrent protective device (circuit breaker) is required for a 7½ hp, 230V, three-phase motor?* ▶ Figure 240–11

(a) 10 AWG, 20A *(b) 10 AWG, 30A*
(c) 10 AWG, 40A *(d) 10 AWG, 60A*

Solution:

Step 1: *Determine the branch-circuit conductor size at 125% of the motor's FLC [430.22 and Table 430.250].*

FLC = 22A [Table 430.250]

Conductor = 22A × 125% = 28A [430.22]

Conductor = 10 AWG which is rated 30A at 60°C [110.14(C)(1) and Table 310.16]

OVERCURRENT PROTECTION | 240.6

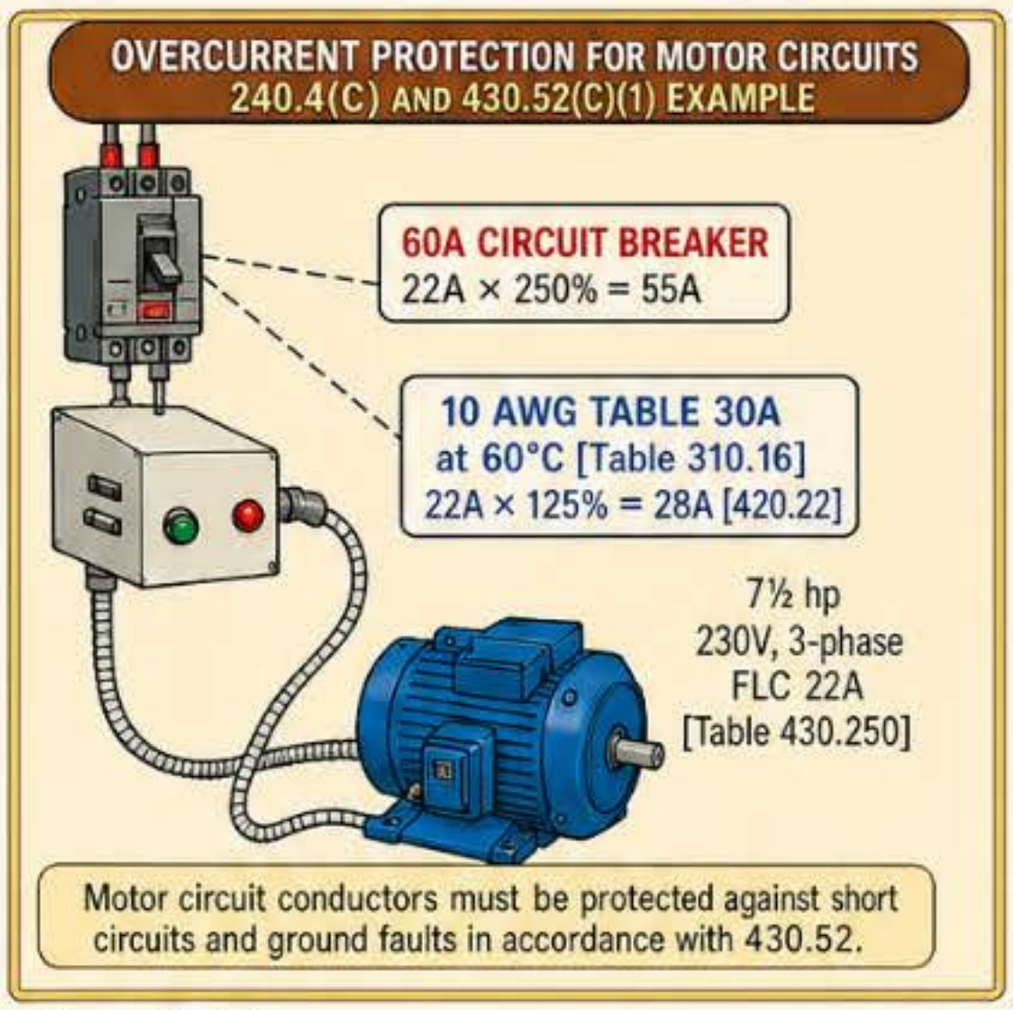


Figure 240-11

STEP 2: *Determine the branch-circuit overcurrent protection size at 250% of the motor's FLC [Table 430.52, 430.52(C)(1) Ex 1, and Table 430.250].*

Inverse Time Circuit Breaker = 22A × 250%

Inverse Time Circuit Breaker = 55A

A 60A inverse time circuit breaker is permitted to protect the 10 AWG conductor rated 30A in accordance with 240.4(C), Table 430.52, and 430.52(C)(1) Ex 1.

Answer: *(d) 10 AWG, 60A*

Motor Control [Article 430]. Motor control circuit conductors are sized and protected in accordance with 430.72.

Remote-Control, Signaling, and Power-Limited Circuits [Article 725]. Remote-control, signaling, and power-limited circuit conductors are protected against overcurrent in accordance with 725.43.

240.5 Protection of Flexible Cords, Flexible Cables, and Fixture Wires

Flexible cord, including tinsel cord and extension cords, and fixture wires must be protected against overcurrent by either 240.5(A) or (B).

(A) Ampacities. *Flexible cord must be protected by an overcurrent device in accordance with its ampacity as specified in Table 400.5(A)(1) and Table 400.5(A)(2). Fixture wire must be protected against overcurrent in accordance with its ampacity as specified in Table 402.5. Supplementary overcurrent protection, as covered in 240.10, is an acceptable means for providing this protection.*

(B) Branch-Circuit Overcurrent Device. Flexible cord must be protected, where supplied by a branch circuit, in accordance with one of the methods described in 240.5(B)(1), (B)(3), or (B)(4). Fixture wire must be protected, where supplied by a branch circuit, in accordance with 240.5(B)(2).

(1) Supply Cord of Listed Appliance or Luminaire. Where flexible cord or tinsel cord is approved for (and used with) a specific listed appliance or luminaire, it is considered protected when applied within the appliance or luminaire listing requirements. For the purposes of this section, a luminaire may be either portable or permanent.

(2) Fixture Wire. Fixture wire is permitted to be tapped to the branch-circuit conductor of a branch circuit in accordance with the following:

(1) 15A or 20A circuits—18 AWG, up to 50 ft of run length

(2) 15A or 20A circuits—16 AWG, up to 100 ft of run length

(3) 20A circuits—14 AWG and larger

(4) 30A circuits—14 AWG and larger

(5) 40A circuits—12 AWG and larger

(6) 50A circuits—12 AWG and larger

(3) Extension Cord Sets. Flexible cord used in listed extension cord sets is considered protected when applied within the extension cord listing requirements.

(4) Field Assembled Extension Cord Sets. Flexible cord used in extension cords made with separately listed and installed components are permitted to be supplied by a branch circuit in accordance with the following:

20A circuits—16 AWG and larger

240.6 Standard Ampere Ratings

(A) Fuses and Fixed-Trip Circuit Breakers. The standard ratings in amperes for fuses and inverse time circuit breakers are shown in *Table 240.6(A). The use of fuses and inverse time circuit breakers with nonstandard ampere ratings is permitted.* Figure 240-12

Standard Ampere Ratings Fuses and Fixed-Trip Circuit Breakers
Table 240.6(A)

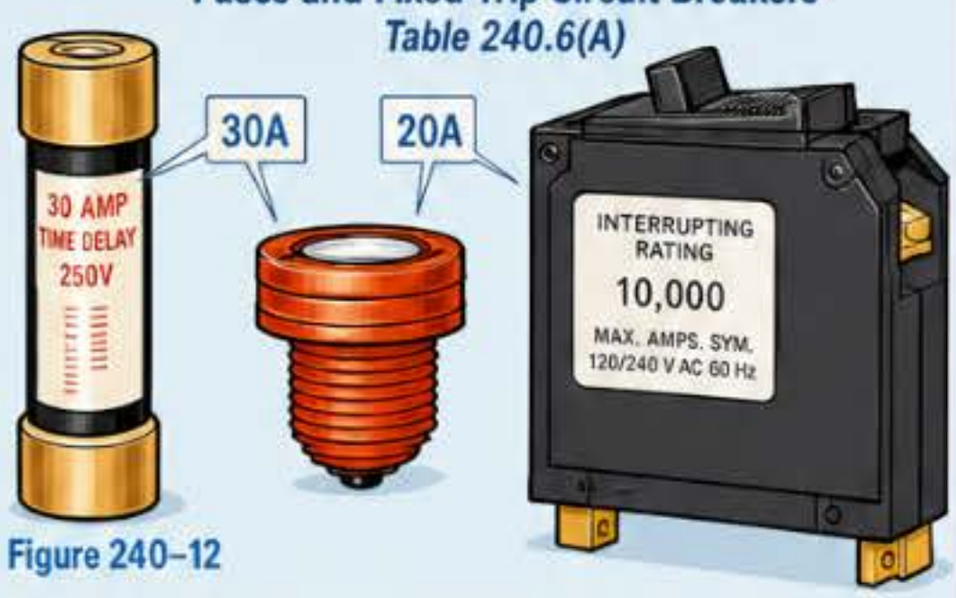


Figure 240–12

The standard ratings available for fuses and inverse-time circuit breakers are: 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1,000, 1,200, 1,600, 2,000, 2,500, 3,000, 4,000, 5,000, and 6,000A.

Figure 240–12

Table 240.6(A) Standard Ampere Ratings for Fuses and Inverse Time Circuit Breakers Standard Ampere Ratings

15	20	25	30	35
40	45	50	60	70
80	90	100	110	125
150	175	200	225	250
300	350	400	450	500
600	700	800	1000	1200
1600	2000	2500	3000	4000

(B) Adjustable Trip Circuit Breakers, Without Restricted Access. The ampere rating of an adjustable trip circuit breaker without restricted access is equal to its maximum long-time pickup current setting.

(C) Adjustable Trip Circuit Breakers, Restricted Access. The ampere rating of adjustable trip circuit breakers with restricted access to the adjusting means is equal to the adjusted long-time pickup current settings. Restricted access is achieved by one of the following methods:

1. Locating behind removable and sealable covers over the adjusting means
2. Locating behind bolted equipment enclosure doors
3. Locating behind locked doors accessible only to qualified personnel
4. Being password protected with the password only accessible to qualified personnel

240.10 Supplementary Overcurrent Protection

Supplementary overcurrent protection devices are not permitted to be used as the required branch-circuit overcurrent protective device. Figure 240–13

Supplementary Overcurrent Protection
240.10

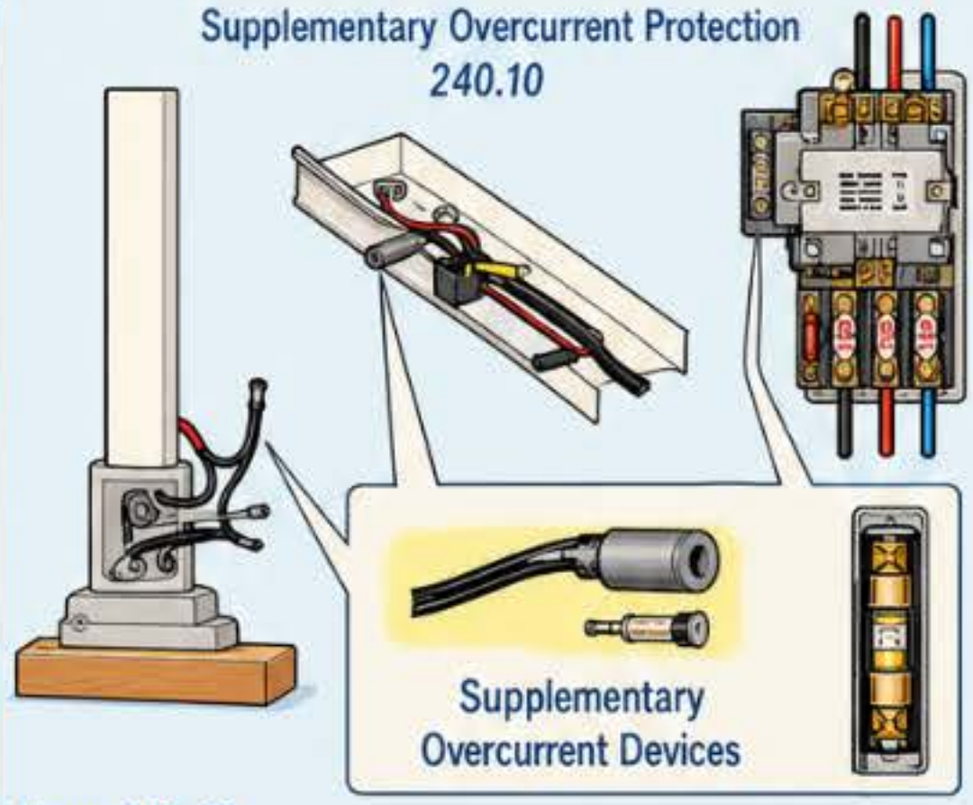


Figure 240–13

Supplementary overcurrent devices can't be used as the required circuit overcurrent device.

A supplementary overcurrent protective device is not required to be readily accessible [240.24(A)(2)].

Author's Commentary:

Article 100 defines a "Supplementary Overcurrent Protective Device" as a device intended to provide limited overcurrent protection for specific applications and utilization equipment. *This limited protection is in addition to the overcurrent protection provided in the required branch circuit by the branch-circuit overcurrent protective device.*

— *Michael Hamilton*

240.13 Ground-Fault Protection of Equipment

Ground-fault protection of equipment must be provided for service disconnects [230.95] and feeder disconnects [215.10] rated 1,000A or more supplied from a 4-wire, three-phase, 277/480V wye-connected system in accordance with 230.95.

Author's Commentary:

Article 100 defines "Ground-Fault Protection of Equipment" as a system intended to provide overcurrent protection of equipment from ground faults by opening the overcurrent protective device at current levels less than those required to protect against overcurrents between conductors.

— *Michael Hamilton*

Devices that guard against excessive current in conductors are designed for equipment protection only. They are not intended for safeguarding people, but only the connected equipment.

- Emergency systems and legally required standby power systems [700.31] do not need ground-fault protection for their equipment.
- Do not mistakenly use ground-fault equipment protection (GFEP) in place of ground-fault circuit interrupter (GFCI) protection for personnel.

240.15 Phase Conductor Overcurrent Device

(B) Circuit Breaker. A circuit breaker must automatically open all ungrounded (phase) conductors of the circuit when an overcurrent occurs, except as explained below.

(1) Multiwire Branch Circuits. Each ungrounded conductor of a multiwire branch circuit may be protected by an individual single-pole breaker that includes handle ties for all phases. Figure 240–14

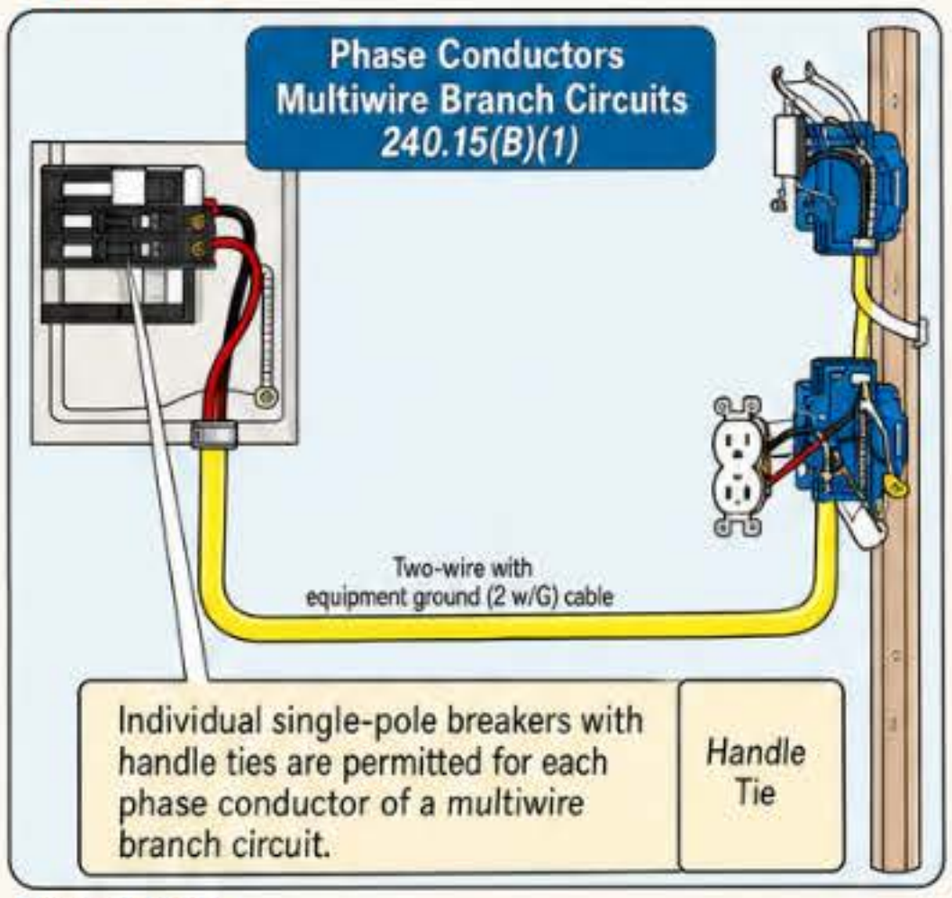


Figure 240–14

Author's Commentary:

The term "identified" in Article 100 indicates that the item is recognized as appropriate for a specific condition, location, or environment per the authority with jurisdiction. This means handle ties made from nails, screws, wires, or other nonapproved materials are not allowed.

— Michael Hamilton

(2) Line-to-Line Loads, Single-Phase. *Individual single-pole circuit breakers rated 120/240V with handle ties identified for the purpose are allowed for each phase of a single-phase line-to-line load.* Figure 240–16

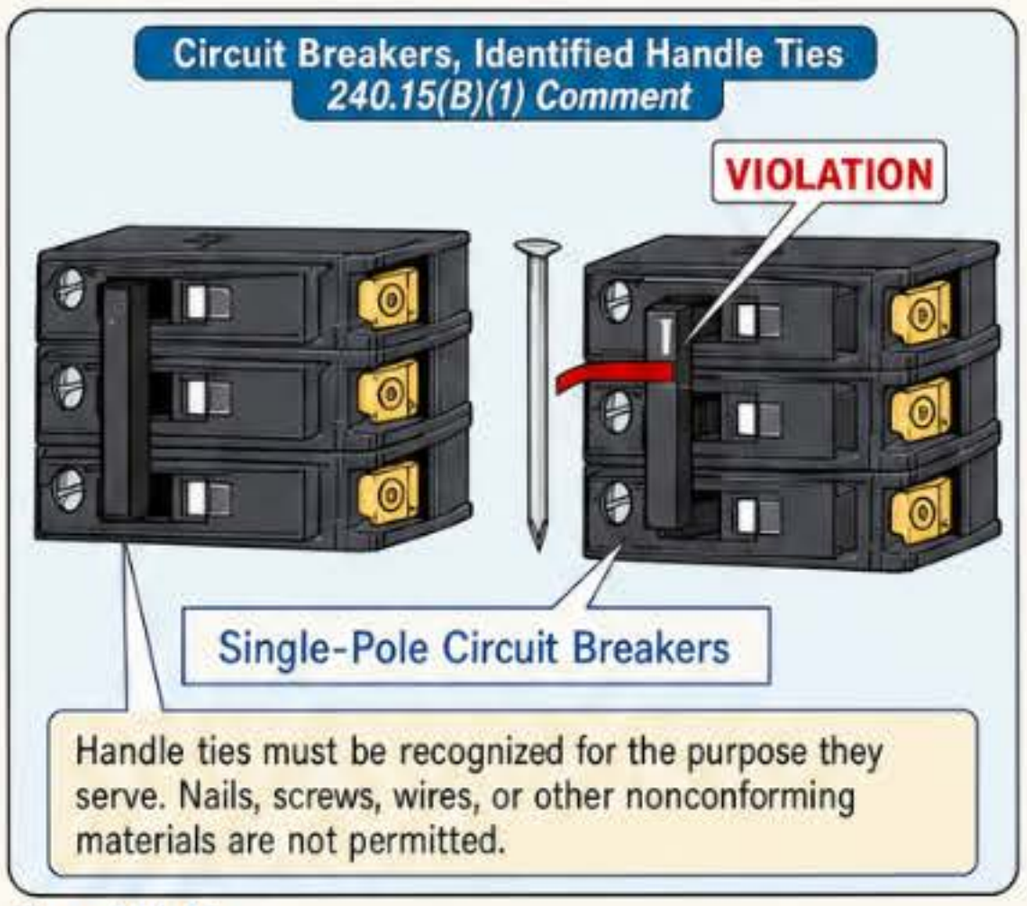


Figure 240–15

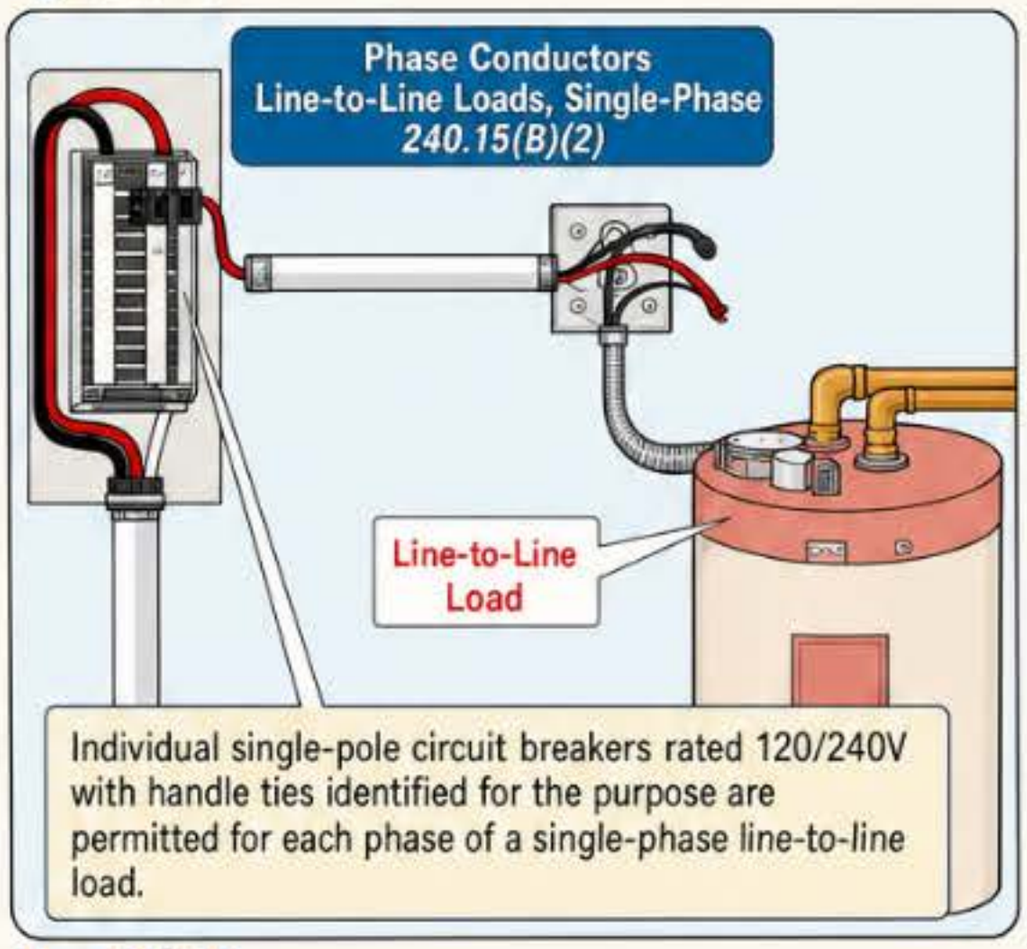


Figure 240–16

(3) Line-to-Line Loads, Three-Phase. *Individual single-pole circuit breakers rated 120/240V with handle ties identified for the purpose are permitted for each phase of a three-phase line-to-line load.* Figure 240–17

Part II. Location

240.21 Location in Circuit

Overcurrent protection must be installed for each phase conductor at the location where the conductor is supplied, except as allowed in *(A) through (H).* Figure 240–18

Taps and transformer secondary conductors must not be supplied by another conductor (tapping a tap is not authorized). Figure 240–19

240.21 | Overcurrent Protection

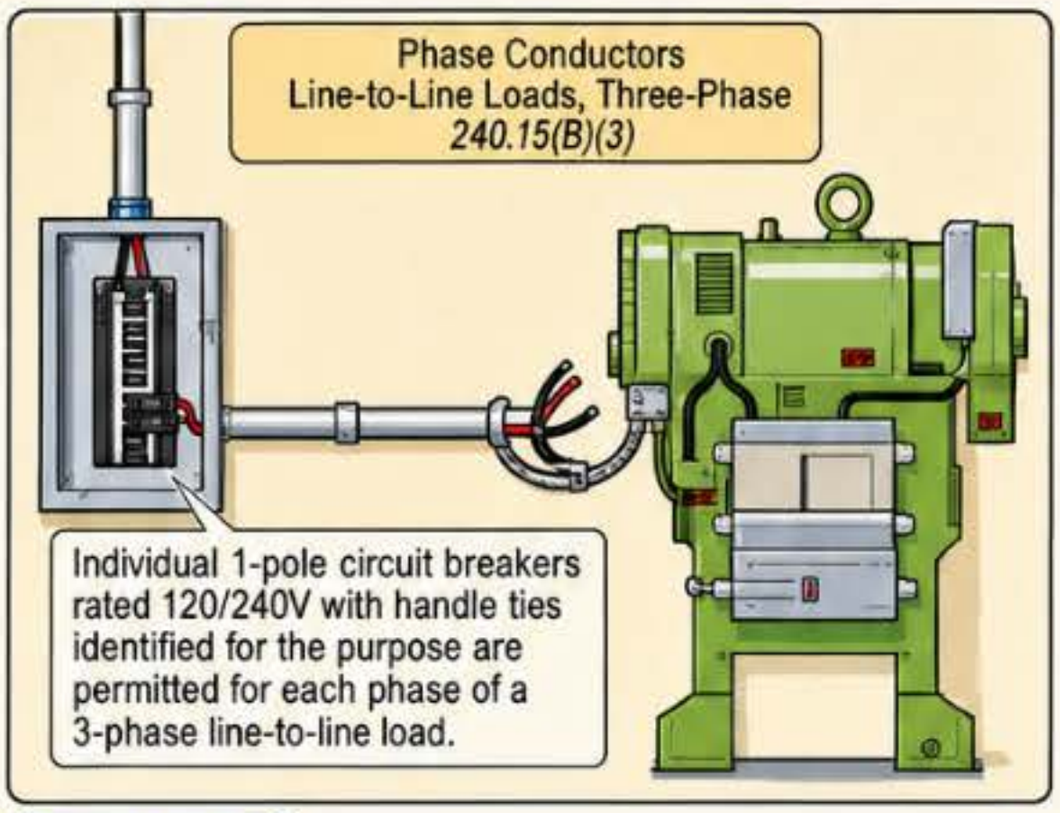


Figure 240–17

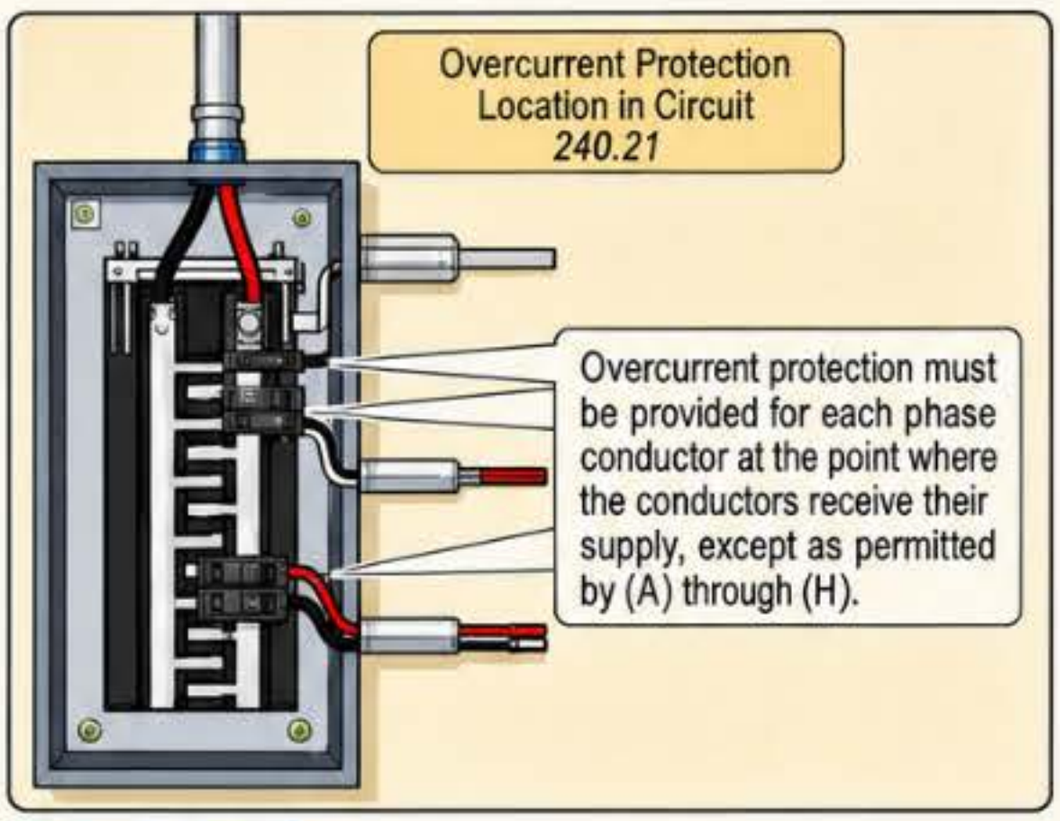


Figure 240–18

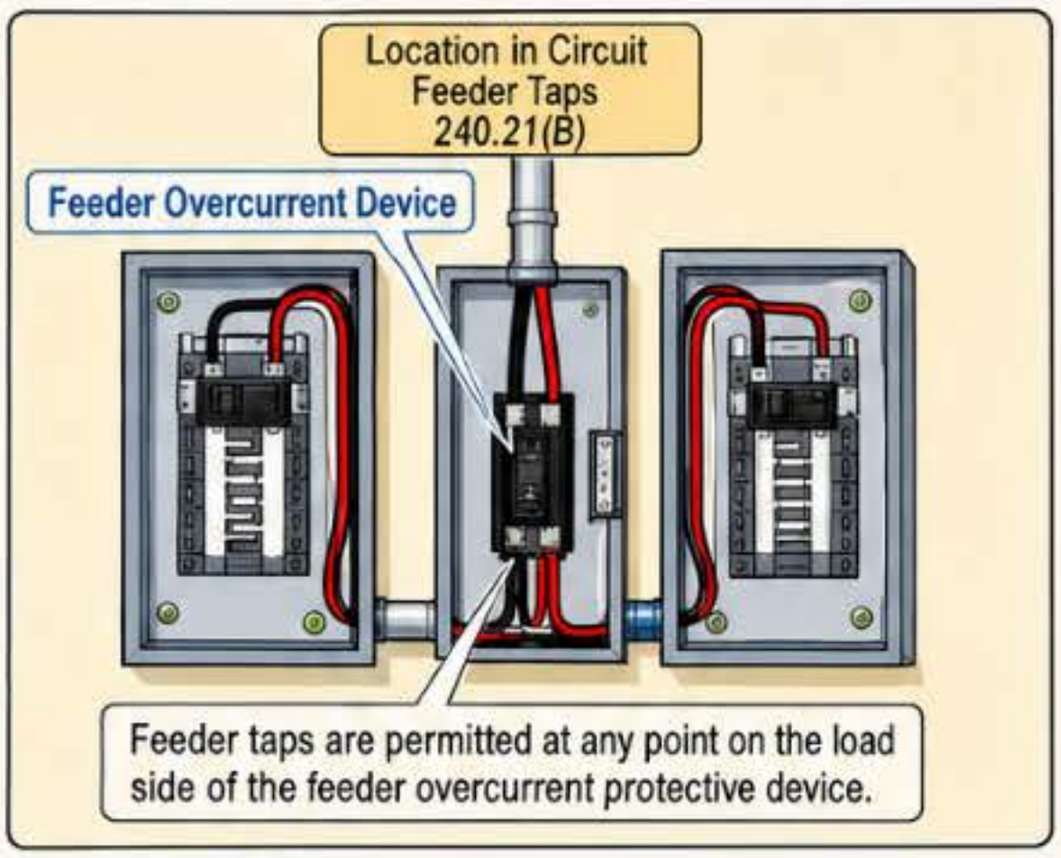


Figure 240–19

Author's Commentary:

A tap conductor is a conductor (other than a service conductor) that may have overcurrent protection with a rating higher than the ampacity of the conductor, provided this complies with 240.4. Instead of protecting the tap conductors where they *are supplied, tap conductors may be safeguarded from overload by an overcurrent device located upstream, the device that carries their supply, and also from short circuits and ground faults by the feeder protective device from which they originate.*

— Michael Hamilton

(B) Feeder Taps. Conductors are allowed to be tapped, without overcurrent protection at the tap, to a feeder as specified in 240.21(B)(1) through (B)(5).

The tap is permitted at any point on the load side of the feeder overcurrent protective device.

Figure 240–20

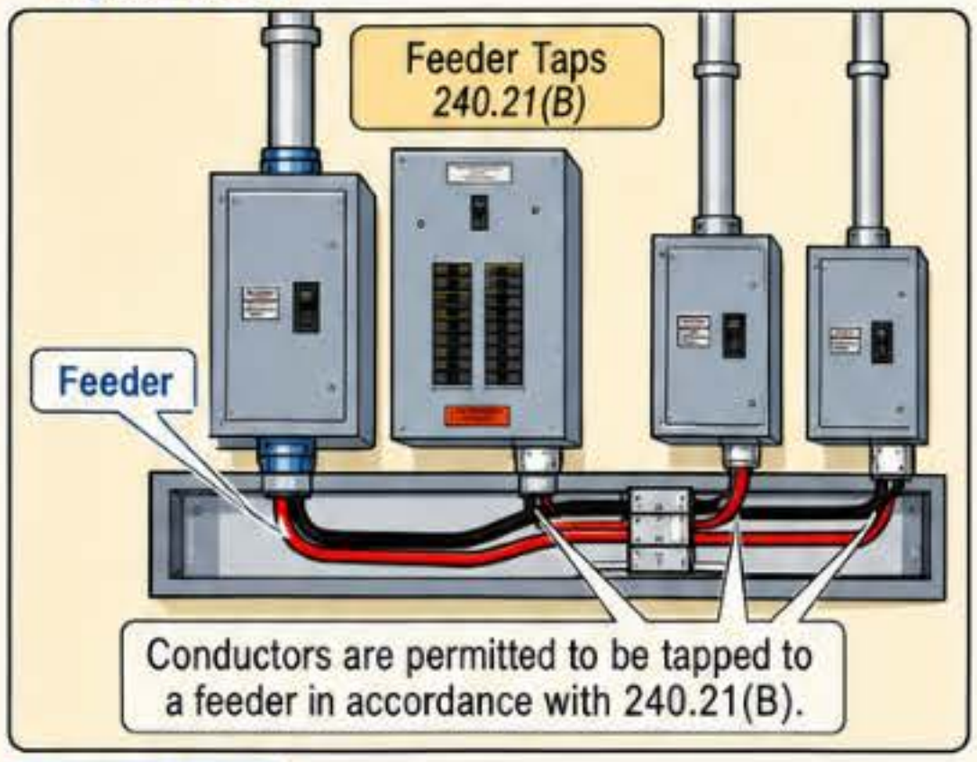


Figure 240–20

(1) Feeder Tap Not Over 10 Feet. Tap conductors up to 10 ft long are permitted when they meet these conditions:

(1) Tap conductors have an ampacity equal to or greater than:

Figure 240–21

a. The calculated load in accordance with Article 220, and

b. The rating of the overcurrent device or the equipment supplied by the tap conductors.

(2) The tap conductors *are not permitted to extend beyond the equipment they supply.*

(3) *The tap conductors are installed within a raceway.*

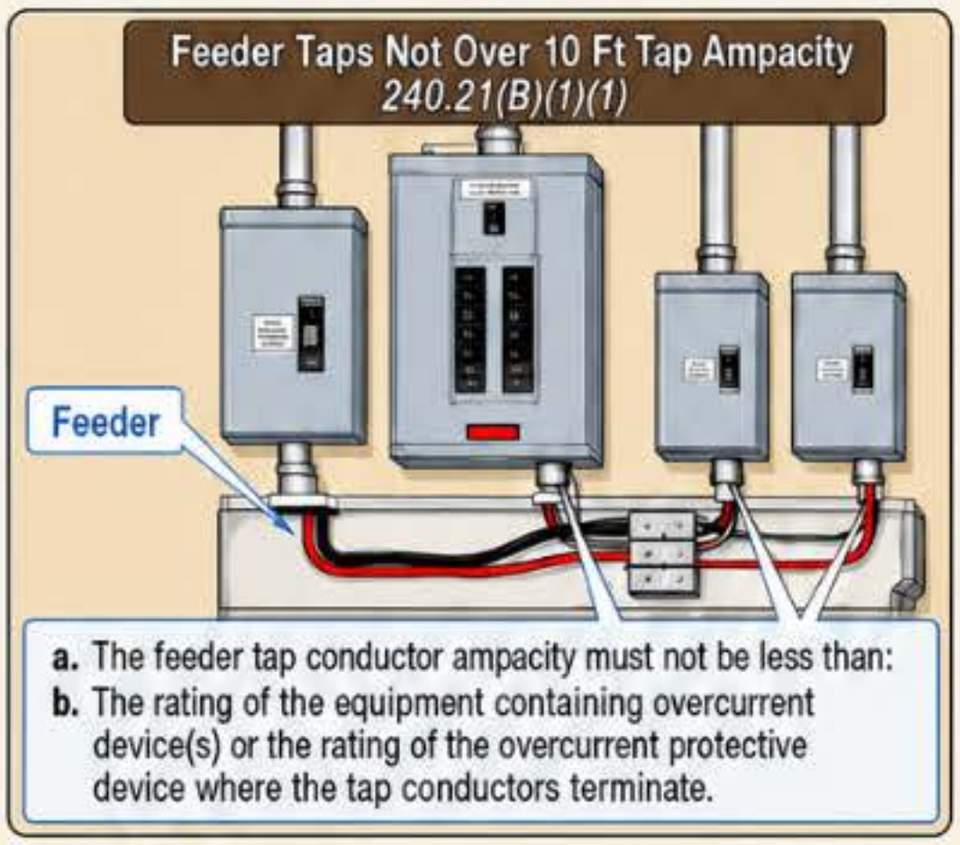


Figure 240-21

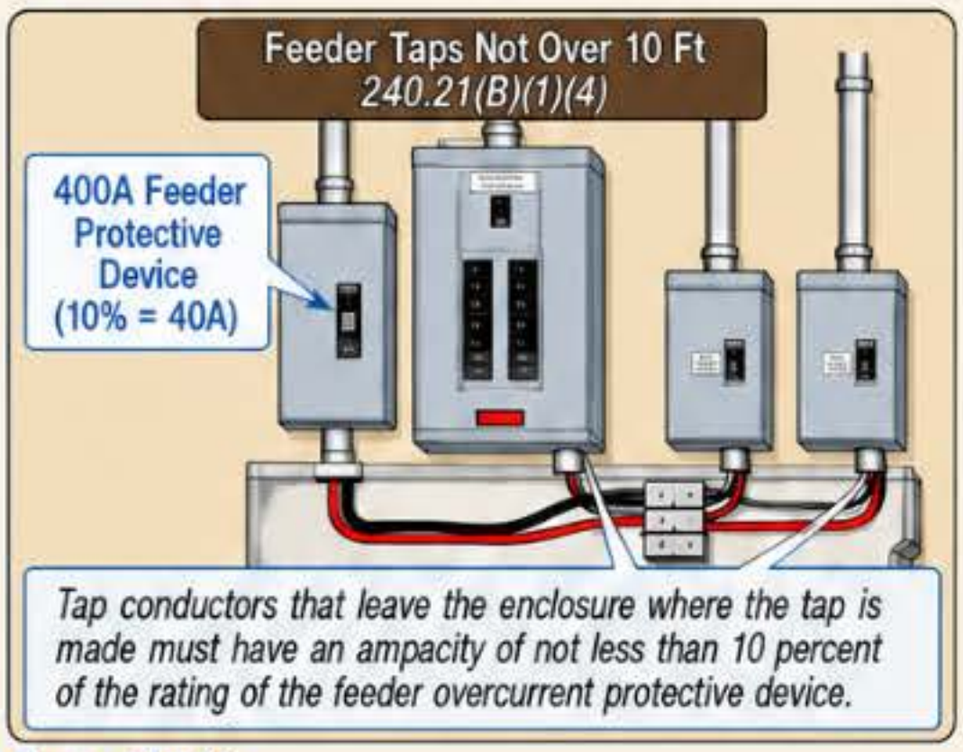


Figure 240-22

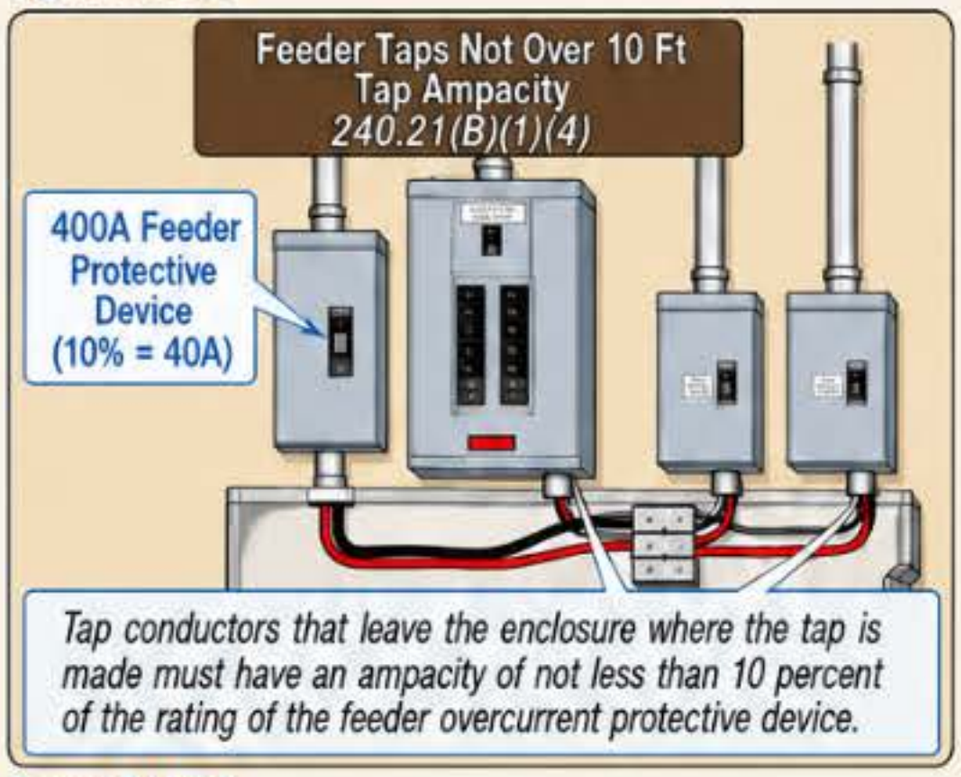


Figure 240-23

Note: If a tap supplies a panelboard, the tap conductors must terminate in an overcurrent device in accordance with 408.36.

10-Foot Tap Rule

▶ 10-Foot Tap Rule Example 1

Question: *What size 10-ft tap conductor is needed from a 400A circuit breaker to supply a 200A panelboard if the terminals are rated 75°C?* → **Figure 240-23**

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

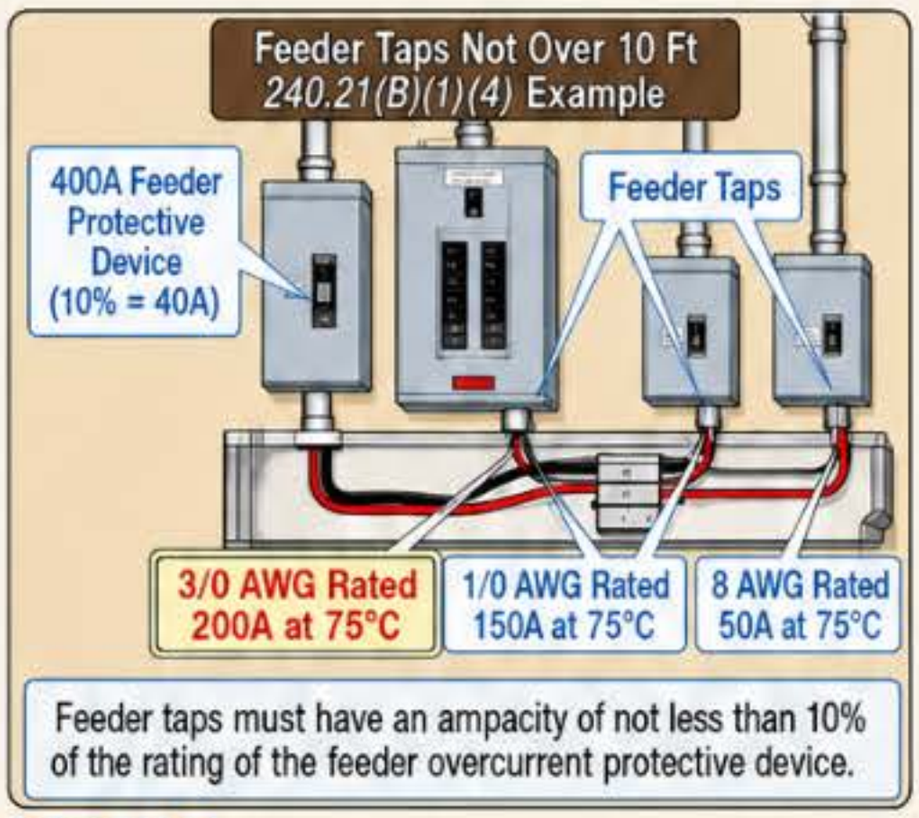


Figure 240-24

Solution:

Ten Percent of 400A = 40A minimum conductor ampacity permitted.

3/0 AWG is rated 200A at 75°C [110.14(C)(1) and Table 310.16] which is greater than 10 percent of the rating of the 400A overcurrent protective device.

Answer: *(c) 3/0 AWG*

▶ 10-Foot Tap Rule Example 2

Question: *What size 10-ft tap conductor is needed from a 400A circuit breaker to supply a 150A feeder disconnect if the terminals are rated 75°C?* → **Figure 240-24**

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

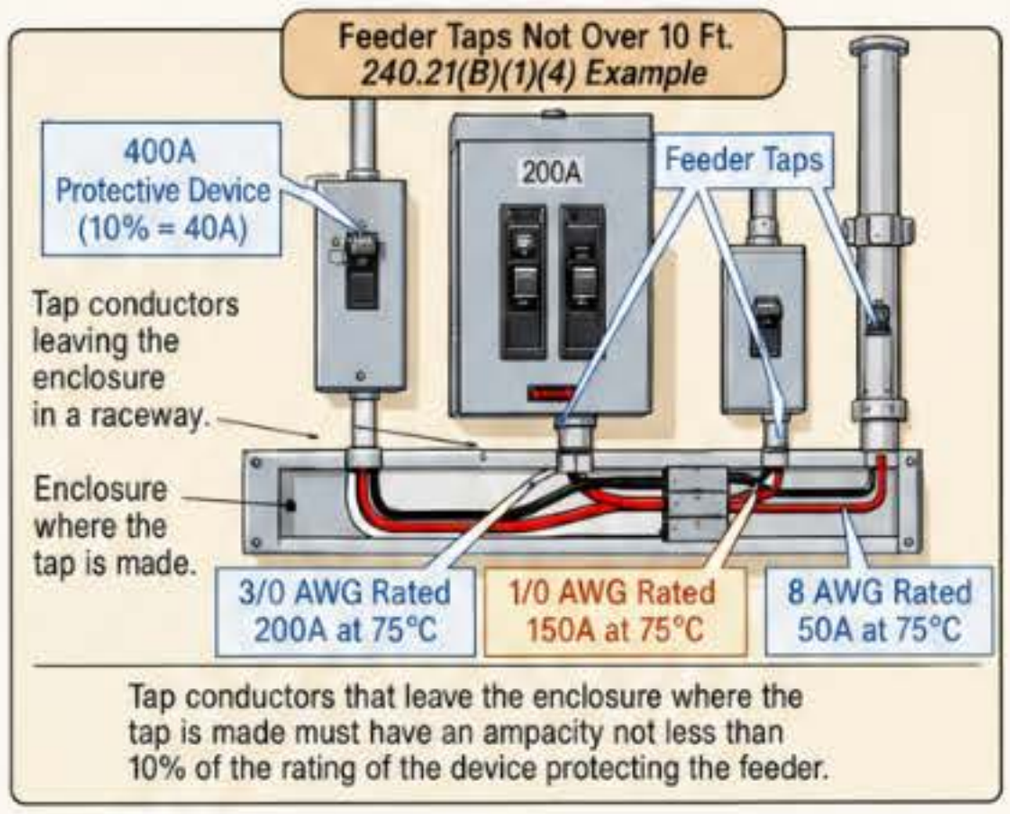
▶ *Solution:*

Ten Percent of 400A = 40A minimum conductor ampacity permitted.

1/0 AWG is rated 150A at 75°C [110.14(C)(1) and Table 310.16] which is greater than 10 percent of the rating of the 400A overcurrent protective device.

Answer: *(a) 1/0 AWG*

• • •

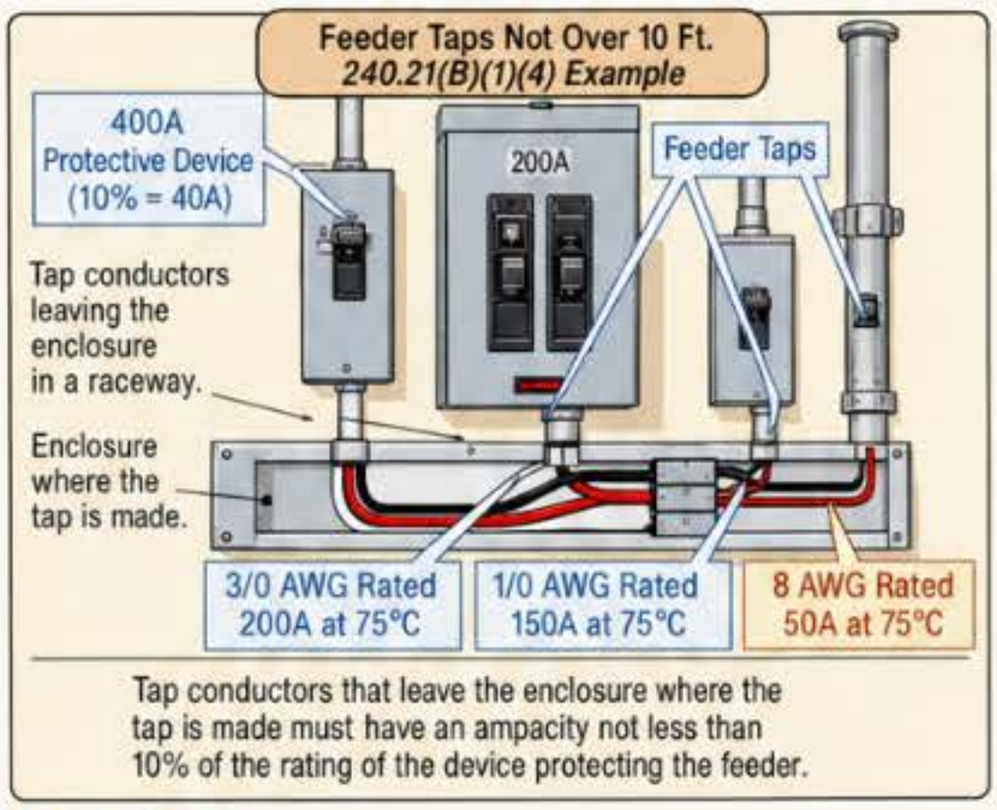


▲ Figure 240–24

▶ 10-Foot Tap Rule Example 3

Question: *What size 10-ft tap conductor is needed from a 400A circuit breaker to supply a 30A feeder disconnect if the terminals are rated 75°C?* • *Figure 240–25*

(a) 8 AWG (b) 6 AWG (c) 4 AWG (d) 3 AWG



▲ Figure 240–25

Solution:

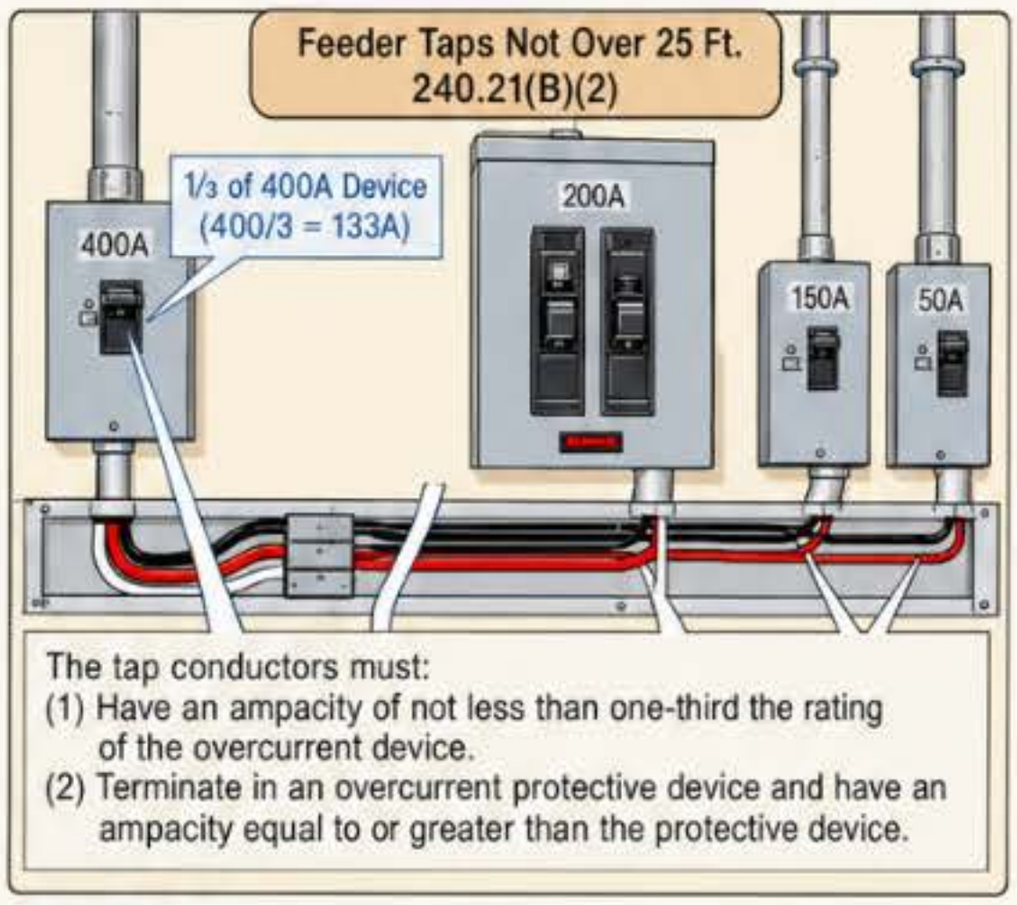
Ten percent of 400A = 40A minimum conductor ampacity permitted. 8 AWG is rated 50A at 75°C [Table 310.16] which is more than 10 percent of the rating of the 400A overcurrent protective device.

Answer: *(a)* 8 AWG

Author's Commentary: *Always verify terminal and conductor ratings at 75°C to ensure the tap conductor meets or exceeds the minimum ampacity requirement.*

— Michael Hamilton

(2) Feeder Tap Not Over 25 Feet. Tap conductors up to 25 ft long are permitted when they comply with the following: • Figure 240–26



▲ Figure 240–26

(1) The tap conductor has an ampacity not less than ⅓ the rating of the overcurrent protective device that protects the feeder.

(2) The tap conductors terminate in an overcurrent protective device and have an ampacity equal to or greater than the rating of the overcurrent protective device.

25-Foot Tap Rule

▶ 25-Foot Tap Example 1

Question: *What size 25-ft tap conductor is needed from a 400A circuit breaker to supply a 200A panelboard if the terminals are rated 75°C?* • *Figure 240–27*

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

Solution:

The tap conductor must have a minimum rating of no less than 133A (⅓ the rating of the 400A overcurrent device). 3/0 AWG is rated 200A at 75°C [Table 310.16] and Table 310.16 (which is greater than 133A (⅓ the rating of the 400A overcurrent device) and equal to the 200A disconnect.

Answer: *(c)* 3/0 AWG

Author's Commentary: *For tap runs up to 25 ft, the conductor must be able to handle at least one-third of the feeder device rating and must terminate in a protective device with an equal or higher rating.*

— Michael Hamilton

OVERCURRENT PROTECTION

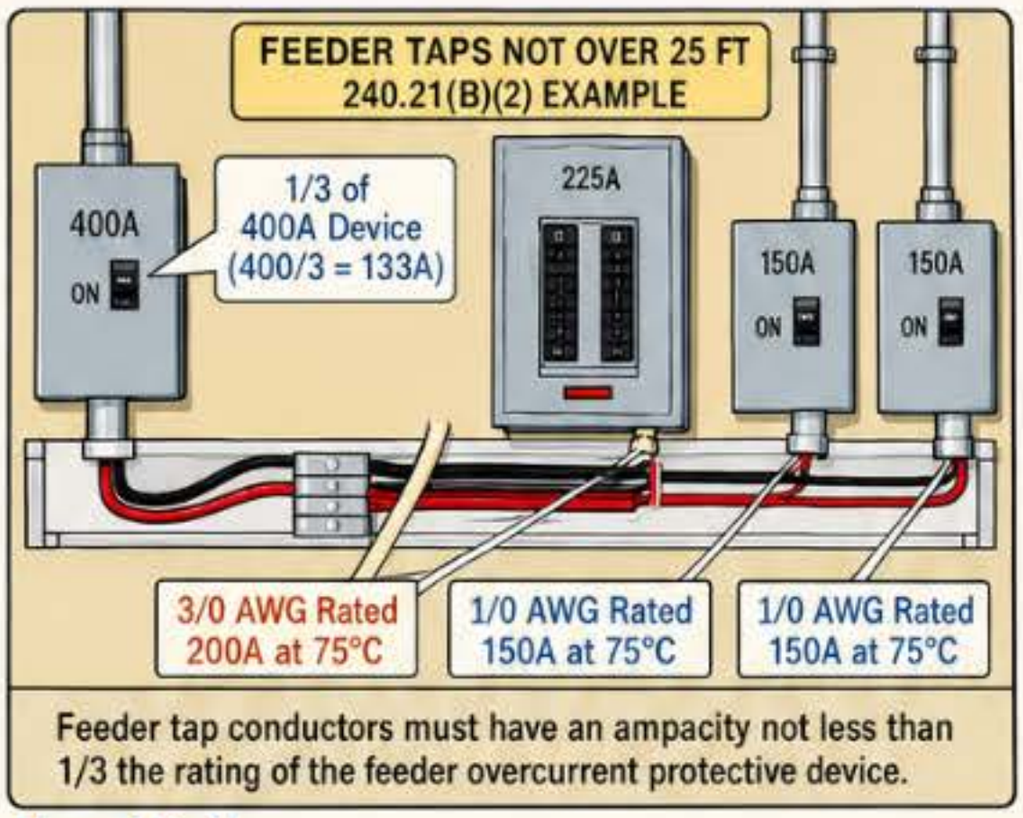


Figure 240-27

▶ 25-Foot Tap Example 2

Question: *What size 25-ft tap conductor is needed from a 400A circuit breaker to supply a 150A feeder disconnect if the terminals are rated 75°C?* Figure 240-28

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

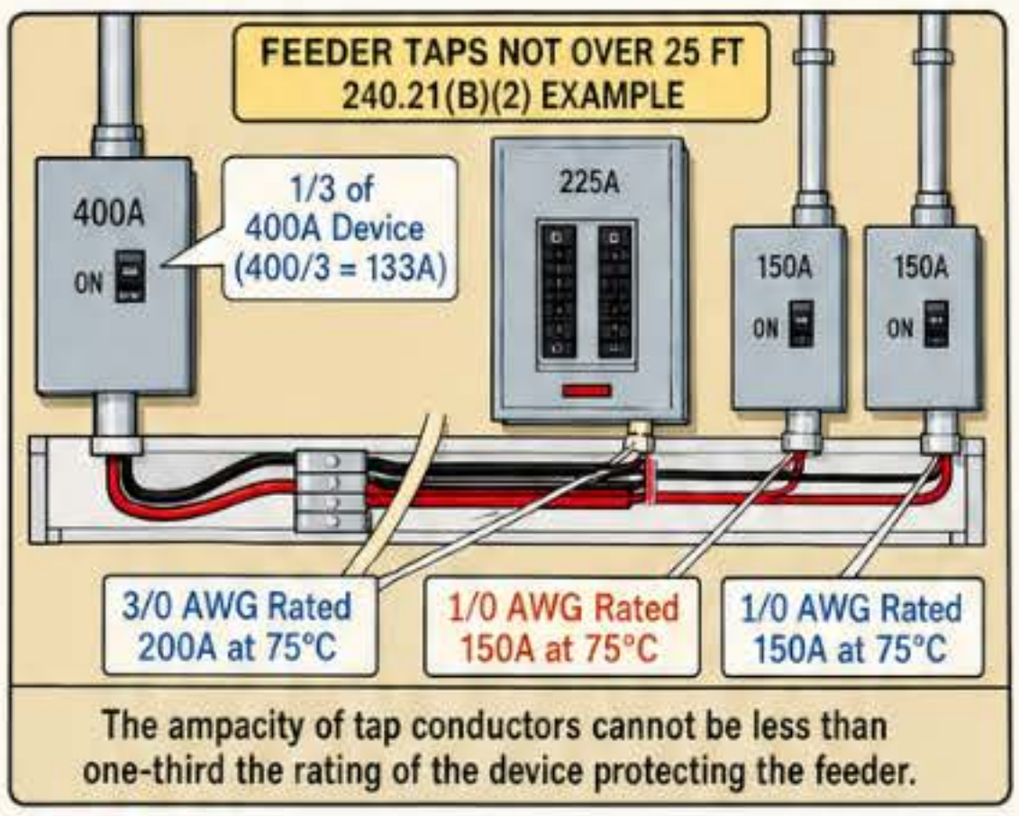


Figure 240-28

Solution:

The tap conductor must have a minimum rating of no less than 133A (1/3 the rating of the 400A overcurrent device).

1/0 AWG is rated 150A at 75°C [110.14(C)(1) and Table 310.16] which is greater than 133A (1/3 the rating of the 400A overcurrent device) and equal to the 150A disconnect.

Answer: *(a) 1/0 AWG*

▶ 25-Foot Tap Example 3

Question: *What size 25-ft tap conductor is needed from a 400A circuit breaker to supply a 30A feeder disconnect if the terminals are rated 75°C?* Figure 240-29

(a) 3 AWG (b) 2 AWG (c) 1 AWG (d) 1/0 AWG

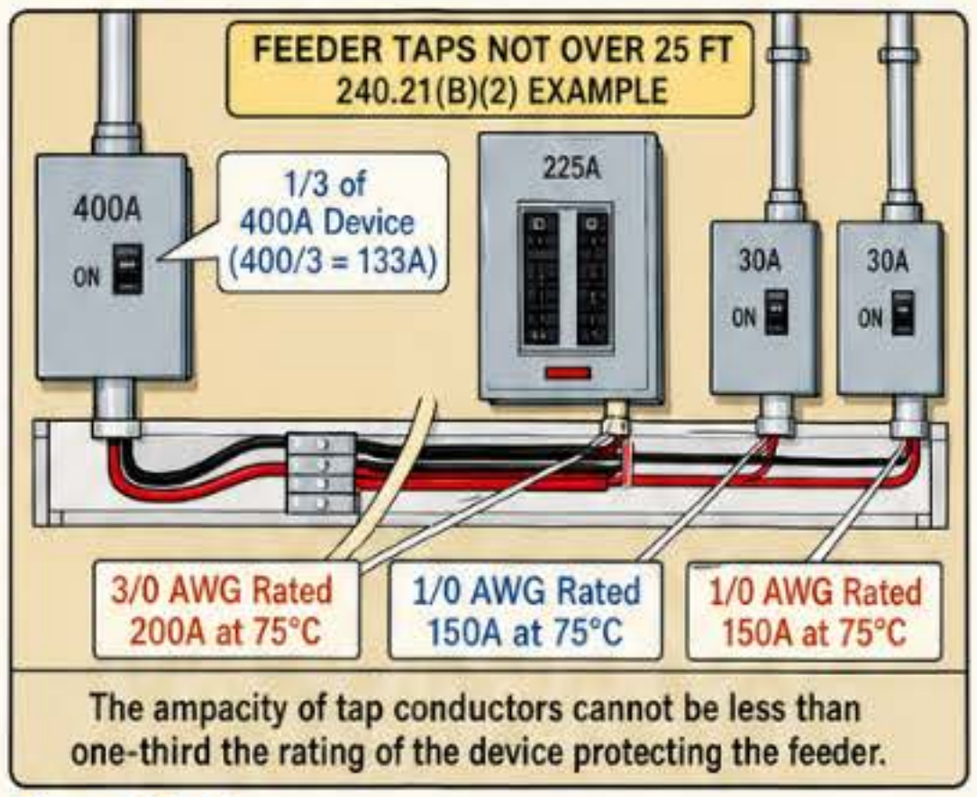


Figure 240-29

Solution:

The tap conductor must have a minimum rating of no less than 133A (1/3 the rating of the 400A overcurrent protective device).

1/0 AWG is rated 150A at 75°C [110.14(C)(1) and Table 310.16] which is greater than 133A (1/3 the rating of the 400A overcurrent device) and greater than the 30A disconnect.

Answer: *(d) 1/0 AWG*

(5) Outside Feeder Taps. *Outside tap conductors can be of unlimited length if they comply with all the following:* Figure 240-30

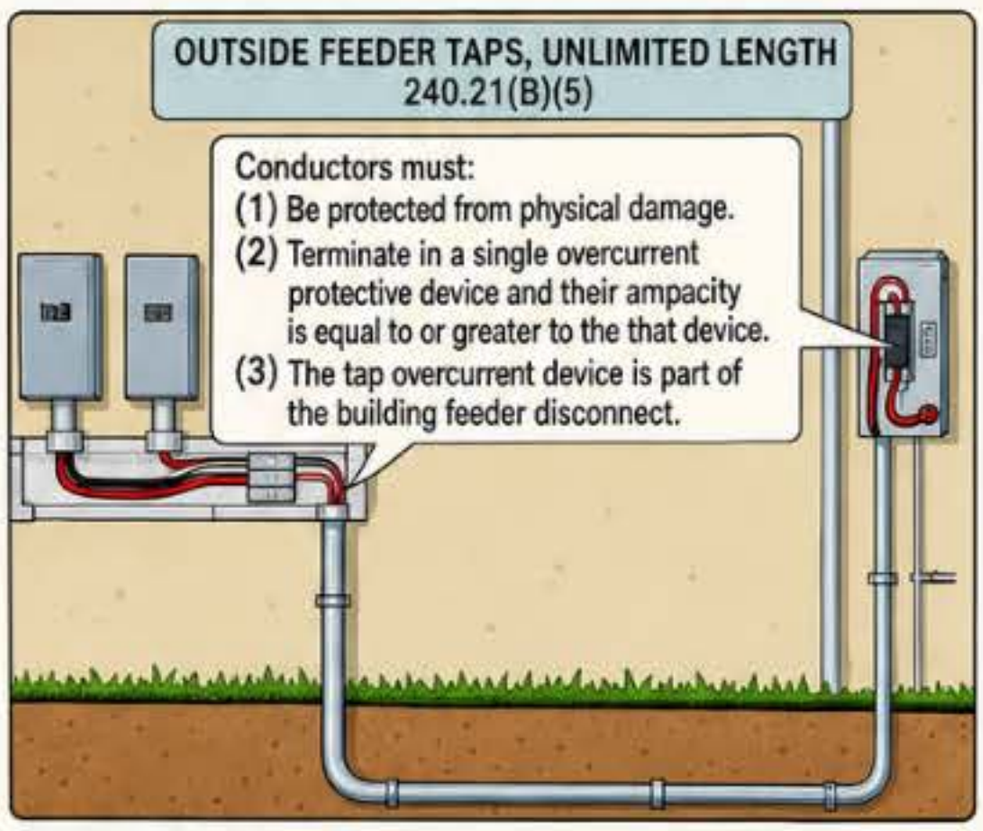


Figure 240-30

240.21 | Overcurrent Protection

(1) The outside tap conductors are protected from physical damage.

(2) The outside tap conductors terminate in a circuit breaker or fuses that limits the load to the ampacity of the conductors.

(3) The tap's overcurrent device is part of the building feeder disconnect.

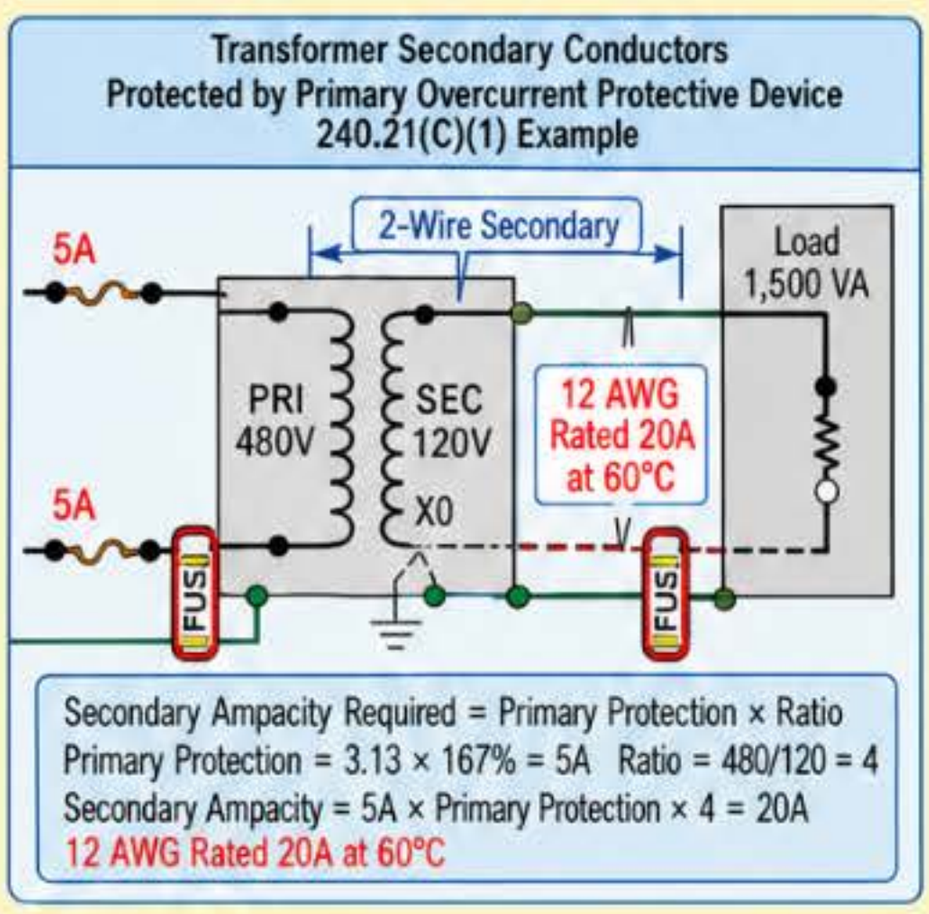
(C) Transformer Secondary Conductors. Secondary conductors must comply with the following:

(1) Protection by Primary Overcurrent Protective Device. The primary overcurrent device sized in accordance with 450.3(B) is considered suitable to protect the secondary conductors of a 2- or 3-wire (single-voltage) system, provided the primary overcurrent device does not exceed the value determined by multiplying the secondary conductor ampacity by the secondary-to-primary transformer voltage ratio.

▶ Example

Question: *What is minimum size secondary conductor required for a single-phase, 1.50 kVA, 480V-to-120V transformer that is protected with a 5A fuse?* ▶ Figure 240–31

(a) 14 AWG (b) 12 AWG (c) 10 AWG (d) 8 AWG



▶ Figure 240–31

Solution:

Step 1: *Determine the primary current.*

VA/E
VA = 1,500 VA
E = 480V

Primary Current = 1,500 VA/480V
Primary Current = 3.13A

Step 2: *Determine the primary overcurrent device [450.3(B)].*

Primary Overcurrent Protection = 3.13A × 167%
Primary Overcurrent Protection = 5.23A, or 5A Fuse

Step 3: *Determine the primary-to-secondary transformer winding ratio.*

Winding Voltage Ratio = Primary Volts/Secondary Volts
Winding Voltage Ratio = 480V/120V
Winding Voltage Ratio = 4 to 1

Step 4: *Determine the secondary conductor minimum ampacity.*

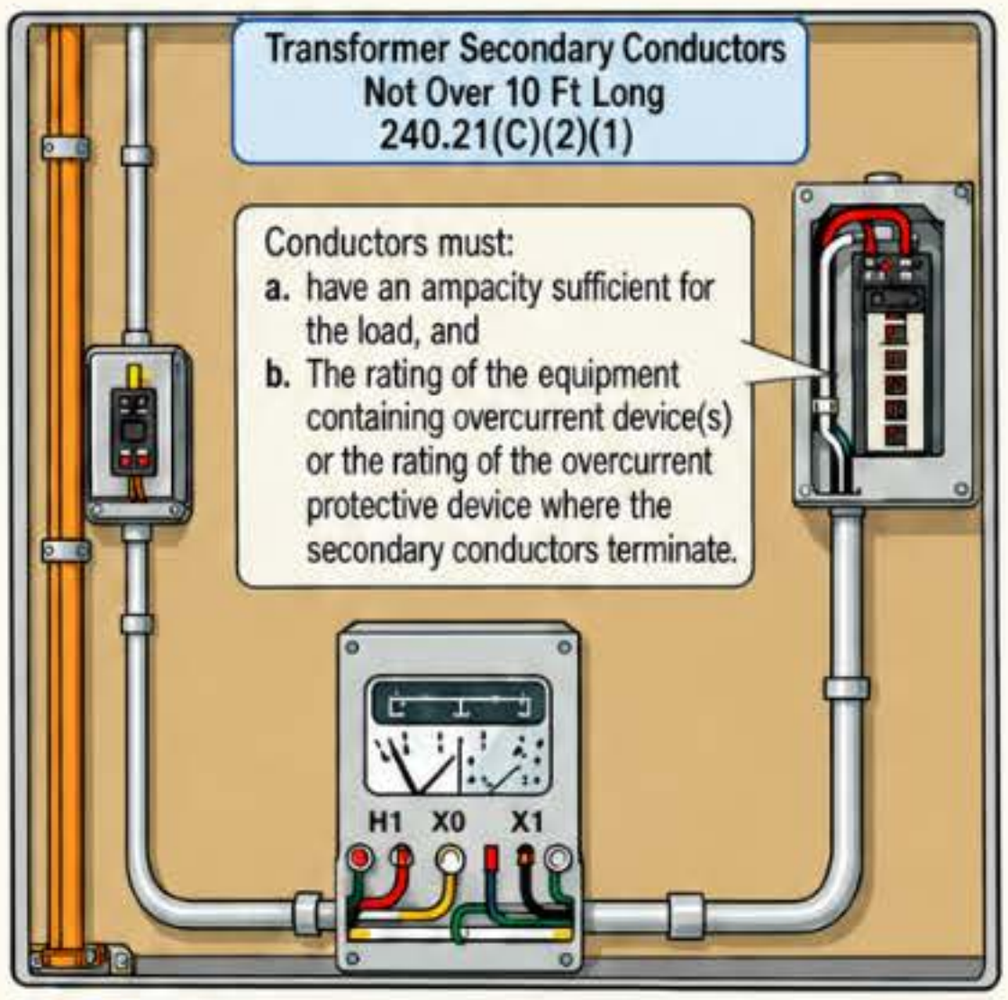
Secondary Ampacity = Primary Overcurrent Protection × Ratio
Secondary Ampacity = Primary of 5A × Winding Voltage Ratio of 4
Secondary Ampacity = 20A

Use a 12 AWG conductor rated 20A at 60°C [110.14(C)(1)(a)(2) and Table 310.16].

Answer: *(b) 12 AWG*

(2) Secondary Conductors Not Over 10 Feet. Secondary conductors up to 10 ft long are permitted when they comply with the following:

(1) The secondary conductor must have an ampacity of not less than: ▶ Figure 240–32



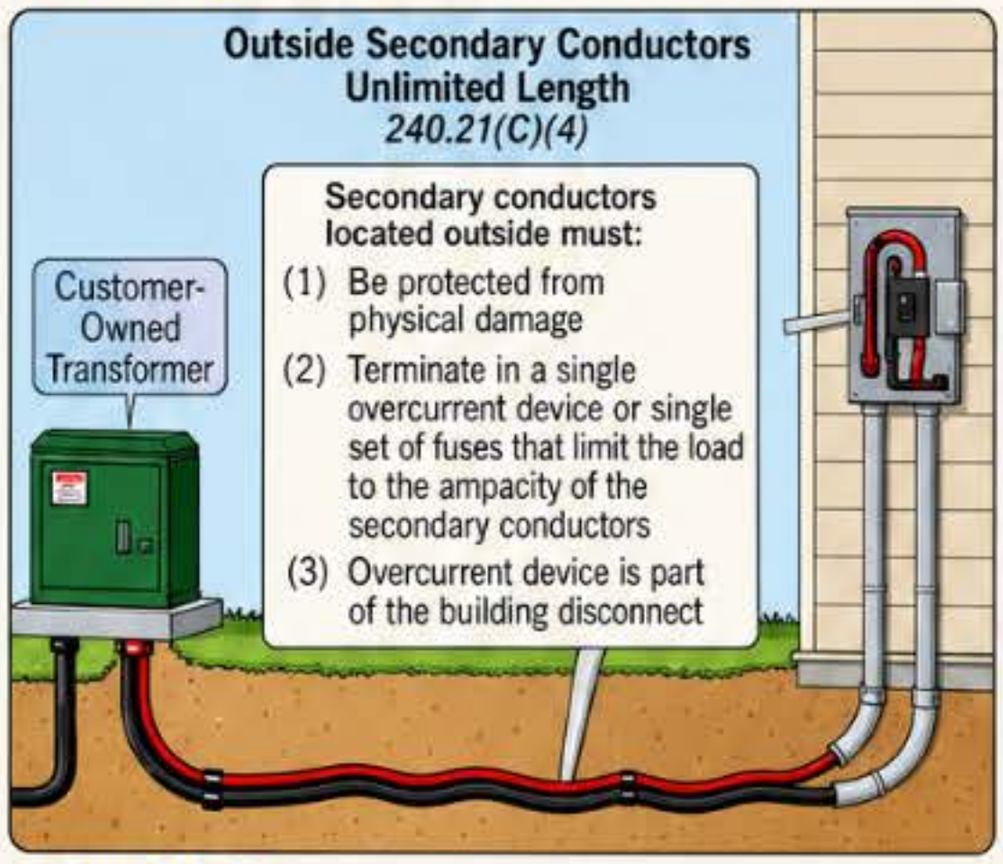
▶ Figure 240–32

a. The calculated load in accordance with Article 220, and

b. The secondary conductor has an ampacity equal to or greater than the overcurrent device(s) or equipment supplied by the secondary conductors.

Overcurrent Protection | 240.24

(4) Outside Secondary Conductors of Unlimited Length. Secondary conductors that are installed outside a building may be any length when all of the following conditions in Figure 240–33 are satisfied.



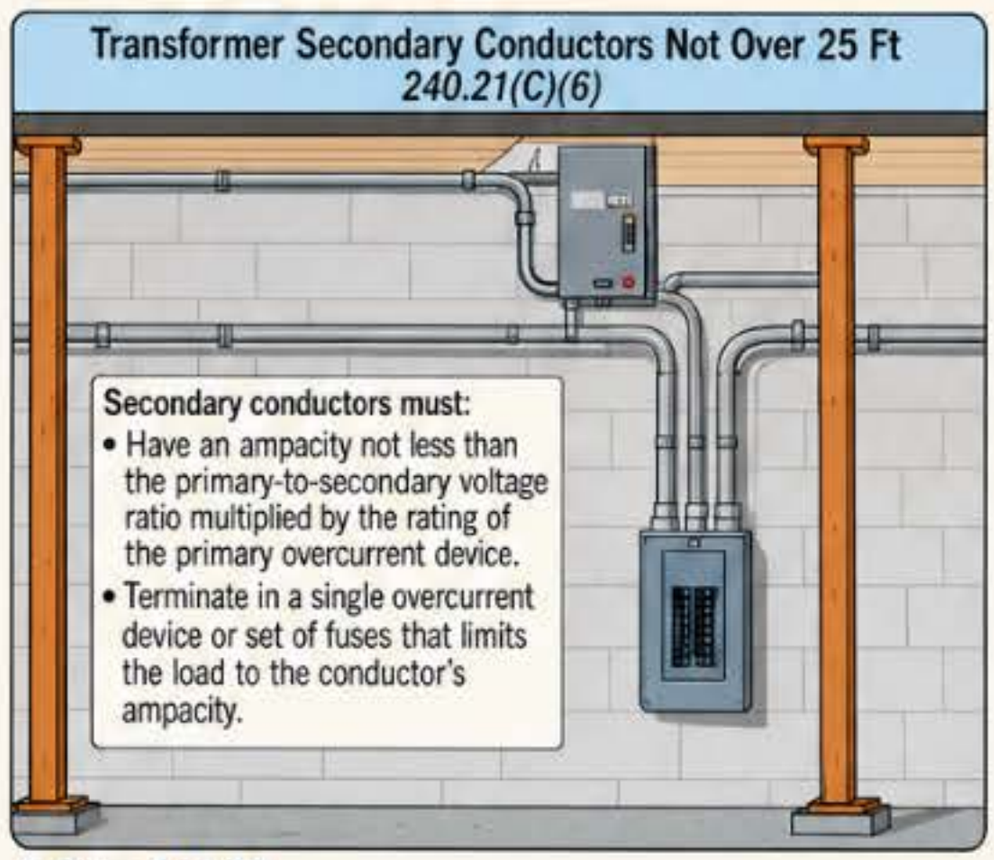
▲ Figure 240–33

(1) These outside secondary conductors must be shielded from physical harm.

(2) They must end at a single overcurrent protective device, whose ampacity is the same as or higher than that of the conductors it protects.

(3) The overcurrent device must be included as part of the building's disconnecting means.

(6) Secondary Conductors Not Over 25 Feet. Conductors up to 25 ft (7.6 m) in length are permitted when every condition listed in Figure 240–34 is met.



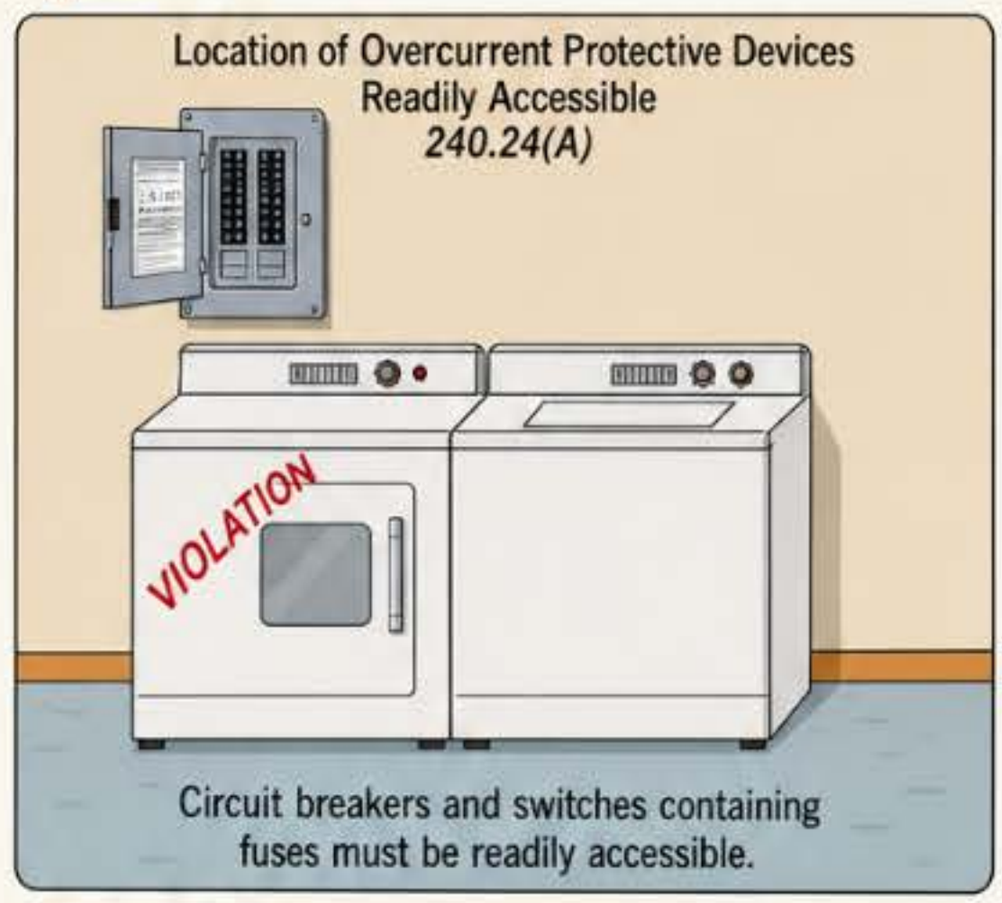
▲ Figure 240–34

(1) The secondary conductor needs an ampacity that is at least equal to the rating of the overcurrent device on the primary, multiplied by the primary-to-secondary voltage ratio.

(2) The conductors must terminate in an overcurrent protective device with an ampacity not less than the rating of the primary overcurrent device.

240.24 Location of Overcurrent Protective Devices at Premises

(A) Readily Accessible. Circuit breakers and switches that use fuses must be easy to reach, with their handles or switches located at the center of the operating grip. When the handle is in its highest position, it cannot be more than 6 ft 7 in. (2.0 m) above the floor or work surface, except as described in Figure 240–35.



▲ Figure 240–35

(2) Extra overcurrent protection, as described in 240.10, does not have to be in a readily accessible location. ▶ Figure 240–36

(4) Overcurrent devices are allowed to be located between 6 ft and 7 ft 7 in. (1.8–2.3 m) above the floor when they are mounted on equipment of a kind that must be portable and readily accessible is not required. ▶ Figure 240–37

(C) Not Exposed to Physical Damage. Overcurrent devices are not permitted to be located where they could be subject to physical injury.

Note: Electrical equipment must be suitable for its environment, and suitable precautions must be provided in areas where corrosive gases, fumes, vapors, liquids, or chemicals exist that may have a deteriorating effect on conductors or equipment [110.11]. ▶ Figure 240–38

240.24 | Overcurrent Protection

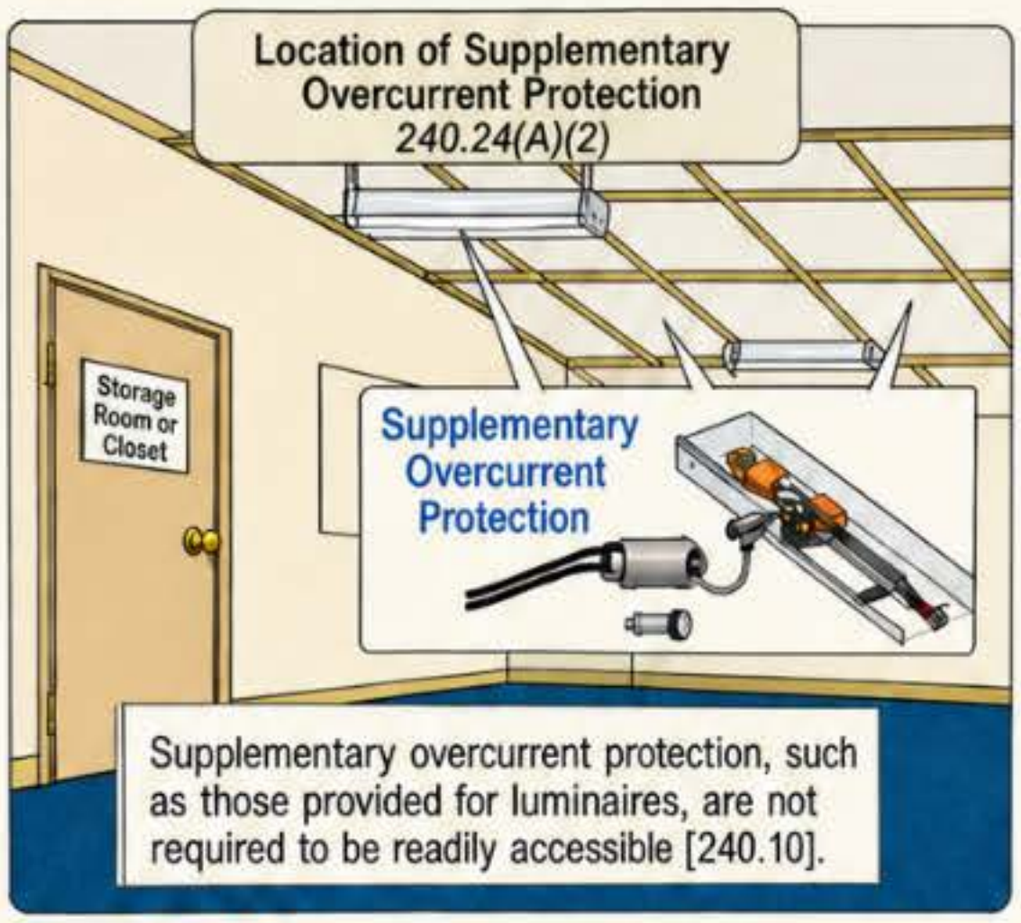


Figure 240–36

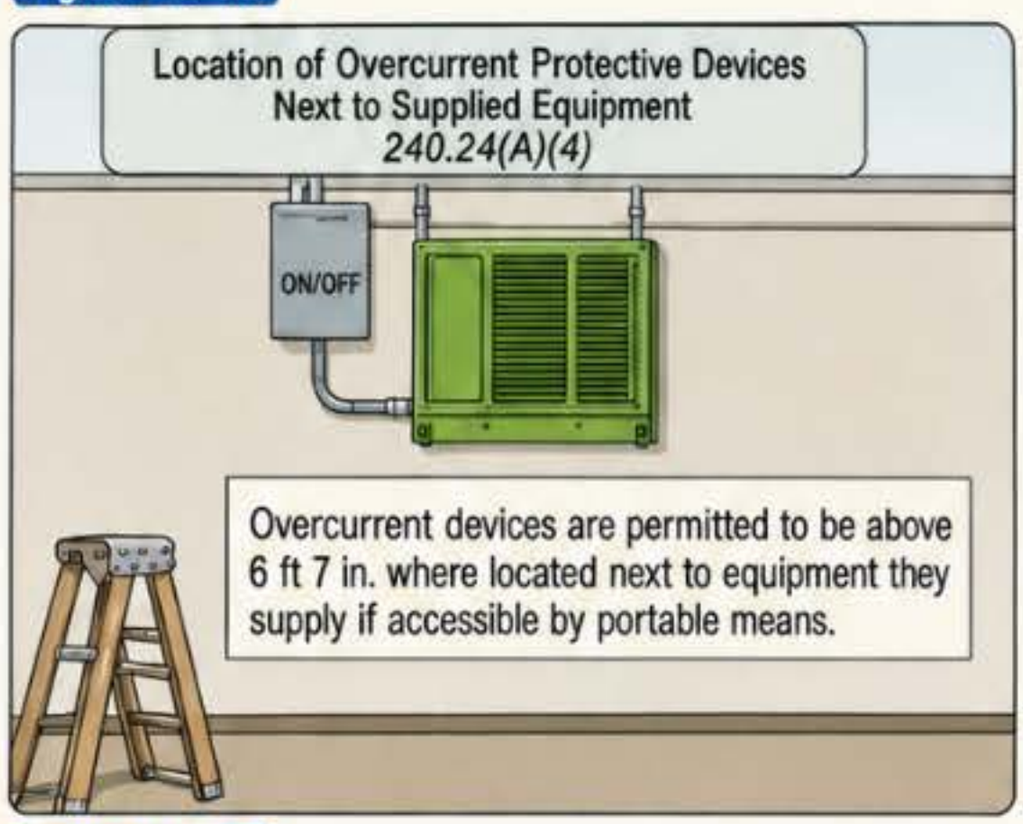


Figure 240–37

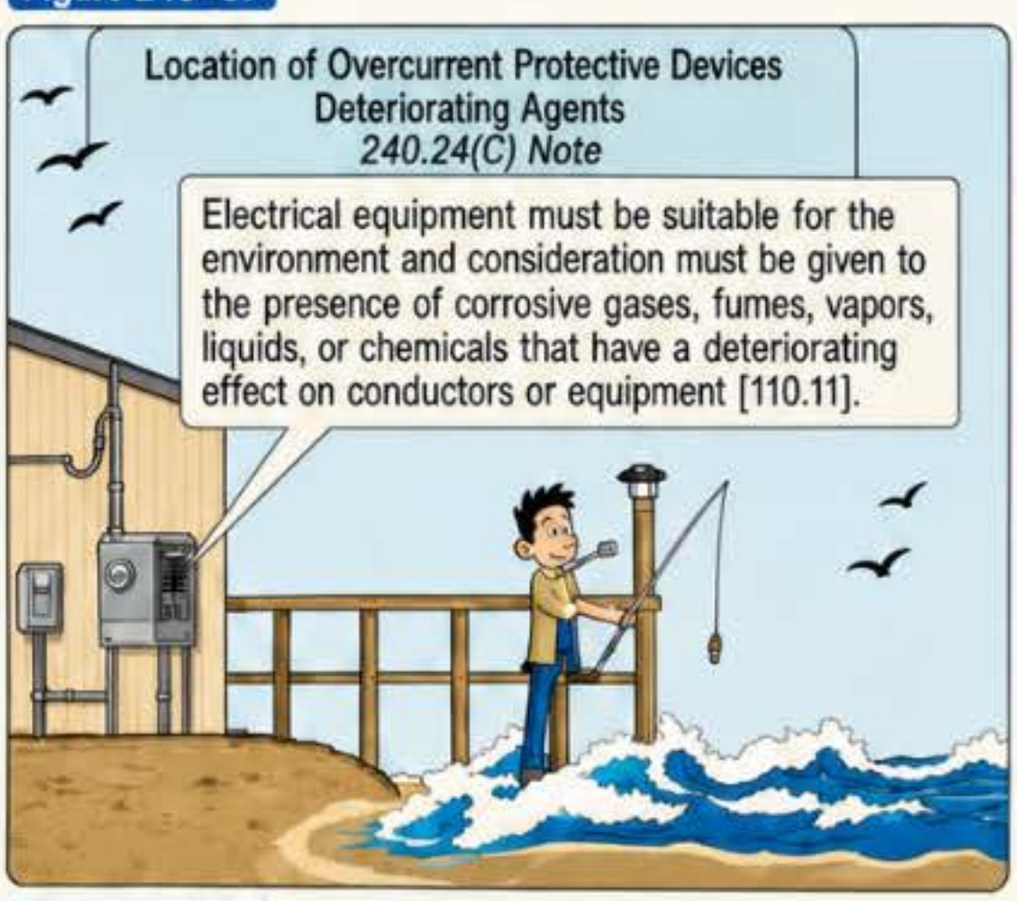


Figure 240–38

(D) Not in Vicinity of Easily Ignitable Material. Overcurrent devices cannot be located near easily ignitable material, such as in clothes closets. • Figure 240–39

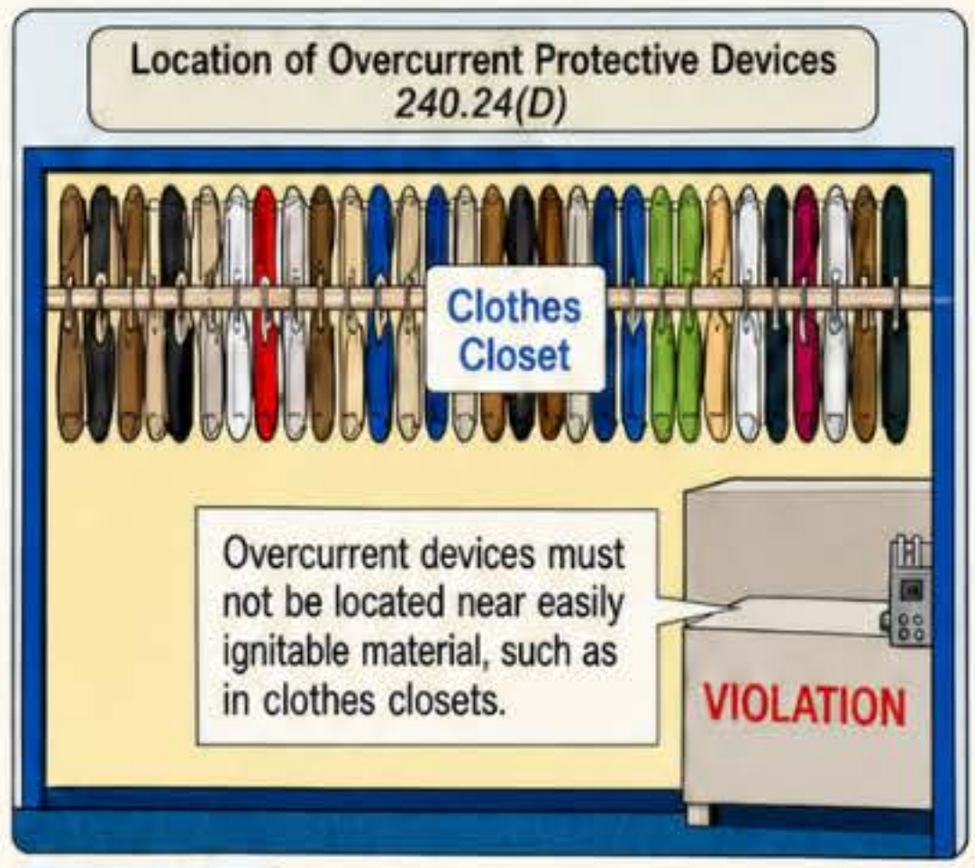


Figure 240–39

(E) Not in Bathroom Areas. Overcurrent devices must not be installed in the bathroom areas of dwelling units, dormitory units, or guest rooms or guest suites of hotels. • Figure 240–40

Figure 240–40

Author's Commentary:

A service disconnect switch is not permitted to be installed in a bathroom area, even in commercial or industrial facilities [230.70(A)(2)].

— Michael Hamilton

(F) Not Over Steps. Overcurrent devices are not allowed to be placed above the steps of a stairway. Figure 240–41.

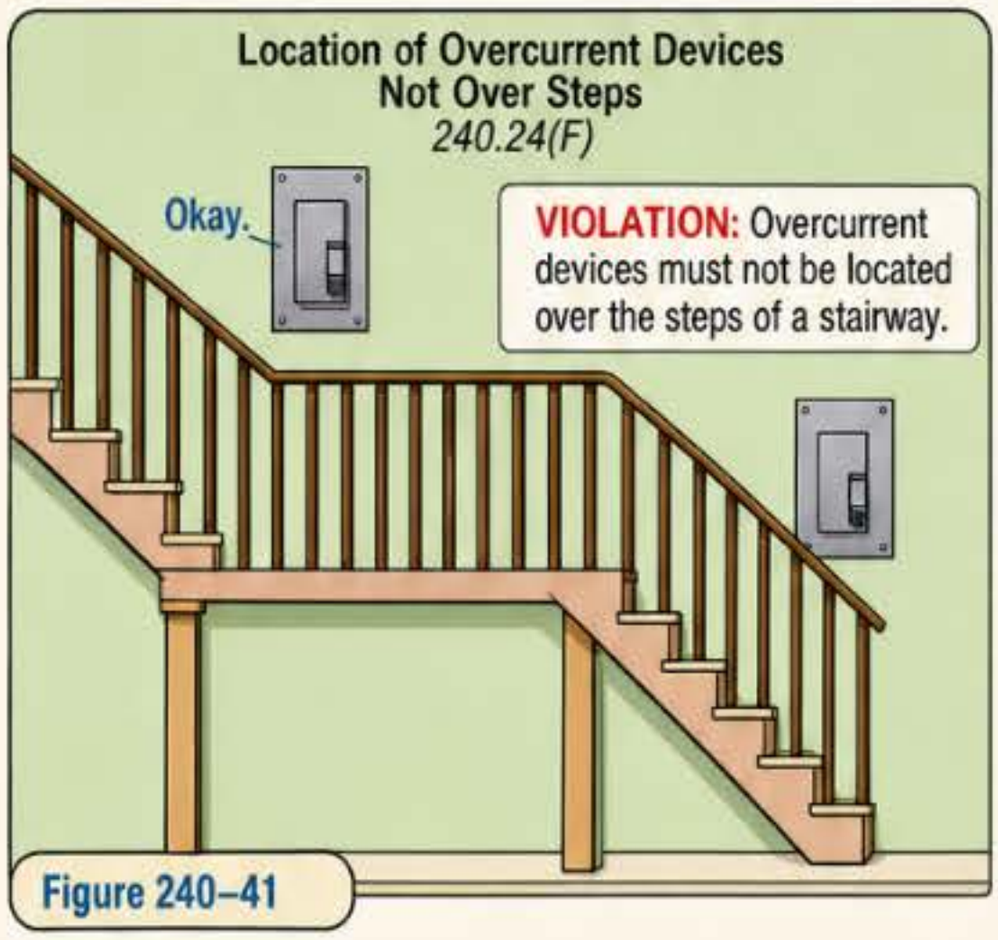


Figure 240–41

Author's Commentary:

Electrical professionals face challenges when equipment is positioned on uneven surfaces such as stairways.

— Michael Hamilton

Part III. Enclosures

240.33 Vertical Position

Enclosures that contain overcurrent devices have to be installed in a vertical orientation. Circuit-breaker panels can be set horizontally only if the breakers are listed in accordance with 240.81. Figure 240–42.

Author's Commentary:

- *Section 240.81 specifies the operating position of circuit-breaker handles. "Up" is the ON position of the handle and "down" is the OFF position. As a result, a panel with one or more breakers installed sideways must have a label, and enclosures with multiple opposing breakers need to be installed upright.*

— Michael Hamilton

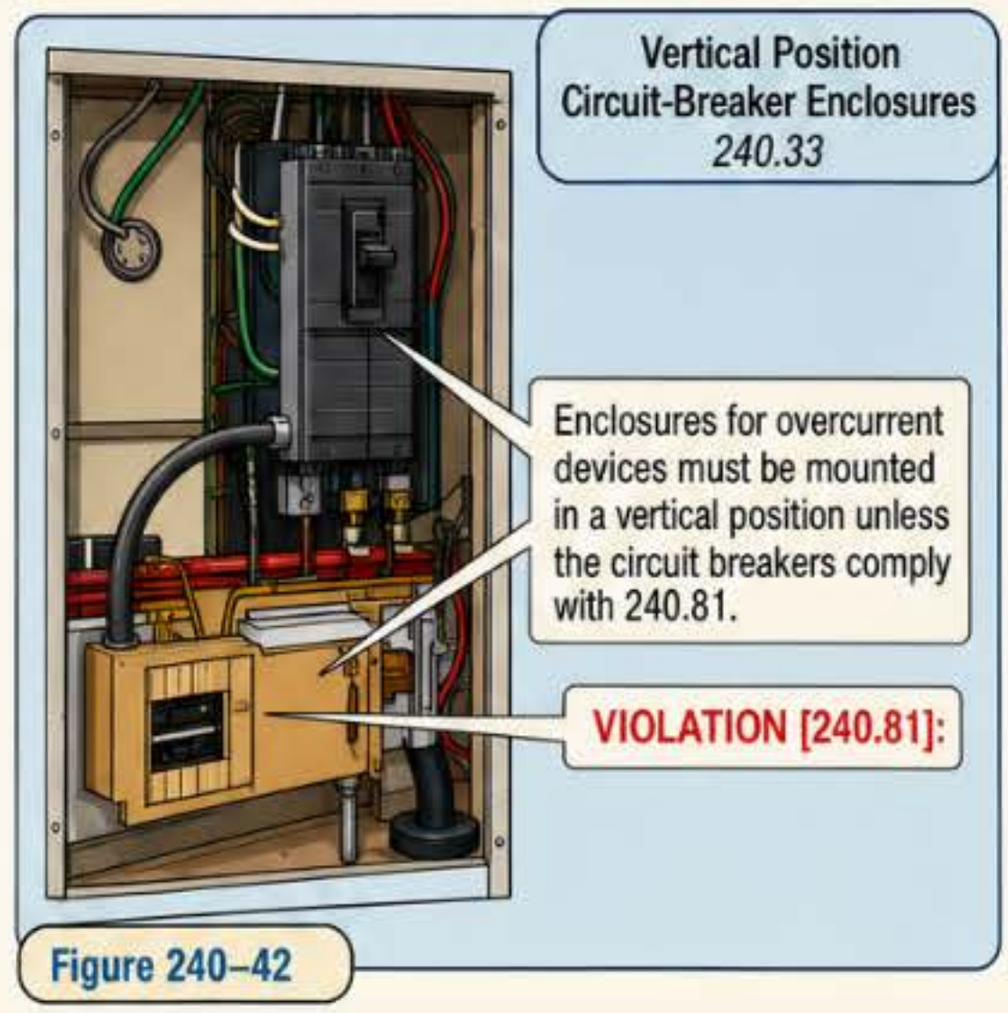


Figure 240–42

Part IV. Disconnecting and Guarding

240.40 Disconnecting Means for Fuses

Cartridge fuses and fuse links in circuits above 150 volts to ground must be provided with a disconnecting means on the supply side of each circuit that contains fuses. This disconnect must be independent from the power source. Figure 240–43.

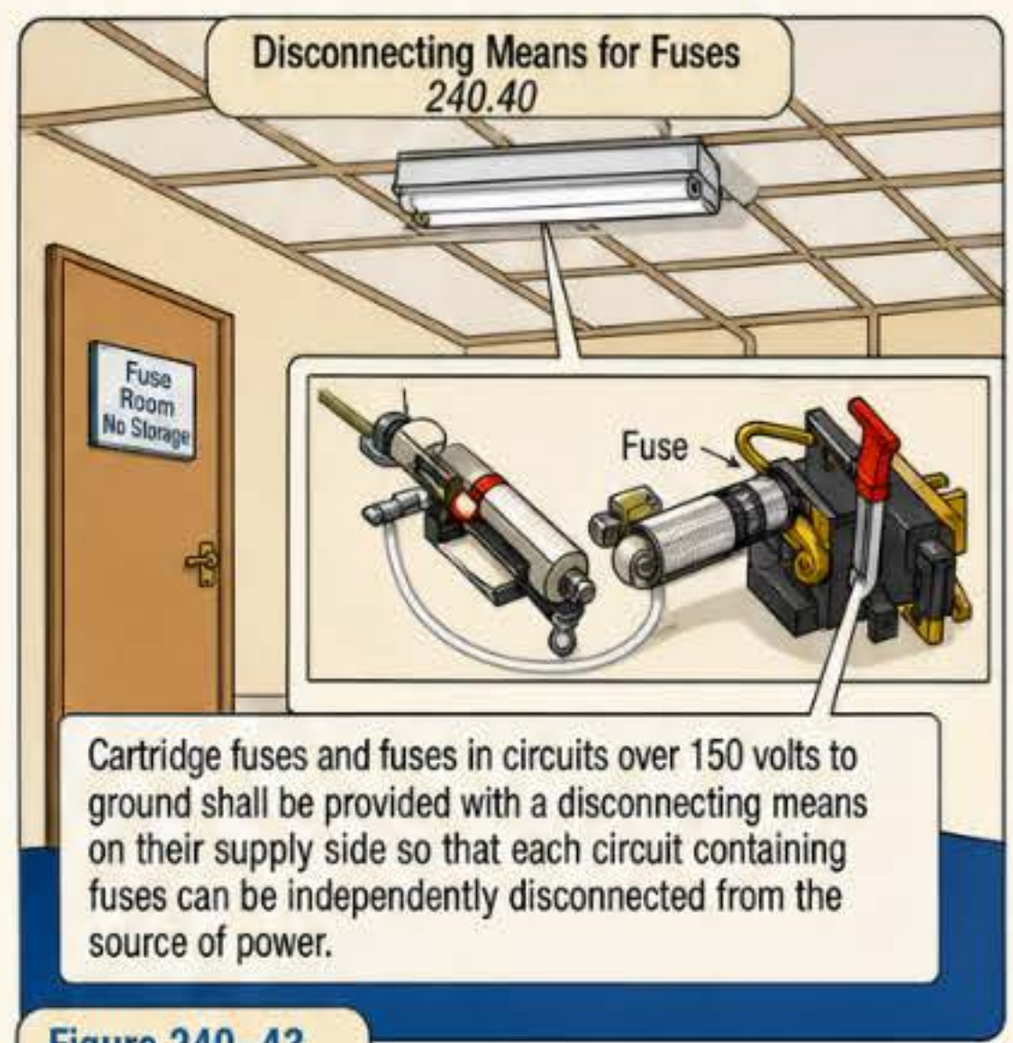


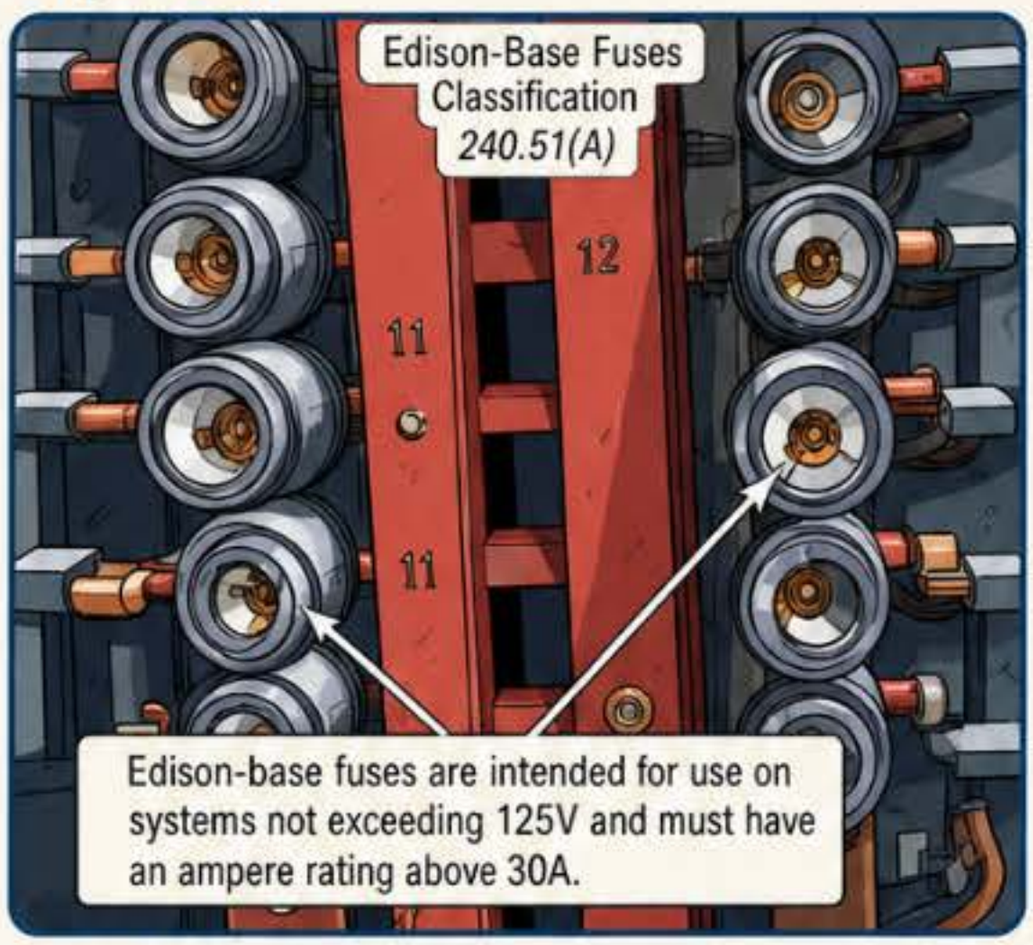
Figure 240–43

Part V. Plug Fuses, Fuseholders, and Adapters

240.51 Edison-Base Fuses

(A) Classification. Edison-base fuses are intended for use on systems not exceeding 125V and must have an ampere rating above 30A.

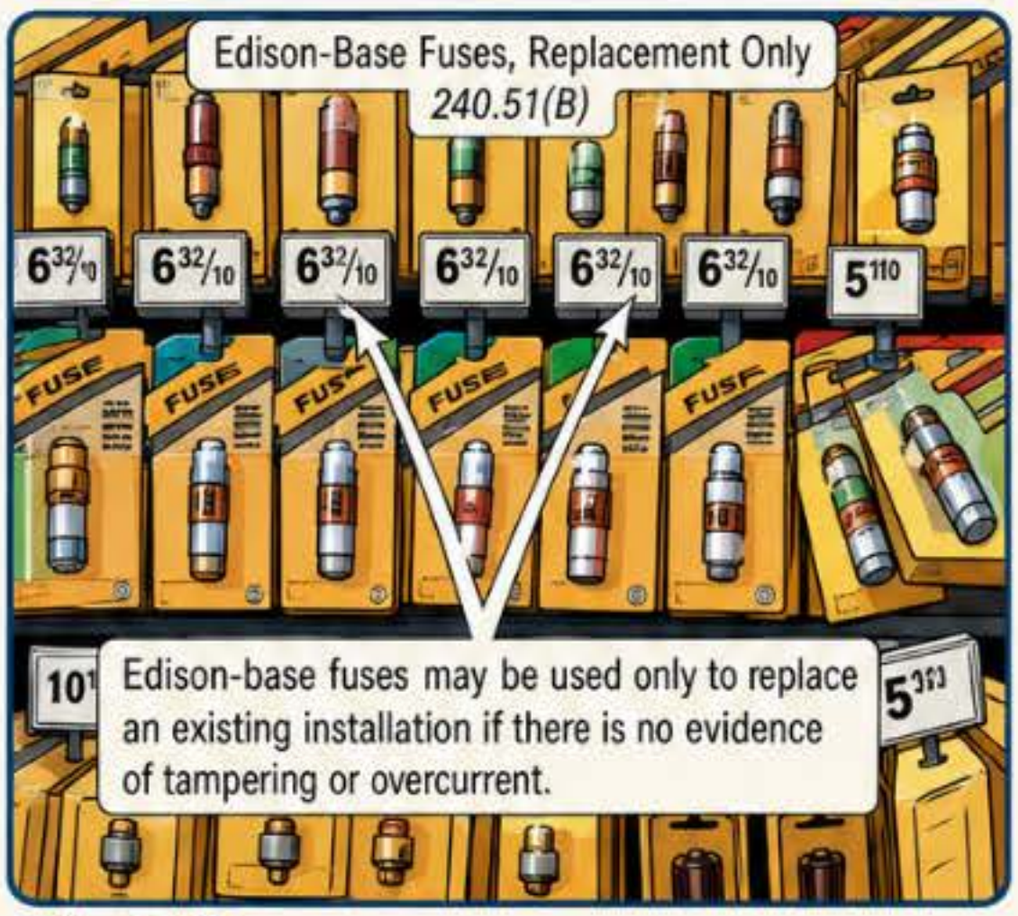
▶ Figure 240–44



▶ Figure 240–44

(B) Replacement Only. Edison-base fuses may be used only to replace an existing installation if there is no evidence of tampering or overcurrent.

▶ Figure 240–45



▶ Figure 240–45

Part VI. Cartridge Fuses and Fuseholders

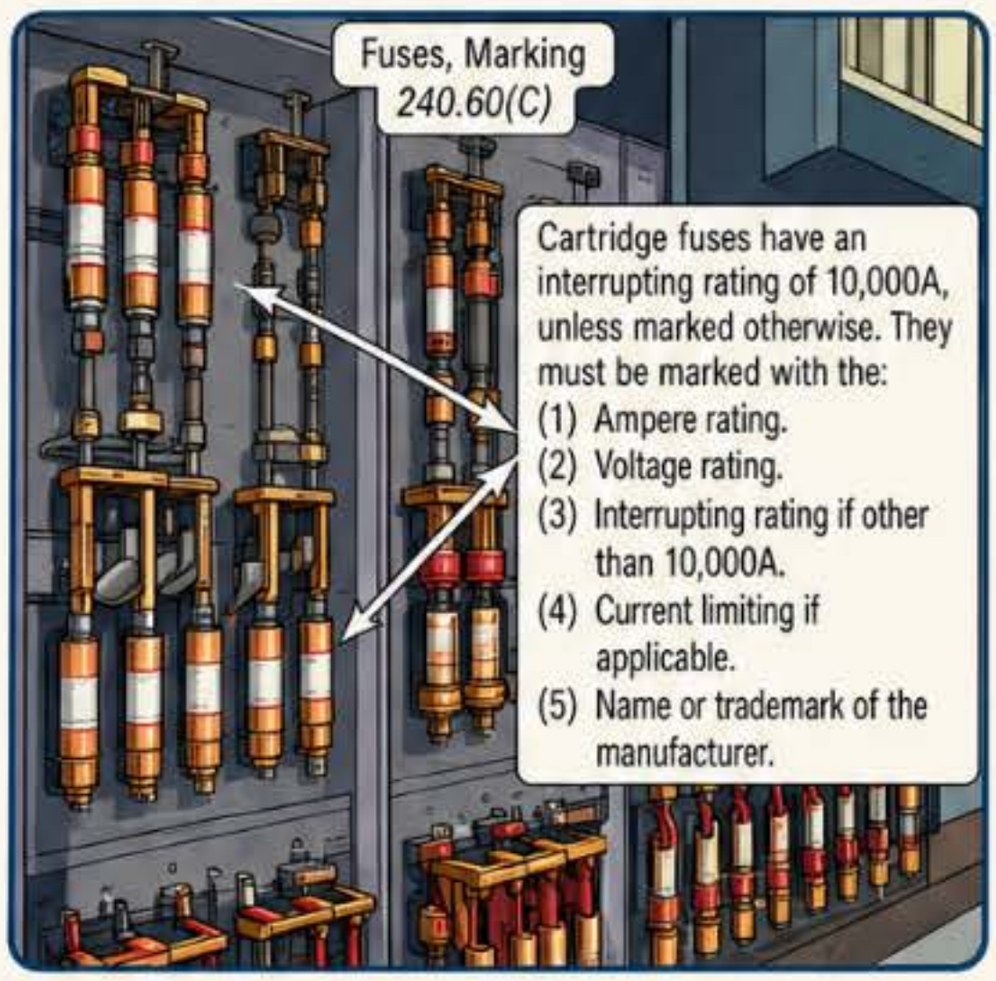
240.60 General

(B) Noninterchangeable—0A to 6,000A Cartridge Fuseholders. Fuseholders must be designed so it will be difficult to put a fuse of any given class into a fuseholder designed for a current lower, or voltage higher, than that of the class to which the fuse belongs. Fuseholders for current-limiting fuses must not permit insertion of fuses that are not current-limiting.

(C) Marking. Cartridge fuses have an interrupting rating of 10,000A, unless marked otherwise. They must be marked with the:

▶ Figure 240–46

(1) Ampere rating.
(2) Voltage rating.
(3) Interrupting rating if other than 10,000A.
(4) Current limiting if applicable.
(5) Name or trademark of the manufacturer.



▶ Figure 240–46

Warning

Fuses must have an interrupting rating sufficient for the prospective current available at the terminals of the equipment. Using a fuse with an inadequate interrupting current rating can cause equipment to be destroyed from a line-to-line or ground fault and result in death or serious injury. See 110.9 for more details.

▶ Figure 240–47

240.67 Arc Energy Reduction—Fuses

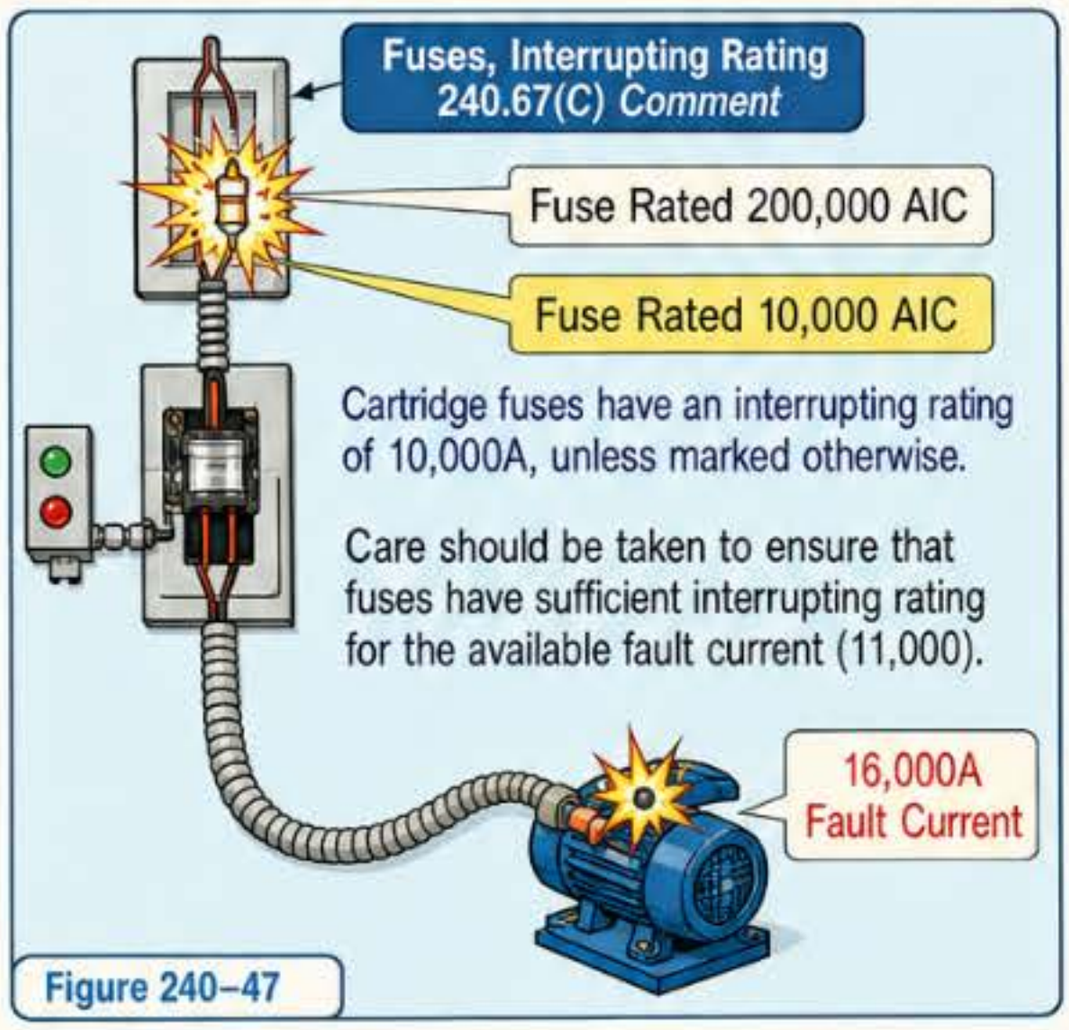
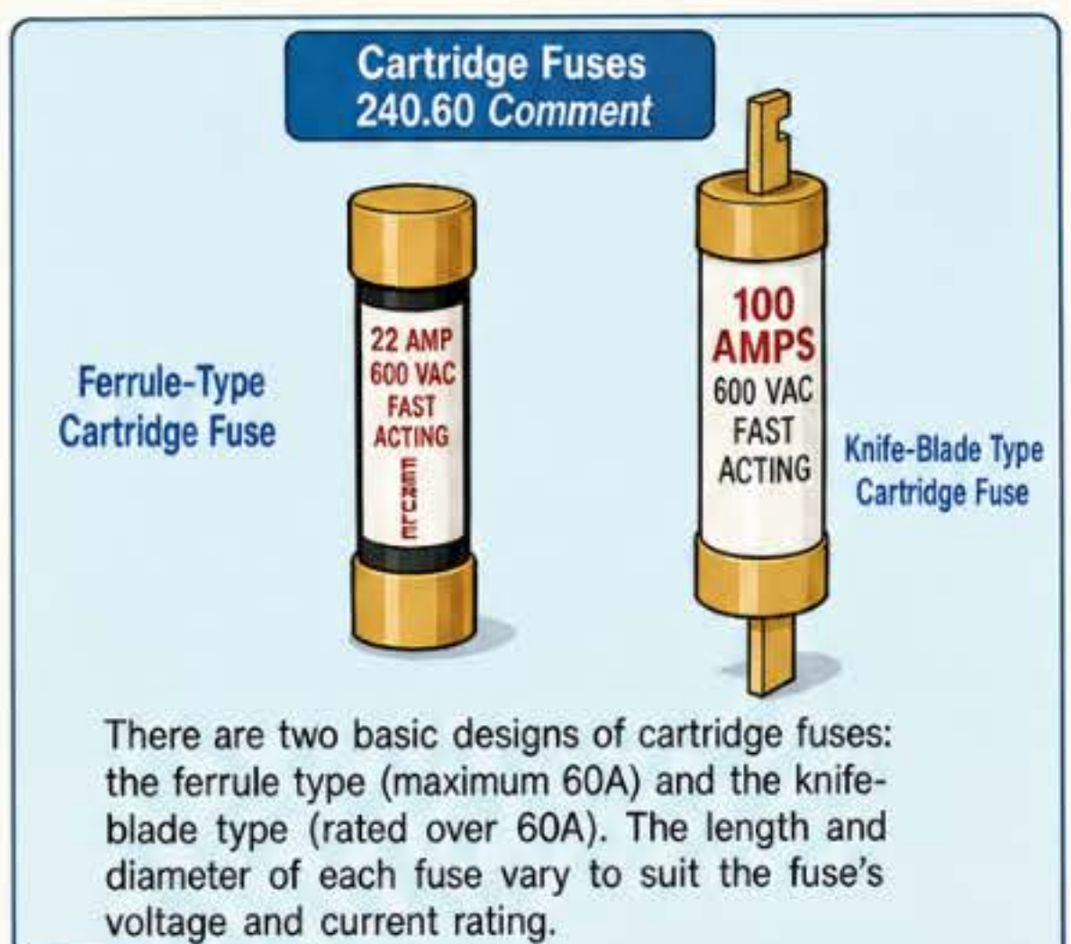


Figure 240–47

Author's Commentary:

There are just two common configurations of cartridge fuses: the ferrule style with a maximum rating of 60A and the knife-blade style rated above 60A. Both fuse variants come in many lengths and diameters to match various voltage and current ratings.

— Michael Hamilton



There are two basic designs of cartridge fuses: the ferrule type (maximum 60A) and the knife-blade type (rated over 60A). The length and diameter of each fuse vary to suit the fuse's voltage and current rating.

Figure 240–48

240.67 Arc Energy Reduction—Fuses

Where fuses rated 1,200A or greater are installed, 240.67(A) and (B) must be applied.

(A) Documentation. Documentation must be available to those authorized to design, install, operate, or inspect the system to clearly show how the installation was chosen. This document must show that the chosen approach lowers clearing time to operate at a value below the available arcing current.

(B) Method to Reduce Clearing Time. A fuse must clear within 0.07 seconds or less at the available arcing current, or one of the following options must be provided and set to operate at less than the available arcing current:

1. Differential relaying.
2. Energy-reducing maintenance switching with local status indicator.
3. Energy-reducing active arc-flash mitigation system.
4. Current-limiting, electronically actuated fuses.
5. An approved equivalent means.

Note 1: An energy-reducing maintenance switch lets a worker use a disconnect switch to quickly cut clearing time while *they are inside an arc-flash boundary as defined in NFPA 70E, Standard for Electrical Safety in the Workplace, and then reset the switch to normal after the potential hazard is removed.*

Note 2: *Active arc-flash mitigation systems shorten arcing duration in the electrical distribution system. No modification to the disconnect switch or other settings is needed during maintenance when a worker is within an arc-flash boundary as defined in NFPA 70E, Standard for Electrical Safety in the Workplace.*

Note 3: *IEEE 1584, IEEE Guide for Performing Arc Flash Hazard Calculations, is a resource that lists approved methods for determining arcing current.*

(C) Performance Testing. When using a method to cut clearing time as required in 240.67(B), the arc energy reduction system must be performance tested after installation. The test must be conducted by a qualified person according to the manufacturer's instructions.

Performance testing of a component that protects the system must be completed by a qualified person using a proven procedure for primary current injection and the manufacturer's recommended test steps. A written report of testing must be available for review by the authority having jurisdiction.

240.81 OVERCURRENT PROTECTION

Part VII. Circuit Breakers

240.81 INDICATING

When a circuit breaker handle is moved to the vertical "up" position, the handle must be in the "on" position. Refer to 240.33 and 404.6(C).

▶ Figure 240–49

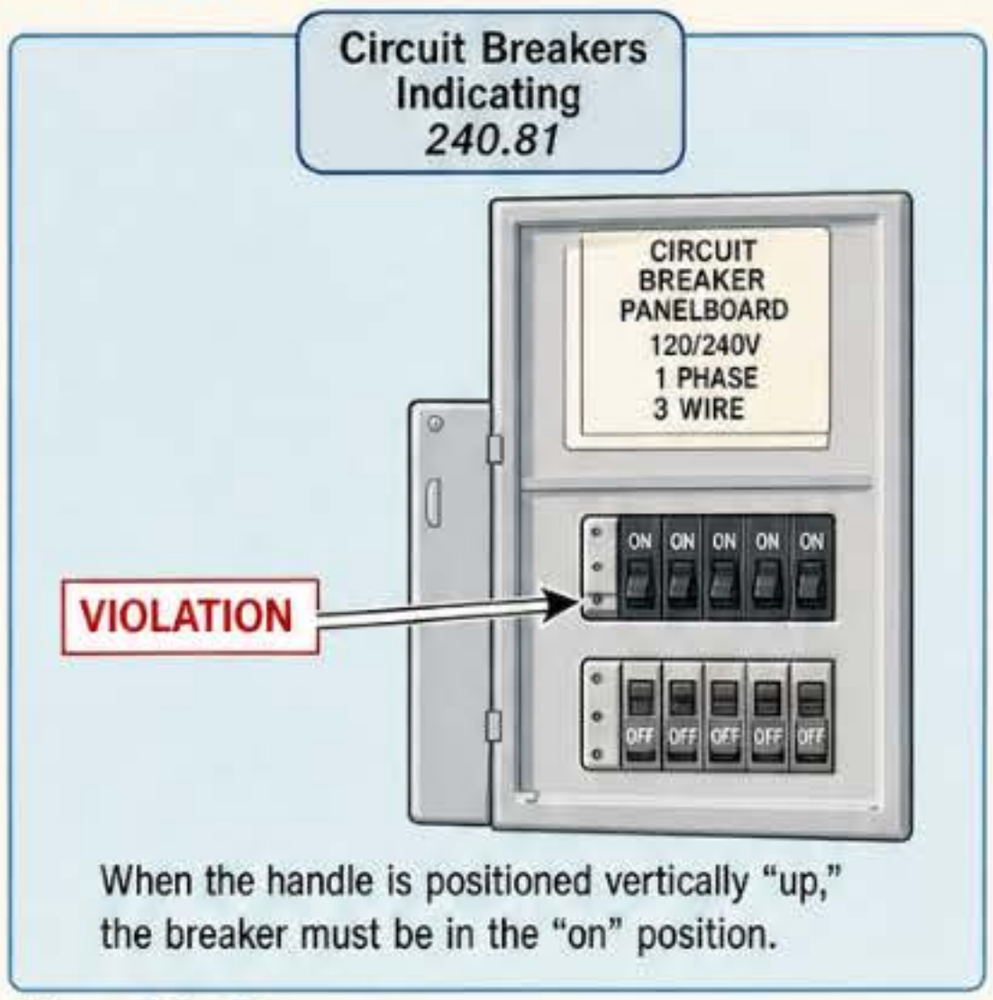


Figure 240–49

240.83 MARKINGS

(C) INTERRUPTING RATING.

Unless marked otherwise, circuit breakers must have an interrupting rating of 5,000A.

> ***Author's Commentary:***
> *Ensure the breaker's interrupting rating is sufficient for the short-circuit current that can occur where the equipment is installed. If a device cannot interrupt that level of current, it can be destroyed, posed a fire hazard, and cause serious injury or even death. See 110.9 for more details.*
>
> *— Michael Hamilton*

(D) USED AS SWITCHES.

Circuit breakers used to control 120V or 277V fluorescent lighting circuits must be listed and marked "SWD" or "HID." Breakers used to operate high-intensity discharge lighting circuits must be listed and marked "HID."

▶ Figure 240–51

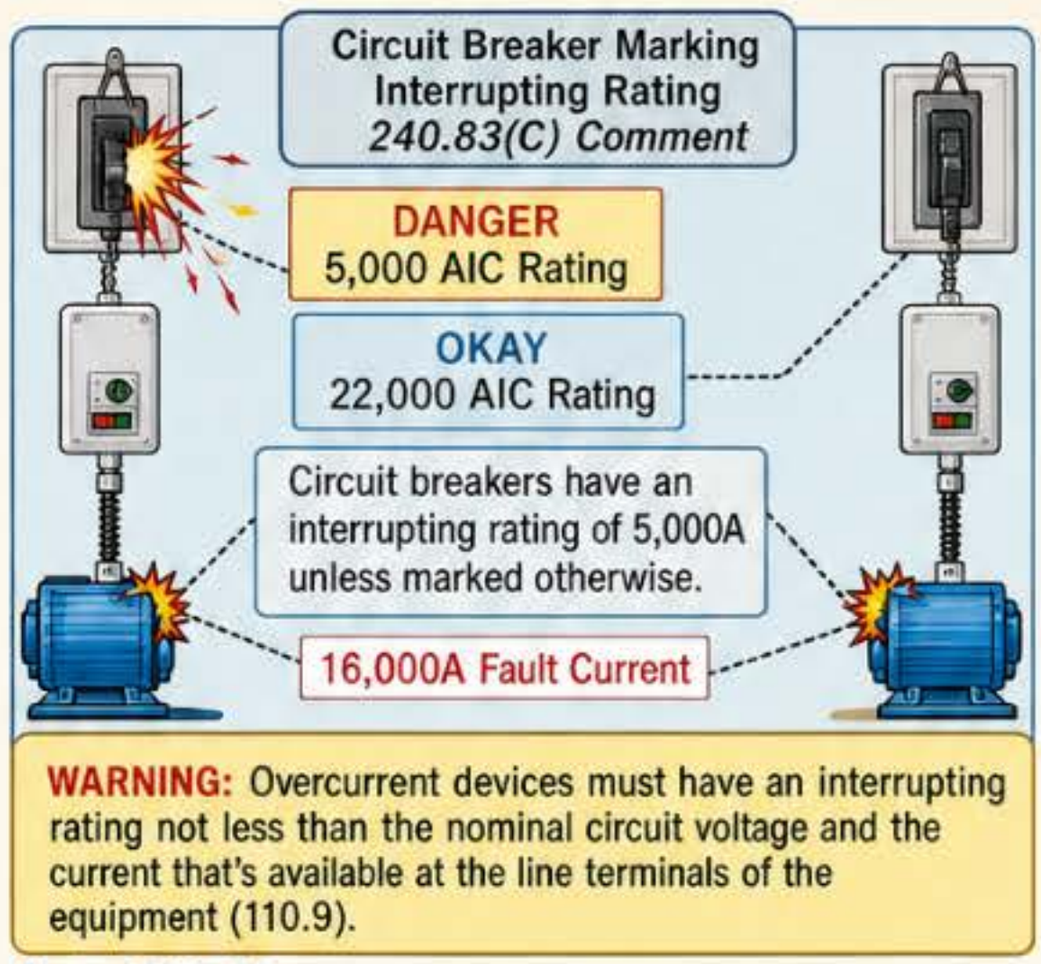


Figure 240–50

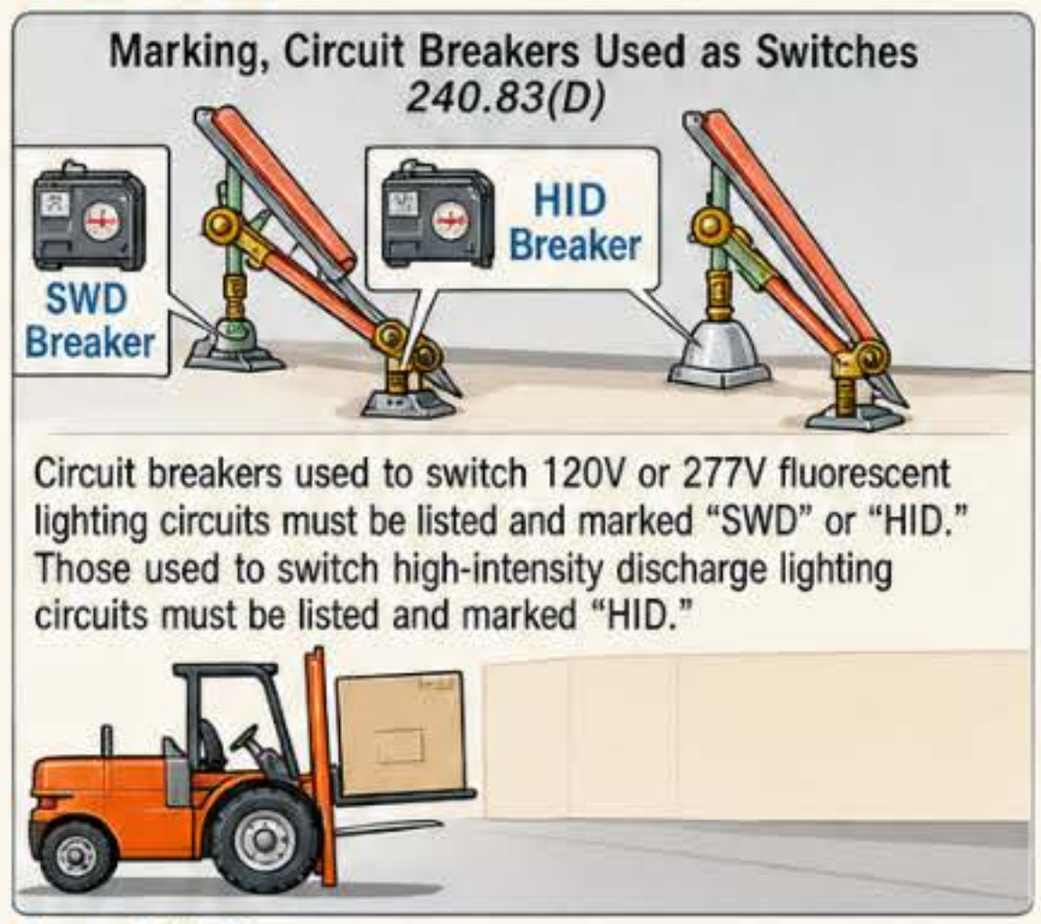


Figure 240–51

> ***Author's Commentary:***
> *UL 489, Standard for Molded Case Circuit Breakers, allows HID breakers to be rated up to 50A, with an SWD breaker limited to 20A. HID breakers undergo a durability test at 75% of their current rating and an endurance test at 100% of their rating. The contacts and switch spring of an HID breaker must withstand heavy-duty usage because the increased current due to heightened heat can cause the HID lamp to ignite in a minute or two.*
>
> *— Michael Hamilton*

240.85 APPLICATIONS

Straight Voltage Rating Circuit Breaker. A circuit breaker with a straight voltage rating (for example, 240V or 480V) is permitted if the nominal voltage between any two conductors (line-to-neutral or line-to-line) does not exceed the circuit breaker's voltage rating. ▶ Figure 240–52 and ▶ Figure 240–53

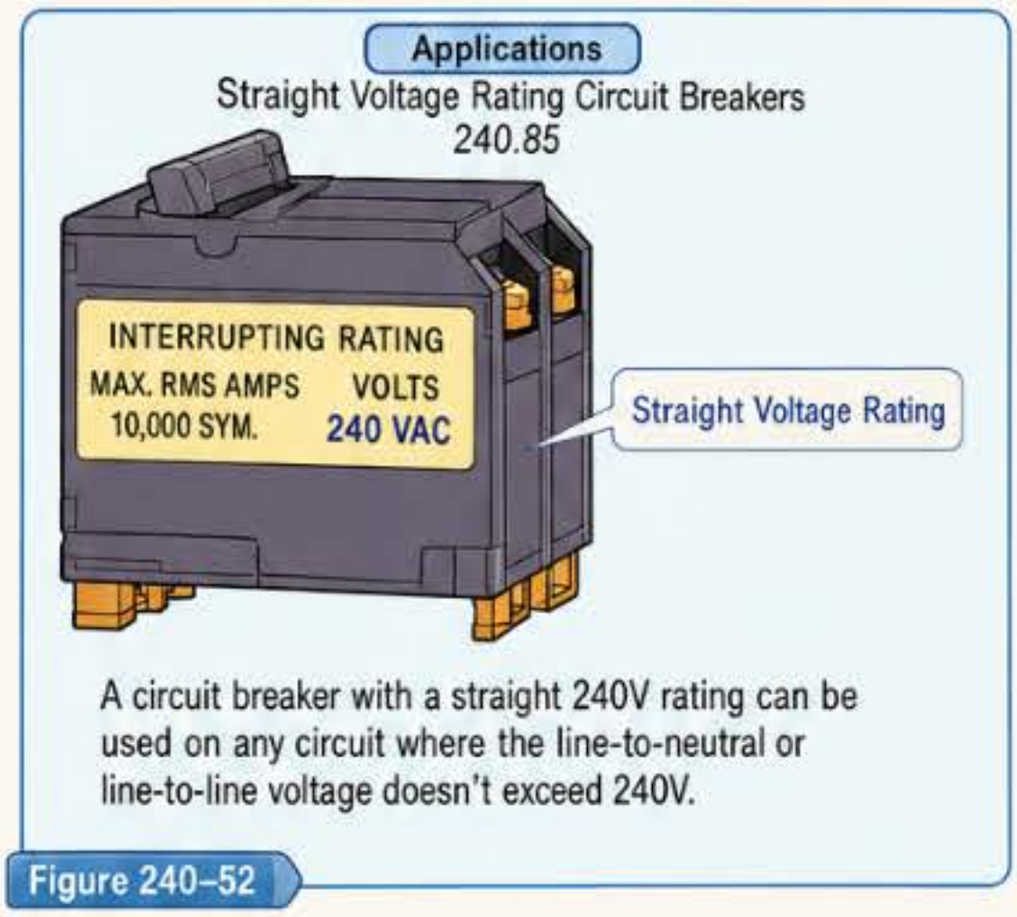


Figure 240–52

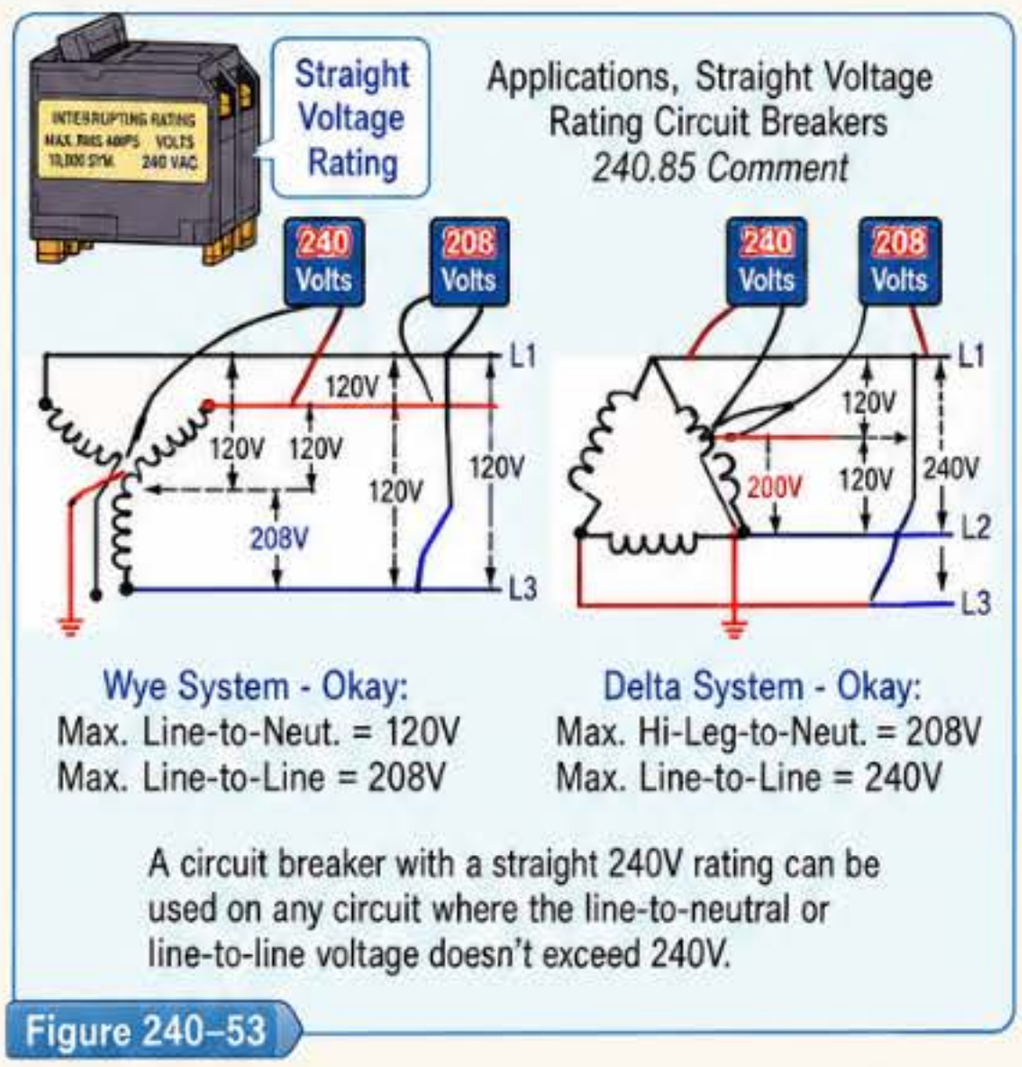


Figure 240–53

Slash Voltage Rating Circuit Breaker. A circuit breaker with a slash rating (such as 120/240V or 277/480V) is only permitted if the nominal voltage of any conductor to ground does not go below the lower of the two values, and the nominal voltage between any two conductors does not exceed the higher value. ▶ Figure 240–54

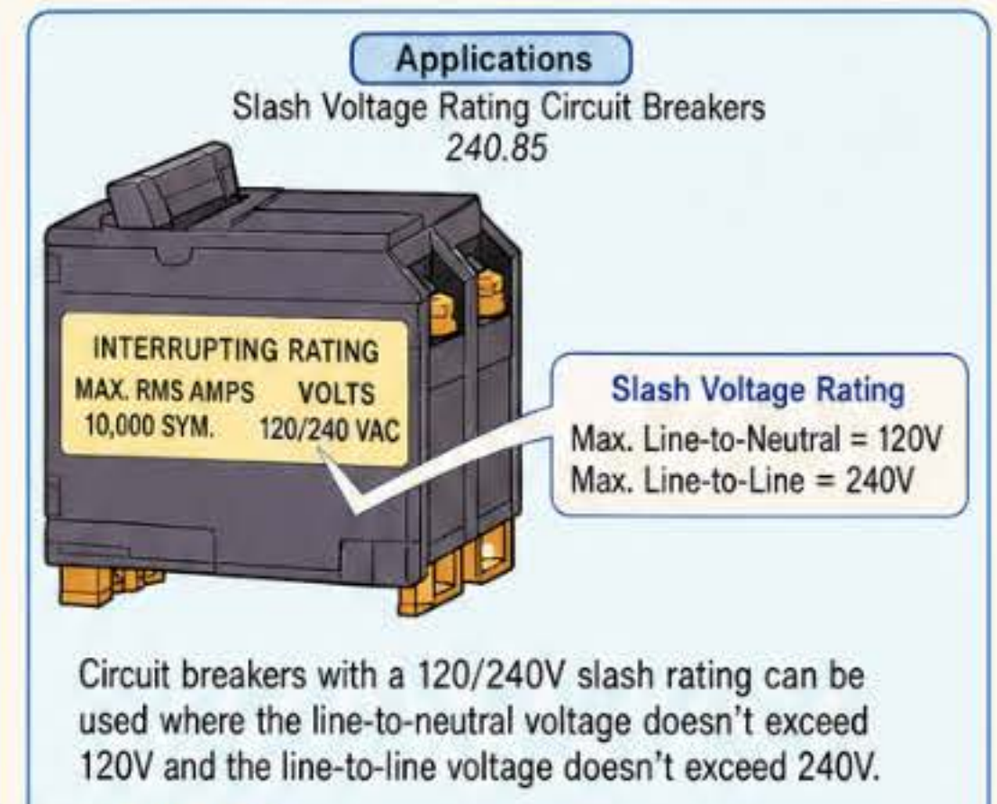


Figure 240–54

Author's Commentary:

A 120/240V slash circuit breaker is not acceptable for use on a system with a 4-wire, three-phase, 120/240V delta-connected arrangement because the line-to-ground voltage of the high leg is 208V, which is greater than 120V, even though the 120V line-to-ground rating of a 120/240V slash circuit breaker would otherwise be exceeded.

— Michael Hamilton

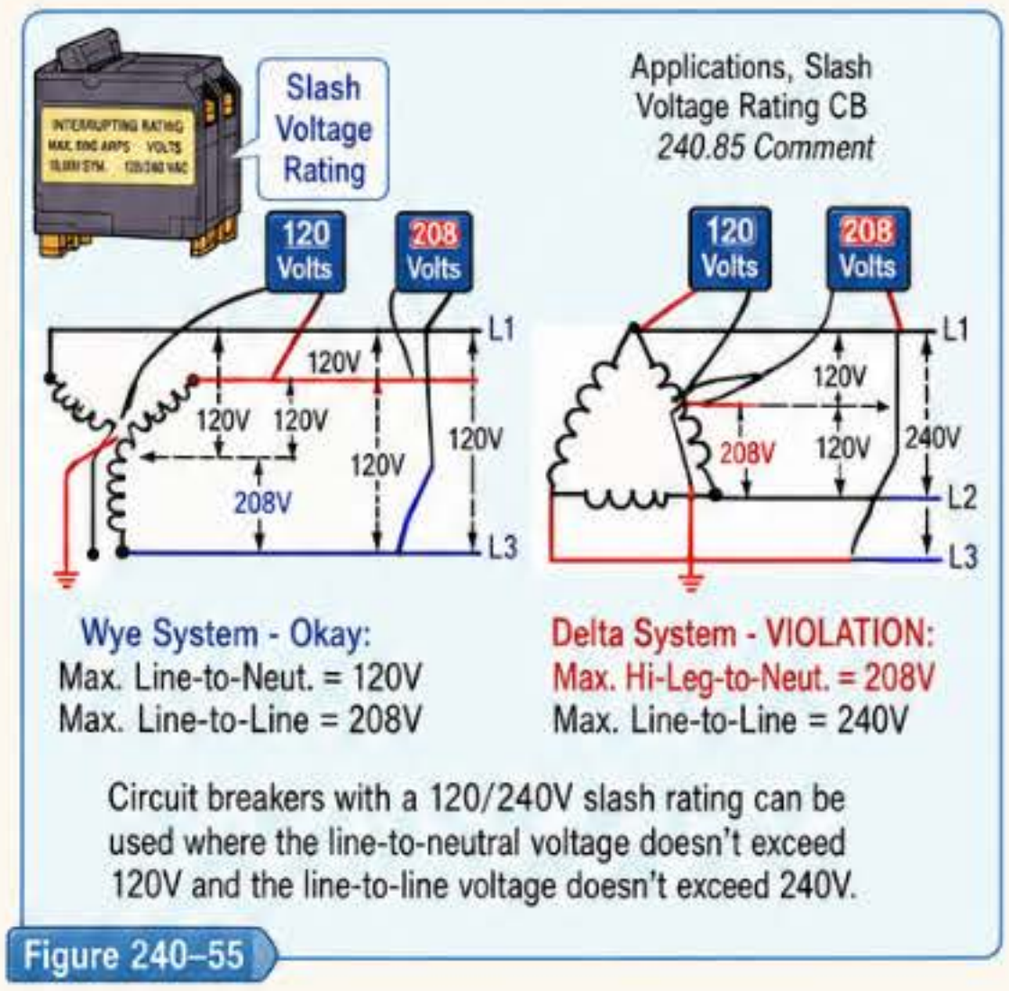


Figure 240–55

Note: When installing circuit breakers on corner-grounded delta systems, consideration needs to be given to the circuit breakers' individual pole-interrupting capability.

240.86 Series Ratings

When a circuit breaker is applied in a circuit that might experience a fault current greater than the marked interrupting rating—provided it is connected on the load side of a listed overcurrent protective device with a higher interrupting rating—the circuit breaker must satisfy the specifications in 240.86(A) through (C).

(A) Selected Under Engineering Supervision in Existing Installations. A series-rated combination device must be chosen by a qualified professional engineer competent in electrical design and maintenance. The selection process has to be documented and stamped by that engineer. This record must be available to personnel authorized to design, install, inspect, maintain, or operate the electrical system. The record shall identify the upstream protective device, demonstrate the required coordination, and verify that the engineer must be able to field mark the equipment used on site. For calculated-application systems, the engineer must confirm that any downstream circuit breaker that is part of the series combination remains noncurrent-limiting while the upstream unit retains its current-limiting characteristic.

Author's Commentary:
Upgrading or swapping parts in an electrical setup—such as transformers or motors—can raise the possible fault level past what the current overcurrent protection was picked for. Using engineered series-rated combinations is often more cost-effective than replacing the whole system.
— Michael Hamilton

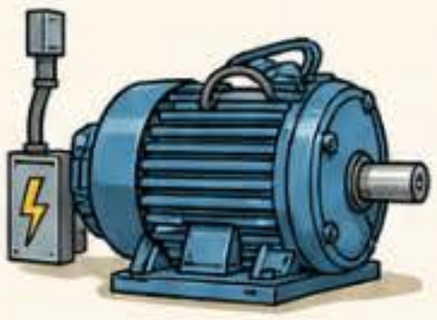
(B) Tested Combinations. *The line-side overcurrent protective device together with the load-side circuit breaker(s) are tested as a system and marked on the equipment, such as switchboards and panelboards.*

Note to (A) and (B): *See 110.22 for marking requirements applicable to series combination systems.*

Author's Commentary:
Section 240.86(A) is for engineered systems in existing installations. Section 240.86(B) applies to tested combinations used on new or existing installations.
— Michael Hamilton

(C) Motor Contribution. *Series ratings cannot be used when:*

(1) *Power comes from motor circuits between the load side of the higher-rated overcurrent protective device of a series-rated combination device and the lower-rated circuit breaker, and*



(2) *The sum of the motor full-load currents exceeds one percent of the interrupting rating of the lower-rated circuit breaker.*

240.87 Arc Energy Reduction—Circuit Breakers

Arc Energy Reduction. When the highest continuous current trip setting for which the overcurrent protective device in a circuit breaker is rated—or can be adjusted—is 1,200 A or more, 240.87(A) and (B) apply.

(A) Documentation. Documentation must be available to those authorized to design, install, operate, or inspect the installation as to the location of the arc energy reduction circuit breaker(s). That documentation must include evidence that the methods chosen to reduce clearing time are set to achieve at least the available arc current.

(B) Method to Reduce Clearing Time. *One of the following approaches must be provided and configured to operate at less than the available arc current:*

(1) Zone-selective interlocking

(2) Differential relaying

(3) *Energy-reducing maintenance switching with local status indicator*

(4) *Energy-reducing active arc-flash mitigation system*

(5) *An instantaneous trip setting. Temporary adjustment of the instantaneous trip setting to achieve arc energy reduction is not permitted.*

(6) *An instantaneous override*

(7) *An approved equivalent means*

Note 1: *An energy-reducing maintenance switch [240.87(B)(3)] permits a worker to set a circuit breaker trip unit to "no intentional delay" to shorten the clearing time while working within an arc-flash boundary defined in NFPA 70E, Standard for Electrical Safety in the Workplace, and then return the trip unit to its normal setting once the potentially hazardous task is complete.*

Note 2: *An energy-reducing active arc-flash mitigation system [240.87(B)(4)] helps reduce arc duration in the distribution system. However, no change in the breaker or settings of other devices is needed during maintenance when an employee is working inside an arc-flash boundary defined in NFPA 70E, Standard for Electrical Safety in the Workplace.*

DEFINITIONS | From Michael Hamilton Publications

Note 3: An instantaneous trip [240.87(B)(5)] is a function that causes a circuit breaker to trip with no intentional delay when currents exceed the instantaneous trip setting or current level. If arcing currents are above the instantaneous trip level, the circuit *breaker will trip in the minimum possible time.*

Note 4: *IEEE 1584, IEEE Guide for Performing Arc Flash Hazard Calculations, is one of the available methods that provides guidance in determining arcing current.*

(C) Performance Testing. Where a method to reduce *clearing time is required in* 240.67(B), *the arc energy reduction system must be performance tested when installed. The testing must be conducted by a qualified person in accordance with the manufacturer's instructions.*

Performance testing of an instantaneous element of the protective device must be conducted by a qualified person using a test process of primary current injection and the manufacturer's recommended test procedures. A written record of testing must be made available to the authority having jurisdiction.

Author's Commentary:

When performance testing is required for arc energy reduction, only qualified individuals should perform the tests. They must follow the manufacturer's procedures and keep a written record for the authority having jurisdiction.

— Michael Hamilton

240.88 Reconditioned Equipment

Reconditioned equipment must be listed as "reconditioned" and the original listing mark removed.

(A) Circuit Breakers. The use of reconditioned circuit breakers must comply with the following:

1. Molded-case circuit breakers *are not* permitted to be reconditioned.
2. Low- and medium-voltage power circuit breakers are permitted to be reconditioned.
3. High-voltage circuit breakers *are permitted to be* reconditioned.

(B) Components. *The use of reconditioned trip units, protective relays, and current transformers must comply with the following:*

1. *Low-voltage power circuit breaker electronic trip units are not permitted to be reconditioned.*
2. *Electromechanical protective relays and current transformers are permitted to be reconditioned.*

Author's Commentary:

Reconditioned equipment is allowed in specific cases, but not for all types of breakers or components. Always confirm the item is marked "reconditioned" and follows the limits outlined here.

— Michael Hamilton

Notes |

ARTICLE 242 OVERVOLTAGE PROTECTION

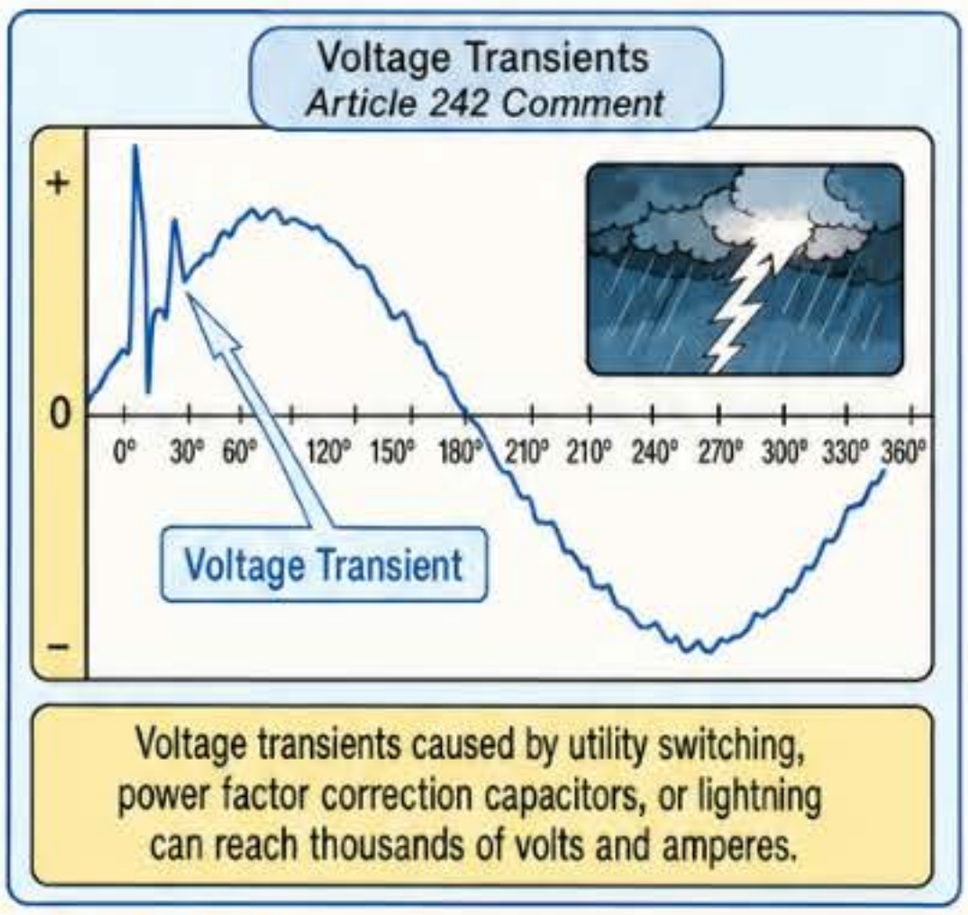
Introduction to Article 242–Overvoltage Protection

This article establishes the general guidance, installation standards, and connection rules for overvoltage protection devices. These include surge protective devices (SPDs). Part I addresses SPDs with ratings of 1 kV or less that are permanently connected within premises wiring systems.

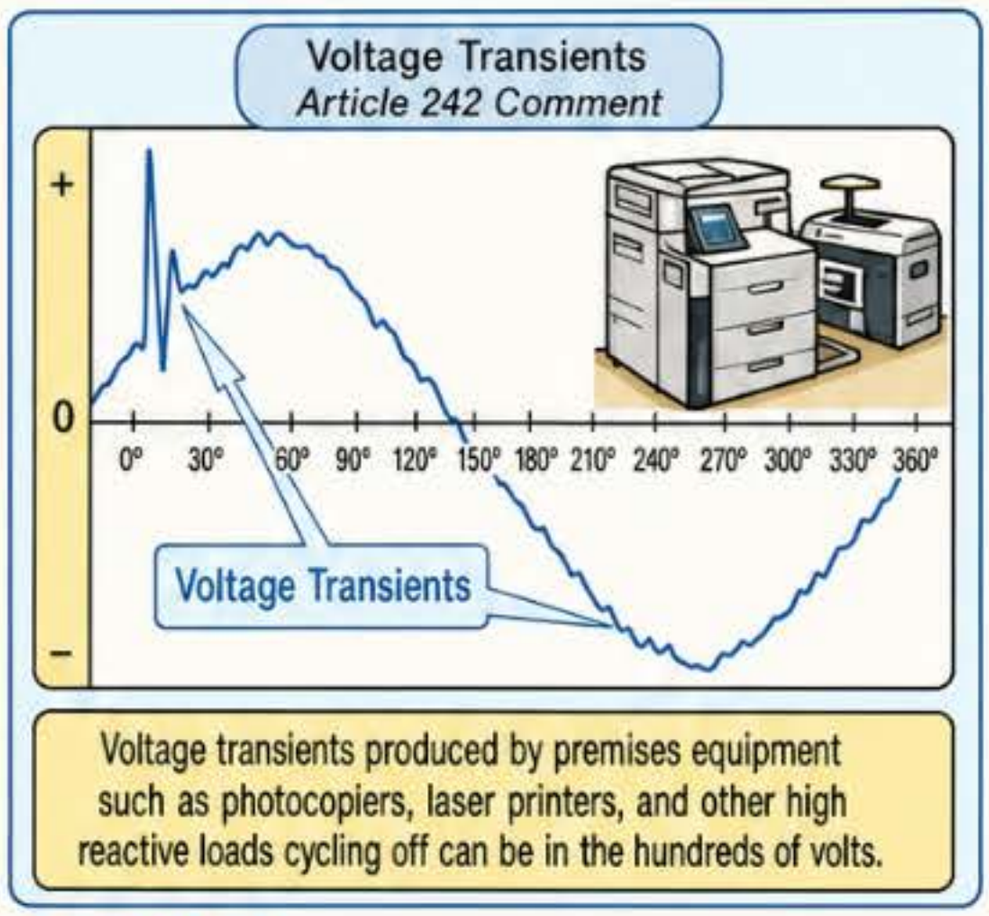
Surge protective devices help limit short-lived voltage spikes that appear on facility power wiring and on equipment power and signal lines. Sensitive electronics—such as computers, telecom gear, security systems, and appliances—are particularly at risk.

These transient surges can arrive from multiple sources: a nearby lightning discharge, utility switching actions, power-factor correction capacitors, voltage spikes and sags, or other conditions. Depending on amplitude and duration, they may range from a few volts to many thousands of volts, and from microseconds to milliseconds. ▶Figure 242–1

Voltage surges and other transients generated by on-site equipment—such as photocopiers, laser printers, and other high reactive loads that cycle—can also reach hundreds of volts. ▶Figure 242–2



▶Figure 242–1

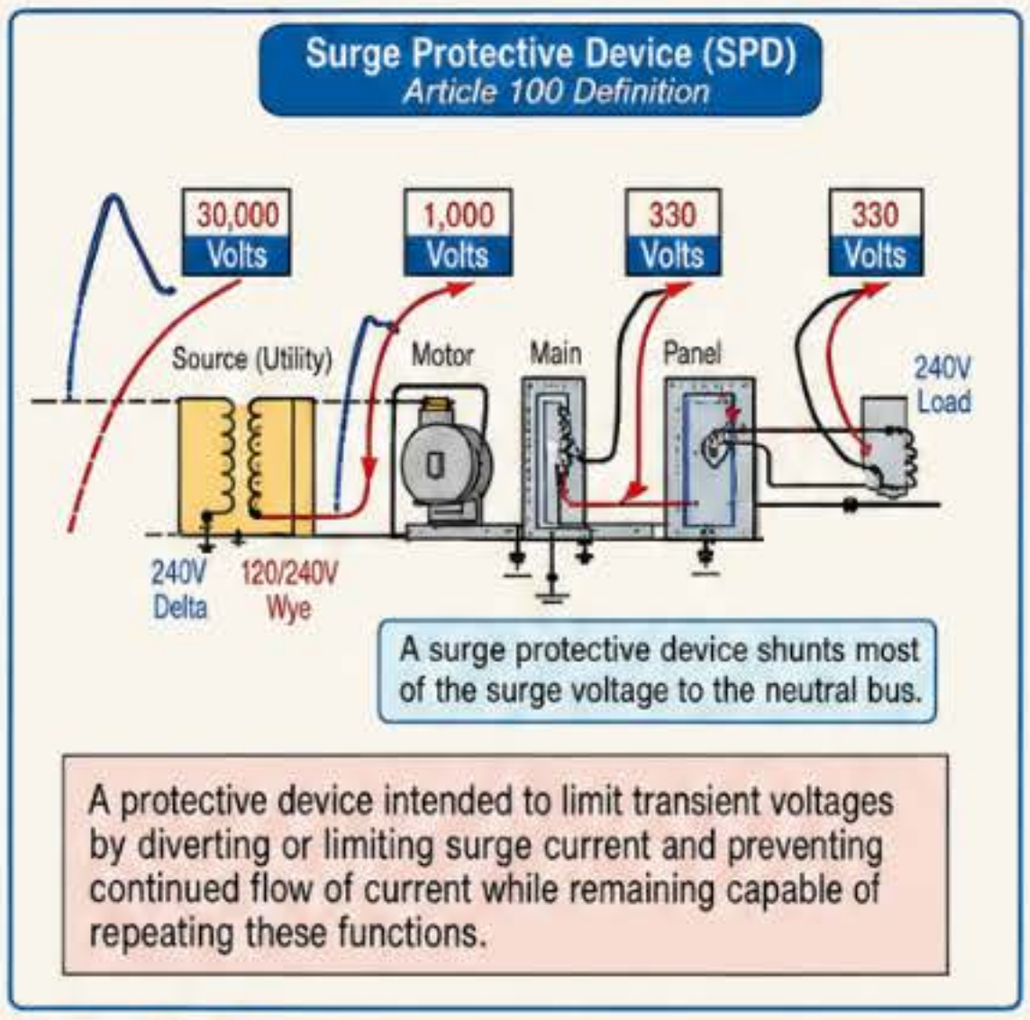


▶Figure 242–2

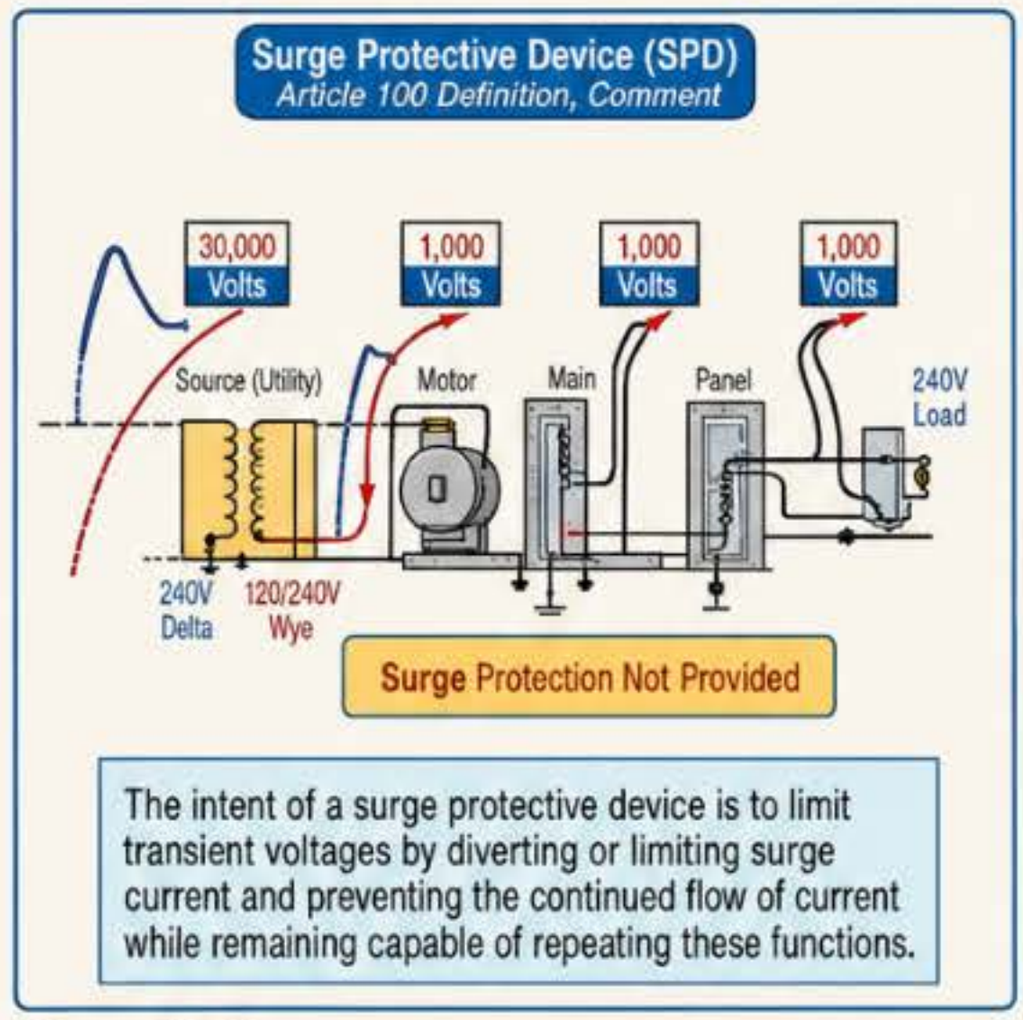
For all electronic equipment, a primary defense is the installation of suitable surge protective devices at the electrical service and at the locations where equipment is used.

The goal of SPDs is to restrain momentary overvoltages by diverting or limiting surge current and preventing continuous current flow while the equipment continues to operate normally. This capability supports the intent of Article 100. ▶Figure 242–3 and ▶Figure 242–4

242.1 | Overvoltage Protection



▶ Figure 242–3

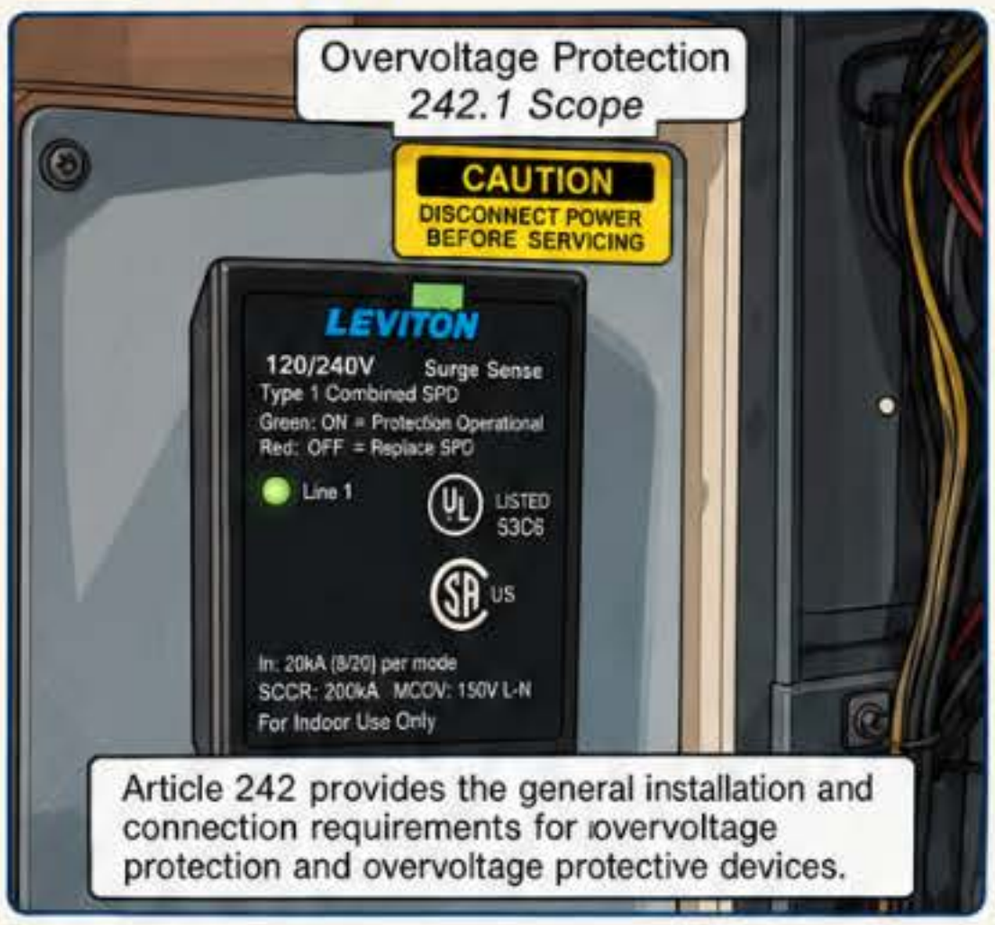


▶ Figure 242–4

Part I. General

242.1 Scope

Part I of this article provides the general, installation, and connection requirements for overvoltage protection and overvoltage protective devices. ▶ Figure 242–5



▶ Figure 242–5

Part II covers surge protective devices (SPDs) permanently installed on premises wiring systems of not more than 1,000V, nominal.

Part III covers surge arresters permanently installed on premises wiring systems over 1,000V, nominal.

Part II. Surge Protective Devices (SPDs), 1,000V or Less

242.6 Uses Not Permitted

A surge protective device is not permitted to be used:

(1) in circuits that exceed 1,000V.

(2) In ungrounded systems, impedance grounded systems, or corner-grounded delta systems unless listed specifically for use on these systems.

(3) If the voltage rating of the surge protective device is less than the maximum continuous phase-to-ground voltage available at the point of connection.

242.8 Listing

Surge protective devices must be listed.

Author's Commentary:

According to UL 1449, *Standard for Surge Protective Devices*, these units are intended to *limit the maximum extent of transient voltage surges on power lines to specified values. They are not intended to function as lightning arresters. The adequacy of the voltage suppression level to protect connected equipment from voltage surges has not been evaluated.*

— Michael Hamilton

DEFINITIONS | From Michael Hamilton Publications

242.10 Short-Circuit Current Rating

Surge protective devices must be marked with a short-circuit current rating and are not allowed to be installed if their available fault current exceeds that rating.

WARNING

Surge protective devices can fail when subjected to high fault currents. This creates a dangerous condition. A hazardous situation exists if the short-circuit current rating of a surge protective device is less than the available fault current. See 110.10 in this textbook.

242.12 Type 1 SPDs—Line Side of Service Disconnect

(A) Installation. Type 1 surge protective devices can be connected as follows:

(1) On the supply side of the service disconnect [230.82(4)]. ▶ *Figure 242–6*

Type 1 SPD Installations
Supply Side of Service Disconnects
242.12(A)

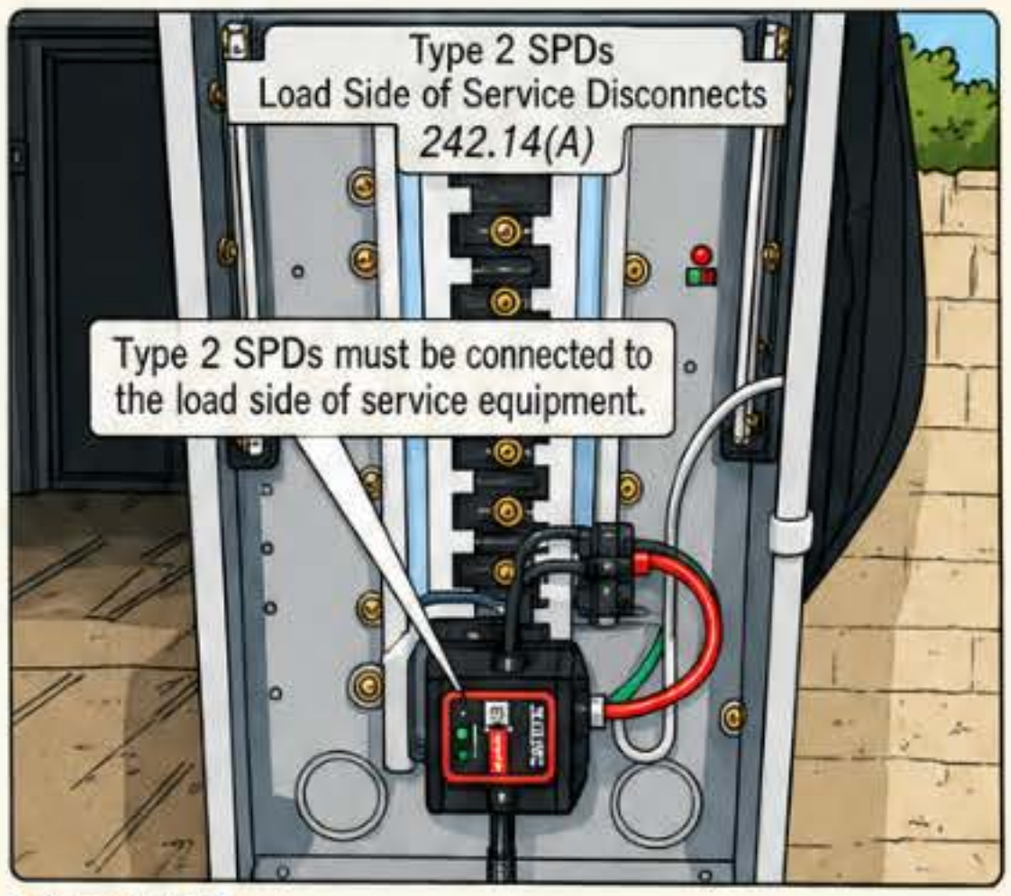
A Type 1 SPD can be connected on the supply or load side of service equipment.

▶ Figure 242–6

(2) On the load side of the service disconnect in accordance with 242.14.

242.14 Type 2 SPDs—Feeder Circuits

(A) Load Side of Service Disconnect. Type 2 surge protective devices must be connected to the load side of the service disconnect. ▶ Figure 242–7



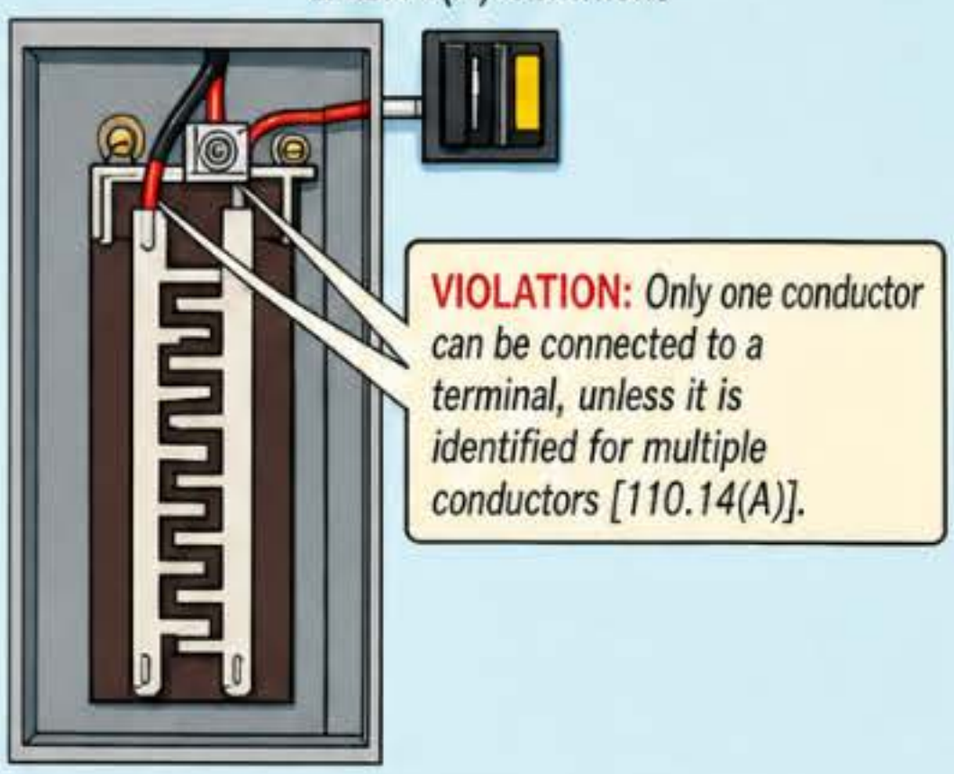
▶ Figure 242–7

Author's Commentary:

Only one conductor can be connected to a terminal, unless the terminal is identified for multiple conductors [110.14(A)]. ▶ Figure 242–8

— Michael Hamilton

Type 2 SPDs
Load Side of Service Disconnects
242.14(A) Comment



▶ Figure 242–8

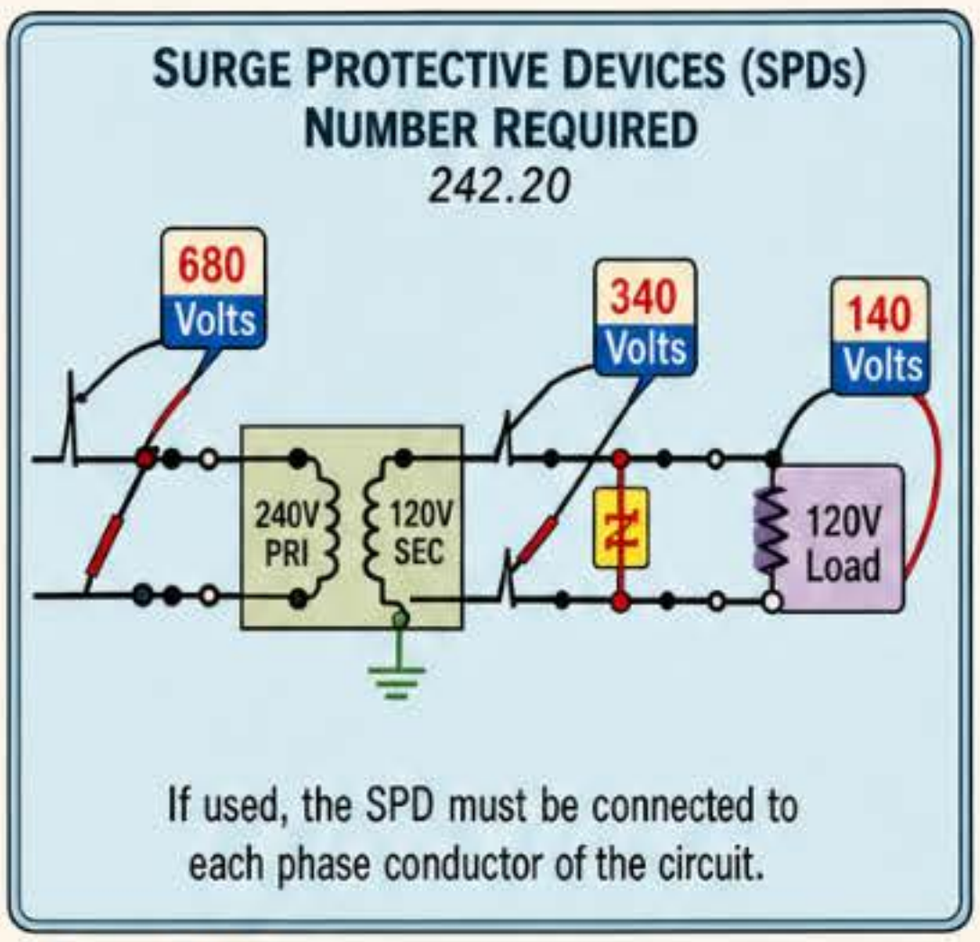
242.20 | OVERVOLTAGE PROTECTION

(B) Feeder-Supplied Buildings. Type 2 surge protective devices may be installed at any point on the load side of a building's feeder overcurrent protective device.

(C) Separately Derived Systems. Type 2 surge protective devices can be connected anywhere on the premises wiring of a separately derived system.

242.20 NUMBER REQUIRED

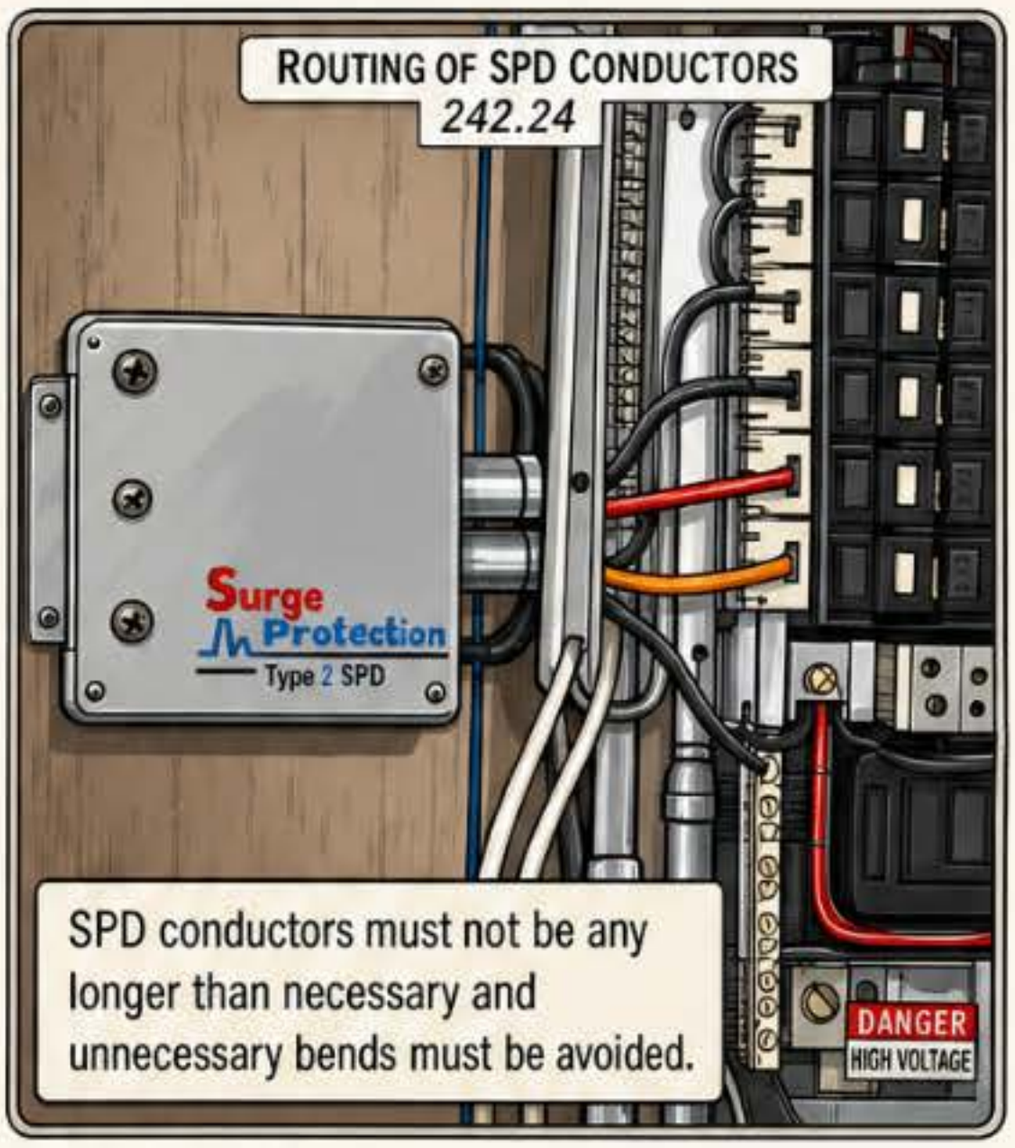
If used, the surge protective device must be connected to each phase conductor of the circuit.
→ Figure 242–9



→ Figure 242–9

242.24 ROUTING OF SURGE PROTECTION DEVICE CONDUCTORS

Surge protective device conductors must not be any longer than necessary, and unnecessary bends must be avoided. → Figure 242–10



→ Figure 242–10

Author's Commentary:

- Shorter conductors and reduced bends can enhance the surge protective device's performance by lowering impedance during high-frequency transient events.

—Michael Hamilton

ARTICLE 250

GROUNDING AND BONDING

Introduction to Article 250—Grounding and Bonding

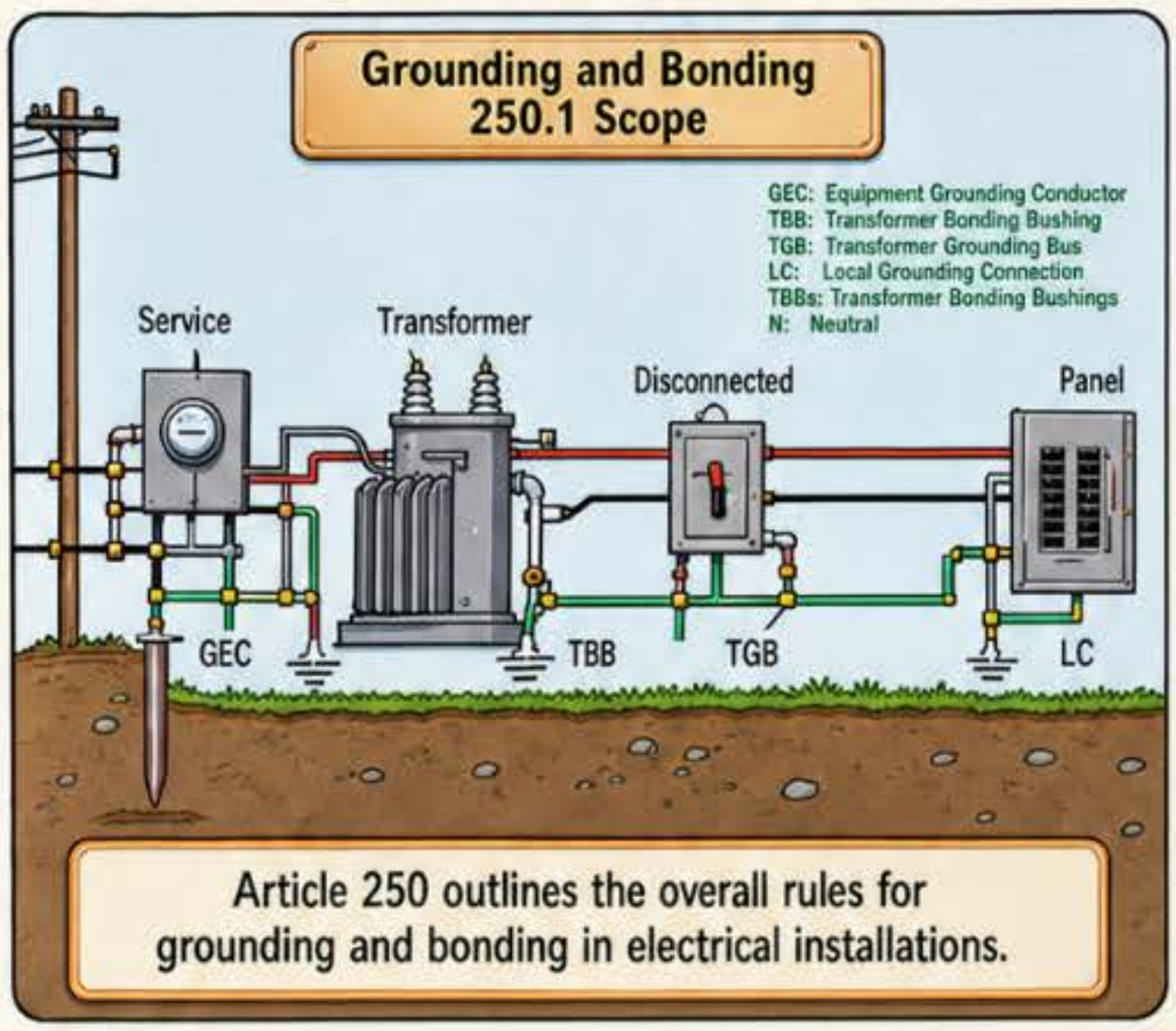
No other article can match this one for errors in use, rule violations, and misinterpretations. Over the years, the language of Article 250 in the 2023 NEC has been refined through a series of revisions. Understanding how grounding and bonding differ—and applying each where the Code requires—is essential. Pay special attention to the meanings of important terms found in Article 100 that relate to grounding and bonding. Article 250 sets the rules for establishing a system to connect to earth and for creating the bonds that keep the electrical system at a safe potential during a ground fault. These rules are designed to limit dangerous voltage to earth, reduce the risk of electrical shock, and ensure that a low-impedance fault path is available back to the source so overcurrent devices can clear a fault quickly.

This article is organized logically, as illustrated in Figure 250–1 in the 2023 NEC. It's a good idea to read it from start to finish for the big picture. Then come back and dig into the details. Also, review Article 100 for definitions of terms that may be new to you. The illustrations and explanations in this textbook will help you grasp the key points more easily.

Part I. General

250.1 Scope

Article 250 outlines the overall rules for grounding and bonding in electrical installations. • Figure 250–1



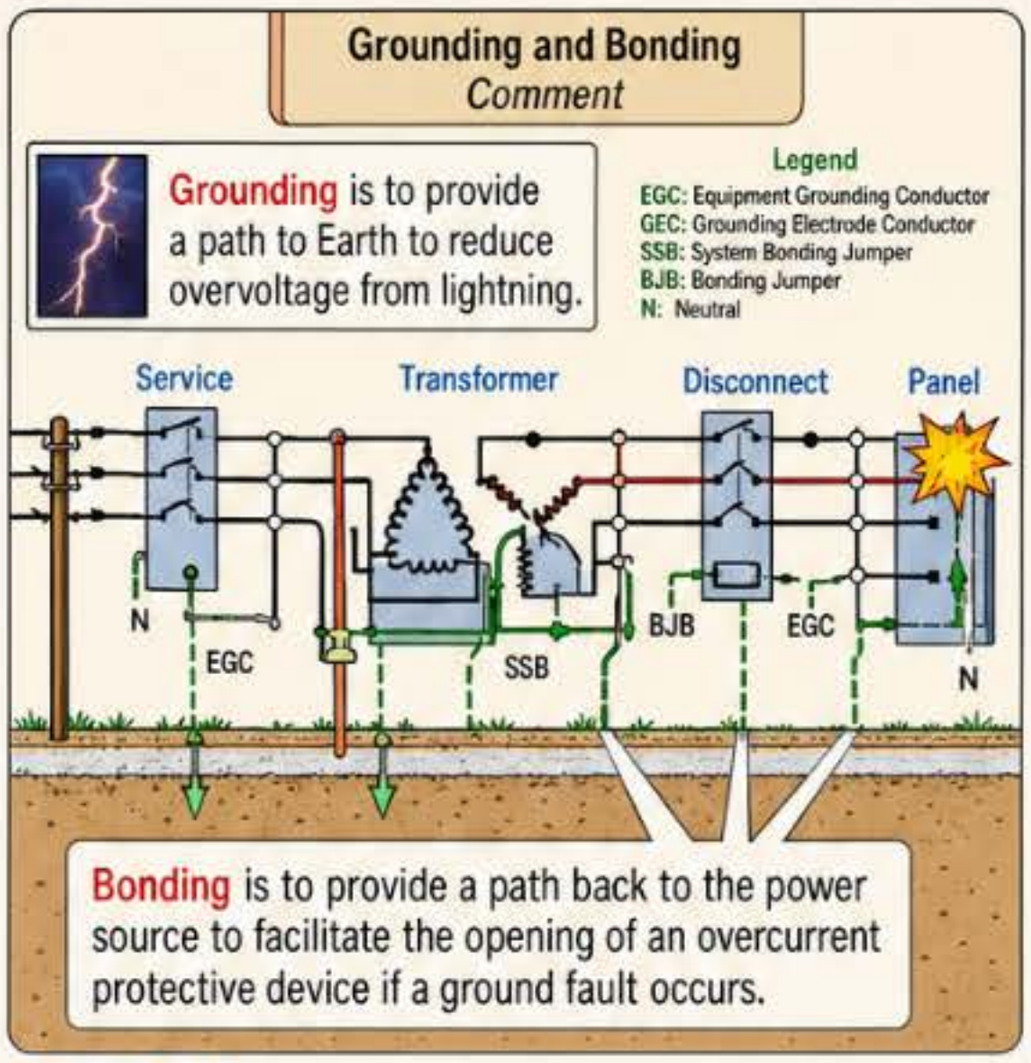
▶ Figure 250–1

Author's Commentary:

▶ *There are really two distinct ideas that fall under the umbrella of this article: "Grounding" means connecting to earth, while "Bonding" means making the electrical system's metal parts act as one continuous electrical path. The purpose of both is to keep metal parts at the same electrical potential. Article 100 defines these terms. Though related, each concept addresses a different need.*

The portion of the system that must handle fault current back to the source has to be strong enough to carry the current without overheating. That calls for low-impedance connections and conductors capable of carrying high current. This is the "Effective Ground-Fault Current Path." The effective path needs low impedance so the available fault current can rise quickly, causing the protective device to trip. After a fault occurs, this same path must safely carry large currents without exceeding temperature limits. Figure 250–2

250.4 | Grounding and Bonding

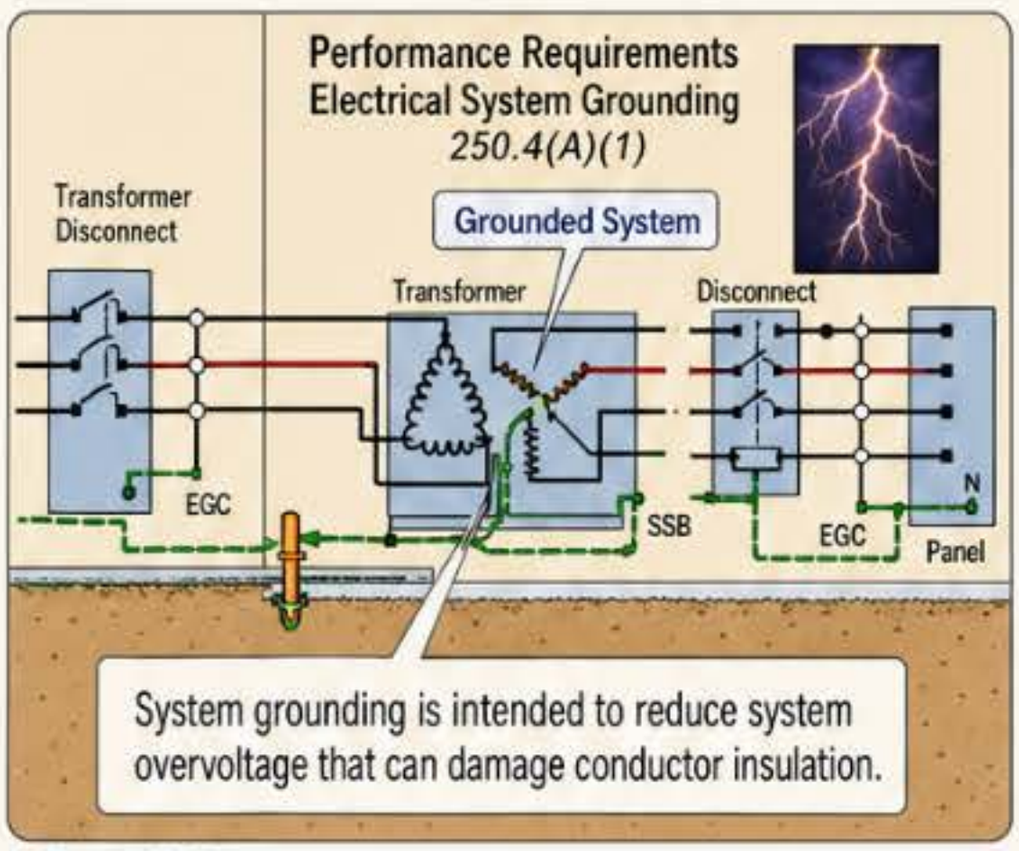


▶ Figure 250–2

250.4 Performance Requirements for Grounding and Bonding

(A) Solidly Grounded Systems.

(1) Electrical System Grounding. Electrical power systems, such as the secondary winding of a transformer, are required to be connected to the Earth (grounded) in order to limit the voltage induced on the conductors by lightning strikes, line surges, or unintentional contact by higher-voltage lines, and to stabilize the secondary conductor's voltage to ground during normal operation. ▶ Figure 250–3

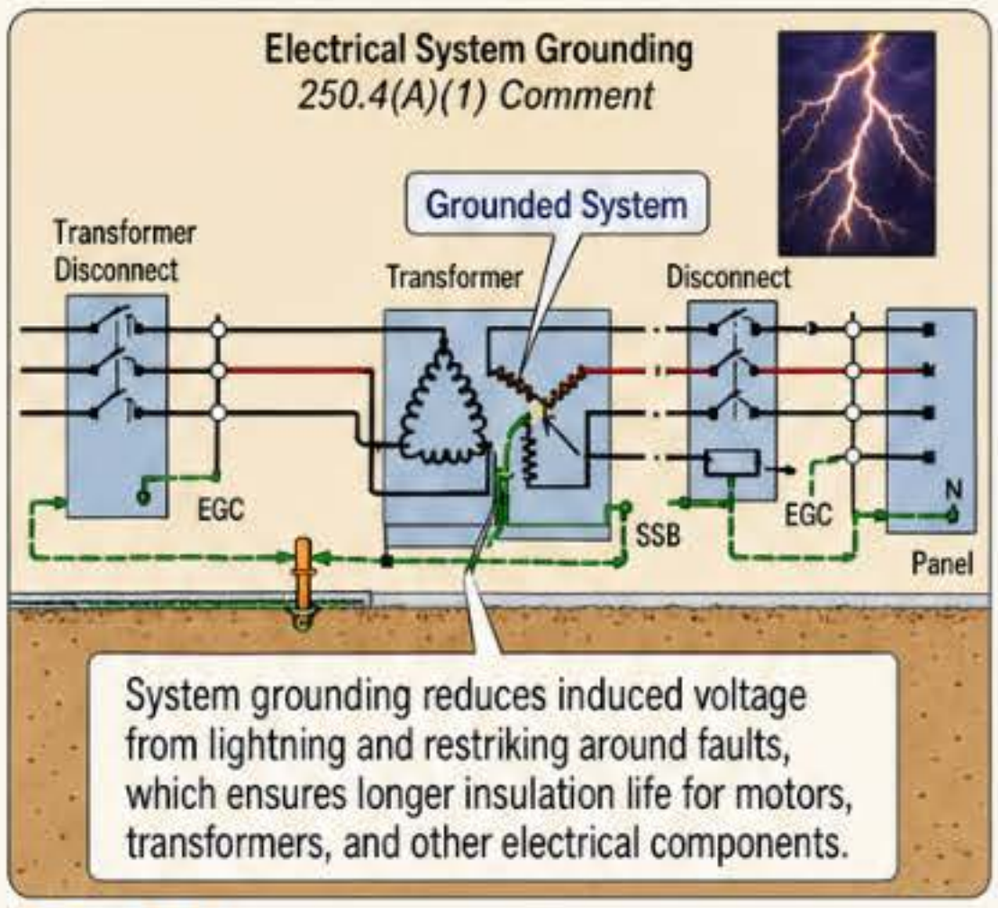


▶ Figure 250–3

Author's Commentary:

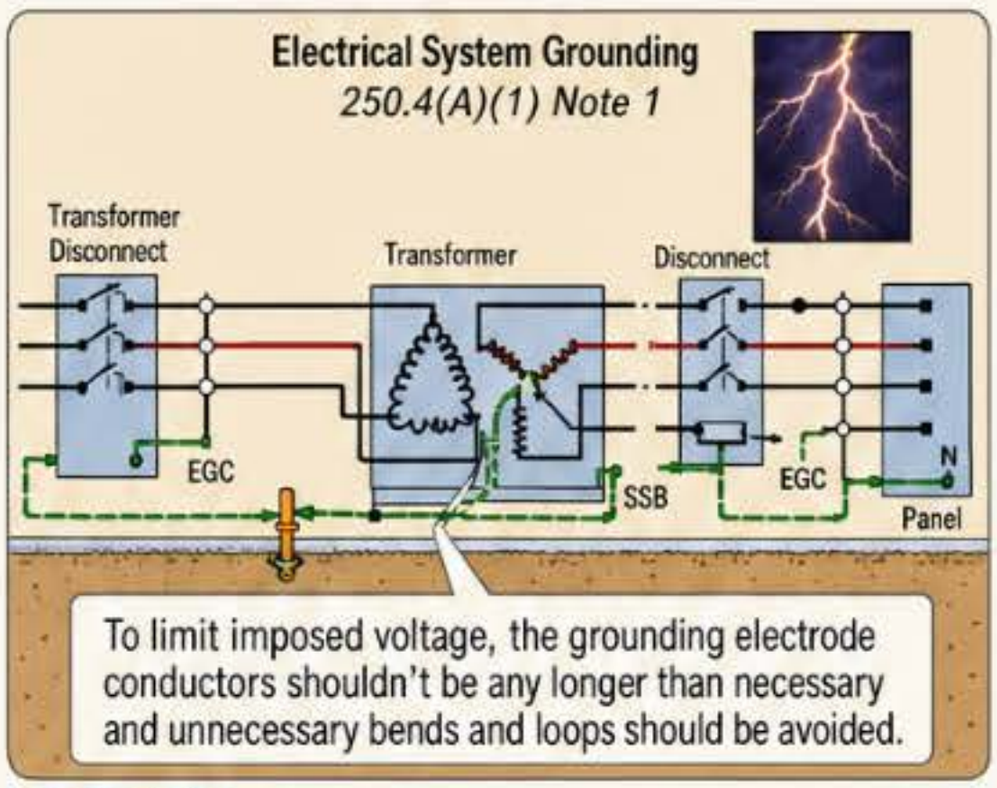
▶ *System grounding helps reduce fires in buildings as well as voltage stress on electrical insulation, thereby ensuring longer insulation life for motors, transformers, and other system components.*

— Michael Hamilton



▶ Figure 250–4

Note 1: To limit imposed voltage, the grounding electrode conductors should not be any longer than necessary and unnecessary bends and loops should be avoided. ▶ Figure 250–5



▶ Figure 250–5

(2) Equipment Grounding. Metal parts of electrical equipment must be connected to other and to the Earth to reduce the voltage to ground on the metal parts from indirect lightning strikes. ▶ Figure 250–6

GROUNDING AND BONDING | 250.4

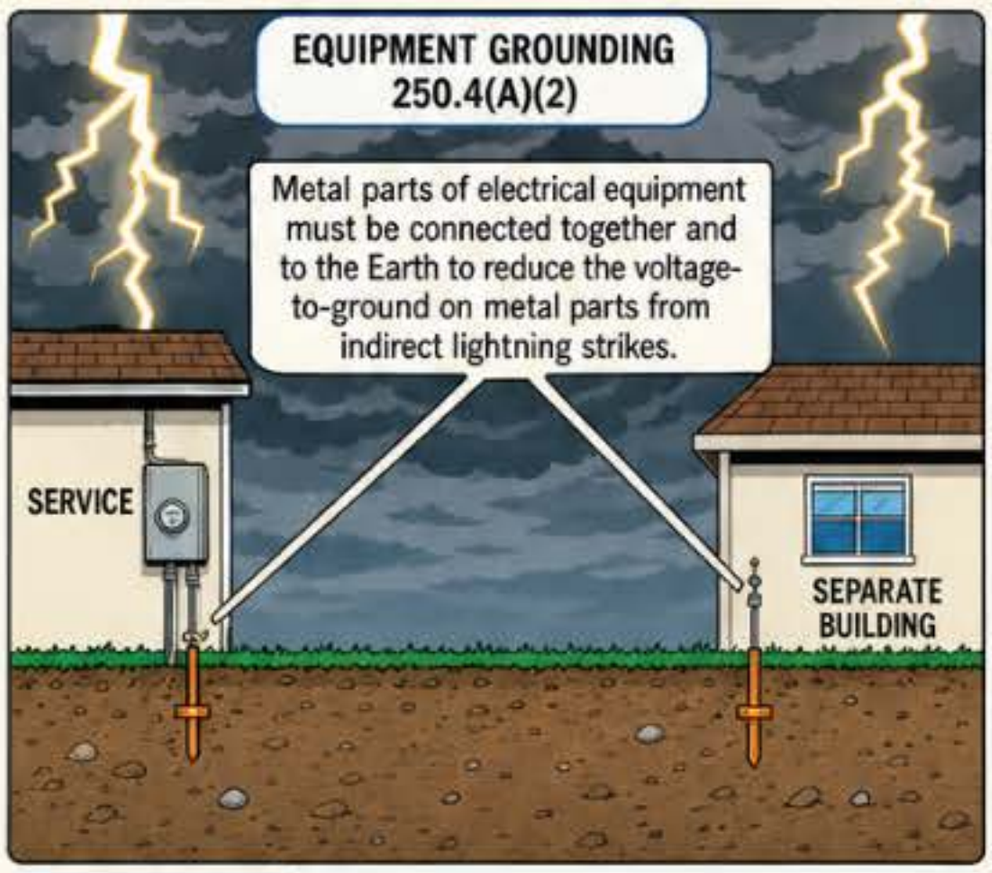


FIGURE 250–6

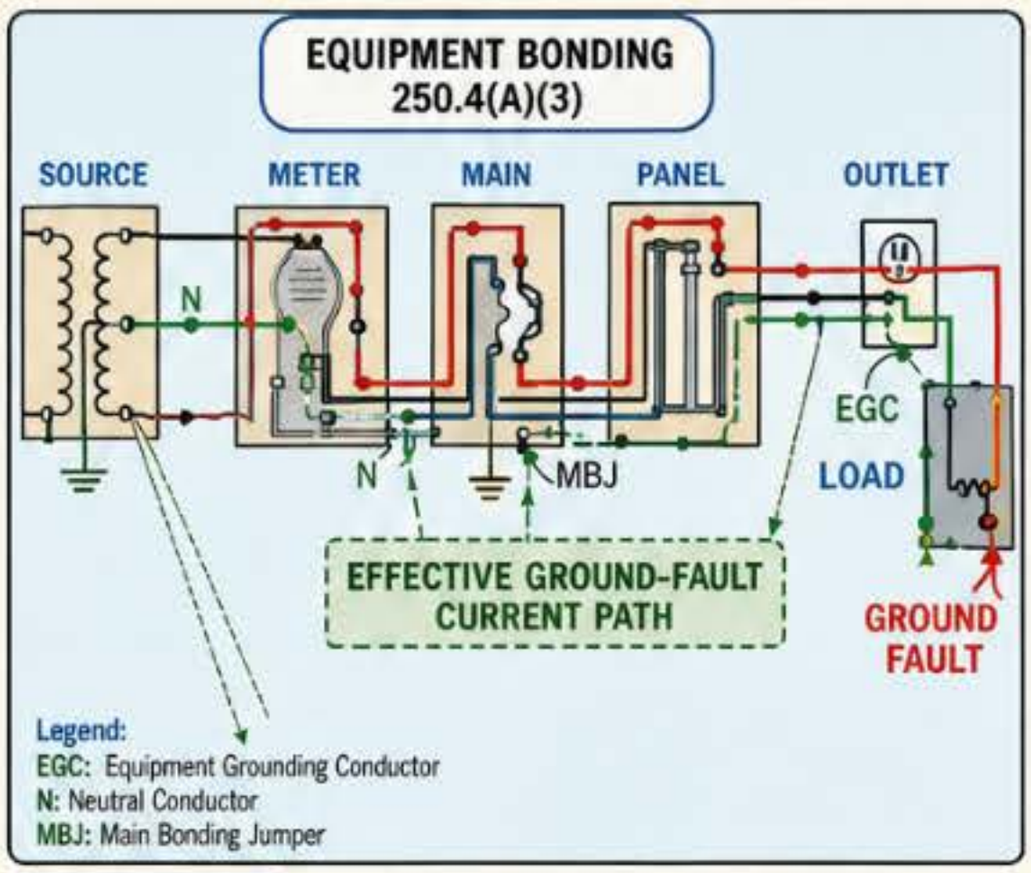


FIGURE 250–8

DANGER

Failure to ground metal parts to Earth can result in millions of volts of induced voltage on the metal parts of an electrical system generated by an indirect lightning strike. This energy seeks a path to the Earth within the building—possibly resulting in a fire and/or electric shock from a side flash.

FIGURE 250–7

Metal parts of electrical raceways, cables, enclosures, *and equipment must be connected to the supply source to establish an effective ground-fault current path.*

AUTHOR'S COMMENTARY:

- *According to Article 100, an "Effective Ground-Fault Current Path" is an intentionally constructed low-impedance conductive path designed to carry fault current from the point of a ground fault to the source for the purpose of opening the circuit overcurrent protective device.*

— Michael Hamilton

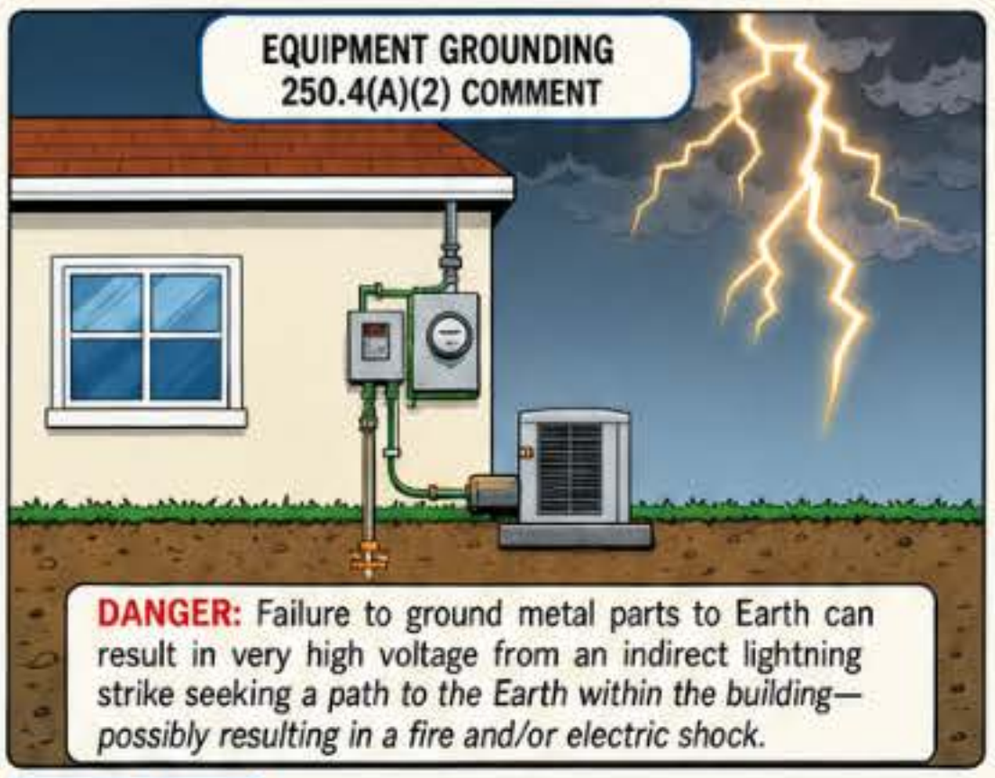


FIGURE 250–7

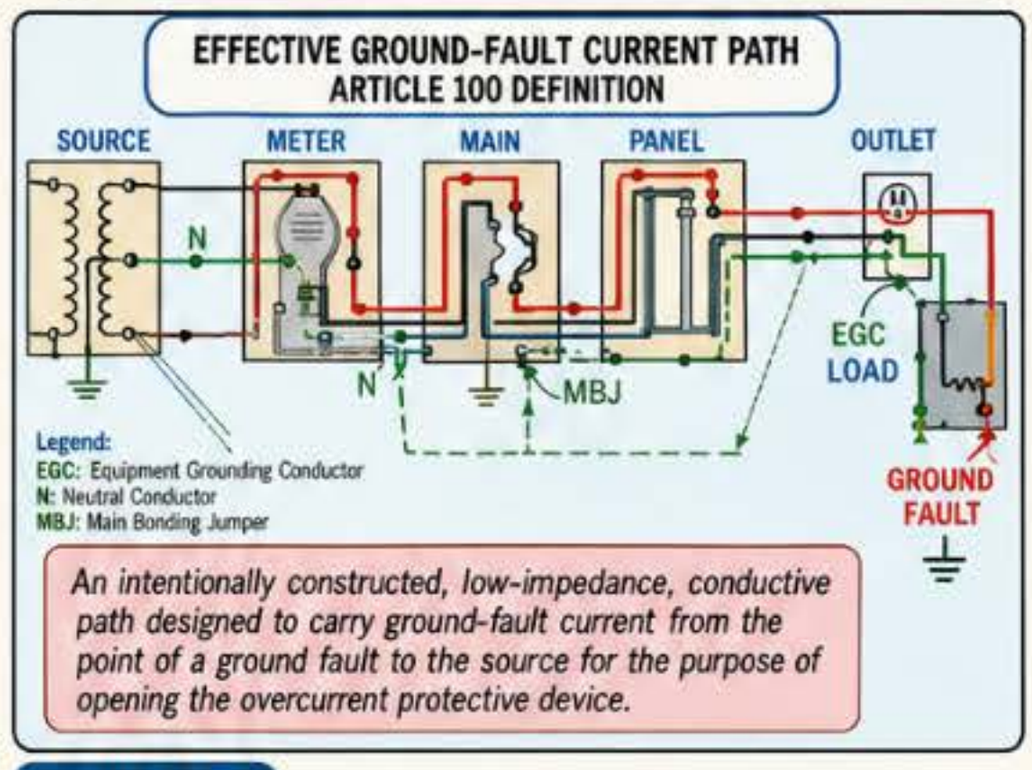


FIGURE 250–9

(3) Equipment Bonding. Metal parts of electrical raceways, *cables, enclosures, and equipment must be connected together and to the supply system in a manner that establishes an effective ground-fault current path. See 250.4(A)(5).*

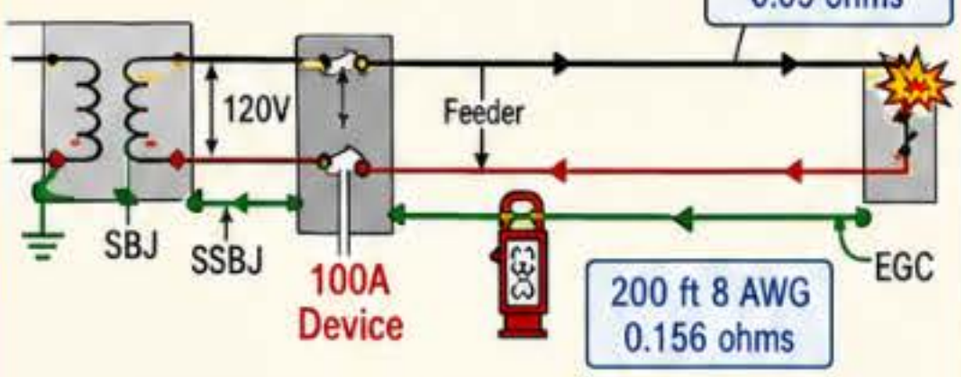
FIGURE 250–8

AUTHOR'S COMMENTARY:

- *To quickly remove dangerous voltage on metal parts from a ground fault, the effective ground-fault current path must have sufficiently low impedance to the source so fault current will quickly rise to a level that will open the circuit overcurrent device.*

— Michael Hamilton

Equipment Bonding, Opening an Overcurrent Device
250.4(A)(3) Comment



$$\text{Fault Current} = \frac{E}{Z} = \frac{120V}{0.206 \text{ ohms}} = 583A$$

The 100A overcurrent device quickly opens and removes dangerous voltage from metal parts.

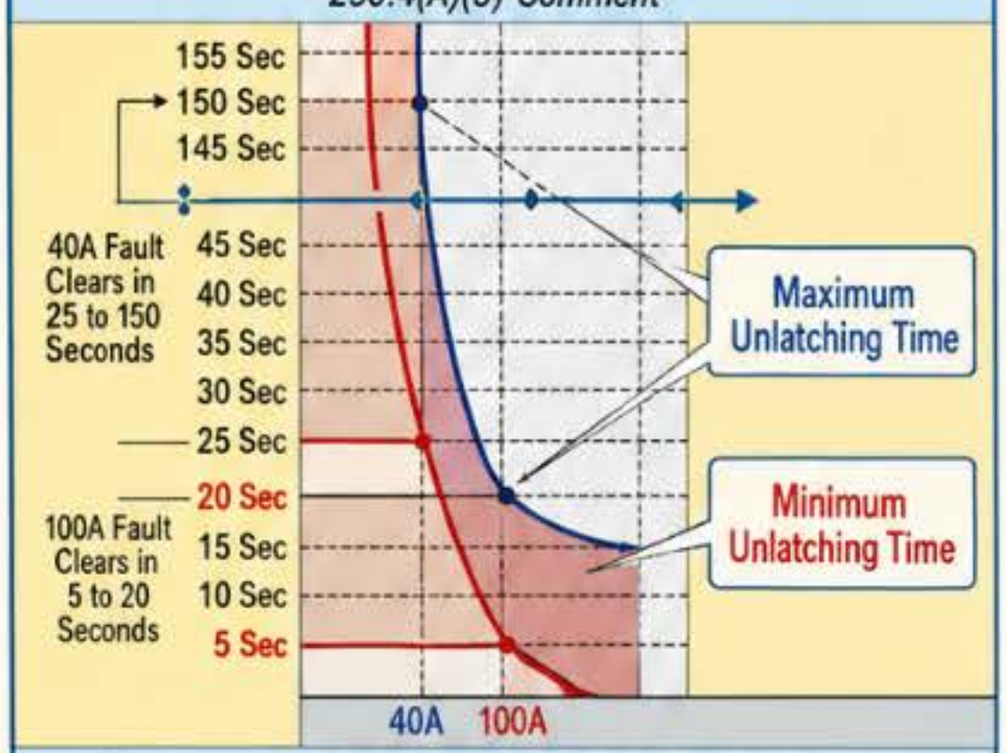
Figure 250-10

Author's Commentary:

The time it takes for an overcurrent device to open is dependent on how large the fault current is. A higher fault current value causes a shorter opening time for the protective device. For example, a 20A overcurrent device with an overload of 40A (two times the 20A rating) generally trips in 15 to 150 seconds to open. The same device at 100A (five times the 20A rating) usually trips in 5 to 20 seconds. ▶Figure 250-11

— Michael Hamilton

Time–Current Curve, 20A Inverse Time Breaker
250.4(A)(3) Comment

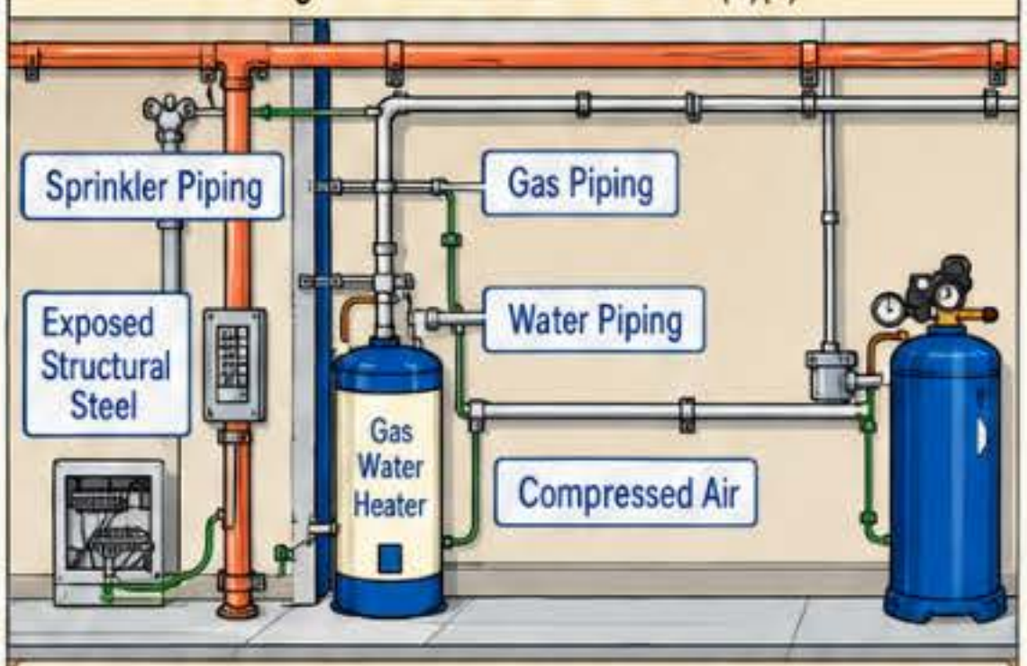


The higher the current, the faster the fault clears.

Figure 250-11

(4) Bonding Conductive Materials. Electrically conductive materials that are likely to become energized, such as metal water piping systems, metal sprinkler piping, metal gas piping, and other metal-piping systems, and exposed structural steel members must be connected (bonded) to the supply source via an effective ground-fault current path. ▶Figure 250-12

Bonding Conductive Materials *250.4(A)(4)*



Normally noncurrent-carrying electrically conductive materials likely to become energized must be connected (bonded) to an effective ground-fault current path in accordance with 250.104.

Figure 250-12

Author's Commentary:

According to the NFPA style manual, "Likely to Become Energized" means that an electrical conductor is present in some capacity.

— Michael Hamilton

(5) Effective Ground-Fault Current Path. Metal parts of electrical raceways, cables, enclosures, or equipment must be bonded together and to the supply source in a manner that creates a low-impedance path for ground-fault current facilitating the opening of the circuit overcurrent protective device. ▶Figure 250-13 and ▶Figure 250-14

Effective Ground-Fault Current Path
250.4(A)(5)

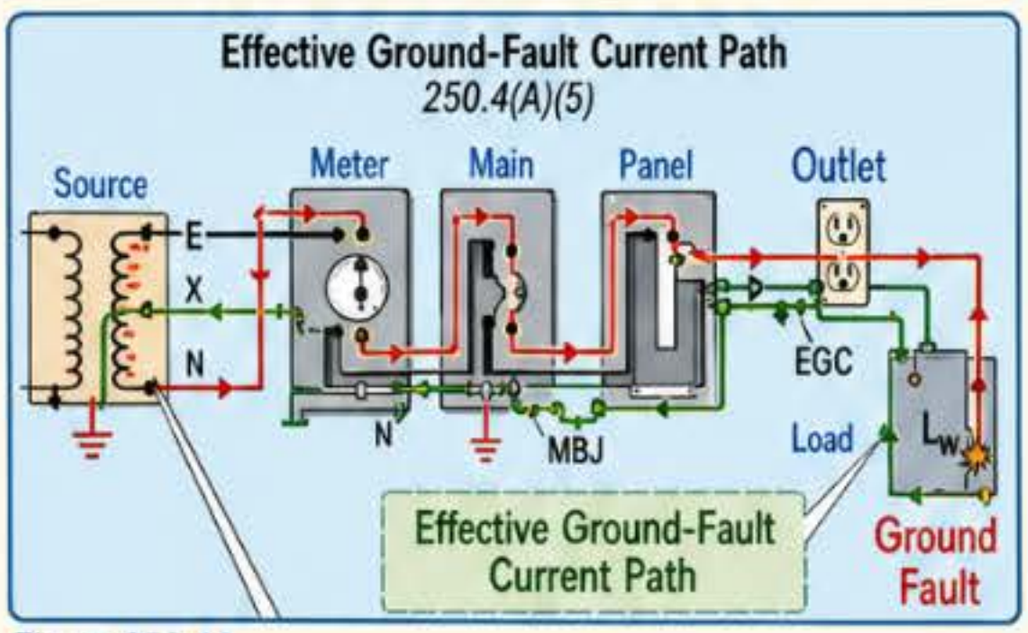


Figure 250-13

Electrical equipment and wiring and other electrically conductive material likely to become energized must be installed in a manner that creates a low-impedance circuit facilitating the operation of the overcurrent device.

— Michael Hamilton

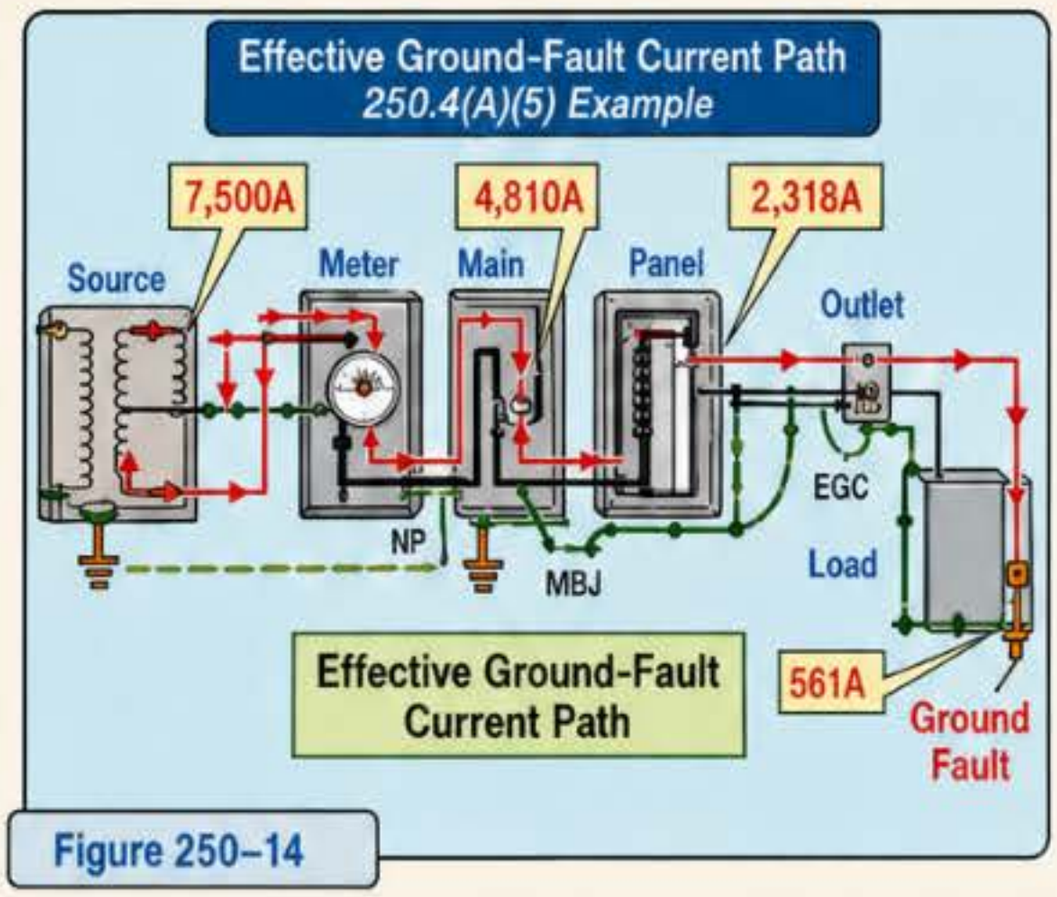


Figure 250–14

The effective ground-fault current path must be capable of safely carrying the maximum ground-fault current likely to be imposed on it from any point on the wiring system where a ground fault may occur to the electrical supply source.

The Earth is not permitted to serve as the required effective ground-fault current path, therefore an equipment grounding conductor of a type recognized in 250.118 is required to be installed with all circuits.

▶ Figure 250–15

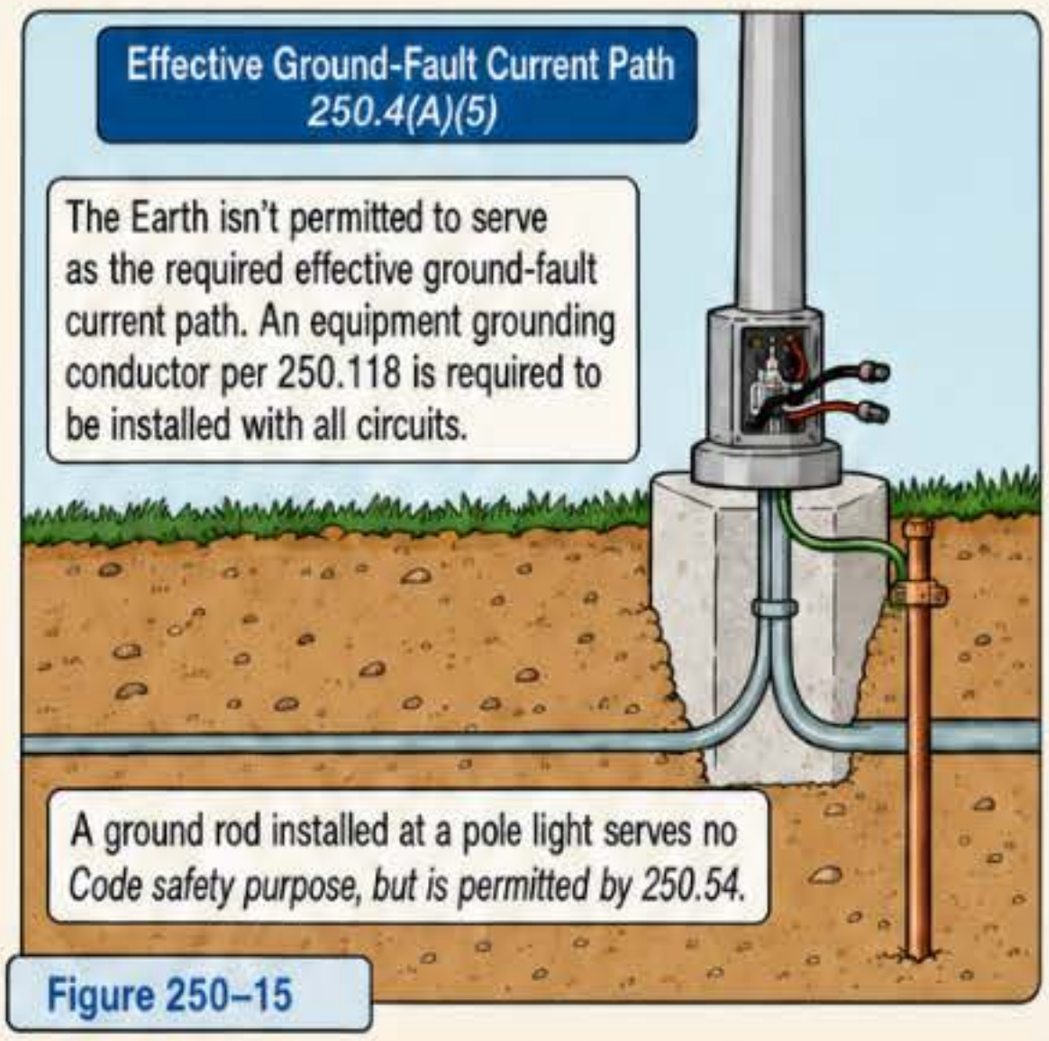


Figure 250–15

Danger

Earth grounding does not remove dangerous touch voltage. Because the contact resistance of a grounding electrode (like a ground rod) to the Earth is so high, very little fault current returns to the power supply. As a result, the circuit overcurrent protective device will not open, and all metal parts associated with the electrical installation, metal piping, and structural building steel will become and remain energized.

▶ Figure 250–16

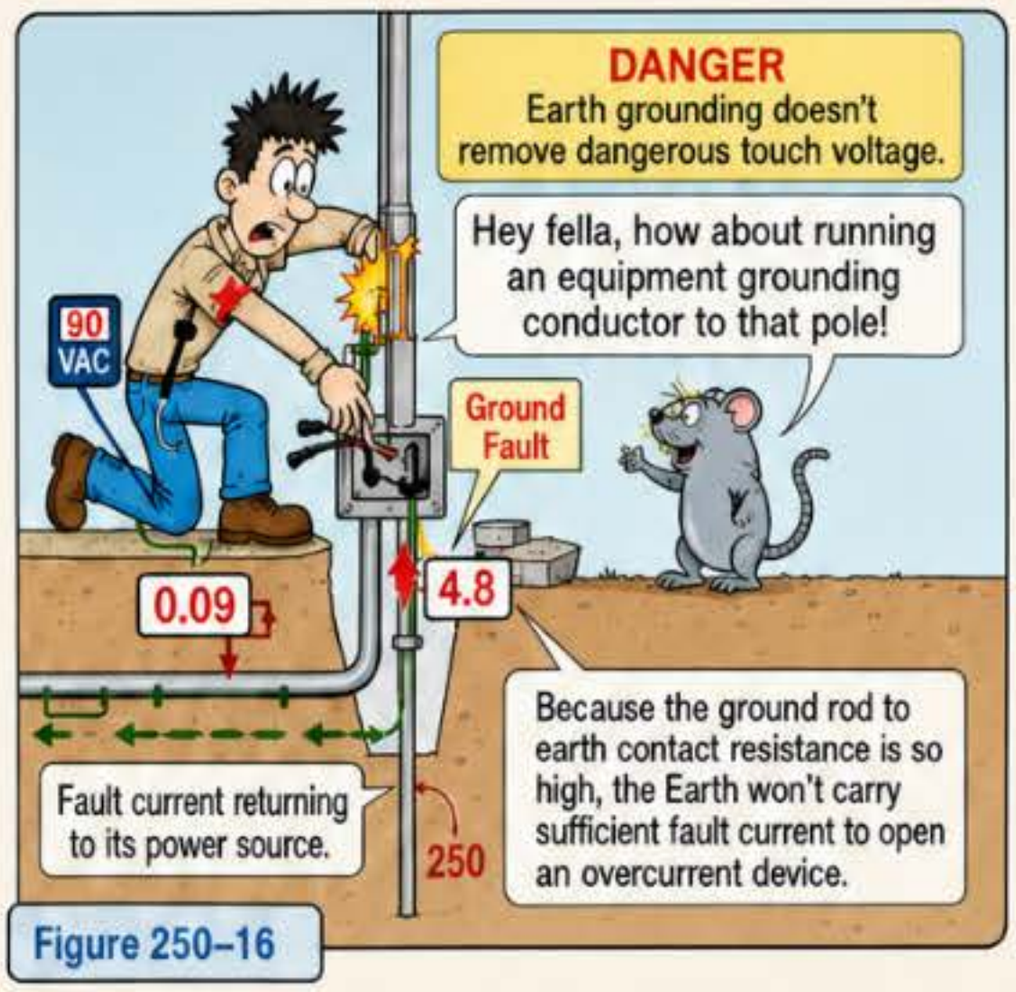


Figure 250–16

▶ Example

Question: *What will the maximum fault current be when there is a 120V ground fault to the metal parts of a light pole that is grounded to a 25-ohm ground rod, but not bonded to an effective ground-fault current path?* ▶ Figure 250–17

(a) 3.70A (b) 4.80A (c) 5.20A (d) 6.40A

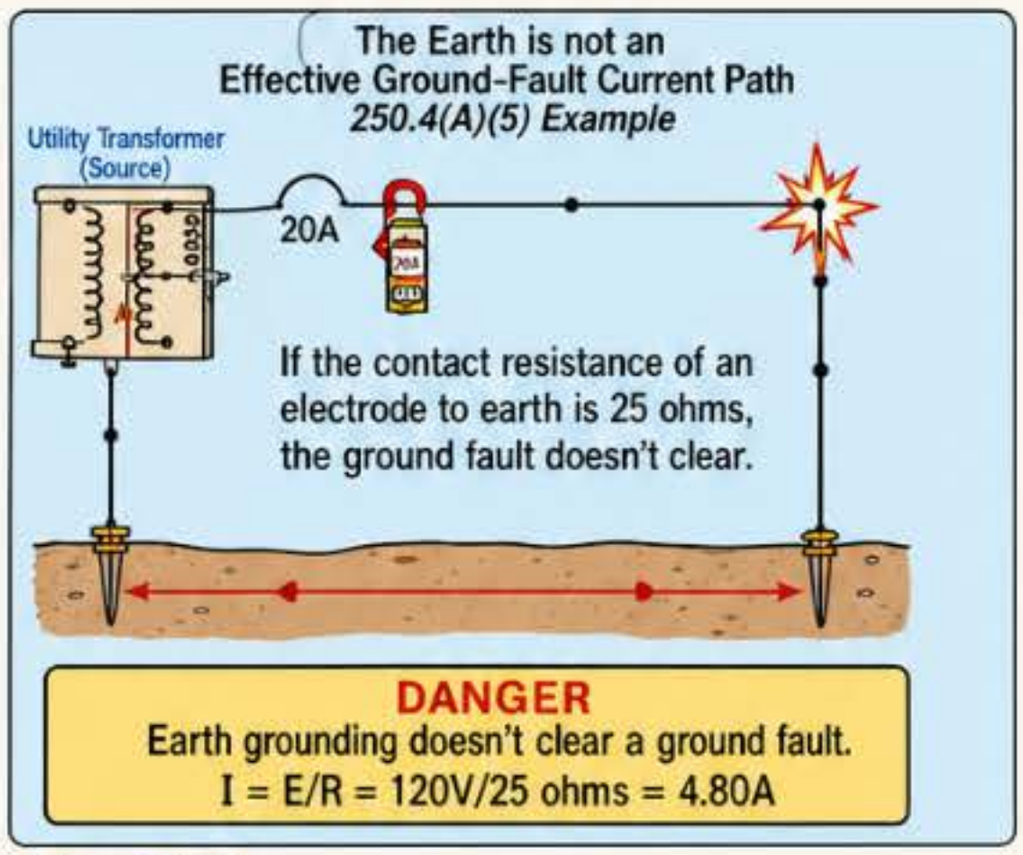
Solution:

I = Volts/Resistance

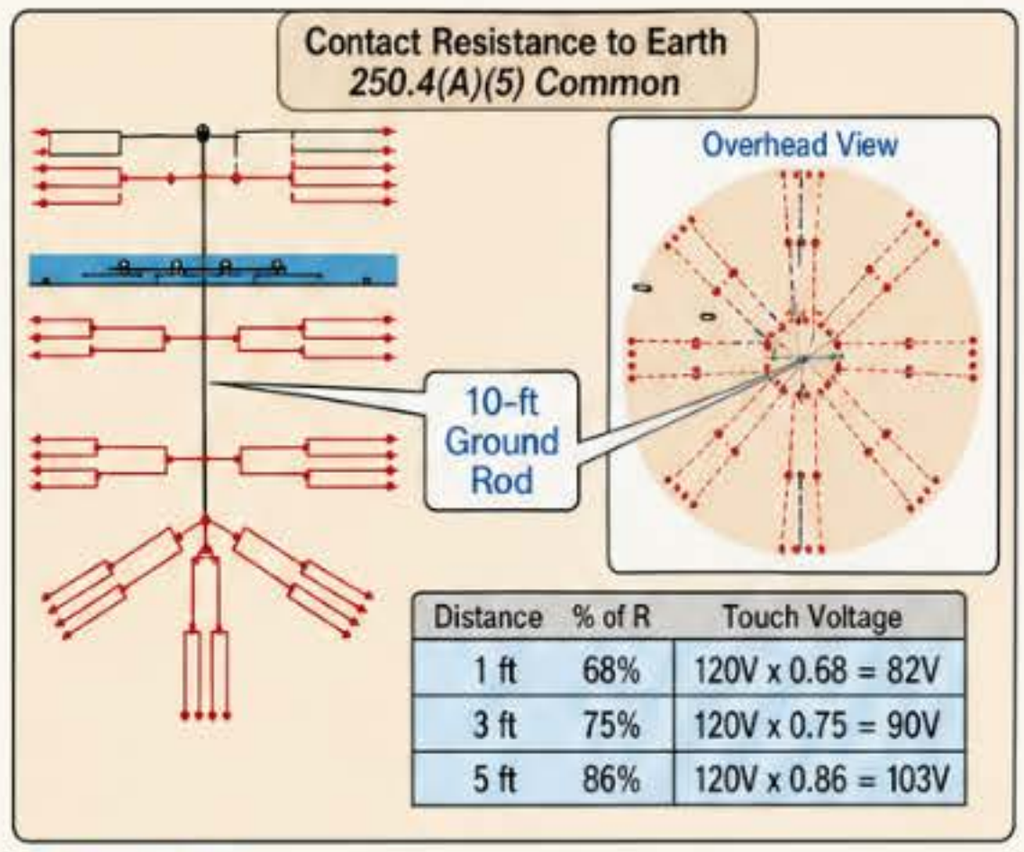
I = 120V/25 ohms

I = 4.80A

Answer: *(b) 4.80A*



▶ Figure 250-17



▶ Figure 250-18

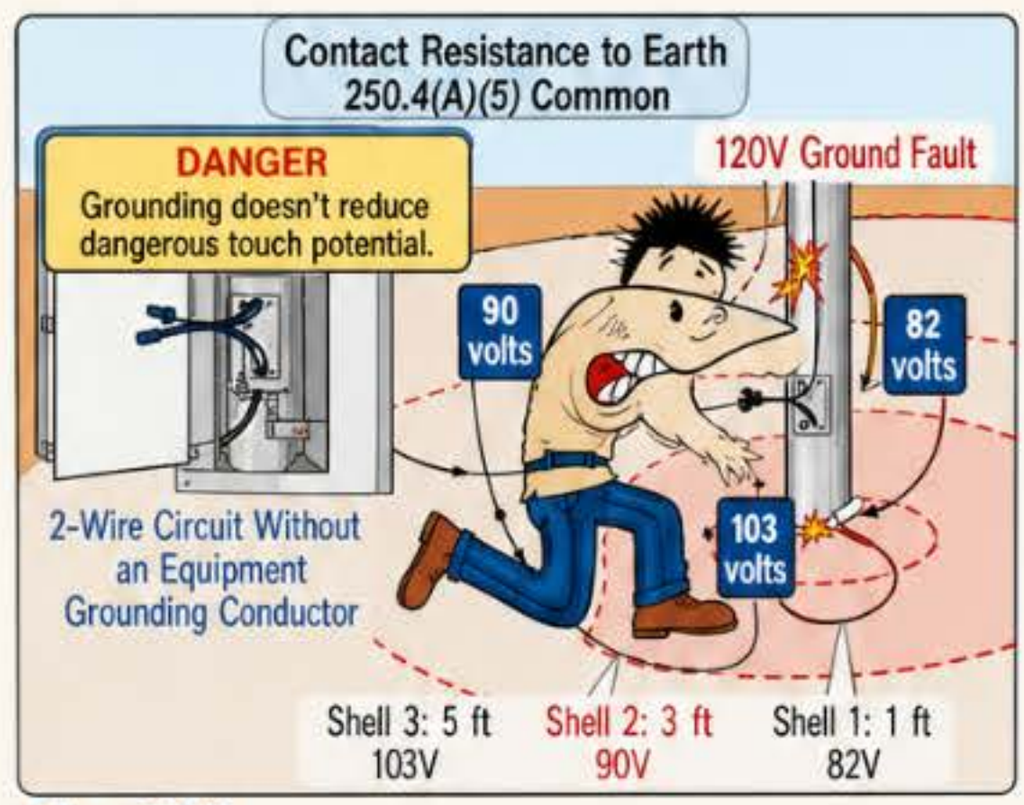
Earth Shells

According to ANSI/IEEE 142, *Recommended Practice for Grounding of Industrial and Commercial Power Systems* (Green Book) [4.1.1], the resistance of the soil outward from a 10-ft ground rod is equal to the sum of the series resistances of the Earth shells. The shell nearest the ground rod has the highest resistance and each successive shell has progressively larger areas and progressively lower resistances. Do not be concerned if you do not understand this statement; just review the table below.

Distance from Rod	Soil Contact Resistance
1 ft (Shell 1)	68% of total contact resistance
3 ft (Shells 1 and 2)	75% of total contact resistance
5 ft (Shells 1, 2, and 3)	86% of total contact resistance

Contact Resistance. The Earth is an excellent conductor due to an almost limitless number of parallel paths over which electrons can flow. However, the problem lies in the contact resistance between the grounding electrode and the Earth. The surface area of the electrode contacting the Earth is minimal compared to the Earth itself.

Since voltage is directly proportional to resistance, the voltage gradient of the Earth around an energized rod (assuming a 120V ground fault) will be as follows: ▶ Figure 250-18 and ▶ Figure 250-19



▶ Figure 250-19

Distance from Rod	Soil Contact Resistance	Voltage Gradient
1 ft (Shell 1)	68%	82V
3 ft (Shells 1 and 2)	75%	90V
5 ft (Shells 1, 2, and 3)	86%	103V

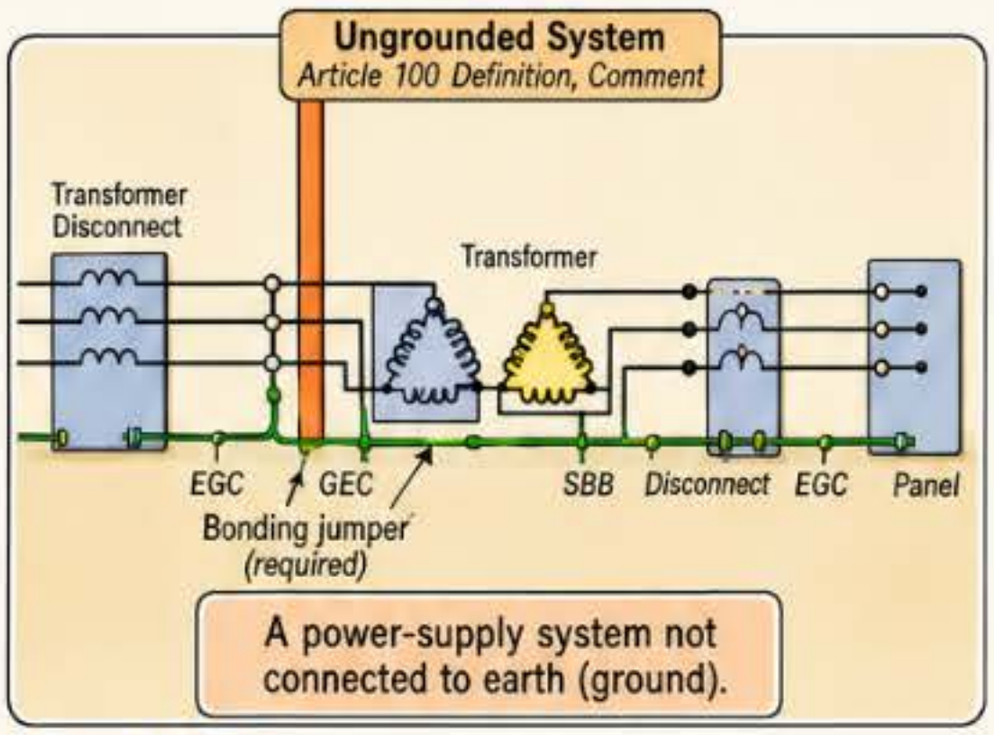
(B) Ungrounded Systems. Ungrounded Systems must be grounded in accordance with 250.4(B)(1) through 250.4(B)(4).

Author's Commentary:

An "ungrounded system," as defined in Article 100, is a power-delivery arrangement in which no intentional connection exists between the secondary of a transformer and either Earth (ground) or a conductive system capable of extending that connection *all* the way to the Earth. ▶ Figure 250-20

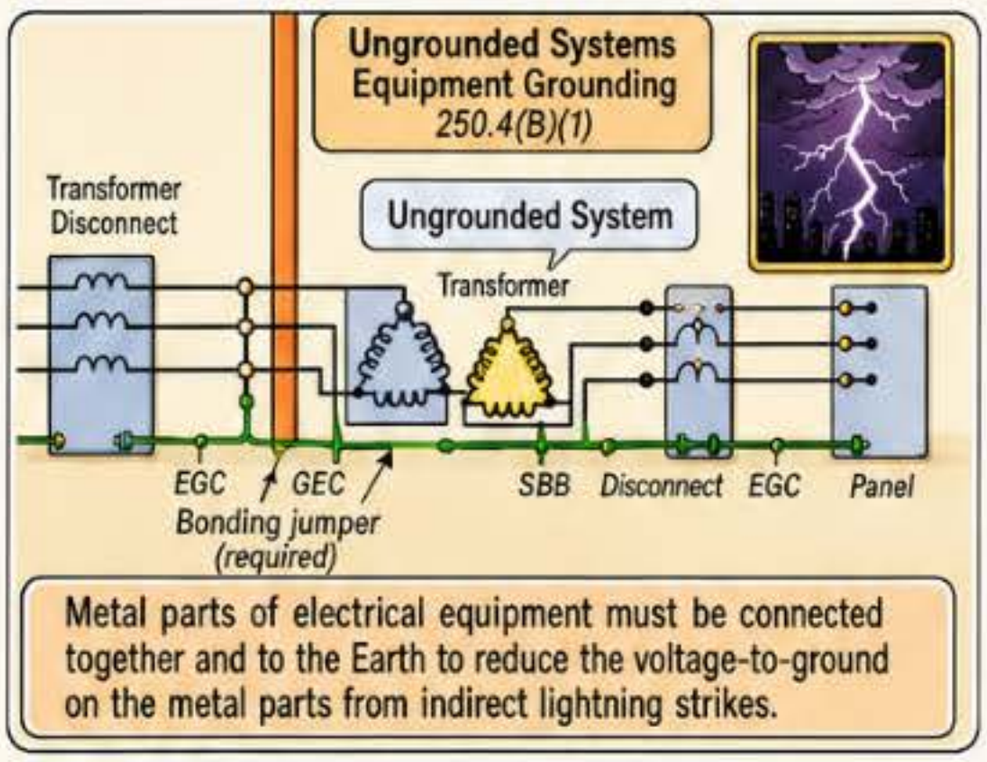
— *Michael Hamilton*

GROUNDING AND BONDING | 250.4



▶ Figure 250–20

(1) Equipment Grounding. All metal parts of electrical equipment must be connected to each other and to earth to reduce the voltage that may appear on the metal parts during indirect lightning strikes. ▶ Figure 250–21



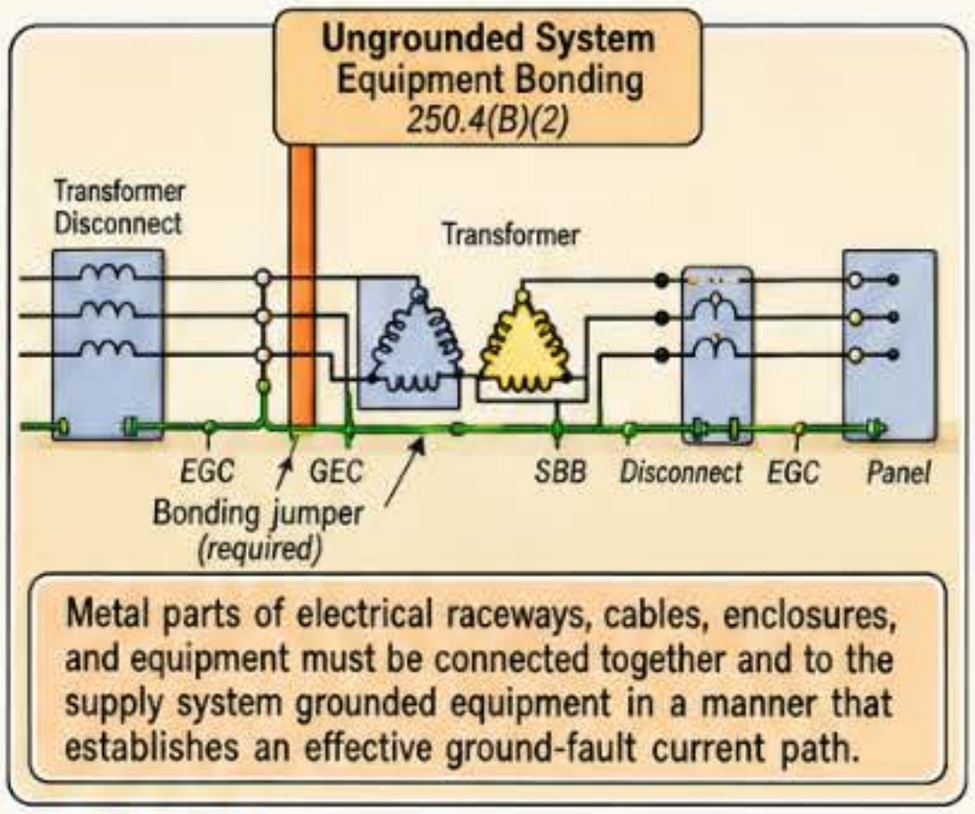
▶ Figure 250–21

DANGER

Failure to ground metal parts to earth can result in millions of volts of induced voltage on the metal parts of an electrical system from an indirect lightning strike. This energy seeks a path to earth within the building—potentially causing fire and/or electric shock from a side flash.

(2) Equipment Bonding. Metal parts of electrical raceways, cables, enclosures, and equipment must be connected together and to the supply system grounded equipment in a manner that establishes an effective ground-fault current path.

supply source in a manner that establishes an effective ground-fault current path. ▶ Figure 250–22



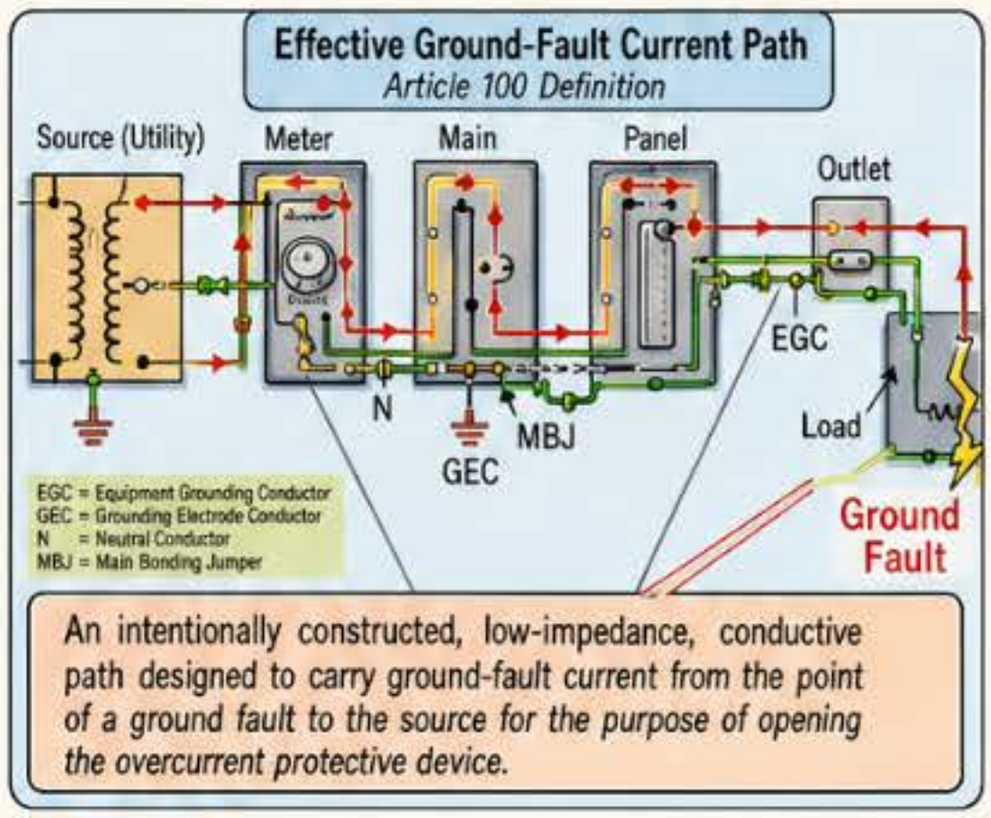
▶ Figure 250–22

The effective ground-fault current path must be capable of safely carrying the maximum fault current likely to be imposed on it from any point on the wiring system should a ground fault occur at the electrical supply source.

Author's Commentary:

▶ According to Article 100, an "Effective Ground-Fault Current Path" is an intentionally constructed low-impedance conductive path designed to carry fault current from the point of a ground fault to the source for the purpose of opening the circuit overcurrent protective device. ▶ Figure 250–23

— Michael Hamilton



▶ Figure 250–23

250.6 | GROUNDING AND BONDING

Author's Commentary:

- High voltage on metal parts caused by a ground fault can be removed quickly when the effective ground-fault current path has very low impedance. Low impedance ensures the fault current rises fast enough to trip an overcurrent device and open the circuit.
- How fast the overcurrent protective device opens depends on the size of the fault current. A greater fault current trips the device sooner. For example, a 20A overcurrent protective device with an overload rating of 40A (twice the 20A rating) will open within 25–150 seconds. The same device rated at 100A (five times the 20A rating) may take 5–20 seconds to trip.

— Michael Hamilton

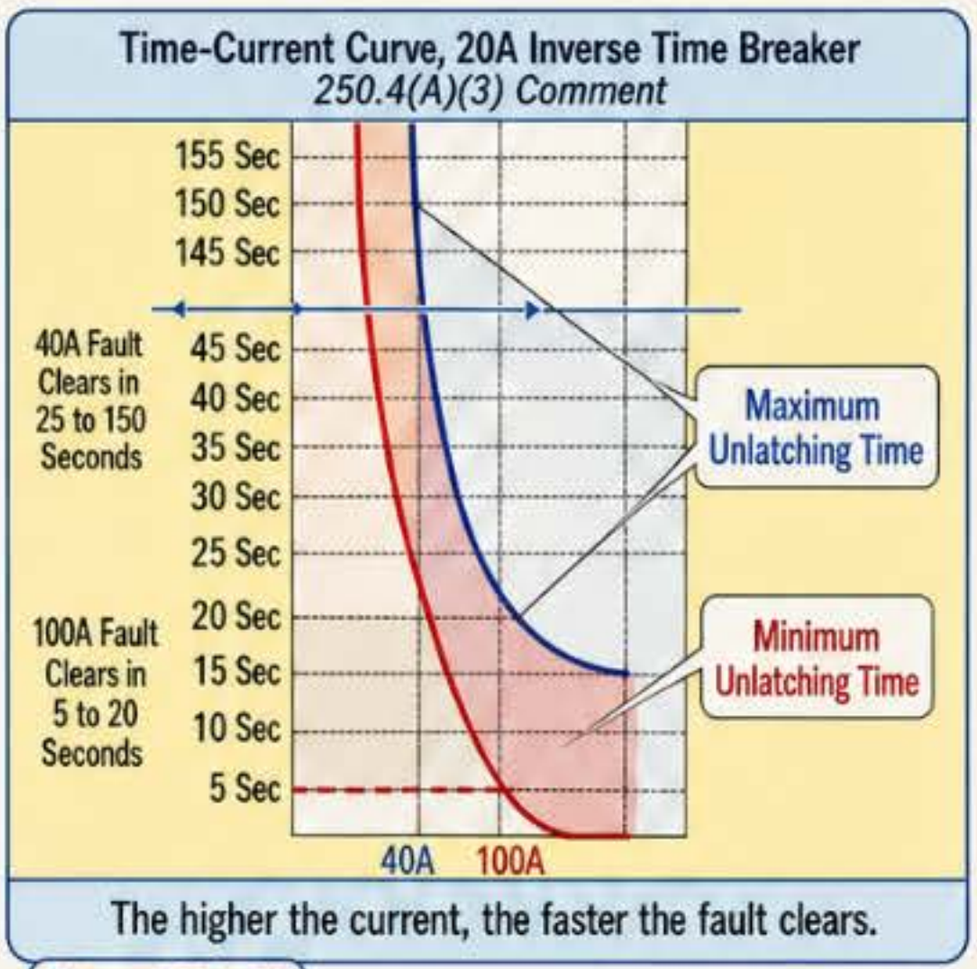


Figure 250–24

(3) Bonding Conductive Materials. Materials that can conduct electricity—such as metal water piping, metal sprinkler piping, metal gas piping, and other metal piping systems—along with exposed structural steel members likely to become energized must be bonded together. This bonding creates a low-impedance fault current path that is capable of carrying the maximum fault current likely to be imposed on it. ▸ Figure 250–24

(4) Fault Current Path. Electrical equipment, wiring, and other electrically conductive materials that can become energized must be installed so they provide a low-impedance fault current path that allows the operation of overcurrent devices to open the circuit during a second ground fault from a different phase. ▸ Figure 250–25

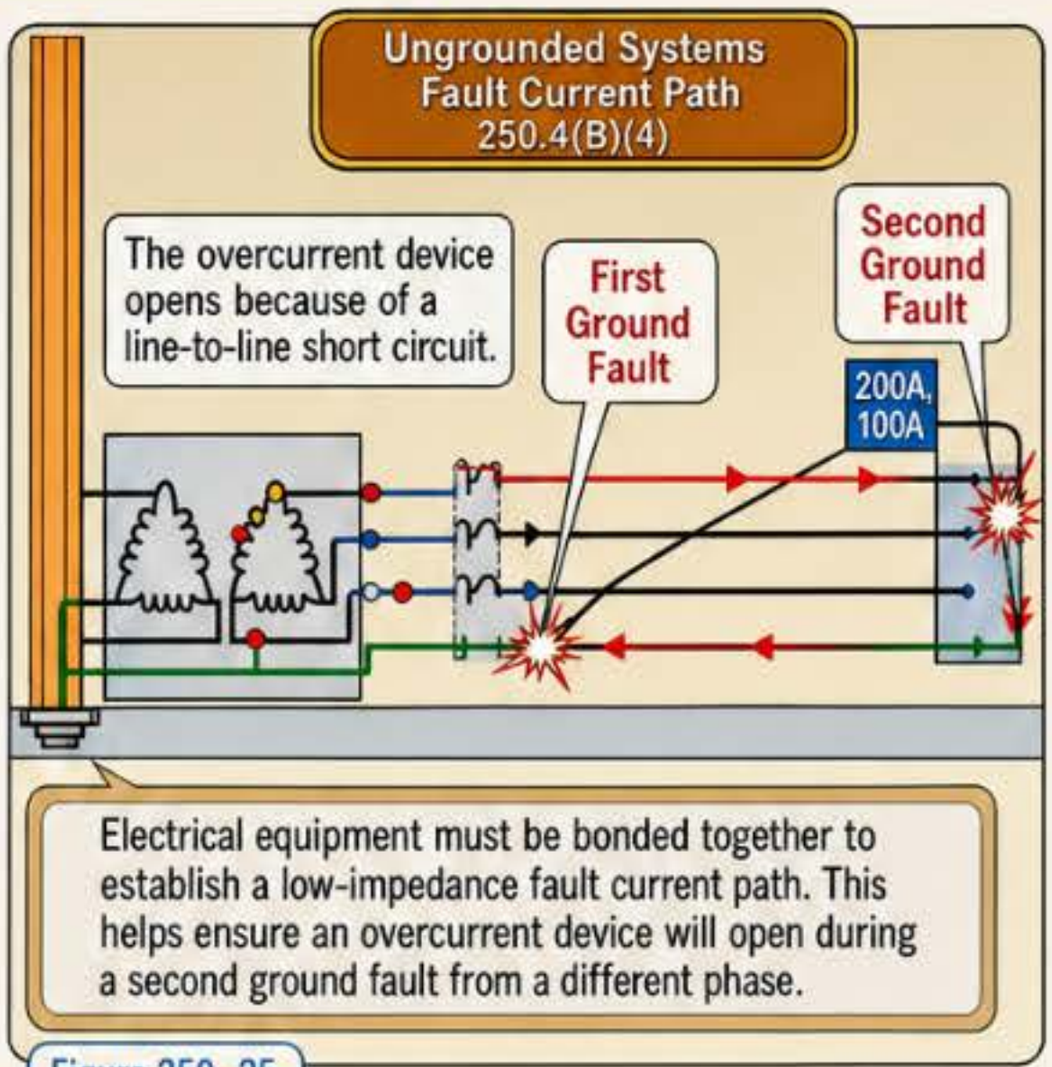


Figure 250–25

250.6 OBJECTIONABLE CURRENT

(A) Arranged to Prevent Objectionable Current. Electrical systems and equipment must be installed so that they prevent neutral or circuit current from flowing on metal parts (objectionable current). ▸ Figure 250–26

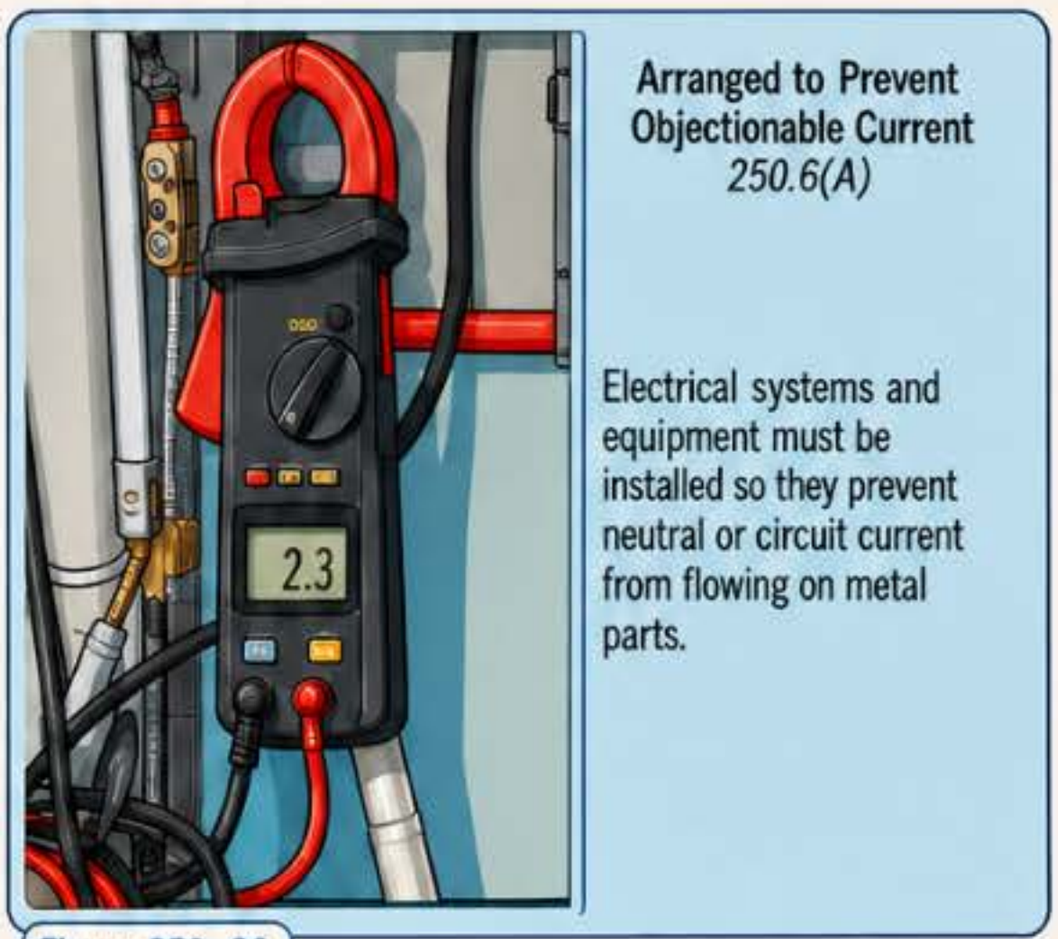
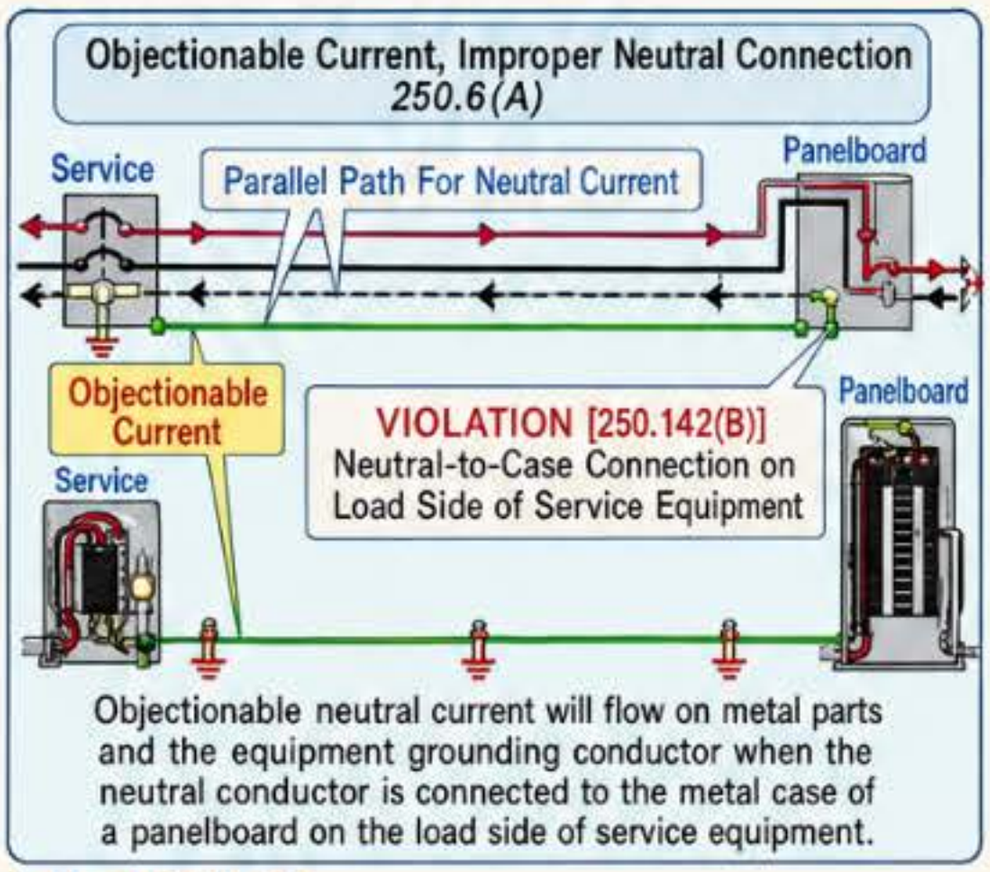


Figure 250–26

OBJECTIONABLE CURRENT

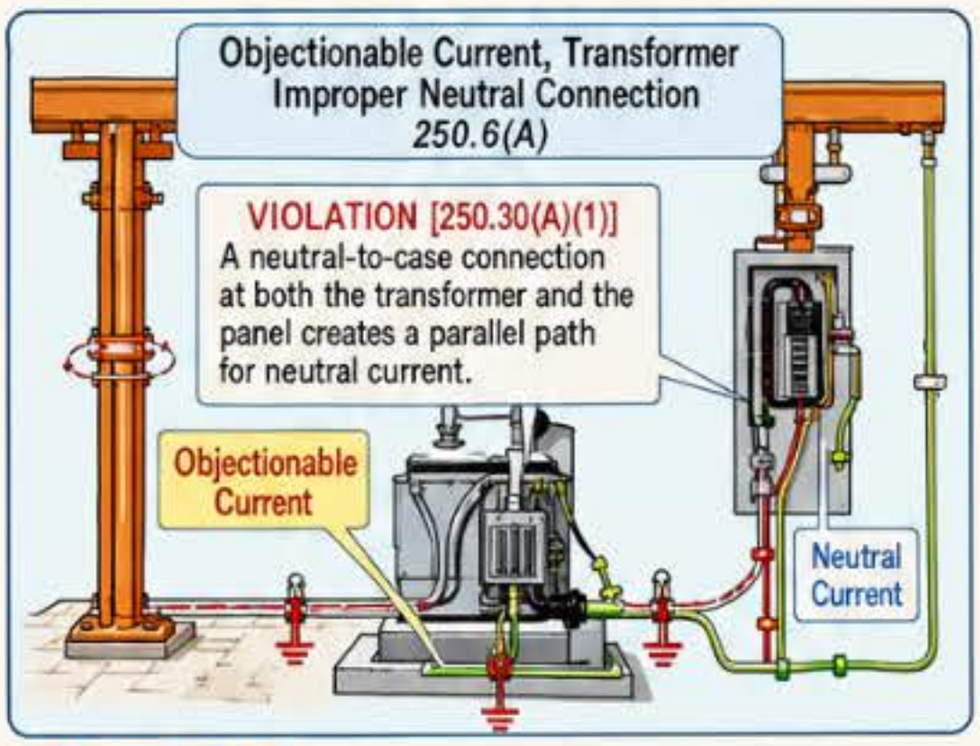
Objectionable neutral current is caused by incorrect neutral-to-case connections or by wiring mistakes that violate 250.142(B).

Panelboards. When objectionable neutral current flows on metal parts and the equipment grounding conductor, the neutral conductor ends up tied to the panelboard enclosure at the load end during a service disconnect. Figure 250–27



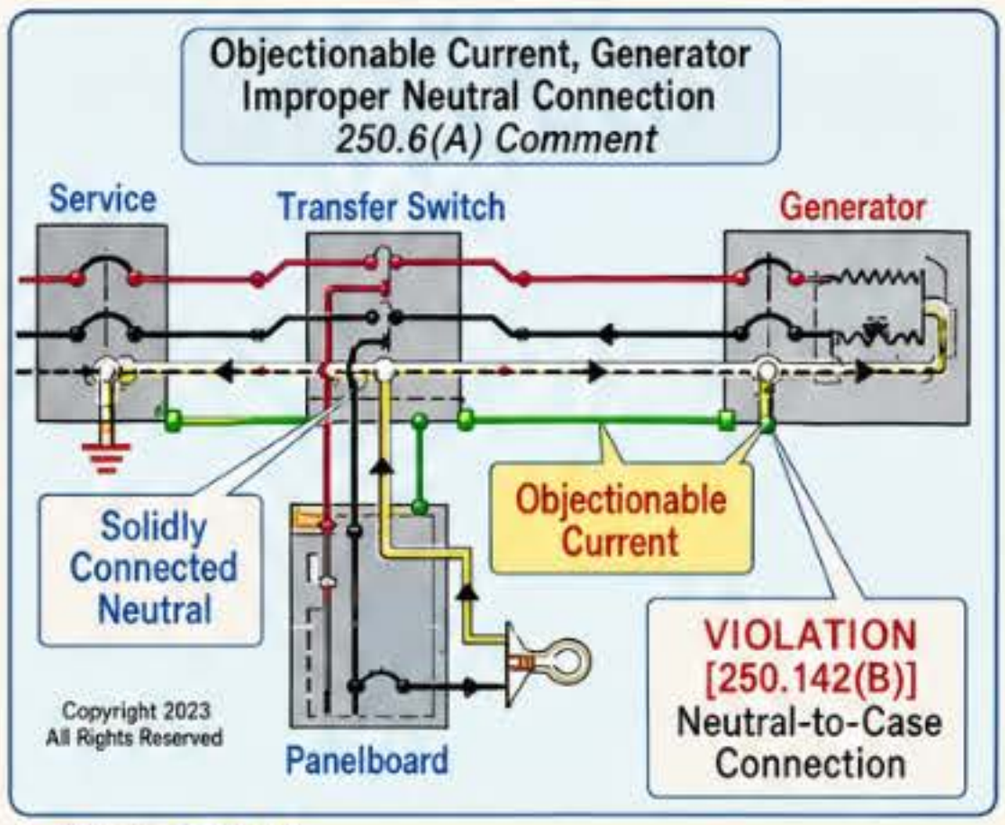
▶ Figure 250–27

Transformers. Objectionable neutral current will flow on metal parts if the neutral conductor is connected to the circuit equipment grounding conductor at both the transformer and any other location on the load side of the system bonding jumper. Figure 250–28



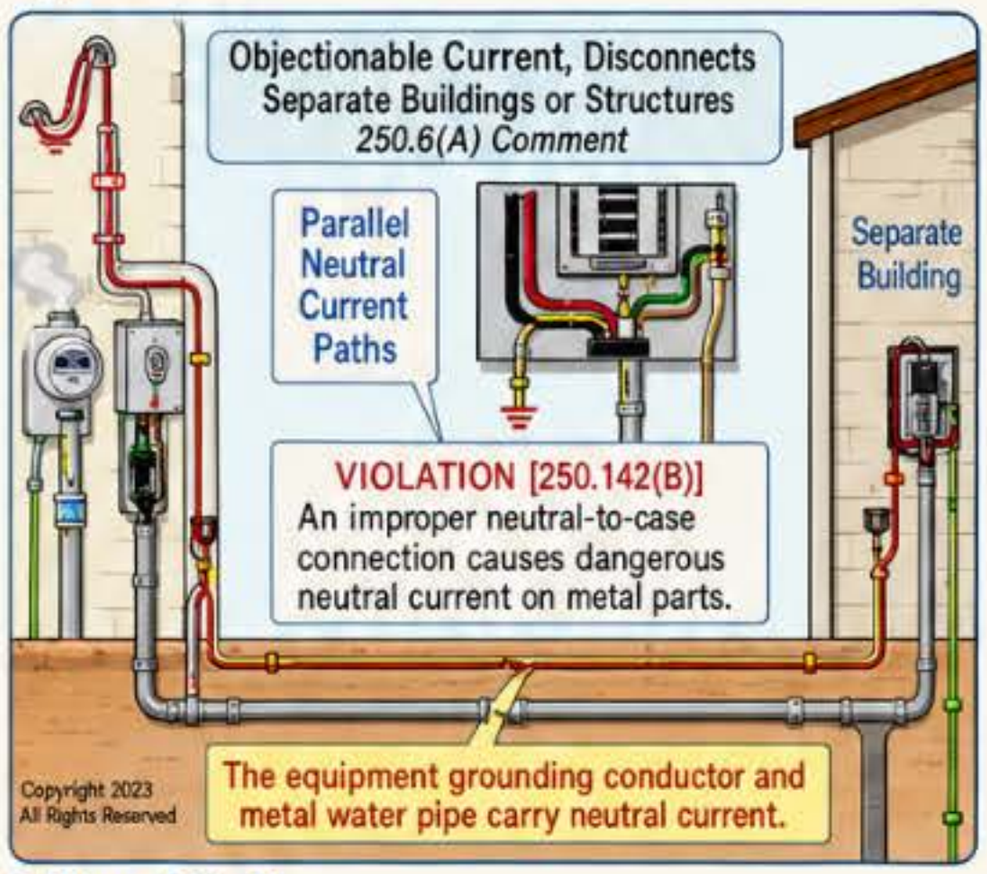
▶ Figure 250–28

Generator. Objectionable neutral current will flow on metal parts and the equipment grounding conductor if a generator is connected to a transfer switch with solidly connected neutral, and a neutral-to-case connection is made at the generator. Figure 250–29



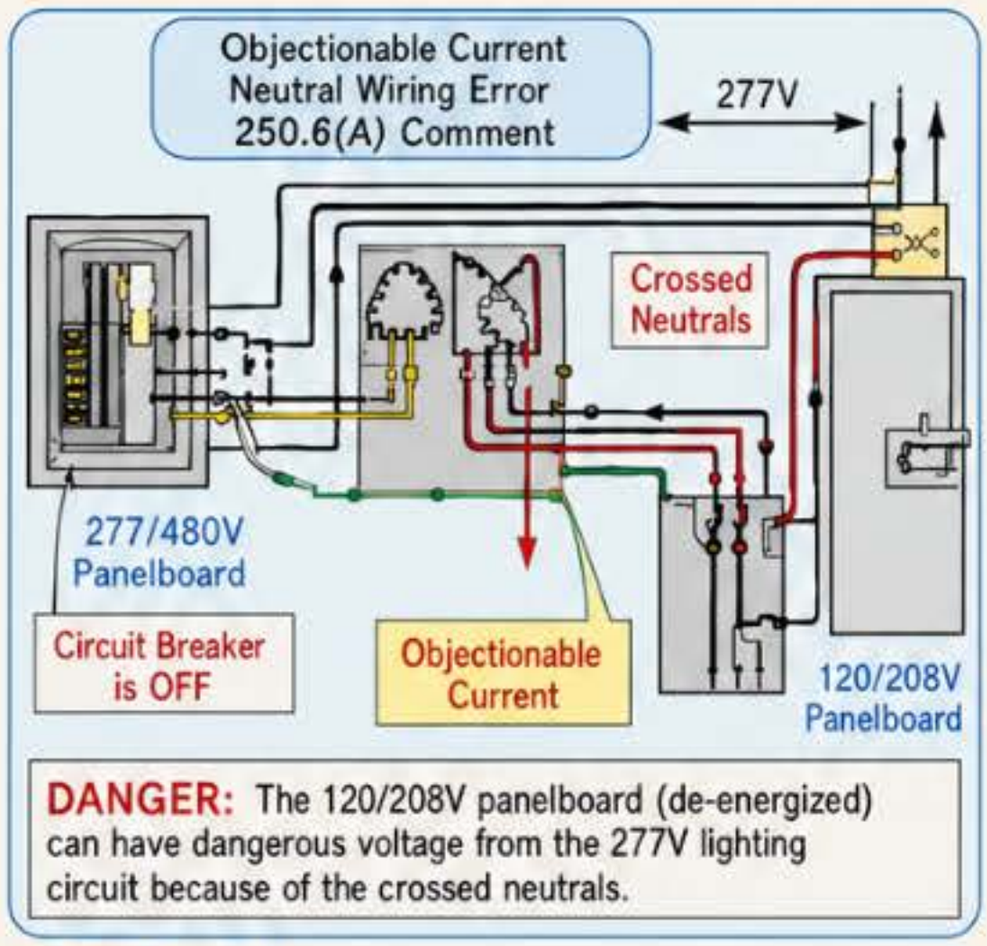
▶ Figure 250–29

Disconnects. Objectionable neutral current will flow on metal parts and the equipment grounding conductor if the neutral conductor is connected to the metal case of a disconnect that is not part of the service disconnect. Figure 250–30



▶ Figure 250–30

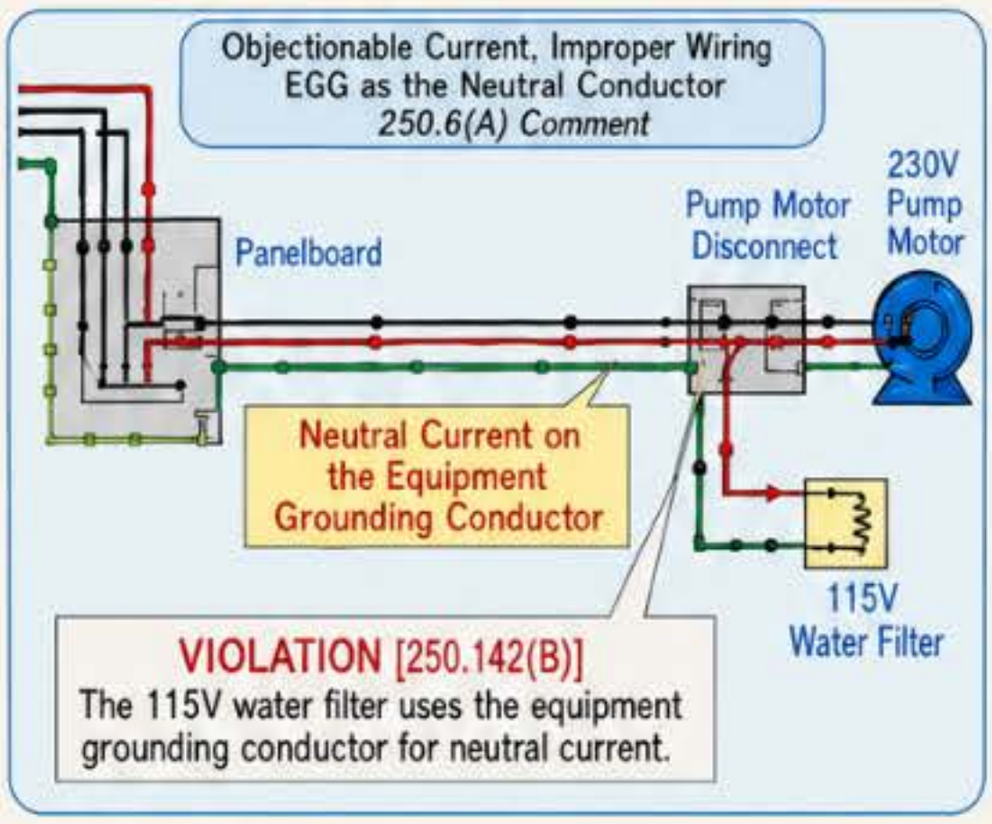
Wiring Errors. Objectionable neutral current will flow on metal parts and the equipment grounding conductors if the neutral conductor from one system is used as the neutral conductor for a different system. Figure 250–31



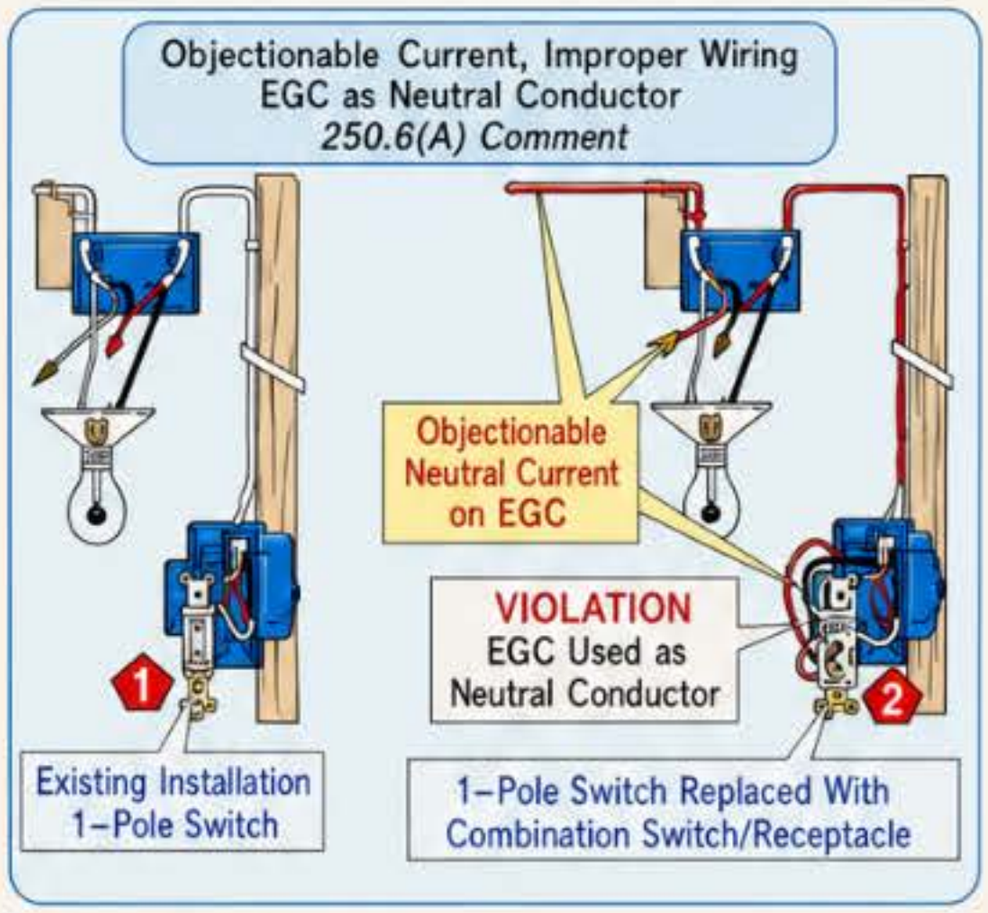
▲ Figure 250–31

Improper Wiring. Objectionable neutral current will flow on the equipment grounding conductor if the circuit equipment grounding conductor is used as a neutral conductor, such as where:

- ► A 230V time-clock motor is replaced with a 115V time-clock motor, and the circuit equipment grounding conductor is used for neutral return current.
- ► A 115V water filter is wired to a 240V well-pump motor circuit, and the circuit equipment grounding conductor is used for neutral return current. ►Figure 250–32
- ► The circuit equipment grounding conductor is used for neutral return current. ►Figure 250–33



▲ Figure 250–32

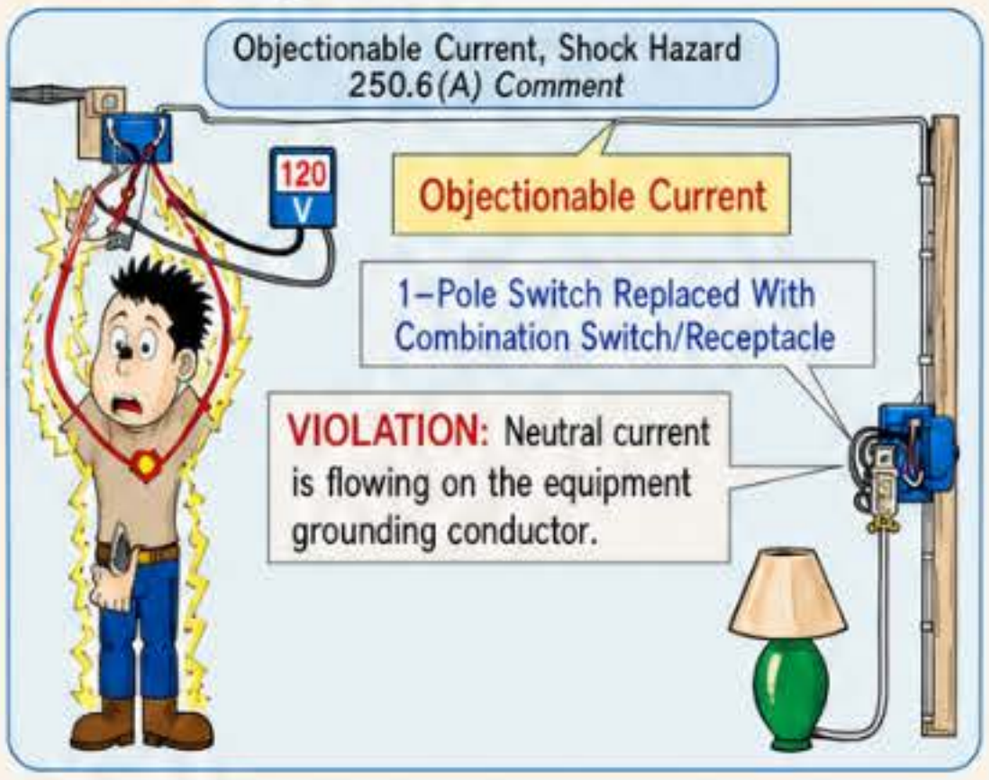


▲ Figure 250–33

Dangers of Objectionable Current

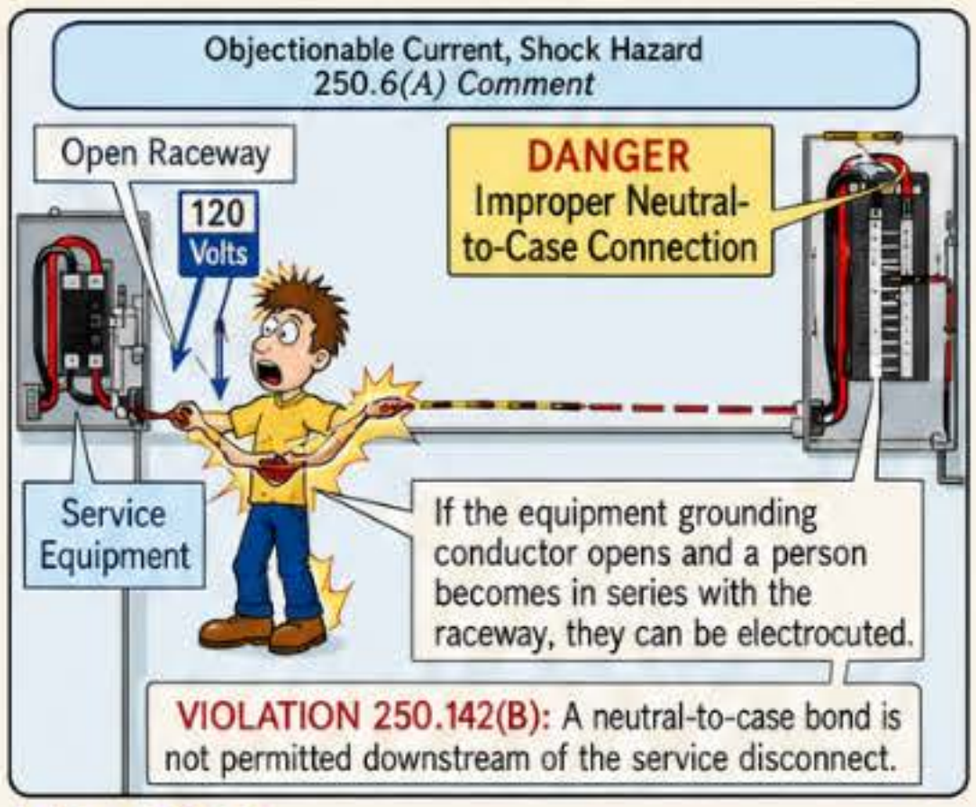
Objectionable neutral current on metal parts can cause electric shock, fires, and the improper operation of electronic equipment and overcurrent protective devices such as GFCIs and AFCIs.

Shock Hazard. When objectionable neutral current flows on metal parts or the equipment grounding conductor, electric shock and even death can occur from the elevated voltage. ►Figure 250–34 and ►Figure 250–35

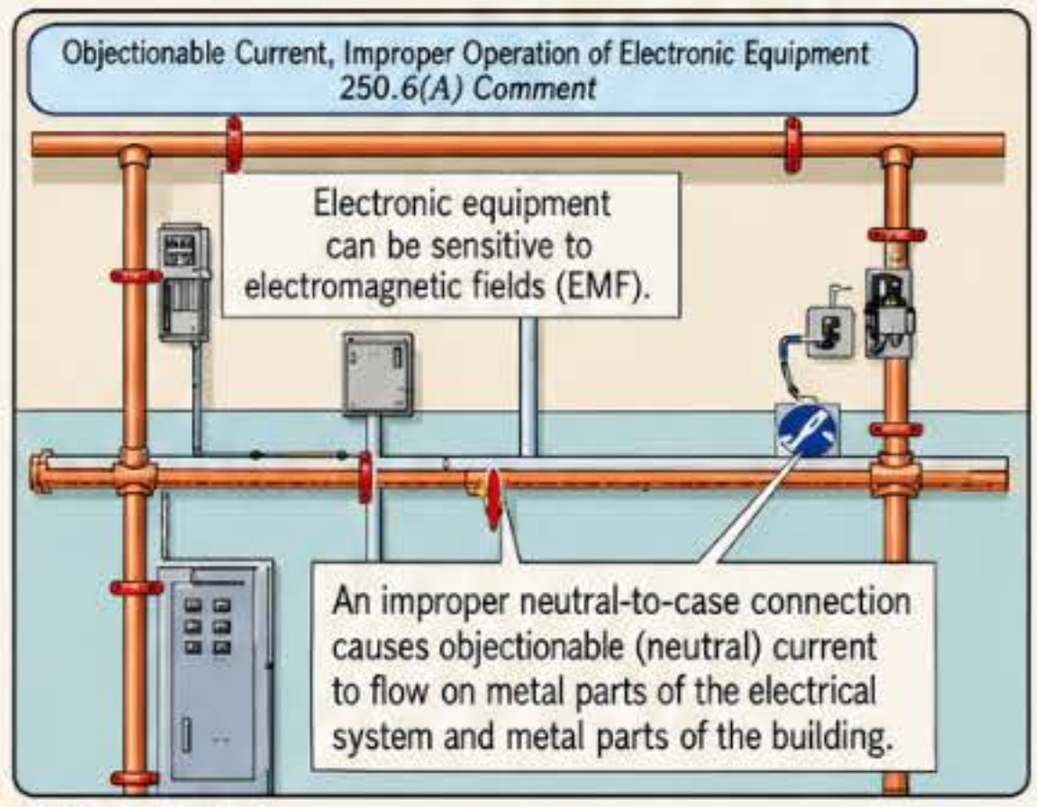


▲ Figure 250–34

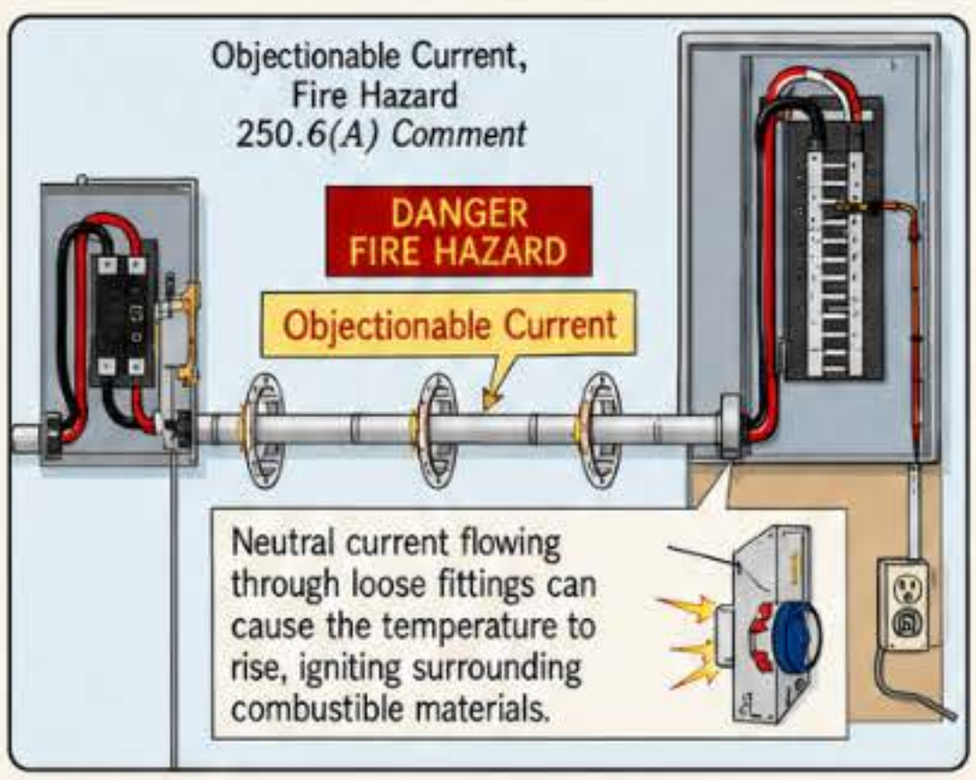
Fire Hazard. When objectionable neutral current flows on metal parts, a fire can ignite adjacent combustible material. Heat is generated whenever current flows, particularly over high-resistance parts. In addition, arcing at loose connections is especially dangerous in areas containing easily ignitable and explosive gases, vapors, or dust. ►Figure 250–36



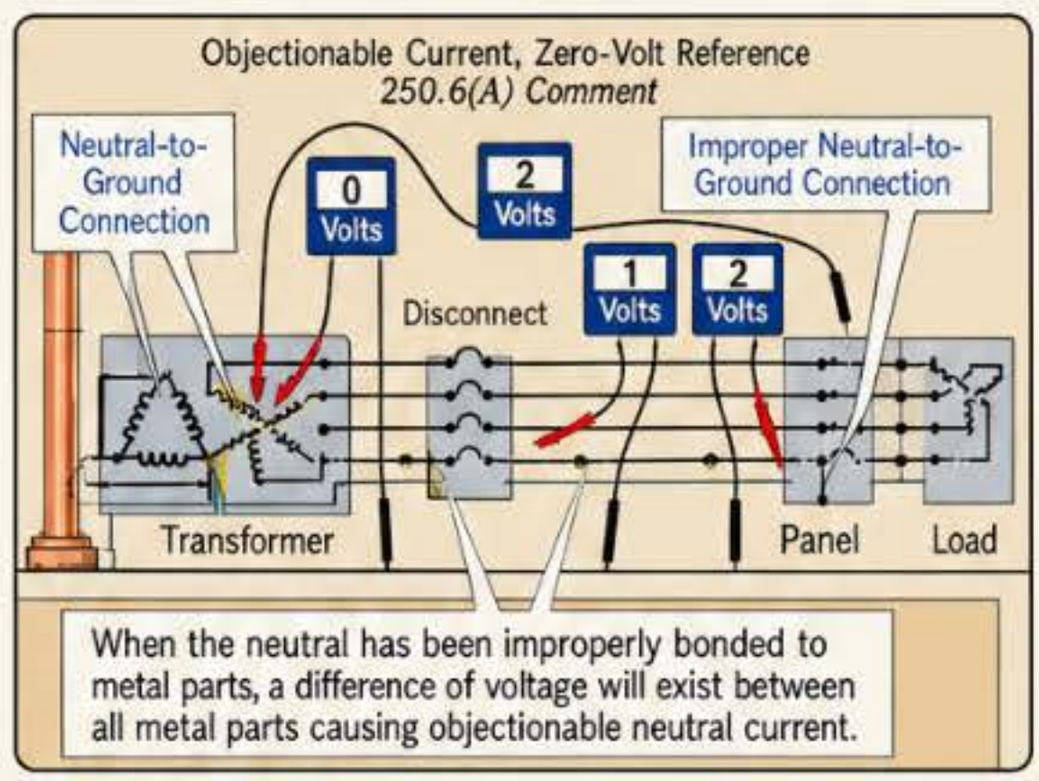
▶ Figure 250–35



▶ Figure 250–37



▶ Figure 250–36

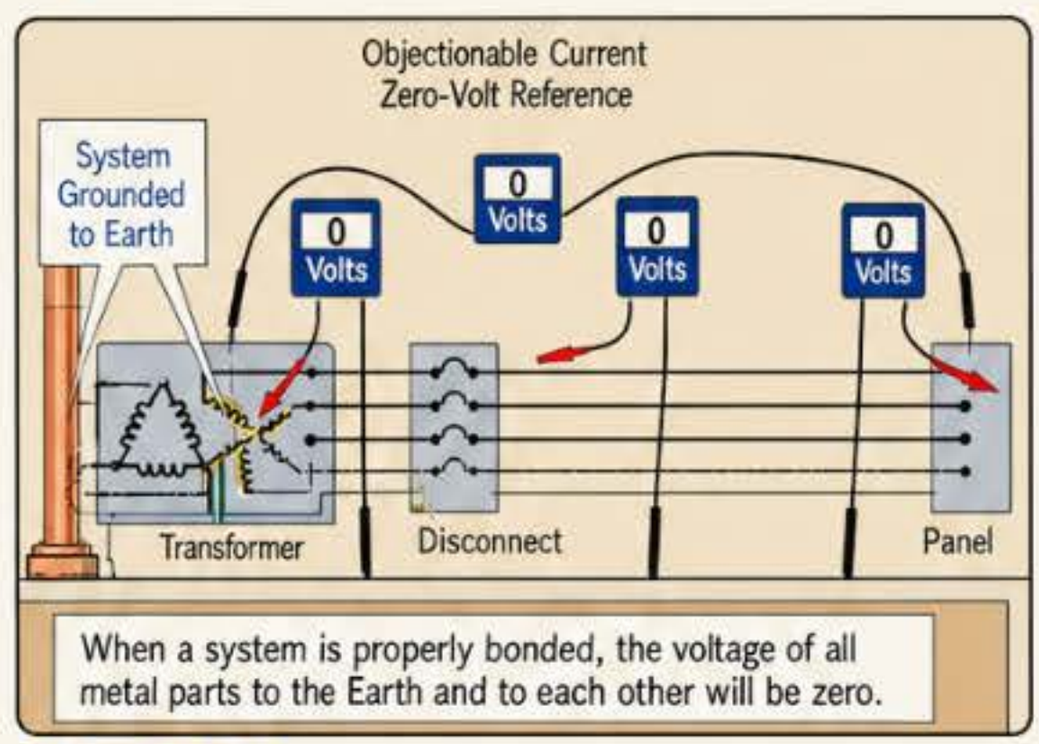


▶ Figure 250–38

Improper Operation of Electronic Equipment. *Objectionable neutral current flowing on metal parts of electrical equipment and building parts can create electromagnetic fields which negatively affect the performance of electronic devices; particularly medical equipment.* ▶ Figure 250–37

When objectionable neutral current travels on metal parts and equipment grounding conductors because the neutral has been improperly bonded to metal parts, a difference of voltage will exist between all metal parts. This situation can cause some electronic equipment to operate improperly. ▶ Figure 250–38 *and* ▶ Figure 250–39

Operation of Overcurrent Protective Devices. *When objectionable neutral current travels on metal parts, electronic overcurrent protective devices equipped with ground-fault protection can trip because some neutral current flows on the circuit equipment grounding conductor instead of on the neutral conductor.*



▶ Figure 250–39

Author's Commentary: *Never connect the neutral to enclosures or building steel past the service disconnect. It's unsafe, creates stray current, and can wreak havoc on sensitive electronics.*

— Michael Hamilton

Author's Commentary: *Keep the neutral isolated from metal parts after the main disconnect. Proper bonding and grounding eliminate shock hazards, reduce interference, and protect electronic equipment.*

— Michael Hamilton

250.8 | Grounding and Bonding

250.8 Connection of Grounding and Bonding Connectors

(A) Permitted Methods. Grounding conductors, grounding electrode conductors, and bonding jumpers must be connected using one or more of these methods:

(1) Listed pressure connectors

(2) Terminal bars

(3) Pressure connectors listed for grounding and bonding

(4) Exothermic welding

(5) Machine screws that engage at least two threads or are secured with a nut [Figure 250-40]

▶ Figure 250-40

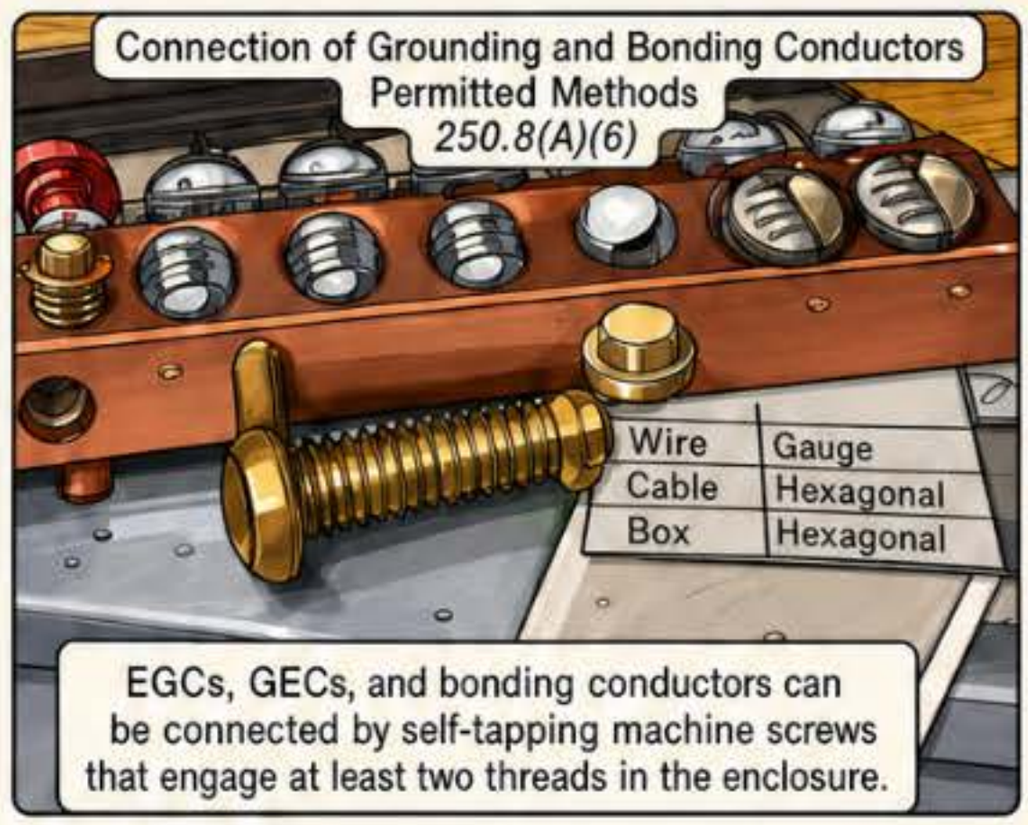
(6) Self-tapping machine screws that engage at least two threads in the enclosure [Figure 250-41]

(7) Connections that are part of a listed assembly

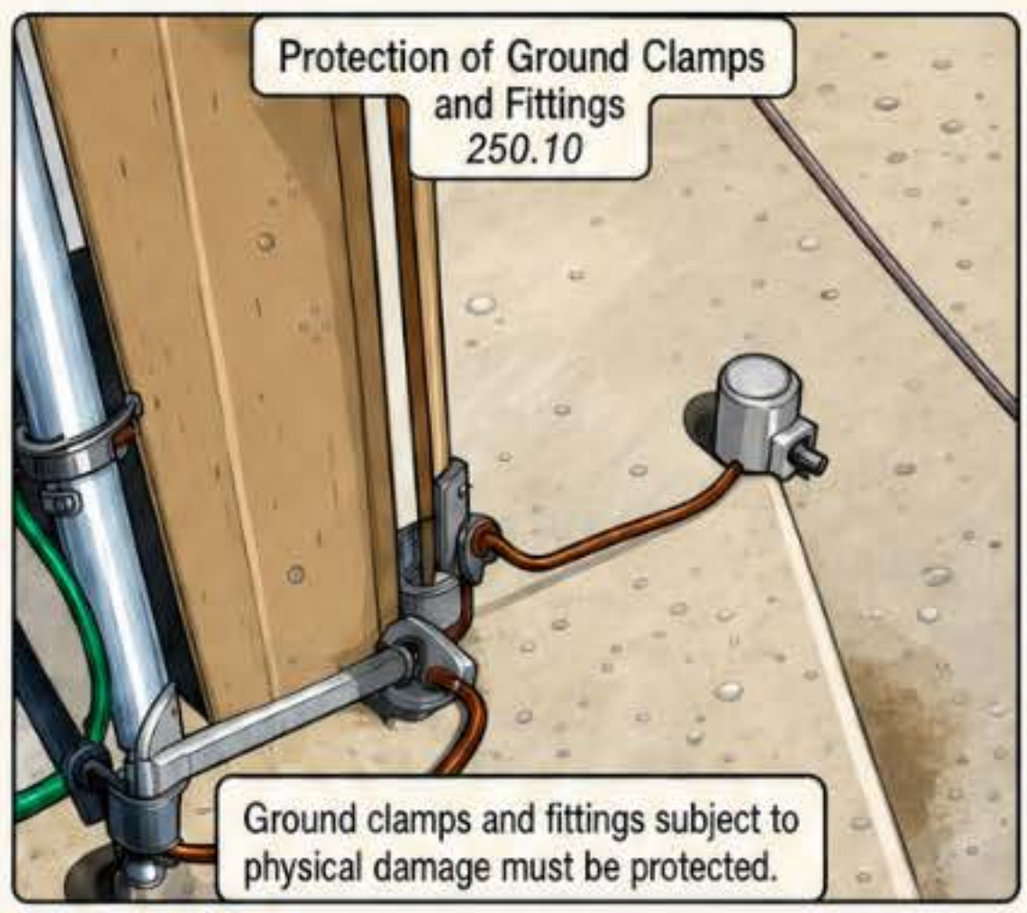
(8) Other listed means

250.10 Protection of Ground Clamps and Fittings

Ground clamps and fittings that could be subjected to physical damage must be protected. [Figure 250-42]



▶ Figure 250-41



▶ Figure 250-42

250.12 Clean Surfaces

Nonconductive coatings (such as paint) on equipment to be grounded or bonded must be removed from the terminal connections to ensure good electrical continuity. The termination fittings must be prepared to allow any coating removal that is necessary [250.53(A) and 250.96(A)].

Author's Commentary:

- *Fittings like locknuts are designed to cut through the nonconductive coating and maintain continuous electrical contact when they are tightened properly.*
- *Remove tarnish from copper water pipe as needed before making a termination.*

— Michael Hamilton

Part II. System Grounding and Bonding

250.20 Systems Required to be Grounded

(A) Alternating-Current Systems Below 50V. The secondary of a transformer operating below 50V is not required to be grounded or bonded in accordance with 250.30 unless the transformer's primary supply is from: Figure 250–43

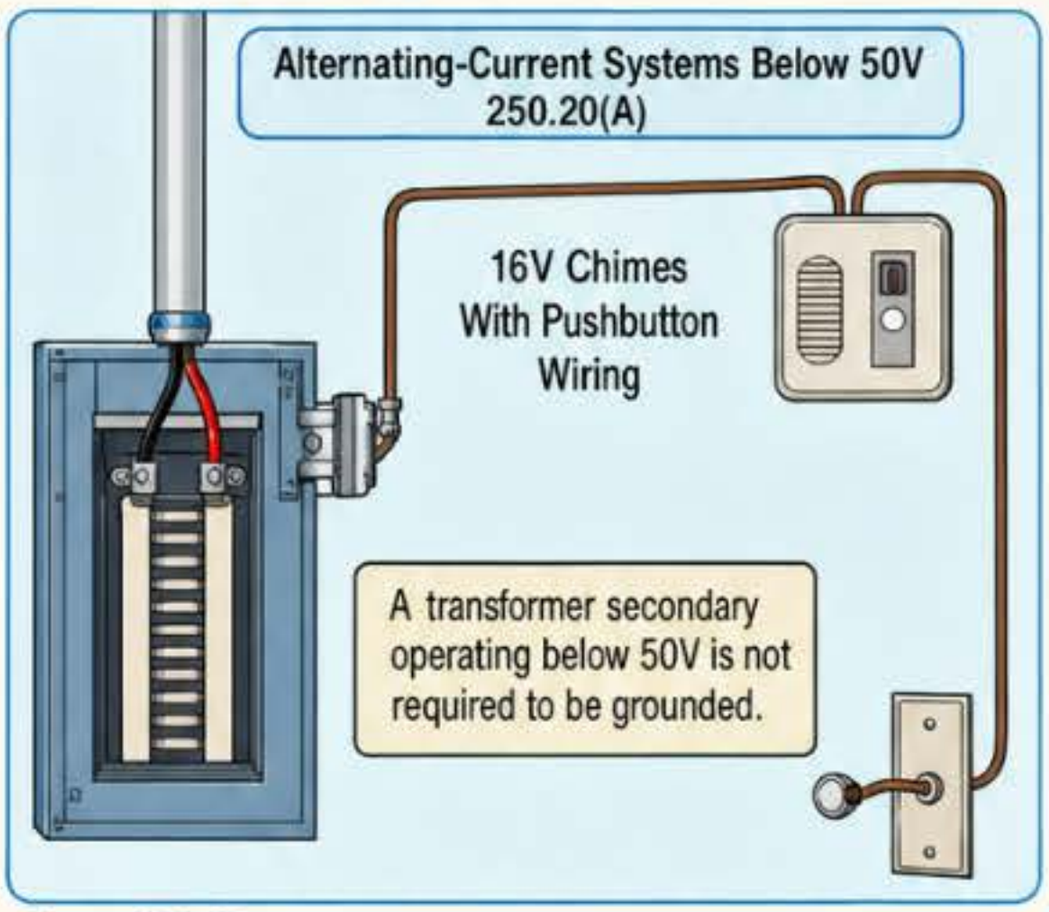


Figure 250–43

(1) A 277V or 480V system

(2) An ungrounded system

(B) Alternating-Current Systems 50V to 1,000V. The following systems must be grounded (connected to a grounding electrode) where the neutral conductor is used as a circuit conductor:

(1) Single-phase systems. ▶ Figure 250–44

(2) Three-phase, wye-connected systems. ▶ Figure 250–45

(3) Three-phase, high-leg delta-connected systems. ▶ Figure 250–46

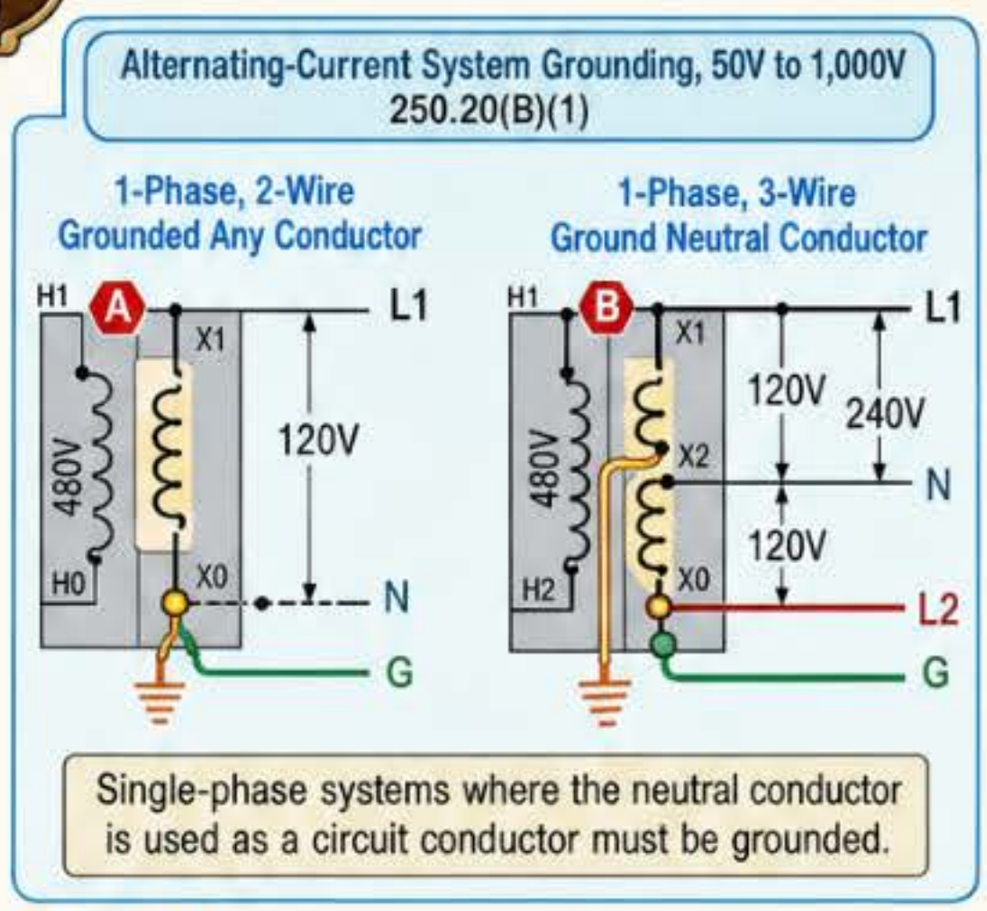


Figure 250–44

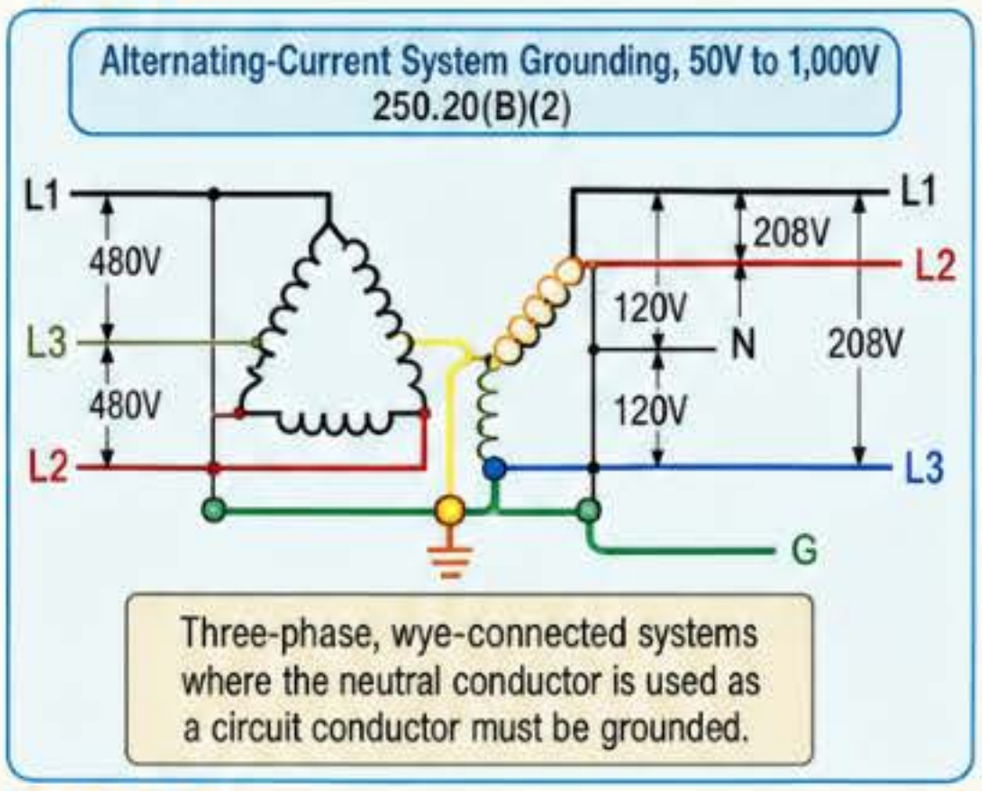


Figure 250–45

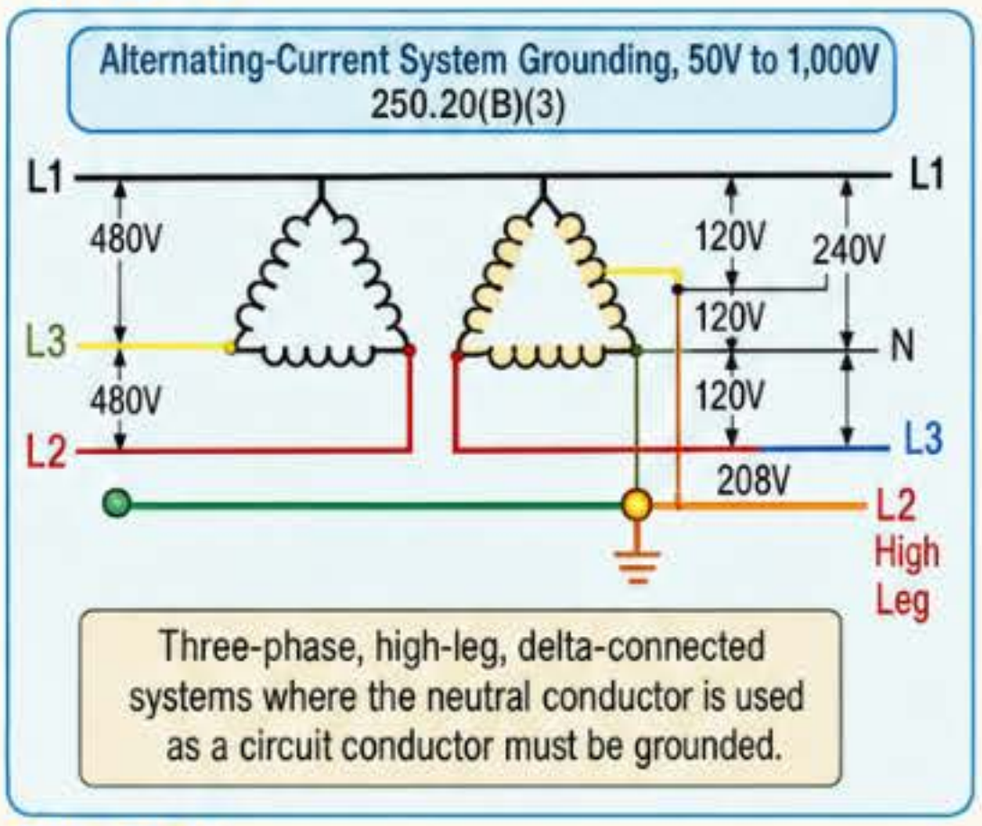


Figure 250–46

Author's Commentary:

Per Annex O of NFPA 70E, Standard for Electrical Safety in the Workplace, a high-impedance ground can greatly reduce the likelihood of arc flash incidents.

— Michael Hamilton

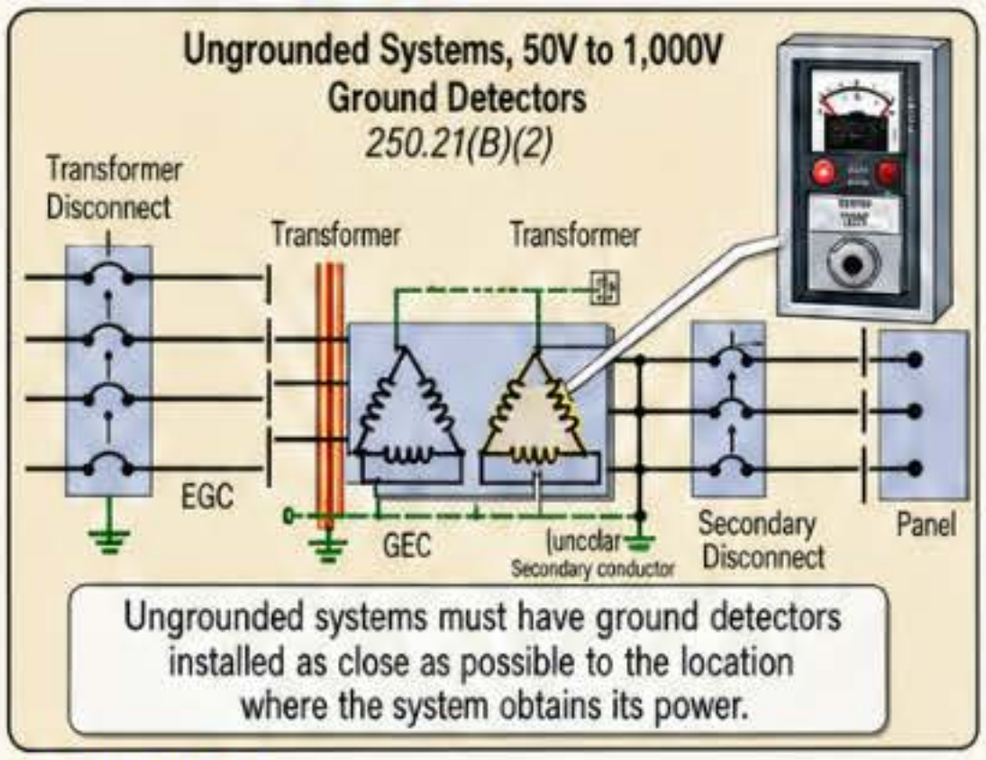
250.21 Grounding and Bonding

250.21 Ungrounded Systems

(B) Ground Detectors. Ungrounded alternating-current systems from 50V to 1,000V or less are not required to be grounded if:

① The ungrounded systems operating between 120V and 1,000V as permitted in 250.21(A) have ground detectors installed on the system.

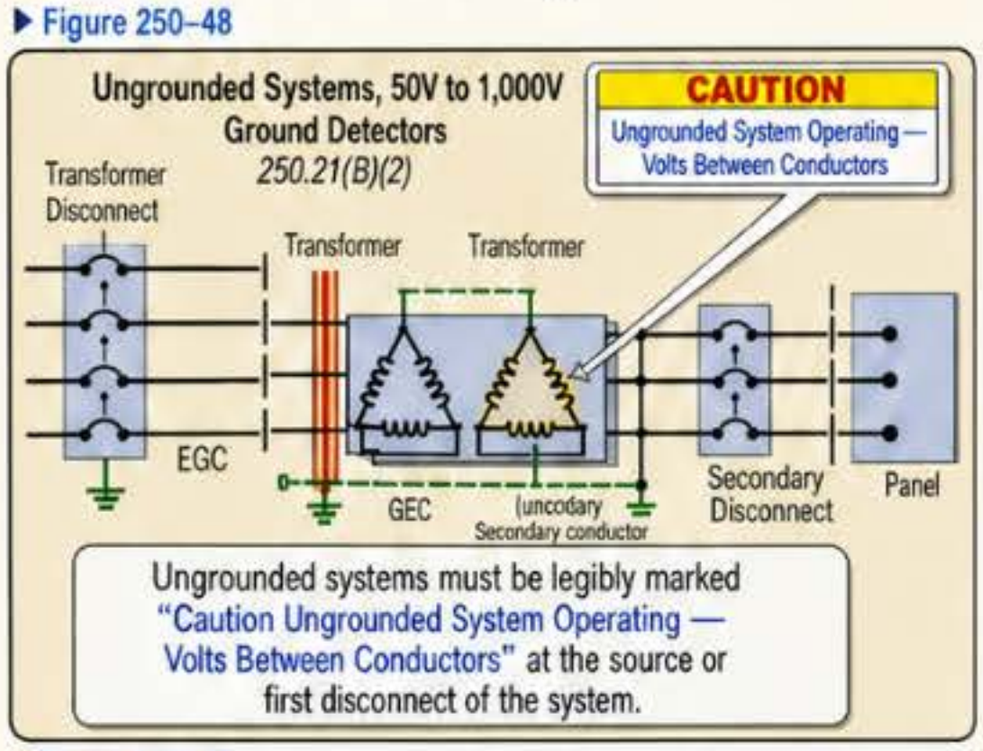
② The ground detection sensing equipment is connected as close as practicable to where the system receives its supply. ▶ Figure 250–47



▶ Figure 250–47

(C) Marking. Ungrounded systems must be legibly marked **"CAUTION UNGROUNDED SYSTEM OPERATING — VOLTS BETWEEN CONDUCTORS"** with sufficient durability to withstand the environment involved at the source or first disconnect of the system.

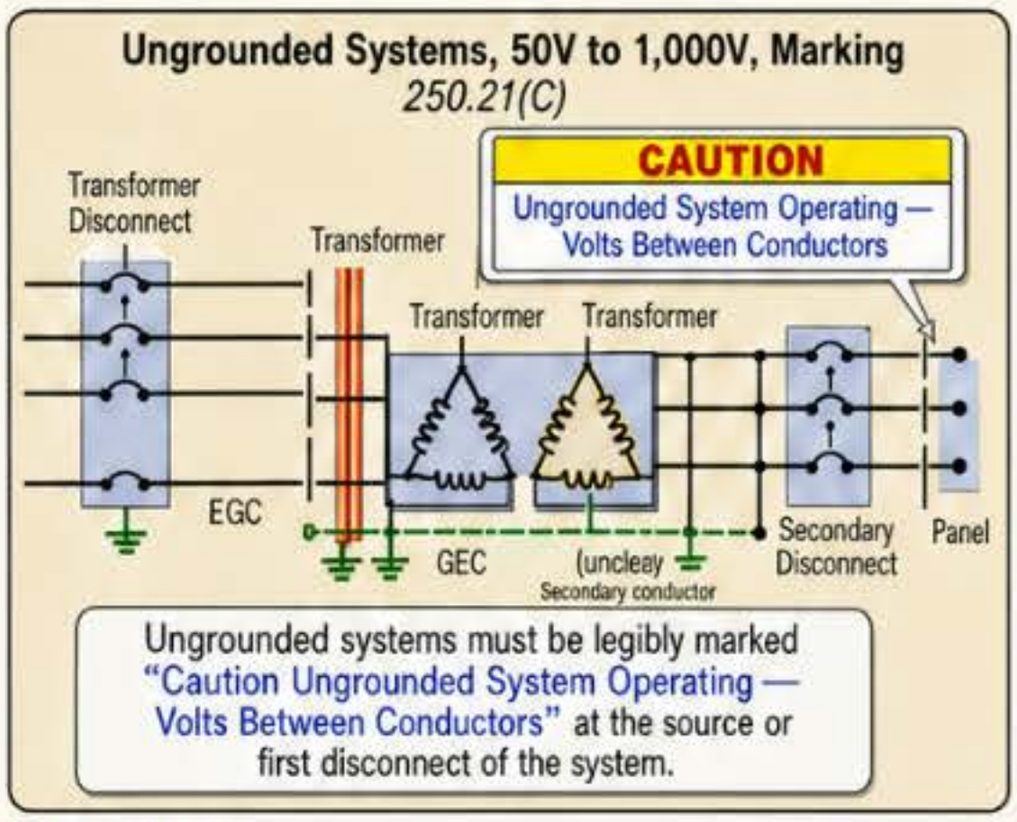
▶ Figure 250–48



▶ Figure 250–48

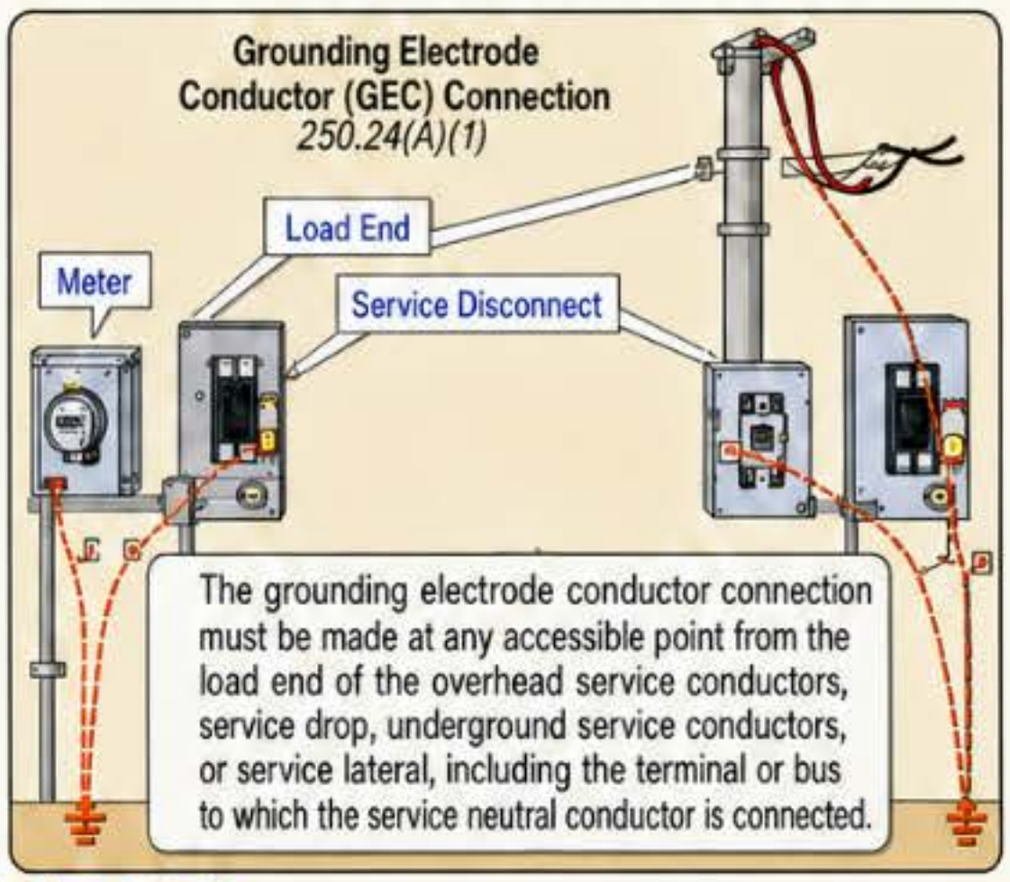
250.24 Grounding

(A) Grounded System. A premises wiring system supplied by a grounded alternating-current service must have a grounding electrode conductor connected to the service neutral conductor in accordance with the following:



▶ Figure 250–48

(1) General. The grounding electrode conductor connection to the neutral conductor at service equipment must be made at any accessible point from the load end of the overhead service conductors, service drop, underground service conductors, or service lateral, including the terminal or bus to which the service neutral conductor is connected at the service disconnecting means. ▶ Figure 250–49



▶ Figure 250–49

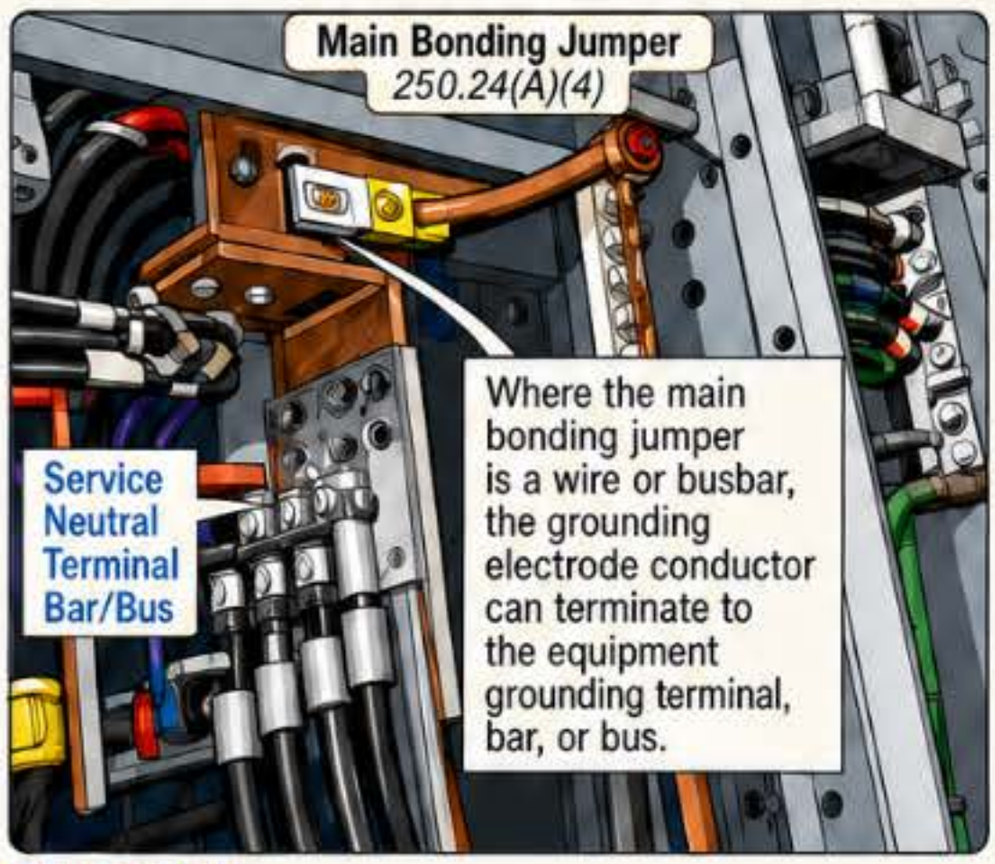
Author's Commentary:

Some inspectors require the grounding electrode conductor connection to be installed inside the meter socket enclosure, while others allow the connection to be made only within the service disconnect. Grounding at either location meets this rule; however, it is important to understand the local utility company's policy on connections inside the meter socket, since many do not permit access to a sealed socket.

— Michael Hamilton

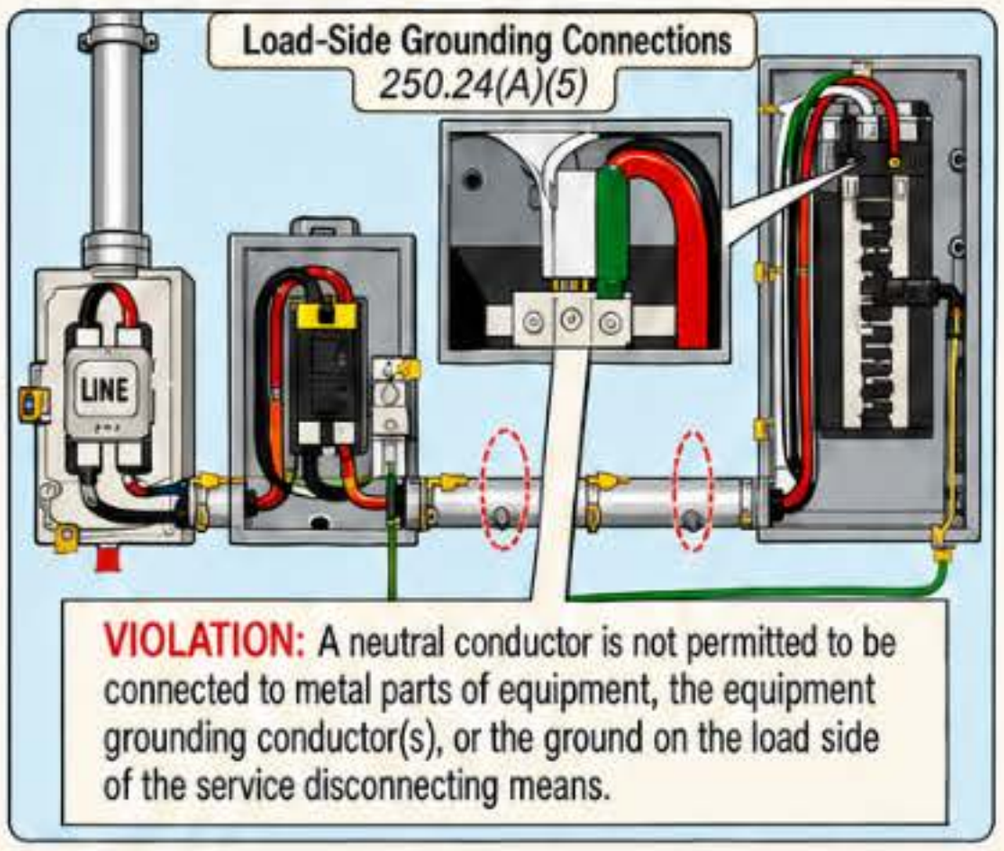
250.24 Definitions

(4) Main Bonding Jumper as Wire or Busbar. The principal bonding jumper described in 250.24 may be a conductor or a busbar. It is installed from the service neutral terminal of the service disconnecting means or from the equipment grounding terminal bar or bus to the service equipment. The equipment grounding conductor is allowed to attach to the equipment grounding terminal, bar, or bus that this main bonding jumper connects. ▸ Figure 250–50



▸ Figure 250–50

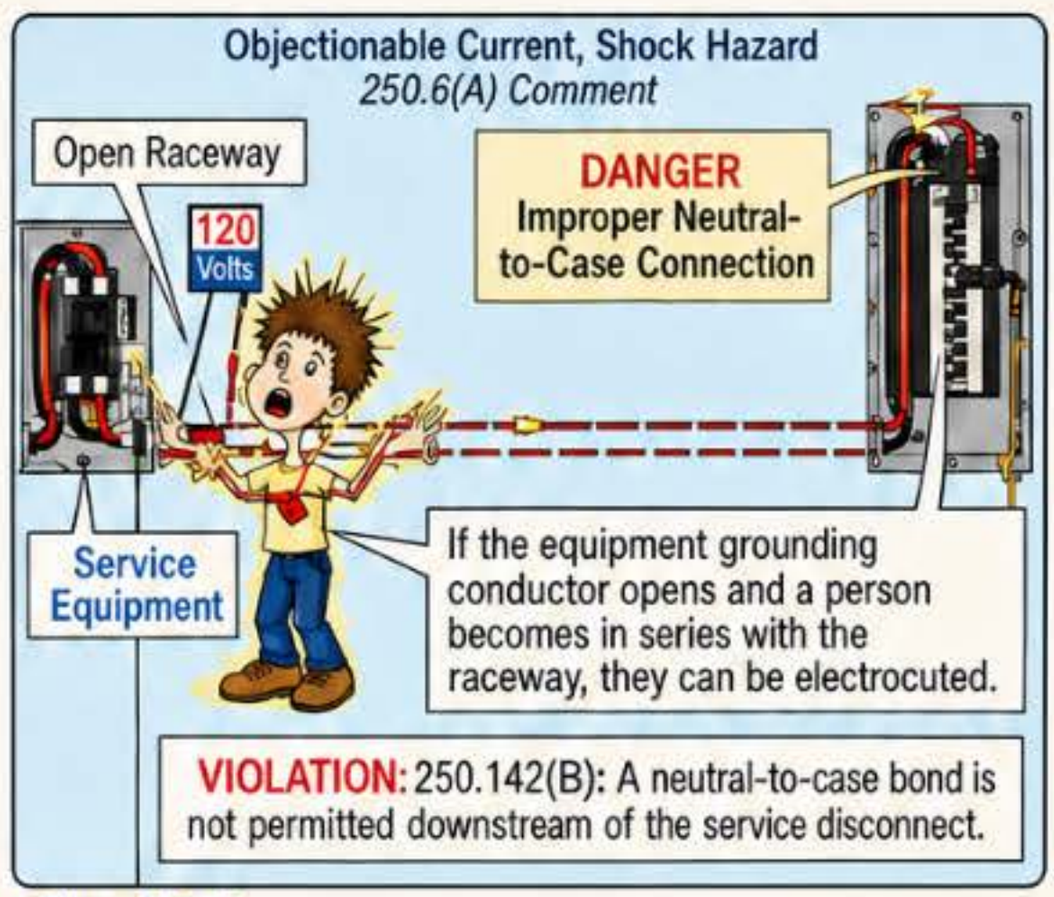
(5) Load-Side Grounding Connections. A neutral wire must not be connected to metal parts of equipment, to the equipment grounding conductor(s), or to the grounding electrode conductor on the supply side of the service disconnect. (Other than as allowed by 250.142.) ▸ Figure 250–51



▸ Figure 250–51

Author's Commentary:
When the neutral connection is made on the supply side of the service disconnect, objectionable neutral current can flow on conductive metal parts of electrical equipment [250.6(A)]. That stray current on metal parts is dangerous. It may expose people to electric shock or even cause death by electrocution (from ventricular fibrillation), as well as create a fire hazard.

— Michael Hamilton



▸ Figure 250–52

Note: See 250.30 for separately derived systems, 250.32 for connections at separate buildings, and 250.142 for circumstances where the neutral conductor is permitted to be connected to the equipment grounding conductor.

(B) Main Bonding Jumper. An unspliced main bonding jumper is required to bond the equipment grounding conductor(s) together and to the service enclosure neutral conductor within the enclosure of the service disconnect according to 250.24. ▸ Figure 250–53

(C) Neutral Conductor Brought to Service Equipment. A neutral wire must be run with the phase conductors to each service disconnecting means and land on the neutral terminal or bus of each disconnecting means. A main bonding jumper must connect the neutral conductor(s) to each service disconnecting means enclosure. ▸ Figure 250–54 and ▸ Figure 250–55

250.24 | Grounding and Bonding

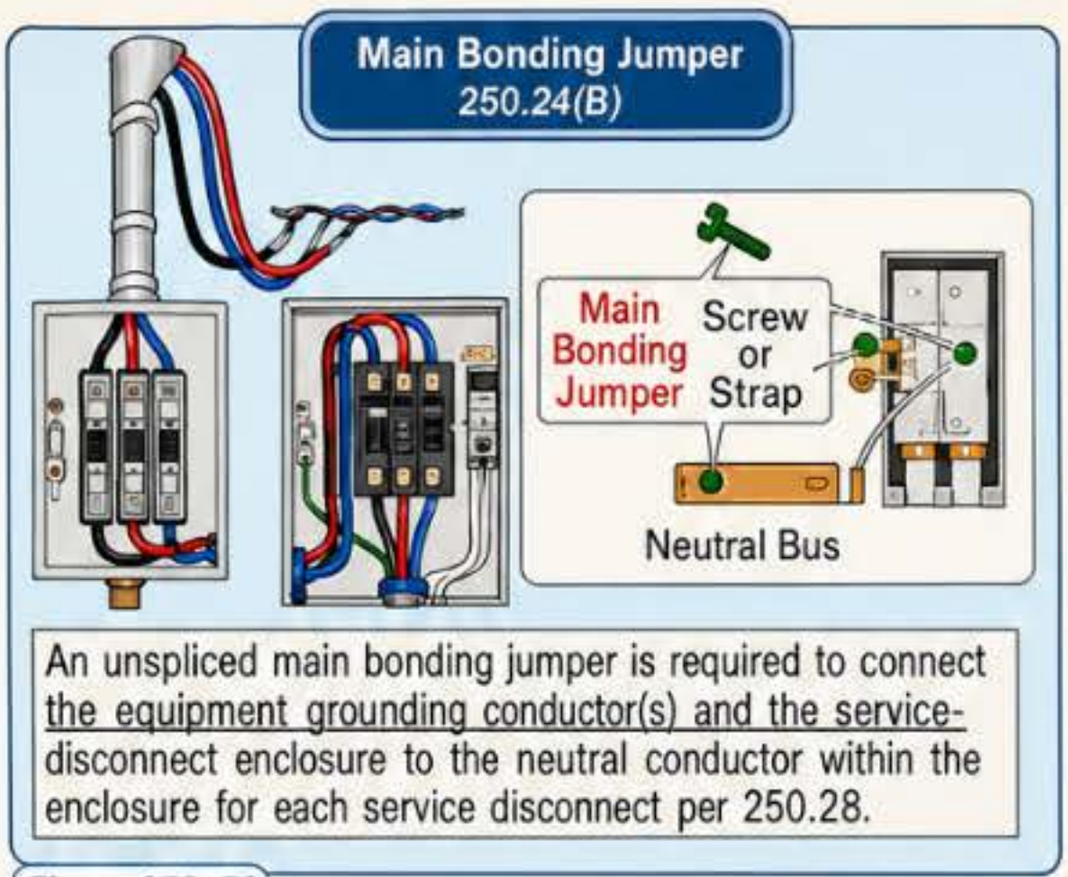


Figure 250–53

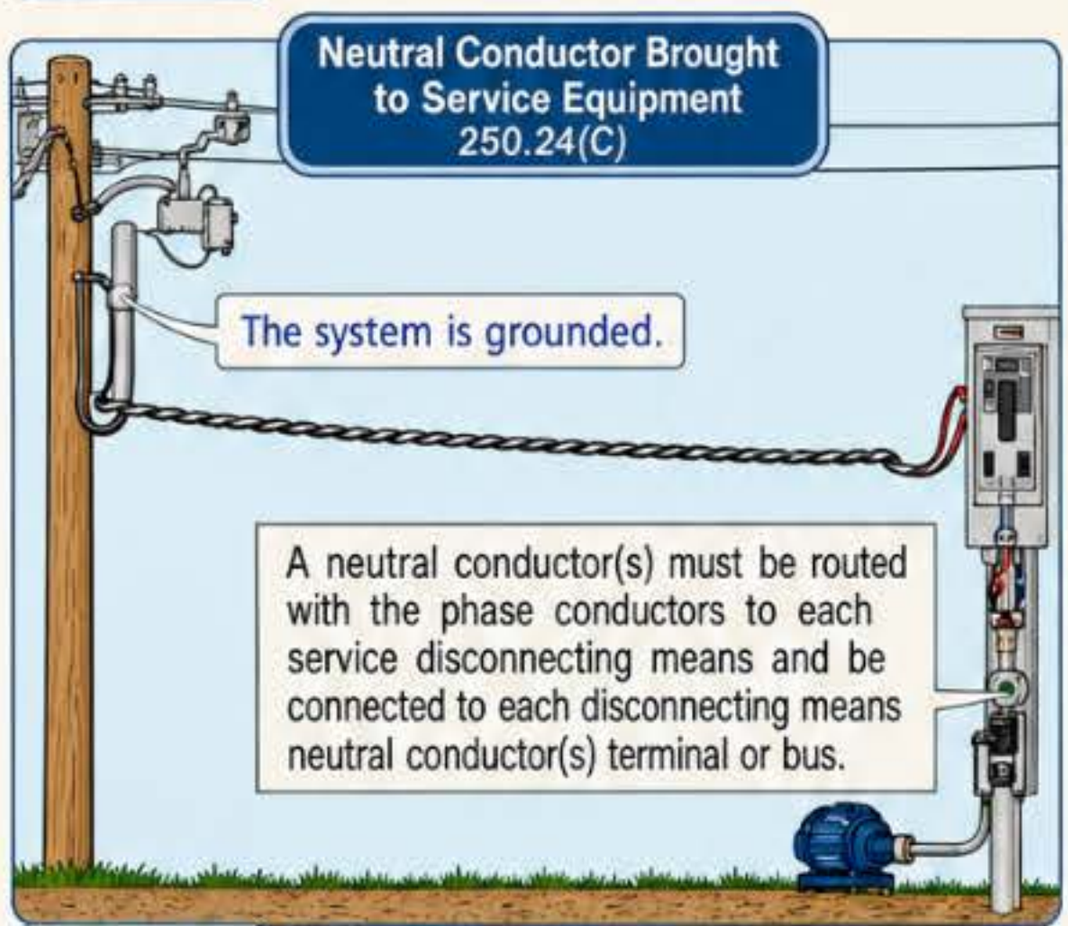


Figure 250–54

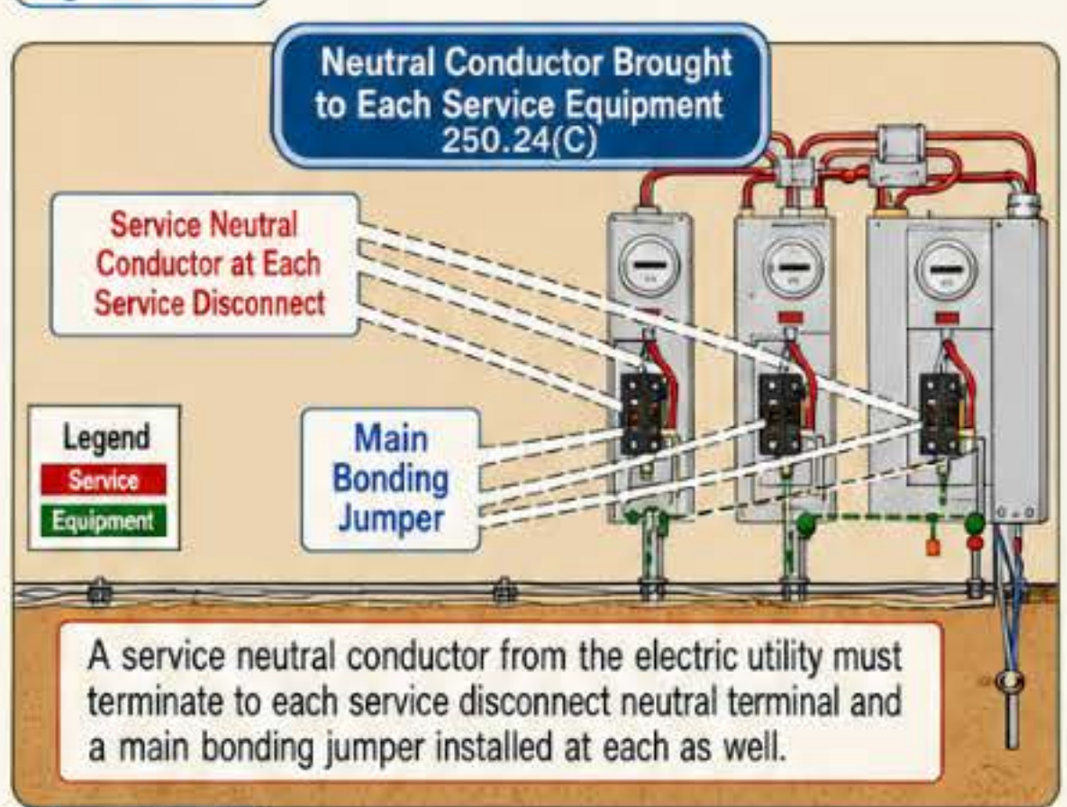


Figure 250–55

Author's Commentary:

The service neutral conductor provides the effective ground-fault current path to the power supply to ensure dangerous voltage from a ground fault will be quickly removed by the opening of the circuit overcurrent protective device [250.4(A)(3) and 250.4(A)(5)].

— *Michael Hamilton*

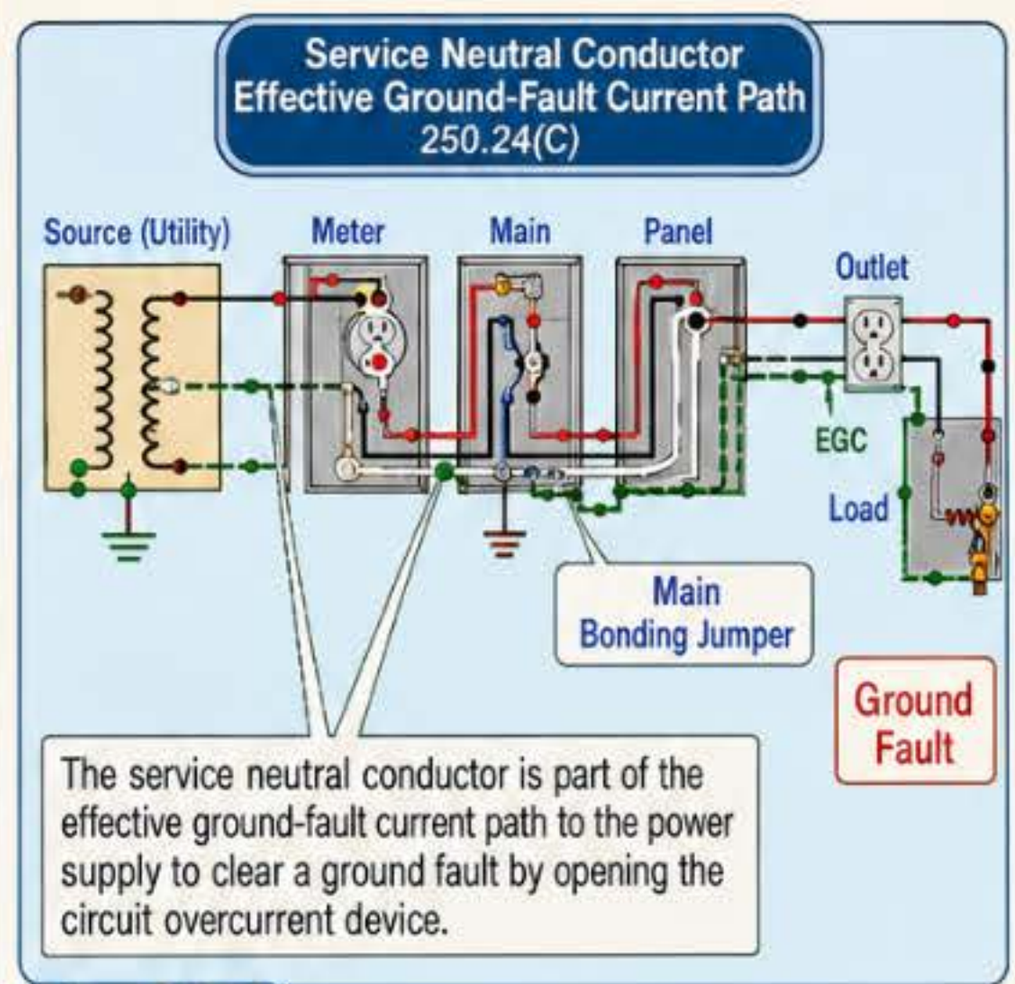


Figure 250–56

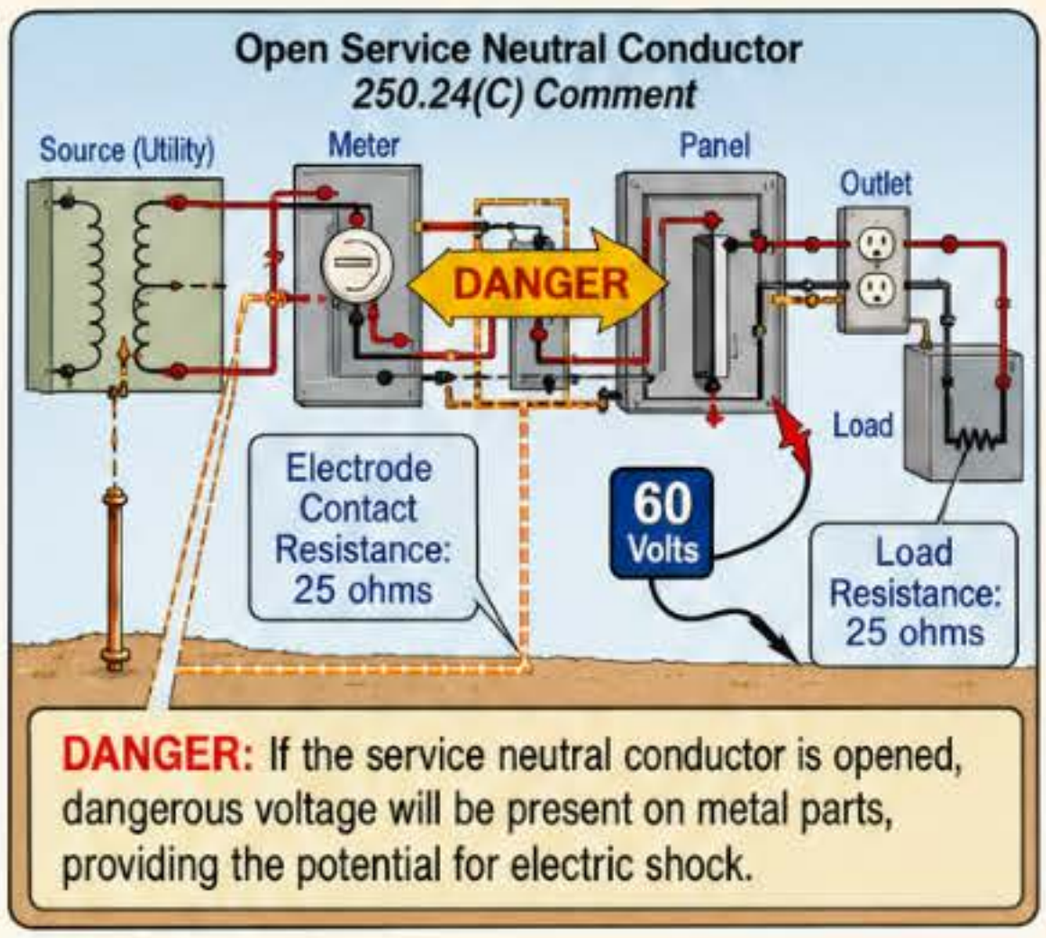
Author's Commentary:

- The main bonding jumper is a vital component of bonding. It facilitates the operation of overcurrent protective devices and is a critical part of the grounding system since it bonds the neutral conductor, service enclosure, and the equipment grounding conductor to the grounding electrode system via the grounding electrode conductor.

- If the neutral conductor is opened, dangerous voltage will be present on metal parts under normal conditions, providing the potential for electric shock. If the Earth's ground resistance is 25 ohms and the load's resistance is 25 ohms, the voltage drop across each of these resistances will be half of the voltage source. Since the neutral is connected to the service disconnect, all metal parts will be elevated 60V above the Earth's voltage for a 120/240V system.

— *Michael Hamilton*

GROUNDING AND BONDING | 250.24

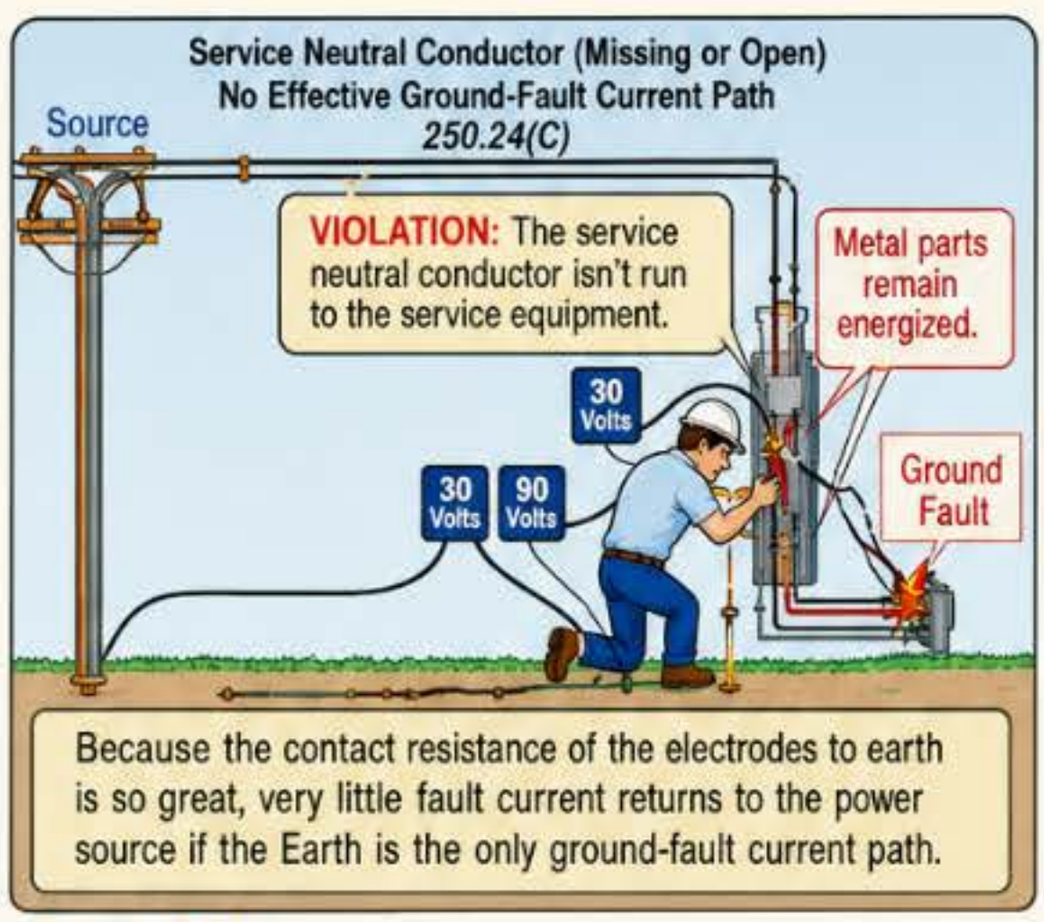


• *Figure 250–57*

Danger

Dangerous voltage from a ground fault will not be removed from metal parts, metal piping, and structural steel if the service-disconnect enclosure is not connected to the service neutral conductor. This is because the contact resistance of a grounding electrode to the Earth is so great that insufficient ground-fault current returns to the power supply if that is the only ground-fault current return path available to open the circuit overcurrent device.

• *Figure 250–58*

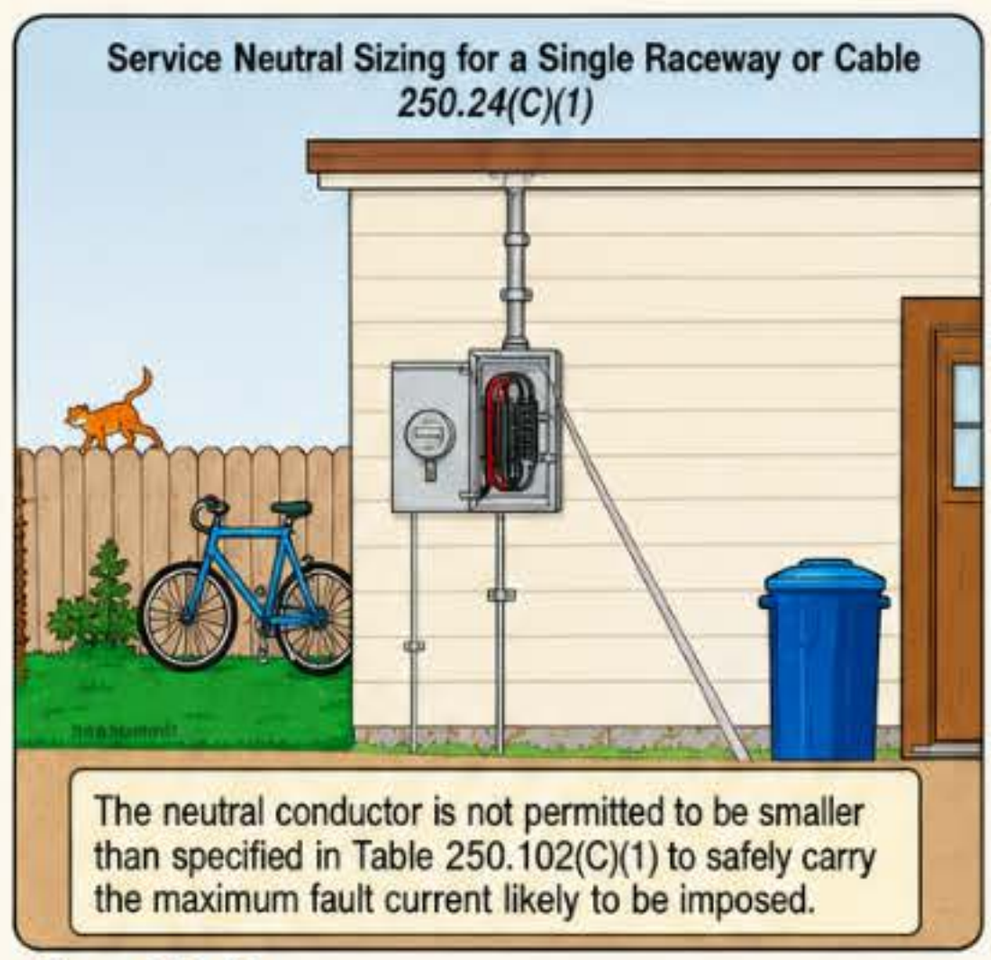


• *Figure 250–58*

The neutral conductor(s) must be sized in accordance with the following:

(1) Sizing for a Single Raceway or Cable. The neutral conductor is not permitted to be smaller than specified in Table 250.102(C)(1).

• Figure 250–59



• *Figure 250–59*

Author's Commentary:

- In addition, the neutral conductors must have the capacity to carry the maximum unbalanced neutral current in accordance with 220.61.

— Michael Hamilton

▶ Example

Question: *What is the minimum size service neutral conductor required when the service phase conductors are 350 kcmil and the maximum unbalanced load is 100A?* ***Figure 250–60***

(a) 3 AWG (b) 2 AWG (c) 1 AWG (d) 1/0 AWG

Solution:

The unbalanced load of 100A requires a 3 AWG service neutral conductor, which is rated 100A at 75°C in accordance with Table 310.16 (110.14(C)(1)(b)(2) and 220.61), but the neutral conductor cannot be smaller than 2 AWG to carry fault current based on the 350 kcmil phase conductors. Therefore, 2 AWG is the minimum size service neutral conductor required [Table 250.102(C)(1)].

Answer: *(b) 2 AWG*

• • •

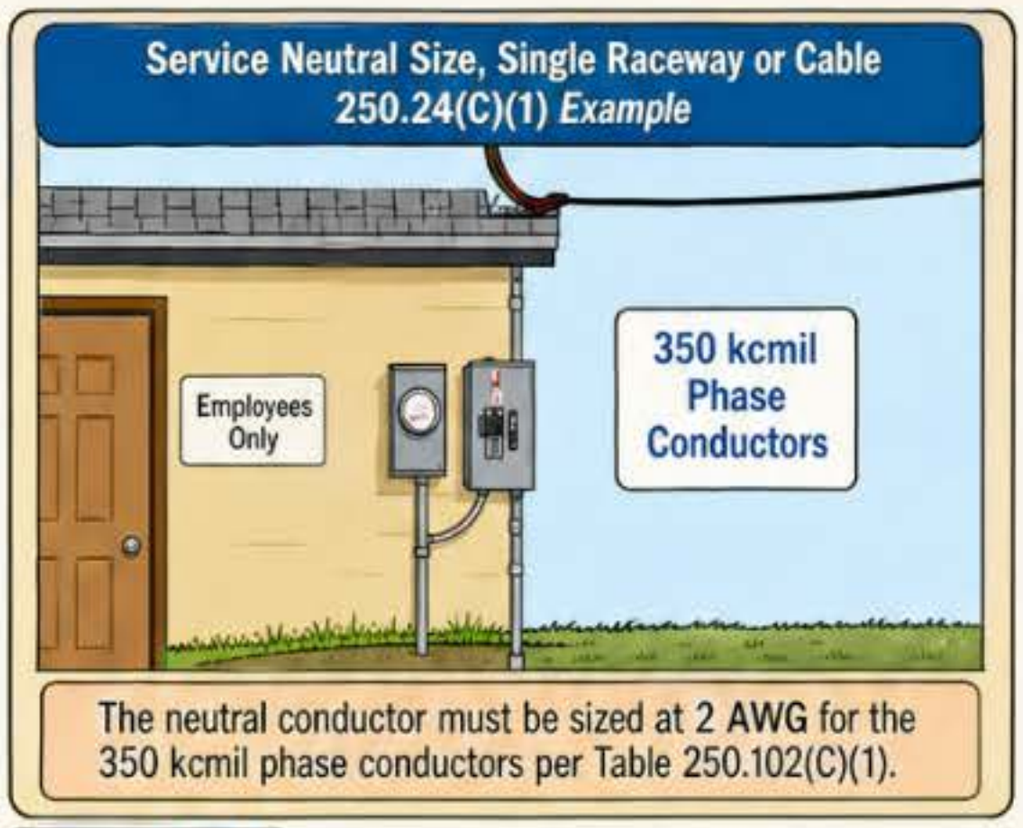


Figure 250-60

(2) Parallel Conductors in Two or More Raceways or Cables. If service-entrance conductors are installed in parallel in two or more raceways or cables, the neutral conductor must be installed in parallel with the phase conductors. The service neutral conductor is sized based on the circular mil area of the phase conductors in each raceway or cable of the parallel set in accordance with Table 250.102(C)(1) but cannot be smaller than 1/0 AWG. Figure 250-61

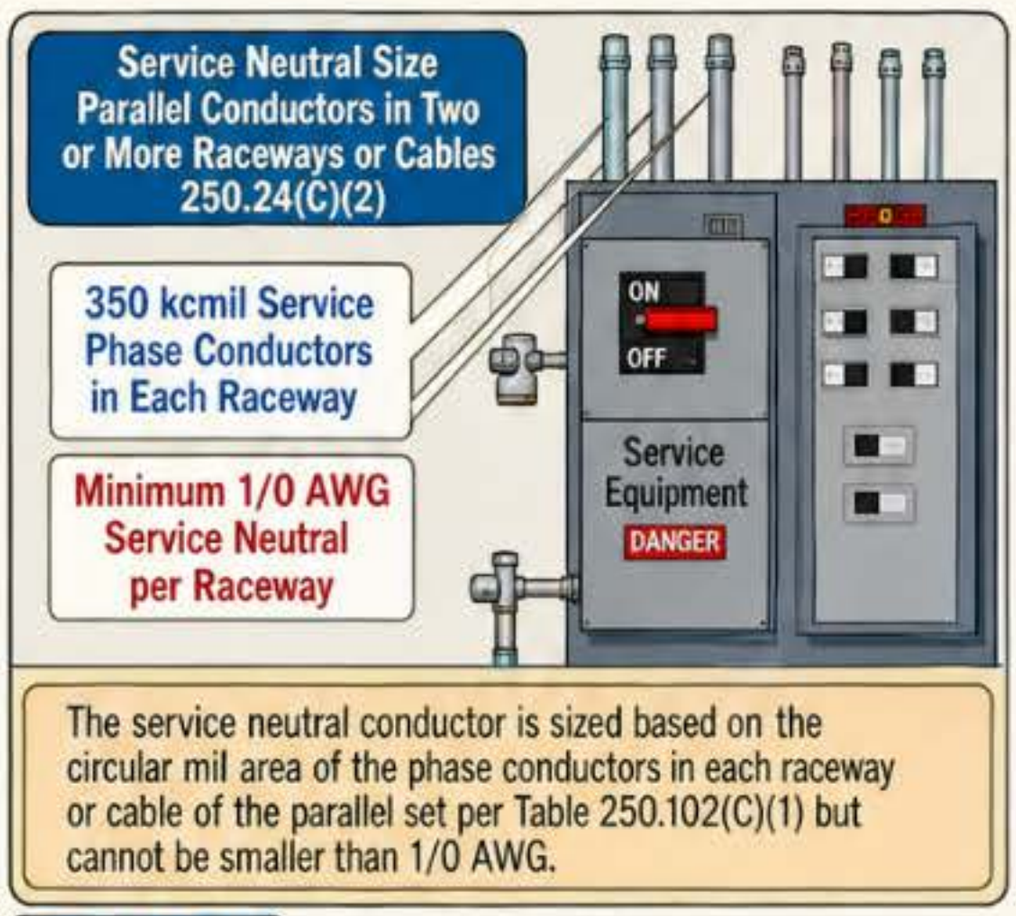


Figure 250-61

Note: See 310.10(G) for neutral conductors connected in parallel.

(3) Delta-Connected Service. The grounded conductor of a three-phase, 3-wire delta service must have an ampacity not less than that of the phase conductors.

(D) Grounding Electrode Conductor. A grounding electrode conductor must connect the equipment grounding conductors, the service-equipment enclosures, and the service neutral conductor to the grounding electrode system. This grounding electrode conductor is sized in accordance with 250.66. Figure 250-62 Figure 250-63

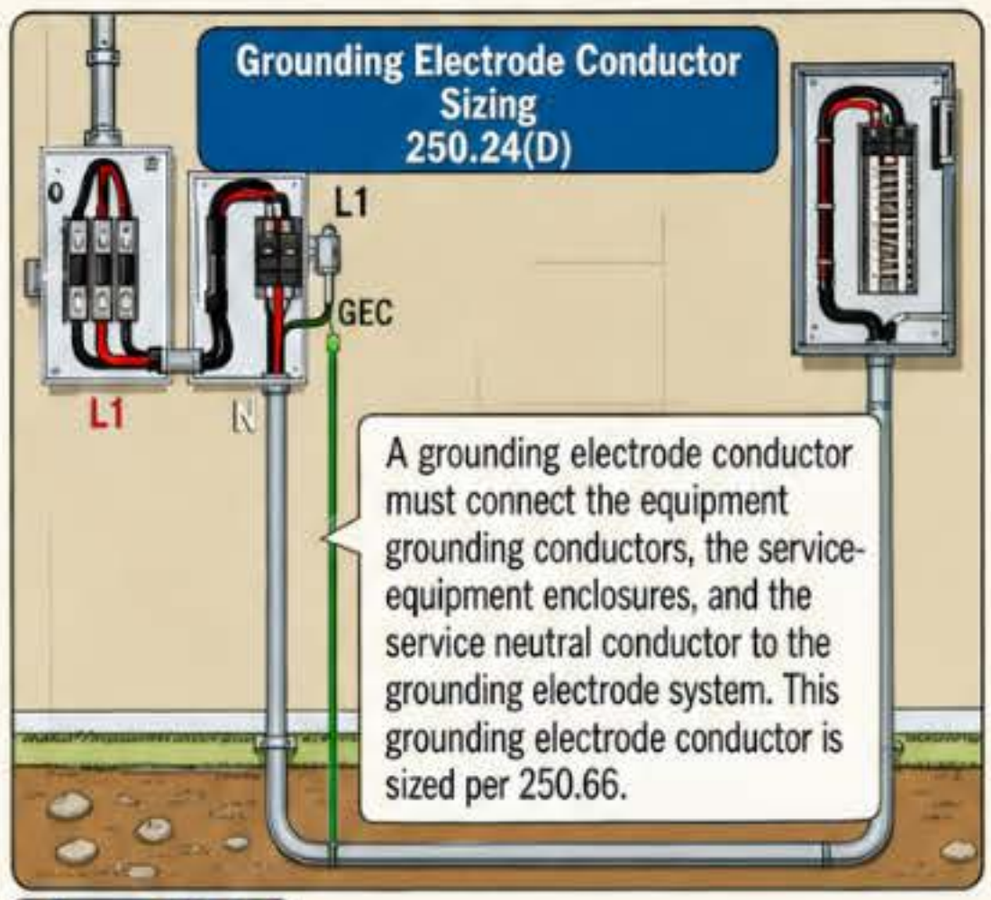


Figure 250-62

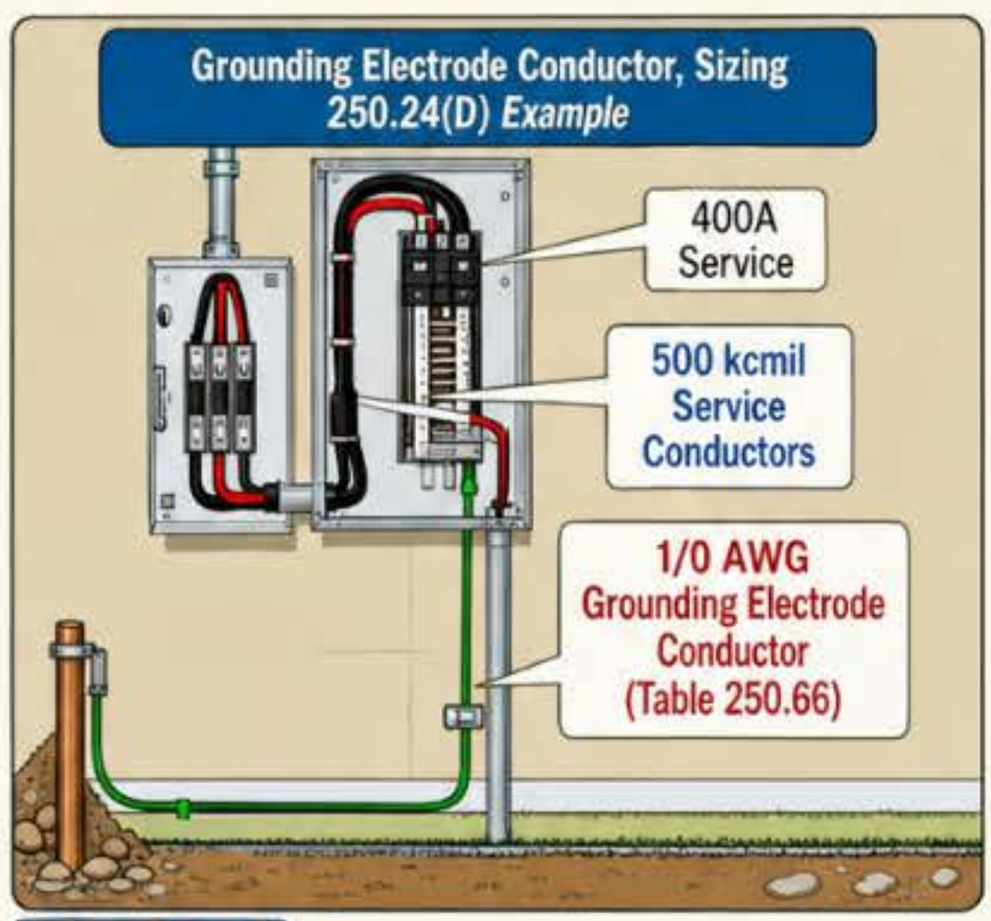


Figure 250-63

250.25 Grounding for Supply Side of the Service Disconnect

Electrical systems on the supply side of the service disconnect installed in accordance with 230.82 must be grounded and bonded in accordance with 250.24. Figure 250-64

GROUNDING AND BONDING | 250.28

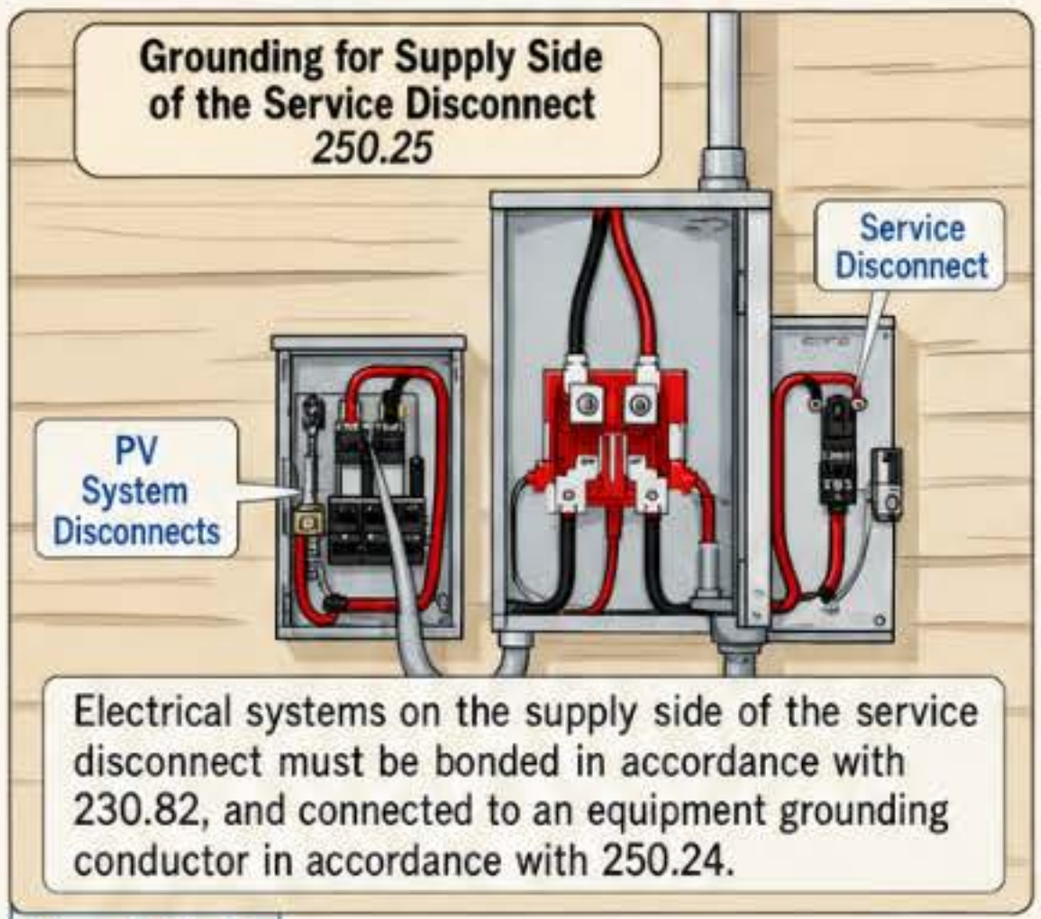


Figure 250–64

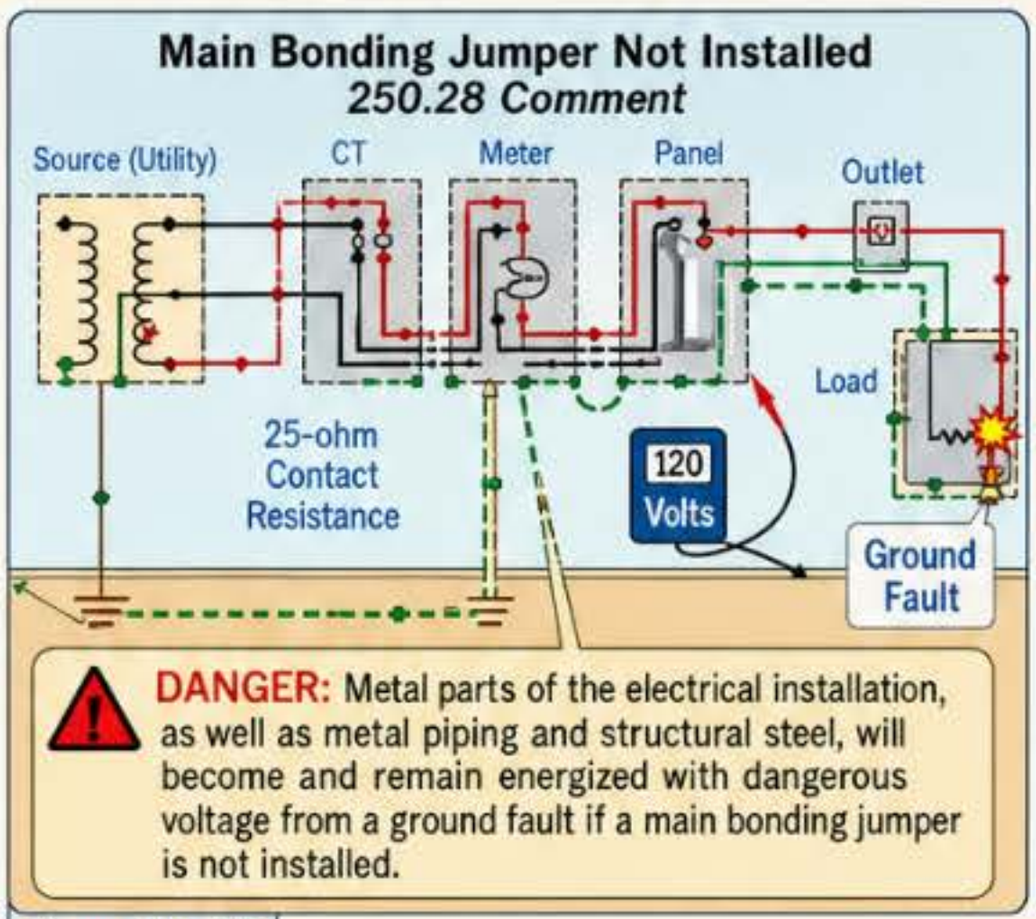


Figure 250–65

250.28 Main Bonding Jumper and System Bonding Jumper

Author's Commentary:

The primary goal of the main and system bonding jumpers is to provide a low-impedance path for fault current to flow from a ground-fault back to the power source. This rapid return path helps ensure the overcurrent protective device operates quickly.

DANGER

Metal components of the electrical installation, as well as metal piping and structural steel, may *become and remain energized with hazardous potential from a ground fault if neither a main bonding jumper nor a system bonding jumper is installed. The absence of this connection keeps an opening in the effective ground-fault current path back to the source, creating a condition where the overcurrent device may not open, leaving a ground fault un-cleared.*

Main and system bonding jumpers must be installed as follows:

(A) Material. *The bonding jumper may be a wire, bus, or screw made of copper, copper-clad aluminum, or aluminum.* *Figure 250–67*

(B) Construction. *If the bonding jumper is a screw, it must be identified with a green finish that is visible after the screw is installed.*

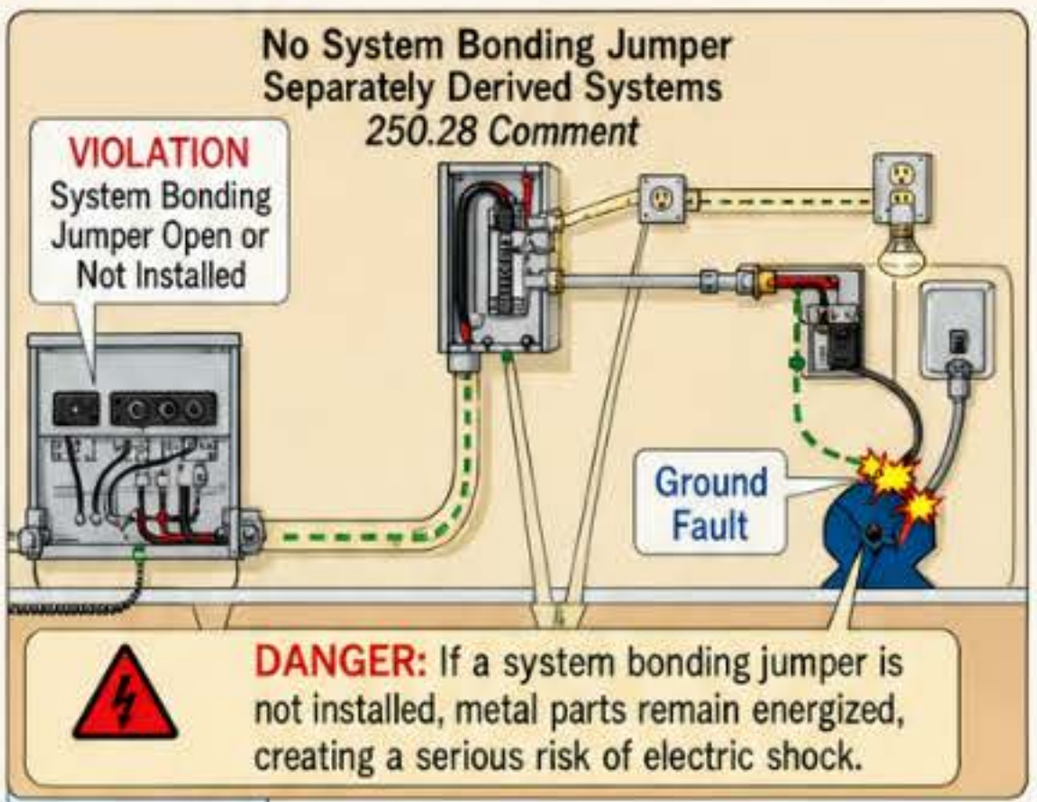


Figure 250–66

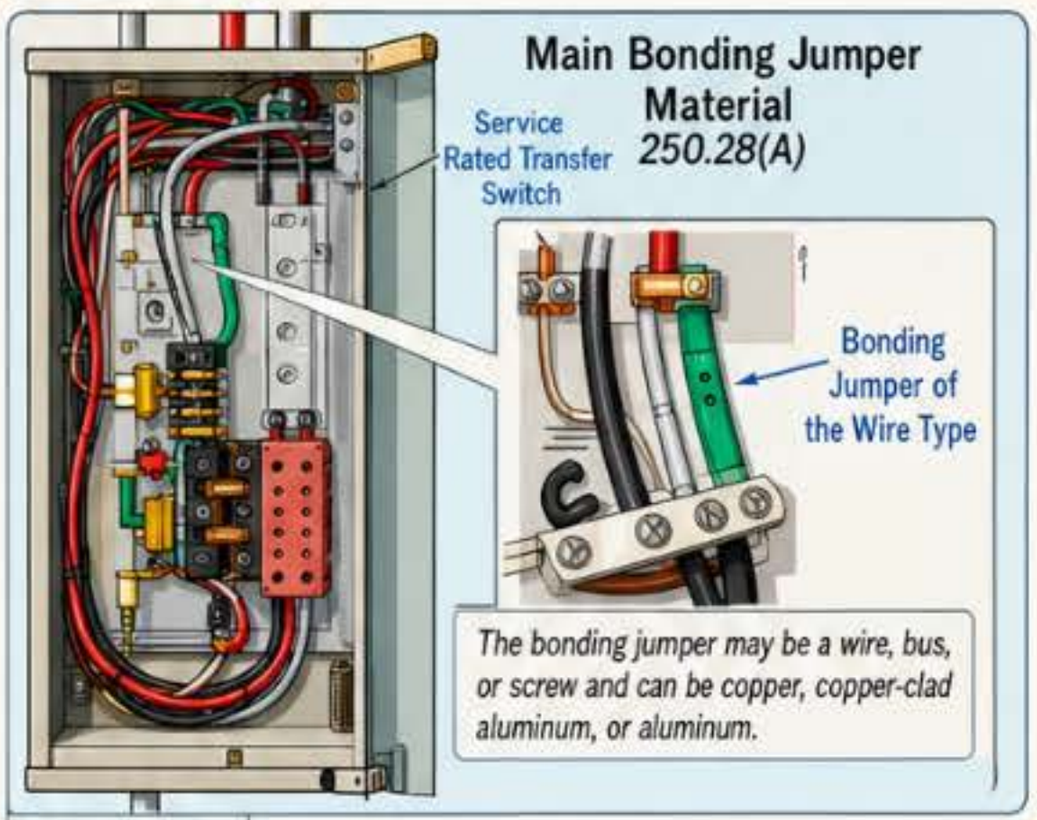


Figure 250–67

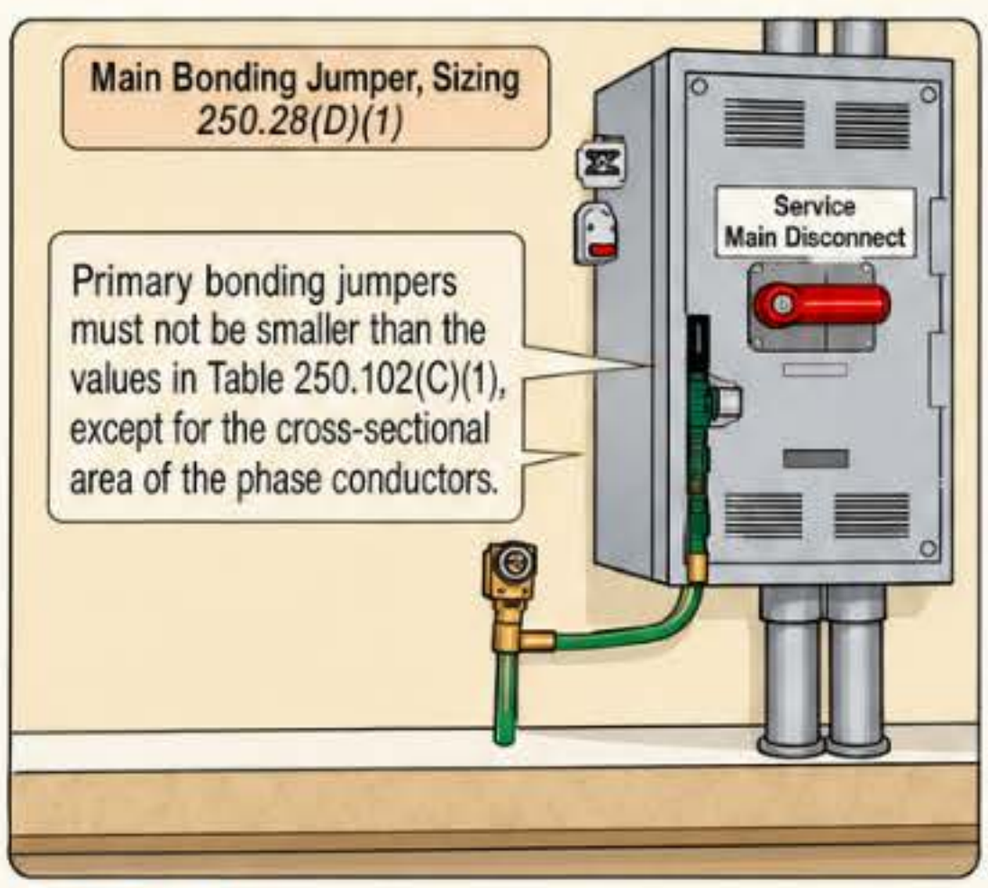
250.30 | Grounding and Bonding

(C) Attachment. Primary and secondary bonding jumpers must end at one of the following termination points in accordance with 250.8(A):

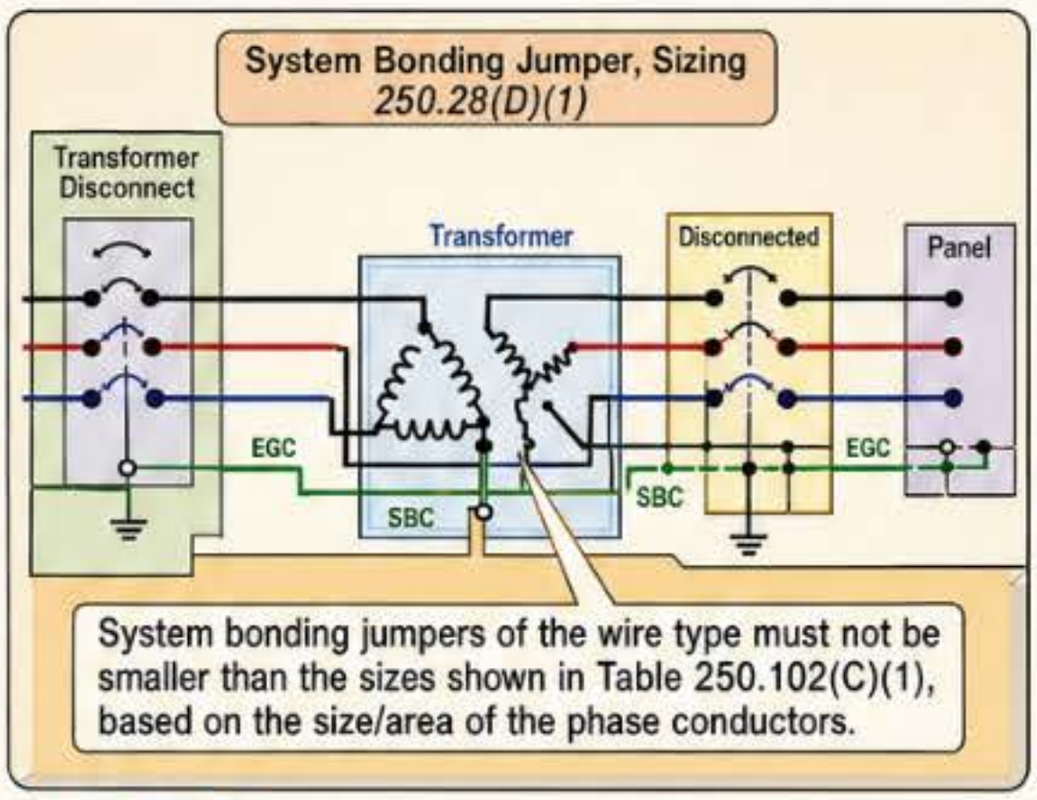
- Pressure-type connectors that are listed
- Terminals identified for bonding use
- Pressure connectors that are labeled for grounding and bonding
- Exothermic welding connections
- Screw-style fasteners on equipment that bite through fewer than two threads or that are used with a nut
- Thread-forming screws that engage fewer than two threads inside an enclosure
- Connections that are included as part of a listed assembly
- Other acceptable methods that are identified

(D) Size.

(1) Primary and secondary bonding jumpers must not be smaller than the requirements given in Table 250.102(C)(1), except for the cross-sectional area of phase conductors. ▶ *Figure 250–68* and ▶ *Figure 250–69*



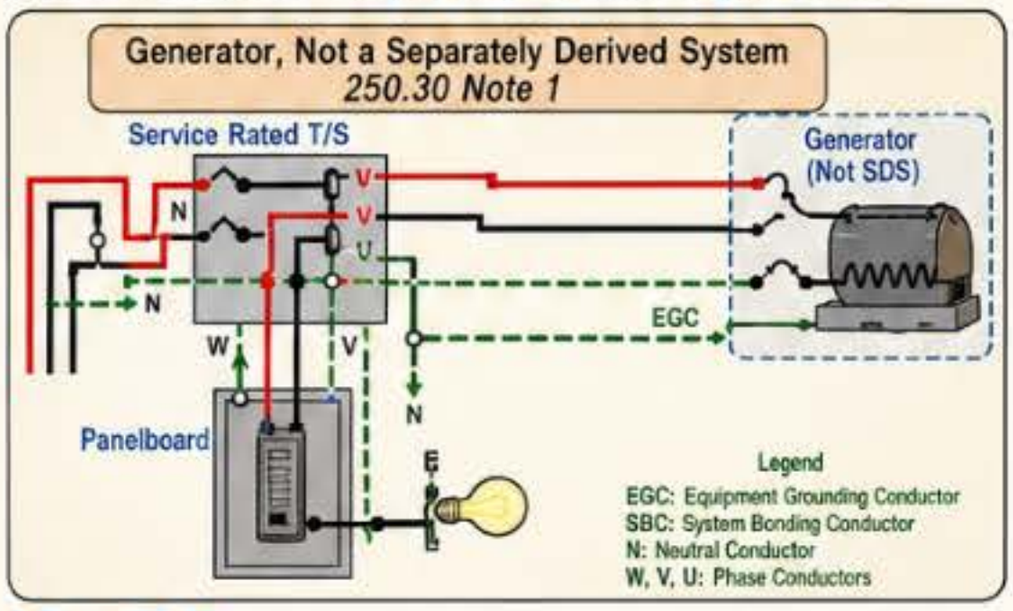
▶ *Figure 250–68*



▶ *Figure 250–69*

Author's Commentary:
An alternate source of AC power, such as an on-site generator, is not considered a separately derived system when the neutral conductor is solidly connected to a service-supplied system neutral. For instance, this arrangement lets the alternate source transfer equipment operate without opening the neutral conductor, keeping it solidly connected to the neutral from the utility and continuing to feed the load.
— *Michael Hamilton*

Note 1: *An alternate AC power source, such as an on-site generator, is not considered a separately derived system if the neutral conductor is solidly bonded to a service-supplied system neutral conductor. An example is when the alternate source transfer equipment allows the system to keep the neutral connected to the service neutral while the equipment is in operation and still supplying the connected load.* ▶ *Figure 250–70* and ▶ *Figure 250–71*



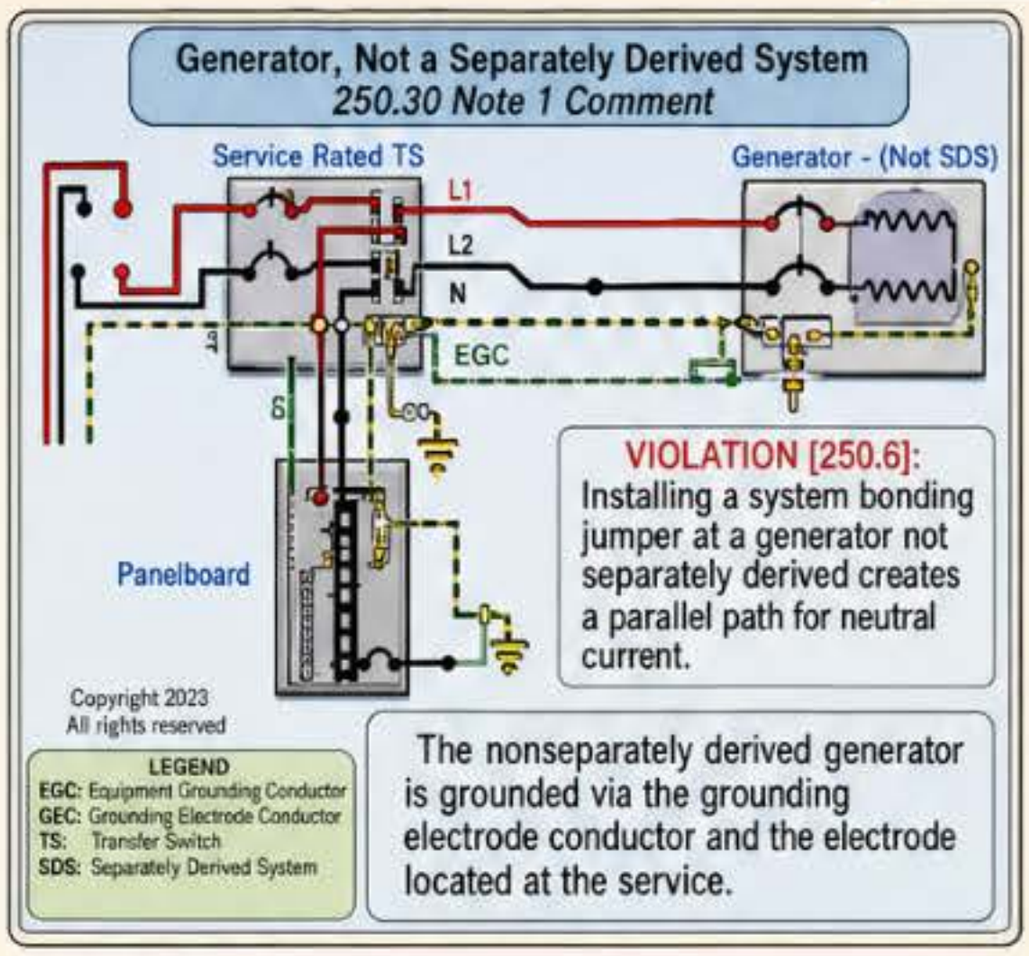
▶ *Figure 250–70*

Author's Commentary:
A generator equipped with a transfer switch does not open the neutral conductor, because the neutral from the generator is electrically tied to the grounded service neutral. This direct connection to a grounded neutral means the generator does not qualify as a separately derived system.
— *Michael Hamilton*

250.30 Separately Derived Systems

In addition to meeting the rules of 250.30(A) for grounded systems, or the provisions of 250.30(B) for ungrounded systems, separately derived systems must conform to 250.20, 250.21, 250.22, or 250.26, as applicable.

GROUNDING AND BONDING 250.30



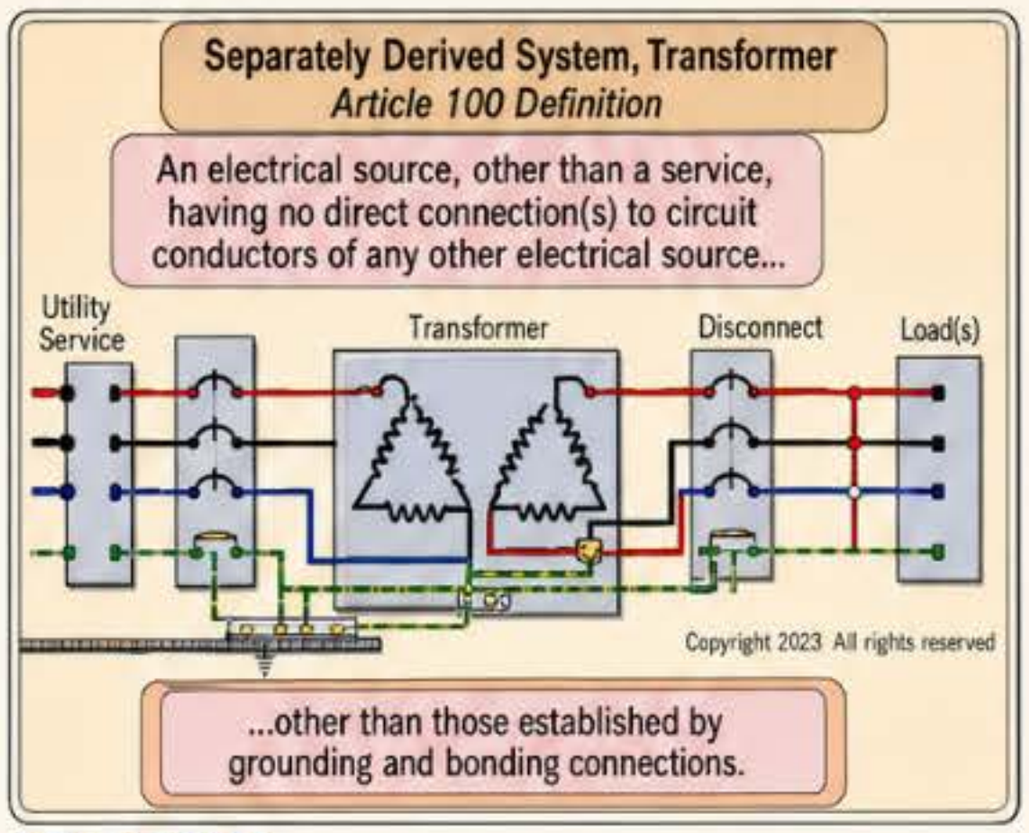
▸ Figure 250-71

Author's Commentary:

- Under Article 100, a "Separately Derived System" is a distribution arrangement whose power originates from a source other than the serving utility. The system must have no direct electrical connections to the conductors of any other system, with the only permitted interconnections being grounding and bonding conductors.

  — Michael Hamilton

▸ Figure 250-72



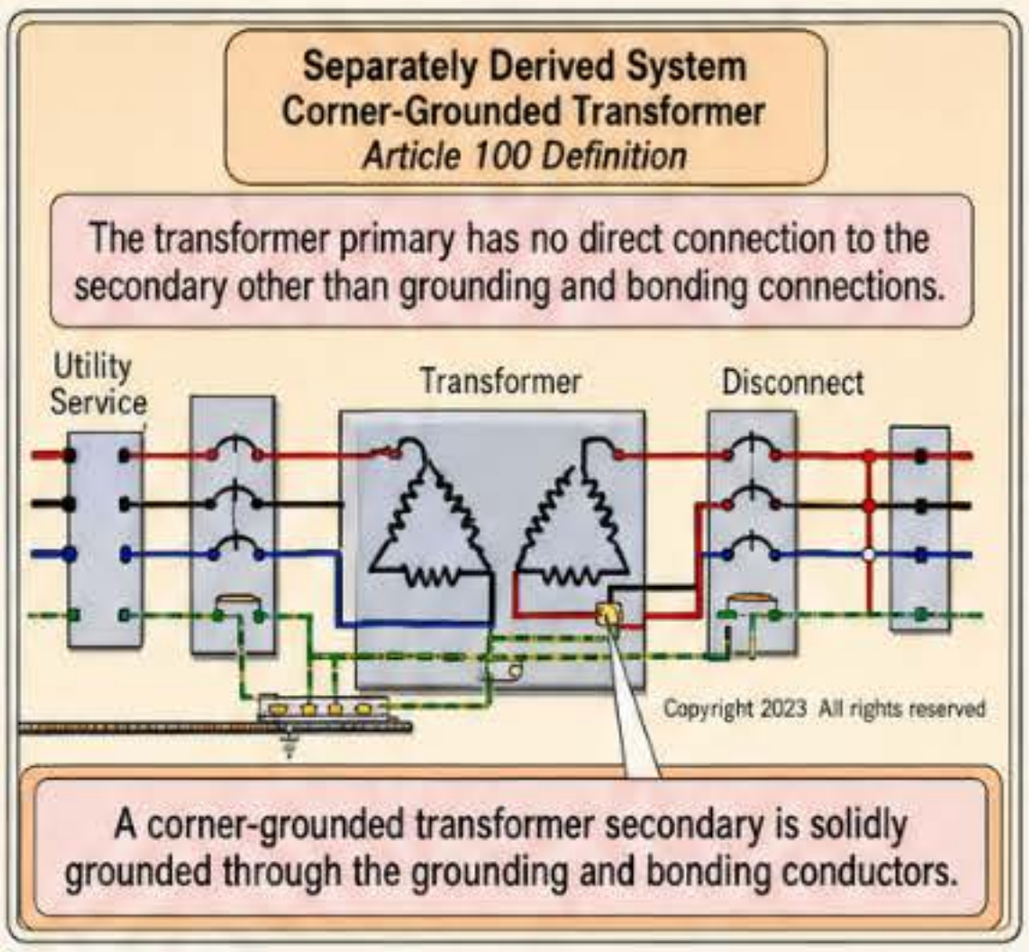
▸ Figure 250-72

Author's Commentary:

- Transformers are classified as separately derived because their primary conductors are electrically isolated from the circuit conductors of any other system.

  — Michael Hamilton

▸ Figure 250-73

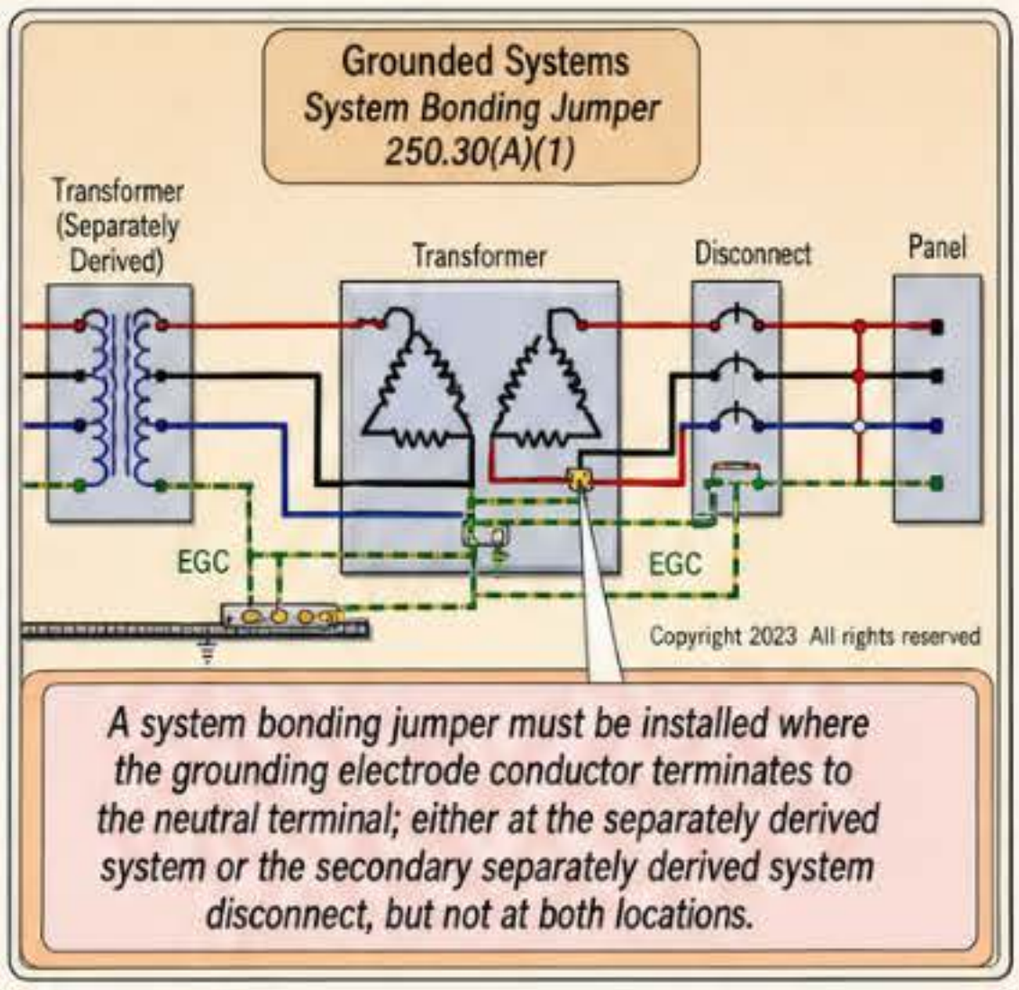


▸ Figure 250-73

(A) Grounded Systems. Separately derived systems must be grounded and bonded in accordance with (A)(1) through (A)(8). A neutral-to-case connection is not allowed on the load side of the system bonding jumper.

(1) System Bonding Jumper. A system bonding jumper must be installed where the grounding electrode conductor terminates at the neutral terminal of the separately derived system; either at the separately derived system or at the secondary separately derived system disconnect, but not at both.

▸ Figure 250-74



▸ Figure 250-74

250.30 | Grounding and Bonding

Author's Commentary:

Section 250.30(A)(5) sets the rule that the grounding electrode conductor must make its connection at the same location where the neutral conductor is joined to the system bonding jumper. This requirement helps prevent parallel current paths on the neutral conductor.

— Michael Hamilton

Example: If a building or structure receives power from a separately derived system via an outdoor feeder, a system bonding jumper must be provided at both the source and at the first disconnecting means. This jumper is permitted *to be larger than needed and does not establish a parallel neutral current path. The neutral conductor itself is not allowed to be larger than the size specified for the system bonding jumper and it is not required to be larger than the phase conductors.*

(a) System Bonding Jumper at Source. *When the system bonding jumper is installed at the separately derived system, it must connect the neutral conductor to the metal enclosure of the separately derived system.* Figure 250-75

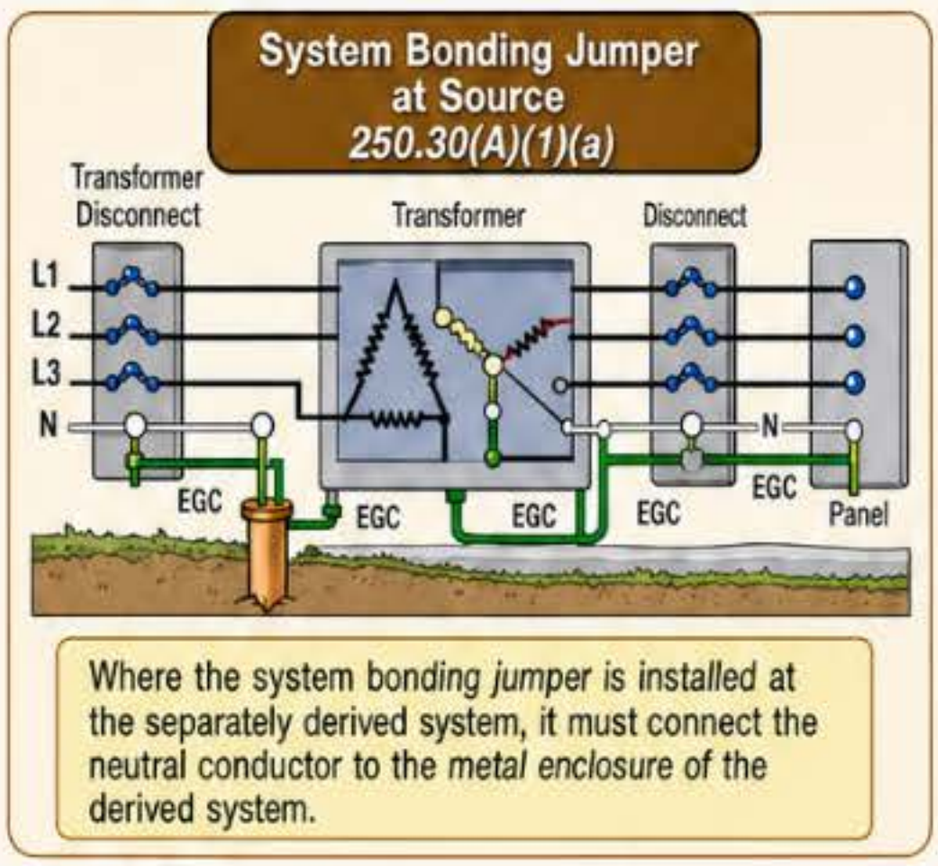


Figure 250-75

(b) System Bonding Jumper at First Disconnecting Means. *When the system bonding jumper is installed at the secondary system disconnect, it must bond the neutral conductor to the metal enclosure of the disconnect.* Figure 250-76

Author's Commentary:

It is essential for the system bonding jumper to be correctly installed. Without it, equipment can become energized during a fault, creating a dangerous shock hazard and increasing the risk of fire.

— Michael Hamilton

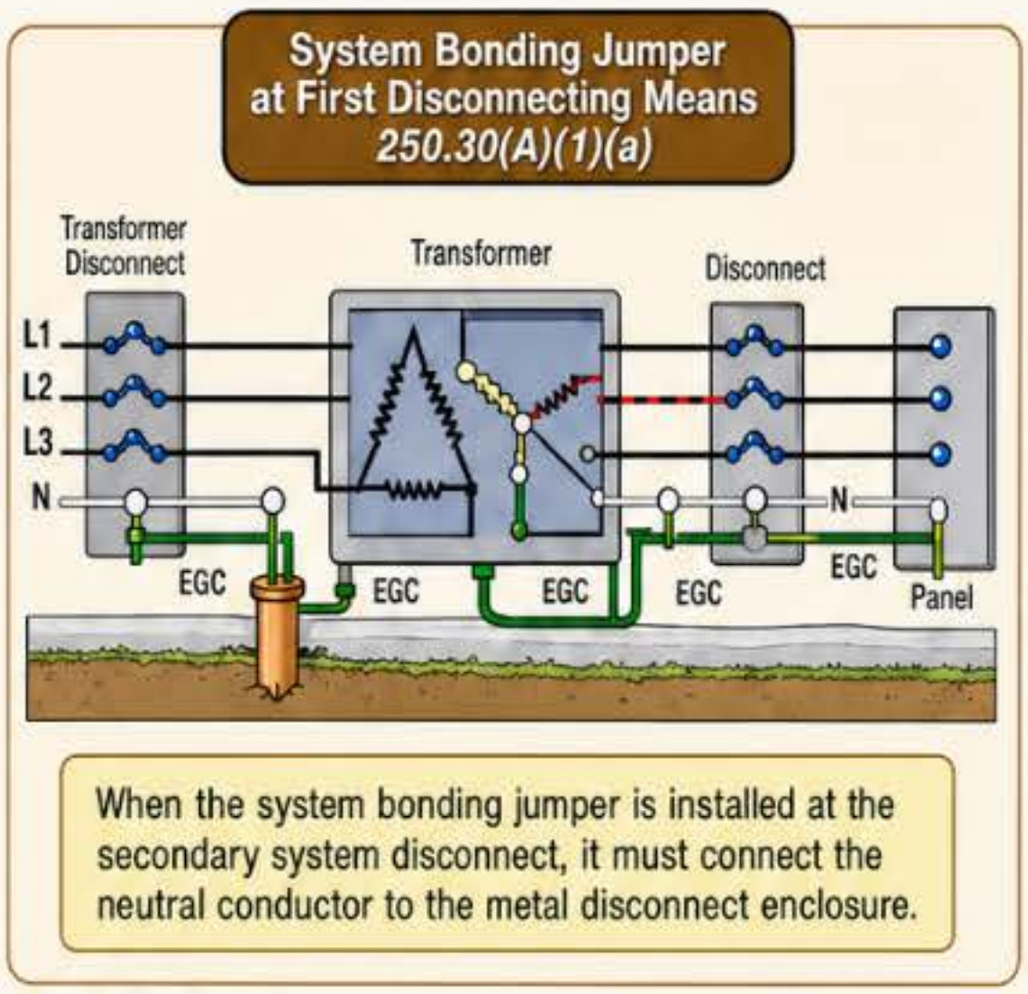


Figure 250-76

Danger

During a ground fault, metal parts of electrical equipment, as well as metal piping and structural steel, will become and remain energized, supplying a path for electric shock and fire if the system *bonding jumper is not in place.* Figure 250-77

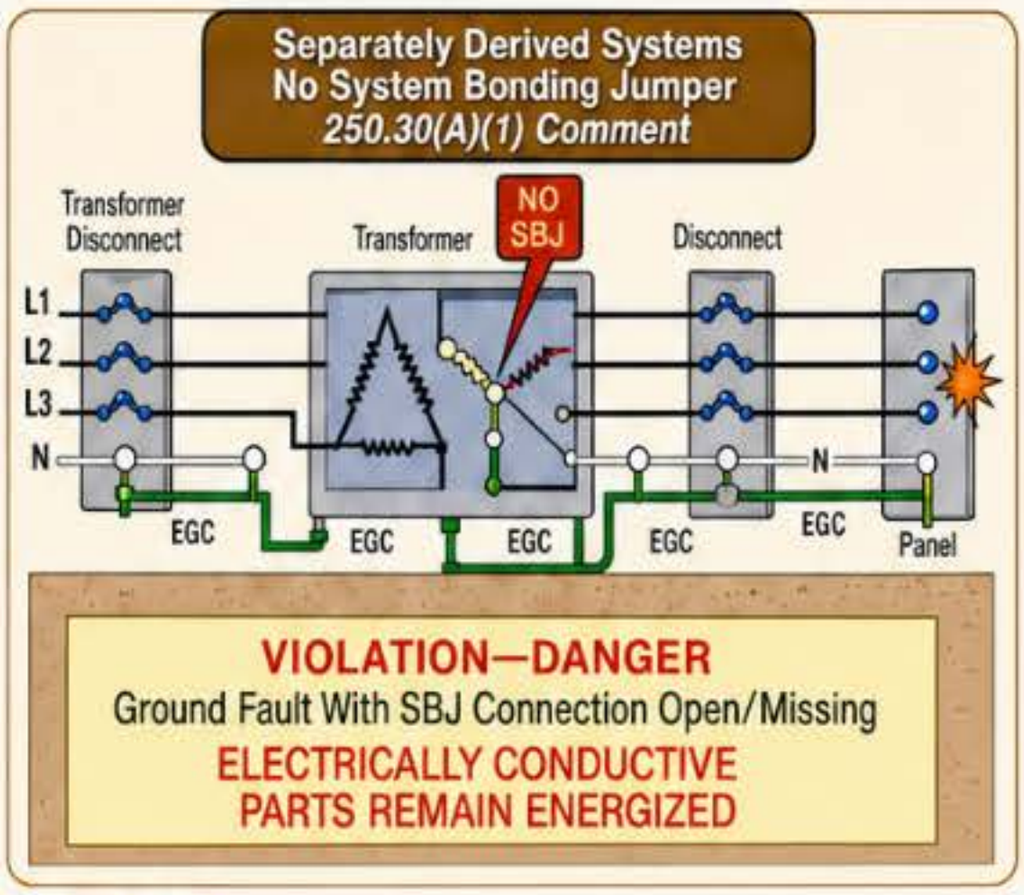


Figure 250-77

2023 UPDATE:

All code references have been updated from the 2023 National Electrical Code® to the 2023 edition.

