

Module 1.9 — Enclosures, Site Grounding & Equipment Hookup

Picking and mounting outdoor enclosures, grounding grade-mounted equipment, hooking up HVAC, motors, poles and EV chargers, and proving it all before you energize.

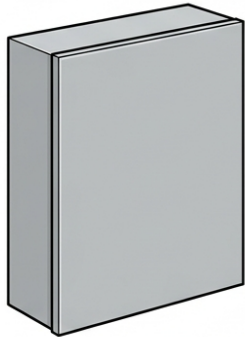
Why this module. Module 1.8 got the raceway underground and back up to grade. This module covers what sits at the top of the riser: the enclosure, how it is mounted and sealed, how the equipment and the site are grounded, and how the equipment is hooked up and proven safe before it is energized. It applies to any grade-mounted equipment: a disconnect for a rooftop or pad HVAC unit, a meter rack, a light pole, a pump panel, or an EV charger. It walks step by step through picking and mounting an enclosure, building a strut rack, installing a ground ring and making a CADWELD connection, terminating flex, laying out working space, labeling, and testing.

Part A — Reading an Enclosure Rating

An enclosure type number tells you what environment the box is built to survive. NEC 110.28 requires switchboards, panelboards, meter sockets, enclosed switches, transfer switches, and controllers to "be marked with an enclosure-type number," and says Table 110.28 "shall be used for selecting these enclosures for use in specific locations other than hazardous (classified) locations." The ratings are defined by the NEMA standard now titled **NEMA EN 10250-2024** (formerly NEMA 250); the 2026 NEC Informational Note cites it under the new name.

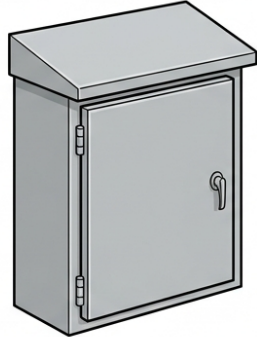
READING THE ENCLOSURE RATING

NEMA/UL Type 1



Indoor only — protects against incidental contact, no weather protection

NEMA/UL Type 3R



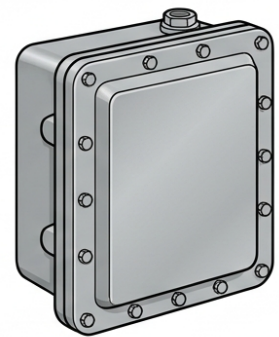
Outdoor — rain and ice, NOT dust or washdown

NEMA/UL Type 4X



Outdoor/indoor — windblown dust, hose-directed water, PLUS corrosion resistance

NEMA/UL Type 7 / 9



Hazardous locations — Type 7 explosionproof (gas/vapor), Type 9 dust-ignitionproof (dust)

Four ratings you will actually see on site — indoor, outdoor/rain, corrosion-resistant, and hazardous-location.

NEMA/UL Type	Indoor / outdoor	Protects against (NEMA definitions, condensed)	Typical use
1	Indoor	Contact with hazardous parts; falling dirt	Dry electrical rooms, indoor panels, MCCs
12	Indoor	"Constructed (without knockouts)"; falling dirt, circulating dust, lint, fibers, flyings; dripping and light splashing	Dusty plant floors
12K	Indoor	Same as 12, with knockouts	Same
3R	Both	Falling dirt; rain, sleet, snow; undamaged by ice on the outside. No windblown-dust rating.	Outdoor disconnects, meter sockets, pedestals not washed down
3	Both	3R plus windblown dust	Outdoors in blowing dust
3S	Both	Type 3, and "external mechanism(s) remain operable when ice laden"	Handles that must work when iced over
4	Both	Windblown dust; rain, sleet, snow, splashing and hose-directed water; ice	Washdown areas
4X	Both	Type 4 plus "an additional level of protection against corrosion"	Salt air, chemicals, food plants

Rockwell's MCC selection guide lists rough IP equivalents: Type 1 about IP20 to IP40, Type 12 IP53 to IP54, Type 3R IP44, Type 4 IP65. A Type 1 enclosure with a gasketed door is sometimes called "1G" for dust-sensitive indoor areas.

The words on the label

The 110.28 Informational Note ties the common words to the types. "Rainproof" = 3R and 3RX. "Raintight" = 3, 3S, 3SX, 3X, 4, 4X, 6, 6P. "Watertight" = 4, 4X, 6, 6P. "Dusttight" = 3, 3S, 3SX, 3X, 4, 4X, 5, 6, 6P, 12, 12K, 13. The note also warns that "Some type 4X enclosures may be marked 'indoor only.'"

No enclosure rating stops condensation. 110.28: the enclosures "are not intended to protect against conditions such as condensation, icing, corrosion, or contamination that may occur within the enclosure or enter via the raceway or unsealed openings." Water that runs down the inside of a conduit, or warm air that condenses in a cold box, is your job to stop with seals and drains (Part D).

NEMA 4X. 4X is the corrosion-resistant version of Type 4. It has the same dust, hose, and ice protection, built in stainless steel (304 or 316) or fiberglass instead of painted steel. Federal design criteria UFC 3-520-01 says: "Use NEMA 4X stainless steel switch enclosures for switches located on building exteriors in areas where salt spray or extended high humidity is a concern."

