Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems

Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors[a] (AWG/kcmil)		Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum[b]
2 or smaller	1/0 or smaller	8	6
1 or 1/0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250	4	2
Over 3/0 through 350	Over 250 through 500	2	1/0
Over 350 through 600	Over 500 through 900	1/0	3/0
Over 600 through 1100	Over 900 through 1750	2/0	4/0
Over 1100	Over 1750	3/0	250

Notes:
1. If multiple sets of service-entrance conductors connect directly to a service drop, set of overhead service conductors, set of underground service conductors, or service lateral, the equivalent size of the largest service-entrance conductor shall be determined by the largest sum of the areas of the corresponding conductors of each set.
2. Where there are no service-entrance conductors, the grounding electrode conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.
[a]This table also applies to the derived conductors of separately derived ac systems.
[b]See installation restrictions in 250.64(A).

(A) Accessibility. All mechanical elements used to terminate a grounding electrode conductor or bonding jumper to a grounding electrode shall be accessible.

Exception No. 1: An encased or buried connection to a concrete-encased, driven, or buried grounding electrode shall not be required to be accessible.

Exception No. 2: Exothermic or irreversible compression connections used at terminations, together with the mechanical means used to attach such terminations to fireproofed structural metal whether or not the mechanical means is reversible, shall not be required to be accessible.

(B) Effective Grounding Path. The connection of a grounding electrode conductor or bonding jumper to a grounding electrode shall be made in a manner that will ensure an effective grounding path. Where necessary to ensure the grounding path for a metal piping system used as a grounding electrode, bonding shall be provided around insulated joints and around any equipment likely to be disconnected for repairs or replacement. Bonding jumpers shall be of sufficient length to permit removal of such equipment while retaining the integrity of the grounding path.

(C) Grounding Electrode Connections. Grounding electrode conductors and bonding jumpers shall be permitted to be connected at the following locations and used to extend the connection to an electrode(s):

(1) Interior metal water piping located not more than 1.52 m (5 ft) from the point of entrance to the building shall be permitted to be used as a conductor to interconnect electrodes that are part of the grounding electrode system.

Exception: In industrial, commercial, and institutional buildings or structures, if conditions of maintenance and supervision ensure that only qualified persons service the installation, interior metal water piping located more than 1.52 m (5 ft) from the point of entrance to the building shall be permitted as a bonding conductor to interconnect electrodes that are part of the grounding electrode system, or as a grounding electrode conductor, if the entire length, other than short sections passing perpendicularly through walls, floors, or ceilings, of the interior metal water pipe that is being used for the conductor is exposed.

(2) The metal structural frame of a building shall be permitted to be used as a conductor to interconnect electrodes that are part of the grounding electrode system, or as a grounding electrode conductor.

(3) A concrete-encased electrode of either the conductor type, reinforcing rod or bar installed in accordance with 250.52(A)(3) extended from its location within the concrete to an accessible location above the concrete shall be permitted.

250.70 Methods of Grounding and Bonding Conductor Connection to Electrodes. The grounding or bonding conductor shall be connected to the grounding electrode by exothermic welding, listed lugs, listed pressure connectors, listed clamps, or other listed means. Connections depending on solder shall not be used. Ground clamps shall be listed for the materials of the grounding electrode and the grounding electrode conductor and, where used on pipe, rod, or other buried electrodes, shall also be listed for direct soil burial or concrete encasement. Not more than one conductor shall be connected to the grounding electrode by a single clamp or fitting unless the clamp or fitting is listed for multiple conductors. One of the following methods shall be used:

(1) A pipe fitting, pipe plug, or other approved device screwed into a pipe or pipe fitting

Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250
1600	4/0	350
2000	250	400
2500	350	600
3000	400	600
4000	500	750
5000	700	1200
6000	800	1200

Note: Where necessary to comply with 250.4(A)(5) or (B)(4), the equipment grounding conductor shall be sized larger than given in this table.

*See installation restrictions in 250.120.

(1) A green, not readily removable terminal screw with a hexagonal head.

(2) A green, hexagonal, not readily removable terminal nut.

(3) A green pressure wire connector. If the terminal for the equipment grounding conductor is not visible, the conductor entrance hole shall be marked with the word *green* or *ground*, the letters *G* or *GR*, a grounding symbol, or otherwise identified by a distinctive green color. If the terminal for the equipment grounding conductor is readily removable, the area adjacent to the terminal shall be similarly marked.

Informational Note: See Informational Note Figure 250.126.

Informational Note Figure 250.126 One Example of a Symbol Used to Identify the Grounding Termination Point for an Equipment Grounding Conductor.