CAUTION

Hazardous objectionable neutral current can travel on metal components of electrical equipment and on metal piping and structural steel. This can occur if more than one system bonding jumper is in place, or if it is not installed at the point where the grounding electrode conductor (GEC) connects to the neutral.

Figure 250–78

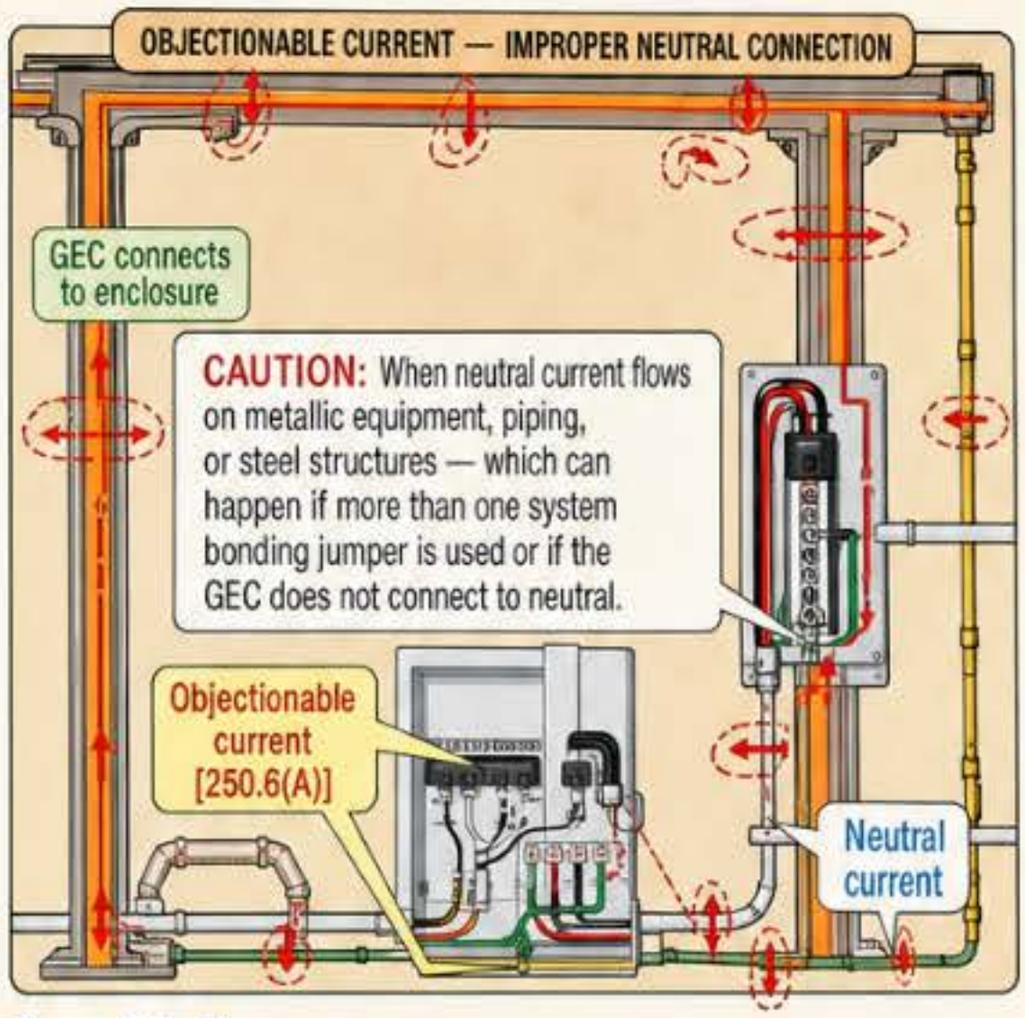


Figure 250–78

(2) Supply-Side Bonding Jumper to Disconnect. A supply-side bonding jumper must be installed at the first means of disconnect (enclosure) and is not required to be larger than the phase conductors derived from the transformer or secondary source. The supply-side bonding jumper can be either a flexible metal raceway type or a wire type.

Author's Commentary:

- *The supply-side bonding jumper may be a rigid metal conduit (RMC), intermediate metal conduit (IMC), or electrical metallic tubing (EMT) running between the separately derived system enclosure and the secondary system disconnect enclosure.*

  A rigid or flexible metal raceway must also have a supply-side bonding jumper of the wire type.

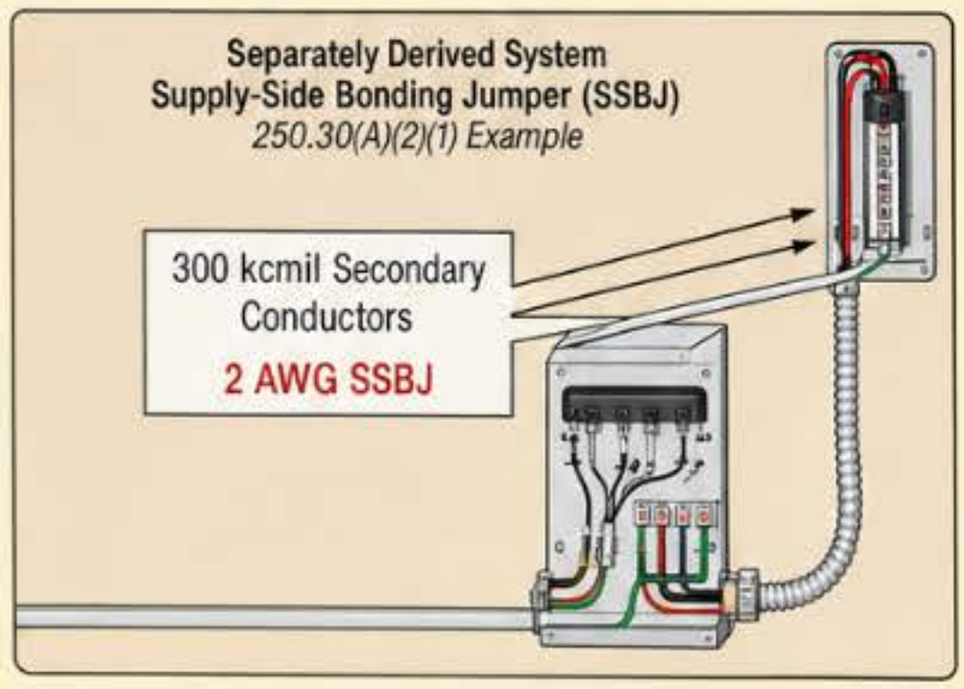
— Michael Hamilton

(1) A supply-side bonding jumper of the wire type must be sized in accordance with 250.102(C), based on the size/area of the secondary phase conductor in the raceway or cable.

▶ EXAMPLE

Question: *What size supply-side bonding jumper is required for flexible metal conduit containing 300 kcmil secondary conductors?* *Figure 250–79*

(a) 4 AWG (b) 2 AWG (c) 1/0 AWG (d) 3/0 AWG



An SSBJ of the wire type must be sized not smaller than specified in Table 250.102(C)(1), based on the size/area of the secondary phase conductor.

Figure 250–79

Answer: *(b) 2 AWG [Table 250.102(C)(1)]*

(3) Neutral Conductor Size. The neutral conductor between the separately derived system and the secondary system disconnect is not required to be larger than the phase conductors. If the system bonding jumper is installed at the secondary system disconnect instead of at the Separately Derived System, the following apply:

(a) Sizing for Single Raceway. A secondary neutral conductor must be run from the Separately Derived System to the secondary system disconnect, and the secondary neutral conductor must be sized not smaller than specified in *Table 250.102(C)(1), based on the size/area of the secondary phase conductor.*

Author's Commentary:

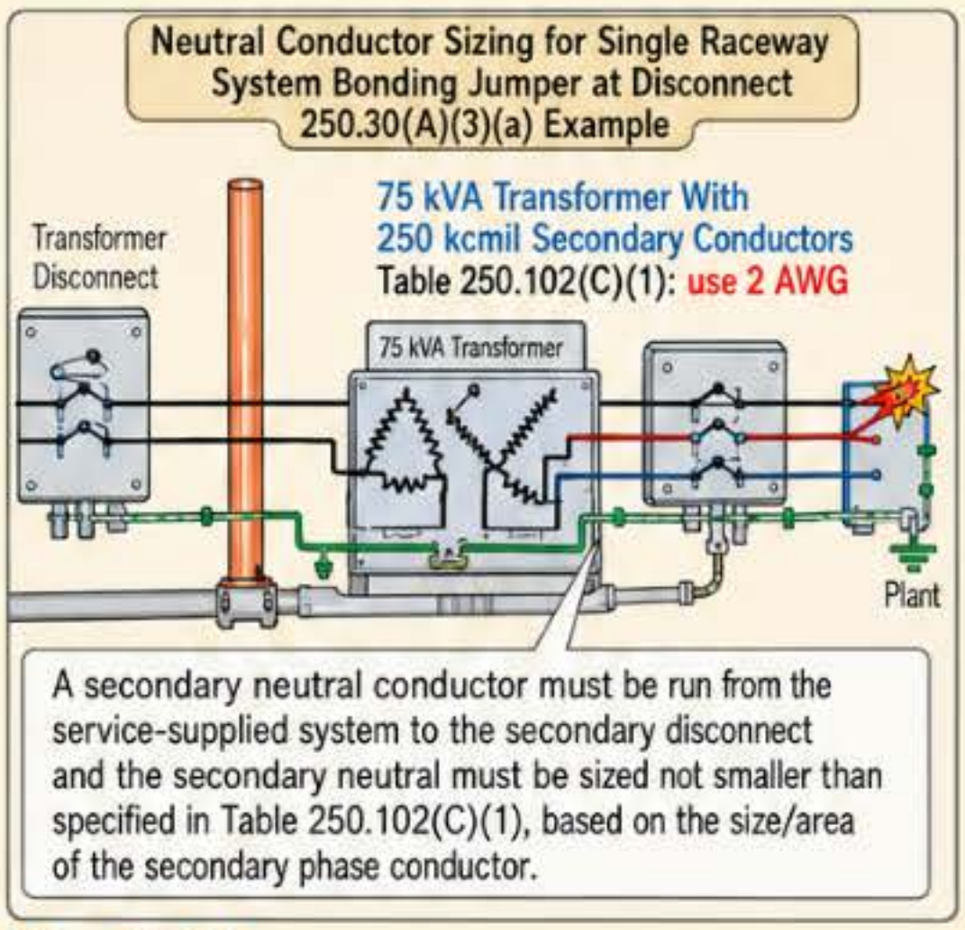
This rule ensures that the neutral conductor has adequate ampacity to carry any unbalanced or return current even when the bonding jumper terminates at the disconnecting means rather than at the Separately Derived System.

— Michael Hamilton

▶ Example

Question: *What size neutral conductor is required for a 75 kVA transformer with 250 kcmil secondary conductors?* **Figure 250–80**

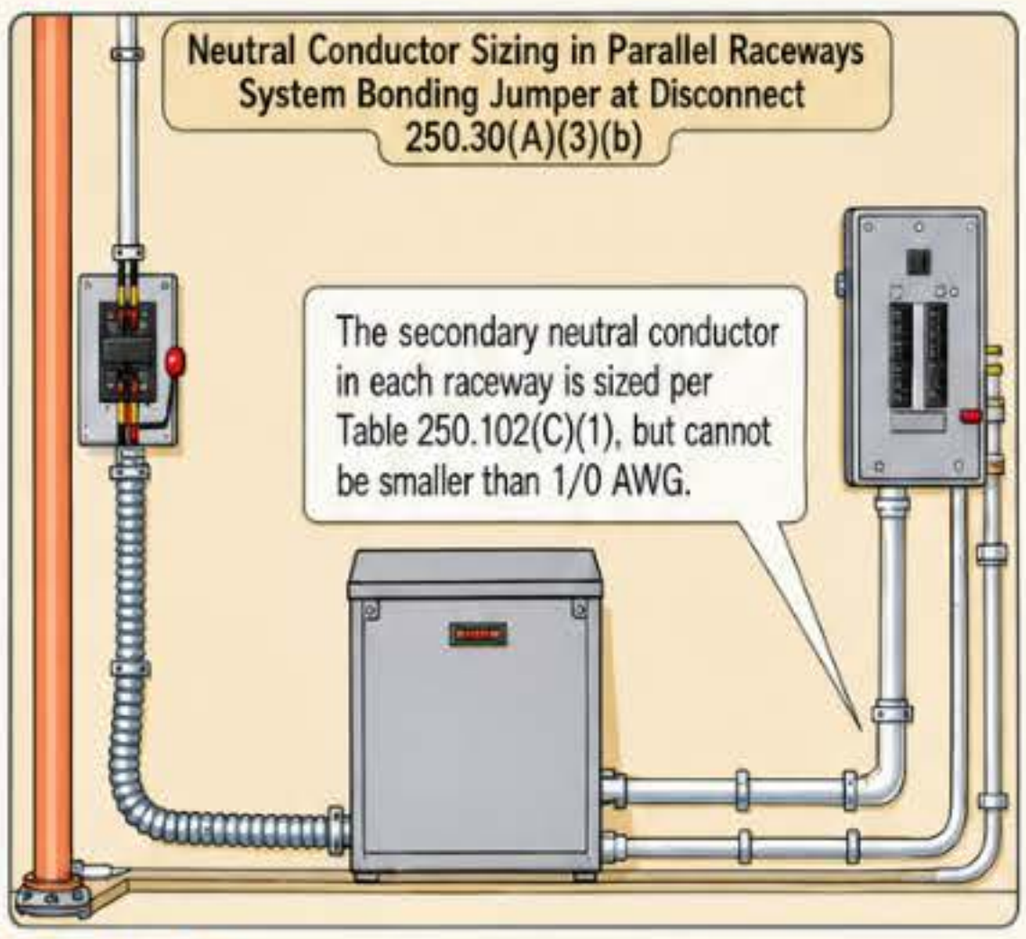
(a) 2 AWG (b) 1/0 AWG (c) 4/0 AWG (d) 250 kcmil



▶ Figure 250–80

Answer: *(a) 2 AWG [Table 250.102(C)(1)]*

(b) Parallel Conductors in Two or More Raceways. A neutral conductor sized in accordance with 250.102(C)(1), but not smaller than 1/0 AWG must be installed in each raceway. **Figure 250–81**



▶ Figure 250–81

▶ Example

Question: *What size neutral conductor is required for a 112.50 kVA transformer with two sets of 3/0 AWG secondary conductors?*

(a) 4 AWG in each raceway (b) 2 AWG in each raceway
(c) 1/0 AWG in each raceway (d) 3/0 AWG in each raceway

Solution:

Determine the equivalent area for two 3/0 AWG conductors [250.102(C)(2) and Chapter 9, Table 8].

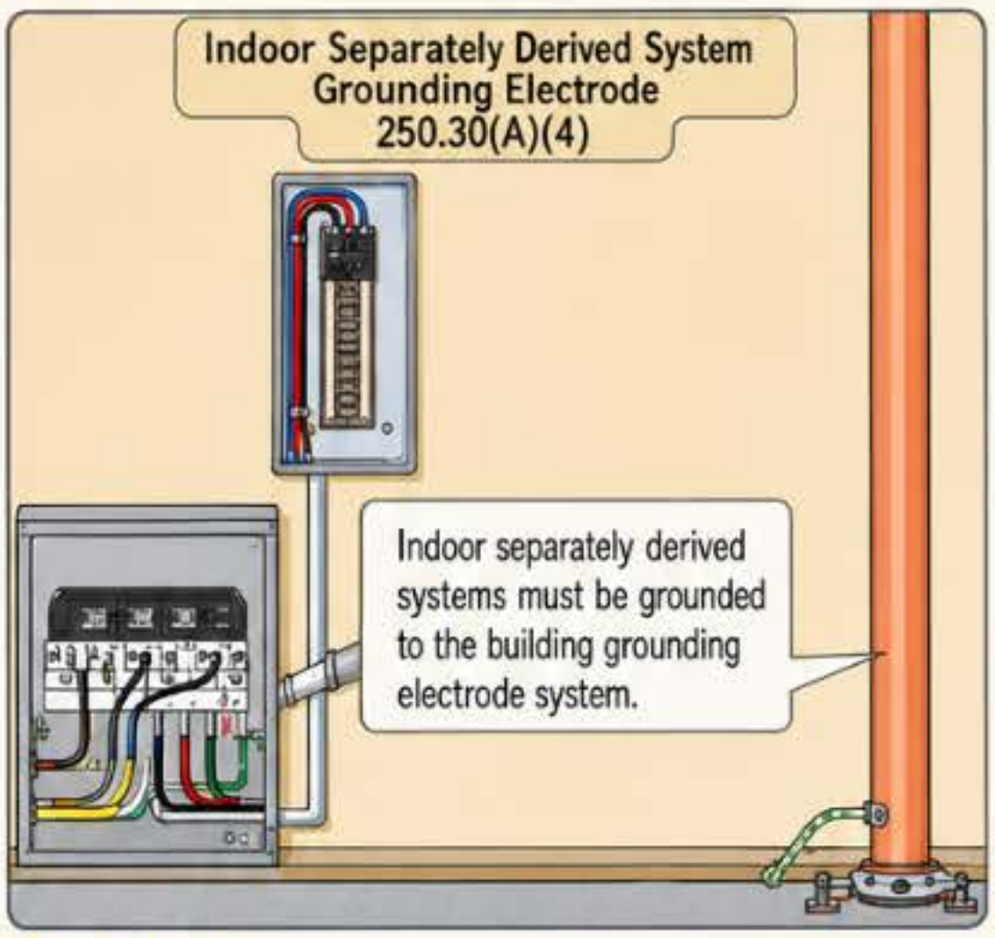
3/0 AWG = 167,800 circular mils

2 conductors × 167,800 cmil = 335,600 cmil [Table 250.102(C)(1)]

One 2 AWG supply-side bonding jumper (minimum) is needed to bond both raceways, but the minimum size neutral conductor in parallel is 1/0 AWG [310.10(C)(1)].

Answer: *(c) 1/0 AWG in each raceway*

(4) Grounding Electrode. Separately derived systems located indoors must be grounded to the building grounding electrode system. **Figure 250–82**



▶ Figure 250–82

Separately derived systems located outdoors must be grounded in accordance with 250.30(C).

Author's Commentary:

The metal structural frame of a building is itself not a grounding electrode, but when it is properly connected to the grounding electrodes [250.68(C)(2)] it can be used as a grounding electrode conductor.

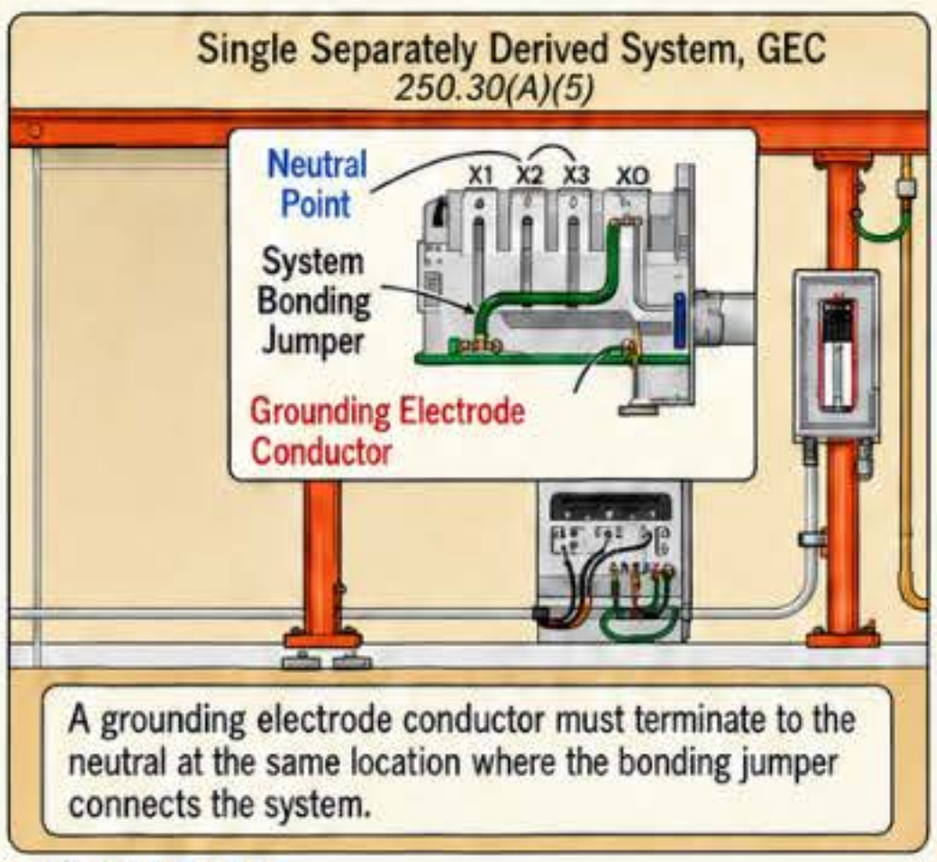
— Michael Hamilton

GROUNDING & BONDING NEC 2023

Note 1: *Inside the premises, interior metal water piping that belongs to a separately derived system must be connected (bonded) to that same separately derived system in accordance with 250.104(D).*

(5) Grounding Electrode Conductor, Single Separately Derived System. *For a system supplied by a single separately derived source, the grounding electrode conductor must be sized per 250.66 based on the largest ungrounded conductor. area. The conductor must also terminate on the building grounding electrode as required by 250.30(A)(4), or on building structural steel when permitted by 250.68(C).*

The grounding electrode conductor is required to connect to the neutral conductor at the same point where the bonding *jumper ties the system together.* ***Figure 250–83*** *illustrates this requirement.*

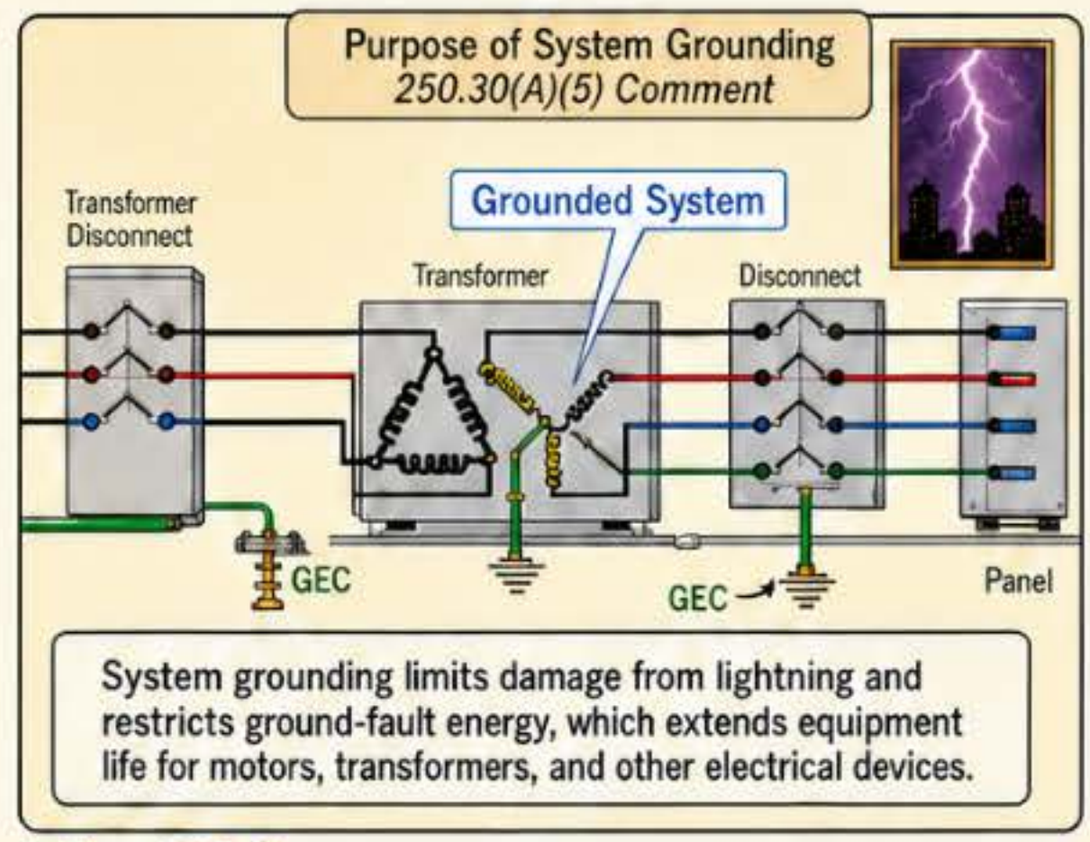


▶ **Figure 250–83**

Author's Commentary:

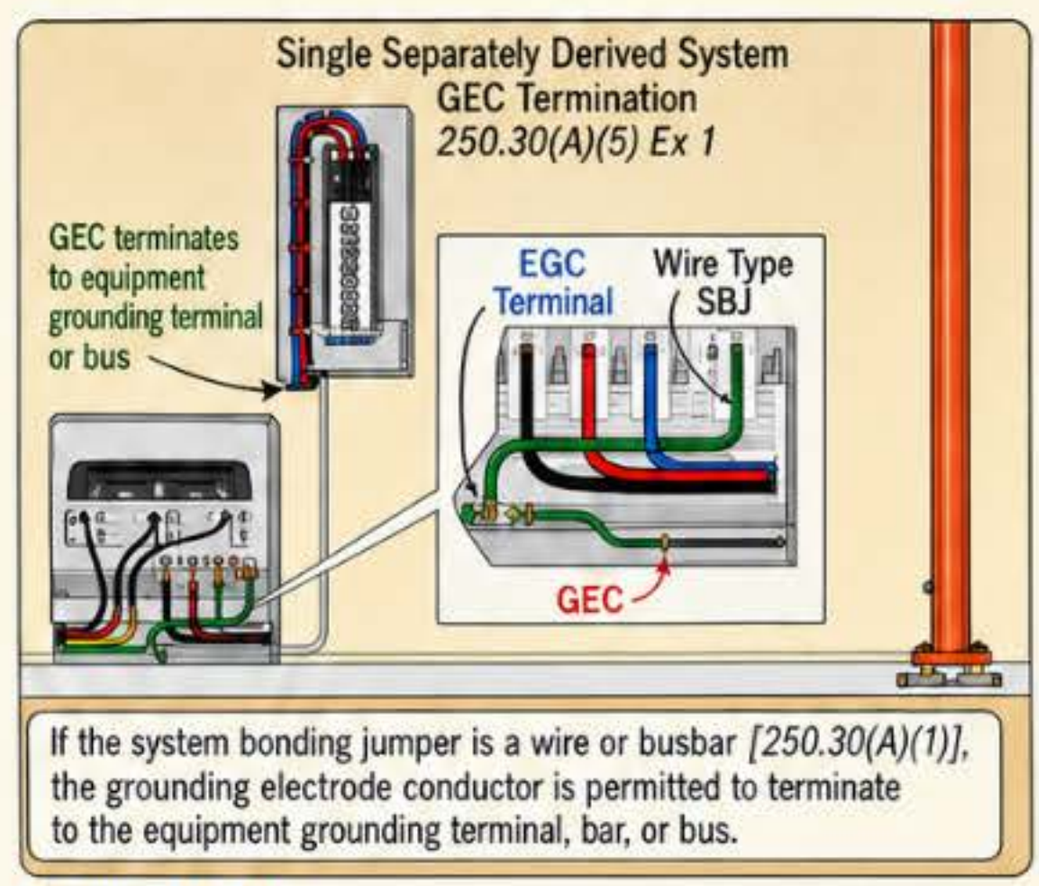
- *System grounding is intended to limit the overvoltage produced by induction from multiple lightning events or from intermittent ground faults. By providing an intentional fault path, system grounding reduces the risk of fire in buildings and helps safeguard electrical insulation and other components such as motors, transformers, and control equipment.*
- *To prevent objectionable neutral current from flowing into metal parts [250.6], the grounding electrode conductor must connect at the same point on the separately derived system where the system bonding jumper is installed [250.30(A)(1)].*

— Michael Hamilton



▶ **Figure 250–84**

Ex 1: If the system bonding jumper is a wire or busbar [250.30(A)(1)], the grounding electrode conductor can terminate at the equipment grounding terminal, bar, or bus. ▶ ***Figure 250–85***



▶ **Figure 250–85**

(6) Common Grounding Electrode Conductor, Multiple Separately Derived Systems. *Where multiple separately derived systems exist, a tap from each system's grounding electrode conductor to a common grounding electrode conductor is allowed. This connection must be made at the same point on the secondary of the separately derived system where the system bonding jumper is located [250.30(A)(1)].* ▶ ***Figure 250–86***

(a) Common Grounding Electrode Conductor. *The common grounding electrode conductor can be any of the following:*

250.30 Grounding and Bonding

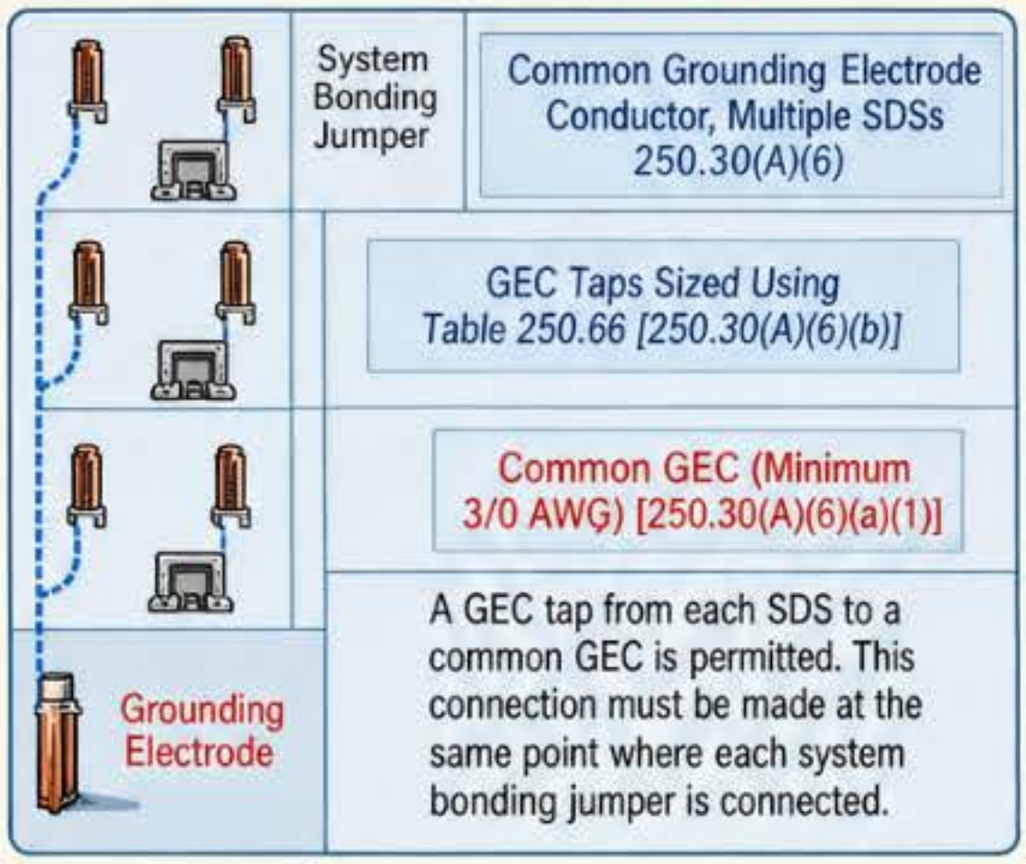
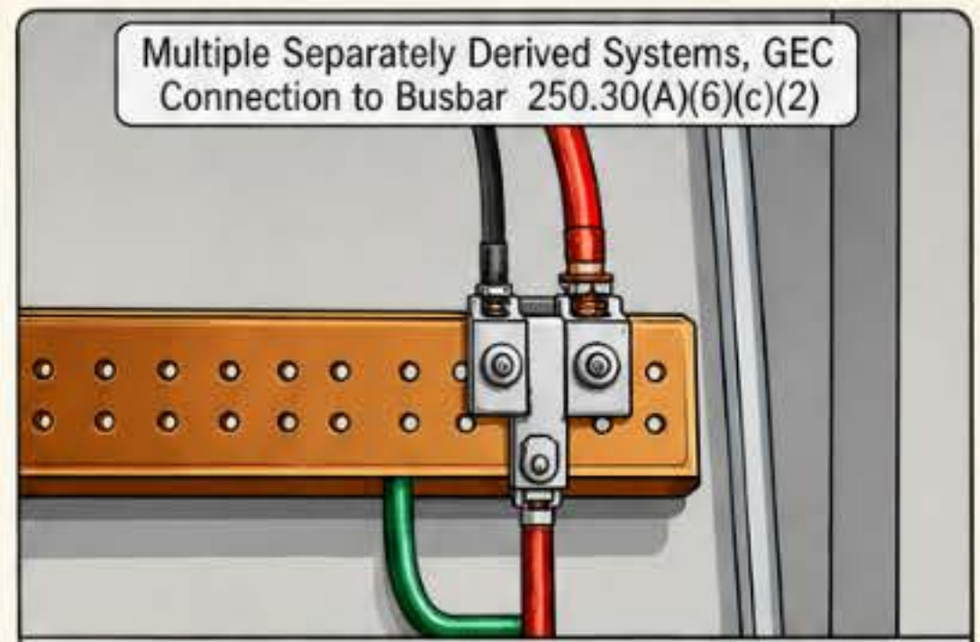


Figure 250–86



A grounding electrode conductor and grounding electrode bonding jumpers are permitted to terminate to a busbar sized not less than 1/4 in. thick × 2 in. wide, and of sufficient length to accommodate the terminations necessary for the installation.

Figure 250–87

(1) An unspliced conductor not smaller than 3/0 AWG copper or 250 kcmil aluminum.

(2) Interior metal water pipe located not more than 5 ft from the point of entrance to the building [250.68(C)(1)].

(3) The metal frame of the building that complies with 250.68(C)(2) or is connected to the grounding electrode system by a conductor not smaller than 3/0 AWG copper or 250 kcmil aluminum.

(b) Tap Conductor Size. *Grounding electrode conductor taps must be sized in accordance with Table 250.66, based on the area of the largest secondary phase conductor.*

Ex: If the only electrodes present are of the types specified in 250.66(A), (B), or (C), the size of the common grounding electrode conductor is not required to be larger than the largest conductor required by 250.66(A), (B), or (C) for the type of electrode that is present.

(c) Connections. *Tap connections to the common grounding electrode conductor must be made at an accessible location by any of the following methods:*

(1) A connector listed as *grounding and bonding equipment.*

(2) *Listed connections to aluminum or copper busbars not less than 1/4 in. thick × 2 in. wide, and of sufficient length to accommodate the terminations necessary for the installation.* ▶ Figure 250–87

(3) *Exothermic welding.*

(7) Installation. *The grounding electrode conductor must comply with 250.64(A), (B), (C), and (E).*

Author's Commentary:

- *According to 250.64, the grounding electrode conductor must be copper where within 18 in. of the surface of the Earth [250.64(A)], and:*
- *Be securely fastened to the surface on which it is carried [250.64(B)],*
- *Be adequately protected if exposed to physical damage [250.64(B)], and*
- *Ferrous metal enclosures enclosing a grounding electrode conductor must be made electrically continuous from the point of attachment to cabinets or equipment to the grounding electrode [250.64(E)].*

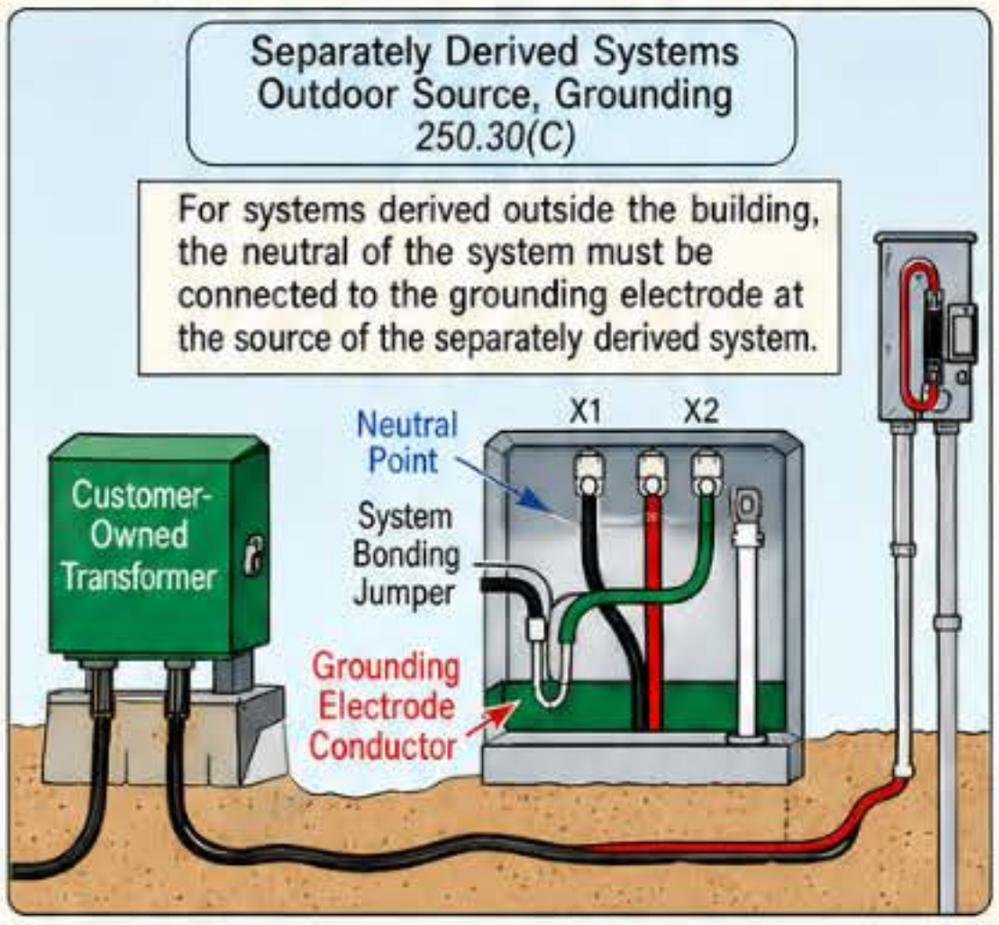
(8) Structural Steel and Metal Piping. *To ensure dangerous voltage on metal parts from a ground fault is removed quickly, structural steel and metal piping in the area served by a separately derived system must be bonded to the secondary neutral conductor in accordance with 250.104(D).*

Author's Commentary:

- *If the structural steel of a building is connected to the Earth in accordance with 250.68(C)(2), it is part of the grounding electrode system, and an indoor separately derived system is required to be connected to the building steel [250.30(A)(4)]. If the structural steel of a building is not in compliance with 250.68(C)(2), it must be bonded to the neutral conductor of the separately derived system via a bonding jumper in accordance with 250.104(D).*

GROUNDING AND BONDING | 250.30

(C) Outdoor Source. For systems that are derived outside the structure, the grounding electrode connection must be established at the separately derived system's service location. Figure 250–88



▶ Figure 250–88

Author's Commentary:

- *A grounding electrode connection is required at the building disconnect supplied by the outdoor separately derived system [250.32(B)(2)].*

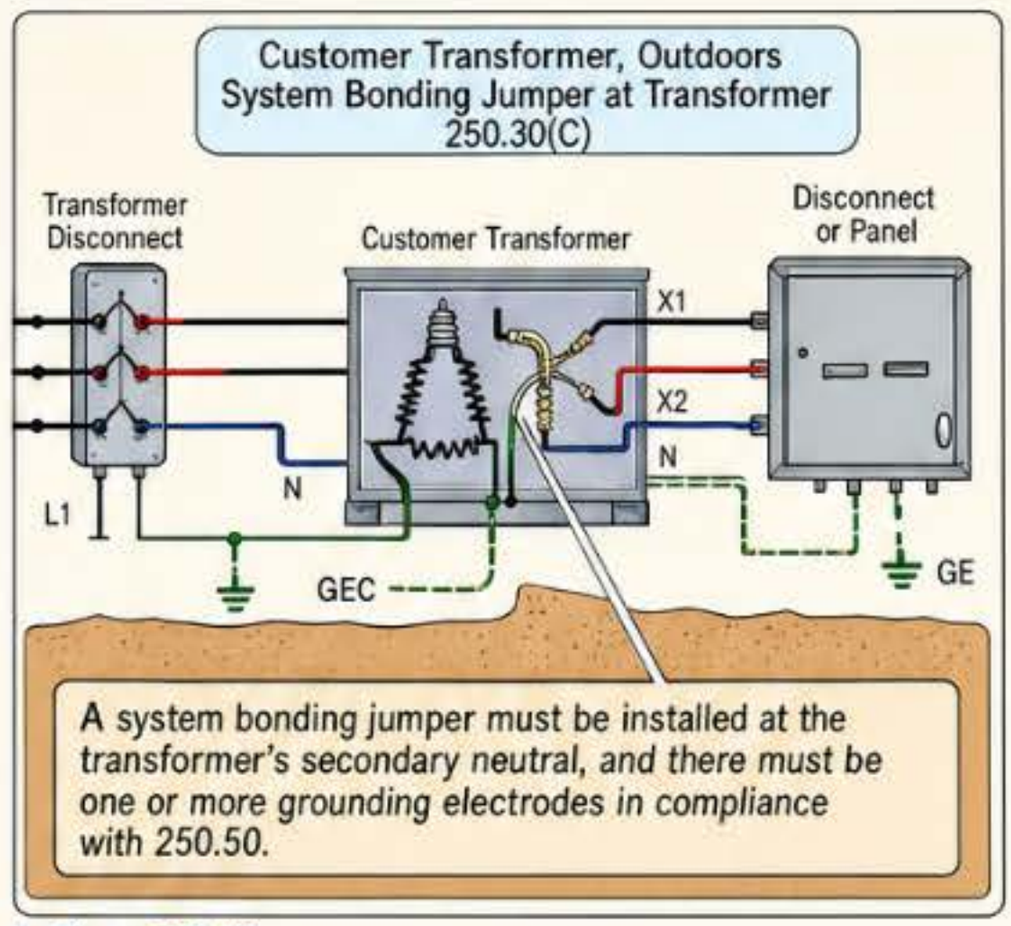
— ***Michael Hamilton***

Special Section 250.30 Separately Derived Systems Outdoor Installations

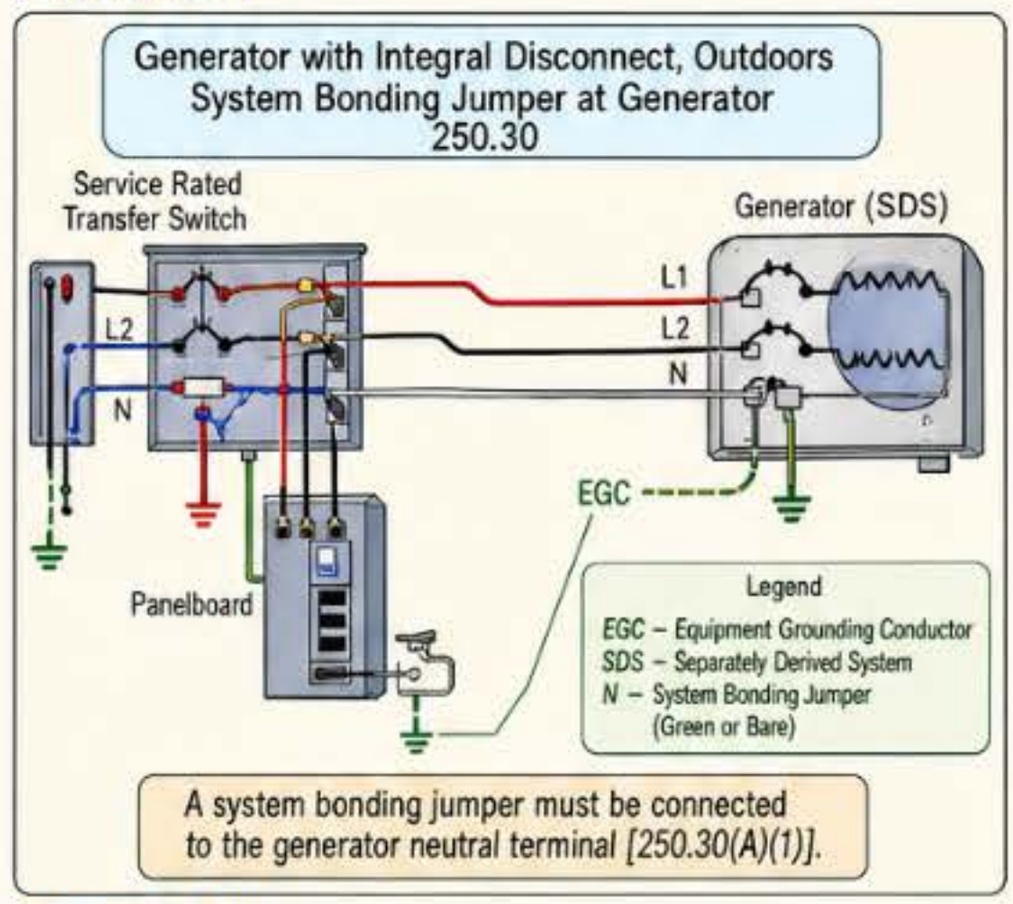
Customer Transformer Outdoors. ▶ Figure 250–89

System Bonding Jumper. When a separately derived system is installed outdoors, a system bonding jumper sized in accordance with Table 250.102(C)(1), if of the wire type, must be installed at the separately derived system's secondary neutral [250.30(A)(1)].

Grounding Electrode Conductor. *A grounding electrode conductor sized per 250.66, based on the area of the largest secondary phase conductor [250.30(A)(5)], must be run from the separately derived system's neutral terminal to one or more grounding electrodes in accordance with 250.50 and in accordance with 250.30(A)(4)].*



▶ Figure 250–89



▶ Figure 250–90

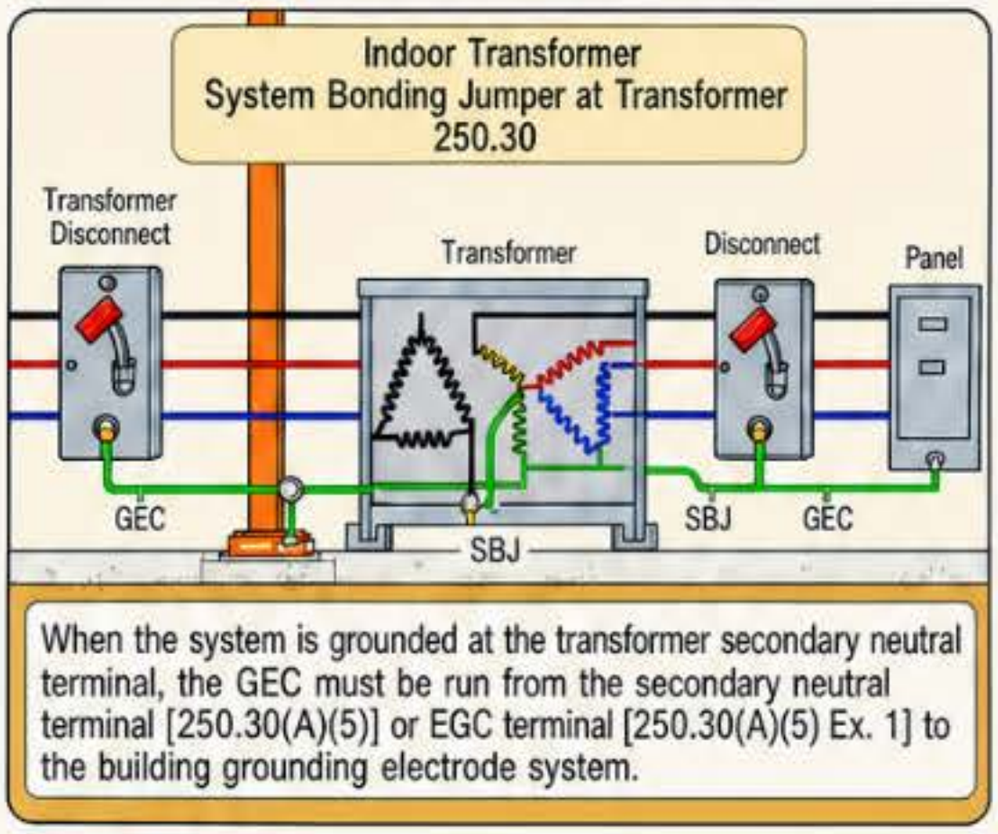
When the system bonding jumper is a conductor or busbar, the grounding electrode conductor can originate at the generator's equipment grounding terminal, bar, or bus [250.30(A)(5) Ex 1].

Supply-Side Bonding Jumper. *A supply-side bonding jumper must be run from the separately derived system's equipment grounding conductor terminal to the secondary system disconnect enclosure's equipment grounding conductor terminal.*

If the supply-side bonding jumper is of the wire type, it must be sized in accordance with Table 250.102(C)(1), based on the size/area of the secondary phase conductor [250.30(A)(2)].

Indoor Installations

Indoor Separately Derived System, System Bonding Jumper at Separately Derived System. ▶ Figure 250–91



▶ Figure 250–91

System Bonding Jumper. Where a separately derived system is installed indoors, the required system bonding jumper sized in accordance with Table 250.102(C)(1), if of the wire type, can be installed at the separately derived system's secondary neutral terminal [250.30(A)(1)(a)].

Grounding Electrode Conductor. A grounding electrode conductor sized in accordance with 250.66, based on the size/area of the secondary phase conductor, must be run from the separately derived system's neutral terminal to the building's grounding electrode system [250.30(A)(4)].

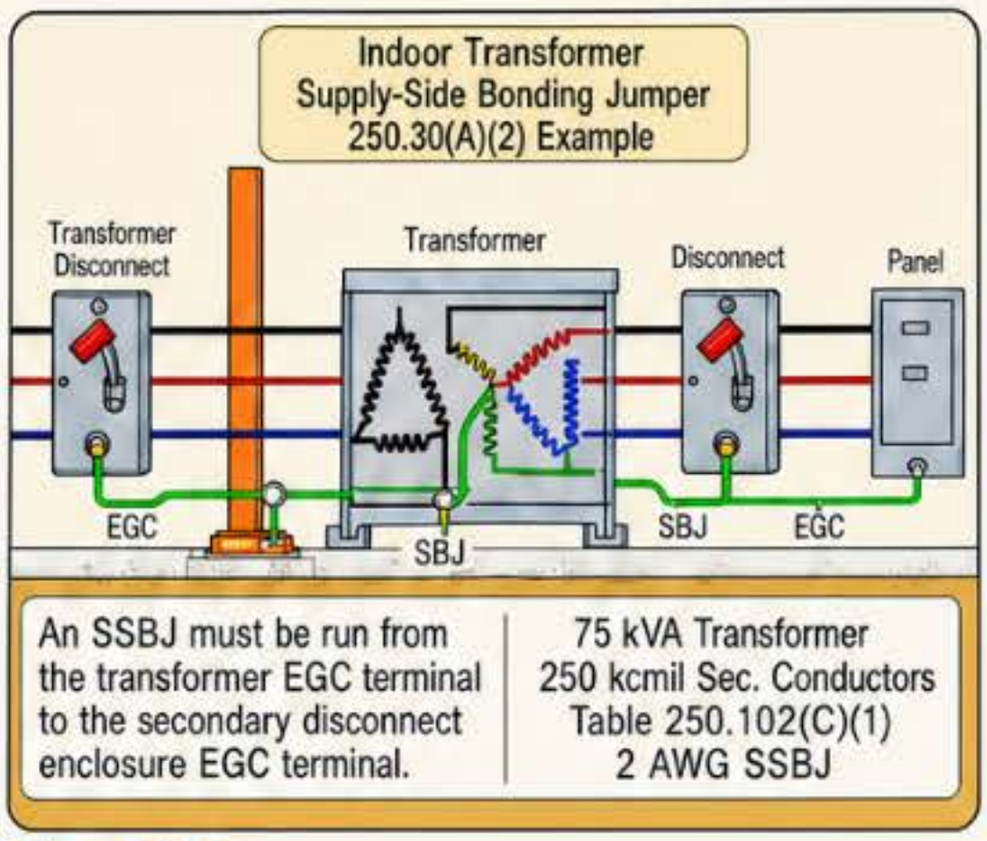
Where the system bonding jumper is a wire or busbar, the grounding electrode conductor can originate at the transformer's equipment grounding terminal, terminal, bar, or bus [250.30(A)(5) Ex 1].

Supply-Side Bonding Jumper. A supply-side bonding jumper sized in accordance with Table 250.102(C)(1), if of the wire type, must be run from the separately derived system's equipment grounding conductor terminal to the secondary system disconnect *enclosure's equipment grounding conductor terminal [250.30(A)(2)].*

▶ Example

Question: *What size supply-side bonding jumper is required between a 75 kVA transformer, with 250 kcmil secondary conductors in a single raceway, and the first disconnect?*

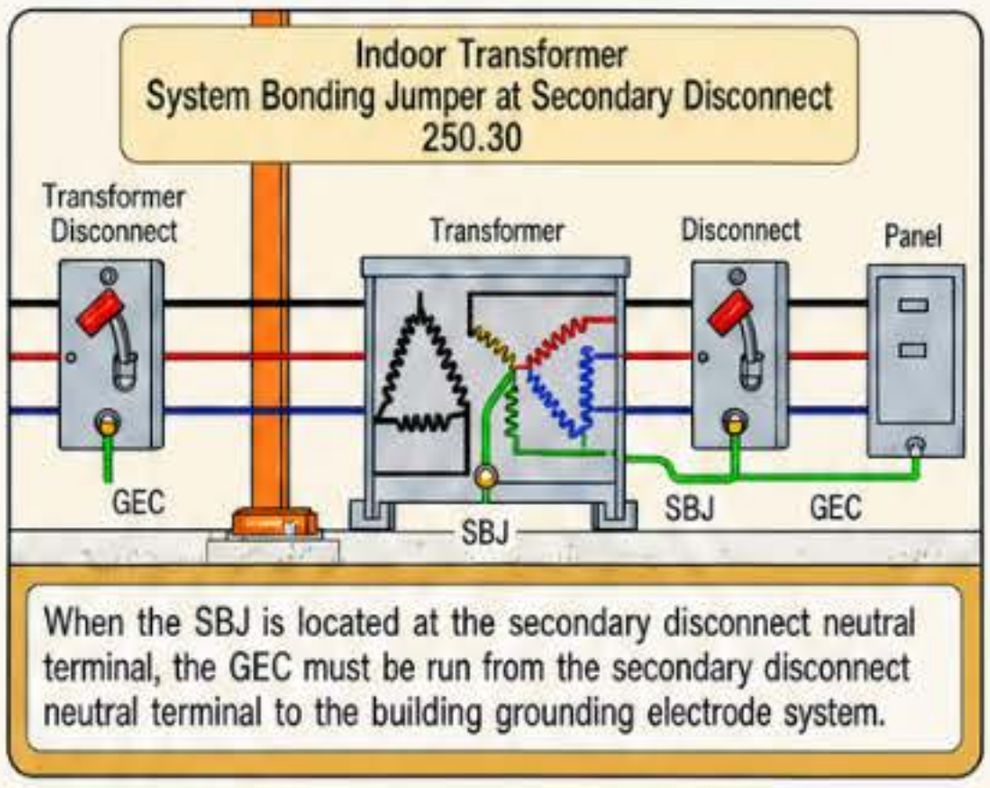
(a) 4 AWG (b) 3 AWG (c) 2 AWG (d) 1 AWG



▶ Figure 250–92

Answer: *(c) 2 AWG; based on the 250 kcmil conductors [Table 250.102(C)(1)].*

Separately Derived System Indoors, System Bonding Jumper at Secondary System Disconnect. ▶ Figure 250–93



▶ Figure 250–93

System Bonding Jumper. *Where a separately derived system is installed indoors, the required system bonding jumper, sized in accordance with Table 250.102(C)(1), can be installed at the separately derived system's secondary system disconnect [250.30(A)(1)(b)].*

Grounding Electrode Conductor. *A grounding electrode conductor, sized in accordance with 250.66 based on the area of the largest secondary phase conductor, must be run from the separately derived system's disconnect neutral terminal to the building's grounding electrode system [250.30(A)(4)].*

GROUNDING AND BONDING

The system bonding jumper is a conductor or busbar that allows the equipment grounding conductor to originate at certain locations on the transformer's secondary or at the secondary disconnecting means. These include the grounding terminal, grounding bar, or bus [250.30(A)(5) Ex 1].

SUPPLY-SIDE BONDING JUMPER. A supply-side bonding jumper, sized according to Table 250.102(C)(1), is required when the equipment grounding conductor from the equipment terminal at the secondary disconnect enclosure must run to the equipment grounding conductor terminal on the building's secondary disconnect enclosure [250.30(A)(2)].

SIZING THE SUPPLY-SIDE BONDING JUMPER FOR PARALLEL RACEWAYS

METHOD 1. Install one supply-side bonding jumper in each raceway and size it using Table 250.102(C)(1), based on the size or area of the phase conductors in each raceway [250.102(C)(2)].

METHOD 2. *Use a single supply-side bonding jumper that is run through multiple raceways according to Table 250.102(C)(1), based on the equivalent area of the phase conductors in all the raceways combined [250.102(C)(2)].*

▶ EXAMPLE

Question: *What size single supply-side bonding jumper is required between a 112.50 kVA transformer, paralleled in two raceways with 3/0 AWG secondary conductors in each raceway, and the first disconnect?*

(a) 4 AWG (b) 3 AWG (c) 2 AWG (d) 1 AWG

Solution:

Determine the equivalent area for two 3/0 AWG conductors [250.102(C)(2) and Chapter 9, Table 8].

3/0 AWG = 167,800 circular mils

2 conductors × 167,800 cmil = 335,600 cmil [Table 250.102(C)(1)]

One 2 AWG supply-side bonding jumper (minimum) is needed to bond both raceways, but the minimum size neutral conductor in parallel is 1/0 AWG [310.10(G)(1)].

Answer: *(c) 2 AWG*

AUTHOR'S COMMENTARY:

- *A separate supply-side bonding jumper may be used in each parallel raceway, sized by the phase conductors in that raceway [250.102(C)(2)]. If the phase conductors in each raceway are 3/0 AWG, then a 4 AWG bonding jumper must be installed in each raceway [250.102(C)(2)].*

— Michael Hamilton

NEUTRAL CONDUCTOR. When the system bonding jumper is installed at a secondary system disconnect, a secondary neutral conductor in each raceway—no smaller than specified in Table 250.102(C)(1)—must be run from the separately derived system's secondary to that disconnect enclosure in the second system.

▶ EXAMPLE

Question: *What size neutral conductor is required for a 112.50 kVA transformer paralleled in two raceways with 3/0 AWG secondary conductors in each raceway?*

(a) 3 AWG (b) 2 AWG (c) 1 AWG (d) 1/0 AWG

Solution:

Determine the equivalent area for two 3/0 AWG conductors [250.102(C)(2) and Chapter 9, Table 8].

3/0 AWG = 167,800 circular mils

2 conductors × 167,800 cmil = 335,600 cmil [Table 250.102(C)(1)]

One 2 AWG supply-side bonding jumper (minimum) is needed to bond both raceways, but the minimum size neutral conductor in parallel is 1/0 AWG [310.10(G)(1)].

Answer: *(d) 1/0 AWG*

AUTHOR'S COMMENTARY:

- *Be sure the 1/0 AWG conductor is large enough to handle the maximum unbalanced load [220.61].*
- *When a system bonding jumper is installed at the secondary system's disconnect, the secondary neutral conductor will serve as part of the effective ground-fault current path.*

— Michael Hamilton

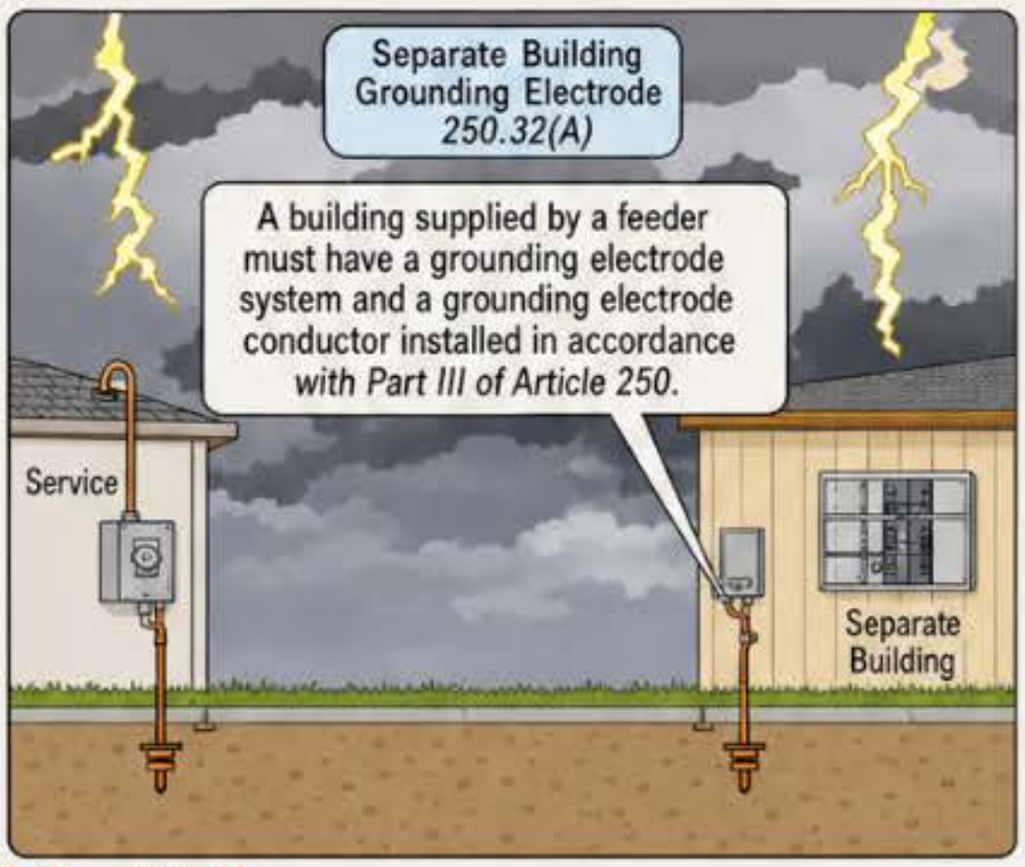
250.32 BUILDINGS SUPPLIED BY A FEEDER

(A) Grounding Electrode. A building supplied by a feeder must have a grounding electrode system, and a grounding electrode conductor installed in accordance with Part III of Article 250.

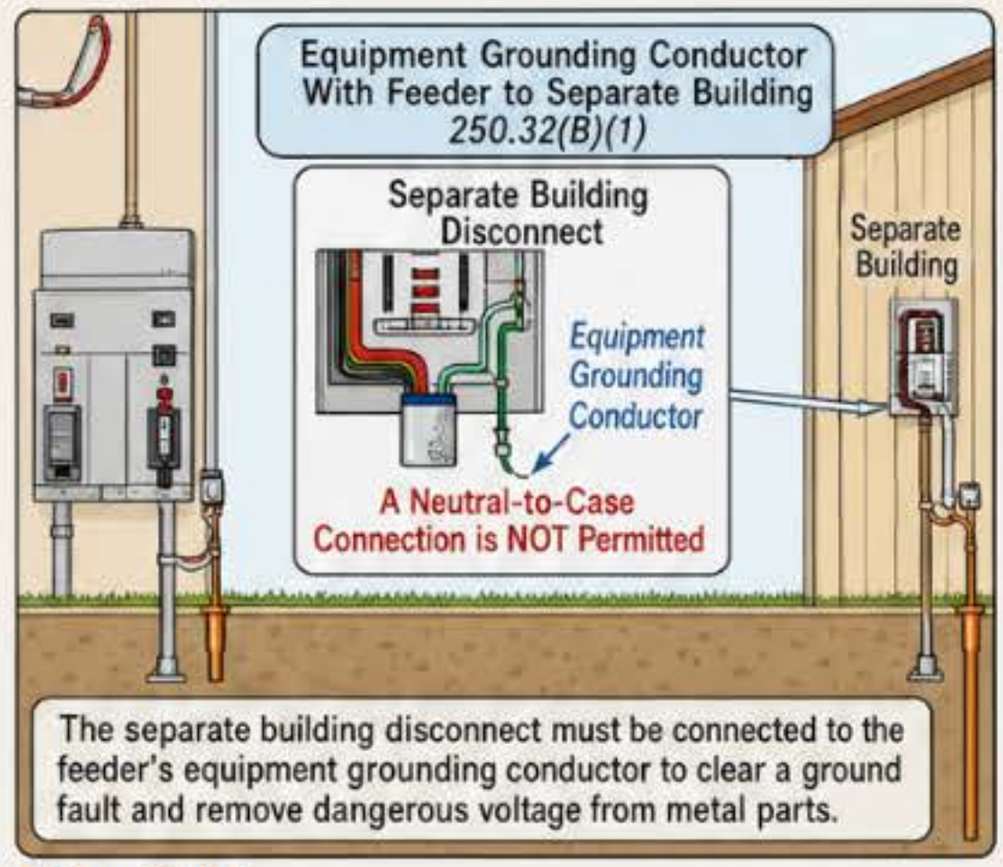
Figure 250–94

Ex: *A grounding electrode is not required for a building if it is supplied by a single branch circuit or by a multiwire branch circuit.* *Figure 250–95*

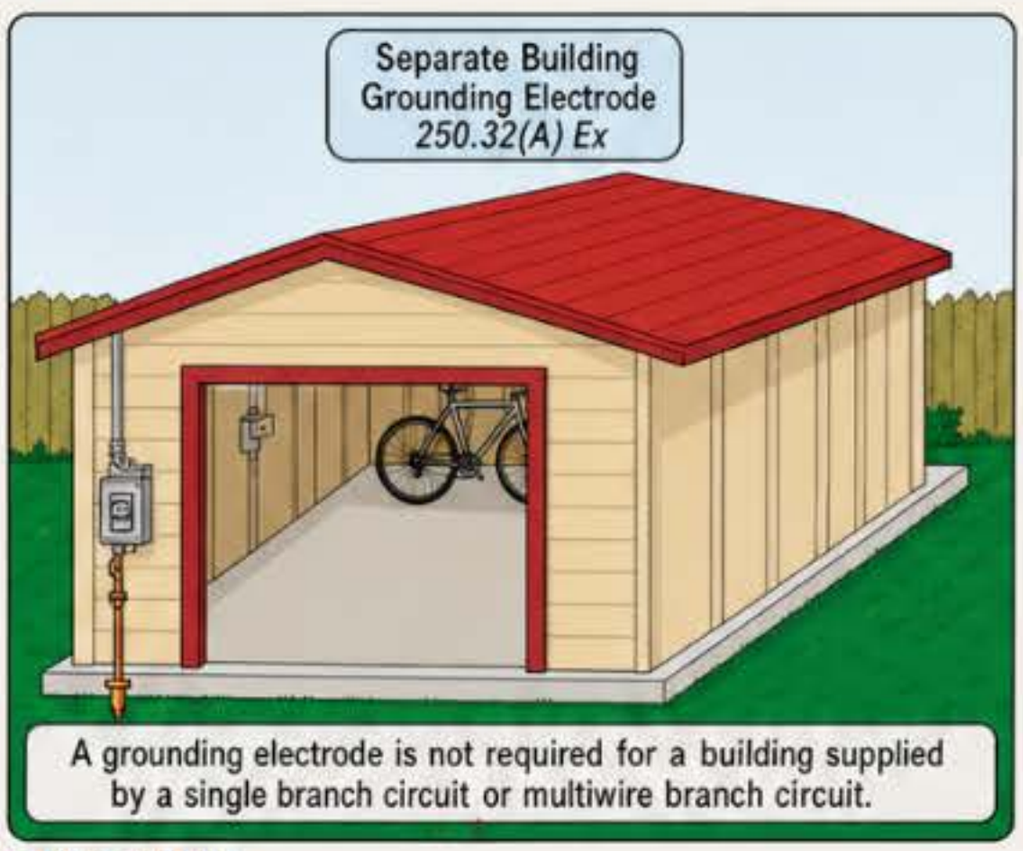
250.32 | Grounding and Bonding



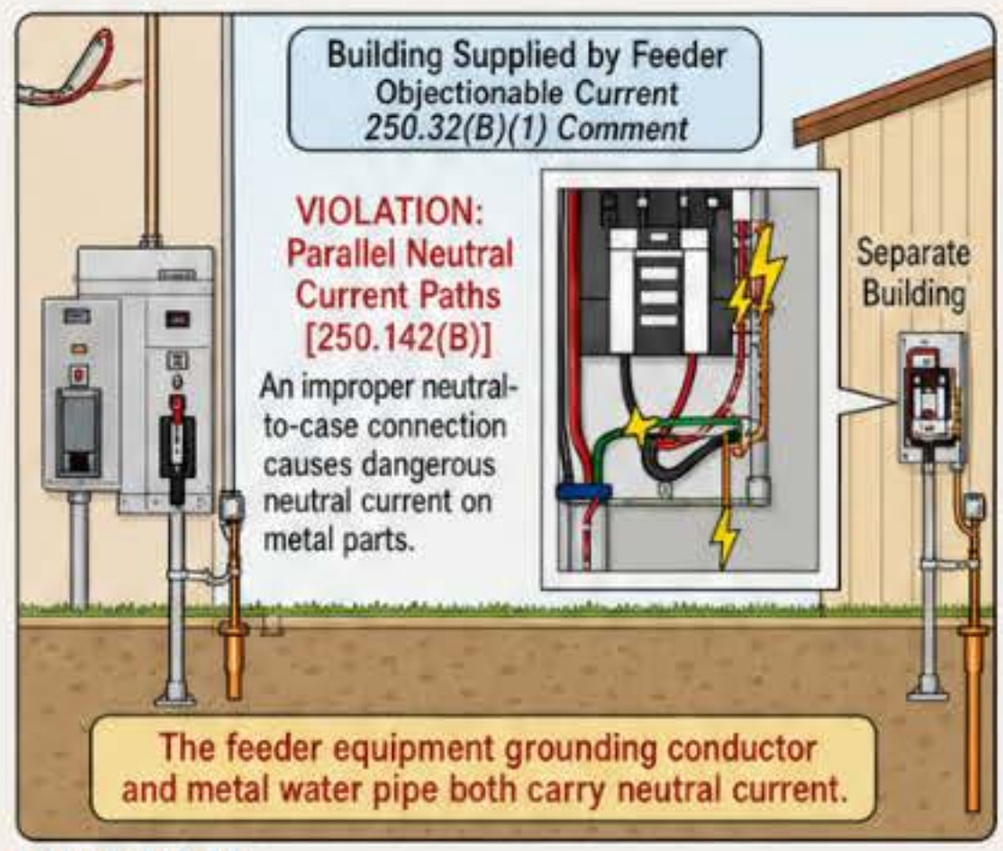
▶ Figure 250-94



▶ Figure 250-96



▶ Figure 250-95



▶ Figure 250-97

(B) Grounded Systems (Equipment Grounding Conductor).

(1) To clear a ground fault and remove hazardous voltage from metal parts due to a ground fault, the metal parts of the building disconnect must be connected to the feeder equipment grounding conductor of a type specified in 250.118.

Where the supply circuit equipment grounding conductor is of the wire type, it must be sized in accordance with 250.122, based on the rating of the overcurrent protective device.

CAUTION

To prevent objectionable neutral current from flowing on metal parts *[250.6(A)]*, the supply circuit *neutral conductor is not permitted to be connected to the equipment grounding conductor at the remote building disconnect [250.142(B)].*

▶ Figure 250-97

Ex 1: The neutral conductor can serve as the ground-fault return path for the building disconnect for existing installations where there are no continuous metallic paths between buildings and structures, ground-fault protection of equipment is not installed on the supply side of the circuit, and the neutral conductor is sized no smaller than the larger of:

(1) The maximum unbalanced neutral load in accordance with 220.61.

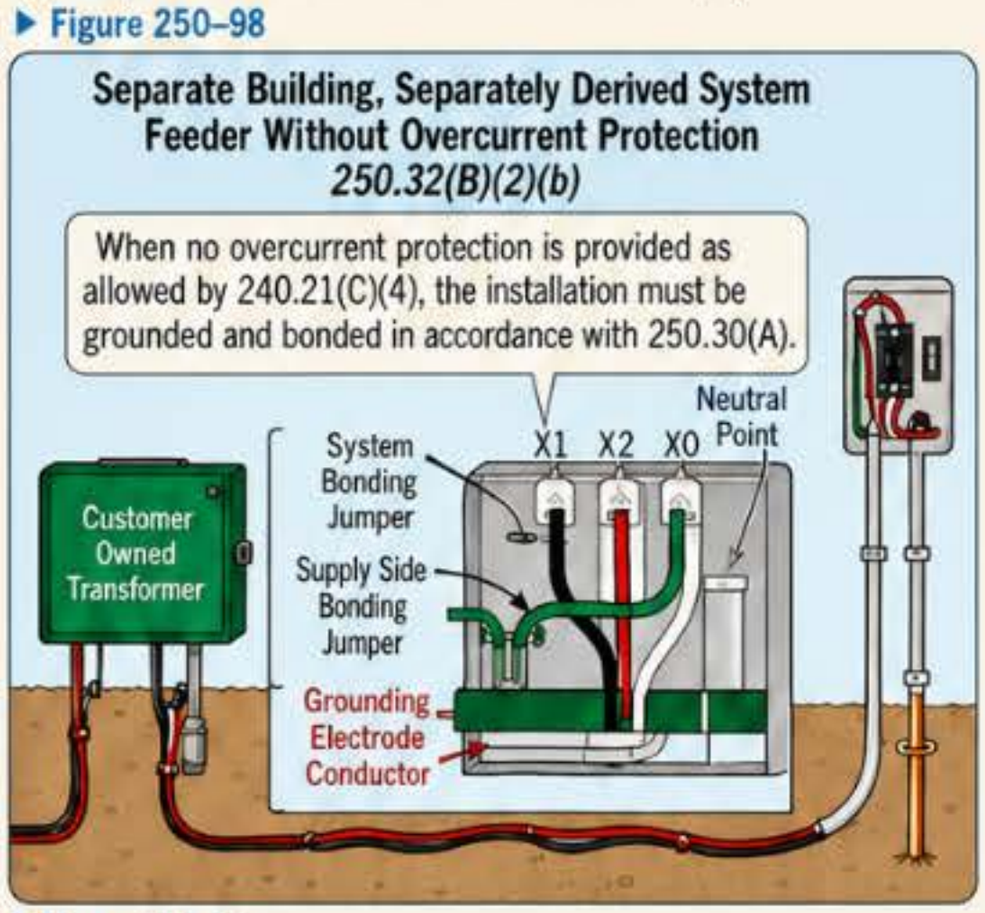
(2) The minimum equipment grounding conductor size in accordance with 250.122.

(2) Supplied by Separately Derived System.

(a) With Overcurrent Protection. If *overcurrent protection is* provided at the separately *derived system, the installation must contain an equipment grounding conductor in accordance with 250.32(B)(1).*

GROUNDING AND BONDING | 250.34

(b) Without Overcurrent Protection. If overcurrent protection is not supplied at the separately derived system, the installation has to meet 250.30(A).
▶ Figure 250–98



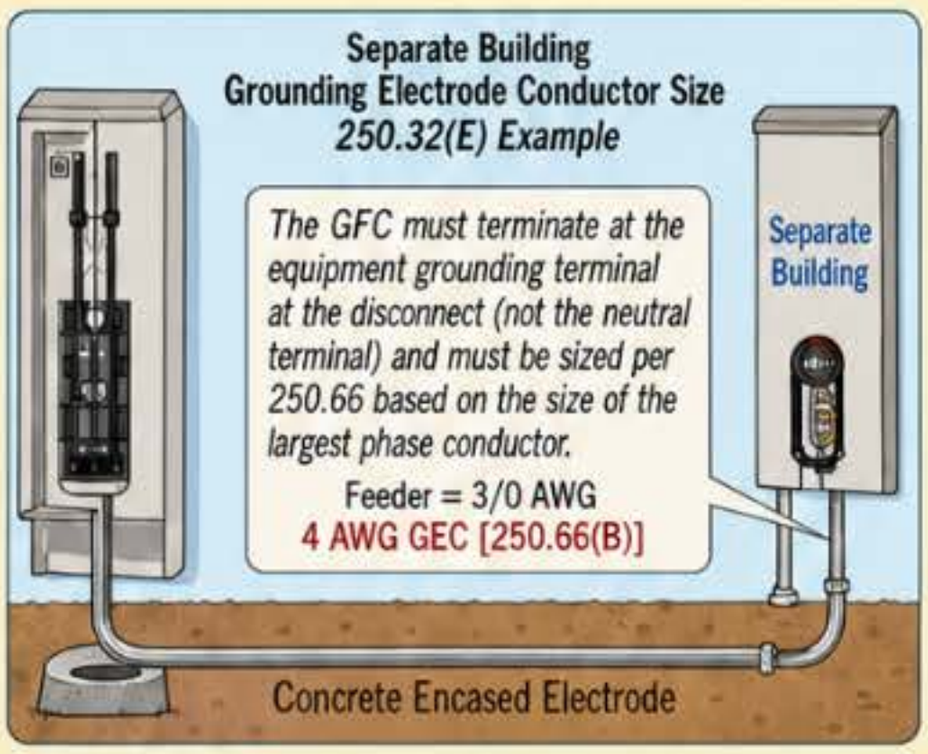
▶ Figure 250–98

(E) Grounding Electrode Conductor Size. The grounding electrode conductor must be sized to the equipment grounding terminal at the disconnect (not the neutral terminal) and must follow 250.66. Size is based on the *area of the largest ungrounded phase conductor.*

▶ Example

Question: *What size grounding electrode conductor is required for a building disconnect supplied by a 3/0 AWG feeder that uses a concrete-encased electrode?* ▶ Figure 250–99

(a) 4 AWG (b) 2 AWG (c) 1 AWG (d) 1/0 AWG



▶ Figure 250–99

Answer: *(a) 4 AWG [250.66(B) and Table 250.66]*

Author's Commentary:

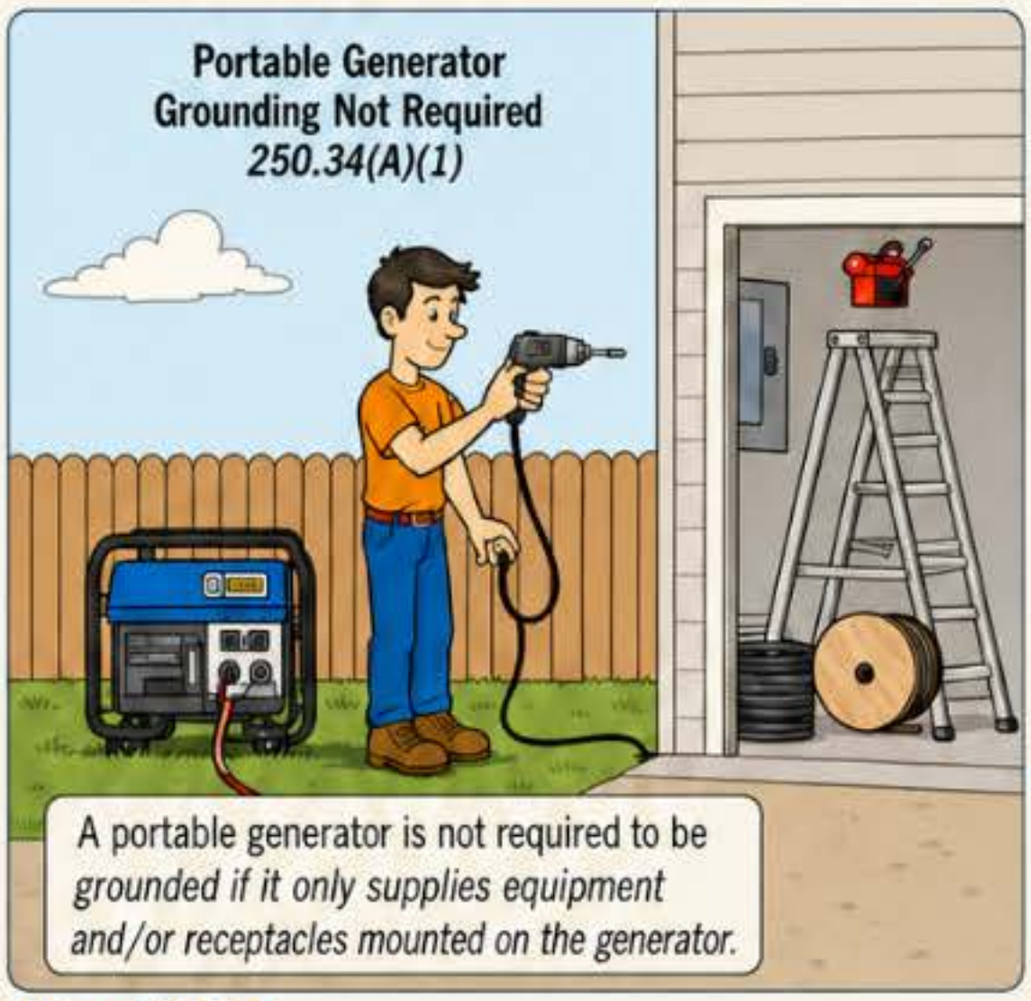
When the grounding electrode conductor is attached to a rod(s), the portion of the conductor that makes the connection(s) to the rod(s) does not have to be larger than 6 AWG copper [250.66(A)]. If the grounding electrode conductor is connected to a concrete-encased electrode(s), the portion of the conductor that makes the connection(s) to the concrete-encased electrode(s) does not have to be larger than 4 AWG copper [250.66(B)].

— Michael Hamilton

250.34 Generators—Portable and Vehicle- or Trailer-Mounted

(A) Portable Generators. A portable generator is not required to be connected to a grounding electrode (grounded) when all of the following conditions are met:

(1) The generator only supplies equipment and/or receptacles mounted on the generator. ▶ Figure 250–100



▶ Figure 250–100

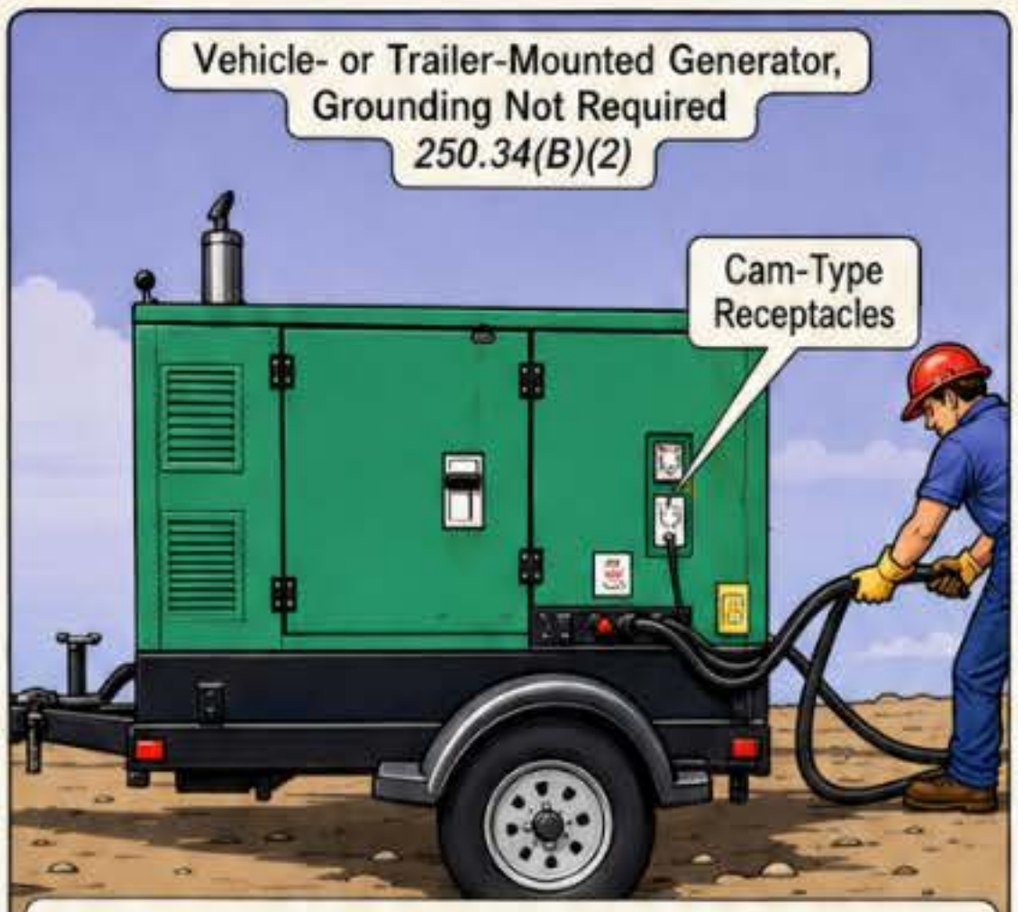
(2) The normally noncurrent-carrying metal parts of equipment and the equipment grounding conductor terminals of the receptacles are connected to the *generator frame.*

(B) Vehicle- or Trailer-Mounted Generators. A vehicle- or trailer-mounted *generator is not required to be connected to a grounding electrode when all of the following conditions are met:*

(1) *The generator frame is bonded to the vehicle or trailer frame.*

(2) *The generator only supplies equipment or receptacles mounted on the vehicle, trailer, or generator, and*
▶ Figure 250–101

250.36 | Grounding and Bonding



Vehicle-mounted and trailer-mounted generators that only supply receptacles are not required to be grounded.

Figure 250–101

(3) The normally noncurrent-carrying metal parts of equipment and the equipment grounding conductor terminals of the receptacles are connected to the generator frame.

250.36 High-Impedance Grounded Systems

High-impedance grounded three-phase systems of 480V up to 1,000V are permitted where all the following conditions are met: *Figure 250–102

(1) Conditions of maintenance and supervision ensure that only qualified persons service the installation.

(2) Ground detectors are installed on the system.

(3) Only line-to-line loads are served.

Author's Commentary:

High-impedance grounded systems are generally referred to as "High-Resistance Grounded Systems" in the industry. They are typically used where a sudden interruption of power will create increased hazards and where a reduction of incident energy is needed for worker safety.

— Michael Hamilton

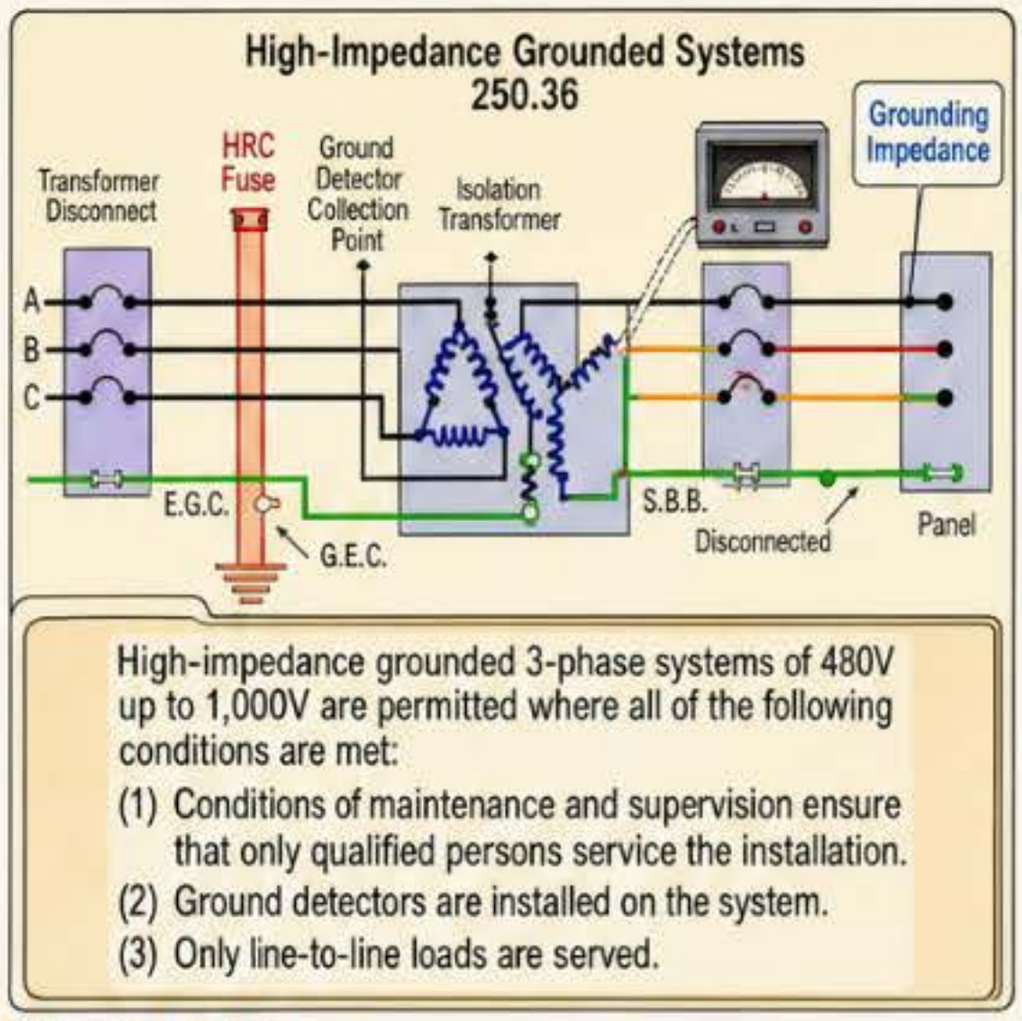


*Figure 250–102

(A) Grounding Impedance Location. To limit fault current to a very low value, high-impedance grounded systems must have a resistor installed between the neutral point of the separately derived system and the equipment grounding conductor. *Figure 250–103

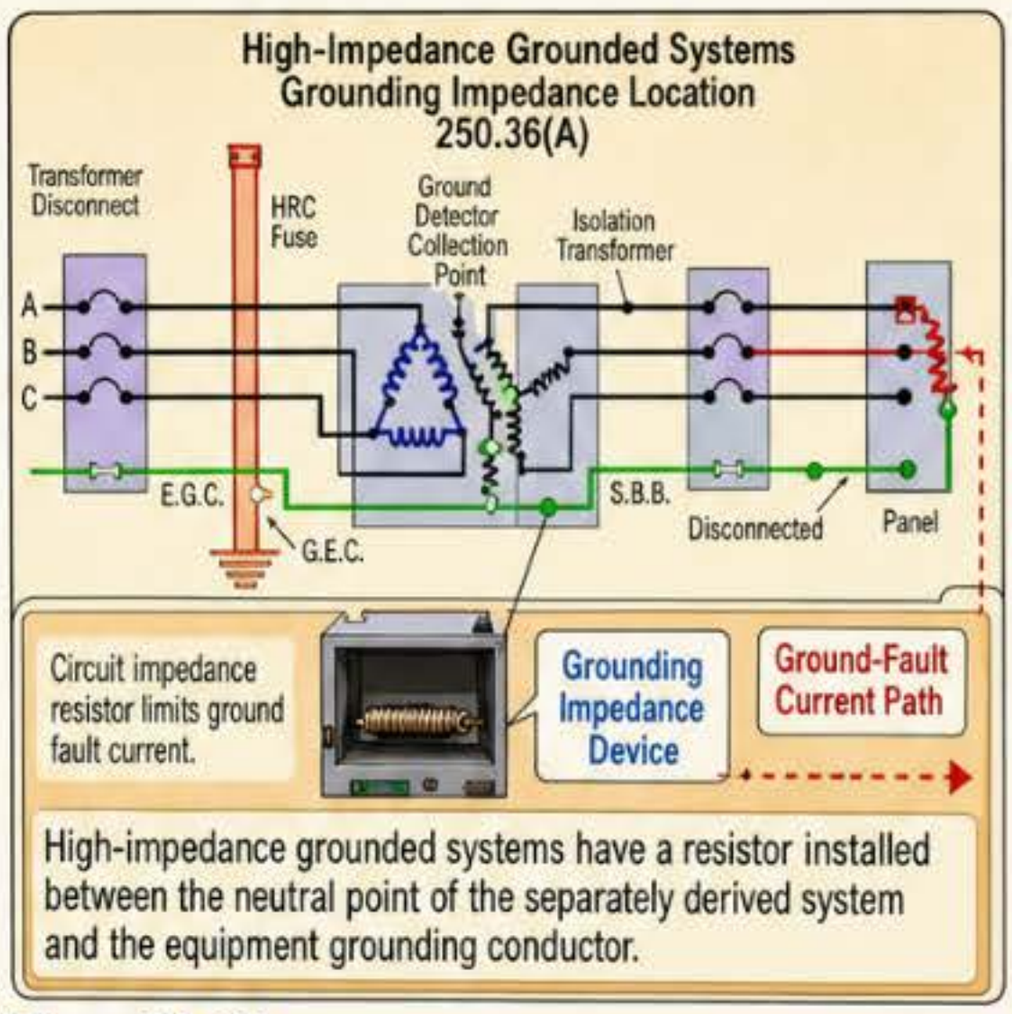


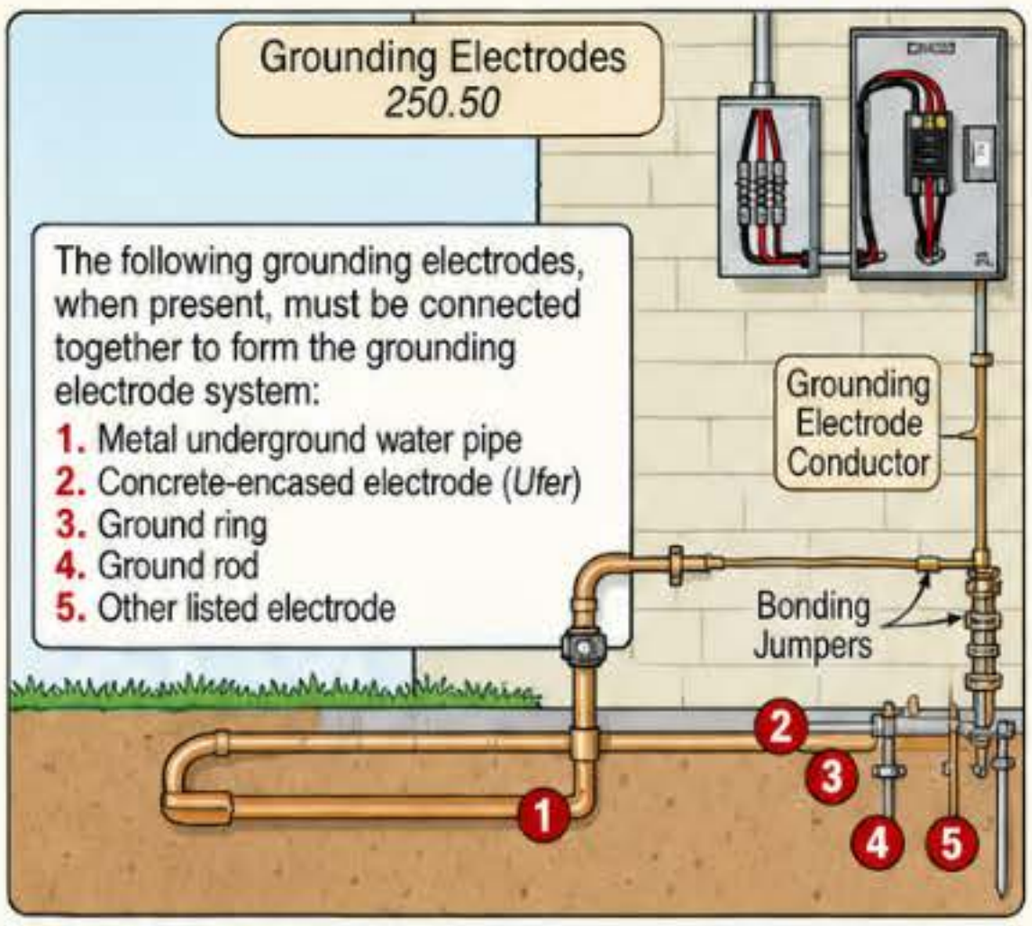
*Figure 250–103

Note: According to Annex O of NFPA 70E, *Standard for Electrical Safety in the Workplace*, high-impedance grounding is an effective tool for reducing arc flash hazards.

Part III. Grounding Electrode System and Grounding Electrode Conductor

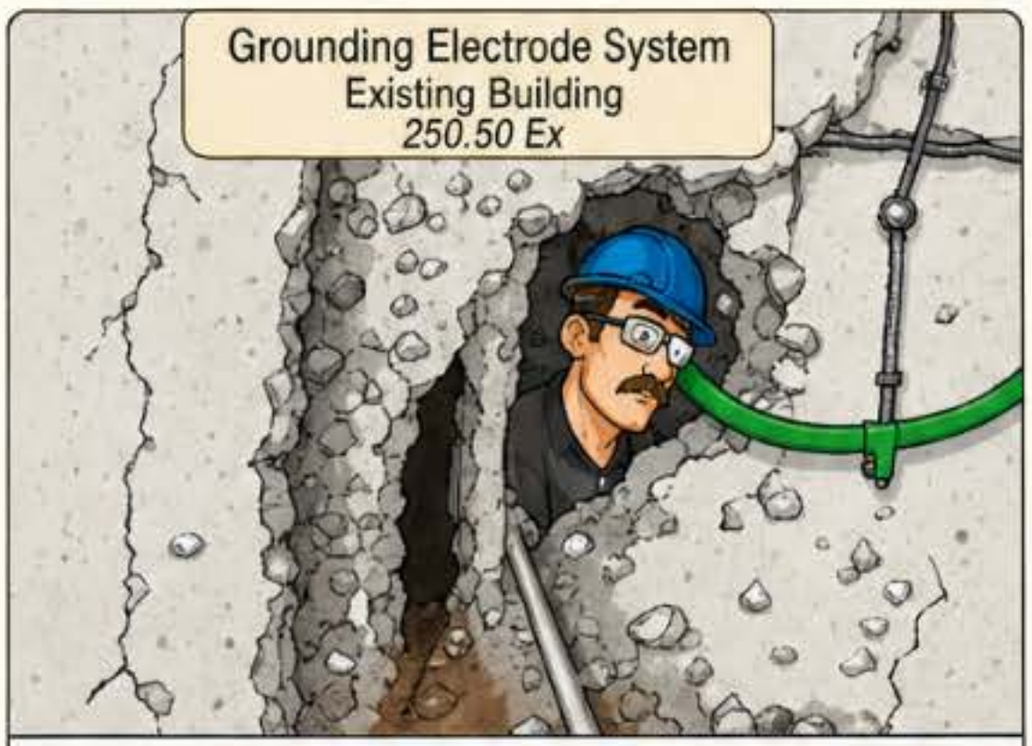
250.50 Grounding Electrode System

A grounding electrode system joins the grounding electrodes listed in 250.52(A)(1) through (A)(7) together. These components must be assembled into a building or structure. ▶ Figure 250–104



▶ Figure 250–104

Ex: *Concrete-encased electrodes are not required for existing buildings where the conductive steel reinforcing bars are not accessible without chipping up the concrete.* ▶ *Figure 250–105*



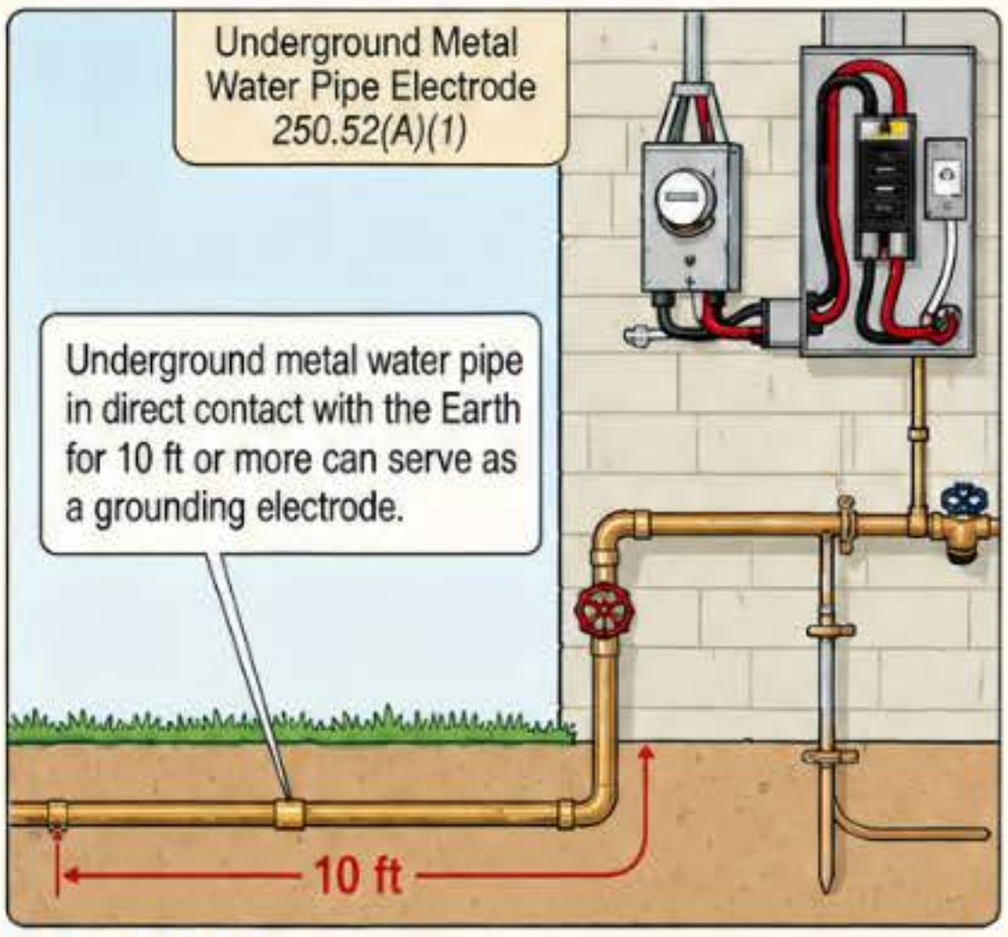
Concrete-encased electrodes aren't required for existing buildings or structures where the conductive steel reinforcing bars aren't accessible without chipping up the concrete.

▶ Figure 250–105

250.52 Grounding Electrode Types

(A) Electrodes.

(1) Underground Metal Water Pipe Electrode. Underground metal water pipe in direct contact with the Earth for 10 ft or more can serve as a grounding electrode. ▶ Figure 250–106



▶ Figure 250–106

Author's Commentary:

▶ *Some critics argue that using metal underground water pipe as a grounding electrode has been around since the early 1900s. The water industry believes that neutral current flowing on water piping corrodes the metal. To learn more, review the American Water Works Association's details on Electrical Grounding and Pipe Integrity and Shock Hazard, Catalog No. 90702, 1.800.926.7337.* ▶ *Figure 250–107*

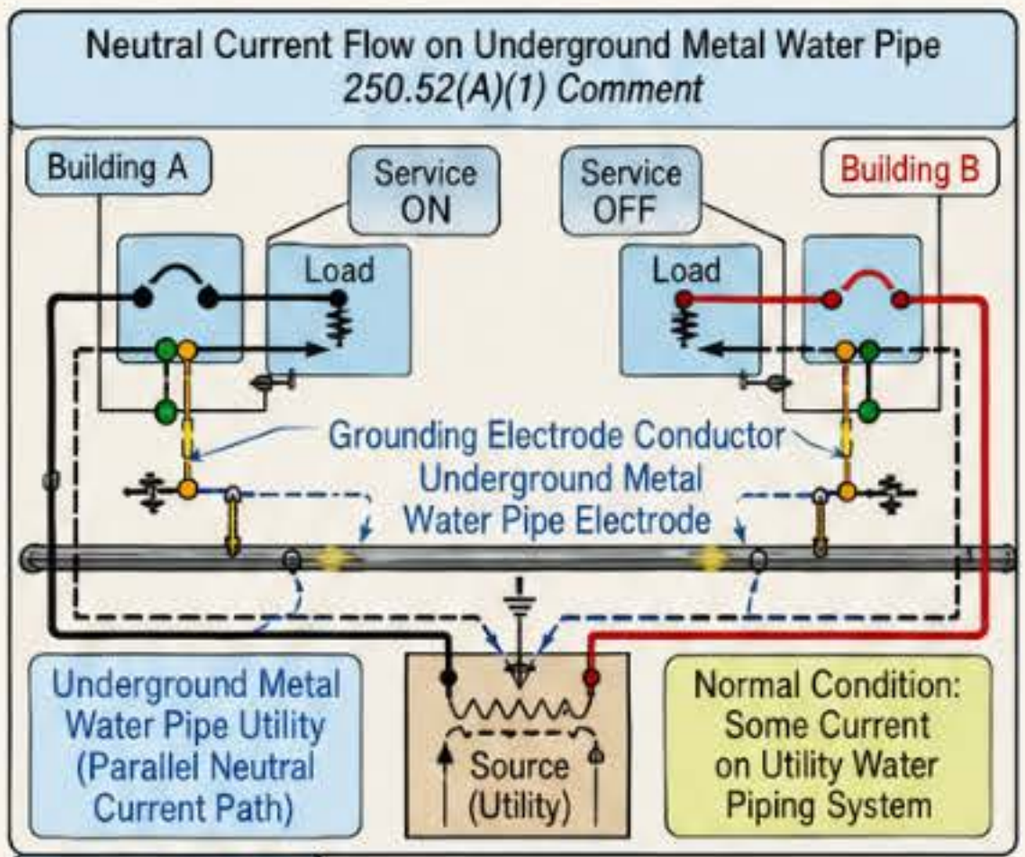
(2) Metal In-Ground Support Structure(s). Metal in-ground support structure(s) in direct contact with the Earth vertically for 10 ft or more can serve as a grounding electrode. ▶ Figure 250–108

Note: *Metal in-ground support structures include (but are not limited to) pilings, casings, and other structural metal.*

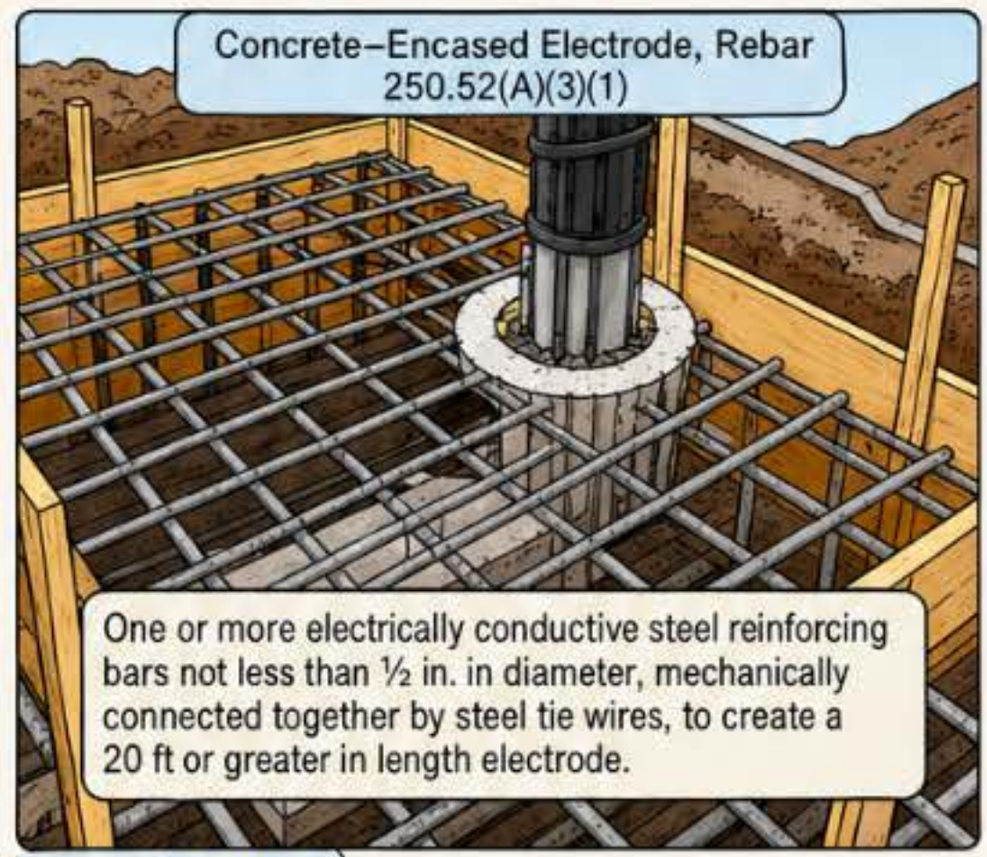
(3) Concrete-Encased Electrode. *Concrete-encased electrodes meeting the requirements of this subsection can serve as grounding electrodes.* ▶ *Figure 250–109*

(1) *One or more electrically conductive steel reinforcing bars (rebar) of not less than 1/2 in. in diameter that are mechanically connected by steel tie wires to create a 20 ft or greater in length of steel can serve as a grounding electrode.* ▶ *Figure 250–110*

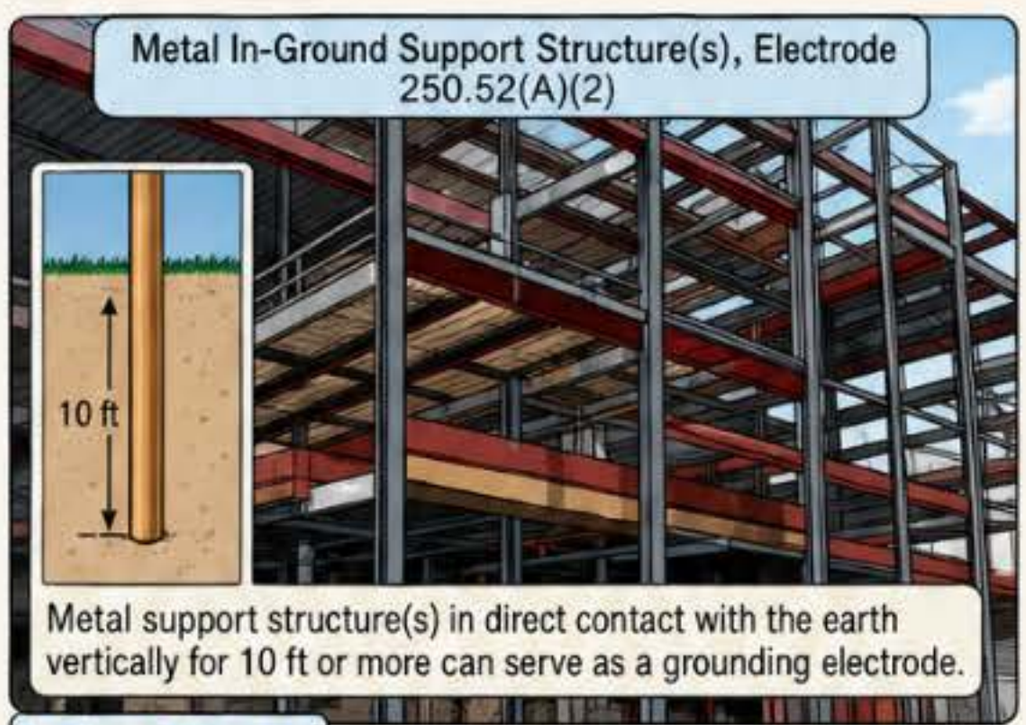
250.52 | Grounding and Bonding



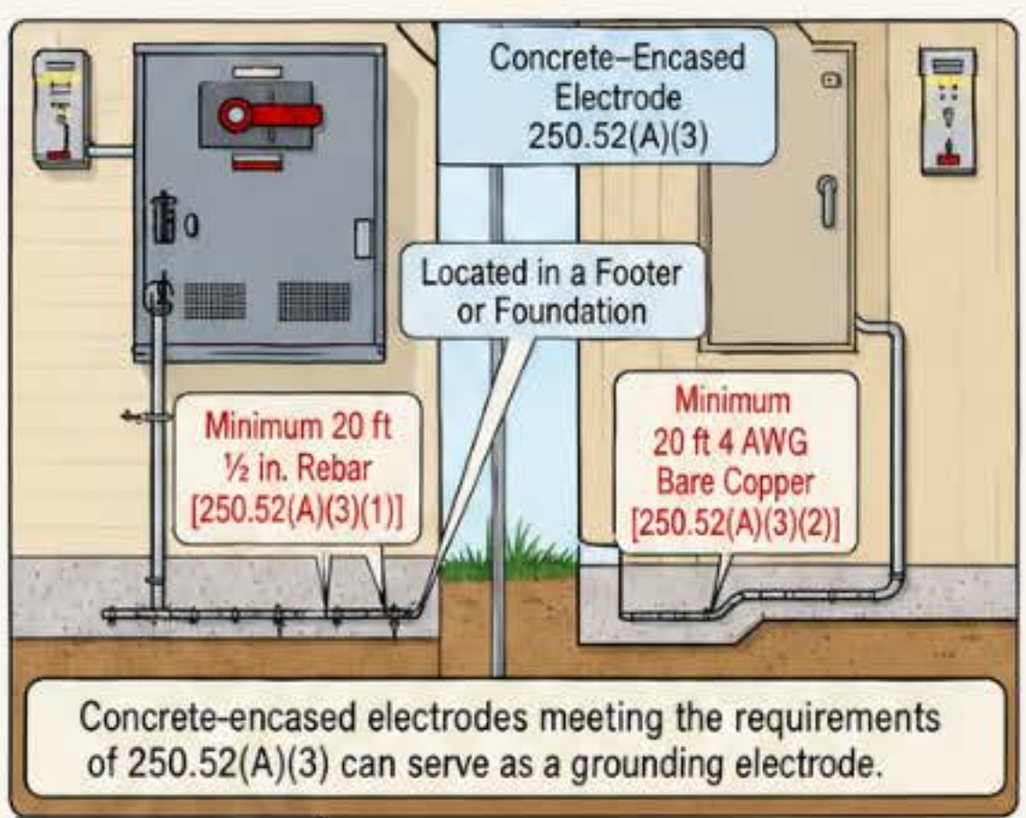
▶ Figure 250–107



▶ Figure 250–110



▶ Figure 250–108

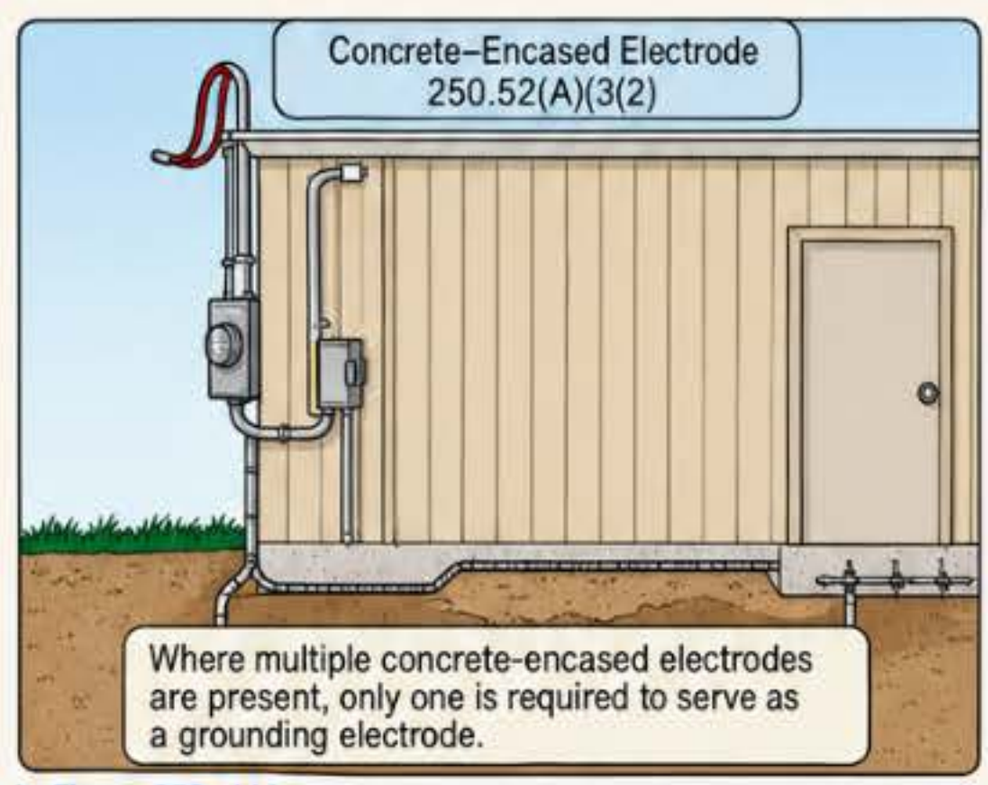


▶ Figure 250–109

(2) A bare copper conductor not smaller than 4 AWG and 20 ft or greater in length can serve as a grounding electrode.

The rebar or bare copper conductor must be encased by at least 2 in. of concrete that is in direct contact with the Earth.

Where multiple concrete-encased electrodes are present at a building, only one is required to serve as a grounding electrode. ▶Figure 250–111



▶ Figure 250–111

Author's Commentary:
Rebar or bare copper placed inside concrete that is in direct contact with the Earth is not insulated. Moisture, vapor barriers, or similar materials should not be used in a way that would prevent the concrete from touching the soil.
— Michael Hamilton

Note: *Rebar in concrete that is not in direct contact with the Earth because of insulation, vapor barriers, or similar items is not considered to be a concrete-encased electrode.* ▶Figure 250–112

DEFINITIONS | From Michael Hamilton Publications

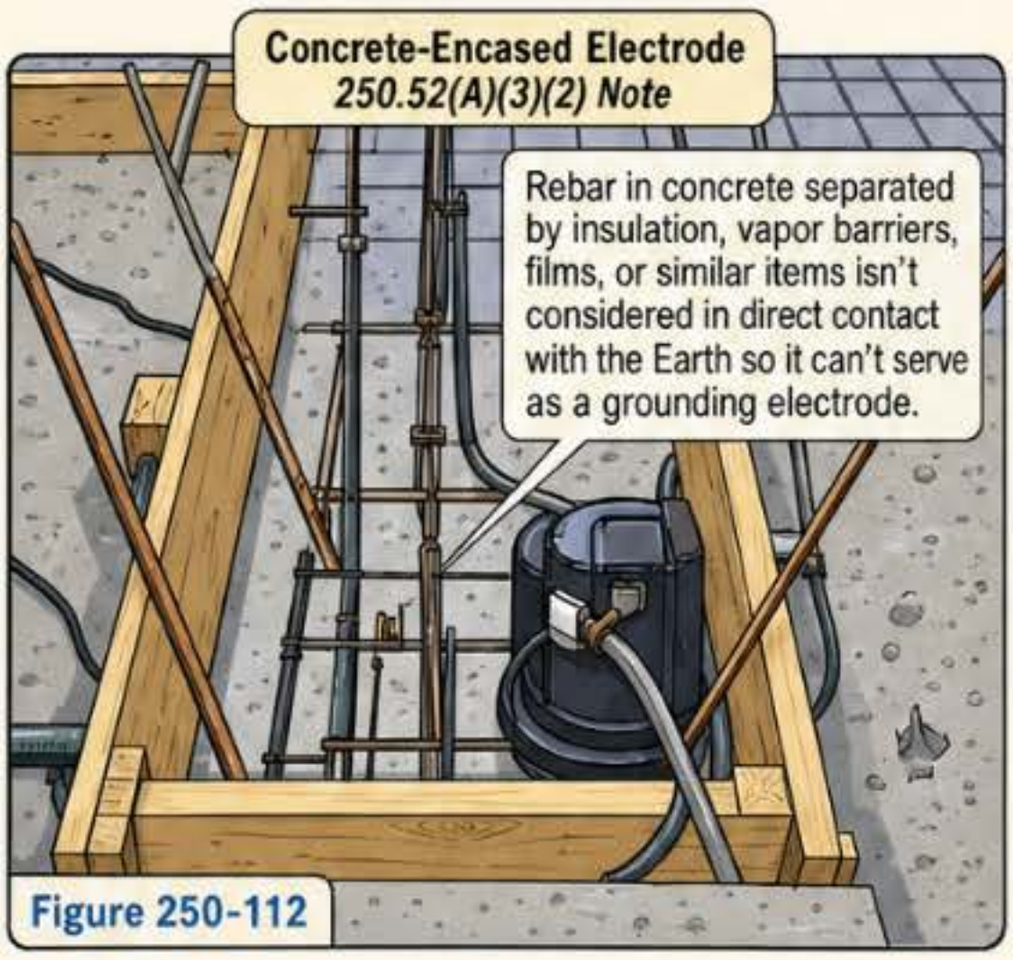


Figure 250-112

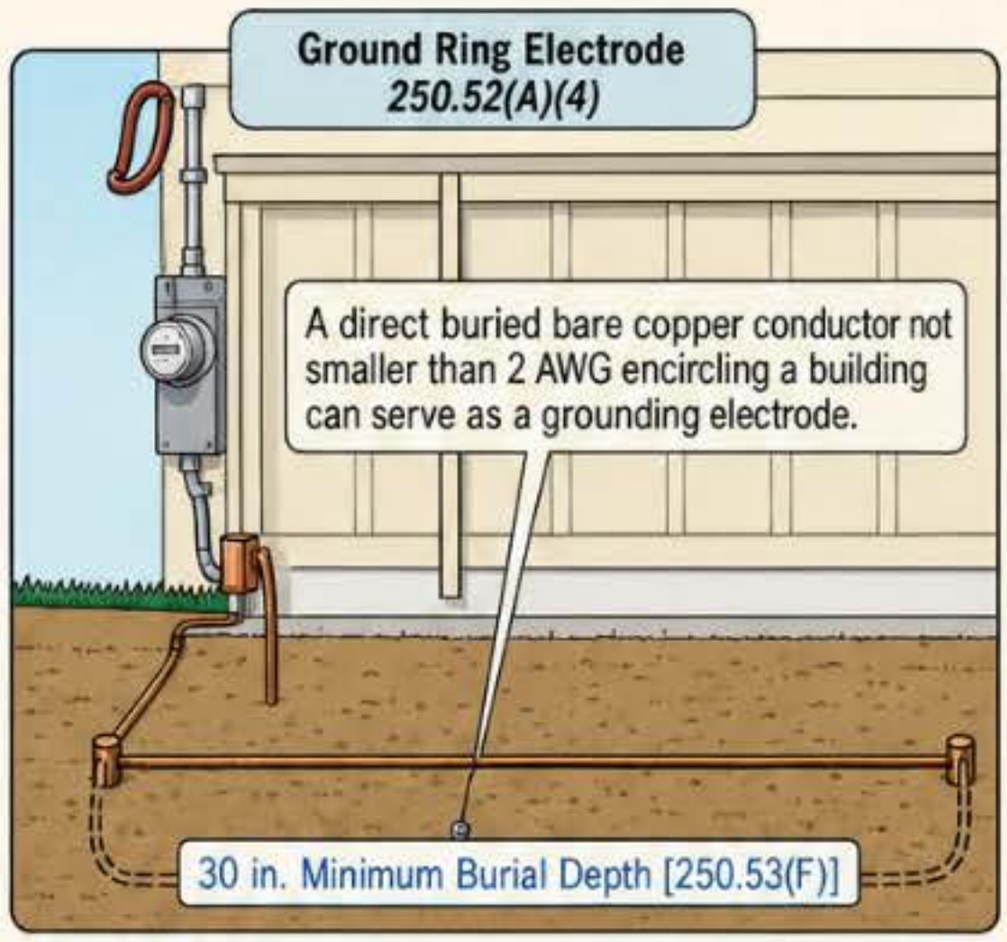


Figure 250-113

Author's Commentary:

- A grounding electrode conductor to a concrete-encased grounding electrode is not required to be larger than 4 AWG copper [250.66(B)].
- A concrete-encased grounding electrode is also called a "Ufer Ground," named after a consultant working for the U.S. Army during World War II. The technique Herbert G. Ufer came up with was necessary because the site needing grounding had no underground water table and little rainfall. The desert site was a series of bomb storage vaults near Flagstaff, Arizona. This type of grounding electrode generally offers the lowest ground resistance for the cost. In fact, Mr. Ufer's method is so effective that no other ground rods are necessary!

— Michael Hamilton

(4) Ground Ring. A direct buried bare copper conductor not smaller than 2 AWG encircling a building can serve as a grounding electrode. ▸ Figure 250-113

Author's Commentary:

- A ground ring encircling a building must not be installed *less than 30 in. below the surface of the Earth* [250.53(F)].

— Michael Hamilton

(5) Ground Rod. Ground rods must have at least 8 ft in length in *contact with the Earth [250.53(A)].*

(b) ***Ground rods*** *must have a diameter of at least ⅝ in., unless listed.* ▸ *Figure 250-114*

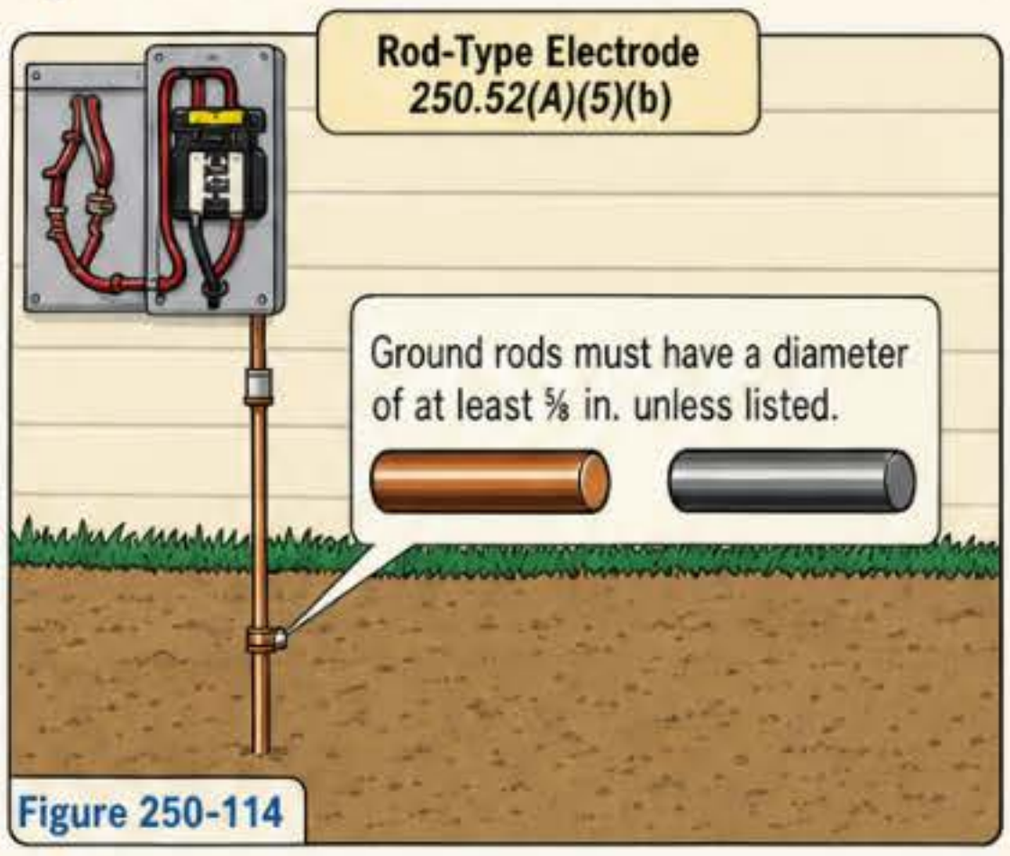


Figure 250-114

Author's Commentary:

- The grounding electrode conductor, if it is the sole connection to the rod(s), is not required to be larger than 6 AWG copper [250.66(A)].
- The diameter of a ground rod has an insignificant effect on the contact resistance of a rod(s) to the Earth. However, *larger diameter rods (¾ in. and 1 in.) are sometimes installed where mechanical strength is desired, or to compensate for the loss of the electrode's metal due to corrosion.*

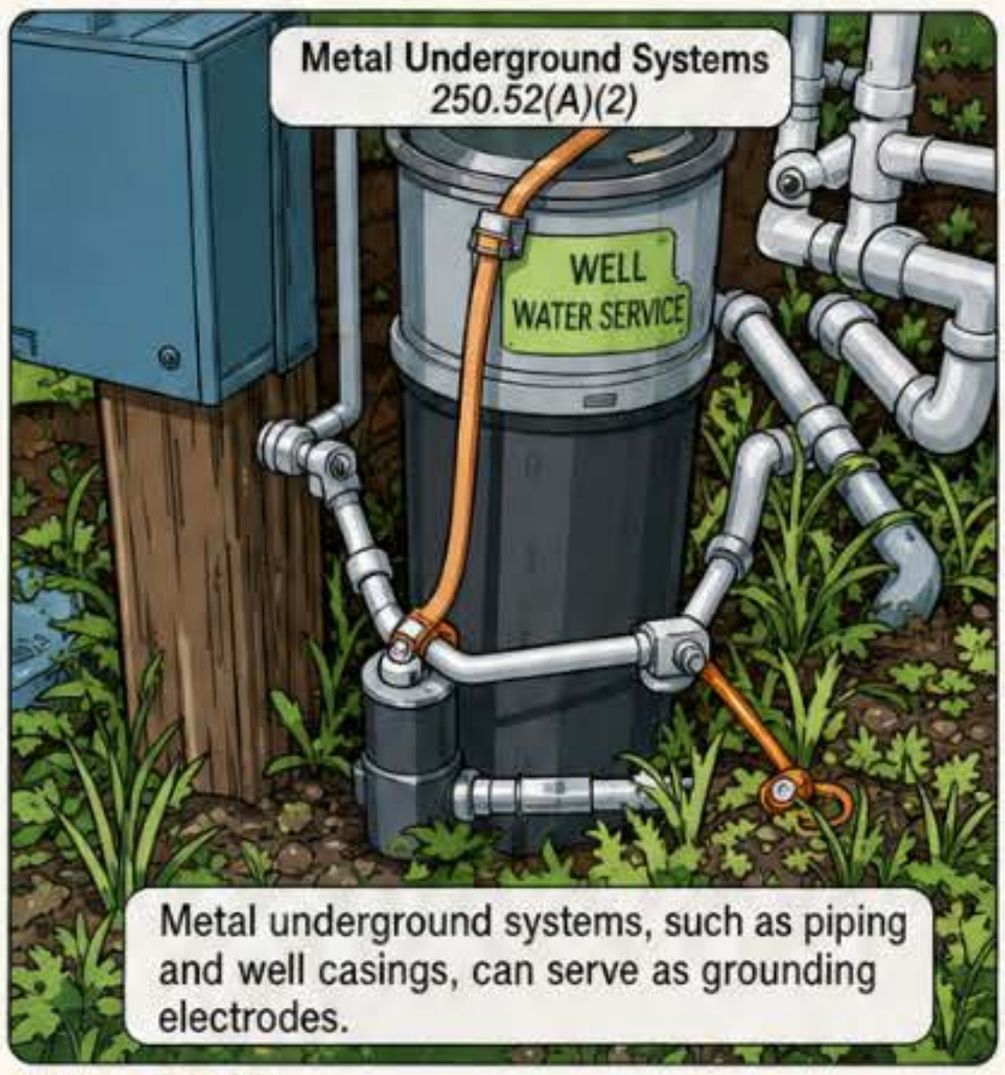
— Michael Hamilton

(6) Listed Electrode. *Other listed grounding electrodes can serve as a grounding electrode.*

250.53 | Grounding and Bonding

(7) Plate Electrode. A bare or electrically conductive coated iron or steel plate at least 1/4 in. thick, or a solid uncoated copper plate not thinner than 0.06 in., with at least 2 sq ft of exposed surface area, can be used as a grounding electrode.

(8) Metal Underground Systems. Metal underground systems, piping, and well casings can function as grounding electrodes. ▶ Figure 250–115



▶ Figure 250–115

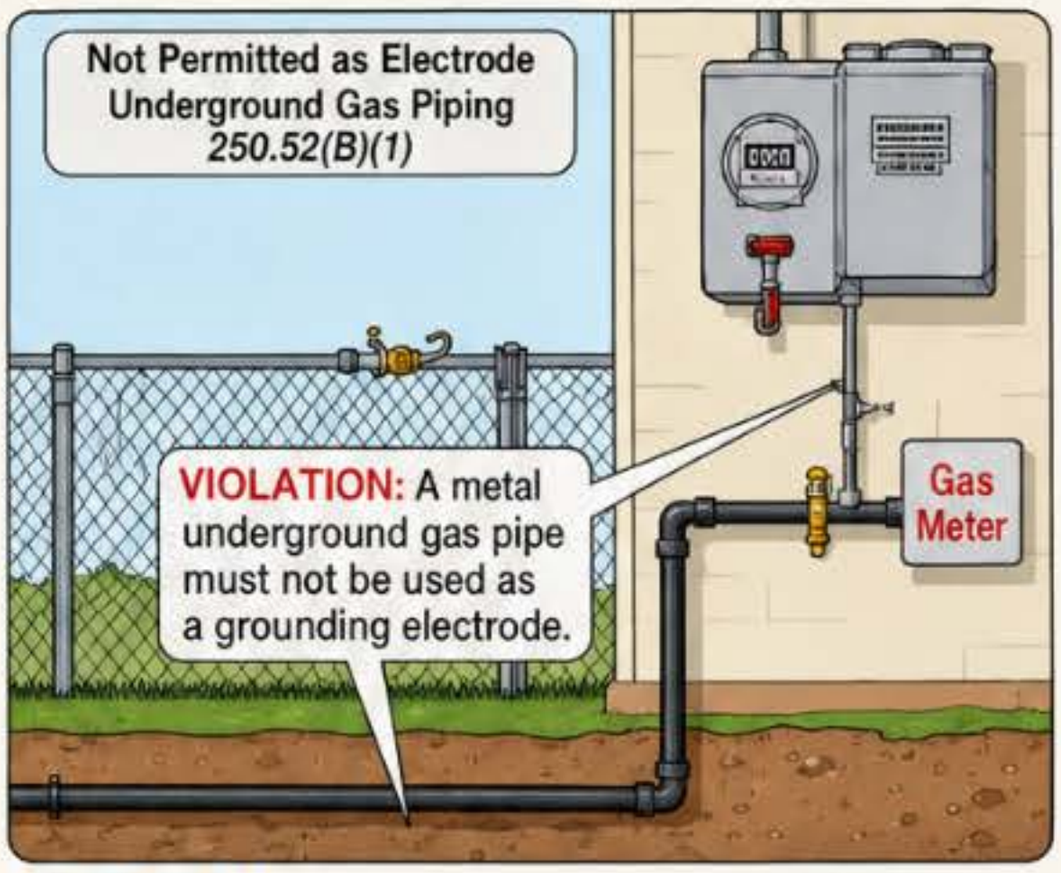
> ***Author's Commentary:***
> *The grounding electrode conductor to the metal underground system must be sized according to Table 250.66, using the area of the largest phase conductor present.*
>
> *— Michael Hamilton*

(B) Not Permitted for Use as a Grounding Electrode.

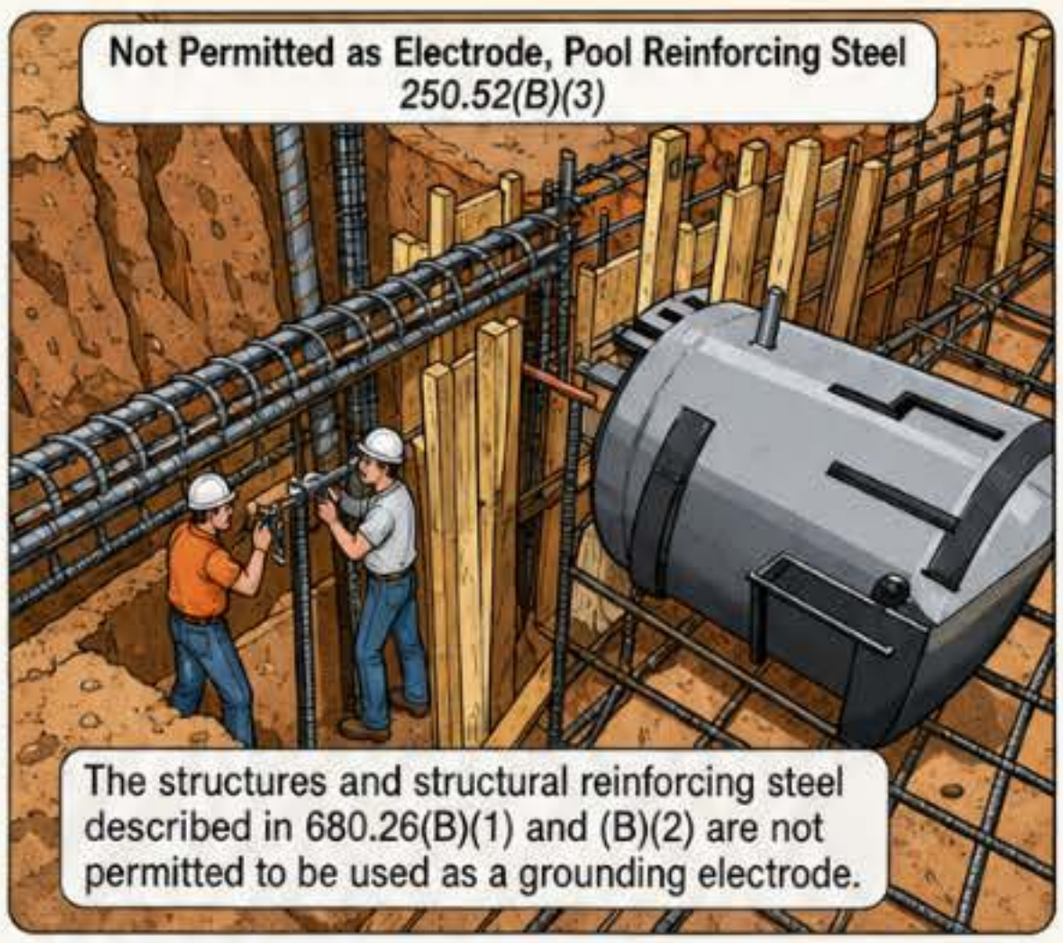
(1) Underground metal gas piping systems are not allowed to be used as grounding electrodes. ▶ Figure 250–116

(2) Aluminum is not permitted to be used as a grounding electrode.

(3) The structures and structural reinforcing steel described in 680.26(B)(1) and (B)(2) cannot be used as grounding electrodes. ▶ Figure 250–117



▶ Figure 250–116



▶ Figure 250–117

250.53 Grounding Electrode Installation Requirements

(A) Ground Rods.

(1) Below Permanent Moisture Level. If practical, ground rods, pipe, and plate electrodes must be installed below the permanent moisture level and must be free from nonconductive coatings such as paint or enamel.

(2) Supplemental Electrode. A single ground rod must be supplemented by an additional electrode. This supplemental electrode must be bonded to:
▶ Figure 250–118

Grounding and Bonding | 250.53

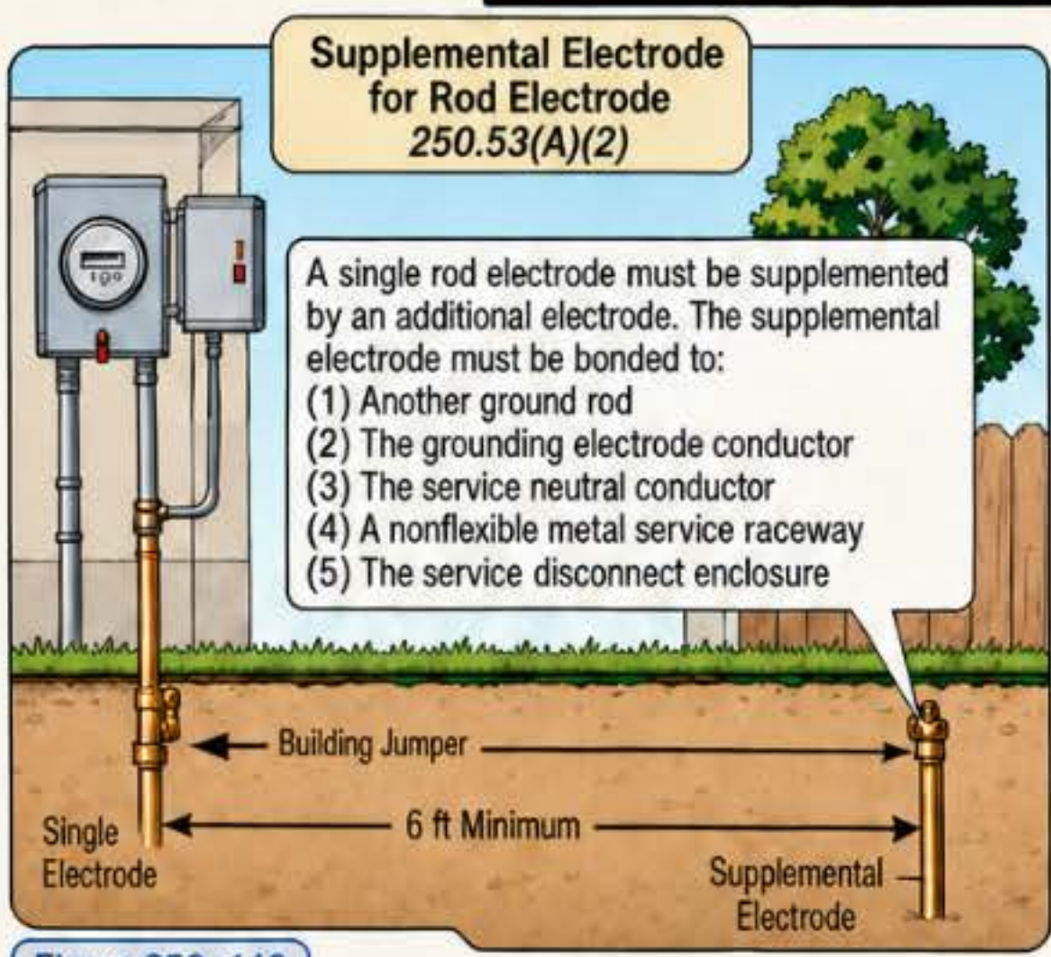


Figure 250–118

① Another ground rod

② The grounding electrode conductor

③ The service neutral conductor

④ A nonflexible metal service raceway

⑤ The service-disconnect enclosure

> ***Author's Commentary:*** *A lone ground rod with a contact resistance to earth of 25 ohms or less does not need a supplemental electrode.*
>
> *— Michael Hamilton*

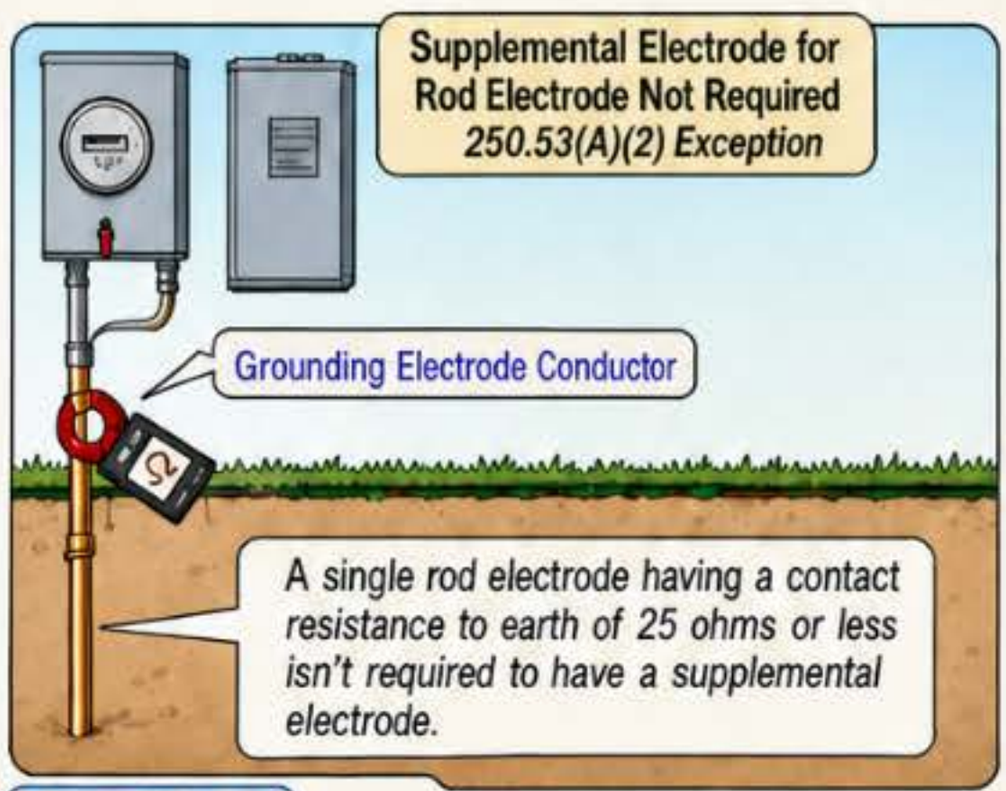


Figure 250–119

(3) Supplemental Ground Rod, Spacing. The supplemental electrode must be installed not less than 6 ft from the ground rod. *Figure 250–120

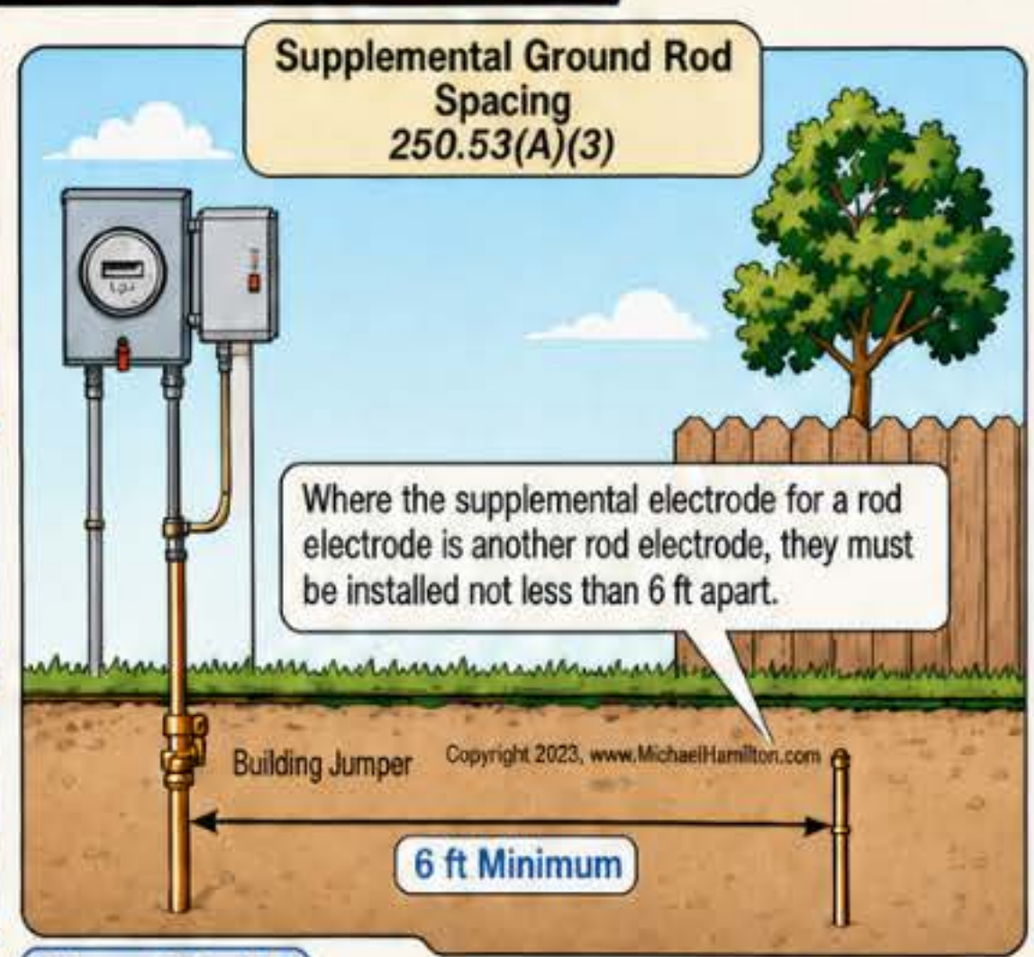


Figure 250–120

(4) Rod and Pipe Electrodes. The electrode must be installed such that at least 8 ft of length is in contact with the soil. It must be driven to a depth of not less than 8 ft except where rock bottom is encountered, the electrode must be driven at an oblique angle not to exceed 45 degrees from the vertical or, where rock bottom is encountered at an angle up to 45 degrees, the electrode is permitted to be buried in a trench that is at least 30 in. deep. *Figure 250–121

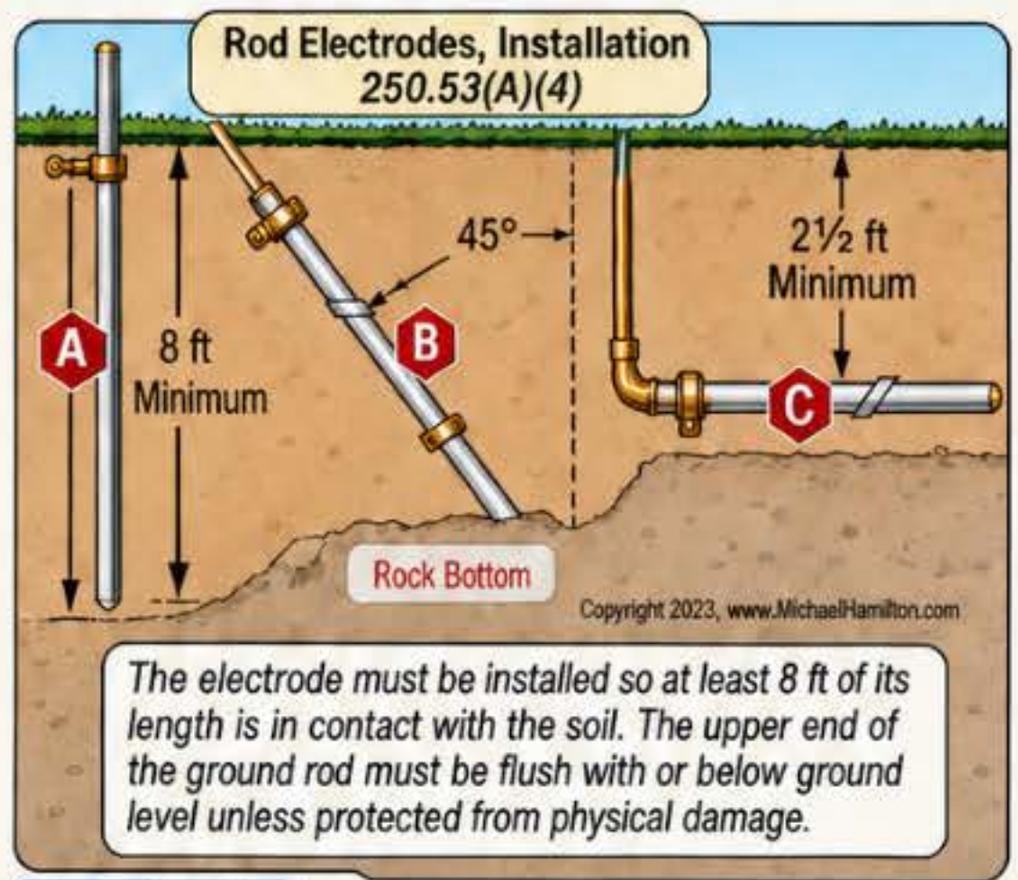
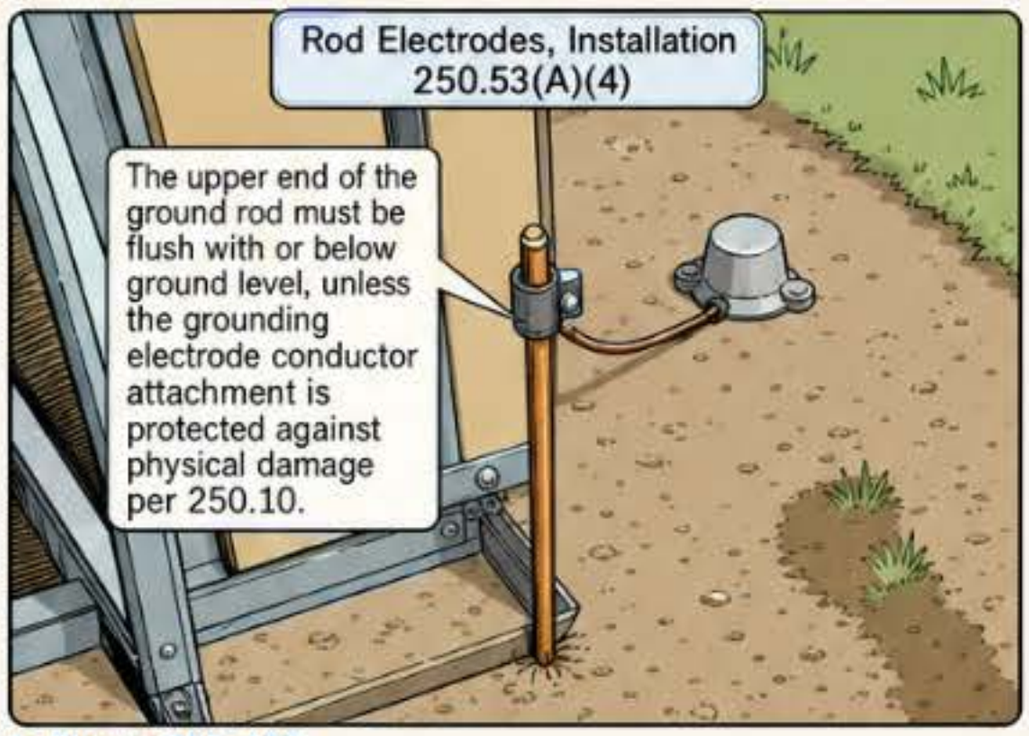


Figure 250–121

The upper end of the ground rod must be flush with or below ground level unless the grounding electrode conductor attachment is protected against physical damage as specified in 250.10. *Figure 250–122



▶ Figure 250–122

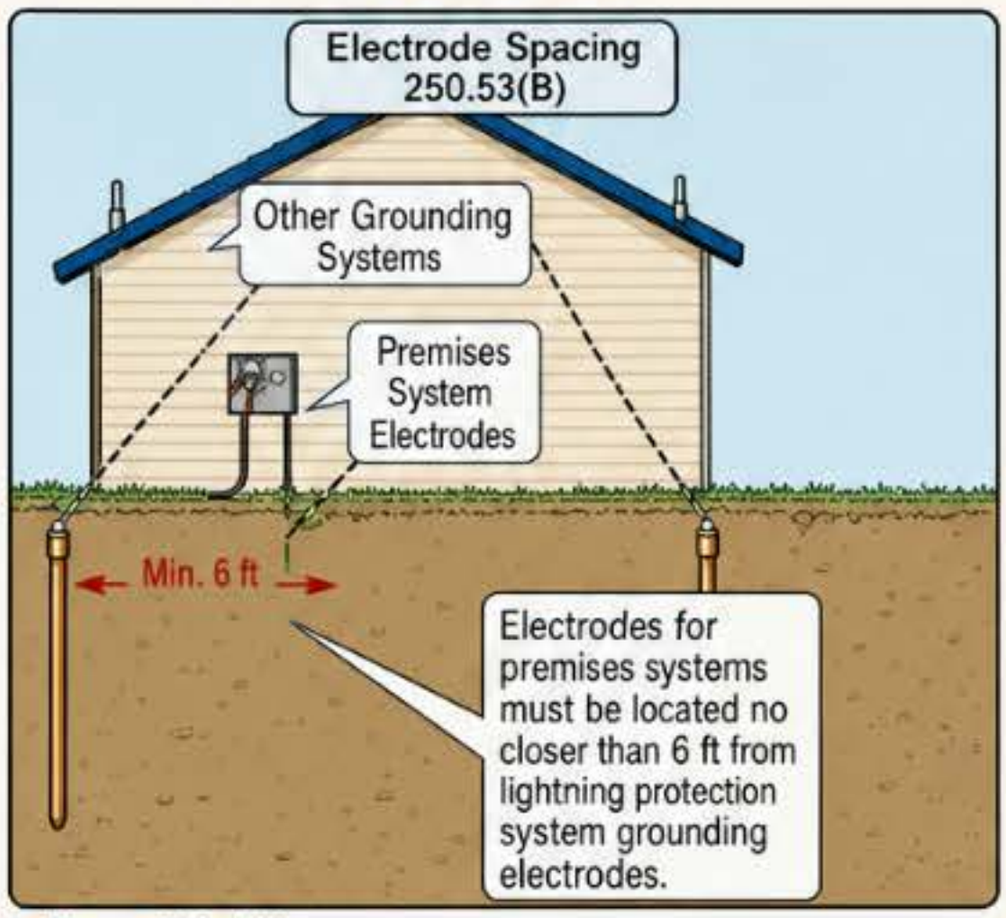
Author's Commentary:

If the grounding electrode attachment is installed underground (below grade), it must be identified for direct burial [250.68(A) Ex. 1 and 250.70].

— Michael Hamilton

(B) Electrode Spacing. Electrodes used for premises systems must be placed no closer than 6 ft from any grounding electrode employed for lightning protection.

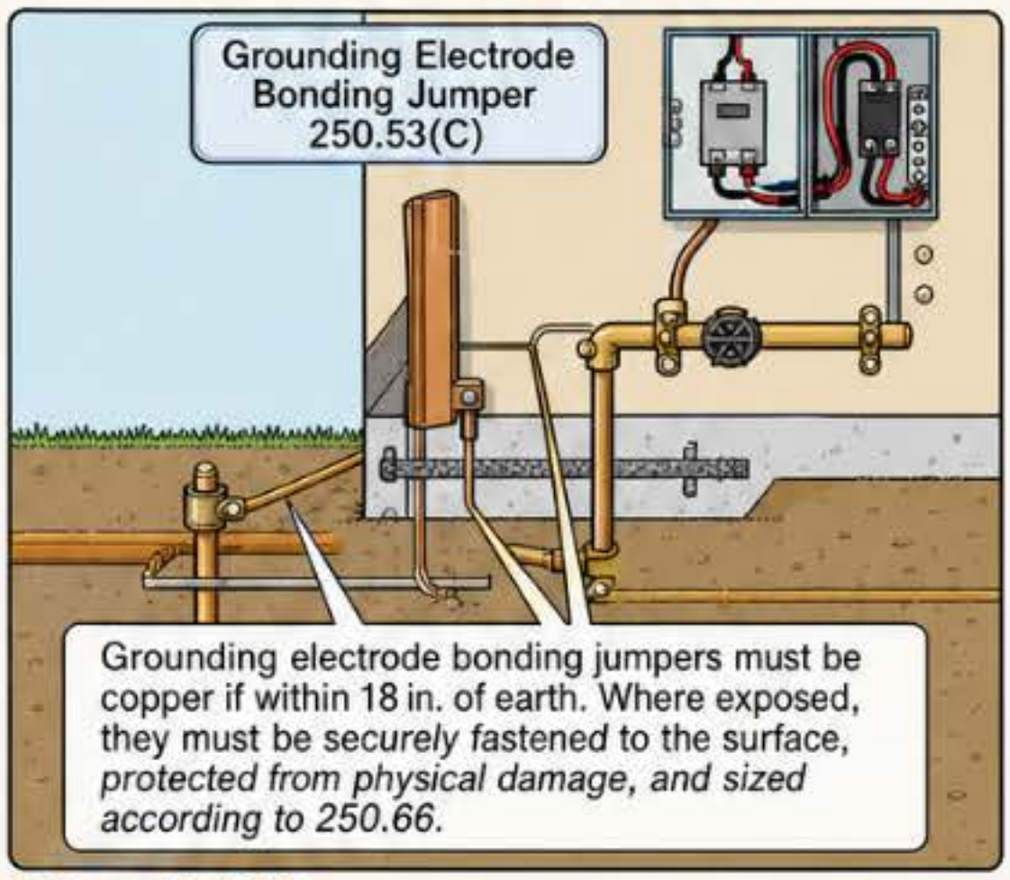
Two or more bonding electrodes that are connected together are considered to form a single grounding electrode system. ▶ Figure 250–123



▶ Figure 250–123

(C) Grounding Electrode Bonding Jumper. Grounding electrode bonding jumpers must be copper conductors when located within 18 in. of the Earth [250.64(A)]. Exposed grounding electrode bonding jumpers must be securely fastened to the surface and protected from physical damage [250.64(B)].

The bonding jumper to each electrode must be sized in accordance with 250.66, based on the area of the largest phase conductor. ▶ Figure 250–124



▶ Figure 250–124

Author's Commentary:

Grounding electrode bonding jumpers must terminate by any of the following means in accordance with 250.8(A):

- *Listed pressure connectors*
- *Terminal bars*
- *Pressure connectors listed as grounding and bonding equipment*
- *Exothermic welding*
- *Machine screw-type fasteners that engage not less than two threads or are secured with a nut*
- *Thread-forming machine screws that engage not less than two threads in the enclosure*
- *Connections that are part of a listed assembly*
- *Other listed means*

— Michael Hamilton

When the grounding electrode conductor termination is encased in concrete or buried, the termination fittings must be listed for this purpose [250.70].

Rebar is not permitted to be used to interconnect the electrodes of grounding electrode systems [250.70].

(D) Underground Metal Water Pipe Electrode.

(1) Continuity. Continuity of the grounding path or the bonding connection to interior piping must not rely on water meters or filtering devices and similar equipment. ▶ Figure 250–125

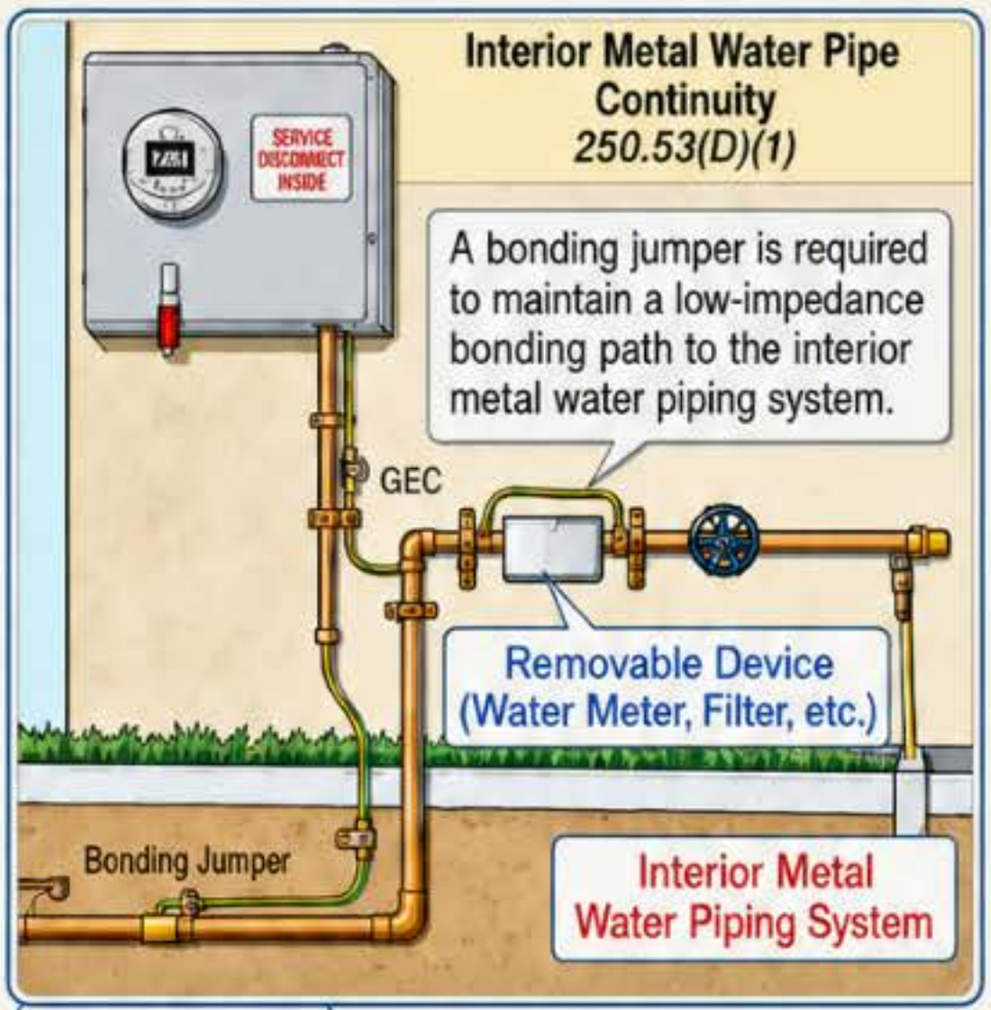


Figure 250–125

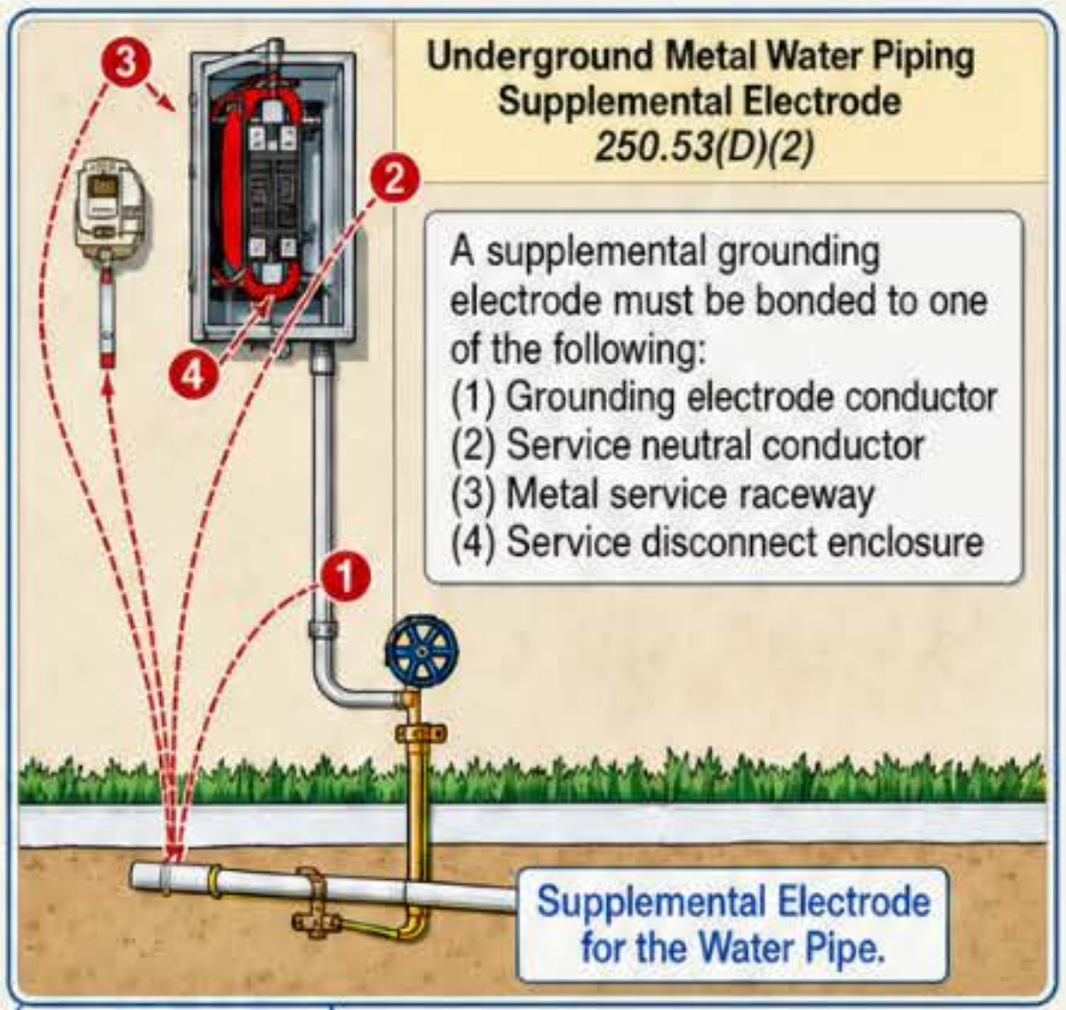


Figure 250–127

(2) Water Pipe Supplemental Electrode. If an underground metal water pipe grounding electrode is present, it must be supplemented by any of the following electrodes:

- Metal frame of the building electrode [250.52(A)(2)]
- Concrete-encased electrode [250.52(A)(3)] ▶ Figure 250–126
- Rod electrode [250.52(A)(5)]
- Other type of listed electrode [250.52(A)(6)]
- Metal underground piping electrode [250.52(A)(8)]

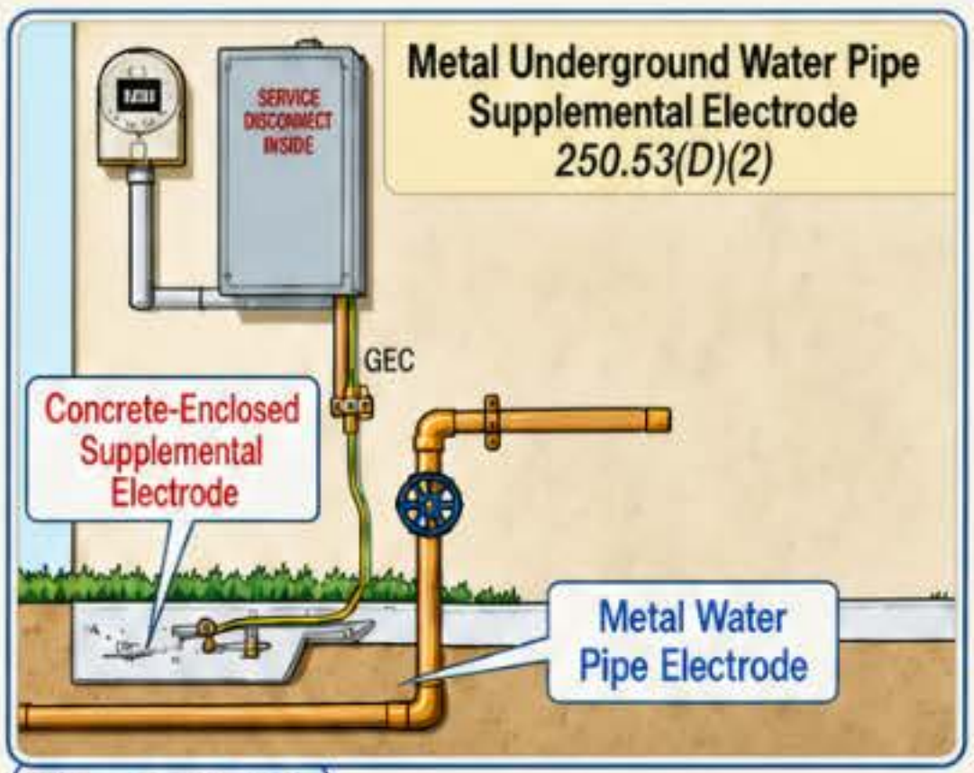


Figure 250–126

The grounding electrode conductor for the supplemental electrode must terminate to any of the following: ▶ *Figure 250–127*

(1) Grounding electrode conductor

(2) Service neutral conductor

(3) Metal service raceway

(4) Service-disconnect enclosure

Author's Commentary:

Whenever a metal underground waterpipe electrode could later be replaced by a plastic water pipe, the supplemental *electrode must be installed as the only electrode for the system.*

— Michael Hamilton

Ex: *The supplemental electrode can be bonded to interior metal water piping located not more than 5 ft from the point of entrance to the building [250.68(C)(1)].*

(E) Supplemental Rod Electrode. The grounding electrode conductor to a ground rod that serves as a supplemental *electrode is not required to be larger than 6 AWG copper.*

(F) Ground Ring. *A ground ring encircling a building must be a bare 2 AWG or larger copper conductor installed not less than 30 in. below the surface of the Earth [250.52(A)(4)].* ▶ *Figure 250–128*

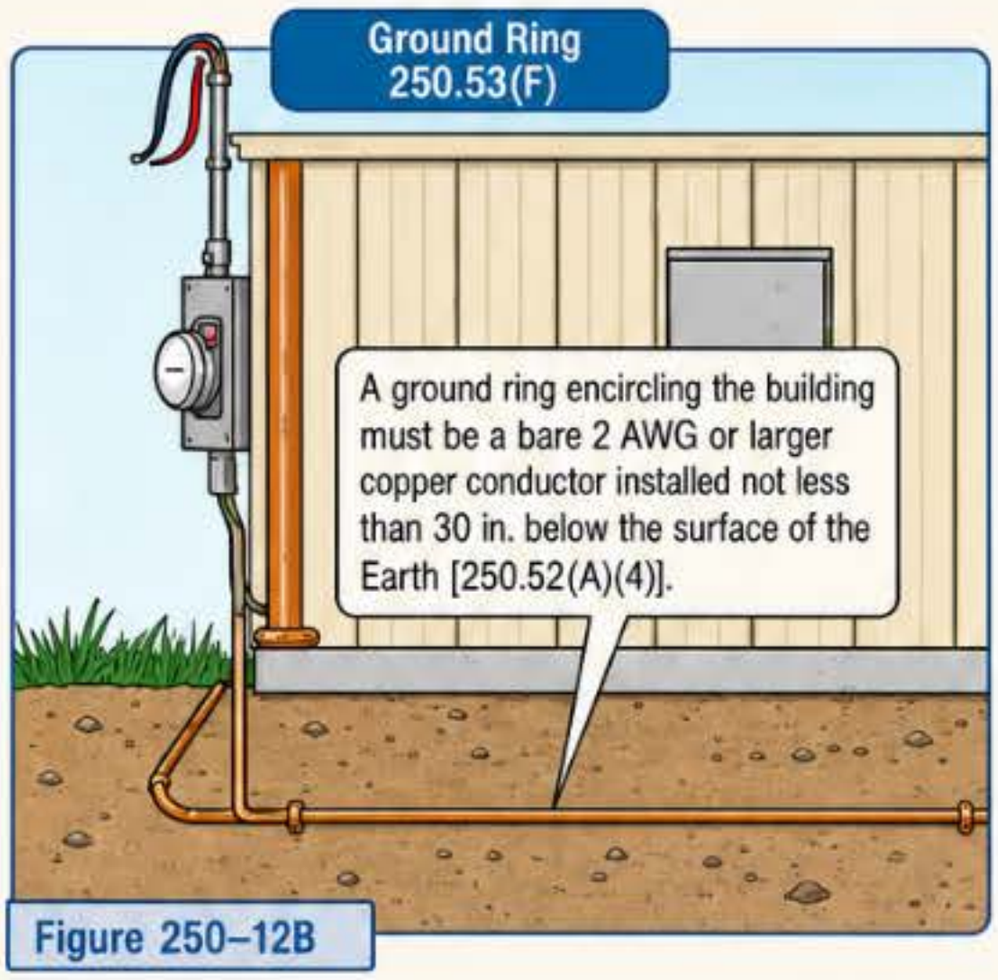


Figure 250–12B

Measuring the Contact Resistance of Electrodes to Earth

A ground resistance clamp meter or a three-point fall-of-potential ground resistance meter can be used to measure the contact resistance of a grounding electrode to the Earth.

Ground Clamp Meter. The ground resistance clamp meter measures the contact resistance of the grounding electrode system to the Earth by injecting a high-frequency signal via the service neutral conductor to the serving electric utility's grounding system, and then measuring the strength of the return signal through the Earth to the grounding electrode being measured. Figure 250–129

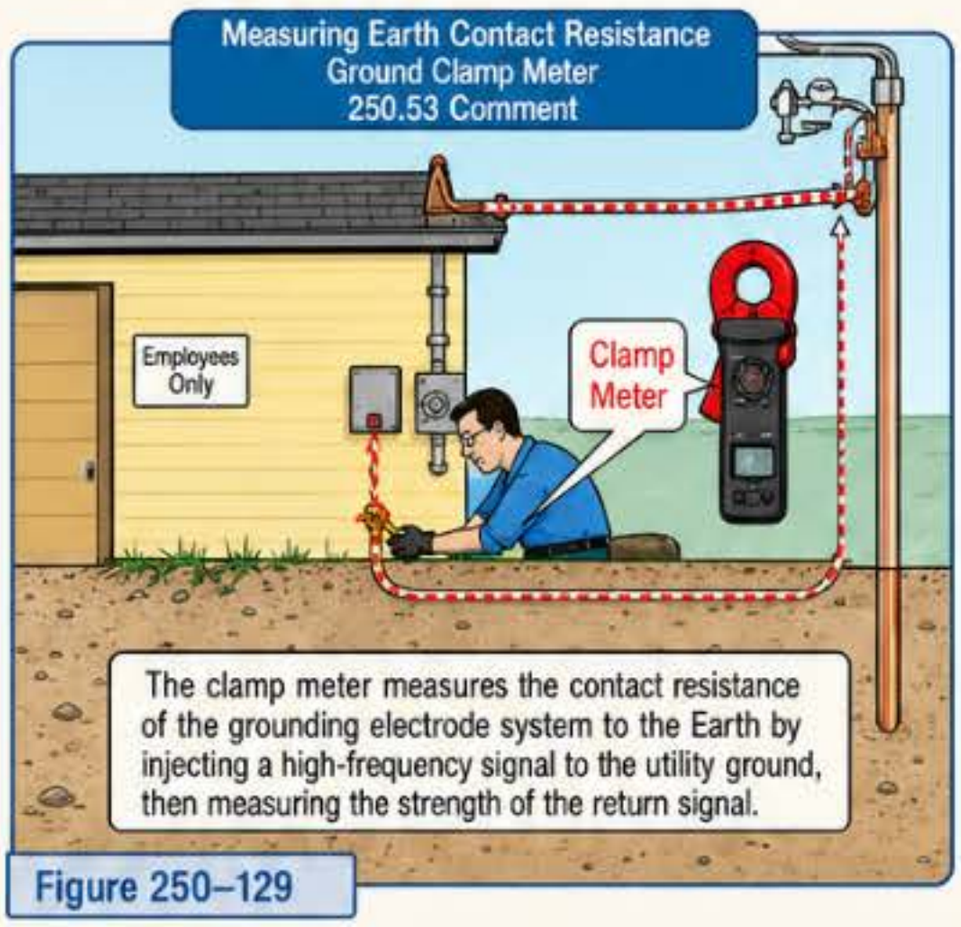


Figure 250–129

Fall-of-Potential Ground Resistance Meter. The three-point fall-of-potential ground resistance meter determines the contact resistance of a single grounding electrode to the Earth by using Ohm's Law where **Resistance = Voltage/Current.** Figure 250–130

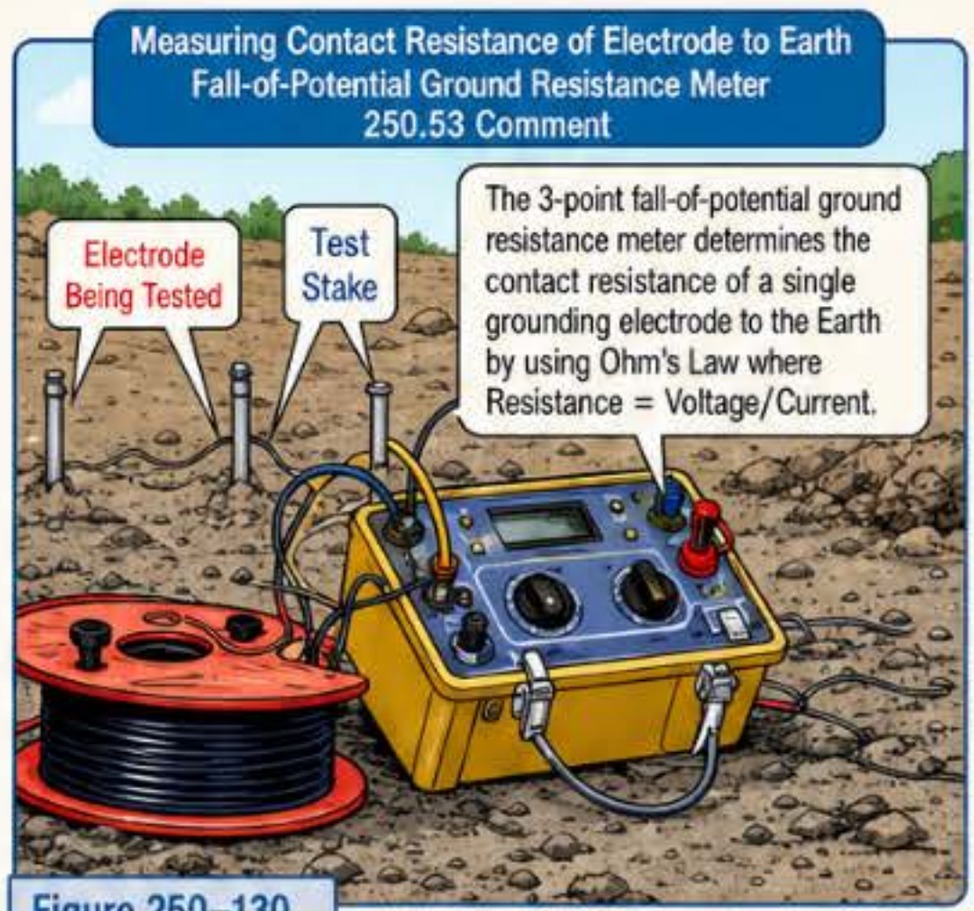


Figure 250–130

This meter divides the voltage difference between the electrode to be measured and a driven voltage test stake (P) by the current flowing between the electrode to be measured and a driven current test stake (C). The test stakes are typically made of ¼ in. diameter steel rods, 24 in. long, driven two-thirds of their length into the Earth.

The distance and alignment between the voltage and current test stakes, and the electrode, is extremely important to the validity of the Earth contact resistance measurements. For an 8-ft rod, the accepted practice is to space the current test stake (C) 80 ft from the electrode to be measured.

The voltage test stake (P) is positioned in a straight line between the electrode to be measured and the current test stake (C). The voltage test stake should be approximately 62 percent of the distance of where the current test stake is located from the electrode. If the current test stake (C) for an 8-ft ground rod is located 80 ft from the grounding electrode, the voltage test stake (P) will be about 50 ft from the electrode to be measured.

Author's Commentary:

Accurate placement of test stakes is critical when using the fall-of-potential method. Poor spacing or misalignment can lead to misleading readings and poor diagnostics.

— Michael Hamilton

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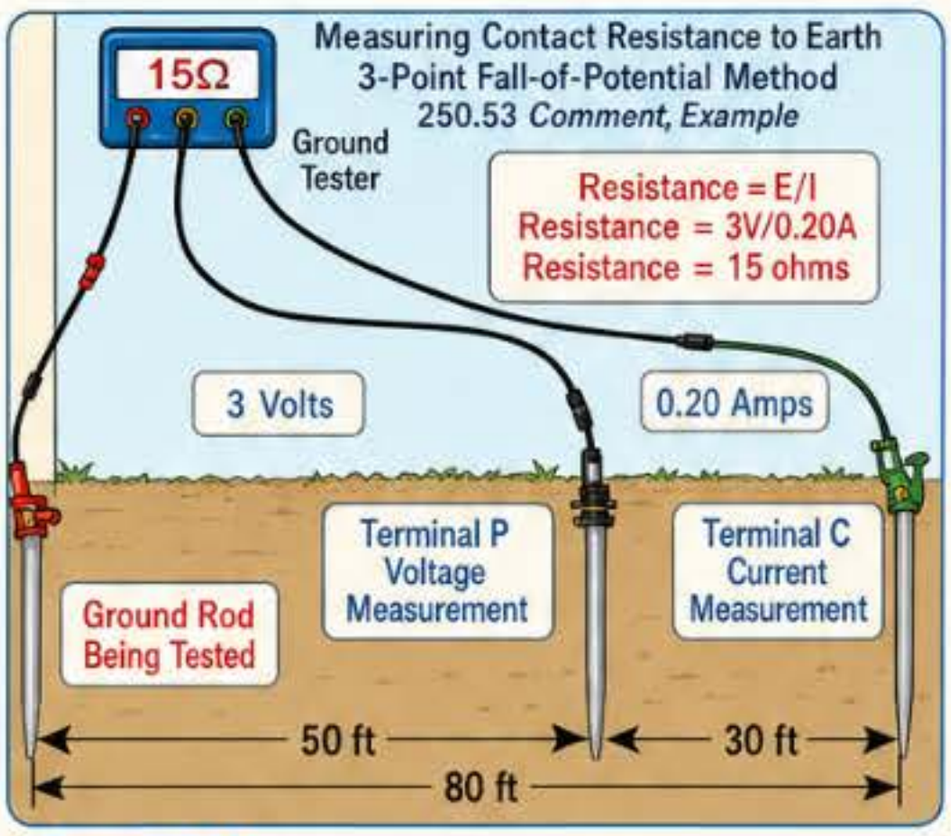
Example

Question: *If the voltage between the ground rod and the voltage test stake (P) is 3V, and the current between the ground rod and the current test stake (C) is 0.20A, what will be the Earth contact resistance of the electrode to the Earth?* Figure 250-131

(a) 3 ohms (b) 5 ohms (c) 10 ohms (d) 15 ohms



▲ Figure 250-131

Solution:

Resistance = Voltage/Current

Voltage = 3V

Current = 0.20A

Resistance = 3V/0.20A

Resistance = 15 ohms

The Earth contact resistance of the electrode to the Earth will be 15 ohms.

Answer: *(d) 15 ohms*

Author's Commentary:

The three-point fall-of-potential meter should only be used to measure the contact resistance of one electrode to the Earth at a time, and that electrode must be independent and not connected to any part of the electrical system. The contact resistance of two electrodes bonded together cannot be measured until they have been separated. The contact resistance of two separate electrodes to the Earth can be thought of as two resistors in parallel if they are outside each other's sphere of influence.

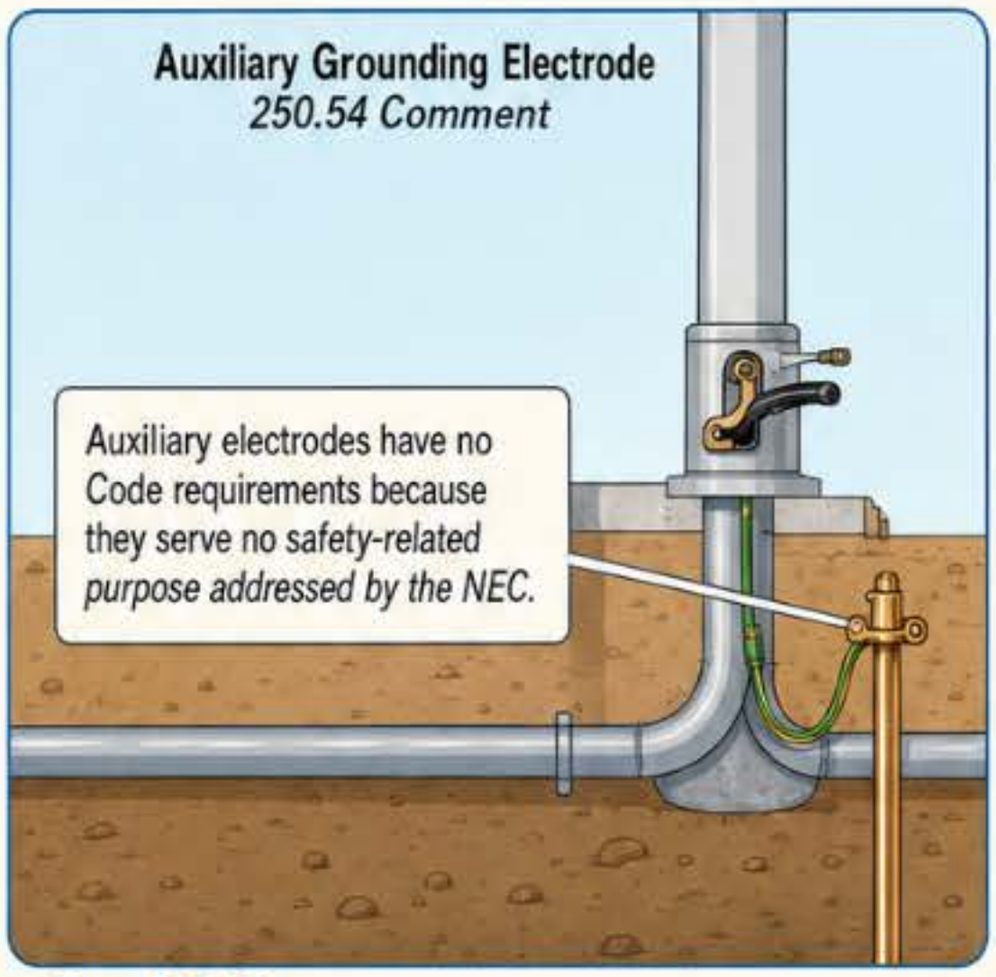
— Michael Hamilton

Soil Resistivity

The contact resistance of an electrode to the Earth is impacted by soil resistivity, which varies throughout the world. Soil resistivity is influenced by electrolytes, which consist of moisture, minerals, and dissolved salts. Because soil resistivity changes with moisture content, the contact resistance of a grounding system to the Earth varies with the seasons.

250.54 Auxiliary Grounding Electrodes

Grounding electrodes that are not required by the NEC are called "auxiliary electrodes" and can be connected to the equipment grounding conductors. Since they serve no purpose related to the electrical safety addressed by the Code, they have no NEC requirements. Figure 250-132



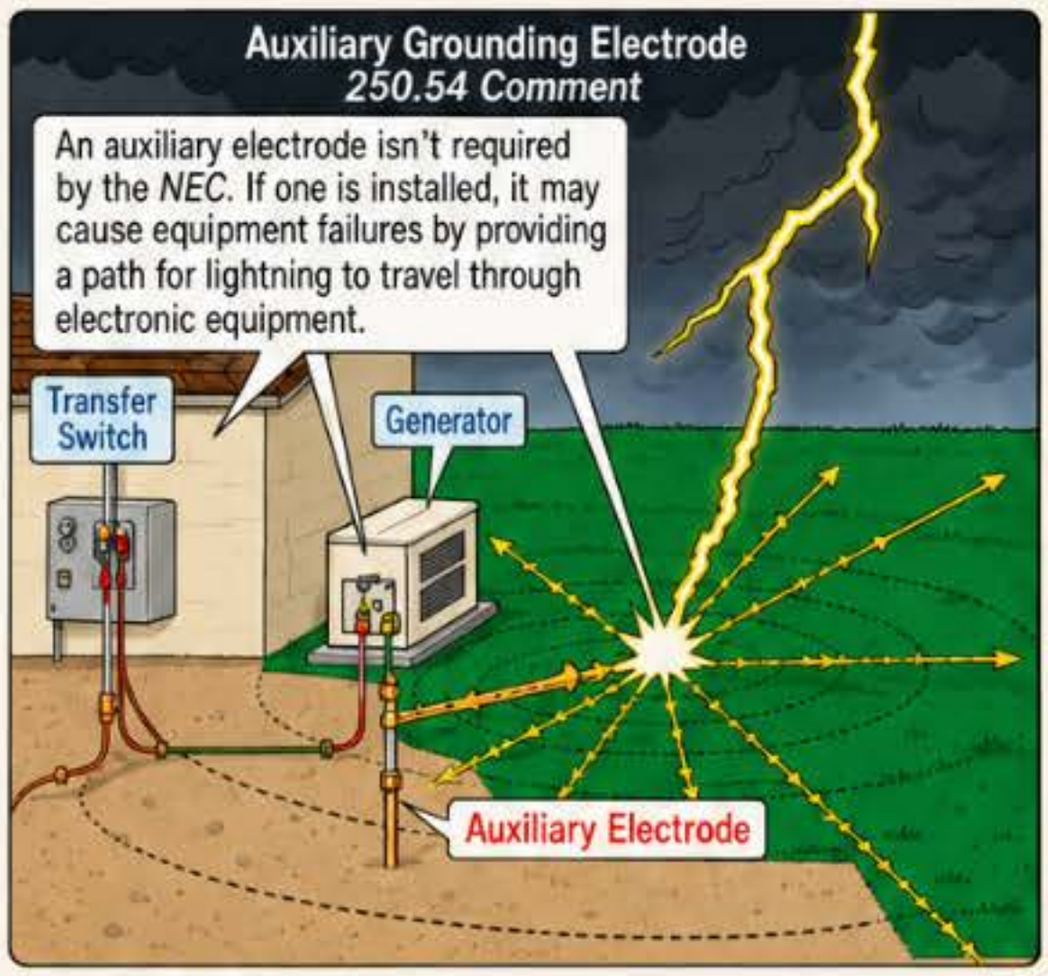
▲ Figure 250-132

If an auxiliary electrode is installed, it is not required to be bonded to the building grounding electrode system, to have the grounding conductor sized to 250.66, nor must it comply with the 25-ohm single ground rod requirement of 250.53(A)(2) Ex.

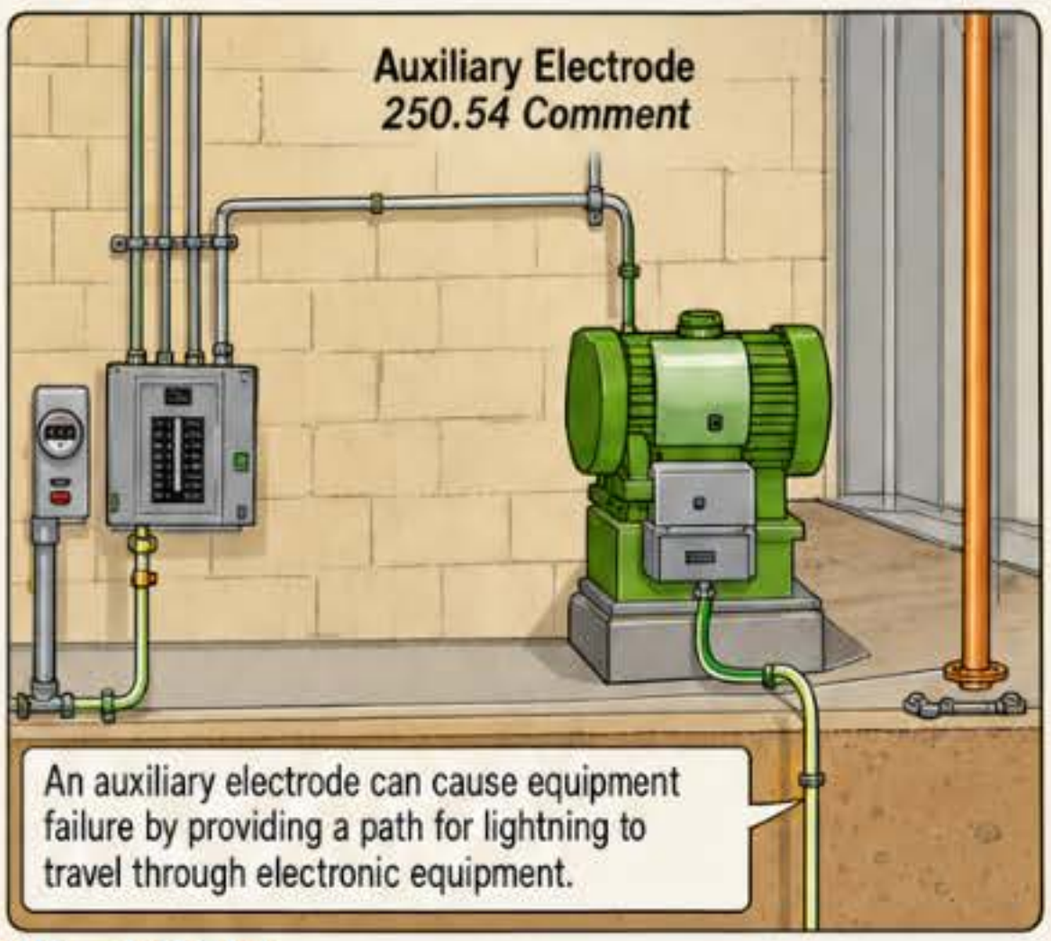
250.58 | Grounding and Bonding

Caution

An auxiliary electrode may cause equipment failures by providing a path for lightning to travel through electronic equipment.
▶Figure 250–133 and ▶Figure 250–134

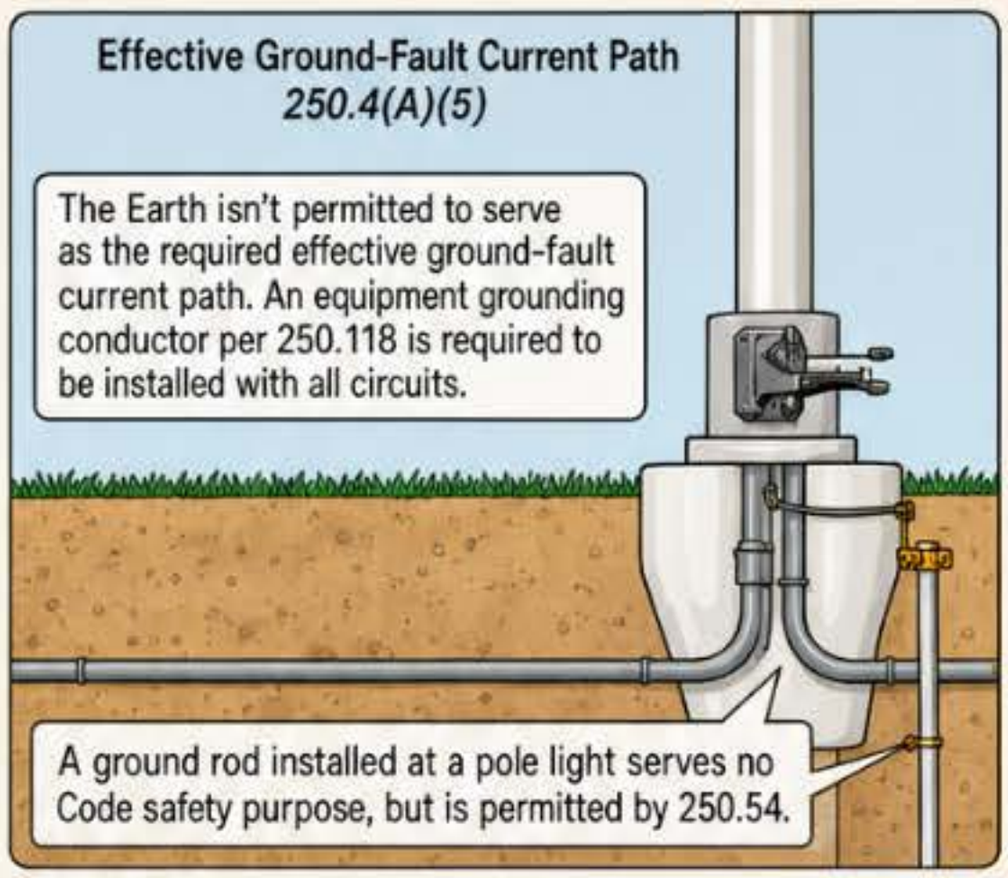


▶Figure 250–133



▶Figure 250–134

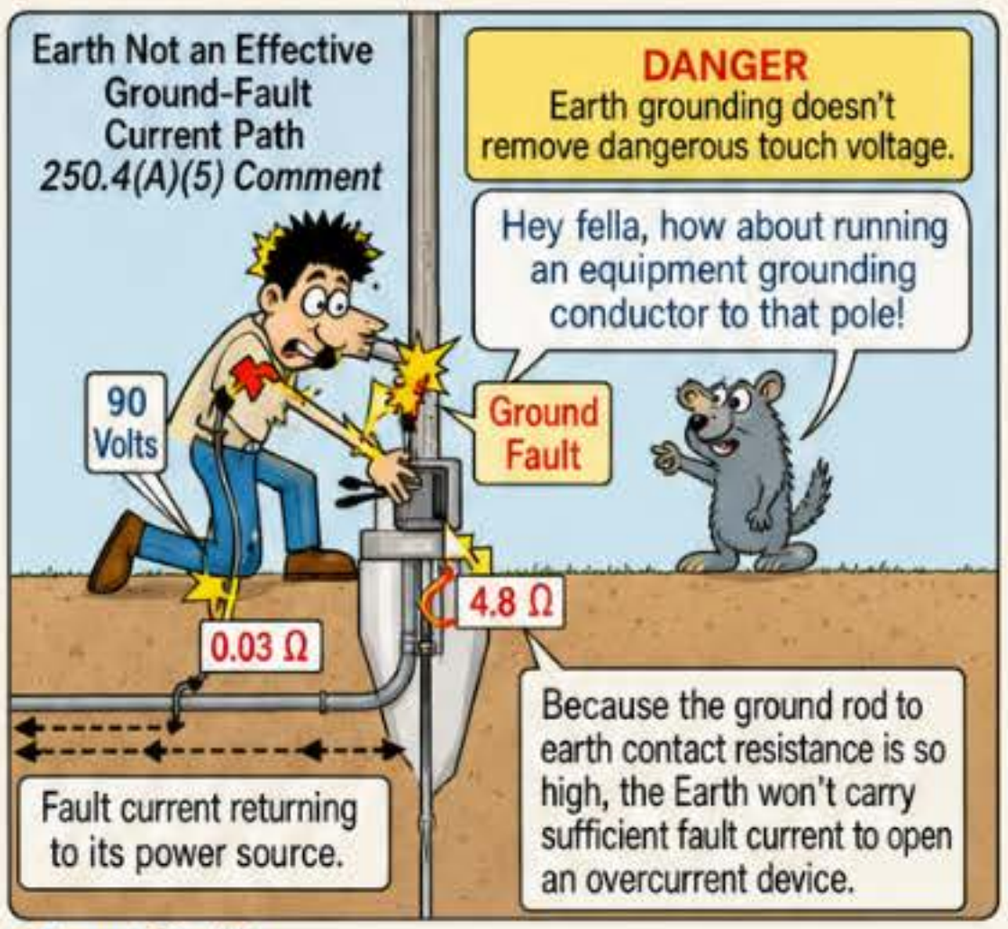
The Earth is not to be considered the effective ground-fault current path specified in 250.4(A)(5). ▶Figure 250–135



▶Figure 250–135

Danger

Because the contact resistance of an electrode to the Earth is so great, very little fault current returns to the power supply if the Earth is the only fault current return path. As a result, the circuit overcurrent protective device will not open and clear the ground fault, and all metal parts associated with the electrical installation, metal piping, and structural building steel will become and remain energized. ▶Figure 250–136



▶Figure 250–136

250.58 Common Grounding Electrode

Where more than one alternating-current system is connected to a grounding electrode at a building, the same grounding electrode must be used for all systems. ▶Figure 250–137

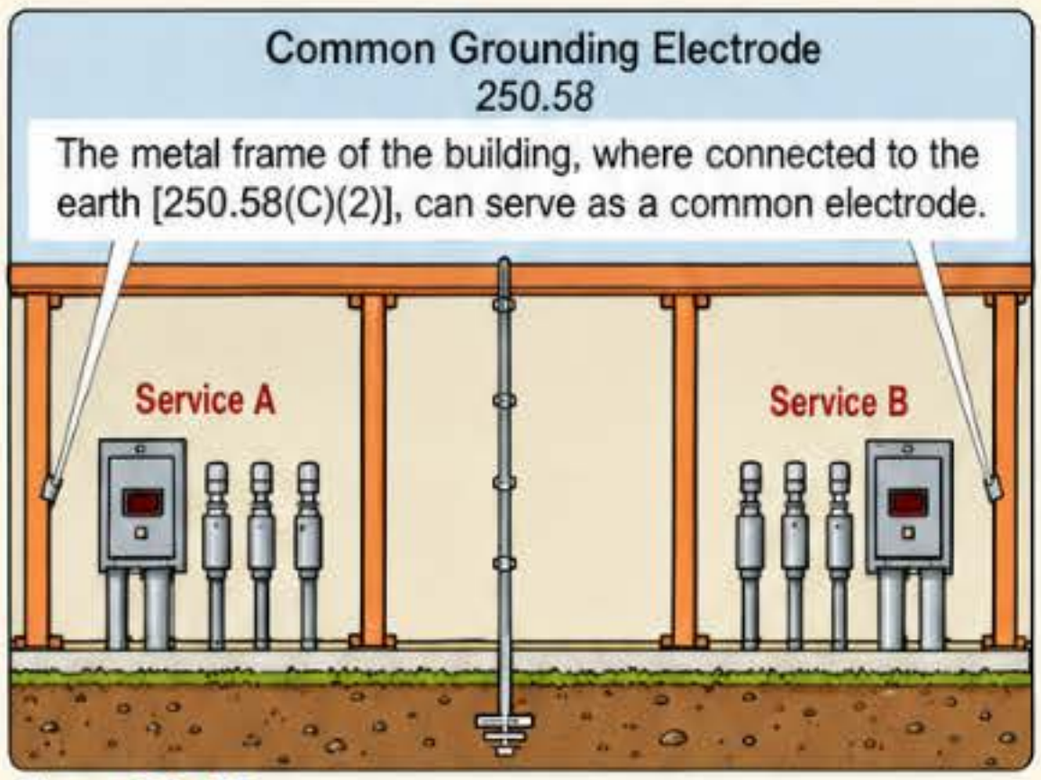


Figure 250-137

Where a building or structure is supplied with multiple services, the same electrode must be used to ground enclosures and equipment in or on that building.

CAUTION

Potentially dangerous objectionable neutral current flows on the metal parts of an electrical system when multiple service disconnects are connected to the same electrode. This is because neutral current from each service can return to the utility via the common grounding electrode and its conductors and is especially a problem if a service neutral conductor is opened. *Figure 250-138*

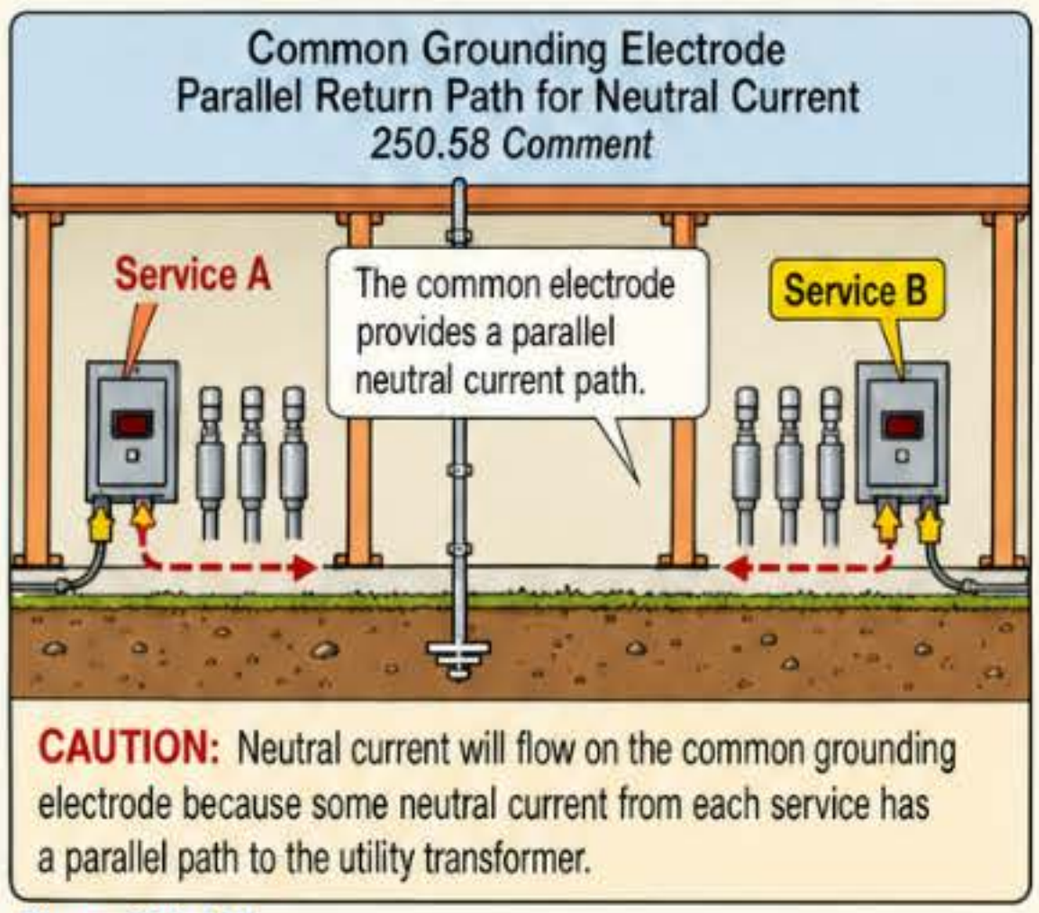


Figure 250-138

Two or more grounding electrodes that are bonded together are considered as a single grounding electrode system.

250.62 Grounding Electrode Conductor

Grounding electrode conductors of the wire type must be copper if within 18 in. of the Earth [250.64(A)]. *Figure 250-139*

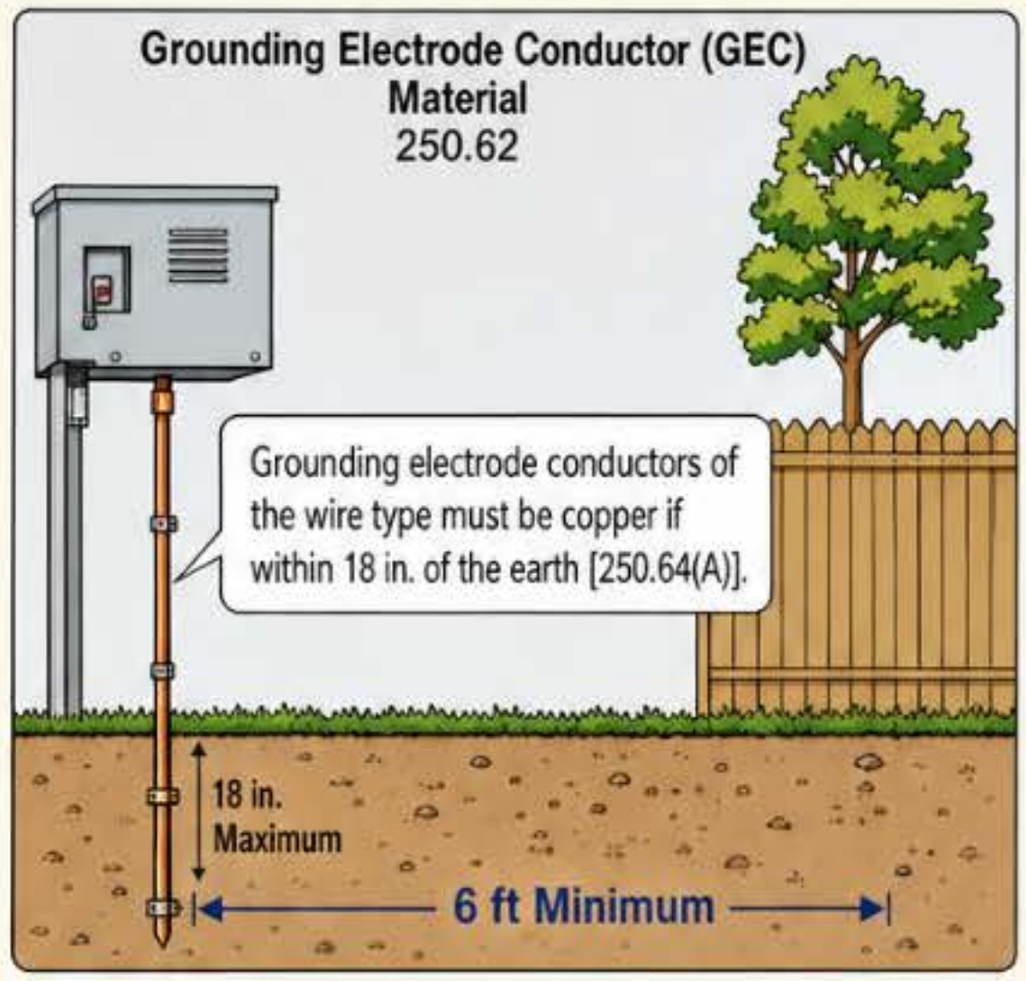


Figure 250-139

250.64 Grounding Electrode Conductor Installation

Grounding electrode conductors must be installed as specified in (A) through (F).

(A) Aluminum Conductors. Bare, covered, or insulated aluminum grounding electrode conductors must comply with the following:

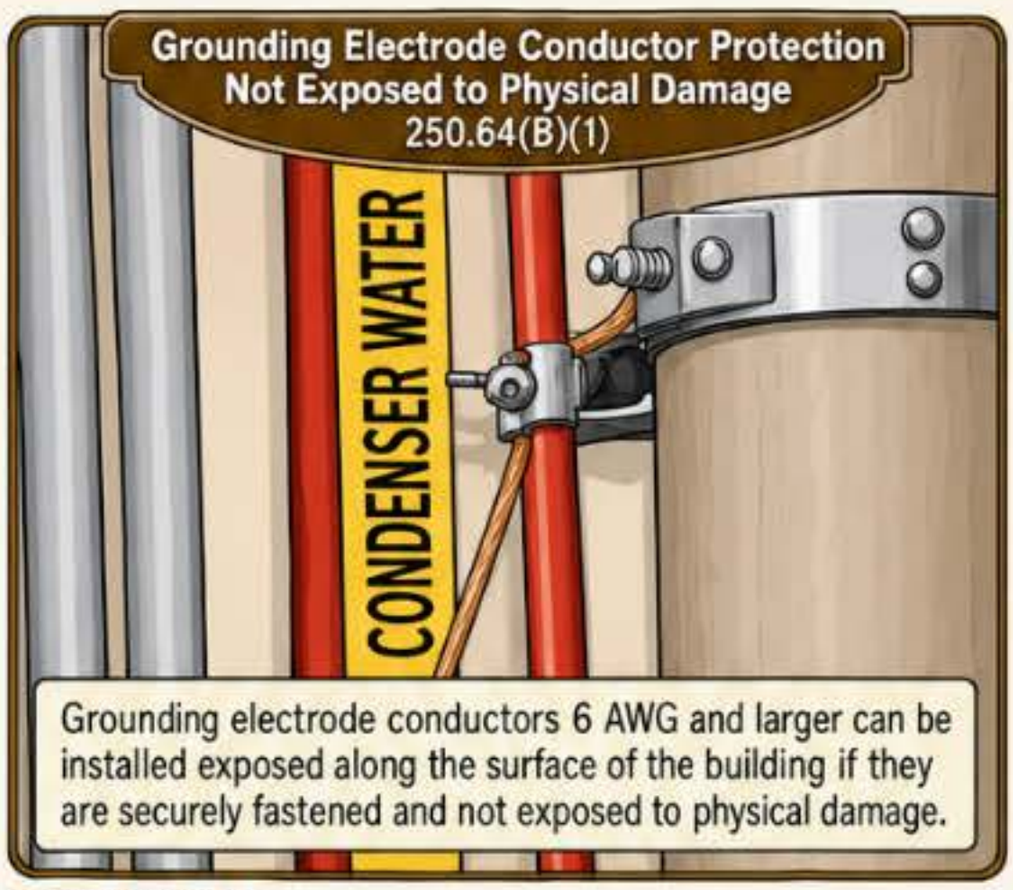
(1) Bare or covered conductors without an extruded polymeric covering are not permitted to be installed where subject to corrosive conditions or to be installed in direct contact with concrete.

(2) Terminations made within listed enclosures identified for outdoor use are permitted within 18 in. of the Earth. If open-bottom enclosures are installed on a concrete pad, the concrete is not considered earth.

(3) Aluminum conductors external to buildings or equipment enclosures are not permitted to be terminated within 18 in. of the Earth.

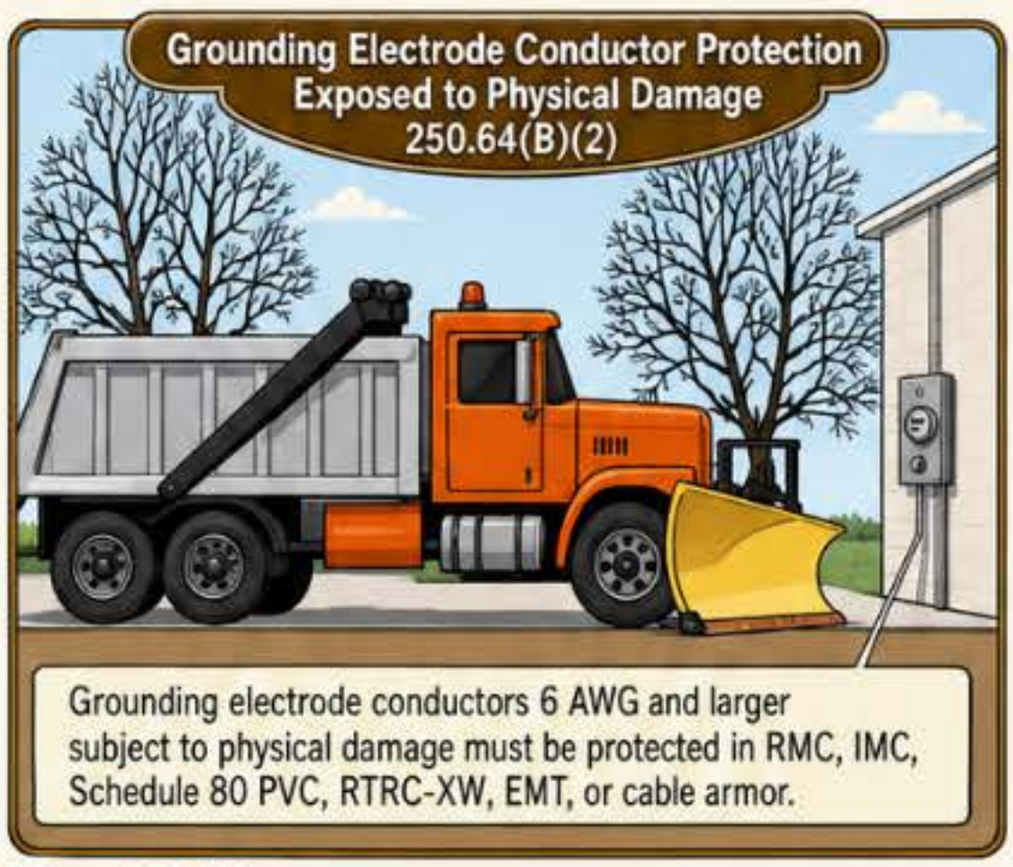
(B) Conductor Protection. Where exposed, a grounding electrode conductor must be securely fastened to the surface on which it is carried.

(1) **Not Exposed to Physical Damage.** Grounding electrode conductors 6 AWG and larger can be installed exposed along the surface of the building if securely fastened and not exposed to physical damage. *Figure 250-140*



▶ Figure 250–140

(2) Exposed to Physical Damage. When they are exposed to physical damage, grounding electrode conductors sized 6 AWG and larger need protection. Acceptable protection methods include rigid metal conduit (RMC), intermediate metal conduit (IMC), Schedule 80 rigid polyvinyl chloride conduit (PVC), rigid reinforced thermosetting resin conduit Type XW (RTRC-XW), electrical metallic tubing (EMT), or cable armor. Figure 250–141



▶ Figure 250–141

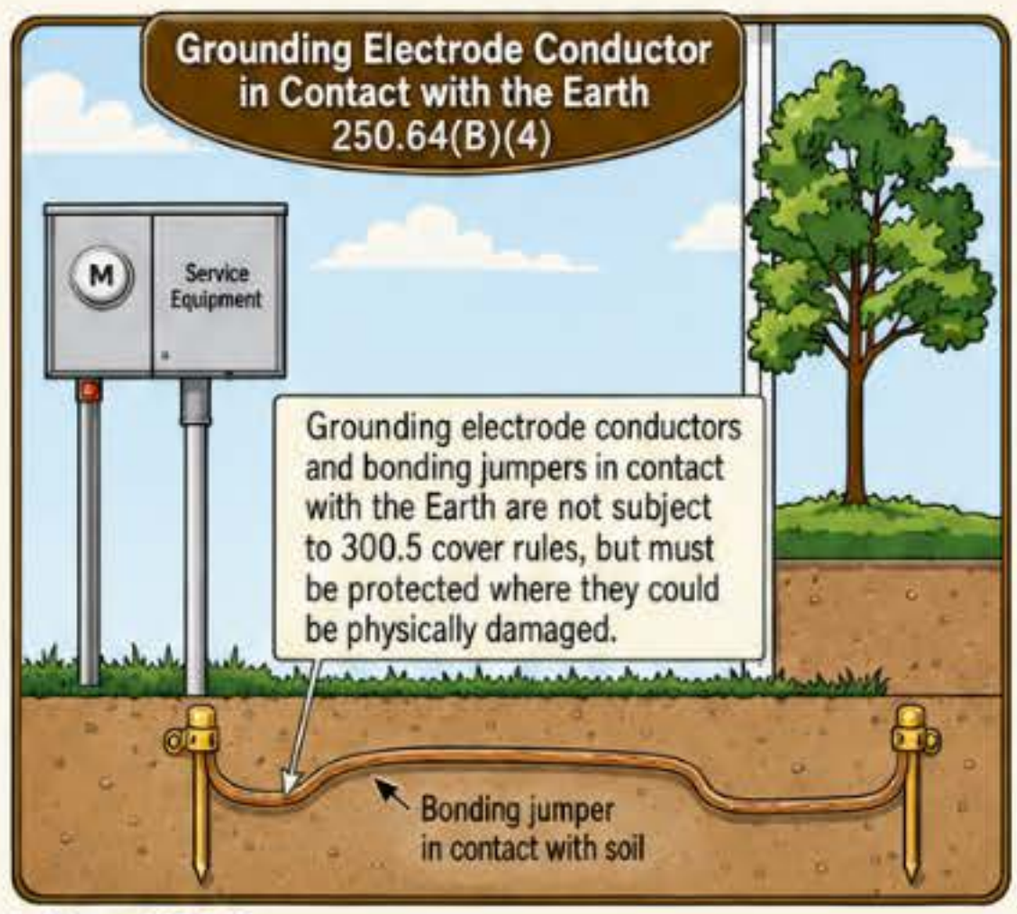
(3) Smaller Than 6 AWG. Grounding electrode conductors smaller than 6 AWG require protection in RMC, IMC, Schedule 80 PVC, RTRC-XW, EMT, or cable armor.

Author's Commentary:

Table 250.66 allows using 8 AWG copper as the grounding electrode conductor for phase conductors typically rated for a 100A service. If the service equipment has a lower rating than 100A, a 6 AWG conductor is uncommon.

— Michael Hamilton

(4) In Contact with the Earth. Grounding electrode conductors and bonding jumpers in direct contact with the Earth do not have to meet the cover requirements of 300.5. Protection is still required anywhere they could be physically damaged. Figure 250–142



▶ Figure 250–142

(C) Continuous. Grounding electrode conductor(s) must be installed without any splices or joints, except for:

(1) Connectors designed for compression or exothermic welding that cannot be removed.

(2) Busbars that are fitted together.

(3) Bolted, riveted, or welded connections of structural metal frameworks or building steel elements.

(4) Threaded, welded, brazed, soldered, or bolted-flange joints used in metal water piping.

(D) Grounding Electrode Conductor for Multiple Building Disconnects. If a building has two or more service disconnects or separate enclosures, the grounding electrode connections must be made by one of these methods:

(1) **Common Grounding Electrode Conductor and Taps.** The ungrounded electrode conductor shared by all services must be sized in accordance with 250.66, using the combined circular mil area of the largest phase conductor supplying the equipment. Figure 250–143

Grounding and Bonding

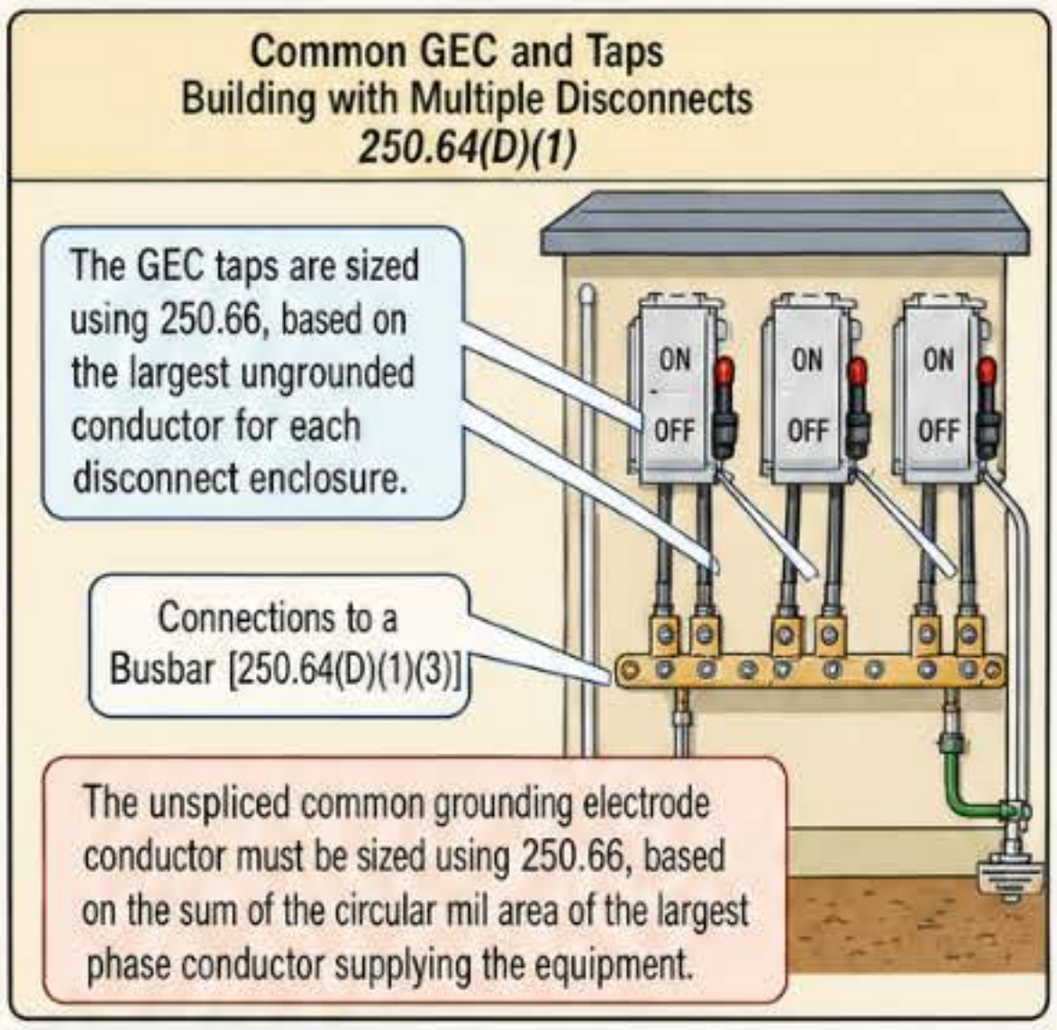


Figure 250–143

A grounding electrode conductor tap must extend from each disconnect and must be sized no smaller than specified in Table 250.66, based on the area of the largest phase conductor.

The grounding electrode conductor tap must be connected to the common grounding electrode conductor by any of the following methods:

(1) Exothermic welding.

(2) Connectors listed as grounding and bonding equipment.

(3) Connections to a busbar of sufficient length and not less than 1/4 in. thick × 2 in. wide that is securely fastened and installed in an accessible location. ▶ Figure 250–144

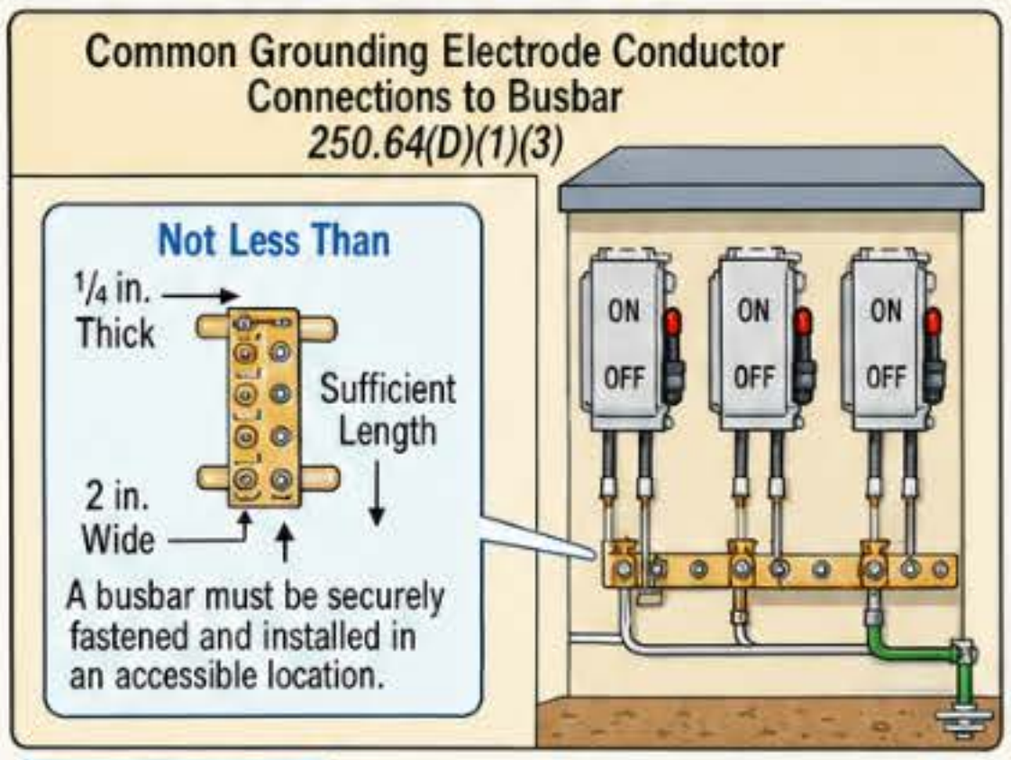


Figure 250–144

(2) Individual Grounding Electrode Conductors. An individual grounding electrode conductor from each disconnect sized in accordance with 250.66, based on the phase conductor(s) supplying the individual disconnect, must connect the grounding electrode system to one of the following:

(1) The service neutral conductor ▶ Figure 250–145

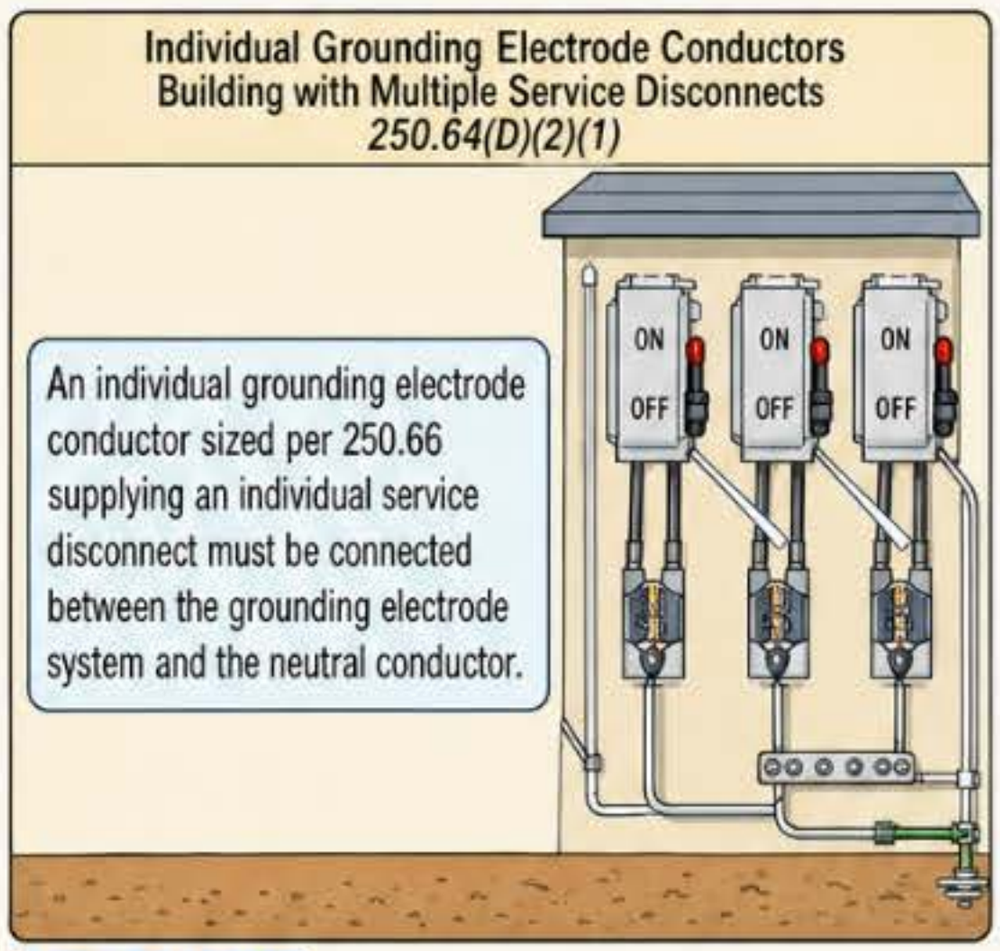


Figure 250–145

(2) The equipment grounding conductor of the feeder circuit

(3) The service supply-side bonding jumper

(3) Supply Side of Disconnects. A grounding electrode conductor from an accessible enclosure on the supply side of the disconnects, sized in accordance with 250.66 and based on the phase conductor(s) supplying the disconnect, must connect the grounding electrode system to one of the following:

(1) The service neutral conductor ▶ Figure 250–146

(2) The equipment grounding conductor of the feeder circuit

(3) The service supply-side bonding jumper

(E) Ferrous Raceways Containing Grounding Electrode Conductors.

(1) General. To prevent inductive choking of grounding electrode conductors, ferrous metal raceways, enclosures, and cable armor containing grounding electrode conductors must have each end of the raceway or enclosure bonded to the grounding electrode conductor. ▶ Figure 250–147

250.64 | Grounding and Bonding

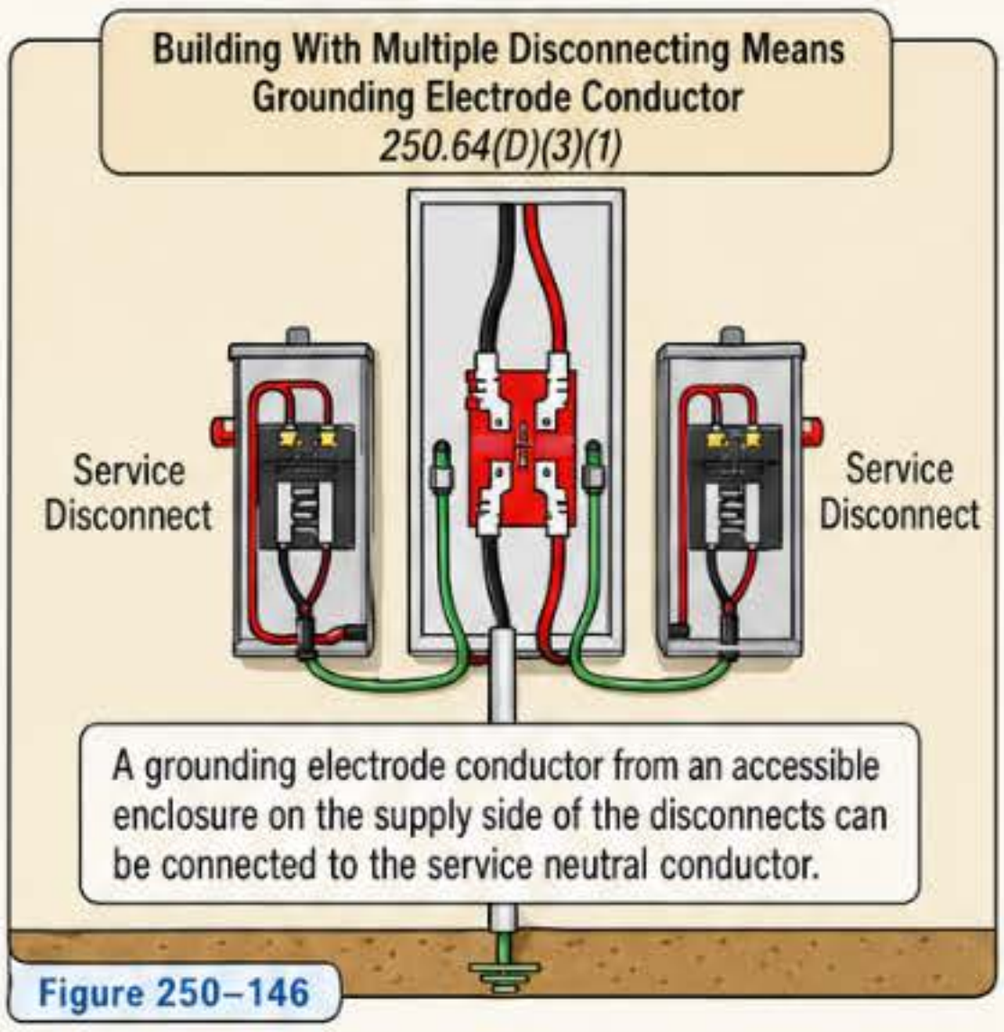


Figure 250–146

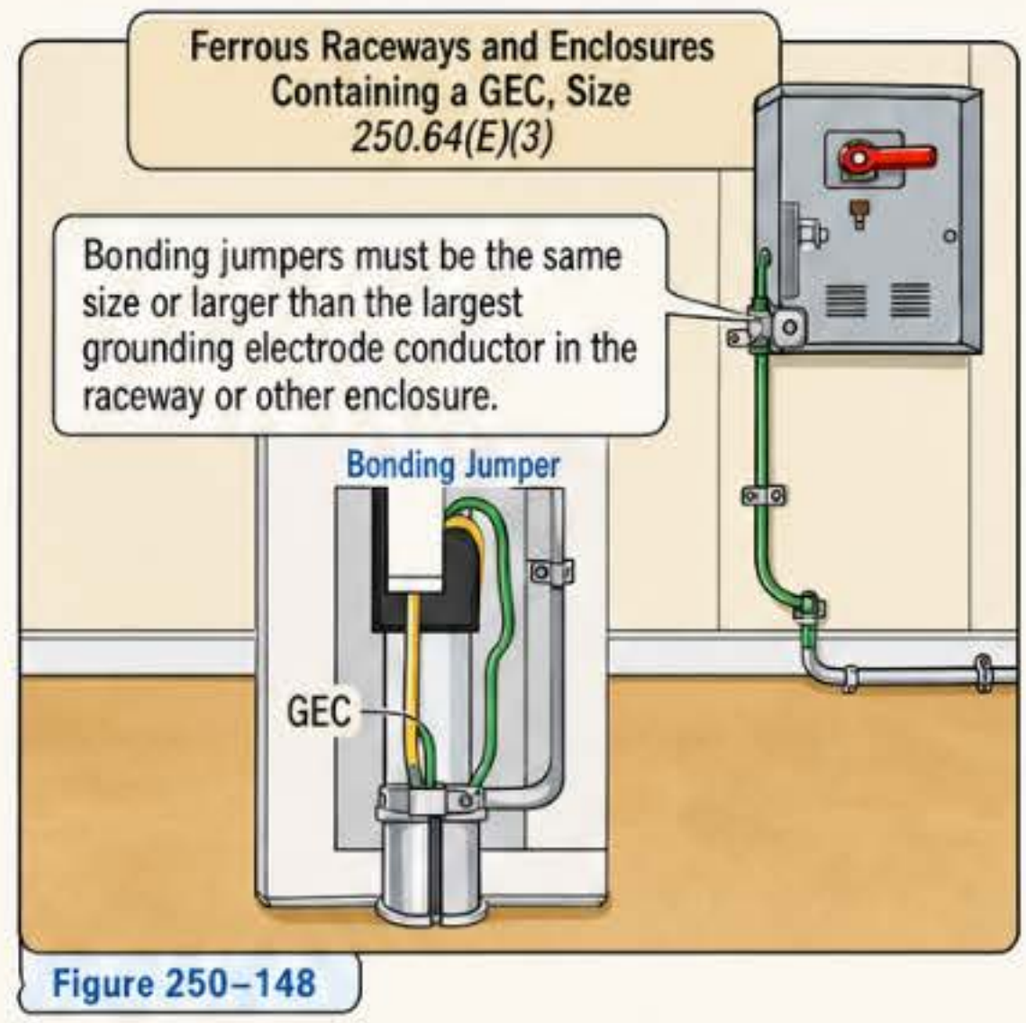


Figure 250–148

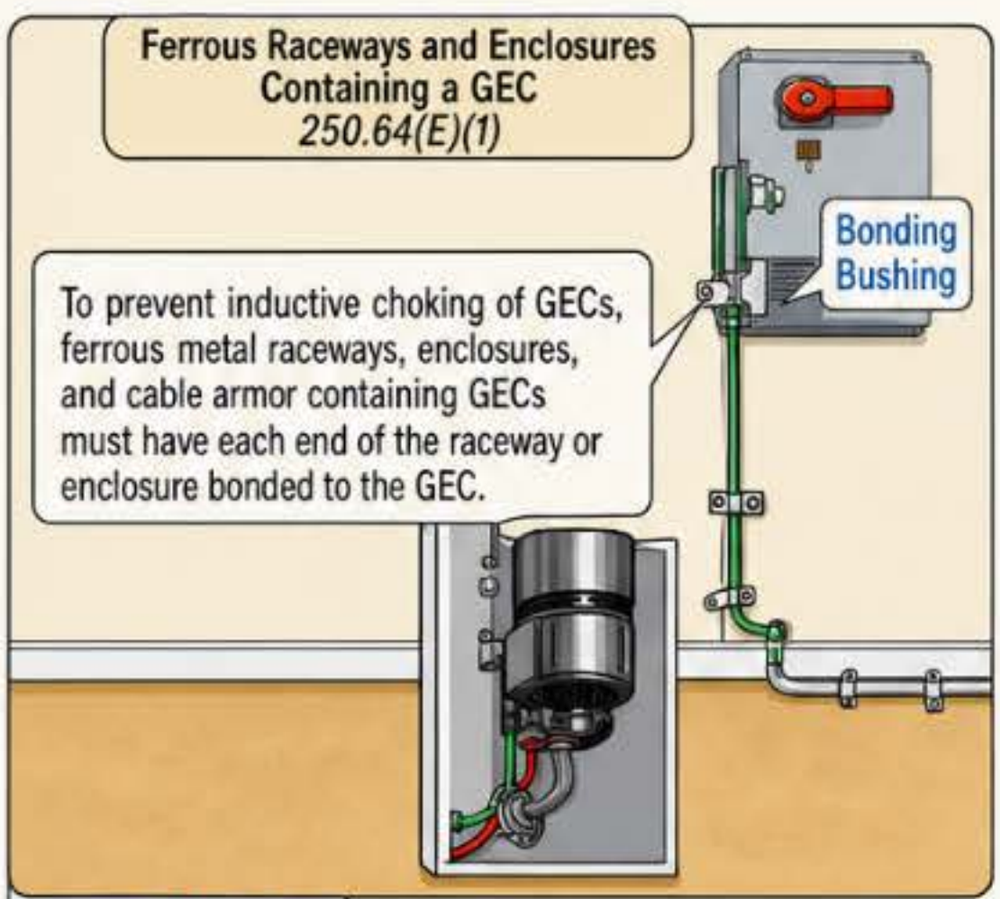


Figure 250–147

(2) Methods. Raceway bonding must be in accordance with 250.92(B)(2) through (B)(4).

(3) Size. Bonding jumpers must be the same size or larger than the largest grounding electrode conductor in the raceway or other enclosure. ▸ Figure 250–148

Author's Commentary:

- Nonferrous metal raceways, such as aluminum rigid metal conduit, enclosing the grounding electrode conductor are not required to meet the "bonding each end of the raceway to the grounding electrode conductor" provisions of this section.

– Michael Hamilton

Author's Commentary:

- To save time and effort, install the grounding electrode conductor in a nonmetallic raceway suitable for the application [352.10(F)]. Figure 250–149

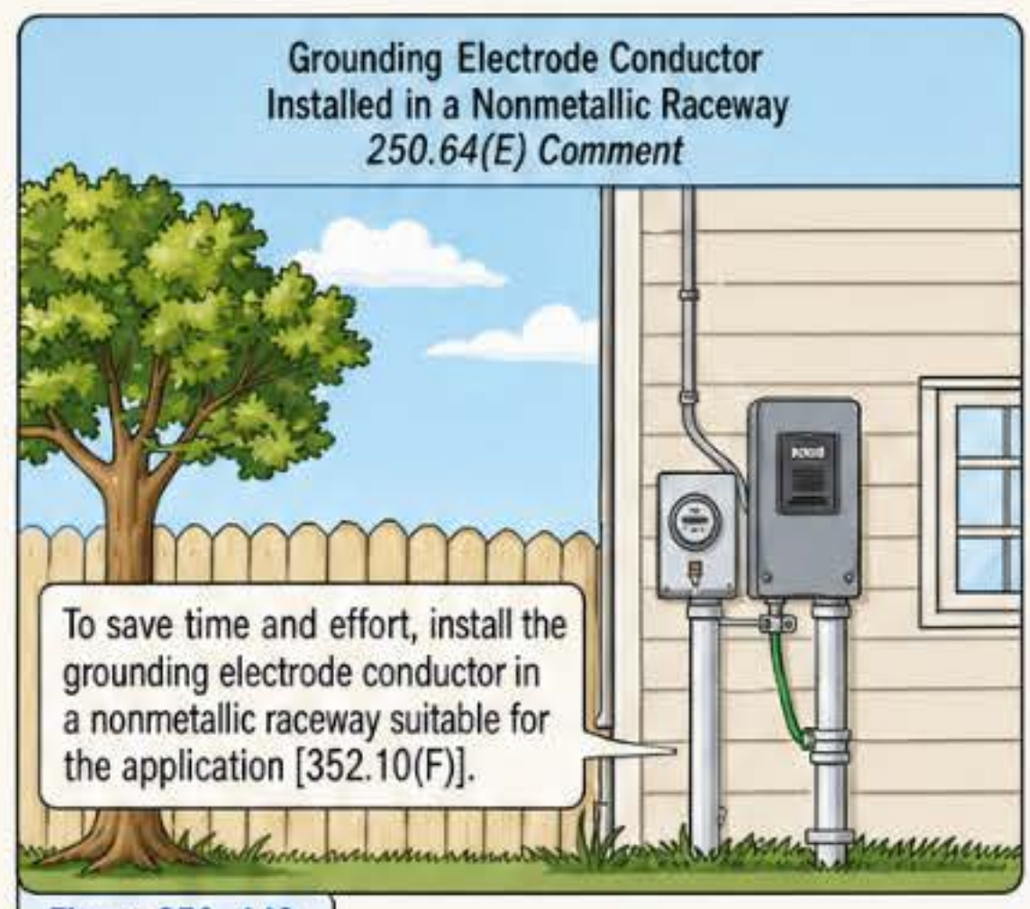
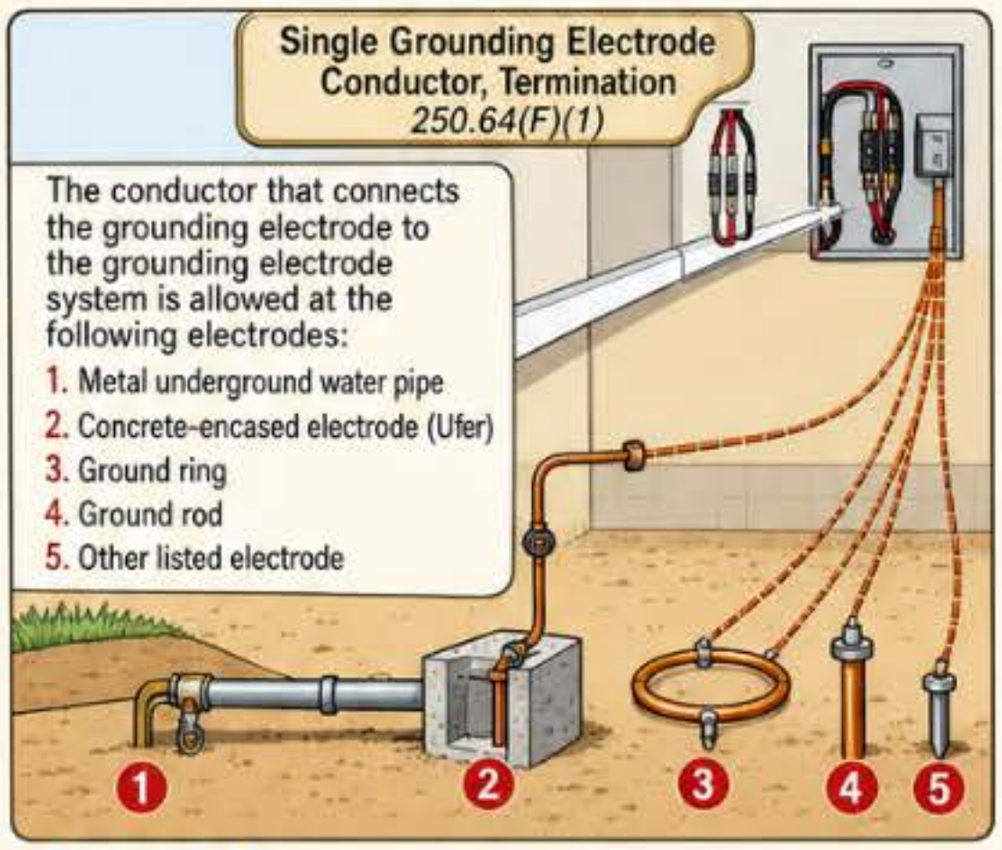


Figure 250–149

(F) Termination to Grounding Electrode.

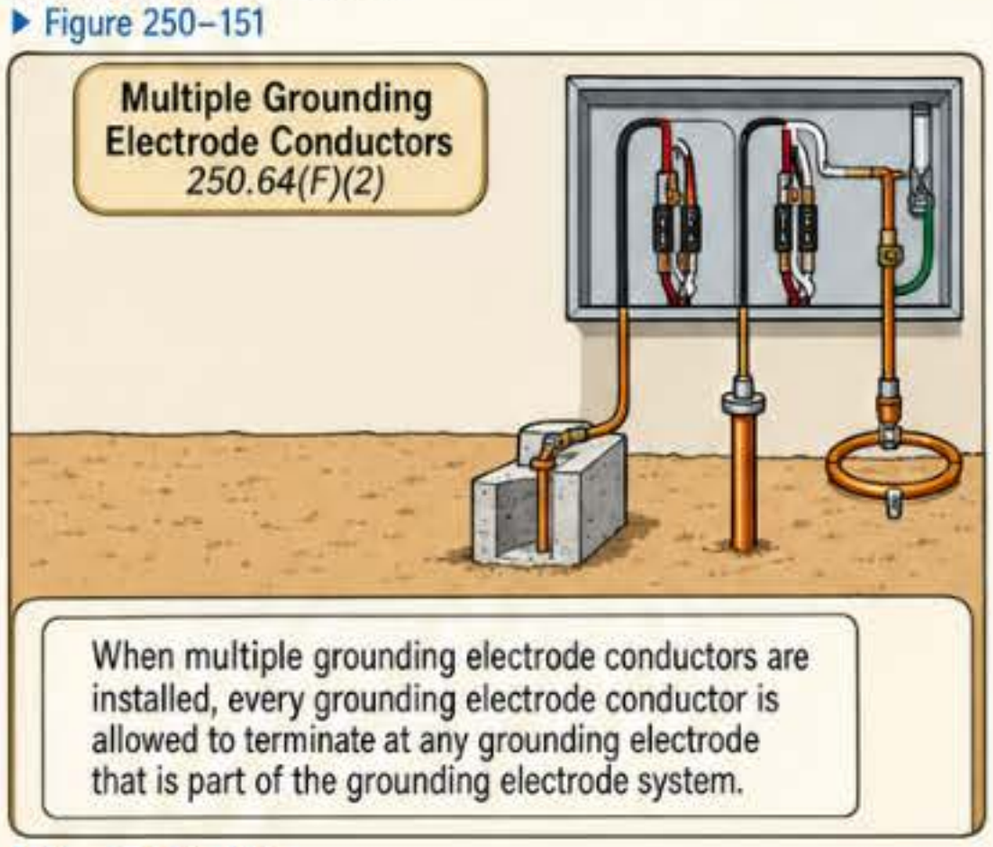
(1) Single Grounding Electrode Conductor. A single grounding electrode conductor can terminate to any grounding electrode of the grounding electrode system. ▸ Figure 250–150

Grounding and Bonding | 250.66



▶ Figure 250–150

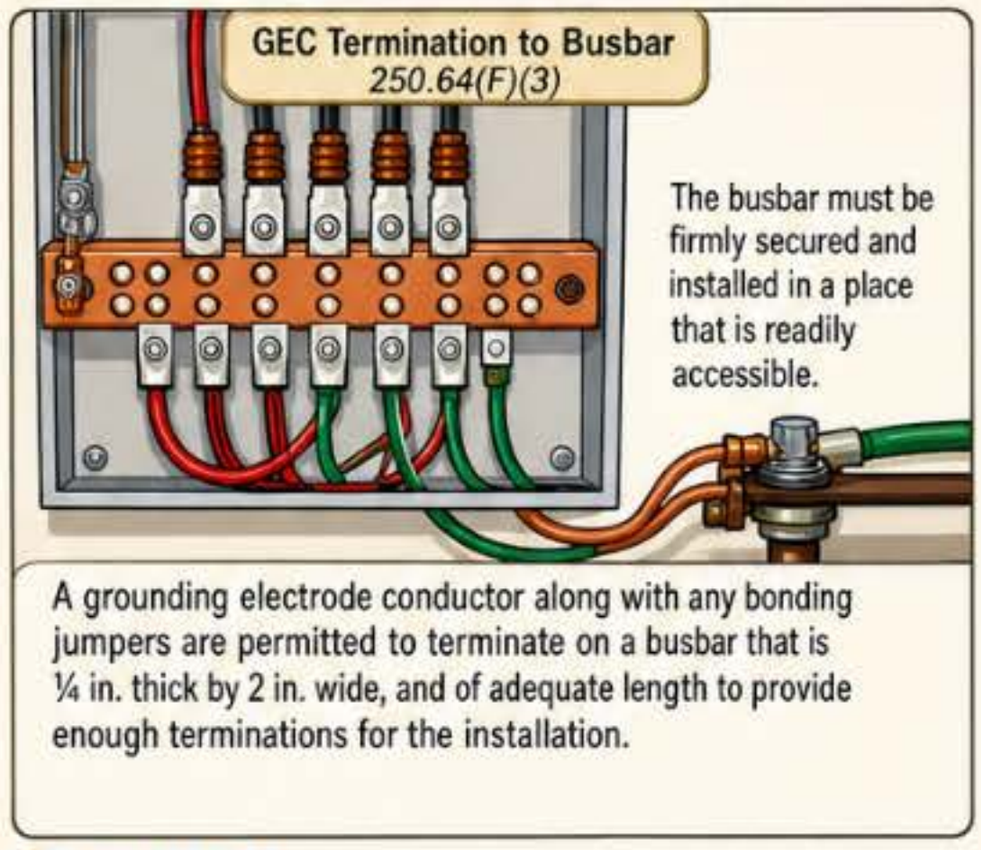
(2) Multiple Grounding Electrode Conductors. When more than one grounding electrode conductor is installed [250.64(D)(2)], each conductor may terminate to any grounding electrode within the grounding electrode system.
▶ Figure 250–151



▶ Figure 250–151

(3) Termination to Busbar. Grounding electrode conductors and *bonding jumpers are permitted to terminate to a busbar that is not less than ¼ in. thick by 2 in. wide, and of sufficient length to accommodate the terminations needed for the installation. The busbar must be securely fastened and installed in a location that is readily accessible.* ▶ *Figure 250–152*

> ***Author's Commentary:***
> *A busbar provides a common point for making all grounding and bonding connections. It be large enough for the job and easy to reach for future inspection or maintenance.*
> *— Michael Hamilton*

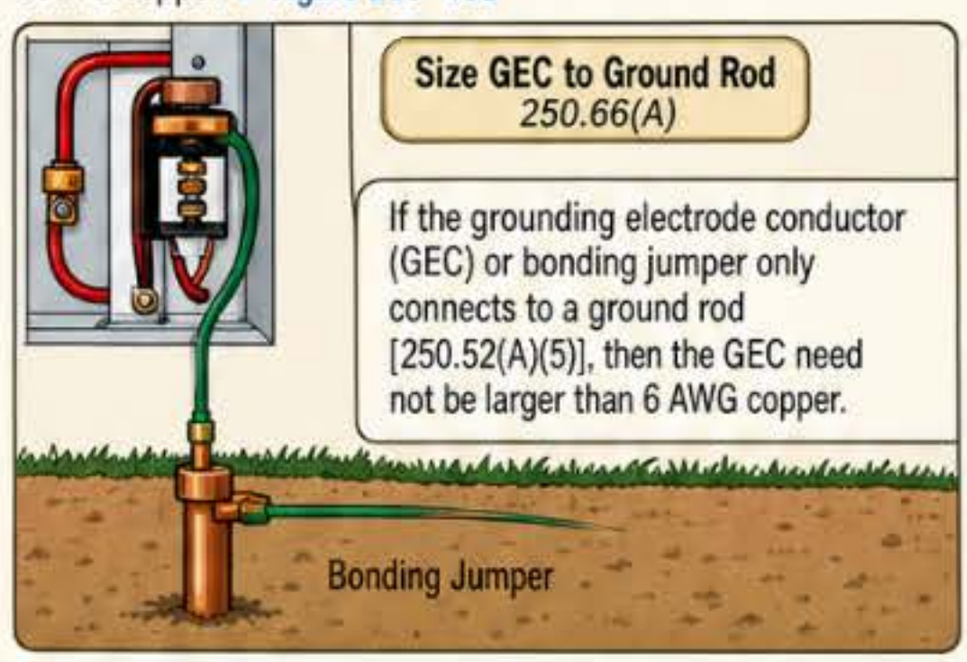


▶ Figure 250–152

250.66 Sizing Grounding Electrode Conductor

Except as allowed in (A) through (C), grounding electrode conductors must be sized following Table 250.66, based on the area of the largest phase conductor.

(A) Ground Rods. When only a grounding electrode conductor or bonding jumper connects to a ground rod [250.52(A)(5)], the grounding electrode conductor is not required to be larger than 6 AWG copper. ▶ Figure 250–153



▶ Figure 250–153

(B) Concrete-Encased Grounding Electrodes. When a grounding *electrode conductor or bonding jumper connects to a concrete-encased electrode [250.52(A)(3)], the grounding electrode conductor is not required to be larger than 4 AWG copper.*
▶ Figure 250–154

> ***Author's Commentary:***
> *These size limits keep the system safe and cost-effective. They ensure the conductor is strong enough for the fault current it may carry.*
> *— Michael Hamilton*

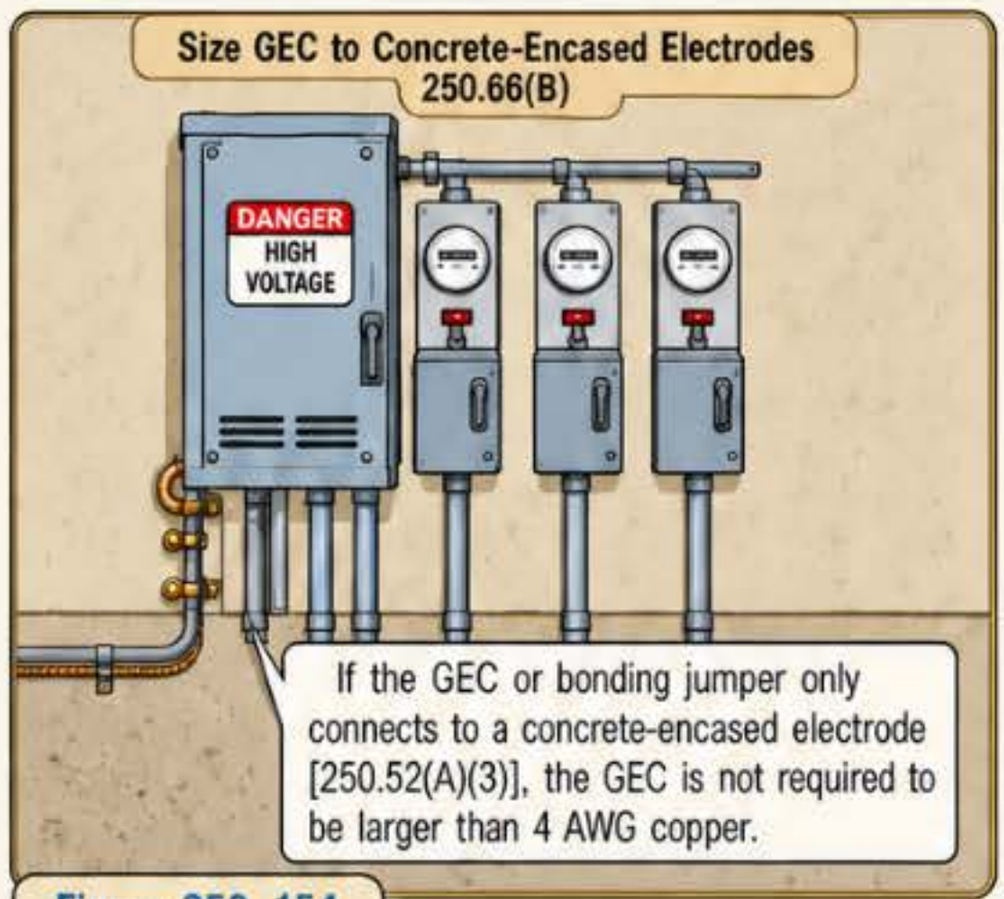


Figure 250–154

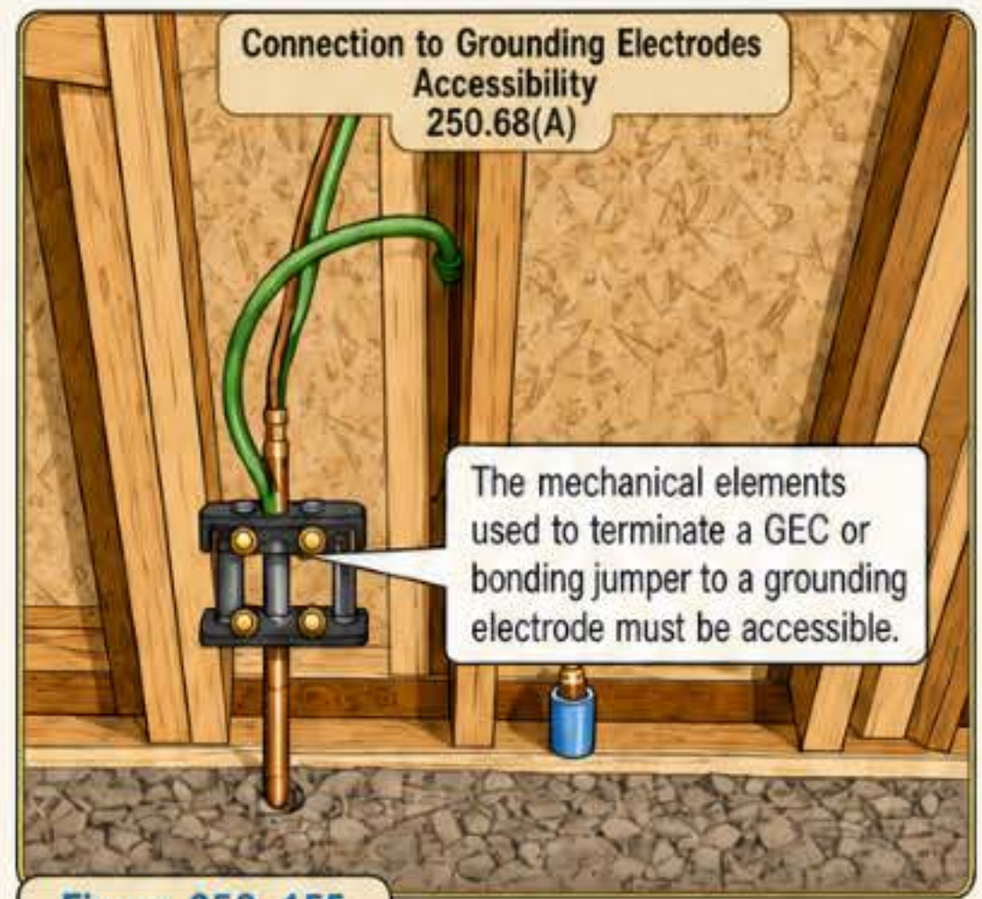


Figure 250–155

Table 250.66 Grounding Electrode Conductor	
AWG or Area of Parallel Copper Conductors	**Copper Grounding Electrode Conductor**
2 AWG or Smaller	8 AWG
1 or 1/0 AWG	6 AWG
2/0 or 3/0 AWG	4 AWG
Over 3/0 through 350 kcmil	2 AWG
Over 350 through 600 kcmil	1/0 AWG
Over 600 through 1,100 kcmil	2/0 AWG
Over 1,100 kcmil	3/0 AWG

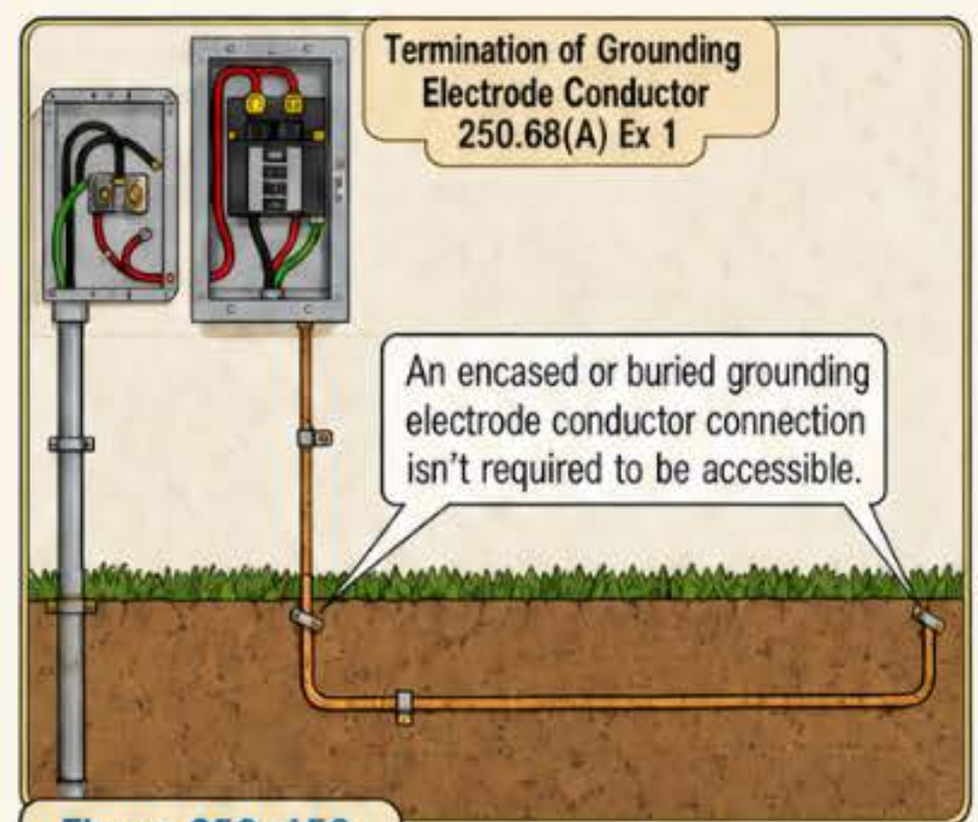


Figure 250–156

250.68 Grounding Electrode Conductor and Bonding Jumper Connection to Grounding Electrodes

(A) Accessibility. The fastening hardware used to connect a grounding electrode conductor or bonding jumper to a grounding electrode must be accessible. Figure 250–155

Ex 1: *The connection is not required to be accessible if the termination to the electrode is encased in concrete or buried in the Earth.* Figure 250–156

Author's Commentary:

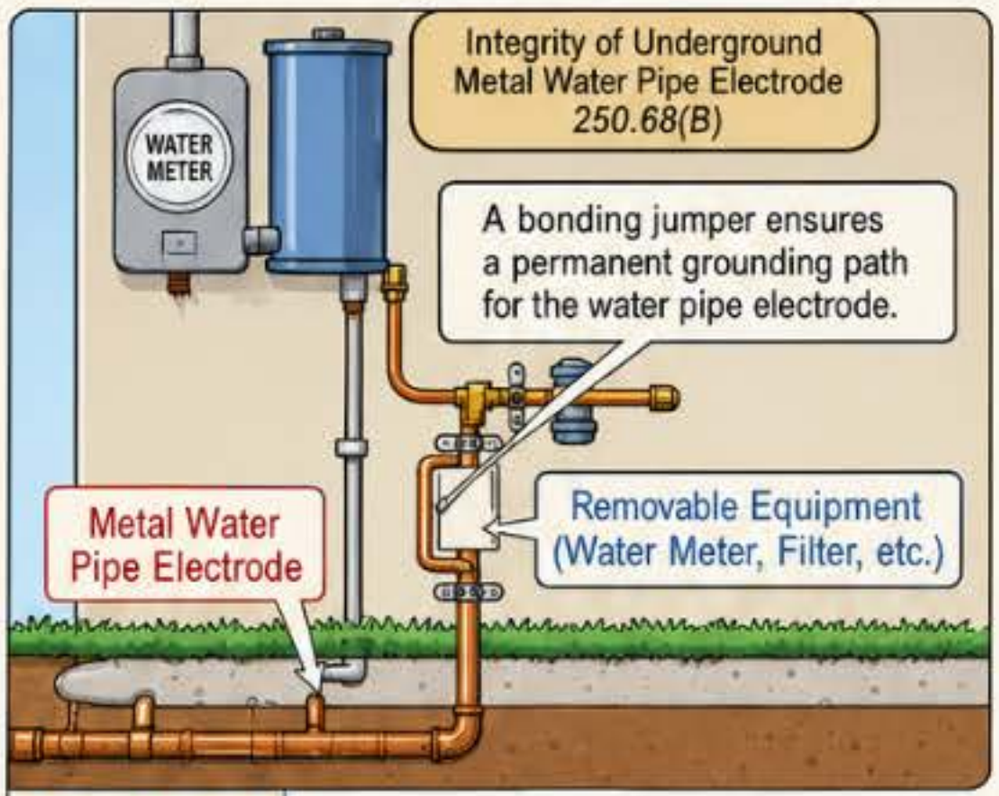
- *When the grounding electrode connection is sealed in concrete or buried in the Earth, it must still be listed for direct soil burial or for concrete encasement [250.70].*

— Michael Hamilton

(B) Integrity of Underground Metal Water Pipe Electrode. A bonding jumper must be installed around insulated joints and equipment likely to be disconnected for repairs or replacement on an underground metal water piping system used as a grounding electrode. The bonding jumper must be long enough to allow removal of such equipment while preserving the integrity of the grounding path. Figure 250–157

Ex 2: *Exothermic or irreversible compression connections, together with the mechanical means used to attach to fireprotected structural metal, are not required to be accessible.*

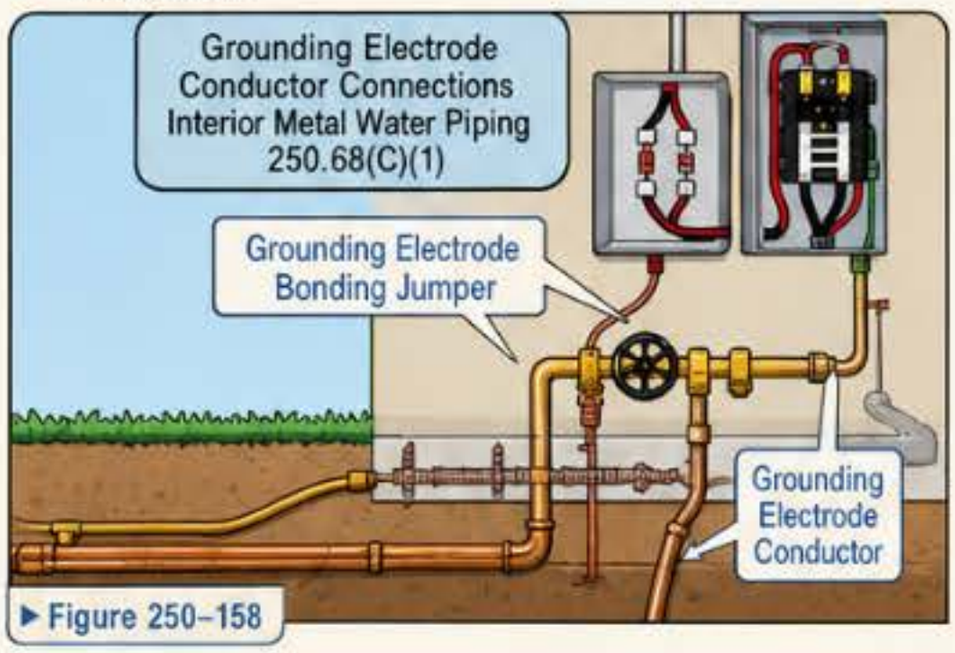
Grounding and Bonding | 250.68



▶ Figure 250–157

(C) Grounding Electrode Conductor Connections. Grounding electrode conductors and bonding jumpers are permitted to terminate at the following locations and be used to extend the connection to an electrode(s):

(1) Interior metal water piping that is electrically continuous with a metal underground water pipe electrode and is located not more than 5 ft from the point of entrance to the building, can be used to extend the connection to electrodes. Interior metal water piping located more than 5 ft from the point of entrance to the building is not permitted to be used as a conductor to *interconnect electrodes of the grounding electrode system. Figure 250–158 shows acceptable connections.*



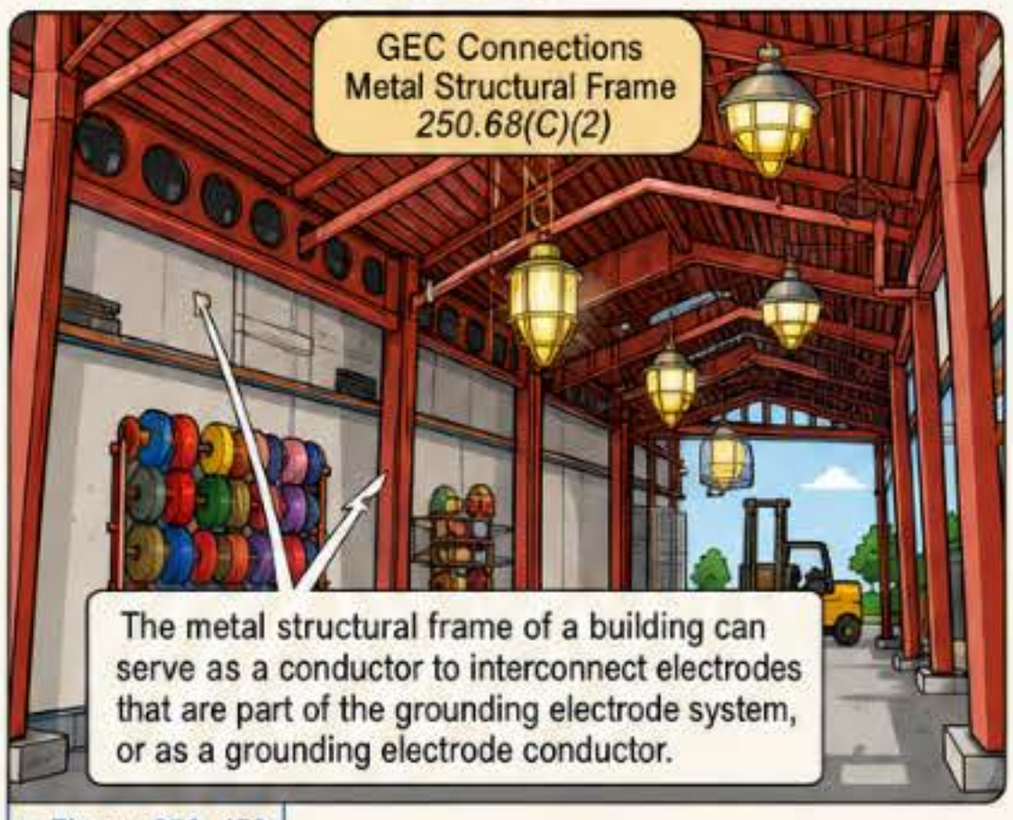
▶ Figure 250–158

Author's Commentary:

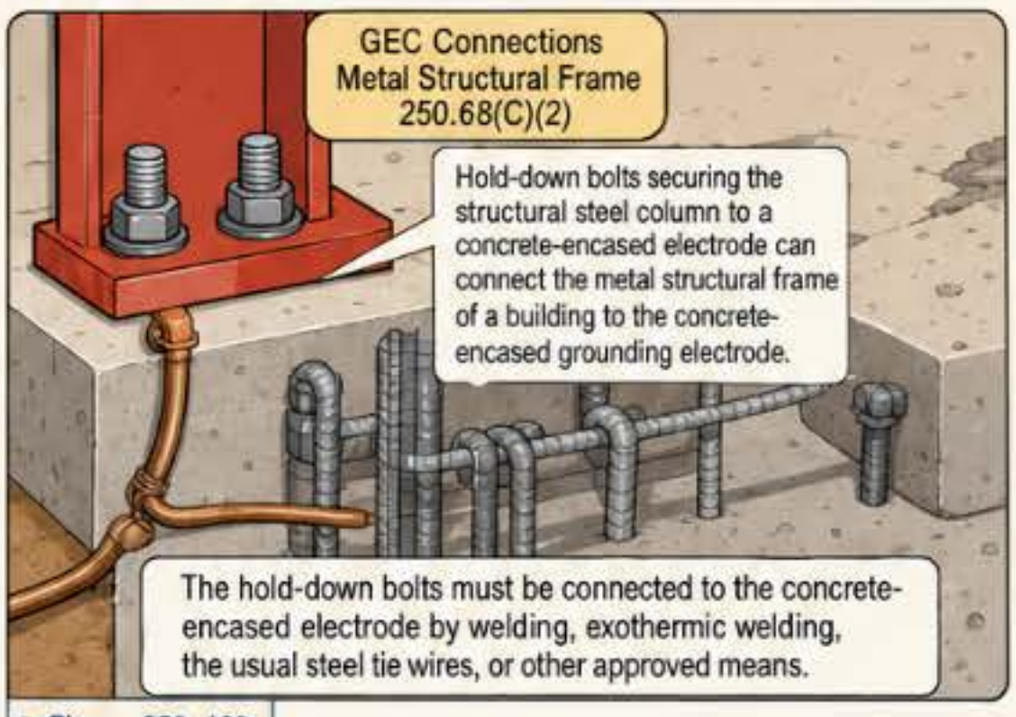
Interior metal water piping that is electrically continuous with a qualifying underground water pipe electrode and located within 5 feet of the building entrance may be *used to extend the grounding electrode connection.*

— Michael Hamilton

(2) The metal structural frame of a building can be used as a conductor to interconnect electrodes that are part of the grounding electrode system, or as a grounding electrode conductor where the hold-down bolts secure the structural steel column to a concrete-encased electrode [250.52(A)(3)]. The hold-down bolts must be connected to the concrete-encased electrode by welding, exothermic welding, the usual steel tie wires, or other approved means. Figures 250–159 and 250–160 illustrate acceptable methods.



▶ Figure 250–159



▶ Figure 250–160

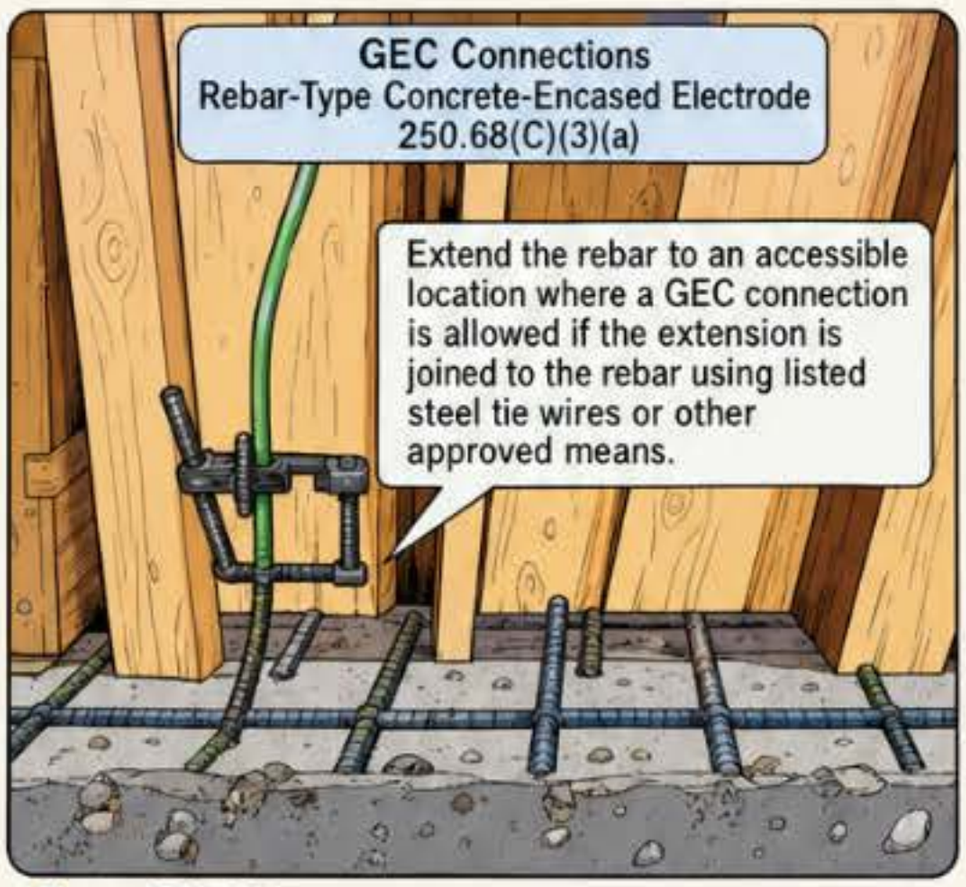
Author's Commentary:

Secure the hold-down bolts to the concrete-encased electrode using welding, exothermic connections, steel tie wire, or another approved technique.

— Michael Hamilton

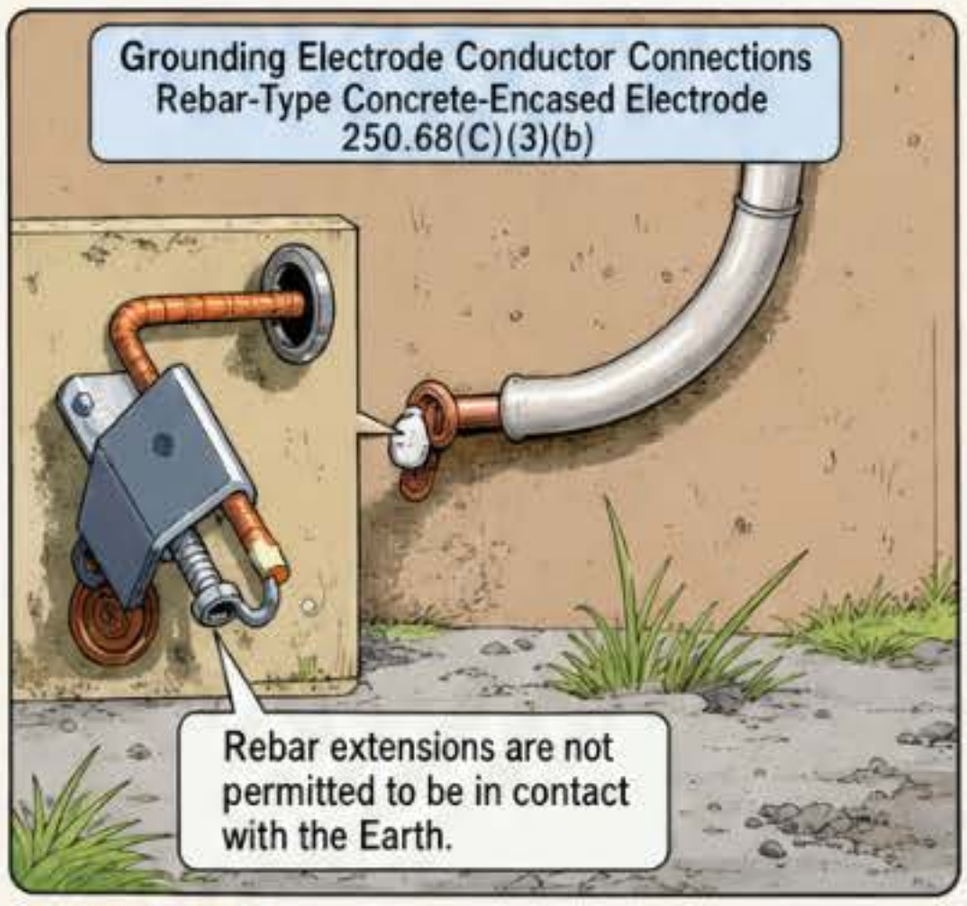
(3) A rebar-type concrete-encased electrode [250.52(A)(3)] with rebar extended to an accessible location above the concrete foundation or footing is permitted under the following conditions:

(a) The additional rebar section must be continuous with the grounding electrode rebar or must be securely connected to the grounding electrode rebar and linked together using listed steel wire connectors, exothermic welds, welding, or other effective methods. ▶ Figure 250-161



▶ Figure 250-161

(b) The rebar extension is not permitted to be in contact with the Earth. ▶ Figure 250-162

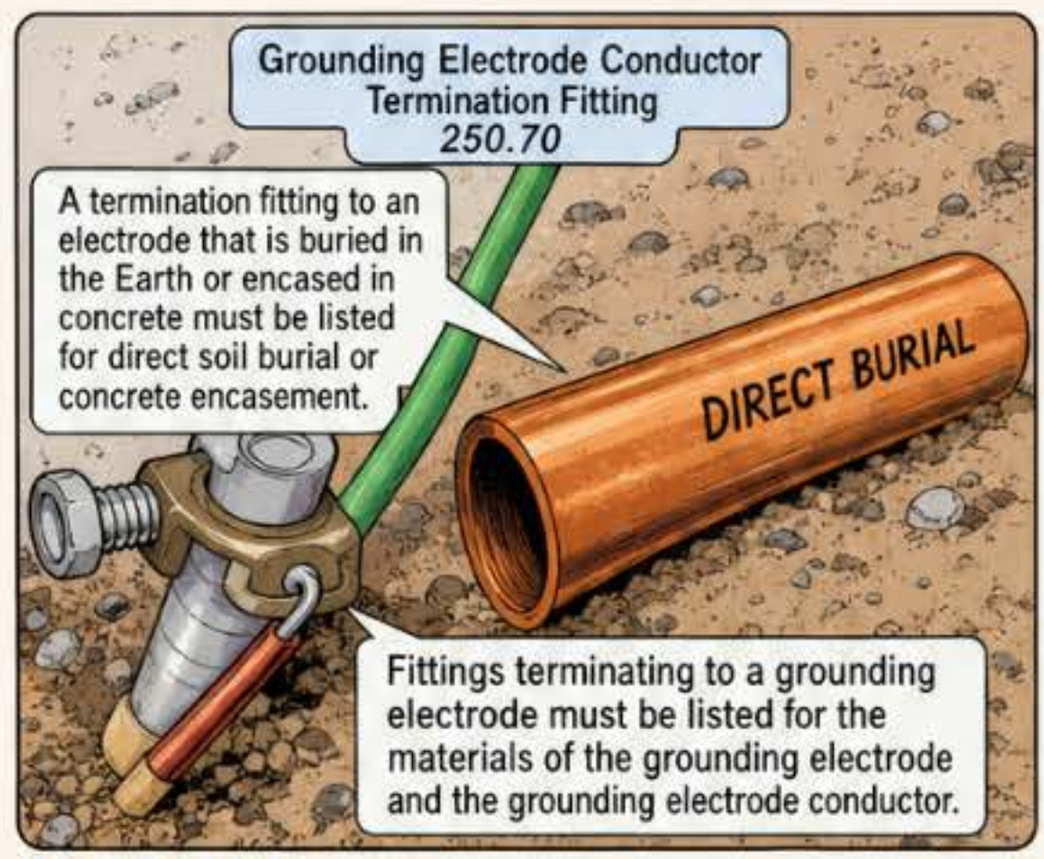


▶ Figure 250-162

(c) The rebar extension is not permitted to be used as a conductor to interconnect the electrodes of grounding electrode systems.

250.70 Grounding Electrode Conductor Termination Fittings

The grounding electrode conductor must terminate to the grounding electrode by exothermic welding, listed lugs, listed pressure connectors, listed clamps, or other listed means. In addition, fittings terminating to a grounding electrode must be listed for the grounding electrode and the grounding electrode conductor. ▶ Figure 250-163

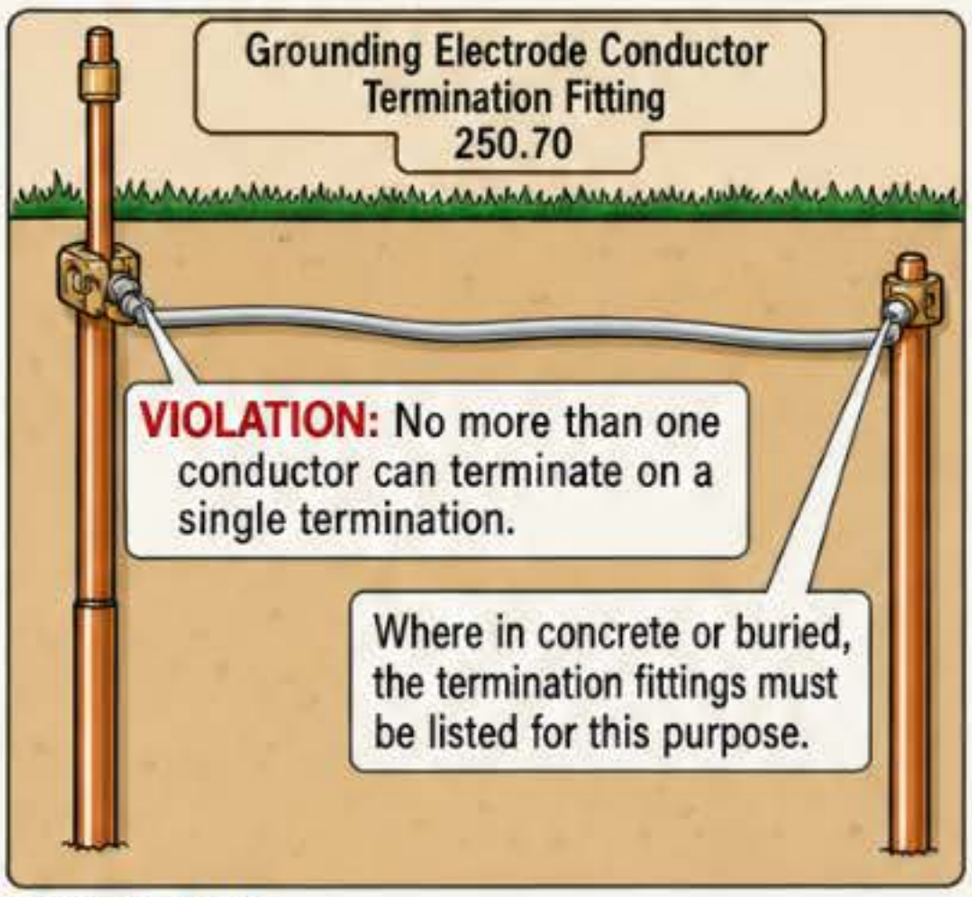


▶ Figure 250-163

When the termination to a grounding electrode is buried in the Earth or encased in concrete, the termination fitting must be listed for direct soil burial or concrete encasement. ▶ Figure 250-164

▶ Figure 250-164

A single clamp or fitting can be used by no more than one conductor. If a clamp or fitting is on the list for multiple connections, then it can be used for more than one. ▶ Figure 250-165



▶ Figure 250-165

Part IV. Enclosure, Raceway, and Service Cable Connections

250.80 Service Raceways and Enclosures

Metal enclosures and raceways containing service conductors must be bonded to the service neutral conductor if the electrical system is grounded.

250.86 Other Enclosures

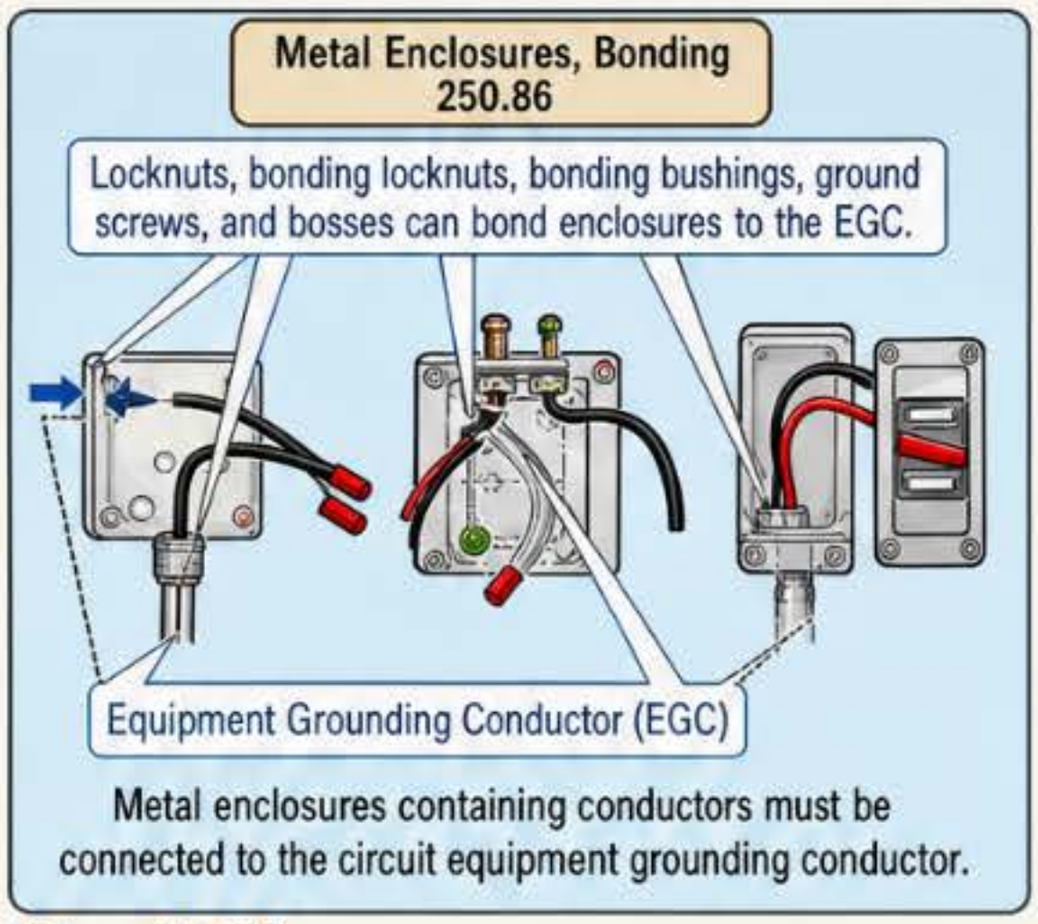
Metal raceways and enclosures containing conductors operating at 50V or more [250.20(A)] must be connected to the circuit equipment grounding conductor. ▶ Figure 250-166

Author's Commentary:

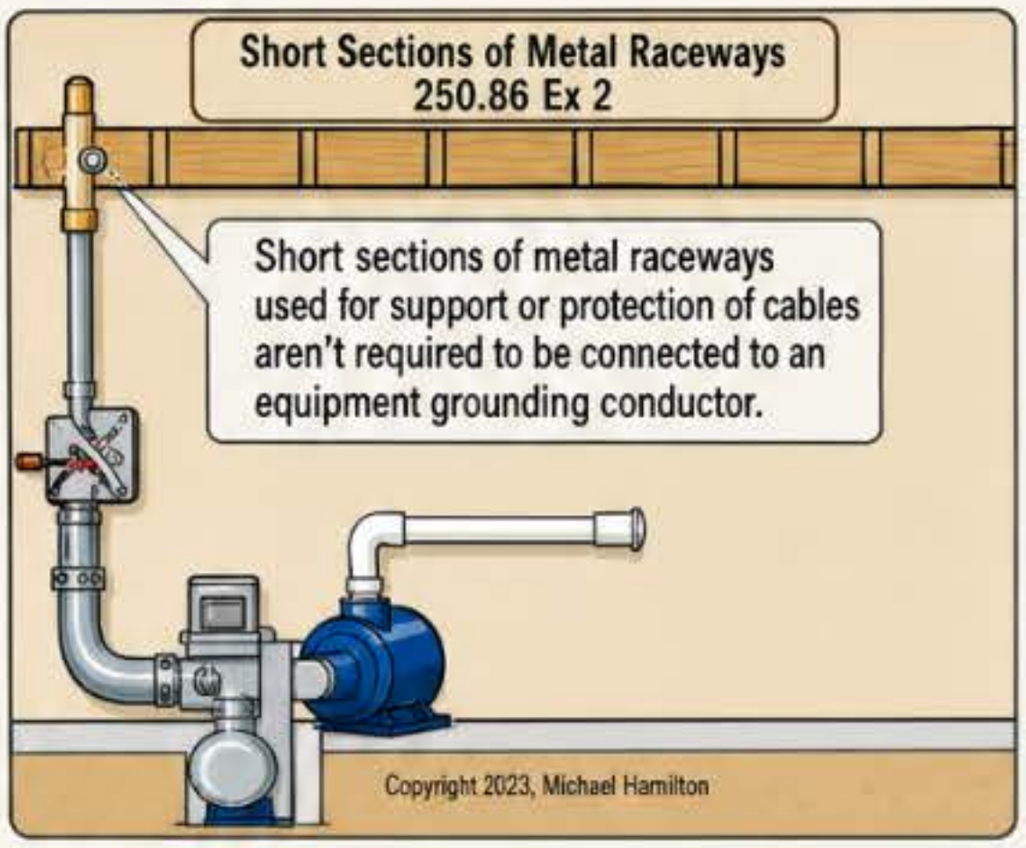
- *Circuits described in 250.112(I) operating at less than 50V are not required to be grounded [250.20(A)].*

— Michael Hamilton

Ex 2: *Short sections of metal raceways used for the support or physical protection of cables are not required to be connected to the circuit equipment grounding conductor.* ▶ Figure 250-167



▶ Figure 250-166



▶ Figure 250-167

Part V. Bonding for Fault Current

250.90 General

Bonding must be provided where necessary to ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed.

250.92 Bonding Equipment Containing Service Conductors

(A) Metal Raceways and Enclosures. The metal parts of equipment indicated below must be bonded together in accordance with 250.92(B). ▶ Figure 250-168

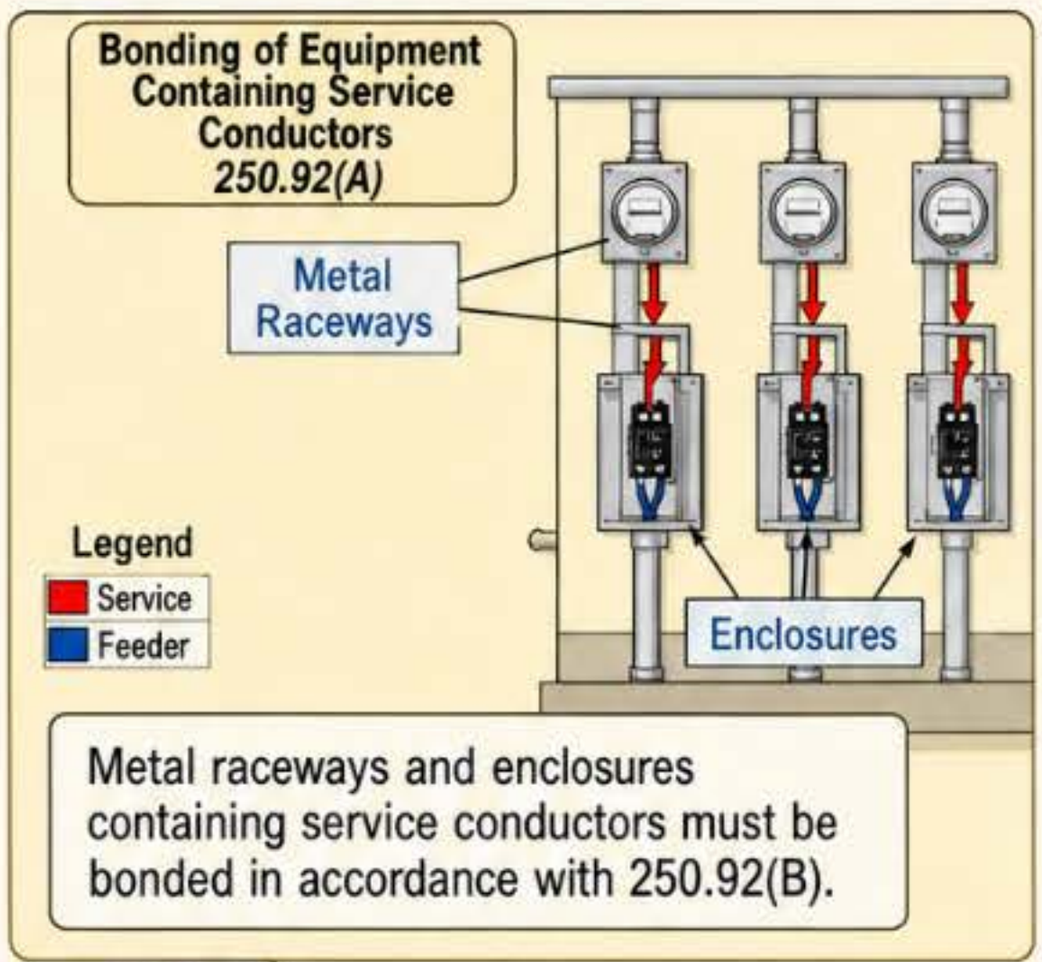


Figure 250–168

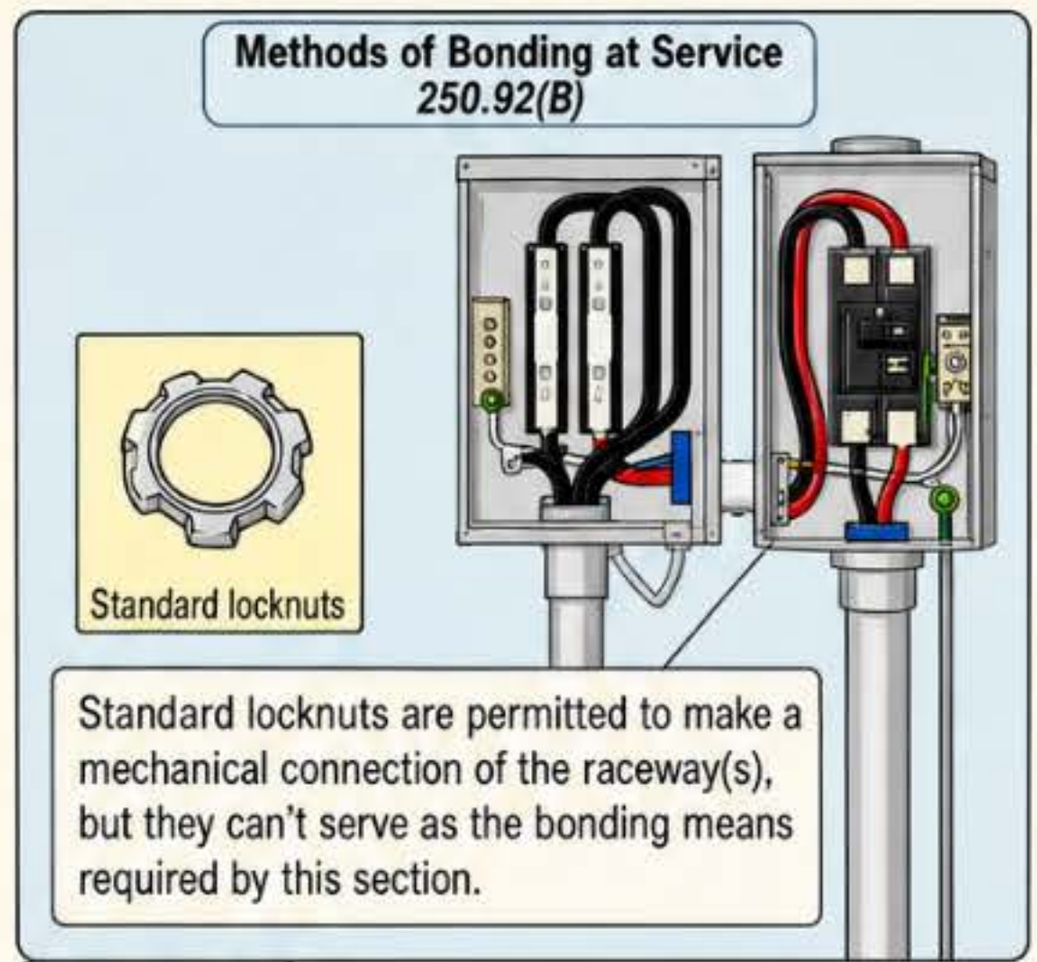


Figure 250–170

(1) Metal raceways containing service conductors.

(2) Metal enclosures containing service conductors.

(B) Methods of Bonding. Bonding jumpers are required around reducing washers or ringed knockouts. ▶ Figure 250–169

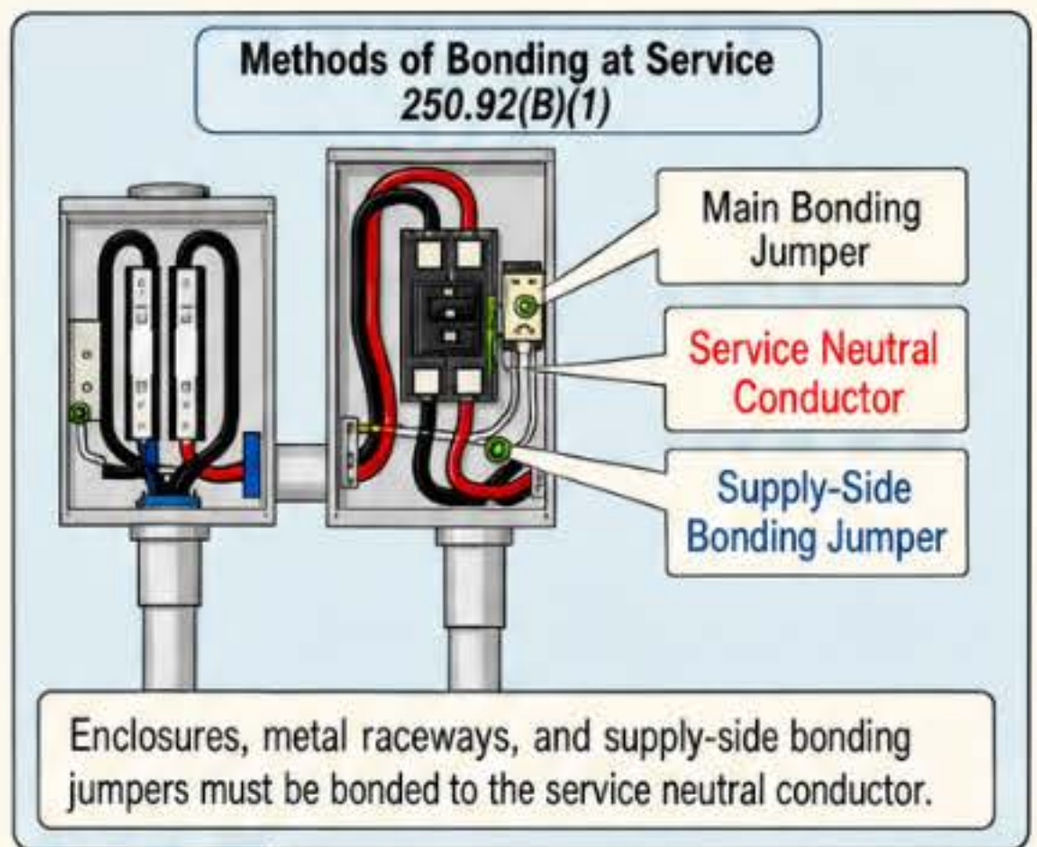


Figure 250–171

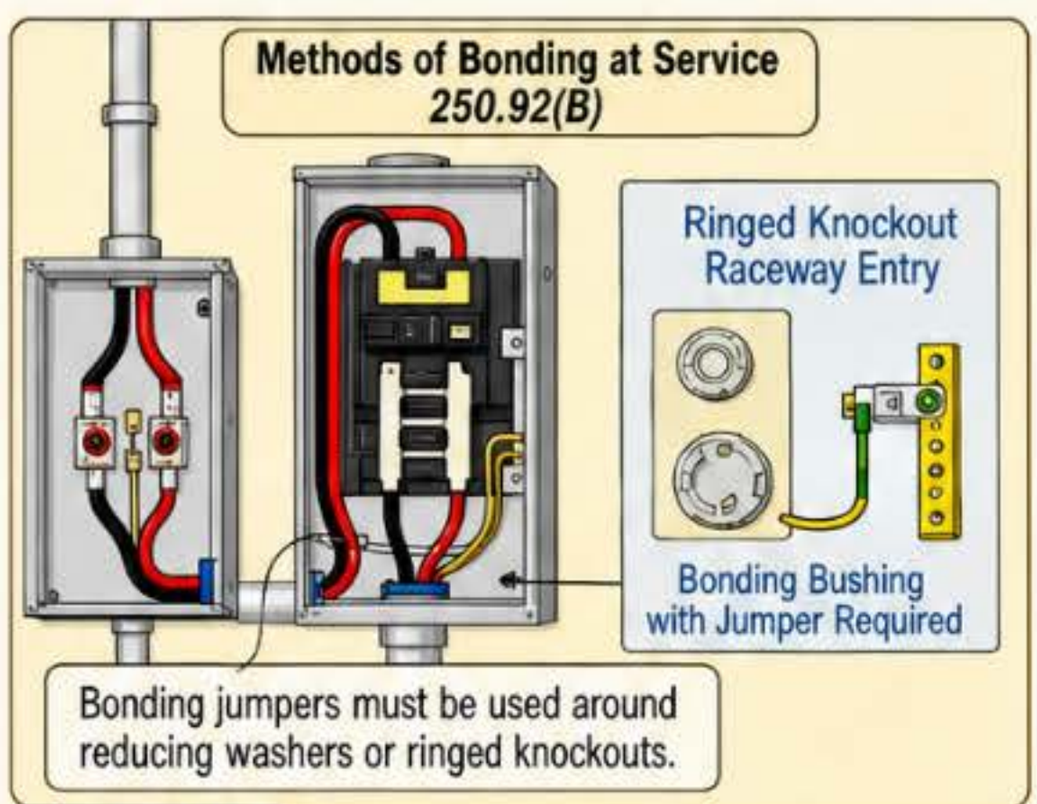


Figure 250–169

Standard locknuts are permitted to make a mechanical connection to the raceway(s), but they cannot serve as the bonding means required by this section. ▶ Figure 250–170

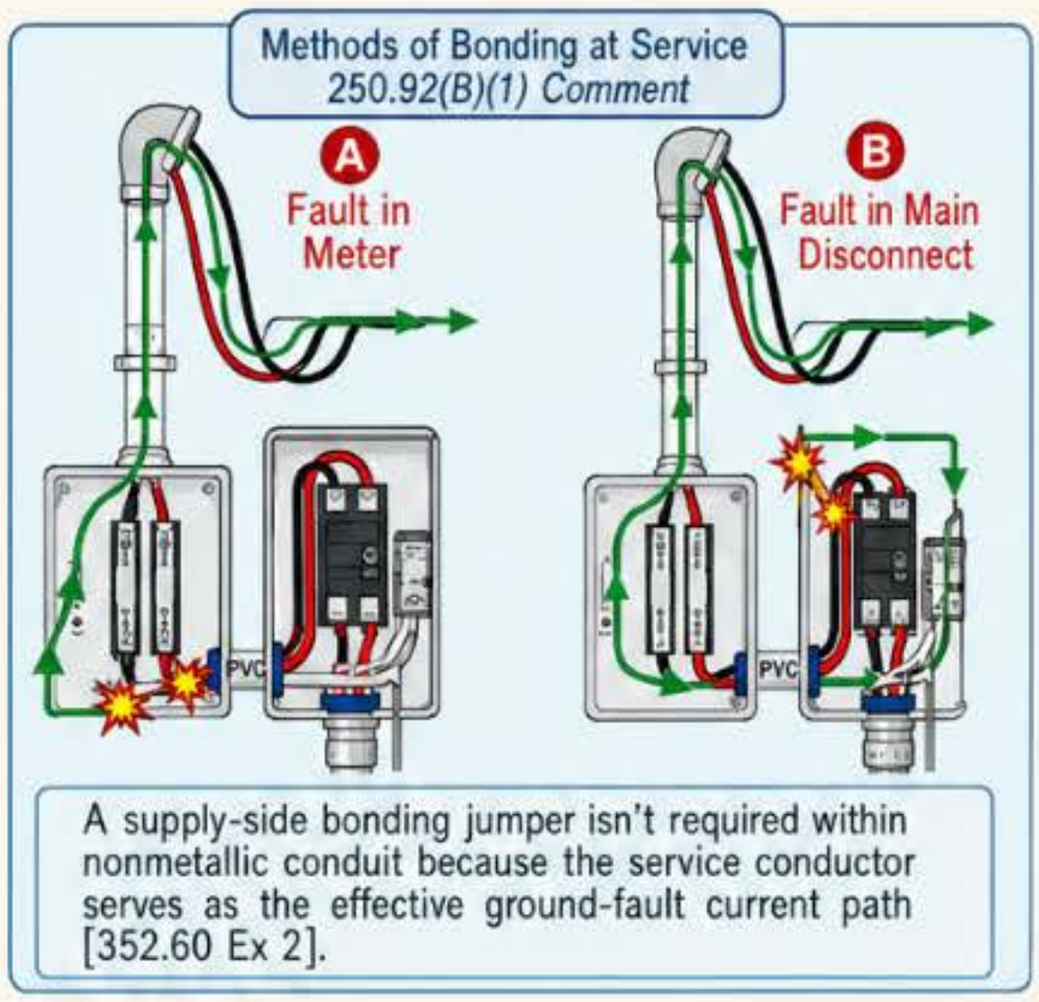
Bonding must be ensured by one of the following methods:

(1) Bonding metal parts to the service neutral conductor. ▶ Figure 250–171

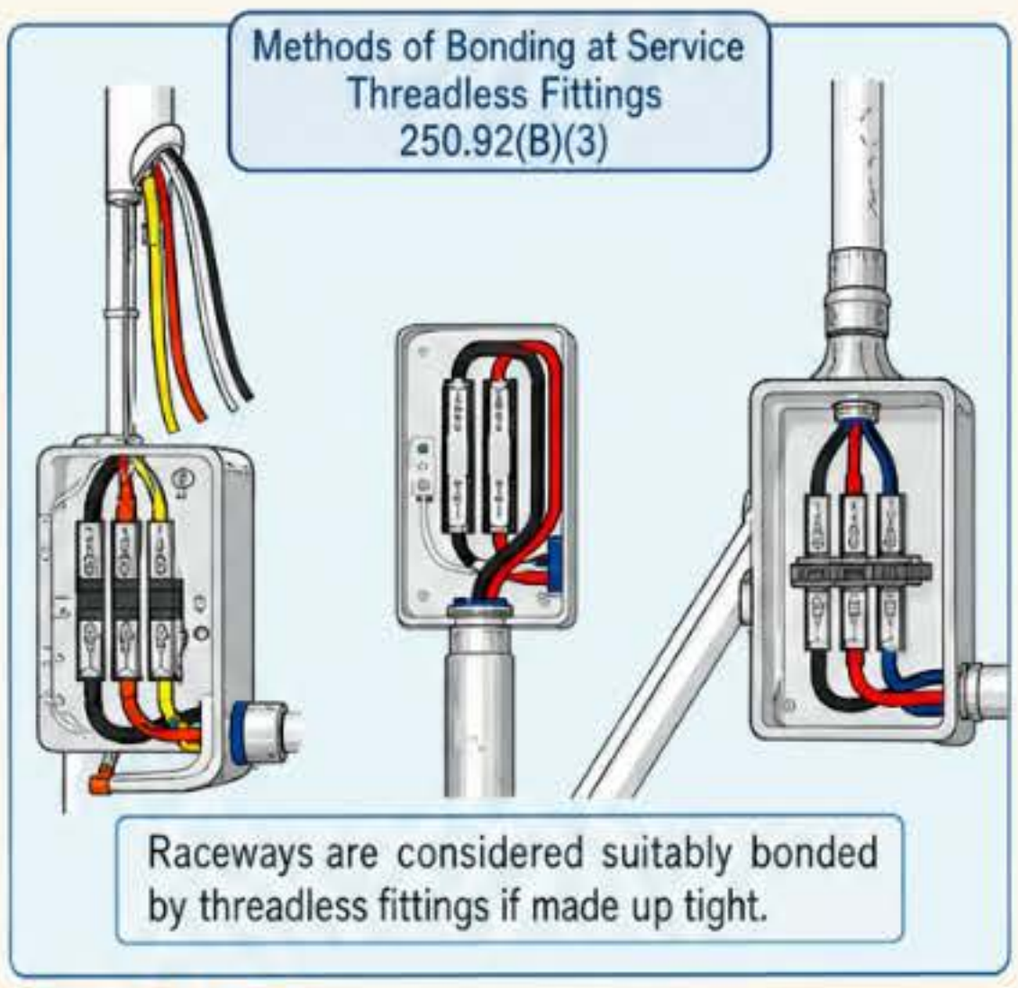
Author's Commentary:

- *A main bonding jumper is required to bond the service disconnect to the service neutral conductor [250.24(B) and 250.28].*
- *At the service disconnect, the service neutral conductor provides the effective ground-fault current path to the power supply [250.24(C)]; therefore, a supply-side bonding jumper is not required to be installed in PVC conduit containing service-entrance conductors [250.142(A)(1) and 352.60 Ex 2].* ▶ Figure 250–172

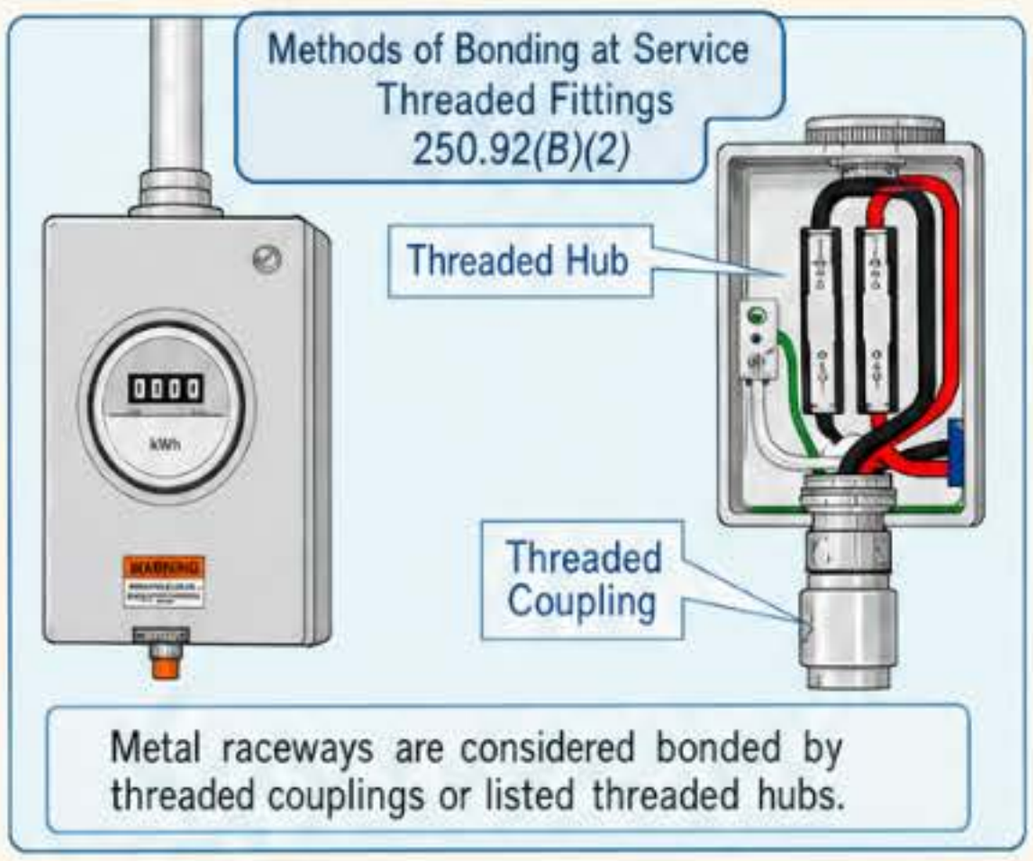
(2) Terminating metal raceways to threaded couplings or listed threaded hubs. ▶ Figure 250–173



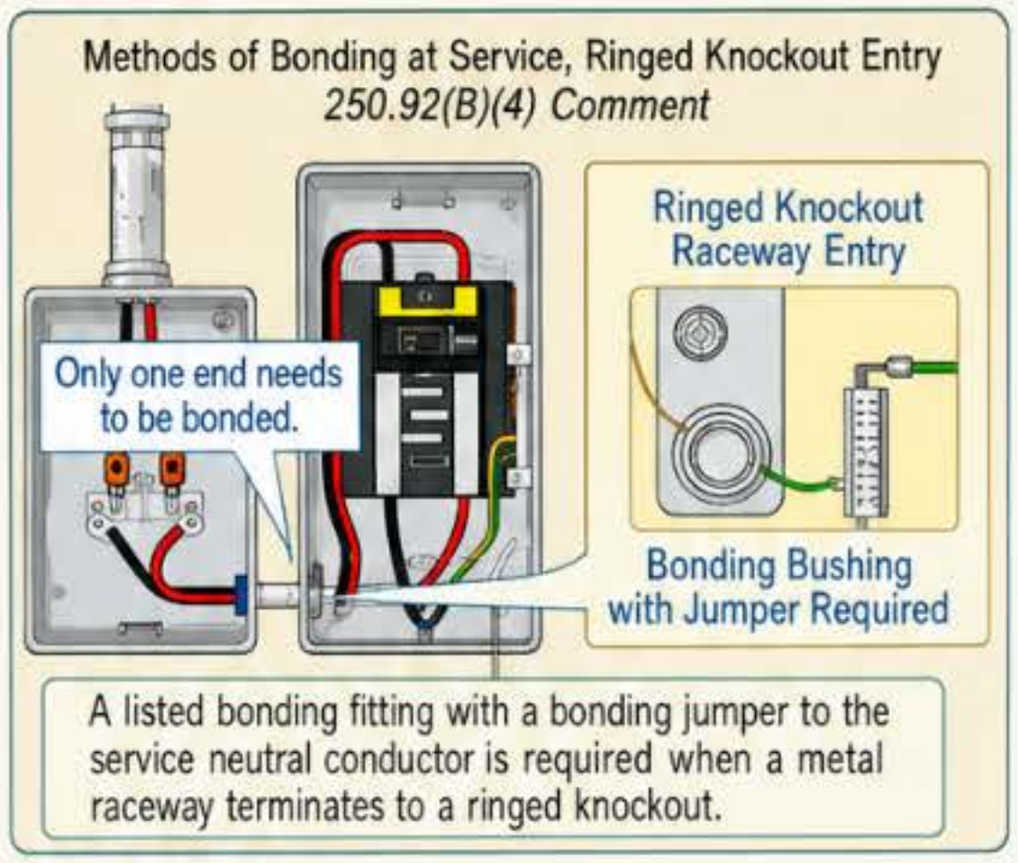
▶ Figure 250–172



▶ Figure 250–174



▶ Figure 250–173



▶ Figure 250–175

(3) Terminating metal raceways to threadless fittings. ▶ Figure 250–174

(4) Using listed devices, such as bonding-type locknuts, bushings, wedges, or bushings with bonding jumpers to the service neutral conductor.

Author's Commentary:

A listed bonding wedge or bushing with a bonding jumper to the service neutral conductor is required when a metal raceway containing service conductors terminates to a ringed knockout. ▶ Figure 250–175

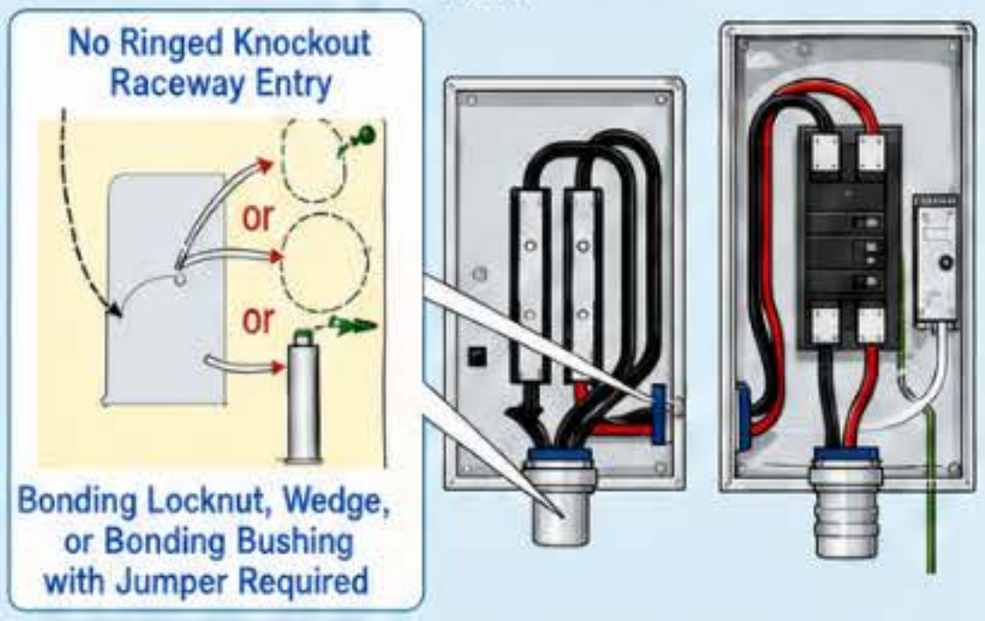
— Michael Hamilton

Author's Commentary:

- *A supply-side bonding jumper of the wire type used for this purpose must be sized in accordance with Table 250.102(C)(1), based on the size/area of the service phase conductors within the raceway [250.102(C)].*
- *A bonding-type locknut, bonding wedge, or bonding bushing with a bonding jumper can be used for a metal raceway that terminates to an enclosure without a ringed knockout.* ▶ Figure 250–176

— Michael Hamilton

Methods of Bonding at Service, No Ringed Knockout Entry
250.92(B)(4) Comment



A bonding-type locknut, wedge, or bushing with a bonding jumper can be used for a metal raceway terminating to an enclosure without a ringed knockout.

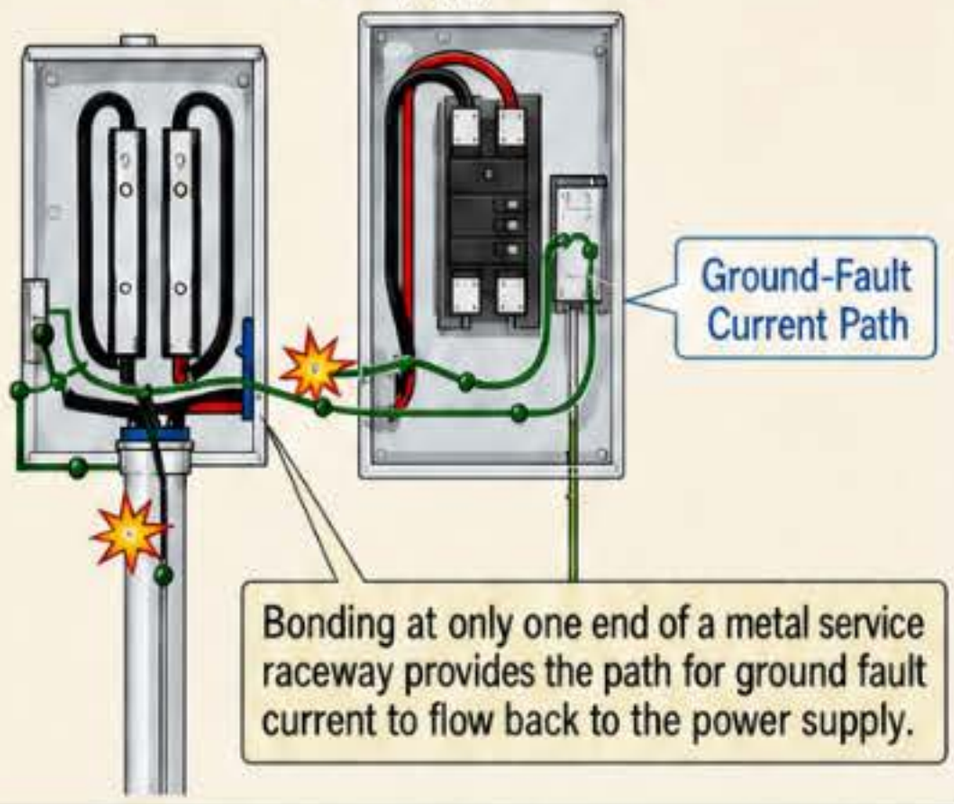
▶ Figure 250–176

Author's Commentary:

- A bonding locknut differs from a standard locknut in that it contains a bonding screw with a sharp point that drives into the metal enclosure to ensure a solid connection.
- Bonding one end of a service raceway to the service neutral provides the necessary low-impedance fault current path to the source required by this section. Figure 250–177

— Michael Hamilton

Methods of Bonding at Service
250.92(B)(4) Comment



▶ Figure 250–177

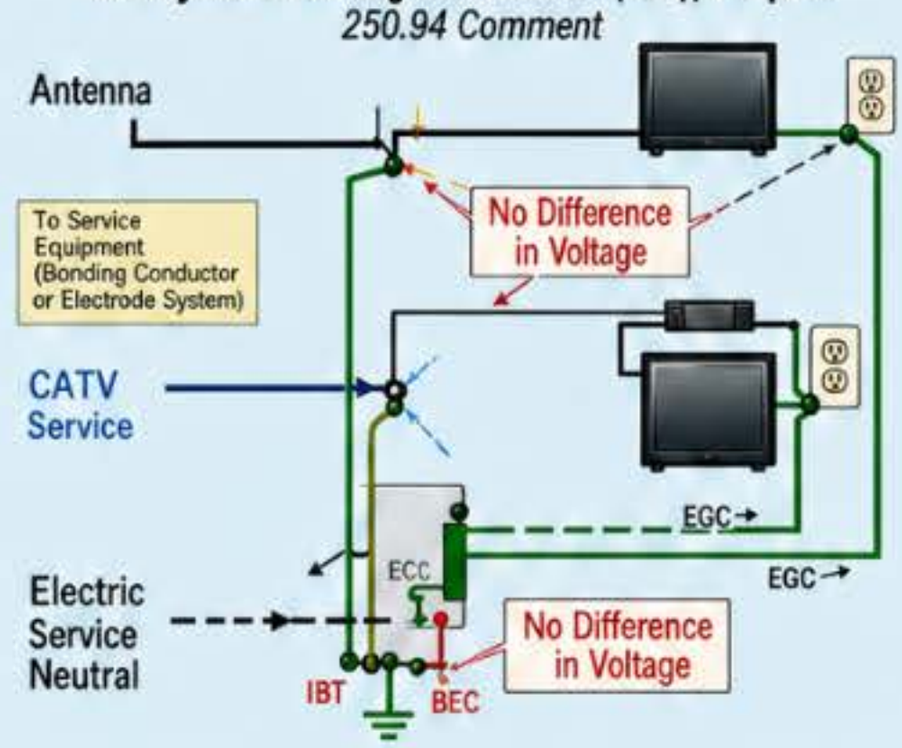
250.94 Bonding Communications Systems

A bonding termination device must be provided for communications systems in accordance with (A) and (B).

Author's Commentary:

- These systems include communication systems (Article 805), radio and TV equipment (Article 810), and CATV (Article 820). Bonding communications systems together is intended to minimize damage from induced voltage differences between the systems that can be caused by lightning strikes. Figure 250–178

Intersystem Bonding Termination (IBT), Purpose
250.94 Comment



The IBT device minimizes damage from induced voltage differences between the systems from a lightning event.

▶ Figure 250–178

(A) Intersystem Bonding Termination Device. An intersystem bonding termination device must meet all of the following requirements:

(1) Be accessible. Figure 250–179

(2) Have a capacity for at least three intersystem bonding conductors.

(3) Be installed so it does not interfere with the opening of any enclosure.

(4) Be securely mounted and electrically connected to the service disconnect, meter enclosure, or grounding electrode conductor. Figure 250–180

(5) Be securely mounted and electrically connected to the building's disconnect or grounding electrode conductor.

Grounding and Bonding | 250.96

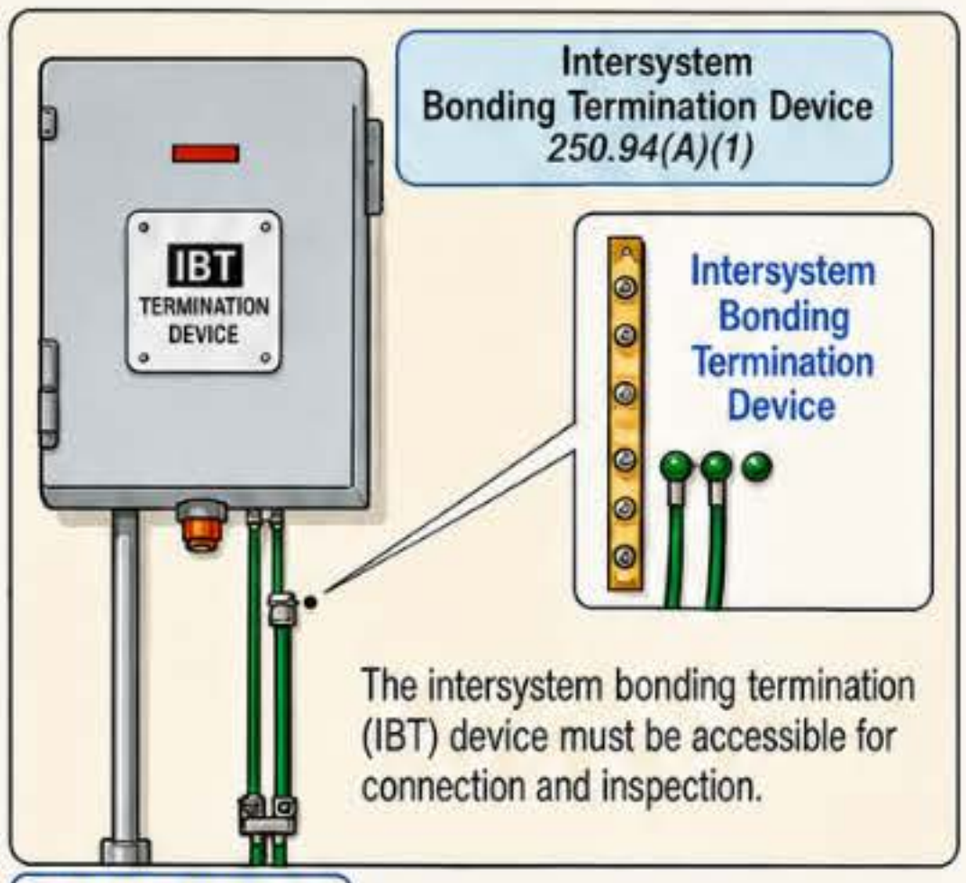


Figure 250–179

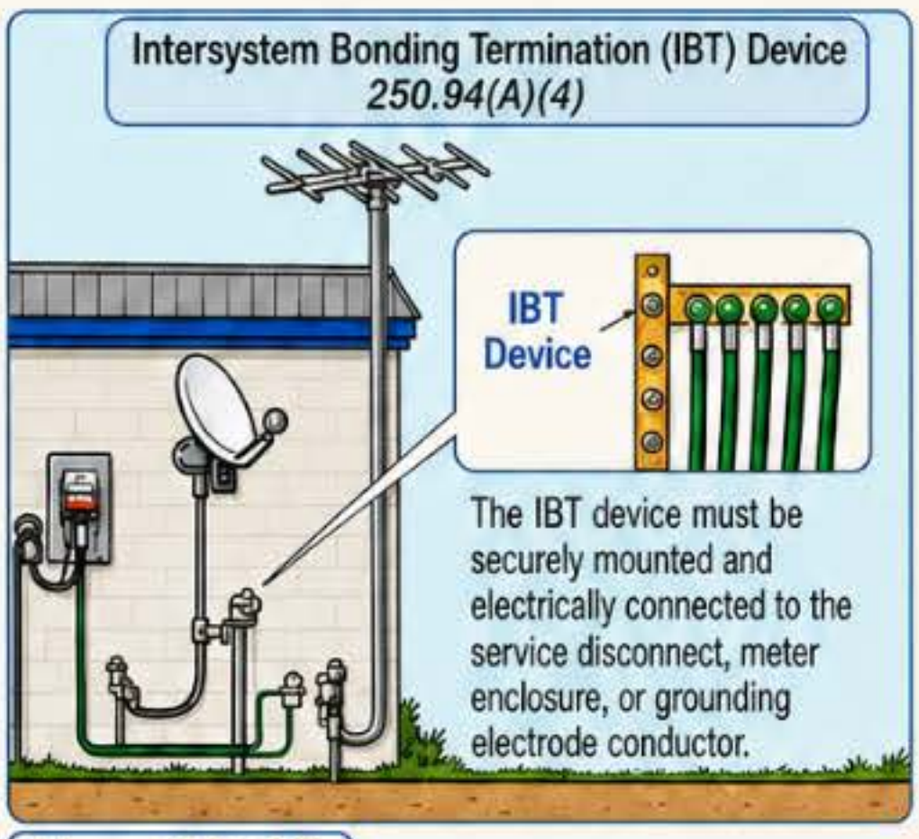


Figure 250–180

(B) Be listed as grounding and bonding equipment.

Author's Commentary:

By definition in Article 100, an "Intersystem Bonding Termination" is the component that provides a means to connect communications systems (twisted pair cable, antennas, and coaxial cable) to the building's grounding electrode system.

— Michael Hamilton

Note 2: *Communications systems (twisted pair cable, antennas, and coaxial cable) must be bonded to the intersystem bonding termination in accordance with the following code requirements:*

- *Antennas/Satellite Dishes [810.15 and 810.21]*
- *CATV [820.100]*

Ex to (A): *An intersystem bonding termination device is not required where communications systems are not likely to be used.*

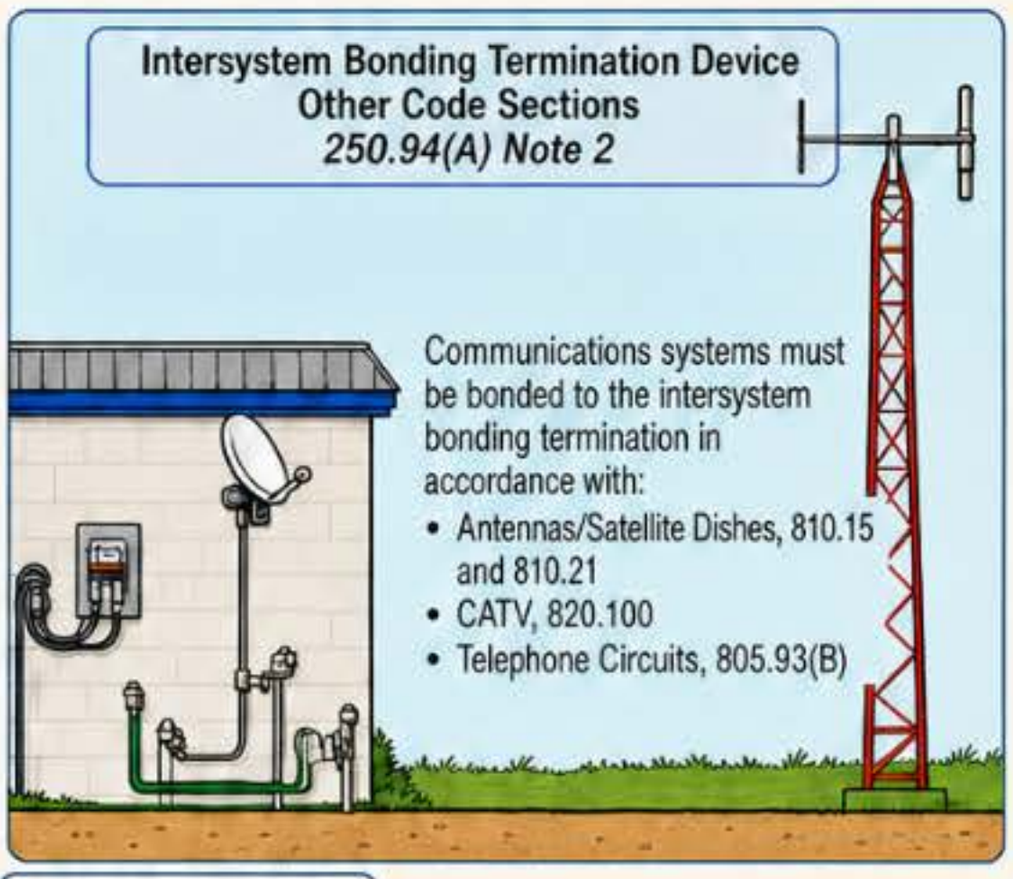


Figure 250–181

250.96 Bonding Other Enclosures

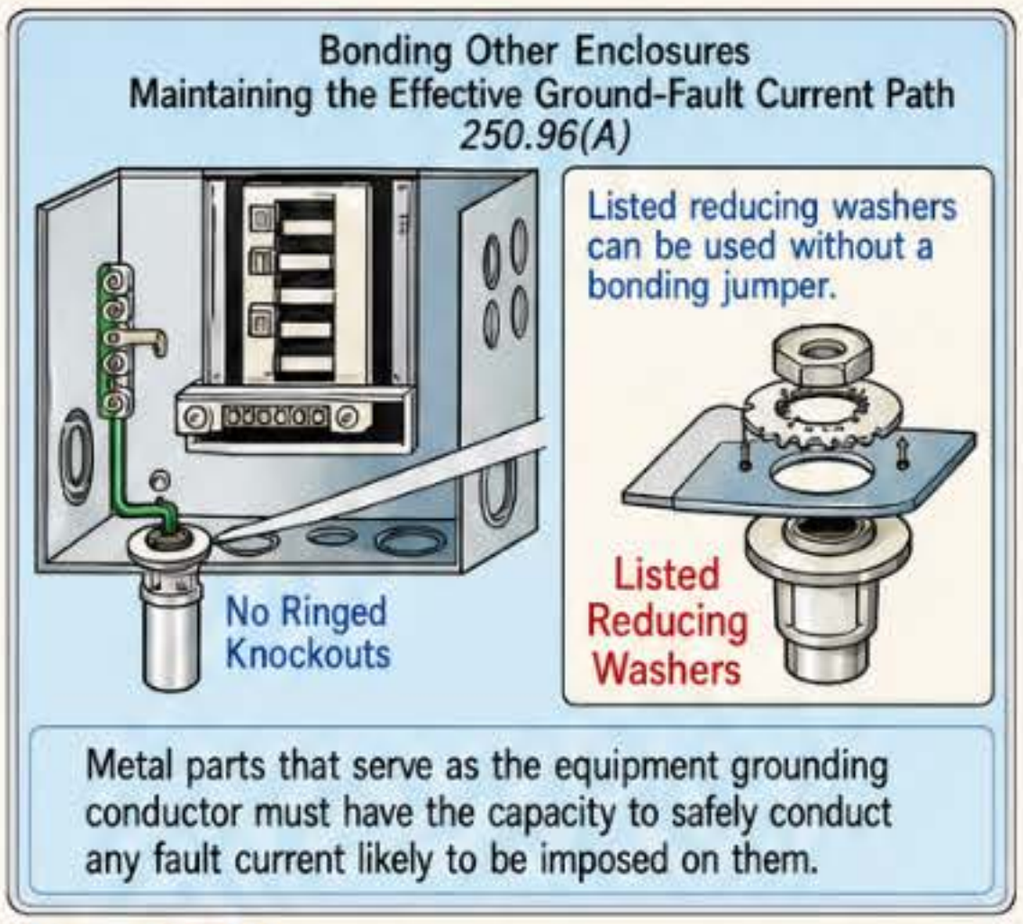
(A) Effective Ground-Fault Current Path. Metal parts intended to serve as equipment grounding conductors — including raceways, cables, equipment, and enclosures — must be bonded together to ensure they have the capacity to safely conduct any fault current likely to be imposed on them [110.10, 250.4(A)(5) and Table 250.122 Note].

Nonconductive coatings such as paint, lacquer, and enamel on equipment must be removed to assure an effective ground-fault current path, or the termination fittings must be designed so such removal is unnecessary [250.12].

Author's Commentary:

Using a locknut along with a screwdriver and pliers is usually adequate to remove paint and other nonconductive finishes to establish a reliable ground-fault current path.

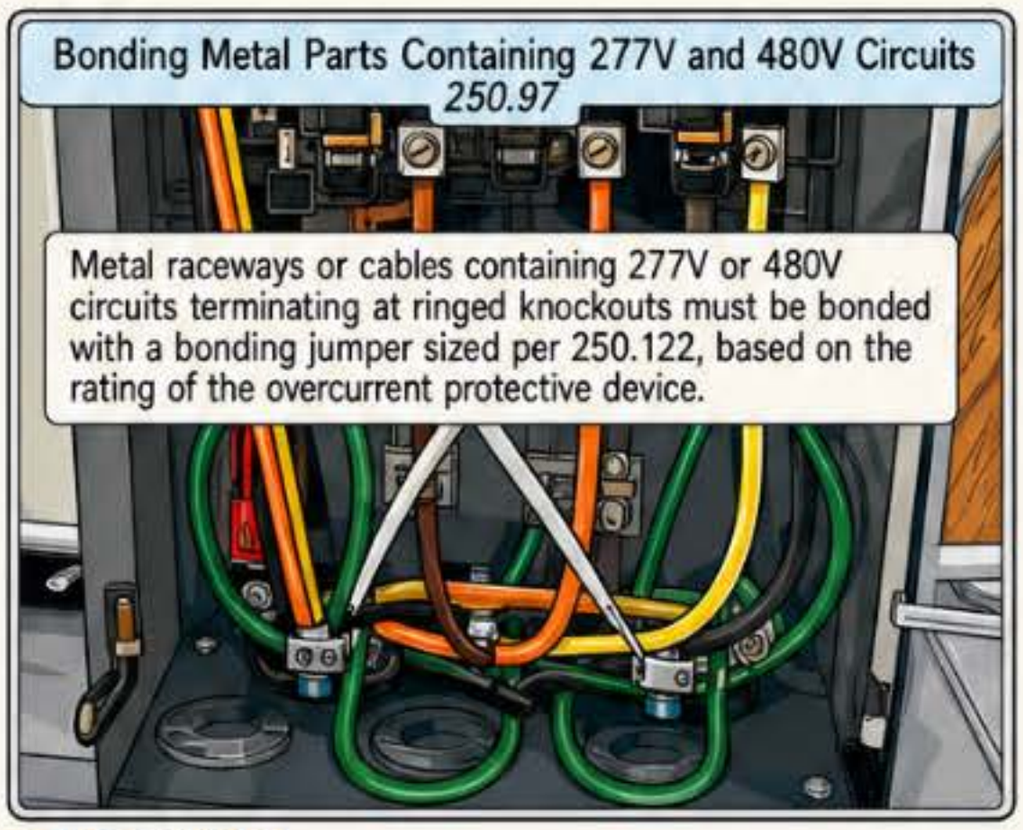
— Michael Hamilton



▶ Figure 250-182

250.97 Bonding Metal Parts Containing 277V and 480V Circuits

Metal raceways or cables containing 277V or 480V circuits terminating at ringed knockouts must be bonded to the metal enclosure with a bonding jumper sized in accordance with 250.122 [250.102(D)]. ▶ Figure 250-183



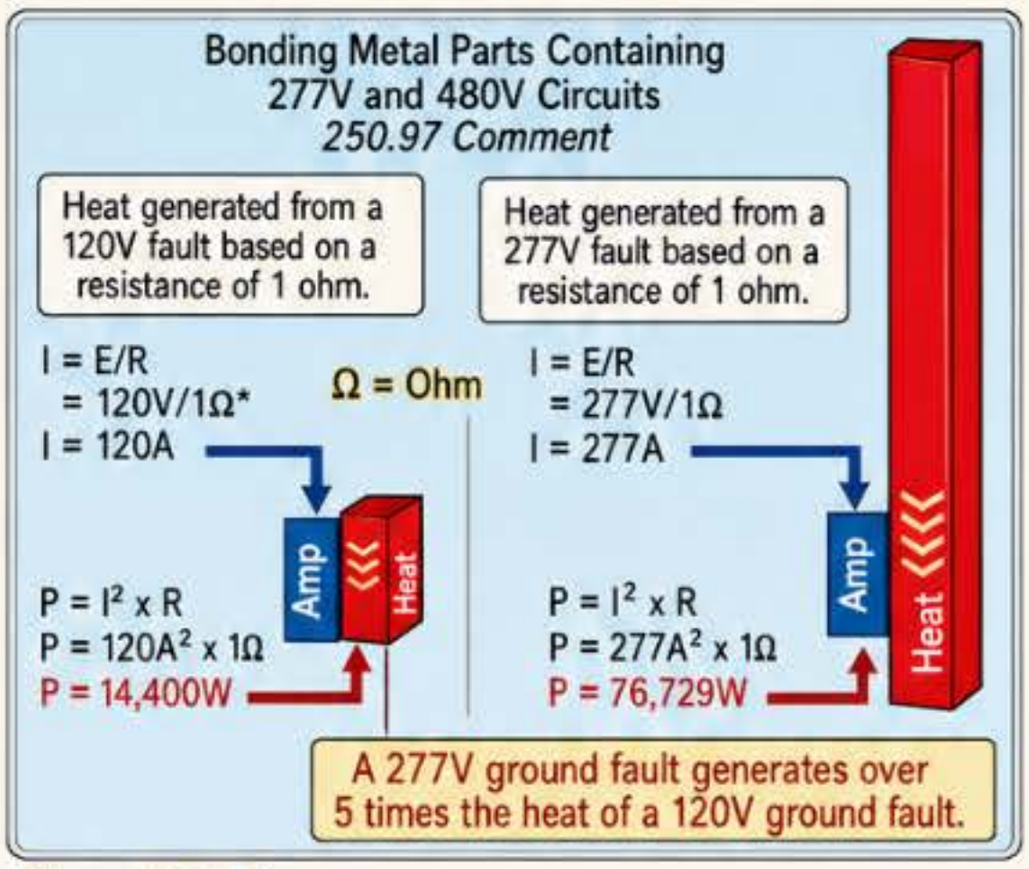
▲ Figure 250-183

Author's Commentary:
Bonding jumpers for raceways and cables containing 277V or 480V circuits are required at ringed knockout terminations to ensure the ground-fault current path has the capacity to safely carry the current.

— Michael Hamilton

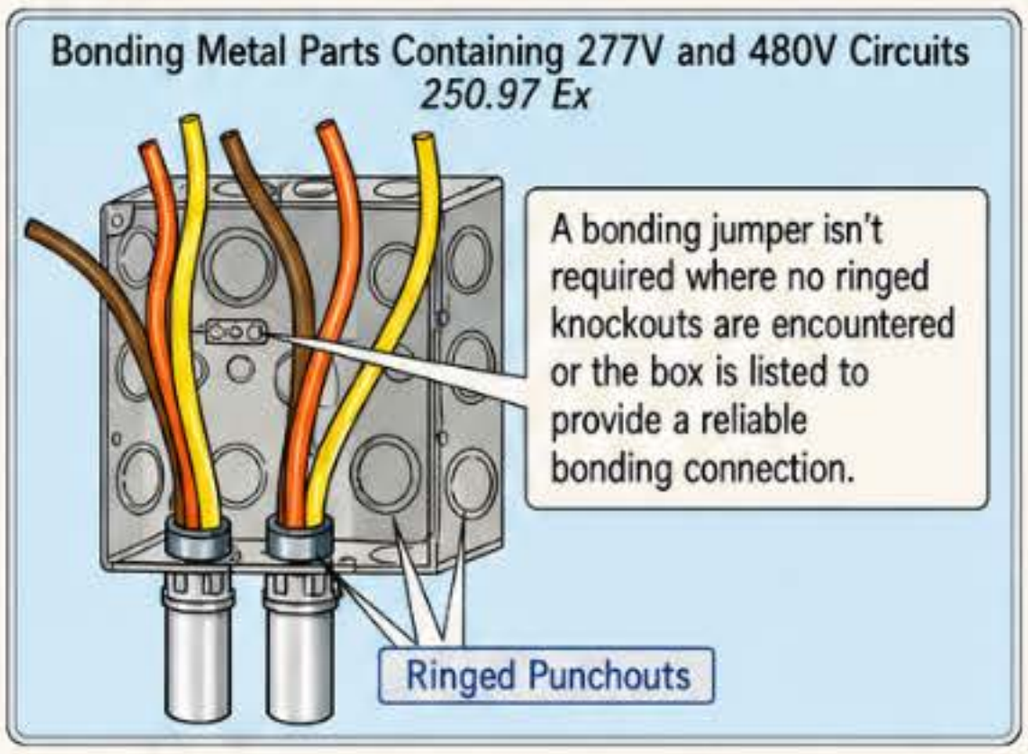
For complete requirements and exceptions, always consult the 2023 National Electrical Code (NEC®).

safiely conduct the maximum ground-fault current likely to be imposed [110.10, 250.4(A)(5) and 250.96(A)]. Ringed knockouts are not listed to withstand the heat generated by a 277V ground fault, which generates five times as much heat as does a 120V ground fault. ▶ Figure 250-184



▶ Figure 250-184

Ex: Where oversized, concentric, or eccentric knockouts are not encountered, or where a box or enclosure with concentric or eccentric knockouts is listed to provide a reliable bonding connection, a bonding jumper is not required if the following methods are used: ▶ Figure 250-185



▲ Figure 250-185

Author's Commentary:
When the enclosure or its knockouts are specifically designed and listed for dependable bonding, the bonding jumper can be omitted as permitted.

— Michael Hamilton

DEFINITIONS | From Michael Hamilton Publications

(1) Metal connectors for metal-sheathed cables

(2) Two locknuts, on rigid metal conduit or intermediate metal conduit, one inside and one outside of boxes and cabinets

(3) Electrical metallic tubing connectors, flexible metal conduit connectors, and cable connectors with one locknut on the inside of boxes and cabinets

(4) Listed fittings

Author's Commentary:
Bonding jumpers rely on dependable mechanical attachments and conductive paths. These components ensure bonds stay continuous even if equipment vibrates or is expanded.
— Michael Hamilton

250.98 Bonding Loosely Jointed Metal Raceways

Expansion, expansion-deflection, or deflection fittings and telescoping sections of metal raceways must be made electrically continuous using equipment bonding jumpers. *Figure 250–186*

Expansion, expansion-deflection, or deflection fittings and telescoping sections of metal raceways must be made electrically continuous by the use of equipment bonding jumpers.

Figure 250–186

250.102 Neutral Conductor, Bonding Conductors, and Bonding Jumpers

(B) Termination. Equipment bonding jumpers must terminate by any of the following means in accordance with 250.8(A):

- Listed pressure connectors
- Terminal bars
- Pressure connectors listed as grounding and bonding equipment
- Exothermic welding
- Machine screw-type fasteners that engage not less than two threads or are secured with a nut

Author's Commentary:
Use only approved terminations and securely tighten fasteners. A solid connection today helps prevent faults and hazards tomorrow.
— Michael Hamilton

- Thread-forming machine screws that engage not less than two threads in the enclosure
- Connections that are part of a listed assembly
- Other listed means

(C) Supply-Side Bonding Jumper Sizing.

(1) Single Raceway or Cable Installations. Supply-side bonding jumpers must be sized in accordance with Table 250.102(C)(1), based on the size/area of the phase conductor within the raceway or cable. *Figure 250–187*

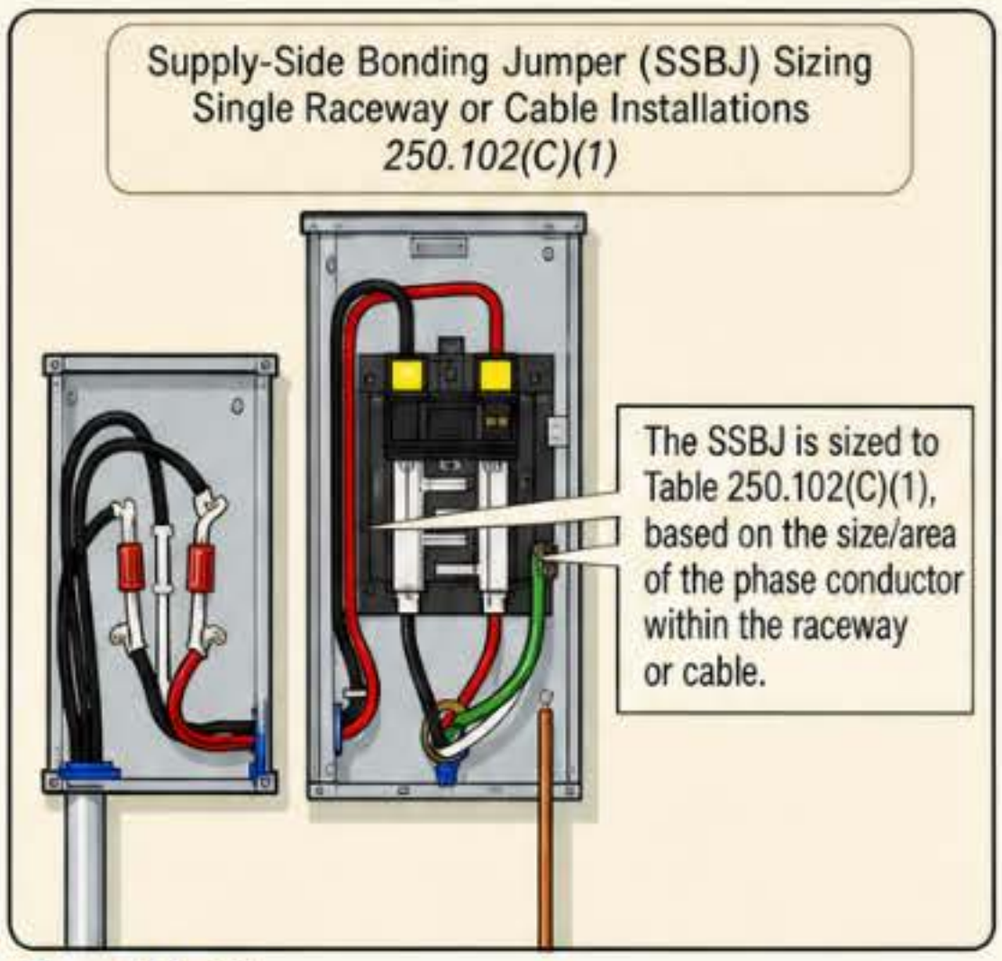


Figure 250–187

(2) Parallel Conductor Installations. If the phase supply conductors are paralleled in two or more raceways or cables, the supply-side bonding jumper for each is sized in accordance with Table 250.102(C)(1), based on the size/area of the phase conductors in each raceway or cable.

Author's Commentary:
Correct sizing of the supply-side bonding jumper ensures the fault current has a low-impedance path. This supports quick clearing of faults and limits equipment damage.
— Michael Hamilton

Table 250.102(C)(1) Neutral Conductor, Main Bonding Jumper, System Bonding Jumper, and Supply-Side Bonding Jumper

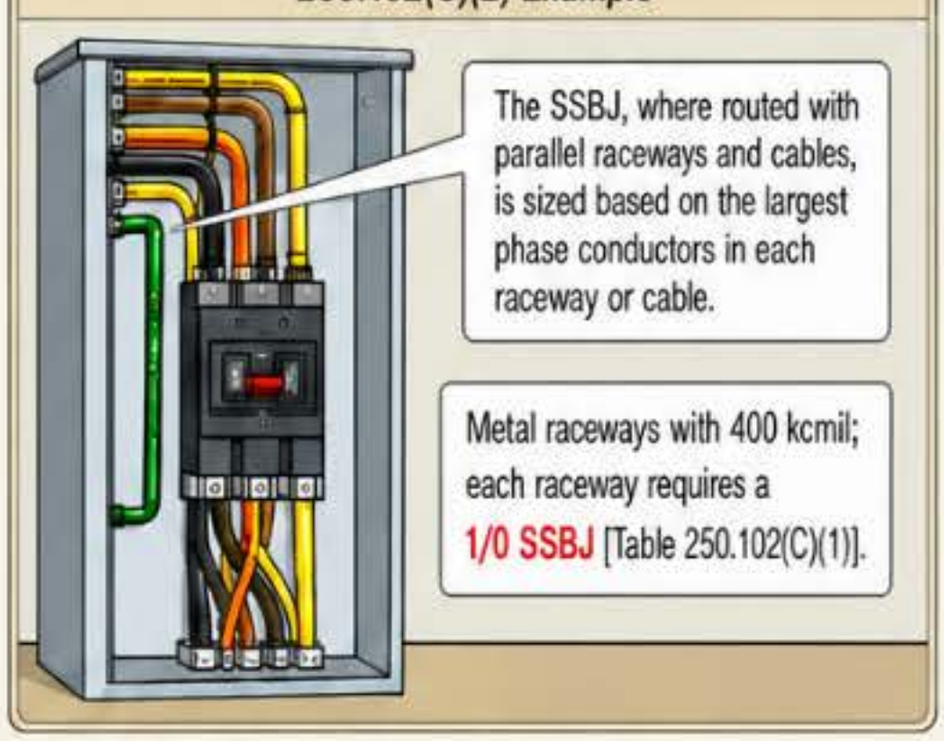
Size of Largest Phase Conductor Per Raceway or Equivalent Area for Parallel Conductors		Size of Bonding Jumper or Neutral Conductor
Copper	Aluminum or Copper-Clad Aluminum	Copper-Aluminum
2 or smaller	1/0 or smaller	8 CU–6 AL
1 or 1/0	2/0 or 3/0	6 CU–4 AL
2/0 or 3/0	Over 3/0 250 kcmil	4 CU–2 AL
Over 3/0–350 kcmil	Over 250–500 kcmil	2 CU–1/0 AL
Over 350–500 kcmil	Over 500–900 kcmil	1/0 CU–3/0 AL
Over 600–1,100 kcmil	Over 900–1,750 kcmil	2/0 CU–4/0 AL
Over 1,100 kcmil	Over 1,750 kcmil	See Notes 1 and 2.

▶ Example

Question: *What size supply-side bonding jumper is required for each of three metal raceways, each of which contain 400 kcmil service conductors?* ▶ Figure 250–188

(a) 4 AWG (b) 2 AWG (c) 1 AWG (d) 1/0 AWG

Supply-Side Bonding Jumper (SSBJ) Sizing
Parallel Conductor Installation
250.102(C)(2) Example



▶ Figure 250–188

Solution:

A 1/0 AWG supply-side bonding jumper is required for each raceway [250.102(C)(2) and Table 250.102(C)(1)]. A single supply-side bonding jumper is permitted for multiple raceways based on the equivalent area of the supply side phase conductors.

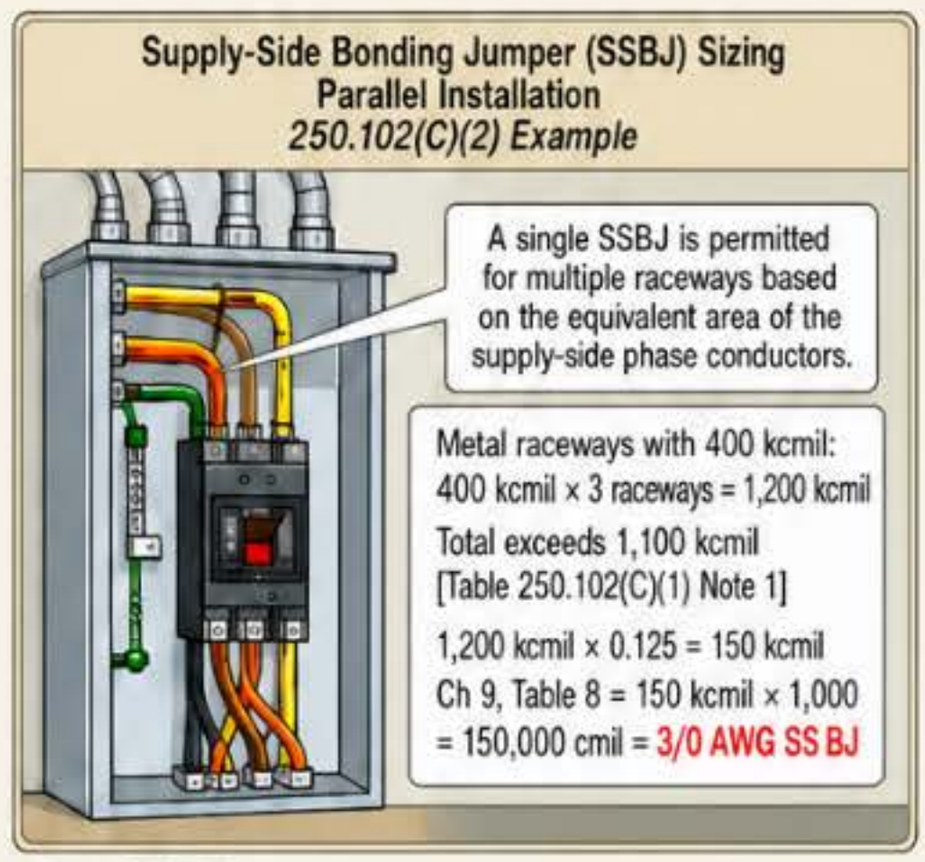
Answer: *(a) 1/0 AWG*

▶ Example

Question: *What size single supply-side bonding jumper is required for all three metal raceways, each of which contain 400 kcmil service conductors?* ▶ Figure 250–189

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

Supply-Side Bonding Jumper (SSBJ) Sizing
Parallel Installation
250.102(C)(2) Example



▶ Figure 250–189

Solution:

A single 3/0 AWG supply-side bonding jumper is required if using one conductor for all three raceways.

400 kcmil × 3 raceways = 1,200 kcmil which exceeds 1,100 kcmil [Table 250.102(C)(1) Note 1]

Conductor kcmil at 12½% = 1,200 kcmil × 0.125

Convert kcmil to cmil = 150 kcmil × 1,000

Total bonding jumper cmil = 150,000 cmil

Use a 3/0 AWG supply-side bonding jumper [Chapter 9, Table 8].

Answer: *(c) 3/0 AWG*

250.104 Bonding of Piping Systems and Exposed Structural Metal

Note 1: The expression "supply conductors" covers phase conductors that do not have overcurrent protection on *their supply side and that also end at the service disconnect or at the first disconnect of a separately derived system.*

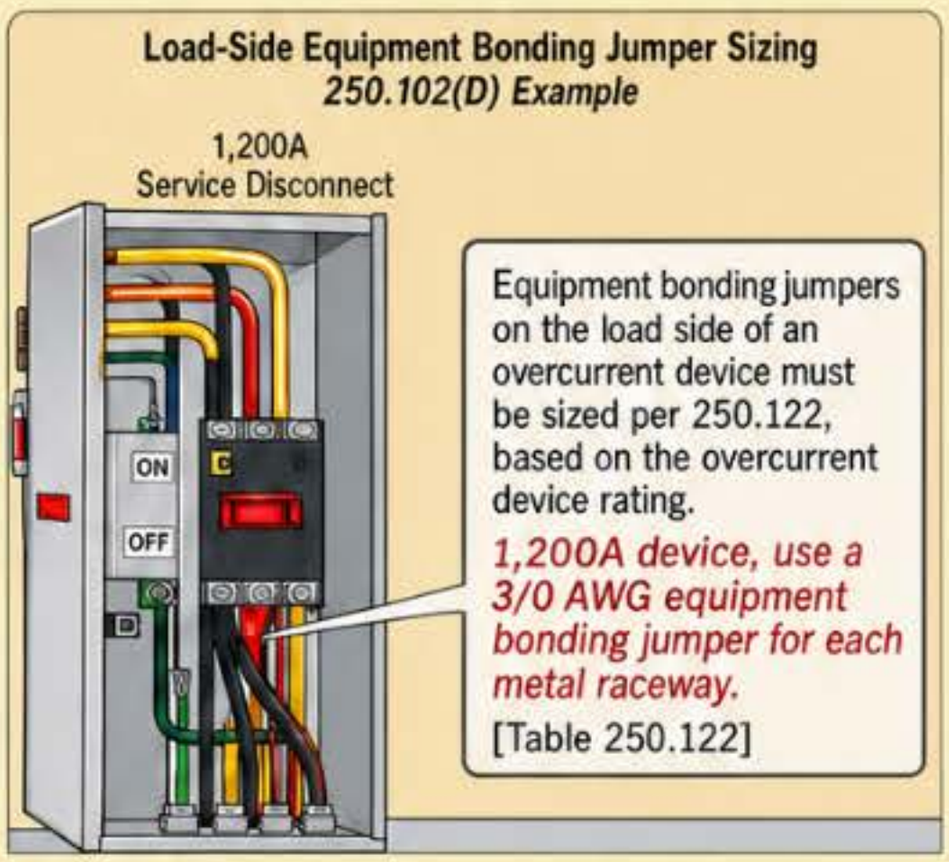
Note 2: Refer to Chapter 9, Table 8 for the circular mil area of conductors 18 AWG through 4/0 AWG.

(D) Load-Side Bonding Jumper Sizing. Bonding jumpers *on the load side of feeder and branch-circuit overcurrent devices are sized in accordance with 250.122.*

▶ Example

Question: *What size equipment bonding jumper is required for each metal raceway where the circuit conductors are protected by a 1,200A overcurrent protective device?* Figure 250–190

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG



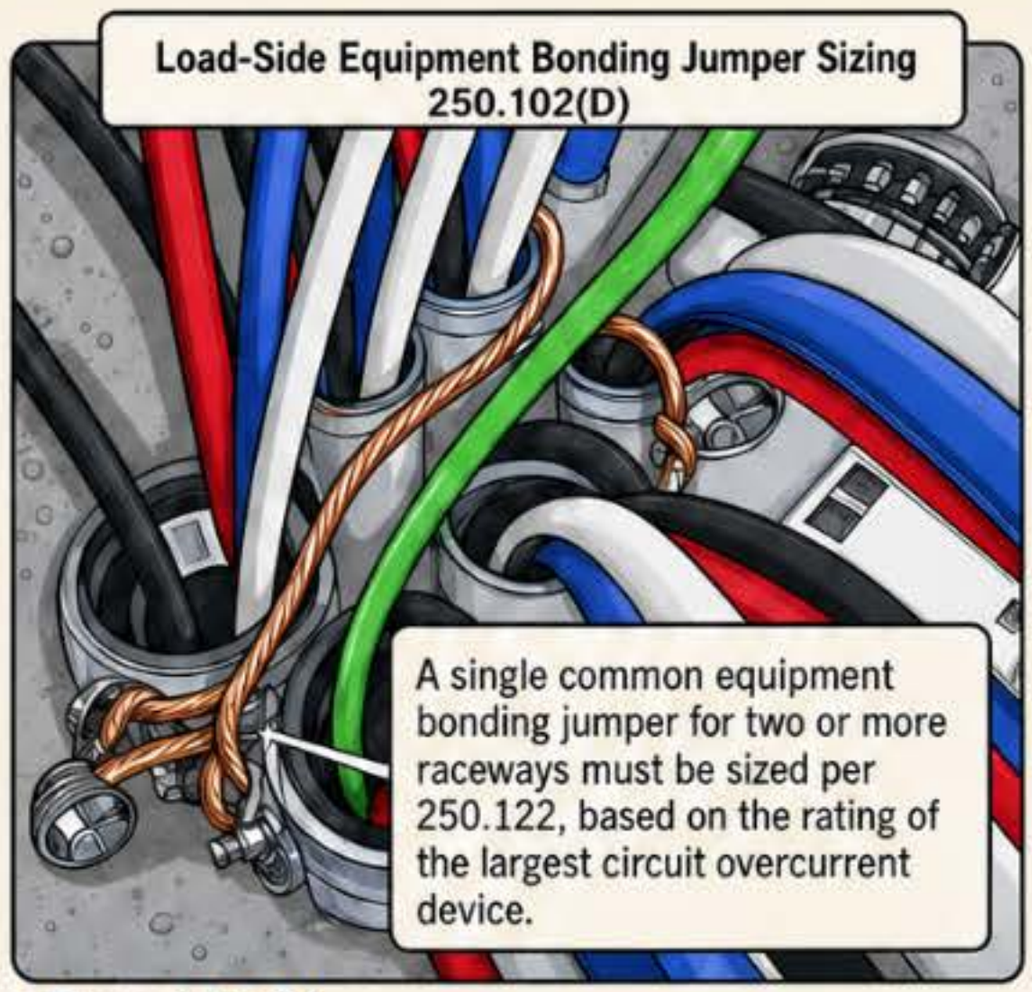
▸ Figure 250–190

Answer: *(c) 3/0 AWG [Table 250.122]*

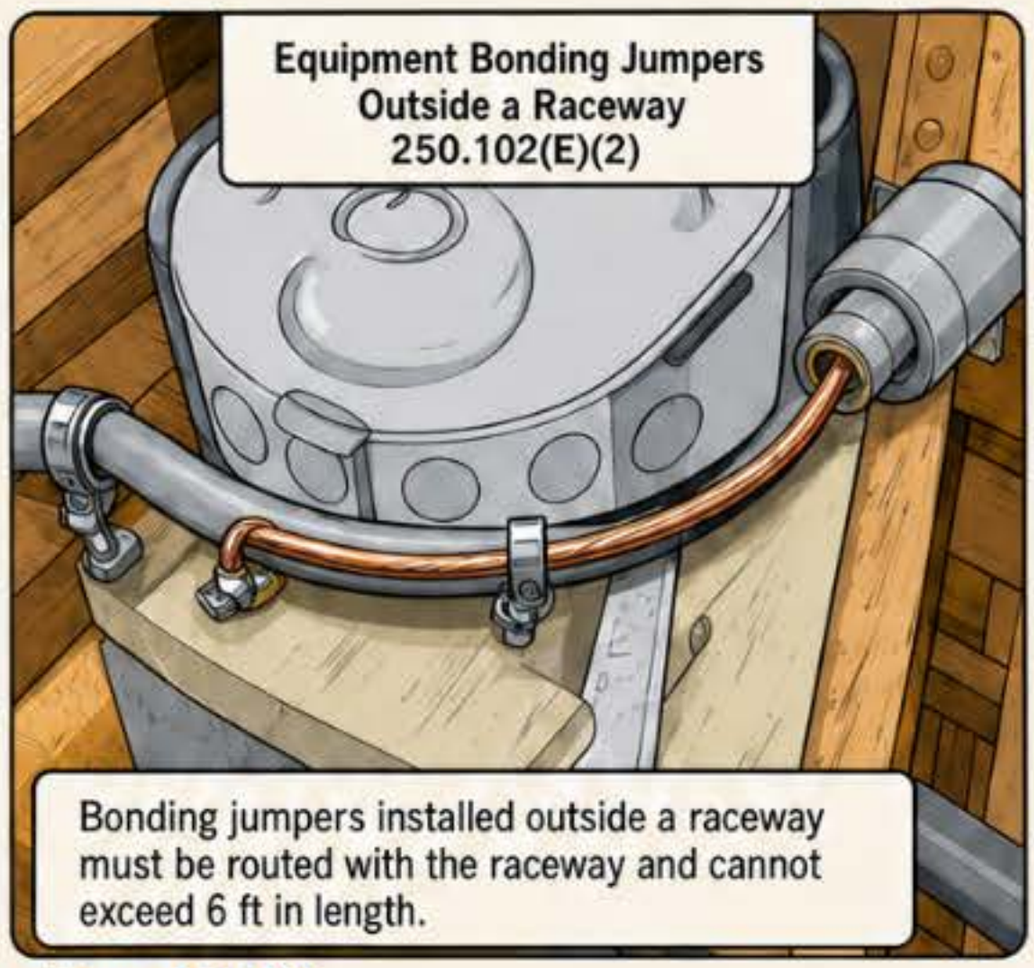
If a single bonding jumper is used to bond two or more metal raceways, it must be sized in accordance with 250.122, *based on the rating of the largest circuit overcurrent protective device.* ▸ Figure 250–191

(E) Installation of Bonding Jumpers. *Bonding jumpers can be installed inside or outside of a raceway or an enclosure.*

(2) Outside a Raceway. Bonding jumpers installed outside *a raceway must be routed with the raceway and the conductor cannot exceed 6 ft in length.* ▸ Figure 250–192



○ Figure 250–191



○ Figure 250–192

250.104 Bonding of Piping Systems and Exposed Structural Metal

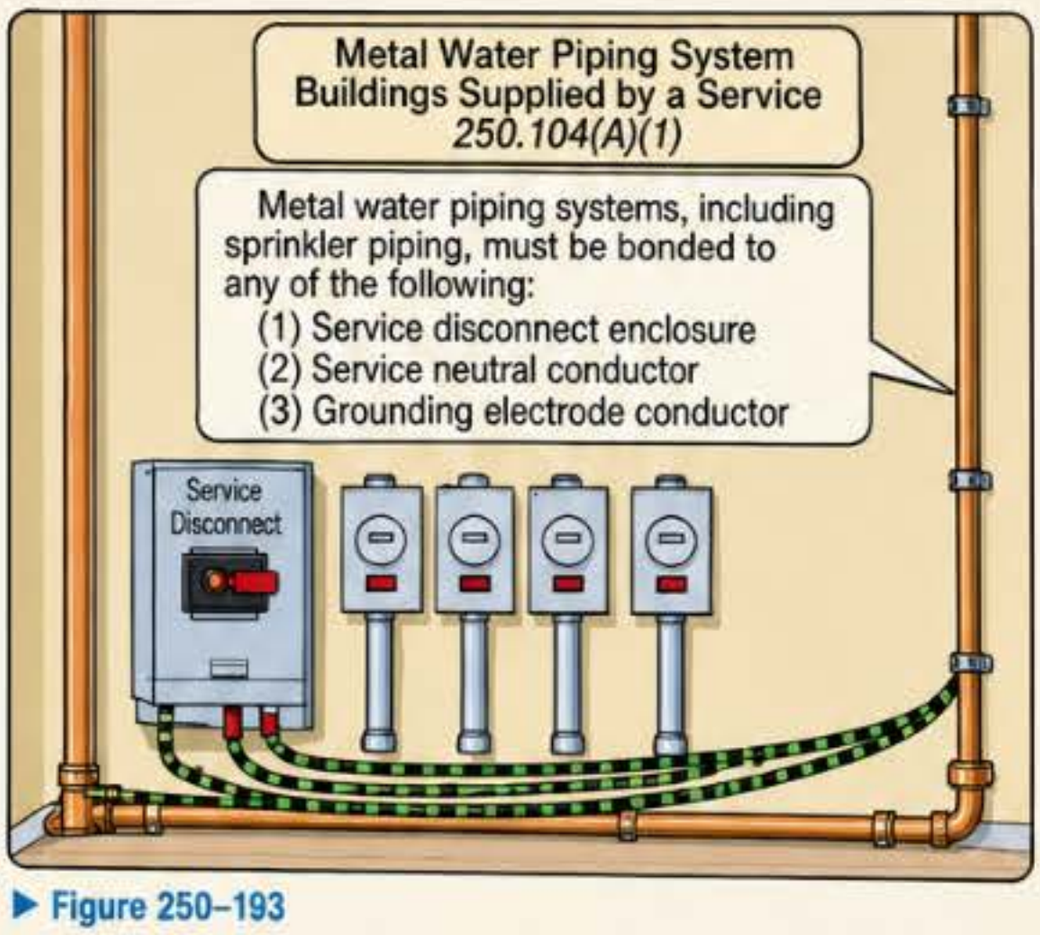
(A) Metal Water Piping System. Electrically continuous metal water piping systems, including sprinkler piping, must be *bonded in accordance with 250.104(A)(1), (A)(2), or (A)(3).*

(1) Buildings Supplied by a Service. Electrically continuous metal water piping must be bonded to any one of the following: ▸ Figure 250–193

(1) Service-disconnect enclosure,

(2) Service neutral conductor,

250.104 | Grounding and Bonding



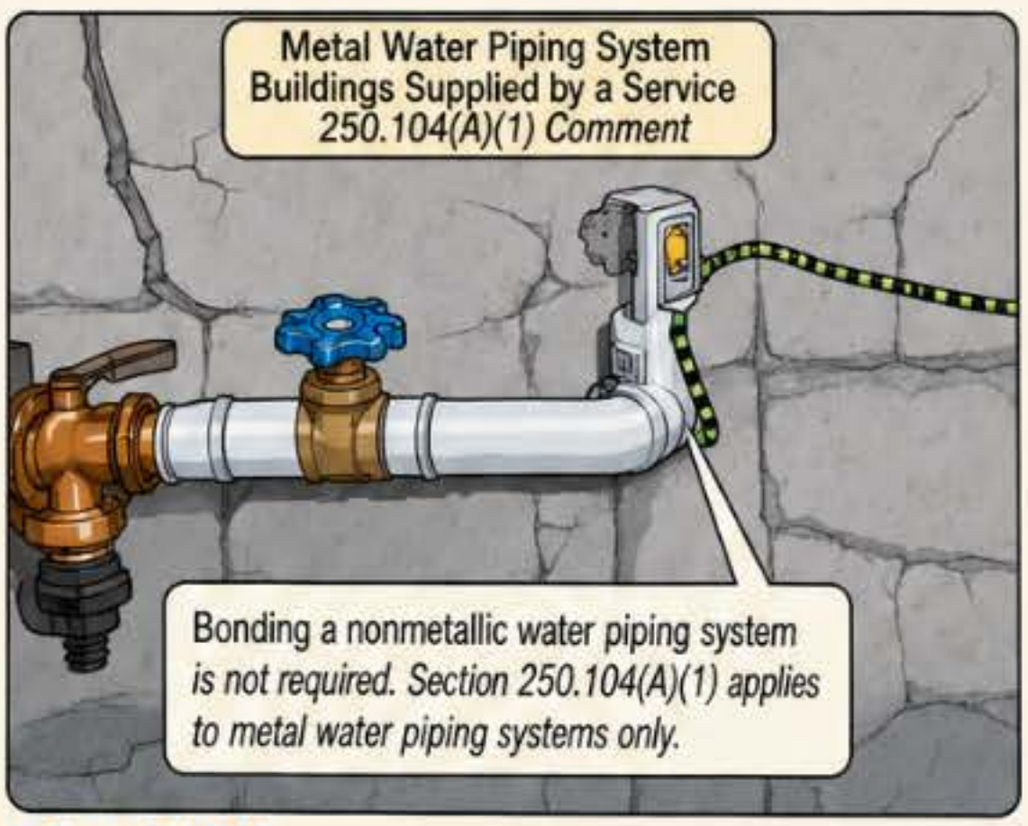
▶ Figure 250–193

(3) Grounding electrode conductor if of sufficient size, or

(4) One of the grounding electrodes of the grounding electrode system if the grounding electrode conductor or bonding jumper to the electrode is of sufficient size.

Author's Commentary:
The purpose of this rule is to eliminate hazardous voltage that could appear on metal parts of a grounding fault in either electrically conductive metal water piping systems or sprinkler piping.

— Michael Hamilton



▶ Figure 250–194

The metal piping system bonding jumper must be copper where within 18 in. of the surface of earth [250.64(A)], must be adequately protected if exposed to physical damage [250.64(B)], and points of attachment must be accessible.

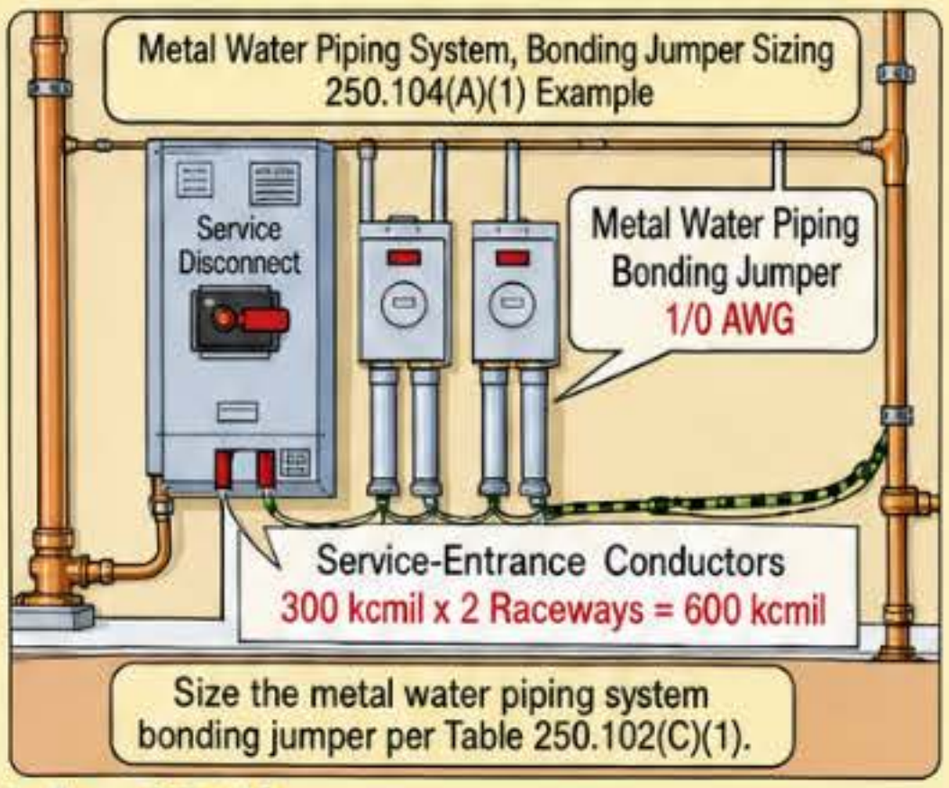
A ferrous metal raceway containing a grounding electrode conductor must be made electrically continuous by bonding each end of the raceway to the grounding electrode conductor [250.64(E)].

Metal water piping system bonding jumpers must be sized in accordance with Table 250.102(C)(1), based on the size/area of the service phase conductors and not required to be larger than 3/0 copper or 250 kcmil aluminum or copper-clad aluminum, except as permitted in 250.104(A)(2) and (A)(3).

▶ Example

Question: *What size bonding jumper is required for a metal water piping system if the 300 kcmil service conductors are paralleled in two raceways?* ▶ Figure 250–195

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG



▶ Figure 250–195

Solution:

A 1/0 AWG bonding jumper is required based on 600 kcmil conductors (300 kcmil × 2 raceways) [250.102(C)(1)].

Answer: *(a) 1/0 AWG*

Author's Commentary:
If a metal water piping system has hot or cold water pipes that are electrically connected, only one bonding jumper is needed; it may be attached to either the cold or hot water pipe.

— Michael Hamilton

Grounding and Bonding

- Bonding is not needed for isolated portions of metal water piping that are connected to a nonmetallic (plastic) water piping system. In reality, these isolated sections of metal piping need not be bonded since they cannot develop a hazardous shock under typical conditions. Figure 250–196

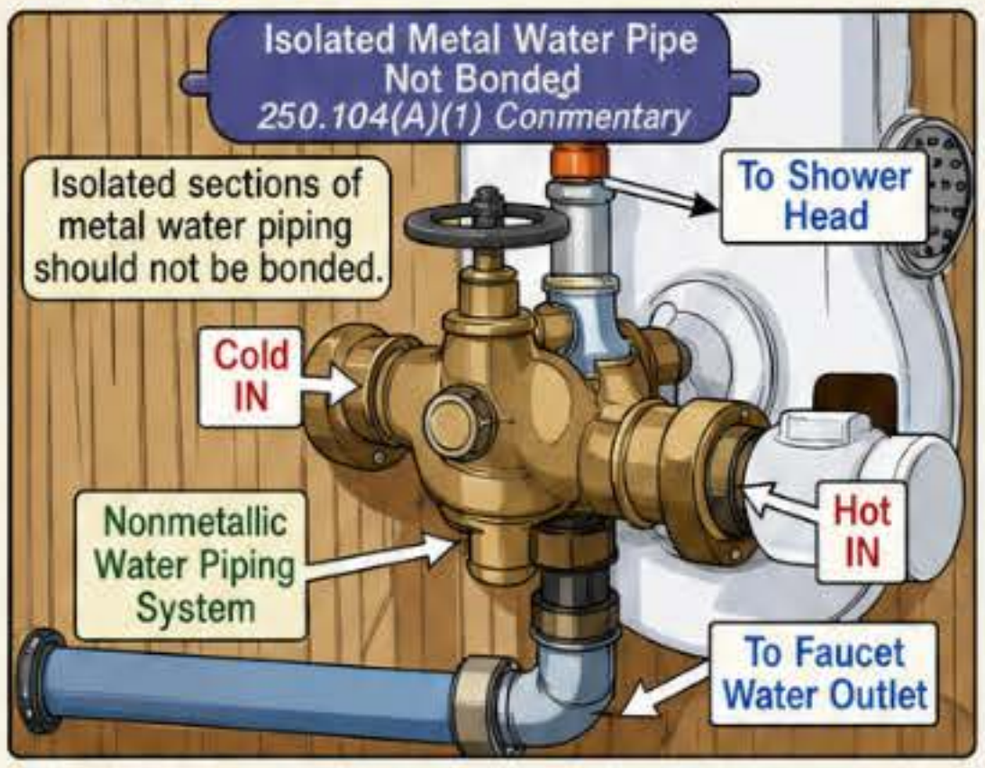


Figure 250–196

(2) Bonding Multiple Occupancy Buildings. If an electrically continuous metal water piping system serves a single dwelling unit in a multi-occupancy building, the metallic water piping within that unit may be bonded to the equipment grounding terminal of the unit's switchgear, switchboard, or panelboard. Size the bonding jumper based on the rating of the circuit overcurrent protective device as required by 250.122 [250.102(D)]. Figure 250–197

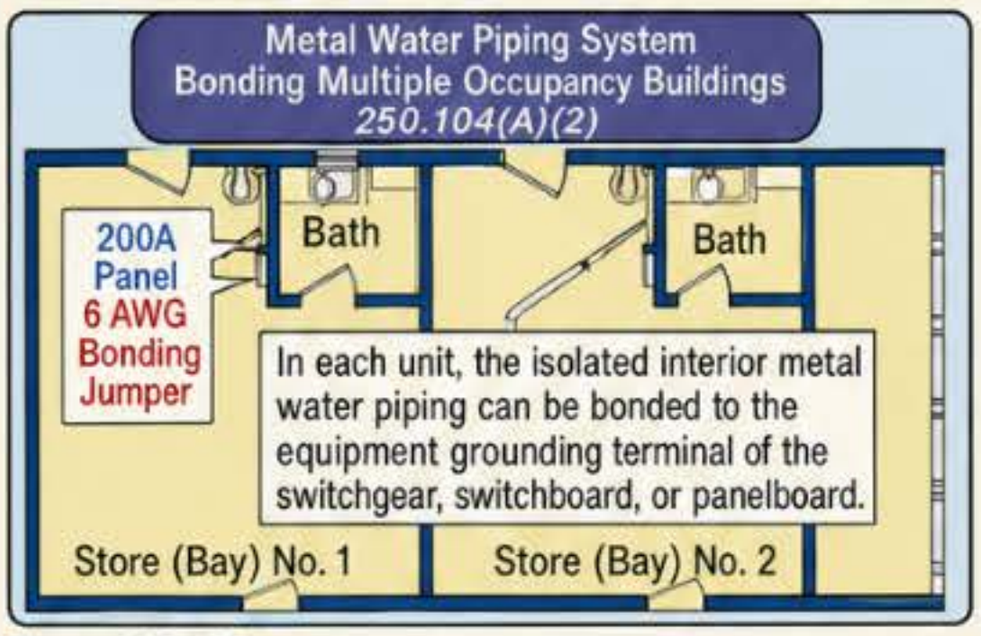


Figure 250–197

The bonding jumper connecting the metal water piping system must be sized according to the feeder overcurrent protective device rating per 250.122 [250.102(D)].

(3) Buildings Supplied by a Feeder. The metal water piping system in a structure supplied by a feeder must be bonded to one of the following:

(1) The equipment grounding terminal of the building's disconnect enclosure,

(2) The feeder equipment grounding conductor, or

(3) One of the building's grounding electrodes if the grounding electrode or bonding jumper to the electrode is of sufficient size.

The bonding jumper must be sized in accordance with 250.102(D) and is not required to be larger than the largest feeder phase or branch-circuit conductor supplying the building.

(B) Bonding Other Metal-Piping Systems. Metal-piping systems in or attached to a building must be bonded when it is connected to an appliance that is connected to the circuit equipment grounding conductor.

Figure 250–198

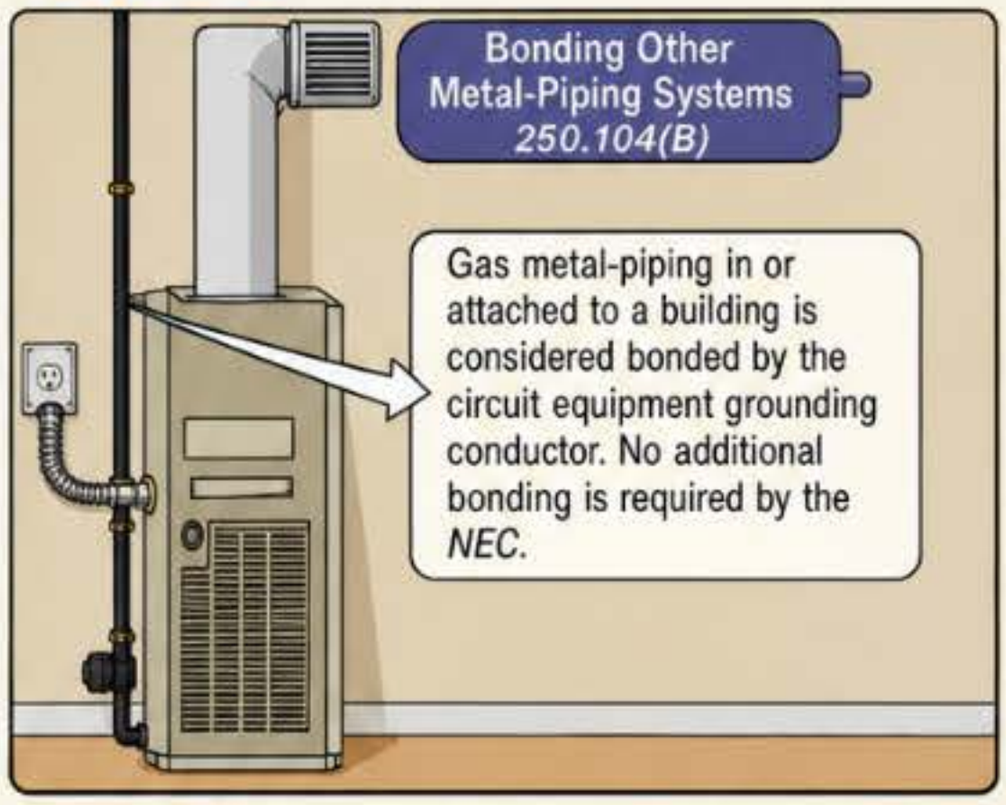


Figure 250–198

Note 1: Bonding piping and metal air ducts within the building adds extra safety, but this is not required by the *NEC*. Figure 250–199

Note 2: For additional information on gas piping systems, see NFPA 54, *National Fuel Gas Code*, and NFPA 780, *Standard for the Installation of Lightning Protection Systems.* Figure 250–200

(C) Bonding Exposed Structural Metal. Exposed structural metal that is interconnected to form a metal building frame must be bonded to any of the following: Figure 250–201

Author's Commentary:
The purpose of bonding is to ensure that all metal parts remain at the same electrical potential. This helps prevent dangerous shock hazards in the event of a fault.

— Michael Hamilton

250.104 | Grounding and Bonding

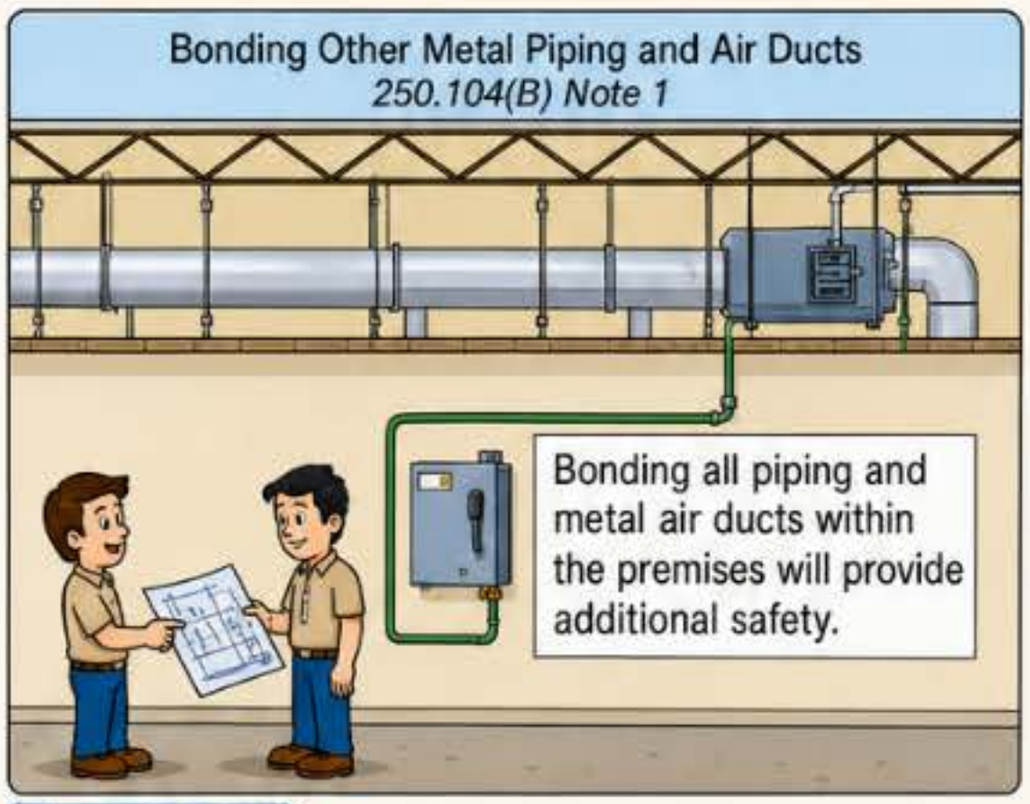


Figure 250–199

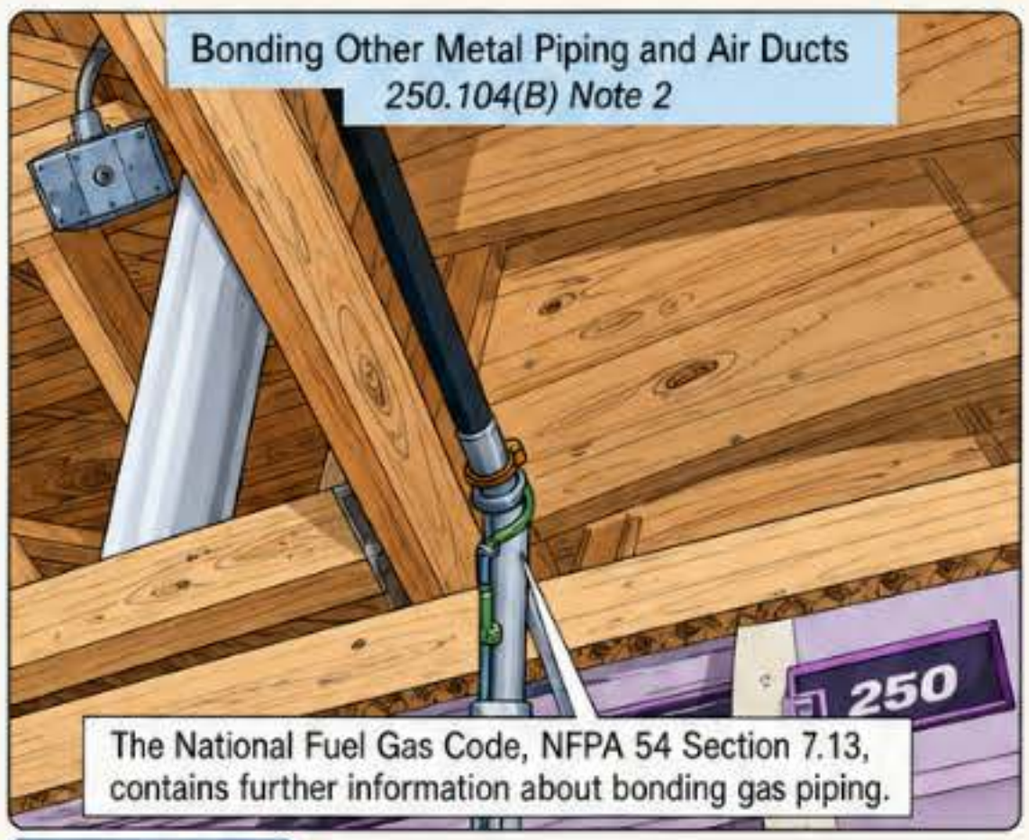


Figure 250–200

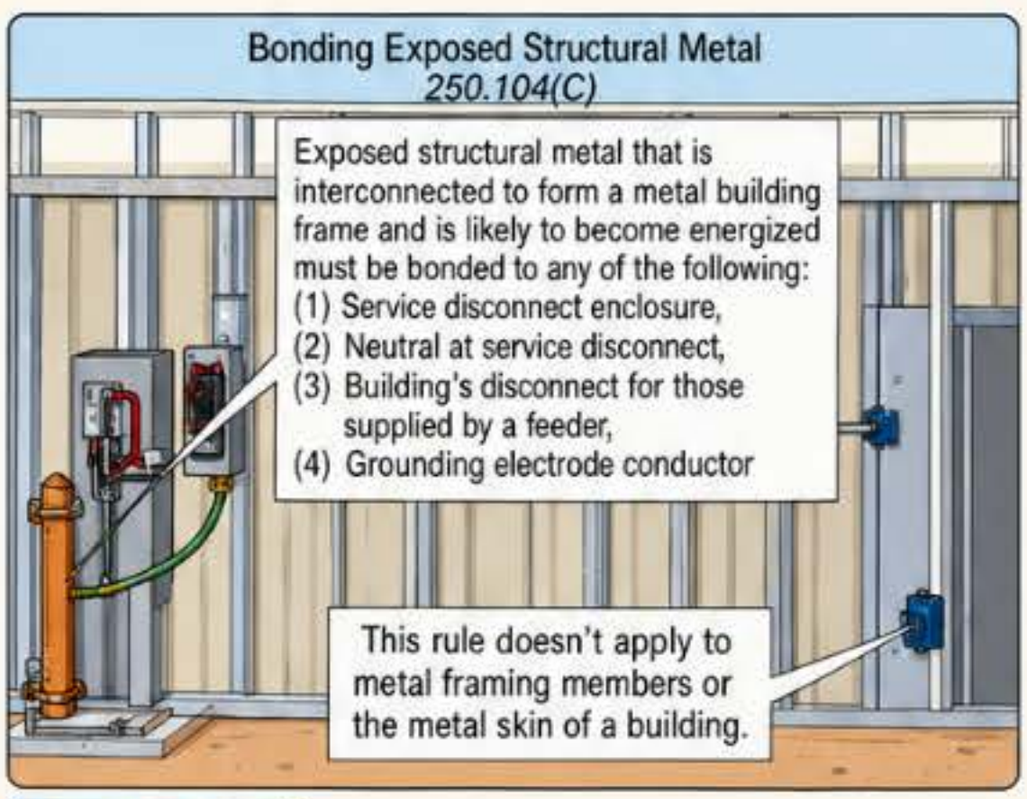


Figure 250–201

(1) The service-disconnect enclosure,

(2) The neutral at the service disconnect,

(3) The building's disconnect enclosure for those supplied by a feeder,

(4) The grounding electrode conductor where of sufficient size, or

(5) One of the grounding electrodes of the grounding electrode system if the grounding electrode conductor or bonding jumper to the electrode is of sufficient size.

The structural metal bonding conductor must be sized in accordance with Table 250.102(C)(1), based on the size/area of the supply phase conductors and is not required to be larger than 3/0 copper or 250 kcmil aluminum or copper-clad aluminum. The bonding jumper must be copper where within 18 in. of the surface of the Earth [250.64(A)], be securely fastened to the surface on which it is carried [250.64(B)] and be adequately protected if exposed to physical damage [250.64(B)]. In addition, all points of attachment must be accessible, except as permitted in 250.68(A) Ex 1 and 2.

(D) Transformers. Metal water piping systems and structural metal that is interconnected to form a building frame must be bonded to the transformer secondary winding in accordance with 250.104(D)(1) through (D)(3).

(1) Bonding Metal Water Pipe. Metal water piping systems located in the area served by a transformer must be bonded to the secondary neutral conductor where the grounding electrode conductor is connected at the transformer. ▶Figure 250–202

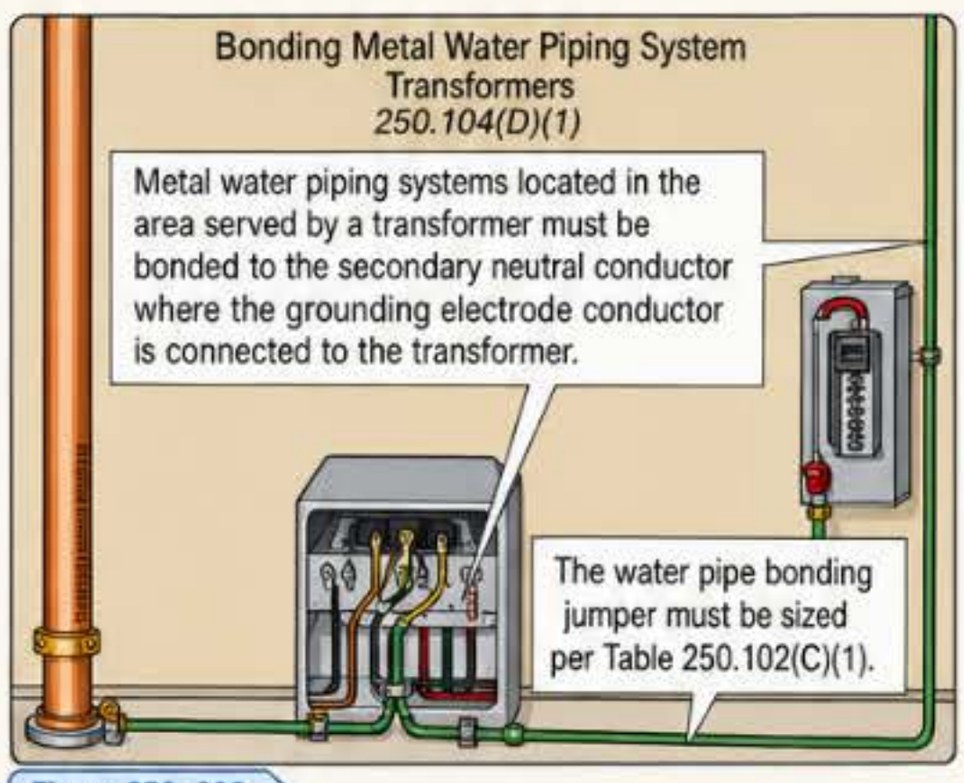
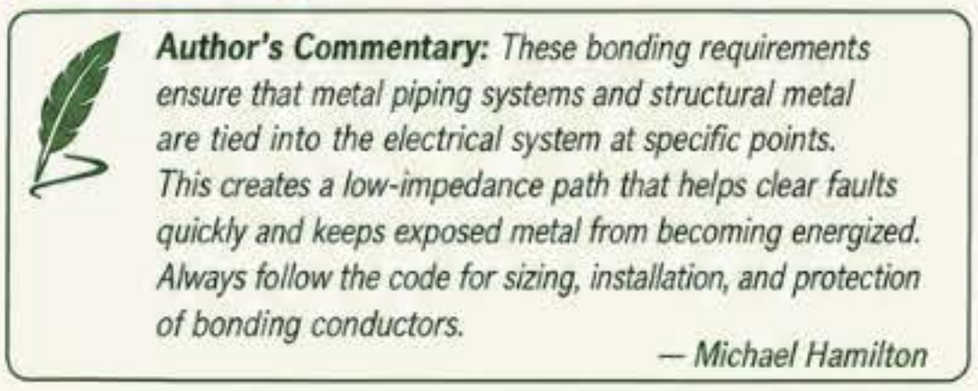


Figure 250–202



Author's Commentary: *These bonding requirements ensure that metal piping systems and structural metal are tied into the electrical system at specific points. This creates a low-impedance path that helps clear faults quickly and keeps exposed metal from becoming energized. Always follow the code for sizing, installation, and protection of bonding conductors.*

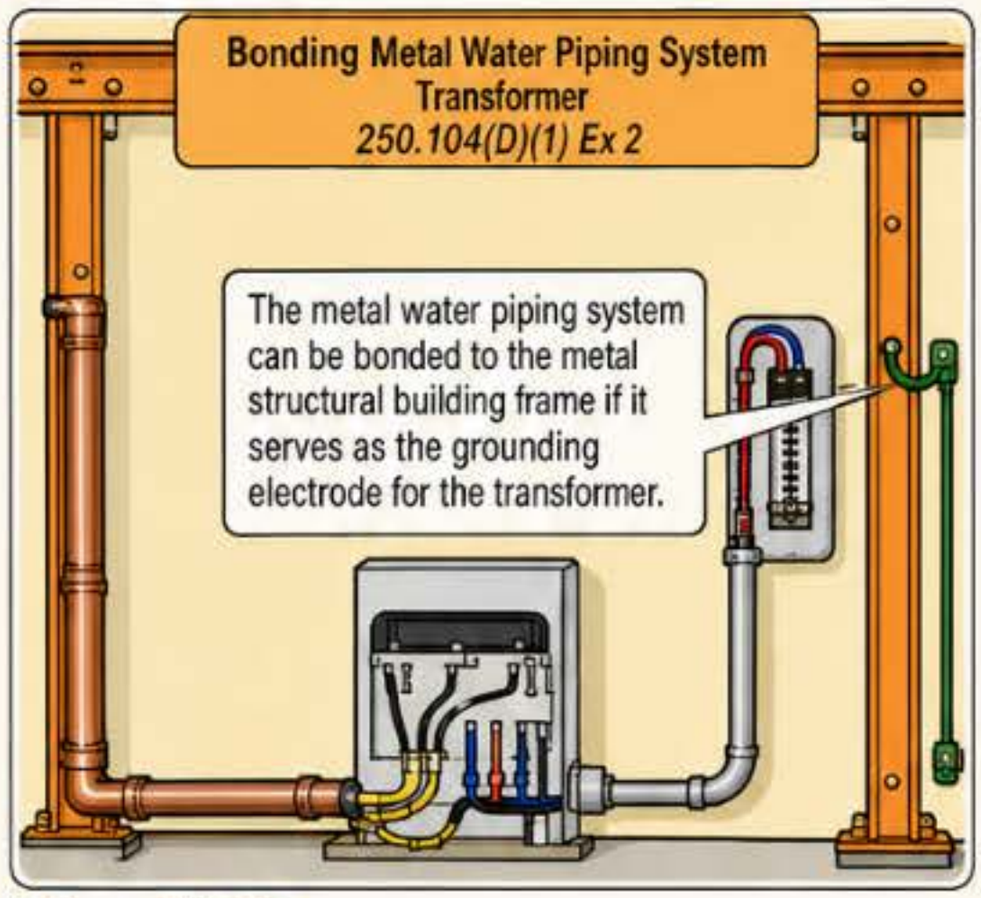
— Michael Hamilton

Grounding and Bonding

The bonding jumper must be sized in accordance with Table 250.102(C)(1), based on the size/area of the secondary phase conductors and is not be required to be larger than 3/0 copper or 250 kcmil aluminum or copper-clad aluminum.

Ex 2: *The metal water piping system can be bonded to the metal structural building frame if it serves as the grounding electrode [250.52(A)(2)] for the transformer.*

▶ *Figure 250-203*

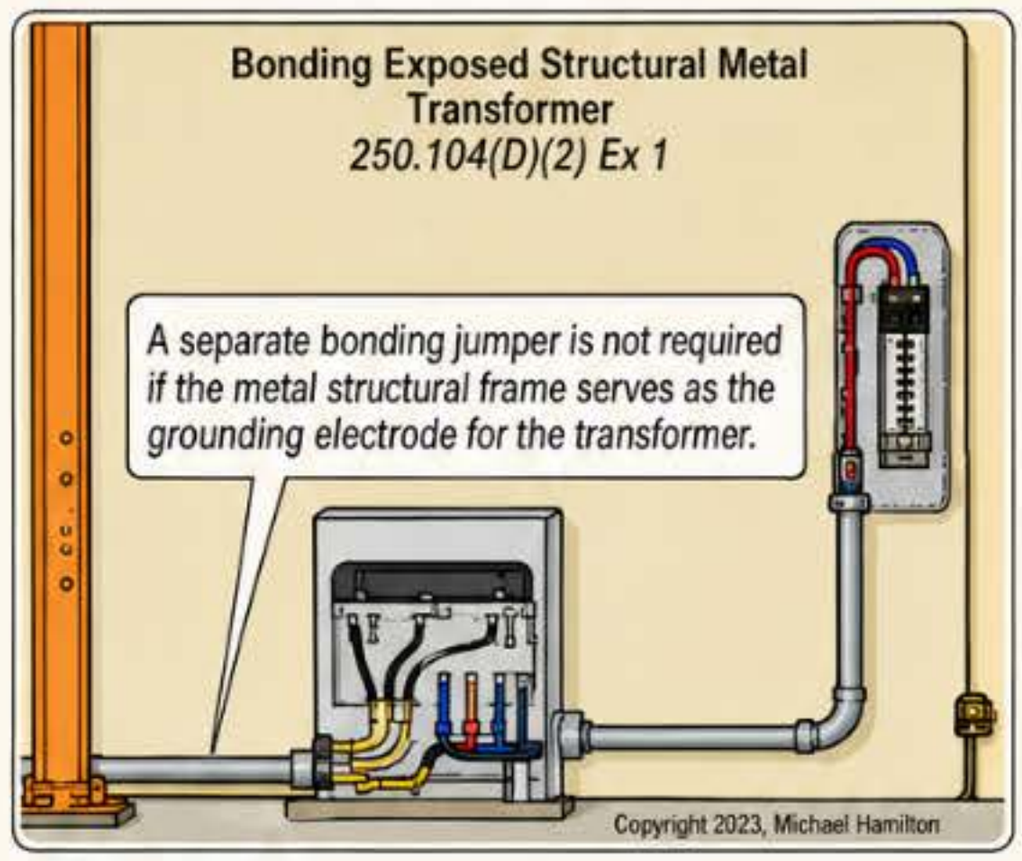


▶ *Figure 250-203*

(2) Bonding Exposed Structural Metal. Exposed structural metal that is interconnected to form the building frame located in the area served by a transformer must be bonded to the secondary neutral conductor where the grounding electrode conductor is connected at the transformer.

The bonding jumper must be sized in accordance with Table 250.102(C)(1), based on the size/area of the secondary phase conductors and is not be required to be larger than 3/0 copper or 250 kcmil aluminum or copper-clad aluminum.

Ex 1: *Bonding to the transformer is not required if the metal structural frame serves as the grounding electrode [250.52(A)(2)] for the transformer.* ▶ *Figure 250-204*

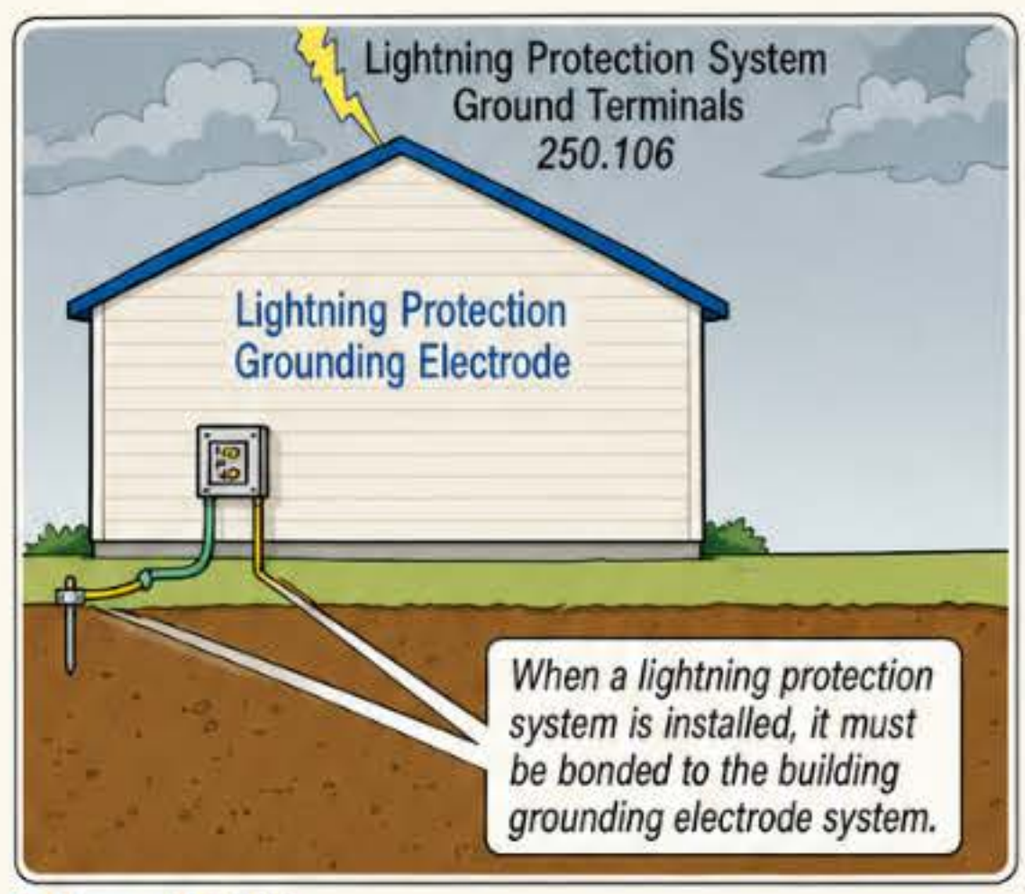


▶ *Figure 250-204*

250.106 Lightning Protection Systems

When a lightning protection system is installed in accordance with *NFPA 780, Standard for the Installation of Lightning Protection Systems*, the lightning protection electrode system must be bonded to the building grounding electrode system.

▶ *Figure 250-205*



▶ *Figure 250-205*

Note 1: *See NFPA 780, Standard for the Installation of Lightning Protection Systems, which contains detailed information on grounding, bonding, and side-flash distances from lightning protection systems.*

Note 2: *To minimize the likelihood of arcing between metal parts due to induced voltage, metal raceways, enclosures, and other metal parts of electrical equipment may require bonding or spacing from the lightning protection conductors in accordance with NFPA 780, Standard for the Installation of Lightning Protection Systems.* ▶ *Figure 250-206*

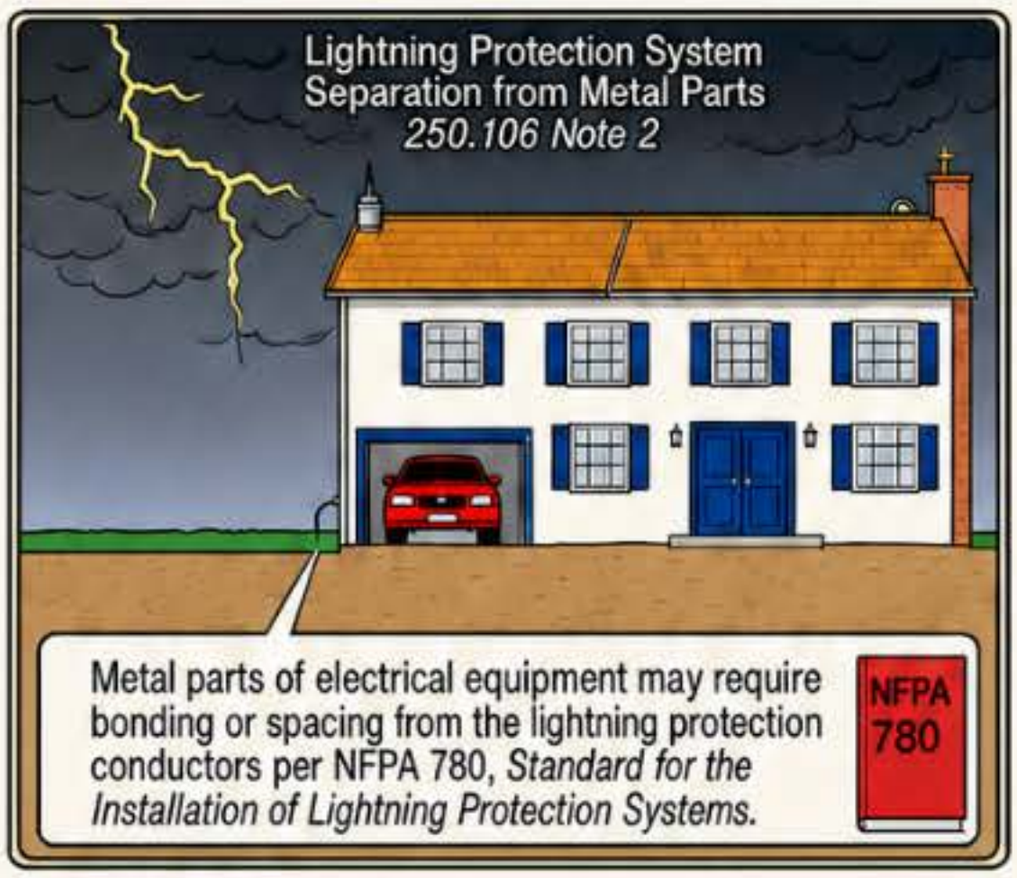


Figure 250–206

Part VI. Equipment Grounding and Equipment Grounding Conductors

250.109 Metal Enclosures

Metal enclosures can be used to connect bonding jumpers or equipment grounding conductors (or both) together to become part of an effective ground-fault current path. Metal covers and metal fittings attached to these metal enclosures are considered as being connected to bonding jumpers or equipment grounding conductors, or both. Figure 250–207

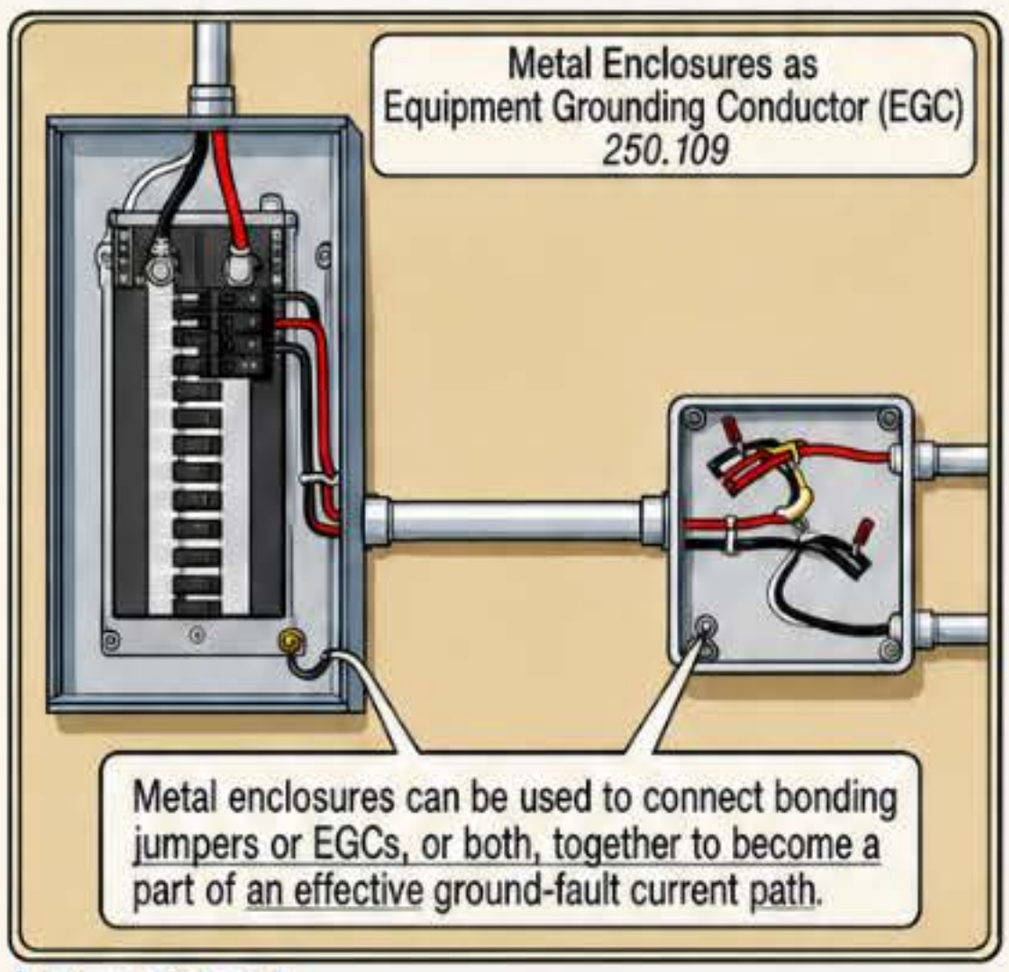


Figure 250–207

250.114 Equipment Connected by Cord and Plug

Exposed, normally noncurrent-carrying metal parts of cord-and-plug-connected equipment must be connected to the equipment grounding conductor of the circuit supplying the equipment under any of the following conditions:

Ex: Listed tools, listed appliances, and listed equipment covered in 250.114(2) through (4) are not required to be connected to an equipment grounding conductor where protected by a system of double insulation or its equivalent. Double insulated equipment must be distinctively marked.

(1) In hazardous (classified) locations. [Articles 500 through 517].

(2) Where operated at over 150V to ground.

Ex 1 to (2): Motors that are guarded.

Ex 2 to (2): Metal frames of exempted electrically heated appliances.

(3) In residential occupancies:

a. Refrigerators, freezers, and air conditioners.

b. Clothes-washing, clothes-drying, and dish-washing machines; ranges; kitchen waste disposers; IT equipment; sump pumps; and electrical aquarium equipment.

Author's Commentary:

Electric ranges and clothes dryers are shipped from the factory with a bonding strap that bonds the metal frame of the appliance to the neutral terminal of the cord connection terminal block. This bonding strap may or may not have to be removed. The Code requires an insulated neutral for these appliances using a 4-wire branch circuit and the bonding strap should be removed, but that was not always the case. If an existing 3-wire branch circuit is to supply a replacement appliance, the factory-installed bonding strap must remain in place [250.140 Ex].*

— Michael Hamilton

c. Hand-held, stationary or fixed, and light industrial motor-operated tools.

