

Module 1.8 — Underground & Site Distribution

From the 811 call to the as-built: trench safety, burial depth, duct banks, PVC joints and expansion, risers, handholes, pads, pole bases, voltage drop, and pulling underground.

Why this module. Commercial site work spends much of its life underground. Parking-lot lighting, sign circuits, EV chargers, gate operators, and the service from the utility transformer all leave the building, go into the dirt, and come back up at the equipment. This module follows that path in field order: call 811 and locate, dig a safe trench, bury at the right depth, build a duct bank, glue and expand PVC correctly, bring the riser up, size handholes, set a transformer pad and pole bases, check voltage drop on long runs, pull the wire, and pass the open-trench inspection.

Part A — Where It's Legal, and How Deep

Before the first shovel: the 811 sequence (Alabama law)

Every buried power, gas, water, and fiber line on the site is a hazard to you and a repair bill to the company. Alabama's underground damage-prevention law (Code of Alabama Title 37, Chapter 15) sets the steps. Other states use the same pattern with different day counts.

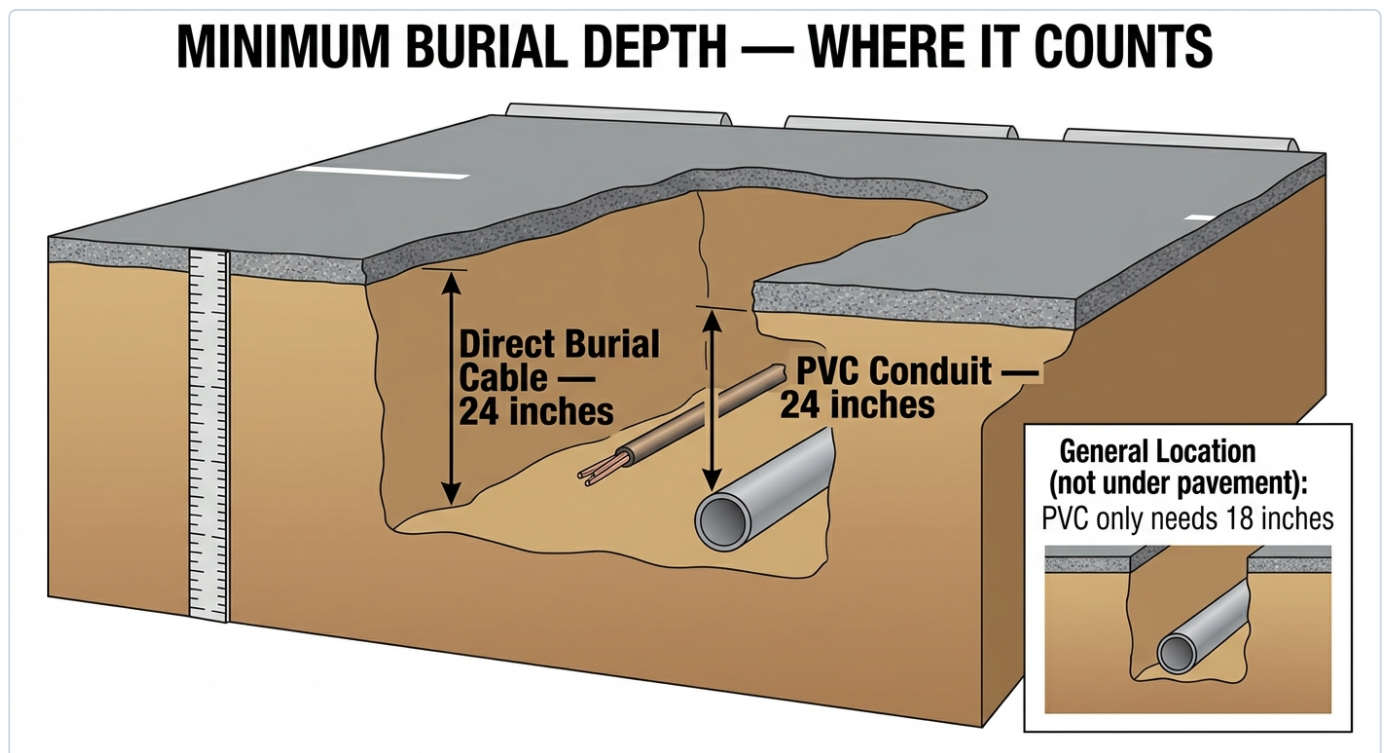
1. **White-line the route.** Mark where you plan to dig with white paint, flags, or stakes. Alabama requires premarking when the dig site can't be described precisely (§37-15-4(c)).
2. **Call 811** (in Alabama also 800-292-8525 or the Alabama 811 web portal). Notice must be given "at least two but not more than 10 working days prior to the start of the proposed excavation, not including the day of notification" (§37-15-4(b)). Working days leave out weekends and nine listed holidays.
3. **Track the ticket.** A ticket is good for 20 working days. Renew it 2 working days before it runs out.
4. **Wait for the start time, then check responses.** Confirm every utility listed on the ticket has marked or answered "clear" before you dig.
5. **Read the paint.** The APWA color code: white = proposed dig, **red = electric power**, orange = communications, yellow = gas or oil, blue = water, green = sewer, purple = reclaimed water, pink = survey marks.
6. **Respect the tolerance zone.** The zone is the width of the marked line plus 18 inches on each side. Inside it, hand dig, pothole, or vacuum excavate until the line is exposed. No machine teeth in the zone.
7. **Hire a private locate.** 811 members mark only their own lines, up to their meter or demarcation point. Customer-owned lines are not marked: parking-lot light circuits, sign

circuits, the electric from the meter to the building, irrigation. On a commercial site most of what you can hit belongs to the owner. A private locator finds those.

8. **Stop if you hit something.** If you uncover or damage a line, stop and notify 811 and the line's owner. OSHA also requires the location of utilities to be "determined prior to opening an excavation" (29 CFR 1926.651(b)(1)).

Burial depth: Table 300.7(A)

Burial depth is called "cover." It is set by the **location** and the **wiring method**. Cover is measured from the top of the cable or raceway up to finished grade (Note 1 to the table). In the 2023 NEC this was Table 300.5(A); in 2026 it is Table 300.7(A).



Minimum cover depth by wiring method and location — measured from the top of the conductor/raceway to finished grade.

Location (0-1000 V)	Col 1 Direct-burial cable	Col 2 RMC / IMC	Col 3 PVC or other nonmetallic raceway listed for direct burial
All locations not listed below	24"	6"	18"
In a trench below 2" of concrete or equivalent	18"	6"	12"
Under a building	0 (in a raceway, or MC/MI identified for direct burial)	0	0
Under a 4" or thicker exterior slab with no vehicle traffic, slab extending 6" or more past the run	18"	4"	4"
Under streets, highways, roads, alleys, driveways, and parking lots	24"	24"	24"
One- and two-family dwelling driveways and outdoor parking	18"	18"	18"
Airport runways and adjacent areas	18"	18"	18"

Columns 4 and 5 of the table cover residential 120 V GFCI branch circuits of 20 A or less and 30 V landscape lighting. They rarely apply on commercial sites.