Step by step: picking the enclosure

1. Read the spec and the one-line for the required Type. The spec wins.
2. If the spec is silent, pick from the location: dry indoor = 1; dusty plant = 12; outdoor, not washed down = 3R; outdoor with blowing dust or ice on the handle = 3 or 3S; washdown = 4; salt air, chemicals, food plant = 4X.
3. Check the nameplate for the Type number (110.28 requires it).
4. Watch for convertible switches. Eaton switches listed "Type 12 (3R)" ship as Type 12; "if being used as Type 3R the drain screw should be removed in the field." Square D's manual says the same: Type 12 "may be used for Type 3R applications by removing drip screw."
5. For EV chargers, check 625.50: outdoors, the coupling means is stored at least 24" above grade unless the equipment is listed otherwise.

NEMA 7 & 9 — the hazardous-location ratings

These map to the Class/Division system in **NEC Article 500**, not to weather:

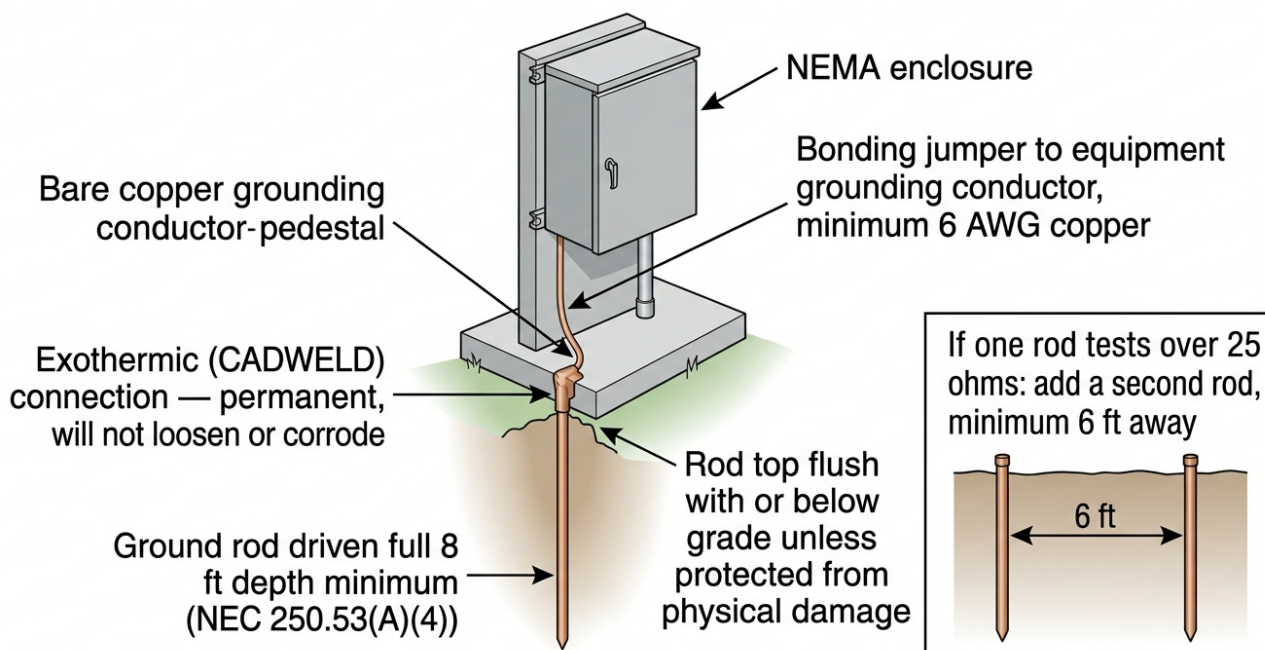
- **Type 7, explosionproof.** Rated for **Class I** locations (ignitable gases or vapors). Built to contain an internal explosion and cool the escaping gases so they won't ignite the surrounding atmosphere.
- **Type 9, dust-ignitionproof.** Rated for **Class II** locations (combustible dust). Built to keep dust out and keep internal arcs, sparks, and heat from igniting dust settled on or near the enclosure.

Class I = flammable gas or vapor. **Class II** = combustible dust. **Class III** = easily ignitable fibers and flyings. **Division 1** = the hazard is present under normal operating conditions. **Division 2** = the hazard is present only under abnormal conditions, such as a ruptured container or a ventilation failure.

Part B — Grounding & Bonding at Grade-Mounted Equipment

Outdoor equipment needs a grounding and bonding system that survives decades in wet dirt. Module 1.7 covers the full grounding electrode system. This Part covers the pieces you build on a site.

GROUNDING A GRADE-MOUNTED ENCLOSURE



A grade-mounted enclosure: rod depth, connection method, and bonding jumper size — all code minimums, not just good practice.

NEC 2026 — 250.52 and 250.53: rods and rings

- **Rods (250.52(A)(5)):** at least 8 ft long and $\frac{5}{8}$ " diameter unless listed; pipe at least $\frac{3}{4}$ " trade size, galvanized.
- **Depth (250.53(A)(4)):** at least 8 ft in contact with soil, driven vertically. In rock, drive at up to 45°, or lay it in a trench at least 30" deep.
- **Top of rod:** flush with or below grade, unless the above-ground end and its connection are protected from damage.
- **Spacing (250.53(A)(3)):** multiple rods "not less than 1.8 m (6 ft) apart." The Informational Note says spacing of "twice the length of the longest rod" works better.
- **The 25-ohm rule (250.53(A)(2) Exception):** a single rod that tests 25 ohms or less needs no second electrode. Otherwise install a second rod at least 6 ft away. Two rods need no test.
- **Jumper (250.53(E)):** the jumper that is the only connection to a supplemental rod need not be larger than 6 AWG copper or 4 AWG aluminum.
- **Ground ring (250.52(A)(4), 250.53(F)):** "encircling the building or structure, in direct contact with the earth, consisting of at least 6.0 m (20 ft) of bare copper conductor not smaller than 2 AWG," buried at least 30" deep.
- **Auxiliary electrodes (250.54):** a rod at a light pole or other equipment may connect to the equipment grounding conductor, need not meet the 25-ohm rule, "but the earth shall not be used as an effective ground-fault current path."
- **Lightning protection (250.106):** its ground terminals "shall be bonded to the building or structure grounding electrode system."