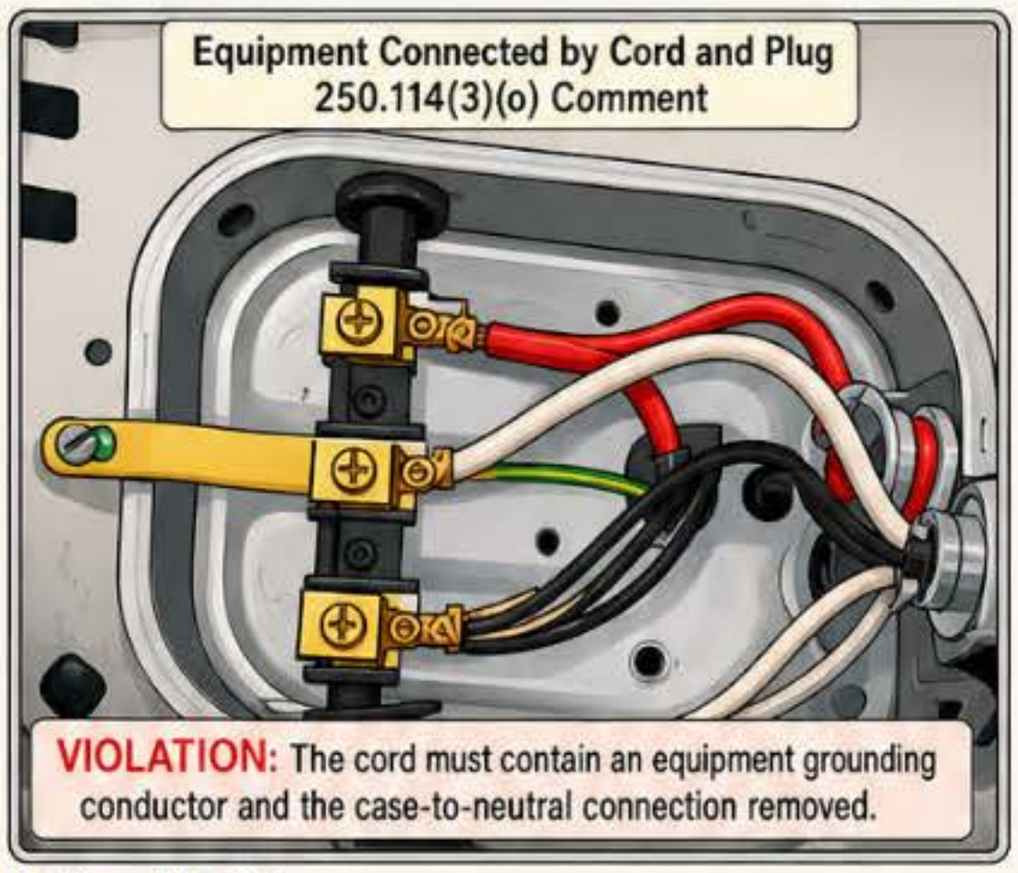
d. Motor-operated hedge clippers, lawn mowers, snow-blowers, and wet scrubbers.

e. Portable handlamps and portable luminaires.

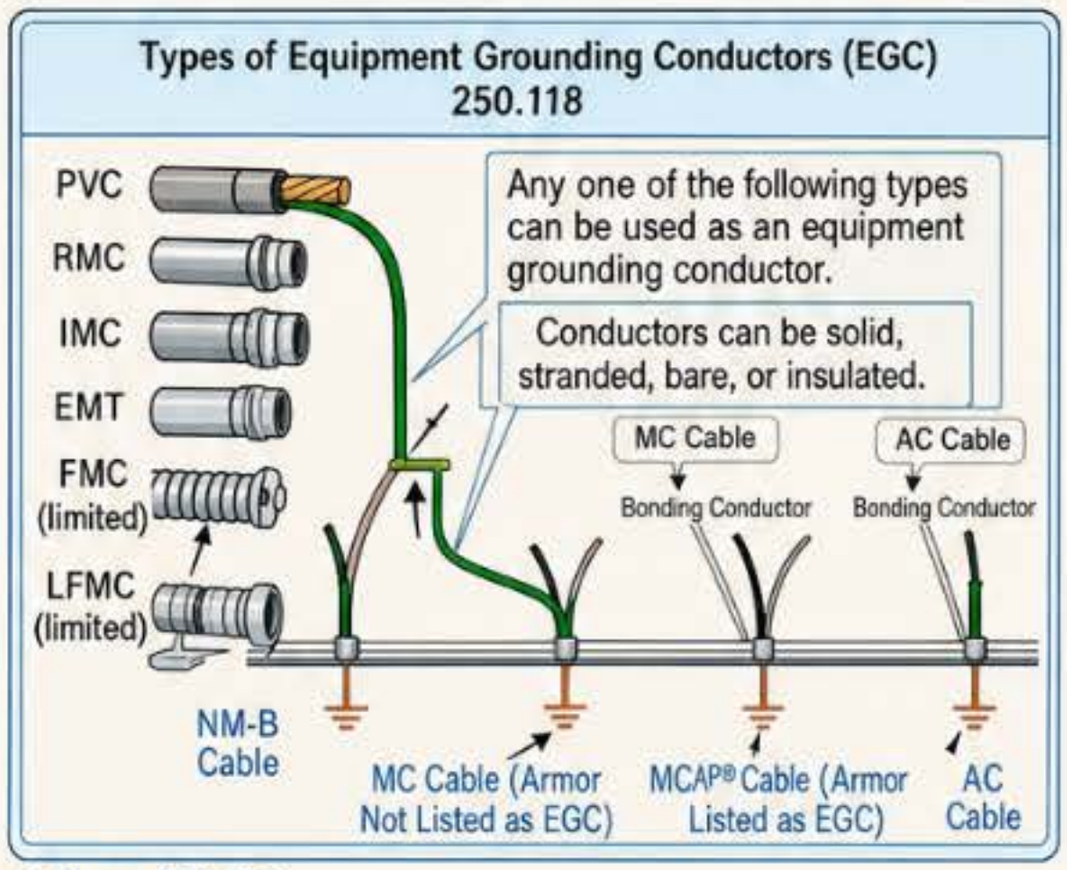
(4) In other than residential occupancies:

a. Refrigerators, freezers, *and air conditioners.*

Grounding and Bonding



▶ Figure 250–208



▶ Figure 250–209

b. Clothes-washing, clothes-drying, and dish-washing machines; IT equipment; sump pumps; and electrical aquarium equipment.

c. Hand-held, stationary or fixed, and light industrial motor-operated tools.

d. Motor-operated hedge clippers, lawn mowers, snow-blowers, and wet scrubbers.

e. Portable handlamps and portable luminaires.

f. Appliances used in damp or wet locations or by persons standing on the ground, standing on metal floors, or working inside of metal tanks or boilers.

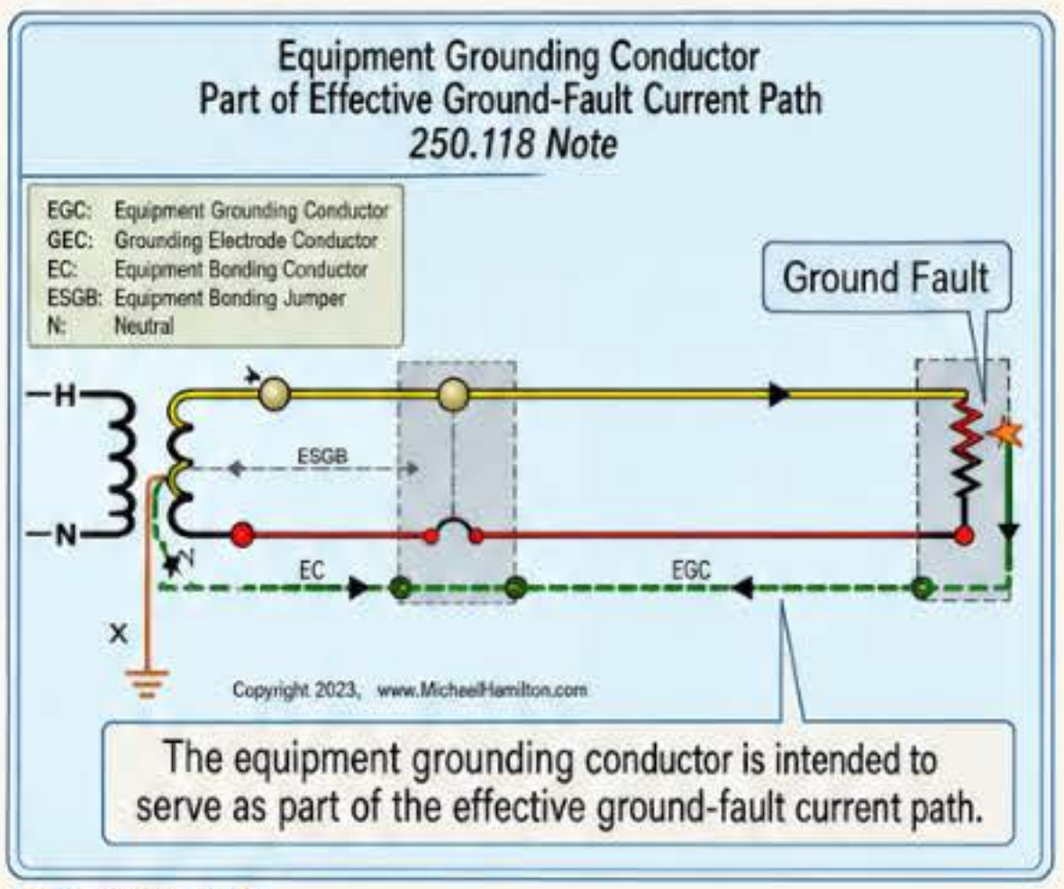
g. Tools likely to be used in wet or conductive locations.

Ex: *Tools and portable handlamps and portable luminaires likely to be used in wet or conductive locations are not required to be connected to an equipment grounding conductor where supplied through an isolating transformer with an ungrounded secondary not over 50V.*

250.118 Types of Equipment Grounding Conductors

The equipment grounding conductor can be any one of the following types: ▶Figure 250–209

Note: The equipment grounding conductor is intended to serve as part of the *effective ground-fault current path [Article 100].* ▶Figure 250–210



▶ Figure 250–210

Author's Commentary:

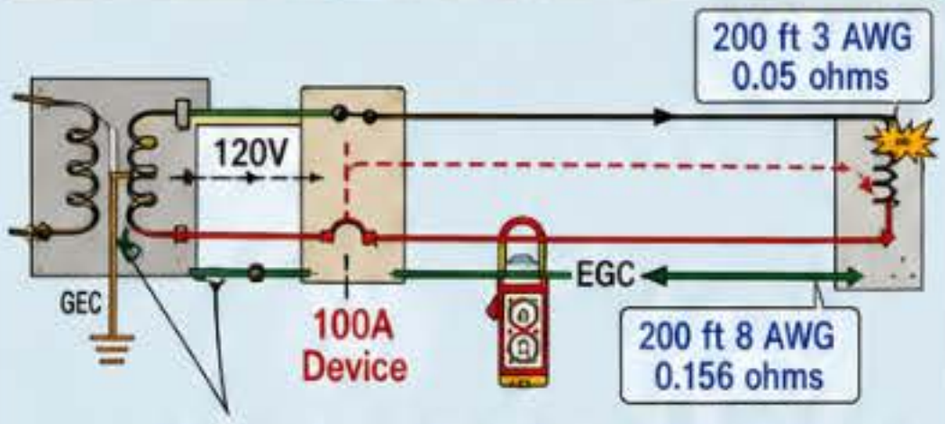
The effective ground-fault current path [Article 100] is an intentionally constructed low-impedance conductive path designed to carry fault current from the point of a ground fault on a wiring system to the electrical supply source. Its purpose is to quickly remove dangerous voltage from a ground fault by opening the circuit overcurrent protective device. ▶Figure 250–211

— *Michael Hamilton*

(1) A bare or insulated copper, aluminum, or copper-clad aluminum conductor sized in accordance with 250.122. ▶Figure 250–212

(2) Rigid metal conduit.

Equipment Grounding Conductor
Part of Effective Ground-Fault Current Path
250.118 Note Comment



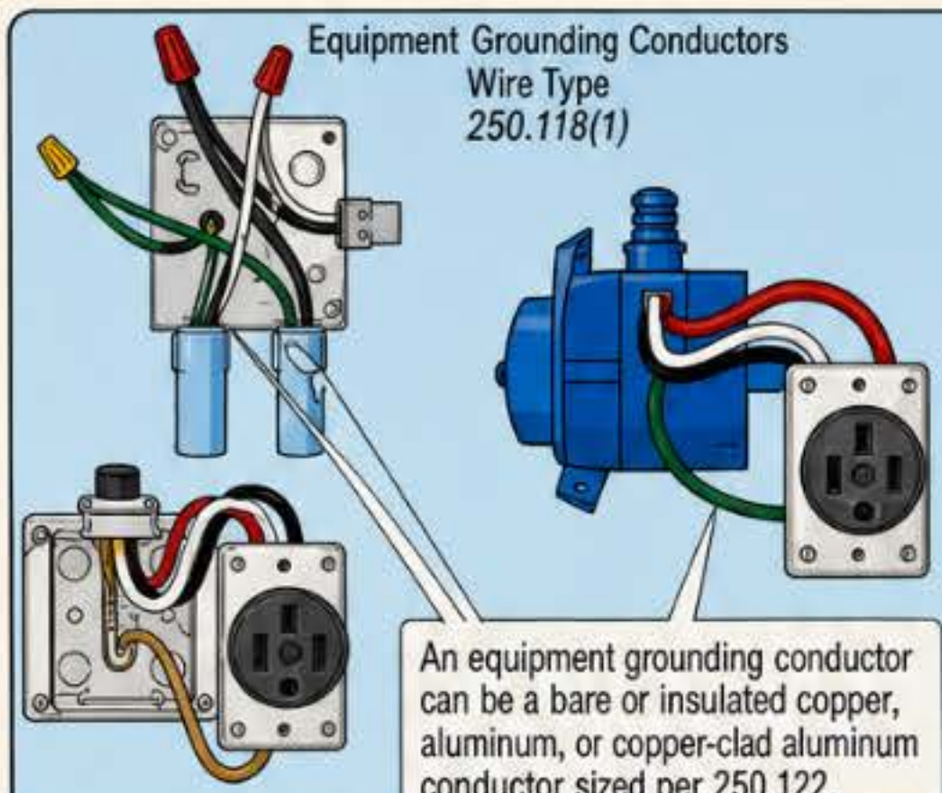
Effective Ground-Fault Current Path (Article 100)

$$\text{Fault Current} = \frac{E}{Z} = \frac{120\text{V}}{0.206 \text{ ohms}} = 583\text{A}$$

The 100A overcurrent device quickly opens and removes dangerous voltage from metal parts.

Figure 250–211

Equipment Grounding Conductors
Wire Type
250.118(1)



An equipment grounding conductor can be a bare or insulated copper, aluminum, or copper-clad aluminum conductor sized per 250.122.

Figure 250–212

(3) Intermediate metal conduit.

(4) Electrical metallic tubing.

(5) Listed flexible metal conduit where: ▶ Figure 250–213

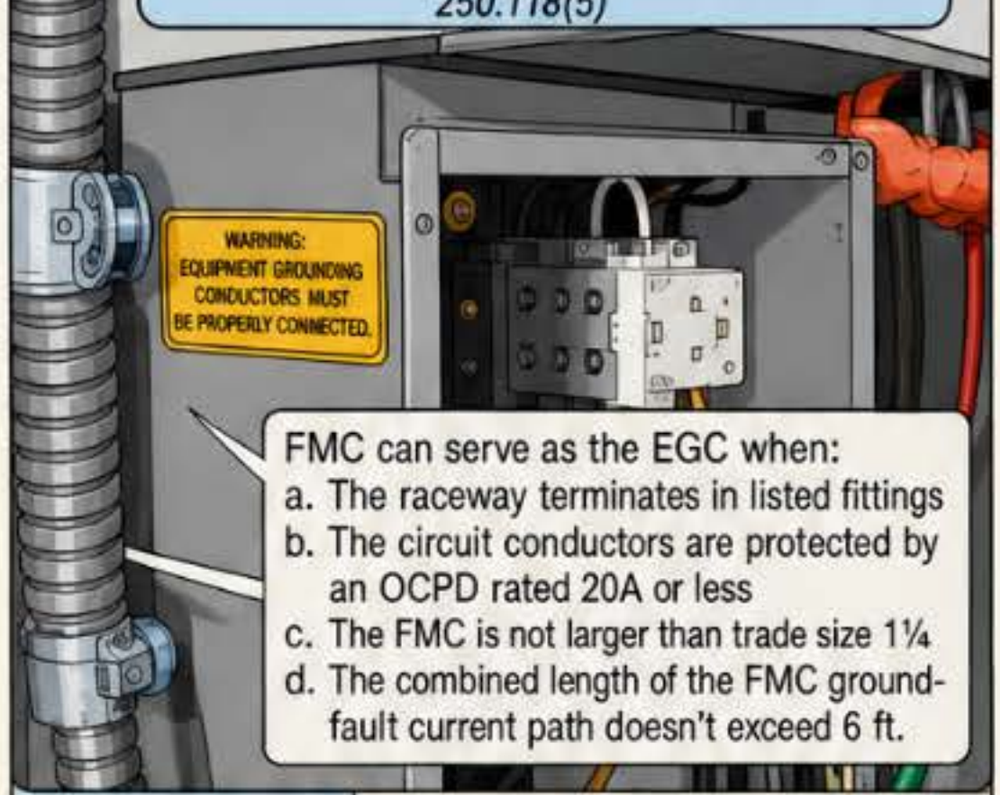
a. The raceway terminates in listed fittings.

b. The circuit conductors are protected by an overcurrent device rated 20A or less.

c. The size of the flexible metal conduit does not exceed 1¼.

d. The combined length of the flexible conduit in the same effective ground-fault current path does not exceed 6 ft.

Equipment Grounding Conductor (EGC), FMC
250.118(5)



FMC can serve as the EGC when:

a. The raceway terminates in listed fittings

b. The circuit conductors are protected by an OCPD rated 20A or less

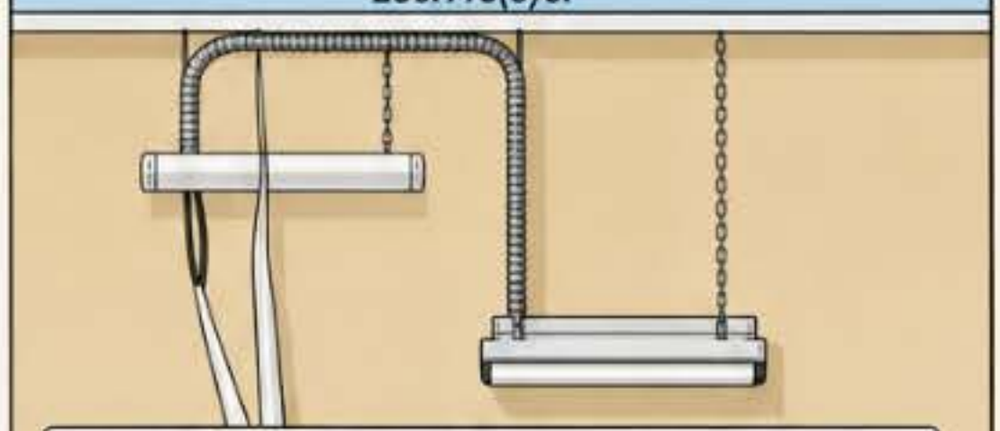
c. The FMC is not larger than trade size 1¼

d. The combined length of the FMC ground-fault current path doesn't exceed 6 ft.

Figure 250–213

e. If flexibility is required to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, an equipment grounding conductor of the wire type must be installed with the circuit conductors in accordance with 250.102(E). ▶ Figure 250–214

Equipment Grounding Conductor (EGC), FMC
Flexibility Required
250.118(5)e.



Where flexibility is required to minimize the transmission of vibration or provide flexibility for movement, an equipment grounding conductor of the wire type must be installed.

Figure 250–214

(6) Listed liquidtight flexible metal conduit where: ▶ Figure 250–215

a. The raceway terminates in listed fittings.

b. For ⅜ in. through ½ in., the circuit conductors are protected by overcurrent protective devices rated 20A or less.

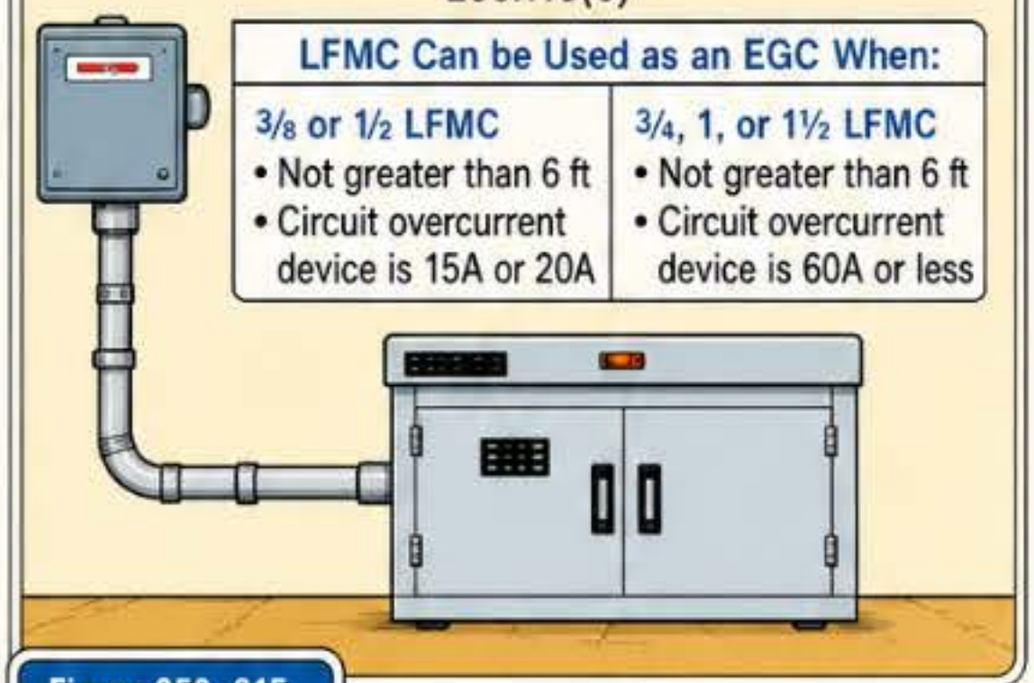
Author's Commentary:

The equipment grounding conductor is a crucial safety link. It provides a low-impedance route for fault current, ensuring overcurrent protection devices operate quickly to clear faults and keep metal parts safe from hazardous voltage.

— Michael Hamilton

GROUNDING AND BONDING 250.118

Equipment Grounding Conductor (EGC), LFMC Flexibility Not Required
250.118(6)



LFMC Can be Used as an EGC When:	
3/8 or 1/2 LFMC • Not greater than 6 ft • Circuit overcurrent device is 15A or 20A	3/4, 1, or 1½ LFMC • Not greater than 6 ft • Circuit overcurrent device is 60A or less

Figure 250–215

c. For 3/8 in. through 1½ in., the circuit conductors are shielded by overcurrent protective devices rated 60A or less.

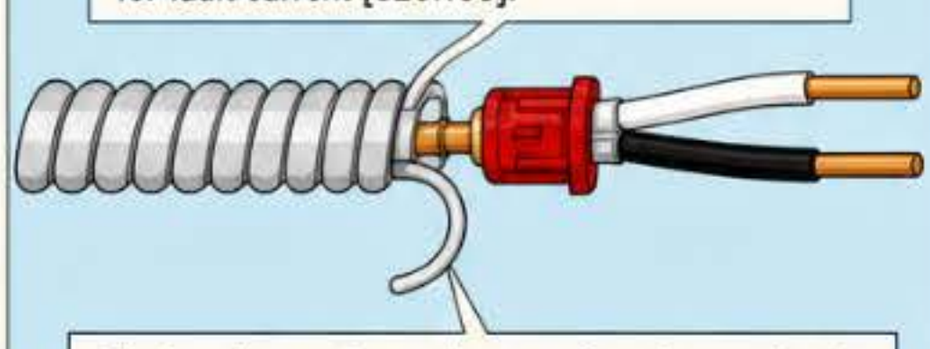
d. The combined length of the flexible metal conduit in the same *effective ground-fault current path* does not exceed 6 ft.

e. If flexibility is required to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, an equipment grounding conductor of the wire type must be installed with the circuit conductors in accordance with 250.102(E).

(8) The sheath of Type AC cable. Figure 250–216.

Equipment Grounding Conductor (EGC)
Type AC Cable
250.118(8)

Type AC cable sheath can be used as an EGC where the combination of the interlocking armor and the bonding strip provides a path for fault current [320.108].



The bonding strip can be cut off at the termination or it can be used to secure the anti-short bushing.

Figure 250–216

Author's Commentary:

The internal aluminum bonding strip is not an equipment grounding conductor, but it allows the interlocked armor of Type AC cable to serve as an equipment grounding conductor because it reduces the impedance of the armored spirals to ensure a ground fault will be cleared. It is the aluminum bonding strip in combination with the cable armor that creates the circuit equipment grounding conductor. Once the bonding strip exits the cable it can be cut off because it no longer serves any purpose.

— Michael Hamilton

(9) The sheath of Type MC cable.

(10) Type MC cable:

a. That contains an insulated or uninsulated equipment grounding conductor. Figure 250–217.

Equipment Grounding Conductor (EGC)
Type MC Cable (Traditional)
250.118(10)a.

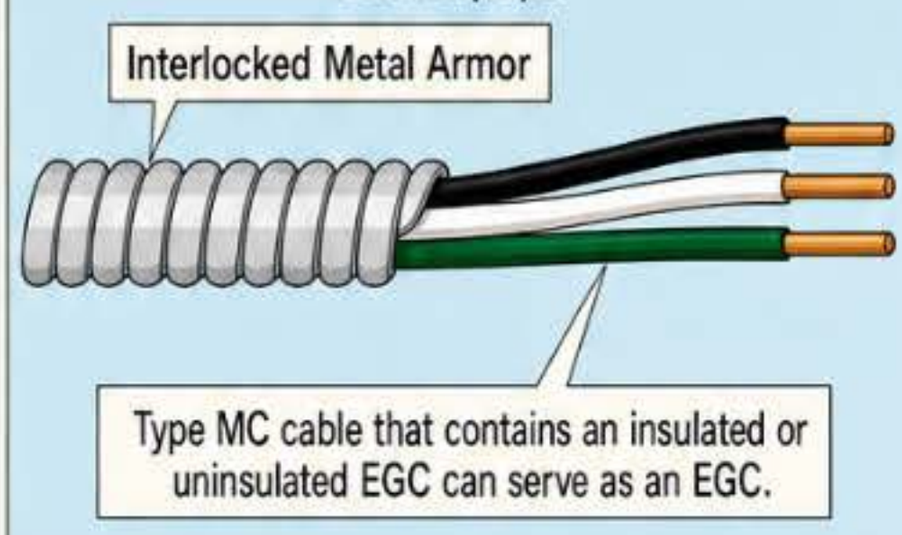


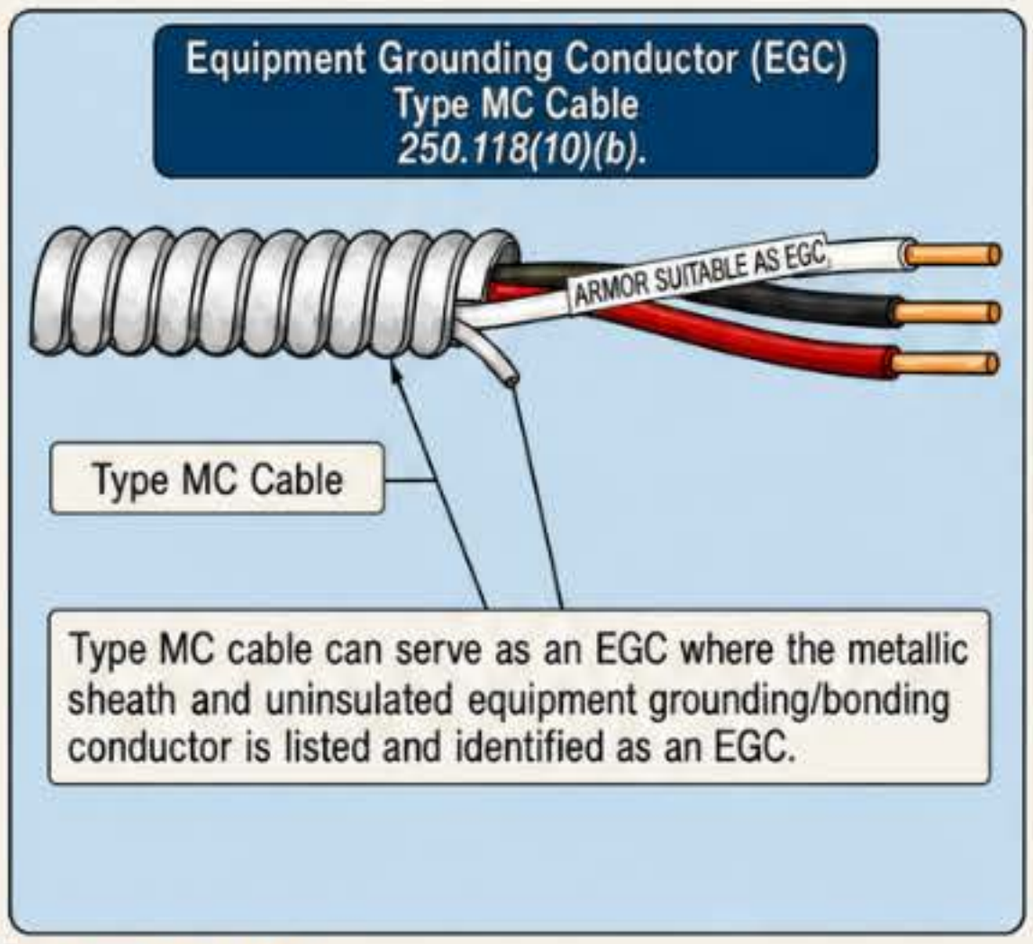
Figure 250–217

b. Where the metallic sheath and uninsulated equipment grounding/bonding conductor is listed and identified as an equipment grounding conductor. Figure 250–218.

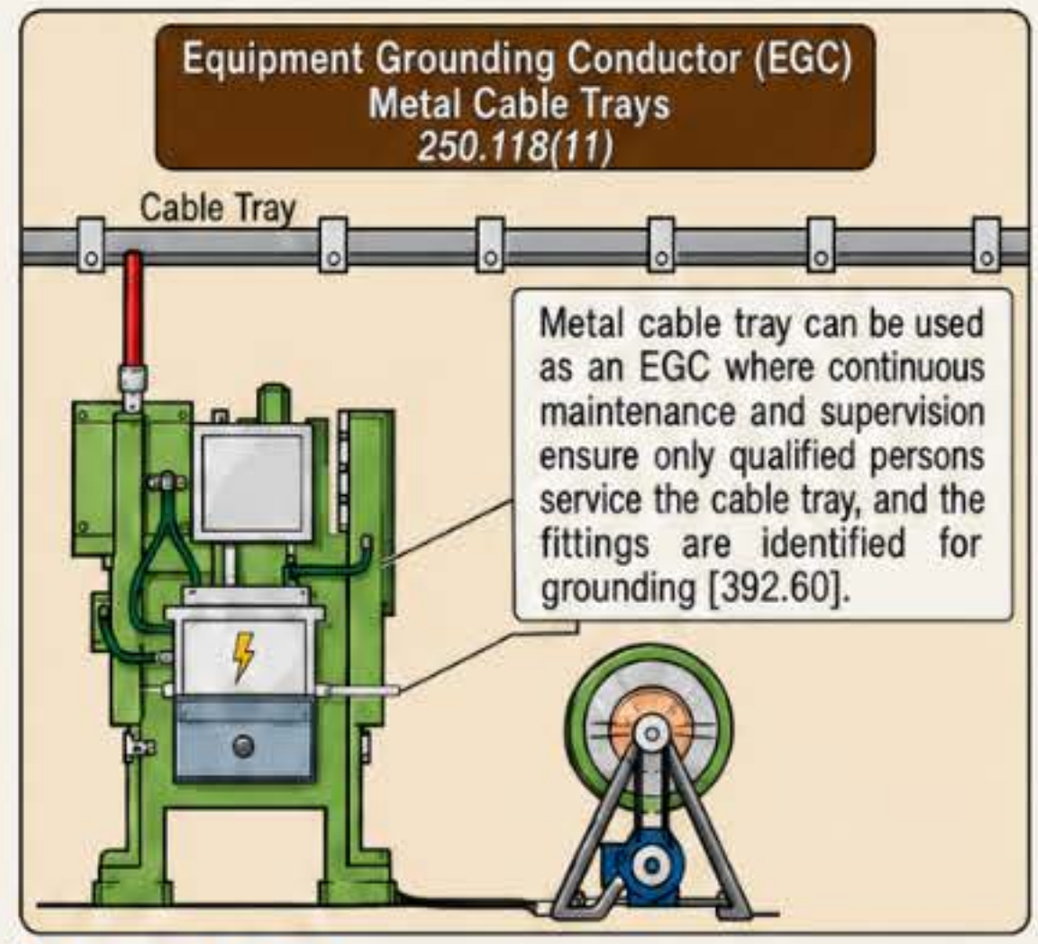
Author's Commentary:

Once the bare aluminum grounding/bonding conductor of Type MC cable exits the cable it can be cut off because it no longer serves any purpose. The effective ground-fault current path must be maintained by the use of fittings specifically listed for Type MC-AP® cable [330.6]. See 300.12, 300.15, and 330.108.

— Michael Hamilton

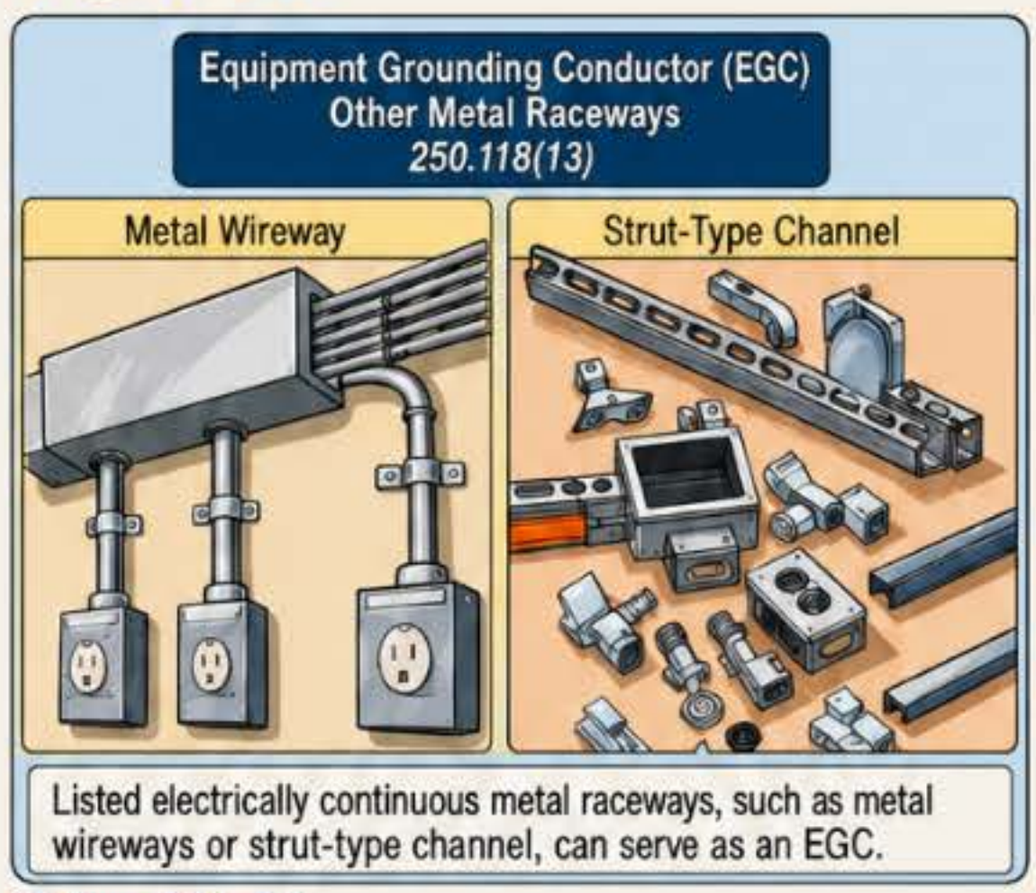


▶ Figure 250–218



▶ Figure 250–220

▶ Figure 250–219



▶ Figure 250–221

c. When the metallic sheath of smooth or corrugated tube-type MC cable is listed and identified as an equipment grounding conductor it can serve as an equipment grounding conductor.

(11) Metal cable trays if continuous maintenance and supervision ensure only qualified persons will service the cable tray; the cable tray and fittings are identified for grounding; and the cable tray, fittings [392.10], and raceways are bonded together using bolted mechanical connectors or bonding jumpers sized and installed in accordance with 250.102 [392.60]. Figure 250–220

(13) Other listed electrically continuous metal raceways such as metal wireways [Article 376] or strut-type channel raceways [384.60]. Figure 250–221

(14) Surface metal raceways listed for grounding [Article 386].

Note: For a definition of effective ground-fault current path, see Article 100.

Author's Commentary:

▶ Listed offset nipples and metal fittings for metal cable, conduit, and tubing are considered suitable for grounding circuits where installed in accordance with the *NEC*, except as noted for flexible metal conduit fittings and liquid-tight flexible metal conduit fittings. *See UL Product Spec™ Guide, Information for "Conduit Fittings" (OWIT).*

— Michael Hamilton

250.119 Identification of Equipment Grounding Conductors

The *Code* does not require an insulating jacket on equipment grounding conductors; they are permitted to be uninsulated (bare) or insulated.

When equipment grounding conductors smaller than 6 AWG are insulated, they must have a continuous outer covering that is either green, or green with one or more yellow stripes. Figure 250–222

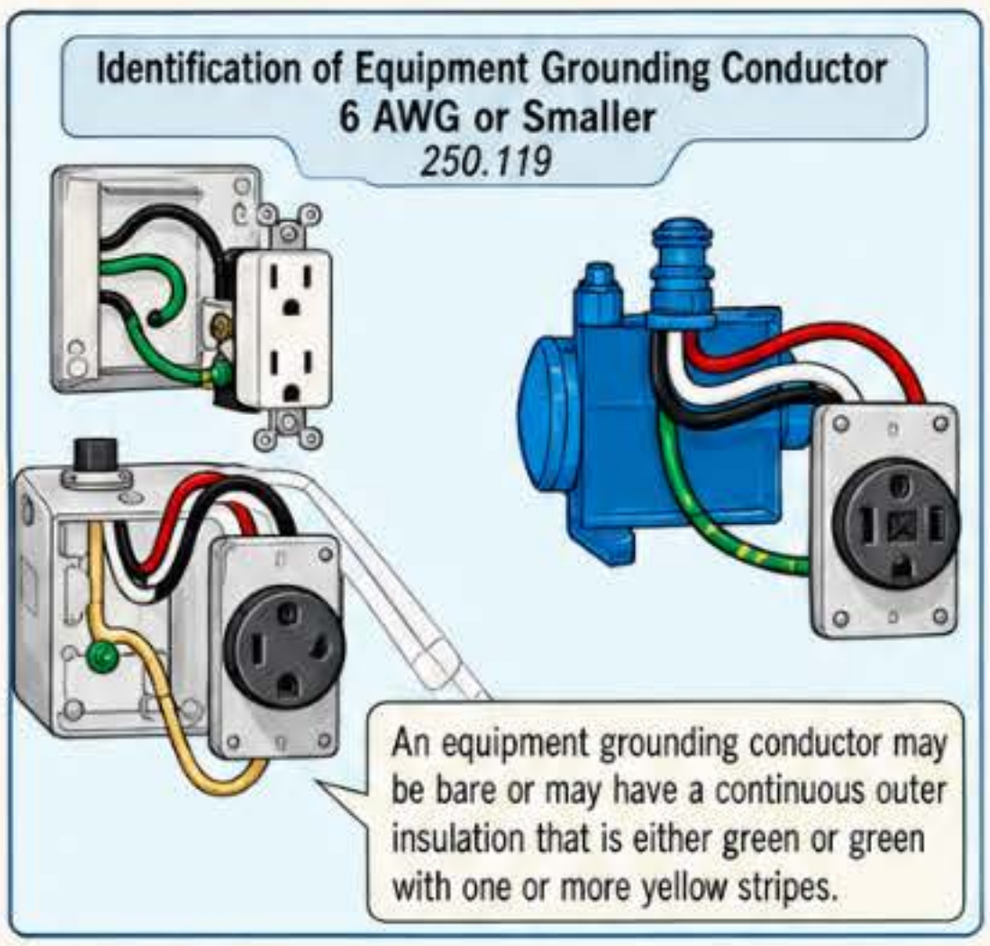


Figure 250–222

Conductors that are insulated green or green with one or more yellow stripes are prohibited from being used as ungrounded (hot) or grounded (neutral) circuit conductors.

Author's Commentary:

The NEC does not permit the use of the color green for the identification of grounding electrode conductors. Figure 250–223

— Michael Hamilton

(A) Conductors 4 AWG and Larger.

(1) Identified Where Accessible. Insulated equipment grounding conductors 4 AWG and larger must be reidentified at the point *where they are accessible.* Figure 250–224

(2) Identification Methods. *The identification must surround the conductor and be accomplished by one of the methods shown in Figure 250–225.*

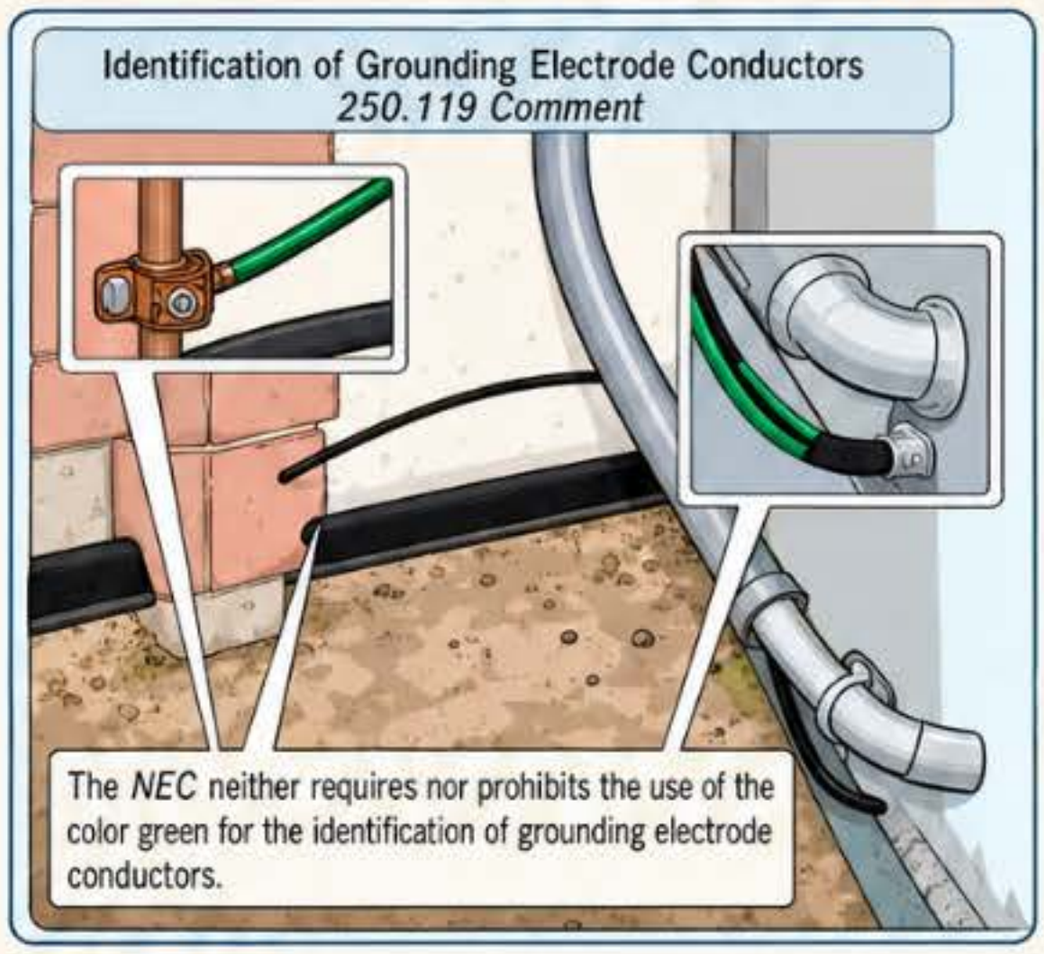


Figure 250–223

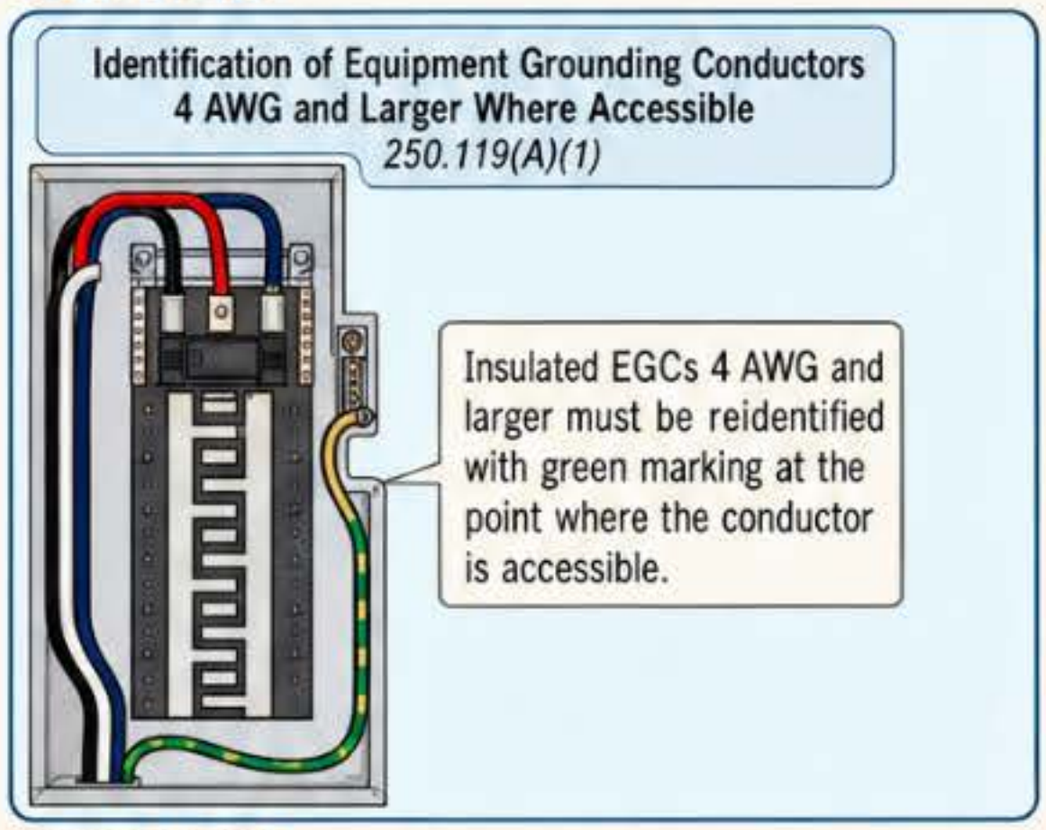


Figure 250–224

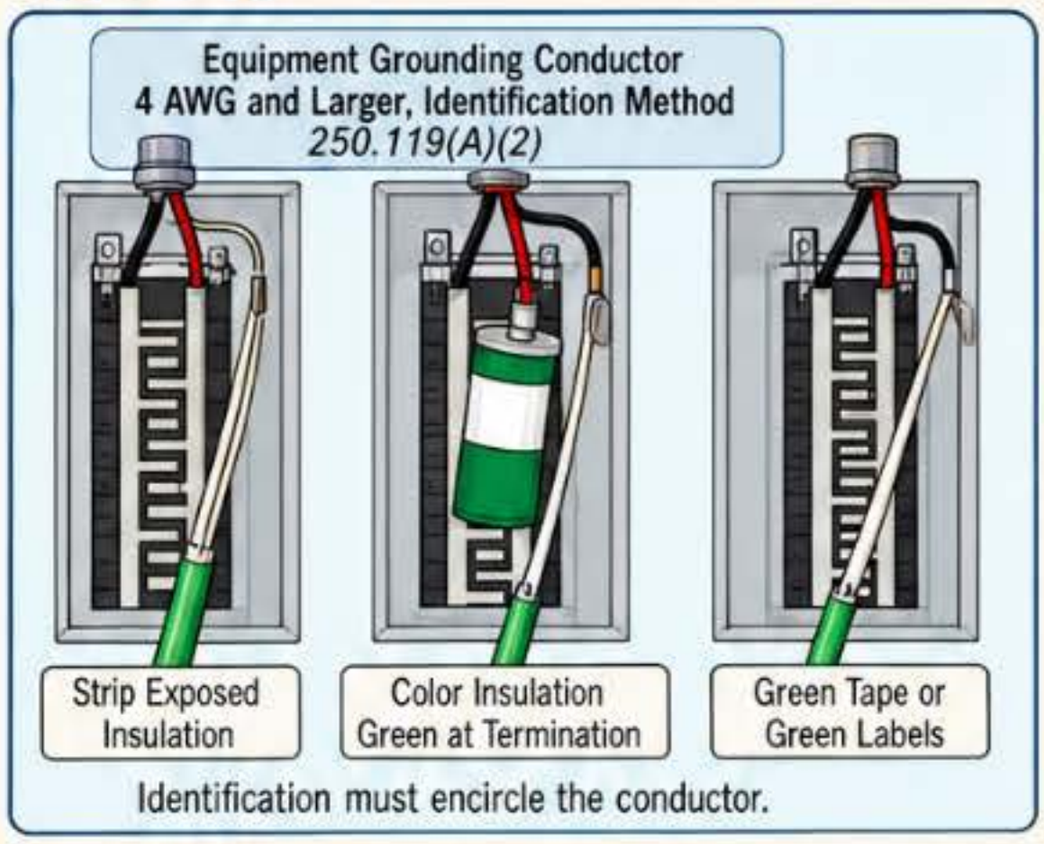


Figure 250–225

a. Removing the conductor insulation

b. Coloring the insulation green at termination

c. Marking the insulation at termination with green tape or green adhesive labels

(B) Multiconductor Cable.

One or more insulated conductors in a multiconductor cable, at the time of installation, are permitted to be permanently identified as equipment grounding conductors at each end and at every point where the conductors are accessible by one of the following means:

(1) Stripping the insulation from the entire exposed length.

(2) Coloring the exposed insulation green.

(3) Marking the exposed insulation with green tape or green adhesive labels. Identification must encircle the conductor.

250.120 Equipment Grounding Conductor Installation

An equipment grounding conductor must be installed as follows:

(A) Fittings Made Tight. For raceways, cable trays, cable armor, cablebus framework, or cable sheaths, the fittings and terminations must be made tight using suitable tools.

(B) Aluminum Conductors. Equipment grounding conductors of bare, covered, or insulated aluminum must be installed as follows:

(1) Unless part of a Chapter 3 wiring method, bare or covered conductors are not permitted to be installed where subject to corrosive conditions or in direct contact with concrete, masonry, or the Earth.

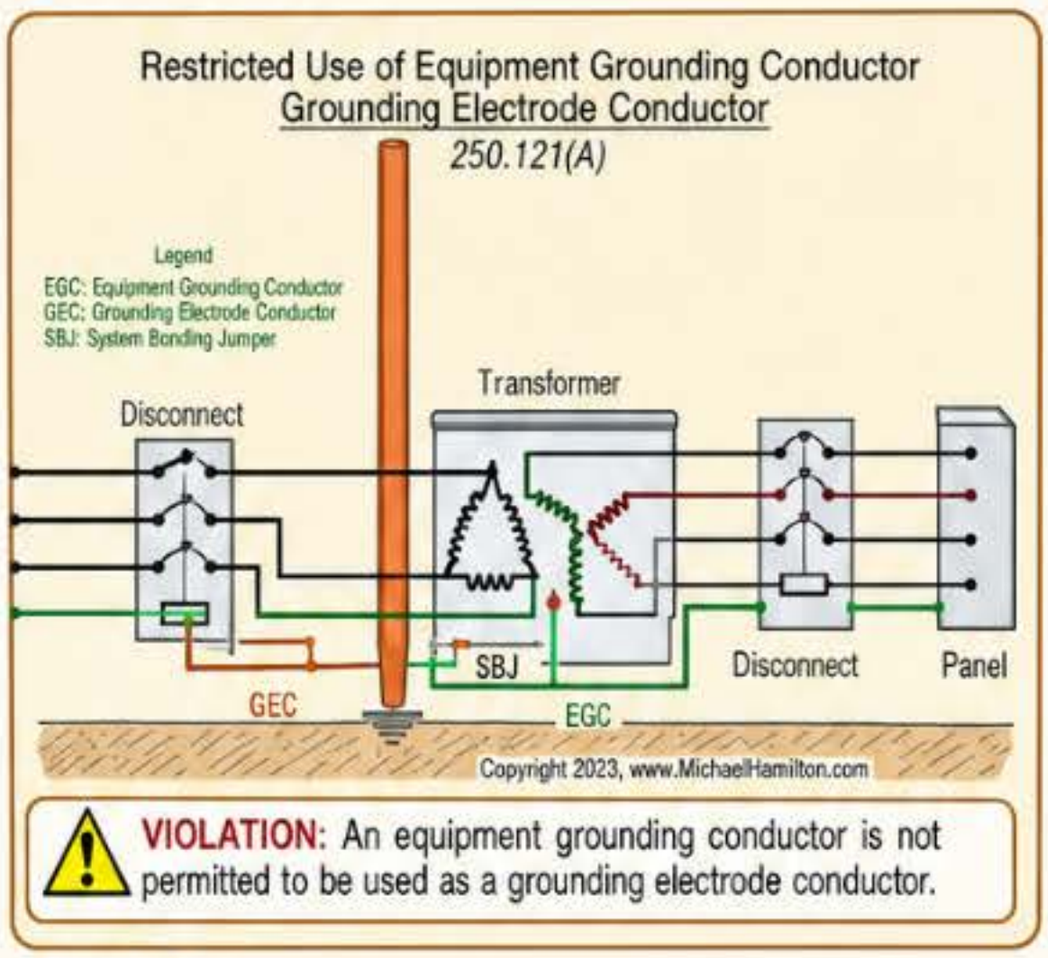
(2) Terminations made within outdoor enclosures that are listed and identified for the environment are permitted within 18 in. of the bottom of the enclosure.

(3) Aluminum conductors external to buildings or enclosures are not permitted to be terminated within 18 in. of the Earth, unless terminated within a listed wire connector system.

(C) Exposed. Exposed equipment grounding conductors 8 AWG and smaller for direct-current circuits [250.134(B) Ex.2], such as required by 690.45 for solar PV systems, are permitted to be run separately from the circuit conductors. 8 AWG or smaller exposed equipment grounding conductors must be protected from physical damage and must be installed within a raceway or cable.

250.121 Restricted Use of Equipment Grounding Conductors

(A) Grounding Electrode Conductor. An equipment grounding conductor is not permitted to be used as a grounding electrode conductor. Figure 250–226



▶ Figure 250–226

Ex: An equipment grounding conductor meeting the requirements for an equipment grounding conductor and grounding electrode conductor can be used as a grounding electrode conductor.

(B) Metal Frame of Building. The structural metal frame of a building must not be used as an equipment grounding conductor.

Author's Commentary:

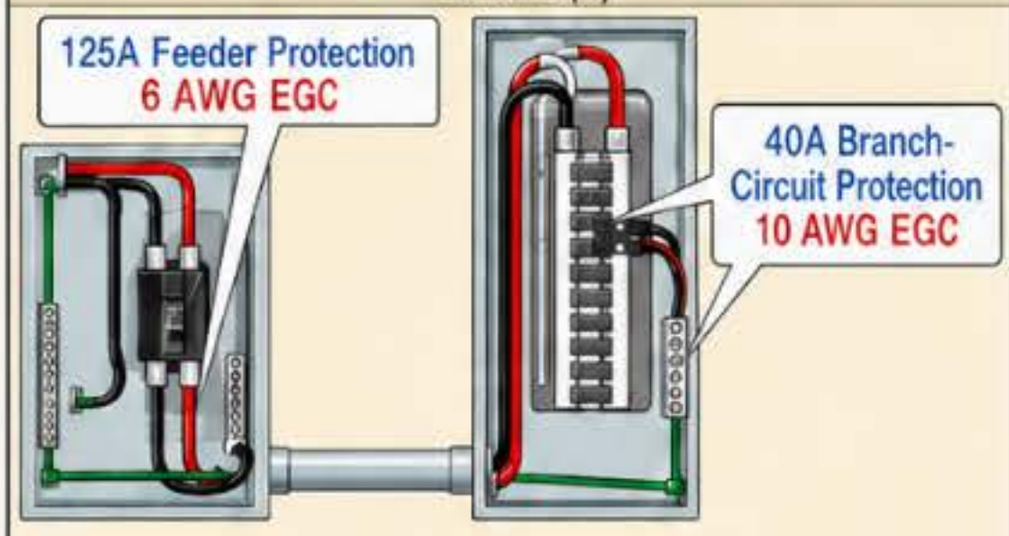
Here is a perfect example of why it is so important for you to have a complete understanding of the terminology used throughout the Code. While the structural metal frame of a building is not permitted to be used as an "equipment grounding conductor," the metal structure of a building is permitted to be used as a "grounding electrode conductor." Knowing the difference is what makes the difference!

— Michael Hamilton

250.122 Sizing Equipment Grounding Conductors

(A) General. Equipment grounding conductors must be sized not smaller than shown in Table 250.122; however, the equipment grounding conductor is not required to be larger than the phase conductors. Figure 250–227

Sizing Equipment Grounding Conductors (EGC) of the Wire Type
250.122(A)



Equipment grounding conductors must be sized not smaller than shown in Table 250.122, however, they are not required to be larger than the phase conductors.

Figure 250–227

(B) Increased in Size. If phase conductors are increased in size for any reason other than as required in 310.15(B) or 310.15(C), wire-type equipment grounding conductors, if installed, must be increased in size proportionately to the increase in the circular mil area of the phase conductors. Figure 250–228

Sizing Equipment Grounding Conductors increase in Size
250.122(B)

If phase conductors are increased in size for any reason other than as required in 310.15(B) or 310.15(C), wire-type equipment grounding conductors (if installed) must be increased in size proportionately to the increase in the circular mil area of the phase conductors.

Figure 250–228

Ex: Equipment grounding conductors can be sized by a qualified person to provide an effective ground-fault current path in accordance with 250.4(A)(5) or (B)(4).

Author's Commentary:

- *Phase conductors are sometimes increased in size to accommodate conductor voltage drop, short-circuit rating, or simply for future capacity.*

Table 250.122 Sizing Equipment Grounding Conductor

Overcurrent Protective Device Rating	Copper Conductor
15A	14 AWG
20A	12 AWG
25A–60A	10 AWG
70A–100A	8 AWG
110A–200A	6 AWG
225A–300A	4 AWG
350A–400A	3 AWG
450A–500A	2 AWG
600A	1 AWG
700A–800A	1/0 AWG
1,000A	2/0 AWG
1,200A	3/0 AWG

Note: Where necessary to comply with 250.4(A)(5) or (B)(4), the equipment grounding conductor might be required to be sized larger than given in this table.

▶ Example

Question: *If the phase conductors for a 40A circuit (with 75°C terminals) are increased in size from 8 AWG to 6 AWG due to voltage drop, the circuit equipment grounding conductor must be increased in size from 10 AWG to ____.* ▶ Figure 250–229

(a) 8 AWG (b) 6 AWG (c) 4 AWG (d) 3 AWG

Solution:

The circular mil area of 6 AWG is 59 percent more than 8 AWG (26,240 cmil/16,510 cmil) [Chapter 9, Table 8]. According to Table 250.122, the circuit equipment grounding conductor for a 40A overcurrent protective device will be 10 AWG (10,380 cmil), but the circuit equipment grounding conductor for this circuit must be increased in size by a multiplier of 159 percent.

• • •

Conductor Size = 10,380 cmil × 159%
Conductor Size = 16,504 cmil

The circuit equipment grounding conductor must be increased to 8 AWG [Chapter 9, Table 8].

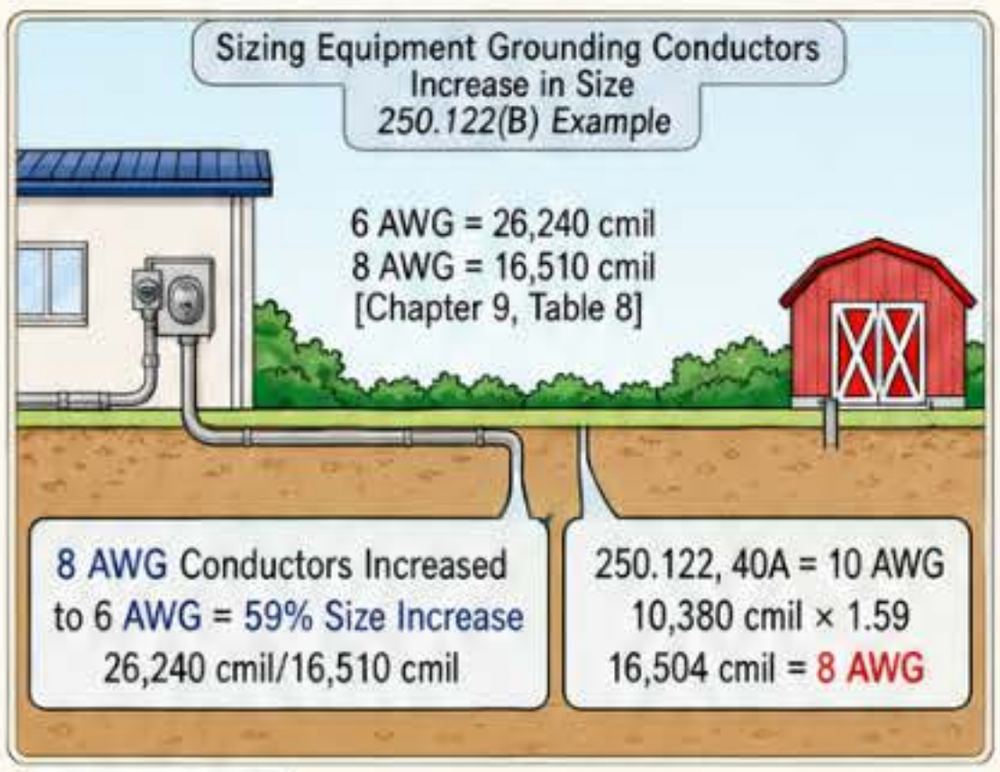


Figure 250–229

Answer: *(a) 8 AWG*

(C) Multiple Circuits. A single equipment grounding conductor sized in accordance with Table 250.122 when multiple circuits are installed in the same raceway, cable, trench, or cable tray. ▶ Figure 250–230

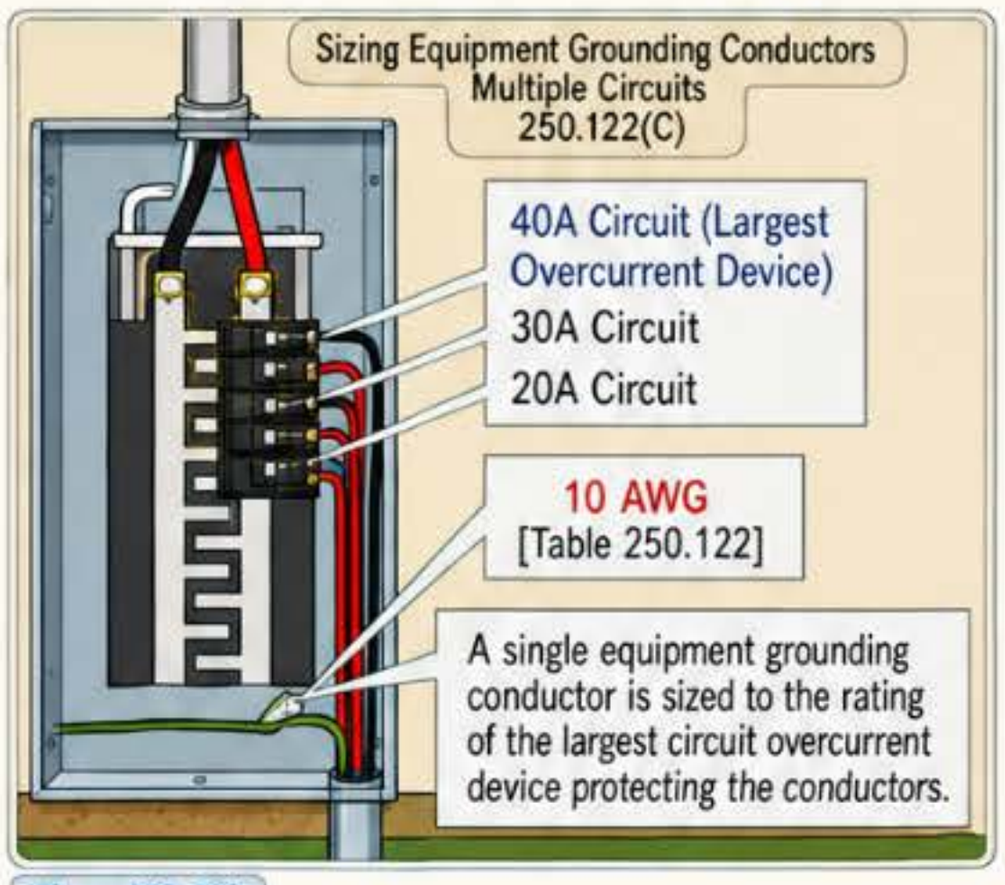


Figure 250–230

(D) Motor Branch Circuits. Equipment grounding conductors for motor circuits must be sized in accordance with *250.122(D)(1) or (D)(2)*.

(1) General. The equipment grounding conductor must not be smaller than determined by 250.122(A), based on the rating of the motor circuit branch-circuit short-circuit and ground-fault protective device sized in accordance with 430.52(C)(1) Ex 1.

Author's Commentary:
The equipment grounding conductor is not required to be larger than the motor circuit conductors. See 250.122(A).
— Michael Hamilton

▶ Example

Question: *What size equipment grounding conductor of the wire type is required for a 14 AWG motor branch circuit (430.22) protected with a 2-pole, 30A circuit breaker in accordance with 430.22 and 430.52(C)(1)?* ▶ *Figure 250–231*

(a) 14 AWG (b) 12 AWG (c) 10 AWG (d) 8 AWG

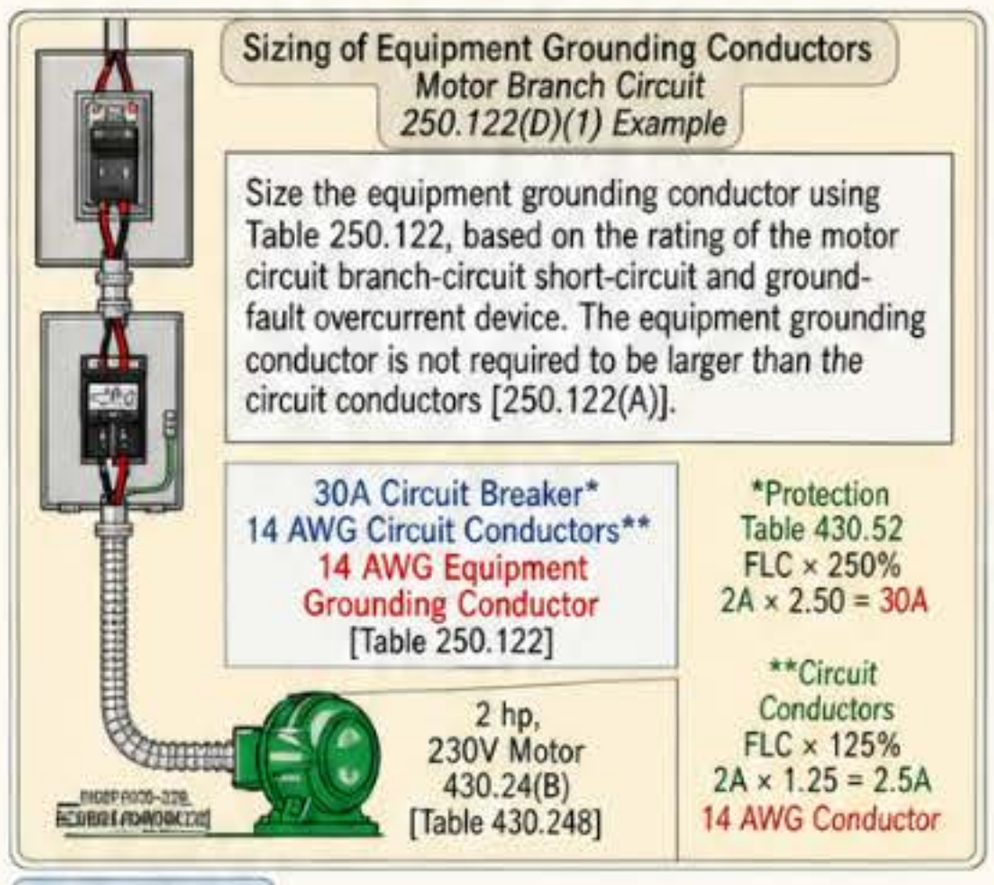


Figure 250–231

Solution:

The equipment grounding conductor is not required to be larger than the 14 AWG motor branch-circuit conductors [250.122(D)(1) and 250.122(A)].

Answer: *(a) 14 AWG*

(F) Parallel Conductors. Where circuit conductors are installed in parallel in accordance with 310.10(G), an equipment grounding conductor of the wire type must be installed in accordance with the following:

(1) Nonmetallic Raceways or Cable Trays

(a) Parallel Conductors in a Single Nonmetallic Raceway or Cable Tray. If parallel circuit conductors are installed in a single

Grounding and Bonding | 250.122

Nonmetallic raceways or cable trays need a **single wire-type equipment grounding conductor** sized in accordance with Table 250.122, based on the rating of the circuit overcurrent protective device. This conductor must be installed with the parallel circuit conductors.

(b) Parallel Conductors in Multiple Nonmetallic Raceways. When parallel circuit conductors run in multiple nonmetallic raceways, each raceway must contain its own wire-type equipment grounding conductor. ▶ Figure 250–232

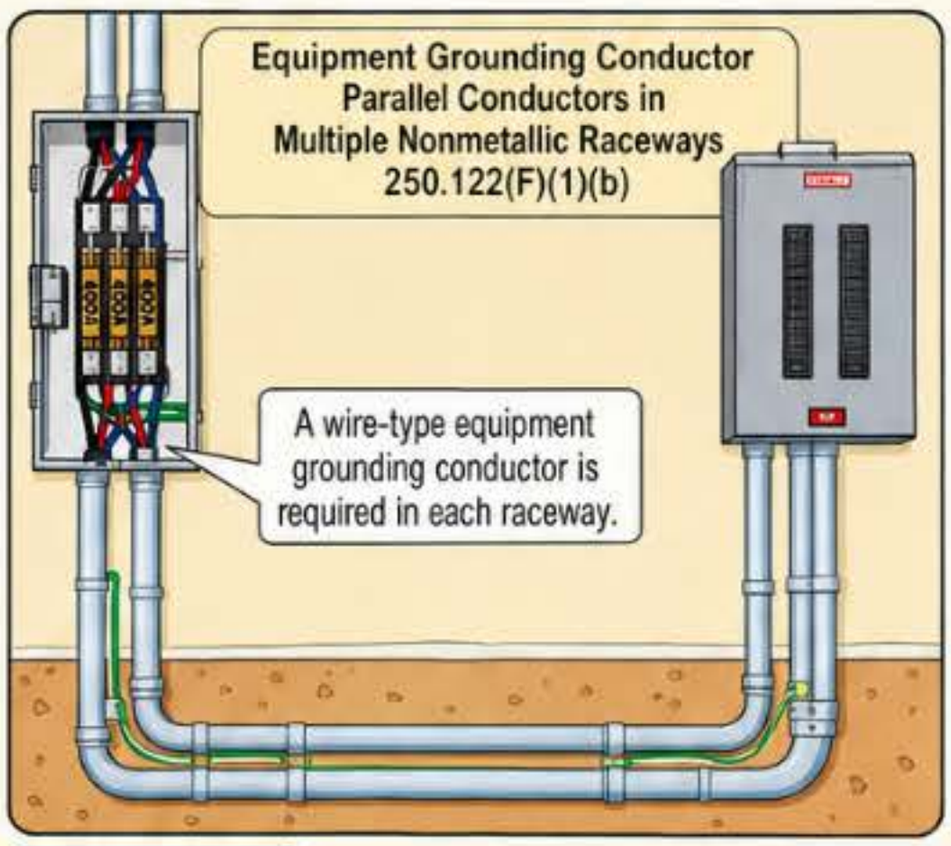


Figure 250–232

The equipment grounding conductors in each raceway must be sized in accordance with Table 250.122. ▶ Figure 250–233

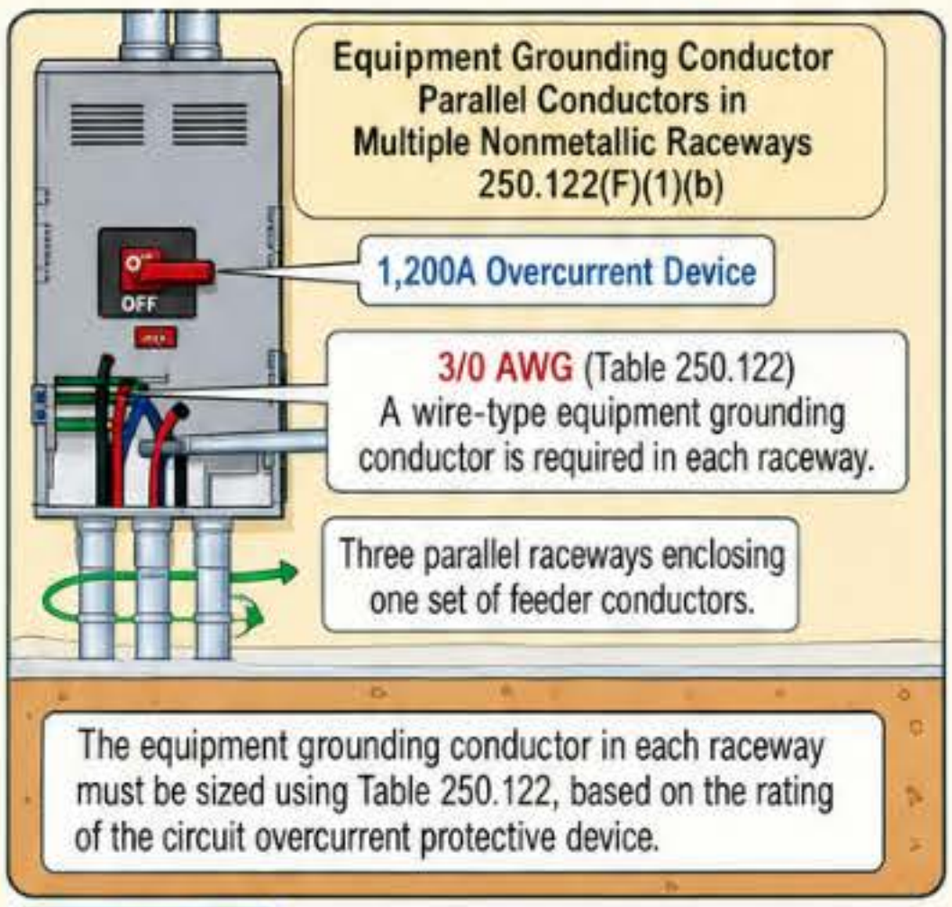


Figure 250–233

▶ **Example**

Question: *What size copper equipment grounding conductor of the wire type is needed for a 4,000A feeder that includes thirteen parallel sets of 500 kcmil conductors in PVC conduit?*

(a) 250 kcmil (b) 300 kcmil (c) 400 kcmil (d) 500 kcmil

Solution:

Based on Table 250.122, the equipment grounding conductor in each raceway must not be smaller than 500 kcmil.

Answer: *(d) 500 kcmil*

(c) Wire-Type Equipment Grounding Conductors in Cable Trays. Wire-type equipment grounding conductors installed in cable trays must meet the minimum requirements of 392.10(B)(1)(c).

(d) Metal Raceways or Cable Trays. Metal raceways can satisfy the equipment grounding conductor requirement per 250.118 and cable trays comply with 392.60(B) as the required equipment grounding conductor.

(2) Parallel Multiconductor Cables.

(a) *Except as provided in 250.122(F)(2)(c) for raceway or cable tray installations, the equipment grounding conductor in each multiconductor cable must be sized in accordance with 250.122, based on the overcurrent protective device for the feeder or branch circuit.* ▶ Figure 250–234

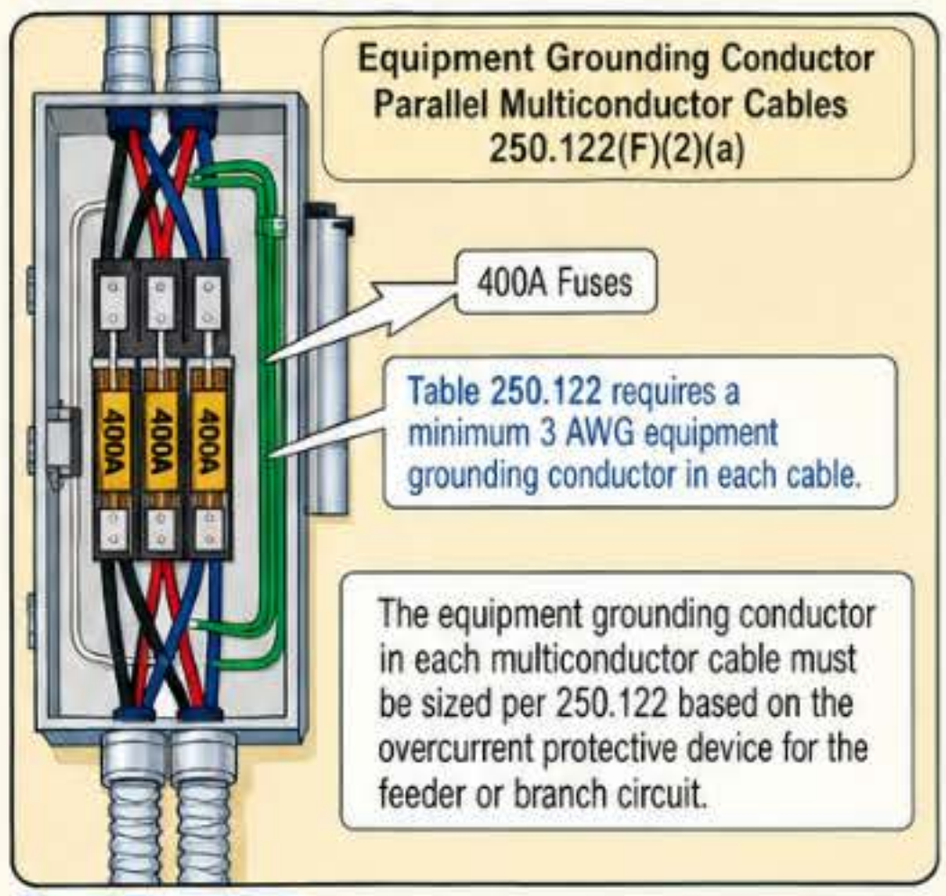


Figure 250–234

(b) If circuit conductors of multiconductor cables are connected in *parallel, the equipment grounding conductor(s) in each cable must be connected in parallel.*

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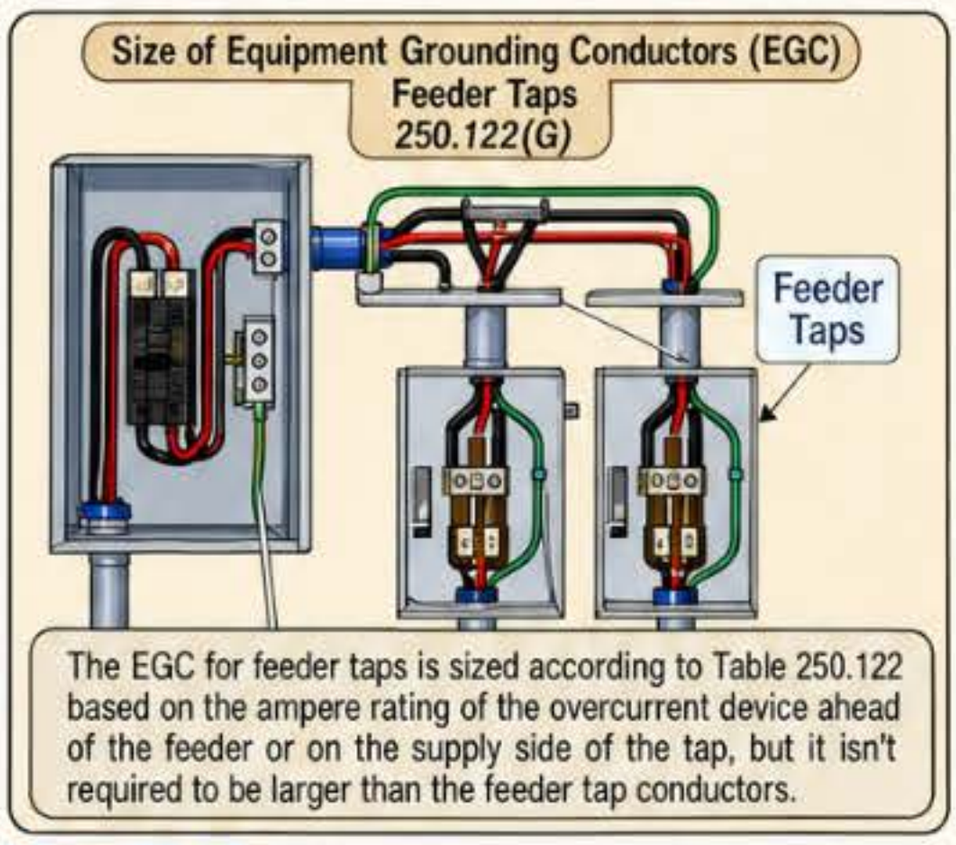
(c) When multiconductor cables are routed together in a shared raceway or on a common cable tray, a single equipment grounding conductor, sized per Table 250.122, may be used in combination with the equipment grounding conductors that are provided within the individual multiconductor cables. All of the grounding conductors involved must be tied together to form a continuous path.

(d) Equipment grounding conductors that are installed in cable trays must comply with the requirements of 392.10(B)(1)(c).

Cable trays that satisfy 392.60(B) and metal raceways that meet 250.118 can be used as the required equipment grounding conductor.

(g) Feeder Tap Conductors. The equipment grounding conductors for feeder taps are not allowed to be smaller than listed in Table 250.122, based on the ampere rating of the overcurrent device ahead of the feeder or on the supply side of the tap. The feeder equipment grounding conductor does not have to be larger than the tap conductors.



▶ Figure 250–235

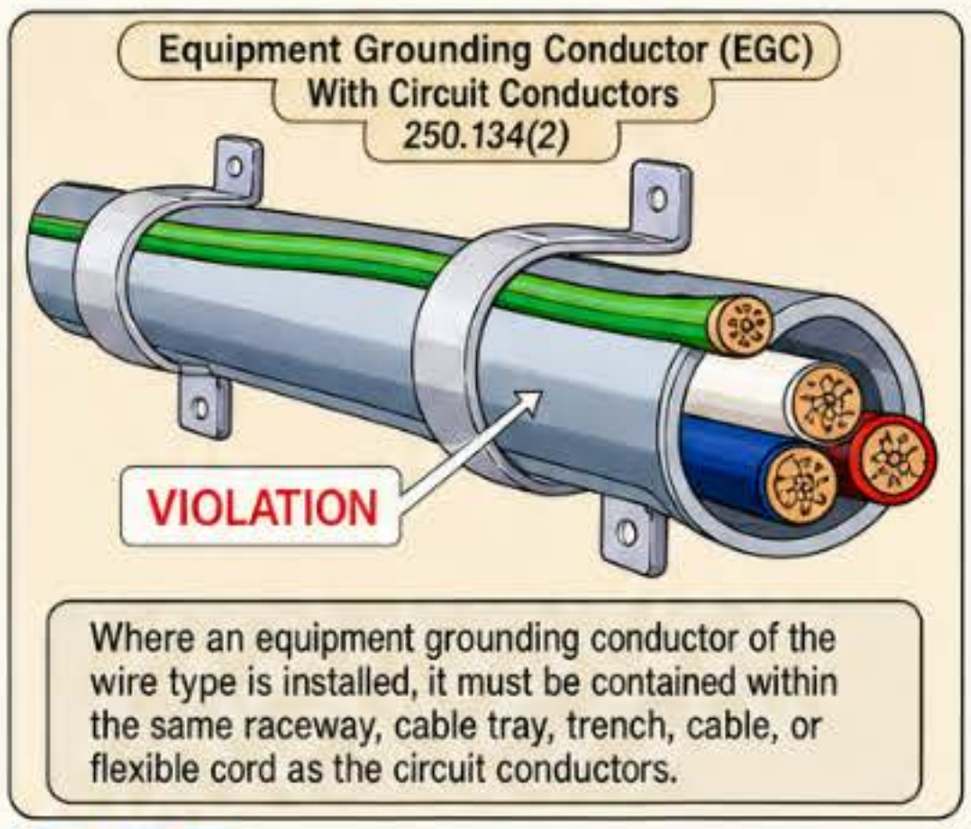
Part VII. Methods of Equipment Grounding Conductor Connections

250.134 Equipment Connected by Permanent Wiring Methods

Except as permitted for services or separately derived systems [250.142(A)], metal parts of equipment, raceways, and enclosures must be connected to an equipment grounding conductor by any of the following methods:

(1) Equipment Grounding Conductor. By connecting to one of the equipment grounding conductor types identified in 250.118(2) through (14).

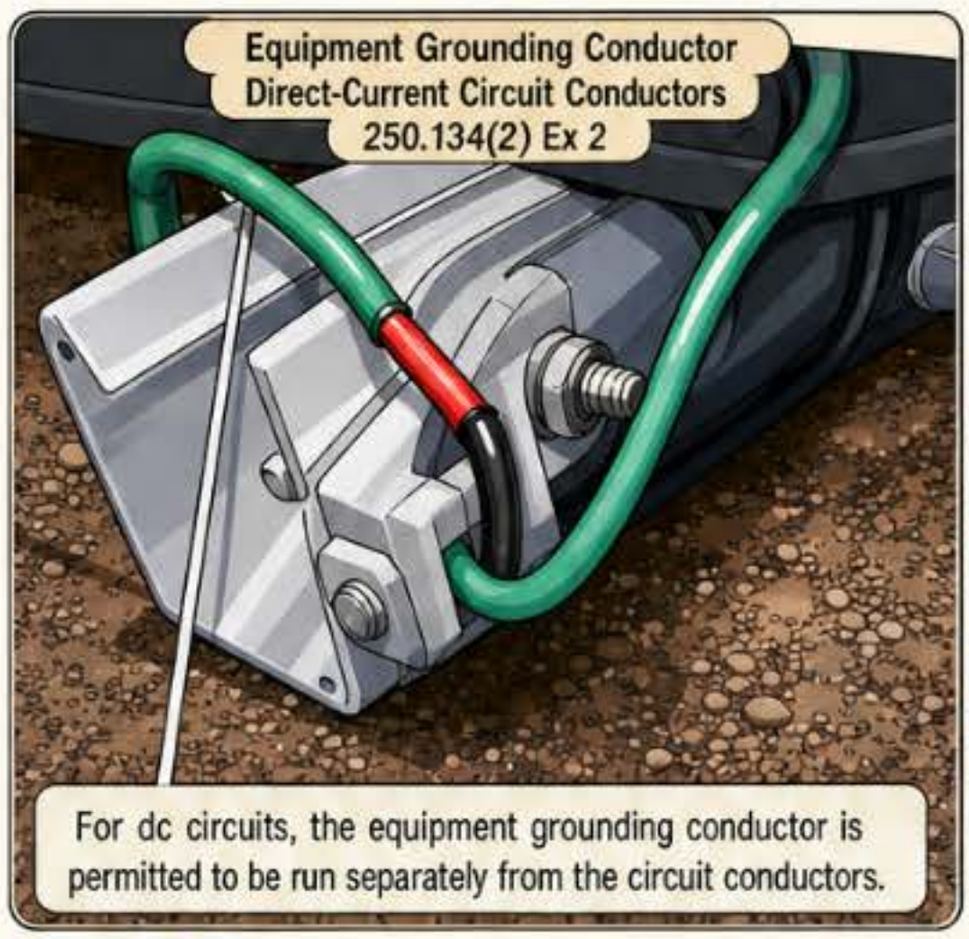
(2) With Circuit Conductors. When an equipment grounding conductor of the wire type is installed, it must be contained within the same raceway, cable tray, trench, cable, or flexible cord as the circuit conductors.



▶ Figure 250–236

Ex 2: For direct-current circuits, the equipment grounding conductor is permitted to be run separately from the circuit conductors.

▶ Figure 250–237



▶ Figure 250–237

GROUNDING AND BONDING 250.140

250.136 Equipment Secured to Grounded Metal Supports

Metal equipment and enclosures that are electrically connected to a metal rack or framework are considered part of the equipment grounding conductor (EGC) system when the rack or structure is bonded to an equipment grounding conductor in accordance with 250.134.

Figure 250–238

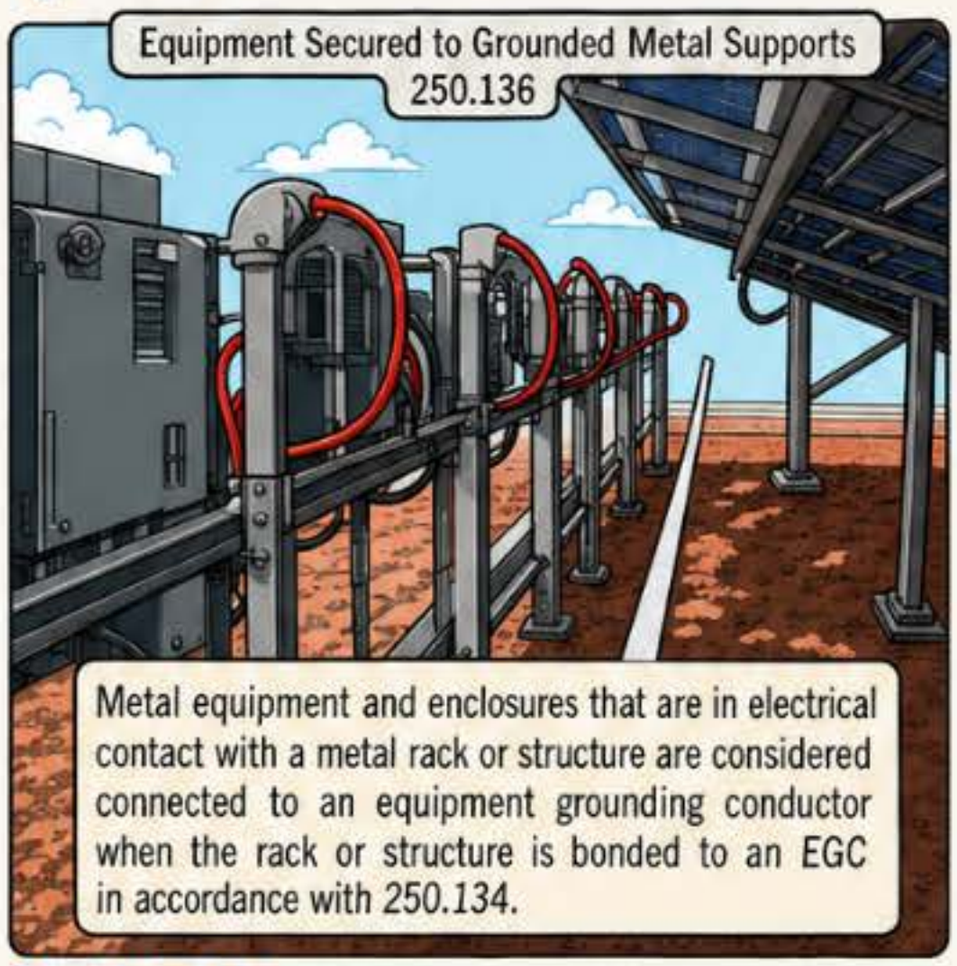


Figure 250–238

250.138 Cord-and-Plug-Connected

(A) Equipment Grounding Conductor. Metal parts of cord-and-plug-connected equipment must be connected to an equipment grounding conductor that terminates to a grounding-type attachment plug.

Figure 250–239

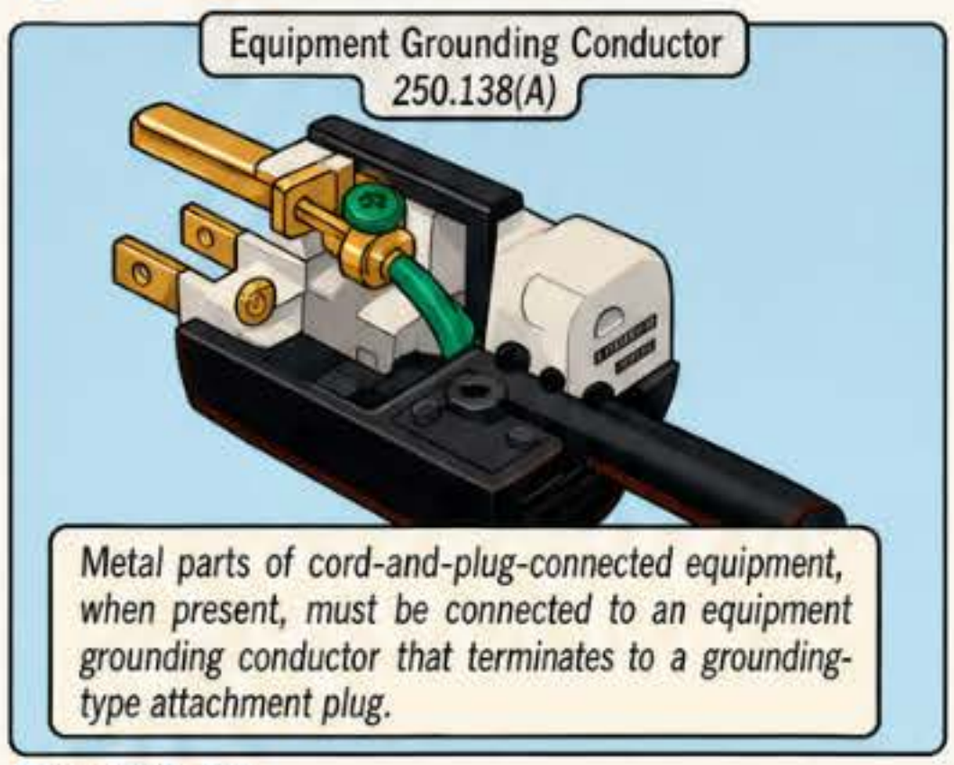


Figure 250–239

250.140 Frames of Ranges, Ovens, and Clothes Dryers

Frames of electric ranges, wall-mounted ovens, counter-mounted cooking units, clothes dryers, and outlet boxes that are part of the circuit for these appliances must be connected to the circuit equipment grounding conductor in accordance with 250.134.

Figure 250–240

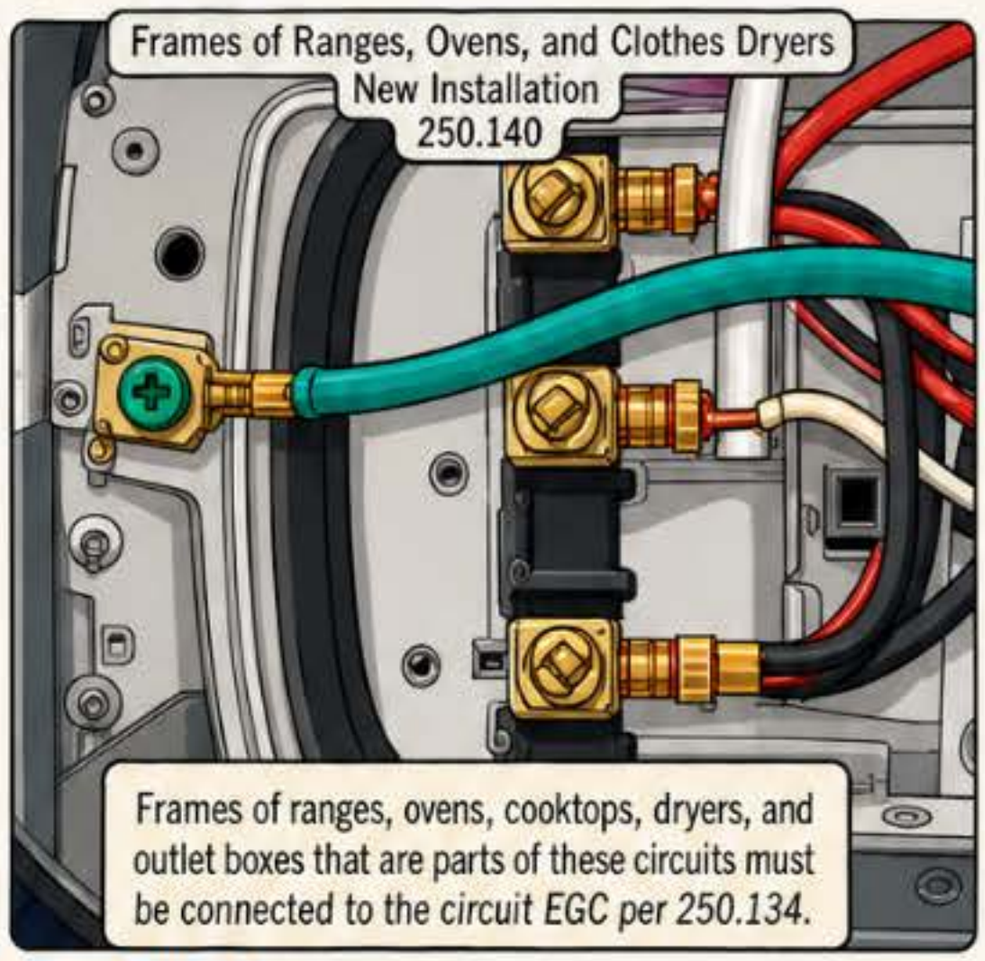


Figure 250–240

Caution

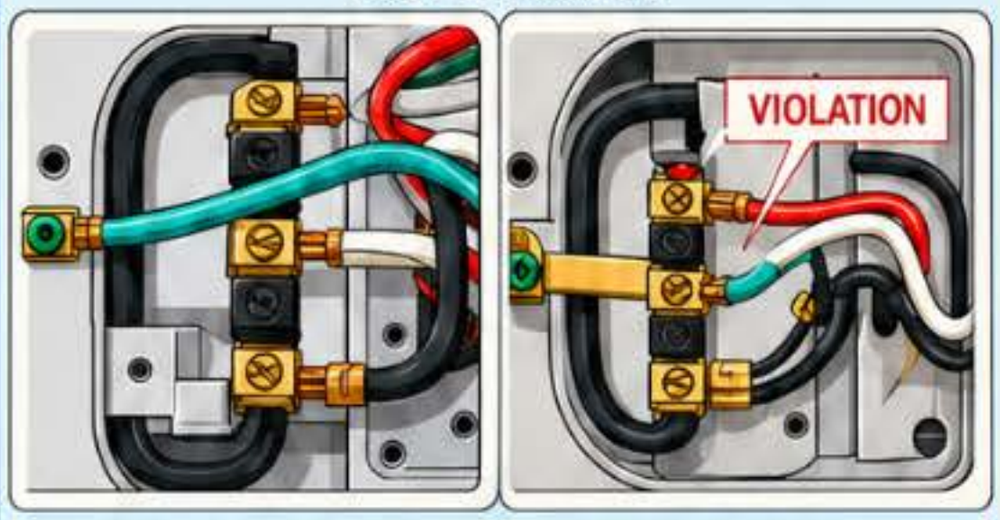
Ranges, dryers, and ovens may have their metal cases connected to the neutral conductor at the factory. This neutral-to-case connection must be removed when these appliances are installed in new construction, and a 4-wire flexible cord and receptacle must be used [250.142(B)].

Figure 250–241

Ex: *For existing installations, if an equipment grounding conductor is not present in the outlet box, the frames of electric ranges, wall-mounted ovens, counter-mounted cooking units, clothes dryers, and outlet boxes that are part of the circuit for these appliances may be connected to the circuit's neutral conductor.*

Figure 250–242

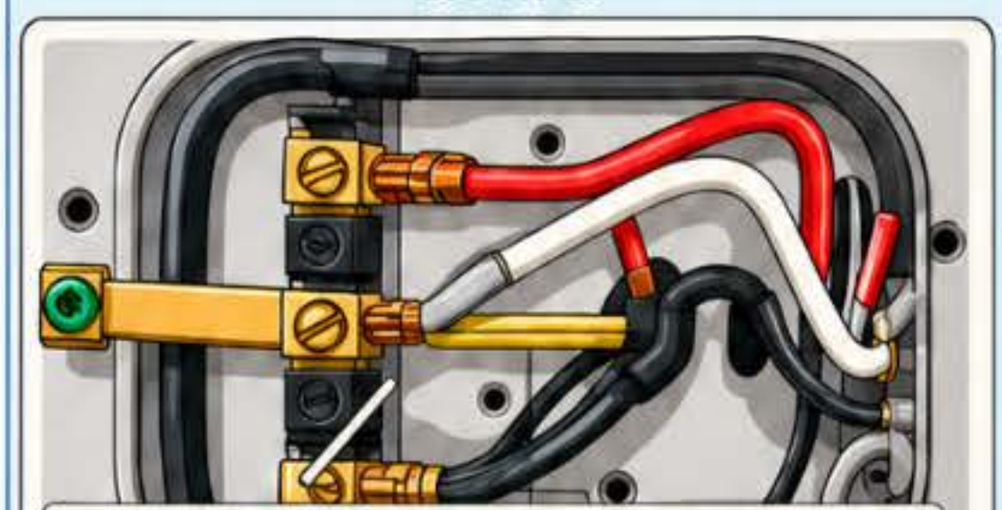
Frames of Ranges, Ovens, and Clothes Dryers
New Installation
250.140 Comment



Caution: Ranges, dryers, and ovens may have their metal cases connected to the neutral conductor at the factory. This neutral-to-case connection must be removed when these appliances are installed in new construction.

Figure 250–241

Frames of Ranges, Ovens, and Clothes Dryers
Existing Installation
250.140 Ex



For existing installations, where an EGC isn't present in the outlet box, the frames and outlet boxes that are part of the circuit can be connected *to the circuit neutral conductor.*

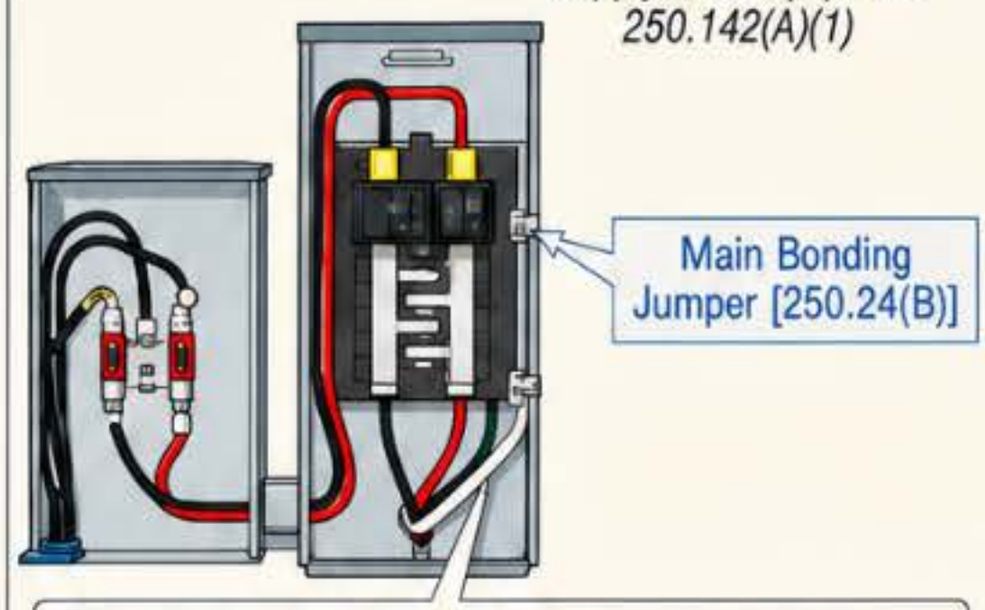
Figure 250–242

250.142 Neutral Conductor for Effective Ground-Fault Current Path

(A) Services and Separately Derived Systems. The neutral conductor is permitted to be connected to metal parts of equipment, raceways, and enclosures for the purpose of serving as the effective ground-fault current path for fault current returning to the source at one of the following locations:

- On the supply side of service disconnect in accordance with 250.24(A). Figure 250–243

Neutral Conductor
Supply-Side Equipment
250.142(A)(1)



The service neutral conductor serves as the effective ground-fault current path for fault current returning to the source in accordance with 250.24(A).

Figure 250–243

Author's Commentary:
I see this section as defining where the neutral-to-case connection is allowed to occur so the neutral can help carry ground-fault current back to the source. The main bonding jumper is used when making this connection on the supply side.
— Michael Hamilton

(2) Main Disconnect. On the supply side or within the enclosure of the main disconnecting means for separate buildings as provided in 250.32(B)(1) Ex 1.

(3) Separately Derived Systems. On the supply side or within the separately derived system disconnect in accordance with 250.30(A)(1).

Author's Commentary:
The neutral-to-case bond is also allowed on the supply side of a separately derived system disconnect when the system bonding jumper is installed following 250.30(A)(1).
— Michael Hamilton

(B) Equipment on Load Side of Service Disconnect. Except as permitted in 250.142(A), the neutral conductor is not permitted to be connected to the equipment grounding conductor on the load side of the service disconnect [250.24] or separately derived system disconnect [250.30(A)]. Figure 250–244

Note: *The neutral-to-case connection points discussed on this page are the only locations where the neutral is allowed to be bonded to the equipment grounding conductor.*

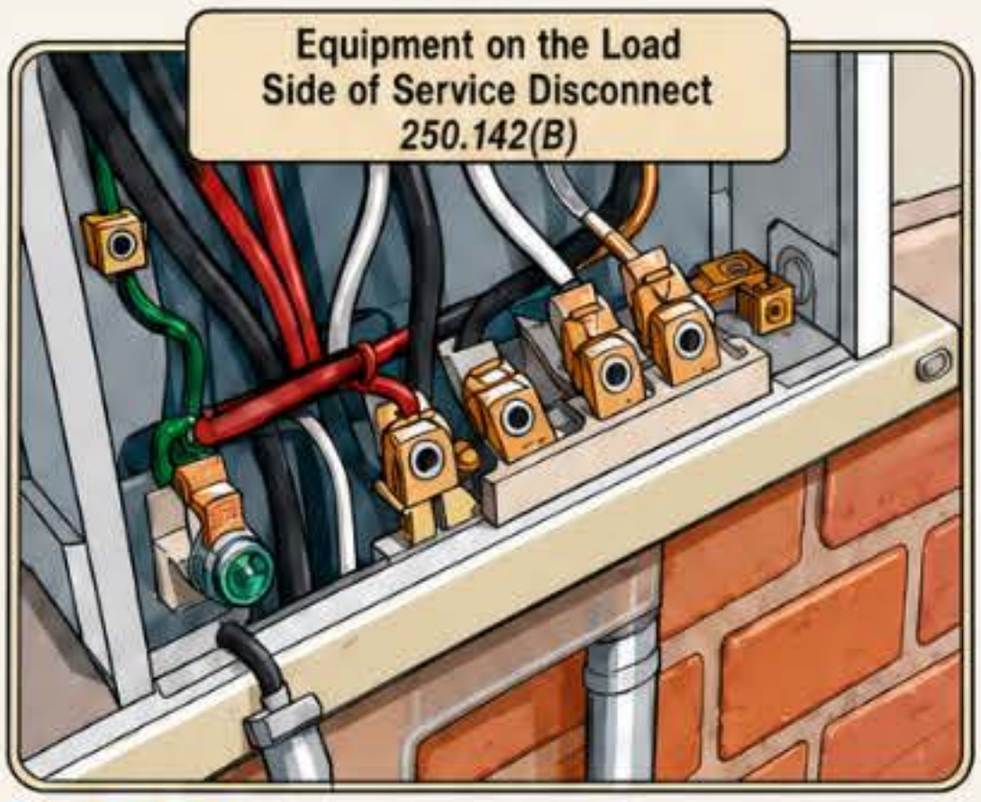


Figure 250–244

VIOLATION: With one exception in 250.142(A), the neutral *conductor is not allowed to be connected to an equipment grounding conductor on the load side of the service disconnect.*

Ex 1: In existing installations, the frames of ranges, wall-mounted ovens, counter-mounted cooking units, and clothes dryers can *be connected to the neutral conductor in accordance with 250.140 Ex.*

Ex 2: *The neutral conductor may be connected to meter socket enclosures on the load side of the service disconnect.** Figure 250–245

(1) Ground-fault protection of equipment is not provided on service disconnect.

(2) Meter socket enclosures are located *right next to the service* disconnect.

(3) The *neutral conductor is sized per 250.122.*

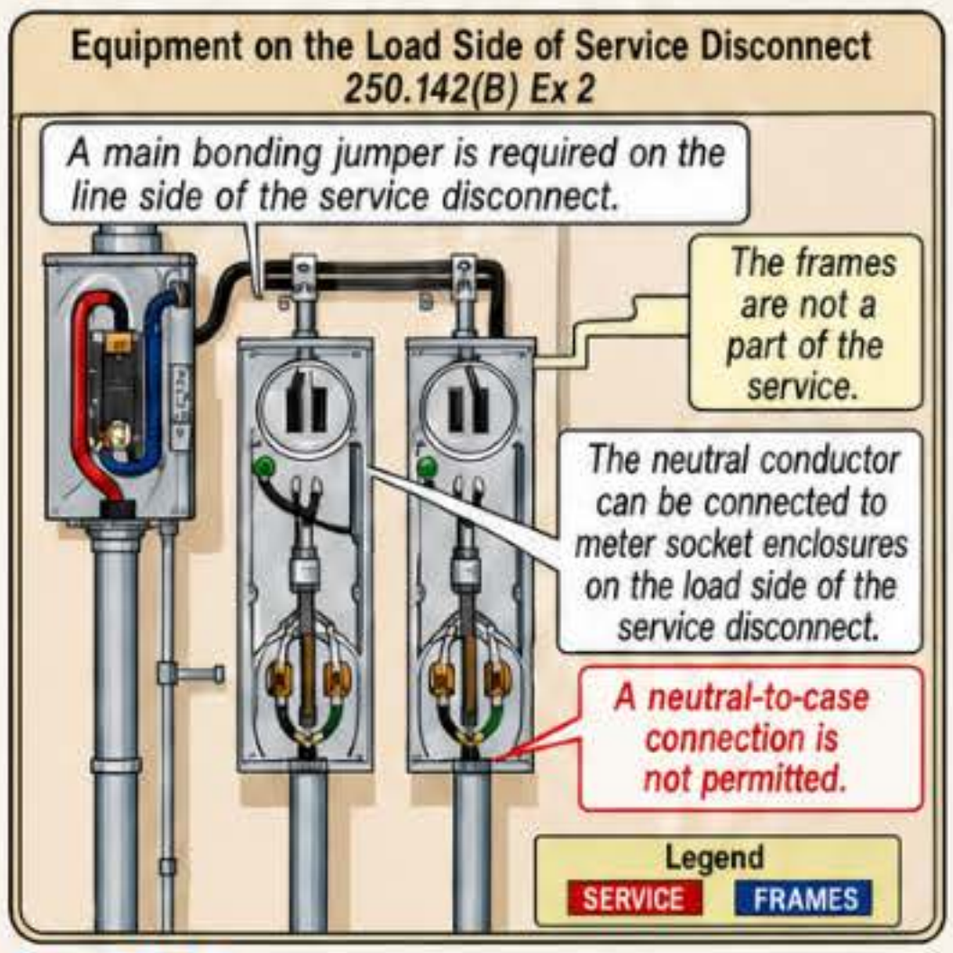


Figure 250–245

250.146 Connecting Receptacle Grounding Terminal to an Equipment Grounding Conductor

An equipment bonding jumper is required to connect the grounding contacts of a receptacle to a metal box connected to an equipment grounding conductor, except as permitted in (A) through (D). * Figure 250–246

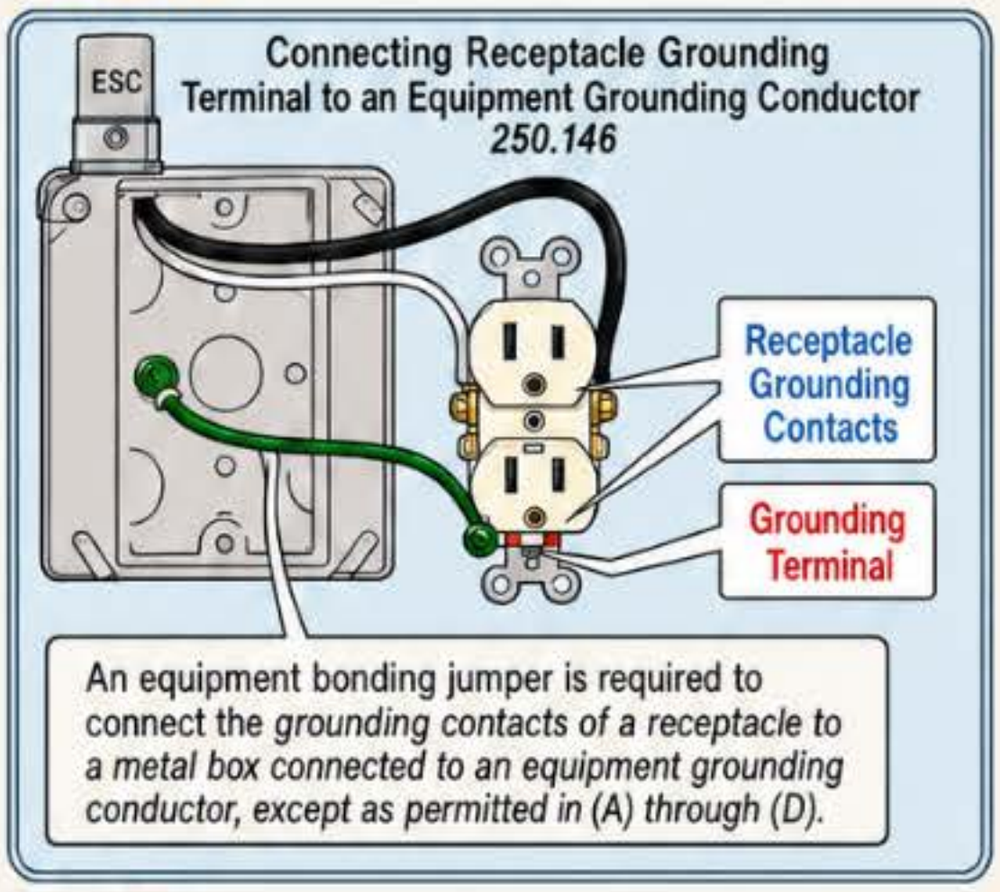


Figure 250–246

Author's Commentary:

▶ *The NEC does not restrict the position of the receptacle grounding terminal; it can face up, down, or sideways. Code cross-references specify the mounting orientation of receptacles, but that has always been rejected.*

— Michael Hamilton

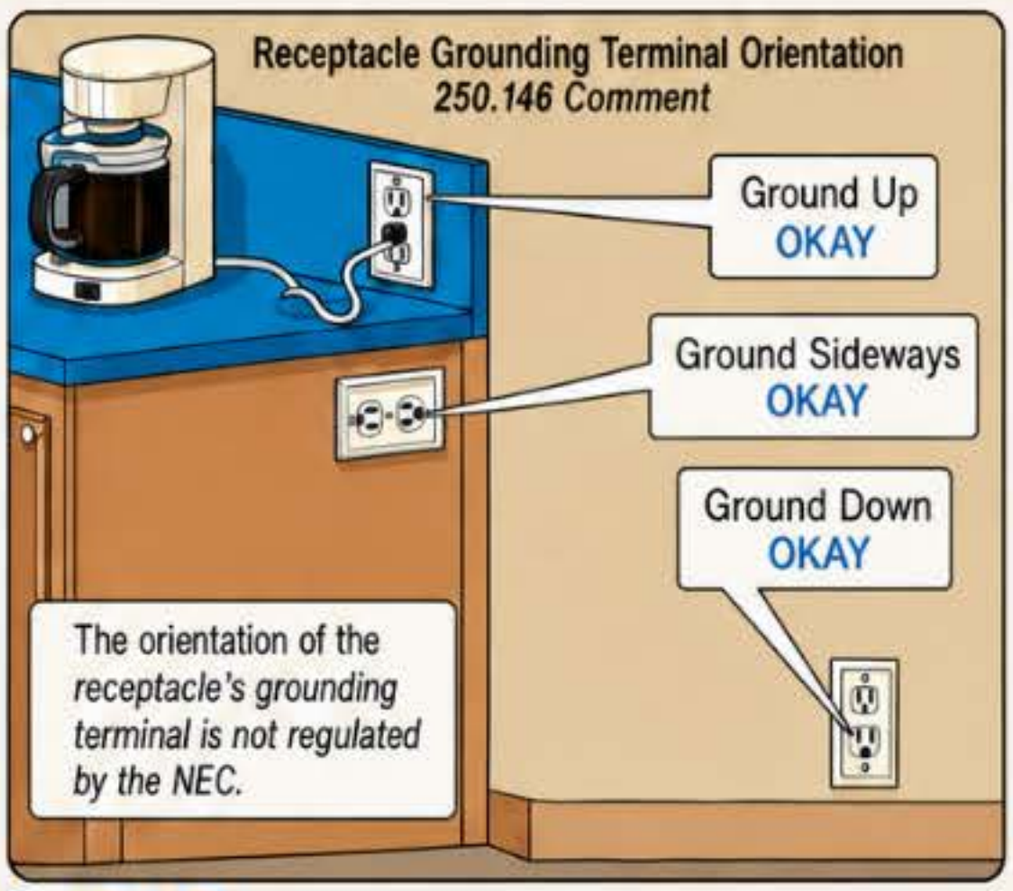
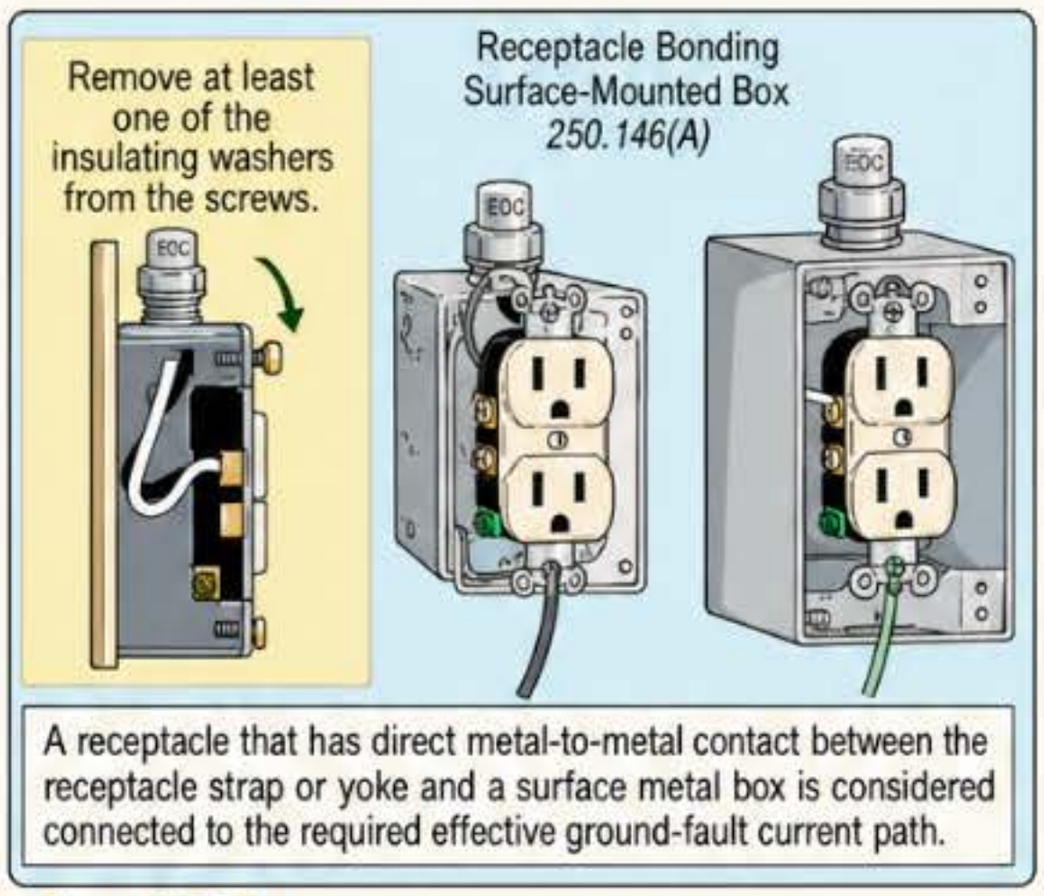


Figure 250–247

* *Reference to "service disconnect" is synonymous with "service equipment." Reference to "load side" is synonymous with "service supply side." Reference to "line side" is synonymous with "source side."*

(A) Surface-Mounted Box. A receptacle that has direct metal-to-metal contact between the receptacle strap or yoke and a surface metal box is considered connected to the required effective ground-fault current path. To ensure adequate metal-to-metal contact, at least one of the insulating retaining washers on the yoke screw must be removed. ▸Figure 250–248

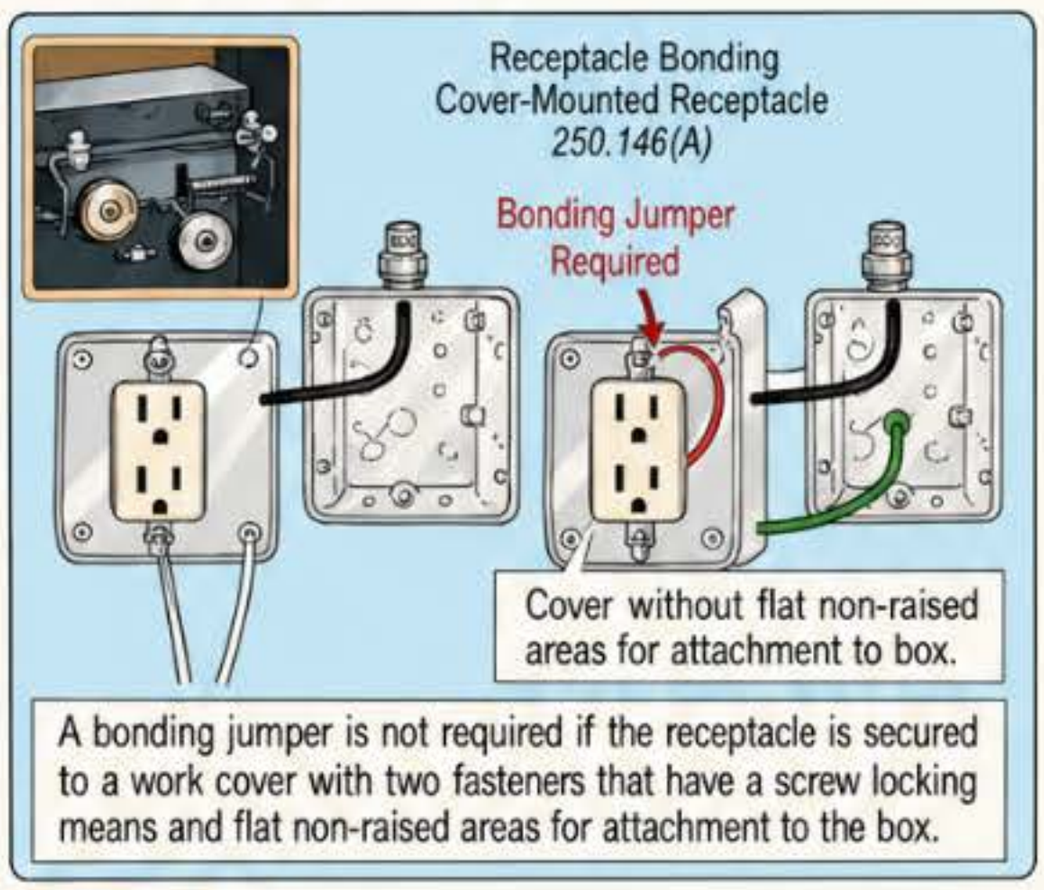


▸Figure 250–248

A receptacle installed on a cover is considered to be connected to the required effective ground-fault current path under both of the following conditions:

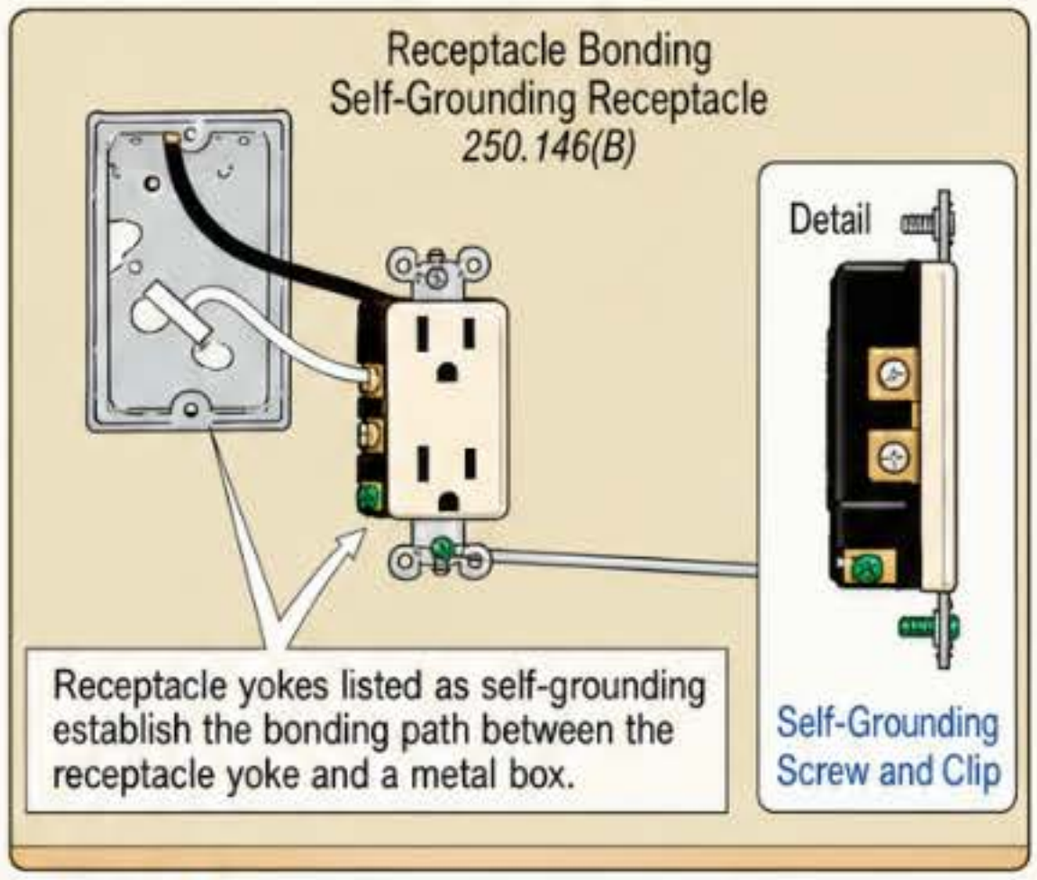
(1) The receptacle is attached to the metal cover with at least two fasteners that have a thread locking feature, or screw or nut locking means.

(2) The cover mounting holes are located on a flat non-raised portion of the cover. ▸Figure 250–249



▸Figure 250–249

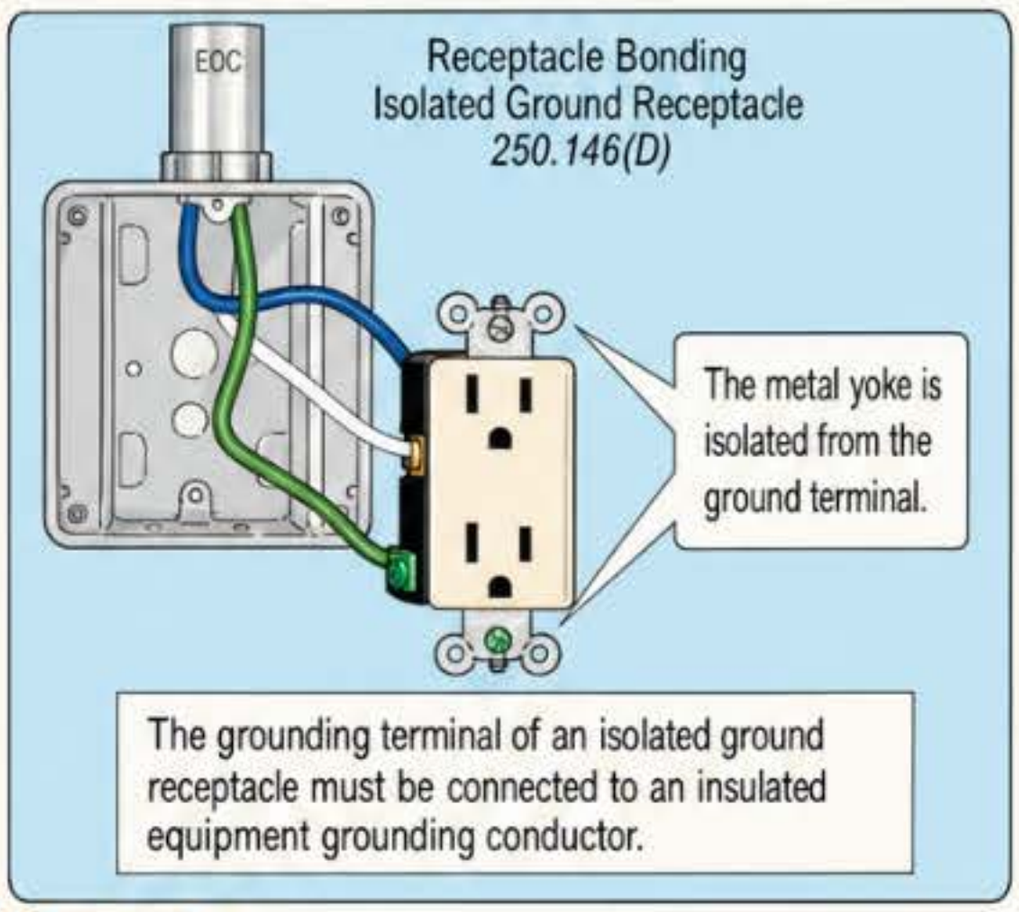
(B) Self-Grounding Receptacles. Receptacle yokes listed as self-grounding establish the equipment bonding between the receptacle yoke and a metal box. ▸Figure 250–250



▸Figure 250–250

(C) Floor Boxes. Listed metal floor boxes must establish the bonding path between the receptacle yoke and a metal box.

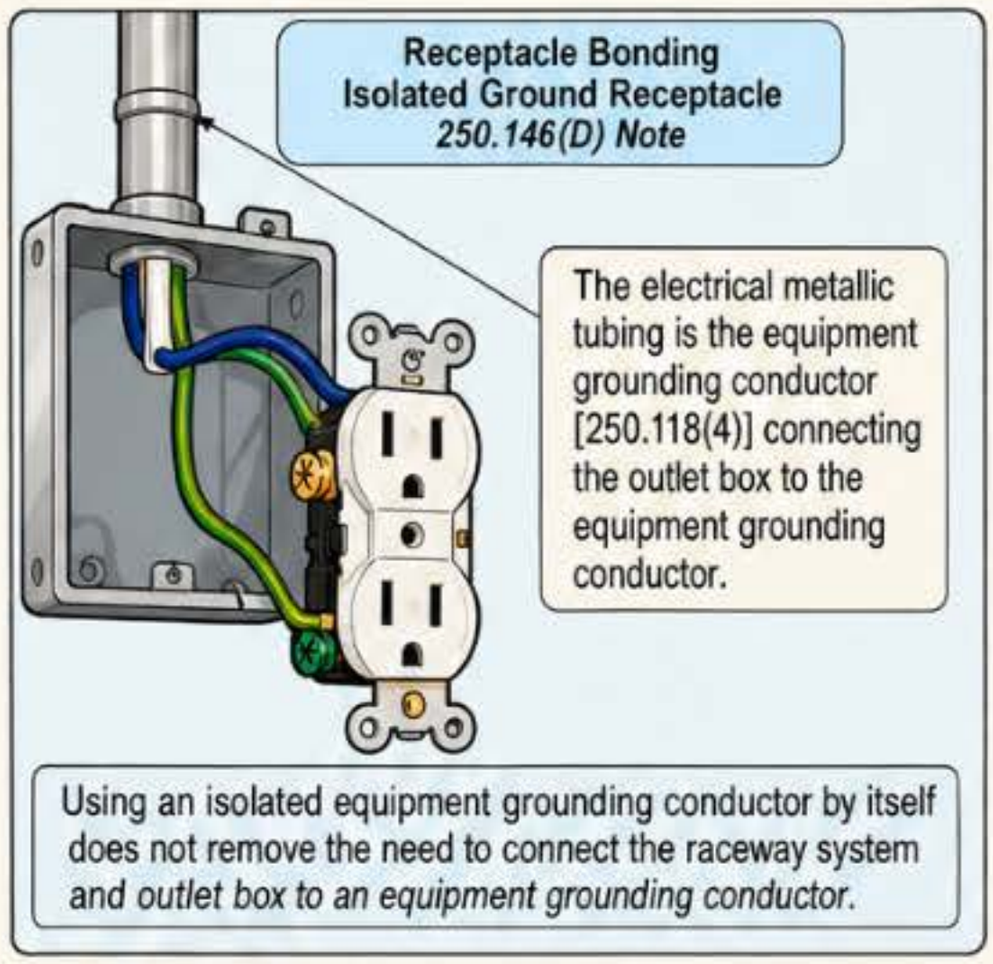
(D) Isolated Ground Receptacles. The grounding terminal of an isolated ground receptacle must be connected to an insulated equipment grounding conductor. ▸Figure 250–251



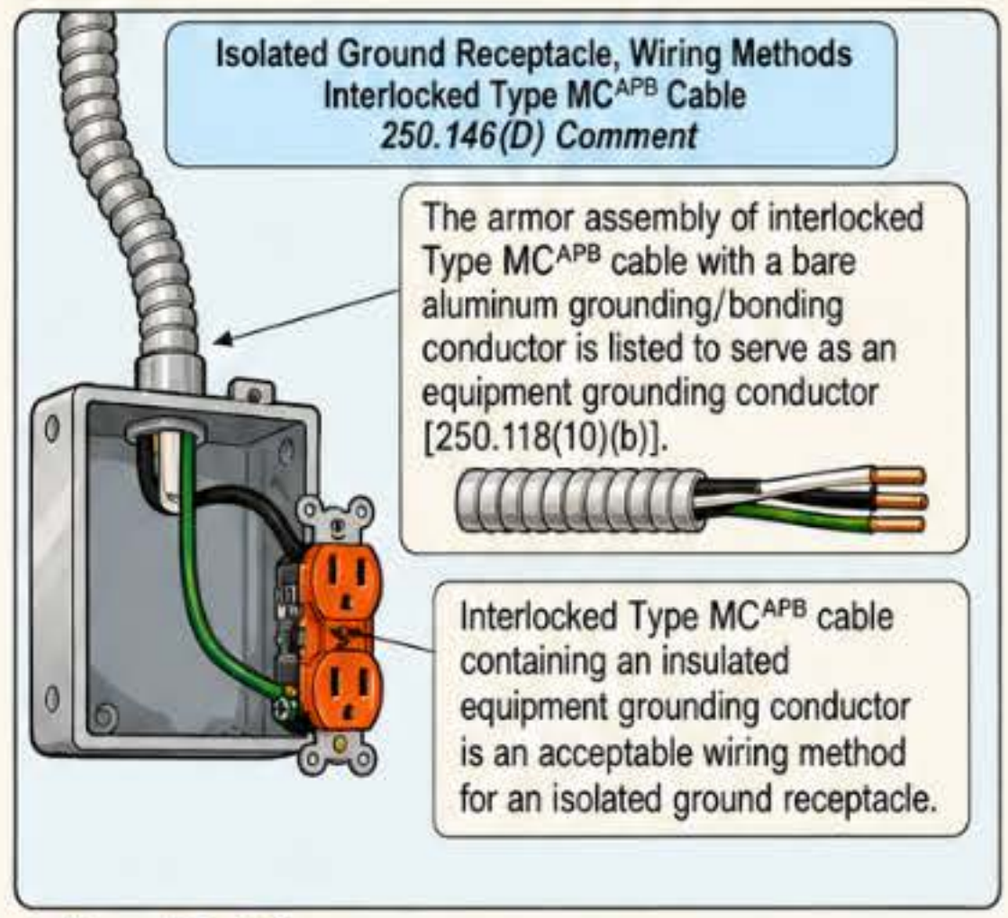
▸Figure 250–251

Note: Use of an isolated equipment grounding conductor does not relieve the requirement for connecting the raceway system and outlet box to an equipment grounding conductor. ▸Figure 250–252

GROUNDING AND BONDING



▲ Figure 250–252

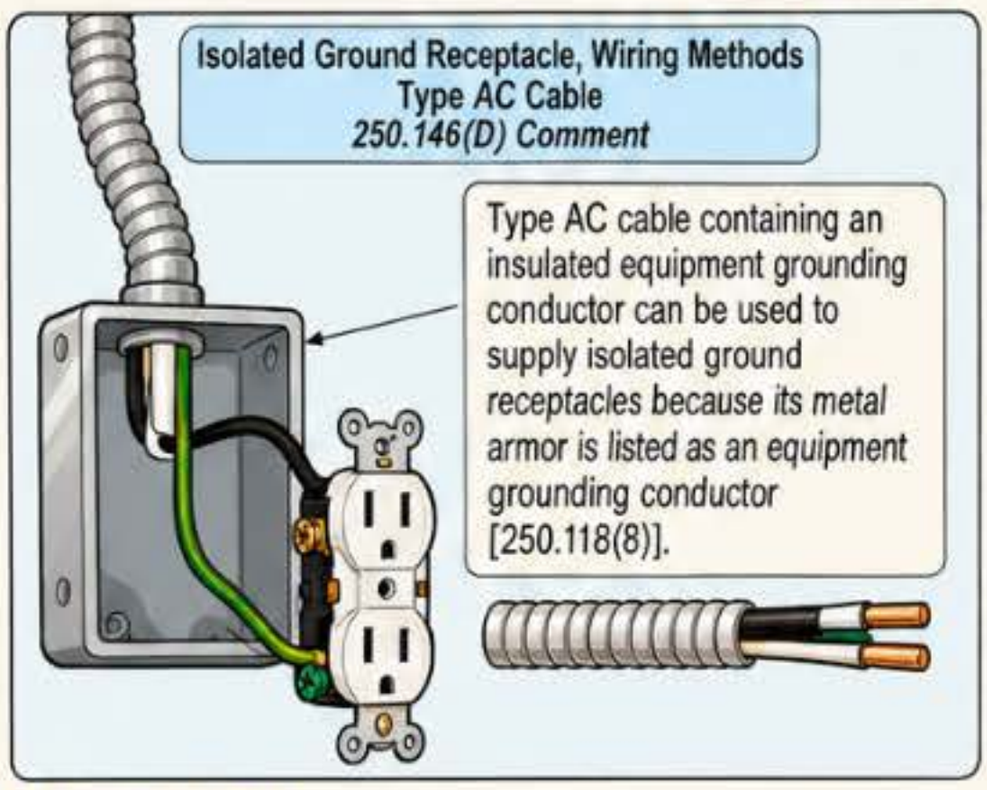


▲ Figure 250–254

Author's Commentary:

- Type AC cable that includes an insulated equipment grounding conductor may be used to supply isolated ground receptacles because the metal armor of that cable is recognized as an equipment grounding conductor [250.118(8)].
- Interlocked Type MC^APB cable with a 10 AWG bare aluminum grounding/bonding conductor can be used to supply isolated ground receptacles because the combination of the metal armor and the 10 AWG bare aluminum conductor is listed as an equipment grounding conductor [250.118(10)(b)]. *An interlocked Type MC^APB cable is an acceptable wiring method for an isolated ground receptacle.*

— Michael Hamilton

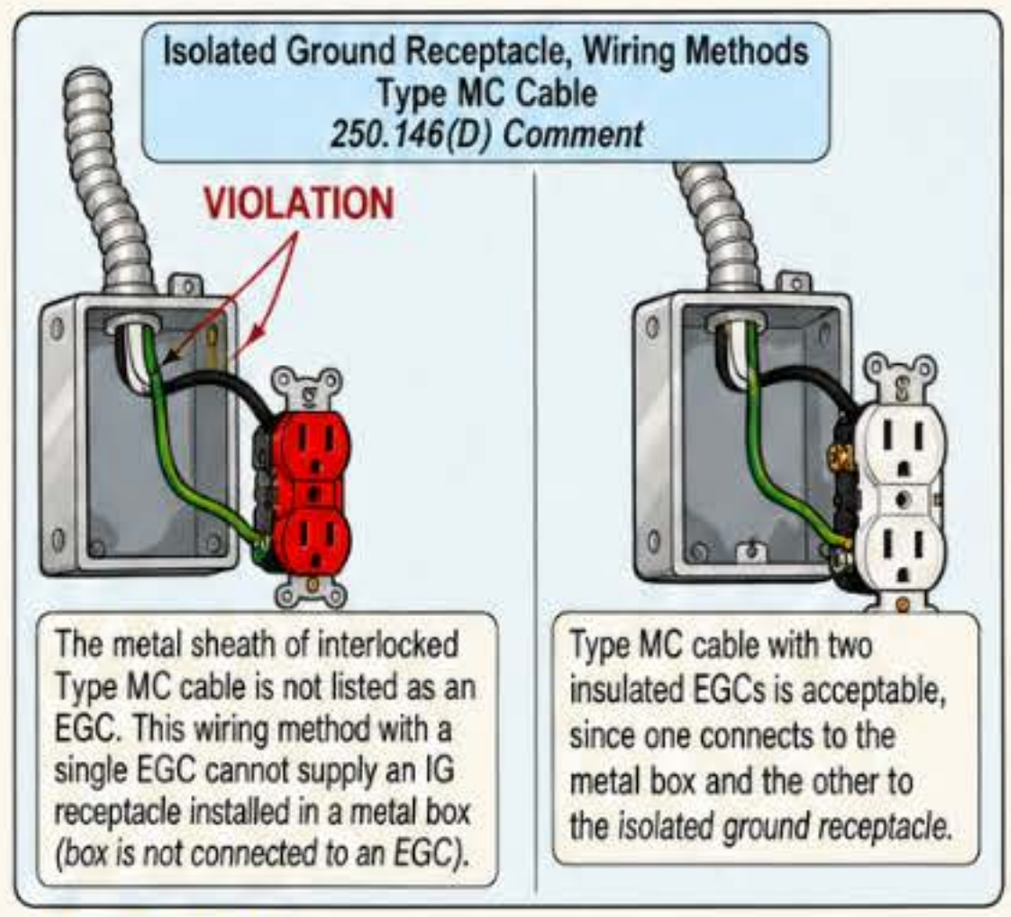


▲ Figure 250–253

CAUTION

Type MC cable using the metal armor of traditional *interlocked Type MC* cable with an insulated *equipment grounding conductor* is not listed as an *equipment grounding conductor*. Therefore, wiring methods that use only a single equipment grounding conductor cannot supply an isolated ground receptacle. *Type MC cable with two insulated equipment grounding conductors is acceptable since one connects to the metal box and the other connects to the isolated ground receptacle.*

▲ Figure 250–255



▲ Figure 250–255

Author's Commentary:

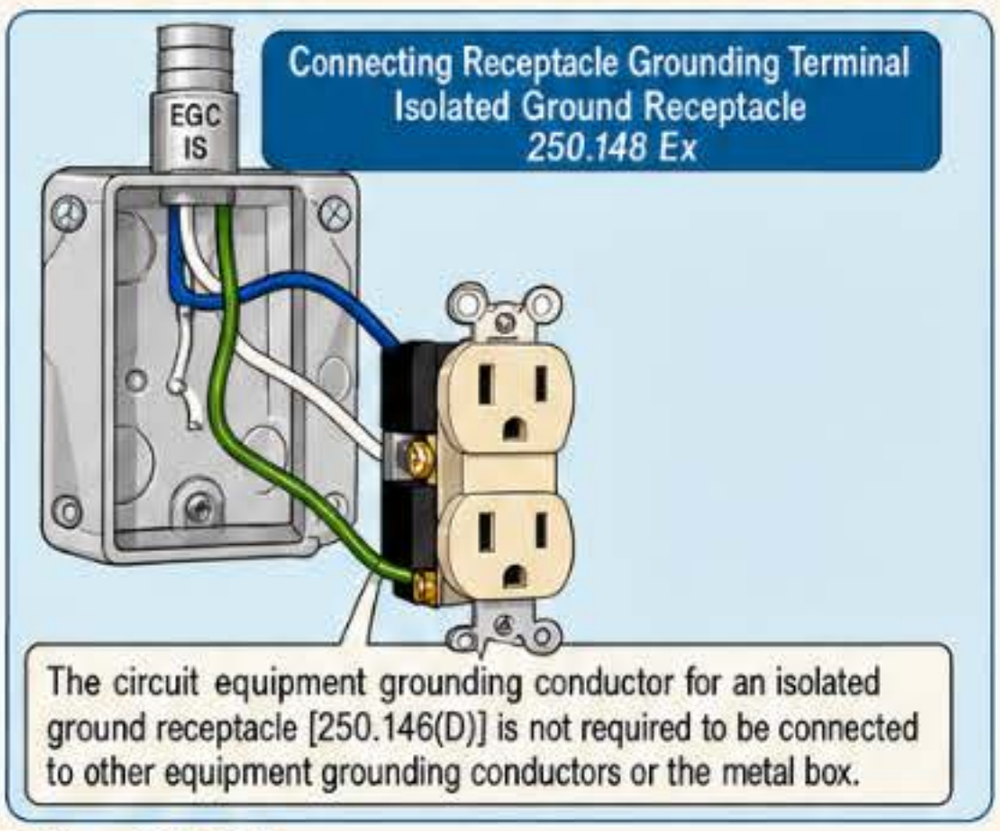
- When is it appropriate to install an isolated ground receptacle, and how is an isolated grounding system designed? These are common design questions that are not addressed in the *NEC* alone [90.1(A)]. In most situations, using an isolated ground receptacle is wasteful and unnecessary. For instance, IEEE 1100, *Powering and Grounding Electronic Equipment (Emerald Book) reports, "The results from applying an isolated ground approach vary widely from no observable impact to conditions that are worse than under the effects sought, depending on the details of the application, the intended effects, or the level of electrical noise at the time the system is configured and connected" [6.5.3.2].*
- In practice, many electrical installations require an *isolated grounding arrangement. However, for these arrangements to be effective, seek engineering advice early to achieve a sound design. Otherwise, systems may be poorly conceived, installed incorrectly, and inadequately maintained.*

— Michael Hamilton

250.148 Continuity and Attachment of Equipment Grounding Conductors in Boxes

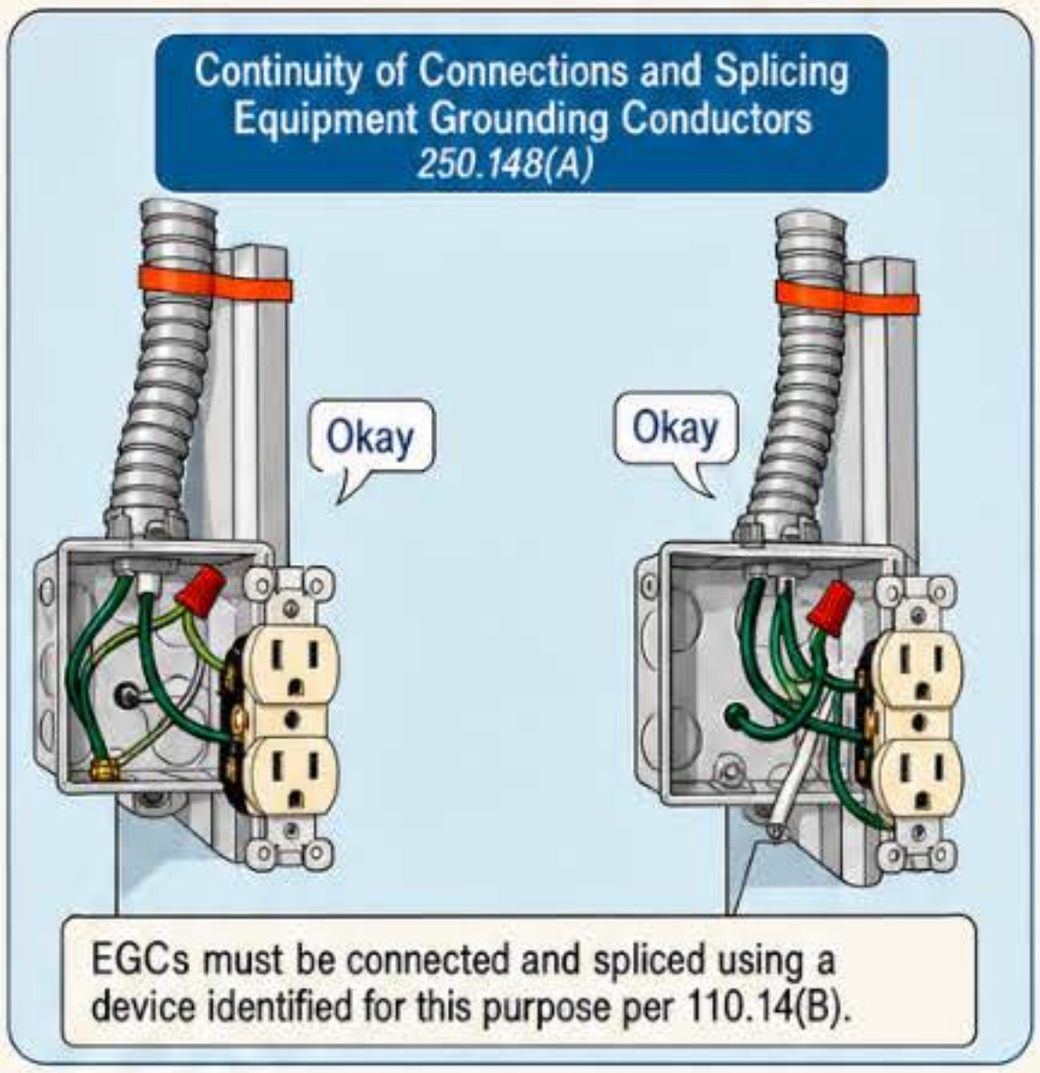
Equipment grounding conductors associated with circuit conductors that are spliced or terminated on equipment within a box must be connected in, or to, the box in accordance with 250.8 and 250.148(A) through (D).

Ex: The circuit equipment grounding conductor for an isolated ground receptacle [250.146(D)] is not required to be connected to the other equipment grounding conductors or to the metal box. Figure 250–256



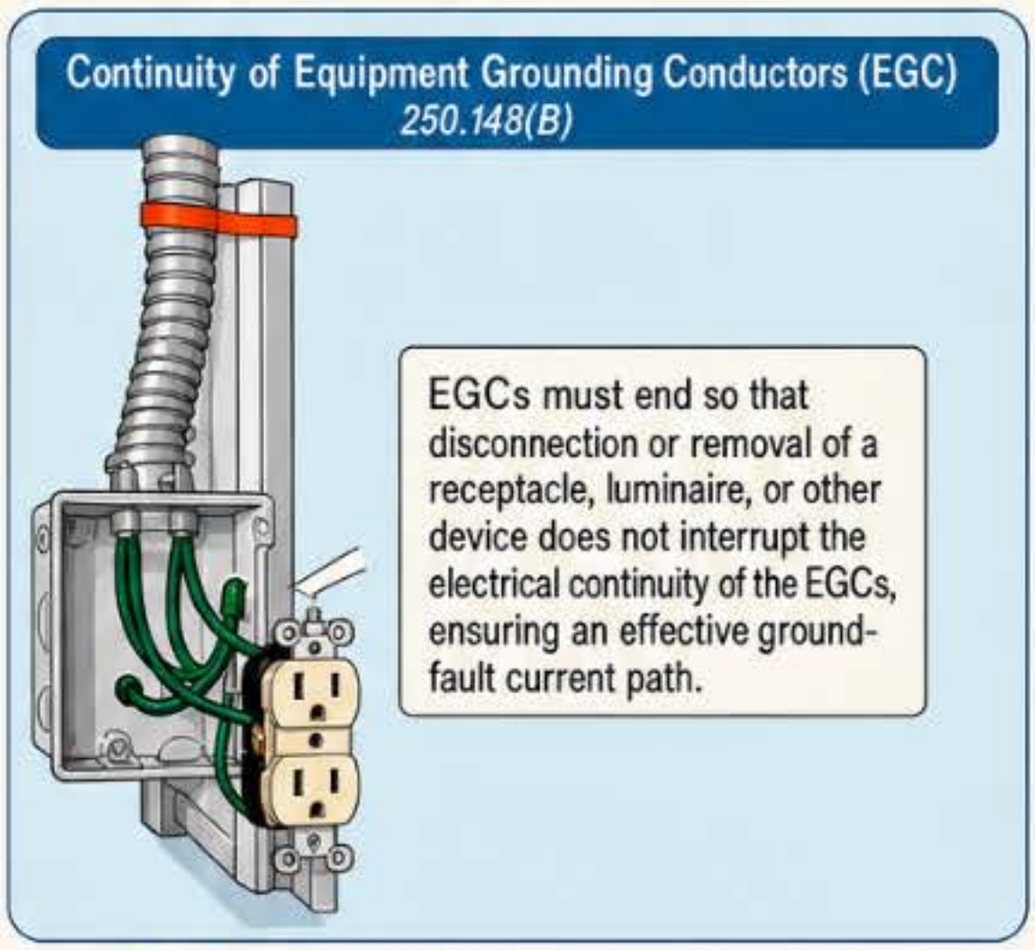
▶ Figure 250–256

(A) Connections and Splices. Equipment grounding conductors must be connected and spliced with a device identified for the purpose in accordance with 110.14(B). Figure 250–257



▶ Figure 250–257

(B) Continuity of Equipment Grounding Conductors. Equipment grounding conductors must end in a way that ensures a continuous connection or can be removed from a receptacle, luminaire, or other device without interrupting the electrical continuity of the equipment grounding conductor(s), providing an effective ground-fault current path. Figure 250–258



▶ Figure 250–258

DEFINITIONS | From Michael Hamilton Publications

(C) Metal Boxes. Items used to provide equipment grounding conductors for circuit conductors that are either spliced or terminated on equipment within a metal box must have their conductors spliced together (250.148) and also connected to the metal box in accordance with 250.8.

Terminating Equipment Grounding Conductors to Metal Boxes
250.148(C)

Equipment grounding conductors for circuit conductors that are spliced or terminated on equipment within a metal box must be spliced together and have a connection to the metal box per 250.8.

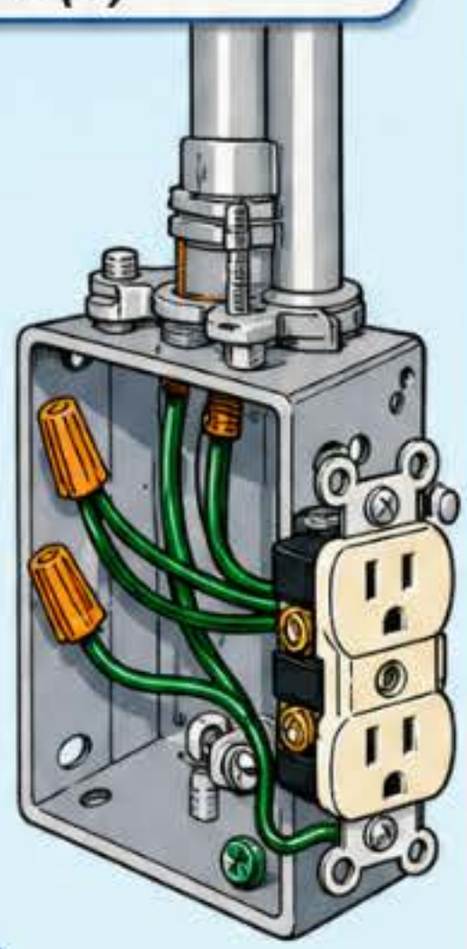


Figure 250–259

Terminating Equipment Grounding Conductors to a Metal Box
250.148(C) Comment

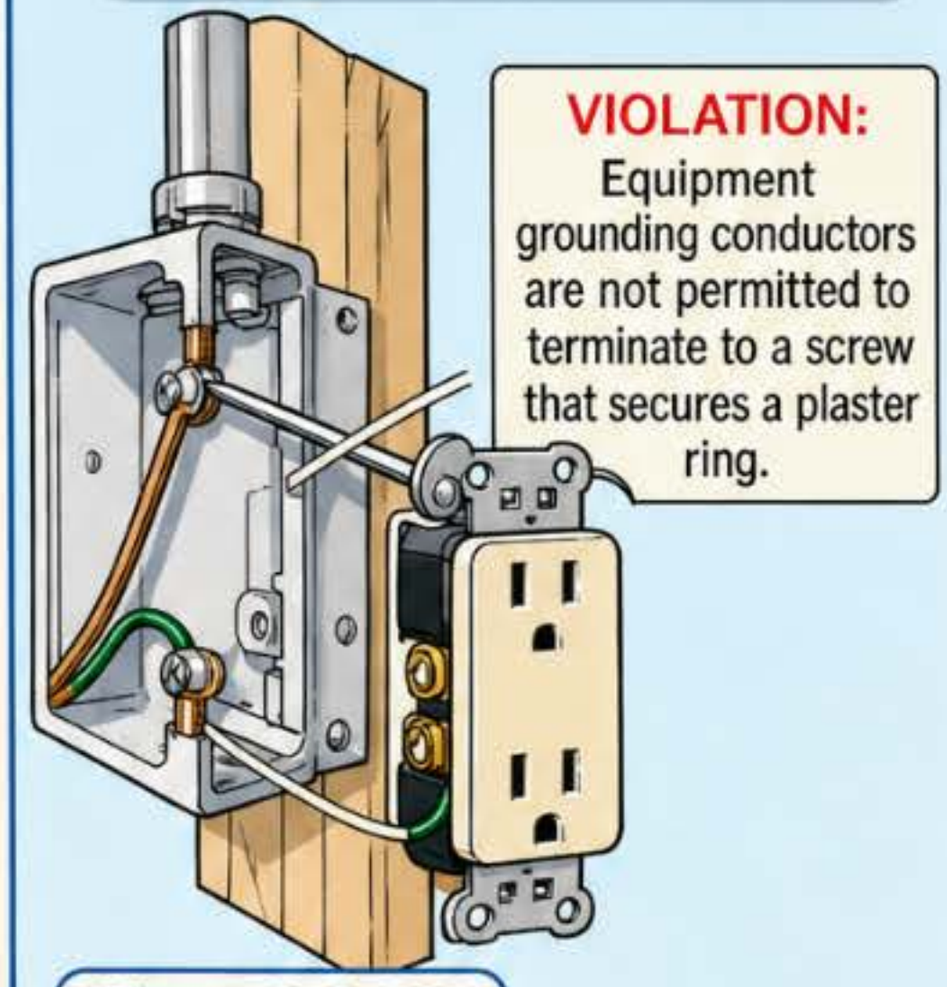


Figure 250–260

(D) Nonmetallic Boxes. Equipment grounding conductors in a nonmetallic outlet box must be arranged such that a connection can be made to any fitting or device in that box requiring connection to an equipment grounding conductor.

Author's Commentary:

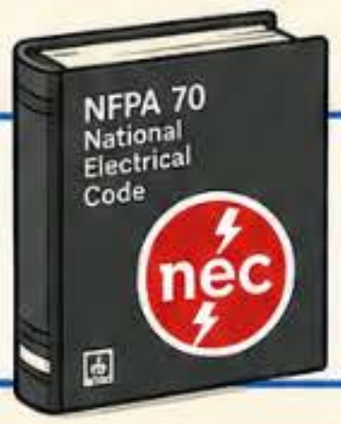
- Equipment grounding conductors are not allowed to terminate to a screw that secures a plaster ring.

  See Figure 250–260.

— Michael Hamilton

Notes

CHAPTER 2 PRACTICE QUESTIONS



Please use the **2023 *Code*** book to answer the following questions.

CHAPTER 2—WIRING AND PROTECTION

1. An insulated grounded conductor _____ or smaller shall be identified by a continuous white or gray outer finish, or by three continuous white or gray stripes along its entire length on other than green insulation.

(a) 8 AWG
(b) 6 AWG
(c) 4 AWG
(d) 3 AWG

2. At the time of installation, grounded conductors _____ or larger can be identified by distinctive white or gray markings at their terminations.

(a) 10 AWG
(b) 8 AWG
(c) 6 AWG
(d) 4 AWG

3. Each multiwire branch circuit shall be provided with a means that will simultaneously disconnect all _____ conductors at the point where the branch circuit originates.

(a) circuit
(b) grounded
(c) grounding
(d) ungrounded

4. In other than dwelling units, GFCI protection shall be provided for all 125V through 250V receptacles supplied by single-phase branch circuits rated 150V or less to ground, 50A or less, where receptacles are installed within _____ ft from the top inside edge of the bowl of a sink.

(a) 3
(b) 4
(c) 5
(d) 6

5. 120V, single-phase, 15A and 20A branch circuits supplying outlets and devices installed in _____ of hotels and motels shall be protected by any of the means described in 210.12(A)(1) through (6).

(a) guest rooms
(b) conference rooms
(c) lobbies and common hallways
(d) game rooms

6. If a 20A branch circuit supplies multiple receptacles, the receptacles shall have an ampere rating of no less than _____.

(a) 10A
(b) 15A
(c) 20A
(d) 30A

7. The total rating of utilization equipment fastened in place, other than luminaires, shall not exceed _____ of a multiple outlet branch circuit rating.

(a) 25%
(b) 50%
(c) 80%
(d) 100%

Chapter 2 Practice Questions

8. At least one receptacle outlet shall be located within _____ ft of the outer end of a peninsular countertop or work surface.
(a) 1
(b) 2
(c) 3
(d) 4

9. At least one lighting outlet controlled by a listed wall-mounted control device shall be installed in every habitable room, kitchen, and bathroom of a dwelling unit.
(a) True
(b) False

10. Where a lighting outlet(s) is installed for interior stairways, there shall be a listed wall-mounted control device at each floor level and landing level that includes an entryway to control the lighting outlet(s) where the stairway between floor levels has six risers or more unless remote, central, or automatic control is used.
(a) True
(b) False

11. For attics and underfloor spaces, utility rooms, and basements in all occupancies, at least _____ lighting outlet(s) containing a switch or controlled by a wall switch shall be installed where these spaces are used for storage or certain equipment requiring servicing.
(a) one
(b) two
(c) three
(d) four

12. Each feeder disconnect rated 1,000A or more and installed on solidly grounded wye electrical systems of more than 150V to ground, but not exceeding _____ phase-to-phase, shall be provided with ground-fault protection of equipment in accordance with 230.95.
(a) 50V
(b) 100V
(c) 150V
(d) 600V

Author's Commentary:
These questions test your understanding of lighting outlets, control locations, special area requirements, and feeder disconnect ground-fault protection.
— Michael Hamilton

13. Where a premises wiring system contains feeders supplied from more than one nominal voltage system, each ungrounded conductor of a feeder shall be identified by phase or line and system by _____ or other approved means.
(a) color coding
(b) marking tape
(c) tagging
(d) any of these

14. The 125 percent multiplier for a continuous load as specified in 210.20(A) _____ included when using the unit loads in table 220.12 for calculating the minimum lighting load for a specified occupancy.
(a) is
(b) is not
(c) is permitted to be
(d) shall not be

15. Where the lighting load for a nondwelling building is designed and constructed to comply with an energy code adopted by the local authority, the lighting load shall be permitted to be calculated using the unit values specified in the _____.
(a) energy code
(b) manufacturer's instructions
(c) *NEC*
(d) lighting design manual

16. Grounding electrode conductors or supply-side bonding jumpers or conductors shall not be permitted within raceways containing service conductors.
(a) True
(b) False

17. The vertical clearance of final spans of overhead service conductors above, or within _____ ft measured horizontally of platforms, projections, or surfaces that will permit personal contact shall be maintained in accordance with 230.24(B).
(a) 3
(b) 6
(c) 8
(d) 10

Author's Commentary:
Carefully review NEC rules on feeder identification, continuous loads, energy-code buildings, bonding restrictions, and overhead service clearances.
— Michael Hamilton

18. Overhead service conductors shall have a minimum clearance from final grade of _____ above areas or sidewalks accessible only to pedestrians, measured from final grade or other accessible surface where the voltage does not exceed 150 volts to ground.

(a) 8 ft
(b) 10 ft
(c) 12 ft
(d) 15 ft

19. Overhead service conductors shall have a minimum vertical clearance of _____ ft from final grade over residential property and driveways, as well as over commercial areas not subject to truck traffic where the voltage does not exceed 300 volts-to-ground.

(a) 10
(b) 12
(c) 15
(d) 18

20. The minimum clearance for overhead service conductors not exceeding 600V that pass over commercial areas subject to truck traffic is _____ ft.

(a) 10
(b) 12
(c) 15
(d) 18

21. Underground service conductors shall have _____.

(a) adequate mechanical strength
(b) sufficient ampacity for the loads calculated
(c) 90°C insulation rating
(d) adequate mechanical strength and sufficient ampacity for the loads calculated

22. Where exposed to the weather, raceways enclosing service-entrance conductors shall be _____ for use in wet locations and arranged to drain.

(a) approved or listed
(b) listed and identified
(c) suitable
(d) listed and labeled

23. Service-entrance and overhead service conductors shall be arranged so that _____ will not enter the service raceway or equipment.

(a) dust
(b) vapor
(c) water
(d) lightning

24. A service disconnecting means shall be installed at a(n) _____ location.

(a) dry
(b) readily accessible
(c) outdoor
(d) indoor

25. A service disconnecting means shall not be installed in bathrooms.

(a) True
(b) False

26. For installations that supply only limited loads of a single branch circuit, the service disconnecting means shall have a rating not less than _____.

(a) 15A
(b) 20A
(c) 25A
(d) 30A

27. Outside feeder tap conductors can be of unlimited length without overcurrent protection at the point they receive their supply if the tap conductors _____.

(a) are protected from physical damage
(b) terminate at a single circuit breaker or a single set of fuses that limits the load to the ampacity of the tap conductors
(c) the overcurrent device is part of the building feeder disconnect
(d) all of these

28. Where a method to reduce clearing time for fuses rated 1200A or greater is required in accordance with 240.67(B), the _____ reduction system shall be performance tested when first installed on site.

(a) ground-fault
(b) short-circuit
(c) arc-fault
(d) arc-energy

Chapter 2 Practice Questions

29. A Type 2 surge protective device is allowed to be connected either on the line side or the load side of the service equipment.

(a) True
(b) False

30. In grounded systems, typically noncurrent-carrying conductive materials that may become energized must be connected _____ in a way that provides an effective low-impedance ground-fault current path.

(a) together
(b) to the electrical supply source
(c) to the closest grounded conductor
(d) together and to the electrical supply source

31. Equipment normally not intended to carry current, such as grounded electrical systems, circuit conductors, surge arresters, surge-protective devices, and conductive parts of equipment, shall be installed and arranged to prevent objectionable current flow.

(a) True
(b) False

32. Alternating-current circuits of less than 50V must be grounded when fed by a transformer whose supply system exceeds 150 volts to ground.

(a) True
(b) False

33. For a separate building or structure supplied by a separately derived system where overcurrent protection is not provided for the supply conductors to the building/structure as allowed by 240.21(C)(4), the installation must be _____ in accordance with 250.30(A).

(a) AFCI protected
(b) grounded and bonded
(c) isolated
(d) all of these

34. The size of a grounding electrode conductor for a building/structure supplied by a feeder must not be smaller than that identified in _____ based on the largest ungrounded supply conductor.

(a) 250.66
(b) 250.102
(c) 250.122
(d) Table 310.16

35. Concrete-encased electrodes of _____ shall not be required to be part of the grounding electrode system when the steel reinforcing bars or rods are not readily accessible for use without disturbing the concrete.

(a) hazardous (classified) locations
(b) health care facilities
(c) existing buildings or structures
(d) agricultural buildings with equipotential planes

36. Rod and pipe grounding electrodes shall not be less than _____ in length.

(a) 6 ft
(b) 8 ft
(c) 10 ft
(d) 20 ft

37. Where practicable, rod, pipe, and plate electrodes shall be installed _____.

(a) directly below the electrical meter
(b) on the north side of the building
(c) below permanent moisture level
(d) all of these

38. Where rock bottom is encountered at an angle up to 45 degrees when driving a rod or pipe electrode, the electrode shall be permitted to be buried in a trench _____ deep.

(a) 30 in
(b) 6 ft
(c) 8 ft
(d) 10 ft

39. Where bonding jumper(s) are used to connect the grounding electrodes together to form the grounding electrode system, rebar is permitted to be used as a conductor to interconnect the electrodes.

(a) True
(b) False

40. If a building or structure is fed by a service or a feeder with _____ or more disconnecting means in separate enclosures, the grounding electrode connections must be made in accordance with 250.64(D)(1), 250.64(D)(2), or 250.64(D)(3).

(a) one
(b) two
(c) three
(d) four

PRACTICE QUESTIONS | 250.148

41. In a system, the grounding electrode conductor or the bonding jumper connected to a concrete-encased electrode is not allowed to extend to other types of electrodes that need a larger conductor. The grounding electrode conductor must not be bigger than _____ AWG copper.

(a) 10 (b) 8
(c) 6 (d) 4

42. An encased or buried connection to a concrete-encased, driven, or buried grounding electrode must be accessible.

(a) True
(b) False

43. When bonding enclosures, metal raceways, frames, and fittings, any nonconductive paint, enamel, or similar coating must be removed from:

(a) contact surfaces
(b) threads
(c) contact points
(d) all of these

44. What is the smallest copper equipment bonding jumper size allowed for a 40A rated circuit?

(a) 14 AWG
(b) 12 AWG
(c) 10 AWG
(d) 8 AWG

45. Metal water piping system(s) must be bonded to the _____ or to one or more grounding electrodes used, if the grounding electrode conductor or bonding jumper to the grounding electrode is of sufficient size.

(a) grounded conductor at the service
(b) service equipment enclosure
(c) grounding electrode conductor if of sufficient size
(d) any of these

Author's Commentary:
Bonding metal water piping helps maintain the piping at the same electrical potential as the system. You can connect to the service, the equipment enclosure, or a properly sized grounding electrode conductor.
— Michael Hamilton

45. The metal water piping system(s) installed in or attached to a building or structure [250.104(A)(3)] shall be bonded to _____.

(a) the building or structure disconnecting means enclosure where located at the building or structure
(b) the equipment grounding conductor run with the supply conductors
(c) one or more grounding electrodes used
(d) any of these

47. The grounded conductor of each separately derived system shall be bonded to the nearest available point of the metal water piping system(s) in the area served by each separately derived system and each bonding jumper shall be sized in accordance with Table 250.102(C)(1) based on the largest ungrounded conductor of the separately derived system.

(a) True
(b) False

48. A separate water piping bonding jumper is required if the metal frame of a building or structure is used as the grounding electrode for a separately derived system and is bonded to the metal water piping in the area served by the separately derived system.

(a) True
(b) False

Author's Commentary:
The extra bonding jumper ensures the water piping and building frame stay at the same potential as the separately derived system.
— Michael Hamilton

49. Type MC cable provides an effective ground-fault current path and is recognized by the 2023 *NEC* as an equipment grounding conductor when _____.

(a) it contains an insulated or uninsulated equipment grounding conductor in compilance with 250.118(1)
(b) the cable assembly contains a bare copper conductor
(c) only when it is hospital grade Type MC cable
(d) it is terminated with bonding bushings

50. A(n) _____ shall be used to connect the grounding terminal of a grounding-type receptacle to a metal box that is connected to an equipment grounding conductor.

(a) equipment bonding jumper
(b) grounded conductor jumper
(c) equipment bonding jumper or grounded conductor jumper
(d) equipment bonding jumper and grounded conductor jumper

Notes

CHAPTER 3

WIRING METHODS AND MATERIALS

Introduction to Chapter 3—Wiring Methods and Materials

Chapter 3 is dedicated to wiring methods and materials, and outlines the specific instalation requirements for conductors, cables, raceways, and fittings. This chapter presents detailed guidance on the installations and limitations associated with each method. Not understanding the information in this chapter may cause installations to be made incorrectly. Take the time to study carefully and verify that every installation you perform complies with these requirements. Ignoring the rules for the wiring methods in Chapter 3 can lead to serious issues such as power interruptions, fire hazards, and overall poor system performance.

The wiring method you select will depend on multiple factors, including job specifications, Code requirements, the surrounding environment, the type of building construction, and cost considerations, just to name a few.

Chapter 3 begins with rules that are common to most wiring methods [Article 300]. It then addresses conductors [Article 310], cabinets, cutout boxes, and meter socket enclosures [Article 312], and boxes and conduit bodies [Article 314]. The topics that follow become more specialized and deal with individual wiring methods, such as specific types of cables [Articles 320 through 340] and different raceways [Articles 342 through 390]. The chapter concludes with Article 392, a support system.

Notice as you read through the various wiring method articles that the *Code* tries to use similar section numbering for similar subjects from one article to the next, using the *same digits after the decimal point in* the section number for the same topic. *This makes it easier to locate the specific requirements of a particular article. For example, the rules for securing and supporting can be found in the section that ends with ".30" of each article.*

Wiring Method Articles

- **Article 300—General Requirements for Wiring Methods and Materials.** Article 300 contains the overarching requirements for all wiring methods included in the *NEC*, except for signaling and communications systems (communications, antennas, and coaxial cable), which are covered in Chapters 7 and 8.
- **Article 310—Conductors for General Wiring.** This article provides the general requirements for conductors, such as insulation markings, ampacity ratings, and conductor use. It also includes a section that addresses single-family dwelling service and feeder conductors *exclusively*. Article 310 does not apply to conductors that are part of *flexible cords, fixture wires, or conductors that are an integral part of equipment* [90.7 and 310.1].
- **Article 312—Cabinets and Meter Socket Enclosures.** *Article 312 covers the installation and construction specifications for cabinets and meter socket enclosures.*
- **Article 314—Outlet, Device, Pull, and Junction Boxes; Conduit Bodies; Fittings; and Handhole Enclosures.** This article details the installation *requirements for outlet boxes, pull and junction boxes, as well as conduit bodies and handhole enclosures.*

• • •

Cable Articles

Articles 320 through 340 cover many distinct varieties of cables. If you invest time learning these cable types, you will be able to:

- Determine what is available for a given task.
- Identify cable constructions that have special *NEC* requirements.
- Avoid purchasing cables that you cannot install due to *Code* limitations or an incompatible wiring method.

The following provides a concise overview of these included articles.

- **Article 320—Armored Cable (Type AC).** Armored cable consists of insulated conductors, sized 14 AWG through 1 AWG, individually wrapped with waxed paper. The conductors are enclosed in a flexible metal (steel or aluminum) spiral sheath that interlocks at the edges. Many electricians refer to this metal cable as "BX®," a trade name for this style of flexible metal conduit.

- **Article 330—Metal-Clad Cable (Type MC).** Metal-clad cable uses insulated conductors wrapped in a metal sheath that may be either corrugated or smooth. This sheath can be aluminum tubing, corrugated steel, or interlocked steel or aluminum. Type MC cable is highly adaptable and can be used in a wide range of locations and situations. It is the most commonly installed metal cable because it works well as both an armored cable and as a flexible metal conduit.

- **Article 334—Nonmetallic-Sheathed Cable (Type NM).** Commonly called "Romex®," this cable contains two, three, or four insulated conductors, sized 14 AWG through 2 AWG. It is wrapped with a nonmetallic outer jacket. Because it includes an additional bare equipment grounding conductor, this cable is widely used for residential installations but may be allowed in some commercial locations.

- **Article 336—Power and Control Tray Cable (Type TC).** Tray cable for power and control applications is flexible, cost-effective, and easy to install. It provides minimal physical protection for the conductors, so the installation requirements are strict. Its low cost and simple installation make it a common choice for many industrial wiring applications.

- **Article 338—Service-Entrance Cable (Types SE and USE).** Service-entrance and underground service-entrance cables may be a single conductor or a multiconductor assembly enclosed by an overall nonmetallic jacket or sheath. These cables are usually used for services not exceeding 1,000 volts but can also be used for feeder and branch circuits. When a service conductor (single or assembly) is used, it is typically identified as Type "SE." When the assembly includes two insulated phase conductors and a bare neutral (ground) conductor, it is identified as Type "USE." Type SE cable normally includes three conductors (two ungrounded plus one neutral), while Type USE includes those same three conductors plus an additional insulated neutral.

- **Article 340—Underground Feeder and Branch-Circuit Cable (Type UF).** Type UF cable is designed for direct burial. It is resistant to moisture, fungi, and corrosion and can be installed in damp earth. This cable includes 14 AWG through 4/0 AWG (340.104). A thermoplastic jacket surrounds the insulated conductors.

Raceway Articles

Articles 342 through 390 cover numerous raceway types. Refer to Article 100 for the definition of raceway. When you become familiar with these raceway varieties, you will be able to:

- Determine what is available for a given task.
- Recognize raceway types that have special *Code* requirements.
- Avoid purchasing raceways that you cannot install due to *NEC* rules or an incompatible wiring method.

Here is a brief overview of each those included in this book:

- **Article 342—Intermediate Metal Conduit (Type IMC).** IMC is a round metal raceway with the same outside diameter as rigid metal conduit. The wall of IMC is thinner than rigid metal conduit, so it has a larger interior cross-sectional area for conductors. Because IMC is lighter and generally less expensive, the NEC permits its use wherever rigid metal conduit is allowed. Its strength is greater than that of rigid metal conduit, even though the wall thickness varies. IMC may also be made from a different steel alloy, giving it greater strength.
- **Article 344—Rigid Metal Conduit (Type RMC).** RMC is much like IMC, except its wall is thicker, so the interior cross-sectional area is smaller. RMC is heavier than IMC and may only be used for the same applications that listed for IMC.
- **Article 348—Flexible Metal Conduit (Type FMC).** FMC is a flexible, circular metal raceway made by winding a helically formed strip of either steel or aluminum. Common trade names are "Greenfield" (often shortened to "Flex").
- **Article 350—Liquidtight Flexible Metal Conduit (Type LFMC).** LFMC is similar in construction to FMC but has an outer jacket that is liquidtight, nonmetallic, and resistant to sunlight. Beneath the jacket is a flexible metal core with integral couplings, connectors, and fittings. It is installed primarily to protect electrical conductors in wet locations. Trade names include "Sealtite®" or "liquidtight." LFMC is comparable to FMC but includes an additional thermoplastic cover.
- **Article 352—Rigid Polyvinyl Chloride Conduit (Type PVC).** PVC conduit is a nonmetallic raceway made of rigid polyvinyl chloride. It is round in cross section and is used with either integral, solvent-welded, or listed couplings, connectors, and fittings. It is authorized for electrical installations.
- **Article 356—Liquidtight Flexible Nonmetallic Conduit (Type LFNC).** LFNC is a flexible, nonmetallic raceway—most often called "Carflex®." It is circular in cross section and has an outer, liquidtight, nonmetallic, sunlight-resistant jacket over a flexible core, with listed couplings, connectors, and fittings.
- **Article 358—Electrical Metallic Tubing (EMT).** EMT is a thin-wall, round metal raceway designed to safeguard and route conductors and cables. It is lighter than rigid metal conduit and IMC. EMT uses threaded, set-screw, or all-connector fittings; couplings are threaded. It is offered in a range of sizes and is typically finished in gray or blue.
- **Article 362—Electrical Nonmetallic Tubing (ENT).** ENT is pliable, corrugated, nonmetallic raceway made of PVC. It functions similarly to flexible tubing and is sometimes called "Smurf Pipe" or "Smurf Tube" because it was originally available in blue. Today it is available in multiple colors such as red and yellow.
- **Article 376—Metal Wireways.** A wireway is a sheet-metal enclosure with hinged or removable covers used to house and protect electrical conductors and cables. It must be a complete, continuous system.
- **Article 380—Multoutlet Assemblies.** A multoutlet assembly is a surface-mounted raceway designed to contain conductors and receptacles. It is built either at the work site or in the factory.
- **Article 386—Surface Metal Raceways.** Surface metal raceway is a metal raceway mounted to a *surface, along with associated accessories, in which conductors are placed after installation of the raceway system.*

Cable Tray

- **Article 392—Cable Trays.** A cable tray consists of units or sections with fittings used to support *and secure cables and raceways. Cable trays are not raceways; they are support systems for* cables, raceways, and enclosures.

Author's Commentary:
Understanding the characteristics and best uses for each wiring method and material helps you select the right solution for every installation, ensuring safety, reliability, and code compliance.

— Michael Hamilton

Notes

ARTICLE 300 GENERAL REQUIREMENTS FOR WIRING METHODS AND MATERIALS

Introduction to Article 300—General Requirements for Wiring Methods and Materials

Article 300 sets forth the baseline rules for every wiring method recognized in the 2023 NEC. It does not cover twisted-pair cable and coaxial cable (which are addressed in Chapters 7 and 8) unless Article 300 is specifically cited.

This article focuses on how to install, route, splice, guard, and secure conductors and raceways. The way you interpret and apply the requirements of Article 300 generally becomes evident in the finished work. Many of these requirements influence the appearance, service life, and even the safety of the electrical system. Imagine you accidentally dig up a plant in the yard and hit a service cable! After studying and understanding the rules in this article, you will be able to act right away because the burial depth requirements of 300.5 were likely violated or ignored. Even when issues aren't apparent, they may exist.

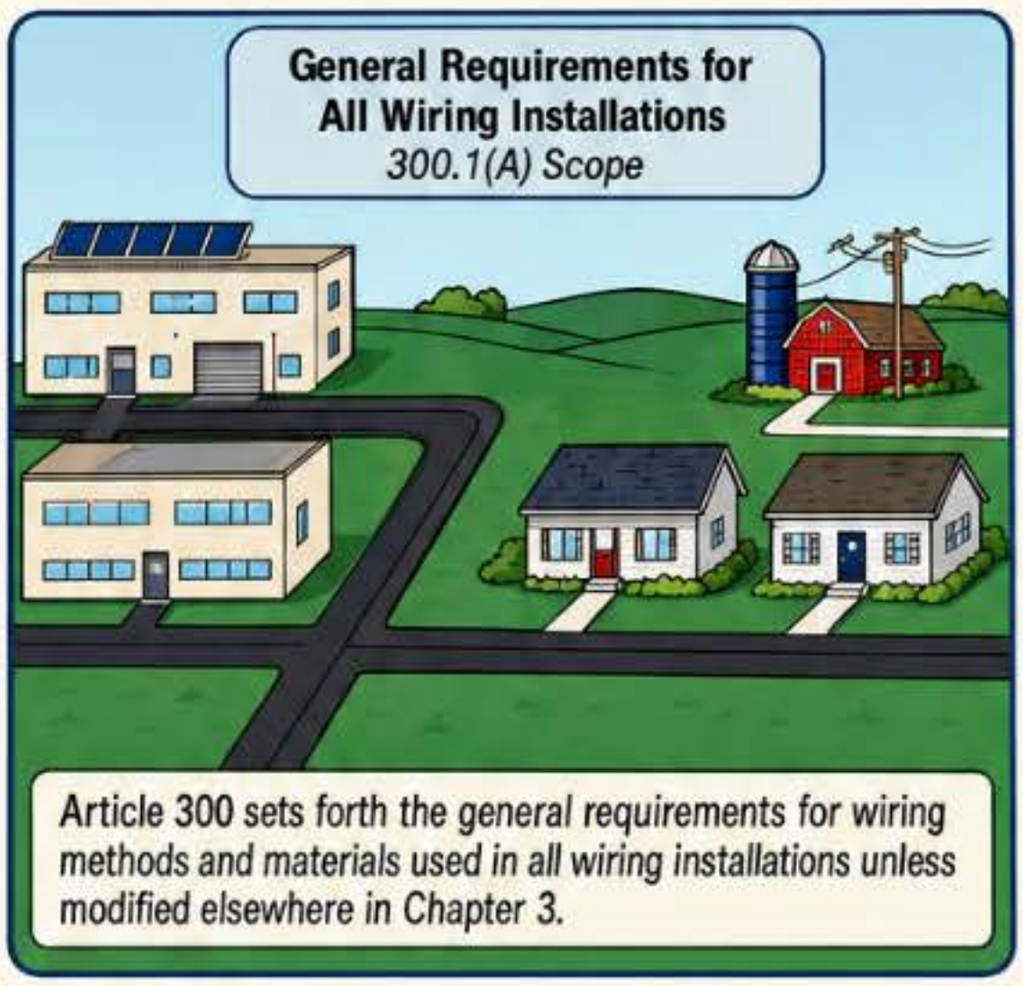
Gaining a solid grasp of this article is the first step toward correct and safe use of the wiring methods discussed in Chapter 3. Make sure to study the related illustrations and consult the definitions in Article 100 as needed.

Part I. General Requirements

300.1 Scope

(A) All Wiring Installations. Article 300 presents the general requirements for wiring methods and materials used in power and lighting installations.

▶ Figure 300–1



▶ Figure 300–1

Author's Commentary:

The material in Article 300 does not cover wiring methods for Class 2 and Class 3 circuits, fire alarm systems, communication systems, or conductors and coaxial cables used as twisted pairs. However, the chapter rules for those wiring methods (Chapters 7 and 8) may point back to Article 300, and any such references govern where they apply.

— *Michael Hamilton*

(B) Integral Parts of Equipment. The rules in Article 300 do not apply to the *integral parts of electrical equipment.*

▶ Figure 300–2

Author's Commentary:

Internal wiring that is part of a piece of equipment is built according to product standards and not the NEC intent. The internal wiring is typically processed in a lab, inspected by authorized testing personnel, and does not require field inspection.

— *Michael Hamilton*

(C) Trade Sizes. The allowable trade sizes for raceways are listed in Table 300.1(C).

300.3 General Requirements for Wiring Methods and Materials

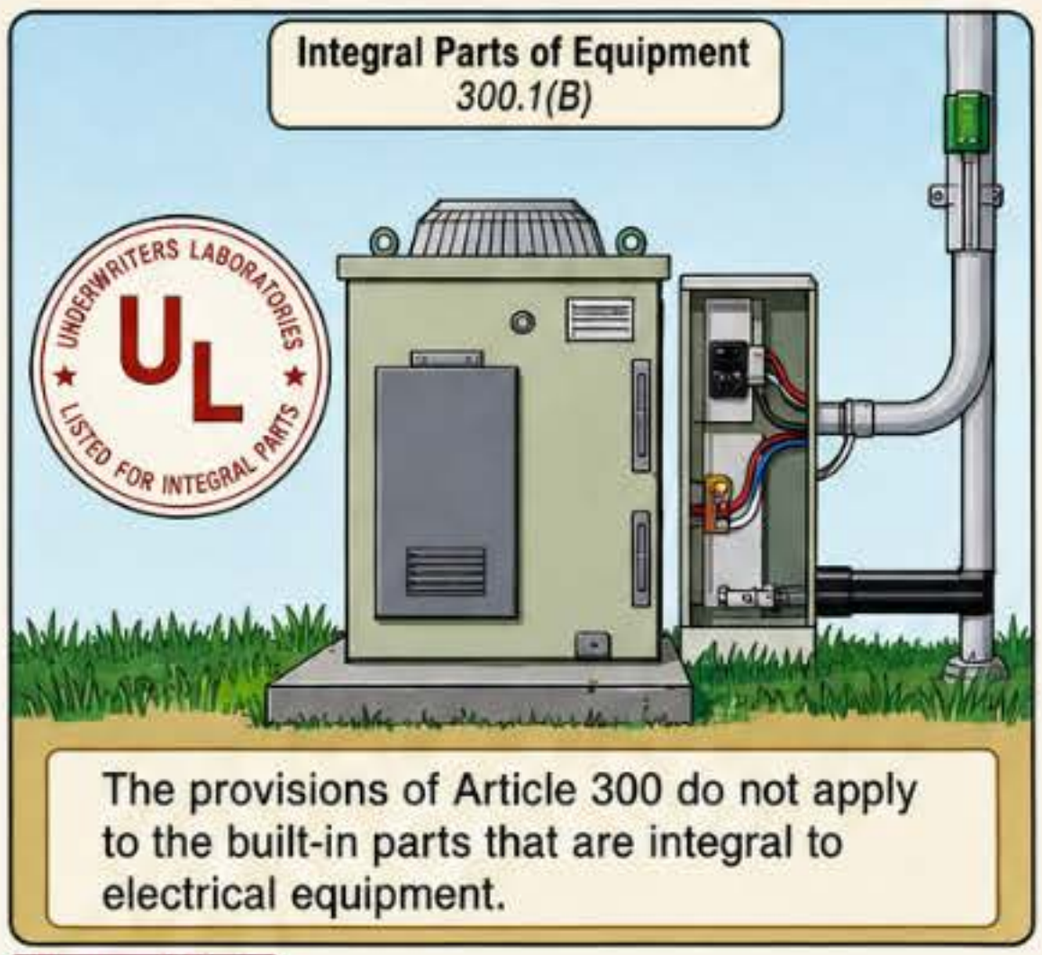


Figure 300–2

Author's Commentary:

In practice, raceways come in standard trade sizes such as ½ inch, 1 inch, and so on. To select the correct size, use Trade Size ½ inch or Trade Size 2 inches from the reference table. Then, translate that trade size into the actual dimensions with the phrase "Trade Size."

— Michael Hamilton

300.3 Conductors

(A) Single Conductors. Per Chapter 3, wiring methods that rely on individual insulated conductors must be contained in a raceway, cable, or enclosure.

Figure 300–3

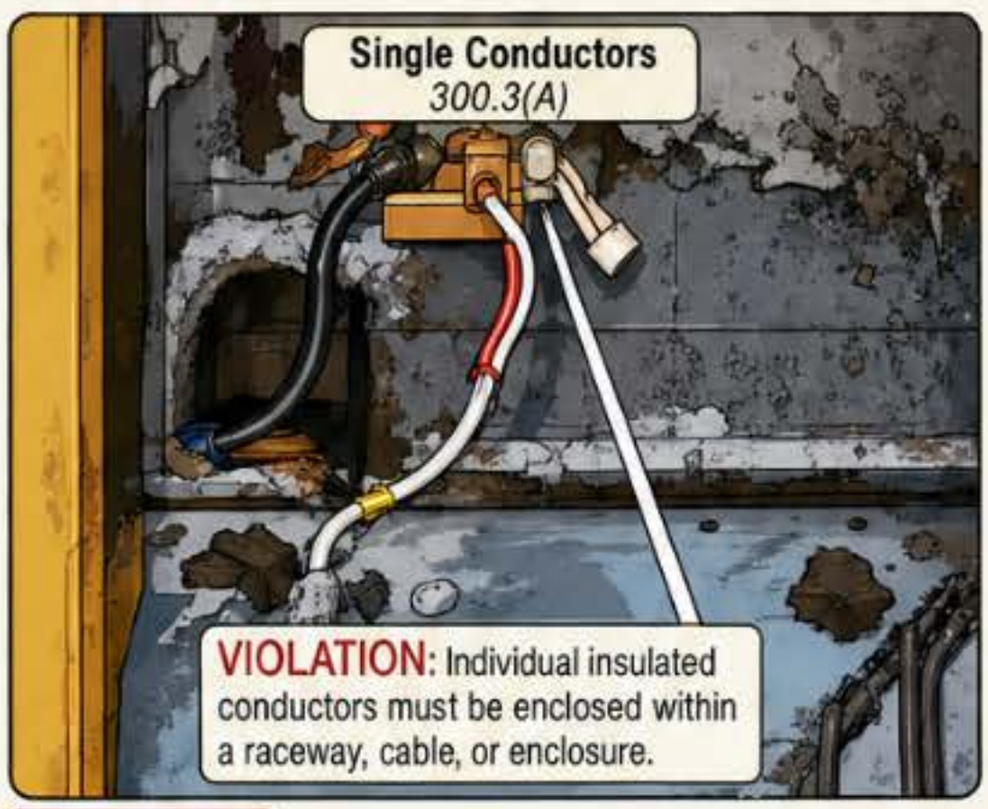


Figure 300–3

(B) Circuit Conductors Grouped Together. All conductors of the same circuit—including the neutral and equipment grounding conductors—must be installed together in the same raceway, cable, trench, cord, or cable tray; except as permitted by (1) through (4).

Figure 300–4 and Figure 300–5

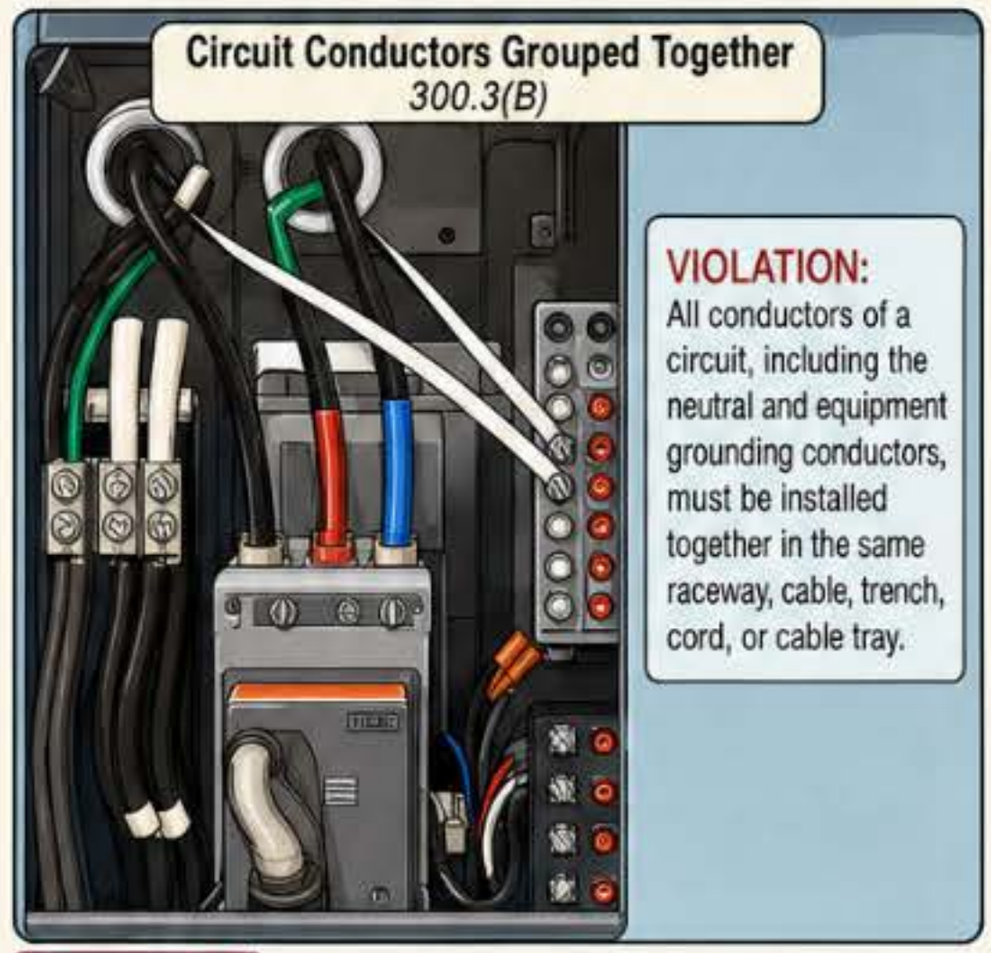


Figure 300–4

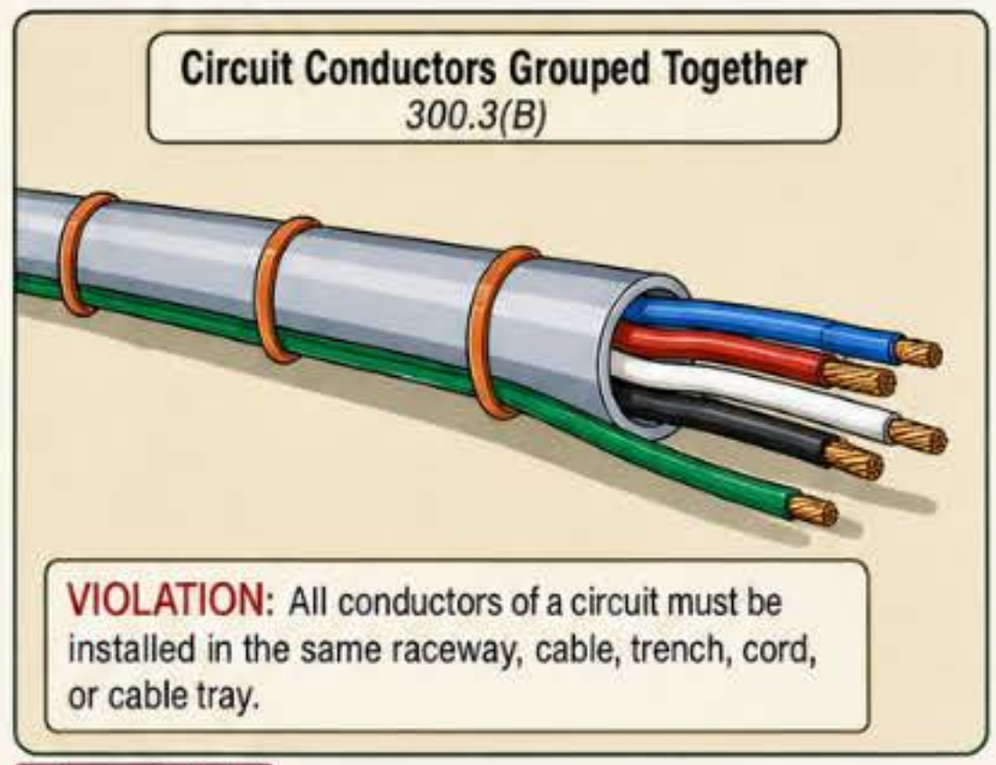
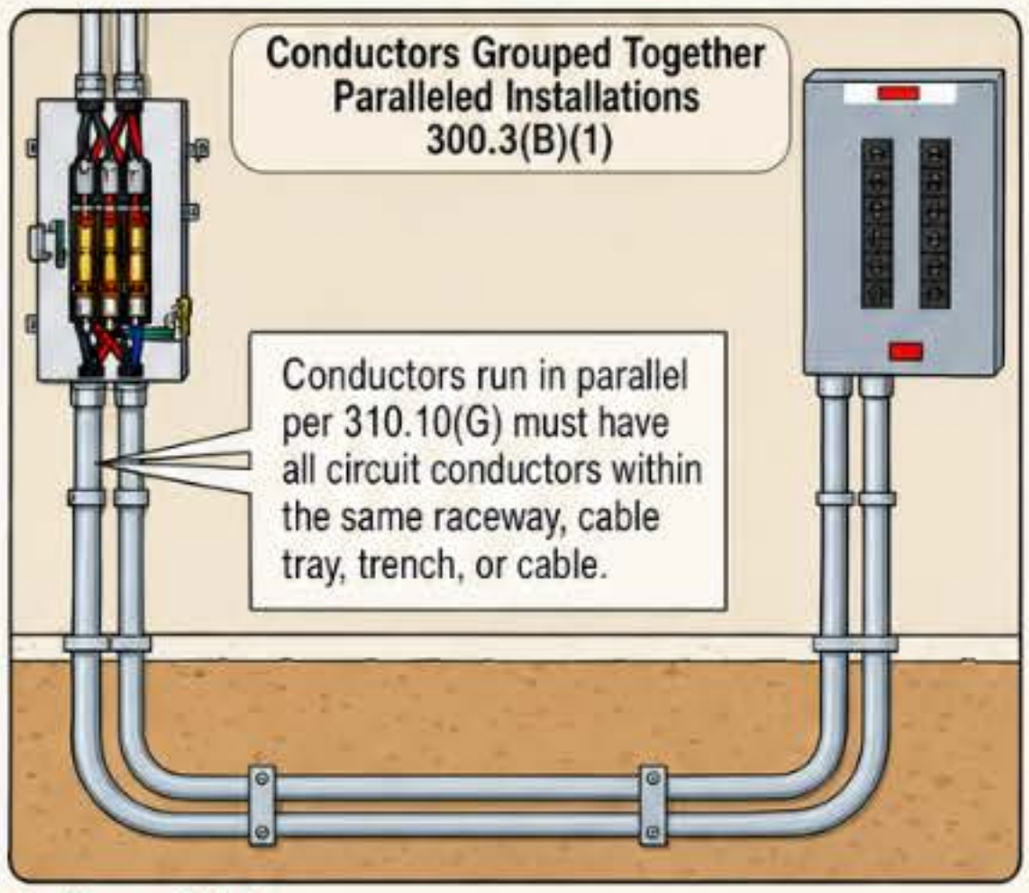


Figure 300–5

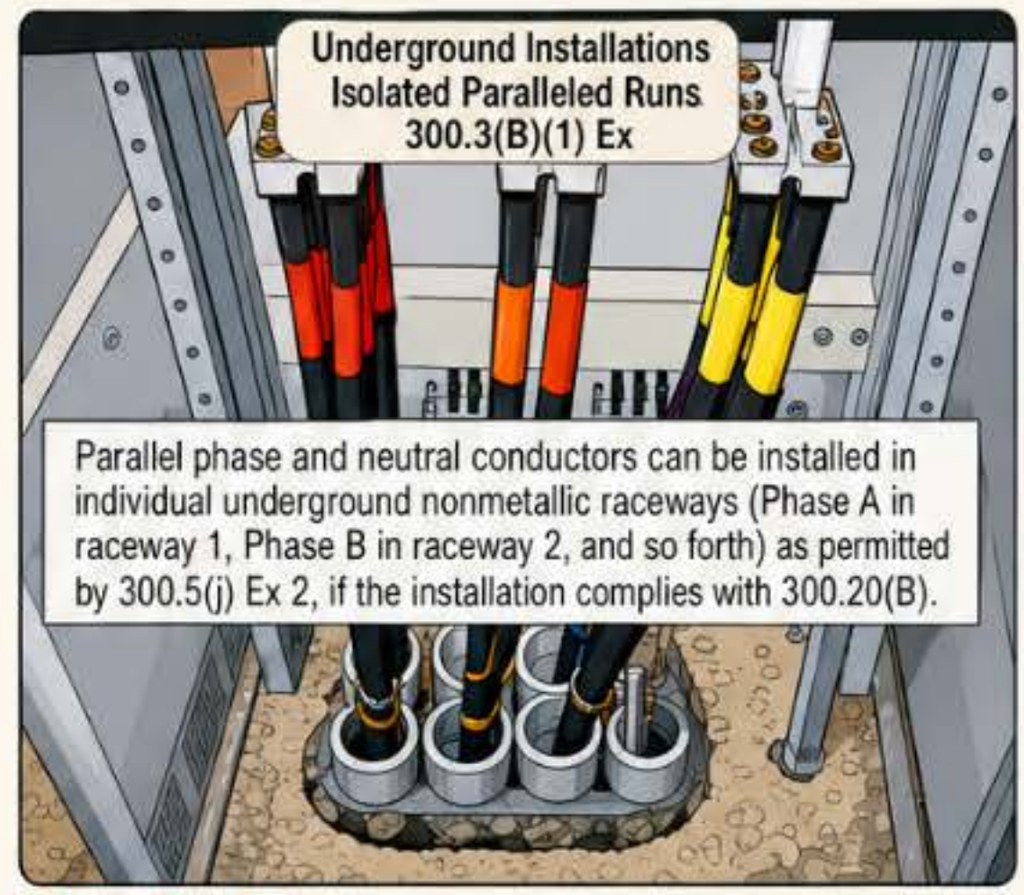
(1) Paralleled Installations. *When conductors are installed in parallel according to 310.10(G), all sets of circuit conductors must be bundled together within the same raceway, cable tray, trench, or cable.*

Figure 300–6

General Requirements for Wiring Methods and Materials 300.3



▶ Figure 300–6

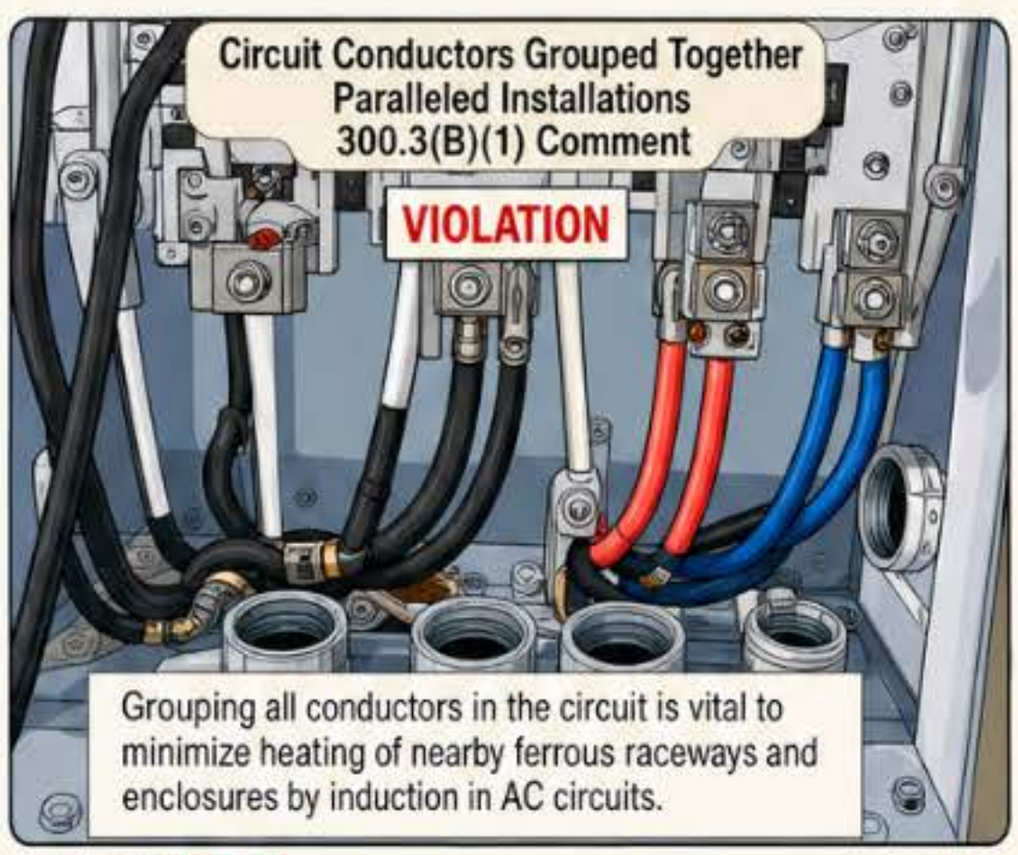


▶ Figure 300–8

Author's Commentary:

Bundling every conductor in a circuit is a key way to limit heating of nearby metal raceways and enclosures caused by induction in AC systems. See 300.20(A).

— Michael Hamilton

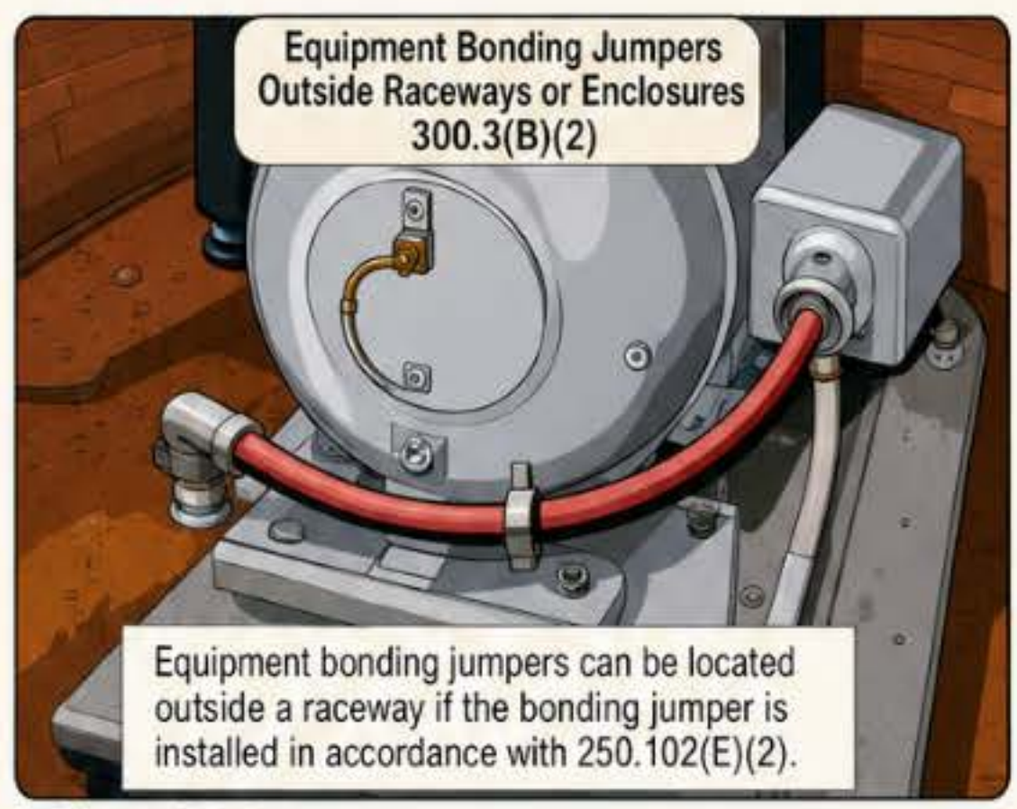


▶ Figure 300–7

Connections, taps, or extensions made from paralleled conductors must connect to *all* conductors of the paralleled set.

Ex: Parallel phase and neutral conductors can be installed in individual underground nonmetallic raceways (Phase A in raceway 1, Phase B in raceway 2, and so forth) as permitted by 300.5(j) Ex 2 if the installation complies with 300.20(B). Figure 300–8

(2) Outside a Raceway or an Enclosure. Equipment bonding jumpers can be located outside of a raceway if the bonding jumper is installed in accordance with 250.102(E)(2). ▶ Figure 300–9



▶ Figure 300–9

For direct-current circuits, the equipment grounding conductor can be run separately from the circuit conductors in accordance with 250.134(2) Ex 2. ▶ Figure 300–10

(C) Conductors of Different Systems.

(1) Mixing. Power conductors rated 1,000 V or less can occupy the same raceway, cable, or enclosure if every conductor has an insulation voltage rating no less than the maximum circuit voltage. ▶ Figure 300–11

300.3 General Requirements for Wiring Methods and Materials

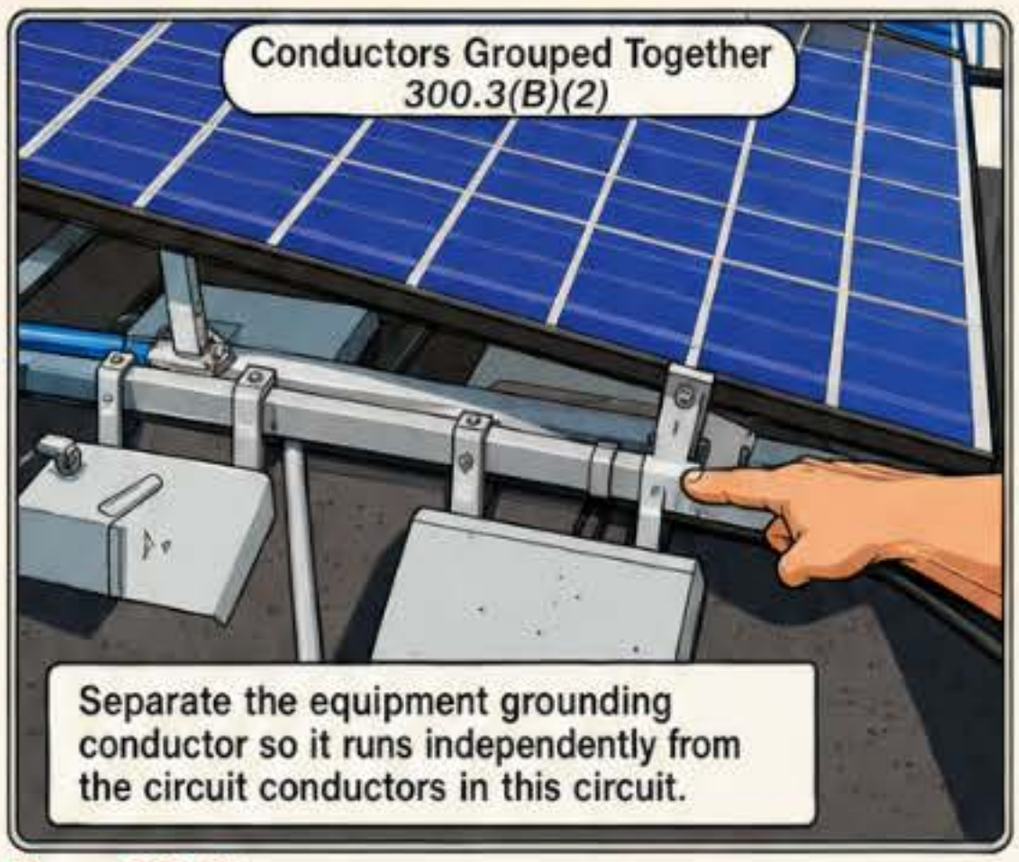


Figure 300-10

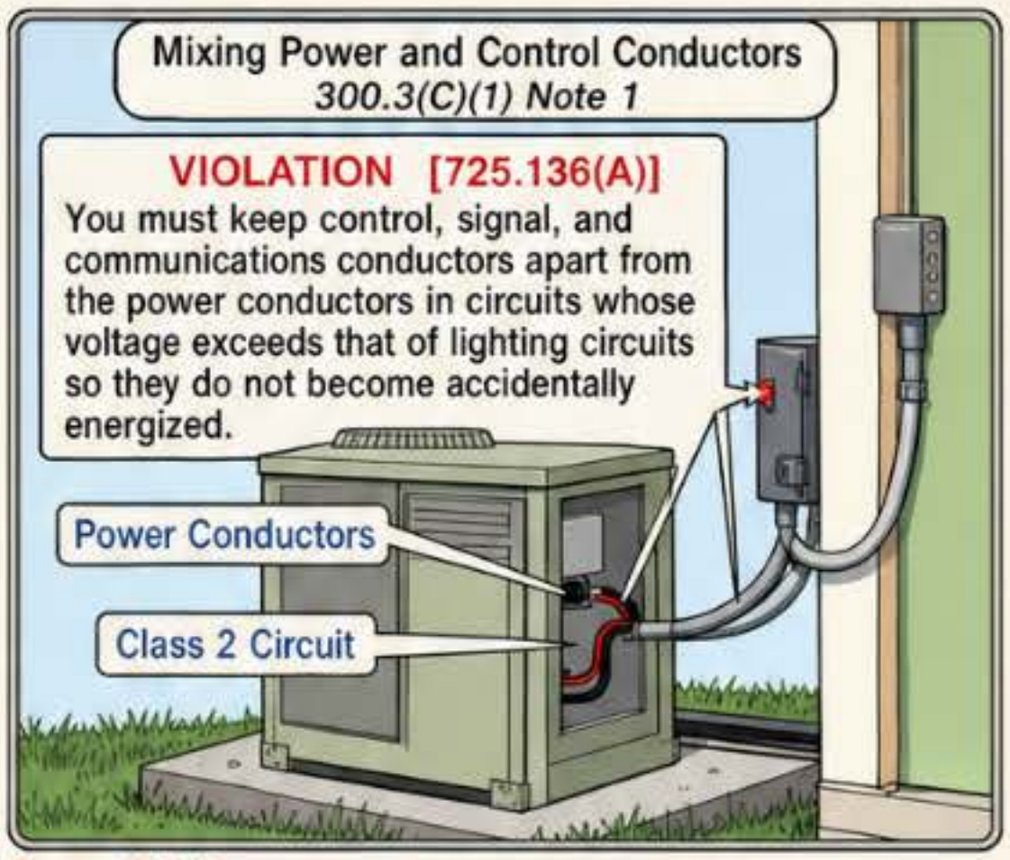


Figure 300-12

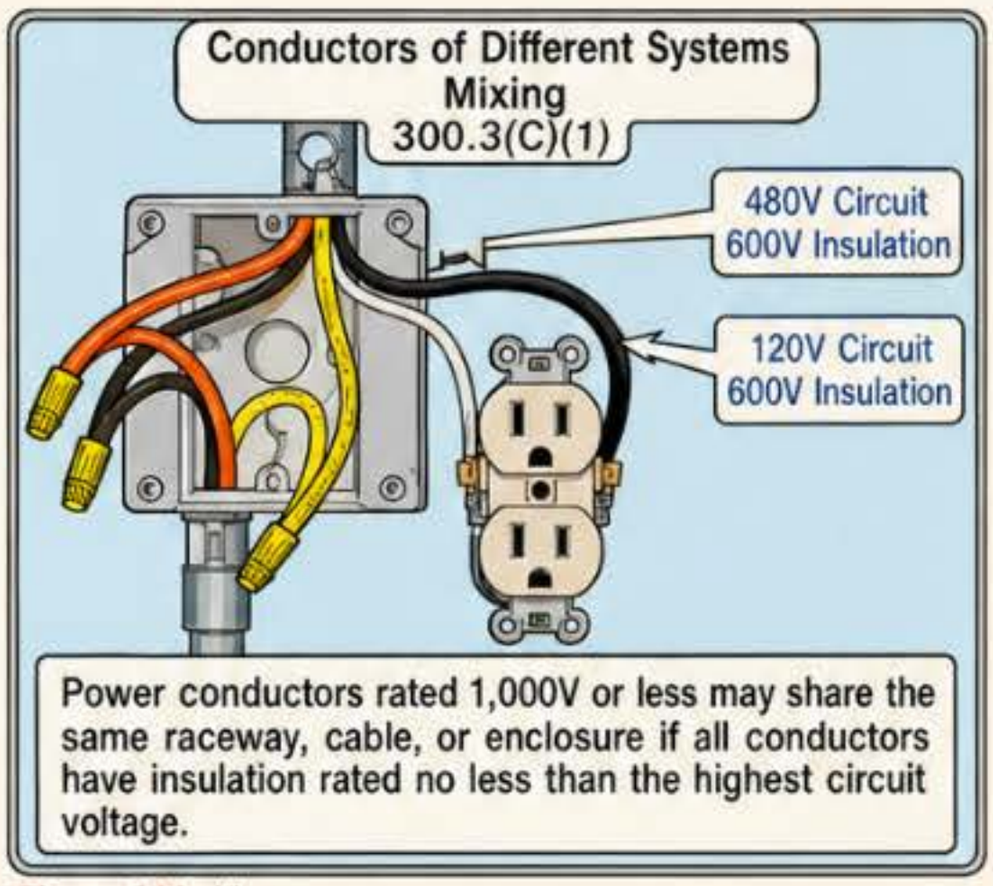


Figure 300-11

Author's Commentary:

- Communications, control, and signaling wires must be routed in separate pathways from power and lighting conductors whose voltage is higher, so the low-voltage circuits cannot accidentally energize the control, signal, or communications wiring. Figure 300-12
- Class 1 circuit conductors [725.48(B)(1)] may be installed with associated conductors having insulation voltage ratings that are not less than the highest circuit voltage [300.3(C)(1)].
- After reclassification as Class 1 [725.130(A) Ex 2], a Class 2 circuit can be installed with associated conductors [725.48(B)(1)] if their insulation ratings are not less than the maximum circuit voltage [300.3(C)(1)]. Figure 300-13

Author's Commentary:

- Control, signaling, and communications wiring must occupy dedicated raceways different from power and lighting circuits at higher voltages. Keeping them separate prevents the control, signaling, or communications conductors from being energized unexpectedly. Figure 300-12
- Class 1 Control Circuits, 725.48
- Class 2 Control Circuits, 725.136(A)
- Communications Circuits, 805.133(A)(1)(c)
- Coaxial Cable, 820.133(A)
- Fire Alarm Circuits, 760.136(A)
- Sound Circuits, 640.9(C)

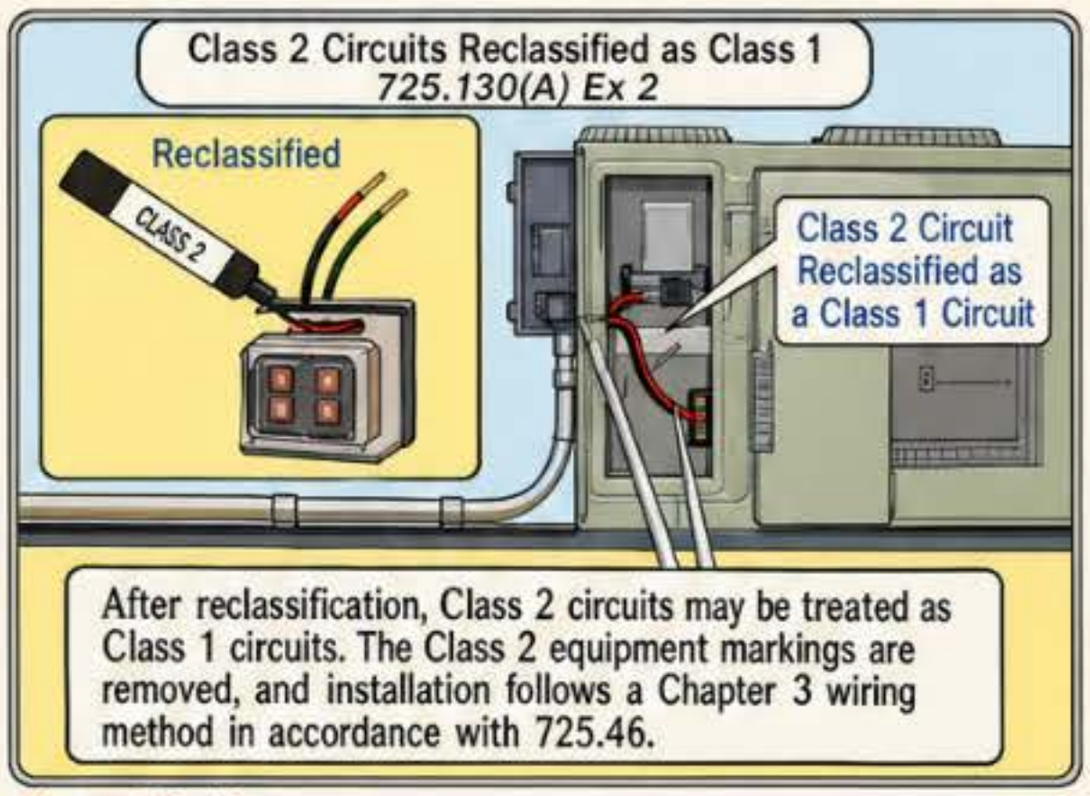


Figure 300-13

GENERAL REQUIREMENTS FOR WIRING METHODS AND MATERIALS | 300.4

300.4 Protection Against Physical Damage

All wiring subject to physical impact, as well as conductors, raceways, and cables, must be safeguarded in accordance with (A) through (H).

(A) Cables and Raceways Through Wood Members.

Author's Commentary:

Whenever wiring methods pass through lumber, certain rules must be followed. These requirements can be found in 300.4(A)(1) and (2).

— Michael Hamilton

When the following wiring methods are routed through wood framing members, they must comply with either 300.4(A)(1) or (2).

- Armored Cable, Article 320
- Electrical Nonmetallic Tubing, Article 362
- Flexible Metal Conduit, Article 348
- Liquidtight Flexible Metal Conduit, Article 350
- Liquidtight Flexible Nonmetallic Conduit, Article 356
- Metal-Clad Cable, Article 330
- Nonmetallic-Sheathed Cable, Article 334
- Service-Entrance Cable, Article 338
- Underground Feeder and Branch-Circuit Cable, Article 340

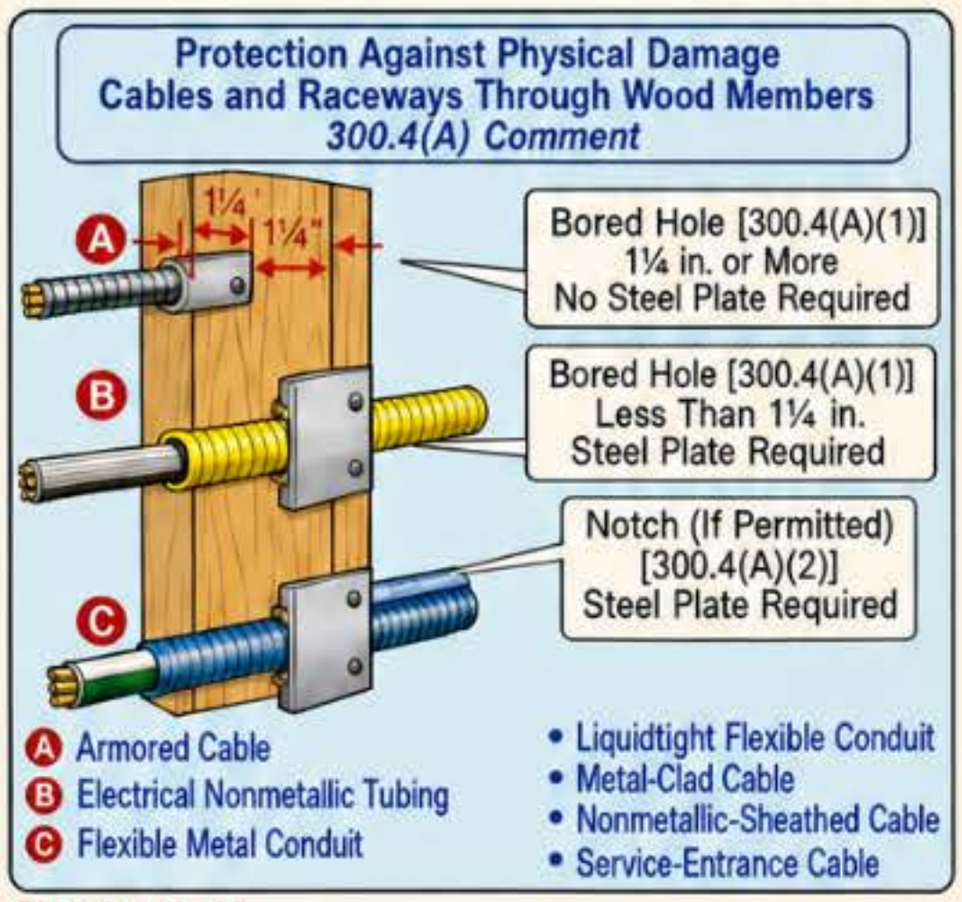


Figure 300–14

(1) Bored Holes in Wood Members. Holes drilled through wood framing members to pass above cables or raceways *must be located no closer than 1¼ in. from the edge of the member. If the edge of a hole is less than 1¼ in. from the edge, a 1/16 in. thick steel plate of adequate size must be installed to protect the wiring method from screws and nails.*

Figure 300–15

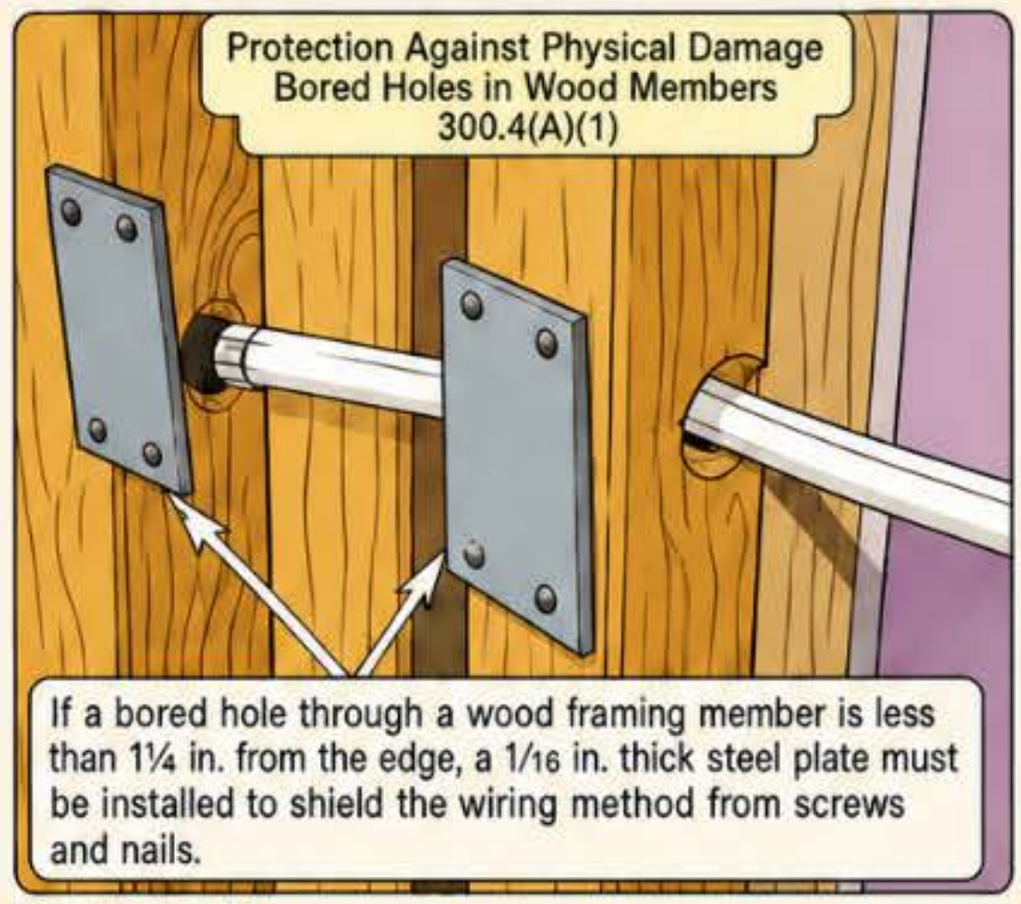


Figure 300–15

Example: A steel plate is not needed to protect rigid metal conduit, intermediate metal conduit, PVC conduit, or electrical metallic tubing.

(2) Notches in Wood Members. When routing cables or raceways through wood framing, the building code permits notches provided that a gap *of at least ¼ in.* remains between *the notch and the end of the member, and the wiring method is shielded within the notched area from screws and nails.*

Figure 300–16

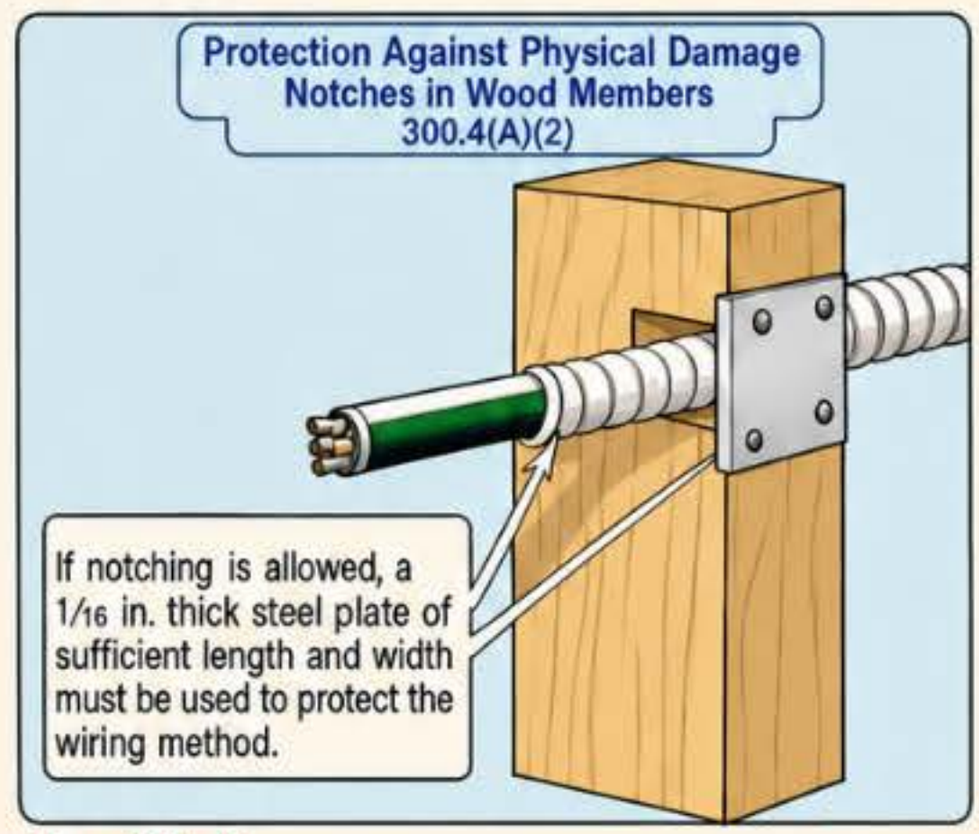


Figure 300–16

Example: A steel plate is not needed to protectt rigid metal conduit, intermediate metal conduit, PVC conduit, or electrical metallic tubing.

CAUTION

Many wood and metal framing members (especially joists and beams) have specific drilling and/or notching requirements intended to preserve structural integrity. Always verify with the building official for the project before commencing work.

(B) Nonmetallic-Sheathed Cable and Electrical Nonmetallic Tubing Through Metal Framing Members.

(1) Type NM Cable, Metal Framing Members. Where Type NM cable passes through factory-made openings in metal framing members, the cable must be safeguarded by retained bushings or listed grommets that cover all sharp or rough edges. This protective fitting must be firmly secured to the framing member in the opening before the cable is pulled. Figure 300–17

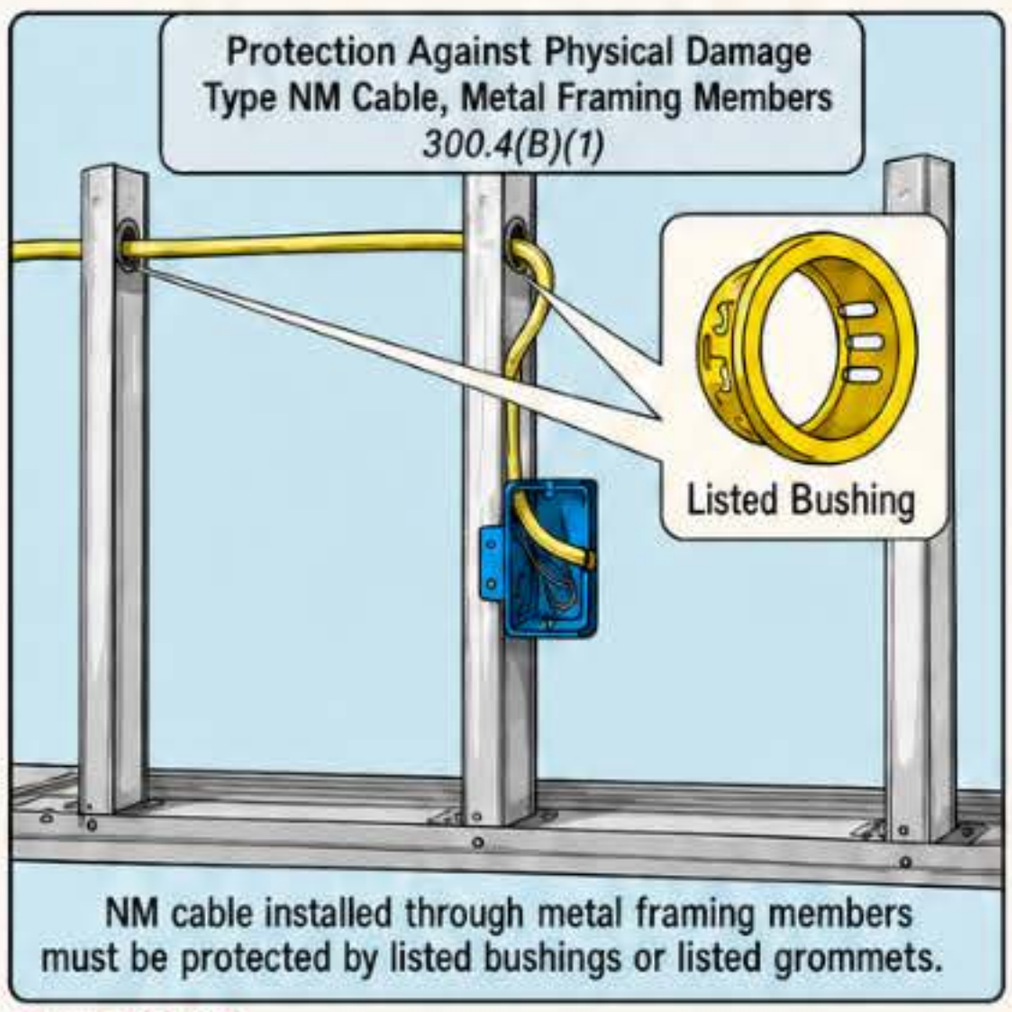


Figure 300–17

(2) Type NM Cable and Electrical Nonmetallic Tubing. If nails or screws are likely to penetrate Type NM cable or electrical nonmetallic tubing, a metal sleeve, steel plate, or steel clip not less than ⅛ in. in thickness must be used to shield the cable or tubing.

Ex: A listed and marked steel plate less than ⅛ in. thick that provides equal or superior protection against nail or screw penetration is allowed.

(C) Behind Suspended Ceilings. Wiring methods such as boxes, enclosures, cables, or raceways installed behind panels designed to allow access must be supported in accordance with this code and the rules in the applicable article. Figure 300–18

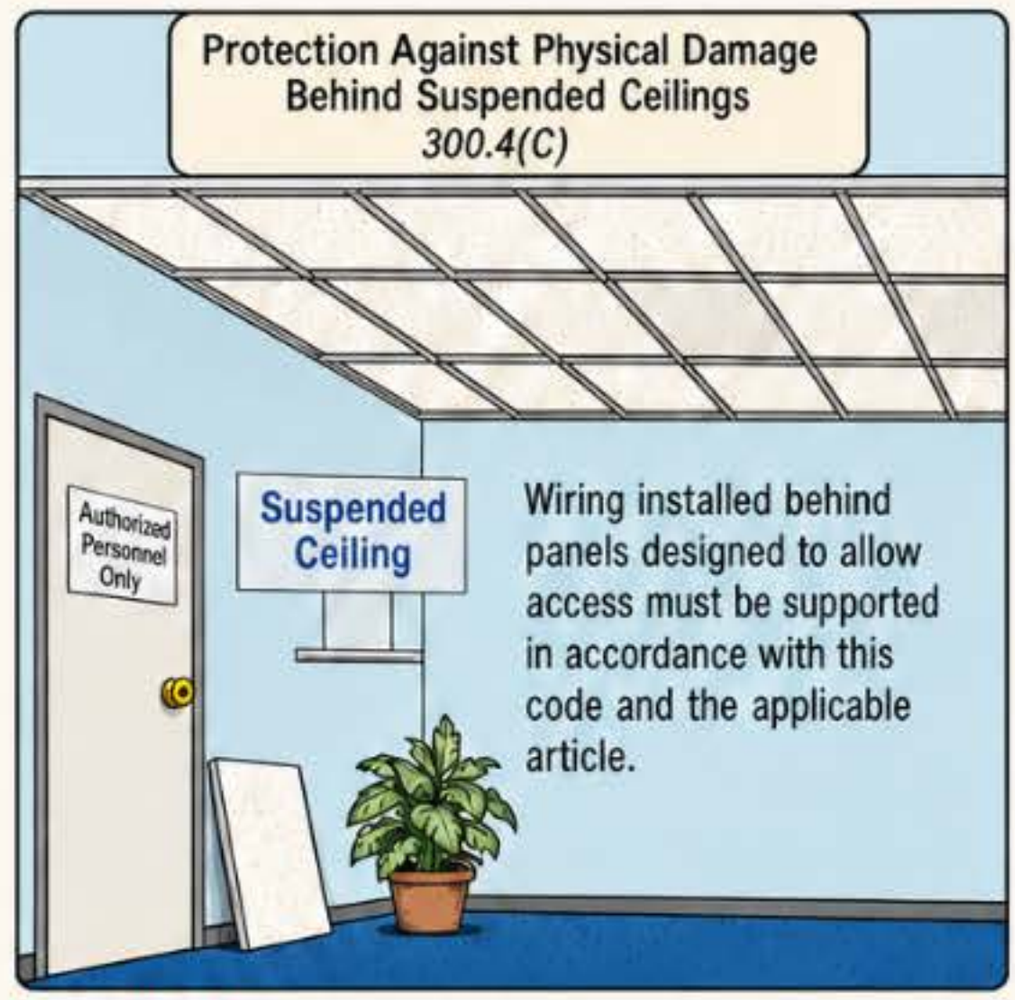


Figure 300–18

Author's Commentary:

The rules for protecting wiring in suspended ceilings vary by method. Check each wiring method in Chapter 3 for any additional support requirements.

— Michael Hamilton

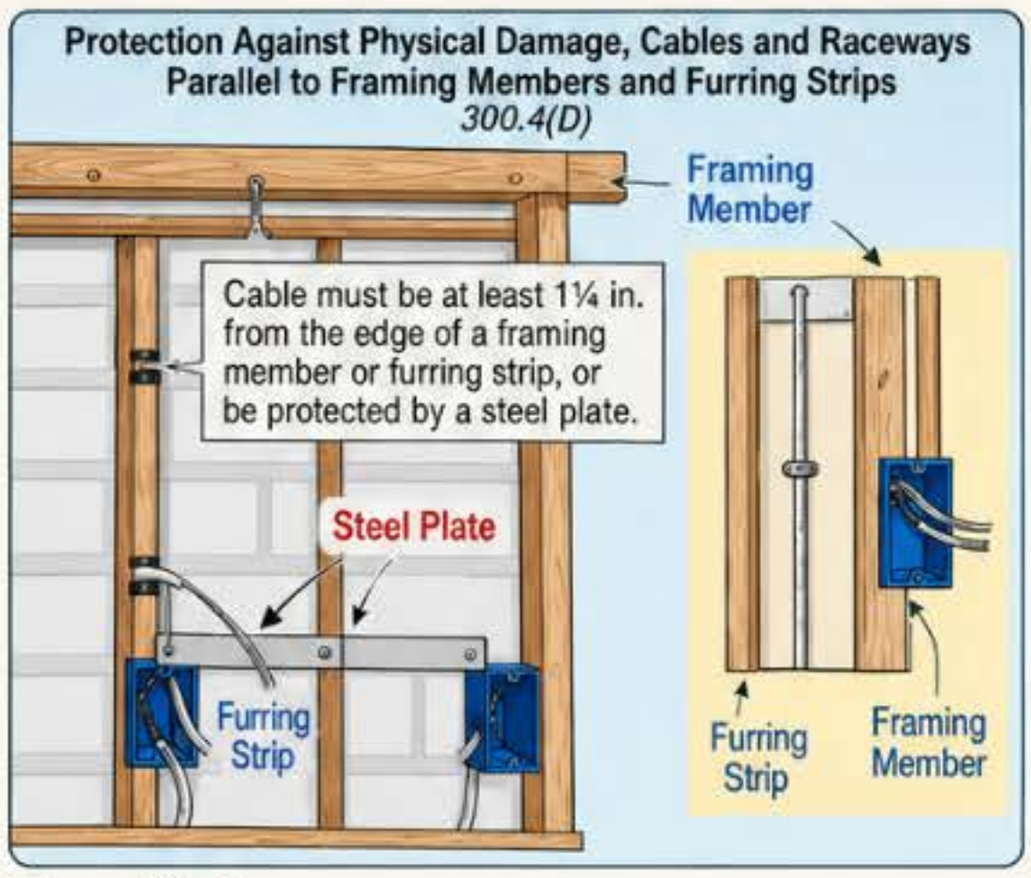
Comparable support requirements also appear in Chapters 6, 7, and 8 for the following wiring methods:

- Audio Cable, 640.5 and 640.6(A)
- Communications (Twisted Pair) Cable and Coaxial Cable, 800.21 and 800.24
- Control and Signaling Cable, 725.21 and 725.24
- Fire Alarm Cable, 760.21 and 760.24
- Optical Fiber Cable, 770.21 and 770.24

(D) Cables and Raceways Parallel to Framing Members and Furring Strips. Cables or raceways run parallel to framing members or furring strips must be protected by securing the wiring method not less than 1¼ in. from the nearest edge of the framing member or furring strip. If the edge of the framing member or furring strip is less than 1¼ in. away, ⅛ in. thick steel plate of sufficient length and width must be installed to protect the wiring method from screws and nails.

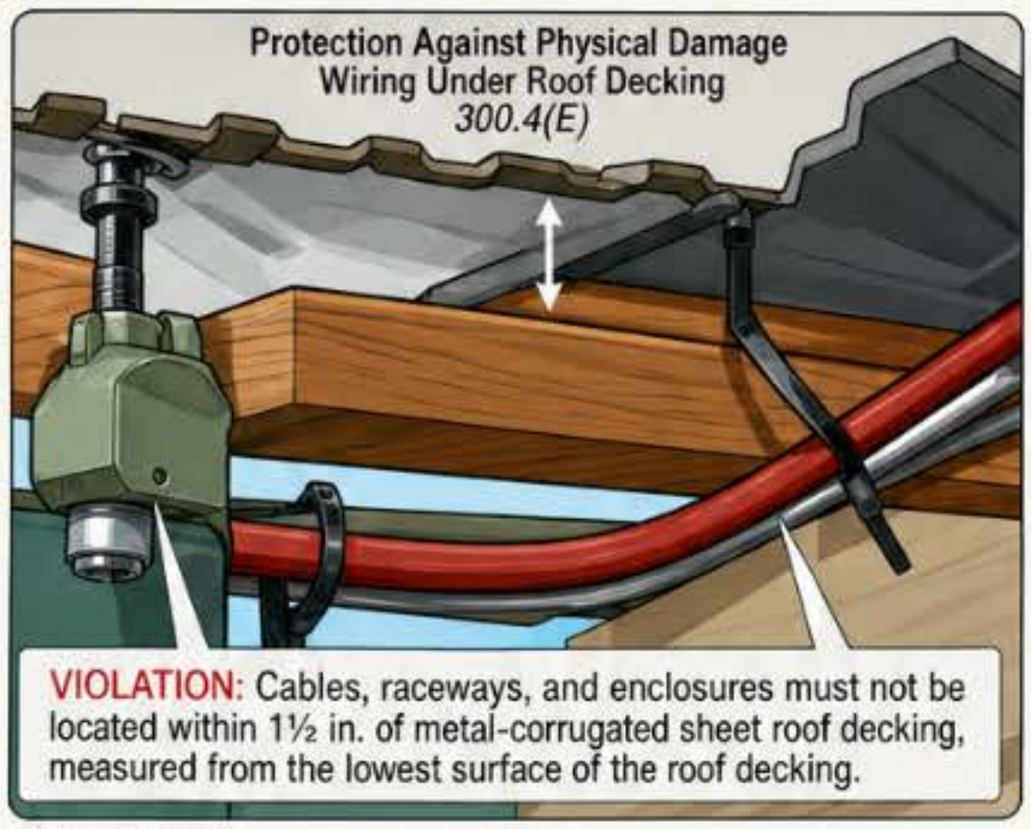
Ex 1: Protection is not required for rigid metal conduit, intermediate metal conduit, PVC conduit, or electrical metallic tubing.

General Requirements for Wiring Methods and Materials | 300.4

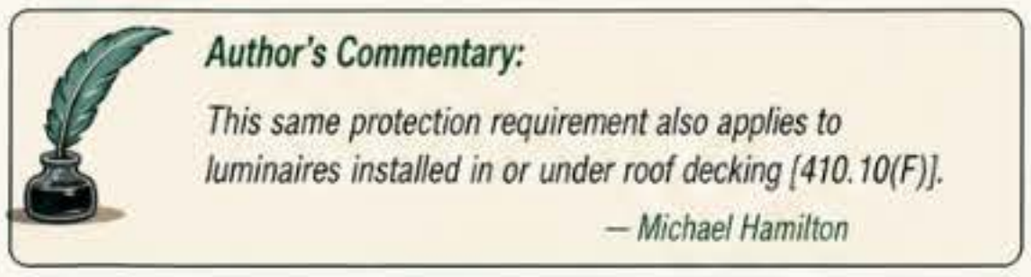


▸ Figure 300–19

(E) Wiring Under Roof Decking. Cables, raceways, and enclosures under metal-corrugated sheet roof decking are not permitted to be located within 1½ in. of the roof decking measured from the lowest surface of the roof decking to the top of the cable, raceway, or box. ▸ Figure 300–20



▸ Figure 300–20



Author's Commentary:

This same protection requirement also applies to luminaires installed in or under roof decking [410.10(F)].

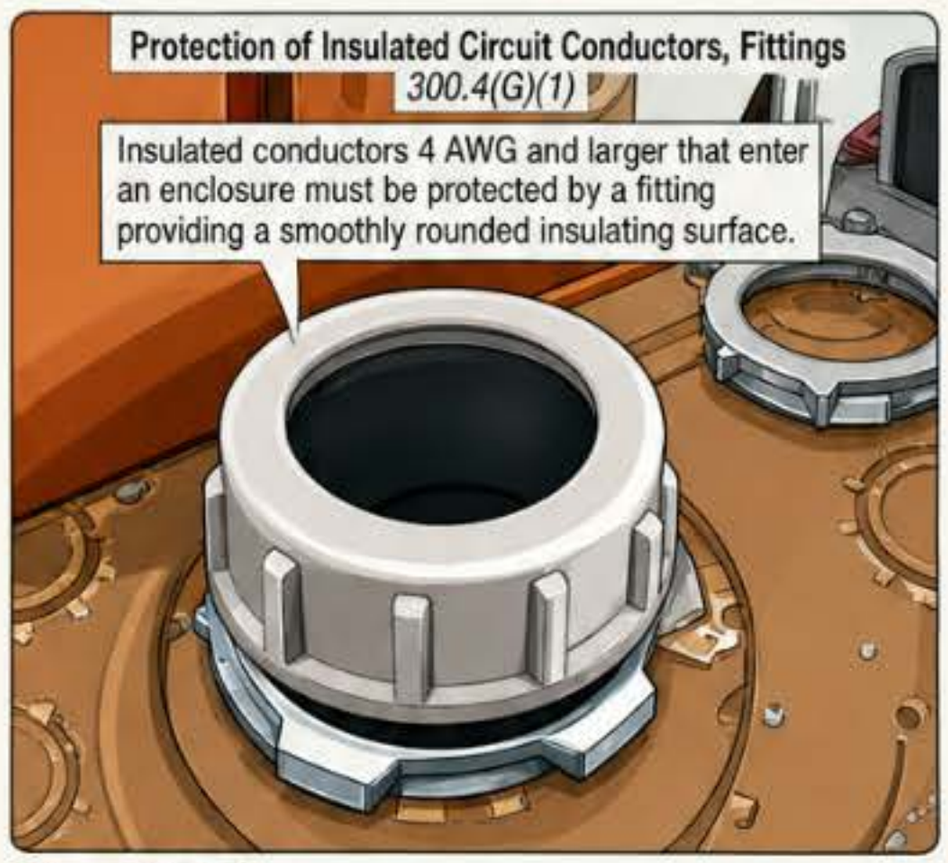
— Michael Hamilton

Note: *Raceways or cables installed under metal roof decking may be penetrated by screws or other mechanical devices designed to "hold down" the waterproof membrane or roof insulating material.*

Ex: *Spacing from roof decking does not apply to rigid metal conduit and intermediate metal conduit.*

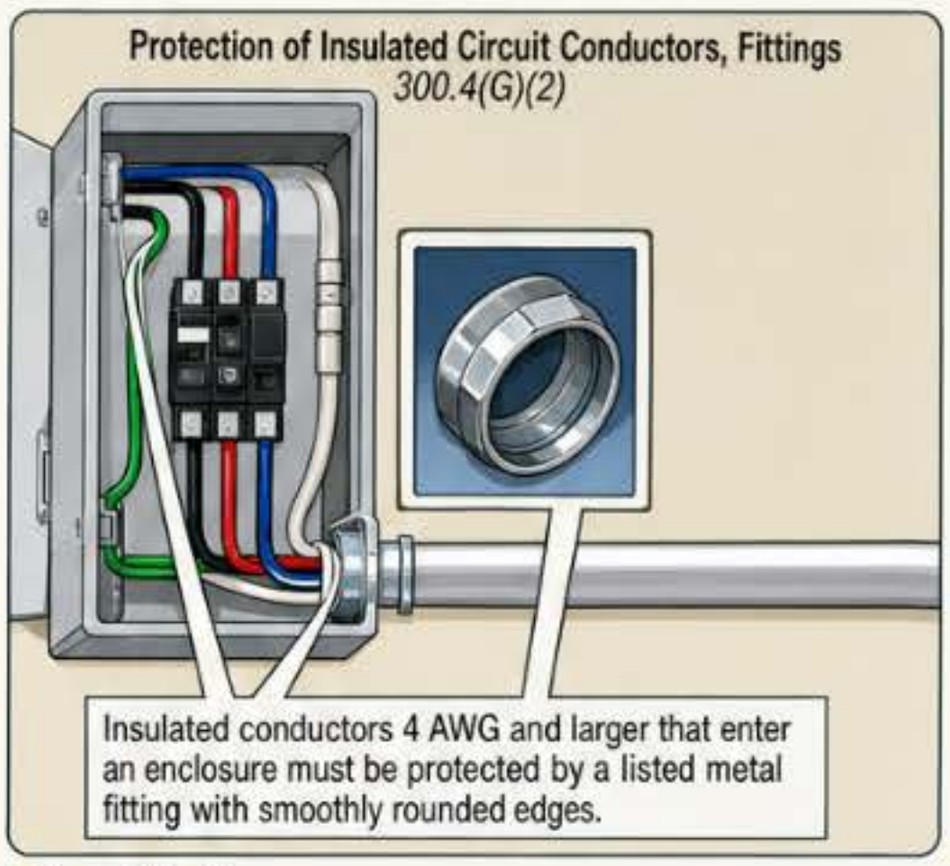
(G) Fittings. Raceways containing insulated circuit conductors 4 AWG and larger that enter a cabinet, box, enclosure, or raceway, must have the conductors protected as follows:

(1) A fitting providing a smoothly rounded insulating surface ▸ Figure 300–21



▸ Figure 300–21

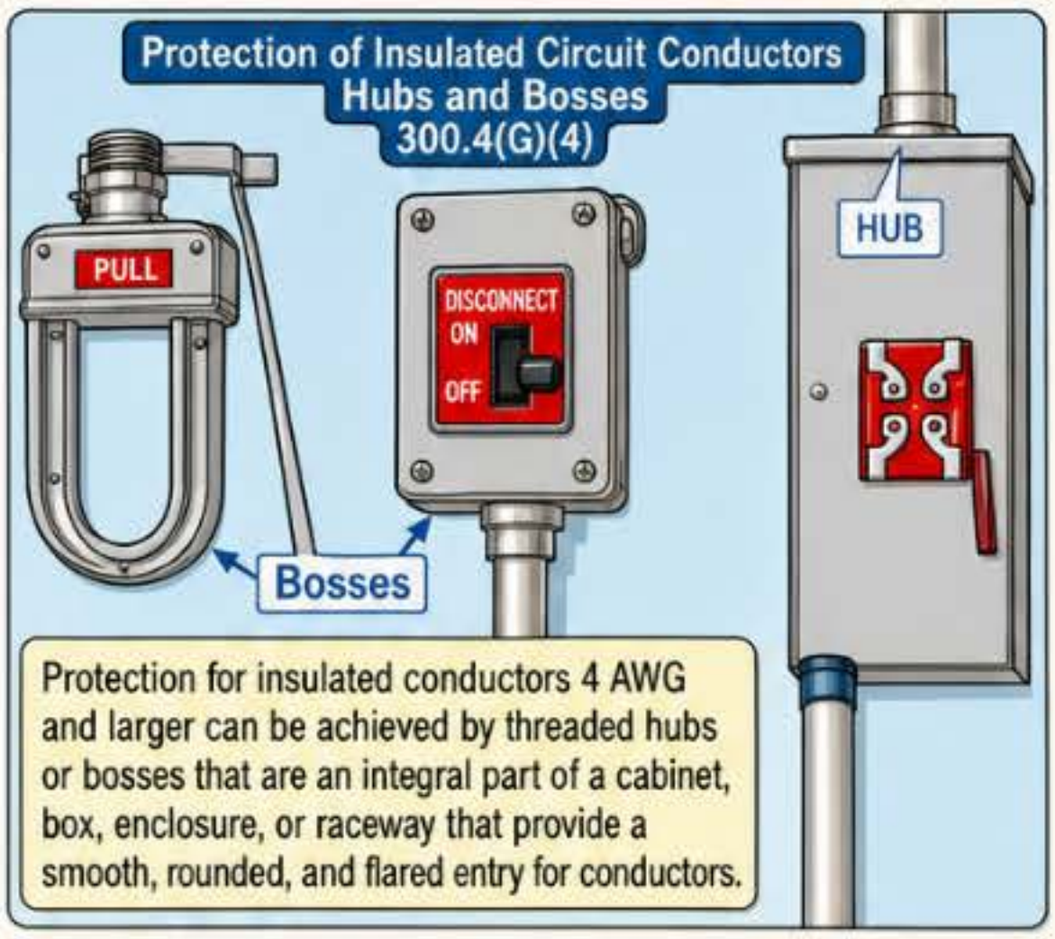
(2) A listed metal fitting that has smoothly rounded edges ▸ Figure 300–22



▸ Figure 300–22

(3) Separation from the fitting or raceway using an identified insulating material securely fastened in place

(4) Threaded hubs or bosses that are an integral part of a cabinet, box, enclosure, or raceway provide a smooth, rounded, and flared opening for the conductors. ▶ Figure 300–23



▶ Figure 300–23

Author's Commentary:

▶ Whenever an intermediate metallic conduit (IMC) or rigid metal conduit (RMC) enters an enclosure without using a connector, a bushing is required regardless of the size of the conductor [342.46 and 344.46].

— Michael Hamilton

(H) Structural Joints. A listed expansion or deflection fitting, or another method approved by the authority having jurisdiction, must be used whenever a raceway crosses a structural joint. This allows for movement of the building without damaging the raceway due to expansion, contraction, or deflection.

300.5 Underground Installations

(A) Minimum Cover Requirements. When cables or raceways are installed underground, they must be protected by a minimum cover depth in accordance with Table 300.5. ▶ Figure 300–24

Author's Commentary:

▶ *Table 300.5 Note 1 defines "cover" as the shortest vertical distance measured between the top of any direct-buried conductor, cable, or raceway and the final grade of the finished surface, concrete, or other equivalent cover.*

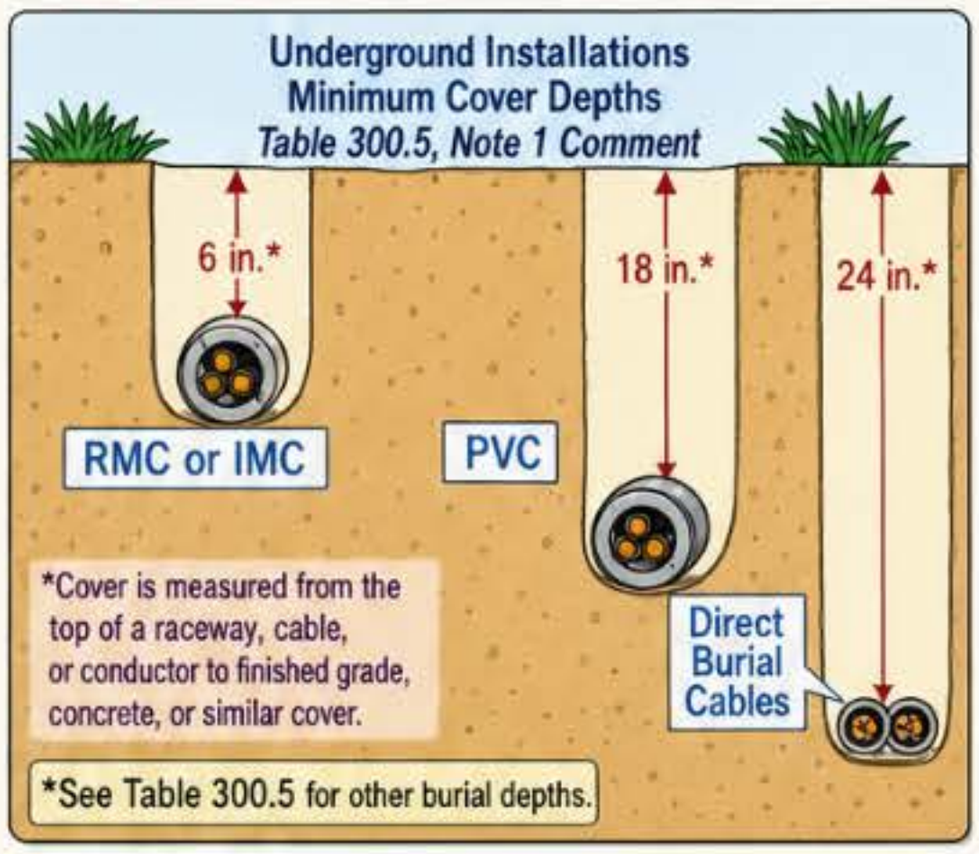
— Michael Hamilton

▶ Figure 300–25 and ▶ Figure 300–26

Underground Installations
Minimum Cover Requirements
Table 300.5

	Column 1 UF or USE Cables or Conductors	Column 2 RMC or IMC	Column 3 Nonmetallic Raceways or Cables in Concrete	Column 4 Residential 15A & 20A GFCI 120V Branch Ckts
Dwelling Unit Driveway and Parking Area	18 in.	18 in.	18 in.	12 in.
Under Roadway Driveway Parking Lot	24 in.	24 in.	24 in.	24 in.
Other Locations	24 in.	6 in.	18 in.	12 in.

▶ Figure 300–24



▶ Figure 300–25

▶ Figure 300–26

General Requirements for Wiring Methods and Materials | 300.5

Table 300.5 Minimum Cover Requirements in Inches

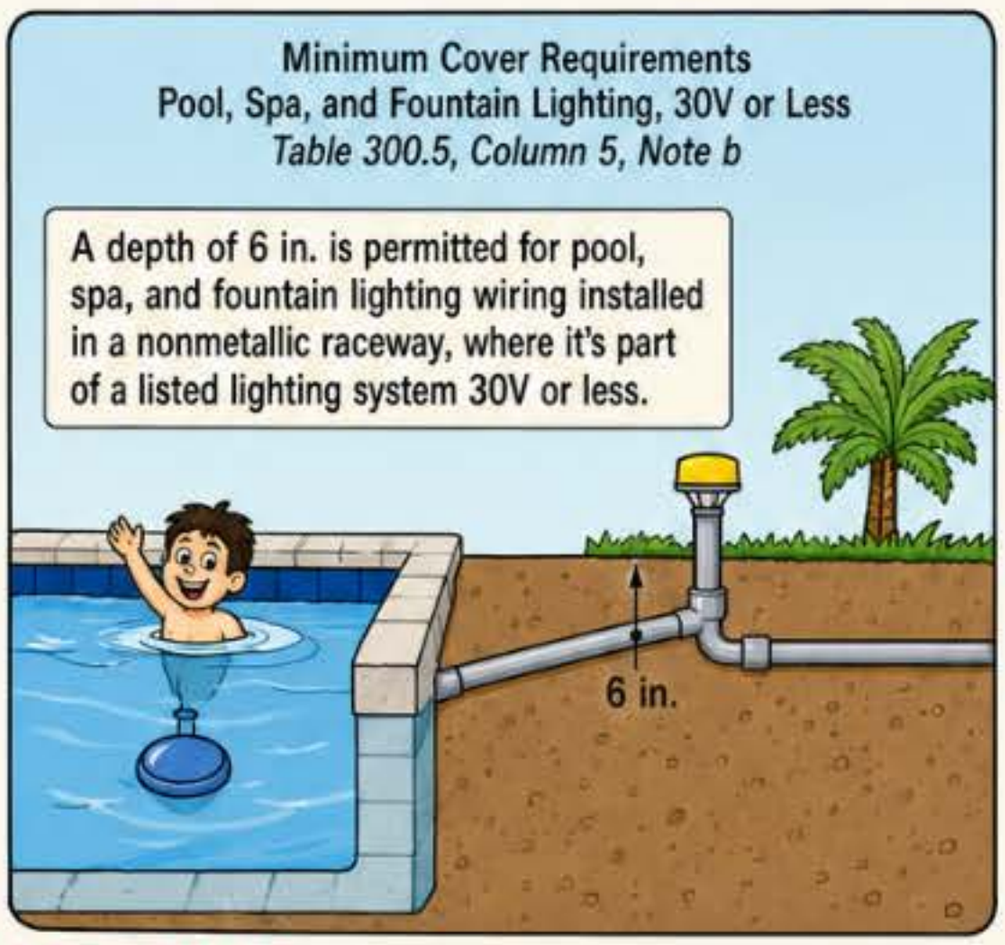
Location	Column 1 Buried Cables	Column 2 RMC or IMC	Column 3 Nonmetallic Raceways
Under Building	0	0	0
Dwelling Unit	24*	6	18*
Dwelling Unit Driveway	18*	18*	18*
Under Roadway	24	24	24
Other Locations	18*	6	18*

**Residential branch circuits rated 120V or less with GFCI protection and maximum protection of 20A.*

See the table in the NEC for full details.

b. A depth of 6 in. is permitted for pool, spa, and fountain lighting wiring installed in a nonmetallic raceway, where part of a listed 30V or less lighting system. ▶ Figure 300–27

Note 1 to Table 300.5: *"Cover" is defined as the shortest distance from the top of the underground cable or raceway to the top surface of finished grade.*



▶ Figure 300–27

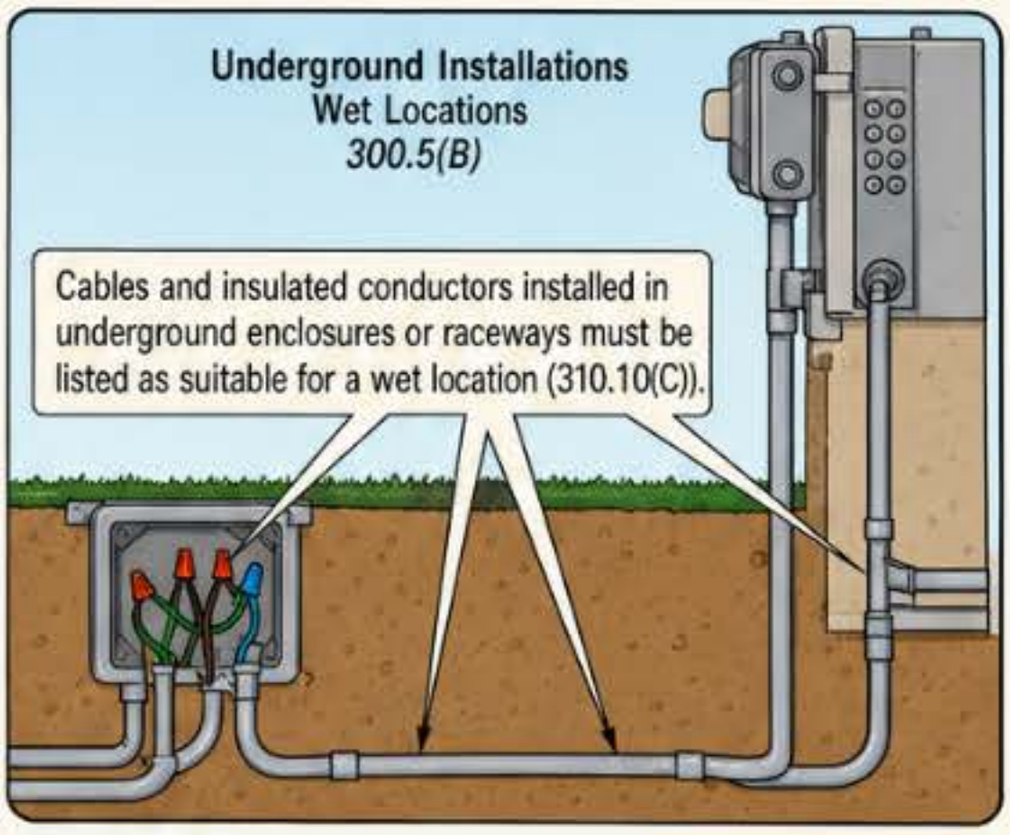
Author's Commentary:
The requirements for cover in 300.5 don't apply to signaling, communications, and other power-limited wiring systems. ▶ Figure 300–28

- Class 2 and 3 Circuits, 725.3
- Communications Cables and Raceways, 90.3
- Coaxial Cable, 90.3
- Fire Alarm Circuits, 760.3
- Optical Fiber Cables and Raceways, 770.3

— Michael Hamilton

▶ Figure 300–28

(B) Wet Locations. Cables and insulated conductors installed in underground enclosures or raceways must be listed as suitable for a wet location (310.10(C)). ▶ Figure 300–29



▶ Figure 300–29

300.5 General Requirements for Wiring Methods and Materials

Author's Commentary:
The rules in this section establish the fundamentals that keep electrical installations safe and reliable. They tell us where wiring must be located, the level of protection required underground and inside buildings, and how to guard conductors from physical damage.
— Michael Hamilton

(C) Cables and Conductors Under Buildings. Cables and conductors installed beneath a building floor must be placed within a raceway that continues beyond the outside walls of the structure. ▶ **Figure 300–30**

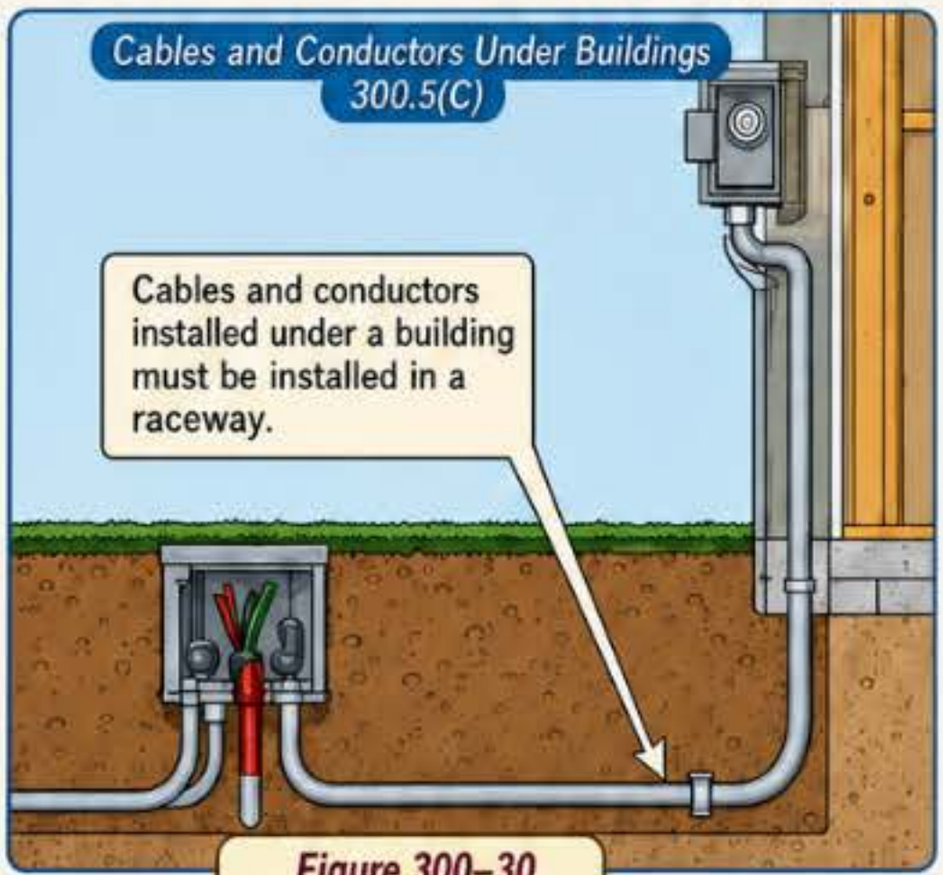


Figure 300–30

Ex 2: Type MC Cable listed for direct burial or concrete encasement is permitted under a building without installation within a raceway [330.10(A)(5) and 330.10(A)(11)]. ▶ ***Figure 300–31***

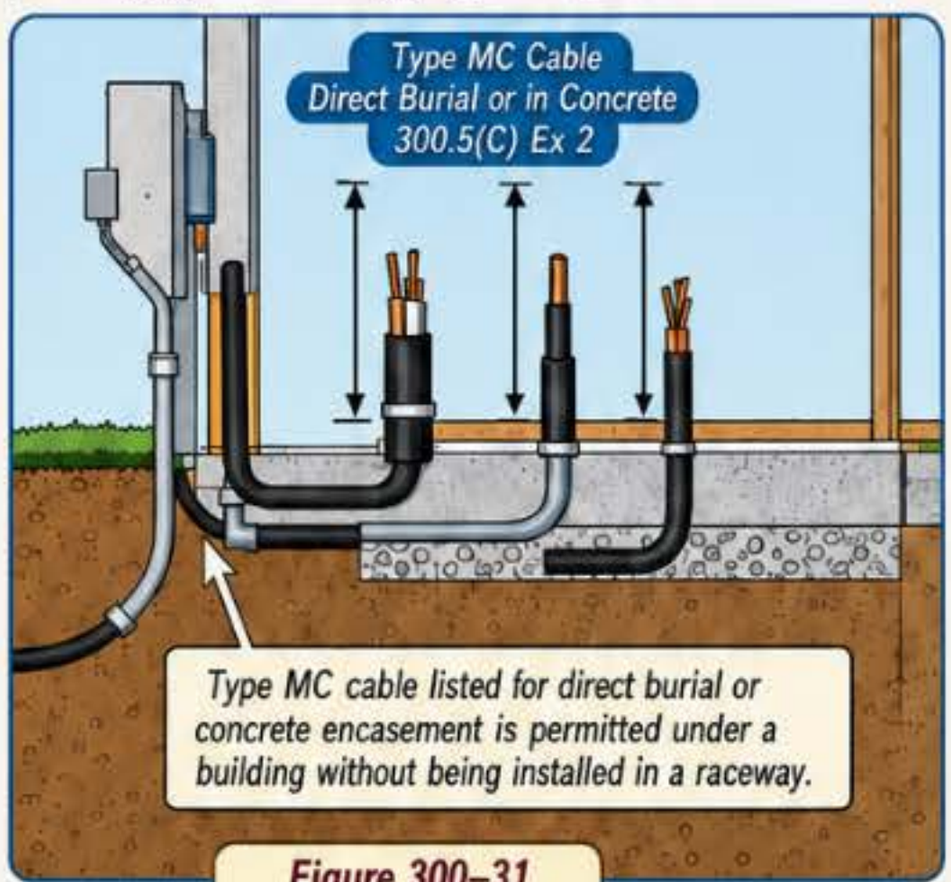


Figure 300–31

(D) Protecting Underground Cables and Conductors. Direct-buried conductors and cables such as Types MC, UF, and USE installed underground must be shielded from damage according to (1) through (4).

(1) Emerging from Grade. Direct-buried cables and conductors that come up out of the ground must be protected from physical injury. Protection is required to extend more than 18 in. below grade, and protection above ground must rise to a height of no less than 8 ft. ▶ **Figure 300–32**

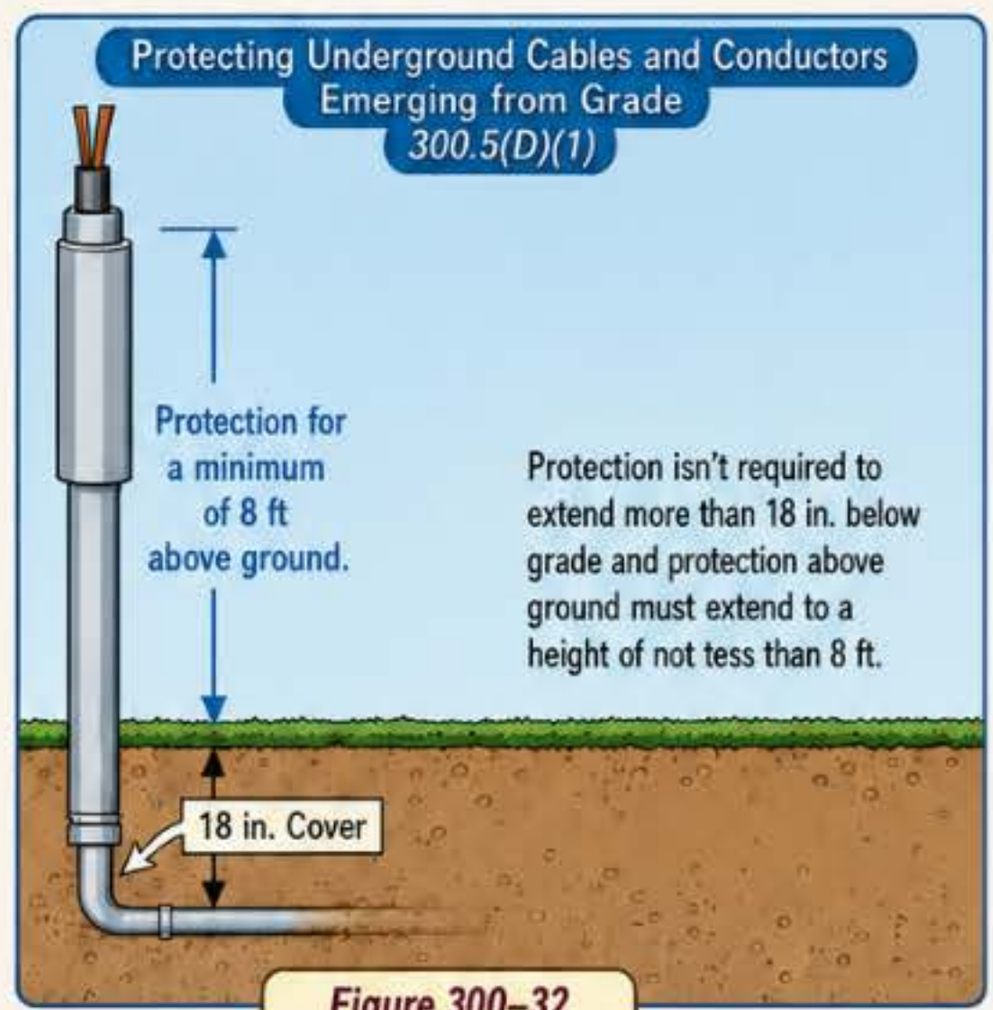


Figure 300–32

(2) Conductors Entering Buildings. Underground conductors and cables that enter a building must be protected at the point of entrance.

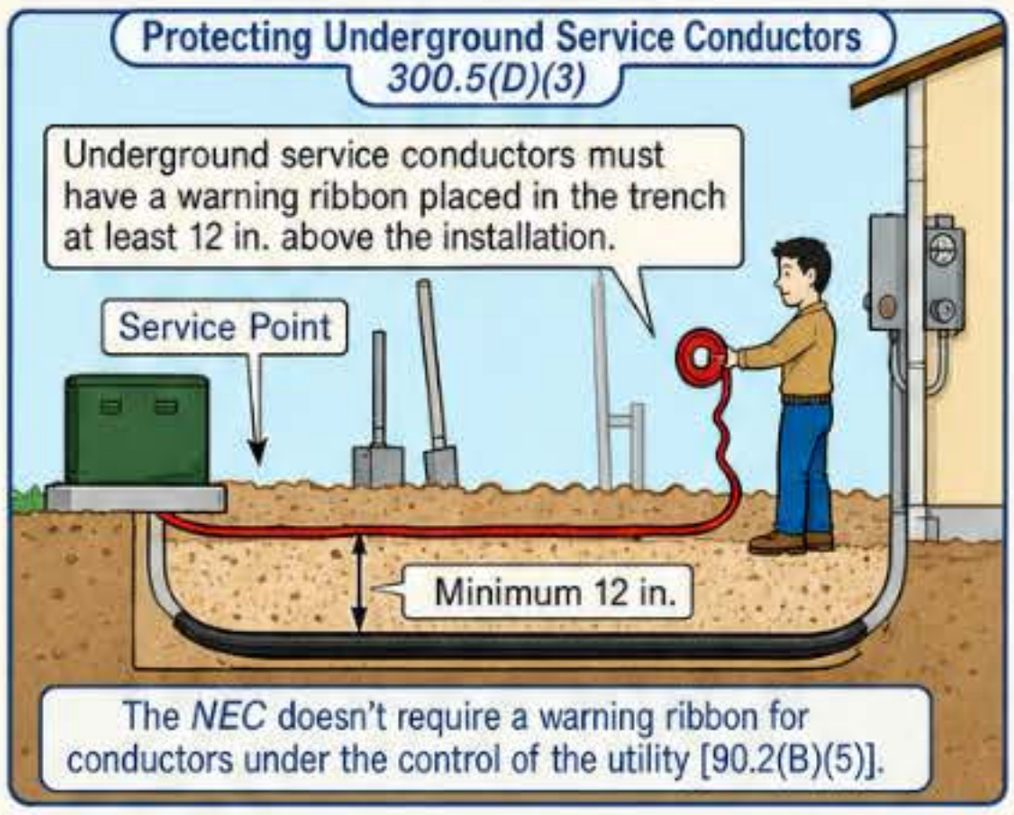
(3) Underground Service Conductors. Underground service conductors *must have their location identified by a warning ribbon placed in the trench at least 12 in. above the underground conductor installation.* ▶ ***Figure 300–33***

Author's Commentary:
The NEC does not require a warning ribbon for conductors under the exclusive control of the utility [90.2(B)(5)].
— Michael Hamilton

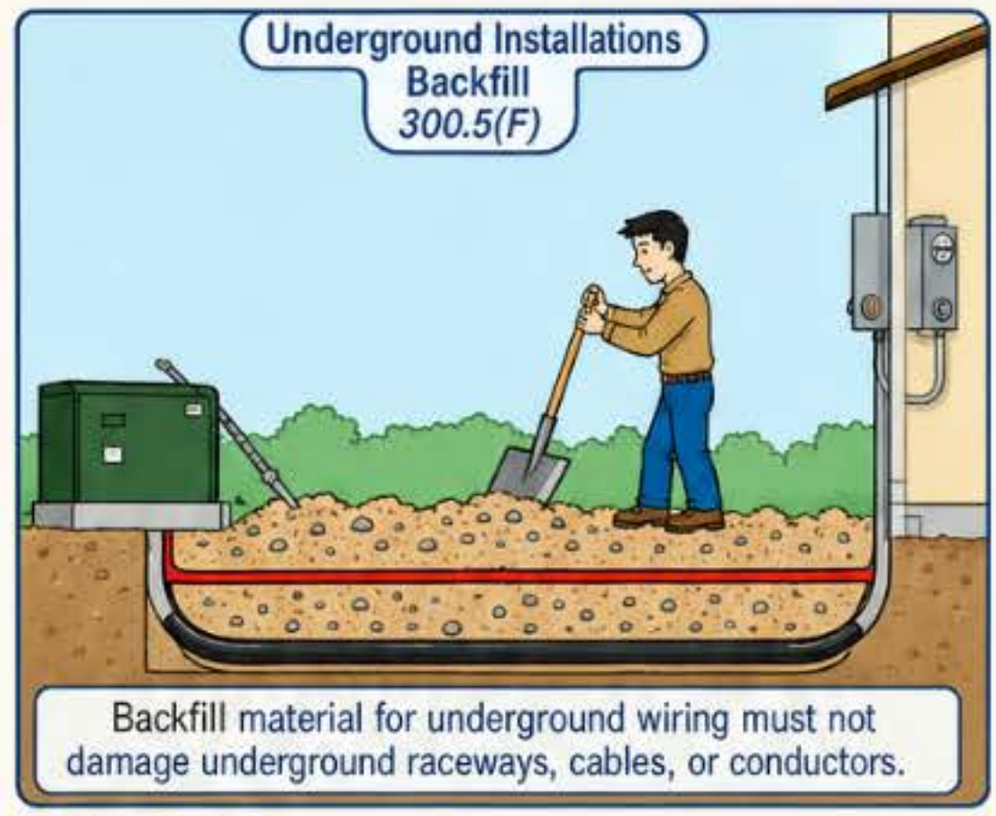
(4) Raceway Damage. *Where a raceway is subject to physical damage, the conductors must be installed in EMT, RMC, IMC, or Schedule 80 PVC conduit.*

(E) Underground Splices and Taps. *Direct-buried conductors or cables can be spliced or tapped underground without a splice box [300.15(G)] if the splice or tap is made in accordance with 110.14(B).* ▶ ***Figure 300–34***

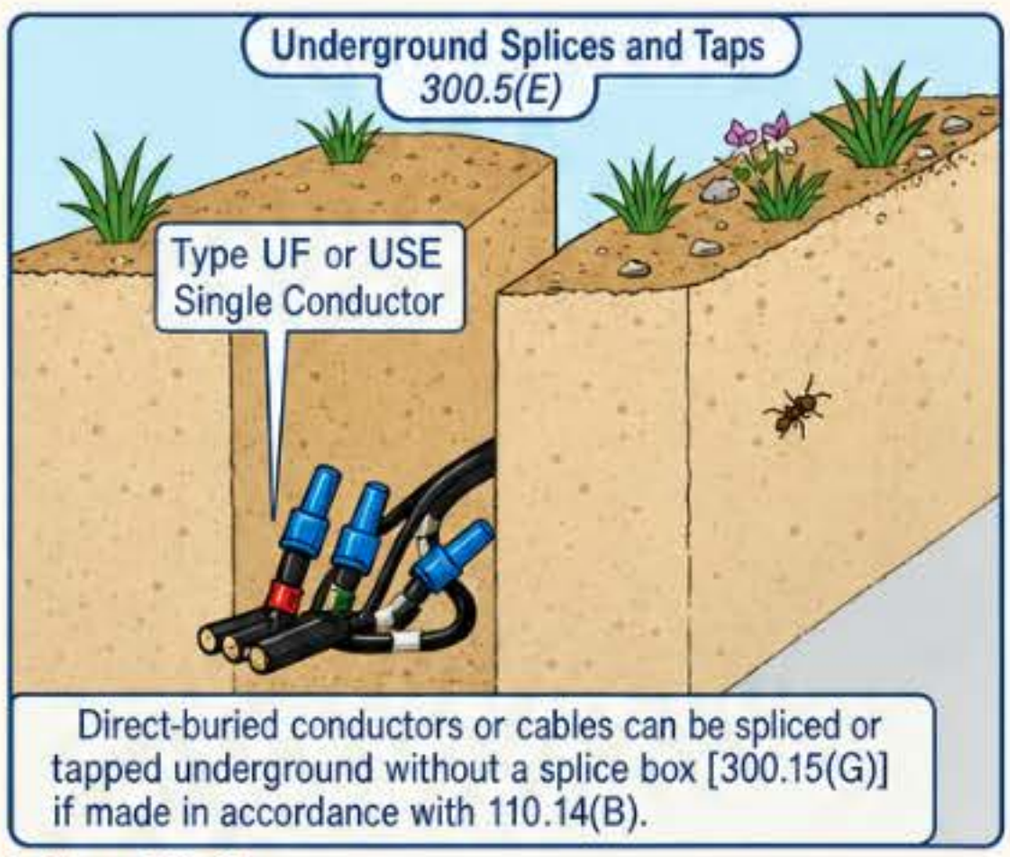
General Requirements for Wiring Methods and Materials | 300.5



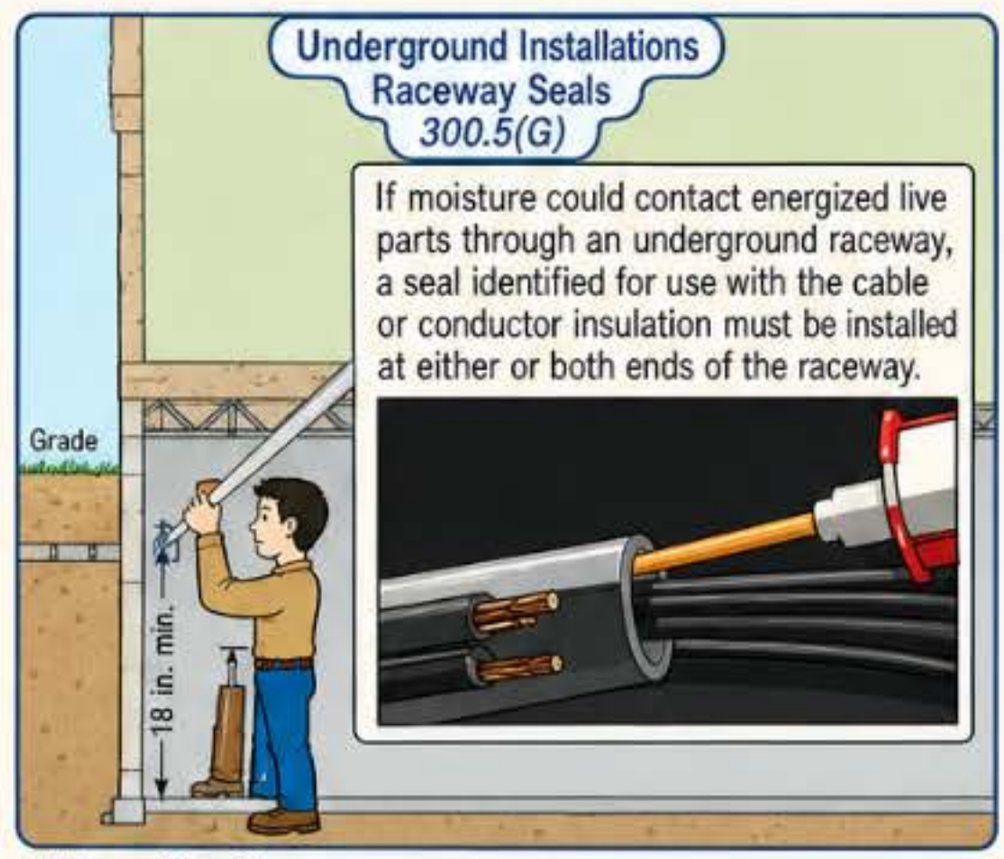
▶ Figure 300–33



▶ Figure 300–35



▶ Figure 300–34



▶ Figure 300–36

(F) Backfill. Backfill material for underground wiring is not permitted to damage underground raceways, cables, or conductors. ▶ Figure 300–35

> ***Author's Commentary:***
> *Use granular soil free of sharp or heavy rocks. Choose fill that won't shift or settle in a way that could stress or harm buried raceways or cables.*
> ***— Michael Hamilton***

(G) Raceway Seals. If moisture could contact energized live parts through an underground raceway, a seal identified for use with the cable or conductor insulation must be installed at either or both ends of the raceway [225.27 and 230.8]. ▶ Figure 300–36

> ***Author's Commentary:***
> *Seals help prevent moisture migration inside conduits, reducing corrosion and potential insulation breakdown. Match the sealant to the cable or conductor type.*
> ***— Michael Hamilton***

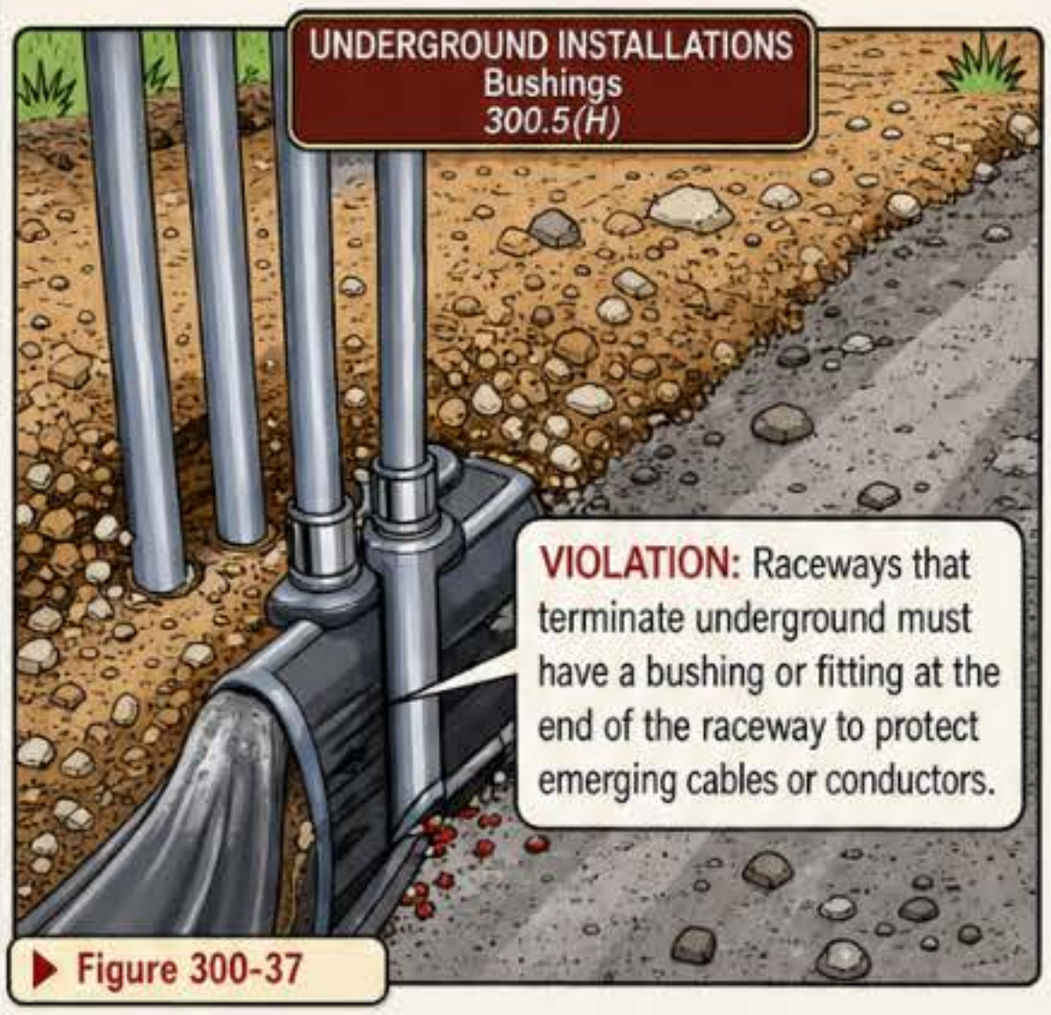
(H) Bushing. Raceways that terminate underground must have a bushing or fitting at the end of the raceway to protect emerging cables or conductors. ▶ Figure 300–37

> ***Author's Commentary:***
> *A proper bushing shields cables from abrasion at the raceway opening and helps maintain the system's mechanical integrity.*
> ***— Michael Hamilton***

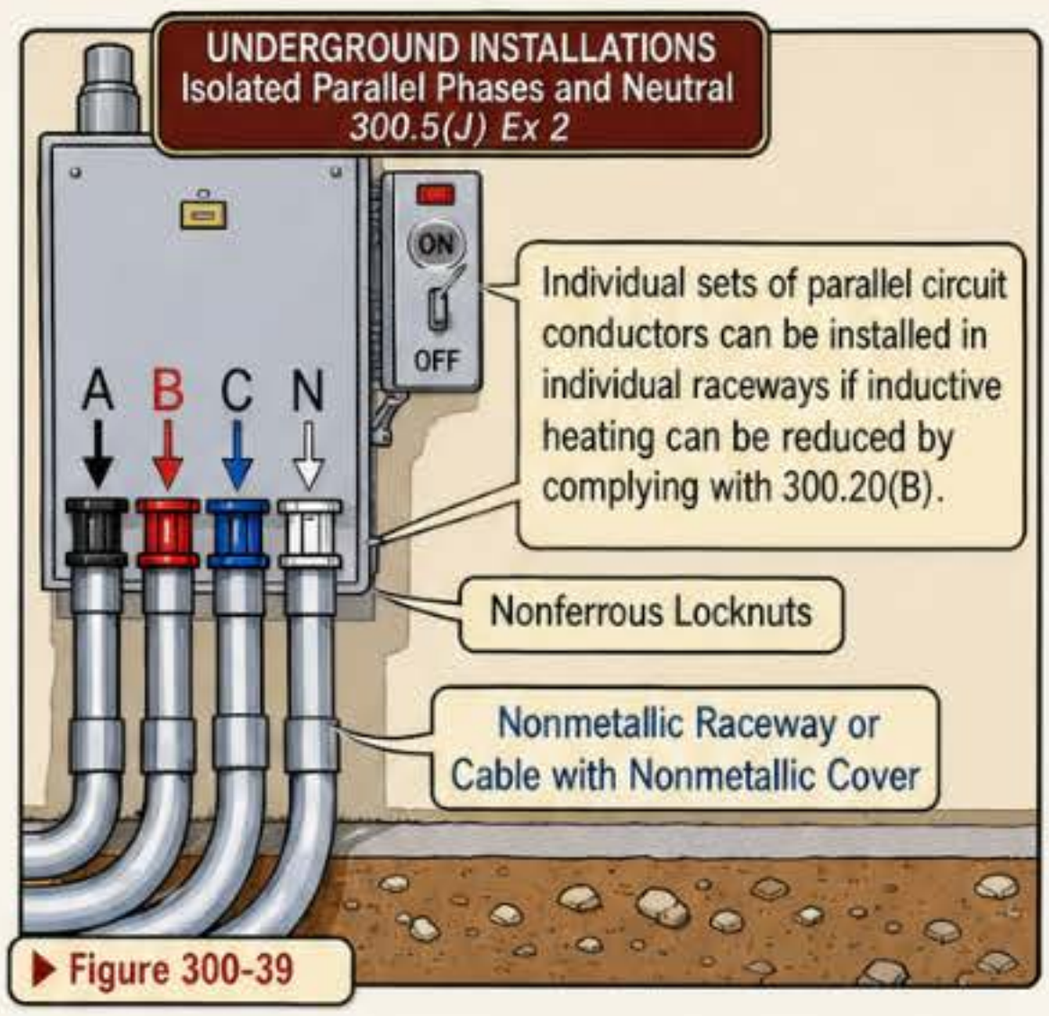
(I) Conductors of the Same Circuit. Underground conductors of the same circuit (including the equipment grounding conductor) must be installed inside the same raceway, multiconductor cable, or near each other in the same trench. See 300.3(B). ▶ Figure 300–38

> ***Author's Commentary:***
> *Keeping all conductors of a circuit together promotes safety, reduces inductive effects, and simplifies installation and troubleshooting.*
> ***— Michael Hamilton***

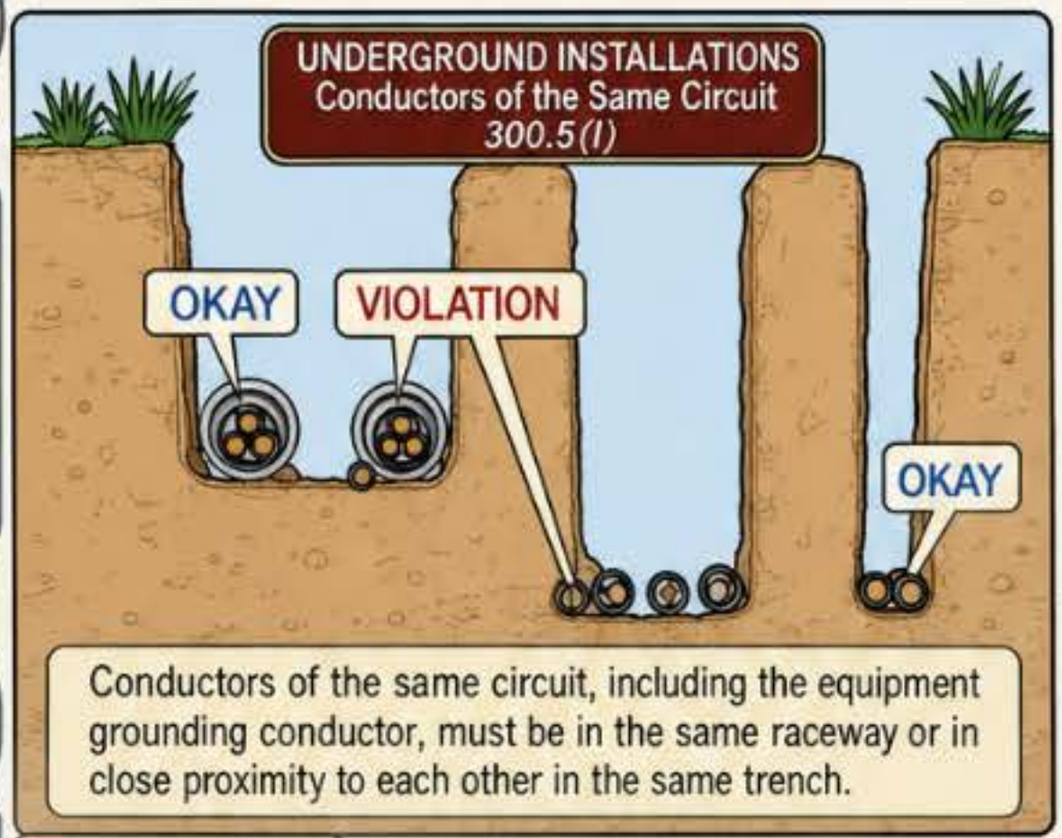
300.6 | General Requirements for Wiring Methods and Materials



▶ Figure 300-37



▶ Figure 300-39



▶ Figure 300-38

Ex 2: Underground parallel conductors can have the conductors of each phase or neutral installed in separate nonmetallic raceways where inductive heating at raceway terminations is reduced by the use of aluminum locknuts and by cutting a slot between the individual holes through which the conductors pass as required by 300.20(B). ▶ Figure 300-39

(J) Earth Movement. Direct-buried conductors, cables, or raceways that may be affected by settlement or frost must be arranged to prevent damage to conductors or equipment connected to the wiring. ▶ Figure 300-40

▶ Figure 300-40

Author's Commentary:

Separating phase and neutral conductors in individual PVC conduits makes it easier to terminate larger parallel installations, but it also results in elevated electromagnetic fields (EMF). Keeping the phase and neutral conductors close to each other helps reduce circuit impedance.

— Michael Hamilton

300.6 Protection Against Corrosion and Deterioration

Raceways, cable trays, cablebus, cable armor, boxes, cable sheathing, cabinets, elbows, couplings, fittings, supports, and support hardware must be suitable for the environment. ▶ Figure 300-41

General Requirements for Wiring Methods and Materials | 300.7

Protection Against Corrosion and Deterioration 300.6

VIOLATION: Raceways, cable armor, boxes, elbows, fittings, and supports must be of materials suitable for the environment.

Figure 300-41

Author's Commentary:
Section 110.11 has similar requirements regarding deteriorating agents.
— Michael Hamilton

(A) Ferrous Metal Equipment. Ferrous metal raceways, enclosures, cables, cable trays, fittings, and support hardware must be protected against corrosion by a coating of listed corrosion-resistant material. Where conduit is threaded in the field, the threads must be coated with an approved electrically conductive, corrosion-resistant compound such as zinc galvanizing or KOPR-Shield®.

Note: *Field-cut threads are those threads that are cut anywhere other than at the factory.*

Author's Commentary:
- *Ferrous metals are those that are prone to higher degrees of oxidation or ferrous oxide; most commonly called "rust." The use of nonferrous materials is preferred in locations and environments that lead to this type of deterioration.*
- *Nonferrous metal raceways, such as aluminum rigid metal conduit, do not have to meet the provisions of this section. See 300.6(B).*

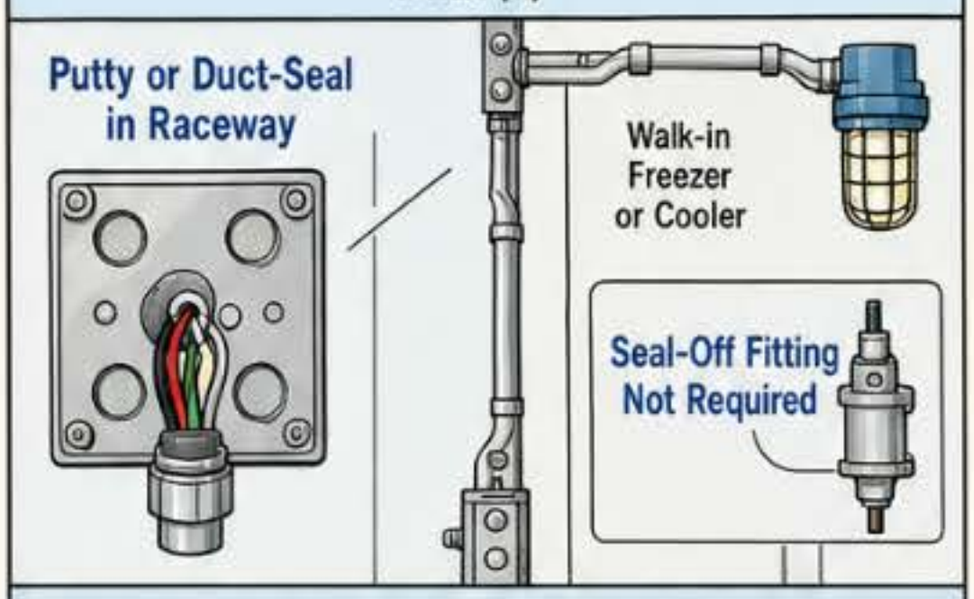
— Michael Hamilton

300.7 Raceways Exposed to Different Temperatures

Scan this QR code for a video of Michael Hamilton explaining this topic; it's a sample from the videos that accompany this textbook.

(A) Sealing. If a raceway is subjected to different temperatures, and where condensation is known to be a problem, the raceway must be filled with a material approved by the authority having jurisdiction that will prevent the circulation of warm air to a colder section of the raceway. Sealants must be identified for use with cable insulation, conductor insulation, a bare conductor, a shield, or other components. Figure 300-42

Raceways Exposed to Different Temperatures, Sealing 300.7(A)



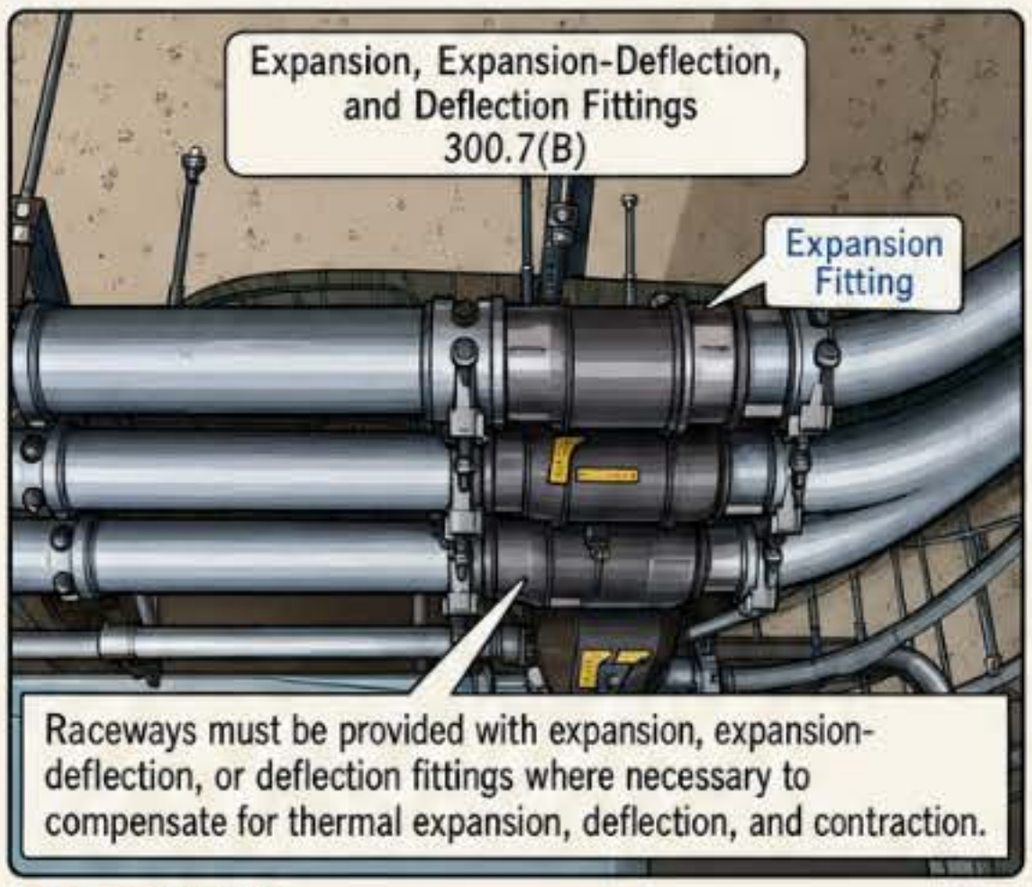
Raceways must be sealed to prevent the circulation of warm air to a colder section of the raceway or sleeve. Sealants must be identified for use with cable insulation, conductor insulation, a bare conductor, a shield, or other components.

Figure 300-42

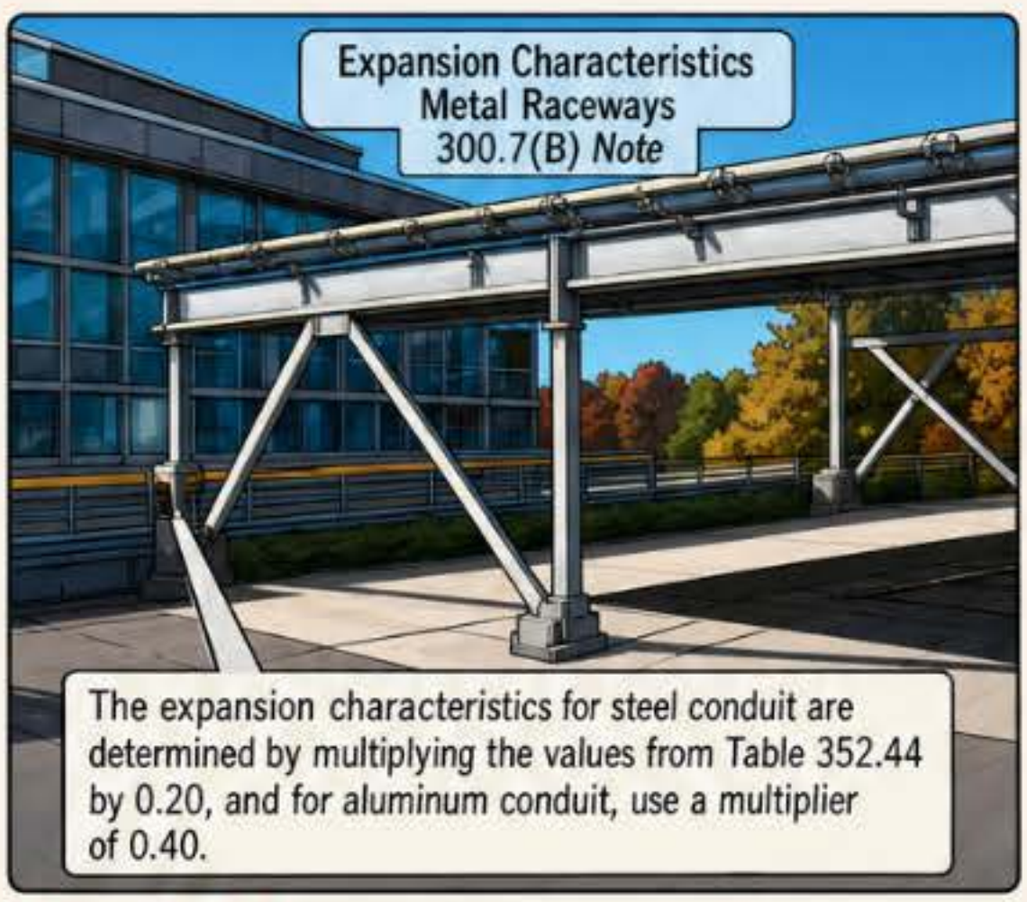
Author's Commentary:
One common product used for this is electrical duct seal and it is so identified. There are other identified products such as Polywater's FST Duct Sealant. Typical expanding foams used to seal buildings are not identified for this application.
— Michael Hamilton

(B) Expansion, Expansion-Deflection, and Deflection Fittings. Raceways must be provided with expansion, expansion-deflection, or deflection fittings where necessary to compensate for thermal expansion, deflection, and contraction. Figure 300-43

Note: *Table 352.44 provides the expansion characteristics for PVC conduit. The expansion characteristics for steel conduit are determined by multiplying the values from Table 352.44 by 0.20, and those for aluminum raceways are determined by multiplying the values from Table 352.44 by 0.40. Table 355.44 provides the expansion characteristics for reinforced thermosetting resin conduit (RTRC).* Figure 300-44



▶ Figure 300–43



▶ Figure 300–44

300.9 Raceways in Wet Locations Above Grade

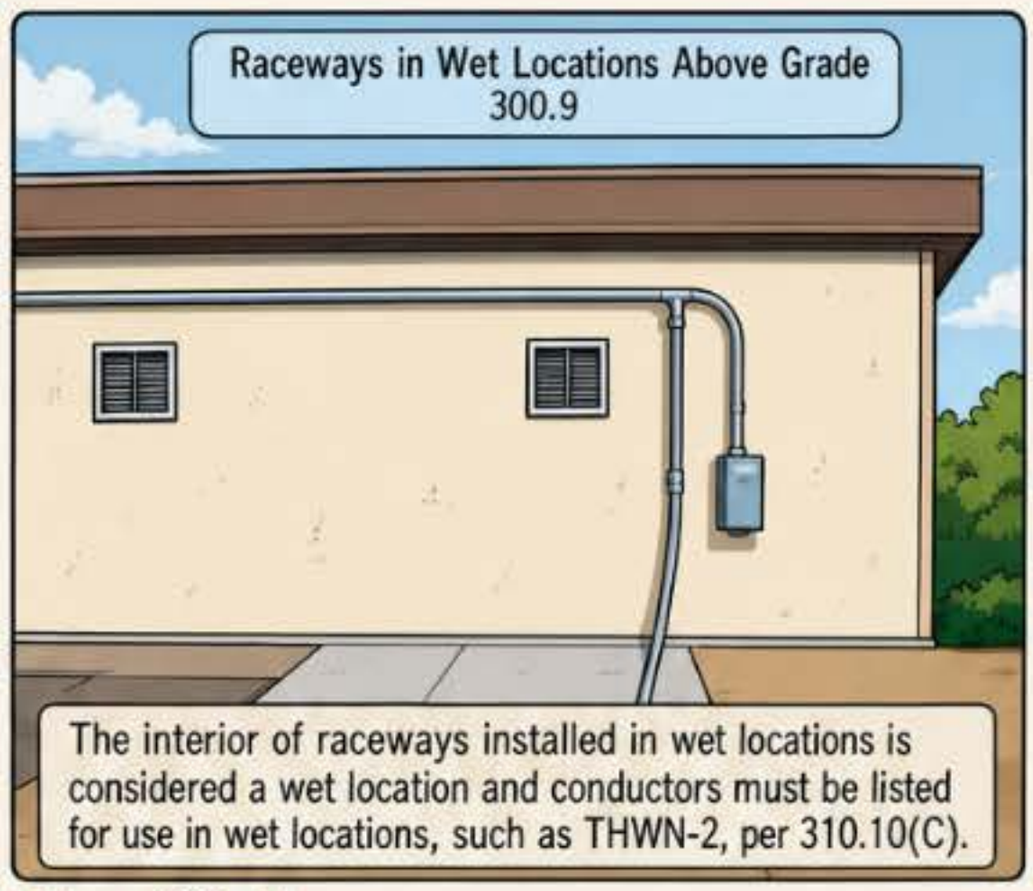
The interior of raceways installed in wet locations above ground is considered a wet location. Insulated conductors and cables installed in raceways in aboveground wet locations must be listed for use in wet locations in accordance with 310.10(C).

▶ Figure 300–45

Author's Commentary:

- In addition to 310.10(C), Table 310.4(A) can be used to find other insulation types permitted in wet locations.

— Michael Hamilton



▶ Figure 300–45

300.10 Electrical Continuity

Metal raceways, cable armor, and other metal enclosures must be metallically joined into a continuous electrical conductor to provide effective electrical continuity [110.10 and 250.4(A)].

▶ Figure 300–46

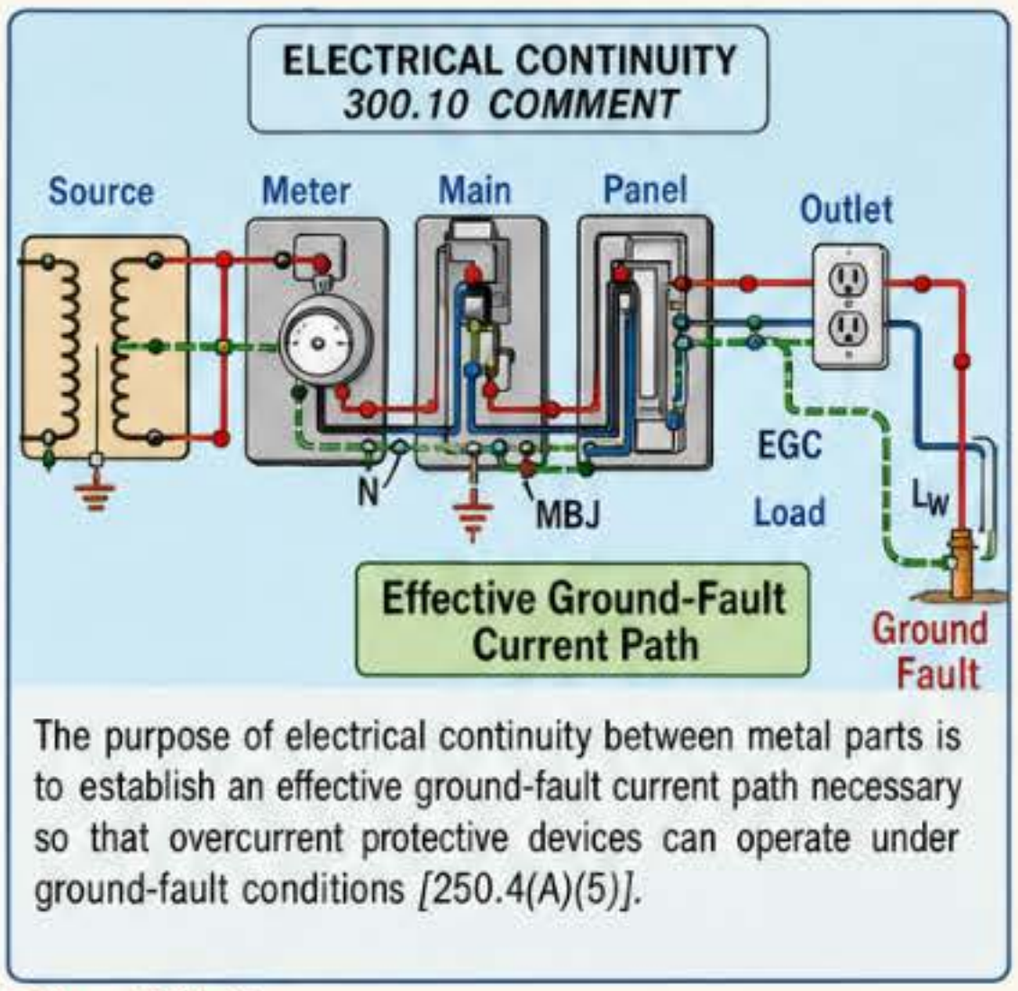
▶ Figure 300–46

Author's Commentary:

- The purpose of electrical continuity between metal parts is to establish the effective ground-fault current path needed to enable the operation of the circuit overcurrent protective device in the event of a ground fault [250.4(A)(5)].

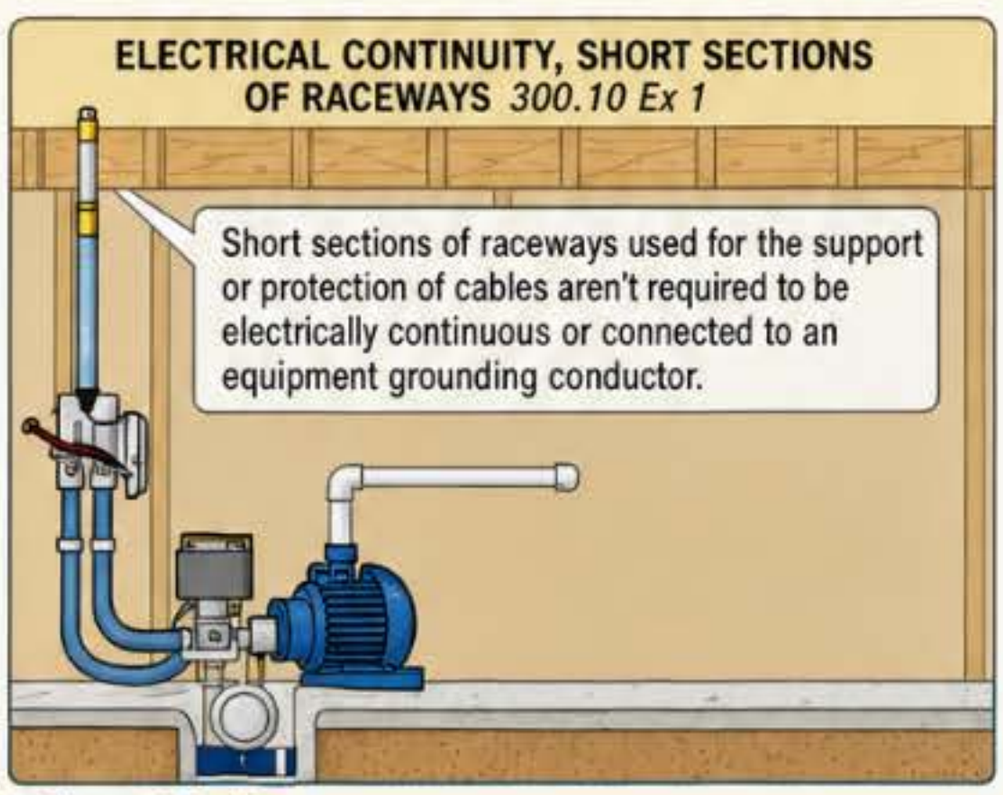
— Michael Hamilton

GENERAL REQUIREMENTS FOR WIRING METHODS AND MATERIALS 300.11



▶ Figure 300–47

Ex 1: Short lengths of metal raceways used for the support or protection of cables are not required to be electrically continuous, nor are they required to be connected to an equipment grounding conductor [250.86 Ex 2 and 300.12 Ex 1]. ▶ Figure 300–48

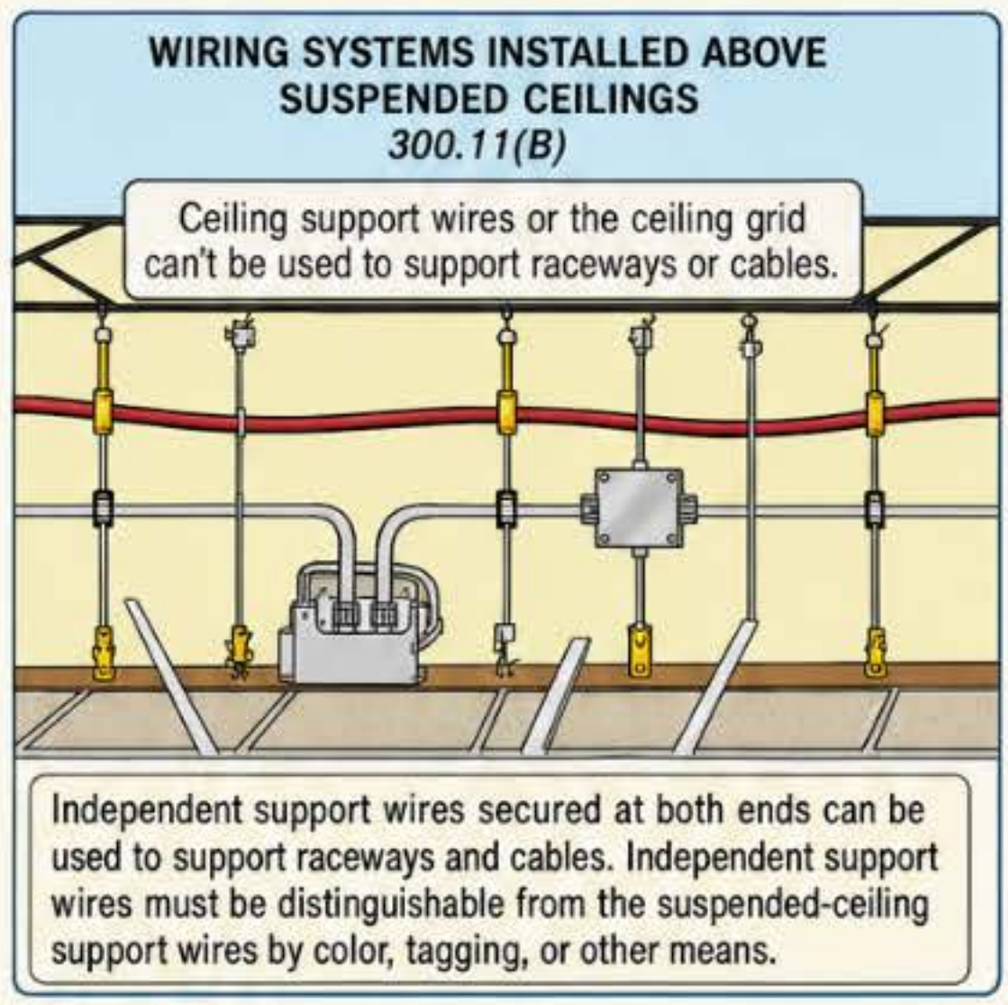


▶ Figure 300–48

300.11 Securing and Supporting

(A) Secured in Place. Raceways, cable assemblies, and enclosures must be securely fastened in place.

(B) Wiring Systems Installed Above Suspended Ceilings. Ceiling support wires or the ceiling grid is not permitted to support raceways or cables. *Independent support wires secured at both ends can be used to support raceways or cables.* ▶ Figure 300–49



▶ Figure 300–49

(1) Fire-Rated Assemblies. Electrical wiring within the cavity of a fire-rated ceiling assembly can be supported by independent support wires attached to the ceiling assembly. The independent support wires must be distinguishable from the suspended-ceiling support wires by color, tagging, or other effective means.

> ***Author's Commentary:***
> *Outlet boxes [314.23(D)] and luminaires can be secured to the suspended-ceiling grid if the luminaire is securely fastened to the ceiling-framing members by mechanical means such as bolts, screws, or rivets, or by the use of clips or other securing means identified for use with the type of ceiling-framing member(s) used [410.36(B)].*
>
> — *Michael Hamilton*

(C) Raceways Used for Support. Raceways are not permitted to support other wiring methods, except as follows: ▶ Figure 300–50 and ▶ Figure 300–51

(1) Identified. If the raceway or means of support is identified as a means of support.

(2) Class 2 and 3 Circuits. Class 2 and 3 cables can be supported by the raceway that supplies power to the equipment controlled by the Class 2 or 3 circuit. ▶ Figure 300–52

(D) Cables Not Used as Means of Support. Cables are not *permitted to support other wiring methods.* ▶ Figure 300–53

300.12 | General Requirements for Wiring Methods and Materials

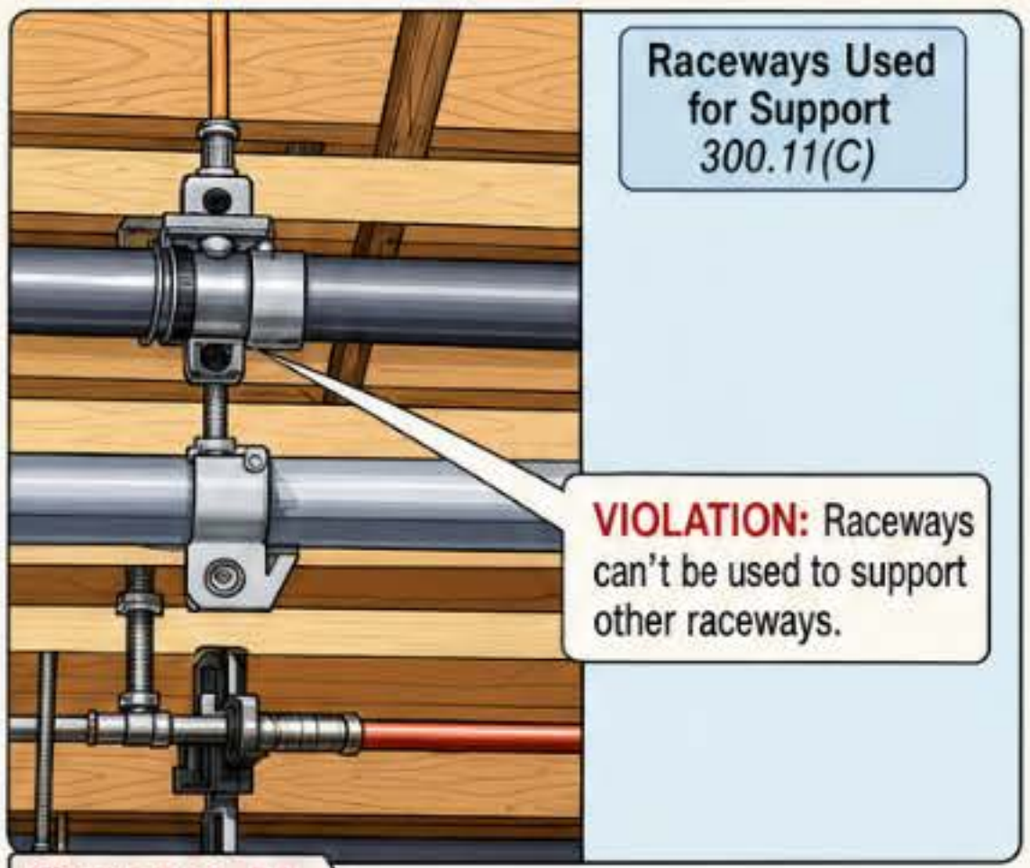


Figure 300–50

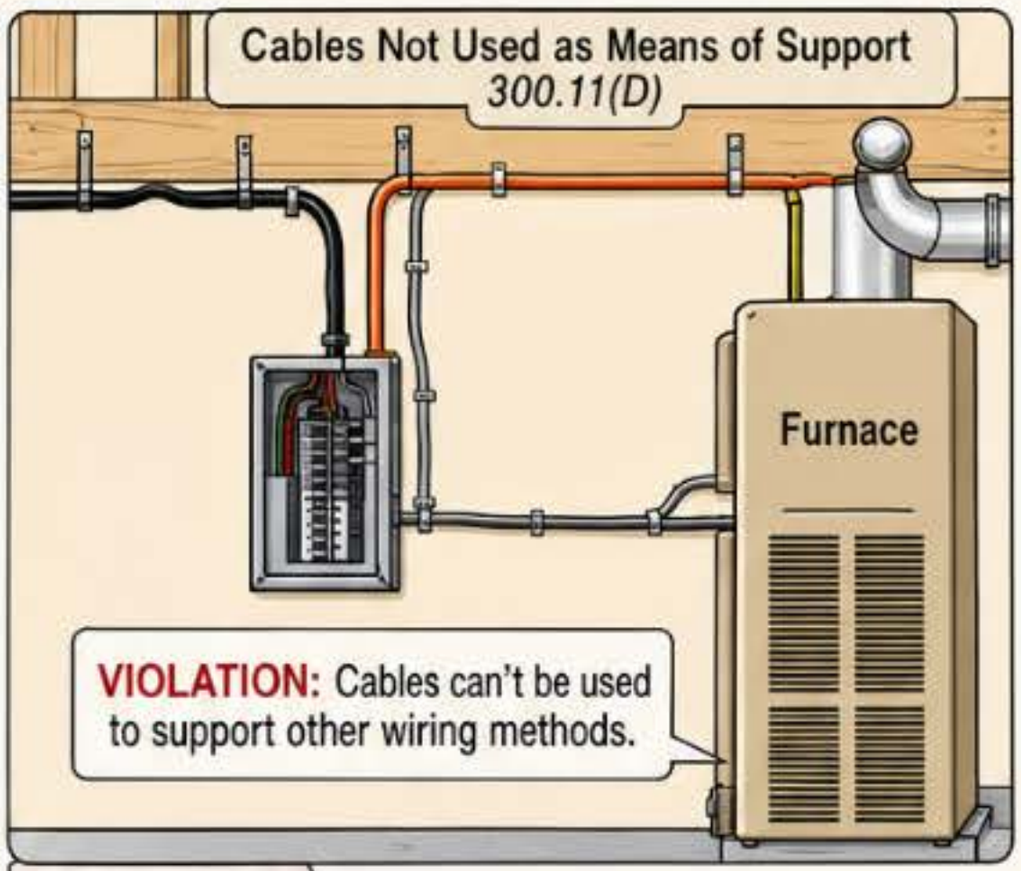


Figure 300–53

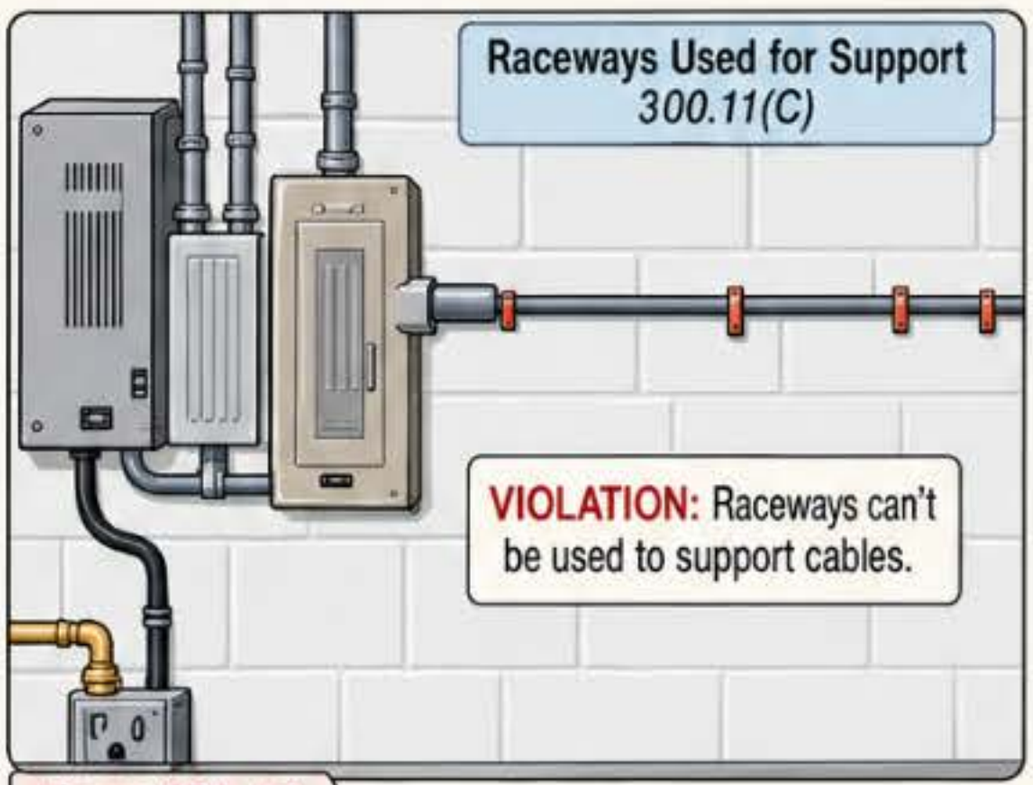


Figure 300–51

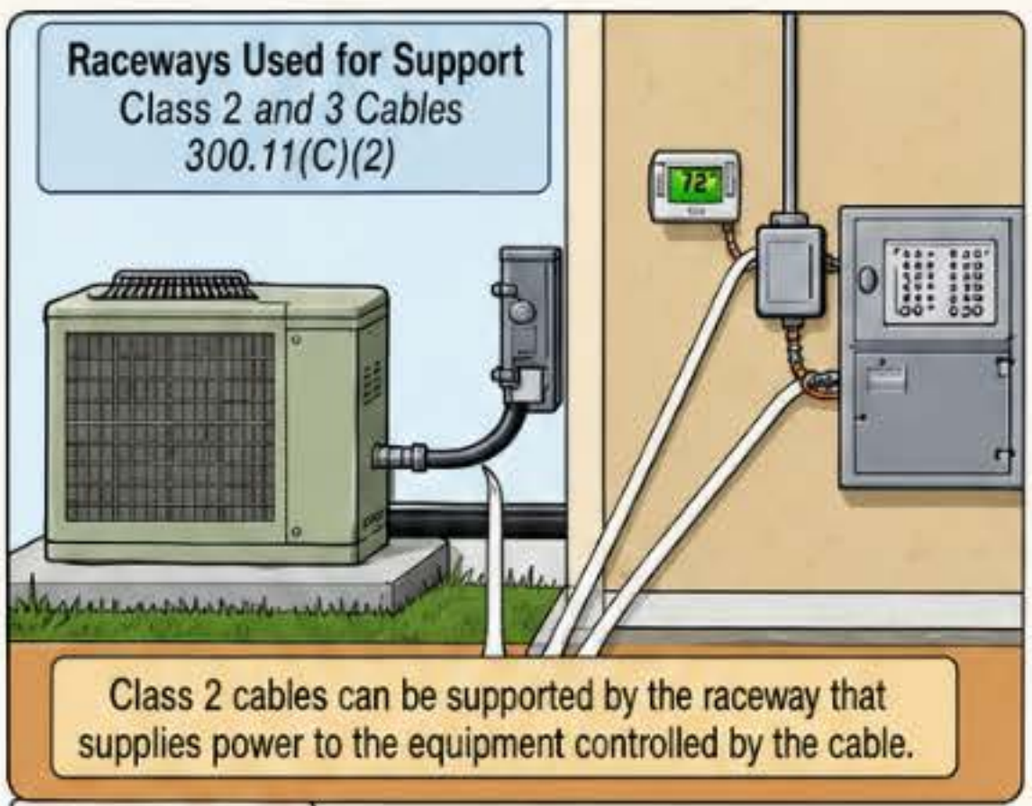


Figure 300–52

300.12 Mechanical Continuity

Raceways and cable sheaths must be mechanically continuous between boxes, cabinets, and fittings. See **Figure 300–54** and **Figure 300–55**.

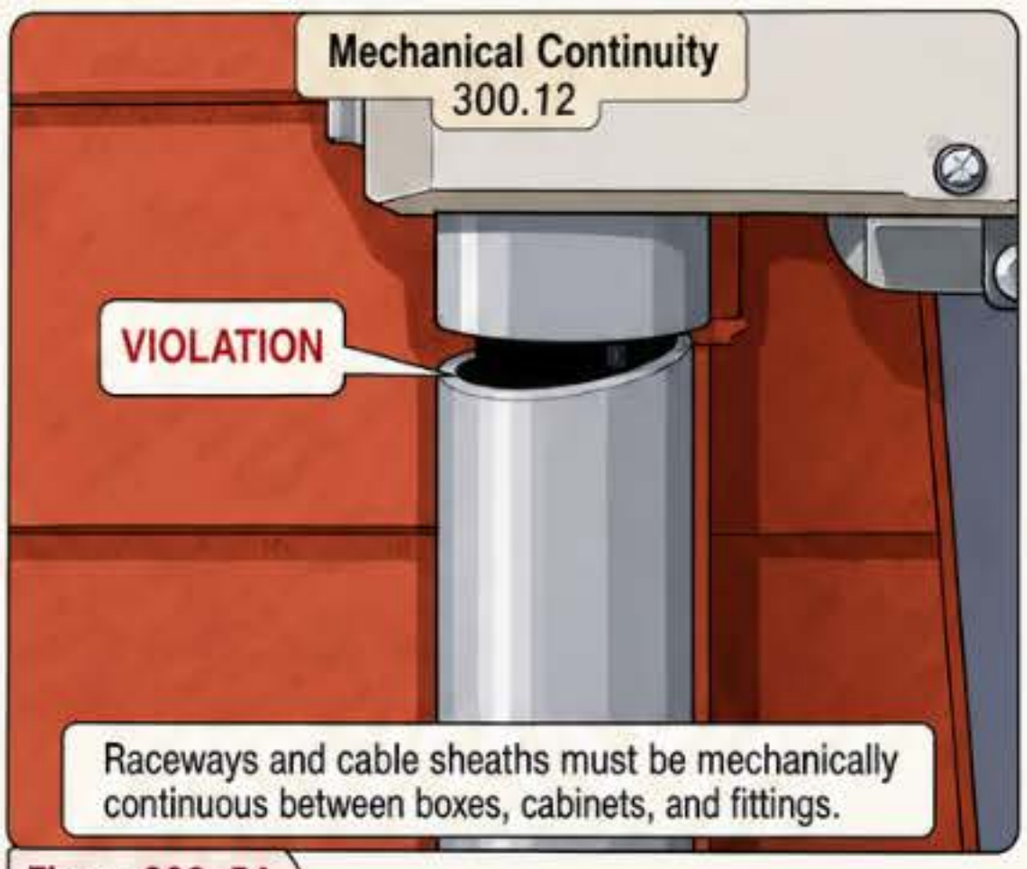
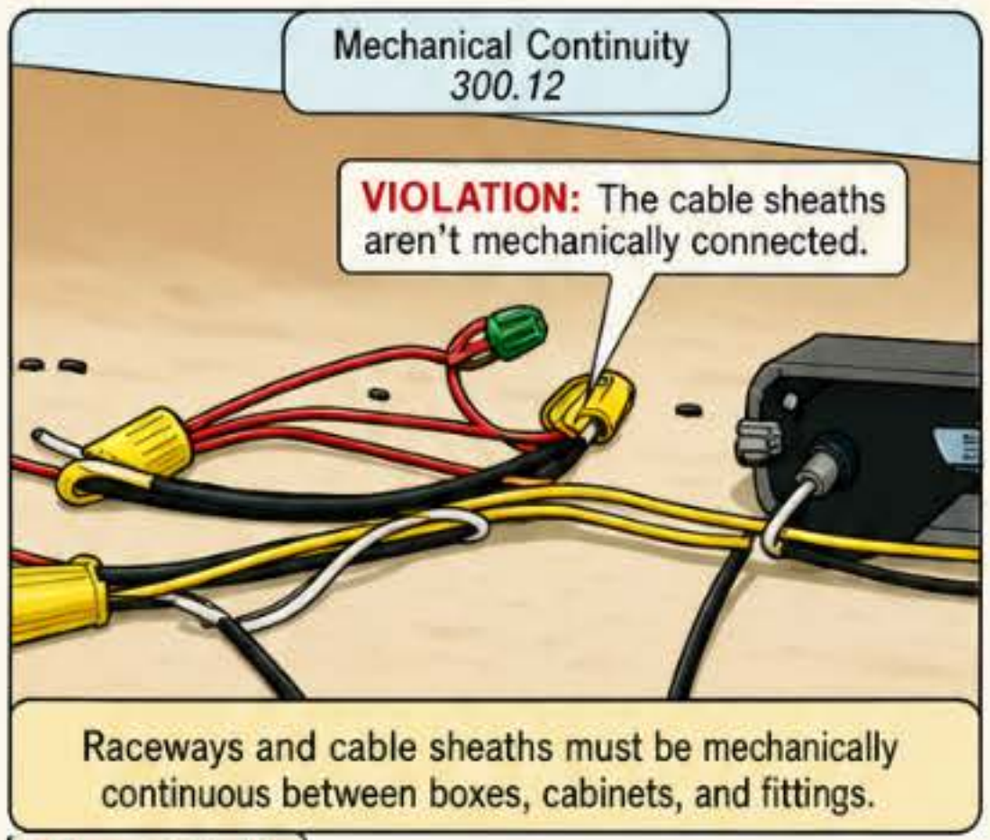


Figure 300–54

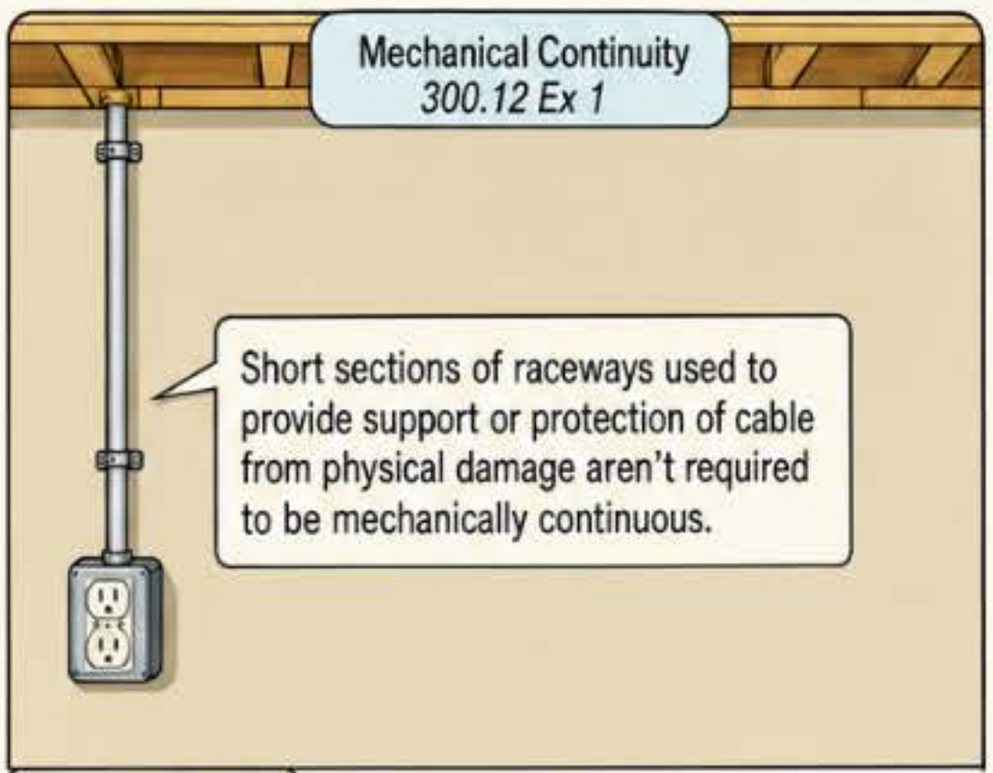
Ex 1: *Short sections of raceways used to provide support or protection of cables from physical damage are not required to be mechanically continuous [250.86 Ex 2 and 300.10 Ex 1]. See* **Figure 300–56**.

Ex 2: *Raceways and cables installed into the bottom of open-bottom equipment such as switchboards, motor control centers, and floor or pad-mounted transformers are not required to be mechanically secured to the equipment. See* **Figure 300–57**.

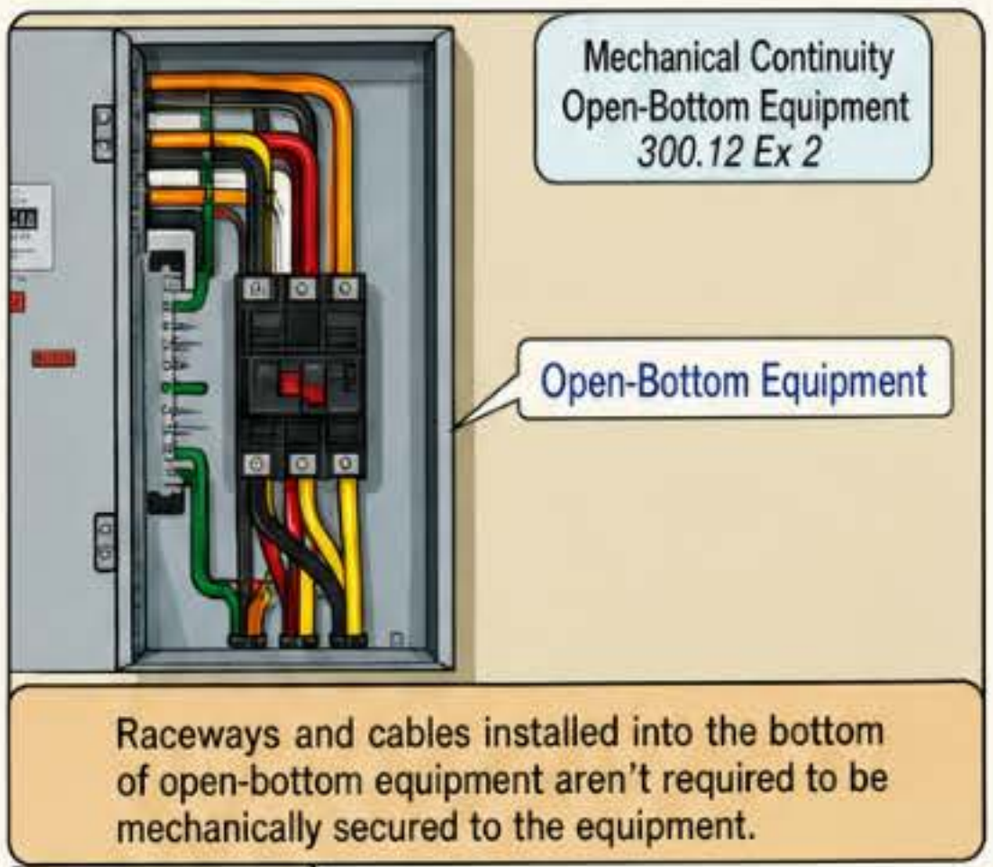
General Requirements for Wiring Methods and Materials | 300.13



▶ Figure 300–55



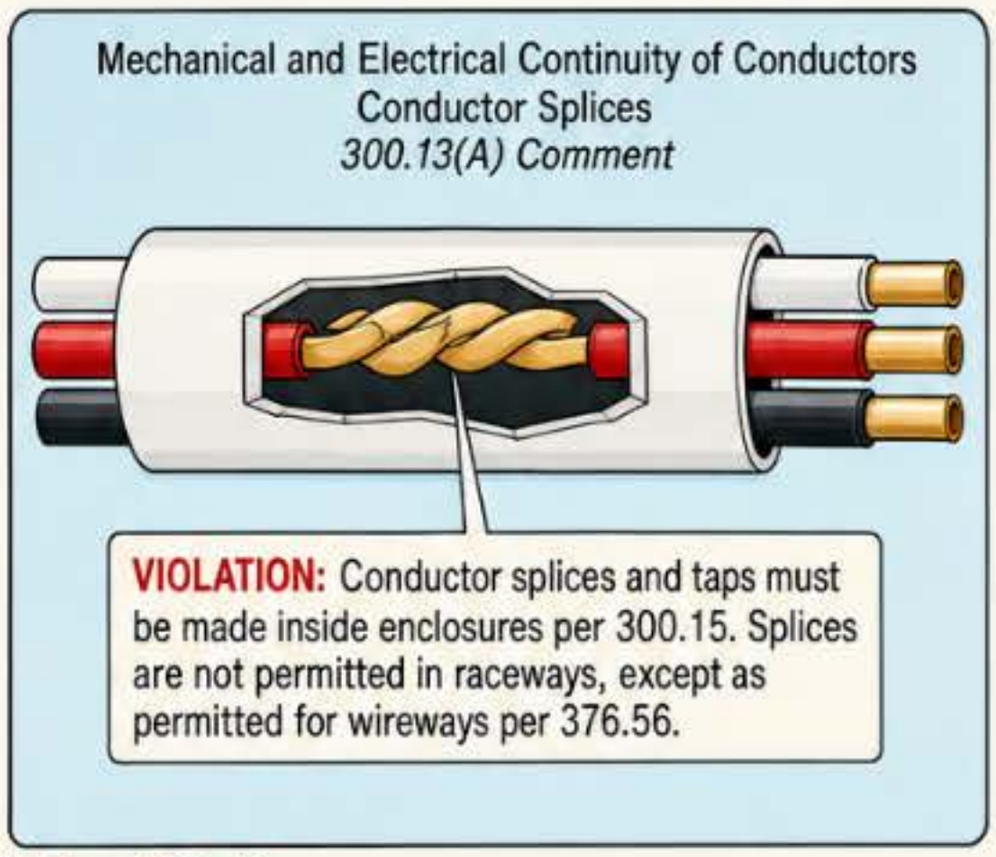
▶ Figure 300–56



▶ Figure 300–57

300.13 Mechanical and Electrical Continuity of Conductors-Splices and Pigtails

(A) Conductor Splices. Conductor splices and taps must be made inside enclosures in accordance with 300.15. Splices are not permitted in raceways, except as permitted for wireways in 376.56. ▶ Figure 300–58



▶ Figure 300–58

(B) Device Removal—Neutral Continuity. Continuity of the neutral conductor of a multiwire branch circuit is not permitted to be interrupted by the removal of a wiring device.

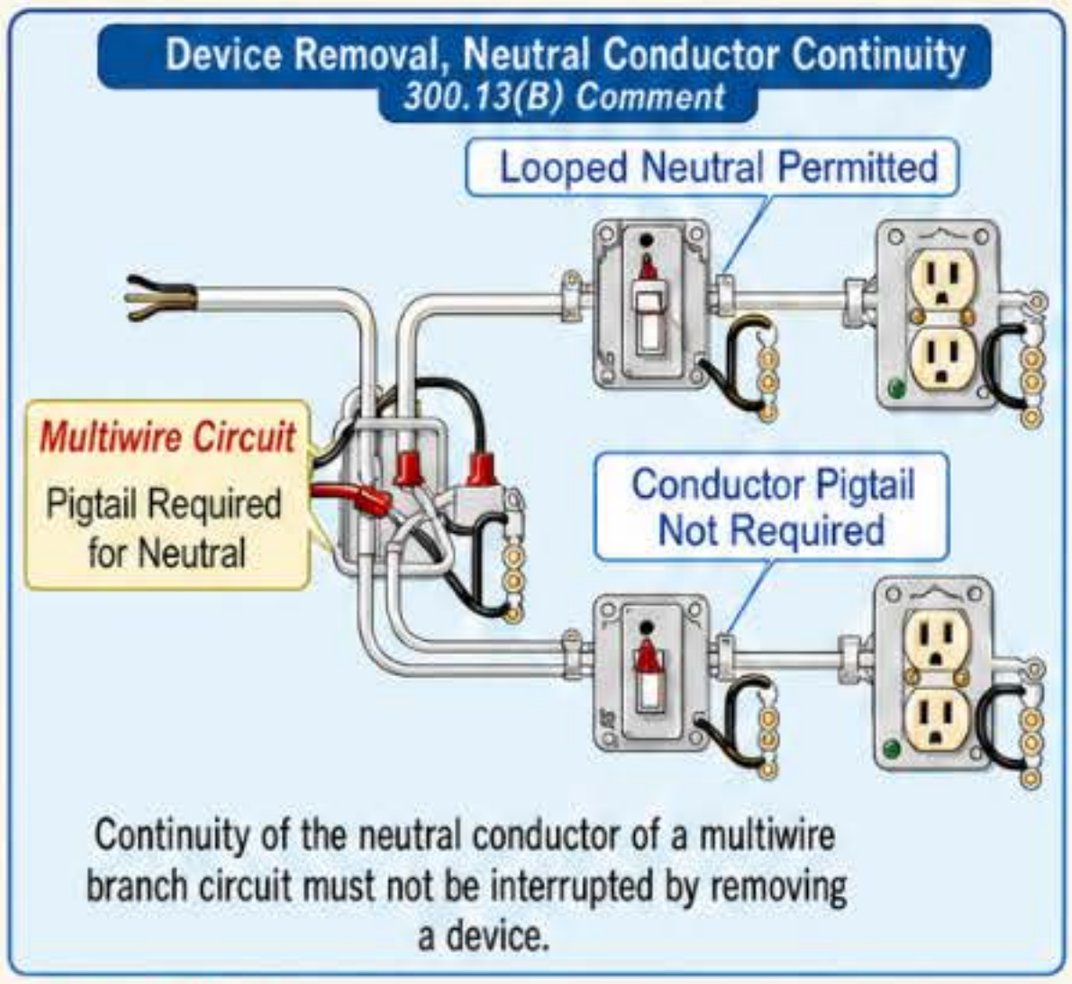
Author's Commentary:

- *This means that (for multiwire applications) the neutral conductors must be spliced together, and a pigtail must be provided for the wiring device.*
- *The opening of the phase conductors, or the neutral conductor of a 2-wire circuit while a device is replaced does not cause a safety hazard, so pigtailing these conductors is not required [110.14(B)].*

Caution

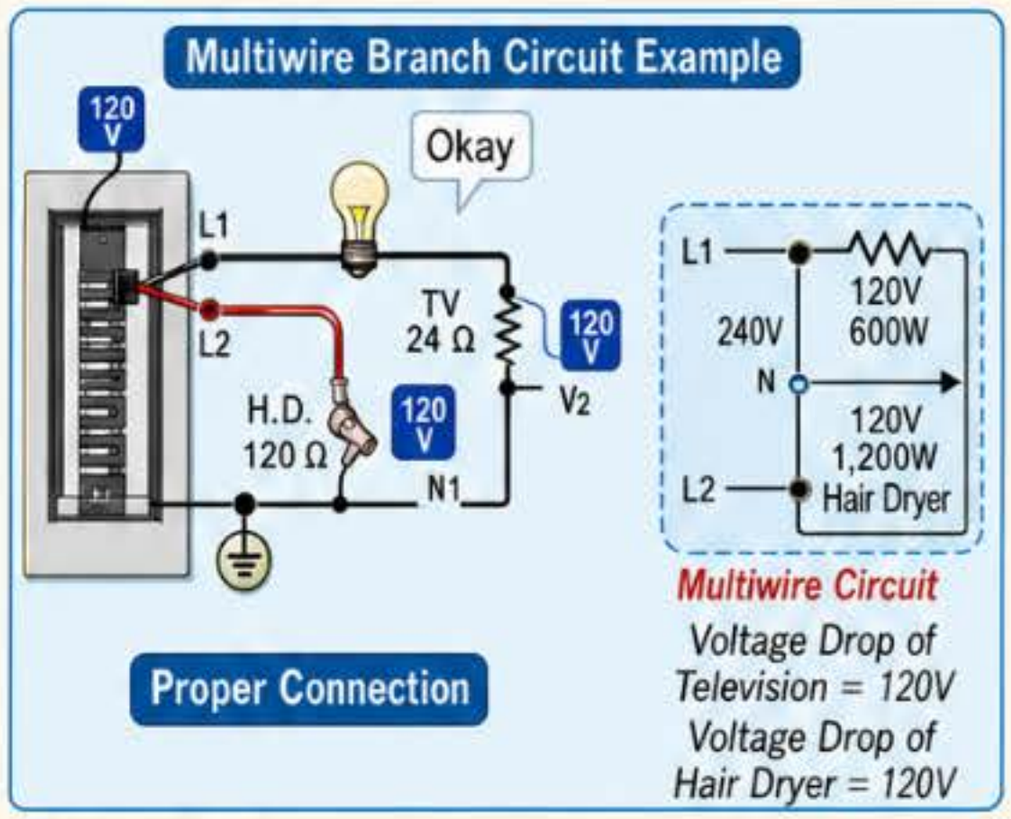
If the continuity of the neutral conductor of a multiwire circuit is interrupted (opened), the resulting over- or undervoltage can cause a fire and/or destruction of electrical equipment.

300.14 General Requirements for Wiring Methods and Materials



▲ Figure 300–59

Voltage of television = 6.70 × 24 ohms
Voltage of television = 160V



▲ Figure 300–60

▶ Hazard of Open Neutral Example

Example: *If the neutral conductor is interrupted on a 3-wire, 120/240V multiwire circuit that supplies a 1,200W, 120V hair dryer and a 600W, 120V television, it will cause the 120V television to momentarily operate at 160V before it burns up. This can be determined as follows.* ****Figure 300–60*** *and* ****Figure 300–61***

Step 1: *Determine the resistance of each appliance.*

$R = E^2/P$

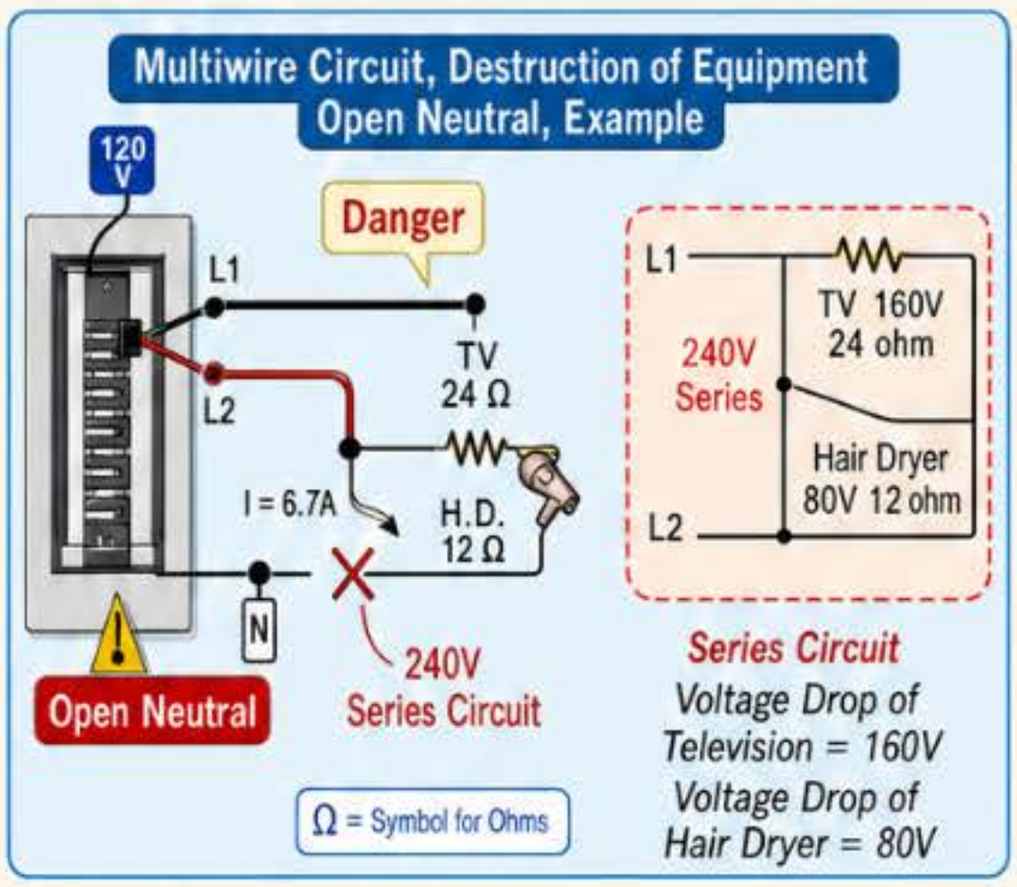
R of the hair dryer = 120V²/ 1,200W
R of the hair dryer = 12 ohms
R of the television = 120V²/ 600W
R of the television = 24 ohms

Step 2: *Determine the current of the circuit.*

I = Volts/Resistance
Volts = 240V
R = 36 ohms (12 ohms + 24 ohms)
I = 240V/36 ohms
I = 6.70A

Step 3: *Determine the operating voltage for each appliance.*

Volts = I × R
I = 6.70A
R = 12 ohms for the hair dryer and 24 ohms for the TV.
Voltage of hair dryer = 6.70A × 12 ohms
Voltage of hair dryer = 80V
Voltage of television = 6.70A × 24 ohms
Voltage of television = 160V



▲ Figure 300–61

300.14 Length of Free Conductors

At least 6 in. of conductor, measured from the point in the box where the conductors enter the enclosure, must be available at each point for conductor splices or terminations. ▶ **Figure 300–62**

Boxes with openings less than 8 in. at any dimension must have at least 6 in. of conductor, measured from the point where the conductors enter the box, and at least 3 in. of conductor outside the box. ▶ **Figure 300–63**

General Requirements for Wiring Methods and Materials | 300.15

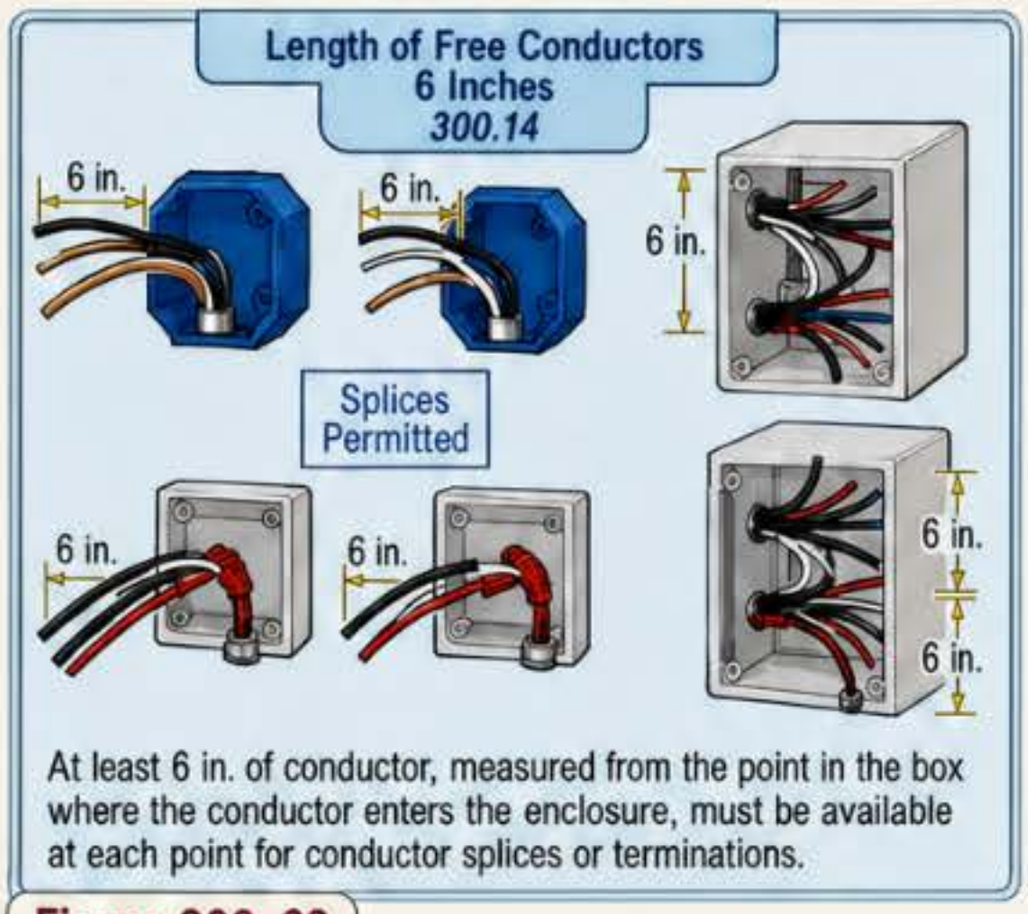


Figure 300–62

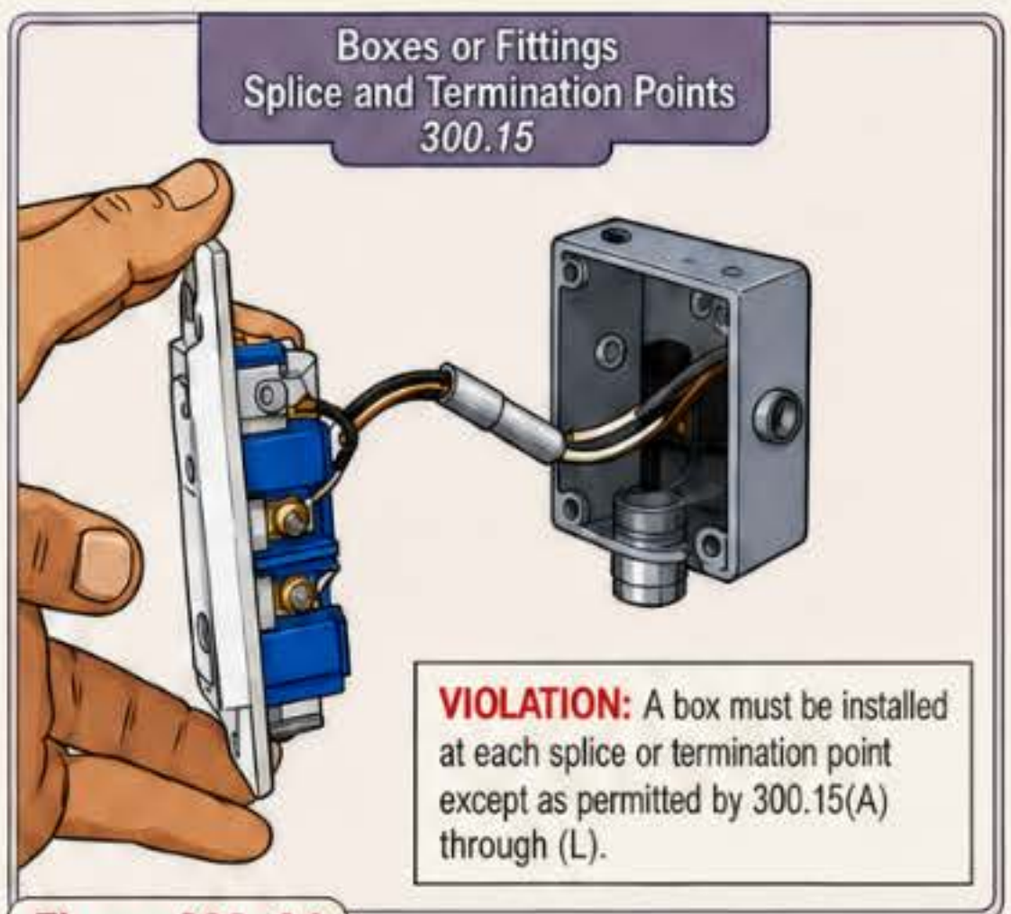


Figure 300–64

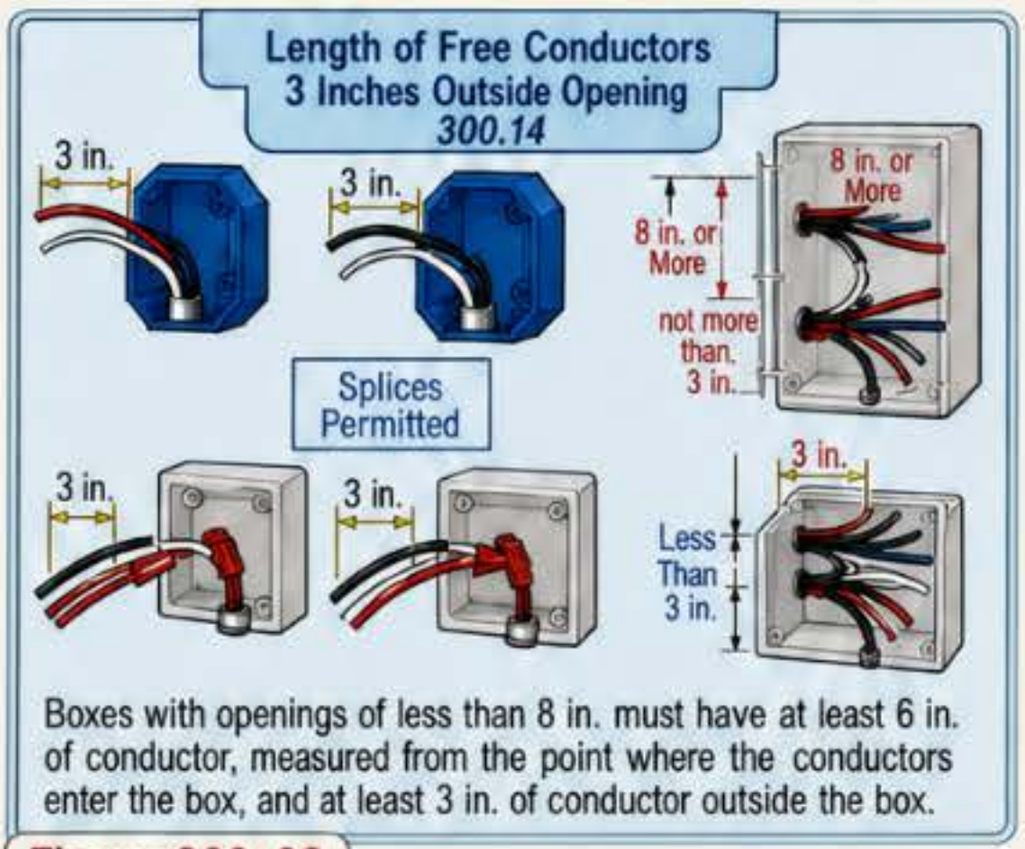


Figure 300–63

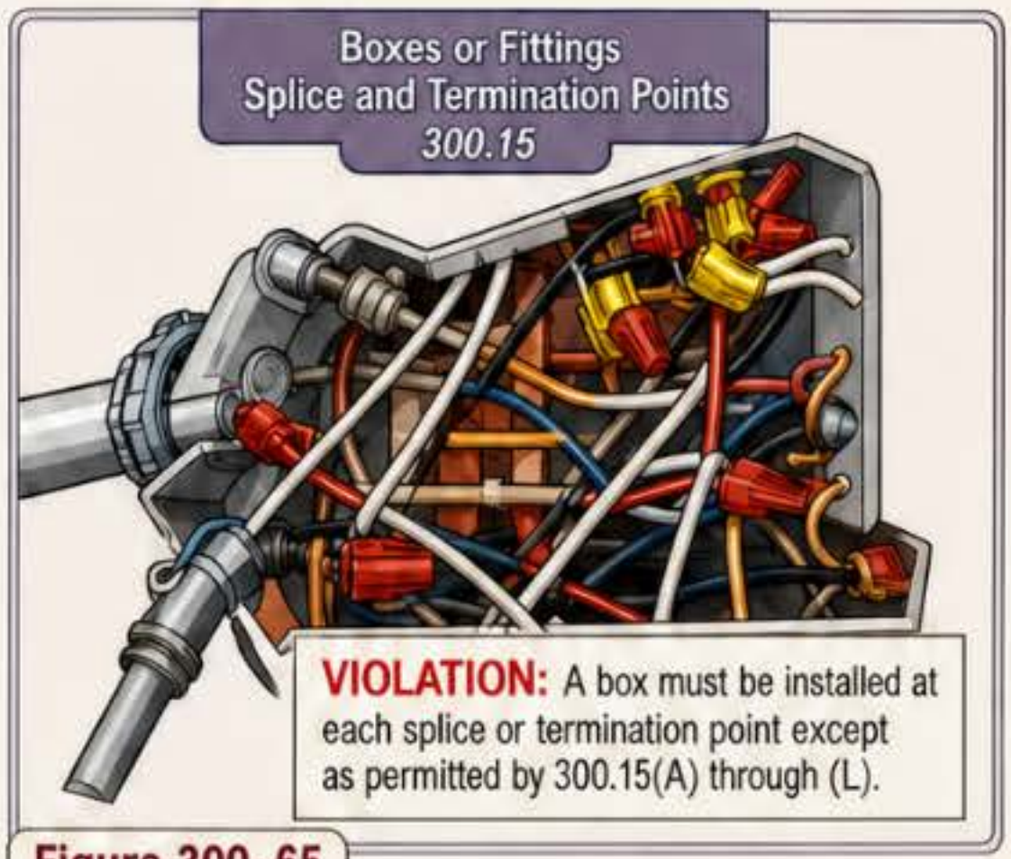


Figure 300–65

300.15 Boxes or Fittings

A box must be installed at each splice or termination point, except as permitted by 300.15(A) through (L). ▸ Figure 300–64 and ▸ Figure 300–65

Author's Commentary:

Conductors can be spliced in a conduit body in accordance with 314.16(C). ▸ Figure 300–66

— Michael Hamilton

Fittings and connectors can only be used with the specific wiring methods for which they are designed and listed. ▸ Figure 300–67

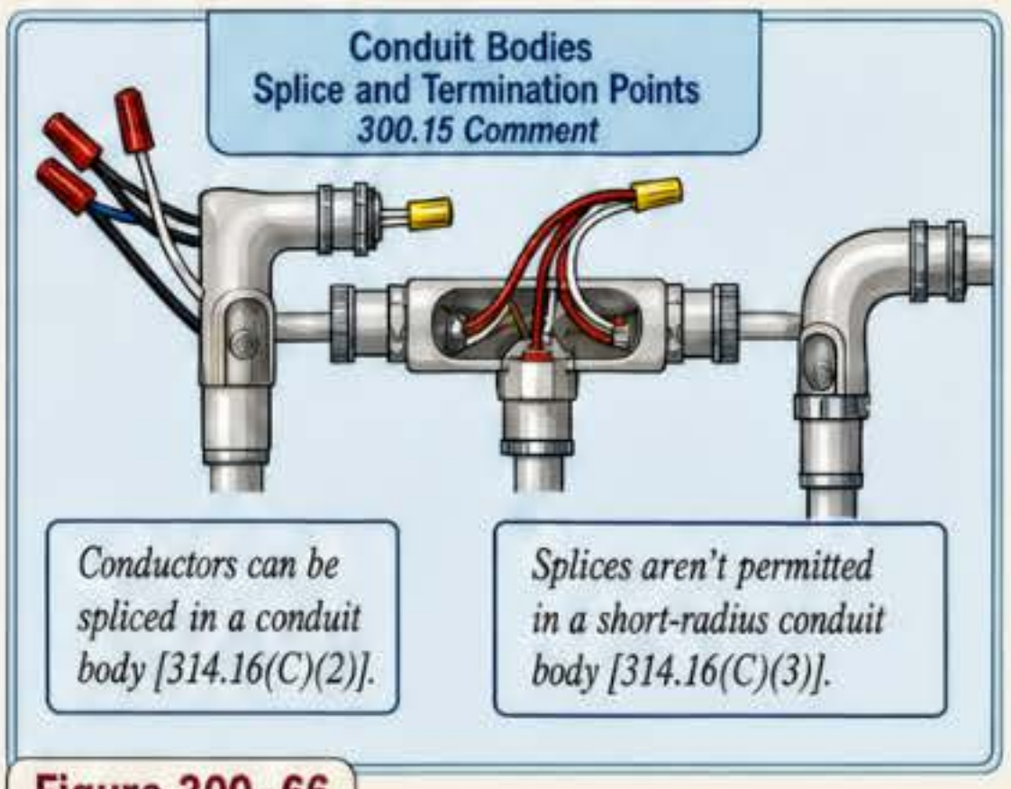
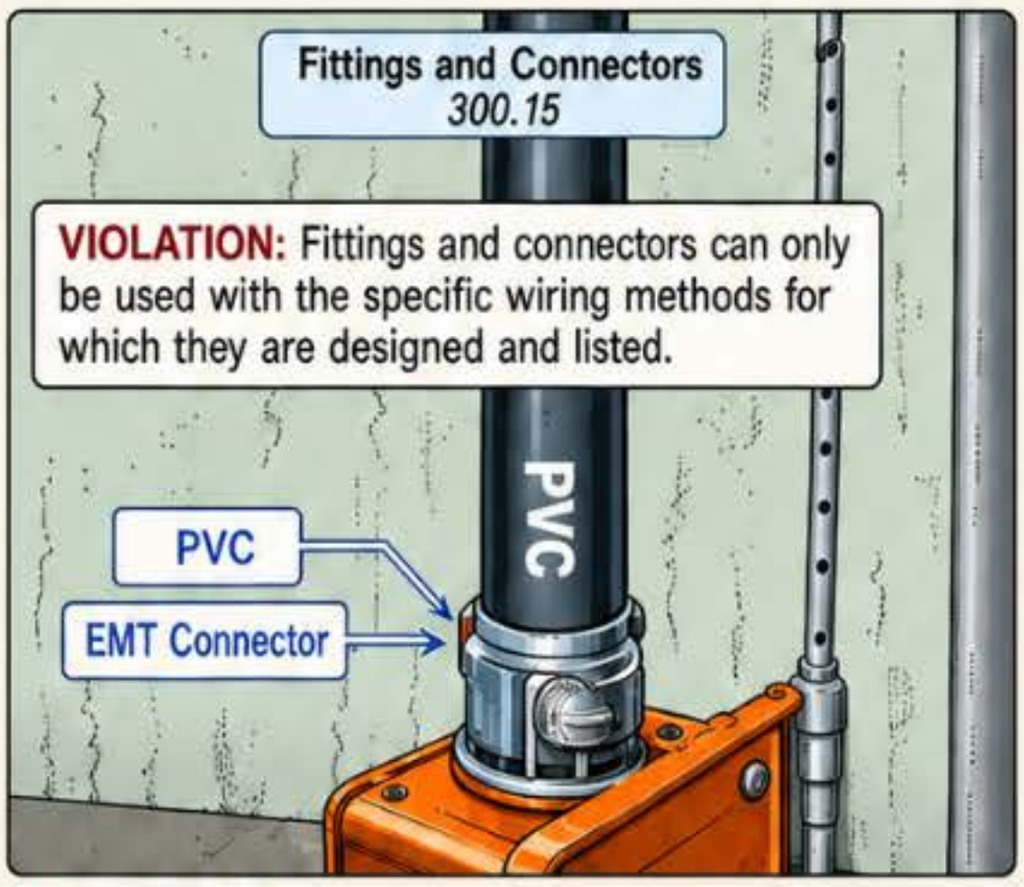
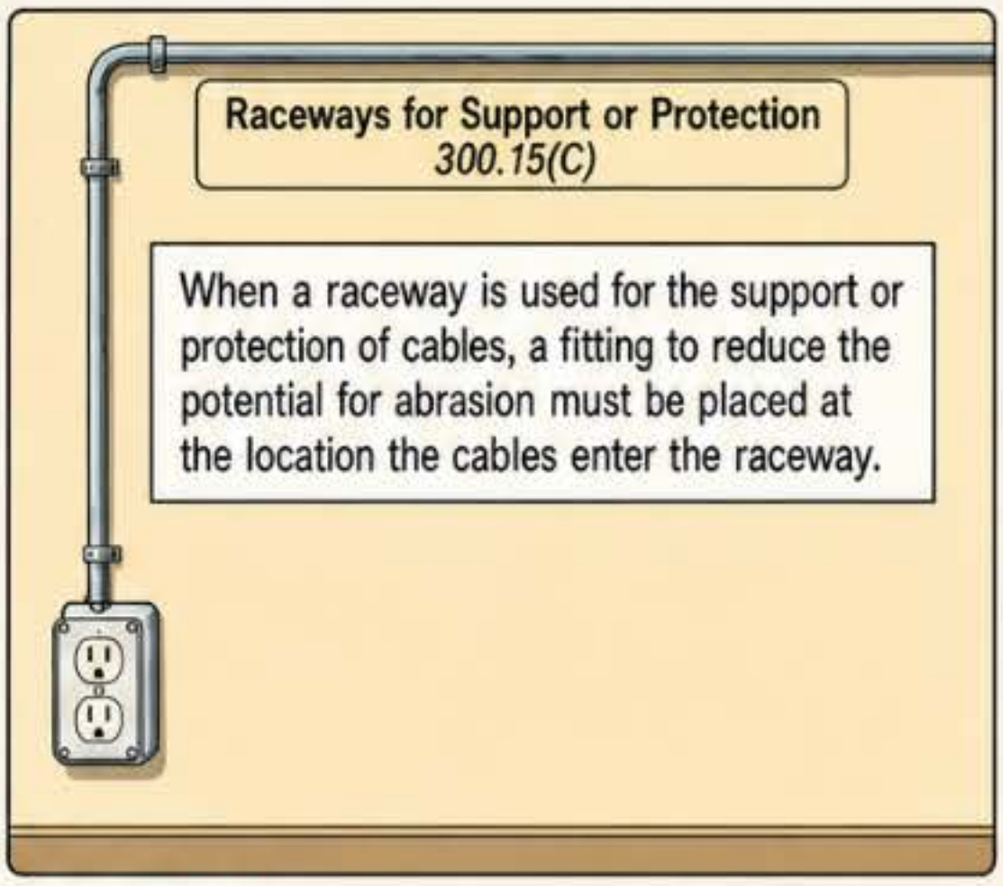


Figure 300–66

300.15 | General Requirements for Wiring Methods and Materials



▶ Figure 300–67



▶ Figure 300–68

Author's Commentary:

- *Use of NM cable connectors is not allowed with Type AC cable, nor are electrical metallic tubing (EMT) fittings allowed with rigid metal conduit (RMC) or intermediate metal conduit (IMC) unless both are listed for each other's use.*
- *PVC conduit couplings and connectors may be used with electrical nonmetallic tubing (ENT) when the adhesive joining the two together is in accordance with the manufacturer's instructions (see 2023 NEC 110.3(B)).*

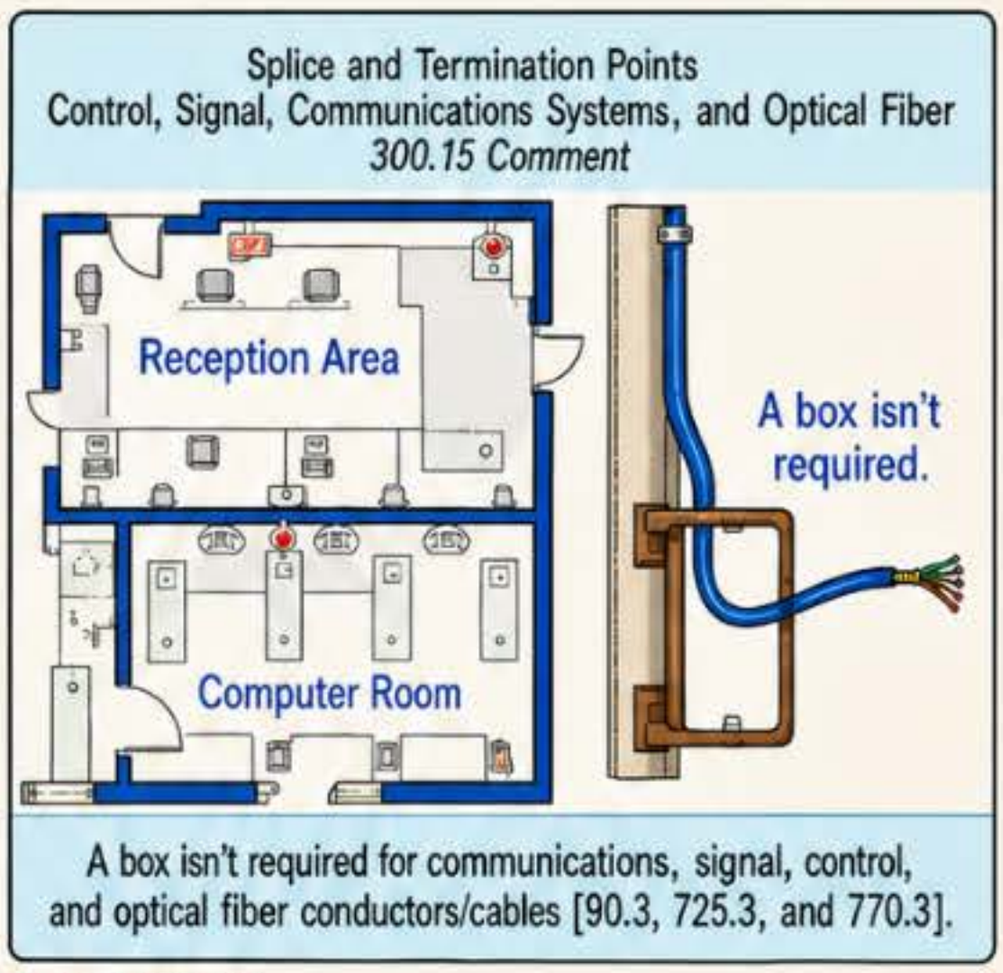
(A) Wiring Methods with Interior Access. A box is not required for installing wiring methods that provide internal access, such as wireways, multiconductor assemblies, and surface raceways.

(C) Raceways for Support or Protection. When a raceway serves to support or protect cables, a fitting to minimize abrasion potential must be installed where the cables enter the raceway. ▶ Figure 300–68

Author's Commentary:

The following signaling and communications cables or raceways do not require boxes:

- *Class 2 and 3 Control and Signaling, 725.3*
- *Communications, 90.3*
- *Coaxial Cable, 90.3*
- *Optical Fiber, 770.3*



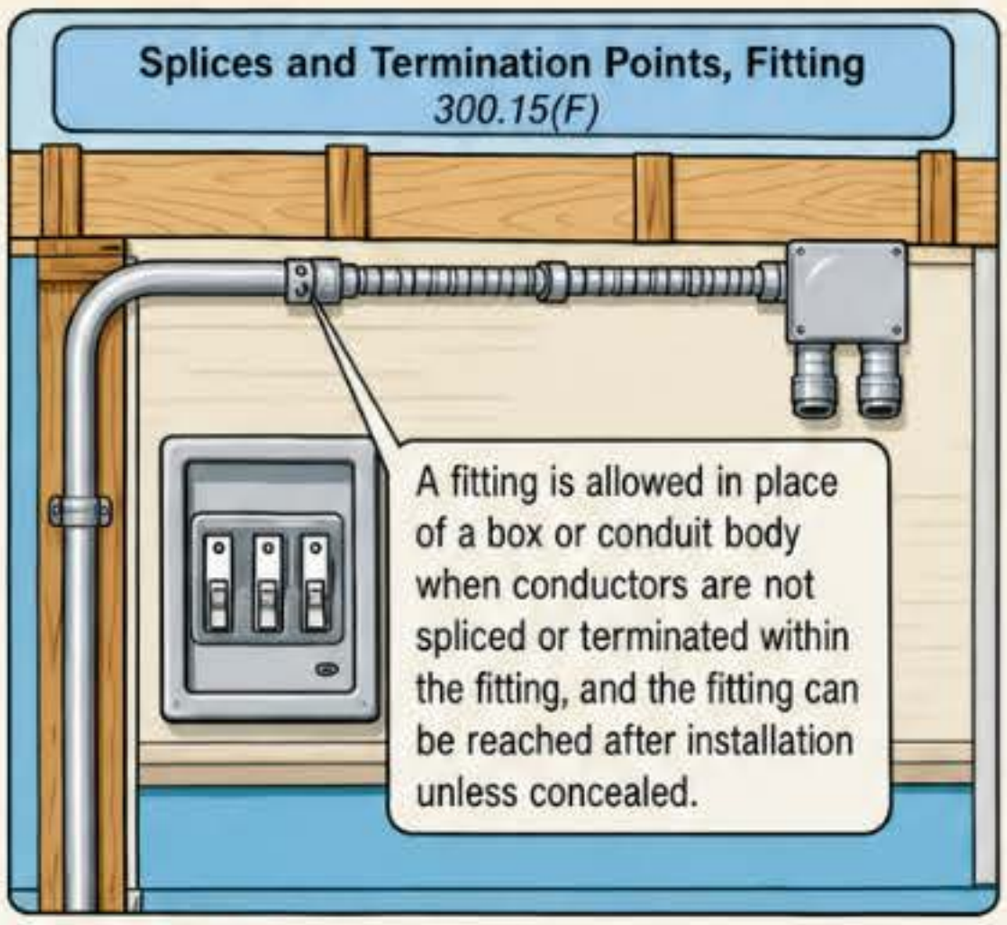
▶ Figure 300–69

(F) Fittings. A permitted fitting may be used in place of a box or conduit body where conductors are not spliced or terminated within the fitting. The fitting must be accessible after installation, unless it is listed for concealed installation. ▶ Figure 300–70

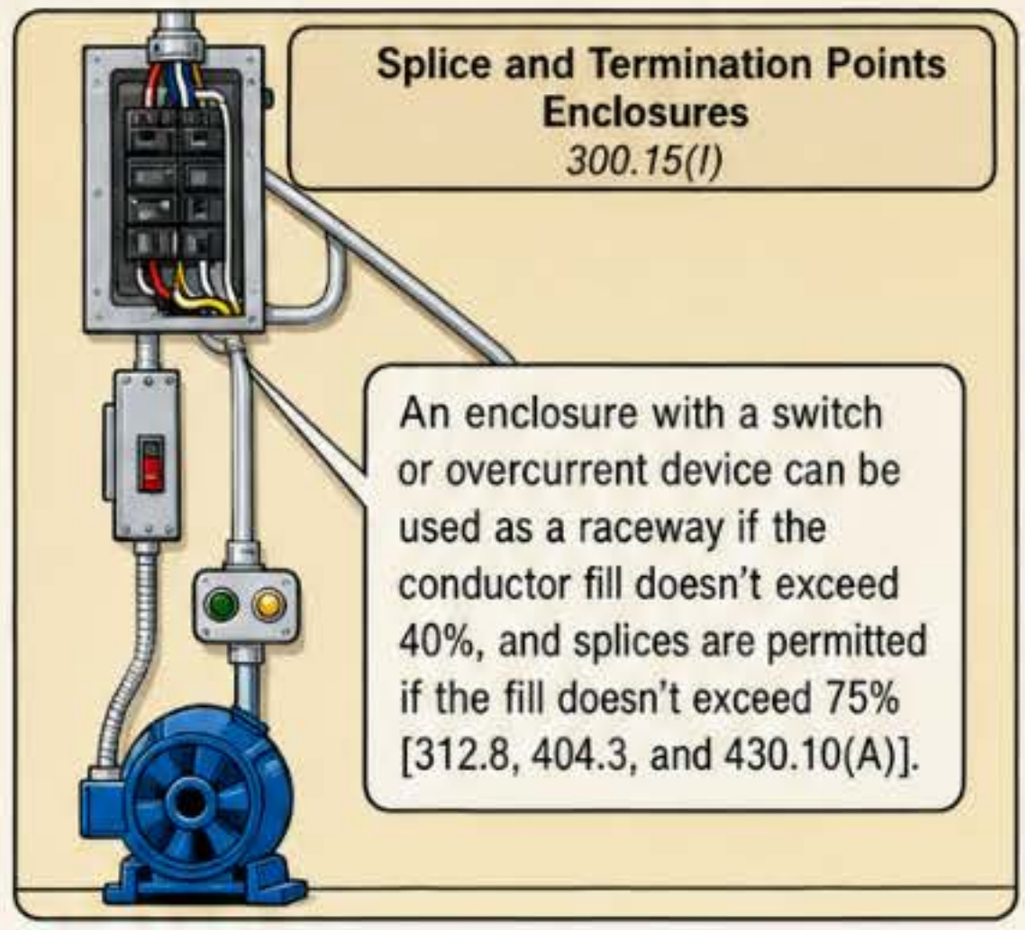
(G) Underground Splices. No box is required when a splice is made underground if the conductors are joined using a splicing device listed for direct burial. See 110.14(B) and 300.5(E).

(H) Type NM Cable Interconnector Device. *A box is not required when a listed nonmetallic-sheathed cable interconnector device is used for exposed cable wiring or concealed repair wiring in an existing building in accordance with 334.40(B).* ▶ Figure 300–71

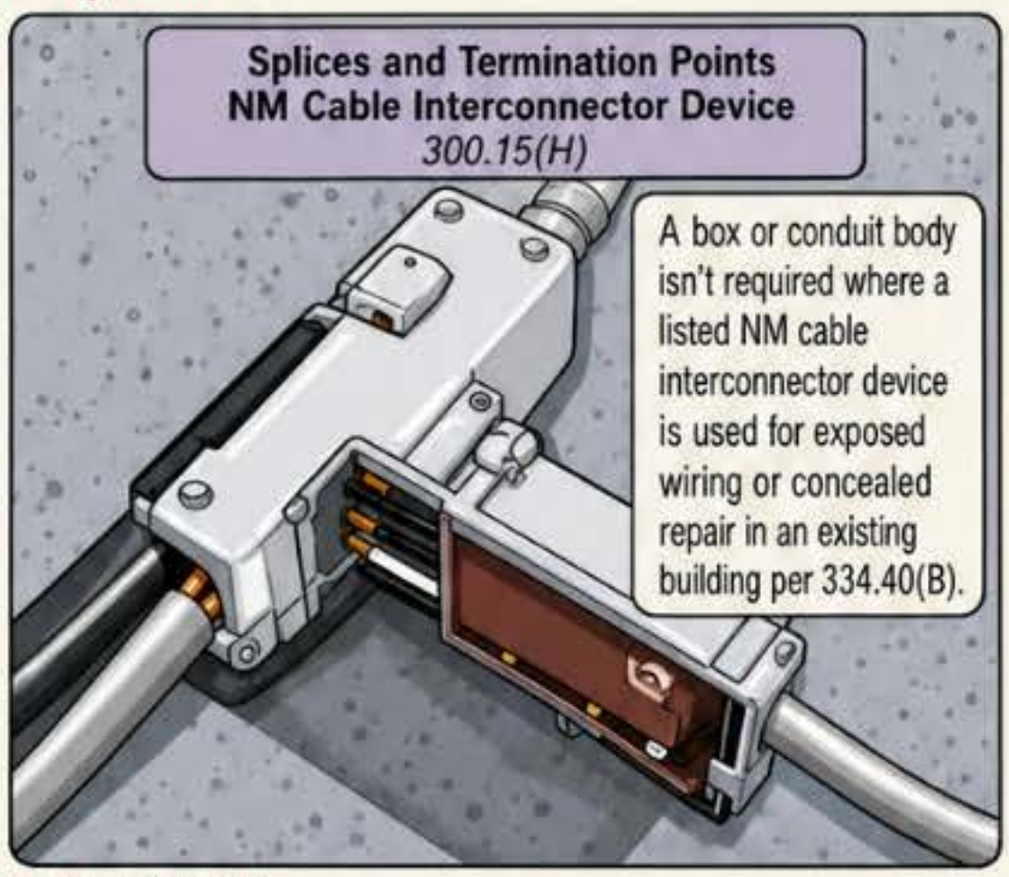
SECTION 300.17 — GENERAL REQUIREMENTS FOR WIRING METHODS AND MATERIALS (2023)



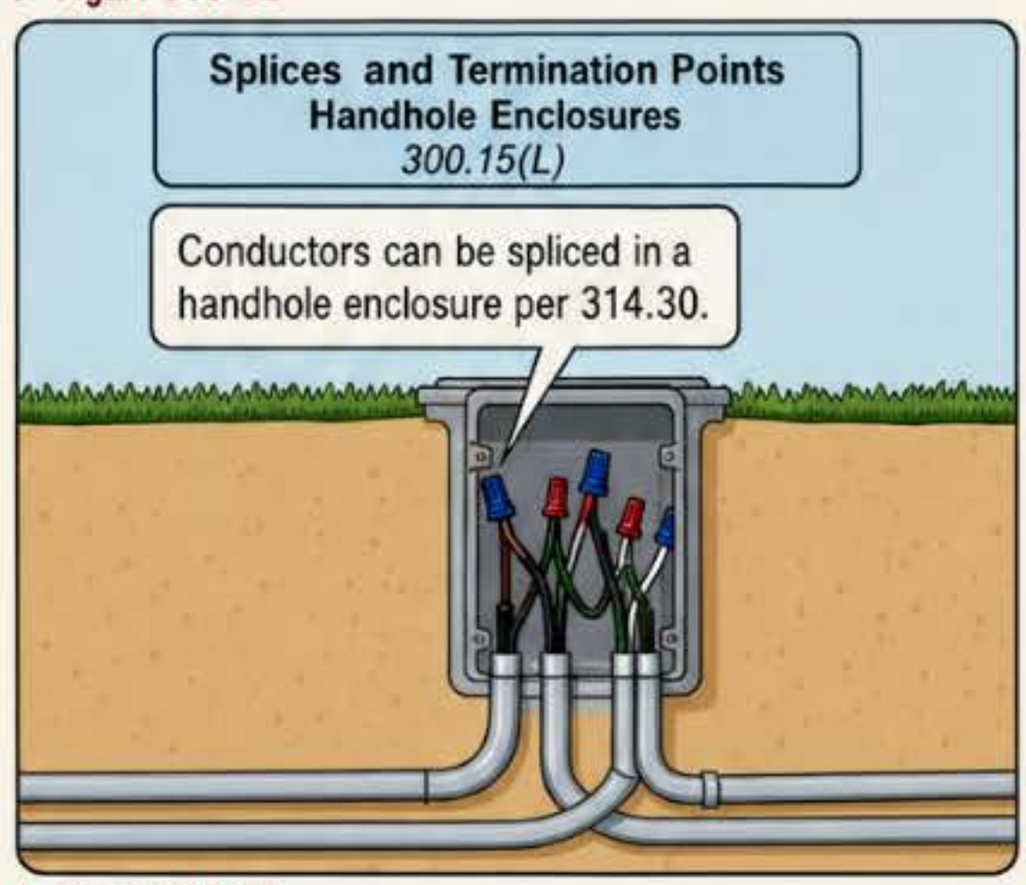
▶ Figure 300-70



▶ Figure 300-72



▶ Figure 300-71



▶ Figure 300-73

(I) Enclosures. A box or conduit body is not required where a splice is made in a cabinet containing switches or overcurrent protective devices if the splices or taps do not fill the wiring space at any cross section to more than 75 percent, and the wiring at any cross section does not exceed 40 percent. See 312.8 and 404.3(B). ▶ Figure 300-72

(L) Handhole Enclosures. A box is not required for conductors installed in a handhole enclosure installed in accordance with 314.30. ▶ Figure 300-73

> ***Author's Commentary:***
> *A handhole enclosure is used for underground wiring and is designed to permit entry by people, but not to serve as an enclosure [Article 100].*
>
> ***— Michael Hamilton***

▶ Equipment used for splices or terminations in a handhole enclosure must be listed for wet locations [110.14(B) and 314.30(C)].

300.17 Number and Size of Conductors in a Raceway

Raceways must be large enough to permit the installation and removal of conductors without damaging the conductors' insulation.

Note: See the "xxx.22" section of the specific wiring method for more information about the number of conductors permitted.

Author's Commentary:

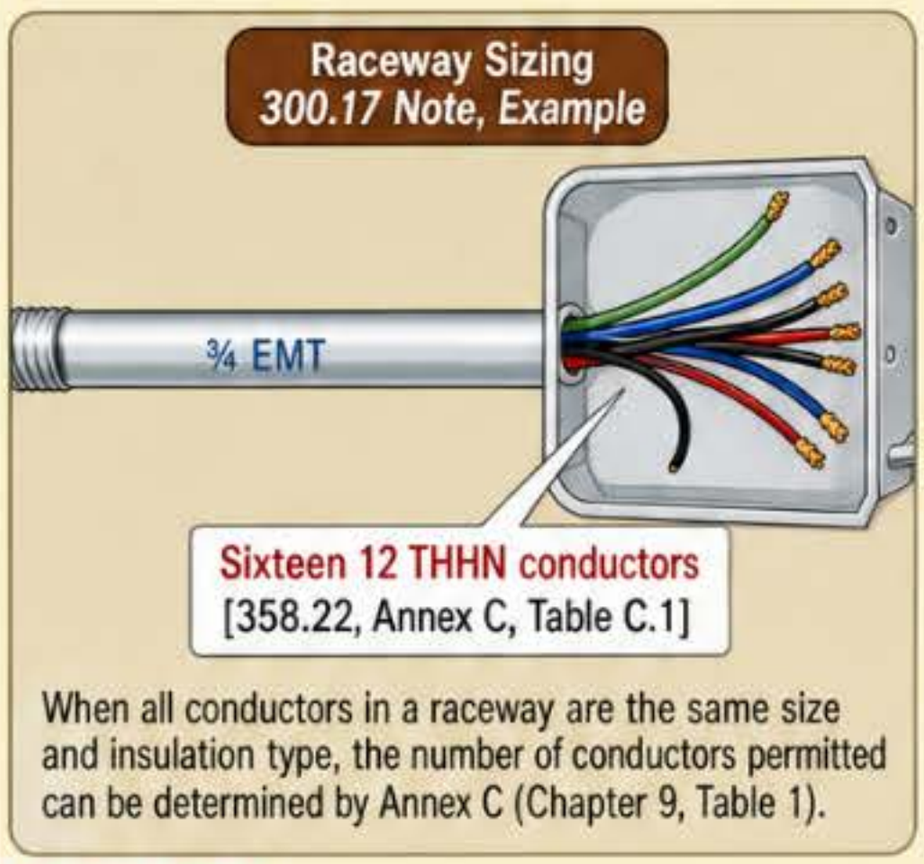
If the conductors inside a raceway all have the *same cross-sectional size and use the same type of insulation, the allowed number of conductors, or the raceway size, can be determined from Annex C.*

▶ Example

Question: *How many 12 THHN conductors are permitted in trade size ¾ electrical metallic tubing (EMT)?*

▶ Figure 300–74

(a) 10 (b) 12 (c) 14 (d) 16



When all conductors in a raceway are the same size and insulation type, the number of conductors permitted can be determined by Annex C (Chapter 9, Table 1).

▶ Figure 300–74

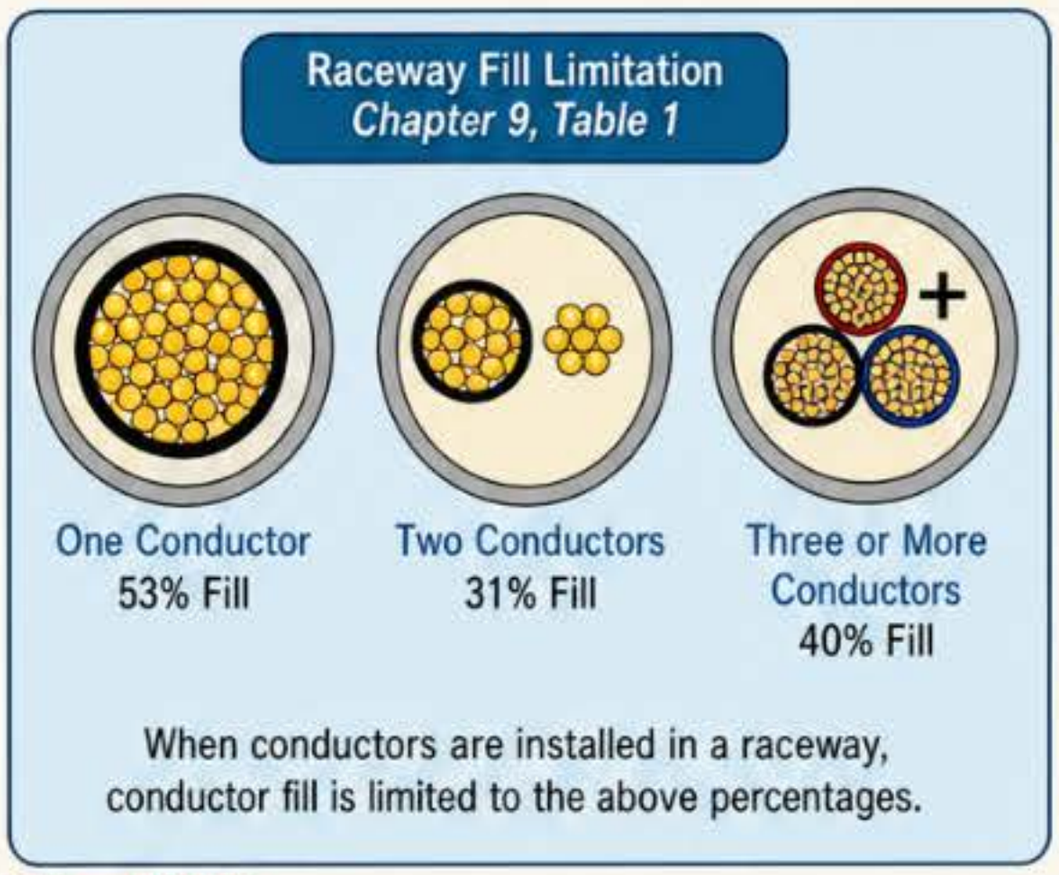
Answer: *(d) 16 [Annex C, Table C.1]*

Author's Commentary:

When more than one conductor size is placed in a raceway, refer to the percentage fill limits in Table 1 and Note (6) of Chapter 9. ▶ Figure 300–75

Chapter 9, Table 1	
Number	**Percent Fill**
1 Conductor	53%
2 Conductors	31%
3 or More	40%

These percentages apply when the length of each conductor and the number of bends in the raceway fall within reasonable limits *[Chapter 9, Table 1, Table Note 1].*

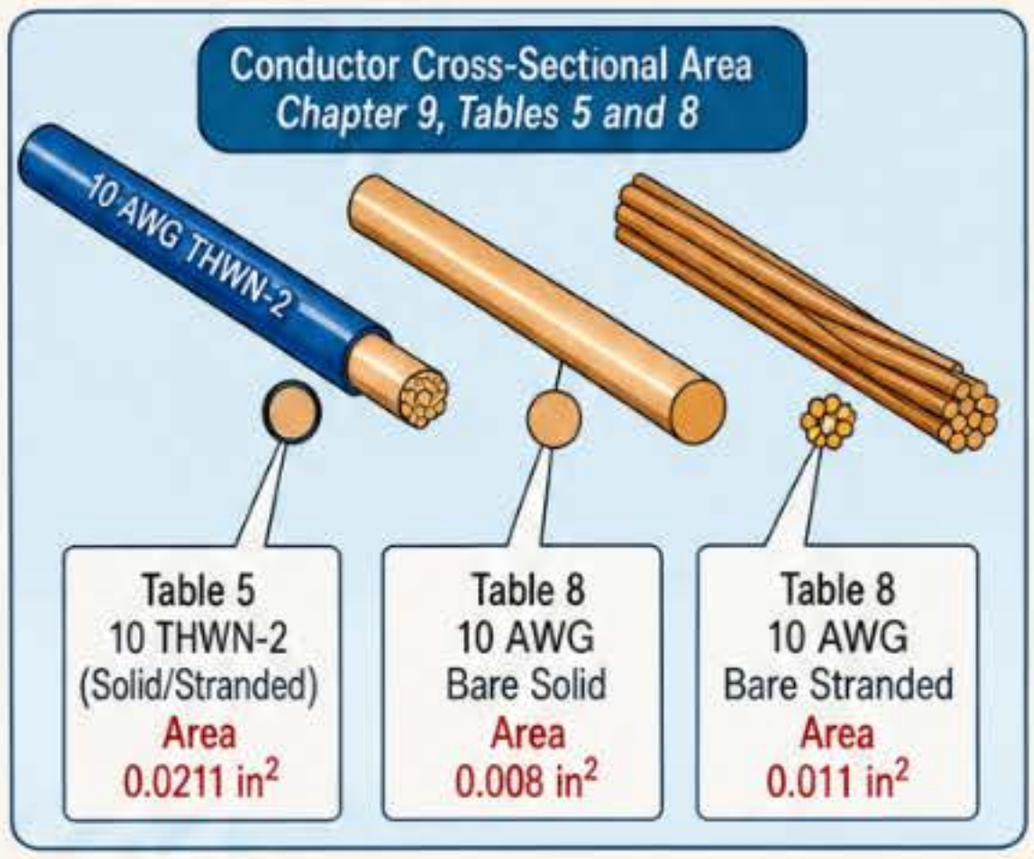


▶ Figure 300–75

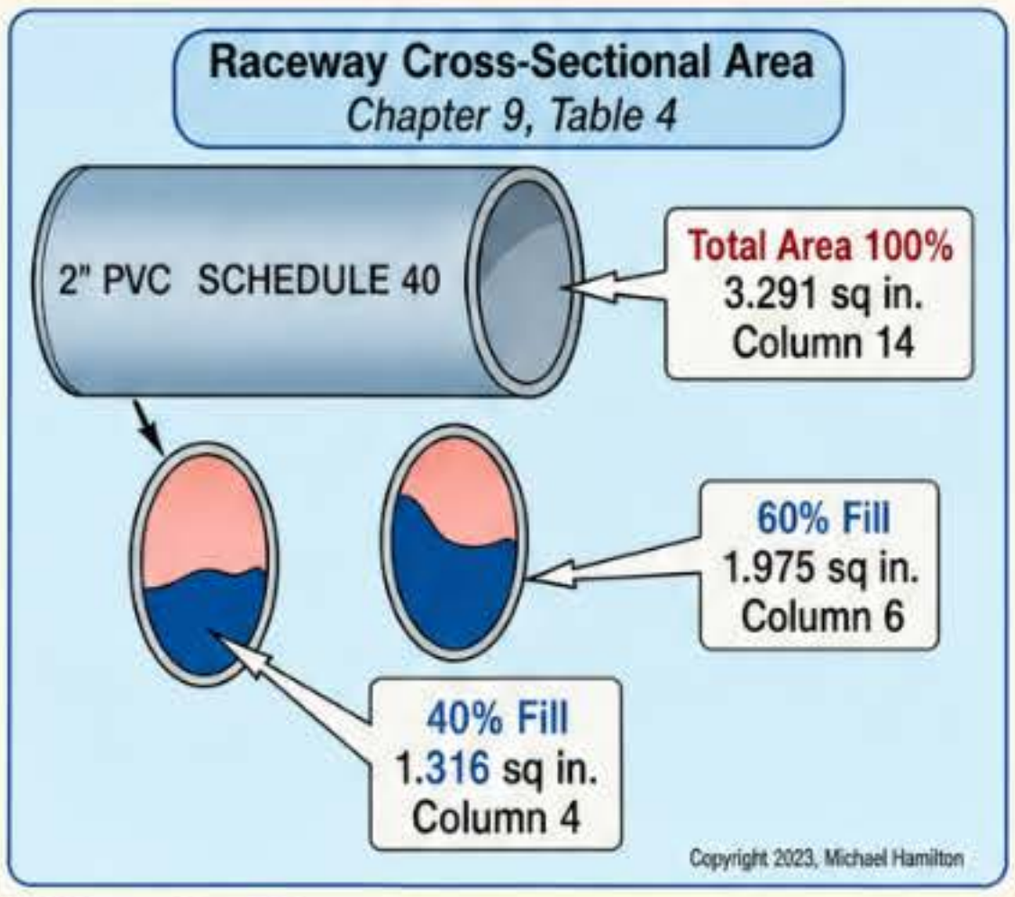
Author's Commentary:

Follow these steps for sizing raceways:

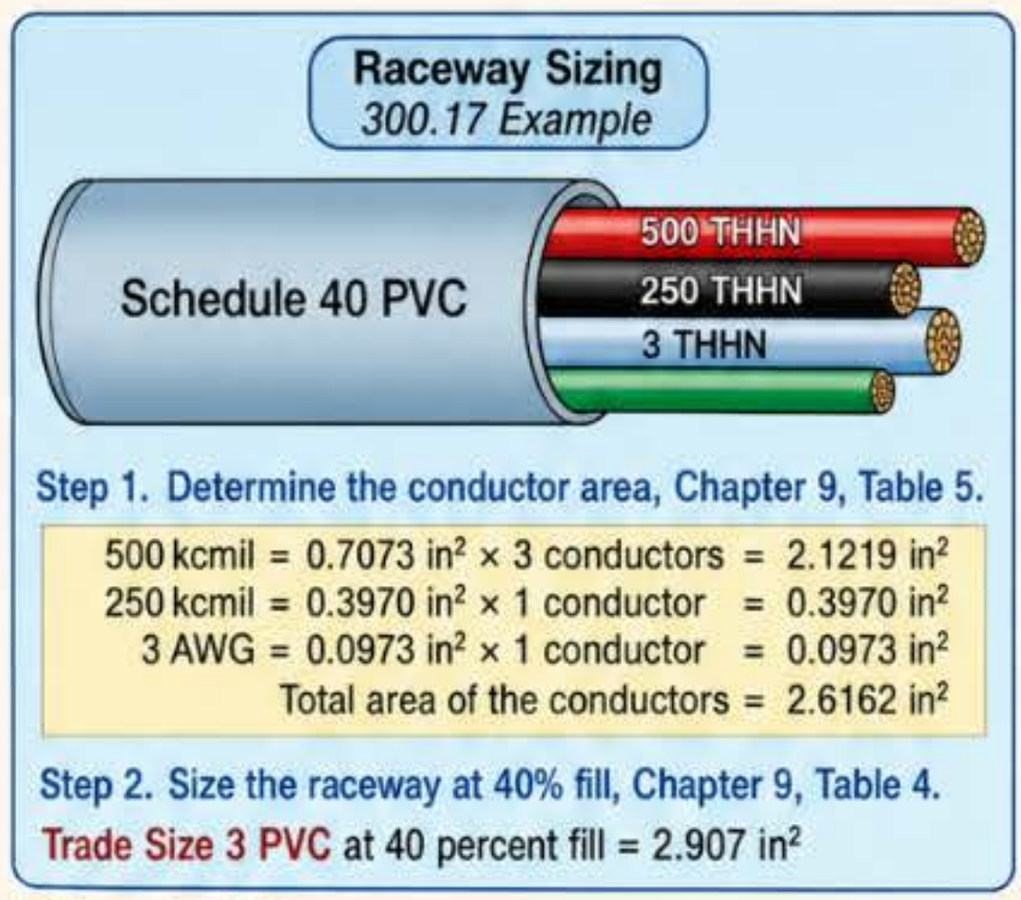
- **Step 1:** When planning a raceway, first calculate the total area needed for the conductors (Chapter 9, Table 5 for insulated conductors and Chapter 9, Table 8 for bare conductors). ▶ Figure 300–76
- **Step 2:** Select the raceway from Chapter 9, Table 4 that corresponds with the percent fill listed in Chapter 9, Table 1. ▶ Figure 300–77



▶ Figure 300–76



▶ Figure 300–77



▶ Figure 300–78

▶ Example

Question: *Which size Schedule 40 PVC conduit is needed for the following conductors?* ▶ Figure 300–78

- *3–500 THHN*
- *1–250 THHN*
- *1–3 THHN*

(a) Trade Size 1 *(b) Trade Size 2*
(c) Trade Size 3 *(d) Trade Size 4*

Solution:

Step 1: *Calculate the total area required for the conductors (Chapter 9, Table 5).*

500 THHN	*0.7073 × 3 =*	*2.1219 in²*
250 THHN	*0.3970 × 1 =*	*0.3970 in²*
3 THHN	*0.0973 × 1 =*	*+ 0.0973 in²*
Total Area =		*2.6162 in²*

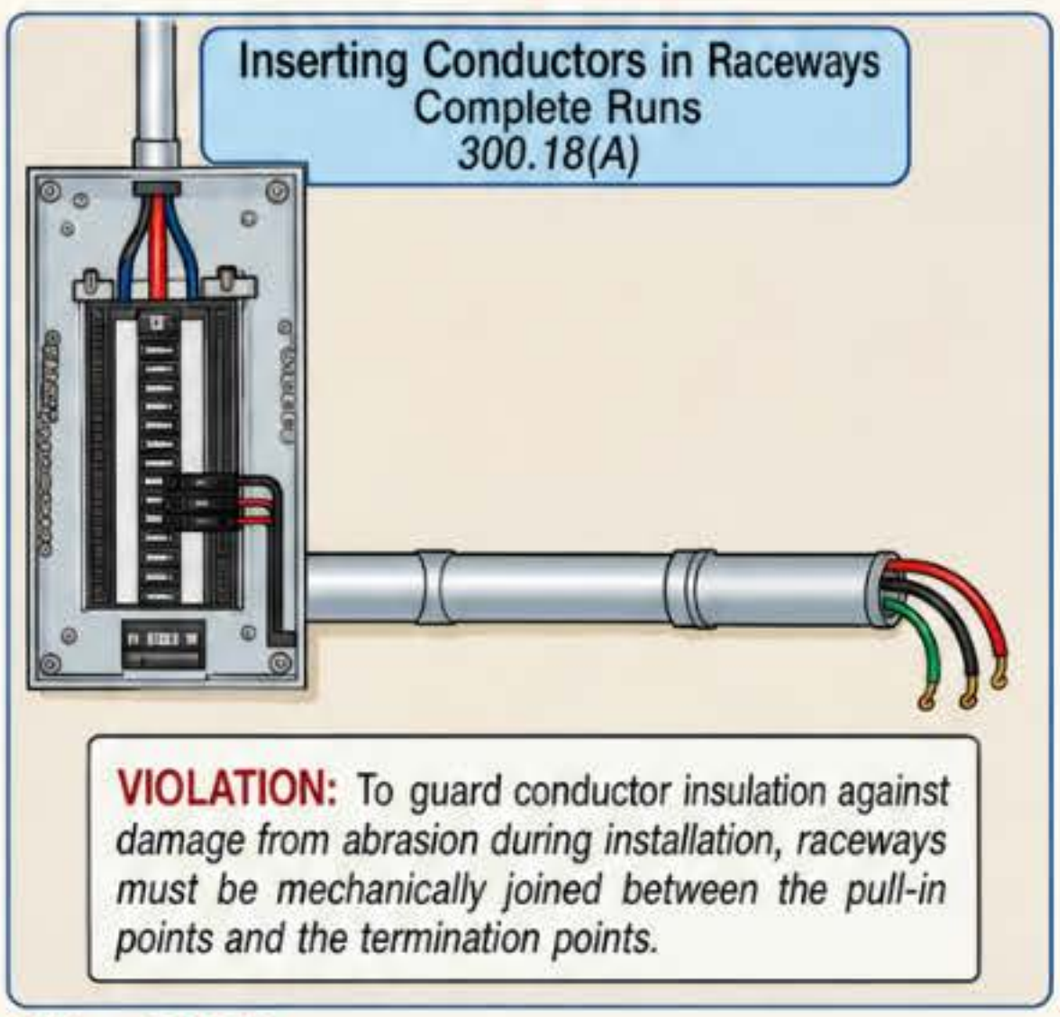
Step 2: *From Chapter 9, Table 4, pick a raceway that allows 40 percent fill.*

Using Trade Size 3 Schedule 40 PVC gives 2.907 sq in. of conductor space at 40 percent fill.

Answer: *(c) Trade Size 3*

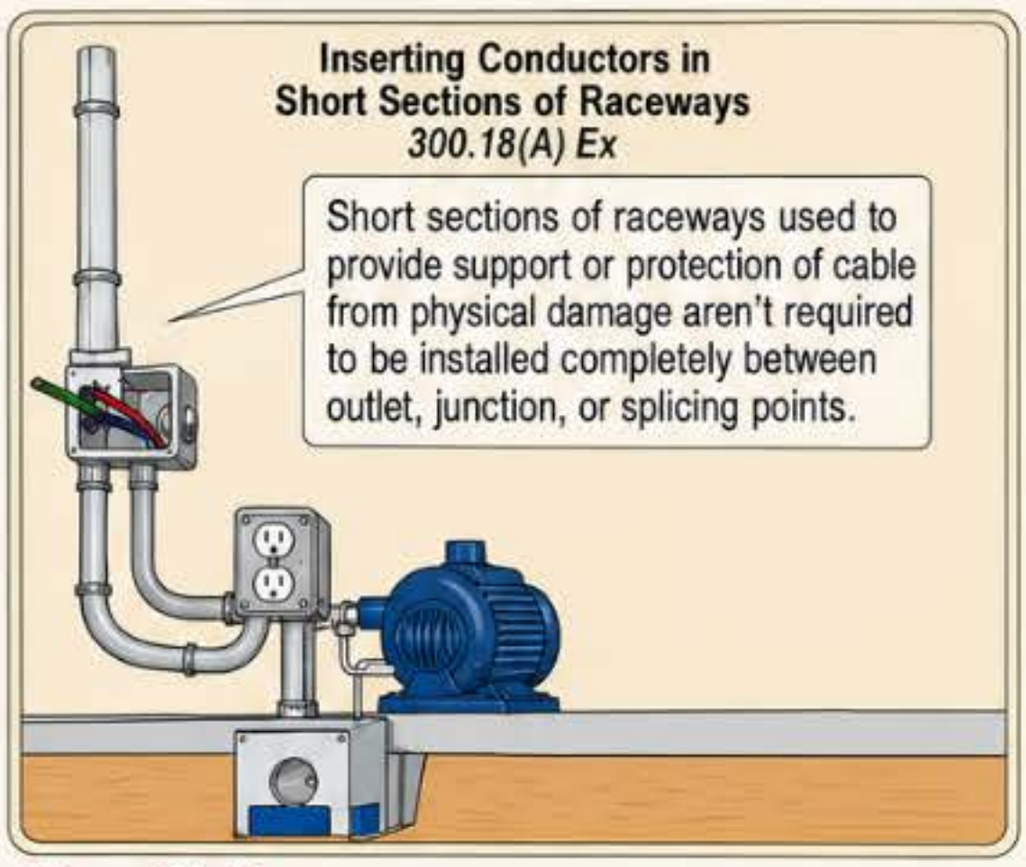
300.18 Inserting Conductors in Raceways

(A) Complete Runs. To shield conductor insulation from abrasion while installing, raceways must be mechanically assembled between the points where the conductors are pulled in and where they will be terminated. See 300.10 and 300.12. ▶ Figure 300–79



▶ Figure 300–79

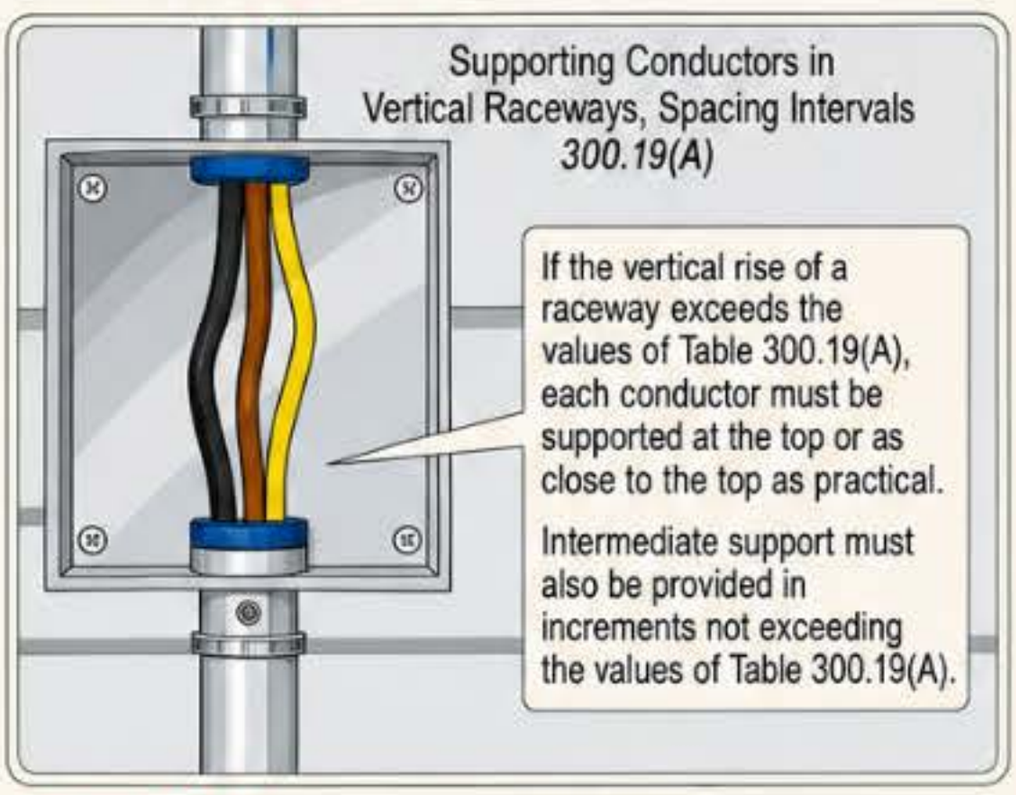
Ex: Short sections of raceways used for the protection of cables from physical damage are not required to be complete. ▶ Figure 300–80



▸ Figure 300–80

300.19 Supporting Conductors in Vertical Raceways

(A) Spacing Intervals. If the vertical rise of a raceway exceeds the values of Table 300.19(A), each conductor must be supported at the top or as close to the top as practical. Intermediate support must also be provided in increments not exceeding the values of Table 300.19(A). ▸ Figure 300–81



▸ Figure 300–81

Author's Commentary:

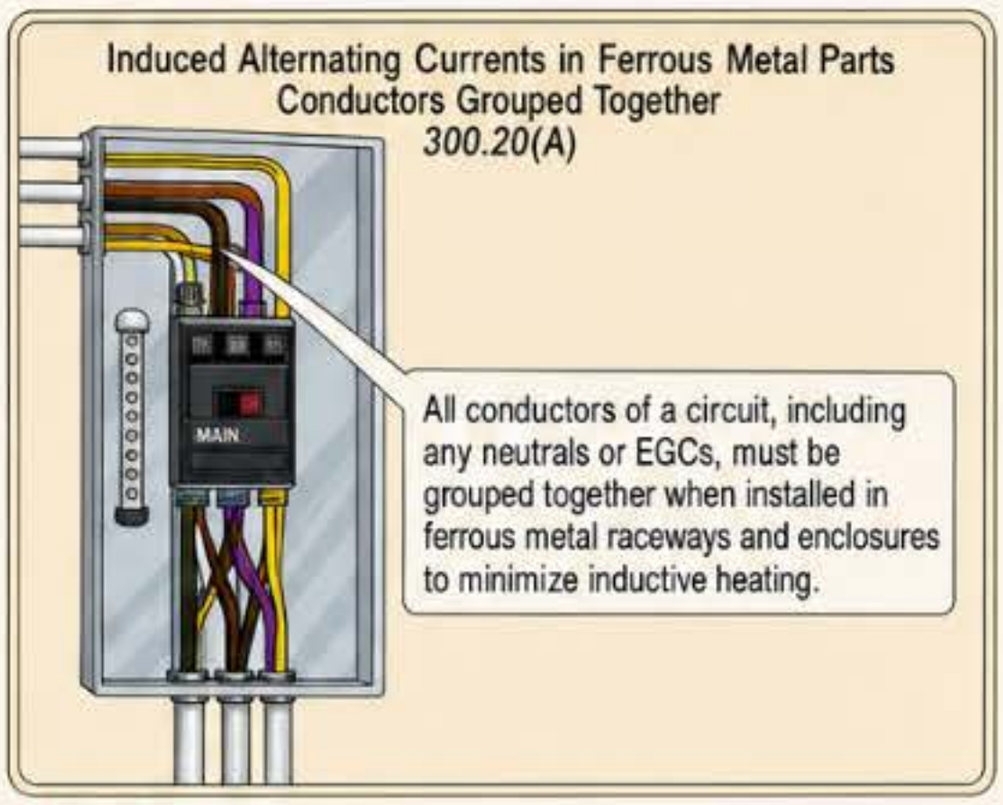
A great deal of weight accumulates in long vertical runs of conductors and can cause them to drop out of the raceway (sometimes called a "runaway") if they are not properly secured. There have been many cases where conductors in a vertical raceway were released from the pulling "basket" or "grip" at the top without being secured. Sheer weight and gravity take over, accelerating the conductors down and out of the raceway and injuring those at the bottom of the installation.