The parking-lot trap. Everywhere else in the table, rigid metal conduit lets you dig a shallower trench (6" instead of 18–24"). Under vehicle traffic, it does not help. Streets, driveways, and parking lots require 24" for every wiring method because the depth protects the run from the load above.

Table notes you will use

- **Note 2:** a raceway approved for burial only when concrete-encased needs a concrete envelope at least 2" thick.
- **Note 3:** less depth is allowed where the conductors rise for terminations or splices.
- **Note 5:** in solid rock, run metal raceway or nonmetallic raceway permitted for direct burial, covered by at least 2" of concrete down to the rock.
- **Note 6:** direct-buried EMT must meet 358.10.
- **Over 1000 V:** use Table 305.15(A) (Table 300.50 in 2023). For 22 kV or less: direct burial 30", raceway 18" in general, and 24" under streets and parking lots.

NEC 2026 — 300.7 Underground Installations (300.5 in 2023)

300.7(A): "Direct-buried cable, conduit, or other raceways shall be installed to meet the minimum cover requirements of Table 300.7(A)."

300.7(B): "The interior of enclosures or raceways installed underground shall be considered to be a wet location." Conductors in underground conduit must be a wet-rated type per 310.10(C): THWN, THWN-2, XHHW, XHHW-2, RHW, THW, TW, or another type listed for wet locations. Plain THHN with no wet rating is not allowed underground.

300.7(C): cables and conductors under a building must be in a raceway.

Service lateral, underground service conductors, feeder, branch circuit

The name of the conductor tells you which rules apply. These are the Article 100 definitions.

Term	Article 100 meaning	Field meaning
Service lateral	"The underground conductors between the utility electric supply system and the service point."	The utility's side.
Service conductors, underground	"between the service point and the first point of connection to the service-entrance conductors in a terminal box, meter, or other enclosure"	On an Alabama Power pad-mount service, the customer furnishes and installs the Sch 40 conduit, adapters, and conductors from the pad-mount to the meter. No breaker protects these conductors.
Feeder	"All circuit conductors between the service equipment ... and the final branch-circuit overcurrent device."	Main switchboard to a remote panel or a charger subpanel.
Branch circuit	From the final overcurrent device to the outlet.	Last breaker to the light pole or charger.

Service conductors get the extra rules below: the warning ribbon in 300.7(D)(3) and the elbow bonding exception in 250.80. Alabama Power's handbook adds: "Schedule 80 building riser conduit required if subject to physical damage."

Part B — Duct Banks & Trenching

Trench safety: OSHA 29 CFR 1926 Subpart P

A trench collapse buries a worker in seconds. These rules are federal law on every job.

Rule	What it requires	OSHA
Competent person	Someone "capable of identifying existing and predictable hazards ... and who has authorization to take prompt corrective measures." Inspects the trench daily, and again after rain or anything that makes it worse.	1926.650(b), 1926.651(k)(1)
Cave-in protection	Required for every trench unless it is all stable rock, or it is under 5 ft deep and the competent person finds no sign of a possible cave-in. Under 5 ft is not automatically safe.	1926.652(a)(1)
Sloping with no soil test	1½ horizontal to 1 vertical (34°)	1926.652(b)(1) (i)
Sloping by soil type (under 20 ft deep)	Stable rock vertical; Type A ¾:1 (53°); Type B 1:1 (45°); Type C 1½:1 (34°)	Subpart P App. B
Trench box	You may dig no more than 2 ft below the bottom of the shield, and only if the shield is rated for the full depth and no soil is lost from behind it.	1926.652(g)(2)
Spoil pile and equipment	At least 2 ft back from the edge	1926.651(j)(2)
Ladder, stair, or ramp	In trenches 4 ft or deeper, no more than 25 ft of travel to reach it	1926.651(c)(2)
Air testing	Over 4 ft deep where low oxygen or a hazardous atmosphere could exist	1926.651(g)(1)
Traffic	High-visibility vests when exposed to public vehicle traffic	1926.651(d)

Do not enter a trench the competent person has not looked at today. Water in the bottom, cracks at the edge, a spoil pile at the lip, or a machine running close by are reasons to stay out and get the competent person.

Step by step: trench and bedding for direct-buried conduit (no concrete)

These are typical numbers from the federal guide specification UFGS 33 71 02. The project spec overrides them; the NEC sets only the minimums in Part A.

1. Grade the trench bottom smooth, with at least 3" between the conduit and the trench wall.
2. Where there is rock, soft spots, or sharp material, dig 3" deeper and fill back with sand or earth fine enough to pass a ¼" sieve. Tamp it level.
3. Lay the conduit (Part C for joints).
4. Cover the first 6" with compacted sand. Backfill the rest in 3–6" lifts, compacting each lift.
5. Keep bad backfill out. NEC 300.7(F): no "large rocks, paving materials, cinders, large or sharply angular substances, or corrosive material" where it could damage the raceway or

prevent compaction. Where needed, use "granular or selected material, suitable running boards, suitable sleeves."

6. Lay warning tape (below).

Warning tape

The NEC requires a warning ribbon only for services. 300.7(D)(3): direct-buried service conductors, and raceways holding service conductors, that are not in concrete and are buried 18" or deeper "shall have their location identified by a warning ribbon that is placed in the trench at least 300 mm (12 in.) above the underground installation." Most project specs require tape on every run anyway. Typical spec wording: red tape 6" wide, 12" above the conduit, extended 12" past each trench end; some specs call for metallic-backed tape or a #10 trace wire so a locator can find the run later.