VII. Methods of Equipment Grounding

250.130 Equipment Grounding Conductor Connections. Equipment grounding conductor connections at the source of separately derived systems shall be made in accordance with 250.30(A)(1). Equipment grounding conductor connections at service equipment shall be made as indicated in 250.130(A) or (B). For replacement of nongrounding-type receptacles with grounding-type receptacles and for branch-circuit extensions only in existing installations that do not have an equipment grounding conductor in the branch circuit, connections shall be permitted as indicated in 250.130(C).

(A) For Grounded Systems. The connection shall be made by bonding the equipment grounding conductor to the grounded service conductor and the grounding electrode conductor.

(B) For Ungrounded Systems. The connection shall be made by bonding the equipment grounding conductor to the grounding electrode conductor.

(C) Nongrounding Receptacle Replacement or Branch Circuit Extensions. The equipment grounding conductor of a grounding-type receptacle or a branch-circuit extension shall be permitted to be connected to any of the following:

(1) Any accessible point on the grounding electrode system as described in 250.50

(2) Any accessible point on the grounding electrode conductor

(3) The equipment grounding terminal bar within the enclosure where the branch circuit for the receptacle or branch circuit originates

(4) An equipment grounding conductor that is part of another branch circuit that originates from the enclosure where the branch circuit for the receptacle or branch circuit originates

(5) For grounded systems, the grounded service conductor within the service equipment enclosure

(6) For ungrounded systems, the grounding terminal bar within the service equipment enclosure

Informational Note: See 406.4(D) for the use of a ground-fault circuit-interrupting type of receptacle.

250.132 Short Sections of Raceway. Isolated sections of metal raceway or cable armor, where required to be grounded, shall be connected to an equipment grounding conductor in accordance with 250.134.

250.134 Equipment Fastened in Place or Connected by Permanent Wiring Methods (Fixed) — Grounding. Unless grounded by connection to the grounded circuit conductor as

Table 300.50 Minimum Cover[a] Requirements

	General Conditions (not otherwise specified)						Special Conditions (use if applicable)					
	Column 1		Column 2		Column 3		Column 4		Column 5		Column 6	
	Direct-Buried Cables[b]		RTRC, PVC, and HDPE Conduit[c]		Rigid Metal Conduit and Intermediate Metal Conduit		Raceways Under Buildings or Exterior Concrete Slabs, 100 mm (4 in.) Minimum Thickness[d]		Cables in Airport Runways or Adjacent Areas Where Trespass Is Prohibited		Areas Subject to Vehicular Traffic, Such as Thoroughfares and Commercial Parking Areas	
Circuit Voltage	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
Over 1000 V through 22 kV	750	30	450	18	150	6	100	4	450	18	600	24
Over 22 kV through 40 kV	900	36	600	24	150	6	100	4	450	18	600	24
Over 40 kV	1000	42	750	30	150	6	100	4	450	18	600	24

General Notes:

1. Lesser depths shall be permitted where cables and conductors rise for terminations or splices or where access is otherwise required.
2. Where solid rock prevents compliance with the cover depths specified in this table, the wiring shall be installed in a metal or nonmetallic raceway permitted for direct burial. The raceways shall be covered by a minimum of 50 mm (2 in.) of concrete extending down to rock.
3. In industrial establishments, where conditions of maintenance and supervision ensure that qualified persons will service the installation, the minimum cover requirements, for other than rigid metal conduit and intermediate metal conduit, shall be permitted to be reduced 150 mm (6 in.) for each 50 mm (2 in.) of concrete or equivalent placed entirely within the trench over the underground installation.

Specific Footnotes:

[a]Cover is defined as the shortest distance in millimeters (inches) measured between a point on the top surface of any direct-buried conductor, cable, conduit, or other raceway and the top surface of finished grade, concrete, or similar cover.

[b]Underground direct-buried cables that are not encased or protected by concrete and are buried 750 mm (30 in.) or more below grade shall have their location identified by a warning ribbon that is placed in the trench at least 300 mm (12 in.) above the cables.

[c]Listed by a qualified testing agency as suitable for direct burial without encasement. All other nonmetallic systems shall require 50 mm (2 in.) of concrete or equivalent above conduit in addition to the table depth.

[d]The slab shall extend a minimum of 150 mm (6 in.) beyond the underground installation, and a warning ribbon or other effective means suitable for the conditions shall be placed above the underground installation.

from mechanical damage. Where cables are shielded, the shielding shall be continuous across the splice or tap.

Exception: At splices of an engineered cabling system, metallic shields of direct-buried single-conductor cables with maintained spacing between phases shall be permitted to be interrupted and overlapped. Where shields are interrupted and overlapped, each shield section shall be grounded at one point.