Field practice that holds up outdoors

- **Concrete-encased (Ufer) electrodes** often beat driven rods. Concrete draws moisture from the surrounding earth, which keeps resistance low and steady in dry weather.
- **Buried connections:** exothermic (CADWELD) welds or listed high-compression connections made with a hydraulic or electric tool (UFC 3-520-01). A mechanical clamp underground can loosen or corrode over the years; a weld fuses the conductors into one piece.
- **Siting:** ERICO recommends rods and rings "at least 24 inch from the foundation footer and 18 inch outside the roof drip line."
- **Federal projects:** UFC 3-520-01 raises rods to 10 ft by $\frac{3}{4}$ " and spacing to 10 ft.

Step by step: installing a ground ring

1. Call 811 and get a private locate (Module 1.8).
2. Trench at least 30" deep (250.53(F)), at least 24" off the footer and 18" outside the drip line.
3. Lay bare copper, 2 AWG minimum and at least 20 ft by code. ERICO notes the ring is "seldom less than 1/0 AWG copper" in practice, and bonds "at least one column every 50 feet."

4. Add rods at the corners. Use three rods in a triangle only if the spacing is at least the rod length; "Three rods in a straight line spaced at least equal to the length of the individual ground rods are more efficient."
5. Where a ground conductor passes through a foundation wall below the water table, cast a water stop (CADWELD Type SS splice) into the wall.
6. Make every buried connection exothermic or listed compression.
7. Set a test well (PVC pipe with a screw cap) over one rod so it can be tested later.
8. Photograph every buried joint before backfill.

Step by step: an exothermic (CADWELD) connection

Source: nVent ERICO Cadweld Installation and Inspection Guide. Kit: the mold matching the tag (connection type plus conductor and rod size), handle clamp, weld-metal cartridge per the tag, steel disk, starting material, flint igniter, torch, soft mold brush, wire brush, and packing.

Burn and spatter hazard. The reaction exceeds 2,500°F. Moisture in the mold or on the conductor causes "spewing of hot material." Wear safety glasses and gloves, clear flammables, warn the crew, and don't look at the flash.

1. Wire-brush the conductor and rod clean and dry them with the torch.
2. Preheat the mold to drive out moisture. "Graphite absorbs moisture."
3. Set the conductors in the mold, close the handle clamp, and pack any gaps.
4. Drop the steel disk in, concave side up, over the tap hole.
5. Pour in the weld metal, then the starting material on top. Close the lid.
6. Ignite from the side with the flint igniter and step back.
7. Wait about 30 seconds, open the mold, and brush out the slag with the soft brush.
8. Inspect. Reject: porous weld (moisture), heavy slag (the disk leaked), fins (mold not closed or worn), no bond (dirty conductor).

Common types: GR, GT, GY, and GB for rod connections; RD for pole rebar; VS for fence posts.

The pad-mount transformer ground grid

The utility's book governs the grid under its transformer. The NEC governs the customer side. Examples of what utility books require:

Utility	Grid requirement
National Grid ESB 754/759	Bare copper "soft drawn 19 strand, minimum size #2/0 AWG" as "an outer loop around the transformer pad," connected to at least 2 rods at opposite corners, at least 8 ft apart; two pigtails at least 3 ft above the pad; metal conduits bonded with #4 Cu solid; "Ground connections shall be exothermic or pressed type"; 25 ohms or less on delta systems under 15 kV.
PG&E Greenbook 045292	Two $\frac{5}{8}$ " $\times$ 8 ft copperclad rods at least 6 ft apart with a continuous ground wire under the pad through both windows; transformer not set until 14 days after the pour.
Alabama Power (Southern Company)	#2 bare copper ground bus cast in the pad and tied to the rebar (Module 1.8 Part F).

Where customer equipment sits within 10 ft of the transformer, utility specs commonly require the two grids to be bonded together. Read the serving utility's book for the job.

Light poles

ERICO: "Keep in mind that the earth cannot serve as the sole equipment grounding conductor. Light standards which are grounded by the use of a separate ground rod must also be grounded with an equipment grounding conductor." State DOT standards (for example FDOT Index 715-001) show a #6 copper pole ground conductor and a grounding lug in the pole base.