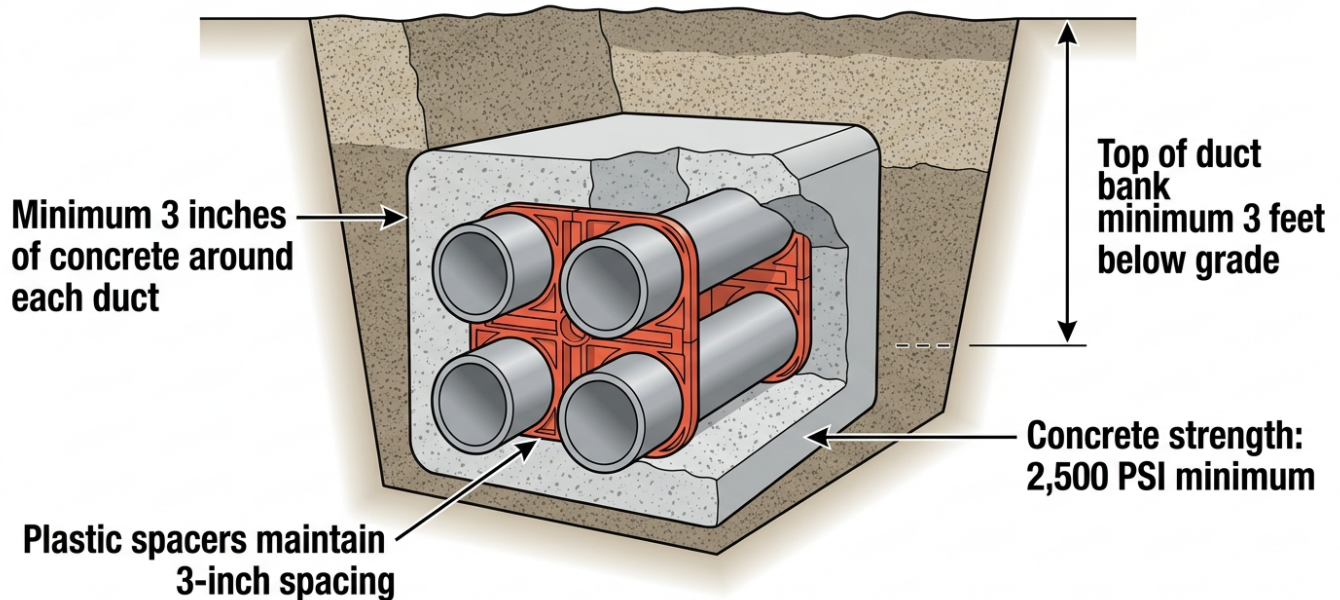
Earth movement

300.7(J): arrange runs so settling ground or frost does not damage them. The Informational Note lists "S" loops, "expansion fittings in raceway risers to fixed equipment," and flexible connections.

Step by step: a concrete-encased PVC duct bank

A duct bank is a group of conduits held in spacers and encased in concrete. It protects the whole group and gives a known path for future work. Sources: the Navy's NAVEDTRA 14027 manual and UFGS 33 71 02.

CONCRETE-ENCASED DUCT BANK



Concrete-encased duct bank — spacers hold conduit separation, concrete carries the load.

1. **Lay out and slope.** Run straight between structures. Slope about 1 ft per 100 ft, and never less than 3" per 100 ft, so water drains. If both ends can't drain one way, slope from the middle toward both ends.
2. **Dig and tamp** the bottom hard and even.
3. **Set the base spacers.** UFGS: interlocking base and intermediate spacers with a top lock, at least 2 spacer assemblies per 10 ft, at least 3" between conduits (12" between power and signal where the spec says so). The Navy method is to embed spacers about 1" into a 3" bottom layer of concrete.
4. **Lay conduit and stagger the joints** by row and layer, so couplings don't line up in one weak spot. Start rows with different-length sticks.
5. **Anchor against floating.** Wet concrete floats empty PVC. Drive rebar beside the spacer assemblies and tie it to them before the pour.
6. **Plug every duct end** so concrete and dirt stay out.
7. **Call for the pre-pour inspection** (Part J).
8. **Pour.** At least 3" of concrete on all sides and between ducts. Strength: the Navy manual says 2,500 psi at 28 days; many owner specs call for 3,000 psi. Vibrate it. Red dye is normally required for medium-voltage banks; follow the spec on whether it is mixed in (for example 8 lb per cubic yard) or dusted on top.
9. **Backfill only after the concrete sets.** LADWP's spec, for example, allows no backfill until 2 hours after the pour unless approved.

Depth to the top	Who says so
18" to top of raceway (24" under traffic)	NEC Table 300.7(A), Column 3
18" to top of envelope (24" under pavement)	UFGS 33 71 02 (federal projects)
3 ft to the top of the upper ducts	Navy manual practice (NAVEDTRA 14027). It is not an NEC rule. Use it only if your project spec calls for it.

- **Reinforcing:** unreinforced banks are typical for 18–48" of cover with no traffic or light traffic. Under heavy trucks, cranes, rail, or soil changes, the UFGS table calls for 4 #4 bars with #3 ties at 3 ft on center for banks up to 30" wide. Extend the encasement 5 ft past pavement edges.
- **Bends:** UFGS minimum manufactured sweep radius is 18" for ducts under 3" and 36" for 3" and larger. Short-radius 90s only at pole and equipment risers. The NEC limit is 360° of bends between pull points (352.24(B); 352.26 in 2023).

Directional boring

- 300.7(K): "Cables or raceways installed using directional boring equipment shall be approved for the purpose."
- HDPE conduit (353.10) comes "in continuous lengths from a reel" and is allowed "in direct burial installations in earth or concrete." Above ground only when encased in 2" or more of concrete. Transition HDPE to PVC or rigid before it enters a box or riser.
- Pothole (hand dig or vacuum) every utility that crosses the bore path before you bore. The tolerance-zone rule applies.

Seals, spare ducts, and buried splices

- 300.7(G): raceways where moisture could reach live parts "shall be sealed or plugged at either or both ends. Spare or unused raceways shall also be sealed." The sealant must be identified for use with the cable insulation. A service raceway entering a building is sealed per 230.8.
- UFGS: plug empty conduits with weep-hole plugs and leave a pull rope of at least 200 lb strength with 3 ft of slack at each end.
- 300.7(E): direct-buried conductors may be spliced or tapped without a box. Use a splice kit listed for direct burial.
- 300.7(I): all conductors of a circuit, including the equipment grounding conductor, go in the same raceway. Direct-buried single conductors of one circuit go in the same trench, close together (Exception No. 1).

Part C — PVC Conduit: Selecting & Installing

PVC (rigid polyvinyl chloride) conduit is the default underground raceway. 352.10(H) permits it for direct burial and for underground runs encased in concrete. It does not rust. It cannot go in

ambient heat over 50°C (122°F) unless listed for it (352.12(D)). Trade sizes run ½" to 6"; larger is allowed underground only, backfilled per 300.7(F) (352.20).

Schedule 40 vs. Schedule 80

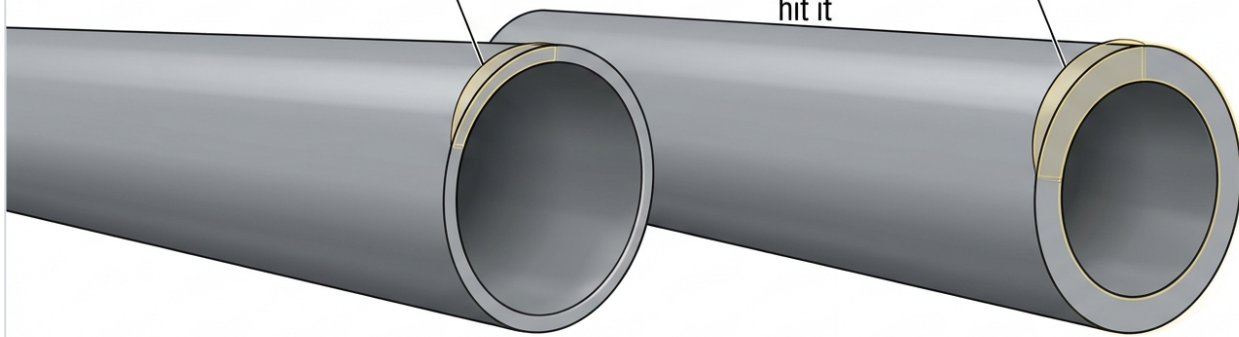
SCHEDULE 40 vs SCHEDULE 80 PVC — KNOW THE DIFFERENCE