— Michael Hamilton

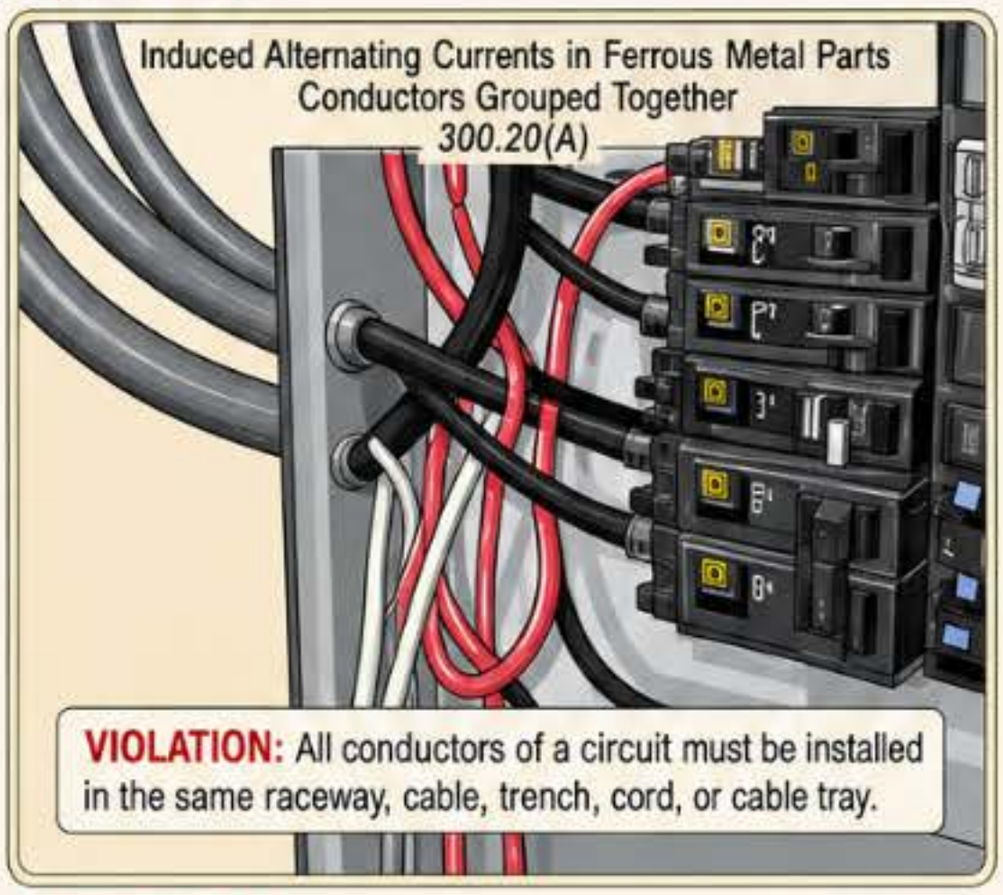
raceway were released from the pulling "basket" or "grip" (at the top) without being secured. Sheer weight and gravity take over, accelerating the conductors down and out of the raceway and injuring those at the bottom of the installation.

300.20 Induced Alternating Currents in Ferrous Metal Parts

(A) Conductors Grouped Together. To minimize the induction heating of ferrous metal raceways and enclosures, and to maintain an effective ground-fault current path, all conductors of a circuit (including any neutral and equipment grounding conductors) must be installed in the same raceway, cable, trench, cord, or cable tray. See 250.102(E), 300.3(B), 300.5(I), and 392.20(C). ▸ Figure 300–82 ▸ Figure 300–83



▸ Figure 300–82



▸ Figure 300–83

General Requirements for Wiring Methods and Materials 300.20 2023

Author's Commentary:

When the current in a conductor is made to alternate by means of a changing magnetic field, that field is produced around the conductor. The strength of this field grows and shrinks in step with the alternating current. In the U.S., utility power switches polarity 60 times each second (60 Hz). Consequently, the surrounding field flips polarity 120 times a second and also reverses direction 120 times a second. The enlargement and contraction of this magnetic field nudges the free electrons in nearby ferrous metals, causing them to vibrate and release heat. This effect is known as hysteresis heating.

— Michael Hamilton

- Magnetic substances oppose swift changes in magnetic fields. As the field alternates, tiny regions (hysteresis loops) appear and vanish within the material. This resistance to change produces eddy currents—circuits formed within the metal—which generate heat. Metals with high magnetic permeability can have their hysteresis losses anywhere from 100 to 500 times higher than materials that are nonmagnetic.
- Molecules of steel and iron line up with the magnetic field. When the field flips, these molecules must realign to the opposite direction, which takes energy and creates heat. The greater the current, the stronger the magnetic field, and the more heat is produced in ferrous metal parts.

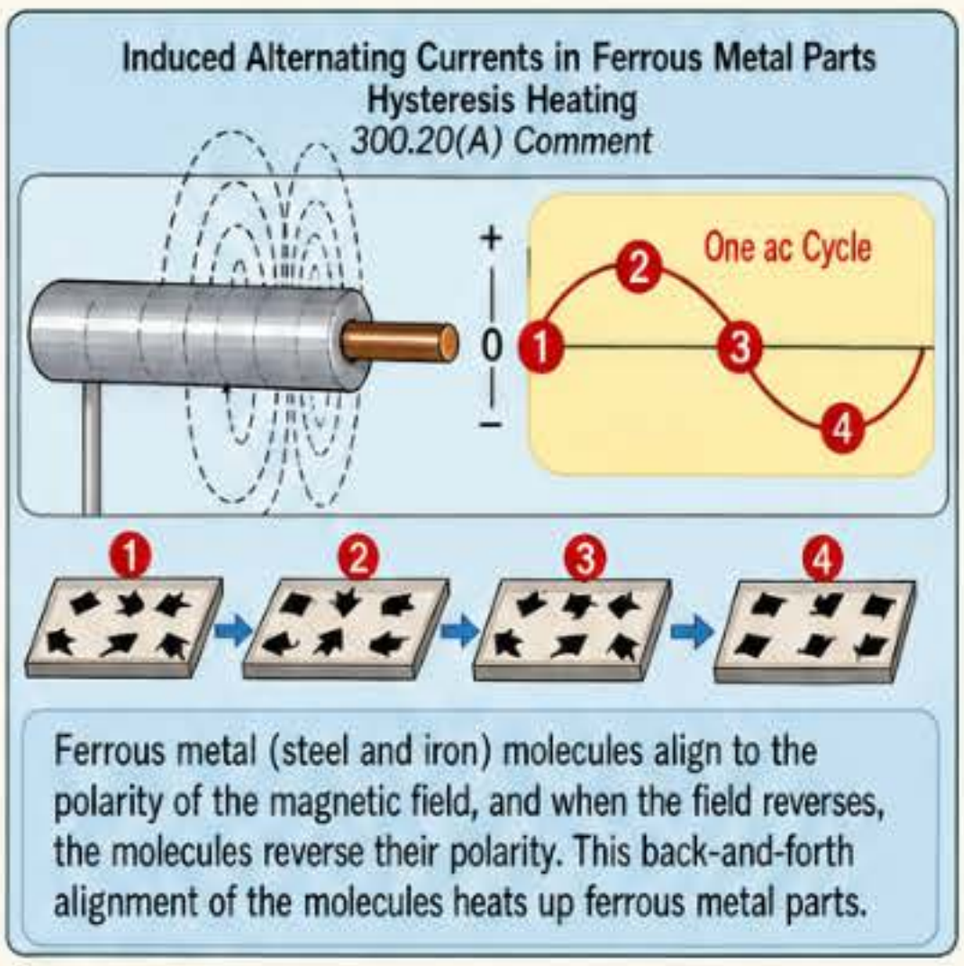


Figure 300–84

Author's Commentary:

When conductors on the same circuit are bundled, the magnetic fields from different conductors oppose one another. This opposition creates a reduced magnetic field around the group. The smaller field produces less current induction in nearby ferrous components or enclosures, which in turn lowers hysteresis heating of the surrounding metal enclosure.

— Michael Hamilton

(B) Single Conductors. If a conductor that carries alternating current passes through metal that has magnetic characteristics, the heating caused by inductive effects must be minimized by either putting slots in the metal between each individual hole through which the conductors pass or by installing insulation barriers in the circuit locations. These barriers must extend far enough to separate all of the conductors.

Author's Commentary:

When a lone conductor is installed in nonmetallic raceways as allowed by 300.5(I) Ex 2, the inductive heating of the metal box can be decreased by using aluminum locknuts and by cutting slots between the individual wire openings.

— Michael Hamilton

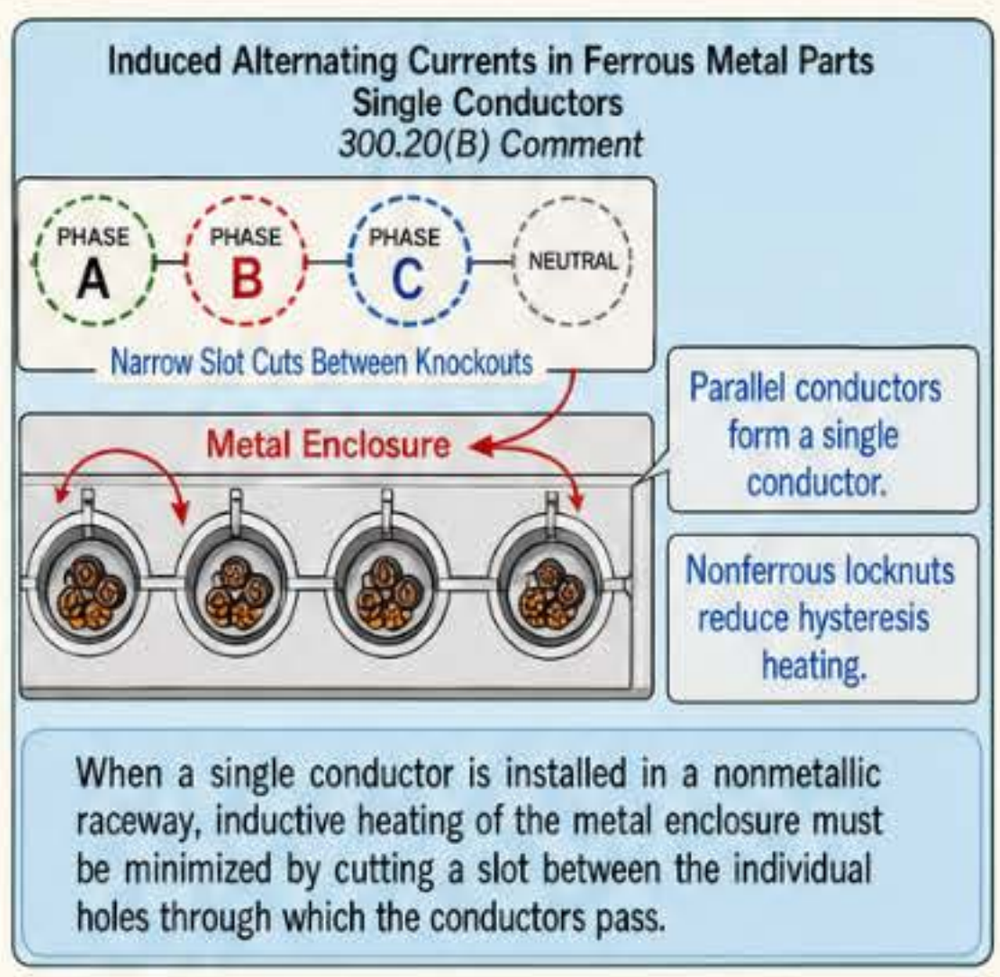


Figure 300–85

Note: Because aluminum is a nonmagnetic metal, aluminum parts do not heat up due to hysteresis heating.

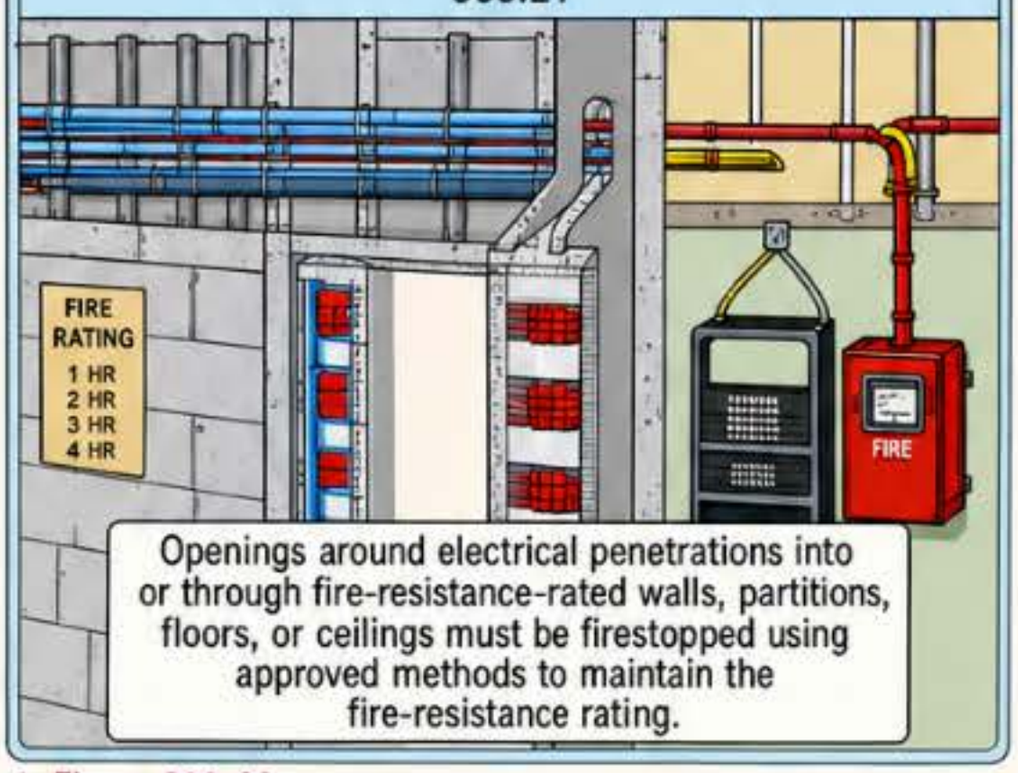
300.21 Spread of Fire or Products of Combustion

Scan this QR code for a video by Michael Hamilton that explains this topic. It is supplemented by videos that accompany this textbook.

Electrical equipment and its wiring must be installed in a manner that limits the spread of fire or the release of combustion by-products. Openings around penetrations in, or through, fire-resistance-rated assemblies—such as walls, partitions, floors, and ceilings—are required to be firestopped using approved materials so the assembly's fire-resistance rating is maintained.

▸ Figure 300-86

Spread of Fire or Products of Combustion
300.21



Openings around electrical penetrations into or through fire-resistance-rated walls, partitions, floors, or ceilings must be firestopped using approved methods to maintain the fire-resistance rating.

▸ Figure 300-86

Author's Commentary:

Fire-stopping materials are listed for the specific types of wiring methods and the construction of the assembly they penetrate.

— Michael Hamilton

Note: Directory listings for electrical construction materials published by recognized testing laboratories include installation limitations necessary to maintain the fire-resistance rating of the assembly. The building code also imposes restrictions on penetrations in opposite sides of a fire-resistance-rated wall. Outlet boxes must be separated horizontally by at least 24 in. when installed in a fire-rated assembly, unless an outlet box is listed for closer spacing or protected by fire-resistant "putty pads," in accordance with the manufacturer's instructions.

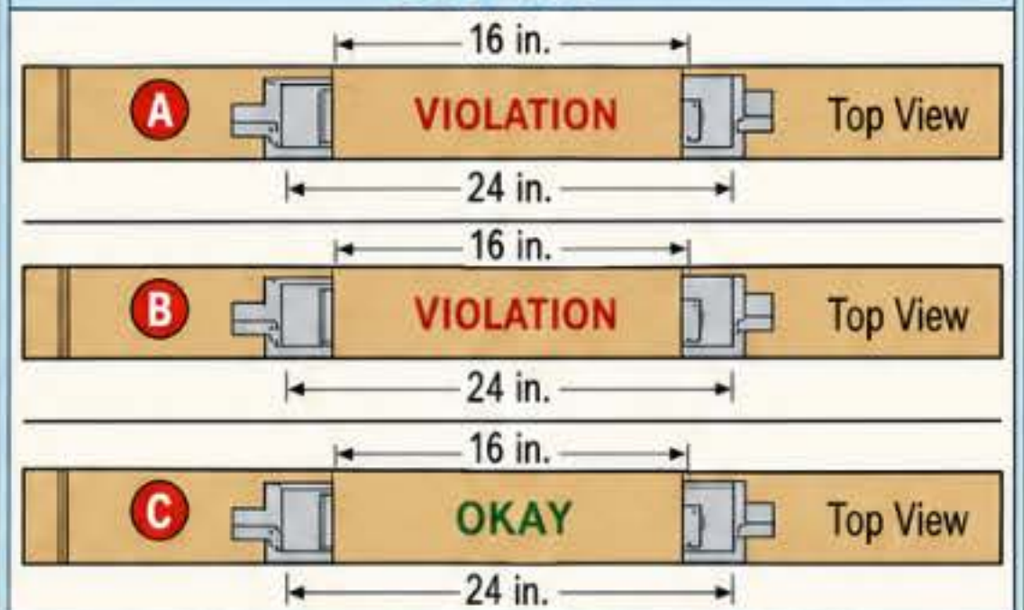
▸ Figure 300-88 and ▸ Figure 300-89

Spread of Fire or Products of Combustion
Examples of Approved Firestopping Methods.
300.21 Comment

Firestopping materials are selected to match the types of wiring methods and the construction details of the assembly they penetrate.

▸ Figure 300-87

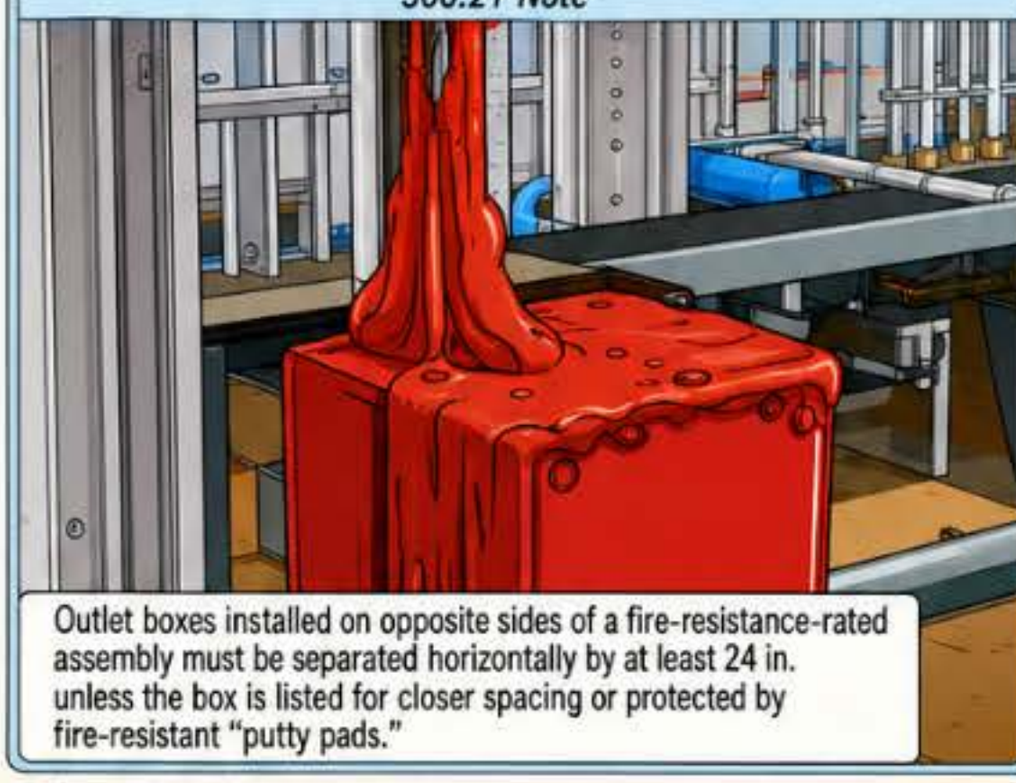
Spread of Fire or Products of Combustion
300.21 Note



Three examples (shown from above) of outlet boxes mounted on opposite sides of a fire-rated assembly:
Maintain a minimum horizontal separation of 24 in. unless outlet boxes are listed to be closer or protected with fire-resistant "putty pads."

▸ Figure 300-88

Spread of Fire or Products of Combustion
300.21 Note



Outlet boxes installed on opposite sides of a fire-resistance-rated assembly must be separated horizontally by at least 24 in. unless the box is listed for closer spacing or protected by fire-resistant "putty pads."

▸ Figure 300-89

General Requirements for Wiring Methods and Materials 300.22

Author's Commentary:

- Fire-resistance rated assemblies must be identified on the plans. If steel boxes are used, they must also be securely fastened to the framing. *White Book, Guide Information for Electrical Equipment, Type Boxes* are not allowed in those assemblies.
- This requirement also governs the control, signaling, and communication cables installed in raceways.

- *Communications and Coaxial Cable, 800.26*
- *Control and Signaling, 725.3(B)*
- *Fire Alarms, 760.3(A)*
- *Optical Fiber, 770.26*
- *Sound Systems, 640.3(A)*

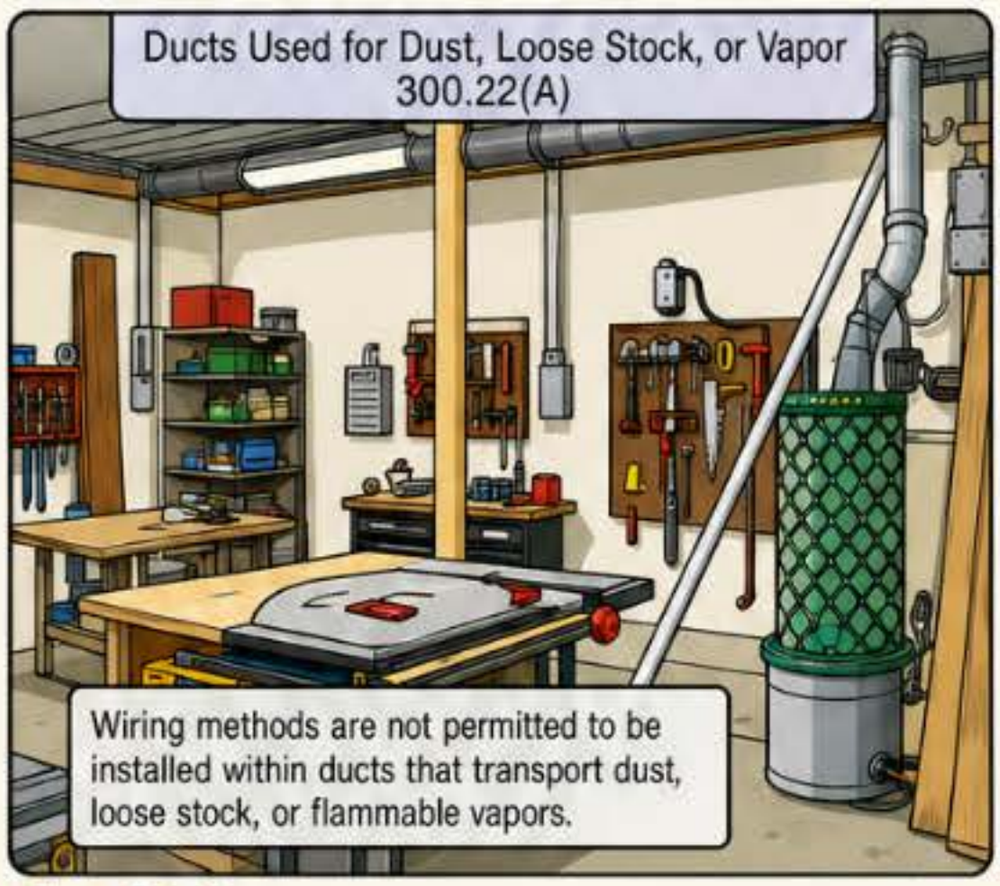
— Michael Hamilton

300.22 Wiring in Ducts and Plenum Spaces

Scan this QR code for a video from Michael Hamilton that explains this topic, or visit his website's library and view the video in the *300 – Wiring Methods and Materials* section.

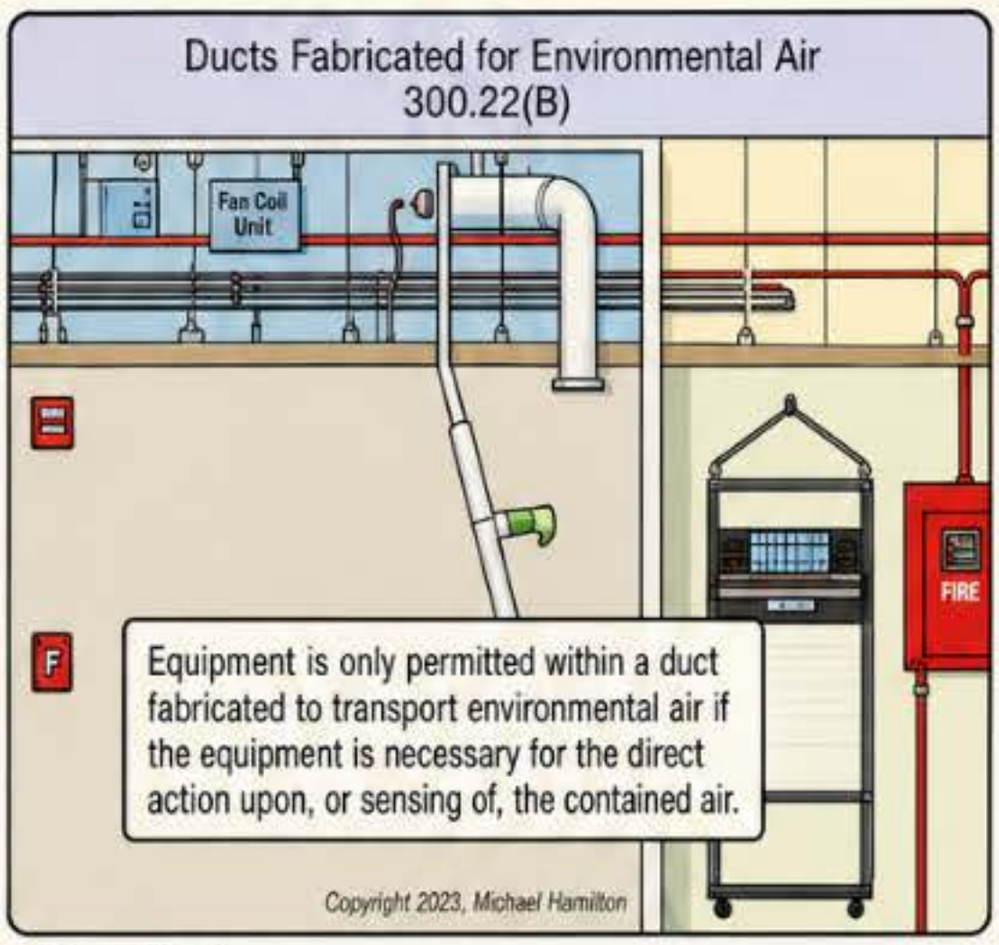
This section covers the installation and use of electrical wiring and equipment inside ducts used for dust, loose stock, or vapor removal; ducts specifically built for environmental air; and plenum spaces used in environmental air.

(A) Ducts Used for Dust, Loose Stock, or Vapor. Installing wiring methods in ducts that transport dust, loose stock, or flammable vapors is not allowed. ▸Figure 300–90



▸Figure 300–90

(B) Ducts Fabricated for Environmental Air. Equipment is only permitted within a duct fabricated to transport environmental air if if the equipment is necessary for the direct action upon, or sensing of, the contained air. ▸Figure 300–91



▸Figure 300–91

Type MC Cable without an overall nonmetallic covering and metal raceways can be installed in ducts fabricated to transport environmental air. Flexible metal conduit in lengths not exceeding 4 ft can be used to connect physically adjustable equipment and devices within the fabricated duct.

(C) Plenum Spaces for Environmental Air. This section applies only to the space above a suspended ceiling or below a raised floor used for environmental air. It does not apply to habitable rooms or areas of buildings, the prime purpose of which is not air handling.

Note 1: *The spaces or cavities above a suspended ceiling and below a raised floor used for environmental air are examples of the type of plenum space to which this section applies.* ▸Figure 300–92

(1) Wiring Methods. *Metal raceways, Type AC cable, and Type MC cable without a nonmetallic cover, electrical metallic tubing, intermediate metal conduit, rigid metal conduit, flexible metal conduit, or accessible surface metal raceways or metal wireways with metal covers.* ▸Figure 300–93

Cable ties for securing and supporting must be listed for use in a plenum space. ▸Figure 300–94

300.22 | General Requirements for Wiring Methods and Materials

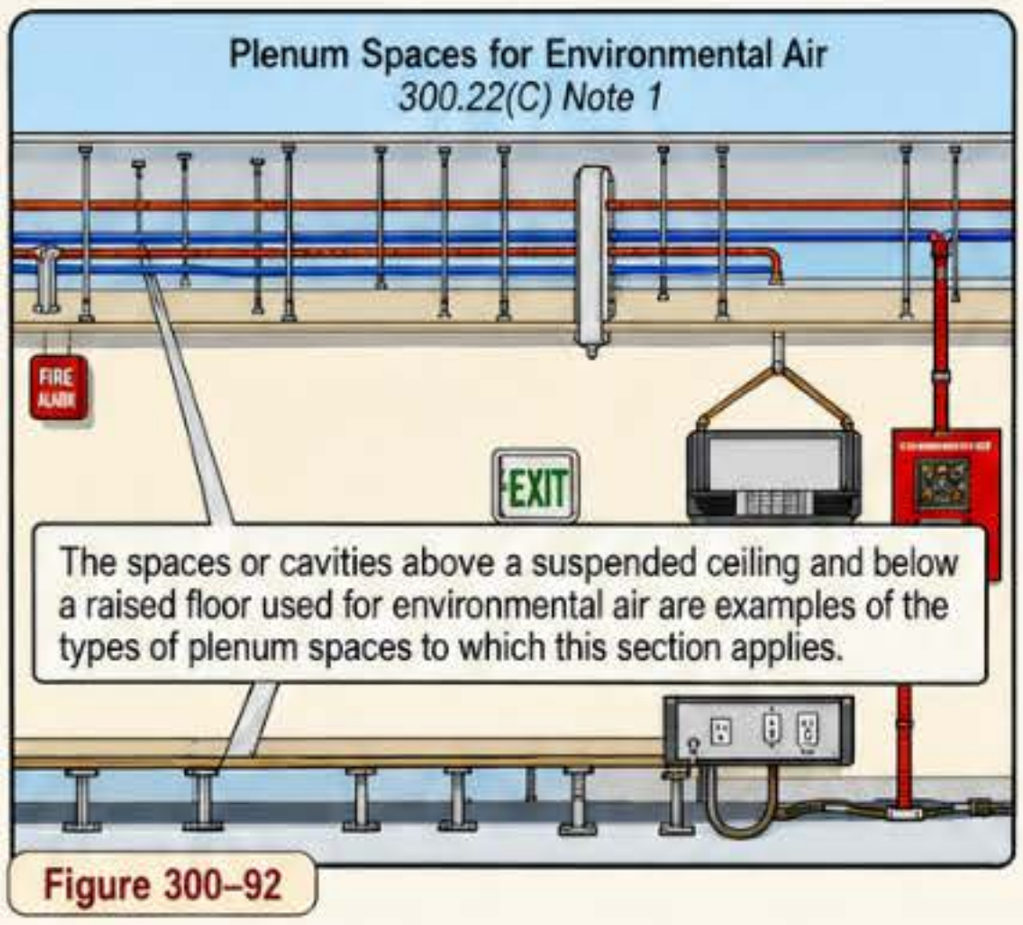


Figure 300–92

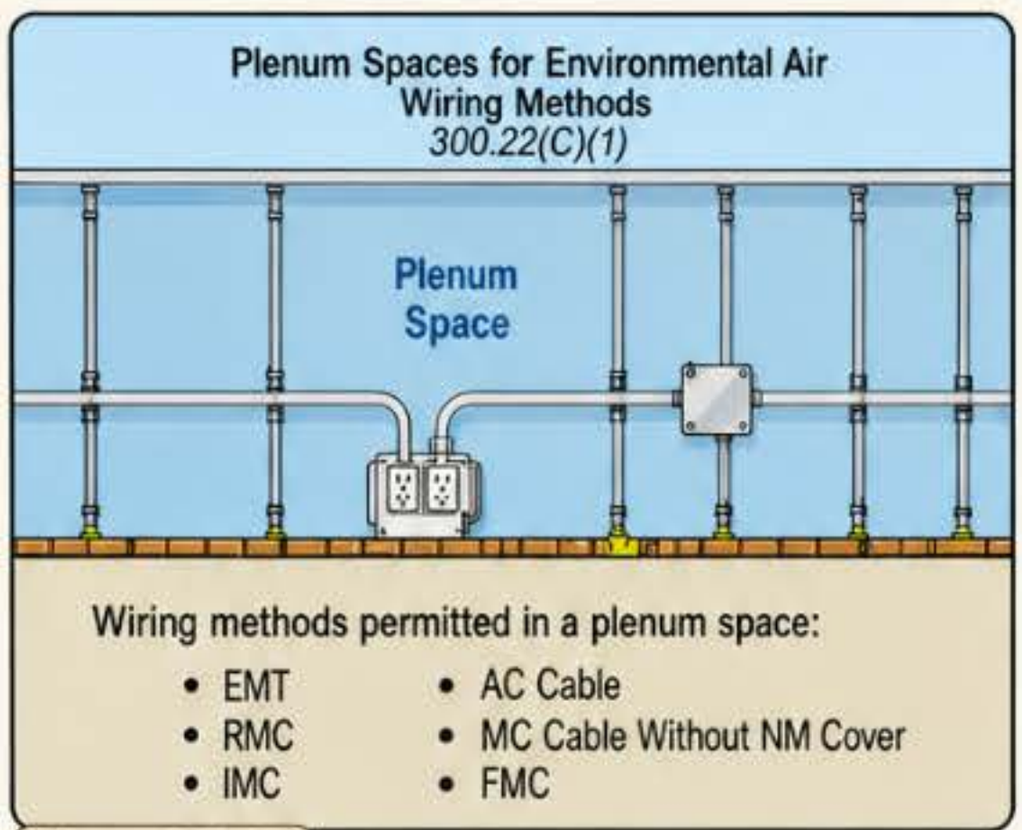


Figure 300–93

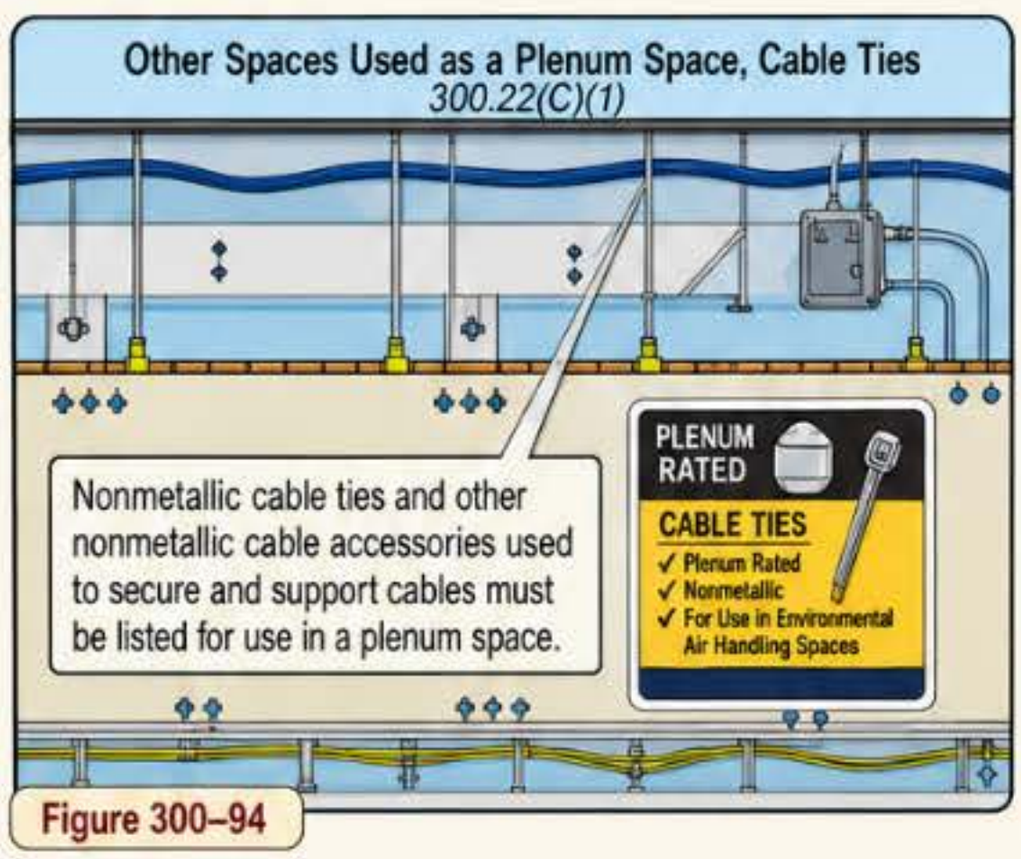


Figure 300–94

Author's Commentary:

Cables used for automated control, signaling, and communication systems, along with raceways for these cables, are allowed in plenum spaces provided they comply with the following rules:

- Communications Cable and Coaxial Cable, 800.3(C) and Table 800.154(a)
- Control and Signaling, 725.3(C) Ex 2 and Table 725.154
- Fire Alarms, 760.3(B) Ex 2 and Table 760.154
- Optical Fiber Cables and Raceways, Table 770.154(a)
- Sound Systems, 640.9(C) and Table 725.154

— Michael Hamilton

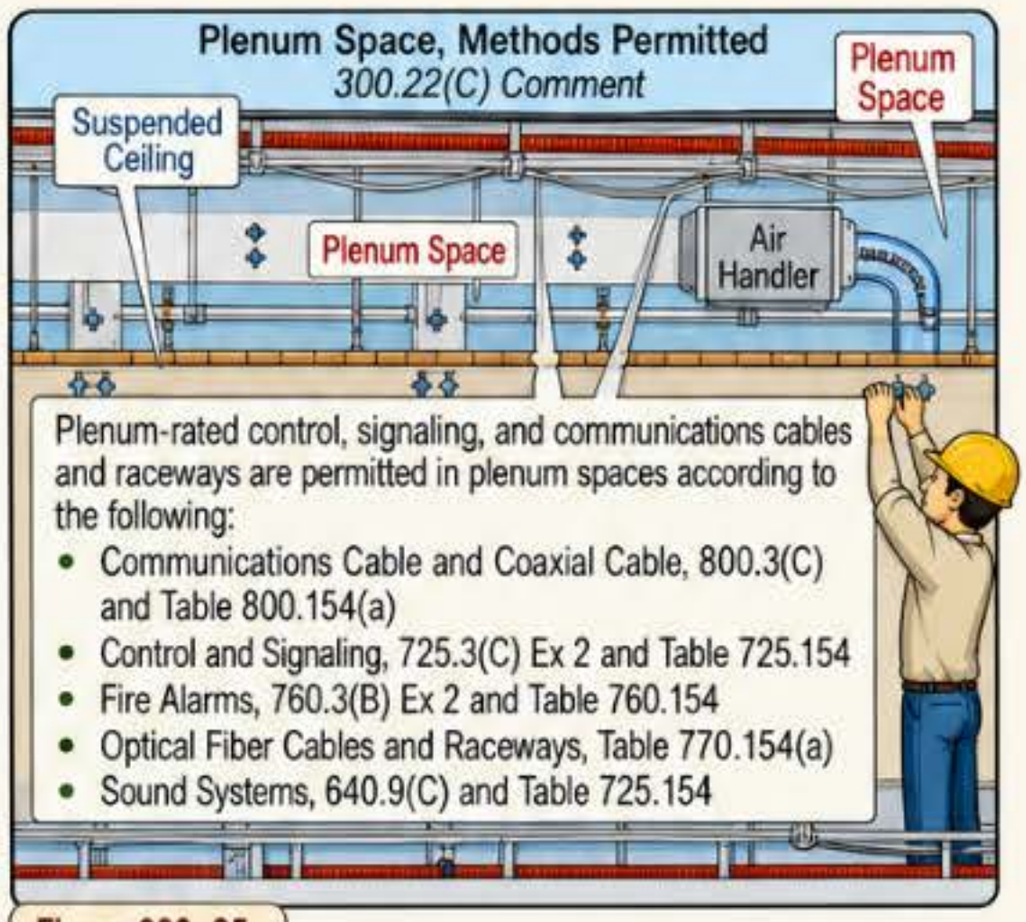


Figure 300–95

(2) Cable Tray Systems.

(a) Metal Cable Tray Systems. Metal cable tray systems can be installed to support the wiring methods and equipment permitted to be installed in a plenum space. Figure 300–96

(3) Equipment. Electrical equipment with a metal enclosure or a nonmetallic enclosure listed for use in an air-handling space can be installed in a plenum space. Figure 300–97

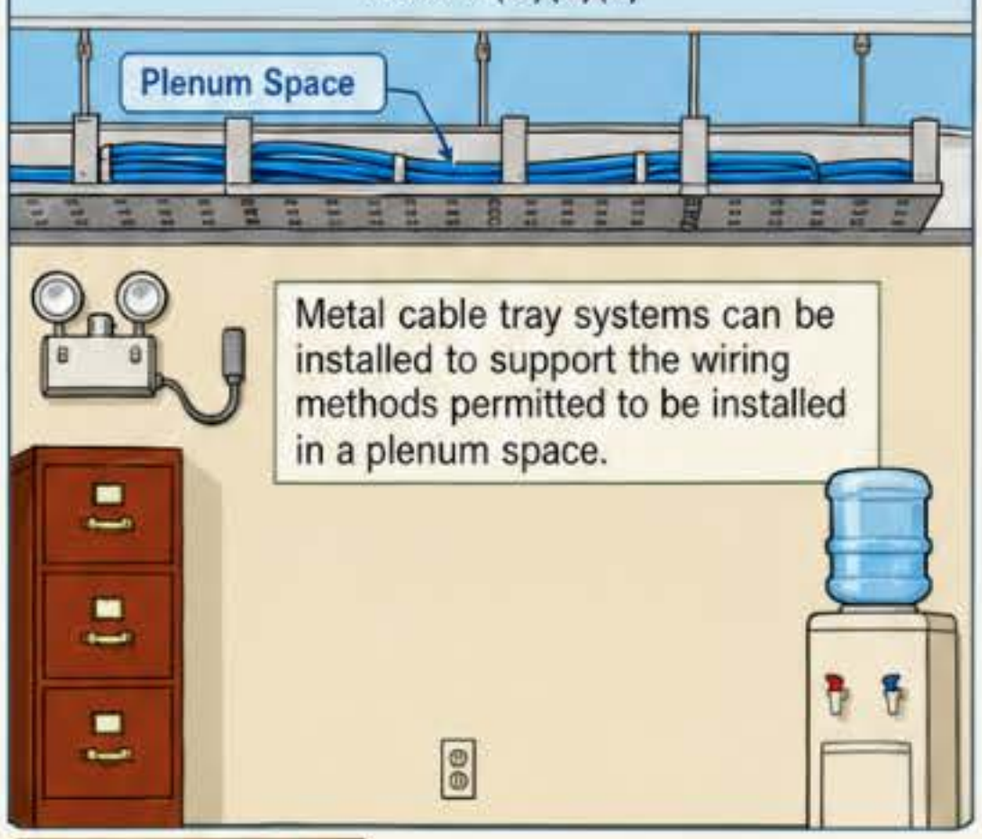
Author's Commentary:

Examples of electrical equipment permitted in plenum spaces are air handlers, junction boxes, and dry-type transformers; however, transformers are not permitted to be rated over 50 kVA when located in hollow spaces [450.13(B)].

— Michael Hamilton

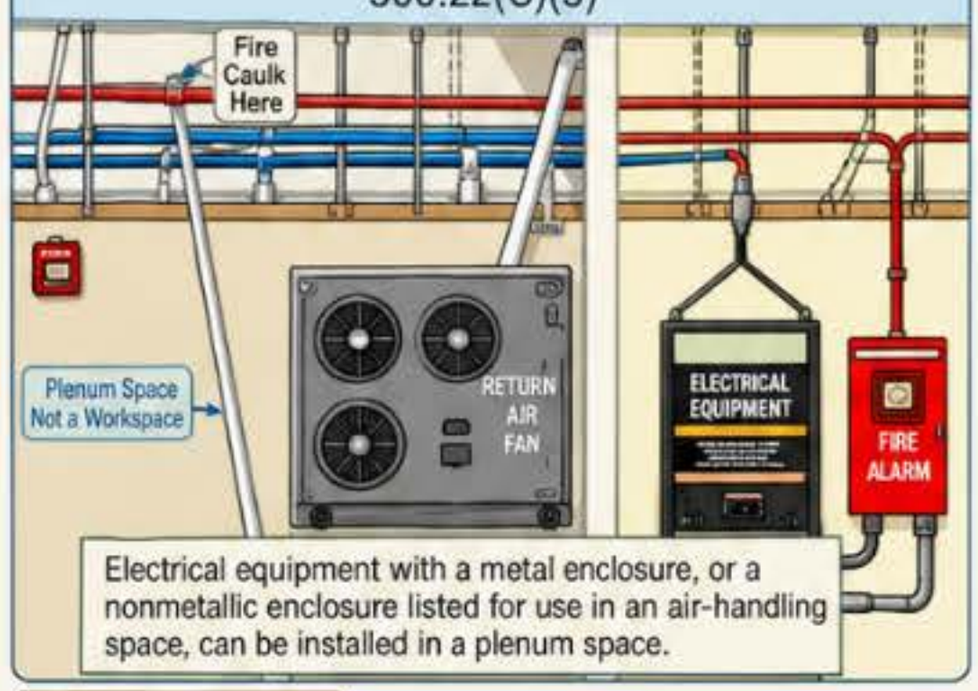
GENERAL REQUIREMENTS FOR WIRING METHODS AND MATERIALS 300.25

Plenum Spaces for Environmental Air Metal Cable Tray Systems
300.22(C)(2)(a)



▸ Figure 300-96

Plenum Spaces for Environmental Air, Equipment
300.22(C)(3)



▸ Figure 300-97

300.23 Panels Designed to Allow Access

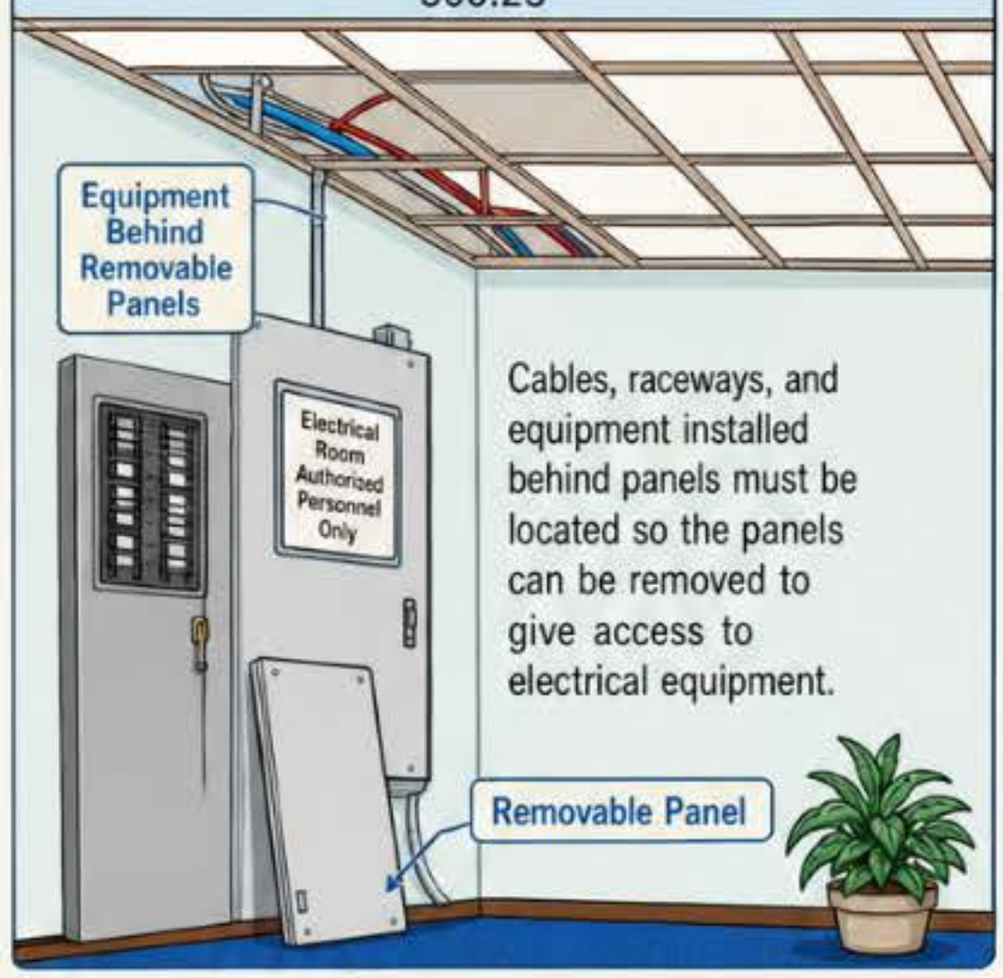
Cables, raceways, and equipment installed behind panels must be located so the panels can be removed to give access to electrical equipment.

Author's Commentary:

Access to equipment must not be hindered by the buildup of cables that would block removal of suspended-ceiling panels. Control, signaling, and communications cables must be arranged and supported so movable ceiling panels can be taken out to reach electrical equipment.

— Michael Hamilton

Panels Designed to Allow Access
300.23



▸ Figure 300-98

- Communications Cable and Coaxial Cable, 800.21
- Control and Signaling Cable, 725.21
- Fire Alarm Cable, 760.21
- Optical Fiber Cable, 770.21
- Audio Cable, 640.5

300.25 Exit Enclosures (Stair Towers)

When an exit enclosure is required to be separated from the building, only the wiring methods serving equipment permitted by the authority having jurisdiction in the exit enclosure are permitted to be installed within the exit enclosure.

Author's Commentary:

The term "separated from the building" does not imply they are entirely detached. Article 100 defines a building as a structure standing alone or a structure made up of adjoining parts separated by fire-rated assemblies. The intention is to prevent the rules for the main building's walls from being used to classify or "separate" walls around stair towers. Usually, stair towers only need lighting and heating to function. If a stair tower landing is the only place for a sub-panel (for instance), document special approval from the authority having jurisdiction.

— Michael Hamilton

Note: *For additional information, see NFPA 101, Life Safety Code®, 7.1.3.2.1(10)(b).*

Notes

ARTICLE 310 CONDUCTORS FOR GENERAL WIRING

Introduction to Article 310—Conductors for General Wiring

This article sets out the broad rules for conductors, including identification requirements, ampacity values, and conditions of use. It does not apply to components that are part of flexible cords, fixture wires, or integral parts of equipment [90.7 and 300.1(B)].

Why do some tables start as many as thirty pages apart? For instance, Table 310.17 lists ampacities, while Table 310.16 covers the same type of conductor used in almost every circuit except 75A and smaller. To find Article 100, review the definition of "Ampacity" and the meaning of "conditions of use." Those tables show the highest continuous current a conductor can carry without its insulation failing during normal service under the specified conditions in the tables. Across the ***NEC 2023***, information is supported by tables. Example: Section 310.16 lists voltage ratings from 0V through 2,000V. Reviewing those limits is essential; if you skip reading the *Code* section tied to each table and any footnotes before deciding what is needed for your task, you could introduce a serious safety risk.

THHN, THWN-2, RHH, and similar markings indicate insulation types. The "W" suffix fits wet locations. Each insulation category has a limit on heat it can withstand. When current passes through a conductor, it generates heat. The surrounding insulation must resist that heat, aided by factors such as whether the conductor is in free air or within a raceway. Consider what happens when you put on a heavy sweater, a jacket, and then a coat all at once—you'll get warm fast. Skin cannot release heat while all those layers trap it.

Insulation on conductors degrades as it ages; this is called "aging." Its breakdown develops over years in service and requires maintenance by qualified personnel. If a conductor's operating temperature is above the ampacity listed in the proper table (and the result is insulation temperature beyond its design limit), its insulation will degrade sooner and may fail catastrophically. Exceeding a conductor's ampacity is therefore a serious hazard.

Part I. General

310.1 Scope

Article 310 describes the general requirements for conductors rated up to and including 2,000V. This includes their identification, ampacity values, and conditions for use. ► *Figure 310–1*

Note: *For flexible cords and cables, see Article 400. For fixture wires, see Article 402.*

310.3 Conductors

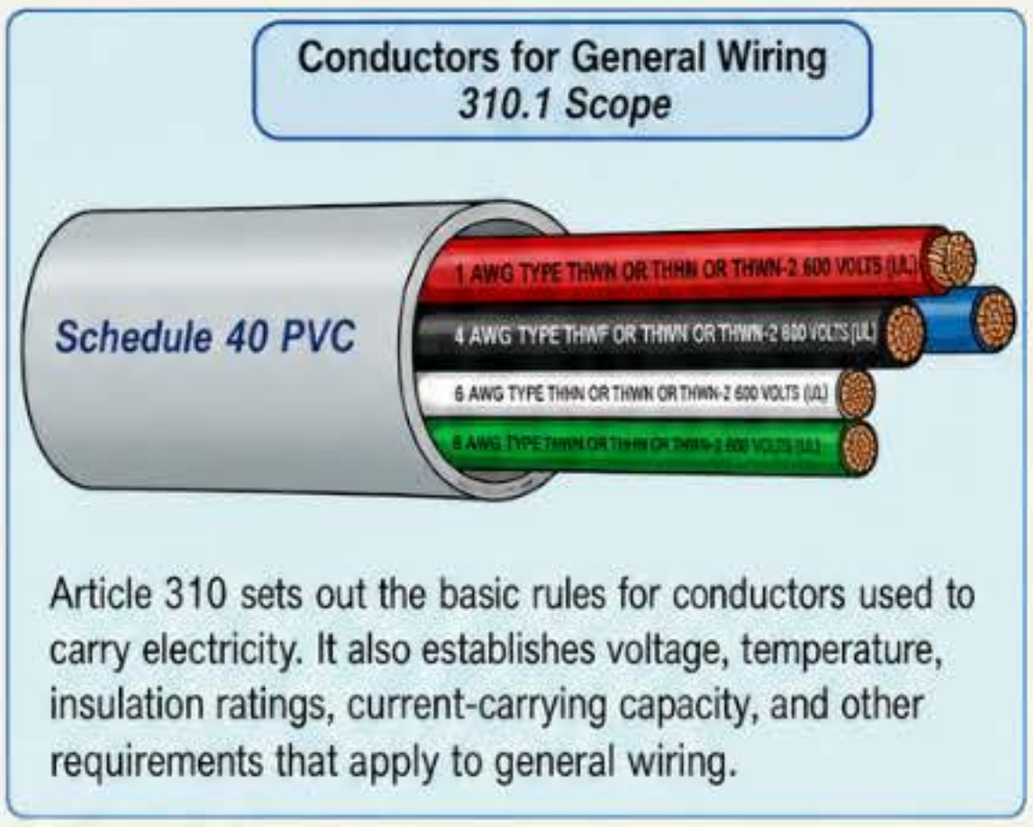
(A) Minimum Size Conductors. The smallest allowable conductor sizes are 14 AWG copper or 12 AWG aluminum or copper-clad aluminum, unless a different size is permitted elsewhere in the Code.

Author's Commentary:

- A common misconception is that 12 AWG copper is the thinnest conductor allowed for commercial or industrial installations. While often true, the *NEC 2023 does not mandate a job minimum based on NEC rules—it might be set by project specifications or local code.*
- *Conductors thinner than 14 AWG are permitted on Class 1 remote-control systems [725.43], fixture wires [402.6], and motor-control circuits [Table 430.72(B)].*

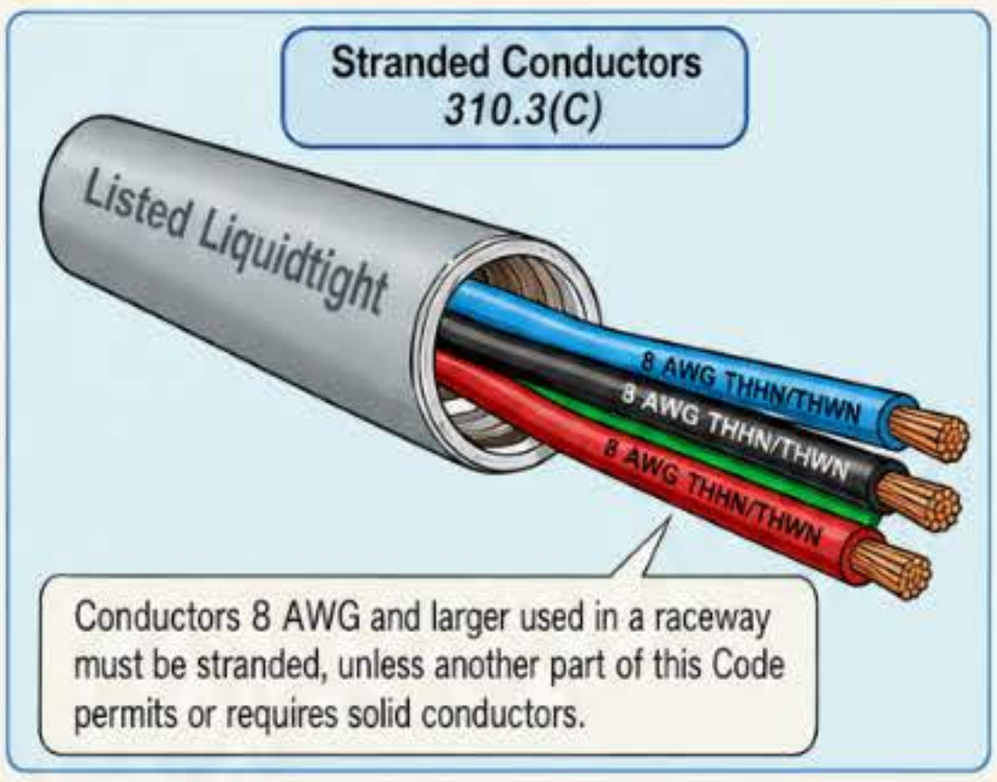
— Michael Hamilton

310.4 | Conductors for General Wiring



▸ **Figure 310–1**

(C) Stranded Conductors. Conductors that are 8 AWG or larger and installed in raceways **must be stranded**, unless specifically allowed or required elsewhere in this *Code* to be solid.



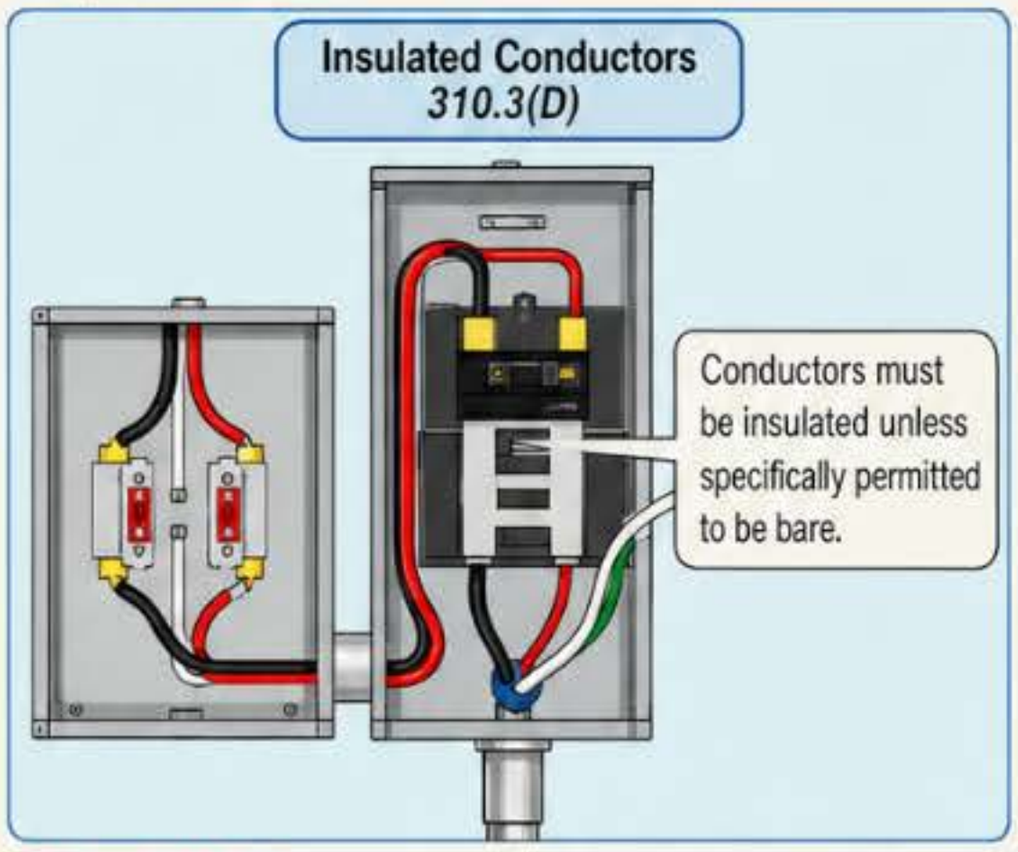
▸ **Figure 310–2**

> ***Author's Commentary:***
> *Per 250.120(C), exposed and grounding conductors that are 8 AWG or smaller, as well as conductors for direct-current circuits [250.134(2) Ex 2], are treated as if they were solar photovoltaic (PV) system conductors. They may be run separately from the circuit conductors. When 8 AWG or smaller exposed or grounding conductors might be subject to physical damage, they must be installed in a raceway or a cable.*
>
> *— Michael Hamilton*

- A grounding electrode conductor is an example where an 8 AWG and larger solid conductor can be installed in a raceway when it is required to be protected from physical damage [250.64(B)].

(D) Insulated. Bare conductors must be insulated, unless specifically permitted to be left uninsulated.

▸ **Figure 310–3**



▸ **Figure 310–3**

Part II. Construction Specifications

310.4 Conductor Construction and Application

Table 310.4(A) lists information on conductor insulation properties such as identification, maximum operating temperature, intended use, insulation, and outer covering characteristics. Only the conductors listed in Tables 310.4(A) may be used for the applications identified.

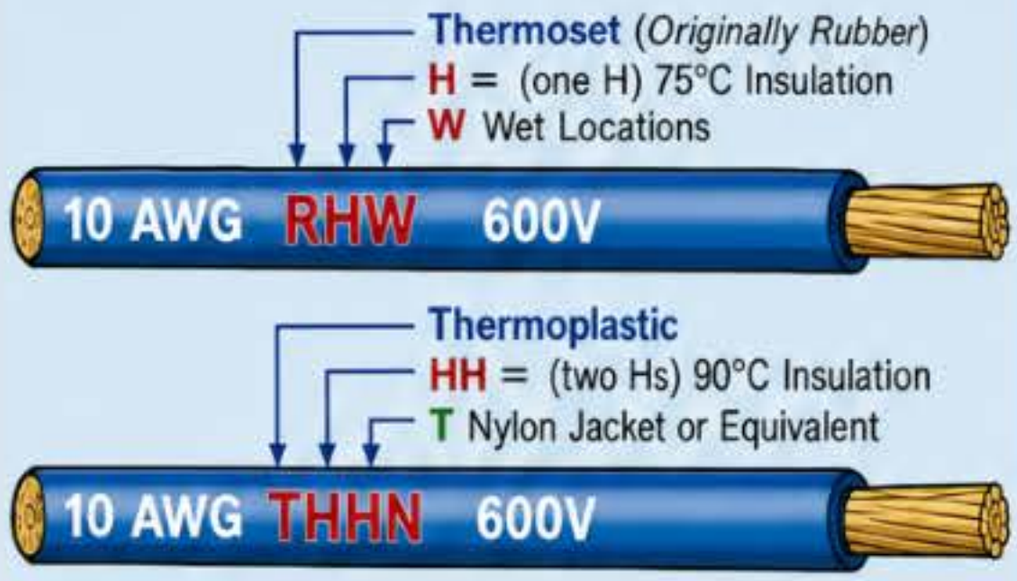
> ***Author's Commentary:***
> The following decodes the lettering used to identify *conductor insulation types [Table 310.4(A)]*:
> - ***No H*** *60°C insulation rating*
> - ***H*** *75°C insulation rating*
> - ***HH*** *90°C insulation rating for dry locations*
> - ***-2*** *90°C insulation rating for wet locations*
> - ***N*** *Nylon outer covering*
> - ***T*** *Thermoplastic insulation*
> - ***U*** *Underground*
> - ***W*** *Permitted in wet or damp locations*
>
> *— Michael Hamilton*

DEFINITIONS | From Michael Hamilton Publications

Table 310.4(A) Conductor Applications and Insulations

Type Letter	Column 2	Column 3	Column 4	Column 5	Column 6
	Insulation	Max. Operating Temperature	Application	Sizes Available AWG or kcmil	Outer Covering
RHH	Flame-retardant thermoset	90°C	Dry and damp locations	14 – 2,000	Moisture-resistant, flame-retardant, nonmetallic
RHW	Flame-retardant, moisture-resistant thermoset	75°C	Dry and wet locations	14 – 2,000	Moisture-resistant, flame-retardant, nonmetallic
RHW-2	Flame-retardant, moisture-resistant thermoset	90°C	Dry and wet locations	14 – 2,000	Moisture-resistant, flame-retardant, nonmetallic
THHN	Flame-retardant, heat-resistant thermoplastic	90°C	Dry and damp locations	14 – 1,000	Nylon jacket or equivalent
THHW	Flame-retardant, moisture- and heat-resistant thermoplastic	75°C 90°C	Wet locations Dry locations	14 – 1,000	None
THW	Flame-retardant, moisture- and heat-resistant thermoplastic	75°C	Dry, damp, and wet locations	14 – 2,000	None
THW-2	Flame-retardant, moisture- and heat-resistant thermoplastic	90°C	Dry, damp, and wet locations	14 – 1,000	None
THWN	Flame-retardant, moisture- and heat-resistant thermoplastic	75°C	Dry, damp, and wet locations	14 – 1,000	Nylon jacket or equivalent
THWN-2	Flame-retardant, moisture- and heat-resistant thermoplastic	90°C	Dry, damp, and wet locations	14 – 1,000	Nylon jacket or equivalent
TW	Flame-retardant, moisture-resistant thermoplastic	60°C	Dry, damp, and wet locations	14 – 2,000	None
USE	Heat- and moisture-resistant	75°C	See Article 338	14 – 2,000	Moisture-resistant nonmetallic
USE-2	Heat- and moisture-resistant	90°C	Dry, damp, and wet locations	14 – 2,000	Moisture-resistant nonmetallic

Conductor Construction and Application
Lettering on Insulation
Table 310.4(A) Comment



In general, only conductors contained in Table 310.4(A) are permitted to be used, except where otherwise permitted by the *NEC*.

▶ **Figure 310–4**

In general, only those conductors contained in Table 310.4(A) can be used, except where otherwise permitted in the *NEC*. Some examples are PV wire, PV cables, or DG cable [690.31(C)].

Author's Commentary:

It is common to see conductors with a multiple insulation rating, such as THHN/THWN. This type of conductor can be used in a dry location at the THHN 90°C ampacity; if it is used in a wet location, you must adhere to the THWN ampacity rating of the 75°C column of Table 310.16 for THWN insulation types.

— Michael Hamilton

Conductor Applications and Insulations
Table 310.4(A) Comment

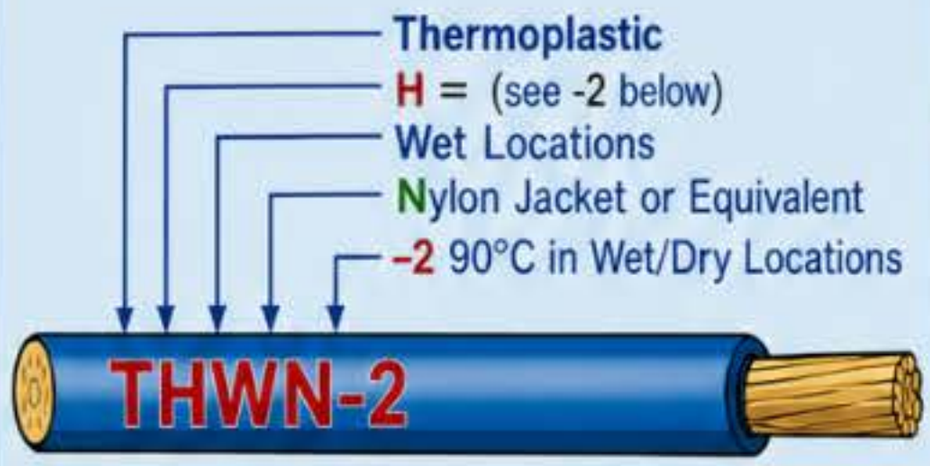
It's common to see conductors with multiple insulation ratings. THHN/THWN can be used in a dry location at the THHN 90°C ampacity, or if used in a wet location, you must adhere to the THWN ampacity rating of the 75°C column.

▶ **Figure 310–5**

When a "-2" is added at the end of an insulation type (such as THWN-2), that means the conductor can be used in a wet or dry location at the 90°C ampacity rating.

▶ **Figure 310–6**

Conductor Applications and Insulations
Table 310.4(A)



When a "-2" is added to the end of an insulation type (such as THWN-2) the conductor can be used in a wet or dry location at its 90°C ampacity rating.

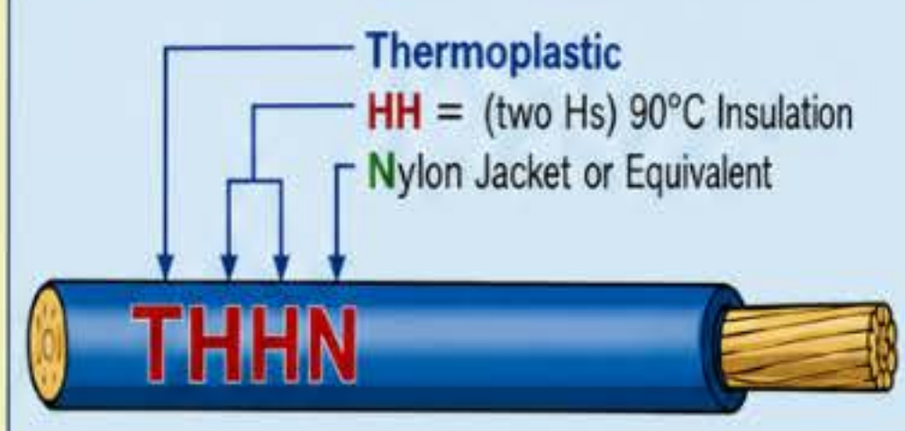
▶ **Figure 310–6**

▶ Table 310.4(A) Conductor Insulation Example

Question: *Which of the following describe(s) type THHN insulation?* ▶ **Figure 310–7**

(a) Thermoplastic insulation.
(b) Suitable for dry or damp locations.
(c) A maximum operating temperature of 90°C.
(d) all of these

Conductor Applications and Insulations
Table 310.4(A) Example



▶ **Figure 310–7**

Answer: *(d) all of these*

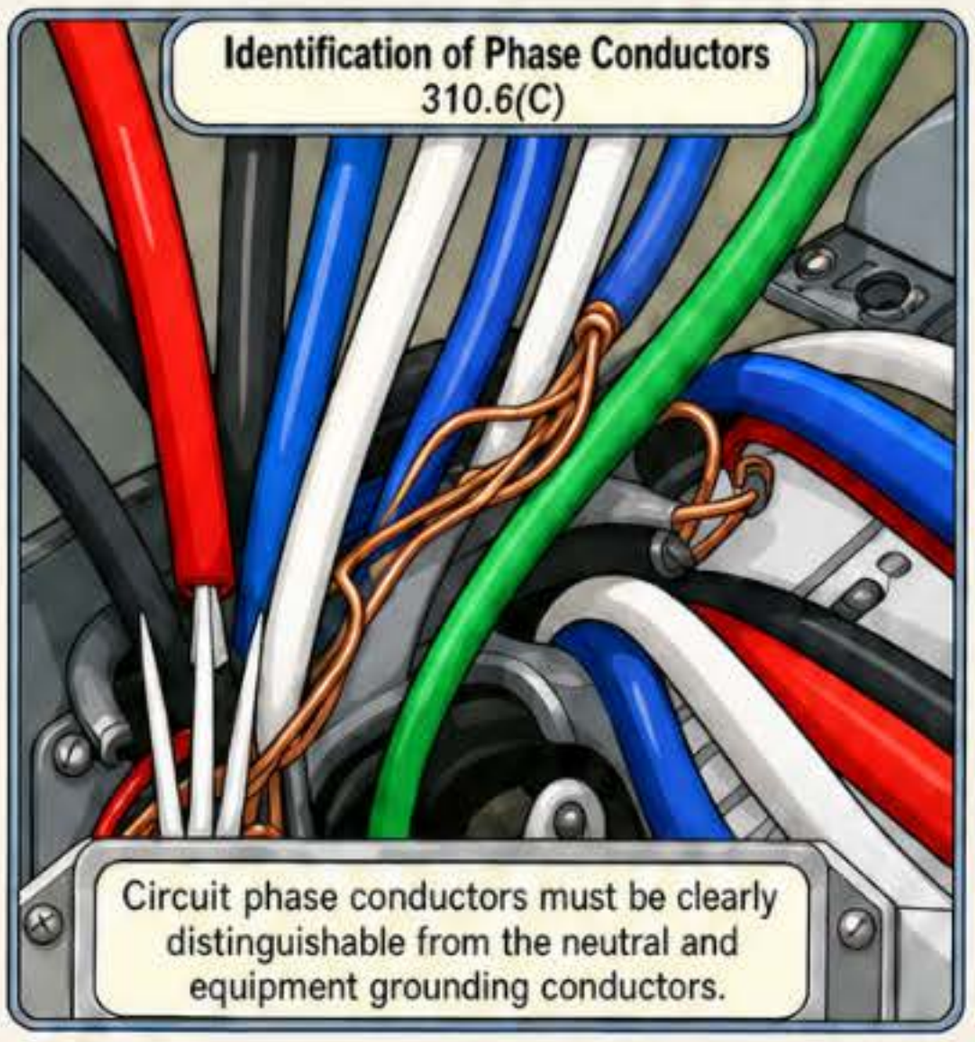
310.6 Conductor Identification

(A) Neutral Conductor. Branch-circuit neutral conductors shall be recognized in accordance with 200.6.

(B) Equipment Grounding Conductor. Equipment grounding conductors may be bare, covered, or insulated. Insulated equipment grounding conductors that are 6 AWG or smaller must be either green, or green with one or more yellow bands in compliance with 250.119.

Insulated equipment grounding conductors that are 4 AWG or larger may be permanently marked green at the point of installation (where accessible) in compliance with 250.119(A).

(C) Identification of Phase Conductors. Circuit phase conductors must have a finish that is visibly different from the neutral and equipment grounding conductors. ▶ Figure 310–8



▶ Figure 310–8

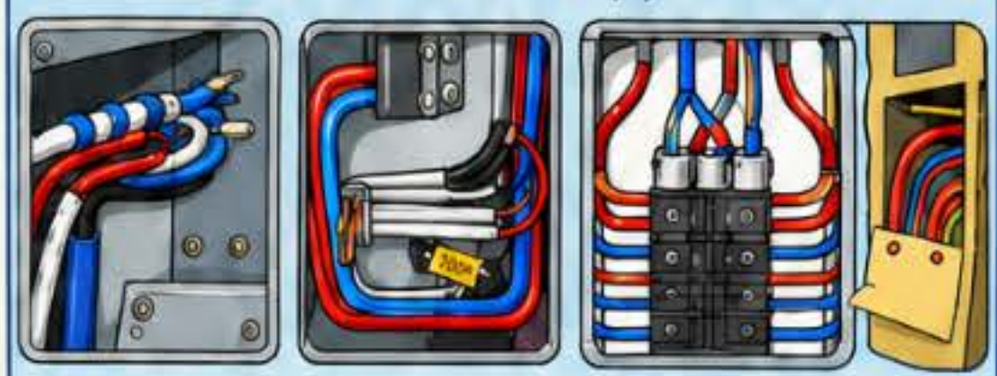
Where premises wiring is supplied from more than one nominal voltage system, branch-circuit phase conductors shall be identified in accordance with 210.5(C) and feeders must be identified in accordance with 215.12(C).

Example: Conductor identification is permitted in accordance with 200.7.

Author's Commentary:
The NEC does not mandate a specific color code for phase conductors. In practice, electricians commonly use the following color systems:
- *120/240V, single-phase—black, red, and white*
- *120/208V, three-phase—black, red, blue, and white*
- *120/240V, three-phase—black, orange, blue, and white*
- *277/480V, three-phase—brown, orange, yellow, and gray; or, brown, purple, yellow, and gray*

— Michael Hamilton

Common Phase Conductor Identification Methods
210.5, 215.12, and 310.6(C) Comment



Although the NEC does not require a specific color code for phase conductors, electricians often use the following for power and lighting conductor identification:
- 120/240V, single-phase—black, red, and white
- 120/208V, three-phase—black, red, blue, and white
- 120/240V, three-phase—black, orange, blue, and white
- 277/480V, three-phase—brown, orange, yellow, and gray; or, brown, purple, yellow, and gray

▶ Figure 310–9

Part III. Installation

310.10 Uses Permitted

The conductors described in Table 310.4(A) are approved for use in any of the wiring methods covered in Chapter 3.

(B) Dry and Damp Locations. Insulated conductors typically used in dry and damp locations include THHN, THHW, THWN, THWN-2, XHHW, XHHW-N, and XHHW-2.

(C) Wet Locations. Insulated conductors typically used in wet locations include THHW, THWN, THWN-2, XHHW, XHHW-2, XHHW-N, and XHHW-2.

Author's Commentary:
The letter "W" in the insulation type means the conductor is rated for use in wet locations.

— Michael Hamilton

(D) Locations Exposed to Direct Sunlight. Insulated conductors or cables used where exposed to the direct rays of the sun must comply with the following:

(1) Conductors and cables must be listed as sunlight resistant, or listed and marked as being sunlight resistant.
▶ Figure 310–10

310.10 • Conductors for General Wiring

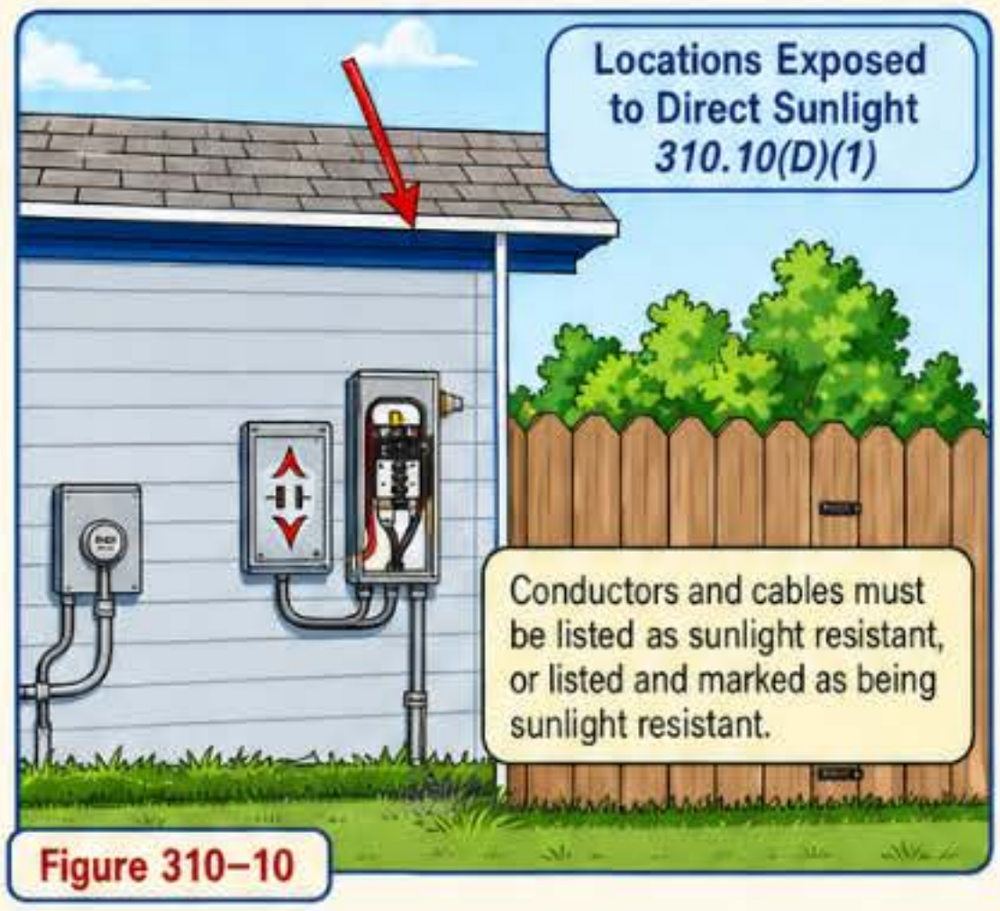


Figure 310–10

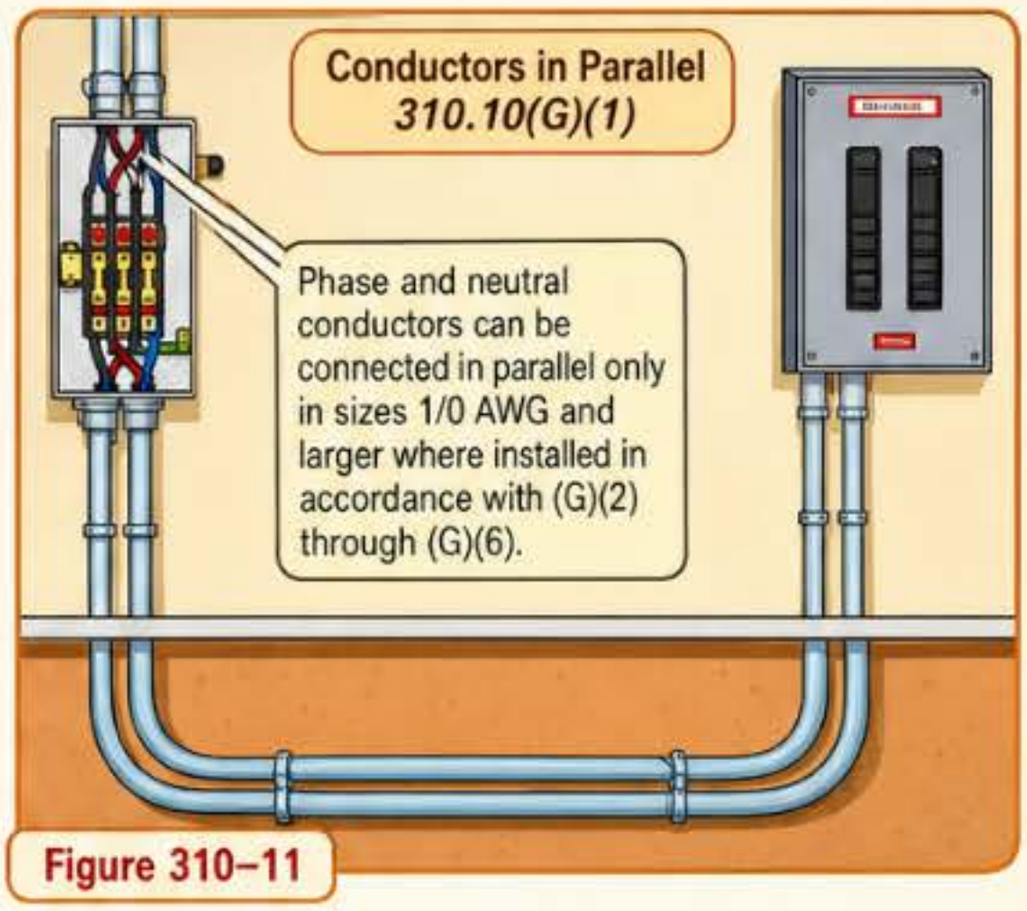


Figure 310–11

(2) Conductors and cables must be covered with insulating material (such as tape or sleeving) that is listed, or listed and marked, as being sunlight resistant.

(E) Direct Burial Conductors. Conductors used for direct burial applications must be of a type identified for such use.

(F) Corrosive Conditions. Conductors exposed to oils, greases, vapors, gases, fumes, liquids, or other substances having a harmful effect on the conductor or insulation must be of a type suitable for the application.

(G) Conductors in Parallel.

(1) General. Phase and neutral conductors are permitted to be connected in parallel (electrically joined at both ends) for conductor sizes 1/0 AWG and larger in accordance with (G)(2) through (G)(6). ➡ Figure 310–11

(2) Conductor and Installation Characteristics. When circuit conductors are installed in parallel, they must be connected so the current will be evenly distributed between the individual parallel conductors. This is accomplished by requiring all circuit conductors within each parallel set to: ➡ Figure 310–12

1. *Be the same length.*
2. *Be of the same conductor material (copper, aluminum, or copper-clad aluminum).*
3. *Be the same size in circular mil area (minimum 1/0 AWG).*
4. *Have the same type of insulation.*
5. *Terminate in the same manner (set screw versus compression fitting).*

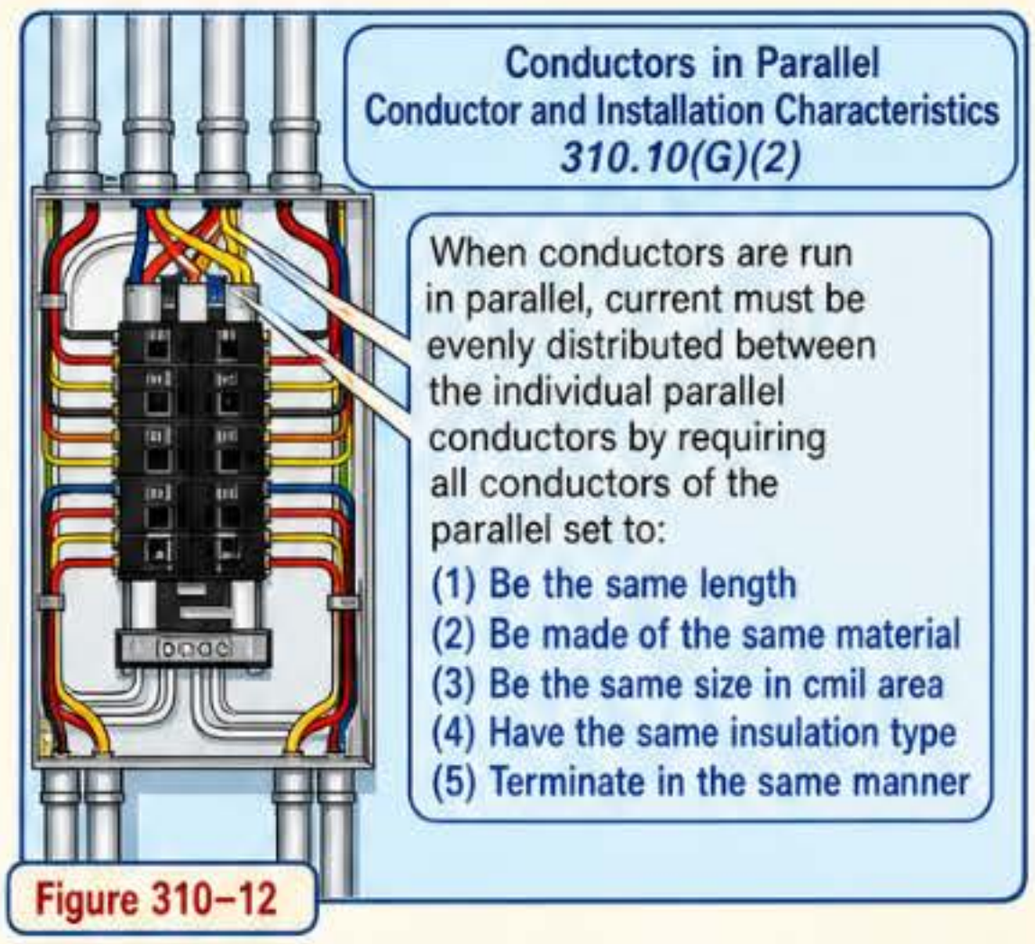


Figure 310–12

Parallel sets of conductors are not required to have the same physical characteristics as those of another set to achieve balance. Conductors of one phase, neutral, or equipment grounding conductor of a parallel set are not required to have the same physical characteristics as those of another phase, neutral, or equipment grounding conductor. ➡ Figure 310–13

Author's Commentary: *Parallel connections are powerful but only when every conductor in the set shares identical properties and installation details. Any mismatch leads to uneven current, overheating, and possible failure. Follow all five requirements without exception.*

— Michael Hamilton

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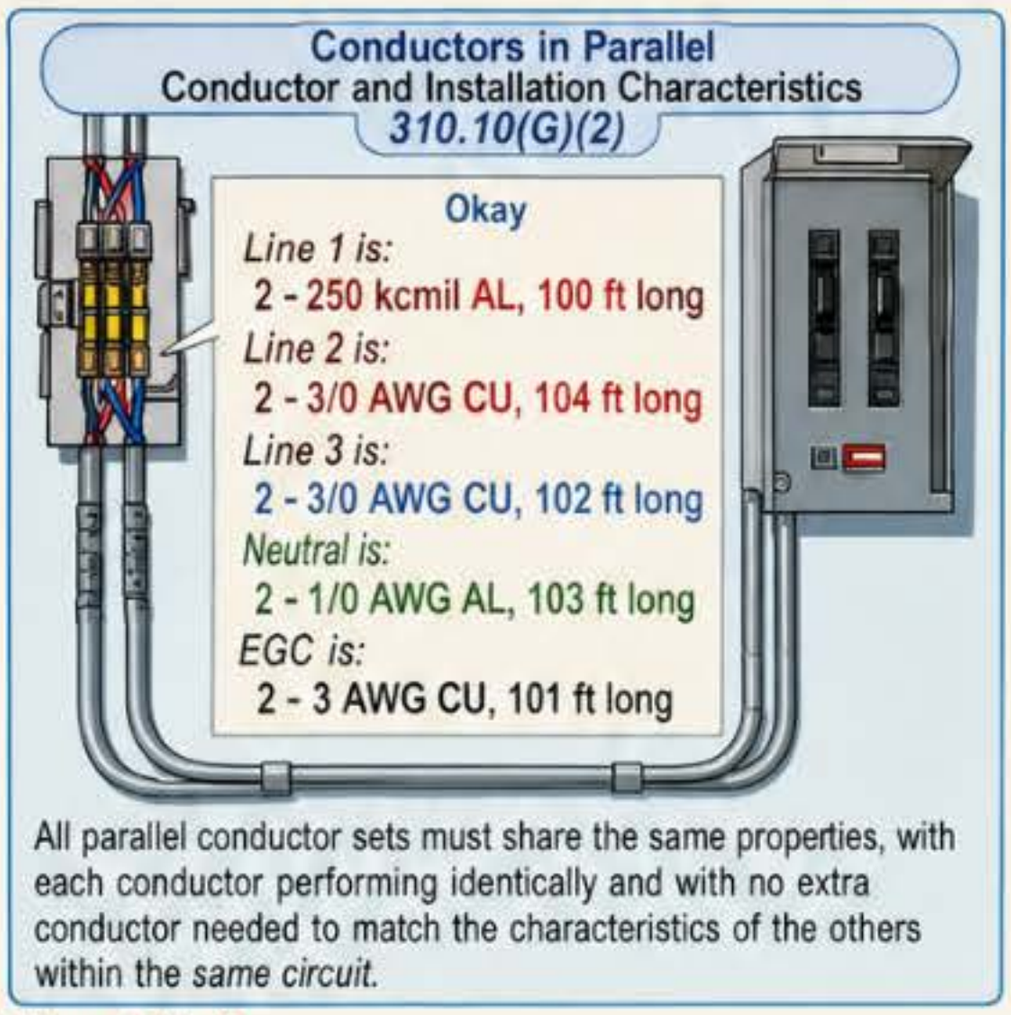


Figure 310-13

Author's Commentary:

- When parallel circuit conductors are installed in different raceways, each raceway must include a phase A, B, C, a neutral (if used), and an equipment grounding conductor (if used). If all phase "A" conductors are grouped in one raceway, all phase "B's" in another, and all phase "C's" in a third, the magnetic fields surrounding the conductors will not cancel and may lead to inductive heating in violation of 300.20(A) unless proper steps are taken to reduce the inductive effect. Figure 300-14

— Michael Hamilton

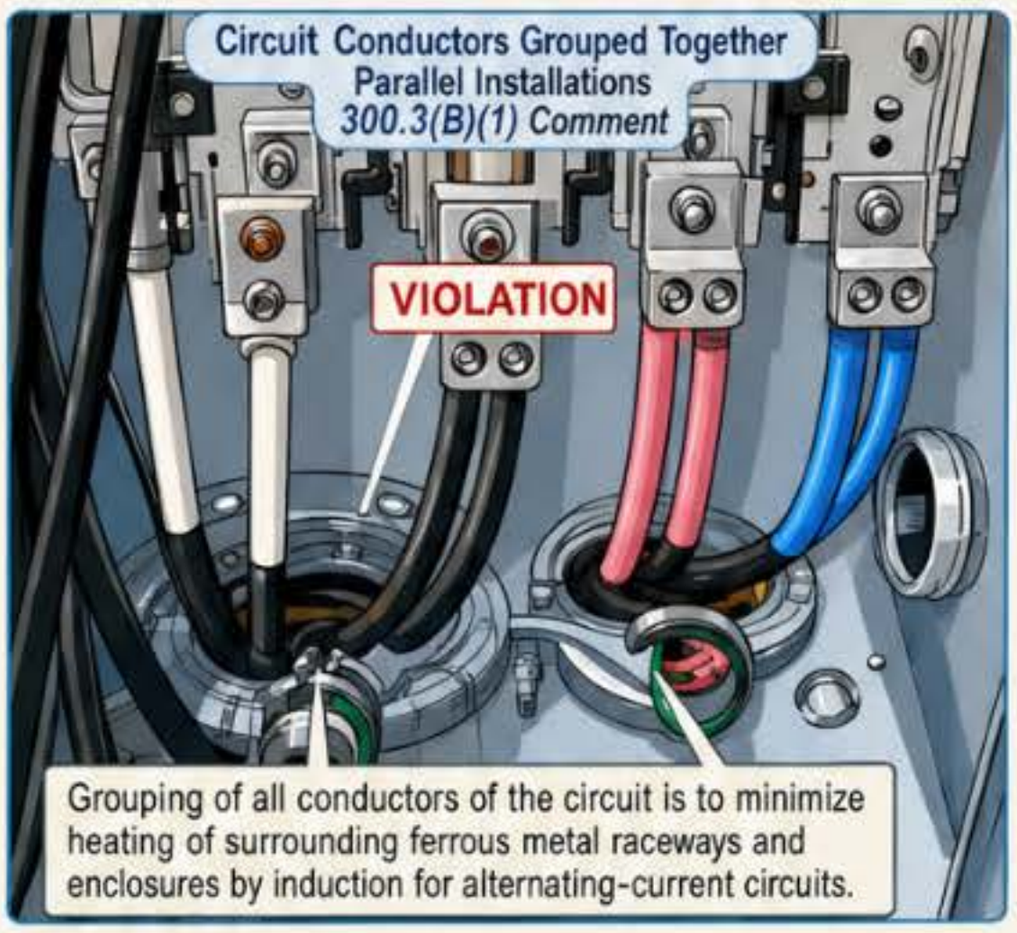


Figure 310-14

(3) Separate Raceways or Cables. Raceways or cables that contain parallel conductors must have identical numbers of conductors and the same electrical characteristics.

Figure 310-15

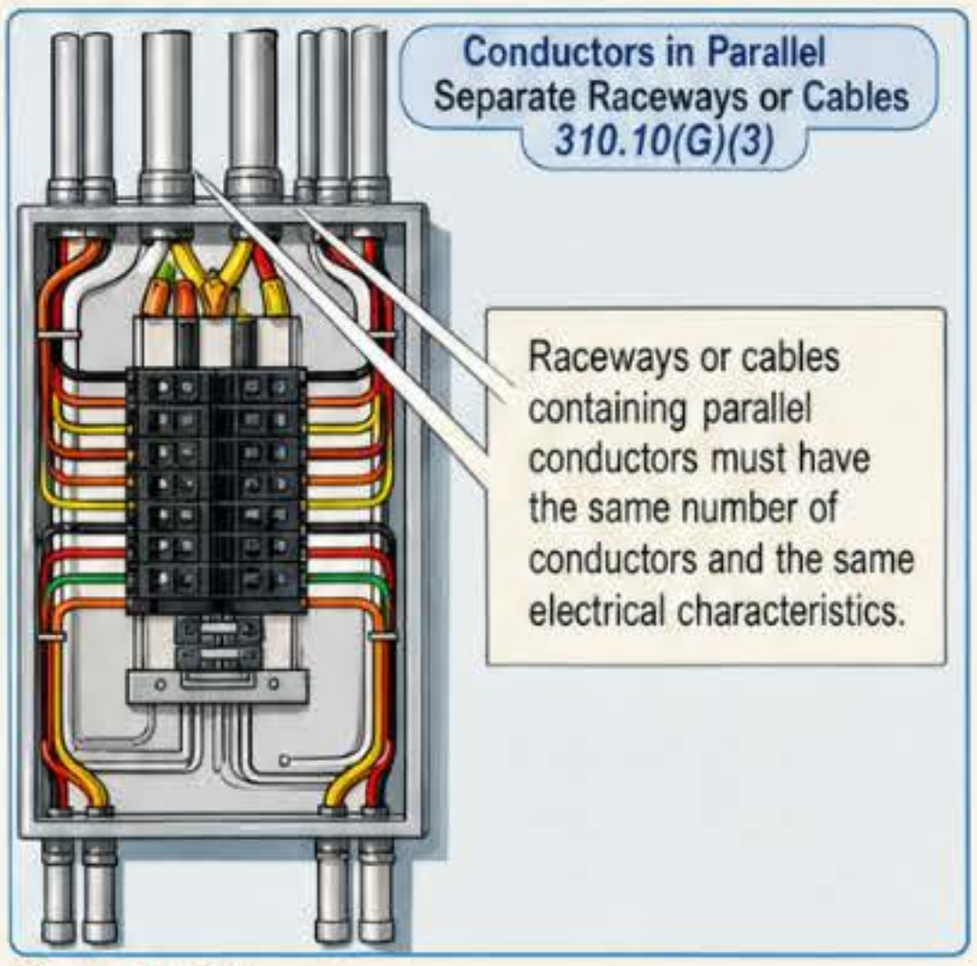


Figure 310-15

Author's Commentary:

- Parallel conductor sets must include all circuit conductors in the same raceway [300.3(B)(1)]. Figure 310-16

— Michael Hamilton

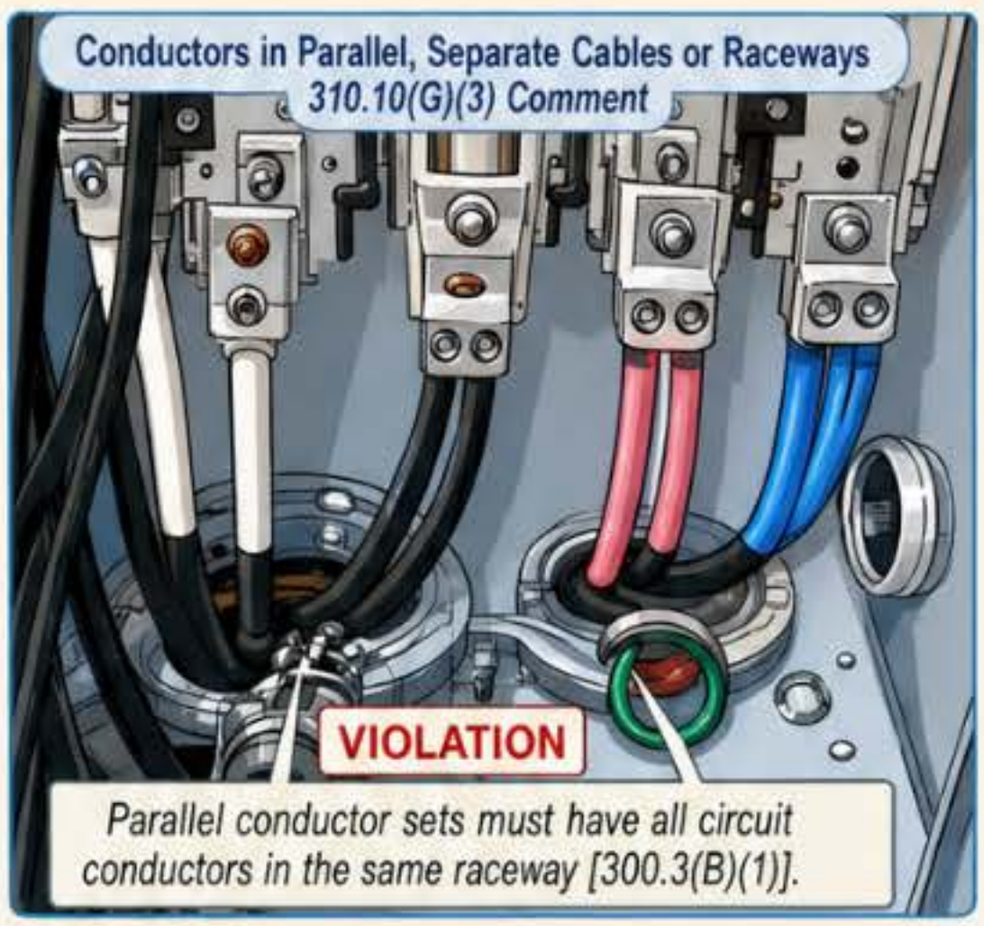


Figure 310-16

310.12 Conductors for General Wiring

Author's Commentary:

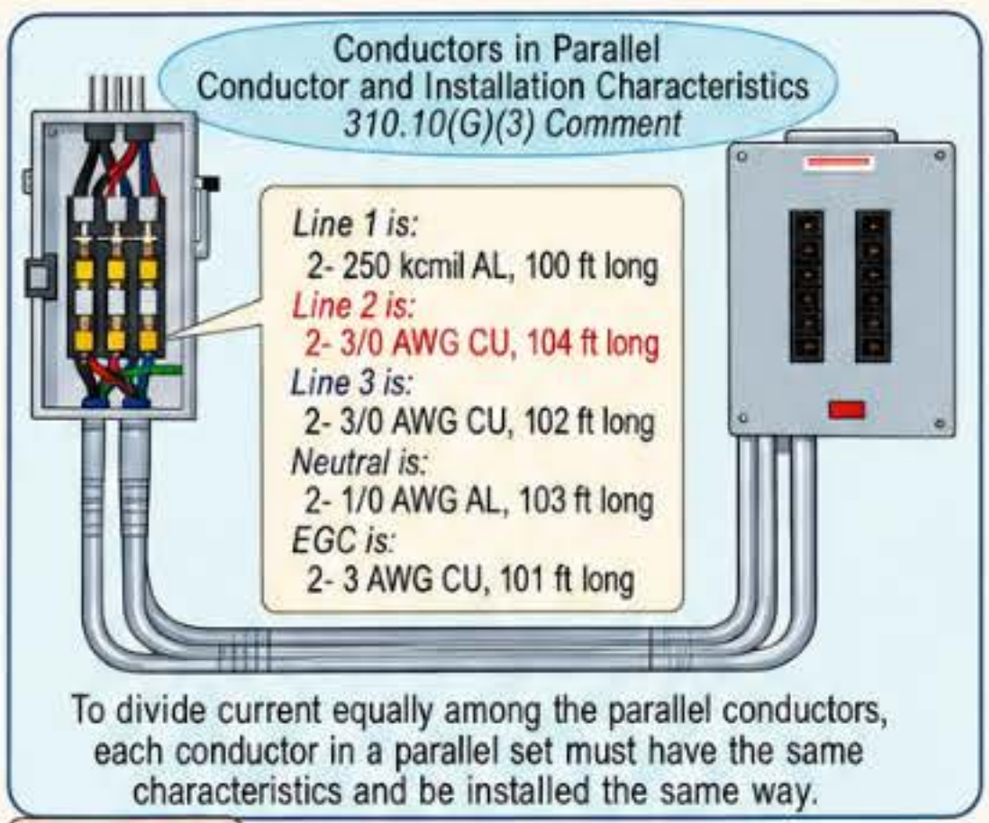
When parallel runs share a metal raceway, and separate runs share PVC conduit, the metal raceway conductors see higher heat for a given impedance (ohms) than the same circuits in nonmetallic raceway. This produces uneven circuit distribution among parallel conductors.

— Michael Hamilton

If one set of parallel conductors is installed in a metal raceway and other conductors are installed in PVC conduit, the conductors in the metal raceway experience more opposition to current flow (impedance) compared with identical conductors in the nonmetallic raceway. As a result, current won't be shared equally between the parallel conductors.

For current to be divided evenly among the individual parallel conductors, each conductor (within a parallel set) must match the others. Example: a 400A feeder with a neutral load of 240A can be paralleled as follows:

- Phase A; Two–250 kcmil THHN aluminum, 100 ft
- Phase B; Two–3/0 THHN copper, 104 ft
- Phase C; Two–3/0 THHN copper, 102 ft
- Neutral; Two–1/0 THHN aluminum, 103 ft
- Equipment grounding conductor; Two–3 AWG THHN copper, 101 ft



To divide current equally among the parallel conductors, each conductor in a parallel set must have the same characteristics and be installed the same way.

Figure 310–17

Author's Commentary:

The minimum 1/0 AWG conductor size for parallel does not apply to equipment grounding conductors [310.10(G)(5)].

— Michael Hamilton

(4) Conductor Ampacity Adjustment. Each current-carrying conductor of a paralleled set must be included when counting current-carrying conductors for the ampacity adjustment, in accordance with 310.15(C)(1). Figure 310–18

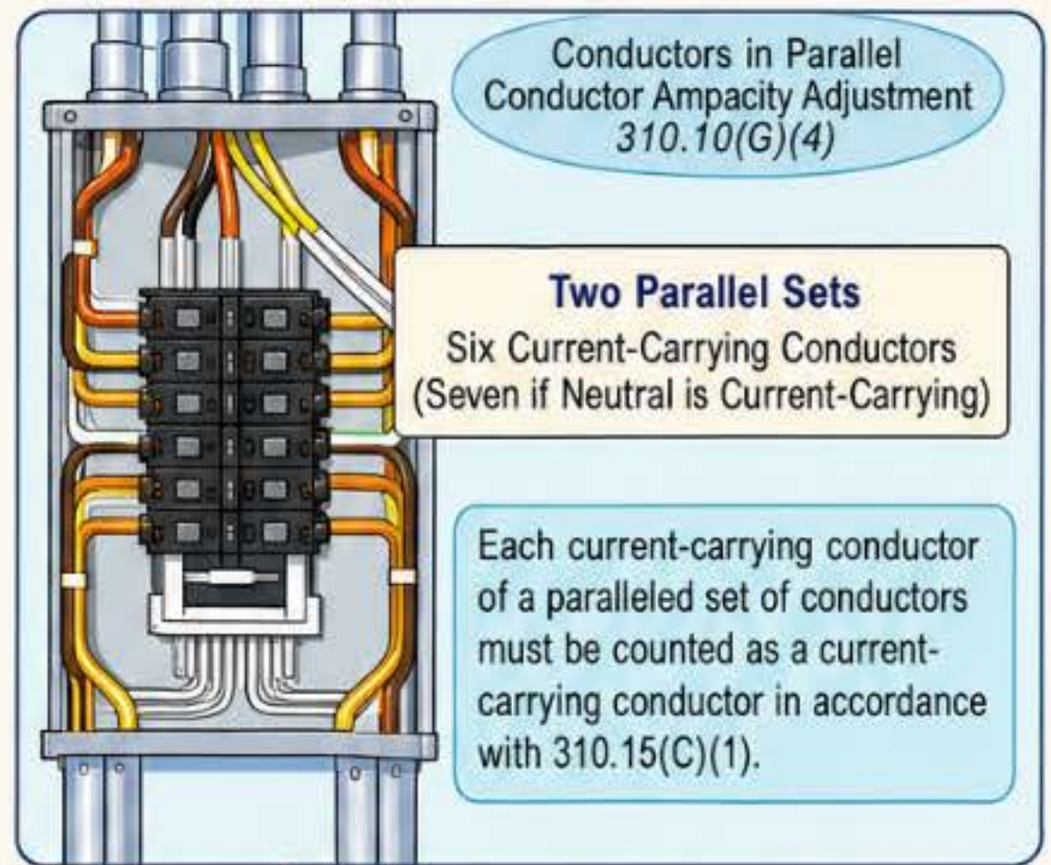


Figure 310 – 18

(5) Equipment Grounding Conductors. The equipment grounding conductors for parallel circuits must be sized in accordance with 250.122(F). Figure 310–19

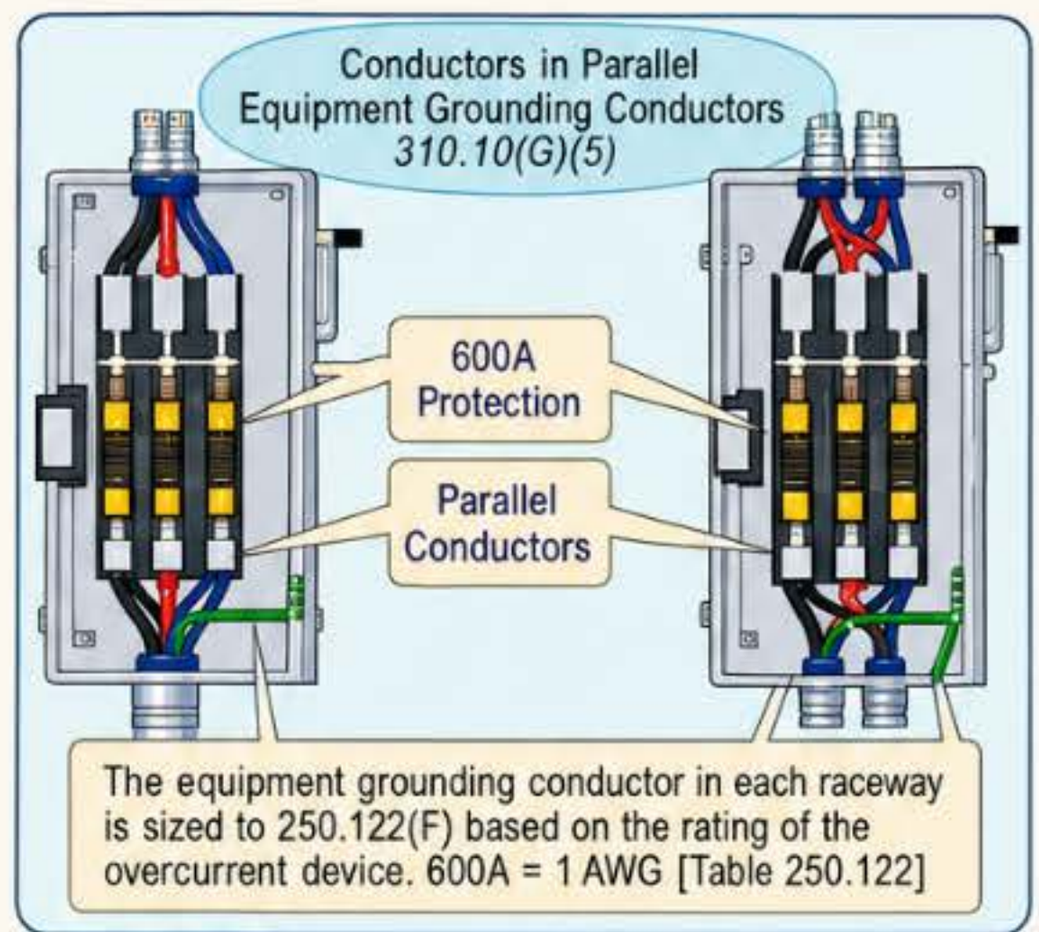
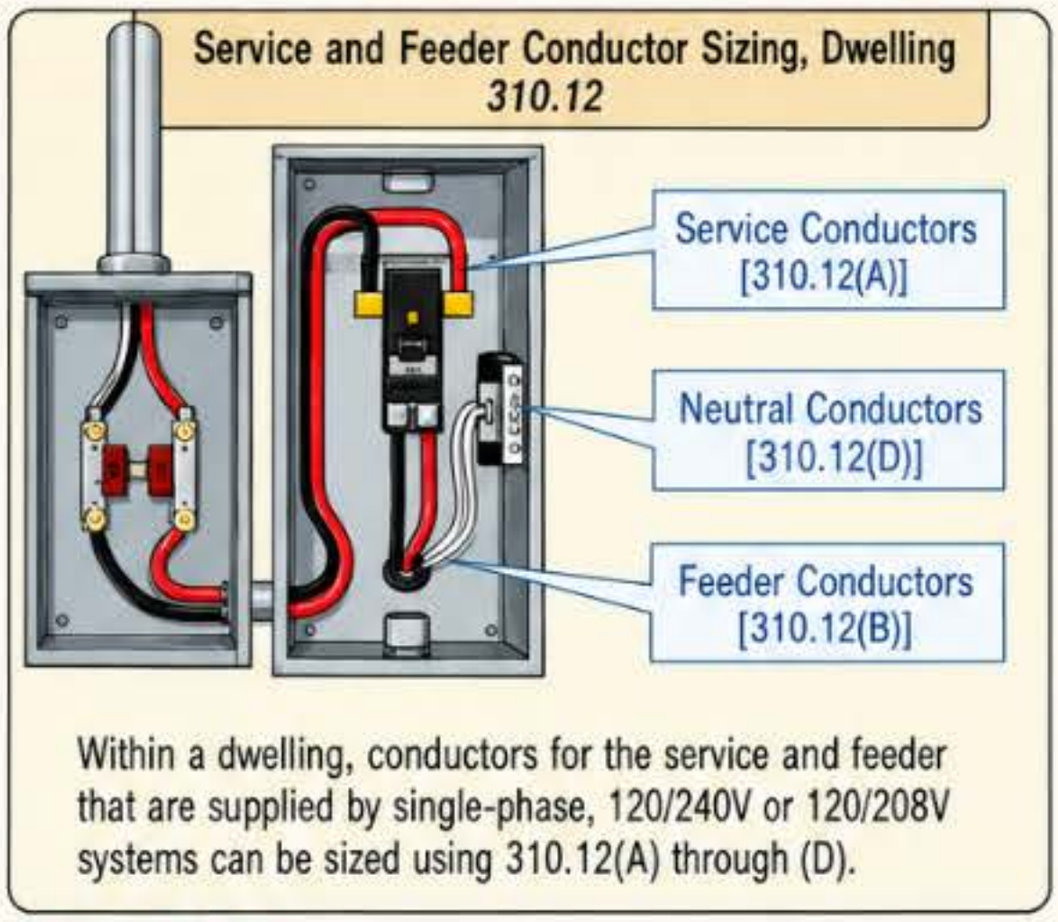


Figure 310–19

310.12 Single-Phase Dwelling Services and Feeders

Dwelling unit service conductors supplied by a single-phase, 120/240V system and dwelling unit feeder conductors supplied by a 120/240V or 120/208V system can be sized in accordance with the following: Figure 310–20

Conductors for General Wiring | 310.12



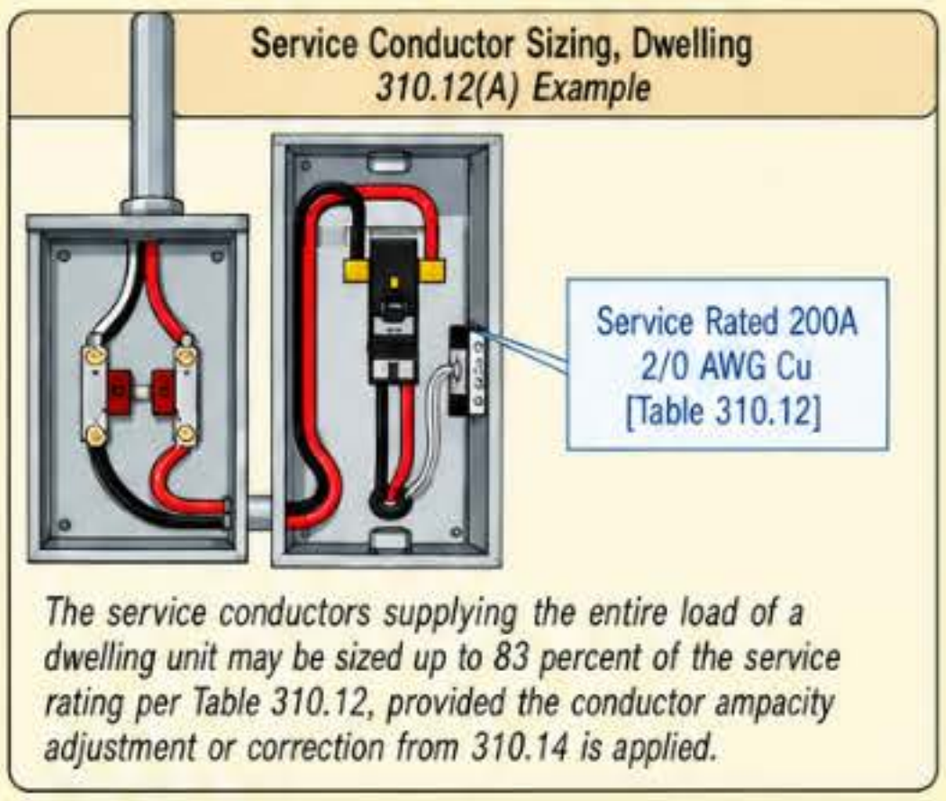
▶ Figure 310–20

(A) Services. Single-phase, 120/240V service conductors that supply the entire load of a dwelling unit can be sized according to Table 310.12. Where the conductor ampacity requires it, an adjustment or correction must also be made as specified in 310.14.

▶ Example

Question: *What size service conductors are needed if the calculated load for a dwelling unit calls for a service disconnect rated at 200A?*

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG



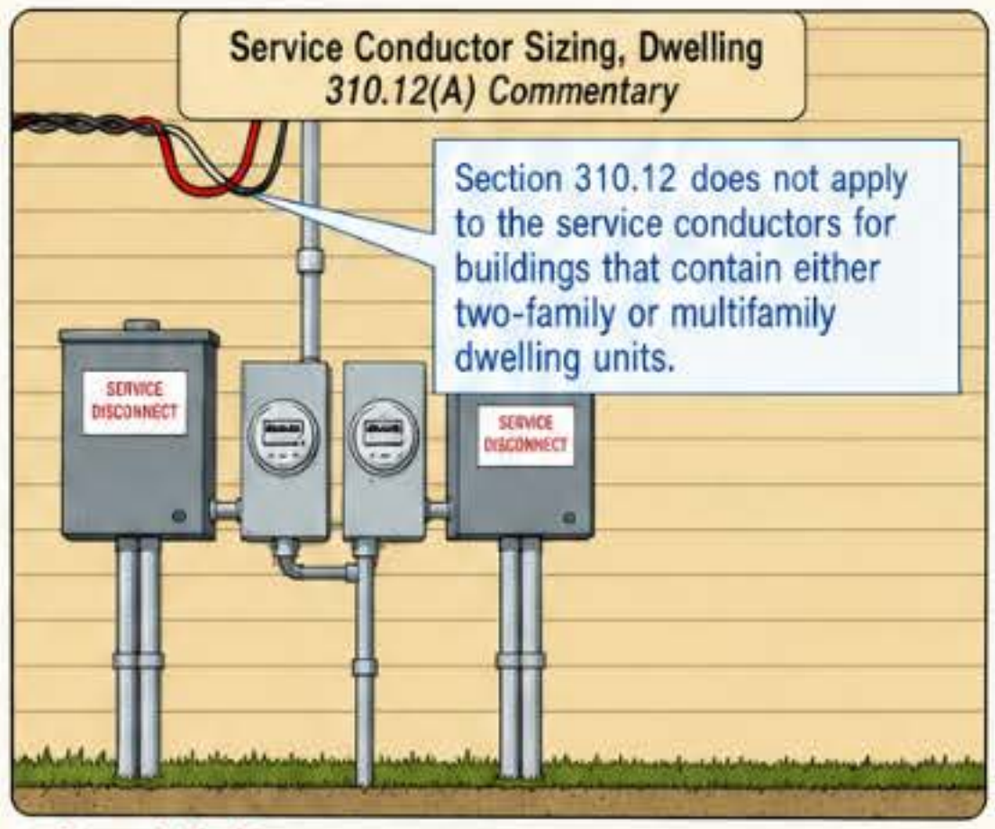
▶ Figure 310–21

Answer: *(b) 2/0 AWG [Table 310.12]*

Author's Commentary:

Section 310.12 does not apply to service conductors for either two-family or multifamily dwelling buildings.

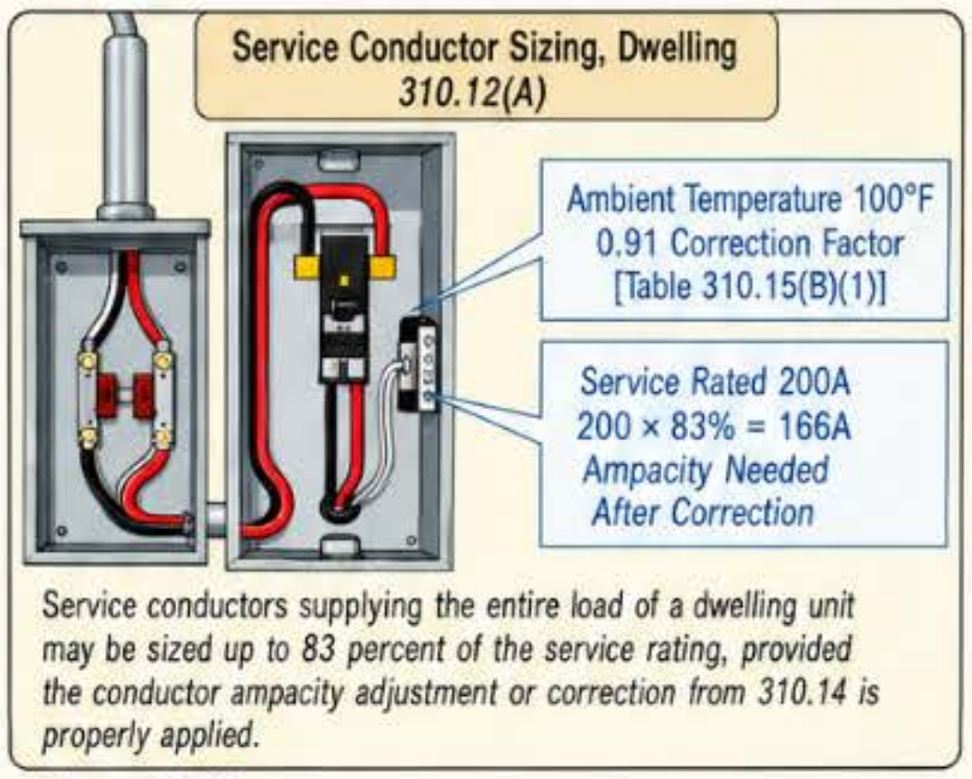
— Michael Hamilton



▶ Figure 310–22

Service conductors that supply the entire load of a dwelling unit can be sized up to 83 percent of the service rating—provided the conductor ampacity is adjusted or corrected as required in 310.14.

▶ Figure 310–23

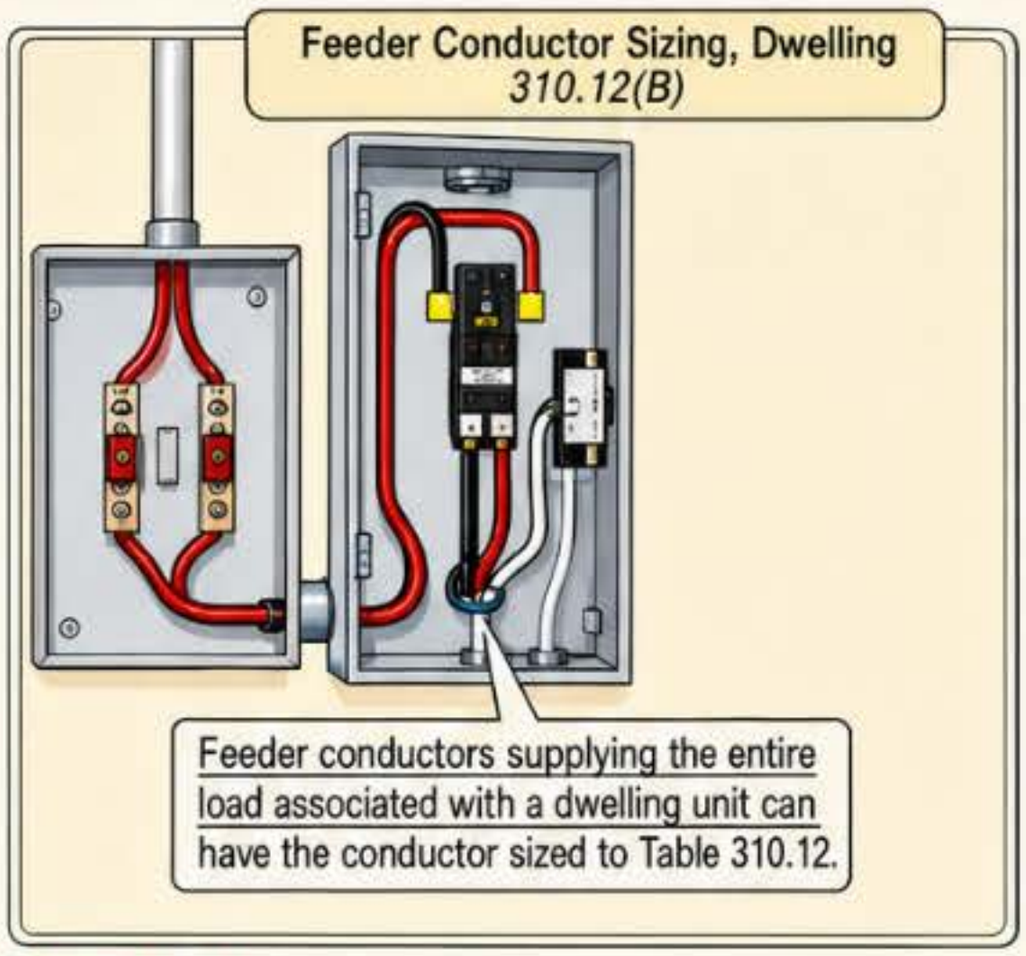


▶ Figure 310–23

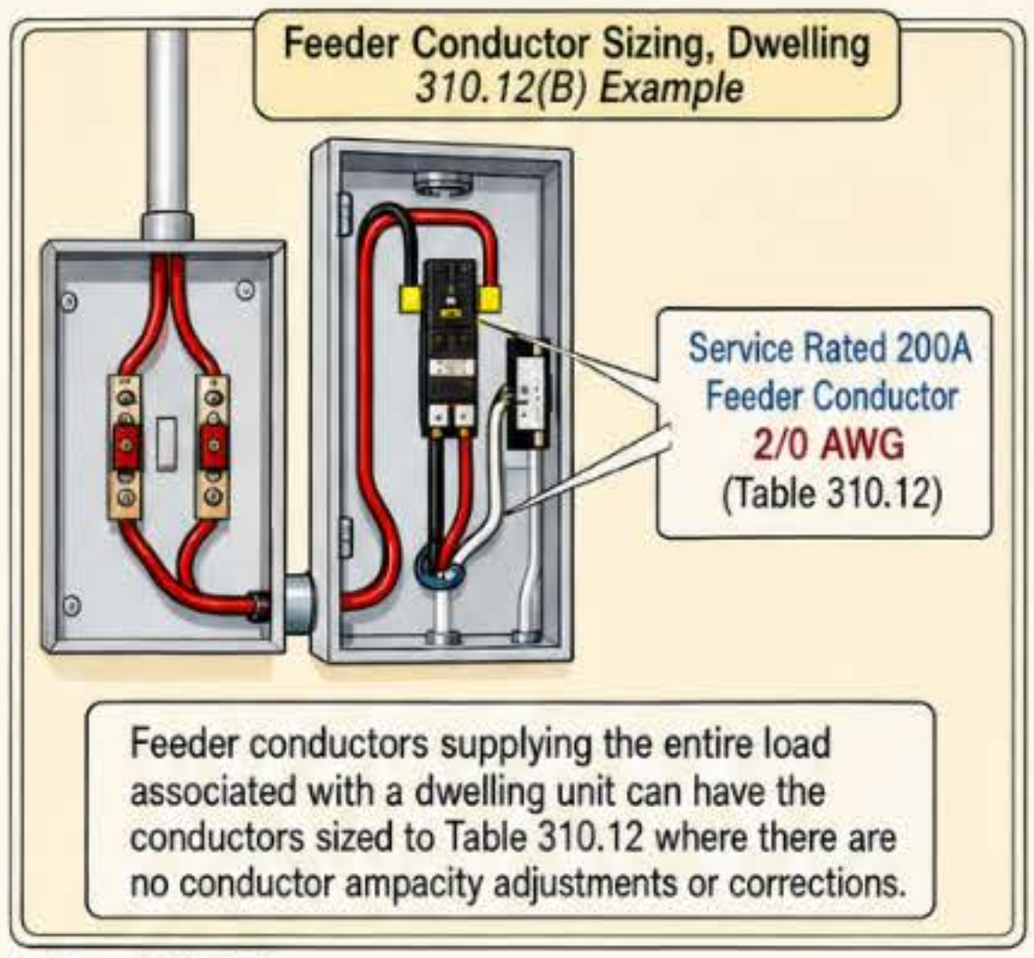
(B) Feeders. Single-phase, 120/240V or 120/208V feeder conductors that supply the entire load of a dwelling unit can be sized in accordance with Table 310.12, with any ampacity adjustment or correction performed as required by 310.14.

▶ Figure 310–24 and Figure 310–25

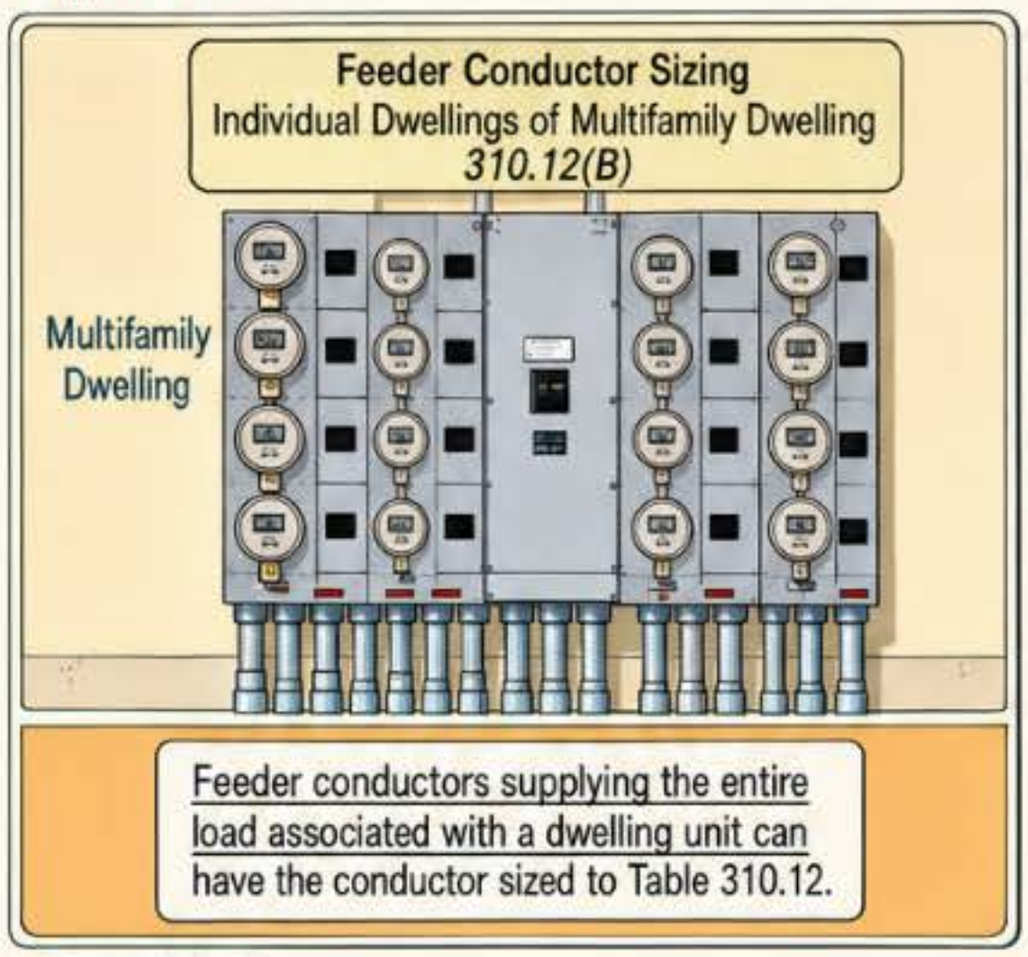
310.12 | Conductors for General Wiring



▶ Figure 310–24



▶ Figure 310–26



▶ Figure 310–25

▶ Example

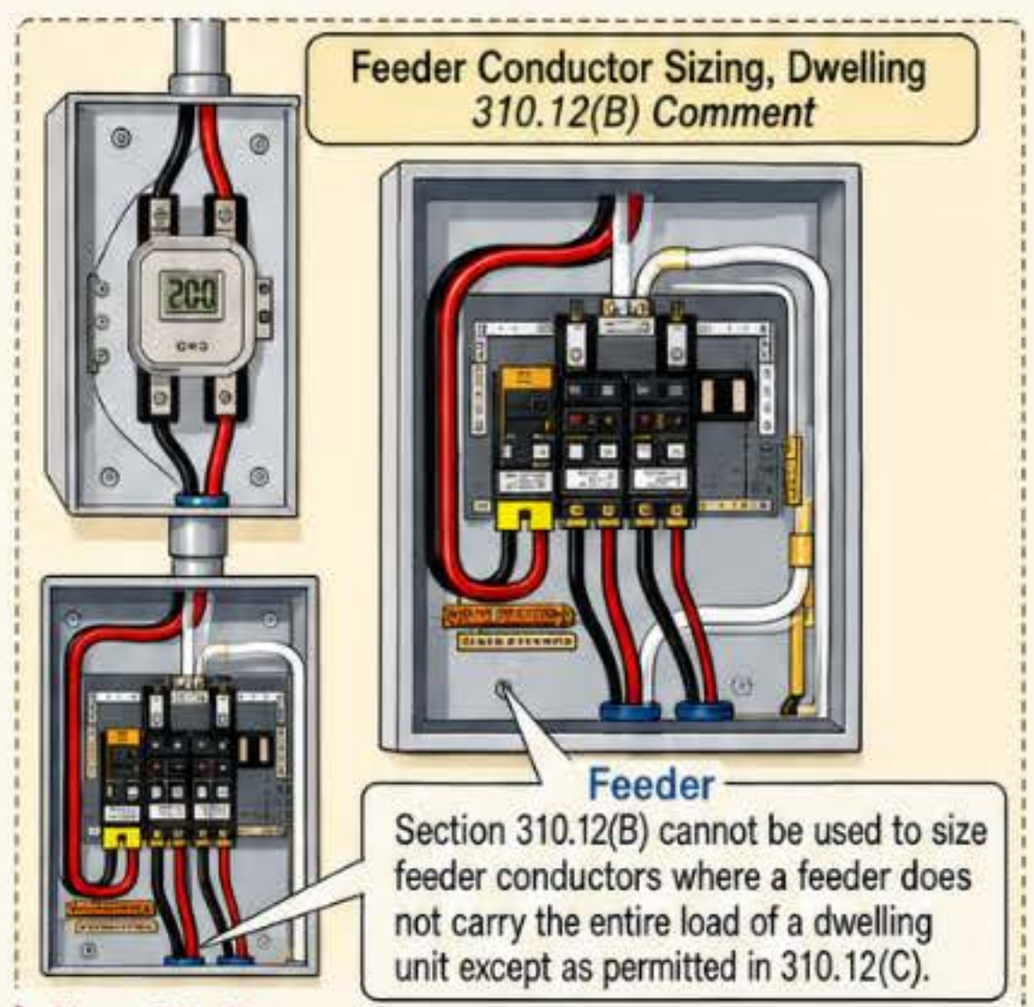
Question: *What size feeder conductors are required if the calculated load for a dwelling unit requires a service disconnect rated 200A, and the feeder conductors carry the entire load of the dwelling unit?* ▶Figure 310–26

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

Answer: *(b) 2/0 AWG (Table 310.12)*

Author's Commentary:

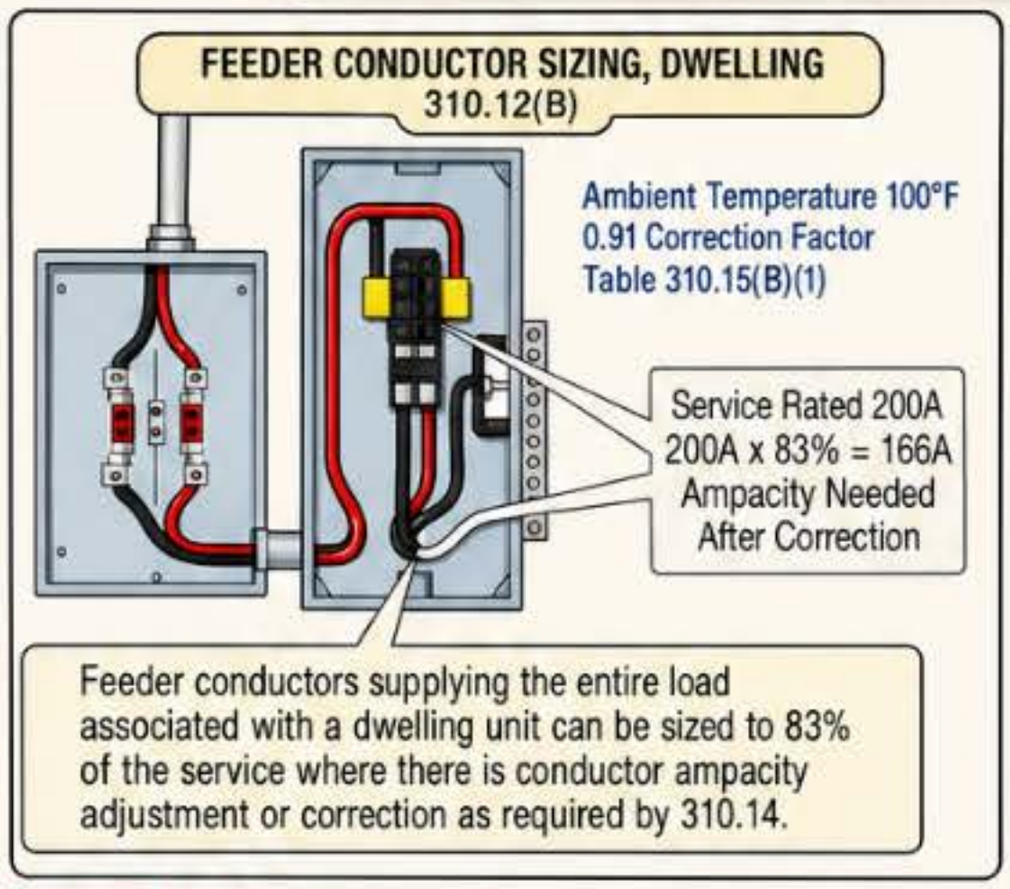
- *Table 310.12 cannot be used to size feeder conductors where a feeder does not carry the entire load of the dwelling unit, except as permitted in 310.12(C).* ▶ Figure 310–27



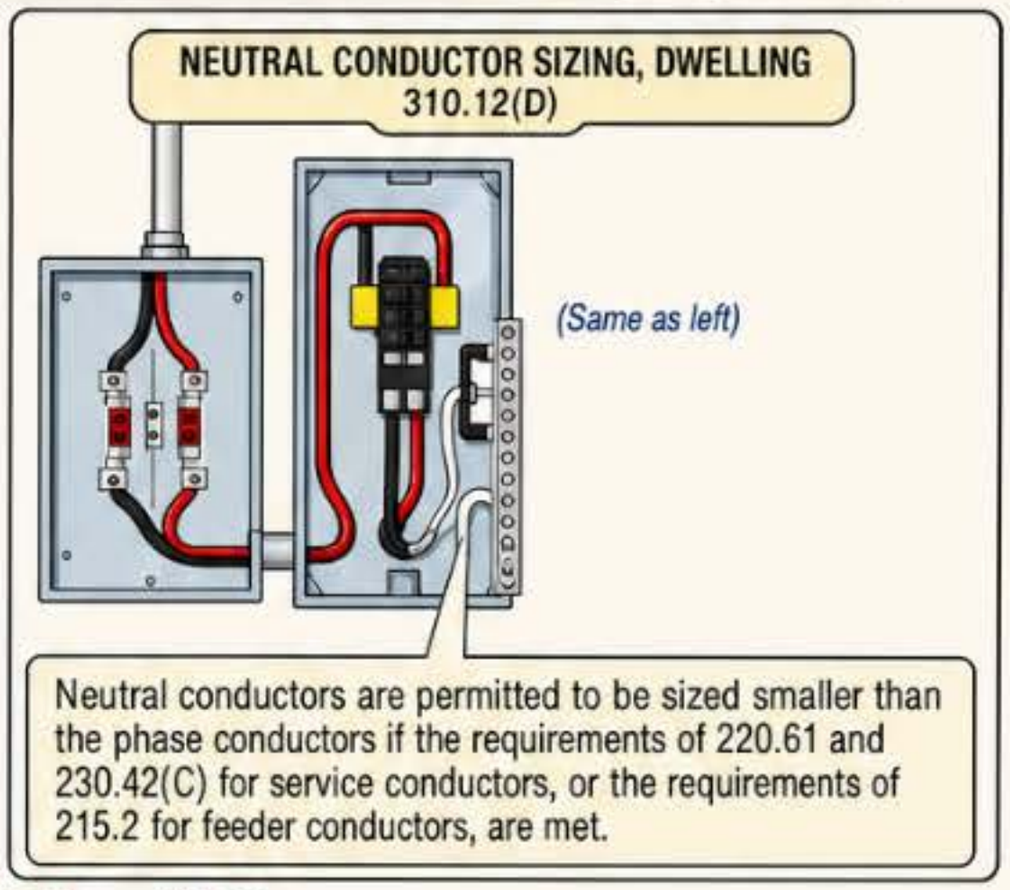
▶ Figure 310–27

Feeder conductors supplying the entire load associated with a dwelling unit can be sized to 83 percent of the service where there is conductor ampactiy adjustment or correction as required by 310.14. ▶Figure 310–28

CONDUCTORS FOR GENERAL WIRING 310.14

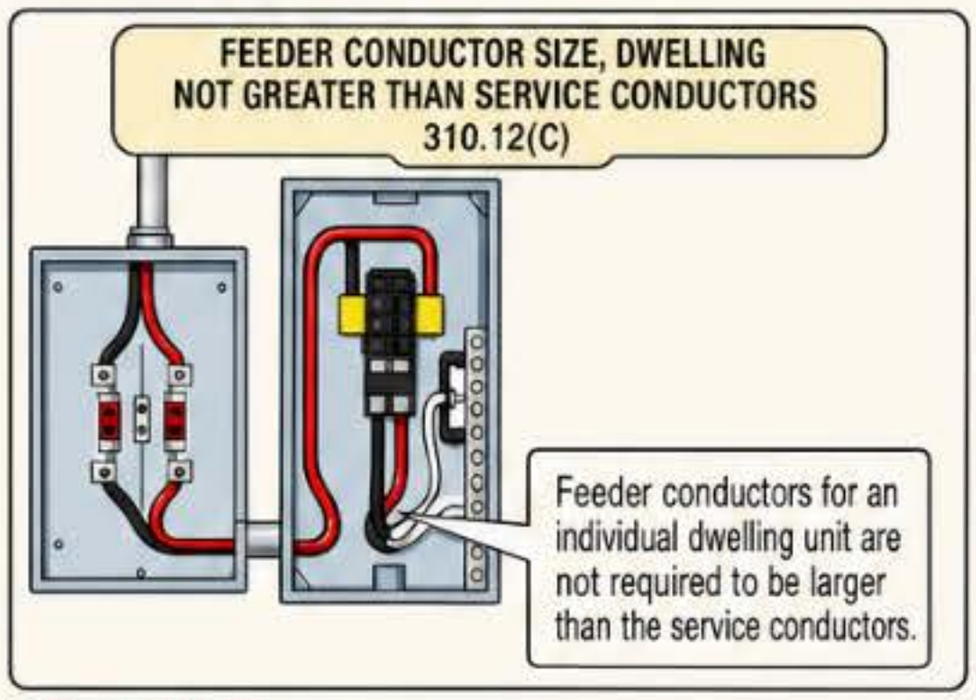


▶ Figure 310-28



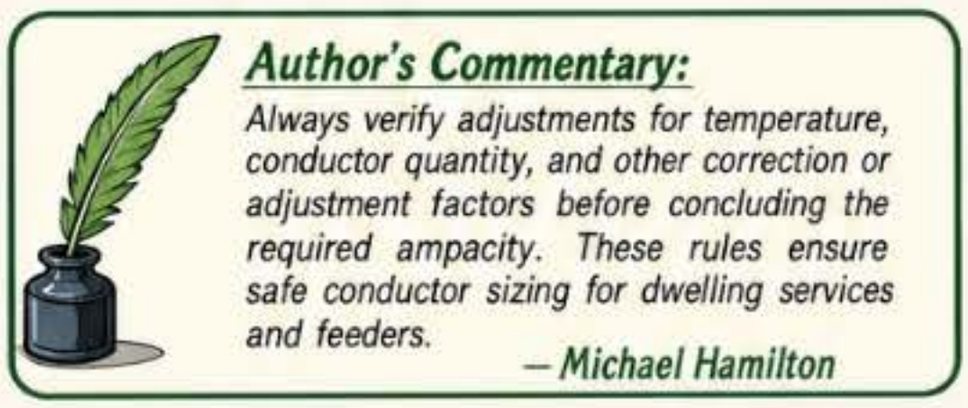
▶ Figure 310-30

(C) Feeder Conductors Not Greater Than Service Conductors. Feeder conductors for an individual dwelling unit sized to Table 310.12 are not required to be larger than the service conductors sized to Table 310.12. ▶ Figure 310-29



▶ Figure 310-29

(D) Neutral Conductors. Neutral conductors are permitted to be sized smaller than the phase conductors in accordance with 220.61 and 230.42 for service conductors, and 215.2 and 220.61 for feeder conductors. ▶ Figure 310-30



Author's Commentary:

Always verify adjustments for temperature, conductor quantity, and other correction or adjustment factors before concluding the required ampacity. These rules ensure safe conductor sizing for dwelling services and feeders.

— Michael Hamilton

TABLE 310.12 SINGLE-PHASE DWELLING SERVICES AND FEEDERS

Service or Feeder Rating	Copper	Aluminum or Copper-Clad Aluminum
100A	4 AWG	2 AWG
110A	3 AWG	1 AWG
125A	2 AWG	1/0 AWG
150A	1 AWG	2/0 AWG
175A	1/0 AWG	3/0 AWG
200A	2/0 AWG	4/0 AWG
225A	3/0 AWG	250 kcmil
250A	4/0 AWG	300 kcmil
300A	250 kcmil	350 kcmil
350A	350 kcmil	500 kcmil
400A	400 kcmil	600 kcmil

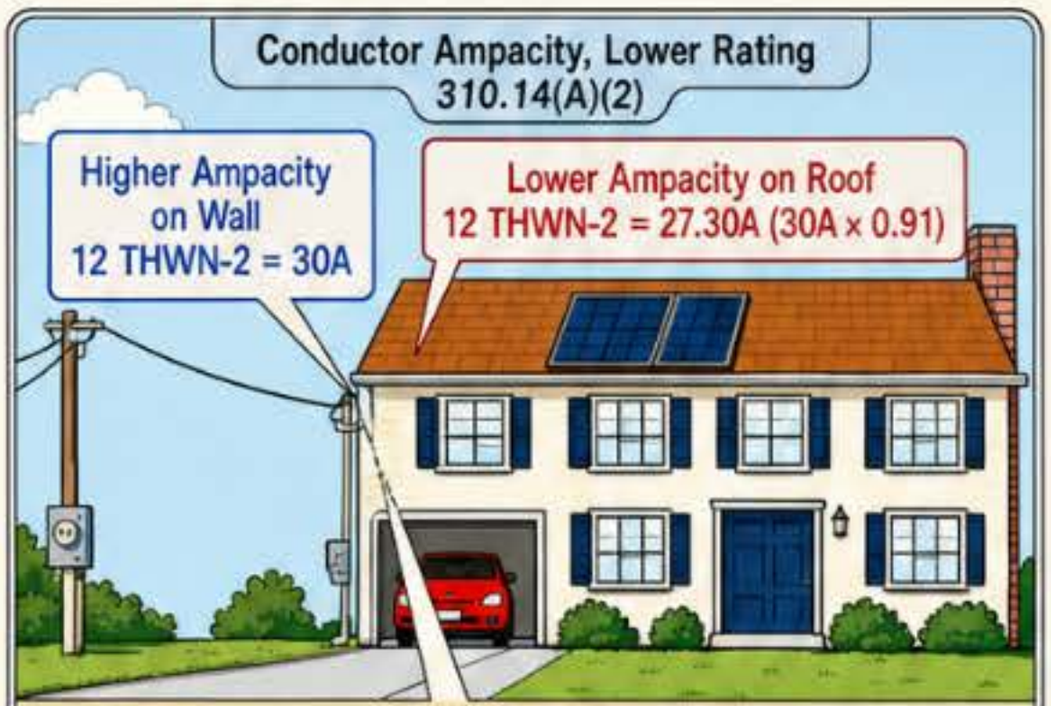
310.14 AMPACITIES FOR CONDUCTORS RATED 0V TO 2,000V

(A) General Requirements

(1) Tables or Engineering Supervision. The ampacity of a conductor can be determined either by using the tables contained in the 2023 *NEC* as corrected and adjusted in accordance with 310.15, or under engineering supervision as provided in 310.14(B).

310.15 | Conductors for General Wiring

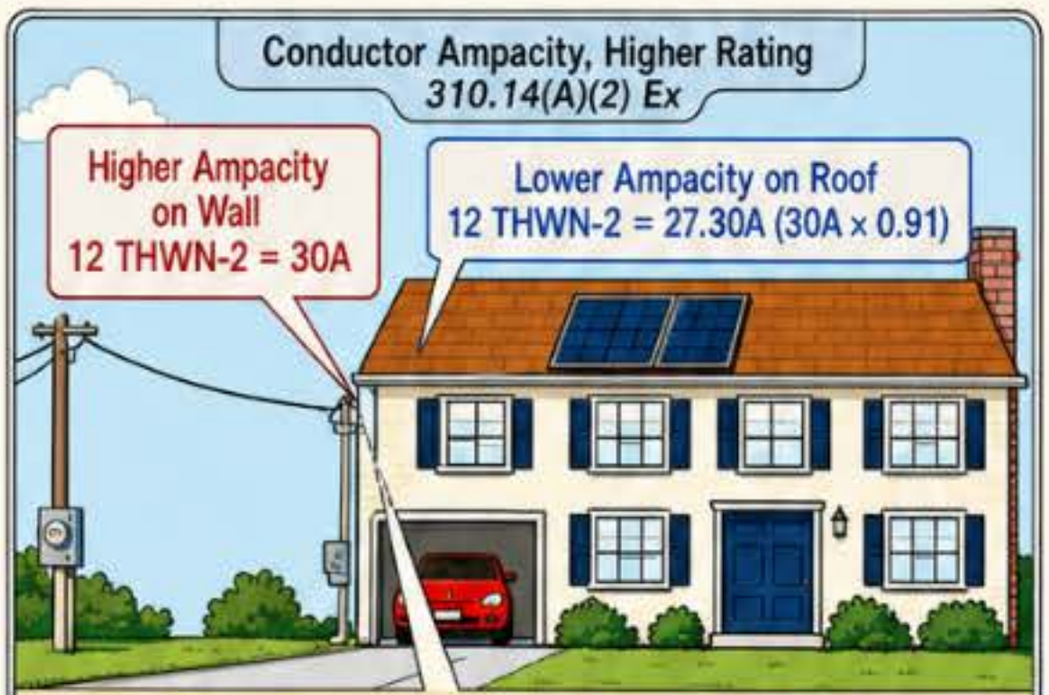
(2) Conductor Ampacity—Lower Rating. When more than one ampacity applies to the same length of conductor for a circuit, the smallest allowable ampacity must be selected for that circuit. **Figure 310–31**



Where more than one ampacity applies for a given circuit length, the lowest ampacity value must be used for the circuit. ***This entire circuit is rated 27.30A.***

Figure 310–31

Ex: *When different ampacities apply to parts of a circuit because of temperature correction [310.15(B)(1)] or conductor bundling [Table 310.15(C)(1)], the higher ampacity can apply for the entire circuit if the length of the lower ampacity does not exceed the lesser of 10 ft or 10 percent of the length of the total circuit.* ***Figure 310–32***



When different ampacities apply to part of a circuit because of temperature correction or conductor adjustment, the higher ampacity can apply for the entire circuit if the length of the lower ampacity does not exceed the lesser of 10 ft or 10% of the length of the total circuit.

Figure 310–32

(3) Insulation Temperature Limitation. *Conductors are not permitted to be used where the operating temperature exceeds that designated for the type of insulated conductor involved.*

Note 1: The insulation temperature rating of a conductor [Table 310.4(A) and Table 311.10(A)] is the maximum temperature a conductor can withstand over a long period without serious degradation. Factors that influence conductor operating temperature include:

(1) Ambient temperature that can vary along the conductor length as well as over time [Table 310.15(B)(1)].

(2) Heat generated internally in the conductor as the result of load current flow.

(3) The rate at which generated heat dissipates into the ambient medium.

(4) Adjacent load-carrying conductors that have the effect of raising the ambient temperature and impeding heat dissipation [Table 310.15(C)(1)].

Author's Commentary:

The insulation temperature rating of a conductor must be restricted to an operating temperature that prevents damage to the conductor's insulation. If the conductor runs excessively warm, the I^2R heating within the conductor can impair its insulation. For this reason, elevated conductor operating temperatures created by current flow in the conductors and conductor bundling might need to be limited.

— Michael Hamilton

310.15 Ampacity Tables

(A) General. Ampacities for conductors are contained in Table 310.16.

The temperature ampacity correction of 310.15(B)(1) and adjustment ampacity factors of 310.15(C)(1) are applied to the ampacities listed in Table 310.16, based on the conductor insulation temperature rating.

Author's Commentary:

The Table 310.16 ampacity must be corrected when the ambient temperature is not between 78°F and 86°F and must be adjusted when more than three current-carrying conductors are bundled together. The temperature correction multiplier [310.15(B)(1)] and adjustment multiplier [310.15(C)(1)] are applied to the conductor ampacity, based on the temperature rating of the conductor insulation as contained in Table 310.16, typically in the 90°C column.

— Michael Hamilton

CONDUCTORS FOR GENERAL WIRING | 310.15

Conductor Ampacity, Correction and Adjustment
310.15(B)(1) and Table 310.15(C)(1) Comment

This raceway contains only **three current-carrying** conductors.

Table 310.16 ampacities are based on an ambient temperature between 78°F and 86°F and no more than three current-carrying conductors bundled together.

Ampacity Correction

If the ambient temperature is below 78°F or above 86°F, the conductor ampacity changes. [Table 310.15(B)(1)].

Ambient Temperature

Ampacity Adjustment

If the number of current-carrying conductors exceeds three, the conductor ampacity decreases [Table 310.15(C)(1)].

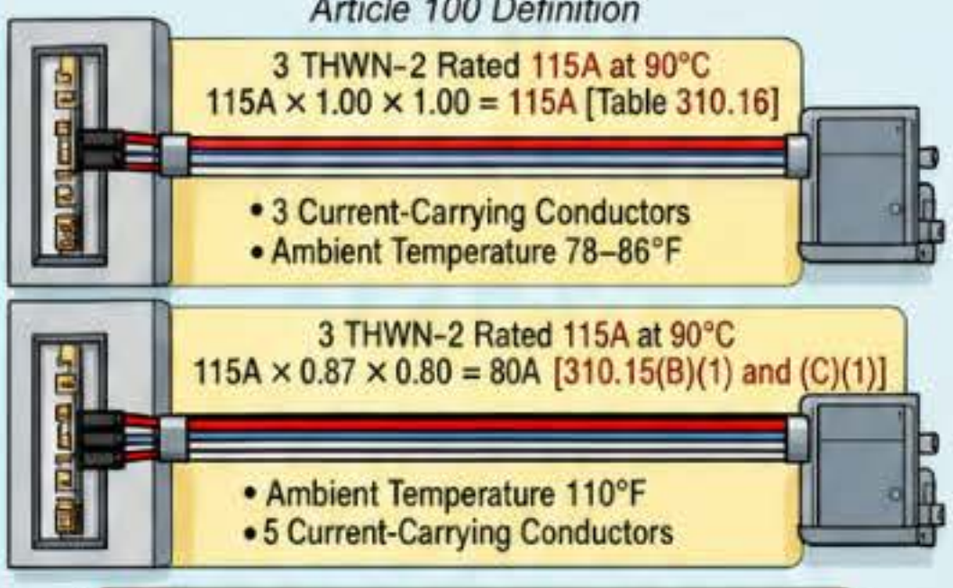
Conductor Bundling

▶ Figure 310-33

Author's Commentary:

- *When correcting or adjusting conductor ampacity, the ampacity is based on the conductor material and its insulation temperature rating as listed in the appropriate column of Table 310.16, not the temperature rating of the terminal [110.14(C)].*
- *According to Article 100, the ampacity of a conductor is the maximum current a conductor can carry continuously, under the conditions of use, without exceeding its temperature rating. — Michael Hamilton*
- *The neutral conductor might be a current-carrying conductor; but only under the conditions specified in 310.15(E). Equipment grounding conductors are never considered current-carrying [310.15(F)]. — Michael Hamilton*

Ampacity
Article 100 Definition



The maximum current, in amperes, a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

▶ Figure 310-34

(B) Ambient Temperature Correction Factors.

(1) General. Ampacities for ambient temperatures other than those shown in the ampacity tables must be corrected in accordance with Table 310.15(B)(1). ▶ Figure 310-35

Ambient Temperature Ampacity Correction
310.15(B)(1)

Ampacities for ambient temperatures other than those shown in the ampacity tables must be corrected in accordance with Table 310.15(B)(1).

▶ Figure 310-35

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F) and 90°C Insulation

Ambient Temperature °F	Ambient Temperature °C	Correction Factor 90°C Conductors
50°F or less	10°C or less	1.15
51–59°F	11–15°C	1.12
60–68°F	16–20°C	1.08
69–77°F	21–25°C	1.04
78–86°F	26–30°C	1.00
87–95°F	31–35°C	0.96
96–104°F	36–40°C	0.91
105–113°F	41–45°C	0.87
114–122°F	46–50°C	0.82
123–131°F	51–55°C	0.76
132–140°F	56–60°C	0.71
141–149°F	61–65°C	0.65
150–158°F	66–70°C	0.58
159–167°F	71–75°C	0.50

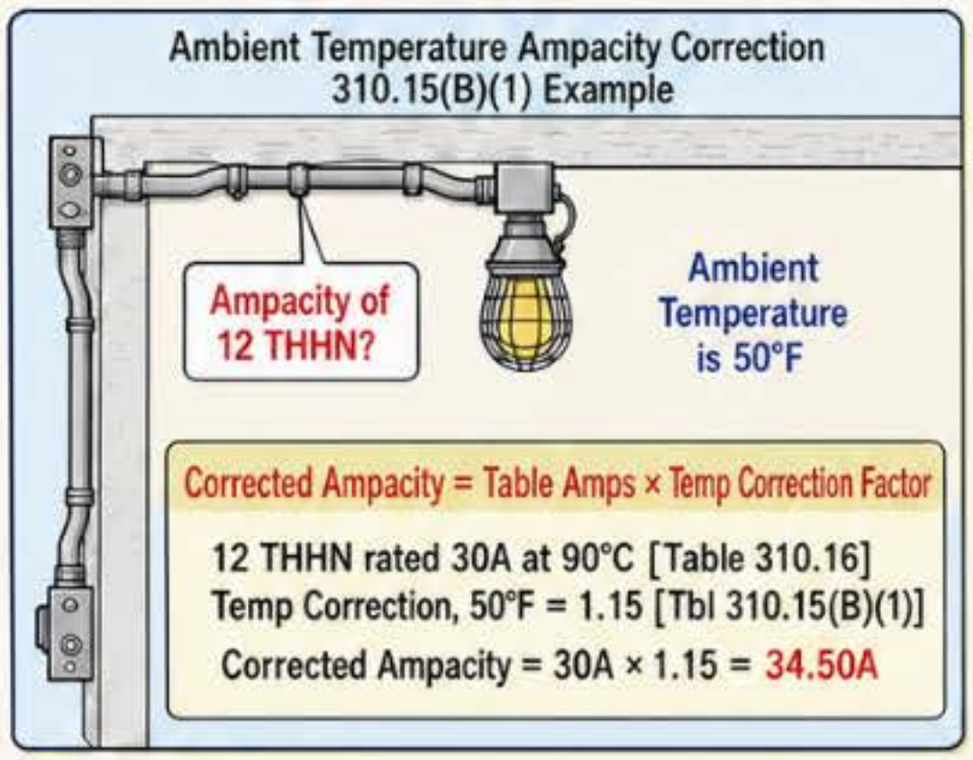
310.15 | Conductors for General Wiring

Corrected Conductor Ampacity—Ambient Temperature Correction
Formula: Corrected Ampacity = Table 310.16 Ampacity × Ambient Correction Factor

▶ Ambient Temperature Below 86°F Example

Question: *What is the ampacity of a 12 THHN conductor when installed in an ambient temperature of 50°F?* ***Figure 310–36***

(a) 20A (b) 25A (c) 31A (d) 35A



▶ Figure 310–36

Solution:

The conductor ampacity for 12 THHN is 30A at 90°C [Table 310.16].

The correction factor for a 90°C conductor installed in an ambient temperature of 50°F is 1.15 [Table 310.15(B)(1)].

Corrected Ampacity = 30A × 1.15
Corrected Ampacity = 34.50A; round to 35A

Note: *Ampacity increases when the ambient temperature is less than 86°F.*

Answer: *(d) 35A*

▶ Ambient Temperature Above 86°F Example

Question: *What is the ampacity of a 6 THWN-2 conductor installed in an ambient temperature of 122°F?* ***Figure 310–37***

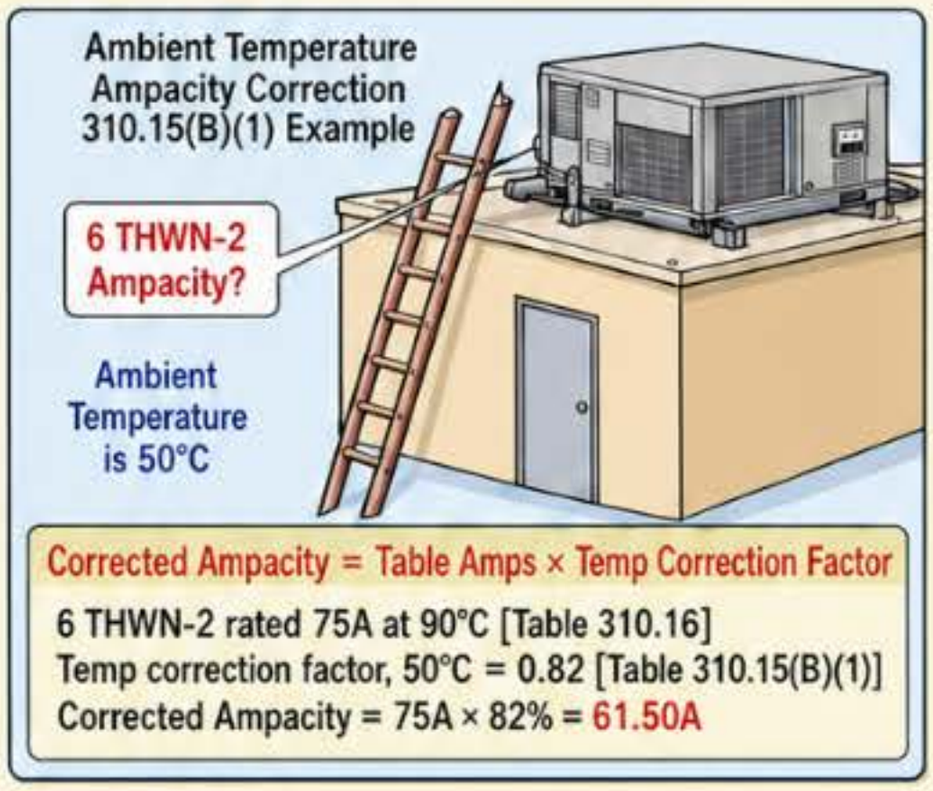
(a) 35A (b) 53A (c) 62A (d) 75A

Solution:

The conductor ampacity for 6 THWN-2 is 75A at 90°C [Table 310.16].

The correction factor for a 90°C conductor installed in an ambient temperature of 122°F is 0.82 [Table 310.15(B)(1)].

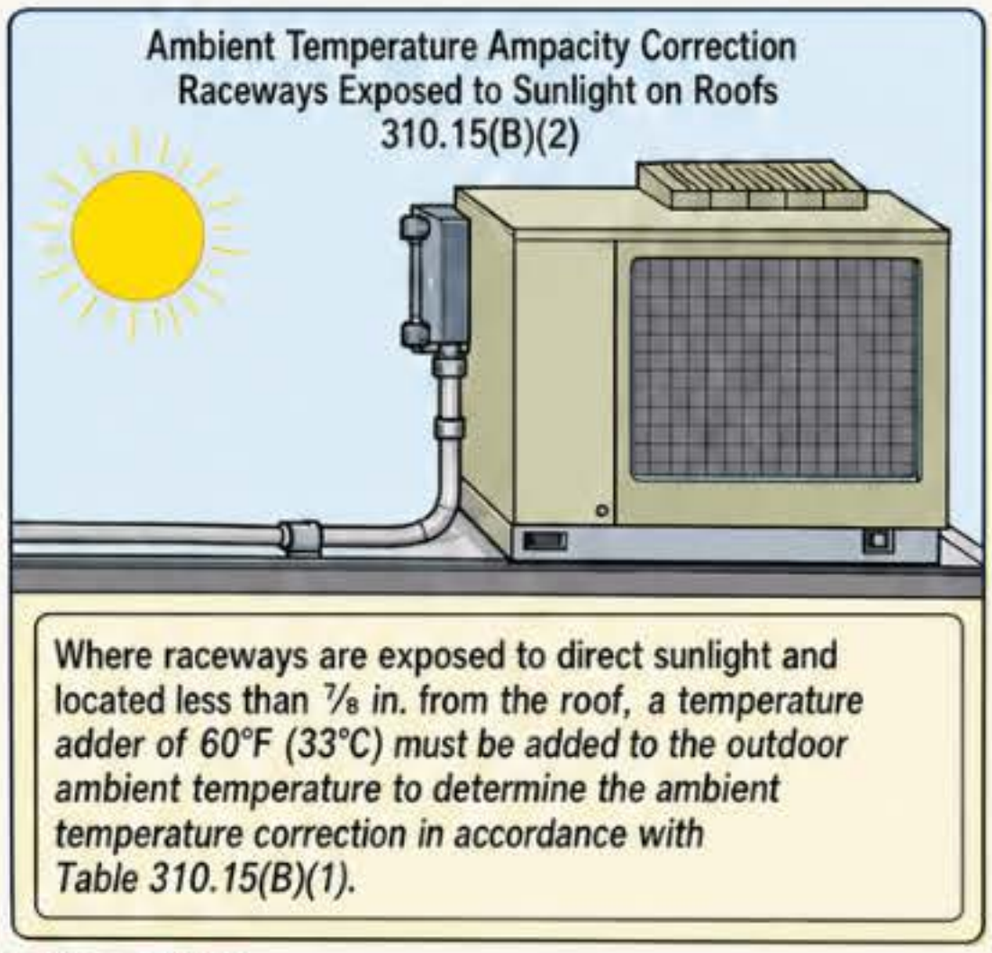
Corrected Ampacity = 75A × 82%
Corrected Ampacity = 61.50A; round to 62A



▶ Figure 310–37

Answer: *(c) 62A*

(2) Raceways and Cables Exposed to Sunlight on Rooftops. Where raceways or cables are exposed to direct sunlight and located less than ⅞ *in. above the roof, a temperature adder of 60°F (33°C) must be added to the outdoor ambient temperature to determine the ambient temperature correction in accordance with Table 310.15(B)(1).* ***Figure 310–38***



▶ Figure 310–38

DEFINITIONS | From Michael Hamilton Publications

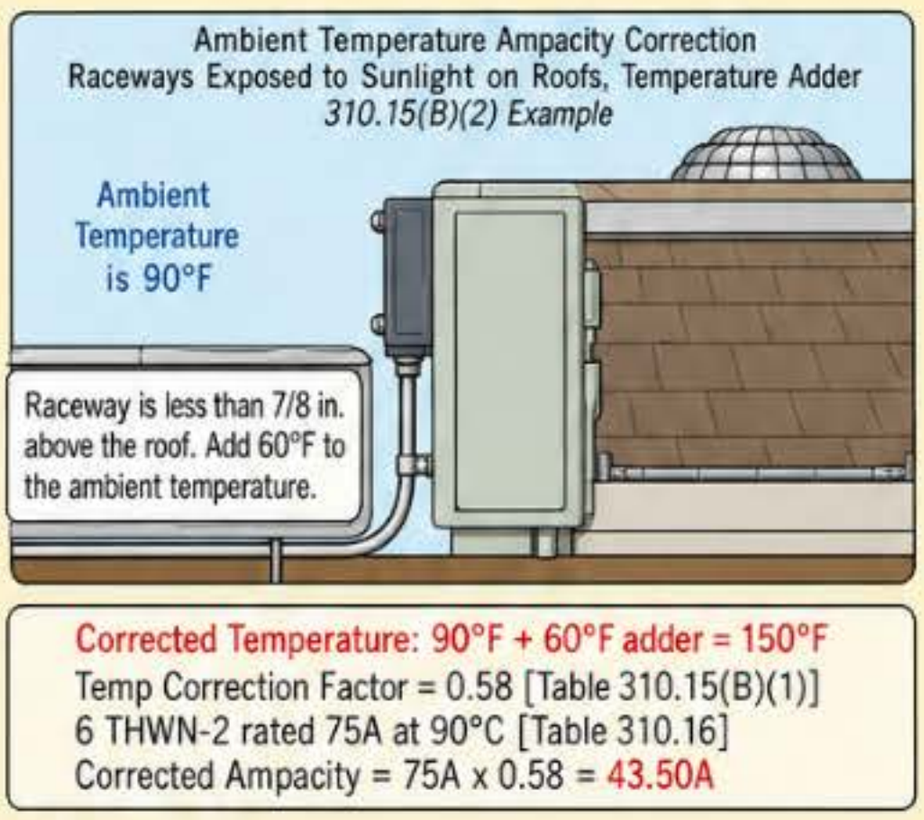
Author's Commentary:
The purpose of the temperature adder is to account for the fact that air inside raceways and cables that are exposed to direct sunlight becomes much hotter than the surrounding air.

— *Michael Hamilton*

▶ Example

Question: *What is the ampacity of a 6 THWN-2 in a raceway situated ½ in. above the roof, where the surrounding temperature is 90°F?*

(a) 40A (b) 41A (c) 42A (d) 44A



◀ Figure 310–39

Solution:

Corrected Temperature = 90°F + 60°F adder
Corrected Temperature = 150°F

The temperature correction factor for 150°F = 0.58 [Table 310.15(B)(1)]

6 THWN-2 is rated 75A at 90°C [Table 310.16]

Corrected Ampacity = 75A x 58%
Corrected Ampacity = 43.50A; round to 44A

Answer: *(d) 44A*

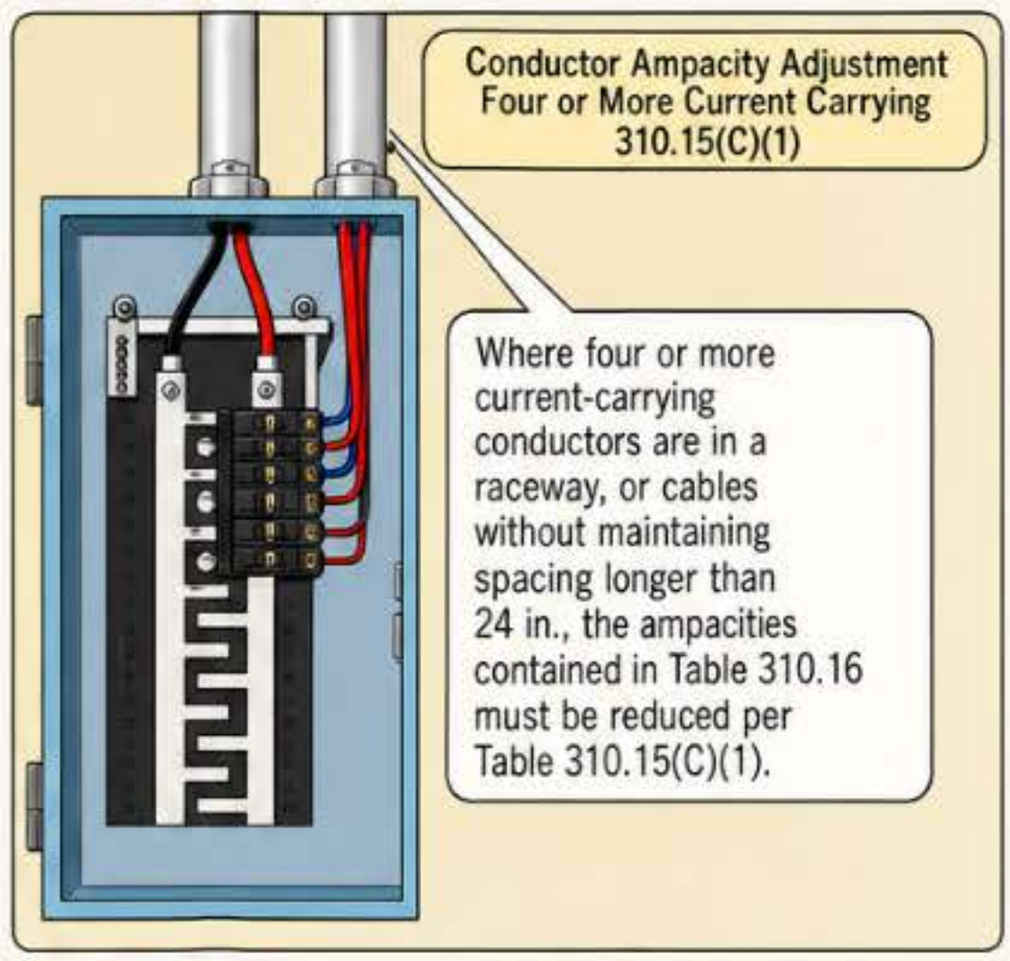
Ex: *Type XHHW-2 insulated conductors are not subject to the rooftop temperature adder.*

Note 1: *See the ASHRAE Handbook—Fundamentals (www.ashrae.org) as a source for the ambient temperatures in various locations.*

(C) Conductor Bundle Adjustment.

(1) Four or More Current-Carrying Conductors. Where four or more current-carrying conductors are contained in a raceway that is longer than 24 in., the ampacities contained in Table 310.16 must be reduced in accordance with Table 310.15(C)(1).

Where multiconductor cables are installed without maintaining spacing for a continuous length longer than 24 in., the ampacities contained in Table 310.16 must be reduced in accordance with Table 310.15(C)(1). ▶ Figure 310–40



◀ Figure 310–40

Author's Commentary:
The neutral conductor may be a current-carrying conductor, but only under the conditions specified in 310.15(E). Equipment grounding conductors are never treated as current-carrying [310.15(F)].

— *Michael Hamilton*

Table 310.15(C)(1) Conductor Ampacity Adjustment for More Than Three Current-Carrying Conductors

Number of Conductors[1]	Adjustment
4–6	80%
7–9	70%
10–20	50%
21–30	45%
31–40	40%
41 and above	35%

[1] *Does not include conductors that cannot be energized at the same time.*

310.15 | Conductors for General Wiring

Author's Commentary:

- Ampacity must be adjusted downward any time four or more current-carrying conductors share a raceway or cable. Heat cannot escape as easily when crowded, so the current each conductor can safely carry must be reduced. When there are fewer than four current-carrying conductors, no adjustment is needed.

— *Michael Hamilton*

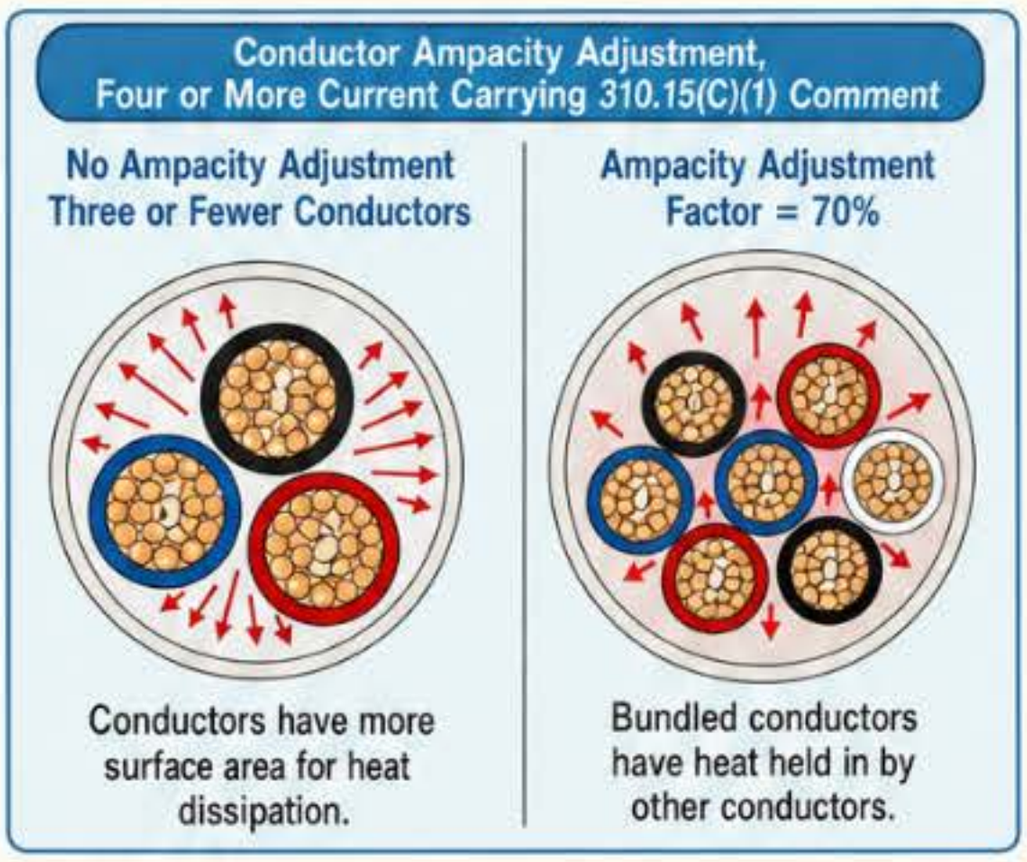


Figure 310–41

▶ Ampacity Adjustment Example 1

Question: *What is the adjusted ampacity of four current-carrying 12 THWN-2 conductors in a raceway?* ▶ **Figure 310–42**

(a) 20A *(b) 24A* *(c) 29A* *(d) 32A*

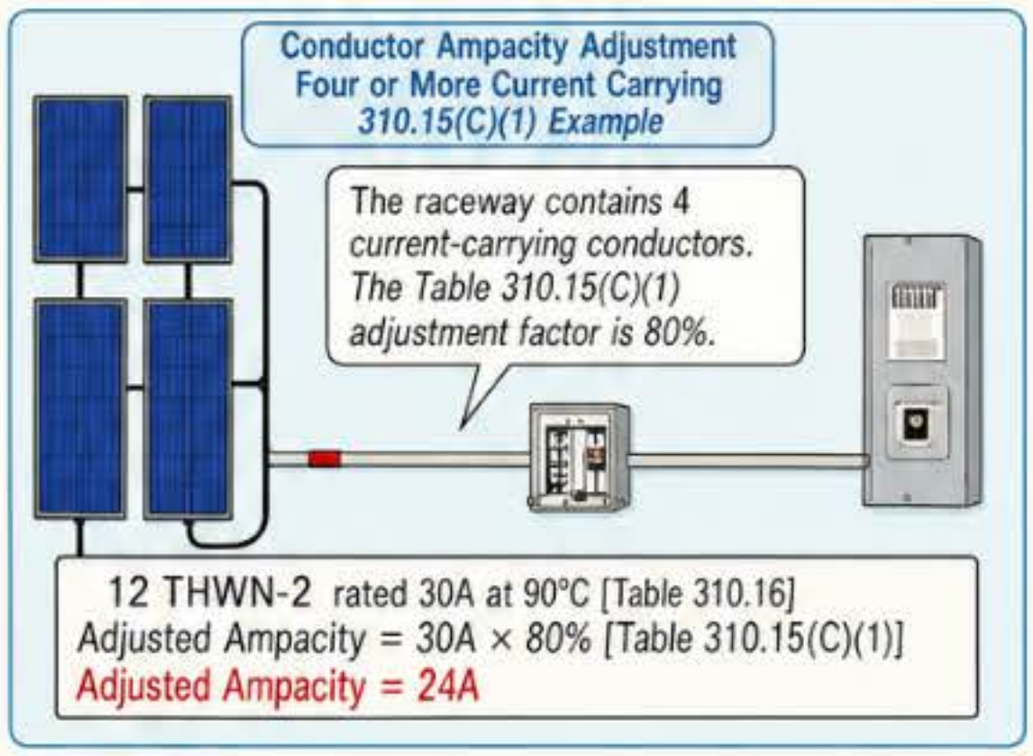


Figure 310–42

Solution:

Adjusted Ampacity = Table 310.16 Ampacity × Bundled Ampacity Adjustment Factor from Table 310.15(C)(1)

12 THWN-2 is rated 30A at 90°C [Table 310.16].

The adjustment factor for four current-carrying conductors is 80 percent [Table 310.15(C)(1)].

Adjusted Ampacity = 30A × 80%

Adjusted Ampacity = 24A

Answer: *(b) 24A*

▶ Ampacity Adjustment Example 2

Question: *What is the adjusted ampacity of eight current-carrying 12 THWN-2 conductors in a raceway?* ▶ **Figure 310–43**

(a) 16A *(b) 21A* *(c) 35A* *(d) 43A*

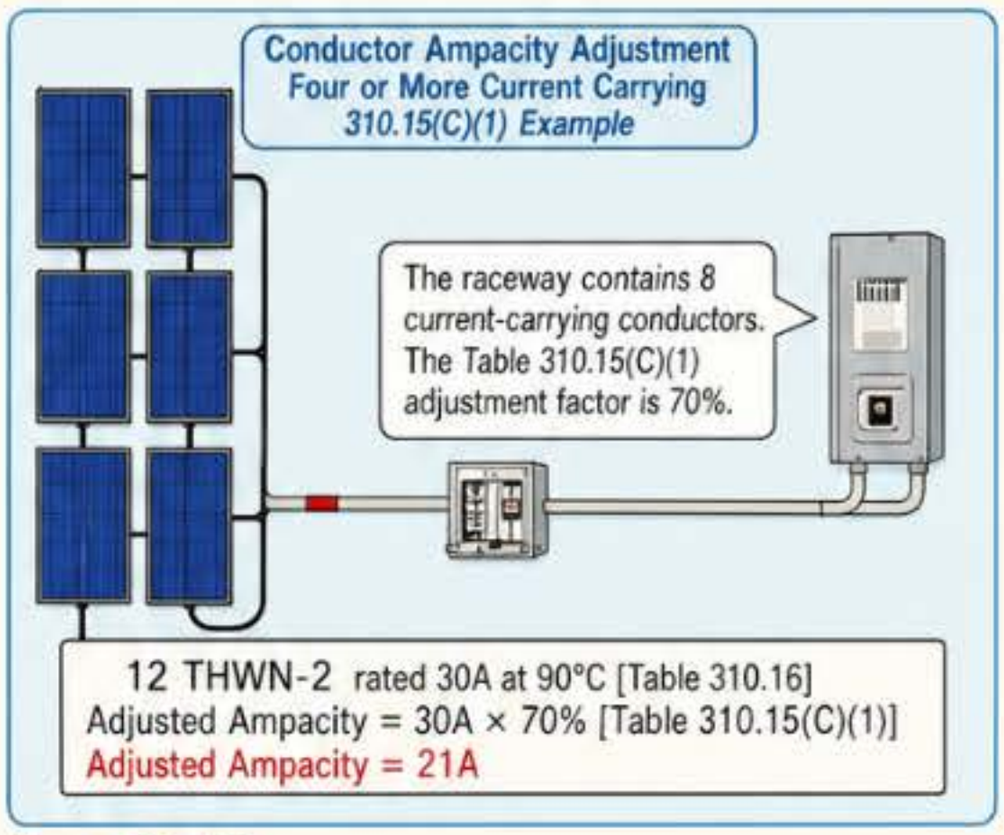


Figure 310–43

Solution:

Adjusted Ampacity = Table 310.16 Ampacity × Bundled Ampacity Adjustment Factor from Table 310.15(C)(1)

12 THWN-2 is rated 30A at 90°C [Table 310.16].

The adjustment factor for eight current-carrying conductors is 70 percent [Table 310.15(C)(1)].

Adjusted Ampacity = 30A × 70%

Adjusted Ampacity = 21A

Answer: *(b) 21A*

Conductors for General Wiring | 310.15

(a) Cable tray installations must comply with 392.80 wherever conductors are routed.

(b) The conductor ampacity adjustment values from Table 310.15(C)(1) are inapplicable for raceway installations in which the wiring length does not exceed 24 in. ▶ **Figure 310–44**

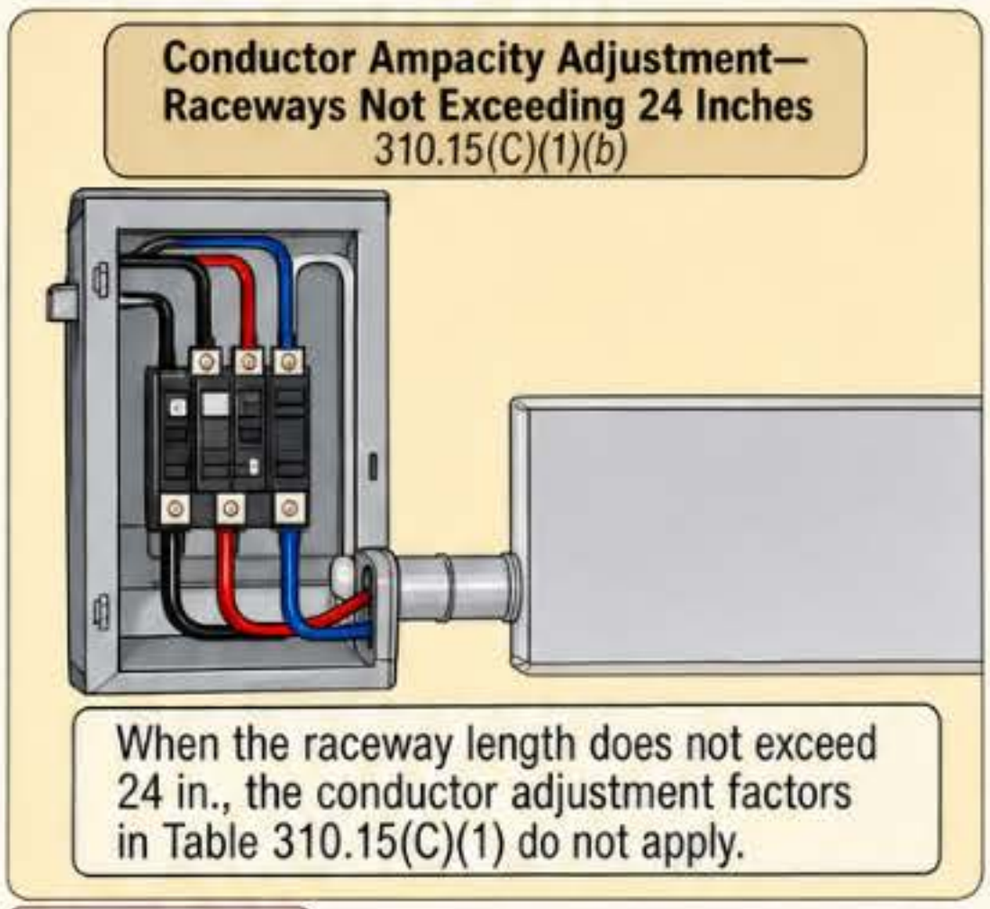


Figure 310–44

▶ Ampacity Adjustment—Raceway Not Exceeding 24 In. Example

Question: *What is the allowable ampacity of five 3/0 THWN-2 conductors in a raceway that does not exceed 24 in. in length?* ▶ **Figure 310–45**

(a) 150A (b) 195A (c) 205A (d) 225A

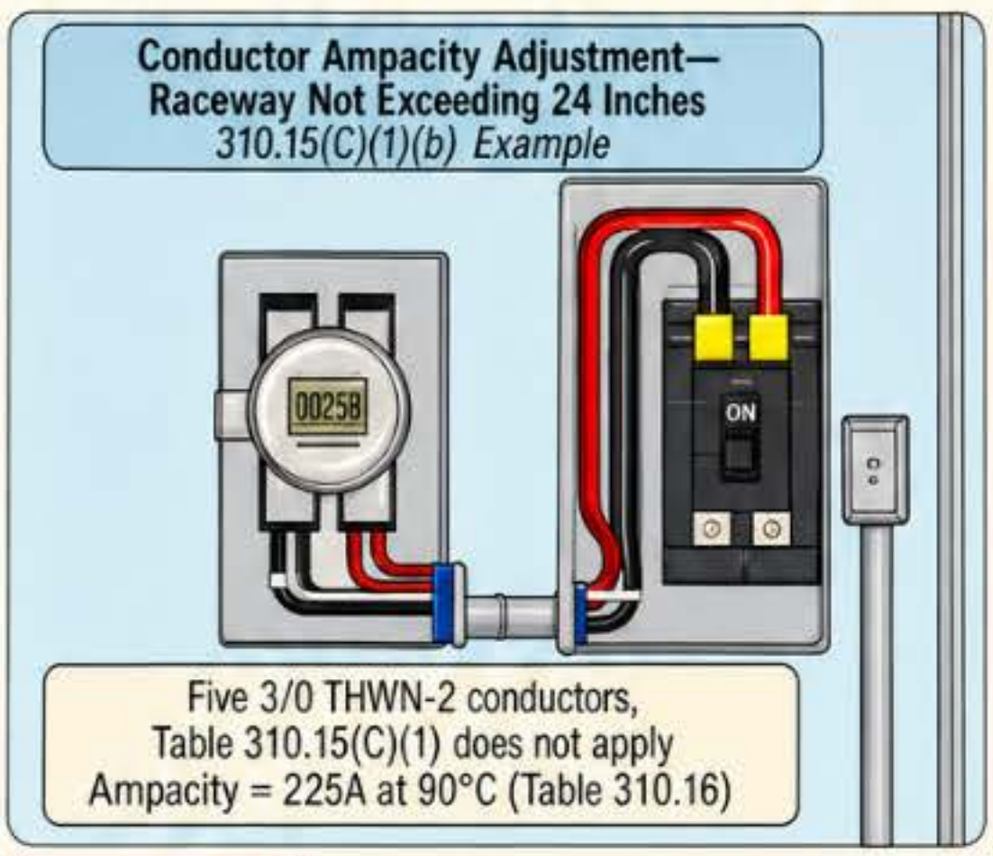


Figure 310–45

Solution:
3/0 THWN-2 is rated for 225A at 90°C (Table 310.16).
Answer: *(d) 225A*

(d) The conductor ampacity adjustment values from Table 310.15(C)(1) do not apply to Type AC or Type MC cable under the following conditions: ▶ **Figure 310–46**

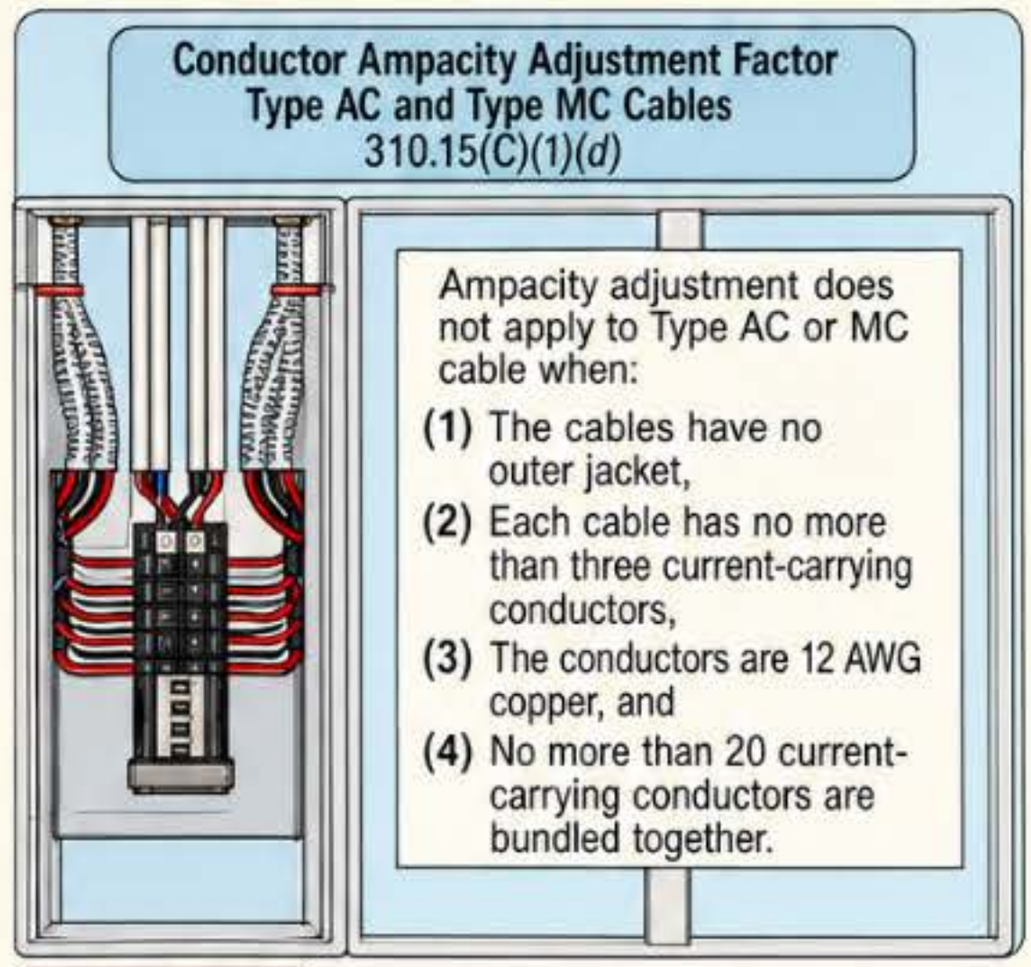


Figure 310–46

(1) The cables do not have an outer jacket.

(2) Each cable contains no more than three current-carrying conductors.

(3) The conductors are 12 AWG copper.

(4) No more than 20 current-carrying conductors *(ten 2-wire cables or six 3-wire cables) are bundled together.*

Example: *A 60 percent adjustment factor may be applied if more than 20 current-carrying conductors are bundled together in these cables.*

(E) Neutral Conductor. *Neutral conductors must be treated as current-carrying conductors in line with the following rules.*

(1) Not Considered Current Carrying. *The neutral conductor in a 3-wire, single-phase, 120/240V system, or in a 4-wire, three-phase, 120/208V or 277/480V wye-connected system, is not a current-carrying conductor for the purpose of applying conductor ampacity adjustment factors as specified in Table 310.15(C)(1).* ▶ ***Figure 310–47***

310.15 Conductors for General Wiring

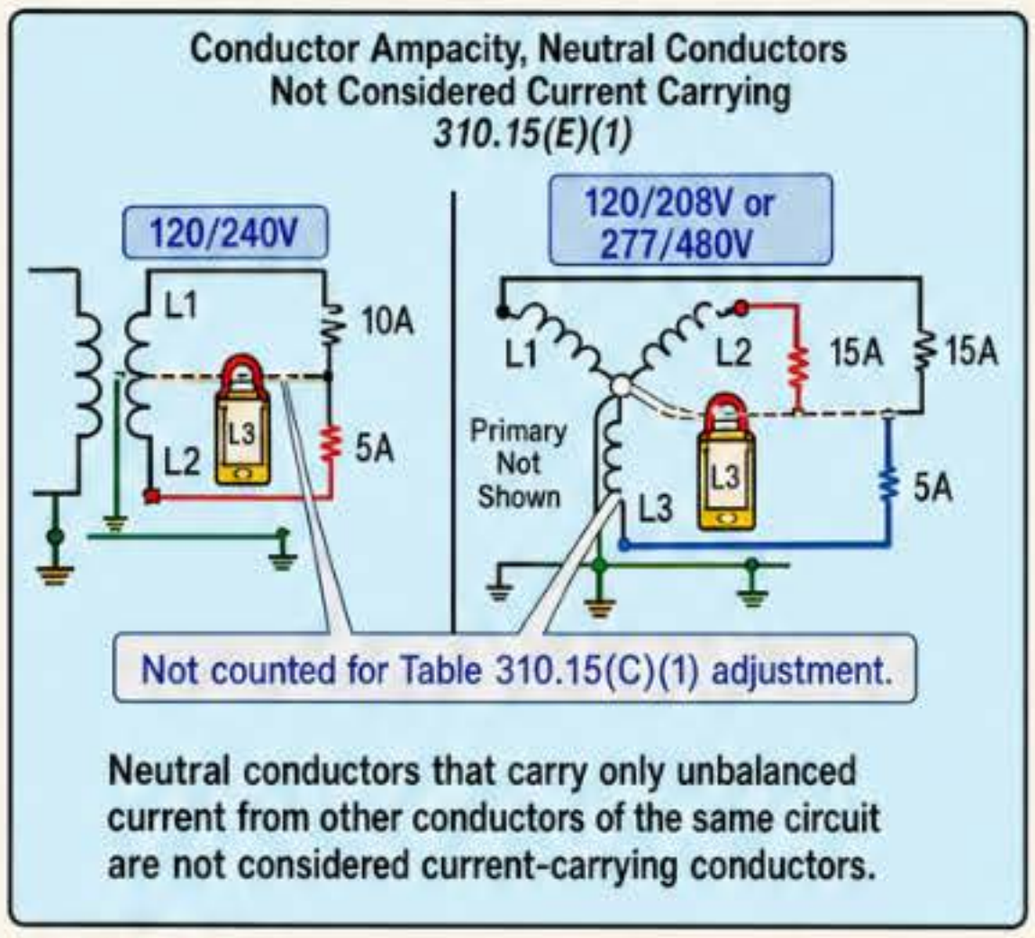


Figure 310-47

(2) Considered Current Carrying. The neutral conductor of a 3-wire circuit from a 4-wire, three-phase, wye-connected system carries approximately the same current as the line-to-neutral load currents of the other conductors and is considered a current-carrying conductor for conductor ampacity adjustments in accordance with Table 310.15(C)(1). • Figure 310-48

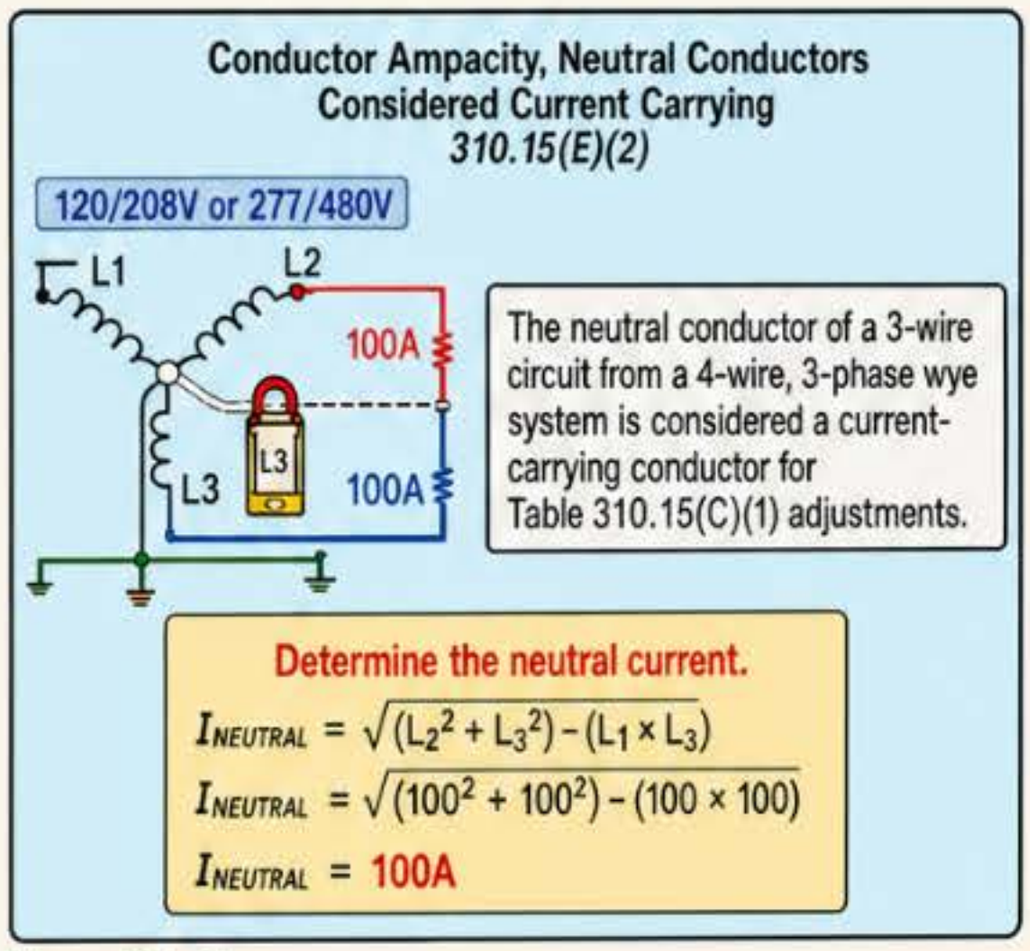


Figure 310-48

Unbalanced 3-Wire Wye Secondary Neutral Current Formula:

$I_{Neutral} = \sqrt{(I_{Line1}^2 + I_{Line2}^2) - (I_{Line1} \times I_{Line2})}$

► Neutral Conductor Current Example

Question: *What is the neutral current for two 16A, 120V circuits? The system is a 120/208V, three-phase, 4-wire, wye-connected system.* • **Figure 310-49**

(a) 8A *(b) 16A* *(c) 32A* *(d) 40A*

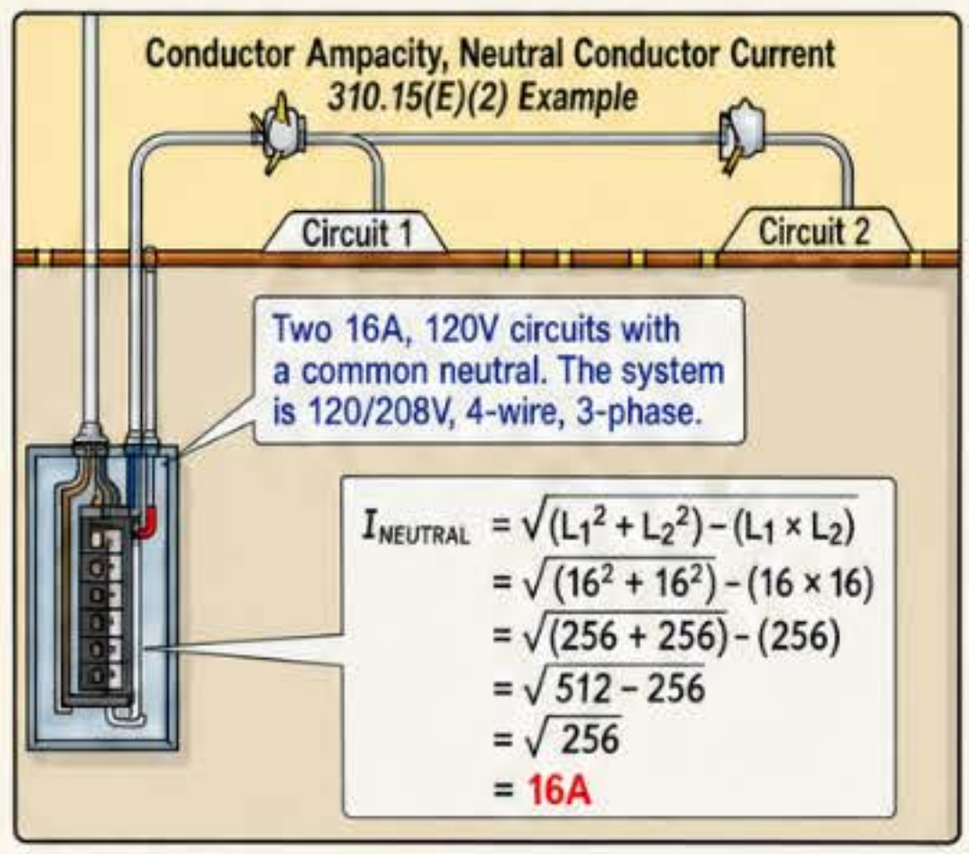


Figure 310-49

Solution:

$I_{NEUTRAL} = \sqrt{(I_{LINE1}^2 + I_{LINE2}^2) - (I_{LINE1} \times I_{LINE2})}$

$I_{NEUTRAL} = \sqrt{(16^2 + 16^2) - (16 \times 16)}$

$I_{NEUTRAL} = \sqrt{(512 - 256)}$

$I_{NEUTRAL} = \sqrt{256}$

$I_{NEUTRAL} = 16A$

Answer: *(b) 16A*

(3) Considered Current Carrying. *On a 4-wire, 3-phase, wye circuit where the major portion of the load consists of nonlinear loads, the neutral conductor is considered a current-carrying conductor for conductor ampacity adjustments in accordance with Table 310.15(C)(1).* • **Figure 310-50**

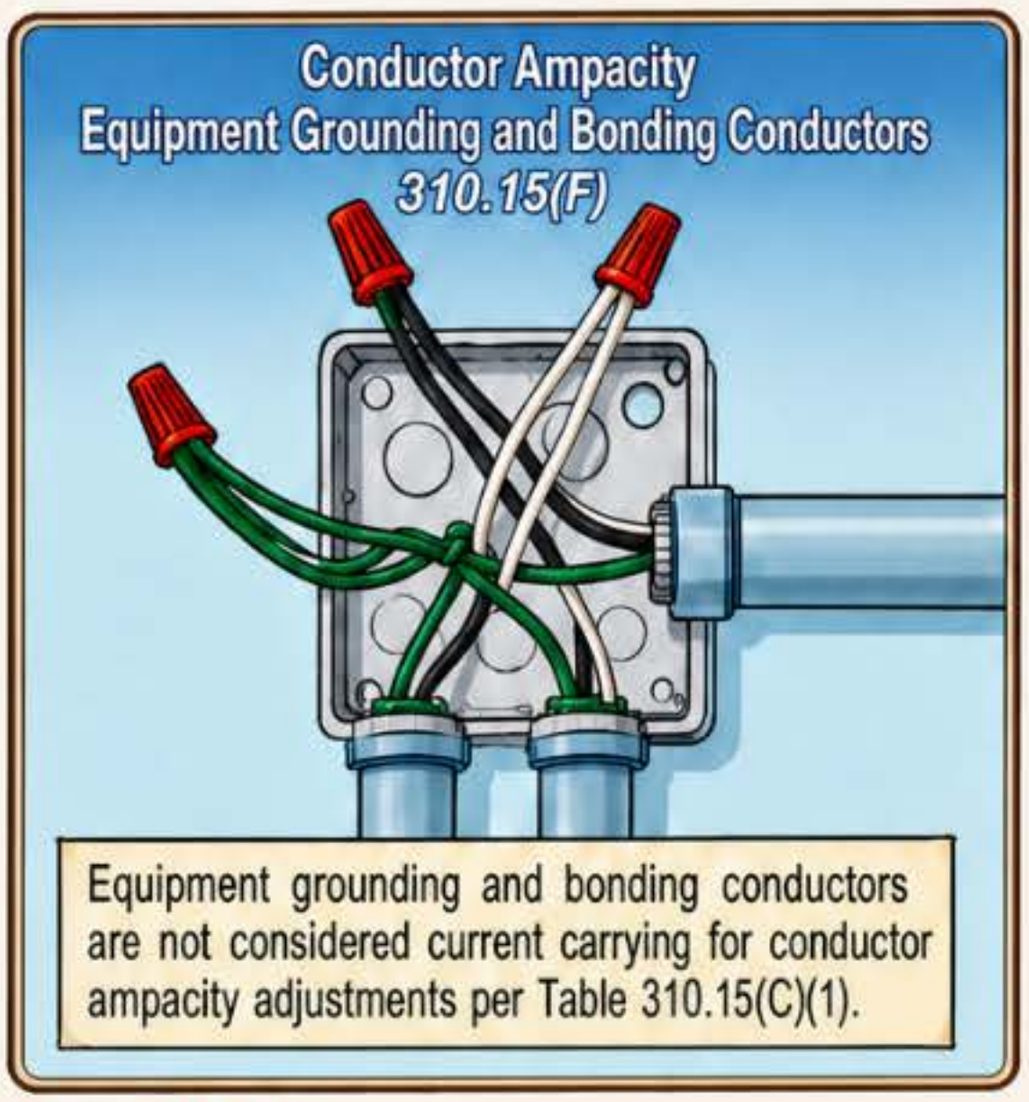
Author's Commentary:

According to Article 100, a "Nonlinear Load" is a load where the current waveform does not follow the applied sinusoidal voltage waveform.

— Michael Hamilton

(F) Equipment Grounding and Bonding Conductor. Equipment grounding and bonding conductors are not considered current carrying for conductor ampacity adjustments in accordance with Table 310.15(C)(1). • **Figure 310-51**

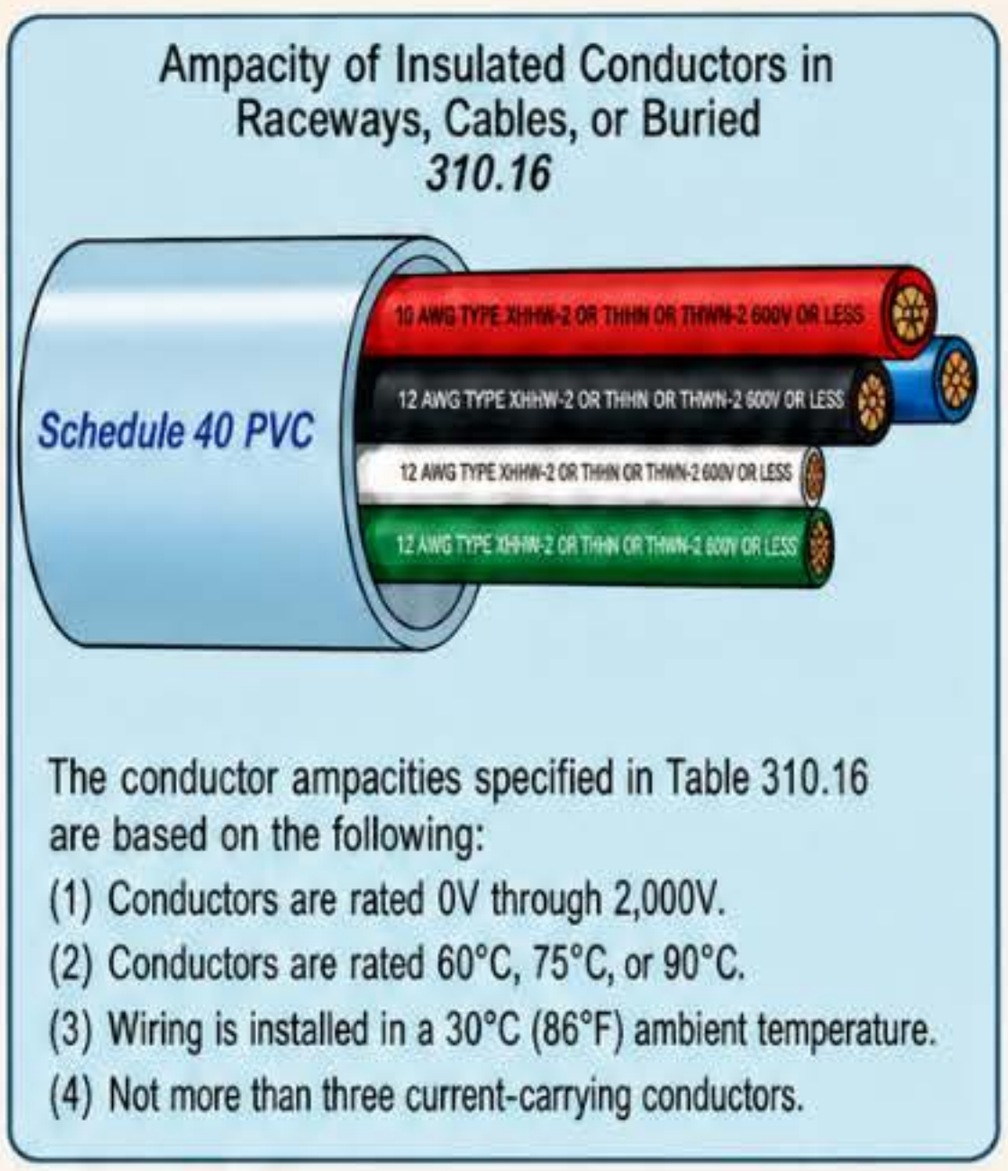
▶ Figure 310–50



▶ Figure 310–51

310.16 Ampacities of Insulated Conductors in Raceways, Cables, or Buried

The conductor ampacities specified in Table 310.16 are based on the following conditions: ▶ Figure 310–52



▶ Figure 310–52

(1) Conductors are rated 0V through 2,000V.

(2) Conductors are rated 60°C (140°F), 75°C (167°F), or 90°C (194°F).

(3) Wiring is installed in a 30°C (86°F) ambient temperature.

(4) There are not more than three current-carrying conductors.

310.16 | Conductors for General Wiring

Table 310.16 Ampacities of Insulated Conductors Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

Copper							Aluminum				
	60°C (140°F)	75°C (167°F)		90°C (194°F)			60°C (140°F)	75°C (167°F)		90°C (194°F)		
Size AWG kcmil	TW UF	RHW THW XHHW	THHW THWN USE	RHH THHW USE-2	RHW-2 THW-2 XHHW	THHN THWN-2 XHHW-2	TW UF	THHW THWN	THWN XHHW	THHN THWN-2 XHHW	THW-2 THHW XHHW-2	Size AWG kcmil
14	15	20		25			15	20		25		12
12	20	25		30			25	30		35		10
10	30	35		40			35	40		45		8
8	40	50		55			40	50		55		6
6	55	65		75			55	65		75		4
4	70	85		95			65	75		85		3
3	85	100		115			75	90		100		2
2	95	115		130			85	100		115		1
1	110	130		145			100	120		135		1/0
1/0	125	150		170			115	135		150		2/0
2/0	145	175		195			130	155		175		3/0
3/0	165	200		225			150	180		205		4/0
4/0	195	230		260			170	205		230		250
250	215	255		290			195	230		260		300
300	240	285		320			210	250		280		350
350	260	310		350			225	270		305		400
400	280	335		380			260	310		350		500
500	320	380		430								

Notes:

1. *Section 310.15(B) must be referenced for the ampacity correction factors where the ambient temperature is other than 30°C (86°F).*
2. *Section 310.15(C)(1) must be referenced for more than three current-carrying conductors.*
3. *Section 310.16 must be referenced for conditions of use.*

Author's Commentary:

Use this table when three or fewer current-carrying conductors share a raceway, cable, or are buried directly in the earth. First, find the conductor size in the outer columns, then move across to the insulation type and temperature rating you're using. The number where they intersect is the allowable ampacity in amperes.

— Michael Hamilton

ARTICLE 312 CABINETS

Introduction to Article 312—Cabinets

The rules in this article govern how cabinets are selected and used to enclose electrical equipment. The location where a cabinet is installed can make a big difference. For example, cabinets are not allowed in places that are damp or where they might be exposed to water.

Every enclosure must meet the needs of the environment in which it is placed, no matter how it will be used. For instance, openings must be sealed and conductors protected from damage, moisture, and other hazards. Cabinets must also be able to withstand the physical stress caused by the conductors they contain.

Article 408 covers switchboards, switchgear, and panelboards, with a focus on the interior (or "guts"), while Article 312 covers only the cabinet or outer shell (the "box") used to hold the panelboard. Important points such as wire-bending space at the terminals of panelboards are included in this article.

Part I. Scope and Installation

312.1 Scope

Article 312 sets out the requirements for installing and building cabinets that enclose panelboards, cutout boxes, and meter cans. ▶ Figure 312-1

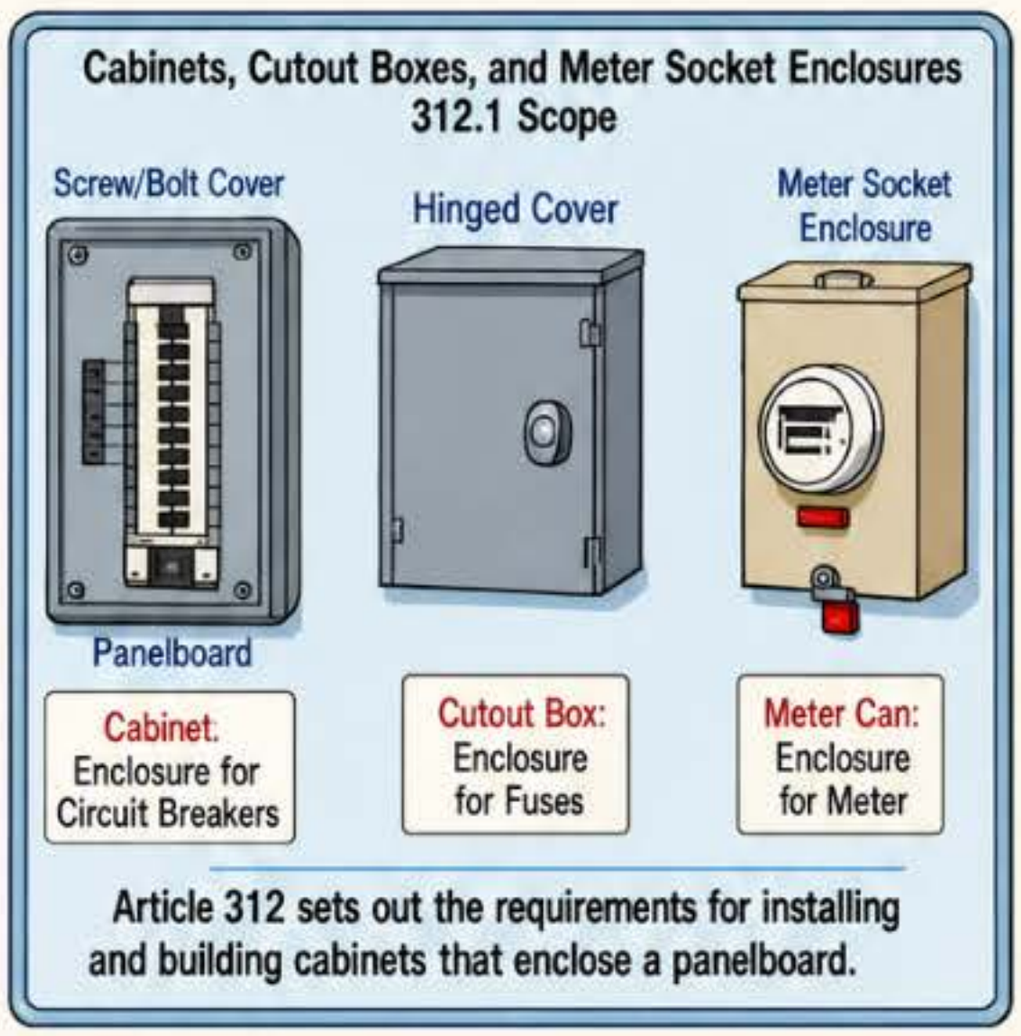


Figure 312-1

312.2 Damp or Wet Locations

Cabinets placed in damp or wet areas must be built to keep moisture out.

Raceways or cables that enter a weatherproof enclosure above the level of any uninsulated live parts must use fittings approved for wet locations. ▶ Figure 312-2

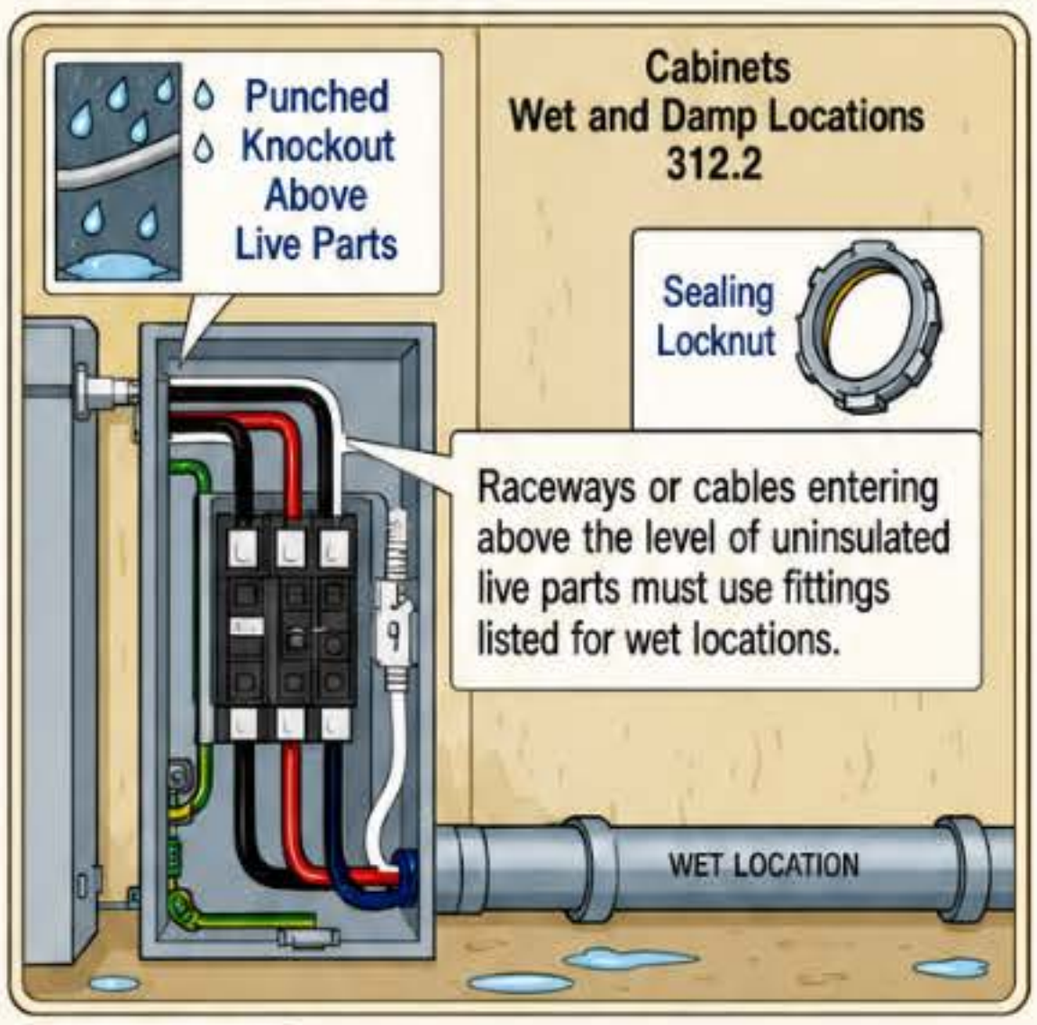


Figure 312-2

312.3 Cabinets

Author's Commentary:

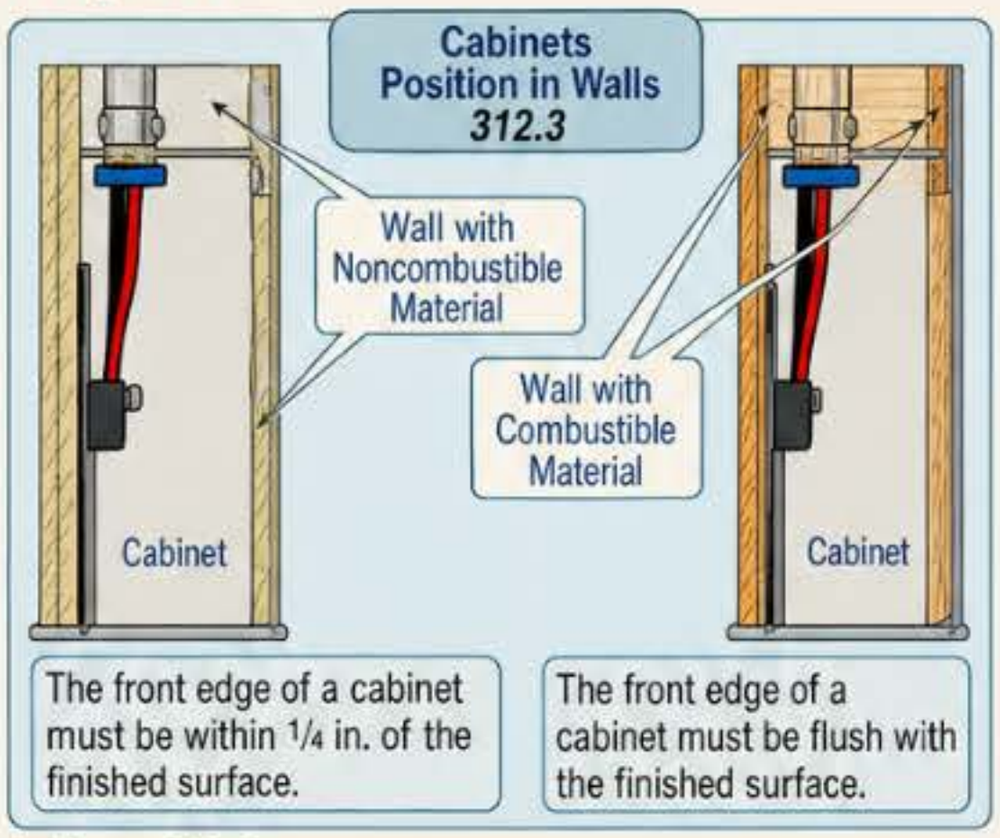
- *The term "weatherproof" refers to construction that shields against the elements so that moisture will not interfere with reliable functioning of equipment [Article 100].*

— Michael Hamilton

312.3 Position in Walls

When mounting cabinets in walls made of noncombustible material, the front edge of the cabinet may be set back no more than 1/4 in. from the finished surface. In walls built with wood or other combustible materials, cabinets must be flush with the finished surface or project outward.

▶ Figure 312–3

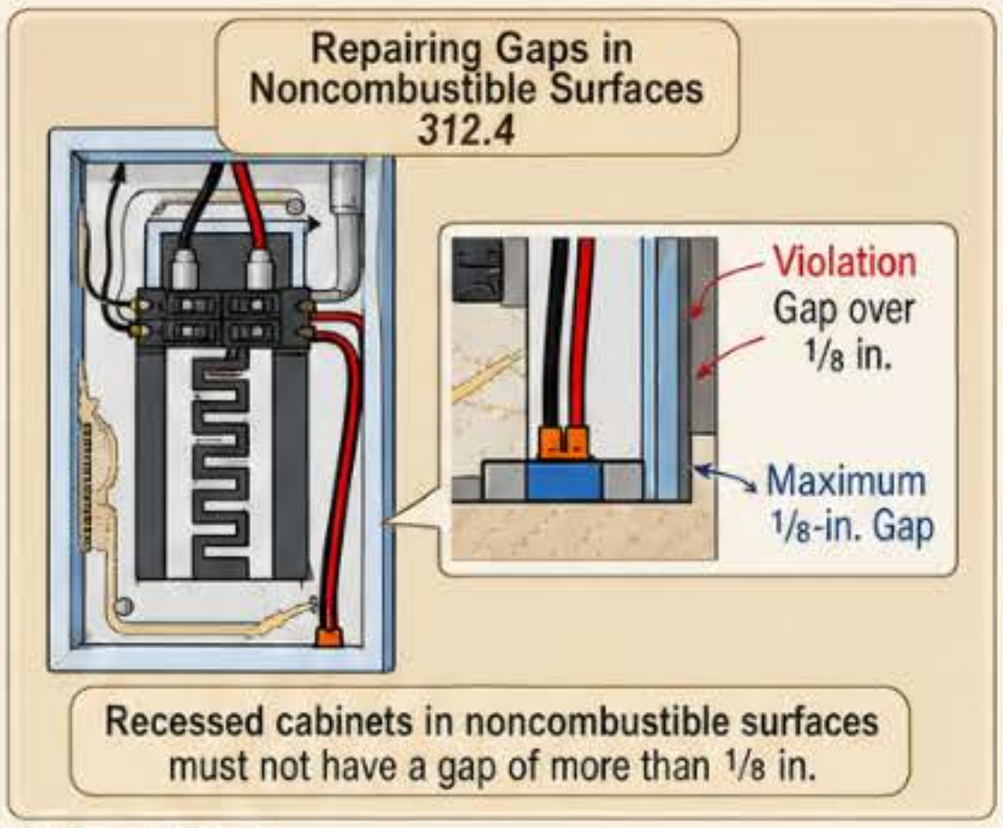


▶ Figure 312–3

312.4 Repairing Gaps in Noncombustible Surfaces

For recessed cabinets in noncombustible surfaces (such as plaster, drywall, or plasterboard), there must not be any gap exceeding 1/8 in. at any point along the edge of the cabinet.

▶ Figure 312–4

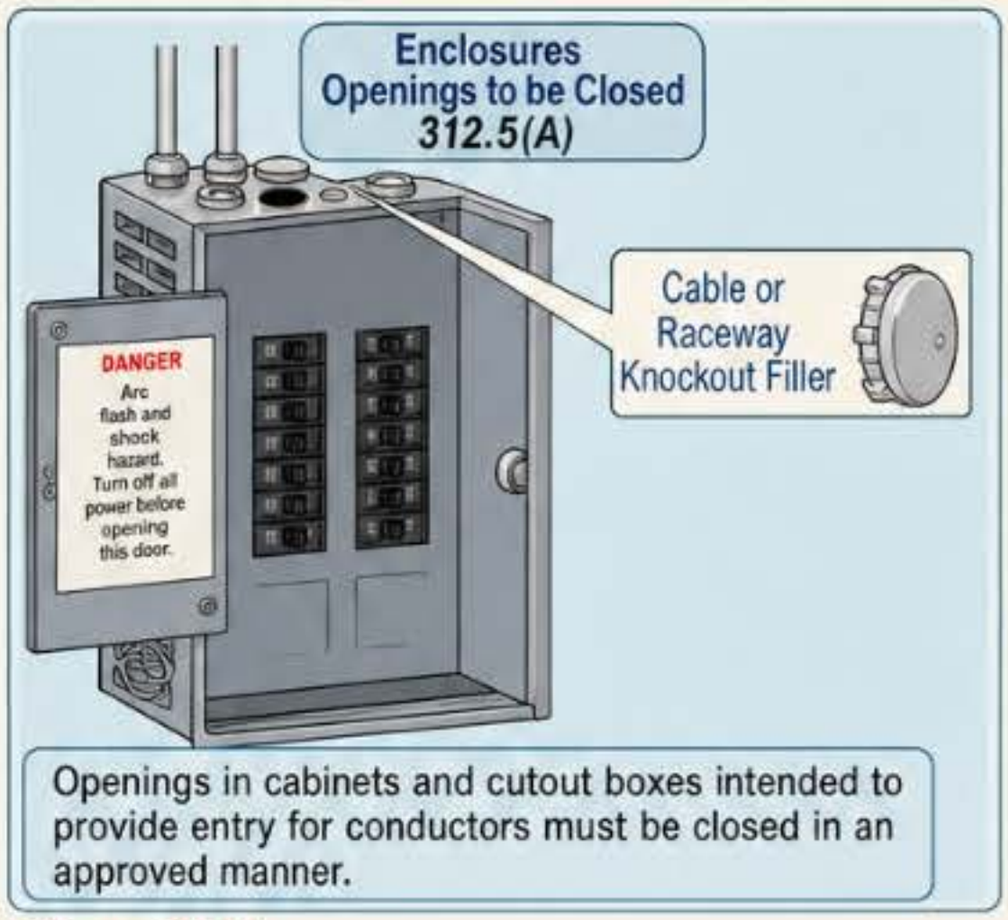


▶ Figure 312–4

312.5 Enclosures

(A) Opening to be Closed. *All openings through cabinets, cutout boxes, or meter socket enclosures that allow conductors to enter must be closed in an approved way.*

▶ Figure 312–5



▶ Figure 312–5

(C) Cable Termination. Cables must be secured to the cabinet, cutout box, or meter socket enclosure with fittings designed and listed for the cable. See 300.12 and 300.15.

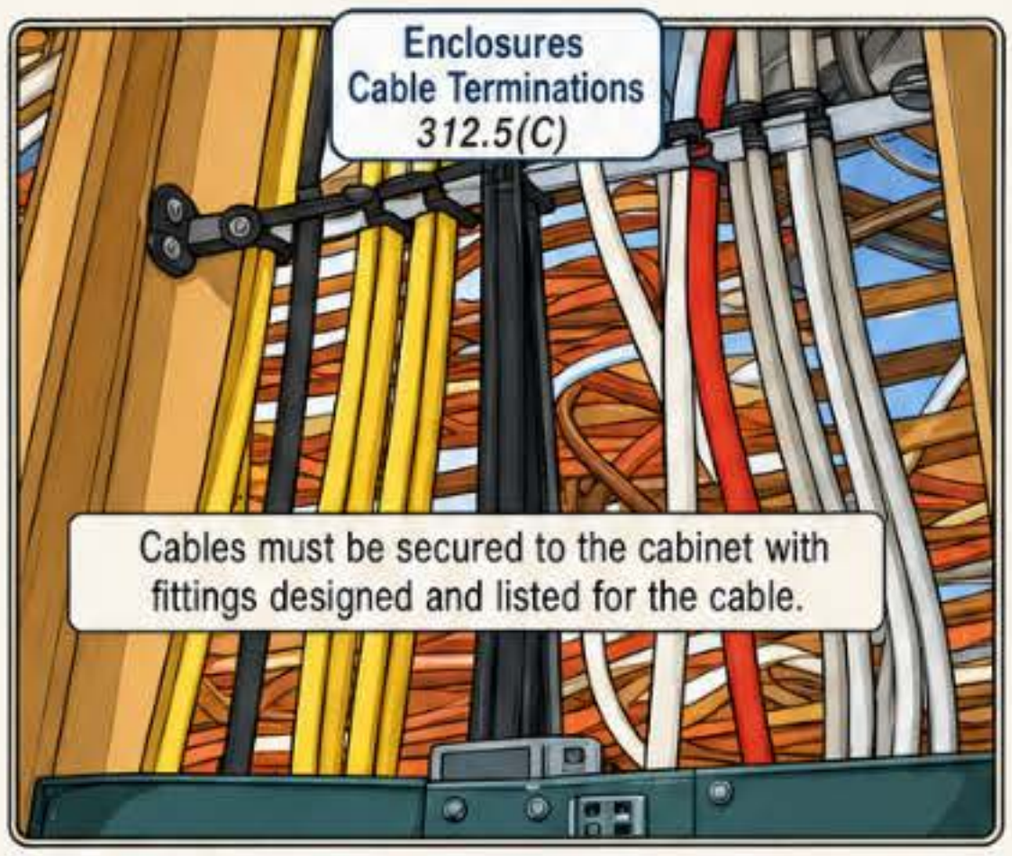
▶ Figure 312–6 and Figure 312–7

Author's Commentary:

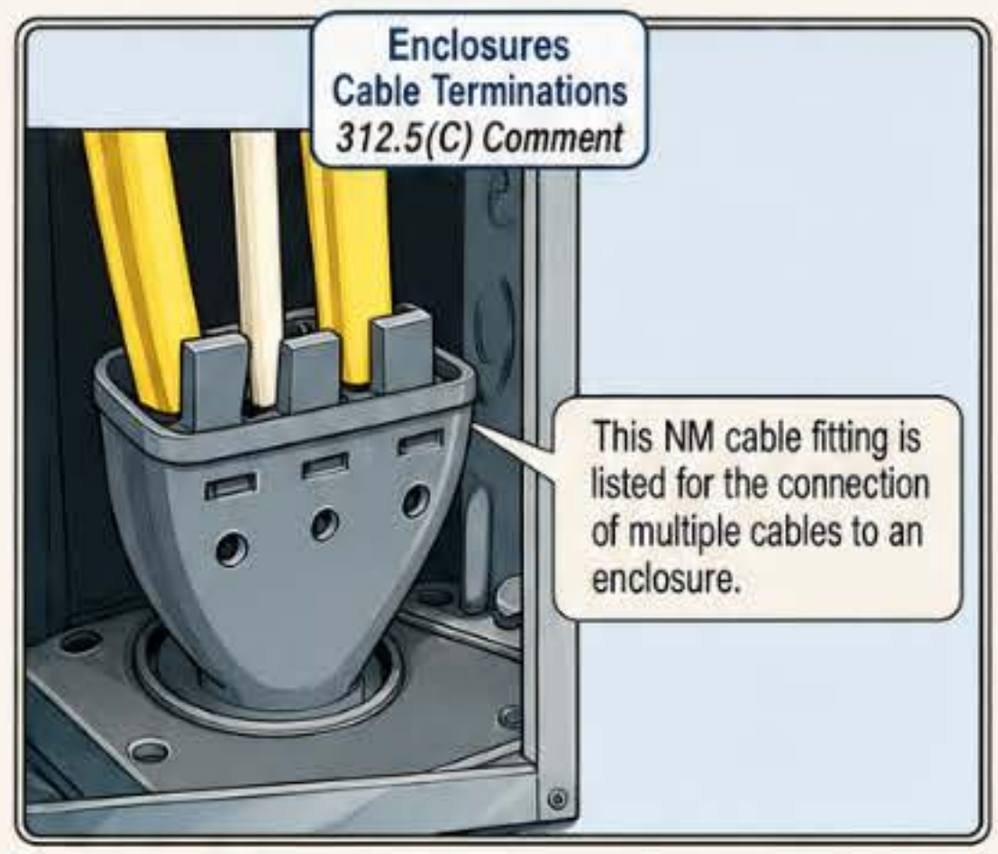
- *Clamps or cable connectors are permitted only when used with one cable, unless the identified clamp or fitting is listed for more than one. UL Type NM cable clamps are recognized for up to two or more Type NM cables inside a single fitting (UL White Book, Guide Information for Electrical Equipment).*

— Michael Hamilton

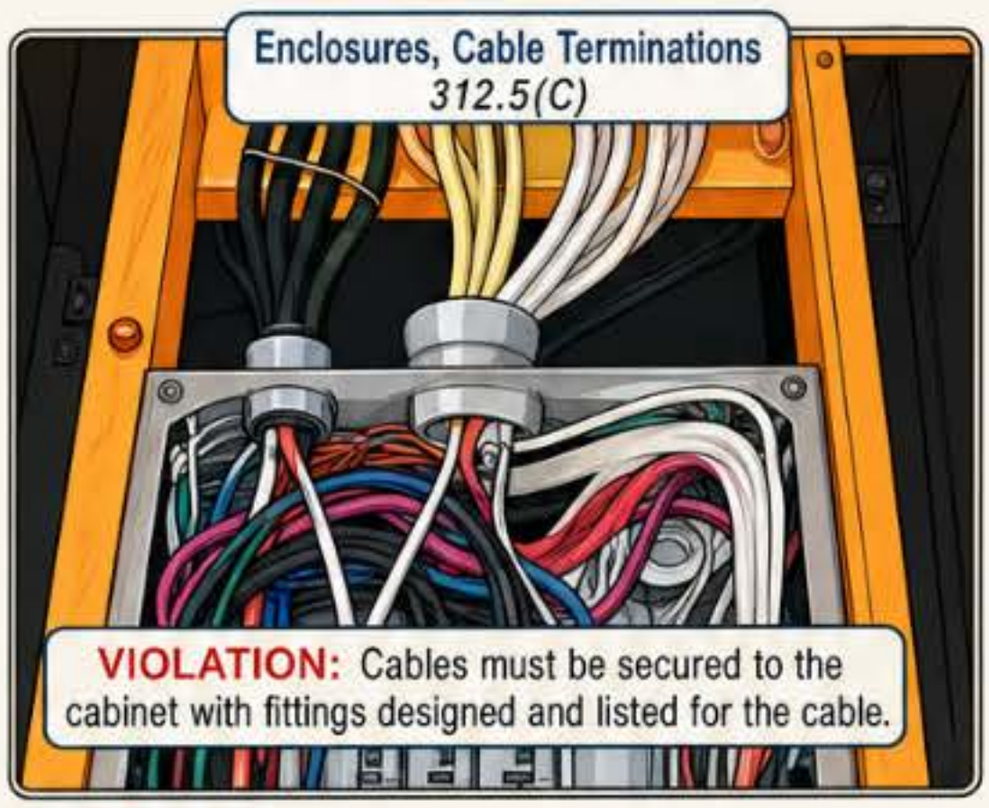
▶ Figure 312–8 and Figure 312–9



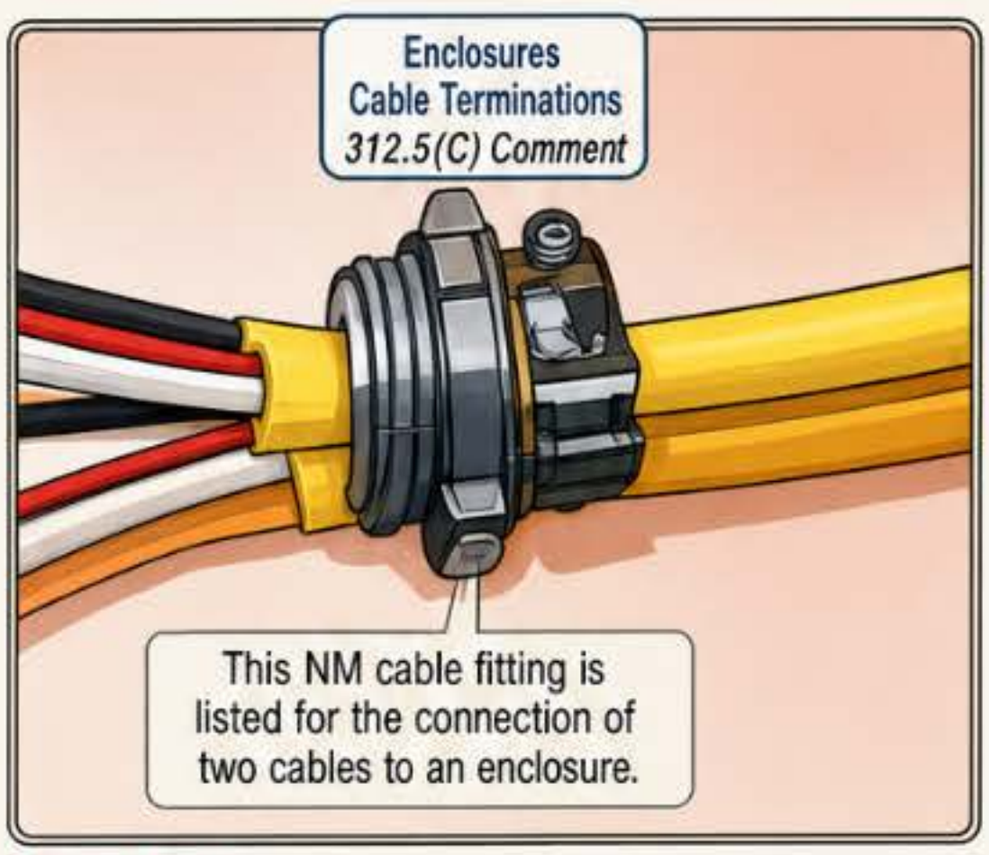
▶ Figure 312-6



▶ Figure 312-9

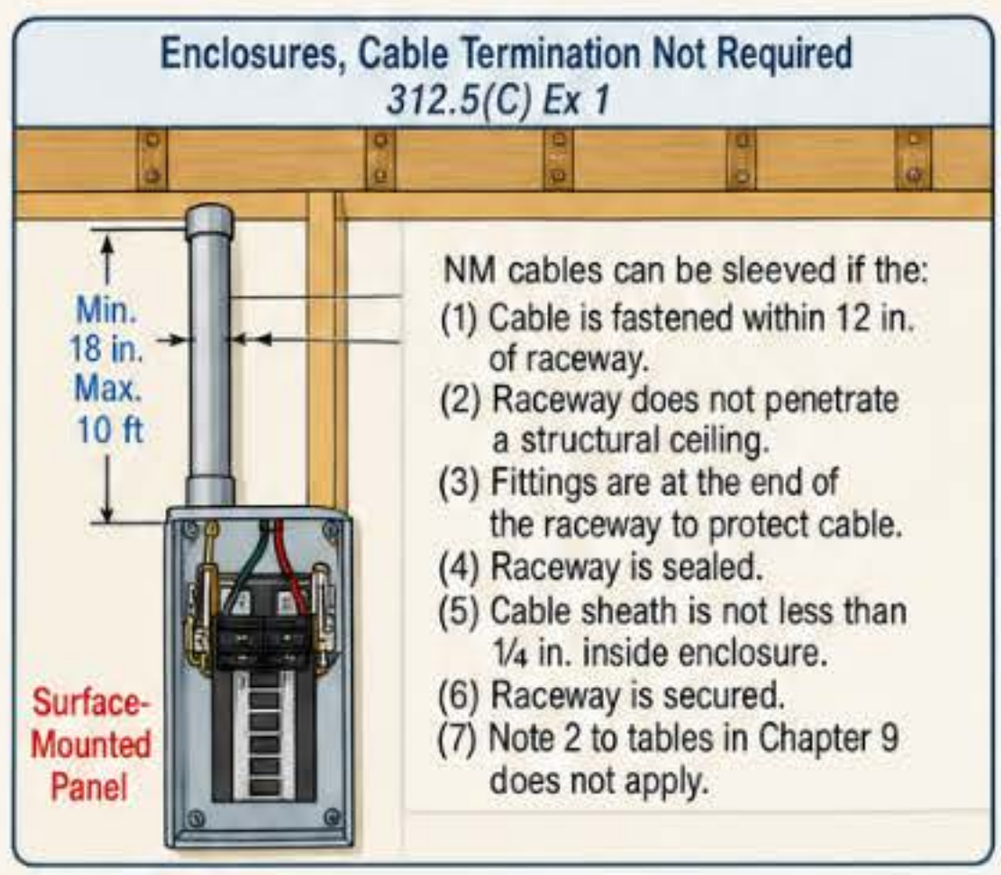


▶ Figure 312-7



▶ Figure 312-8

Ex 1: Cables with nonmetallic sheaths are not required to be secured to the cabinet, cutout box, and meter socket enclosure if the cables enter the top of a surface-mounted enclosure through a nonflexible raceway not less than 18 in. or more than 10 ft long, if all the following conditions are met: ▶ Figure 312-10



▶ Figure 312-10

(1) Each cable is fastened within 12 in. from the raceway.

(2) The raceway does not penetrate a structural ceiling.

(3) Fittings are provided on the raceway to protect the cables from abrasion.

(4) The raceway is sealed.

(5) Each cable sheath extends not less than ¼ in. into the enclosure.

(6) The raceway is properly secured.

Author's Commentary:

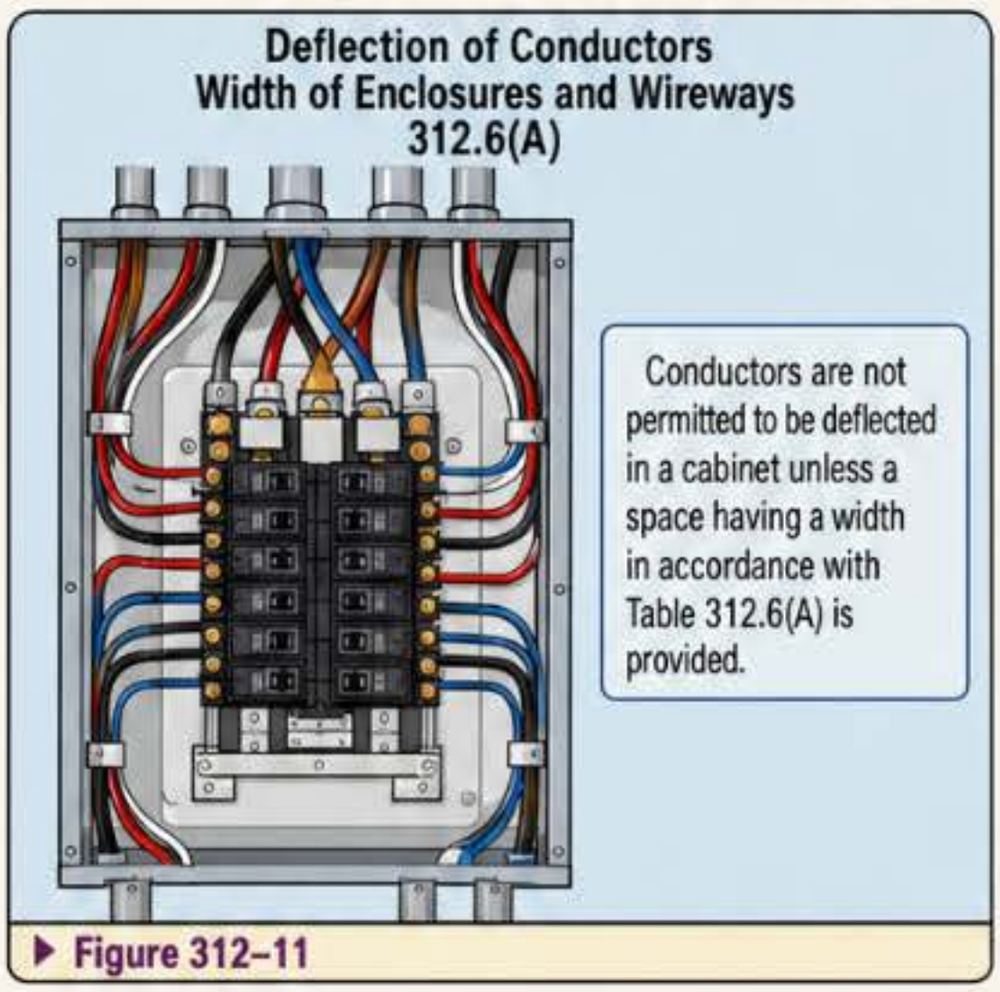
If a raceway or tubing is used in place of the wiring methods listed in Table 9, Chapter 1, note 2 does not apply to that situation.

— Michael Hamilton

312.6 Deflection of Conductors

Every conductor entering or leaving a cabinet or meter socket enclosure has to meet the clearance rules in 312.6(A) and 312.6(B).

(A) Width of Enclosures and Wireways. You must not allow conductors to deflect in any cabinet unless you provide a clear width in accordance with Table 312.6(A). ▶ Figure 312–11



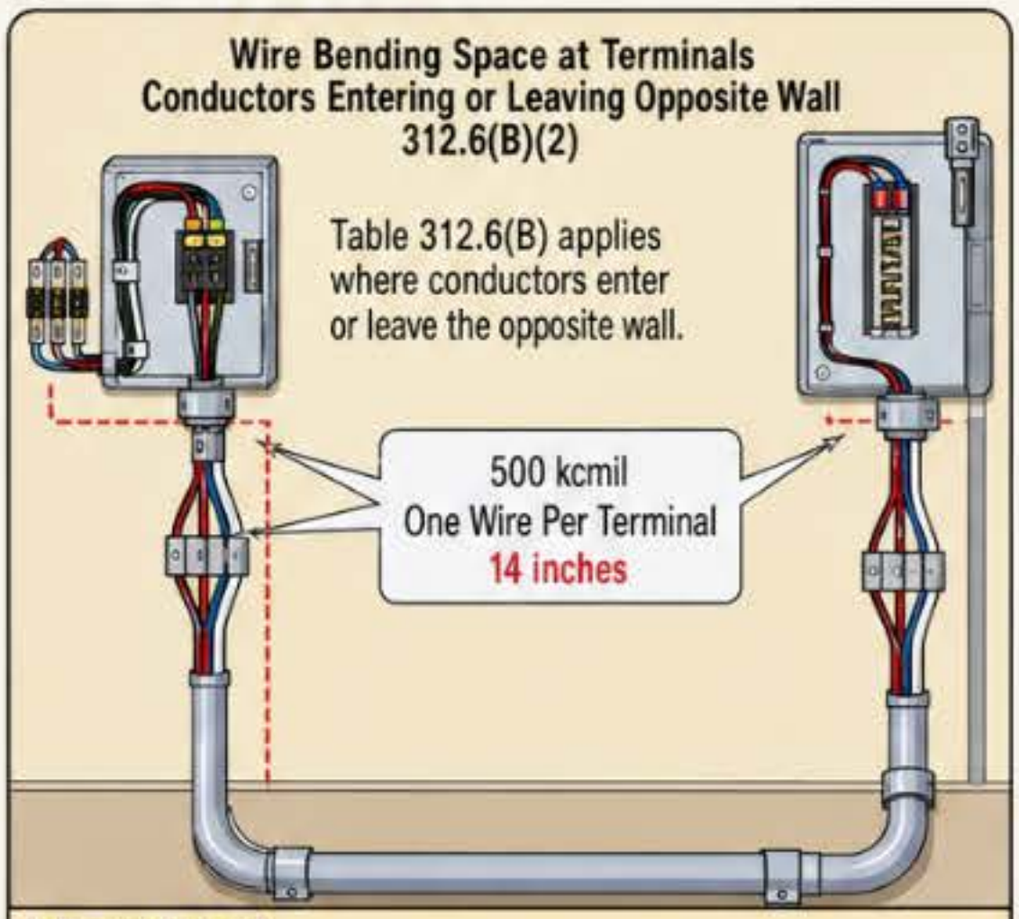
▶ Figure 312–11

Table 312.6(A) Minimum Wire–Bending Space

Wire Size (AWG or kcmil)	Inches
8–6	1½
4–3	2
2	2½
1	3
1/0–2/0	3½
3/0–4/0	4
250	4½
300–350	5
400–500	6
600–700	8

(B) Wire-Bending Space at Terminals.

(2) Conductors Entering or Leaving Opposite Wall. Table 312.6(B) applies where the conduit or raceway punches enter or leave the cabinet through the wall opposite its terminal. ▶ Figure 312–12



▶ Figure 312–12

Table 312.6(B) Minimum Wire–Bending Space

Wire Size (AWG or kcmil)	Inches
2	3½
1	4½
1/0	5½
3/0	6½
250	8½
350	12
500	14
600	15

312.8 Overcurrent Device Enclosures

Scan this QR code for a video from Michael Hamilton explaining this topic; it's a sample from the videos that accompany this textbook.

Cabinets are allowed to contain wiring as permitted by 312.8(A) and (B).

(A) Splices, Taps, and Feed-Through Conductors. The wiring space within cabinets can be used for conductors feeding through, spliced, or tapped where all the following conditions are met:

DEFINITIONS | From Michael Hamilton Publications

(1) At no point within a cross section of the wiring space may the combined area of all conductors be greater than 40 percent of that cross-sectional area. **312-13**

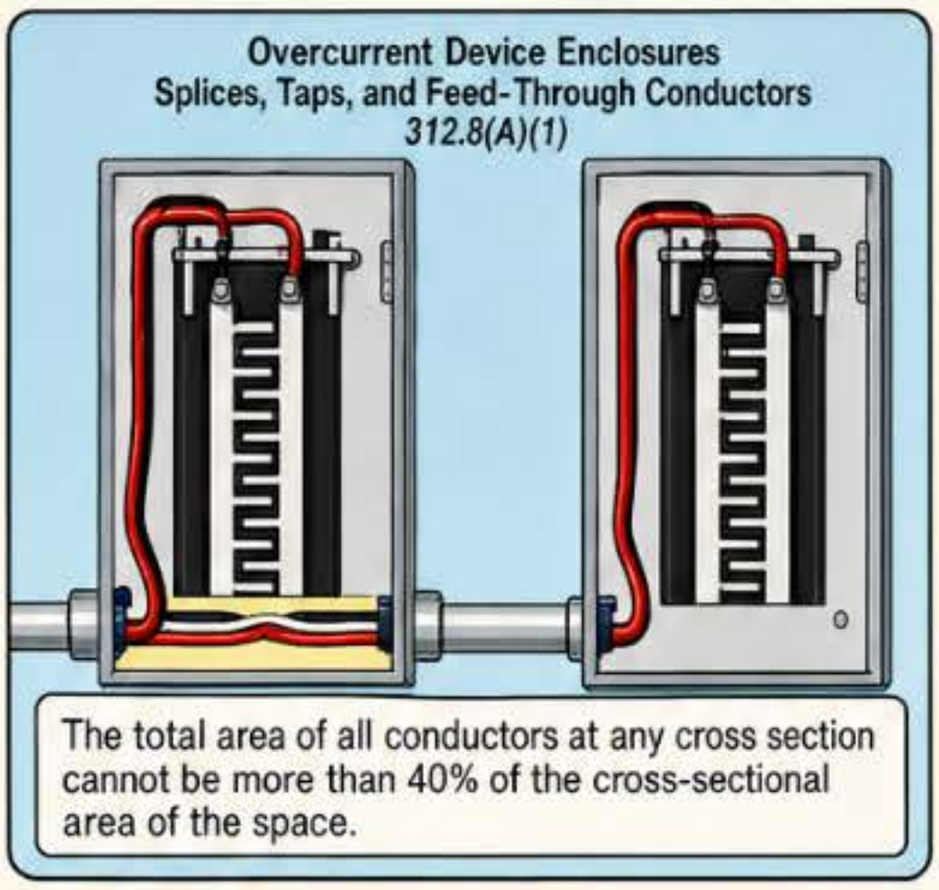


Figure 312-13

(2) The combined area of all conductors, splices, and taps at any cross section must be no more than 75 percent of the cross-sectional area of that space. **Figure 312-14**

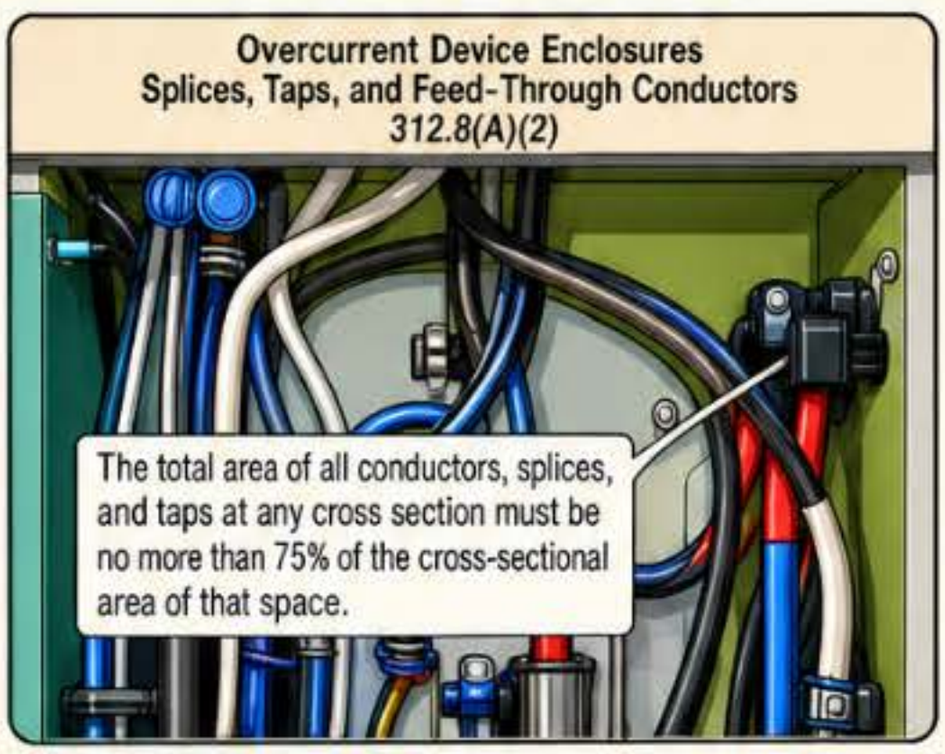


Figure 312-14

Author's Commentary:

The 40% and 75% limits apply to all conductors, every splice, and every tap found anywhere in the cross-sectional area. Only the individual conductors, splices, or taps being added at the moment are considered.

— Michael Hamilton

(3) When conductors pass through the cabinet, a durable permanently attached warning label that meets 110.21(B) must be applied on the cabinet to clearly indicate where the disconnects are located for those feed-through conductors. **Figure 312-15**

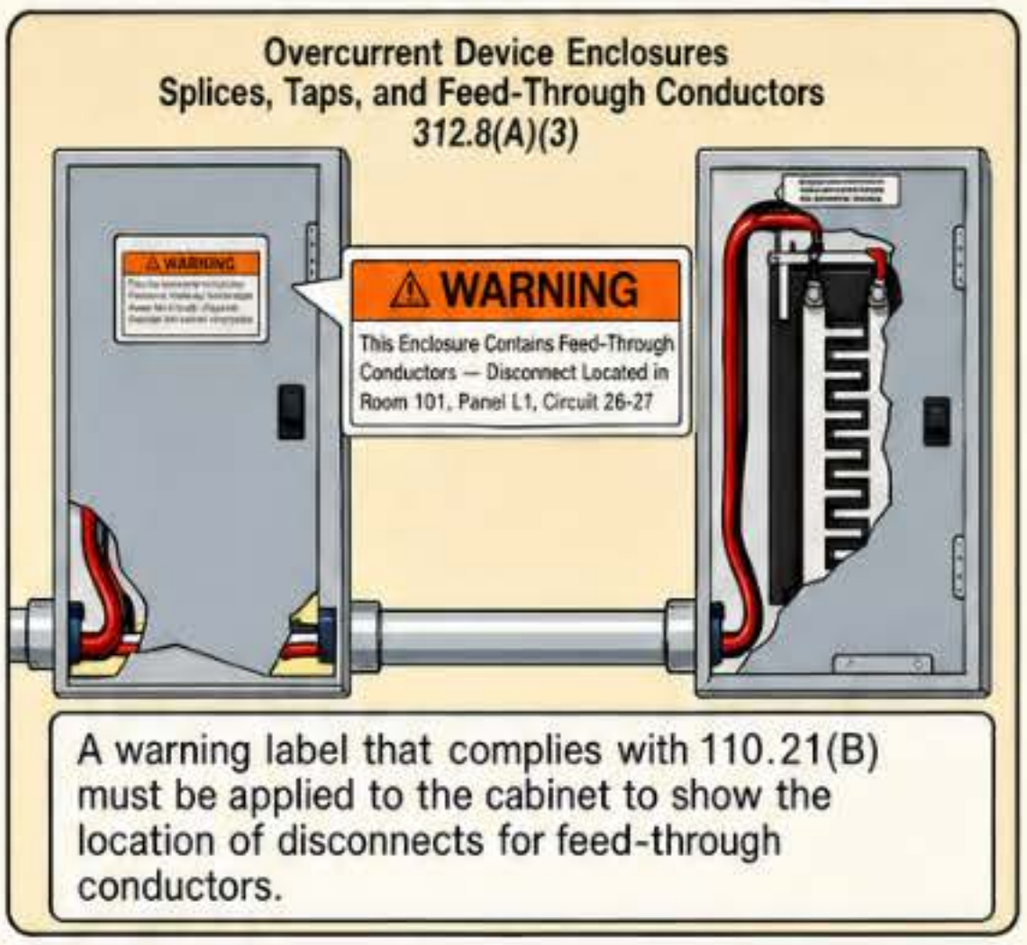


Figure 312-15

(B) Power Monitoring or Energy Management Equipment. Enclosures that contain switches or overcurrent devices are permitted to contain power monitoring or energy management equipment when all of the following conditions are satisfied:

(1) Identification. The power monitoring or energy management equipment is recognized as a field-installable accessory as part of the listed equipment, or it is a listed kit evaluated for field installation in switch or overcurrent device enclosures.

(2) Area. The total area of all conductors, splices, taps, and equipment at any cross section of the wiring space must be 75 percent or less of the cross-sectional area.

(3) Conductors. Conductors used only for control or instrument circuits must comply with either 312.8(B)(3)(a) or (b).

(a) Conductors must comply with 725.49.

(b) Conductors smaller than 18 AWG, but not smaller than 22 AWG for a single conductor and 26 AWG for a multiconductor cable, are permitted where the conductors and cable assemblies meet all of these conditions:

(1) Conductors or cables are located in raceways or routed along one or more walls of the enclosure and secured at intervals not greater than 10 in.

312.10 Cabinets

(2) Enclosures shall be fastened within 10 in. of every termination.

(3) The enclosures must be secured to keep them from making contact with any current-carrying parts inside.

(4) The enclosures are intended for the system voltage and shall not be rated less than 600V.

(5) The enclosures shall have an insulation temperature rating of at least 90°C.

Author's Commentary: These rules ensure enclosures are securely mounted near their terminations, isolated from live parts, properly rated for the system voltage, and built with insulation that can withstand at least 90°C.

— Michael Hamilton

Metal Enclosures 312.10(A)

VIOLATION: Metal enclosures within the scope of this article must be protected both inside and outside against corrosion.

Figure 312-16

Part II. Construction Specifications

312.10 Material

(A) Metal Enclosures. Metal enclosures within the scope of this article must be protected both inside and outside against corrosion.

▶ **Figure 312-16**

ARTICLE 314 OUTLET, PULL, AND JUNCTION BOXES; CONDUIT BODIES; AND HANDHOLE ENCLOSURES

Introduction to Article 314—Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures

This article sets out the requirements for installing outlet boxes, pull and junction boxes, conduit bodies, and handhole enclosures. When the cabinets addressed in Article 312 are used, the conditions of use are based on the type of material and the equipment selected for the installation.

The guidance provided here will help you choose an outlet box sized appropriately for its cubic-inch capacity and determine the smallest measurements needed for pull boxes. There are also limits on the amount of weight that can be supported by an outlet box, along with rules for supporting raceways or outlet boxes on different surfaces. Article 314 will also help you understand these installation rules so that your work is consistent with the *2023 NEC*. Clear illustrations are included to help you visualize the completed installation.

Part I. Scope and General

314.1 Scope

This article covers the rules for installing outlet boxes, pull and junction boxes, conduit bodies, and handhole enclosures.

Figure 314–1

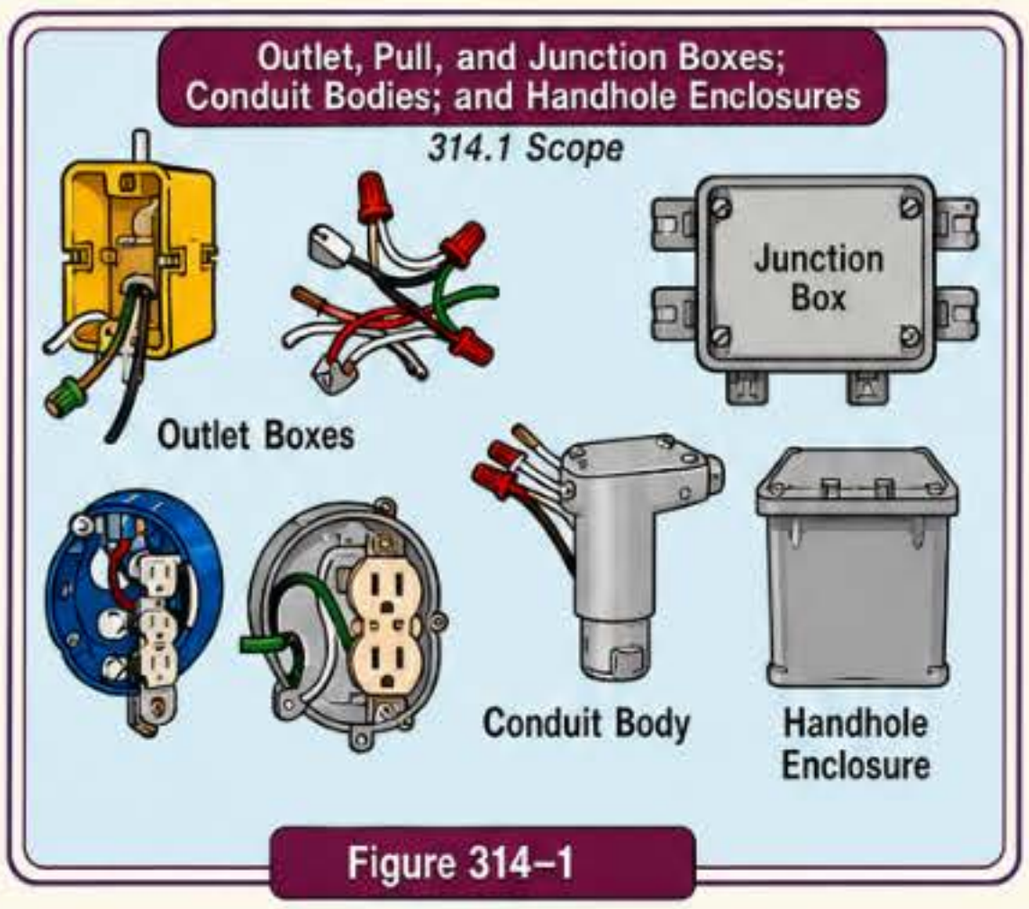


Figure 314–1

314.3 Nonmetallic Boxes

Nonmetallic boxes may be used only with nonmetallic cables and raceways.

Example: *Metal raceways and metal cables can be used with nonmetallic boxes only if the raceways and cables are bonded together in the nonmetallic box.*

Figure 314–2

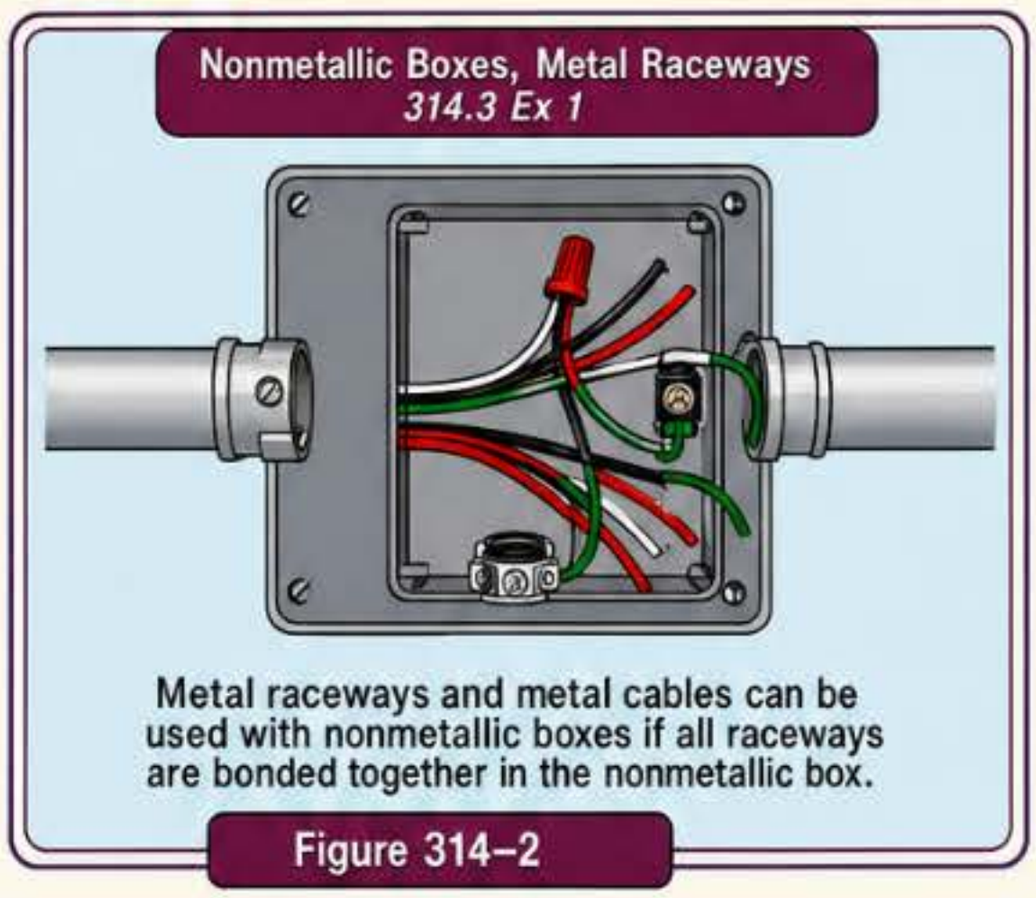


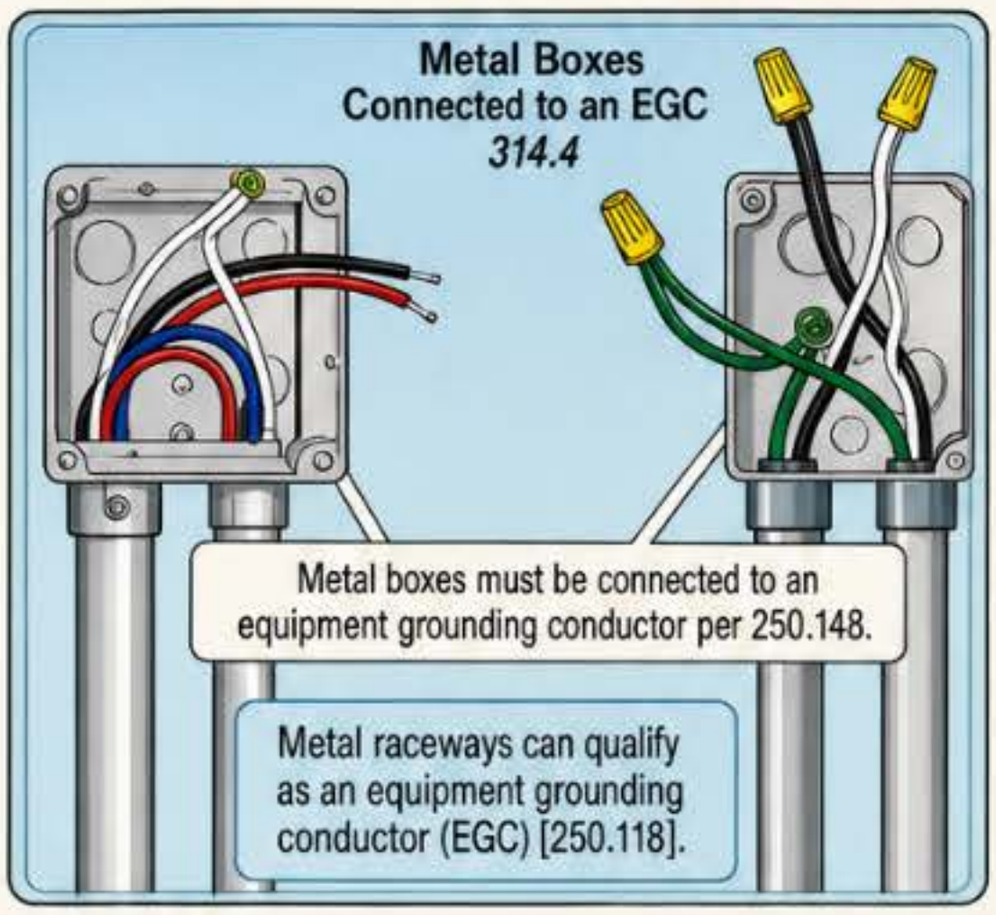
Figure 314–2

Author's Commentary: *Article 314 is all about the enclosures that keep wiring connections accessible and protected. Understanding box fill, support rules, and bonding requirements is essential for safe, reliable installations that pass inspection the first time.*

— Michael Hamilton

314.4 Metal Boxes

Metal boxes must be connected to an equipment grounding conductor in accordance with 250.148. ▶ Figure 314–3



▶ Figure 314–3

Part II. Installation

314.15 Damp or Wet Locations

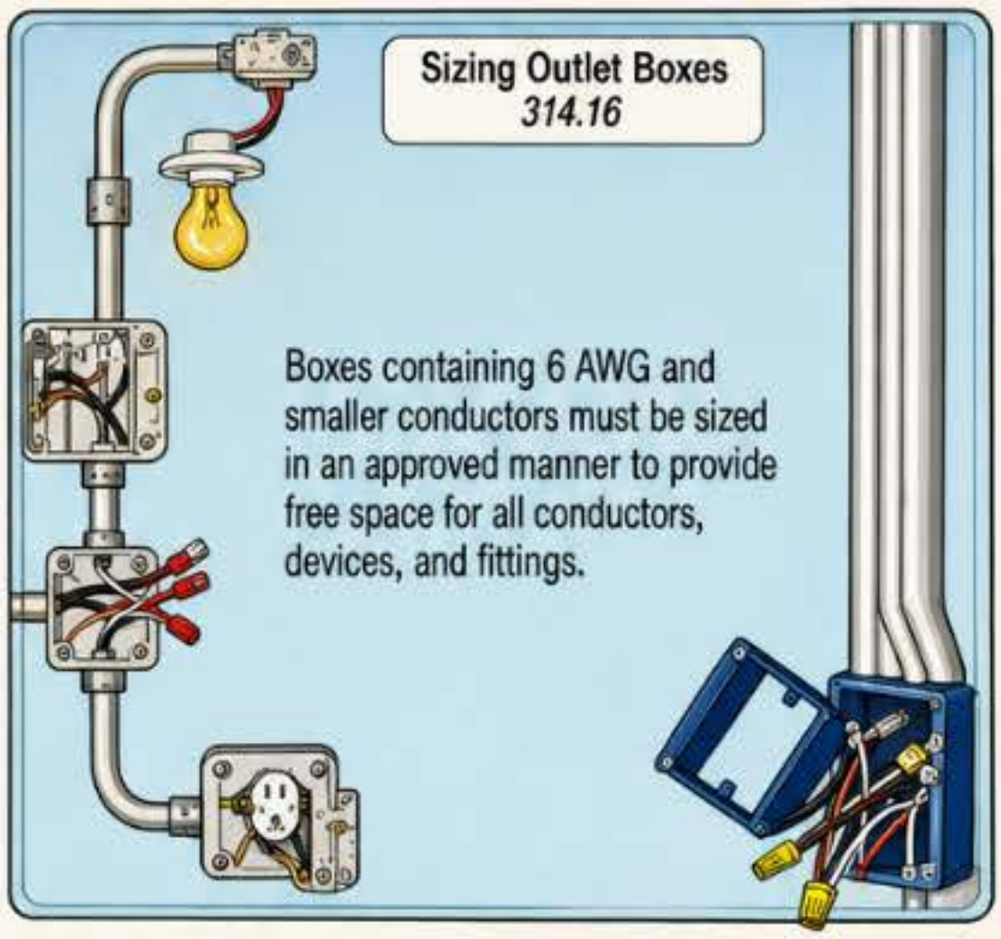
Boxes, conduit bodies, and fittings in damp or wet locations must be listed for use in wet locations. ▶ Figure 314–4 and ▶ Figure 314–5

▶ Figure 314–4

▶ Figure 314–5

314.16 Sizing Outlet Boxes

Boxes containing 6 AWG and smaller conductors must be sized in an approved manner to provide free space for all conductors, devices, and fittings. In no case can the volume of the box, as calculated in 314.16(A), be less than the volume requirement as calculated in 314.16(B). ▶ Figure 314–6 and ▶ Figure 314–7



▶ Figure 314–6

Author's Commentary:
Moisture and electrictty are a dangerous mix. Make sure enclosures in damp or wet areas are built and installed to keep water out and protect people and equipment.
— Michael Hamilton

Author's Commentary:
Proper box sizing prevents overcrowding, keeps wires cool, and leaves room for connections and future work.
— Michael Hamilton

Outlet, Pull, and Junction Boxes: Conduit Bodies; and Handhole Enclosures 314.16

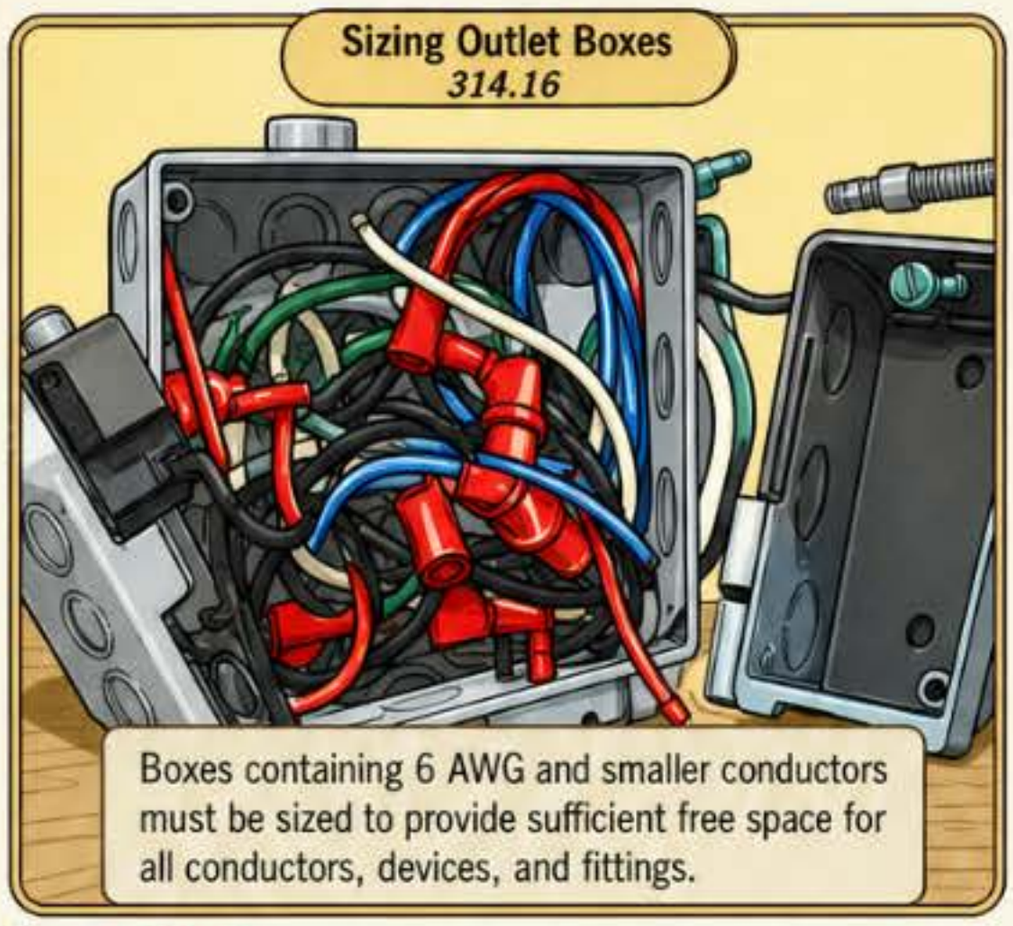


Figure 314–7

Boxes and conduit bodies enclosing conductors 4 AWG or larger must also comply with the provisions of 314.28.

(A) Box Volume Calculations. The volume of a box is the total volume of its assembled parts including plaster rings, raised covers, and extension rings. The total volume includes only those parts marked with their volumes in cubic inches (cu in.) [314.16(A)] or included in Table 314.16(A).

Figure 314–8

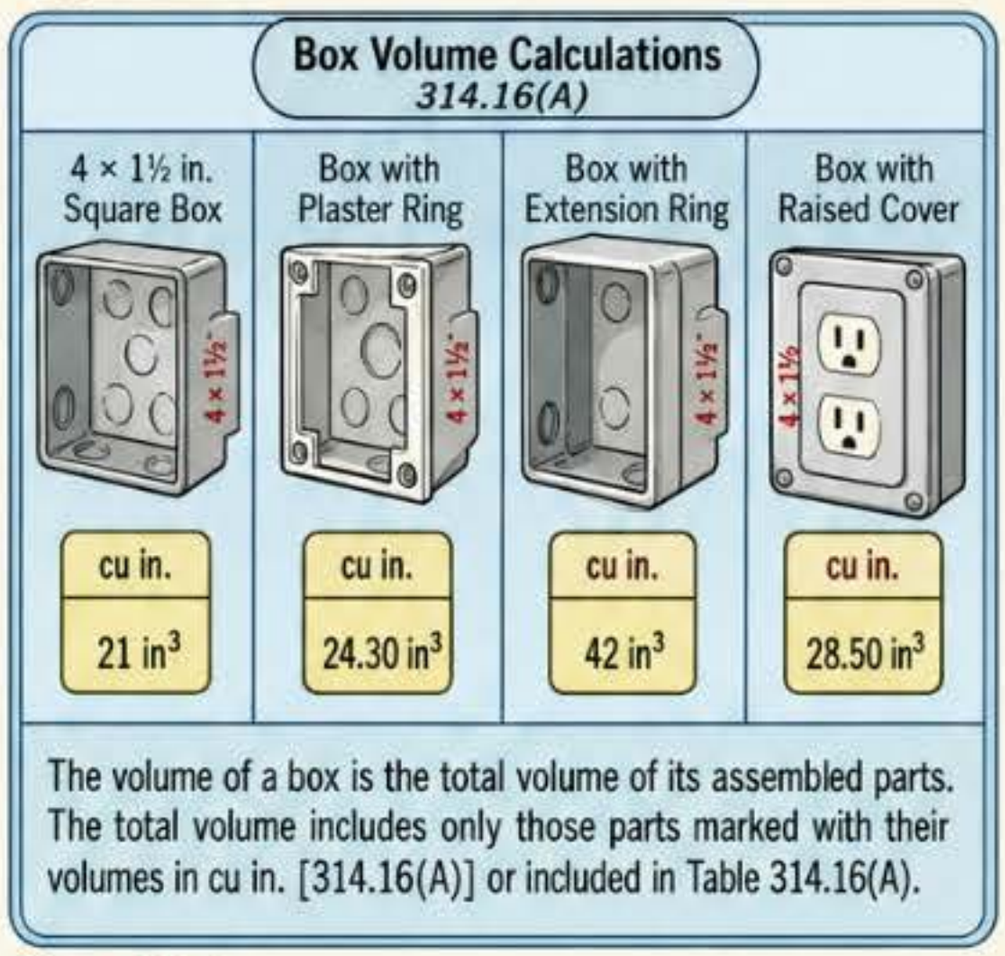


Figure 314–8

Author's Commentary:

- *When determining the size of boxes and conduit bodies that contain conductors 4 AWG and larger, follow 314.28, and for handhole enclosures, follow the requirements in 314.30(A). Outlet boxes are commonly used for attaching devices and light fixtures and must provide enough internal volume for all conductors, devices, and fittings. The combined volume of the conductors, devices, and fittings inside the box must not exceed the box's cubic-inch capacity.*

— Michael Hamilton

Table 314.16(A) Metal Boxes

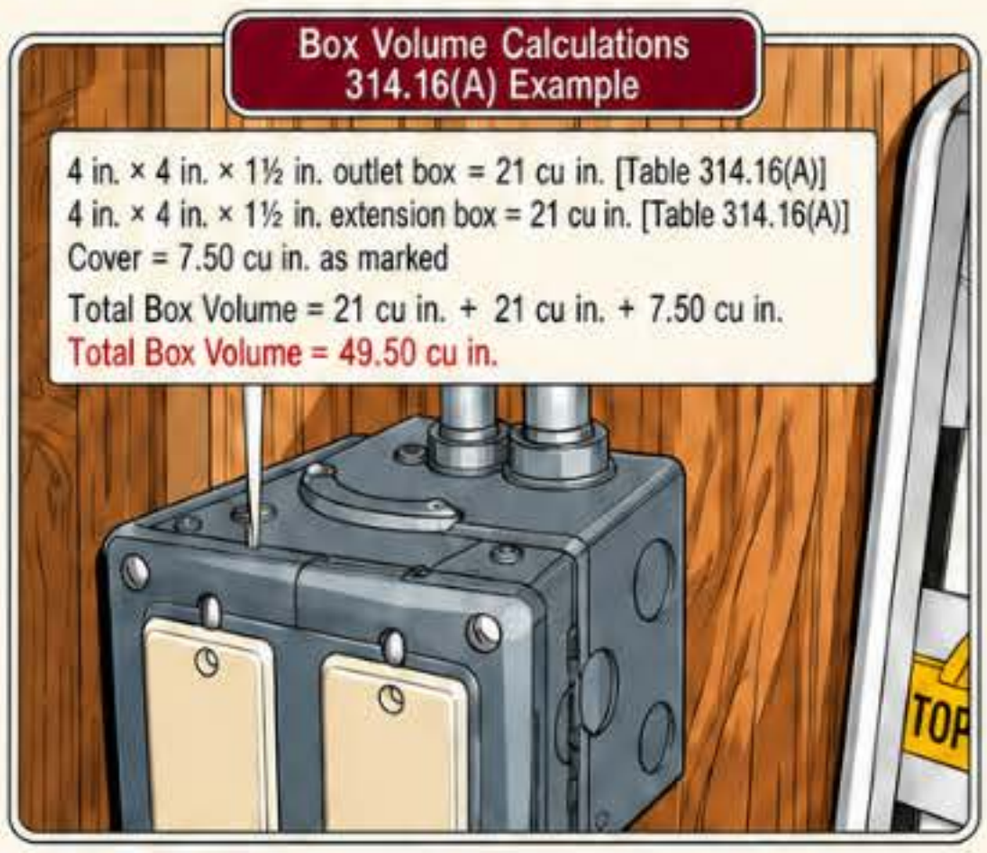
Box Trade Size		Minimum Volume	Maximum Number of Conductors (arranged by AWG size)					
in.	Box Shape	in³	18	16	14	12	10	8
(4 × 1¼)	round/octagonal	12.50	8	7	6	5	5	5
(4 × 1½)	round/octagonal	15.50	10	8	7	6	6	5
(4 × 2¼)	round/octagonal	21.50	14	12	10	9	8	7
(4 × 1¼)	square	18.00	12	10	9	8	7	6
(4 × 1½)	square	21.00	14	12	10	9	8	7
(4 × 2¼)	square	30.30	20	17	15	13	12	10
(4⅛ × 1¼)	square	25.50	17	14	12	11	10	8
(4⅛ × 1½)	square	29.50	19	16	14	13	11	9
(4⅛ × 2¼)	square	42.00	28	24	21	18	16	14

▶ Example

Question: *Determine the total box volume needed for a 4 in. × 4 in. × 1½ in. outlet box and for a 4 in. × 4 in. × 1½ in. extension box with a domed cover that is marked "7.50 cu in."*

See **Figure 314–9.**

(a) 44.50 cu in. (b) 46.50 cu in. (c) 47.50 cu in. (d) 49.50 cu in.



▶ Figure 314–9

Solution:

Volume of 4 in. × 4 in. × 1½ in. outlet box = 21 cu in. [Table 314.16(A)]
Volume of 4 in. × 4 in. × 1½ in. extension box = 21 cu in. [Table 314.16(A)]
Cover Volume = 7.50 cu in. as marked

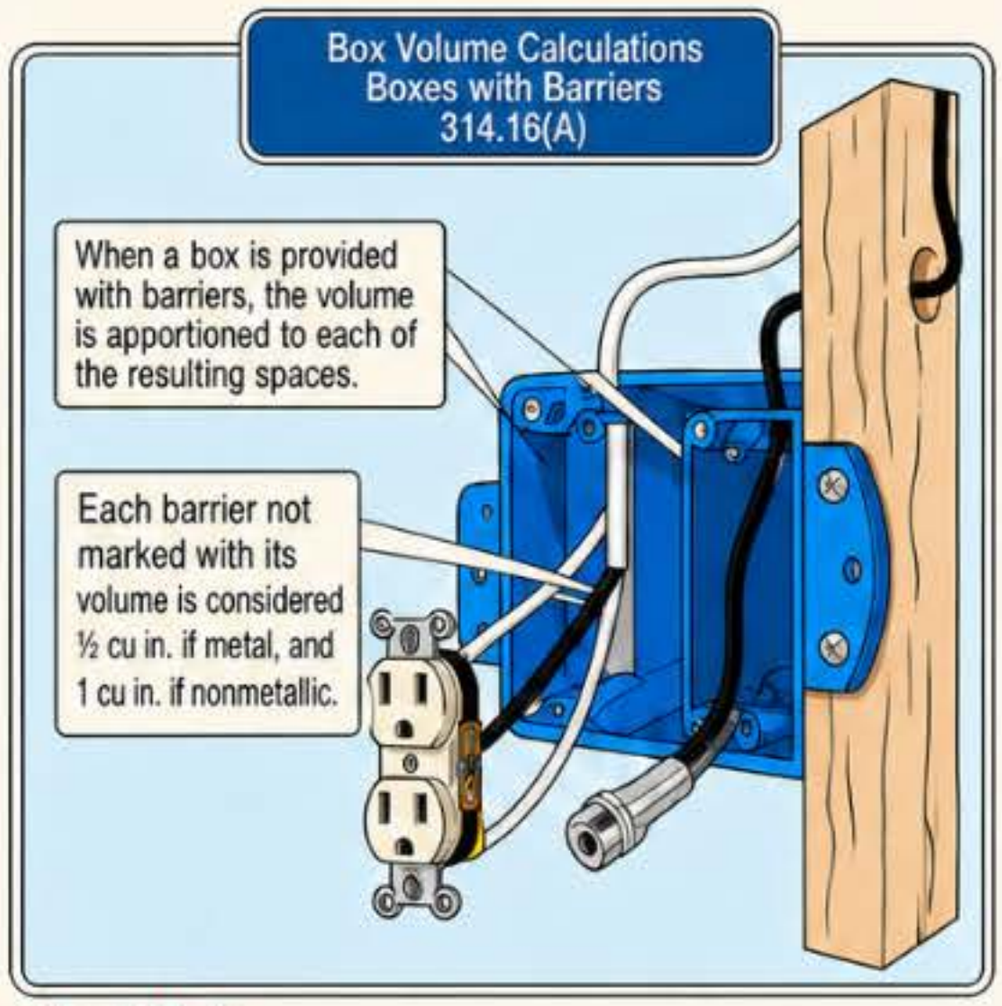
Total Volume = 21 cu in. + 21 cu in. + 7.50 cu in.
Total Volume = 49.50 cu in.

Do not calculate the actual volume of a box contained in Table 314.16(A), since the table volume is based on the inside dimensions of the box, not the outside dimensions.

Answer: *(d) 49.50 cu in.*

Where a box is provided with barriers, the volume is apportioned to each of the resulting spaces. Each barrier, if not marked with its volume, is considered to take up *½ cu in. if metal and 1 cu in. if nonmetallic.* See **Figure 314–10.**

Author's Commentary:
When all the conductors in an outlet box are the same size (so insulation thickness doesn't matter), Table 314.16(A) can be used to figure out how many conductors are allowed in the box. If the conductor sizes vary, you'll need to calculate the actual box volume required.
— Michael Hamilton



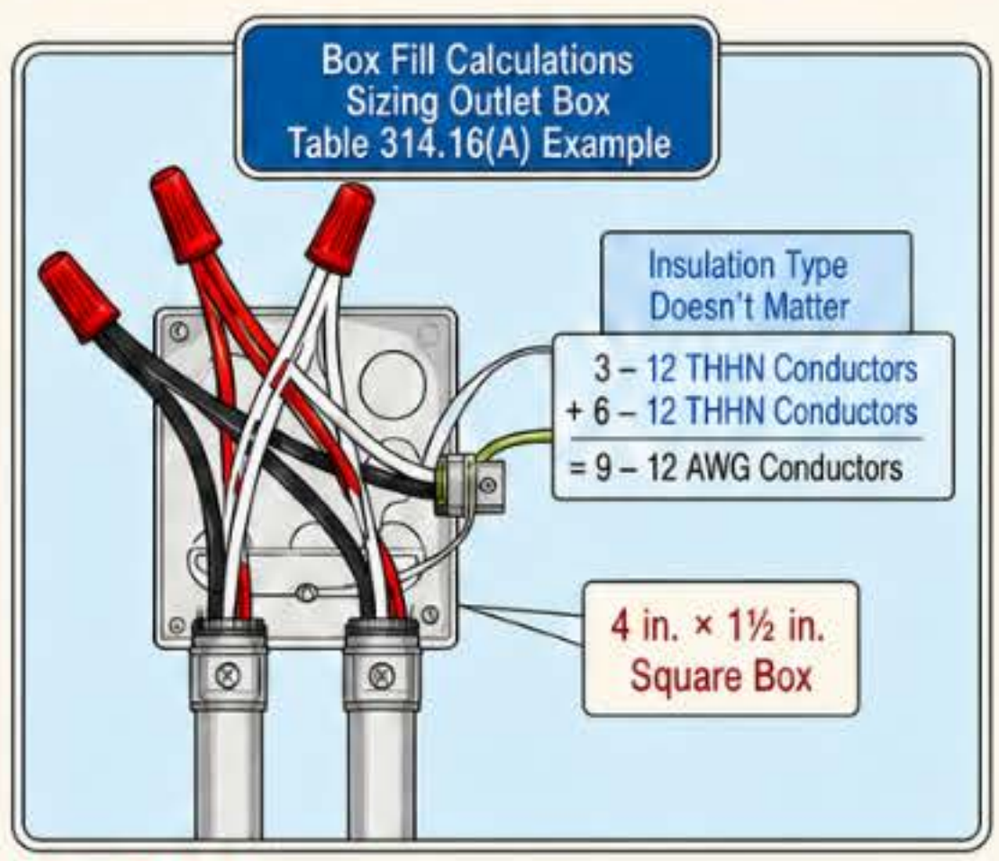
▶ Figure 314–10

- If the outlet box contains switches, receptacles, luminaire studs, luminaire hickeys, cable clamps, or equipment grounding conductors, then allowance must be made for these items which are *not reflected in Table 314.16(A).*

▶ Table 314.16(A) Example

Question: *Which 4-in. square outlet box will be required for three 12 THHN and six 12 THHN conductors? See* **Figure 314–11.**

(a) 4 in. × 1¼ in. square (b) 4 in. × 1½ in. square
(c) 4 in. × 2½ in. square (d) 4 in. × 2½ in. with extension



▶ Figure 314–11

Answer: *(b) 4 in. × 1½ in. square*

OUTLET, PULL, AND JUNCTION BOXES; CONDUIT BODIES; AND HANDHOLE ENCLOSURES 314.16

(B) Box Fill Calculations. The rules in Table 314.16(A) do not include devices such as switches, receptacles, luminaire (light) studs, luminaire hickeys, cable clamps, or equipment grounding conductors. To determine how much space these items occupy, use 314.16(B)(1) through (B)(5) and then add those amounts to the conductor volumes from Table 314.16(A) to find the total box volume needed for all conductors, devices, and fittings. **Figure 314–12**

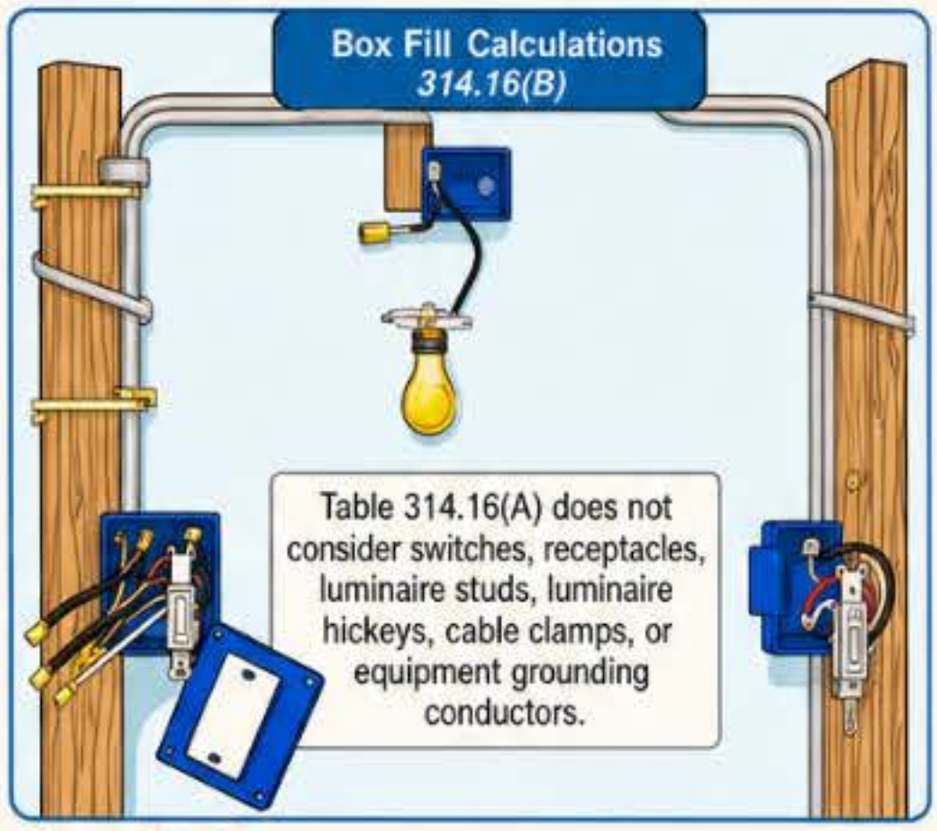


Figure 314–12

Raceway and cable fittings—including locknuts and bushings—are not included in box fill calculations. **Figure 314–13**

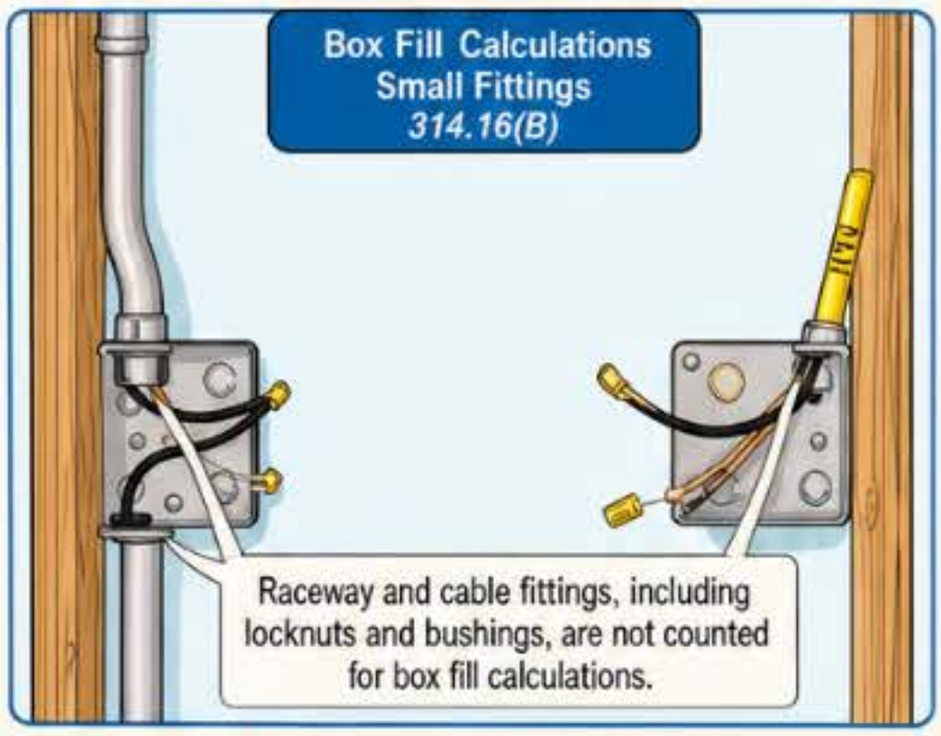


Figure 314–13

Each space within a box that has a barrier separating areas must be calculated separately. **Figure 314–14**

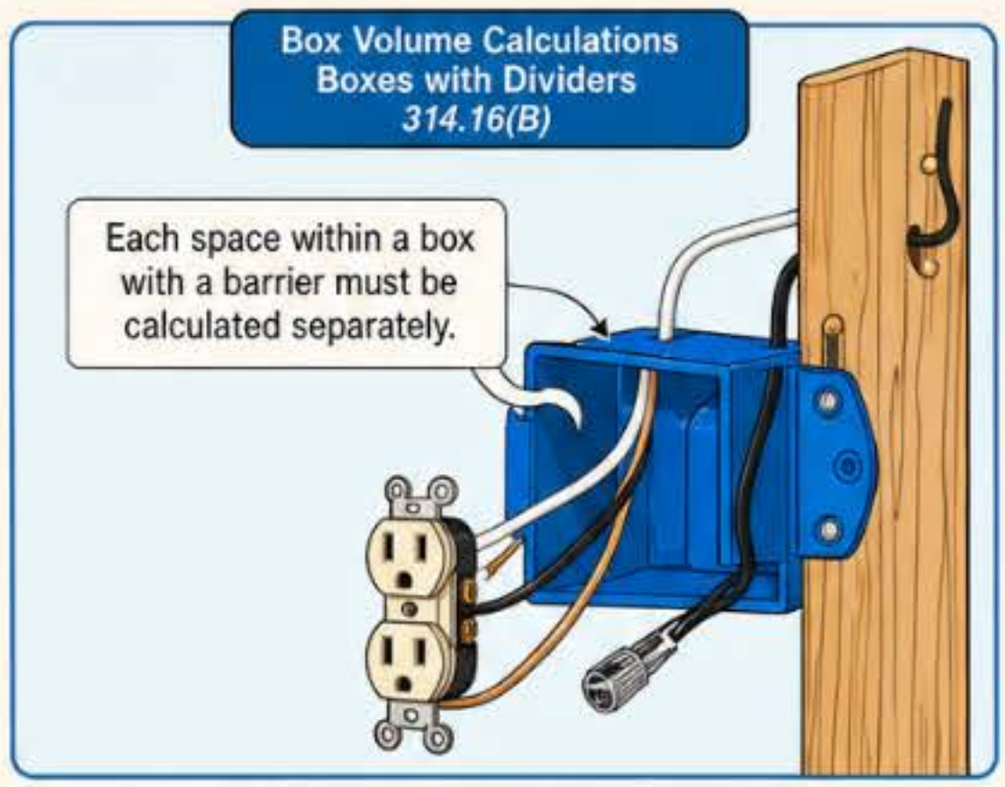


Figure 314–14

(1) Conductor Volume. Every conductor begins outside the box and is terminated inside. If a splice occurs inside the box, it counts as one conductor volume as described in Table 314.16(B). **Figure 314–15**

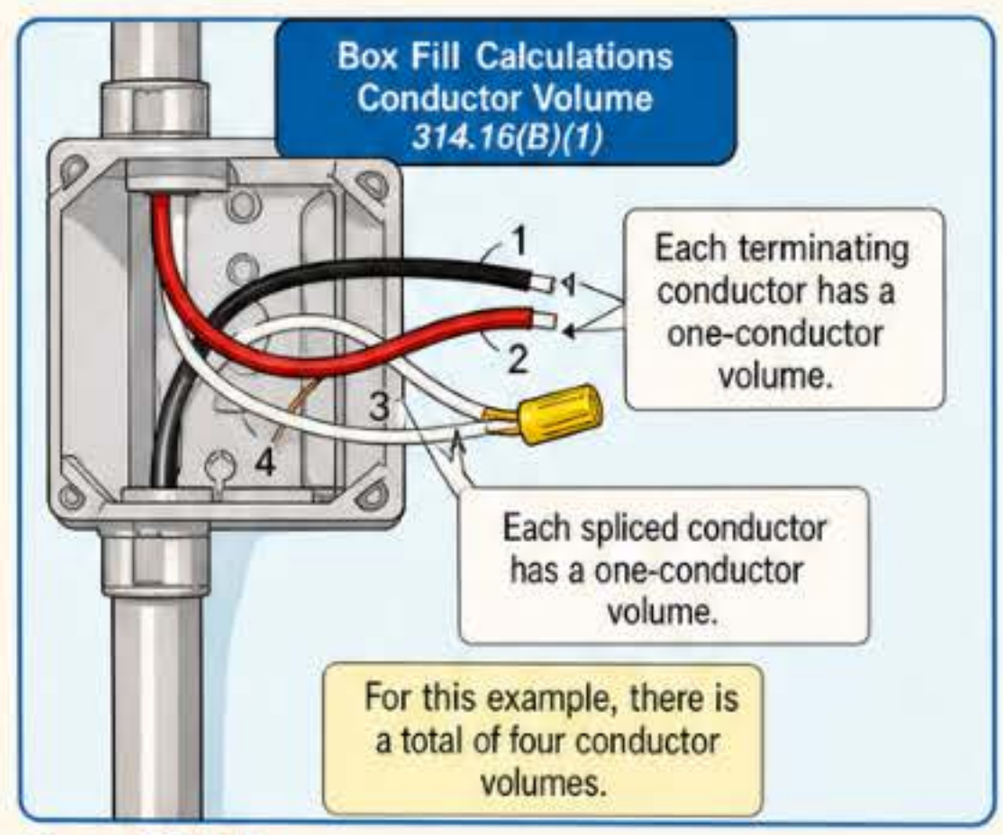


Figure 314–15

Author's Commentary:

- *Table 314.16(B) lists conductor volumes for 18 AWG through 6 AWG. For example, one 14 AWG conductor has a volume of two units. If a box contains four 14 AWG conductors, the total volume is eight units.*
- *Conductor insulation thickness is not a factor in box fill calculations.*

— Michael Hamilton

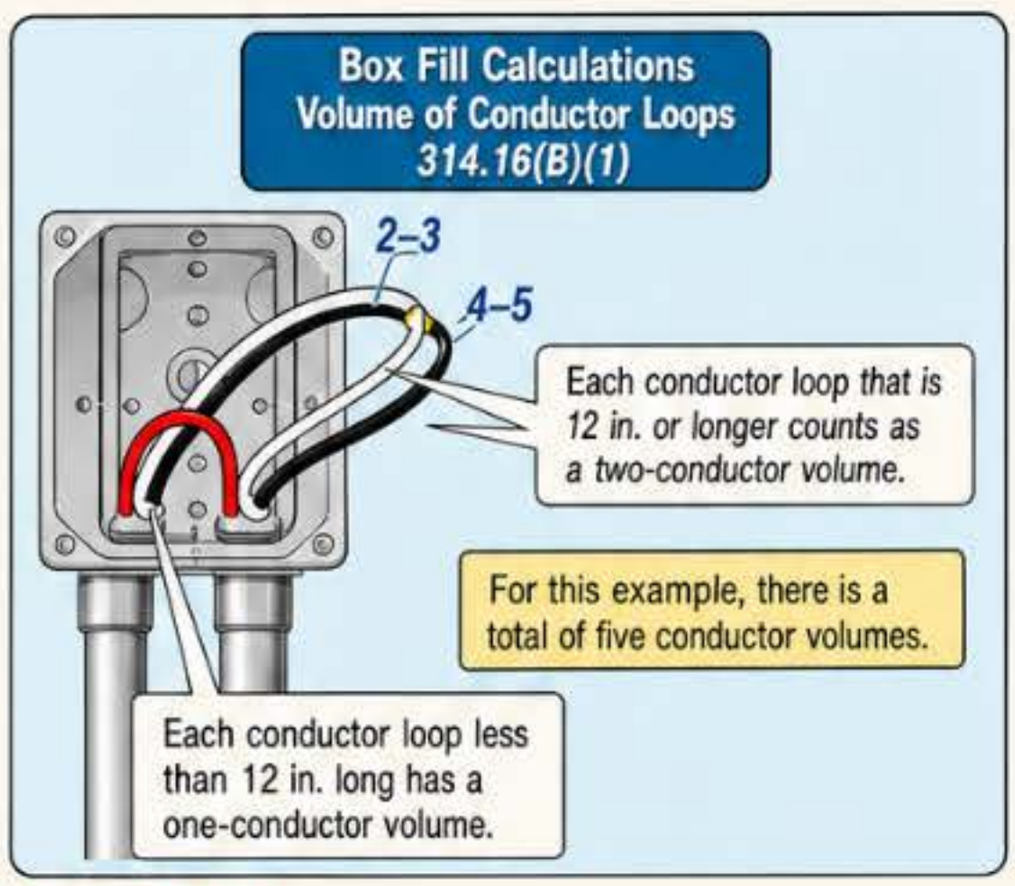
314.16 | Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures

Table 314.16(B) Volume Allowance Required per Conductor

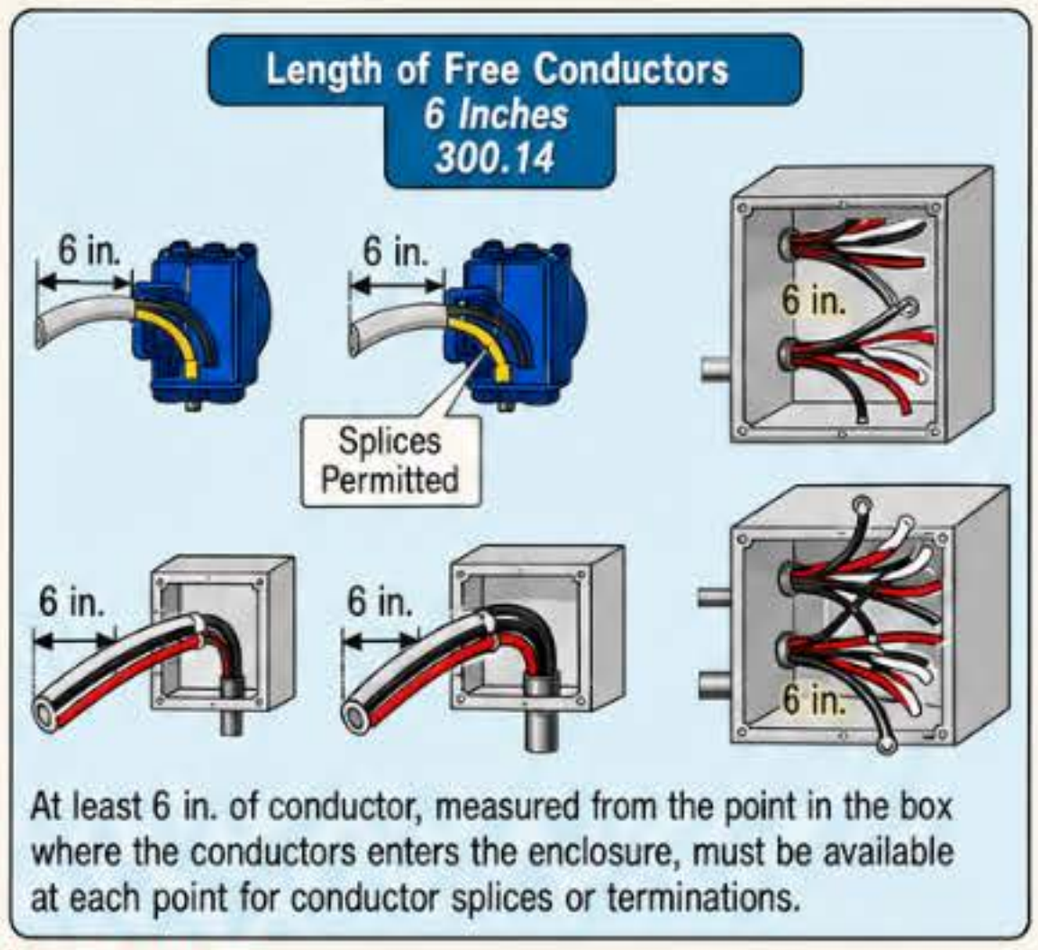
Conductor AWG Size	Free Space Required for Each Conductor (cu in.)
18	1.50
16	1.75
14	2.00
12	2.25
10	2.50
8	3.00
6	5.00

Each conductor loop having a total length of less than 12 in. is considered a single conductor volume, and each conductor loop having a length of at least 12 in. is considered as two conductor volumes in accordance with Table 314.16(B) [300.14].

▶ Figure 314–16

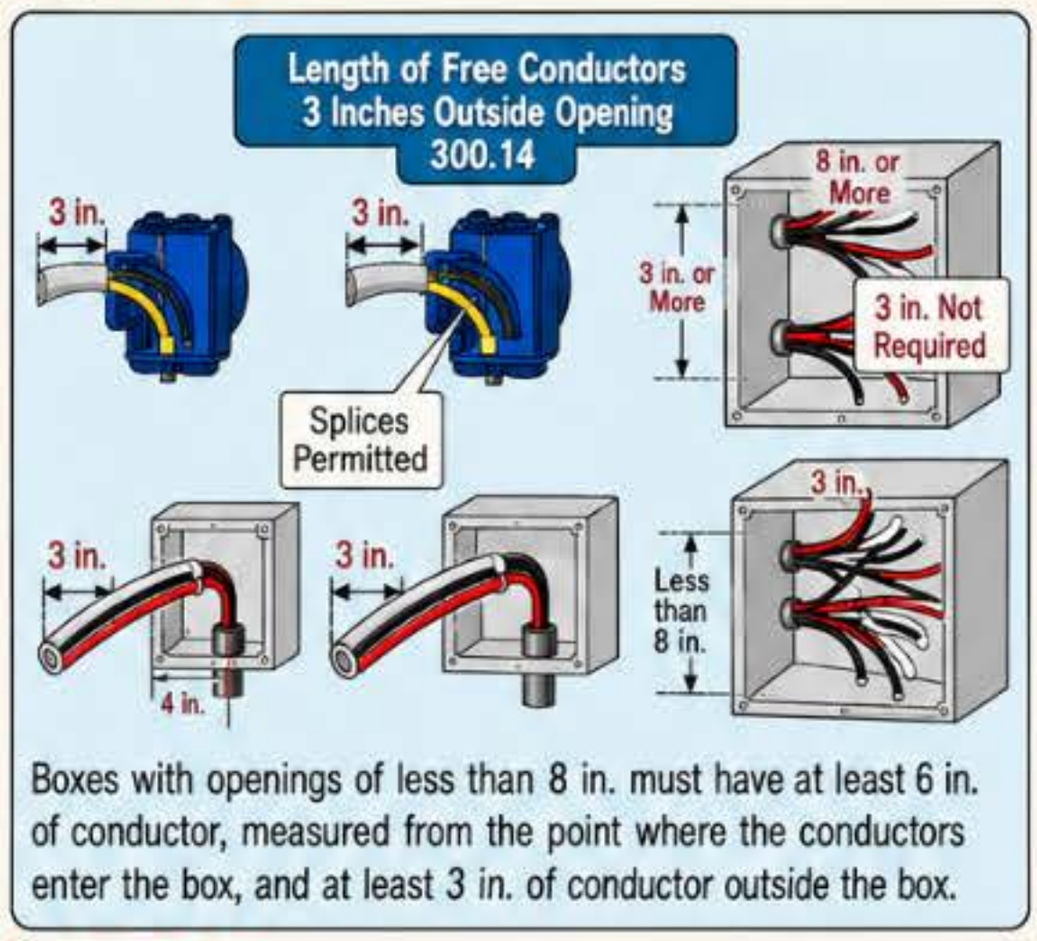


▶ Figure 314–16



At least 6 in. of conductor, measured from the point in the box where the conductors enters the enclosure, must be available at each point for conductor splices or terminations.

▶ Figure 314–17



Boxes with openings of less than 8 in. must have at least 6 in. of conductor, measured from the point where the conductors enter the box, and at least 3 in. of conductor outside the box.

▶ Figure 314–18

Conductors that originate and terminate within the box, such as pigtails and bonding jumpers, are not counted as a conductor volume. Figure 314–19

Ex: *Equipment grounding conductors and not more than four fixture wires are not counted as a conductor volume if they enter the box from a domed luminaire or similar canopy, such as a ceiling paddle fan canopy.* Figure 314–20

(2) *Cable Clamp Volume.* *Cable clamps that are part of the outlet box are counted as a single conductor volume based on the largest conductor in the box in accordance with Table 314.16(B).* Figure 314–21

Author's Commentary:

- *A minimum of 6 in. of conductor, measured from the point in the box where the conductor enters the enclosure, must be made available at every location intended for splices or terminations.* Figure 314–17
- *Enclosures whose openings are less than 8 in. in any dimension must have at least 6 in. of conductor, measured from the point where the conductors enter the box, and at least 3 in. of conductor extending outside the box.* Figure 314–18

— Michael Hamilton

Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures

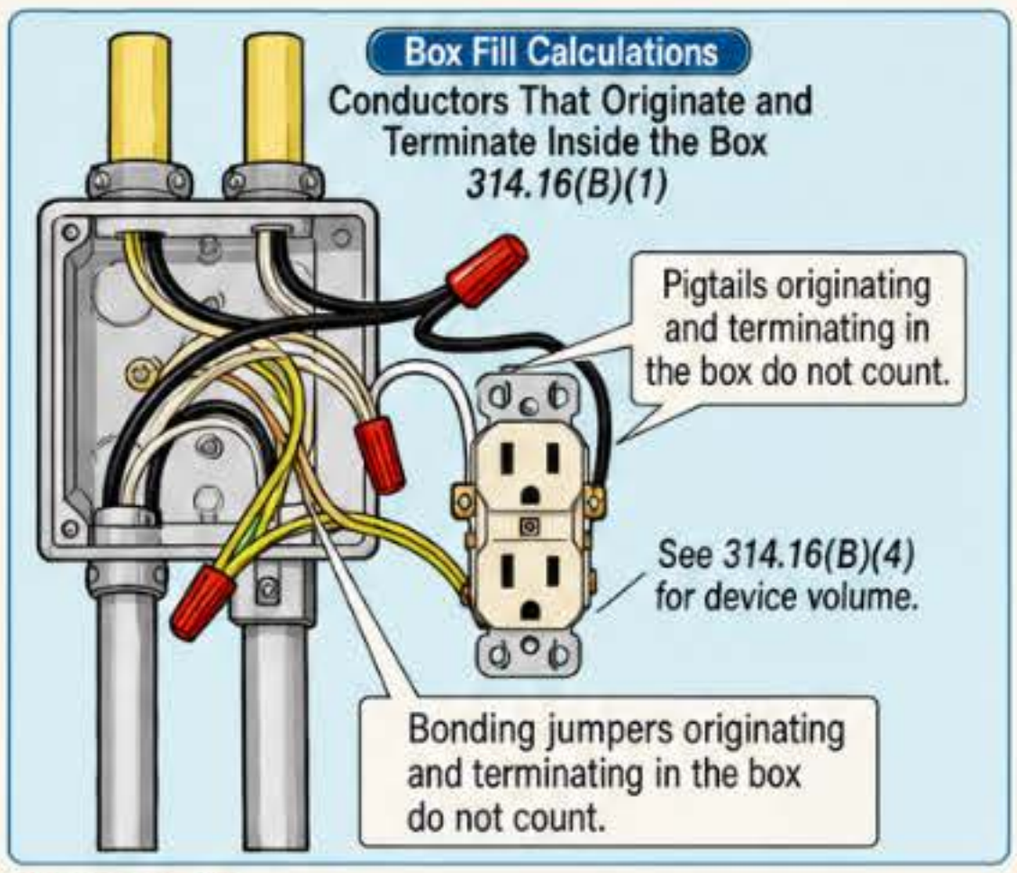


Figure 314–19

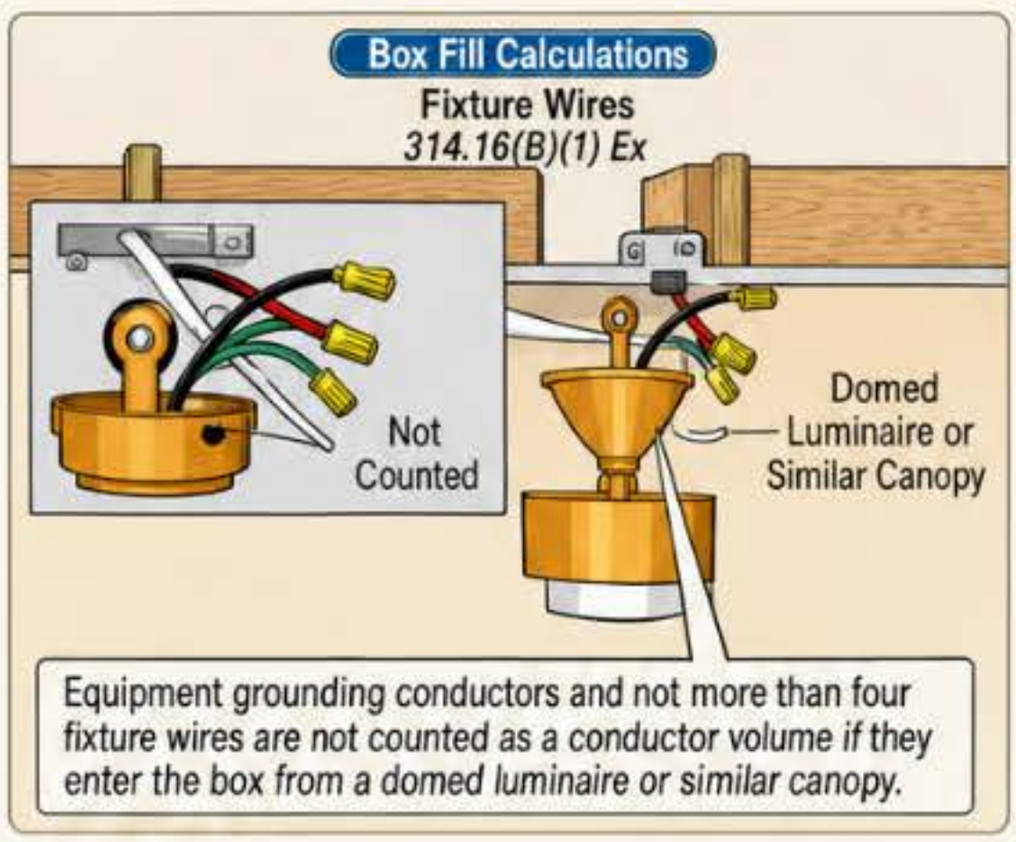


Figure 314–20

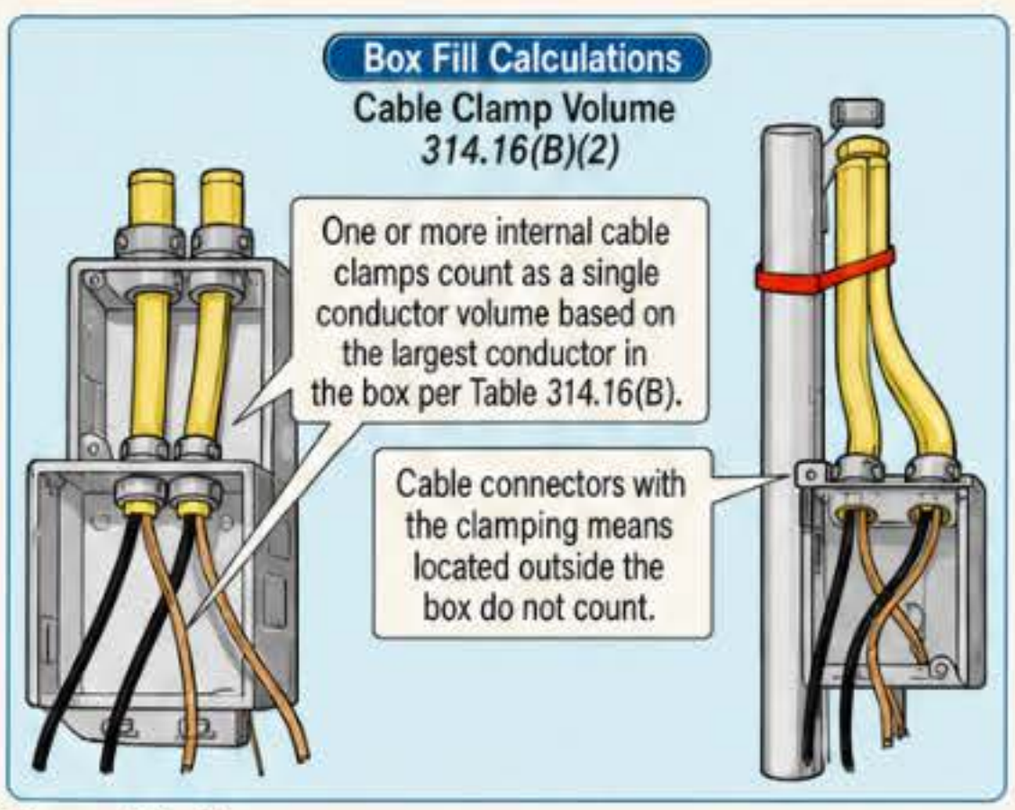


Figure 314–21

(3) Support Fitting Volume. Each luminaire stud or luminaire hickey counts as a single conductor volume based on the largest conductor that enters the box in accordance with Table 314.16(B). **Figure 314–22**

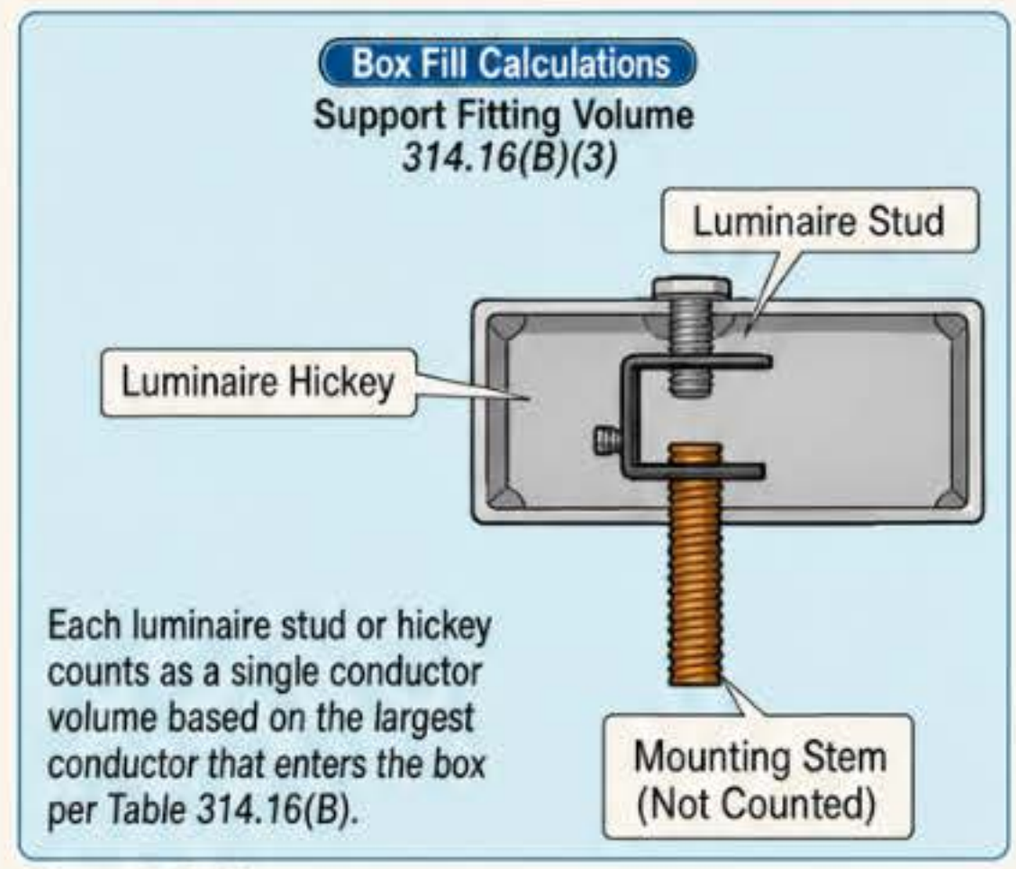


Figure 314–22

(4) Device Yoke Volume. Each single-gang device yoke counts as two conductor volumes based on the largest conductor that terminates on the device in accordance with Table 314.16(B). **Figure 314–23**

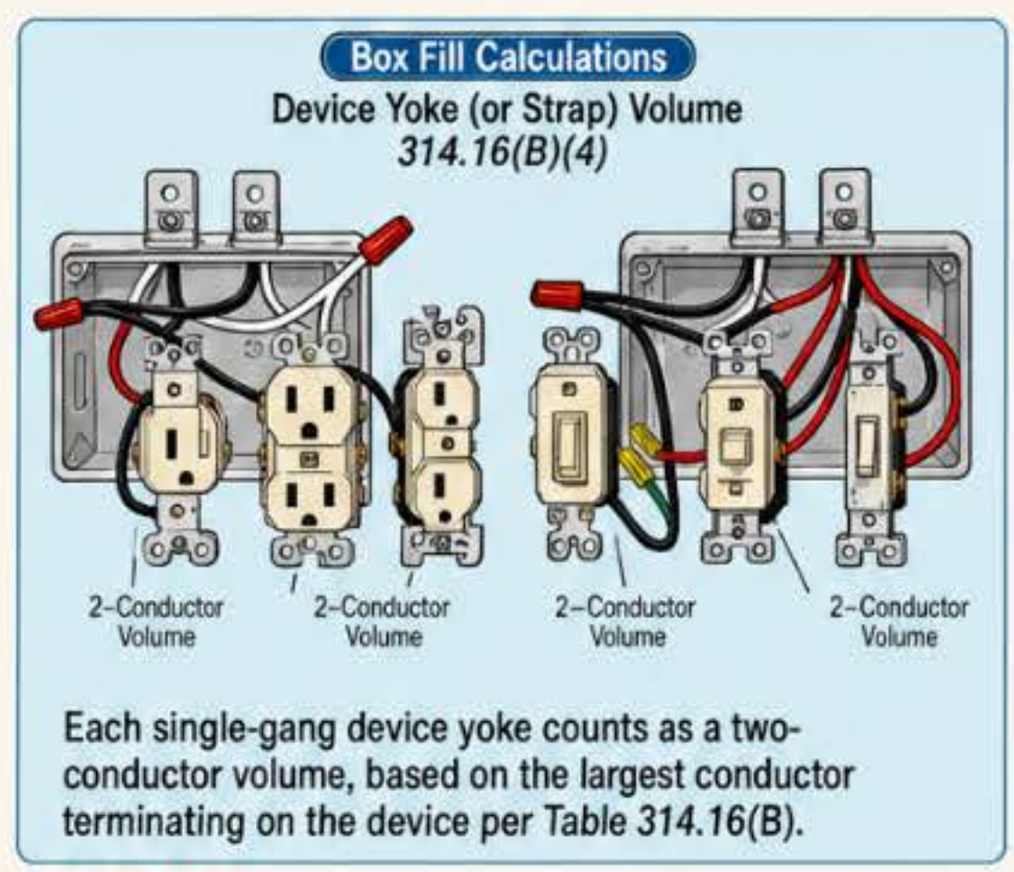
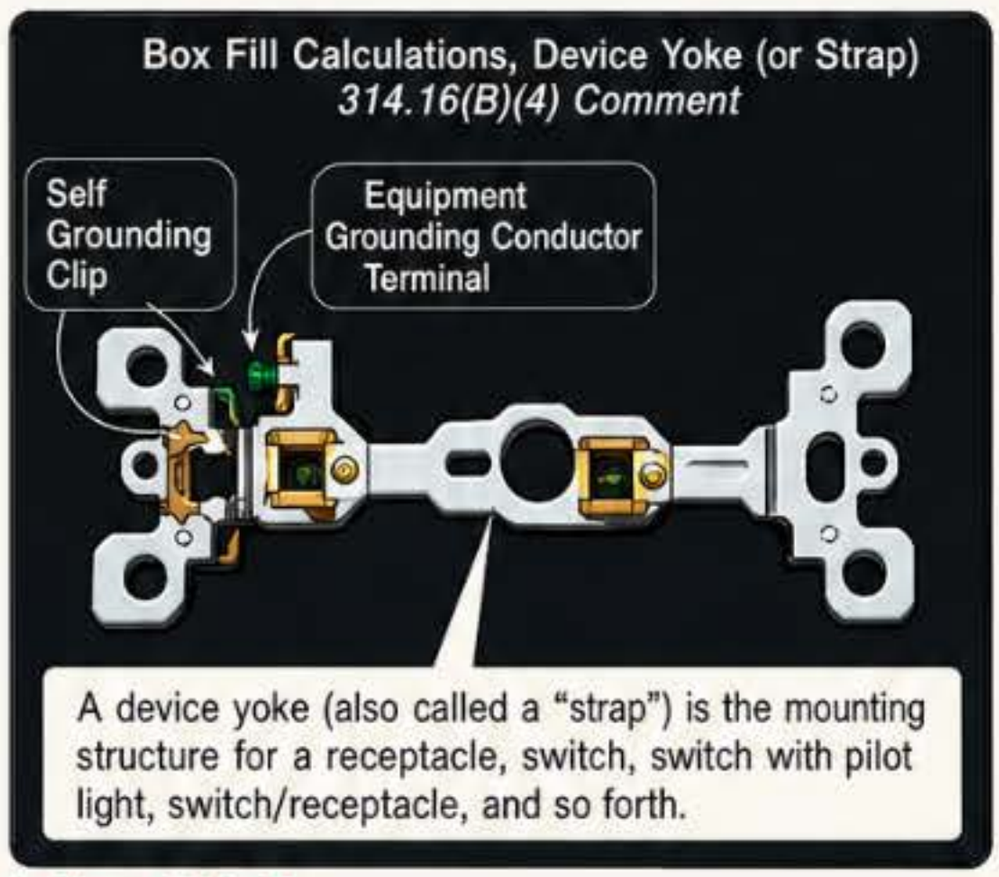


Figure 314–23

Author's Commentary:

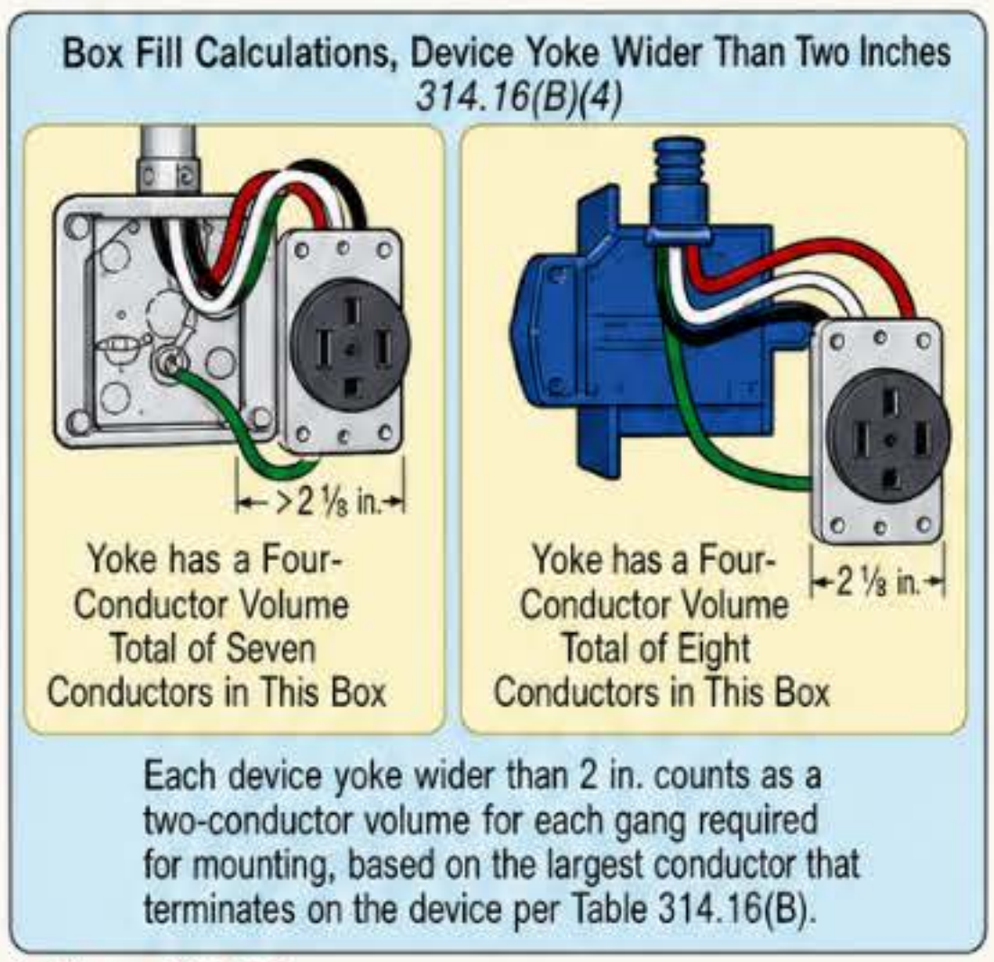
- A device yoke (also called a "strap") is the mounting structure for a receptacle, switch, switch with pilot light, switch/receptacle combination, and so forth.

— Michael Hamilton



▶ **Figure 314-24**

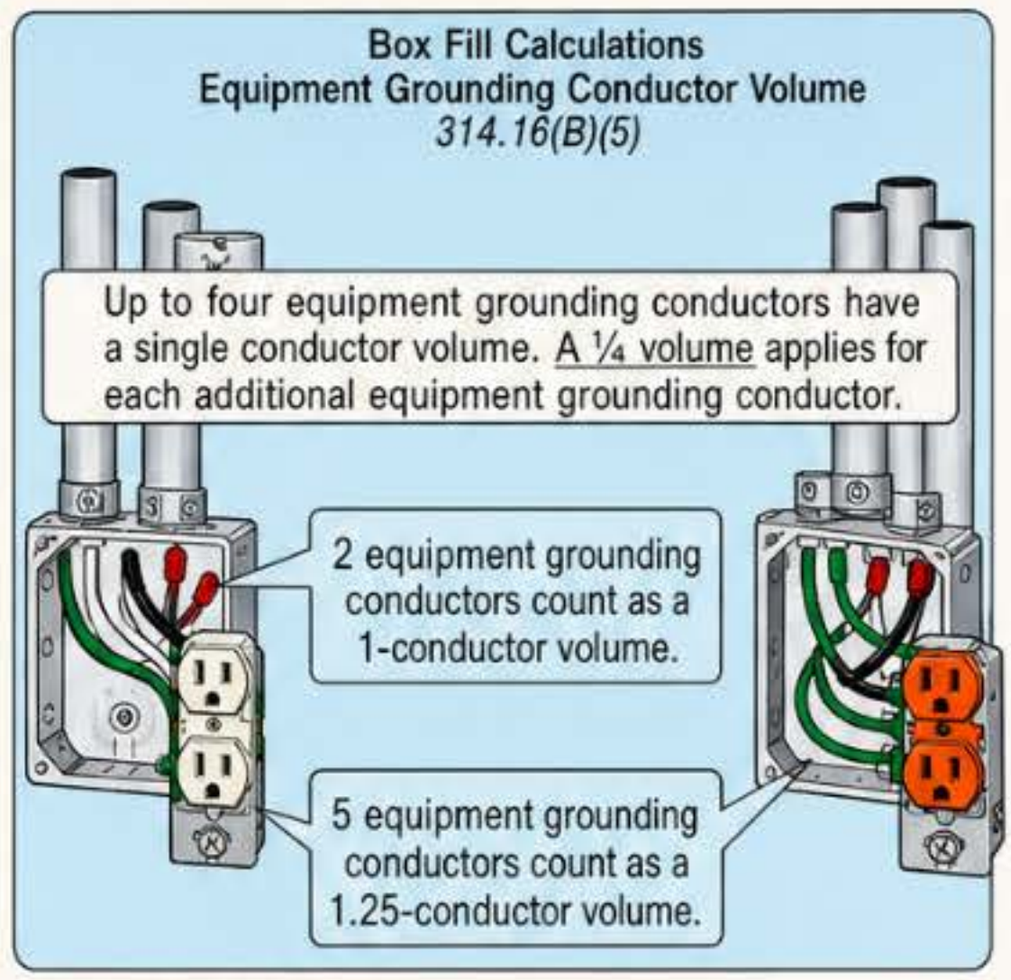
Each device yoke wider than 2 in. counts as a two-conductor volume for each gang required for mounting, based on the largest conductor that terminates on the device in accordance with Table 314.16(B). **Figure 314-25**



▶ **Figure 314-25**

(5) Equipment Grounding Conductor Volume. Up to four equipment grounding conductors count as a single conductor volume, based on the largest equipment grounding conductor that enters the box in accordance with Table 314.16(B).

A ¼ volume allowance applies for each additional equipment grounding conductor or equipment bonding jumper that enters the box, based on the largest equipment grounding or bonding conductor. **Figure 314-26**



▶ **Figure 314-26**

▶ Number of Conductors Example

Question: *What is the total number of conductors used for box fill calculations in a 4-in. square × 2½ in. deep box with two internal cable clamps, one single-pole switch, one duplex receptacle, one 14/3 with ground NM cable, and one 14/2 with ground NM cable?* **Figure 314-27**

(a) 5 conductors *(b) 7 conductors*
(c) 9 conductors *(d) 11 conductors*

Solution:

Switch and Conductors	*5–14 AWG conductors †*
Receptacles and Conductors	*2–14 AWG conductors †*
Equipment Grounding Conductor	*1–14 AWG conductor*
Cable Clamps	*1–14 AWG conductor*
Total	*11–14 AWG conductors*

†Two conductors for the device and three conductors terminating
†Two conductors for the device and two conductors terminating

Each 14 AWG conductor counts as 2 cu in. (Table 314.16(B)).
11 conductors × 2 cu in. = 22 cu in.

If the cubic-inch volume of the plaster ring is not stamped on it, or given in the problem, it cannot be included in the box volume. Without knowing the plaster ring volume, a 4-in. square by 2½ in. deep box is the minimum required for this example.

Answer: *(d) 11 conductors*

DEFINITIONS | From Michael Hamilton Publications

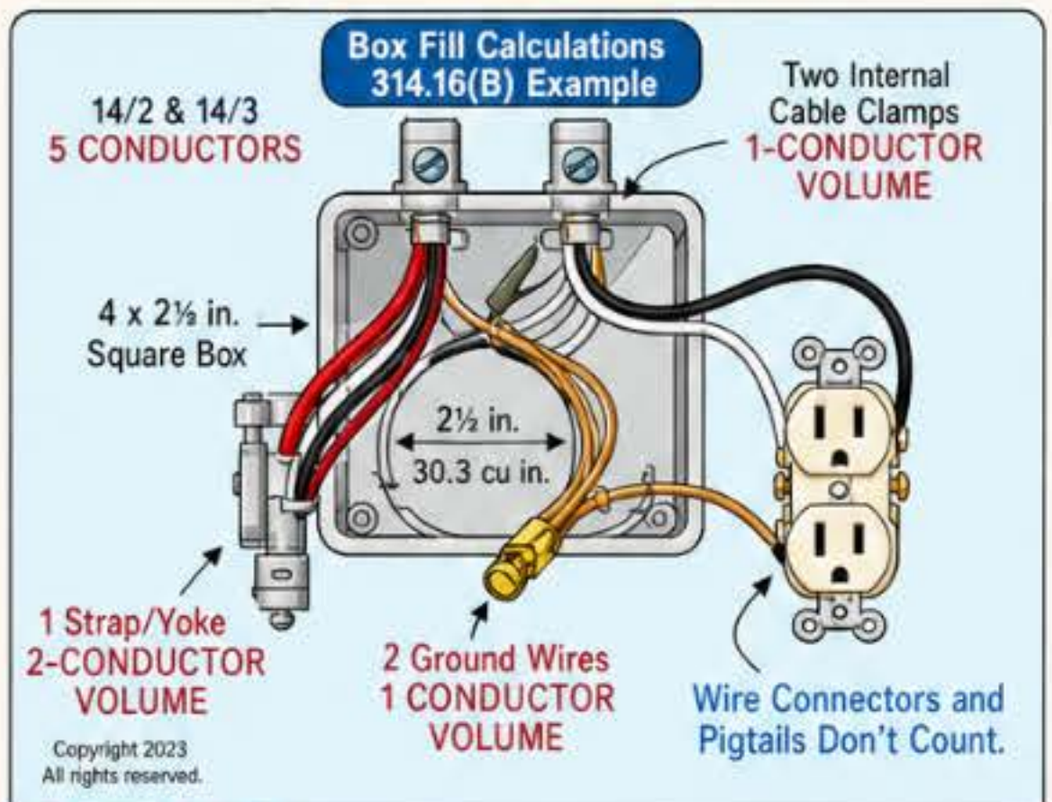
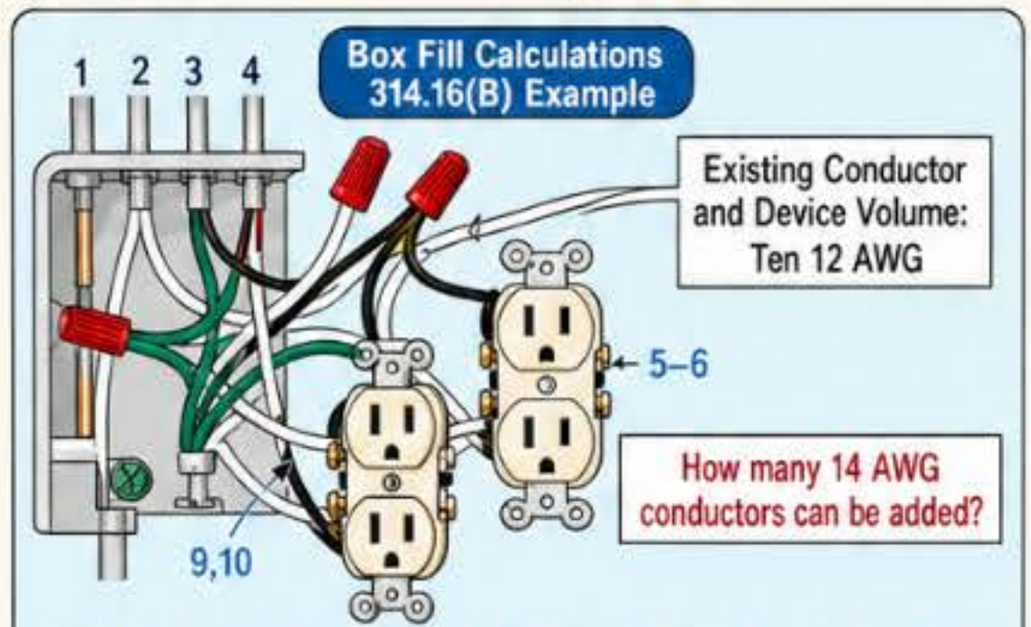


Figure 314-27

▶ Box Fill Example

Question: *Imagine 14 AWG conductors are pulled into a 4 in. square by 2½ in. deep box with a plaster ring around it. The box includes two receptacles, five 12 AWG conductors, and two 12 AWG equipment grounding conductors.* ***Figure 314-28*** *corresponds to this setup.*

(a) 4 conductors *(b) 5 conductors*
(c) 6 conductors *(d) 7 conductors*



Step 1. Volume of box/ring: 30.30 + 3.60 cu in. = 33.90 cu in.
Step 2. Volume of existing conductors/devices:
Ten 12 AWG x 2.25 cu in. = 22.50 cu in.
Step 3. Remaining volume:
33.90 cu in. – 22.50 cu in. = 11.40 cu in.
Step 4. Number of 14 AWG added: 11.40/2.00 cu in. = 5

Figure 314-28

Solution:

Step 1: *Determine the volume of the box assembly (314.16(A)).*

Box Assembly Volume = Box 30.30 cu in. + 3.60 cu in. plaster ring

Box Assembly Volume = 33.90 cu in.

Step 2: *Determine the volume of the devices and conductors in the box:*

Two receptacles	*4–12 AWG*
Five 12 AWG conductors	*5–12 AWG*
Two 12 AWG equipment grounding conductors	*1 – 2 AWG*

Total Device Volume and Conductors = Ten–12 AWG × 2.25 cu in.

Total Device Volume and Conductors = 22.50 cu in.

Step 3: *Determine the remaining volume permitted for the 14 AWG conductors (volume of the box minus the volume of the conductors).*

Remaining Volume = 33.90 cu in. – 22.50 cu in.

Remaining Volume = 11.40 cu in.

Step 4: *Determine the number of 14 AWG conductors (at 2.00 cu in. each) permitted in the remaining volume of 11.40 cu in.:*

14 AWG = 2.00 cu in. each (Table 314.16(B))

11.40 cu in./2.00 cu in. = 5 conductors

Five 14 AWG conductors can be pulled through.

Answer: *(b) 5 conductors*

(C) Conduit Bodies

(2) Splices. *Splices are permitted in conduit bodies that are legibly marked by the manufacturer with their volume. The maximum number of conductors permitted in a conduit body is limited in accordance with 314.16(B).*

▶ Number of Conductors in Conduit Body Example

Example: *Suppose 12 AWG conductors are spliced in an 11.80 cu in. conduit body.* ***Figure 314-29*** *corresponds to this situation.*

(a) four conductors *(b) five conductors*
(c) six conductors *(d) seven conductors*

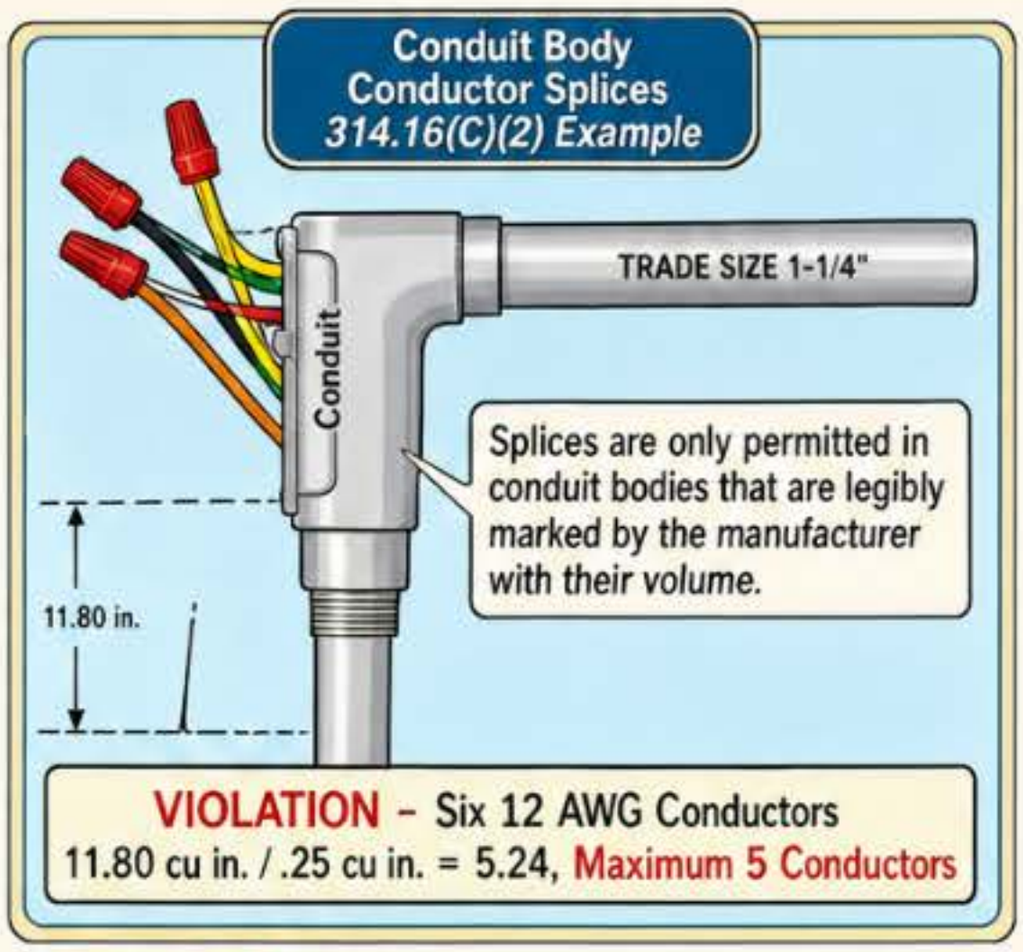
Solution:

12 AWG = 2.25 cu in. (Table 314.16(B))

11.80 cu in./2.25 cu in. = 5.24 conductors

Answer: *(b) five conductors*

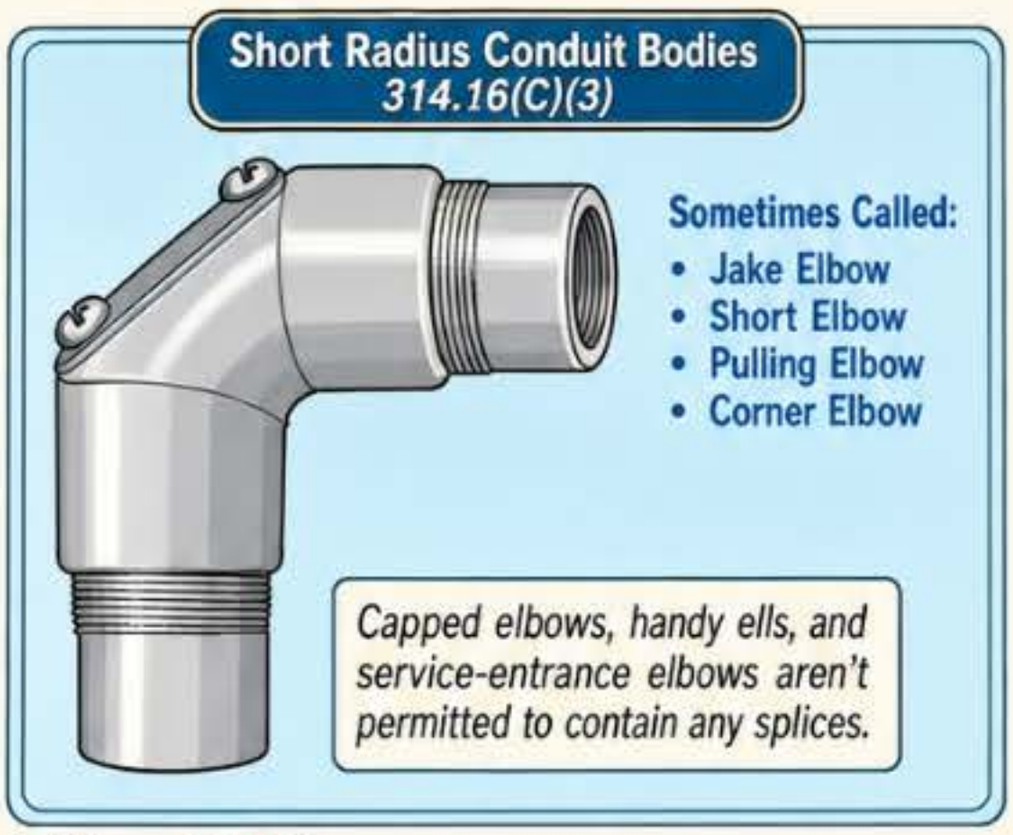
314.17 | Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures



▶ Figure 314-29

(3) Short Radius Conduit Bodies. Capped elbows, handy ells, and service-entrance elbows are not permitted to contain any splices.

▶ Figure 314-30

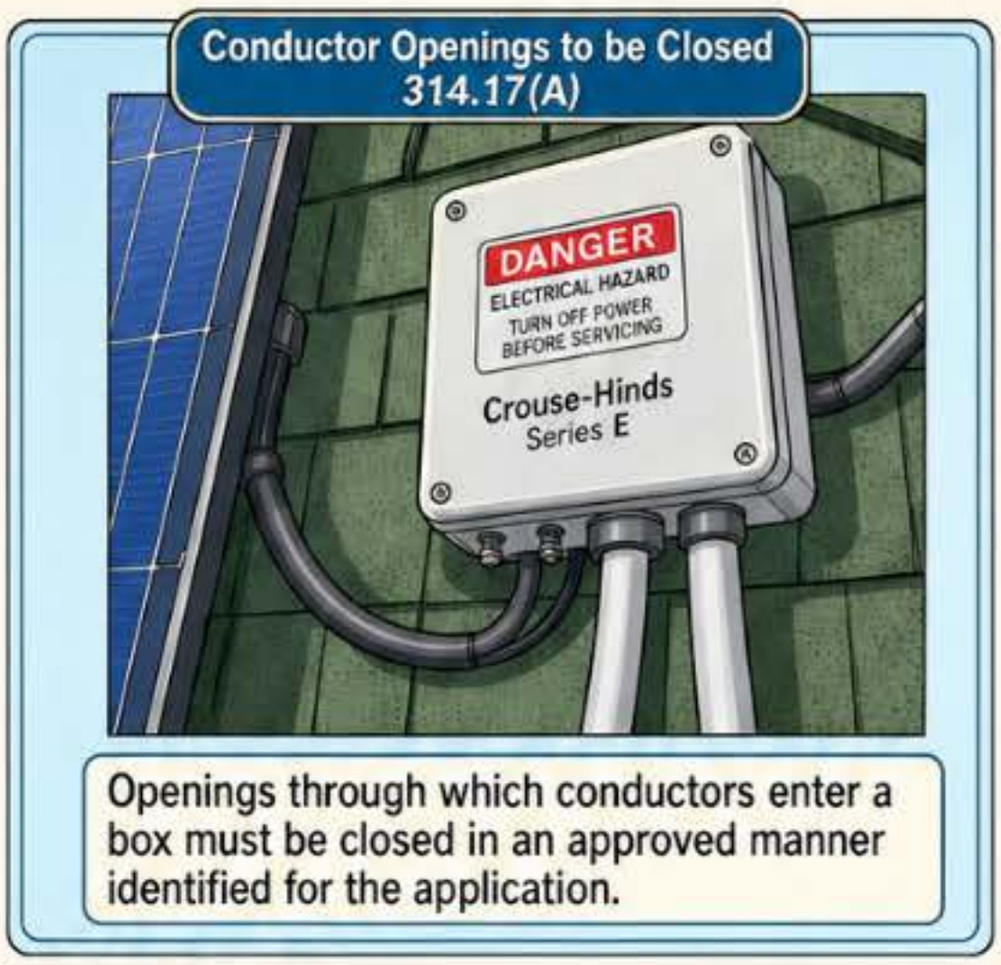


▶ Figure 314-30

314.17 Conductors That Enter Boxes or Conduit Bodies

(A) Openings to be Closed. *Unused openings through which conductors enter a box must be closed in an approved manner identified for the application.*

▶ Figure 314-31



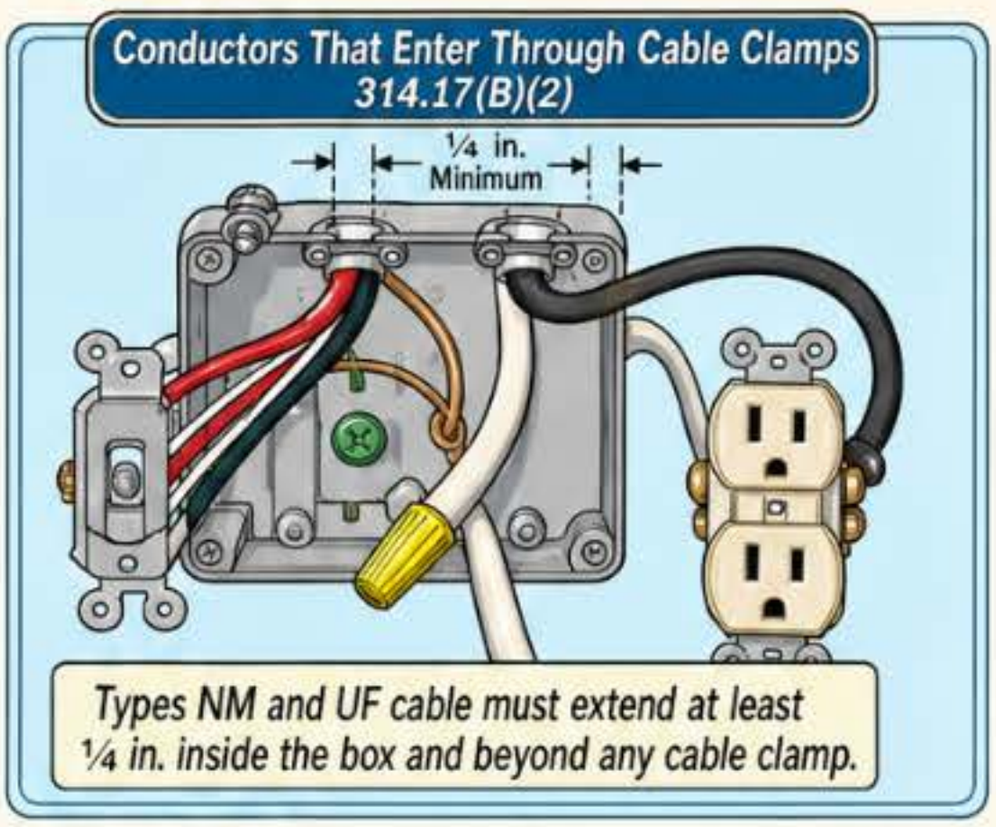
▶ Figure 314-31

Author's Commentary:
Unused cable or raceway openings must be effectively closed by fittings that provide protection substantially equivalent to the wall of the equipment [110.12(A)].
— Michael Hamilton

(B) Boxes. The installation of the conductors in boxes must comply with the following:

(2) Conductors Entering Through Cable Clamps. Where cable assemblies (Type NM or UF) are used, the sheath must extend not less than ¼ in. inside the box and beyond any cable clamp.

▶ Figure 314-32



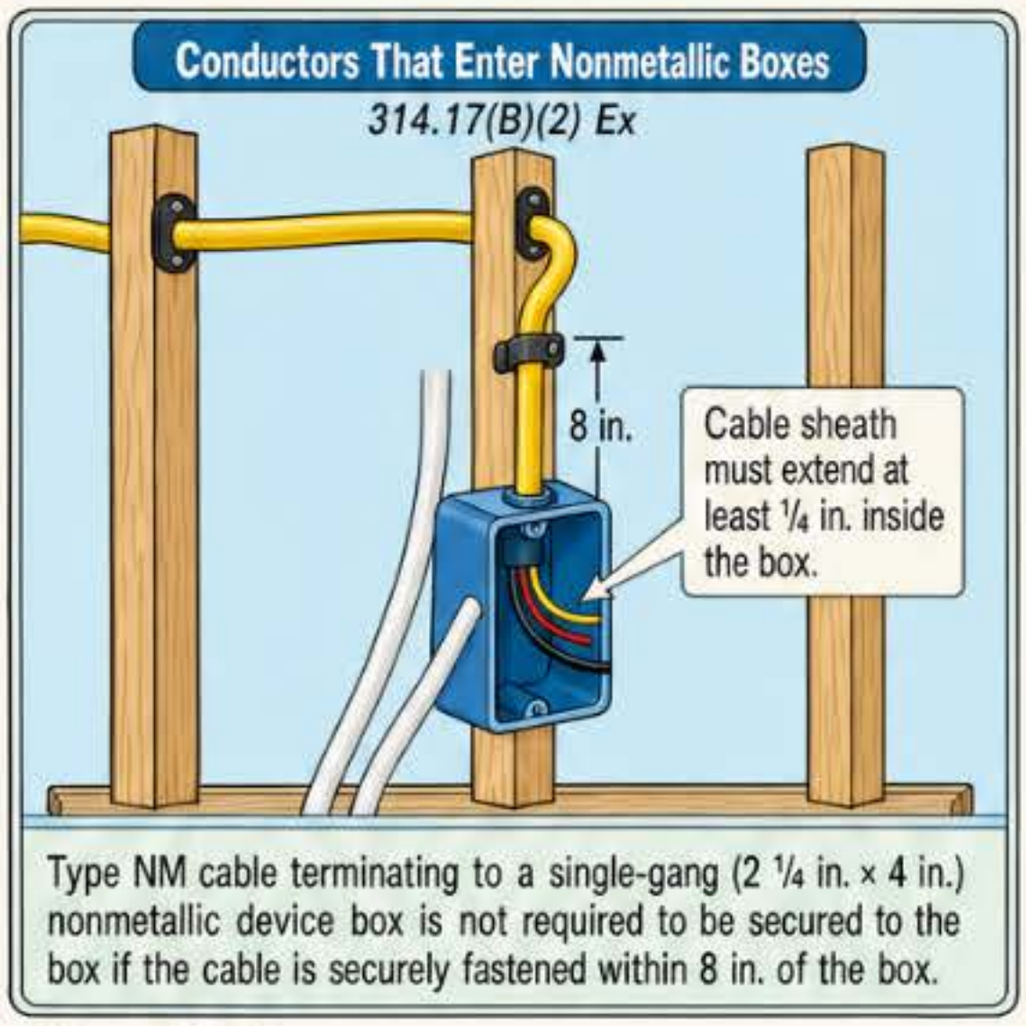
▶ Figure 314-32

Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures 314.21

Author's Commentary:

- Two Type NM cables can be terminated in a single cable clamp if it is listed for this purpose [UL White Book].

Example: *A Type NM cable that terminates in a single-gang nonmetallic box does not need to be fastened to the box when the cable is securely held within 8 in. of the box and the sheath extends at least ¼ in. inside.* • *Figure 314–33*



• *Figure 314–33*

314.20 Flush-Mounted Box Installations

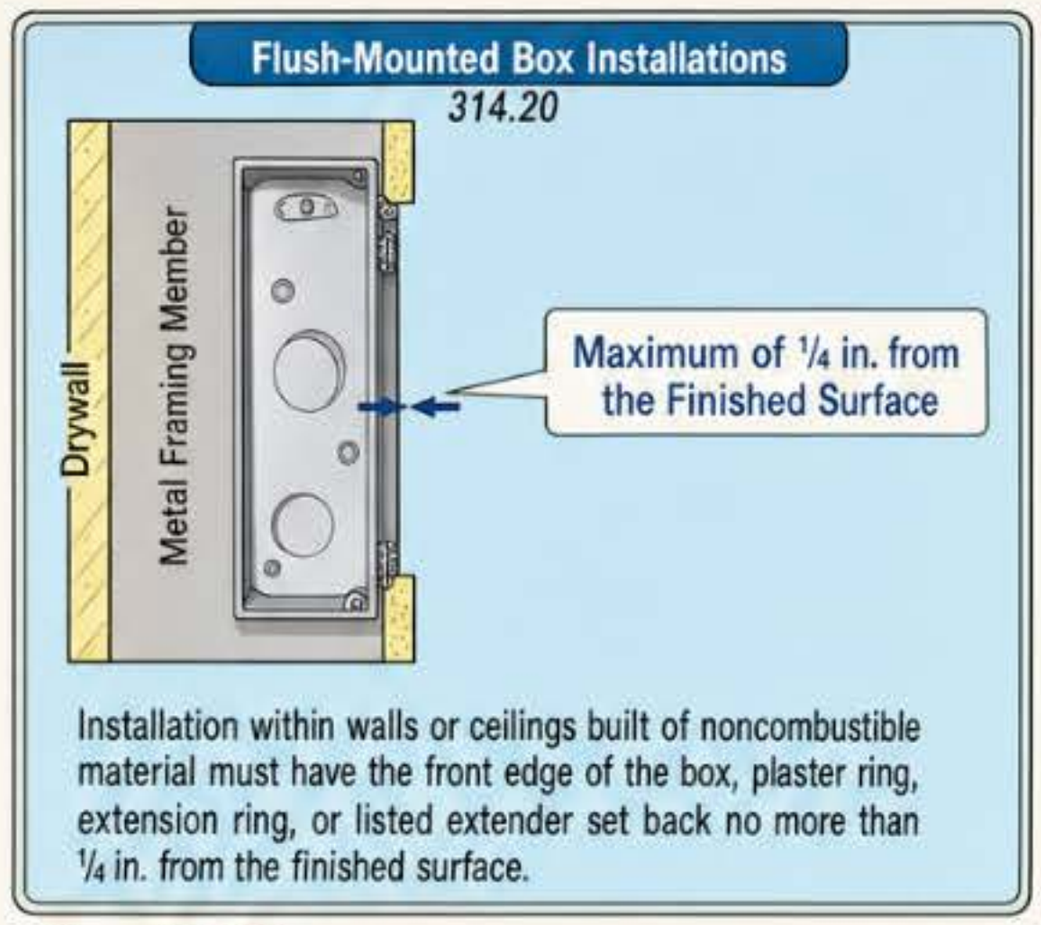
When a wall or ceiling is built of noncombustible material, the front edge of the box, plaster ring, extension ring, or listed extender must not project more than ¼ in. beyond the finished surface. • *Figure 314–34*

When a wall or ceiling is constructed of wood or other combustible material, the front edge of the box, plaster ring, extension ring, or listed extender may not extend past the finished surface. • *Figure 314–35*

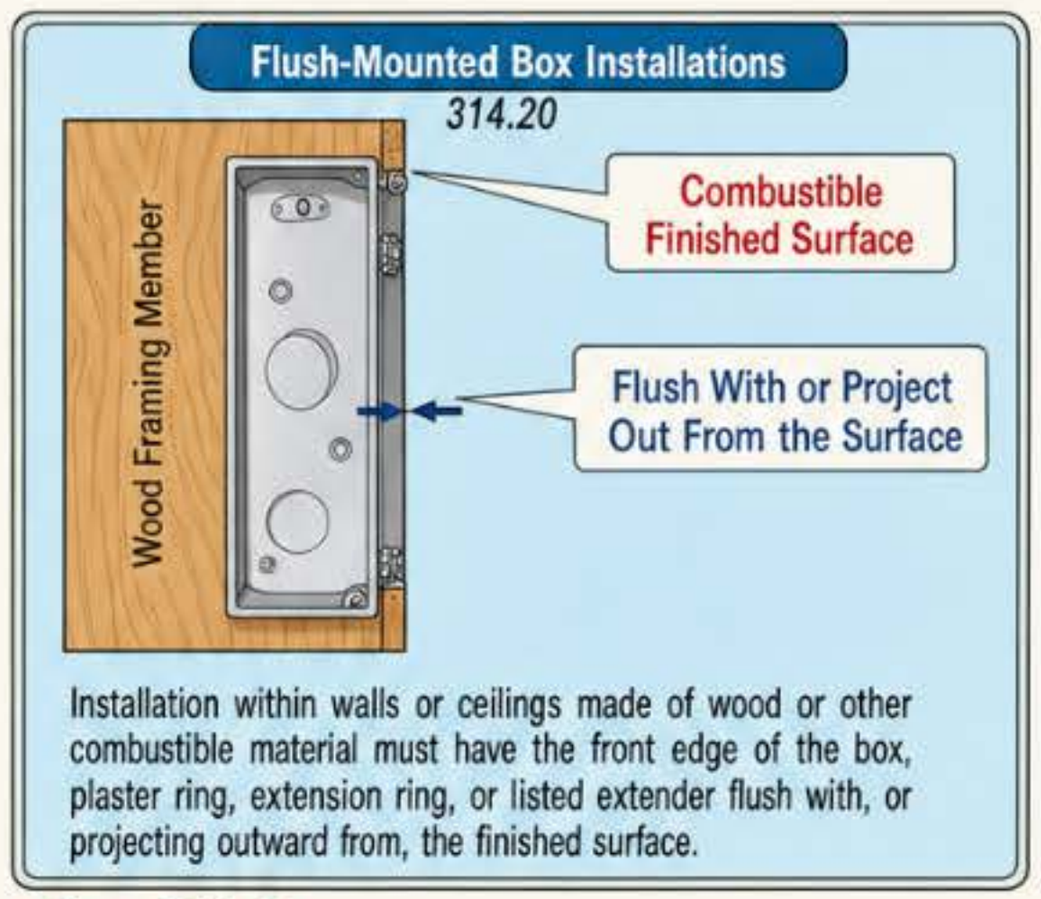
Author's Commentary:

- *Plaster rings and extension rings come in various thicknesses to satisfy the depth needs above.*
- *Finished surfaces such as backsplashes or tile might need to be considered to ensure compliance with the requirements of this section.*

— Michael Hamilton



• *Figure 314–34*



• *Figure 314–35*

314.21 Repairing Noncombustible Surfaces

Openings around boxes that are recessed within noncombustible surfaces (such as plaster, drywall, or plasterboard) must be patched so that no gap exceeds ¼ in. at the edge of the box. • *Figure 314–36*

Author's Commentary:

- *Additional examples of noncombustible surfaces include ceramic wall tile, ceramic or marble floor tile, brick, concrete block, and various types of stone; all of which are governed by the requirements of 314.20 and 314.21.*

— Michael Hamilton

314.22 | Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures

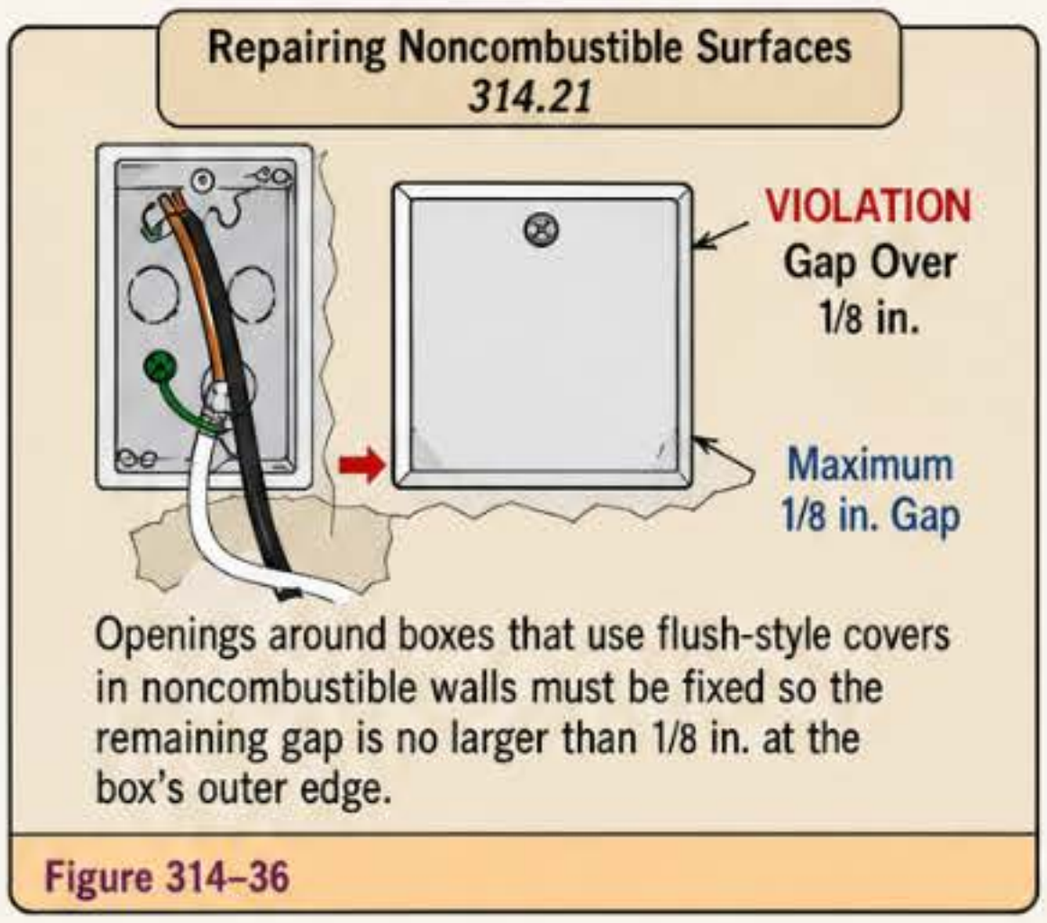


Figure 314–36

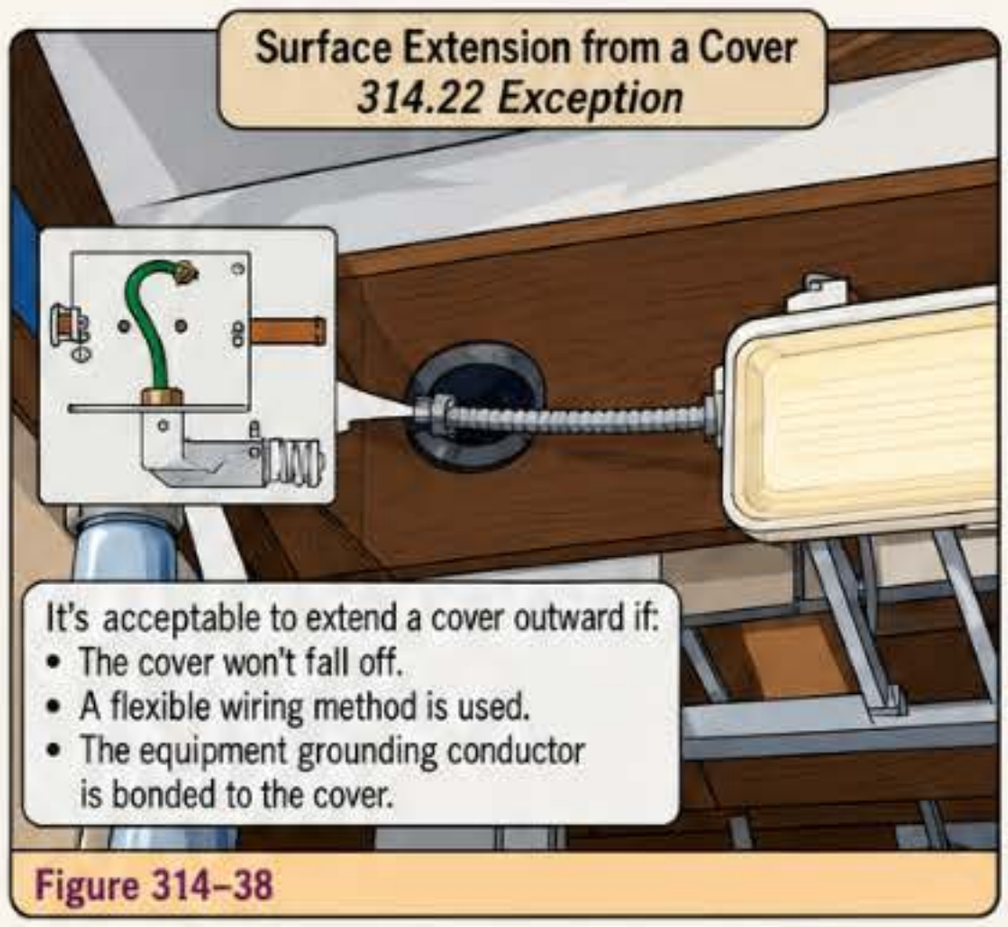


Figure 314–38

314.22 Surface Extensions

A surface extension must be built using an extension ring mounted over the box. Figure 314–37

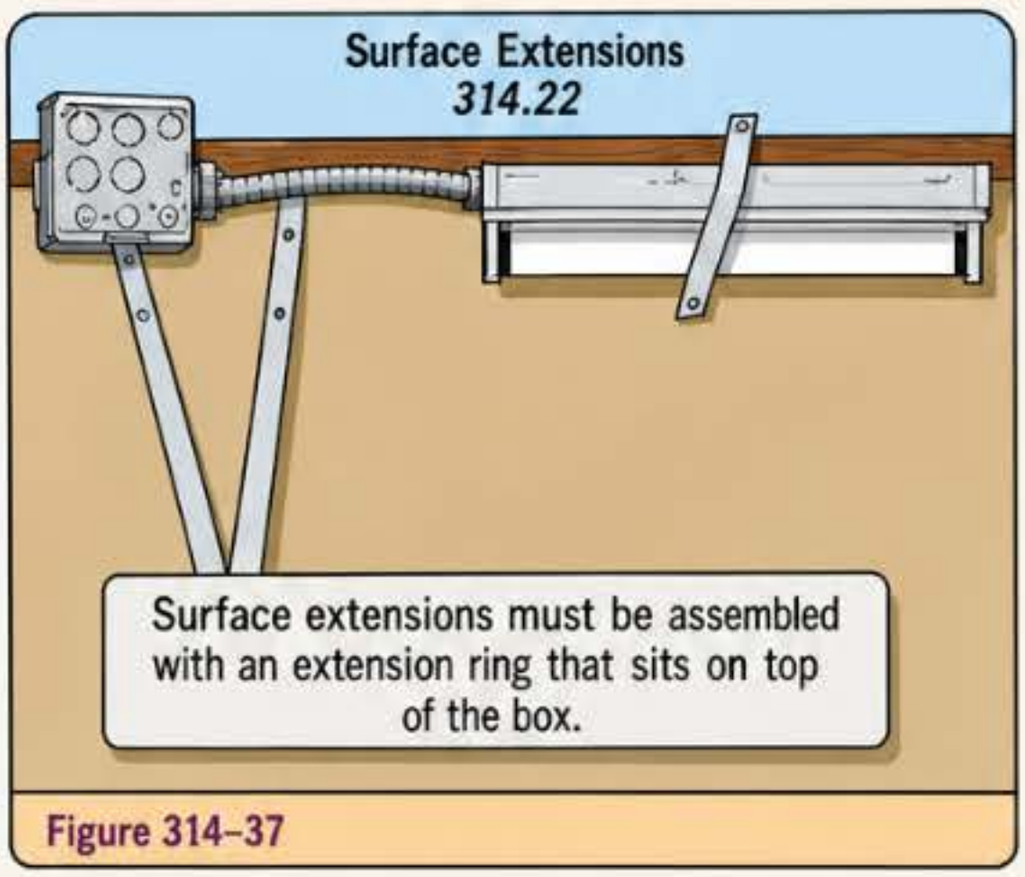


Figure 314–37

> ***Author's Commentary:***
> *Using an extension from the cover itself is allowed only when the design keeps the cover secure. If the mounting screws can loosen and let the cover hang or fall, use an extension ring instead. This keeps the connection solid and maintains a reliable equipment grounding path between the box and the cover.*
>
> *— Michael Hamilton*

314.23 Support of Boxes

(A) Surface. Boxes may be fastened to any surface that provides sufficient support.

(B) Structural Mounting. An enclosure supported by a building structural member must be secured directly or with a metal, plastic, or wood brace.

(2) Braces. A box can have support from any structural member or from a metal, plastic, or wood brace. Figure 314–39

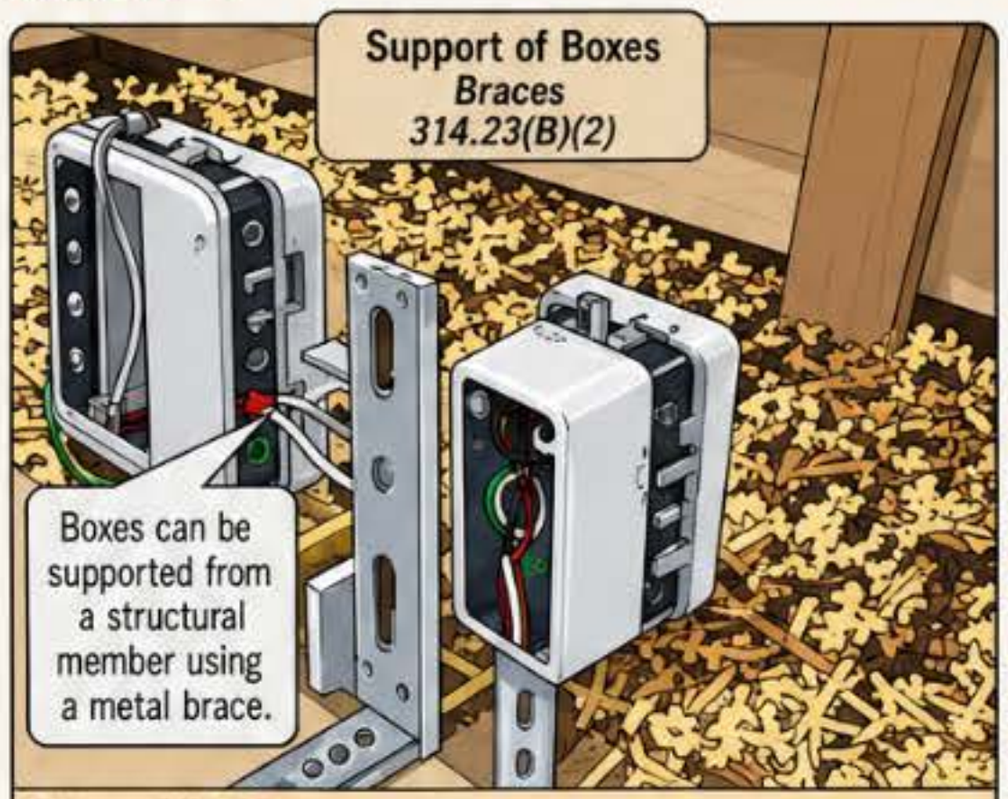
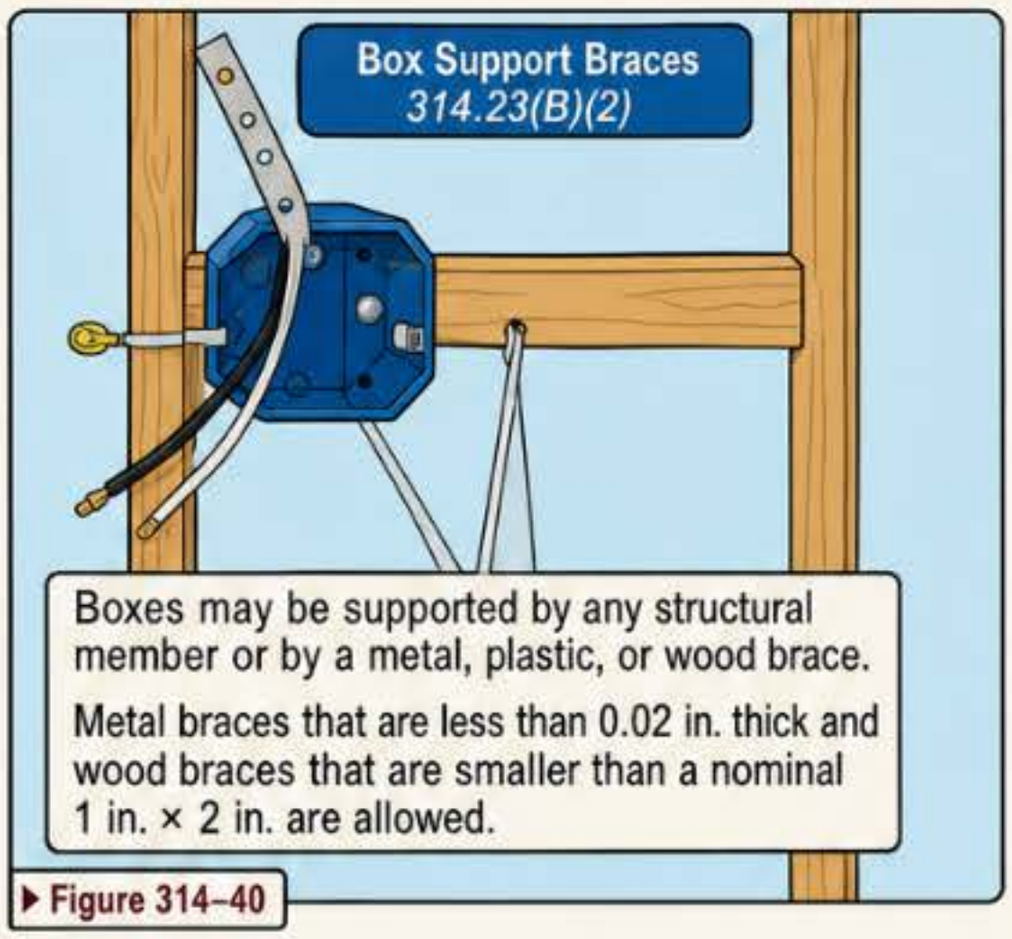


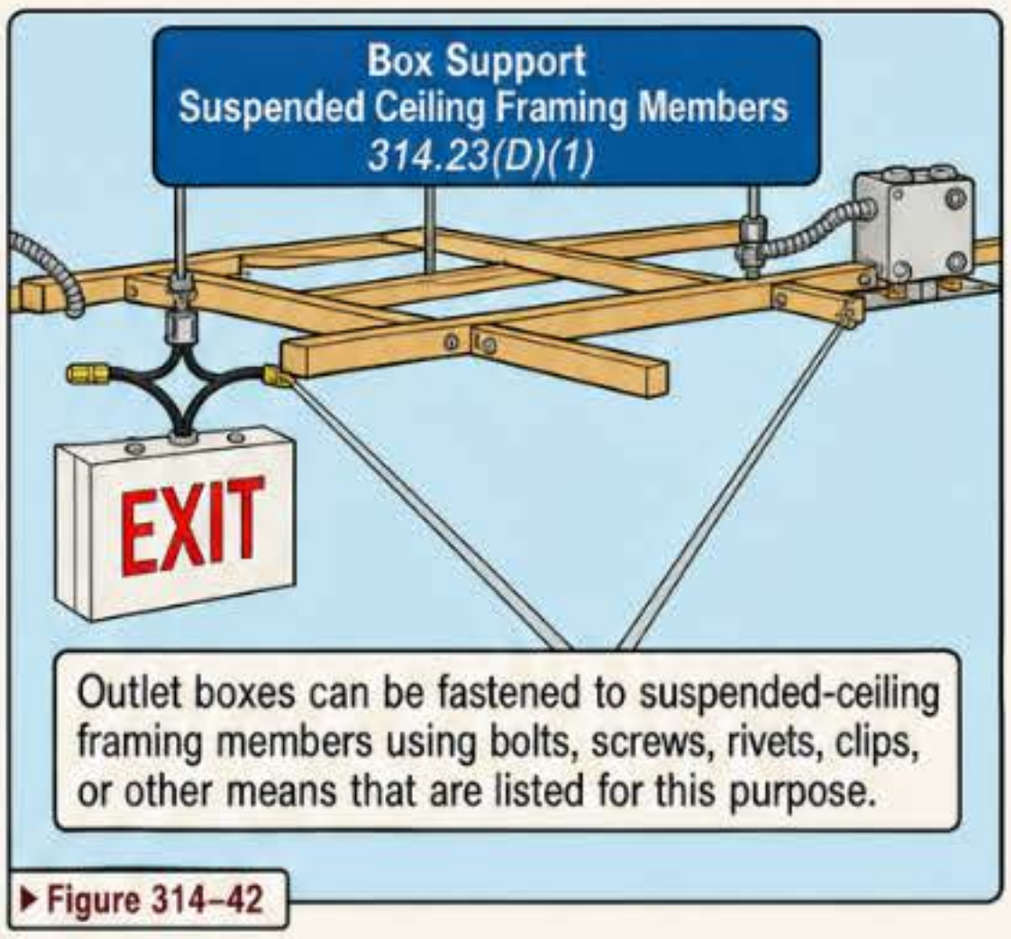
Figure 314–39

> ***Author's Commentary:***
> *Metal braces must be at least 0.02 in. thick. Wood braces need a minimum actual size of 1 in. × 2 in.* Figure 314–40

Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures 314.23



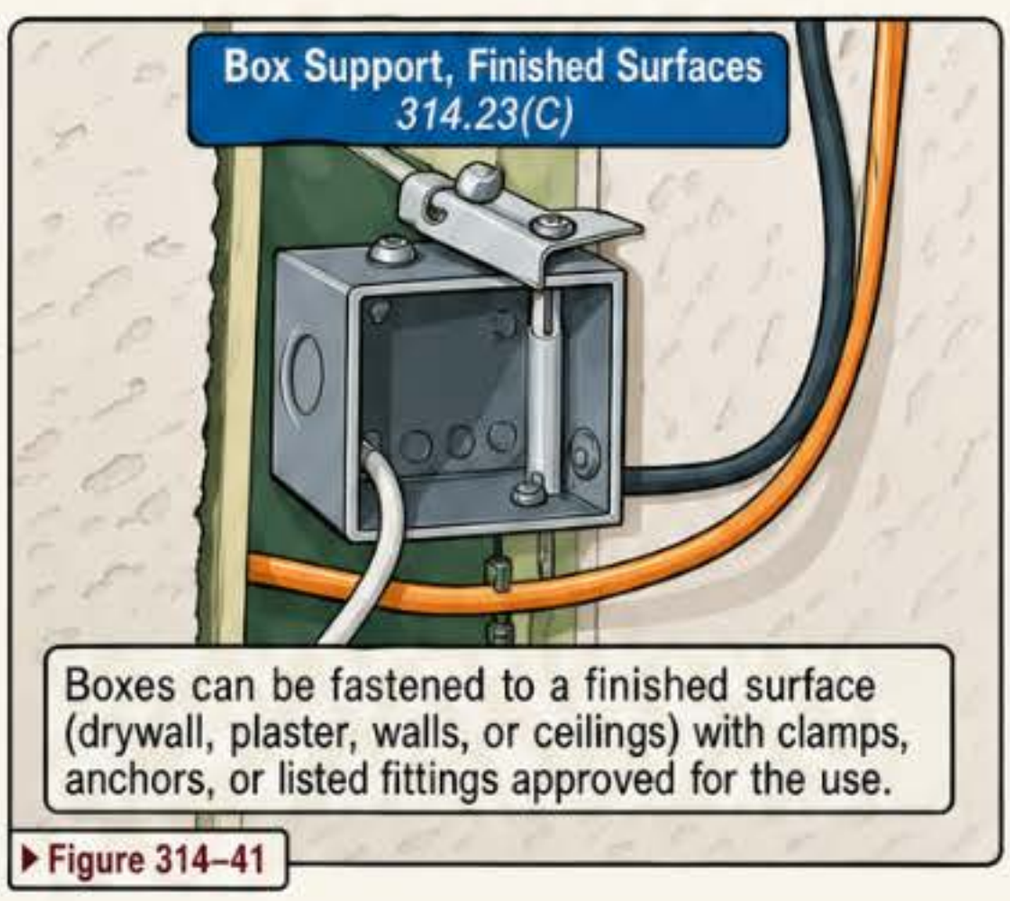
▶ Figure 314–40



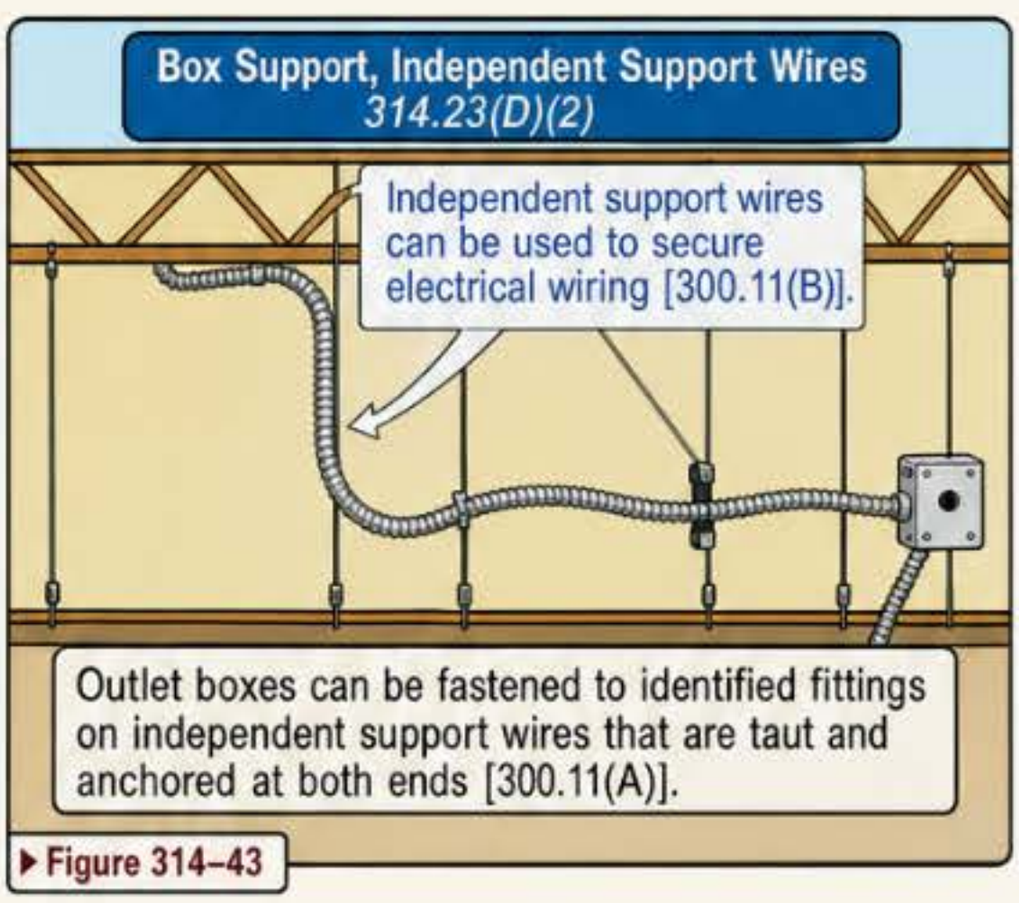
▶ Figure 314–42

(C) Finished Surface Support. Outlet boxes may be attached to a finished surface—such as a drywall panel, plaster, wall, or ceiling—using clamps or listed fittings suitable for the application. Figure 314–41

(2) Independent Support Wires. Outlet boxes can be secured with identified fittings to independent support wires in accordance with 300.11(B). Figure 314–43



▶ Figure 314–41



▶ Figure 314–43

(D) Suspended-Ceiling Support. Outlet boxes may be supported by the structural or supporting components of a suspended ceiling when fastened by any of the following methods:

(1) Ceiling Framing Members. An outlet box may be attached to suspended-ceiling framing members using bolts, screws, rivets, clips, or any other listed device for securing the framing member(s). Figure 314–42

(E) Threaded Raceway-Supported Boxes Without Devices or Luminaires. Two intermediate metal or rigid metal conduits, or threaded wrenches threading into the enclosure, may support an outlet box that does not contain equipment or a luminaire if each raceway is supported within 36 inches of the box or within 18 inches when all conduit entries are on the same side. Figure 314–44

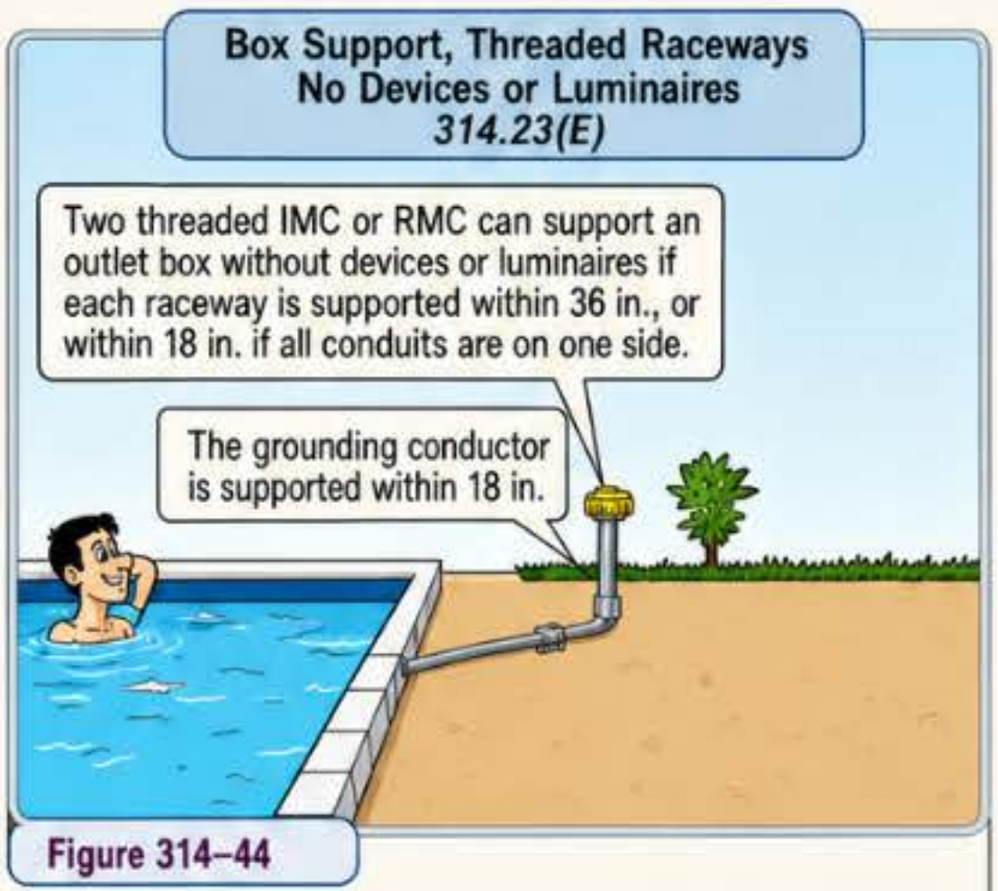


Figure 314–44

Example: The following wiring methods are permitted to support a conduit body of any size, including a conduit body constructed with only one conduit entry, provided the trade size of the conduit body is not larger than the largest trade size of the conduit or tubing. ***Figure 314–45**

(1) Intermediate metal conduit, Type IMC
(2) Rigid metal conduit, Type RMC
(3) Rigid polyvinyl chloride conduit, Type PVC
(4) Reinforced thermosetting resin conduit, Type RTRC
(5) Electrical metallic tubing, Type EMT

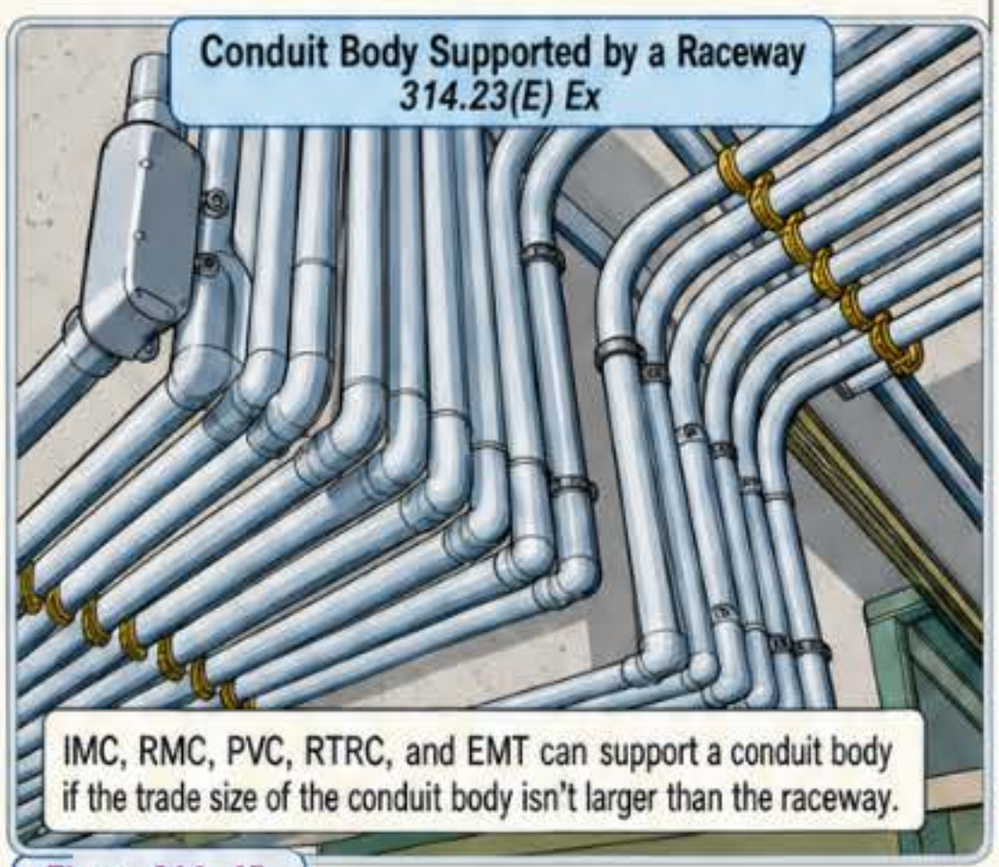


Figure 314–45

> **Author's Commentary:** *Using the raceway itself to hold up certain boxes and conduit bodies can simplify the installation and reduce the amount of material needed. Always verify that support points meet the required distance limits.*
>
> *– Michael Hamilton*

(F) Threaded Raceway-Supported Boxes with Devices or Luminaires. Two intermediate metal or rigid metal conduits, threaded and secured to the enclosure, can be used to support an outlet box containing devices or luminaires if each raceway is supported within 18 in. of the box. ***Figure 314–46**, ***Figure 314–47**, and ***Figure 314–48**

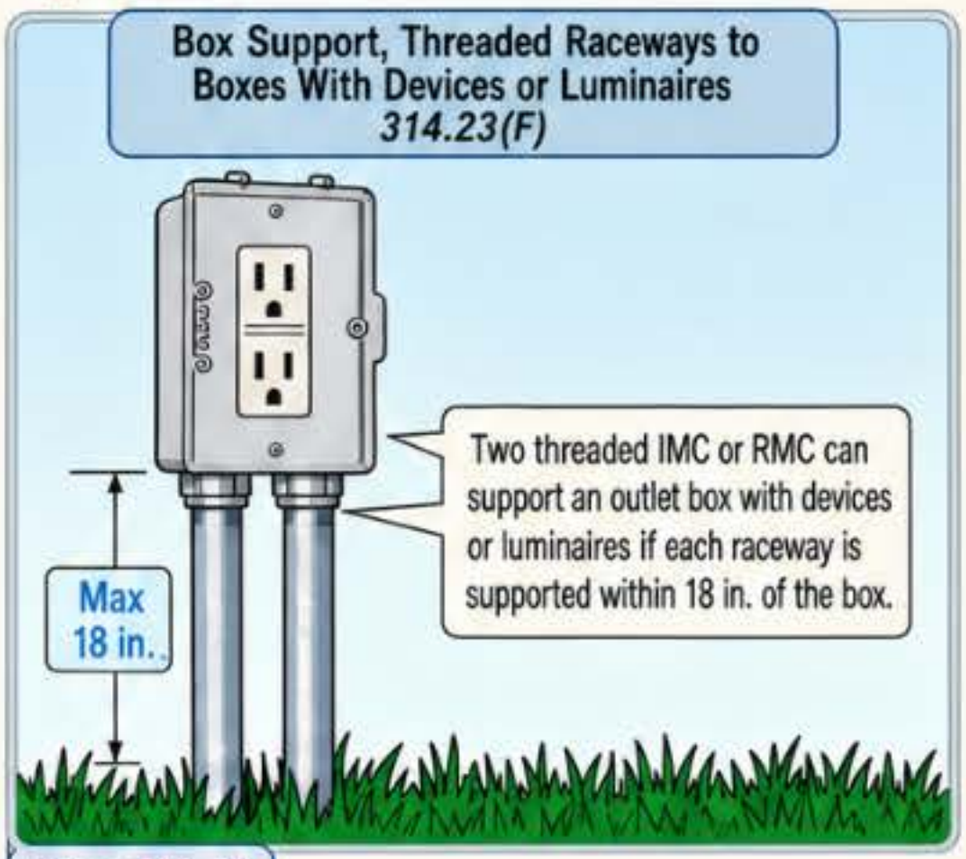


Figure 314–46

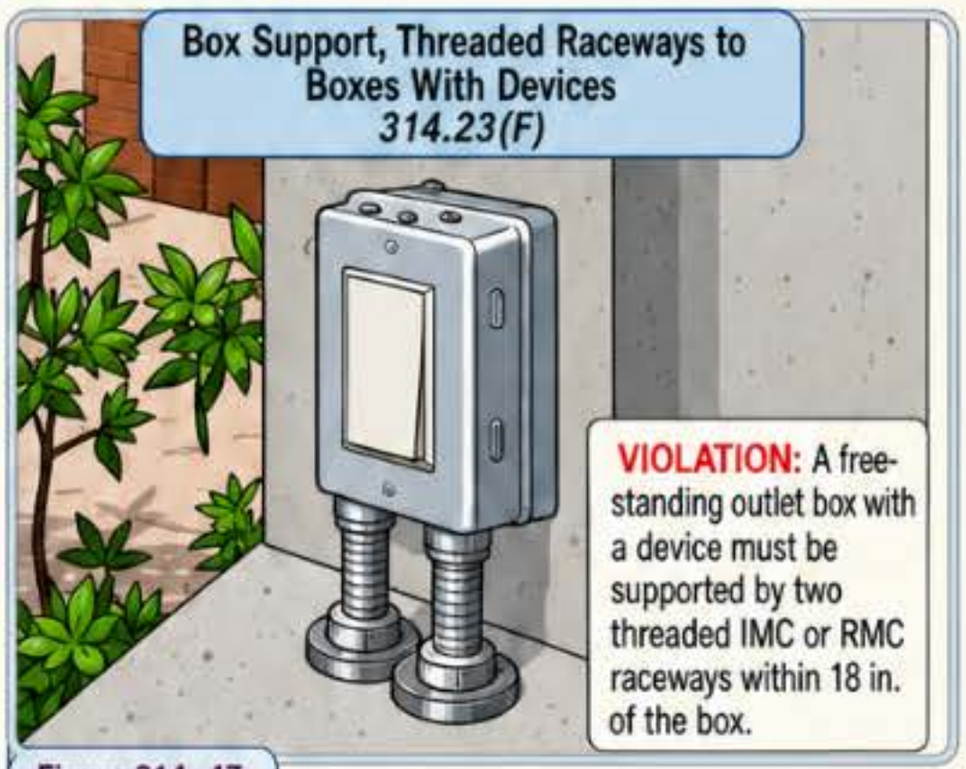


Figure 314–47

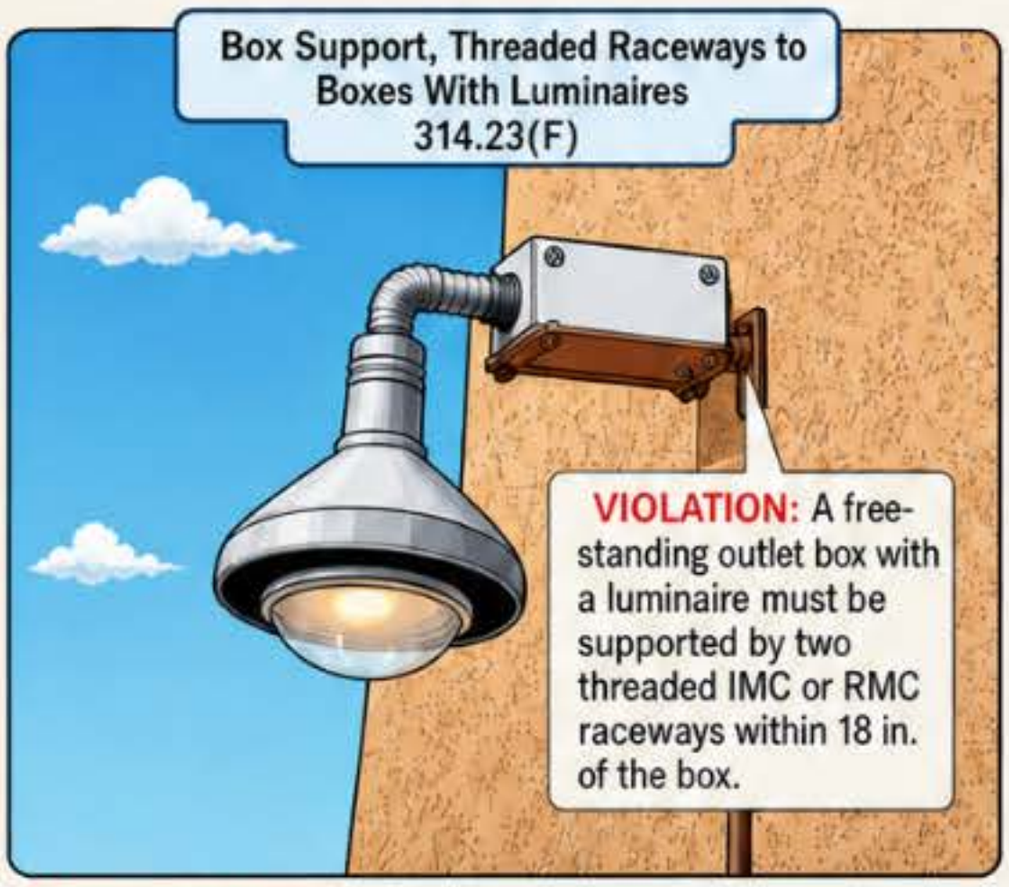
(G) Boxes in Concrete or Masonry. Boxes must be identified as suitably protected from corrosion and be securely embedded in concrete or masonry.

(H) Pendant Boxes.

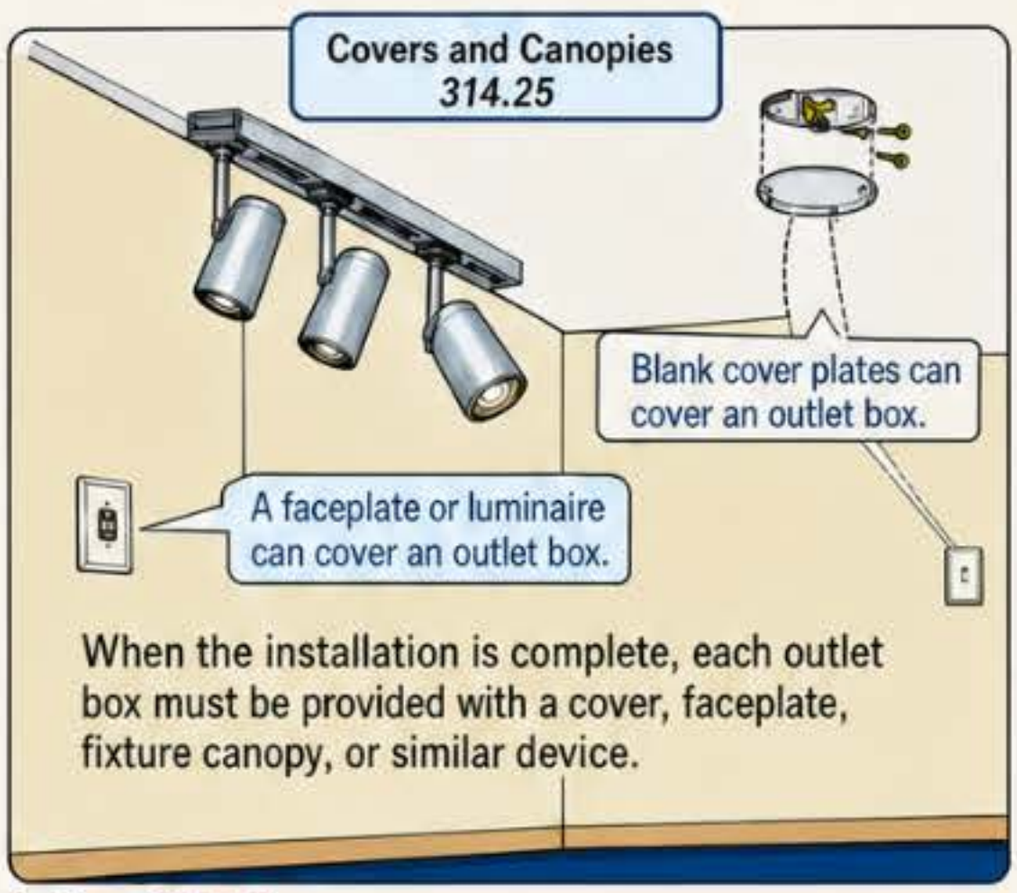
(1) Flexible Cord. Boxes containing a hub can be supported from a flexible cord connected to fittings that prevent tension from being transmitted to joints or terminals [400.10]. ***Figure 314–49**

> **Author's Commentary:** *Never allow the weight of a box to hang on wiring connections. Always use the raceway or a separate support so that terminals and splices are not strained.*
>
> *– Michael Hamilton*

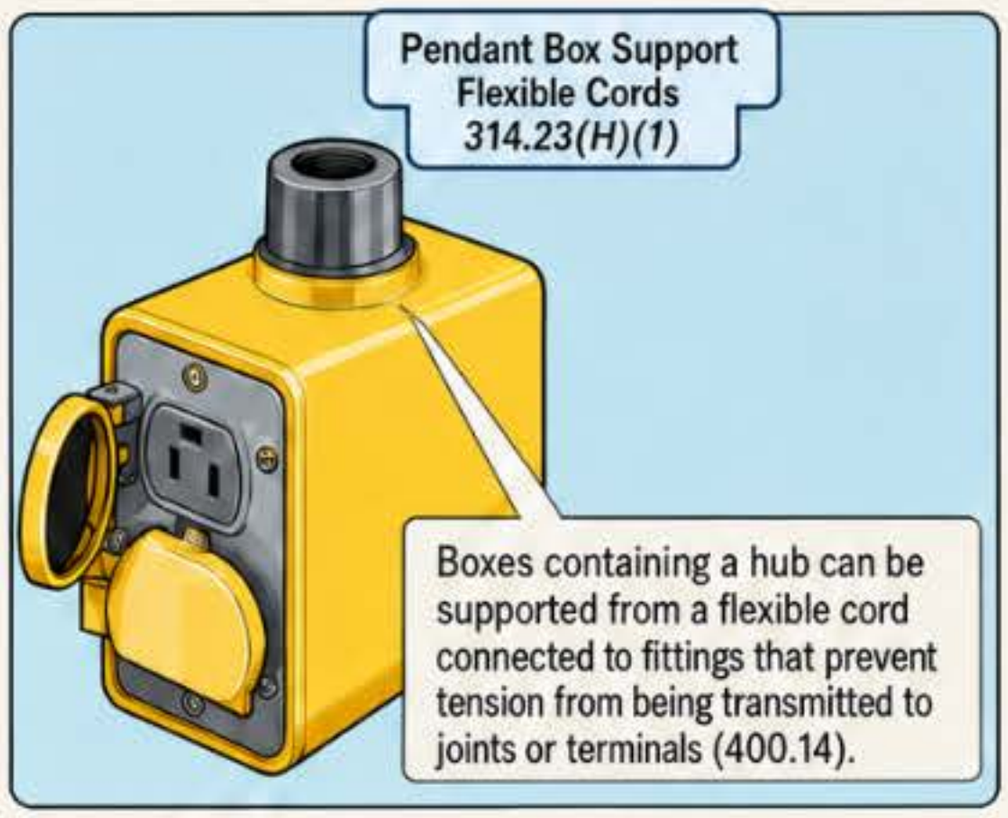
Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures | 314.25



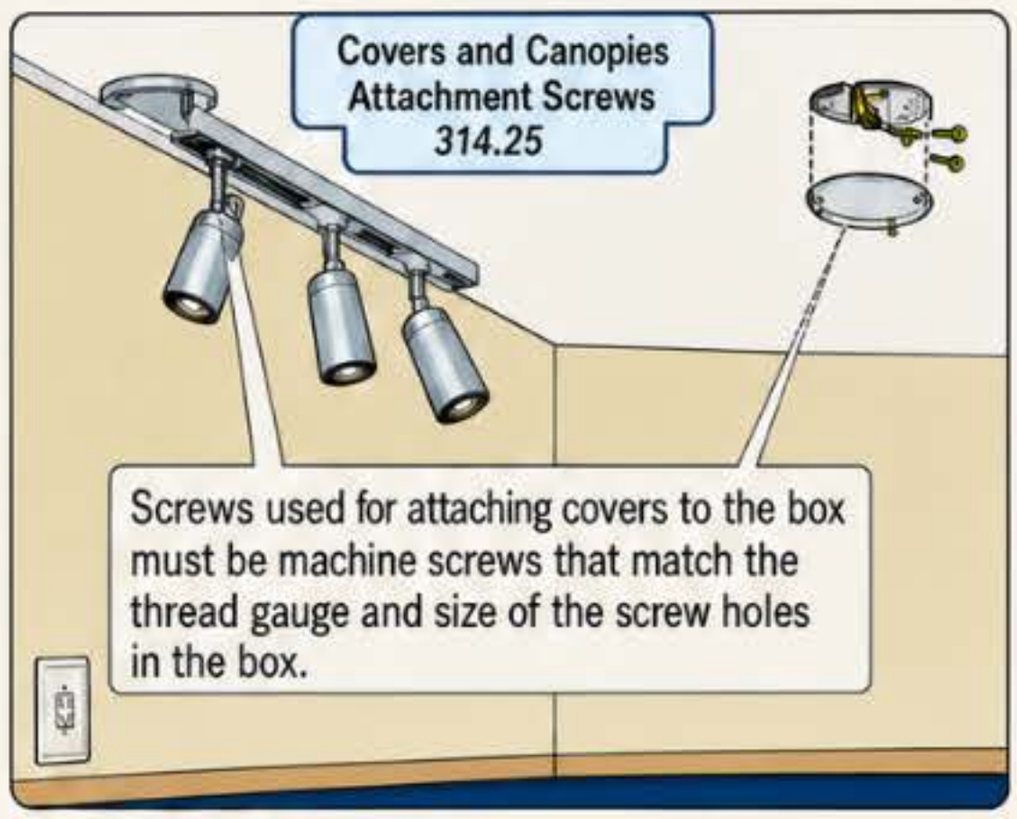
▶ Figure 314–48



▶ Figure 314–50



▶ Figure 314–49



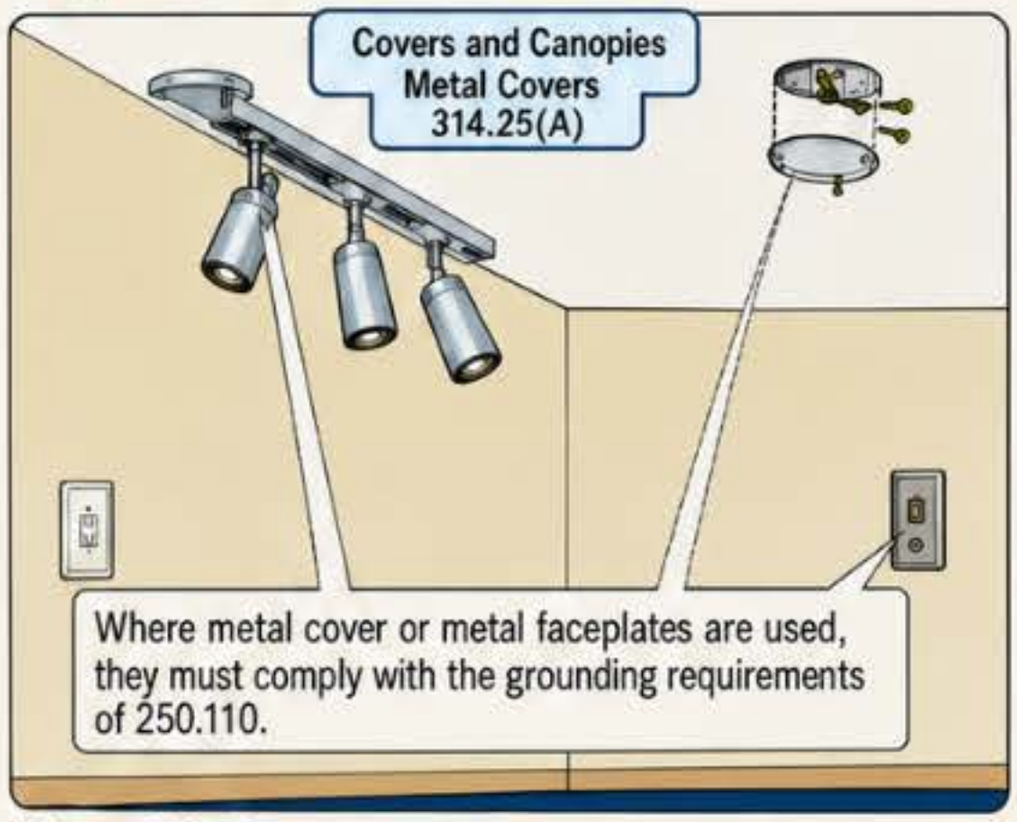
▶ Figure 314–51

314.25 Covers and Canopies

When the installation is complete, each outlet box must be provided with a cover, faceplate, fixture canopy, or similar device. ▶ Figure 314–50

Screws used for attaching covers to the box must be machine screws that match the thread gage and size of the screw holes in the box. ▶ Figure 314–51

(A) Metal Covers. Metal covers are only permitted if they can be connected to the circuit equipment grounding conductor (250.110). ▶ Figure 314–52



▶ Figure 314–52

314.27 | Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures

Author's Commentary:

Switch box covers that serve as the equipment grounding conductor, in accordance with 404.9(B), must be bonded to that conductor. Likewise, receptacle box covers that bond to the circuit equipment grounding conductor must comply with 406.6(B).