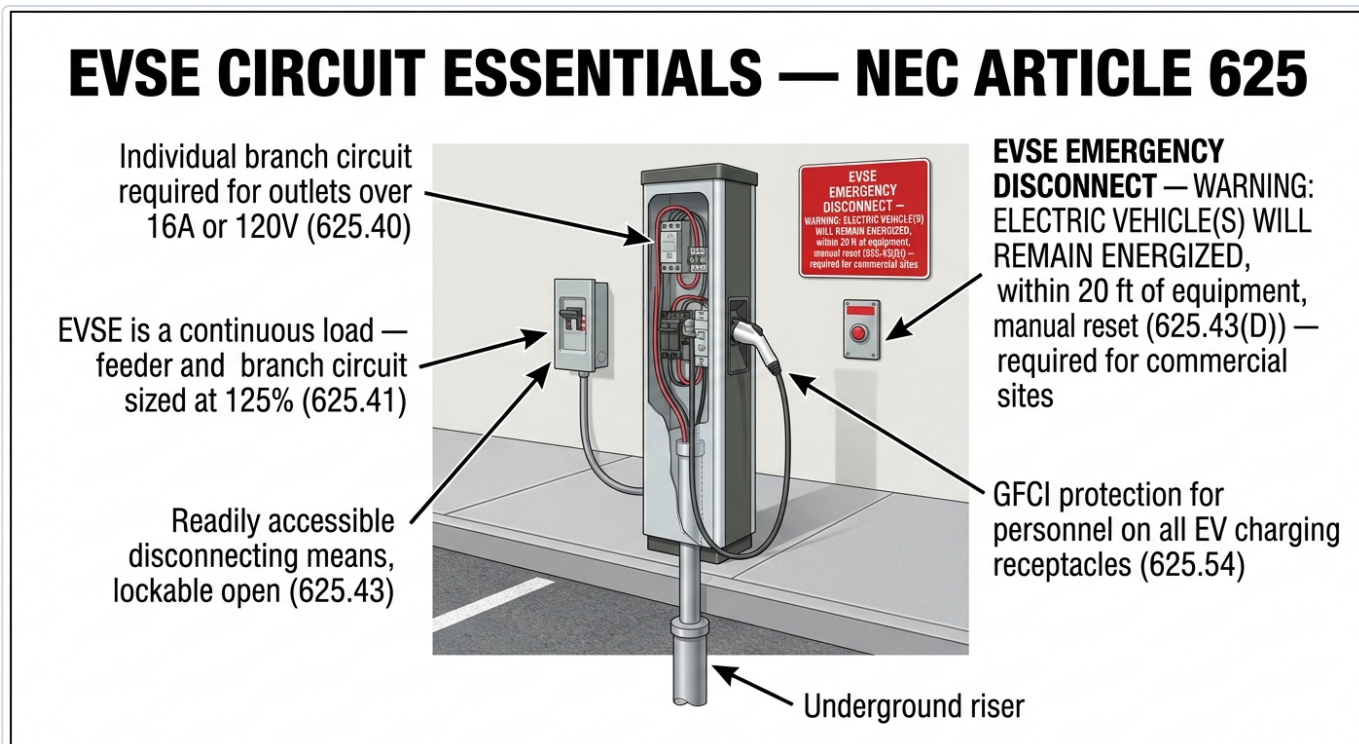
1. Set anchor bolts per the template (Module 1.8 Part G).
2. Drive a rod beside the base if specified. It is an auxiliary electrode (250.54).
3. Pull a wire equipment grounding conductor with the circuit.
4. Land the EGC and the rod lead on the pole's grounding terminal, reachable from the handhole (410.30(B)(3)).
5. Bond a hinged base to the pole (410.30(B)(4)).
6. Bond any metal conduit to the pole with an EGC sized per 250.122 (410.30(B)(5)).

Fences and lightning

- The NEC fence-bonding rule, 270.14 (250.194 in 2023), applies to substations over 1000 V. Fences within 16 ft of exposed conductors or equipment are bonded with wire jumpers "at each fence corner and at maximum 50 m (160 ft) intervals," gates are bonded to their posts, and each gate post is bonded to the electrode system. Ordinary low-voltage site fences have no general NEC bonding rule; follow the project drawings.
- Lightning protection is designed by certified lightning-protection installers to NFPA 780. Your job is the bond from its ground terminals to the grounding electrode system (250.106).

Part C — EVSE Circuit Essentials (NEC Article 625)

EVSE (electric vehicle supply equipment) is the charger. Article 625 governs the circuit that feeds it, separately from the raceway (Module 1.8) and the enclosure (Part A). Module 1.10 covers EV power flow and load management in depth.



What Article 625 actually requires at the pedestal — branch circuit, sizing, disconnect, and the commercial-specific emergency shutoff.

- **625.40:** "Each outlet installed for the purpose of supplying EVSE greater than 16 amperes or 120 volts shall be supplied by an individual branch circuit." Exception: one branch circuit may feed several EVSE under a power control system or adjustable settings (625.42(A) or (B)).
- **625.41:** "EVSE and WPTE, including bidirectional EVSE and WPTE, shall be considered continuous loads." WPTE is wireless power transfer equipment. Continuous means conductors and overcurrent protection at 125% of the load (Module 1.4).
- **625.43(C):** permanently connected EVSE needs a disconnect "in a readily accessible location," lockable open per 110.25. If the disconnect is remote, put a plaque on the equipment saying where it is. Cord-and-plug EVSE rated 60 A or less, or 150 V or less to ground, may use the plug as the disconnect.
- **625.43(D),** other than one- and two-family dwellings: every permanently connected EVSE needs a clearly identified **emergency disconnect** that is within sight of the equipment and within 20 ft of it; kills power to all EVSE in sight of it; is marked "EVSE EMERGENCY DISCONNECT" and "WARNING: ELECTRIC VEHICLE(S) WILL REMAIN ENERGIZED" per 110.22(A); is manual reset; and opens all ungrounded conductors at once. The 625.43(C) disconnect may serve as the emergency disconnect if it meets all of these.

- **625.44:** cord-and-plug EVSE uses an attachment plug "rated not less than 125 percent of the maximum rating of the equipment."
- **625.54:** all receptacles installed for EV charging require GFCI protection for personnel.

Worked example: an EV charging site in a parking lot (a past YES Electric project type).

A bank of permanently connected 48 A chargers sits outdoors at the top of the parking-lot risers. Each charger gets its own branch circuit (625.40) sized for a continuous load: $48 \times 1.25 = 60$ A breaker and conductors. The pedestal enclosures are NEMA 3R. Each charger has a lockable, readily accessible disconnect (625.43(C)). Because the site is not a dwelling, the crew also installs an emergency disconnect within sight and within 20 ft of the chargers, marked with both 625.43(D) phrases, manual reset, opening all ungrounded conductors.