SCHEDULE 40 — standard wall

General purpose: exposed, encased, most underground runs

SCHEDULE 80 — heavy wall

Required by NEC 352.10(K) where subject to physical damage — e.g. a conduit riser sticking up in a parking lot where a vehicle or cart could hit it



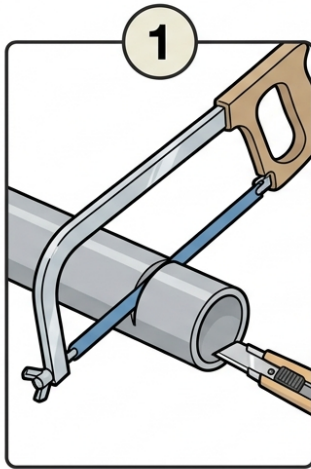
Same outside diameter — fittings interchange between both, per NEC Informational Note.

Same fittings, different wall. Schedule 80 is required, not optional, wherever the run is subject to physical damage.

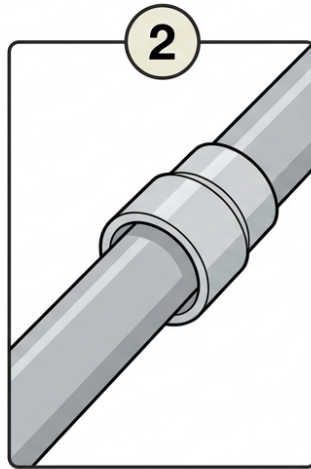
- **Schedule 40** is standard wall. It is the default for buried, encased, and general exposed runs.
- **Schedule 80** is heavy wall. 352.10(K): "Where subject to physical damage. Schedule 80 PVC conduit, Schedule 80 PVC elbows, and listed fittings for PVC conduit shall be used." 352.12(C) is the matching prohibition on Sch 40 in that spot. A riser coming out of a parking lot or drive lane, where a bumper, cart, or plow can reach it, is the common case.
- Both schedules share the same outside diameter. The Informational Note to 352.10(K) says "All listed PVC conduit fittings are suitable for connection to both Schedule 40 and Schedule 80 PVC conduit," so a Sch 80 riser joins Sch 40 below grade with a standard coupling. Sch 80's thicker wall means a smaller inside diameter, so check conduit fill against the Sch 80 table.

Step by step: solvent cementing PVC conduit

SOLVENT-WELDING PVC — 4 STEPS



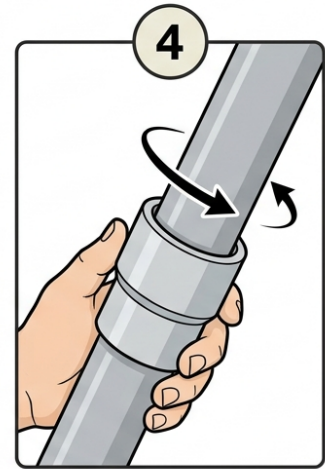
**Cut square
& deburr**



**Dry-fit — 2/3
into socket**



**Apply primer
(purple) then
cement**



**Insert with 1/4
turn, hold 30
seconds**

The figure shows purple primer, which is plumbing practice. PVC conduit makers such as Carlon say primer is not required when the parts are clean and dry. Cut, deburr, clean, cement, quarter-turn, and hold.

1. **Cut square** with a fine-tooth saw or PVC cutter. Use a miter box for 2" to 6".
2. **Deburr** inside and outside and round the inside edge. 352.28: "All cut ends shall be trimmed inside and outside to remove rough edges."
3. **Dry-fit.** The pipe should start into the socket about two-thirds of the way.
4. **Clean** the socket and the pipe end of dirt and moisture.
5. **Cement.** Put a uniform coat of the conduit maker's cement on the pipe end, the full depth of the socket. Carlon: "Primers are not required for the solvent cementing of PVC conduit." Use the cement made for the conduit brand.
6. **Push to the bottom of the socket with a quarter turn** and hold it about 30 seconds. Once set, the joint can't be repositioned.
7. **Check the bead.** A good joint shows a continuous bead of cement all the way around (IPEX guide). Gaps mean too little cement.
8. **Let it set** before you move it (table below), and let it cure before pulling wire.

Air temperature	1/2-1 1/4"	1 1/2-2"	2 1/2-4"
60-100°F	2 min	5 min	30 min
40-60°F	5 min	10 min	2 h
0-40°F	10 min	15 min	12 h

Carlson set times before disturbing the joint. Standard cements are not recommended below 40°F; Carlson's All Weather cement is rated 5–100°F. 352.48 says joints are "made by an approved method," which means the manufacturer's instructions.

Supporting PVC (352.30)

PVC must be fastened so it can move with temperature. Strap within 3 ft of each box, then at the spacing in Table 352.30(B):

Trade size	½-1"	1¼-2"	2½-3"	3½-5"	6"
Max support spacing	3 ft	5 ft	6 ft	7 ft	8 ft

PVC carries no fault current. A metal raceway can serve as the equipment grounding path. PVC is not in the 250.118 list of grounding paths, so every PVC run carrying power needs a separate equipment grounding conductor pulled in with the circuit conductors. Underground, 300.7(I) puts it in the same raceway.

Sunlight resistance: 352.100, 352.120 and 300.8(C)(1) (300.6 in 2023)

PVC used above ground must resist sunlight as part of its listing (352.100), and its marking shows it where it applies (352.120 Informational Note). The general rule for any nonmetallic raceway in the sun is 300.8(C)(1): "materials shall be listed as sunlight resistant or identified as sunlight resistant." Check the print on the stick before you build an exposed riser.

Expansion fittings: PVC moves with temperature

352.44 requires an expansion fitting where the length change "is expected to be 6 mm (¼ in.) or greater in a straight run between securely mounted items such as boxes, cabinets, elbows." Buried PVC sees small temperature swings. The fittings matter on risers and exposed runs. Carlson advises adding 30°F to the air-temperature range for runs in direct sun.

Temperature change	40°F	60°F	70°F	80°F	100°F	120°F	140°F
PVC length change per 100 ft (Table 352.44)	1.62"	2.43"	2.84"	3.24"	4.06"	4.87"	5.68"

Worked example 1. A 100 ft exposed PVC run with a 70°F swing changes length by 2.84" (Table 352.44), far past the ¼" trigger. Without an expansion fitting it buckles at a bend or pulls apart at a coupling.

Worked example 2 (Carlson method). A 90 ft exposed 2" run on a sunny wall. Air ranges from –10°F to 110°F, so the change is 120°F. Length change = $0.90 \times 4.87 = 4.38"$. One Carlson E945J (2", 8" travel) covers it. Installed at 65°F, set the piston at $(110 - 65) \div 120 = 0.375$ of its travel: $0.375 \times 8" = 3"$ **retracted**, so it can still open when it gets cold and close when it gets hot.