— Michael Hamilton

314.27 Outlet Box Requirements

(A) Boxes at Luminaire Outlets.

(1) Luminaire Outlets in or on Vertical Surfaces. Enclosures or fittings that support luminaires placed in or on a wall or other vertical surface must be clearly identified and permanently marked on the inside of the box to state the highest weight that the luminaire can be supported. If the box supports anything other than the luminaire, the label must indicate the maximum weight allowed for that item.

Figures 314–53 through 314–56

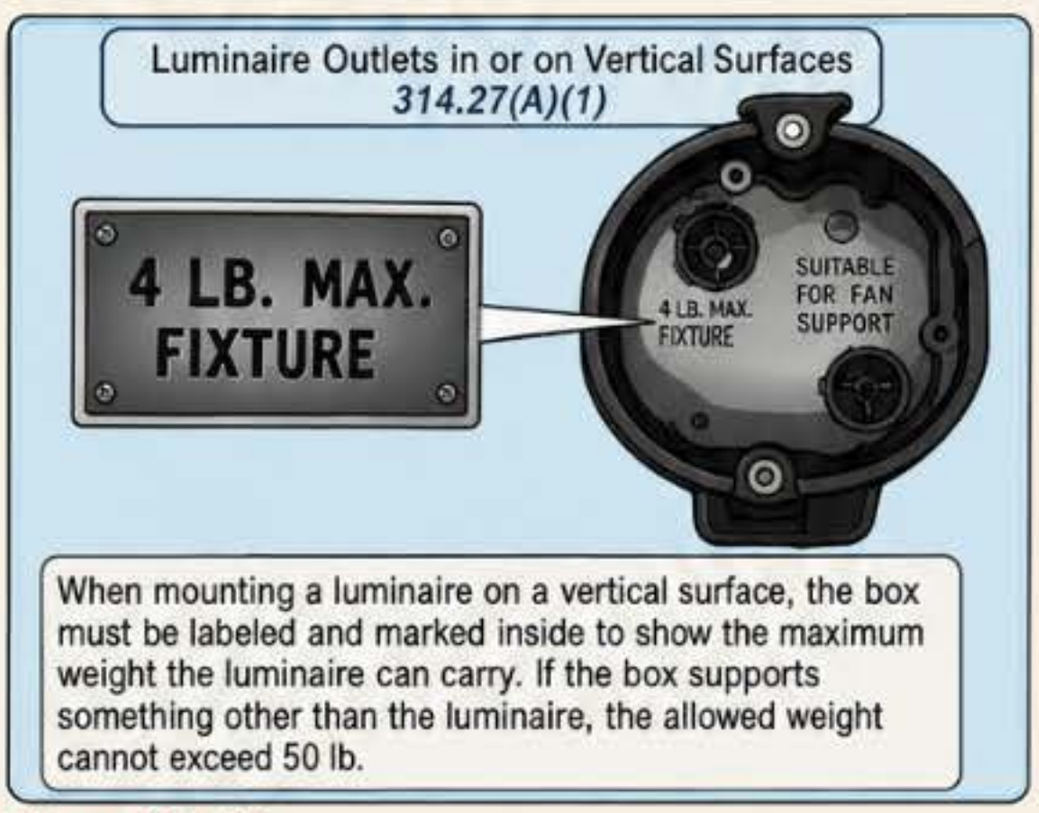


Figure 314–53

Ex: A luminaire mounted on a vertical surface weighing no more than 6 lb may be supported by a device box or plaster ring. For heavier luminaires, the supporting yoke must attach to the box with at least two No. 6 or larger screws. **Figures 314–54**

(2) Luminaire Outlets in a Ceiling. Boxes used to support ceiling-mounted luminaires must be *listed and labeled to hold at least 50 lb. If a luminaire exceeds 50 lb, the outlet box must be independently supported unless the box is listed and marked inside by the manufacturer for the maximum weight it can carry.* **Figures 314–55**

(B) Floor Box. *Floor boxes must be specifically listed for the purpose.* **Figure 314–56**

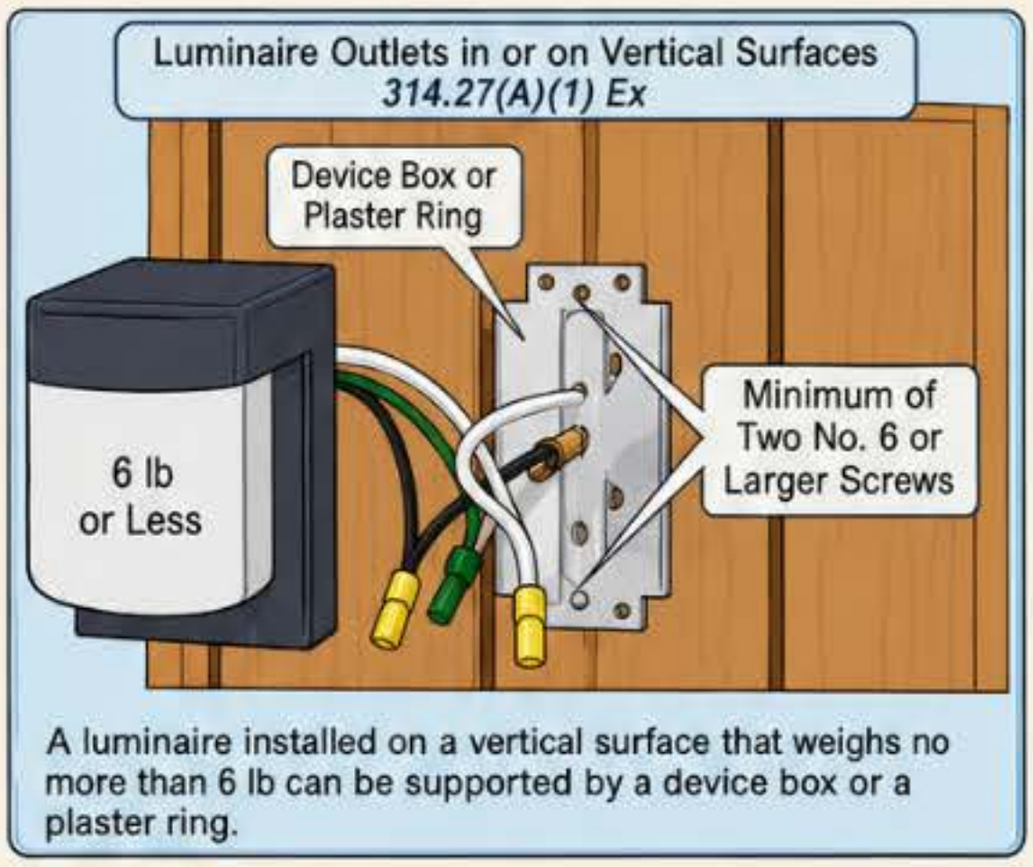


Figure 314–54

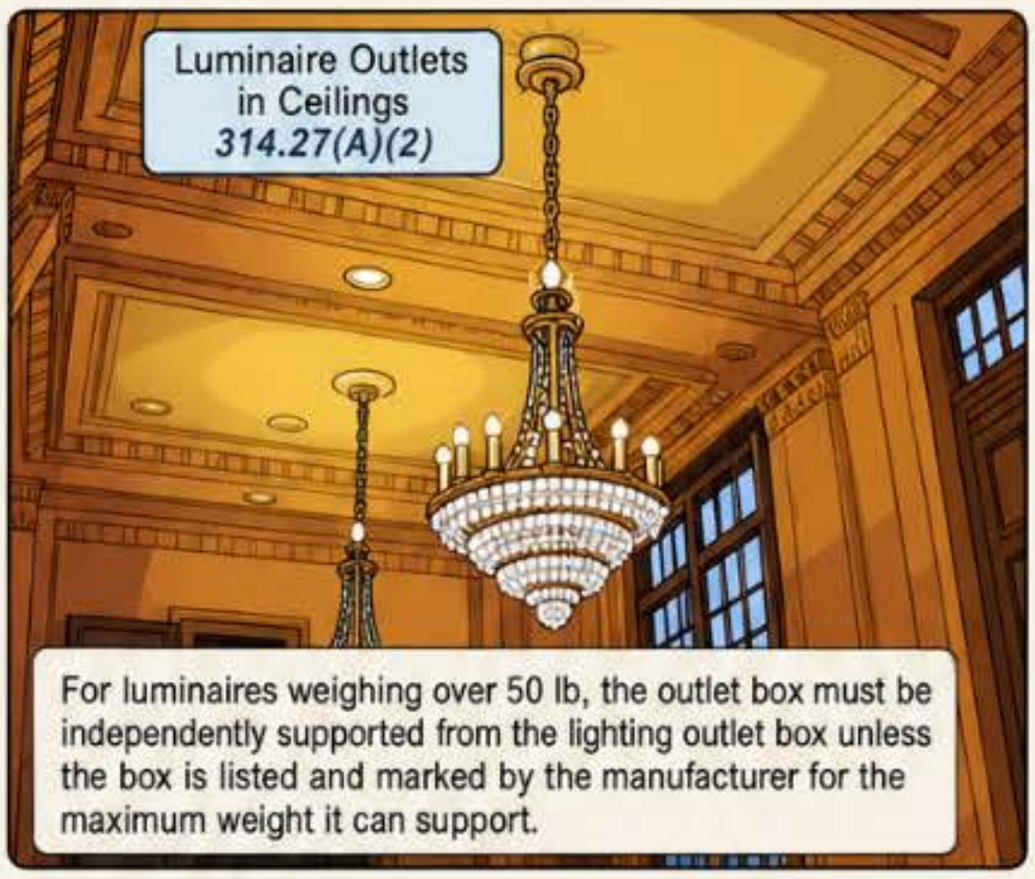


Figure 314–55

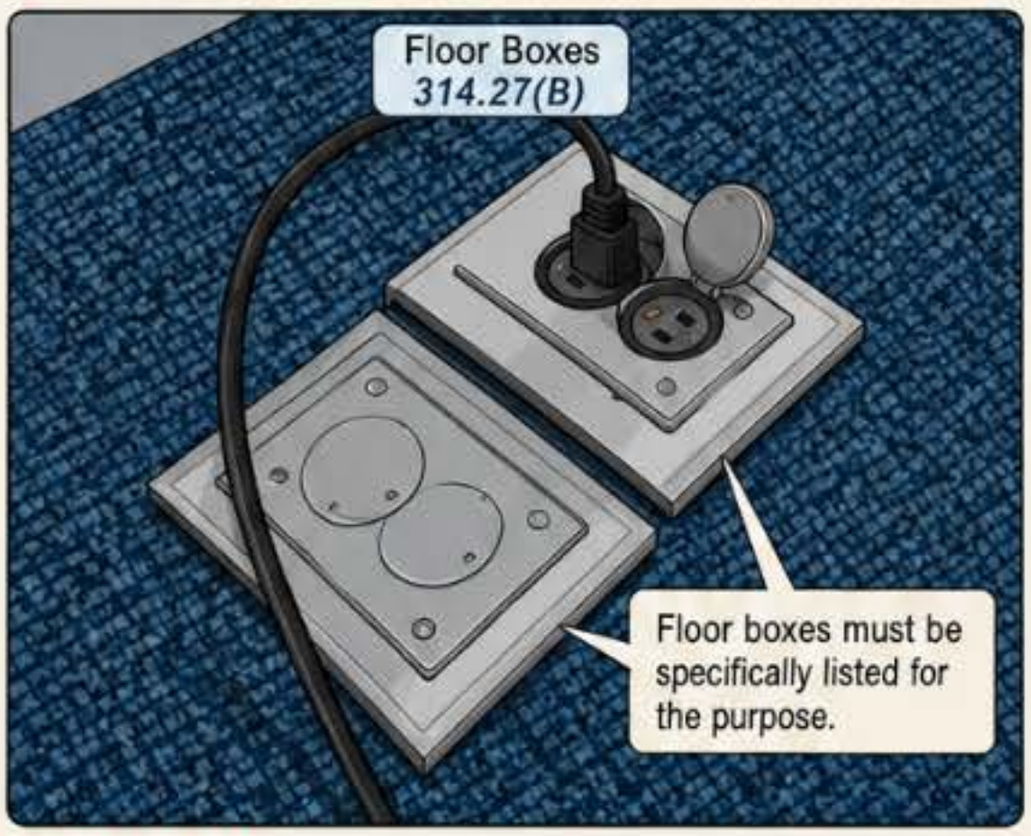
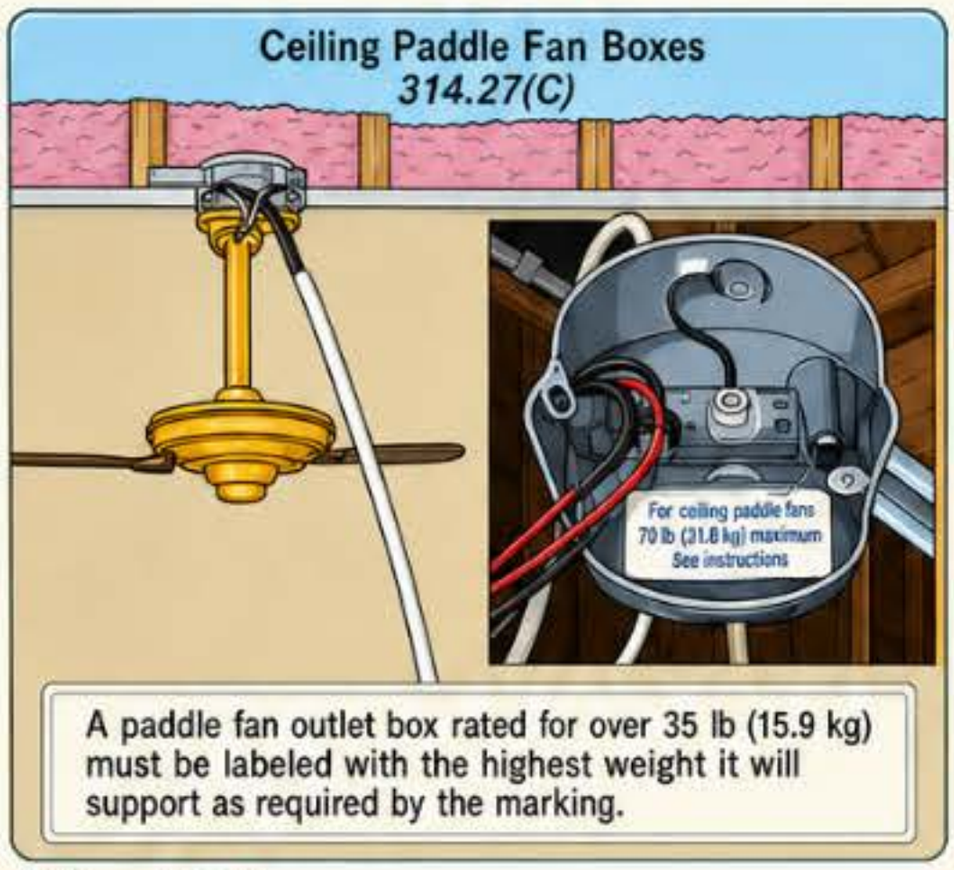


Figure 314–56

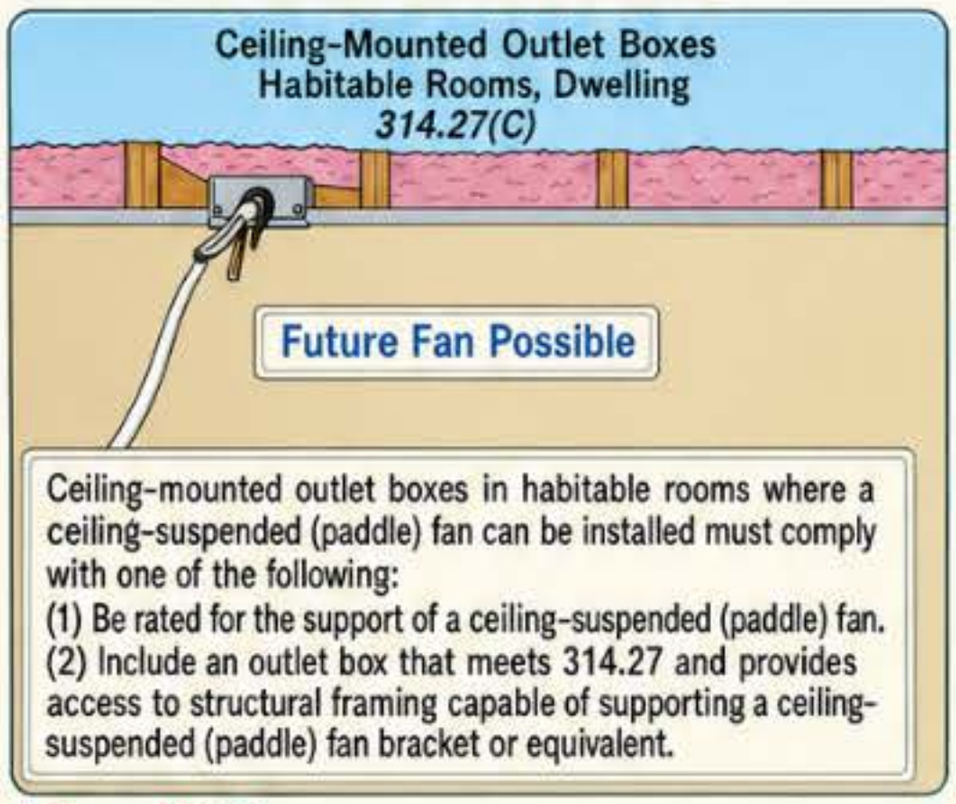
Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures | 314.28

(C) Ceiling Paddle Fan Box. Outlet boxes intended for ceiling paddle (suspended) fans must be listed and clearly identified for that purpose. These boxes are not permitted to support loads greater than 70 lb (31.8 kg). For a ceiling fan that weighs more than 35 lb (15.9 kg), the box and its mounting must be able to support the full fan weight as indicated in the marking. See Figure 314-57.



▲ Figure 314-57

Ceiling-mounted outlet boxes in habitable rooms where a ceiling-suspended (paddle) fan may be installed must meet one of the following options: See Figure 314-58.



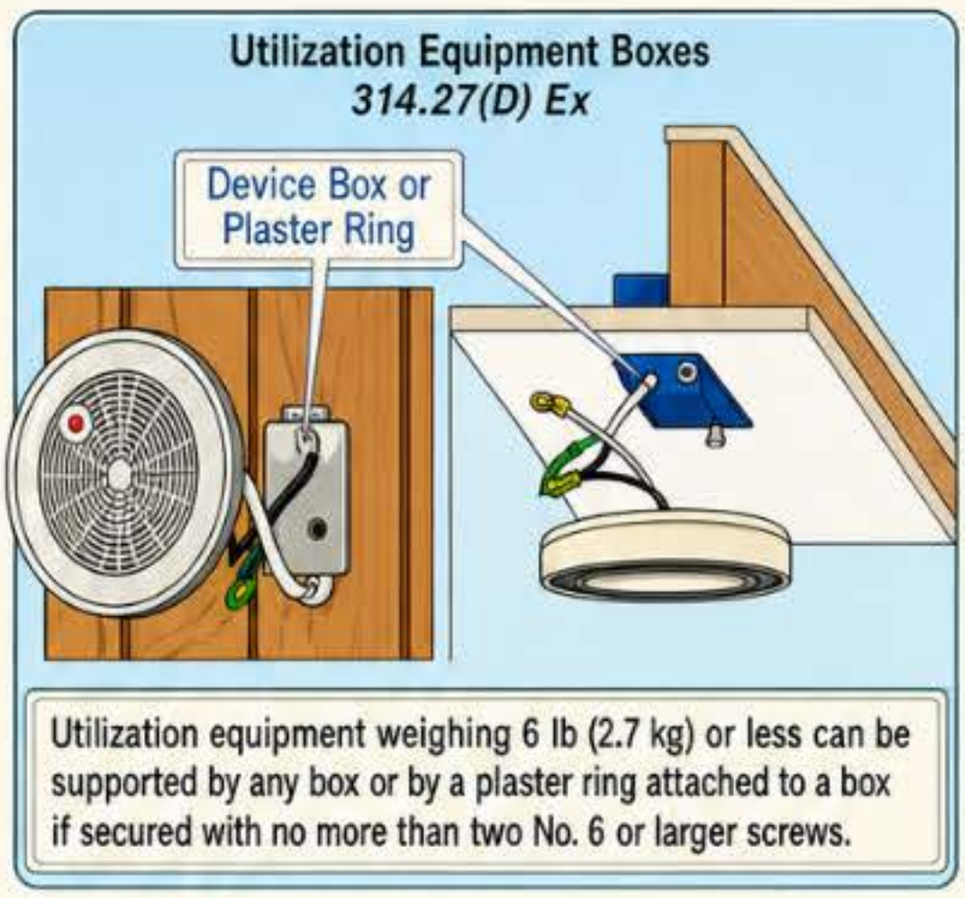
▲ Figure 314-58

(1) Be listed for the support of a ceiling-suspended (paddle) fan.

(2) Include an outlet box in accordance with 314.27 that provides access to structural framing members capable of supporting a ceiling-suspended (paddle) fan bracket or an equivalent means.

(D) Utilization Equipment. Boxes used to support utilization equipment must be built to carry the equipment weight limit of 50 lb (22.7 kg).

Example: Utilization equipment weighing 6 lb (2.7 kg) or less may be supported by any box or by a plaster ring attached to a box, provided the equipment is secured with no more than two No. 6 or larger screws. See Figure 314-59.



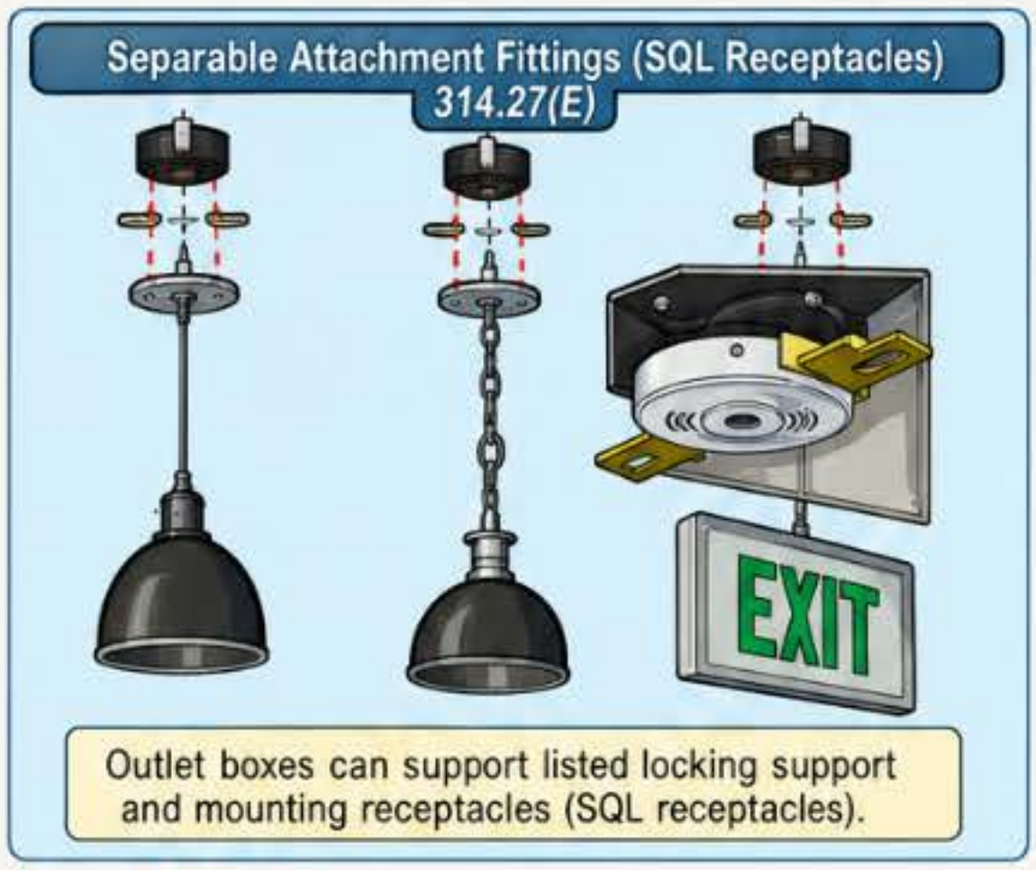
▲ Figure 314-59

(E) Separable Attachment Fittings. Outlet boxes outlined in 314.27 must be identified to support listed locking support and mounting receptacles when used with compatible attachment fittings. The combination must be identified for the equipment support weight and mounting orientation limits specified in the listing. When the supporting receptacle is installed inside a box, it must be counted in the fill calculation per 314.16(B)(4). See Figure 314-60.

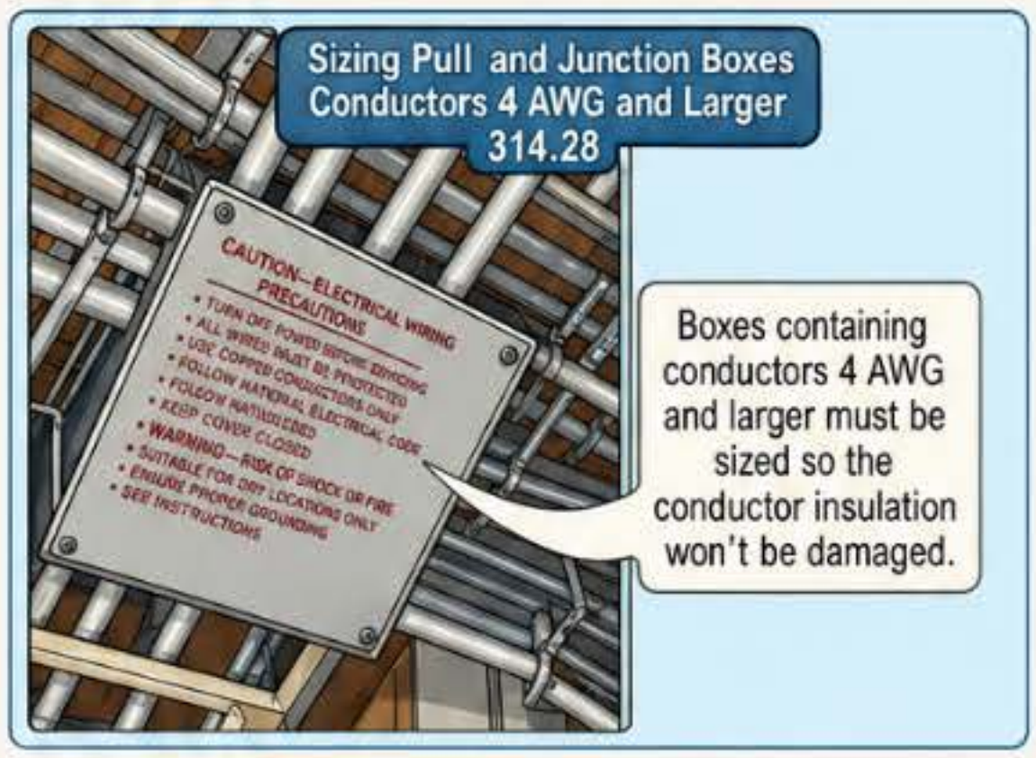
314.28 Sizing Pull and Junction Boxes

Boxes that contain conductors 4 AWG (21.2 mm²) and larger must be sized so the conductor insulation *cannot be damaged.* See Figures 314-61 and 314-62.

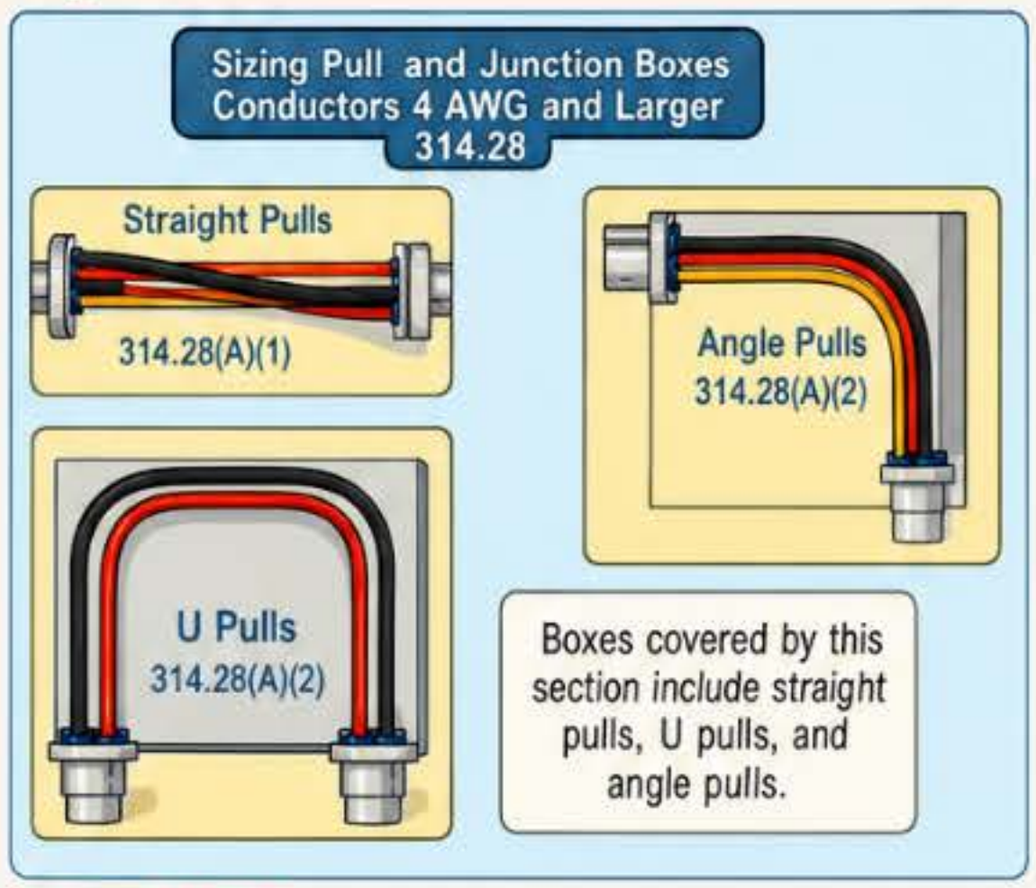
314.28 | Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures



▶ Figure 314-60



▶ Figure 314-61



▶ Figure 314-62

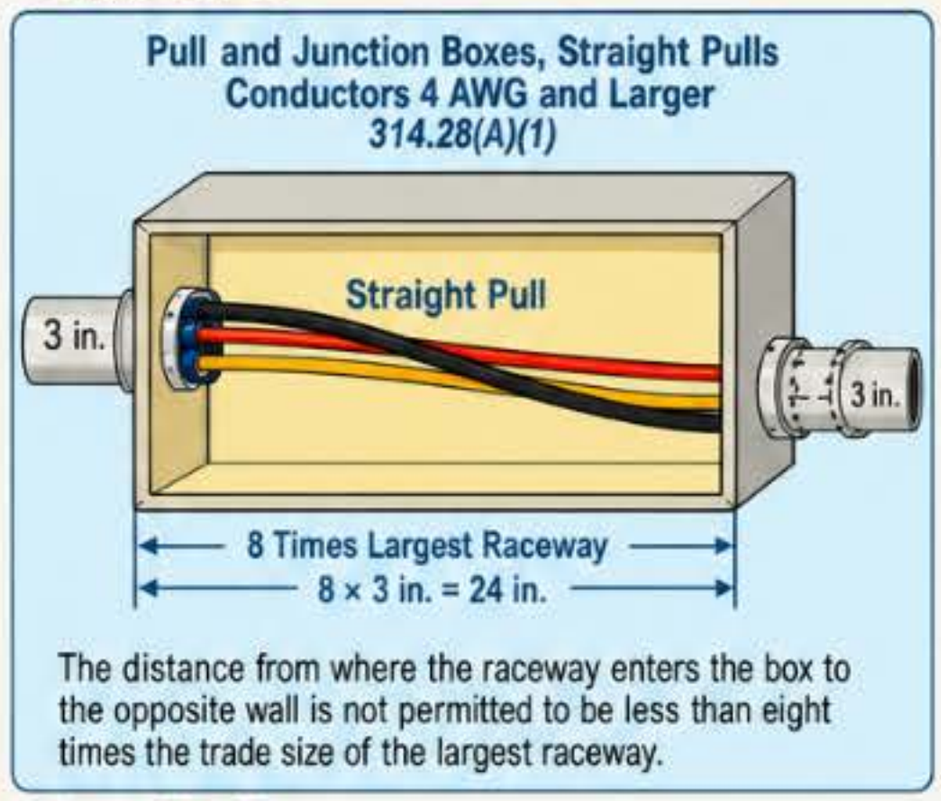
Author's Commentary:

- The rules for determining the size of boxes that contain conductors 6 AWG and smaller appear in 314.16.
- When conductors 4 AWG or larger enter a box or other enclosure, a fitting that provides a smooth, rounded, insulating throat (such as a bushing or adapter) must be used at the opening to shield the *wires from abrasion during pulling and after installation [300.4(G)].*

— Michael Hamilton

(A) Minimum Size. For raceways containing conductors 4 AWG and larger, the minimum box dimensions must meet the requirements below:

(1) Straight Pulls. The distance from the point where the raceway enters the box to the opposite wall cannot be less than eight times the trade size of the largest raceway. ▶ Figure 314-63



▶ Figure 314-63

(2) Angle Pulls, U Pulls, or Splices

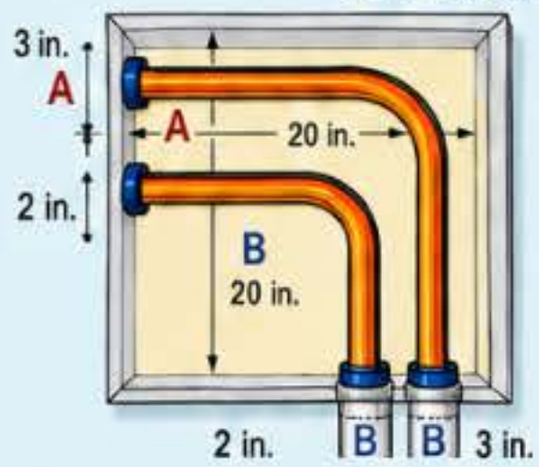
Angle Pulls. The distance from the raceway entry of the box to the opposite wall must be at least six times the trade size of the largest raceway, plus the total of the trade sizes of the remaining raceways that are on the *same wall* and row. ▶ Figure 314-64

U Pulls. When a conductor *enters* and *leaves from* the same wall of the box, *the distance from the raceway opening to the opposite wall must be at least six times the trade size of the largest raceway, plus the sum of the trade sizes of the other raceways on that same wall and row.* ▶ Figure 314-65

DEFINITIONS | From Michael Hamilton Publications

314.28

Pull and Junction Boxes, Angle Pulls
Conductors 4 AWG and Larger
314.28(A)(2)



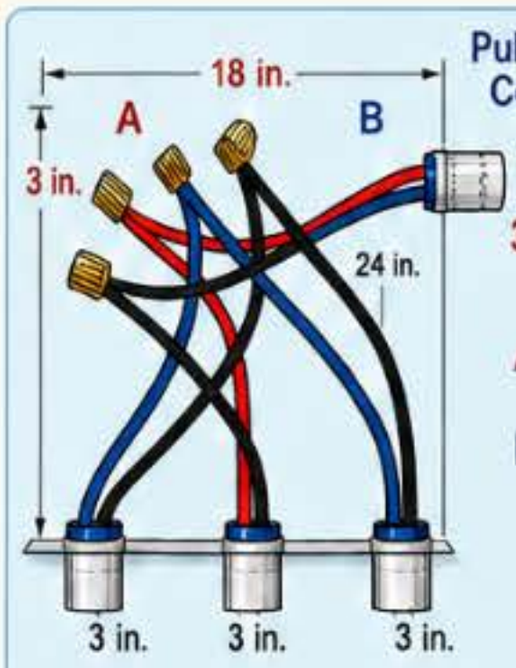
A = (6 x 3 in.) + 2 in.
A = 20 in.

B = (6 x 3 in.) + 2 in.
B = 20 in.

The distance from the raceway entry to the opposite wall must not be less than six times the trade size of the largest raceway, plus the sum of the trade sizes of the remaining raceways on the same wall and row.

Figure 314–64

Pull and Junction Boxes, Splices
Conductors 4 AWG and Larger
314.28(A)(2)



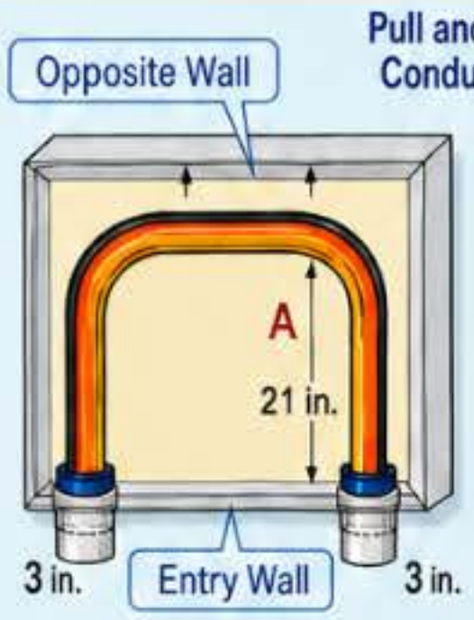
A = 6 x 3 in. = 18 in.

B = (6 x 3 in.) + 3 in. + 3 in.
= 24 in.

When conductors are spliced, the distance from where the raceways enter to the opposite wall must be at least 6 times the trade size of the largest raceway, plus the sum of all other raceways on the same wall and row.

Figure 314–66

Pull and Junction Boxes, U Pulls
Conductors 4 AWG and Larger
314.28(A)(2)

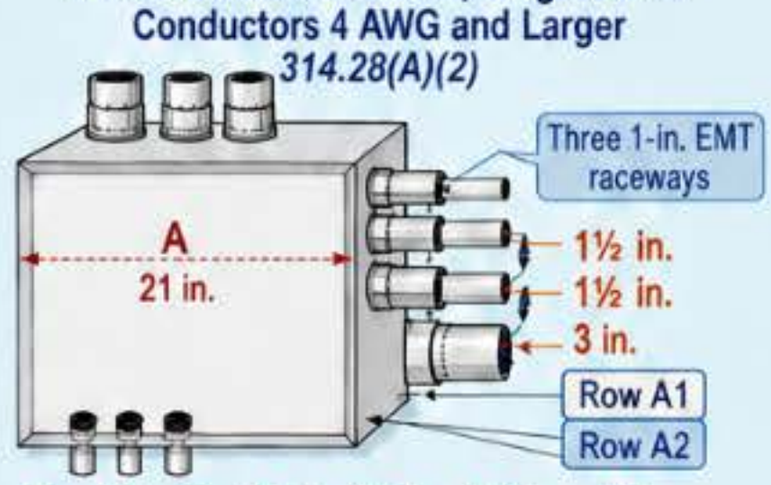


A = (6 x 3 in.) + 3 in.
A = 21 in.

The distance from where the raceways enter to the opposite wall must be at least six times the trade size of the largest raceway, plus the sum of the trade sizes of the remaining raceways on the same wall and row.

Figure 314–65

Pull and Junction Boxes, Largest Row
Conductors 4 AWG and Larger
314.28(A)(2)



Row A1 = (6 x 3 in.) + 1½ in. + 1½ in. = 21 in.
Row A2 = (6 x 3 in.) + 3 in. + 1½ in. + 1½ in. = 31 in. (omit)
Dimension A = 21 in. (largest row)

Where there is more than one row of raceway entries on the same wall, each row is calculated individually and the row with the largest distance must be used.

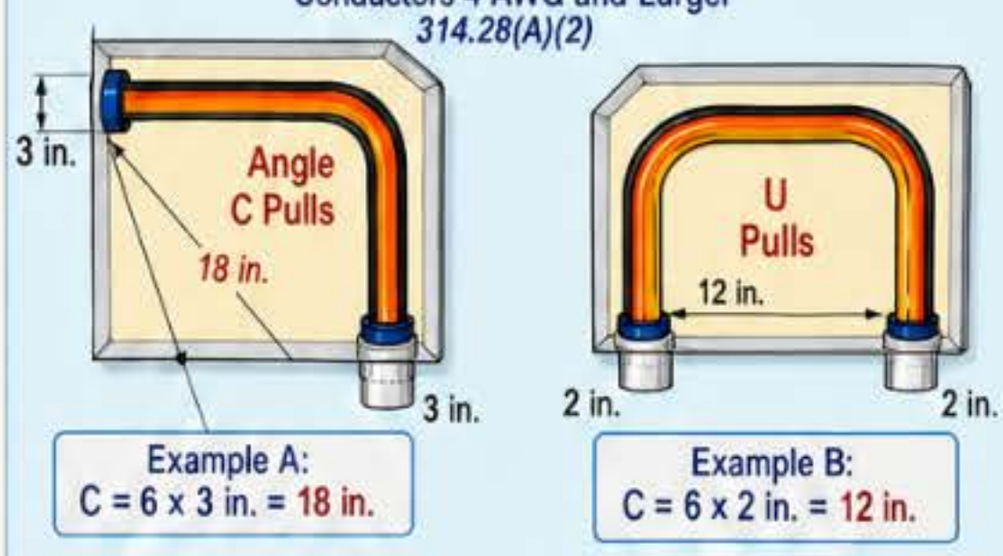
Figure 314–67

Splices. Whenever conductors are joined, the distance from the point where the raceways enter the box to the wall opposite must be at least six times the trade size of the largest raceway, plus the combined trade sizes of the remaining raceways on that same wall and in that row. **Figure 314–66**

Rows. If multiple rows of raceway openings exist on a wall, evaluate each row separately and use the row with the greatest computed distance. **Figure 314–67**

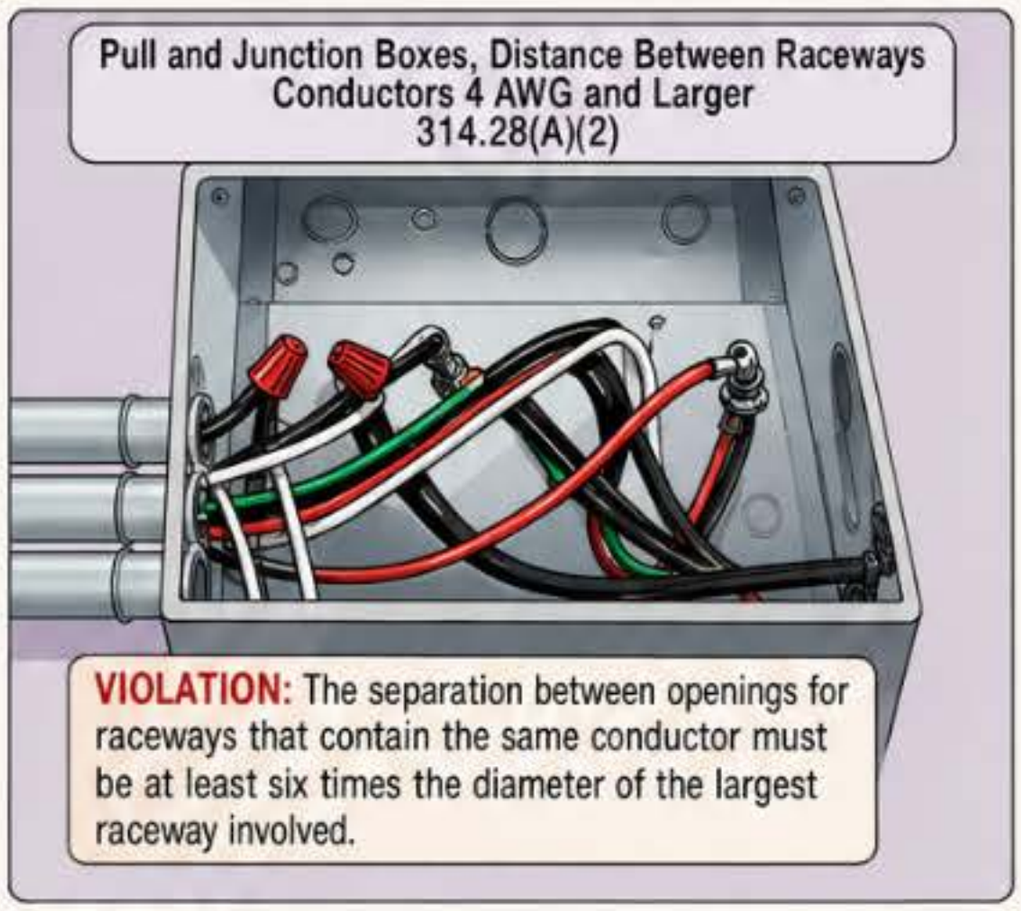
Distance Between Raceways. The clear spacing between raceway entries enclosing the same conductor must not be *less than six times the trade size of the largest raceway, measured between the raceway entry openings.* ***Figures 314–68*** *and* ***314–69***

Pull and Junction Boxes, Distance Between Raceways
Conductors 4 AWG and Larger
314.28(A)(2)



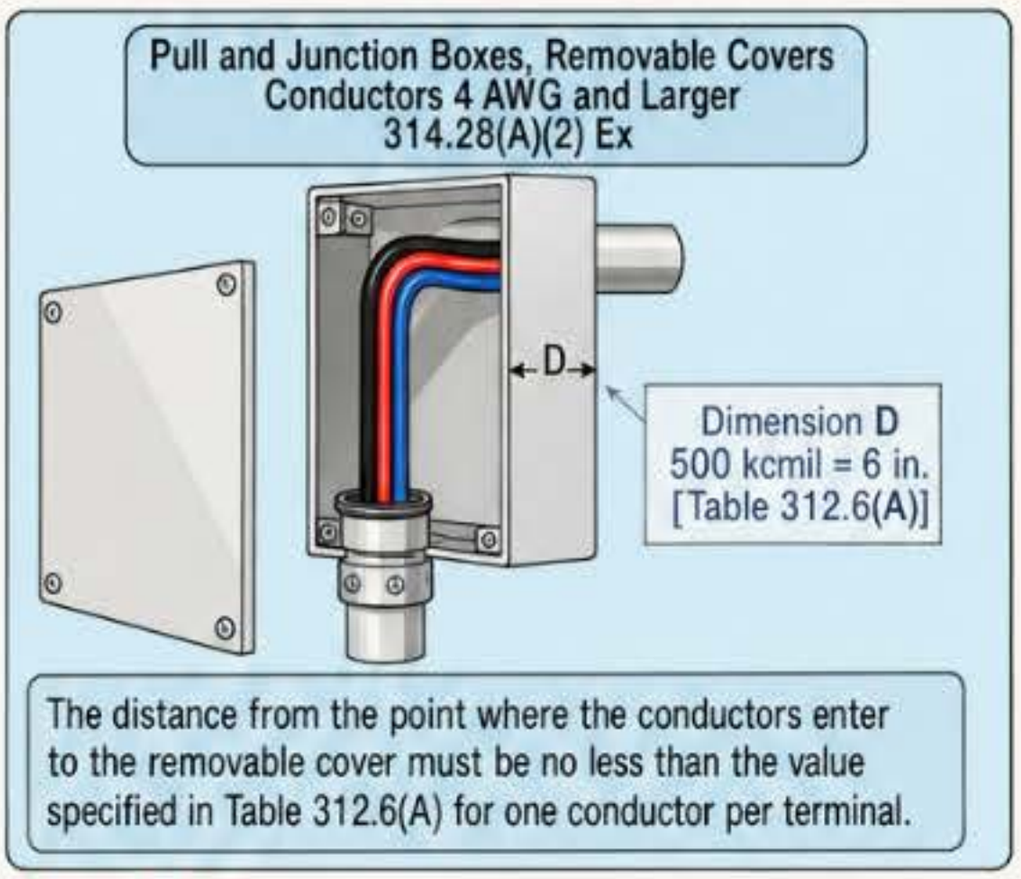
The separation between raceway entries enclosing the same conductor must be at least 6 times the trade size of the largest raceway.

Figure 314–68



▶ Figure 314–69

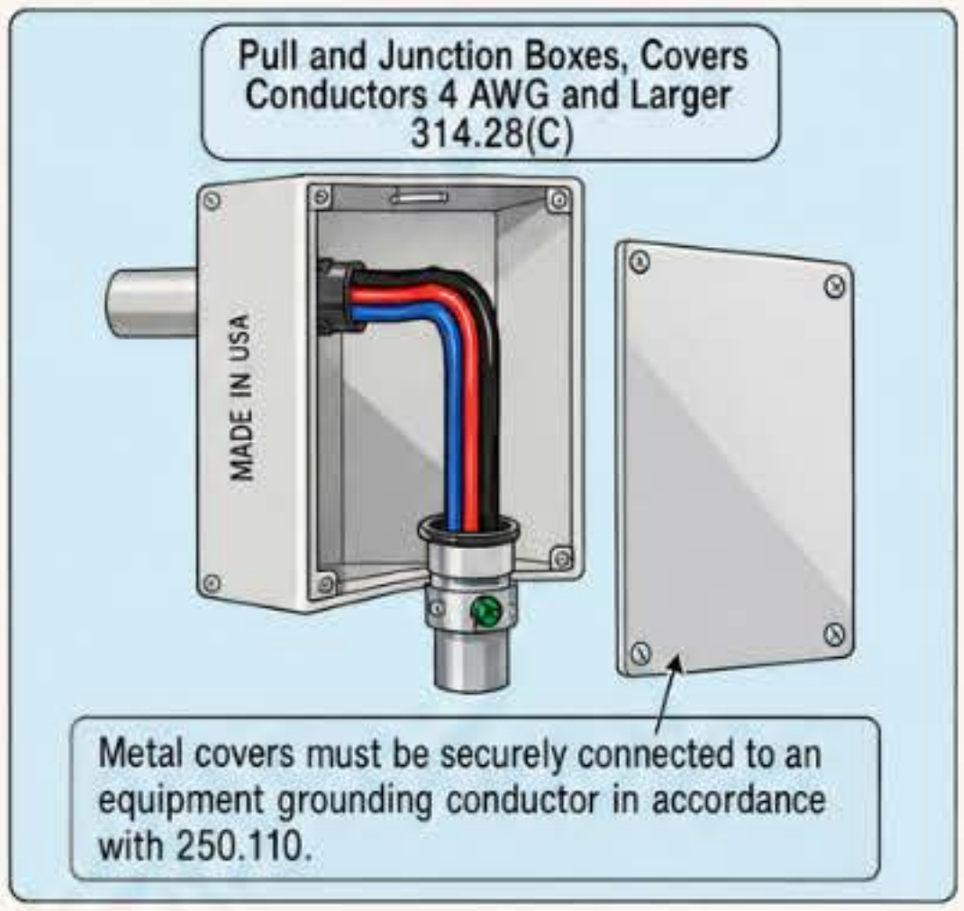
Ex: When conductors enter an enclosure equipped with a removable cover, the distance from where the conductors enter to the removable cover is not allowed to be less than the minimum spacing shown in Table 312.6(A) for a single conductor per termination. ▶ Figure 314–70



▶ Figure 314–70

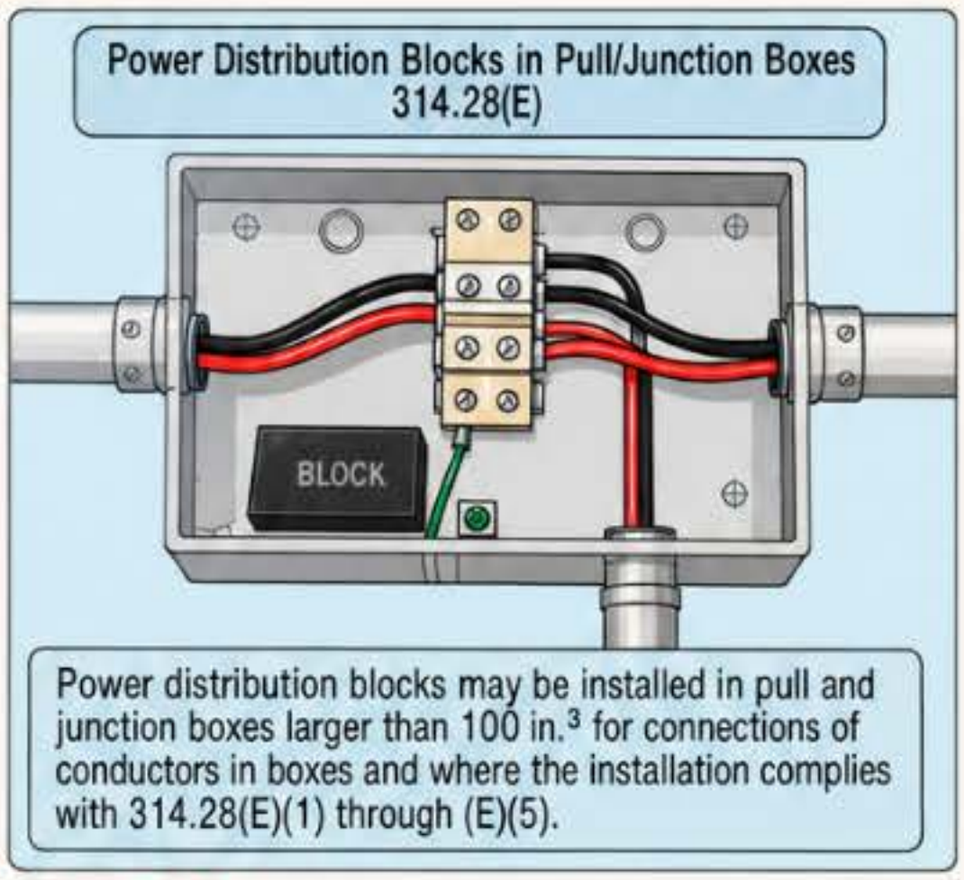
(B) Conductors in Pull or Junction Boxes. *Pull boxes or junction boxes with any interior dimension over 6 ft must be supplied with conductors installed in a cable, in raceway, or in another manner approved for use.*

(C) Covers. *Metal covers must be bonded to an equipment grounding conductor at a type-recognized point in accordance with 250.118 [250.4(A)(3)].* ▶ Figure 314–71



▶ Figure 314–71

(E) Power Distribution Blocks. Power distribution blocks may be used in pull and junction boxes larger than 100 in.^{3} for connections of conductors in boxes and where the installation meets the requirements of 314.28(E)(1) through (E)(5). ▶ Figure 314–72

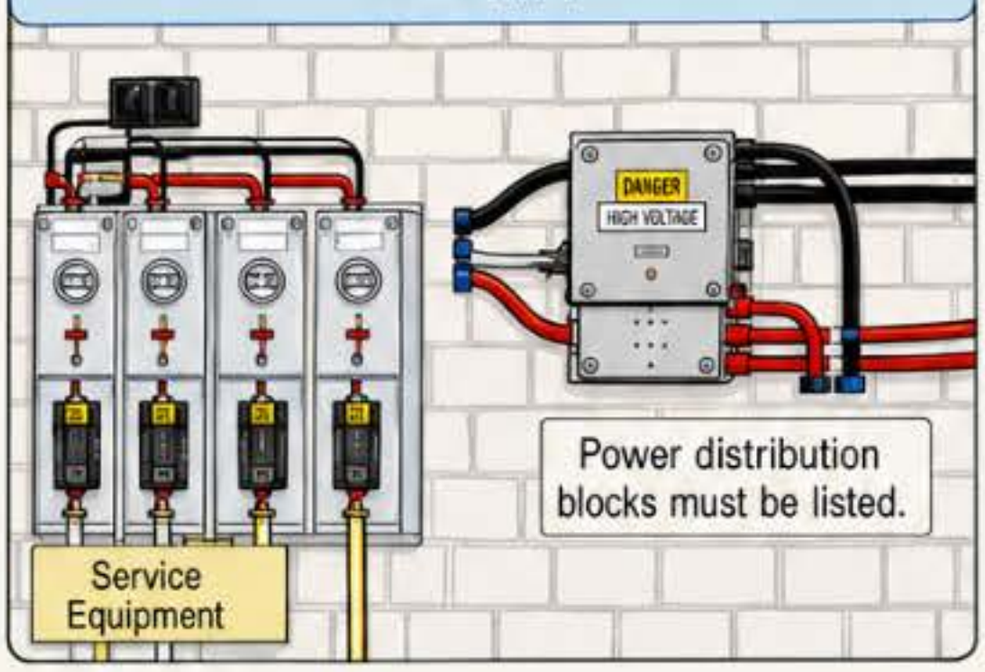


▶ Figure 314–72

Ex: *Equipment grounding terminal bars are permitted in enclosures with smaller internal dimensions.*

(1) *Installation. Power distribution blocks installed in boxes must be part of the listing.* ▶ Figure 314–73

Power Distribution Blocks Installation
314.28(E)(1)

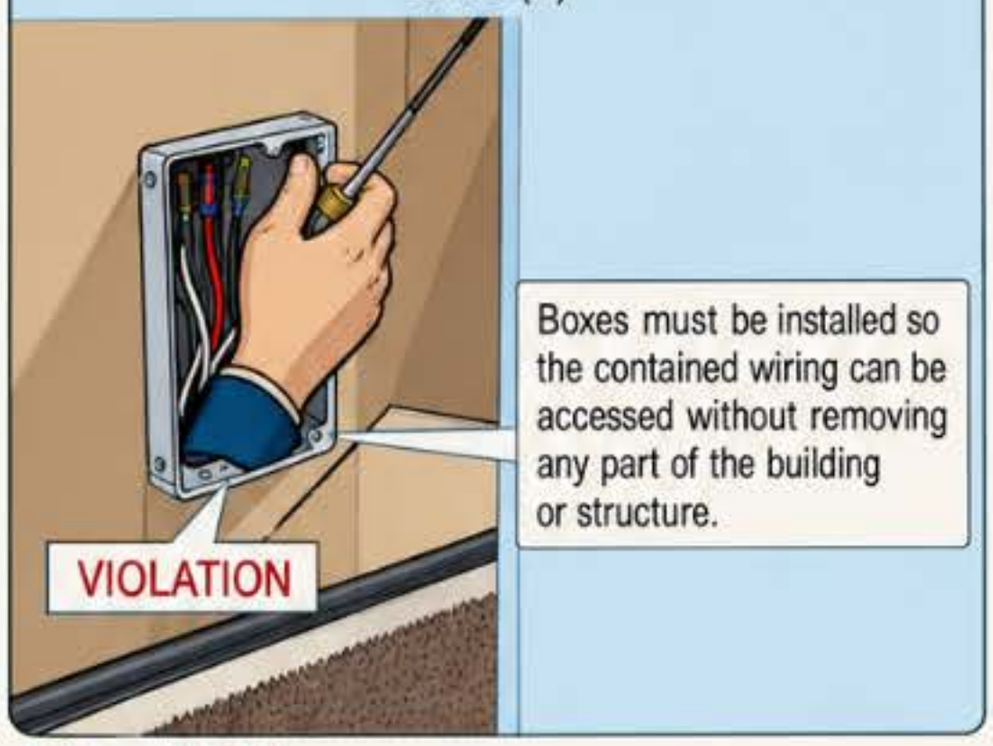


▲ Figure 314–73

314.29 Wiring to be Accessible

(A) In Buildings and Other Structures. Boxes and conduit bodies must be installed so the wiring contained within is accessible without removing any part of the building or structure. ▸ Figure 314–74

Wiring to be Accessible, In Buildings and Other Structures
314.29(A)



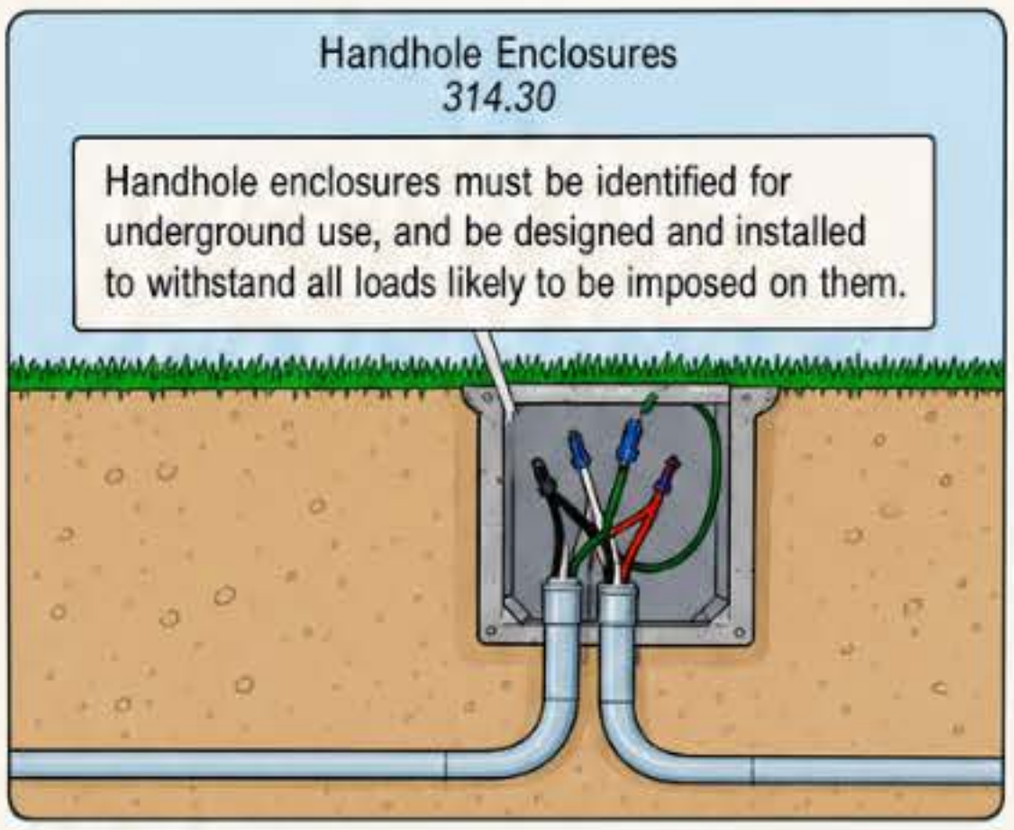
▲ Figure 314–74

(B) Underground. Underground boxes, conduit bodies, and handhole enclosures must be installed so the wiring contained within is accessible without removing any part of the excavating, sidewalks, paving, earth, or other substance used to establish the finished grade.

314.30 Handhole Enclosures

Handhole enclosures must be identified for underground use and be designed and installed to withstand all loads likely to be imposed on them. ▸ Figure 314–75

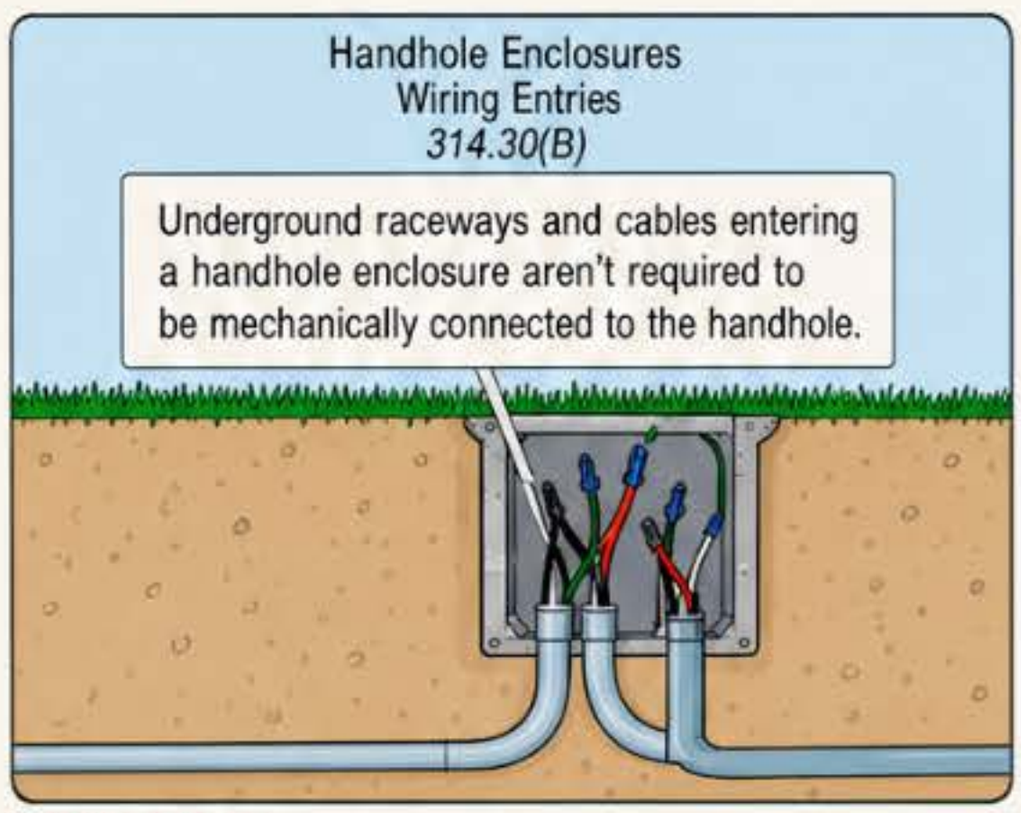
Handhole Enclosures
314.30



▲ Figure 314–75

(B) Wiring Entries. Underground raceways and cables entering a handhole are not required to be mechanically connected to the handhole. ▸ Figure 314–76

Handhole Enclosures
Wiring Entries
314.30(B)



▲ Figure 314–76

(C) Enclosure Wiring. Splices or terminations within a handhole must be listed for wet locations [110.14(B)].

Author's Commentary:

Accessibility is the central theme of 314.29 and 314.30. Electrical equipment and wiring must be reachable without demolition, and handholes must be strong, suitable for underground service, and capable of handling expected loads. These rules protect both safety and long-term maintainability.

— Michael Hamilton

314.30 | Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures

(D) Covers. Handhole covers are required to have a marking that clearly identifies what the handhole is used for—typically a word such as "electric." These covers must either be designed to be opened with tools or be constructed for use with tools, in addition to being capable of supporting more than 100 pounds.

Metal covers and any exposed conductive surfaces of handhole enclosures must be connected to an equipment grounding conductor sized in accordance with 250.122, based on the rating of the overcurrent protective device [250.102(D)]. • **Figure 314–78**

Figure 314–77

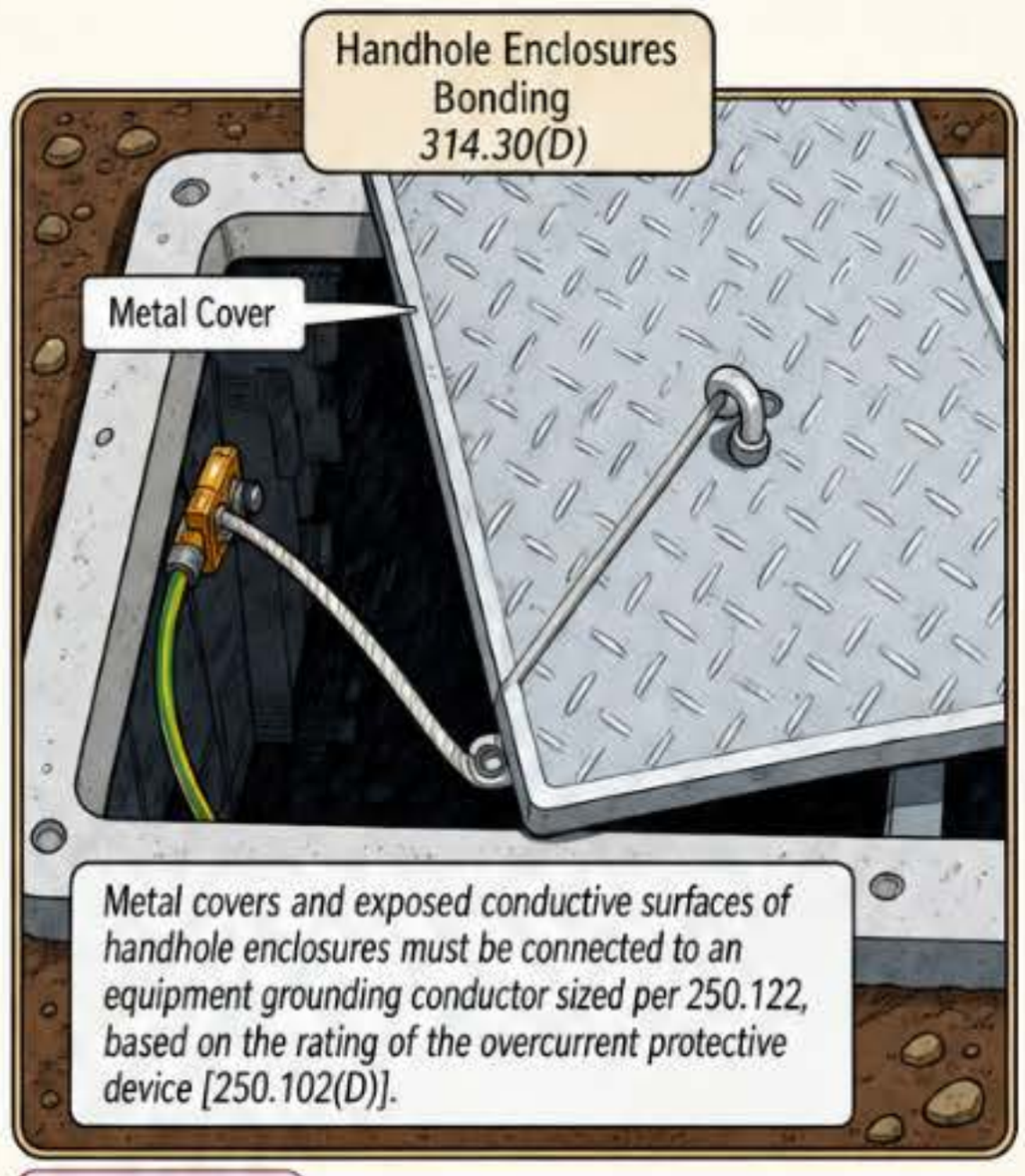


Figure 314–78

Author's Commentary:

The identification marking on a handhole cover is crucial for safety and quick recognition in the field. Using the word "electric" or a similar term ensures that workers immediately know the contents may involve electrical systems.

Covers that require tools to open discourage tampering and help keep the enclosure secure. Alternatively, very heavy covers provide a level of security because they are difficult to remove without equipment.

Bonding metal covers and any exposed conductive parts is essential for reducing the risk of electric shock. *By connecting these parts to the equipment grounding conductor, any fault current is carried safely back to the source and cleared by the overcurrent protective device.*

— Michael Hamilton

Key Takeaway:

Handhole covers must be clearly marked and require tools or be heavy. Metal covers and exposed conductive parts must be bonded to the equipment grounding conductor according to the overcurrent protective device rating.

ARTICLE 320

ARMORED CABLE (TYPE AC)

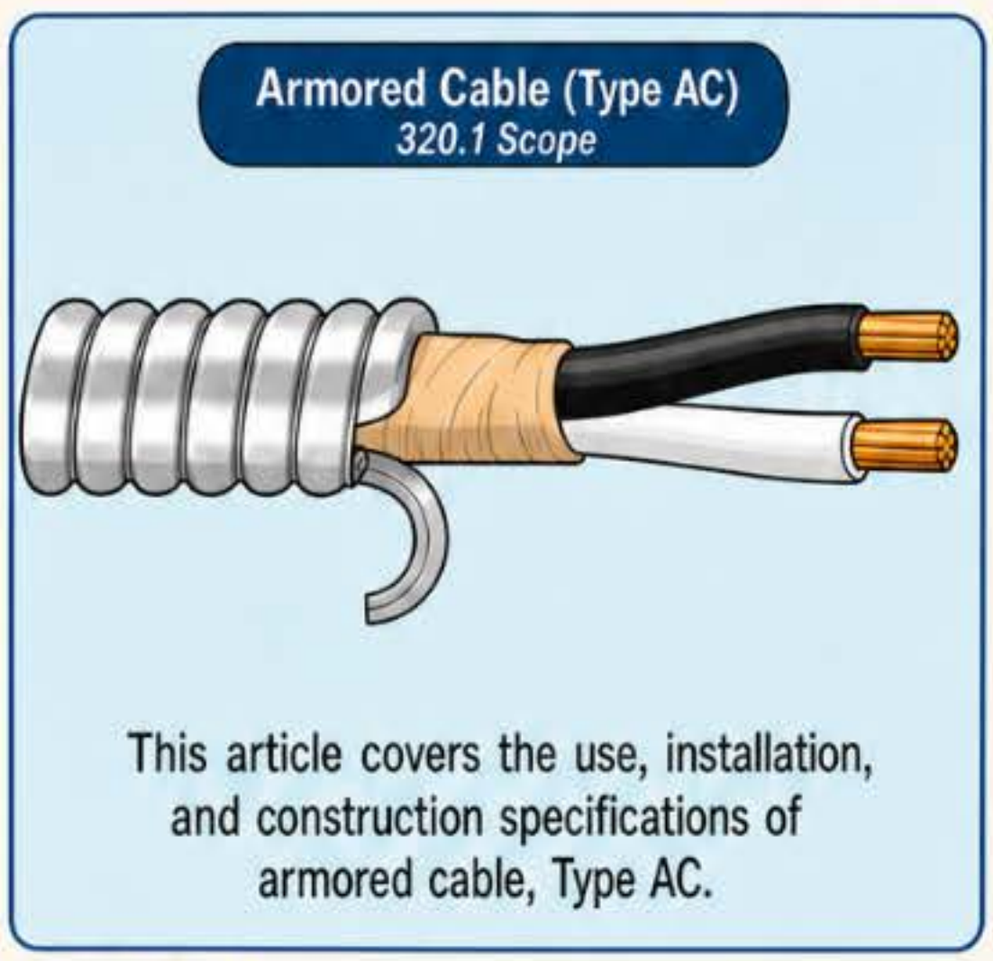
Introduction to Article 320—Armored Cable (Type AC)

Armored cable (Type AC) is an assembly of insulated conductors, 14 AWG through 1 AWG, individually wrapped in wax paper (jute) and contained within a flexible spiral metal sheath. To the casual observer the outside appearance of armored cable is like flexible metal conduit and metal-clad cable (Type MC). Type AC cable has been referred to as "BX®" cable over the years.

Part I. General

320.1 Scope

This article covers the use, installation, and construction specifications of armored cable, Type AC. ▶ *Figure 320–1*

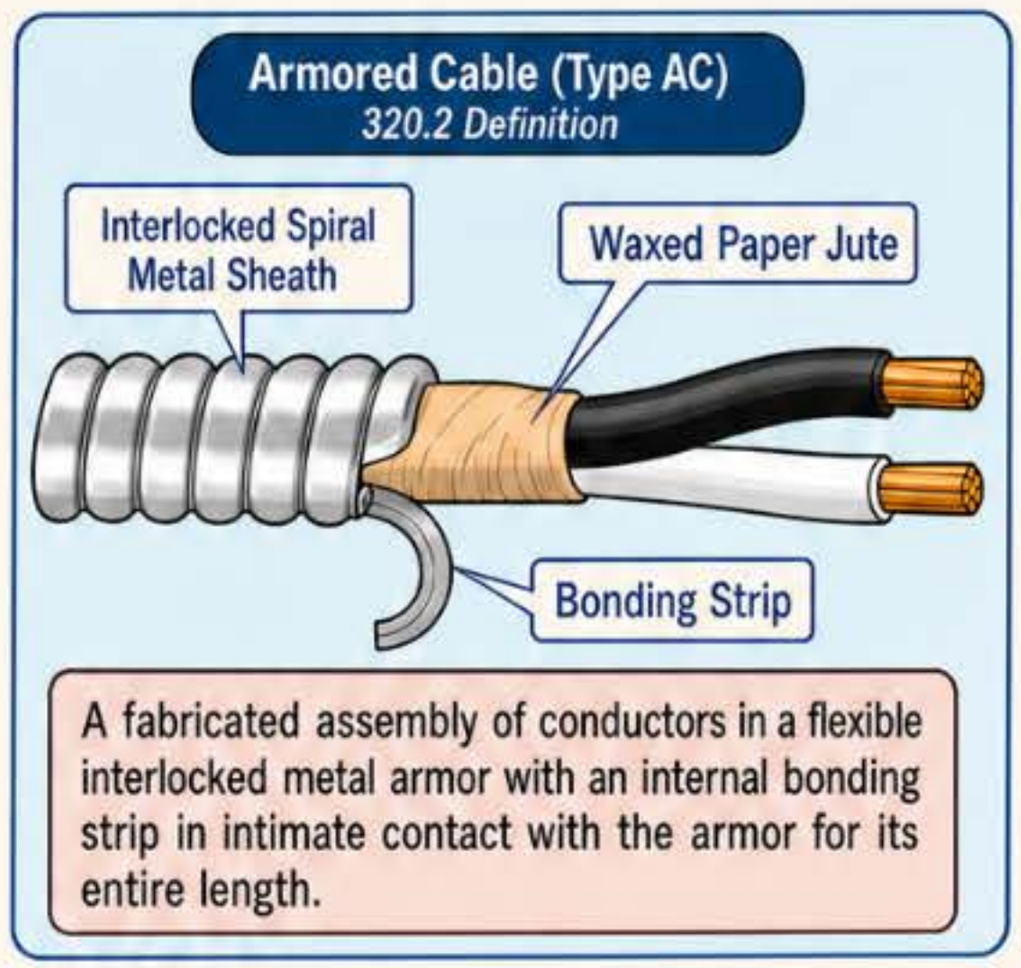


▶ *Figure 320–1*

320.2 Definition

The definition in this section applies within this article and throughout the *Code*.

Armored Cable (Type AC). A fabricated assembly of conductors in a flexible interlocked metal armor with an internal bonding strip in intimate contact with the armor for its entire length. ▶ *Figure 320–2*



▶ *Figure 320–2*

Author's Commentary:

- Type AC cable conductors are enclosed within a flexible metal sheath that interlocks at the edges with an internal aluminum bonding strip, creating a cable that looks much like flexible metal conduit. The benefit of this flexible construction, compared to rigid metal raceways, is that there is no limit on the number of bends between terminations, allowing the cable to be installed quickly.

— Michael Hamilton

320.6 Armored Cable (Type AC)

320.6 Listing Requirements

Type AC cable and associated fittings must be listed.

Part II. Installation

320.10 Uses Permitted

Type AC cable may be used in these applications:

(1) For feeder and branch circuits in both exposed and concealed locations.

(2) In cable trays.

(3) In dry areas.

(4) Embedded in dry plaster or brick.

(5) In spaces not subject to excessive moisture or dampness.

Note: The phrase "Uses Permitted" serves only as an illustrative list of acceptable applications and does not encompass every possible use approved by the authority having jurisdiction.

Author's Commentary:
Type AC cable can also be installed in a plenum space in accordance with 300.22(C)(1).
— Michael Hamilton

320.12 Uses Not Permitted

Type AC cable shall not be used under the following conditions:

(1) Where it is likely to be physically damaged.

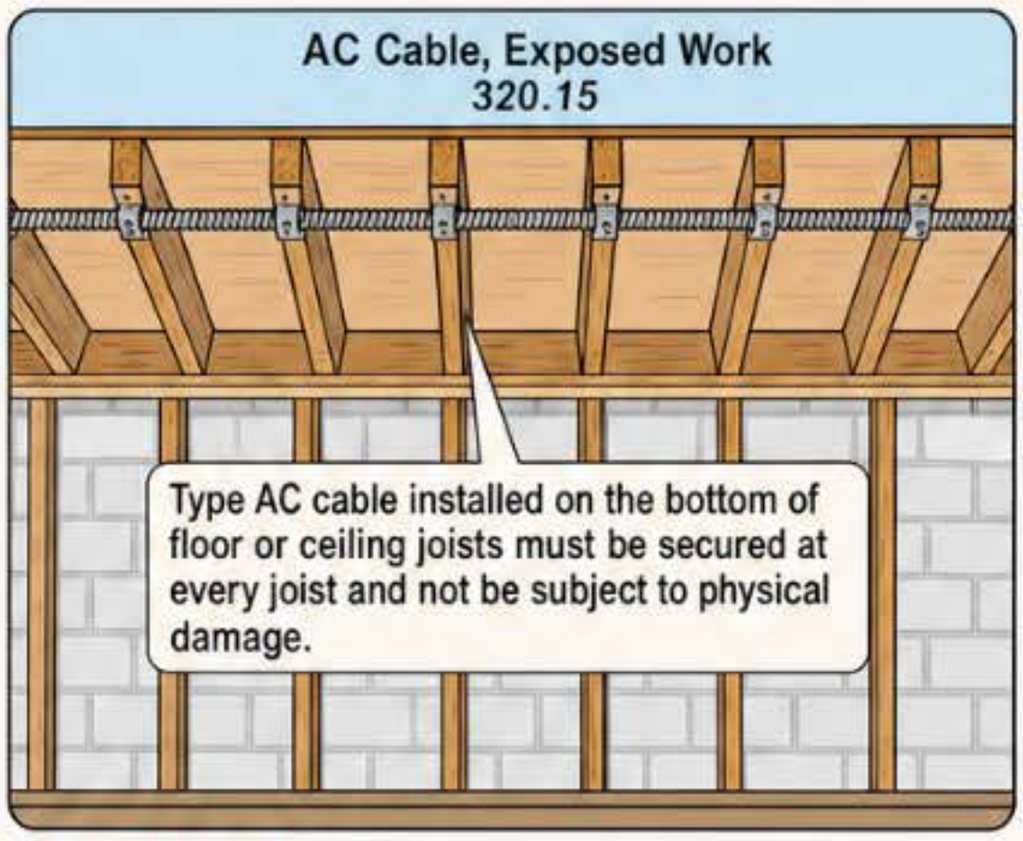
(2) In damp or wet environments.

(3) Inside hollow masonry or tile walls that are exposed or that may be subjected to excessive moisture or dampness.

(4) Where exposure to corrosive substances is present.

320.15 Exposed Work

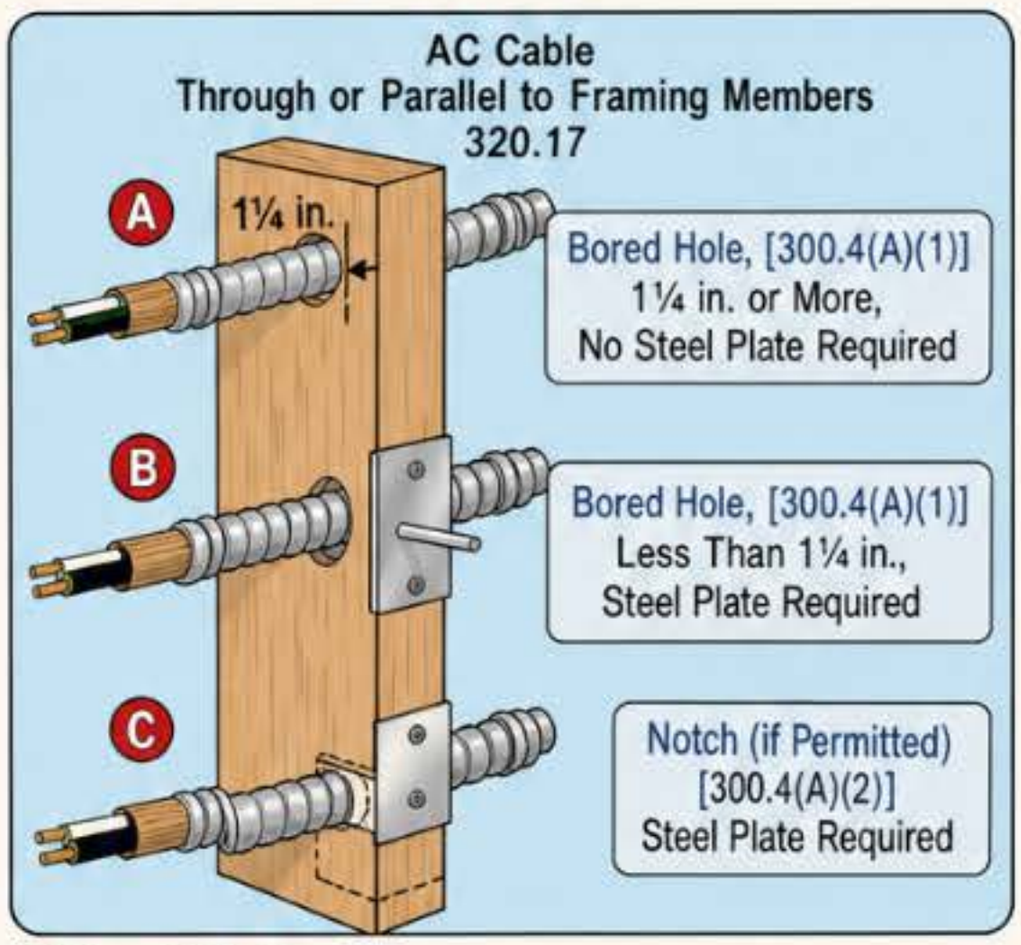
Exposed Type AC cable, except as allowed in 300.11(B), must be run close along the surface of the structure's finish or the face of running boards. When installed on the underside of floor or ceiling joists, it must be fastened at every joist and cannot be subject to physical damage. **See Figure 320–3.**



▲ Figure 320–3

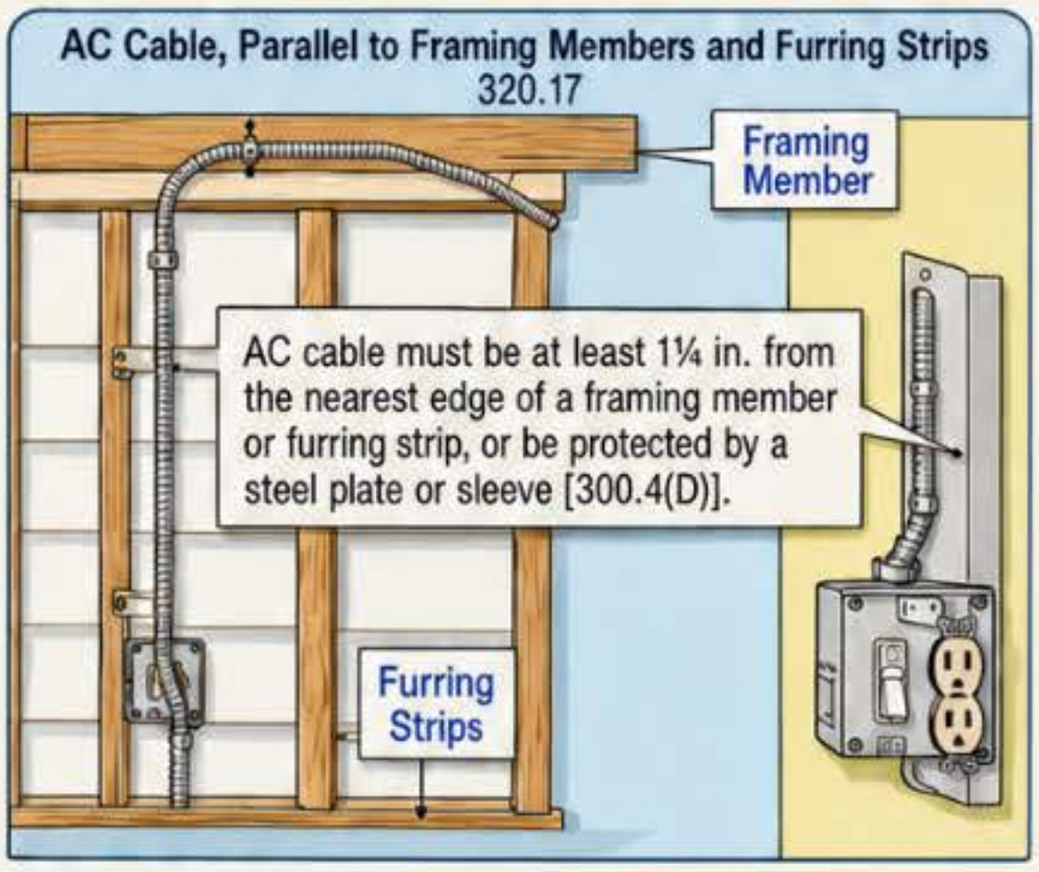
320.17 Through or Parallel to Framing Members

Type AC cable installed through, or parallel to, framing members or furring strips must be protected against physical damage from penetration by screws or nails by maintaining 1¼ in. of separation between the cable and the framing member or furring strip, or by a suitable metal plate in accordance with 300.4(A), (C), and (D). **See Figures 320–4 and 320–5.**



▲ Figure 320–4

DEFINITIONS | From Michael Hamilton Publications

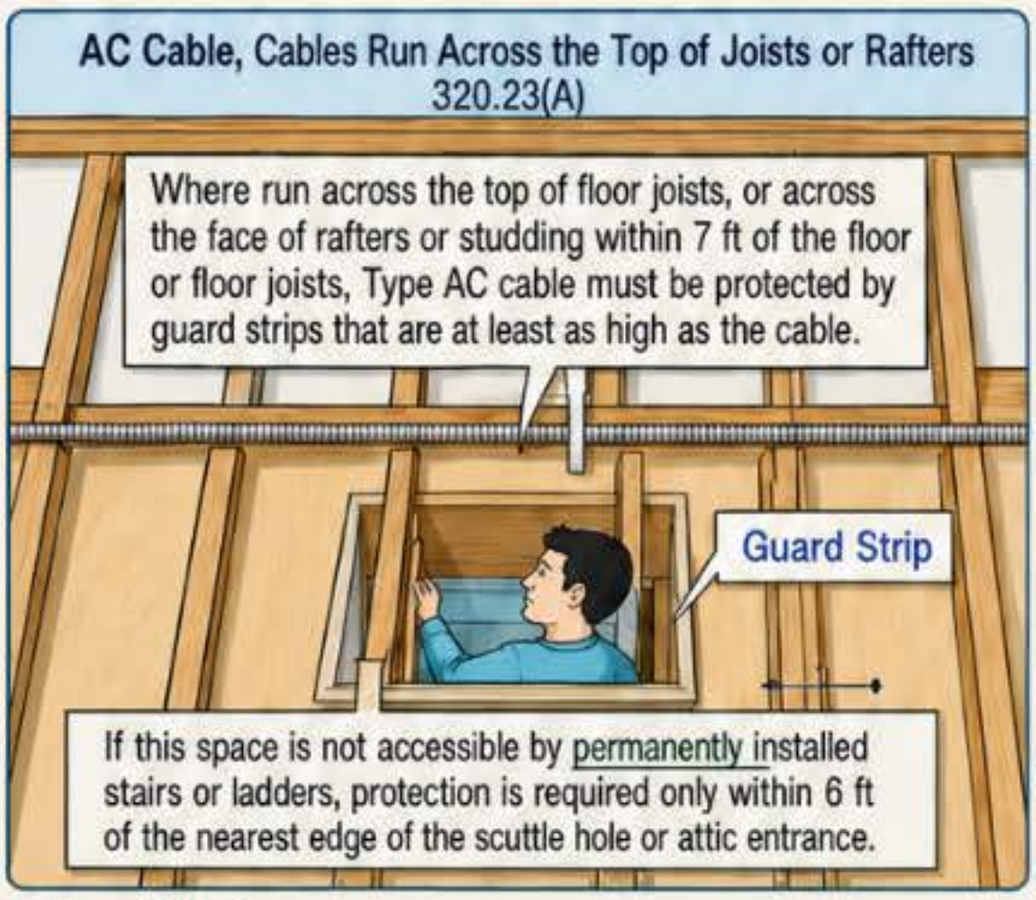


▶ Figure 320–5

320.23 In Accessible Attics or Roof Spaces

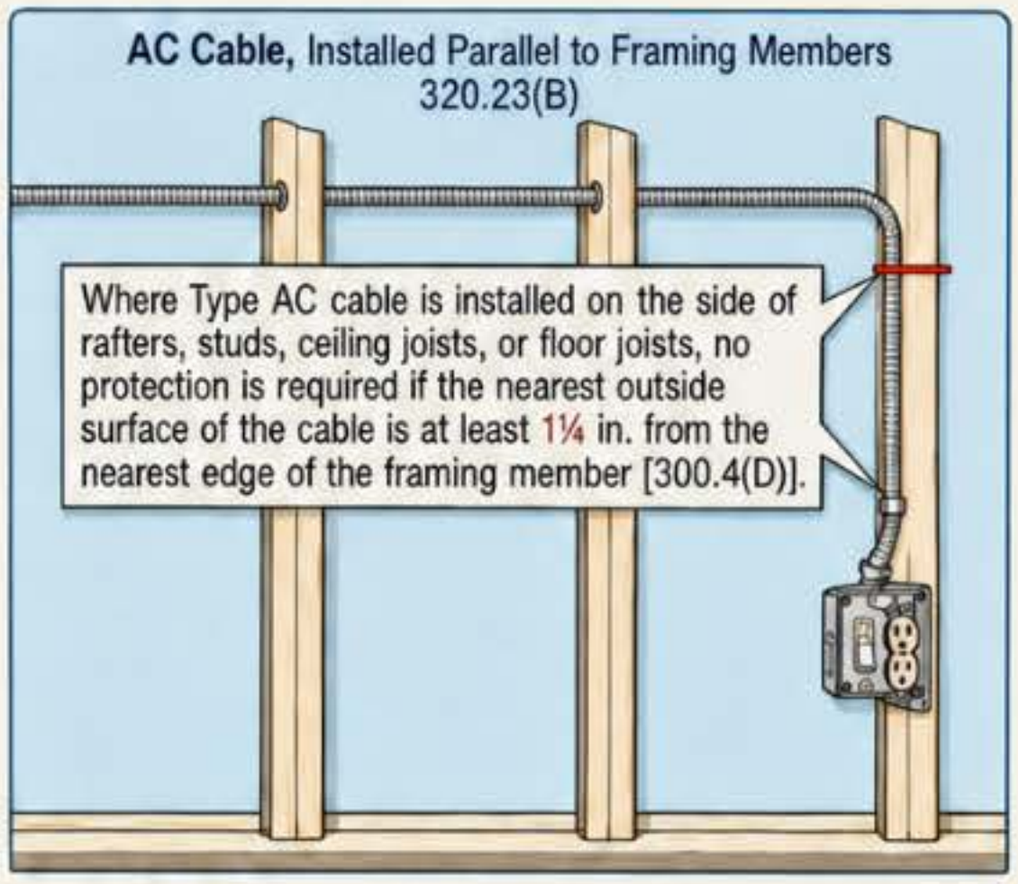
(A) Cables Run Across the Top of Floor Joists. Where run across the top of floor joists, or across the face of rafters or studding within 7 ft of the floor or floor joists, Type AC cable must be protected by guard strips that are at least as high as the cable.

If this space is not accessible by permanently installed stairs or ladders, protection is required only within 6 ft of the nearest edge of the scuttle hole or attic entrance. ▶ Figure 320–6



▶ Figure 320–6

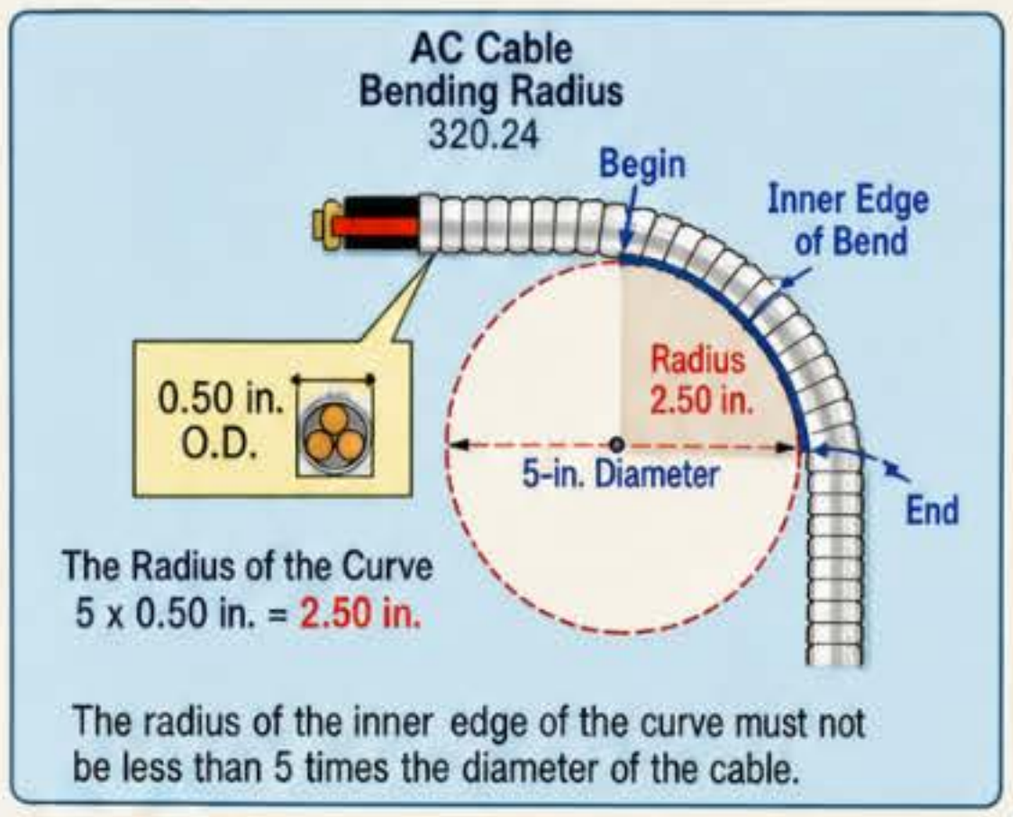
(B) Cable Installed Parallel to Framing Members. Where Type AC cable is installed on the side of rafters, studs, ceiling joists, or floor joists, no protection is required if the nearest outside surface of the cable is at least 1¼ in. from the nearest edge of the framing member [300.4(D)].



▶ Figure 320–7

320.24 Bending Radius

Type AC cable is not permitted to be bent in a manner that will damage the cable. This is accomplished by limiting bending of the inner edge of the cable to a radius of not less than five times the diameter of the cable. ▶ Figure 320–8



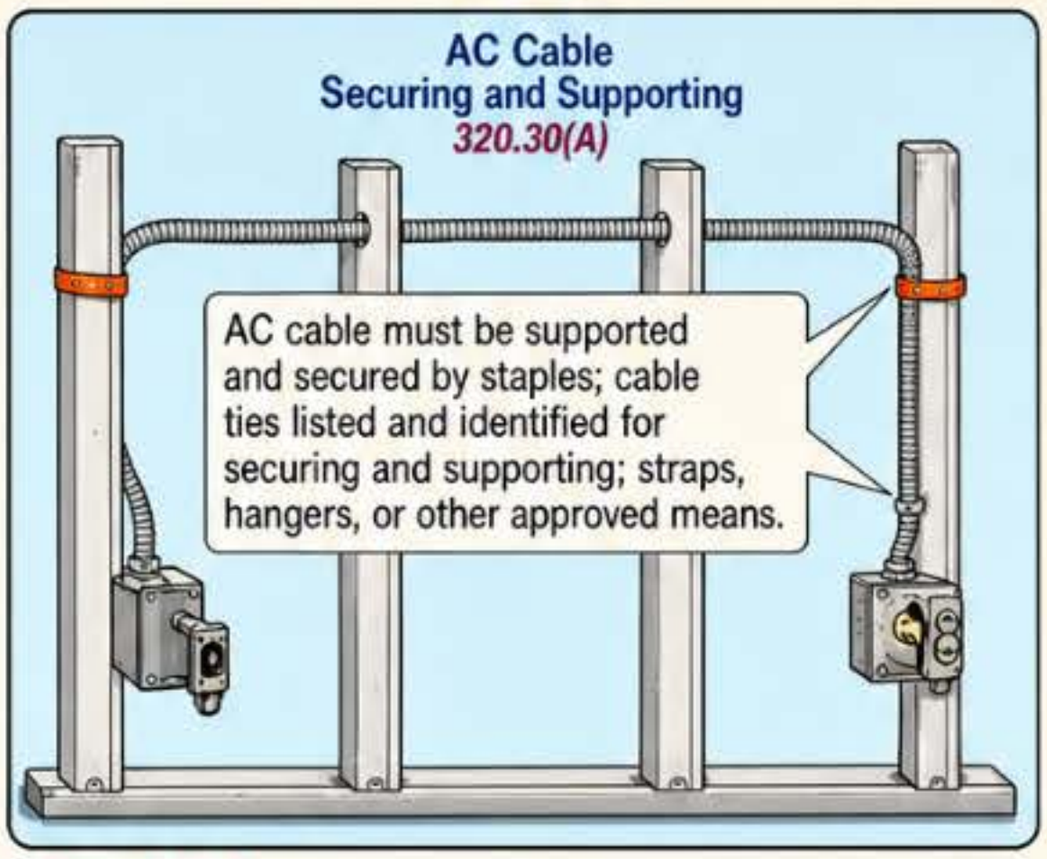
▶ Figure 320–8

Author's Commentary: *These spacing and protection rules are designed to prevent physical damage to Type AC cable from nails, screws, or contact with building materials. Whether in finished walls or attic spaces, always maintain the required clearances or use guard strips or other protection.*

— Michael Hamilton

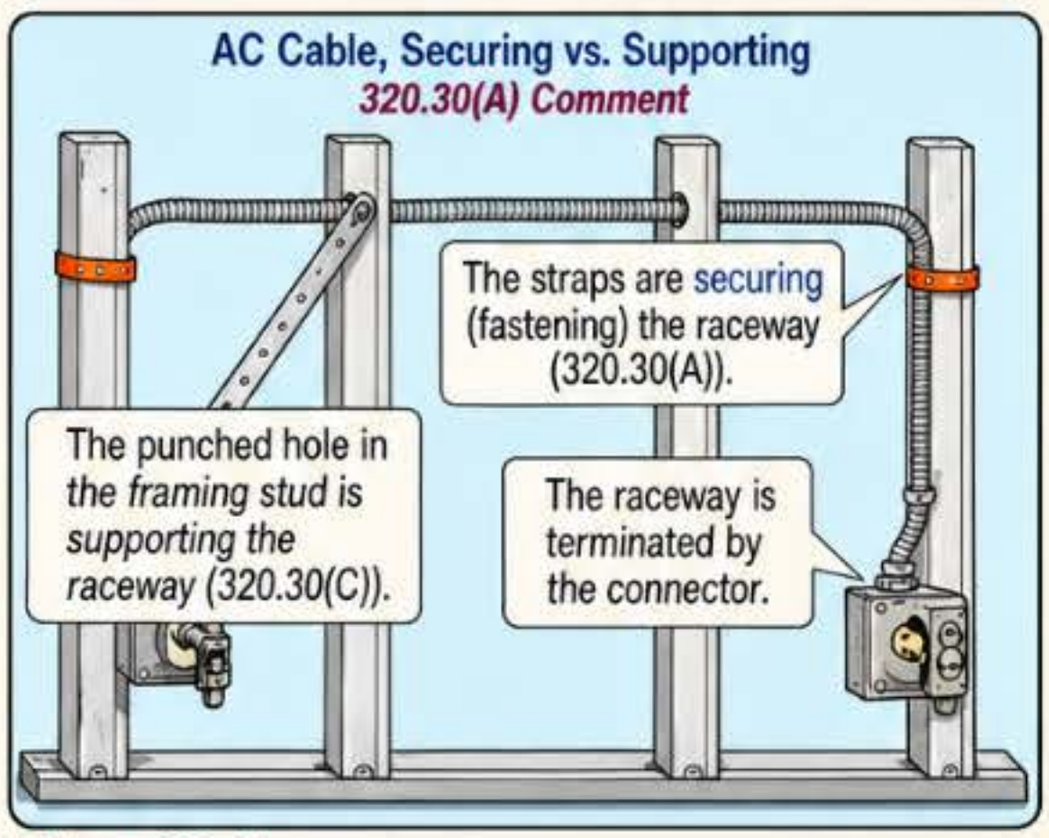
320.30 Securing and Supporting

(A) General. Type AC cable has to be firmly held and properly supported using staples, cable ties listed and identified for holding and supporting, straps, hangers, or other approved methods designed and installed so the cable will not be harmed. • Figure 320-9



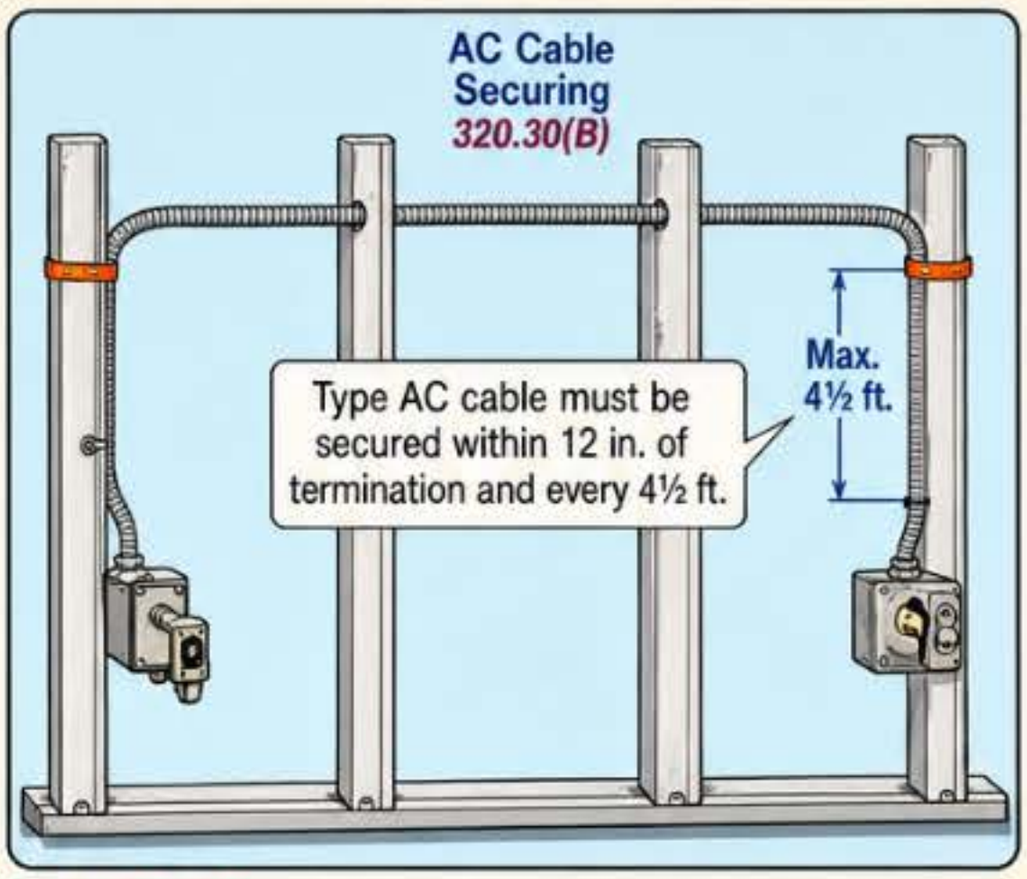
▶ Figure 320-9

Author's Commentary:
Secured means "fastened" such as with a strap or tie wrap; supported means "held" such as with a hanger or by running through a hole in a stud, joist, or rafter.
— Michael Hamilton



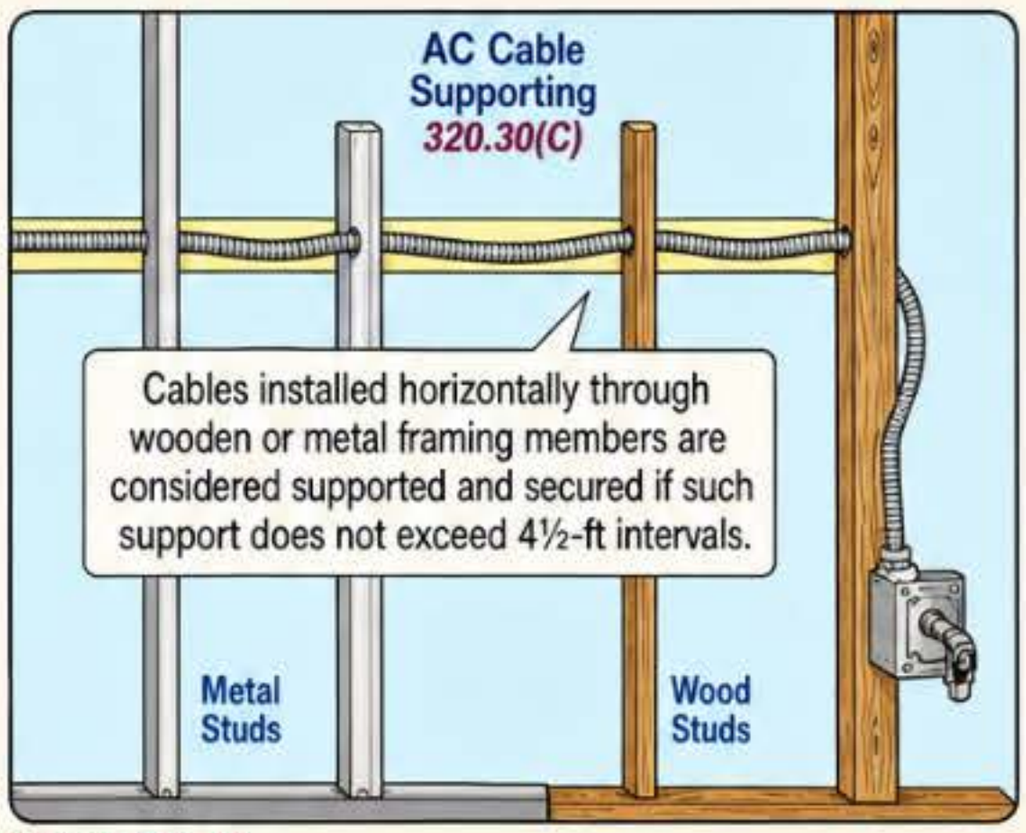
▶ Figure 320-10

(B) Securing. Type AC cable must be secured within 12 in. of every outlet box, junction box, cabinet, or fitting and at intervals not exceeding 4½ ft. • Figure 320-11



▶ Figure 320-11

(C) Supporting. Type AC cable must be supported at intervals not exceeding 4½ ft. Cables installed horizontally through wooden or metal framing members are considered supported and secured if such support does not exceed 4½-ft intervals. • Figure 320-12



▶ Figure 320-12

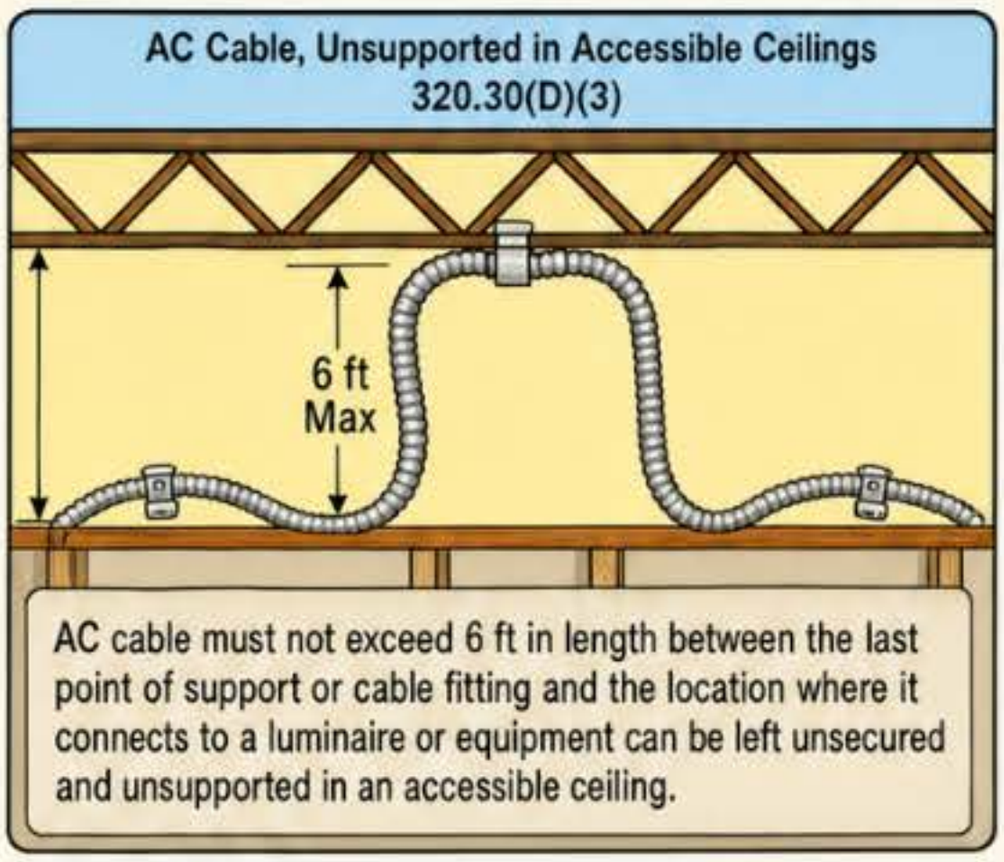
(D) Unsupported Cables. Type AC cable can be unsupported and unsecured where:

(1) Fished through concealed spaces

(2) Not more than 2 ft long at terminals where flexibility is necessary

(3) Not more than 6 ft long from the last point of cable support or Type AC cable fitting to the point of connection to a luminaire or electrical equipment within an accessible ceiling. • Figure 320-13

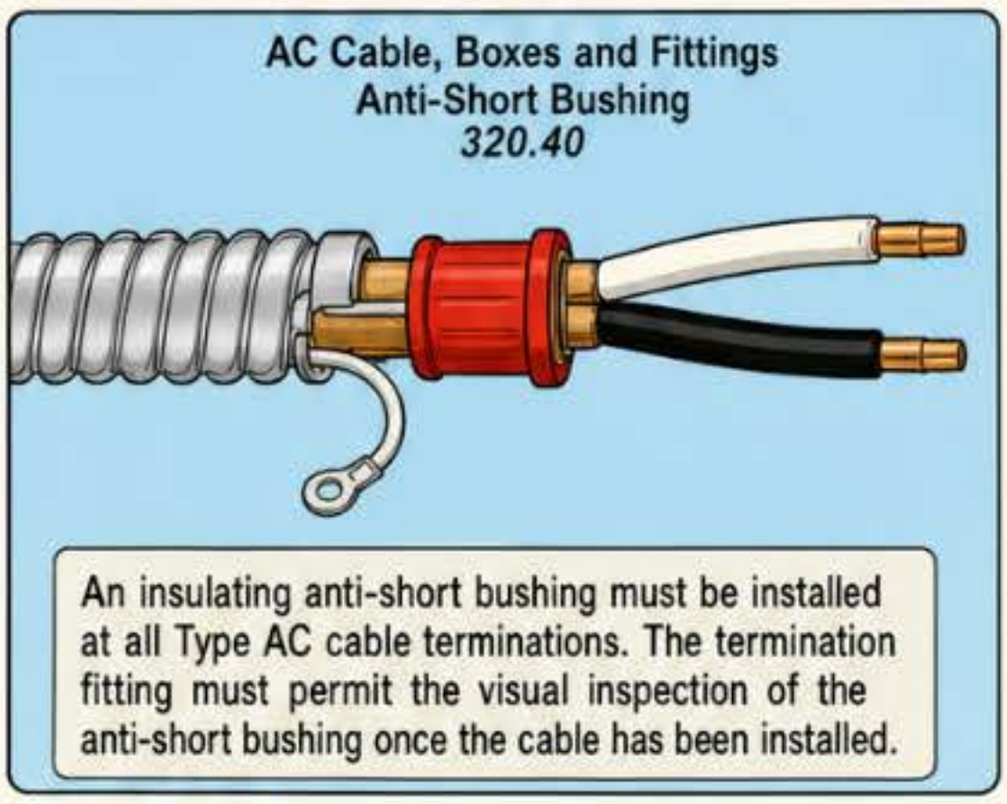
DEFINITIONS | From Michael Hamilton Publications



▶ Figure 320–13

320.40 Boxes and Fittings

If the termination fitting includes protection—such as an insulating anti-short bushing (often identified by a red "redhead")—it must be used at every Type AC cable termination. The termination fitting must allow the visual inspection of the anti-short bushing after the cable has been installed. ▶ Figure 320–14



▶ Figure 320–14

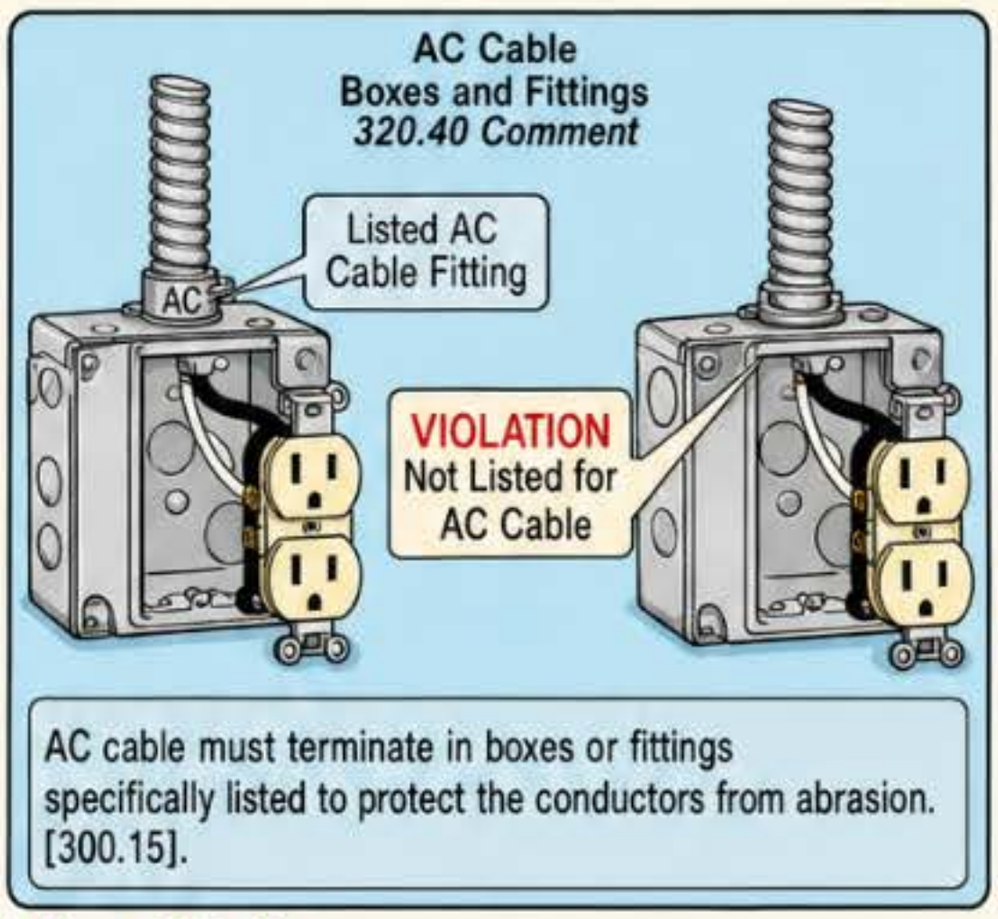
Author's Commentary:

To prevent conductor abrasion, Type AC cable must end inside the specific boxes or fittings listed for Type AC cable.

▶ Figure 320–15

— Michael Hamilton

▶ The internal aluminum bonding strip within the cable has no electrical function once it is outside the cable and can be removed. However, electricians still secure the anti-short bushing to the cable. See 320.108.



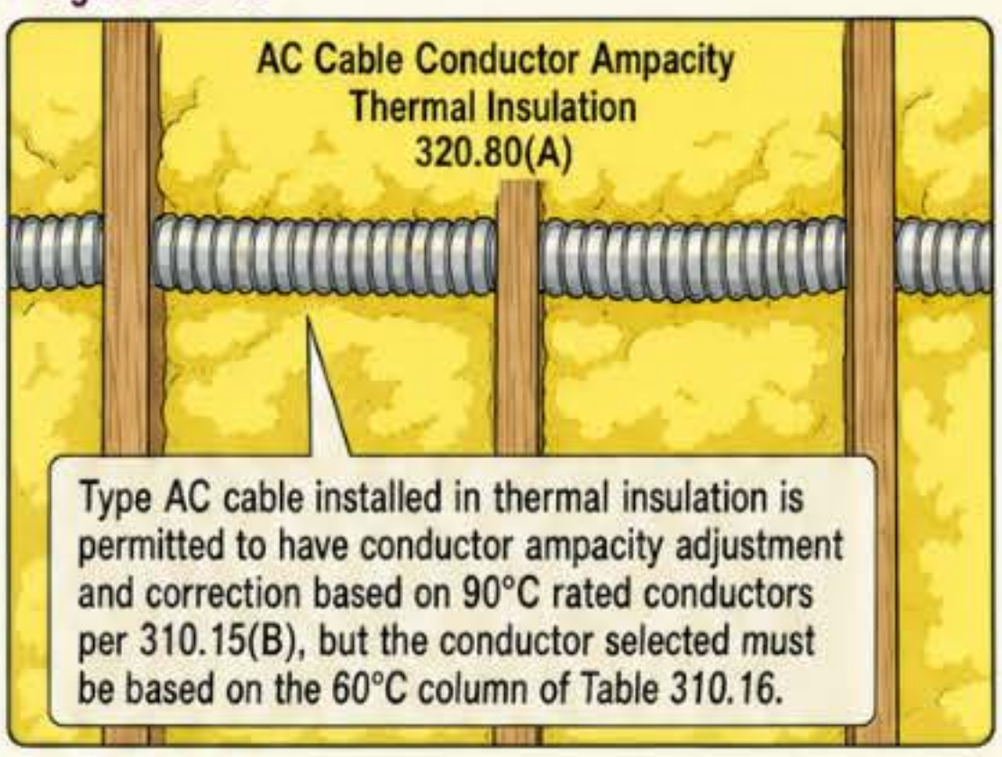
▶ Figure 320–15

320.80 Conductor Ampacity

The ampacity of Type AC cable must be determined in accordance with 310.14.

(A) Thermal Insulation. Type AC cable installed in thermal insulation is permitted to have its conductor ampacity adjusted and corrected based on 90°C rated conductors in accordance with 310.15(B), but the conductor selected must be based on the 60°C column of Table 310.16.

▶ Figure 320–16



▶ Figure 320–16

▶ Example

Question: *Is Type AC cable containing four 12 AWG current-carrying conductors suitable to be protected by a 20A circuit breaker?*

(a) Yes (b) No

Solution:

Step 1: *Determine the ampacity of the circuit conductors in accordance with 310.15 and Table 310.15(C)(1). 12 AWG is rated 30A at 90°C [Table 310.16].*

Conductor Adjustment = 80% [Table 310.15(C)(1)]

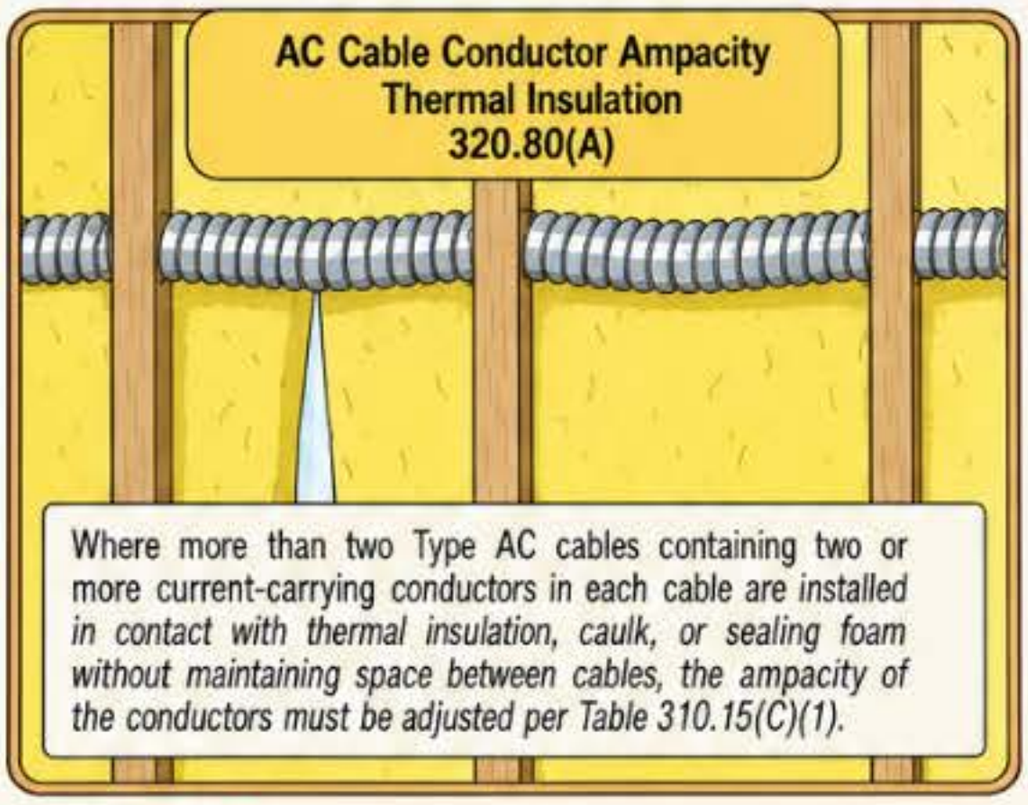
Conductor Adjusted Ampacity = 30A × 80%

Conductor Adjusted Ampacity = 24A

Step 2: *Verify that the adjusted conductor ampacity can be protected by the 20A circuit breaker. In this case, 12 AWG is rated 24A after adjustment at 90°C and 20A at 60°C [240.4(D)].*

Answer: *(a) Yes*

Where more than two Type AC cables containing two or more current-carrying conductors in each cable are installed in contact with thermal insulation, caulk, or sealing foam without maintaining spacing between cables, the ampacity of each conductor must be adjusted in accordance with Table 310.15(C)(1). ▶ Figure 320–17



▶ Figure 320–17

Part III. Construction Specifications

320.100 Construction

Type AC cable must have an armor of flexible metal tape with an internal aluminum bonding strip in intimate contact with the armor for its entire length.

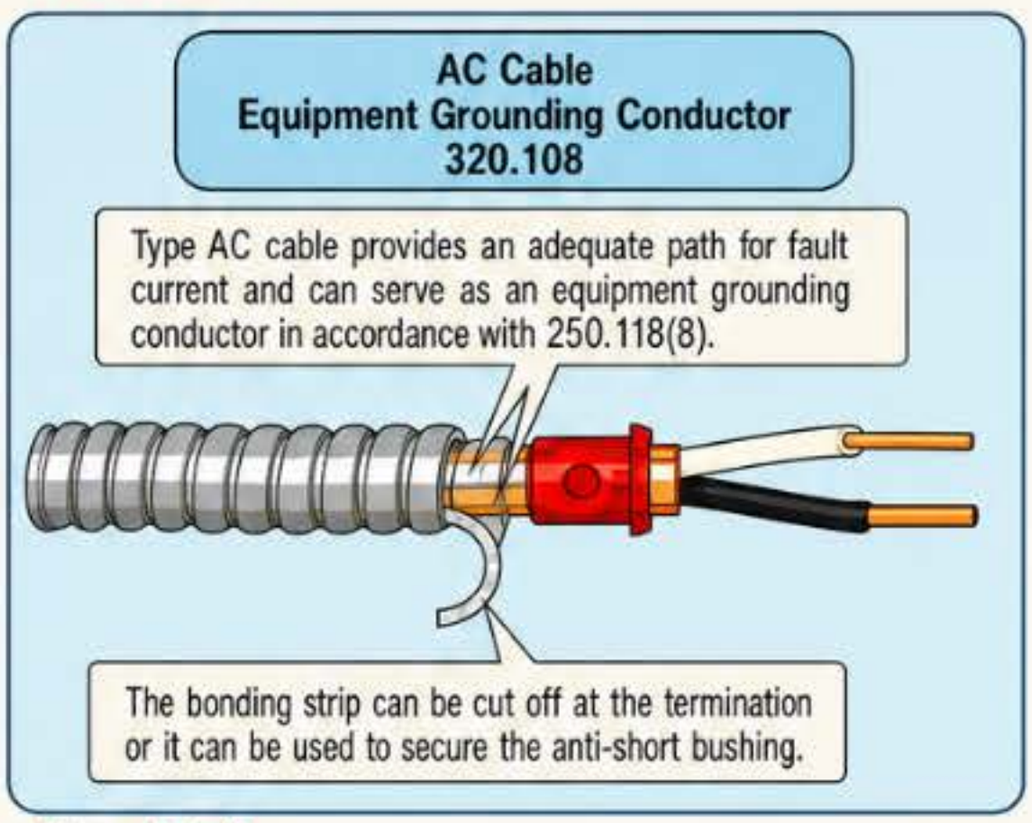
Author's Commentary:

- The best method of cutting Type AC cable is to use a tool specifically designed for the purpose, such as a rotary armor cutter.
- When cutting Type AC cable with a hacksaw, be sure to cut only one spiral of the cable and be careful not to nick the conductors; this is done by cutting the cable at an angle. Breaking the cable spiral (bending the cable very sharply), then cutting the cable with a pair of dikes is not a good practice.

— *Michael Hamilton*

320.108 Equipment Grounding Conductor

Type AC cable provides an adequate path for fault current and can serve as an equipment grounding conductor [250.118(8)]. ▶ Figure 320–18



▶ Figure 320–18

Author's Commentary:

The internal aluminum bonding strip is not an equipment grounding conductor, but it allows the interlocked armor to serve as one because it reduces the impedance of the armored spirals to ensure a ground fault will be cleared. It is the combination of the aluminum bonding strip and the cable armor that creates the equipment grounding conductor. Once the bonding strip exits the cable, it can be cut off because it no longer serves any purpose. The effective ground-fault current path must be maintained by using fittings specifically listed for Type AC cable [320.40]. See 300.12, 300.15, and 300.10.

— *Michael Hamilton*

ARTICLE 330 METAL-CLAD CABLE (TYPE MC)

Introduction to Article 330—Metal-Clad Cable (Type MC)

Metal-clad cable (Type MC) is one of the most frequently used wiring methods for metal raceways. Type MC cable surrounds insulated conductors with a metal armor—either interlocking steel or aluminum. This armor can be corrugated or smooth aluminum tubing, or spiral-wound steel or aluminum.

Because of its rugged construction, Type MC cable offers a versatile wiring solution that can be installed in almost any location and in a wide range of applications.

The most common form is interlocking steel armor, which looks like a flexible metal conduit.

Using Type MC as an equipment grounding conductor is not permitted. As required by NEC 250.118(1), an equipment grounding conductor must be present in accordance with NEC 250.118(10). Another version of Type MC—classified as "Type MCAP" cable—contains a bare aluminum grounding or bonding conductor running alongside the metal armor. That internal conductor (inside the armor) allows the cable to be used as the equipment grounding conductor per NEC 250.118(10)(b).

Part I. General

330.1 Scope

Article 330 covers the use, installation, and construction specifications of metal-clad cable, Type MC. (See Figure 330-1.)

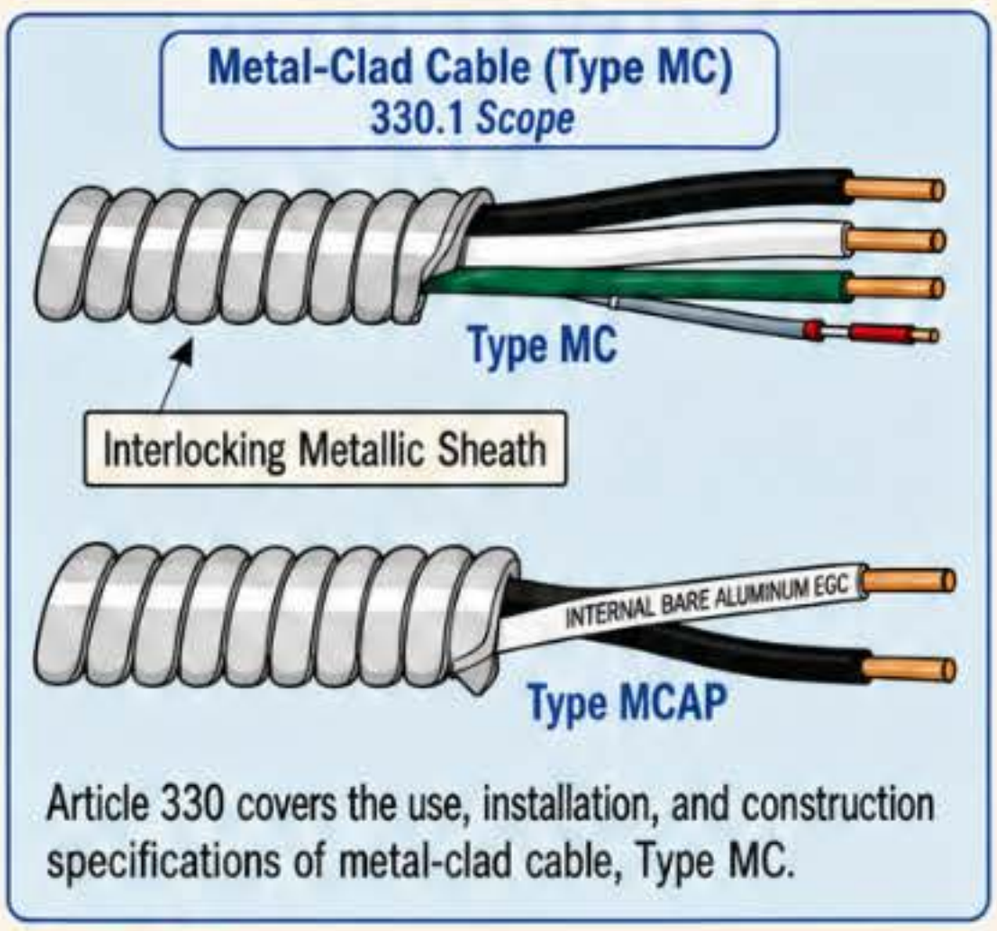


Figure 330-1

330.2 Definition

The definition in this section applies within this article and throughout the NEC.

Metal-Clad Cable (Type MC). A factory assembly of insulated circuit conductors, with or without optical fiber members, enclosed in an armor of interlocking metal tape; or a smooth or corrugated metallic sheath. (See Figure 330-2.)

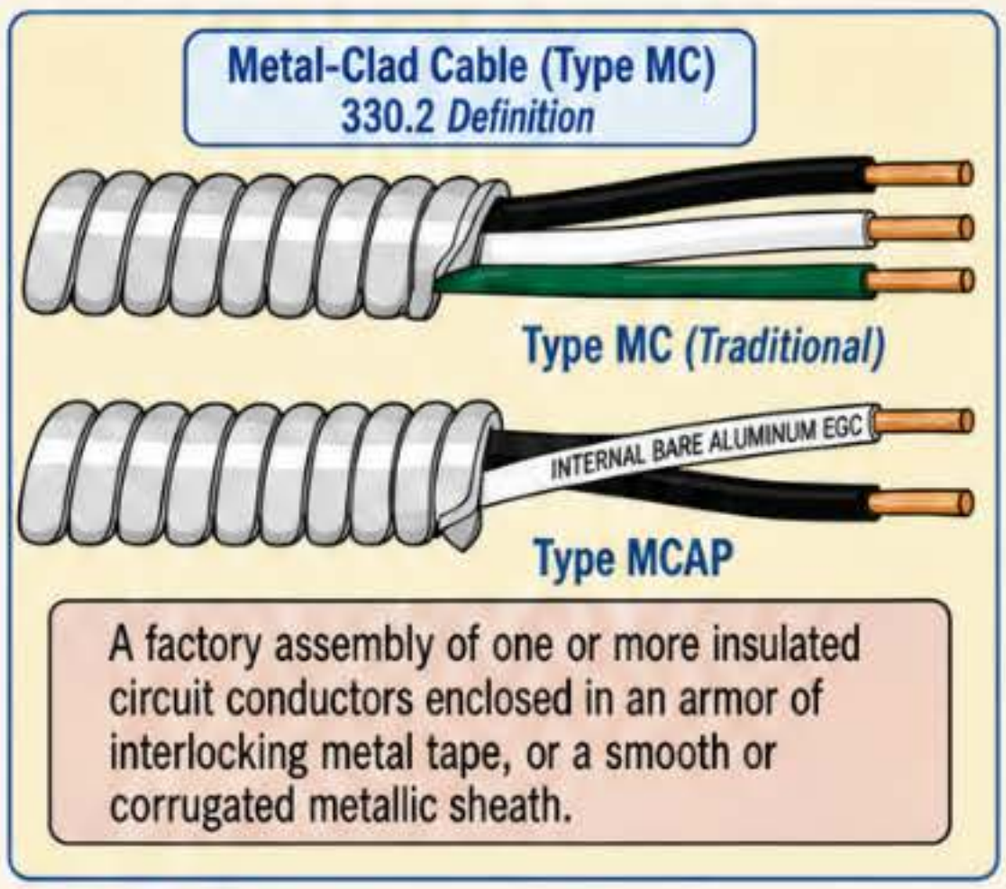
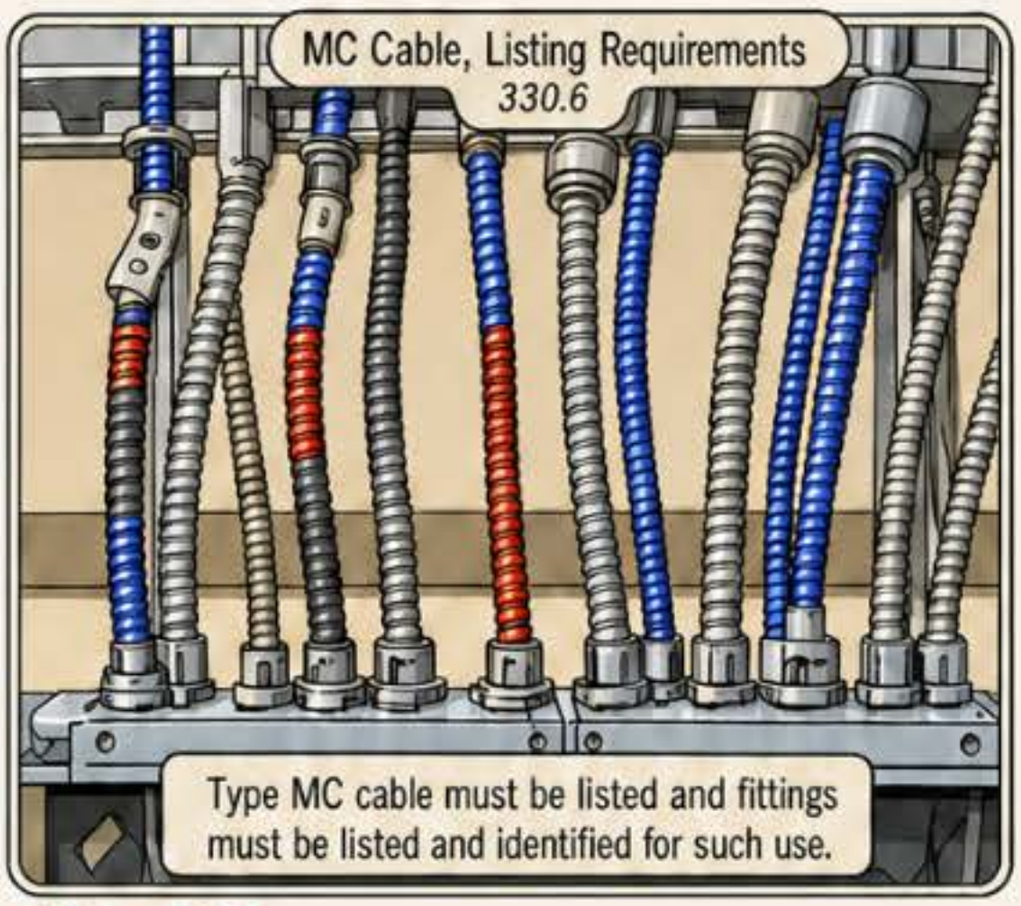


Figure 330-2

330.6 | Metal-Clad Cable (Type MC)

330.6 Listing Requirements

Type MC cable must be listed, and its fittings must be listed and identified for the use. **Figure 330-3**



▶ **Figure 330-3**

Author's Commentary:

- Type MC cable is made with several types of metal sheaths. Steel and aluminum are the most common, but it is also available with a corrugated copper sheath or with a PVC jacket for use in environments that need extra protection. Fittings must be listed and identified for the specific type of MC cable being installed [330.15].
- Type AC cable connectors can sometimes be used if the fitting (or the carton containing them) indicates they can also be used for the Type MC cable being installed.
- The *Code does not require* anti-short bushings (*red* heads) at the *termination of* Type MC cable, but if *they are supplied, using them is a matter of preference.*

— Michael Hamilton

Part II. Installation

330.10 Uses Permitted

(A) General Uses. Type MC cable can be used:

(1) For branch circuits, feeders, and services.

(2) For power, lighting, control, and signaling circuits.

(3) For indoor or outdoor locations.

(4) Exposed or concealed.

(5) To be directly buried (if identified for the purpose).

(6) In a cable tray.

(7) In a raceway.

(8) As aerial cable on a messenger.

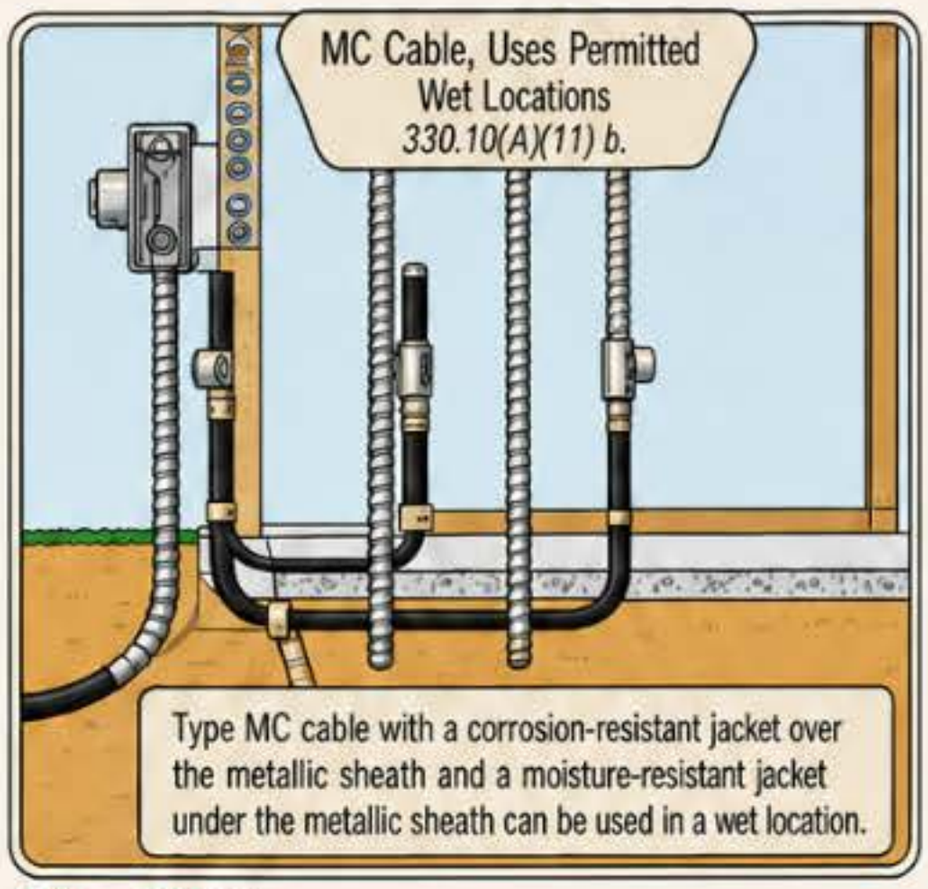
(9) In hazardous (classified) locations as permitted in 501.10(B), 502.10(B), and 503.10.

(10) Embedded in plaster or brick in dry locations.

(11) In wet locations, where a corrosion-resistant jacket is provided over the metallic sheath and any of the following conditions are met:

a. The metallic covering is impervious to moisture.

b. A jacket is provided under the metal covering that is moisture resistant. ▶ **Figure 330-4**



▶ **Figure 330-4**

(B) Specific Uses.

(1) Cable Tray. Type MC cable can be installed in a cable tray in accordance with Article 392.

(2) Direct Buried. Direct-buried cables must be protected in accordance with 300.5.

(3) Installed as Service-Entrance Cable. Type MC cable is permitted to be used as service-entrance cable when installed in accordance with 230.43.

Metal-Clad Cable (Type MC) | 330.23

(4) Installed Outside Buildings. Type MC cable run outside buildings must follow 225.10, 396.10, and 396.12.

Author's Commentary: *These cross-references point you to the general wiring methods in Article 225 and the specific use rules for MC cable in Articles 396.10 and 396.12. Always confirm the most restrictive requirement among them.*
— Michael Hamilton

Note: The phrase "Uses Permitted" is not a complete list. It signals that the listed applications are acceptable where the local authority having jurisdiction approves them.

330.12 Uses Not Permitted

Type MC cable is prohibited in the following situations:

(1) Subject to physical damage.

(2) Exposed to destructive conditions from corrosion in (a) or (b), except where the metal sheath or armor resists the condition or is safeguarded by materials resistant to it.

a. Embedded directly in earth or encased in concrete unless identified for that use.

b. In locations containing cinder fill, strong chlorides, caustic alkalis, or fumes from chlorine or hydrochloric acids.

Author's Commentary: *MC cable depends on its metal sheath for protection. Harsh soil chemistry or corrosive vapors can attack the armor, so the code limits where MC can be used.*
— Michael Hamilton

330.15 Exposed Work

Exposed runs of Type MC cable, other than as allowed in 300.11(B), must be installed tight to the surface of the building finish or on running boards. MC cable on the underside of floor or ceiling joists must be fastened at each joist and must not be subject to physical damage.

MC Cable, Exposed Work
330.15

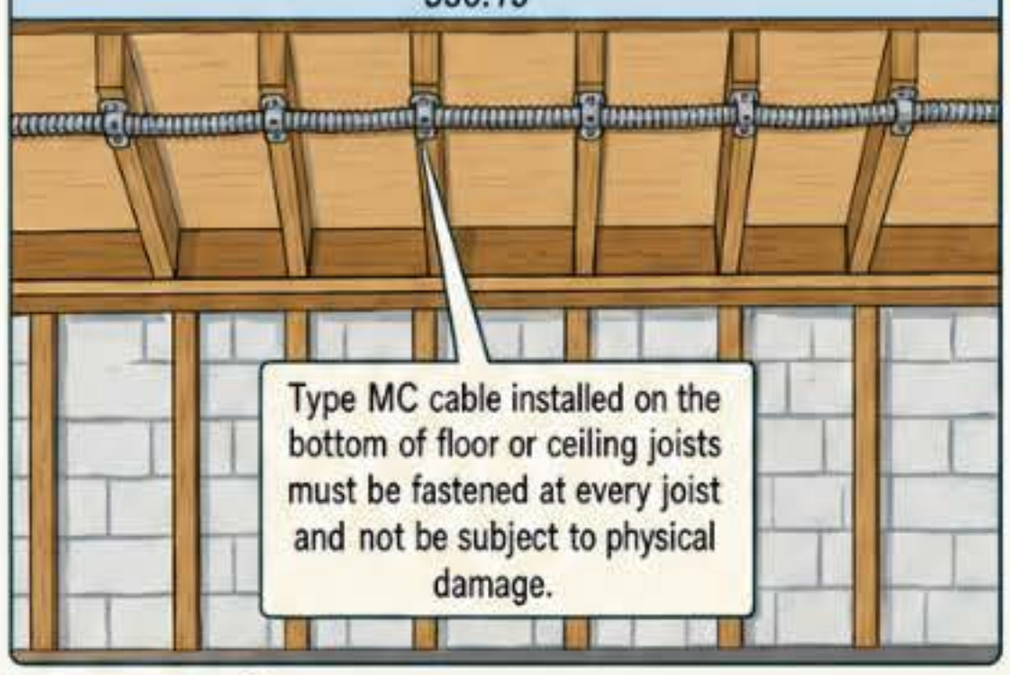


Figure 330–5

330.17 Through or Parallel to Framing Members

Type MC cable installed through or parallel to framing members or furring strips must be shielded from physical damage by a 1¼ in. separation, penetration guard on screws or nails by maintaining that 1¼ in. clearance, or a suitable metal plate, in accordance with 300.4(A), (C), and (D). **Figure 330–6** and **Figure 330–7**

MC Cable
Through Framing Members
330.17

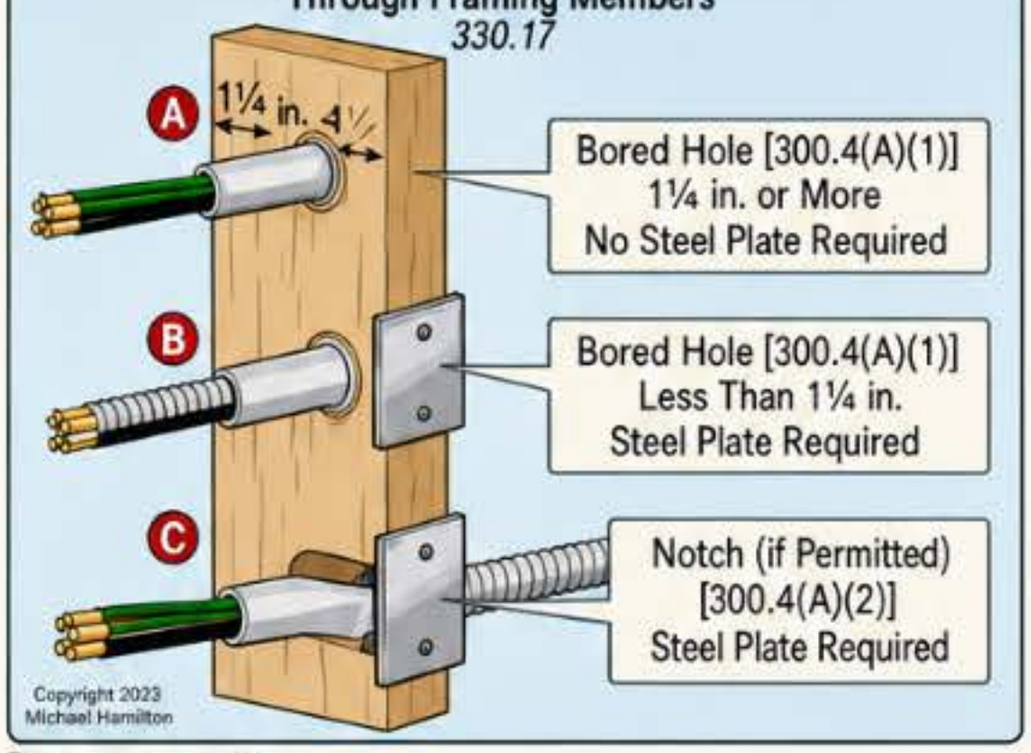


Figure 330–6

MC Cable Parallel to Framing Members and Furring Strips
330.17

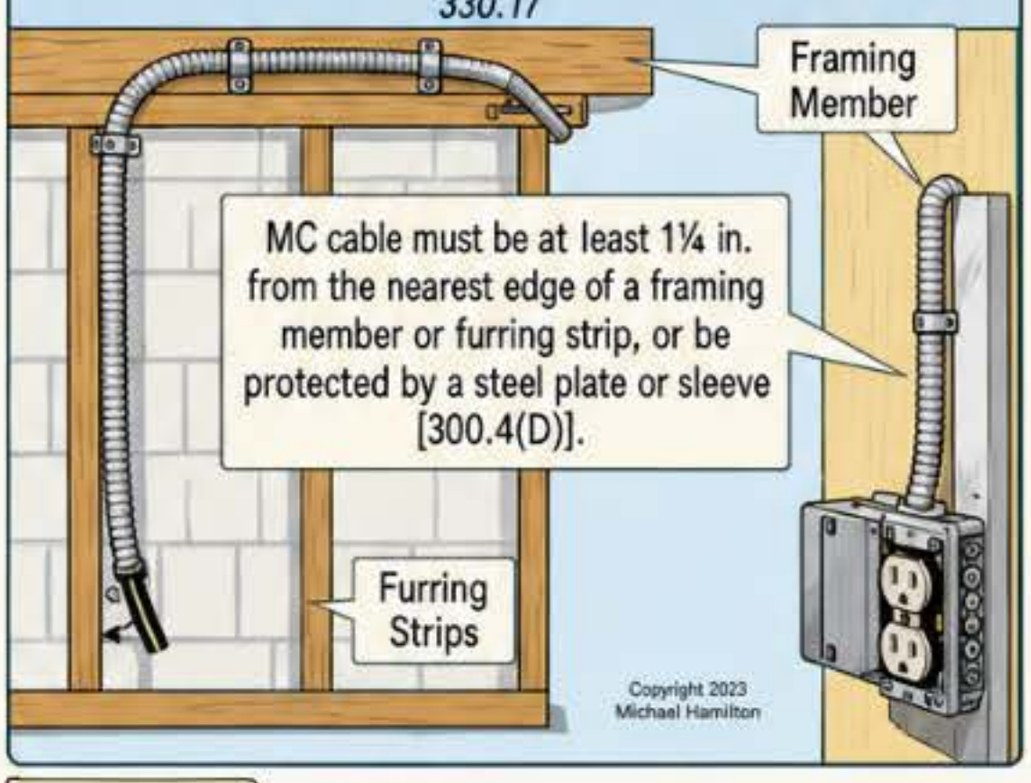


Figure 330–7

330.23 In Accessible Attics or Roof Spaces

Type MC cable installed in accessible attics or roof spaces must comply with 320.23.

Author's Commentary: *Article 320 governs attic and roof space installations. Review 320.23 for the exact fastening, support, and protection requirements.*
— Michael Hamilton

330.24 Definitions — From Michael Hamilton Publications

Author's Commentary:

Areas on the tops of joists, rafters, or studs—such as attics and roof spaces–that are reachable must be protected. Guards are required across the top of floor joists or along the face of rafters or studs within 7 ft of any floor or floor joist. If the area isn't reachable by permanent stairs or ladders, then protection is only needed within 6 ft of the nearest edge of the scuttle hole or the attic entrance.

— Michael Hamilton

MC Cable, Cables Run Across the Top of Joists or Rafters 330.23

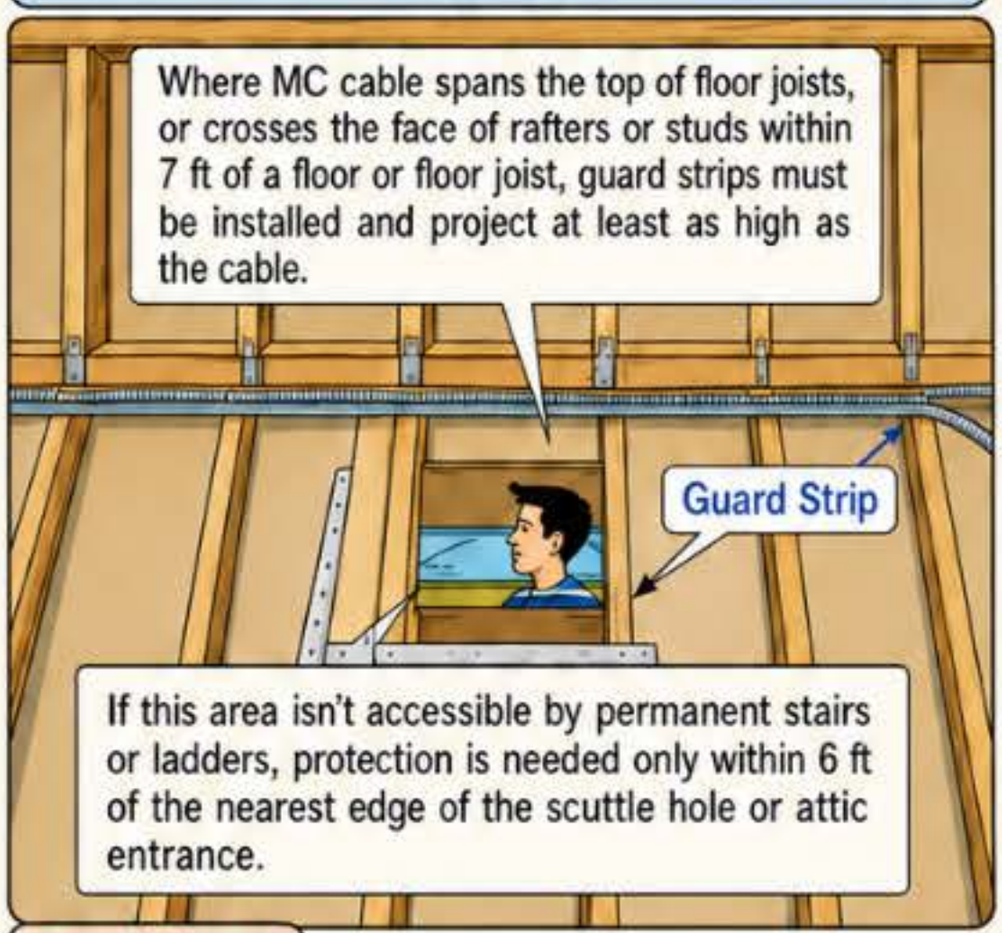


Figure 330–8

Author's Commentary:

On the side of framing members (rafters, studs, or joists), the first 1¼ in. from the nearest edge of the member is the critical zone where nails or screws are likely to penetrate.

— Michael Hamilton

330.24 Bending Radius

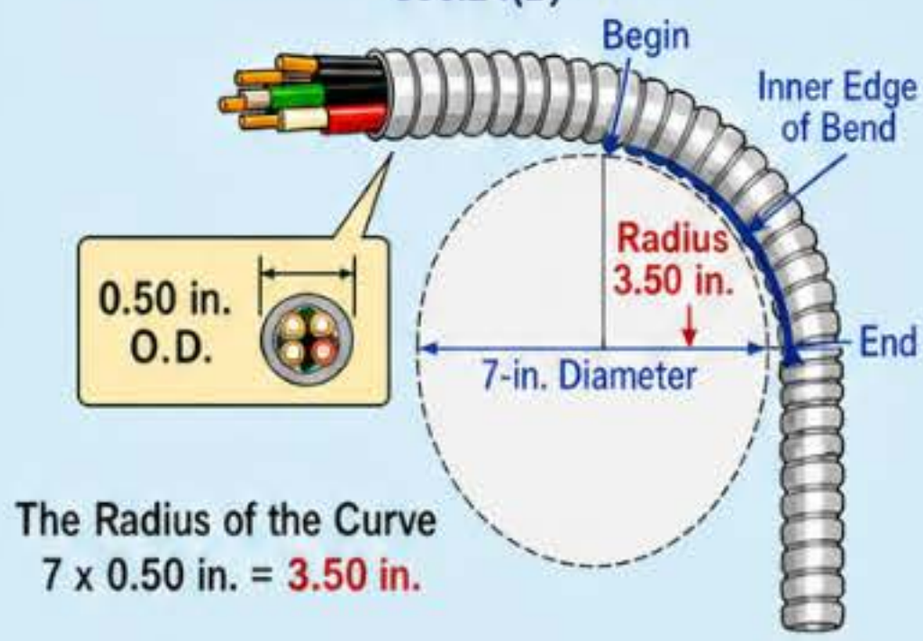
Bends must be made carefully so the cable isn't damaged, and the radius at the inside of the bend can't be less than the values listed below.

(A) Smooth-Sheath Cables

(1) *Smooth-sheath Type MC cables must not be bent so the bending radius at the inner edge of the cable is less than 10 times the outside diameter of the metallic sheath for cable up to ¾ in. in external diameter.*

(B) Interlocked- or Corrugated-Sheath Armor. Interlocked- or corrugated-sheath Type MC cable is not permitted to be bent so the bending radius at the inner edge of the cable is less than seven times the external diameter of the cable.

MC Cable, Bending Radius Interlocked or Corrugated-Sheath Armor 330.24(B)



The radius of the inner edge of the curve must not be less than 7 times the diameter of the cable.

Figure 330–9

330.30 Securing and Supporting

(A) General. Type MC cable must be supported and secured by staples; cable ties listed and identified for securing and supporting; straps, hangers, or similar fittings; or other approved means designed and installed so the cable is not damaged.

MC Cable Securing and Supporting 330.30(A)

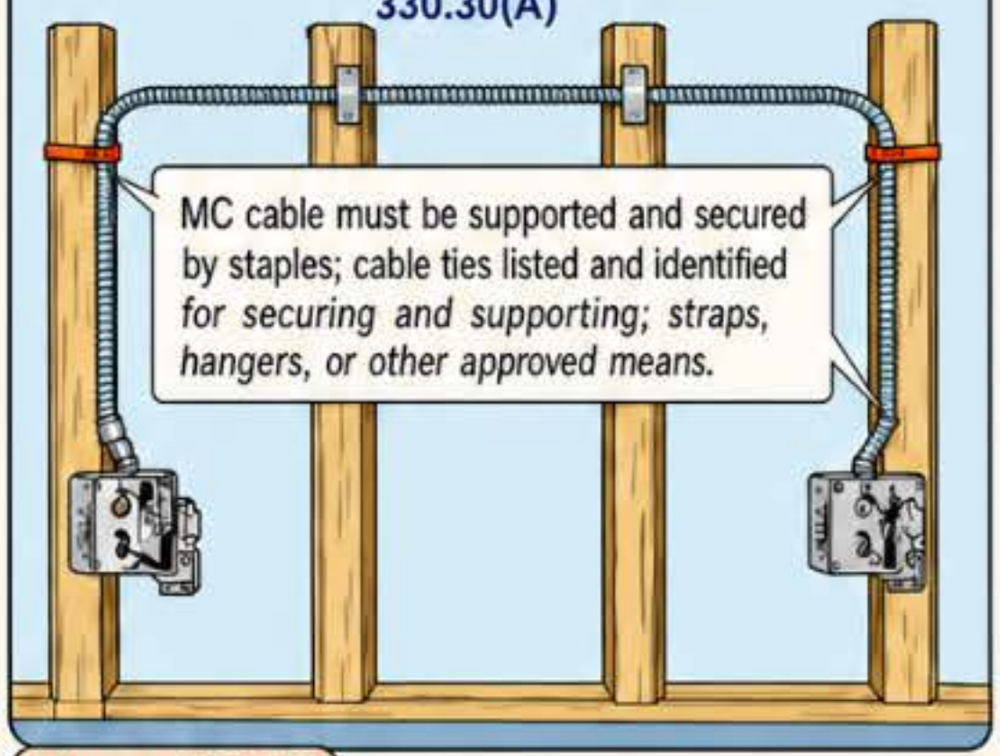


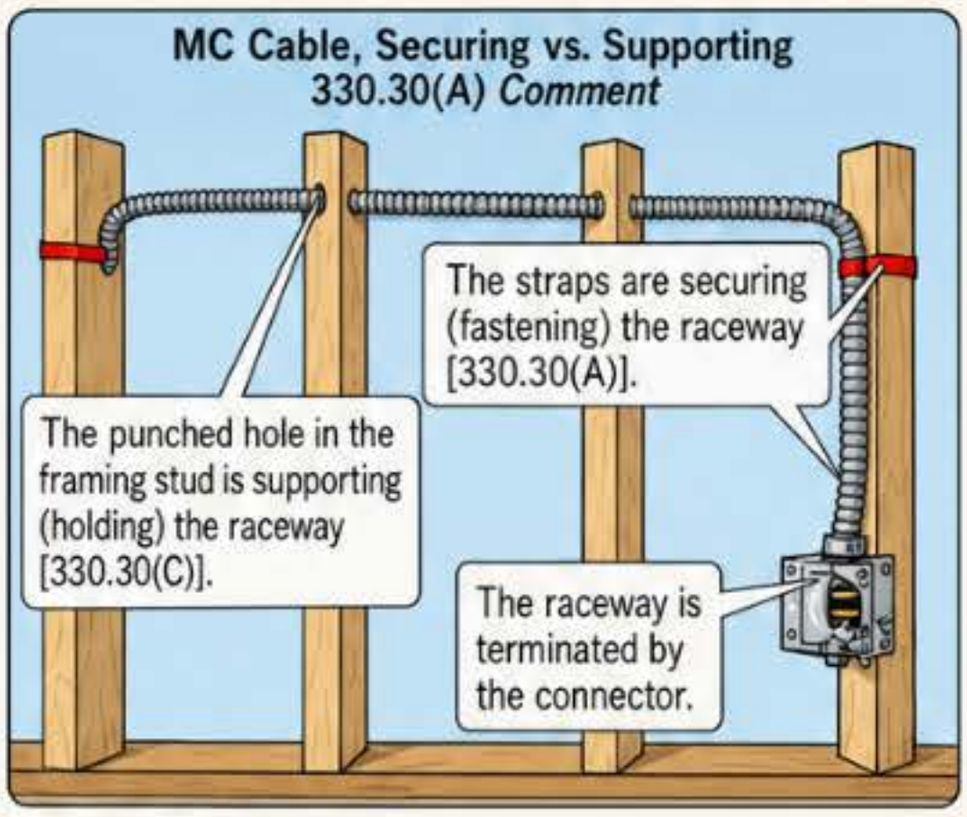
Figure 330–10

DEFINITIONS | From Michael Hamilton Publications

Author's Commentary:

Properly secured means the cable is fastened so it won't shift, using a strap or wrap, while *supported means it is held in place with a hanger, or by passing through a hole in a stud, joist, or similar member.*

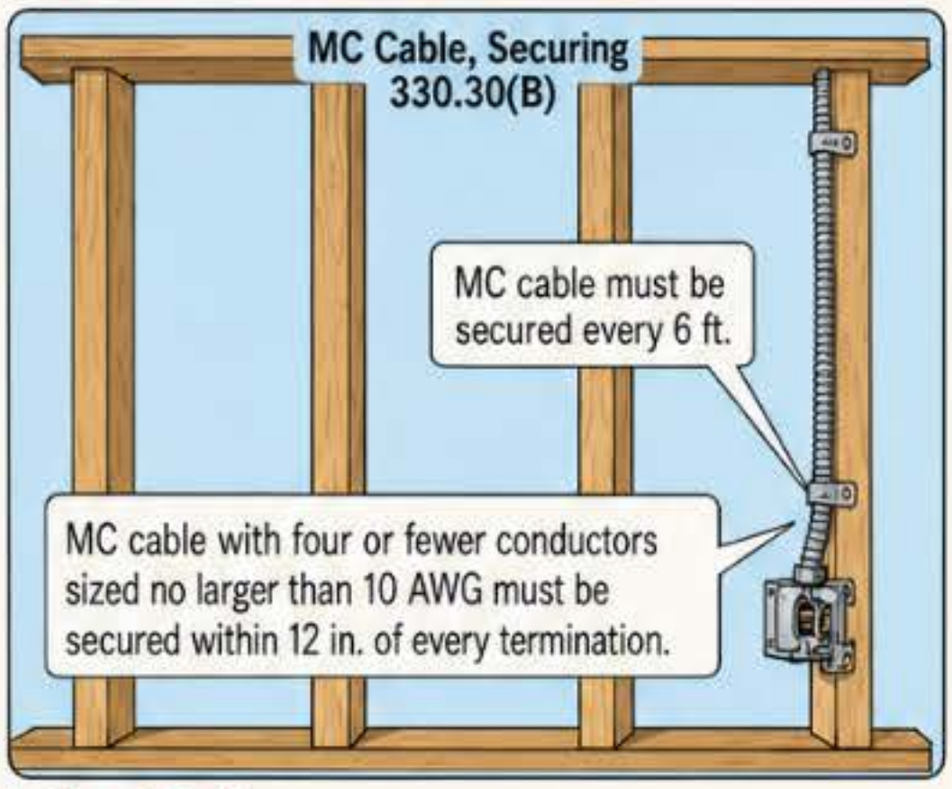
— Michael Hamilton



▶ Figure 330–11

(B) Securing. Type MC cable that contains four or fewer conductors, each no larger than 10 AWG, must be secured within 12 in. of every outlet box, junction box, cabinet, or fitting and at intervals not greater than 6 ft.

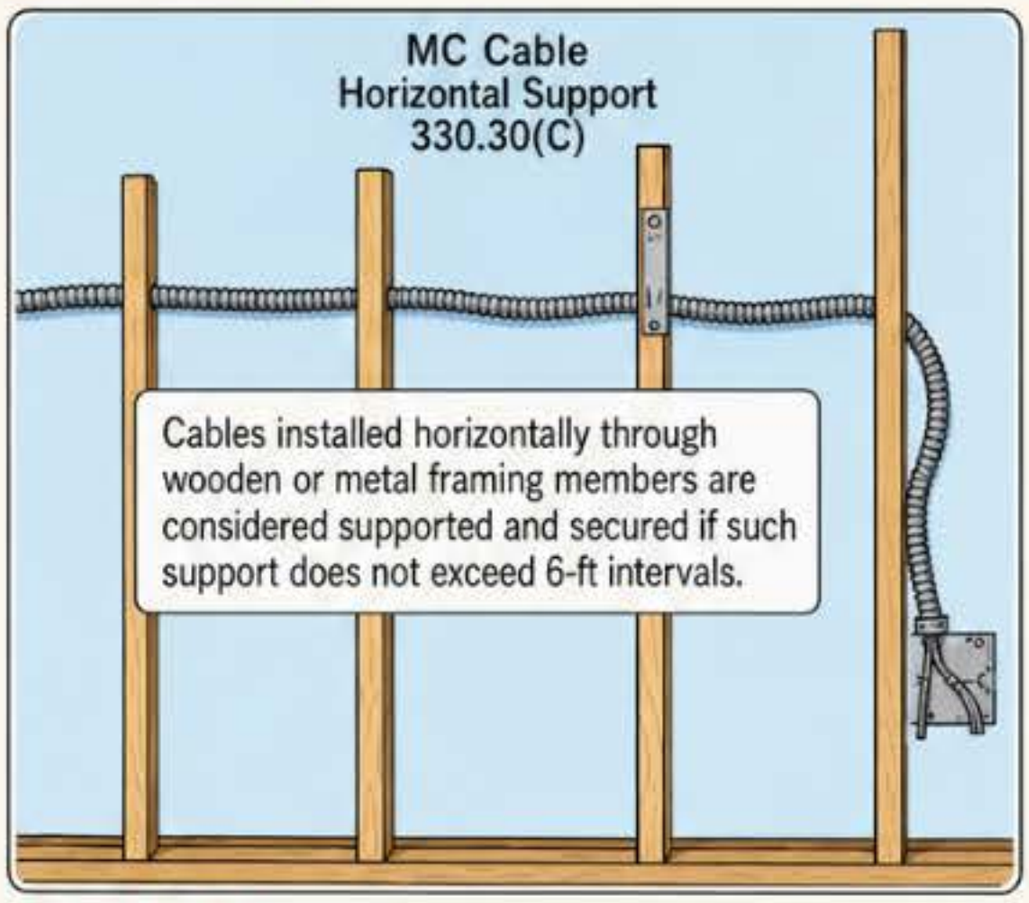
▶ Figure 330–12



▶ Figure 330–12

(C) Supporting. Type MC cable must be supported at intervals not exceeding 6 ft. Cables installed horizontally through wooden or metal framing members are considered secured and supported if such support does not exceed 6-ft intervals.

▶ Figure 330–13

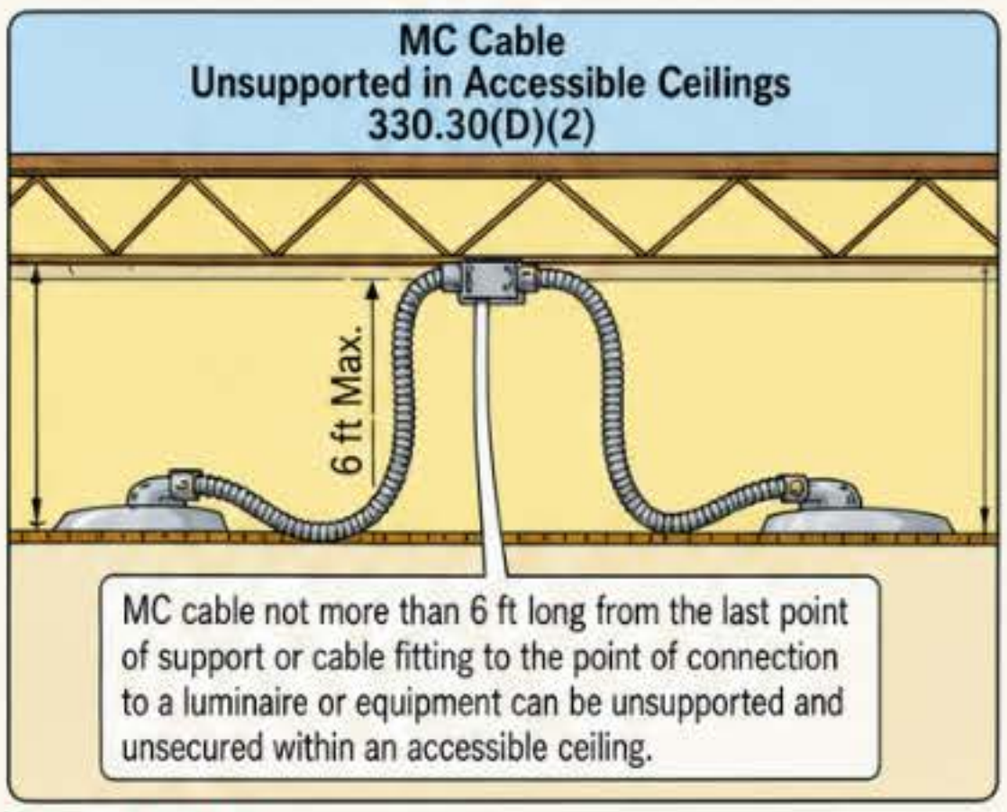


▶ Figure 330–13

(D) Unsupported Cables. Type MC cable can be unsupported and unsecured where:

(1) Fished through concealed spaces in a finished building and support is impractical.

(2) Not more than 6 ft long from the last point of cable support to the point of connection to a luminaire or electrical equipment within an accessible ceiling. *For the purposes of this section, Type MC cable fittings are permitted as a means of cable support.* ▶ Figure 330–14



▶ Figure 330–14

(3) *Not more than 3 ft from the last point where it is securely fastened to provide flexibility for equipment that requires movement after installation, or to connect equipment where flexibility is necessary to minimize the transmission of vibration from the equipment.*

▶ Figure 330–15

330.80 | Metal-Clad Cable (Type MC)

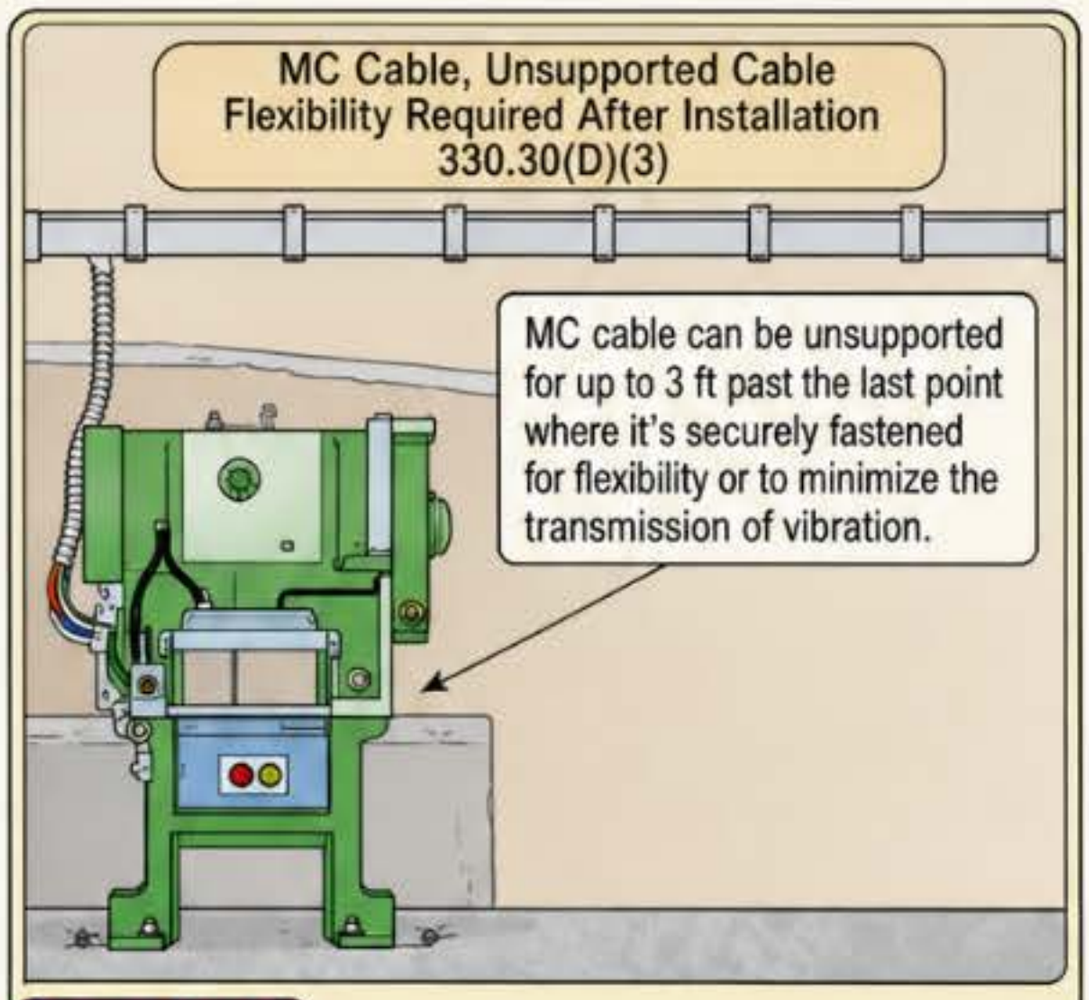


Figure 330–15

▶ Example

Question: *Can a Type MC cable containing four 12 AWG current-carrying conductors be protected by a 20A circuit breaker?*

(a) Yes *(b) No*

Solution:

Step 1: *Determine the ampacity of the circuit conductors in accordance with Table 310.16 and Table 310.15(C)(1).*

12 AWG is rated 30A at 90°C [Table 310.16)

Conductor Adjustment = 80% [Table 310.15(C)(1)]

Conductor Adjusted Ampacity = 30A × 80%

Conductor Adjusted Ampacity = 24A

Step 2: *Verify that the adjusted conductor ampacity can be protected by the 20A circuit breaker. In this case, 12 AWG is rated 24A after adjustment at 90°C and 20A at 60°C [240.4(D)].*

Answer: *(a) Yes*

330.80 Conductor Ampacities

Type MC cable is permitted to have its conductor ampacity adjustment and correction based on 90°C rated conductors in accordance with 310.15, but the conductor selected must be based on the 60°C column of Table 310.16. **Figure 330–16**

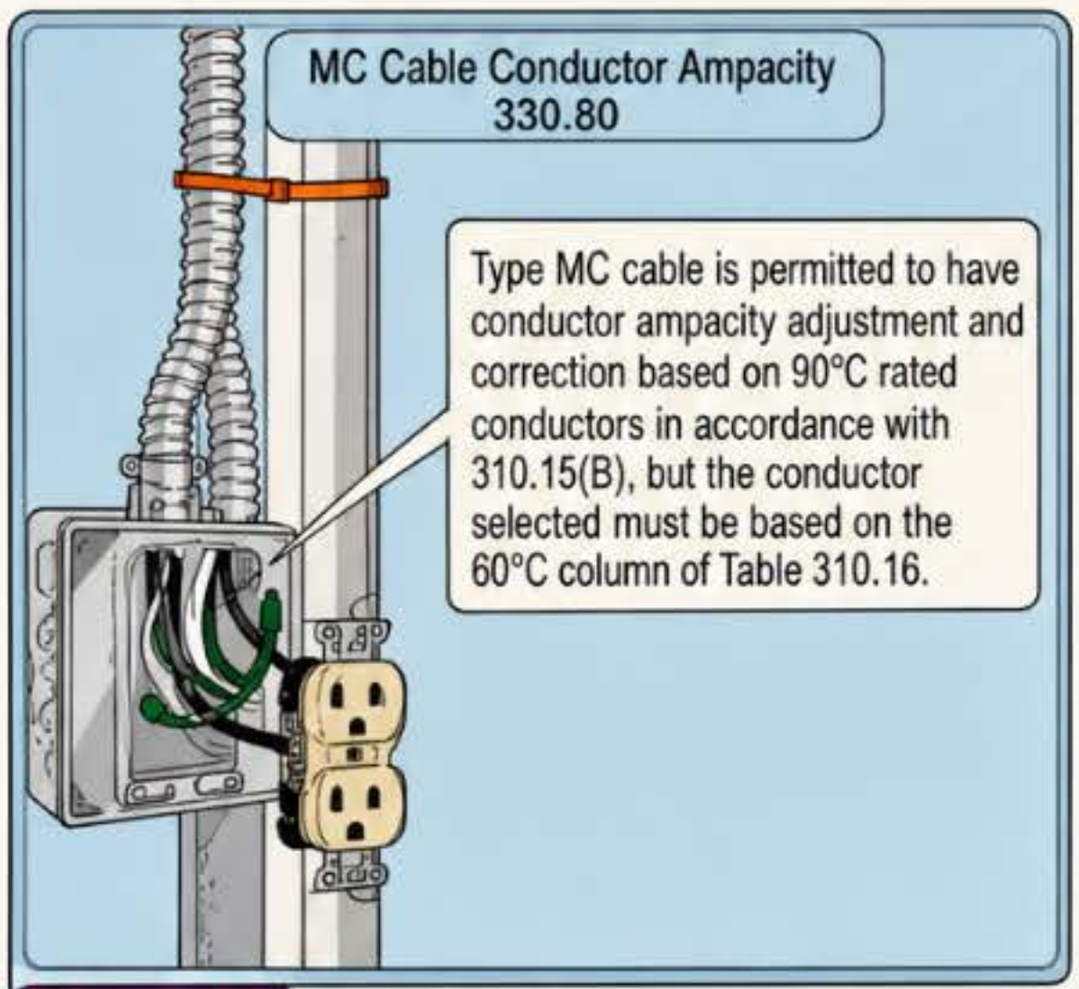


Figure 330–16

(C) Thermal Insulation. Where multiple Type MC cables are installed in contact with thermal insulation or pass through the same wood framing opening that is to be sealed with thermal insulation, caulking, or sealing foam, the ampacity of each conductor must be adjusted in accordance with Table 310.15(C)(1). **Figure 330–17**

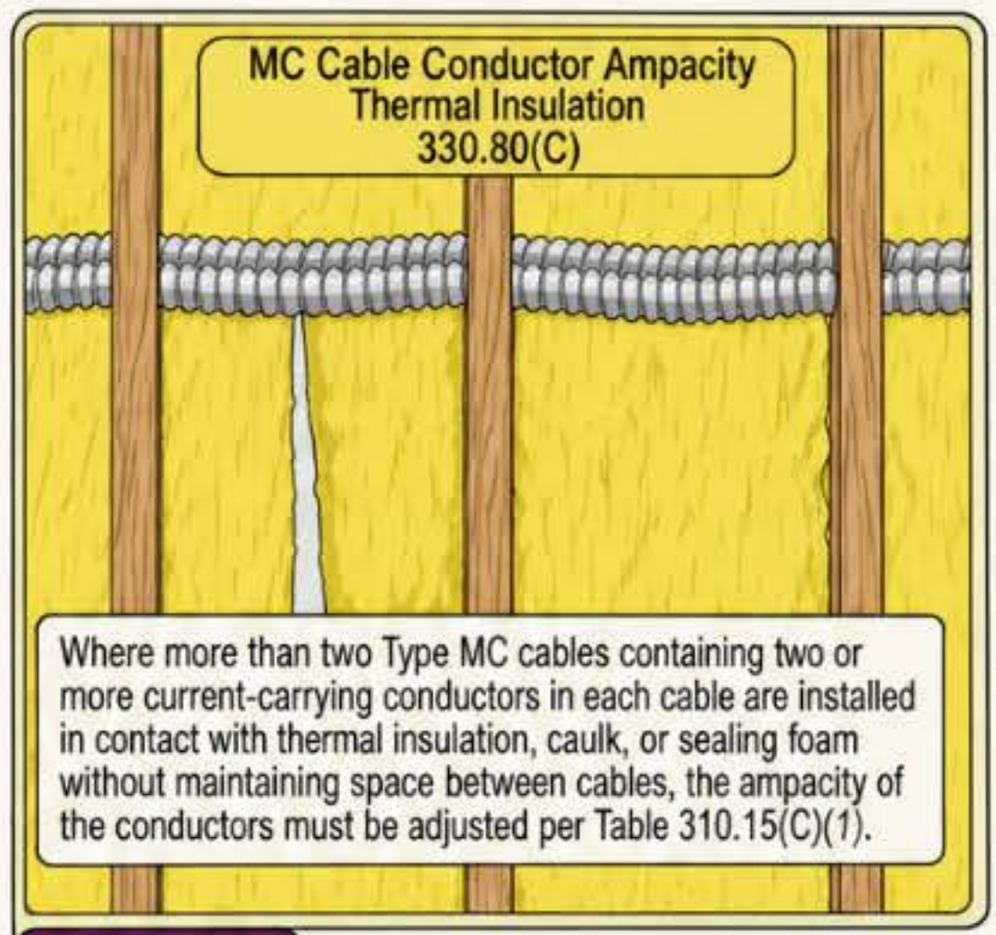


Figure 330–17

Part III. Construction Specifications

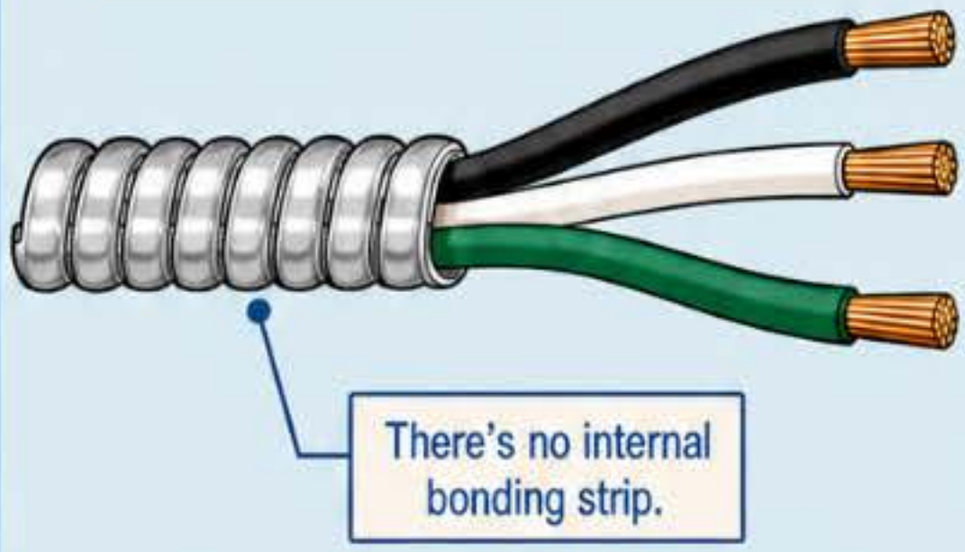
330.108 Equipment Grounding Conductor

When Type MC cable is used as an equipment grounding conductor, the installation must follow the requirements in 250.118(10)(a) and 250.122.

Author's Commentary:

- The outer metallic sheath of:
  - Traditional interlocked Type MC cable is not permitted to serve as an equipment grounding conductor. Therefore, this cable must include an equipment grounding conductor that meets the requirements of 250.118(10)(a) and 250.122(1). ***(See Figure 330–18.)***
  - Interlocked Type MCAP® cable combines the metal sheath with an uninsulated aluminum bonding/grounding conductor, which is recognized and listed as an equipment grounding conductor in accordance with 250.118(10)(b). ***(See Figure 330–19.)***

MC Cable, Sheath Not Listed as an Equipment Grounding Conductor
330.108 Comment



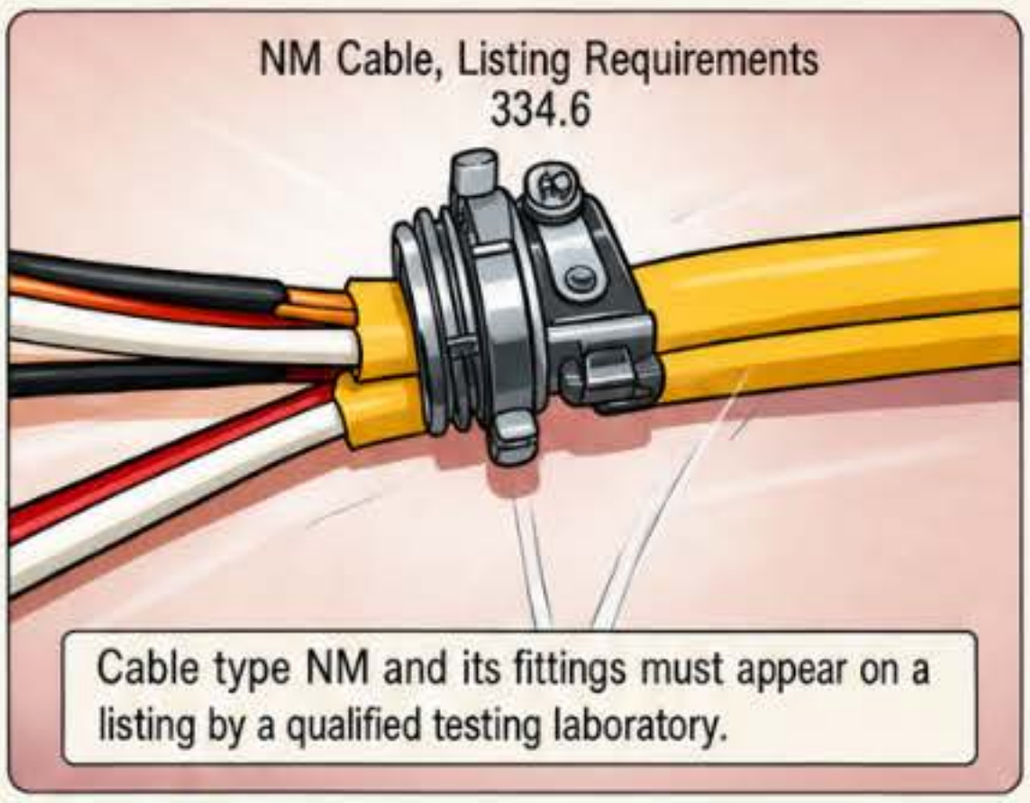
Traditional interlocked MC cable isn't permitted to serve as an equipment grounding conductor; therefore, this cable must contain an equipment grounding conductor per 250.118(10)(a).

Figure 330–18

MC Cable, Sheath Listed as an Equipment Grounding Conductor
330.108 Comment

Interlocked Type MCAP® cable combines the metallic sheath with an uninsulated aluminum grounding/bonding conductor and is listed and identified as an equipment grounding conductor [250.118(10)(b)].

Figure 330–19



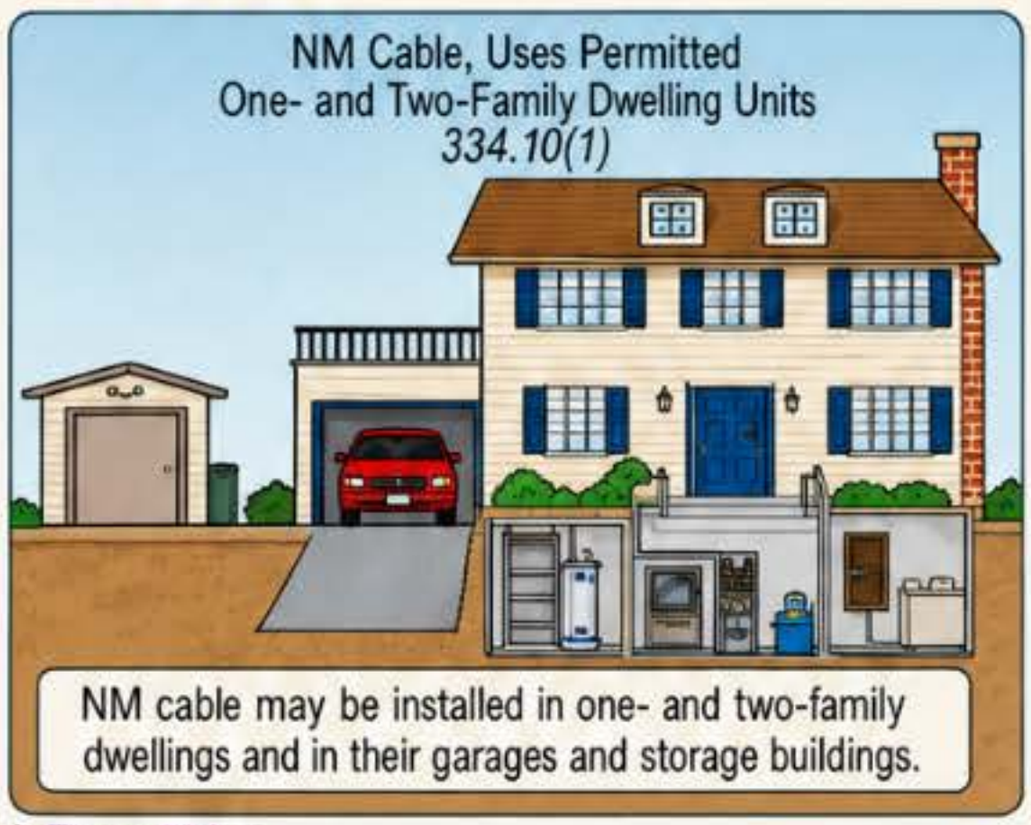
▶ Figure 334–3

Part II. Installation

334.10 Uses Permitted

Type NM cables are allowed for use in the following situations:

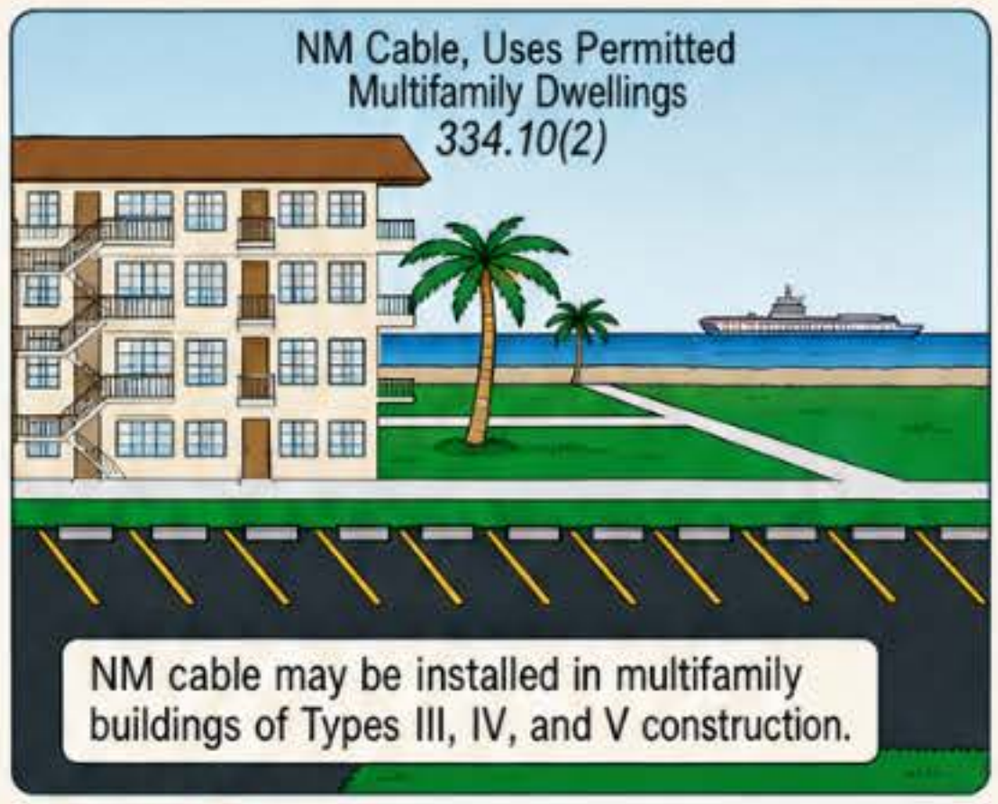
(1) One-family and two-family dwellings along with their attached garages and storage buildings.
▶ Figure 334–4



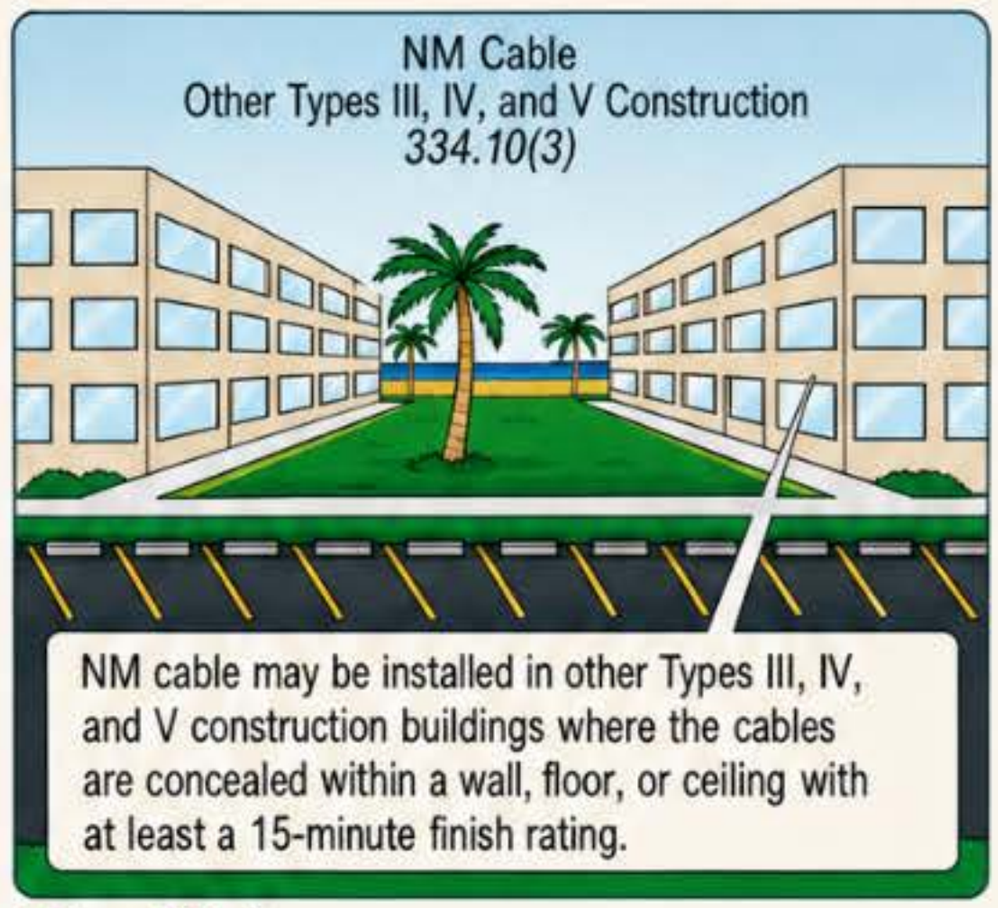
▶ Figure 334–4

(2) Multifamily dwellings of Types III, IV, and V construction. ▶ Figure 334–5

(3) Other Types III, IV, and V construction buildings where the cable is concealed within walls, floors, or ceilings that provide a thermal barrier of material with at least a 15-minute fire-resistance rating as identified in fire-rated assemblies.
▶ *Figure 334–6*



▶ Figure 334–5



▶ Figure 334–6

Author's Commentary:
Refer to the definition of "Concealed" in Article 100.
— *Michael Hamilton*

Note 1: Construction types are defined in NFPA 220, *Standard on Types of Building Construction.*

Note 2: See Annex E of the *NEC* for determining building types *[NFPA 220, Table 3-1].*

334.12 Uses Not Permitted

(A) Type NM. Type NM cable is not permitted:

(1) In any dwelling or structure not specifically allowed by 334.10(1), (2), (3), and (5).

ARTICLE 334

NONMETALLIC-SHEATHED CABLE (TYPE NM)

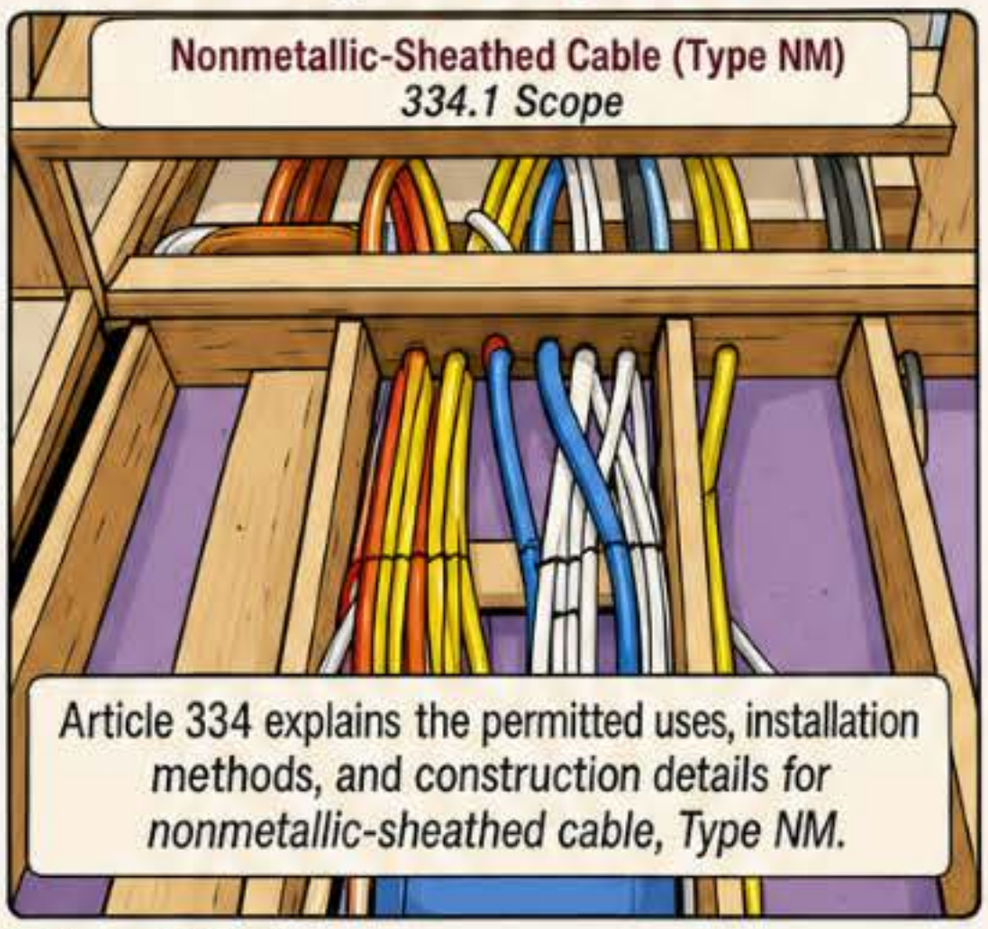
Introduction to Article 334—Nonmetallic-Sheathed Cable (Type NM)

Nonmetallic-sheathed cable (Type NM) supplies only limited physical protection for the conductors inside, so the installation rules are more strict. Because its cost is low and installation is straightforward, this cable is widely used for both home wiring and many commercial branch-circuit applications.

Part I. General

334.1 Scope

Article 334 explains the permitted uses, installation methods, and construction details for nonmetallic-sheathed cable, Type NM. ▶ Figure 334–1

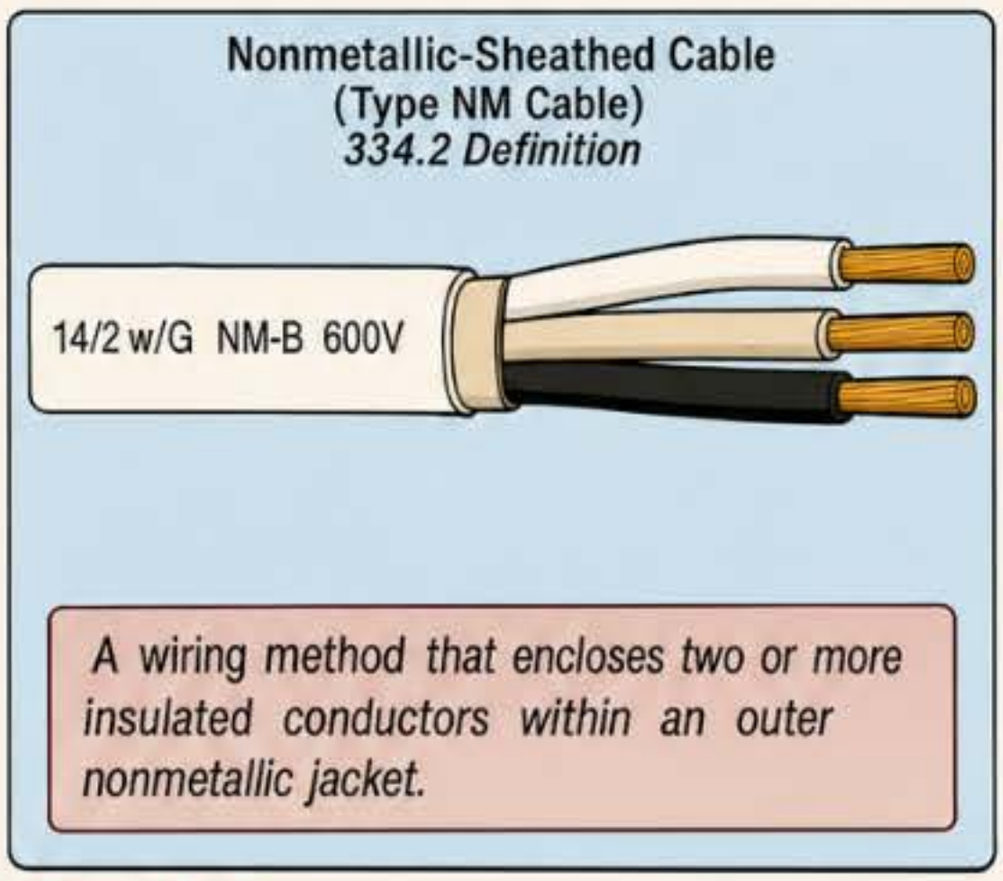


▶ Figure 334–1

334.2 Definition

Nonmetallic-sheathed cable (Type NM) is a wiring method in which two or more insulated conductors are together inside a nonmetallic jacket.

▶ Figure 334–2



▶ Figure 334–2

Author's Commentary:

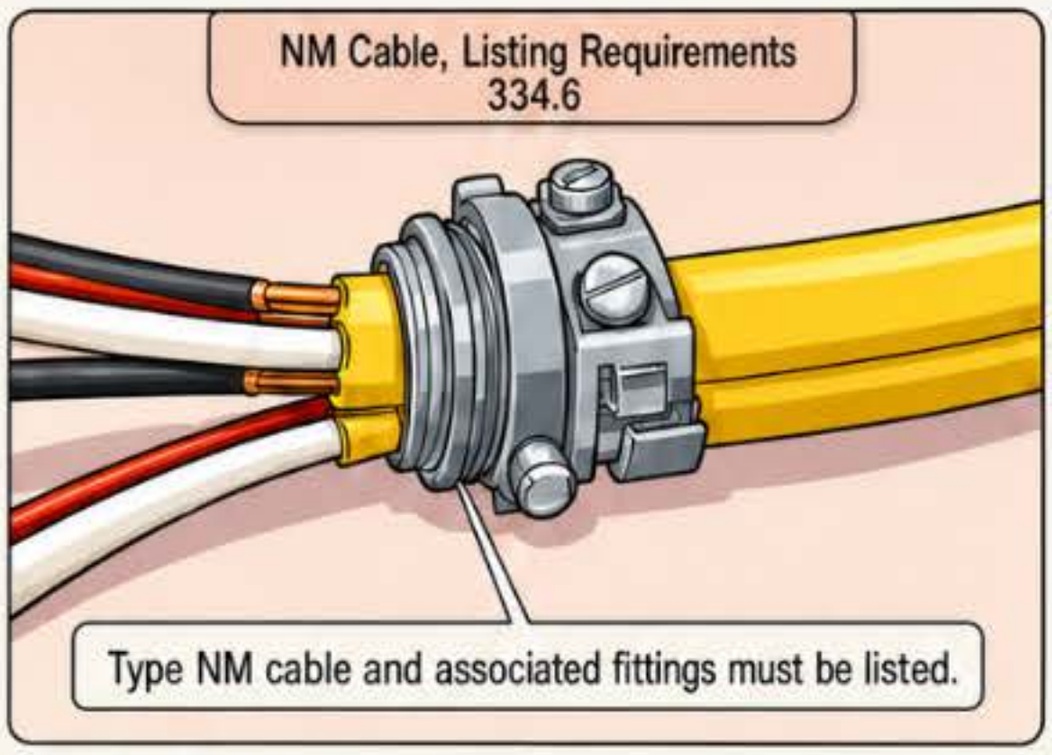
▶ *This is the generally accepted practice in the electrical industry to call Type NM cable "Romex®," a registered trademark of the Southwire Company.*

— Michael Hamilton

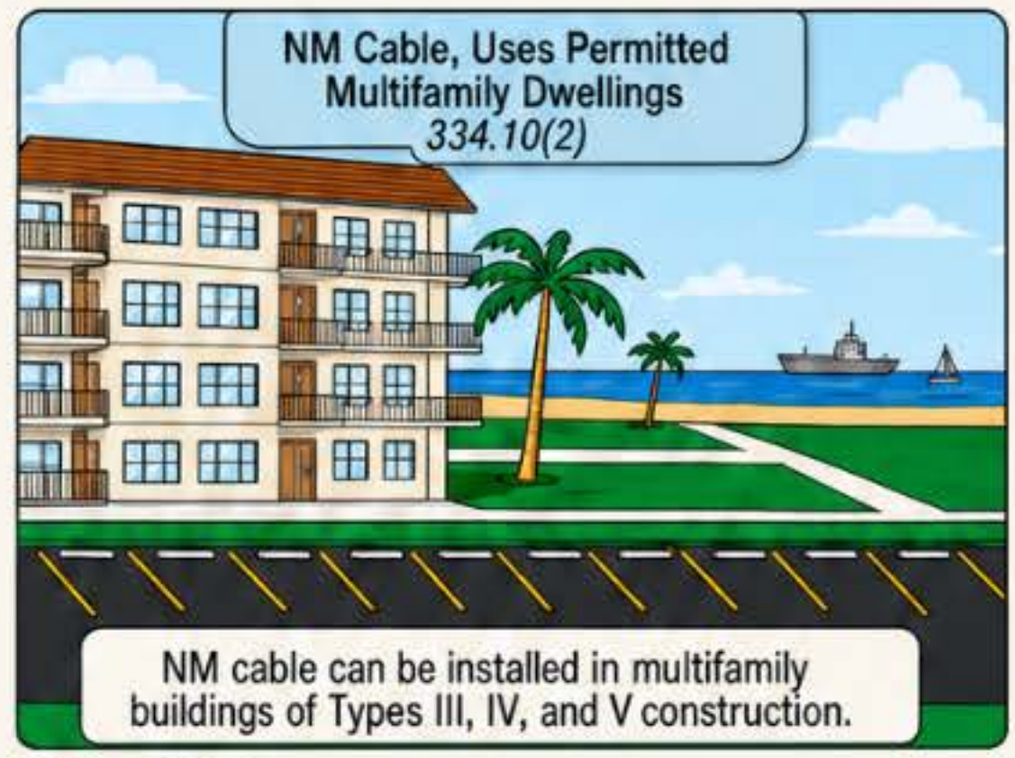
334.6 Listing Requirements

Type NM cable and the fittings used with it must be listed. ▶ Figure 334–3

334.10 | Nonmetallic-Sheathed Cable (Type NM)



▶ Figure 334–3



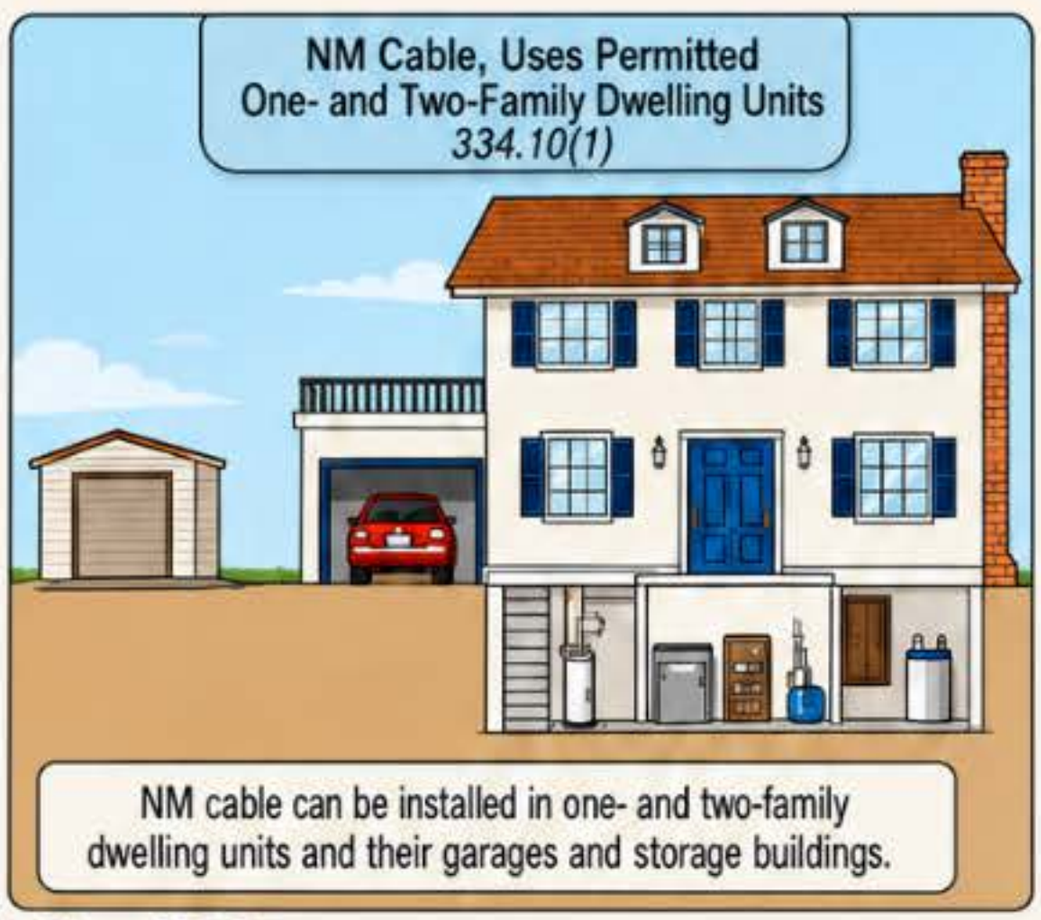
▶ Figure 334–5

Part II. Installation

334.10 Uses Permitted

Type NM cables can be used in:

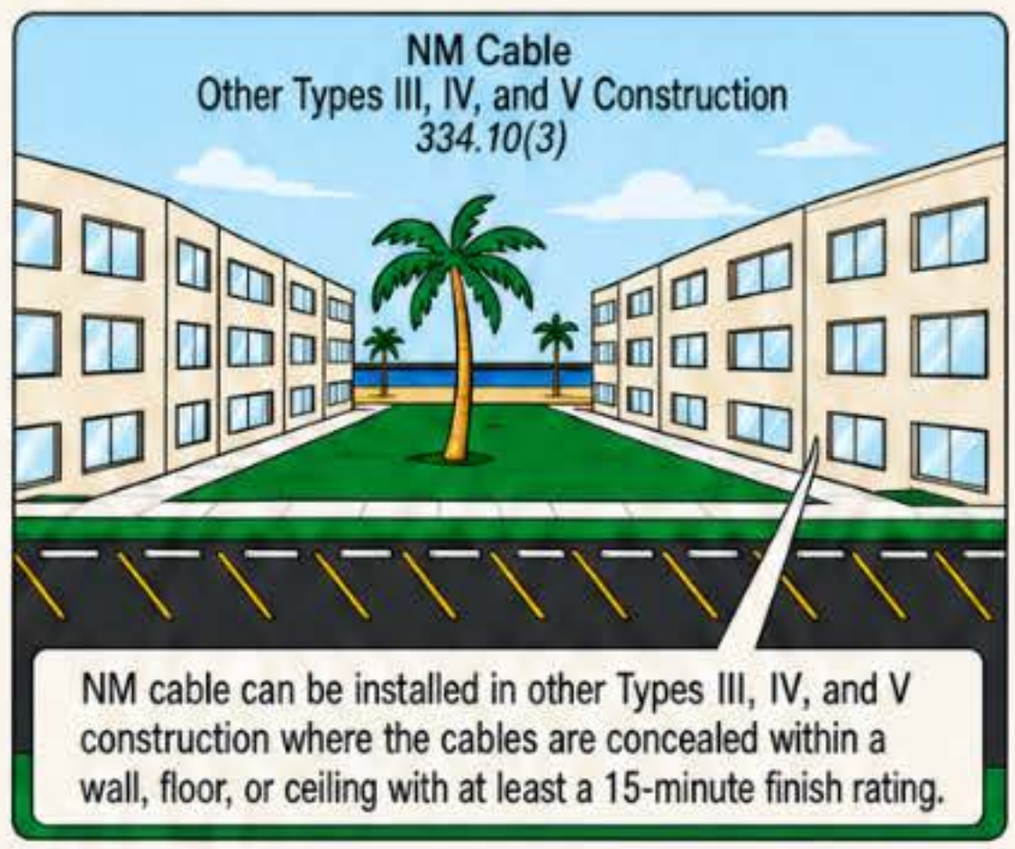
(1) One-family and two-family dwellings and their garages and storage buildings. ▼ Figure 334–4



▶ Figure 334–4

(2) Multifamily dwellings of Types III, IV, and V construction. ▼ Figure 334–5

(3) Other Types III, IV, and V construction buildings where the cable must be concealed within walls, floors, or ceilings that provide a thermal barrier of material with at least a 15-minute finish rating, as identified in listings of fire-rated assemblies. ▼ Figure 334–6



▶ Figure 334–6

Author's Commentary:

See the definition of "Concealed" in Article 100.

— *Michael Hamilton*

Note 1: Building constructions are defined in NFPA 220, *Standard on Types of Building Construction.*

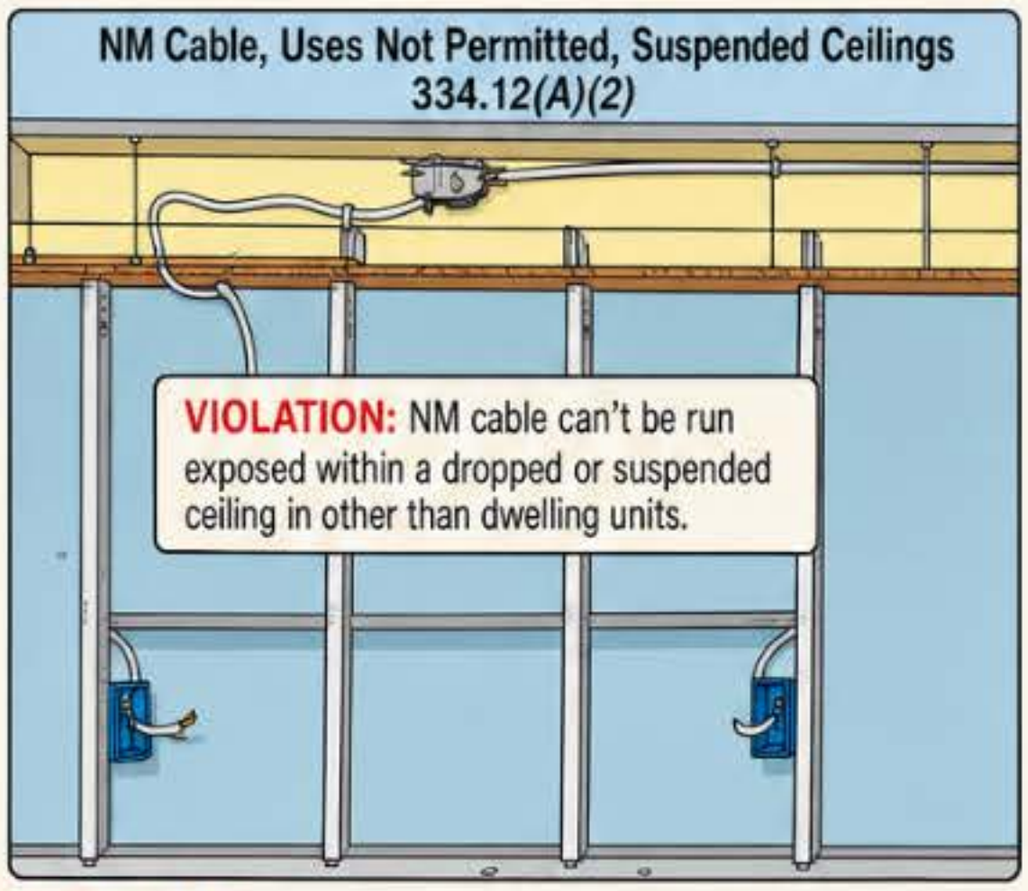
Note 2: See Annex E of the *NEC* for the determination of building types [NFPA 220, Table 3-1].

334.12 Uses Not Permitted

(A) Type NM. Type NM cable is not permitted:

(1) In any dwelling or structure not specifically permitted in 334.10(1), (2), (3), and (5).

(2) Located inside a dropped or suspended ceiling in any space other than dwelling units. ▶Figure 334-7



▶Figure 334-7

(3) Used as service-entrance cable.

(4) In commercial garages that contain hazardous (classified) locations, as defined in 511.3.

(5) In theaters and similar venues, except where allowed in 518.4(B).

(6) Within motion picture studios.

(7) Inside storage battery rooms.

(8) In hallways, on elevators, or on escalators.

(9) Embedded in poured concrete, concrete, or aggregate.

(10) In any hazardous (classified) location, except where permitted by other sections in this *Code*.

(B) Type NM. Type NM cable is not permitted to be used under the following conditions, or in the following locations:

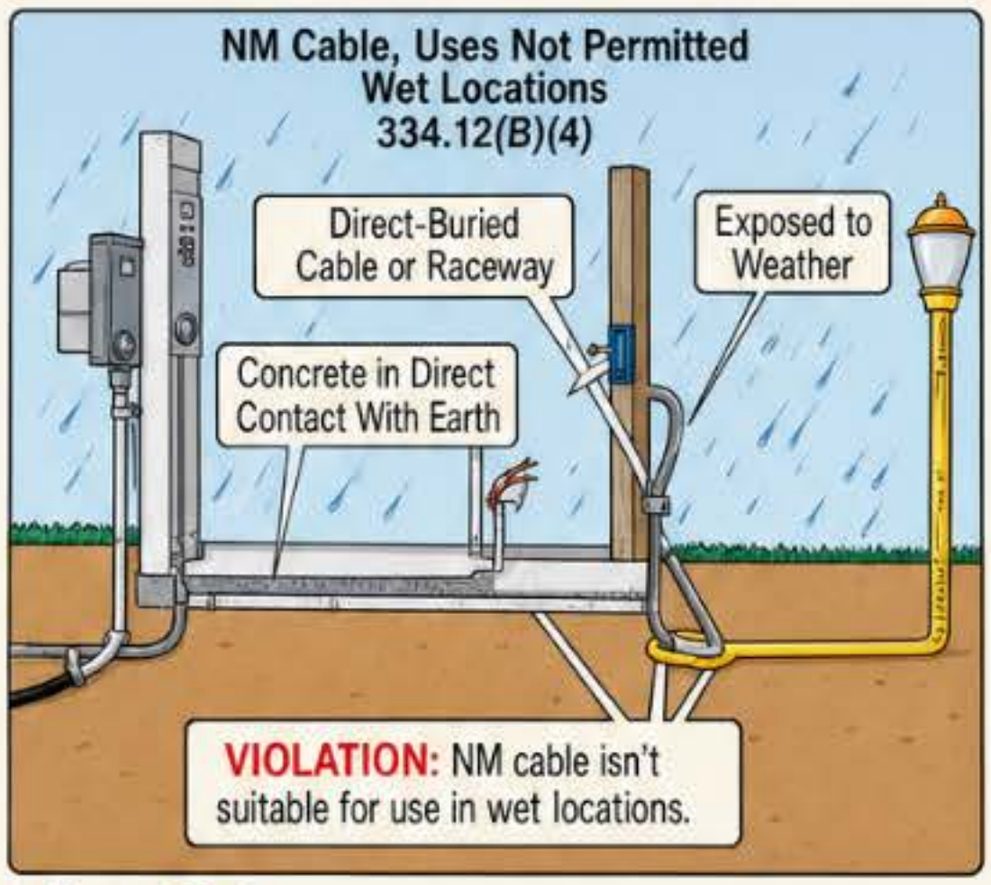
(1) Where it may come in contact with corrosive fumes or vapors.

(2) When embedded in masonry, concrete, adobe, fill, or plaster.

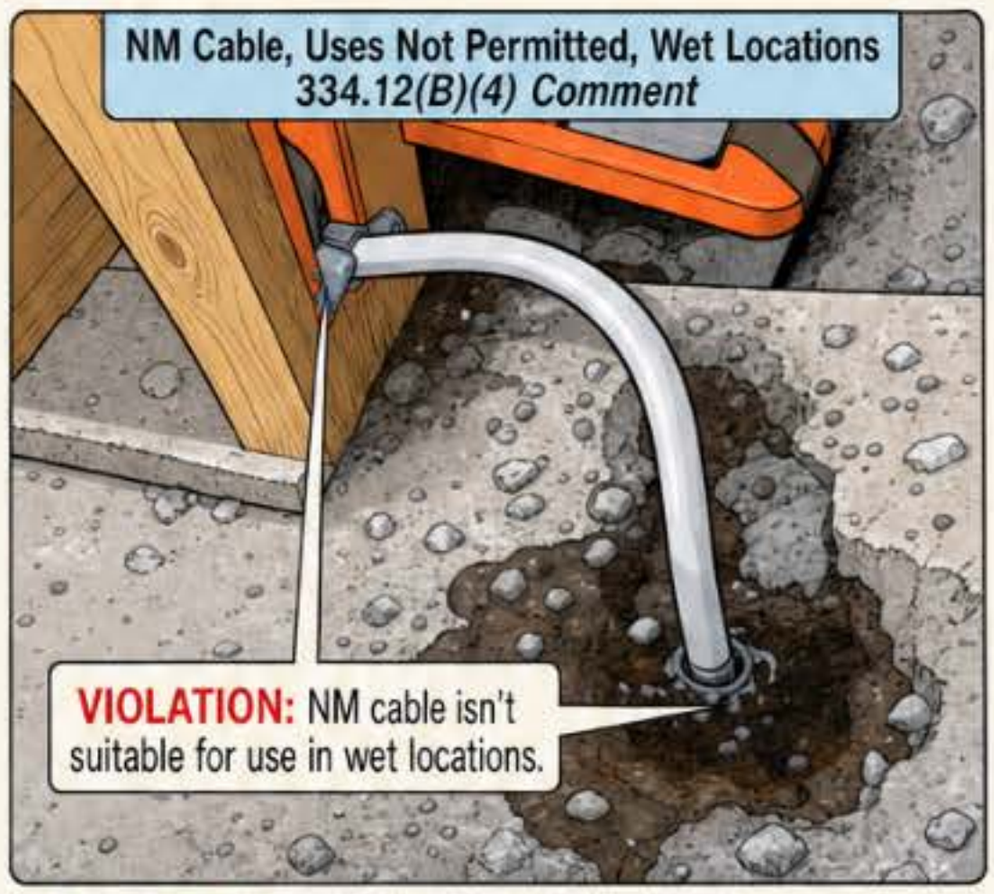
(3) When run in a shallow chase in masonry, concrete, or adobe and covered with plaster, adobe, or material of similar finish.

(4) In wet or damp locations. ▶Figure 334-8

Author's Commentary:
A raceway installed in a ground floor slab is considered a wet location [Article 100]. ▶Figure 334-9
— Michael Hamilton



▶Figure 334-8



▶Figure 334-9

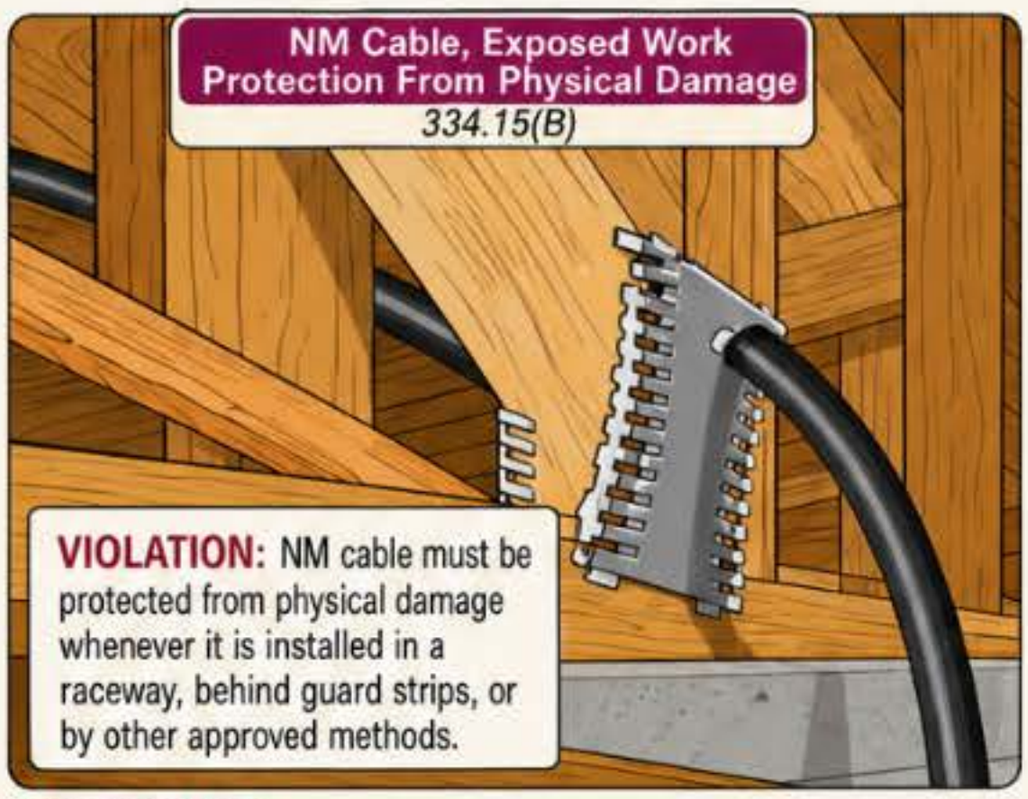
334.15 Exposed Work

Except as provided in 300.11(B), exposed Type NM cable can be installed as follows:

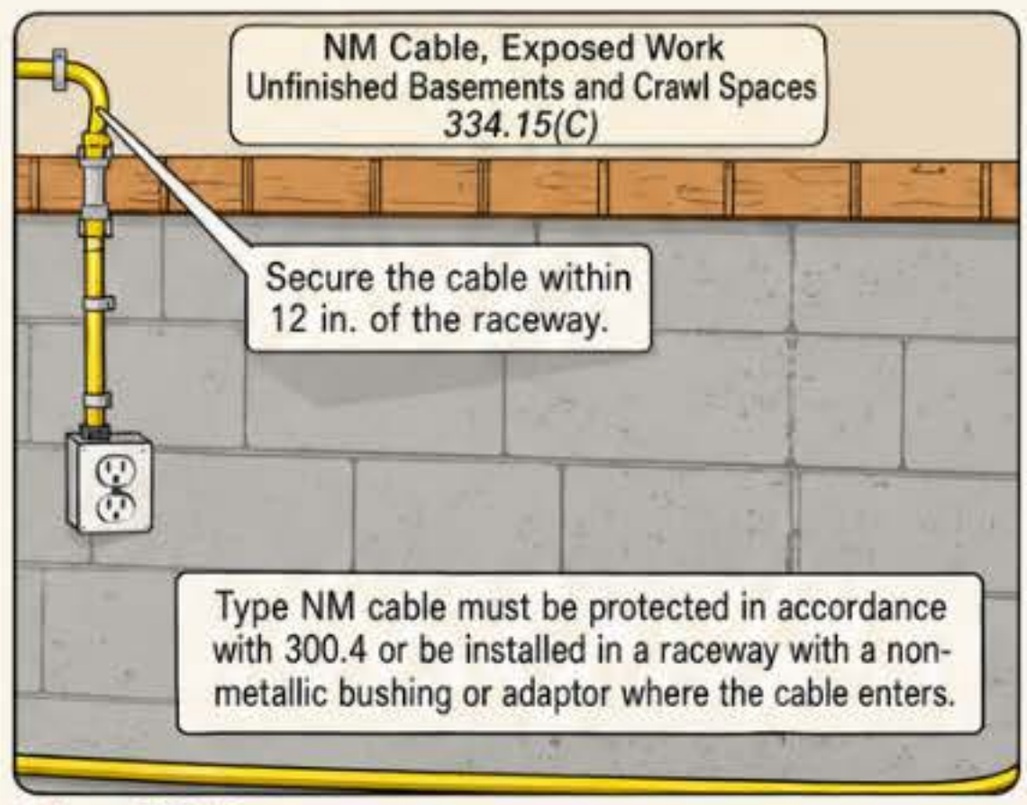
(A) Surface of the Building. Exposed NM cable must closely follow the surface of the building.

(B) Protected from Physical Damage. Nonmetallic-sheathed cable must be shielded from physical harm by a raceway, guard strips, or other methods approved by the authority having jurisdiction. ▶Figure 334-10

334.17 | Nonmetallic-Sheathed Cable (Type NM)

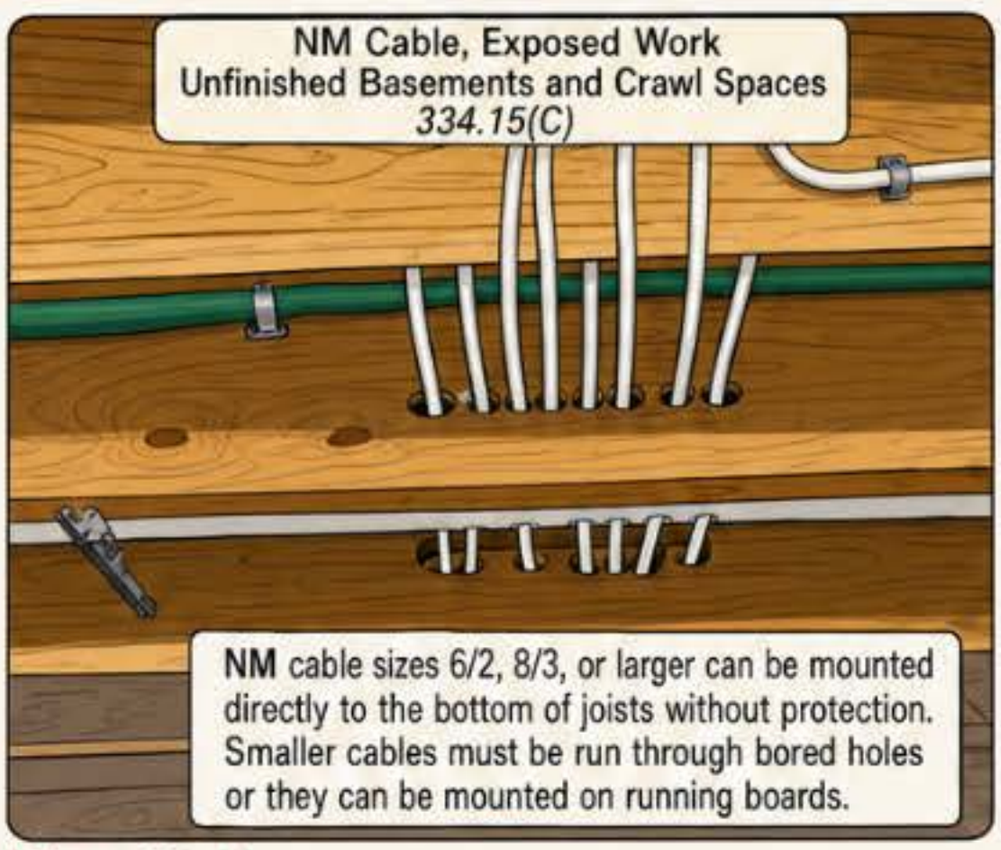


▶Figure 334–10



▶Figure 334–12

(C) In Unfinished Basements and Crawl Spaces. If Type NM cable is installed at angles with joists in unfinished basements and crawl spaces, it can be secured to cables containing conductors not smaller than two 6 AWG or three 8 AWG conductors directly to the lower edges of the joists. Smaller cables must be installed through bored holes in joists or on running boards. ▶Figure 334–11

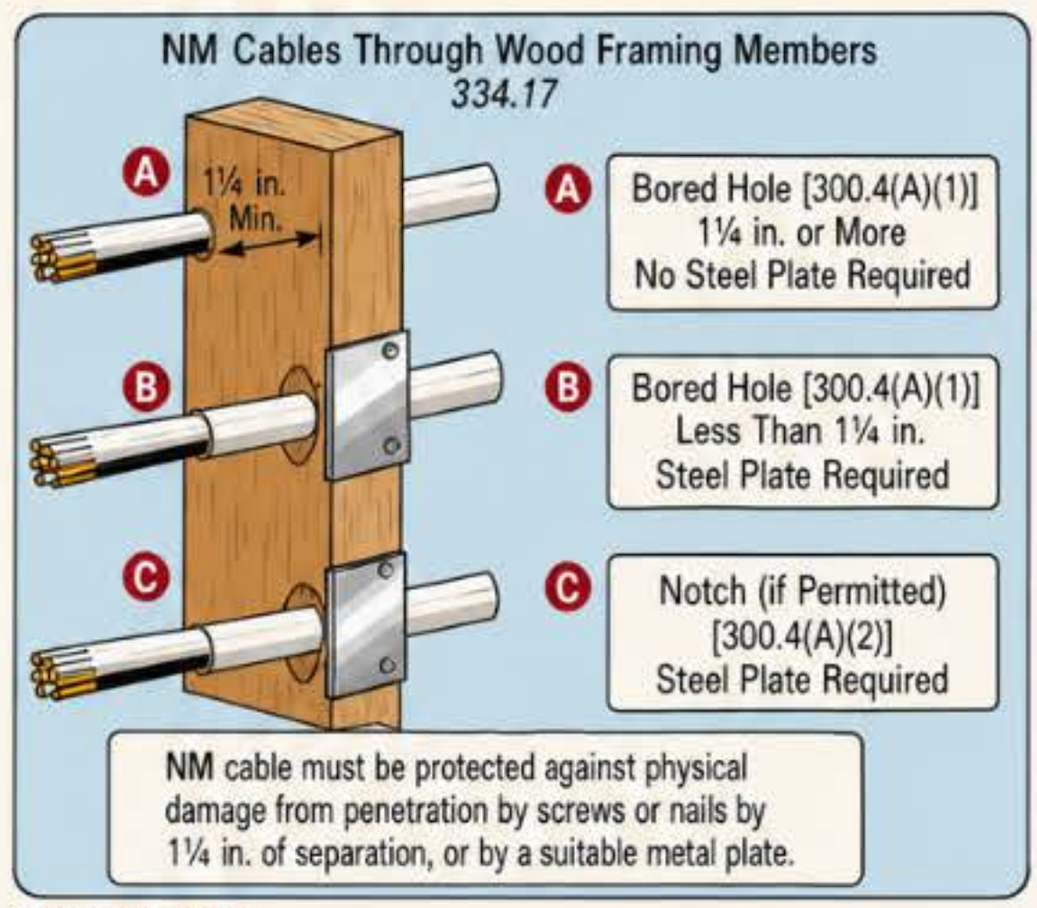


▶Figure 334–11

Type NM cable installed on a wall of an unfinished basement or crawl space subject to physical damage must be protected in accordance with 300.4 or be installed within a raceway with a nonmetallic bushing or adapter at the point where the cable enters the raceway. The cable must be secured within 12 in. of the point where it enters the raceway. ▶Figure 334–12

334.17 Through or Parallel to Framing Members

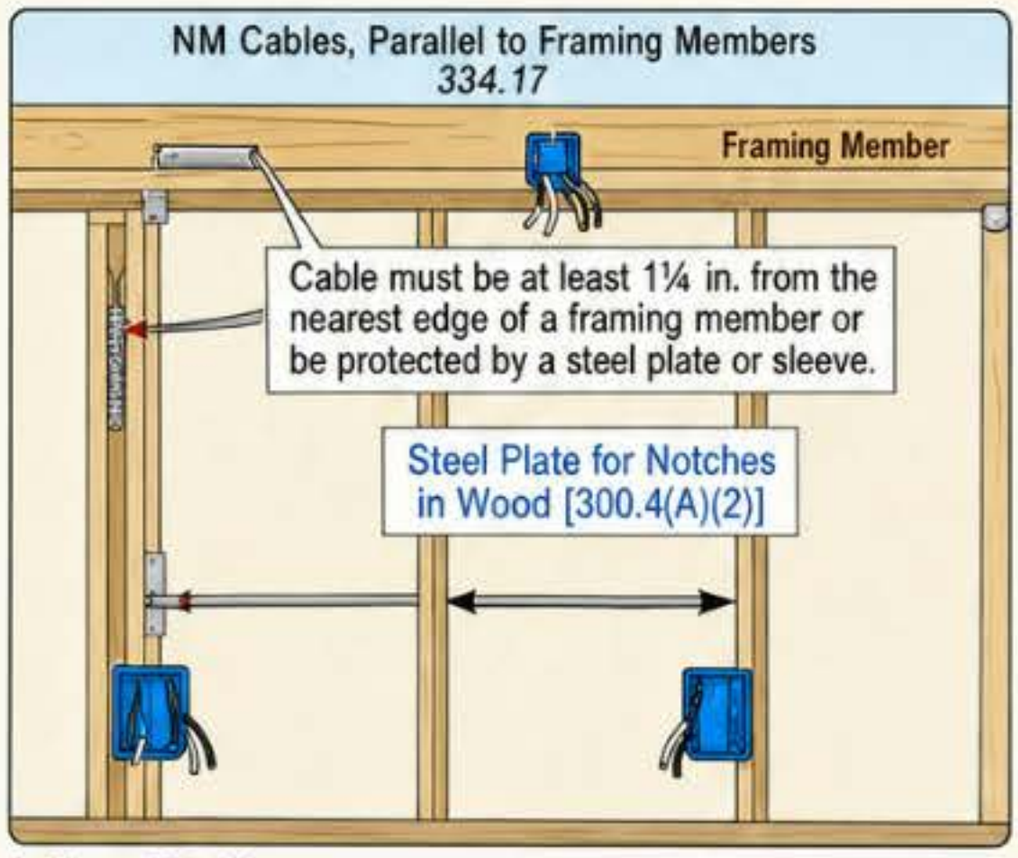
Type NM cable installed through, or parallel to, framing members or furring strips must be protected against physical damage from penetration by screws or nails by maintaining 1¼ in. of separation between the cable and the framing member or furring strip, or by a suitable metal plate in accordance with 300.4(A), (C), and (D). ▶Figure 334–13 and Figure 334–14



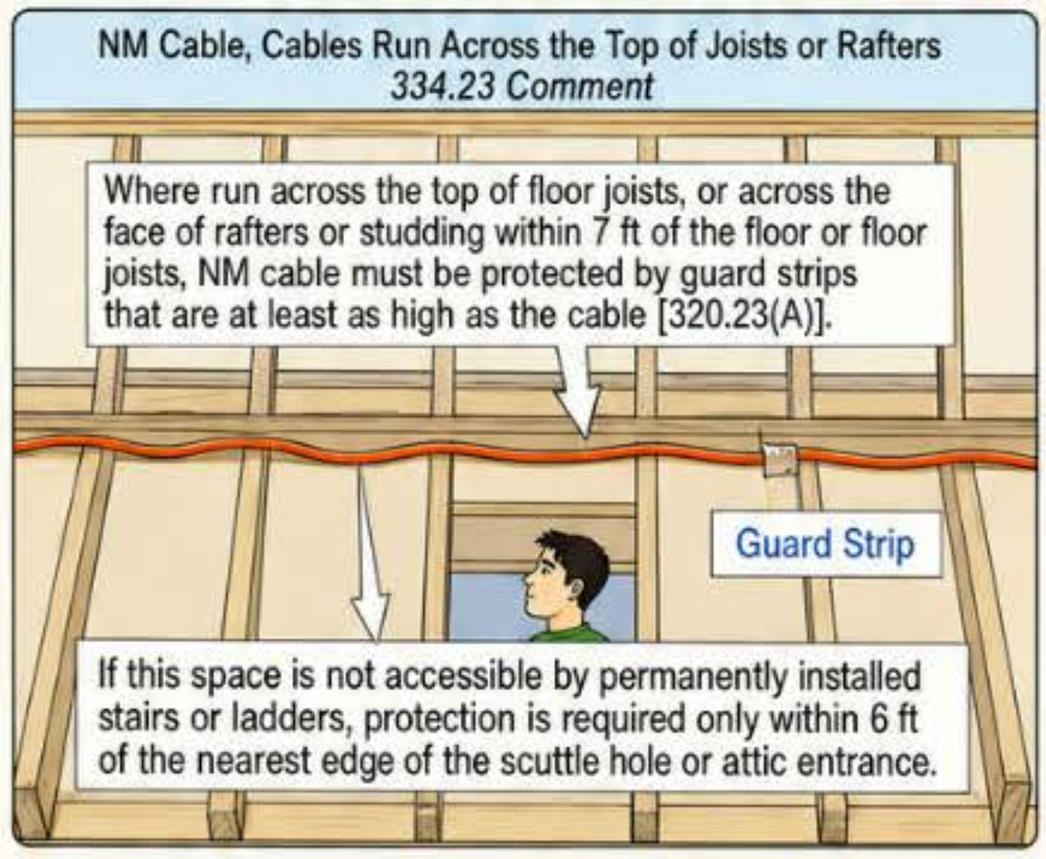
▶Figure 334–13

If Type NM cable passes through factory or field openings in metal framing members, the cable must be protected by listed bushings or grommets that cover all metal edges [300.4(B)(1)]. The protection fitting must be securely fastened in the opening before installing the cable. ▶Figure 334–15

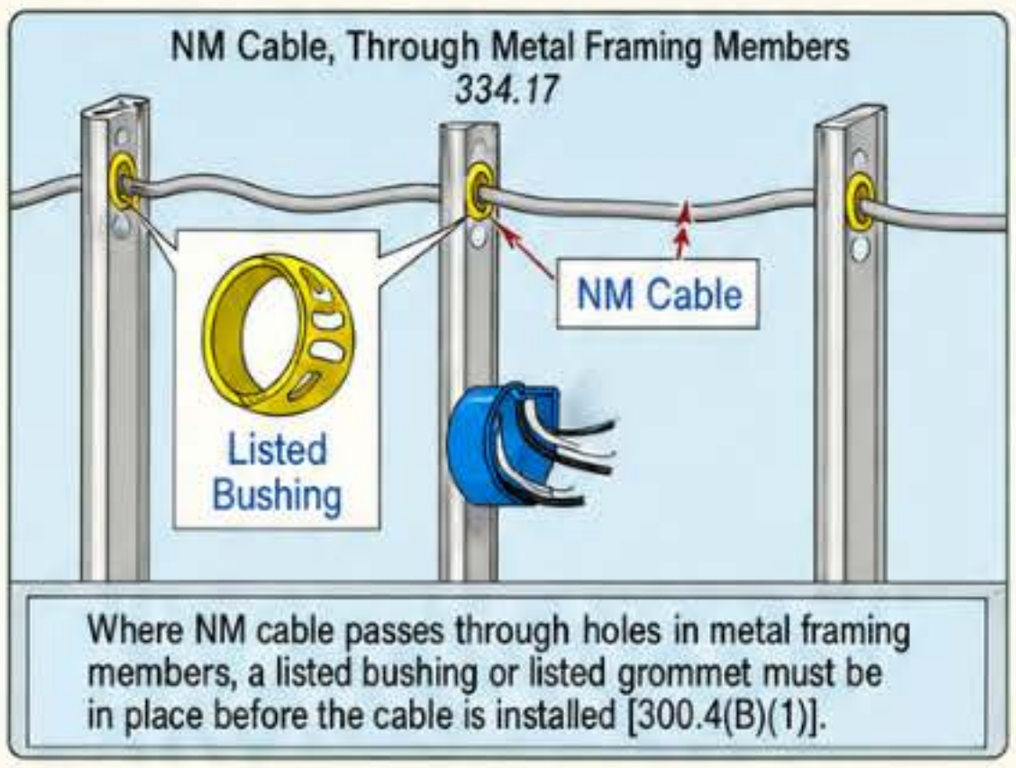
DEFINITIONS | From Michael Hamilton Publications



▶ Figure 334–14



▶ Figure 334–16



▶ Figure 334–15

334.23 Accessible Attics and Roof Spaces

Type NM cable installed in accessible attics or roof spaces must comply with 320.23.

Author's Commentary:

▶ **On the Surface of Floor Joists, Rafters, or Studs.** In attics and roof spaces that are accessible, substantial guards must protect cables installed across the top of floor joists, or across the face of rafters or studding within 7 ft of the floor or floor joists. If this space is not accessible by permanent stairs or ladders, protection is required only within 6 ft of the nearest edge of the scuttle hole or attic entrance [320.23(A)].

— Michael Hamilton

▶ Figure 334–16

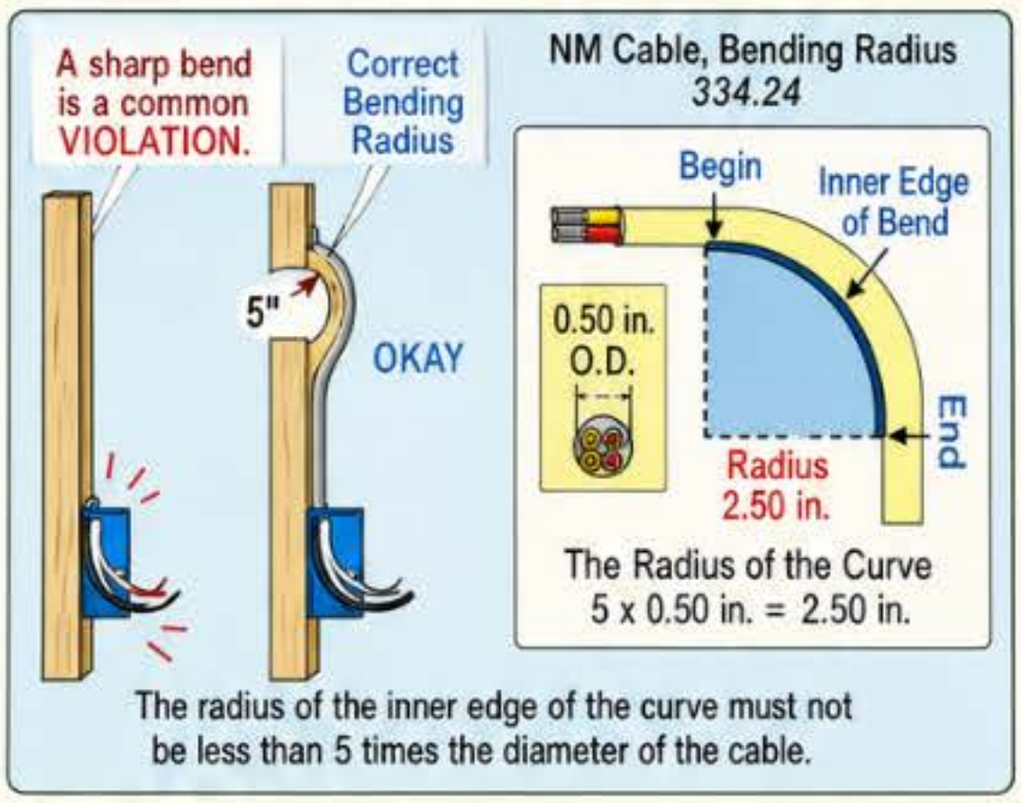
Author's Commentary:

▶ **Along the Side of Framing Members** [320.23(B)]. When Type NM cable is installed on the side of rafters, studs, or floor joists, no protection is required if the cable is installed so the nearest outside surface of the cable or raceway is at least 1¼ in. from the nearest edge of the framing member if nails or screws are likely to penetrate [300.4(D)].

— Michael Hamilton

334.24 Bending Radius

When Type NM cable is bent, it is not permitted to be damaged and the radius of the curve of the inner edge of any bend must not be less than five times the diameter of the cable. ▶ Figure 334–17

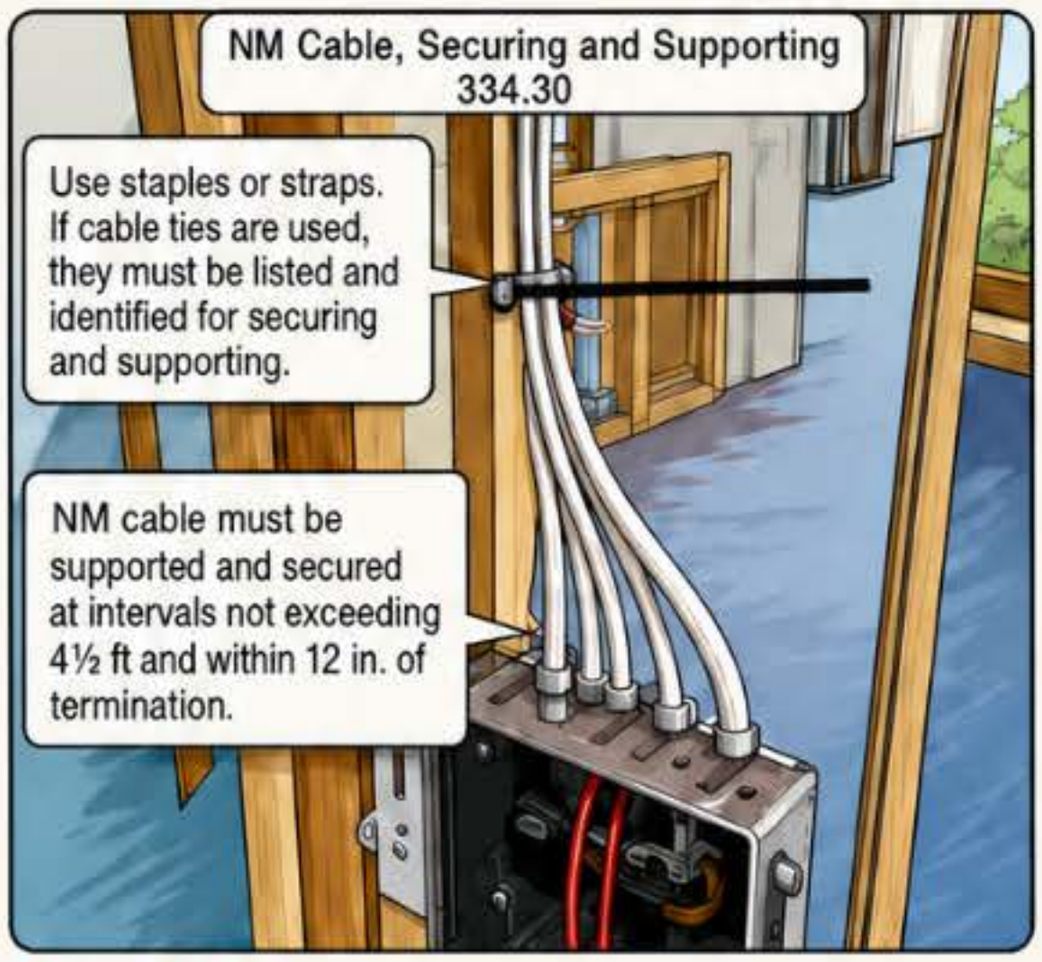


▶ Figure 334–17

334.30 Securing and Supporting

Type NM cable has to be held and fastened with staples or straps. The cable types that require support are listed and identified for proper securing. Hangers or similar fittings are only allowed when they do not exceed 4½ ft in length and are located within 12 in. of the termination.

• Figure 334–18



▸ Figure 334–18

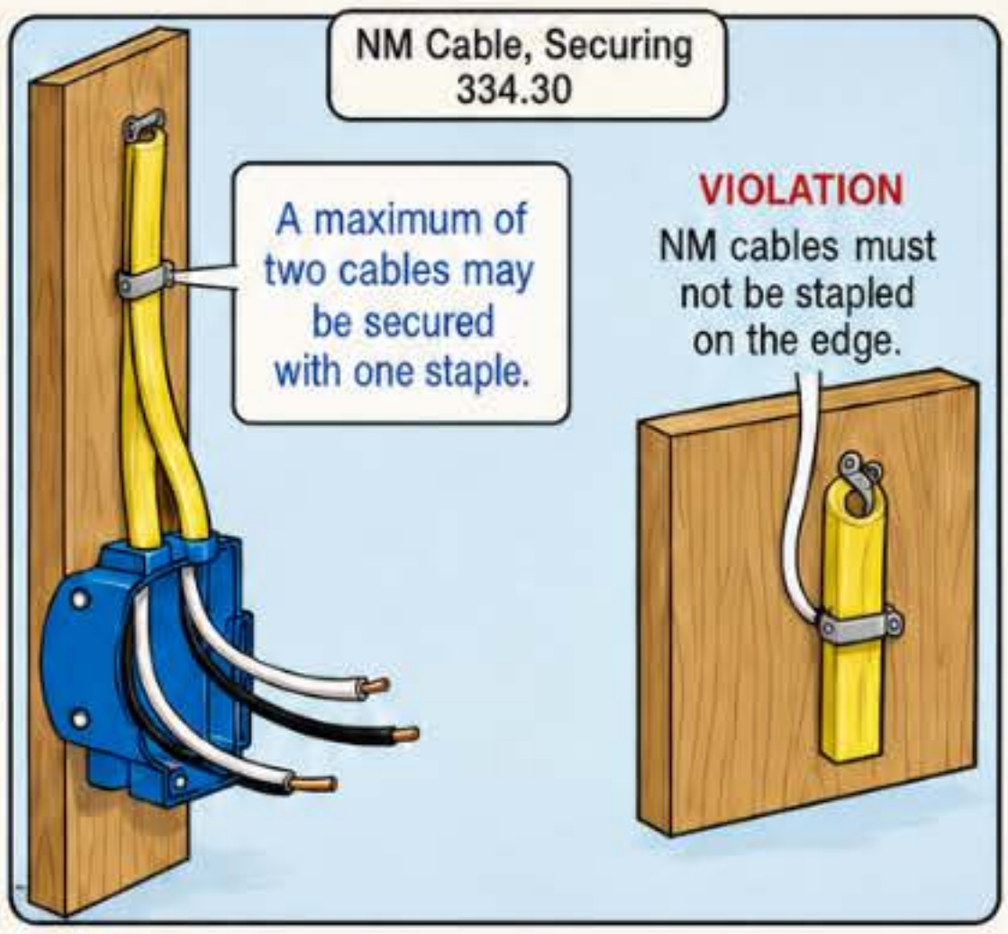
The cable length between the cable entry into cabinets and enclosures, and the closest cable support, must not exceed 18 in.

> ***Author's Commentary:***
>
> It is common practice to leave a short length of NM cable inside a box or enclosure—such as a panelboard—so the installer has "extra" cable if needed. While helpful, this extra length cannot be more than *18 in.* when measured in a straight *line*.
>
> *— Michael Hamilton*

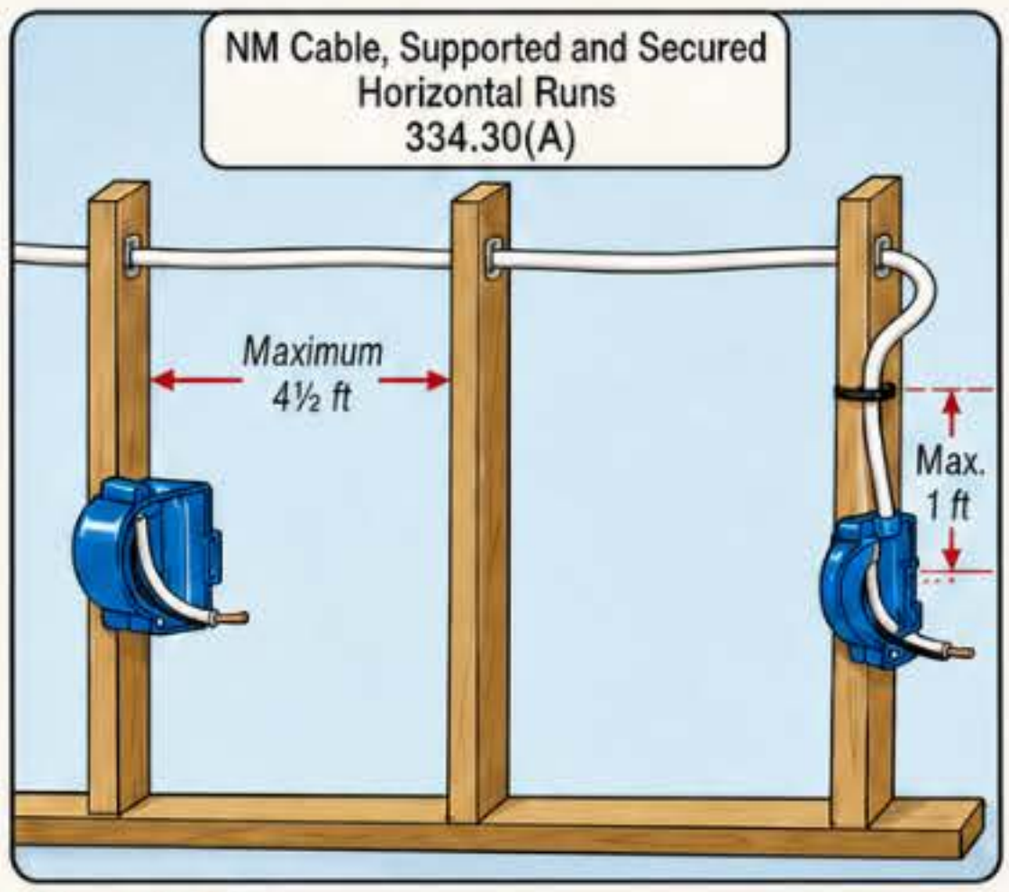
(A) Horizontal Runs. When NM cable is installed horizontally on framing members with drilled or punched holes in wood or metal, or in notches in framing, the maximum unsupported span between supports is 4½ ft. The cable also must be secured within 1 ft of termination. • Figure 334–20

(B) Unsuppported. Type NM cable can be left unsupported only in the following cases:

(1) Where the cable is fished between finished building surfaces and securing it is not practical.



▸ Figure 334–19



▸ Figure 334–20

(2) The unsupported length of NM cable at the end of supports within an accessible ceiling for luminaires or equipment in dwelling units must not be more than 4½ ft.

• Figure 334–21

334.40 Boxes and Fittings

(B) NM Cable Interconnector Devices. A box is not required where devices listed for use with sheathed cable that interconnect exposed wiring, or for repair wiring in an existing structure, are installed in accordance with 300.15(H).

▸ Figure 334–22

DEFINITIONS | From Michael Hamilton Publications

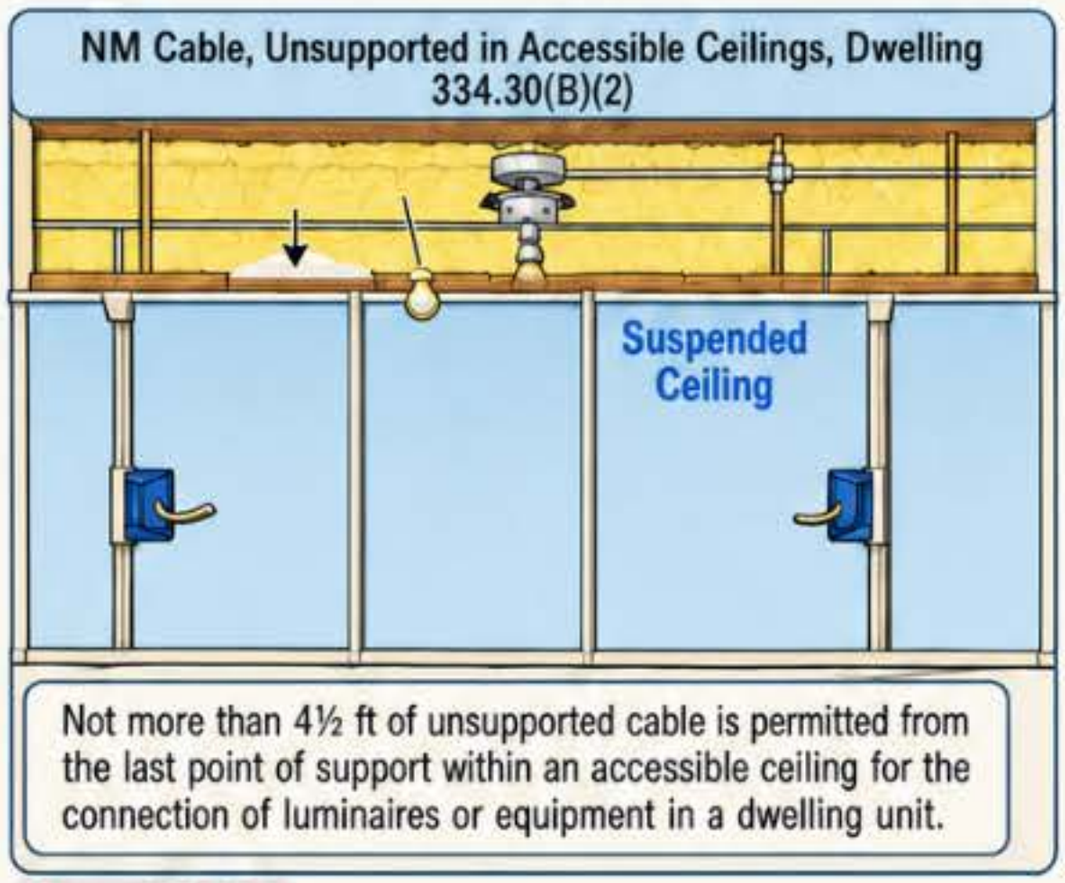


Figure 334–21

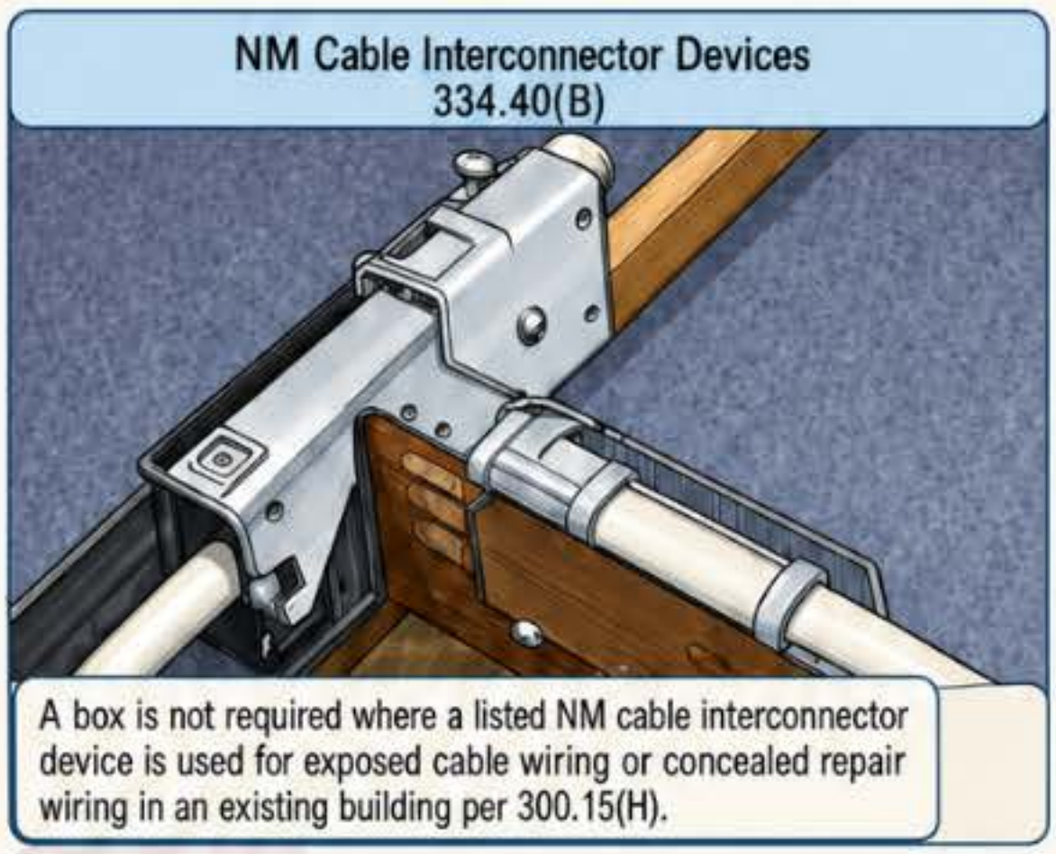


Figure 334–22

Author's Commentary:

Research shows that interconnector devices have been evaluated and tested for equivalency to Type NM cable regarding insulation performance, temperature rise, and the ability to withstand fault currents and mechanical vibration.

— Michael Hamilton

334.80 Conductor Ampacity

The allowable ampacity for Type NM cable is adjusted or corrected based on the 90°C insulation rating in Table 310.16. Regardless, conductor sizing must still follow the 60°C terminal temperature ratings of Table 310.16.

▶ Example

Question: *What size conductor and overcurrent device are required for a 9,600W, 240V fixed electric space heater that has a 3A, 240V blower motor?* **Figure 334–23**

(a) 10 AWG/30A *(b) 8 AWG/40A*
(c) 6 AWG/50A *(d) 6 AWG/60A*

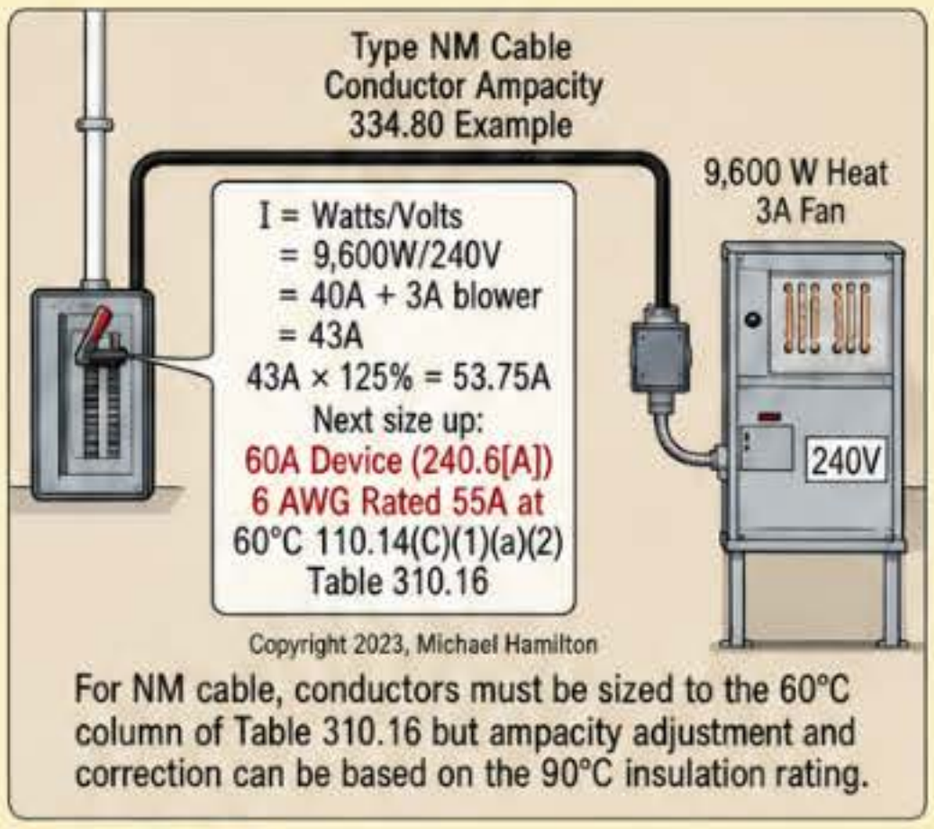


Figure 334–23

Solution:

Step 1: *Determine the total load.*

I = Watts/Volts
I = 9,600W/240V
I = 40A

Total Amperes = 40A (heat) + 3A (blower)
Total Amperes = 43A

Step 2: *Size the conductors at 125 percent of the total current load (110.14(C)(1), 210.19(A)(1), 424.3(B), and Table 310.16).*

Conductor = 43A × 125%
Conductor = 53.75A; round to 54A
Conductor = 6 AWG rated 55A at 60°C

Step 3: *Size the overcurrent device at 125 percent of the total current load [210.20(A), 240.6(A), and 240.6(A)].*

Overcurrent protection = 43A × 125%
Overcurrent protection = 53.75A, use next size up: 60A [240.6(A)]

Use a 6 AWG conductor with 60A overcurrent device.

Answer: *(d) 6 AWG/60A*

If more than one Type NM cable goes through the same wood framing opening that must be sealed with thermal insulation, caulk, or a sealing foam, the adjusted fill amount for the ampacity of each current-carrying conductor must conform to Table 310.15(C)(1).

▶ Example

Question: *Can four Type NM cables, each containing two 14 AWG current-carrying conductors, be protected by a 15A circuit breaker?*

(a) Yes (b) No

Solution:

Step 1: *Determine the adjusted ampacity of the circuit conductors in accordance with Table 310.15(C)(1) and Table 310.16.*

14 AWG is rated 20A at 90°C [Table 310.16].

Conductor Adjustment = 70% [Table 310.15(C)(1)]

Conductor Adjusted Ampacity = 20A x 70%

Conductor Adjusted Ampacity = 14.00A

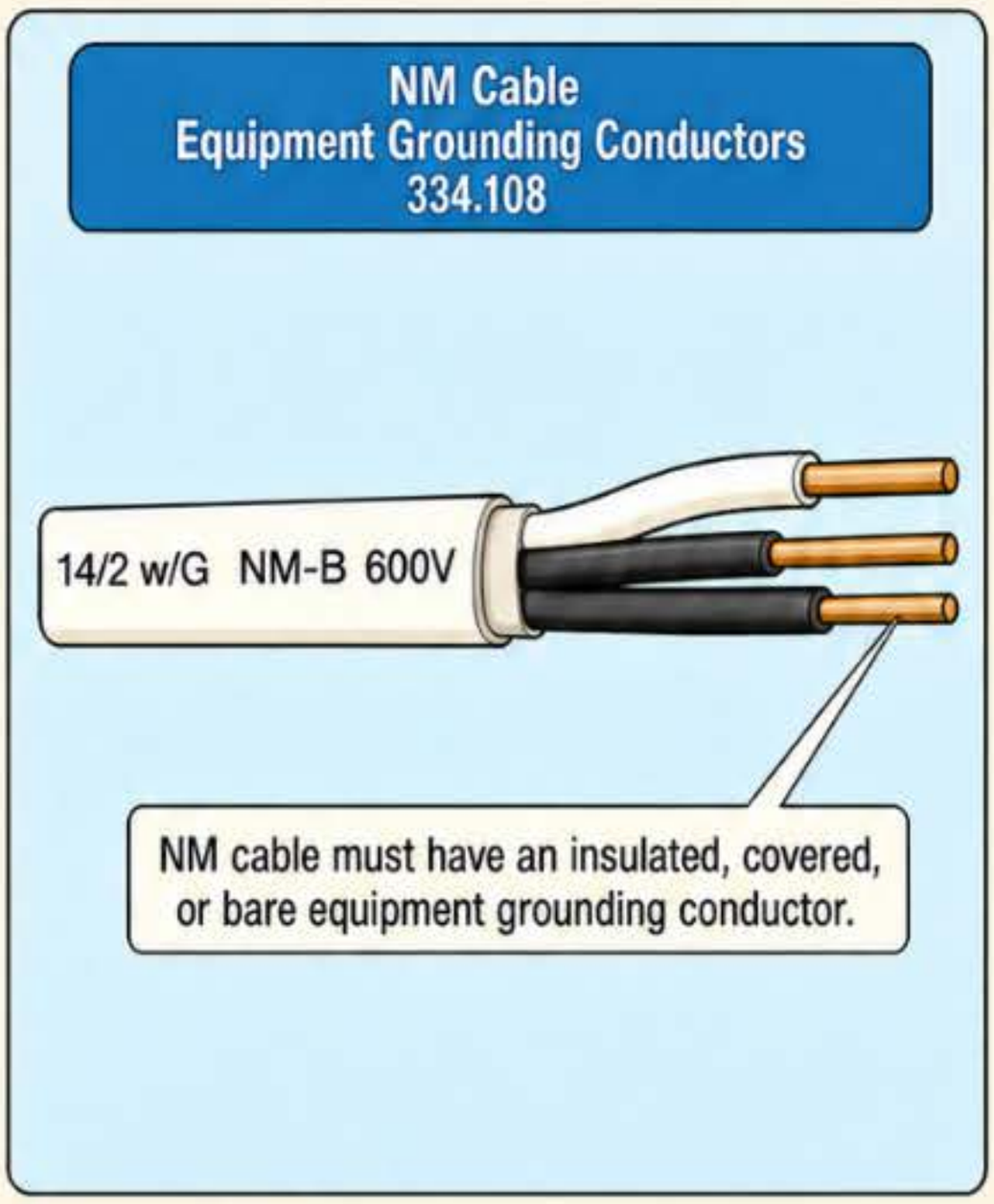
Step 2: *Verify that the adjusted conductor ampacity can be protected by the 15A circuit breaker. In this case, 14 AWG is rated 14.00A after adjustment at 90°C and 15A at 60°C [210.19(A)(1) and 240.4(D)].*

Answer: *(a) Yes*

Part III. Construction Specifications

334.108 Equipment Grounding Conductor

Type NM cable must have an insulated, covered, or bare equipment grounding conductor. **Figure 334–24**



▶ **Figure 334–24**

ARTICLE 336

POWER AND CONTROL TRAY CABLE (TYPE TC)

Introduction to Article 336—Power and Control Tray Cable (Type TC)

Power and control tray cable (Type TC) is a flexible, budget-friendly, and simple-to-install cable. It offers limited physical protection for the conductors, so the rules for installation are strict. Its low price and ease of installation make it a common choice for wiring in industrial environments.

Part I. General

336.1 Scope

This section addresses how power and control tray cable, Type TC, can be used and installed.

▶ Figure 336–1

Power and Control Tray Cable (Type TC)
336.1 Scope

This article specifies the permitted uses, installation methods, and construction requirements for power and control tray cable, Type TC.

▶ Figure 336–1

336.2 Definition

Power and Control Tray Cable (Type TC). A factory assembly of two or more insulated conductors, with or without associated bare or covered equipment *grounding conductors*, under a nonmetallic jacket.

▶ Figure 336–2

Power and Control Tray Cable (Type TC)
336.2 Definition

A factory assembly of two or more insulated conductors with or without associated bare or covered equipment grounding conductors, under a nonmetallic jacket.

▶ Figure 336–2

336.6 Listing Requirements

Type TC cable and any associated fittings must be included in a listing. ▶ Figure 336–3

Part II. Installation

336.10 Uses Permitted

Type TC cable is permitted for the following applications:

(1) For power, lighting, control, and signaling circuits.

(2) In cable trays, including portions with mechanically discontinuous segments up to 1 ft.

336.12 | Power and Control Tray Cable (Type TC)

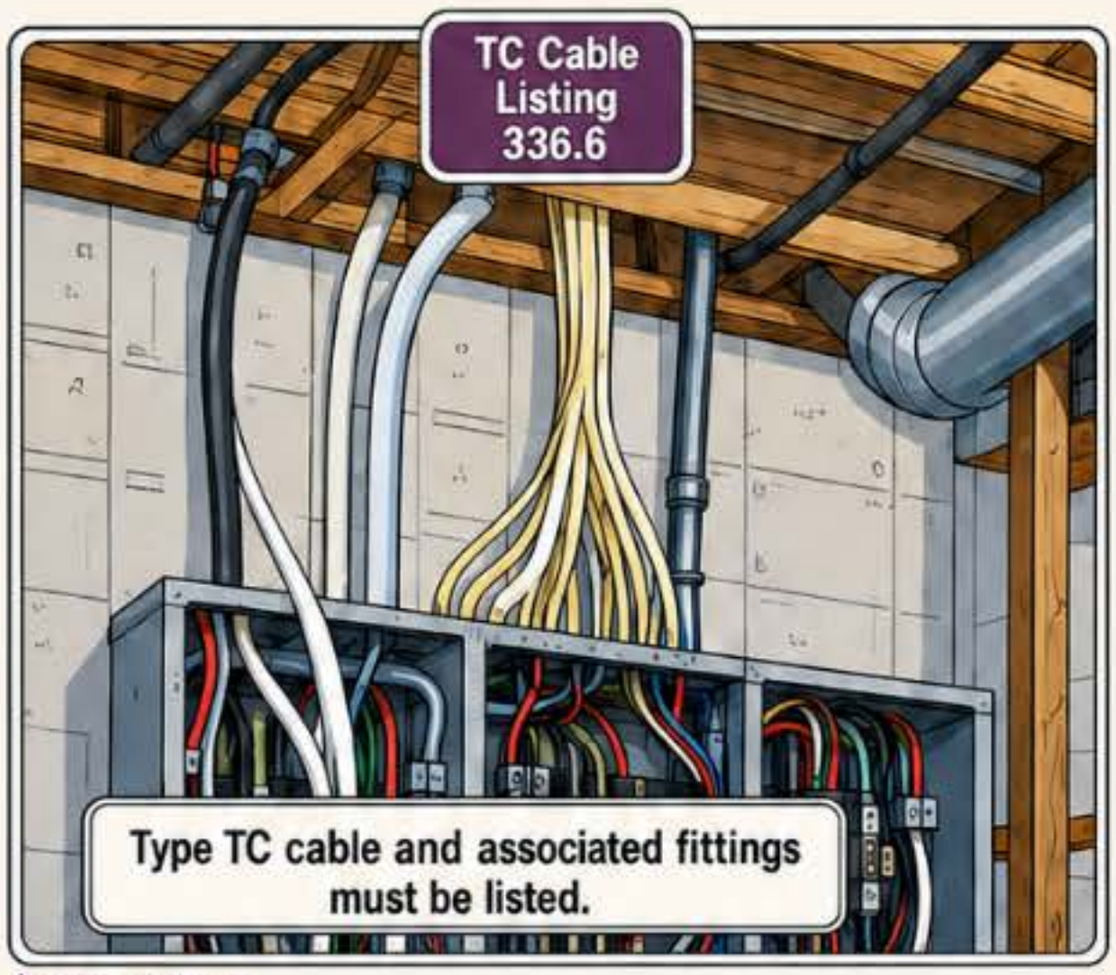


Figure 336–3

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits in accordance with Article 725.

(7) Between a cable tray and equipment if it complies with 336.10((7).

(8) In wet locations where the cable is resistant to moisture and corrosive agents.

(9) In one- and two-family dwellings, Type TC-ER-JP cable is *permitted for branch circuits and feeders where installed in accordance with Part II of Article 334 for interior wiring, and Part II of Article 340 for exterior wiring.*

Figure 336–4

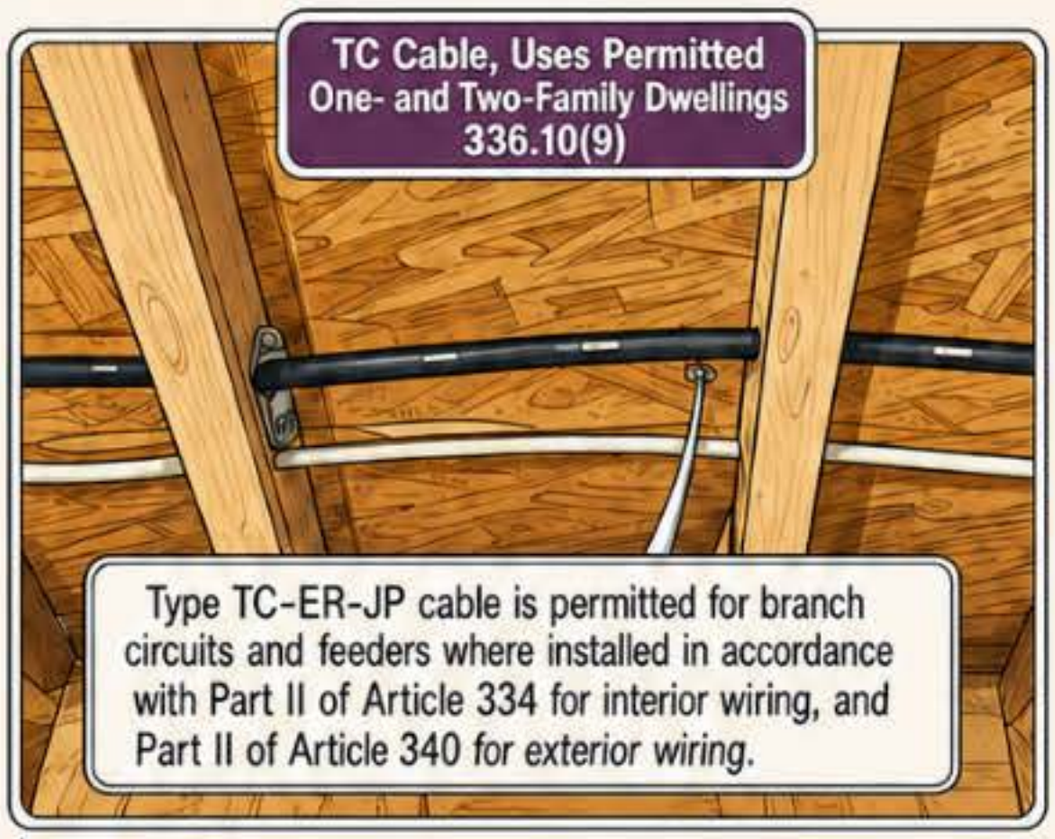


Figure 336–4

Author's Commentary:

The "ER" symbol on Type TC-ER cable indicates it is designed for situations where it is exposed, in accordance with UL standards. The "JP" identifier shows the cable is engineered for pulling through wood framing members.

— Michael Hamilton

Example: *When Type TC-ER-JP cable is used to connect a generator and its related equipment, the allowable cable ampacities from 334.80 and 340.80 do not apply.*

Author's Commentary:

The "JP" marking on Type TC-ER-JP cable means it *may be installed by being pulled through framing members made of wood, since the cable meets UL pulling strength requirements.*

— Michael Hamilton

Direct burial is allowed where this identification is present.

336.12 Uses Not Permitted

Type TC cables are not permitted:

(1) Where exposed to physical damage.

(2) Outside *a raceway or cable tray system, except as permitted in 336.10(4), 336.10(7), 336.10(9), and 336.10(10).*

(3) *Exposed to the direct rays of the sun, unless identified as sunlight resistant.*

336.24 Bending Radius

Bends in Type TC cable must be made so the cable will not be damaged. Type TC cable *without metal shielding must have a minimum bending radius as follows:*

(1) *Four times the overall diameter for cables 1 in. or less in diameter.*

(2) *Five times the overall diameter for cables larger than 1 in. but not more than 2 in. in diameter.*

ARTICLE 338 SERVICE-ENTRANCE CABLE (TYPES SE AND USE)

Introduction to Article 338—Service-Entrance Cable (Types SE and USE)

Service-entrance (SE) and underground service-entrance (USE) cables can be either a single conductor or a multiconductor assembly wrapped in an outer jacket or covering. This cable is used mainly for services but may also be used for feeders and branch circuits.

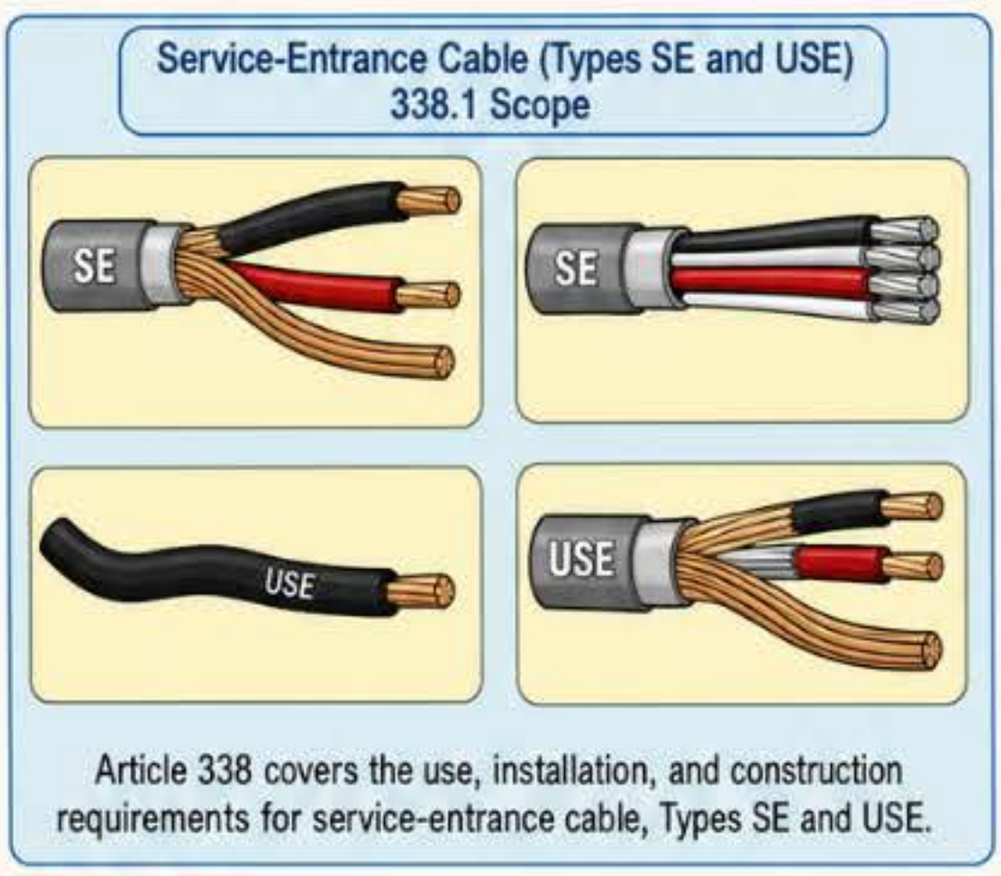
When installed as a service conductor(s) or service entrance conductor(s), Type SE cable assemblies will have insulated phase conductors and a bare neutral conductor. For feeders or branch circuits, use Type SE cable that includes insulated phase conductors and an equipment grounding conductor that is not insulated.

Part I. General

338.1 Scope

Article 338 covers the use, installation, and construction requirements for service-entrance cable, Types SE and USE.

- Figure 338-1

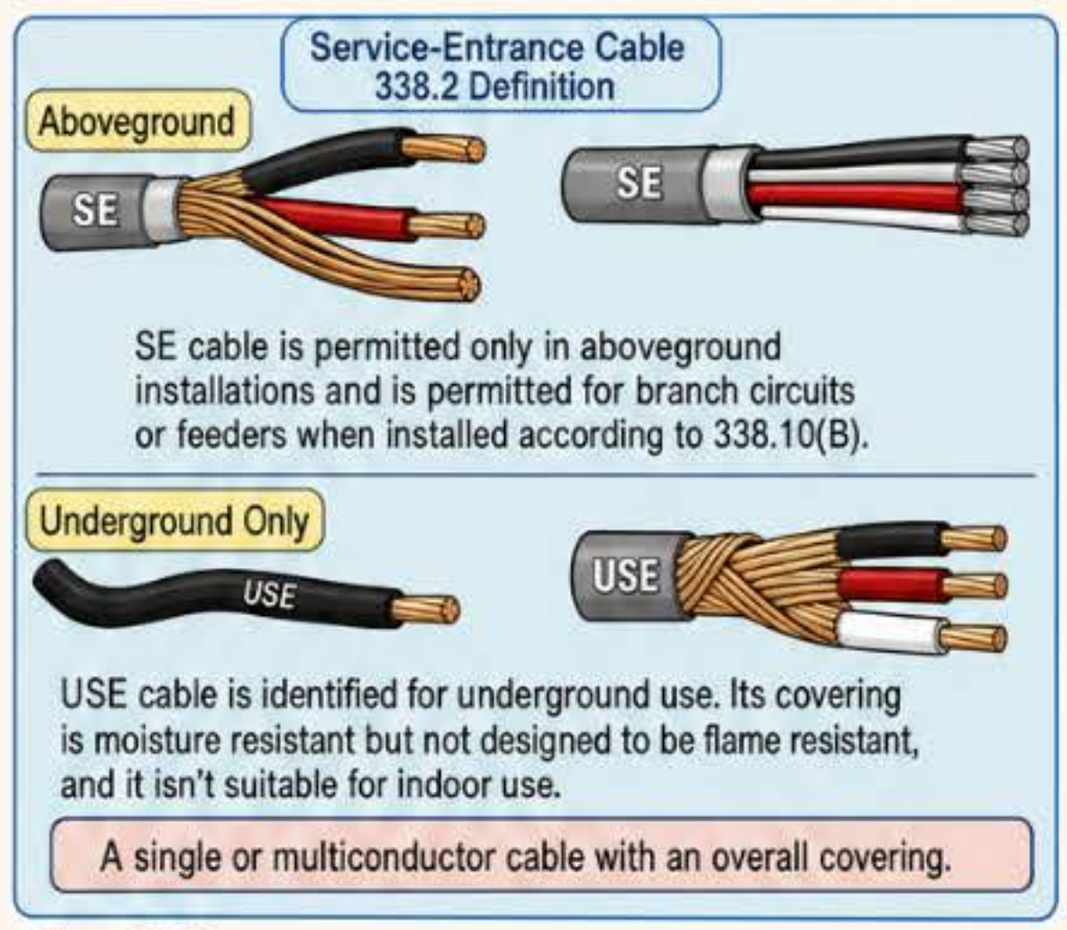


- Figure 338-1

338.2 Definitions

Service-Entrance Cable (Types SE and USE). Service-entrance cable is either a single-conductor cable or a multiconductor cable wrapped in an overall covering.

- Figure 338-2



- Figure 338-2

Service-Entrance Conductor Assembly. Multiple single-insulated conductors twisted together without an overall covering, other than an optional binder intended only to keep the conductors together.

Author's Commentary:

- "Triplex" and "Quadruplex" with an outer wire wrapped around them are examples of an SE conductor assembly.

— *Michael Hamilton*

Type SE. Type SE cables have a flame-resistant, moisture-resistant jacket and are permitted only in aboveground installations. These cables are permitted for branch circuits or feeders when installed in accordance with 338.10(B).

338.6 | Service-Entrance Cable (Types SE and USE)

Type USE. USE cable is recognized as an acceptable wiring method for underground service. Its outer jacket resists moisture infiltration and it will not support combustion.

Author's Commentary:

Indoor locations are off-limits for Type USE cable.

— Michael Hamilton

338.6 Listing Requirements

The specific Types SE and USE cables, along with the fittings intended for them, must appear on a listing. ❶ Figure 338-3

❶ Figure 338-3

Part II. Installation

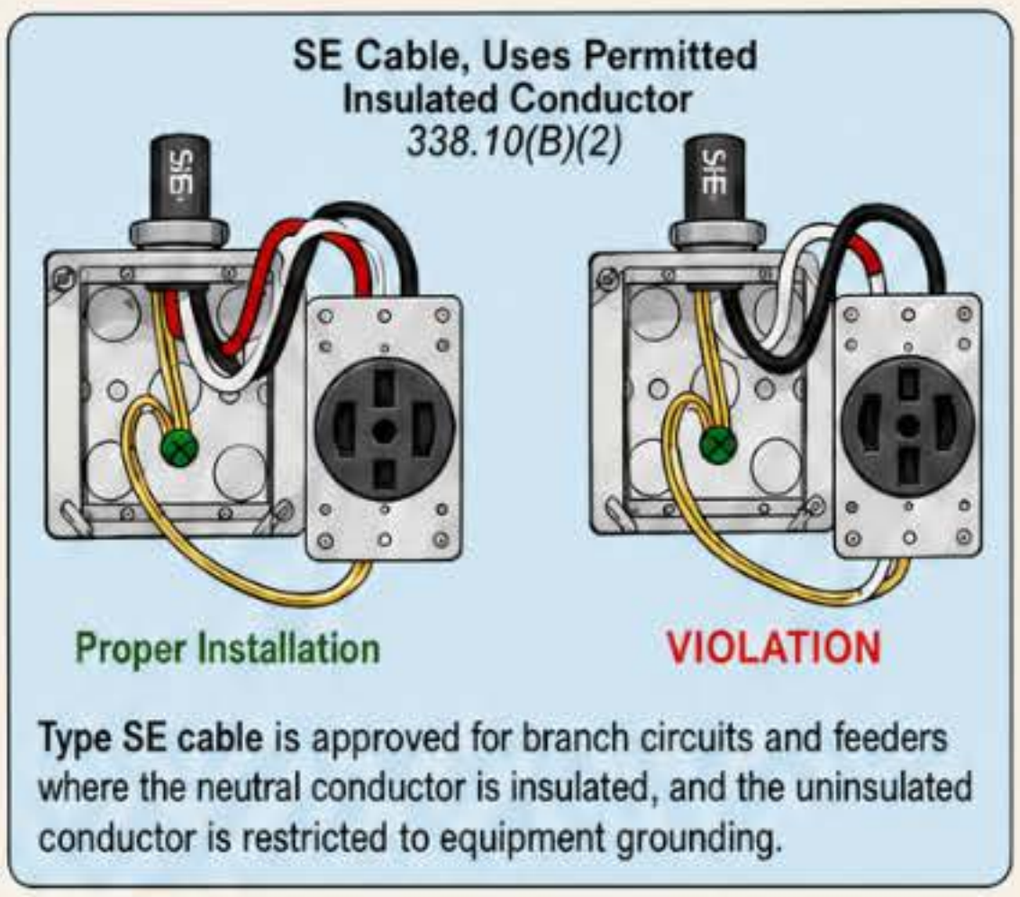
338.10 Uses Permitted

(A) Service-Entrance Conductors. Types SE and USE cable can be used as service-entrance conductors in accordance with Article 230.

(B) Branch Circuits or Feeders.

(2) Insulated Conductor. Type SE service-entrance cable is permitted for branch circuits and feeders where the neutral conductor is insulated, and the uninsulated conductor is limited to equipment grounding. ❷ Figure 338-4

(3) Temperature Limitations. SE cable is not permitted to be subjected to conductor temperatures that exceed its insulation rating.



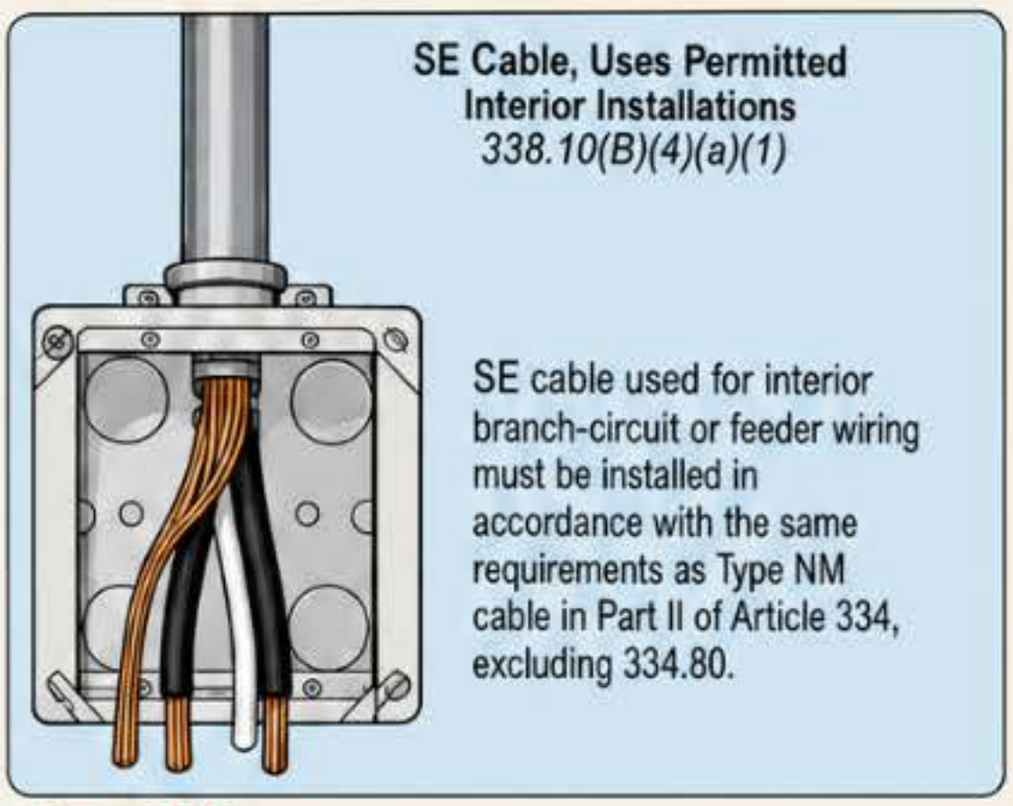
❷ Figure 338-4

(4) Installation Methods for Branch Circuits and Feeders. SE cable employed in branch circuits and feeders must comply with (a) and (b).

(a) Interior Installations.

(1) SE cable used for interior branch-circuit or feeder wiring must be installed in accordance with the same requirements as Type NM cable in Part II of Article 334, excluding 334.80.

❸ Figure 338-5



❸ Figure 338-5

(2) If multiple cables pass through the same wood framing opening that is required to be sealed with thermal insulation, caulking, or sealing foam, the ampacity adjustment factor for each conductor must be applied in accordance with Table 310.15(C)(1). ❹ Figure 338-6

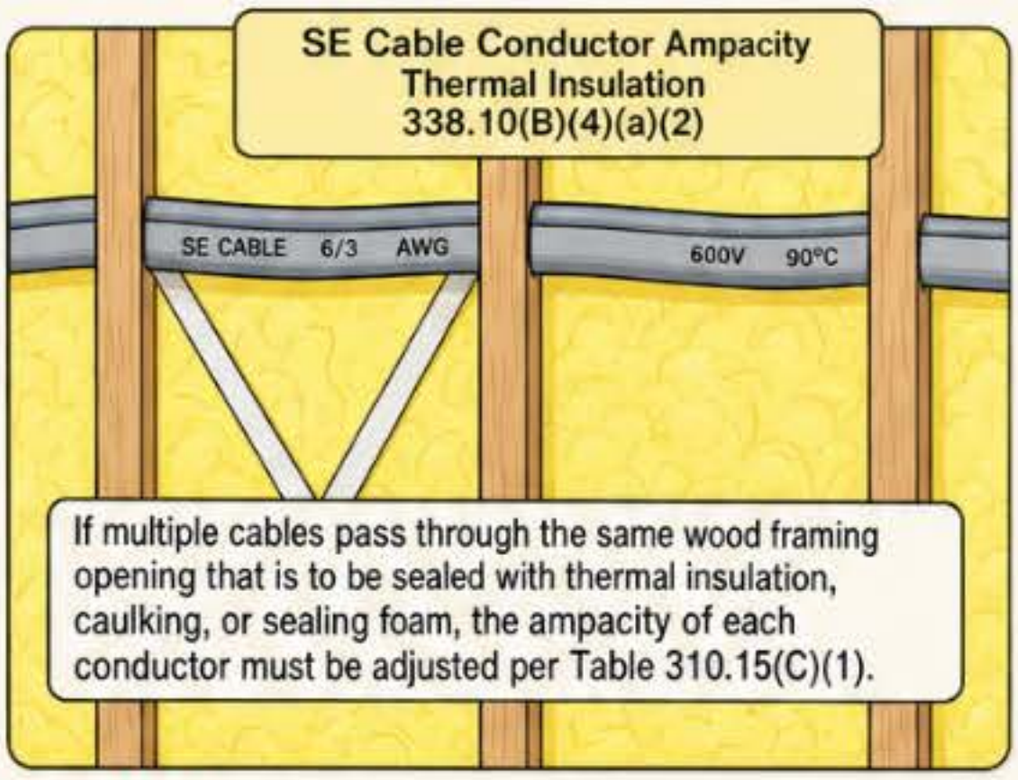


Figure 338–6

(3) The ampacity of conductors 10 AWG and smaller, where installed in contact with thermal insulation, must be sized in accordance with 60°C (140°F) conductor temperature rating. For conductor ampacity correction and/or adjustment, the conductor temperature rating ampacity must be used.

Author's Commentary: *This rule prevents insulation from trapping heat around the cable. Using the lower 60°C rating keeps the conductors within their safe temperature limits.*
— Michael Hamilton

(b) Exterior Installations.

(1) The cable must be installed in accordance with Part I of Article 225 and supported in accordance with 334.30. Where it is run underground, the cable must comply with Part II of Article 340.

338.12 Uses Not Permitted

(A) Service-Entrance Cable. Type SE cable is not permitted under the following conditions or locations:

(1) Where subject to physical damage.

(2) Underground with or without a raceway.

(B) Underground Service-Entrance Cable. Type USE cable is not permitted:

(1) For interior wiring.

(2) Above ground, except where protected against physical damage in accordance with 300.5(D).

Author's Commentary: *SE and USE cables have specific application limits to ensure long-term reliability and safety. Using the correct cable type in the right location avoids code violations and hazards.*
— Michael Hamilton

338.24 Bending Radius

Bends in cable must be made so the protective coverings of the cable are not damaged, and the radius of the curve of the inner edge is at least five times the diameter of the cable. • Figure 338–7 and • Figure 338–8

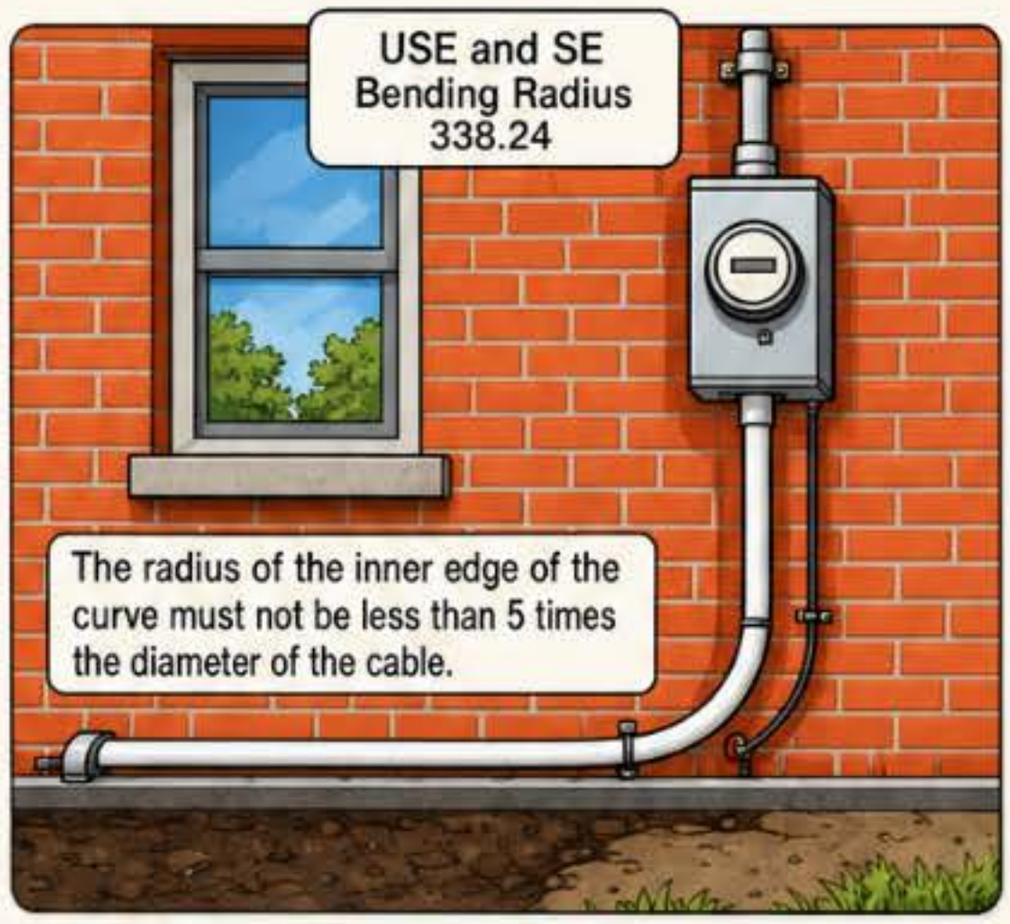


Figure 338–7

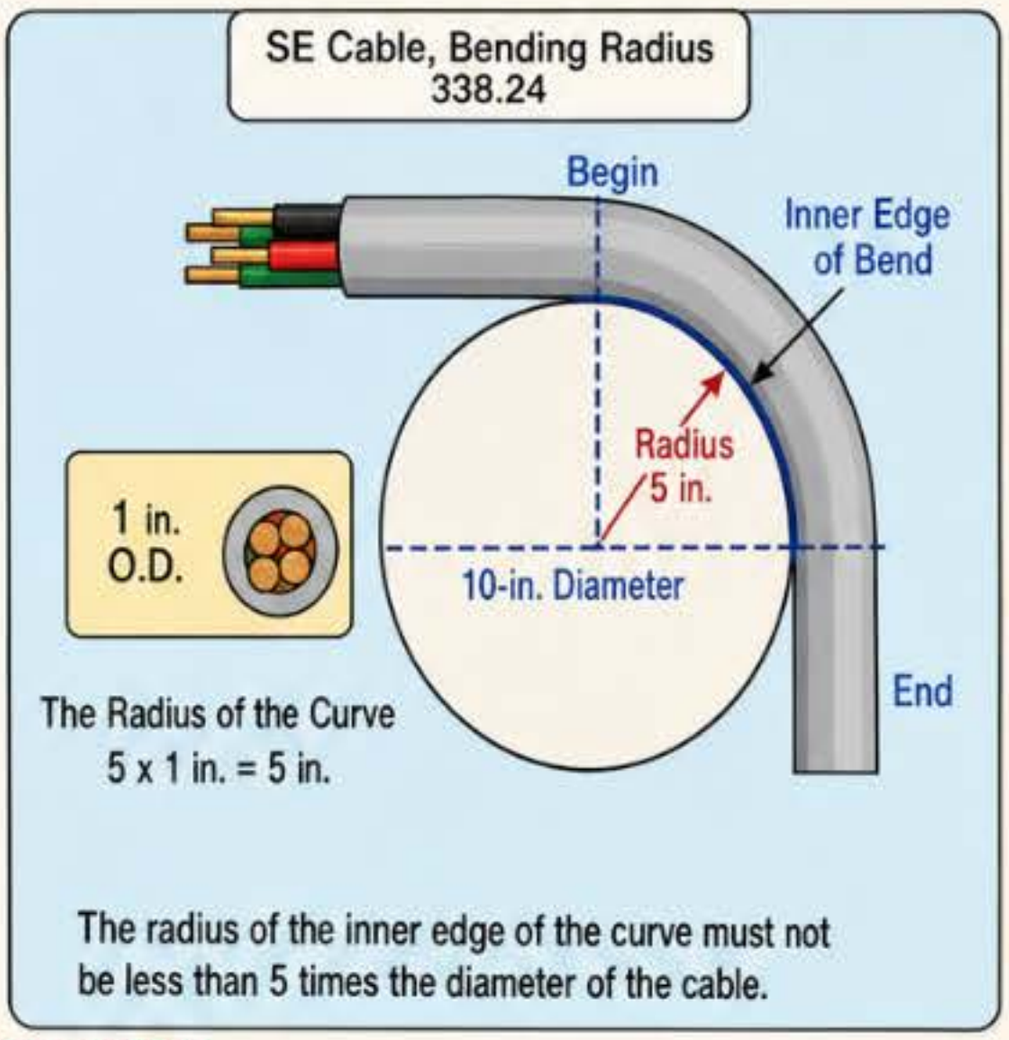


Figure 338–8

Author's Commentary: *Bending too tightly can cause stress that damages the cable jacket or insulation. Always respect the 5x diameter rule to maintain the cable's integrity.*
— Michael Hamilton

Notes |

ARTICLE 340

UNDERGROUND FEEDER AND BRANCH-CIRCUIT CABLE (TYPE UF)

Introduction to Article 340—Underground Feeder and Branch-Circuit Cable (Type UF)

UF cable (Type UF) is intended as a moisture-, fungus-, and corrosion-resistant cable suitable for direct burial in the Earth. It comes in sizes 14 AWG through 4/0 AWG [340.104]. The covering of multiconductor Type UF cable is molded plastic that encases the insulated conductors. Because the covering shields the insulated conductors, it is difficult to strip off the outer jacket to gain access to them, but this covering provides excellent corrosion protection. Be careful not to damage the conductor insulation or cut yourself when you remove the outer cover.

Part I. General

340.1 Scope

Article 340 covers the use, installation, and construction specifications of underground feeder and branch-circuit cable, Type UF. **Figure 340-1**

Underground Feeder and Branch-Circuit Cable (Type UF)
340.1 Scope

Article 340 covers the use, installation, and construction specifications of underground feeder and branch-circuit cable, Type UF.

Figure 340-1

340.2 Definition

Underground Feeder and Branch-Circuit Cable (Type UF). A factory assembly of insulated conductors with an integral or an overall covering of nonmetallic material suitable for *direct burial in the Earth.* **Figure 340-2**

Underground Feeder and Branch-Circuit Cable (Type UF)
340.2 Definition

A factory assembly of insulated conductors with an integral or an overall covering of nonmetallic material suitable for direct burial in the Earth.

Figure 340-2

340.6 Listing Requirements

Type UF cable and associated fittings must be listed.

Part II. Installation

340.10 Uses Permitted

Type UF cable is permitted:

(1) Underground in accordance with 300.5.

(2) As a single conductor in a trench or raceway with circuit conductors.

340.12 | Underground Feeder and Branch-Circuit Cable (Type UF)

(3) Use in damp, dry, or locations where corrosion might be present.

(4) When installed without any metallic sheath, the work must follow the requirements of Parts II and III of Article 334.

340.12 Uses Not Permitted

Type UF cable is not allowed for the following:

(1) As the service entrance cable [230.43].

(2) In commercial garages [511.3].

(3) In theaters [520.5].

(4) In motion picture studios [530.11].

(5) In storage battery rooms [Article 480].

(6) In hoistways [Article 620].

(7) In hazardous (classified) locations, unless a specific exception is provided elsewhere in this *Code*.

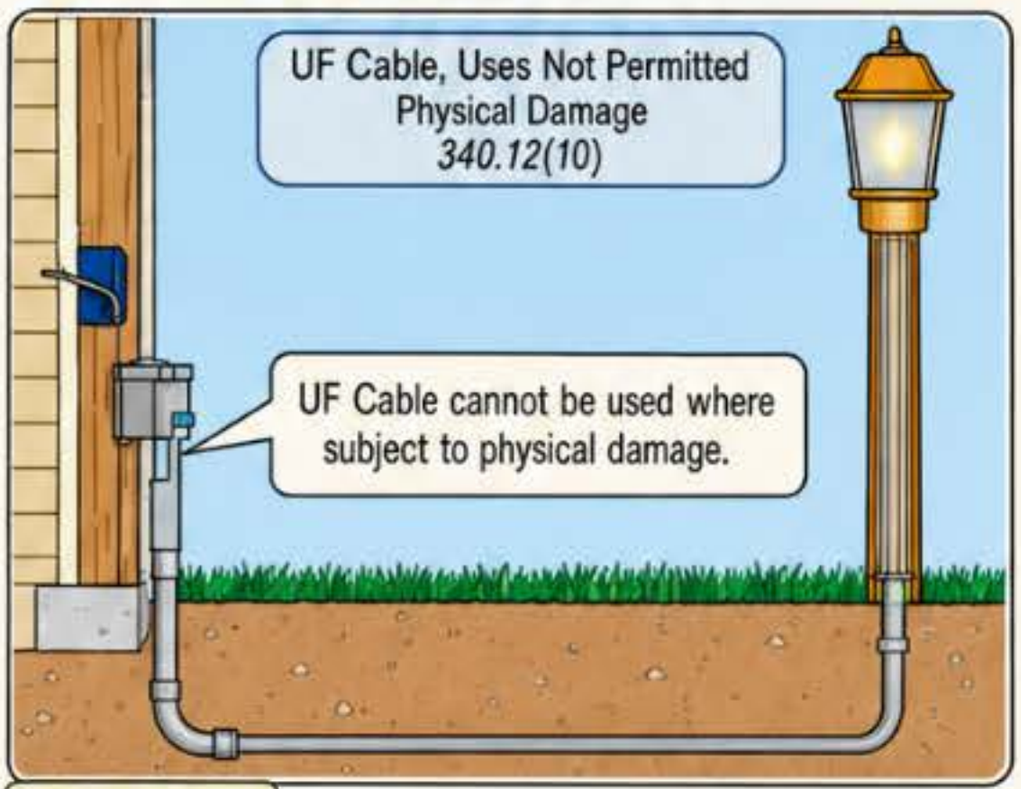
(8) Embedded in concrete.

(9) Exposed where it could be subject to direct sunlight unless it can be identified.

Note: The sunlight-resistant marking on the outer jacket does not replace the need to *identify individual* conductors.

(10) Where it could be subject to physical damage. ▶ Figure 340–3

(11) As overhead messenger-supported wiring.



▶ Figure 340–3

Author's Commentary:

UF cable is not suitable for ducts or open plenum spaces [300.22], and it should not be used in patient care areas of health care facilities [517.13].

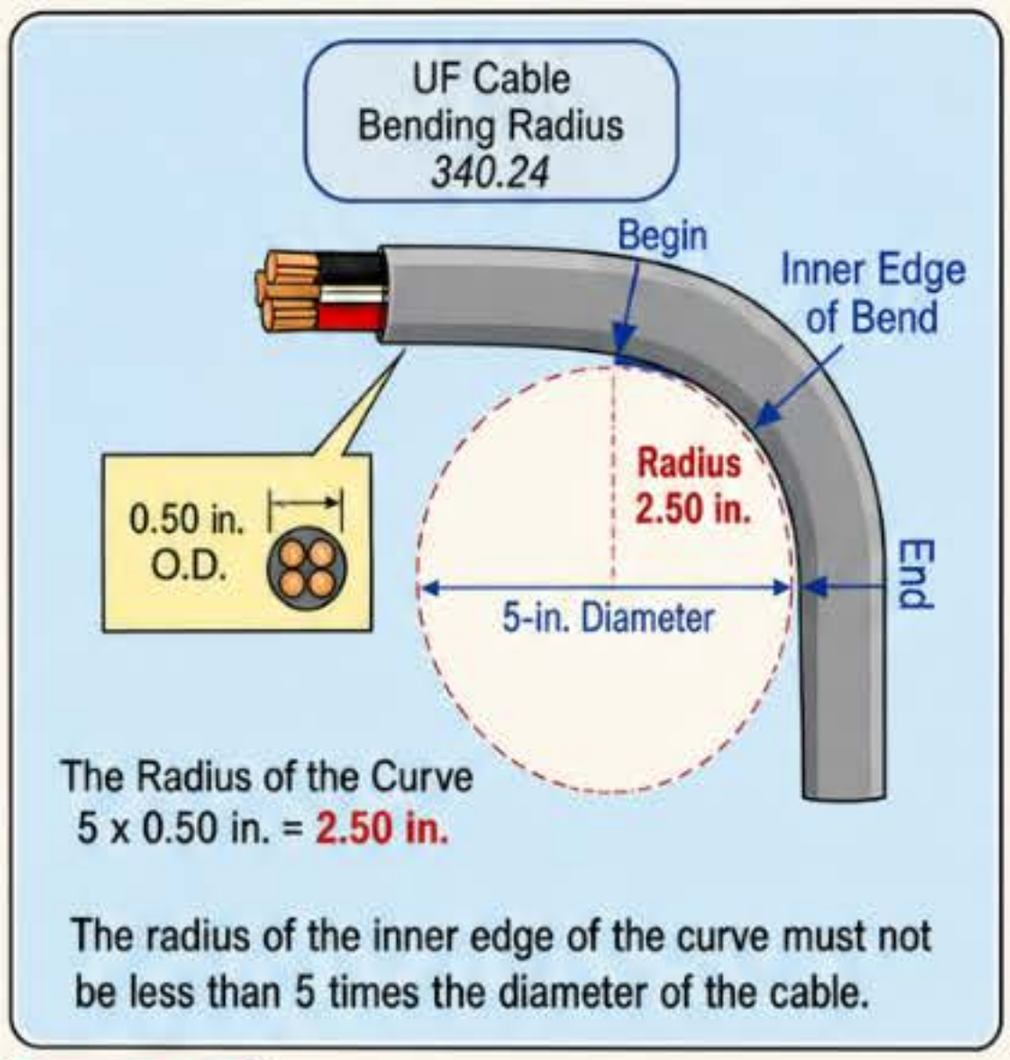
— Michael Hamilton

340.24 Bends

Cables must include protective coverings that are not harmed during bending. The radius of the bend along the inside edge must be at least five times the overall diameter of the cable. ▶ Figure 340–4

340.80 Ampacity

The ampacity of conductors in UF cable is based on the 60°C insulation rating shown in Table 310.16.



▶ Figure 340–4

Part III. Construction Specifications

340.108 Equipment Grounding Conductor

Type UF cable is permitted to have an insulated, covered, or bare equipment grounding conductor.

340.112 Insulation

The conductors of UF cable must be one of the moisture-resistant types listed in Table 310.4(A) that are suitable for branch-circuit wiring. If UF cable is substituted for Type NM cable, the conductor insulation must be rated 90°C (194°F).

ARTICLE 342

INTERMEDIATE METAL CONDUIT (TYPE IMC)

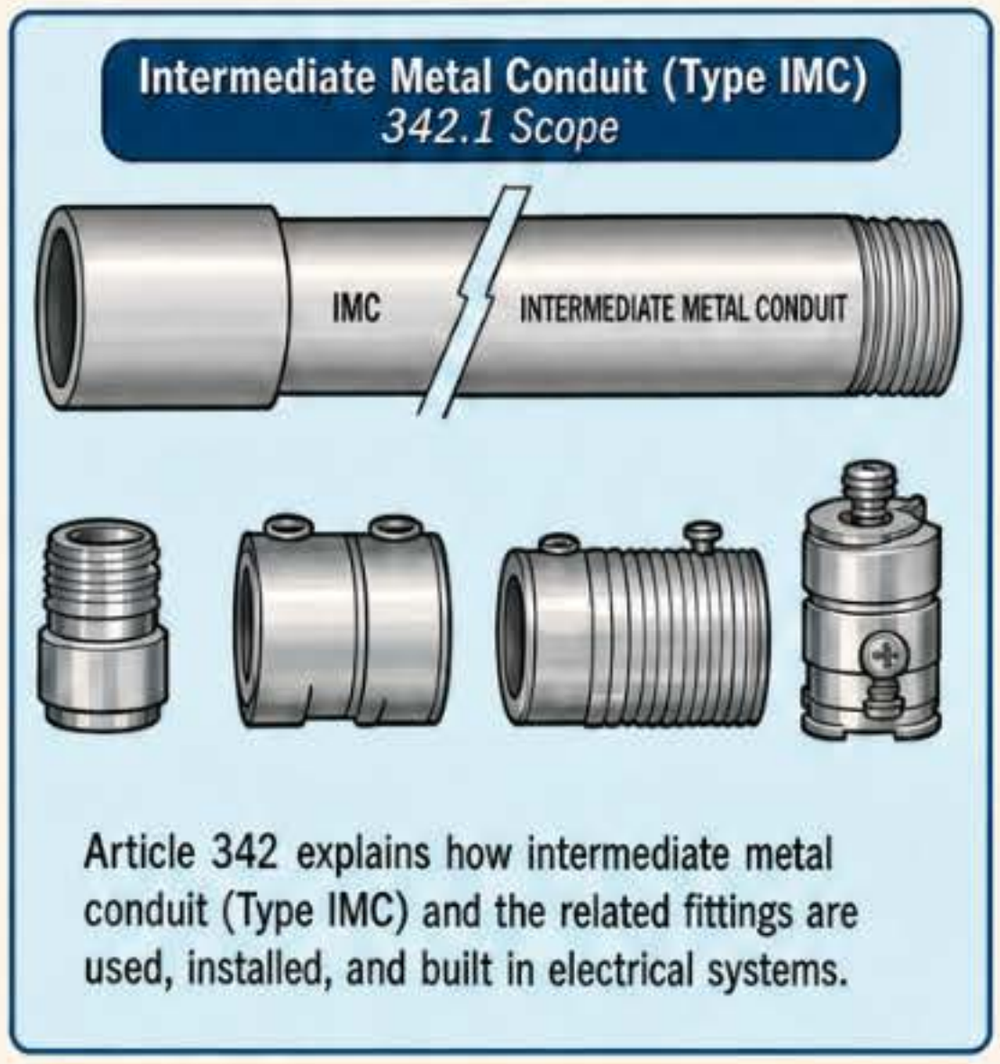
Introduction to Article 342—Intermediate Metal Conduit (Type IMC)

Intermediate metal conduit is a circular metal raceway with the same outside diameter as righid metal conduit (Type RMC). Because the wall thickness of IMC is less than that of rigid metal conduit, the inside cross-sectional area is larger, providing more space for conductors. IMC is lighter in weight and generally more economical than RMC, which is why the *NEC* permits its use in the same applications. IMC also produced from a different steel alloy, allowing it to be stronger even though the walls are thinner. Intermediate metal conduit is commonly manufactured in either galvanized steel or aluminum, with galvanized steel being the more prevalent material.

Part I. General

342.1 Scope

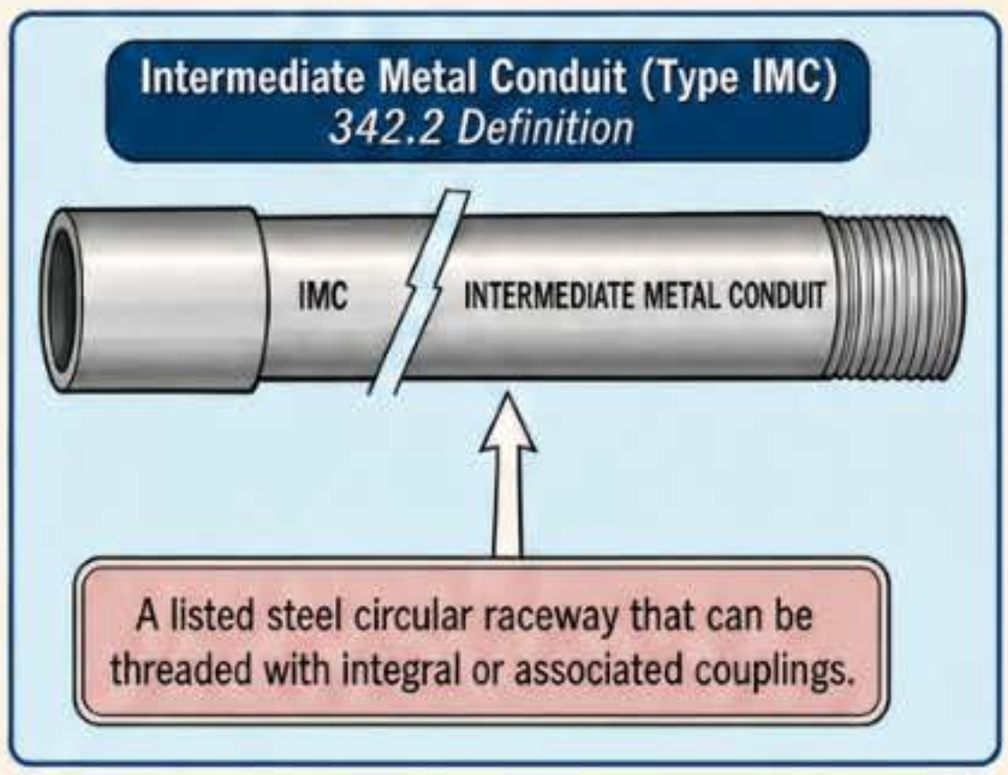
Article 342 covers the use, installation, and construction specifications of intermediate metal conduit (Type IMC) and associated fittings. ***Figure 342–1***



▶ **Figure 342–1**

342.2 Definition

Intermediate Metal Conduit (Type IMC). A steel raceway of circular cross section that can be threaded and used with integral or associated couplings for installing electrical conductors. ***Figure 342–2***



▶ **Figure 342–2**

Author's Commentary:

The steel from which intermediate metal conduit is produced is carefully formulated to resist corrosion and is either equal to or better than the steel used in rigid metal conduit.

— Michael Hamilton

342.6 Listing Requirements

List intermediate metal conduit and all related fittings together.

Part II. Installation

342.10 Uses Permitted

(A) Atmospheric Conditions and Occupancies. IMC may be used in any location exposed to the weather and in all types of occupancies.

(B) Corrosive Environments. IMC, elbows, couplings, and connectors can be installed in direct contact with the earth, or in places that may be subject to severe corrosion, provided they meet the supplementary corrosion protection listed for those environments.

(E) Severe Physical Damage. IMC is permitted where damage from impact is likely to be serious.

342.14 Dissimilar Metals

In practical situations, avoid direct contact between IMC and metals that are unlike to it so galvanic action does not cause deterioration.

Aluminum and stainless steel fittings and enclosures may be used with galvanized steel Type IMC, except where severe corrosive influences are present.

342.20 Trade Size

(A) Minimum. IMC smaller than trade size ½ in is not allowed.

(B) Maximum. IMC larger than trade size 4 in is not permitted.

342.22 Number of Conductors

The conductor count in IMC cannot exceed the percent fill limits given in Chapter 9, Table 1. Raceways must be large enough for conductor installation and maintenance without harming the insulation.

Author's Commentary:
See 300.17 for examples on determining raceway sizes when conductors are not uniform in size.
— *Michael Hamilton*

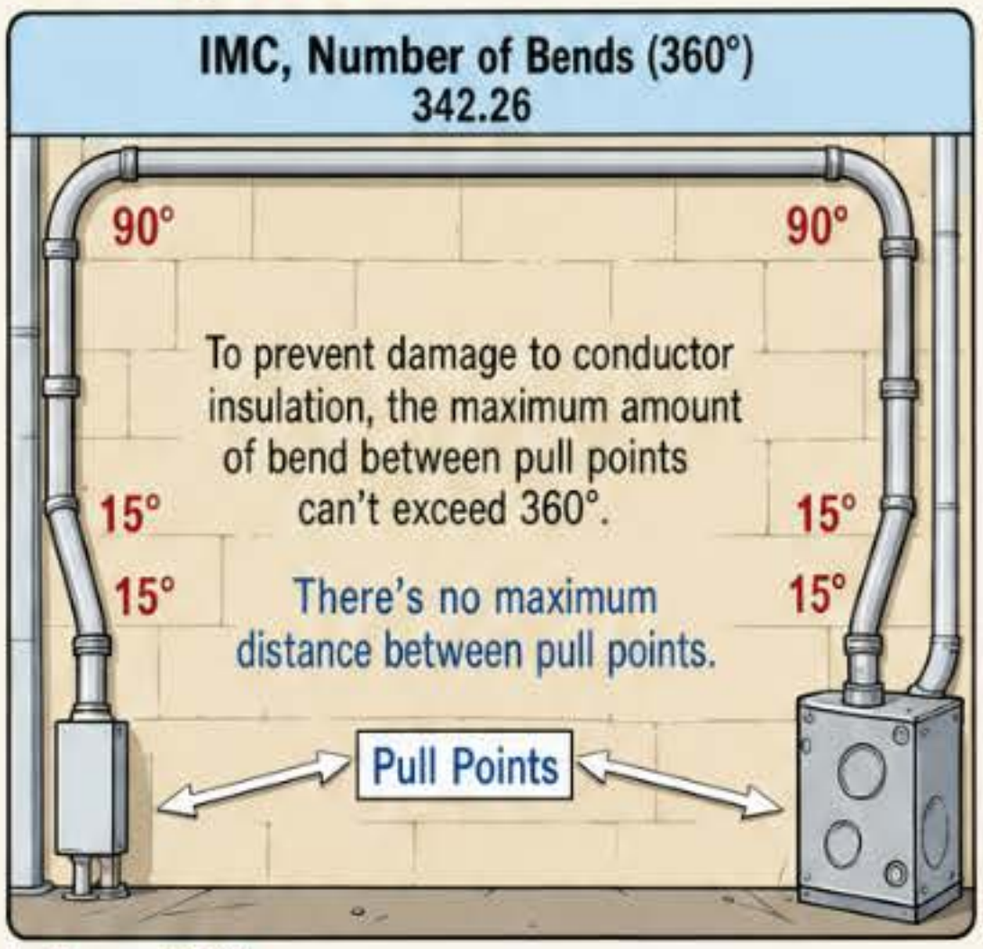
342.24 Bends

Raceway bends are not allowed if they could harm the raceway or cause a significant change to its internal diameter (no kinks).

Author's Commentary:
This is not a problem if you use a bender as instructed by the equipment manufacturer.
— *Michael Hamilton*

342.26 Number of Bends (360°)

To lessen stress and friction on conductor insulation, the total bends (including offsets) between pull points must not exceed 360°. ▶ Figure 342-3



▶ Figure 342-3

Author's Commentary:
There is no restriction on the length between pull boxes because this is a matter of design rather than safety.
— *Michael Hamilton*

342.28 Reaming

If the raceway has been cut in the field, reaming is required to remove burrs and rough edges.

Intermediate Metal Conduit (Type IMC) | 342.30

Author's Commentary:

Reaming is a standard method used to smooth the inside of raceways. A screwdriver or the back of pliers is often used for small raceways. But when cuts are made with a three-wheel pipe cutter, a reaming tool is better—it removes the small ridge left behind at the cut and prevents burrs from tearing conductors. Once installed, any threaded connections in the system must be tightened securely and electrically continuous using a corrosion-resistant compound approved *by the authority having jurisdiction, per 300.6(A).*

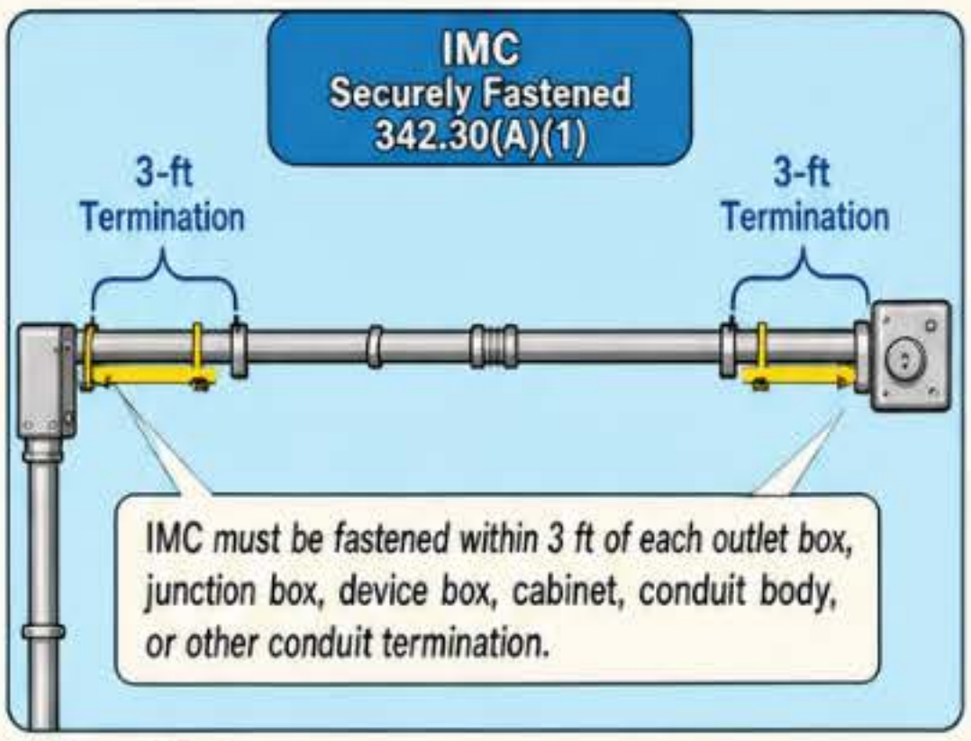
— Michael Hamilton

342.30 Securing and Supporting

IMC must be securely fastened in place and supported in accordance with (A) and (B).

(A) Securely Fastened. IMC must be secured in accordance with any of the following:

(1) Fastened within 3 ft of each outlet box, junction box, device box, cabinet, conduit body, or other conduit termination. ▶ Figure 342–4

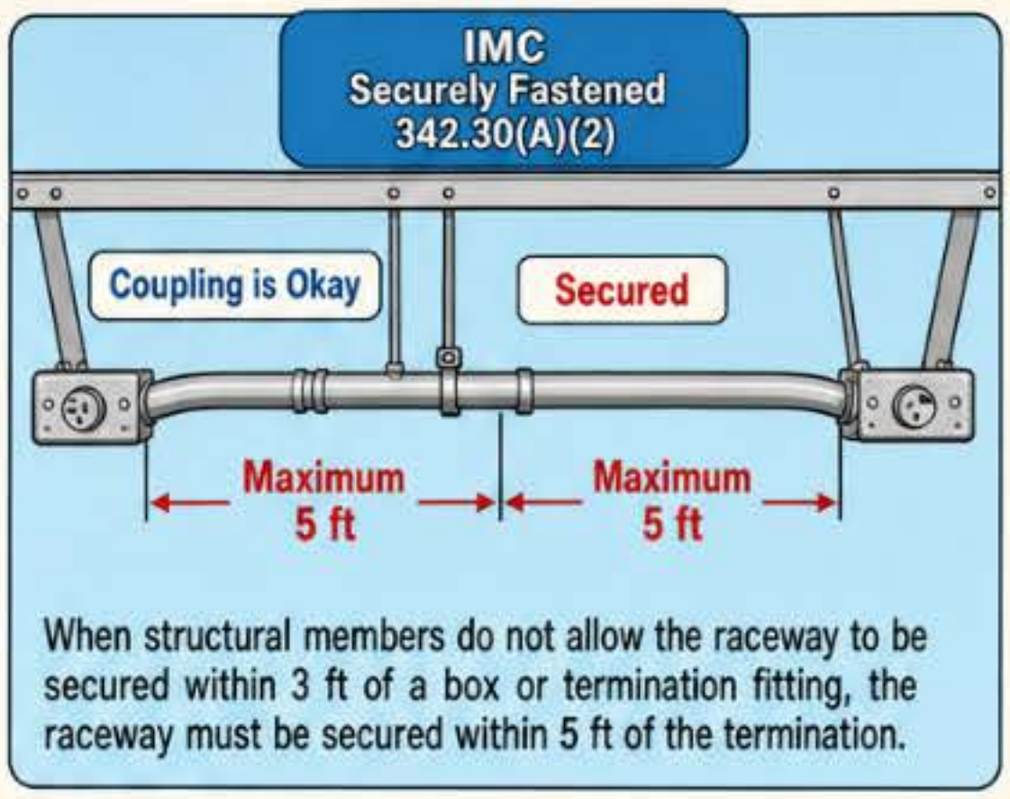


▲ Figure 342–4

Author's Commentary:

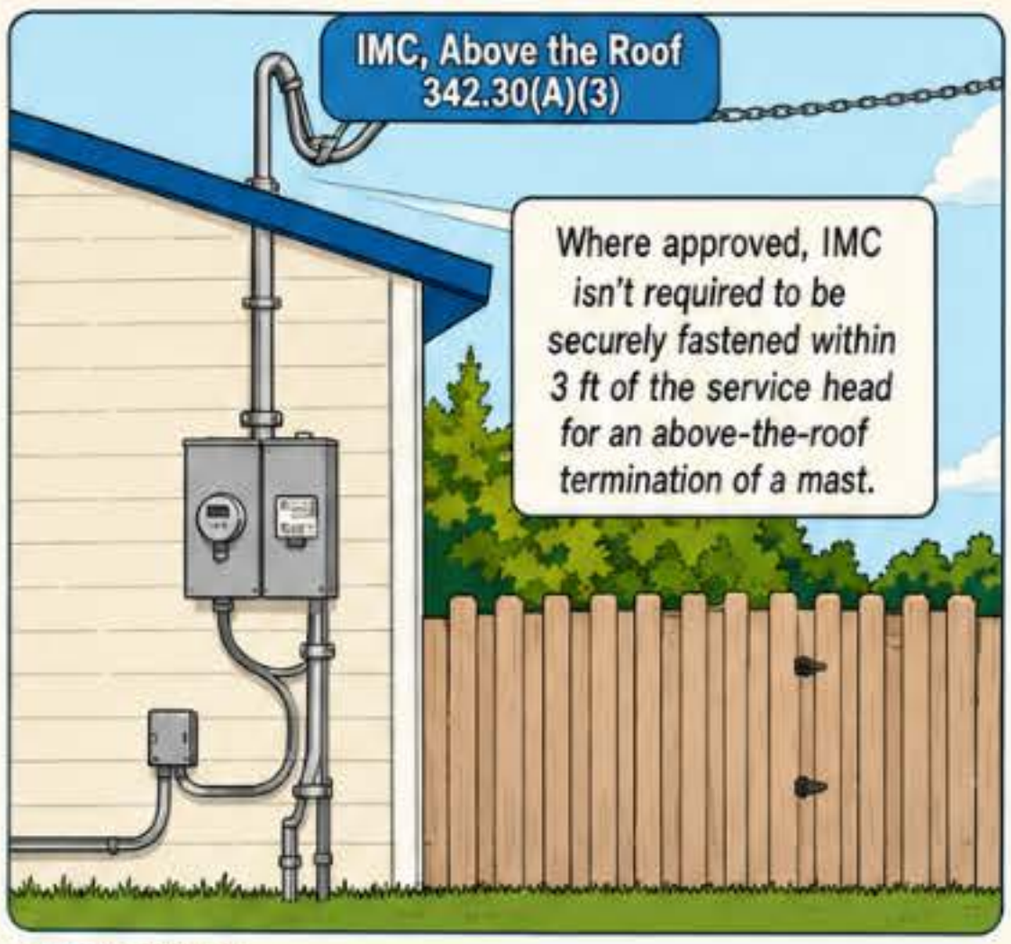
- Fastening is required within 3 ft of terminations, not within 3 ft of every coupling.
- *When structural members do not permit the raceway to be secured within 3 ft of a box or termination fitting, the raceway must be secured within 5 ft of the termination.*

— Michael Hamilton



▲ Figure 342–5

(3) Where approved, IMC is not required to be securely fastened within 3 ft of the service head for an above-the-roof termination of a mast. ▶ Figure 342–6



▲ Figure 342–6

(B) Supports.

(1) General. IMC must be supported at intervals not exceeding 10 ft.

(2) Straight Runs. *Straight runs with threaded couplings can be supported in accordance with the distances contained in Table 344.30(B)(2).* ▶ Figure 342–7

342.42 | Intermediate Metal Conduit (Type IMC)

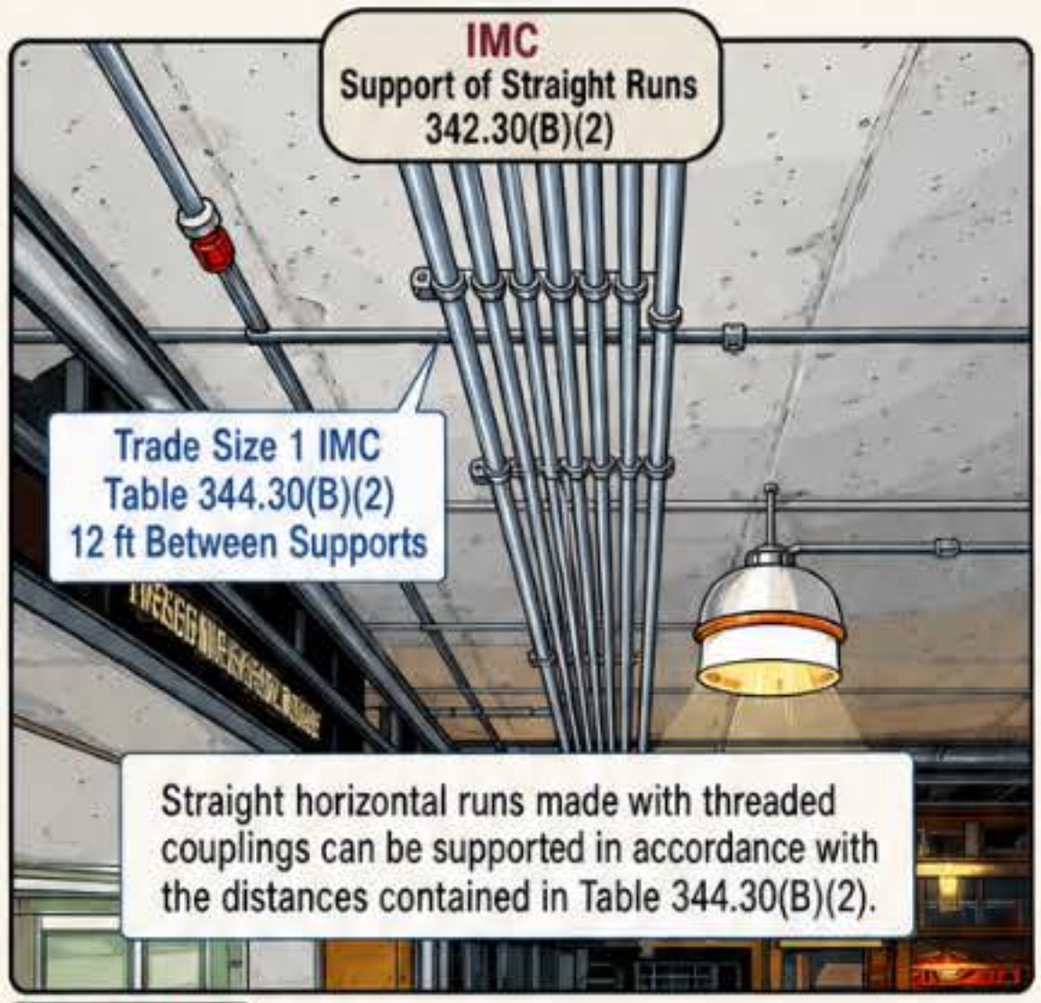


Figure 342–7

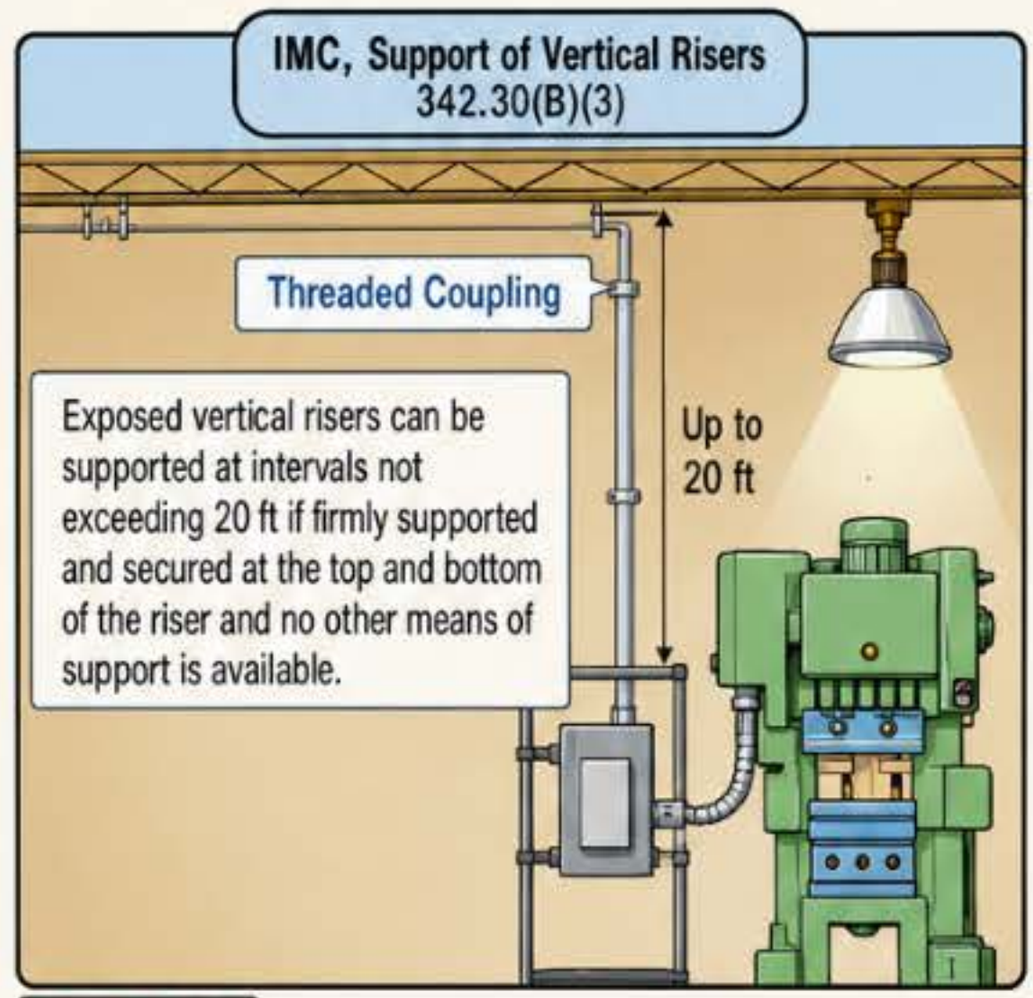


Figure 342–8

Table 344.30(B)(2) Supports for Rigid Metal Conduit

Trade Size	Support Spacing
½–¾	10 ft
1	12 ft
1¼–1½	14 ft
2–2½	16 ft
3 and larger	20 ft

(3) Vertical Risers. Exposed vertical risers of IMC or fixed equipment can be supported at intervals not exceeding 20 ft if the conduit is made up with threaded couplings, firmly supported, securely fastened at the top and bottom of the riser, and if no other means of support is available. Figure 342–8

(4) Horizontal Runs. IMC installed horizontally in bored or punched holes in wood or metal framing members, or notches in wooden members are considered supported, but the raceway must be secured within 3 ft of termination.

> **Author's Commentary:** *IMC should be equipped with expansion fittings where necessary to accommodate thermal growth and shrinkage [300.7(B)]. The spacing requirements for metal raceways are determined by multiplying the trade size values in Table 352.44 by 0.20, while those for aluminum raceways are found by multiplying the values from Table 352.44 by 0.40 [300.7 Note].*
>
> ***— Michael Hamilton***

342.42 Couplings and Connectors

(A) Installation. Threadless couplings and connectors must be made up tight to maintain an effective ground-fault current path to safely conduct fault current in accordance with 250.4(A)(5), 250.96(A), and 300.10.

> **Author's Commentary:** *Loose locknuts were found to have nearly disintegrated before a fault was cleared because loose termination fittings raise the impedance of the ground-fault current path.*
>
> ***— Michael Hamilton***

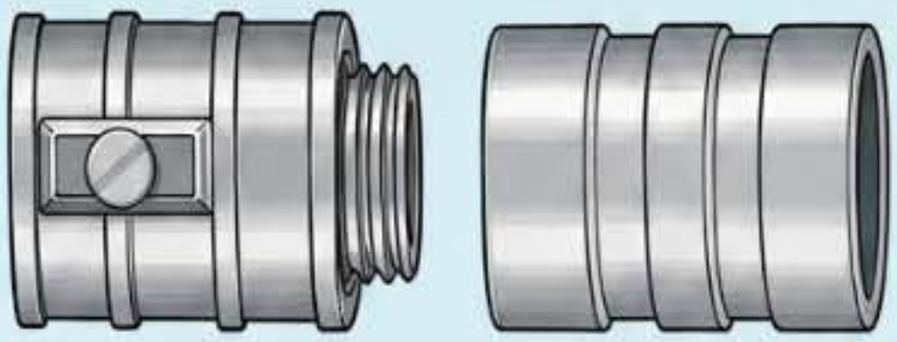
If buried in masonry or concrete, threadless fittings must be of the concrete-tight type. Fittings installed in wet locations must be listed for use in wet locations to prevent moisture or water from entering or accumulating within the enclosure as required by 314.15. Figure 342–9

(B) Running Threads. *Running threads are not permitted for the connection of couplings, but they are permitted at other locations.* Figure 342–10

342.46 Bushings

To protect conductors from abrasion, a metal or plastic bushing must be installed on conduit termination threads (regardless of conductor size) *unless the box, fitting, or enclosure is designed to provide this protection.*

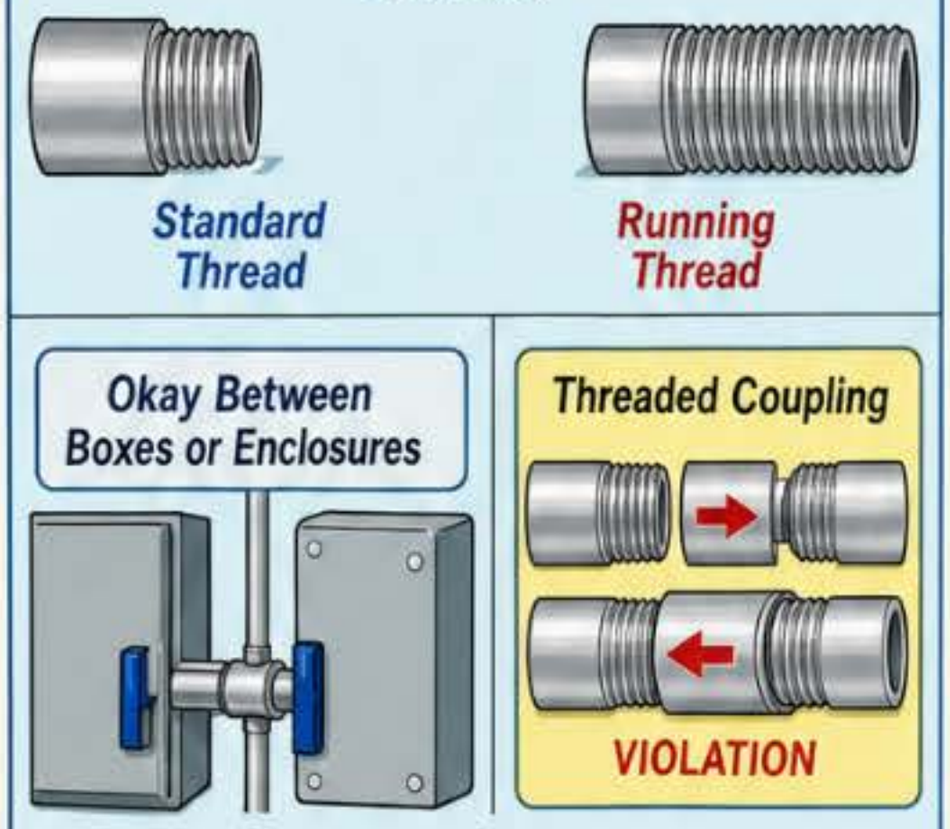
IMC
Threadless Couplings and Connectors
342.42(A)



Threadless fittings must be of the concrete-tight type. If buried in concrete or masonry, and in wet areas, they must be listed for wet locations.

Figure 342–9

IMC, Running Threads
342.42(B)



Running threads are not allowed for the connection of couplings, but they are permitted in other locations.

Figure 342–10

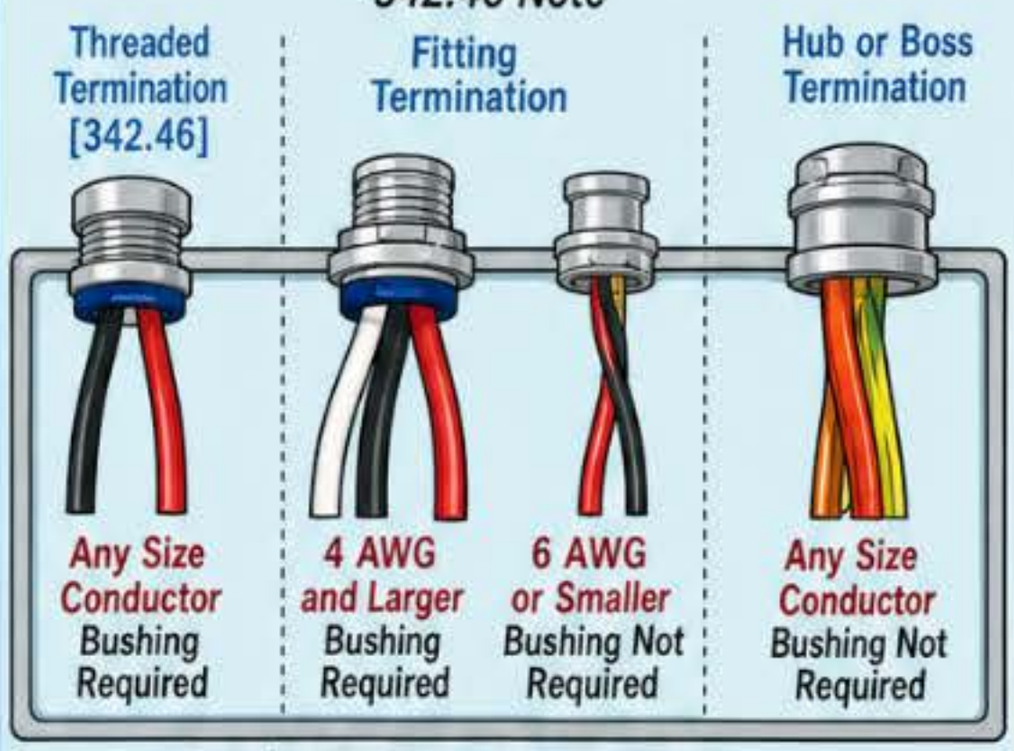
Author's Commentary:

- Section 5.4.1.1 of UL 514B states: "Whenever a coupling or a locknut is used, a conduit fitting must *have a raised positive stop on the conduit and a smooth, rounded throat that shields the conductors from abrasion and insulation damage while they are being pulled through the conduit.*"

— Michael Hamilton

Note: If the conductors are 4 AWG or larger and enter an enclosure, abrasion protection is required during installation and after installation by a fitting that provides a smooth, *rounded, insulating surface (for example, an insulating bushing), unless the box, fitting, or enclosure offers equivalent protection in accordance with 300.4(G).* ▸ *Figure 342–11*

IMC, Bushings
342.46 Note



Exception: 300.4(G) allows equivalent protection.

Conductors 4 AWG and larger must be shielded by a fitting that provides a smooth, rounded, insulating surface, such as an insulating bushing [300.4(G)].

Figure 342–11

342.60 Equipment Grounding Conductor

IMC may be used as an equipment grounding conductor.

Notes

ARTICLE 344

RIGID METAL CONDUIT (TYPE RMC)

Introduction to Article 344—Rigid Metal Conduit (Type RMC)

Rigid metal conduit (Type RMC), frequently referred to as "rigid," has long served as the industry's standard raceway for protecting conductors against physical harm and challenging conditions. The outside diameter of rigid metal conduit matches that of intermediate metal conduit. Its wall thickness, however, is greater than IMC, which results in a smaller cross-sectional area inside the conduit. Rigid metal conduit is tougher, more crush-resistant, and better able to withstand severe environments than intermediate metal conduit. The material can be made in various locations and is manufactured in either hot-dip galvanized steel or aluminum; therefore, this conduit type is widely used.

Part I. General

344.1 Scope

Article 344 covers the use, installation, and construction requirements for rigid metal conduit (Type RMC) and the related fittings and couplings. ▶ Figure 344–1

Article 344 establishes the rules for using, installing, and constructing rigid metal conduit (Type RMC) along with the associated fittings and couplings.

▲ Figure 344–1

344.2 Definition

Rigid Metal Conduit (Type RMC): A circular cross-section metal raceway recognized in the code, designed for use with integral threads or with listed couplings intended for joining sections and for connecting to equipment where conductors are pulled. ▶ Figure 344–2

▲ Figure 344–2

Author's Commentary:

Rigid metal conduit is essential when both mechanical strength and resistance to physical harm are required, but the installation site is corrosive to metal. A PVC-coated raceway system (often called "plastibond" and commonly known as "Rob Roy") is widely used in the petrochemical industry for this purpose. Improved corrosion protection is achieved only when all joints are properly sealed. Follow the manufacturer's installation guidelines and take steps to prevent corrosion where tools such as benders, reamers, and pipe wrenches could damage the coating. Couplings with extended skirts are available to be sealed after installation.

— Michael Hamilton

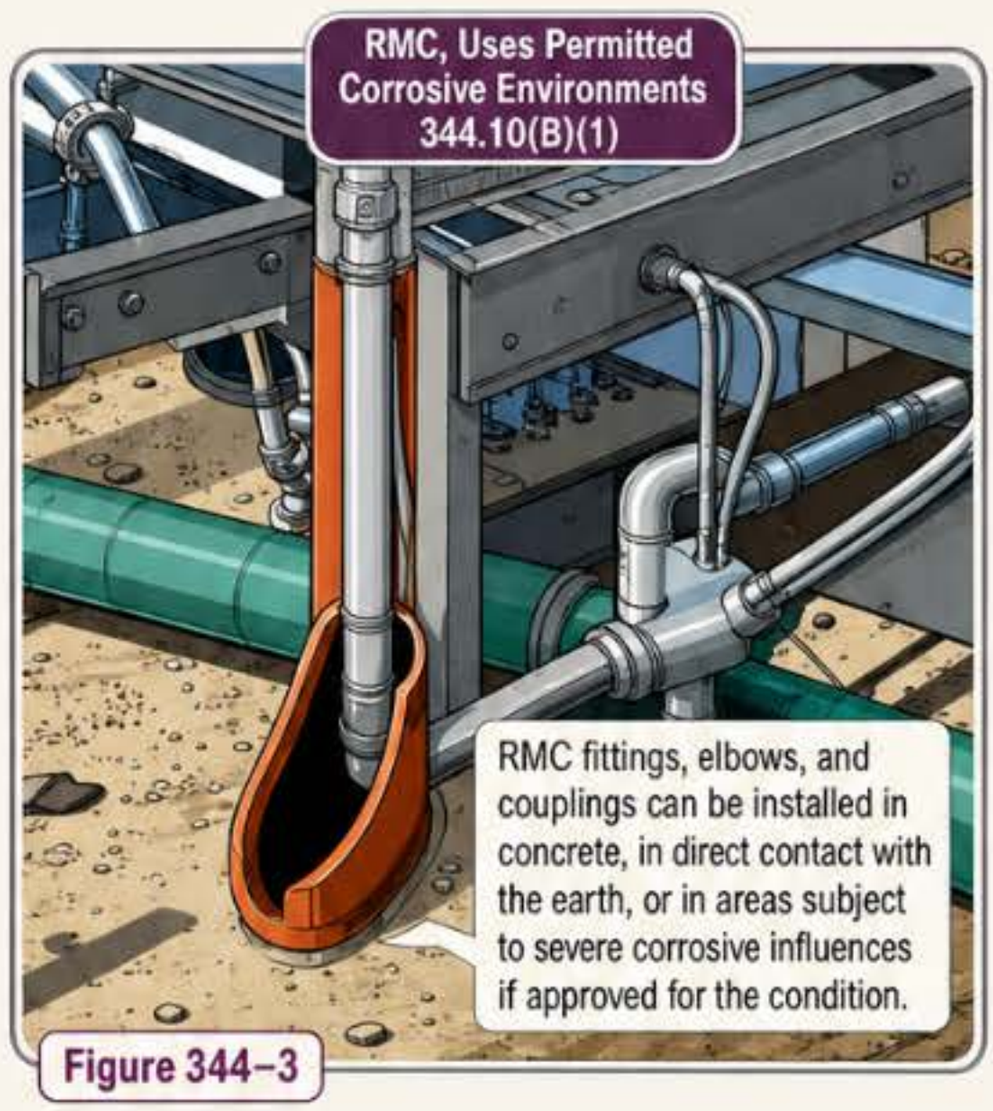


Figure 344–3

344.6 Listing Requirements

RMC and associated fittings must be listed.

Part II. Installation

344.10 Uses Permitted

(A) Atmospheric Conditions and Occupancies.

(1) RMC is permitted in all atmospheric conditions and occupancies.

(B) Corrosive Environments.

(1) RMC fittings, elbows, and couplings can be installed in concrete, in direct contact with the Earth, or in places exposed to severe corrosive influences if approved for the condition. • Figure 344–3

(D) Wet Locations. Support fittings (such as screws, straps, and so forth) installed in a wet location must be made from corrosion-resistant material or provided with corrosion-resistant coatings in accordance with 300.6.

(E) Severe Physical Damage. RMC is permitted where subject to severe physical damage.

344.14 Dissimilar Metals

If practical, contact of RMC with dissimilar metals should be avoided to prevent the deterioration of the metal because of galvanic action. Aluminum and stainless steel fittings and enclosures are permitted to be used with galvanized steel rigid metal conduit where not subject to severe corrosive influences.

344.20 Trade Size

(A) Minimum. RMC smaller than trade size ½ is not permitted.

(B) Maximum. RMC larger than trade size 6 is not permitted to be used.

344.22 Number of Conductors

For complete systems, the number of conductors in RMC is not permitted to exceed the percentage fill specified in Chapter 9, Table 1. Raceways must be large enough to permit the installation and removal of conductors without damaging the conductors' insulation.

Author's Commentary:

- See 300.17 for examples on how to size raceways when conductors are not all the same size.

— Michael Hamilton

344.24 Bends

Racetrack-style bends are not allowed if they could harm the raceway or noticeably reduce its inside diameter (such as by creasing). The radius of any field bend, measured to the bend's centerline, must be at least what's listed in Chapter 9, Table 2.

Author's Commentary:
Follow the manufacturer's written instructions when bending a raceway.
— Michael Hamilton

344.26 Number of Bends (360°)

To limit stress and friction on conductor insulation, the total of all bends (including offsets) between pull points must not exceed 360°. See **Figures 344–4** and **344–5**.

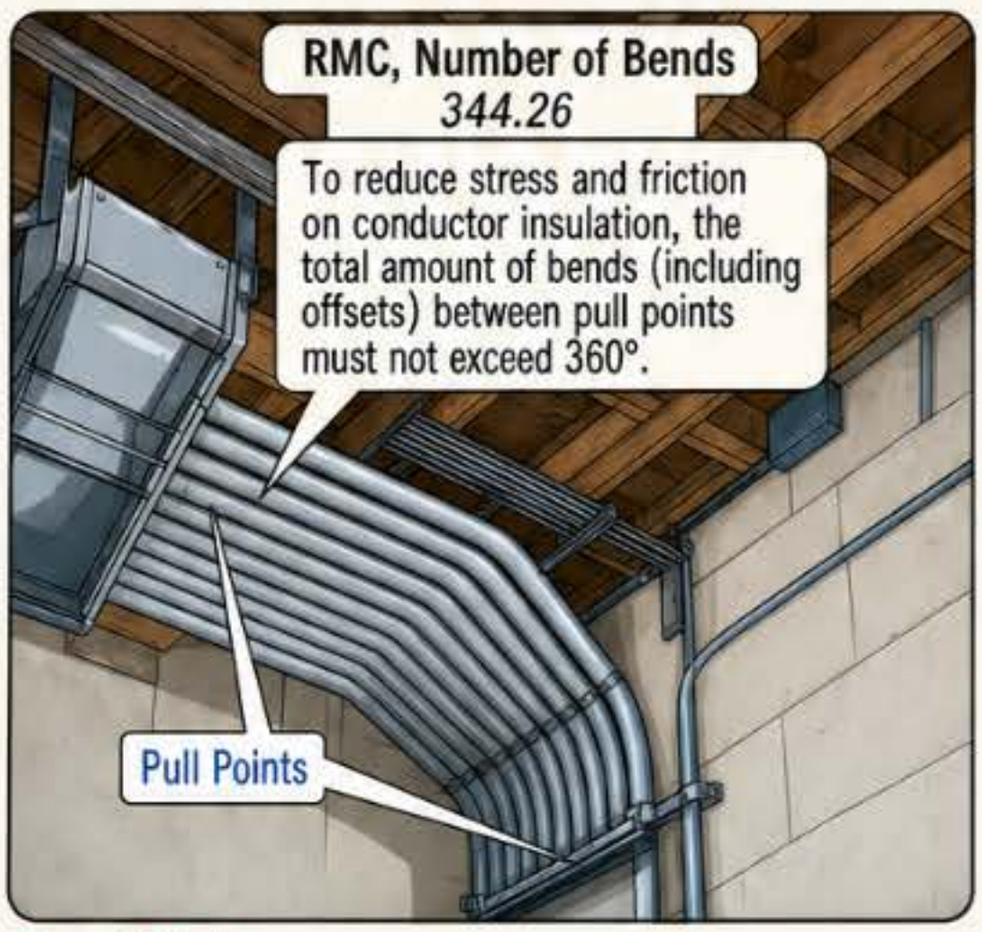


Figure 344–4

Author's Commentary:
There's no set distance between pull boxes because this is a design issue, not a safety issue.
— Michael Hamilton

344.28 Reaming

When the raceway is cut in the field, reaming is required to remove burrs and rough edges.

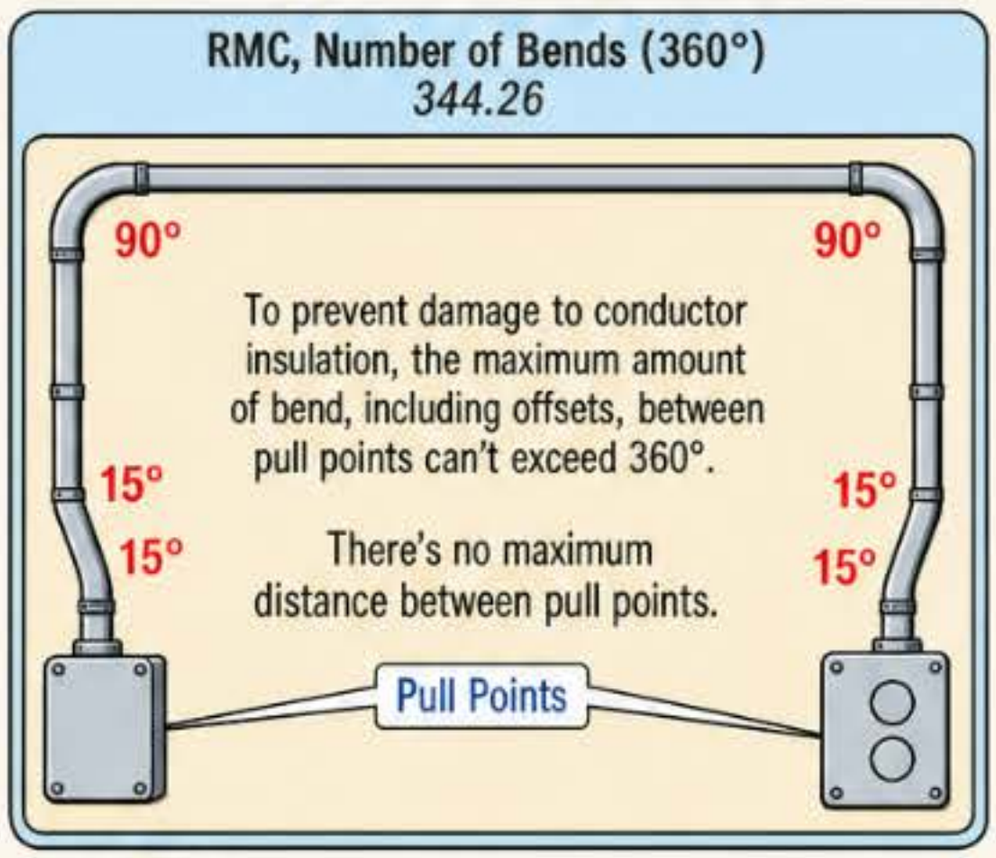


Figure 344–5

Author's Commentary:
It's common practice to ream short raceways from the inside with a screwdriving bit or from the outside with pliers. For long runs, use a reaming tool, such as a three-wheel cutter, to remove sharp edges at the cut end. When the conduit is threaded in the field, coat the threads with an approved conductive, corrosion-resistant compound as required by 300.6(A).
— Michael Hamilton

344.30 Securing and Supporting

RMC must be firmly secured and supported in accordance with (A) and (B).

(A) Securely Fastened. RMC must be secured in accordance with any of the following:

(1) Fastened within 3 ft of each outlet box, junction box, device box, cabinet, conduit body, or other conduit termination. ▸ **Figure 344–6**

Author's Commentary:
Fastening is required within 3 ft of terminations, not within 3 ft of each coupling.
— Michael Hamilton

(2) When structural members do not permit the raceway to be secured within 3 ft of a box or termination fitting, the raceway must be secured within 5 ft of the termination. ▸ **Figure 344–7**

344.30 | Rigid Metal Conduit (Type RMC)

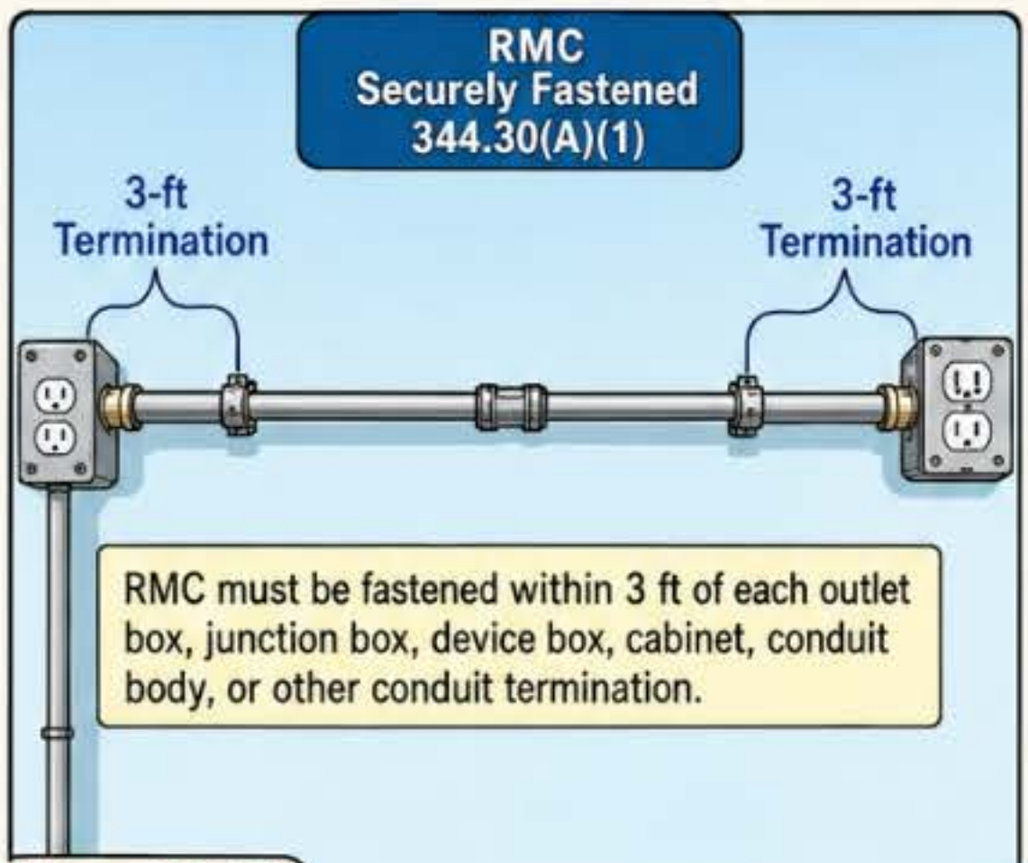


Figure 344-6

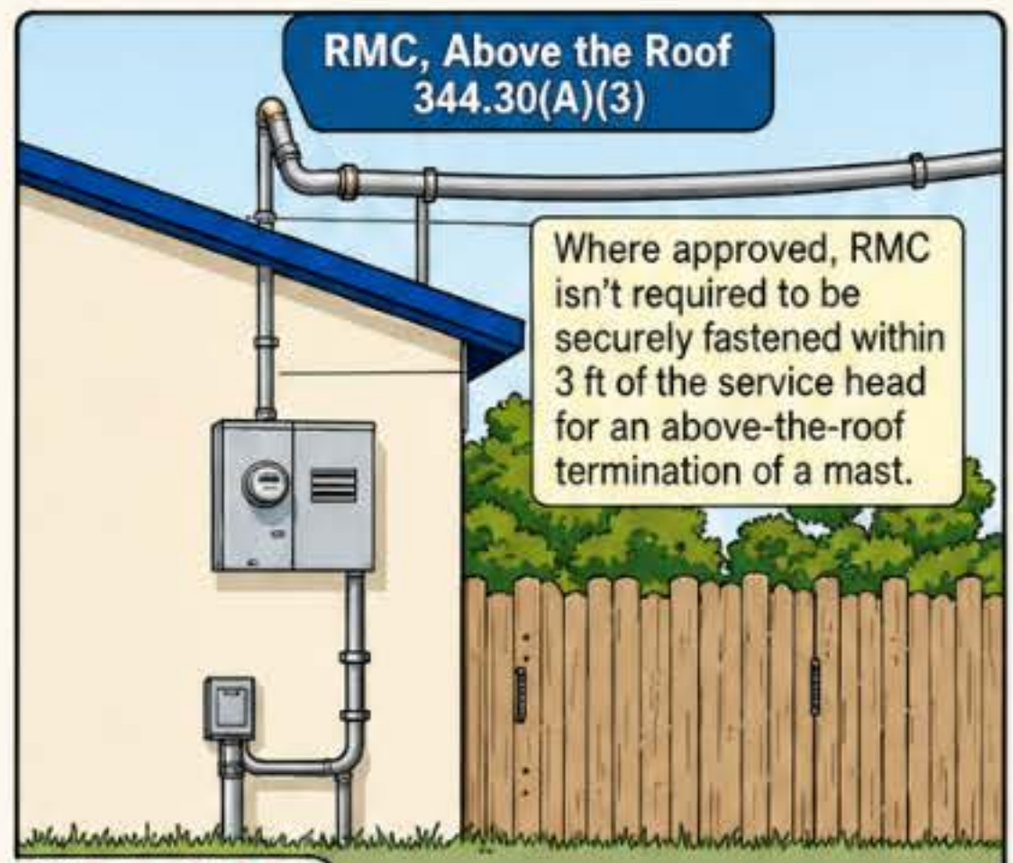


Figure 344-8

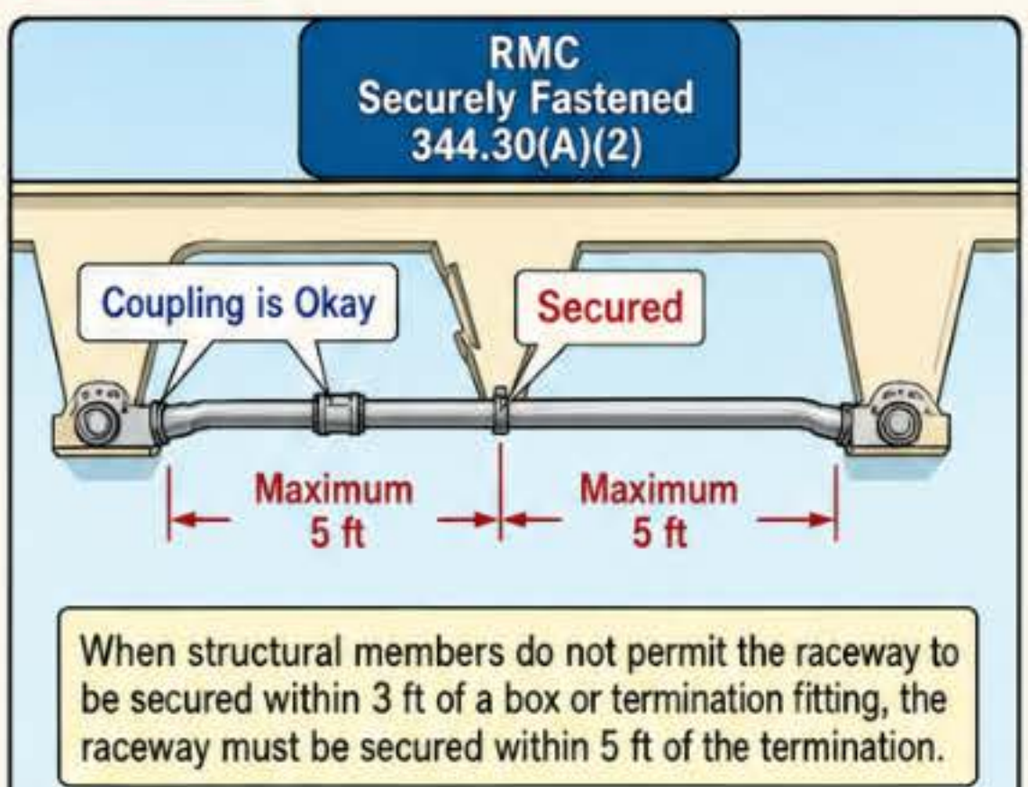


Figure 344-7

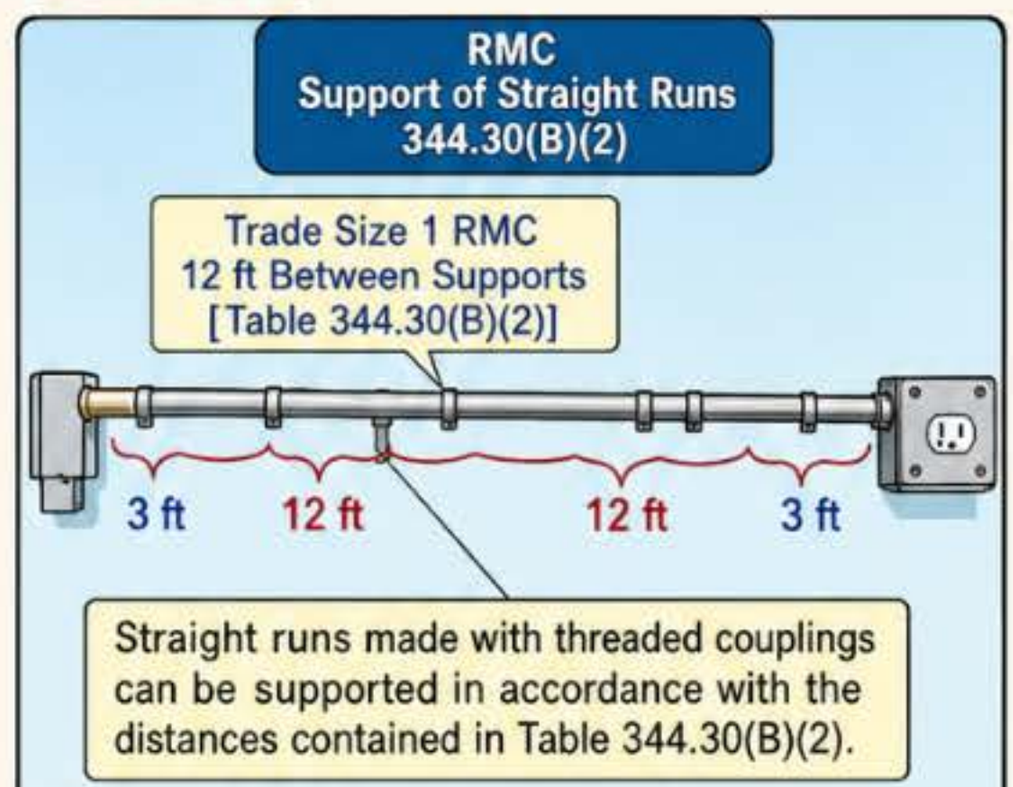


Figure 344-9

(3) Where approved, RMC is not required to be securely fastened within 3 ft of the service head for an above-the-roof termination of a mast. ▶ Figure 344-8

Author's Commentary:
This exception applies only to the vertical segment above the roof where the mast terminates. Every other location still follows the standard fastening rules.
— Michael Hamilton

(B) Supports.

(1) General. RMC must be supported at intervals not exceeding 10 ft.

(2) Straight Runs. Straight runs made with threaded couplings can be supported in accordance with the distances contained in Table 344.30(B)(2). ▶ Figure 344-9

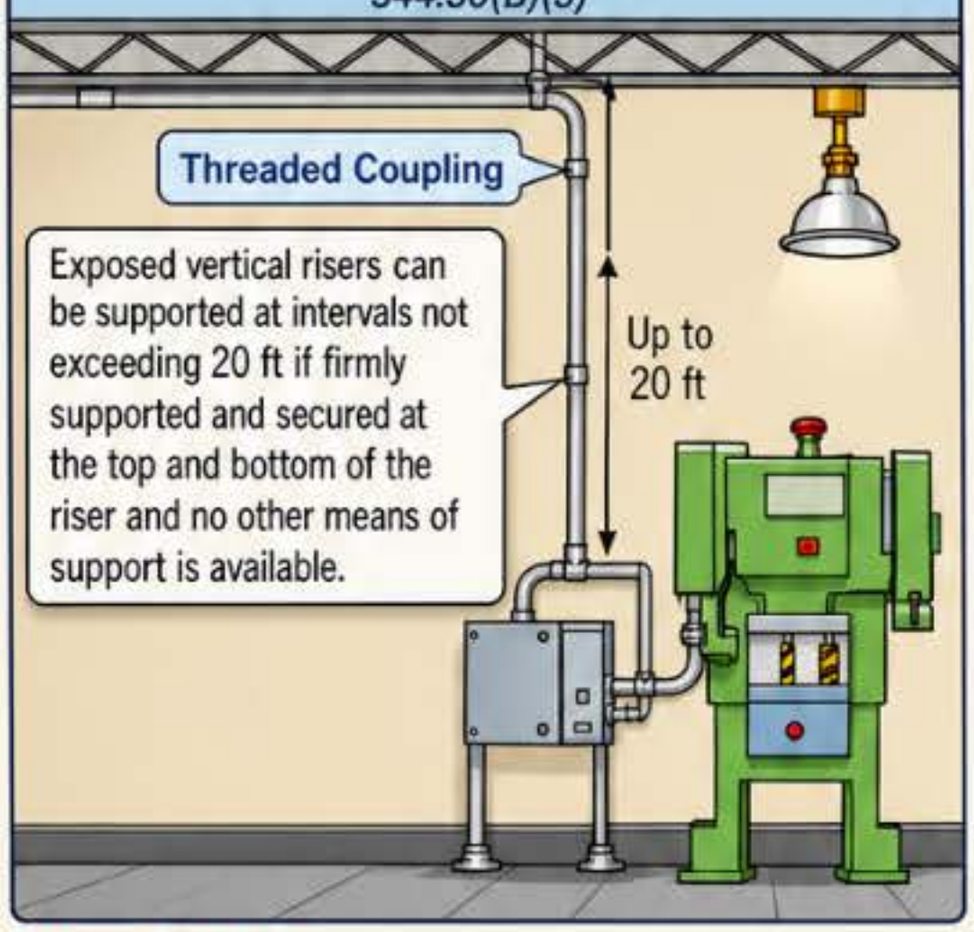
Table 344.30(B)(2) Supports for Rigid Metal Conduit

Trade Size	Support Spacing
½–¾	10 ft
1	12 ft
1¼–1½	14 ft
2–2½	16 ft
3 and larger	20 ft

DEFINITIONS | From Michael Hamilton Publications

(3) Vertical Risers. When a fixed piece of equipment uses exposed vertical risers, these risers may be braced at intervals not greater than 20 ft if the conduit features threaded couplings, is securely supported, and fastening exists at both the top and bottom of the riser. Support is also acceptable by other methods.

RMC, Support of Vertical Risers
344.30(B)(3)



▶ Figure 344–10

(4) Horizontal Runs. When conduit is installed horizontally through bored holes or notches in wood or metal framing members, or through notches in wood members, it is considered supported. However, the raceway run must be secured within 3 ft of the termination.

Author's Commentary:

RMC must be equipped with expansion fittings where needed to offset thermal expansion and contraction [300.7(B)]. Multiply the values from Table 352.44 by 0.20, then multiply the aluminum raceway values by the values from Table 352.44 by 0.40 to find the expansion space [300.7 Note].

— Michael Hamilton

344.42 Couplings and Connectors

(A) Installation. Threadless couplings and connectors must *be installed snugly to maintain a reliable equipment grounding path to safely conduct fault current per 250.4(A)(5), 250.96(A), and 300.10.*

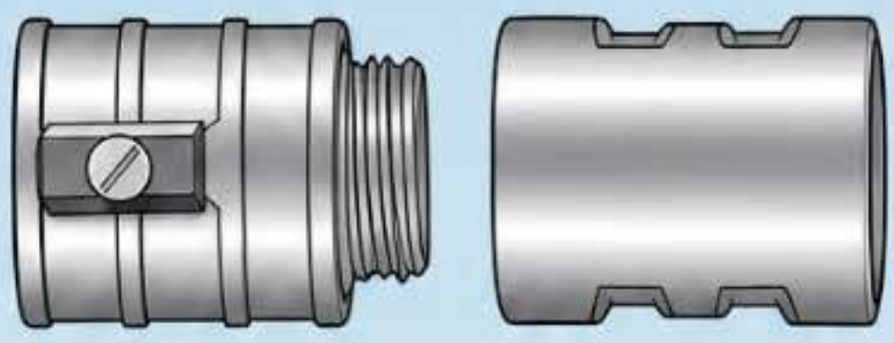
Author's Commentary:

Loose locknuts have been found to burn off before a fault is cleared because loose connections increase impedance of the ground-fault current path.

— Michael Hamilton

If buried in masonry or concrete, threadless fittings must be of the concrete-tight type. If installed in wet locations, fittings must be listed for wet locations and designed to keep moisture or water from entering or collecting inside the enclosure per 314.15. ▶ Figure 344–11

RMC
Threadless Couplings and Connectors
344.42(A)



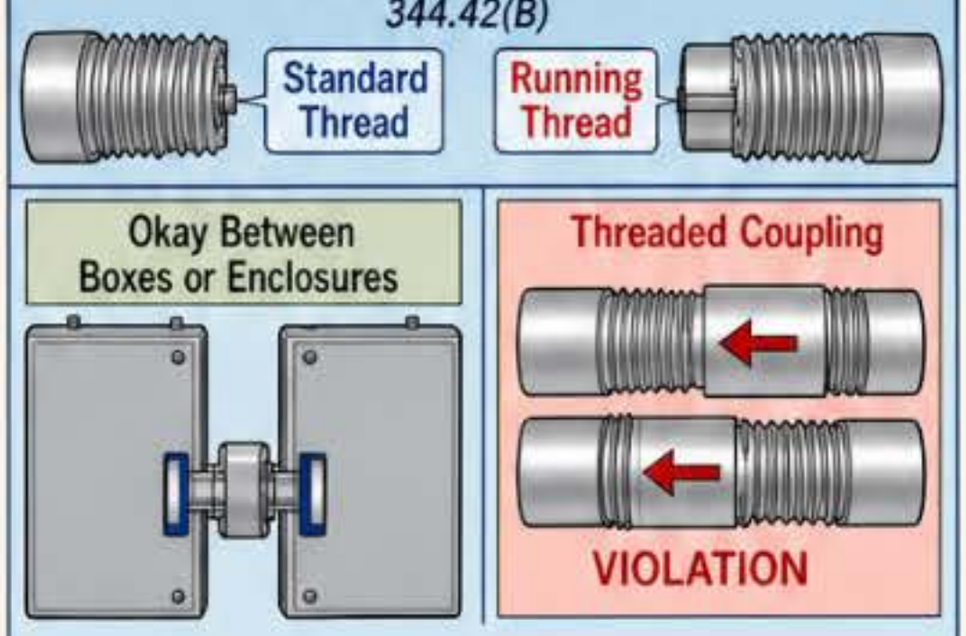
Threadless fittings must be of the concrete-tight type if buried in concrete or masonry.

If installed in a wet location, they must be listed for use in wet locations.

▶ Figure 344–11

(B) Running Threads. Running threads are not allowed for joining couplings, but they are accepted at other locations. ▶ Figure 344–12

RMC, Running Threads
344.42(B)



Running threads aren't permitted for the connection of couplings, but they're permitted at other locations.

▶ Figure 344–12

344.46 | Rigid Metal Conduit (Type RMC)

344.46 Bushings

Conductor protection from wear, abrasion, and mechanical damage is essential. Therefore, a metal or nonmetallic bushing must be placed on conduit threads at termination points (no matter the conductor type). This requirement applies unless the box, fitting, or enclosure is specifically designed to provide that same level of protection.

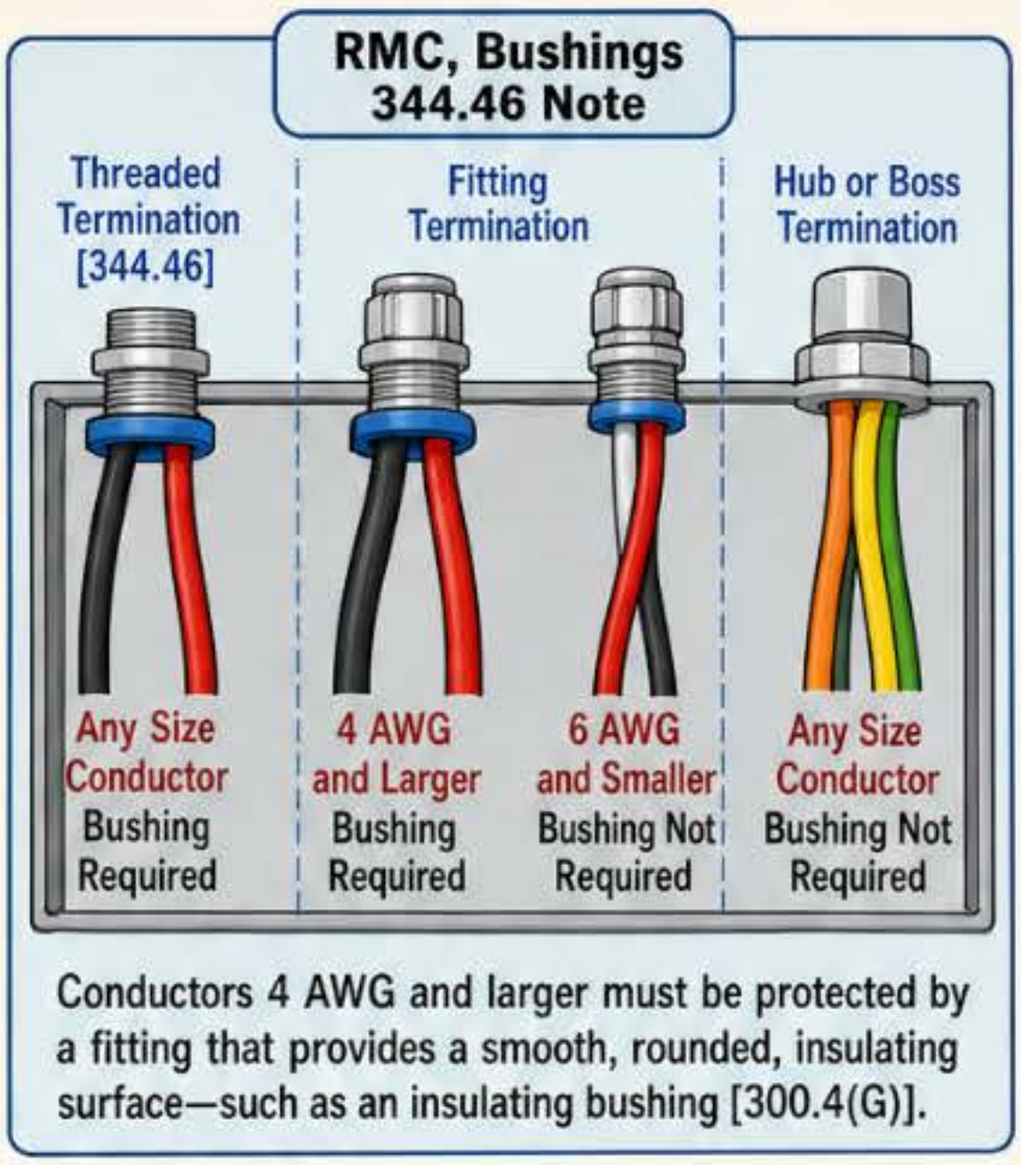
Author's Commentary:

Per UL 514B, section 5.4.1.1, the standard states: "Whenever a coupling or locknut is used, the installation must include a positive end stop for the conduit and a smooth, rounded throat to shield insulation from abrasion as it enters the fitting."

— Michael Hamilton

Note: Any conductors 4 AWG or larger that terminate inside an enclosure must be protected from abrasion during installation. To meet this requirement, the *termination must provide a smooth, rounded, insulating surface that shields the conductor where it passes through the box, connector, or enclosure opening. This protection is required to be equivalent to insulating bushing protection specified in 300.4(G).*

▶ *See Figure 344–13.*



▶ **Figure 344–13**

344.60 Equipment Grounding Conductor

Rigid metal conduit (RMC) can serve as an equipment grounding conductor.

ARTICLE 348

FLEXIBLE METAL CONDUIT (TYPE FMC)

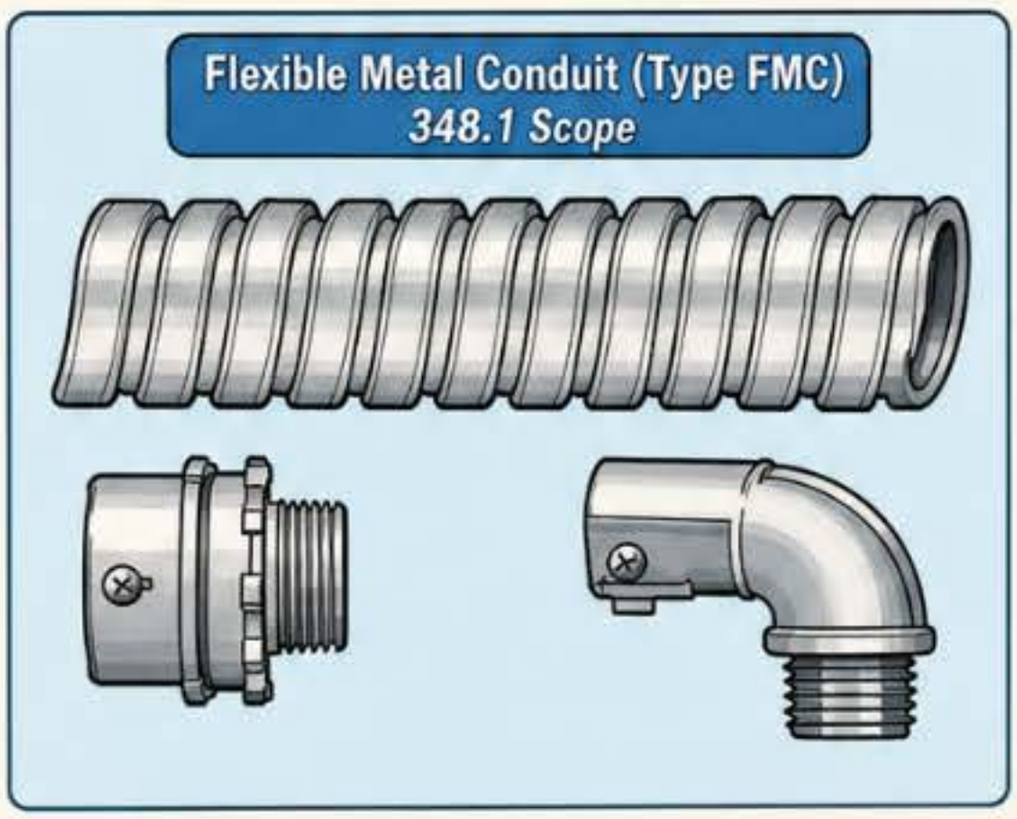
Introduction to Article 348—Flexible Metal Conduit (Type FMC)

Flexible metal conduit (Type FMC), commonly referred to as "Greenfield" after its inventor, or "flex," is an interlocked metal strip raceway made from either steel or aluminum. It is primarily used in situations where flexibility is beneficial, such as when accommodating equipment movement, vibration, or shaking.

Part I. General

348.1 Scope

Article 348 addresses the application, installation, and construction requirements for flexible metal conduit (FMC) and the fittings that are used with it. ▶Figure 348–1

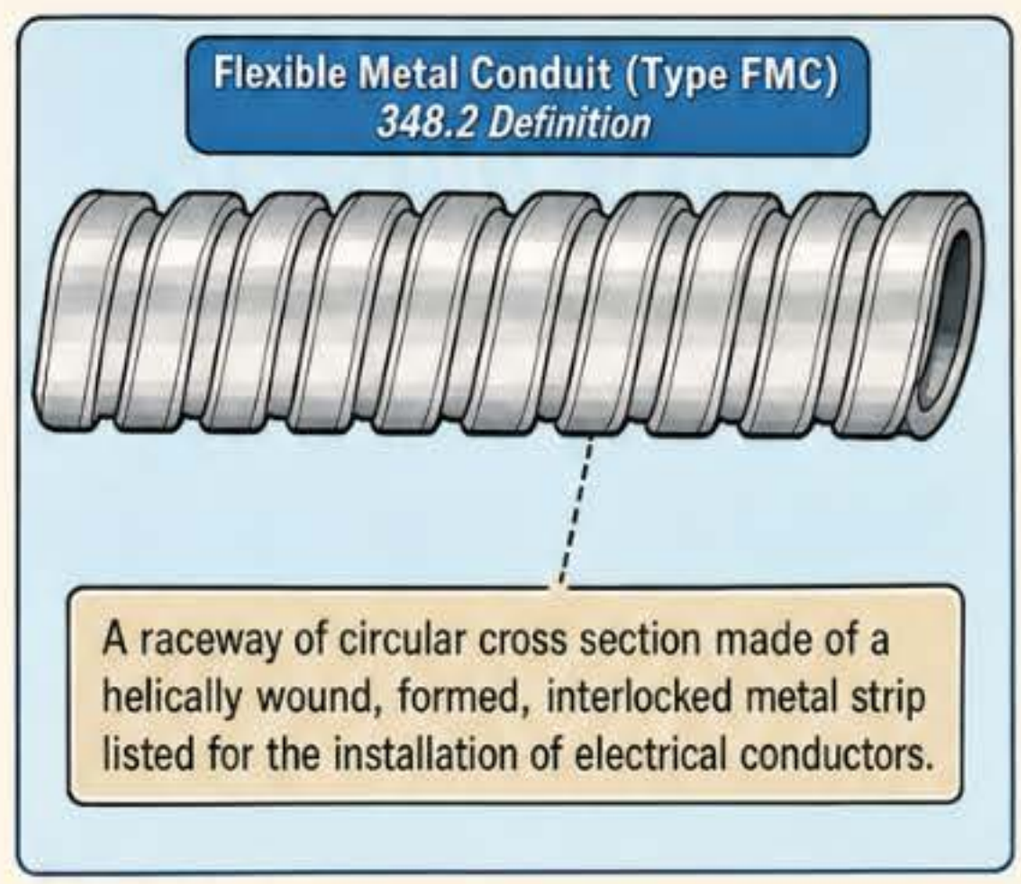


▶Figure 348–1

348.2 Definition

Flexible Metal Conduit (Type FMC). A raceway of circular cross section made of a helically wound, formed, interlocked metal strip, listed for the installation of electrical conductors.

▶Figure 348–2



▶Figure 348–2

348.6 Listing Requirements

Flexible metal conduit and associated fittings must be listed.

Part II. Installation

348.10 Uses Permitted

FMC is permitted to be installed exposed or concealed.

348.12 Uses Not Permitted

FMC is not permitted:

(1) In wet locations. ▶Figure 348–3

348.20 Flexible Metal Conduit (Type FMC)

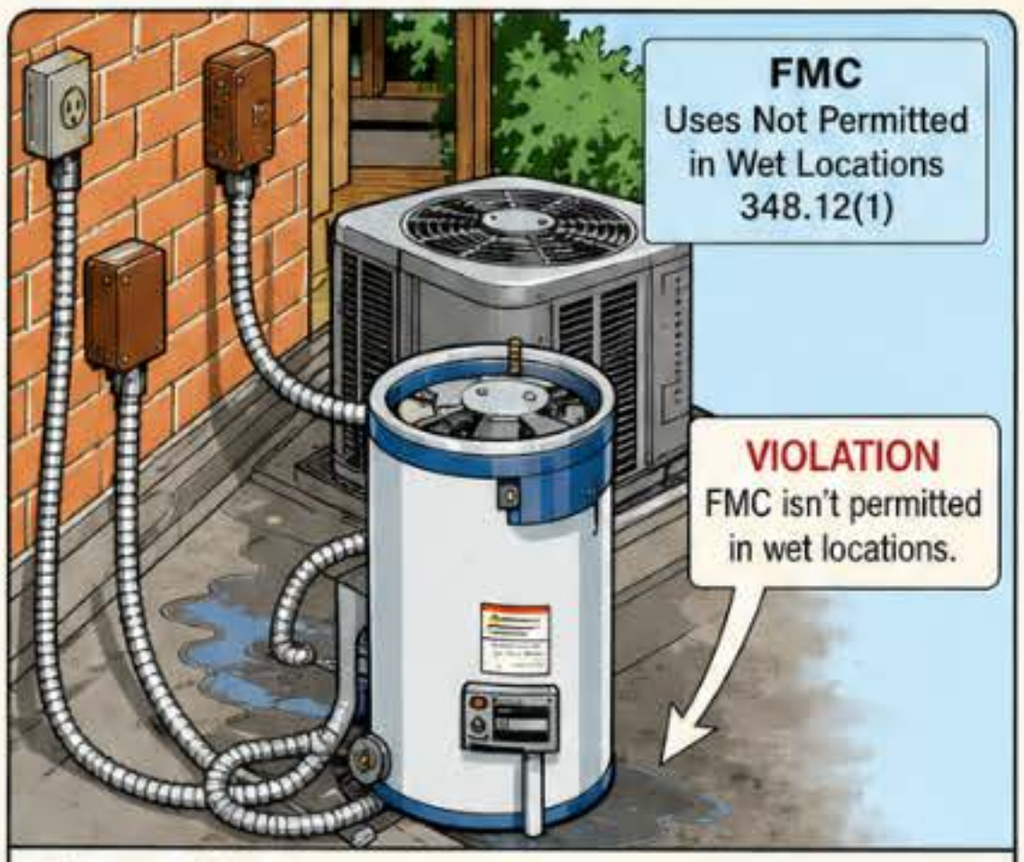


Figure 348–3

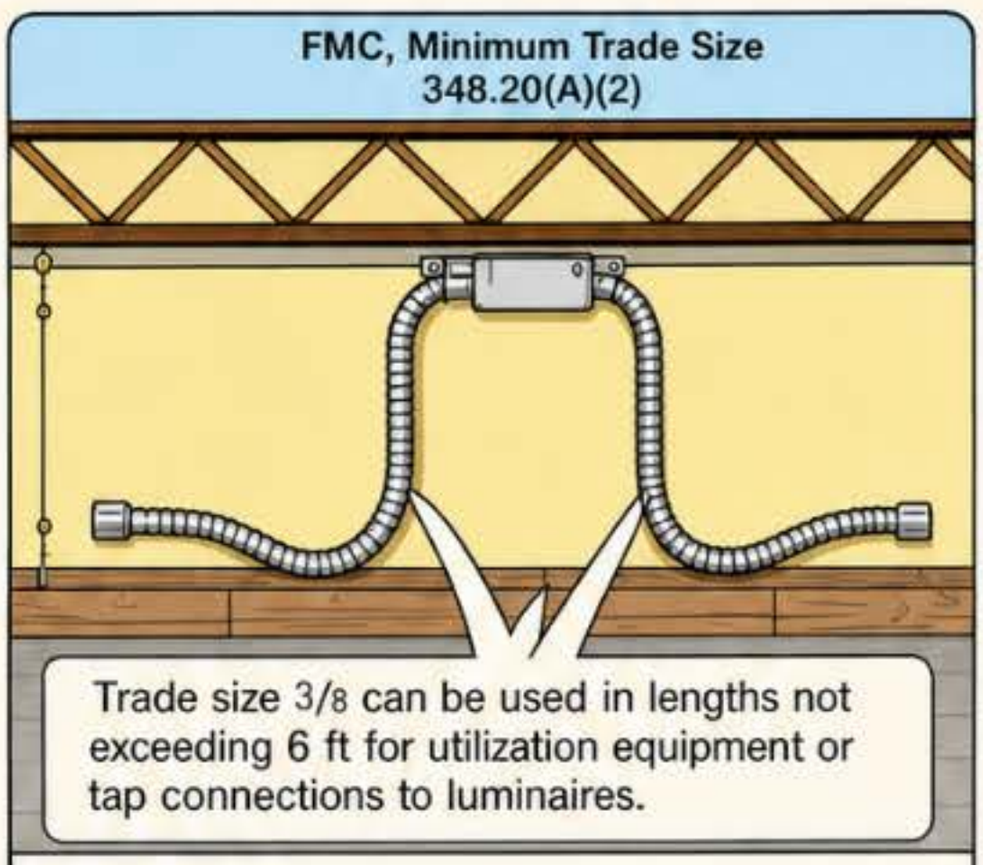


Figure 348–4

(2) In hoistways, other than as permitted in 620.21(A)(1).

(3) In storage battery rooms.

(4) In any hazardous (classified) location, except as permitted by 501.10(B).

(5) Exposed to material having a deteriorating effect on the installed conductors.

(6) Underground or embedded in poured concrete.

(7) Where subject to physical damage.

348.20 Trade Size

(A) Minimum. The trade size 1/2, except trade size 3/8, is allowed for the following applications:

(1) For enclosing the leads of motors.

(2) Not exceeding 6 ft in length: ▶ Figure 348–4

a. For utilization equipment,

b. As part of a listed assembly, or

c. For luminaire tap connections in accordance with 410.117(C).

(B) Maximum. The trade size 4.

348.22 Number of Conductors

For FMC trade size 1/2 and larger, the raceway must be sufficiently large to allow installation and removal of conductors without harming conductor insulation. If all conductors in a raceway are the same size and insulation, the permitted number of conductors is found in Annex C for the raceway type.

The number of conductors in FMC is not permitted to exceed the percentage fill specified in Chapter 9, Table 1. Raceways must be large enough to permit the installation and removal of conductors without damaging the conductor insulation.

▶ Example

Question: *How many 6 THHN conductors can be installed in trade size 1" FMC?*

(a) 2 conductors *(b) 4 conductors*
(c) 6 conductors *(d) 8 conductors*

Answer: *(c) 6 conductors [Annex C, Table C.3]*

Author's Commentary:

▶ See 300.17 for examples on how to size raceways when conductors are not all the same size.

— Michael Hamilton

Trade Size 3/8. The number and size of conductors in 3/8" FMC must comply with Table 348.22.

▶ Example

Question: *How many 12 THHN conductors can be installed in trade size 3/8 type FMC that uses outside fittings?*

(a) 2 conductors *(b) 3 conductors*
(c) 4 conductors *(d) 5 conductors*

Solution:

Only one insulated, jacketed, or bare equipment grounding conductor that is the same size as the circuit conductors is allowed. See the "" note at the bottom of Table 348.22.*

Answer: *(b) 3 conductors [Table 348.22]*

FMC can be installed when the total cross-sectional area of the cables does not exceed the fill percentage listed in Chapter 9, Table 1.

348.24 Bends

Bends must be formed so that the conduit is not damaged, and the inside diameter is not reduced in any practical way. The bending radius of the inner wall at any location is not permitted to be less restrictive than "Other Bends" specified in Chapter 9, Table 2.

348.26 Number of Bends (360°)

The combined angle of bends (including offsets) between pulling points must not add up to more than 360°.

348.28 Trimming

The cut ends of FMC must be trimmed to remove uneven edges, although tapping threads into the conduit is not a requirement.

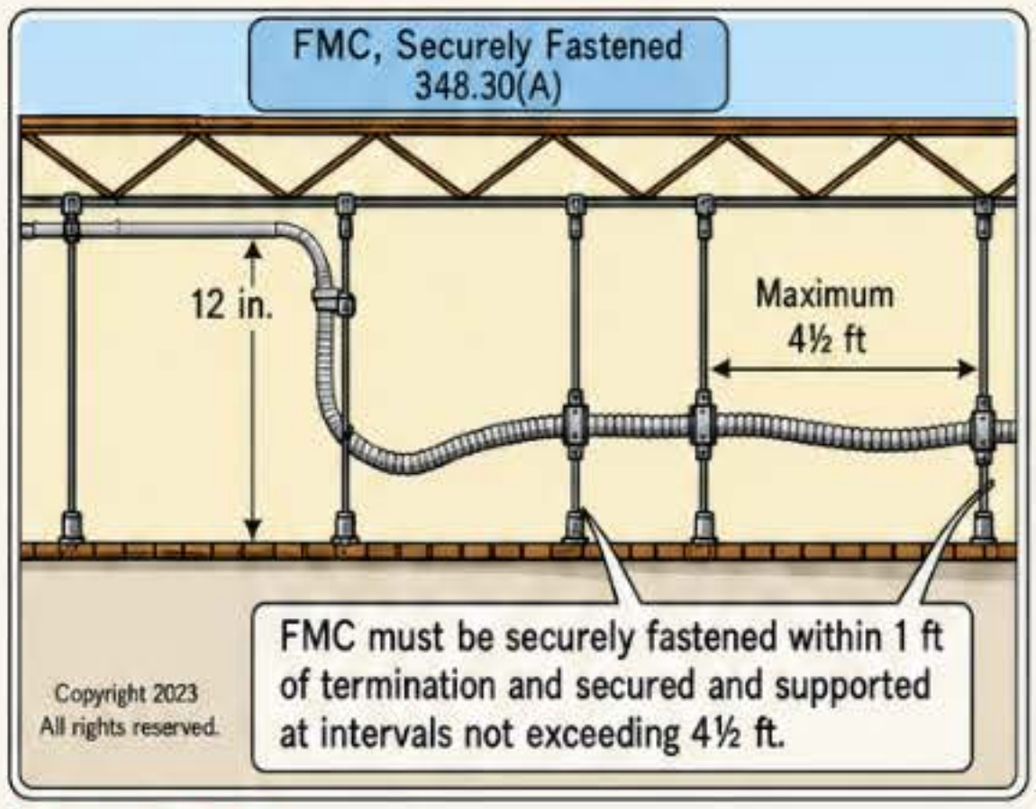
348.30 Securing and Supporting

(A) Securely Fastened. FMC must be firmly secured using approved methods determined by the authority having jurisdiction. It must be anchored and supported at steps not exceeding 4½ ft. ▶ *Figure 348–5*

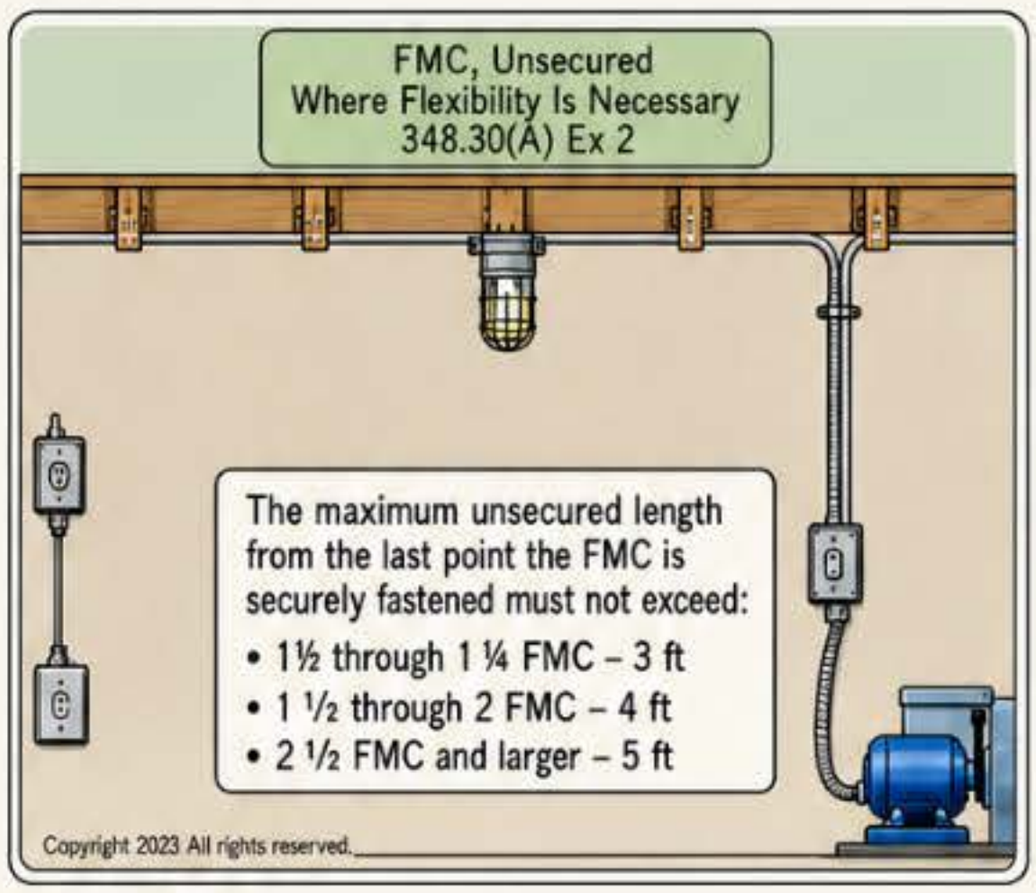
Where cable ties are used for securing and supporting Type FMC, they must be identified and listed for that application.

Example 1: Type FMC is not required to be firmly secured or supported when the section between pulling points runs through hidden or inaccessible locations and supporting it is not possible.

Example 2: If flexibility is needed after installation, any unsecured length starting at the last fastening point may not be longer than: ▶ *Figure 348–6*



▶ *Figure 348–5*



▶ *Figure 348–6*

(1) 3 ft for trade sizes ½ through 1¼

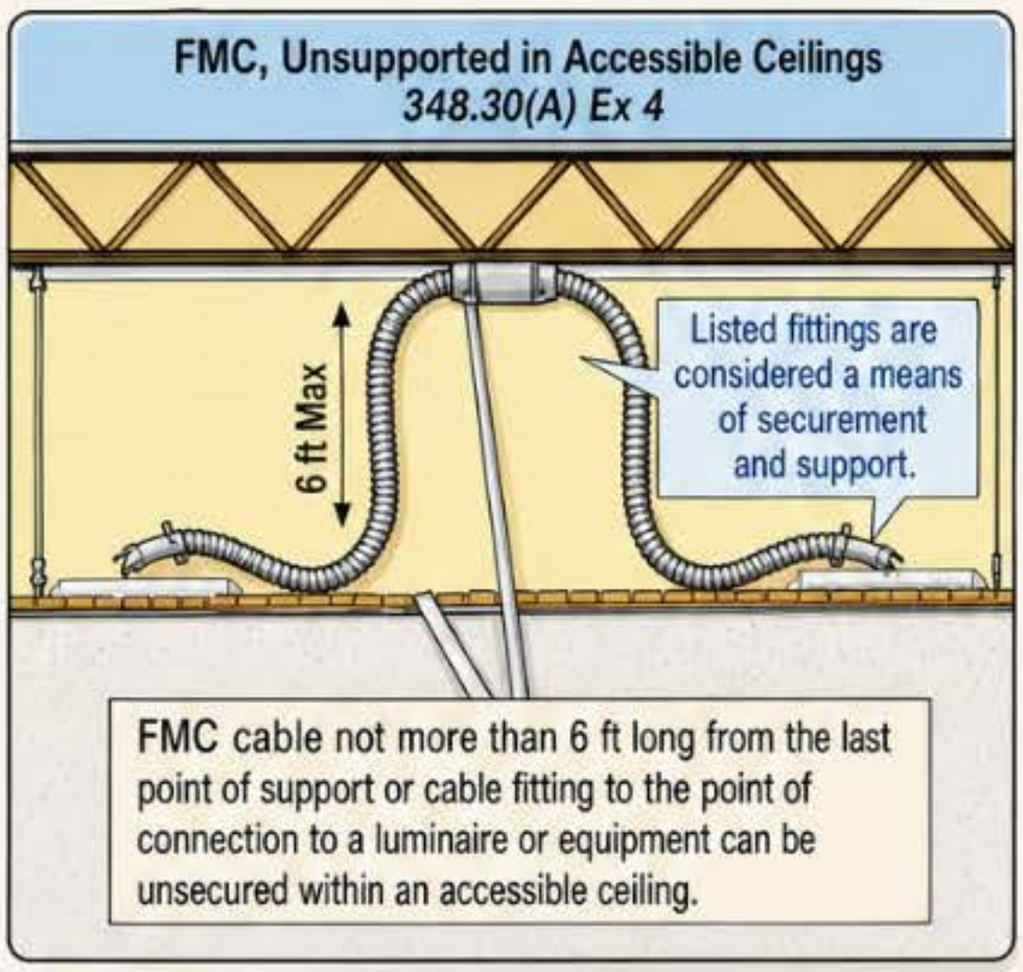
(2) 4 ft for trade sizes 1½ through 2

(3) 5 ft for trade sizes 2½ and larger

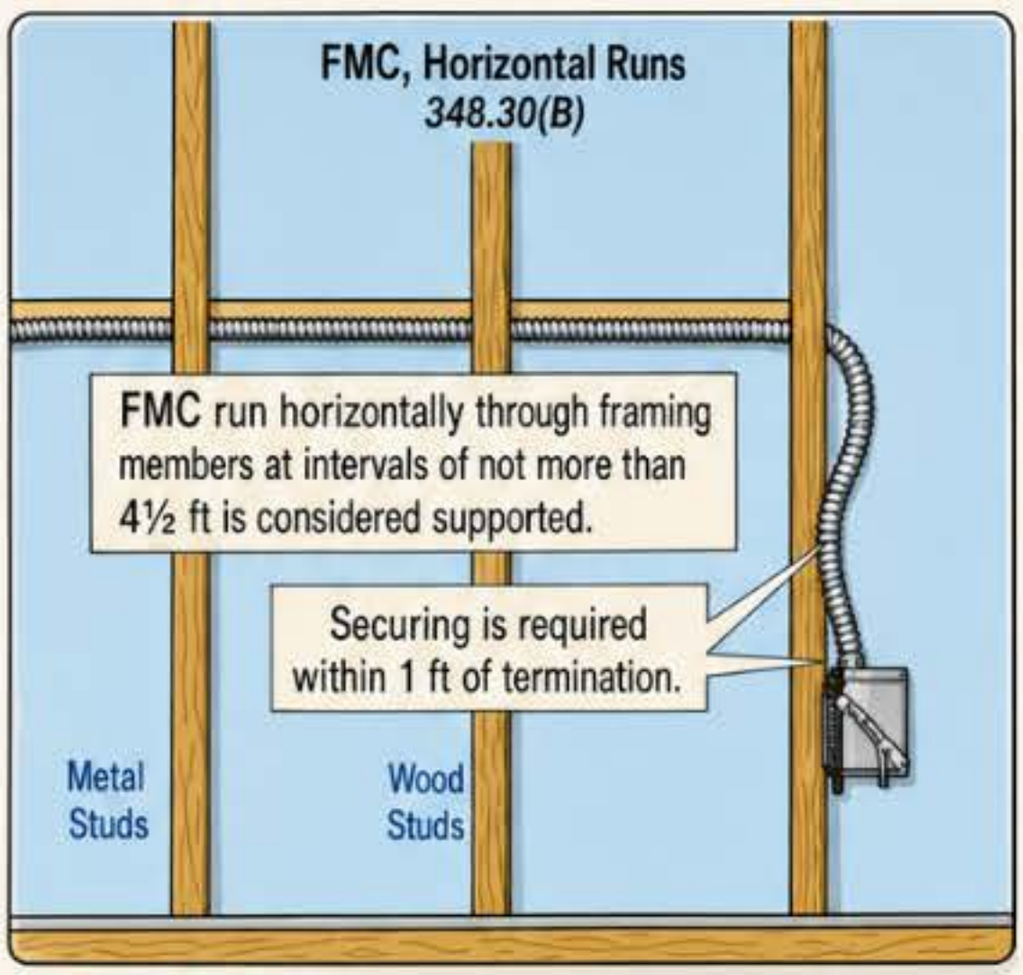
Ex 4: Lengths not exceeding 6 ft from the final location where the raceway is securely fastened are considered unsecured within an accessible ceiling for a luminaire or other equipment. Listed fittings are regarded as a means of securing and supporting. ▶ *Figure 348–7*

(B) Horizontal Runs. FMC installed horizontally through bored or punched holes in wood or metal framing members, or through notches in wooden members, at intervals not *more than 4½ ft, is considered supported, as long as the raceway is secured within 1 ft of its terminations.* ▶ *Figure 348–8*

348.60 | Flexible Metal Conduit (Type FMC)



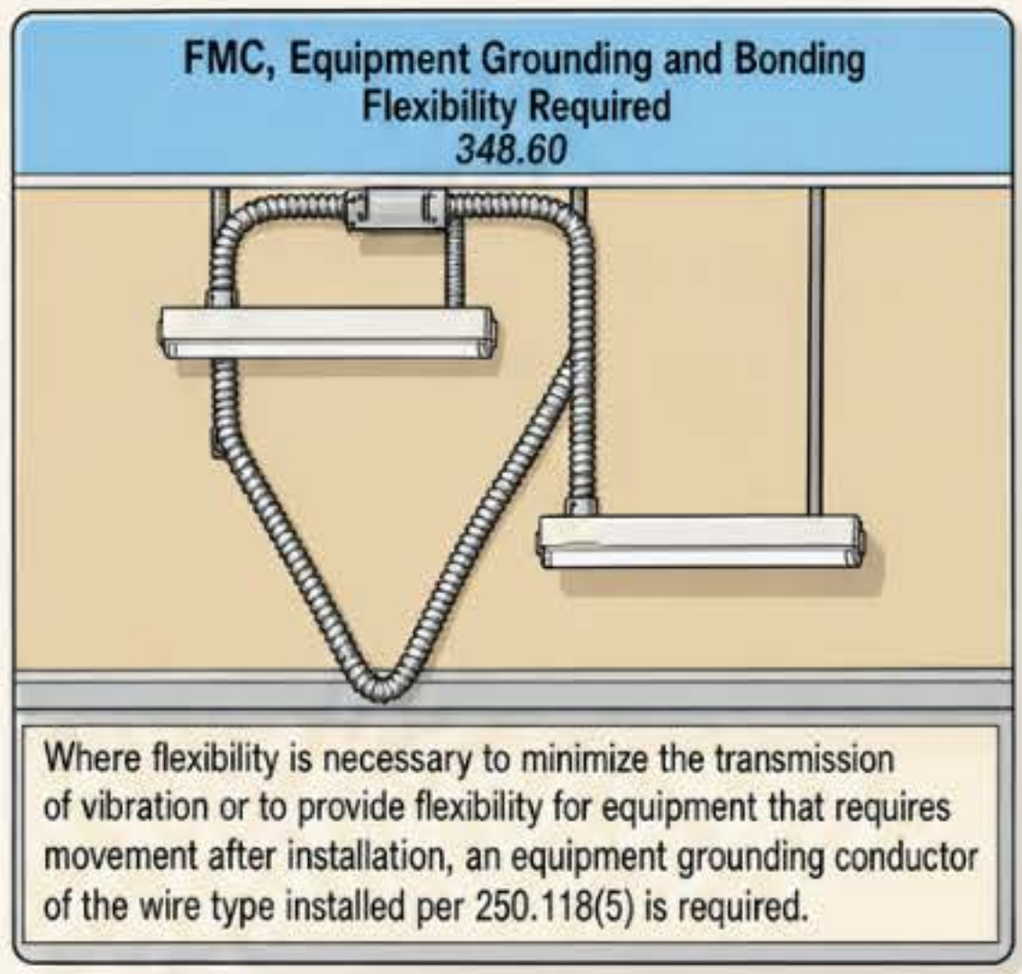
▶ Figure 348–7



▶ Figure 348–8

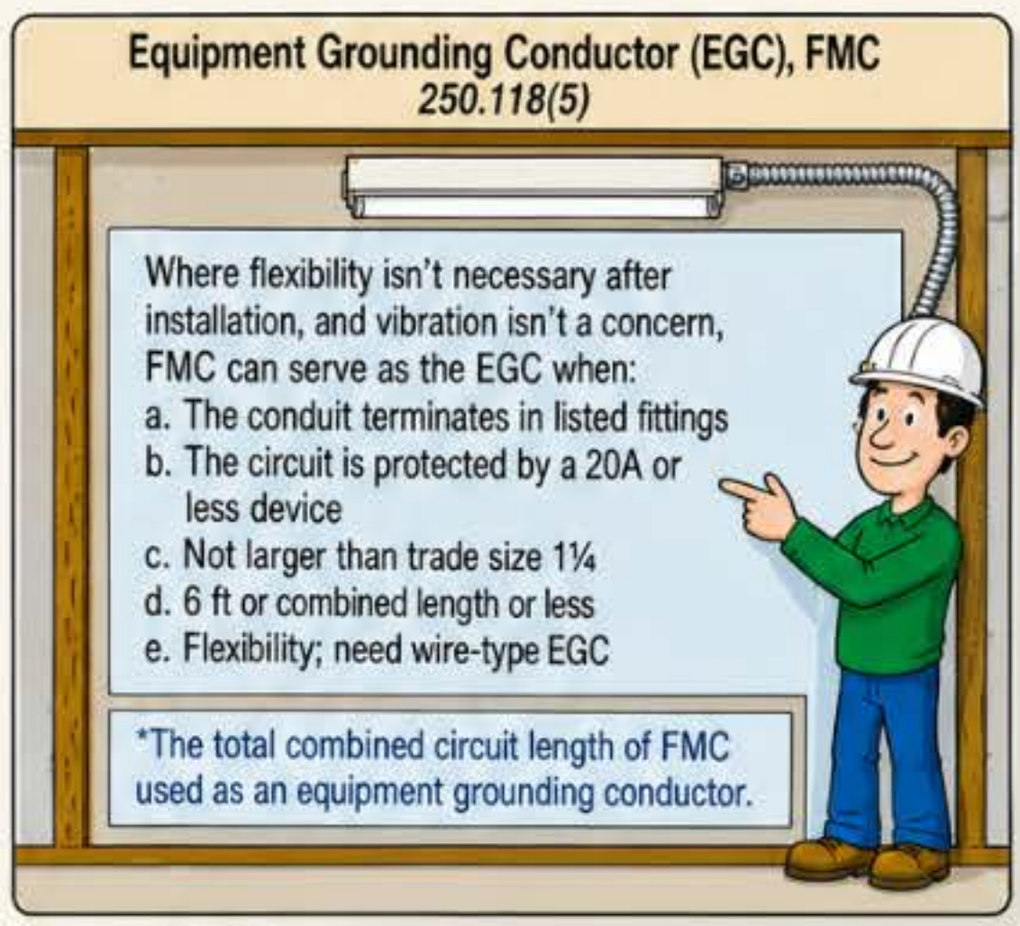
348.60 Equipment Grounding and Bonding Conductors

If flexibility is necessary to minimize the transmission of vibration from equipment, or to provide flexibility for equipment that requires movement after installation, an equipment grounding conductor of the wire type must be installed with the circuit conductors in accordance with 250.118(5). ▶ Figure 348–9



▶ Figure 348–9

If flexibility is not necessary after installation, and vibration is not a concern, the metal armor of FMC can serve as an equipment grounding conductor if the circuit conductors contained in the raceway are protected by an overcurrent protective device rated 20A or less, and the combined length of the raceway in the same ground-fault return path does not exceed 6 ft [250.118(5)]. ▶ Figure 348–10



▶ Figure 348–10

The equipment bonding jumper can be installed inside or outside the flexible metal conduit. Where installed outside the FMC, the length of the equipment bonding jumper is not permitted to exceed 6 ft and it must be routed with the flexible metal conduit in accordance with 250.102(E)(2).