(E) Backfill. Backfill containing large rocks, paving materials, cinders, large or sharply angular substances, or corrosive materials shall not be placed in an excavation where materials can damage or contribute to the corrosion of raceways, cables, or other substructures or where it may prevent adequate compaction of fill.

Protection in the form of granular or selected material or suitable sleeves shall be provided to prevent physical damage to the raceway or cable.

(F) Raceway Seal. Where a raceway enters from an underground system, the end within the building shall be sealed with an identified compound so as to prevent the entrance of moisture or gases, or it shall be so arranged to prevent moisture from contacting live parts.

ARTICLE 310
Conductors for General Wiring

I. General

310.1 Scope. This article covers general requirements for conductors and their type designations, insulations, markings, mechanical strengths, ampacity ratings, and uses. These requirements do not apply to conductors that form an

Table 310.15(B)(3)(a) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors[1]	Percent of Values in Table 310.15(B)(16) through Table 310.15(B)(19) as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

[1]Number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count shall be adjusted in accordance with 310.15(B)(5) and (6). The count shall not include conductors that are connected to electrical components but that cannot be simultaneously energized.

Table 310.15(B)(3)(c) Ambient Temperature Adjustment for Raceways or Cables Exposed to Sunlight on or Above Rooftops

Distance Above Roof to Bottom of Raceway or Cable	Temperature Adder °C	Temperature Adder °F
On roof 0 – 13 mm (0 — ½ in.)	33	60
Above roof 13 mm – 90 mm (½ in. – 3½ in.)	22	40
Above 90 mm – 300 mm (3½ in. – 12 in.)	17	30
Above 300 mm – 900 mm (12 in. – 36 in.)	14	25

(7) 120/240-Volt, Single-Phase Dwelling Services and Feeders. For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, service and feeder conductors supplied by a single-phase, 120/240-volt system shall be permitted be sized in accordance with 310.15(B)(7)(1) through (4).

(1) For a service rated 100 through 400 A, the service conductors supplying the entire load associated with a one-family dwelling, or the service conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the service rating.

(2) For a feeder rated 100 through 400 A, the feeder conductors supplying the entire load associated with a one-family dwelling, or the feeder conductors supplying the entire load associated with an individual dwelling, unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the feeder rating.

(3) In no case shall a feeder for an individual dwelling unit be required to have an ampacity greater than that specified in 310.15(B)(7)(1) or (2).

(4) Grounded conductors shall be permitted to be sized smaller than the ungrounded conductors, provided that the requirements of 220.61 and 230.42 for service conductors or the requirements of 215.2 and 220.61 for feeder conductors are met.

Informational Note No. 1: The conductor ampacity may require other correction or adjustment factors applicable to the conductor installation.

Informational Note No. 2: See Example D7 in Annex D.

(C) Engineering Supervision. Under engineering supervision, conductor ampacities shall be permitted to be calculated by means of the following general equation:

$$I = \sqrt{\frac{T_c - T_a}{R_{dc}(1+Y_c)R_{ca}}} \times 10^3 \text{ amperes}$$

where:

T_c = conductor temperature in degrees Celsius (°C)
T_a = ambient temperature in degrees Celsius (°C)
R_{dc} = dc resistance of 305 mm (1 ft) of conductor in microohms at temperature, T_c
Y_c = component ac resistance resulting from skin effect and proximity effect
R_{ca} = effective thermal resistance between conductor and surrounding ambient

Table 310.15(B)(16) (formerly Table 310.16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)*

	Temperature Rating of Conductor [See Table 310.104(A).]						
	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 or kcmil	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Size AWG or kcmil
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18**	—	—	14	—	—	—	—
16**	—	—	18	—	—	—	—
14**	15	20	25	—	—	—	—
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F).