Steel conduit moves less: multiply Table 352.44 by 0.20 for steel and 0.40 for aluminum (300.9(B) Informational Note No. 1; 300.7(B) in 2023).

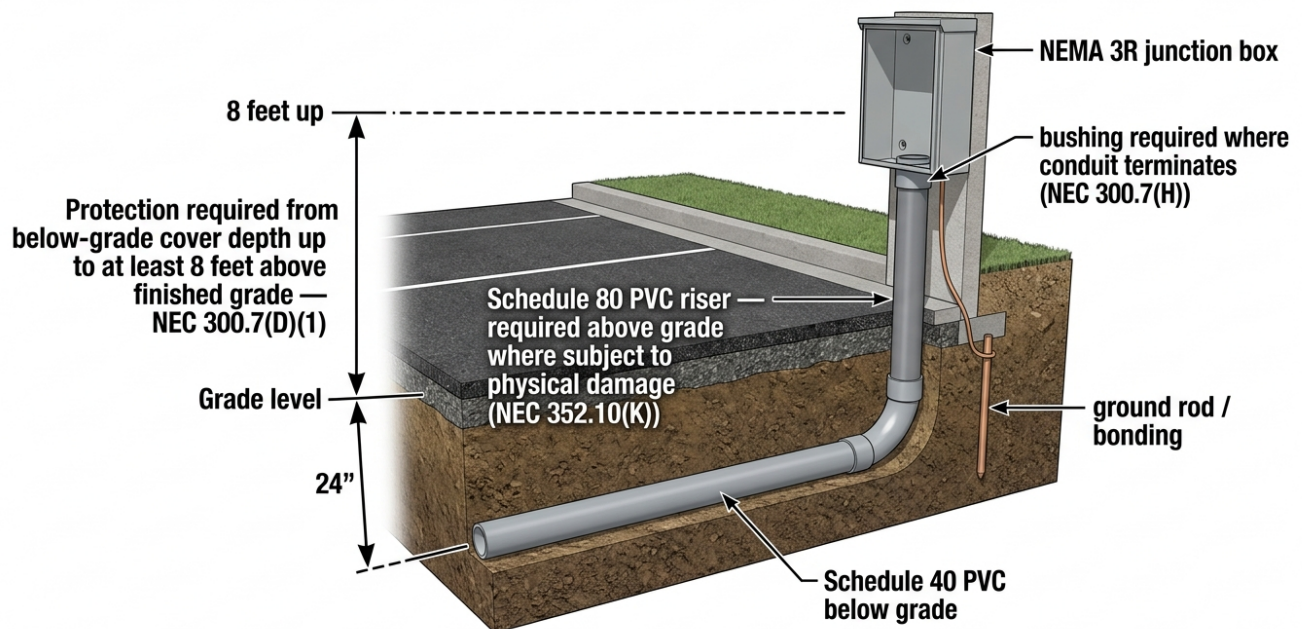
Step by step: installing an expansion fitting (Carlon)

1. Figure the length change and pick a fitting with enough travel (Carlon E945: $\frac{1}{2}$ – $1\frac{1}{2}$ " have 4" travel; 2–6" have 8").
2. Set the piston opening for today's temperature, as in worked example 2.
3. Clamp the barrel tight. Leave the conduit straps loose enough for the pipe to slide.
4. Align the fitting with the run so the piston does not bind.
5. On a vertical riser, put the fitting near the top with the barrel pointing down.
6. With two fittings in one run, fix the center of the run so each end moves toward its own fitting.

Part D — The Riser Transition: Underground to the Box

A riser is where the underground run turns up out of the ground to feed a box, meter, pole, or charger above grade.

THE RISER TRANSITION — UNDERGROUND TO THE NEMA 3R BOX



The riser transition: Schedule 40 below grade, protection required up to 8 ft above grade, bushed into the enclosure.

What the code says, rule by rule

- **300.7(D)(1) Emerging from grade (300.5(D)(1) in 2023):** "Direct-buried conductors and cables emerging from grade and specified in Columns 1 and 4 of Table 300.7(A) shall be protected by enclosures or raceways extending from the minimum cover distance below grade ... to a point at least 2.5 m (8 ft) above finished grade. In no case shall the protection be required to exceed 450 mm (18 in.) below finished grade." This rule is about **direct-buried cable** coming up out of the ground.
- **352.10(K):** if the run is already in PVC conduit end to end, the riser is part of that raceway. It must be Schedule 80 where it is "subject to physical damage," such as a parking lot or drive lane.
- **300.7(D)(4):** where the raceway is subject to physical damage, use EMT, RMC, IMC, RTRC-XW, Schedule 80 PVC, or equivalent.
- **300.7(D)(2):** conductors entering a building are protected to the point of entrance.
- **300.7(H):** a bushing (or terminal fitting with an integral bushed opening) goes on a raceway that ends underground where the conductors come out as direct burial. A seal with the protection of a bushing may be used instead.
- **338.12(B):** USE cable may come above ground only to terminate in an outdoor enclosure, protected per 300.7(D).

Metal elbows and risers: when they must be bonded

Many owner specs require galvanized rigid steel (GRC) elbows and risers for strength, wrapped with 10-mil PVC tape half-lapped or with bitumastic coating to stop corrosion. 300.8(A) requires corrosion protection on ferrous raceways, and field-cut threads must be coated with an approved electrically conductive, corrosion-resistant compound.

- **250.86 Exception No. 3:** a metal elbow in a run of nonmetallic raceway need not be connected to the equipment grounding conductor if it is isolated from contact by at least 18" of cover to any part, or encased in at least 2" of concrete.
- **250.80 Exception:** the same 18" rule for metal elbows in service raceways.
- The exception covers only the buried elbow. An above-grade GRC riser is exposed and must be bonded with a grounding bushing or a listed fitting.

Step by step: building a riser

1. Set the elbow so the riser stands plumb under the equipment knockout. Use Sch 80 PVC (or GRC) where vehicles can reach it.
2. Bring it up to the enclosure. For direct-buried cable, the protection runs to 8 ft above grade or into the enclosure, whichever comes first.
3. Strap it within 3 ft of the box (352.30(A)), then per Table 352.30(B).
4. On a long exposed riser to fixed equipment, add an expansion fitting near the top, barrel down (300.7(J) Informational Note).
5. Terminate with a bushing or adapter at the enclosure (352.46).

6. Seal the raceway after the pull (300.7(G)).
7. Bond any exposed metal riser section.

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

The feeder and branch circuits run under the parking lot, so the cover is 24" for every wiring method (Table 300.7(A)). The crew runs Schedule 40 PVC at that depth, turns up with an elbow, transitions to Schedule 80 for the exposed riser because the riser stands where vehicles drive (352.10(K)), and lands in the enclosure through a bushing. The box at the top of the riser is NEMA 3R because it sits outside in the rain and is not hosed down or exposed to salt spray. Module 1.9 covers enclosure ratings in full.