Part D — Setting the Equipment Outdoors

Code points for outdoor mounting

- **312.4(A)** (312.2 in 2023): in damp or wet locations, enclosures are "placed or equipped such that moisture or water is prevented from entering and accumulating," and mounted with "at least 6 mm ($\frac{1}{4}$ in.) of airspace between enclosures and walls or other supporting" surfaces. Nonmetallic enclosures on concrete or masonry may skip the airspace.
- **312.4(B):** "For enclosures in wet locations, raceways or cables entering above the level of uninsulated live parts shall use fittings listed for wet locations."
- **314.15(C)(1):** field drain holes in boxes listed for damp or wet locations: "not smaller than 3 mm ($\frac{1}{8}$ in.) and not larger than 6 mm ($\frac{1}{4}$ in.)."
- **110.12(A):** unused openings "closed to afford protection substantially equivalent to the wall of the equipment." 110.12(B): no contamination of busbars or terminals.
- **110.13(A):** equipment "firmly secured to the surface on which it is mounted."
- **110.3(B):** install per the listing and the manufacturer's instructions.

The NEMA 3R definition is the source of the top-entry rule: Type 3R "shall have conduit hub or equivalent provision for watertight connection at the conduit entrance when the conduit enters at a level higher than the lowest live part, provision for locking, and provision for drainage."

Step by step: mounting an outdoor enclosure

1. **Lay out height and working space first** (Part E). For utility meters, use the serving utility's book for the height of the meter.
2. **Mount plumb, ON up.** Square D: switches "are tested for operation and environmental enclosure ratings in the vertical position, with ON in the up position."
3. **Keep the $\frac{1}{4}$ " standoff** from the wall with strut or spacers (312.4(A)).
4. **Enter at the bottom or side, below live parts.** If any entry is above the lowest live part in a 3R box, use a listed wet-location hub (312.4(B)). A Myers-type hub has an O-ring

gasket that "assures positive water and dusttight installations." Torque the hub's ground screw to 35 lb-in (Myers IF 1461).

5. **Use the bolt-on hub provision where the switch has one.** Schneider 3R "RB" switches ship with "a bolt on closing cap factory-installed. Order bolt-on hubs separately." Hubs up to 2½" bolt on directly; 3" and larger need field holes.
6. **Protect the guts when you drill.** Square D: "Protect internal components from metal fillings, via drop cloths or orientation of drilling."
7. **Flex into the top only with a drip loop.** Hubbell's 4X switch instructions: "When using the top feed conduit entrance, drip loops must always be formed," and top entries are "not recommended in applications where condensation may be present in conduit." Form the flex so it dips below the entry before it rises into it.
8. **Open the drain.** Remove the factory drain screw on convertible 12/3R units, or drill a ⅛–¼" weep hole at the low point (314.15(C)(1)).
9. **Seal the raceways.** Underground raceways: 300.7(G) (300.5(G) in 2023), "Conduits or raceways through which moisture might contact live parts shall be sealed or plugged at either or both ends." Raceways passing from a warm inside to a cold outside: 300.9(A) (300.7(A) in 2023) requires sealing "to prevent the circulation of warm air to a colder section," by a listed fitting such as a thermal break coupling or another approved means. Use duct seal or a sealant identified for the conductor insulation.
10. **Close every unused knockout** with a listed closure (110.12(A)).
11. **Store gear dry.** Square D says outdoor-rated gear is "not suitable for outdoor storage." Keep it wrapped until it is installed. Their heater guide for condensation: 30–200 A gear 5 W, 400 A 25 W, 600–800 A 50 W, 1200 A 100 W.

Corrosion: 300.8 (300.6 in 2023)

- Materials must be "suitable for the environment." Ferrous parts are protected inside and outside, and field-cut threads are "coated with an approved electrically conductive, corrosion-resistant compound." Stainless is exempt.
- Enamel-only ferrous parts may not be used outdoors or in wet locations (300.8(A)(1)).
- Aluminum in concrete or earth needs extra corrosion protection (300.8(B)). Never set aluminum rigid conduit in concrete uncoated.
- In the field: cold-galvanize every cut end of strut and every field thread on rigid conduit; use stainless or hot-dip galvanized hardware outdoors.
- Strut finishes (Unistrut catalog): pregalvanized (0.75 mil zinc) is rated "for indoor and outdoor applications"; hot-dip galvanized (about 2.6 mil) is "the coating of choice for applications where severe corrosion is a design factor"; electroplated (0.2 mil) is "recommended for dry indoor use."

Step by step: a strut stand or meter rack

Utility books differ. These published examples show the usual build:

Utility book	Requirement
Snohomish-area PUD	"two pieces of Unistrut channel embedded in a 12" diameter poured concrete footing 36" deep"; channel at least "hot dip galvanized 12 gauge steel 1½" x 1½""; "The concrete footing should not encase the service riser conduits."
Ameren Missouri	"Wooden, stand-alone support structures are not allowed"; "Extend bonding jumper from meter socket / meter-main combo to the nearest vertical support pipe"; foam backfill not allowed.
Vermont Electric Co-op	Rigid steel posts at least 2" in 8" x 48" concrete; "Individual conduit supports shall not be used as both a support and as a wire conduit."