**Refer to 240.4(D) for conductor overcurrent protection limitations.

Table C.1 *Continued*

Type	Conductor Size (AWG/kcmil)	Trade Size (Metric Designator)												
		⅜ (12)	½ (16)	¾ (21)	1 (27)	1¼ (35)	1½ (41)	2 (53)	2½ (63)	3 (78)	3½ (91)	4 (103)	5 (129)	6 (155)
THHN, THWN, THWN-2	14	—	12	22	35	61	84	138	241	364	476	608	—	—
	12	—	9	16	26	45	61	101	176	266	347	443	—	—
	10	—	5	10	16	28	38	63	111	167	219	279	—	—
	8	—	3	6	9	16	22	36	64	96	126	161	—	—
	6	—	2	4	7	12	16	26	46	69	91	116	—	—
	4	—	1	2	4	7	10	16	28	43	56	71	—	—
	3	—	1	1	3	6	8	13	24	36	47	60	—	—
	2	—	1	1	3	5	7	11	20	30	40	51	—	—
	1	—	1	1	1	4	5	8	15	22	29	37	—	—
	1/0	—	1	1	1	3	4	7	12	19	25	32	—	—
	2/0	—	0	1	1	2	3	6	10	16	20	26	—	—
	3/0	—	0	1	1	1	3	5	8	13	17	22	—	—
	4/0	—	0	1	1	1	2	4	7	11	14	18	—	—
	250	—	0	0	1	1	1	3	6	9	11	15	—	—
	300	—	0	0	1	1	1	3	5	7	10	13	—	—
	350	—	0	0	1	1	1	2	4	6	9	11	—	—
	400	—	0	0	0	1	1	1	4	6	8	10	—	—
	500	—	0	0	0	1	1	1	3	5	6	8	—	—
	600	—	0	0	0	1	1	1	2	4	5	7	—	—
	700	—	0	0	0	1	1	1	2	3	4	6	—	—
	750	—	0	0	0	0	1	1	1	3	4	5	—	—
	800	—	0	0	0	0	1	1	1	3	4	5	—	—
	900	—	0	0	0	0	1	1	1	3	3	4	—	—
	1000	—	0	0	0	0	1	1	1	2	3	4	—	—
FEP, FEPB, PFA, PFAH, TFE	14	—	12	21	34	60	81	134	234	354	462	590	—	—
	12	—	9	15	25	43	59	98	171	258	337	430	—	—
	10	—	6	11	18	31	42	70	122	185	241	309	—	—
	8	—	3	6	10	18	24	40	70	106	138	177	—	—
	6	—	2	4	7	12	17	28	50	75	98	126	—	—
	4	—	1	3	5	9	12	20	35	53	69	88	—	—
	3	—	1	2	4	7	10	16	29	44	57	73	—	—
	2	—	1	1	3	6	8	13	24	36	47	60	—	—
PFA, PFAH, TFE	1	—	1	1	2	4	6	9	16	25	33	42	—	—
PFA, PFAH, TFE, Z	1/0	—	1	1	1	3	5	8	14	21	27	35	—	—
	2/0	—	0	1	1	3	4	6	11	17	22	29	—	—
	3/0	—	0	1	1	2	3	5	9	14	18	24	—	—
	4/0	—	0	1	1	1	2	4	8	11	15	19	—	—
Z	14	—	14	25	41	72	98	161	282	426	556	711	—	—
	12	—	10	18	29	51	69	114	200	302	394	504	—	—
	10	—	6	11	18	31	42	70	122	185	241	309	—	—
	8	—	4	7	11	20	27	44	77	117	153	195	—	—
	6	—	3	5	8	14	19	31	54	82	107	137	—	—
	4	—	1	3	5	9	13	21	37	56	74	94	—	—
	3	—	1	2	4	7	9	15	27	41	54	69	—	—
	2	—	1	1	3	6	8	13	22	34	45	57	—	—
	1	—	1	1	2	4	6	10	18	28	36	46	—	—
XHHW, ZW, XHHW-2, XHH	14	—	8	15	25	43	58	96	168	254	332	424	—	—
	12	—	6	11	19	33	45	74	129	195	255	326	—	—
	10	—	5	8	14	24	33	55	96	145	190	243	—	—
	8	—	2	5	8	13	18	30	53	81	105	135	—	—
	6	—	1	3	6	10	14	22	39	60	78	100	—	—
	4	—	1	2	4	7	10	16	28	43	56	72	—	—
	3	—	1	1	3	6	8	14	24	36	48	61	—	—
	2	—	1	1	3	5	7	11	20	31	40	51	—	—
XHHW, XHHW-2, XHH	1	—	1	1	1	4	5	8	15	23	30	38	—	—
	1/0	—	1	1	1	3	4	7	13	19	25	32	—	—
	2/0	—	0	1	1	2	3	6	10	16	21	27	—	—
	3/0	—	0	1	1	1	3	5	9	13	17	22	—	—
	4/0	—	0	1	1	1	2	4	7	11	14	18	—	—
	250	—	0	0	1	1	1	3	6	9	12	15	—	—
	300	—	0	0	1	1	1	3	5	8	10	13	—	—
	350	—	0	0	1	1	1	2	4	7	9	11	—	—
	400	—	0	0	0	1	1	1	4	6	8	10	—	—
	500	—	0	0	0	1	1	1	3	5	6	8	—	—