Plain-English: what does "NEMA 3R" mean?

NEMA (the National Electrical Manufacturers Association) writes the standard for electrical enclosure ratings. The rating number tells you what the box can keep out.

- **NEMA 1:** basic indoor box. Keeps fingers off the wires. No rain, dust, or outdoor use.
- **NEMA 3R:** outdoor, rain-rated. Rain and melting ice run off instead of getting in. It does not stop dust or a hose spray.
- **NEMA 4:** indoor or outdoor. Stops wind-blown dust, rain, and a hose sprayed straight at it. Used where equipment gets washed down.
- **NEMA 4X:** the same as a 4, made of stainless steel or fiberglass so it won't corrode. Used near salt air and chemicals.

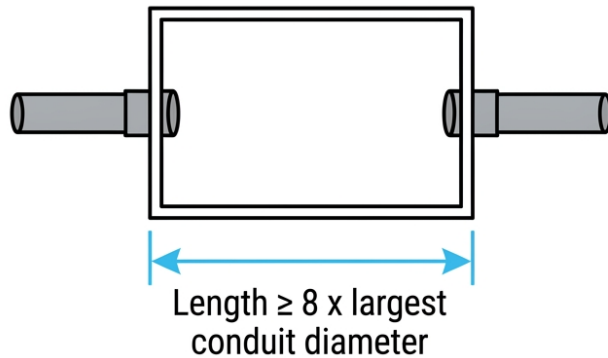
Ask "inside or outside, and does it get wet?" Dry room: 1. Outside, rain only: 3R. Outside and hosed down or dusty: 4. Same as 4 near salt or chemicals: 4X. Module 1.9 covers the full comparison, including the hazardous-location ratings 7 and 9.

Part E — Handholes & Pull Boxes

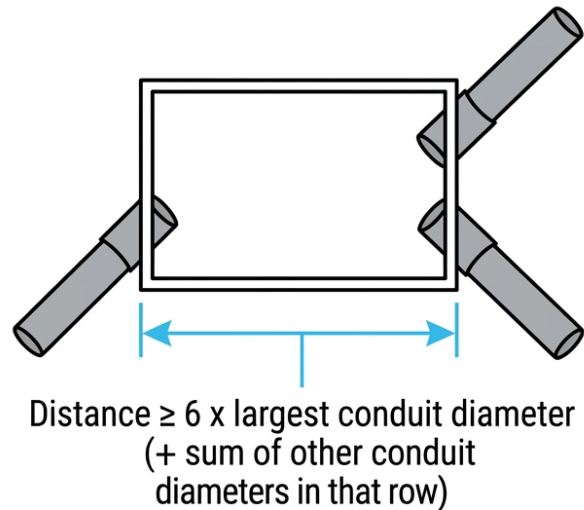
Long runs, splice points, and changes of direction need a box big enough to work the conductors without damaging them.

PULL BOX SIZING — NEC 314.28

STRAIGHT PULL



ANGLE / U PULL



Pull box sizing is a straight formula, not a guess — driven by the largest conduit entering the box.

Pull and junction box sizing: NEC 314.28(A)

This sizing rule applies to raceways with conductors **4 AWG and larger**. Smaller conductors use the box-fill rules instead.

- **(A)(1) Straight pull:** box length at least **8 ×** the trade size of the largest raceway.
- **(A)(2) Angle or U pull, or splices:** distance from each raceway entry to the opposite wall at least **6 ×** the largest raceway in that row, plus the sum of the other raceways in the same row on the same wall. Figure each row separately. Two entries holding the same conductor must be at least **6 ×** the larger raceway apart.
- **314.28(B):** in boxes with any dimension over 6 ft, secure the conductors in an approved manner.

Worked example 3. Straight pull, largest raceway 3": minimum length $8 \times 3 = \mathbf{24"}$. Angle pull with one 3" and one 2" entering the left wall: $6 \times 3 + 2 = \mathbf{20"}$ to the opposite wall. A 3" raceway that enters and leaves on the same wall (a U pull) needs its two entries at least $6 \times 3 = \mathbf{18"}$ apart. Then pick the next listed handhole that meets both dimensions and the load rating for its location.

Worked example 4. A 2" conduit with 4 AWG or larger conductors: an angle pull box needs at least $6 \times 2 = 12"$ to the opposite wall (plus any other raceways in that row). A straight pull box needs at least $8 \times 2 = 16"$ of length.

Handholes: 314.29 and 314.30

- 314.30: handholes must be "designed and installed to withstand all loads likely to be imposed" and be "identified for use in underground systems." The Informational Note points to ANSI/SCTE 77, which rates handholes by load tier. Use a tier rated for the traffic that can reach the box; confirm the tier with the project spec.
- 314.30(A): size per 314.28(A) for 1000 V and under. For a bottomless handhole, measure to the removable cover.
- 314.30(B): raceways must extend into the handhole; a mechanical connection is not required.
- 314.30(C): conductors and splices inside are listed for wet locations.
- Covers: marked to show their use (for example "ELECTRIC"); require tools to open or weigh over 100 lb; metal covers bonded per 250.92 for service conductors or 250.96(A) for feeders and branch circuits.
- 314.29(B): underground boxes and handholes must be reachable "without excavating sidewalks, paving, earth, or other substance that is to be used to establish the finished grade." A listed box under gravel is allowed if its location is described and the description is available to those who maintain it.

Manholes

Utility-scale runs with many splices use a manhole, a vault a person works inside. The Navy manual: cable reel lengths of 400–600 ft limit manhole spacing; keep runs straight between manholes; a drain hole goes in the floor. A manhole is a confined space. Ventilate and test the air before entry, and use an observer and harness where required.

Part F — Pad-Mount Transformer Pads and Service Conduits

On many commercial services the utility sets a pad-mounted transformer on a concrete pad that the contractor builds. Alabama Power and Georgia Power both use Southern Company specs SUH-16.001 and SUH-16.002 for pads and conduit entrances. The utility engineer sets the pad's location and orientation. Always build from the drawing the utility gives you for that job.

Step by step: pad and secondary conduits (Southern Company spec)

1. Get the utility's pad location, orientation, and pad size. Do not move the pad without the utility engineer.
2. Check clearances. The pad is not near fire escapes, doors, windows, or vents; not within 4 ft of a hydrant; not under an overhang. Georgia Power's location guide: 10 ft from buildings and 14 ft from doors, and 10 ft by 10 ft clear in front of the fuse side, with truck access. It can go as close as 3 ft only with written fire-marshal approval.
3. Stub the secondary conduits into the pad's cable window. "Start on right and work left" (SUH-16.001). Georgia Power requires the secondary conduits to be "run and stubbed out at the final transformer location prior to GPC's setting the transformer and pad," with a maximum of 12 conductors per phase.