1. Call 811, then confirm the utility's location for the rack and the working space in front of it.
2. Auger two holes (12" diameter by 36" deep is typical). Set hot-dip galvanized strut or rigid steel posts plumb at the equipment's hole spacing. Brace them, pour, and crown the concrete so water runs away from the post.
3. Keep the riser conduits out of the footing concrete. Add an expansion fitting on PVC risers where the utility requires it.
4. After the concrete cures, bolt on the horizontal strut with spring nuts and bolts (hot-dip galvanized or stainless). Cold-galvanize the cut ends.
5. Mount the socket or disconnect with the ¼" standoff and bottom entries.
6. Bond the strut frame to the equipment grounding system.
7. Add bollards where vehicles can hit the rack (110.26(E)(2)(a)).

EVSE pedestal foundations (manufacturer examples)

- ChargePoint CT4000: "Do not use expanding anchor bolts. Do not install the CT4000 on an asphalt surface." For a new pour, the concrete block extends at least 2 ft on all sides; bolt threads stand 3" above the concrete; conduit stands 12-24" above; bolts go 6" into wet concrete through the plastic template, plumb.
- CT4000 on an existing slab at least 6" thick: drill 1" x 6" holes, blow out the dust, inject epoxy, rotate the bolts in, and let the epoxy cure before torquing. Bolts at least 15" from the front edge, 12" from the sides, 6" from the rear.
- Enphase/ClipperCreek HCS pedestal: pad at least 18" per side by 18" deep; 36" behind the curb with no wheel stop, 12" with one.

Part E — General Equipment Hookup

Which disconnect, and where

Equipment	NEC 2026	Rule
HVAC and refrigeration	440.14	"within sight from, and readily accessible from" the unit. May be on or in the unit, but not on access panels or over the nameplate, and must have 110.26(A) working space.
Split-system HVAC	440.15	Outdoor disconnect in other than one- and two-family dwellings identifies the indoor unit it serves.
Appliance, $\frac{1}{8}$ hp or less	422.31(A)	The branch breaker may serve if it is "within sight from the appliance or be lockable open in accordance with 110.25."
Motor-operated appliance over $\frac{1}{8}$ hp	422.31(B)	Disconnect per 430.109, within sight or lockable open.
Motor controller	430.102(A)	"located in sight from the motor controller location"
Motor	430.102(B)	In sight from the motor and driven machinery, with a limited exception (Module 1.6).
EVSE	625.43	Part C above.

"In sight" (110.29) means visible and not more than 50 ft away. "Lockable" (110.25) means the "provisions for locking shall remain in place with or without the lock installed."

Flexible conduit at the equipment

- **LFMC** (liquidtight flexible metal conduit): not where subject to physical damage (350.12). Secure within 12" of each box and every 4½ ft (350.30(A)).
- **LFMC as the grounding path** (350.60, 250.118(A)(6)): only "where flexibility is not required after installation," $\frac{3}{8}$ – $\frac{1}{2}$ " trade size on circuits of 20 A or less, $\frac{3}{4}$ – $1\frac{1}{4}$ " on 60 A or less, and no more than 6 ft of flex in the ground path. A wire EGC is required "where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation."
- **LFNC** (liquidtight flexible nonmetallic conduit): "Only fittings listed for use with LFNC" (356.42). Runs over 6 ft secured every 3 ft and within 12" of each box (356.30). It is nonmetallic, so pull a wire EGC.
- **Over 250 V to ground** (480Y/277 V): continuity at concentric or eccentric knockouts uses a bonding bushing or bonding locknut with a jumper (250.97, 250.92(B)). "Standard locknuts or bushings shall not be the only means" at services.
 1. Cut the flex square and trim the end (350.28).
 2. Use a listed straight connector. Angle connectors only where exposed.
 3. In wet locations, put the sealing ring or gasket on the outside of the enclosure wall.
 4. Leave a drip loop so water runs off before it reaches the fitting.
 5. Pull a wire EGC to any unit that vibrates: condenser, pump, motor (350.60(B)).

6. Land the EGC on the equipment grounding lug, never on a cover screw.

Working space outdoors: 110.26

Voltage to ground	Condition 1 (no grounded parts across)	Condition 2 (grounded wall across, e.g. concrete, brick)	Condition 3 (live parts across)
0-150 V	3 ft	3 ft	3 ft
151-600 V (277/480 V)	3 ft	3½ ft	4 ft

- Width: the equipment width or 30", whichever is greater, with doors able to open 90°.
- Height: "2.0 m (6½ ft) or the height of the equipment, whichever is greater." A pad may extend up to 6" beyond the front of the equipment.
- Outdoors (110.26(E)(2)): enclosures identified for the location; protected from unauthorized persons, "vehicular traffic," and leaking piping; no architectural feature in the working space; dedicated space equal to the footprint from grade to 6 ft above, with no foreign piping.
- In the field: stake out the 3 ft by 30" box on the pad before you set strut. Keep bollards, landscaping, and condensers out of it.

Labels

- **110.22(A):** each disconnect "legibly marked to indicate its purpose." In other than one- and two-family dwellings, the marking includes "the identification and location of the circuit source that supplies the disconnecting means." Example: RTU-3 DISCONNECT. FED FROM PANEL HA CKT 7,9,11, ELEC RM 102.
- **110.21(B):** field-applied hazard markings use warning words, colors, or symbols per ANSI Z535, and "shall be permanently affixed to the equipment or wiring method and shall not be handwritten." Only the variable parts may be handwritten.
- EVSE: the 625.43(D) emergency-disconnect wording and the 625.43(C) remote-disconnect plaque.

Part F — Prove It Before You Energize

Three different tests answer three different questions. Use the right instrument for each.