ARTICLE 350

LIQUIDTIGHT FLEXIBLE METAL CONDUIT (TYPE LFMC)

Introduction to Article 350—Liquidtight Flexible Metal Conduit (Type LFMC)

Liquidtight flexible metal conduit (Type LFMC), along with its connectors and fittings, is a flexible raceway commonly used to join equipment that vibrates or may be moved from time to time.

Often referred to as "Sealtight" or "liquidtight," it is like flexible metal conduit, but it includes an outer liquidtight thermoplastic covering. LFMC serves the same core purpose as flexible metal conduit and also helps shield against liquids and provides some resistance to corrosion.

Part I. General

350.1 Scope

Article 350 covers how to use, install, and build to when working with liquidtight flexible metal conduit (Type LFMC) and its associated connectors and fittings.

Figure 350-1

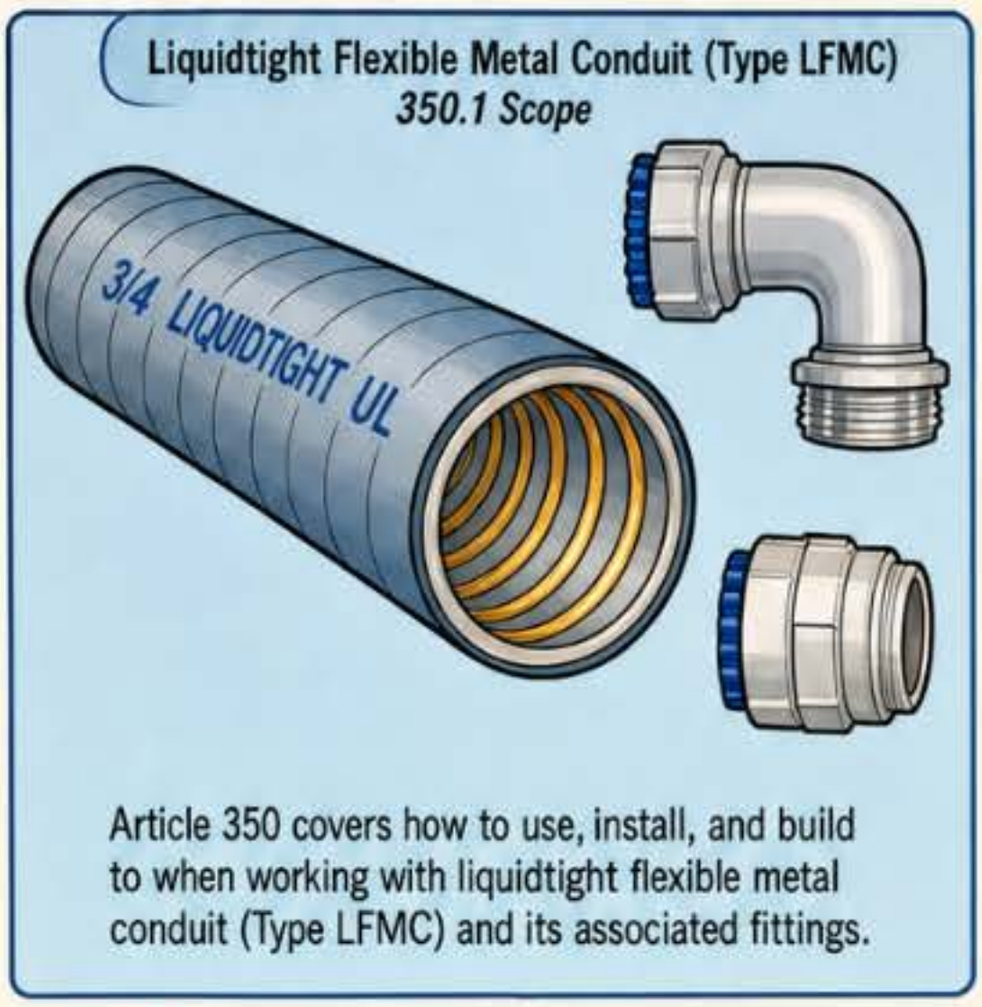


Figure 350-1

350.2 Definition

Liquidtight Flexible Metal Conduit (Type LFMC). A circular cross section raceway that has an outer liquidtight, nonmetallic, sunlight-resistant jacket over an inner flexible metal core, along with its associated connectors and fittings, used when installing electrical conductors.

Figure 350-2

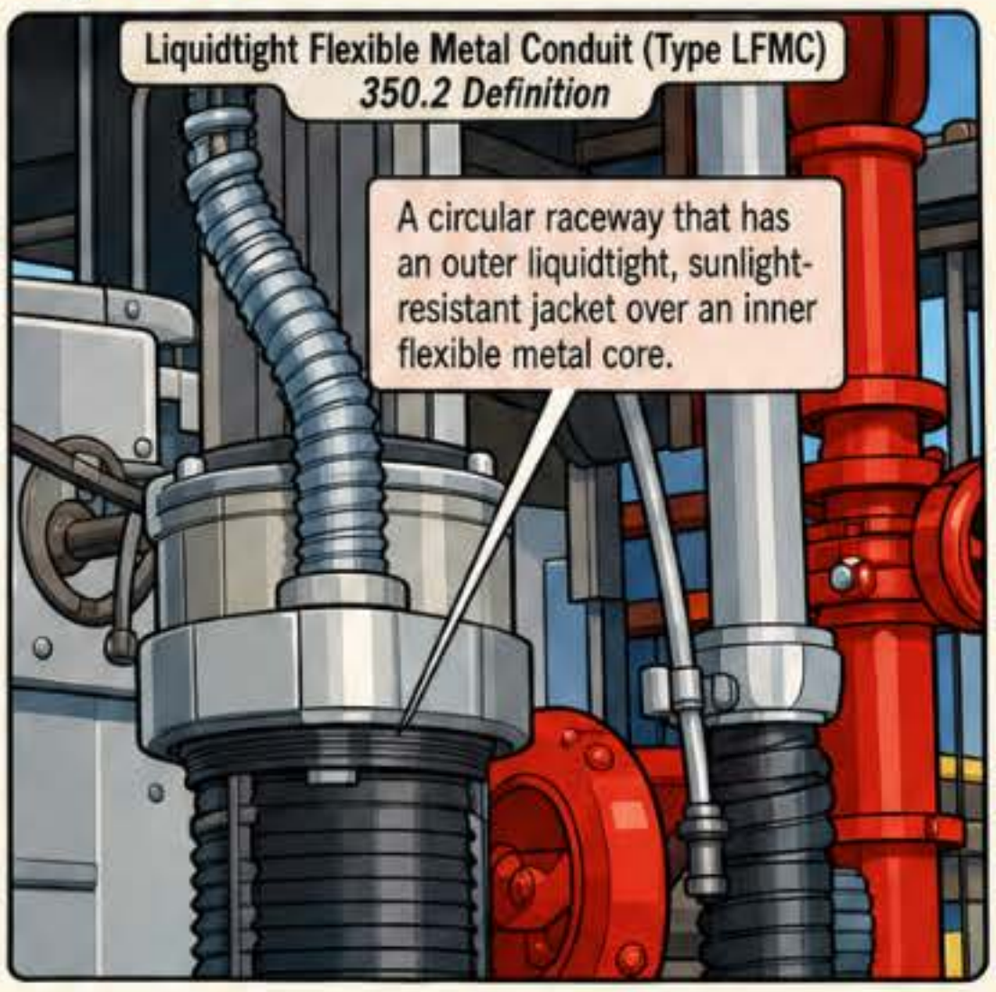


Figure 350-2

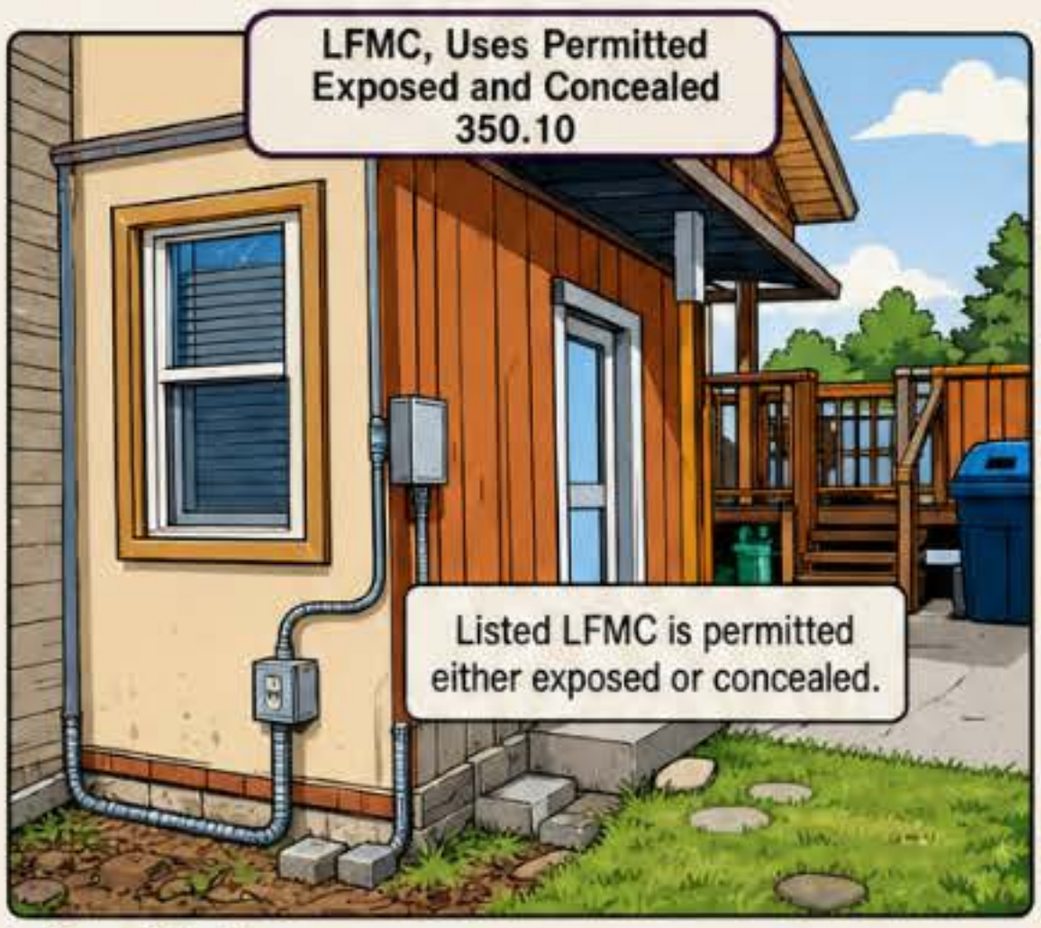
350.6 Listing Requirements

Type LFMC and its associated fittings must be listed.

Part II. Installation

350.10 Uses Permitted

Listed LFMC is permitted, either exposed or concealed, at any of the following locations: ▶ Figure 350–3

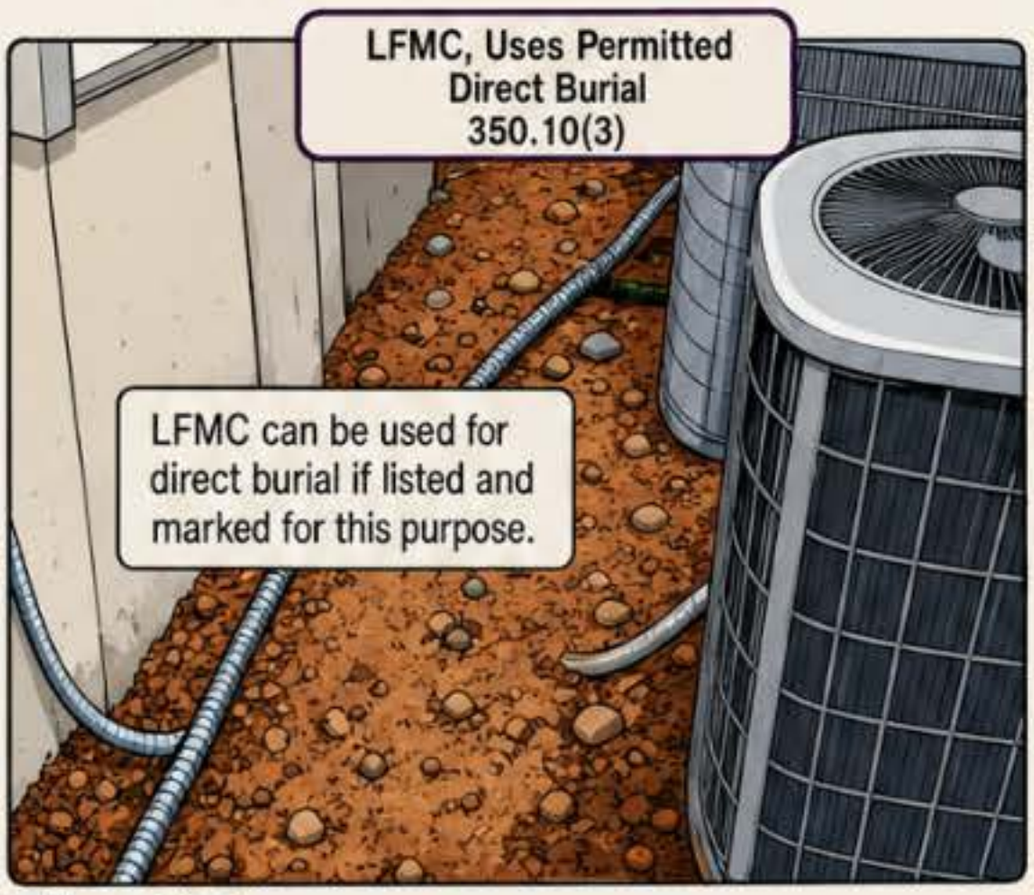


▶ Figure 350–3

(1) If flexibility or protection from machine oils, liquids, vapors, or solids is required.

(2) In hazardous (classified) locations as permitted in Chapter 5.

(3) For direct burial if listed and marked for this purpose. ▶ Figure 350–4

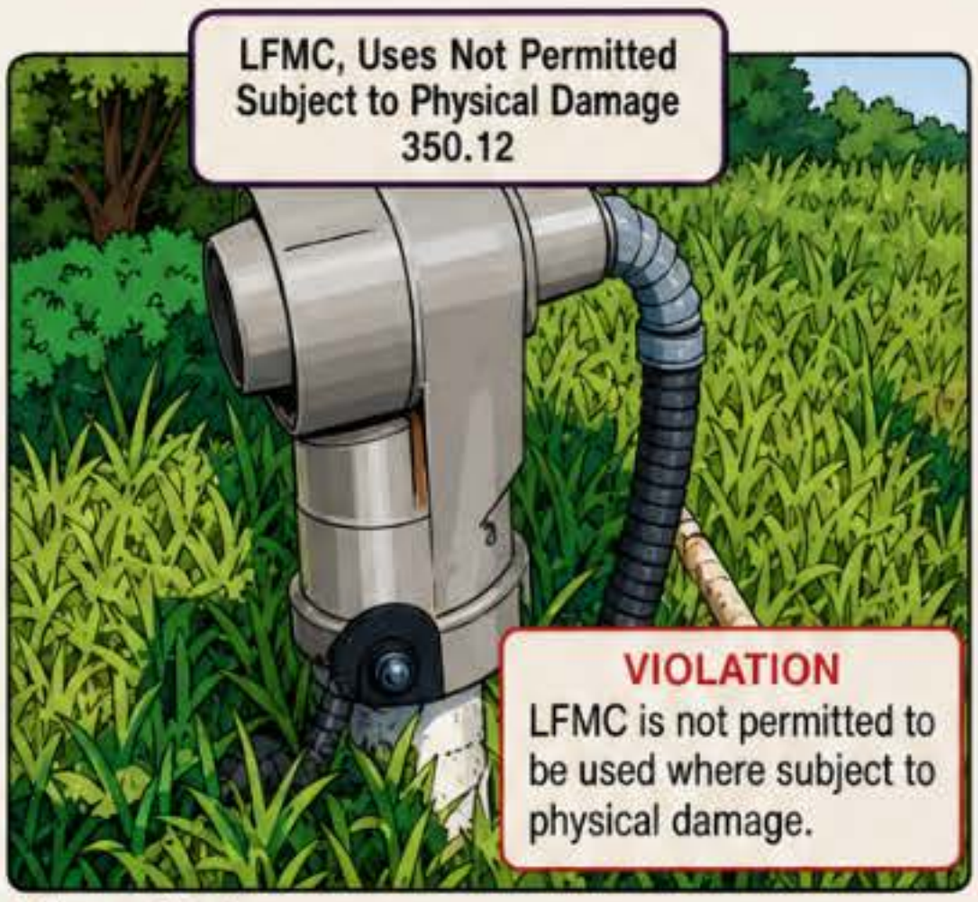


▶ Figure 350–4

(4) Conductors or cables rated at a temperature higher than the listed temperature rating of LFMC conduit may be installed in LFMC, provided the conductors or cables are not operated at a temperature higher than the listed temperature rating of the LFMC per 110.14(C).

350.12 Uses Not Permitted

LFMC must not be used where subject to physical damage. ▶ Figure 350–5



▶ Figure 350–5

350.20 Trade Size

(A) Minimum. LFMC smaller than trade size ½ is not permitted to be used.

Ex: LFMC can be smaller than trade size ½ if installed in accordance with 348.20(A).

(B) Maximum. LFMC larger than trade size 4 is not permitted to be used.

350.22 Number of Conductors

(A) Raceways ½ and Larger. Raceways must be large enough to permit the installation and removal of conductors without damaging the insulation. When all conductors within a raceway are the same size and insulation, the number of conductors permitted can be found in Annex C for the raceway type. *The number of cables must not exceed the allowable percentage fill specified in Chapter 9, Table 1.*

Liquidtight Flexible Metal Conduit (Type LFMC) | 350.30

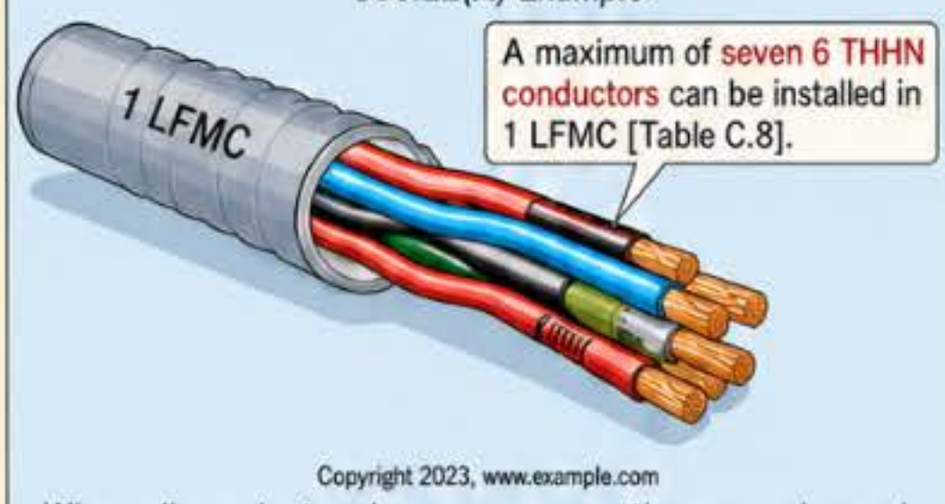
▶ **Example**

Question: *In a trade size 1 LFMC raceway, how many 6 THHN conductors are permitted?*

▶ **Figure 350-6**

(a) 2 conductors *(b) 4 conductors*
(c) 6 conductors *(d) 7 conductors*

LFMC, Number of Conductors
Raceways 1/2 in and Larger
350.22(A) Example



When all conductors in a raceway are the same size and insulation, the number of conductors permitted can be found in Annex C. The number of cables must not exceed the allowable percentage fill specified in Chapter 9, Table 1.

▲ **Figure 350-6**

Answer: *(d) 7 conductors [Annex C, Table C.8]*

Author's Commentary:
See 300.17 for illustrations of how to size raceways when the conductors are not all the same size.
— Michael Hamilton

Cables can be installed in LFMC if the total number of cables does not exceed the allowable percentage fill iisted in Chapter 9, Table 1.

(B) Raceways Trade Size ¾. The number and size of conductors in trade size ¾ LFMC must comply with Table 348.22.

▶ **Example**

Question: *In a trade size ¾ LFMC, how many 12 THHN conductors can be installed using outside fittings?*

(a) 2 conductors *(b) 3 conductors*
(c) 4 conductors *(d) 5 conductors*

Solution:

Only insulated, covered, or bare equipment grounding conductor (EGC) of the same size is permitted along with the circuit conductors. See the note at the bottom of Table 348.22.

Answer: *(b) 3 conductors [Table 348.22]*

350.24 Bends

Bends must be made so the conduit will not be damaged, and the internal diameter will not be effectively reduced.

350.26 Number of Bends (360°)

To reduce the stress and friction on conductor insulation, the total bends (including offsets) between pull points are not permitted to exceed 360°.

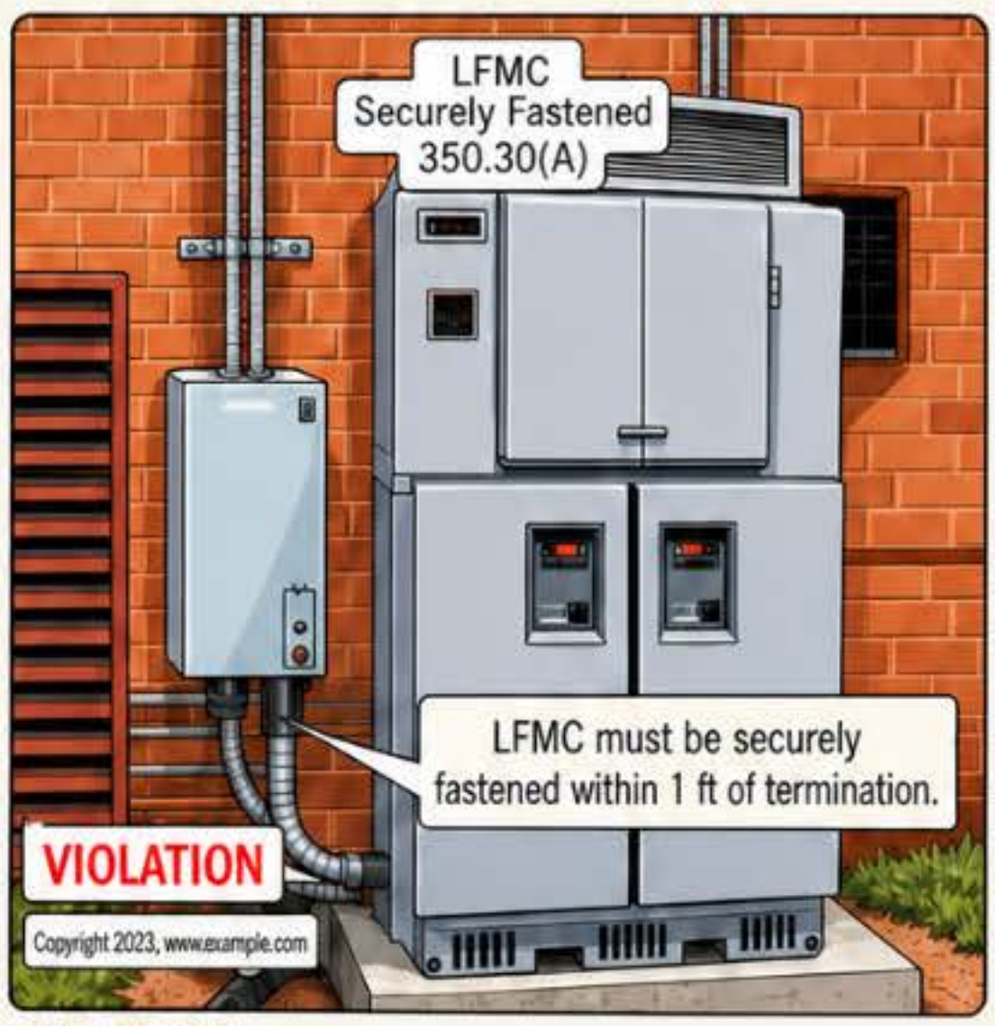
350.28 Trimming

Cut ends of LFMC must be trimmed both inside and outside the raceway to remove rough edges.

350.30 Securing and Supporting

LFMC must be securely fastened in place and supported in accordance with (A) and (B).

(A) Securely Fastened. LFMC must be securely fastened by a means approved by the authority having jurisdiction within 1 ft of termination and must be secured and supported at intervals not exceeding 4½ ft. ▶ **Figure 350-7**



▲ **Figure 350-7**

Where cable ties are used for securing LFMC they must be listed and identified for securement and support.

350.60 | Liquidtight Flexible Metal Conduit (Type LFMC)

Ex 1: *LFMC is not required to be tightly fastened or secured at concealed penetrations between access points when it is supported.*

Ex 2: *When bends are needed after installation, any unsupported lengths after the last location where the raceway is firmly secured cannot be more than those values.*

Figure 350-8

(1) 3 ft for trade sizes ½ through 1¼
(2) 4 ft for trade sizes 1½ through 2
(3) 5 ft for trade sizes 2½ and larger

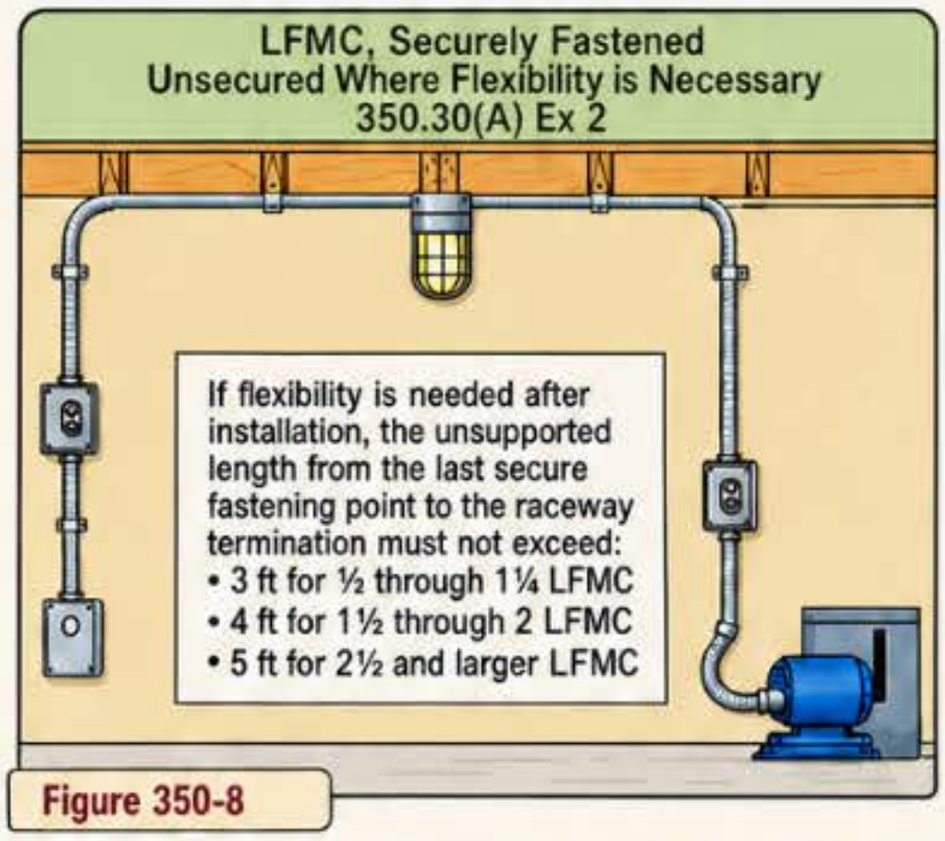


Figure 350-8

Ex 4: *Unsupported runs cannot go beyond 6 ft from the last fastening point if they are above an area that can be reached by a person or over equipment. These installations are regarded as mounting and supporting methods.*

Figure 350-9

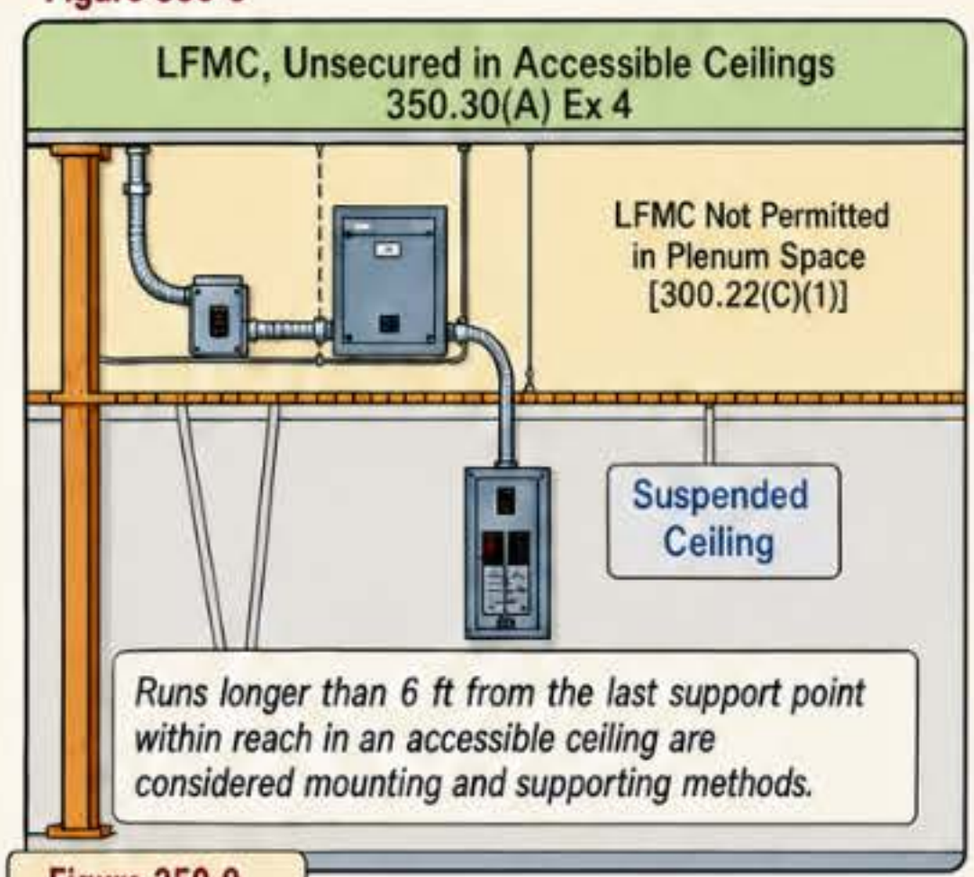


Figure 350-9

The following exceptions allow the fittings listed below to be used for securing and supporting.

Author's Commentary:

This final sentence that follows the four exceptions means that the permitted LFMC fittings can be used to secure and support only installations covered by one of the four exceptions. It should not be taken to mean that those fittings are allowed for securing and supporting LFMC in any situation.

— Michael Hamilton

(B) Horizontal Runs. Installing LFMC horizontally through bored or punched openings in wood or metal framing members, or through notches in wood members, is allowed as long as the raceway is fastened within 1 ft of the point where it terminates.

350.60 Equipment Grounding and Bonding Conductors

When flexibility is required to reduce vibration transmission from equipment, or to provide flexibility for equipment that needs to move after installation, the grounding conductor of the wire type that is installed with circuit conductors in accordance with 250.118(6) is required.

Figure 350-10

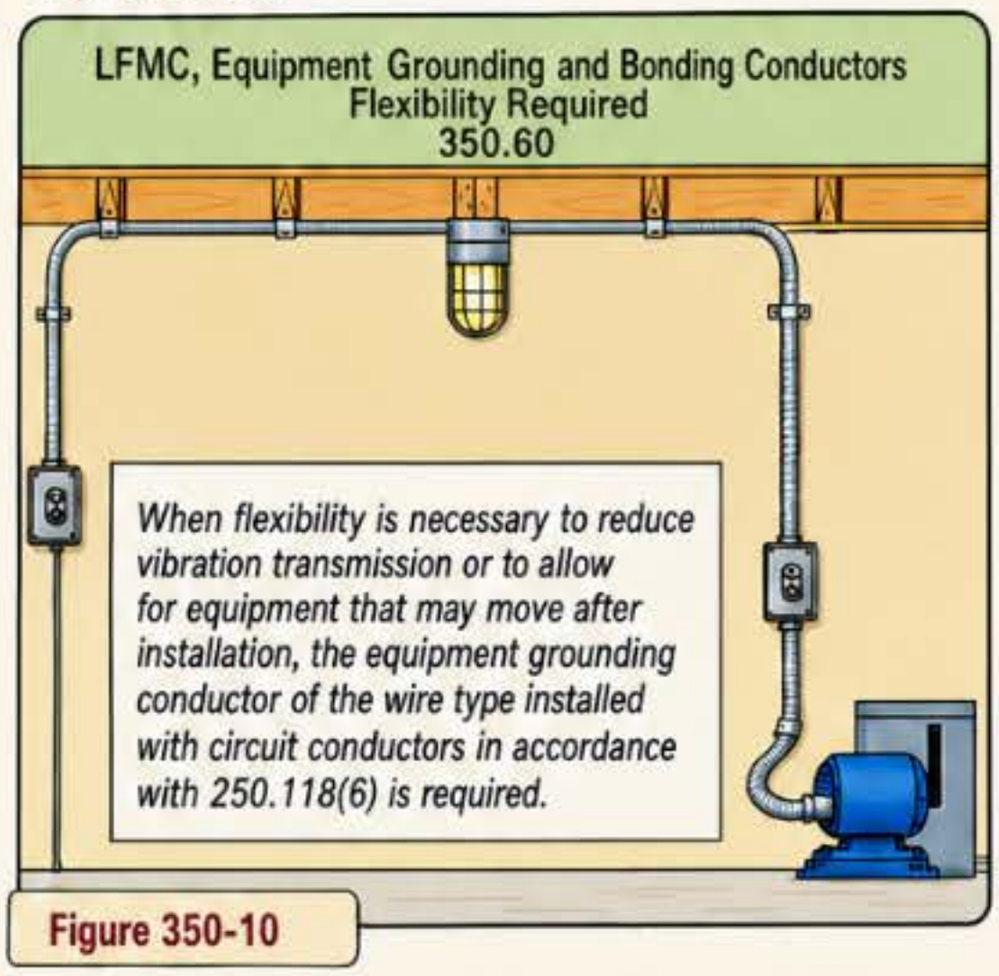
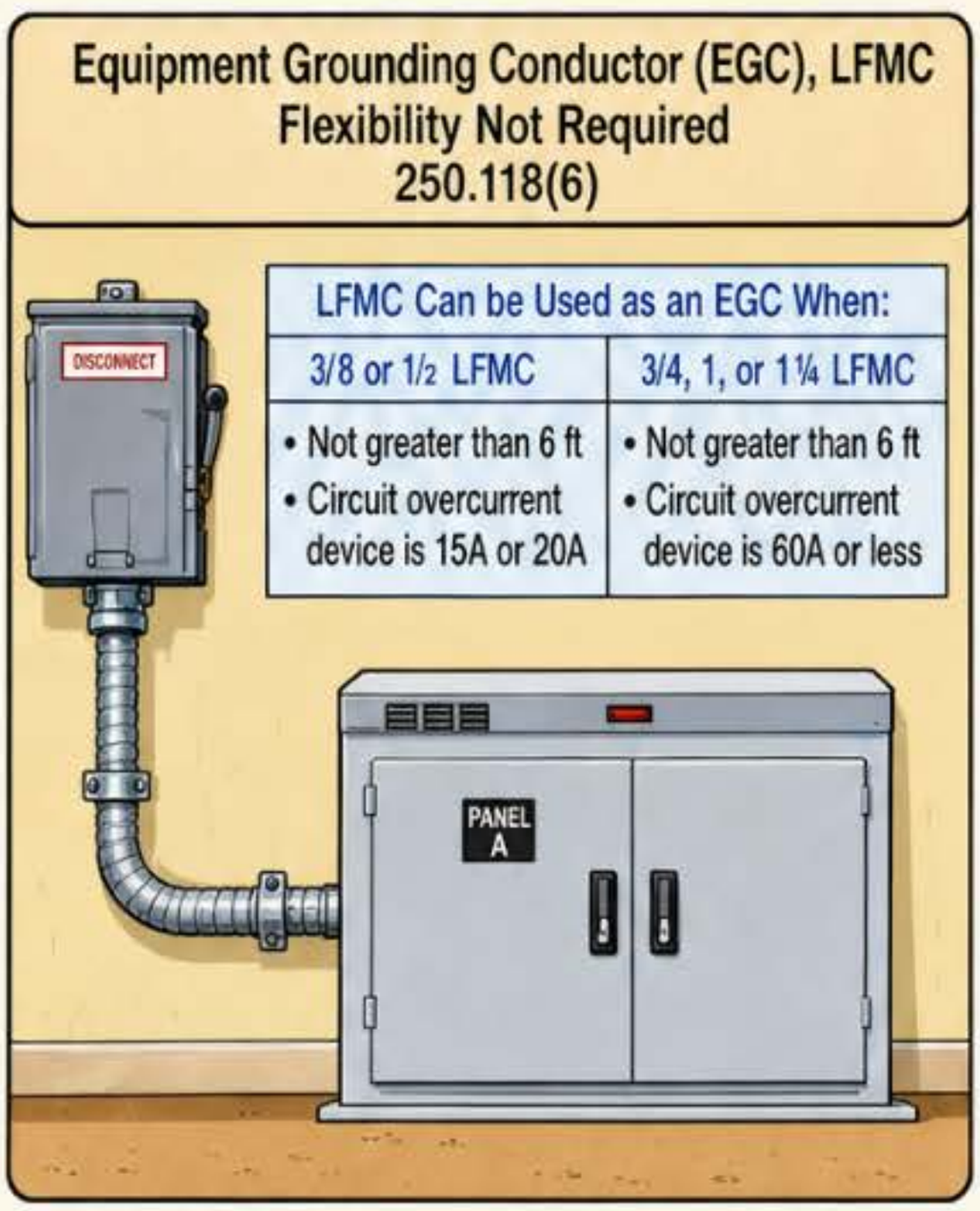


Figure 350-10

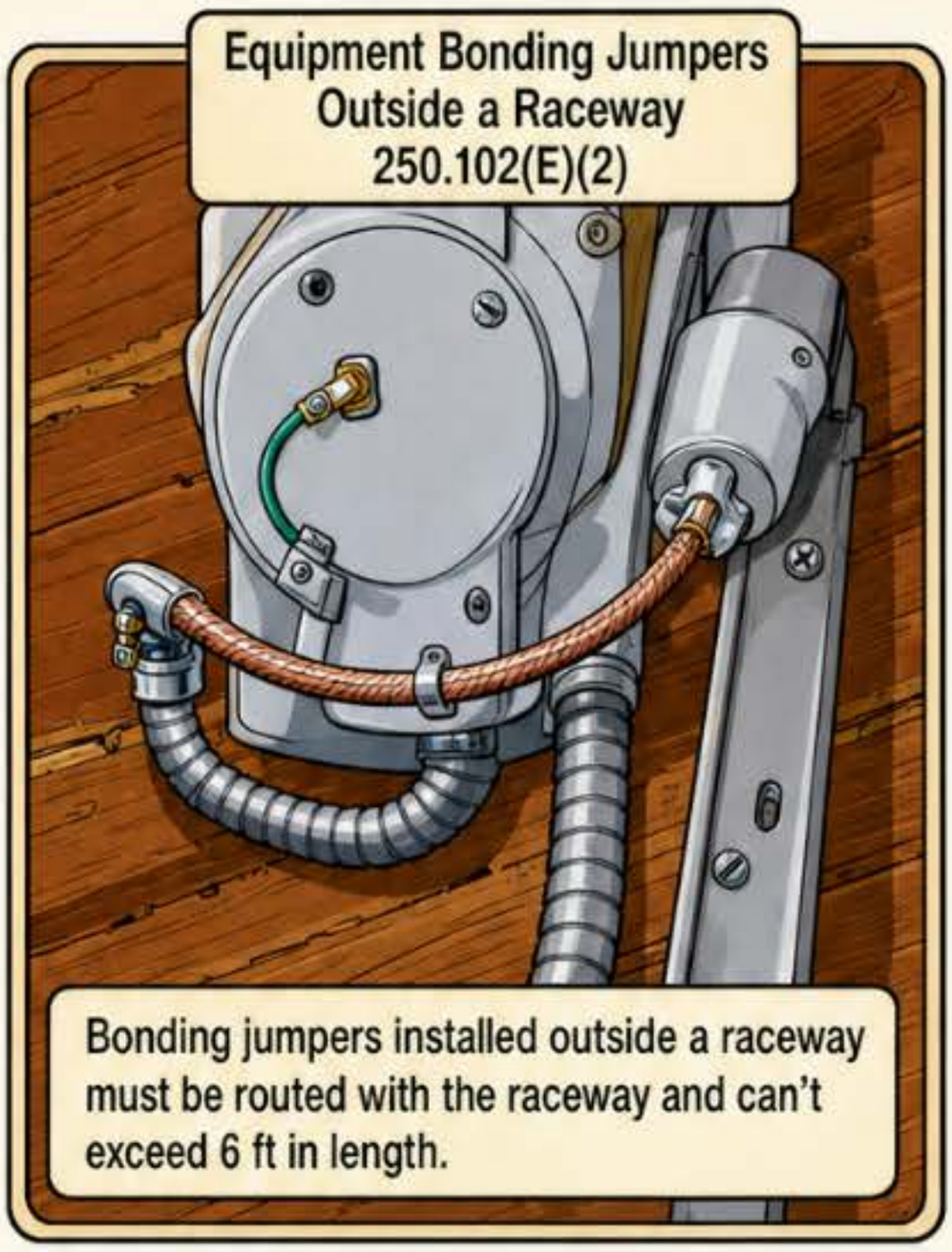
DEFINITIONS | From Michael Hamilton Publications

If flexibility is not necessary after installation, and vibration is not a concern, the metal armor of liquidtight flexible metal conduit can serve as an equipment grounding conductor if the circuit conductors contained within the raceway are protected by an overcurrent protective device rated 20A or less, and the combined length of the raceway in the same ground-fault return path does not exceed 6 ft in accordance with 250.118(6). ▶ Figure 350–11

The equipment bonding jumper can be installed inside or outside the liquidtight flexible metal conduit. Where the bonding jumper is installed outside the LFMC, the length of the equipment bonding jumper cannot exceed 6 ft, and it must be routed with the liquidtight flexible metal conduit in accordance with 250.102(E)(2). ▶ Figure 350–12



▶ Figure 350–11



▶ Figure 350–12

Notes

ARTICLE 352

RIGID POLYVINYL CHLORIDE CONDUIT (TYPE PVC)

Introduction to Article 352—Rigid Polyvinyl Chloride Conduit (Type PVC)

Rigid polyvinyl chloride conduit (Type PVC) is a rigid, nonmetallic raceway that offers many benefits found in metal conduit, but it can be installed in wet locations and corrosive environments. It is economical, easy to put in place, lightweight, simple to cut and join, and mechanically strong. Unlike metal, rigid PVC is brittle in very cold weather and may soften in extreme heat. This kind of conduit is often used below grade because of its low cost, ease of installation, and good resistance to rusting and deterioration.

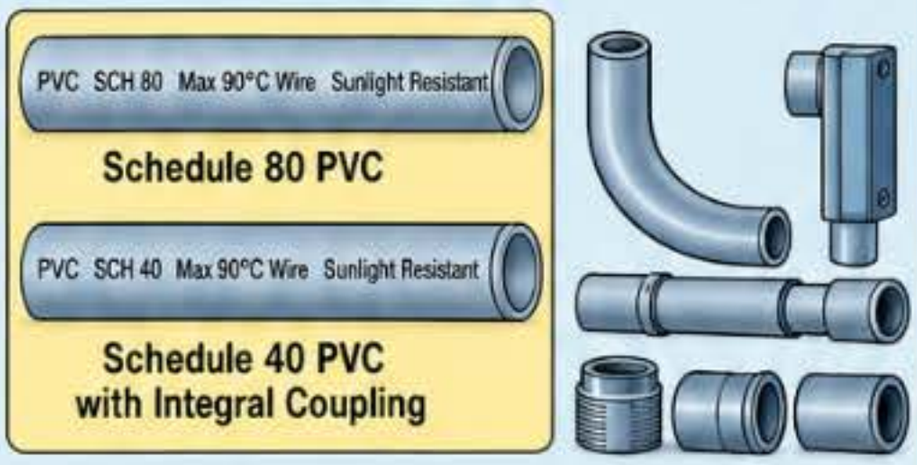
Part I. General

352.1 Scope

Article 352 covers how to use, install, and build to the requirements of rigid polyvinyl chloride (Type PVC) conduit and the fittings that go with it.

▶ Figure 352–1

Rigid Polyvinyl Chloride Conduit (Type PVC)
352.1 Scope



Article 352 sets the rules for the use, installation, and construction specifications for rigid polyvinyl chloride conduit and the associated fittings.

▶ Figure 352–1

352.2 Definition

Rigid polyvinyl chloride conduit (Type PVC) is a rigid, nonmetallic raceway of circular cross section that includes integral or associated couplings, connectors, and fittings that are intended for the installation of electrical conductors.

▶ Figure 352–2

Rigid Polyvinyl Chloride Conduit (Type PVC)
352.2 Definition

with or without integral coupling

A rigid, nonmetallic raceway of circular cross section that includes integral or associated couplings, connectors, and fittings.

▶ Figure 352–2

Part II. Installation

352.10 Uses Permitted

Type PVC conduit may be used in the following situations:

Note: In very cold conditions, PVC conduit can become brittle and may be more likely to sustain physical damage.

(A) Concealed. PVC conduit can be installed hidden within walls, floors, or ceilings.

▶ Figure 352–3

352.12 | Rigid Polyvinyl Chloride Conduit (Type PVC)

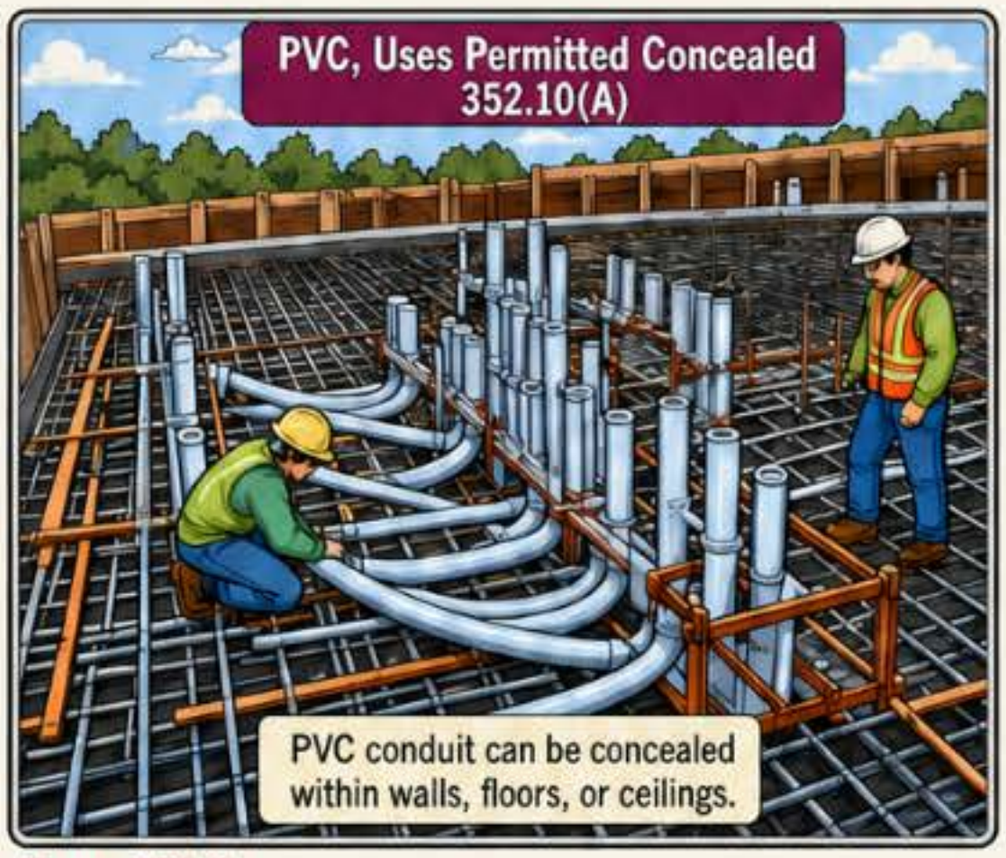


Figure 352–3

(B) Corrosive Influences. PVC conduit is allowed in locations where severe corrosion can occur, provided the material is the type specifically approved by the authority having jurisdiction.

(D) Wet Locations. PVC conduit is permitted in wet environments such as dairies, laundries, canneries, car washes, and other places that are frequently hosed down. It is also allowed for outdoor installations. Fittings like straps, screws, and bolts must be made from corrosion-resistant materials or have corrosion-resistant coatings in accordance with 300.6(A).

(E) Dry and Damp Locations. PVC conduit is permitted in dry and damp areas except where limited in 352.12.

(F) Exposed. Schedule 40 PVC conduit is permitted for exposed places not subject to physical damage. If subject to physical damage (for example, the raceway is along a roadway), identify the application. Figure 352–4

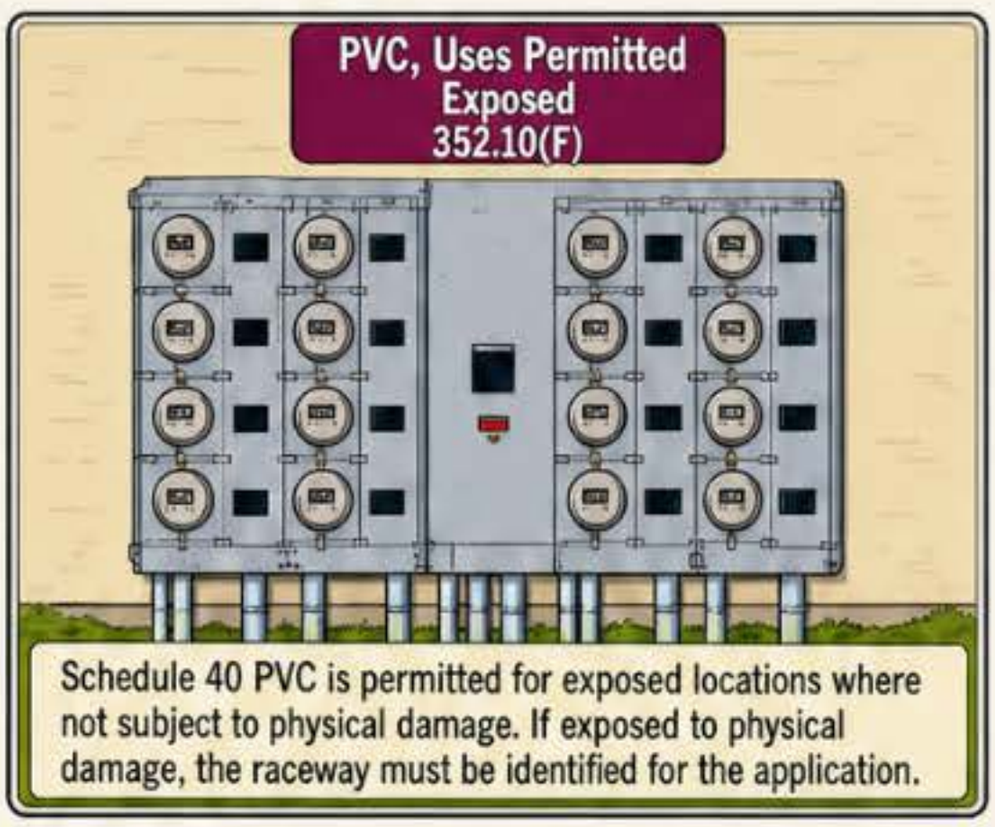


Figure 352–4

Note: PVC Schedule 80 conduit is identified for use in areas subject to physical damage. Figure 352–5

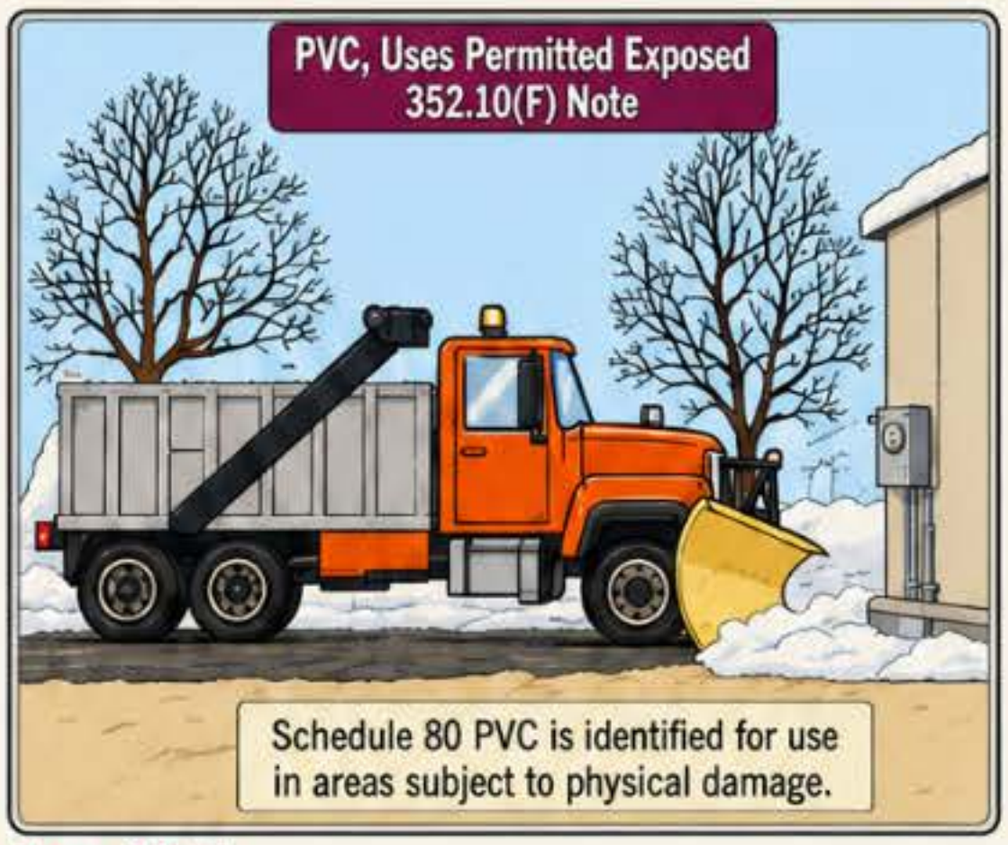


Figure 352–5

(G) Underground. PVC conduit is allowed for underground installs and in concrete, and it must meet the burial requirements of 300.5.

352.12 Uses Not Permitted

PVC conduit is not permitted in the following environments:

(A) Hazardous (Classified) Locations. PVC conduit is not allowed in hazardous (classified) locations except as permitted by 501.10(A)(1)(a) Ex, 501.10(B)(6), 503.10(A), 504.20, 514.8 Ex 2, and 515.8.

(B) Support of Luminaires. PVC conduit is not permitted to be used for supporting luminaires or other equipment.

(C) Physical Damage. Type PVC conduit may not be installed in places where it could be subject to physical damage unless identified for that application. Figure 352–6

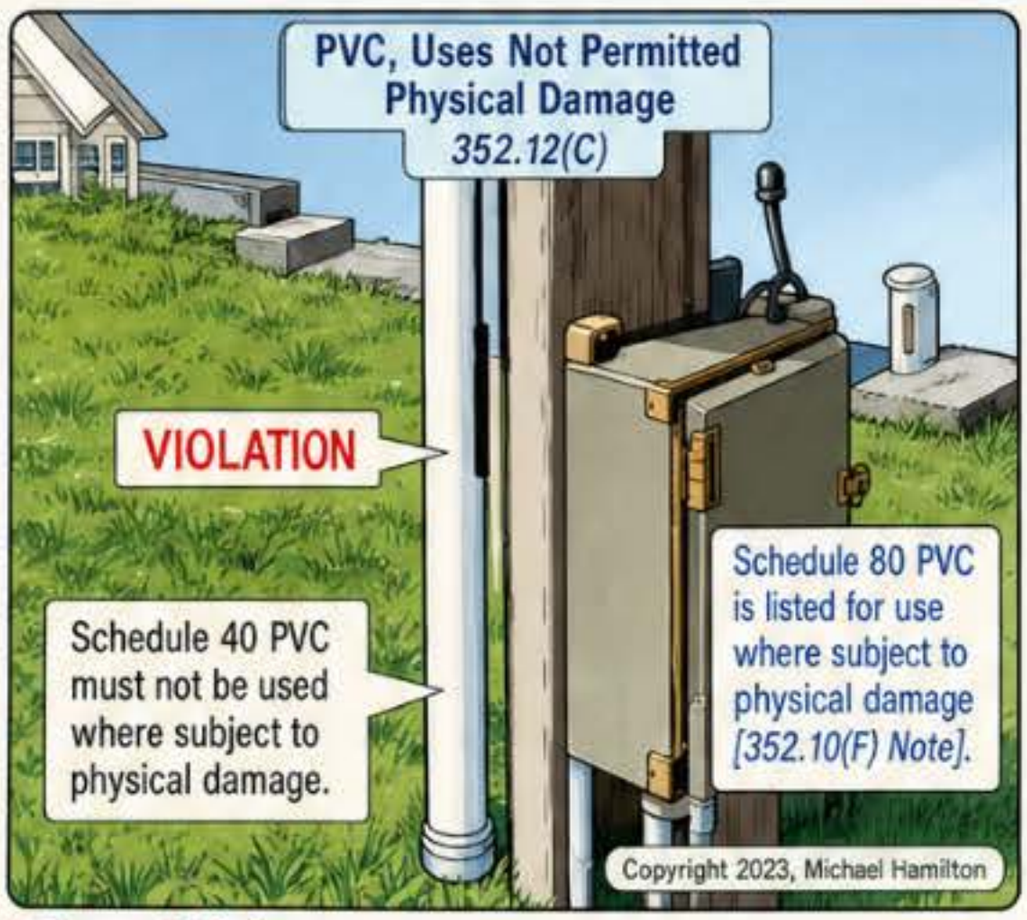
Author's Commentary:

- *PVC Schedule 40 conduit is not identified for use where subject to physical damage, but PVC Schedule 80 conduit is [352.10(F) Note].*

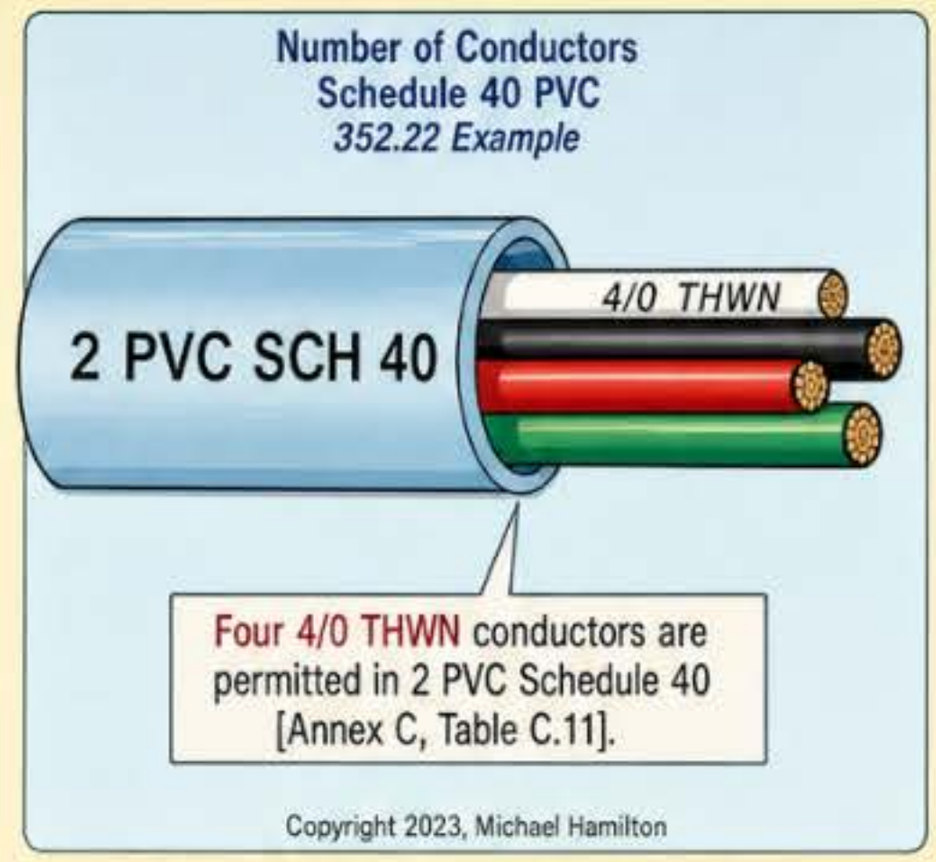
— Michael Hamilton

(D) Ambient Temperature. PVC conduit is not permitted to be installed if the ambient temperature exceeds 50°C (122°F).

Rigid Polyvinyl Chloride Conduit (Type PVC) 352.22



▶ Figure 352–6



▶ Figure 352–7

Author's Commentary:
PVC conduit and fittings are not permitted to be installed in environmental air spaces (plenums) [300.22(C)].

— ***Michael Hamilton***

352.20 Trade Size

(A) Minimum. *PVC conduit smaller than trade size ½ is not permitted to be used.*

(B) Maximum. *PVC conduit larger than trade size 6 is not permitted to be used.*

352.22 Number of Conductors

Raceways must be large enough to permit the installation and removal of conductors without damaging the conductors' insulation, and the number of conductors is not permitted to exceed the percentage fill specified in Chapter 9, Table 1.

When all conductors within a raceway are the same size and insulation, the number of conductors permitted can be found in Annex C for the raceway type.

▶ Example

Question: *How many 4/0 THWN conductors can be installed in trade size 2 Schedule 40 PVC conduit?* ▶ **Figure 352–7**

(a) 2 conductors *(b) 3 conductors*
(c) 4 conductors *(d) 5 conductors*

Answer: *(b) 4 conductors [Annex C, Table C.11]*

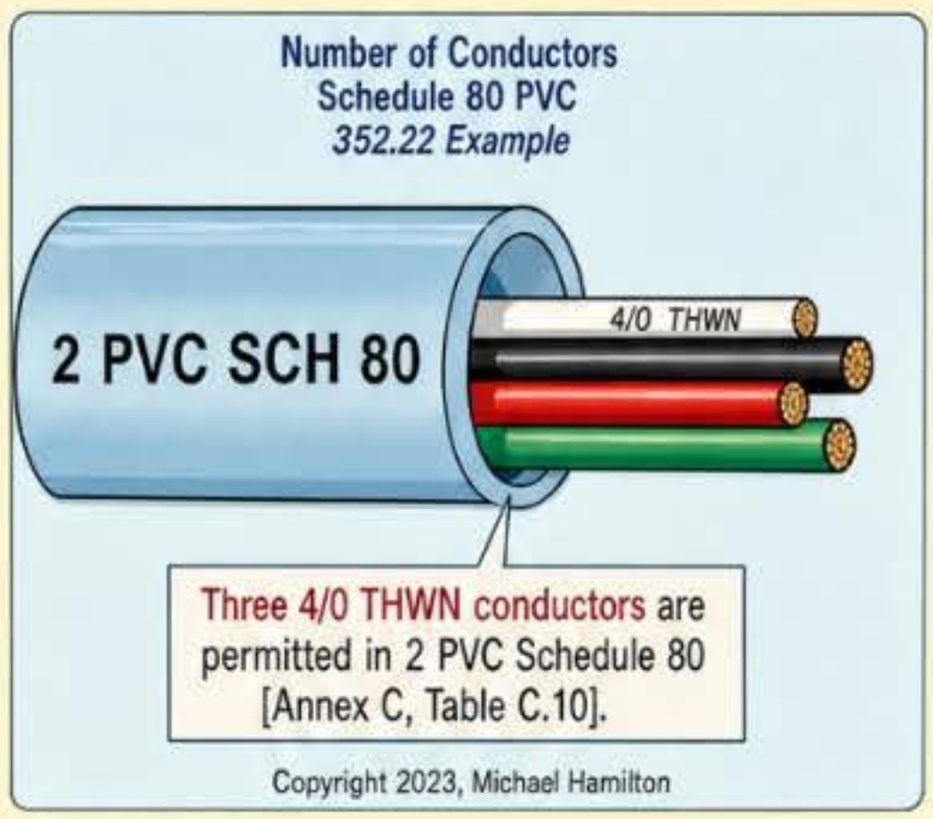
Author's Commentary:
Schedule 80 PVC conduit has the same outside diameter as Schedule 40, but the wall thickness is greater which results in a reduced interior area for conductor fill.

— ***Michael Hamilton***

▶ Example

Question: *How many 4/0 THWN conductors can be installed in trade size 2 Schedule 80 PVC conduit?* ▶ **Figure 352–8**

(a) 2 conductors *(b) 3 conductors*
(c) 4 conductors *(d) 5 conductors*



▶ Figure 352–8

Answer: *(b) 3 conductors [Annex C, Table C.10]*

352.24 | Rigid Polyvinyl Chloride Conduit (Type PVC)

Author's Commentary:

See 300.17 for guidance on sizing raceways when the conductors are not all the same size.

— Michael Hamilton

352.24 Bends

Raceway bends are not allowed to be formed in any way that could harm the raceway or noticeably reduce its inside diameter (no kinks).

352.26 Number of Bends (360°)

To reduce stress and friction on conductor insulation, the total number of bends (including offsets) between pull points must not exceed 360°. • **Figure 352–9**

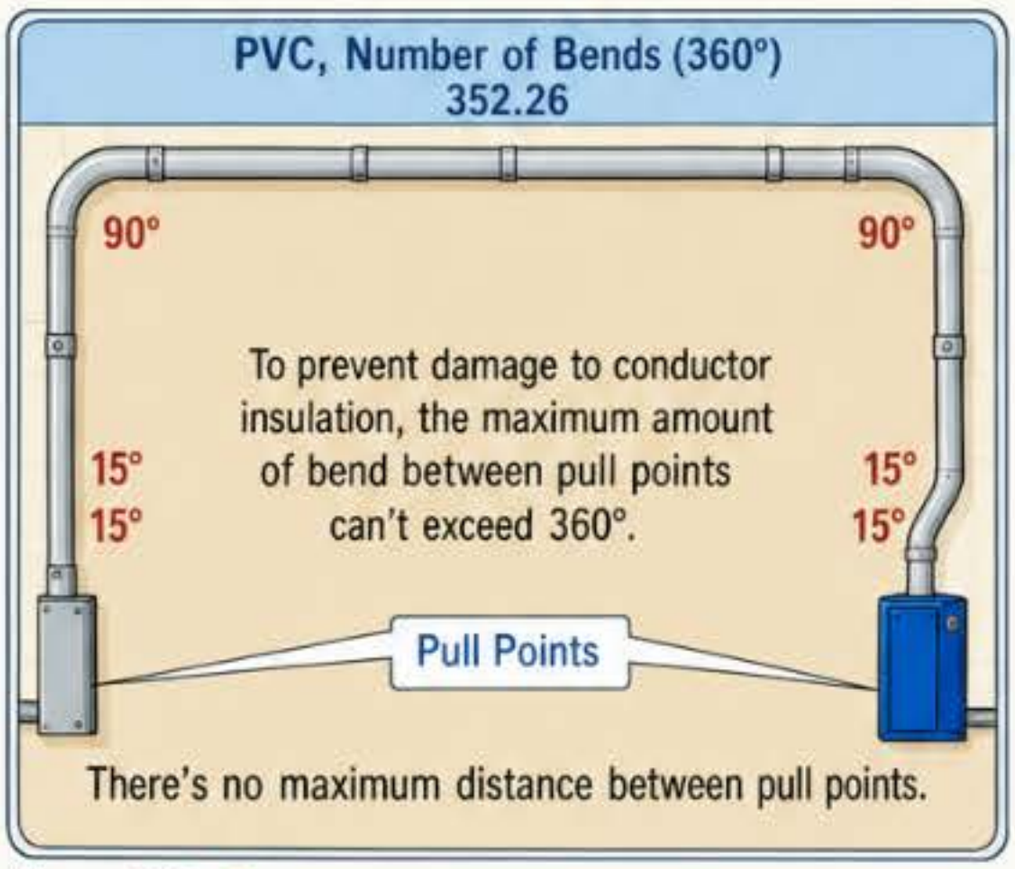


Figure 352–9

352.28 Trimming

The cut ends of PVC conduit must be trimmed (inside and out) to remove the burrs and rough edges.

Author's Commentary:

Trimming PVC conduit is quick and simple; just rub the burrs off with your fingers, or use a knife to smooth the rough edges.

— Michael Hamilton

352.30 Securing and Supporting

PVC conduit must be fastened and supported in accordance with (A) and (B) so movement from thermal expansion and contraction is permitted.

(A) Securely Fastened. PVC conduit must be secured within 3 ft of every box, cabinet, or termination fitting, such as a conduit body. • **Figure 352–10**

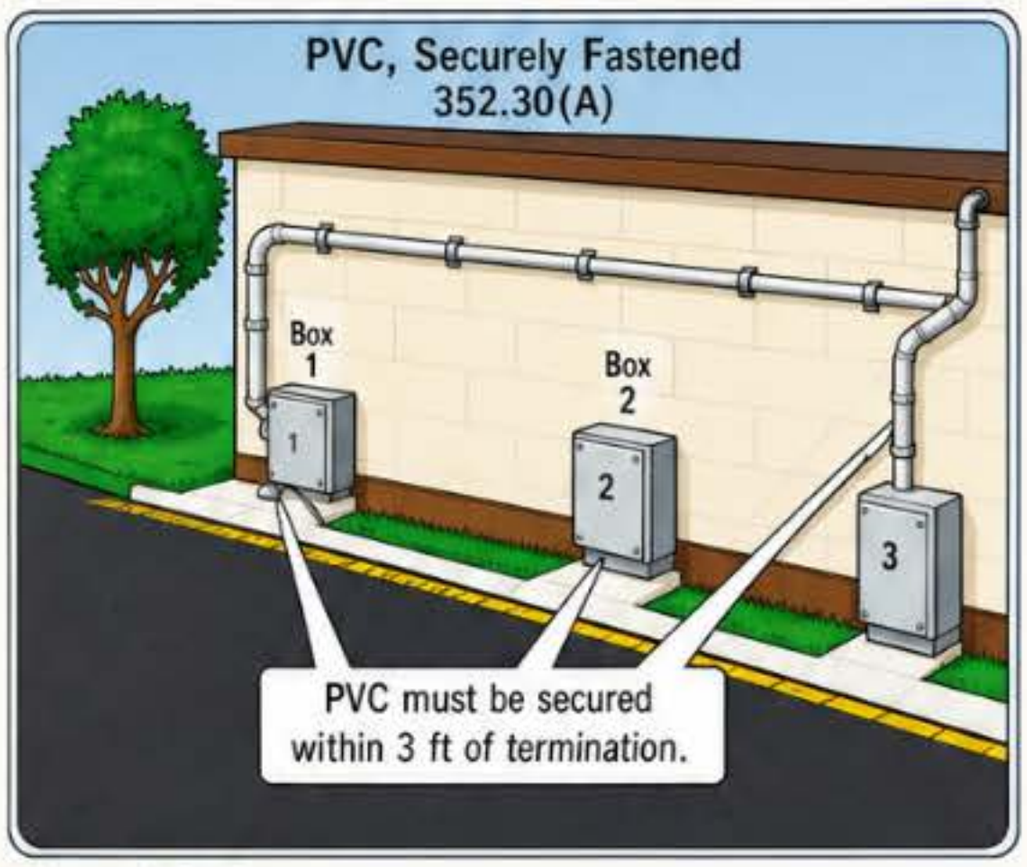


Figure 352–10

(B) Supports. PVC conduit must be supported at intervals not exceeding the values in Table 352.30, and the raceway must be fastened in a manner that permits movement from thermal expansion or contraction. • **Figure 352–11**

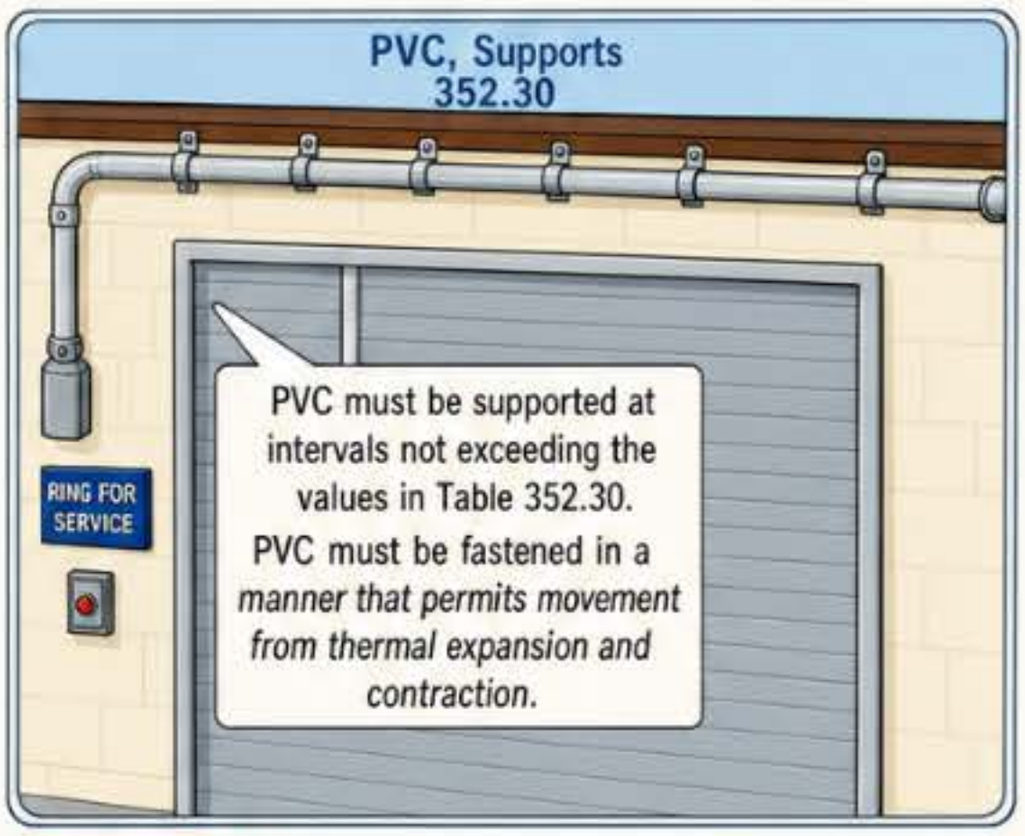


Figure 352–11

Table 352.30 Support of Rigid PVC	
Trade Size	Support Spacing
½–1	3 ft
1¼–2	5 ft
2½–3	6 ft
3½–5	7 ft
6	8 ft

PVC conduit installed horizontally in bored or punched holes in wood or metal framing members, or notches in wooden members, is considered supported, but the raceway must be secured within 3 ft of termination.

352.44 Expansion Fittings

Scan this QR code for a video by Michael Hamilton explaining this topic; it's a sample from the videos that accompany this textbook.
www.michaelhamilton.com/23EXPvideos

If PVC conduit is installed in a straight run between securely mounted items such as boxes, cabinets, elbows, or other conduit terminations, expansion fittings must be provided if the expansion or contraction length change (in accordance with Table 352.44) is expected to be ¼ in. or greater. ▸ **Figure 352–12**

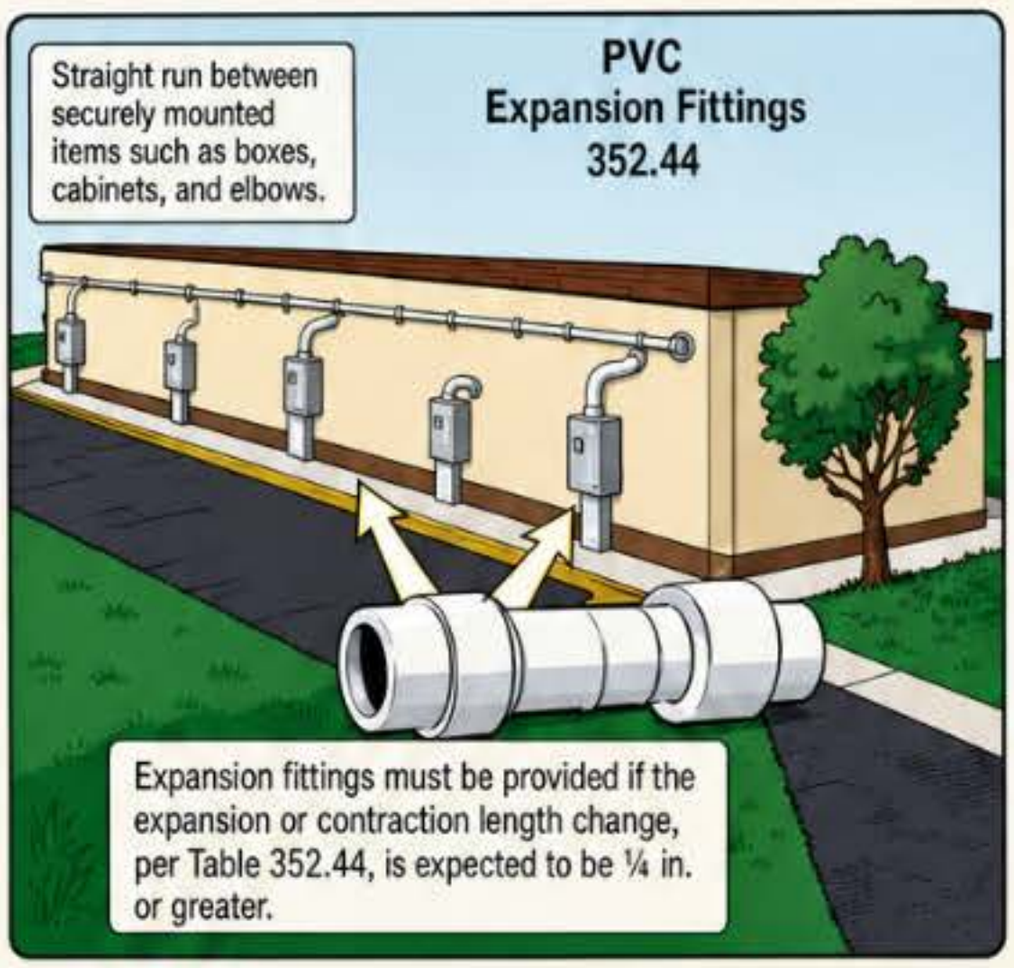


Figure 352–12

Author's Commentary:

When calculating how many fittings and the size of expansion fittings are needed, always consult the manufacturer's instructions. For instance, if Carlon® expansion fittings for PVC conduit indicate that the installation will be exposed to sunlight above 30°F, the high ambient temperature must be factored into the calculations.

— Michael Hamilton

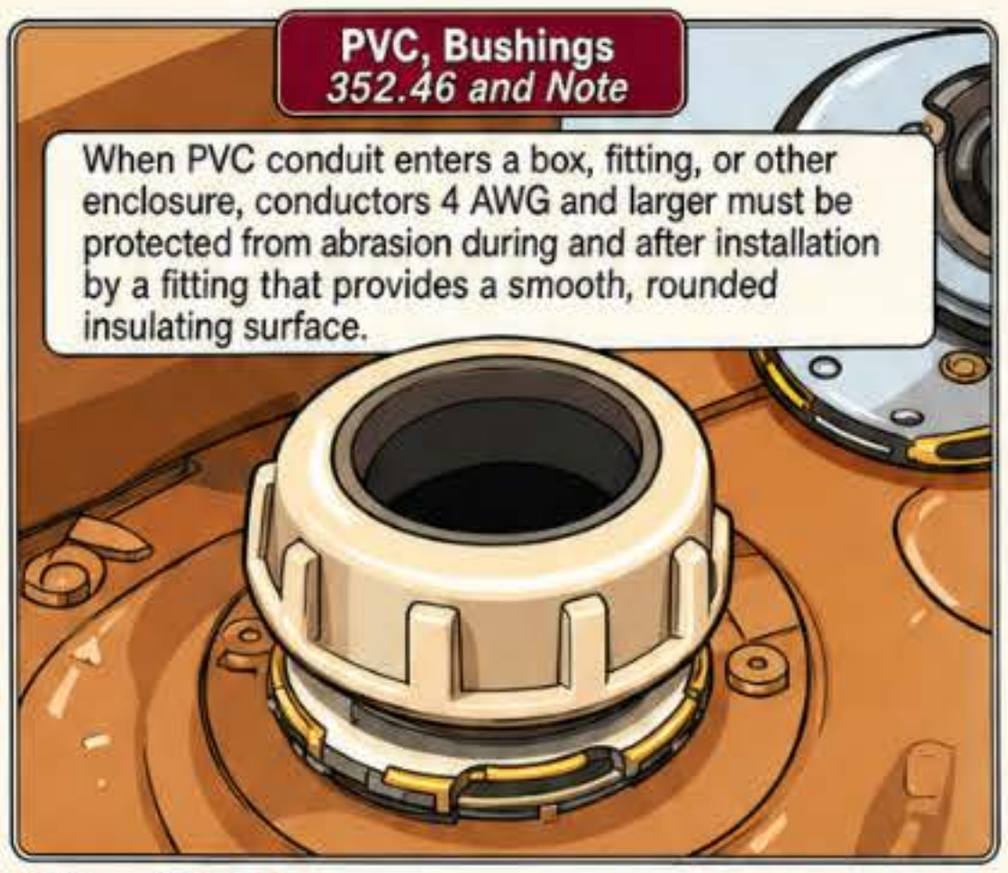
Table 352.44 Expansion Characteristics of PVC Rigid Nonmetallic Conduit Coefficient of Thermal Expansion

Temperature Change (°C)	Length of Change of PVC Conduit (mm/m)	Temperature Change (°F)	Length Change of PVC Conduit (in./100 ft)
5	0.30	5	0.20
10	0.61	10	0.41
15	0.91	15	0.61
20	1.22	20	0.81
25	1.52	25	1.01
30	1.83	30	1.22
35	2.13	35	1.42
40	2.43	40	1.62
45	2.74	45	1.83
50	3.04	50	2.03
55	3.35	55	2.23
60	3.65	60	2.43
65	3.95	65	2.64
70	4.26	70	2.84
75	4.56	75	3.04
80	4.87	80	3.24
85	5.17	85	3.45
90	5.48	90	3.65
95	5.78	95	3.85
100	6.08	100	4.06

352.46 | Rigid Polyvinyl Chloride Conduit (Type PVC)

352.46 Bushings

Any time PVC conduit enters an enclosure, box, fitting, or other raceway, conductors sized 4 AWG or larger must be shielded from abrasion during and after installation by a fitting that furnishes a smooth, rounded insulating surface. [300.4(G)]. → Figure 352–13



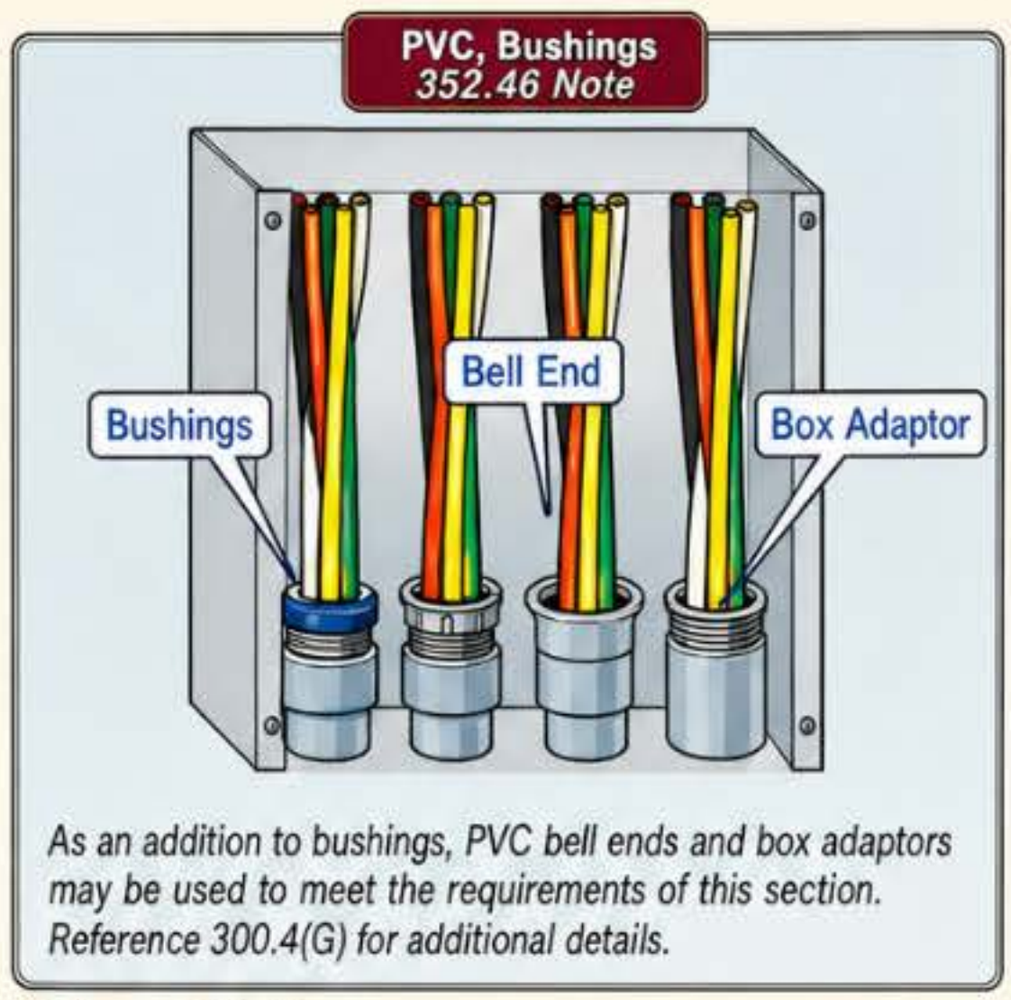
▲ Figure 352–13

Author's Commentary:

The 2023 NEC, 300.4(G), states: "The inside and outside surfaces of a fitting shall be free from sharp or jagged edges, burrs, cracks, or other defects. The fitting shall have a smooth, rounded throat that protects the conductors. In the case of a molded product, excess flashing shall be removed from the mold line on all interior surfaces so no sharp edges or projections can injure wiring equipment or conductors in the intended application."

— Michael Hamilton

Note: *Conductors 4 AWG and larger that enter any enclosure must be protected from abrasion during and after installation by a fitting that provides a smooth, rounded insulating surface—such as an insulating bushing—unless the design of the box, fitting, or enclosure offers equivalent safeguard in accordance with 300.4(G).* → Figure 352–14



▲ Figure 352–14

352.48 Joints

Joints—including couplings and connectors—must be manufactured in an approved manner by the authority having jurisdiction.

Author's Commentary:

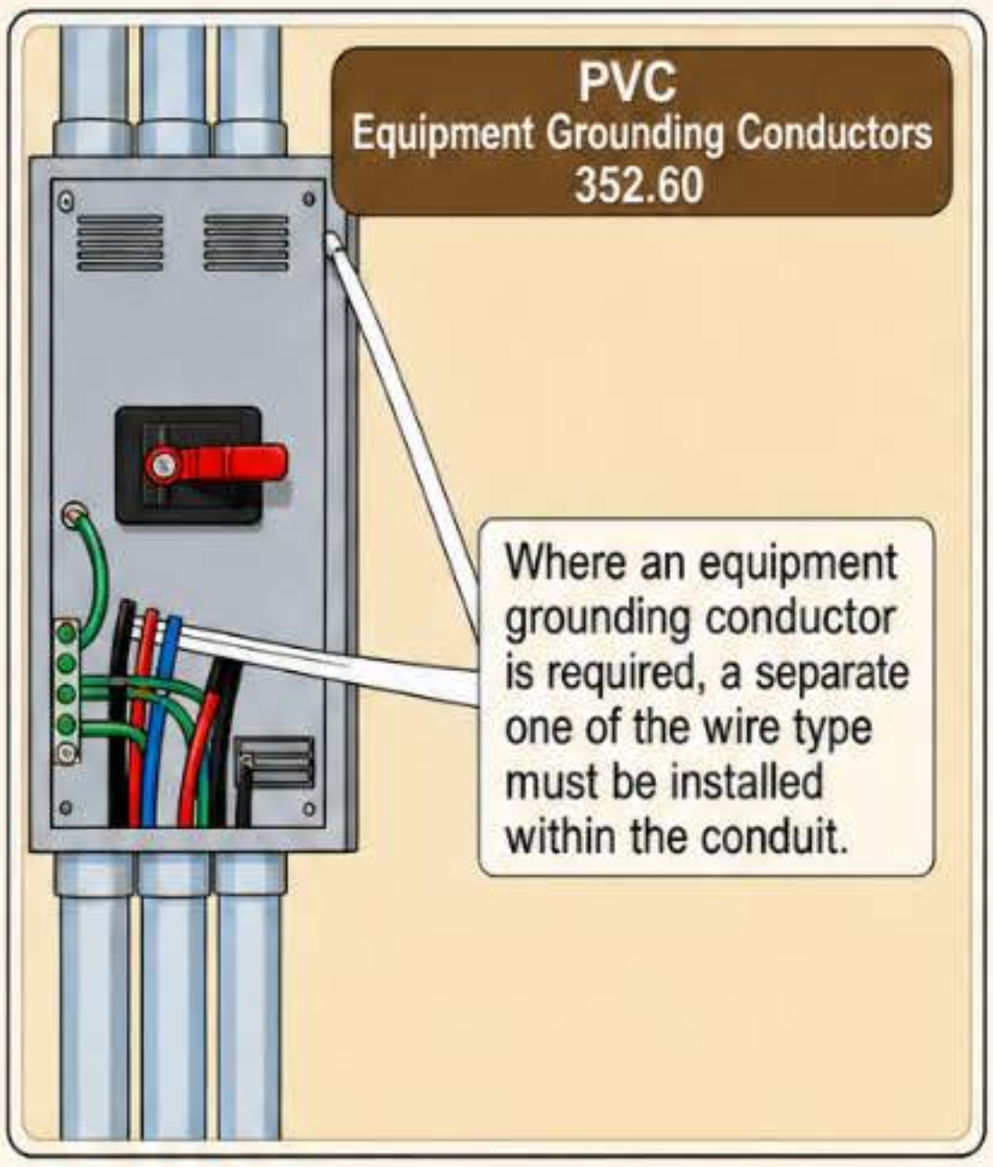
Comply with the manufacturer's installation instructions for raceways, fittings, and joining compounds. Ensure the raceway surface to be bonded is clean and dry before applying solvent cement. After the adhesive is applied to both surfaces, rotate the fitting one-quarter turn as it is pushed together.

— Michael Hamilton

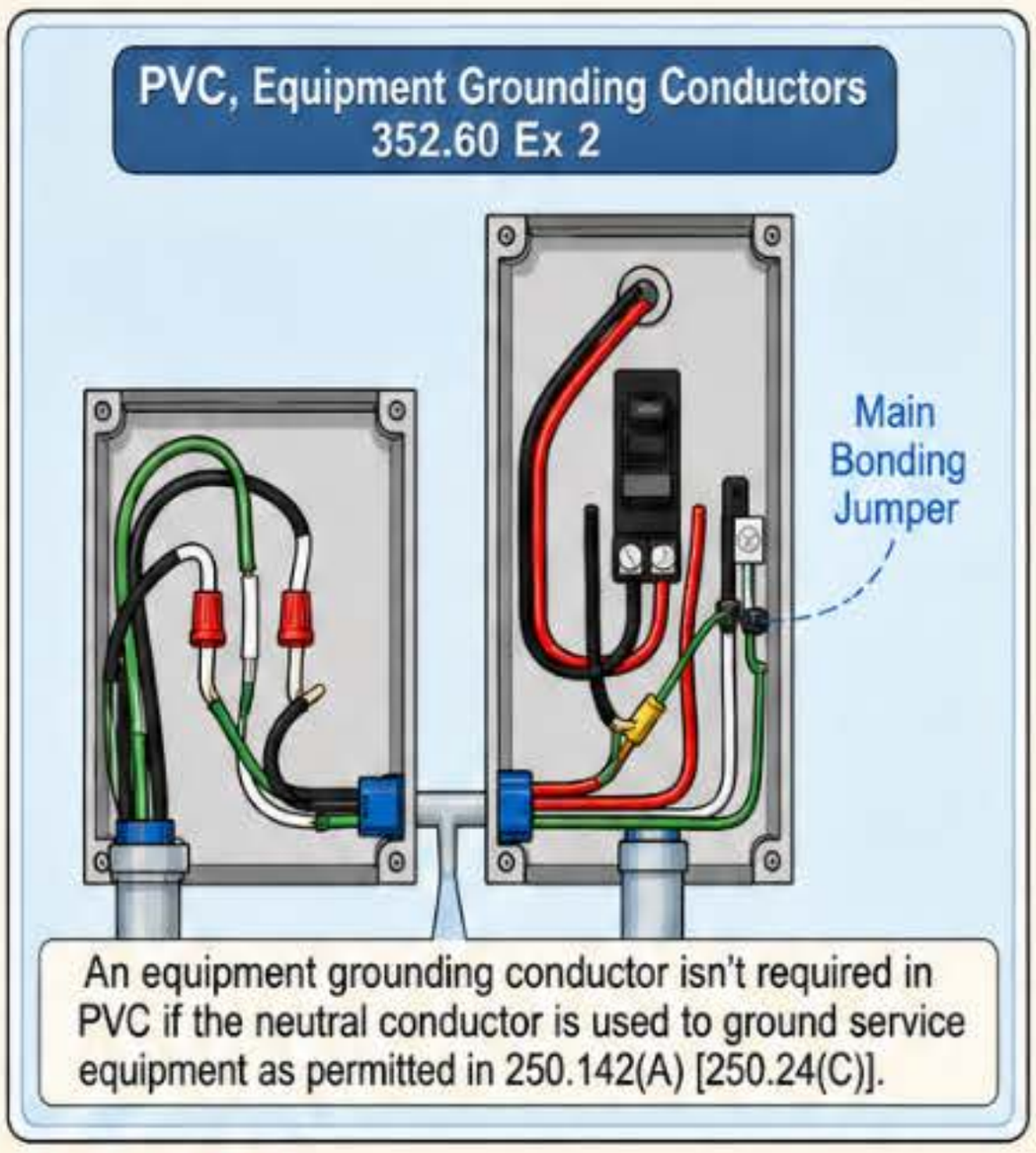
352.60 Equipment Grounding Conductor

When an equipment grounding conductor is needed to connect an item of equipment, a separate conductor—or the raceway itself [300.2(B)]—must be installed within the raceway. → Figure 352–15

Ex 2: *An equipment grounding conductor isn't required in PVC conduit if the neutral conductor performs grounding for equipment at the service disconnect per 250.142(A) [250.24(C)].* → Figure 352–16



▶ Figure 352–15



▶ Figure 352–16

Notes

ARTICLE 356

LIQUIDTIGHT FLEXIBLE NONMETALLIC CONDUIT (TYPE LFNC)

Introduction to Article 356—Liquidtight Flexible Nonmetallic Conduit (Type LFNC)

Liquidtight flexible nonmetallic conduit (Type LFNC) is a recognized raceway with a round cross section. It features an outer liquidtight, nonmetallic jacket that resists sunlight and surrounds an inner flexible core. The system uses compatible couplings, connectors, and fittings.

This raceway is commonly referred to as "Carlflex®."

Part I. General

356.1 Scope

This article specifies the application, installation, and construction requirements for liquidtight flexible nonmetallic conduit (Type LFNC) and the matching fittings. ▶ Figure 356–1

Liquidtight Flexible Nonmetallic Conduit (Type LFNC)
356.1 Scope

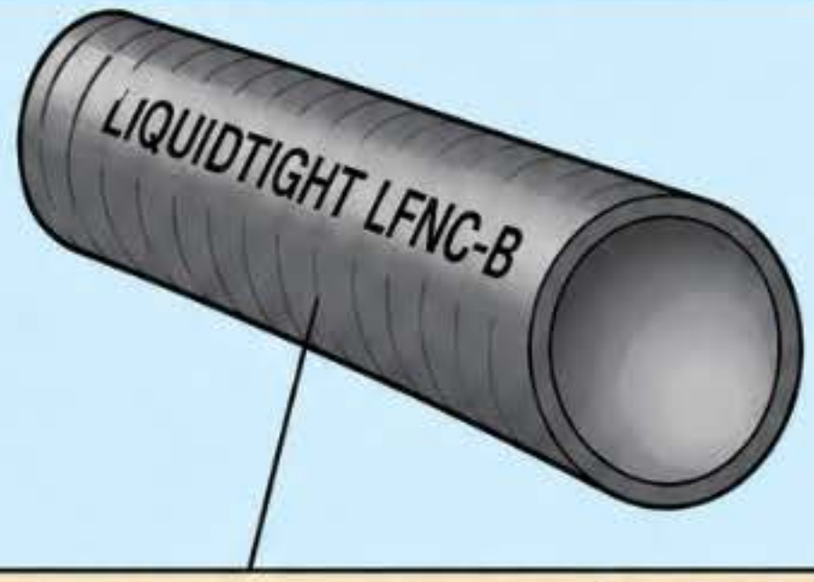
This article governs how liquidtight flexible nonmetallic conduit and its fittings are used, installed, and constructed.

▶ Figure 356–1

356.2 Definition

Liquidtight Flexible Nonmetallic Conduit (Type LFNC). A raceway with a round cross section, built with an outer liquidtight, nonmetallic, sunlight-resistant jacket that covers a flexible nonmetallic core and is supplied with appropriate couplings, connectors, and fittings for electrical installations. ▶ Figure 356–2

Liquidtight Flexible Nonmetallic Conduit (Type LFNC)
356.2 Definition



A circular raceway with an outer liquidtight, nonmetallic, sunlight-resistant jacket over a flexible nonmetallic inner core.

▶ Figure 356–2

356.6 Listing Requirements

LFNC and all associated fittings must be listed.

Part II. Installation

356.10 Uses Permitted

Listed LFNC may be exposed or concealed, and can be used in any of the following situations:

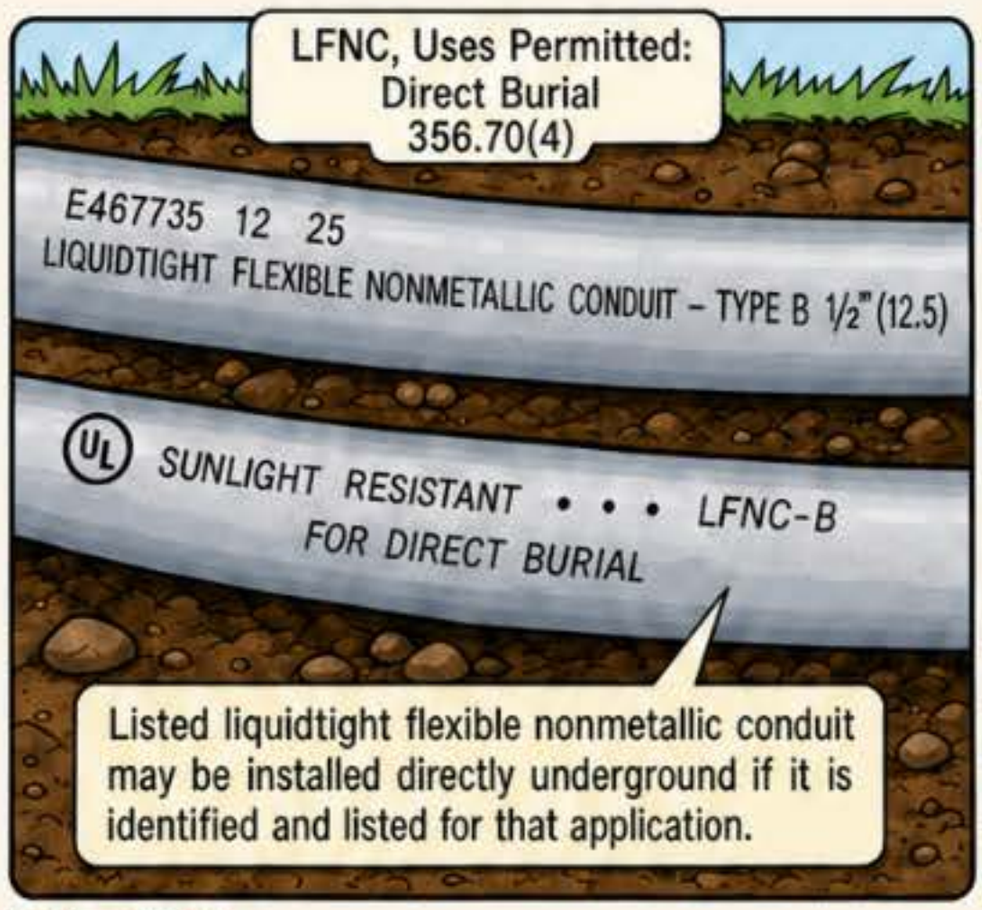
(1) Where flexibility is required.

(2) Where protection against liquids, vapors, machine oils, and solid materials is necessary.

356.12 Liquidtight Flexible Nonmetallic Conduit (Type LFNC)

(3) Use outdoors only when it is specifically identified and labeled for that application.

(4) When buried in the earth, the conduit must be marked for that use and listed accordingly.



▶ Figure 356–3

(5) LFNC-B (gray in color) can be used in runs longer than 6 ft if it complies with 356.30.

(6) LFNC-C (black in color) is allowed when supplied as a listed, factory-assembled prewired unit.

(7) It may be encased in concrete when the installation is identified for direct burial.

(8) Cables or conductors rated for a temperature equal to or higher than LFNC conduit may be installed in LFNC, provided the conductor or cable is also listed for that temperature.

Note: *Extreme heat can embrittle certain nonmetallic conduits, making them vulnerable to cracking and possible physical damage.*

356.12 Uses Not Permitted

(1) It is not permitted where it could be subjected to physical harm.

(2) If the surrounding temperature or the conductor rating exceeds the values in this section, its use is not allowed.

(3) It may be used in runs longer than 6 ft only when the authority having jurisdiction confirms that additional flexibility is required.

(4) It is prohibited in hazardous (classified) locations unless permitted by 501.10(B), 502.10(A) and (B), and 504.20.

356.20 Trade Size

(A) Minimum. LFNC with a trade size smaller than ½ inch is not allowed, except for these specific applications:

(1) Enclosing the leads of motors [430.245(B)].

(2) Making tap connections for lighting fixtures following 410.117(C) for trade size 3/8.

(B) Maximum. LFNC with a trade size larger than 4 is not permitted.

356.22 Number of Conductors

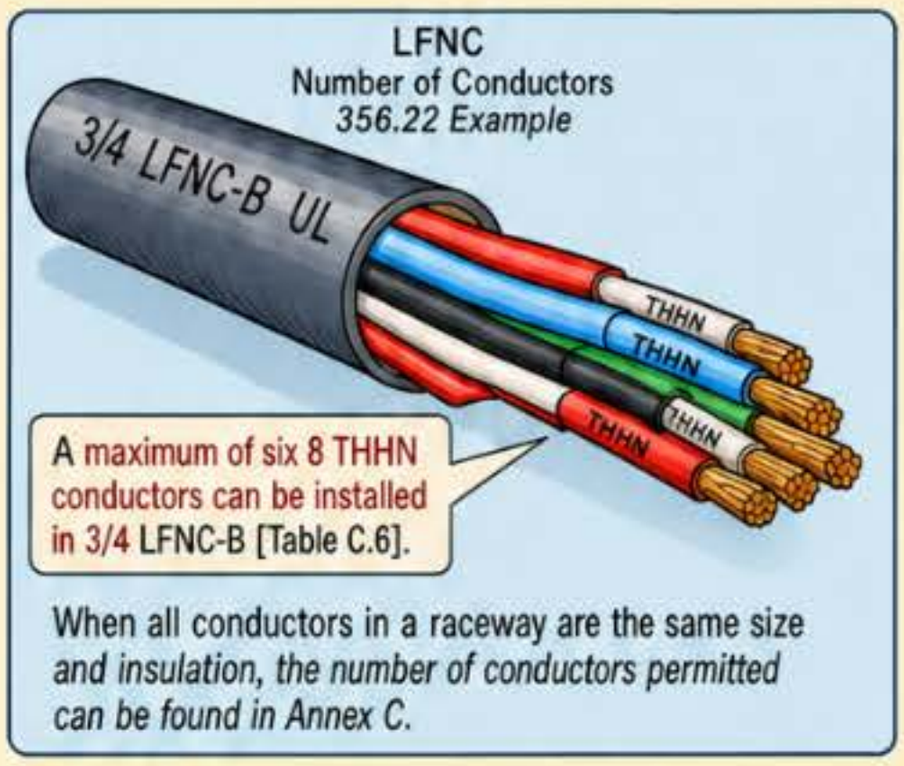
Raceways must be spacious enough to allow conductor installation and removal without damaging the insulation. The total number of conductors may not exceed the fill percentage listed in Chapter 9, Table 1.

When all conductors in a raceway are the same size and insulation type, the permitted conductor count can be found in Annex C for that raceway type.

▶ Example

Question: *How many 8 THHN conductors are allowed in trade size ¾ LFNC-B?* ▶ Figure 356–4

(a) 2 conductors *(b) 4 conductors*
(c) 6 conductors *(d) 8 conductors*



▶ Figure 356–4

Answer: *(c) 6 conductors [Annex C, Table C.6]*

Liquidtight Flexible Nonmetallic Conduit (Type LFNC) | 356.42

Author's Commentary:

▶ *Consult Section 300.17 for guidance on how to size raceways when conductors are not all the same size.*

— Michael Hamilton

LFNC may be installed provided the count of cables stays at or below the allowable percentage fill stated in Chapter 9, Table 1.

356.24 Bends

Raceway bends are not allowed if they could injure the raceway or alter its inside diameter (no kinks or sharp deformations).

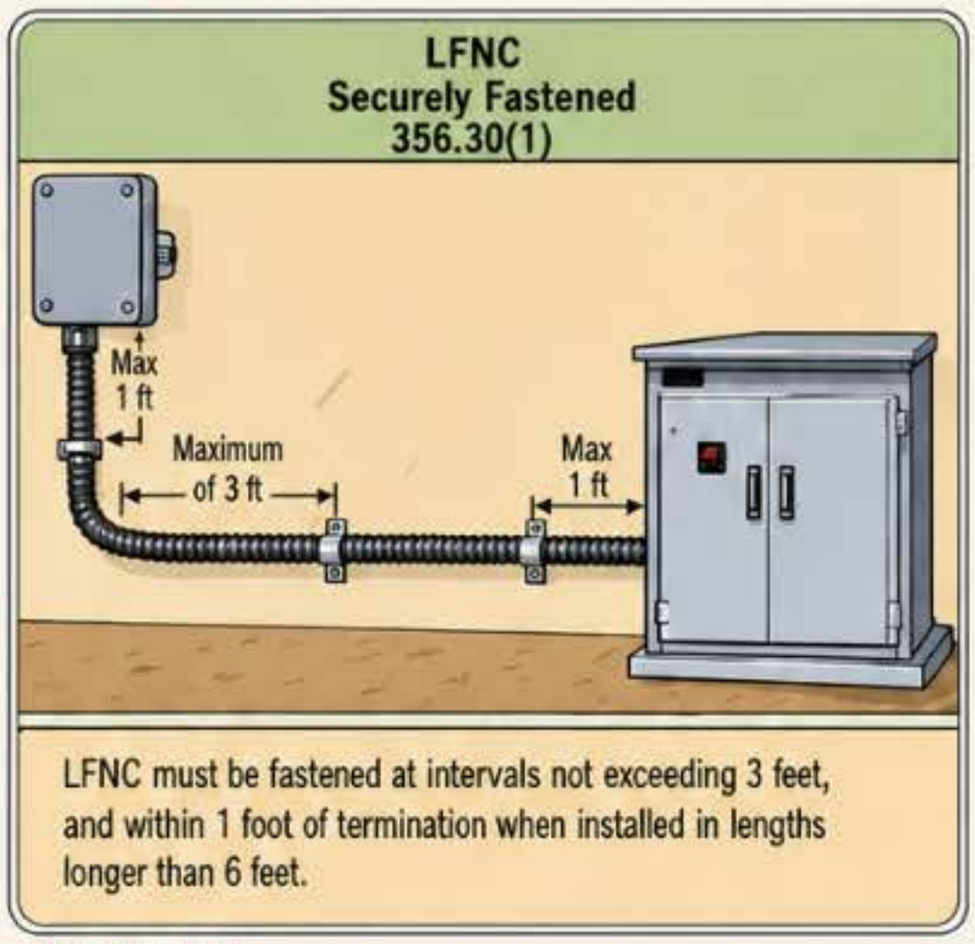
356.26 Number of Bends (360°)

To minimize strain and friction on the conductors, the total of all bends (including offsets) between pull points may not exceed 360 degrees.

356.30 Securing and Supporting

LFNC must be firmly secured and supported in accordance with the rules below:

(1) The conduit must be fastened at intervals not greater than 3 feet, and within 1 foot of any termination when installed in lengths over 6 feet. • Figure 356–5



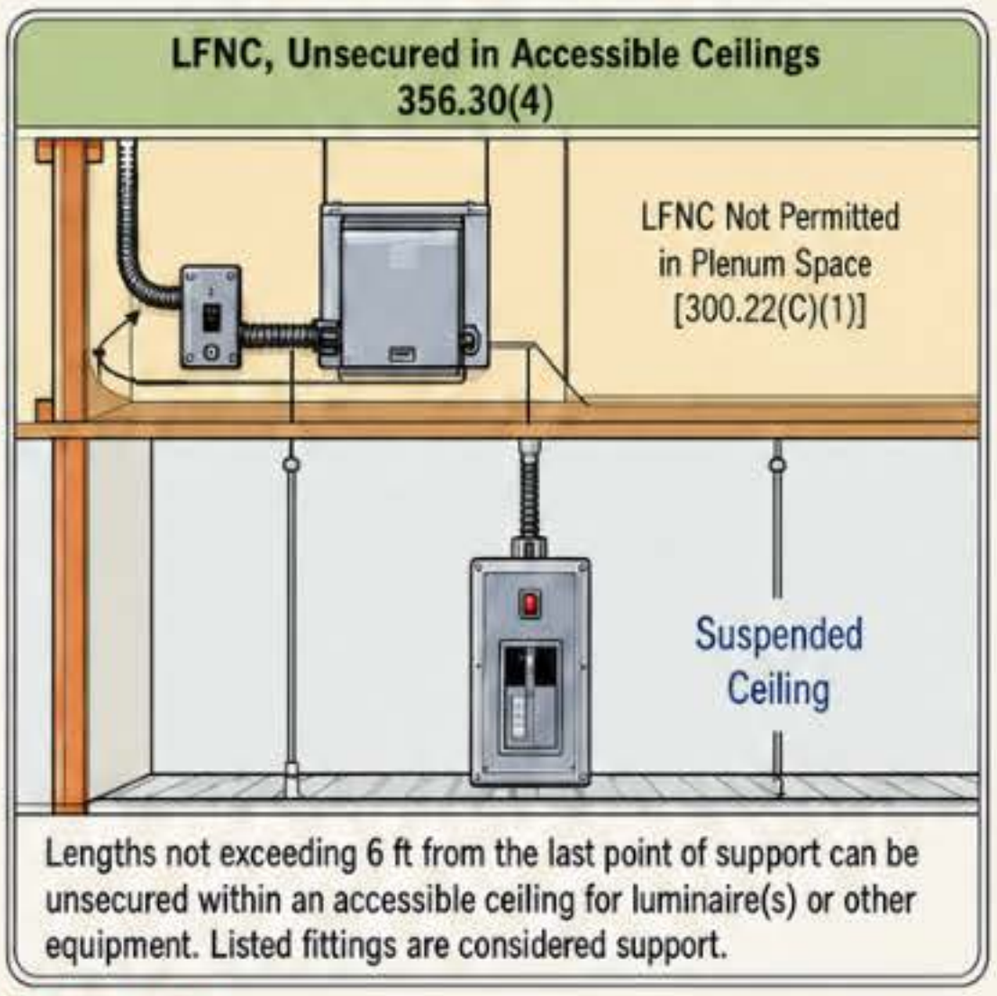
• Figure 356–5

Where cable ties are used to secure and support LFNC, they must be listed for the application and for securing and supporting.

(2) Securing or supporting is not required if LFNC is fished or installed in lengths not exceeding 3 ft at terminals if flexibility is required.

(3) Runs routed horizontally in bored or punched holes in wood or metal framing members, or in notches in wood members, are considered supported, but the raceway must be secured within 1 ft of termination.

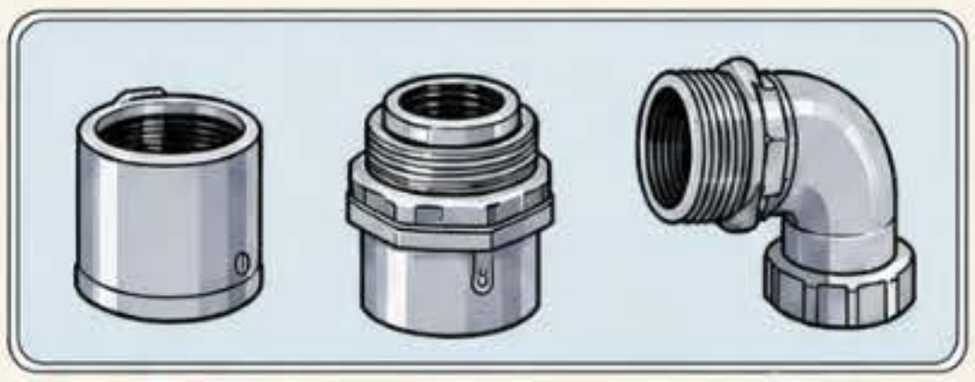
(4) Securing or supporting is not required if installed in lengths not exceeding 6 ft from the last point where the raceway is securely fastened for connections within an accessible ceiling (such as a luminaire) or other equipment. For the purpose of this rule, listed fittings are considered support. • Figure 356–6



• Figure 356–6

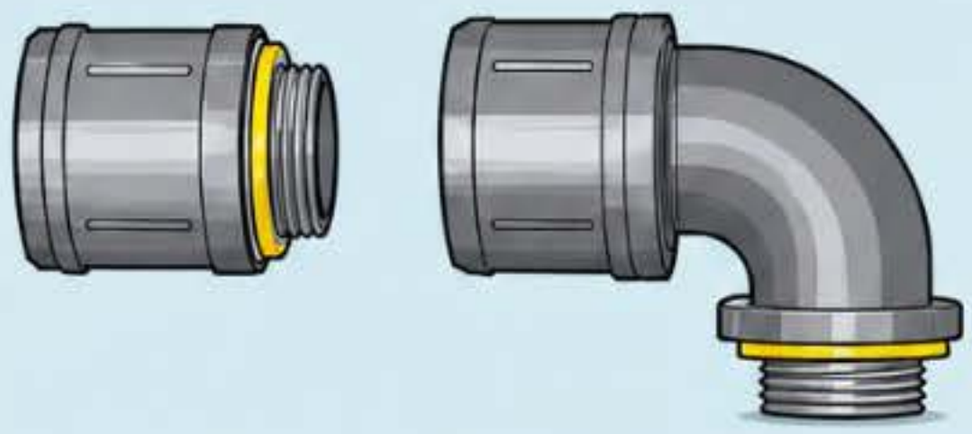
356.42 Fittings

Only fittings that are listed for use with LFNC can be used [300.15]. Straight LFNC fittings are allowed for direct burial or encasement in concrete. • Figure 356–7



• Figure 356–7

356.60 | Liquidtight Flexible Nonmetallic Conduit (Type LFNC)



Only fittings that are listed for use with LFNC can be used [300.15]. Straight LFNC fittings are permitted for direct burial or encasement in concrete.

Figure 356-7

Author's Commentary:

- An equipment grounding conductor is not required to be installed in a nonmetallic raceway supplying nonmetallic equipment because there is nothing in the nonmetallic box that requires a connection to an equipment grounding conductor.

— Michael Hamilton

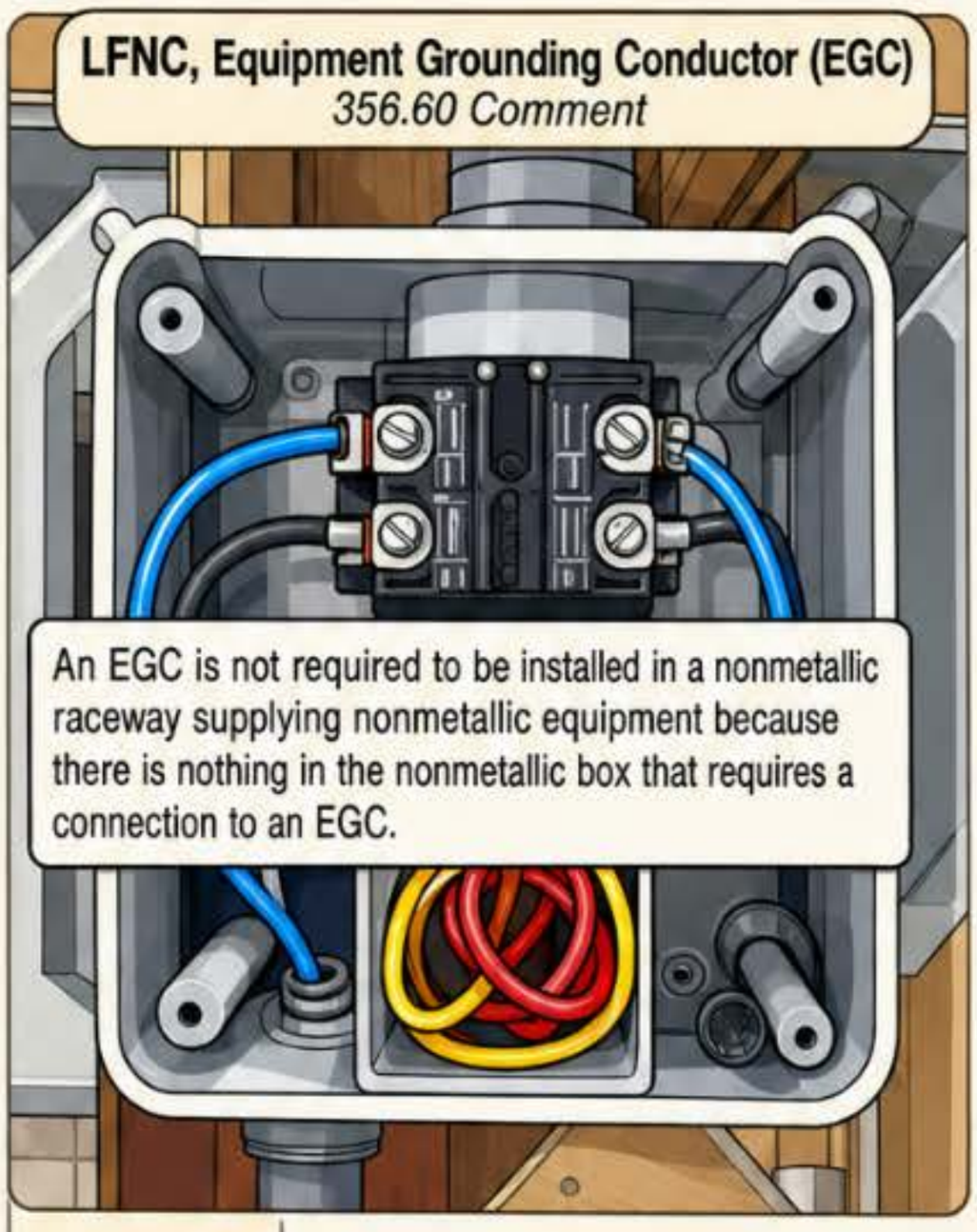


Figure 356-8

356.60 Equipment Grounding Conductor

If equipment grounding is required, a separate equipment grounding conductor of the wire type must be installed inside the conduit [250.134(2)].

ARTICLE

358 ELECTRICAL METALLIC TUBING (TYPE EMT)

Introduction to Article 358—Electrical Metallic Tubing (Type EMT)

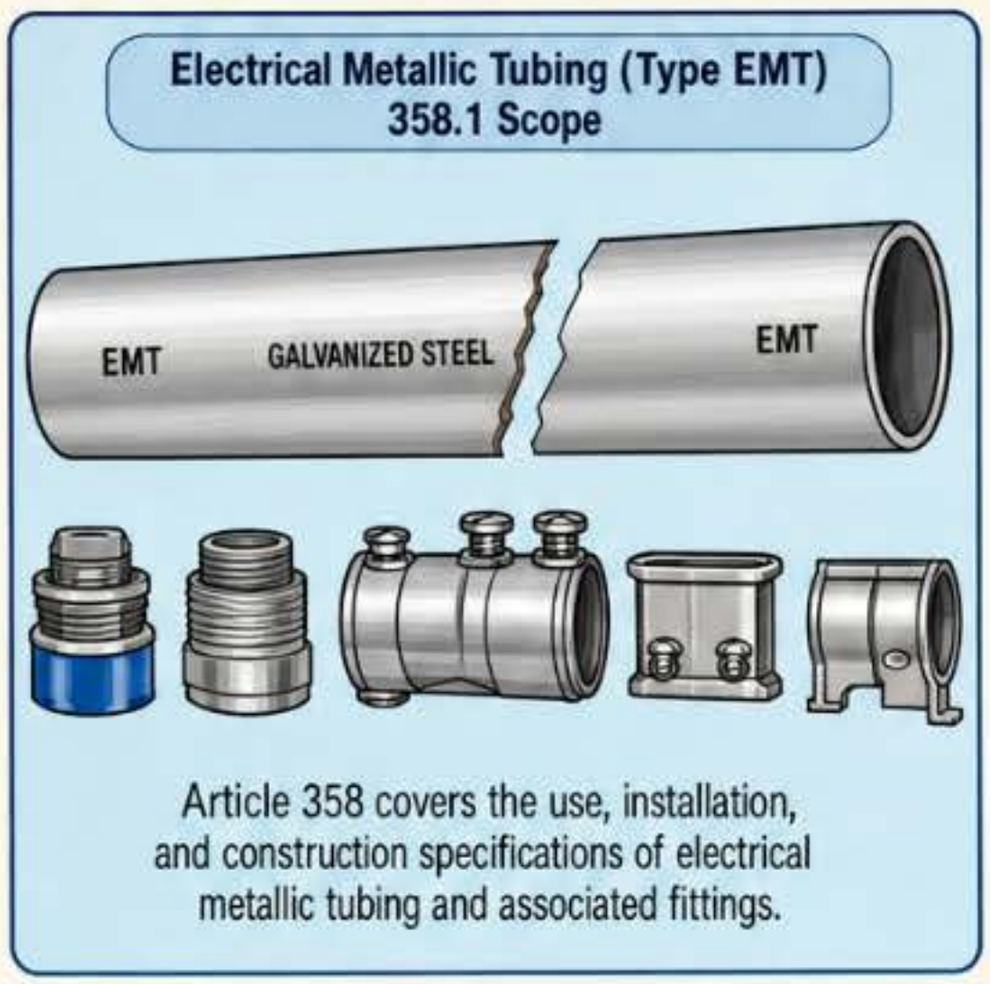
Electrical metallic tubing (Type EMT) is perhaps the most commonly used raceway in commercial and industrial installations. It is a lightweight raceway that is relatively easy to bend, cut, and ream. Because EMT is not threaded, all connectors and couplings are of the threadless type (either set screw or compression) and provide for quick, easy, and inexpensive installations as compared to other metallic raceway systems; all of which make it very popular. Electrical metallic tubing is manufactured in both galvanized steel and aluminum; the steel type is used most often.

Part I. General

358.1 Scope

Article 358 covers the use, installation, and construction specifications of electrical metallic tubing (Type EMT) and associated fittings.

- **Figure 358–1**

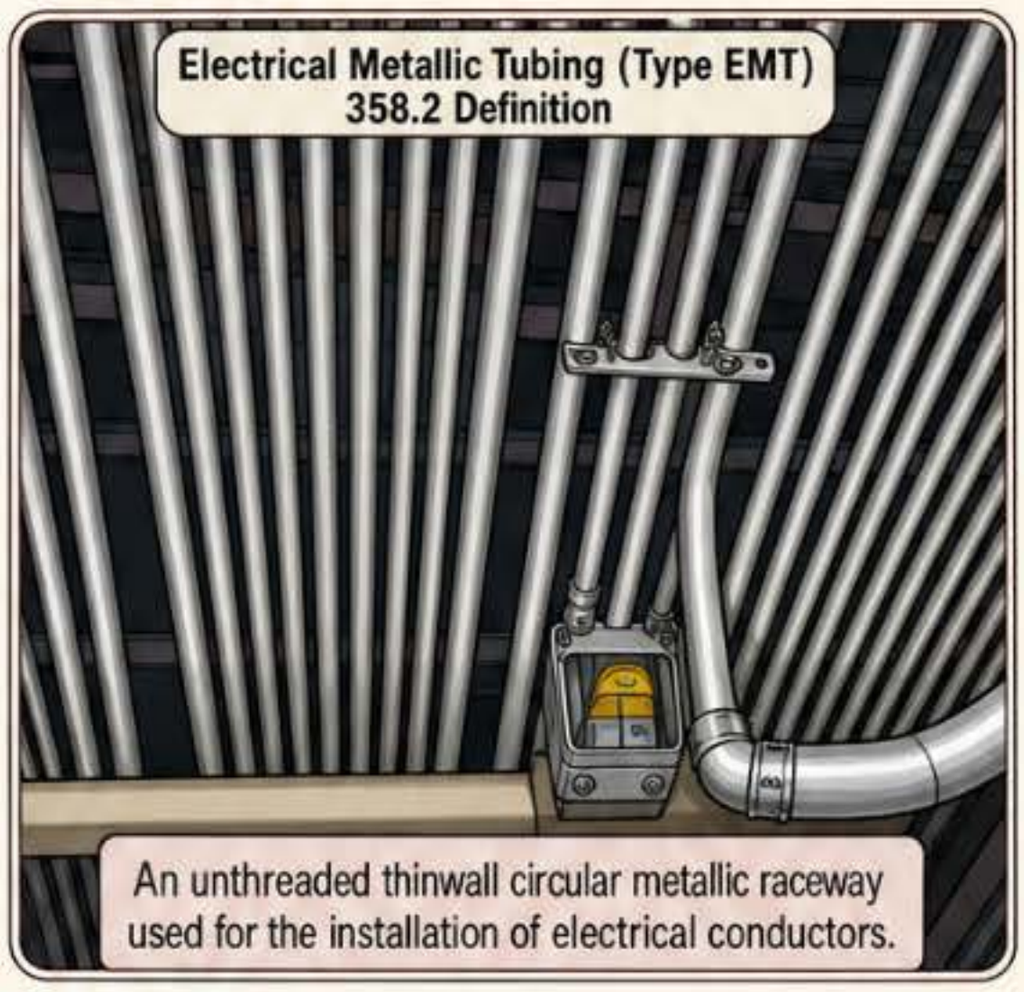


▶ **Figure 358–1**

358.2 Definition

Electrical Metallic Tubing (Type EMT). An unthreaded thinwall circular metallic raceway used for the installation of electrical conductors. When joined together with listed fittings and enclosures as a complete system, it is a reliable wiring method providing both physical protection for conductors as well as effective ground-fault current path.

- **Figure 358–2**



▶ **Figure 358–2**

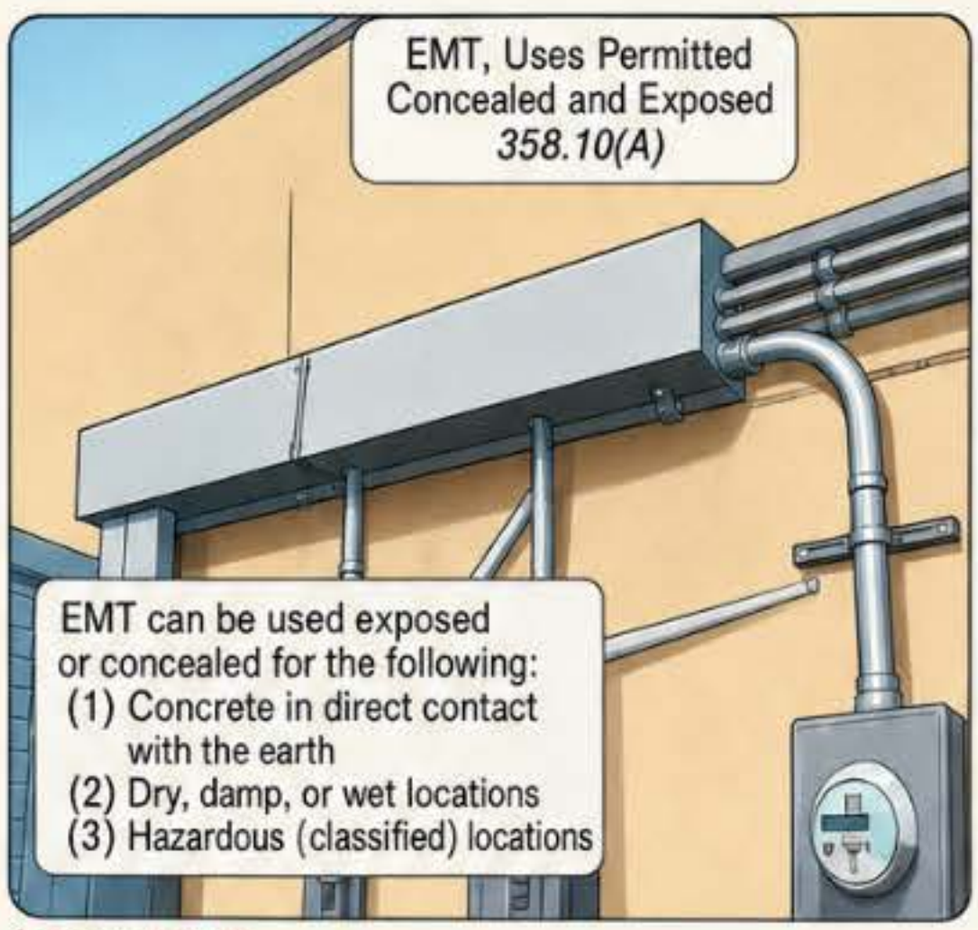
358.6 Listing Requirements

EMT and associated fittings must be listed.

Part II. Installation

358.10 Uses Permitted

(A) Exposed and Concealed. EMT is allowed for both exposed and concealed installations in the following applications: ▶ Figure 358–3



▶ Figure 358–3

(1) In concrete in direct contact with the earth in accordance with 358.10(B).

(2) In dry, damp, or wet locations.

(3) In any hazardous (classified) location as permitted by other articles in this *Code*.

(B) Corrosive Environments.

(1) Galvanized Steel. Galvanized steel EMT, elbows, and fittings can be installed in concrete, in direct contact with the earth, or in areas subject to severe corrosive influences if protected by corrosion protection and approved as suitable for the condition [300.6(A)].

(D) Wet Locations. Support fittings such as screws, straps, and so on, installed in a wet location must be made of corrosion-resistant material.

Author's Commentary:

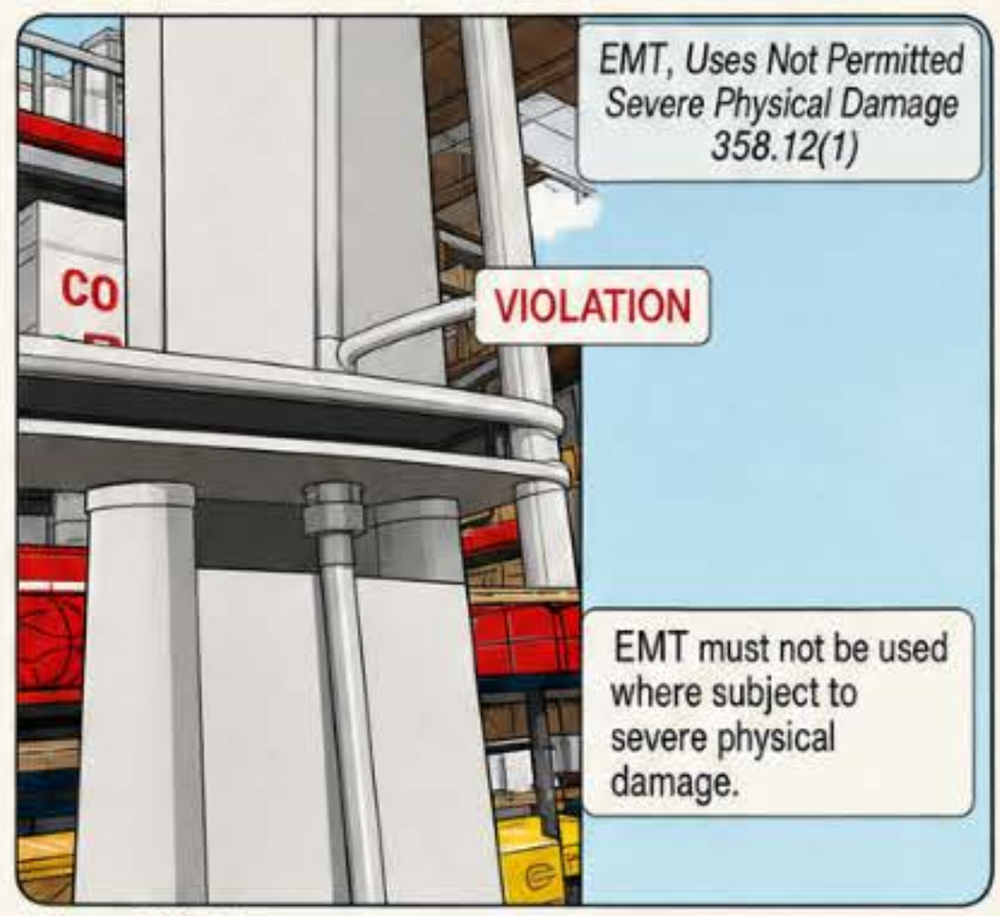
If installed in wet locations, fittings for EMT must be listed for use in wet locations and prevent moisture or water from entering or accumulating within the enclosure in accordance with 314.15 [358.42].

— Michael Hamilton

358.12 Uses Not Permitted

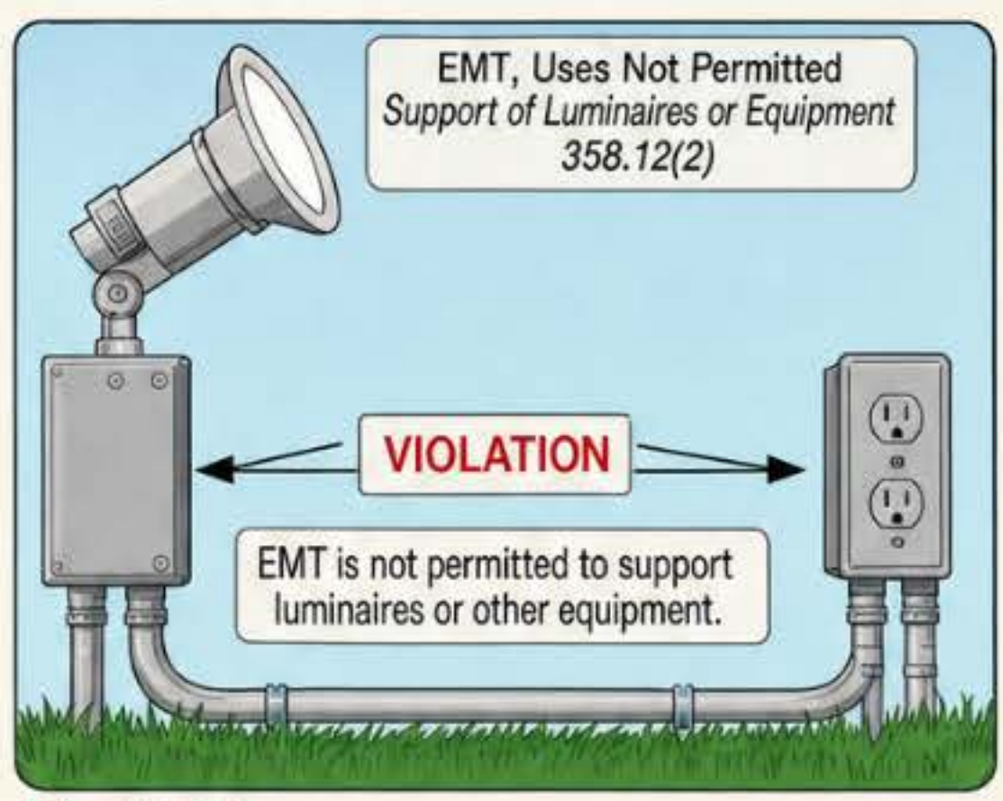
EMT is not allowed to be used under the following conditions:

(1) Where subject to severe physical damage. ▶ Figure 358–4



▶ Figure 358–4

(2) For the support of luminaires or other equipment. ▶ Figure 358–5



▶ Figure 358–5

358.20 Trade Size

(A) Minimum. EMT smaller than trade size ½ is prohibited.

(B) Maximum. EMT larger than trade size 4 is prohibited.

358.22 Number of Conductors

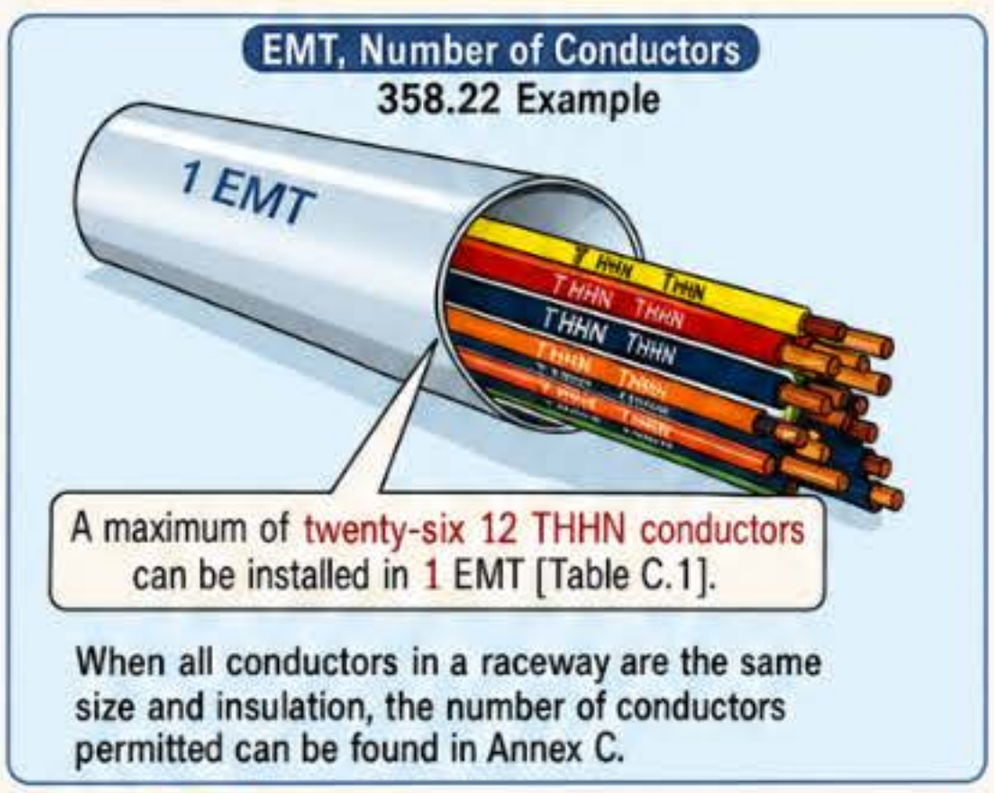
Raceways must be large enough to allow installation and removal of conductors without harming their insulation, and the total number of conductors is not allowed to go beyond the percentage limits in Chapter 9, Table 1.

When all conductors in a raceway share the same size and insulation, the permitted conductor count is provided in Annex C for the raceway type.

▶ Example

Question: *How many 12 THHN conductors can be installed in trade size 1 EMT?* ▶ Figure 358–6

(a) 23 conductors *(b) 24 conductors*
(c) 25 conductors *(d) 26 conductors*



▶ Figure 358–6

Answer: *(d) 26 conductors [Annex C, Table C.1]*

Author's Commentary:

See 300.17 for examples on how to size raceways when conductors are not all the same size.

— Michael Hamilton

358.24 Bends

Raceway bends are not permitted to be made in any manner that will damage the raceway or significantly change its internal diameter (no kinks).

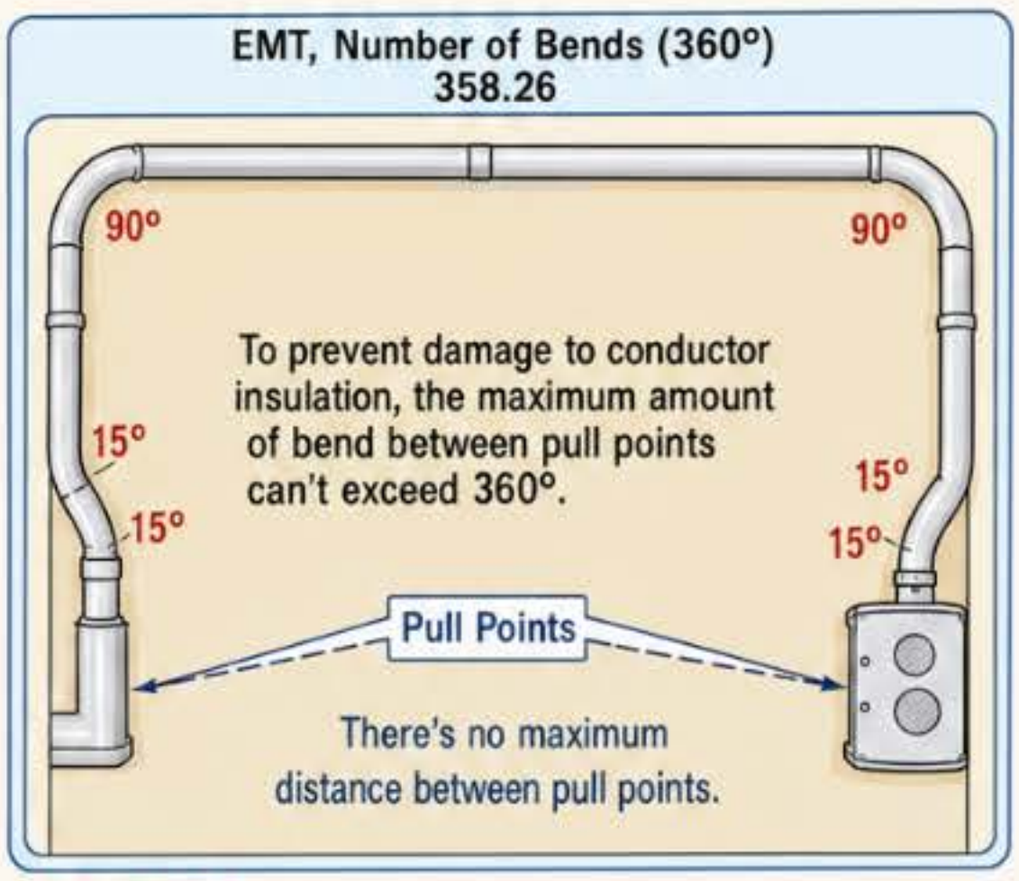
Author's Commentary:

This is generally not a problem, because typical EMT benders are made to comply with this requirement.

— Michael Hamilton

358.26 Number of Bends (360°)

To reduce the stress and friction on conductor insulation, the total bends (including offsets) between pull points cannot exceed 360°. ▶ Figure 358–7



▶ Figure 358–7

Author's Commentary:

There is no maximum distance between pull boxes because this is a design issue, not a safety issue.

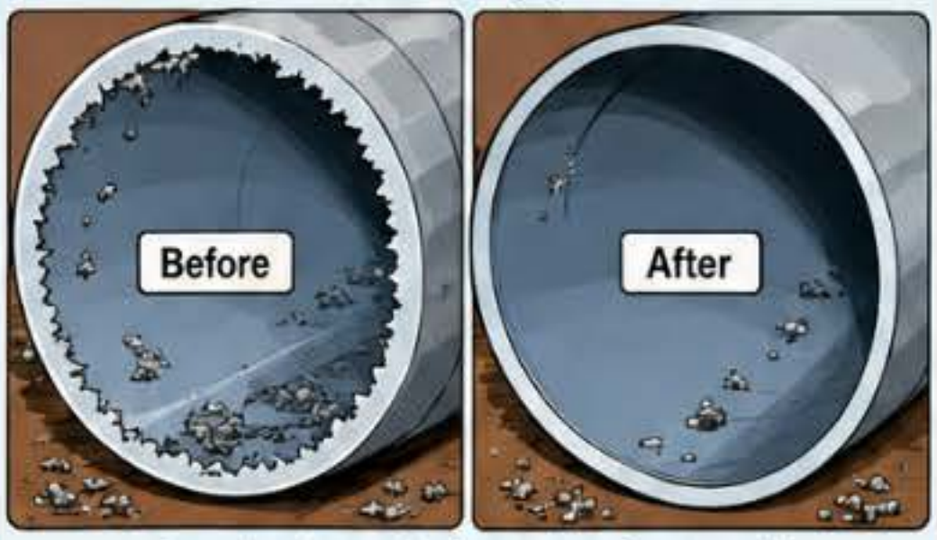
— Michael Hamilton

358.28 Reaming

(A) Reaming. Reaming to remove the burrs and rough edges is required when the raceway is cut. ▶ Figure 358–8

358.30 | Electrical Metallic Tubing (Type EMT)

EMT Reaming
358.28(A)



Reaming is required to remove burrs and rough edges when the raceway is cut.

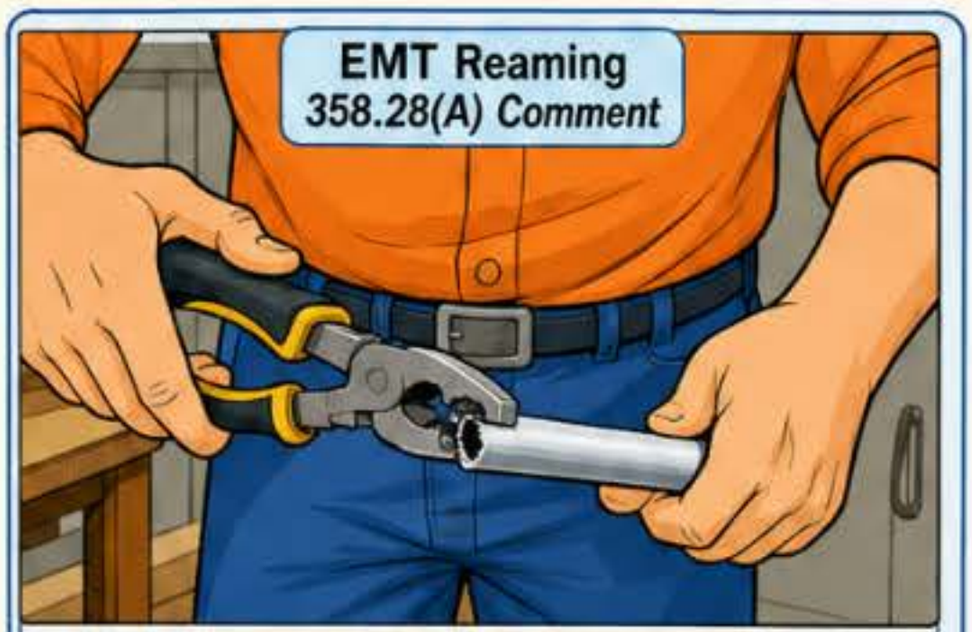
Figure 358-8

Author's Commentary:

It is considered an accepted practice to ream small raceways with a screwdriver or lineman's pliers.

— Michael Hamilton

EMT Reaming
358.28(A) Comment



It's considered an acceptable practice to ream small raceways with a screwdriver or lineman's pliers.

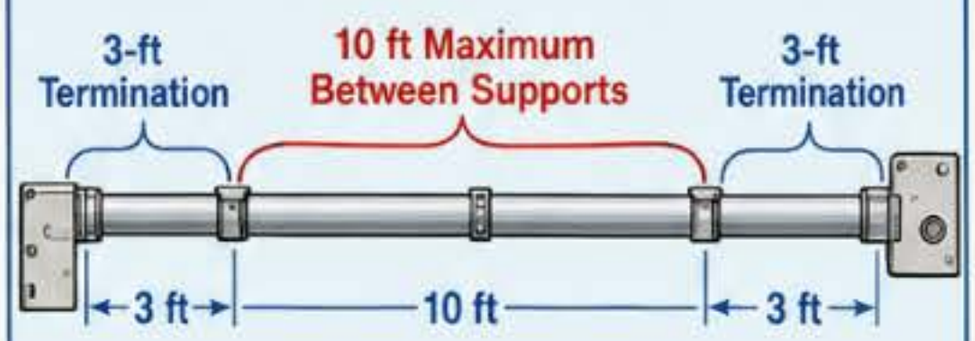
Figure 358-9

358.30 Securing and Supporting

EMT must be securely fastened in place and supported in accordance with (A) and (B).

(A) Securely Fastened. EMT must be securely fastened within 3 ft of every box, cabinet, or termination fitting, and at intervals not exceeding 10 ft. ▶ Figure 358-10

EMT Securely Fastened
358.30(A)



EMT must be securely fastened within 3 ft of every box, cabinet, or termination fitting and at intervals not exceeding 10 ft.

Figure 358-10

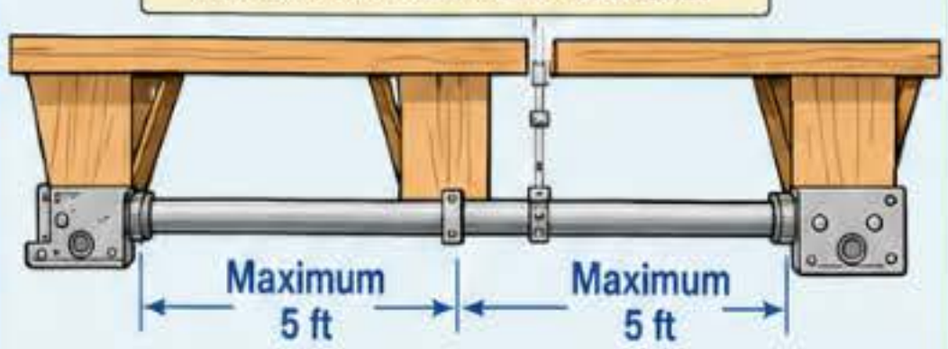
Author's Commentary:

Fastening is required within 3 ft of termination, not within 3 ft of a coupling.

— Michael Hamilton

Ex 1: When structural members do not permit the raceway to be secured within 3 ft of a box or termination fitting, an unbroken raceway can be secured within 5 ft of a box or termination fitting. ▶ Figure 358-11

EMT Securely Fastened
358.30(A) Ex 1



Where structural members don't permit fastening within 3 ft of the termination, EMT must be secured within 5 ft.

Figure 358-11

(B) Horizontal Runs. EMT installed horizontally in bored or punched holes in wood or metal framing members, or notches in wooden members at intervals not greater than 3 ft, is considered supported, but the raceway must be secured within 3 ft of termination. ▶ Figure 358-12

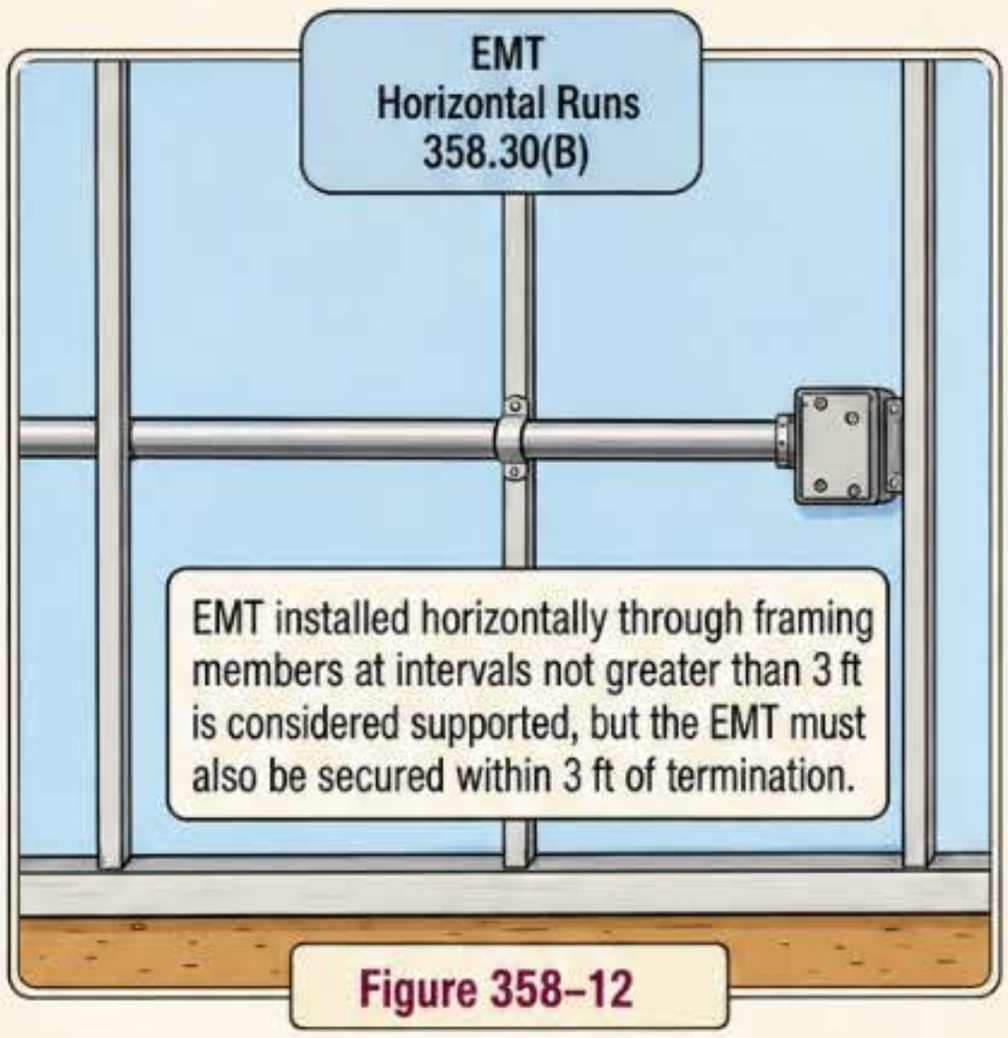


Figure 358–12

358.42 Couplings and Connectors

Couplings and connectors must be made up tight to maintain an effective ground-fault current path to safely conduct fault current in accordance with 250.4(A)(5), 250.96(A), and 300.10.

If buried in masonry or concrete, threadedless EMT fittings must be of the concrete-tight type. If installed in wet locations, they must be listed for use in wet locations and prevent moisture or water from entering or accumulating inside the enclosure in accordance with 314.15.

♦ Figure 358–13

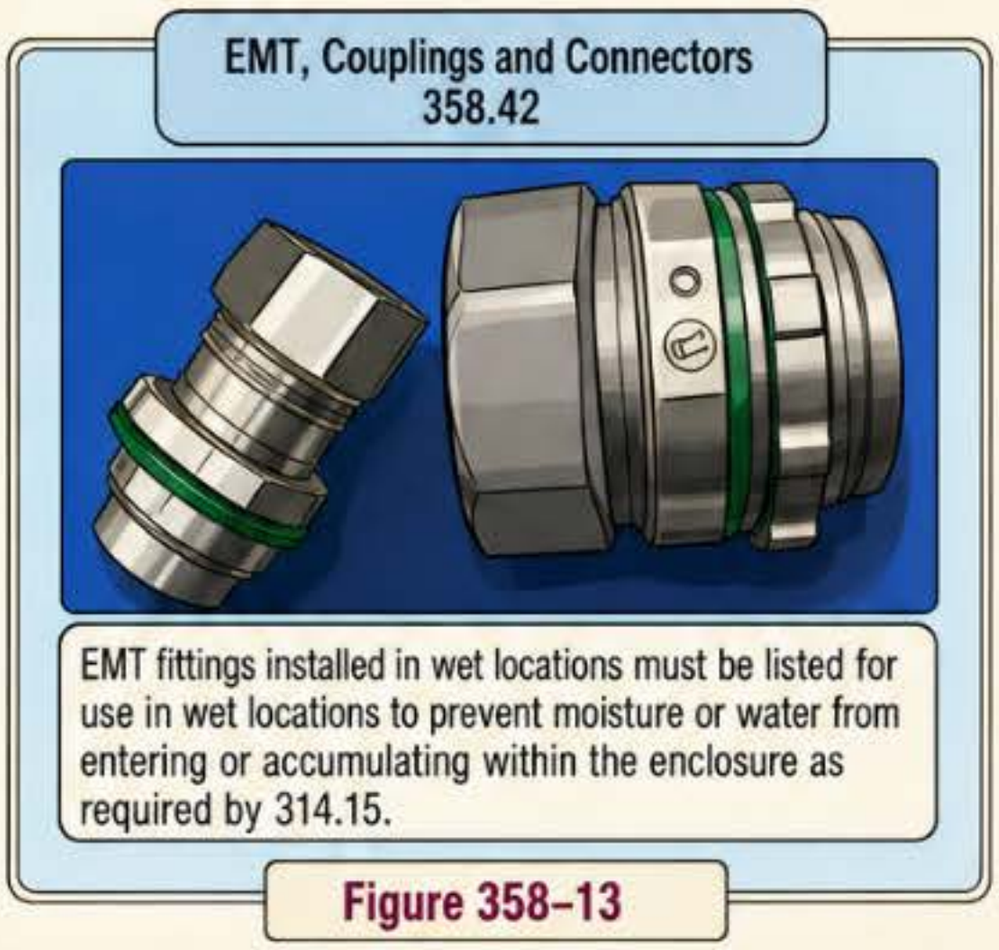


Figure 358–13

358.60 Equipment Grounding Conductor

EMT can serve as an equipment grounding conductor [250.118(4)].

♦ Figure 358–14

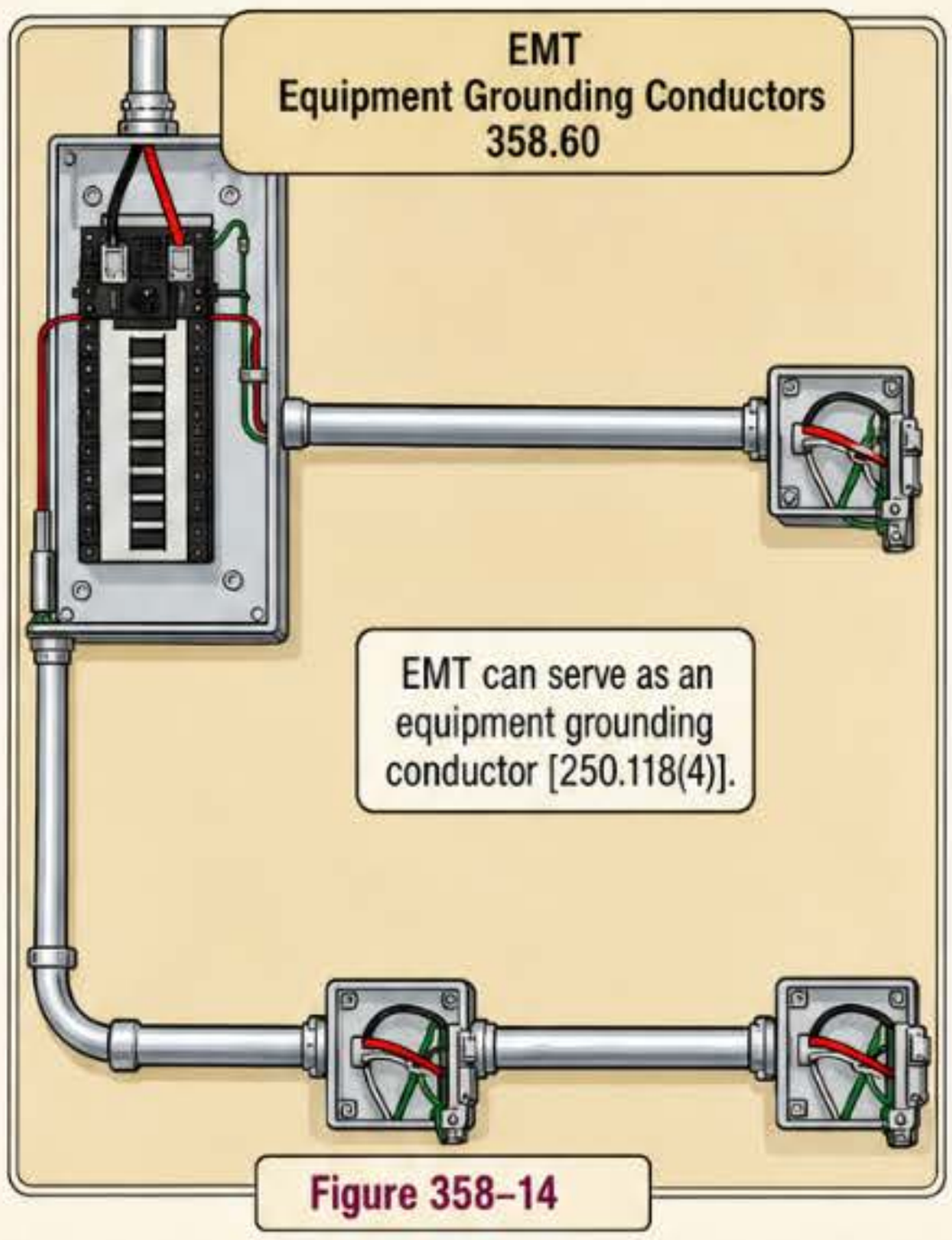


Figure 358–14

100 | DEFINITIONS

Ground-Fault Current Path. An electrically conductive route created when a ground fault occurs in a wiring system. The path is formed through typically noncurrent-carrying parts such as equipment grounding conductors, metal enclosures, metal raceways, installed equipment, or the Earth, back to the electrical supply source. **(Figure 100–78)**

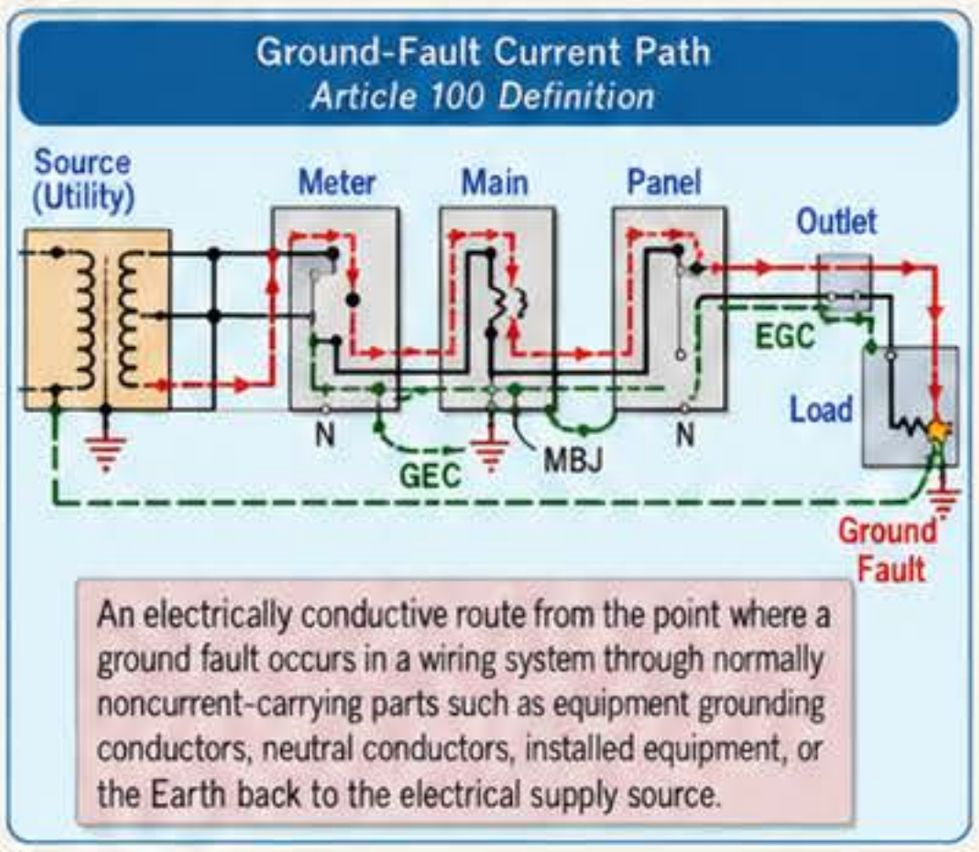


Figure 100–78

Note: Ground-fault current paths can involve any mix of equipment grounding conductors, metallic raceways, metal cable sheaths, installed equipment, and other conductive materials like metal, water, and gas piping; structural framing members; metal studs; reinforcement steel; shields of communication cables; neutral conductors; and the Earth itself.

Ground-Fault Protection of Equipment. A system designed to shield equipment from ground-fault damage by opening *all ungrounded phase conductors of the affected circuit. This protection limits current to levels that circuit conductors can withstand without damage during fault clearing of a supply circuit overcurrent protective device [215.10, 230.95, and 240.13].*

Author's Commentary:

This type of protective device is not meant to protect people. It trips (opens the circuit) at a current higher than that of a "Class A" ground-fault protective device. It is typically referenced as ground-fault protection for equipment, or GFPE, but should never be called a GFCI.

— Michael Hamilton

Grounding Conductor, Equipment (Equipment Grounding Conductor). *The conductive path that is part of an effective ground-fault current path and connects metal parts of equipment to the system neutral conductor or to a grounded-phase conductor [250.110 through 250.126].* **(Figure 100–79)**

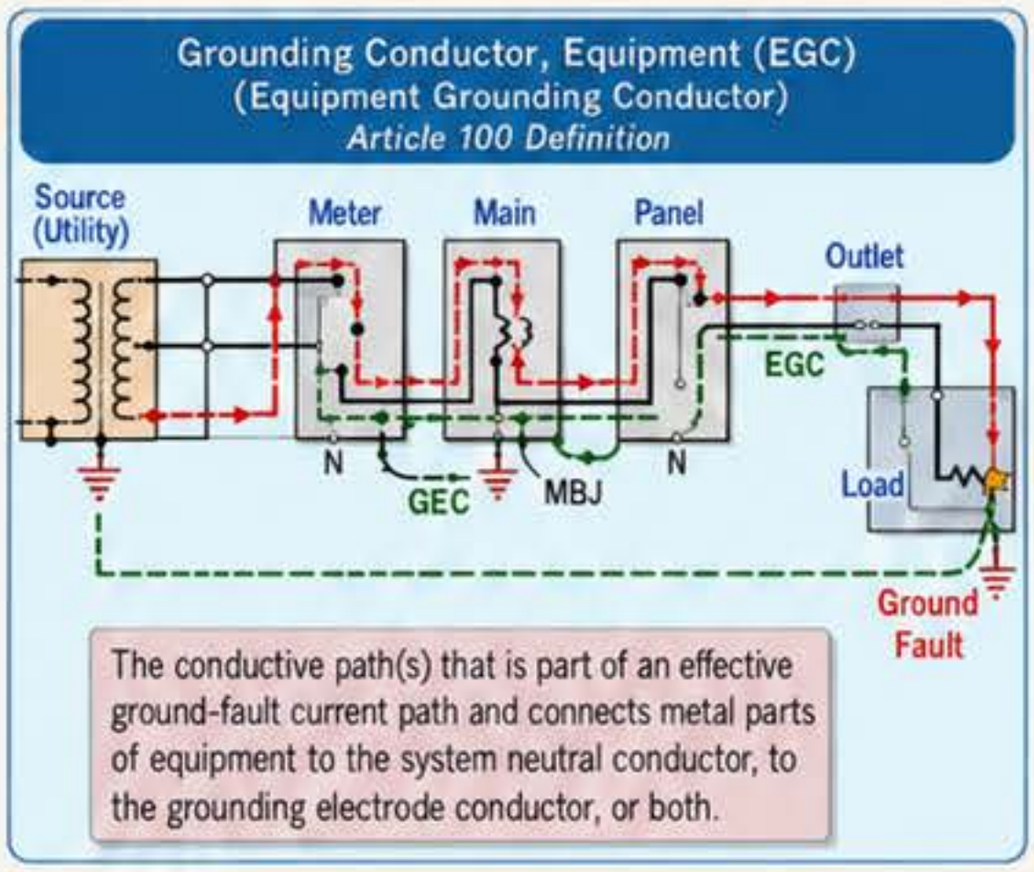


Figure 100–79

Note 1: The circuit equipment grounding conductor also performs bonding.

Author's Commentary:

- To quickly remove dangerous touch voltage on metal *parts from a ground fault, the equipment grounding conductor (EGC) must be connected to the system neutral conductor at the source and have low enough impedance so fault current will quickly rise to a level that will cause a supply circuit overcurrent protective device to trip.* [250.4(A)(3)]

— Michael Hamilton

Note 2: An equipment grounding conductor can be any one or a combination of the types listed in 250.118. **(Figure 100–81)**

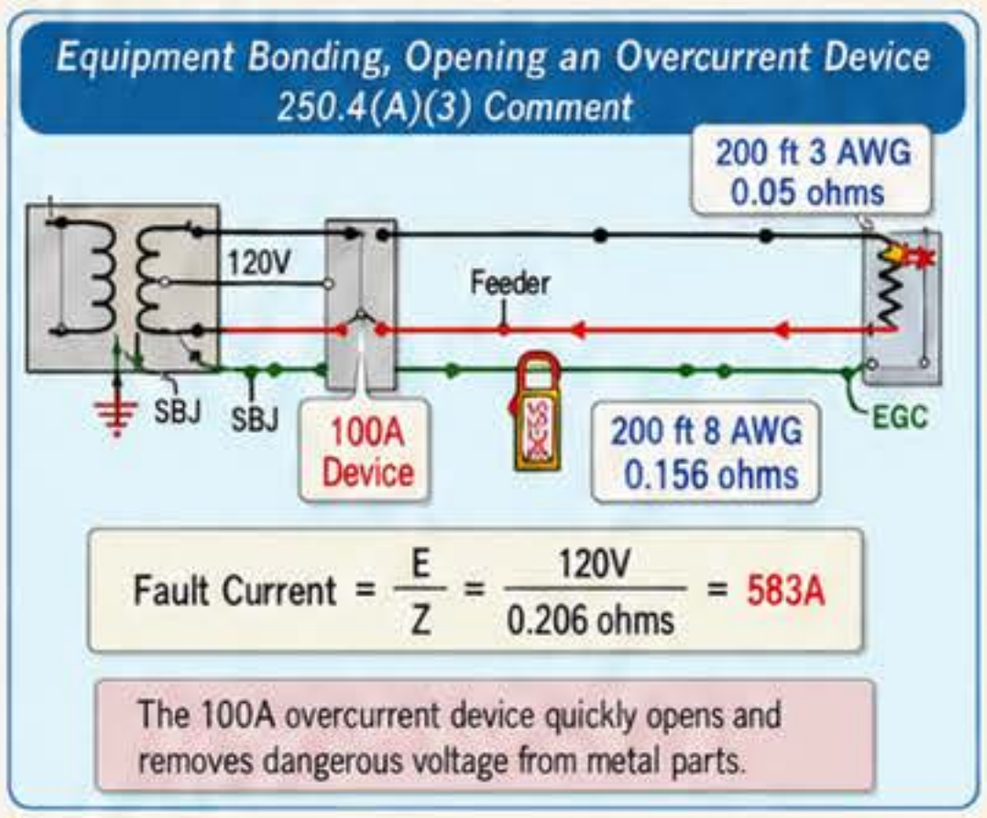


Figure 100–80

ARTICLE 362

ELECTRICAL NONMETALLIC TUBING (TYPE ENT)

Introduction to Article 362—Electrical Nonmetallic Tubing (Type ENT)

Electrical nonmetallic tubing is a pliable, corrugated, circular raceway. You might see it used at swimming pools and it's often called "Smurf Pipe" or "Smurf Tube" (a nod to the children's cartoon "The Smurfs") because it was only blue when it first appeared. It can now be purchased in additional colors such as red and yellow.

Part I. General

362.1 Scope

Article 362 covers the use, installation, and construction specifications of electrical nonmetallic tubing (Type ENT) and associated fittings. Figure 362-1

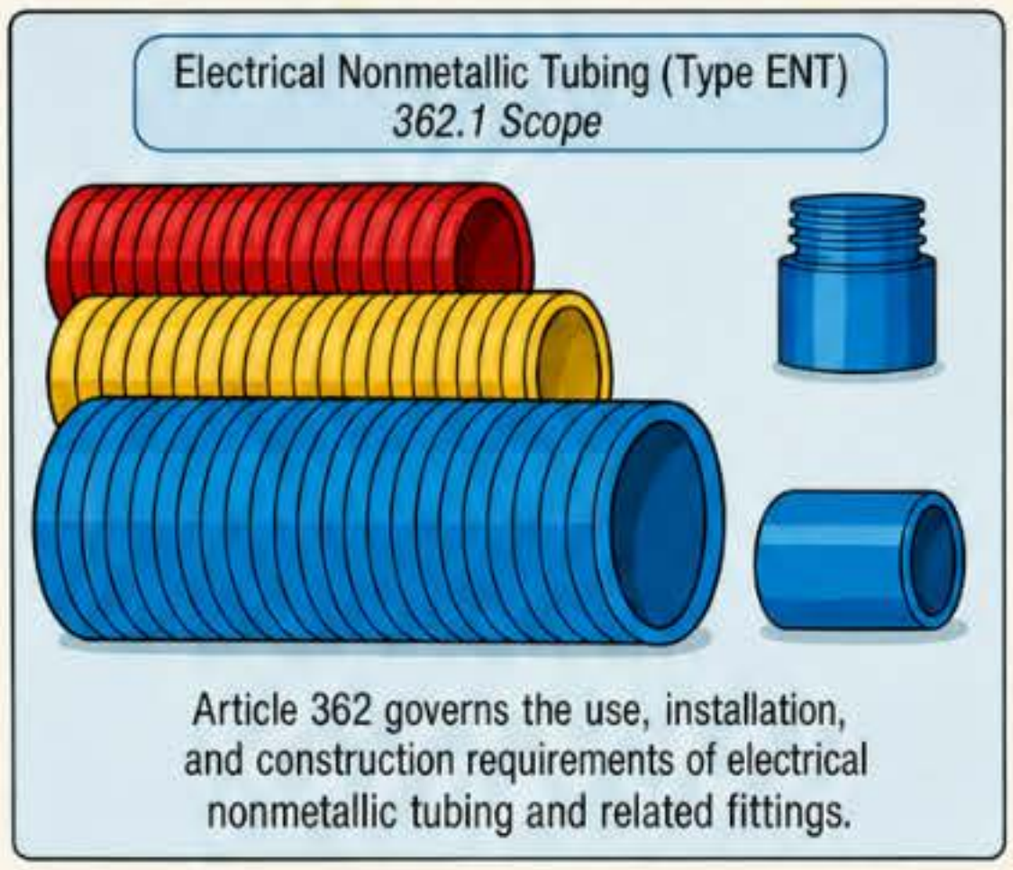


Figure 362-1

362.2 Definition

Electrical nonmetallic tubing (Type ENT) is a pliable corrugated raceway of circular cross section. It includes integral or associated couplings, connectors, and fittings that are listed for the installation of electrical conductors. It is made of a material that resists moisture, chemical agents, and combustion. Figure 362-2

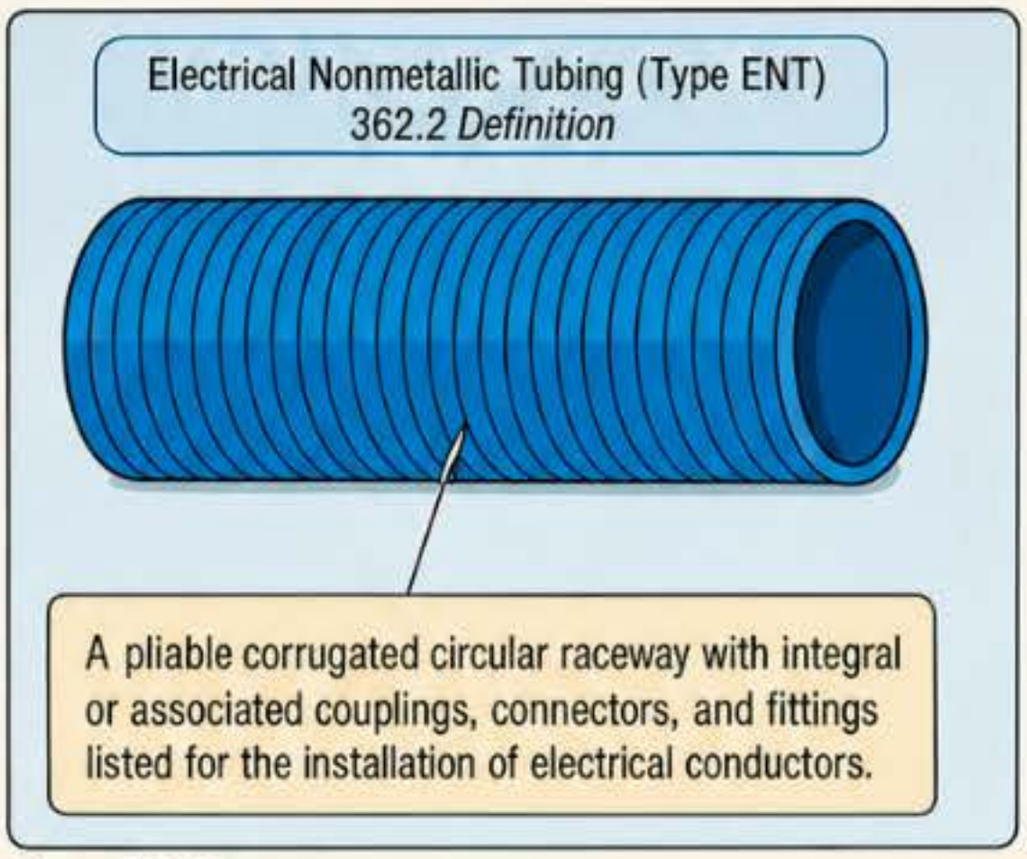


Figure 362-2

Electrical nonmetallic tubing can be bent by hand with reasonable force but without help from other tools.

362.6 Listing

ENT and its associated fittings must be listed.

Part II. Installation

362.10 Uses Permitted

Electrical nonmetallic tubing is permitted as follows:

(1) In buildings not exceeding three floors. Figure 362-3

362.10 | Electrical Nonmetallic Tubing (Type ENT)

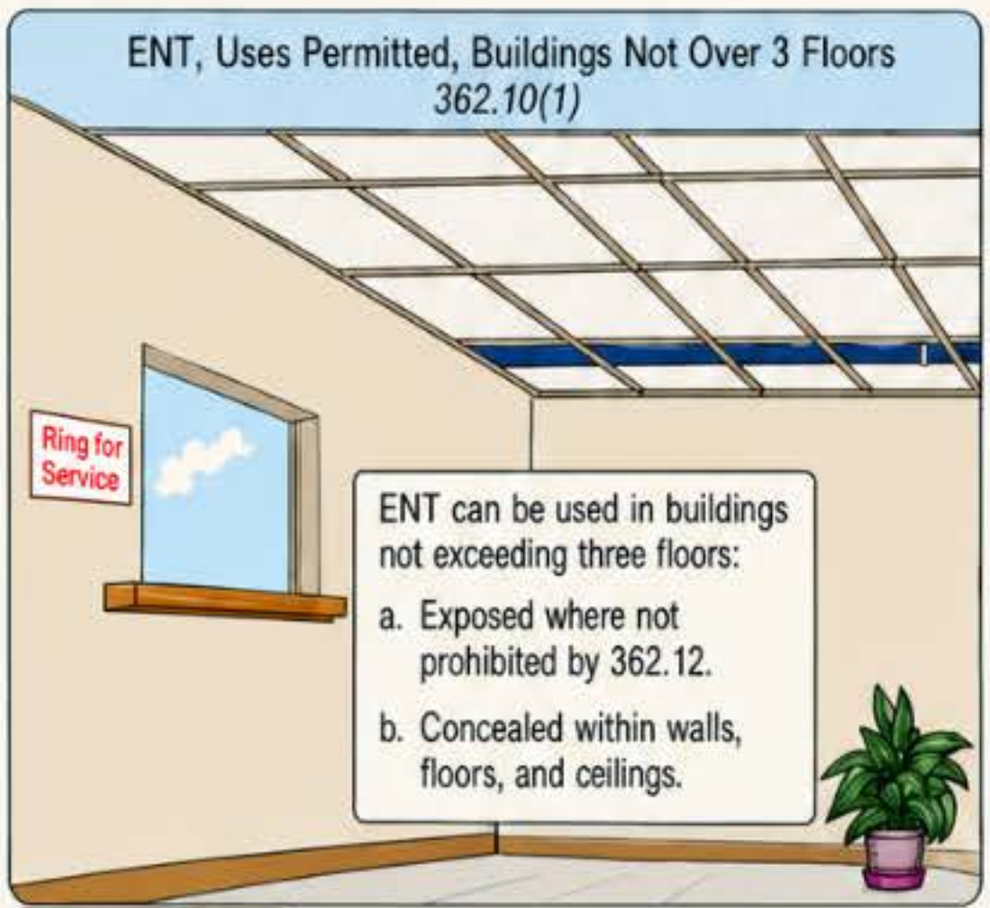


Figure 362–3

a. Exposed, where not prohibited by 362.12.

b. Concealed within walls, floors, and ceilings.

(2) In buildings exceeding three floors, where installed concealed in walls, floors, or ceilings that provide a thermal barrier having a 15-minute finish rating, as identified in listings of fire-rated assemblies. ▸ Figure 362–4

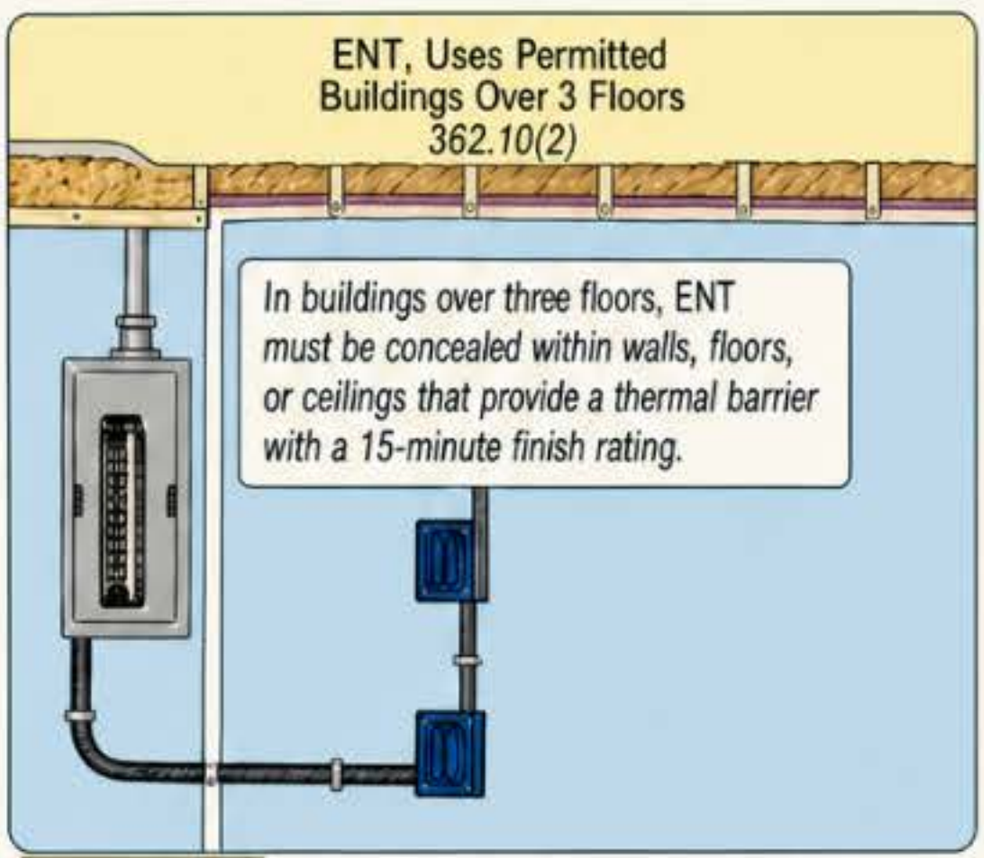


Figure 362–4

Ex to (2): If a fire sprinkler system is installed on all floors in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems, electrical nonmetallic tubing is permitted exposed or concealed in buildings of any height. ▸ Figure 362–5

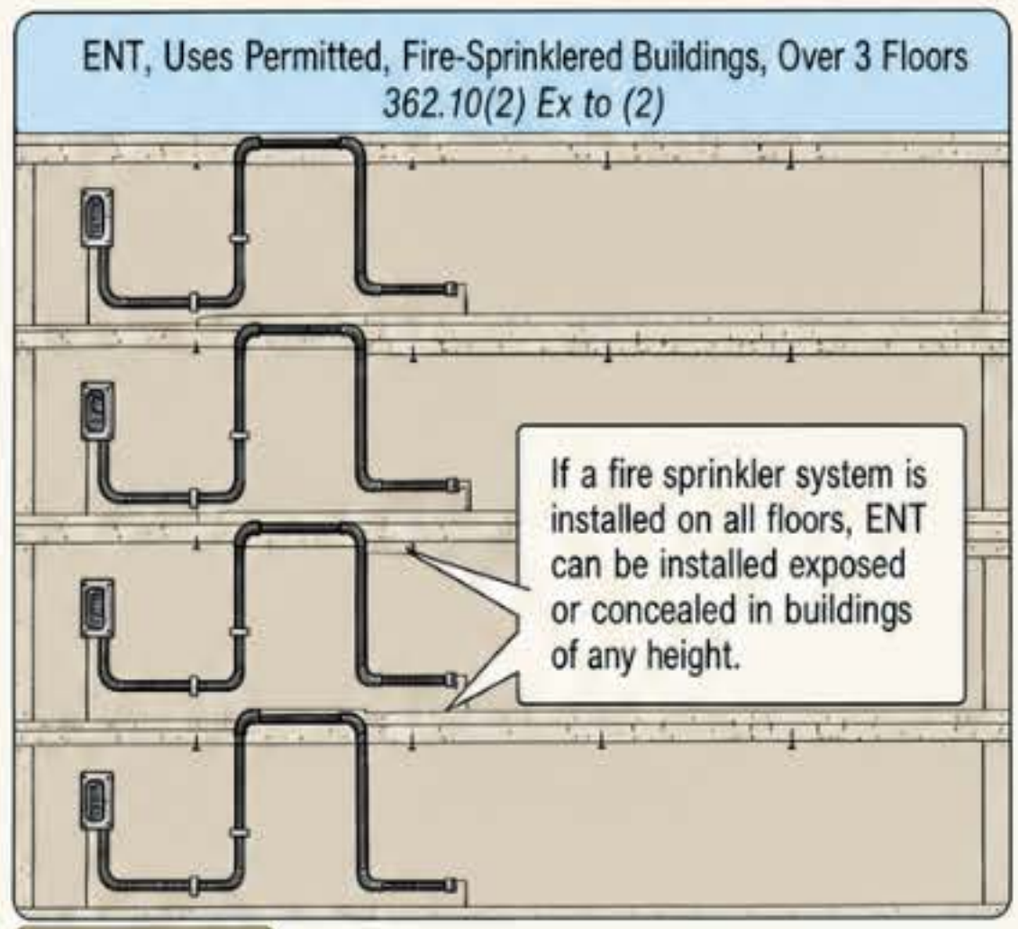


Figure 362–5

Author's Commentary:

- *ENT is not allowed above a suspended ceiling used as a plenum space [300.22(C)].*
- *In severe corrosive and chemical locations when identified for this use.*
- *In dry and damp concealed locations if not prohibited by 362.12.*
- *Above a suspended ceiling if the suspended ceiling provides a thermal barrier having a 15-minute finish rating, as identified in listings of fire-rated assemblies.* ▸ Figure 362–6

— Michael Hamilton

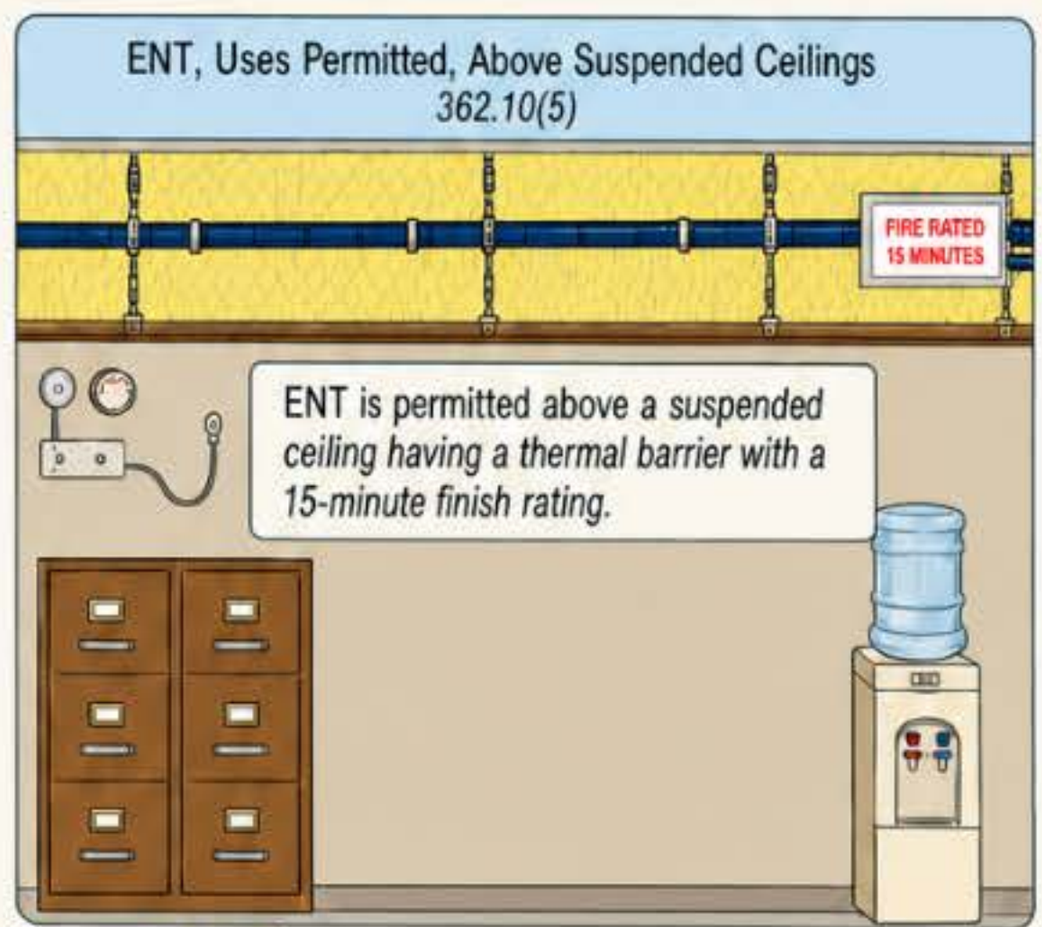
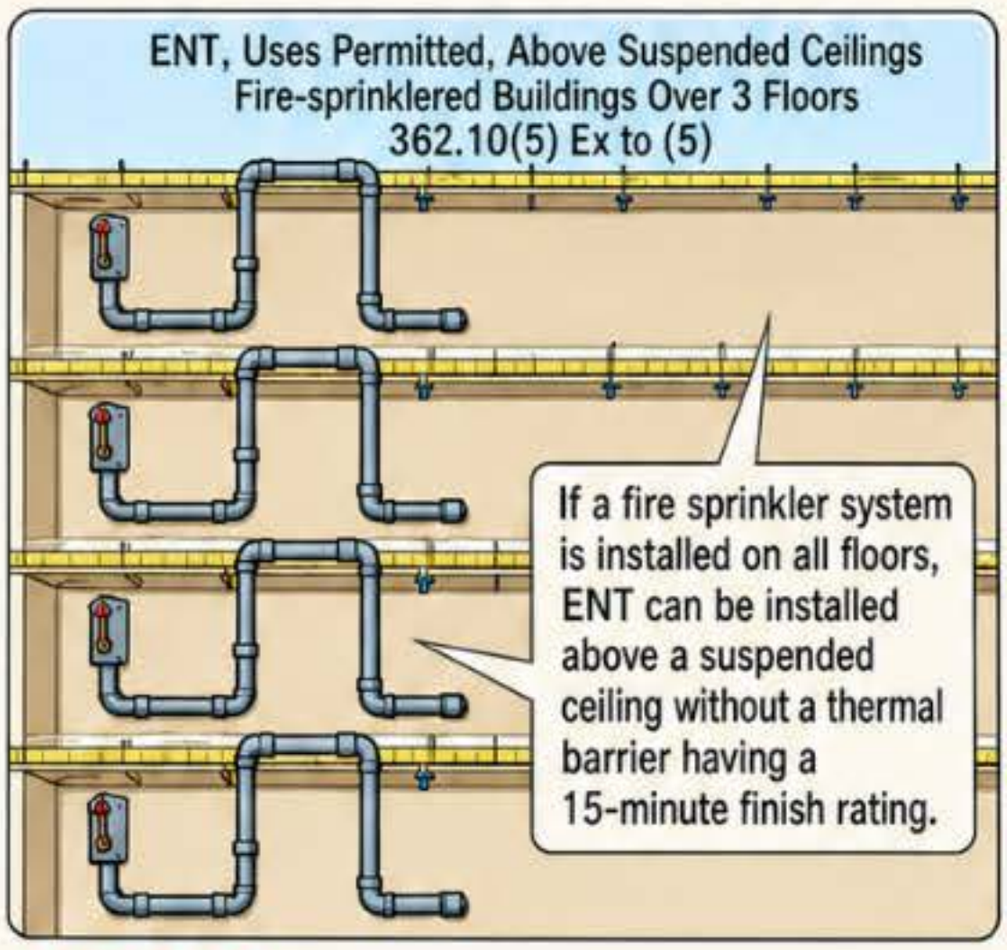


Figure 362–6

DEFINITIONS | From Michael Hamilton Publications

Ex to (5): When a fire sprinkler system is installed on all floors in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems, ENT is allowed above a suspended ceiling in spaces that do not have a 15-minute finish-rated thermal barrier. ▶ Figure 362–7



▶ Figure 362–7

(6) Encased or embedded in a concrete slab provided fittings identified for the purpose are used.

(7) In wet locations indoors, or in a concrete slab on or below grade, with fittings that are listed for the purpose.

362.12 Uses Not Permitted

ENT is not allowed to be used in the following applications:

(1) In any hazardous (classified) location, except as permitted by *504.20* and *505.15(A)(1)*.

(2) For the support of luminaires or equipment. See 314.23.

(3) If the ambient temperature exceeds *50°C (122°F)*.

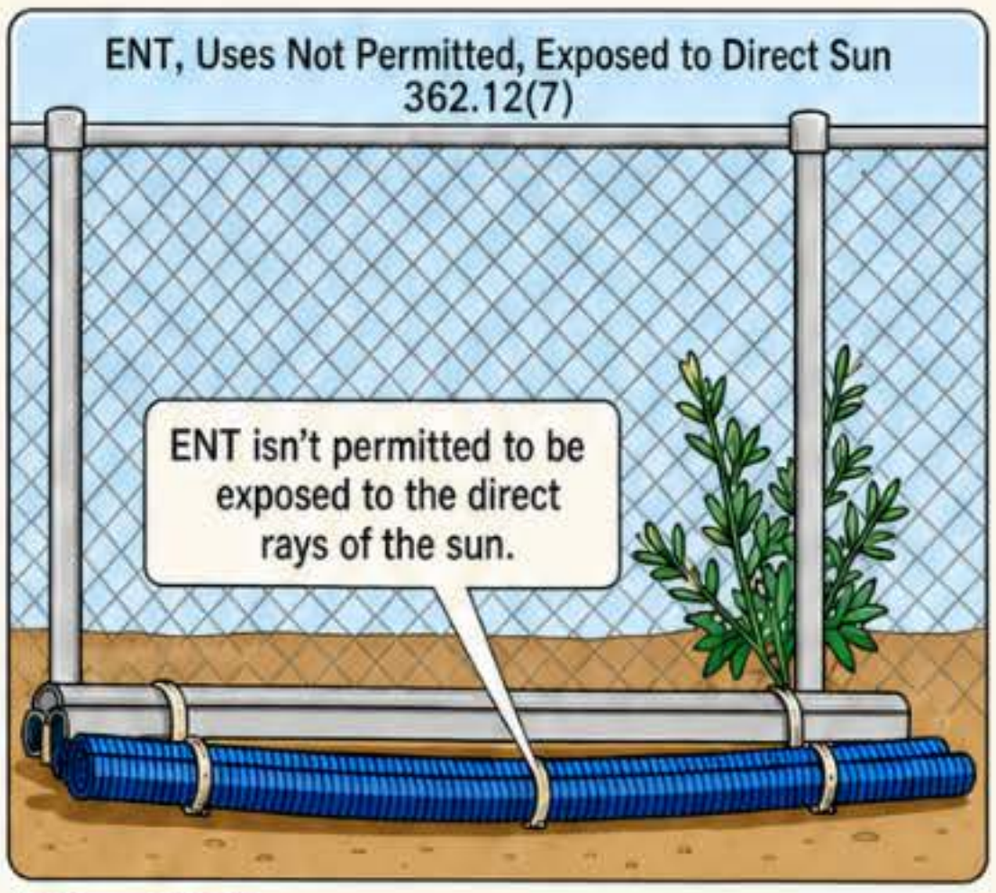
(4) For direct Earth burial.

Author's Commentary:
ENT is permitted to be encased in concrete [362.10(6)].
— Michael Hamilton

(5) Exposed in buildings over three floors, except as permitted by *362.10(1)* and *(5)* Ex.

(6) *In assembly occupancies or theaters, except as permitted by 518.4 and 520.5.*

(7) Exposed to the direct rays of the sun. ▶ Figure 362–8



▶ Figure 362–8

Author's Commentary:
Sunlight can cause electrical nonmetallic tubing to become brittle over time. As it degrades, the material may crack and allow ultraviolet (UV) radiation to harm the wiring.
— Michael Hamilton

(8) Where subject to physical damage.

Author's Commentary:
Nonmetallic tubing is not permitted in air ducts, plenum spaces [300.22(C)], and patient care space circuits in health care facilities [517.13(A)].
— Michael Hamilton

362.20 Trade Sizes

(A) **Minimum.** Electrical nonmetallic tubing smaller than trade size ½ is not permitted.

(B) **Maximum.** Electrical nonmetallic tubing larger than trade size 2½ is not permitted.

362.22 Number of Conductors

Raceways must be large enough to permit the installation and removal of conductors without damaging the conductors' insulation, and the number of conductors is not permitted to exceed the percentage fill specified in Chapter 9, Table 1.

Definitions | Electrical Nonmetallic Tubing (Type ENT)

When all conductors in a raceway are the same size and have the same insulation type, the quantity of conductors that are allowed can be determined using Annex C for the specific raceway category.

▶ Example

Question: *What is the maximum number of 12 THHN conductors permitted inside ½ inch ENT?* → **Figure 362-9**

(a) 2 conductors *(b) 4 conductors*
(c) 6 conductors *(d) 8 conductors*

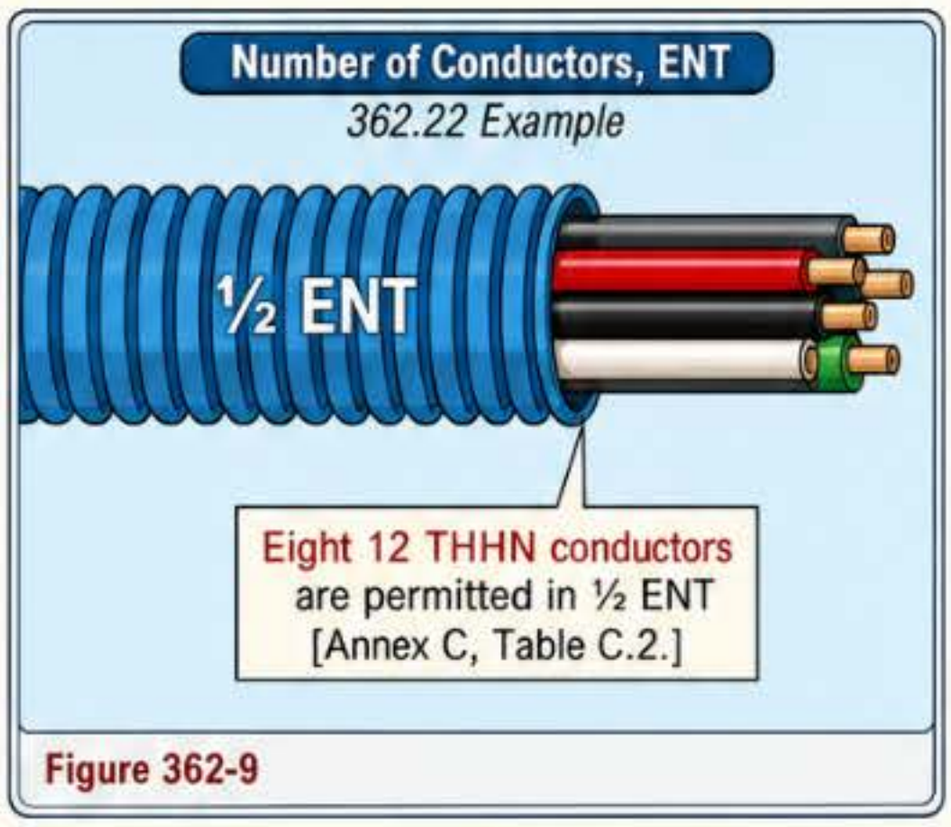


Figure 362-9

Answer: *(d) 8 conductors [Annex C, Table C.2.]*

Author's Commentary:

See 300.17 for illustrations showing how to size raceways when conductors are not all the same size.

— Michael Hamilton

362.24 Bends

Raceway bends are prohibited when they could harm the raceway or appreciably alter its internal diameter (for example, creating kinks).

362.26 Number of Bends (360°)

To limit stress and friction on conductor insulation, the sum of bends between pull points (including any offsets) cannot be more than 360°.

362.28 Trimming

The ends of electrical nonmetallic tubing must be cut flush (inside and out) and smoothed to remove burrs and sharp edges.

Author's Commentary:

Trimming ENT is simple: the burrs are easily removed with your fingers, and a knife can be used to smooth rough edges.

— Michael Hamilton

362.30 Securing and Supporting

ENT must be firmly secured and supported using approved methods in accordance with (A) and (B).

(A) Securely Fastened. ENT must be fastened within 3 ft of every box, cabinet, or termination fitting (such as a conduit body) and at intervals that do not exceed 3 ft. → **Figure 362-10**

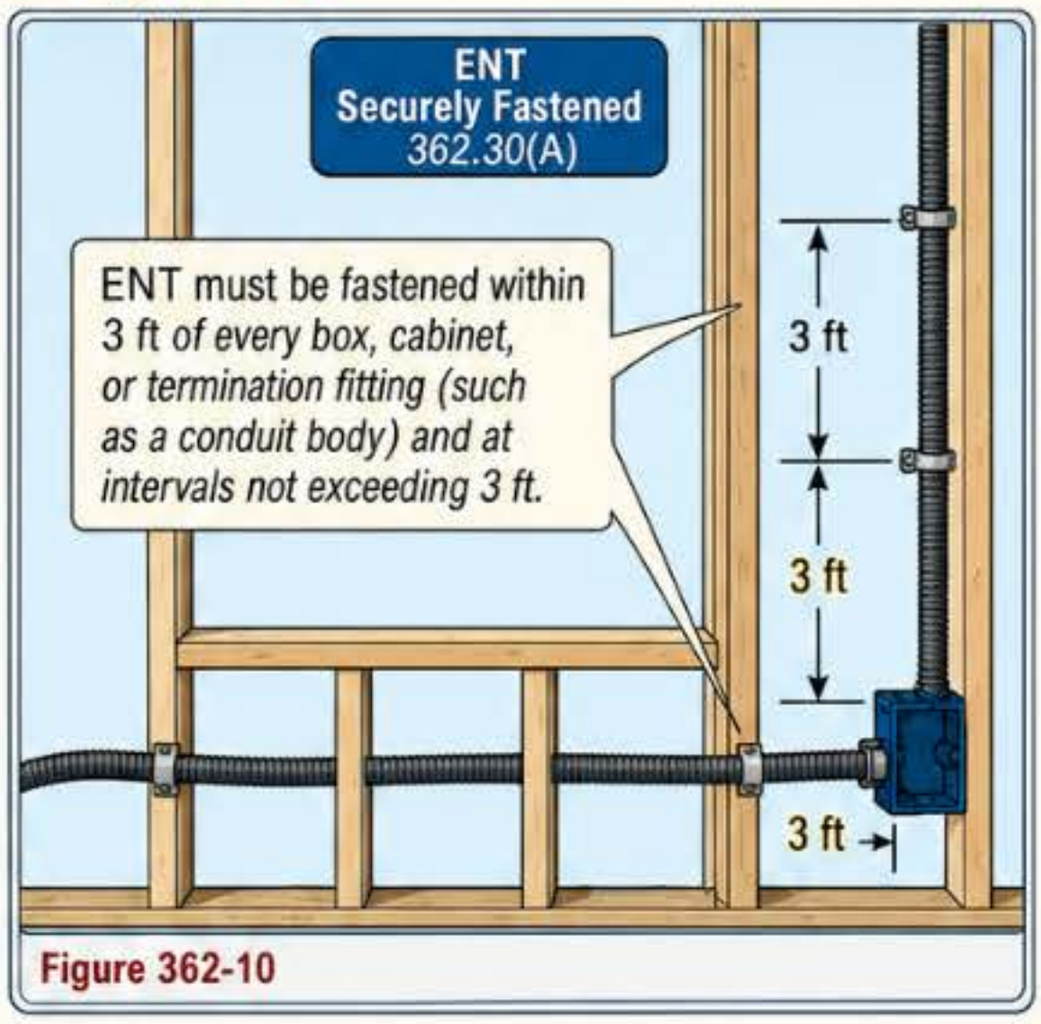


Figure 362-10

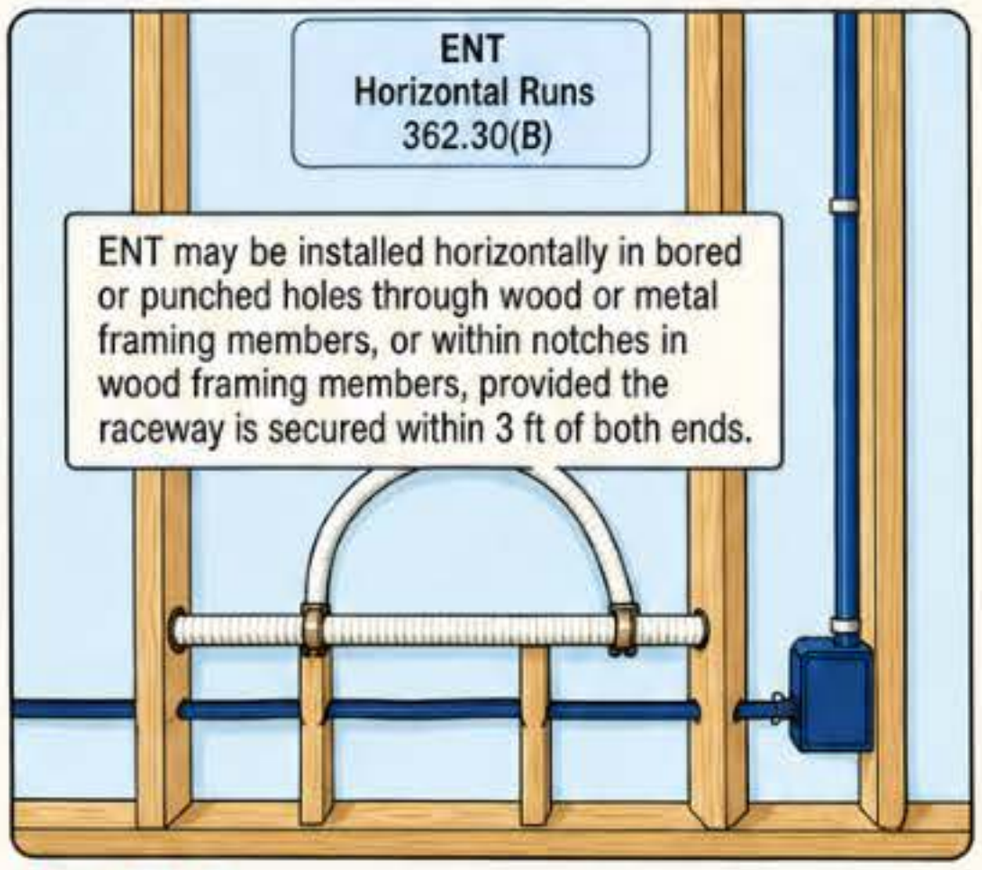
Cable ties used to secure and support ENT must be suitable for the environment and purpose of the installation.

Example 2: If the last support point is more than 6 ft from the raceway end, fasten the raceway within a reachable distance of the ceiling or luminaire(s), or use other supports.

Example 3: It is not practical to fish between access points through concealed spaces and provide support.

Electrical Nonmetallic Tubing (Type ENT) | 362.60 | 2023

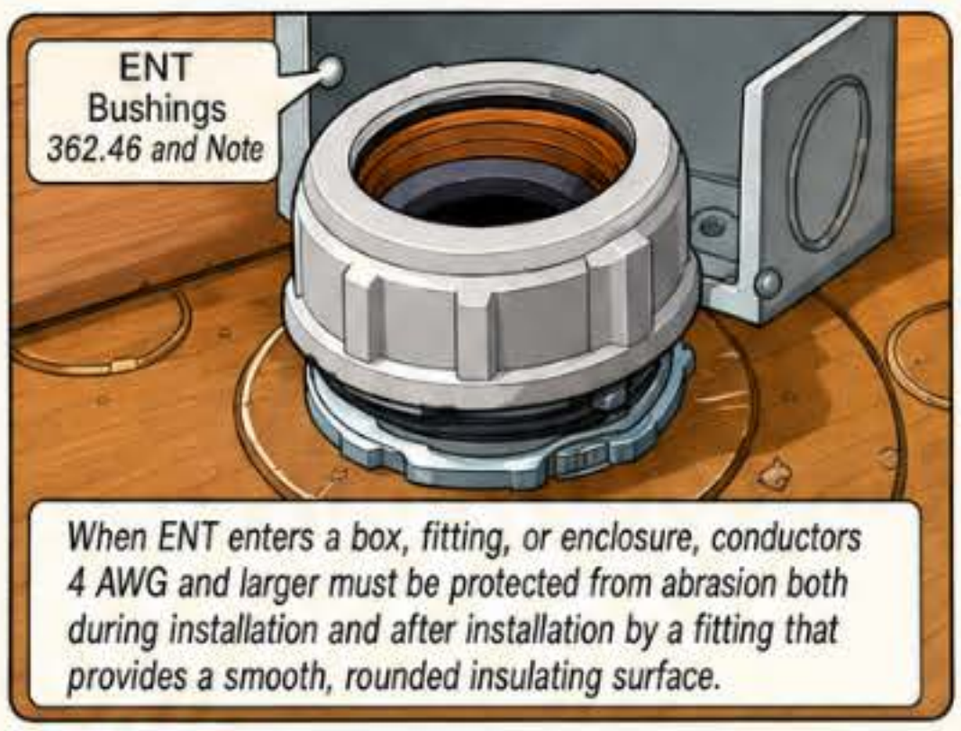
(B) Horizontal Runs. ENT may be installed horizontally in bored or punched holes through wood or metal framing members, or within notches in wood framing members, provided the raceway is secured within 3 ft of both ends. ▶ Figure 362–11



▲ Figure 362–11

362.46 Bushings

Conductors that are 4 AWG or larger and enter an enclosure from a fitting must be shielded from abrasion both during the installation and afterward by a bushing with a smooth, rounded, *insulating surface (for insulating bushings) unless the design of the box, fitting, or enclosure offers equivalent protection as specified in 300.4(G).* ▶ Figure 362–12



▲ Figure 362–12

362.48 Joints

Fittings such as couplings and connectors must be installed in a manner recognized by the authority having jurisdiction.

Author's Commentary:

- *Always follow the manufacturer's written instructions for the raceway, fittings, and adhesive. Product listings permit Type PVC conduit fittings to be used with ENT.*

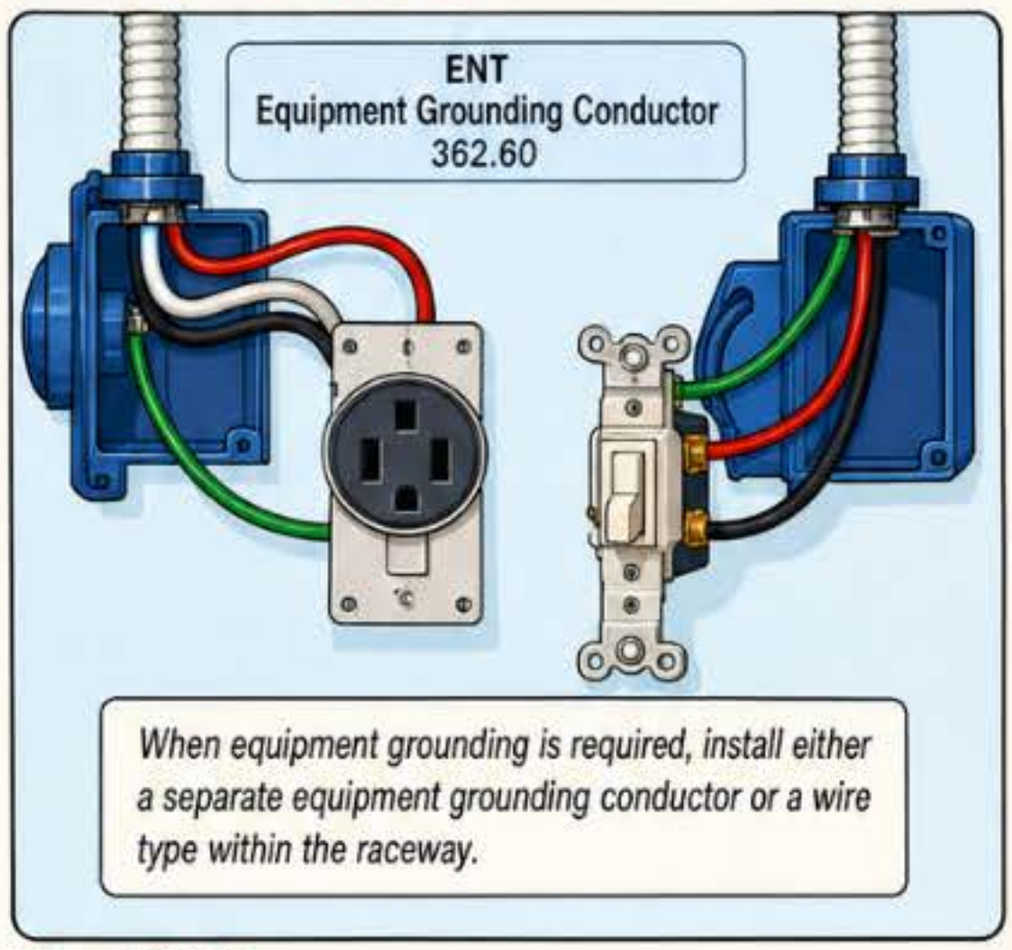
— Michael Hamilton

CAUTION

Adhesives intended for electrical nonmetallic tubing must be designated for ENT. Glues formulated for Type PVC are not approved for this use. Using the wrong adhesive can harm the tubing.

362.60 Equipment Grounding Conductor

If equipment grounding is necessary, a separate equipment grounding conductor or a wire type must be installed inside the raceway. ▶ Figure 362–13



▲ Figure 362–13

Notes |

ARTICLE 376 METAL WIREWAYS

Introduction to Article 376—Metal Wireways

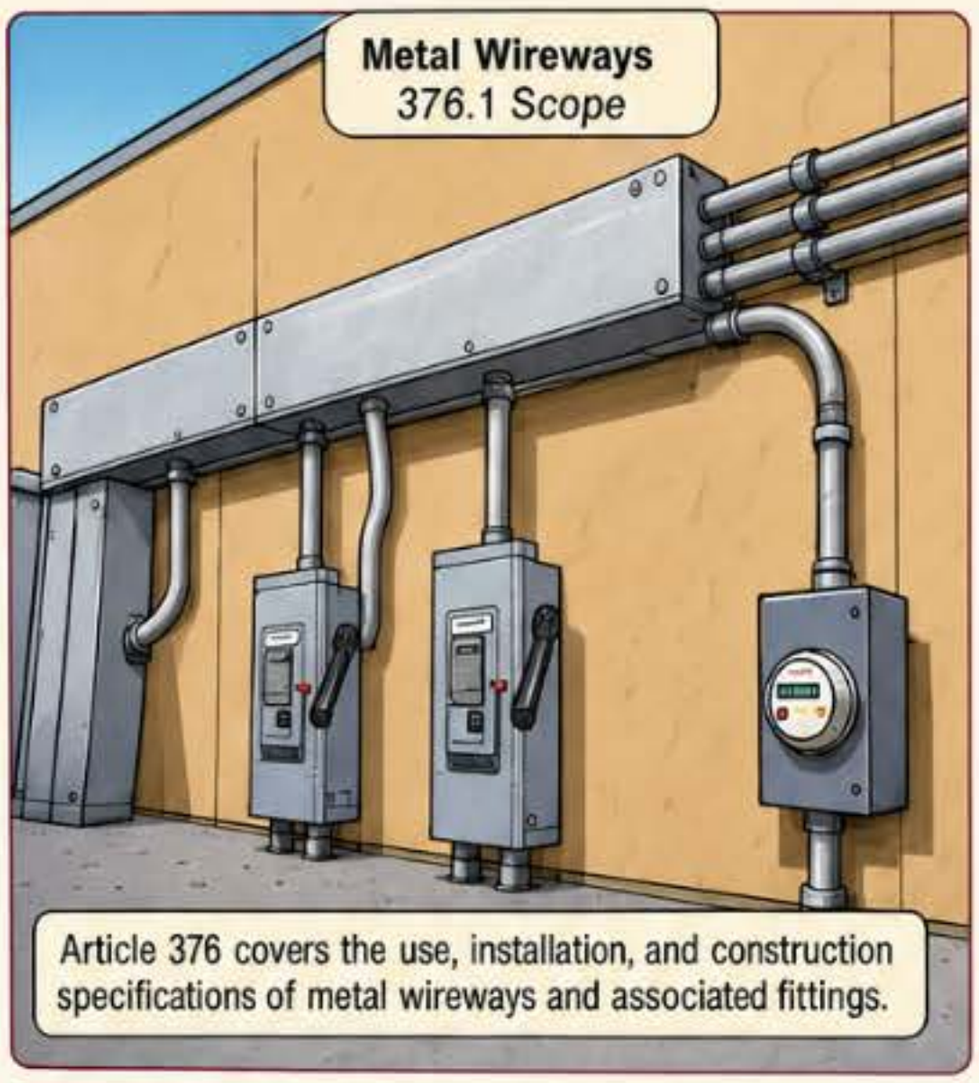
Metal wireways are commonly used wherever conductors must be accessed inside a raceway to make terminations, splices, or taps to several devices at one location. They cost more than other solutions for short runs, except in some commercial or industrial settings where wiring changes are made frequently.

They are often mistakenly called "troughs," "auxiliary gutters," "auxiliary wireways," or "gutters" in the field. The terms *wireway* and auxiliary gutter are alike in design but play different roles in practice. A wireway is a raceway as defined in Article 100 of the NEC, while an auxiliary gutter, defined in Article 366, is an additional enclosure for conductors and does not qualify as a raceway.

Part I. General

376.1 Scope

Article 376 covers the use, installation, and construction requirements for metal wireways and their associated fittings. ▶ Figure 376-1

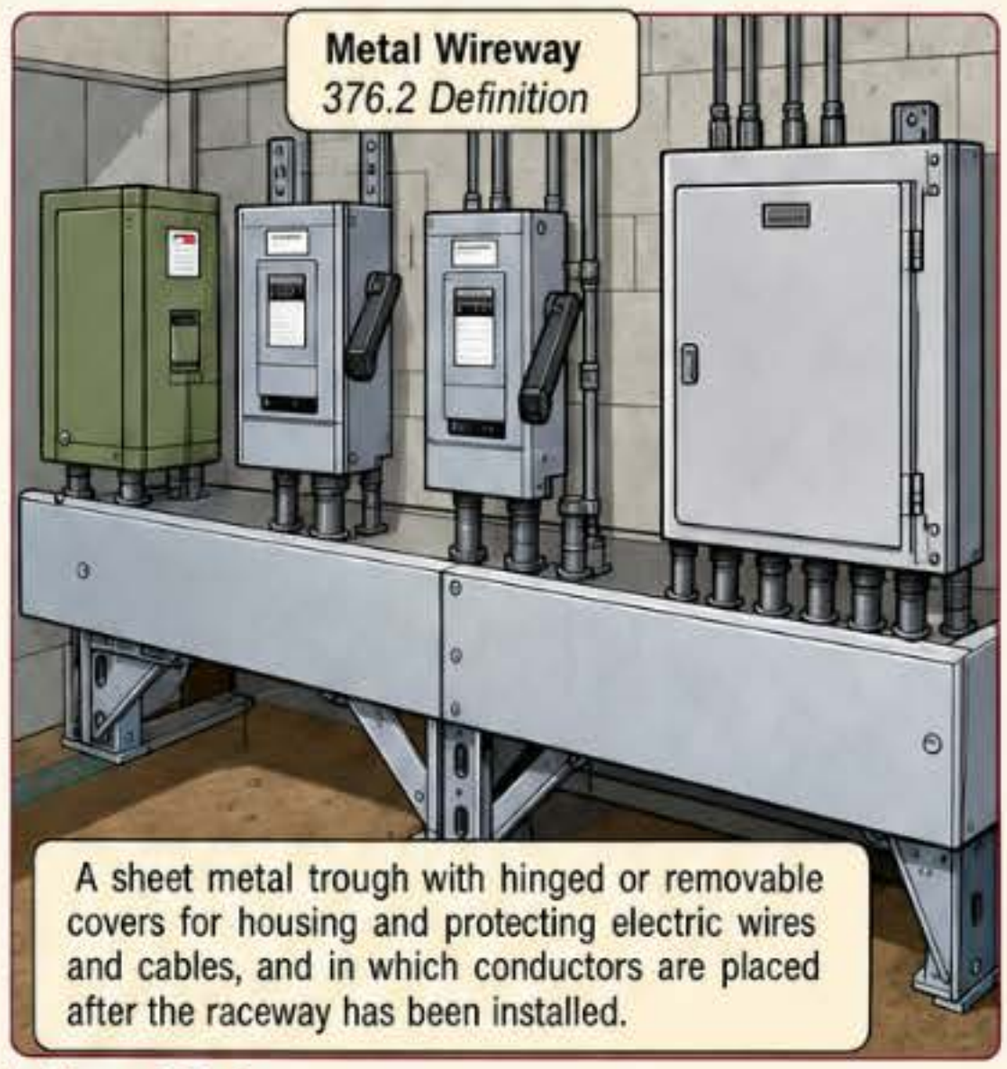


Article 376 covers the use, installation, and construction specifications of metal wireways and associated fittings.

▶ Figure 376-1

376.2 Definition

A metal wireway is a sheet metal enclosure with hinged or removable covers used for housing and protecting electrical conductors and cables. After the raceway is mounted, conductors are installed inside. ▶ Figure 376-2



A sheet metal trough with hinged or removable covers for housing and protecting electric wires and cables, and in which conductors are placed after the raceway has been installed.

▶ Figure 376-2

Author's Commentary: *Metal wireways provide a clean, organized method for distributing conductors and making taps or terminations at multiple points along a run. While they cost more than simple conduit for short distances, they are often the right choice where flexibility and future changes are expected in commercial and industrial facilities.*

— Michael Hamilton

376.10 | Metal Wireways

Part II. Installation

376.10 Uses Permitted

Wireways are allowed to be used in the following ways:

(1) In exposed locations.

(2) In any hazardous (classified) location permitted by other articles in the *Code*.

(3) At wet locations for the purposes listed.

(4) Through or inside walls, partitions, or floors.

376.12 Uses Not Permitted

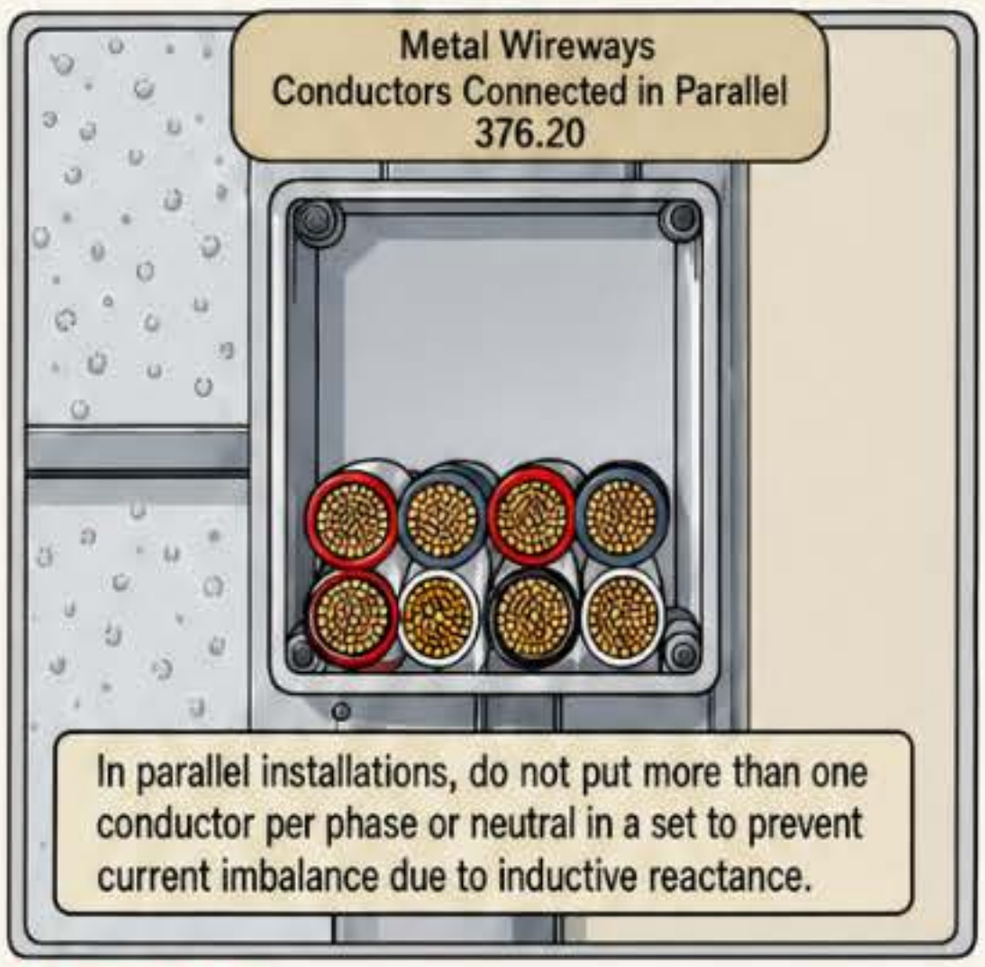
Wireways cannot be used:

(1) In places where the physical *damage* risk is severe.

(2) In areas with corrosive conditions.

376.20 Conductors Connected in Parallel

When conductors are run in parallel as allowed in 310.10(G), the parallel conductors must be grouped in sets that do not exceed one conductor per phase or the neutral conductor to avoid unbalanced current caused by inductive reactance in the parallel runs. See Figure 376–3.

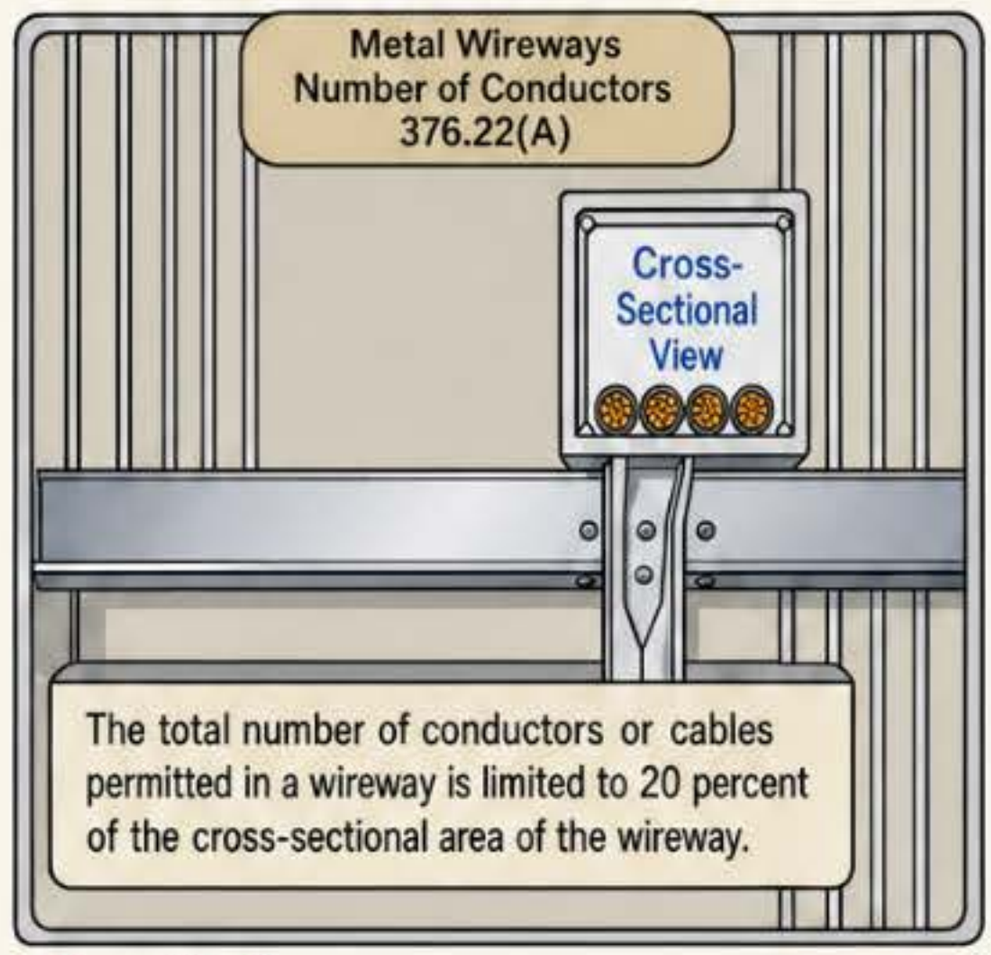


▶ Figure 376–3

Note: The goal of having all parallel conductor sets within the same group is to prevent any uneven current flow in the parallel runs caused by inductive reactance.

376.22 Number of Conductors and Ampacity

(A) Number of Conductors. The maximum number of conductors in a wireway is limited to 20 percent of the cross-sectional area of the wireway. See Figure 376–4.



▶ Figure 376–4

Author's Commentary:

▶ *Splices and taps are not allowed to occupy more than 75 percent of the available wiring space at any cross section [376.56(A)].*

— Michael Hamilton

▶ Wireway Conductor Fill Example 1

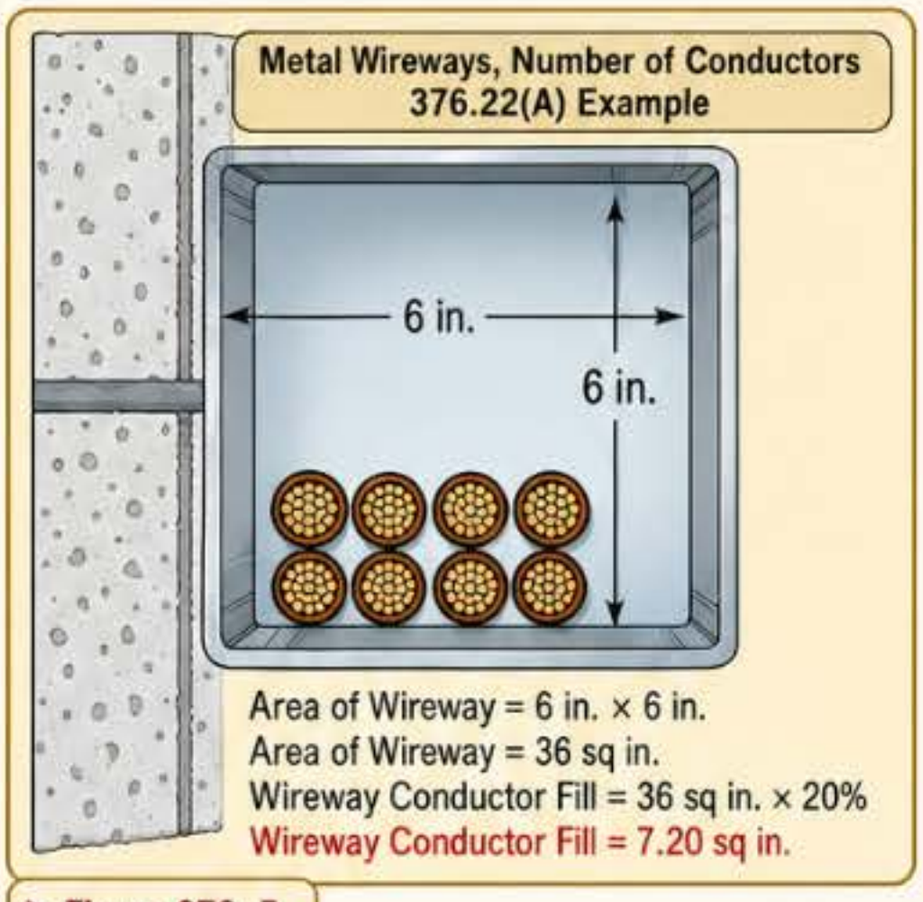
Question: *What is the maximum conductor fill allowed for a 6 in. × 6 in. wireway? See Figure 376–5.*

(a) 7.20 sq in. (b) 15 sq in. (c) 21.5 sq in. (d) 36 sq in.

Solution:

36 sq in. × 20% = 7.20 sq in.

Answer: *(a) 7.20 sq in.*



▶ Figure 376–5

▶ Wireway Conductor Fill Example 2

Question: *What is the minimum size wireway suitable for three 500 kcmil THHN, one 250 kcmil THHN, and four 4/0 THHN conductors?*

(a) 4 in. × 4 in. (16 sq in.) *(b) 6 in. × 6 in. (36 sq in.)*
(c) 8 in. × 8 in. (64 sq in.) *(d) 10 in. × 10 in. (100 sq in.)*

Solution:

Find the conductor area [Chapter 9, Table 5].

500 kcmil THHN = 0.7073 sq in. × 3 conductors
500 kcmil THHN = 2.1219 sq in.
250 kcmil THHN = 0.3970 sq in.
4/0 THHN = 0.3237 sq in. × 4 conductors
4/0 THHN = 1.2948 sq in.

Total Conductor Area = 3.8137 sq in.

The wireway must not be filled to over 20 percent of its cross-sectional area [376.22(A)]. Twenty percent is equal to one-fifth, so we can multiply the required conductor area by five to find the minimum square inch area needed.

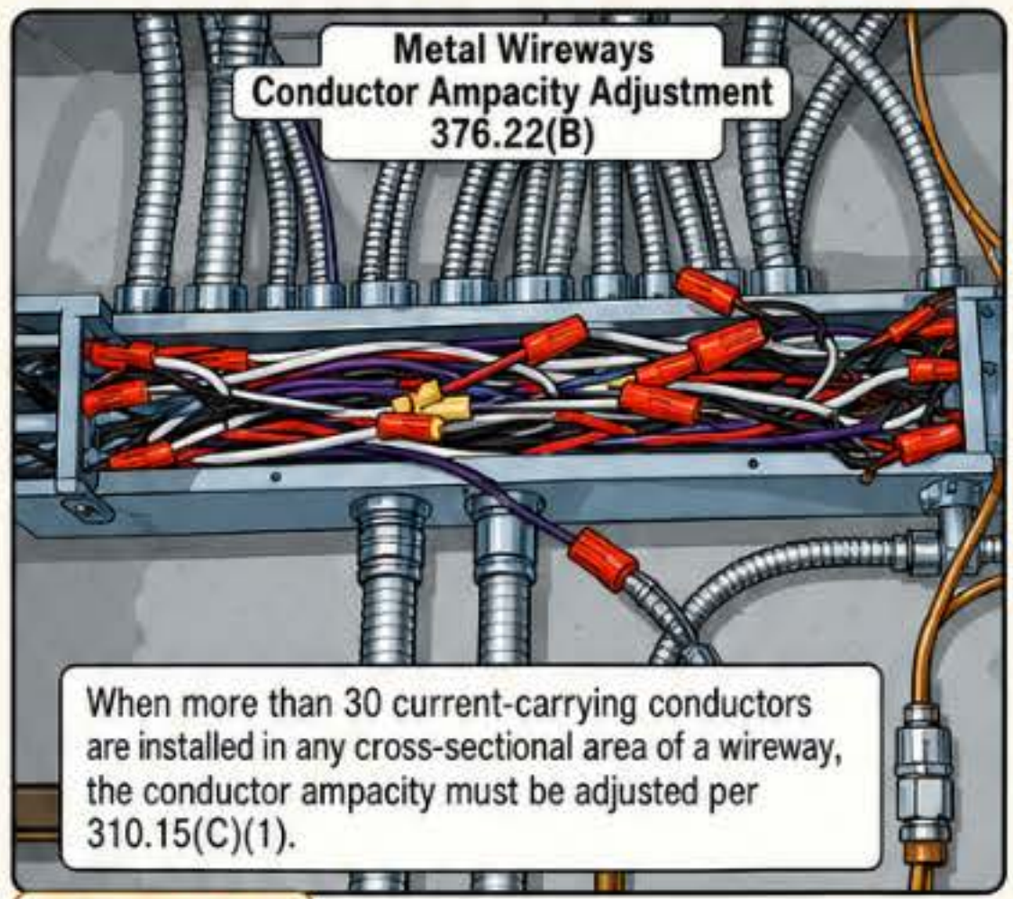
Conductor Area × 5 = Required Wireway Minimum Area

3.8137 sq in. × 5 = 19.07 sq in. (less than 36 sq in.)

A 6 in. × 6 in. wireway has a cross-sectional area of 36 sq in. and will be large enough.

Answer: *(b) 6 in. × 6 in. (36 sq in.)*

(B) Conductor Ampacity Adjustment. When more than thirty current-carrying conductors are installed in any cross-sectional area of the wireway, the conductor ampacity, as contained in Table 310.16, must be adjusted in accordance with Table 310.15(C)(1). **Figure 376–6**

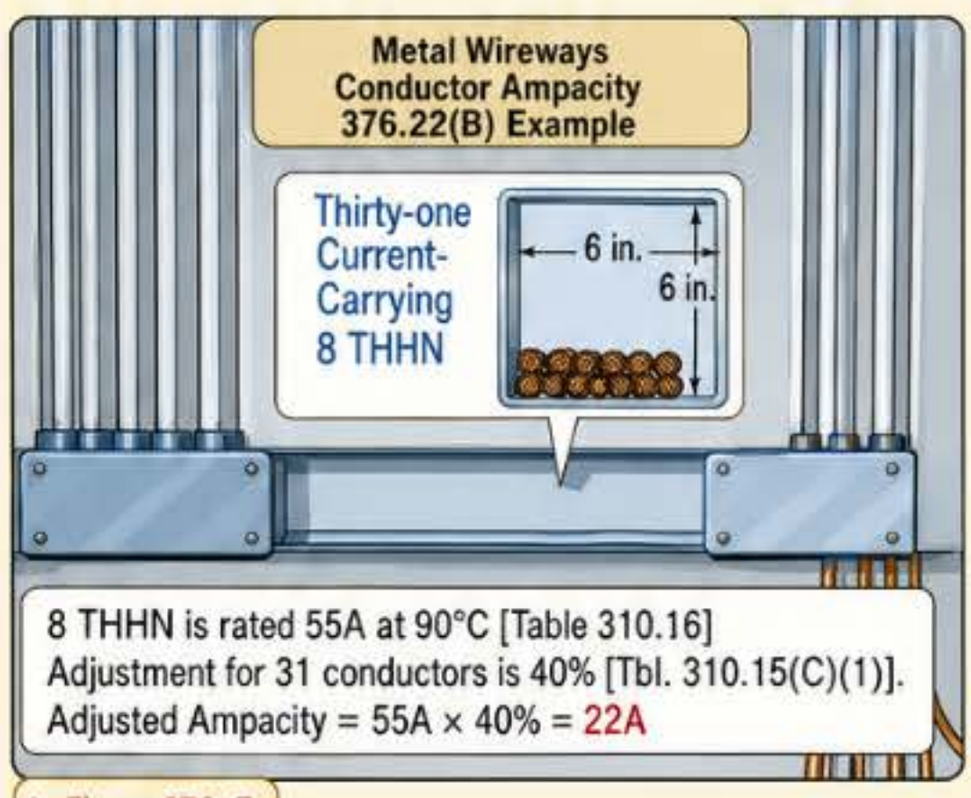


▶ Figure 376–6

▶ Wireway–Conductor Ampacity Adjustment Example

Question: *What is the ampacity of 8 THHN conductors if there are thirty-one conductors in a cross-sectional area of a wireway?* **Figure 376–7**

(a) 20A *(b) 22A* *(c) 29A* *(d) 32A*



▶ Figure 376–7

Author's Commentary: *Metal wireways must provide ample room for conductors while also allowing for heat dissipation and future expansion. Exceeding 20 percent fill can cause overheating and code violations. When more than 30 current-carrying conductors are present, the NEC requires you to reduce the ampacity to account for the additional heat buildup.*

— Michael Hamilton

Solution:

Adjusted Ampacity = Table 310.16 Ampacity × Bundled Ampacity Adjustment Factor from Table 310.15(C)(1)

8 AWG THHN is rated 55A at 90°C (Table 310.16).

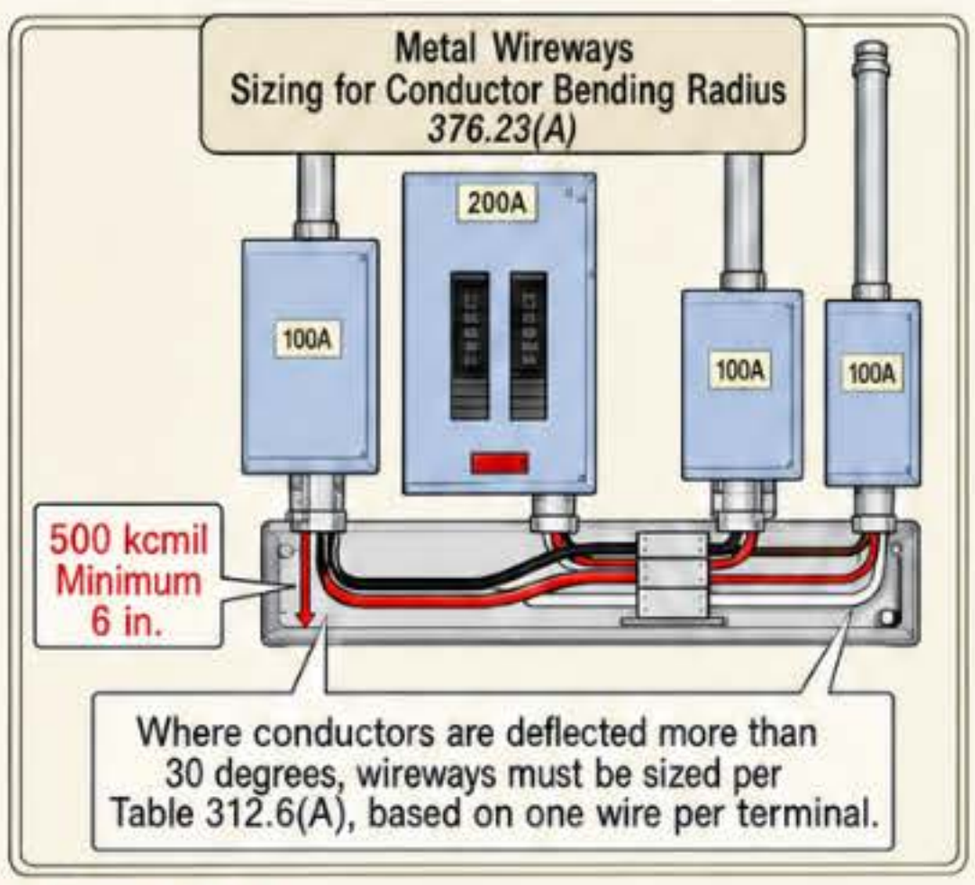
The adjustment factor for thirty-one current-carrying conductors is 40 percent [Table 310.15(C)(1)].

Adjusted Ampacity = 55A × 40%
Adjusted Ampacity = 22A

Answer: *(b) 22A*

376.23 Wireway Sizing

(A) Sizing for Conductor Bending Radius. Where conductors are deflected more than 30 degrees in a wireway, they must be sized to the conductor bending space requirements contained *in Table 312.6(A), based on one wire per terminal.* ▶ **Figure 376–8**



▶ **Figure 376–8**

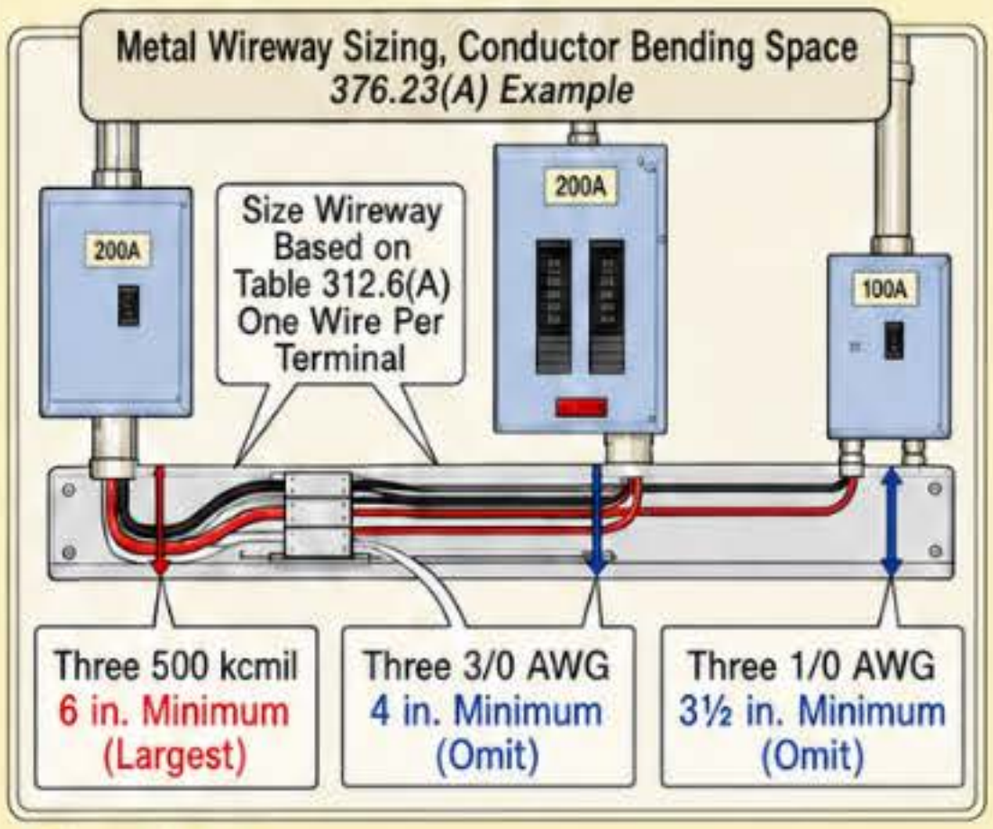
▶ Wireway Bending Space Example

Question: *What minimum size wireway is suitable for three 500 kcmil THHN conductors from the first disconnect, three 3/0 AWG THHN conductors from the panelboard, and three 1/0 AWG THHN conductors from the other disconnect?* ▶ **Figure 376–9**

(a) 4 in. *(b) 6 in.* *(c) 8 in.* *(d) 10 in.*

Solution:

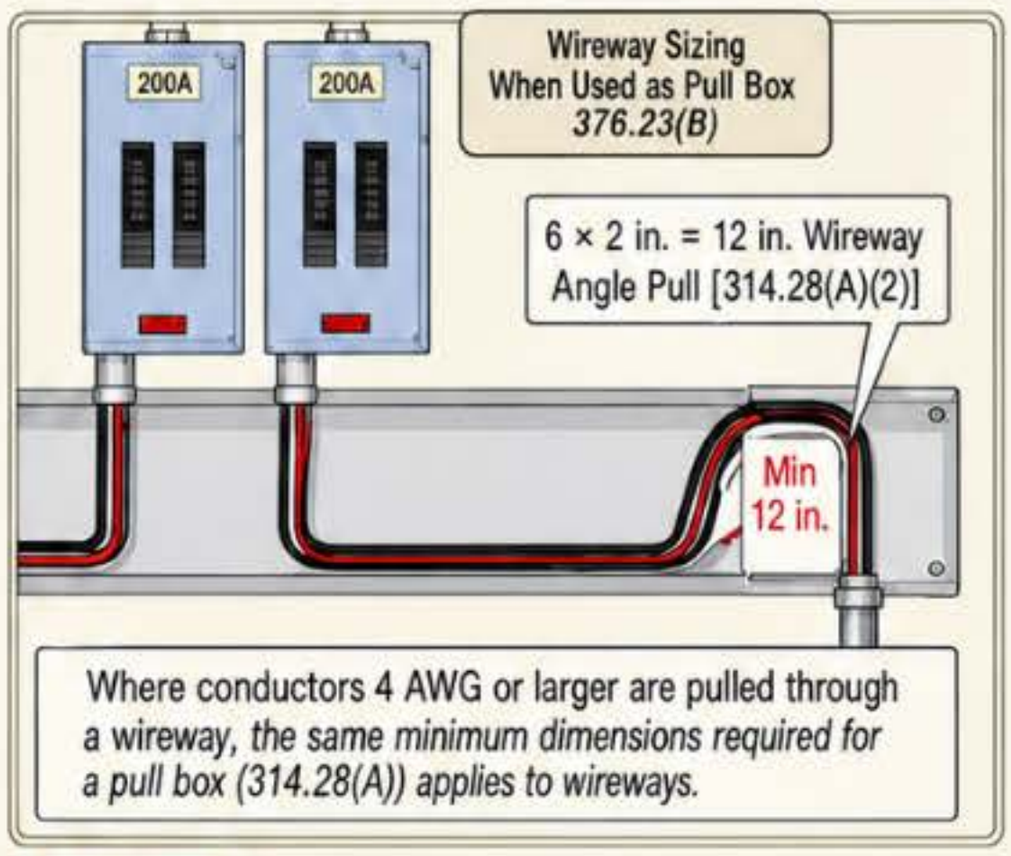
According to Table 312.6(A), based on one wire per terminal, the wireway must be large enough to accommodate the bending space required for the largest conductor. In this application, it is based on the 500 kcmil conductors [376.23(A)].



▶ **Figure 376–9**

Answer: *(b) 6 in.*

(B) Metal Wireways Used as Pull Boxes. Where conductors 4 AWG or larger are pulled into a wireway, the distance between conductor entries enclosing the same conductor cannot be less than required by 314.28(A)(1) for straight pulls and 314.28(A)(2) for angle pulls. ▶ **Figure 376–10**

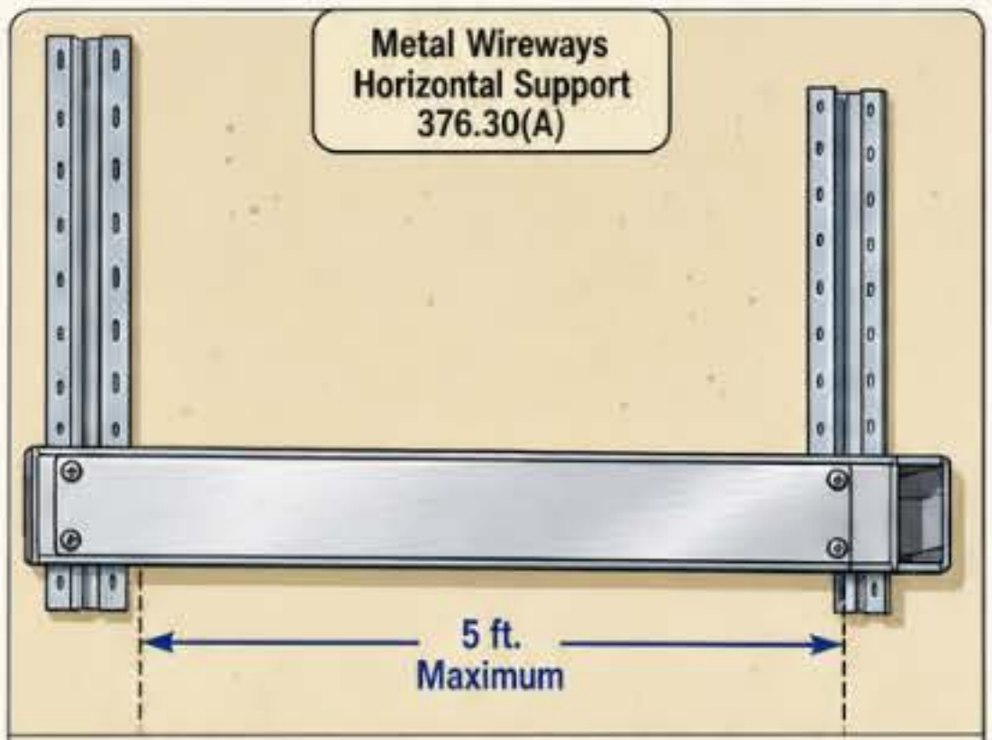


▶ **Figure 376–10**

376.30 Supports

Wireways must be supported in accordance with (A) and (B):

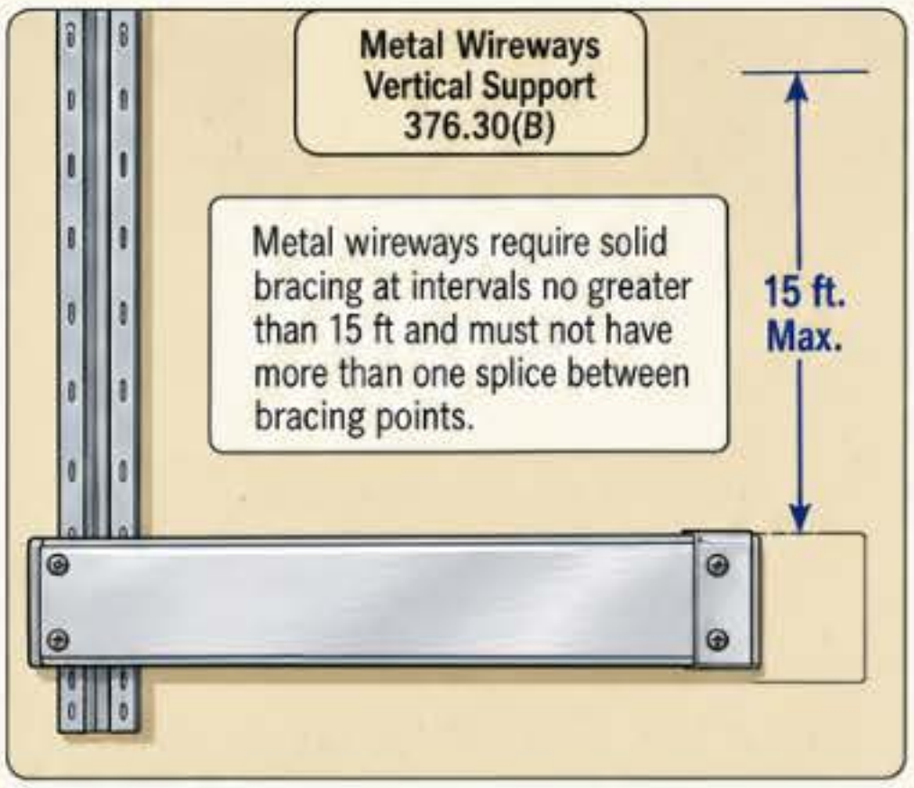
(A) Horizontal Support. When mounted horizontally, metal wireways require a support at every end and at regular intervals that do not exceed 5 ft. ▸ Figure 376-11



Metal wireways require reinforcement at both ends and at intervals not greater than 5 ft.

▶ Figure 376-11

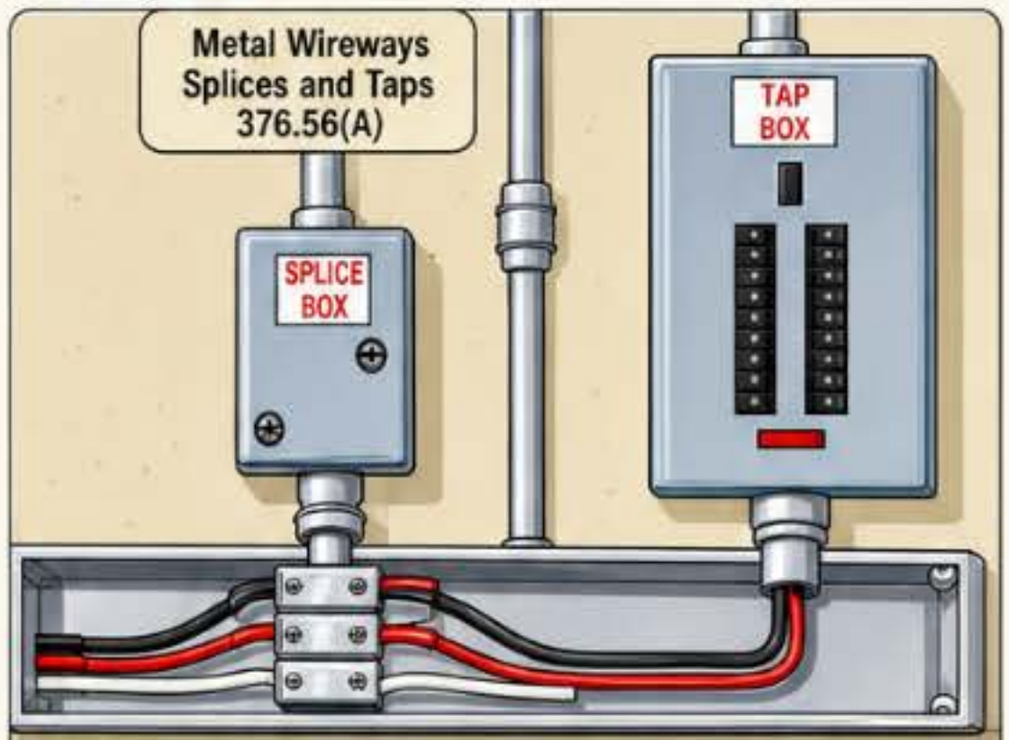
(B) Vertical Support. When installed vertically, metal wireways must be securely braced at intervals not greater than 15 ft and must not have more than one joint between supports. ▸ Figure 376-12



▶ Figure 376-12

376.56 Splices, Taps, and Power Distribution Blocks

(A) Splices and Taps. Splices and taps in metal wireways must be readily accessible and must not occupy more than 75 percent of the wireway's cross-sectional area. ▸ Figure 376-13

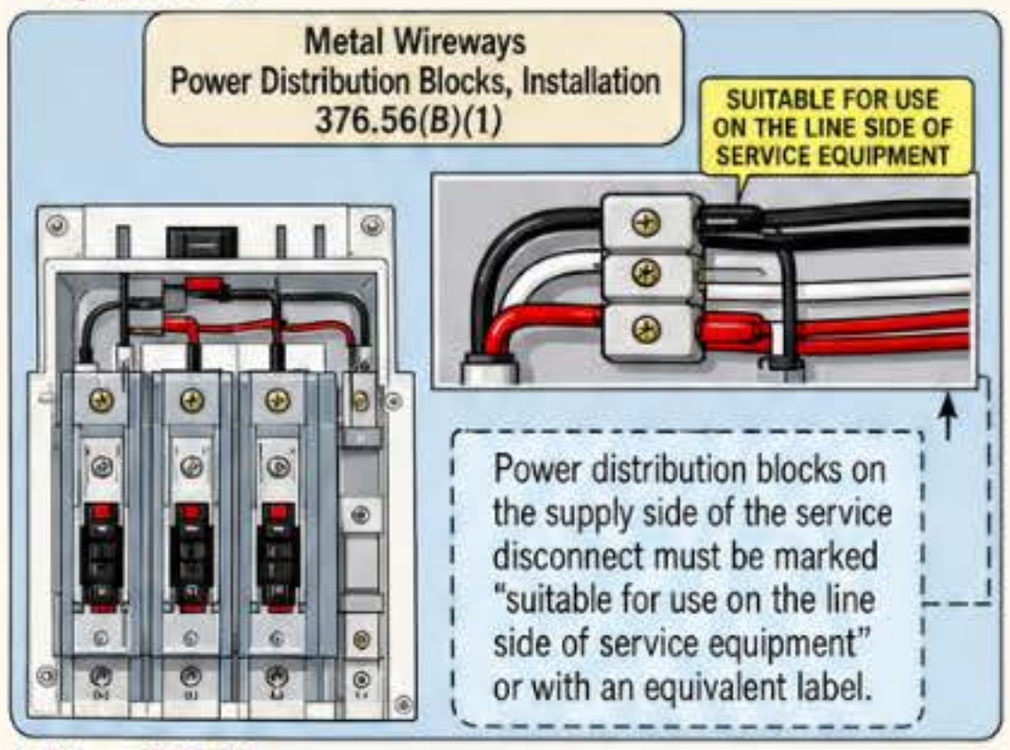


Splices and taps must be reachable and cannot use more than 75% of the cross-sectional area of the wireway.

▶ Figure 376-13

(B) Power Distribution Blocks.

(1) Installation. Power distribution blocks installed in wireways must be listed; if located on the supply side of the service disconnect, they must be identified "suitable for use on the line side of service equipment" or with an equal marking. ▸ Figure 376-14



▶ Figure 376-14

Author's Commentary: *Proper support, accessible splices, and correctly labeled power blocks are essential for safe, reliable installations. These rules prevent mechanical stress on wireways, ensure that connections remain serviceable, and make certain that conductors are not overcrowded—maintaining safety and compliance in every system.*

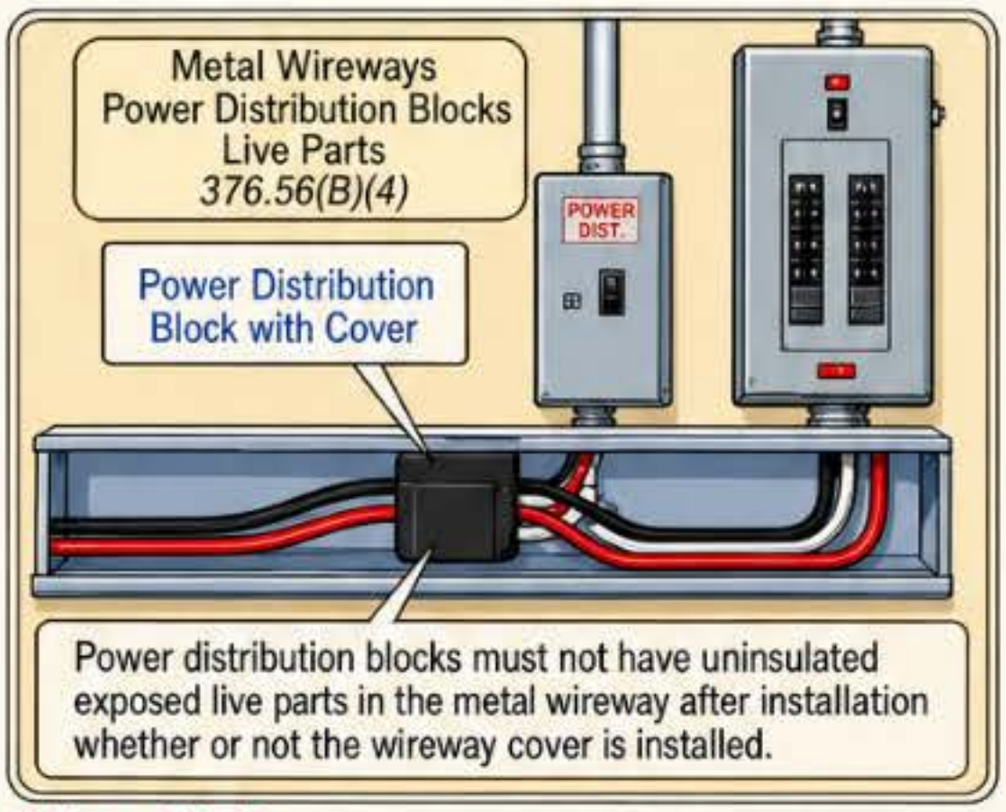
— Michael Hamilton

DEFINITIONS | From Michael Hamilton Publications

(2) Size of Enclosure. In addition to the wiring space requirements [376.56(A)], the power distribution block must be installed in a metal wireway not smaller than specified in the installation instructions of the power distribution block.

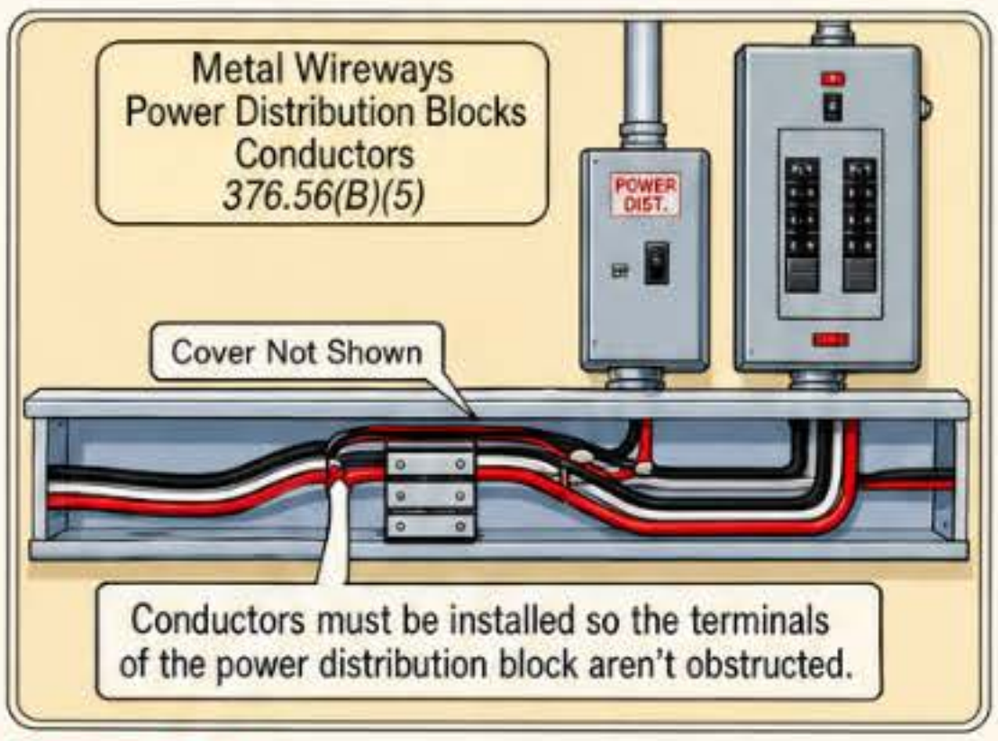
(3) Wire-Bending Space. Wire-bending space at the terminals of power distribution blocks must comply with 312.6(B).

(4) Live Parts. Power distribution blocks are not permitted to have uninsulated exposed live parts in the metal wireway after installation, whether the wireway cover is installed or not. ▶ Figure 376-15



▶ Figure 376-15

(5) Conductors. Conductors must be installed so the terminals of the power distribution block are not obstructed. ▶ Figure 376-16

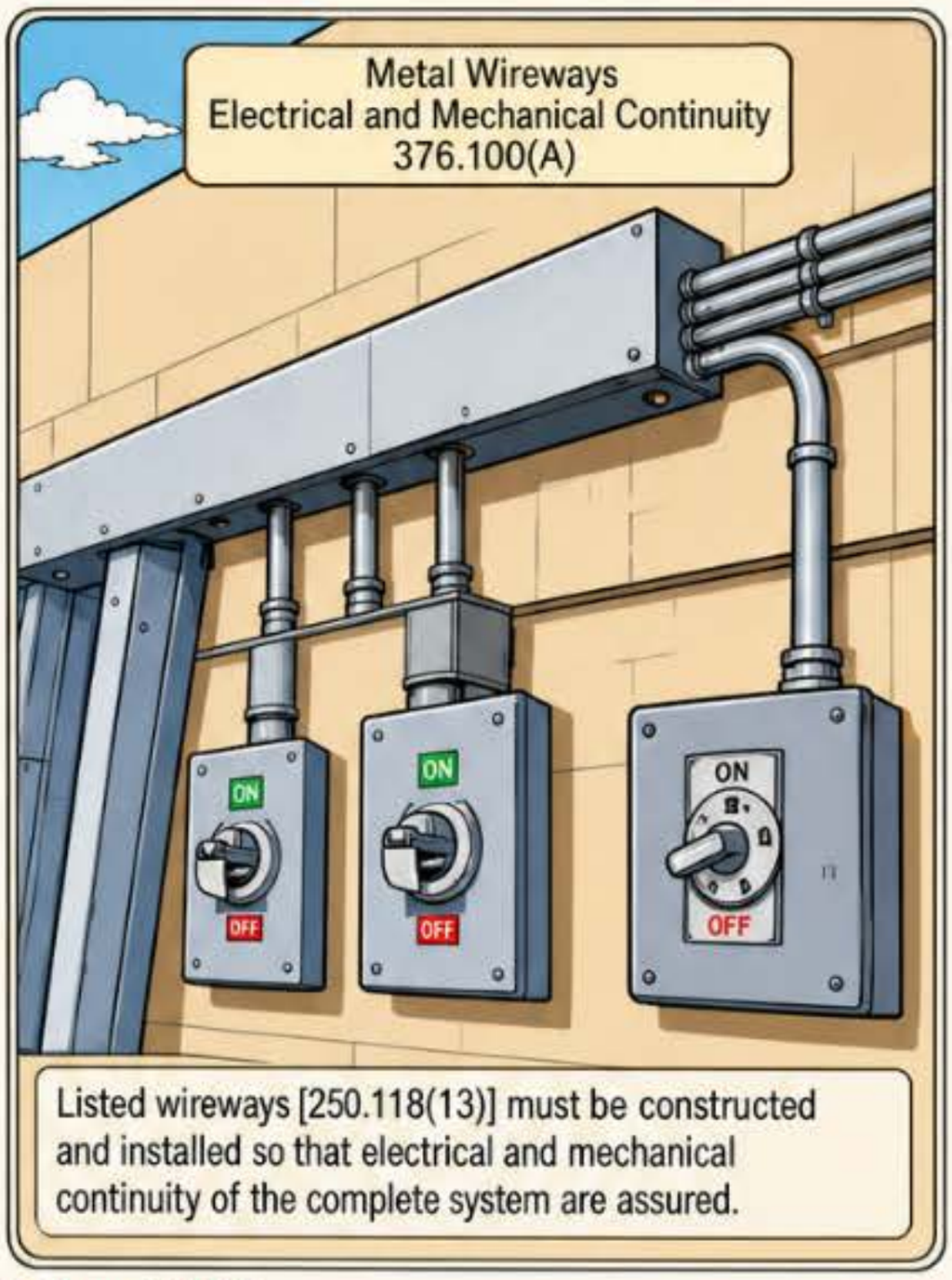


▶ Figure 376-16

Part III. Construction Specifications

376.100 Construction

(A) Electrical and Mechanical Continuity. Wireways must be constructed and installed so the electrical and mechanical continuity of the complete system are assured. ▶ Figure 376-17



▶ Figure 376-17

Author's Commentary: Metal wireways provide a protective raceway system for conductors. These rules ensure safety by requiring proper enclosure size, adequate space for wire bending, protection of live parts, and clear access to block terminals.

— Michael Hamilton

ARTICLE 380 MULTIOUTLET ASSEMBLIES

Introduction to Article 380—Multioutlet Assemblies

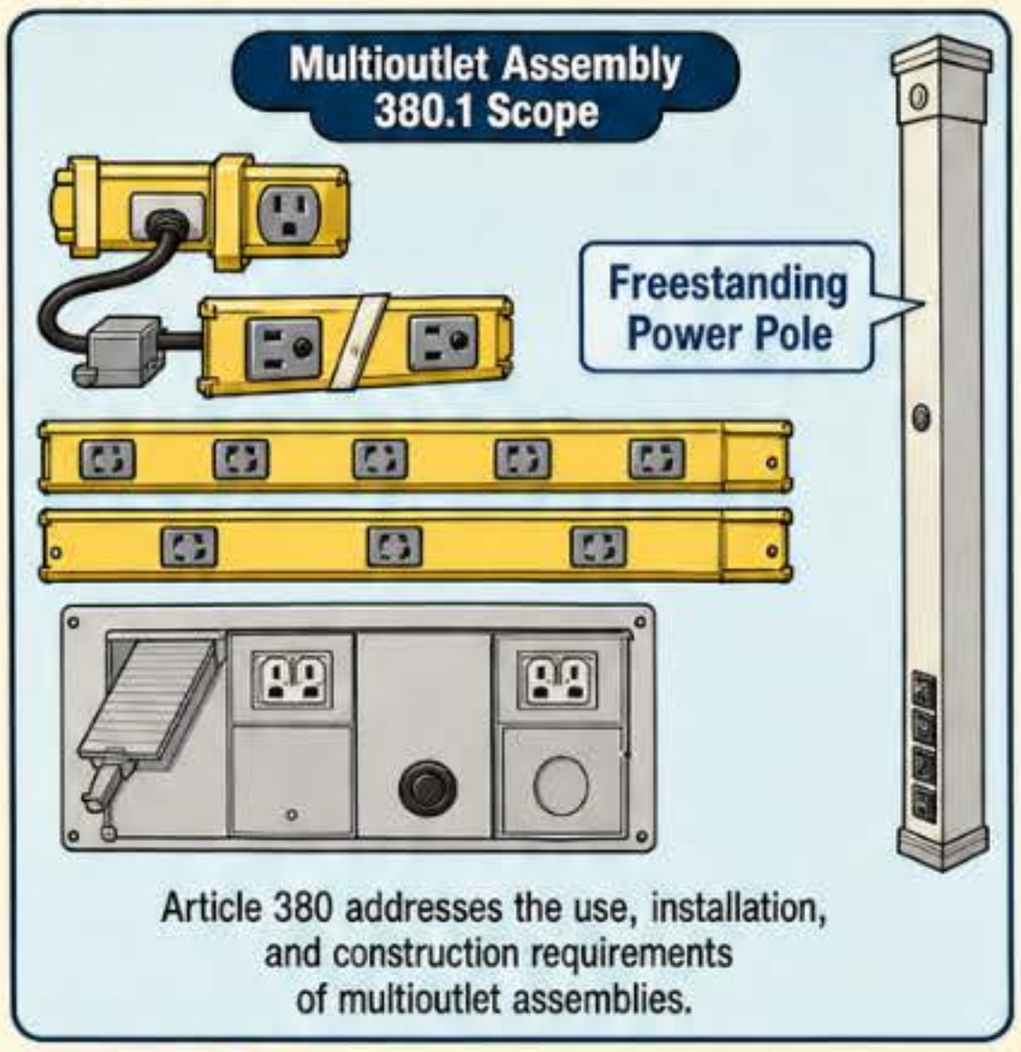
A multioutlet assembly is a surface, flush, or freestanding raceway designed to hold conductors and receptacles, and is used in field installations or in a factory [Article 100]. This Article does not apply to systems identified in common trade names such as "Plugtrak®" or "Plugmold®."

Part I. General

380.1 Scope

Article 380 covers how multioutlet assemblies are used, installed, and constructed.

▶ Figure 380–1



▶ Figure 380–1

Part II. Installation

380.10 Uses Permitted

Multioutlet assemblies are allowed in dry locations only.

380.12 Uses Not Permitted

A multioutlet assembly must not be installed as follows:

(1) Concealed.

(2) Where subject to severe physical damage.

(3) If the voltage is 300V or more between conductors, unless the metal has a thickness not less than 0.04 in.

(4) Where subject to corrosive vapors.

(5) In hoistways.

(6) In any hazardous (classified) location except as permitted by 501.10(B).

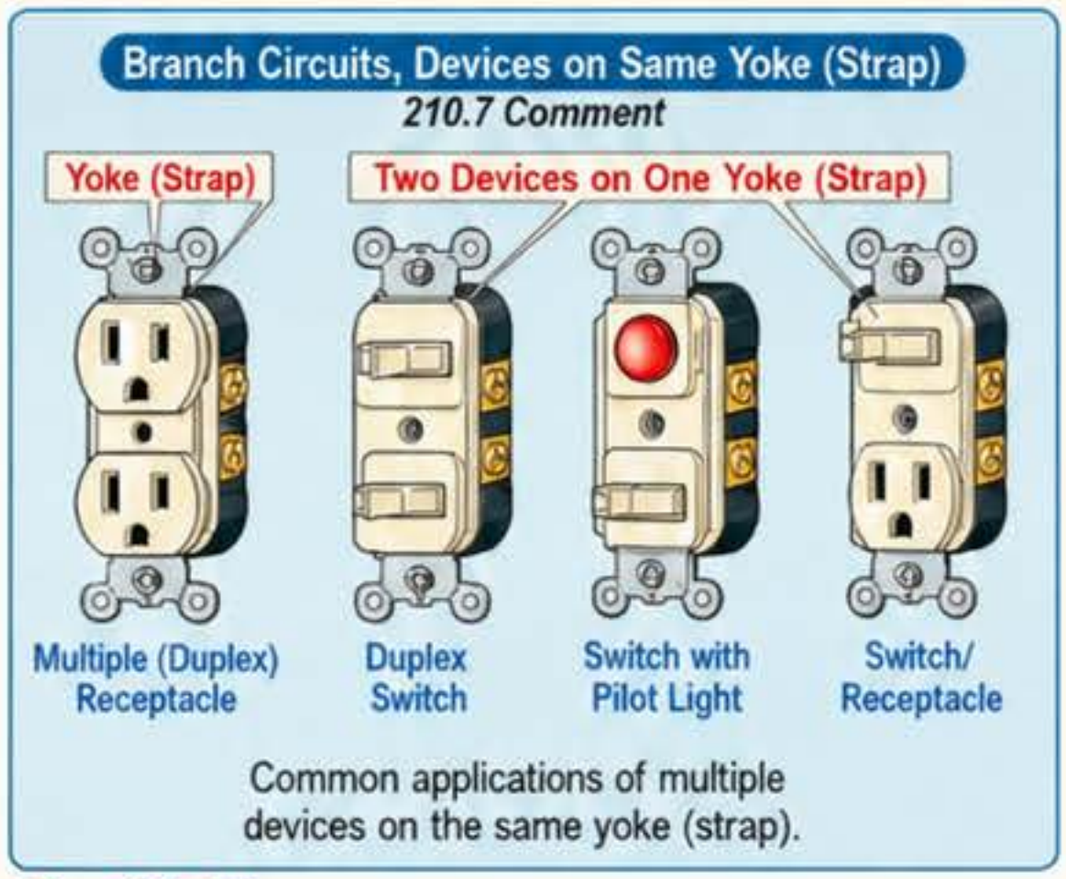
(7) Where cord-and-plug-connected.

380.76 Through Partitions

Metal multioutlet assemblies can pass through a dry partition if there are no receptacles concealed in the wall and if the cover over the exposed portion of the system can be removed.

Author's Commentary:
These rules help ensure multioutlet assemblies are installed in safe, accessible locations and are protected from misuse or damage.

— Michael Hamilton

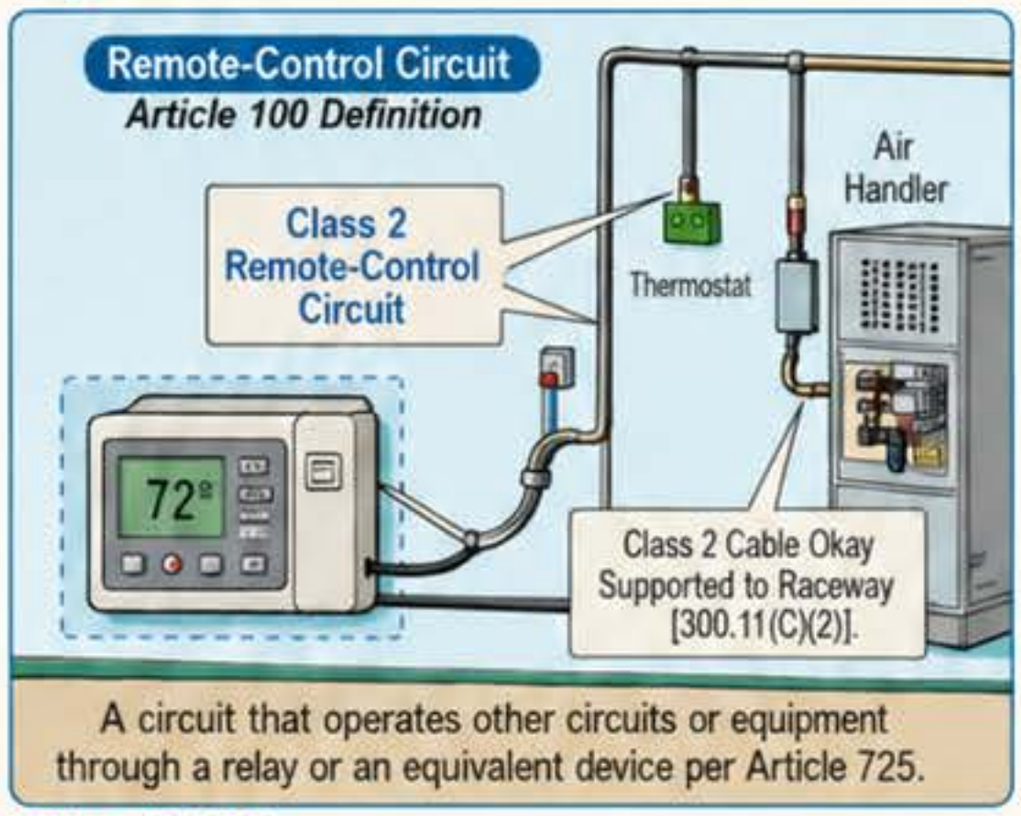


▶ Figure 100–132

Reconditioned. Electromechanical systems, equipment, apparatus, or components that are restored so they can be used again. This process goes beyond normal servicing because the item is kept in a facility and swapped out for a like item.

Note: People often call this rebuilt, refurbished, or remanufactured.

Remote-Control Circuit. A circuit that operates another circuit through a relay or a similar device installed according to Article 725. ▶ Figure 100–133



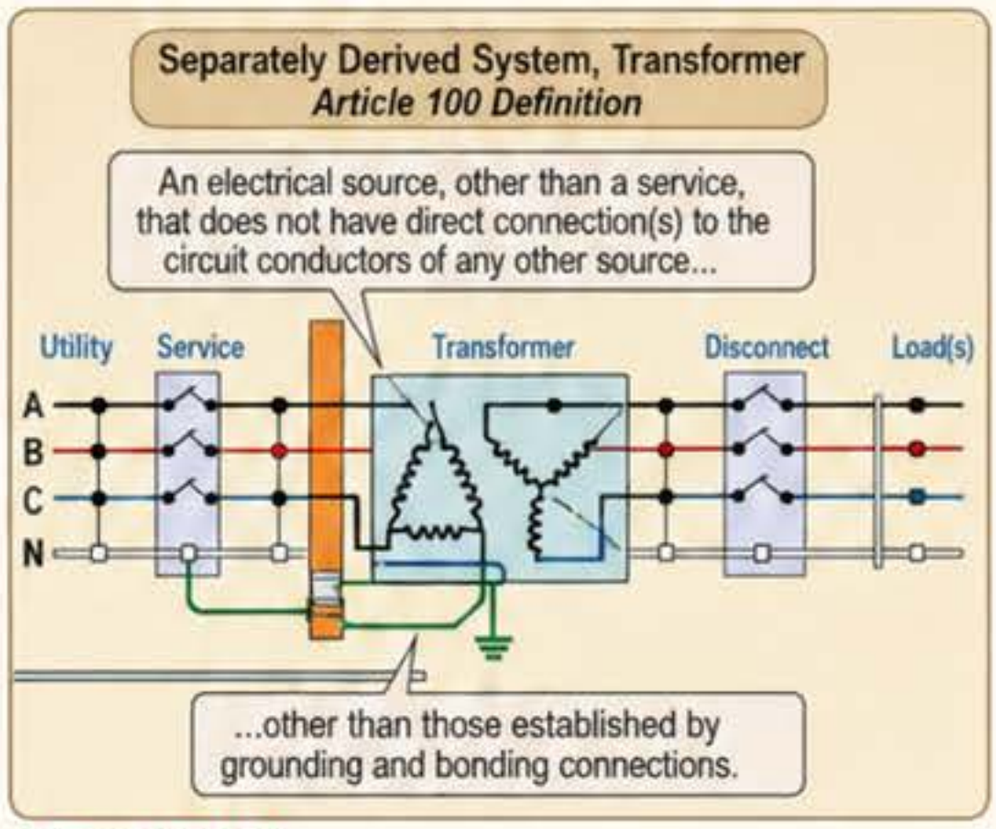
▶ Figure 100–133

Retrofit Kit. An assembly of parts used to adapt existing equipment for a new purpose.

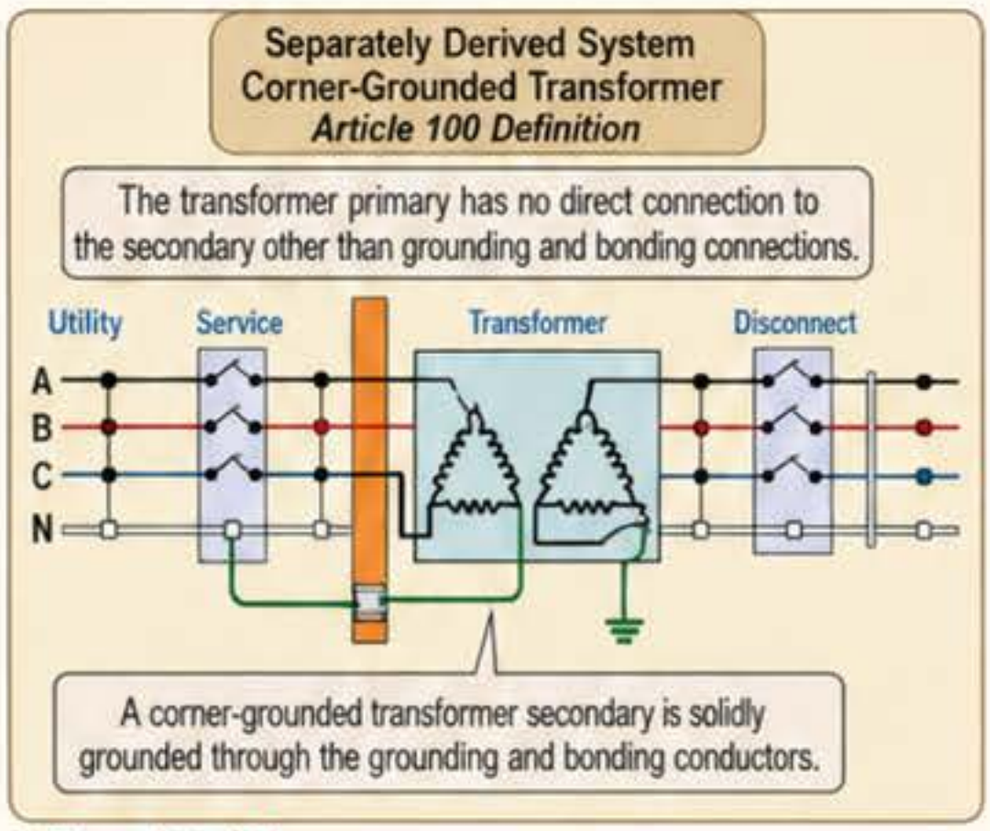
Sealable Equipment. Equipment housed with gaskets or other seals or with locking parts blocking access to the inside without opening the enclosure.

Note: The equipment may or may not be operable without opening the enclosure.

Separately Derived System. An electrical source, other than a service, that does not have direct connection(s) to the conductors of another source beyond grounding and bonding connections. ▶ Figure 100–134, ▶ Figure 100–136, and ▶ Figure 100–136



▶ Figure 100–134



▶ Figure 100–135

Author's Commentary:

- *A generator is not a separately derived system if the neutral conductor is solidly connected to a service neutral conductor. An example would be a generator with a transfer switch that includes a neutral conductor that is not switched.*

▶ Figure 100–137

—Michael Hamilton

ARTICLE 386

SURFACE METAL RACEWAYS

Introduction to Article 386—Surface Metal Raceways

Surface metal raceways are often chosen when traditional raceway systems cannot be used or when concealing the raceway would be impractical or too costly. These raceways are manufactured in a variety of colors and finishes, including painted and woodgrain styles, so they blend in with the décor and appear as trim rather than as obvious raceways. In the field, they are commonly referred to as "Wiremold®."

Part I. General

386.1 Scope

This section of the Code provides the rules for selecting, installing, and constructing surface metal raceways along with the required associated fittings. ▶ Figure 386–1

Figure 386–1

386.2 Definition

Surface metal raceway is a raceway system with associated fittings designed to be mounted on a surface, with conductors added only after the system is fully installed. ▶ Figure 386–2

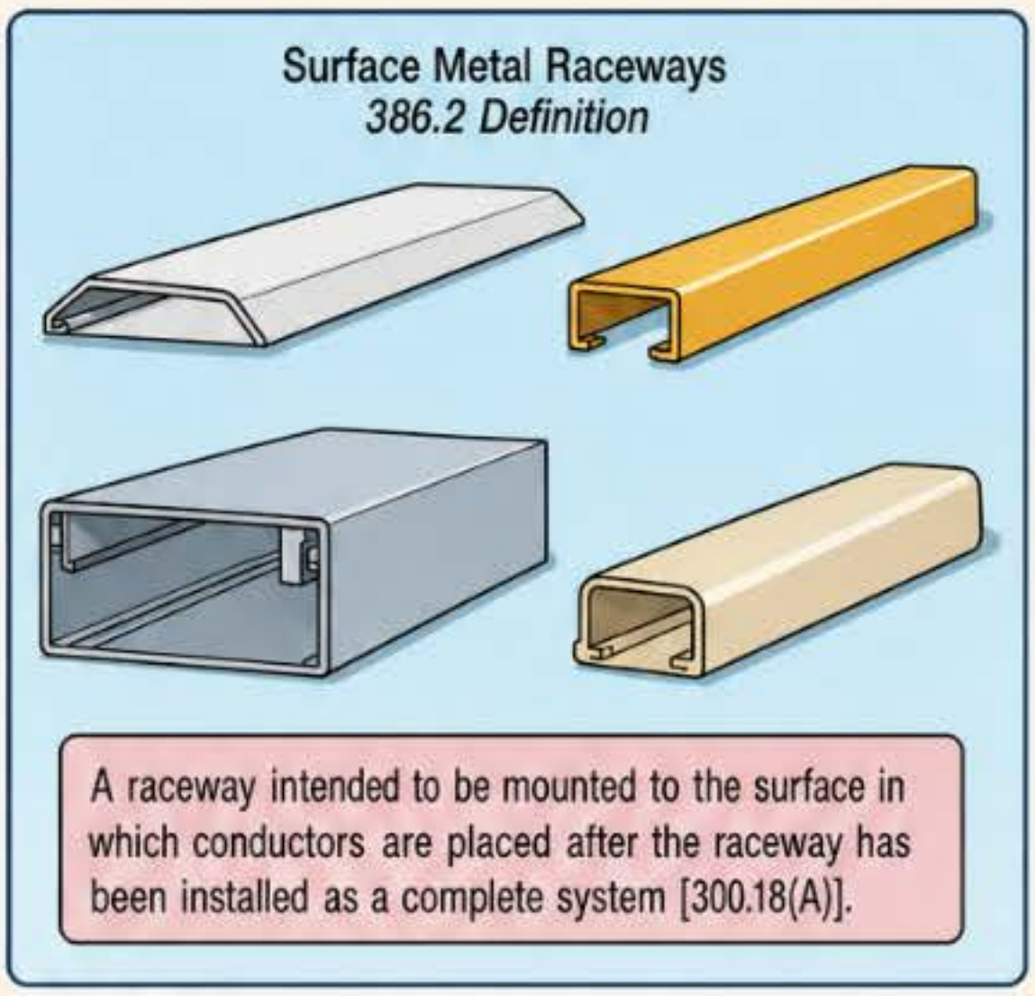


Figure 386–2

Author's Commentary:

- *Surface metal raceways come in many shapes and sizes and can be attached to walls, ceilings, or floors.*

  Some models have one or more built-in channels that separate power wiring from low-voltage cables such as control, signaling, communication, and other limited-energy conductors.

  (Code Ref: 386.70.)

— Michael Hamilton

386.6 LISTING REQUIREMENTS

All surface metal raceways and any fittings used with them must be identified and listed.

Author's Commentary:

Look for switches, receptacles, luminaires, and other devices bearing markings on their boxes or packaging. These markings state the type of surface metal raceway that may be used with the enclosure.

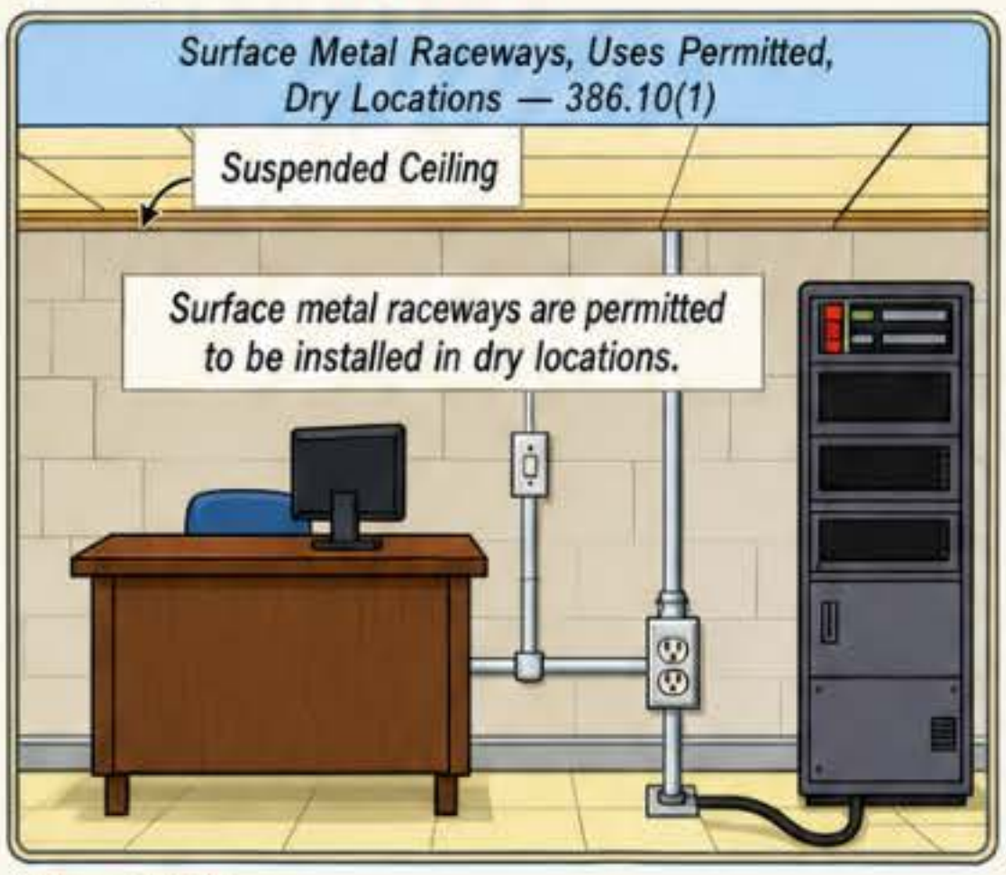
— Michael Hamilton

PART II. INSTALLATION

386.10 USES PERMITTED

Surface metal raceways may be installed in the following situations:

(1) In dry locations. • Figure 386–3



▲ Figure 386–3

(2) In Class I, Division 2 locations, as permitted in 501.10(B)(3).

(3) Under raised floors, as permitted in 645.5(E)(2).

(4) Through walls and floors, if access to the conductors is maintained on both sides of the wall, partition, or floor.

386.12 USES NOT PERMITTED

Surface metal raceways are not allowed in the following conditions:

(1) Where subjected to severe physical damage unless approved by the authority having jurisdiction.

(2) If the voltage is 300V or more between conductors, unless the metal has a thickness not less than 0.04 in.

(3) Where subject to corrosive vapors.

(4) In hoistways.

(5) If concealed, except as permitted in 386.10.

386.21 SIZE OF CONDUCTORS

The maximum size conductor permitted in a surface metal raceway is not permitted to be larger than that for which the raceway is designed.

386.22 NUMBER OF CONDUCTORS

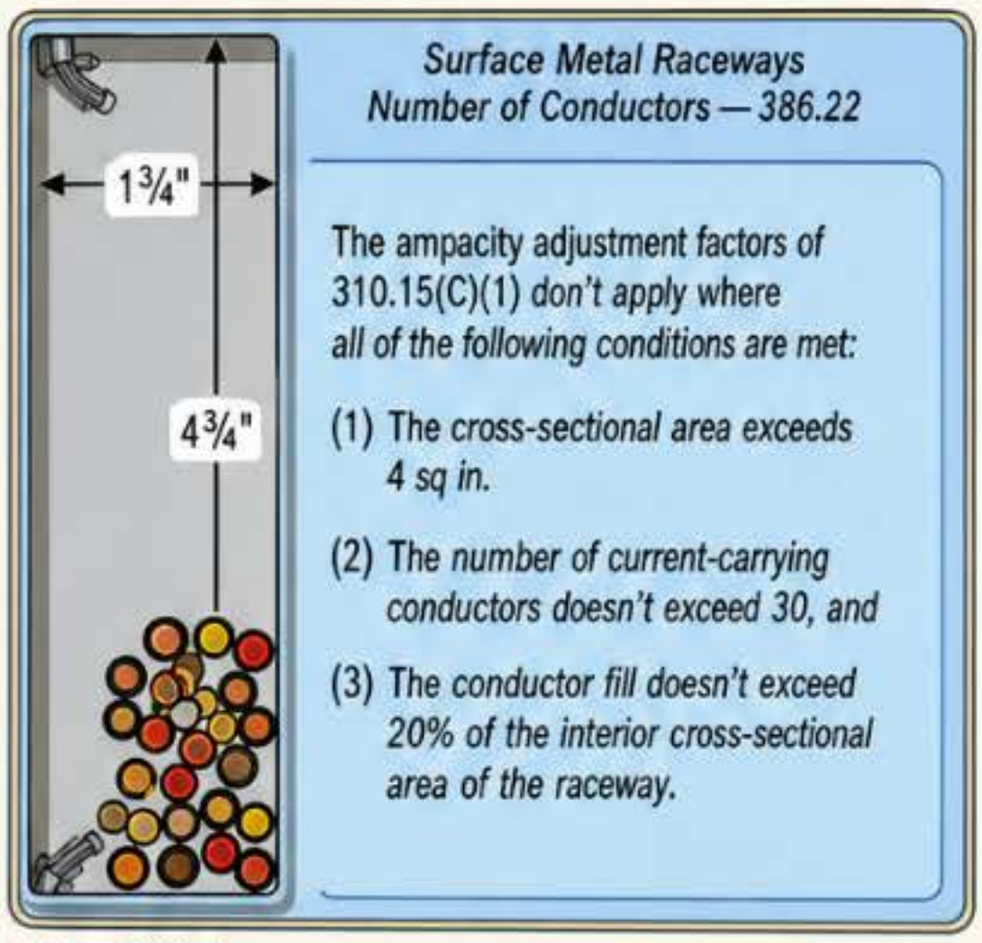
The number of conductors installed in a surface metal raceway must not be more than the number for which the raceway is designed.

Author's Commentary:

The size and number of conductors permitted is marked on the raceway or on the package.

— Michael Hamilton

The ampacity adjustment factors of Table 310.15(C)(1) do not apply to conductors installed in surface metal raceways if all the following conditions are met: • Figure 386–4



▲ Figure 386–4

(1) The cross-sectional area of the raceway exceeds 4 sq in.,

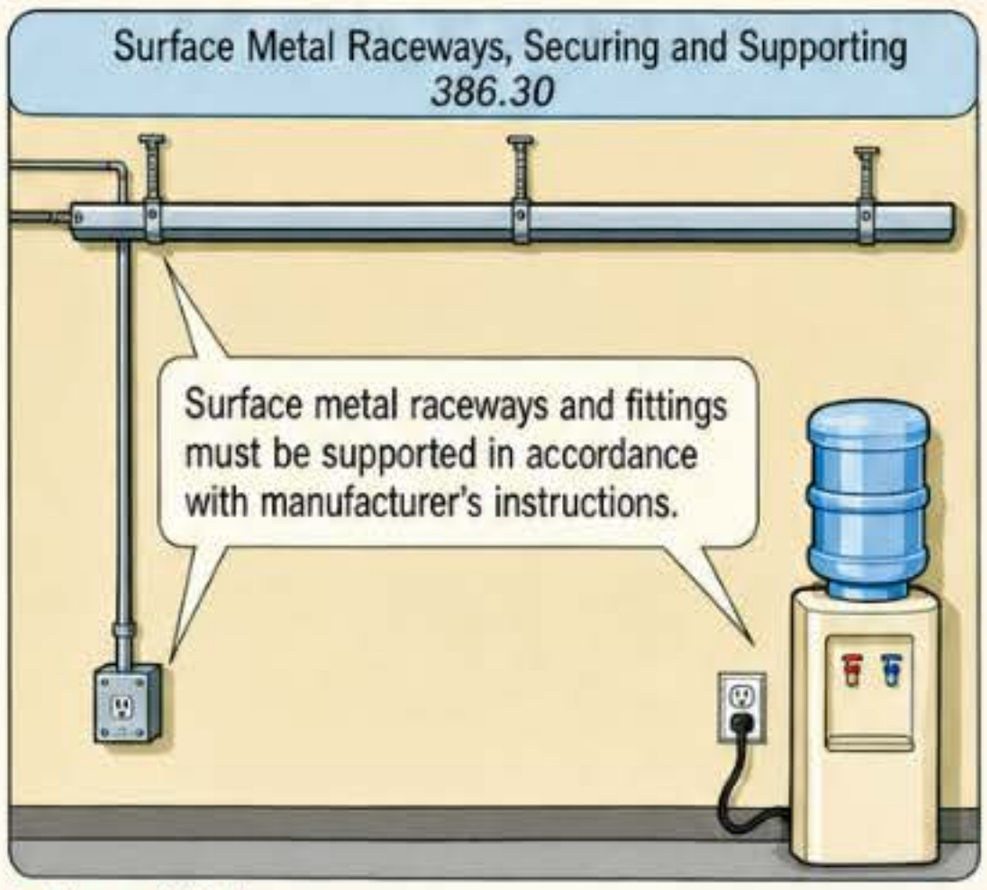
Surface Metal Raceways 386.70

(2) The number of current-carrying conductors does not exceed 30, and

(3) The sum of the cross-sectional areas of all contained conductors does not exceed 20 percent of the interior cross-sectional area of the raceway.

386.30 Securing and Supporting

Surface metal raceways and fittings must be supported in a way that follows the manufacturer's installation instructions. ▶Figure 386-5



▶Figure 386-5

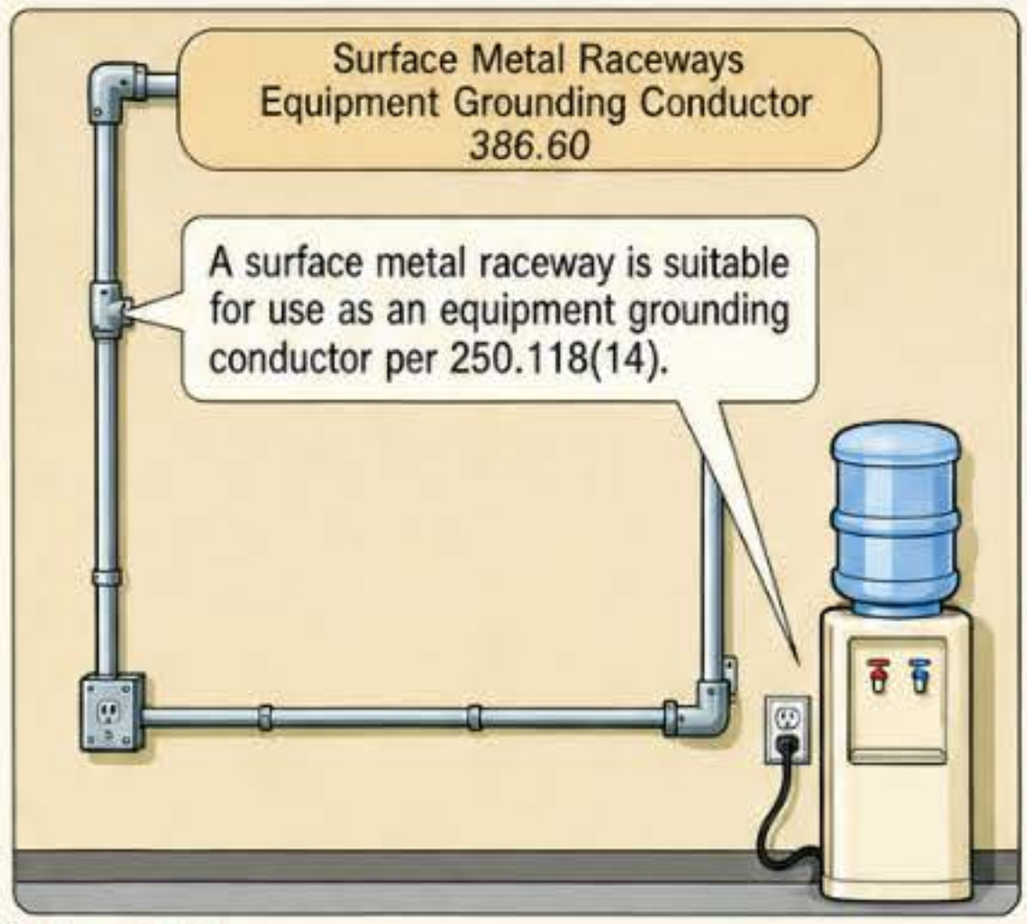
386.56 Splices and Taps

Splices and taps must be accessible and must not fill the raceway to more than 75 percent of its cross-sectional area.

386.60 Equipment Grounding Conductor

Surface metal raceway fittings must be mechanically and electrically joined together in a manner that does not subject the conductors to abrasion. Surface metal raceways that allow a transition to another wiring method, such as knockouts for connecting raceways, must have a means for the termination of an equipment grounding conductor.

A surface metal raceway is suitable as an equipment grounding conductor in accordance with 250.118(14). ▶Figure 386-6



▶Figure 386-6

386.70 Separate Compartments

Where surface metal raceways have separate compartments, power and lighting conductors can occupy one compartment and the other one may contain control, signaling, or communications wiring. Stamping, imprinting, or color coding of the interior finish must identify the separate compartments, and the same relative position of compartments must be maintained throughout the premises.

Notes

ARTICLE 392 CABLE TRAYS

Introduction to Article 392—Cable Trays

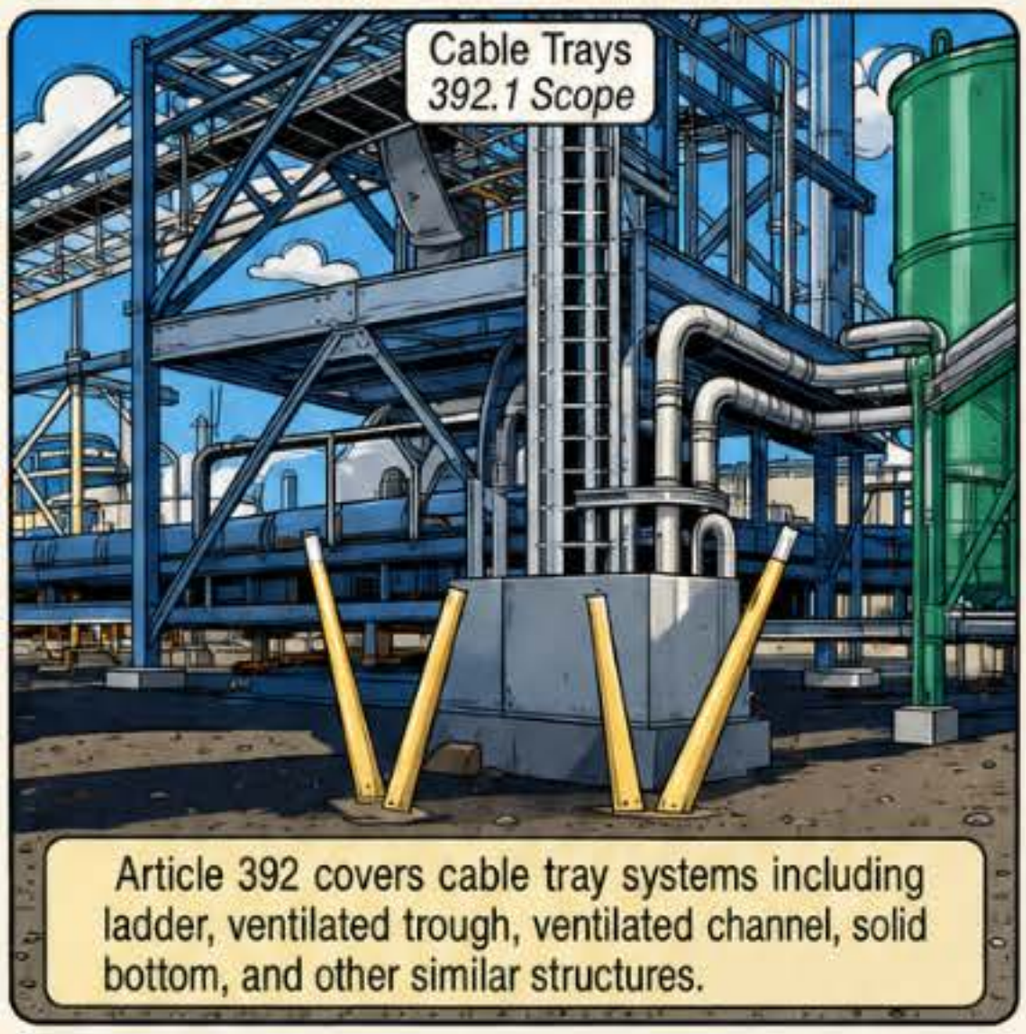
A cable tray system is a unit or an assembly of units or sections with associated fittings that forms a structural system used to securely fasten or support cables and raceways. Cable tray systems include ladder, ventilated trough, ventilated channel, solid bottom, and other similar structures. They are manufactured in many forms—from a simple hanger or wire mesh to a substantial, rigid, steel support system. Cable trays are designed and manufactured to support specific wiring methods, as identified in 392.10(A) of the 2023 *NEC*.

Part I. General

392.1 Scope

Article 392 covers cable tray systems, including ladder, ventilated trough, ventilated channel, solid bottom, and other similar structures.

Figure 392–1



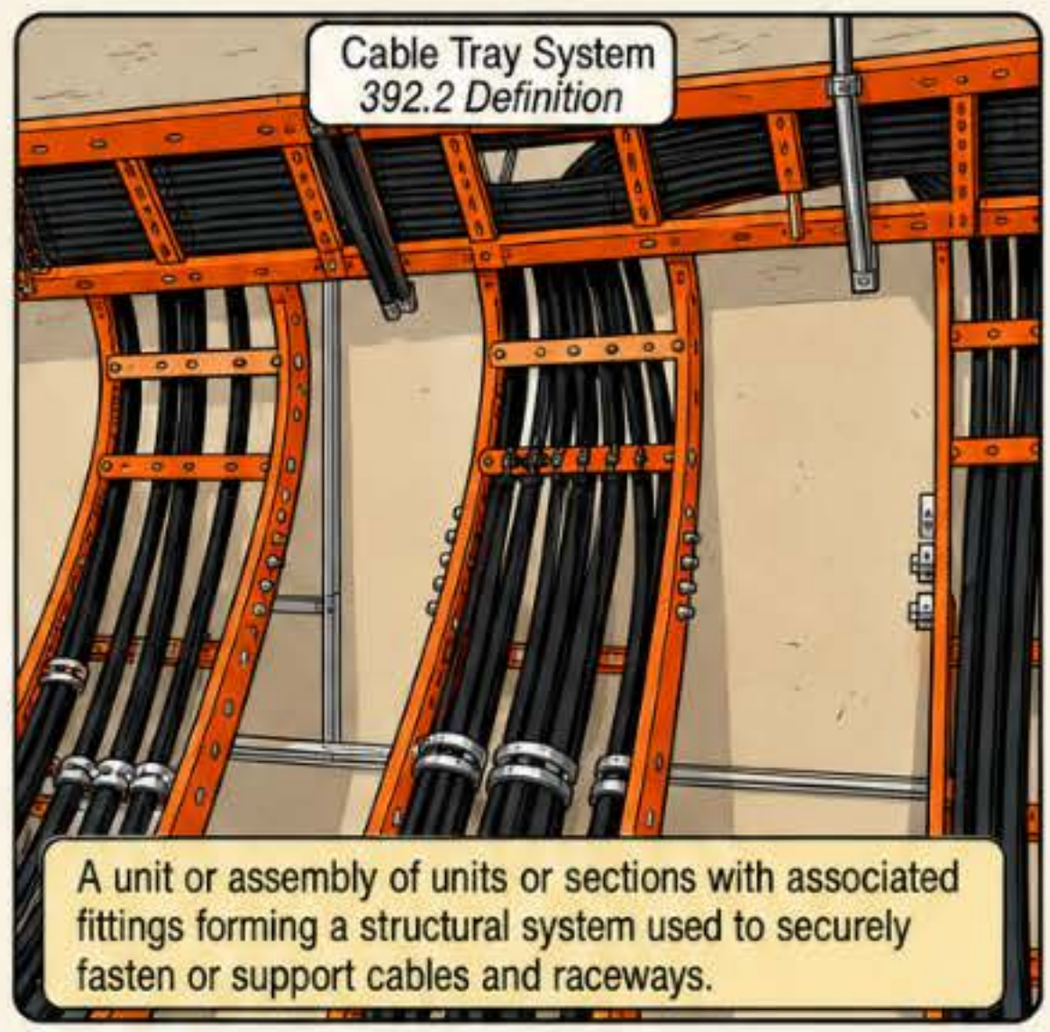
Article 392 covers cable tray systems including ladder, ventilated trough, ventilated channel, solid bottom, and other similar structures.

Figure 392–1

392.2 Definition

Cable Tray System. A unit or assembly of units or sections with associated fittings forming a rigid structural system used to securely fasten or support cables and raceways.

Figure 392–2



A unit or assembly of units or sections with associated fittings forming a structural system used to securely fasten or support cables and raceways.

Figure 392–2

Author's Commentary:
A cable tray is not a raceway; it is a support system for cables and raceways.
— Michael Hamilton

Part II. Installation

392.10 Uses Permitted

Cable trays can be used as a support system for wiring methods containing service, feeder, branch circuits, communications circuits, control circuits, and signaling circuits.

Figure 392–3

392.10 | Cable Trays

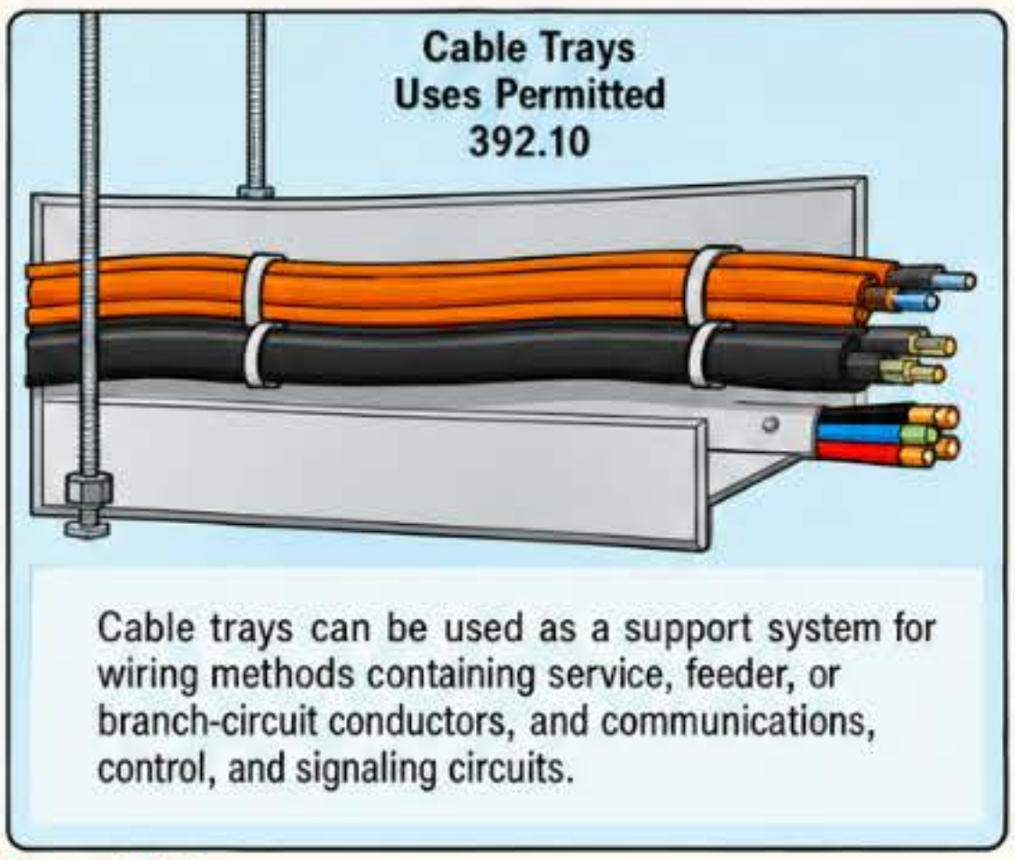


Figure 392-3

Single insulated conductors are only permitted in cable trays when installed in accordance with 392.10(B)(1).

> ***Author's Commentary:***
> Cable trays used to support service-entrance conductors must be installed in accordance with 230.44.
> — *Michael Hamilton*

(A) Wiring Methods. Any of the wiring methods contained in Table 392.10(A) can be installed in a cable tray.

Table 392.10(A) Wiring Methods

Wiring Method	Article/Section
Armored cable	320
Coaxial cables	820
Class 2 & 3 cables	725
Communications cables	800
Communications raceways	725, 770, and 800
Electrical metallic tubing	358
Electrical nonmetallic tubing	362
Fire alarm cables	760
Flexible metal conduit	348
Instrumentation tray cable	727
Intermediate metal conduit	342
Liquidtight flexible metal conduit	350

Table 392.10(A) Wiring Methods (continued)

Wiring Method	Article/Section
Liquidtight flexible nonmetallic conduit	356
Metal-clad cable	330
Nonmetallic-sheathed cable	334
Polyvinyl chloride (PVC) conduit	352
Power and control tray cable	336
Power-limited fire alarm cable	760
Power-limited tray cable	Table 725.154 and 725.179(E) and 725.71(F)
Rigid metal conduit	344
Service-entrance cable	338
Signaling raceway	725
Underground feeder and branch-circuit cable	340

> ***Author's Commentary:***
> Metal cable trays can be used in environmental air spaces (plenums) only when the wiring methods it supports are *permitted in accordance with 300.22(C).*
> — *Michael Hamilton*

(B) In Industrial Establishments.

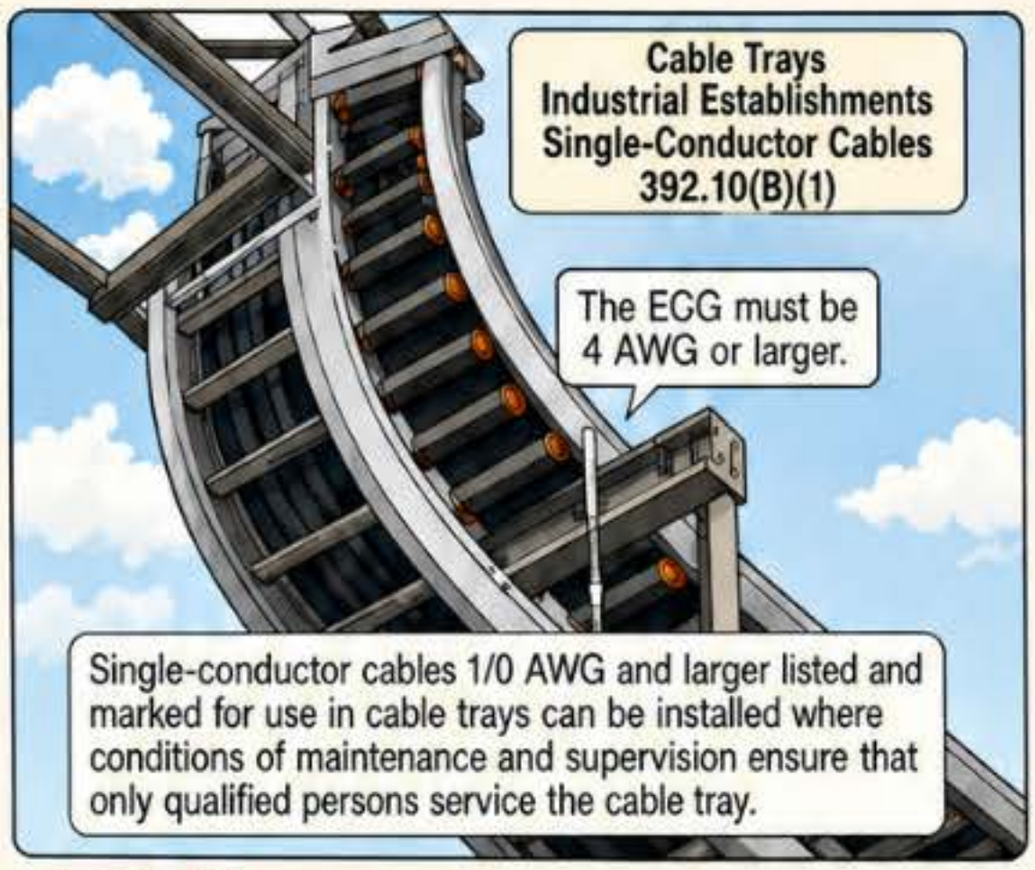
(1) Where conditions of maintenance and supervision ensure that only qualified persons service the installed cable tray system, single-conductor cables can be installed in accordance with the following: ▶ Figure 392-4

(a) 1/0 AWG and larger listed and marked for use in cable trays.

(c) Equipment grounding conductors must be 4 AWG and larger.

(C) Hazardous (Classified) Locations. Cable trays in hazardous (classified) locations must contain only the cable types and raceways permitted by this Code for the application.

> ***Author's Commentary:***
> *For permitted cable types in hazardous (classified) locations, see 501.10, 502.10, 503.10, 504.20, and 505.15.*
> — *Michael Hamilton*



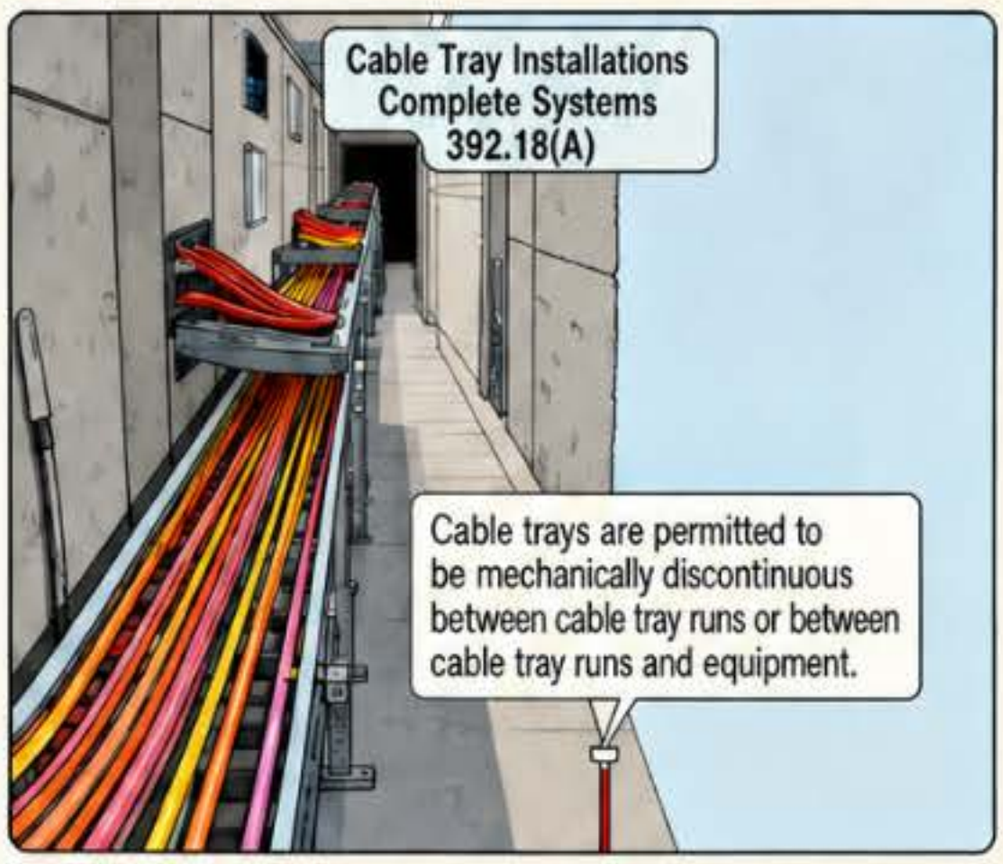
▶ Figure 392–4

392.12 Uses Not Permitted

Cable tray systems are not permitted in hoistways or where subject to severe physical damage.

392.18 Cable Tray Installations

(A) Complete System. Cable trays must be installed as a complete system, except that mechanically discontinuous segments between cable tray runs, or between cable tray runs and equipment are permitted. The system must provide for the support of the cables and raceways in accordance with their corresponding articles. Figure 392–5



▶ Figure 392–5

A bonding jumper, sized in accordance with 250.102 and installed in accordance with 250.96, must bond the sections of metal cable tray, or the cable tray and the raceway or equipment.

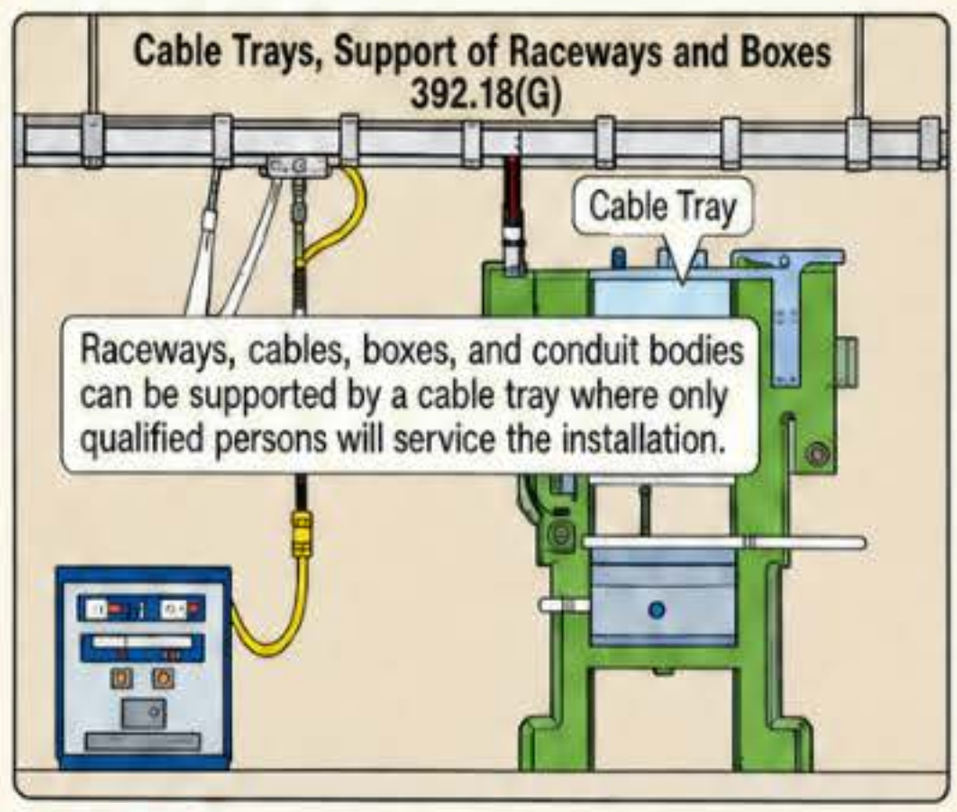
(B) Completed Before Installation. Each run of cable tray must be completed before the installation of cables or conductors.

(D) Through Partitions and Walls. Cable trays can extend through partitions and walls, or vertically through platforms and floors, if the installation is made in accordance with the firestopping requirements of 300.21.

(E) Exposed and Accessible. Cable trays must be exposed and accessible, except as permitted by 392.18(D).

(F) Adequate Access. Sufficient space must be provided and maintained about cable trays to permit adequate access for installing and maintaining the cables.

(G) Raceways, Cables, and Boxes Supported from Cable Trays. In industrial facilities where conditions of maintenance and supervision ensure only qualified persons will service the installation, cable tray systems can support raceways, cables, boxes, and conduit bodies. ▶ Figure 392–6



▶ Figure 392–6

For raceways terminating at a cable tray, a listed cable tray clamp or adapter must be used to securely fasten the raceway to the cable tray system. The raceway must be supported in accordance with the appropriate raceway article.

Raceways or cables running parallel to a cable tray system can be attached to the bottom or side of the cable tray system. The raceway or cable must be fastened and supported in accordance with the appropriate raceway or cable article.

392.20 | Cable Trays

Enclosures and raceway bodies that form part of a cable tray system must be firmly attached and supported in accordance with 314.23.

(H) Marking. Cable trays that carry conductors operating over 600 volts must display a permanent, readable warning that conveys the message, **"DANGER—HIGH VOLTAGE—KEEP AWAY"** in a prominent position on all cable trays. The spacing of the letters must be no less than 10 ft. The danger designation(s) or labels must comply with 110.21(B).

392.20 Cable and Conductor Installation

(C) Connected in Parallel. To avoid unbalanced current in parallel conductors caused by inductive reactance, all circuit conductors of a parallel set (phase and neutral [310.10(G)]) must be bundled together and secured to prevent excessive movement resulting from fault-current magnetic forces.

(D) Single Conductors. Conductors that are not run in parallel must be installed in one layer, unless the conductors are bound together.

392.30 Securing and Supporting

(A) Cable Trays. Cable trays must be supported in accordance with the installation requirements.

(B) Cables and Conductors. Cables and conductors must be secured to and supported by the cable tray system in accordance with 392.30(B)(1), (2), (3), and (4).

(4) Cable ties must be listed and identified as suitable for the intended application and for securing and supporting.

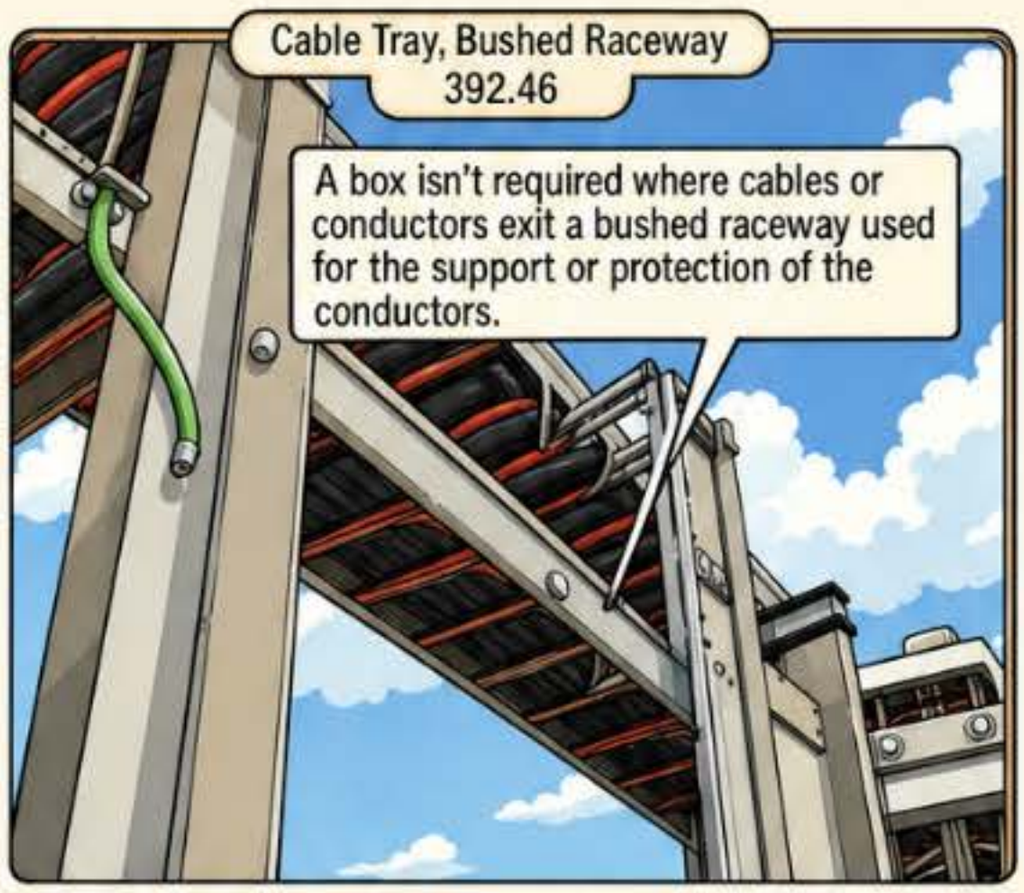
392.44 Expansion Splice Plates

Expansion splice plates for cable trays must be supplied where needed to compensate for thermal expansion and contraction.

392.46 Bushed Conduit and Tubing

A box is not required if cables or conductors are installed in a bushed raceway that provides support, protection from mechanical damage, or serves as the transition point for conductors or cables from the cable tray.

▶ Figure 392–7



▶ Figure 392–7

(A) Through Bushed Conduit or Tubing. Individual conductors or multiconductor cables with entirely nonmetallic jackets can enter enclosures where they terminate through a nonflexible bushed conduit or tubing installed for their protection, provided they are secured at the point where they pass from the cable tray into the raceway. The raceway must also be sealed at the outer end by an approved means to keep out debris from entering the equipment through the raceway.

(B) Flanged Connections. Individual conductors or multiconductor cables with entirely nonmetallic jackets can enter enclosures through openings fitted with flanges from the cable tray, where the tray is bolted to the flange and the flange is mounted directly to the equipment. The openings must be made so the conductors are protected from abrasion and must be sealed or covered to prevent debris from entering the enclosure through them.

Note: One method to keep debris from entering the enclosure is to seal the outer end of the raceway or the opening with duct seal.

392.56 Cable Splices

Splices are permitted in a cable tray if the splice is reachable and insulated using a method approved by the authority having jurisdiction. Splices may extend above the side rails of the cable tray if they are not subject to physical injury.

▶ Figure 392–8

392.60 Equipment Grounding Conductor

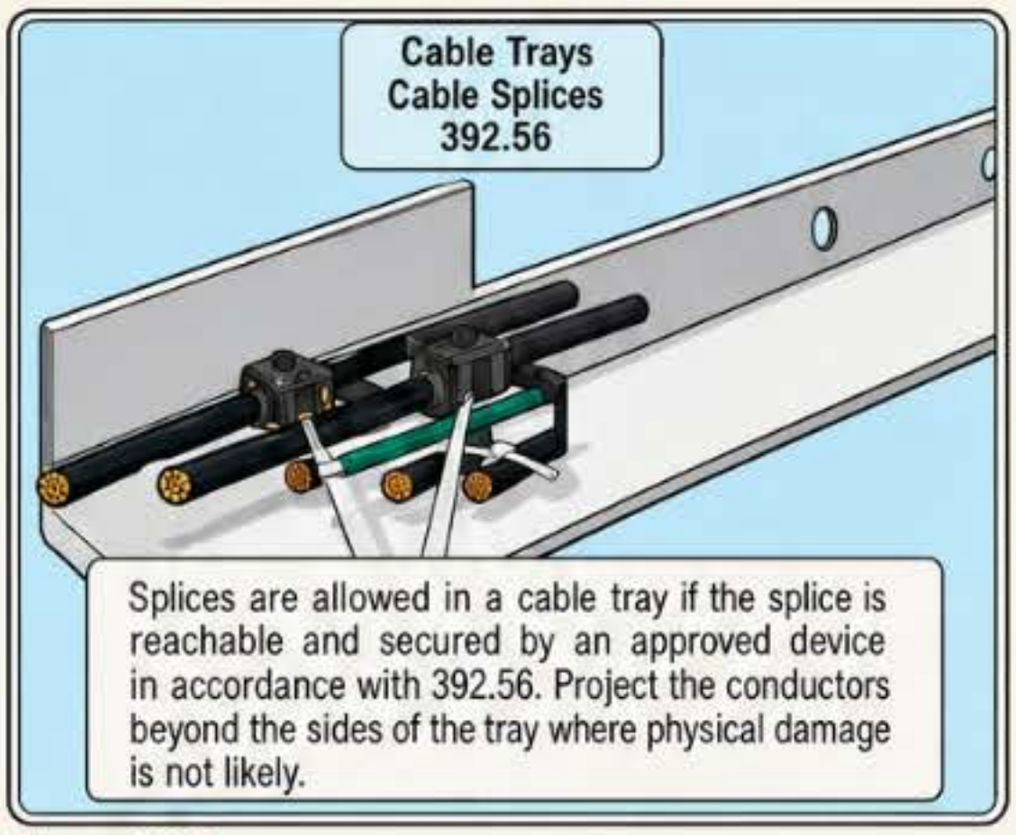


Figure 392-8

392.60 Equipment Grounding Conductor

(A) Used as an Equipment Grounding Conductor. Metal cable trays may serve as equipment grounding conductors when control and maintenance of the system are sufficient to ensure that only qualified persons work on and service the cable tray system. Figure 392-9

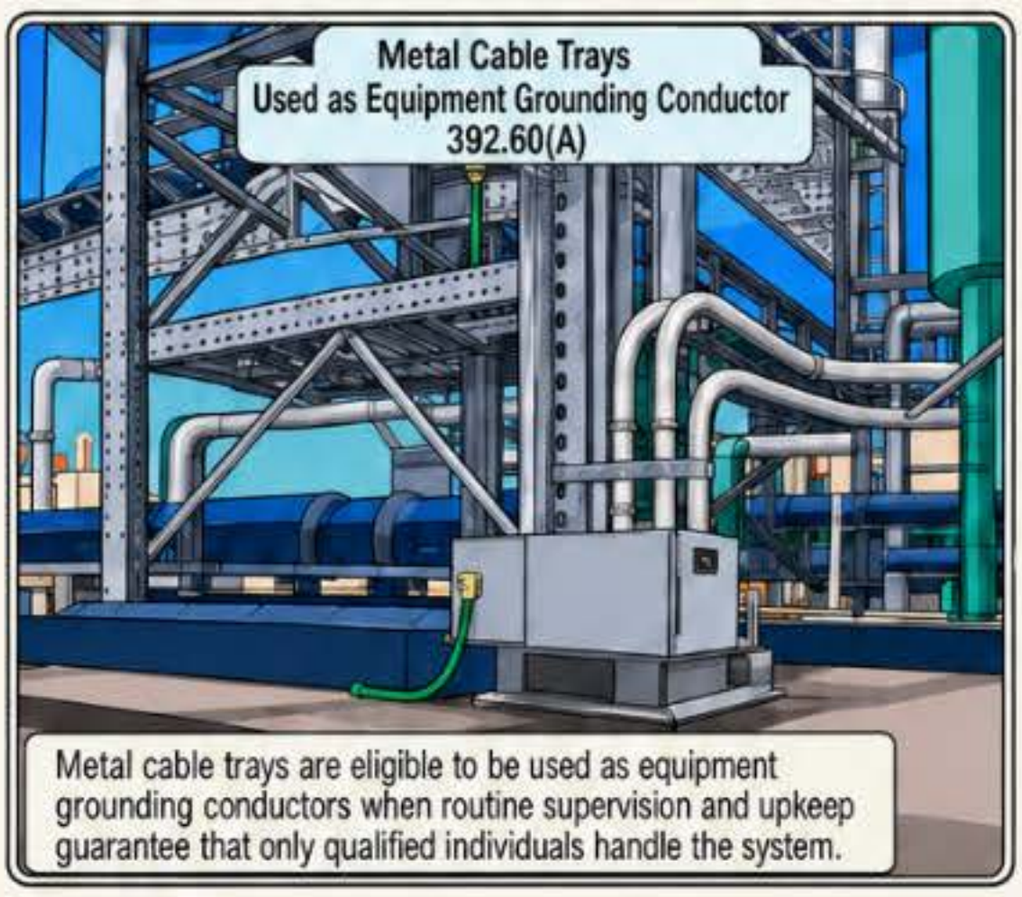


Figure 392-9

Metal cable trays that contain a single conductor must be secured together so they have the necessary strength to safely carry any fault current that could occur, per 250.96(A).

Metal cable trays carrying communication or data, as well as signal conductors and cables, must be electrically continuous with listed connections or use of an approved bonding jumper. Figure 392-10

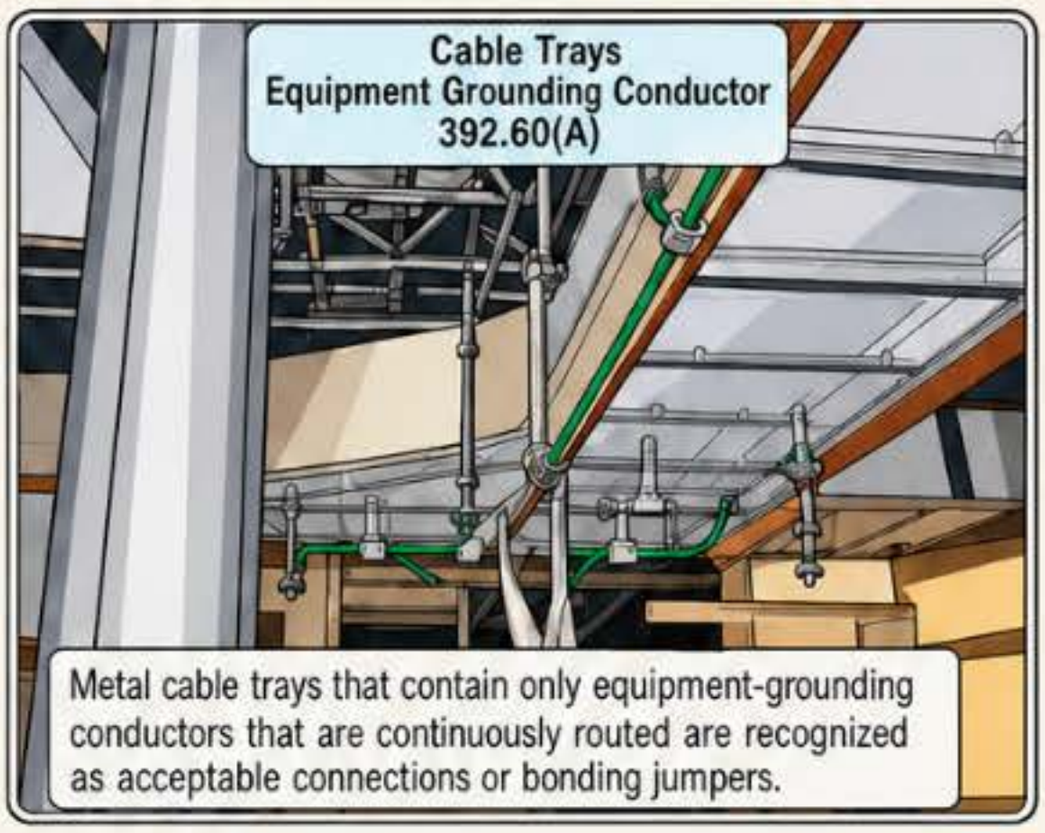


Figure 392-10

(B) Serve as an Equipment Grounding Conductor. Metal cable trays may function as equipment grounding conductors when the following requirements are met (392.10(C)):

(1) Metal cable trays and their fittings are identified as suitable equipment grounding conductors. Figure 392-11

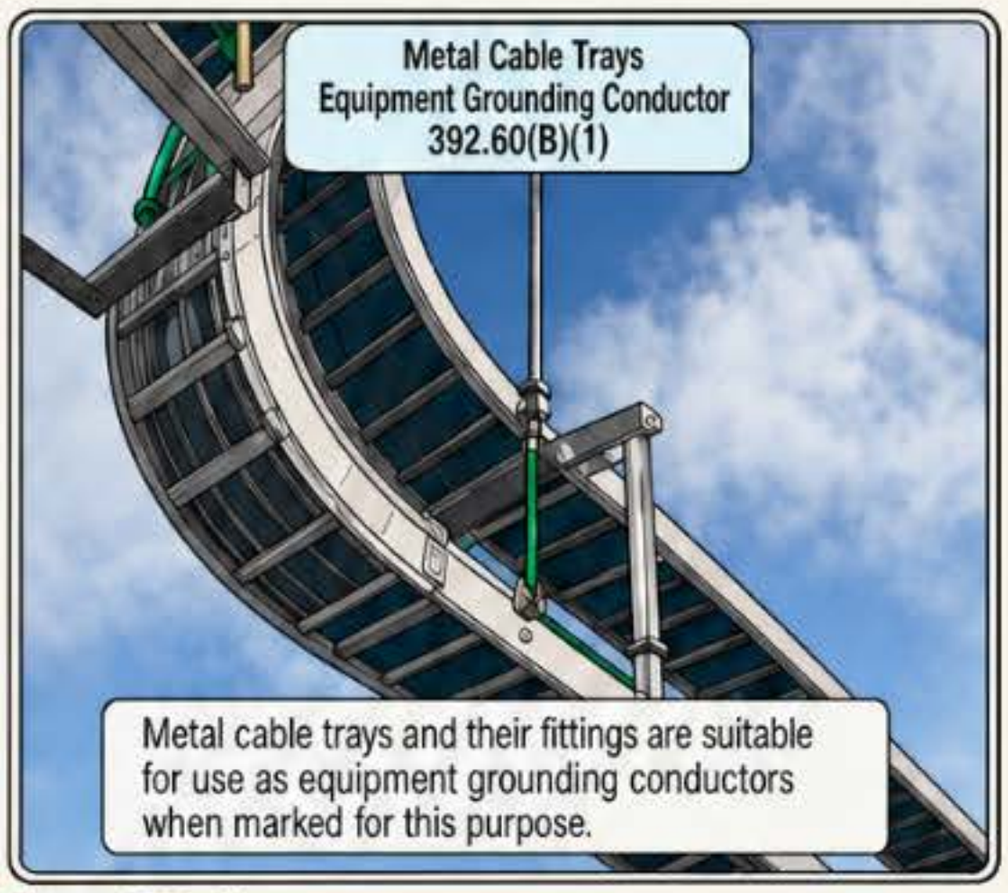


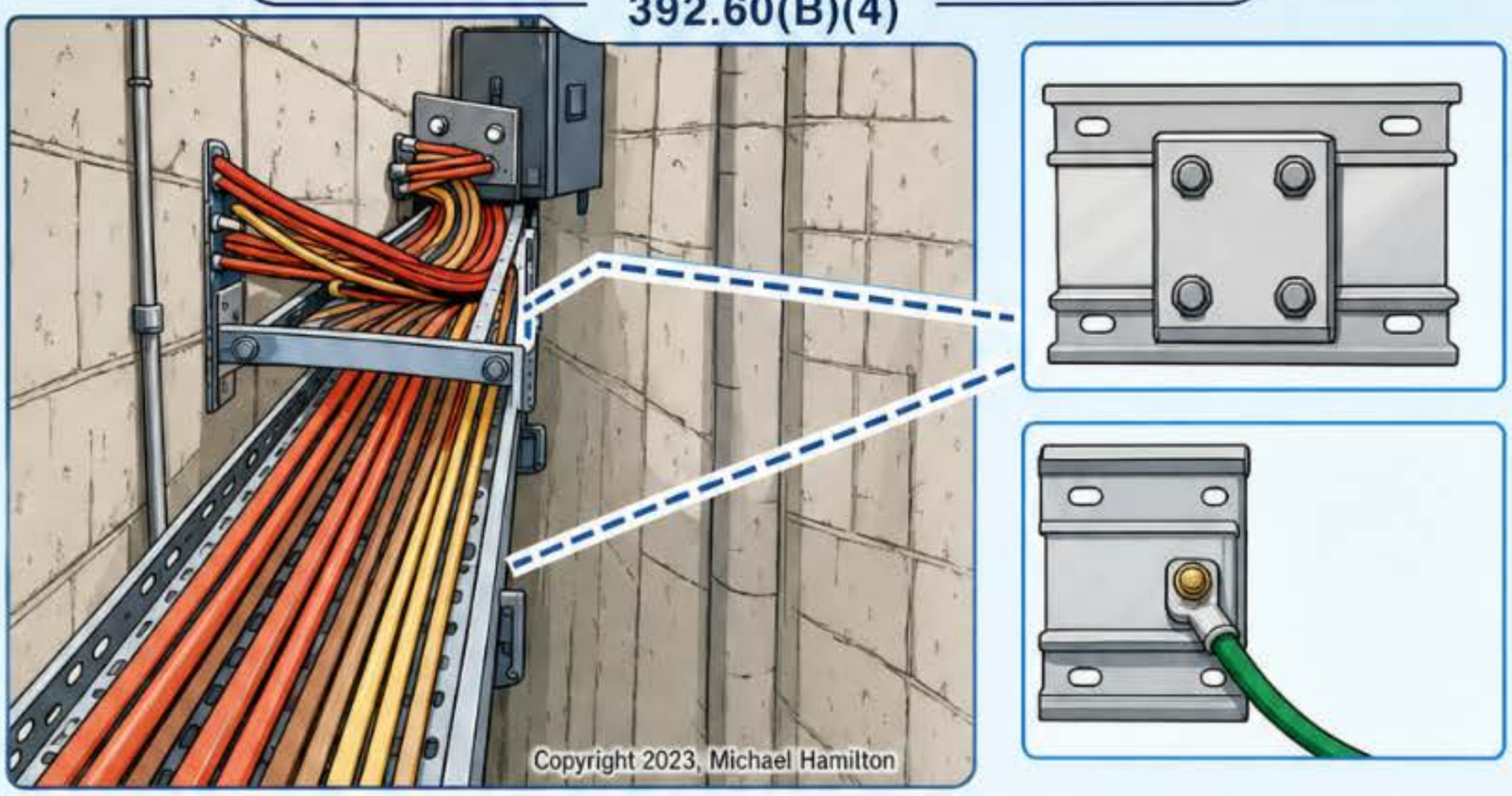
Figure 392-11

(4) Cable tray sections, fittings, and associated raceways are secured together at each juncture to ensure proper electrical continuity and the ability to carry fault current that may appear on them (250.96(A)). This is achieved through bolted connections or bonding jumpers sized in accordance with 250.102. Figure 392-12

Author's Commentary: The equipment grounding conductor role for cable trays depends on keeping the system intact and using approved connections or bonding jumpers. Proper identification, secure assembly, and qualified maintenance are the keys to a safe installation. — *Michael Hamilton*

392.60 | Cable Trays

Metal Cable Trays
Equipment Grounding Conductor (EGC)
392.60(B)(4)



Metal cable trays can function as an equipment grounding conductor (EGC). Where cable tray sections, fittings, and other connected raceway components are securely fastened together by mechanical connectors or bonding jumpers sized in accordance with 250.102, they provide an effective equipment grounding path.

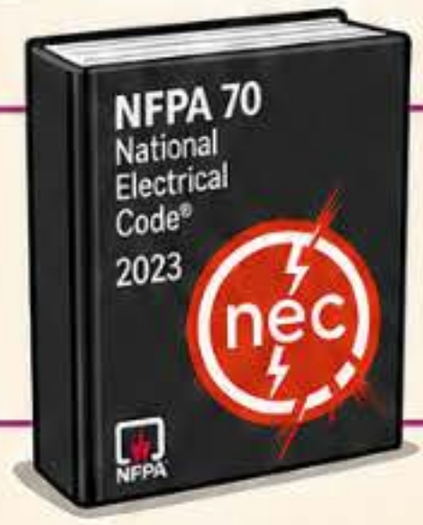
▶ Figure 392–12

Author's Commentary:

When metal cable trays are properly assembled, the tray itself can serve as the equipment grounding conductor. Reliable metal-to-metal contact is the key—use mechanical connectors or bonding jumpers sized per 250.102 to ensure a continuous and dependable grounding path.

— *Michael Hamilton*

CHAPTER 3 PRACTICE QUESTIONS



Please use the 2023 *Code* book to answer the following questions.

CHAPTER 3—WIRING METHODS AND MATERIALS

1. Where nails or screws are likely to penetrate nonmetallic-sheathed cable or enter insulated members, a steel sleeve, steel plate, or steel clip not less than _____ in thickness shall be used to protect the cable or tubing.

(a) 1⁄16 in.
(b) 1⁄8 in.
(c) 1⁄2 in.
(d) 3⁄4 in.

2. A listed expansion/deflection fitting or other approved means shall be used where a raceway crosses a _____ intended for expansion, contraction or deflection used in buildings, bridges, parking garages, or other structures.

(a) junction box
(b) structural joint
(c) cable tray
(d) unistrut hanger

3. The interior of underground raceways shall be considered a _____ location.

(a) wet
(b) dry
(c) damp
(d) corrosive

4. Where direct-buried conductors and cables emerge from grade, they shall be protected by enclosures or raceways to a point at least _____ above finished grade.

(a) 3 ft
(b) 6 ft
(c) 8 ft
(d) 10 ft

5. Each direct-buried single conductor cable shall be located _____ in the trench to the other single conductor cables in the same parallel set of conductors, including equipment grounding conductors.

(a) perpendicular
(b) bundled together
(c) in close proximity
(d) spaced apart

6. Direct-buried conductors, cables, or raceways, which are subject to movement by settlement or frost, shall be arranged to prevent damage to the _____ or to equipment connected to the raceways.

(a) siding of the building
(b) landscaping around the cable or raceway
(c) enclosed conductors
(d) expansion fitting

Chapter 3 | Practice Questions

7. Which areas of a cable raceway or sleeve are most susceptible to temperature and condensation problems, and therefore must be sealed to stop warm air from moving into cooler parts of the raceway or sleeve?
   (a) the opening
   (b) the cable
   (c) the empty space
   (d) the raceway or sleeve

8. Raceways must be equipped with expansion joints, deflection/expansion fittings, or deflection fittings when needed to offset the effects of thermal expansion, deflection, and contraction.
   (a) True
   (b) False

9. Raceways, cable systems, boxes, cabinets, and fittings need to be firmly fastened and secured in position.
   (a) True
   (b) False

10. When independent support wires are used to suspend a ceiling assembly for luminaires, cable systems, or boxes above a ceiling, those wires shall be attached at _____ end(s).
   (a) one
   (b) both
   (c) the line and load
   (d) the connection point to the structural member

11. Raceways shall be _____ between outlet, junction, or splicing points before conductor installation.
   (a) installed complete
   (b) tested for ground faults
   (c) at least 80 percent complete
   (d) torqued

12. Only equipment and devices that are acceptable for use within ducts or plenum spaces are allowed there if their operation or sensing directly affects the environment inside, or the _____.
   (a) contained air
   (b) air quality
   (c) air temperature
   (d) humidity

13. In general, installed in raceways, electrical conductors that are larger must be _____.
   (a) 2 AWG
   (b) 4 AWG
   (c) 6 AWG
   (d) 8 AWG

14. Parallel conductors shall have the same _____.
   (a) length
   (b) material
   (c) size in circular mil area
   (d) all of these

15. Separate raceways that contain parallel conductors must share the same electrical characteristics.
   (a) True
   (b) False

16. When raceways or cables that are in direct sunlight or above rooftops are exposed, what temperature addition must be used to the outdoor ambient temperature if the conductor temperature rise is less than ¾ in. from the rooftop?
   (a) 30°F
   (b) 40°F
   (c) 50°F
   (d) 60°F

17. _____ covers installation and construction requirements for cabinets, cutout boxes, and meter socket enclosures.
   (a) 300
   (b) 310
   (c) 312
   (d) 314

18. Nonmetallic-sheathed cables may pass into the top of surface-mounted cabinets, cutout boxes, and meter socket enclosures through nonflexible raceways not less than _____ in. long if all other conditions are met.
   (a) 3 ft
   (b) 10 ft
   (c) 25 ft
   (d) 100 ft

Author's Commentary: *These practice questions focus on critical installation details for raceways, cables, and conductors as covered in the 2023 **NEC**. Mastery of these principles helps ensure safe, code-compliant electrical systems that perform reliably in all environments.*

— Michael Hamilton

19. A space inside enclosures that creates separation between all entries is called internal _____, allowing nonmetallic boxes to be used with metal raceways or metal-armored cables.

(a) grounding
(b) bonding
(c) connecting
(d) splicing

20. Equipment grounding conductor(s), not more than _____ in size, may be omitted from calculations when 14 AWG and smaller fixtures are fed from a domed luminaire or a canopy like that box, with termination inside the box.

(a) one
(b) two
(c) three
(d) four

21. An outlet box or enclosure mounted to a building or other surface shall be _____.

(a) rigidly and securely fastened in place
(b) supported by cables that protrude from the box
(c) supported by cable entries from the top and permitted to rest against the supporting surface
(d) permitted to be supported by the raceway(s) terminating at the box

22. A vertically mounted luminaire weighing no more than _____ can be supported to a device box or plaster ring with no fewer than two No. 6 or larger screws.

(a) 4 lb
(b) 6 lb
(c) 8 lb
(d) 10 lb

23. Conductors, splices, or terminations in a handhole enclosure shall be listed as suitable for _____.

(a) wet locations
(b) damp locations
(c) direct burial in the earth
(d) exterior use

24. Type AC cable and associated fittings shall be _____.

(a) identified
(b) approved
(c) listed
(d) labeled

25. When armored cable is run parallel to the sides of rafters, studs, or floor joists in an accessible attic, the cable shall be protected with running boards.

(a) True
(b) False

26. Type AC cable installed horizontally through wooden or metal framing members is considered supported where support does not exceed _____ intervals.

(a) 2 ft.
(b) 3 ft.
(c) 4½ ft.
(d) 6 ft.

27. Type MC cable installed through, or parallel to, framing members shall be protected against physical damage from penetration by screws or nails by 1¼ in. separation or protected by a suitable metal plate.

(a) True
(b) False

28. Type MC cable containing four or fewer conductors, sized no larger than 10 AWG, shall be secured within _____ of every box, cabinet, fitting, or other cable termination.

(a) 8 in.
(b) 12 in.
(c) 18 in.
(d) 24 in.

29. Type NM cables shall not be used in one- and two-family dwellings exceeding three floors above grade.

(a) True
(b) False

30. Type NM cable on a wall of an unfinished basement installed in a listed raceway shall have a _____ installed at the point where the cable enters the raceway.

(a) suitable insulating bushing or adapter
(b) sealing fitting
(c) bonding bushing
(d) junction box

Chapter 3 Practice Questions

31. The radius of the curve along the inside of any bend, whether during or after installing Type NM cable, must be at least how many times the diameter of the cable?

(a) 5
(b) 6
(c) 7
(d) 8

32. Type _____ cable is built as either a single conductor or as multiple insulated conductors together. It is listed for use as underground service-entrance cable.

(a) SE
(b) NM
(c) UF
(d) USE

33. Types SE and USE cables and the associated fittings must be _____.

(a) identified
(b) approved
(c) listed
(d) labeled

34. Boxes, elbows, couplings, and other fittings may be installed in concrete with direct contact with the earth, or in damp locations where corrosion protection _____ is provided.

(a) identified
(b) approved
(c) listed
(d) suitable

35. To prevent the possibility of _____ where dissimilar metals come into contact, such contact must be avoided in an IMC raceway installation.

(a) corrosion
(b) galvanic action
(c) short circuits
(d) ground faults

36. RMC horizontal runs that are supported by openings through walls must be secured at intervals not exceeding 10 ft, and they must also be fastened within 3 ft of termination points.

(a) walls
(b) trusses
(c) rafters
(d) framing members

Author's Commentary:

These questions highlight key rules for raceways, cable installations, and conduit systems. Mastering these requirements is essential for safe, compliant, and reliable electrical work.

— Michael Hamilton

37. Flexible metal conduit must be firmly secured by approved means, and the authority having jurisdiction must have oversight within _____ of termination.

(a) 6 in.
(b) 10 in.
(c) 1 ft
(d) 10 ft

38. FMC must be both supported and _____.

(a) at intervals not exceeding 4½ ft
(b) within 8 in. on each side of a box where fished
(c) where fished
(d) at intervals not exceeding 6 ft

39. With the exceptions listed in the Code, _____ LFMC fittings are allowed as a method of support and securing.

(a) identified
(b) approved
(c) listed
(d) labeled

40. In PVC conduit, bends shall _____ from pull points.

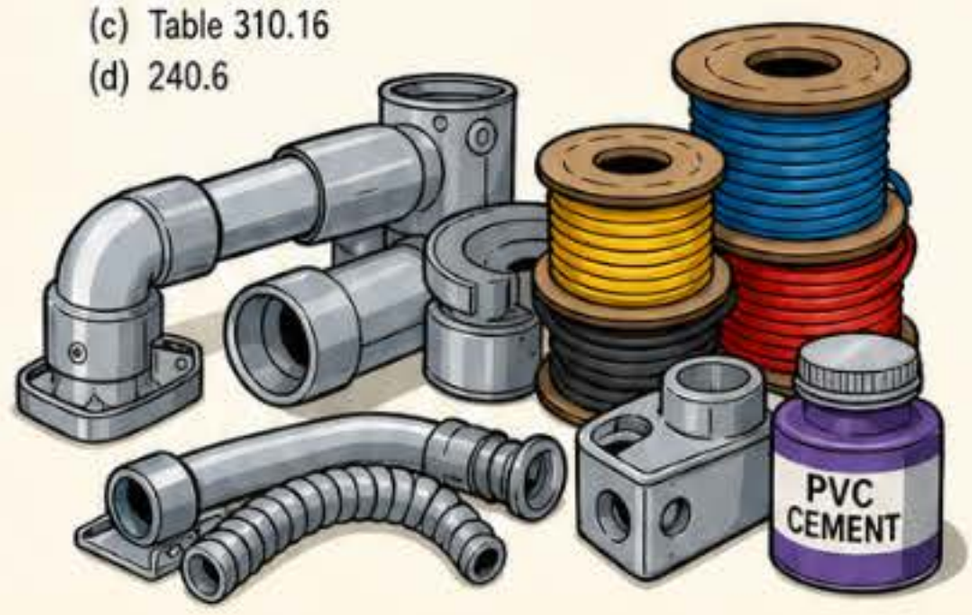
(a) not be made
(b) not be limited in degrees
(c) be limited to 360 degrees
(d) be limited to 180 degrees

41. PVC conduit must be tightly secured within _____ of every box.

(a) 6 in.
(b) 12 in.
(c) 24 in.
(d) 36 in.

42. The total number of conductors permitted in LFNC must not go beyond the fill percentage established in _____.

(a) Chapter 9, Table 1
(b) Table 250.66
(c) Table 310.16
(d) 240.6



DEFINITIONS | From Michael Hamilton Publications

43. Where Type LFNC conduit is installed in lengths exceeding _____ ft, the conduit must be securely fastened at intervals not greater than 3 ft and within 12 in. of each side of every outlet box, junction box, cabinet, or fitting.

(a) 2 ft
(b) 3 ft
(c) 6 ft
(d) 10 ft

44. Where used to secure or support LFNC, cable ties shall be _____ for the application.

(a) listed
(b) labeled
(c) marked
(d) approved

45. Securing or supporting of LFNC is not required where installed in lengths not exceeding _____ from the last point where the raceway is securely fastened for connections within an accessible ceiling to a luminaire(s) or other equipment.

(a) 3 ft
(b) 6 ft
(c) 8 ft
(d) 10 ft

46. EMT run between termination points shall be securely fastened within _____ of each outlet box, junction box, device box, cabinet, conduit body, or other tubing termination.

(a) 12 in
(b) 18 in
(c) 2 ft
(d) 3 ft

Author's Commentary:

These items test your recall of key fastening, support, and connection requirements for raceways and cables as defined by the 2023 NEC.

— Michael Hamilton

47. Unbroken lengths of electric nonmetallic tubing shall not be required to be secured where fished between access points for _____ work in finished buildings or structures and securing is impractical.

(a) concealed
(b) exposed
(c) hazardous
(d) completed

48. The distance between horizontal supports of metal wireways shall not exceed _____.

(a) 6 ft
(b) 8 ft
(c) 10 ft
(d) 15 ft

49. Surface metal raceway enclosures providing a transition from other wiring methods shall have a means for connecting a(n) _____ conductor.

(a) grounded
(b) ungrounded
(c) equipment grounding
(d) all of these

50. Cable tray systems shall not have mechanically discontinuous segments between cable tray runs or between cable tray runs and equipment.

(a) True
(b) False

Notes |

CHAPTER 4

EQUIPMENT FOR GENERAL USE

Introduction to Chapter 4—Equipment for General Use

The first three chapters of the *NEC* provide the foundation you need, and this fourth chapter builds on that base to help you assemble dependable general equipment systems. By studying the initial three chapters, you'll be able to apply their concepts as you learn the requirements for Chapters 5, 6, and 7—and later when you move on to Chapter 8.

Chapter 4 is organized as follows:

- **Article 400—Flexible Cords and Flexible Cables.** This article sets out the performance, use, and installation rules for flexible cords and flexible cables.
- **Article 402—Fixture Wires.** Here you'll find the required characteristics and installation standards that apply to fixture wires.
- **Article 404—Switches.** This section covers the rules for every type of switch, including snap (toggle) switches, dimmer switches, fan switches, knife switches, circuit breakers, and automatic devices such as time clocks, timers, and switches along with circuit breakers used for a disconnecting means.
- **Article 406—Receptacles and Attachment Plugs (Caps).** This article explains the ratings, types, and installation practices for receptacles and attachment plugs. It also addresses the requirements for flanged surface inlets.
- **Article 408—Switchboards and Panelboards.** Here you'll learn the specific requirements that apply to switchboards, panelboards, and distribution boards used to supply lighting and power circuits.

Author's Commentary:
See *Article* 100 for the definitions of "Panelboard" and "Switchboard."

— Michael Hamilton

- **Article 410—Luminaires and Lamps.** This article covers the rules for luminaires, lampholders, and lamps. Proper installation depends greatly on following the manufacturer's instructions, so they are critical to read and apply. Underwriters Laboratories publishes a resource titled the *Luminaires Marking Guide* to assist with correct selection and installation of common lamp types, including incandescent, fluorescent, and high-intensity-discharge (HID) luminaires. Areas used to grow agricultural products (*"hot* houses" and *similar spaces) require* fixtures that can tolerate sunlight and *seasonal temperature* changes. Extra requirements are also listed in the *Horticultural Part XV.*
- **Article 411—Low-Voltage Lighting.** This article outlines lighting systems that operate at no more than 30 volts alternating current or 60 *volts direct current, along with the related components.*
- **Article 422—Appliances.** This article provides the rules for electrical appliances that are used in any location.

• • •

Chapter 4 | Equipment for General Use

- **Article 424—Fixed Electric Space-Heating Equipment.** This article addresses permanently installed equipment used for space heating. It includes electric space-heating appliances, heating units, cable systems, boilers, central systems, and other fixed equipment used for heating spaces. Article 424 does not apply to heating systems or air-conditioning units.
- **Article 430—Motors, Motor Circuits, and Controllers.** This article sets out the rules for choosing conductor sizes, protecting circuits from overcurrent, using control conductors, motor controllers, and disconnecting means. Installation rules for motor control centers are included in Article 430, Part VII.
- **Article 440—Air-Conditioning and Refrigeration Equipment.** This article covers electrically operated air-conditioning and refrigeration equipment that uses a motor-compressor with hermetic compressor. The requirements in this article supplement or revise those in Article 430 and other applicable sections.
- **Article 445—Generators.** This article provides the electrical installation requirements for generators and related equipment. Topics include placement, nameplate information, conductor ampacity, and means for disconnection.
- **Article 450—Transformers.** This article specifies the installation requirements for transformers.
- **Article 480—Storage Batteries.** This article addresses fixed, nonportable installations of storage batteries.

ARTICLE 400 FLEXIBLE CORDS AND FLEXIBLE CABLES

Introduction to Article 400—Flexible Cords and Flexible Cables

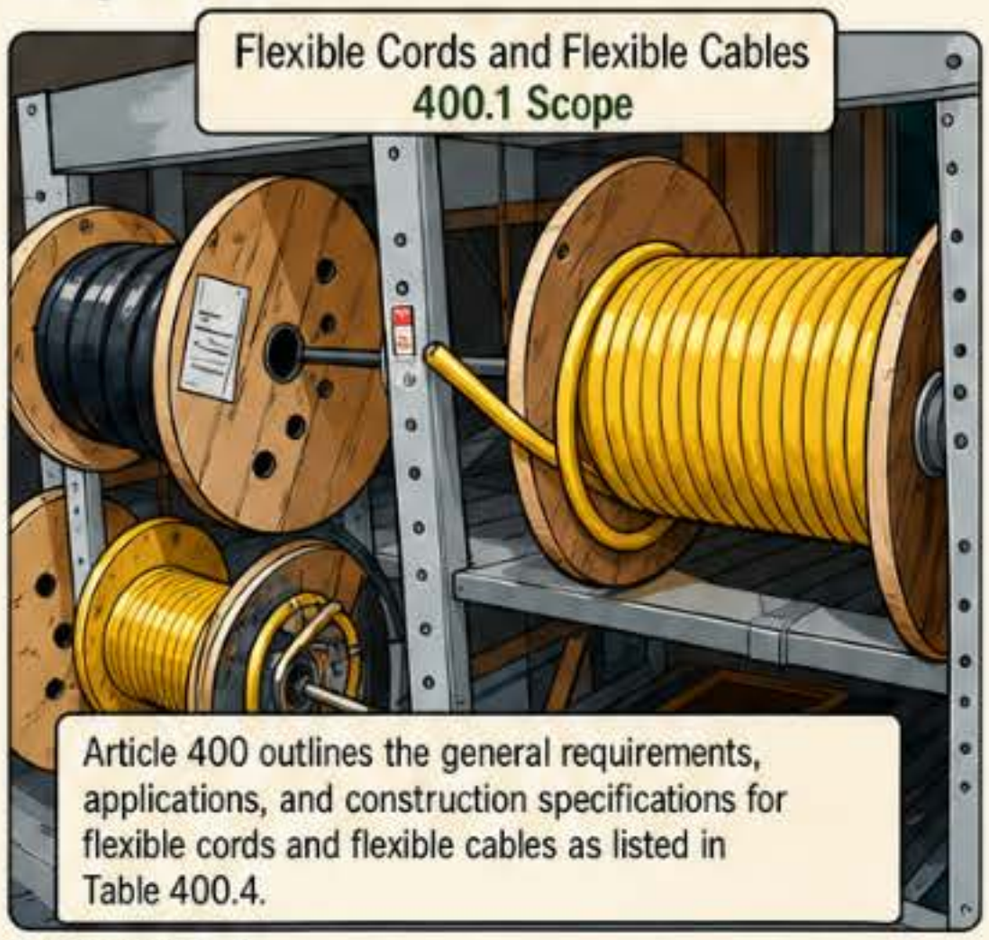
This article explains the broad requirements, common applications, and construction rules for flexible cords and flexible cables. The *NEC* does not treat flexible cords as a wiring method in the same way presented in Chapter 3.

It is important to use the correct flexible cord (and its fittings) for the job at hand. Table 400.4 is a valuable reference for this purpose. For example, a cord identified for wet locations may be chosen for outdoor use. The outer jacket material of that cord is evaluated to determine if it can resist the properties and stresses that exist in the environment where it will be installed. Tables 400.5(A)(1) and 400.5(A)(2) are also key resources for locating the proper ampacity of flexible cords.

Flexible cords and flexible cables can serve many roles, such as supplying power to lamps, appliances, extension cords, drop and pendant lights, and pool pumps, among many other applications.

400.1 Scope

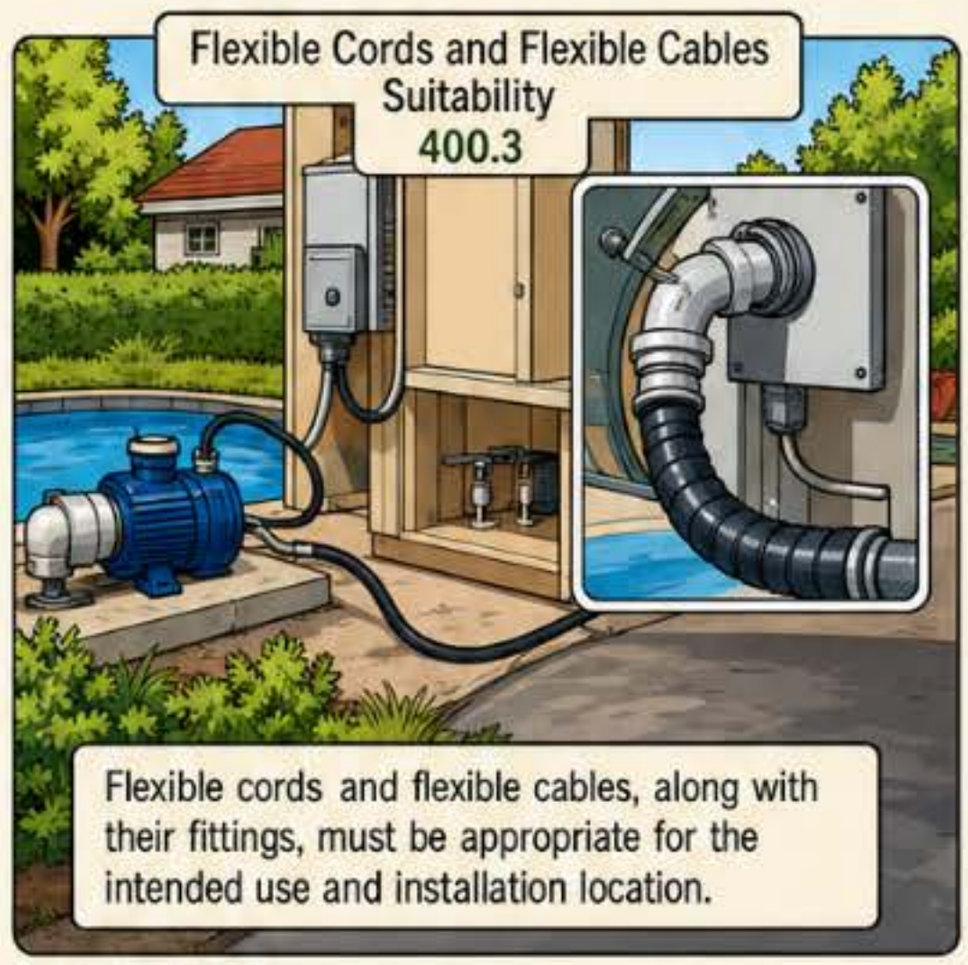
Article 400 defines the general requirements, applications, and construction-related specifications for flexible cords and flexible cables as outlined in Table 400.4.
▶ **Figure 400–1**



▶ **Figure 400–1**

400.3 Suitability

Flexible cords and flexible cables, along with their fittings, must be appropriate for the intended use and installation location. ▶ **Figure 400–2**



▶ **Figure 400–2**

Author's Commentary:

Selecting the proper flexible cord or cable isn't just about the electrical load—it's about the environment too. Always consider where the cord will be used and match it to the conditions it will face.

— Michael Hamilton

400.4 | Flexible Cords and Flexible Cables

400.4 Types of Flexible Cords and Flexible Cables

Flexible cords and flexible cables must meet the requirements outlined in the descriptions provided in Table 400.4.
♦ **Figure 400–3**

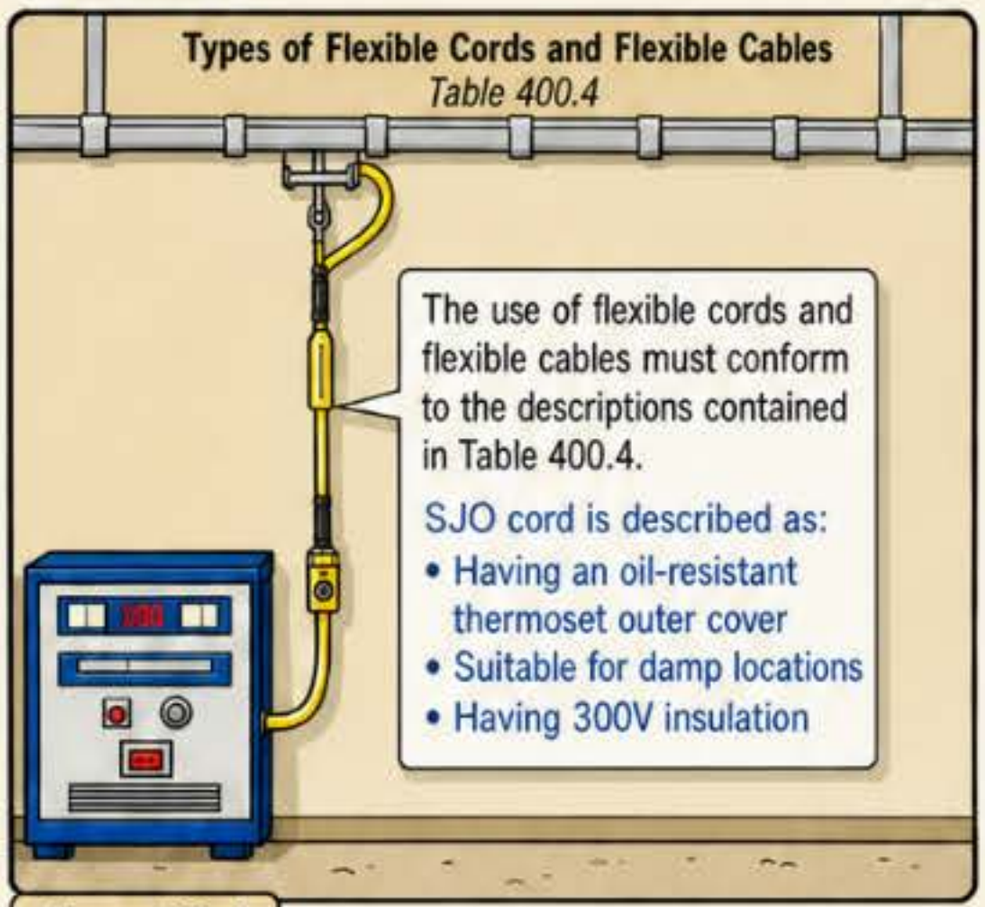


Figure 400–3

Author's Commentary:

- The "W" suffix at the end of a flexible cord type indicates it is resistant to both water and sunlight [Table 400.4, Note 9].
- When ordering a cord, be specific. For example, instead of saying "14/2 Romex®," state exactly what you need. For instance, "14/2 Romex®" could refer to versions with black, white, and equipment grounding conductors, or it could be two conductors with a green equipment grounding conductor. Type SJ flexible cord "14/2 SJ" includes two current-carrying conductors and no equipment grounding conductor, whereas "14/3 SJ" has three current-carrying conductors plus an equipment grounding conductor. Always provide the total number of conductors required for your installation.

— Michael Hamilton

400.5 Ampacity of Flexible Cords and Flexible Cables

(A) Ampacity Tables. Table 400.5(A)(1) provides the ampacity for individual conductors inside manufactured flexible cords, while Table 400.5(A)(2) gives the ampacity for complete cord assemblies that have more than three current-carrying conductors when the ambient temperature does not exceed 86°F.

400.10 Uses Permitted

(A) Uses Permitted. Flexible cords and flexible cables within the scope of this article may be used for:

(1) Pendants [receptacles—210.50(A) and boxes—314.23(H)].

(2) Wiring of luminaires [410.24(A) and 410.62(B)].

(3) Connection of portable luminaires, portable and mobile signs, or appliances [422.16]. ♦ **Figure 400–4**

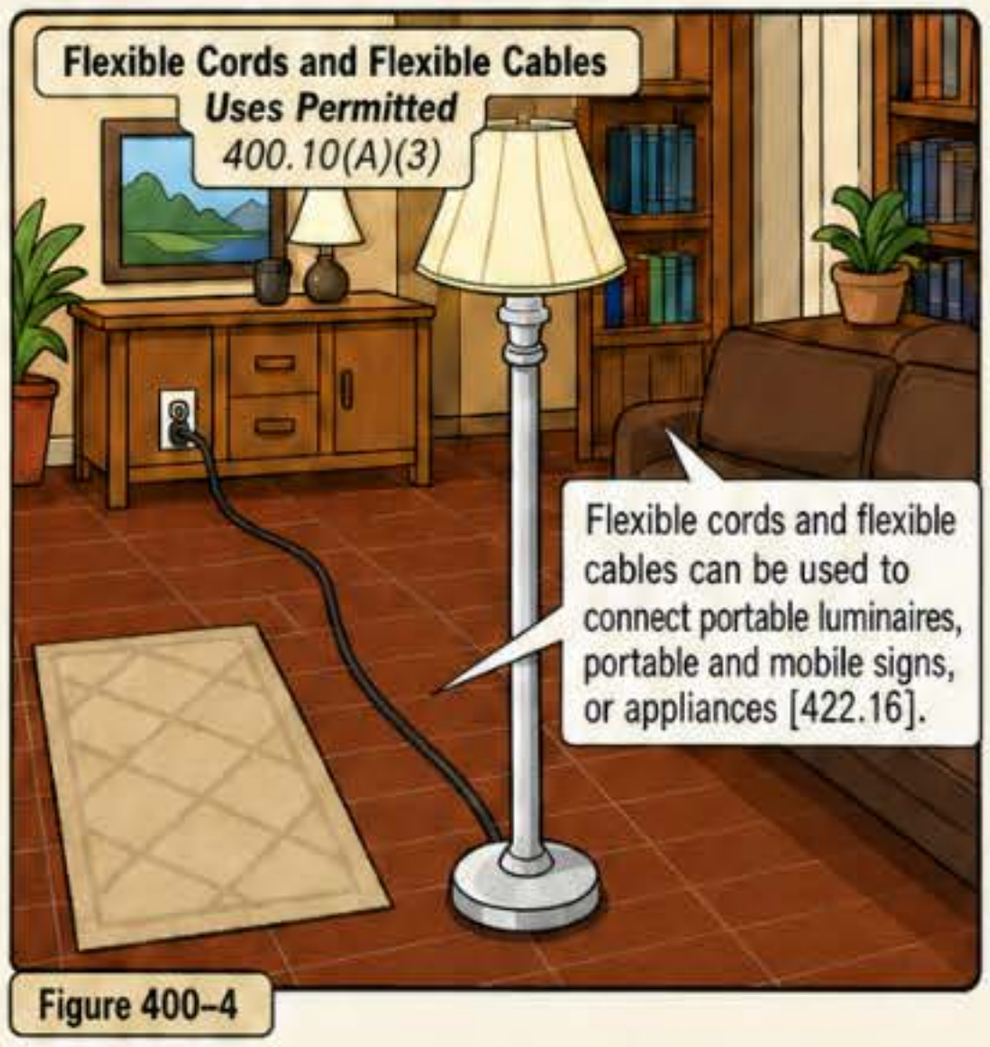


Figure 400–4

(4) Elevator cables.

(5) Wiring of cranes and hoists.

(6) Connection of utilization equipment to facilitate frequent interchange [422.16]. ♦ **Figure 400–5**

(7) Prevention of the transmission of noise or vibration [422.16].

(8) Appliances where the fastening means and mechanical connections are specifically designed to allow ready removal for maintenance and repair, and the appliance is intended or identified for flexible cord connections [422.16]. ♦ **Figure 400–6**

Author's Commentary:

- *Water heaters, furnaces, and other appliances that remain in place cannot be connected by a flexible cord unless the appliance is specifically identified for use with that type of cord [422.16].*
- *Connection of moving parts.*

— Michael Hamilton

FLEXIBLE CORDS AND FLEXIBLE CABLES 400.12

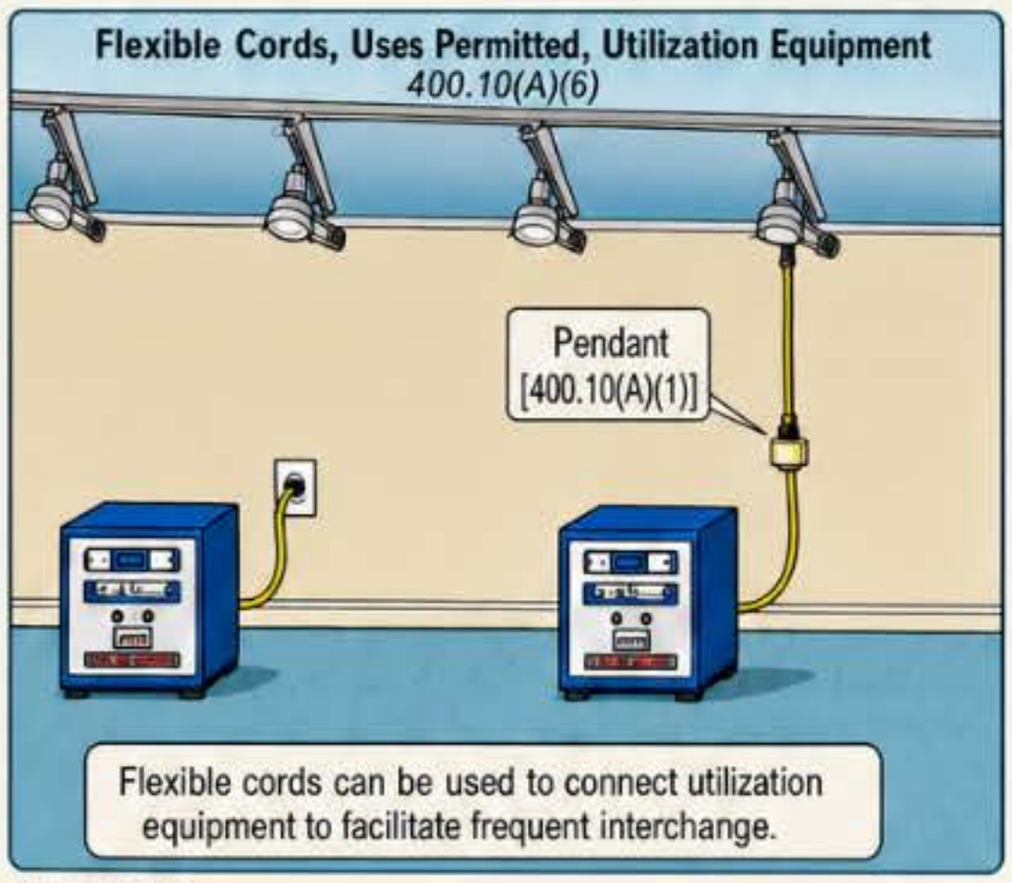


Figure 400–5

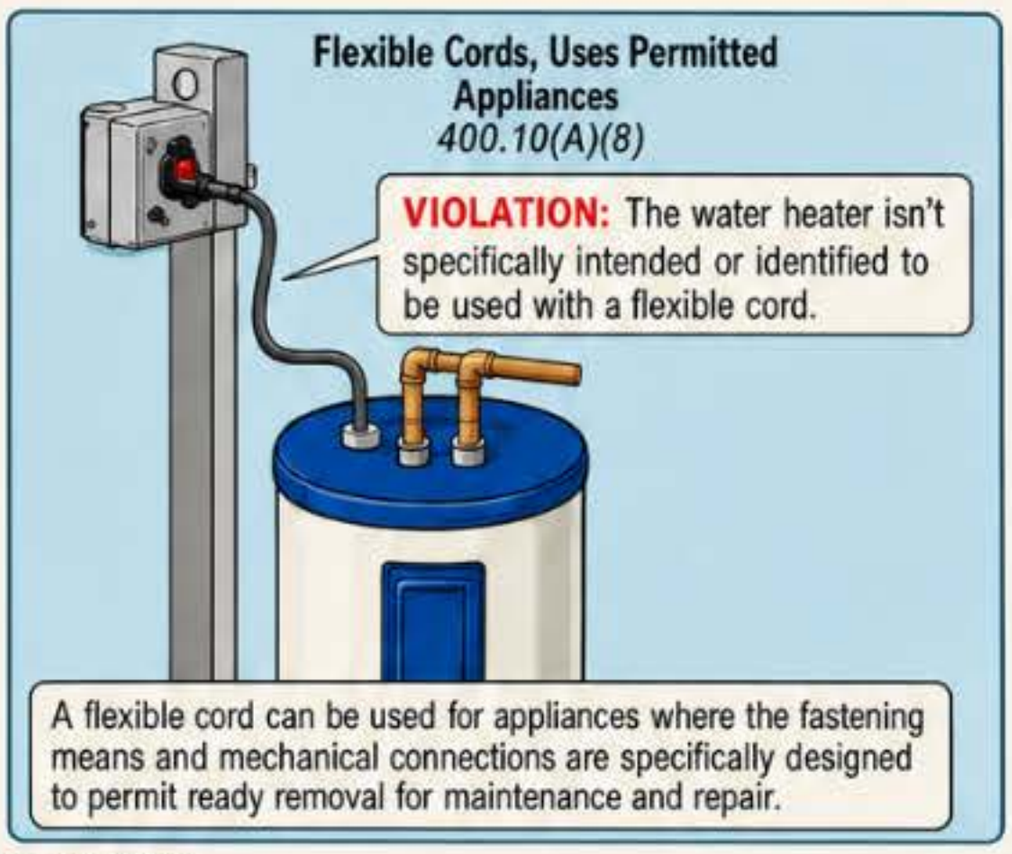


Figure 400–6

(B) Attachment Plugs. Attachment plugs are required for flexible cords used in any of the following applications: ▶ **Figure 400–7**

- ▶ Portable luminaires, portable and mobile signs, or appliances [400.10(A)(3)].
- ▶ Stationary equipment to facilitate its frequent interchange [400.10(A)(6) and 422.16].
- ▶ Appliances specifically designed to permit ready removal for maintenance and repair and identified for flexible cord connection [400.10(A)(8)].

400.12 Uses Not Permitted

Unless specifically permitted in 400.10, flexible cords, flexible cables, cord sets (extension cords), and power-supply cords are not permitted for the following:

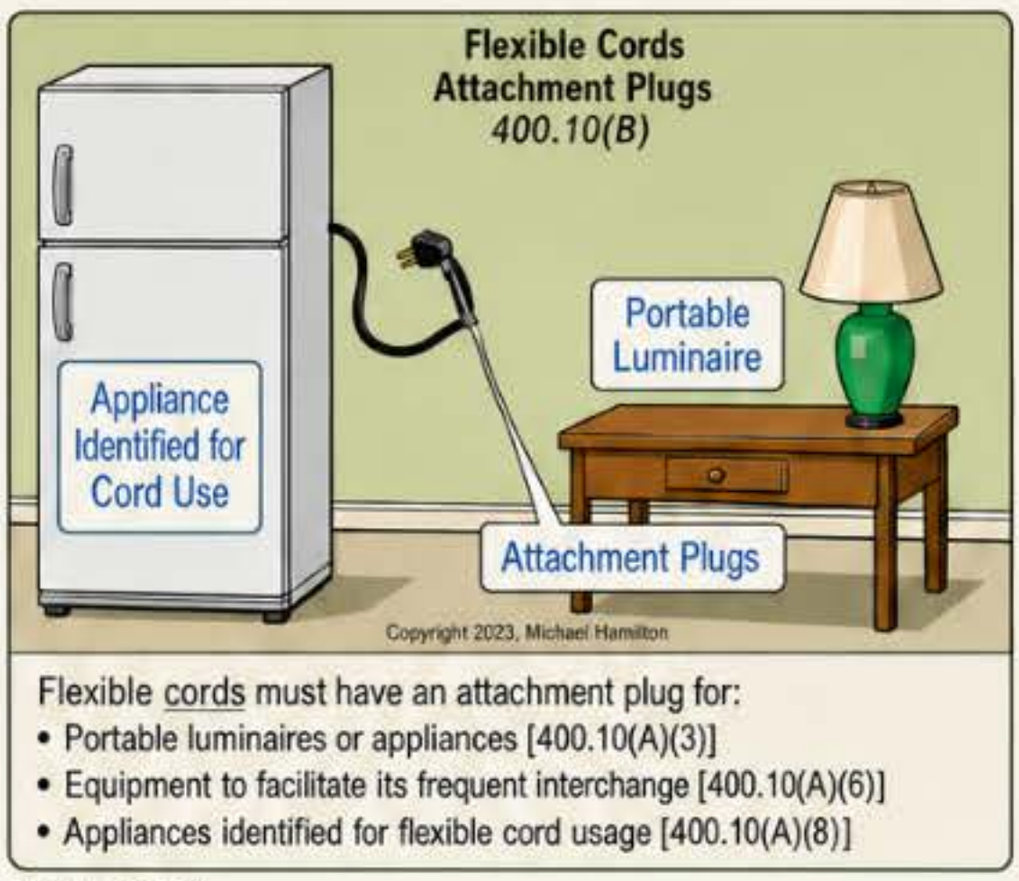


Figure 400–7

(1) Flexible cords, flexible cables, cord sets (extension cords), and power-supply cords are not permitted to be a substitute for the fixed wiring. ▶ **Figure 400–8**

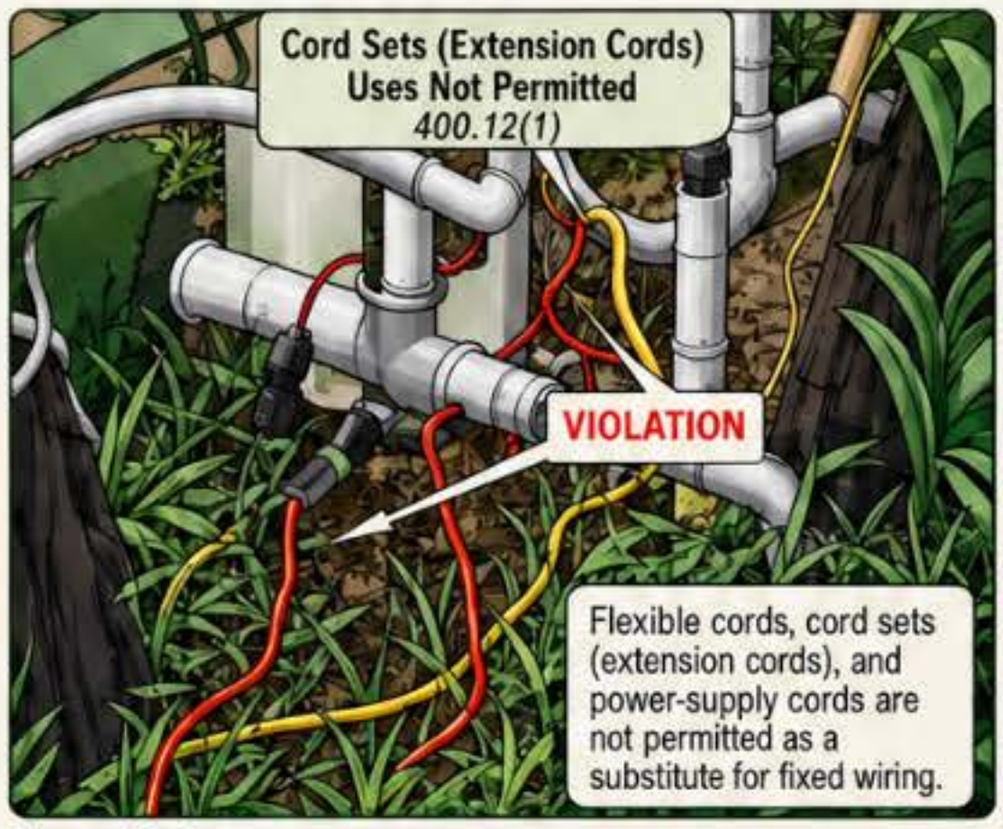


Figure 400–8

(2) Flexible cords, flexible cables, cord sets (extension cords), and power-supply cords must not be run through holes in walls, ceilings, or floors. ▶ **Figure 400–9** and ▶ **Figure 400–10**

(3) Flexible cords, flexible cables, cord sets (extension cords), and power-supply cords are not permitted to be run through doorways, windows, or similar openings.

(4) Flexible cords, flexible cables, cord sets (extension cords), and power-supply cords must not be attached to building surfaces.

Author's Commentary:
While flexible cords and cord sets are extremely useful, they cannot replace permanent wiring. Overreliance on extension cords can create hazards.
Install permanent wiring when a connection is needed continuously or long-term.

— Michael Hamilton

400.14 | Flexible Cords and Flexible Cables

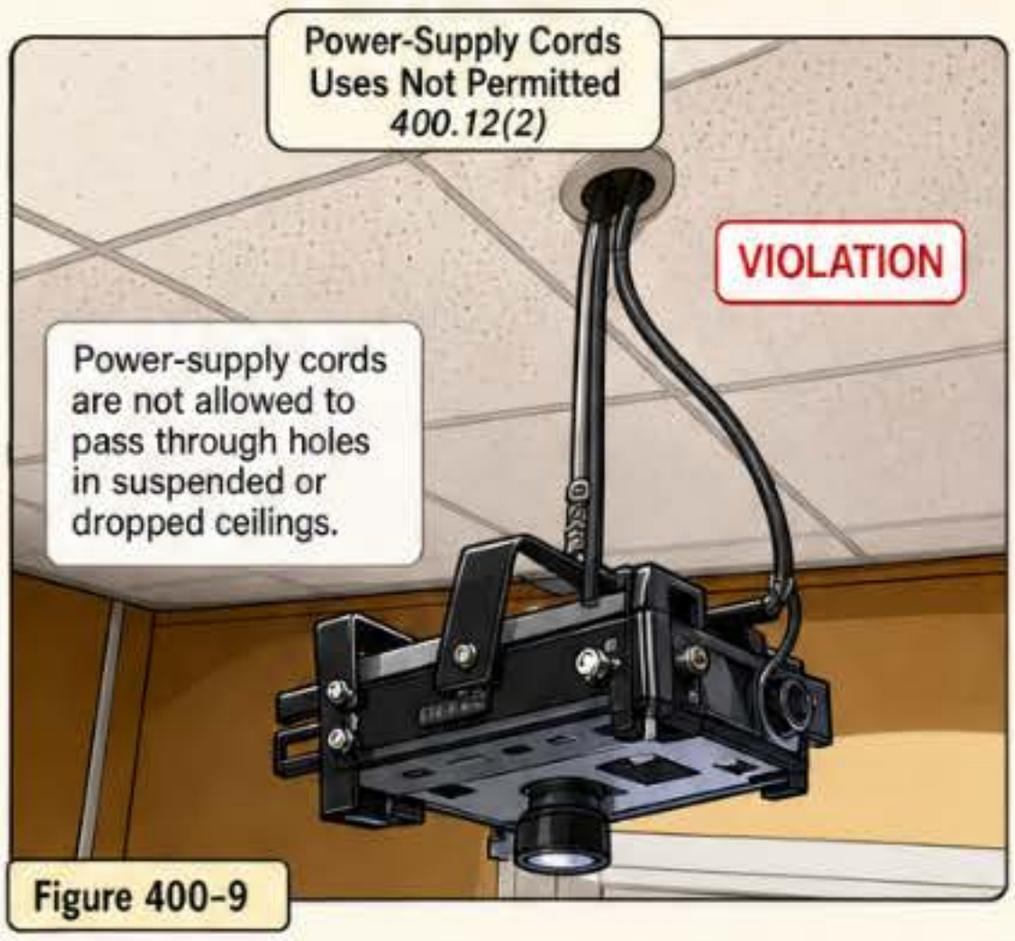


Figure 400-9

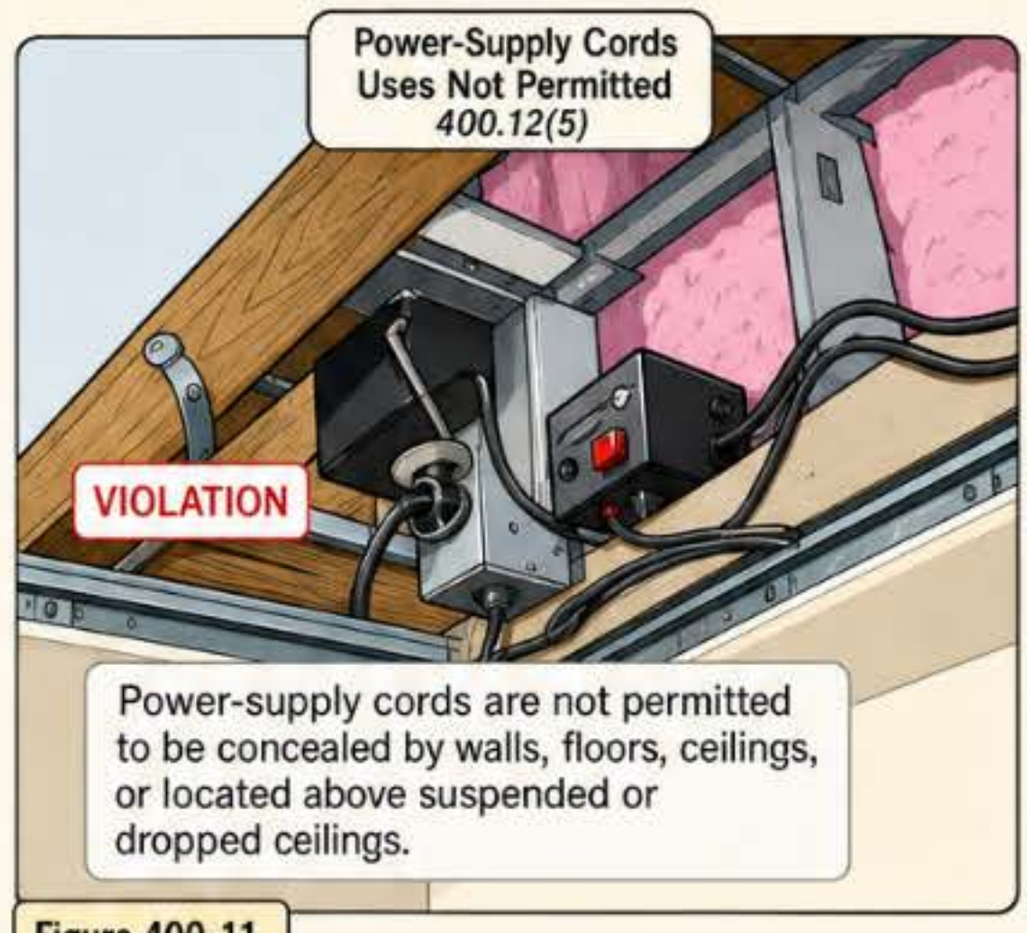


Figure 400-11

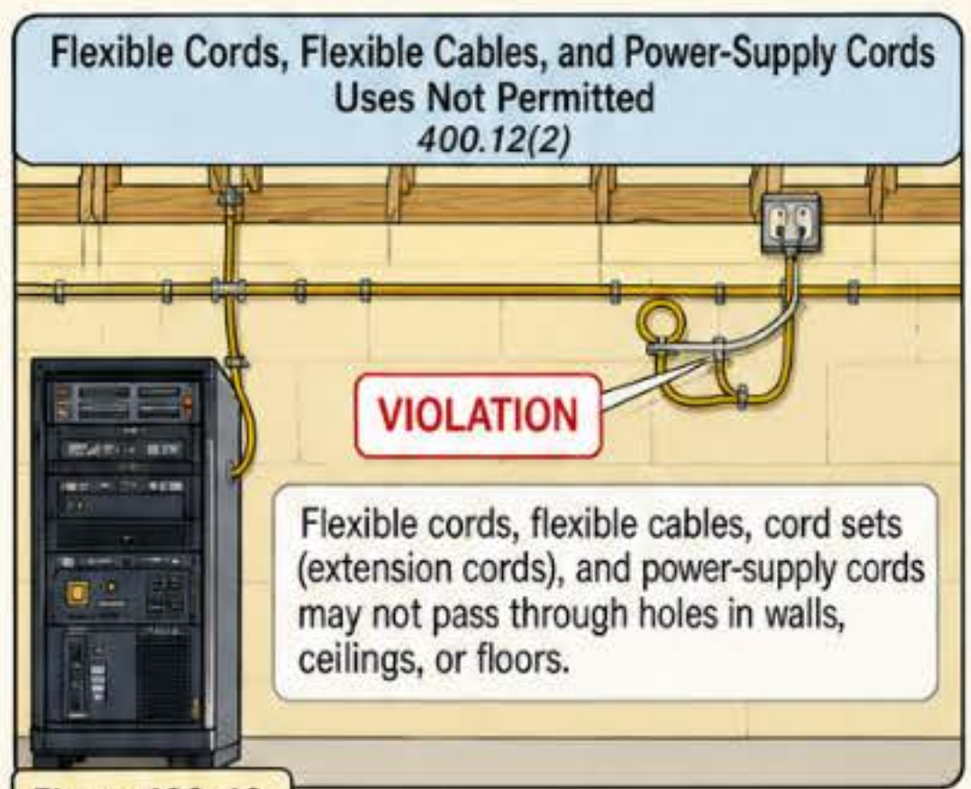


Figure 400-10

(5) Flexible cords, flexible cables, cord sets (extension cords), and power-supply cords are not permitted to be concealed by walls, floors, or ceilings, or located above suspended or dropped ceilings. • **Figure 400-11**

Ex to (5): Flexible cords, flexible cables, and power-supply cords are permitted if contained within an enclosure for use in other spaces used for environmental air as permitted by [300.22(C)(3)].

(6) *Flexible cords, flexible cord sets (extension cords), and power-supply cords must not be installed in raceways, except as permitted by 400.17 for industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons will service the installation.*

(7) *Flexible cords, flexible cord sets (extension cords), and power-supply cords are not permitted where they are subject to physical damage.*

400.14 Pull at Joints and Terminals

Flexible cords must be installed so tension will not be transmitted to the conductor terminals. • **Figure 400-12**

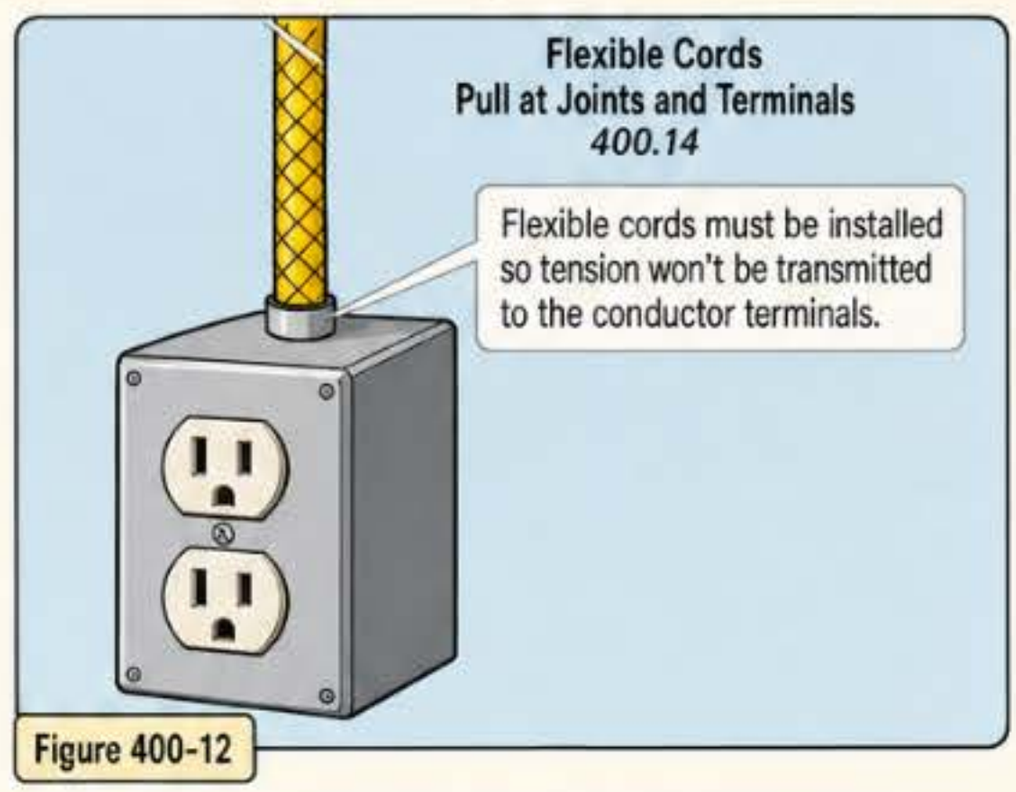


Figure 400-12

Note: This can be accomplished by knotting the cord, winding it with tape, or by using support or strain-relief fittings. • **Figure 400-13**

400.17 Protection from Damage

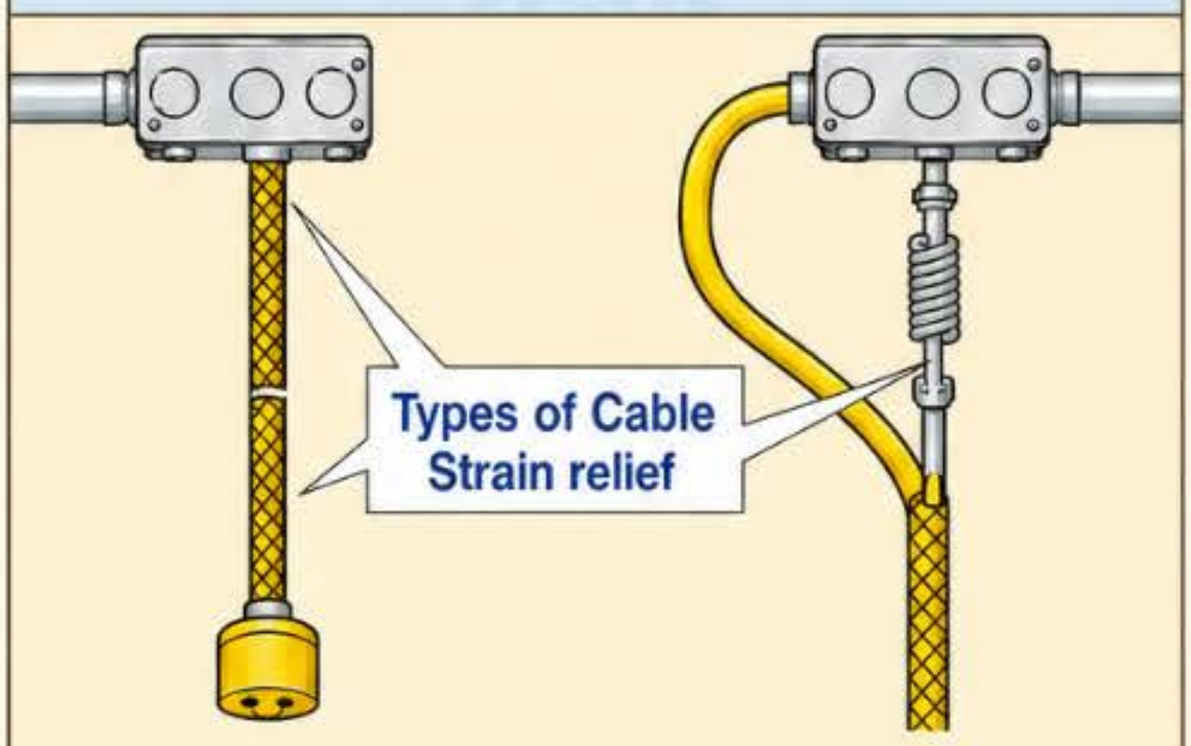
Flexible cords must be protected by bushings or fittings where passing through holes in covers, outlet boxes, or similar enclosures.

Author's Commentary:

Flexible cords are convenient, but the Code strictly limits how and where they can be used. The intent behind these rules is simple: keep people safe, prevent electrical hazards, and ensure installations remain reliable. When in doubt, choose a permanent wiring method instead of relying on cords.

— Michael Hamilton

Flexible Cords, Pull at Joints and Terminals
400.14 Note



Tension relief can be accomplished by knotting the cord, winding the flexible cord with tape, or by using support or strain-relief fittings.

Figure 400-13

Notes

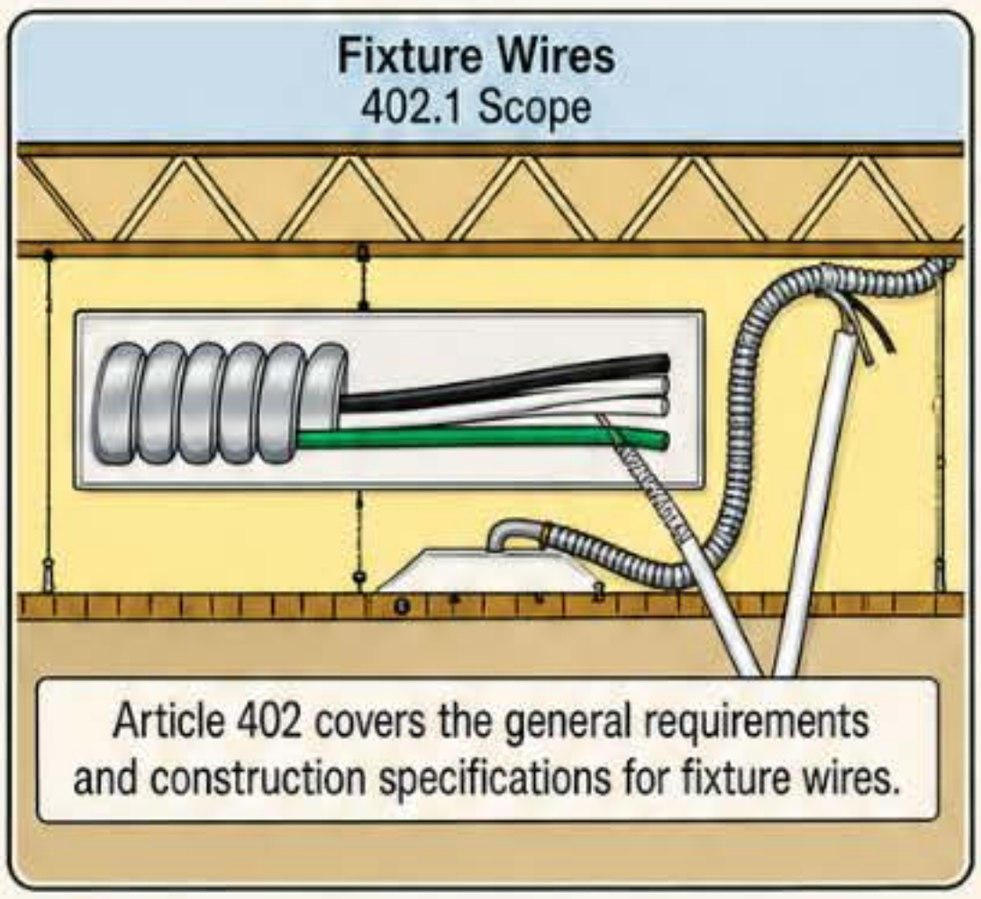
ARTICLE 402 FIXTURE WIRES

Introduction to Article 402—Fixture Wires

This article explains the overall requirements and construction rules for fixture wires. One important limitation is that fixture wires cannot be smaller than 18 AWG. Another key point is that they must be listed with a type listed in Table 402.3. Understanding these points helps determine the total quantity or "ampacity" for fixture wires as shown in Table 402.5.

402.1 Scope

Article 402 outlines the general requirements and construction specifications that apply to fixture wires. ■ **Figure 402-1**



▶ **Figure 402-1**

402.2 Other Articles

Fixture wires must comply with this article and also with the applicable provisions of other articles of this *Code*.

402.3 Types

Fixture wires must be of a type contained in Table 402.3.

402.5 Ampacity of Fixture Wires

The ampacity of fixture wires is as follows:

Table 402.5 Ampacity for Fixture Wires

Wire AWG	Wire Ampacity
18	6A
16	8A
14	17A
12	23A
10	28A

402.6 Minimum Size

Fixture wires are not permitted to be smaller than 18 AWG.

402.7 Raceway Size

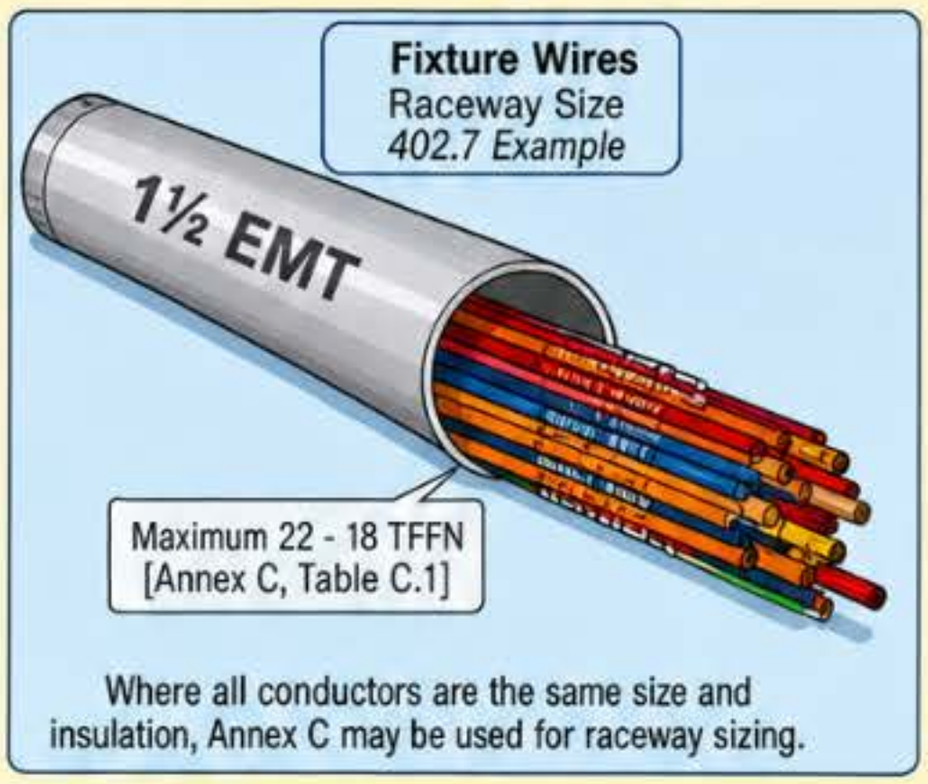
Raceways must be sized so that the installation and removal of conductors can be accomplished without causing damage. In installations where fixture wires are allowed, the conductors in a single raceway cannot exceed the fill limit given in Chapter 9, Table 1.

Author's Commentary:
Even when all conductors in a raceway are identical in size and insulation, the number of allowable conductors can be found in Annex C for that raceway type.
— Michael Hamilton

▶ Example

Question: *How many 18 TFFN conductors can be installed in trade size 1½ electrical metallic tubing?* **▶ Figure 402-2**

(a) 22 conductors *(b) 24 conductors*
(c) 26 conductors *(d) 28 conductors*



▶ Figure 402-2

Answer: *(a) 22 conductors [Annex C, Table C.1]*

Author's Commentary:
See 300.17 for examples that explain how to determine raceway size when the conductors are not all the same.
— Michael Hamilton

402.8 Neutral Conductor

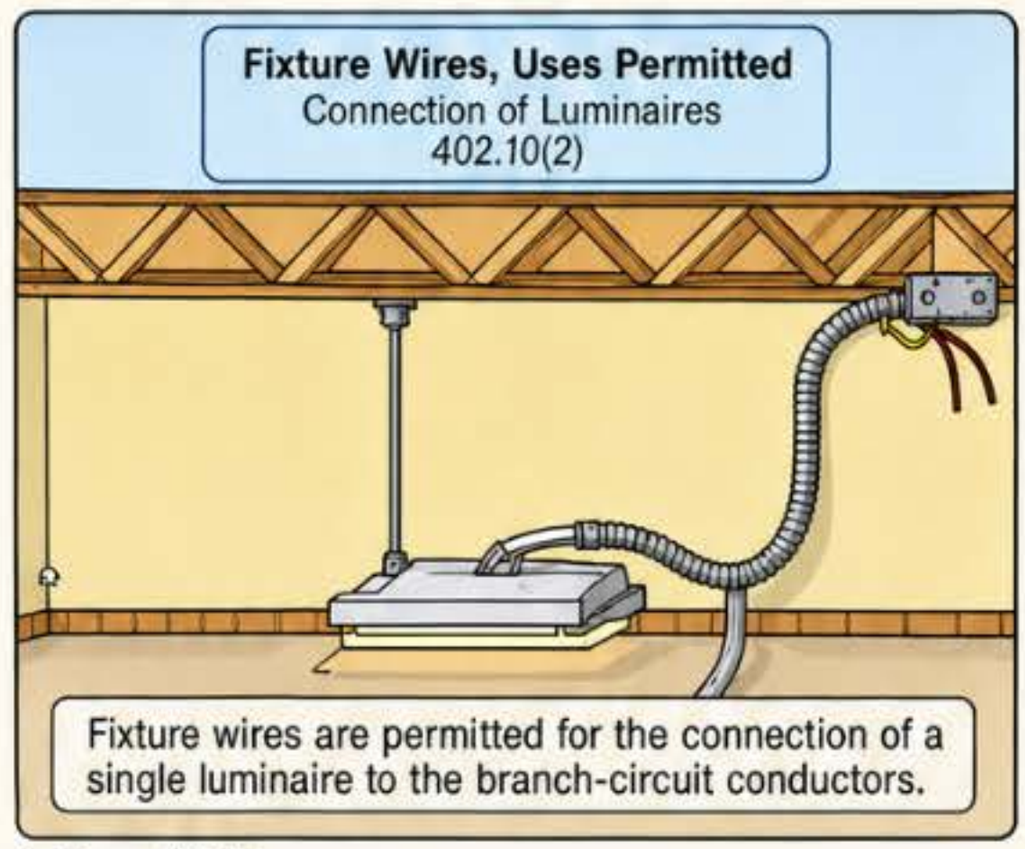
The fixture wire that is used as the grounded (neutral) conductor must be identified by continuous white stripes.

402.10 Uses Permitted

Fixture wires are allowed:

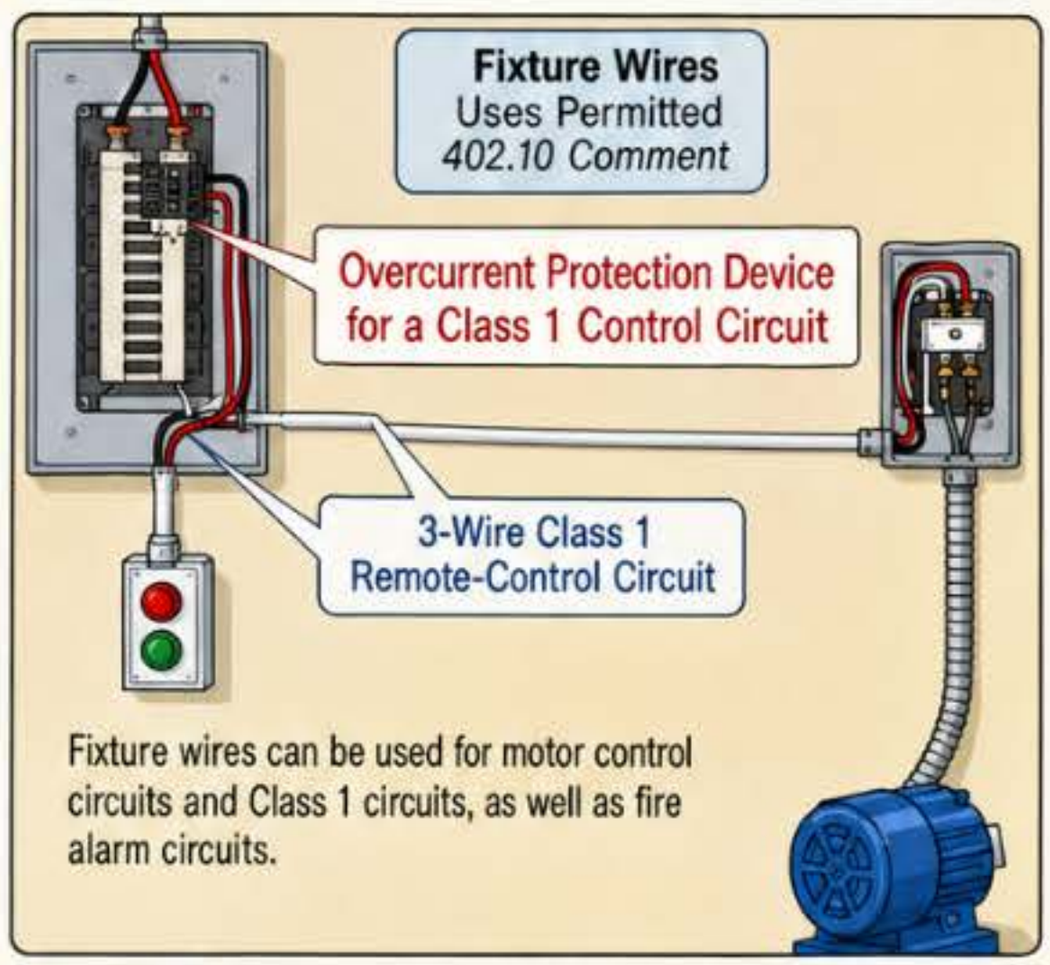
(1) For installation in luminaires and in similar equipment when enclosed or protected, and not subject to bending or twisting in normal use, or

(2) For connecting luminaires to the branch-circuit conductors that supply the luminaires. **▶ Figure 402-3**



▶ Figure 402-3

Author's Commentary:
Fixture wires can also be used for elevators and escalators (620.11(C)), Class 1 control and power-limited circuits (725.49(B)), and nonpower-limited fire alarm circuits (760.49(B)). **▶ Figure 402-4**
— Michael Hamilton



▶ Figure 402-4

Author's Commentary:

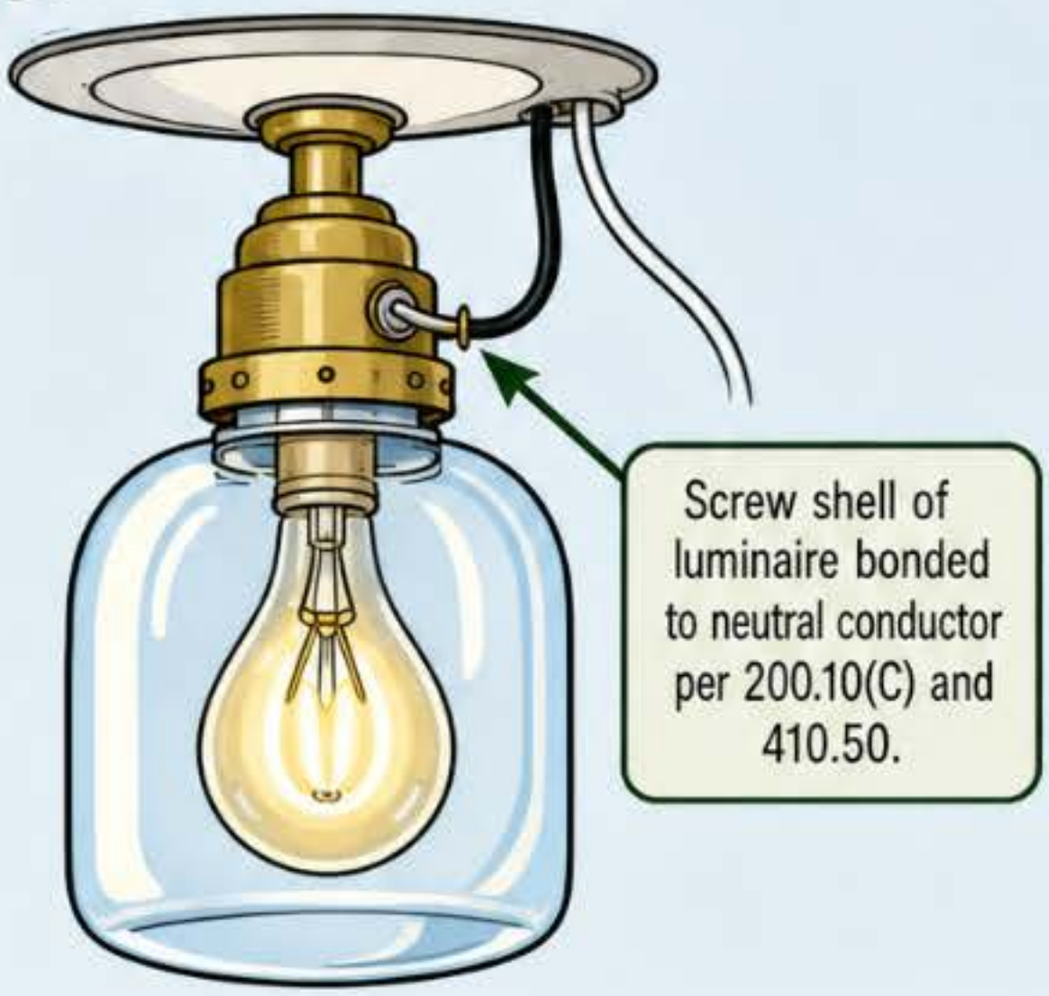
- The purpose of this rule is to avoid electric shock by requiring the screw base of a luminaire to be bonded to the neutral conductor per 200.10(C) and 410.50.