4. Form and reinforce: #4 rebar on a 12" × 12" grid, 4" below the top, 2" of clear cover, a 1" bevel on the top edges, top flat and smooth.
 5. Alabama Power only: cast a #2 bare copper ground bus in the pad, tied to the rebar, with a 4" loop into the cable window. Where enhanced grounding is called for: 100 ft of #2 copper in the trench bottom, or 32 ft of stacked ground rods, on both the primary and secondary sides.
 6. Pour concrete of at least 3,000 psi at 28 days, placed within 1½ hours of mixing.
 7. Cure at least 72 hours before the utility sets the transformer.
- **Meter on its own pedestal** (Alabama Power): a #12 bare copper bonding conductor if the meter is within 6 ft of the transformer; a customer-installed 8 ft ground rod with a #6 copper grounding electrode conductor; 1¼" Sch 40 or galvanized metering conduit.
 - **Service conduits from the pad to the meter** are customer-installed Sch 40, with Sch 80 risers where subject to physical damage (Alabama Power Commercial Meter Installation Handbook). These are service conductors: the 300.7(D)(3) ribbon applies to them when direct-buried 18" or deeper and not in concrete.

Part G — Site Lighting Pole Bases

NEC 2026 410.30(B): metal and nonmetallic poles supporting luminaires

- (1) A handhole at least 2" × 4" with a wet-location cover, so you can reach the supply splices. Exceptions: a pole 8 ft or shorter with no splice in it, and a pole 20 ft or shorter with a hinged base.
- (2) A threaded fitting or nipple opposite the handhole if the raceway does not run inside the pole.
- (3) A metal pole has an equipment grounding terminal you can reach from the handhole.
- (4) A hinged base is bonded to the pole.
- (5) Metal raceways and equipment grounding conductors are bonded to the metal pole with an EGC sized per 250.122.
- (6) Conductors in vertical poles are supported per 300.21.

Step by step: setting anchor bolts and a pole

1. Use the foundation an engineer designed for the local soil and wind.
2. Transfer the paper bolt template to plywood.
3. Set the anchor bolts plumb through the template, with a nut on the template to fix the bolt projection (Current Lighting's table gives 3–4" depending on the pole). Hooks point outward, with at least 3" of concrete to the edge of the hole.
4. Bring the conduit stub-ups up inside the template's clear area.
5. Pour and vibrate. Let the concrete reach full strength before loading it.
6. Set a leveling nut and washer under the base plate and a top nut and washer above. Level the pole from two faces.

7. Grout under the base only if the pole maker says to. Current Lighting says grout to full contact with a drain channel; Techlight does not recommend grout because it traps water, and requires a weep tube if it is used.
8. Never leave a pole standing without its luminaire and arms. A bare pole can vibrate and fail.

Part H — Voltage Drop on Long Site Runs

Site runs are long, and long runs lose voltage. 215.4(A) Informational Note No. 2 says feeders sized for no more than 3% drop, with feeder plus branch circuit no more than 5% total, "will provide reasonable efficiency of operation." The same note appears for branch circuits at 210.19. These are recommendations. Project specs often make them mandatory.

Formulas: single-phase $VD = 2 \times I \times R \times L \div 1000$. Three-phase $VD = 1.732 \times I \times R \times L \div 1000$. I is amps, L is one-way length in feet, and R is ohms per 1000 ft from NEC Chapter 9 Table 8.

Uncoated copper, 75°C	#10	#6	#4	3/0	4/0
Ohms per 1000 ft (Chapter 9 Table 8)	1.24	0.491	0.308	0.0766	0.0608

Worked example 5 (feeder). 480Y/277 V three-phase, 150 A, 3/0 copper, 400 ft one way. $VD = 1.732 \times 150 \times 0.0766 \times 0.400 = 7.96$ V. $7.96 \div 480 = \mathbf{1.66\%}$. It passes 3%.

Worked example 6 (pole-lighting branch circuit). 277 V single-phase, 12 A lumped at the end, 600 ft one way.

Wire	Math	Drop	Result
#10	$2 \times 12 \times 1.24 \times 0.600$	17.86 V = 6.4%	Fails
#6	$2 \times 12 \times 0.491 \times 0.600$	7.07 V = 2.55%	Passes 3%
#4	$2 \times 12 \times 0.308 \times 0.600$	4.44 V = 1.6%	Passes

When you upsize the circuit conductors for voltage drop, the equipment grounding conductor is upsized in proportion (NEC 2026 250.122(D), 250.122(B) in 2023). For more exact answers on large feeders, Chapter 9 Table 9 gives AC impedance by raceway type.

Part I — Pulling Wire Underground

Numbers from the Southwire Power Cable Installation Guide and UFGS 33 71 02.

1. **Prove the duct.** For 3" and larger, pull a flexible mandrel about 12" long, slightly smaller than the duct's inside diameter, then a stiff brush. A stuck mandrel finds a crushed or out-of-round duct before the cable is on the reel.
2. **Check the cable:** size and type match the drawings, no shipping damage, end seals on, no nails or staples on the reel. Do not install PVC-jacketed cable below 14°F (−10°C).

3. **Lubricate** with a listed lubricant compatible with the jacket. No waxes or greases. Lube the cable and the duct during the pull.
4. **Keep tension under the limits.** Allowed tension is the lower of the pulling device rating and the conductor limit. A basket grip is traditionally limited to 1,000 lb; a pulling eye to its rating or 10,000 lb. The copper conductor limit is 0.008 lb per circular mil.
5. **Watch sidewall pressure** at bends. For one cable, sidewall pressure = tension ÷ bend radius in feet. The limit for 600 V nonshielded cable is 500 lb/ft.
6. **Watch for jamming.** Three cables in a conduit can wedge. Jam ratio = conduit inside diameter ÷ cable diameter. Jamming risk is significant between 2.8 and 3.0, and small below 2.5 or above 3.2. Keep clearance of at least 10% of the conduit inside diameter or 1".
7. **If the numbers don't work:** use larger bend radii, less fill, fewer bends, pull from the other end, pull in stages, or shorten the pull. Pull downhill from the highest structure.
8. **Cut off the cable under the basket grip** before terminating. It is damaged.

Worked example 7. Three 3/0 copper conductors (167,800 circular mils each). Conductor limit = $0.008 \times 167,800 \times 3$ = about 4,027 lb (confirm the multi-conductor formula in the Southwire guide). A basket grip caps this pull at about 1,000 lb, so a long pull needs a pulling eye. At a 36" (3 ft) sweep with 1,200 lb of tension, sidewall pressure is $1,200 \div 3$ = 400 lb/ft, under the 500 lb/ft limit.

Direct-burial cable types

Cable	Allowed	Not allowed
USE (underground service entrance)	Underground, including direct burial. Bend radius at least 5 × its diameter (338.24).	Interior wiring; above ground except coming up to an outdoor enclosure, protected per 300.7(D) (338.12(B)).
UF (underground feeder)	Underground including direct burial (340.10). 14 AWG Cu to 4/0. Ampacity at the 60°C column (340.80).	Service-entrance cable, embedded in concrete, in sunlight unless identified sunlight resistant, where subject to physical damage (340.12).