Question	Instrument	Typical acceptance
Is the ground rod making good contact with the earth?	Fall-of-potential earth tester (new, isolated rod) or clamp-on earth tester (existing multi-grounded system)	25 ohms or less for one rod to stand alone; specs often ask for 5 ohms
Is the wire insulation sound?	Insulation-resistance tester (megohmmeter, "megger")	Project spec, e.g. 100 megohms at 1,000 V DC for 600 V cable
Are the connections tight?	Calibrated torque tool	The manufacturer's marked value (110.14(D))

A megger does not test a ground rod. A megohmmeter measures insulation resistance in millions of ohms. Earth resistance is a few ohms and needs an earth tester.

Step by step: fall-of-potential test on a new rod (Fluke, AEMC)

1. Disconnect the rod from the system so only the electrode is measured. A lifted grounding conductor on a live system is an electrical hazard; treat it under NFPA 70E controls.
2. Connect the leads: E (green) to the rod, H (red) to the outer current stake, S (blue) to the inner potential stake.
3. Drive the current stake 8 to 10 times the rod depth away (a 10 ft rod puts it 80–100 ft out).
4. Set the potential stake at 62% of that distance and read. Repeat at 52% and 72%.
5. If the three readings are close, average them. If not, move the current stake farther out and repeat.
6. Over 25 ohms on a single rod: drive a second rod at least 6 ft away (better, twice the rod length) and bond it.

Clamp-on earth testing

Megger's guide: "The clamp-on method is effective only in situations where there are multiple grounds in parallel. It cannot be used on isolated grounds as there is no return path. Therefore, it cannot be used for installation checks or commissioning new sites." AEMC's reading guide: 0–1 ohm means you measured a local loop, not earth; 5–25 ohms is typical for a single rod; OL means no bond. Measure ground current first; AEMC's 3711 manual says do not proceed if ground current is over 5 A or noise over 50 V. On a buried ring, the clamp reads the ring loop, not the earth.

Worked example 1 (AEMC 3711 manual). 101 rods in parallel at 25 ohms each. Clamp one rod: $25 + 25 \div 100 = 25.25$ ohms, displayed as 25.2 ohms. The many parallel paths make the return almost zero, so the clamp reads the one rod.

Step by step: insulation-resistance test on a new feeder

1. Lock out and verify absence of voltage (OSHA 1910.333; NFPA 70E 120.6).

2. Lift anything that can't take the test voltage: EV charger electronics, VFDs, surge protective devices, controls, electronic neutrals. Schneider also says to remove trip-unit rating plugs marked "Disconnect Plug Before Dielectric Test."
3. Test each conductor to ground and to each other conductor. For 600 V cable, 1,000 V DC is typical (NETA Table 10.1; University of Michigan spec: "100 megohms minimum in one minute or less").
4. For switchboards, Schneider's QED-2 manual uses 500–1,000 V DC: "If the resistance reads less than one megohm... the system may be unsafe and must be investigated."
5. Record every reading. Some specs flag readings that are not within 20% of each other.
6. Discharge, reconnect, and restore.

Torque

110.14(D): tighten terminals to the value "indicated on equipment or in installation instructions provided by the manufacturer," using an approved means such as a calibrated torque tool.

Example published values from Schneider's QED-2 switchboard bulletin: ¼" bolt 50–75 lb-in, ⅜" bolt 175–225 lb-in, ½" bolt 250–350 lb-in. Mark or stripe each connection after you torque it.

Re-energizing (OSHA 1910.333(b)(2)(v))

1. "verify that all tools, electrical jumpers, shorts, grounds, and other such devices have been removed."
2. Warn everyone exposed to stay clear.
3. Each lock is removed by the person who put it on.

Common mistakes

Mistake	Fix	Source
Conduit into the top of a 3R box with a plain connector and locknut	Listed wet-location hub, or enter below live parts	312.4(B); NEMA 3R definition
Plain locknuts at a concentric knockout on 480 V	Bonding bushing or locknut with jumper	250.92(B), 250.97
Drain screw left in a 12/3R switch used outdoors	Remove it for 3R service	Eaton
Rods closer than 6 ft	6 ft minimum; twice the rod length is better	250.53(A)(3)
"Megger" used on a ground rod	Fall-of-potential or clamp-on earth tester	Megger, AEMC
Clamp-on tester on a new isolated rod	Fall-of-potential; clamp-on needs parallel paths	Megger clamp-on guide
Light pole grounded only by its rod	Wire EGC to the pole lug; the rod is auxiliary	250.54, 410.30(B)
Enclosure too small for the bending space	Check Table 312.9(B)(2) before ordering. One conductor per terminal entering the opposite wall: 3/0 Cu needs 6½", 4/0 Cu 7", 250 kcmil 8½"	312.9 (312.6 in 2023)
Riser not sealed; water or condensation runs into the gear	Duct seal or identified sealant	300.7(G), 300.9(A)
Enclosure flat against a wet wall	¼" standoff	312.4(A)
HVAC disconnect on the access panel or over the nameplate	Relocate	440.14
Handwritten hazard labels	Engraved or printed label	110.21(B)
Concrete encasing the meter-rack riser	Keep the footing off the riser	Utility books
Expansion anchors or asphalt under an EV pedestal	Cast-in or epoxy bolts in concrete	ChargePoint CT4000
Untreated field cuts on strut and rigid conduit	Cold galvanize; conductive thread compound	300.8(A)