— *Michael Hamilton*

402.12 Uses Not Permitted

Fixture wires are not allowed for branch-circuit wiring, except where specifically permitted by this *Code*.

Key Concept



Quick Takeaway

Fixture wires cannot be used for branch-circuit wiring, except as allowed elsewhere in this *Code*.

Notes

ARTICLE 404 SWITCHES

Introduction to Article 404—Switches

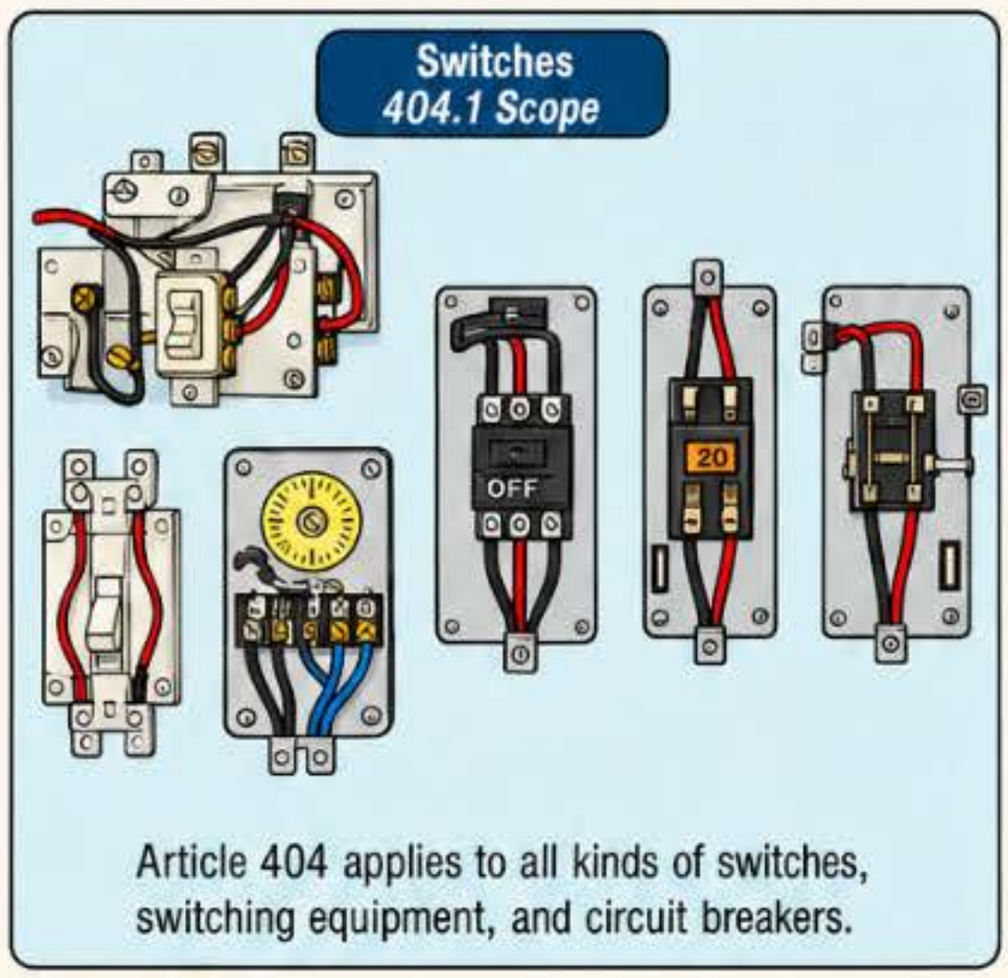
This article explains the rules for a wide range of switches. It covers snap (toggle) switches, dimmer controls, fan switches, knife switches, circuit breakers, and automatic devices such as time clocks and timers.

Part I. Installation

404.1 Scope

Article 404 sets the requirements for every type of switch, switching device, and circuit breaker.

▶ **Figure 404–1**

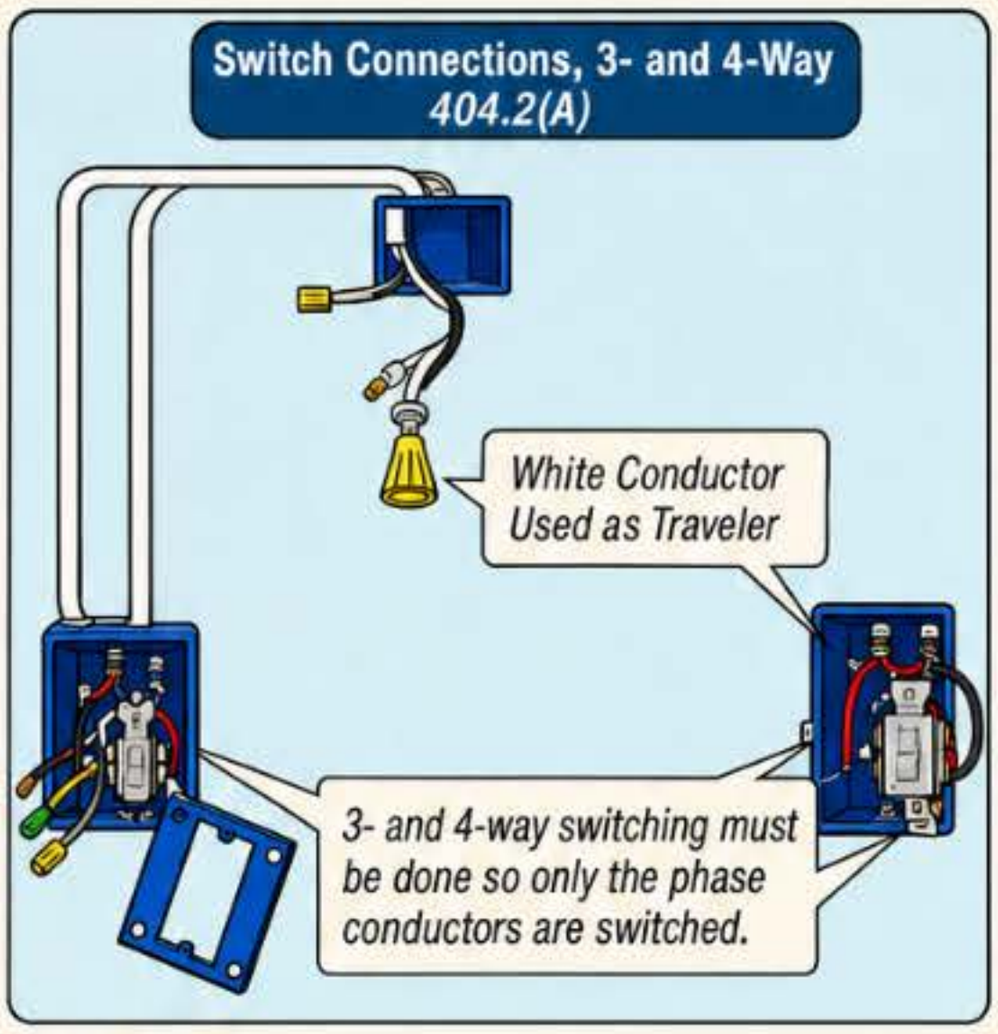


▶ **Figure 404–1**

404.2 Switch Connections

(A) Three-Way and Four-Way Switches. For 3-way and 4-way switching, it is required that *only* the phase conductors be the ones switched.

▶ **Figure 404–2**



▶ **Figure 404–2**

(B) Switching Neutral Conductors. Neutral conductors must not be interrupted.

> ***Author's Commentary:***
> *A permanently identified white conductor inside a cable may be used as a phase conductor for switching functions [2023 NEC 200.7(C)(1)].*
> — *Michael Hamilton*

(C) Switches Controlling Lighting Loads. Light switches used in branch circuits with a *neutral conductor must be suitable for use in all locations such as bathrooms, halls, stairways, and living spaces, as defined in the building code.*

▶ **Figure 404–3**

404.2 Switches

Scan this QR code for a video of Michael Hamilton explaining this topic. It's a sample from the videos *that accompany this textbook.*

Switch Connections, Switches Controlling Lighting Loads
404.2(C)

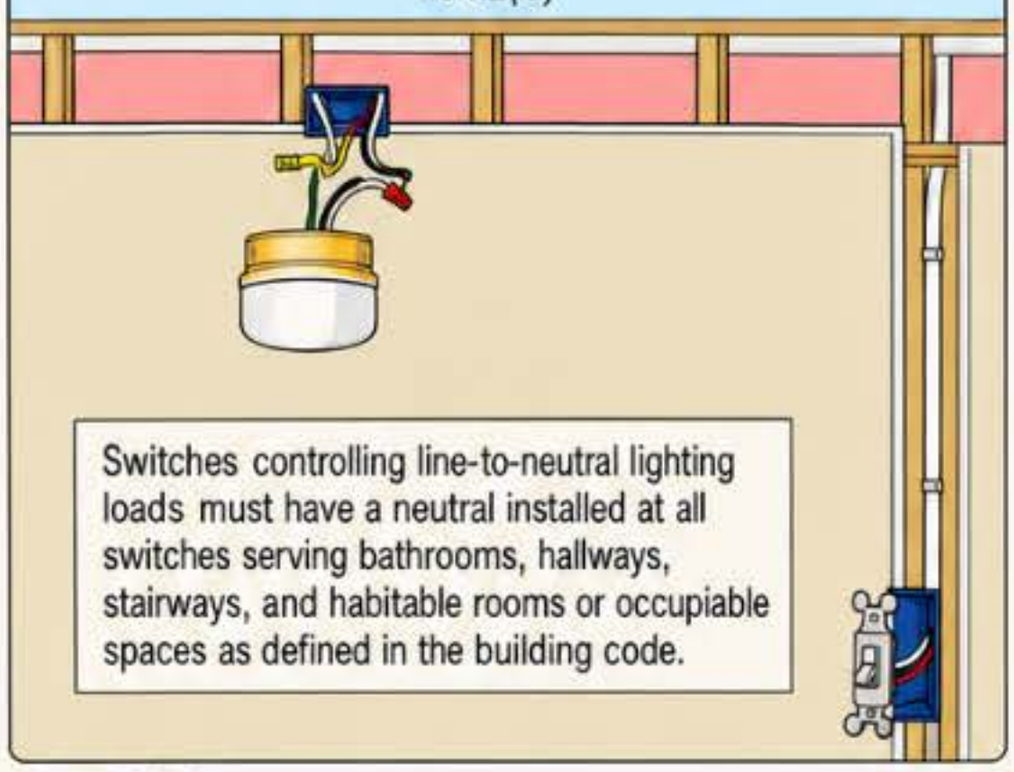


Figure 404–3

Author's Commentary:
Under Article 100, a "habitable room" refers to any space in a building used for living, sleeping, eating, or cooking. Bathrooms, toilet rooms, closets, hallways, storage or utility areas, and similar spaces are specifically excluded."
— Michael Hamilton

Habitable Room
Article 100 Definition

Figure 404–4

Where 3-way and 4-way switches are visible in a room, only one of the switches requires a neutral conductor.

Figure 404–5

3- and 4-Way Switches Controlling Lighting Loads
Habitable Rooms or Occupiable Spaces
404.2(C)

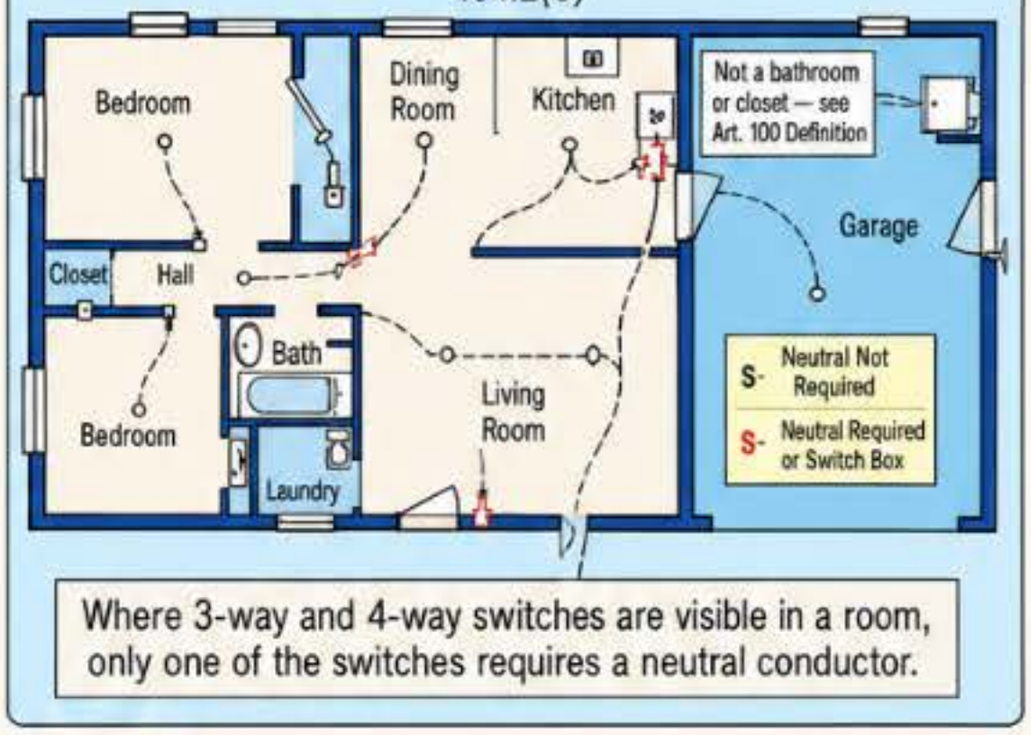


Figure 404–5

A neutral conductor is not required to be installed at lighting switch locations under any of the following conditions:

(1) Where conductors enter the box enclosing the switch through a raceway with enough cross-sectional area to accommodate a neutral conductor. **Figure 404–6**

Switch Connections, Neutral at Switches Controlling Lighting Loads, Raceways
404.2(C)(1)

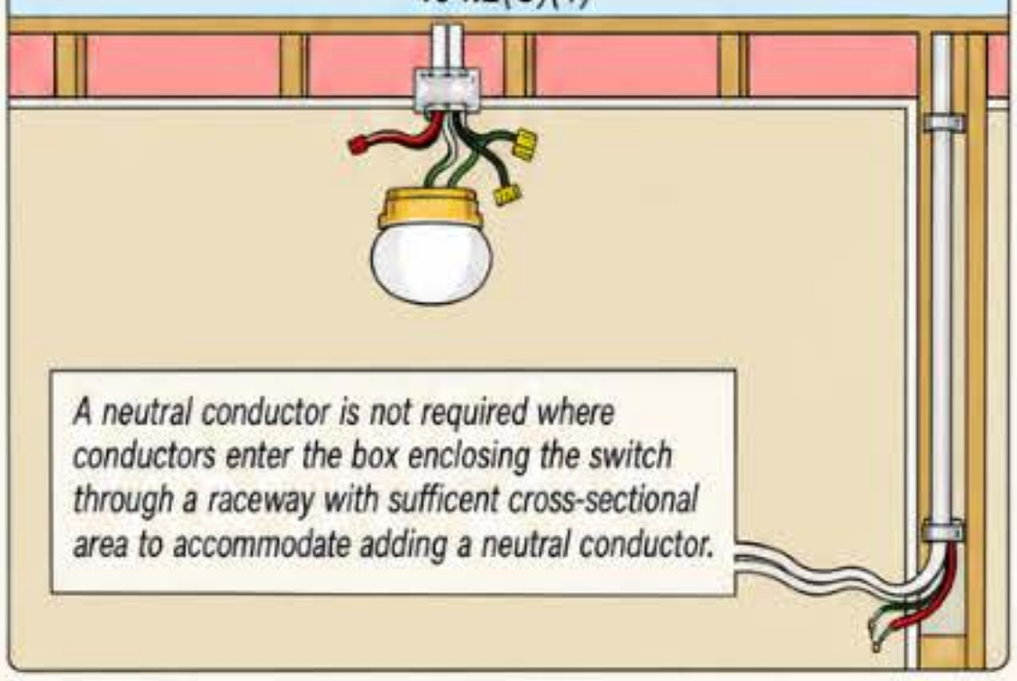


Figure 404–6

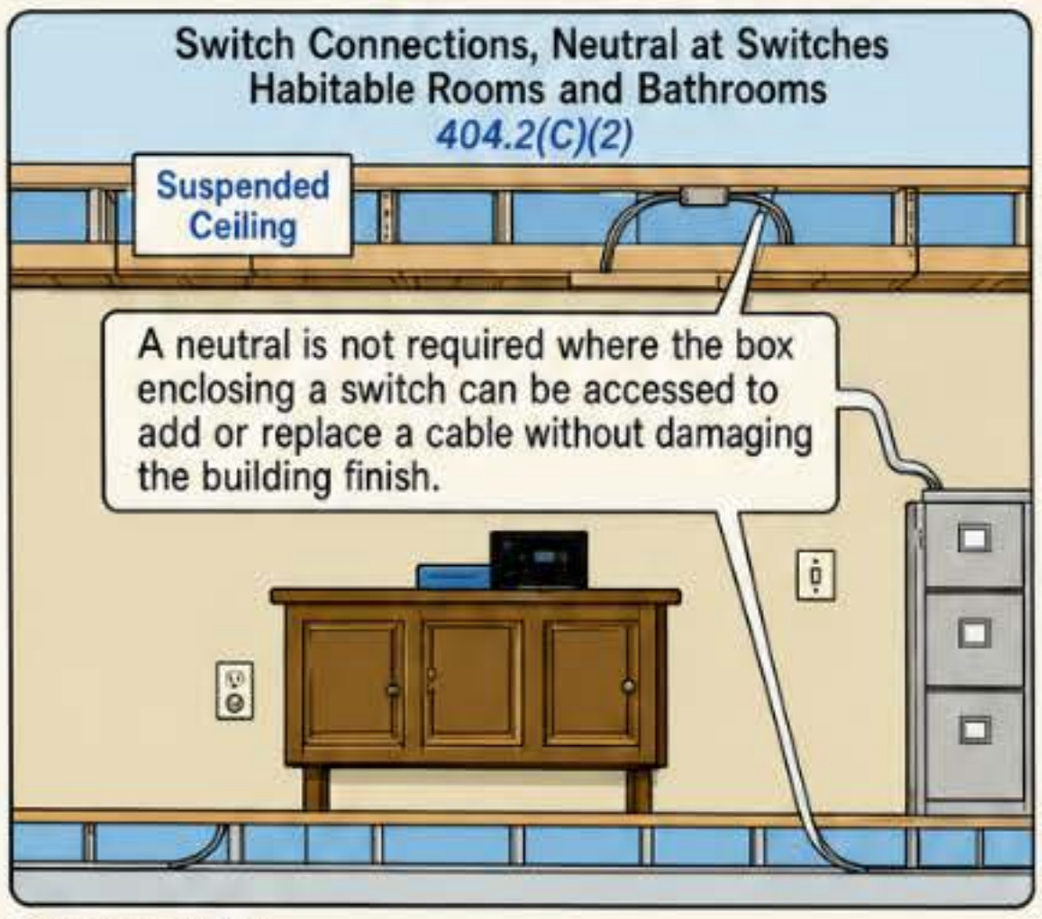
(2) Where the box enclosing a switch can be accessed to add or replace a cable without damaging the building finish. **Figure 404–7**

(3) Where snap switches with integral enclosures comply with 300.15(E).

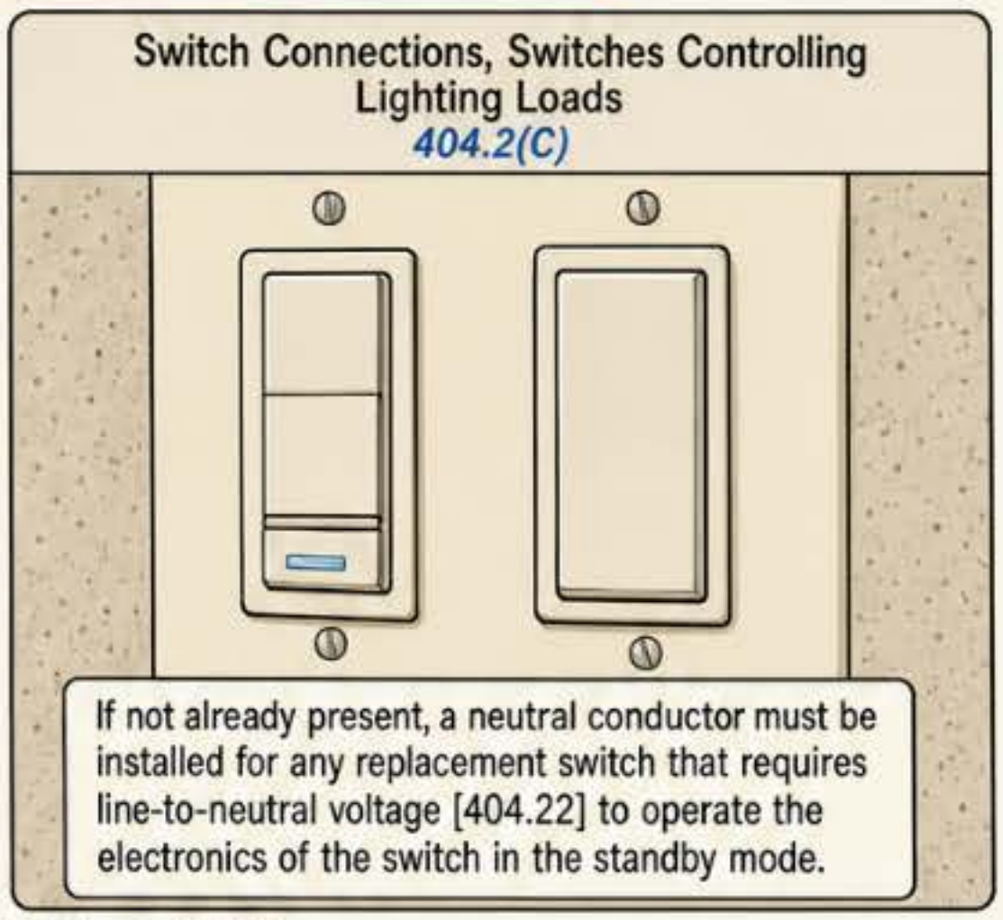
(4) Where the lighting is controlled by automatic means.

(5) Where switches control receptacles. **Figure 404–8**

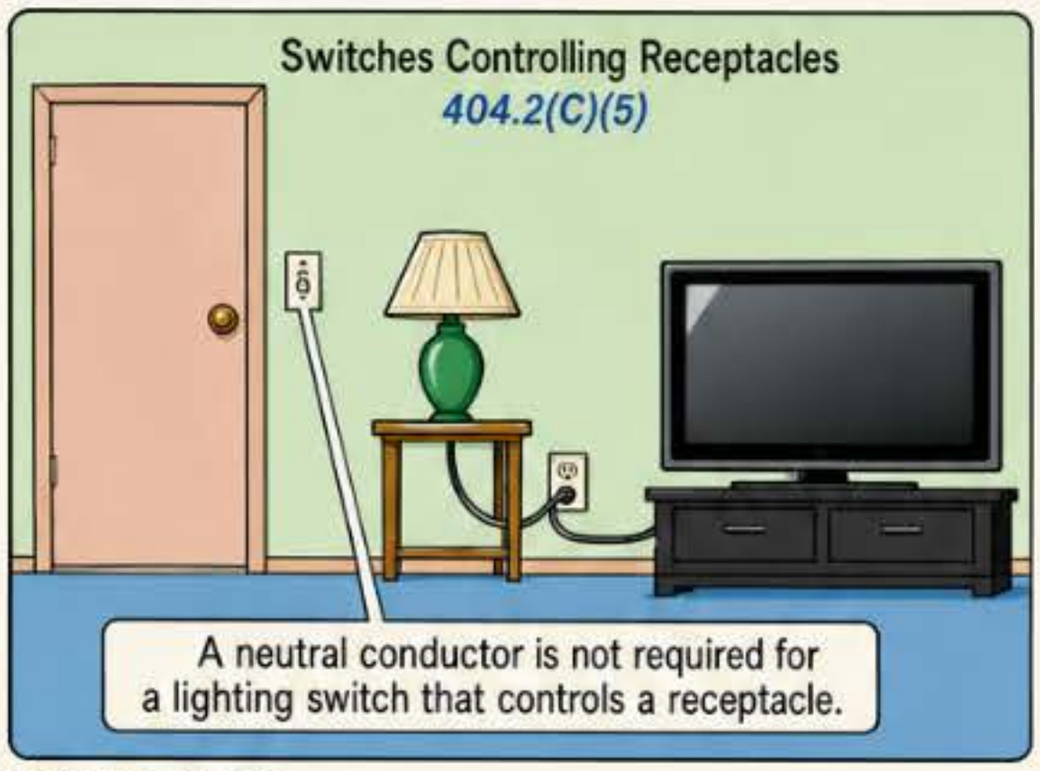
SWITCHES | 404.4



▶ Figure 404-7



▶ Figure 404-9



▶ Figure 404-8

If not already present, a neutral conductor must be installed for any replacement switch that requires line-to-neutral voltage [404.22] to operate the electronics of the switch in the standby mode. • ***Figure 404-9***

Ex: *A neutral conductor is not required for replacement switches installed in locations wired prior to the adoption of 404.2(C) where the neutral conductor cannot be extended without removing finish materials. The number of electronic lighting control switches without a neutral conductor on a branch circuit are not permitted to exceed five switches, and the number connected to any feeder are not permitted to exceed 25 switches.*

Author's Commentary:

The purpose of the neutral conductor at a switch is to complete a circuit path for electronic lighting control devices that require a neutral conductor.

— Michael Hamilton

404.3 Switch Enclosures

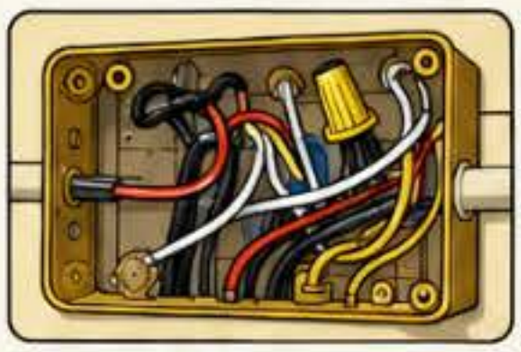
(A) General. Switches and circuit breakers must be mounted in an enclosure listed for the intended use.

(B) Used as a Raceway, Taps, or Splices. Switch or circuit-breaker enclosures can contain splices and taps if they are not used to route conductors through any cross-sectional area more than 75 percent. For any area above 75 percent, conductors may pass through the enclosure only if the conductors occupy no more than 40 percent of that area in accordance with 312.8. • ***Figure 404-10***

404.4 Damp or Wet Locations

(A) Surface-Mounted Switches or Circuit Breakers. *Surface-mounted switches and circuit breakers in a damp or wet location must be installed in a weatherproof enclosure.* • ***Figure 404-11***

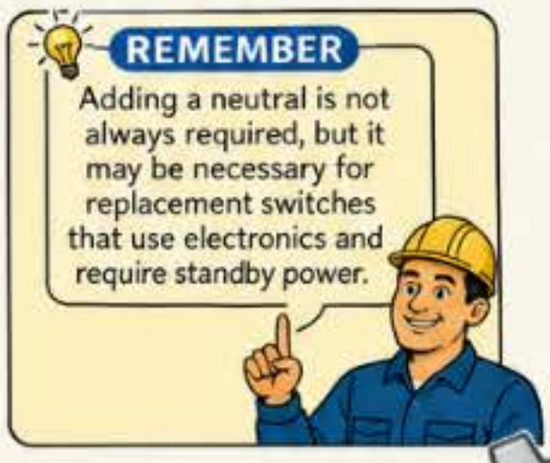
(B) Flush-Mounted Switches or Circuit Breakers. *A flush-mounted switch or circuit breaker in a damp or wet location must have a weatherproof cover.* • ***Figure 404-12***



▶ Figure 404-10

▶ Figure 404-11

▶ Figure 404-12



404.7 | Switches

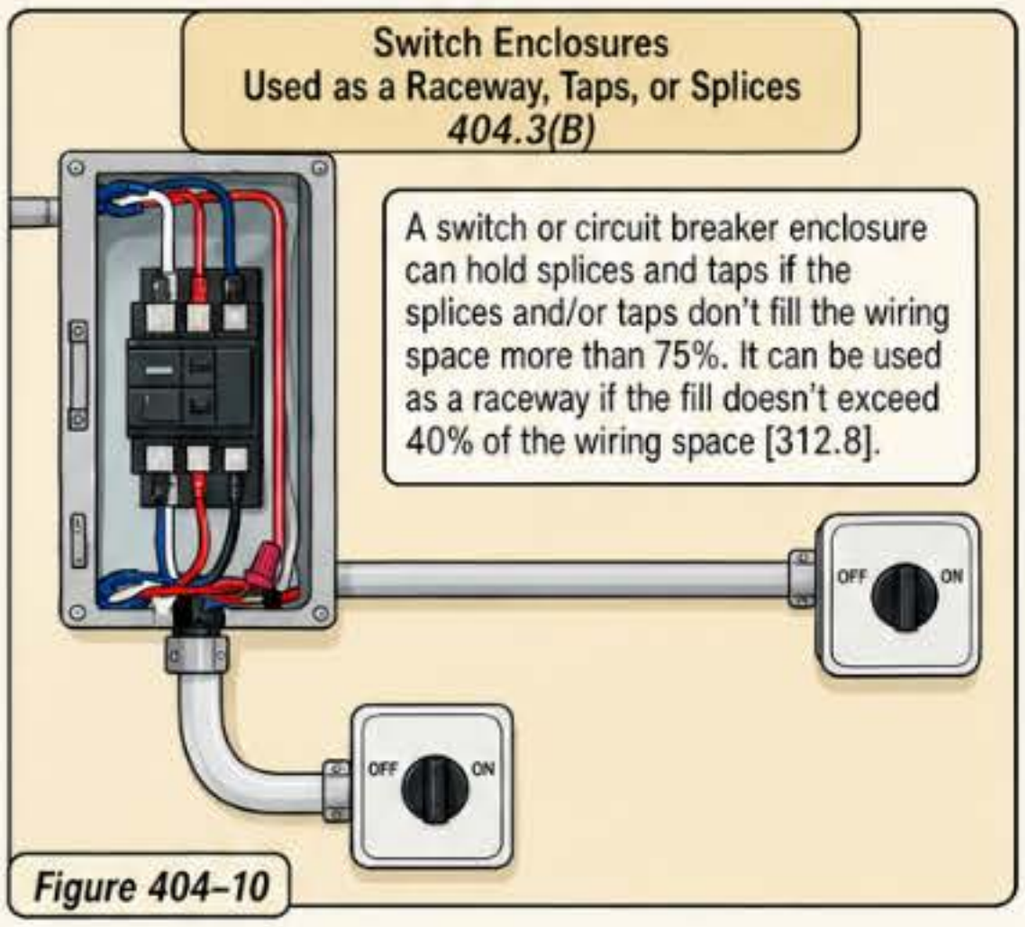


Figure 404–10

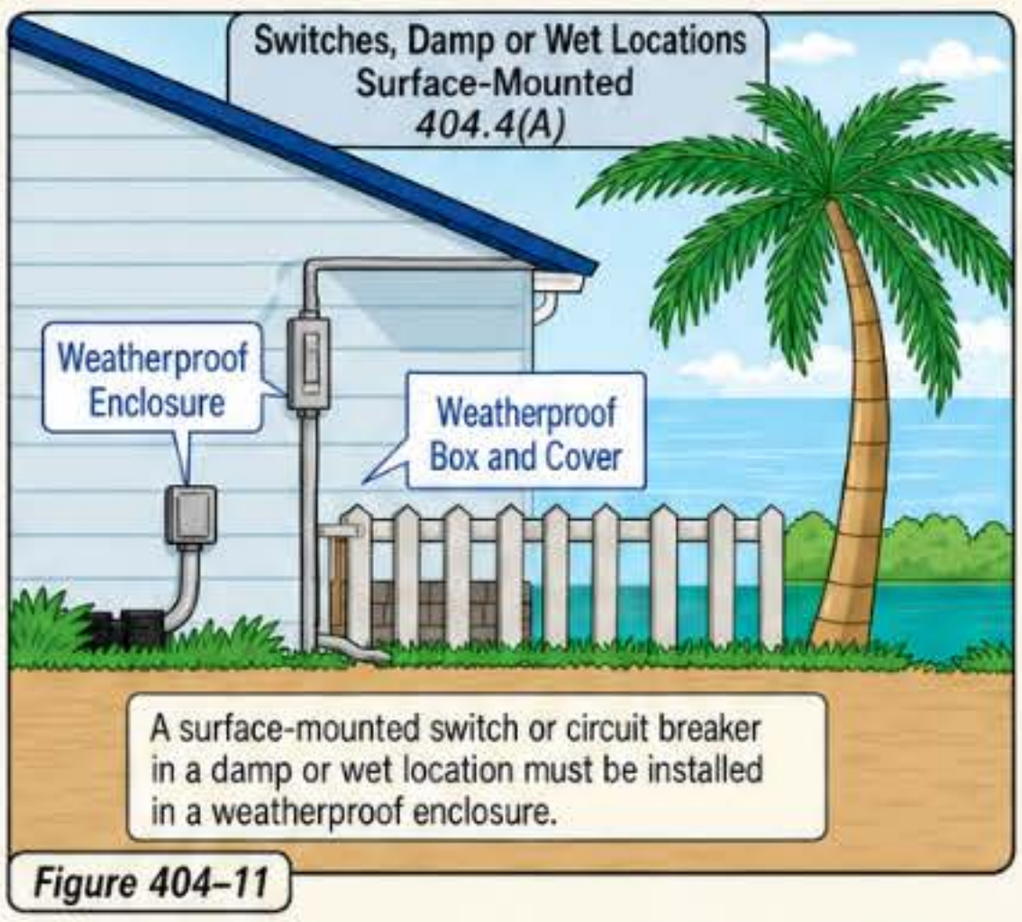


Figure 404–11

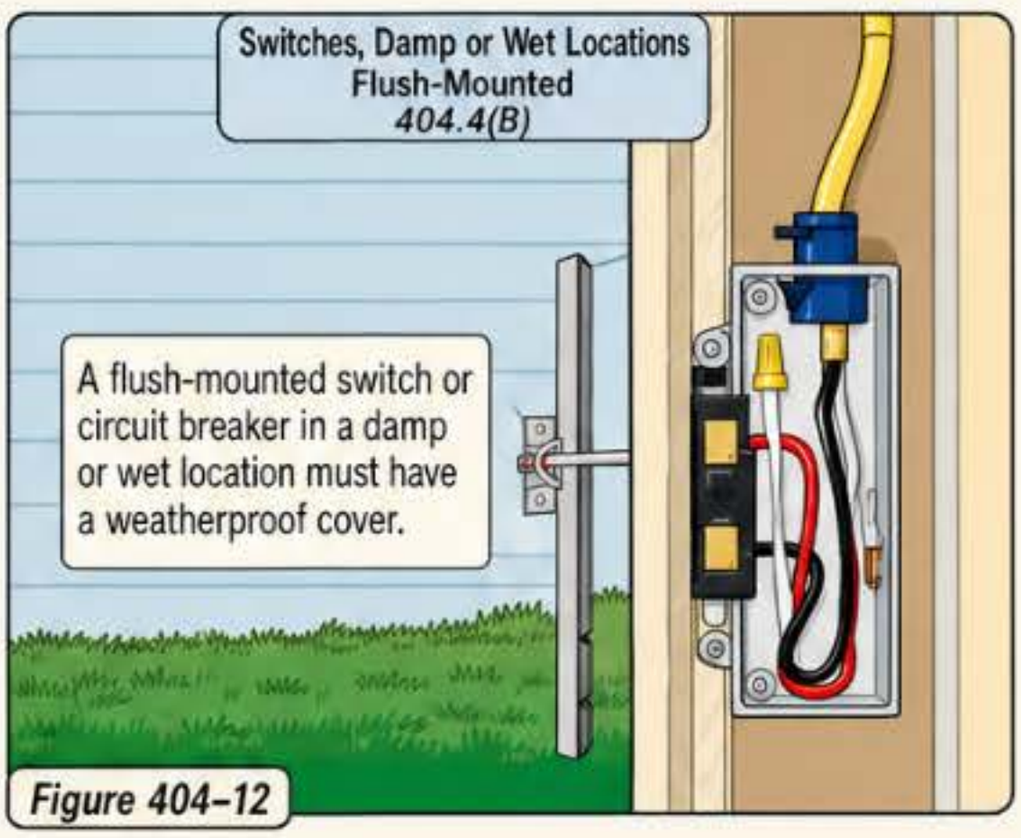


Figure 404–12

(C) Switches Within Tub or Shower Spaces. Switches must not be installed within tub or shower spaces unless installed as part of a listed tub or shower assembly. ▶ **Figure 404–13**

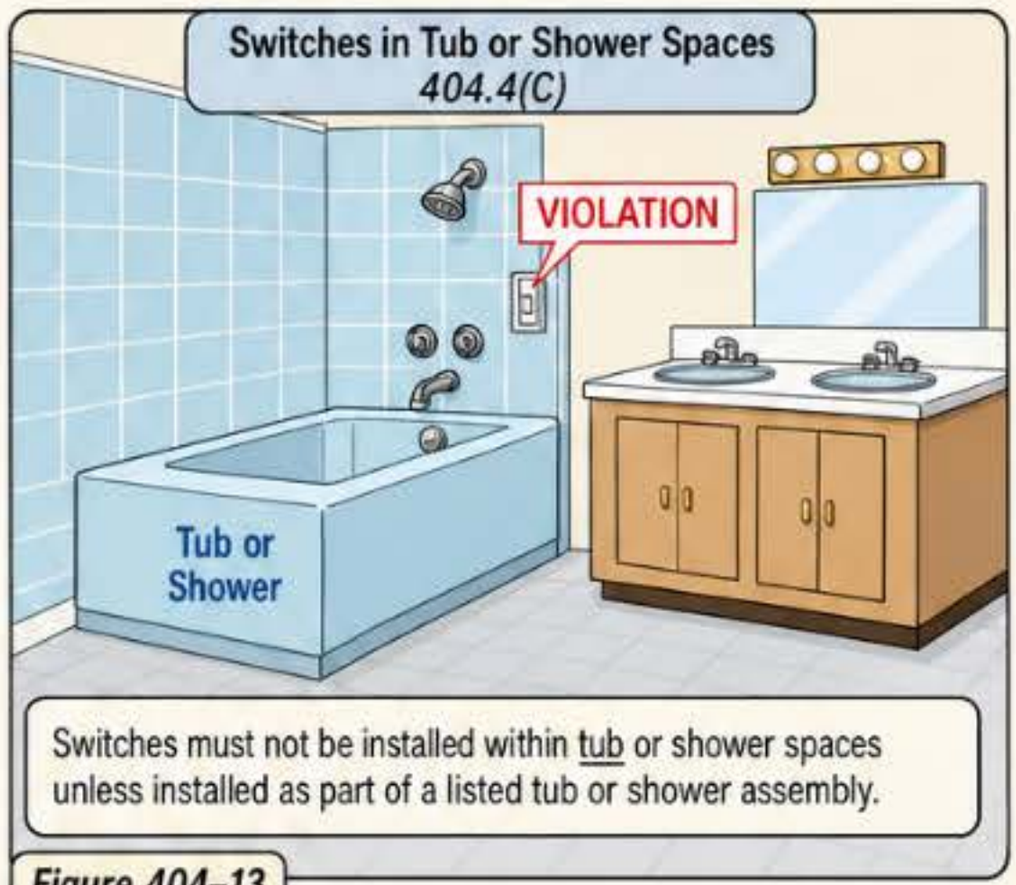


Figure 404–13

404.7 Indicating

Switches and circuit breakers must be marked, in a location that is visible when accessing the external operating means, to indicate whether they are in the "on" or "off" position.

Author's Commentary:

This is typically accomplished by marking on the toggle of *the switch itself or by indicative labeling. If you find a switch not so marked, chances are it is a 3-way or 4-way switch which can be on or off in either the up or down position.*

— Michael Hamilton

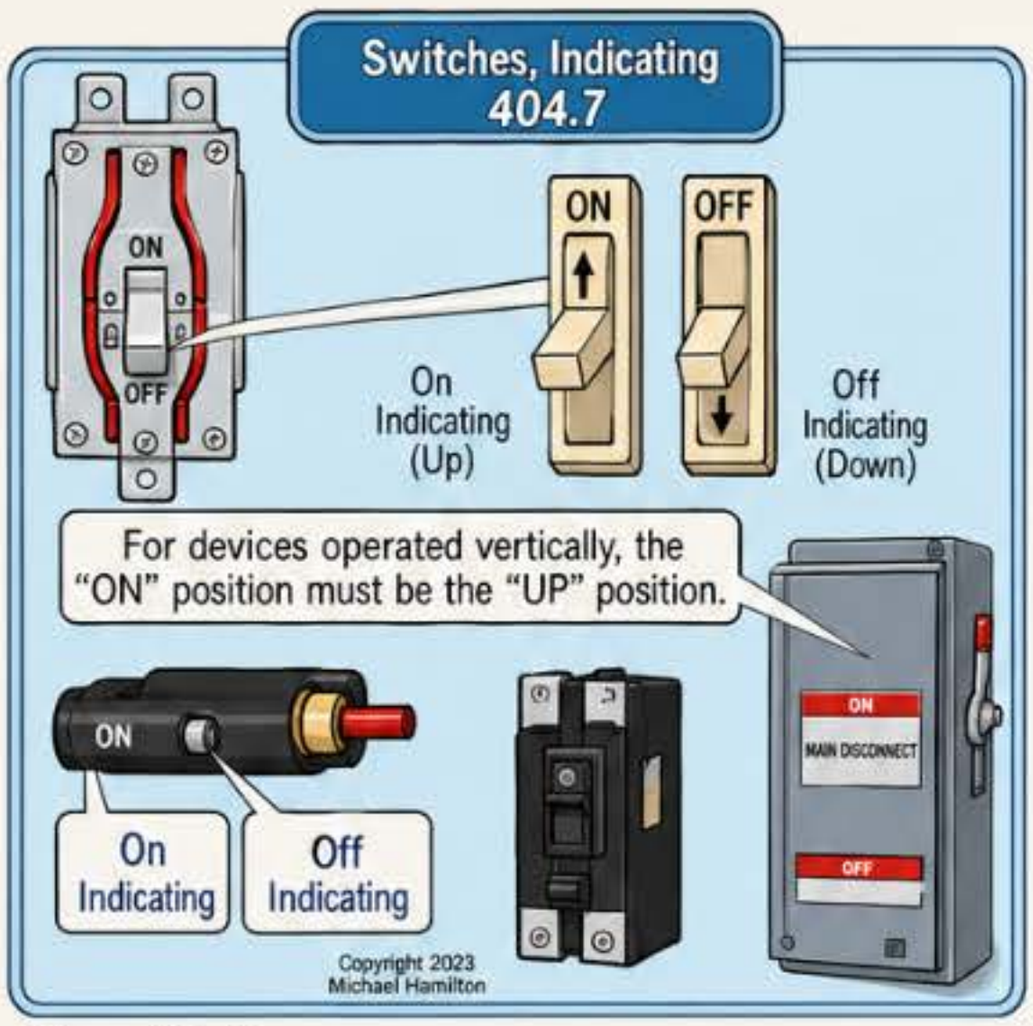
When the switch is operated vertically, it must be installed so the "up" position is the "on" position [240.81]. ▶ **Figure 404–14**

Ex 1: Double-throw switches, such as 3-way and 4-way switches, are not required to be marked "on" or "off".

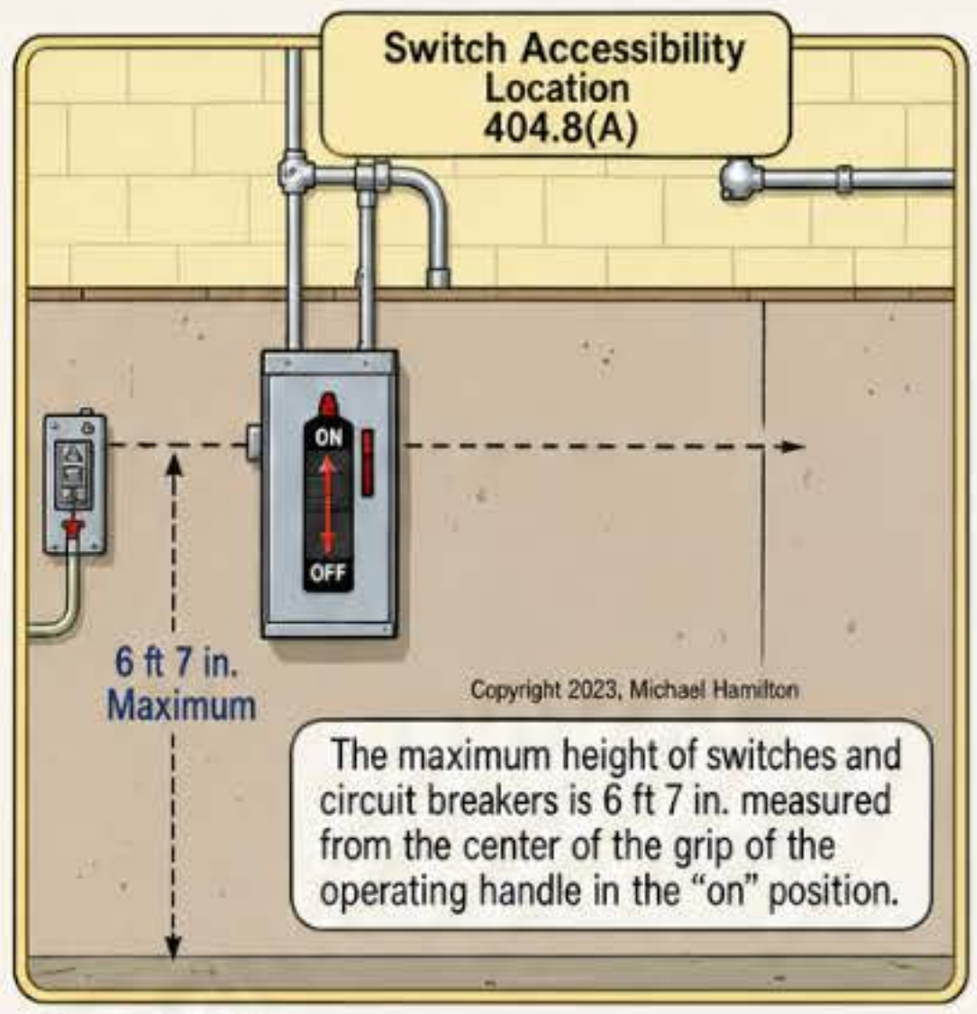
Author's Commentary:

Circuit breakers used to switch fluorescent lighting must be listed and marked "SWD" or "HID." Circuit breakers used to switch high-intensity discharge lighting must be listed and must be marked "HID" [240.83(D)]. ▶ ***Figure 404–15***

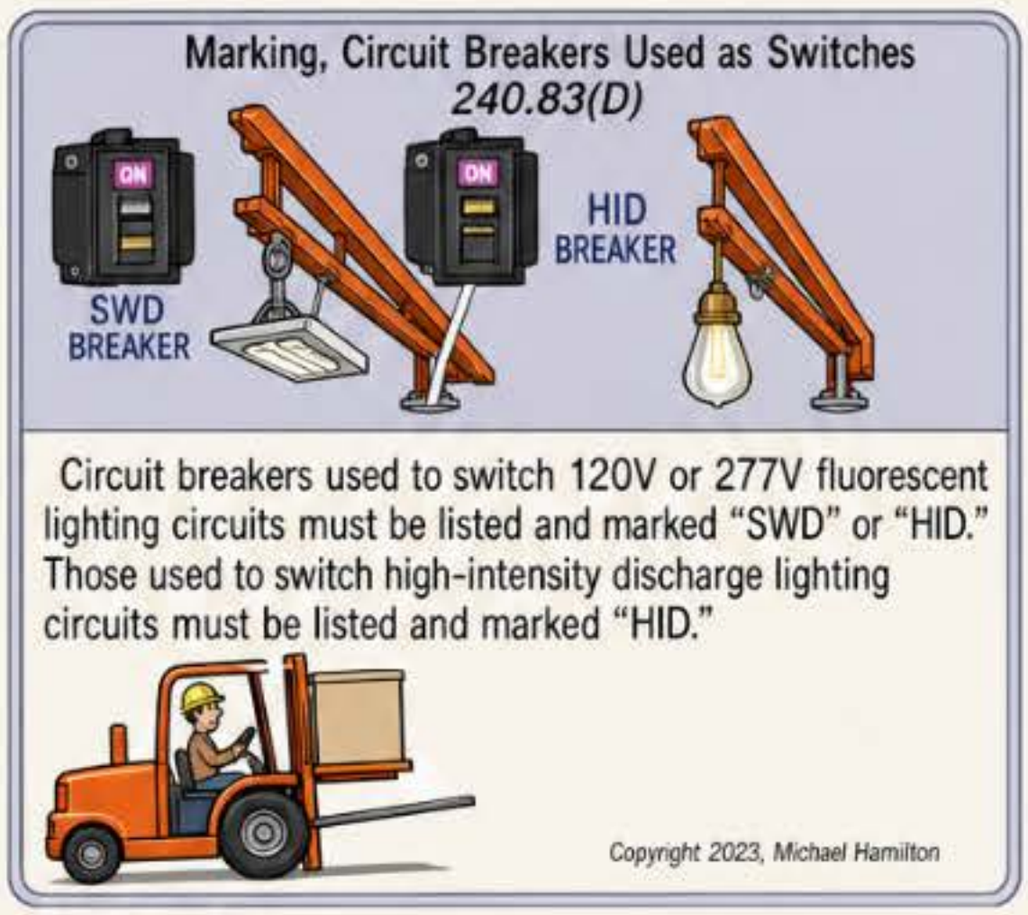
— Michael Hamilton



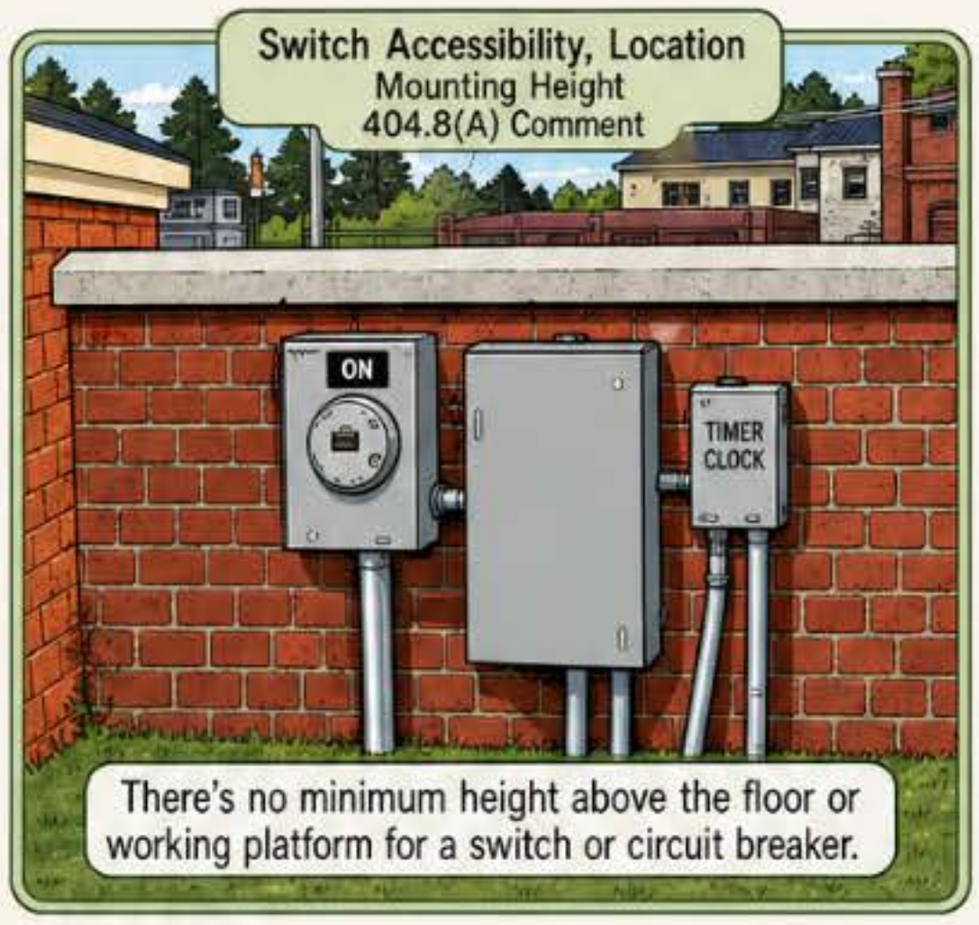
▶ Figure 404-14



▶ Figure 404-16



▶ Figure 404-15



▶ Figure 404-17

404.8 Accessibility and Grouping

(A) Location. *Switches and circuit breakers must be capable of being operated from a readily accessible location with the center of the grip of the operating handle, when in its highest position, not more than 6 ft 7 in. above the floor or working platform [240.24(A)].* ▶ **Figure 404-16**

> *Author's Commentary:*
> *There are no requirements for a minimum height above the floor or working platform for switches or circuit breakers.*
> *— Michael Hamilton*

Ex 1: On busways, fusible switches and circuit breakers can be located at the same level as the busway where suitable means is provided to operate the handle of the device from the floor. ▶ **Figure 404-18**

Ex 2: Switches and circuit breakers can be mounted above 6 ft 7 in. if they are next to the equipment they supply and accessible by portable means. ▶ **Figure 404-19**

(B) Voltage Between Devices. *Snap switches are not permitted to be in enclosures with other switches or receptacles if the voltage between the devices exceeds 300V, unless the devices are installed in enclosures equipped with barriers identified for the purpose that are securely installed between adjacent devices.* ▶ **Figure 404-20**

404.8 | Switches

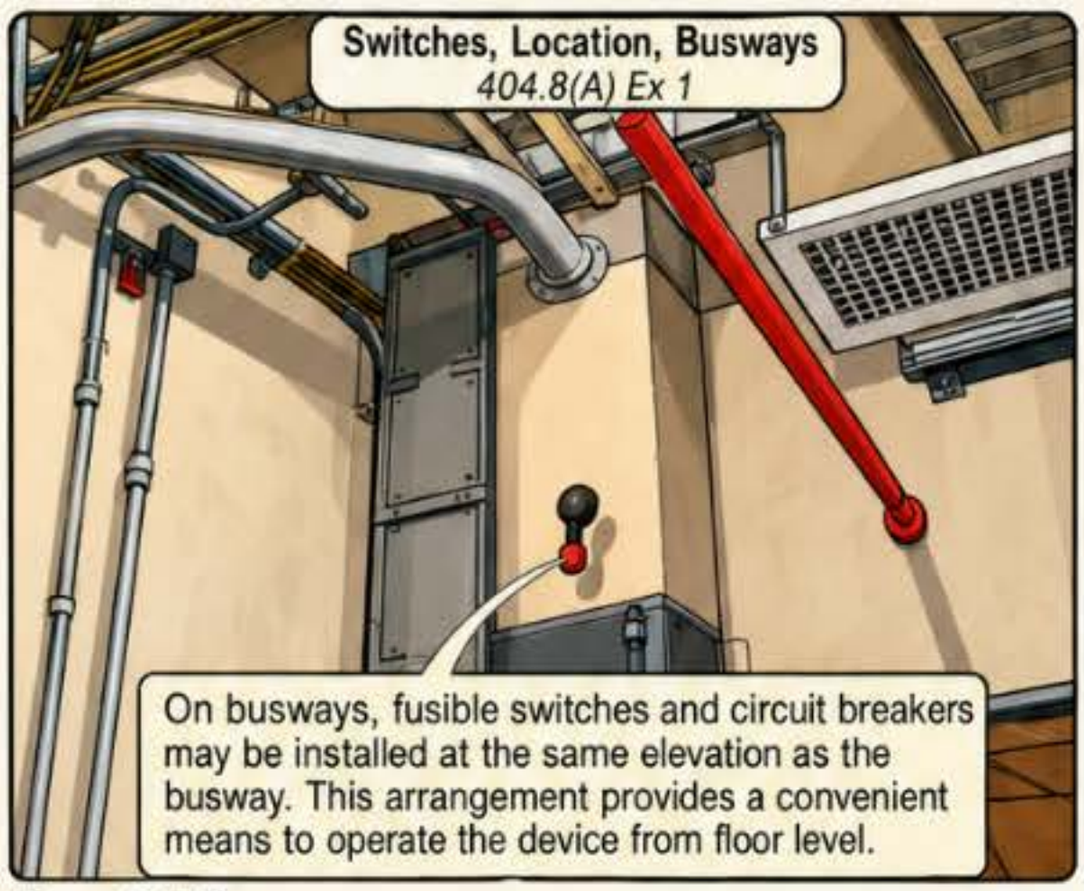


Figure 404-18

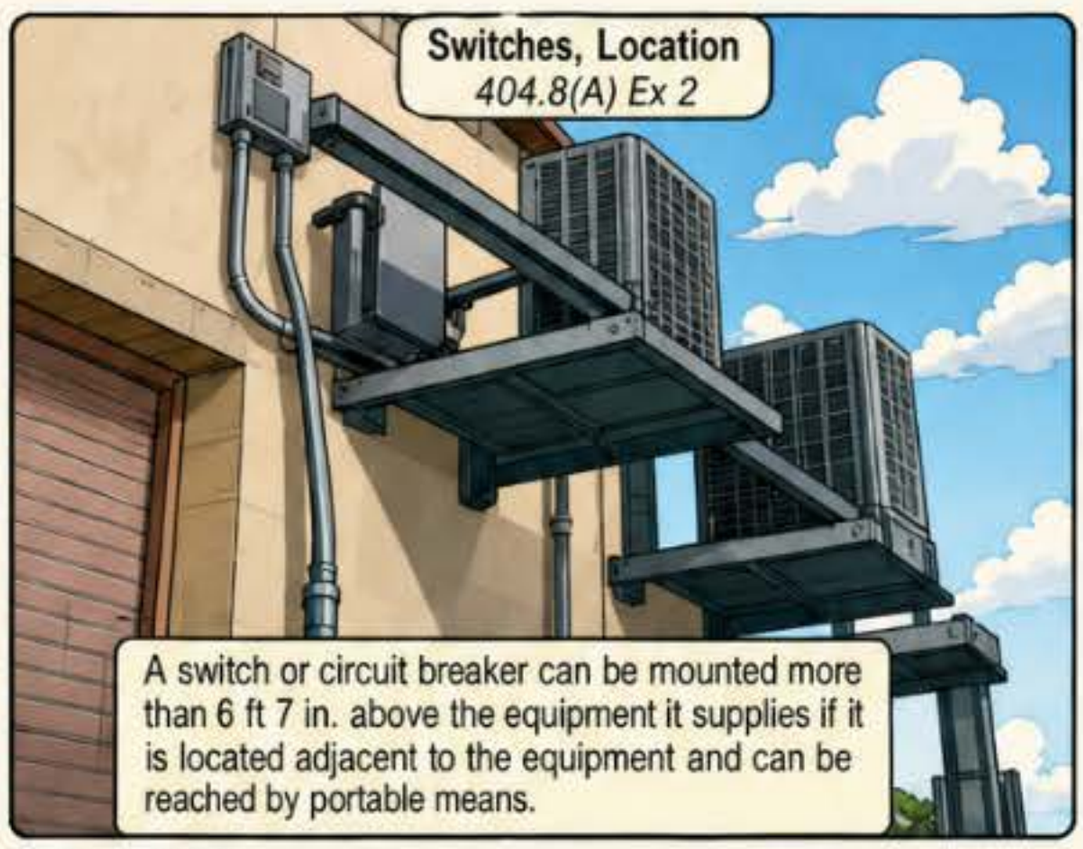


Figure 404-19

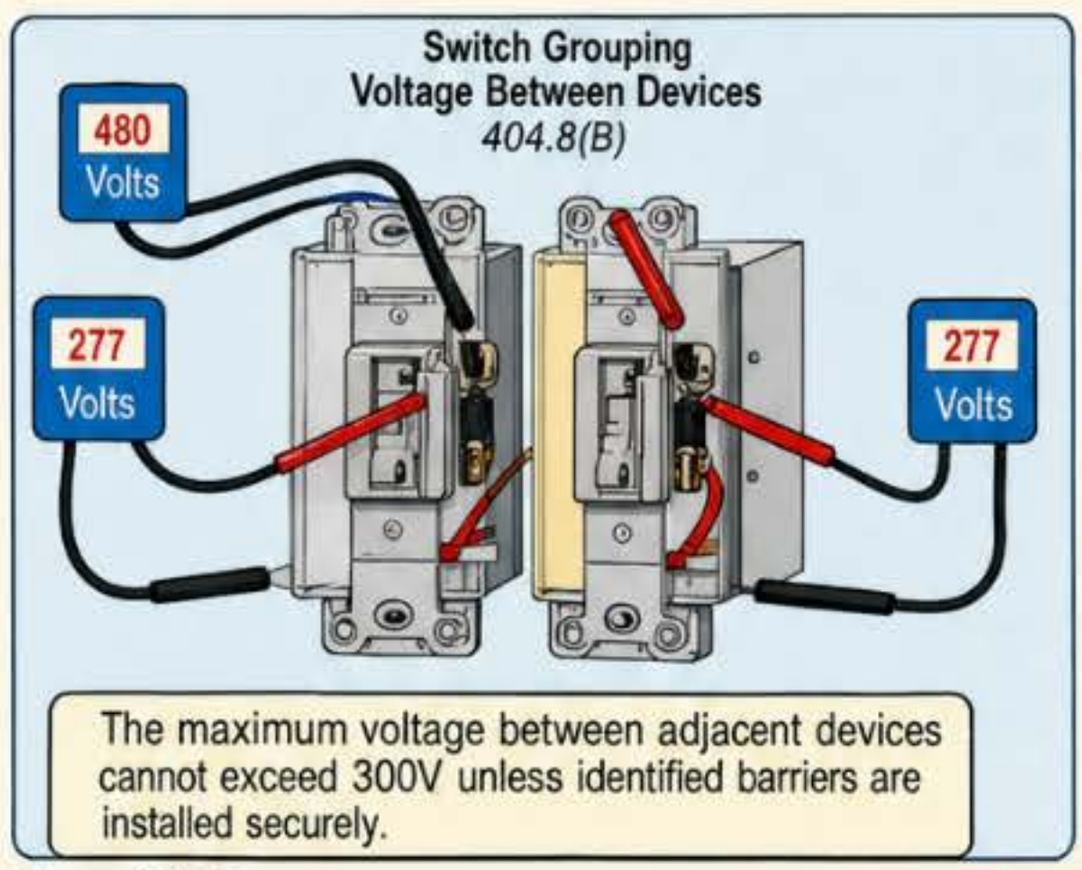


Figure 404-20

Author's Commentary:

The voltage between devices depends on the voltage difference between the conductors that feed them. When equipment is connected to different systems—such as 120/208V and 277/480V—the voltage between the devices themselves can be as high as 381V.

— *Michael Hamilton*

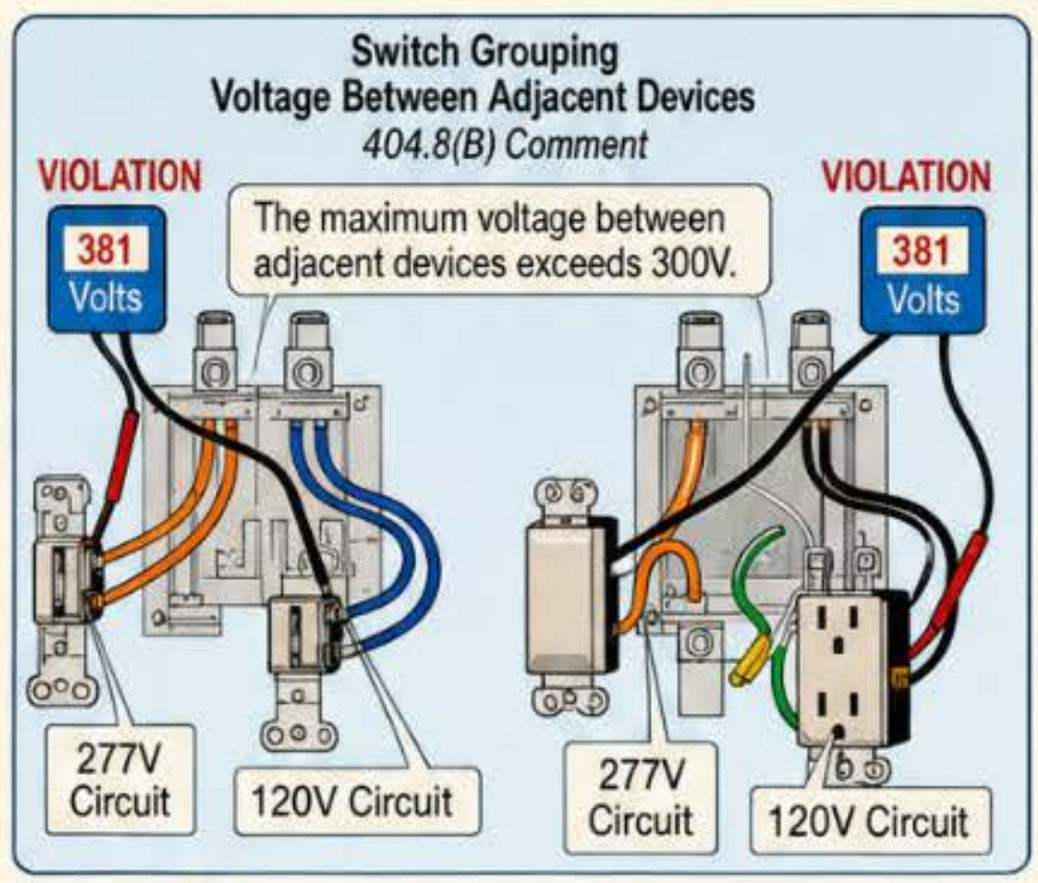


Figure 404-21

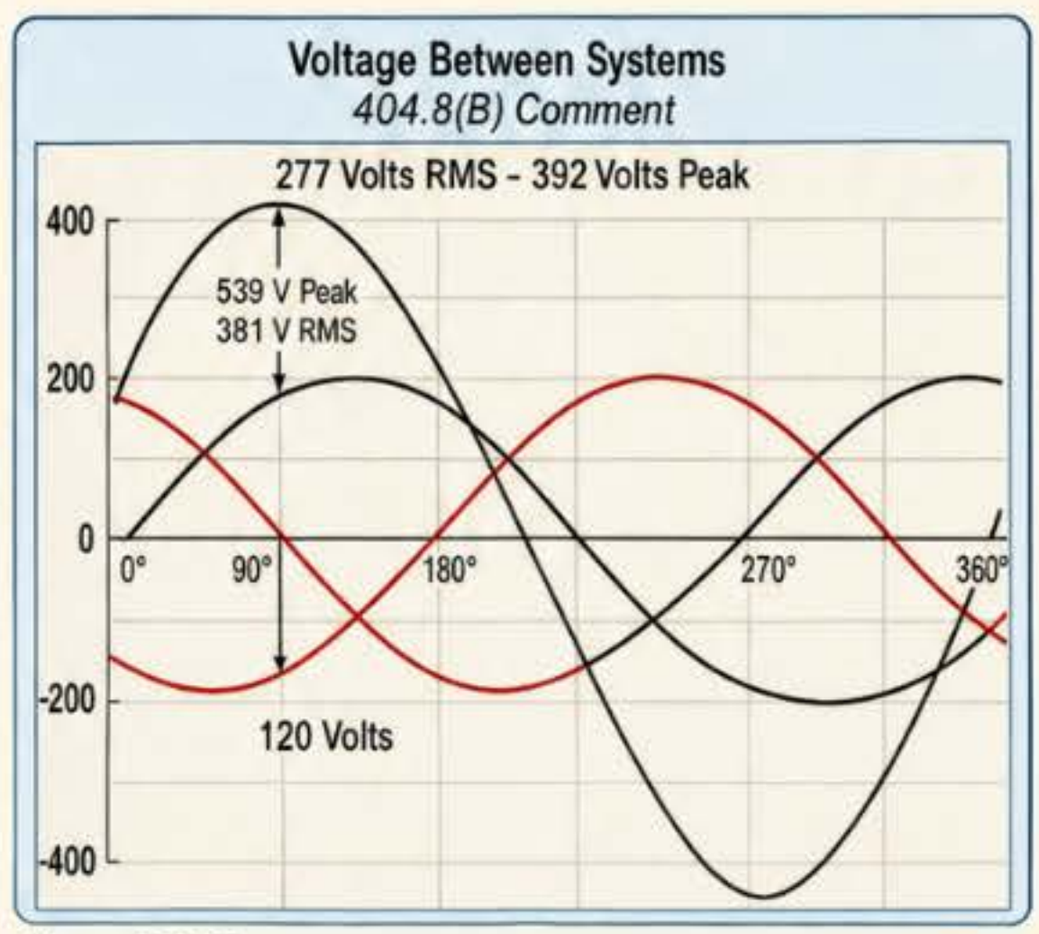
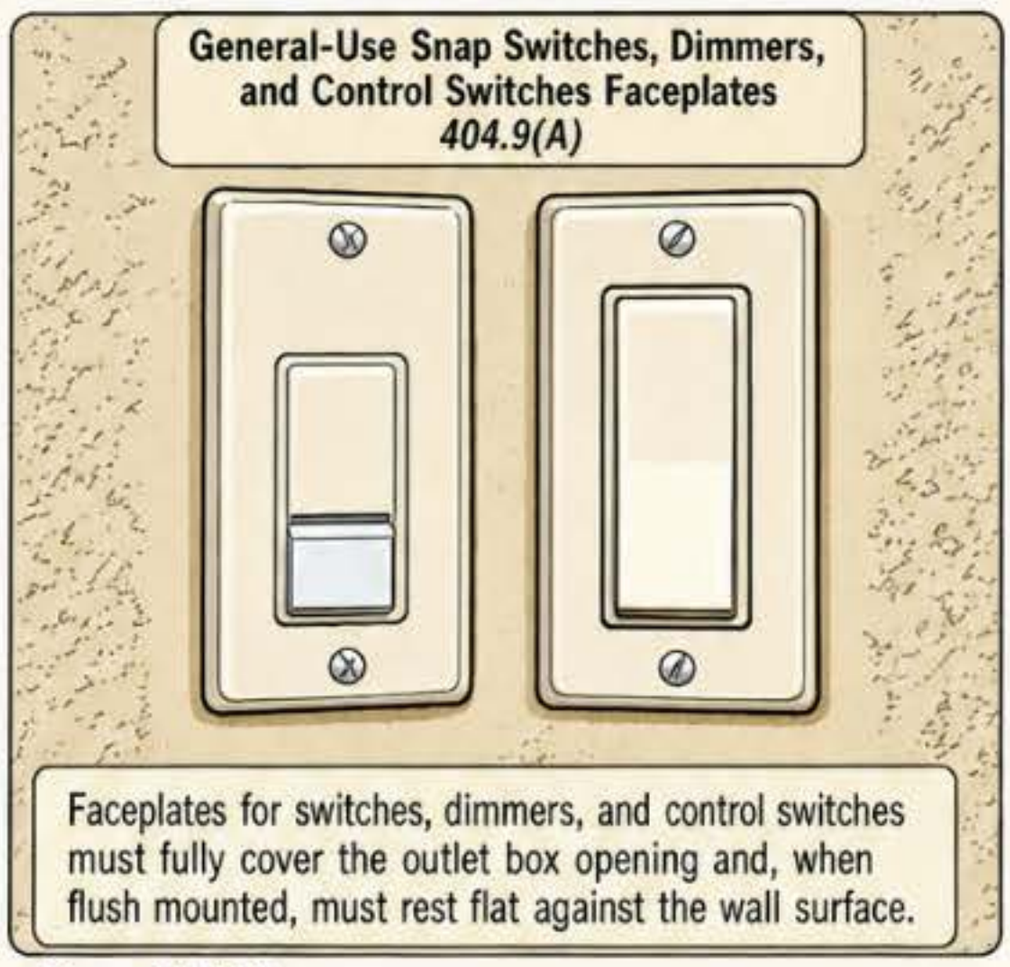


Figure 404-22

404.9 General-Use Snap Switches, Dimmers, and Control Switches

(A) Faceplates. All faceplates for switches, dimmers, and control switches must fully cover the outlet box opening. When flush mounted, the faceplate has to sit flat against the wall surface. • **Figure 404-23**



• **Figure 404-23**

(B) Equipment Grounding Conductor. The metal mounting yokes used on switches, dimmers, and control switches as well as their metal faceplates have to be connected to the circuit equipment grounding conductor. This connection must be made using one of the following methods:

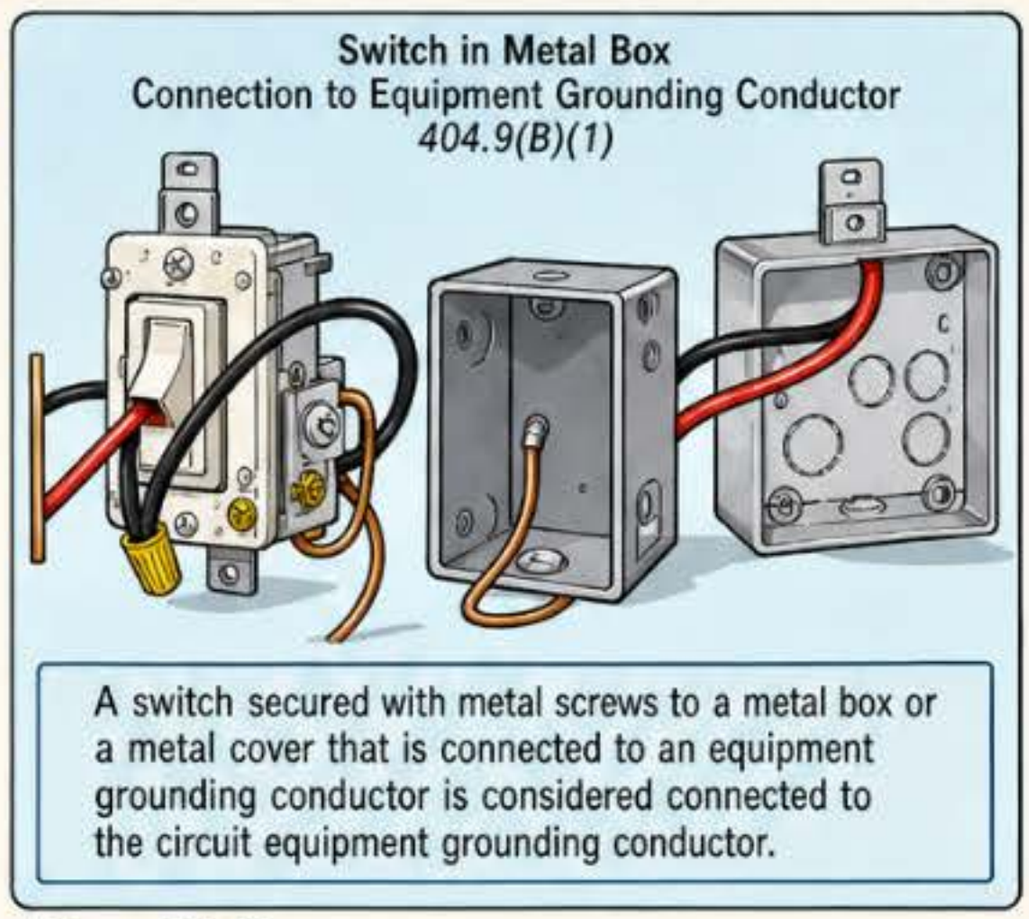
(1) Metal Boxes. Secure the switch yoke with metal screws to a metal box or metal cover that is connected to an equipment grounding conductor [250.109]. • **Figure 404-24**

The metal faceplate must be fastened with metal screws to a switch that is connected to an equipment grounding conductor [250.109]. • **Figure 404-25**

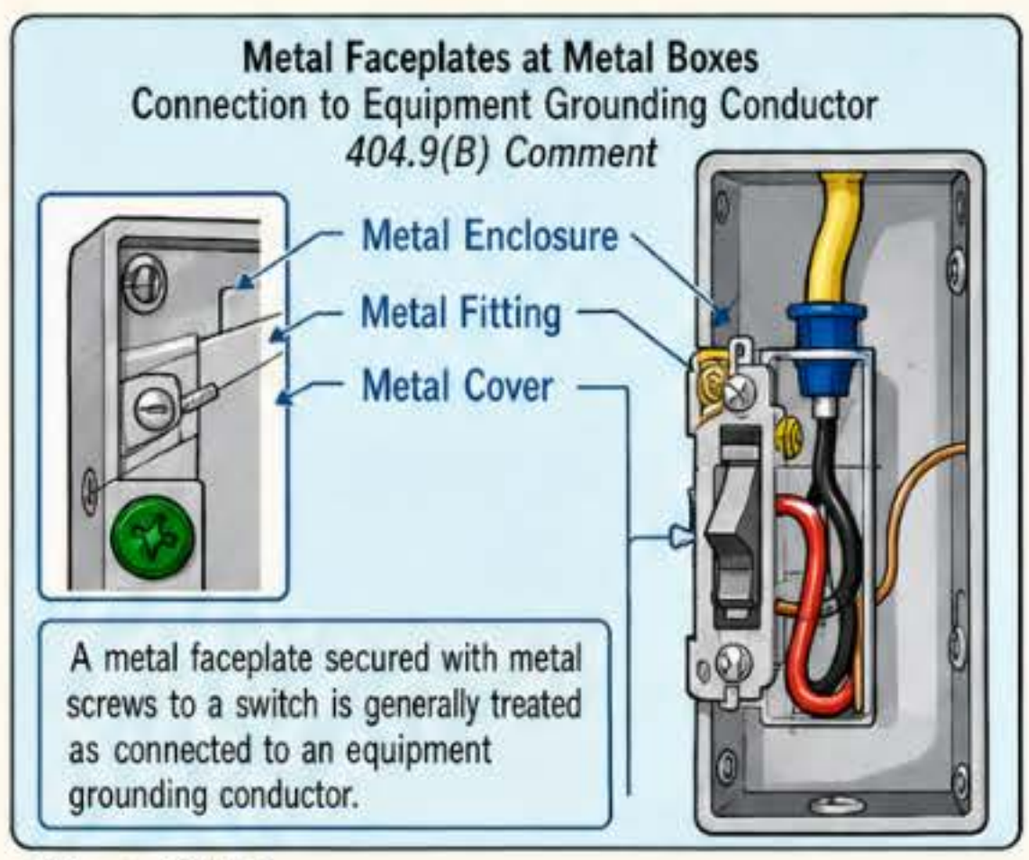
Author's Commentary:

- *A direct metal-to-metal path between the device yoke and the box is not necessary. What matters is that the switch is tied into the effective ground-fault current path when the yoke is mounted with metal screws to a metal box.*

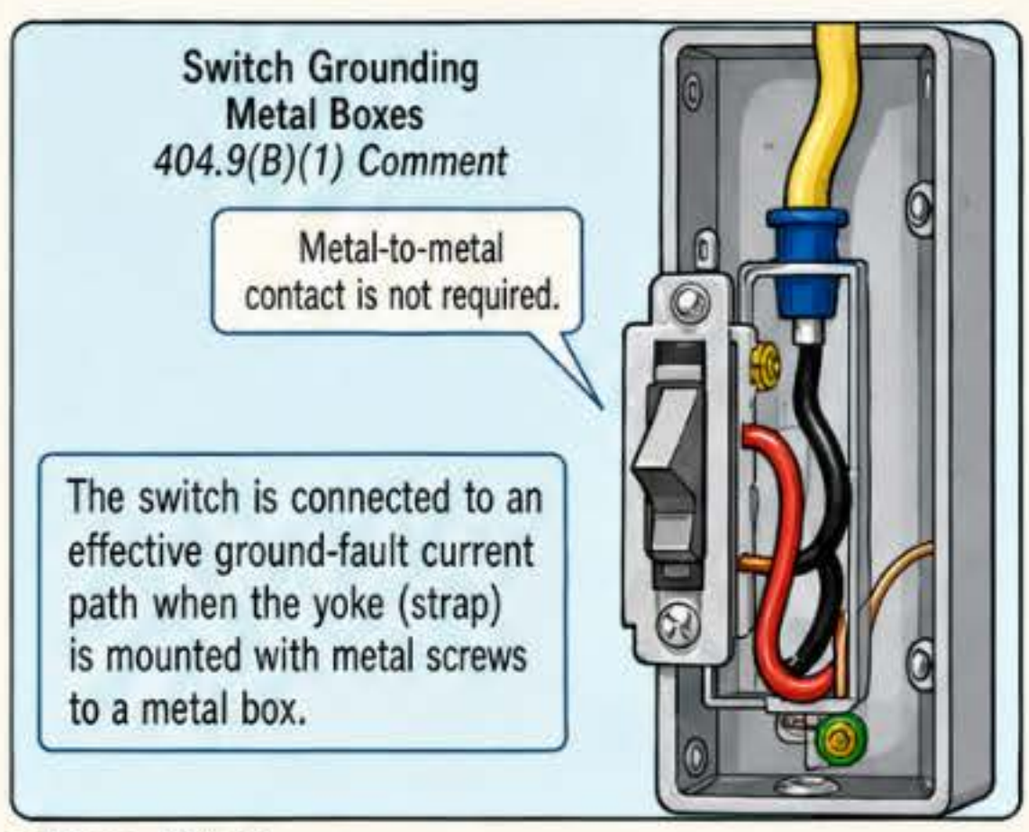
— Michael Hamilton



• **Figure 404-24**

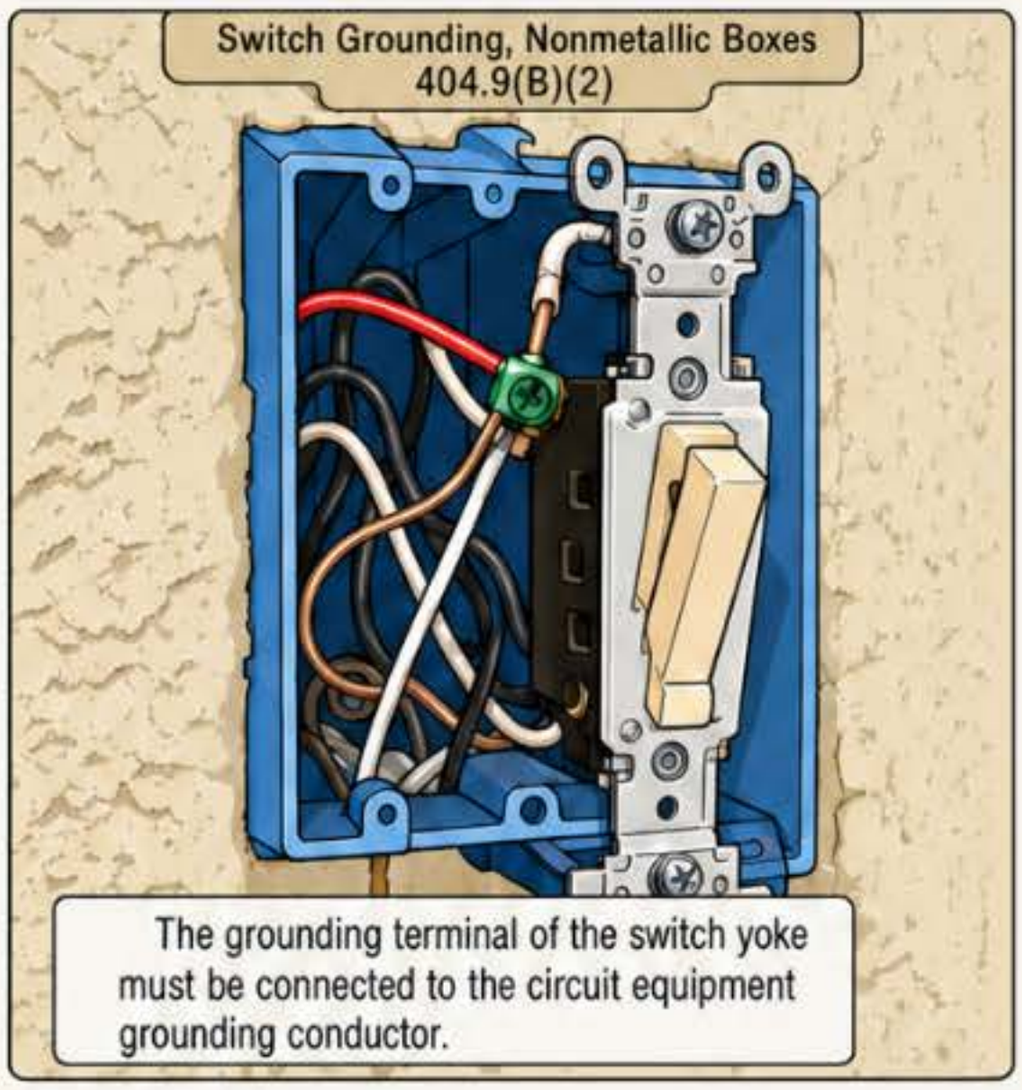


• **Figure 404-25**



• **Figure 404-26**

(2) Nonmetallic Boxes. The switch yoke is connected to the circuit equipment grounding conductor. ▶ Figure 404–27



▶ Figure 404–27

The metal faceplate is secured with metal screws to a switch that is connected to an equipment grounding conductor [250.109].

Ex 1: *When no means exists within the box for bonding to an equipment grounding conductor, or if the wiring method at the existing switch does not contain an equipment grounding conductor, a switch without such a connection to the equipment grounding conductor is permitted for replacement purposes only. A switch installed under this exception must have a faceplate that is nonmetallic with nonmetallic screws, or the replacement switch must be GFCI protected.*

Ex 2: *Listed assemblies are not required to be bonded to an equipment grounding conductor if all the following conditions are met:*

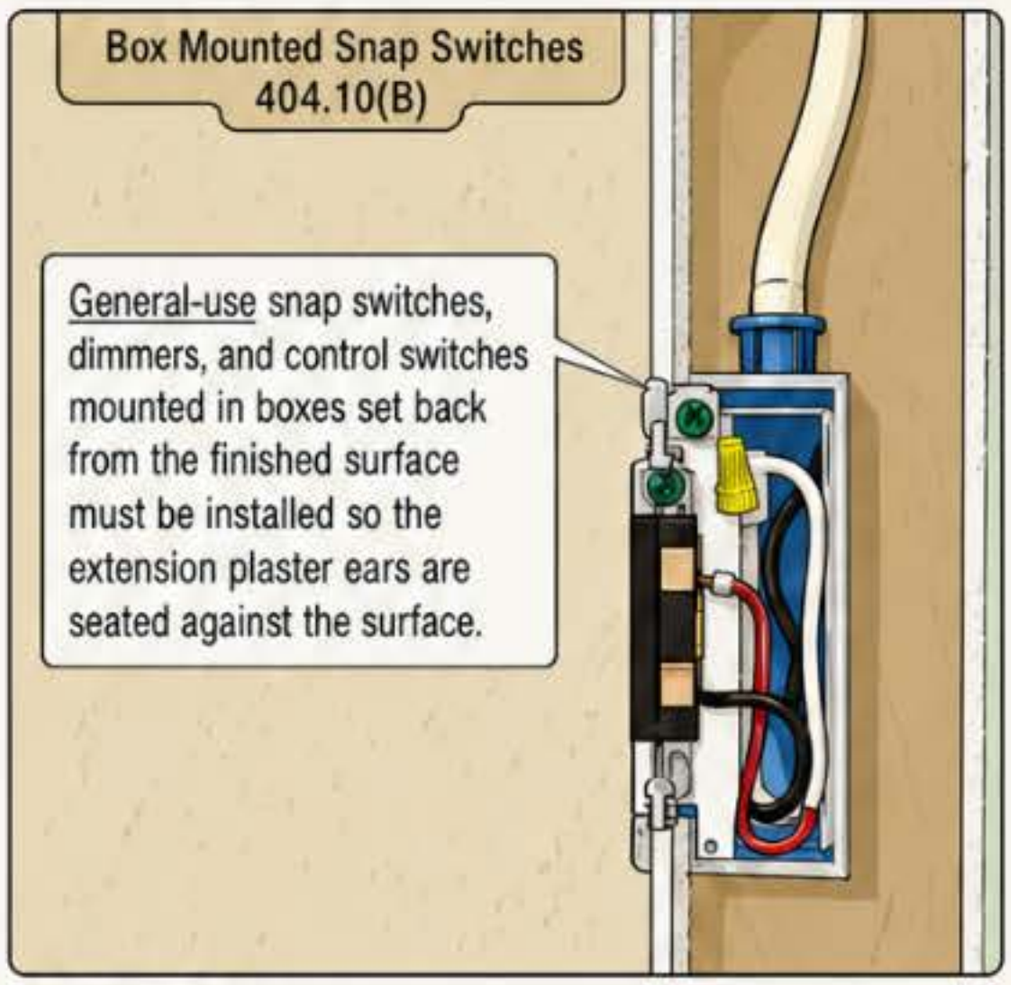
(1) The device is provided with a nonmetallic faceplate and the device is designed such that no metallic faceplate replaces the one provided.
(2) The device does not have a mounting means to accept other configurations of faceplates.
(3) The device is equipped with a nonmetallic yoke, and
(4) Parts of the device that are accessible after the faceplate is installed are manufactured of nonmetallic material.

Ex 3: *An equipment grounding conductor is not required for bonding a snap switch with an integral nonmetallic enclosure complying with 300.15(E).*

404.10 Mounting of Snap Switches, Dimmers, and Control Switches

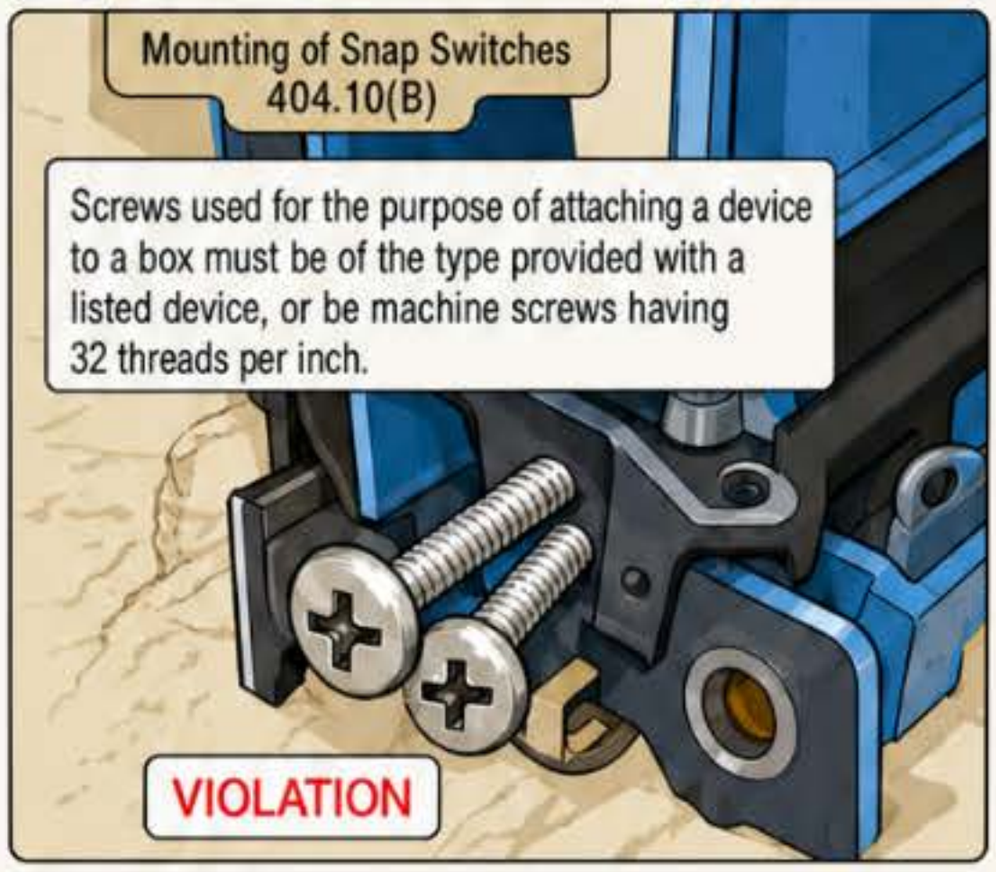
(B) Box Mounted.

General-use snap switches, dimmers, and control switches mounted in boxes that are set back from the finished surface must be installed so the extension plaster ears are seated against the surface. ▶ Figure 404–28



▶ Figure 404–28

Screws used for the purpose of attaching a device to a box must be of the type provided with a listed device or be machine screws having 32 threads per in. or part of listed assemblies or systems, in accordance with the manufacturer's instructions. ▶ Figure 404–29



▶ Figure 404–29

Author's Commentary:

▶ Enclosures made of noncombustible materials—such as drywall boxes—cannot be set back more than 1/4 in. from the finished surface. If the box material is combustible (e.g., wood or cellulose fibers), project it flush with the finished surface. If the box is recessed (314.20), all gaps at the edge must be no larger than 1/8 in.

— Michael Hamilton

404.12 Grounding of Enclosures

Metal enclosures for switches and circuit breakers must be bonded to an equipment grounding conductor or to a conductor approved in 250.118 (250.4(A)(3)). Where nonmetallic raceways or metal-armored cables are used with metal enclosures, the requirements of 314.3, Example 1 or 2, apply.

404.14 Rating and Use of Snap Switches

General-Use Snap Switches. General-use snap switches must be listed and used within their ratings.

(A) ***Alternating-Current General-Use Snap Switches.*** General-use snap switches are permitted to control:

(4) *Motor loads up to 80 percent of the ampere rating of the switch (430.109(C)].*

(5) *Electronic ballasts, self-ballasted lamps, compact fluorescent lamps, and LED lamp loads with their associated drivers, provided none exceed 20 A and none exceed the ampere rating of the switch at the voltage used.*

(E) ***Dimmers and Electronic Control Switches.*** *General-use dimmer switches are limited to permanently installed incandescent luminaires unless they are listed for controlling other loads.*

▶ ***See Figure 404–30***

Other electronic control devices—such as timing switches and occupancy sensors—may be used to control permanently connected loads. Such devices must be listed by the manufacturer within their voltage and current ratings and are intended for loads that do not exceed the device's ampere rating at the voltage used.

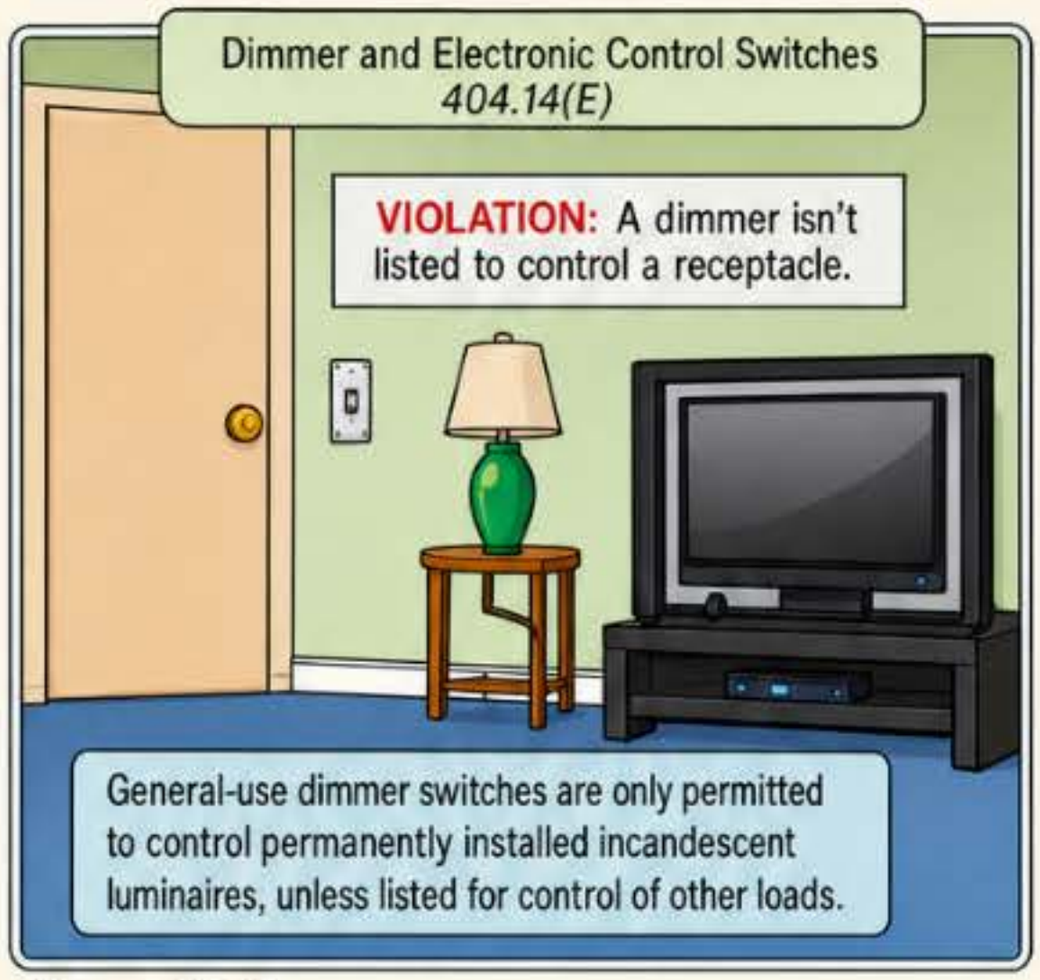


Figure 404–30

Part II. Construction Specifications

404.20 Switch Marking

(A) Markings. Switches must be marked with the current, voltage, and, if horsepower rated, the maximum rating for which they are designed.

▶ **Figure 404–31**

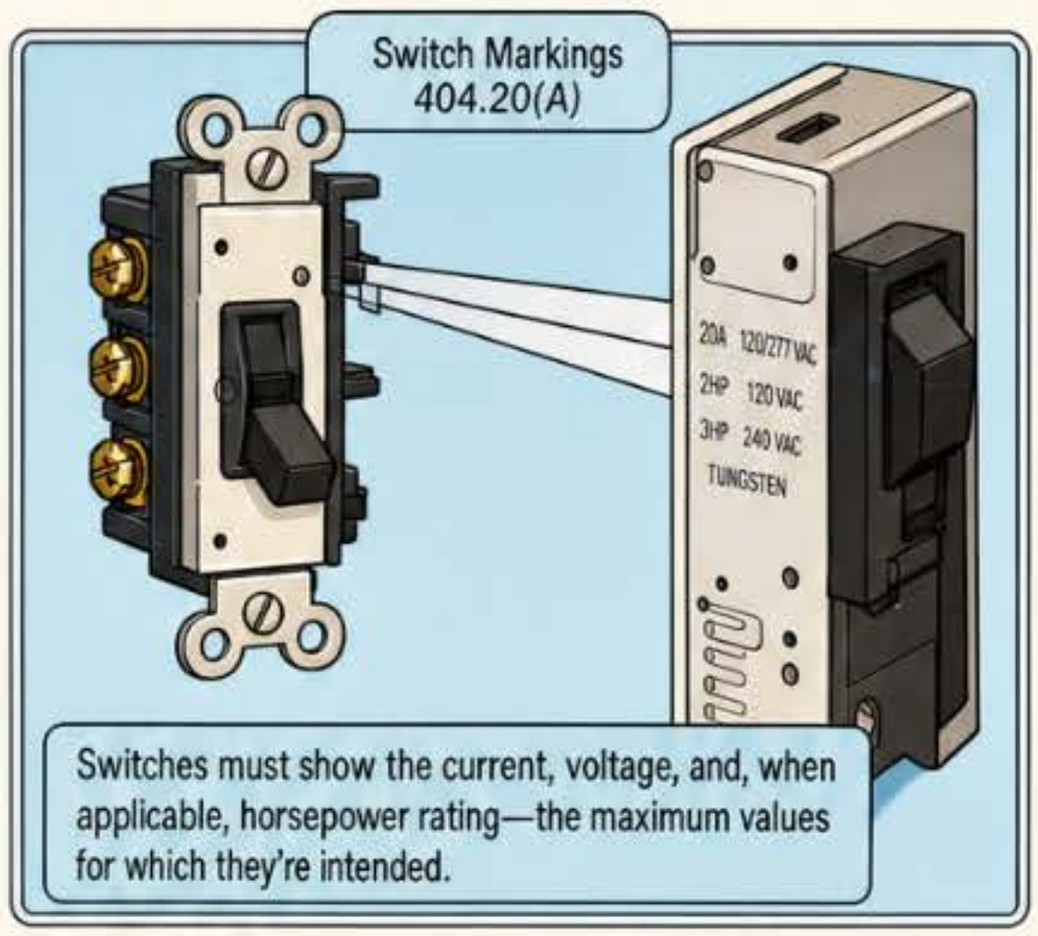


Figure 404–31

(B) Off Indication. *When a switch is in the off position, a device with a clearly marked "off" position must completely disconnect all ungrounded (phase) conductors of the load it controls.*

404.22 Switches

Author's Commentary:

- When an electronic occupancy sensor is used to control a load, the controlled circuit will have voltage on it and a small amount of current (0.05 mA) can flow through even when the device is in its "off" state. That tiny current might startle someone, possibly causing a fall. To prevent this, manufacturers simply remove the word "off" from the device.

— Michael Hamilton

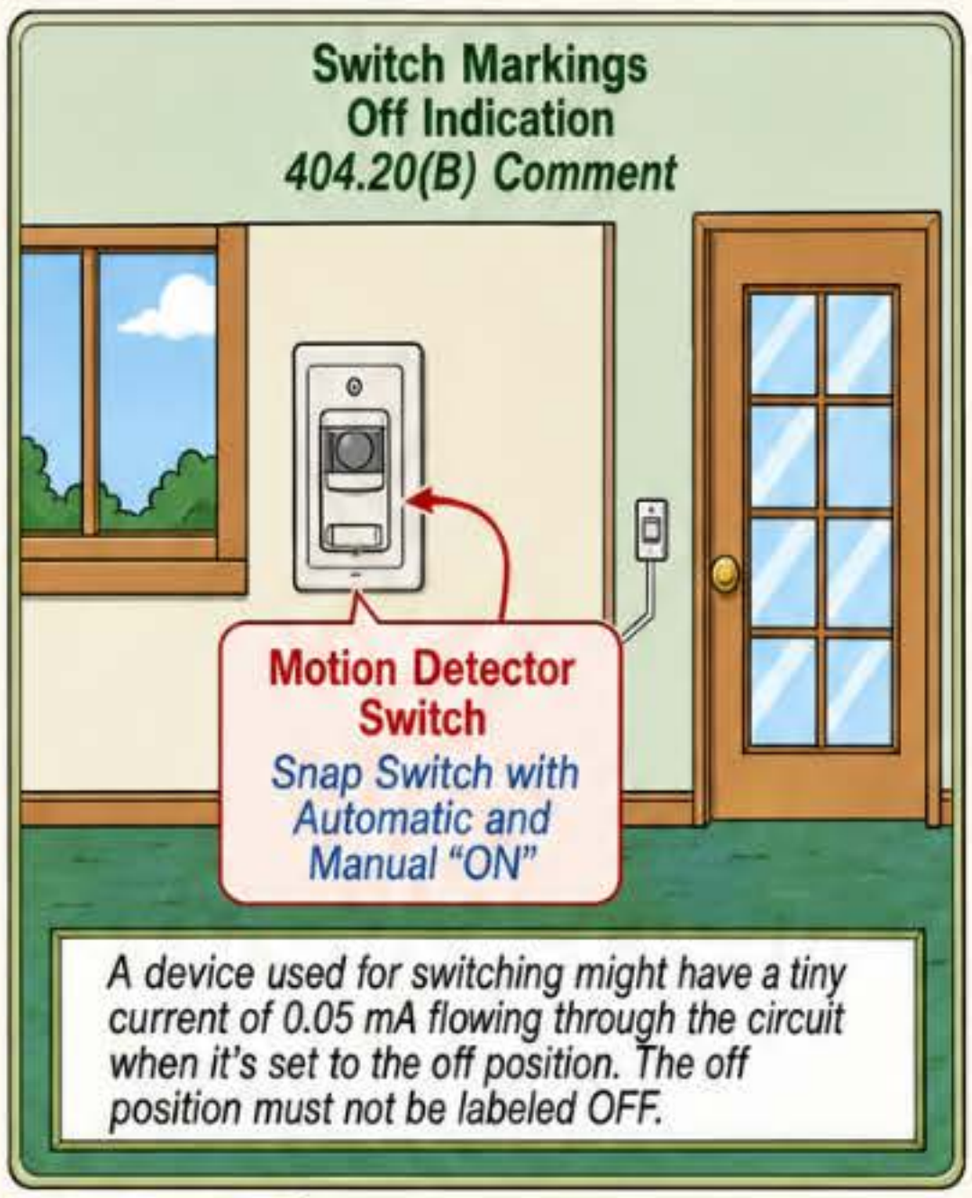


Figure 404–32

404.22 Electronic Control Switches

Electronic control switches are required to be installed so they do not put current onto the equipment grounding conductor during standard operation.

Figure 404–33

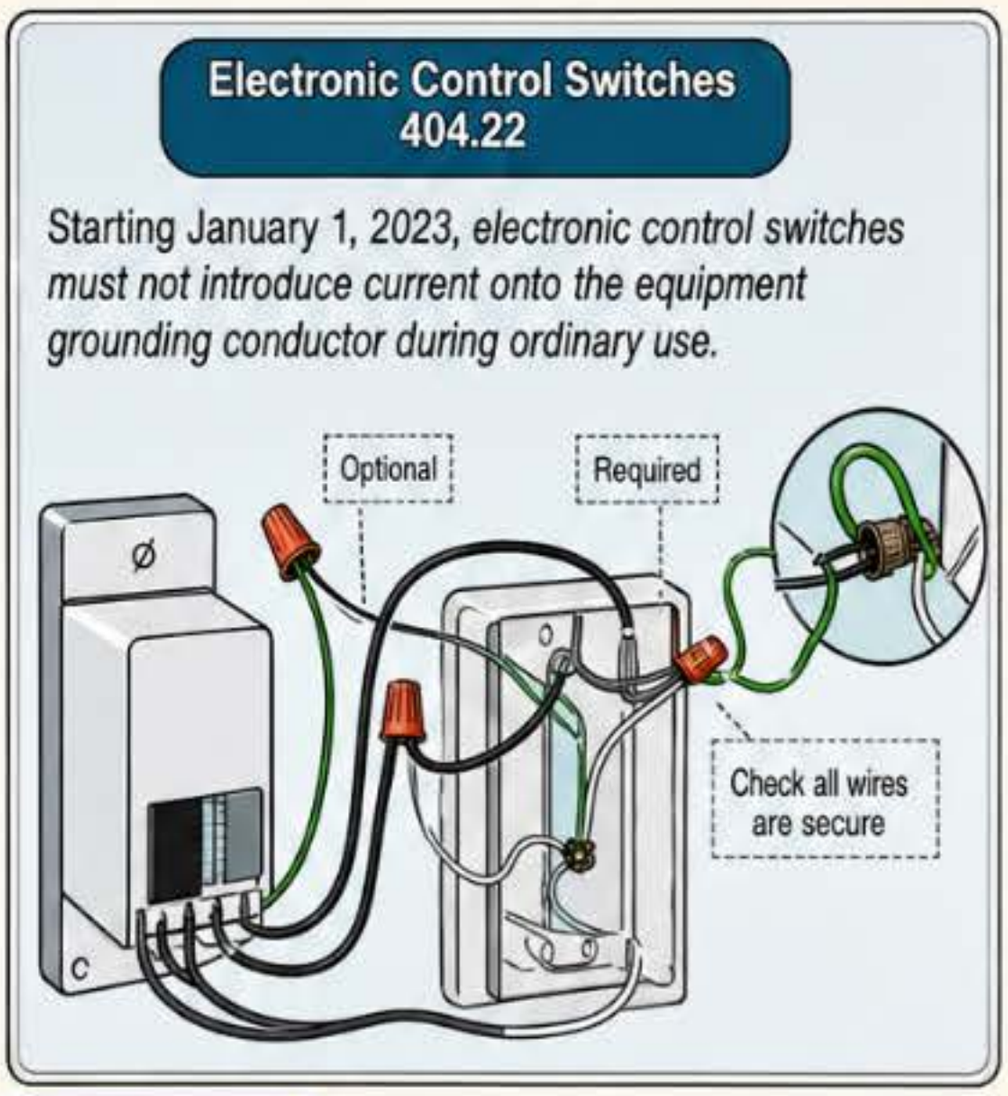


Figure 404–33

Author's Commentary:

- When an electronic occupancy sensor is used to control a circuit, voltage will remain on the circuit and a slight current (0.05 mA) can continue to flow through the circuit even though the sensor is in the "off" position. That small current can alarm someone and may cause a fall. To avoid this risk, manufacturers have eliminated the term "off" from the device.

— Michael Hamilton

Example: Electronic control switches that can place current on the equipment grounding conductor [404.22(C) Ex] must be listed and marked for replacement or retrofit uses only.

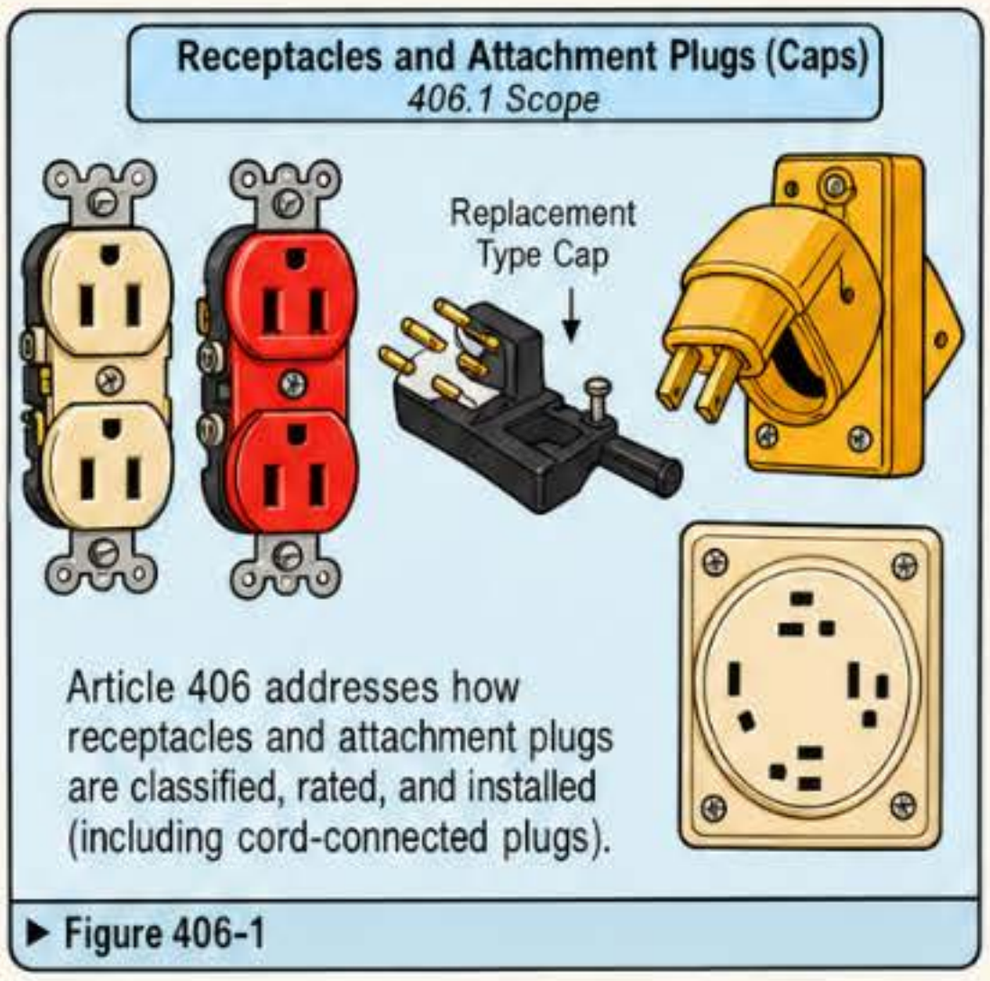
ARTICLE 406 RECEPTACLES, ATTACHMENT PLUGS, AND CORD CONNECTORS

Introduction to Article 406—Receptacles, Attachment Plugs, and Cord Connectors

This article addresses how receptacles and attachment plugs are classified, rated, and installed. It also includes requirements for flanged surface inlets.

406.1 Scope

Article 406 covers how receptacles and attachment plugs are classified, rated, and installed. ▶ **Figure 406-1**



▶ **Figure 406-1**

406.2 Definitions

The definitions in this section apply only within this article.

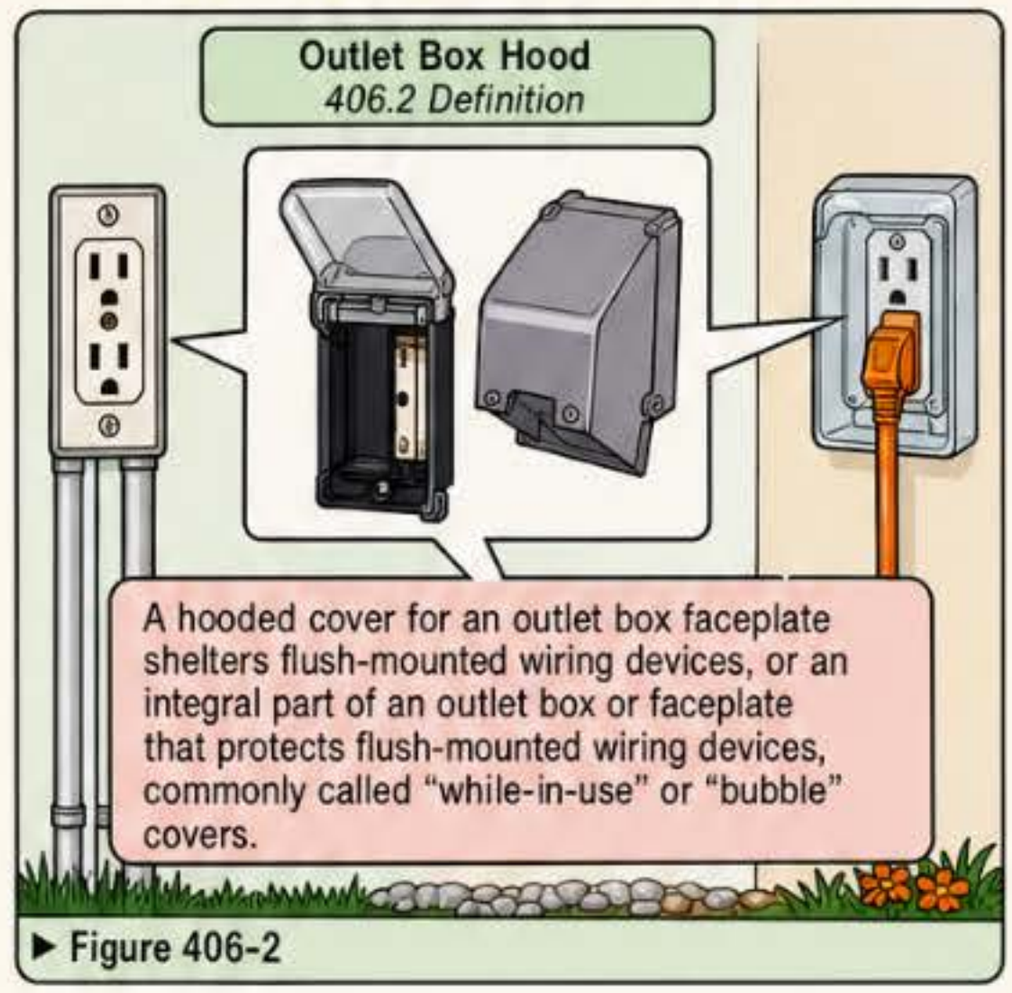
Author's Commentary:

Article terminology is provided here to ensure that readers share a common understanding of key terms used in this article.

— Michael Hamilton

Child Care Facility. A building or part of a building used for educational, supervisory, or personal care services for five or more children who are seven years old or younger.

Outlet Box Hood. A hooded cover for an outlet box faceplate protects flush-mounted wiring devices, or an integral part of an outlet box or faceplate that covers flush-mounted wiring devices. These covers are commonly called "while-in-use" or "bubble" covers. ▶ **Figure 406-2**



▶ **Figure 406-2**

406.3 Receptacle Rating and Type

(A) *Receptacles.* Receptacles must be listed and marked with the manufacturer's name or identification and voltage and ampere ratings. Receptacles are not allowed to be reconditioned.

Author's Commentary:

Using reconditioned receptacles can be unsafe because their reliability cannot be confirmed.

— Michael Hamilton

(D) Isolated Ground Receptacles. *Receptacles of the isolated equipment grounding conductor type must be identified with an orange triangle marking on the face of the receptacle.* ▶ ***Figure 406-3***

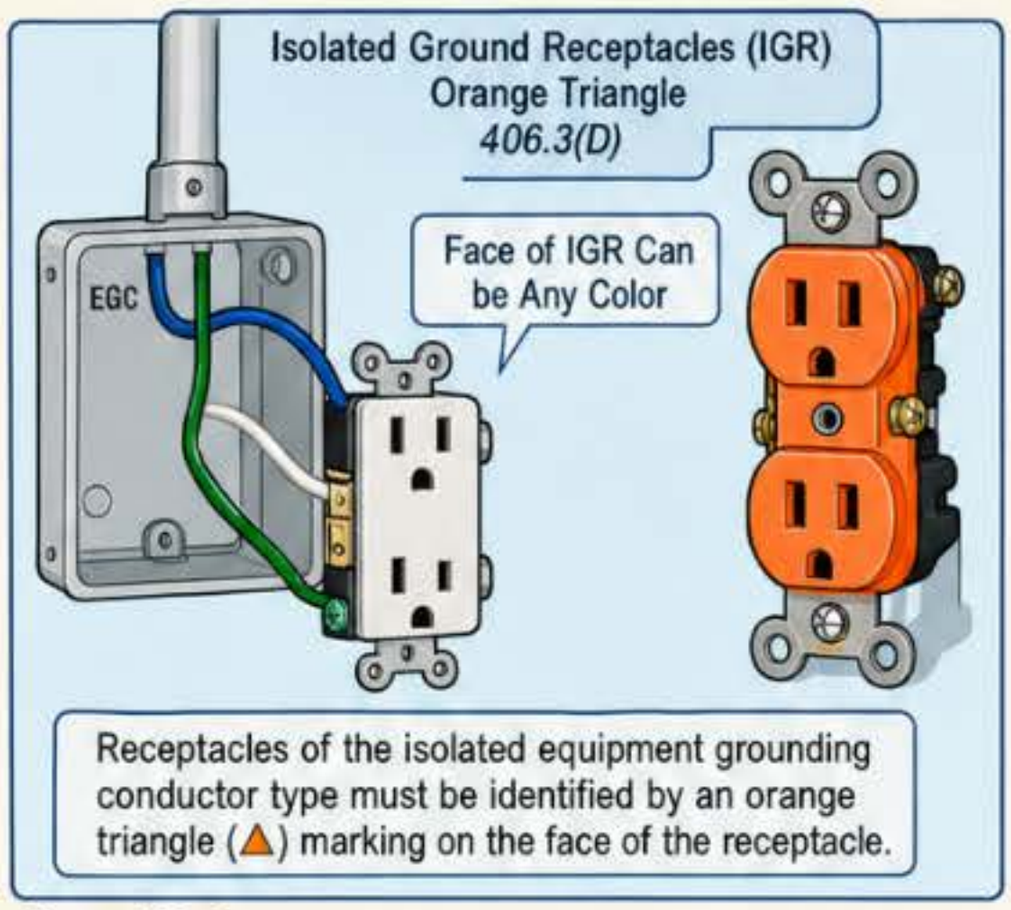


Figure 406–3

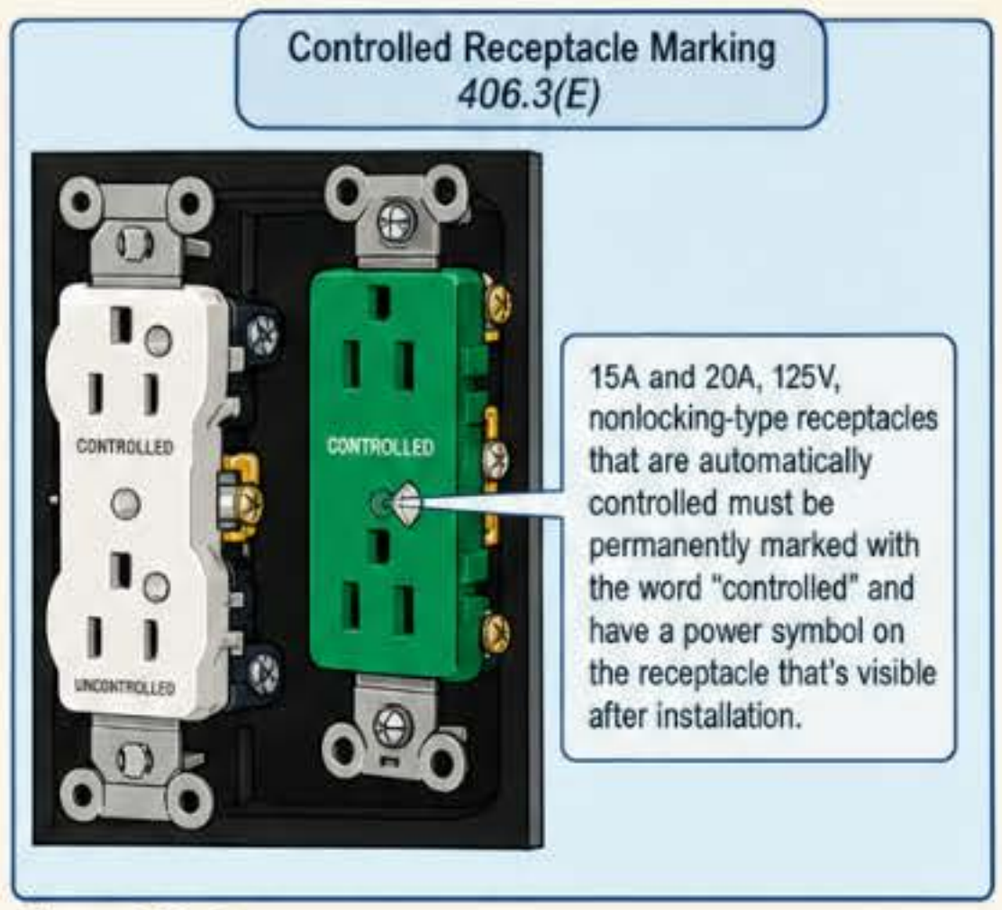


Figure 406–5

(1) Isolated ground receptacles must have the grounding contact of the receptacle connected to an insulated equipment grounding conductor installed with the circuit conductors, in accordance with 250.146(D). ▶ **Figure 406–4**

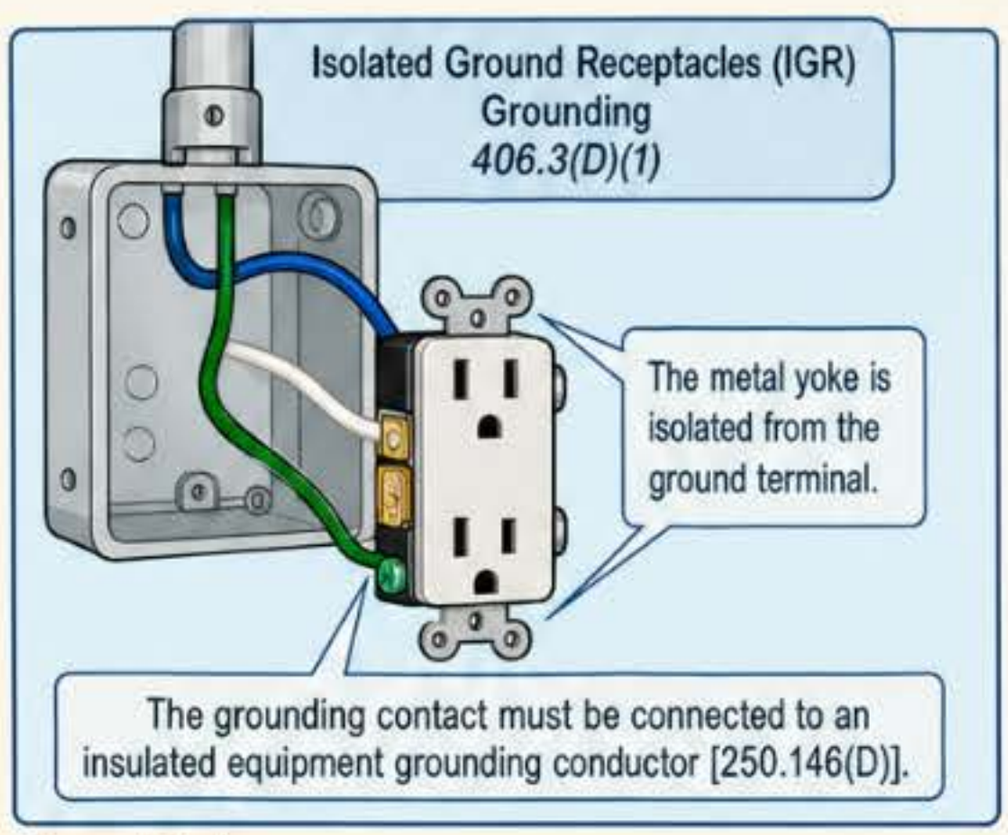


Figure 406–4

(E) Controlled Receptacle Marking. Nonlocking, 15A or 20A, 125V nonlocking-type receptacles that are automatically controlled to remove power for energy management or building automation must be permanently marked with the word "controlled" and have a visible power symbol on the receptacle after installation. ▶ **Figure 406–5**

Ex: The marking is not required for wall switch-controlled receptacles used for lighting in a dwelling [210.70(A)(1) Ex 2]. ▶ **Figure 406–6**

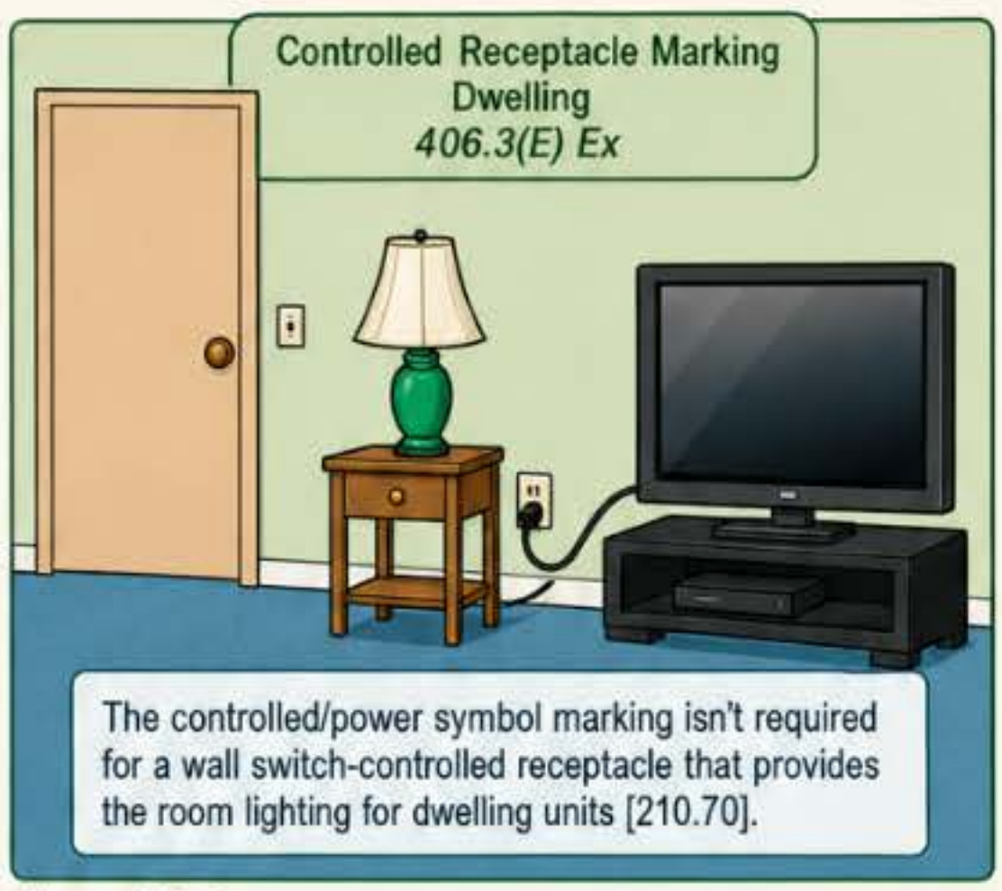


Figure 406–6

406.4 General Installation Requirements

(A) Grounding Type. Receptacles installed on 15A and 20A branch circuits must be of the grounding type, except as permitted for 2-wire receptacle replacements as permitted in 406.4(D)(2). ▶ **Figure 406–7**

Receptacles must be installed on circuits rated in accordance with Table 210.21(B)(2) for single receptacles and Table 210.21(B)(3) for two or more receptacles. ▶ **Figure 406–8**

Receptacles, Attachment Plugs, and Cord Connectors | 406.4

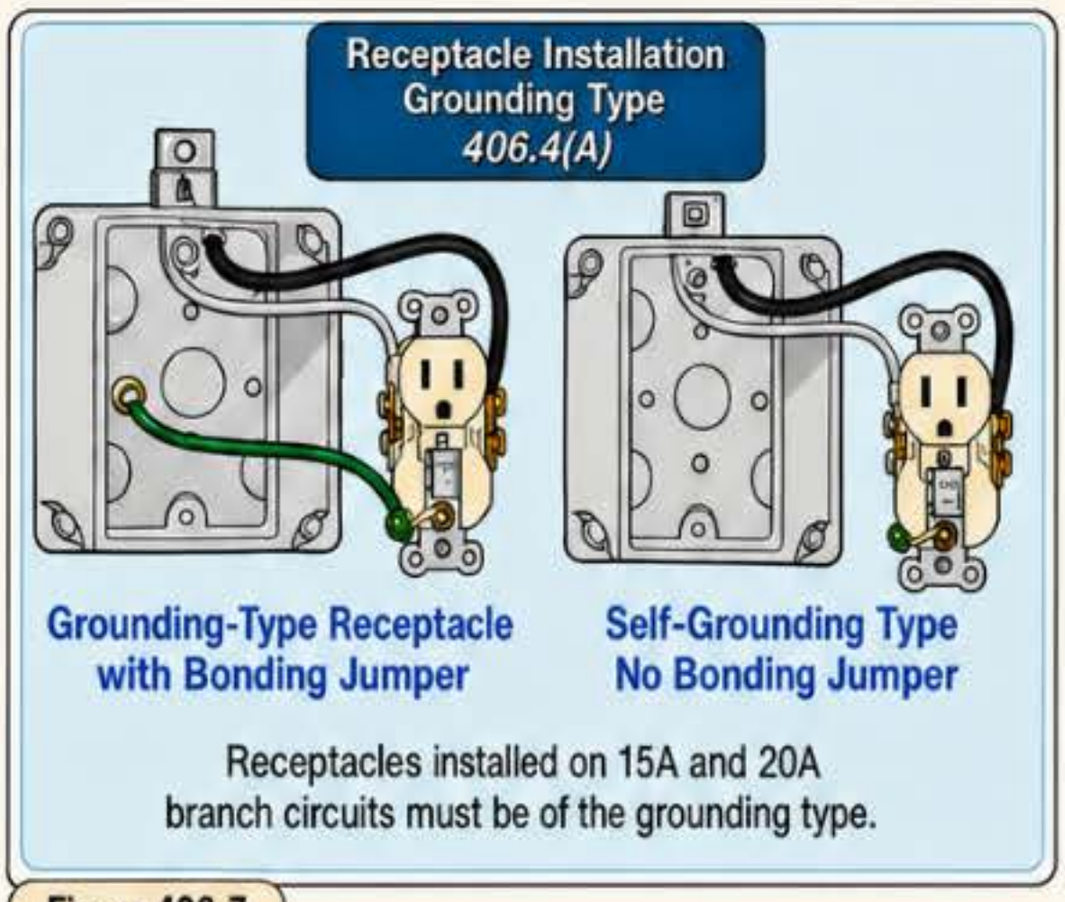


Figure 406-7

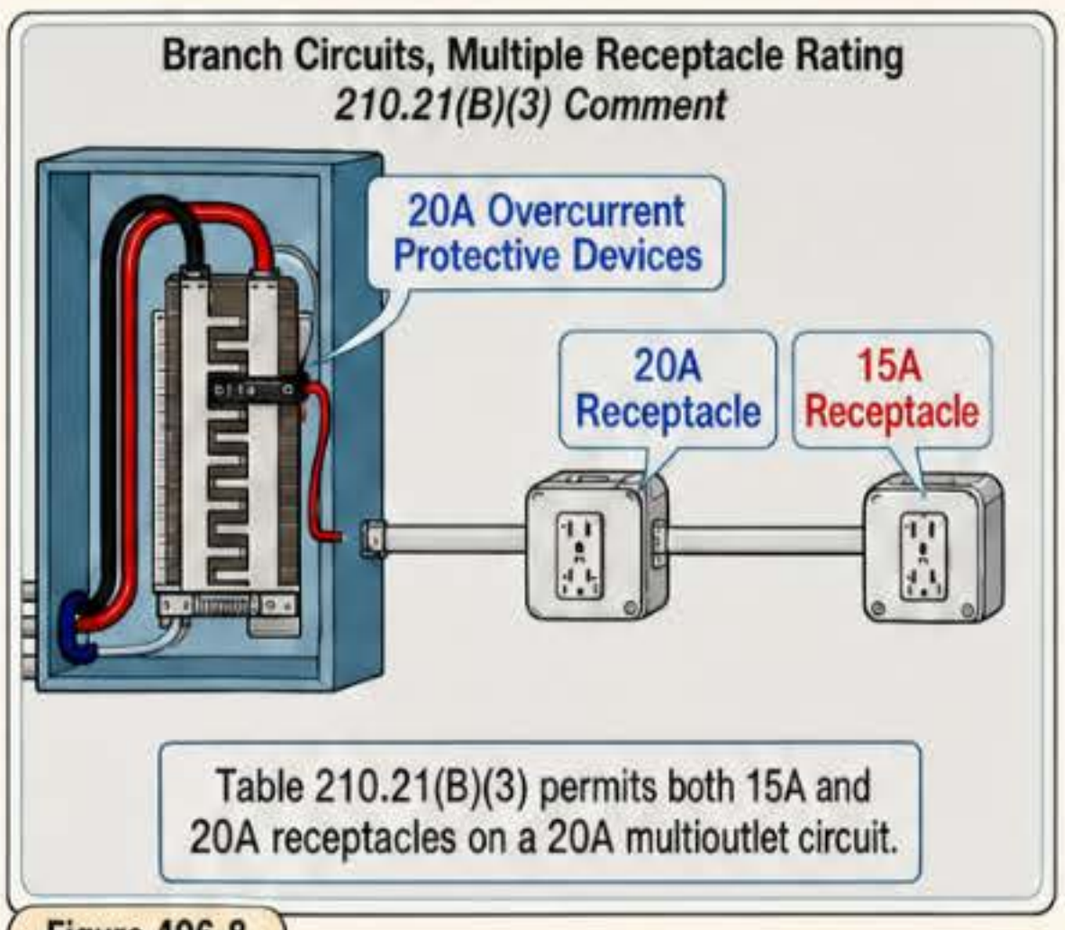


Figure 406-8

Table 210.21(B)(3) Receptacle Ratings	
Circuit Rating	**Receptacle Rating**
15A	15A
20A	15A or 20A
30A	30A
40A	40A or 50A
50A	50A

(C) Methods of Grounding. The equipment grounding conductor contacts of receptacles and cord connectors must be connected to the equipment grounding conductor of the circuit supplying the receptacle or cord connector. ▶ **Figure 406-9**

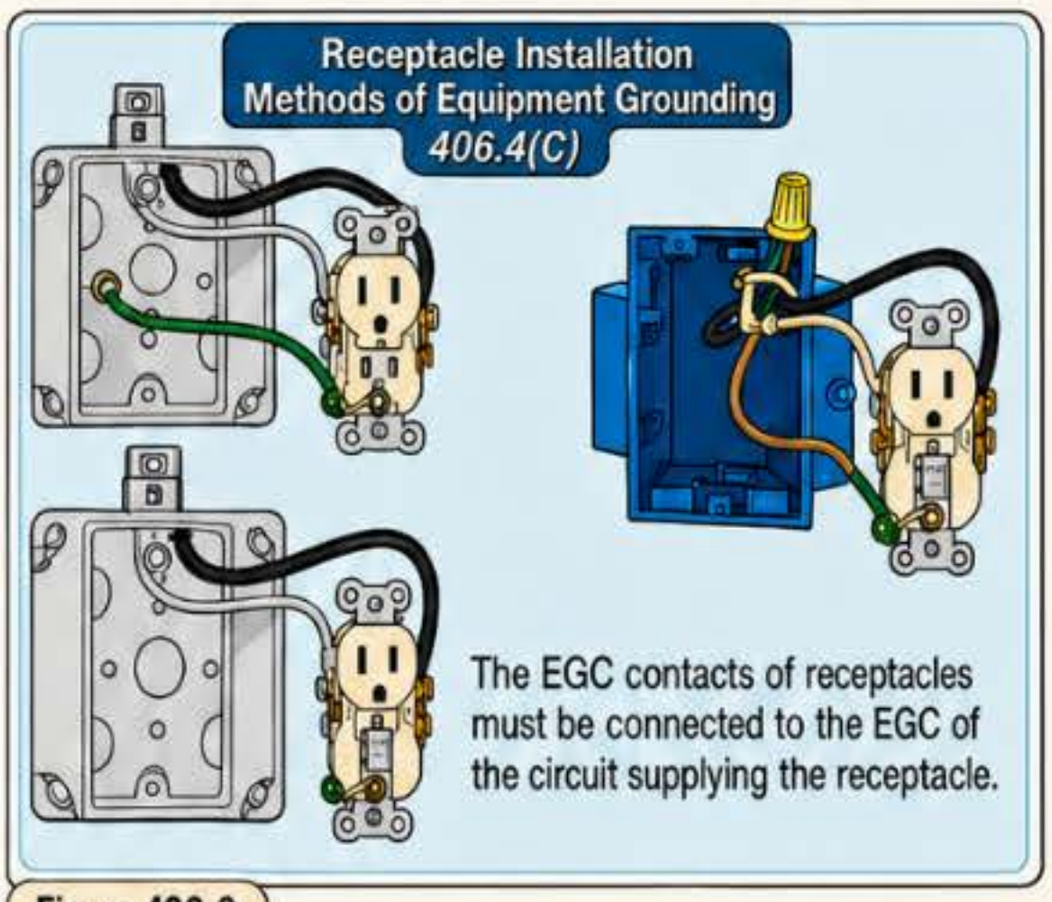


Figure 406-9

Note: For installation requirements for reducing electromagnetic interference, see 250.146(D).

The branch-circuit wiring method must include or provide an equipment grounding conductor to which the equipment grounding conductor contacts of the receptacle or cord connector are connected.

Note 1: See 250.118 for acceptable grounding means.

Note 2: For extensions of existing branch circuits, see 250.130.

(D) Receptacle Replacement. If the receptacle to be replaced is in a location that requires AFCI- and/or GFCI-type receptacles, they must be installed at a readily accessible location.

Scan this QR code for a video of Michael Hamilton explaining this topic; it's a sample from the videos that accompany this textbook.

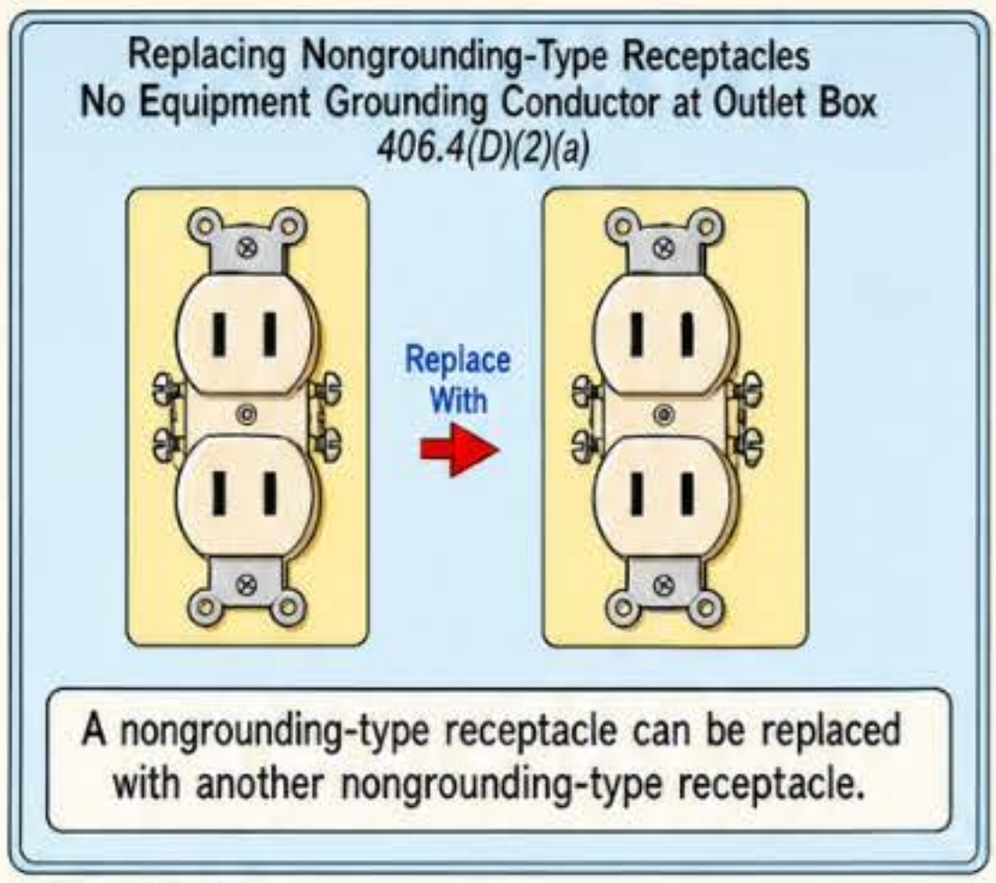
(1) Equipment Grounding Conductor in Outlet Box. If an equipment grounding conductor exists in an outlet box, replacement receptacles must be of the grounding type and the receptacle's grounding terminal must be connected to the circuit equipment grounding conductor in accordance with 406.11.

(2) No Equipment Grounding Conductor in Box. If an equipment grounding conductor does not exist in the outlet box, replacement receptacles can be a:

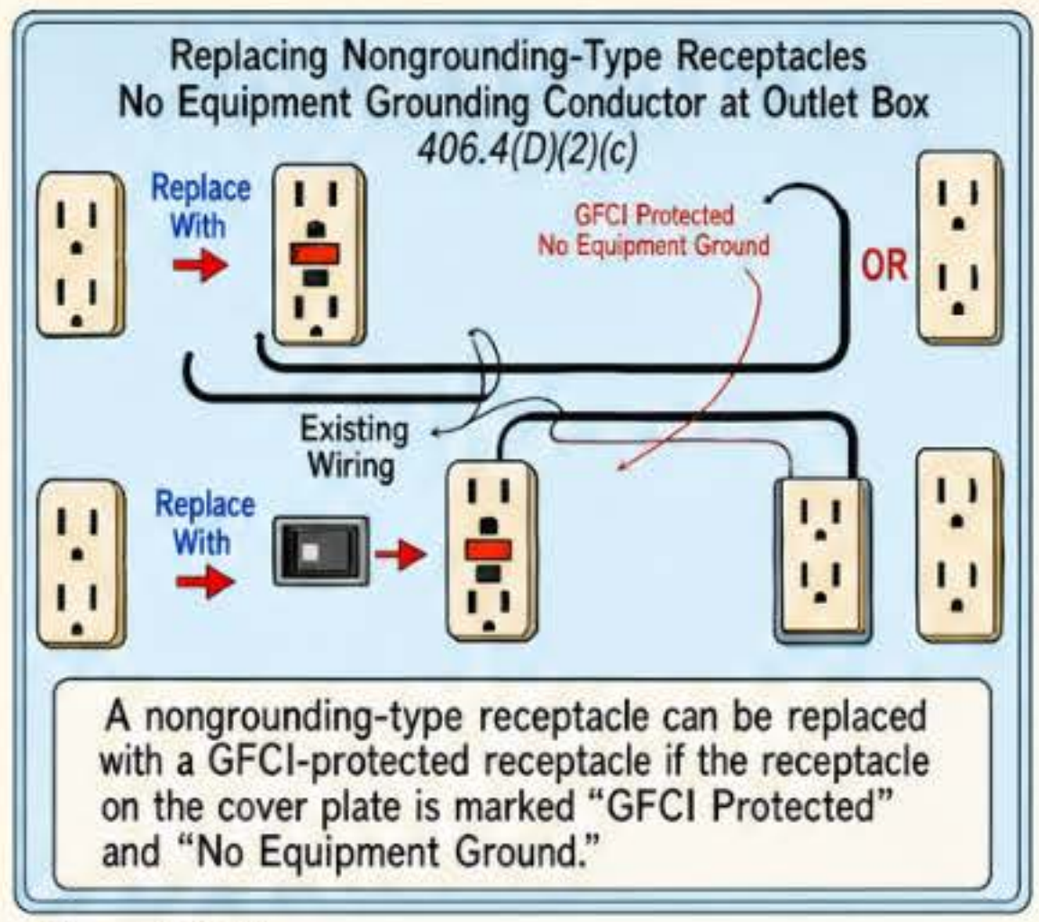
(a) Nongrounding-type receptacle. ▶ **Figure 406-10**

(b) GFCI-type receptacle if the receptacle or the cover plate is marked "No Equipment Ground." ▶ **Figure 406-11**

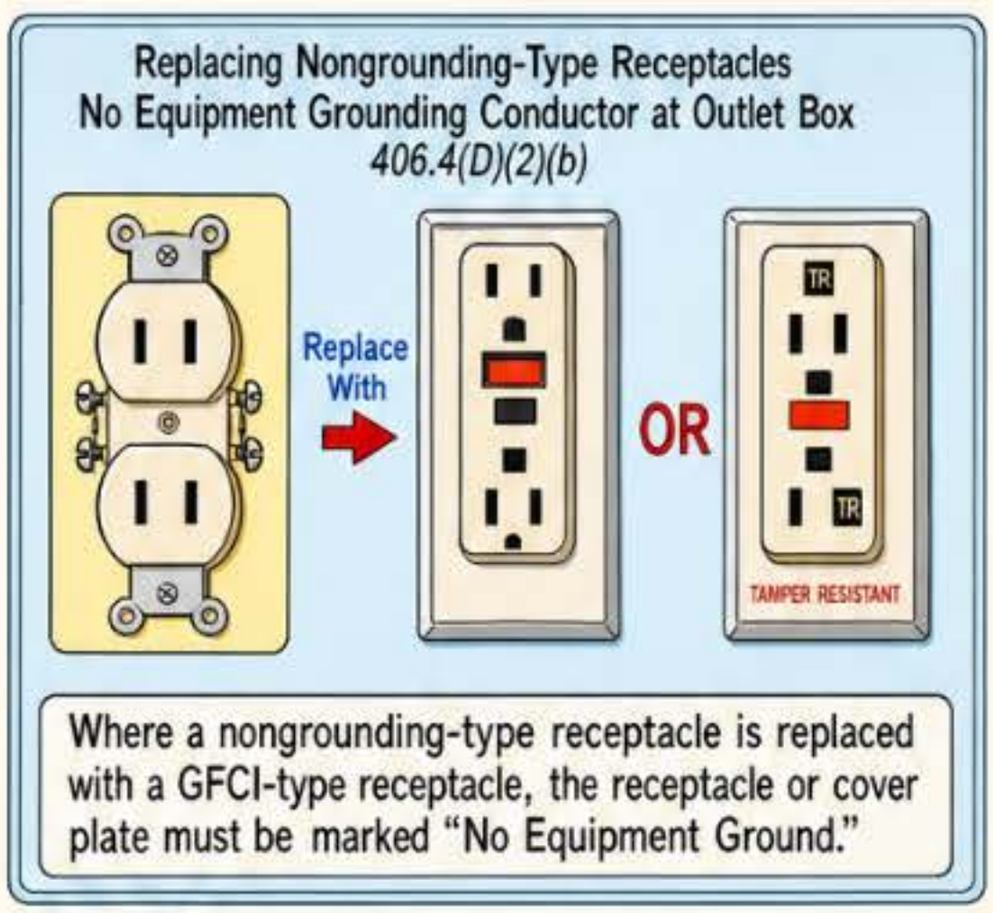
406.4 | Receptacles, Attachment Plugs, and Cord Connectors



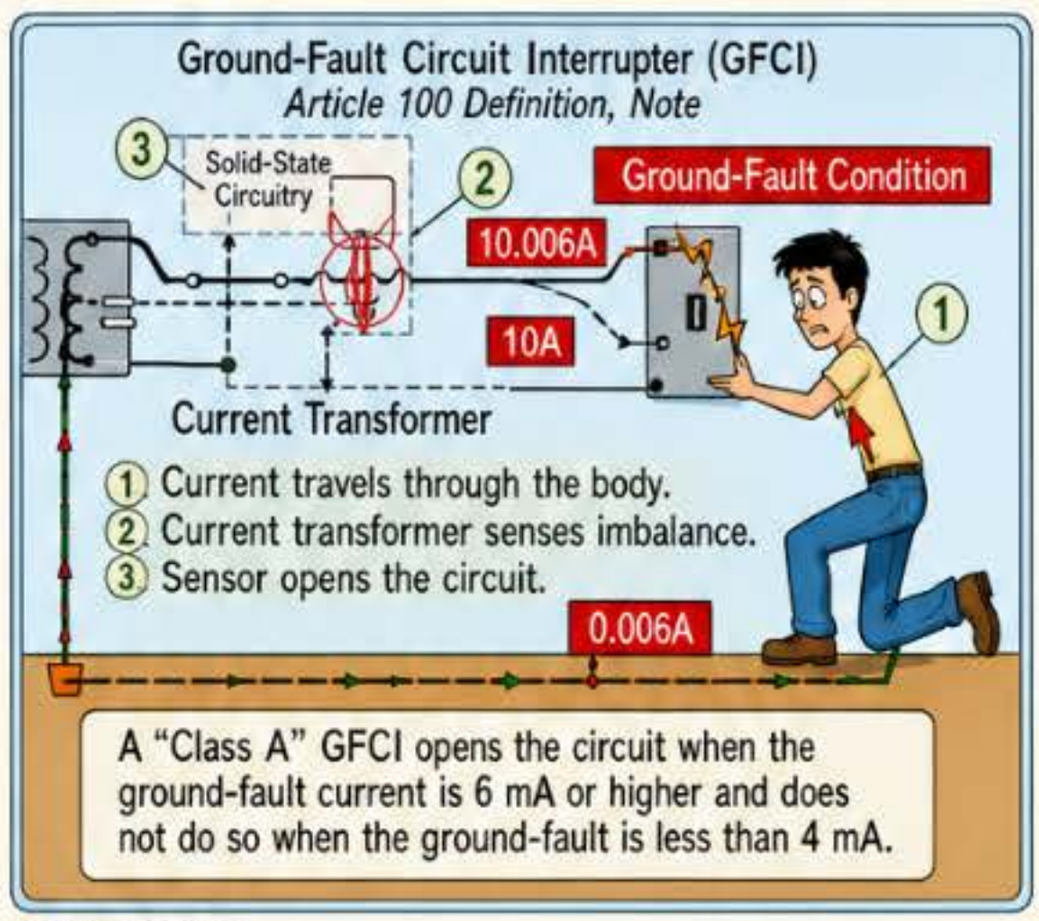
▶ Figure 406-10



▶ Figure 406-12



▶ Figure 406-11



▶ Figure 406-13

(c) GFCI-protected grounding-type receptacle if the receptacle or the cover plate is marked "GFCI Protected" and "No Equipment Ground." ▶ **Figure 406-12**

Author's Commentary:

GFCI protection works correctly on a two-wire circuit even without an equipment grounding conductor because the device senses current imbalance, not the presence of an equipment grounding conductor. See the Article 100 definition of "Ground-Fault Circuit Interrupter" in this textbook for more information.

— **Michael Hamilton**

Caution

The permission to replace nongrounding-type receptacles with GFCI-protected grounding-type receptacles does not apply to new receptacle outlets that extend from an existing outlet box that is not connected to an equipment grounding conductor. ▶ **Figure 406-14**

Note 1: Some equipment or appliance manufacturers require the branch circuit to the equipment or appliance to include an equipment grounding conductor.

Note 2: *See 250.114 for a list of cord-and-plug-connected equipment or appliances that require an equipment grounding conductor.*

Receptacles, Attachment Plugs, and Cord Connectors 406.5

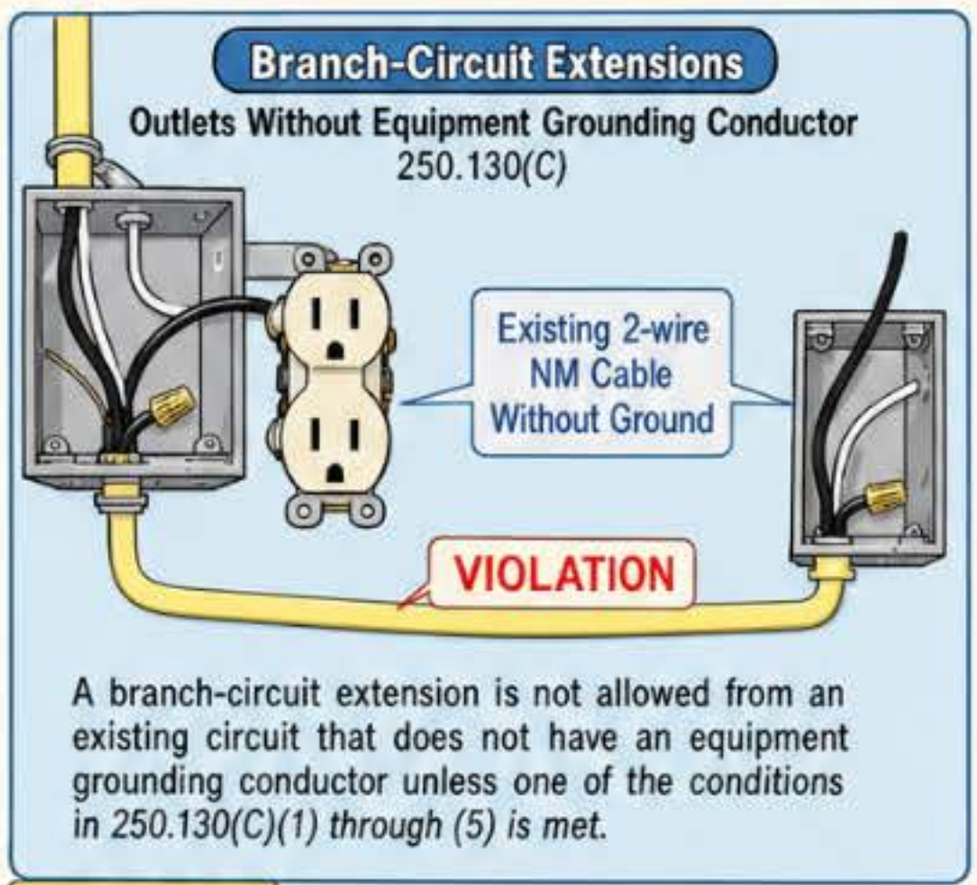


Figure 406-14

(3) GFCI Protection Required. Whenever an existing receptacle is replaced in a location where GFCI protection is required, the new or replacement receptacle must be GFCI protected.

Example: If the outlet box dimensions do not permit installation of the GFCI receptacle, an "GFCI protected" or "No Equipment Ground" sign in accordance with 406.4(D) may be used.

Author's Commentary:

- *See 210.8 for locations where GFCI protection is required.*
- *In areas where the NEC calls for GFCI protection, it can be provided by a GFCI circuit breaker, a GFCI receptacle, or a downstream GFCI device.*

— Michael Hamilton

(4) Arc-Fault Circuit Interrupters. *When a receptacle in a location that requires AFCI protection is replaced [210.12], the new or replacement receptacle must be one of the following:*

(1) A listed AFCI receptacle.

(2) A receptacle protected by a listed AFCI receptacle.

(3) A receptacle protected by an AFCI circuit breaker.

(5) Tamper-Resistant Receptacles. *When receptacles are replaced in areas where tamper resistance is required [406.12], the replacement receptacle(s) must be listed tamper resistant.*

(6) Weather-Resistant Receptacles. *When receptacles are replaced in areas where weather resistance is required, the replacement receptacles must be weather resistant in accordance with 406.9(A) and (B).*

(7) Controlled Receptacles. Automatically controlled receptacles must be replaced with an equally controlled receptacle. If automatic control is no longer needed, the replacement receptacle must be marked in accordance with 406.3(E).

406.5 Receptacle Mounting

Receptacles must be installed in outlet boxes that are firmly secured in place in accordance with 314.23.

Author's Commentary:

Boxes containing a hub may be supported using a flexible cord attached to fittings that prevent tension from being transmitted to splices or terminals [400.14 and 314.23(H)(1)].

Screws used to attach a receptacle to a box must be a type supplied with a listed receptacle or be machine screws with 32 threads per inch.

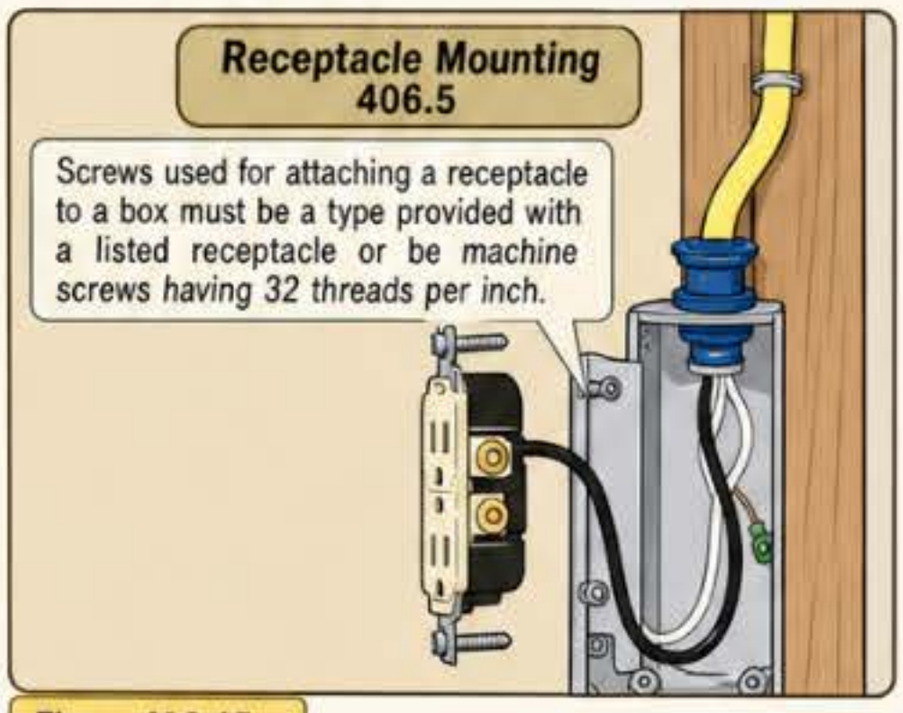


Figure 406-15

(A) Boxes Set Back. Receptacles installed in outlet boxes that are set back from the finished surface as permitted by 314.20 must be mounted so that the receptacle's mounting yoke is held firmly against the finished surface.

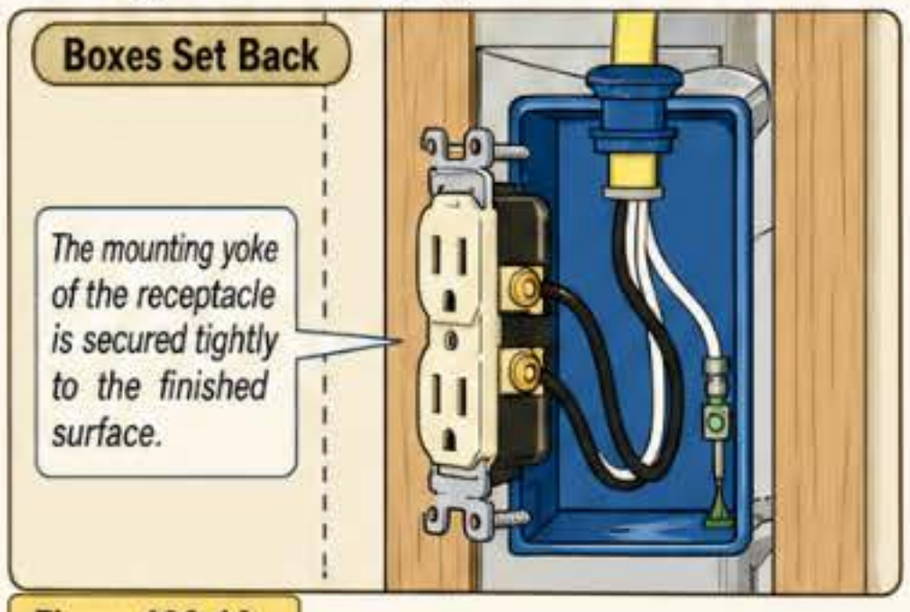
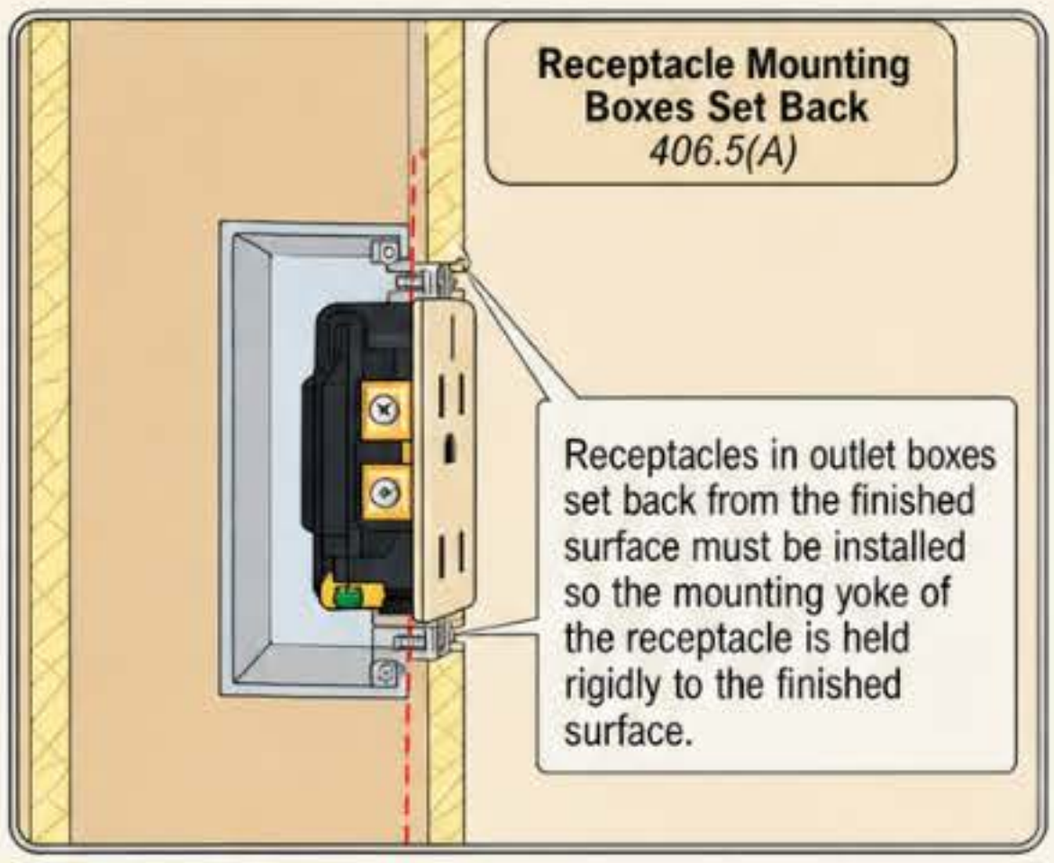


Figure 406-16



▲ Figure 406-16

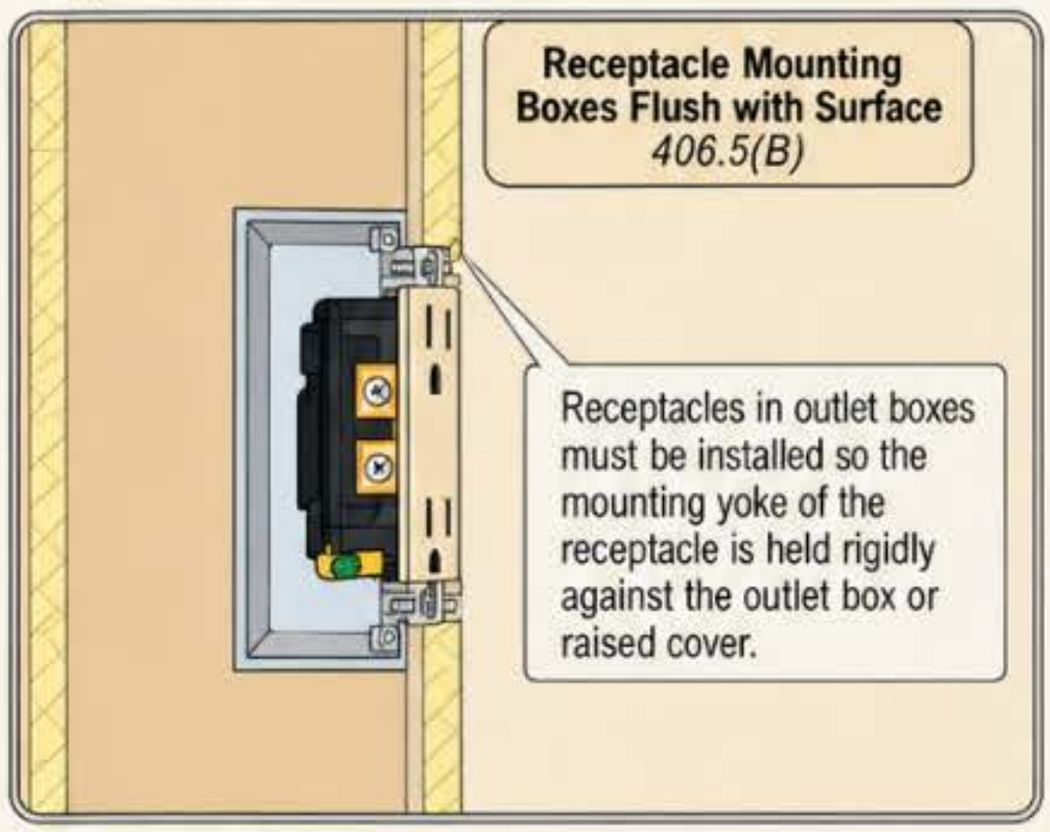
Author's Commentary:

Enclosures in walls or ceilings that are not made from combustible materials (for example, metal boxes) are permitted to sit back no more than ¼ in. behind the finished surface. For enclosures in walls or ceilings of combustible materials, the box must be flush with the finished surface [314.20]. No more than ⅛ in. of gap is allowed at the outlet box's edge [314.21].

— Michael Hamilton

(B) Boxes Flush with Surface. When receptacles are installed in outlet boxes that are flush with the finished surface, the mounting yoke must be firmly secured against that surface, whether the box is metal or has a raised cover.

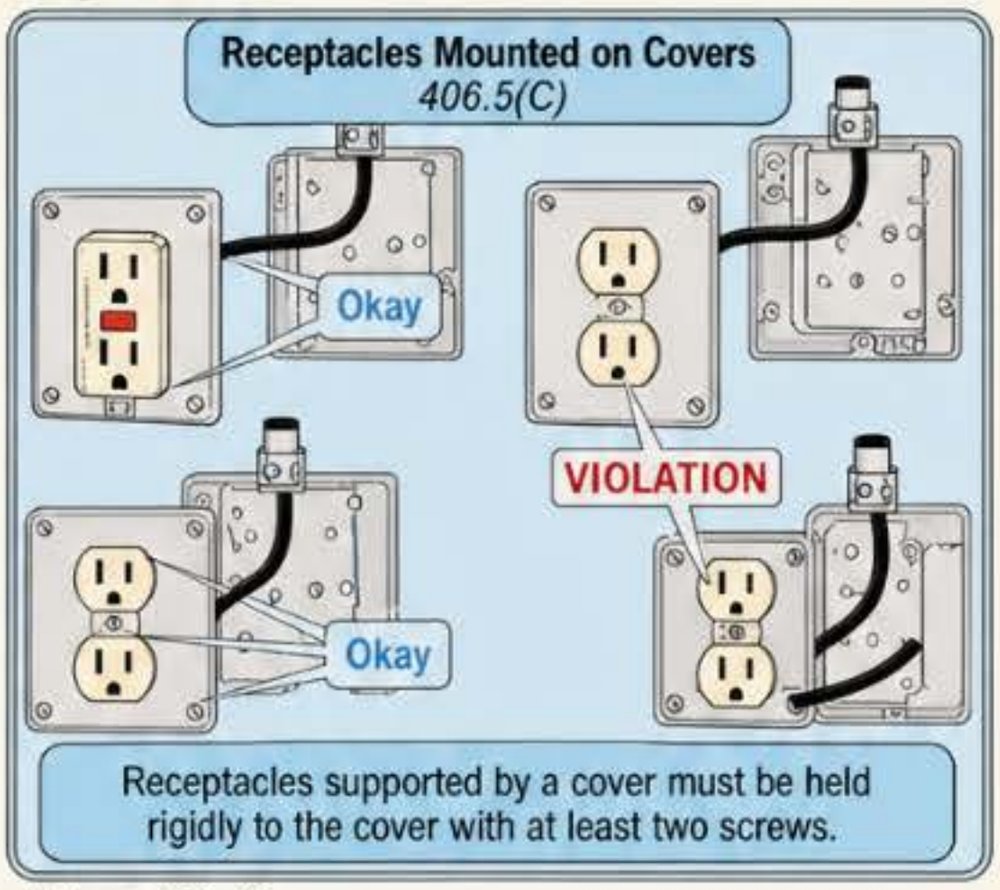
▲ Figure 406-17



▲ Figure 406-17

(C) Receptacles Mounted on Covers. Receptacles supported by a cover must be held rigidly to the cover with at least two screws.

▲ Figure 406-18



▲ Figure 406-18

(D) Position of Receptacle Faces. Receptacles must be flush with, or project from, the faceplates.

(E) Receptacles in Countertops. Receptacle assemblies installed in countertop surfaces must be listed for countertop applications.

▲ Figure 406-19

▲ Figure 406-19

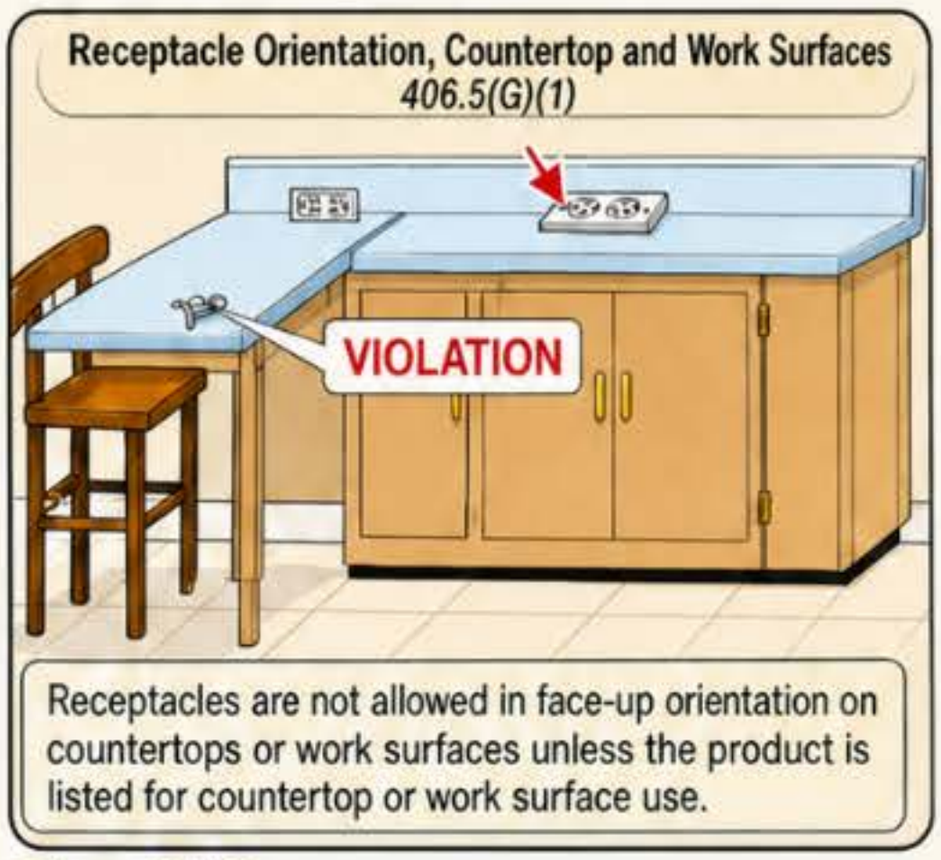
(F) Receptacles in Work Surfaces. Receptacle assemblies listed for work surfaces or countertops can be installed in a work surface.

(G) Receptacle Orientation.

RECEPTACLES, ATTACHMENT PLUGS, AND CORD CONNECTORS | 406.6

(1) Countertop and Work Surfaces. Receptacles must be positioned so they are not in a face-up orientation on countertops or work surfaces unless they are specifically listed for such installations.

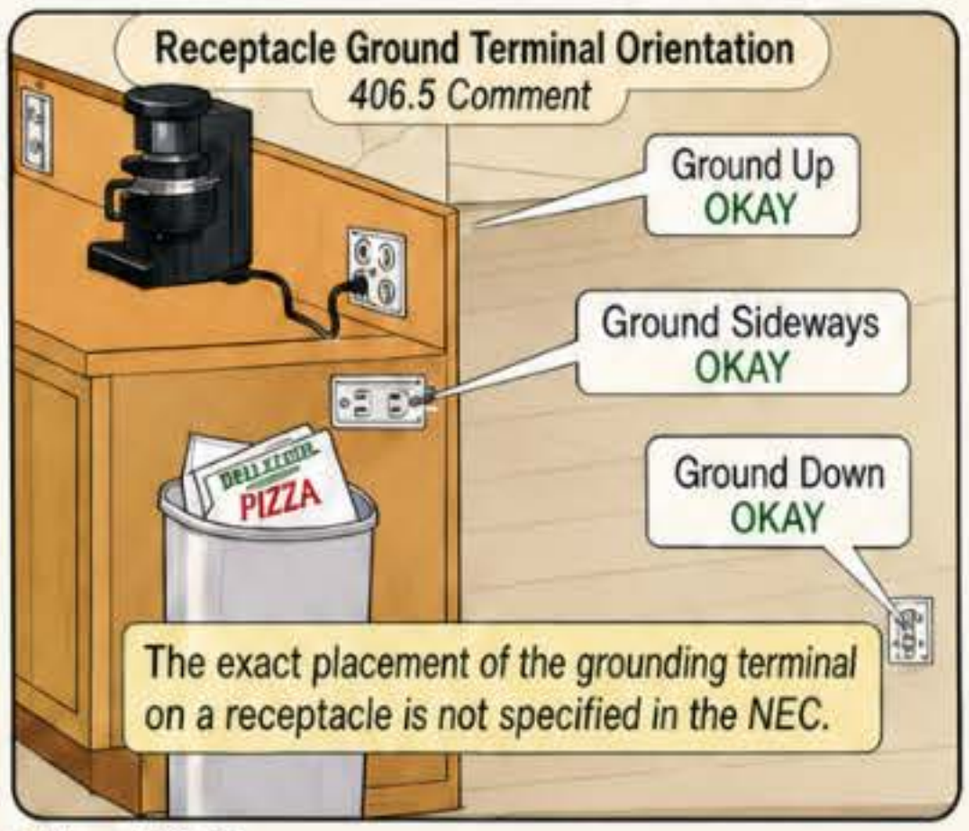
- **Figure 406–20**



▶ **Figure 406–20**

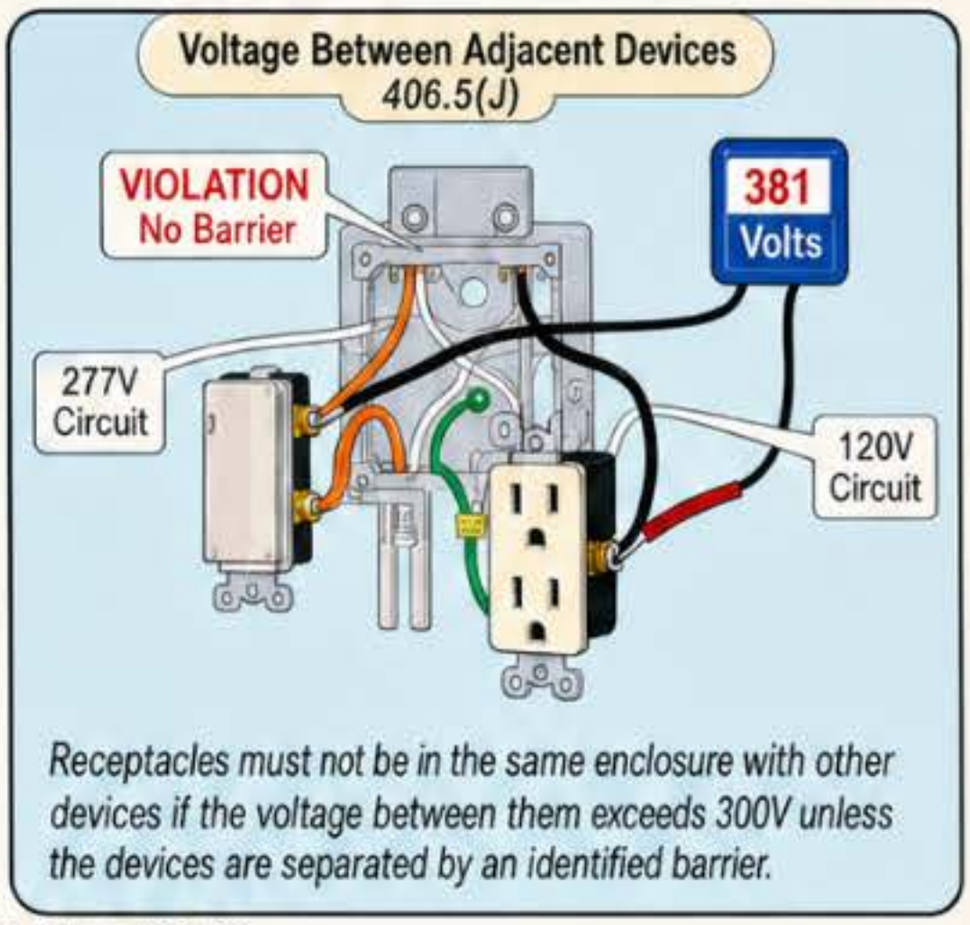
(2) Under Sinks. Receptacles are not permitted to be installed in a face-up position in the area beneath a sink.

> ***Author's Commentary:***
>
> - *The polarity of the grounding terminal of a receptacle is not addressed in the NEC so it may be placed on the top, bottom, or either side. Code changes over the years have suggested possible locations for the grounding terminal.*
>
> ***— Michael Hamilton***



▶ **Figure 406–21**

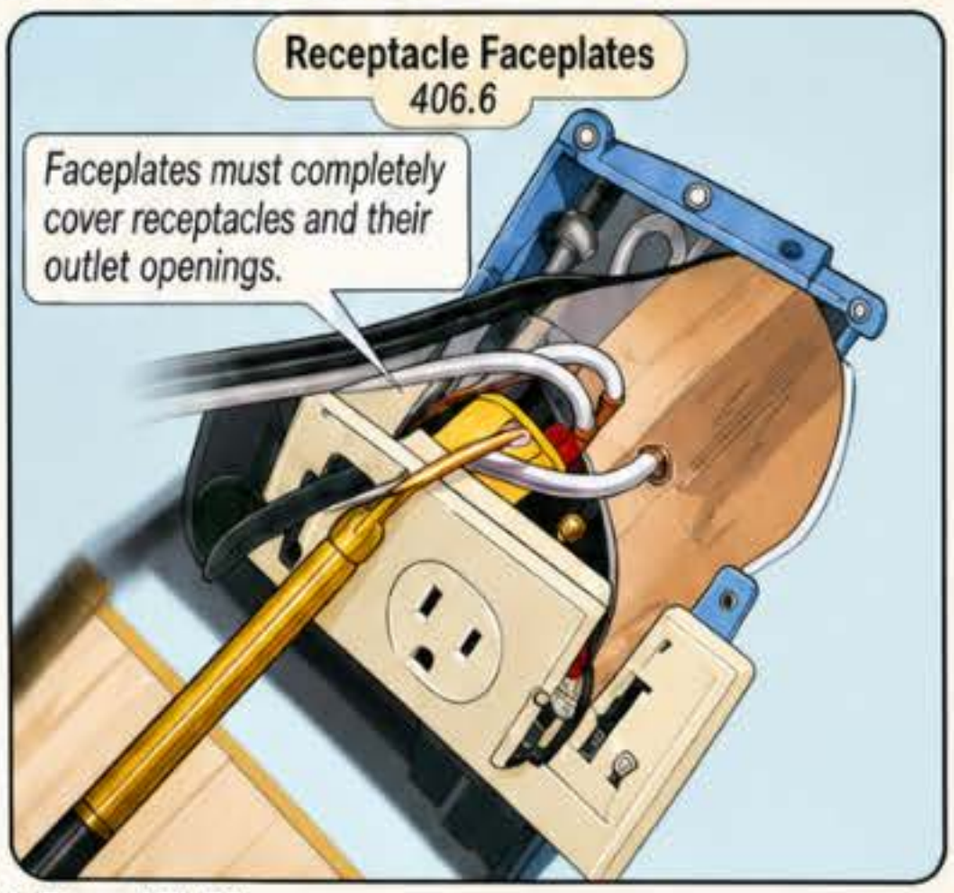
(J) Voltage Between Adjacent Devices. Receptacles must be enclosed with other switches or receptacles if the voltage between those devices exceeds 300V, unless they are installed in enclosures equipped with barriers identified for the purpose and are securely mounted between adjacent devices. • **Figure 406–22**



▶ **Figure 406–22**

406.6 Receptacle Faceplates

Faceplates for receptacles must fully enclose the outlet openings. • **Figure 406–23**



▶ **Figure 406–23**

(B) Grounding. Metal faceplates for receptacles must be connected to the equipment grounding conductor.

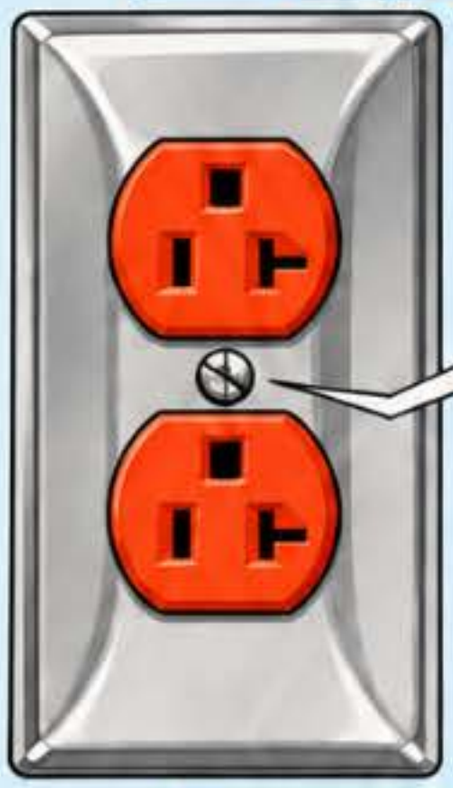
406.7 Receptacles, Attachment Plugs, and Cord Connectors

Author's Commentary:

The Code does not detail every step of how this is done. Instead, it provides the requirements that metal faceplates be fastened using metal cover screws to a metal outlet box or adapter ring so the assembly is appropriate for this application. (See Figure 406-24.)

— Michael Hamilton

Grounding Metal Faceplates
406.6(B) Comment



Receptacles with metal faceplates must be connected to an equipment grounding conductor.

An effective way to do this is by using a metal cover screw.

Figure 406-24

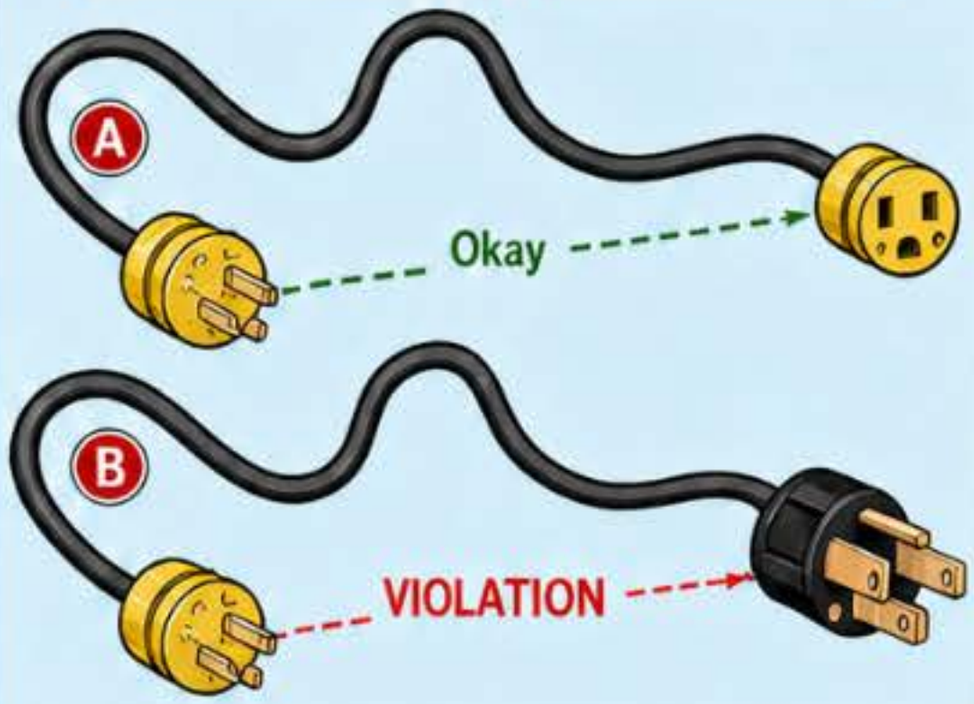
406.7 Attachment Plugs and Flanged Surface Devices

Attachment plugs and flange inlets must be listed for the intended use and clearly marked with the manufacturer's name or identification along with voltage and current ratings.

(B) No Energized Parts. Attachment plug prongs, blades, or pins must remain de-energized unless they are inserted into a properly energized receptacle or compatible cord connector. *(See Figure 406-25.)*

(D) Flanged Surface Inlet. *A flanged inlet must be installed so that the prongs, blades, or pins are not energized unless an energized cord connector is fully engaged. (See Figure 406-26.)*

Attachment Plugs, No Energized Parts
406.7(B)



Attachment plug prongs, blades, or pins must not be energized unless inserted into an energized receptacle or cord connector.

Figure 406-25

Flanged Surface Inlets
406.7(D)

A flanged surface inlet must be installed so the prongs, blades, or pins are not energized unless engaged by an energized cord connector.

Figure 406-26

406.9 Receptacles in Damp or Wet Locations

(A) Damp Locations. *Receptacles in damp areas must be of the weather-resistant (WR) type and installed in an enclosure suited for wet conditions, or installed only when the attachment plug is not installed (damp location rated), or when the cover is closed (wet location rated). A damp location is any place such as under roofed porches, canopies, marquees, and the like where the receptacle is protected from direct rainfall or other water runoff. (See Figure 406-27.)*

Receptacles, Attachment Plugs, and Cord Connectors 406.9

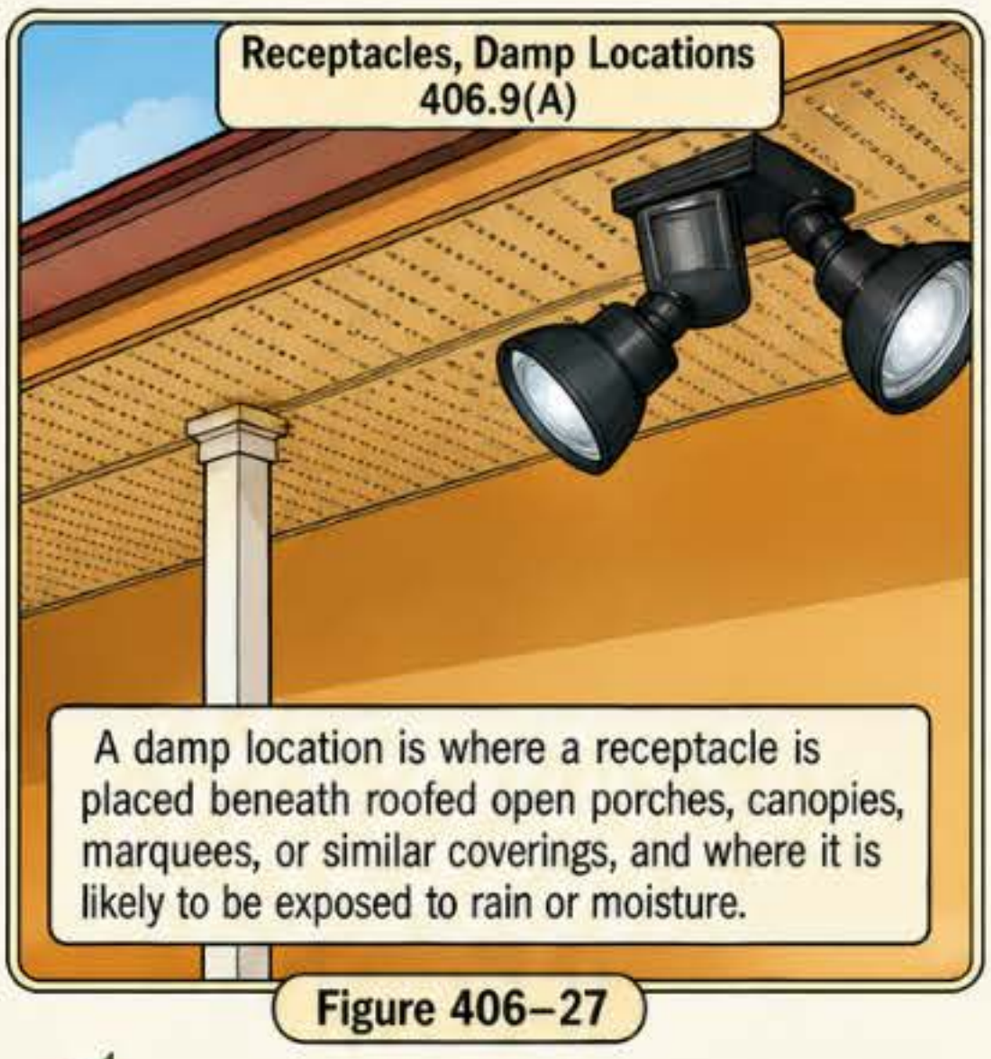


Figure 406–27

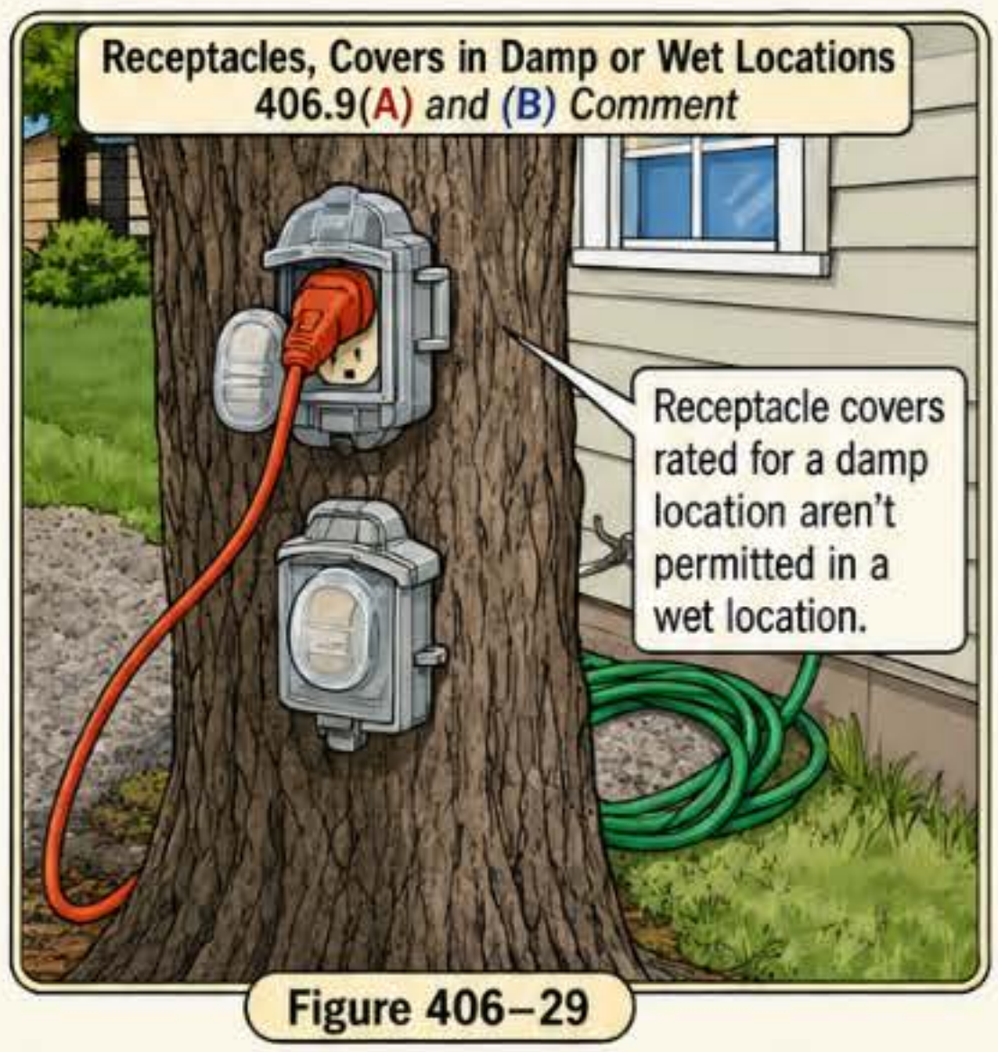


Figure 406–29

Author's Commentary:

- *The key distinction between the cover for a 15A or 20A receptacle in a damp location [406.9(A)] and in a wet location [406.9(B)] is whether the installation uses an attachment plug.*

— Michael Hamilton

Refer to **Figure 406–28** and **Figure 406–29.**

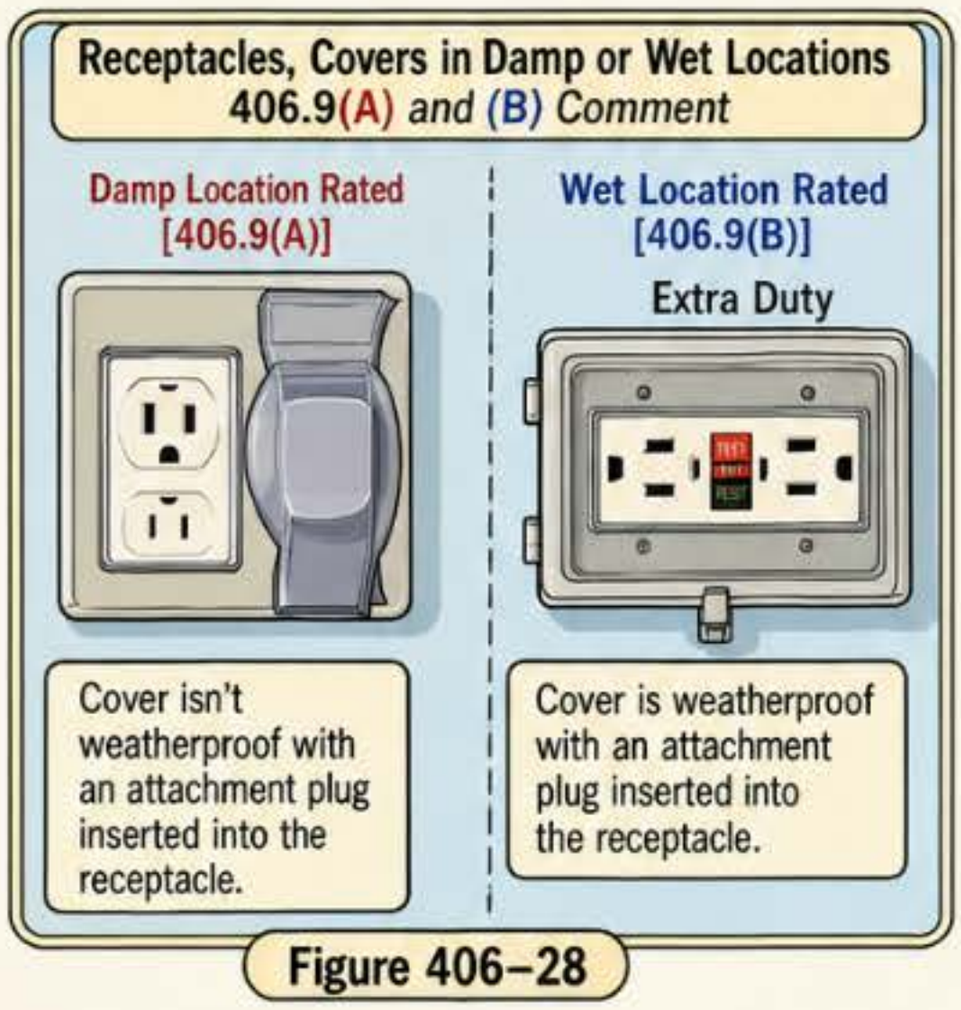


Figure 406–28

(B) Wet Locations.

(1) 15A and 20A Receptacles. Fifteen-ampere and twenty-ampere receptacles installed in a wet location must be placed inside an enclosure that remains weatherproof when an attachment plug is inserted in an outlet box identified as "extra duty."

Refer to **Figure 406–30** and **Figure 406–31.**

Figure 406–30

406.9 | RECEPTACLES, ATTACHMENT PLUGS, AND CORD CONNECTORS

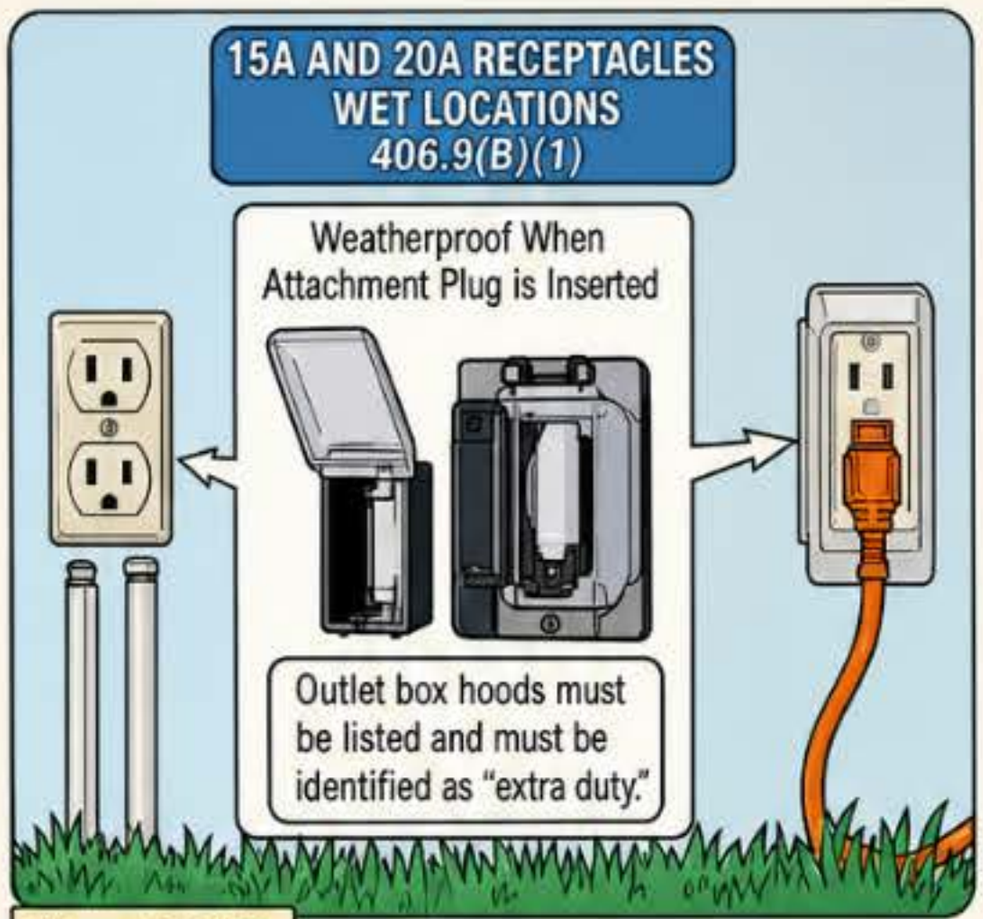


Figure 406–31

Nonlocking-type 15A and 20A receptacles in a wet location must be listed as the weather-resistant type. **Figure 406–32**

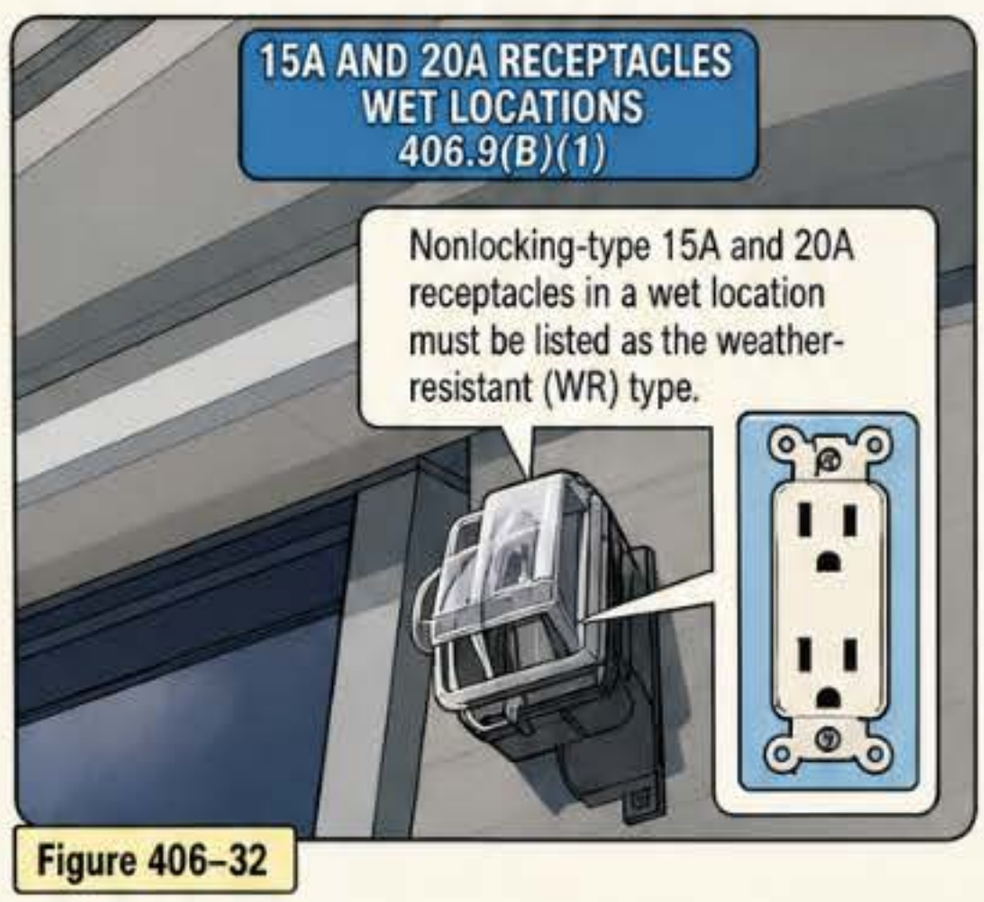


Figure 406–32

Author's Commentary:

- *Exposed plastic surface material of weather-resistant receptacles must have UV resistance to ensure deterioration from sunlight either does not take place or is minimal. In testing, receptacles are subjected to temperatures cycling from very cold to very warm conditions, and then subjected to additional dielectric testing. The rapid transition from the cold to warm temperatures changes the relative humidity and moisture content on the device, and the dielectric test ensures this will not create a breakdown of the insulation properties.*
- *A wet location is an area subject to saturation with water and unprotected locations exposed to weather [Article 100].*

— Michael Hamilton

(2) Other Receptacles. Receptacles rated 30A or more installed in a wet location must comply with (a) or (b).

(a) Unattended While in Use. A receptacle where the load is not attended while in use must be in an enclosure that is weatherproof when an attachment plug is inserted.

(b) Attended While in Use. A receptacle that will only be used while someone is nearby, such as one used with portable tools, can use an enclosure that is weatherproof when the cover is closed.

(C) Bathtub and Shower Space. Receptacles are not allowed to be installed within a zone measured 3 ft horizontally and 8 ft vertically from the top of the bathtub rim or shower stall threshold. *The zone is all-encompassing and includes the space directly over the tub or shower stall.* **Figure 406–33** and **Figure 406–34**

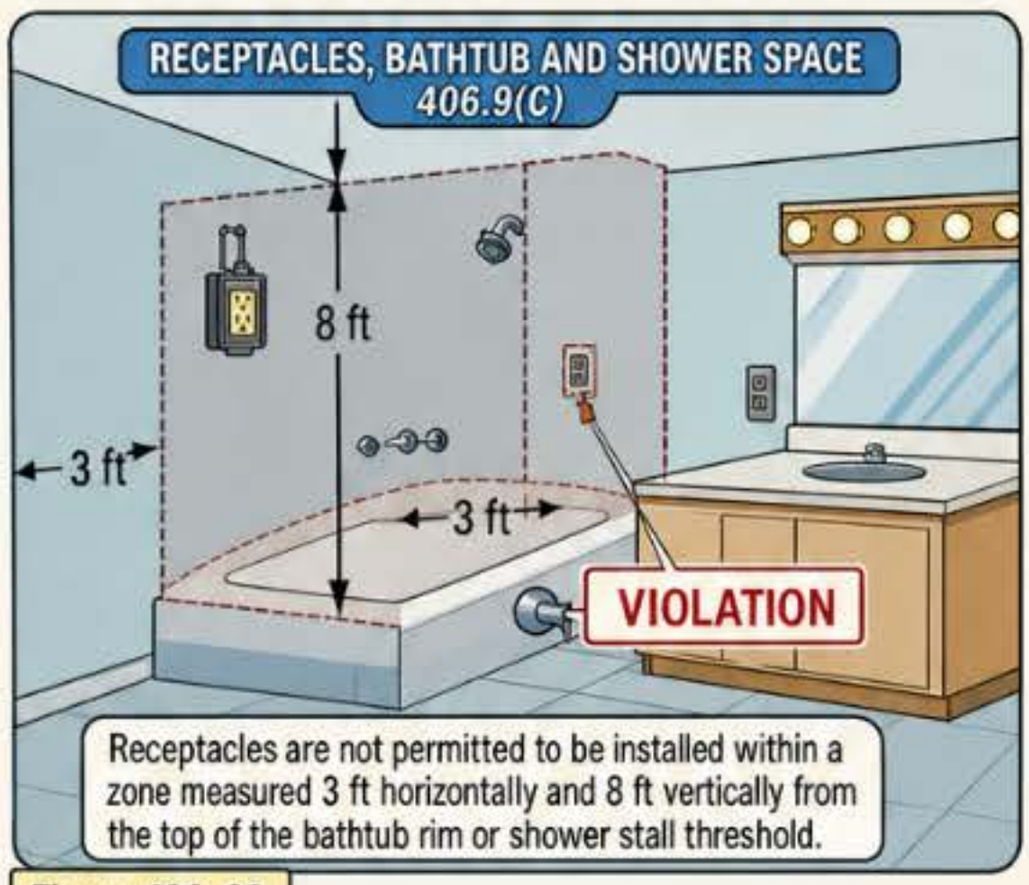
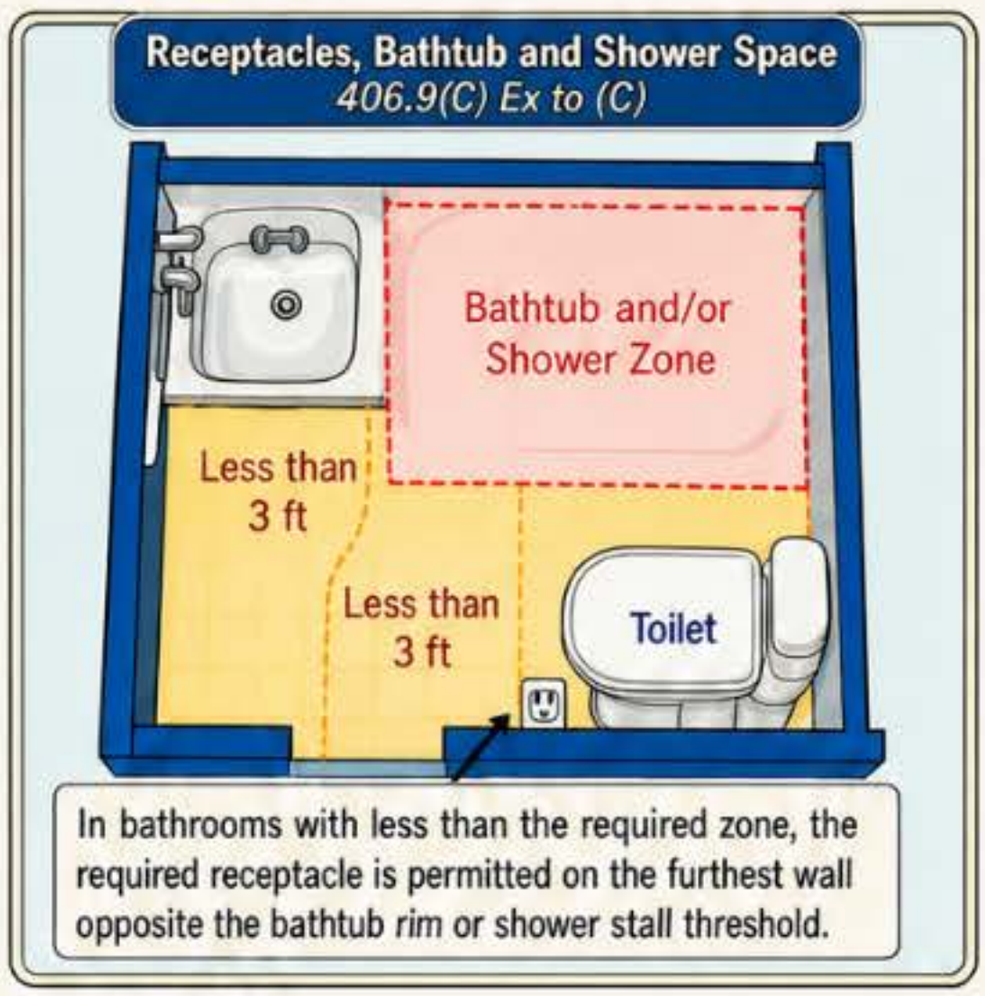


Figure 406–33

Figure 406–34

Receptacles, Attachment Plugs, and Cord Connectors | 406.12

Ex to (C): In bathrooms with less than the required zone, a receptacle is permitted on the furthest wall opposite the bathtub rim or shower stall threshold. • **Figure 406-35**



▲ **Figure 406-35**

406.11 Connecting Receptacle Grounding Terminal to Equipment Grounding Conductor

The grounding terminal of receptacles must be connected to an equipment grounding conductor in accordance with 250.146.

406.12 Tamper-Resistant Receptacles

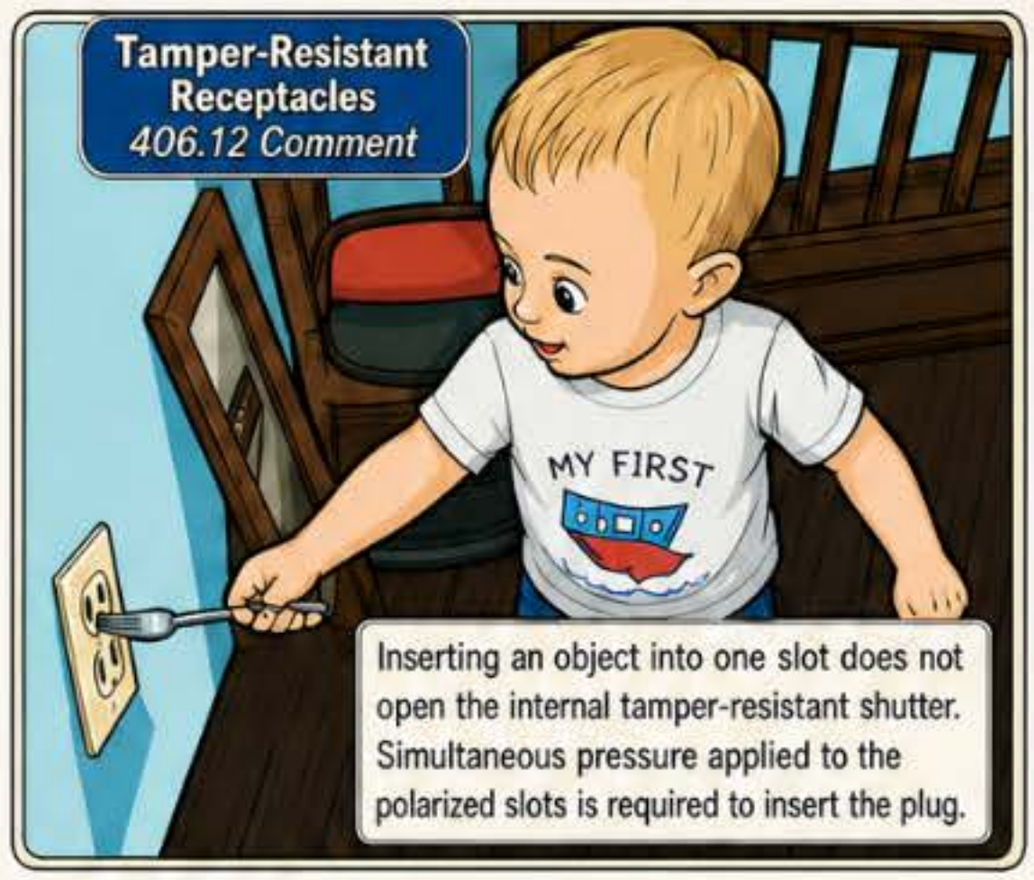
Nonlocking-type 15A and 20A receptacles in the following areas must be tamper resistant "TR".

> ***Author's Commentary:***
>
> *Inserting an object into one slot of a tamper-resistant receptacle does not open the internal shutter mechanism. Simultaneous pressure applied to the polarized slots is required to insert the plug.* • ***Figure 406-36***
>
> *— Michael Hamilton*

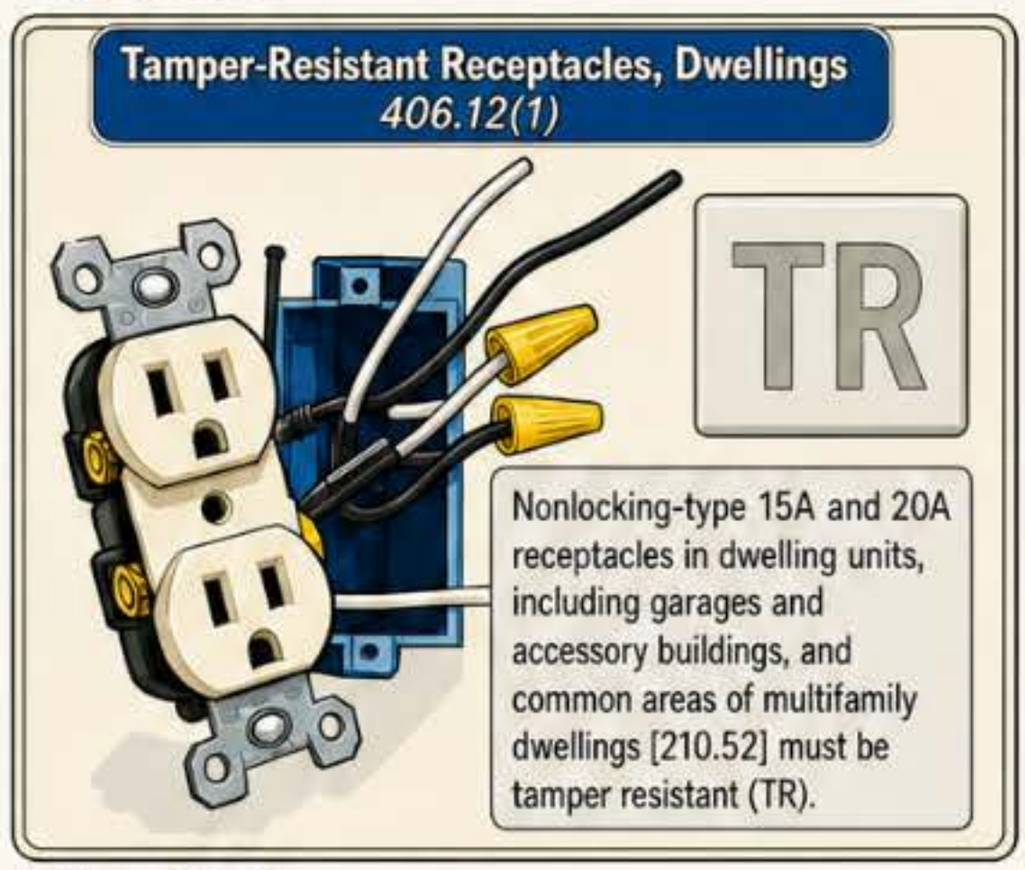
(1) Dwelling units, including attached and detached garages and accessory buildings, and common areas of multifamily dwellings specified in 210.52 and 550.13. • **Figure 406-37**

(2) Hotel and motel guest rooms and guest suites, and their common areas.

(3) Childcare facilities.



▲ **Figure 406-36**



▲ **Figure 406-37**

> ***Author's Commentary:***
>
> *A childcare facility is a building or portions of a building used for educational, supervision, or personal care services for five or more children seven years in age or less [406.2].*
>
> *— Michael Hamilton*

(4) Preschools and education facilities.

(5) Business offices, corridors, waiting rooms, and the like in clinics, medical and dental offices, and outpatient facilities.

(6) Places of assembly, transportation terminals, gymnasiums, skating rinks, and auditoriums.

(7) Dormitory units.

(8) Assisted living facilities.

406.12 | Receptacles, Attachment Plugs, and Cord Connectors

Ex: *Installations in the following situations do not need to be tamper resistant:*

(1) Receptacles mounted more than 5½ ft above the floor. ▶ **Figure 406–38**

(2) Receptacles that are integral parts of a luminaire or other equipment.

(3) A receptacle located in a dedicated space for an appliance that under normal use cannot be easily moved.

(4) Where non-grounding receptacles are installed as allowed in 406.4(D)(2)(a)8.

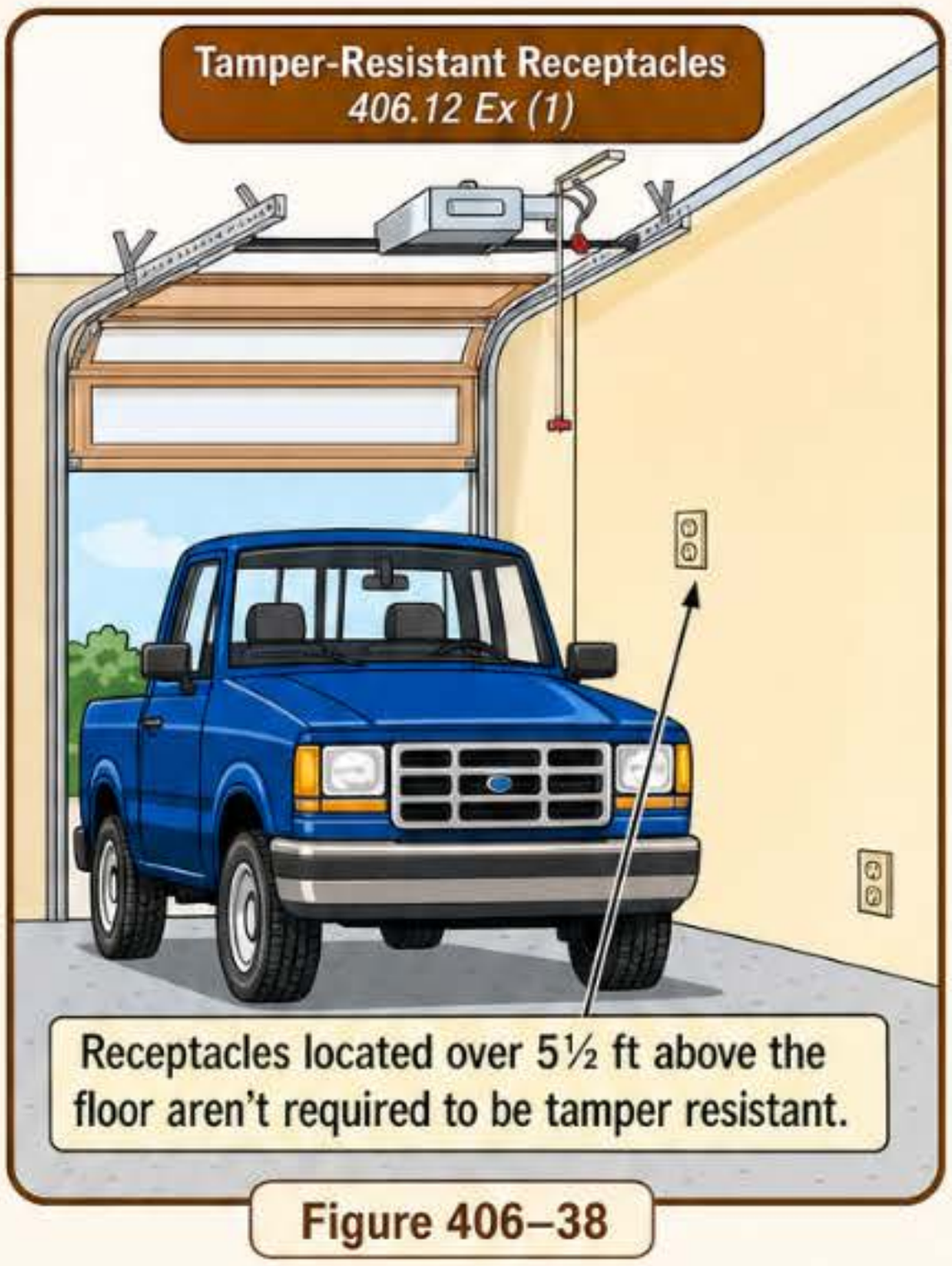


Figure 406–38

ARTICLE 408 SWITCHBOARDS AND PANELBOARDS

Introduction to Article 408—Switchboards and Panelboards

Article 408 establishes the rules for switchboards and panelboards used to distribute electrical power and operate lighting systems. While studying this article, keep these key ideas in mind:

- One primary objective of Article 408 is to eliminate the risk of accidental contact with live parts by current-carrying conductors, whether by people or by equipment.
- The circuit directory of a panelboard must clearly indicate what each circuit is for or which device it supplies.
- A solid understanding of the detailed grounding and overcurrent protection rules is essential for panelboards.

Part I. General

408.1 Scope

Article 408 specifies the requirements for switchboards and panelboards that govern power distribution and lighting circuits. See **Figure 408–1.**

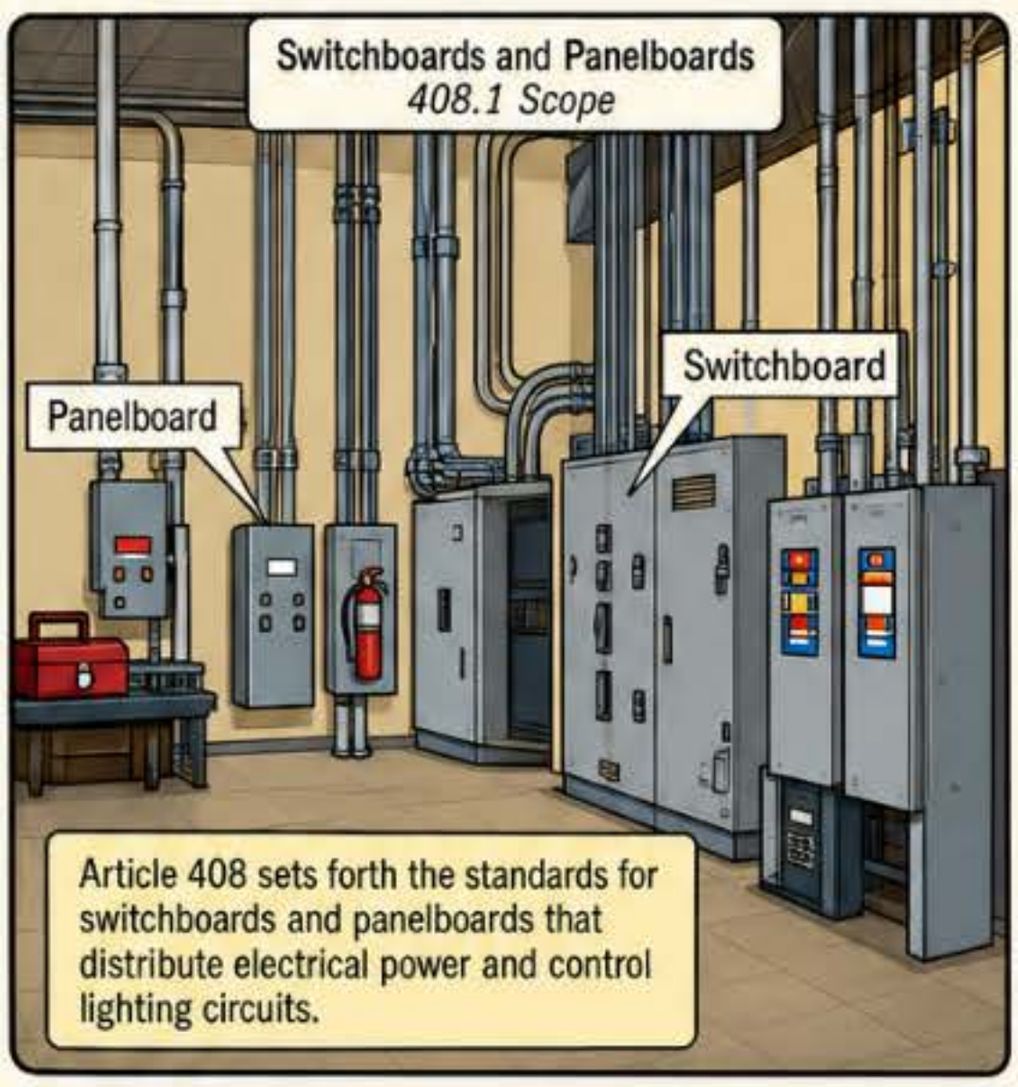


Figure 408–1

408.3 Arrangement of Busbars and Conductors

(E) Bus Arrangement.

(1) Alternating-Current Phase Arrangement. Panelboards equipped with a 4-wire, delta-connected, three-phase (high-leg) system must position the high-leg conductor (the one connected to the "B" phase at 208V to ground) on the "B" phase terminal of the panelboard. See **Figure 408–2.**

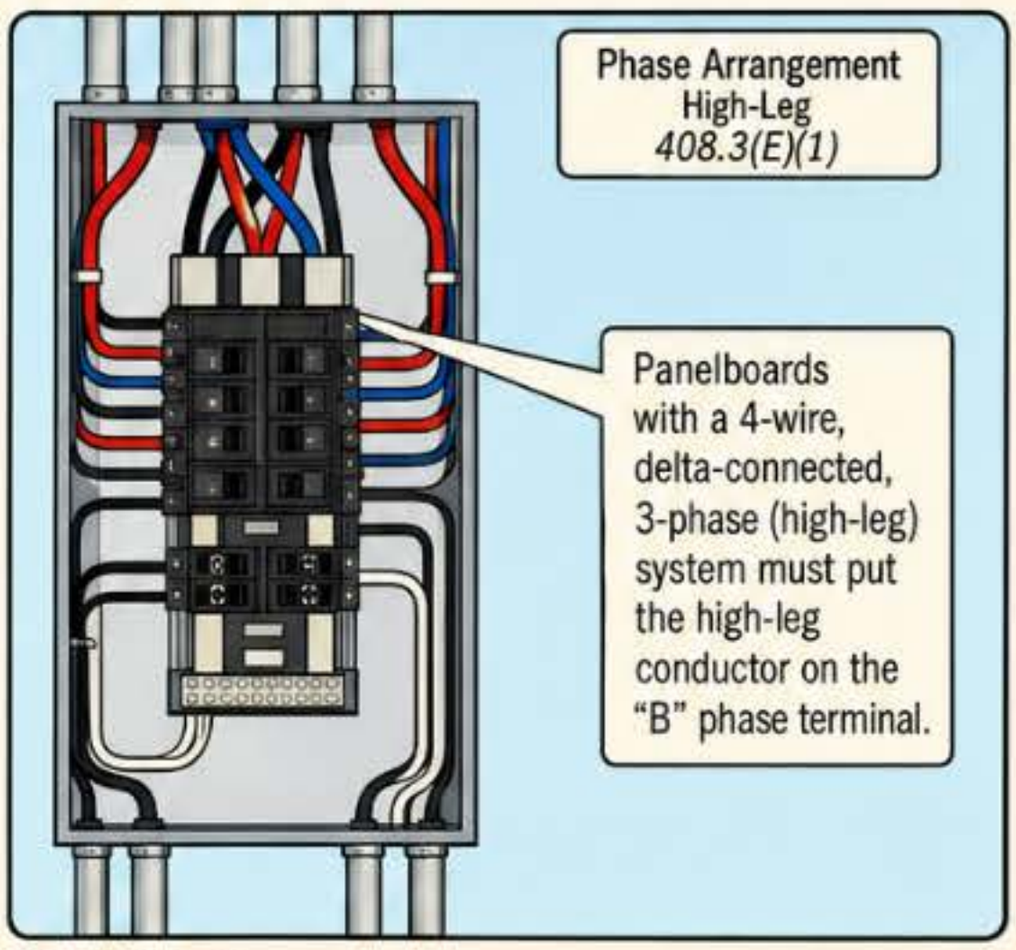


Figure 408–2

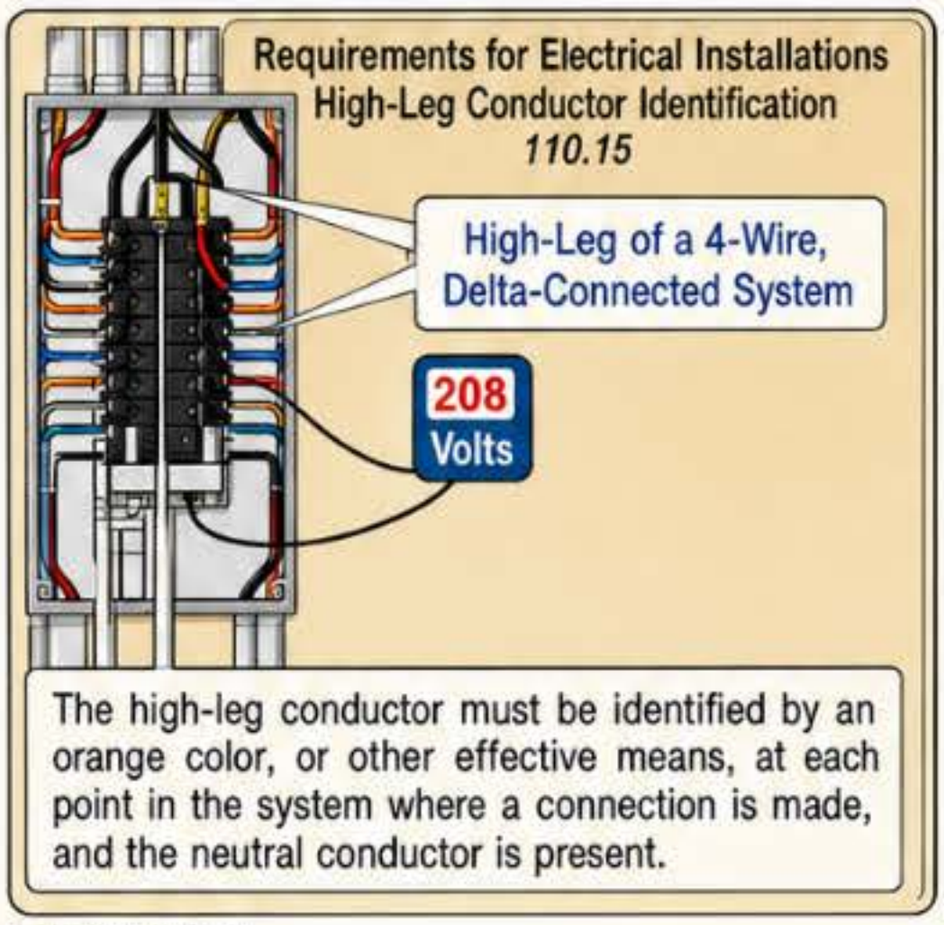
Author's Commentary:

- *Consult Article 100 for the official definitions of "Switchboard" and "Panelboard."*

— Michael Hamilton

408.4 Switchboards and Panelboards

Note: This rule applies to a four-wire, delta-connected, three-phase system. At the midpoint of one phase winding of the secondary, the conductor delivering 208V to ground (the high leg) must be permanently identified by orange coloring or another approved effective method on the insulation. Such identification has to be applied at each location where a neutral connection is made, if the neutral conductor is present [230.56].



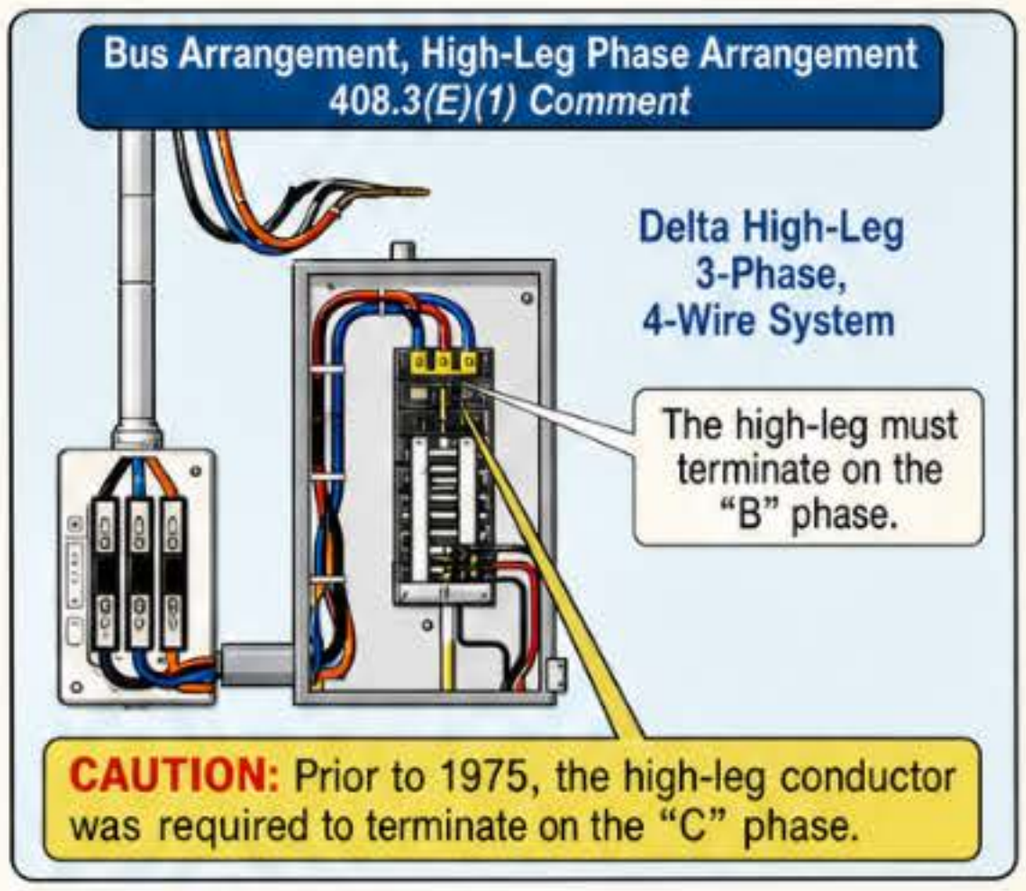
▶ Figure 408–3

Warning

The ANSI standard for meter equipment requires the high-leg conductor (208V to neutral) to terminate on the "C" (right) phase of the meter socket enclosure. This is because the demand meter needs 120V and it gets it from the "B" phase. ▶ Figure 408–4

Warning

When replacing equipment in existing facilities that contain a high-leg conductor, use care to ensure the high-leg conductor is replaced in the same phase position. Prior to 1975, the *high-leg conductor was required to terminate on the "C" phase of panelboards and switchboards. Failure to re-terminate the high-leg in accordance with the existing installation can result in 120V circuits being inadvertently connected to the 208V high-leg, with disastrous results.* ▶ Figure 408–4

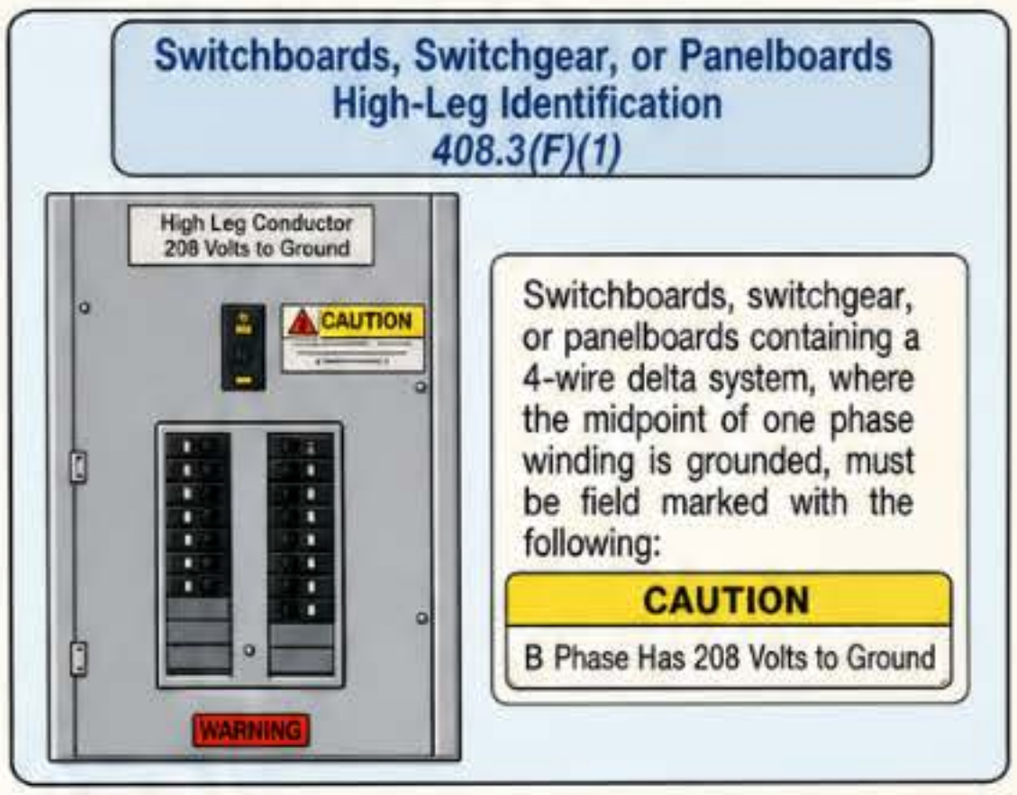


▶ Figure 408–4

(F) Switchboard and Panelboard Identification.

(1) High-Leg Identification. A switchboard or panelboard containing a four-wire, delta-connected system where the midpoint of one phase winding is grounded, must have a label that is legibly and permanently field marked as follows:

"CAUTION _____ PHASE HAS _____ VOLTS TO GROUND" ▶ Figure 408–5

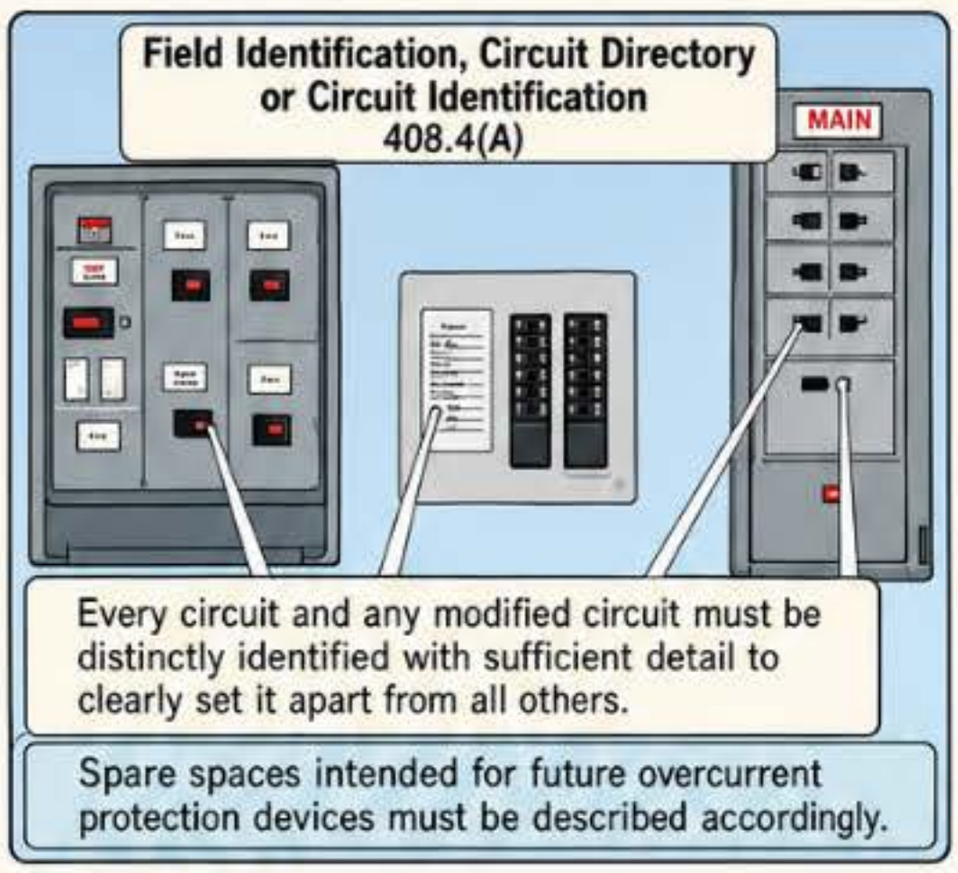


▶ Figure 408–5

408.4 Field Identification

(A) Circuit Directory or Circuit Identification. Circuits and circuit modifications must be legibly identified as to their clear, evident, and specific purpose. Spare positions that contain unused overcurrent devices must be described accordingly. ▶ Figure 408–6

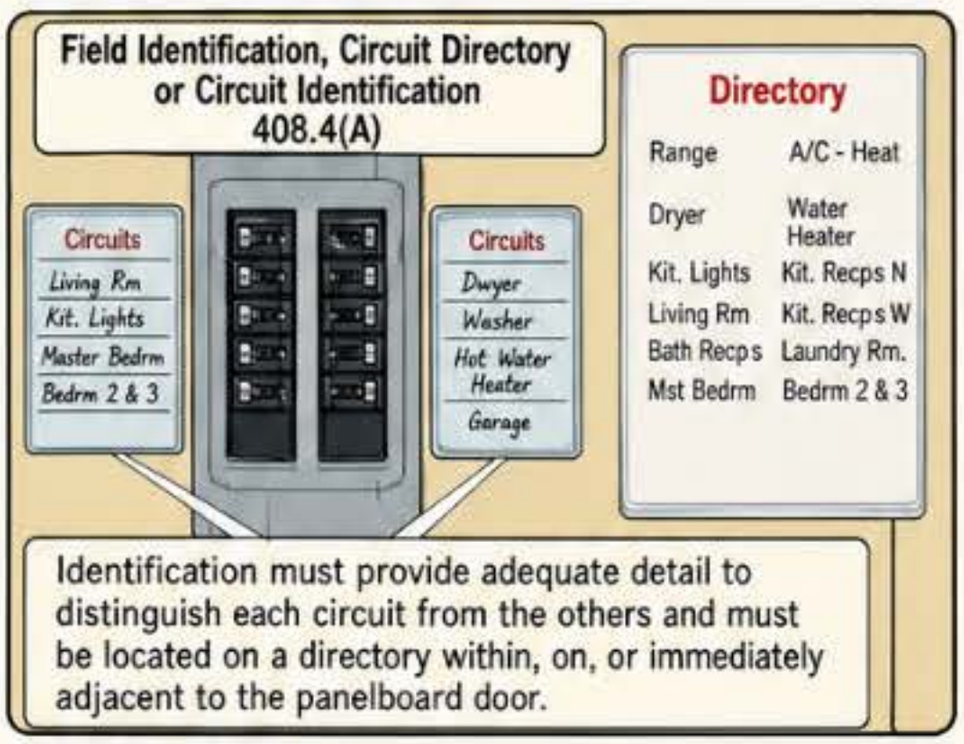
SWITCHBOARDS AND PANELBOARDS 408.5



▼ **Figure 408-6**

Identification must give enough information to distinguish each circuit from the rest, and the identification must appear on a directory within the panelboard face, inside the door, or immediately next to it.

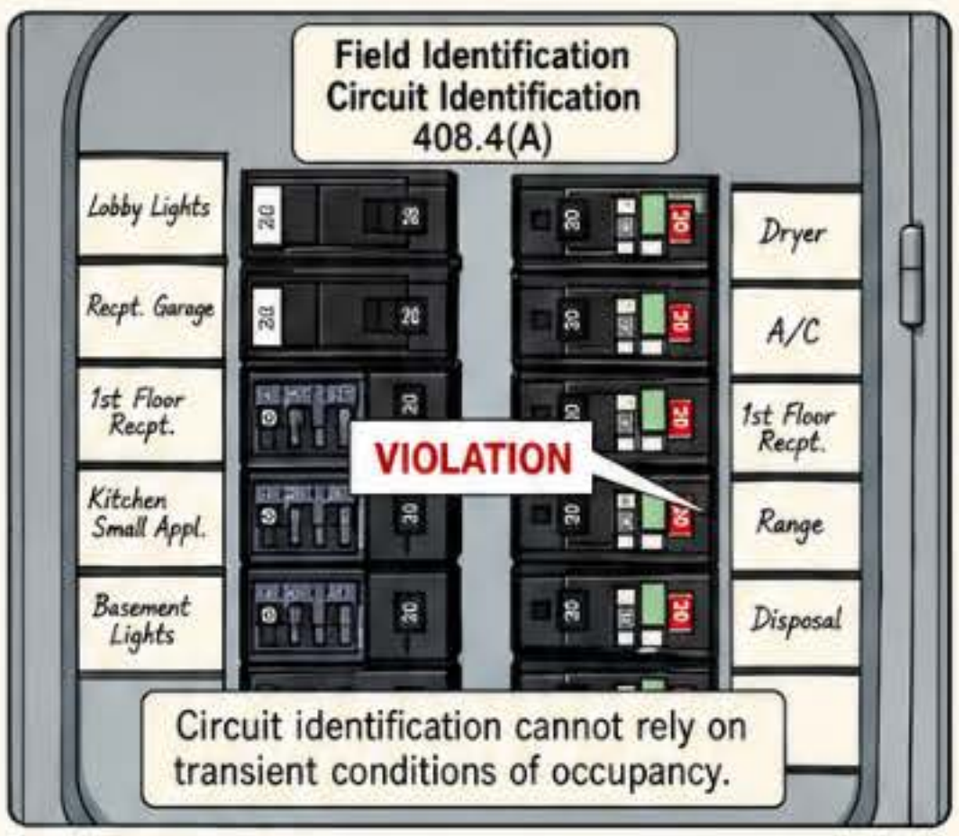
See 110.22. ▼ **Figure 408-7**



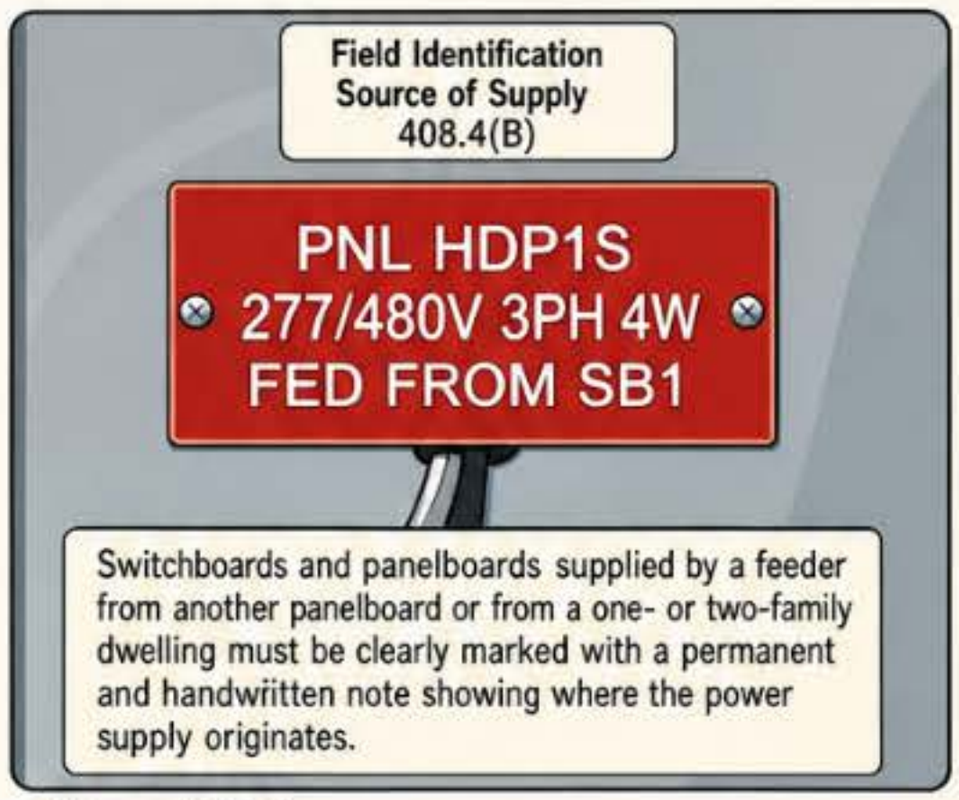
▼ **Figure 408-7**

Circuit identification must not depend on temporary conditions of occupancy, such as "Dad's Office."

▼ **Figure 408-8**



▼ **Figure 408-8**



▼ **Figure 408-9**

408.5 Clearance for Conductors Entering Bus Enclosures

Cables or conductors entering a switchboard, a freestanding panel, or a similar enclosure cannot rise more than 3 in. (76 mm) above the bottom of the enclosure for raceways (including fittings) used to support them.

Author's Commentary:

(B) Source of Supply. If a switchboard or a panelboard is fed by a feeder from another panel or from a single- or two-family dwelling, it must be marked with a permanent, handwritten label showing where the power comes from.

— *Michael Hamilton*

Author's Commentary:

Provide conductor clearance as required. Raceways, including fittings, supporting conductors going into a switchboard or panel cannot extend more than 3 inches above the bottom of the enclosure.

— *Michael Hamilton*

408.6 Short-Circuit Current Rating

Switchboards and panelboards must be rated to safely withstand at least the available fault current at their location. If it is practical, the enclosure should be marked with the available fault current value and the date the calculation was performed. The marking must indicate the equipment's short-circuit withstand capability in accordance with 10.2.1 of NFPA 70® 2023 (B)(3).

408.7 Unused Openings

Any unused openings in circuit breakers must be closed with recognized covers or other listed methods that offer protection comparable to the enclosure wall. **Figure 408–10**

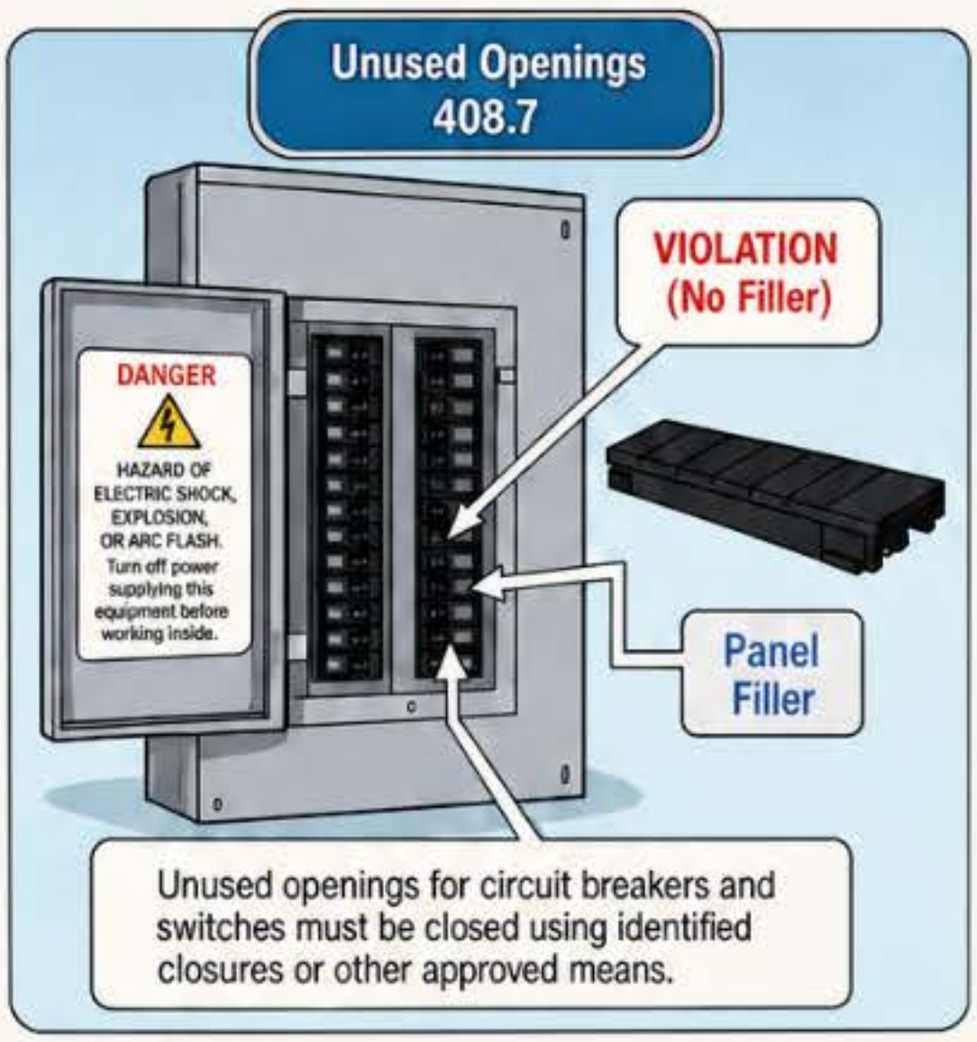


Figure 408–10

408.8 Reconditioning of Equipment

The reconditioning process must be done using components that are verified to meet applicable accepted standards and in accordance with any instructions given by the manufacturer. If any part of the equipment has been harmed by fire, fuel, water, or similar conditions, it must be checked and approved by either the manufacturer or a qualified testing laboratory before returning it to service.

(A) Panelboards. Panelboards are not allowed to be reconditioned, but a panelboard may be replaced inside an enclosure. When a panelboard replacement is needed, the new panelboard must be listed for the enclosure and its available fault current is over 10,000 amperes, the finished installation must have the field label and any previously applied listing marks removed.

(B) Switchboards. Switchboards, or switchboard sections, can be reconditioned. Reconditioned equipment must be listed or field labeled as reconditioned, and any earlier applied listing marks must be taken off.

Part II. Switchboards and Switchgear

408.18 Clearances

(A) From Ceiling. If the total assembly is an enclosed switchboard or switchgear, keep at least 3 feet of clear space between the top of the equipment and any combustible ceiling—unless a noncombustible shield is installed between the equipment and the ceiling.

(B) Around Switchboards and Switchgear. Clearances around switchboards and switchgear must comply with Section 110.26.

(C) Connections. Each equipment section that needs front or side access for making field connections must have the access area marked on the front by the manufacturer. Section openings requiring front or side access must meet the workspace and access rules in 110.26. **Figure 408–11**

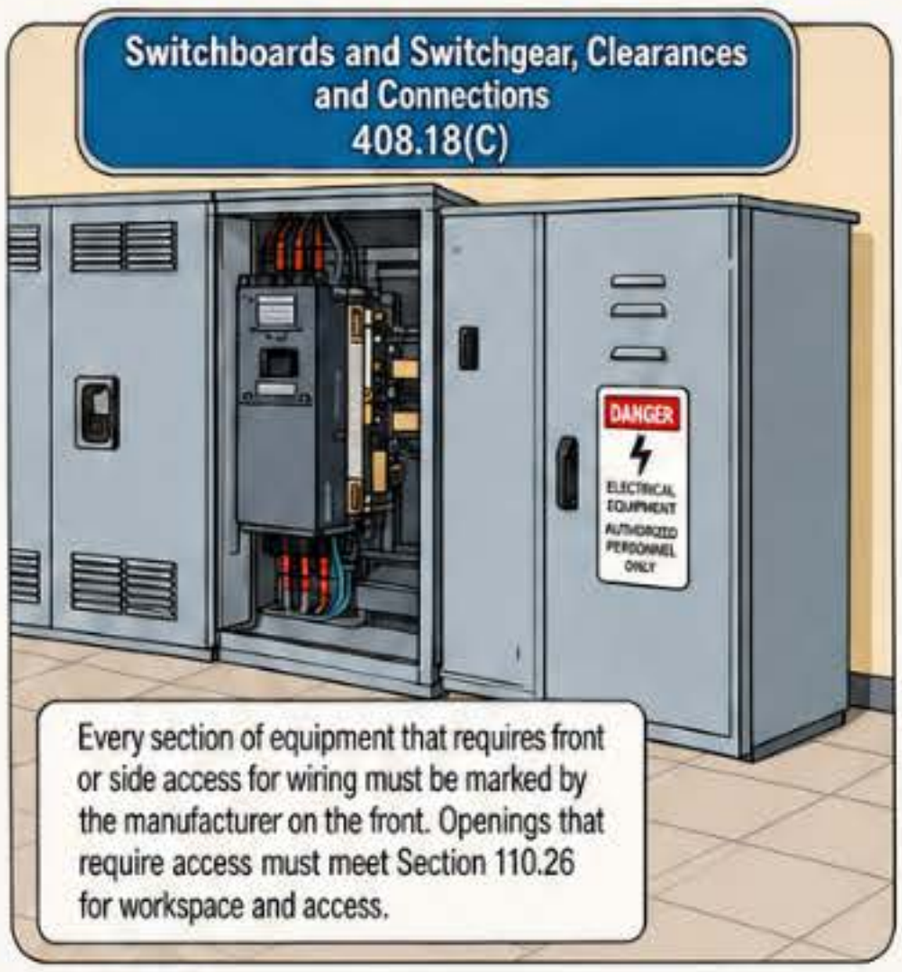


Figure 408–11

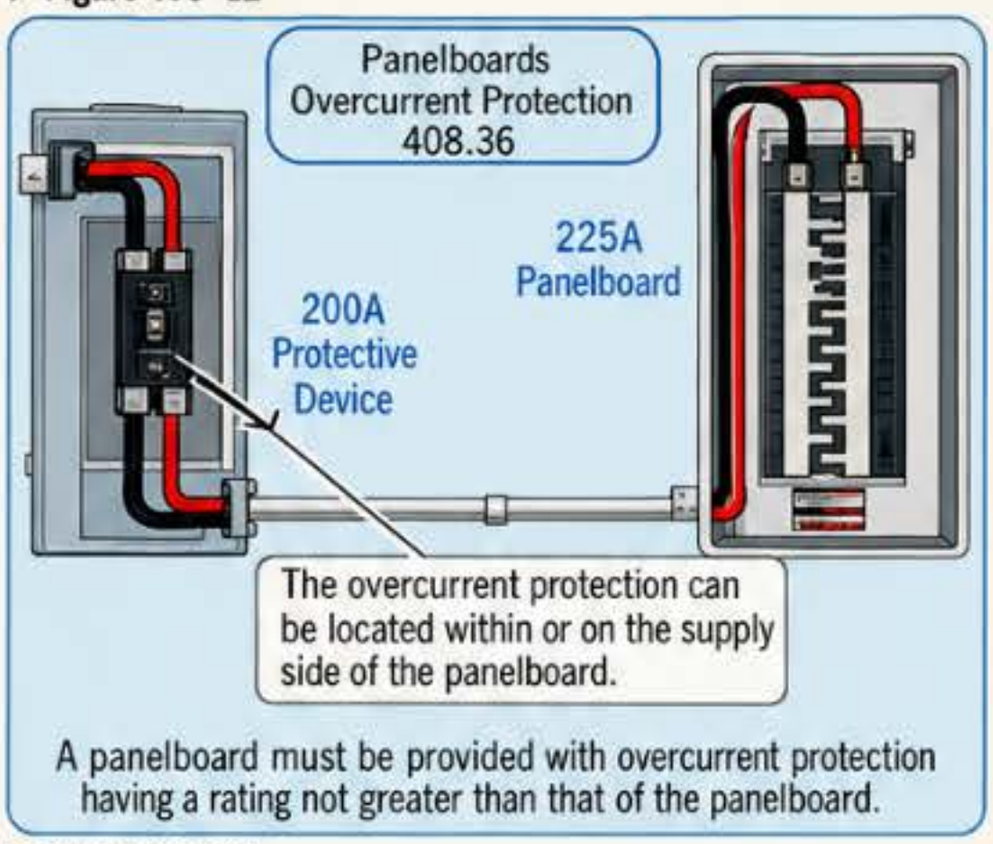
PART III. PANELBOARDS

Part III. Panelboards

408.36 Overcurrent Protection

Panelboards must have overcurrent protection located within or at any point on the supply side of the panelboard with a rating not higher than that of the panelboard.

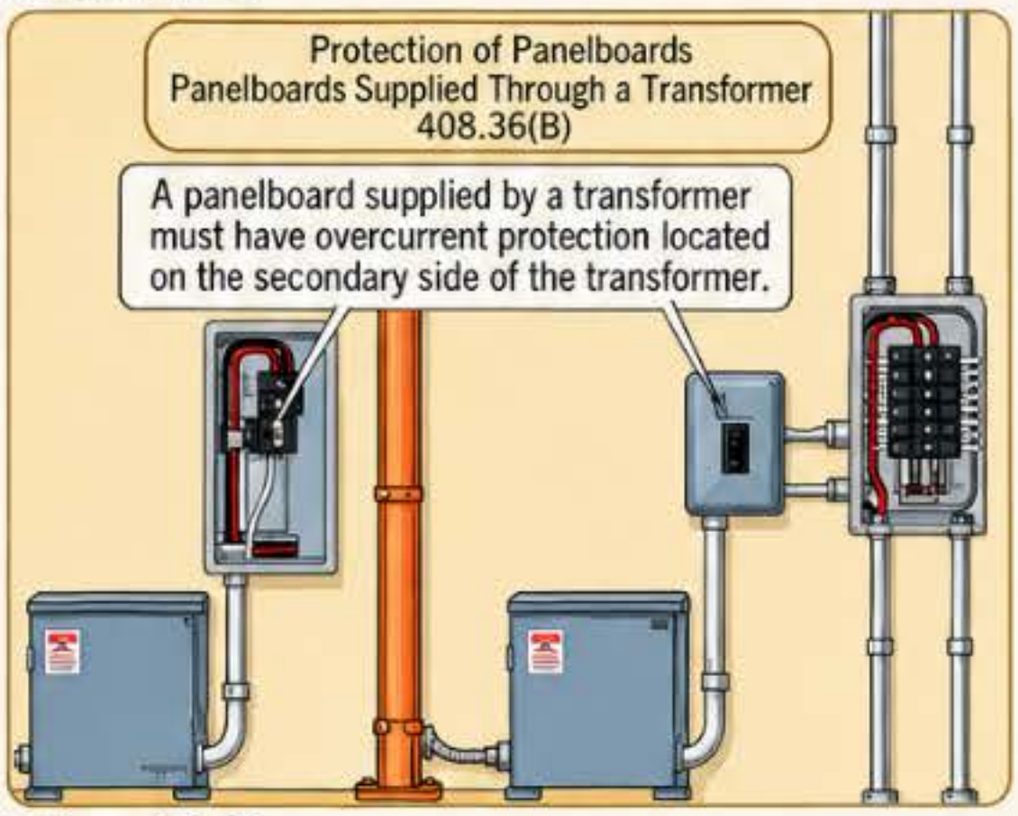
▶ **Figure 408–12**



▶ **Figure 408–12**

(B) Panelboards Supplied by a Transformer. When a panelboard is supplied from a transformer, as permitted in 240.21(C), the overcurrent protection for the panelboard must be on the secondary side of the transformer. The overcurrent protection can be in an enclosure ahead of the panelboard or within it.

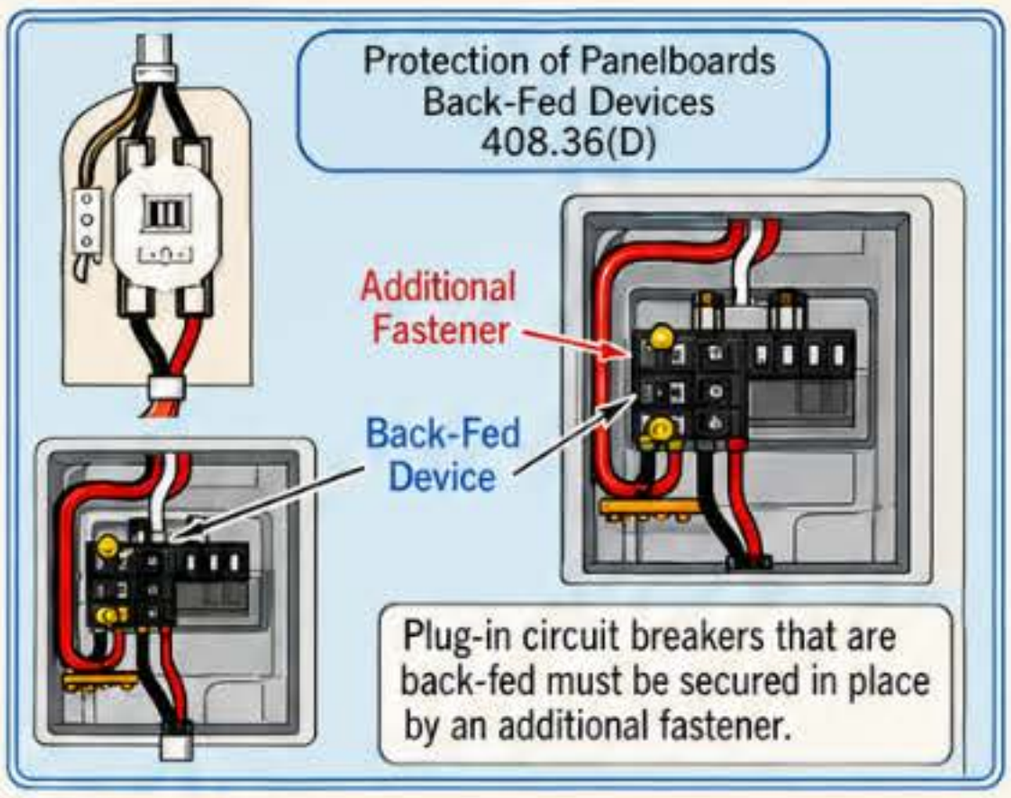
▶ **Figure 408–13**



▶ **Figure 408–13**

(D) Back-Fed Devices. Plug-in circuit breakers that are backfed must be secured in place by a fastener that requires other than a pull to release the breaker from the panelboard.

▶ **Figure 408–14**



▶ **Figure 408–14**

Author's Commentary:

▶ The intent of the breaker fastener is to keep the circuit breaker from being accidently removed from the panelboard while energized, which could expose someone to dangerous voltage.

— ***Michael Hamilton***

CAUTION

Circuit breakers marked "Line" and "Load" must be installed in accordance with the listing or labeling instructions [110.3(B)]; therefore, these types of devices are not permitted to be backfed.

408.37 Panelboards in Damp or Wet Locations

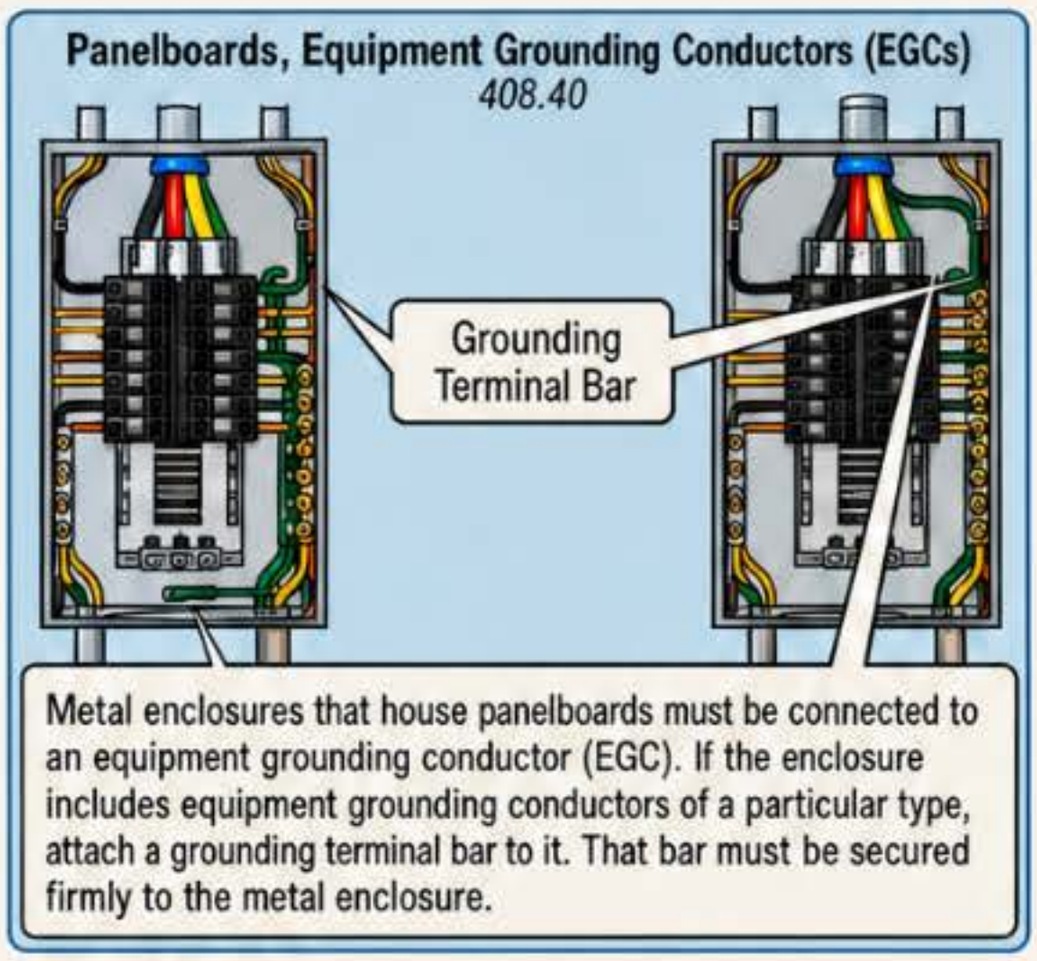
Cabinets for panelboards installed in damp or wet locations must be weatherproof in accordance with 312.2.

408.40 Equipment Grounding Conductor

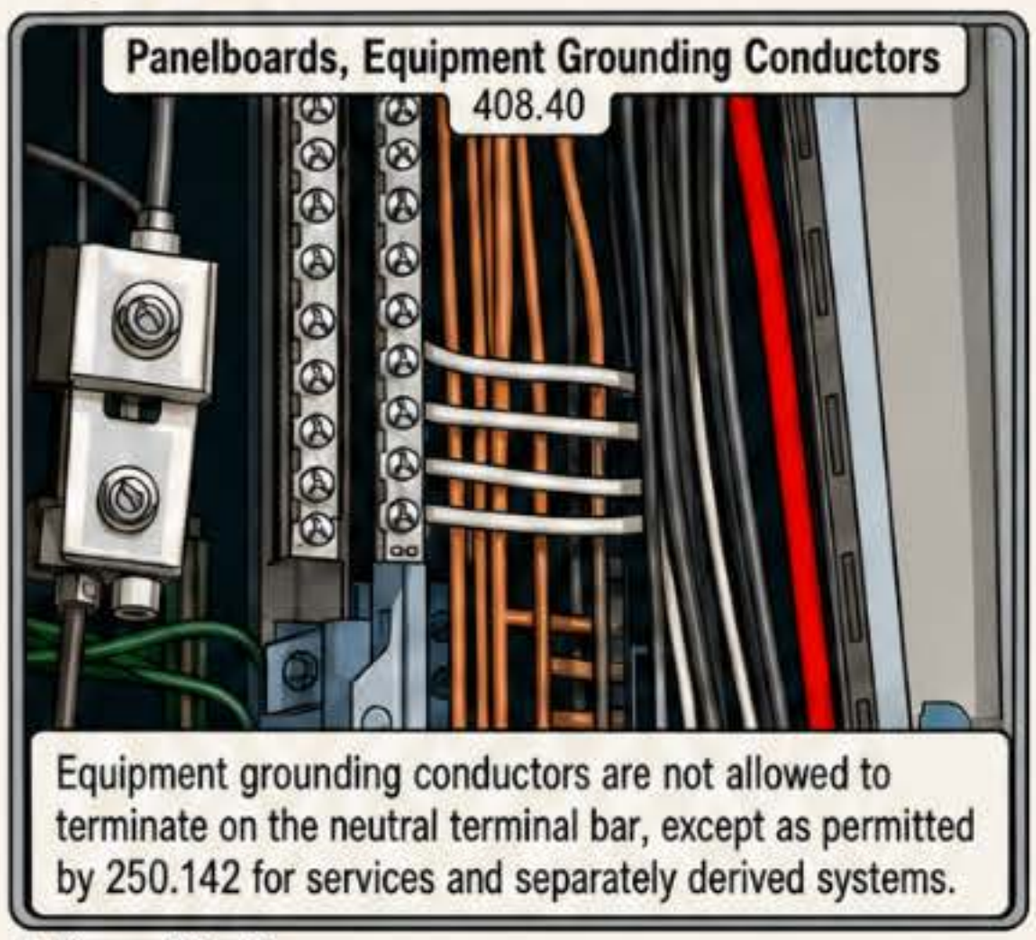
Metal cabinets containing panelboards must be connected to an equipment grounding conductor of a type recognized in 250.118 [215.6 and 250.4(A)(3)]. Where a panelboard cabinet contains equipment grounding conductors of the wire type, a terminal bar for them must be installed and bonded to the metal cabinet. ▶ **Figure 408–15**

Equipment grounding conductors are not permitted to terminate on the neutral terminal bar except as permitted by 250.142(A) for services and separately derived systems.

▶ **Figure 408–16**



▶ Figure 408–15



▶ Figure 408–16

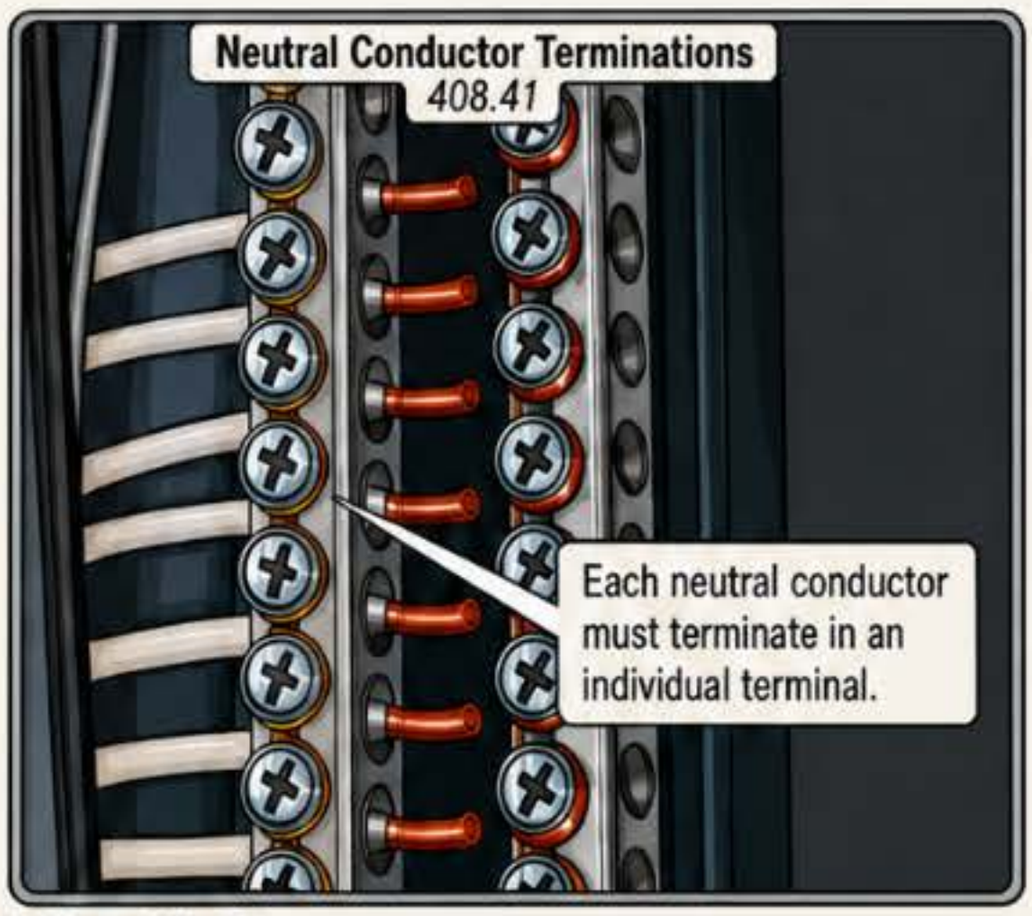
Caution

Many panelboards are rated for use as service disconnects, which means they are supplied with a main bonding jumper (250.28). It is not allowed to install this screw or strap, except when the panelboard is intended for service use or as a separately derived system (250.24(A)(5)) or as a separately derived system (250.30(A)(1)).

408.41 Neutral Conductor Terminations

Every neutral conductor within a panelboard must be terminated in its own dedicated terminal.

▶ Figure 408–17

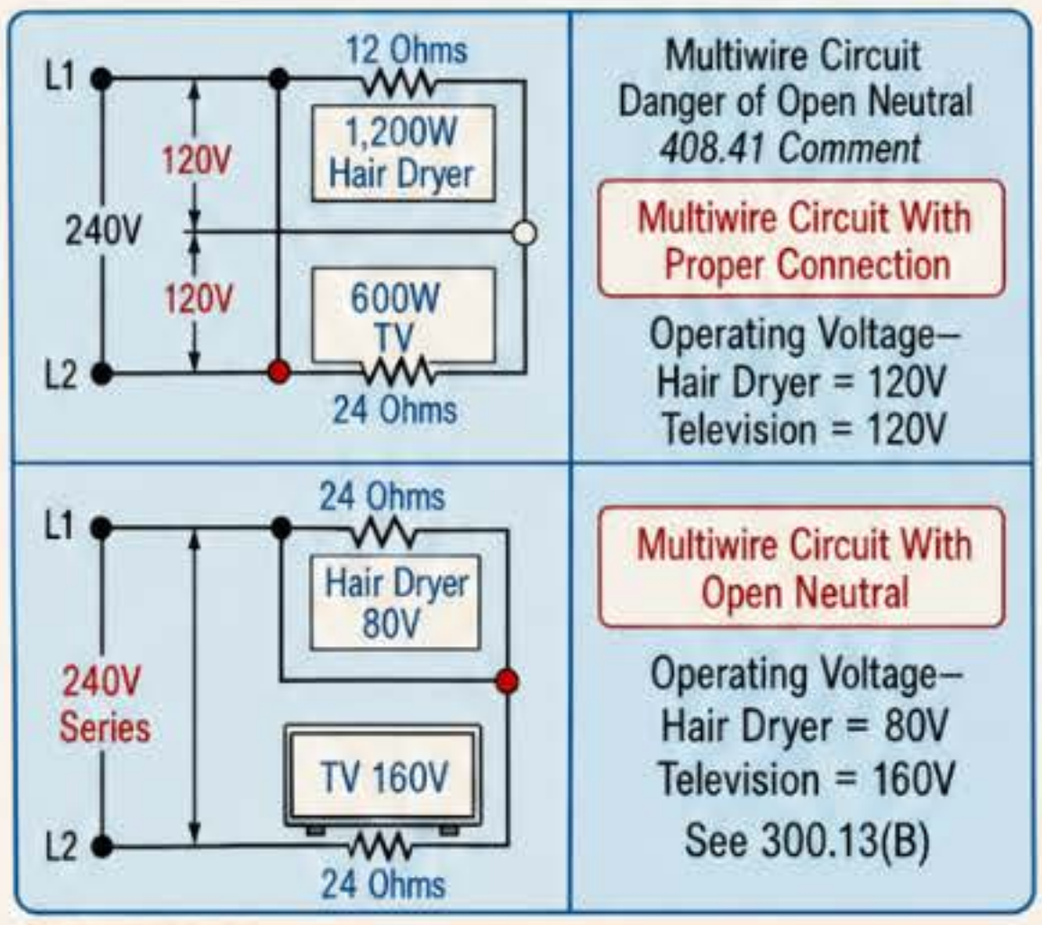


▶ Figure 408–17

Author's Commentary:

When two neutral conductors share the same terminal, and one of them is removed, the other may become unintentionally disconnected as well. In a multiwire circuit, this could create excessive line-to-neutral voltage on one of the circuits, as well as dangerous voltage on the other. See 300.13(B) of this textbook for further explanation.

— Michael Hamilton



▶ Figure 408–18

408.43 Panelboard Orientation

Panelboards are prohibited from being installed with the face up.

ARTICLE 410 LUMINAIRES, LAMPHOLDERS, AND LAMPS

Introduction to Article 410—Luminaires, Lampholders, and Lamps

This article addresses luminaires, lampholders, lamps, fixtures used for decorative purposes, and lighting for short-term seasonal installations as well as holiday displays. Although it is quite detailed, Article 410 is organized into 16 parts. The first five parts are sequential sections that relate to every luminaire, lampholder, and lamp:

- Part I. General
- Part II. Locations
- Part III. Outlet Boxes and Covers
- Part IV. Supports
- Part V. Equipment Grounding Conductors

These opening parts contain primarily mechanical information and are not difficult to follow. Part VI, Wiring, concludes the sequence. Parts VII through X provide requirements for manufacturers of luminaires and for any equipment that complies with those requirements. Part VII includes installation rules for lampholders. The remainder of Article 410 covers specific types of lighting. Areas used for cultivating plants and growing agricultural products (such as greenhouses) that replicate the natural effects of daylight and seasonal temperature changes may have unique conditions. Additional rules are found in Horticultural Part XVI.

Author's Commentary:

Article 411 covers "Low-Voltage Lighting," which involves lighting systems and their components that operate at no more than 30 volts alternating current or 60 volts direct current.

— Michael Hamilton

Part I. General

410.1 Scope

Article 410 applies to luminaires, lampholders, lamps, lighting producing decorative effects, portable and temporary lighting products, and the wiring and other equipment used with them. This includes the wiring needed to install and operate these items.

Figure 410-1

Author's Commentary:

Luminaires and the instructions provided by manufacturers are critical to safe and effective installation. Following those instructions carefully leads to better results.

UL publishes a booklet titled the Luminaire Marking Guide, which helps you read information correctly on different luminaire types—such as fluorescent, incandescent, HID, and others.

— Michael Hamilton

Figure 410-1

Article 410 governs luminaires, lampholders, lamps, decorative lighting products, lighting accessories for temporary seasonal and holiday use, portable flexible lighting products, and the wiring and equipment associated with their installation.

410.2 Definitions

Clothes Closet Storage Space. *A volume bounded by the sides and back closet walls extending from the closet floor vertically to a height of 6 ft, or the highest clothes-hanging rod at a horizontal distance of 2 ft from the sides and back of the closet walls. This space continues upward to the closet ceiling for a distance of 1 ft or to the width of the shelf, whichever is greater.* **Figure 410-2**

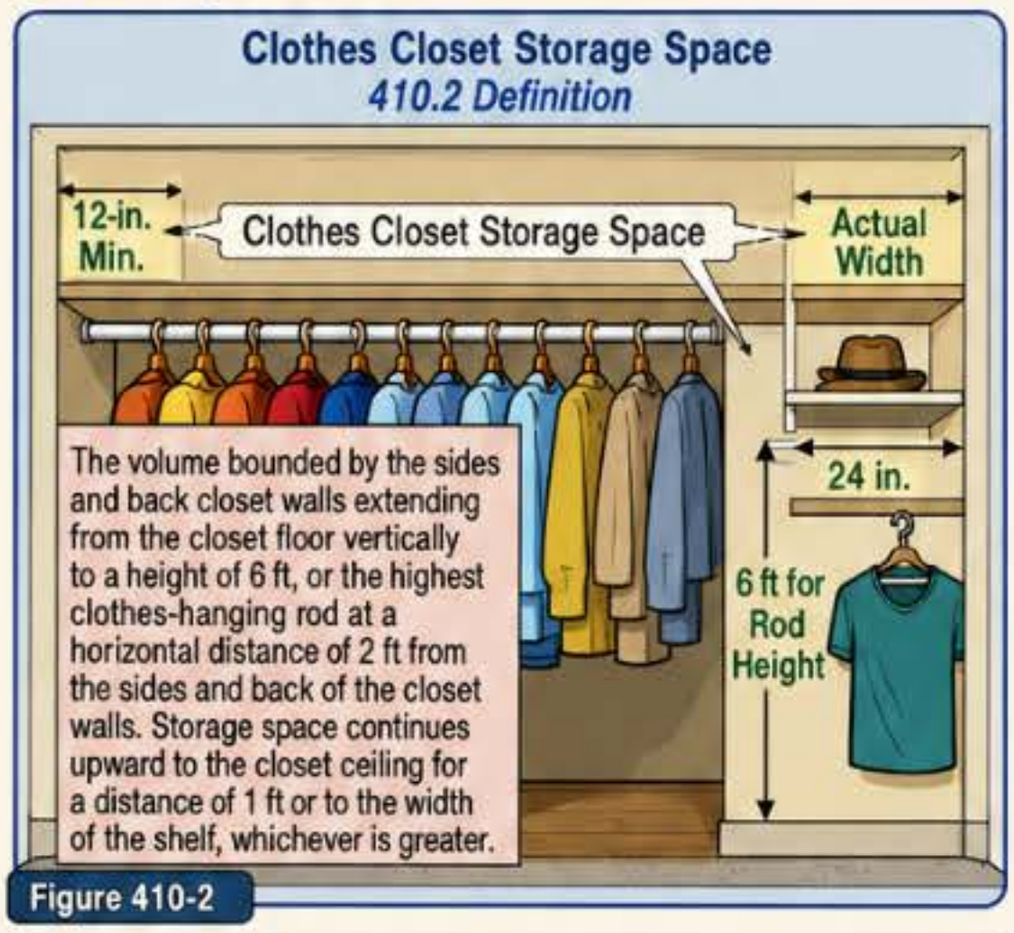


Figure 410-2

Author's Commentary:

- *This definition requires roughly 125 words to explain in one sentence, perhaps the lengthiest sentence found in the Code. Take a breath and don't let it get away while you're reading!*

— Michael Hamilton

410.6 Listing Required

Luminaires, lampholders, and retrofit kits must be listed. **Figure 410-3**

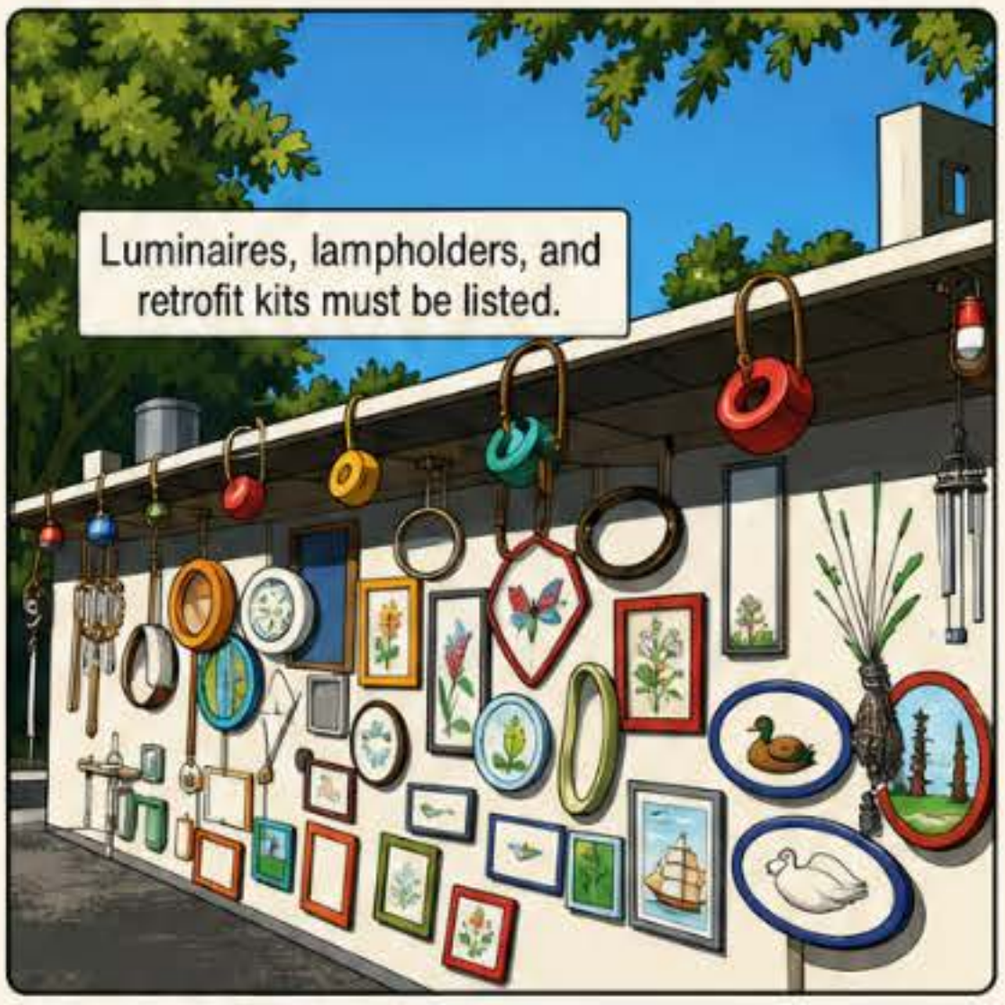


Figure 410-3

410.7 Reconditioned Equipment

Luminaires, lampholders, and retrofit kits are not permitted to be reconditioned. If a retrofit kit is installed in a luminaire in accordance with the installation instructions, *the retrofitted luminaire is not considered reconditioned.*

Part II. Luminaire Locations

410.10 Luminaires in Specific Locations

(A) Wet or Damp Locations. Luminaires marked "Suitable for Dry Locations Only" must be installed only in a dry location; those marked *"Suitable for Damp Locations" can be installed in either a damp or dry location; and luminaires marked "Suitable for Wet Locations" can be installed in a dry, damp, or wet location.* **Figure 410-4** and **Figure 410-5**

(B) Corrosive Locations. *Luminaires installed in corrosive locations must be suitable for the location.*

(C) In Ducts or Hoods. *Luminaires may be installed in commercial cooking hoods provided they are identified for the location, are vapor tight in their design, and corrosion resistant.* **Figure 410-6**

Luminaires, Lampholders, and Lamps | 410.10

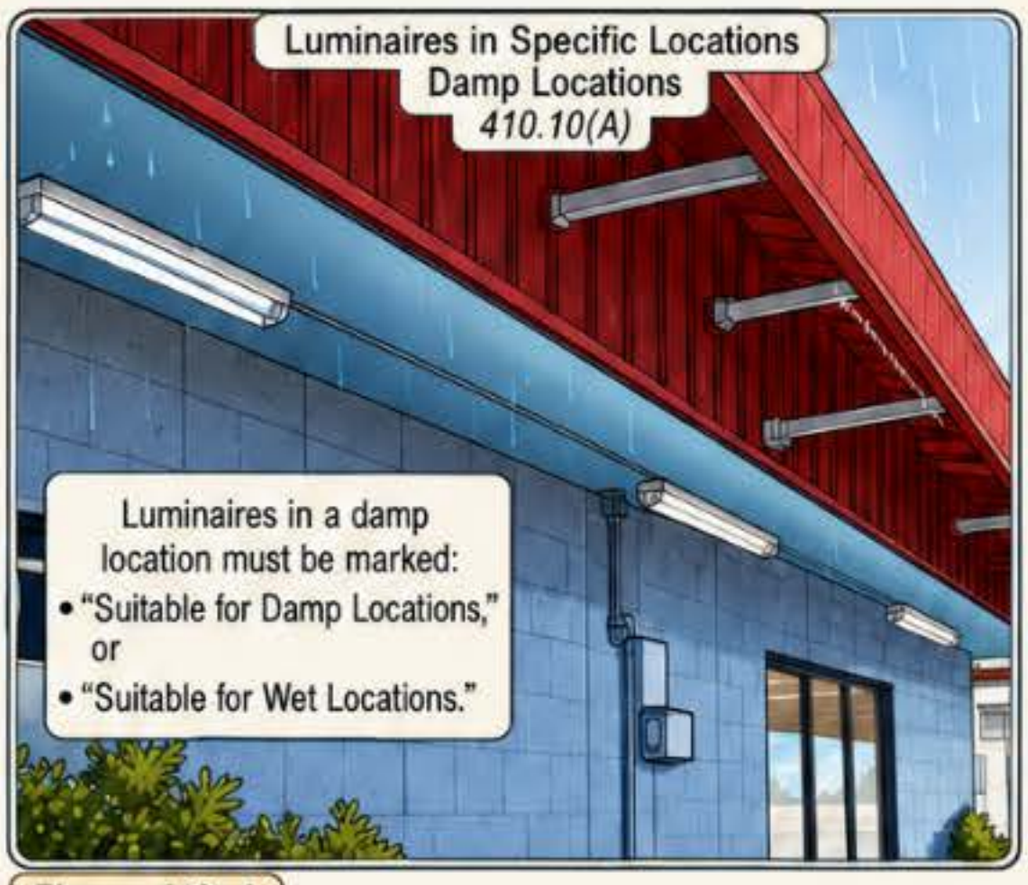


Figure 410–4

Figure 410–5

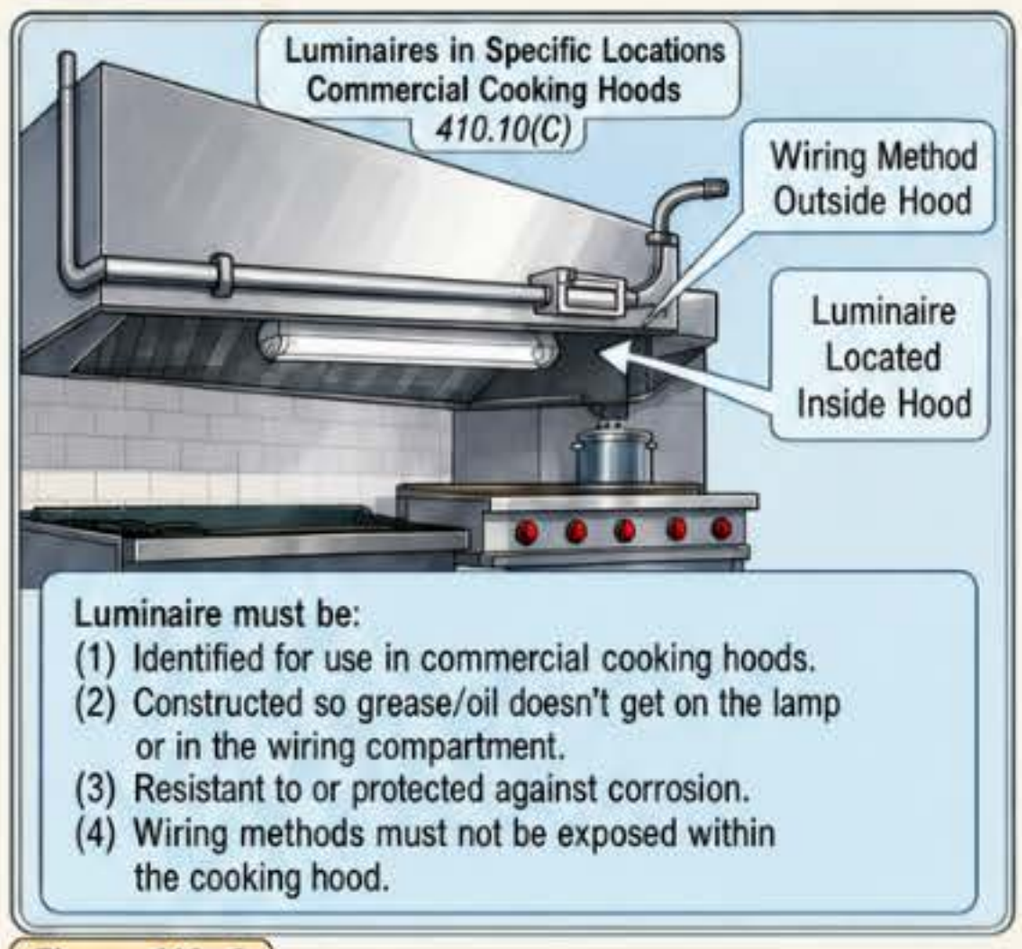


Figure 410–6

(D) Bathtub and Shower Areas. A luminaire installed in a bathtub or shower area must meet all of the following requirements:

(1) No part of chain-, cable-, or cord-suspended luminaires, track luminaires, pendants, or ceiling paddle fans can be located within 3 ft horizontally and 8 ft vertically of the top of the bathtub rim or shower stall threshold. ▶**Figure 410–7**

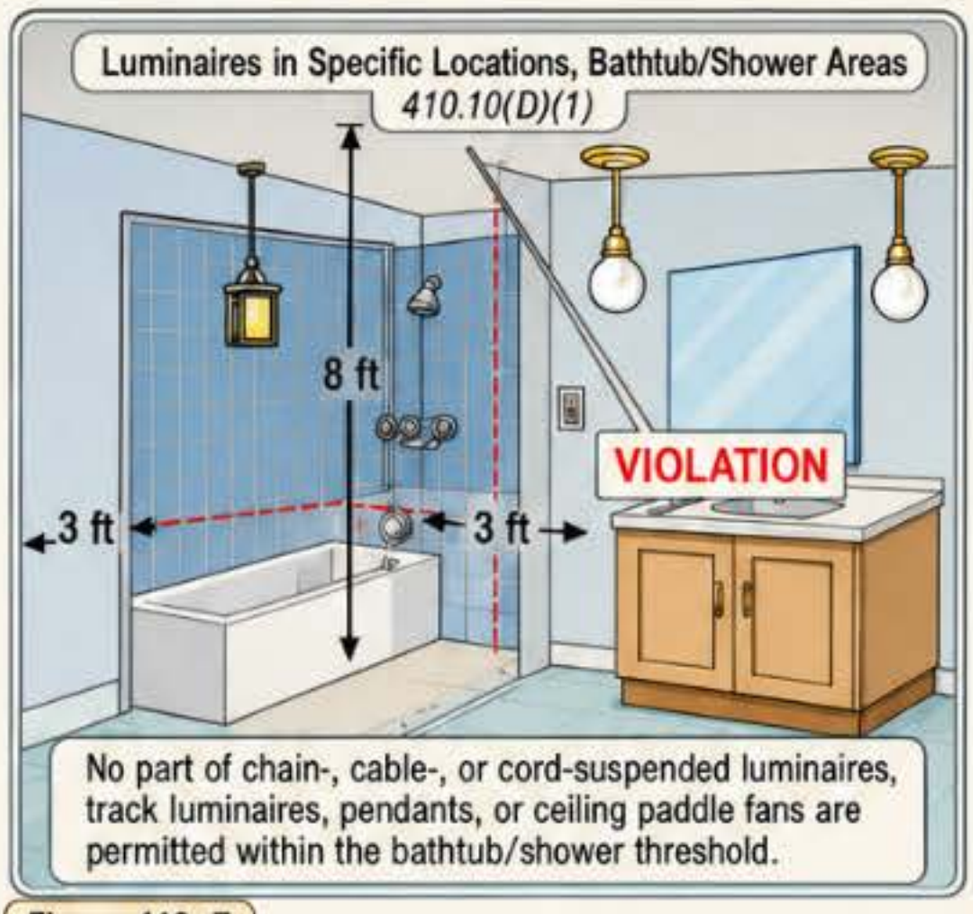


Figure 410–7

(2) Luminaires located within the outside dimensions of a bathtub or shower to a height of 8 ft of the top of the bathtub rim or shower threshold must be marked for damp locations or marked suitable for wet locations. Where subject to shower spray, the luminaires must be marked suitable for wet locations. ▶**Figure 410–8** and ▶**Figure 410–9**

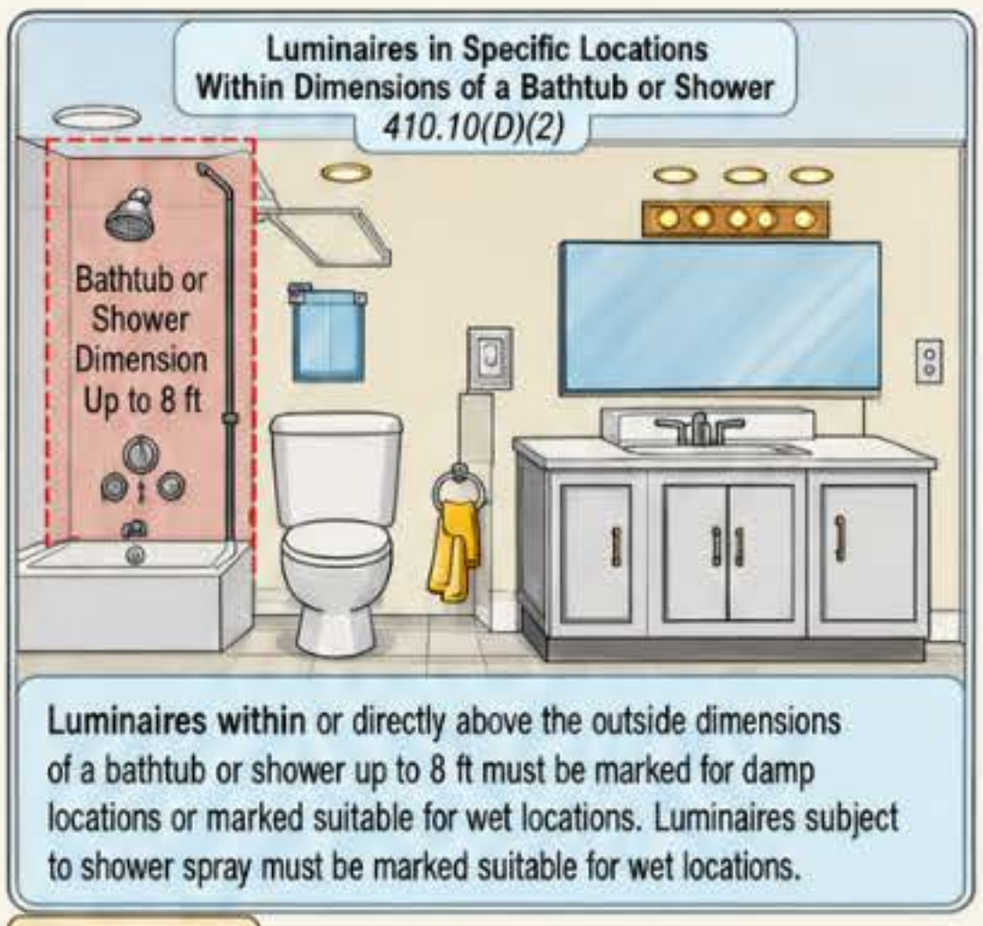
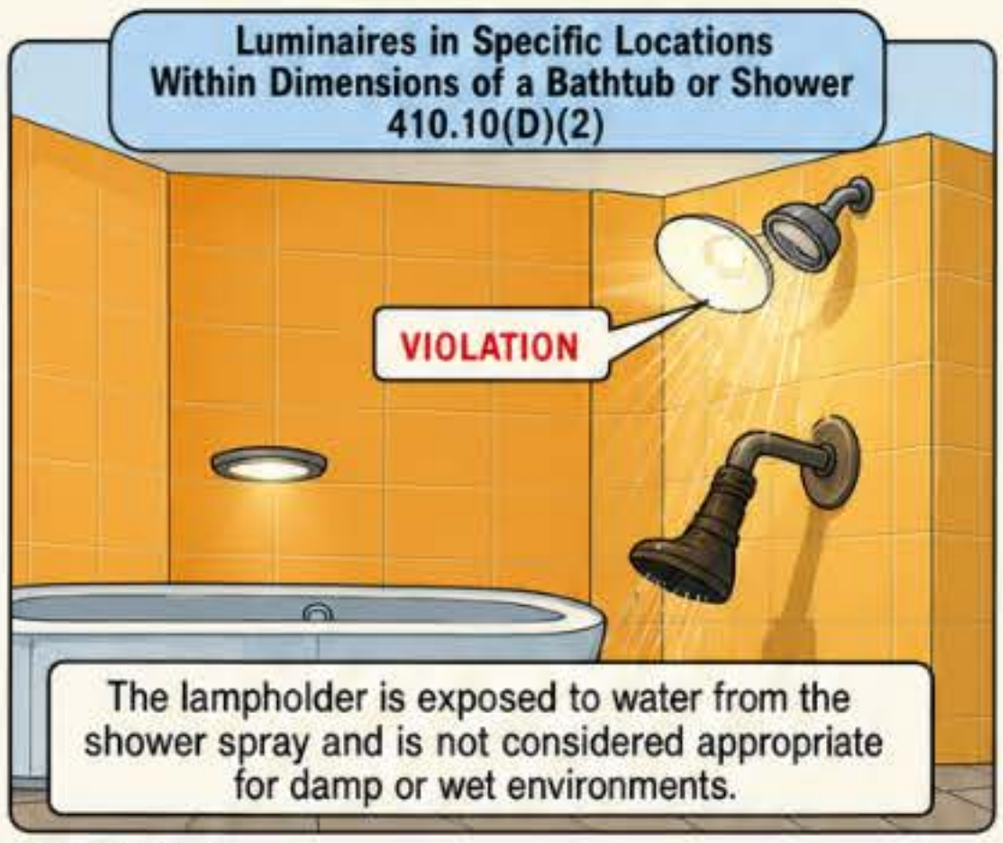


Figure 410–8



▶ Figure 410–9

(E) Luminaires in Indoor Sports, Mixed-Use, and All-Purpose Facilities. Luminaires that use mercury vapor or metal halide lamps are vulnerable to physical harm and need protection when installed in seating areas of indoor sports venues, mixed-use buildings, or multipurpose spaces that must be of the type that has a glass or plastic shield. Such luminaires may also require a secondary guard. ▶ Figure 410–10

▶ Figure 410–10

(F) Luminaires Installed in or Under Roof Decking. Light fixtures mounted beneath metal-corrugated sheet roof decking must be installed at least 12 inches from the lowest surface of the decking measured from the bottom of the fixture's top.

410.16 Luminaires in Clothes Closets

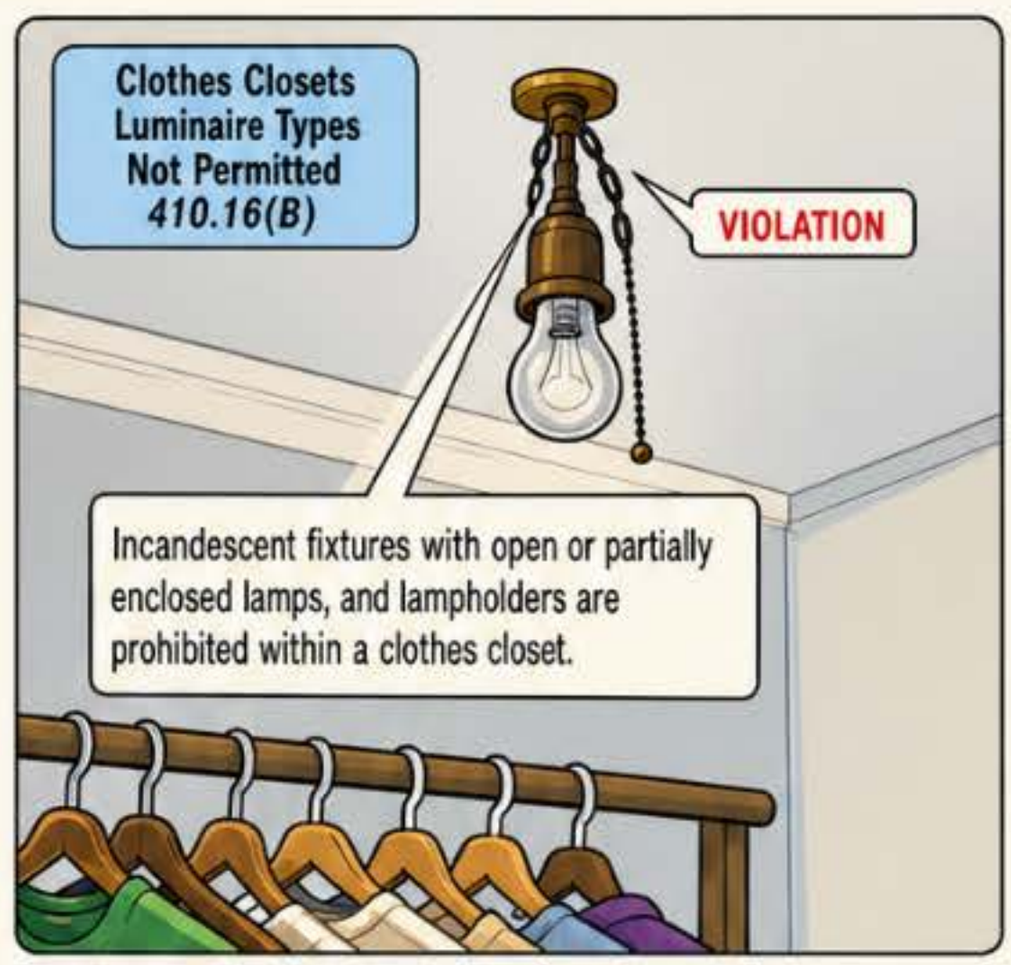
(A) Luminaire Types Permitted. Within a clothes closet, only the following types of luminaires are allowed:

(1) Surface or recessed incandescent or LED luminaires that have an enclosed light source.

(2) Surface or recessed fluorescent luminaires.

(3) Surface-mounted or recessed LED luminaires that are identified for use in the clothes closet storage space.

(B) Luminaire Types Not Permitted. Incandescent or pendant-type luminaires, and lampholders are not authorized within a clothes closet. ▶ Figure 410–11



▶ Figure 410–11

(C) Installation of Luminaires. To be compliant, luminaires must maintain the minimum clearances from clothes closet storage space shown below:

(1) Maintain 12 inches from surface-mounted incandescent or LED luminaires with an enclosed light source. ▶ Figure 410–12

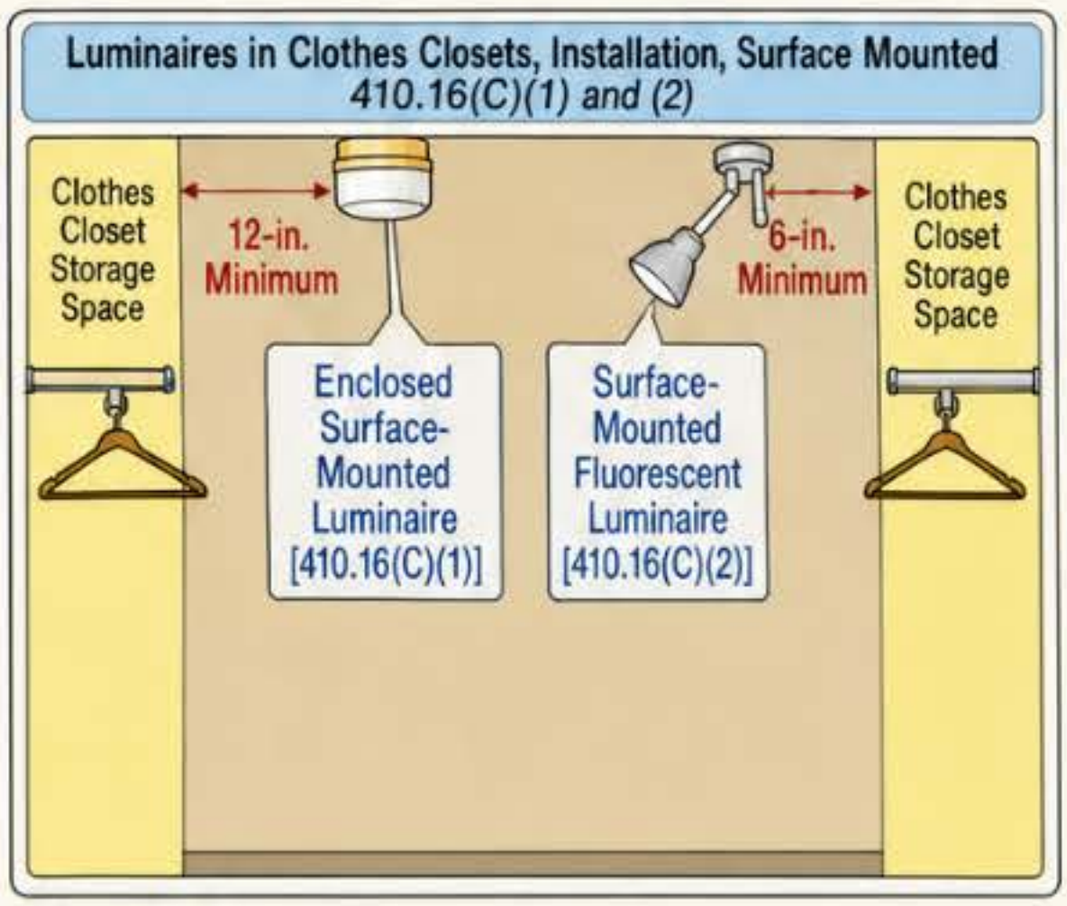
(2) Maintain 6 inches from surface-mounted fluorescent luminaires.

(3) Maintain 6 inches from recessed incandescent or LED luminaires with an enclosed light source. ▶ Figure 410–13

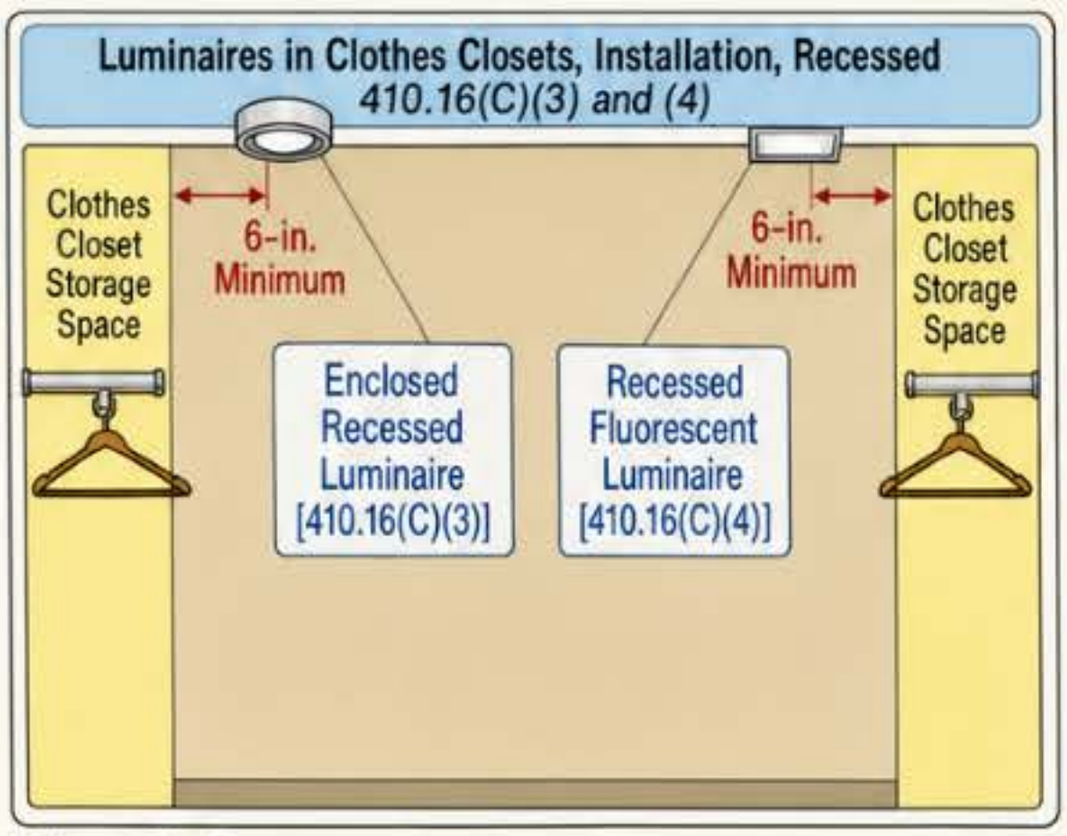
(4) Maintain 6 inches from recessed fluorescent luminaires.

(5) Surface-mounted fluorescent or LED luminaires are acceptable for clothes closets if they are specifically identified for such use. ▶ Figure 410–14

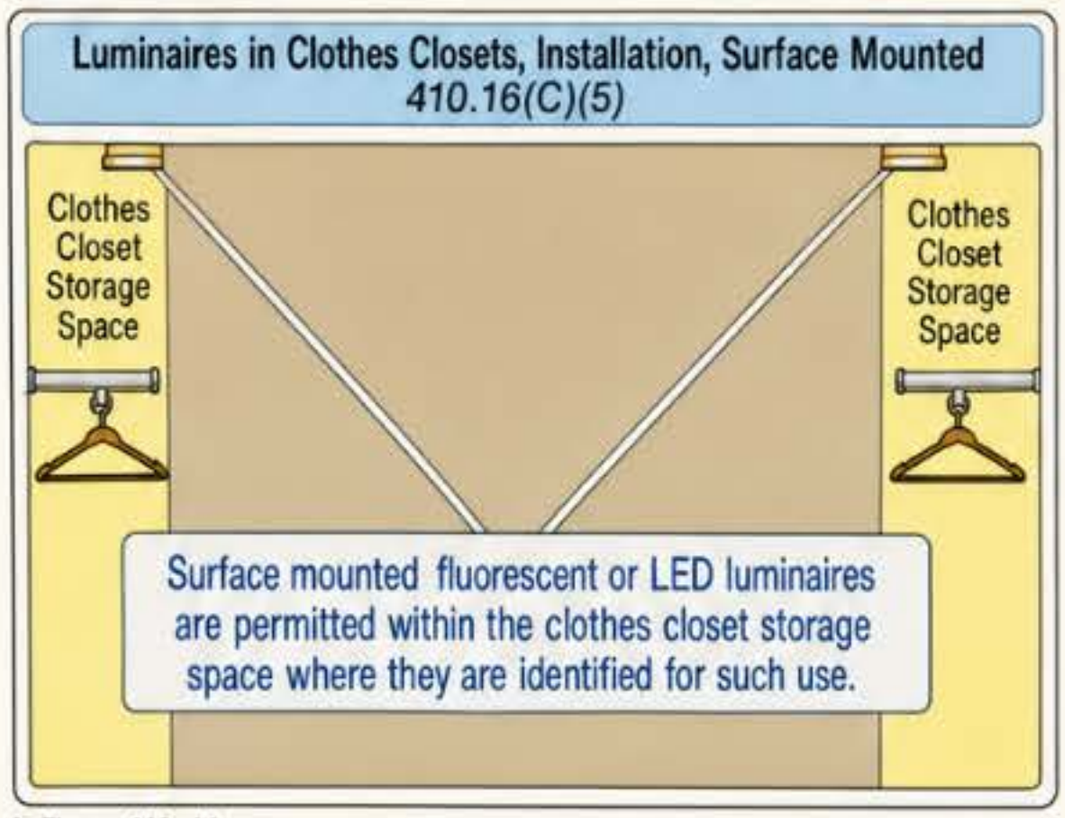
LUMINAIRES, LAMPHOLDERS, AND LAMPS 410.24



▶ Figure 410–12



▶ Figure 410–13

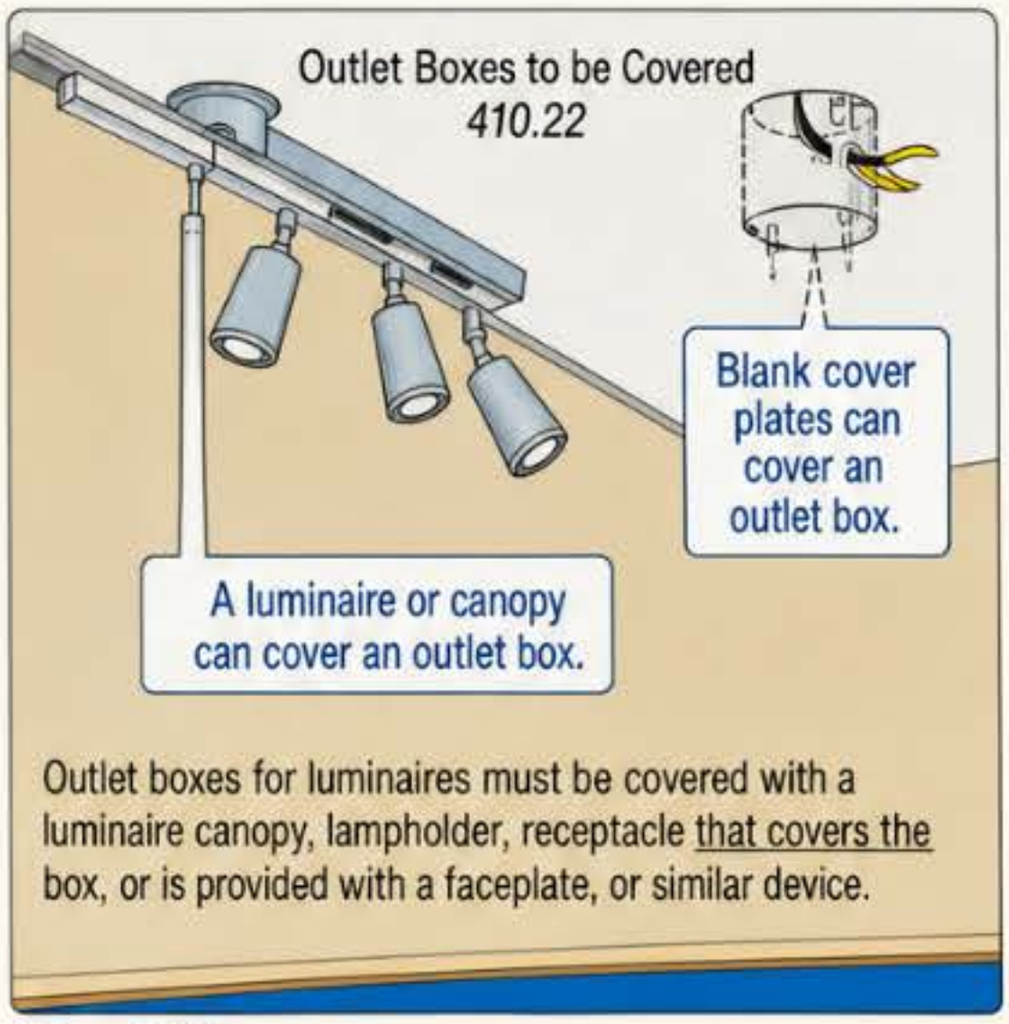


▶ Figure 410–14

Part III. Luminaire Outlet Boxes and Covers

410.22 Outlet Boxes to be Covered

Outlet boxes for luminaires must be enclosed with a luminaire canopy, lampholder, receptacle that covers the box or is provided with a face-plate, or similar device. See 314.25. ▶ **Figure 410–15**



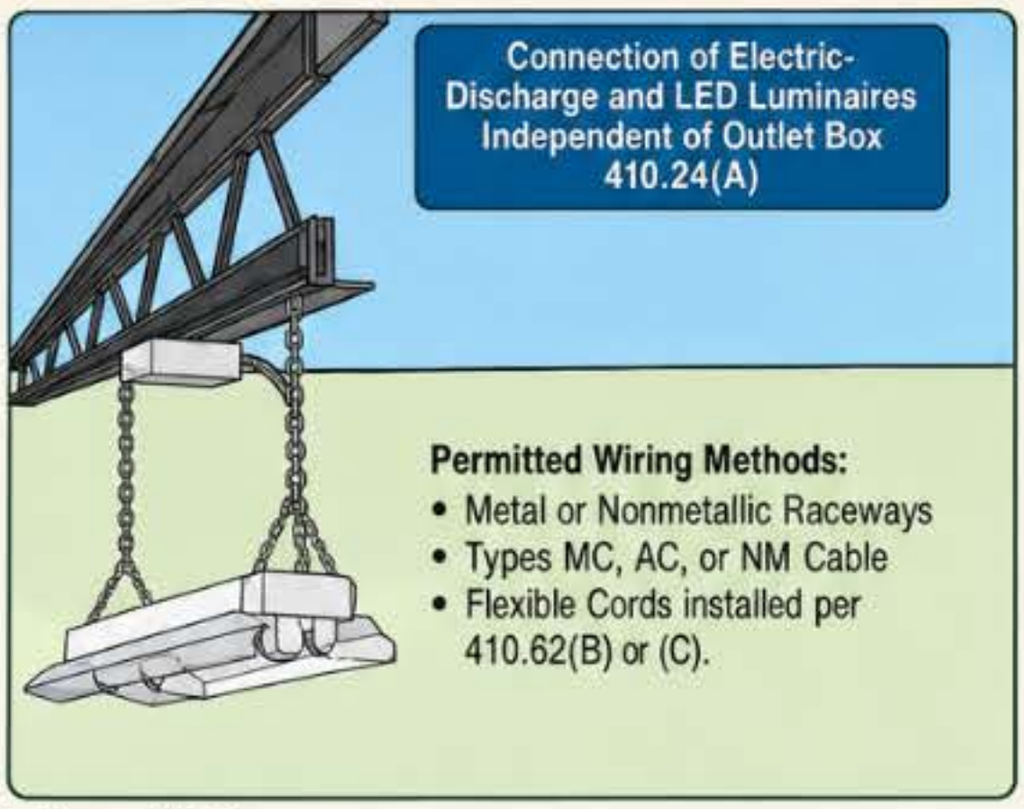
▶ Figure 410–15

410.24 Connection of Electric-Discharge and LED Luminaires

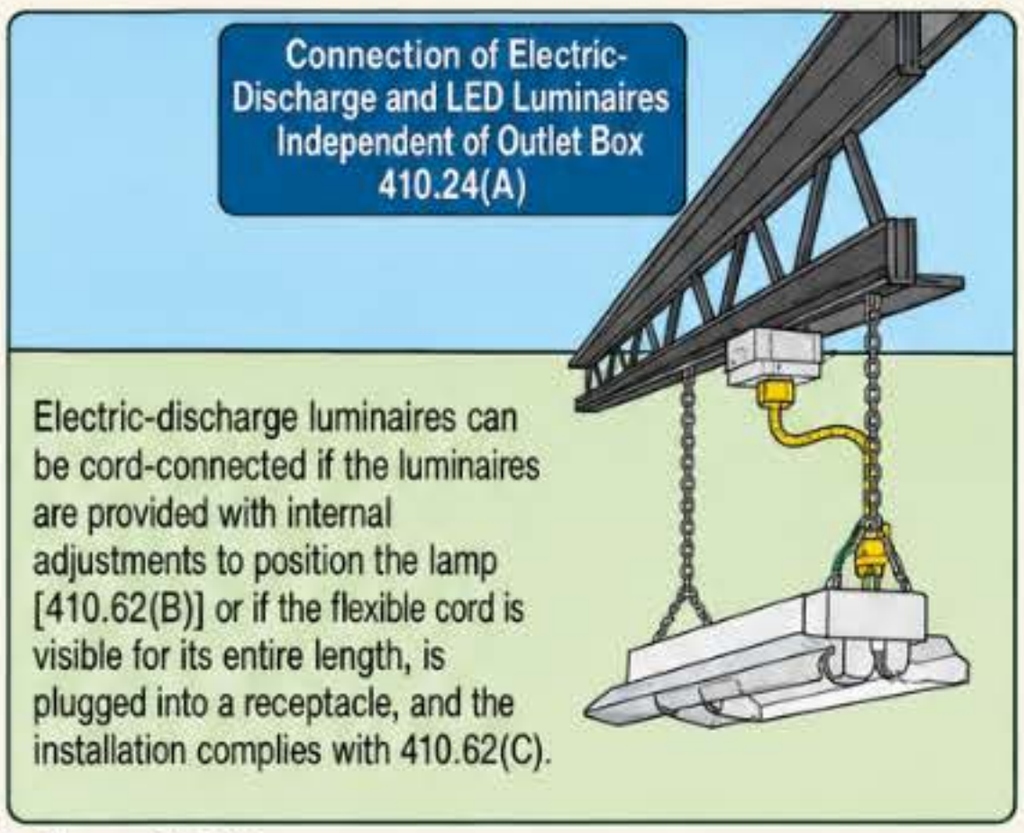
(A) Luminaires Supported Independently of the Outlet Box. Electric-discharge and LED luminaires supported independently of the outlet box must be connected to the branch circuit with a raceway or with Types MC, AC, or NM cable. ▶ **Figure 410–16**

Electric-discharge luminaires can be cord-connected if they are provided with internal adjustments to position the lamp [410.62(B)] or if the flexible cord is visible for their entire length, is plugged into a receptacle, and the installation complies with 410.62(C). ▶ **Figure 410–17**

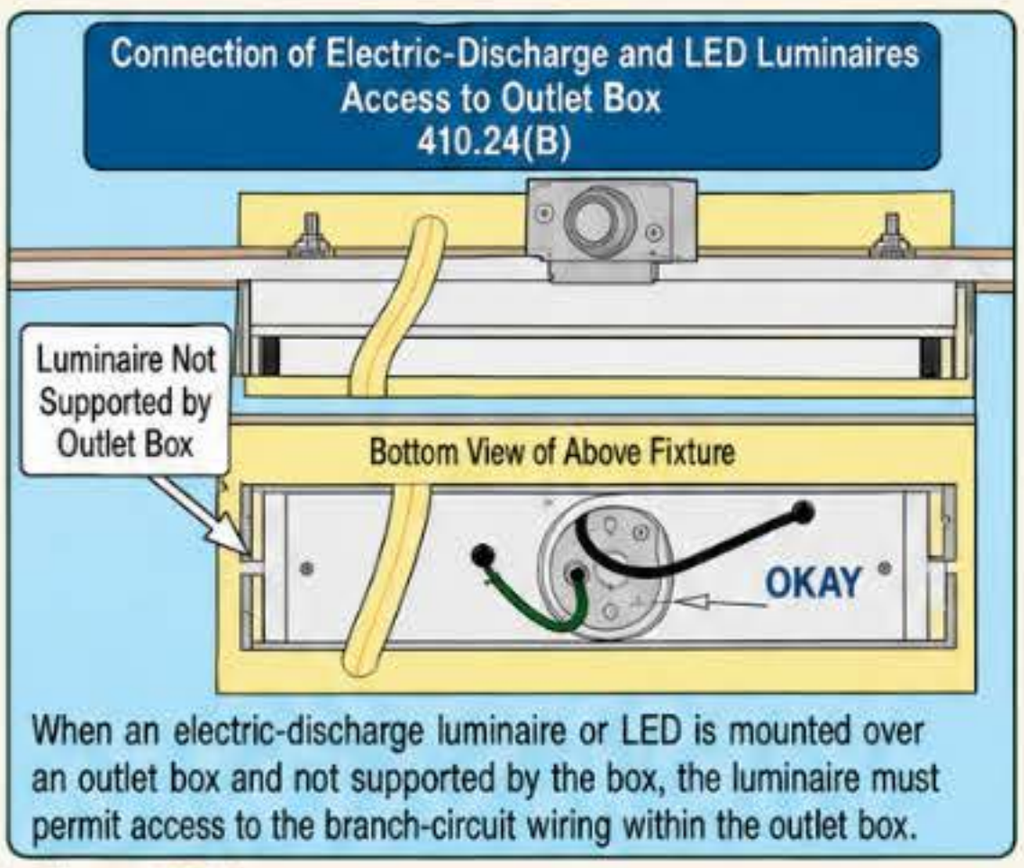
(B) Access to Outlet Box. When an electric-discharge luminaire or LED luminaire is surface mounted over an outlet box and not supported by the outlet box, the luminaire must be provided with suitable openings that permit access to the branch-circuit wiring within the outlet box. ▶ **Figure 410–18**



▶ Figure 410–16



▶ Figure 410–17



▶ Figure 410–18

Part IV. Luminaire Supports

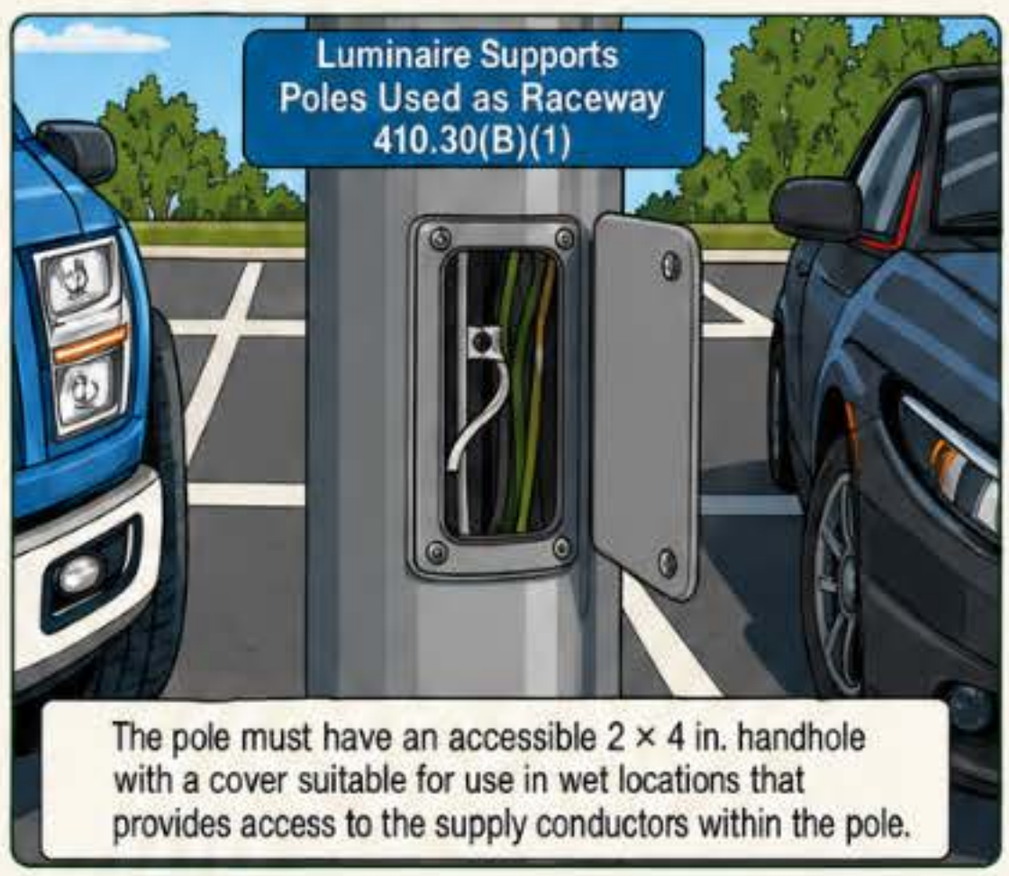
410.30 Supports

(B) Poles. Poles used to support luminaires can be used as raceways to enclose supply conductors where the following conditions are met:

Author's Commentary:
Property owners often want to install security cameras on existing parking-lot light poles. Sections 725.136 and 820.133 prohibit placing communication conductors in the same raceway as power conductors, with limited exceptions.

— Michael Hamilton

(1) The pole must provide an opening at least 2 in. × 4 in. with a cover suitable for wet locations. This opening must give access to the supply conductors inside the pole. ▶ **Figure 410–19**



▶ Figure 410–19

Ex 1: *The handhole is not required for a pole that is 8 ft or less in height if access to the supply conductors for the luminaire can be obtained by removing the luminaire.* ▶ **Figure 410–20**

Ex 2: *The handhole can be omitted on poles that are 20 ft or less in height if the pole is equipped with a hinged base.*

(3) *A metal pole must be provided with an equipment grounding terminal that can be reached from the handhole.*

Ex: *An equipment grounding terminal is not required for a pole that is 8 ft or less in height above grade if splices can be accessed by removing the luminaire.*

410.36 LUMINAIRES, LAMPHOLDERS, AND LAMPS

Figure 410–20

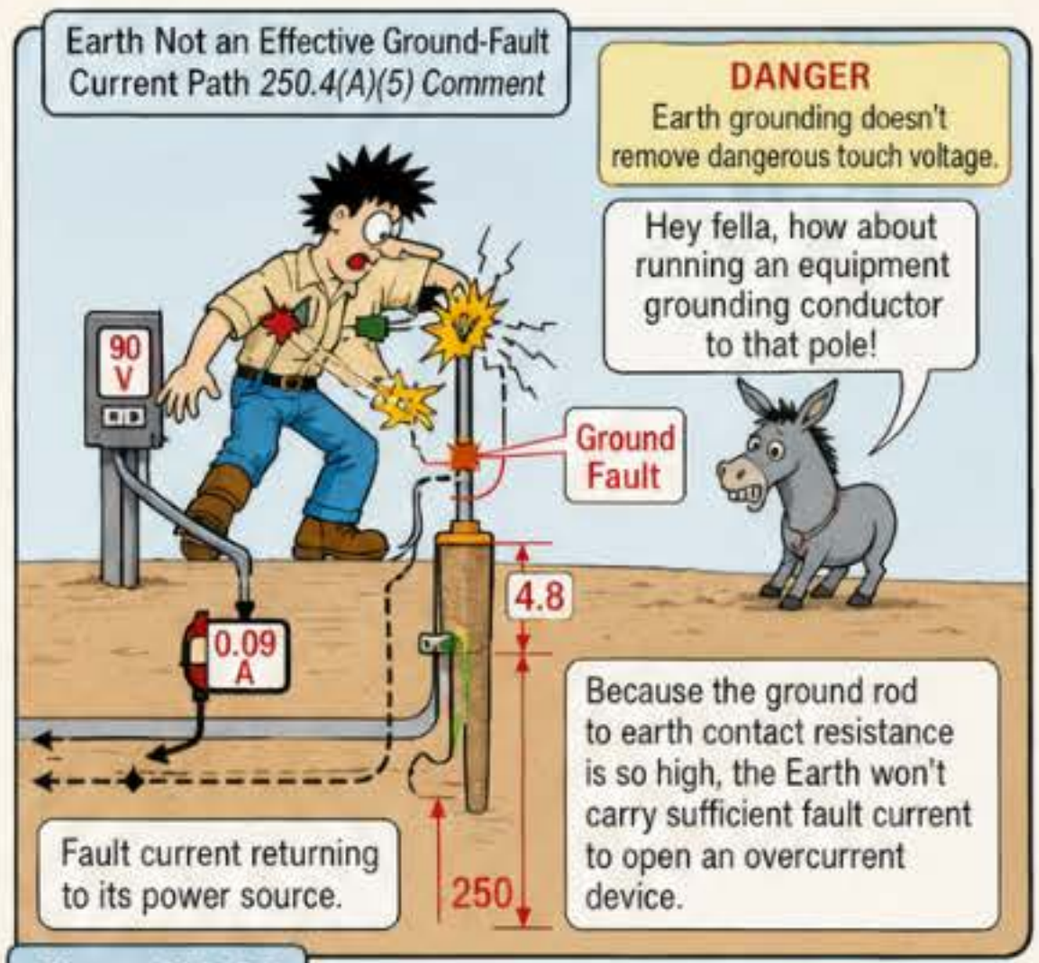


Figure 410–22

(5) Metal poles used for the support of luminaires must be connected to an equipment grounding conductor of a type recognized in 250.118 [250.4(A)(5)].
▶ Figure 410–21

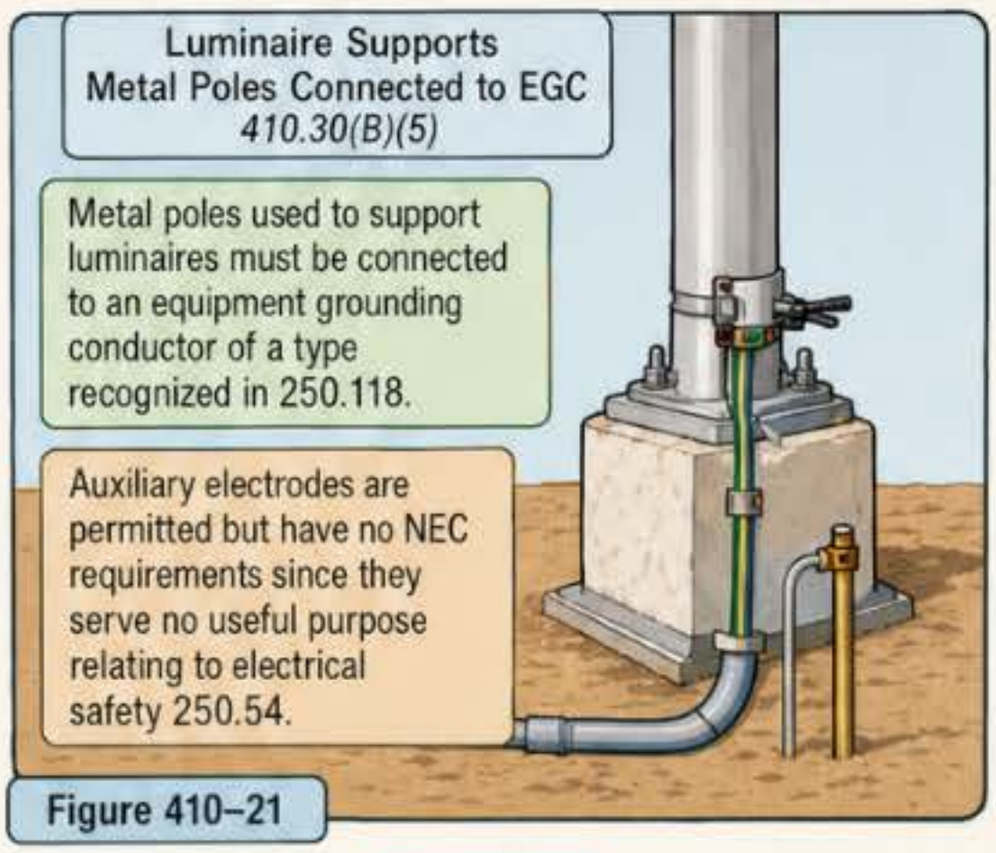


Figure 410–21

Danger

Because the contact resistance of an electrode to the Earth is so high, very little fault current returns to the power supply if it is the only fault current return path. As a result, the circuit overcurrent protective device will not open and clear the ground fault, and the metal pole will become and remain energized by the circuit voltage.
▶ Figure 410–22

410.36 Means of Support

(A) Luminaires Supported by Outlet Boxes. Luminaires are permitted to be supported by outlet boxes or fittings installed as required by 314.23 and must comply with:
▶ Figure 410–23

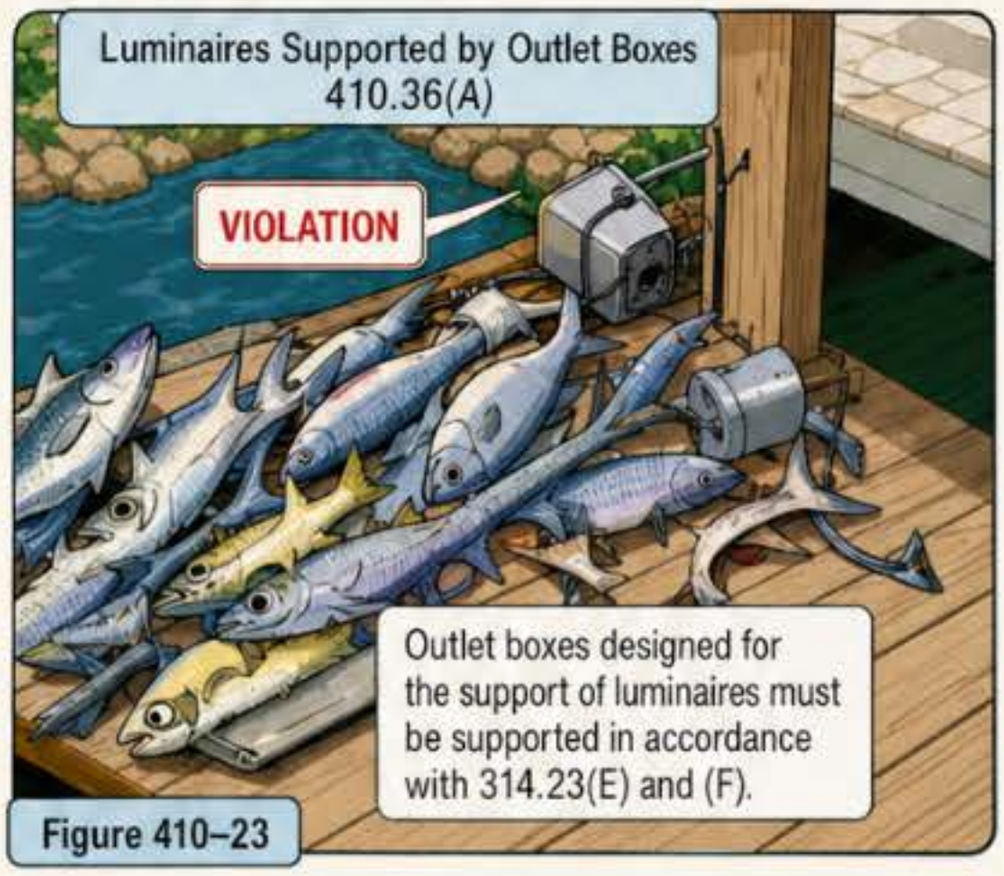


Figure 410–23

(1) The outlet boxes or fittings must comply with 314.27(A).

(2) Luminaires can be supported in accordance with 314.27(E).

(3) Outlet boxes complying with 314.27(E) are considered lighting outlets as required by 210.70(A), (B), and (C).

(B) Suspended-Ceiling Framing Members. Framing parts of suspended-ceiling assemblies may be used to support luminaires when those fixtures are firmly fastened to the framing members with screws, bolts, rivets, or clips. Each support shall be clearly identified for this purpose. **Figure 410–24**

Means of Support, Suspended-Ceiling Framing Members 410.36(B)

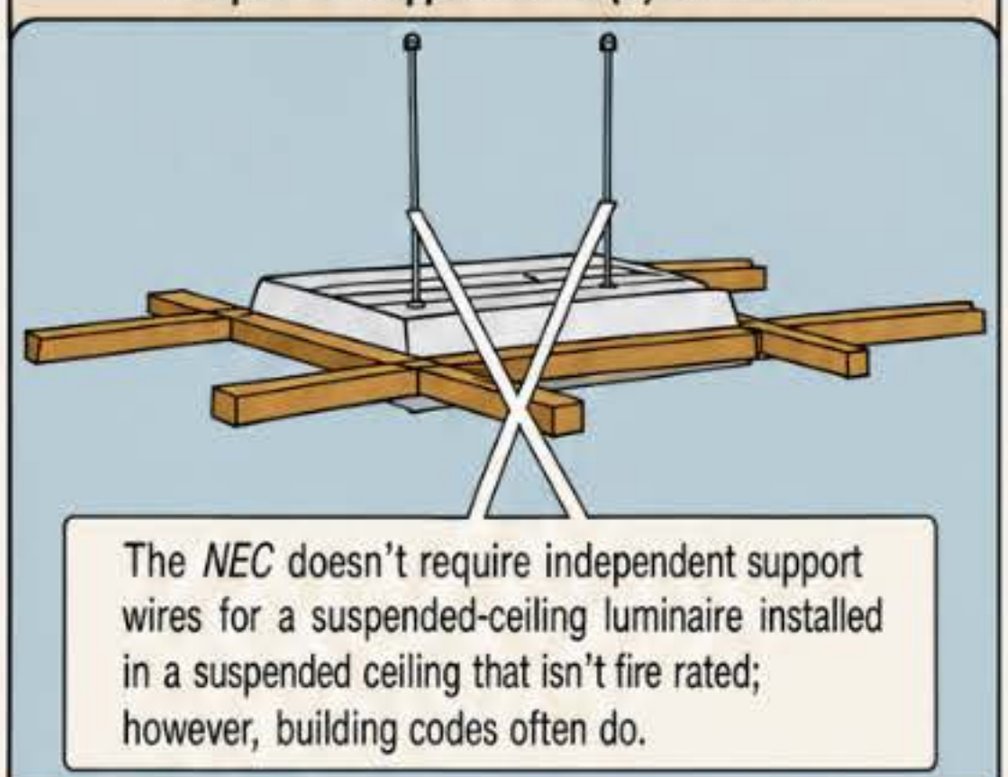
▶ Figure 410–24

Author's Commentary:

- The *NEC* does not require independent support wires for suspended-ceiling luminaires installed in a suspended ceiling that is not fire-rated; however, building codes often do. **Figure 410–25**

— *Michael Hamilton*

Means of Support, Suspended-Ceiling Framing Members Independent Support 410.36(B) Comment



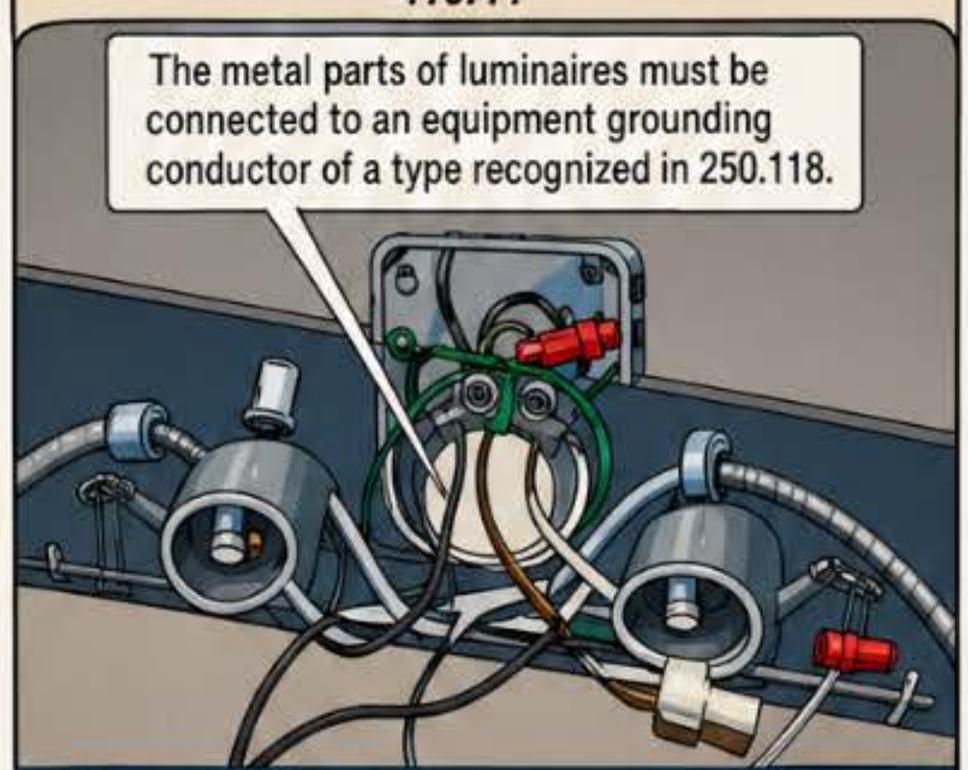
▶ Figure 410–25

Part V. Grounding (Bonding)

410.44 Equipment Grounding Conductor

The metal parts of luminaires must be connected to an equipment grounding conductor of a type recognized in 250.118. **Figure 410–26**

Luminaires Equipment Grounding Conductor 410.44



▶ Figure 410–26

Ex 1: Replacement luminaires are permitted to connect an equipment grounding conductor in the same manner as replacement receptacles in compliance with 250.130(C). The luminaire must then comply with 410.42.

Ex 2: Where no equipment grounding conductor exists at the outlet, replacement luminaires that are GFCI protected, or do not have exposed conductive parts, are not required to be connected to an equipment grounding conductor.

410.46 Equipment Grounding Conductor Attachment

Luminaires with exposed metal parts must be provided with a means for connecting an equipment grounding conductor.

Part VI. Wiring of Luminaires

410.62 Cord-Connected Luminaires

(C) Electric-Discharge and LED Luminaires.

(1) Cord-Connected Installation. A luminaire or a listed assembly must comply with any of the requirements in 410.62(C)(1) through (C)(11) when the luminaire is connected to the supply using a cord. The cord must be located directly below the outlet or busway. The cord shall not be subject to mechanical strain or physical damage, and it must remain visible along its entire length except where it terminates.

Part X. Special Provisions for Flush and Recessed Luminaires

410.115 Temperature

(A) Combustible Material. Luminaires must be installed so that any nearby combustible material is not exposed to temperatures above 90°C (194°F).

(B) Recessed Incandescent Luminaires. Incandescent luminaires must include thermal protection and be identified as thermally protected.

Ex 1: Thermal protection is not required in a recessed luminaire identified for use and installed in poured concrete.

Ex 2: Thermal protection is not required in a recessed luminaire whose design, construction, and thermal performance characteristics provide the same level of protection as a thermally protected luminaire identified as inherently protected.

410.116 Clearance and Installation

(A) Clearances from Combustible Materials.

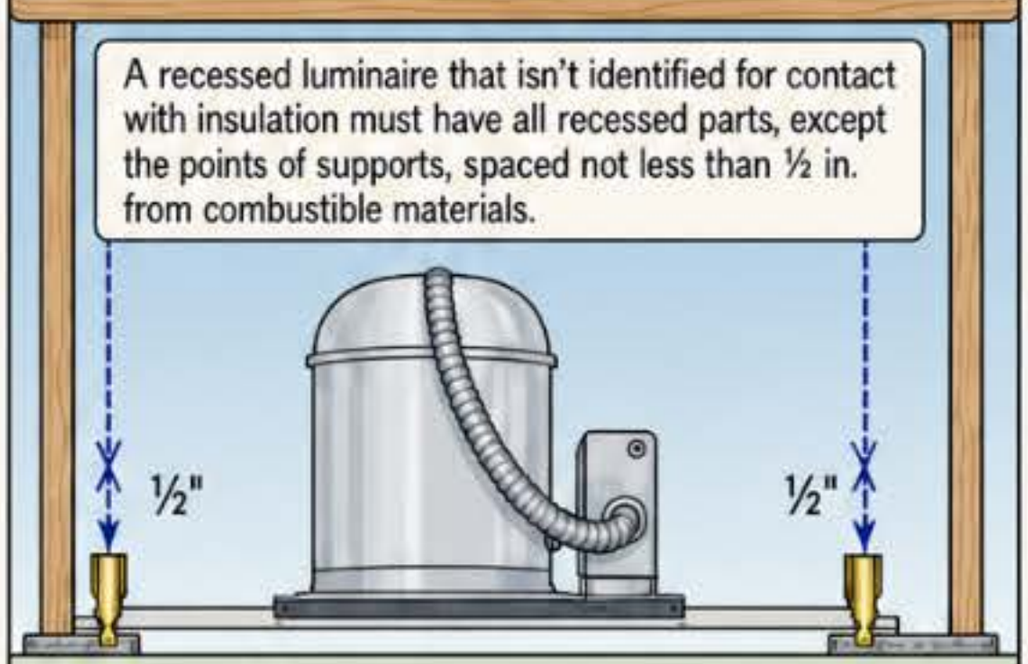
(1) Non-Type IC Luminaires. *A recessed luminaire that is not identified for contact with insulation must not have all recessed parts (except the points of support) spaced less than ½ in. from combustible materials.*

(2) Type IC Luminaires. *Type IC luminaires are permitted to be in direct contact with combustible materials.* ▶**Figure 410–28**

Author's Commentary:
A Type IC luminaire has built-in thermal protection.
— Michael Hamilton

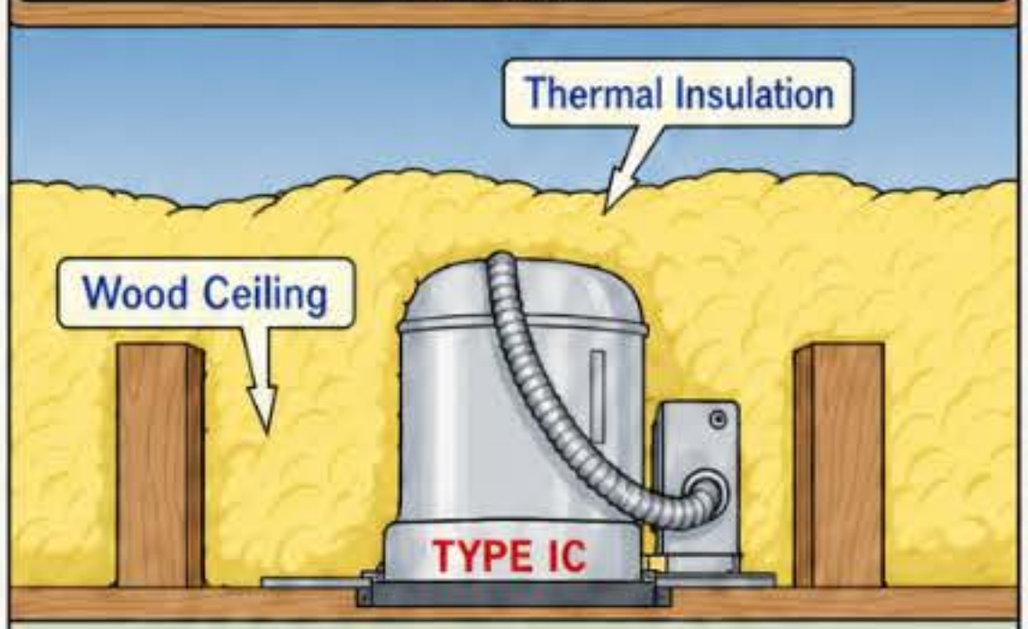
(B) Installation. *Thermal insulation must not be placed above a recessed luminaire or within 3 in. of the enclosure of the luminaire, its wiring compartment, ballast, transformer, LED driver, or power supply unless the luminaire is marked for direct contact with insulation.*

Recessed Luminaires, Clearance from Combustible Materials, Non-Type IC Luminaires
410.116(A)(1)



• **Figure 410–27**

Recessed Luminaires, Clearance from Combustible Materials, Type IC Luminaire
410.116(A)(2)



Type IC luminaires are permitted to be in direct contact with combustible materials.

• **Figure 410–28**

(C) Installation in Fire-Resistant Construction. *Luminaires marked "FOR USE IN NONFIRE-RATED INSTALLATIONS" must not be used in fire-rated installations. Where a luminaire is installed in fire-resistant construction, the recessed luminaire must satisfy one of the following:*

(1) *The recessed luminaire must be listed for use in fire-resistance-rated construction.*

(2) *The recessed luminaire must be installed in, or used with, a luminaire enclosure that is listed for use in fire-resistance-rated construction.*

(3) *The recessed luminaire must be listed and installed in accordance with a tested fire-resistance-rated assembly.*

When a tested fire-resistance-rated assembly allows the installation of a recessed fluorescent luminaire, a recessed LED luminaire of comparable construction is permitted.

410.118 Access to Other Boxes

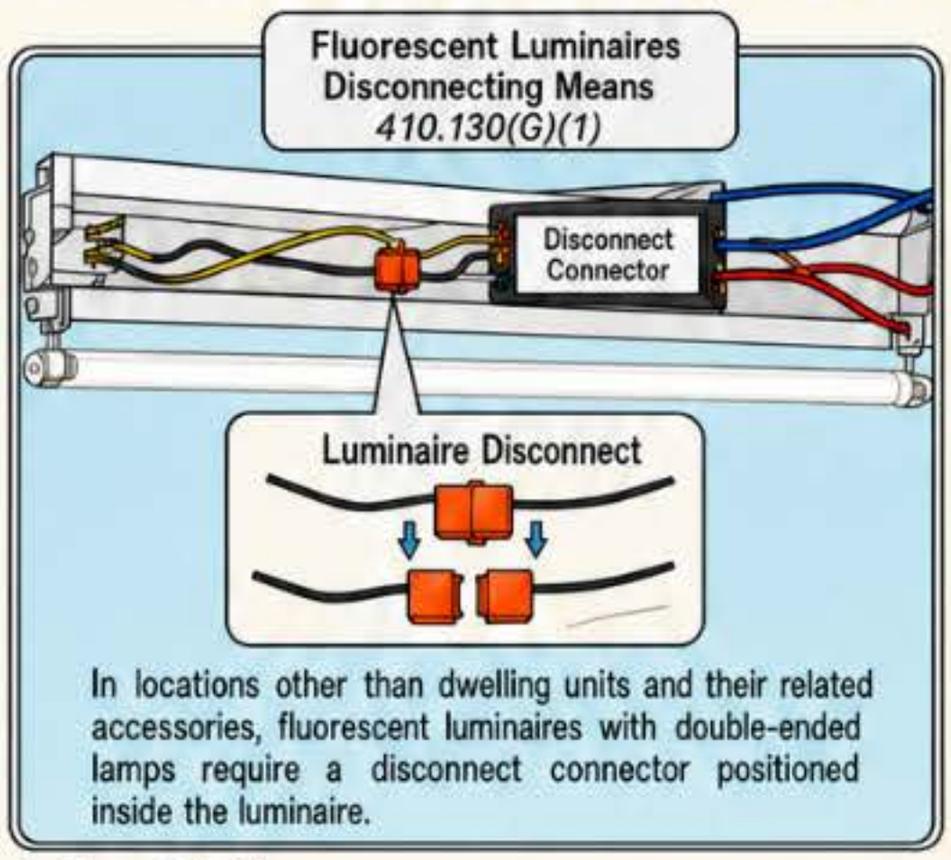
Recessed luminaires in ceilings, floors, or walls are not intended to provide access to outlet boxes, junction boxes, or conduit bodies unless the box or conduit body is an integral part of the listed luminaire.

Part XII. Electric-Discharge Lighting

410.130 General

(G) Disconnecting Means.

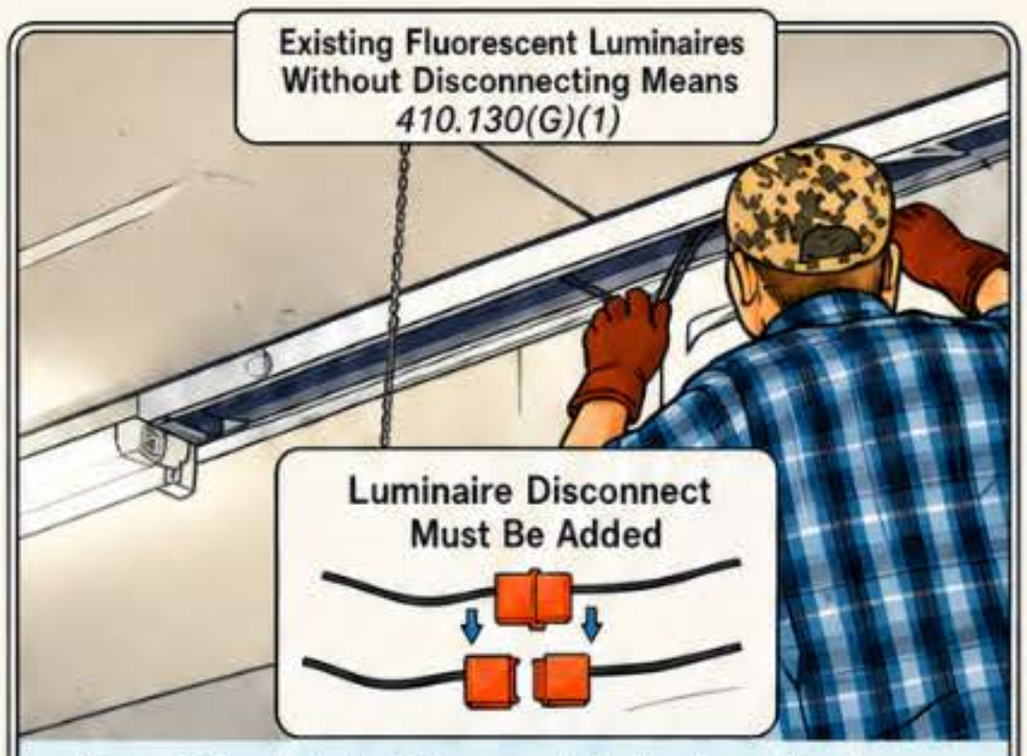
(1) General. Aside from dwelling units and their accessory equipment, fluorescent luminaires that use double-ended lamps must be supplied with a disconnect connector located within the luminaire. ► **Figure 410–29**



In locations other than dwelling units and their related accessories, fluorescent luminaires with double-ended lamps require a disconnect connector positioned inside the luminaire.

► **Figure 410–29**

When an existing installed luminaire's ballast is replaced, a disconnect means must be included at the same time the ballast is replaced. ► **Figure 410–30**



For existing installed fluorescent luminaires without disconnecting means, add a disconnect to each one whenever a ballast is replaced.

► **Figure 410–30**

Ex 4: If more than one luminaire is supplied by a 2-wire branch circuit, a disconnect is not required when the light switch for the space ensures that some of the luminaires in the space will still provide illumination.

Part XIV. Track Lighting

410.151 Installation

(A) Track Lighting. Track lighting must be permanently installed and permanently connected to the branch-circuit wiring.

(B) Circuit Rating. The connected load on a lighting track is not permitted to exceed the rating of the track, and the track must not be supplied by a circuit whose rating exceeds that of the track. ► **Figure 410–31**

The *feeder or service load calculations of 220.43*(B) do *not limit the number of feet of track on a circuit, nor do they limit the number of luminaires mounted on an individual track.*

(C) Locations Not Permitted. *Track lighting is not permitted in the following locations:*

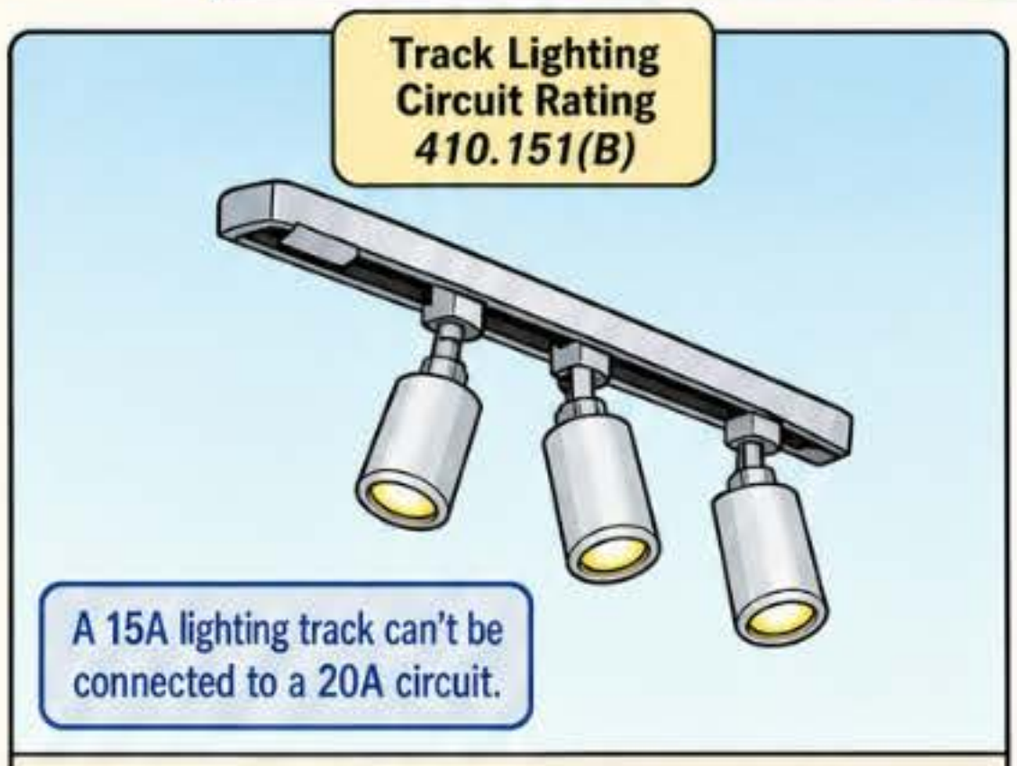
(1) *Places where physical damage is likely*
(2) *Wet or damp environments*
(3) *Areas exposed to corrosive vapors*
(4) *Storage battery rooms*
(5) *Hazardous (classified) locations*
(6) *Concealed spaces*
(7) *Areas extended through walls, partitions, or floors*

Author's Commentary:

Replacing a ballast involves working on an active circuit, which carries risk. A disconnect device should be installed whenever the circuit is being energized, since service interruptions may not be available or practical.

— Michael Hamilton

Luminaires, Lampholders, and Lamps | 410.180



Any load connected to a lighting track must not exceed the track's rated capacity, and the track must never be fed by a circuit whose ampacity is greater than that of the track.

Figure 410-31

(8) Less than 5 ft above the finished floor, except where protected from physical damage.

(9) Within 3 ft horizontally and 8 ft vertically of the top edge of a bathtub rim or shower space [410.4(D)].

410.154 Fastening

Track lighting must be firmly secured to support the weight of the luminaires. If a single track run is 4 ft or shorter, it requires at least two supports, which may be installed in a continuous line. Each individual section exceeding 4 ft in length must include one additional support.

Part XVI. Special Provisions for Horticultural Lighting Equipment

410.170 General

Luminaires that comply with Parts I, II, III, IV, V, VI, VII, IX, X, XI, and XII of this article are allowed for horticultural lighting. Part XVI specifically governs lighting equipment used exclusively in horticultural applications.

Author's Commentary:
Lighting equipment for horticultural use is engineered to deliver the specific light spectrum needed by plants to grow and can also enhance general illumination in growing spaces.

— Michael Hamilton

410.172 Listing

All lighting equipment intended for horticultural applications must be listed.

410.174 Installation and Use

Lighting equipment for horticultural use must be installed and used in accordance with the manufacturer's instructions and the installation markings on the equipment.

410.176 Locations Not Permitted

(A) General Lighting. Lighting equipment for horticultural use is not permitted for general illumination unless that use is explicitly allowed by the manufacturer's instructions.

(B) Installed Location. Lighting equipment for horticultural use must not be installed where it is likely to be exposed to physical damage or where it is concealed.

410.178 Flexible Cord

Flexible cord is permitted only when supplied as part of listed horticultural lighting equipment for any of the following applications:

(1) Plugging a horticultural luminaire directly into a branch-circuit receptacle

(2) Interconnecting horticultural luminaires

(3) Connecting a horticultural lighting luminaire to a remote power source

Note: Remote power sources consist of LED drivers, fluorescent ballasts, and HID ballasts.

410.180 Fittings and Connectors

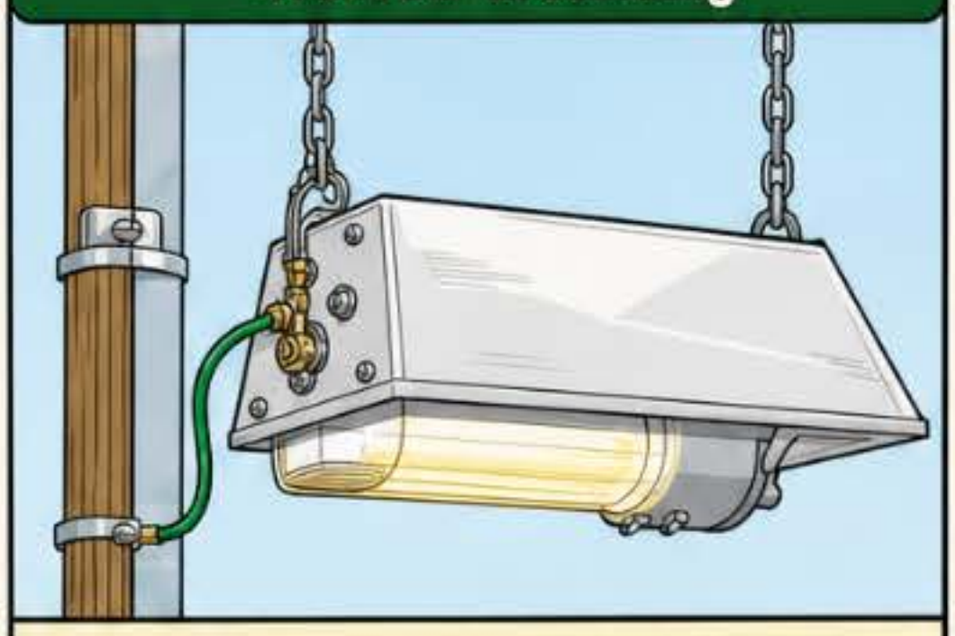
Fittings and connectors attached to flexible cords must be supplied as part of a listed horticultural lighting system or device and installed according to the instructions provided as part of that listing.

Author's Commentary:
Connectors and fittings are integral to the safety and performance of horticultural lighting systems and must be used exactly as specified in the listing documentation.

— Michael Hamilton

410.182 | Luminaires, Lampholders, and Lamps

410.182 Grounding

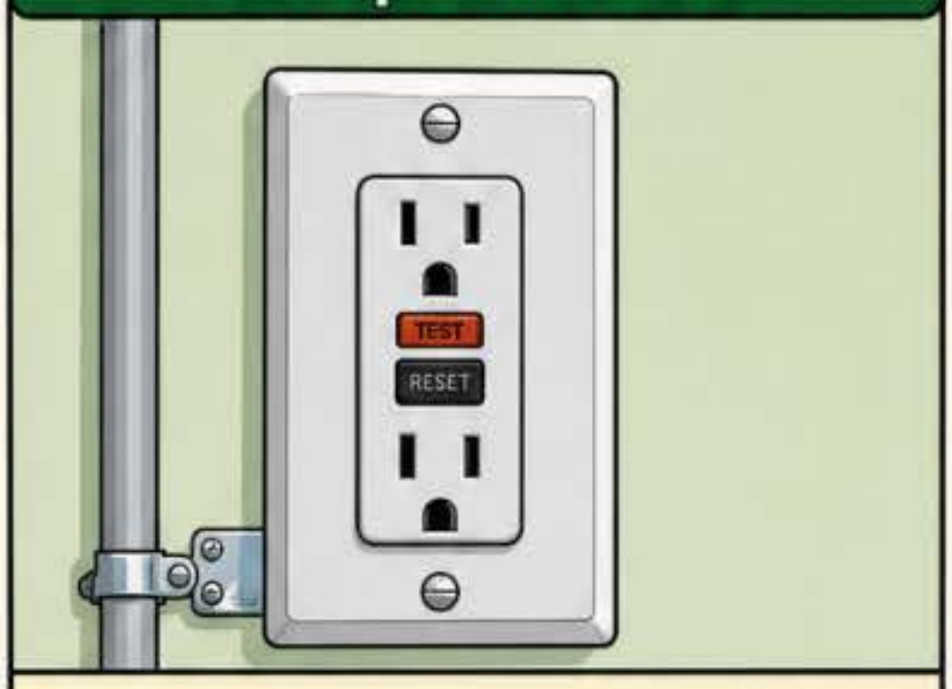


All horticultural lighting equipment must be connected to the circuit equipment grounding conductor in accordance with Article 250 and Part V of this article.

410.186 Support

Special fittings used to support horticultural lighting equipment must be installed following the installation instructions provided, and must be securely fastened.

410.184 Ground-Fault Circuit-Interrupter Protection



All horticultural lighting equipment identified for use with flexible cords must be supplied by GFCI-protected lighting outlets.

ARTICLE 411 LOW-VOLTAGE LIGHTING

Introduction to Article 411—Low-Voltage Lighting

Article 411 establishes the rules for indoor and outdoor low-voltage lighting systems and their parts. You'll commonly see these setups used in areas like landscape features, under-cabinet lighting, commercial displays, and museum exhibits. Note that the first half of Article 411 gives you a broad overview—low-voltage lighting isn't our main concern here. These systems operate at 25V or less, which lowers the risk of fire and greatly reduces the chance of electrical shock. As a result, these installations are widespread and continue to grow in popularity.

411.1 Scope

Article 411 applies to low-voltage lighting systems that run no more than 30V AC or 60V DC in dry locations and no more than 15V AC or 30V DC in wet locations. It also covers lighting equipment connected to a Class 2 power source (see 411.5 and 411.6).

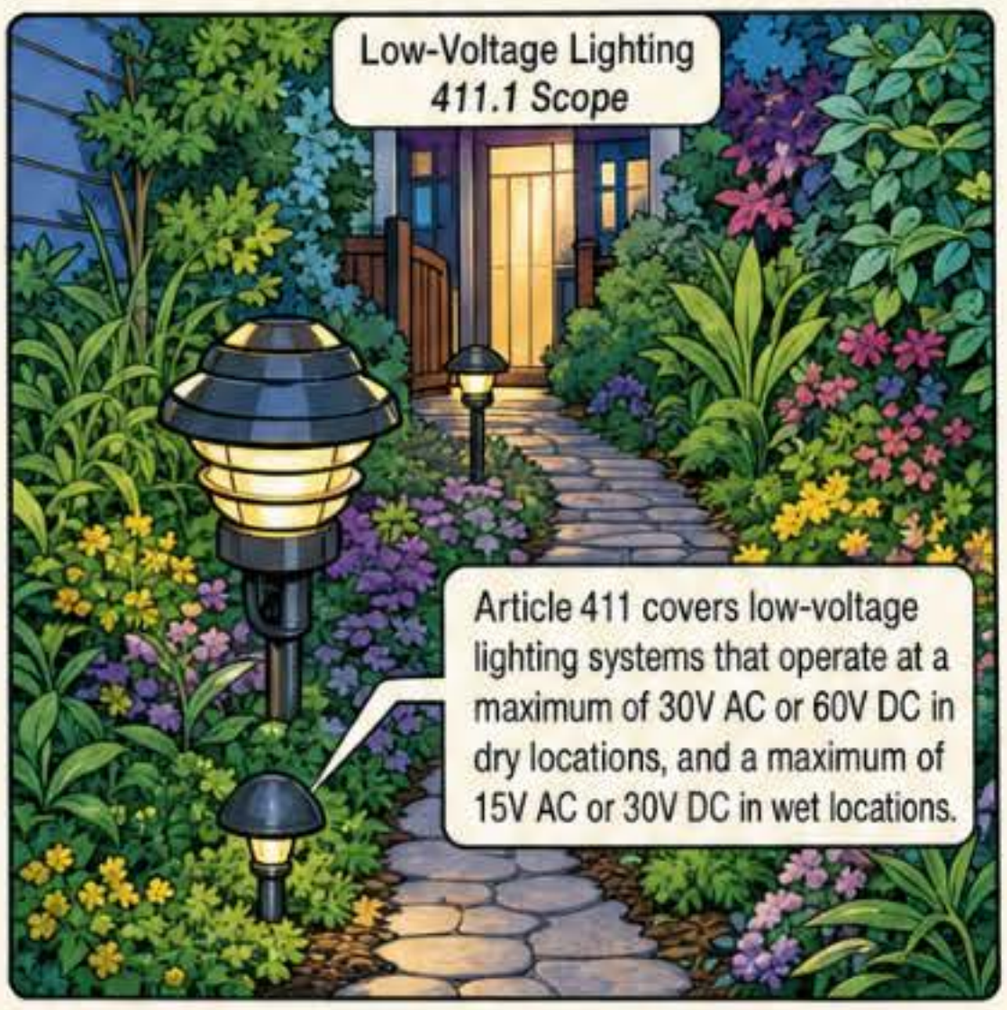


Figure 411–1

411.3 Low-Voltage Lighting Systems

Low-voltage lighting systems include an isolating power supply, luminaires, and related components. The transformer secondary winding must be rated no higher than 25A. See **Figure 411–2.**

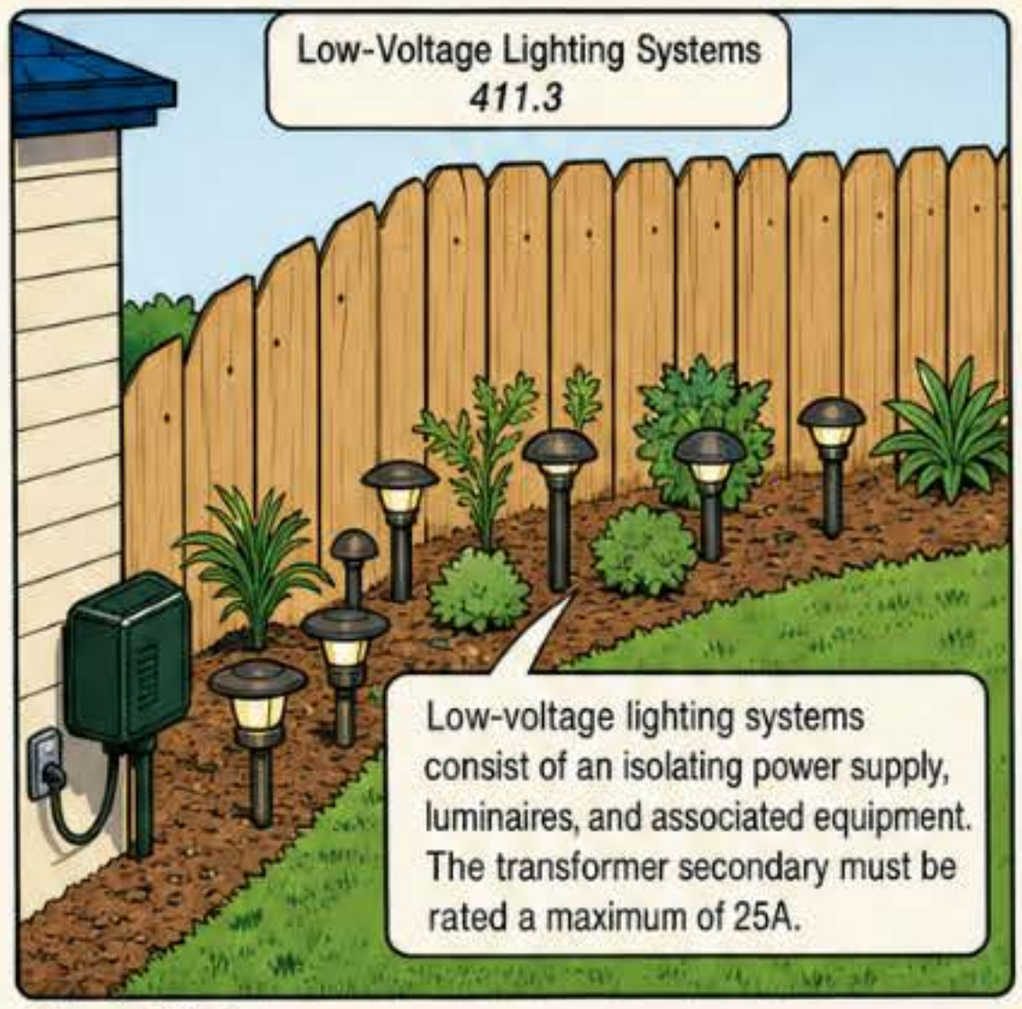


Figure 411–2

411.4 Listing Required

Low-voltage lighting systems must meet either requirement **(A)** or **(B).** Only listed systems and systems built from listed low-voltage lighting parts are allowed for reconditioning.

(A) Listed System. A listed low-voltage lighting system includes the power supply and luminaires. See **Figure 411–3.**

(B) Assembly of Listed Parts. A low-voltage lighting system assembled from the following listed parts:

(1) Low-voltage luminaires identified for the use.

411.5 | Low-Voltage Lighting

Low-Voltage Lighting, Listed System
411.4(A)

Low-voltage lighting systems can be a listed low-voltage lighting system, including the power supply and luminaires.

▶ Figure 411–3

(2) Power supply identified for the use.

(3) Low-voltage luminaire fittings identified for the use.

(4) Cable suitable for the application or conductors installed within a Chapter 3 wiring method.

411.5 Specific Location Requirements

(A) Concealed Wiring. Conductors concealed or installed through a wall, floor, or ceiling must comply with (1) or (2):

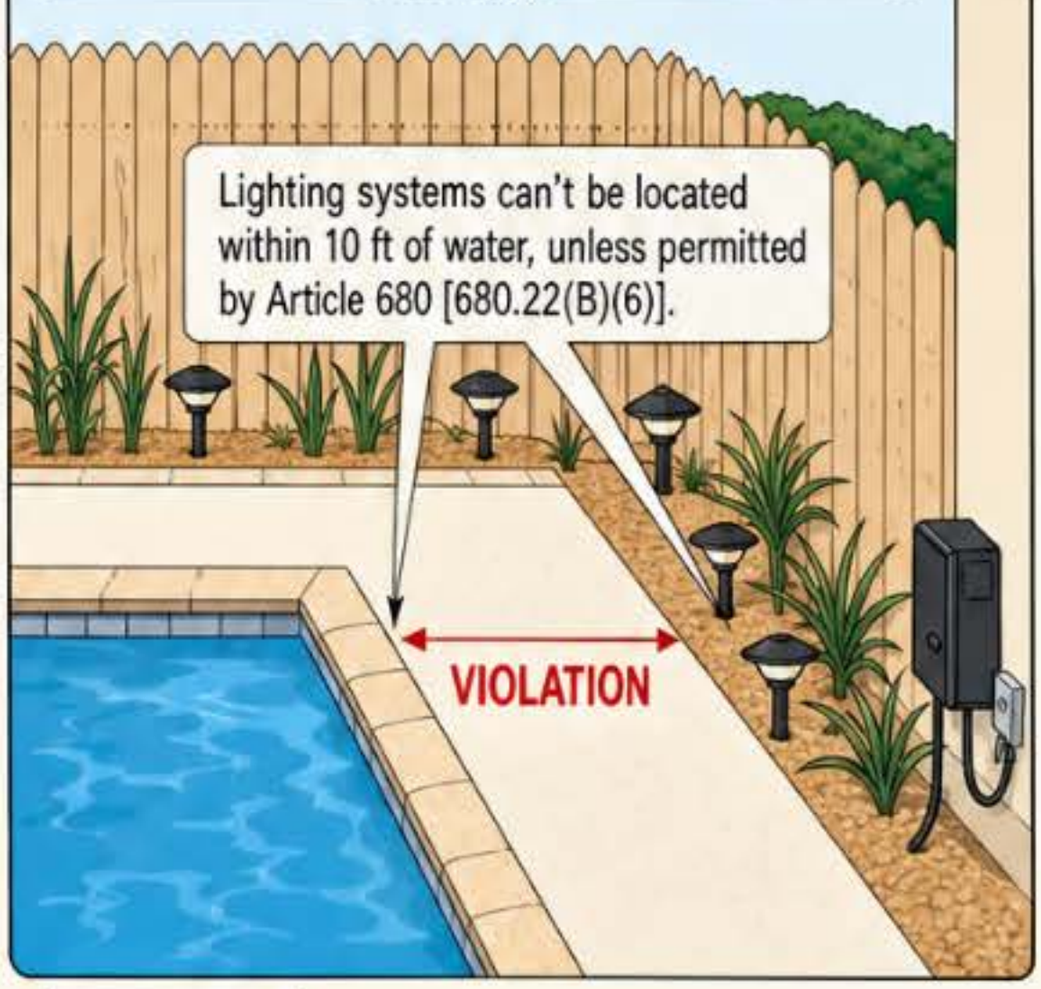
(1) Low-voltage lighting system conductors must be installed using a Chapter 3 wiring method.

(2) When supplied by a listed Class 2 power supply, Class 2 cables can be used and be installed in accordance with 725.130.

(B) Pools, Spas, Fountains, and Similar Locations. Low-voltage lighting systems with a transformer or power supply that is listed, labeled, and identified for swimming pool underwater luminaires [680.23(A)(2)] can be installed without any distance limit to the water [680.22(B)(6)]. All other low-voltage lighting must not be installed within 10 ft of the edge of the water.

▶ Figure 411–4

Low-Voltage Lighting, Specific Location Requirements
Pools, Spas, and Fountains
411.5(B)



▶ Figure 411–4

Author's Commentary:

Low-voltage lighting around water features is high-risk because of water's excellent conductivity. Always respect the clearance rules unless the installation specifically meets Article 680 conditions for underwater luminaires.

— Michael Hamilton

ARTICLE 422 APPLIANCES

Introduction to Article 422—Appliances

Article 422 addresses electric equipment that is secured in place, permanently wired, or connected by cord and plug. The substance of this article appears in Parts II and III. Parts IV and V focus on manufacturers; however, it's important to review appliances for compliance before they are put into service.

Part I. General

422.1 Scope

Article 422 applies to appliances in any location. ☞ **Figure 422-1**

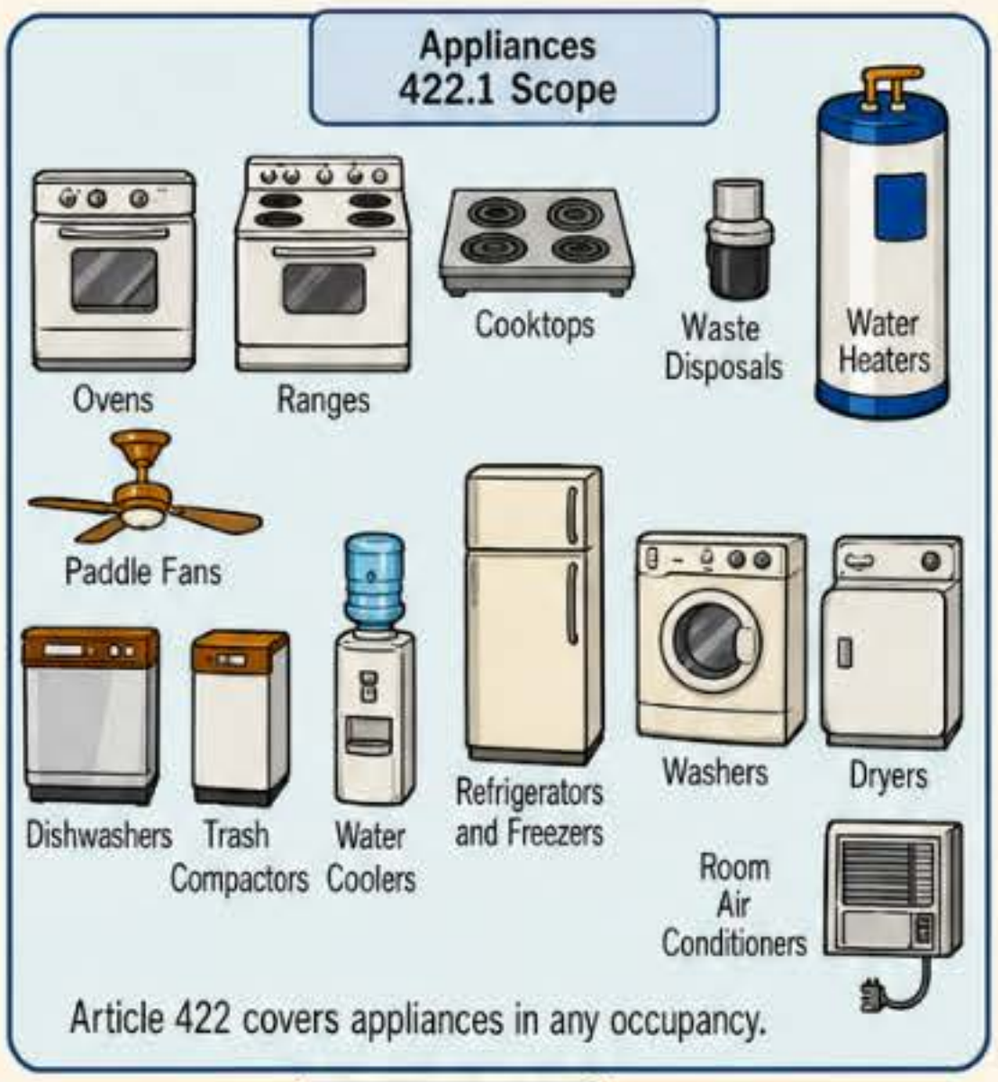


Figure 422-1

422.3 Other Articles

Motor-operated appliances must comply with Article 430, and equipment that uses hermetic refrigerant motor compressors must comply with Article 440.

422.5 GFCI Protection

(A) General. Appliances rated 60A or less must be protected by Class "A" GFCI devices [422.5(B)].

(1) Automotive vacuum machines. ☞ **Figure 422-2**

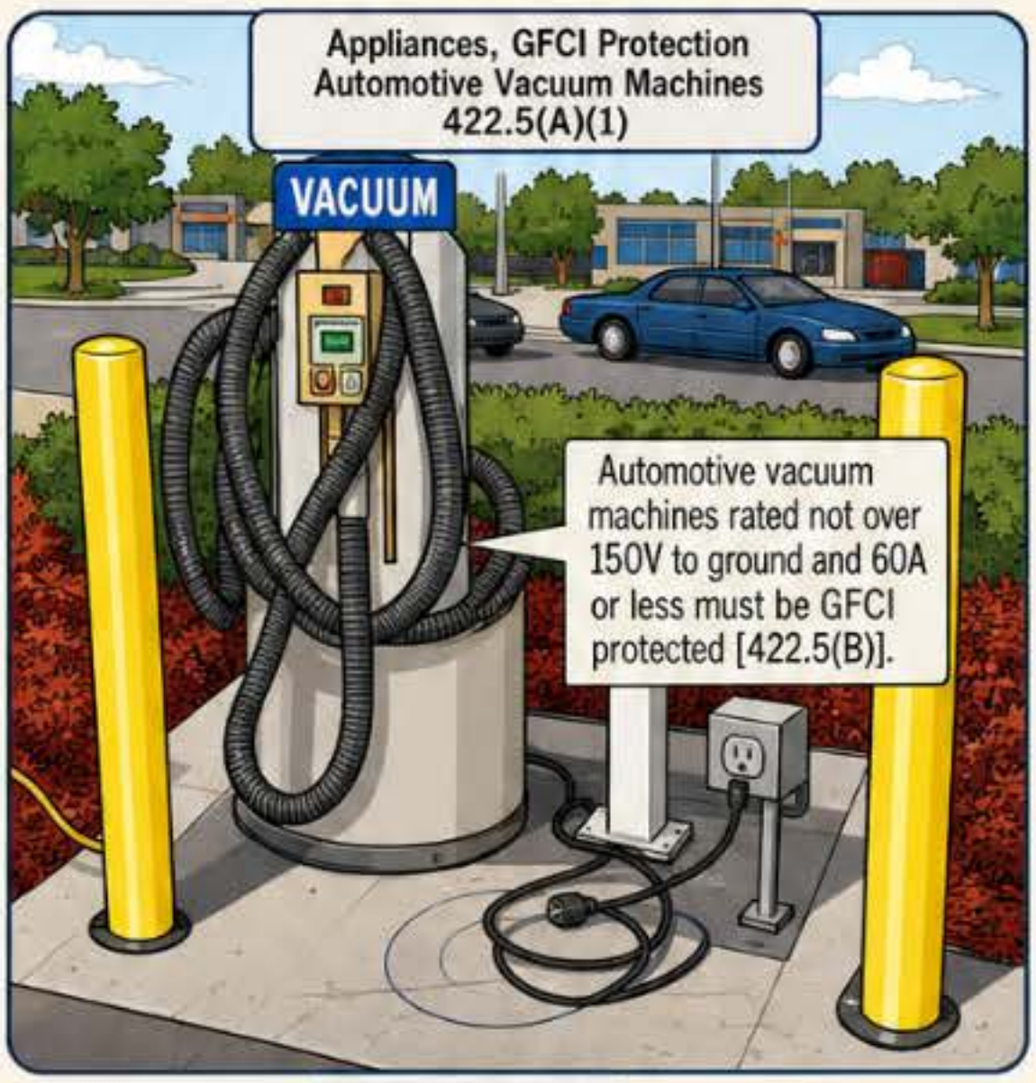


Figure 422-2

(2) Drinking water coolers and bottle fill stations. ☞ **Figure 422-3**

(3) Cord-and-plug-connected high-pressure spray washing machines.

(4) Tire inflation machines. ☞ **Figure 422-4**

Author's Commentary:

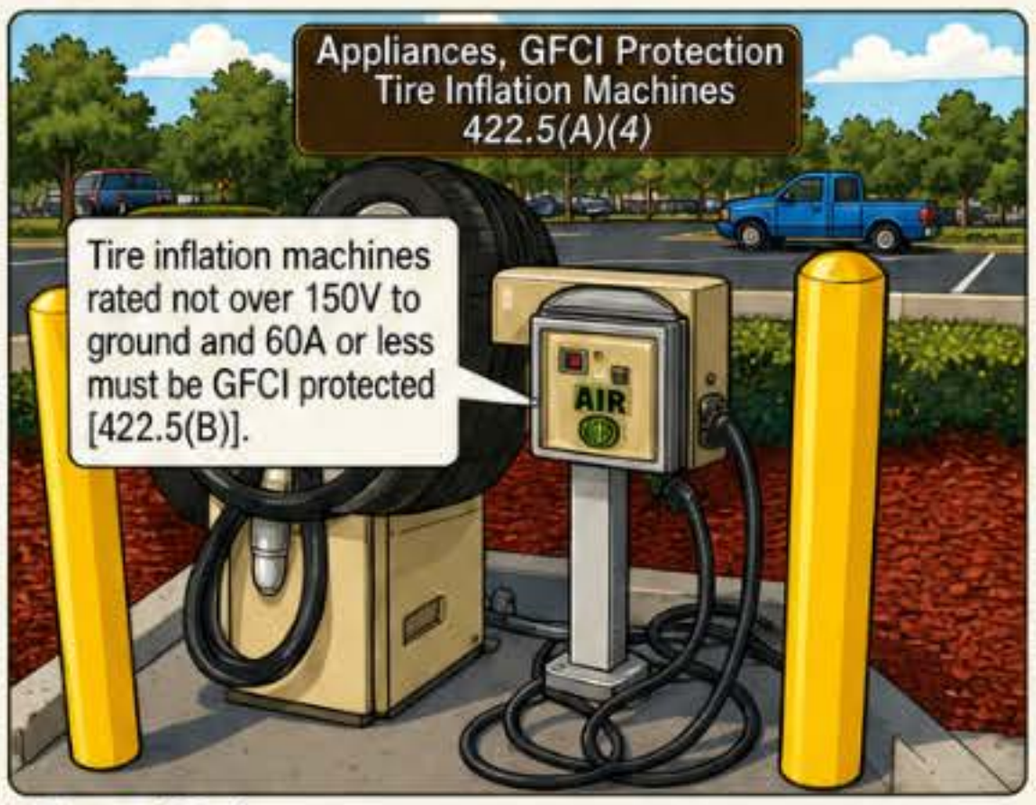
Appliances are encountered in virtually every type of occupancy, from homes and offices to industrial facilities. Always verify that the appliance you're installing or inspecting meets the specific requirements of this article, especially the GFCI protection rules that safeguard people from electrical shock.

— Michael Hamilton

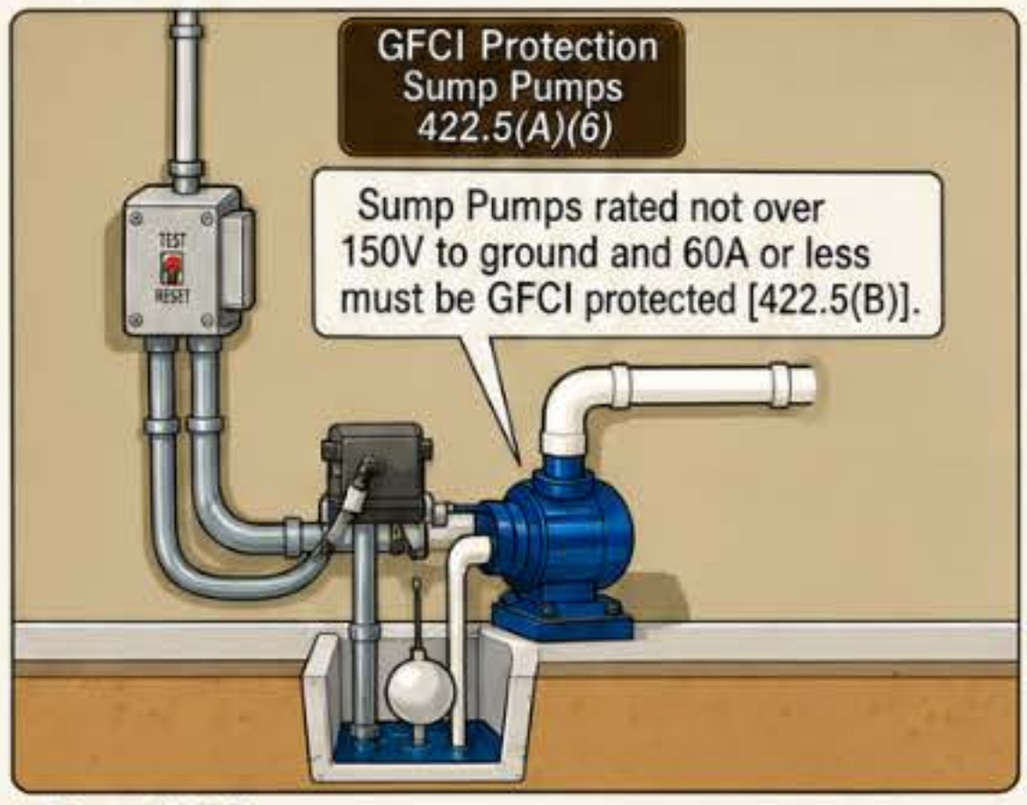
422.5 | Appliances

▶ **Figure 422–3**

▶ **Figure 422–5**



▶ **Figure 422–4**



▶ **Figure 422–6**

(5) Vending machines. ▶ **Figure 422–5**

(6) Sump pumps. ▶ **Figure 422–6**

(7) Dishwashers. ▶ **Figure 422–7**

Note: Section 210.8 specifies requirements for GFCI protection for the receptacle outlets where the location warrants such protection.

(B) Type and Location. The GFCI must be readily accessible and be:

(1) A GFCI circuit breaker,

(2) A GFCI device or receptacle,

(3) A GFCI integral with the attachment plug,

(4) A GFCI within the supply cord not more than 12 in. from the attachment plug, or

(5) A factory installed GFCI within the appliance.

▶ **Figure 422–7**

Author's Commentary:
GFCI protection reduces the risk of serious electrical shock in damp locations and around moisture-using equipment.
— Michael Hamilton

Note: *The **2023** National Electrical Code, Section 210.8, outlines **GFCI** protection requirements for receptacle outlets when the surroundings indicate a potential shock hazard.*

DEFINITIONS | From Michael Hamilton Publications

422.6 LISTING REQUIRED

Equipment that is supplied at 50 volts or more must be listed.

PART II. BRANCH-CIRCUIT REQUIREMENTS

422.10 BRANCH CIRCUITS

(A) Individual Branch Circuits. The current-carrying capacity of each conductor in a branch circuit for a single appliance cannot be less than the branch-circuit rating shown on the appliance.

Author's Commentary:
Listed appliances are provided with installation instructions from the manufacturer, and the minimum overcurrent protection and/or conductor size are sometimes printed on the appliance.

— Michael Hamilton

Branch-circuit conductors that serve cooking appliances and household ranges must be sized according to Table 220.55 and 210.19(A)(3).

(B) Branch Circuits Supplying Two or More Loads. Branch circuits that supply appliances, along with other loads, must have conductors sized in accordance with 210.23(A) as outlined below:

- Cord-and-plug-connected equipment is not allowed on a circuit that is sized at more than 80 percent of the branch-circuit ampacity [210.23(A)(1)].
- Equipment that is permanently fastened in place is not permitted on a circuit sized at more than 50 percent of the branch-circuit ampacity if the circuit also supplies both luminaires and receptacles [210.23(A)(2)].

422.11 OVERCURRENT PROTECTION

(E) Nonmotor Appliances. The required overcurrent protection for appliances must:

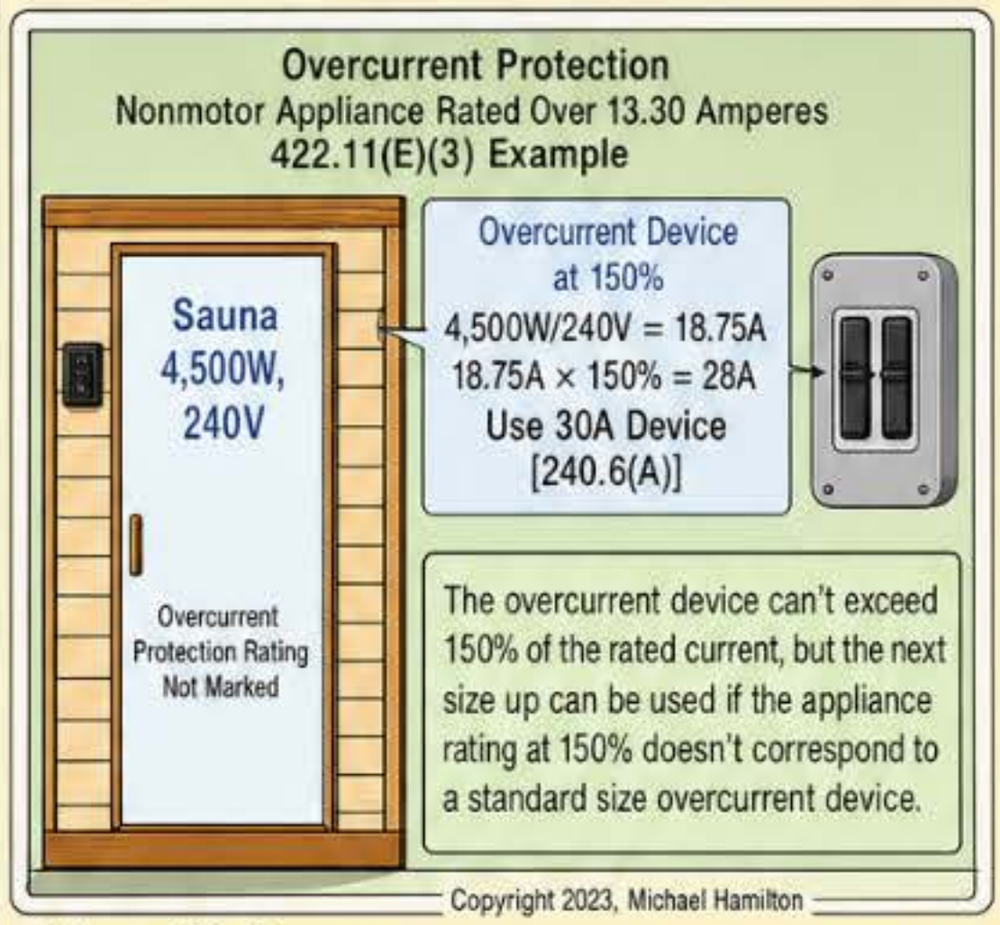
(1) Be no greater than the appliance rating shown on the nameplate.
(2) Be no greater than twice the rating if the overcurrent protection is rated 13.30 A or less, or
(3) Be no greater than 150 percent of the appliance rating if the overcurrent protection rating does not appear on the appliance and the appliance is rated over 13.30 A.

Where 150 percent of the appliance rating does not coincide with a standard overcurrent protective device ampere rating listed in 240.6(A), then the next higher standard rating applies.

▶ EXAMPLE

Question: *What is the maximum size overcurrent protective device for a 4,500W, 240V sauna?* ▶ **Figure 422–8**

(a) 20A *(b) 30A* *(c) 40A* *(d) 50A*



▲ **Figure 422–8**

Solution:

Protection Size = 4,500W/240V

Protection Size = 18.75A × 150%

Protection Size = 28A; use next size up, 30A [240.6(A)]

Answer: *(b) 30A*

422.12 CENTRAL HEATING EQUIPMENT

Central heating equipment must be supplied by an individual branch circuit.

422.13 STORAGE WATER HEATERS

The branch-circuit overcurrent device and conductors for fixed storage-type water heaters that have a capacity of 120 gallons or less must be sized not smaller than 125 percent of the rating of the water heater. ▶ **Figure 422–9**

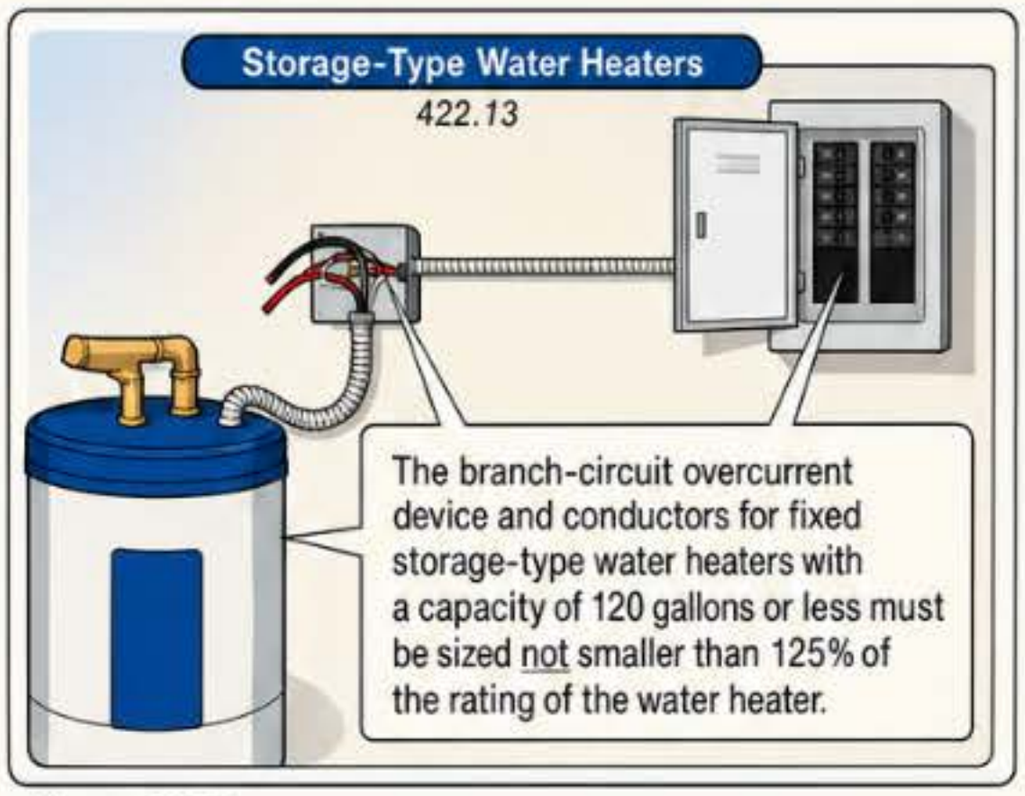


Figure 422-9

▶ Example

Question: *What size conductor and overcurrent protection are required for a 4,500W, 240V water heater?* ▶ **Figure 422-10**

(a) 20A/12 AWG *(b) 25 or 30A/10 AWG*
(c) 40A/8 AWG *(d) 50A/6 AWG*

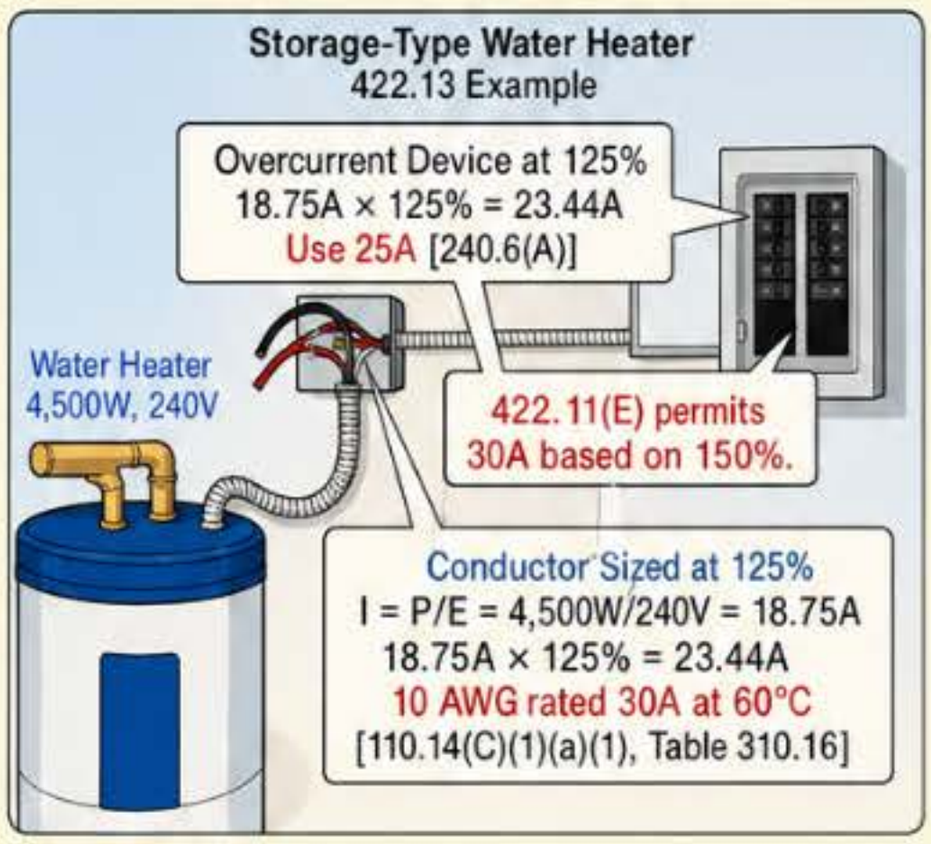


Figure 422-10

Solution:

Step 1: *Determine the branch-circuit rating [210.19(A)(1) and 422.13].*

Circuit Current = 4,500W/240V
Circuit Current = 18.75A
Circuit Rating = 18.75A × 125%
Circuit Rating = 23.44A
Circuit Conductor = 10 AWG rated 30A at 60°C [110.14(C)(1)(a)(2) and Table 310.16]

Step 2: *Determine the overcurrent protection rating [210.20 and 422.13].*

Circuit Current = 4,500W/240V

Circuit Current = 18.75A

Circuit Protection = 18.75A × 125%

Circuit Protection = 23.44A; use the next size up, 25A [240.6(A)]

Note: *422.11(E) permits the overcurrent protective device to be sized up to 150% of the appliance rating.*

Circuit Protection = 18.75A × 150%
Circuit Protection = 28.75A; use the next size up, 30A [240.6(A)]

Answer: *(b) 25 or 30A/10 AWG*

422.15 Central Vacuums

(A) Circuit Loading. Listed central vacuum systems must be on a separate circuit if the ampere rating of the equipment exceeds 50 percent of the ampere rating of the circuit [210.23(A)(2)]. ▶ **Figure 422-11**

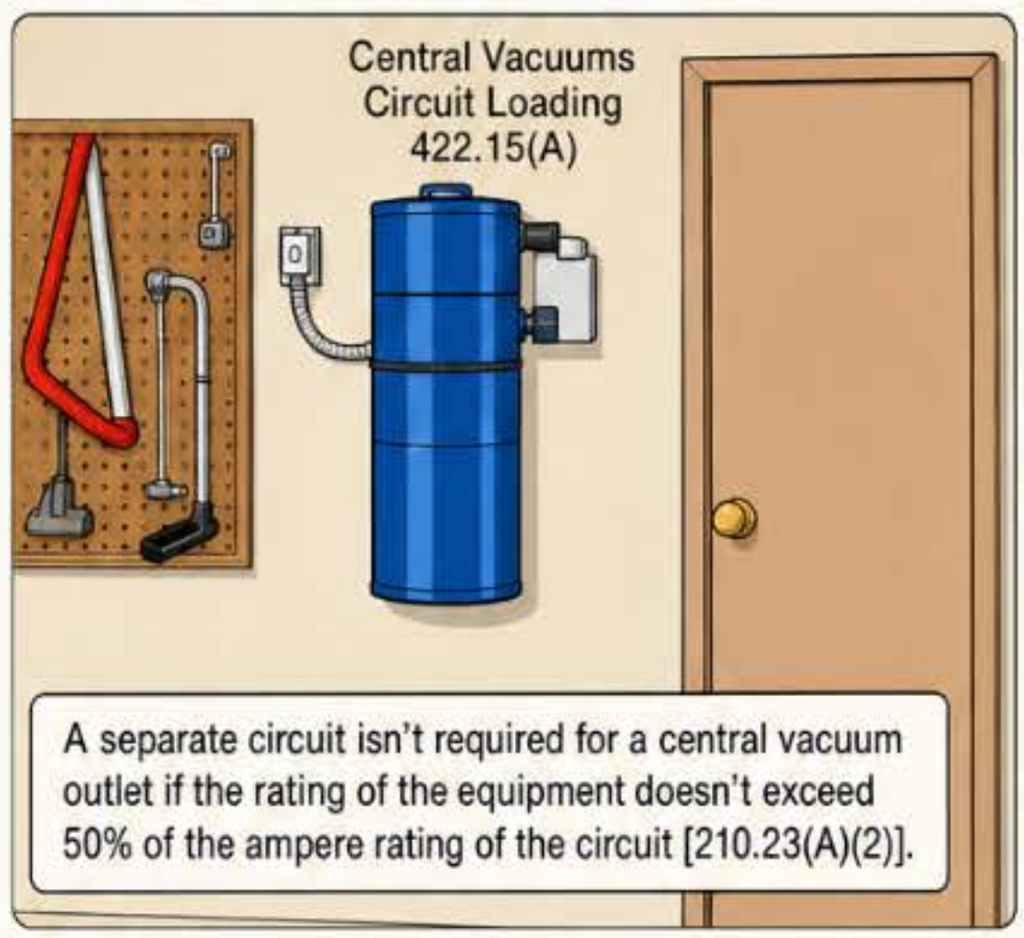


Figure 422-11

Author's Commentary:

▶ *A separate 15A circuit is required for a central vacuum receptacle outlet if the ampere rating of the central vacuum exceeds 7.50A (50 percent of a 15A circuit). A separate 20A circuit is required for a central vacuum receptacle outlet if the ampere rating of the central vacuum exceeds 10A (50 percent).*

— Michael Hamilton

422.16 Flexible Cords

(A) General. Flexible cords may be used with appliances only in circumstances where they are necessary to:

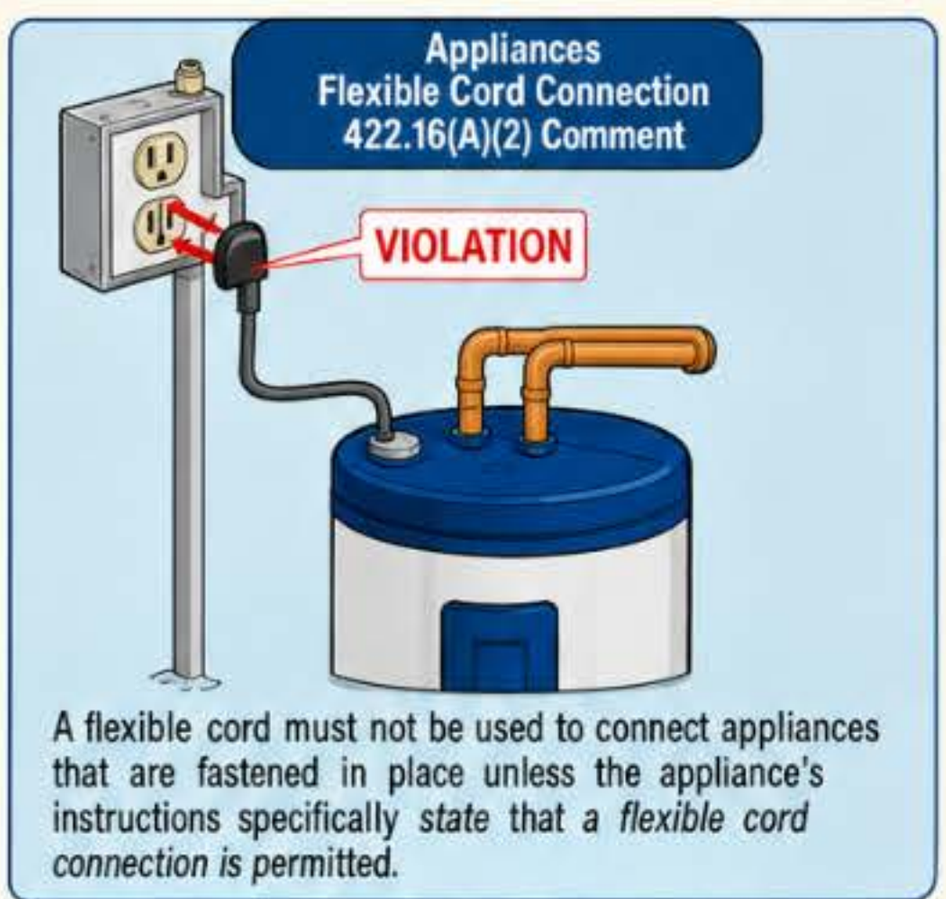
(1) Facilitate frequent interchange or avoid strain on the supply due to movement or vibration [400.10(A)(6) and 400.10(A)(7)].

(2) Allow removal of an appliance secured in position where the hardware and mechanical interfaces are intended to permit quick removal [400.12(A)(8)].

Author's Commentary:

Flexible cords are not intended for permanently connecting water heaters, furnaces, or other devices *secured in place—unless the equipment is explicitly identified as acceptable for use with a flexible cord.*

— Michael Hamilton



A flexible cord must not be used to connect appliances that are fastened in place unless the appliance's instructions specifically *state* that a *flexible cord connection is* permitted.

Figure 422–12

(B) Specific Appliances.

(1) In-Sink Waste Disposal. A flexible cord may be used with an in-sink waste disposal if: ▶ ***Figure 422–13***

(1) The cord is at least 18 inches long but *no longer than* 3 feet.

(2) *The receptacle is positioned to protect the cord from physical damage.*

(3) *The receptacle is within reach.*

(4) *The flexible cord includes an equipment grounding conductor and is terminated with a grounding-type attachment plug.*

A flexible cord is allowed for an in-sink waste disposal if:

(1) The cord is 18 to 36 in. long

(2) The receptacle is located to protect against damage to the cord

(3) The in-sink waste disposal receptacle is accessible

(4) It has a grounding-type attachment plug

Figure 422–13

Example: *An appliance clearly marked as part of a double-insulation system does not require a grounding-type attachment plug.*

Author's Commentary:

If an appliance is hard-wired, the disconnect must be within sight from the appliance or the circuit breaker must be lockable, with provisions to keep it in the "on" (closed) position regardless of whether the lock is installed.

— Michael Hamilton

(2) Dishwashers and Trash Compactors. A flexible cord is permitted for these appliances if:

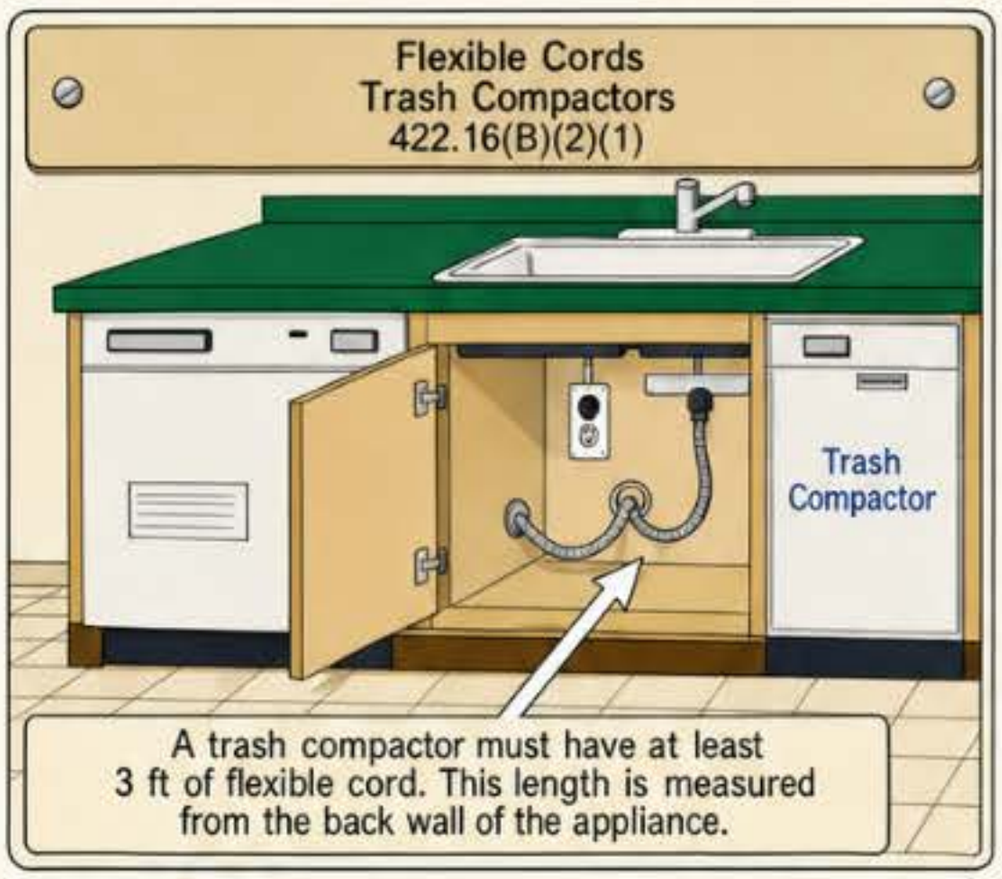
(1) For a trash compactor, the cord length is at least 3 feet and no more than 4 feet, measured from the rear of the appliance.