Underground service conductors over 1000 V follow Article 268 (268.30).

Part J — Inspection and As-Built Records

Hold points: call the inspector before you cover anything

1. Trench depth, width, and bottom before conduit goes in.
2. Conduit placement before encasement or backfill.
3. During the encasement pour, where required.
4. Before final backfill.

Utilities and inspectors enforce these. LADWP, for example, makes the contractor re-expose or remove and replace work that was covered before inspection, at the contractor's cost. Ask the local inspector which hold points they want.

Open-trench checklist

- Depth to the top of the raceway, measured from final grade with a string line or laser. Photograph the tape against the conduit.
- Conduit type and schedule: Sch 40 buried, Sch 80 where exposed to damage, sunlight-resistant marking above ground.
- Sweeps: radius and total degrees per run (360° maximum between pull points).
- Spacer spacing and 3" separation in duct banks.
- Plugs on spare ducts and pull ropes in place.
- Warning tape height (12" above) and color.
- Backfill free of rocks larger than 1" in the first lift (a common utility spec), and compaction tests where the spec calls for them.
- Bushings at underground terminations, and bonding on exposed metal risers.

As-built drawings

- Record offsets from two permanent features (building corner, curb, light pole base) to every bend, stub-up, handhole, and crossing utility. Record depth at each point.
- Photograph each trench segment before backfill with a tape visible in the shot.
- For buried boxes, the location description must be "available to those authorized to access, maintain, or inspect" (314.29 Exception).
- Before energizing: mandrel and clean the ducts, then run the insulation-resistance test the project spec calls for.

Common mistakes

Mistake	Why it matters
Digging before every utility has responded, or trusting 811 marks for customer-owned lines	Parking-lot and sign circuits are not marked by 811
Machine digging inside the 18" tolerance zone	Alabama law; struck lines
Entering an unprotected trench because it is "under 5 ft"	The competent person must still find no cave-in risk
18" of cover under a parking lot	Table 300.7(A) requires 24" there for every method
THHN with no wet rating in underground conduit	300.7(B) makes it a wet location
Purple plumbing primer on conduit, or the wrong brand of cement	Conduit makers specify their own cement; primer is not required
No expansion fitting on a sunny exposed run	Buckles or pulls apart
Sch 40 riser in a drive lane	352.10(K) requires Sch 80
Unplugged spare ducts, unsealed raceways into equipment	300.7(G); water runs into the gear
Exposed GRC riser left unbonded	The 18" exception covers only buried elbows
Pulling past the basket-grip or sidewall-pressure limit	Damaged insulation that fails later
Backfilling before inspection	Re-excavation at the contractor's cost

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

- **Table 300.7(A)** (Table 300.5(A)) cover depth • **300.7(B)** underground is a wet location • **300.7(C)** under buildings • **300.7(D)(1)-(4)** emerging from grade, ribbon for services, damage protection • **300.7(E)-(K)** splices, backfill, seals, bushing, same raceway, earth movement, boring (all 300.5 in 2023).
- **300.8(A), 300.8(C)(1)** (300.6) corrosion and sunlight • **300.9(B)** (300.7(B)) expansion • **Table 305.15(A)** (Table 300.50) over 1000 V.
- **352.10(H), 352.10(K), 352.12(C)/(D), 352.20, 352.24(B)** (352.26), **352.28, 352.30, 352.44, 352.46, 352.48, 352.100, 352.120** PVC.
- **353.10** HDPE • **338.12, 338.24** USE • **340.10, 340.12, 340.80** UF • **268.30** services over 1000 V.
- **314.28(A)** pull boxes, 4 AWG and larger • **314.29, 314.30** handholes • **410.30(B)** pole bases.
- **250.80 Exc., 250.86 Exc. No. 3** buried metal elbows • **250.118** (PVC is not an EGC) • **230.8** service raceway seal.
- **215.4(A) Informational Note No. 2** and **210.19** Informational Note: 3% / 5% voltage drop • Chapter 9 Table 8 resistance.

Hands-On Field Exercise

- Fill out a mock 811 ticket for a site: white-line the route on a site plan, count the working days to the legal start, and list the customer-owned lines a private locator must find.
- With the competent person, walk an open trench and name the soil type, the slope or shoring it needs, the spoil distance, and the ladder location.
- Lay out a mock duct-bank cross-section in chalk or a cut-away box: spacers, 3" concrete on all sides, staggered joints, and the depth to the top that the NEC, UFGS, and Navy each call for.
- Solvent-cement a Sch 40 run with one expansion fitting, setting the piston for today's temperature. Join it to a Sch 80 riser stick with a standard coupling.
- Build a stub-up: Sch 40 below grade turning up to a Sch 80 riser, strapped within 3 ft of the box, ending in a bushing.
- Size a pull box for a 2" conduit with 4 AWG conductors: a straight pull (8×) and an angle pull (6×).
- Run the voltage drop on a 277 V pole circuit from a real site plan and pick the wire size that stays under 3%.
- Take as-built measurements and photos on an open trench before backfill.

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 100, 210, 215, 250, 300, 305, 314, 338, 340, 352, 353, 410; Chapter 9 Table 8.
- OSHA 29 CFR 1926.650-652 and Subpart P Appendix B, Excavations: [osha.gov](https://www.osha.gov)
- Code of Alabama Title 37, Chapter 15, §37-15-2 and §37-15-4: law.justia.com. Alabama 811 Before You Dig and Excavation Manual: [al811.com](https://www.al811.com)

- APWA Uniform Color Code: apwa.org. SC811 Excavator Manual 2026: sc811.com. Nebraska 811 Excavator Manual: nebraska811.com
- NAVEDTRA 14027 Construction Electrician Intermediate, Chapter 4: constructionknowledge.net
- UFGS 33 71 02 Underground Electrical Distribution: wbdg.org
- Southwire Power Cable Installation Guide: southwire.com
- Carlon (ABB) Cements, Primers and Sealers brochure, Cement FAQ, and Expansion Joint installation training: carlonsales.com. IPEX Solvent Welding Installation Guide: ipexna.com
- Southern Company UG Distribution SUH-16.001/16.002/17.001 pad specification, Transformer Pad Locations, and DG Interconnection Construction Guidelines: georgiapower.com
- Alabama Power UG Distribution Specification and Commercial Meter Installation Handbook: alabamapower.com
- Texas State University 26 05 43 (txst.edu), University of Arizona Section 16115 (arizona.edu), C.A. Walker 26 05 43 (cawalker.net): duct bank specifications.
- Seattle City Light Standard 0222.02 (seattle.gov), Mountain Parks Electric Customer-Installed Underground (mpei.com), LADWP Specification 104 (ladwp.com), Logan City Light & Power checklist (revize.com): inspection and installation specs.
- Current Lighting Anchor Bolt Installation Guide (currentlighting.com), Techlight pole instructions (techlightusa.com), N2M light pole instructions (aelnow.com).

Next: Module 1.9 — Enclosures, Site Grounding & Equipment Hookup.