Inspection and checkout list

Item	Acceptance	Source
Enclosure Type	Matches the location; Type number on the nameplate	110.28
Entries	Below live parts or listed hub; unused knockouts closed	312.4(B), 110.12(A)
Drain	Drain screw removed or 1/8–1/4" weep hole	314.15(C)(1)
Mounting	Plumb, ON up, 1/4" standoff, firmly secured	312.4(A), 110.13(A)
Working space	3 ft (3½ or 4 ft at 480 V, Conditions 2 or 3) × 30" × 6½ ft; dedicated space 6 ft above	110.26(A), (E)(2)
Rods	8 ft, 6 ft or more apart, flush, exothermic or listed direct-burial connection	250.53
Ring	2 AWG or larger bare Cu, 30" or deeper	250.52(A)(4), 250.53(F)
Pad grid	Per the utility book	Utility spec
Poles	Grounding terminal, hinged base bonded, wire EGC	410.30(B)
Flex	6 ft or less as an EGC; wire EGC where it vibrates	250.118(A)(6), 350.60
Disconnects	In sight or lockable as required; EV emergency disconnect within 20 ft, marked	440.14, 422.31, 430.102, 625.43
Labels	Permanent, source identified	110.21(B), 110.22(A)
Torque	Marked values, torque tool, striped	110.14(D)
Insulation test	Per spec (e.g. 100 megohms at 1,000 V DC for cable; gear 1 megohm or more per Schneider)	NETA, Schneider
Electrode resistance	25 ohms or less for a single rod, or add a rod; utility grid limit	250.53(A)(2) Exc.

NEC 2026 Checkpoints (2023 number in parentheses where it moved)

- **110.12, 110.13, 110.14(D), 110.21(B), 110.22(A), 110.25, 110.26, 110.28, 110.29** general installation, labels, working space, enclosure types. Standard: **NEMA EN 10250-2024** (formerly NEMA 250).
- **312.4(A)/(B)** (312.2) wet cabinets • **312.9** (312.6) bending space • **314.15(C)** drain holes.
- **300.7(G)** (300.5(G)) raceway seals • **300.8** (300.6) corrosion • **300.9(A)** (300.7(A)) temperature sealing.
- **250.52(A)(4)/(5), 250.53, 250.54, 250.92(B), 250.97, 250.106, 250.118(A)(6), 250.122 • 270.14** (250.194) substation fences.
- **350.12, 350.30, 350.60** LFMC • **356.30, 356.42** LFNC • **410.30(B)** poles.
- **422.31, 430.102, 440.14, 440.15** equipment disconnects • **Article 500** hazardous locations.
- **625.40, 625.41, 625.42, 625.43(C)/(D), 625.44, 625.50, 625.54** EVSE.

Hands-On Field Exercise

- Given four locations (dry electrical room, outdoor parking-lot pedestal, indoor washdown area, a room with flammable vapors), assign the NEMA/UL type for each and explain why.
- Mount a 3R disconnect on strut with a ¼" standoff: bottom entry, one top entry through a listed hub, drain screw removed, unused knockouts closed, raceways sealed.
- Drive a ground rod to full depth and make a CADWELD connection to a bonding jumper. Inspect the weld against the reject list.
- Fall-of-potential test the rod (readings at 52%, 62%, and 72%). If it is over 25 ohms, drive and bond a second rod at the right spacing. Then megger the feeder at 1,000 V DC with the loads lifted and record the readings.
- Terminate LFMC to a condenser with a drip loop and a wire EGC, and write the 110.22(A) disconnect label.
- Given an EV charger nameplate, size the branch circuit at 125%, and sketch where the emergency disconnect goes.
- Stake out the 110.26 working space for a 480 V disconnect on a pad with a brick wall behind the worker.

Sources used in this module (public documents)

- NFPA 70, National Electrical Code 2026 (free read-only access at [nfpa.org](https://www.nfpa.org)): Articles 110, 250, 270, 300, 312, 314, 350, 356, 410, 422, 430, 440, 500, 625.
- NEMA, NEMA Enclosure Types, and NEMA 250-2018 contents and scope: nema.org. Advanced Thermoelectric NEMA type definitions: electracool.com
- Eaton Knowledge Hub, enclosure rating of a safety switch; Eaton Crouse-Hinds Myers hubs and IF 1461: eaton.com
- Schneider Electric / Square D Safety Switch User Manual GEX75737, Enclosed Safety Switches catalog, and QED-2 switchboard bulletin 80043-055-16: se.com

- Rockwell Automation 1495-IN011 conduit hub installation and CENTERLINE 2100 MCC selection guide: literature.rockwellautomation.com
- Hubbell PD1785 4X switch instructions: hubbell.com. Unistrut General Engineering Catalog: unistrut.us
- UFC 3-520-01 Interior Electrical Systems: wbdg.org
- Utility books: Snohomish-area PUD underground requirements (wsimg.com); Ameren Missouri underground specification (ameren.com); Vermont Electric Co-op meter pedestal (vermontelectric.coop); National Grid ESB 754/759 (nationalgridus.com); PG&E Greenbook 045292 (pge.com); Alabama Power UG Distribution Spec (alabamapower.com).
- ERICO, Practical Guide to Electrical Grounding; nVent ERICO Cadweld Installation and Inspection Guide: nvent.com
- FDOT Standard Plans Index 715-001: fdot.gov
- Megger, Clamp-On Ground Testing guide: megger.com. AEMC clamp-on application note and Model 3711 manual: aemc.com. Fluke, Fall-of-Potential Measurement: fluke.com
- NETA maintenance testing tables (Table 10.1); University of Michigan master spec 26 08 00 (umich.edu); Duke University 26 08 01 (duke.edu).
- ChargePoint CT4000 pedestal mount: chargepoint.com. Enphase/ClipperCreek HCS pedestal guide: enphase.com
- OSHA 29 CFR 1910.333: osha.gov. NFPA 70E, 2024 edition: nfpa.org

Next: Module 1.10 — Power Flow: Utility to Charger.