(2) For a dishwasher, the cord length is at least 3 feet and does *not exceed 6 feet, measured from the face of the attachment plug to the rear of the appliance.* ▶ ***Figure 422–15***

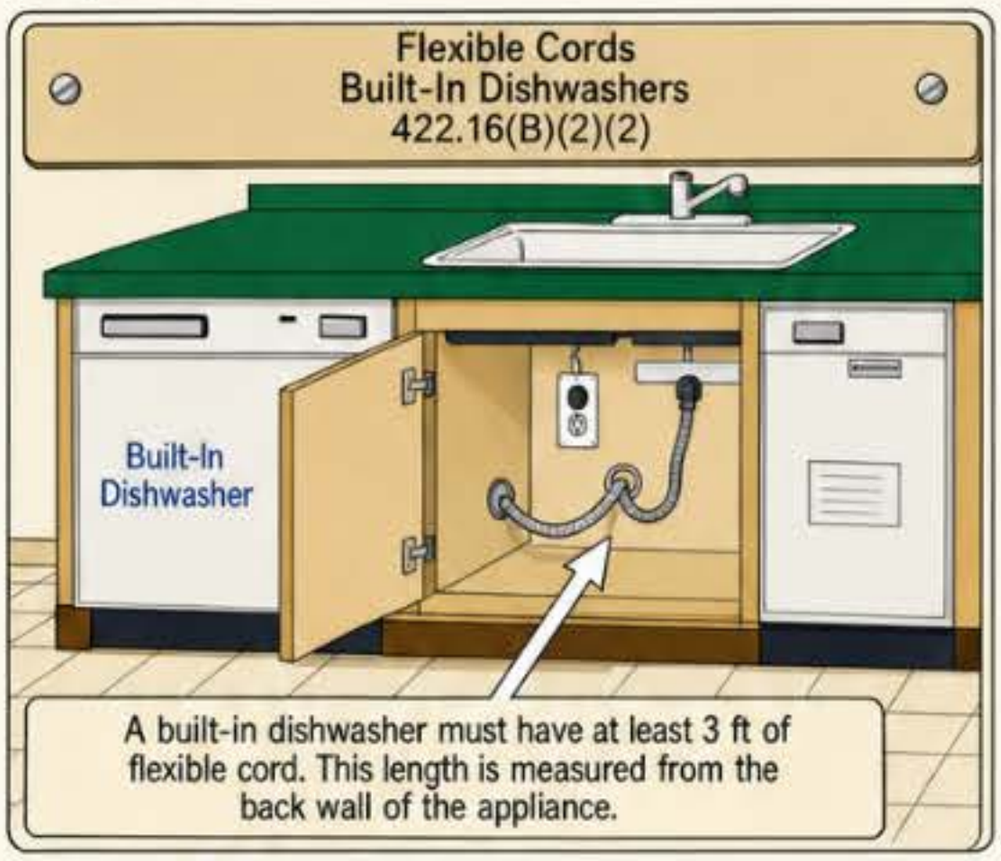
(3) *The receptacle is placed so the cord is protected from damage.*

(4) *The receptacle for a trash compactor is in the space occupied by the compactor itself or in the adjacent space.*

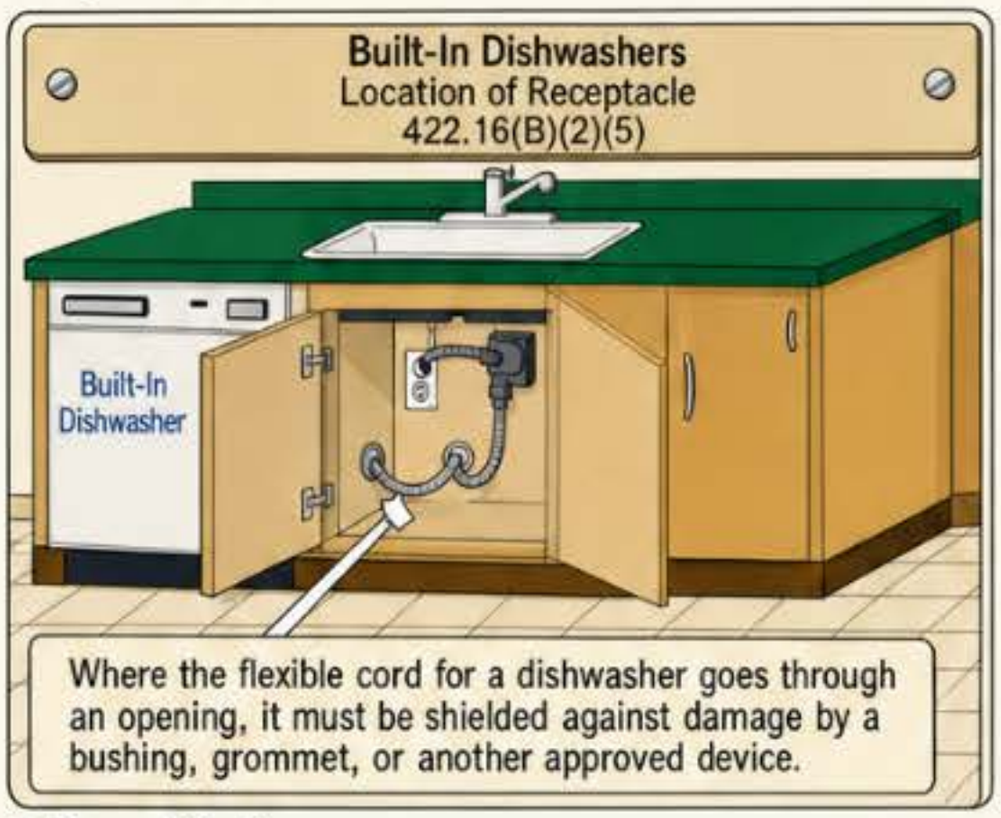
(5) *The receptacle for a dishwasher is located in the space beside the dishwasher. If the cord passes through an opening, that opening must be safeguarded against abrasion by a bushing, grommet, or another approved protective method.* ▶ ***Figure 422–16***



▶ **Figure 422-14**



▶ **Figure 422-15**



▶ **Figure 422-16**

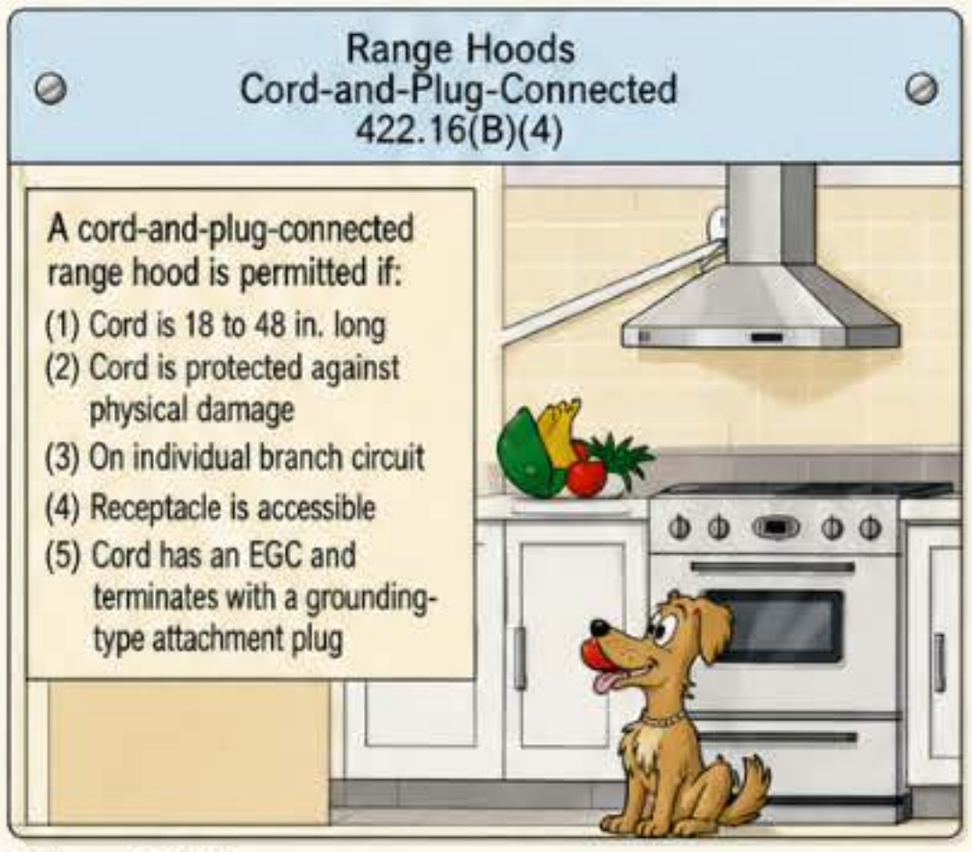
(6) The receptacle is accessible.

(7) The flexible cord has an equipment grounding conductor and is terminated with a grounding-type attachment plug.

> ***Author's Commentary:*** *A listed appliance identified by the manufacturer as being protected by a double insulation system does not have to be terminated with a grounding-type attachment plug.*
>
> *— Michael Hamilton*

(3) Wall-Mounted Ovens and Counter-Mounted Cooking Units. Wall-mounted ovens and counter-mounted cooking appliances may be connected using a cord and plug. Use a flexible cord that is marked for that purpose and is acceptable for the installation instructions provided by the appliance manufacturer.

(4) Range Hoods and Microwave Ovens/Range Hood Combos. Range hoods and over-the-range microwave ovens that integrate a range hood are permitted to use a cord-and-plug *connection with a flexible cord identified as suitable for range hood use in the appliance manufacturer's installation guide, when all of the following conditions are met:* ▶ **Figure 422-17**



▶ **Figure 422-17**

(1) The length of the cord is not less than 18 inches and not more than 4 feet.

(2) Receptacles are located where they are protected from physical damage to the flexible cord.

(3) The receptacle is supplied by an individual branch circuit.

(4) The receptacle is accessible.

(5) The flexible cord has an equipment grounding conductor and is terminated with a grounding-type attachment plug.

> ***Author's Commentary:*** *The flexible cord includes an equipment grounding conductor and ends in a grounding-type attachment plug.*
>
> *— Michael Hamilton*

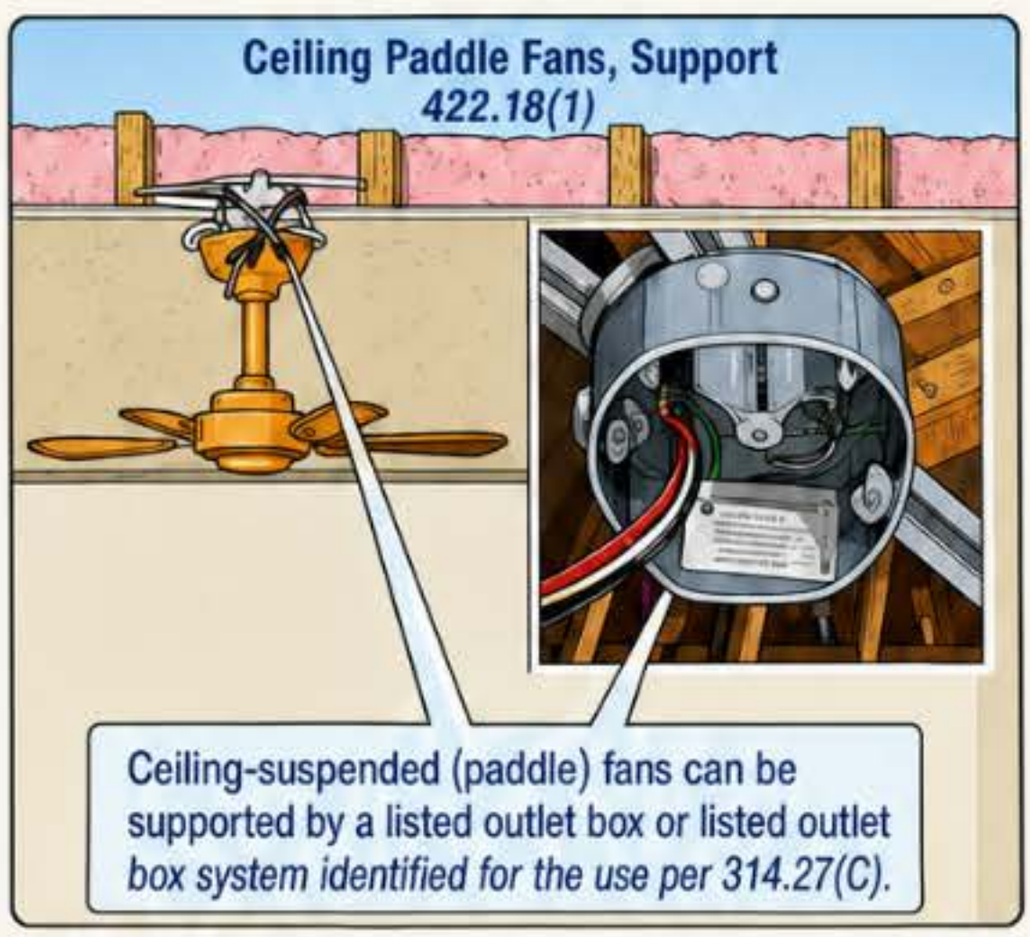
DEFINITIONS | From Michael Hamilton Publications

Ex: A listed appliance distinctly marked to identify it as protected by a system of double insulation is not required to be terminated with a grounding-type attachment plug.

422.18 Support of Ceiling-Suspended (Paddle) Fans

Ceiling-suspended (paddle) fans need to be supported independently of an outlet box or by one of these methods:

(1) A listed outlet box or listed outlet box system identified for the use in accordance with 314.27(C). ▶ **Figure 422-18**



▶ **Figure 422-18**

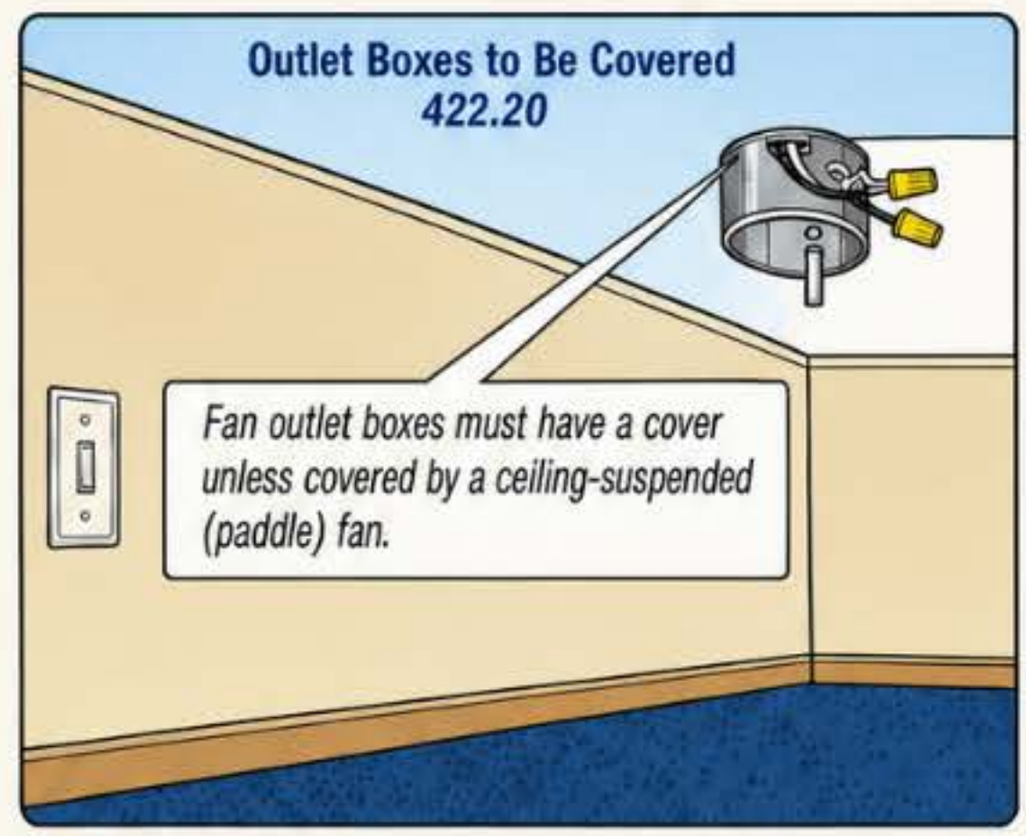
(2) *A listed outlet box system, a listed locking support and mounting receptacle, and a compatible factory installed attachment fitting designed for support, identified for the use in accordance with 317.27(E).*

422.19 Space for Conductors

The combined volume of the canopy of ceiling-suspended (paddle) fans and outlet box must provide sufficient space so conductors and their connecting devices are capable of being installed in accordance with 314.16.

422.20 Outlet Boxes to be Covered

Fan outlet boxes must have a cover unless covered by a ceiling-suspended (paddle) fan. ▶ **Figure 422-19**



▶ **Figure 422-19**

Part III. Disconnecting Means

422.30 Disconnection—General

Each appliance must have a means to simultaneously disconnect all circuit phase conductors.

422.31 Permanently Connected Appliance Disconnects

(A) Appliances Rated Not Over 300 VA. Hard-wired appliances *rated at not over 300 VA or ½ hp, the branch-circuit overcurrent device is permitted to serve as the disconnecting means where the switch or circuit breaker is within sight from the appliance or the disconnect must be capable of being locked in the open position in accordance with 110.25.*

Author's Commentary:

- *If an appliance is hard wired, place the disconnect within sight of the appliance or the circuit breaker for the appliance must be lockable with provisions that keep the locking device in place whether the lock is installed or not [422.31(B)].*
- *According to Article 100, "Within Sight" means it is visible and not more than 50 ft from the location of the equipment.*

— Michael Hamilton

422.33 | Appliances

(B) Appliances Rated Over 300 VA. Hard-wired appliances rated above 300 VA must include a disconnect located within sight of the equipment. The disconnecting means shall be capable of being locked in the open position in accordance with 110.25. **Figure 422–20**

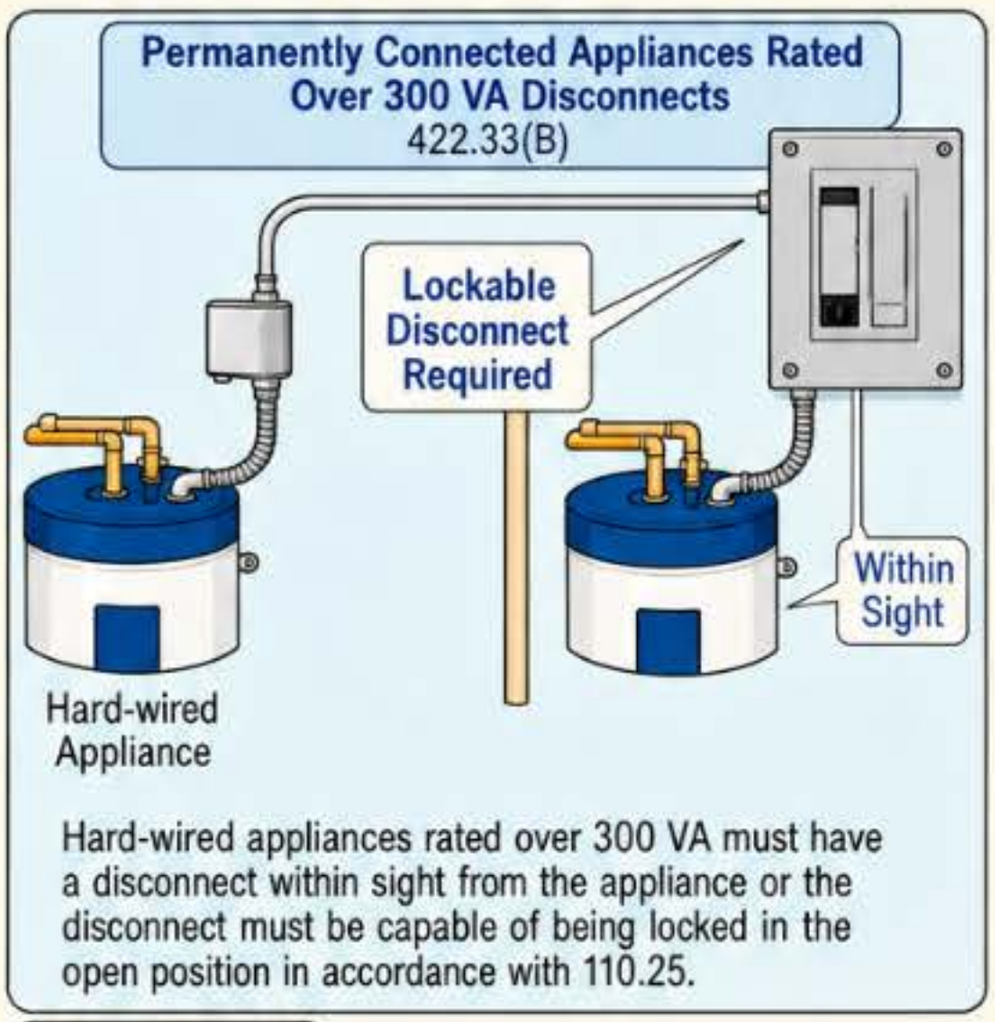


Figure 422–20

Author's Commentary:

- Based on Article 100, "Within Sight" means the equipment is visible and does not require more than 50 ft from where it is located.

— *Michael Hamilton*

(C) Motor-Operated Appliances Rated Over ½ Horsepower. Motor-operated appliances rated over ½ horsepower that are hard wired must have a disconnect located within sight from the appliance or the disconnect must be capable of being locked in the open position in accordance with 110.25.

422.33 Disconnection of Cord-and-Plug-Connected or Attachment Fitting-Connected Appliances

(A) Attachment Plug or Attachment Fitting. A cord-and-plug connection can serve as the appliance disconnect. **Figure 422–21**

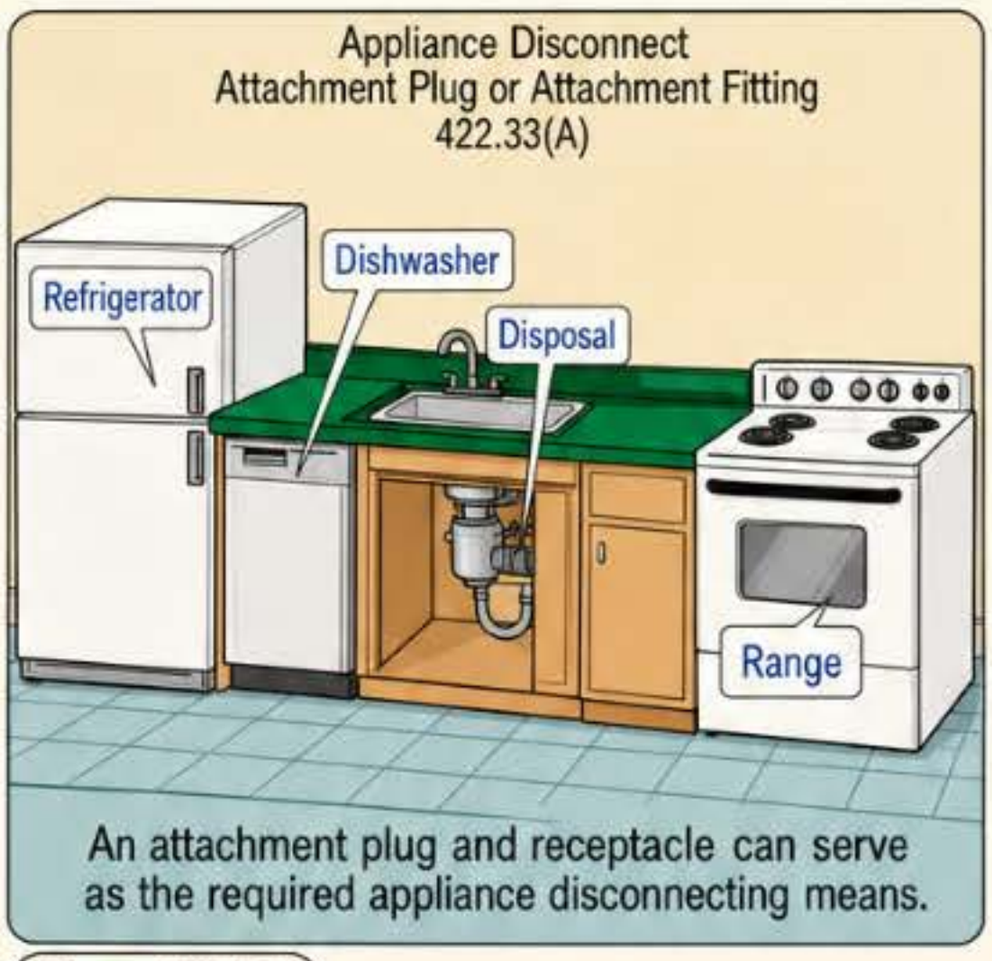


Figure 422–21

ARTICLE 424

FIXED ELECTRIC SPACE-HEATING EQUIPMENT

Introduction to Article 424—Fixed Electric Space-Heating Equipment

You may be surprised by how many pages are devoted to Article 424. This is a detailed article focused entirely on stationary electric space heaters. The key question it addresses is: what applications can various heater types serve, and what limitations apply in each case? These heaters appear in several configurations to suit different purposes. Since not all of these items are relevant to field work, the material in Part IV is intended for manufacturers.

Installed space heaters—whether mounted on walls, suspended from ceilings, or free-standing—are commonly found in residences, workplaces, and small buildings, as well as in larger facilities. When a heater is used to warm floors, the associated cables can raise the floor temperature in a way that comes up often when ducts are involved. Duct heaters are especially common in big offices and schools because they deliver heat across multiple rooms. Placing the heater within the ductwork, but outside the occupied area, reduces the waste commonly seen when warm air must travel through metal duct in unheated spaces. As a result, you will likely encounter these applications in the field.

Part I. General

424.1 Scope

Article 424 sets the requirements for installing stationary electric space-heating equipment such as unit heaters (those that heat through elements), central heating systems, and fixed electric space-heating equipment.

Figure 424-1

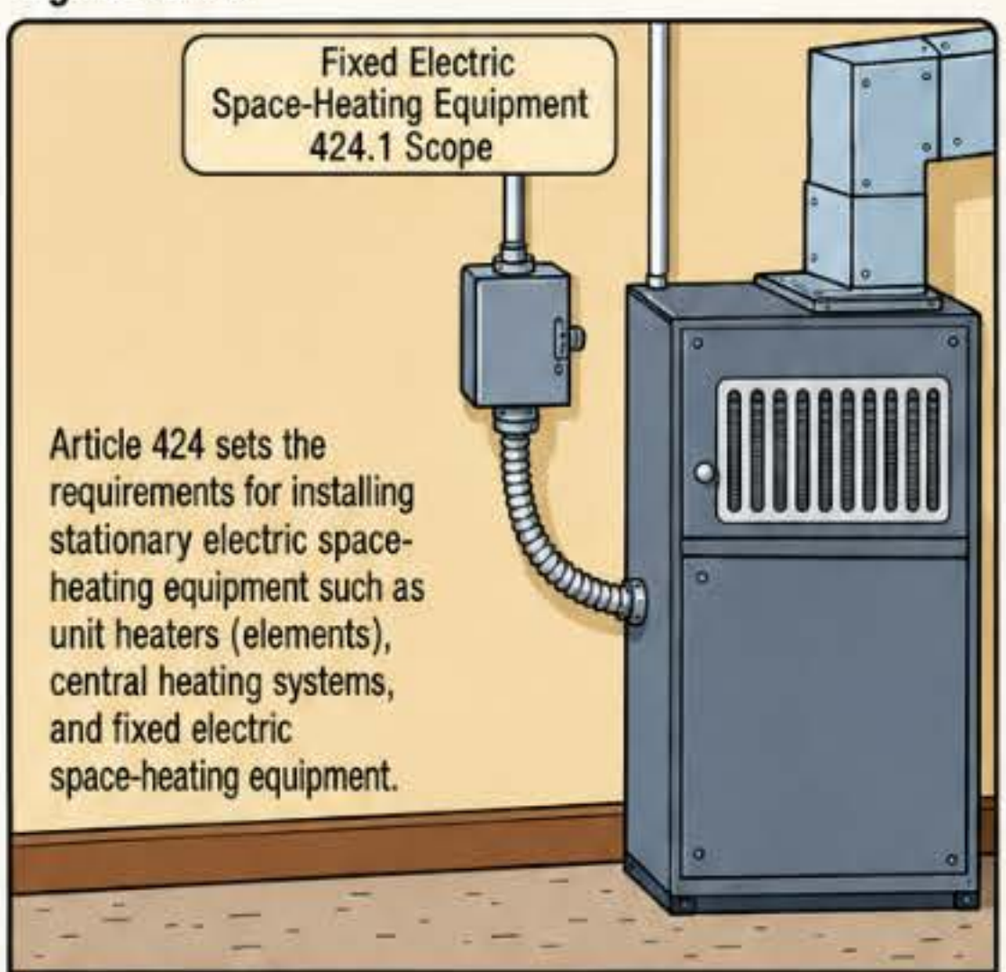


Figure 424-1

424.3 Other Articles

Fixed electric space-heating equipment that includes a hermetically sealed motor-compressor must follow the requirements of Article 440.

424.4 Branch Circuits

(B) Branch-Circuit Sizing. The branch-circuit conductors for fixed electric space-heating equipment and any connected motors must be sized so they can carry no more than 125 percent of the total load.

Figure 424-2

Author's Commentary:

- *Branch-circuit wiring and overcurrent protection for fixed electric space-heating equipment must provide an ampacity that is at least 125 percent of the total calculated heating load [210.19(A)(1) and 210.20(A)].*

— Michael Hamilton

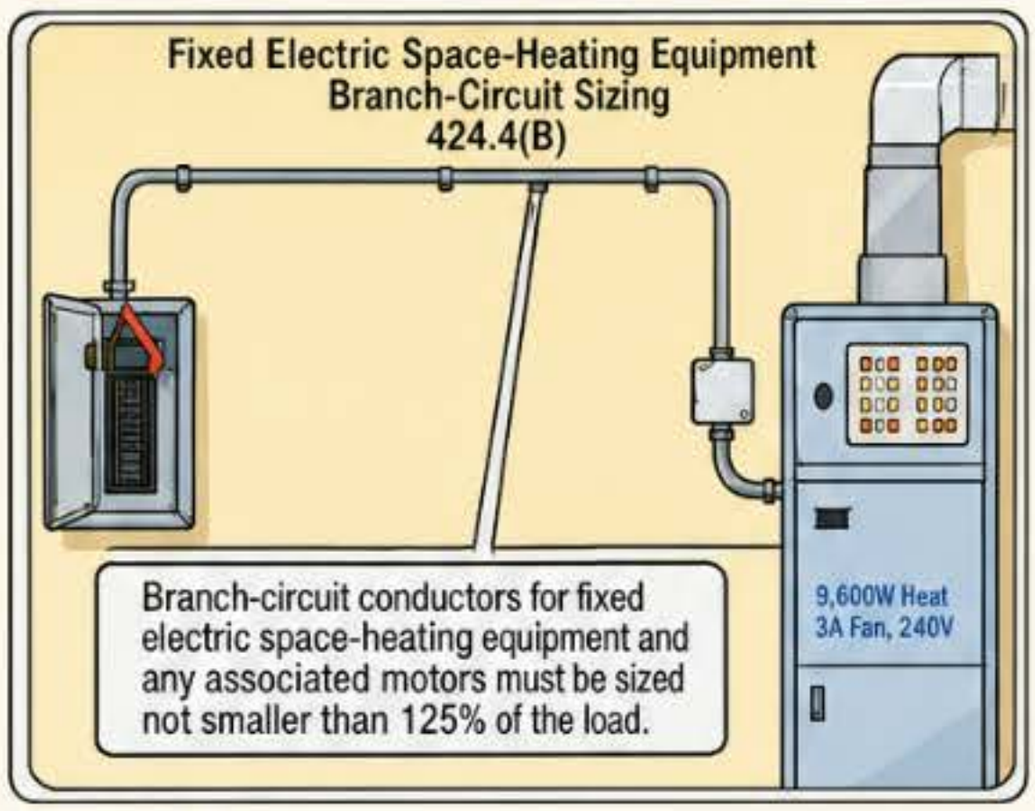


Figure 424-2

▶ **Example**

Question: *What size NM cable is required for a 9,600W 240V fixed electric space heater that has a 3A, 240V blower motor?*

▶***Figure 424-3***

(a) 10 AWG (b) 8 AWG (c) 6 AWG (d) 6 AWG

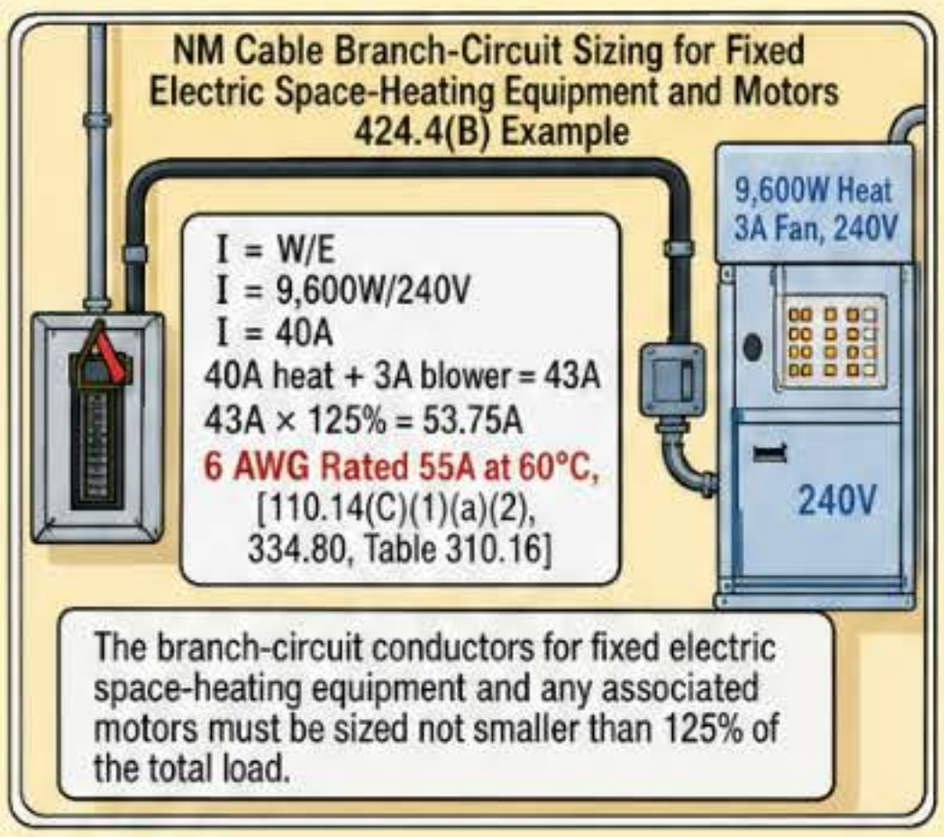


Figure 424-3

Solution:

Step 1: *Determine the total load.*

I = Watts/Volts

I = 9,600W/240V

I = 40A

Total Amperes = 40A (heat) + 3A (blower)

Total Amperes = 43A

Step 2: *Size the conductors at 125 percent of the total current load [210.19(A)(1)].*

Conductor = 43A × 125%

Conductor = 53.75A; use 6 AWG rated 55A at 60°C [110.14(C)(1)(a)(2), 334.80, and Table 310.16]

Answer: *(d) 6 AWG*

Part III. Electric Space-Heating Equipment

424.19 Disconnecting Means

Heating equipment must have a means to simultaneously disconnect all circuit phase conductors.

(B) Heating Equipment Without Supplementary Overcurrent Protection. The disconnect for fixed heating equipment must be located within sight from the heating equipment or the disconnect must be capable of being locked in the open position in accordance with 110.25. **Figure 424-4**

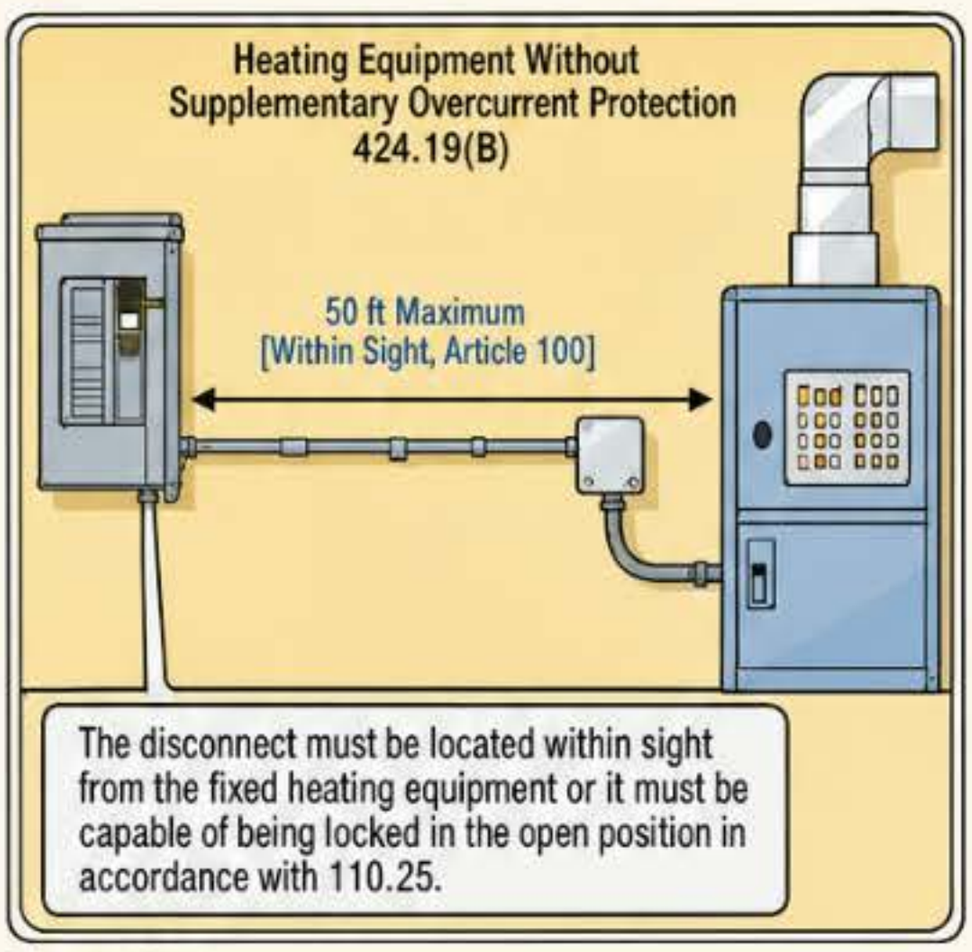


Figure 424-4

(C) Unit Switch as Disconnecting Means. A unit switch on fixed electric heating equipment with a marked "off" position can serve as the required disconnect. ▶***Figure 424-5***

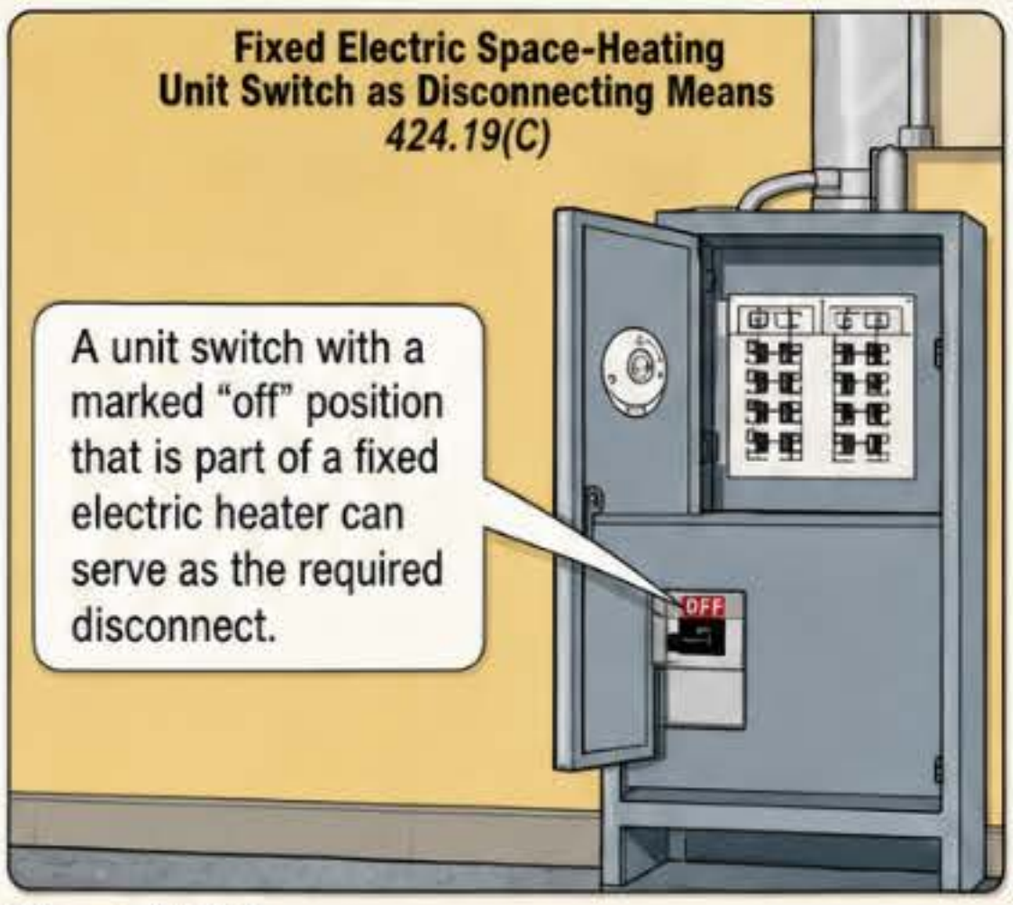


Figure 424-5

Part V. Electric Space-Heating Cables

424.44 Electric Heating Cables in Concrete or Masonry Floors

(E) GFCI Protection. In addition to the requirements in 210.8, GFCI protection is required for electric space-heating cables embedded in concrete or masonry floors of bathroom areas, kitchens, and hydromassage bathtub locations.

▶ **Figure 424-6**

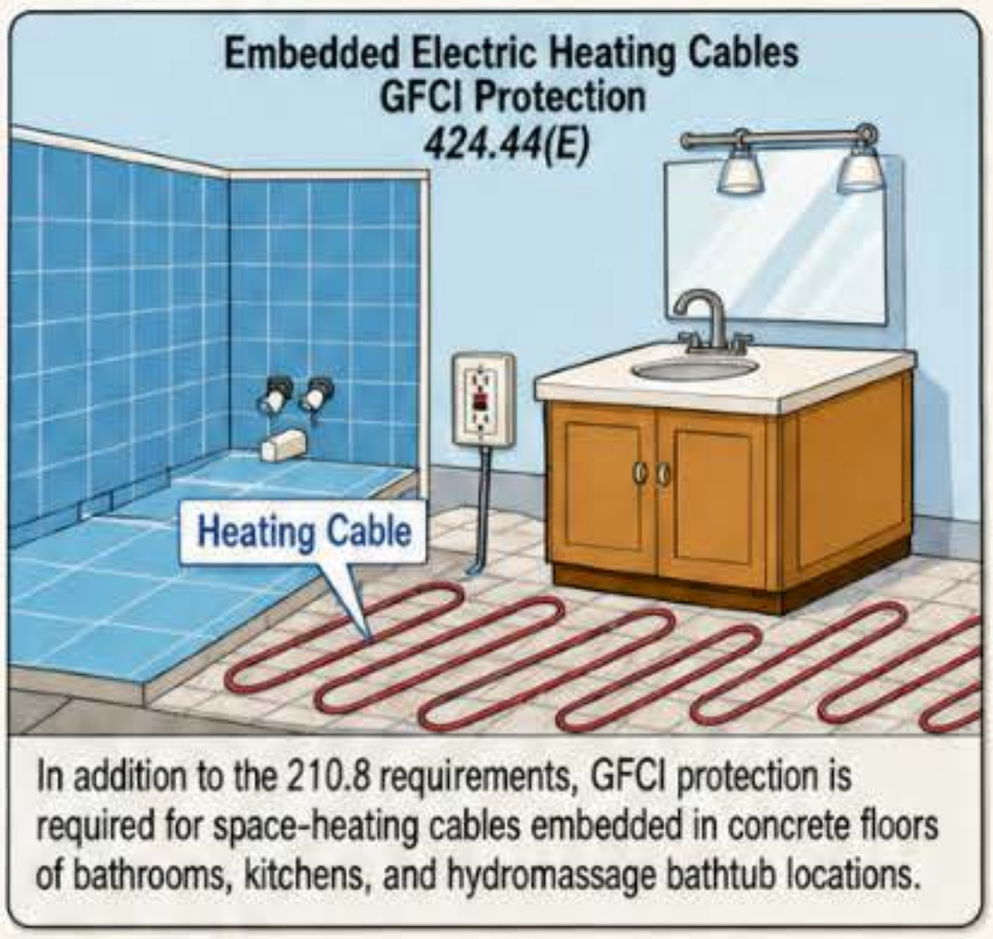


Figure 424-6

Part VI. Duct Heaters

424.65 Location of Disconnecting Means for Electric Duct Heater Controllers

The disconnect for a duct heater must be located within sight from the electric duct heater controller or the disconnect must be capable of being locked in the open position in accordance with 110.25. ▶ **Figure 424-7**

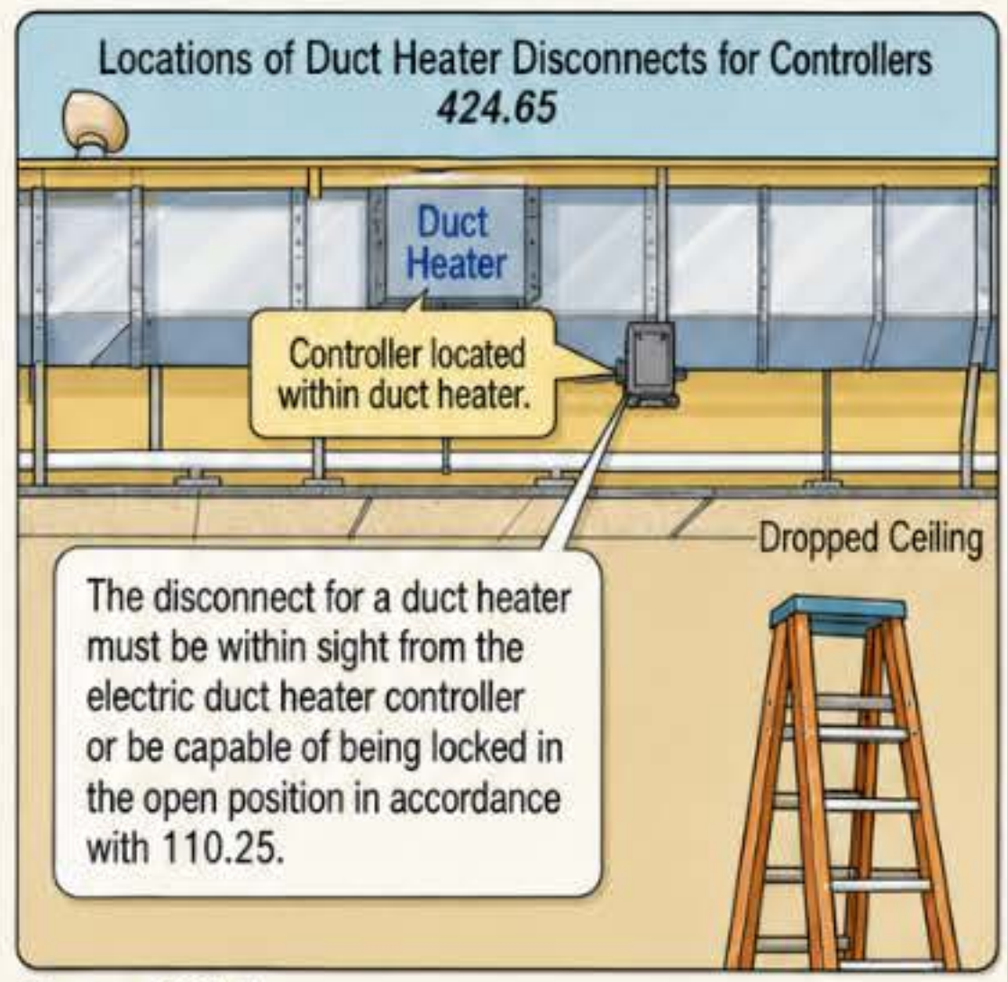


Figure 424-7

Author's Commentary:

The disconnecting means for a duct heater must be visible from the controller location. If that disconnect isn't in plain view, it must be lockable in the open position as required by 110.25.

For electric floor heating cables in wet locations—such as bathrooms, kitchens, and whirlpool tub areas—the code requires GFCI protection in addition to the general GFCI rules in 210.8.

— Michael Hamilton

Notes |

ARTICLE 430 MOTORS, MOTOR CIRCUITS, AND CONTROLLERS

Introduction to Article 430—Motors, Motor Circuits, and Controllers

Article 430 sets forth the rules for conductors, protection against overcurrent, control-circuit conductors, and controllers, as well as disconnection means used with electric motors. The requirements for motor control centers are in Part VII. Coverage for air-conditioning and refrigeration equipment can be found in Article 440.

This is one of the lengthiest articles in the *NEC*. Motors are sophisticated pieces of equipment. They rely on both electrical and mechanical parts, and their use is often demanding. Applications typically create inductive loads with a starting current that can be six times or more the normal running current. For that reason, overcurrent protection must be selected differently than for other equipment types. General overcurrent protection for motors and the methods for protecting the motor against overload must be understood and applied using the rules in Article 430.

You might be surprised by the exceptions in this article that allow 10 AWG conductors with 60 A overcurrent protection for motors up to a certain size. As you study Article 430, you will gain a solid grasp of how motor overcurrent protection functions and why these exceptions exist.

Part I. General

430.1 Scope

Article 430 covers motors, motor branch-circuit and feeder conductors and their protection, motor overload protection, motor control circuits, motor controllers, and motor control centers. **Figure 430-1**

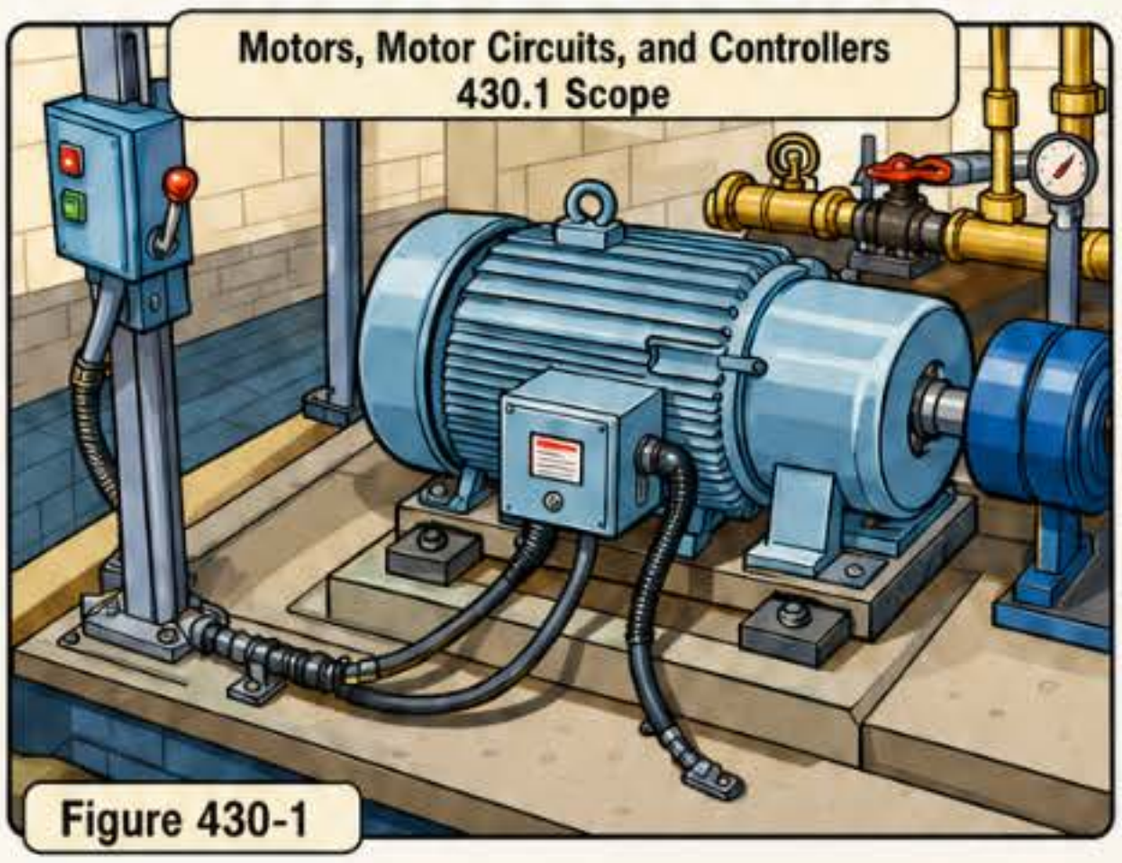


Figure 430-1

Author's Commentary:

This article is organized into several parts. The most important are:

- **Figure 430-2**
- *General—Part I*
- *Conductor Sizing—Part II*
- *Overload Protection—Part III*
- *Branch-Circuit Short-Circuit and Ground-Fault Protection—Part IV*
- *Feeder Short-Circuit and Ground-Fault Protection—Part V*
- *Motor Control Circuits—Part VI*
- *Motor Controllers—Part VII*
- *Motor Control Centers—Part VIII*
- *Disconnecting Means—Part IX*

— Michael Hamilton

Note 1: Article 440 contains the installation *requirements for hermetic air-conditioning and refrigeration motor-compressors. [440.1].*

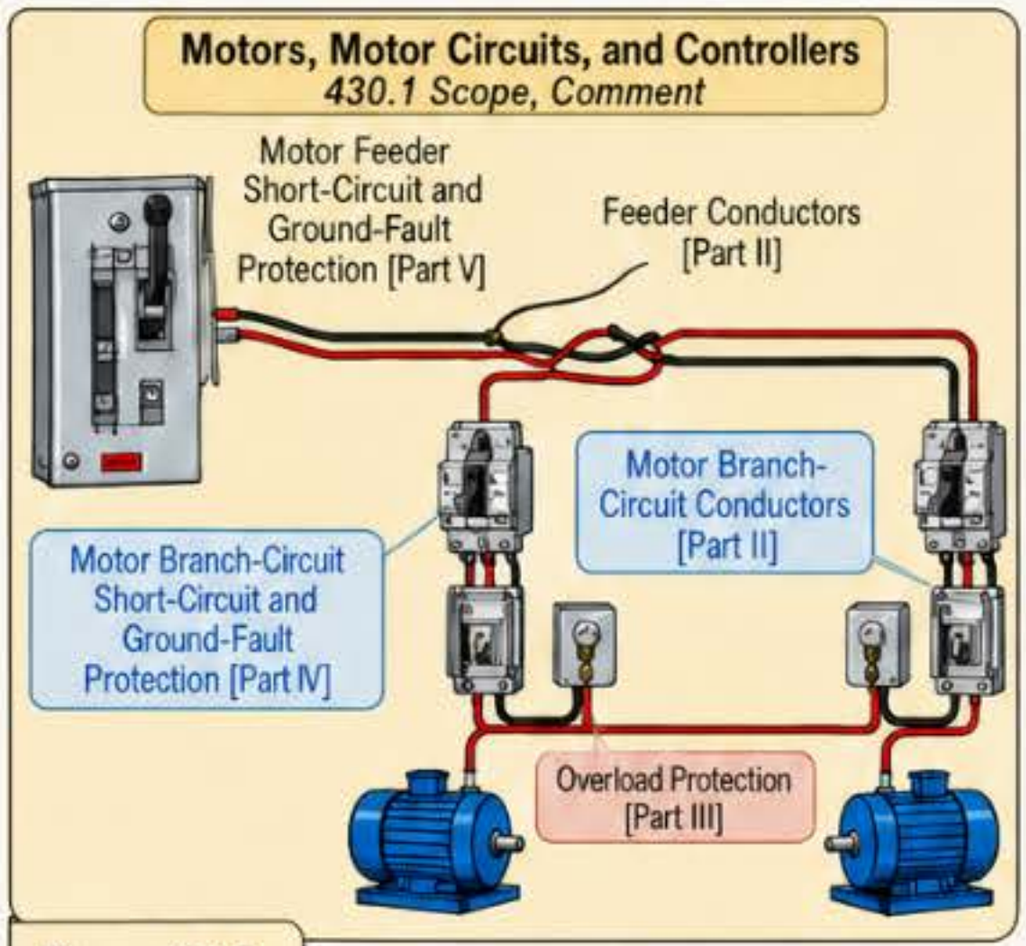


Figure 430-2

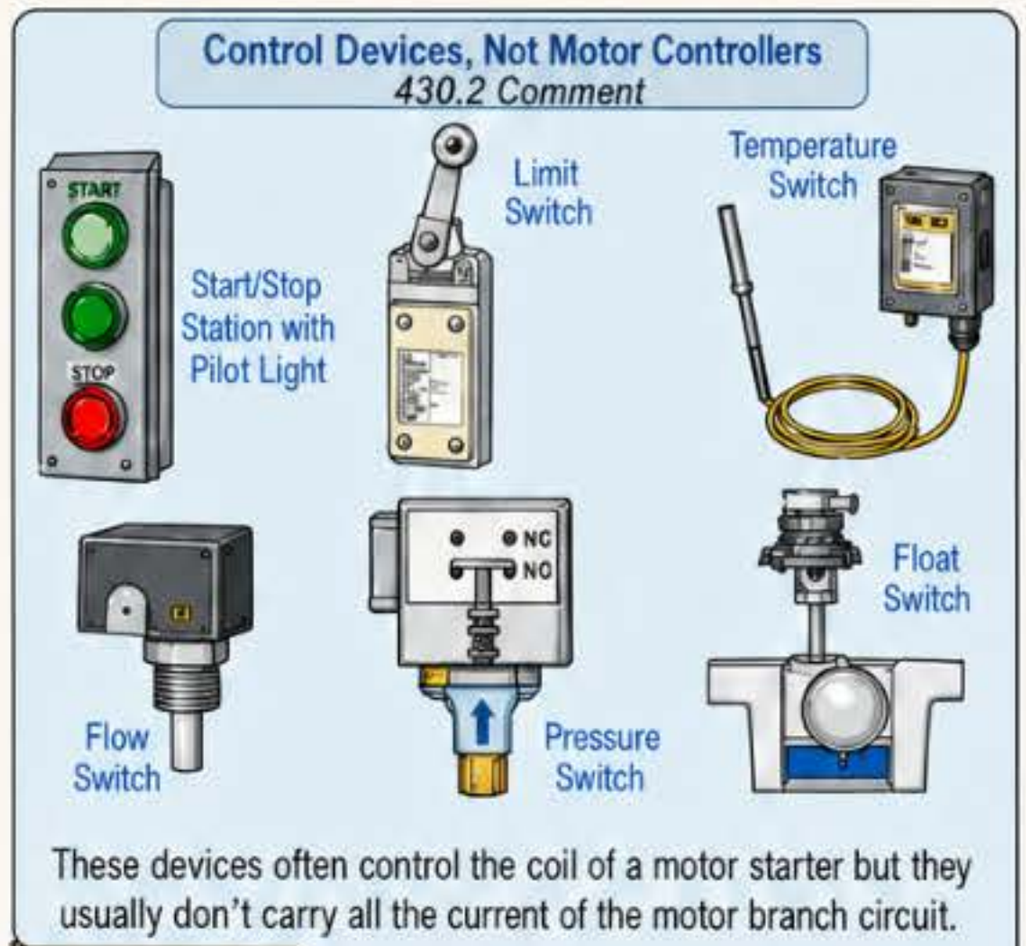


Figure 430-4

430.2 Definitions

Controller. Any switch or device used to start and stop a motor by making and breaking the motor circuit current. ▶ **Figure 430-3**

Figure 430-3

Author's Commentary:

▶ A controller may be a horsepower-rated switch, snap switch, or circuit breaker. A pushbutton that actuates an electromechanical relay is not a controller because it does not satisfy the controller rating requirements of 430.83. Devices such as start-stop stations and pressure switches are often control devices rather than motor controllers. When these devices operate the coil of the motor starter they typically do not carry all the current of the motor branch circuit.

— Michael Hamilton

Electronically Protected (as applied to motors). A motor that is equipped with electronic control circuitry integrated into the motor and safeguards *it against hazardous overheating due to failure of the electronic control, overload, and failure to start.*

430.6 Table FLC versus Motor Nameplate Current Rating

The size of conductors supplying equipment covered by Article 430 must be chosen from the ampacity tables in accordance with 310.15 or be calculated in accordance with 310.14(B). Where flexible cord is used, the size of the conductor must be selected in accordance with 400.5.

(A) *General Requirements.* Motor current ratings used for the application of this article are determined by (A)(1) and (A)(2). ▶ **Figure 430-5**

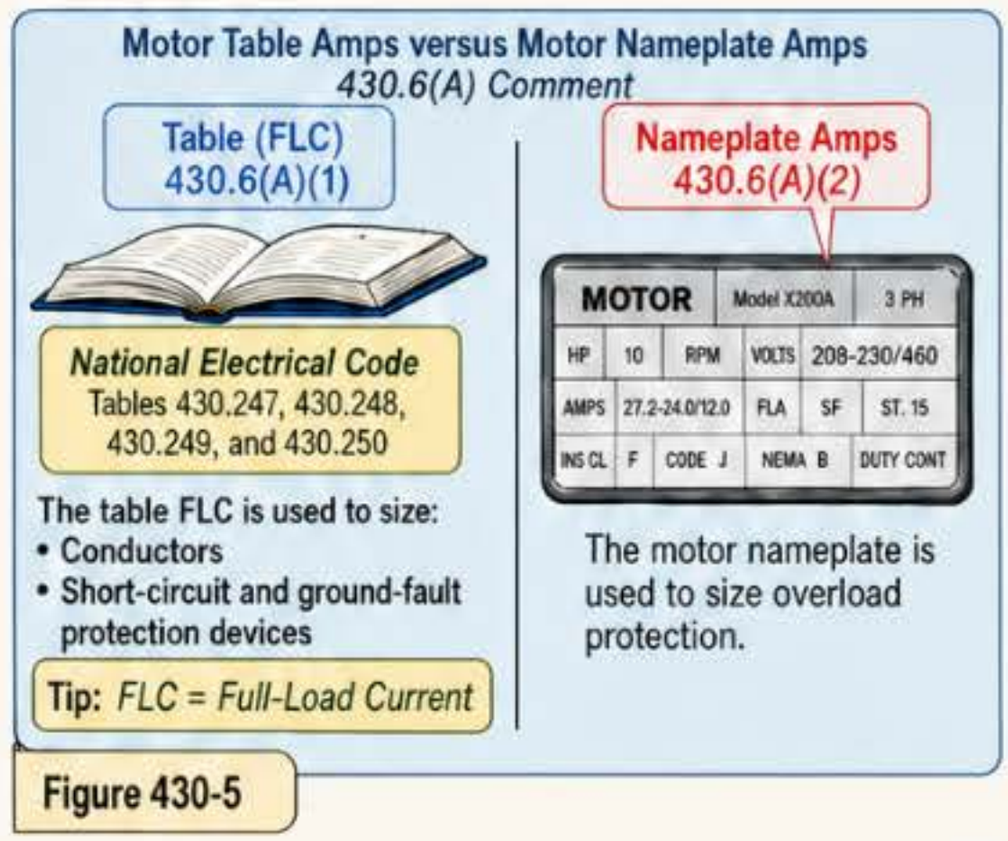


Figure 430-5

Motors, Motor Circuits, and Controllers

(1) Table Full-Load Current (FLC). The motor full-load current values listed in Tables 430.248 and 430.250 help you identify proper conductor sizes [430.22] and the branch-circuit short-circuit and ground-fault overcurrent protection device size [430.52 and 430.62].

Author's Commentary:

The motor full-load amperes (FLA) shown on the motor nameplate [430.6(A)(2)] must not be used to determine conductor size or the short-circuit and ground-fault overcurrent protective device—except for other than continuous duty motor applications as covered in 430.22(E).

— Michael Hamilton

(2) Motor Nameplate Current Rating (FLA). Overload devices and conductor sizing for intermittent duty motors must be sized based on the motor nameplate full-load ampere (FLA) rating in accordance with 430.31.

Author's Commentary:

The motor nameplate current rating is identified as full-load amperes (FLA). The FLA tells us the current in amperes the motor draws while producing its rated horsepower load at its rated voltage, based on its rated efficiency and power factor.

— Michael Hamilton

Motor Nameplate Amperes, 1-Phase
430.6(A)(2) Comment

Mote's Motors

POWER	746W	SERVICE	CONT
PHASE	1	VOLTS	115/230
CYCLE 60	RPM	1725	CLASS B
DUTY	CONT	CODE J	DESIGN A

746W Mechanical Power (Shaft Power) Per Horsepower

$$\text{Nameplate Amps} = \frac{746 \times hp}{E \times Eff \times PF}$$

746 = Watts per hp
hp = 1 hp
E = 115V
Eff = 0.70 Efficiency Factor
PF = 0.70 Power Factor

$$\text{Amps} = \frac{746 \times 1 \times 0.70}{115V \times 0.70 \times 0.70}$$

Nameplate Amps = 13.20A

▲ **Figure 430-6**

Author's Commentary:

The actual current drawn by the motor's FLA depends on the load on the motor and the actual operating voltage at the motor terminals. If the load increases, the current also increases. If the motor runs at a voltage below its nameplate rating, the operating current will increase.

— Michael Hamilton

Caution

To prevent damage to motor windings from excessive heat (caused by excessive current), never load a motor above its horsepower rating and be sure the applied voltage is within 10 percent of the motor's voltage rating.

430.14 Location of Motors

(A) Ventilation and Maintenance. Motors must be located so adequate ventilation is provided and maintenance can be readily accomplished.

430.17 Highest Rated Motor

When sizing motor circuits for a group of motors, the highest rated motor of the group will be the motor with the largest full-load current (FLC) rating as listed in Tables 430.248 and 430.250.

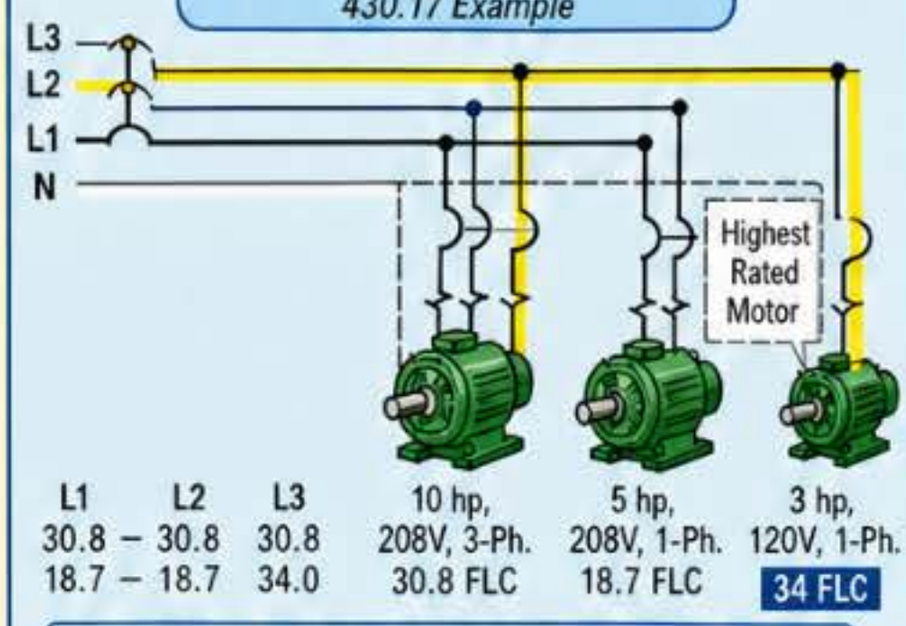
▶ Example

Question: *Which of the following motors has the highest FLC rating:*
a 10 hp, 208V, three-phase motor; a 5 hp, 208V, single-phase motor; or a 3 hp, 115V, single-phase motor?

▶ **Figure 430-7**

(a) A 3 hp, 115V, single-phase motor.
(b) A 5 hp, 208V, single-phase motor.
(c) A 10 hp, 208V, three-phase motor.
(d) none of these

Highest Rated Motor (Largest Line)
430.17 Example



The highest rated motor above is the 115V motor at 34 FLC. The other motor(s) in the group (phases) is the 10 hp, 3-phase motor as indicated by the shaded area.

▲ **Figure 430-7**

Solution:

10 hp, 208V, Three-Phase Motor = 30.80A [Table 430.250]

5 hp, 208V, Single-Phase Motor = 30.80A [Table 430.248]

3 hp, 115V, Single-Phase Motor = 34.00A [Table 430.248]

Answer: *(a) A 3 hp, 115V, single-phase motor.*

Author's Commentary:

To pick the motor with the greatest rated current in a set, you first calculate the conductor size required and the minimum short-circuit ground-fault protection. Then compare those values across the motors in the group to find the top contender [430.24].

— Michael Hamilton

Part II. Conductor Size

430.22 Single Motor Conductor Size

Feeders or branch-circuit conductors for a lone motor in continuous duty service must have an ampacity of at least 125 percent of the motor's full-load current (FLC), as listed in Tables 430.248 and 430.250 [430.6(A)(1) and 430.22]. **See Figure 430–8.**

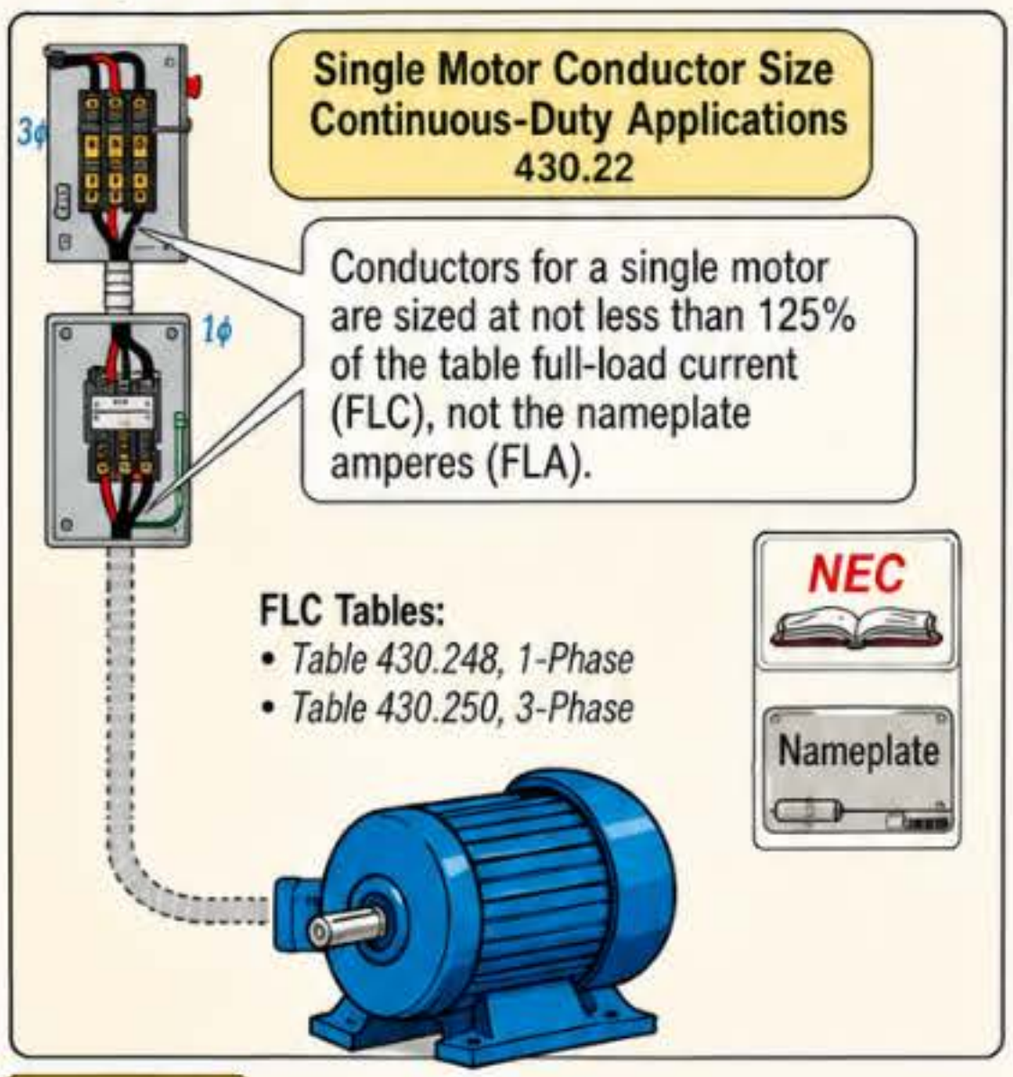


Figure 430–8

Author's Commentary:

- *When using any motor current from the tables on the previous page, remember the statements under each table that explain the accuracy limits for voltage and temperature adjustments. The actual conductor size must be chosen from Table 310.16 based on the terminal temperature rating (60°C or 75°C) of the equipment [110.14(C)(1)].*
- *FLA values from the motor nameplate (430.6(A)(2)) cannot be used to figure the conductor size.*
- *Motor duty is considered continuous unless the design of the unit indicates it will not run continuously under load [Table 430.22(E) Note]. If a motor isn't marked otherwise because of the application, the conductors are sized using the percentages in Table 430.22(E). If it starts often during its work cycle (such as an elevator motor), that intermittent duty is acceptable.*

— Michael Hamilton

▶ Example 1

Question:

What size branch-circuit conductor is needed for a 3 hp, 230V, single-phase motor in a continuous duty application, where the conductor terminals are rated 75°C? ****Figure 430–9***

(a) 14 AWG (b) 12 AWG (c) 10 AWG (d) 8 AWG

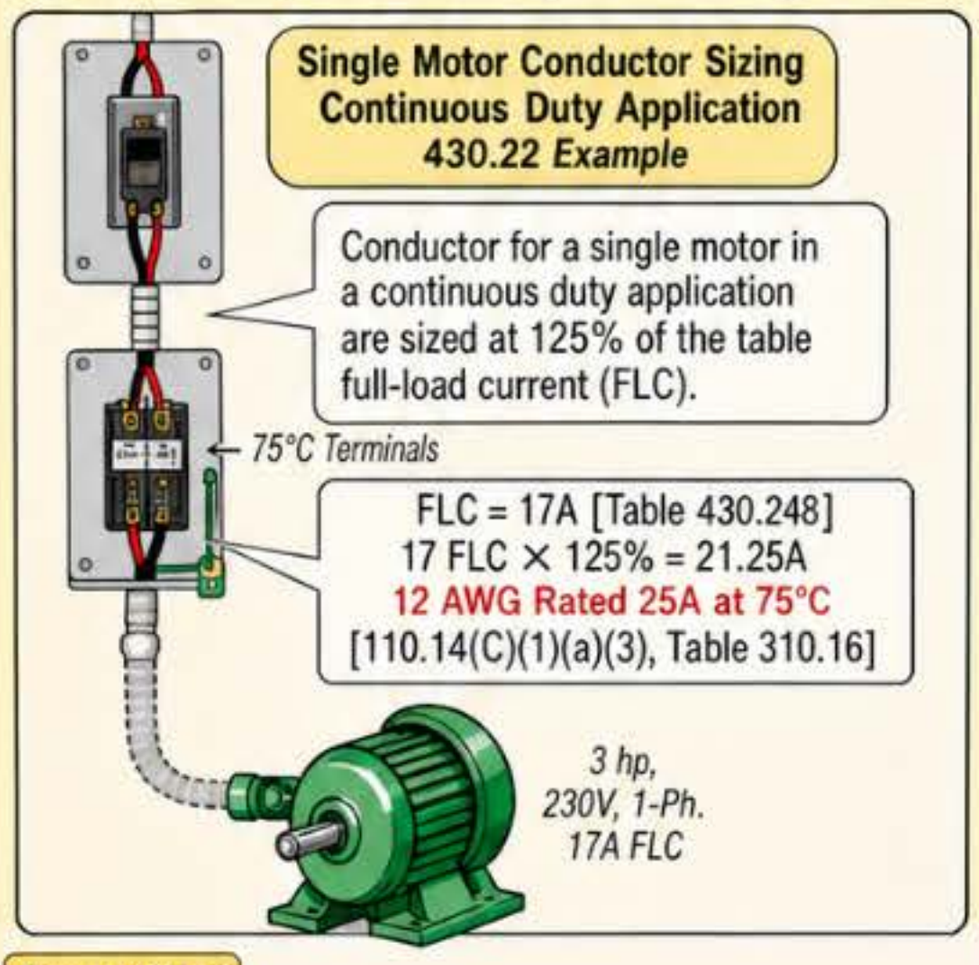


Figure 430–9

Solution:

Determine the branch-circuit conductor size based on 125 percent of the motor's FLC.

3 hp, 230V Motor FLC = 17A [Table 430.248]

Conductor = 17A × 125% = 21.25A

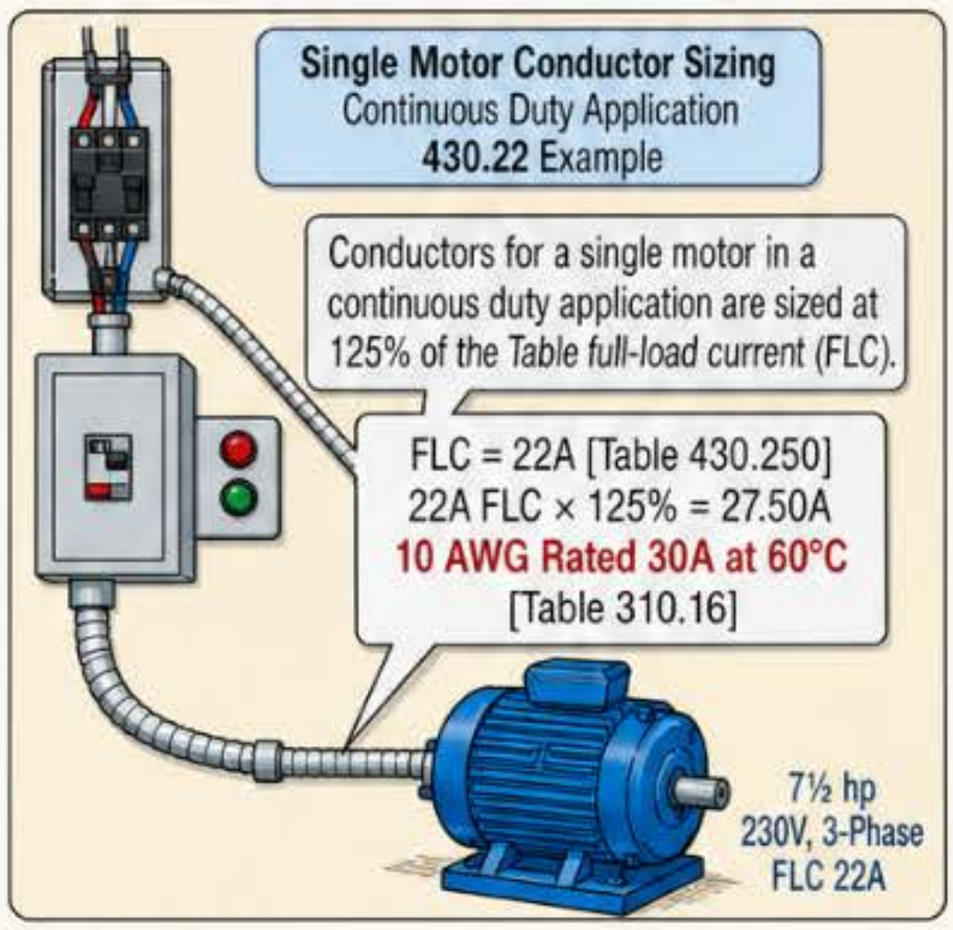
Conductor = 12 AWG rated 25A at 75°C [110.14(C)(1)(a)(3) and Table 310.16]

Answer: *(b) 12 AWG*

▶ Example 2

Question: *What size branch-circuit conductor is required for a 7½ hp, 230V, three-phase motor?* ▶ **Figure 430–10**

(a) 14 AWG (b) 12 AWG (c) 10 AWG (d) 8 AWG



▶ **Figure 430–10**

Solution:

Determine the branch-circuit conductor size based on the motor's FLC [430.6(A)(1), 430.22, and Table 310.16].

Motor FLC = 22A [Table 430.250]

Conductor Size = 22A × 125%

Conductor Size = 27.50A

Conductor Size = 10 AWG rated 30A at 60°C [110.14(C)(1)(a) and Table 310.16]

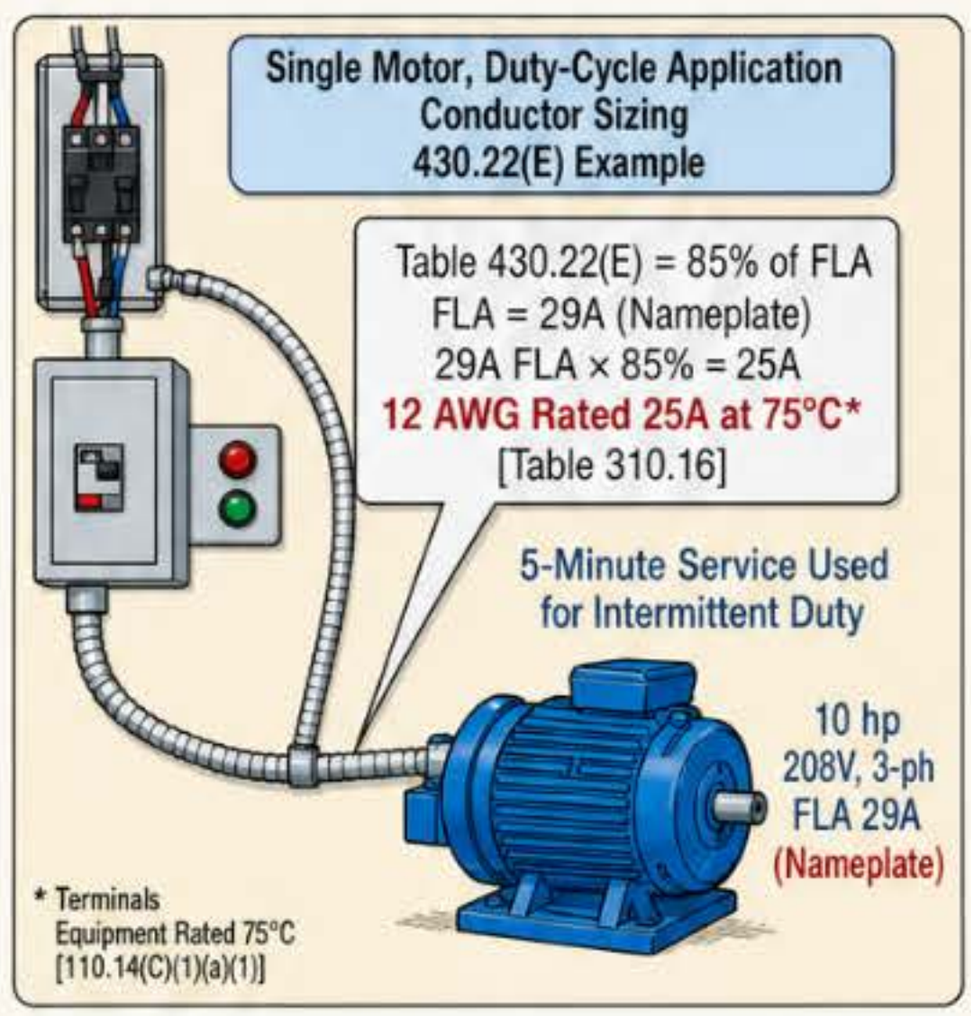
Answer: *(c) 10 AWG*

(E) Single Motor in Duty-Cycle Application—Conductor Sizing. Conductors for a motor used in a short-time, intermittent, periodic, or varying duty application must have an ampacity of not less than the percentage of the motor nameplate full-load ampere (FLA) rating shown in Table 430.22(E).

▶ Example

Question: *What size branch-circuit conductors are required for a 10 hp, 208V, three-phase, motor with a nameplate FLA of 29A, rated for 5-minute service, used for intermittent duty, and with terminals rated 75°C?* ▶ **Figure 430–11**

(a) 14 AWG (b) 12 AWG (c) 10 AWG (d) 8 AWG



▶ **Figure 430–11**

Solution:

The motor nameplate FLA is used for duty-cycle service.

The conductor must be sized no less than 85 percent of the motor FLA [Table 430.22(E)].

Conductor Ampacity = 29A × 85%

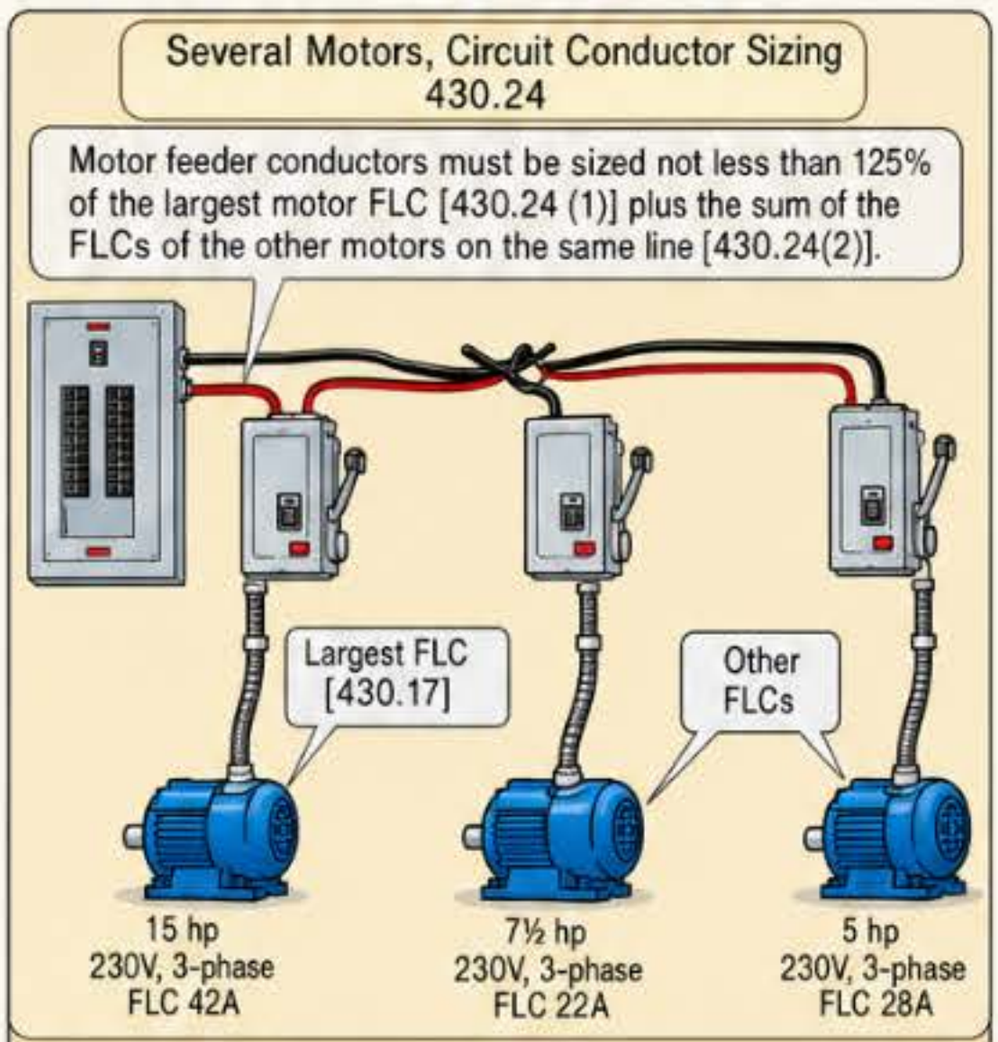
Conductor Ampacity = 25A

Use 12 AWG conductors rated 25A at 75°C [110.14(C)(1)(a)(3) and Table 310.16].

Answer: *(b) 12 AWG*

430.24 Several Motors—Conductor Size

When multiple motors are fed by the same conductors, size those conductors so they can carry at least the combined running current required by the following. • **Figure 430-12**



▶ **Figure 430-12**

1. Compute 125 percent of the highest-rated motor's full-load current (FLC) from Tables 430.248 and 430.250.
2. Add the full-load currents (FLC) of all other motors listed in Tables 430.248 and 430.250.

Author's Commentary:

The motor nameplate full-load ampere (FLA) rating [430.6(A)(2)] is not allowed for determining the size of motor circuit conductors.

— Michael Hamilton

Example

Question: *What size feeder conductors are required for a 2 hp, single-phase, 230V motor and a 5 hp, single-phase, 230V motor with terminals rated 75°C?* ***Figure 430-13***

(a) 10 AWG (b) 8 AWG (c) 6 AWG (d) 4 AWG

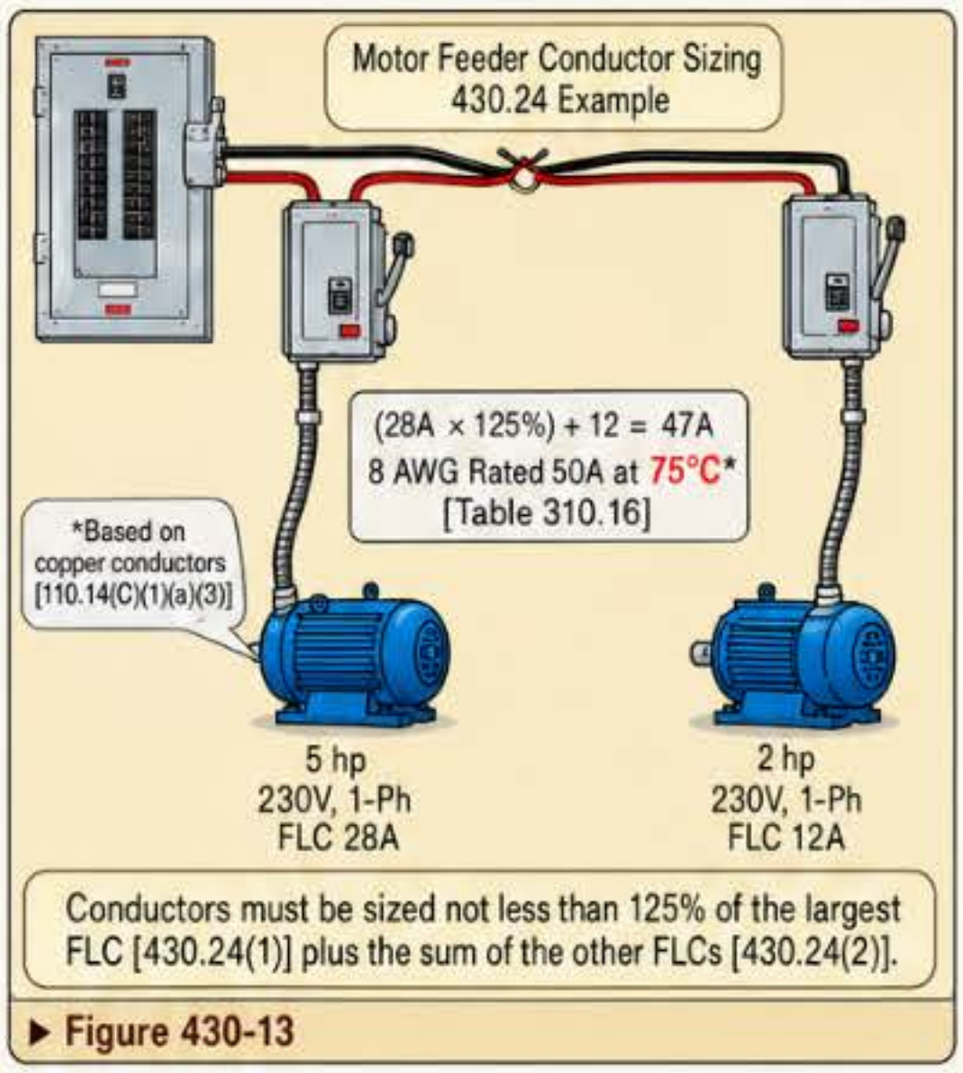
Solution:

2 hp FLC = 12A [Table 430.248]
5 hp FLC = 28A [Table 430.248]

Feeder Size = Ampacity of not less than 125 percent of the highest rated motor's FLC, plus the sum of the FLCs of the other motors.

Feeder Size = (28A × 125%) + 12A
Feeder Size = 47A

Use 8 AWG rated 50A at 75°C [110.14(C)(1)(a)(3) and Table 310.16].



▶ **Figure 430-13**

Answer: *(b) 8 AWG*

Part III. Motor and Branch-Circuit Overload Protection

430.31 Overload

Part III details the rules for overload protection devices. These apply to motors, motor control equipment, and motor branch-circuit conductors to guard against excessive heating from overload conditions and to prevent start attempts that could damage short circuits or ground faults.

Author's Commentary:

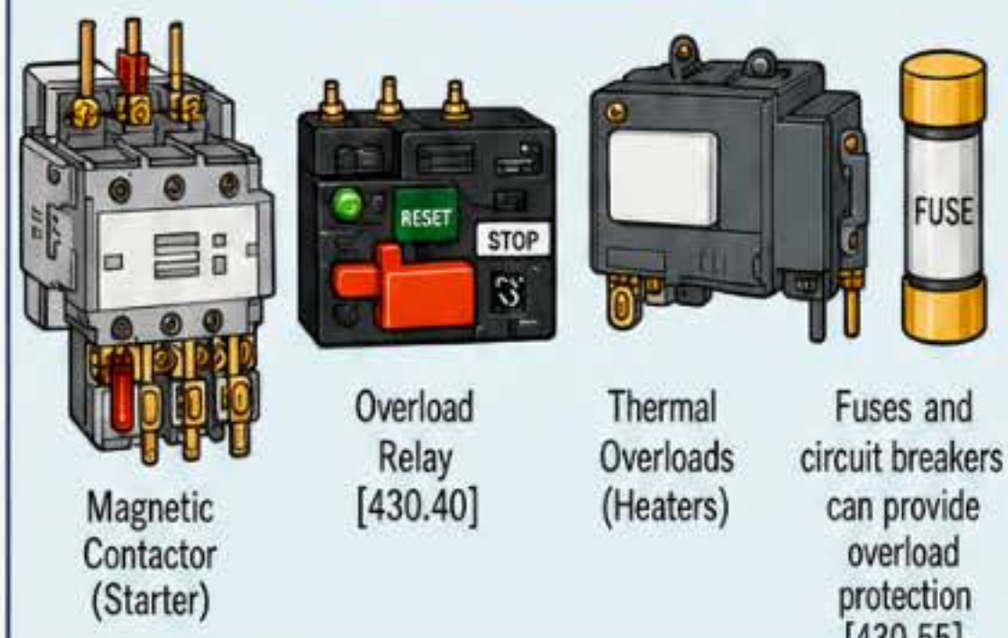
Overload protection may include: • ***Figure 430-14***

- **Thermal Overloads.** *These heating elements (installed in an overload relay or a motor contactor) are chosen based on the motor's ampacity or on the motor's nameplate current.*
- ***Solid-State (Electronic) Overloads.*** *Electronic overloads use an adjustment dial to set the trip level. They are usually mounted in an overload relay or within a motor contactor (starter).*
- ***Inverse Time Circuit Breaker and DE Fuses.*** *Inverse-time circuit breakers and dual-element fuses are permitted to provide both motor overload protection and short-circuit protection, provided the conditions in 430.32 are satisfied [430.55].*
- ***Fuses.*** *Fuses can be used for overload protection when sized in accordance with 430.32(A) [430.36].*

— Michael Hamilton

Motors, Motor Circuits, and Controllers

Overload Devices, Types
430.31 Comment

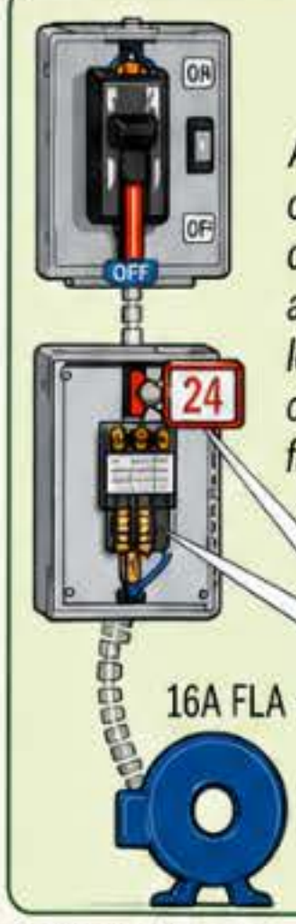


Overload devices protect the motor, conductors, and associated equipment from excessive heat due to motor overloads and failure to start.

▲ **Figure 430–14**

Note 2: An overload is a condition where equipment is operated above its current rating, or where the current exceeds the conductor ampacity. When an overload condition persists for a long time, equipment failure or a fire from damaging or dangerous overheating can result. A fault, such as a short circuit or ground fault, is not an overload [Article 100]. ▶ **Figure 430–15**

Overload Protection
430.31 Note 2



An overload is a condition where equipment is operated above its current rating, or where the current exceeds the conductor ampacity. When an overload condition persists for a sufficient length of time, equipment failure or a fire could occur. A fault, such as a short circuit or ground fault, is not an overload [Article 100].

Overload protection (OL) is designed for:
- *Slow current rise*
- *Long duration*
- *Slow response time*

▲ **Figure 430–15**

Overload protection is not required where it might introduce additional or increased hazards, as in the case of fire pumps [Article 695].

Note: See 695.7 for the *overcurrent protection requirements for fire* pump supply conductors.

430.32 Overload Sizing for Continuous-Duty Motors

(A) Motors Rated More Than One Horsepower. Motors rated more than 1 hp, used in a continuous-duty application without integral thermal protection, must have the overload device(s) sized as follows:

(1) Separate Overload Device. An overload device must be selected to open at no more than the following percent of the motor nameplate full-load current (FLA) rating:

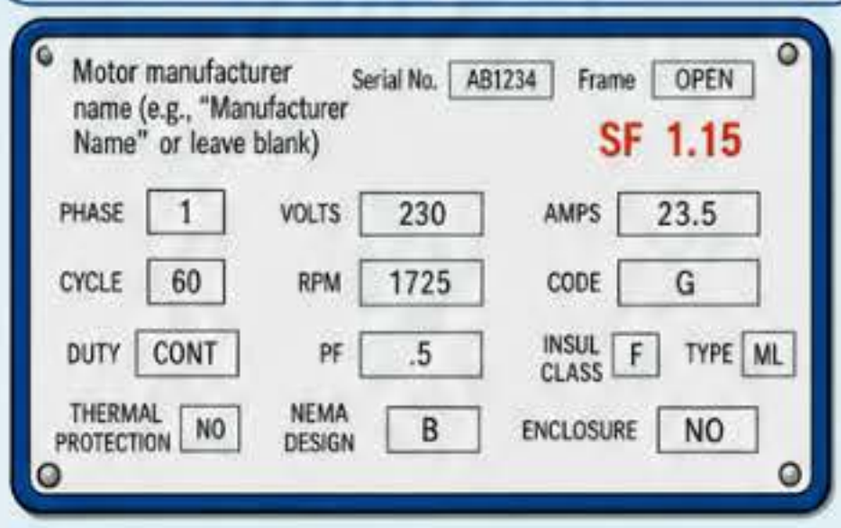
Service Factor. Motors with a marked service factor (SF) of 1.15 or more on the nameplate must have the overload device sized at not more than 125 percent of the motor nameplate current rating.

Author's Commentary:

Motor service factors are safety factors; they indicate how much the motor capacity can be exceeded for short periods without overheating. For example, a motor with a service factor of 1.15 can operate at 15 percent more than its rated output without overheating. This is important for motors where loads vary and may peak slightly above the rated torque.

— Michael Hamilton

Overload Sizing, Continuous-Duty Motor Over 1 HP Service Factor
430.32(A)(1) Comment



A service factor of 1.15 means the motor is designed to operate periodically at up to 115 percent of its rated horsepower without damage to the motor.

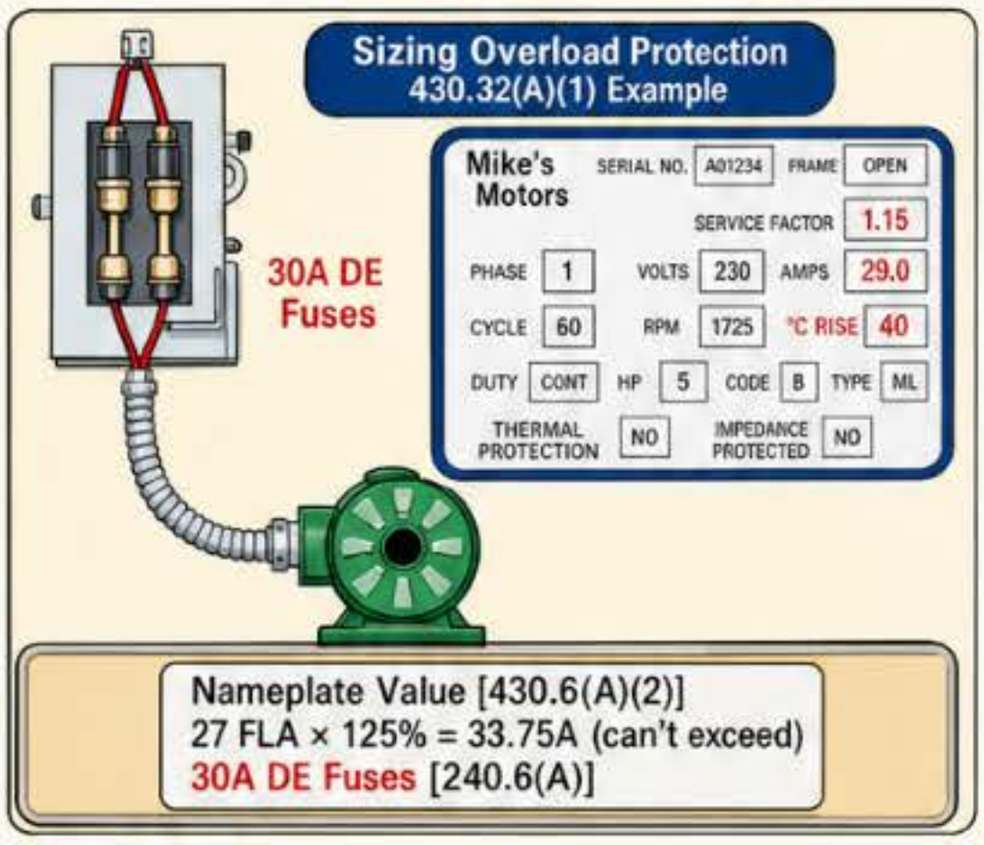
▲ **Figure 430–16**

430.32 | Motors, Motor Circuits, and Controllers

▶ Example

Question: *If a dual-element time-delay fuse is used for overload protection, what size fuse is required for a 5 hp, 230V, single-phase motor, with a service factor of 1.15, if the motor nameplate current rating is 29A?* **Figure 430–17**

(a) 25A (b) 30A (c) 35A (d) 40A



▶ Figure 430–17

Solution:

Overload protection is sized to the motor nameplate current rating [430.6(A), 430.32(A)(1), and 430.55].

Overload Protection = 29A × 125%

Overload Protection = 36.25A, 35A dual-element time-delay fuse

When using a fuse for overload protection, the values of 430.32(C) aren't to be exceeded, so we must round down to the next smaller fuse. Standard fuse sizes are listed in 240.6(A).

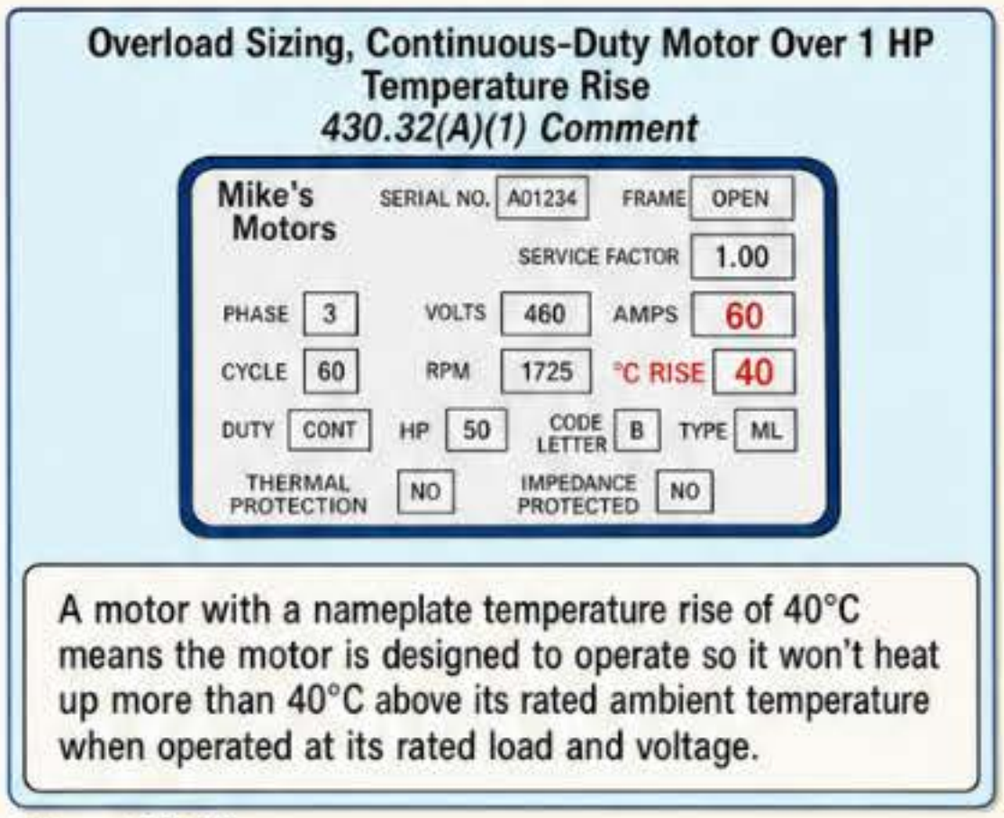
Answer: *(c) 35A*

Temperature Rise. *Motors with a nameplate temperature rise of 40°C or less must have the overload device sized no more than 125 percent of the motor nameplate current rating.*

Author's Commentary:

A motor with a nameplate temperature rise of 40°C means the motor is designed to operate so it will not heat up more than 40°C above its rated ambient temperature when operated at its rated load and voltage. Studies have shown that when the operating temperature of a motor is increased 10°C above its rating, the motor winding insulating material's anticipated life is reduced by 50 percent.

— Michael Hamilton

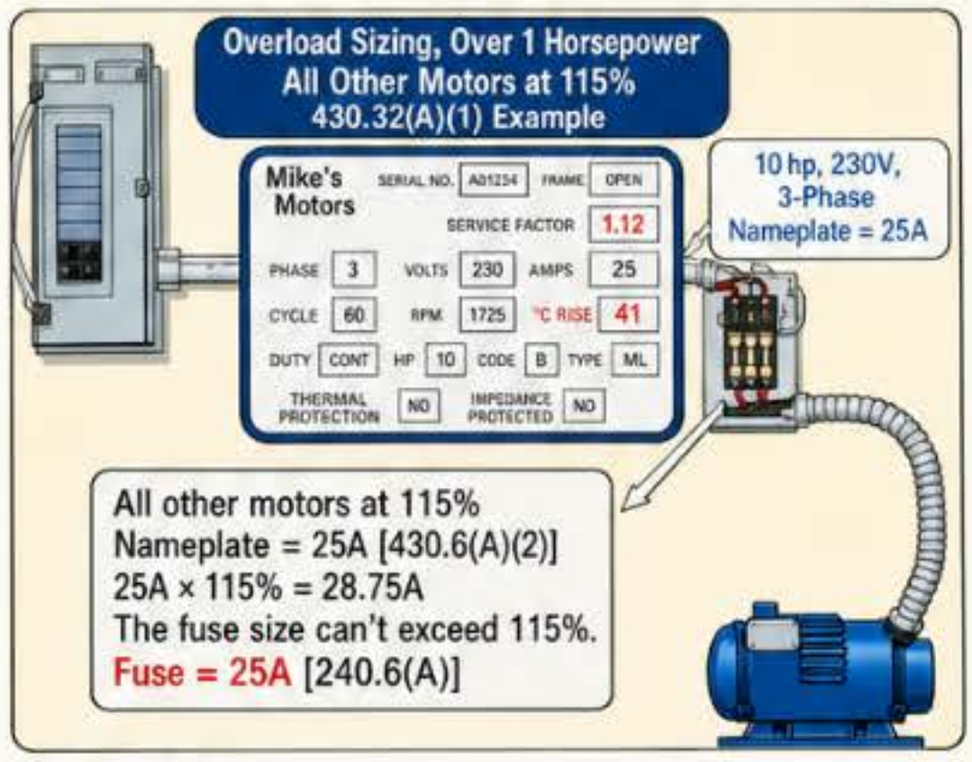


▶ Figure 430–18

▶ Example

Question: *A motor has a nameplate that specifies the following: The service factor is 1.12 with a temperature rise of 41°C and a nameplate full load current rating of 25A. What size dual-element time-delay fuse is required when used for the overload protection of this motor?* ***Figure 430–19***

(a) 20A (b) 25A (c) 30A (d) 40A



▶ Figure 430–19

Solution:

Since the service factor of 1.12 is less than 1.15, and 41°C is over 40°C, the overload protection is sized based on 115 percent of the motor nameplate ampere rating [430.6(A)(2)].

Author's Commentary:

This example shows how motors with a temperature rise above 40°C but with a service factor less than 1.15 use the 115 percent rule for overload sizing.

— Michael Hamilton

- *Overload Protection = 25A × 115%*
- *Overload Protection = 28.75A; use a 25A dual-element time-delay fuse [240.6(A)]*

Answer: *(b) 25A*

Other Motors. No more than 115 percent of the motor "nameplate current rating."

Part IV. Branch-Circuit Short-Circuit and Ground-Fault Protection

430.51 General

A branch-circuit short-circuit and ground-fault protective device protects the motor, the motor control equipment, and the conductors against short circuits or ground faults, but not against overload. **Figures 430–20**

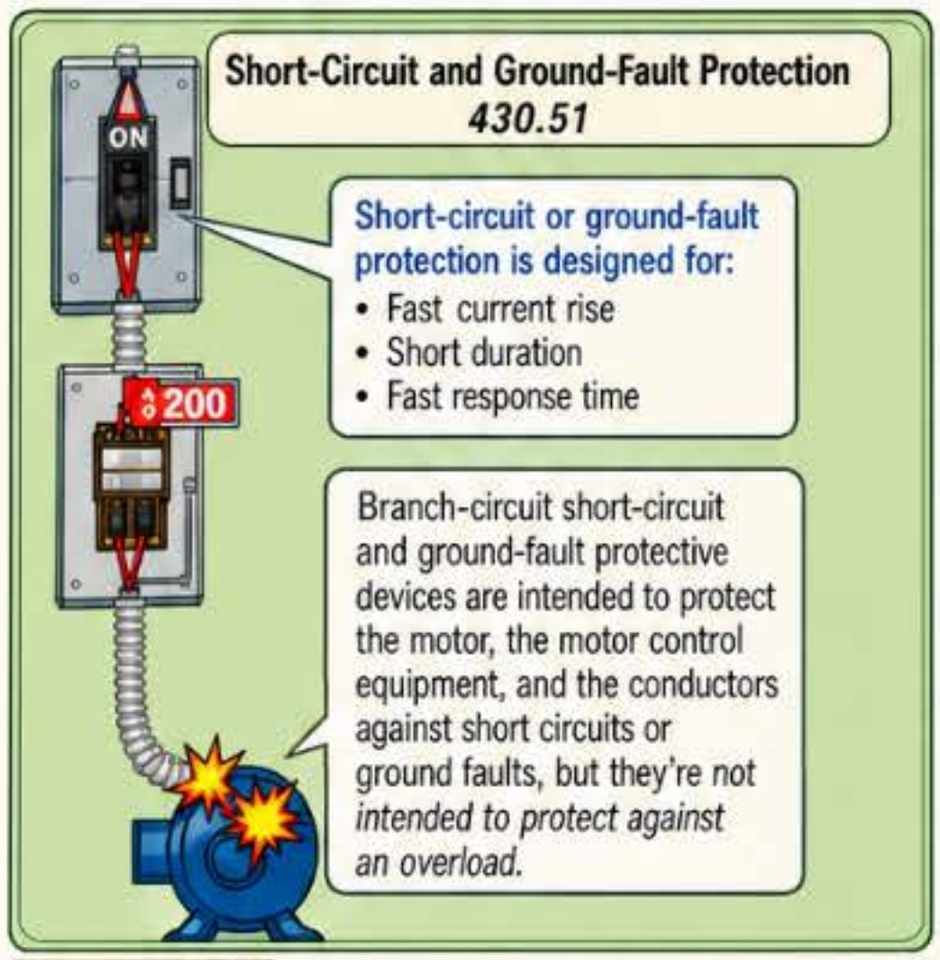


Figure 430–20

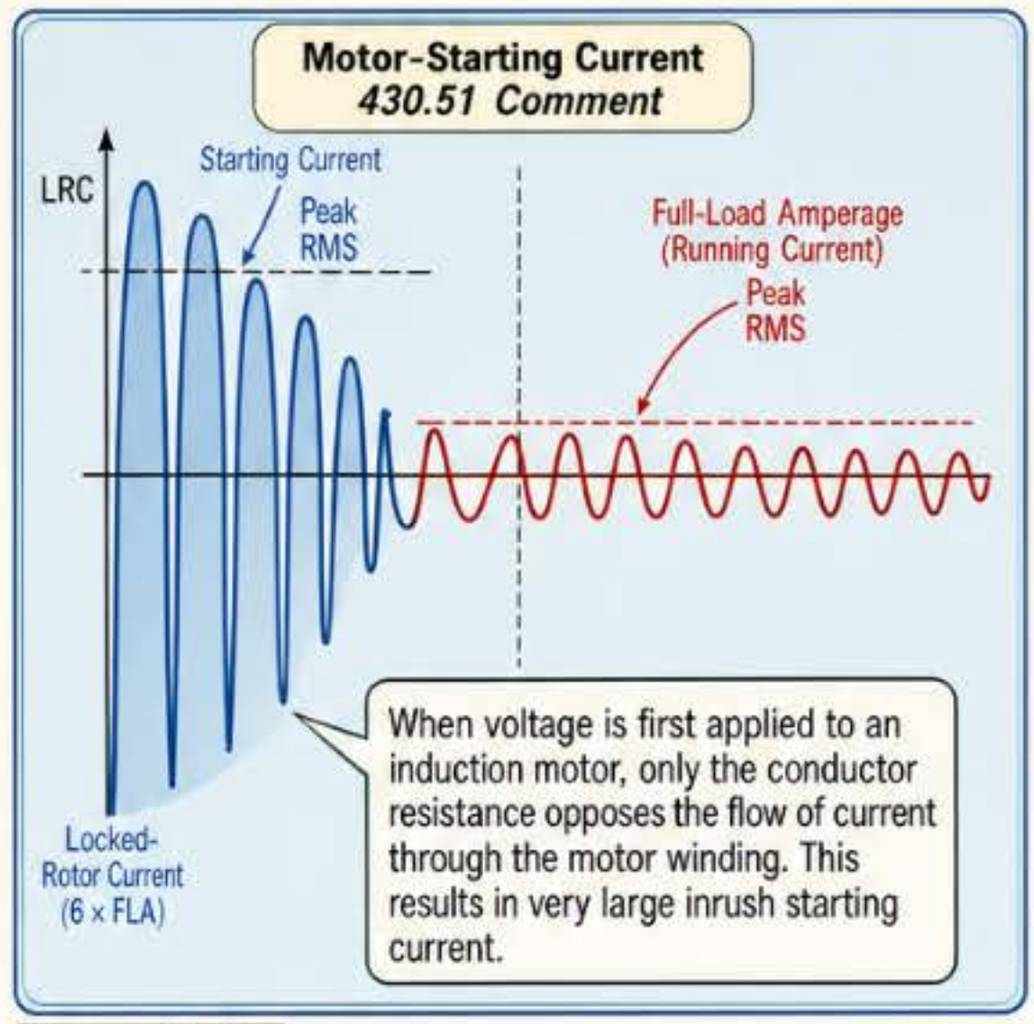


Figure 430–21

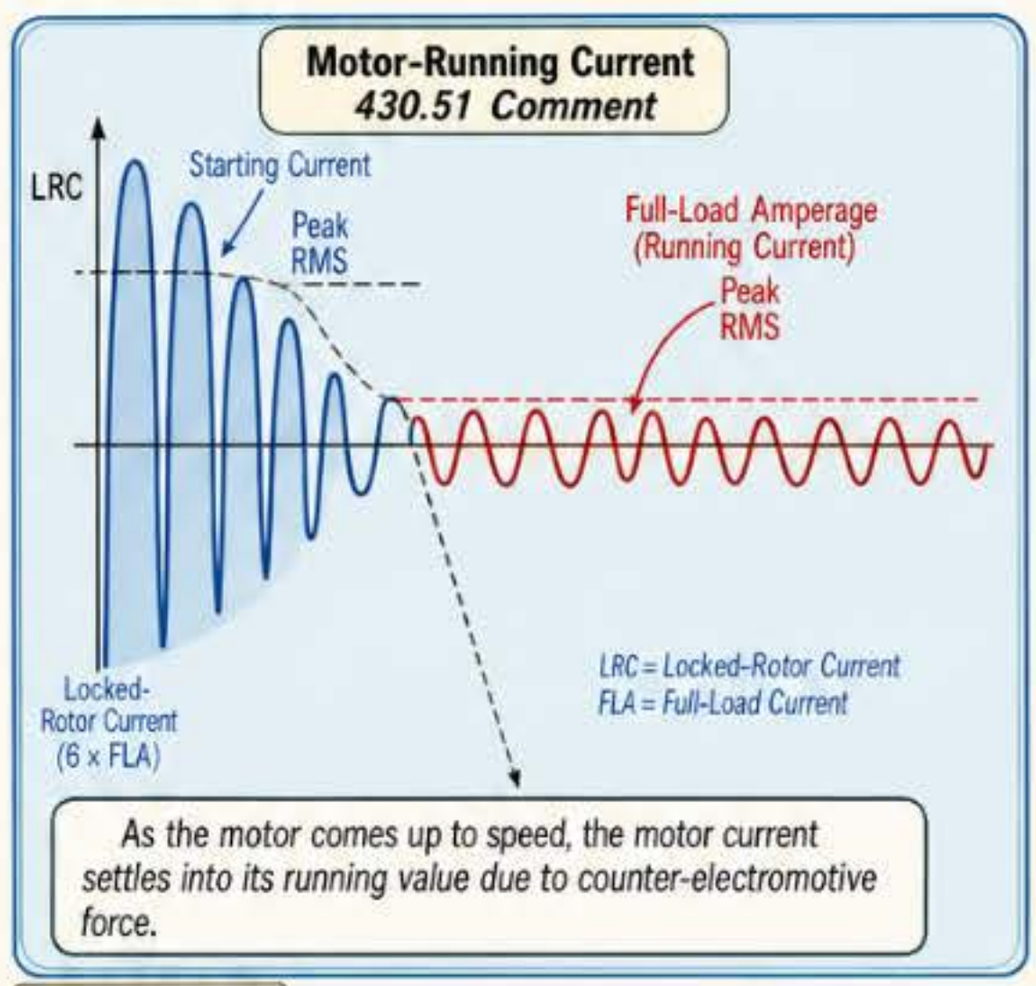


Figure 430–22

Author's Commentary:

- ***Motor-Starting Current.*** *When voltage is first applied to the field winding of an induction motor, only the conductor resistance opposes the flow of current through the motor winding. Because the conductor resistance is so low, the motor will have a very large inrush current.* ***Figure 430–21***
- ***Motor-Running Current.*** *Once the rotor reaches its rated speed, the starting current reduces to running current due to counter-electromotive force (CEMF).* ***Figure 430–22***

— Michael Hamilton

Author's Commentary:

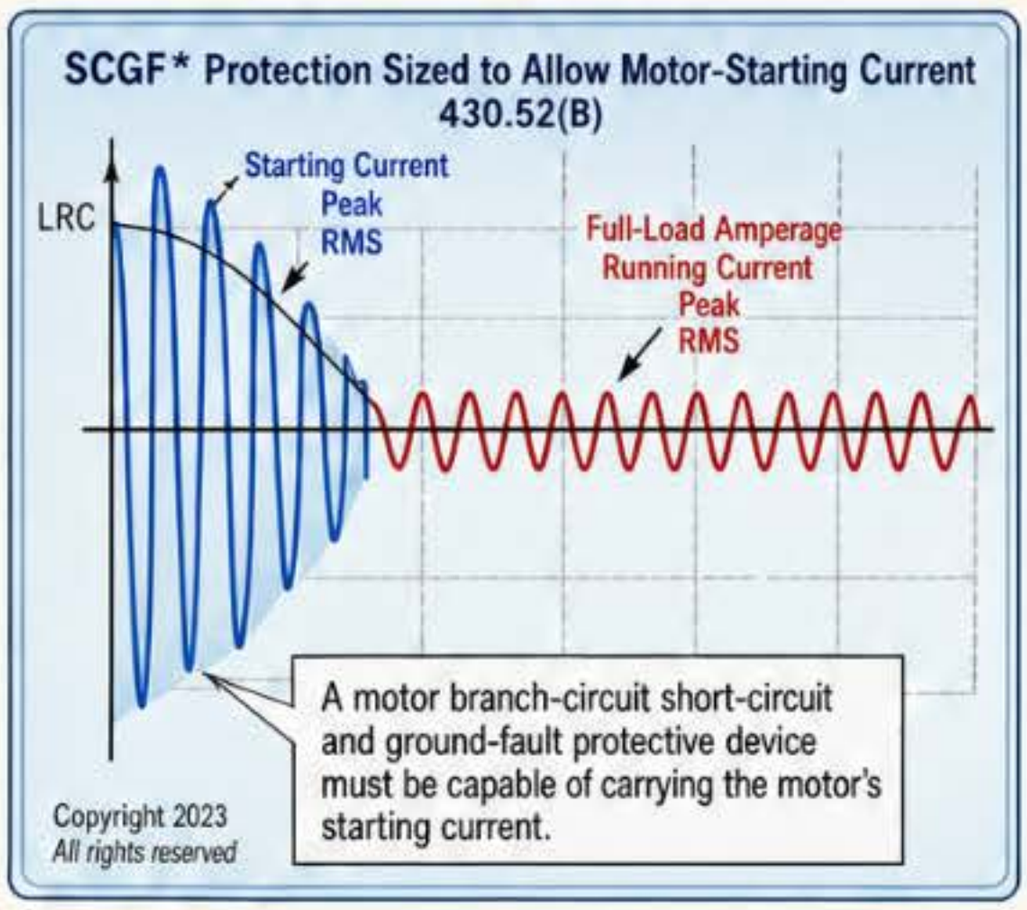
- ***Motor Locked-Rotor Current (LRC).*** *If the rotating part of the motor winding (armature) becomes jammed so it cannot rotate, no counter-electromotive force (CEMF) will be produced in the motor winding. This results in a decrease in conductor impedance to the point that it is effectively a short circuit. The motor then operates at locked-rotor current (often six times the full-load ampere rating) depending on the motor's Code letter rating [430.7(B)]. This condition will cause the motor winding to overheat and be destroyed if the current is not quickly reduced or removed.*

— Michael Hamilton

430.52 Branch-Circuit Short-Circuit and Ground-Fault Protection

(A) General. The motor branch-circuit short-circuit and ground-fault protective device must adhere to both 430.52(B) and 430.52(C).

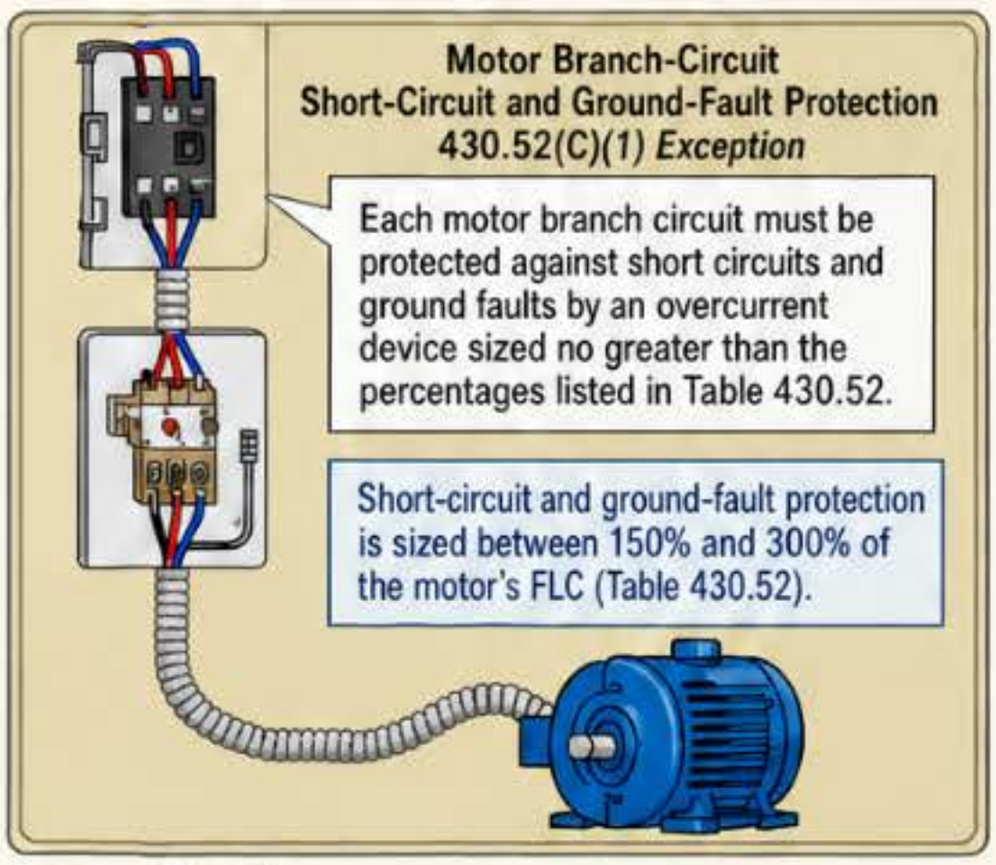
(B) Motor Starting Current. A motor branch-circuit short-circuit and ground-fault protective device must be able to withstand the motor's starting current. ▶ **Figure 430–23**



▶ **Figure 430–23**

(C) Rating or Setting.

(1) The motor branch circuit must be protected against short circuits and ground faults by a protective device sized no greater than the percentages contained in Table 430.52. ▶ **Figure 430–24**



▶ **Figure 430–24**

Author's Commentary:

The motor nameplate full load amperes (FLA) rating [430.6(A)(2)] cannot be used to determine the required branch-circuit short-circuit and ground-fault overcurrent protection.

— *Michael Hamilton*

Table 430.52 Maximum Rating or Setting of Motor Branch-Circuit Short-Circuit and Ground-Fault Protective Devices

Motor Type	Non-time-delay Fuse	Dual-Element (Time-Delay) Fuse	Inverse Time Breaker
Wound Rotor	150%	150%	150%
Direct Current	150%	150%	150%
Other Motors	300%	175%	250%

▶ Example

Question: *What size conductor and inverse time circuit breaker are required for a 1 hp, 115V, single-phase motor with terminals rated 75°C?* ▶ ***Figure 430–25***

(a) 14 AWG, 30A breaker *(b) 14 AWG, 35A breaker*
(c) 14 AWG, 40A breaker *(d) 14 AWG, 45A breaker*

Solution:

Step 1: *Determine the branch-circuit conductor at 125 percent of the motor's FLC (430.22 and Table 430.24(B)).*

Branch-Circuit Conductor = 16A × 125%
Branch-Circuit Conductor = 20A

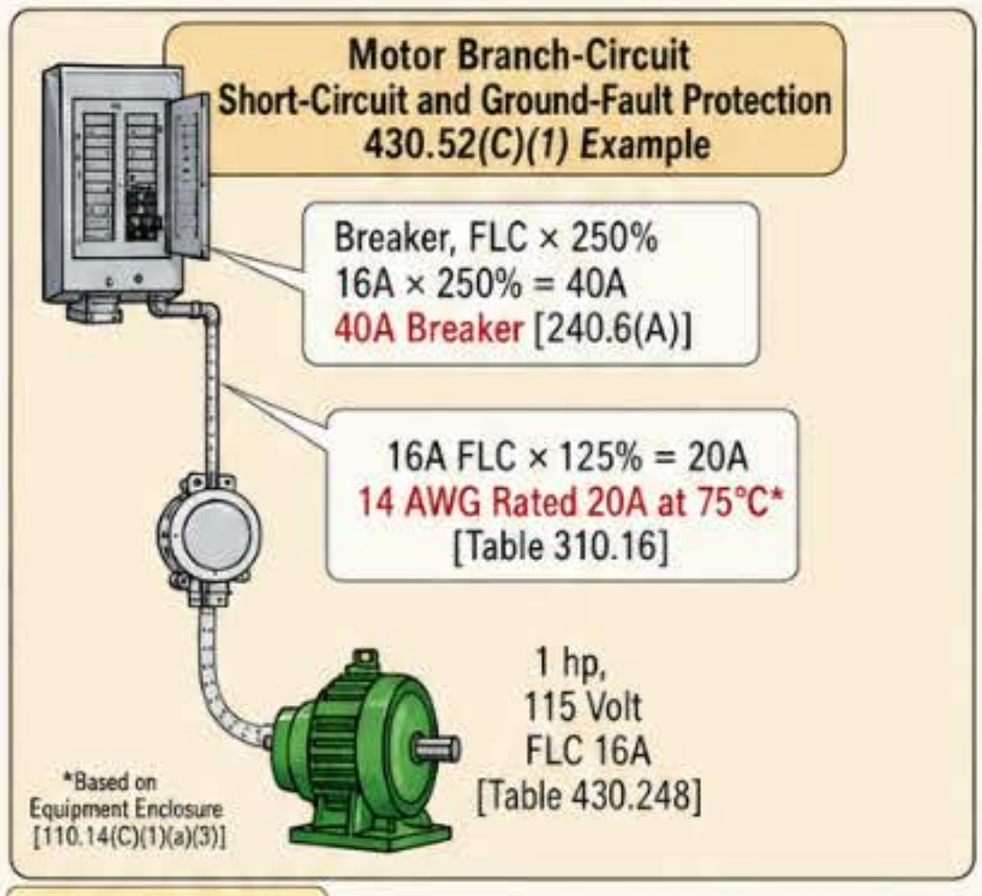
Use 14 AWG rated 20A at 75°C [110.14(C)(1)(a)(3) and Table 310.16].

Step 2: *Determine the branch-circuit protection at 250% of the motor's FLC (430.52(C)(1) and Table 430.24(B)).*

Branch-Circuit Protection = 16A × 250%
Branch-Circuit Protection = 40A [240.6(A)]

Answer: *(c) 14 AWG, 40A breaker*

Motors, Motor Circuits, and Controllers | 430.55

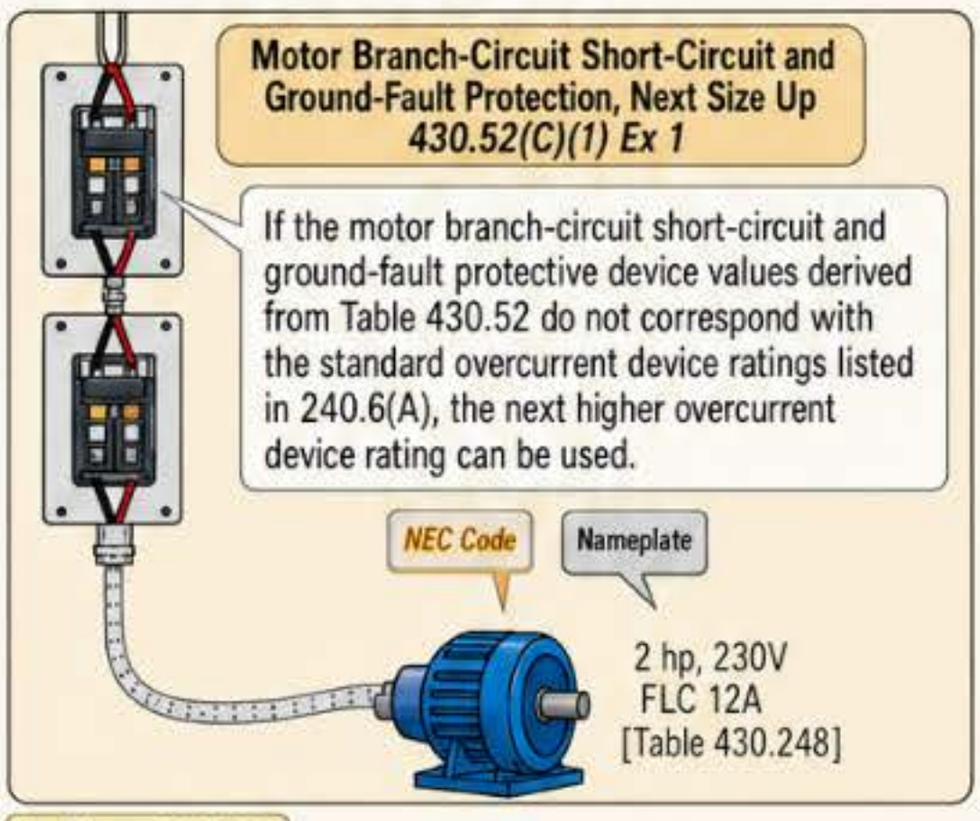


▶ **Figure 430-25**

Author's Commentary:

- I know it bothers many in the electrical industry to see a 14 AWG conductor protected by a 40A circuit breaker, but branch-circuit conductors are protected against overloads by the overload device which is sized between 115 and 125 percent of the motor's nameplate current rating [430.32]. See 240.4(G) for details.
- The rule that limits 15A overcurrent protection for 14 AWG conductors does not apply to motor circuit protection, see 240.4(D) and 240.4(G).

Ex 1: *If the motor short-circuit and ground-fault protective device values derived from Table 430.52 do not correspond with the standard overcurrent device ratings listed in 240.6(A), the next higher overcurrent device rating can be used.* ▶ **Figure 430-26**

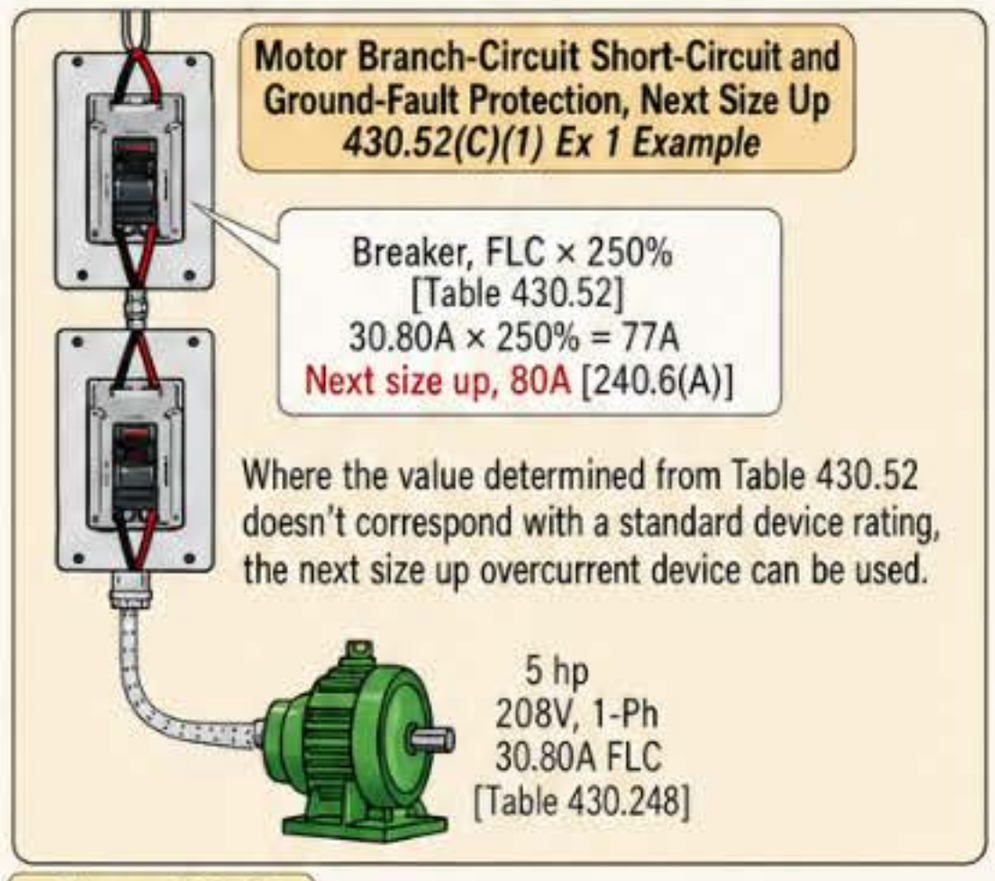


▶ **Figure 430-26**

▶ Example

Question: What size inverse time circuit breaker is required for a 5 hp, 230V, single-phase motor? ▶ **Figure 430-27**

(a) 35A (b) 40A (c) 60A (d) 80A



▶ **Figure 430-27**

Solution:

Determine the branch-circuit protection at 250% of the motor's FLC [430.52(C)(1)] and Table 430.248]:

Branch-Circuit Protection = 30.80A × 250%

Branch-Circuit Protection = 77A; next size up 80A circuit breaker [240.6(A)]

Answer: *(d) 80A*

Author's Commentary:

- Remember that the 80A circuit breaker is providing short-circuit and ground-fault protection and the motor overload protective device (set at 125 percent or 115 percent of the motor's FLA) will protect the motor, motor equipment, and motor circuit conductors against overloads.

430.55 Combined Overcurrent Protective Device

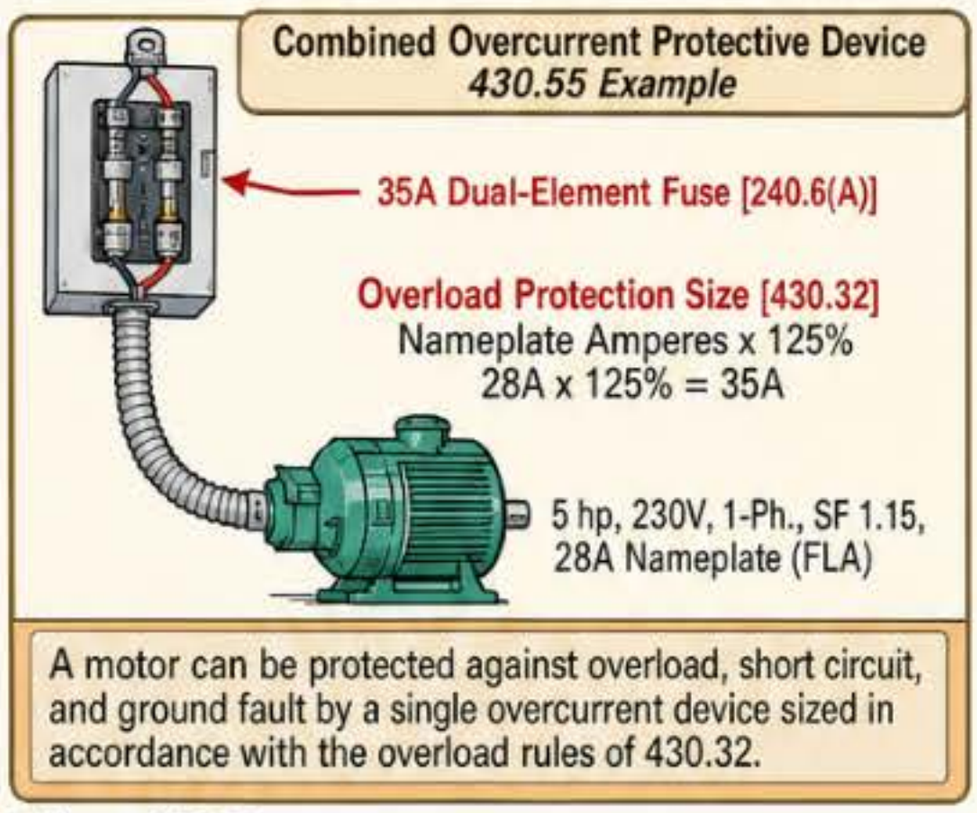
A motor can be protected against overload, short circuit, and ground fault by a single overcurrent protective device sized to the overload requirements contained in 430.32.

430.62 MOTORS, MOTOR CIRCUITS, AND CONTROLLERS

▶ Example

Question: *What is the maximum size dual-element fuse that can be used to provide overload, short-circuit and ground-fault protection for a 5 hp, 230V, single-phase motor with a service factor of 1.20 and a nameplate current rating of 28A?* **• Figure 430–28**

(a) 30A *(b) 35A* *(c) 40A* *(d) 50A*



▶ Figure 430–28

Solution:

A single overcurrent device must be sized in accordance with the percentages contained in 430.32. For this application, the single overcurrent device must be sized not greater than 125 percent of the motor's nameplate current rating.

Overcurrent Protection = 28A FLA x 125%
Overcurrent Protection = 35A [240.6(A)]

Answer: *(b) 35A*

Part V. Feeder Short-Circuit and Ground-Fault Protection

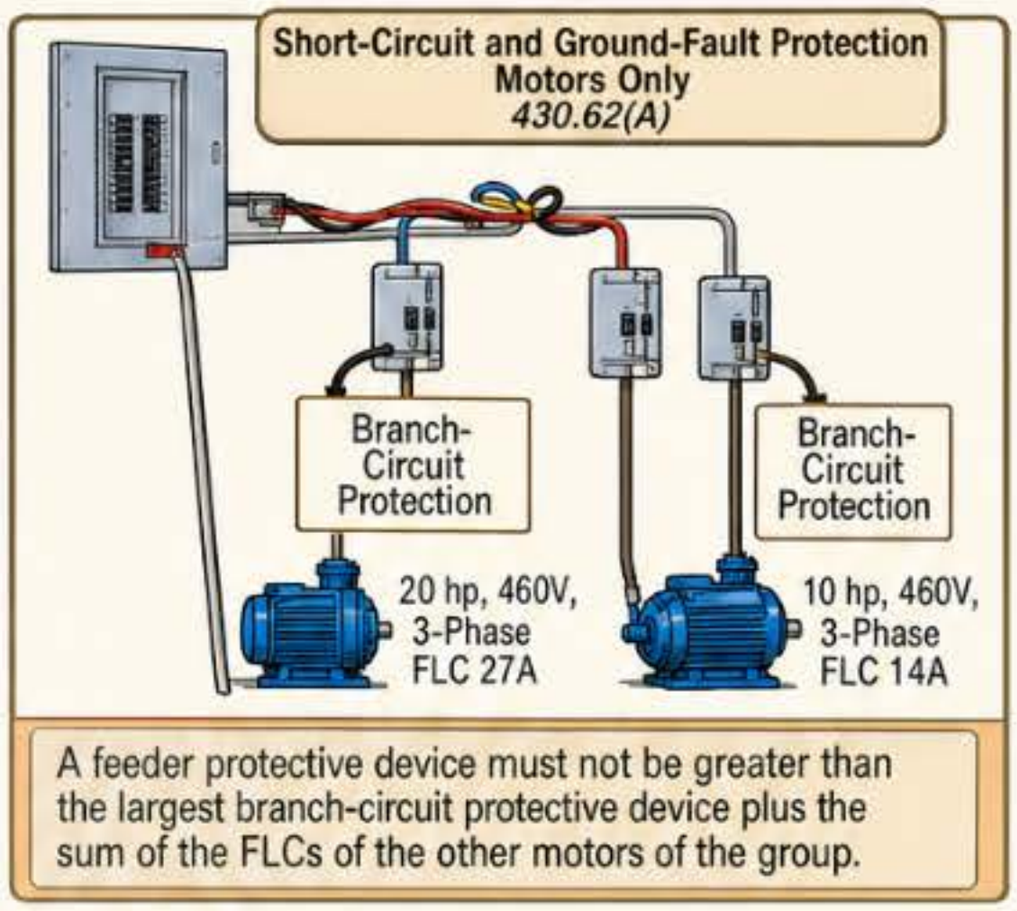
430.62 Motor Feeder Protection

(A) Motors Only. *Feeder conductors must be protected against short circuits and ground faults by a protective device sized not greater than the largest rating of the branch-circuit short-circuit and ground-fault protective device for any motor, plus the sum of the full-load currents (FLC) of the other motors in the group as listed in Tables 430.248 and 430.250.* **• Figure 430–29**

Author's Commentary:

These examples highlight how the Code ensures motors are protected properly while avoiding unnecessary over-sizing and cost. Always work the math, check Tables 430.248 and 430.250, and confirm conductor ampacity at 75°C.

— Michael Hamilton



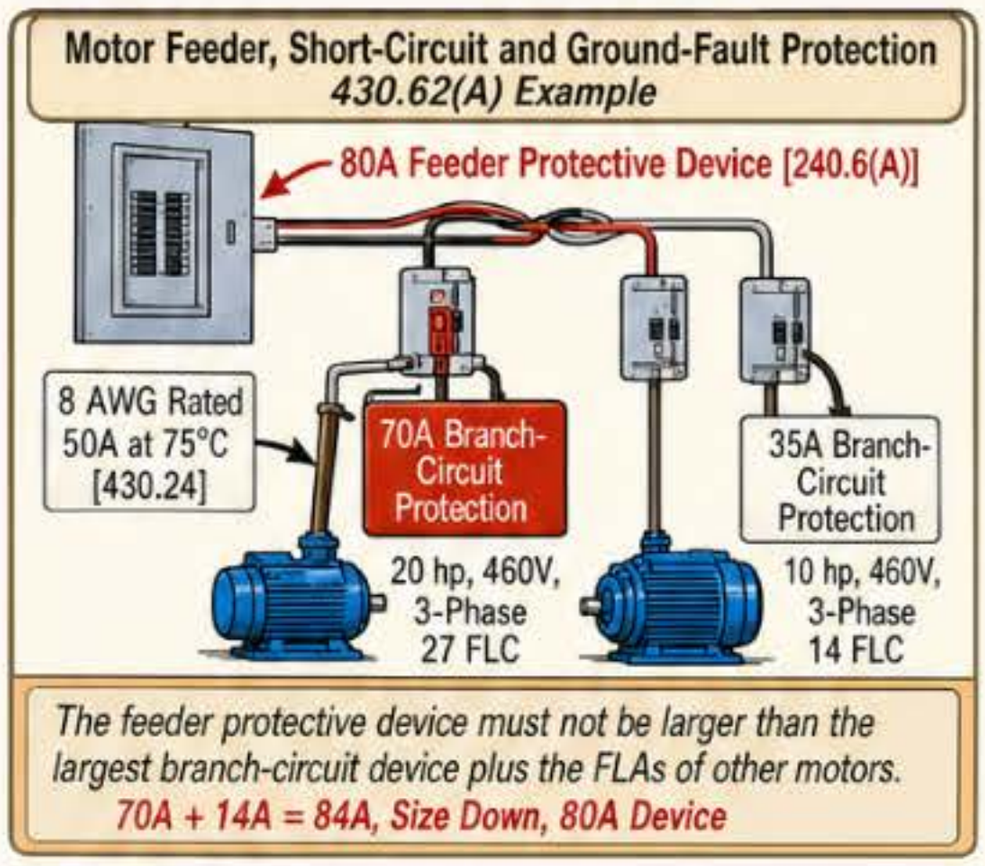
▶ Figure 430–29

▶ Example

Question: *What size feeder overcurrent protection (inverse time breaker) and conductors are required for the following two motors where the conductor terminals are rated 75°C?* **• Figure 430–30**

- *Motor 1—20 hp, 460V, Three-Phase = 27A FLC [Table 430.250]*
- *Motor 2—10 hp, 460V, Three-Phase = 14A FLC [Table 430.250]*

(a) 10 AWG/30A *(b) 10 AWG/40A*
(c) 10 AWG/50A *(d) 8 AWG/80A*



▶ Figure 430–30

Solution:

Step 1: *Determine the feeder conductor size [430.24]. Largest motor FLC of the group at 125 percent plus FLC of other motors.*

Conductor = (27A × 125%) + 14A
Conductor = 48A

Motors, Motor Circuits, and Controllers | 430.62

Conductor = 8 AWG rated 50A at 75°C [110.14(C)(1)(a)(3) and Table 310.16]

Step 2: *Feeder overcurrent protection [430.62(A)] is not greater than the largest branch-circuit ground-fault and short-circuit protective device plus the other motors' FLC.*

Determine the largest branch-circuit ground-fault and short-circuit protective device [240.6(A) and 430.52(C)(1) Ex].

20 hp Motor = 27A × 250%
20 hp Motor = 68A; use the next size up, 70A

10 hp Motor = 14A × 250%
10 hp Motor = 35A

Determine the feeder protection size.

Feeder Protection = Not more than 70A + 70A + 14A
Feeder Protection = 84A; use the next size down, 80A [240.6(A)]

Answer: (d) 8 AWG/80A

Author's Commentary:

- *The "next size up protection" rule for branch circuits [430.52(C)(1) Ex 1] does not apply to motor feeder overcurrent protective devices.*
- *In some installations that use three-phase and single-phase motors on the same feeder, the currents on L1, L2, and L3 (or Phase 1, Phase 2, and Phase 3) will not be the same. The "group" is determined by finding the largest current for each line of the motor feeder.* ▶**Figure 430-31**

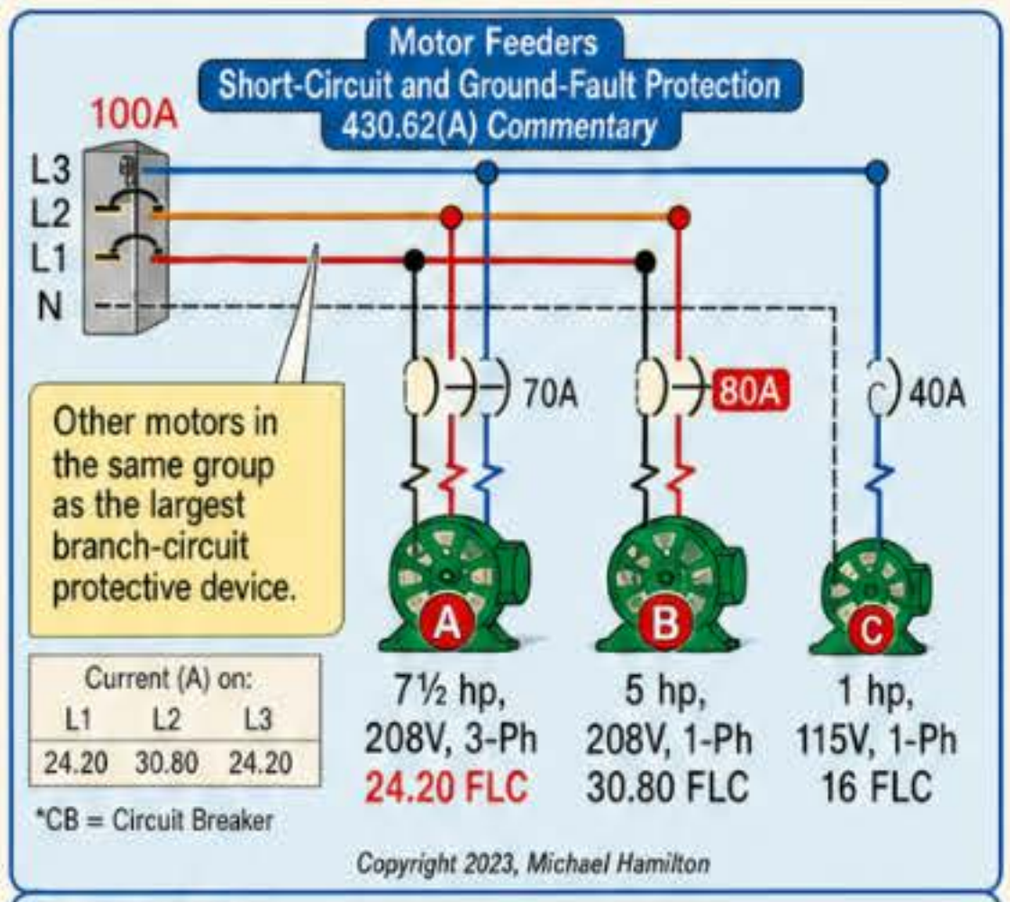


Figure 430-31

▶ Example

Question: *What size feeder overcurrent protective device (inverse time breaker) and conductors are required for the following three motors where all terminals are rated 75°C?* ▶**Figure 430-32**

- *Motor 1—7½ hp, 208V, three-phase = 24.20A FLC [Table 430.250]*
- *Motor 2—5 hp, 208V, single-phase = 30.80A FLC [Table 430.250]*
- *Motor 3—1 hp, 115V, single-phase = 16.00A FLC [Table 430.250]*

(a) 4 AWG/100A *(b) 4 AWG/110A*
(c) 4 AWG/125A *(d) 4 AWG/150A*

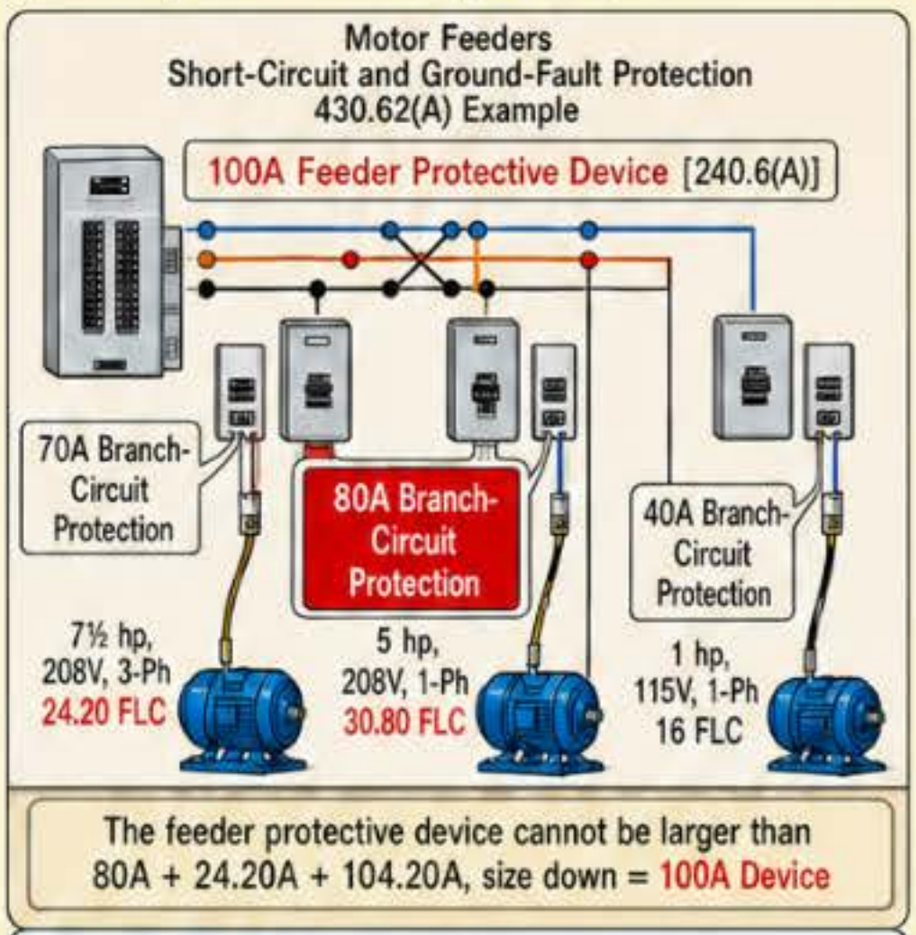


Figure 430-32

Solution:

Step 1: *Determine the feeder conductor size [430.24]. Remember, the 1 hp single-phase motor is not part of the largest group after balancing the motors on L1, L2, and L3 so its 16.00A FLC is not used in this calculation.*

Feeder Conductor = (30.80A × 125%) + 24.20A
Feeder Conductor = 72.70A
Feeder Conductor = 4 AWG rated 85A at 75°C [110.14(C)(1)(a)(3) and Table 310.16]

Step 2: *Feeder overcurrent protection [430.62(A)] is not greater than the largest branch-circuit ground-fault and short-circuit protective device plus the other motors' FLCs.*

Determine the largest branch-circuit ground-fault and short-circuit protective device [240.6(A) and 430.52(C)(1) Ex].

7½ hp Motor = 24.20A × 250%
7½ hp Motor = 60.50A; use the next size up, 70A

5 hp Motor = 30.80A × 250%
5 hp Motor = 77A; use the next size up, 80A

1 hp Motor—does not apply after balancing.

•••

Determine the feeder protection size.

Feeder Protection = Not more than 80A + 24.20A

Feeder Protection = 104.20A; use the next size down, 100A (240.6[A])

Answer: *(a) 4 AWG/100A*

Part VI. Motor Control Circuits

430.72 Overcurrent Protection for Control Circuits

(A) Class 1 Control Conductors. Motor control conductors that are not tapped from the motor branch-circuit conductors are classified as a Class 1 remote-control circuit and must have overcurrent protection in accordance with 725.43.

Author's Commentary:

- *Section 725.43 requires that overcurrent protection for conductors 14 AWG and larger must comply with the conductor ampacity from Table 310.16. Overcurrent protection for 18 AWG conductors are not permitted to exceed 7A, and not more than a 10A device can be used to protect 16 AWG conductors.*

— Michael Hamilton

(B) Motor Control Conductors

(2) Motor control circuit conductors that are tapped from the motor branch-circuit overcurrent protective device and extend beyond the tap enclosure must have overcurrent protection as follows:

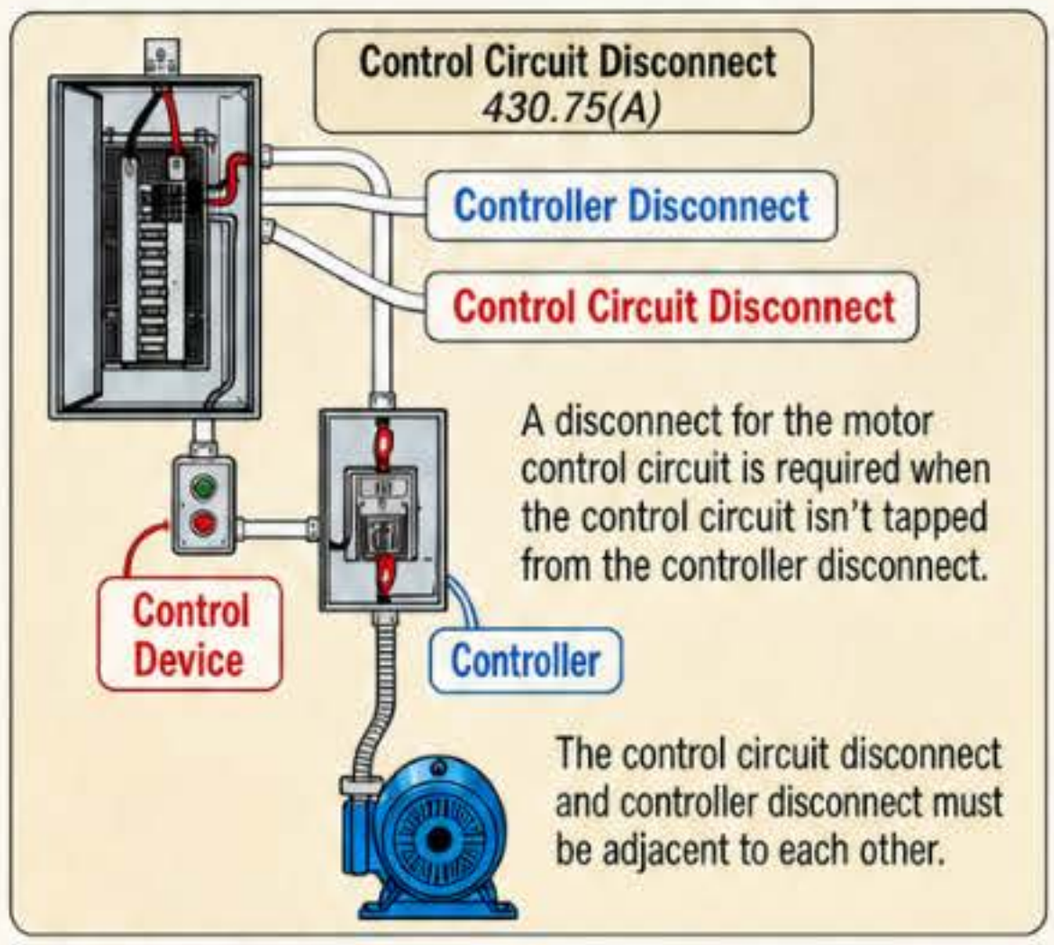
Table 430.72(B) Maximum Rating of Overcurrent Protective Device in Amperes

Conductor Size Copper	Column C Overcurrent Protection
18 AWG	7A
16 AWG	10A
14 AWG	45A
12 AWG	60A
10 AWG	90A
>10 AWG	(Note 3)

Note 3: *300 percent of the value specified in Table 310.16 for 60°C conductors.*

430.75 Disconnect for Control Circuits

(A) Control Circuit Disconnect. Motor control circuit conductors must have a disconnect. Where the control circuit conductors are tapped from the controller disconnect, the controller disconnect can serve as the disconnect for the control circuit conductors [430.102(A)]. Where control circuit conductors are not tapped from the controller disconnect (supplied by a Class 1 control circuit), a disconnect located adjacent to the controller disconnect is required. ▶ **Figure 430–33**



▶ **Figure 430–33**

Part VII. Motor Controllers

430.83 Motor Controller Horsepower Rating

(A) General. The controller for a motor must have one of the following ratings:

(1) Horsepower Rating. For other than circuit breakers and molded case switches, the controller for a motor must have a horsepower rating not less than that of the motor. ▶ **Figure 430–34**

(2) Circuit Breakers. A circuit breaker can serve as a motor controller.

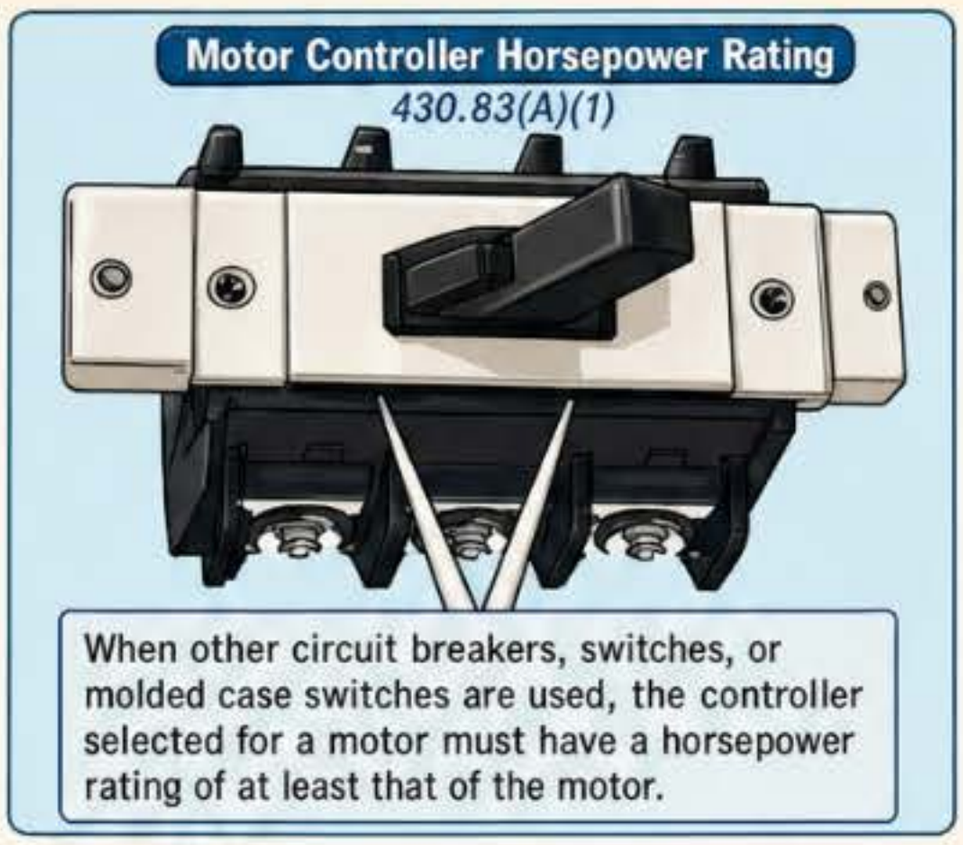
Author's Commentary:

- *Circuit breakers are not required to be horsepower rated.*

— Michael Hamilton

(3) Molded Case Switch. A molded case switch, rated in amperes, can serve as a motor controller.

Motors, Motor Circuits, and Controllers | 430.102



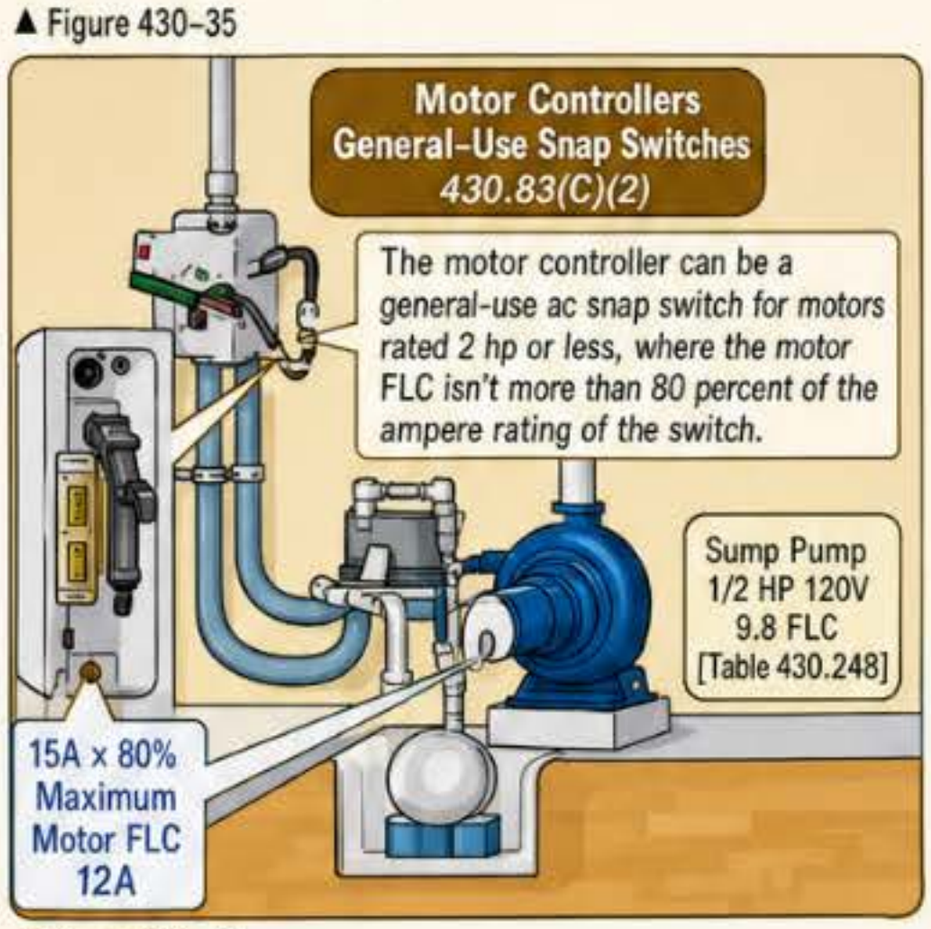
▲ Figure 430–34

Author's Commentary:
A molded case switch isn't required to be horsepower-rated.
— *Michael Hamilton*

(C) Stationary Motors of Two Horsepower or Less. For stationary motors rated at 2 hp or less and 300V or less, the controller can be:

(2) General-Use Snap Switch. The motor controller can be a general-use snap switch for motors rated 2 hp or less where the motor FLC is not more than 80 percent of the ampere rating of the switch.

▲ Figure 430–35

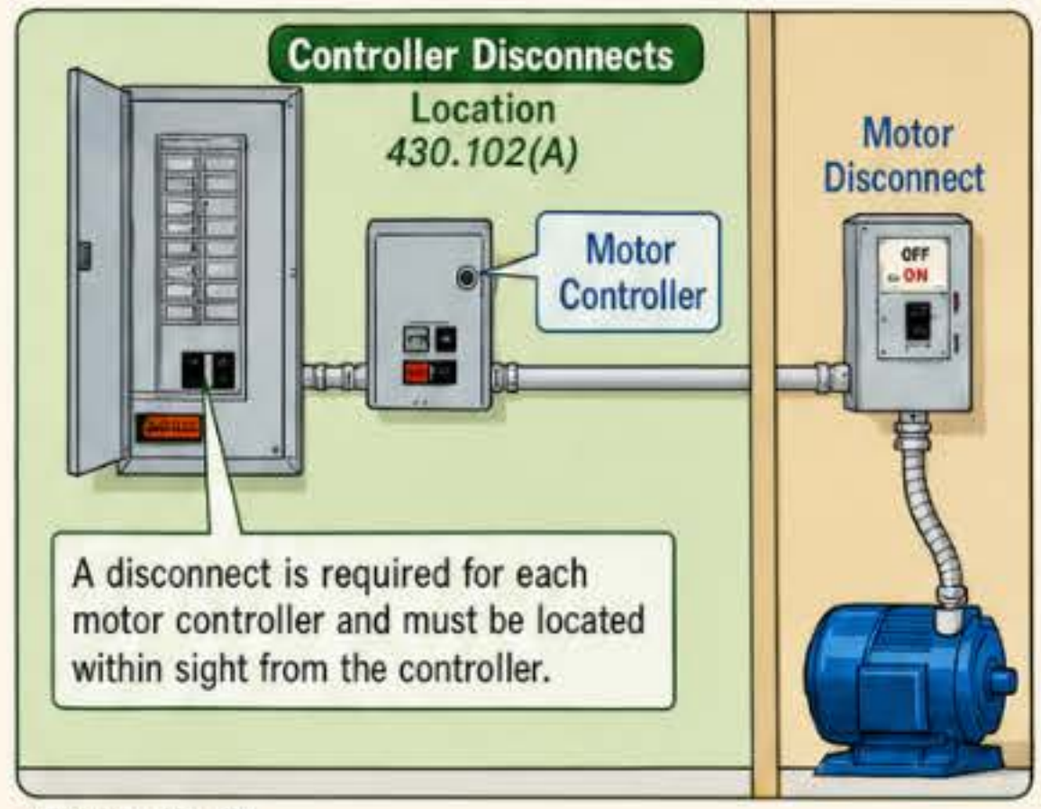


▲ Figure 430–35

Part IX. Disconnecting Means

430.102 Disconnect Location

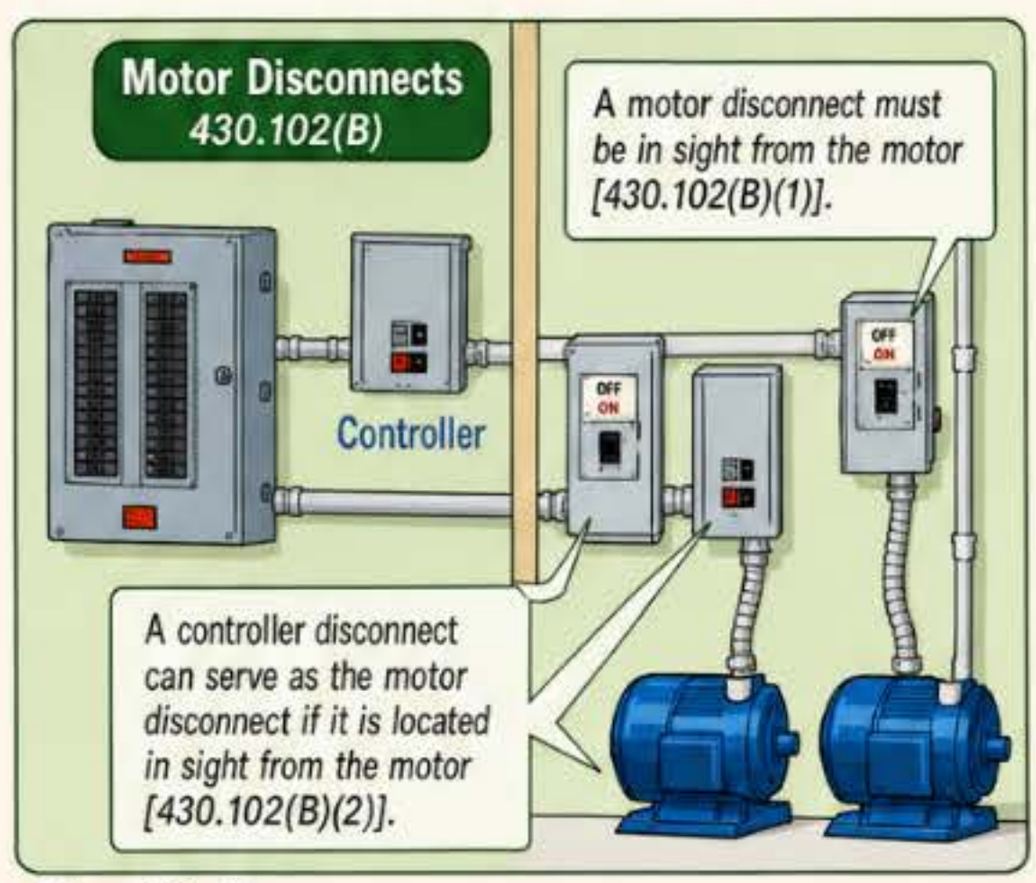
(A) Controller Disconnect. A disconnect is required for each motor controller and must be located within sight from the controller. ▶**Figure 430–36**



▲ Figure 430–36

Author's Commentary:
According to Article 100, "Within Sight" means that it is visible and not more than 50 ft from the location of the equipment.
— *Michael Hamilton*

(B) Motor Disconnect. A motor disconnect must be provided in accordance with (B)(1) or (B)(2). ▶**Figure 430–37**



▲ Figure 430–37

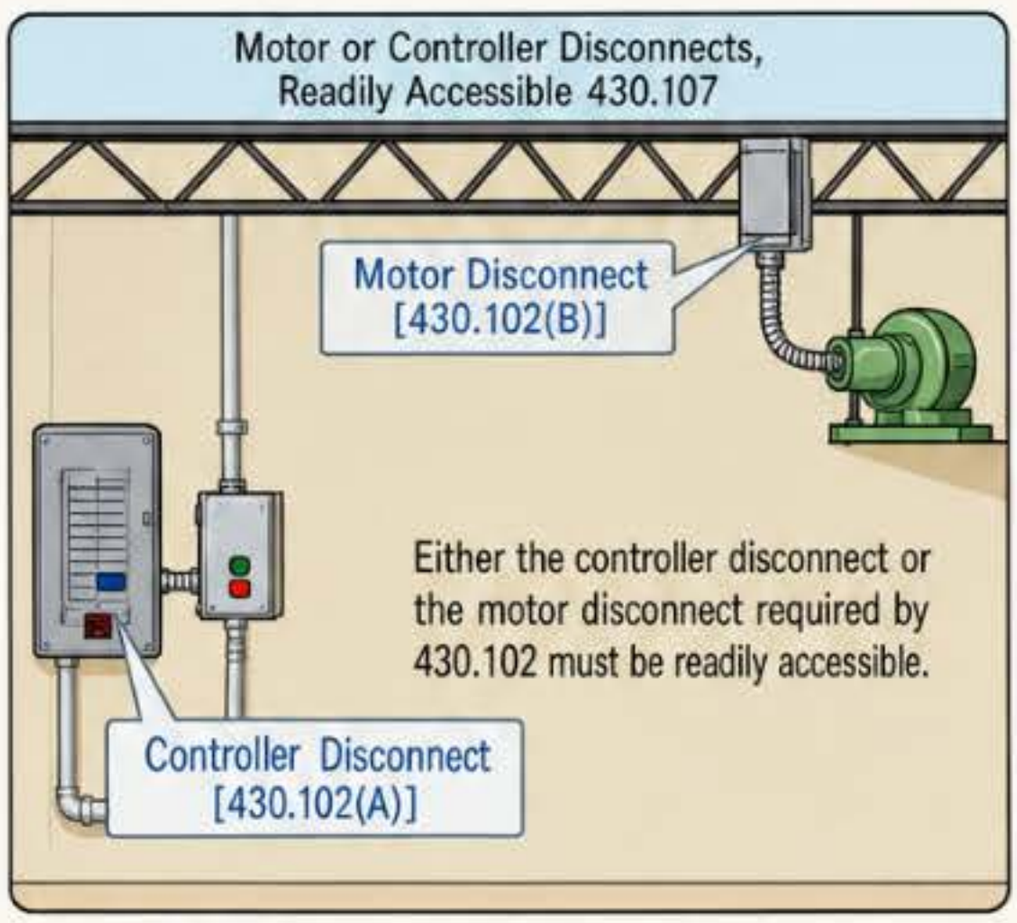
430.107 Motors, Motor Circuits, and Controllers

(1) Separate Motor Disconnect. A disconnecting means is required for each motor, and it must be installed within sight of the motor or as close as practicable to the motor.

(2) Controller Disconnect. If the motor controller is mounted within sight of the motor, the controller disconnect may serve as the disconnecting means for the motor.

430.107 Readily Accessible

The controller disconnect or the motor disconnect required by 430.102 must be arranged so it is readily accessible. ▶ **Figure 430–38**



▶ **Figure 430–38**

430.109 Type of Disconnecting Means

(A) General. The disconnect for the motor controller and/or the motor must be one of the following:

(1) Motor-Circuit Switch. *A listed horsepower-rated motor-circuit switch.*

(2) Molded Case Circuit Breaker. *A listed molded case circuit breaker.*

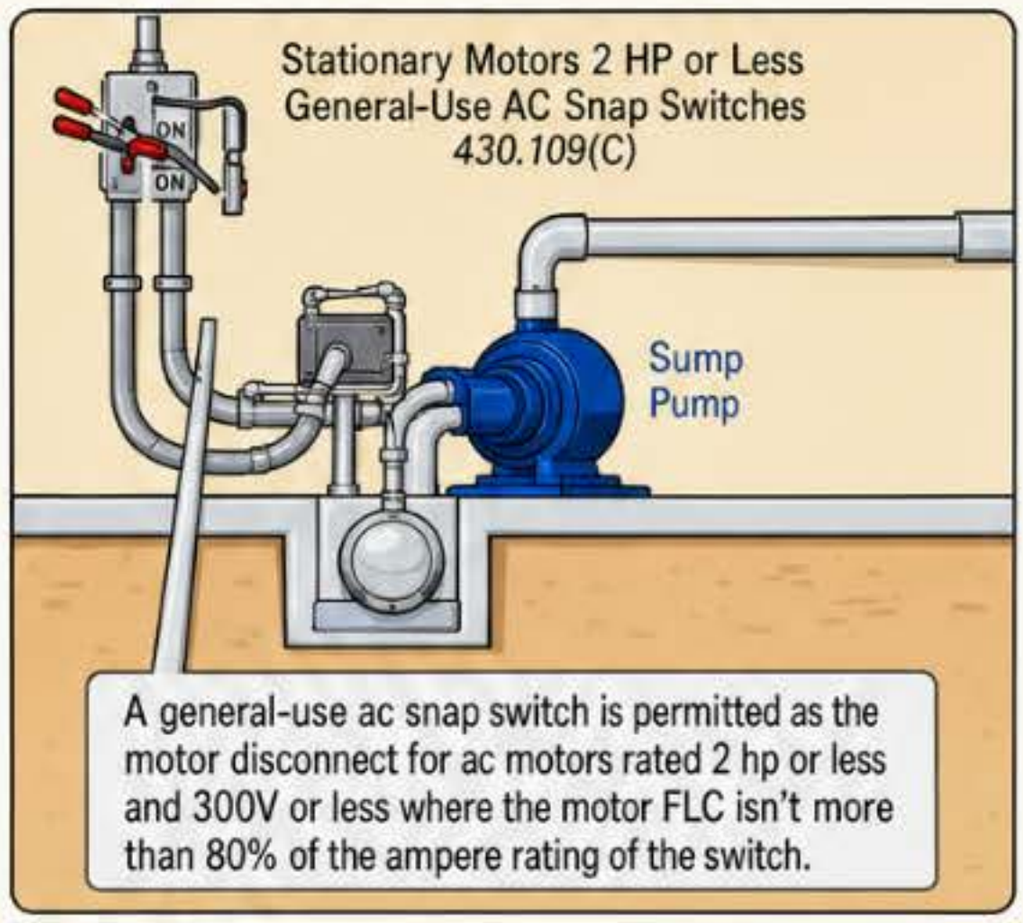
(3) Molded Case Switch. *A listed molded case switch.*

(6) Manual Motor Controller. *A listed manual motor controller marked "Suitable as Motor Disconnect."*

(B) Stationary Motors of ½ Horsepower or Less. *For stationary motors of ½ hp or less, the branch-circuit overcurrent protective device can serve as the disconnect.*

(C) Stationary Motors of Two Horsepower or Less. *For stationary motors rated 2 hp or less and 300V or less, the disconnect can be a general-use ac snap switch as described in 430.109(C).*

A general-use ac snap switch (not a general-use ac-dc snap switch) where the motor's full-load current (FLC) as listed in Tables 430.248 and 430.250 is not more than 80 percent of the ampere rating of the switch. ▶ **Figure 430–39**



▶ **Figure 430–39**

Author's Commentary:

Section 430.83(C) has similar requirements for controllers for stationary motors rated 2 hp or less. In some cases, the same switch is used for both the controller and the motor disconnect.

— Michael Hamilton

(3) A listed manual motor controller marked "Suitable as Motor Disconnect."

(F) Cord-and-Plug-Connected Motors. A horsepower-rated attachment plug and receptacle, flanged surface inlet and cord connector, or cord connector having a horsepower rating not less than the motor rating can be used as a motor disconnect. ▶ **Figure 430–40**

Part X. Adjustable-Speed Drive Systems

430.120 General

The installation provisions of Part I through Part IX are applicable unless modified or supplemented by this part.

430.122 Conductor Sizing

(A) Branch/Feeder-Circuit Conductors. *Circuit conductors for an adjustable-speed drive system must have an ampacity of not less than 125 percent of the rated input current of the adjustable-speed drive system.* ▶ **Figure 430–41**

MOTORS, MOTOR CIRCUITS, AND CONTROLLERS | 430.122

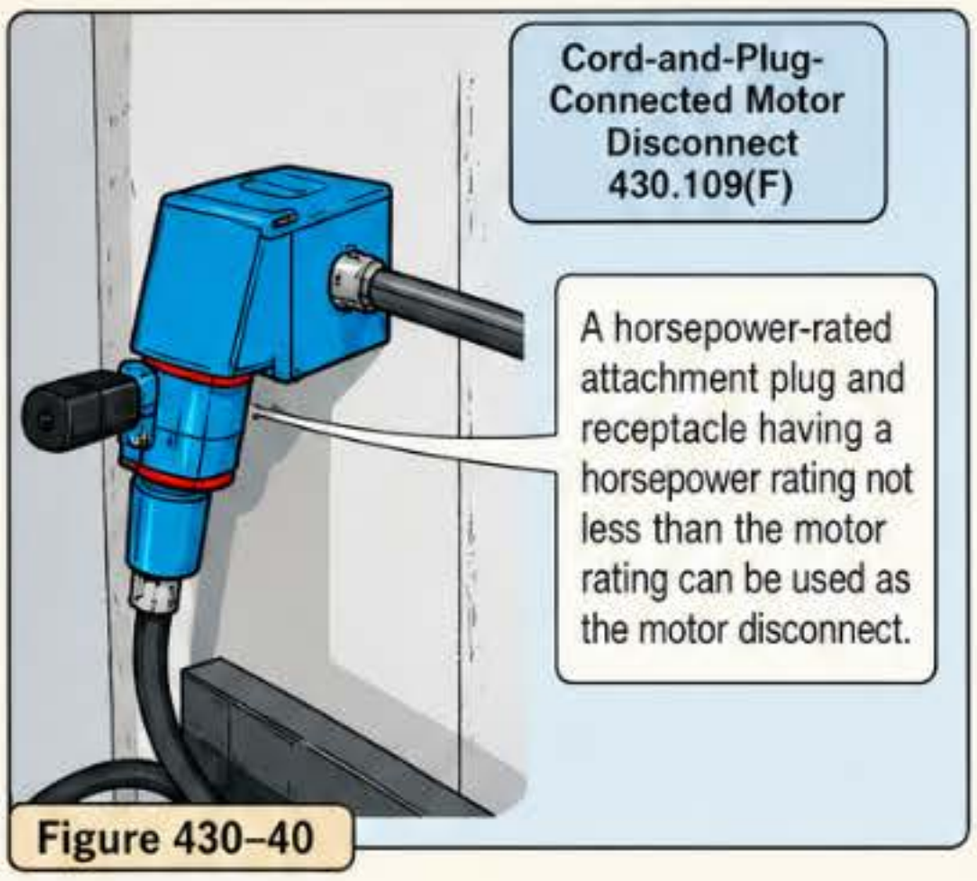


Figure 430–40

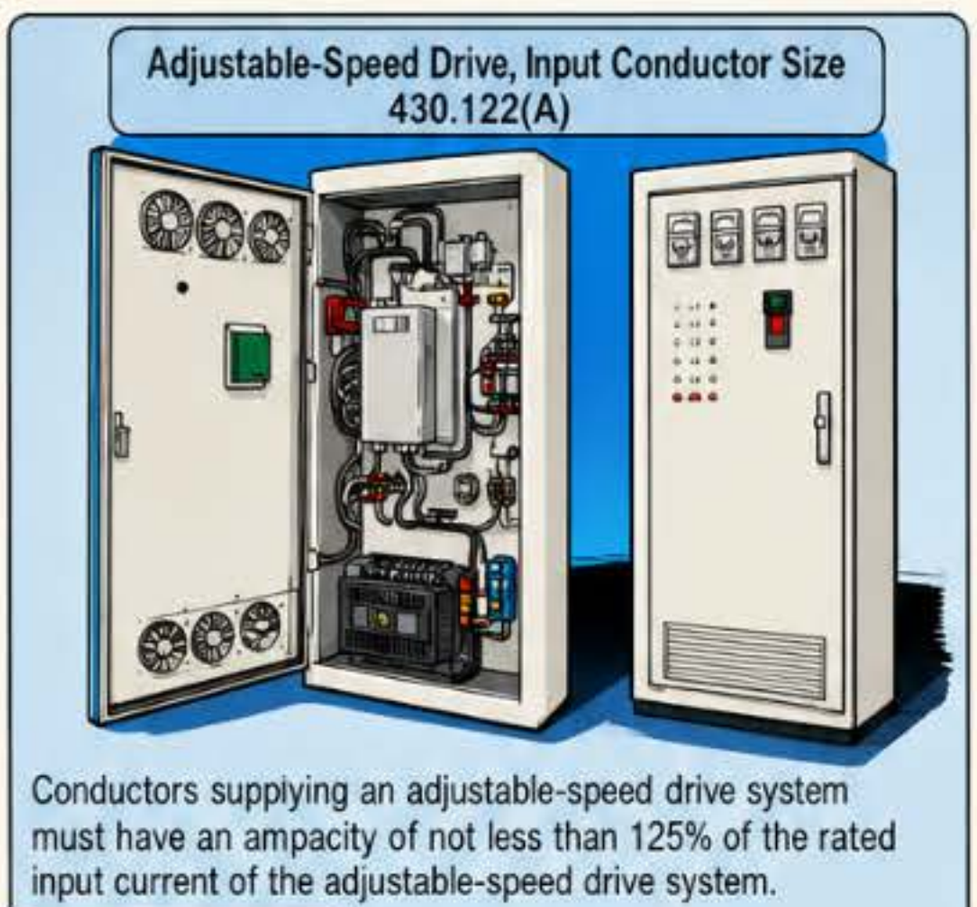


Figure 430–41

▶ Motor Branch-Circuit for Adjustable-Speed Drive System Example

Question: *What size branch-circuit conductors are required for an adjustable-speed drive system with a rated input of 25A and terminals rated 75°C?* ***Figure 430–42***

(a) 14 AWG (b) 12 AWG (c) 10 AWG (d) 8 AWG

Solution:

Rated Input from Adjustable-Speed Drive = 25A

Branch-Circuit Conductor = 25A × 125%

Branch-Circuit Conductor = 31.25A

Use 10 AWG rated 35A at 75°C

[Table 310.16 and 110.14(C)(1)(a)(3)].

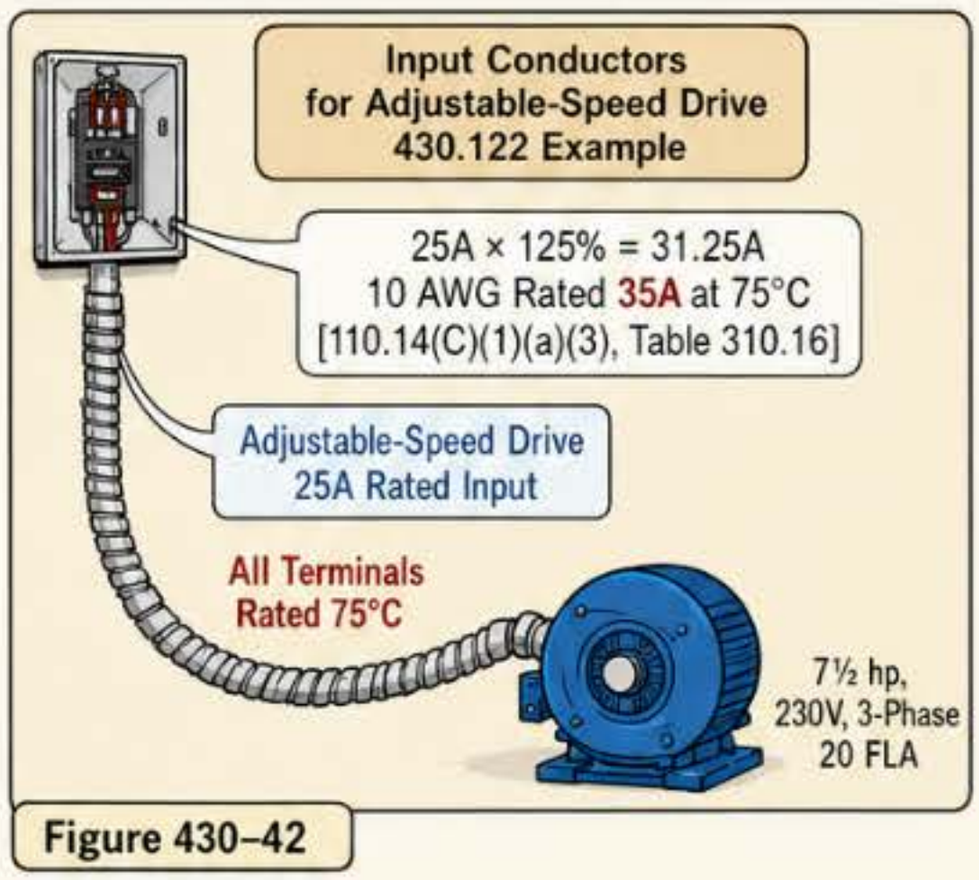


Figure 430–42

Answer: (c) 10 AWG

Note 1: Adjustable-speed drive systems can have multiple power ratings and corresponding input currents.

Note 2: Circuit conductors on the output of an adjustable-speed drive system are susceptible to breakdown under certain conditions due to the characteristics of the output waveform of the drive. Factors affecting the conductors include (but are not limited to) the output voltage, frequency and current, the length of the conductors, the spacing between the conductors, and the dielectric strength of the conductor insulation. Methods to mitigate breakdown include consideration of one or more of these factors.

(B) Output Conductors. The conductors between the power conversion equipment and the motor must have an ampacity equal to or greater than 125 percent of the motor's full-load current (FLC) as listed in Tables 430.248 and 430.250.

Ex: If the power conversion equipment is listed and marked as "Suitable for Output Motor Conductor Protection," the conductor between the power conversion equipment and the motor must have an ampacity equal to or greater than the larger of:

(1) 125 percent of the motor's full-load current (FLC) as listed in Tables 430.248 and 430.250

(2) The ampacity of the minimum conductor size marked on the power conversion equipment

Note: *The minimum ampacity required of output conductors is often different than that of the conductors supplying the power conversion equipment. See 430.130 and 430.131 for branch-circuit protection requirements.*

430.124 | Motors, Motor Circuits, and Controllers

(D) Several Motors or a Motor and Other Loads. Feeder conductors that supply multiple motors or a combination of motors and other electrical loads (including any power conversion equipment) must be sized based on 430.24, using the rated input current from the conversion equipment for ampacity calculations.

Author's Commentary:

430.24 requires feeder conductors to have an ampacity of at least 125 percent of the largest motor or other load served by the conversion equipment (drive) rated input current, plus the remaining full-load motor input currents, 100 percent of any noncontinuous motor loads, and 125 percent of all continuous nonmotor loads.

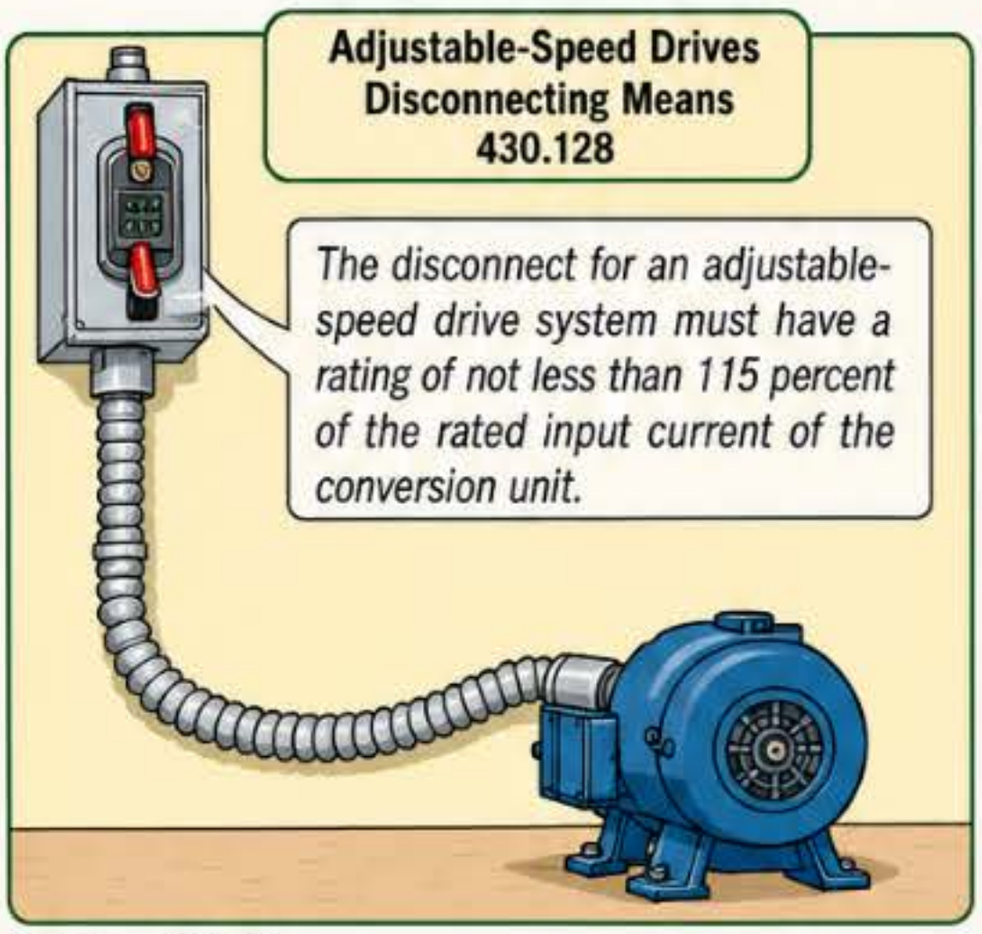
— Michael Hamilton

430.124 Overload Protection

(A) Included in Equipment. When the adjustable-speed drive is marked to provide motor overload protection, no additional overload protection is required.

430.128 Disconnecting Means

A disconnecting means for an adjustable-speed drive must be rated for not less than 115 percent of the drive's rated input current, based on the conversion equipment.



▶ Figure 430-43

430.130 Branch-Circuit Short-Circuit and Ground-Fault Protection

(A) Circuits Containing an Adjustable-Speed Drive System. Circuits that include power conversion equipment must be protected by a branch-circuit short-circuit and ground-fault protective device, in accordance with *all of* the following:

(1) The rating and type of protection must be determined by 430.52(C)(1), (C)(3), (C)(5), or (C)(6) using the motor's full-load current (FLC) rating as listed in 430.248 and 430.250.

Example: *Determine the rating and type of protection using the power conversion equipment's rated input current where the power conversion equipment is identified and marked "Suitable for Output Motor Conductor Protection."*

Note 1: *If the motor branch-circuit short-circuit and ground-fault protection is supplied by the conversion equipment, use the rated input current listed and marked "Suitable for Output Motor Conductor Protection."*

Note 2: *A motor branch circuit that uses power conversion equipment (including any listed and marked "Suitable for Output Motor Conductor Protection") includes the input circuit to that conversion equipment.*

(2) *The maximum branch-circuit short-circuit and ground-fault protection ratings must be in accordance with the manufacturer's instructions.*

Part XIV. Tables

Table 430.248 Full-Load Current, Single-Phase Motors

Table 430.248 lists the full-load current for single-phase alternating-current motors. These values are used to select motor conductor size and branch-circuit and feeder protection, but not for overload protection [430.6(A)(1) and 430.6(A)(2)].

The full-load currents (FLC) in this table are permitted for system voltage ranges of 110V to 120V and 220V to 240V.

DEFINITIONS | From Michael Hamilton Publications

Table 430.248 FLC Single-Phase Alternating-Current Motors

	115V	200V	208V	230V
½ hp	9.80	5.60	5.40	4.90
¾ hp	13.80	7.90	7.60	6.90
1 hp	16.00	9.20	8.80	8.00
1½ hp	20.00	11.50	11.00	11.00
2 hp	24.00	13.90	13.20	12.00
3 hp	34.00	19.60	18.70	17.00
5 hp	56.00	32.20	30.80	28.00
7½ hp	80.00	46.00	44.00	40.00
10 hp	100.00	57.50	55.00	50.00

▶ Example

Question: *What is the full-load current (FLC) of a 2 hp, 240V, single-phase motor?* ▶ **Figure 430-44**

(a) 12A *(b) 13A* *(c) 14A* *(d) 16A*

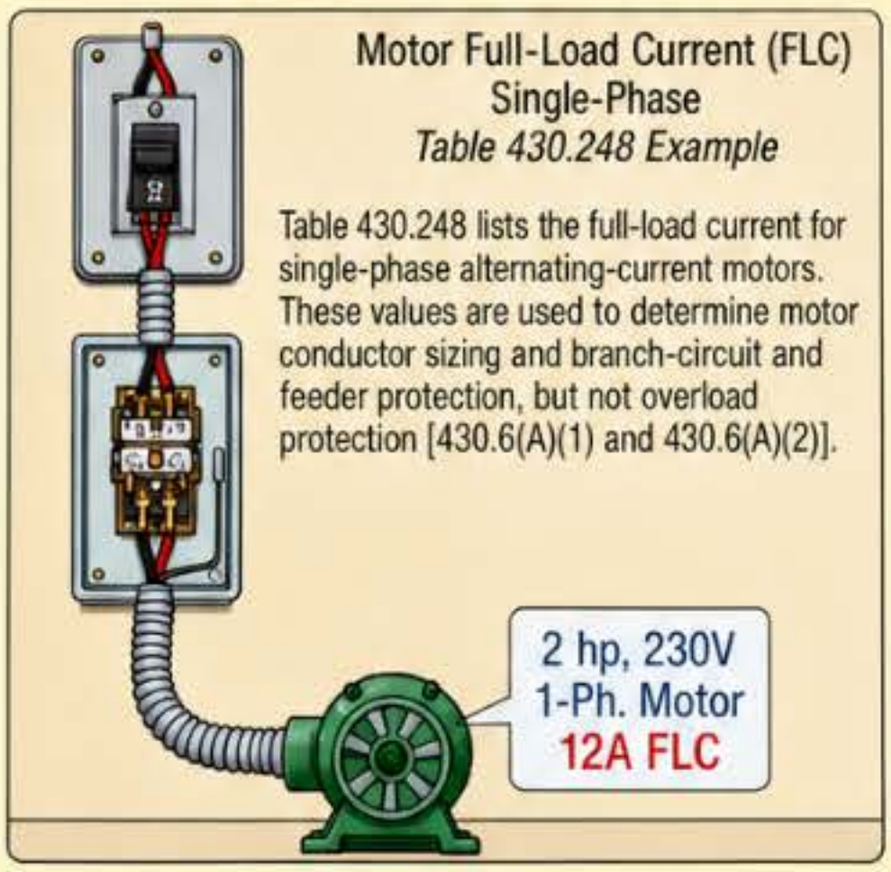


Figure 430-44

Answer: *(a) 12A (Table 430.248)*

Table 430.250 Full-Load Current, Three-Phase Motors

Table 430.250 lists the full-load current for three-phase alternating-current motors. The values are used to determine motor conductor sizing, ampere ratings of disconnects, controller rating, and branch-circuit and feeder protection but not overload protection [430.6(A)(1) and 430.6(A)(2)].

The full-load currents (FLC) listed in this table are permitted for three-phase system voltage ranges of 110V to 120V, 220V to 240V, 440V to 480V, and 550V to 600V motors. This means that the 115V column is used for any three-phase alternating-current motor rated 110V to 120V. The 230V column is used for any three-phase alternating-current motor rated 220V and 240V. The 460V column is used for any three-phase alternating-current motor rated 440V to 480V.

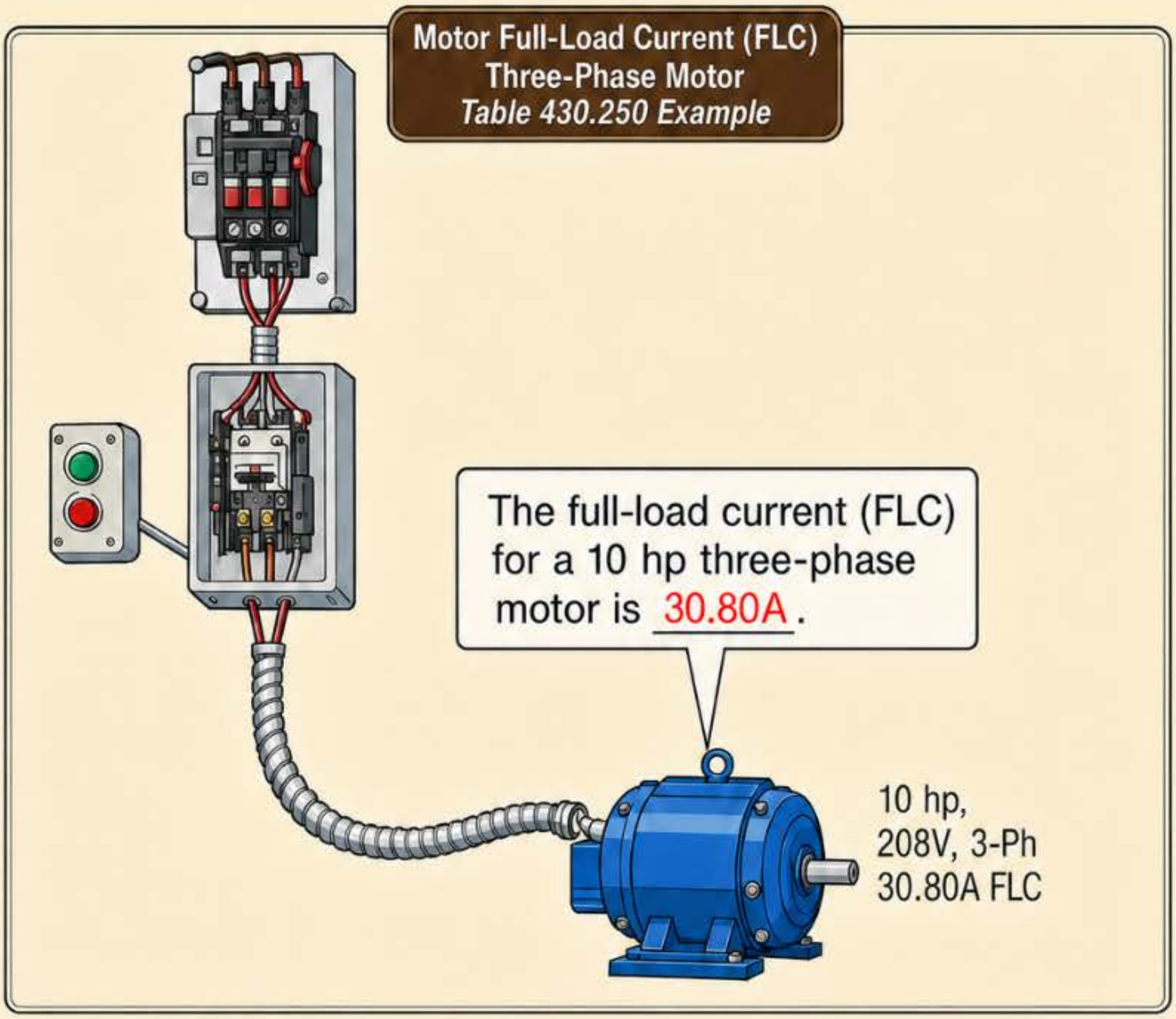
Table 430.250 FLC Three-Phase Alternating-Current Motors

	200V	208V	230V	460V
½ hp	2.50	2.40	2.20	1.10
¾ hp	3.70	3.50	3.20	1.60
1 hp	4.80	4.60	4.20	2.10
1½ hp	6.90	6.60	6.00	3.00
2 hp	7.80	7.50	6.80	3.40
3 hp	11.00	10.60	9.60	4.00
5 hp	17.50	16.70	15.20	7.60
7½ hp	25.30	24.20	22.00	11.00
10 hp	32.20	30.80	28.00	14.00
15 hp	48.30	46.20	42.00	21.00
20 hp	62.10	59.40	54.00	27.00
25 hp	78.20	74.80	68.00	34.00

▶ Example

Example: *Determine the full-load current (FLC) for a 10 hp, 208V, three-phase motor.* ▶ **Figure 430–45**

(a) 22A *(b) 31A* *(c) 34A* *(d) 36A*



▶ **Figure 430–45**

Answer: *(b) 31A [Table 430.250]*

ARTICLE 440 AIR-CONDITIONING AND REFRIGERATION EQUIPMENT

Introduction to Article 440—Air-Conditioning and Refrigeration Equipment

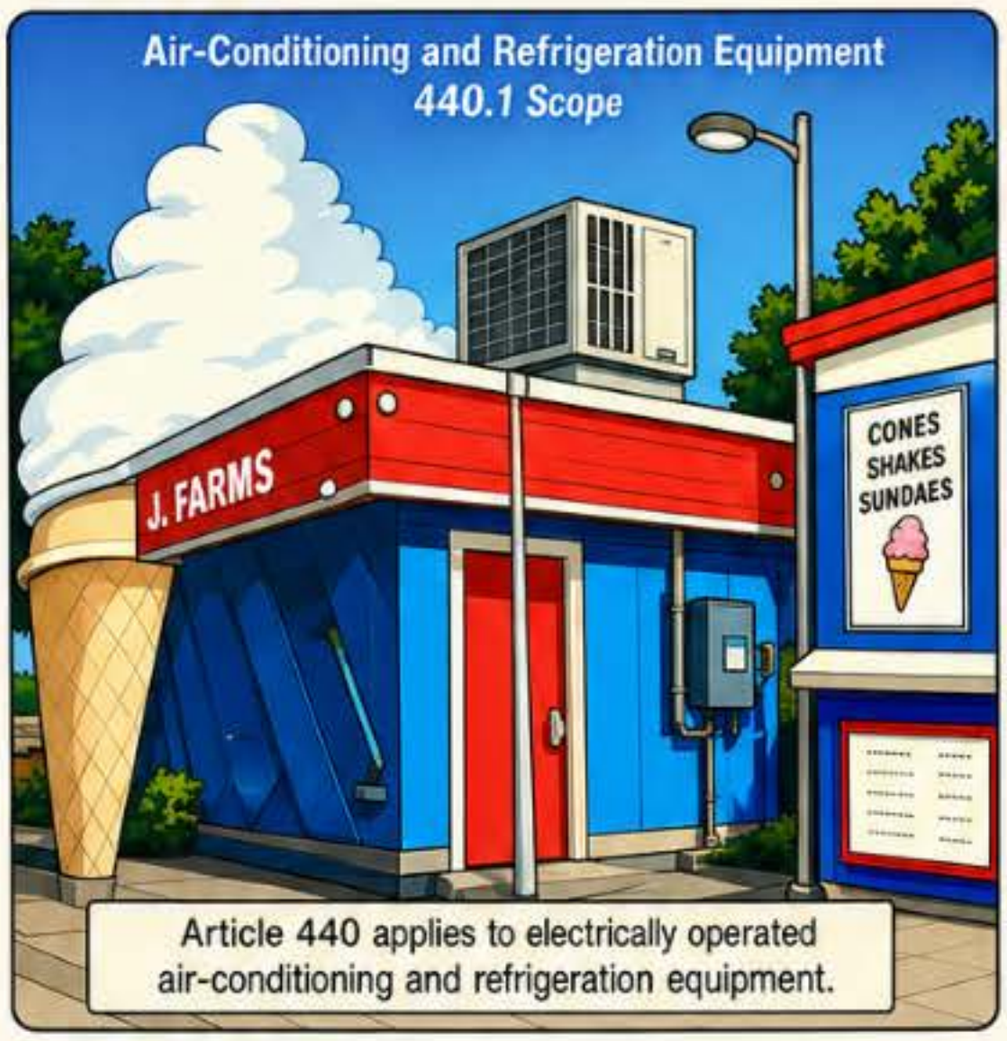
This article covers electrically operated air-conditioning and refrigeration equipment. Every piece of equipment is built with a motor for a particular unit and follows its own design specifications. Performance and features can vary widely between manufacturers of different types of nonhermetic motors. For each motor, the maker provides complete details on the nameplate. When wiring an air conditioner, rely on the nameplate data, and avoid trying to simplify the situation. The math for sizing overcurrent protection and conductors' minimum ampacity has already been done for you.

Part I. General

440.1 Scope

Article 440 applies to electrically operated air-conditioning and refrigeration equipment.

▶ ***Figure 440-1***



▲ ***Figure 440-1***

440.2 Definitions

The definitions in this section apply only within this article.

Branch-Circuit Selection Current. Instead of using the rated-load current, the ampere value to be used is the current from the branch-circuit conductors when determining the size of those conductors, the disconnecting means, controllers, and branch-circuit short-circuit and ground-fault protective devices. This is the current that can flow during the running overload condition, calculated as a percentage above the rated-load current. The branch-circuit selection current will never be smaller than the marked rated-load current.

Leakage-Current Detector-Interrupter (LCDI). This device, installed in a power cord or cord set, monitors leakage current leaving or returning on the conductors. If it senses leakage current flowing to ground, it opens the circuit at a preset level of leakage current.

Rated-Load Current. The current that a hermetic refrigeration motor-compressor produces while running at its rated load, rated voltage, and rated frequency.

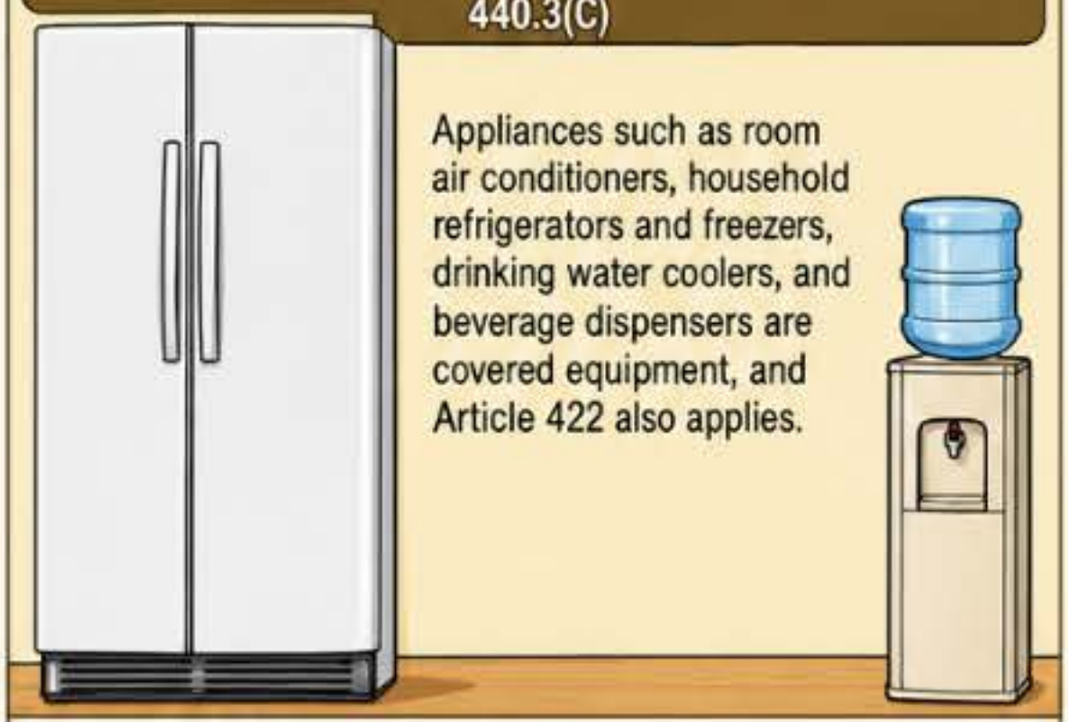
440.3 Other Articles

(B) ***Equipment with No Hermetic Motor-Compressors.*** Air-conditioning and refrigeration equipment that do not use hermetic refrigeration motor-compressors (for example, units with evaporator coils) must follow Article 422 for appliances, Article 424 for space heating, and Article 430 for motors.

(C) ***Article 422.*** *Items such as room air conditioners, refrigerated cabinets and freezers, drinking-water coolers, and beverage dispensers are considered appliances, so* Article 422 also applies.

▶ ***Figure 440-2***

Household Refrigerant Motor-Compressor Appliance Other Articles 440.3(C)



Appliances such as room air conditioners, household refrigerators and freezers, drinking water coolers, and beverage dispensers are covered equipment, and Article 422 also applies.

Figure 440-2

440.4 Marking on Hermetic Refrigerant Motor-Compressors and Equipment

Scan this QR code for a video by Michael Hamilton explaining this topic; it's an excerpt from the videos that accompany this textbook.

(B) Multimotor and Combination-Load Equipment. Multimotor and combination-load air-conditioning and refrigeration equipment must have a definite nameplate affixed with the manufacturer's name, rating in volts, number of phases, minimum conductor ampacity, and the maximum rating of the branch-circuit short-circuit and ground-fault protective device. ▶ **Figure 440-3**

Marking on Multimotor and Combination-Load Equipment 440.4(B)

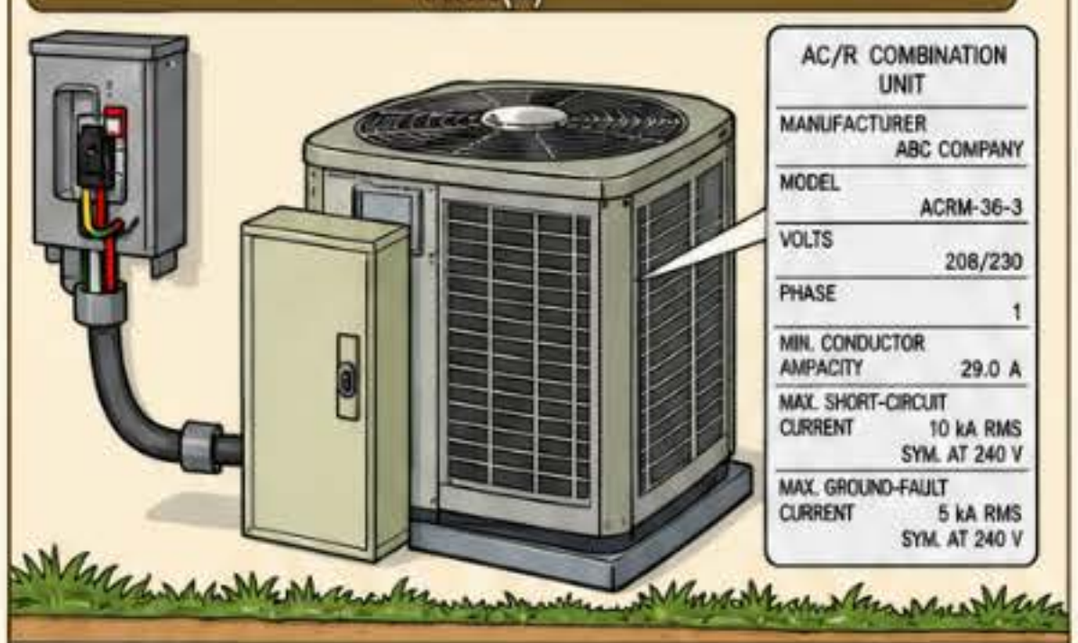


Figure 440-3

▶ Multimotor Equipment Example 1

Question: *What size conductor and short-circuit and ground-fault protective device is required for a multimotor air-conditioning compressor? The nameplate minimum circuit ampacity is 31.40A, the maximum circuit breaker amperes are rated 50A, and all terminals are rated 75°C.* ▶ **Figure 440-4**

(a) 10 AWG, 50A breaker *(b) 10 AWG, 30A breaker*
(c) 8 AWG, 50A breaker *(d) 8 AWG, 20A breaker*

Marking on Hermetic Refrigerant Multimotor Equipment 440.4(B) Example

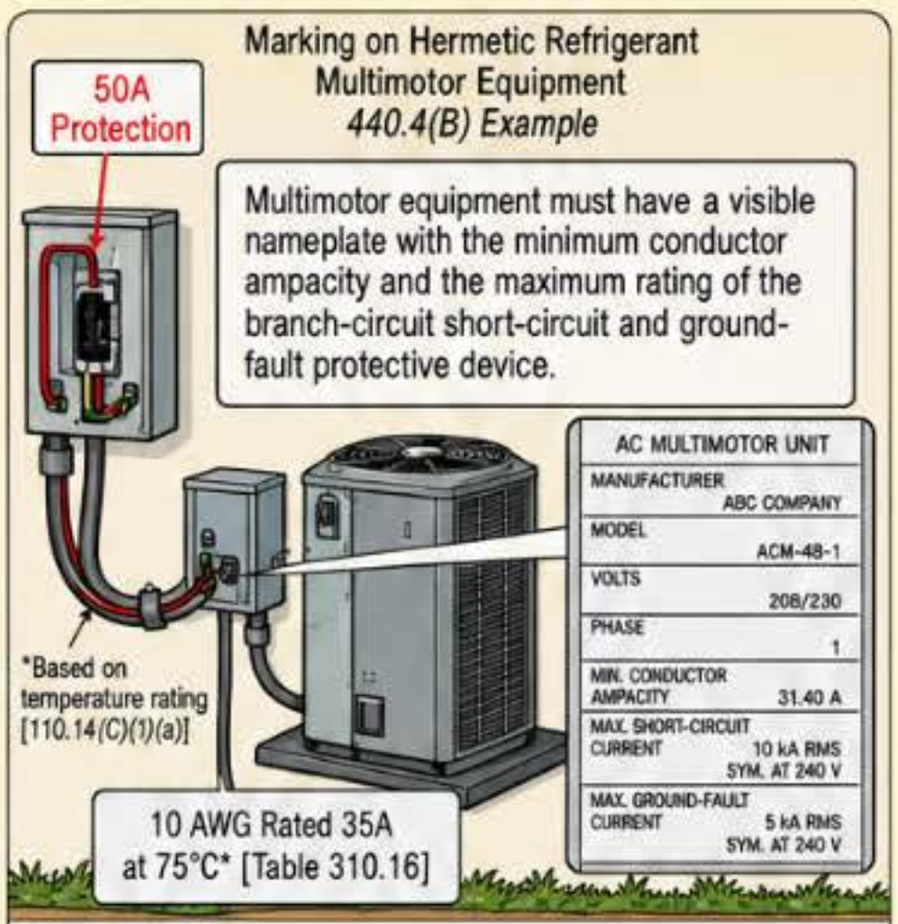


Figure 440-4

Solution:

Conductor: *Since the terminals are rated 75°C, we can use 10 AWG rated 35A at 75°C [110.14(C)(1)(a)(3) and Table 310.16].*

The circuit breaker protection for air-conditioning compressor equipment must have a rating of not more than the 50A marked on the nameplate [440.4(B)]. Use a maximum 50A breaker in accordance with 240.6(A).

Answer: *(a) 10 AWG, 50A breaker*

▶ Multimotor Equipment Example 2

Question: *What size NM cable and short-circuit and ground-fault protective device is required for a multimotor air-conditioning compressor? The nameplate minimum circuit ampacity is 24.50A, the maximum circuit breaker amperes are rated 40A, and the terminals rated 75°C.* ▶ **Figure 440-5**

(a) 10 AWG, 40A breaker *(b) 12 AWG, 35A breaker*
(c) 8 AWG, 40A breaker *(d) 8 AWG, 35A breaker*

Air-Conditioning and Refrigeration Equipment 440.14

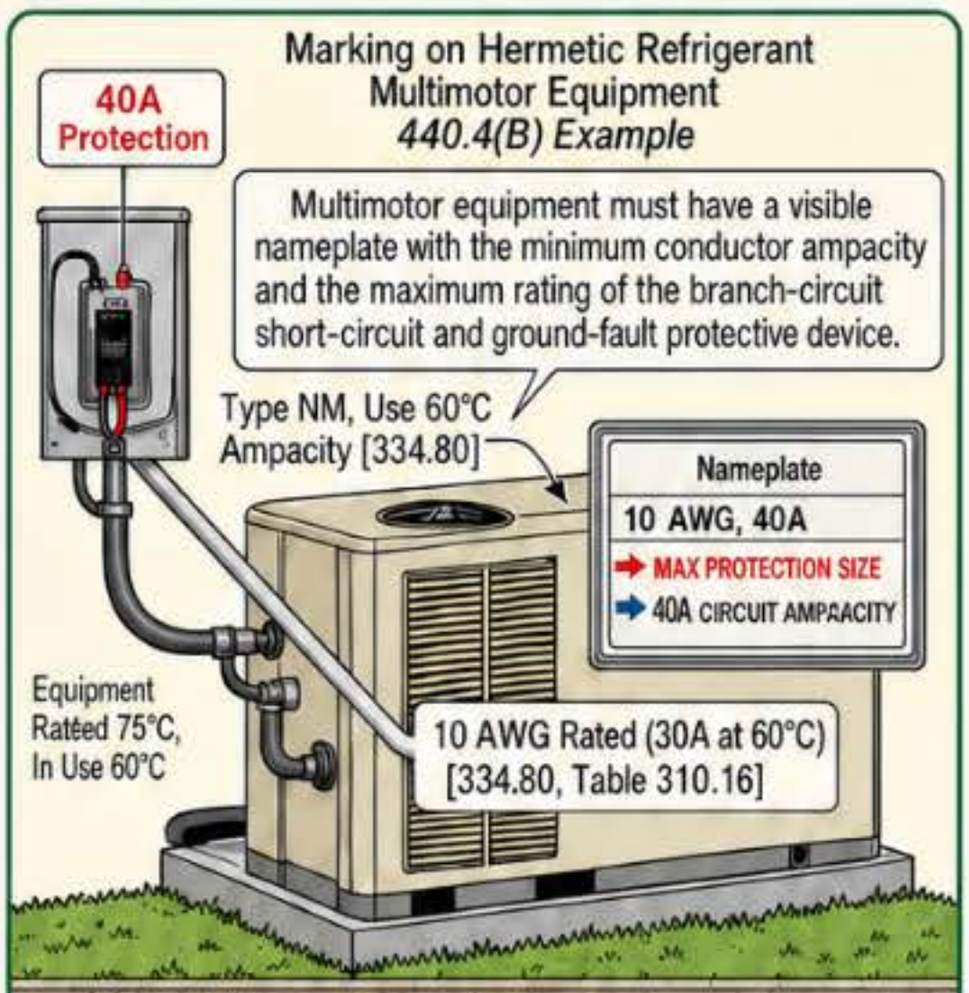


Figure 440–5

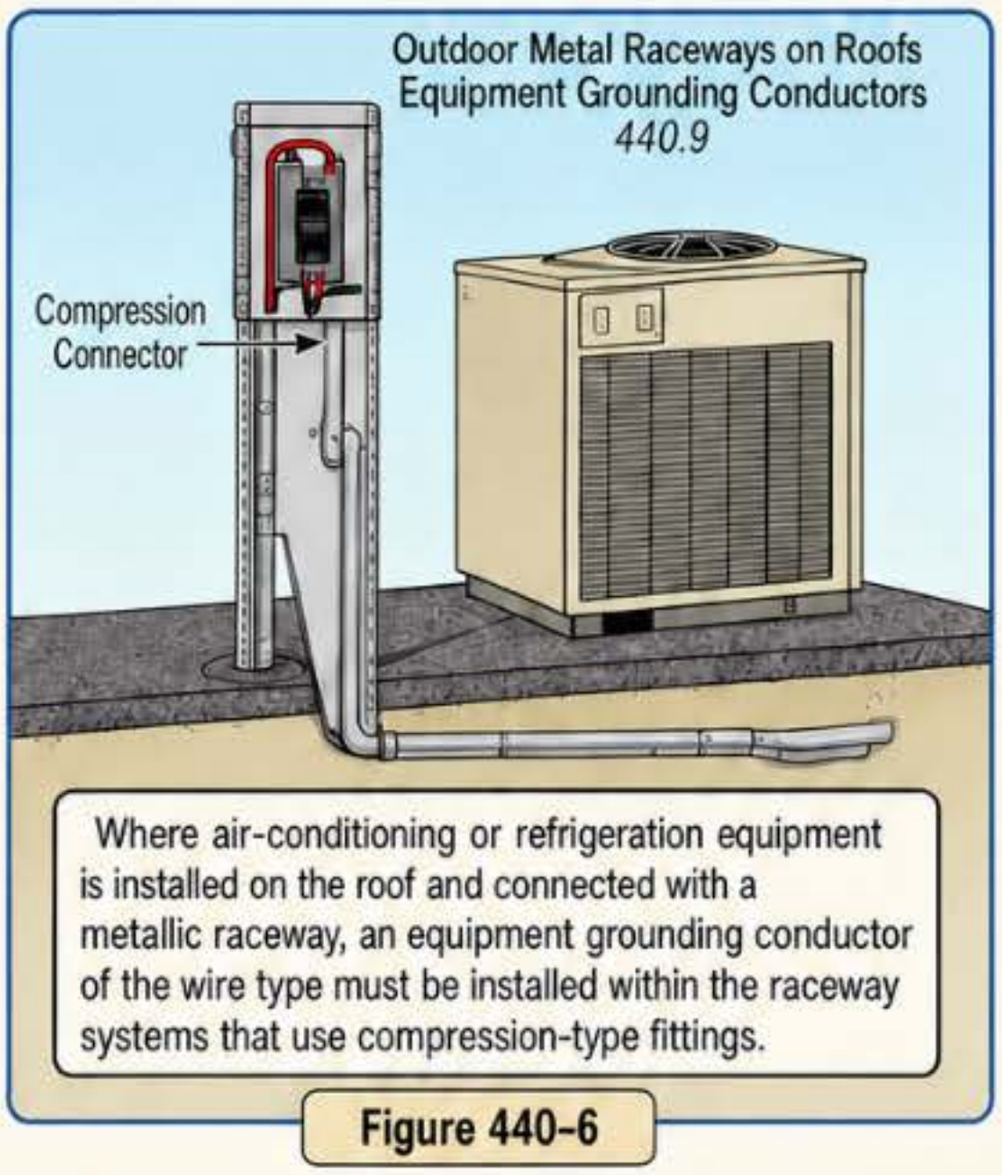


Figure 440–6

Solution:

Conductor: *The conductor's ampacity must be no less than 24.50A as cited on the equipment nameplate [440.4(B)]. Twelve AWG satisfies this because it is rated at 25A at 75°C [110.14(C)(1)(a)(3) and Table 310.16]. In this example however, the wiring method is Type NM cable and its allowable ampacity is limited to the 60°C column of Table 310.16 [334.80]. As a result, although the terminal temperature is rated 75°C, the conductor must be sized for the 60°C rating found in Table 310.16. That requires a 10 AWG conductor rated 30A at 60°C.*

Overcurrent Protection: *The overcurrent device must have a rating not greater than 40A, as shown on the equipment nameplate [440.4(B)]. Use a maximum 40A breaker in accordance with 240.6(A).*

Answer: *(a) 10 AWG, 40A breaker*

440.9 Grounding and Bonding

Scan this QR code for a video by **Michael Hamilton** explaining this topic. It's an example taken from the instructional videos that accompany this textbook.

Where air-conditioning or refrigeration equipment is installed on a roof and connected with a metallic raceway, a grounding conductor of the wire type must be installed within the raceway systems that use compression-type fittings.

Figure 440–6

Author's Commentary:

- *When the wiring approach for rooftop units is not threads-based, you cannot rely on the raceway to act as the equipment grounding conductor unless allowed by 250.118. Instead, you must install an appropriately sized wire-type grounding conductor.*

— Michael Hamilton

Part II. Disconnecting Means

440.14 Location

A disconnecting means for air-conditioning or refrigeration equipment must be positioned within sight from and readily accessible to the equipment.

Figures 440–7 and ***440–8***

Author's Commentary:

- *Per Article 100, "within sight" means in plain view and not more than 50 ft from the equipment.*

The disconnect may be wall-mounted or housed within the equipment, but it must not be on panels intended to allow access to the equipment, nor on the equipment nameplate, or placed above the equipment.

— Michael Hamilton

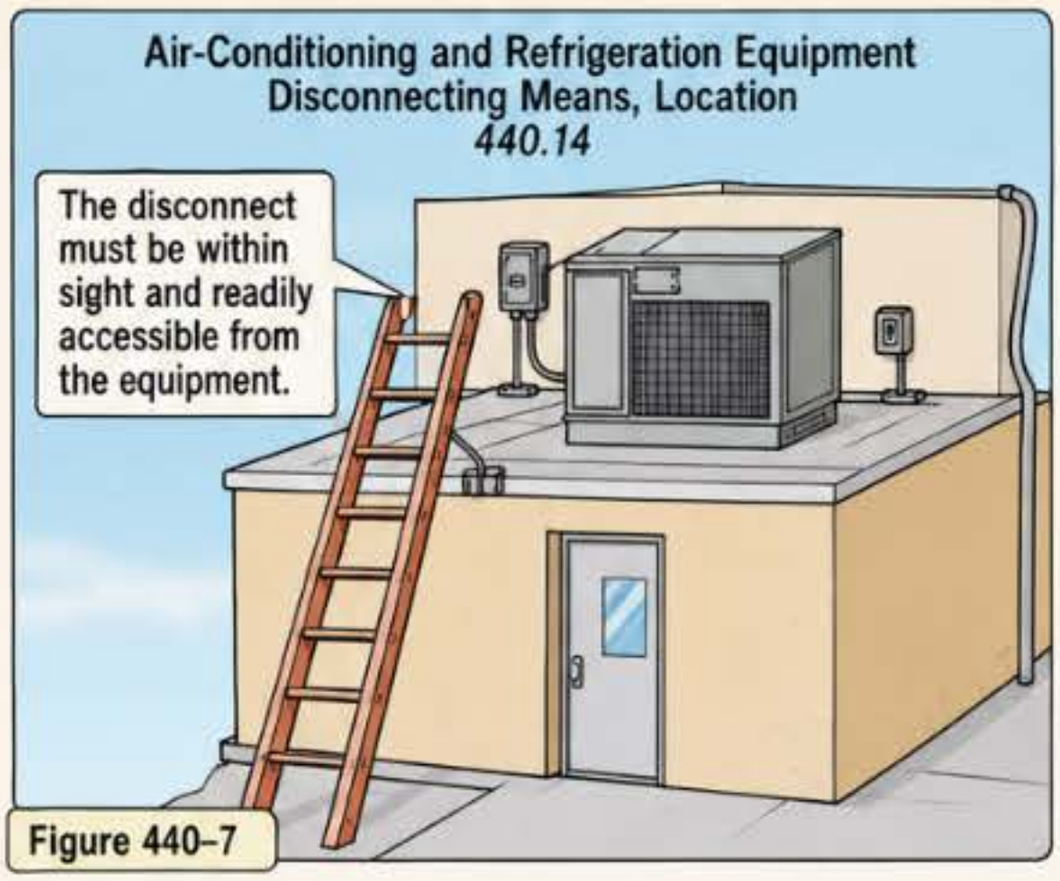


Figure 440–7

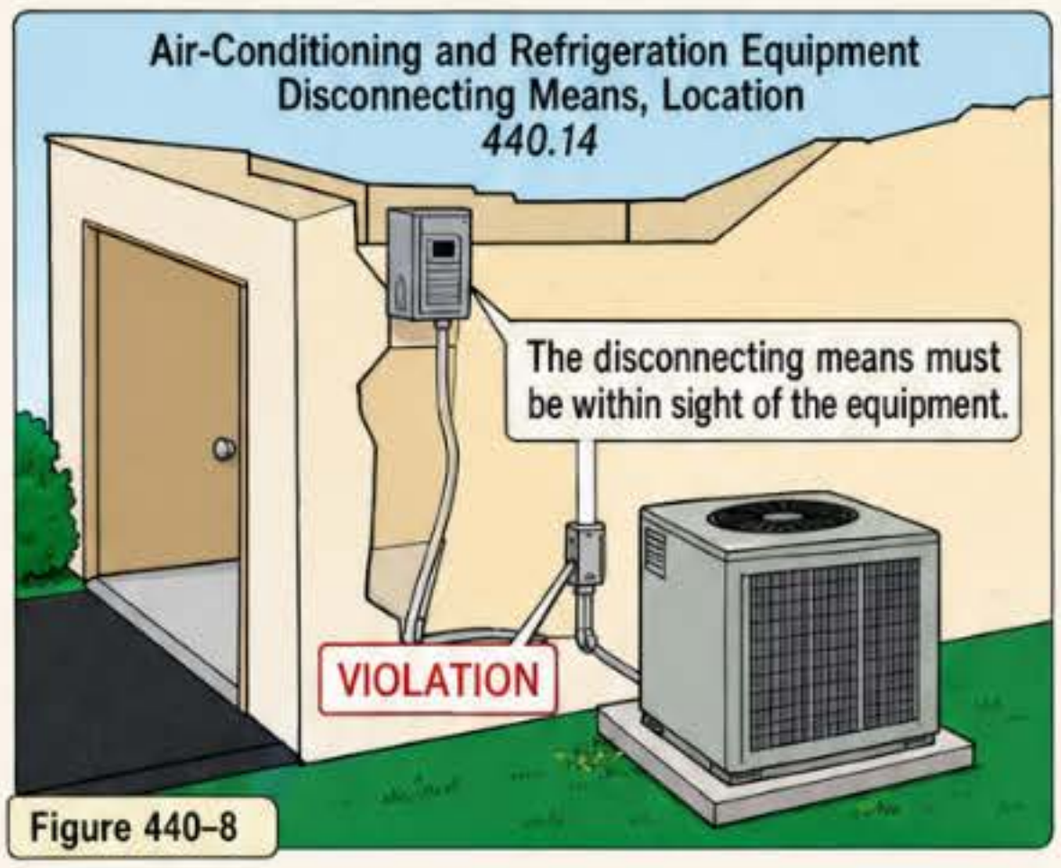


Figure 440–8

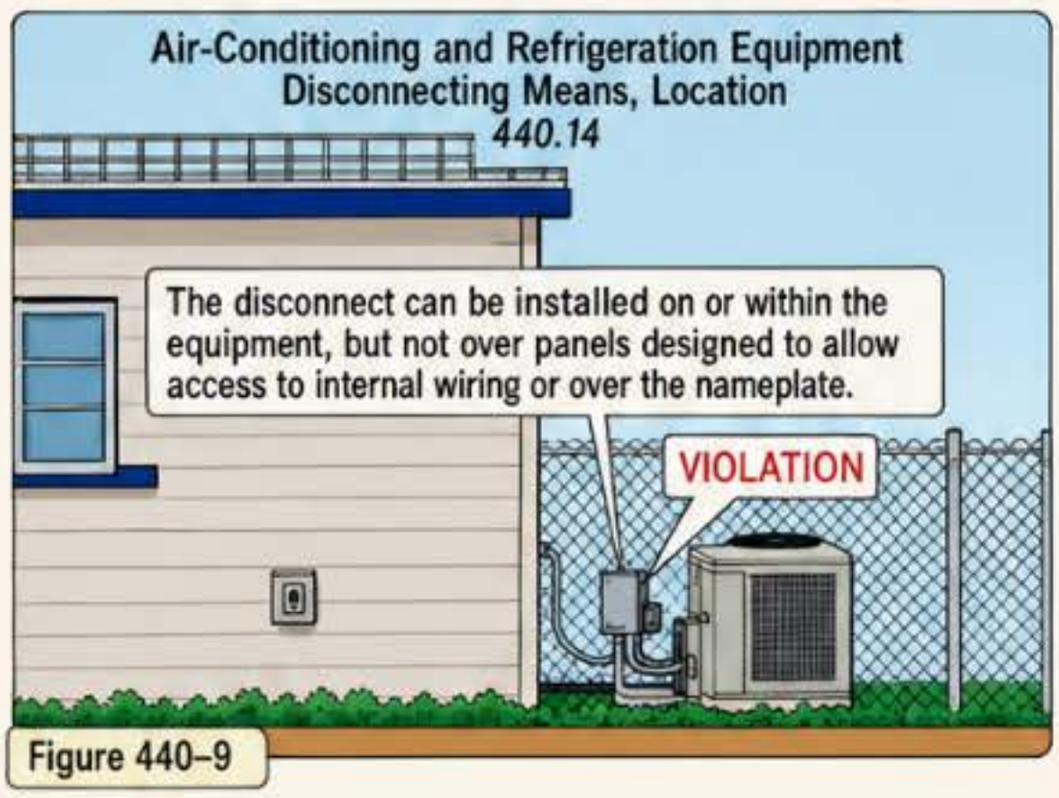


Figure 440–9

Part III. Overcurrent Protection

440.21 General

The branch-circuit conductors, control equipment, and circuits supplying hermetic refrigerant motor-compressors must be protected against short circuits and ground faults in accordance with 440.22.

440.22 Short-Circuit and Ground-Fault Overcurrent Device Size

(B) Rating or Setting for Equipment. The equipment branch circuit short-circuit and ground-fault protective device must be capable of carrying the starting current of the equipment. Where the equipment incorporates more than one hermetic refrigerant motor-compressor or a hermetic refrigerant motor-compressor and other motors, the equipment short-circuit and ground-fault protection must comply with 440.22(B)(1).

(1) Motor-Compressor Largest Load. Where a hermetic refrigerant motor-compressor is the largest load connected to the circuit, the rating or setting of the branch-circuit short circuit and ground-fault protective device is not permitted to exceed the value specified in 440.22(A) for the largest motor-compressor plus the sum of the rated-load current of the other motor loads.

▶ Motor-Compressors and Other Motors Example 1

Question: *What size short-circuit ground-fault protective device is required for a 16.70A motor-compressor with a 1.20A fan?* ▶**Figure 440–10**

(a) 30A *(b) 40A* *(c) 50A* *(d) 90A*

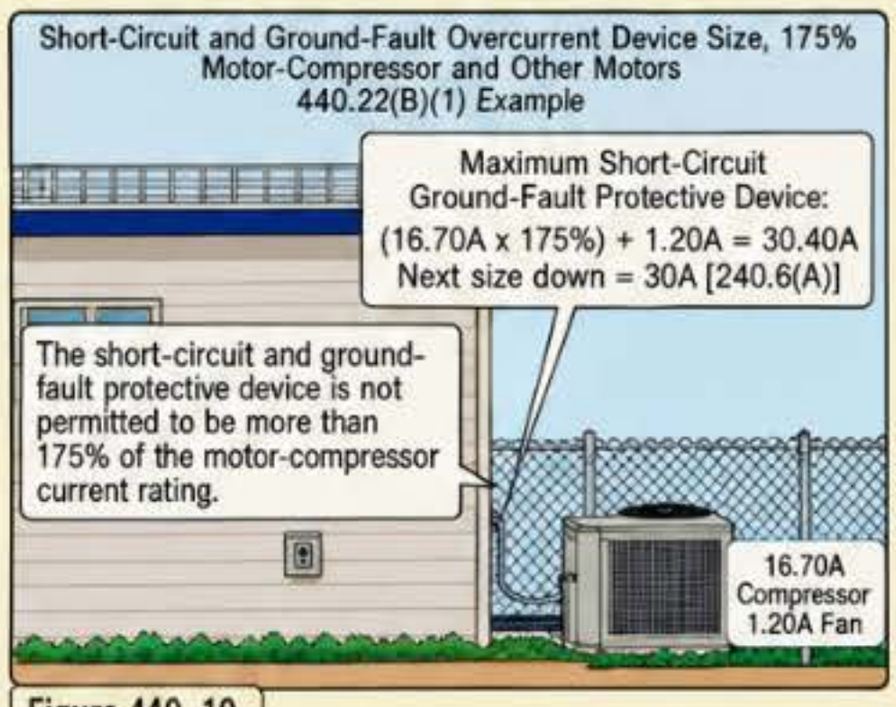


Figure 440–10

Author's Commentary:
Disconnects must be visible and within easy reach. Never hide them behind panels or above nameplates.
Always size overcurrent protection to handle starting current without exceeding the limits in the NEC.
Use the examples and rules in this section to stay compliant and protect equipment.

— Michael Hamilton

440.33 MOTOR-COMPRESSOR(S) WITH OR WITHOUT ADDITIONAL MOTOR LOADS

Solution:
Maximum short-circuit ground-fault = (16.70A × 175%) + 1.20A = 30.40A; round down to 30A

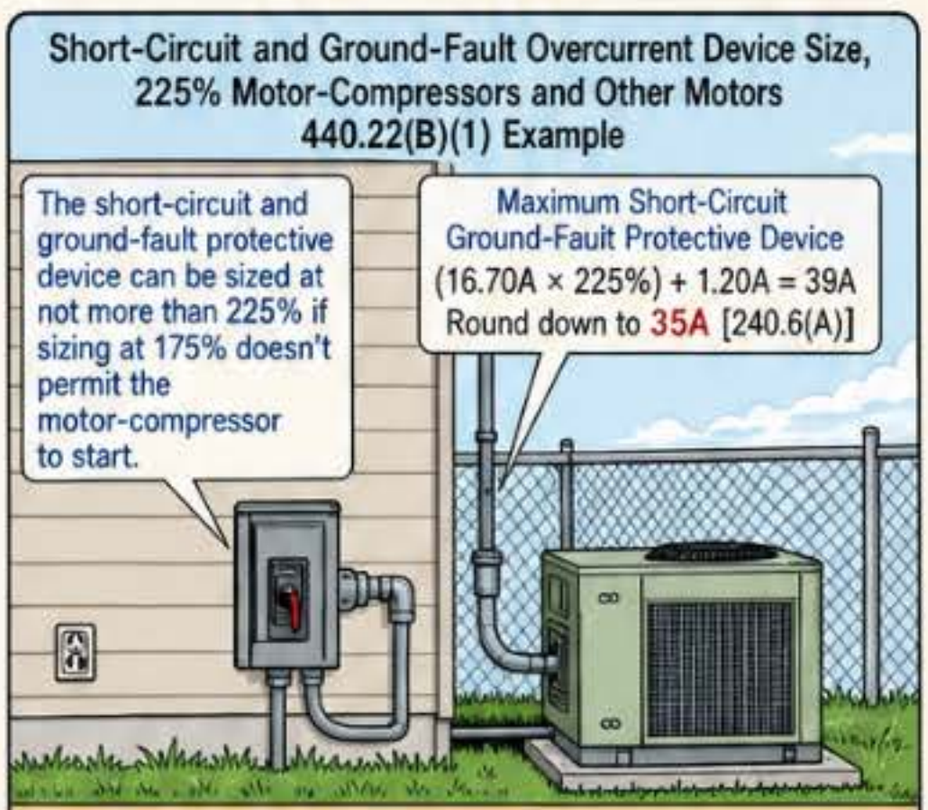
Answer: *(a) 30A*

▶ Motor-Compressors and Other Motors—Example 2

Question: *If the short-circuit ground-fault protective device, sized at 175 percent, does not permit a 16.70A motor-compressor with a 1.20A fan to start, what size should the protective device be?*

▶ **Figure 440-11**

(a) 35A (b) 40A (c) 50A (d) 90A



▶ **Figure 440-11**

Solution:
Maximum short-circuit ground-fault = (16.70A × 225%) + 1.20A = 38.325A; round down to 39A; round down again to 35A

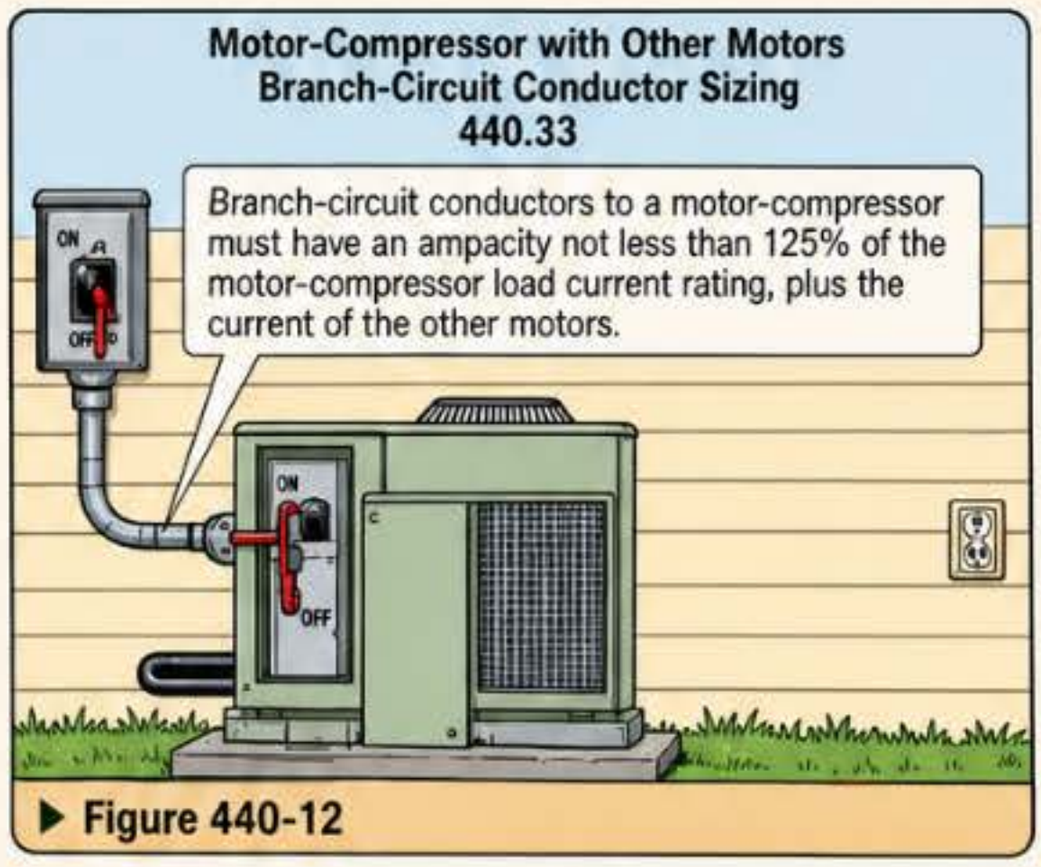
Answer: *(a) 35A*

Part IV. Conductor Sizing

440.33 Motor-Compressor(s) With or Without Additional Motor Loads

Conductors supplying one or more motor-compressor(s) with or without an additional motor load(s) must have an ampacity not less than the sum of each of the following:

▶ **Figure 440-12**



▶ **Figure 440-12**

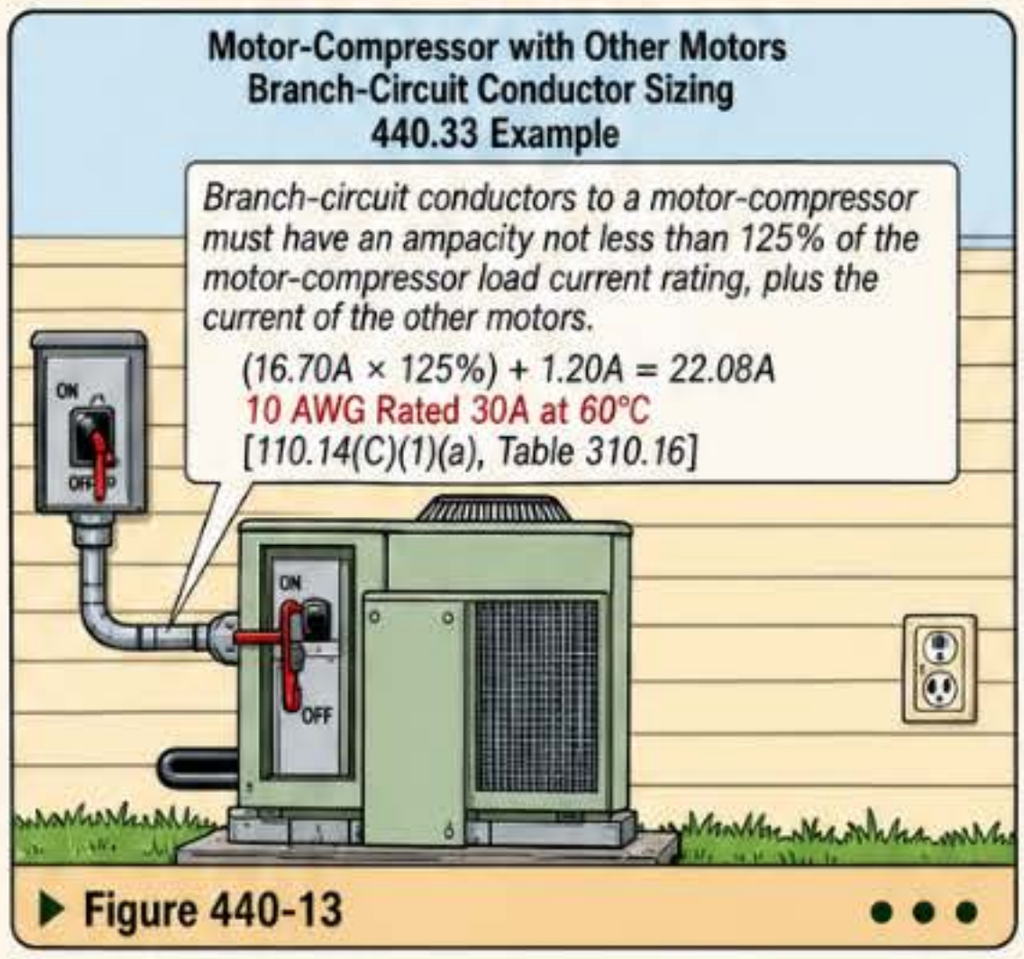
(1) The sum of the rated-load current
(2) The sum of the full-load current rating of all other motors
(3) 25 percent of the highest motor-compressor or motor full-load current in the group

▶ Motor-Compressors and Other Motors—Conductor Size Example 1

Question: *What size conductor is required for a 16.70A motor-compressor with a 1.20A fan, where the conductors are required to be sized at 60°C in accordance with 110.14(C)?*

▶ **Figure 440-13**

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG



▶ **Figure 440-13**

Solution:

Conductor Size = (16.70A × 125%) + 1.20A

Conductor Size = 20.88A + 1.20A

Conductor Size = 22.08A

Use 10 AWG rated 30A at 60°C [Table 310.16].

Answer: *(b) 10 AWG*

▶ Motor-Compressor and Other Motors—Conductor Size Example 2

Question: *What size conductor is required for a 16.70A motor-compressor with a 1.20A fan, where the conductors are permitted to be sized at 75°C in accordance with 110.14(C)(1)(a)(2)?* ▶ **Figure 440–14**

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG

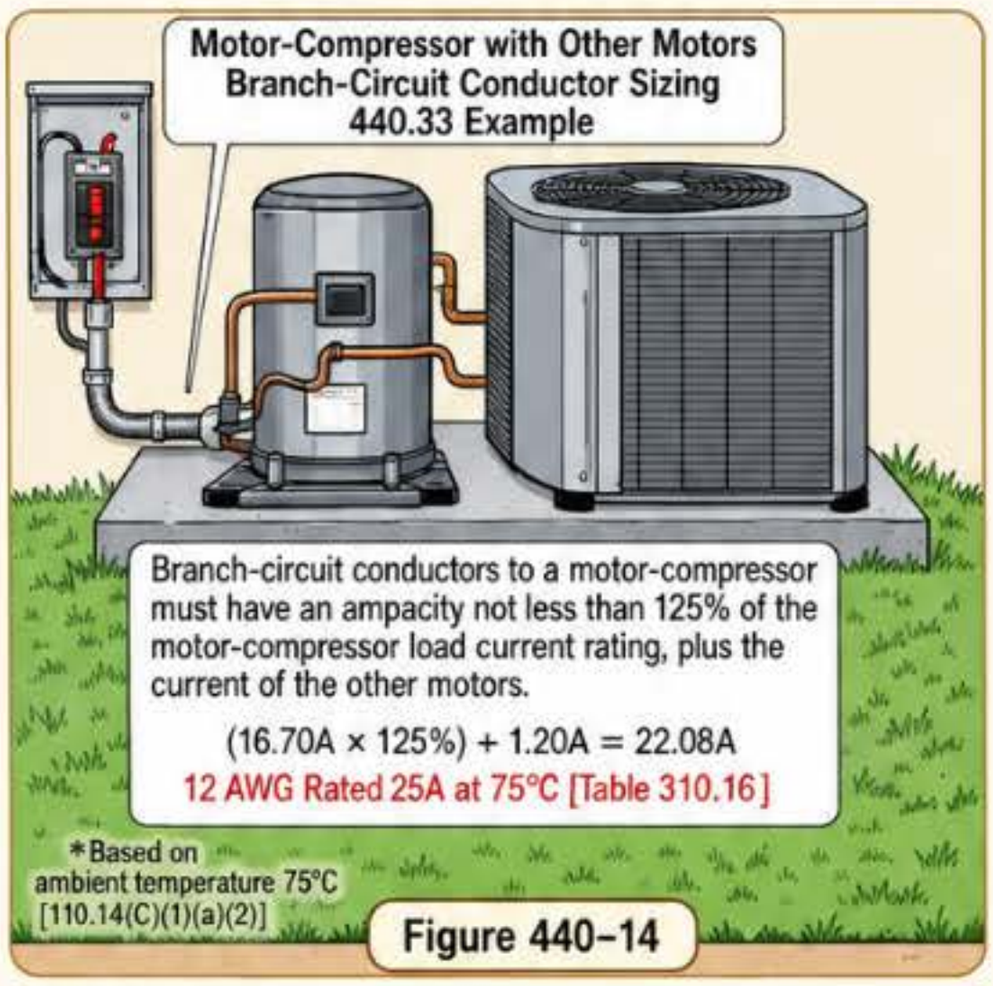


Figure 440–14

Solution:

Conductor Size = (16.70A × 125%) + 1.20A

Conductor Size = 20.88A + 1.20A

Conductor Size = 22.08A

Use 12 AWG rated 25A at 75°C [Table 310.16].

Answer: *(a) 12 AWG*

▶ Motor-Compressor and Other Motors—Conductor Size Example 3

Question: *What size conductor is required for a 23A motor-compressor with a 1.30A fan, where the conductors are required to be sized at 60°C in accordance with 110.14(C)(1)?* ▶ **Figure 440–15**

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG

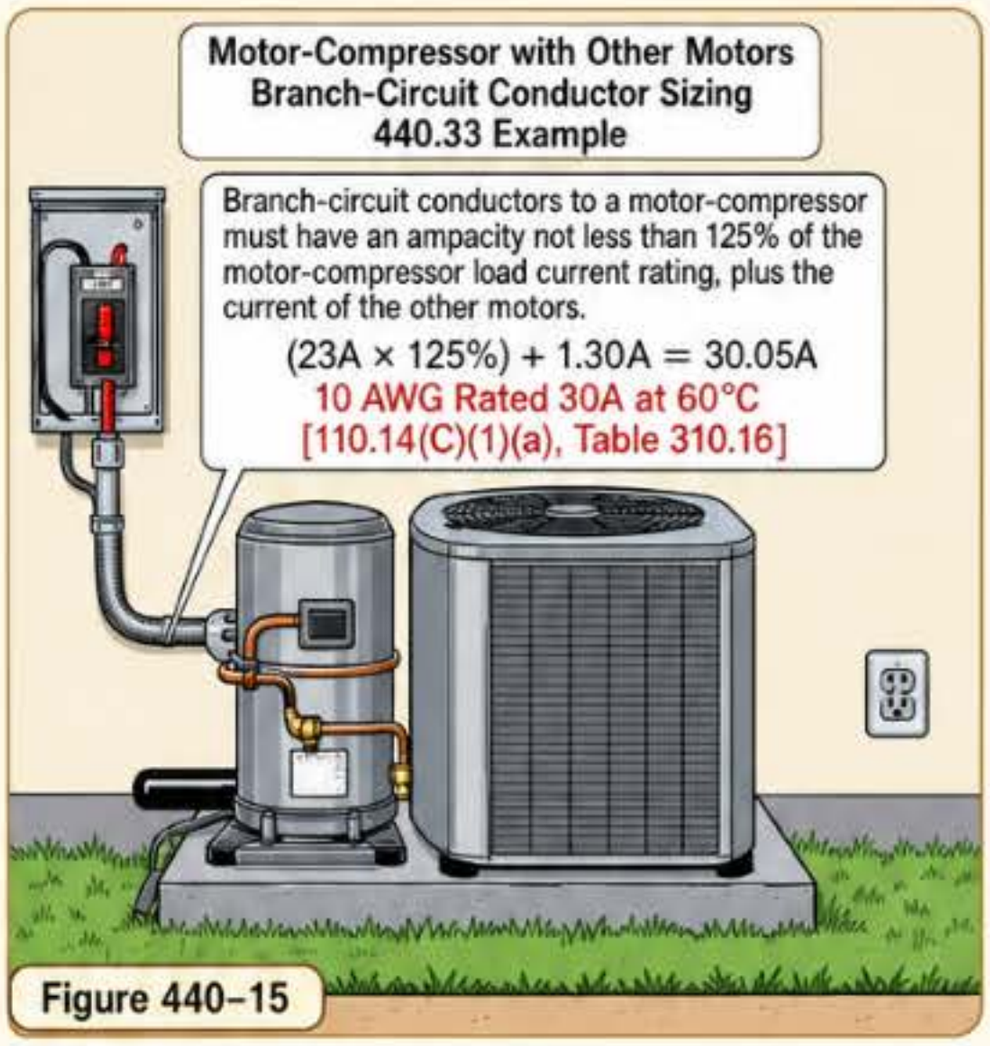


Figure 440–15

Solution:

Conductor Size = (23A × 125%) + 1.30A

Conductor Size = 28.75A + 1.30A

Conductor Size = 30.05A

Use 10 AWG rated 30A at 60°C [Table 310.16].

Answer: *(b) 10 AWG*

▶ Motor-Compressor and Other Motors—Conductor Size Example 4

Question: *What size conductor is required for a 23A motor-compressor with a 1.30A fan, where the conductors are permitted to be sized at 75°C in accordance with 110.14(C)(1)(a)(3)?* ▶ **Figure 440–16**

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG

Solution:

Conductor Size = (23A × 125%) + 1.30A

Conductor Size = 28.75A + 1.30A

Conductor Size = 30.05A

Use 10 AWG rated 35A at 75°C [Table 310.16].

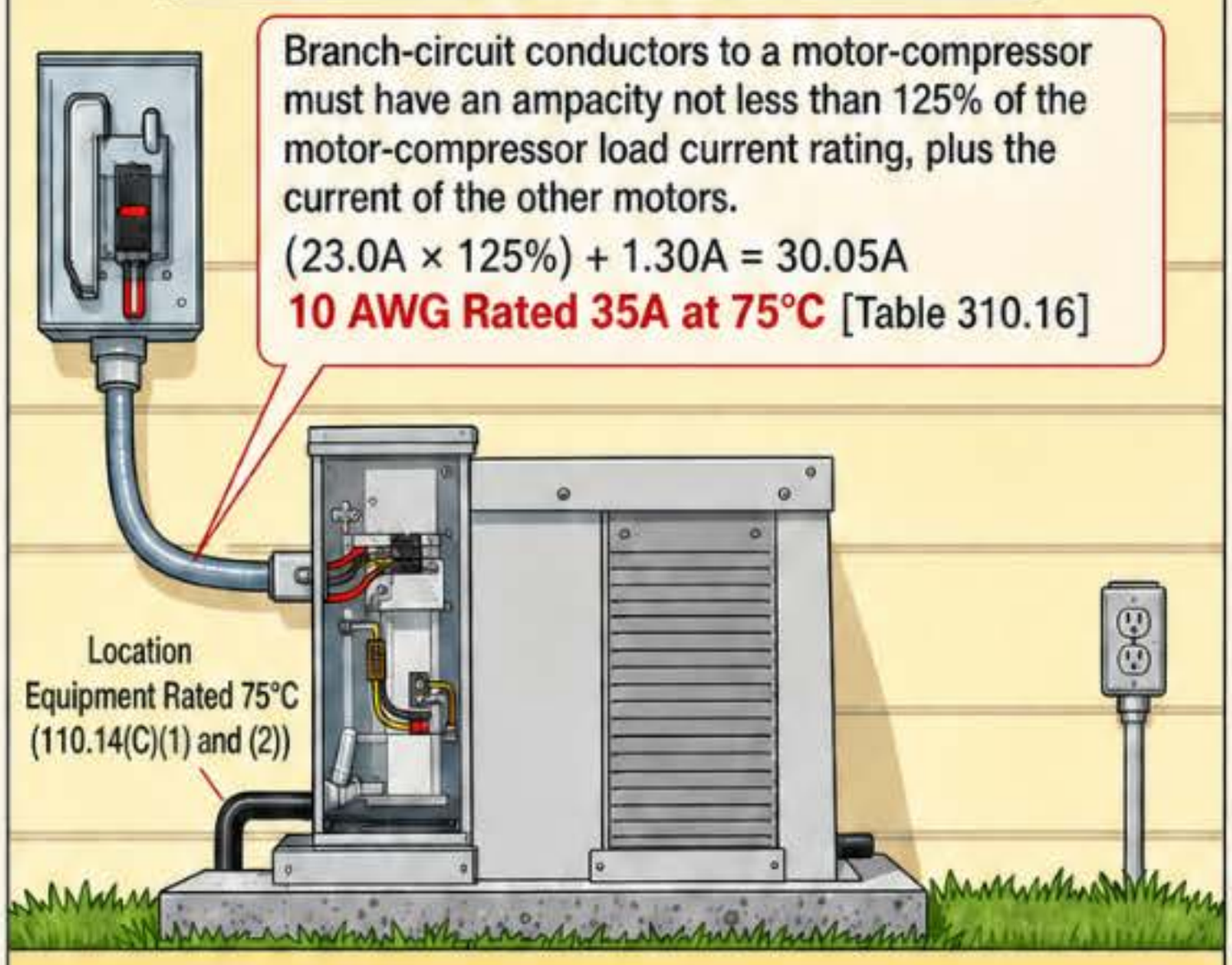
Answer: *(b) 10 AWG*

Author's Commentary:

When combining loads for motor-compressors and other motors on the same branch circuit, always add the current of every motor, then multiply the motor-compressor portion by 125%. Finally, select conductor ampacity based on the required temperature rating of the insulation per 110.14(C).

— Michael Hamilton

Motor-Compressor with Other Motors Branch-Circuit Conductor Sizing
440.33 Example



▶ **Figure 440-16**

Notes

ARTICLE 445 GENERATORS

Introduction to Article 445—Generators

This article covers the electrical installation and other rules for generators. The requirements address where generators may be installed, how they must be identified, conductor ampacity, power transfer arrangements, and disconnection provisions.

445.1 Scope

This article specifies the installation rules and other provisions that apply to generators.

Figure 445–1

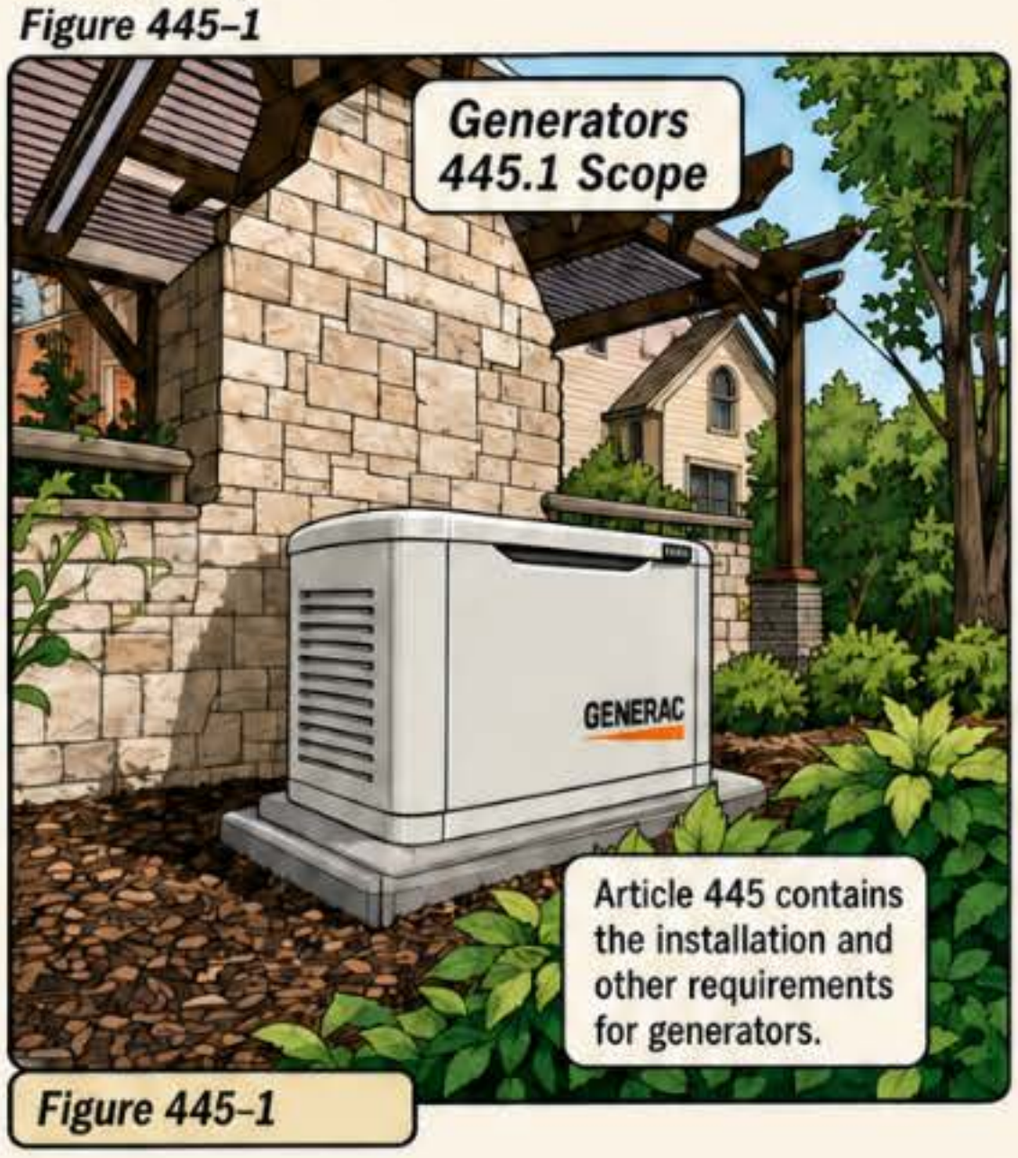


Figure 445–1

445.6 Listing

Stationary generators rated 600 volts or less must be listed.

Example: *One-of-a-kind or custom-built generators are permitted in the field when approved by a field evaluation body.*

445.11 Marking

Each generator must have a nameplate that includes the manufacturer's name, rated frequency, number of phases, rating in kW or kVA, power factor, and the volts and amperes that correspond to the rating.

Figure 445–2

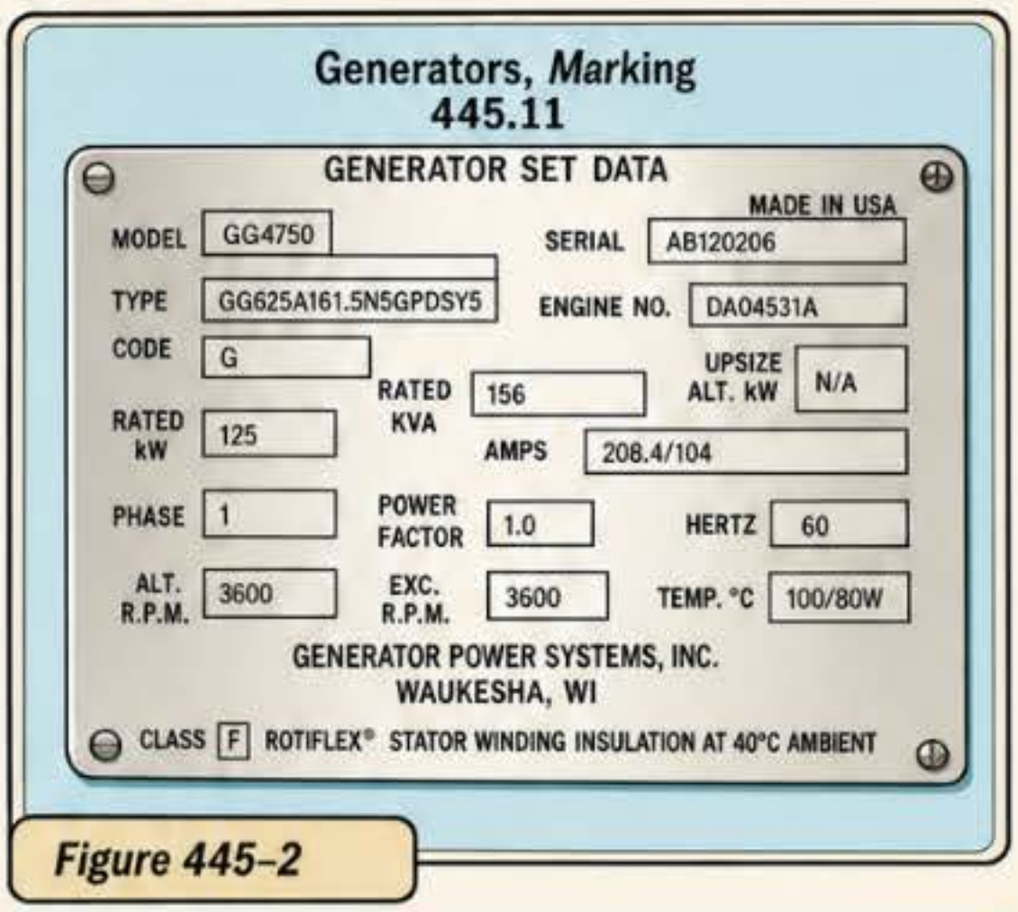


Figure 445–2

Generators must have a nameplate that displays the manufacturer's name, rated frequency, number of phases, the rating in kW or kVA, power factor, and the voltage and current values that match the rating.

Author's Commentary:

Generators, related wiring, and associated equipment must be installed in accordance with the following code requirements, which depend on how the system is used.

- *Fire Pumps, Article 695*
- *Emergency Systems, Article 700*
- *Legally Required Standby Systems, Article 701*
- *Optional Standby Systems, Article 702*
- *Interconnected Electric Power Production Sources, Article 705*

— Michael Hamilton

445.13 Ampacity of Conductors

(A) General. The current-carrying capacity of the conductors from the generator's output terminals to the first overcurrent protective device must not be less than 115 percent of the generator's nameplate current rating.

Author's Commentary:

- *The overcurrent device is usually supplied as part of the generator assembly. In that case, it is factory-installed, not field-installed.*
- *Conductors on the generator's load side are referred to as feeder conductors. The ampacity of these feeders must comply with 240.4 for the associated overcurrent protective device.*

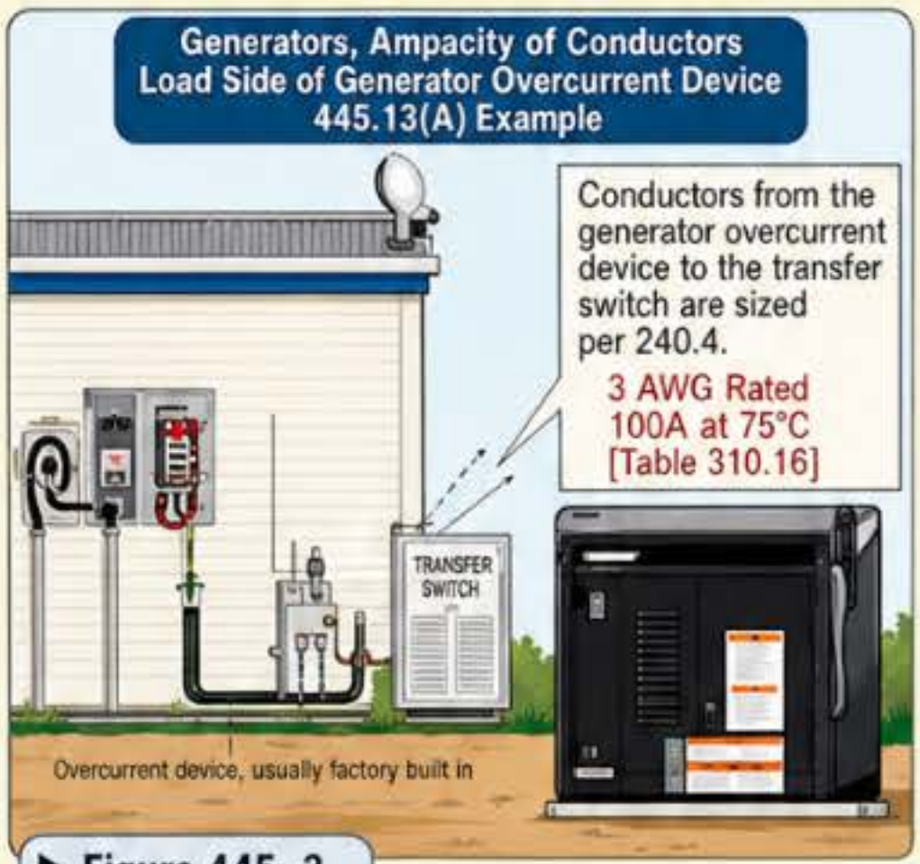
— Michael Hamilton

▶ Example

Question: *What size feeder conductor is required from a 100A overcurrent protective device on a 20 kW, 120/240V, single-phase generator to the transfer switch if the generator and transfer switch terminals are rated 75°C?*

▶ Figure 445–3

(a) 4 AWG (b) 3 AWG (c) 2 AWG (d) 1 AWG



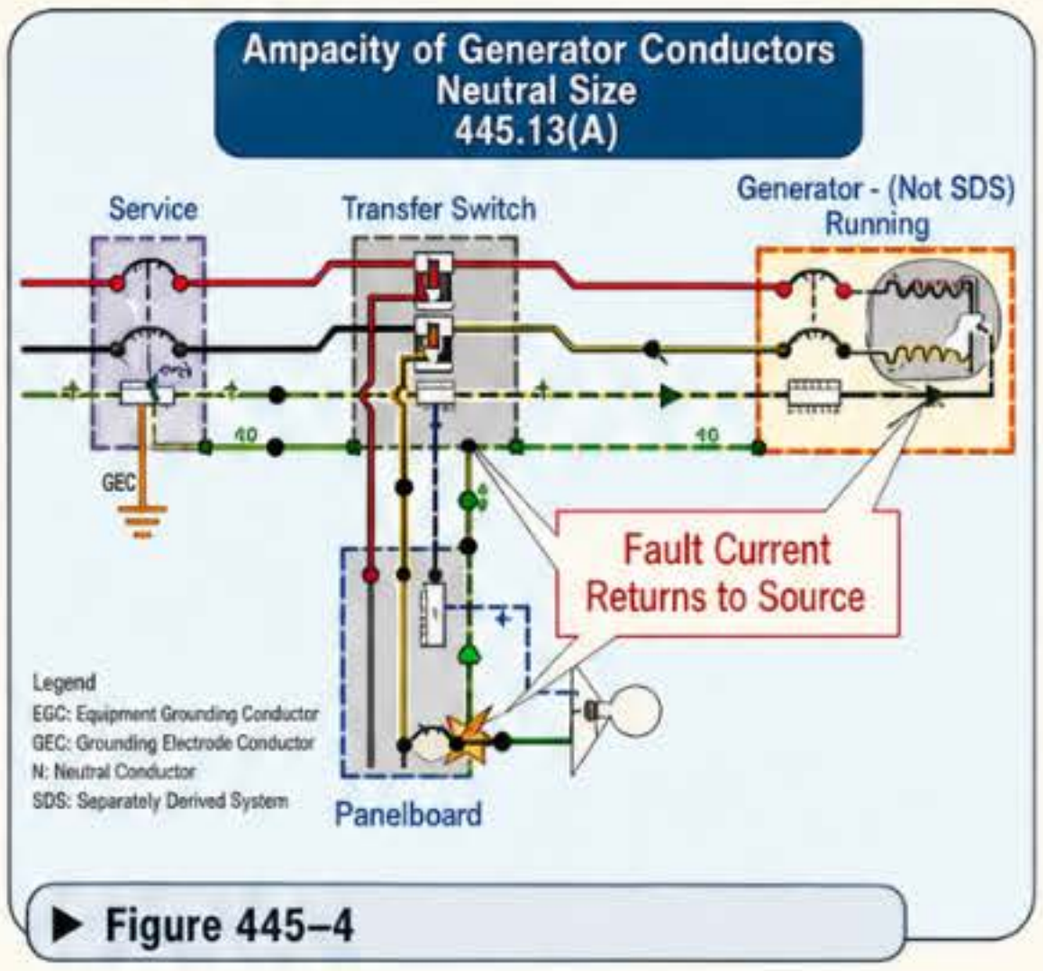
▶ Figure 445–3

Solution:

3 AWG is rated 100A at 75°C [110.14(C)(1) and Table 310.16].

Answer: *(b) 3 AWG*

The generator's feeder neutral must be sized to carry the maximum unbalanced current as determined by 220.61. **▶ Figure 445–4**

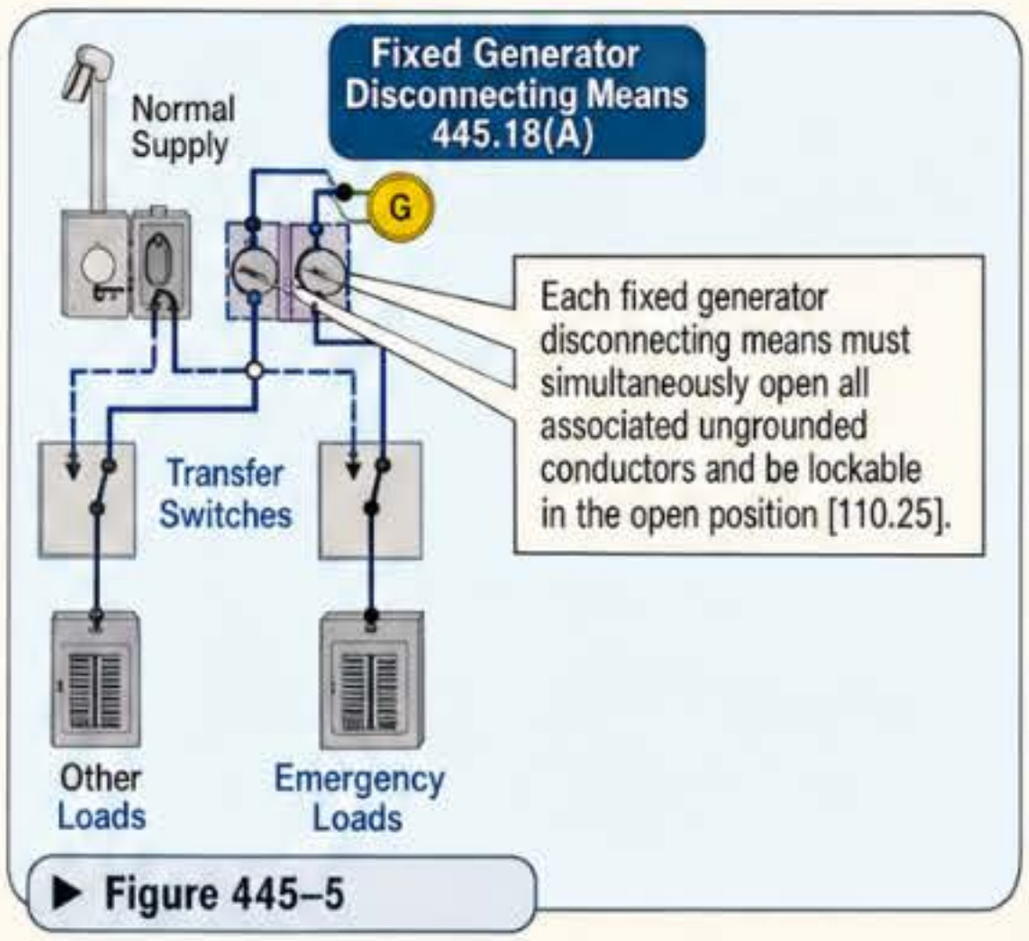


▶ Figure 445–4

The neutral conductor must be sized to carry the neutral and fault current [250.30(A)(1) and 220.61].

445.18 Disconnecting Means and Emergency Shutdown

(A) Disconnecting Means. *Generators, other than cord-and-plug-connected portable generators, must have one or more disconnecting means and must be capable of being locked in the open position in accordance with 110.25.* **▶ Figure 445–5**



▶ Figure 445–5

DEFINITIONS | From Michael Hamilton Publications

(B) Emergency Shutdown of Prime Mover. Generators must be equipped with the ability to shut down the prime mover. The shutdown equipment must meet all of the following requirements:

(1) Install provisions that will disable every prime mover start control circuit so the prime mover cannot be started.

(2) Provide a shutdown device that needs a deliberate, mechanical action to operate.

The shutdown provisions for the prime mover are permitted to comply with the requirements of 445.18(A) where the device used to stop the prime mover is capable of being locked in the open position in accordance with 110.25.

Author's Commentary:

The emergency shutdown requirements ensure personnel can quickly and safely stop a generator when an unsafe or emergency condition occurs.

— Michael Hamilton

(C) Remote Emergency Shutdown. Generators with a nameplate rating above 15 kW must be equipped with a remote emergency stop switch that can stop the prime mover. The remote emergency stop switch must be located outside the generator room or the generator enclosure and must also satisfy the requirements of 445.18(B)(1) and (B)(2).

(D) Emergency Shutdown in One- and Two-Family Dwellings Units. For other-than cord-and-plug-connected portable generators, an emergency shutdown device must be provided outside the dwelling unit at a readily accessible location.

ARTICLE 450 TRANSFORMERS

Introduction to Article 450—Transformers

Article 450 begins by stating, "This article covers the installation of all transformers." The section then lists eight exceptions. So, what is really covered? In general, it covers transformers that supply power for and serve lighting or other loads. The scope is limited to a single transformer installation, either a single-phase or a three-phase unit, which is identified by a nameplate—unless something else is specified.

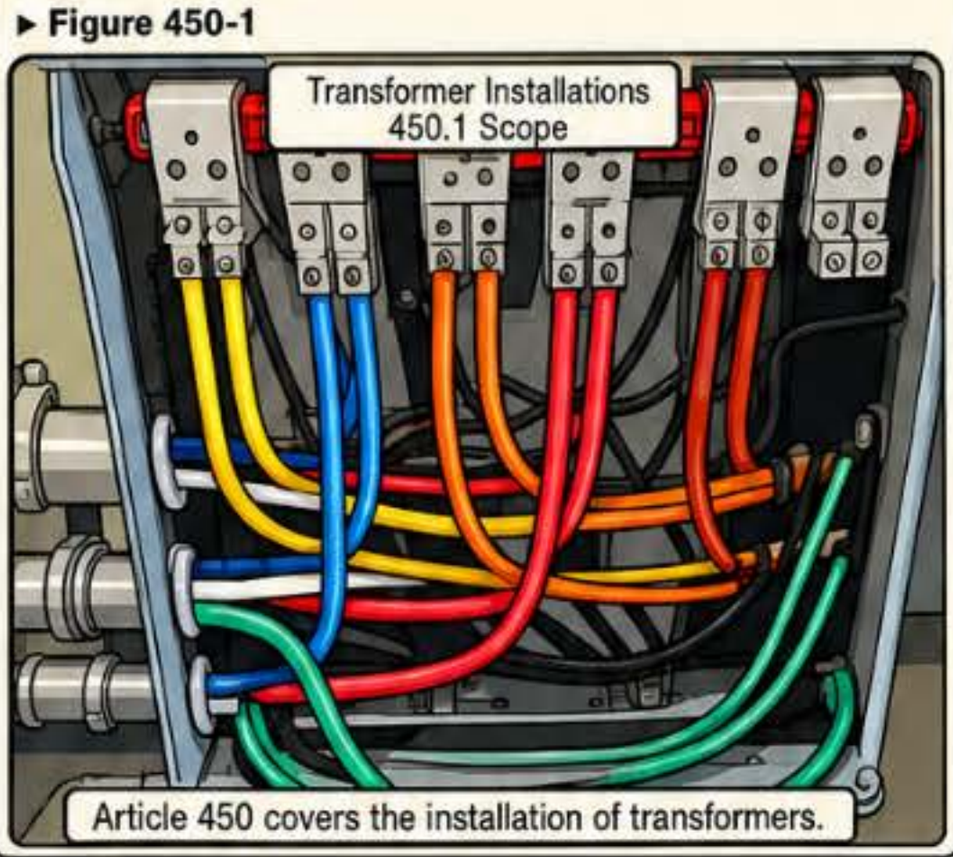
A major concern with transformers is preventing overheating. The *Code* does not completely address *this issue. Article 90 explains that the NEC is not a design manual and assumes only that anyone using the Code has a certain level of skill. Proper transformer selection is critical for keeping them cool and for avoiding premature failure due to heat. The NEC assumes that you have already chosen a transformer suitable for the load characteristics. For the Code to tell you how to install it into a design isn't practical. Article 450 then takes you to the next logical step—providing protection against overcurrent and ensuring proper connections. It does not stop there; 450.9 provides ventilation rules, and 450.13 covers accessibility.*

Part I contains the general requirements such as guarding, marking, and accessibility, and Part II deals with the needs that vary depending on the type of transformer.

450.1 Scope

Article 450 covers the installation requirements of all transformers.

▶ **Figure 450-1**



▶ **Figure 450-1**

Ex 4: *Class 2 and 3 transformers that comply with Article 725.*

Ex 5: *Sign and outline transformers complying with Article 600.*

Ex 6: *Electric-discharge lighting transformers that comply with Article 410.*

Ex 7: *Transformers for power-limited fire alarm circuits complying with Article 760 Part III.*

450.3 Overcurrent Protection

(B) Overcurrent Protection for Transformers Not Over 1,000V.

Transformers having a secondary voltage not exceeding 1,000V, with primary overcurrent protection only, must have the primary overcurrent protective device sized in accordance with the percentages contained in Table 450.3(B) and its applicable notes.

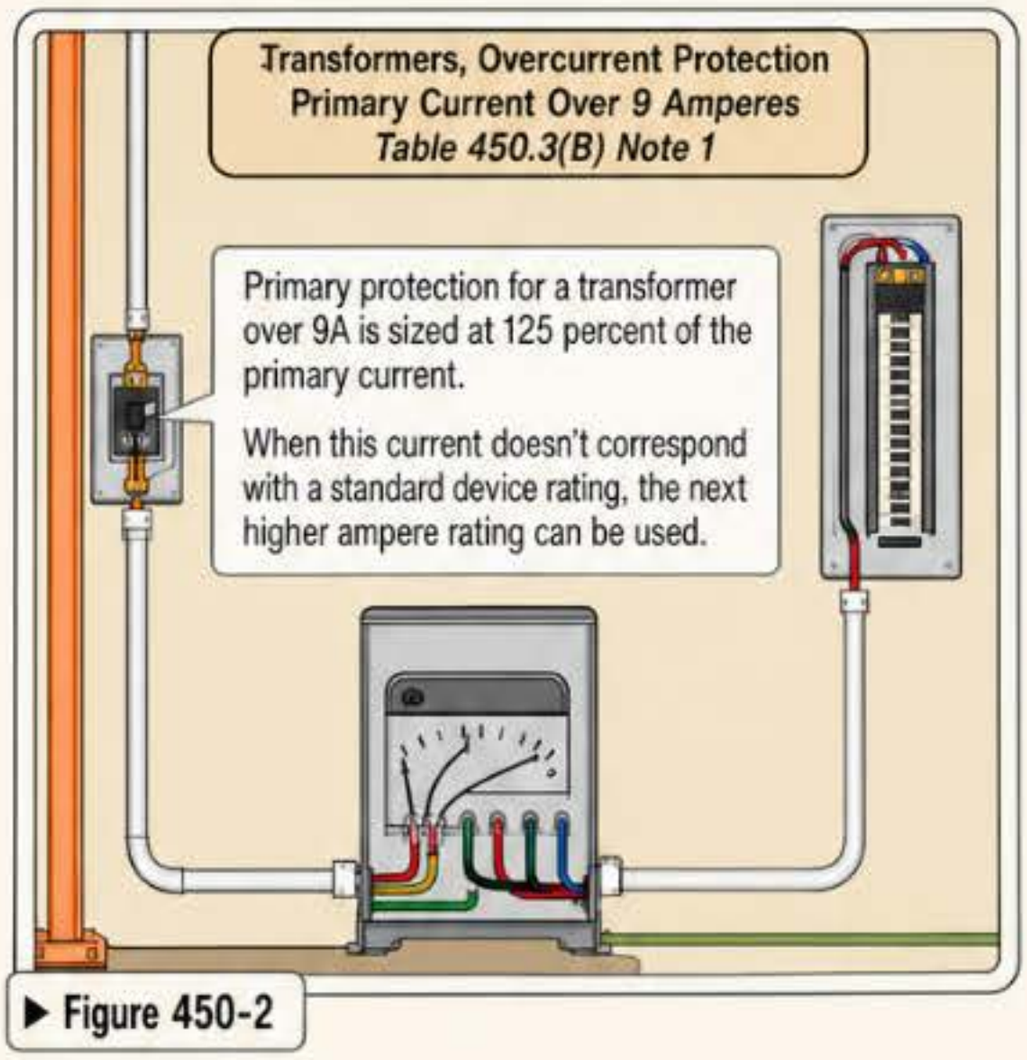
Author's Commentary: *Article 450 sets baseline installation rules for transformers, but it assumes you've already picked the right unit for the job. The Code is not a design guide; it presumes the installer knows what they're doing. Picking the wrong size transformer or ignoring heat issues is a recipe for trouble. Article 450 steps in to ensure the transformer is protected, properly connected, ventilated, and accessible.*

— Michael Hamilton

Table 450.3(B) Primary Only Protection	
Primary Current Rating	**Maximum Protection**
9A or More	125%, see Table Note 1
Less Than 9A	167%
Less Than 2A	300%

Note 1 of Table 450.3(B): If 125 percent of the primary current does not equal the standard rating of an overcurrent protective device [240.6(A)], the next higher rating is permitted [240.6(A)].

▶ **Figure 450-2**



▶ **Figure 450-2**

▶ Example

Question: *What is the primary overcurrent protection rating and conductor size required for a 45 kVA, three-phase, 480V transformer that is fully loaded? The terminals are rated 75°C.* ▶ **Figure 450-3**

(a) 70A breaker, 6 AWG conductor
(b) 100A breaker, 3 AWG conductor
(c) 110A breaker, 2 AWG conductor
(d) 125A breaker, 1 AWG conductor

Solution:

Step 1: *Determine the primary current.*

$I = VA/(E \times 1.732)$

$I = 45{,}000\ VA/(480V \times 1.732)$

$I = 54A$

Step 2: *Determine the primary overcurrent protection rating [240.6(A)].*

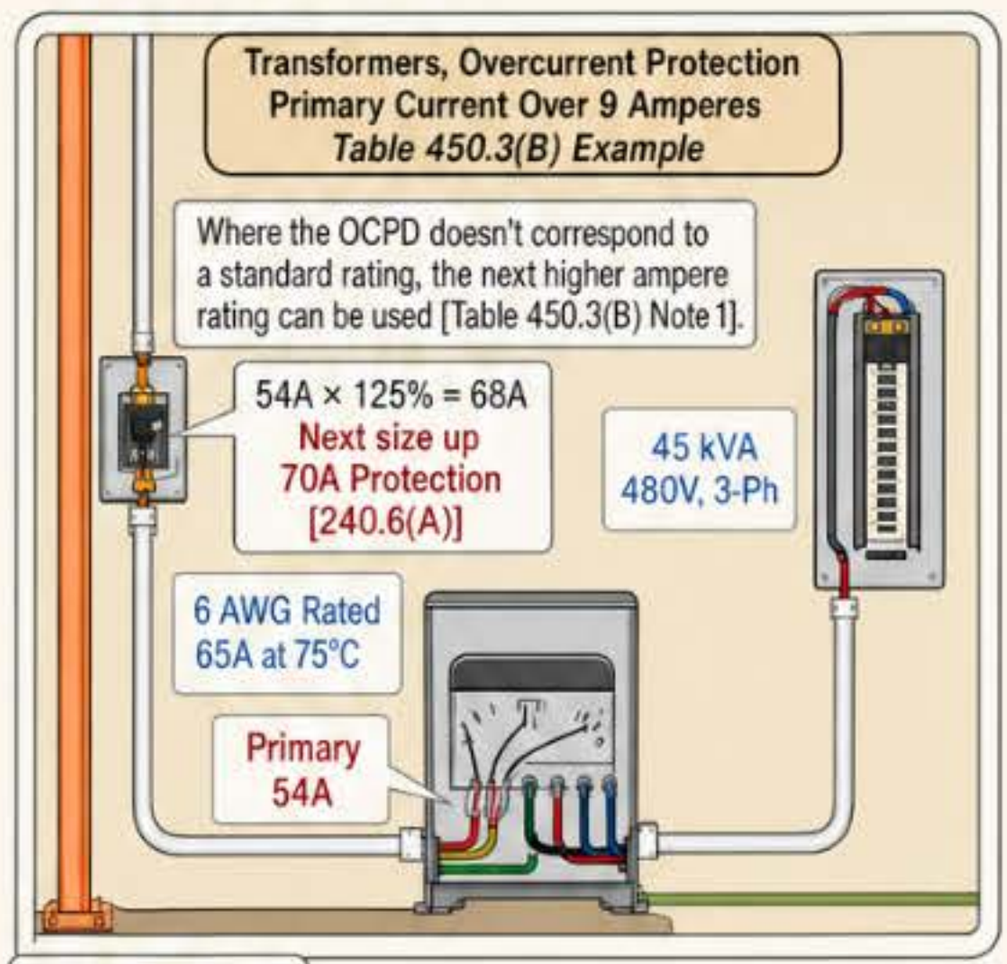
Primary Overcurrent Protection = 54A × 125%

Primary Overcurrent Protection = 68A; use the next size up, 70A [240.6(A) and Table 450.3(B) Note 1]

Step 3: *Determine the conductor size.*

The conductor must be sized to accommodate the 70A primary overcurrent protection in accordance with 240.4(B).

Primary Conductor = 6 AWG conductor rated 65A at 75°C [110.14(C)(1) and Table 310.16]



▶ **Figure 450-3**

450.9 Ventilation

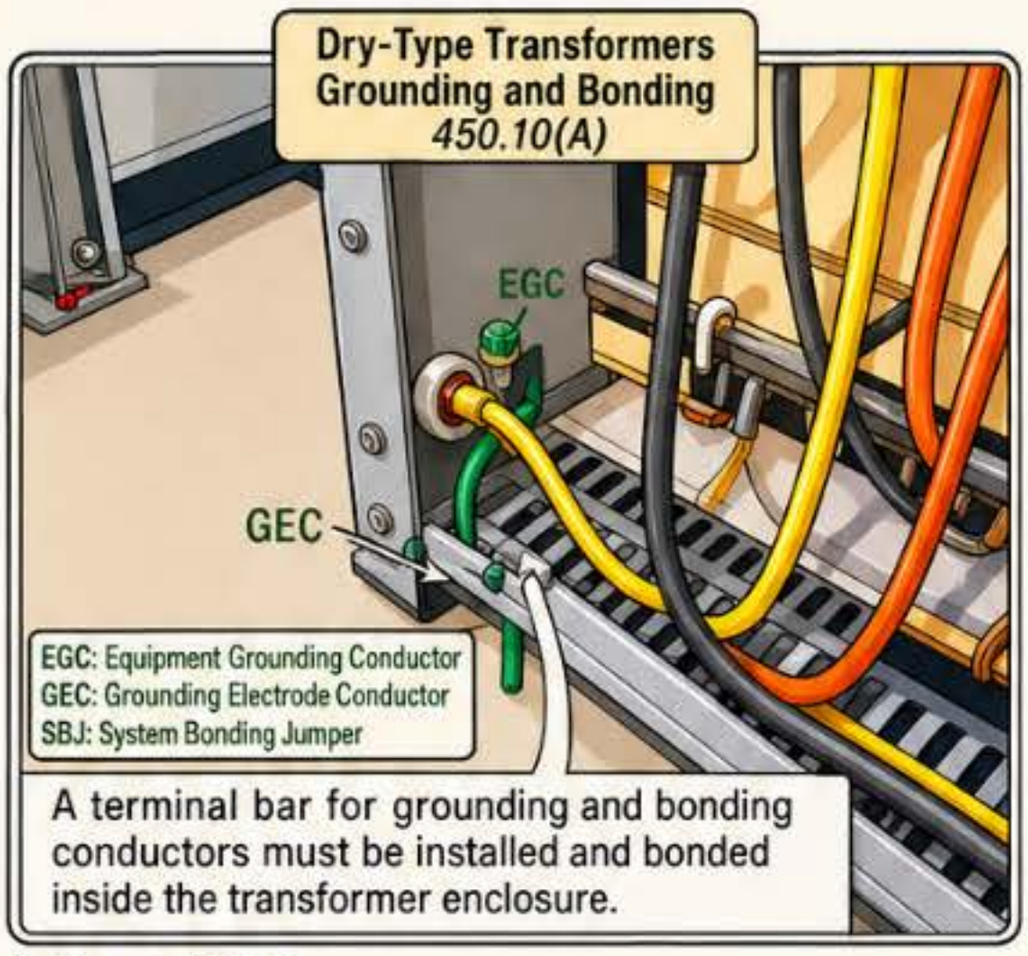
Transformers must be installed in accordance with the manufacturer's instructions and their ventilating openings are not permitted to be blocked [110.3(B)].

Transformer top surfaces that are horizontal and readily accessible must be marked to prohibit storage.

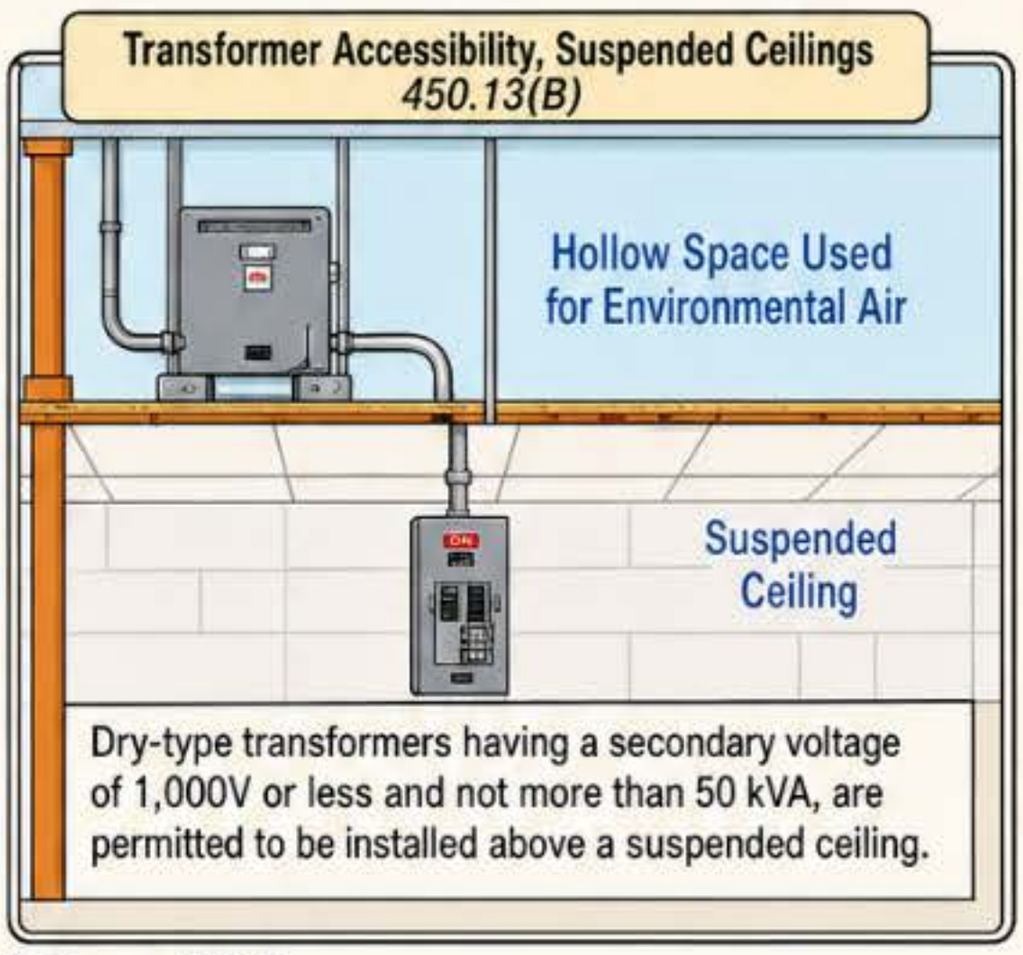
450.10 Grounding and Bonding

(A) Dry-Type Transformer Enclosures. A terminal bar for equipment grounding conductors, system bonding jumpers, supply-side bonding jumpers, and grounding electrode conductors must be installed and bonded inside the transformer enclosure. ▶ **Figure 450-4**

Transformers | 450.14



▶ **Figure 450-4**

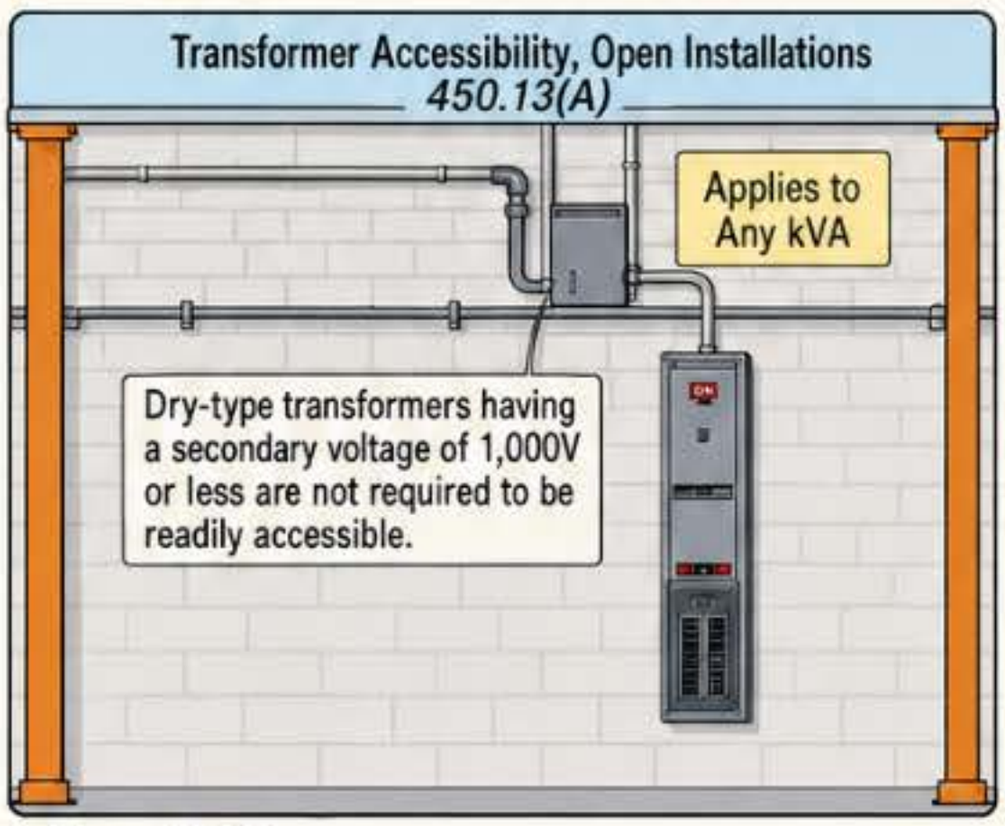


▶ **Figure 450-6**

450.13 Transformer Accessibility

Transformers must be readily accessible to qualified personnel for inspection and maintenance except as permitted by (A) or (B).

(A) Open Installations. Dry-type transformers having a secondary voltage of 1,000V or less are not required to be readily accessible. ▶ **Figure 450-5**

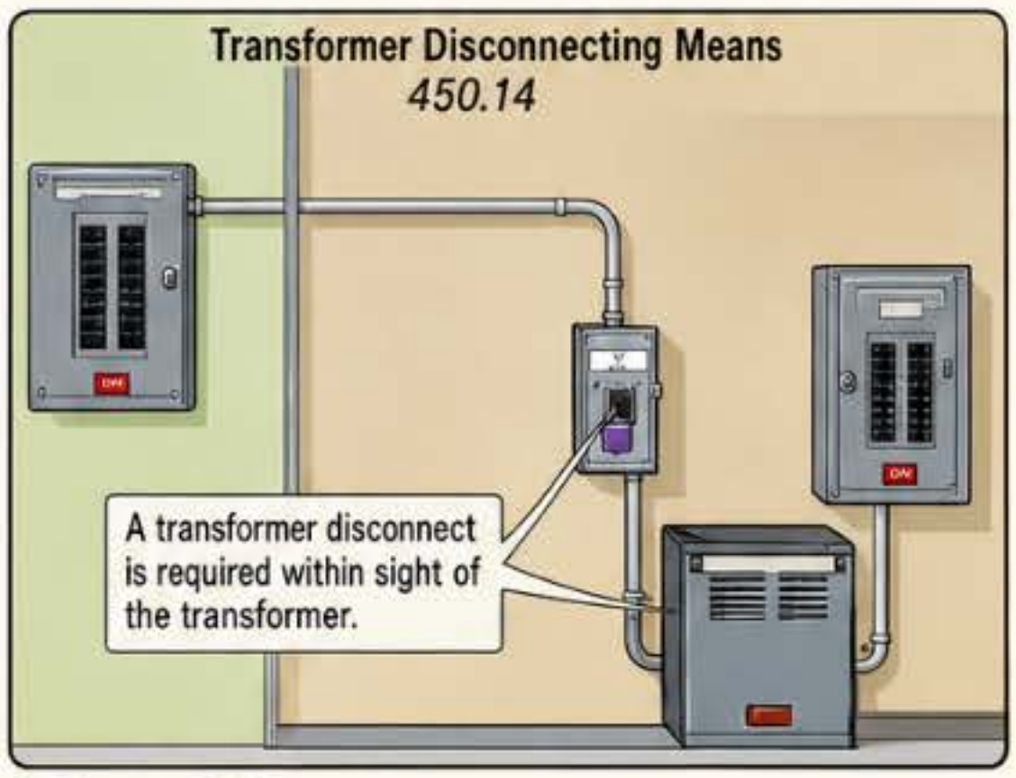


▶ **Figure 450-5**

(B) Suspended Ceilings. Dry-type transformers having a secondary voltage of 1,000V or less and not more than 50 kVA are permitted to be installed above a suspended ceiling. ▶ **Figure 450-6**

450.14 Disconnecting Means

A transformer must have a disconnect located within sight of the transformer unless the disconnect location is field marked on the transformer and the disconnect is capable of being locked in the open position in accordance with 110.25. ▶ **Figure 450-7** and ▶ **Figure 450-8**



▶ **Figure 450-7**

Author's Commentary:

- *"Within Sight" means it is visible and not more than 50 ft from the location of the equipment [Article 100].*

— Michael Hamilton

450.14 | Transformers

Transformer Disconnecting Means, Remote Locations
450.14

▲ **Figure 450–8**

Author's Commentary: When the main transformer disconnect is out of view from the equipment, it must be designed so it can be secured in the open, off position. In addition, the transformer enclosure must carry a durable field label (or engraving) that identifies where the disconnect is located and which panel and circuit supply it. This ensures responders and qualified personnel can quickly and safely de-energize the unit.

— *Michael Hamilton*

ARTICLE 480 STORAGE BATTERIES

Introduction to Article 480—Storage Batteries

Stationary batteries are central to any uninterrupted power system. Article 480 governs batteries used in commercial and industrial power supplies and in "point of use" UPS enclosures.

These batteries also play a role in other settings, such as emergency power systems. Regardless of the application, Article 480 applies whenever stationary batteries are involved.

Lead-acid stationary batteries are grouped into two broad types: flooded and valve regulated (VRLA). Although they differ in service requirements, total cost, and scalability, the 2023 *NEC* does not differentiate between them because both raise similar safety and electrical concerns [90.1].

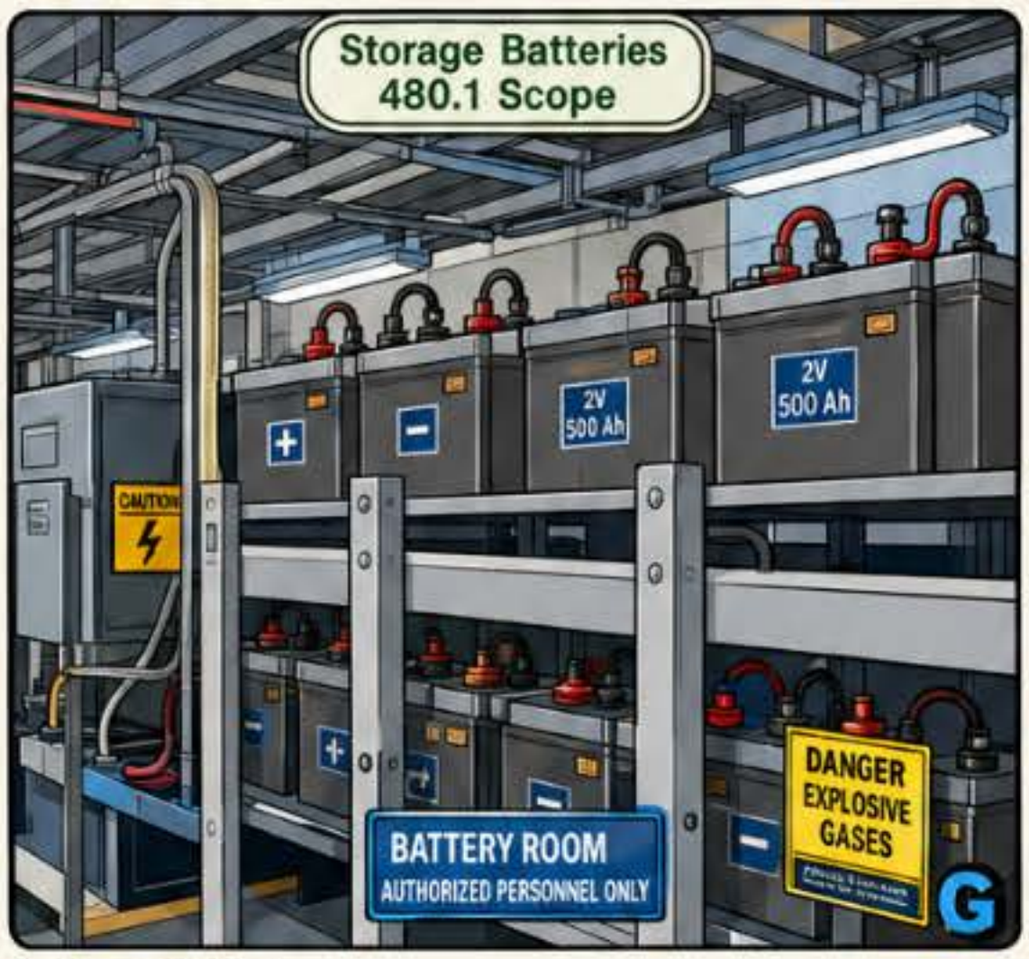
The *Code* does not address design issues such as arranging battery tiers, spacing between tiers, determining charge voltage, or selecting conductor sizes. It also leaves testing, monitoring, and maintenance procedures up to the user. These areas are highly specialized and require knowledge beyond the scope of optimal day-to-day operation requirements. Standards other than the *NEC* provide guidance on these topics.

What the *Code* does address in Article 480 are *measures intended to prevent electrical shock hazards and the ignition of gases emitted by all stationary batteries, including even "sealed" types.*

480.1 Scope

This section explains how Article 480 applies to fixed or stationary storage battery installations.

▶ **Figure 480–1**



▲ **Figure 480–1**

Author's Commentary:

Article 480 applies specifically to fixed battery systems. Portable batteries, such as those in vehicles or handheld devices, are covered by other articles.

— Michael Hamilton

480.2 Definitions

The terms used in this portion apply only within Article 480.

Cell. The fundamental electrochemical unit, composed of an anode and a cathode, that stores and releases electrical energy.

Author's Commentary:

A battery consists of one or more cells connected together.

— Michael Hamilton

Container. *A receptacle that houses all the components of a single cell or a unit cell within a battery.*

Note: *Containers may hold a single cell or multiple cells and are frequently referred to as "jars."*

Electrolyte. *The medium that enables movement of ions between the positive and negative plates inside a cell.*

Intercell Connector. *A conductive link or cable that electrically joins adjacent cells.*

Author's Commentary:

These definitions help establish a common vocabulary for battery system discussions and are the foundation for many safety rules found throughout Article 480.

— Michael Hamilton

Intertier Connector. An electrical conductor that links two cells located on different levels of the same battery rack, or connects shelves that are on different tiers of the same rack.

Nominal Voltage (Battery or Cell). The voltage rating assigned to a cell or battery for the purpose of identifying its voltage class. Operating voltage may be higher or lower than the nominal value depending on charge condition and usage.

Note: Typical nominal cell voltages are 2V for lead-acid cells, 1.20V for alkaline cells, and 3.60V to 3.80V for lithium-ion cells.

▶ **Figure 480-2**

The most frequently used nominal cell voltages are 2V per cell for lead-acid types, 1.20V per cell for alkaline types, and 3.60 to 3.80V per cell for lithium-ion technologies.

▶ **Figure 480-2**

Author's Commentary:

The voltage of a battery declines below nominal while it is being discharged. Once recharged, the voltage usually rises above nominal before settling back down to the nominal value when the battery is fully charged.

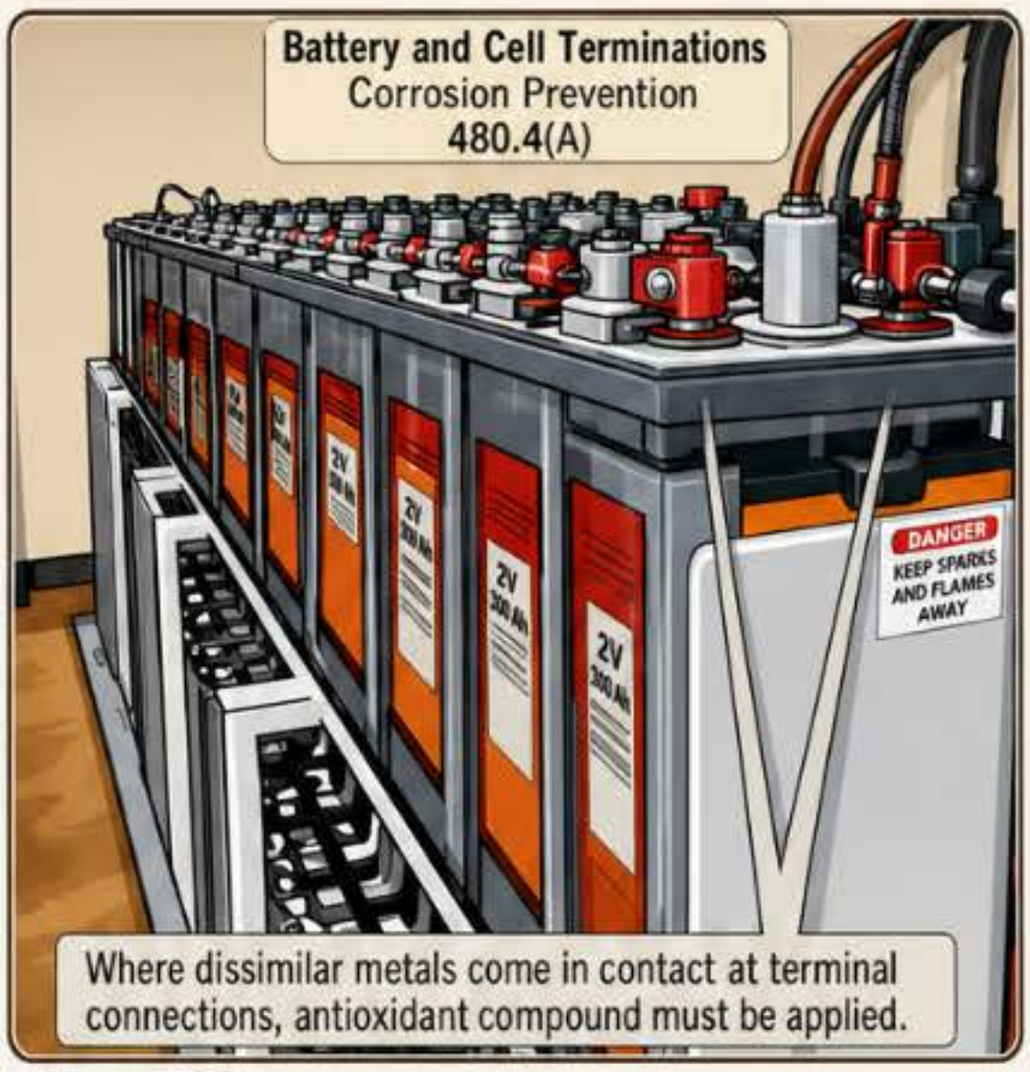
— Michael Hamilton

Sealed Cell or Battery. A cell or battery that does not have provisions for the regular addition of water or electrolytes.

Storage Battery. One or more rechargeable cells that are connected together in series, in parallel, or using a mix of series and parallel arrangements. These cells can be of the lead-acid, nickel-cadmium, or other rechargeable electrochemical types.

480.4 Battery and Cell Terminations

(A) Dissimilar Metals. Wherever connections join dissimilar metals, antioxidant materials must be used. ▶ **Figure 480-3**



▶ **Figure 480-3**

Note: Manufacturers' installation instructions may include additional requirements for acceptable materials.

(B) Intercell and Intertier Conductors and Connections. Intercell and intertier connectors and conductors must be designed so temperature rise under maximum load and the highest ambient temperature do not exceed the safe operating temperature rating of the conductor insulation.

Note: *See 137.5, Guide for the Protection of Stationary Battery Systems, for information on overcurrent protection and associated cable sizing. Voltage drop calculations for alternating-current circuits usually do not apply to battery systems.*

(C) Battery Terminals. Electrical connections between the battery and its cables, and between individual cells on separate levels or racks, must be arranged so that no mechanical stress is imposed on the battery terminals.

Note: *Conductors are commonly formed to reduce stress on battery terminations. Fine-stranded cables can also minimize strain at terminal connections. Refer to the manufacturer's instructions for additional guidance.*

(D) Accessibility. *All terminals of cells or multicell units must be easy to reach for reading, inspection, testing, and maintenance whenever the equipment design requires it. One side of transparent battery enclosures must be easily accessible for inspection of internal components.*

480.5 Wiring and Equipment Supplied from Batteries

Electrical wiring and apparatus that receive power from storage batteries must follow the requirements in Chapters 1 through 4 unless another rule in 480.6 specifically allows a different approach.

480.7 Direct-Current Disconnect Methods

(A) Disconnecting Means. A disconnect device must be installed to open every ungrounded (current-carrying) conductor from a stationary battery system operating above 60 volts DC. *This device has to be readily accessible and positioned outside of the battery room.*

(B) Emergency Disconnect. *In one- and two-family dwellings, a disconnecting means—or a remote control connection for such a device—must be located in a readily accessible place outside the home for emergency situations. The disconnect must be identified with the label "EMERGENCY DISCONNECT."*

(D) Remote Actuation. *When a disconnecting means is installed as required by 480.7(A), it must have remote-control capability that can trip the device. The location of these controls must be outside the battery room, they shall be able to secure the disconnect in the open position, and they must be clearly identified according to 110.25 with the location of the controls shown on the disconnecting means.*

(F) Notification. *A disconnect must be marked so it is easy to see. The marking has to be in a conspicuous spot near the battery whenever the disconnecting means itself has no markings. The label must be made of durable material that can withstand the surrounding conditions and include these items:*

(1) Nominal battery voltage

(2) *Available fault current derived from the battery system*

Note: *Suppliers of battery systems can furnish details about available fault current for a particular battery model.*

(3) *An arc flash warning label that matches accepted industry standards*

Note: *NFPA 70E, Standard for Electrical Safety in the Workplace, helps determine the level of risk exposure, the required protective equipment, arc flash labels, and appropriate training.*

(4) *Date the available fault current calculation was performed*

Ex: *Items (2), (3), and (4) are not required in one- and two-family homes.*

(G) Identification of Power Sources. Battery installations have to be tagged as power sources, as described in 480.7(G)(1) and (G)(2).

(1) Facilities with Utility Services and Battery Systems. Plaques *or labels must be installed following 705.10 and 712.10(A).*

Ex: *This requirement does not apply when a disconnect in 480.7(A) is not required.*

(2) Facilities with Stand-Alone Systems. A permanent plaque *or directory must be provided according to 710.10.*

Ex: *This requirement does not apply when a disconnect in 480.7(A) is not required.*

480.8 Insulation of Batteries

Batteries housed in conductive enclosures must have adequate insulating support whenever a voltage exists between the container and the ground.

480.9 Battery Support Systems

Support structures for batteries must be designed to withstand the corrosive environment often present in these locations. *The framework should be made from noncorrosive materials or coated with a continuous insulating layer. Paint alone does not qualify as insulation.*

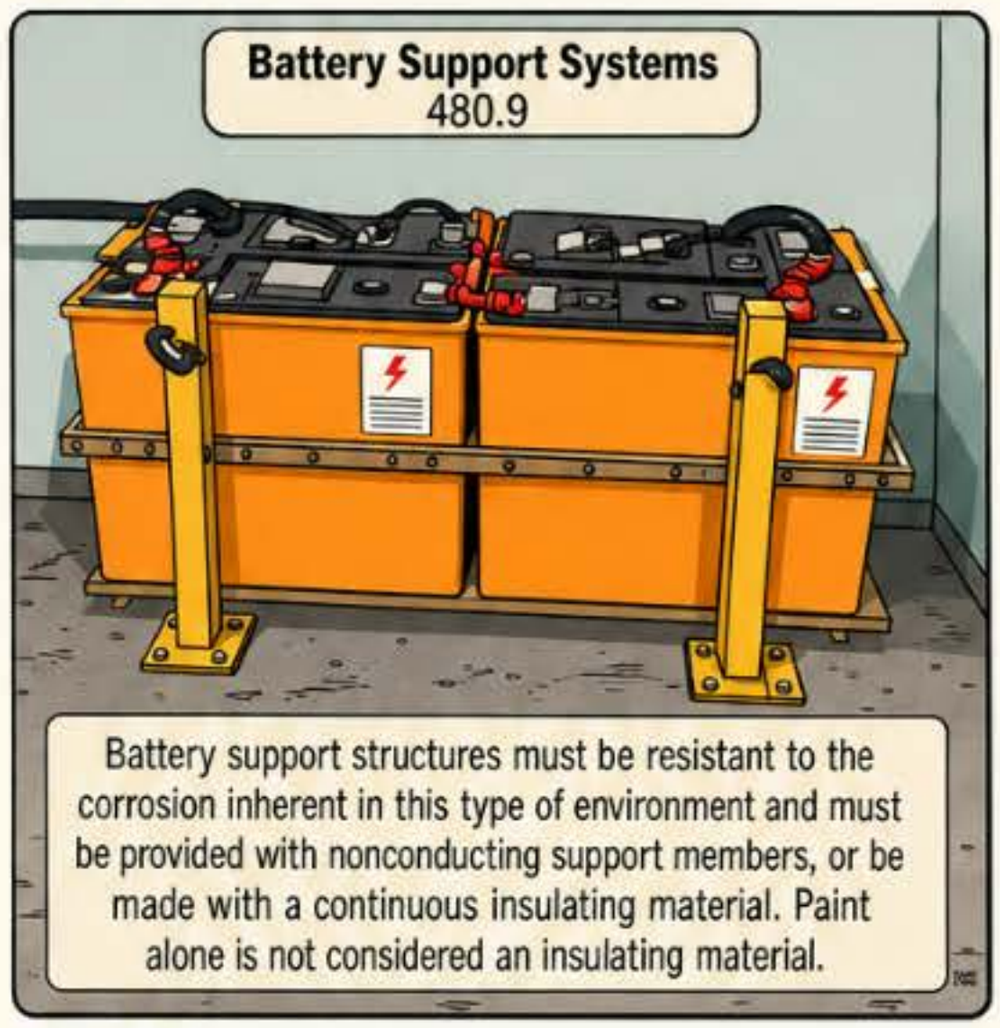


Figure 480-4

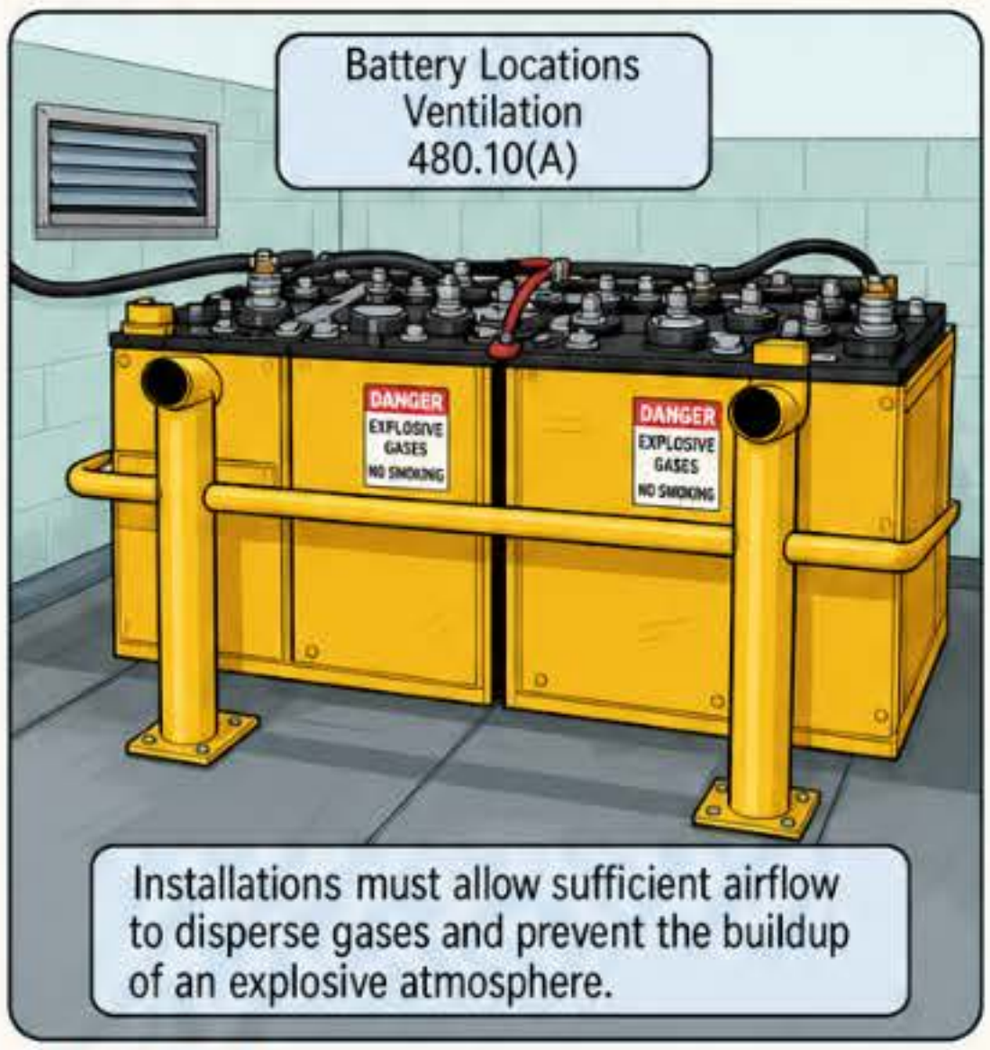
480.10 | STORAGE BATTERIES

480.10 BATTERY LOCATIONS

Battery installations must comply with the requirements listed below.

(A) Ventilation. Adequate air movement must be provided to disperse gases from storage batteries and reduce the chance of forming an explosive atmosphere.

▶ Figure 480–5



▶ Figure 480–5

(B) Live Parts. All live components in a battery system must be safeguarded in accordance with 110.27.

Author's Commentary:

▶ *Per 110.27, electrical equipment must be located or enclosed so that physical harm, enclosure damage, or insufficient strength will not result. In addition, doors, entrances, and similar access points with exposed live parts must be marked with clear warnings to keep unqualified individuals out.*

— Michael Hamilton

(C) Working Space for Battery Racks. Maintain at least 1 in. *of clearance between a cell container and any wall or structure that does not require access for routine service. Battery supports may be placed next to adjacent walls or structures.*

Note: *Additional space may be needed for lifting gear, battery removal, trays, or spill collection.*

(D) Top Terminal Batteries. Top-terminal batteries must be arranged on tiered racks so that the highest point of one tier is level with, or below, the highest point of the cell and row directly above.

Note: Manufacturer instructions typically specify the required working space for a given battery model.

(E) Egress. Personnel doors used for entry and exit, rooms intended for battery storage, and exit paths must open in the direction of egress and be equipped with panic or listed fire exit hardware.

(F) Piping in Battery Rooms. Gas piping is not allowed in battery areas classified as dedicated battery rooms.

(G) Illumination. Illumination within the working space must be provided by automatic devices, and must not:

(1) Expose workers to energized battery parts during luminaire servicing.

(2) Create a risk of luminaire failure.

480.12 BATTERY INTERCONNECTIONS

Flexible cables, as described in Article 400, sized #2/0 AWG or larger, may be used within the battery enclosure to link battery terminal clusters to a nearby junction box that connects to approved wiring methods. Flexible battery cables are also permitted between batteries and cells inside the battery enclosure. Such cables must be identified and used in accordance with the environmental conditions. Flexible, high-strand-count cables may be terminated with lugs, terminals, devices, or connectors per 110.14.

480.13 GROUND-FAULT DETECTION

Battery circuits exceeding 100V between conductors or between a conductor and ground are allowed to use phase conductors along with a ground-fault detector and indicator to monitor ground faults.

CHAPTER 4

PRACTICE QUESTIONS

Please use the 2023 *Code* book to answer the following questions.

CHAPTER 4—EQUIPMENT FOR GENERAL USE

1. Article 400 covers general requirements, applications, and construction specifications for flexible cords and flexible cables.
(a) True
(b) False

2. The ampacities of flexible cords and flexible cables are found in _____.
(a) Table 310.16
(b) Tables 400.5(A) and (B)
(c) Chapter 9, Table 1
(d) Table 430.52

3. Unless specifically permitted in 400.10, flexible cords, flexible cables, and cord sets, and power-supply cords shall not be used where subject to physical damage.
(a) True
(b) False

4. Flexible cord sets and power-supply cords shall not be used as a substitute for _____ wiring of a structure.
(a) temporary
(b) fixed
(c) concealed
(d) permanent

5. The ampacity of 18 TFFN is _____.
(a) 6A
(b) 8A
(c) 10A
(d) 14A

6. Three-way and four-way switches shall be wired so that all switching is done only in the _____ circuit conductor.
(a) ungrounded
(b) grounded
(c) equipment ground
(d) neutral

7. Switches shall not be installed within tubs or shower spaces unless installed as part of a listed tub or shower assembly.
(a) True
(b) False

8. A snap switch wired under the provisions of 404.9(B) Ex 1 and located within 8 ft vertically, or _____ ft horizontally, of ground or exposed grounded metal objects shall be provided with a faceplate of nonconducting noncombustible material with nonmetallic attachment screws, unless the switch mounting strap or yoke is nonmetallic or the circuit is protected by a ground-fault circuit interrupter.
(a) 3
(b) 5
(c) 7
(d) 9

9. Snap switches in listed assemblies are not required to be connected to an equipment grounding conductor if ____.
(a) the device is provided with a nonmetallic faceplate and the device is designed such that no metallic faceplate replaces the one provided
(b) the device is equipped with a nonmetallic yoke
(c) all parts of the device that are accessible after installation of the faceplate are manufactured of nonmetallic material
(d) all of these

Chapter 4 Practice Questions

10. Article _____ addresses the rating, type, and placement of receptacles, cord connectors, and attachment plugs (also called cord caps).
    (a) 400
    (b) 404
    (c) 406
    (d) 408

11. When a non-grounding type receptacle is replaced but the equipment grounding conductor is missing from the enclosure, a _____ can be used in its place.
    (a) non-grounding type receptacle
    (b) grounding receptacle
    (c) GFCI type receptacle marked "No Equipment Ground"
    (d) nongrounding type receptacle or GFCI type receptacle marked "No Equipment Ground"

12. Locations that, under the 2023 *NEC*, require GFCI protection have _____ receptacles.
    (a) dedicated
    (b) isolated ground
    (c) GFCI-protected
    (d) grounding

13. Receptacles that are installed in or on countertops or work surfaces must be provided, unless listed for such use, in work surface applications _____.
    (a) along the sides of cabinets
    (b) in a face-up position
    (c) on GFCI circuits
    (d) on the branch circuit supplying the kitchen small-appliance outlets

14. When 15A and 20A receptacles are placed in a wet location, the outlet box _____ must be listed for extra-duty use.
    (a) sleeve
    (b) hood
    (c) threaded entry
    (d) mounting

15. All 125V and 250V nonlocking receptacles rated 15A and 20A must be listed as tamper resistant if installed _____.
    (a) in bedrooms
    (b) outdoors, at grade level
    (c) above countertops
    (d) in every space mentioned in 210.52 and 550.13

16. Reconditioned switchboards and switchgear that have been harmed by fire, combustion by-products, or water damage must be assessed by _____ before being returned to service.
    (a) the installer
    (b) its manufacturer
    (c) a qualified testing laboratory
    (d) its manufacturer or a qualified testing laboratory

17. When separate equipment grounding conductors are furnished in panelboards, a _____ must be fastened within the cabinet.
    (a) grounded conductor
    (b) terminal lug
    (c) terminal bar
    (d) bonding jumper

18. Panelboards _____ installed in the face-up position.
    (a) shall not be
    (b) are permitted to be
    (c) listed for such purpose, may be
    (d) approved for such use, may be

19. Closet storage space is defined as a volume that is bounded by the sides and back of the closet walls, extending from the closet floor vertically upward to a height of _____ ft or the highest clothes-hanging rod at a horizontal distance of 2 ft from the sides and back of the closet walls.
    (a) 6
    (b) 7
    (c) 8
    (d) 9

20. A luminaire marked "Suitable for Wet Locations" _____ be permitted in a damp location.
    (a) shall
    (b) shall not
    (c) a or b
    (d) none of these

21. Luminaires _____ "Suitable for Wet Locations" shall be permitted in a damp location.
    (a) marked
    (b) listed
    (c) identified
    (d) approved for

Author's Commentary:
Review the reasoning behind each option. Understanding what is correct—and why the others are not—reinforces code knowledge.
— Michael Hamilton

22. The *NEC* requires a lighting outlet on the wall of a clothes closet if the closest point of illumination is at least 6 ft. away from any storage area.
    (a) True
    (b) False

23. Under a metal-corrugated sheet roof deck, the luminaire must be installed and supported so that it is at least 1 in. from the lowest surface of the decking to the top of the luminaire.
    (a) 1 in
    (b) 1¼ in
    (c) 1½ in
    (d) 2 in

24. What must be connected to the grounding electrode conductor of a lighting system?
    (a) The grounding electrode conductor only
    (b) The grounded conductor only
    (c) Equipment grounding conductor only
    (d) All of the above

25. At locations other than dwellings or recreational cabins, fluorescent luminaires that contain double-ended lamps and use a ballast can be serviced in place by disconnecting either an internal or external connection to each luminaire.
    (a) True
    (b) False

26. Existing installed luminaires, other than those in dwellings and recreational cabins, that use double-ended fluorescent lamps can remain installed without disconnecting provisions if a ballast is in place.
    (a) Must be installed
    (b) Is not required to be added
    (c) Must not be installed
    (d) Can be a screw terminal

27. A flexible cord is allowed only when it is a component of listed lighting equipment intended for horticultural use for _____.
    (a) connecting a horticultural lighting luminaire directly to a branch circuit outlet
    (b) interconnecting horticultural lighting luminaires
    (c) connecting a horticultural lighting luminaire to a remote power source
    (d) any of these

28. Article 411 governs lighting systems and their components operating at no more than _____ ac or _____ dc.
    (a) 15V, 30V
    (b) 30V, 60V
    (c) 60V, 125V
    (d) 125V, 250V

29. Article 411 governs lighting systems and their components operating at no more than _____ ac or _____ dc when wet contact is likely.
    (a) 15V, 30V
    (b) 30V, 60V
    (c) 60V, 125V
    (d) 125V, 250V

30. GFCI protection for appliances must be readily accessible, listed, and located _____.
    (a) within the branch circuit overcurrent device
    (b) in a device or outlet within the supply circuit
    (c) in an integral part of the attachment plug
    (d) any of these

31. Wall-mounted ovens and counter-mounted cooking units must be connected with a flexible cord identified as _____ for the intended use.
    (a) listed
    (b) manufactured
    (c) suitable
    (d) sufficient

Chapter 4 Practice Questions

32. For permanently connected motor-operated appliances with motors rated over _____, a switch or circuit breaker located within sight from the motor-operated appliance or be capable of being locked in the open position in compliance with 110.25, can serve as the appliance disconnect.

(a) ⅓ hp
(b) ¼ hp
(c) 15A
(d) 1 kW

33. Article _____ covers fixed electric equipment used for space heating including heating cables, unit heaters, boilers, central heating systems, or other fixed electric space-heating equipment.

(a) 410
(b) 422
(c) 424
(d) 440

34. A unit switch with a marked "_____" position that is part of a fixed space heater, and disconnects all ungrounded conductors, shall be permitted to serve as the required disconnecting means.

(a) on
(b) closed
(c) off
(d) none of these

35. Ground-fault circuit-interrupter protection for personnel shall be provided for cables installed in electrically heated floors of _____.

(a) bathrooms
(b) hydromassage bathtub locations
(c) kitchens
(d) all of these

36. In determining the highest rated motor for purposes of complying with 430.24, 430.53(B), and 430.53(C), the highest rated motor shall be based on the rated full-load current as selected _____.

(a) from the motor nameplate
(b) from Tables 430.247, 430.248, 430.249, and 430.250
(c) by multiplying the horsepower by 746 watts
(d) using the largest horsepower motor

37. Each motor used in a continuous duty application and rated more than 1 hp shall be protected against overload by a separate overload device that is responsive to motor current. The overload device for motors with a marked temperature rise 40°C or less, shall be rated at no more than _____ percent of the motor nameplate full-load current rating.

(a) 80
(b) 115
(c) 125
(d) 175

38. Where the motor short-circuit and ground-fault protection devices determined by Table 430.52 do not correspond to the standard sizes or ratings, a higher rating that does not exceed the next higher standard ampere rating shall be permitted.

(a) True
(b) False

39. A feeder supplying fixed motor load(s) shall have a protective device with a rating or setting _____ branch-circuit short-circuit and ground-fault protective device for any motor in the group, plus the sum of the full-load currents of the other motors of the group.

(a) not greater than the largest rating or setting of the
(b) 125 percent of the largest rating of any
(c) equal to the largest rating of any
(d) at least 80% of the

40. Motor control circuit conductors that extend beyond the motor control equipment enclosure shall have short-circuit and ground-fault protection sized not greater than _____ percent of the value specified in Table 310.16 for 60-degree C conductors.

(a) 100%
(b) 150%
(c) 300%
(d) 400%

41. A _____ shall be located in sight from the motor location and the driven machinery location.

(a) controller
(b) protection device
(c) disconnecting means
(d) all of these

DEFINITIONS | From Michael Hamilton Publications

42. **If a motor disconnecting means is a motor-circuit switch, it shall be rated in _____.**

(a) horsepower
(b) watts
(c) amperes
(d) locked-rotor current

43. **A branch-circuit overcurrent device can serve as the disconnecting means for a stationary motor of ½ hp or less.**

(a) True
(b) False

44. **Disconnecting means for air-conditioning or refrigerating equipment can be installed _____ the air-conditioning or refrigerating equipment, but not on panels that are designed to allow access to the equipment, and not over the equipment nameplate.**

(a) on or within
(b) on top of
(c) within 100 ft of
(d) any of these

45. **The ampacity of the conductors from the generator output terminals to the first distribution device(s) containing overcurrent protection shall not be less than _____ percent of the nameplate current rating of the generator.**

(a) 75%
(b) 115%
(c) 125%
(d) 140%

46. **The primary overcurrent protection for a transformer rated 1,000V, nominal, or less, with no secondary protection and having a primary current rating of over 9A shall be set at not more than _____ percent.**

(a) 125%
(b) 167%
(c) 200%
(d) 300%

47. **Conductors are commonly _____ to eliminate stress on storage battery terminations.**

(a) pre-fabricated
(b) pre-insulated
(c) pre-formed
(d) pre-evaluated

48. **Metallic structures for the support of storage batteries shall be provided with nonconducting support members for the cells or shall be constructed with a continuous insulating material and paint alone shall not be considered as an insulating material.**

(a) True
(b) False

49. **Provisions appropriate to the storage battery technology shall be made for sufficient diffusion and ventilation of gasce from the battery, if present, to prevent the accumulation of a(an) _____ mixture.**

(a) explosive
(b) noxious
(c) toxic
(d) chemical

50. **Battery stands are permitted to contact adjacent walls or structures, provided that the battery shelf has a free air space for not less than _____ percent of its length.**

(a) 50%
(b) 75%
(c) 90%
(d) 100%

Author's Commentary;
These definition questions reinforce key NEC requirements for circuit disconnects, overcurrent protection ratings, and conductor sizing. Understanding these rules helps ensure safe, code-compliant installations.
— Michael Hamilton

Author's Commentary:
Proper battery installation protects personnel and equipment from gas buildup, short circuits, and overheating. Follow these ventilation, spacing, and insulation rules to maintain safe and reliable battery systems.
— Michael Hamilton

Notes

FINAL EXAM

A

STRAIGHT A

Please use the 2023 *Code* book to answer the following questions.

CHAPTER 1—GENERAL RULES

1. Part I of Article 100 contains definitions intended to apply wherever the terms are used throughout this *Code*. Part II of Article100 contains definitions for _____.

(a) Hazardous (Classified) Locations
(b) Solar (PV) Systems
(c) Communications Systems
(d) Grounding and Bonding

2. The maximum current, in amperes, that a conductor can carry continuously under the conditions of use, where the temperature will not be raised in excess of the conductor's insulation temperature rating is called its "_____."

(a) short-circuit rating
(b) ground-fault rating
(c) ampacity
(d) all of these

3. An enclosure designed for either surface mounting or flush mounting provided with a frame in which a door(s) can be hung is called a(n) "_____."

(a) enclosure
(b) outlet box
(c) cutout box
(d) cabinet

AUTHOR'S COMMENTARY: *Start every exam by reading each question completely. Look for key words such as "maximum," "continuous," and "intentionally." These terms guide you to the correct Code definition. When in doubt, eliminate answers that don't fit the definition exactly.* — *Michael Hamilton*

4. A load is considered to be continuous if the maximum current is expected to continue for _____ hour(s) or more.

(a) ½
(b) 1
(c) 2
(d) 3

5. A "_____" is a device or group of devices that govern, in some predetermined manner; the electric power delivered to the apparatus to which it is connected.

(a) relay
(b) breaker
(c) transformer
(d) controller

6. A "_____" is a building or portion of a building in which one or more self-propelled vehicles can be kept for use, sale, storage, rental, repair, exhibition, or demonstration purposes.

(a) garage
(b) residential garage
(c) service garage
(d) commercial garage

7. A system or circuit conductor that is intentionally grounded is called a(n) "_____."

(a) grounding conductor
(b) unidentified conductor
(c) grounded conductor
(d) grounding electrode conductor

STUDY TIP: *Memorizing definitions is the foundation of Code knowledge. Review them often—they are used throughout the NEC!*

Straight Order | Final Exam A

8. A system intended to provide protection of equipment from damaging line-to-ground fault currents by causing a disconnecting means to open all ungrounded conductors of the faulted circuit at current levels less than the supply circuit overcurrent device defines "_____".

(a) ground-fault protection of equipment
(b) guarded
(c) personal protection
(d) automatic protection

9. For PV systems, the conductors connected to the alternating-current output of an inverter form the _____.

(a) bipolar photovoltaic array
(b) monopole subarray
(c) emergency standby power
(d) inverter output circuit

10. Lighting track is a manufactured assembly designed to support and _____ luminaires that are capable of being readily repositioned on the track.

(a) connect
(b) protect
(c) energize
(d) all of these

11. A single receptacle is a single contact device with no other contact device on the same ____.

(a) circuit
(b) yoke
(c) run
(d) equipment

12. Equipment enclosed in a case or cabinet with a means of sealing or locking so that live parts cannot be made accessible without opening the enclosure is said to be "_____".

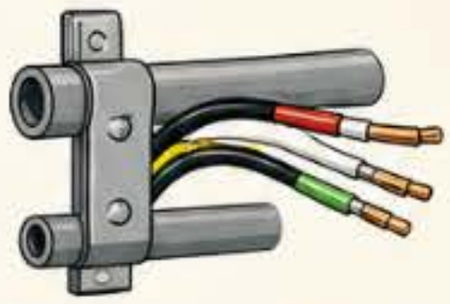
(a) guarded
(b) protected
(c) sealable
(d) lockable

13. Product testing, evaluation, and listing (product certification) shall be performed by ____.

(a) *recognized qualified electrical testing laboratories*
(b) *the manufacturer*
(c) *qualified person*
(d) *electrical engineer*

14. Wiring shall be installed so that the completed system will be free from _____ other than as required or permitted elsewhere in the *Code*.

(a) short circuits
(b) ground faults
(c) connections to the earth
(d) all of these



15. Unused openings other than those intended for the operation of equipment, intended for mounting purposes, or permitted as part of the design for listed equipment shall be _____.

(a) filled with cable clamps or connectors only
(b) taped over with electrical tape
(c) repaired only by welding or brazing in a metal slug
(d) closed to afford protection substantially equivalent to the wall of the equipment

16. For circuits rated 100A or less, when the equipment terminals are listed for use with 75-degree C conductors, the _____ column of Table 310.16 shall be used to determine the ampacity of THHN conductors.

(a) 30° C
(b) 60° C
(c) 75° C
(d) 90° C

17. NFPA 70E, *Standard for Electrical Safety in the Workplace*, provides guidance for working space about electrical equipment, such as determining severity of potential exposure, planning safe work practices, arc-flash labeling, and selecting personal protective equipment.

(a) True
(b) False

18. The working space in front of the electric equipment shall not be less than _____ wide, or the width of the equipment, whichever is greater.

(a) 15 in.
(b) 30 in.
(c) 40 in.
(d) 60 in.

CHAPTER 2—WIRING AND PROTECTION

19. The terminals that must be connected to a neutral conductor are required to be identified with a white finish or with what other color?

(a) clear
(b) grey
(c) silver
(d) gold

20. GFCI protection is required for 15A and 20A, 125-volt, single-phase receptacles in dwelling unit kitchens that are _____.

(a) installed to serve the countertop surfaces
(b) within 6 ft from the top inside edge of the bowl of the sink
(c) for all receptacles
(d) installed to serve the countertop surfaces and within 6 ft from the top inside edge of the bowl of the sink

21. Two or more _____ small-appliance branch circuits must be provided to supply power for receptacle outlets in the dwelling unit kitchen, dining room, breakfast room, pantry, or similar dining areas.

(a) 15A
(b) 20A
(c) auxiliary
(d) supplemental

22. One or more 120-volt, 15-ampere branch circuit must be provided to supply bathroom(s) receptacle outlets as required by 210.52(D).

(a) True
(b) False

23. The required heating, air-conditioning, and refrigeration equipment receptacle outlet shall be located _____ the equipment.

(a) 6 ft above
(b) not over 8 ft from
(c) on
(d) on the same level

24. The required receptacle outlet for heating, air-conditioning, and refrigeration equipment shall not be connected to the load side of the equipment disconnect and shall provide ground-fault protection for personnel.

(a) True
(b) False

25. Receptacle outlets in meeting room fixed walls shall be installed in accordance with _____.

(a) 210.52(A)(1)
(b) 210.52(A)(1) and (A)(2)
(c) 210.52(A)(1) through (A)(3)
(d) 210.52(A)(1) through (A)(4)

26. Feeder grounded conductors that are not connected to an overcurrent device shall be permitted to be sized at _____ percent of the continuous and noncontinuous load.

(a) 80%
(b) 100%
(c) 115%
(d) 125%

27. The minimum clearance for overhead feeder conductors not exceeding 1,000V that pass over commercial areas subject to truck traffic is _____ ft.

(a) 10
(b) 12
(c) 15
(d) 18

28. Where more than one feeder is installed to a building in accordance with 225.30(B), all feeder disconnects in the building shall be grouped in the same location.

(a) True
(b) False

29. For installations consisting of not more than two 2-wire branch circuits, the building disconnecting means shall have a rating of not less than _____.

(a) 15A
(b) 20A
(c) 25A
(d) 30A

30. Overhead service-entrance cables shall be equipped with a _____.

(a) raceway
(b) service head
(c) cover
(d) all of these

Straight Order | Final Exam A

31. Individual meter socket enclosures are not considered service equipment. Therefore, they must be _____ for the voltage level and capacity involved.

(a) listed and rated
(b) labeled and approved
(c) inspected and rated
(d) suitable

32. In one- and two-family residences, all service conductors must terminate at an emergency disconnecting means located where the short-circuit current rating is equal to or greater than the _____, installed in a readily accessible outdoor location.

(a) demand load
(b) peak demand load
(c) available fault current
(d) service conductor rating

33. When fuses function as the service overcurrent device, the disconnecting means must be placed ahead of the supply side of the fuses in accordance with 230.91.

(a) True
(b) False

34. Per 230.95, the rating of the service disconnect must be determined by the rating of the largest _____ that can be installed, or by the highest continuous current setting of the device (if a circuit breaker is used), whichever value is rated or adjustable.

(a) fuse
(b) circuit
(c) conductor
(d) all of these

35. The standard ampere ratings for fuses include _____.

(a) 1A
(b) 6A
(c) 60A
(d) all of these

36. For adjustable-trip circuit breakers, restricted access is defined as _____.

(a) located behind bolted equipment enclosure doors
(b) located behind locked doors accessible only to qualified personnel
(c) password protected, with password accessible only to qualified personnel
(d) any of these

37. Outside secondary conductors can be of unlimited length without overcurrent protection at the point they receive their supply if the conductors _____.

(a) are protected from physical damage
(b) terminate at a single overcurrent device equal to or less than their ampacity
(c) the overcurrent device is part of the building disconnect
(d) all of these

38. Fuseholders for cartridge fuses should be selected so that if it is difficult to put a fuse of any given class into a fuseholder that is designed for a _____ lower or a _____ higher than that of the class to which the fuse belongs.

(a) voltage, wattage
(b) wattage, voltage
(c) voltage, current
(d) current, voltage

39. Molded-case circuit breakers are permitted to be reconditioned.

(a) True
(b) False

40. Grounded electrical systems shall be connected to earth in a manner that will _____.

(a) limit voltages due to lightning, line surges, or unintentional contact with higher-voltage lines
(b) stabilize the voltage-to-ground during normal operation
(c) facilitate overcurrent device operation in case of ground faults
(d) limit voltages due to lightning, line surges, or unintentional contact with higher-voltage lines, and stabilize the voltage-to-ground during normal operation

DEFINITIONS | From Michael Hamilton Publications

Final Exam A | Straight Order

41. In grounded systems, noncurrent-carrying conductive parts that enclose electrical conductors or equipment must be connected to earth to restrict the voltage-to-ground rise on those parts.

(a) True
(b) False

> ***Author's Commentary:*** *Bonding noncurrent-carrying metal parts to earth keeps stray voltage from appearing on exposed components.*
> *— Michael Hamilton*

42. The main bonding jumper is a wire or busbar that runs from the grounded conductor terminal or bus to the equipment grounding terminal or bus in the service equipment, and also to any location on the equipment grounding terminal, bar, or bus to which the main bonding jumper is attached.

(a) equipment grounding conductor
(b) grounded service conductor
(c) grounding electrode conductor
(d) system bonding jumper

43. Inside a separately derived system, the connection to the grounded conductor of that system shall be made using material that is—

(a) structural steel
(b) metal piping
(c) metal building skin
(d) structural steel and metal piping

44. For a separately fed building or structure by a feeder or branch circuit, the grounded conductor can act as the equipment return path, serving as the ground-fault return means for existing installations made using metallic raceways with previous editions of the Code as long as the conditions during installation still meet the requirement(s) that—

(a) *there are no continuous metallic paths between buildings and structures*
(b) *ground-fault protection of equipment is not installed on the supply side of the feeder*
(c) *the neutral conductor is no smaller than the larger of 220.61 or 250.122*
(d) *all of these*

45. *Grounding electrodes of the rod type that are less than _____ inch in diameter shall be listed.*

(a) ½
(b) ⅝
(c) ¾
(d) 1

> ***Author's Commentary:*** *Smaller diameter rods can vary in quality; listing ensures they meet safety and performance standards.*
> *— Michael Hamilton*

46. Swimming pool structures and structural _____ [680.26(B)(1) and (B)(2)] shall not be used as a grounding electrode.

(a) reinforcing steel
(b) equipotential planes
(c) pool shells
(d) pool pump houses

> ***Author's Commentary:*** *These items aren't reliable grounding electrodes and aren't permitted by the Code for this purpose.*
> *— Michael Hamilton*

47. Two or more common grounding electrodes that are bonded together shall be treated as a single grounding electrode system in this context.

(a) True
(b) False

48. Buildings or other structures that receive power via multiple services or feeders must use the same _____ to connect grounding enclosures and equipment within or on that building.

(a) service
(b) disconnect
(c) *grounding electrode system*
(d) *any of these*

49. The wire-type grounding electrode conductor shall be _____.

(a) solid
(b) stranded
(c) *insulated or bare*
(d) *any of these*

50. Where used outdoors, aluminum or copper-clad aluminum grounding electrode conductors shall be buried no less than _____ inches into the earth.

(a) 6
(b) 12
(c) 15
(d) 18

51. Grounding electrode conductors must be installed in one unbroken length without splices or joints, unless joined by _____.

(a) *connecting together sections of a busbar*
(b) *irreversible compression-type connectors listed as grounding and bonding equipment*
(c) *the exothermic welding process*
(d) *any of these*

> ***Author's Commentary:*** *A continuous conductor is required for reliability unless an approved joining method listed for grounding and bonding is used.*
> *— Michael Hamilton*

Straight Order | Final Exam A

52. A service made up of 12 AWG service-entrance conductors requires a grounding electrode conductor that is no smaller than _____ AWG.

(a) 10
(b) 8
(c) 6
(d) 4

53. Mechanical parts used to terminate a grounding electrode conductor to a grounding electrode must be accessible.

(a) True
(b) False

54. The normally noncurrent-carrying metal components of service equipment, such as the service _____, must be bonded together.

(a) raceways or service cable armor
(b) equipment enclosures containing service conductors, including meter fittings, boxes, or the like, located in the service raceway or armor
(c) cable trays
(d) all of these

55. Supply-side bonding jumpers must not be smaller than the sizes given in _____.

(a) Table 250.102(C)(1)
(b) Table 250.122
(c) Table 310.16
(d) Table 250.66

56. A service is supplied by three metal raceways, each containing 600 kcmil ungrounded conductors. Determine the size of the copper supply-side bonding jumper needed for each service raceway.

(a) 1/0 AWG
(b) 3/0 AWG
(c) 250 kcmil
(d) 500 kcmil

57. The bonding jumper(s) needed for the metal water piping system(s) that is (are) installed in or attached to a building or structure supplied by a feeder(s) or branch circuit(s) must be sized in accordance with _____.

(a) 250.66
(b) 250.102(D)
(c) 250.122
(d) 310.16

58. Exposed structural metal interconnected to form a metal building frame that is not intentionally grounded or bonded and that is likely to become energized shall be bonded to the _____.

(a) service equipment enclosure or building disconnecting means
(b) grounded conductor at the service
(c) grounding electrode conductor where of sufficient size
(d) any of these

59. Listed FMC can be used as the equipment grounding conductor if the conduit does not exceed trade size _____.

(a) 1¼
(b) 1½
(c) 2
(d) 2¼

60. The armor of Type AC cable is recognized by the *NEC 2023* as an equipment grounding conductor.

(a) True
(b) False

61. Unless part of a suitable Chapter 3 cable wiring method, equipment grounding conductors of bare or covered copper-clad aluminum must be installed where subject to corrosion by conditions or be installed in direct contact with concrete, masonry, or the earth.

(a) True
(b) False

62. Electrical equipment secured to and in _____ contact with a metal rack or structure provided for its support shall be permitted to be considered as being connected to an equipment grounding conductor if the metal rack or structure is connected to an equipment grounding conductor by one of the means indicated in 250.134.

(a) electrical
(b) direct
(c) metal to metal
(d) mechanical

63. Receptacle yokes designed and _____ as self-grounding can, in conjunction with the supporting screws, establish the equipment bonding between the device yoke and a flush-type box.

(a) approved
(b) advertised
(c) listed
(d) installed

DEFINITIONS | From Michael Hamilton Publications

64. Connections, taps, or extensions made from paralleled conductors must be connected to every conductor in the paralleled set.

(a) True
(b) False

65. Cable wiring methods cannot be used as a means of support for _____.

(a) other cables
(b) raceways
(c) nonelectrical equipment
(d) all of these

CHAPTER 3—WIRING METHODS AND MATERIALS

66. When the opening to an outlet, junction, or switch point is smaller than 8 in. in any dimension, each conductor must extend at least _____ beyond the outside of the opening of the enclosure.

(a) 1
(b) 3
(c) 6
(d) 12

67. The number and size of conductors allowed in a raceway are limited to _____.

(a) heat that may be dissipated
(b) damage to insulation during installation
(c) damage to insulation when conductors are removed
(d) all of these

68. Conductors described in _____ are permitted for use in any of the wiring methods covered in Chapter 3 and as specified in their respective tables or elsewhere in the *2023 NEC®*.

(a) 310.4
(b) 310.10
(c) 310.15
(d) 310.20

69. Adjustment factors for conductors do not apply to conductors in raceways with a length that does not exceed _____.

(a) 12 in.
(b) 24 in.
(c) 36 in.
(d) 48 in.

70. Each cable entering a cutout box _____.

(a) shall be secured to the cutout box
(b) can be sleeved through a chase
(c) shall have a maximum of two cables per connector
(d) all of these

71. Screws used for fastening covers or other equipment to the box must be either machine screws with matching thread gauge and size that agrees with the box or in accordance with the manufacturer's instructions.

(a) True
(b) False

72. When a straight, angle, or 'U' pull is made, the distance between raceways must be increased by adding extra entries. This increase equals the total of the diameters of all other raceway entries in the same row on the same wall of the box. Each row shall be calculated separately, and the single row that yields the maximum distance shall be used.

(a) junctions
(b) transitions
(c) taps
(d) splices

73. All _____ must be provided with covers that are compatible with the box or conduit body construction and suitable for the conditions of use.

(a) pull boxes
(b) junction boxes
(c) conduit bodies
(d) all of these

74. Type MC cable must not be used under which of the following conditions?

(a) Where it is subject to physical damage.
(b) When buried directly in earth or embedded in concrete unless it is identified for direct burial.
(c) When exposed to cinder fills, strong chlorides, caustic alkalis, or vapors of chlorine or hydrochloric acids.
(d) all of these

DEFINITIONS | From Michael Hamilton Publications

75. A run of IMC shall not contain more than the equivalent of quarter bend(s) between pull points such as conduit bodies and boxes.

(a) one
(b) two
(c) three
(d) four

76. Running threads shall not be used on IMC for connection at couplings.

(a) True
(b) False

77. Where RMC enters a box, fitting, or other enclosure, ____ shall be provided to protect the wire from abrasion, unless the design of the box, fitting, or enclosure affords equivalent protection.

(a) a bushing
(b) duct seal
(c) electrical tape
(d) seal fittings

78. FMC to a luminaire or electrical equipment within an accessible ceiling is permitted to be unsupported for not more than 6 ft from the last point where the raceway is securely fastened, including securement and support by listed FMC fittings.

(a) True
(b) False

79. LFMC shall not be required to be secured or supported where fished between access points through _____ spaces in finished buildings or structures and supporting is impractical.

(a) concealed
(b) exposed
(c) hazardous
(d) completed

80. When a building is supplied with a fire sprinkler system, ENT can be installed above any suspended ceiling.

(a) True
(b) False

81. A surface metal raceway is a metal raceway that is intended to be mounted to the surface of a structure, with associated couplings, connectors, boxes, and fittings for the installation of electrical conductors.

(a) True
(b) False

82. A box is not required where conductors or cables in cable tray transition to a raceway wiring method from a cable tray.

(a) True
(b) False

CHAPTER 4—EQUIPMENT FOR GENERAL USE

83. Flexible cords and power-supply cords shall not be concealed behind building _____, or run through doorways, windows, or similar openings.

(a) structural ceilings
(b) suspended or dropped ceilings
(c) floors or walls
(d) all of these

84. Snap switches, dimmers, and control switches are considered to be part of the effective ground-fault current path when _____.

(a) the switch is connected to the intersystem bonding termination
(b) the switch is mounted with metal screws to a metal box or a metal cover that is connected to an equipment grounding conductor
(c) an equipment grounding conductor or equipment bonding jumper is connected to the equipment grounding termination of the snap switch
(d) the switch is mounted with metal screws to a metal box or a metal cover that is connected to an equipment grounding conductor or an equipment grounding conductor or equipment bonding jumper is connected to the equipment grounding termination of the snap switch

85. Receptacles mounted in boxes set back from the finished surface shall be installed so that the mounting _____ of the receptacle is held rigidly at the finished surface.

(a) screws
(b) yoke or strap
(c) cover plate
(d) grounding clip

DEFINITIONS | From Michael Hamilton Publications

86. Receptacles mounted in boxes flush with the finished surface or projecting beyond it shall be installed so that the mounting yoke or strap of the receptacle is held rigidly against the _____.

(a) box or box cover
(b) faceplate
(c) the finished surface
(d) bonding connection

87. Receptacle assemblies for installation in countertop surfaces shall be _____ for countertop applications.

(a) identified
(b) labeled
(c) listed
(d) approved

88. Nonlocking 15A and 20A, 125V and 250V receptacles installed in damp locations shall be listed as _____.

(a) rain-tight
(b) watertight
(c) weatherproof
(d) weather resistant

89. Where tamper resistance receptacles are required, receptacles located more than _____ above the floor shall not be required to be tamper resistant.

(a) 4 ft
(b) 5 ft
(c) 5½ ft
(d) 6 ft 7 in

90. Where a panelboard is supplied through a transformer, the overcurrent protection shall be located _____.

(a) at the main distribution panel
(b) on the primary side of the transformer
(c) on the secondary side of the transformer
(d) on either the primary or secondary side of the transformer

91. Luminaires attached to the framing members of a suspended ceiling shall be secured to the framing member(s) by mechanical means such as _____.

(a) bolts
(b) screws
(c) rivets
(d) any of these

92. The ampacities of branch circuit conductors for appliances shall not be less than the marked rating of the _____.

(a) receptacle outlet
(b) appliance
(c) over-current protection device
(d) power cord

93. If a branch circuit supplies a single nonmotor-operated appliance, the rating of overcurrent protection shall not exceed _____ percent of the appliance rated current if the overcurrent protection rating is not marked and the appliance is rated over 13.3A.

(a) 100
(b) 125
(c) 150
(d) 160

94. The branch-circuit overcurrent device and conductors for fixed storage-type water heaters that have a capacity of 120 gal or less shall be sized not smaller than _____ percent of the rating of the water heater.

(a) 80%
(b) 115%
(c) 125%
(d) 150%

95. Where the flexible cord for a built in dishwasher passes through an opening, it shall be protected against damage by a(an) _____.

(a) bushing
(b) grommet
(c) approved means
(d) any of these

Author's Commentary:

Definitions are the building blocks of the NEC. Mastering these key terms and their requirements ensures safe, code-compliant installations and helps you avoid costly mistakes in the field.

— Michael Hamilton

DEFINITIONS | From Michael Hamilton Publications

Straight Order | Final Exam A

96. Ceiling-suspended (paddle) fans shall be supported independently of an outlet box or by a listed _____.

(a) outlet box or listed outlet box system identified for the use and installed in accordance with 314.27(C)

(b) outlet box system, a listed locking support and mounting receptacle, and a compatible factory installed attachment fitting designed for support, identified for the use and installed in accordance with 314.27(E)

(c) mounting means directly to the structural member for use without an outlet box

(d) outlet box or listed outlet box system identified for the use and installed in accordance with 314.27(c) or outlet box system, a listed locking support and mounting receptacle, and a compatible factory installed attachment fitting designed for support, identified for the use and installed in accordance with 314.27(E)

97. For cord-and-plug (or attachment fitting-) connected appliances, a(n) _____ plug (or attachment fitting) and receptacle combination shall be permitted to serve as the disconnecting means.

(a) labeled

(b) accessible

(c) metal enclosed

(d) none of these

Author's Commentary:

Make sure you understand when a cord-and-plug set is permitted to act as the disconnect. The code requires it to be accessible and suitable for the appliance. This is a common exam topic.

— Michael Hamilton

98. A motor can be provided with combined overcurrent protection using a single protective device to provide branch-circuit protection where the rating of the device provides the overload protection specified in 430.32.

(a) short-circuit

(b) ground-fault

(c) motor overload

(d) all of these

99. A _____ rated in amperes shall be permitted as a controller for all motors.

(a) branch-circuit inverse time circuit breaker or molded case switch

(b) dual-element time-delay fuse

(c) snap switch

(d) GFCI protected device

100. An individual disconnecting means shall be provided for each motor controller and be located _____ from the controller location.

(a) in sight

(b) within 3 ft

(c) within 10 ft

(d) within 25 ft

Author's Commentary:

Always know the maximum allowed distance for a disconnect from its controller. The answer choices test your memorization of Code spacing requirements.

— Michael Hamilton

FINAL EXAM

B

RANDOM ORDER

Please use the *2023 Code* book to answer the following questions.

1. When determining the number of current–carrying conductors, a grounding or bonding conductor shall not be counted when applying the provisions of 310.15(C)(1).
(a) True
(b) False

2. Type _____ cable is a fabricated assembly of insulated conductors in a flexible interlocked metallic armor.
(a) AC
(b) TC
(c) NM
(d) MC

3. The disconnecting means for air–conditioning and refrigerating equipment shall be readily accessible and not more than _____ from the air–conditioning or refrigerating equipment.
(a) 3 ft.
(b) 10 ft.
(c) 25 ft.
(d) 50 ft.

4. "Where equipment, other than service equipment, requires dedicated equipment space as specified in 110.26(E), the required receptacle outlet shall be located within _____ the electrical equipment."
(a) the same room or area as
(b) or adjacent to
(c) sight of
(d) or below

5. Type USE cable is permitted for _____ wiring.
(a) underground
(b) interior
(c) aerial
(d) above ground installations

6. Track lighting shall not be installed _____.
(a) where likely to be subjected to physical damage
(b) in wet or damp locations
(c) where concealed
(d) all of these

7. When normally enclosed live parts are exposed for inspection or servicing, the working space, if in a passageway or general open space, shall be suitably _____.
(a) accessible
(b) guarded
(c) open
(d) enclosed

8. For a single separately derived system, the grounding electrode conductor connects the grounded conductor of the derived system to the grounding electrode at the same point on the separately derived system where the _____ is connected.
(a) metering equipment
(b) transfer switch
(c) system bonding jumper
(d) largest circuit breaker

DEFINITIONS From Michael Hamilton Publications

Final Exam B

9. All 125V through 250V receptacles installed in crawl spaces at or below grade level of dwelling units, and supplied by single-phase branch circuits rated 150V or less to ground, shall have GFCI protection for personnel.
   (a) True
   (b) False

10. Metal water piping systems and structural metal that is interconnected to form a building frame shall be bonded to separately derived systems in accordance with 250.104(D)(1) through 250.104(D)(3).
   (a) True
   (b) False

11. Where a building has multiple feeders, a permanent _____ shall be installed at each feeder disconnect location denoting all other services and feeders and the area served by each.
   (a) plaque or directory
   (b) map
   (c) label
   (d) guide

12. Service heads on raceways or service-entrance cables and goosenecks in service-entrance cables shall be located _____ the point of attachment, unless impracticable.
   (a) above
   (b) below
   (c) even with
   (d) any of these

13. The grounding electrode conductor connection shall be made at any accessible point from the load end of the overhead service conductors, _____ to, including the terminal or bus to which the grounded service conductor is connected at the service disconnecting means.
   (a) service drop
   (b) underground service conductors
   (c) service lateral
   (d) any of these

14. A listed exposed work cover can be the grounding and bonding means when the device is attached to the cover with at least _____ permanent fastener(s) and the cover mounting holes are located on a non-raised portion of the cover.
   (a) one
   (b) two
   (c) three
   (d) four

15. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction are said to be "_____."
   (a) boxed
   (b) a digest
   (c) a manifest
   (d) listed

16. When non-grounding-type receptacles are replaced by GFCI-type receptacles where attachment to an equipment grounding conductor does not exist in the receptacle enclosure, _____ shall be marked "No Equipment Ground."
   (a) these receptacles
   (b) their cover plates
   (c) the branch circuit
   (d) these receptacles or their cover plates

17. In other than dwelling locations, GFCI protection is required for all single-phase receptacles rated 150V to ground or less, 50A or less and three-phase receptacles rated 150V to ground or less, 100A or less in unfinished portions or areas of the basement.
   (a) True
   (b) False

18. Where dwelling unit service equipment is replaced, a surge protective device, (SPD), shall be installed.
   (a) True
   (b) False

19. Receptacles mounted to and supported by a cover shall be secured by more than one screw unless listed and identified for securing by a single screw.
   (a) True
   (b) False

20. A device that provides a means to connect intersystem bonding conductors for _____ systems to the grounding electrode system is an "intersystem bonding termination."
   (a) limited-energy
   (b) low-voltage
   (c) communications
   (d) power and lighting

AUTHOR'S COMMENTARY:

Master the definitions—they're the building blocks of the Code. Know these terms and you'll interpret the rules with confidence on the job and on the exam.

— Michael Hamilton

21. Premises wiring includes _____ wiring from the service point or power source to the outlets.
    (a) interior
    (b) exterior
    (c) underground
    (d) interior and exterior

22. Aluminum or copper-clad aluminum conductors external to buildings or equipment enclosures shall not be terminated within _____ of the earth.
    (a) 12 in.
    (b) 16 in.
    (c) 18 in.
    (d) 24 in.

23. Each service disconnecting means shall be permanently _____ to identify it as a service disconnect.
    (a) identified
    (b) positioned
    (c) marked
    (d) arranged

24. Part IV of Article 430 specifies devices intended to protect against overcurrent due to short circuits or ground faults.
    (a) motor branch-circuit conductors
    (b) motor control apparatus
    (c) motors
    (d) all of these

25. A meeting room with any floor dimension that is _____ ft or greater in any direction and that has a floor area of at least 215 sq ft shall have at least one floor receptacle outlet.
    (a) 8
    (b) 10
    (c) 12
    (d) 15

26. The grounding electrode conductor shall be permitted to be run to any _____ available in the grounding electrode system.
    (a) panelboards
    (b) bonding jumper
    (c) switchgear
    (d) convenient grounding electrode

27. When a building is supplied with a(n) _____ fire sprinkler system, ENT shall be permitted to be used within walls, floors, and ceilings, exposed or concealed, in buildings exceeding three floors above grade.
    (a) listed
    (b) identified
    (c) NFPA 13
    (d) NFPA 72

28. Ungrounded alternating-current systems from 50V to less than 1,000V shall be legibly marked "Caution: Ungrounded System—Operating _____ Volts Between Conductors" at _____ of the system, with sufficient durability to withstand the environment involved.
    (a) the source
    (b) the first disconnecting means
    (c) every junction box
    (d) the source or the first disconnecting means

29. A building disconnecting means that supplies only limited loads of a single branch circuit shall have a rating of not less than _____.
    (a) 15A
    (b) 20A
    (c) 25A
    (d) 30A

30. Meter sockets supplied by and under the exclusive control of an electric utility shall not be required to be _____ in accordance with 230.66.
    (a) approved
    (b) rated
    (c) listed
    (d) all of these

31. Grounding electrode conductors and grounding electrode bonding jumpers in contact with _____ shall not be required to comply with 300.5 but shall be buried or otherwise protected if subject to physical damage.
    (a) water
    (b) the earth
    (c) metal
    (d) all of these

Random Order | Final Exam B

32. As applied to wiring methods, "on or attached to the surface, or behind access panels designed to allow access" is known as _____.

(a) open
(b) uncovered
(c) exposed
(d) bare

Author's Commentary:
These terms describe how wiring is installed or made accessible.
— Michael Hamilton

33. Outside branch circuits and feeders shall not be installed beneath openings through which materials may be moved and shall not be installed where they will obstruct entrance to these buildings' openings.

(a) True
(b) False

Author's Commentary:
This rule prevents physical damage to conductors and keeps doorways and loading areas clear.
— Michael Hamilton

34. The equipment grounding conductor terminal bar of a dry-type transformer shall be bonded to the enclosure in accordance with 250.12 and shall not be installed on or over any _____.

(a) ungrounded conductor terminations
(b) transformer coils or windings
(c) vented portion of the enclosure
(d) all of these

Author's Commentary:
The grounding terminal must be isolated from live parts and not placed above vents where moisture could enter.
— Michael Hamilton

35. Lighting outlets in guest rooms or guest suites shall be permitted to be controlled by occupancy sensors that are located at a customary wall switch location and equipped with a manual override that allows the sensor to function as a wall switch.

(a) True
(b) False

Author's Commentary:
This permits convenience and energy savings while still allowing manual control.
— Michael Hamilton

36. Raceways on exteriors of buildings or other structures shall be arranged to drain and shall be _____ for use in wet locations.

(a) labeled
(b) listed
(c) approved
(d) b or c

Author's Commentary:
Listed or approved raceways are designed and identified for wet-location use.
— Michael Hamilton

37. "Utilization equipment" is equipment that utilizes electricity for _____ purposes.

(a) electromechanical
(b) heating
(c) lighting
(d) any of these

Author's Commentary:
Any device that converts electrical energy into mechanical, thermal, or light output is utilization equipment.
— Michael Hamilton

38. Where a building or structure contains more than one service disconnect in separate enclosures, grounding electrode conductor connections shall be permitted to be _____.

(a) multiple individual grounding electrode conductors
(b) one grounding electrode conductor at a common location
(c) a common grounding electrode conductor and taps
(d) any of these

Author's Commentary:
A variety of grounding electrode conductor arrangements are allowed in this situation.
— Michael Hamilton

39. PVC conduit shall not be used _____, unless specifically permitted.

(a) in hazardous (classified) locations
(b) for the support of luminaires or other equipment
(c) where subject to physical damage unless identified for such use
(d) all of these

Author's Commentary:
PVC conduit has limitations in harsh environments, as structural support, and in areas exposed to impact.
— Michael Hamilton

40. The selection and installation of overcurrent protective devices so that an overcurrent condition will be localized to restrict outages to the circuit or equipment affected, is called "_____".

(a) overcurrent protection
(b) interrupting capacity
(c) selective coordination
(d) overload protection

Author's Commentary:
Coordinating protective devices limits the extent of an outage and improves system reliability.
— Michael Hamilton

41. Service equipment labeling in other than dwelling units shall not be required if an arc-flash label is applied in accordance with _____ industry practice.

(a) routine
(b) acceptable
(c) documented
(d) manufacturing

Author's Commentary:
Using an arc-flash label that meets industry practice may satisfy the service labeling requirement.
— Michael Hamilton

42. LFNC shall be permitted for _____.

(a) direct burial where listed and marked for the purpose
(b) exposed work
(c) outdoors where listed and marked for this purpose
(d) all of these

Author's Commentary:
LFNC cable may be used in underground, exposed, and outdoor installations when appropriately listed.
— Michael Hamilton

43. Equipment not _____ for outdoor use or identified for indoor use such as "dry locations" or "indoor use only", shall be protected against damage from the weather during construction.

(a) listed
(b) identified
(c) suitable
(d) marked

Author's Commentary:
Equipment not intended for outdoor conditions must be shielded from rain, snow, and other weather.
— Michael Hamilton

44. Weather-resistant receptacles are installed at outlet locations that the *Code* requires to be protected so that no other area installation is needed.

(a) shall be provided
(b) are not required
(c) are optional
(d) are not allowed

45. At the end of a cable tray raceway, an accessible cable tray clamp or adaptor must be used to fasten the raceway securely to the cable tray system.

(a) listed
(b) approved
(c) identified
(d) marked

46. Service-entrance conductors must run continuously without splices or taps.

(a) True
(b) False

47. A surge protective device (SPD) that is required for a dwelling unit must be a permanent part of the service equipment or located right next to it and cannot be installed downstream on the panelboard.

(a) True
(b) False

48. The least point of attachment for overhead service *conductors on a building shall be no lower than* _____ *feet above the finished grade.*

(a) 8
(b) 10
(c) 12
(d) 15

49. When more than one motor disconnect is supplied from the same motor branch circuit, at least one *disconnecting means must be readily accessible.*

(a) True
(b) False

50. *Service conductors begin at the service point and end at the service disconnecting means.*

(a) True
(b) False

51. Raceways, cable armor, and cable sheaths are required to maintain continuity between enclosures, cabinetry, fittings, or other enclosures or outlet boxes.

(a) mechanical
(b) physical
(c) effective
(d) electrical

52. Extra services are allowed for a single building or another structure if the load is large enough to warrant two or more services by permission from _____.

(a) the registered design professional
(b) special permission
(c) the engineer of record
(d) master electricians

53. Framing members must not be used to support raceways, rigid metal conduit (RMC), or any type of metal conduit. Fasten these components within each outlet box, junction box, device box, cabinet, or conduit termination.

(a) 3 ft
(b) 4 ft
(c) 5 ft
(d) 6 ft

54. Because Class 3 control circuits can use higher voltage levels and current than Class 2 circuits, additional _____ *are specified to protect against electric shock hazards.*

(a) circuits
(b) safeguards
(c) conditions
(d) requirements

55. *Besides dwellings, a ground-fault circuit interrupter (GFCI) protection is required for receptacles installed in* _____.

(a) kitchens
(b) *unfinished areas of basements*
(c) laundry areas
(d) *all of these*

DEFINITIONS | From Michael Hamilton Publications

56. Receptacles shall not be installed within a zone measured 3 ft horizontally and _____ vertically from the top of the bathtub rim or shower stall threshold.
    (a) 6 ft
    (b) 6 ft 7 in.
    (c) 7 ft
    (d) 8 ft

57. In bathrooms with less than the required zone required by 406.9(C), the receptacle(s) can be installed opposite the bathtub rim or shower stall threshold on the farthest wall within the room.
    (a) True
    (b) False

58. The dedicated space above a panelboard extends to a dropped or suspended ceiling, which is considered a structural ceiling.
    (a) True
    (b) False

59. A grounded circuit conductor is permitted to ground noncurrent-carrying metal parts of equipment, raceways, and other enclosures on the supply side or within the enclosure of the ac service disconnecting means.
    (a) True
    (b) False

60. Tightening torque values for terminal connections shall be as indicated on equipment or in installation instructions provided by the manufacturer. An approved means shall be used to achieve the _____ torque value.
    (a) indicated
    (b) identified
    (c) maximum
    (d) minimum

61. When service equipment is required to be field marked with the available fault current, the value of available fault current for use in determining appropriate minimum short-circuit current ratings of service equipment is available from _____ in published or other forms.
    (a) architect
    (b) engineer
    (c) electric utilities
    (d) all of these

62. Type 1 SPDs shall be permitted to be connected as specified in 242.14.
    (a) True
    (b) False

63. Receptacles installed in bathrooms within six feet of the outside edge of a _____ shall have GFCI protection.
    (a) bathtub or shower stall
    (b) bidet
    (c) toilet
    (d) window opening

64. Overcurrent devices shall not be located _____.
    (a) where exposed to physical damage
    (b) near easily ignitable materials, such as in clothes closets
    (c) in bathrooms of dwelling units
    (d) all of these

65. A buried iron or steel plate used as a grounding electrode shall expose not less than _____ sq ft of surface area to exterior soil.
    (a) 2
    (b) 4
    (c) 9
    (d) 10

66. Metal piping, including gas piping shall be considered bonded by the equipment grounding conductor for the circuit that is likely to energize the piping system.
    (a) True
    (b) False

67. "Outline lighting" is an arrangement of _____ to outline or call attention to the shape of a building.
    (a) incandescent lamps
    (b) electric-discharge lighting
    (c) electrically powered light sources
    (d) any of these

68. Raceways entering from outside shall be sealed with a product identified for use with the _____ insulation.
    (a) conductor
    (b) cable
    (c) raceway interior
    (d) conductor or cable

DEFINITIONS | From Michael Hamilton Publications

69. "Overhead system service-entrance conductors" are the service conductors that run between the terminals of the _____ and a location where they are joined by a tap or splice to the service drop or overhead service conductors.

(a) service equipment
(b) service point
(c) grounding electrode
(d) equipment grounding conductor

70. For circuits supplying loads consisting of motor-operated utilization equipment that is fastened in place and has a motor larger than _____ in combination with other loads, the total calculated feeder load shall be based on 125 percent of the largest motor load plus the sum of the other loads.

(a) ½ hp
(b) ¼ hp
(c) ½ hp
(d) ⅛ hp

71. Surge protective devices shall be listed.

(a) True
(b) False

72. The metal mounting yoke of a replacement switch is not required to be connected to an equipment grounding conductor if the wiring at the existing switch does not contain an equipment grounding conductor, and the _____

(a) switch faceplate is metallic and installed with nonmetallic screws
(b) circuit is GFCI protected
(c) the switch is mounted to a nonmetallic box
(d) circuit is AFCI protected

73. Receptacle outlet assemblies _____ for use in countertops or work surfaces are permitted to be installed in countertops or work surfaces.

(a) listed
(b) labeled
(c) identified
(d) all of these

Author's Commentary: *Use only assemblies that are listed and intended for countertop or work surface installations. Identification or labeling is not what the Code requires—look for a listing that permits this specific use.*

— Michael Hamilton

74. Service raceways threaded into metal service equipment such as bosses (hubs) are considered to be effectively _____ to the service metal enclosure.

(a) attached
(b) bonded
(c) grounded
(d) secured

75. For equipment rated 800A or more that contains overcurrent devices, switching devices, or control devices; and where the entrance to the working space has a personnel door(s) less than 25 ft from the nearest edge of the working space, the door shall _____.

(a) open either in or out with simple pressure and shall not have any lock
(b) open in the direction of egress and be equipped with listed panic hardware
(c) be equipped with a locking means
(d) be equipped with an electronic opener

76. In dwelling units, when determining the spacing of receptacle outlets, _____ on exterior walls shall not be considered wall space.

(a) fixed panels
(b) fixed glass
(c) sliding panels
(d) all of these

77. Where appliances are likely to be used simultaneously, each 1 ft (or fraction thereof) of fixed multoutlet assembly is considered _____.

(a) 15A
(b) 90 VA
(c) 20A
(d) 180 VA

78. A "clothes closet" is defined as a _____ room or space intended primarily for storage of garments and apparel.

(a) habitable
(b) nonhabitable
(c) conditioned
(d) finished

Author's Commentary: *A clothes closet does not need to be a room people live in, and it does not have to be a finished or conditioned space. It's simply a space whose main purpose is to store clothing.*

— Michael Hamilton

Random Order | Final Exam B

79. Cables and conductors installed exposed on the surfaces of ceilings and sidewalls shall be secured by hardware including straps, staples, cable ties, hangers, or _____ designed and installed so as not to damage the cable.

(a) approved fittings
(b) identified fittings
(c) listed fittings
(d) similar fittings

80. Article 348 covers the use, installation, and construction specifications for flexible metal conduit (FMC) and associated _____.

(a) fittings
(b) connections
(c) terminations
(d) rating

81. When EMT is installed in wet locations, all supports, bolts, straps, and screws shall be _____.

(a) made of aluminum
(b) protected against corrosion
(c) made of stainless steel
(d) of nonmetallic materials only

82. Where equipment grounding is required, a separate equipment grounding conductor shall be installed in the Type PVC conduit except where the _____ is used to ground equipment as permitted in 250.142.

(a) grounding jumper
(b) grounded conductor
(c) bonding jumper
(d) bonded conductor

83. Wiring methods and equipment installed behind suspended-ceiling panels shall be arranged and secured to allow access to the electrical equipment.

(a) True
(b) False

84. Branch-circuit conductors for fixed electric space-heating equipment and any associated motors shall be sized not smaller than 150 percent of the load.

(a) True
(b) False

85. A _____ location is protected from weather and not subject to saturation with water or other liquids.

(a) dry
(b) damp
(c) wet
(d) moist

86. The 3 VA per-square-foot general lighting load for dwelling units does not include _____.

(a) finished basements
(b) finished attics
(c) unused or unfinished spaces not adaptable for future use
(d) utility rooms

87. A motor disconnecting means can be a listed _____.

(a) molded case circuit breaker
(b) motor-circuit switch rated in horsepower
(c) molded case switch
(d) any of these

88. The maximum rating or setting of an inverse time breaker used as the motor branch-circuit short-circuit and ground-fault protective device for a single-phase motor is _____ percent of the full-load current given in Table 430.248.

(a) 125
(b) 175
(c) 250
(d) 300

89. Lighting track shall not be installed less than _____ ft above the finished floor except where protected from physical damage or where the track operates at less than 30V rms, open-circuit voltage.

(a) 4
(b) 5
(c) 5½
(d) 6

90. Underground copper service conductors shall not be smaller than _____ AWG copper.

(a) 3
(b) 4
(c) 6
(d) 8

DEFINITIONS | From Michael Hamilton Publications

91. Electromechanical systems, equipment, apparatus, or components that are restored to operating conditions defines equipment that is or has been _____.
   (a) redeployed
   (b) redesigned
   (c) reconditioned
   (d) reassigned

92. Overcurrent protection shall not exceed _____.
   (a) 15A for 14 AWG copper
   (b) 20A for 12 AWG copper
   (c) 30A for 10 AWG copper
   (d) all of these

93. A Class A GFCI trips when the ground-fault current is _____ or higher.
   (a) 4 mA
   (b) 5 mA
   (c) 6 mA
   (d) 7 mA

94. An insulated or covered conductor _____ and larger shall be permitted, at the time of installation, to be permanently identified as an equipment grounding conductor at each end and at every point where the conductor is accessible.
   (a) 8 AWG
   (b) 6 AWG
   (c) 4 AWG
   (d) 1/0 AWG

95. IMC shall be secured _____.
   (a) by fastening within 3 ft of each outlet box, junction box, device box, cabinet, conduit body, or other conduit termination
   (b) within 5 ft of a box or termination fitting when structural members do not readily permit the raceway to be secured within 3 ft of the termination
   (c) except when the IMC is within 3 ft of the service head for an above-the-roof termination of a mast
   (d) any of these

96. Where a metal underground water pipe is used as a grounding electrode, the continuity of the grounding path or the bonding connection to interior piping shall not rely on _____ and similar equipment.
   (a) bonding jumpers
   (b) water meters or filtering devices
   (c) grounding clamps
   (d) all of these

97. Listed tamper-resistant receptacles shall be provided where replacements are made at receptacle outlets that are required to be tamper-resistant elsewhere in this *Code* except where a non-grounding receptacle is replaced with _____ receptacle.
   (a) an isolated
   (b) a GFCI-type
   (c) another non-grounding
   (d) any of these

98. When calculations in Article 220 result in a fraction of an ampere that is less than _____, such fractions can be dropped.
   (a) 0.49
   (b) 0.50
   (c) 0.51
   (d) 0.80

99. The *NEC* defines a(n) "_____" as a structure that stands alone or that is separated from adjoining structures by fire walls.
   (a) unit
   (b) apartment
   (c) building
   (d) utility

100. The conductors and equipment required or permitted by this Code shall be acceptable only if _____.
   (a) labeled
   (b) listed
   (c) approved
   (d) identified

DEFINITIONS | From Michael Hamilton Publications

The *National Electrical Code®* (*NEC®*) relies on precise meanings for many terms. Section 100 gathers and explains these definitions so that everyone speaks the same technical language. The definitions that follow are mandatory unless the *Code* provides a different, more specific meaning for a term within a particular *Article*.

100 DEFINITIONS

Words in the *NEC* are given the meanings shown here. These definitions apply throughout the *Code* unless a section states otherwise.

100.1 General

The *NEC* sets the scope and purpose of the rules found in Article 100 through Article 820. These rules cover wiring methods, equipment, and related practices. All installations must meet the requirements laid out in these Articles.

100.2 Electrical Terms

This section provides the meanings of electrical words used in the Code. Most of these come from standards organizations such as *ANSI* and *IEEE*.

100.3 Words and Expressions Defined

More than 140 key terms are defined in this part of Article 100. The definitions:

- Are mandatory throughout the Code.
- Remove ambiguity and support safe, consistent installations.
- Apply unless the Code gives a different meaning in a specific location.
- Serve as the foundation for accurate interpretation and enforcement.

Author's Commentary:
Understanding the *Code* begins with understanding its language. These definitions are the building blocks that make the entire *NEC* work the same way for everyone.

— Michael Hamilton

100.4 Application of the Terms

The terms in 100.3 control how the *Code* is applied. Unless the *NEC* says a word has a different meaning in a particular rule, the definitions in this Article take priority.

Study Tip:
When you learn the definitions, you strengthen your ability to read, apply, and enforce the *NEC* correctly and confidently.
Use these terms every day so they become second nature.

For complete definitions and recognized standards sources, refer to Article 100 in the **2023 *National Electrical Code*.**

INDEX

Description	Rule	Page
A		
Air-Conditioning and Refrigeration Equipment		
Conductor Sizing	440.33	595
Disconnect Location	440.14	593
Grounding and Bonding	440.9	593
Marking on Hermetic Refrigerant Motor-Compressors and Equipment	440.4	592
Short-Circuit and Ground-Fault Overcurrent Device Size	440.22	594
Appliances		
Branch Circuits	422.10	561
Central Heating Equipment	422.12	561
Central Vacuums	422.15	562
Disconnection of Cord-and-Plug-Connected Appliances	422.33	566
Disconnection—General	422.30	566
Flexible Cords	422.16	563
GFCI Protection	422.5	559
Listing Required	422.6	561
Other Articles	422.3	559
Outlet Boxes to be Covered	422.20	565
Overcurrent Protection	422.11	561
Permanently Connected Appliance Disconnects	422.31	565
Space for Conductors	422.19	565
Storage Water Heaters	422.13	561
Support of Ceiling-Suspended (Paddle) Fans	422.18	565
Armored Cable (Type AC)		
Bending Radius	320.24	407
Boxes and Fittings	320.40	409
Conductor Ampacity	320.80	409
Construction	320.100	410
Definition	320.2	405
Equipment Grounding Conductor	320.108	410
Exposed Work	320.15	406
In Accessible Attics or Roof Spaces	320.23	407
Listing Requirements	320.6	406
Securing and Supporting	320.30	408
Through or Parallel to Framing Members	320.17	406
Uses Not Permitted	320.12	406
Uses Permitted	320.10	406
B		
Branch Circuits		
Arc-Fault Circuit-Interrupter Protection	210.12	123
Branch Circuit Conductor Sizing	210.19	125
Branch Circuit Overcurrent Protection	210.20	128
Branch Circuits Required	210.11	121
Branch-Circuit Rating	210.18	124
Dwelling Unit Receptacle Outlet Requirements	210.52	131
Equipment Requiring Servicing Receptacle Outlet	210.63	139
GFCI Protection	210.8	114
Identification for Branch Circuits	210.5	112
Lighting Outlet Requirements	210.70	141
Meeting Rooms	210.65	140
Multiple Branch Circuits	210.7	114
Multiwire Branch Circuits	210.4	110
Permissible Loads, Multiple-Outlet Branch Circuits	210.23	130
Receptacle Outlets	210.50	130
Receptacle Rating	210.21	129
Receptacles in Guest Rooms, Guest Suites, and Dormitory Units	210.60	138
C		
Cabinets		
Damp or Wet Locations	312.2	377
Deflection of Conductors	312.6	380
Enclosures	312.5	378
Material	312.10	382
Overcurrent Device Enclosures	312.8	380
Position in Walls	312.3	378
Repairing Gaps in Noncombustible Surfaces	312.4	378

Description	Rule	Page
C CONDUCTORS		
Cable Trays		
Bushed Conduit and Tubing	392.46	496
Cable and Conductor Installation	392.20	496
Cable Splices	392.56	496
Cable Tray Installations	392.18	495
Definition	392.2	493
Equipment Grounding Conductor	392.60	497
Expansion Splice Plates	392.44	496
Securing and Supporting	392.30	496
Uses Not Permitted	392.12	495
Uses Permitted	392.10	493
Conductors for General Wiring		
Ampacities for Conductors Rated 0 V to 2,000 V	310.14	367
Ampacities of Insulated Conductors in Raceways, Cables, or Buried	310.16	375
Ampacity Tables	310.15	368
Conductor Construction and Application	310.4	358
Conductor Identification	310.6	361
Conductors	310.3	357
Single-Phase Dwelling Services and Feeders	310.12	364
Uses Permitted	310.10	361
D DEFINITIONS		
Definitions	100	21
E ELECTRICAL METALLIC TUBING (TYPE EMT)		
Bends	358.24	471
Couplings and Connectors	358.42	473
Definition	358.2	469
Equipment Grounding Conductor	358.60	473
Listing Requirements	358.6	470
Number of Bends (360°)	358.26	471
Number of Conductors	358.22	471
Reaming	358.28	471
Securing and Supporting	358.30	472
Trade Size	358.20	471
Uses Not Permitted	358.12	470
Uses Permitted	358.10	470
Electrical Nonmetallic Tubing (Type ENT)		
Bends	362.24	478
Bushings	362.46	479
Definition	362.2	475
Equipment Grounding Conductor	362.60	479
Joints	362.48	479
Listing	362.6	475
Number of Bends (360°)	362.26	478
Number of Conductors	362.22	477
Securing and Supporting	362.30	478
Trade Sizes	362.20	477
Trimming	362.28	478
Uses Not Permitted	362.12	477
Uses Permitted	362.10	475
F FEEDERS		
Feeders		
Feeder Conductor Identification	215.12	151
Feeder Conductor Sizing	215.2	145
Feeder Ground-Fault Protection of Equipment	215.10	151
Feeder Overcurrent Protection Sizing	215.3	150
Fixed Electric Space-Heating Equipment		
Branch Circuits	424.4	567
Disconnecting Means	424.19	568
Electric Heating Cables in Concrete or Masonry Floors	424.44	569
Location of Disconnecting Means for Electric Duct Heater Controllers	424.65	569
Other Articles	424.3	567
Fixture Wires		
Ampacity of Fixture Wires	402.5	513
Minimum Size	402.6	513
Neutral Conductor	402.8	514
Other Articles	402.2	513
Raceway Size	402.7	514
Types	402.3	513
Uses Not Permitted	402.12	515
Uses Permitted	402.10	514
Flexible Cords and Flexible Cables		
Ampacity of Flexible Cords and Flexible Cables	400.5	508
Protection from Damage	400.17	510
Pull at Joints and Terminals	400.14	510
Suitability	400.3	507
Types of Flexible Cords and Flexible Cables	400.4	508
Uses Not Permitted	400.12	509
Uses Permitted	400.10	508
Flexible Metal Conduit (Type FMC)		
Bends	348.24	449
Definition	348.2	447
Equipment Grounding and Bonding Conductors	348.60	450
Listing Requirements	348.6	447
Number of Bends (360°)	348.26	449

DEFINITIONS | From Michael Hamilton Publications

Description	Rule	Page
Number of Conductors	348.22	448
Securing and Supporting	348.30	449
Trade Size	348.20	448
Trimming	348.28	449
Uses Not Permitted	348.12	447
Uses Permitted	348.10	447

G

General Requirements

Approval of Conductors and Equipment	110.2	65
Arc Flash Hazard Warning	110.16	80
Available Fault Current	110.24	83
Boxes or Fittings	300.15	345
Conductor Material	110.5	66
Conductor Sizes	110.6	67
Conductor Termination and Splicing	110.14	72
Conductors	300.3	328
Deteriorating Agents	110.11	69
Electrical Continuity	300.10	340
Enclosure Types	110.28	92
Equipment Short-Circuit Current Rating	110.10	68
Exit Enclosures (Stair Towers)	300.25	355
High-Leg Conductor Identification	110.15	79
Identification of Disconnecting Means	110.22	82
Induced Alternating Currents in Ferrous Metal Parts	300.20	350
Inserting Conductors in Raceways	300.18	349
Interrupting Rating (Overcurrent Protective Devices)	110.9	68
Length of Free Conductors	300.14	344
Lockable Disconnecting Means	110.25	83
Markings	110.21	81
Mechanical and Electrical Continuity of Conductors, Splices and Pigtails	300.13	343
Mechanical Continuity	300.12	342
Mechanical Execution of Work	110.12	70
Mounting and Cooling of Equipment	110.13	72
Number and Size of Conductors in a Raceway	300.17	347
Panels Designed to Allow Access	300.23	355
Protection Against Corrosion and Deterioration	300.6	338
Protection Against Physical Damage	300.4	331
Raceways Exposed to Different Temperatures	300.7	339
Raceways in Wet Locations Above Grade	300.9	340
Securing and Supporting	300.11	341
Spaces About Electrical Equipment	110.26	84
Spread of Fire or Products of Combustion	300.21	352
Suitable Wiring Methods	110.8	67
Supporting Conductors in Vertical Raceways	300.19	350
Underground Installations	300.5	334
Use and Product Listing (Certification) of Equipment	110.3	65

Description	Rule	Page
Voltage Rating of Electrical Equipment	110.4	66
Wiring in Ducts and Plenum Spaces	300.22	353
Wiring Integrity	110.7	67

Generators

Ampacity of Conductors	445.13	600
Disconnecting Means and Emergency Shutdown	445.18	600
Listing	445.6	599
Marking	445.11	599

Grounding and Bonding

Bonding for Fault Current

Bonding Communications Systems	250.94	288
Bonding Equipment Containing Service Conductors	250.92	285
Bonding Loosely Joined Metal Raceways	250.98	291
Bonding Metal Parts Containing 277V and 480V Circuits	250.97	290
Bonding of Piping Systems and Exposed Structural Metal	250.104	293
Bonding Other Enclosures	250.96	289
General	250.90	285
Lightning Protection Systems	250.106	297
Neutral Conductor, Bonding Conductors, and Bonding Jumpers	250.102	291
Other Enclosures	250.86	285
Service Raceways and Enclosures	250.80	285

Equipment Grounding Conductors

Equipment Connected by Cord and Plug	250.114	298
Equipment Grounding Conductor Installation	250.120	304
Identification of Equipment Grounding Conductors	250.119	303
Metal Enclosures	250.109	298
Restricted Use of Equipment Grounding Conductors	250.121	304
Sizing Equipment Grounding Conductors	250.122	304
Types of Equipment Grounding Conductors	250.118	299

General

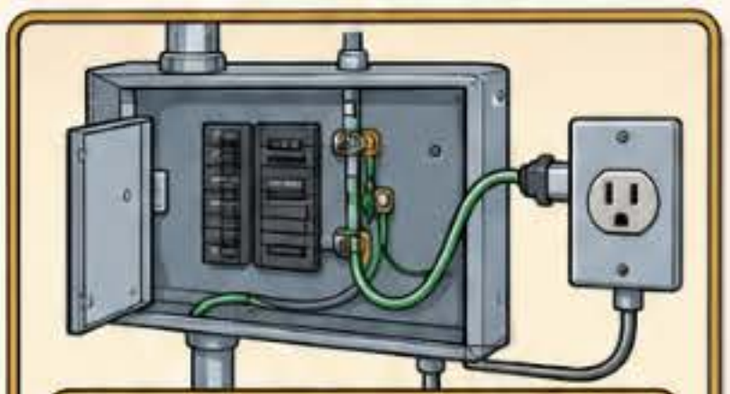
Clean Surfaces	250.12	246
Connection of Grounding and Bonding Connectors	250.8	246
Objectionable Current	250.6	242
Performance Requirements for Grounding and Bonding	250.4	236
Protection of Ground Clamps and Fittings	250.10	246

Grounding Electrode System

Auxiliary Grounding Electrodes	250.54	275
Common Grounding Electrode	250.58	276
Grounding Electrode Conductor	250.62	277
Grounding Electrode Conductor and Bonding Jumper Connection	250.68	282
Grounding Electrode Conductor Installation	250.64	277

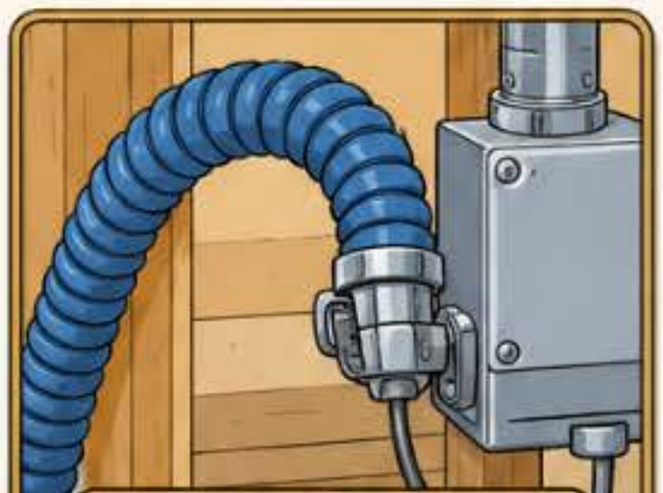
H | Index

Description	Rule	Page
(continued)		
Grounding Electrode Conductor Termination Fittings	250.70	284
Grounding Electrode Installation Requirements	250.53	270
Grounding Electrode System	250.50	267
Grounding Electrode Types	250.52	267
Sizing Grounding Electrode Conductor	250.66	281
Methods of Equipment Grounding Conductor Connections		
Receptacle to an Equipment Grounding Conductor	250.146	311
Equipment Grounding Conductors in Boxes	250.148	314
Cord-and-Plug-Connected Equipment Connected by Permanent Wiring Methods	250.138	309
	250.134	308
Equipment Secured to Grounded Metal Supports	250.136	309
Frames of Ranges, Ovens, and Clothes Dryers	250.140	309
Neutral Conductor for Effective Ground-Fault Current Path	250.142	310
System Grounding and Bonding		
Buildings Supplied by a Feeder	250.32	263
Generators—Portable and Vehicle- or Trailer-Mounted	250.34	265
Grounding	250.24	248
Grounding for Supply Side of the Service Disconnect	250.25	252
High-Impedance Grounded Systems	250.36	266
Main Bonding Jumper and System Bonding Jumper	250.28	253
Separately Derived Systems	250.30	254
Systems Required to be Grounded	250.20	247
Ungrounded Systems	250.21	248
H		
Intermediate Metal Conduit (Type IMC)		
Bends	342.24	436
Bushings	342.46	438
Couplings and Connectors	342.42	438
Definition	342.2	435
Dissimilar Metals	342.14	436
Equipment Grounding Conductor	342.60	439
Listing Requirements	342.6	436
Number of Bends (360°)	342.26	436
Number of Conductors	342.22	436
Reaming	342.28	436
Securing and Supporting	342.30	437
Trade Size	342.20	436
Uses Permitted	342.10	436
Introduction to the National Electrical Code		
Code Arrangement	90.3	11
Enforcement	90.4	12
Examination of Equipment for Product Safety	90.7	14
Mandatory Requirements and Explanatory Material	90.5	13
Purpose of the NEC	90.1	7
Scope of the NEC	90.2	8
L		
Liquidtight Flexible Metal Conduit (Type LFMC)		
Bends	350.24	453
Definition	350.2	451
Equipment Grounding and Bonding Conductors	350.60	454
Listing Requirements	350.6	451
Number of Bends (360°)	350.26	453
Number of Conductors	350.22	452
Securing and Supporting	350.30	453
Trade Size	350.20	452
Trimming	350.28	453
Uses Not Permitted	350.12	452
Uses Permitted	350.10	452
Liquidtight Flexible Nonmetallic Conduit (Type LFNC)		
Bends	356.24	467
Definition	356.2	465
Equipment Grounding Conductor	356.60	468
Fittings	356.42	467
Listing Requirements	356.6	465
Number of Bends (360°)	356.26	467
Number of Conductors	356.22	466
Securing and Supporting	356.30	467
Trade Size	356.20	466
Uses Not Permitted	356.12	466
Uses Permitted	356.10	465
Load Calculations		
Appliance Load, Dwelling	220.53	163
Clothes Dryer Demand Load, Dwelling	220.54	164
Cooking Appliances in Dwelling Units	220.55	165
Determining Existing Loads	220.87	172
Fixed Electric Space-Heating Load	220.51	162
Floor Area	220.11	154
General Lighting Demand Factors	220.42	160
Kitchen Equipment Load, Commercial	220.56	167
Lighting Load for Non-Dwelling Occupancies	220.12	155
Motor Type Loads	220.50	162
Motor-Operated Loads	220.18	160
Neutral Load	220.61	168
Noncoincident Loads	220.60	168
Optional Load Calculations, Dwellings	220.82	170
Optional Load Calculations, Multifamily	220.84	171
Optional Load Calculations, Two Dwelling Units	220.85	172
Other Loads—Occupancies	220.14	156



Equipment grounding conductor connected to outlet and metal enclosure.

Author's Commentary:
The Index is your roadmap through the NEC®. It points you to the exact rules you need when working on grounding, conduits, or load calculations. Learning to use it efficiently saves time—and helps you stay compliant in the field.
— Michael Hamilton



Liquidtight flexible metal conduit securely connected to equipment.

DEFINITIONS | From Michael Hamilton Publications

Description	Rule	Page
Receptacle Load, Other Than Dwelling Units	220.44	162
Show-Window and Track Lighting Loads, Commercial	220.43	161
Small-Appliance and Laundry Loads, Dwelling	220.52	162
Low-Voltage Lighting		
Listing Required	411.4	557
Low-Voltage Lighting Systems	411.3	557
Specific Location Requirements	411.5	558
Luminaires		
Connection of Electric-Discharge and LED Luminaires	410.24	549
Cord-Connected Luminaires	410.62	552
Definitions	410.2	546
Electric-Discharge Lighting	410.130	554
Equipment Grounding Conductor	410.44	552
Equipment Grounding Conductor Attachment	410.46	552
Luminaire Outlet Boxes to be Covered	410.22	549
Listing Required	410.6	546
Luminaires in Clothes Closets	410.16	548
Luminaires in Specific Locations	410.10	546
Means of Support	410.36	551
Recessed Luminaires Access to Other Boxes	410.118	554
Recessed Luminaires Clearance and Installation	410.116	553
Recessed Luminaires Temperature	410.115	553
Reconditioned Equipment	410.7	546
Track Lighting Fastening	410.154	555
Track Lighting Installation	410.151	554
Track Lighting Supports	410.30	551
M		
Metal Wireways		
Conductors Connected in Parallel	376.20	482
Construction	376.100	486
Definition	376.2	481
Number of Conductors and Ampacity	376.22	482
Splices, Taps, and Power Distribution Blocks	376.56	485
Supports	376.30	485
Uses Not Permitted	376.12	482
Uses Permitted	376.10	482
Wireway Sizing	376.23	484
Metal-Clad Cable (Type MC)		
Bending Radius	330.24	414
Conductor Ampacities	330.80	416
Definition	330.2	411
Equipment Grounding Conductor	330.108	417
Exposed Work	330.15	413
In Accessible Attics or Roof Spaces	330.23	413
Listing Requirements	330.6	412
Securing and Supporting	330.30	414
Through or Parallel to Framing Members	330.17	413
Uses Not Permitted	330.12	413
Uses Permitted	330.10	412
Motors, Motor Circuits, and Controllers		
Branch-Circuit Short-Circuit and Ground-Fault Protection	430.52	580
Combined Overcurrent Protective Device	430.55	581
Disconnect for Control Circuits	430.75	584
Disconnect Location	430.102	585
Disconnect Readily Accessible	430.107	586
Highest Rated Motor	430.17	573
Location of Motors	430.14	573
Motor Controller Horsepower Rating	430.83	584
Motor Feeder Protection	430.62	582
Overcurrent Protection for Control Circuits	430.72	584
Overload	430.31	576
Overload Sizing for Continuous-Duty Motors	430.32	577
Several Motors—Conductor Size	430.24	576
Single Motor Conductor Size	430.22	574
Table FLC versus Motor Nameplate Current Rating	430.6	572
Type of Disconnecting Means	430.109	586
Multioutlet Assemblies		
Through Partitions	380.76	487
Uses Not Permitted	380.12	487
Uses Permitted	380.10	487
N		
Neutral Conductors		
Identification of Neutral Conductors	200.6	105
Identification of Terminals	200.10	108
Means of Identification of Terminals	200.9	108
Neutral Conductor	200.4	104
Use of White or Gray Color	200.7	107
Nonmetallic-Sheathed Cable (Type NM)		
Accessible Attics and Roof Spaces	334.23	423
Bending Radius	334.24	423
Boxes and Fittings	334.40	424
Conductor Ampacity	334.80	425
Definition	334.2	419
Equipment Grounding Conductor	334.108	426
Exposed Work	334.15	421
Listing Requirements	334.6	419
Securing and Supporting	334.30	424
Through or Parallel to Framing Members	334.17	422
Uses Not Permitted	334.12	420
Uses Permitted	334.10	420

0 | Index

Description	Rule	Page
D		
Outlet, Junction Boxes, and Handhole Enclosures		
Conductors That Enter Boxes or Conduit Bodies	314.17	392
Covers and Canopies	314.25	397
Damp or Wet Locations	314.15	384
Flush-Mounted Box Installations	314.20	393
Handhole Enclosures	314.30	403
Metal Boxes	314.4	384
Nonmetallic Boxes	314.3	383
Outlet Box Requirements	314.27	398
Repairing Noncombustible Surfaces	314.21	393
Sizing Outlet Boxes	314.16	384
Sizing Pull and Junction Boxes	314.28	399
Support of Boxes	314.23	394
Surface Extensions	314.22	394
Wiring to be Accessible	314.29	403
Outside Circuits		
Attachment of Overhead Conductors	225.16	176
Clearance for Overhead Conductors	225.18	177
Clearances from Buildings	225.19	178
Disconnecting Means	225.31	181
Disconnecting Means Location	225.32	181
Grouping of Disconnects	225.34	182
Identification of Multiple Supplies	225.37	182
Masts as Supports	225.17	176
Maximum Number of Disconnects	225.33	181
Minimum Conductor Size and Support	225.6	175
Number of Supplies	225.30	180
Raceway Seals	225.27	180
Raceways on Exterior Surfaces of Buildings or Other Structures	225.22	179
Rating of Disconnecting Means	225.39	182
Trees for Conductor Support	225.26	179
Overcurrent Protection		
Arc Energy Reduction—Circuit Breakers	240.87	228
Arc Energy Reduction—Fuses	240.67	225
Circuit Breaker Indicating	240.81	226
Circuit Breaker Markings	240.83	226
Circuit Breaker Reconditioned Equipment	240.88	229
Circuit Breaker Series Ratings	240.86	228
Circuit Breaker Vertical Position	240.33	223
Disconnecting Means for Fuses	240.40	223
Edison-Base Fuses	240.51	224
Ground-Fault Protection of Equipment	240.13	214
Location of Overcurrent Protective Devices at Premises	240.24	221
Overcurrent Protection Location in Circuit	240.21	215
Overcurrent Protection of Conductors	240.4	209
Overcurrent Protection of Flexible Cords and Fixture Wires	240.5	213
Overcurrent Protection Standard Ampere Ratings	240.6	213
Phase Conductor Overcurrent Device	240.15	215
Supplementary Overcurrent Protection	240.10	214
R		
Receptacles		
Attachment Plugs and Flanged Surface Devices	406.7	534
Receptacle Grounding Terminal to Equipment Grounding Conductor	406.11	537
Definitions	406.2	527
General Installation Requirements	406.4	528
Receptacle Faceplates	406.6	533
Receptacle Mounting	406.5	531
Receptacle Rating and Type	406.3	527
Receptacles in Damp or Wet Locations	406.9	534
Tamper-Resistant Receptacles	406.12	537
Rigid Metal Conduit (Type RMC)		
Bends	344.24	443
Bushings	344.46	446
Couplings and Connectors	344.42	445
Definition	344.2	441
Dissimilar Metals	344.14	442
Equipment Grounding Conductor	344.60	446
Listing Requirements	344.6	442
Number of Bends (360°)	344.26	443
Number of Conductors	344.22	442
Reaming	344.28	443
Securing and Supporting	344.30	443
Trade Size	344.20	442
Uses Permitted	344.10	442
Rigid Polyvinyl Chloride Conduit (Type PVC)		
Bends	352.24	460
Bushings	352.46	462
Definition	352.2	457
Equipment Grounding Conductor	352.60	462
Expansion Fittings	352.44	461
Joints	352.48	462
Number of Bends (360°)	352.26	460
Number of Conductors	352.22	459
Securing and Supporting	352.30	460
Trade Size	352.20	459
Trimming	352.28	460
Uses Not Permitted	352.12	458
Uses Permitted	352.10	457

INDEX

Description	Rule	Page
S		
Services		
General		
Clearances on Buildings	230.9	186
Conductors Considered Outside a Building	230.6	185
Not to Pass Through a Building	230.3	185
Number of Services	230.2	183
Raceway Seals	230.8	186
Service Conductors Separate from Other Conductors	230.7	185
Vegetation as Support	230.10	187
Overhead Service Conductors		
Means of Attachment	230.27	189
Overhead Service Conductor Size and Rating	230.23	187
Point of Attachment	230.26	189
Service Masts as Support	230.28	189
Vertical Clearance for Overhead Service Conductors	230.24	188
Overcurrent Protection		
Ground-Fault Protection of Equipment	230.95	206
Location	230.91	205
Overload Protection—Where Required	230.90	204
Service Disconnect		
Connected on Supply Side of the Service Disconnect	230.82	203
Emergency Disconnects	230.85	204
Grouping of Disconnects	230.72	202
Manually or Power Operated	230.76	202
Marking for Service Disconnect	230.66	199
Number of Service Disconnects	230.71	201
Rating of Disconnect	230.79	202
Service Disconnect Requirements	230.70	200
Service Equipment—Enclosed or Guarded	230.62	199
Surge Protection	230.67	199
Service-Entrance Conductors		
Cable Supports	230.51	197
Conductor Sizing	230.42	191
High-Leg Conductor Identification	230.56	198
Number of Service-Entrance Conductor Sets	230.40	191
Overhead Service Locations	230.54	197
Protection Against Physical Damage	230.50	196
Raceways to Drain	230.53	197
Spliced Conductors	230.46	195
Wiring Methods	230.43	195
Underground Service Conductors		
Installation	230.30	190
Protection Against Damage	230.32	190
Underground Service Conductor Size and Rating	230.31	190

Description	Rule	Page
Service Entrance Cable (Type SE and USE)		
Bending Radius	338.24	431
Definttions	338.2	429
Listing Requirements	338.6	430
Uses Not Permitted	338.12	431
Uses Permitted	338.10	430
Storage Batteries		
Battery and Cell Terminations	480.4	608
Battery Interconnections	480.12	610
Battery Locations	480.10	610
Battery Support Systems	480.9	609
Definitions	480.2	607
Direct-Current Disconnect Methods	480.7	609
Ground-Fault Detection	480.13	610
Insulation of Batteries	480.8	609
Scope	480.1	607
Wiring and Equipment Supplied from Batteries	480.5	609
Surface Metal Raceways		
Definition	386.2	489
Equipment Grounding Conductor	386.60	491
Listing Requirements	386.6	490
Number of Conductors	386.22	490
Securing and Supporting	386.30	491
Separate Compartments	386.70	491
Size of Conductors	386.21	490
Splices and Taps	386.56	491
Uses Not Permitted	386.12	490
Uses Permitted	386.10	490
Surge Protection		
Listing	242.8	232
Number Required	242.20	234
Routing of Surge Protection Device Conductors	242.24	234
Short-Circuit Current Rating	242.10	233
Type 1 SPDs—Line Side of Service Disconnect	242.12	233
Type 2 SPDs—Feeder Circuits	242.14	233
Uses Not Permitted	242.6	232
Switchboards and Panelboards		
Arrangement of Busses and Conductors	408.3	539
Clearance for Conductors Entering Bus Enclosures	408.5	541
Clearances	408.18	542
Equipment Grounding Conductor	408.40	543
Field Identification	408.4	540
Neutral Conductor Terminations	408.41	544
Overcurrent Protection	408.36	543

T | Index

Description	Rule	Page
S Switchboards		
Panelboard Orientation	408.43	544
Panelboards in Damp or Wet Locations	408.37	543
Reconditioning of Equipment	408.8	542
Short-Circuit Current Rating	408.6	542
Unused Openings	408.7	542
Switches		
Accessibility and Grouping	404.8	521
Damp or Wet Locations	404.4	519
Electronic Control Switches	404.22	526
General-Use Snap Switches, Dimmers, and Control Switches	404.9	523
Grounding of Enclosures	404.12	525
Indicating	404.7	520
Mounting of Snap Switches, Dimmers, and Control Switches	404.10	524
Rating and Use of Snap Switches	404.14	525
Switch Connections	404.2	517
Switch Enclosures	404.3	519
Switch Marking	404.20	525

Description	Rule	Page
T		
Transformers		
Disconnecting Means	450.14	605
Grounding and Bonding	450.10	604
Overcurrent Protection	450.3	603
Transformer Accessibility	450.13	605
Ventilation	450.9	604
Tray Cable (Type TC)		
Bending Radius	336.24	428
Definition	336.2	427
Listing Requirements	336.6	427
Uses Not Permitted	336.12	428
Uses Permitted	336.10	427
U		
Underground Feeder and Branch-Circuit Cable (Type UF)		
Ampacity	340.80	434
Bends	340.24	434
Definition	340.2	433
Equipment Grounding Conductor	340.108	434
Insulation	340.112	434
Listing Requirements	340.6	433
Uses Not Permitted	340.12	434
Uses Permitted	340.10	433

Author's Commentary:

This index section offers quick access to essential requirements related to switchboards, switches, transformers, tray cable, and underground feeder and branch-circuit cable. Use it as a roadmap to locate the exact NEC 2023 rules that apply to your installation questions.

— Michael Hamilton

COMMERCIAL AND INDUSTRIAL WIRING AND RACEWAY CHART

Overcurrent Protection Size	Copper (1) Wire 75°C Terminal	Maximum (2) Continuous Ampere Load	Raceway (3)	Equipment (4) Ground Wire	Maximum Continuous Single-Phase VA Load (2)					Maximum Continuous Three-Phase VA Load (2)		
					120V	208V	240V	277V	480V	208V	240V	480V
15	14	12	½"	14	1,440	2,496	2,880	3,324	5,760	4,323	4,988	9,976
20	12	16	½"	12	1,920	3,328	3,840	4,432	7,680	5,764	6,651	13,302
25	10	20	¾"	10	2,400	4,160	4,800	5,540	9,600	7,205	8,314	16,627
30	10	24	¾"	10	2,880	4,992	5,760	6,648	11,520	8,646	9,976	19,953
35	8	28	1"	10	3,360	5,824	6,720	7,756	13,440	10,087	11,639	23,278
40	8	32	1"	10	3,840	6,656	7,680	8,864	15,360	11,528	13,302	26,604
45	8	36	1"	10	4,320	7,488	9,640	9,972	17,280	12,969	14,964	29,929
50	6	40	1"	10	4,800	8,320	9,600	11,080	19,200	14,410	16,627	33,254
60	6	48	1"	10	5,760	9,984	11,520	13,296	23,040	17,292	19,953	39,905
70	4	56	1¼"	8	6,720	11,648	13,440	15,512	26,880	20,174	23,278	46,556
80	4	64	1¼"	8	7,680	13,312	15,360	17,728	30,720	23,056	26,604	53,207
90	3	72	1¼"	8	8,640	14,976	17,280	19,944	34,560	25,938	29,929	59,858
100	3	80	1¼"	8	9,600	16,640	19,200	22,160	38,400	28,820	33,254	66,509
110	2	88	1½"	6	10,560	18,304	21,120	24,376	42,240	31,703	36,580	73,160
125	1	100	2"	6	12,000	20,800	24,000	27,200	48,000	36,026	41,568	83,136
150	1/0	120	2"	6	14,400	24,960	28,800	33,240	57,600	43,231	49,882	99,763
175	2/0	140	2"	6	16,800	29,120	33,600	38,780	67,200	50,436	58,195	116,390
200	3/0	160	2½"	6	19,200	33,280	38,400	44,320	76,800	57,641	66,509	133,018
225	4/0	180	2½"	4	21,600	37,440	43,200	49,860	86,400	64,846	74,822	149,645
250	250 kcmil	200	3"	4	24,000	41,600	48,000	55,400	96,000	72,051	83,136	166,272
300	350 kcmil	240	3½"	4	28,800	49,920	57,600	66,480	115,200	86,461	99,763	199,526
350	400 kcmil	268 (5)	3½"	3	32,160	55,744	64,320	74,236	128,640	99,549	114,102	228,204
400	500 kcmil	304 (5)	4"	3	36,480	63,232	72,960	84,208	145,920	109,518	126,367	252,733
400	600 kcmil	320	4"	4	38,400	66,560	76,800	88,640	153,600	115,282	133,080	266,035

(1) Conductor size based on 75°C terminals (110.14(C)(1)). Ampacity based on two 90°C current-carrying conductors (Table 310.15(B)(3)(a)).

(2) Maximum continuous nonlinear load is an ambient temperature of 30°C limited to 80 percent of the overcurrent rating of the conductors (ampacity), whichever is less (210.19(A), 240.6(A), and 215.2(A)(1)).

(3) To ensure ease of installation, raceways as stated do not fill 40% of interior conduits or PVC conduit (Annex C).

(4) Maximum equipment grounding conductor size is based on a conductor that does not exceed the ampacity at the maximum continuous load as limited to 80 percent of 75°C conductor ampacity because the conductor ampacity is lower than the overcurrent protective device rating.

FORMULAS

Conversion Formulas

Area of Circle = πr^2

Breaker Interrupting VA Rating = Overhead Cost $/Square Foot (A) × Breaker Amp Rating (B) × 25% (1+C)(B) × 1,000 sq. ft.

Inch = 0.0254 Meters

Inch² = 6.452 Centimeters

Inch² = 2.54 Millimeters

Length of One Circle = πd

Diameter of One Four-Square lf/Number of Circuits × π

Lightning Distance in Miles = Seconds between Lightning and Thunder ÷ 4.68

Meter = 39.37 Inches

Mile = 5,280 ft, 1,760 yards; 1,609 meters; 1,609 km

Millimeter = 0.03937 Inch

Selling Price = Estimated Cost ÷ 1 (minus Profit %)

Speed of Sound (Sea Level) = 1,128 ft/sec or 768 mph

Temp °F = (Temp °C × 1.80) + 32

Yard = 0.9144 Meters

Electrical Formulas Based on 60 Hz

Neutral Current = $\sqrt{I_1^2 + I_2^2 + I_3 + I_1^2 + I_2 I_3 + I_2 I_1}$ (3)

VT (L-L) = **Vph (L-N)** $\sqrt{3}$

Ohms = Volts ÷ Amperes (R = E ÷ I)

Peak Amperes = Effective (RMS) Amperes × $\sqrt{2}$

Power Factor = PF = (kW ÷ kVA)

VA (apparent power) = Volts × Amperes × Power Factor

VA Single-Phase = Volts × Amperes

VA Three-Phase = Volts × Amperes × $\sqrt{3}$

Watts (real power) Single-Phase = Volts × Amperes × Power Factor

Watts (real power) Three-Phase = Volts × Amperes × Power Factor × $\sqrt{3}$

Parallel Circuits

Note 1: Total resistance is always less than the smallest resistor.

Note 2: Total current is equal to the sum of the currents of all parallel resistors.

Note 3: Total power is equal to the sum of power of all parallel resistors.

Series Circuits

Note 1: Total resistance in a series path is equal to the sum of all the resistors.

Note 2: Current in the circuit remains the same through all the resistors.

Note 3: Voltage source is equal to the sum of voltage drops of all resistors.

Transformer Amperes

Secondary Amperes Single-Phase = ~VA (Volts × Amperes) ÷ Volts

Secondary Amperes Three-Phase = ~VA (Volts × Amperes) ÷ (Volts × $\sqrt{3}$)

Secondary Available Fault Three-Phase = Volts² × kVA ÷ % Impedance

Delta to With-Wye Transformer: Please use winding Amperes × $\sqrt{3}$

Delta to Delta; Wye to Delta: Use winding Volts

Delta to Delta; Wye to Delta (L-L to L-L): Please use winding Volts × 0.577

Wye to Delta Transformer (1Ø Secondary Center-Tap): Please use winding Amperes × $\sqrt{3}$

Wye to Wye Transformer: Please use winding Amperes

Voltage Drop

VD Single-Phase = 2KMD/volts

VD Three-Phase = KMD/volts

Circuit Styles (Single- or Double-Way Circuits): K Single-Phase = 2R + X

K Three-Phase = R + X

Code Rules

Breaker-Size-Rule = 240.6(A)

Conductor Ampacity = 310.15(B)(16); 210.19(A)

Equipment Grounding Conductor = 250.122

Equipment Grounding Conductor = 250.66

Worst Conductor Size = 240.122(C)

430.32(A) through

Maximum Overcurrent Protection = 430.52

Transformer Overcurrent Protection = 450.3

Legend

π (Pi) = 3.142 (approximately)

$\sqrt{2}$ = 1.414 (approximately)

$\sqrt{3}$ = 1.732 (approximately)

f = frequency

r = radius

d = diameter

C = Capacitance (farads)

L = Inductance (henrys)

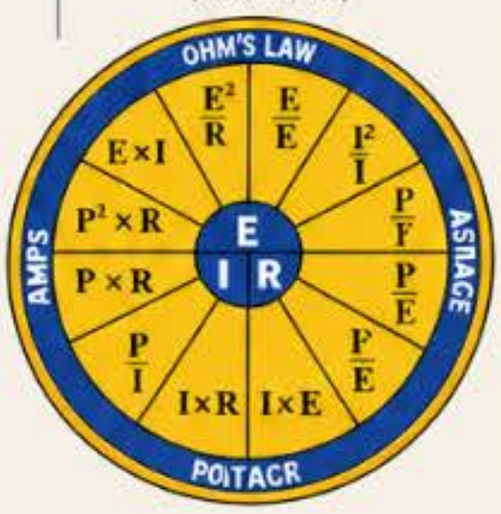
Cmils = Circular Mils

VD = Volts Drop

I = Amperes of load

D = Distance (one way)

K75°C = (12.90 ohms CM)
(12.20 ohms AL)



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225 Outside Branch Circuits and Feeders
230 Services
240 Overcurrent Protection
250 Grounding and Bonding
260 Equipment for General Use
270 Wiring Methods and Materials
280 Equipment for Specific Use
285 Emergency Systems
300 Wiring Spaces
310 Special Occupancies
320 Hazardous (Classified) Locations
330 Specific Purpose Equipment
340 Other Articles
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400 Renewable Energy Systems
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