

Module 1.3 — Conductors, Pulling & Terminations

Big stranded conductors: sized and derated, then pulled and landed step by step with the real numbers for tension, lube, torque, and crimp dies.

Why this module. Residential wire is small, solid, and short. Commercial conductors are **big, stranded, and long**: 4/0 and 500 kcmil feeders pulled hundreds of feet by a crew, then landed on lugs and torqued. This module sizes and derates them, then walks the pull and the terminations **step by step** with the real numbers: pulling tension, lube quantity, torque values, and crimp dies. An undersized conductor cooks, a bad pull damages insulation you can't see, and a loose lug starts fires.

Part A — The Conductors

- **Stranded THHN/THWN-2** (rated 90°C) is the everyday building wire. XHHW-2 is common on feeders. THHN by itself is for dry and damp locations only. The dual marking THHN/THWN-2 is what lets one reel go anywhere, because THWN-2 is on the list of wet-location conductors in NEC 2026 310.10(C) (THWN, THWN-2, XHHW, XHHW-2, XHWN-2).
- **Temperature rating** is 60, 75, or 90°C. The 90°C column gives the highest ampacity, but you rarely get to use it, because the lug is the limit (Part E).
- **Stranding.** Building wire is Class B stranding. Welding cable and flexible cord are much finer (Class K or M). NEC 2026 110.14 says a connector for strands finer than Class B or C must be identified for that class. A standard lug on fine stranded cable lets the strands squeeze out and work loose. Flex-rated connectors carry their own markings.
- **Copper vs. aluminum.** Aluminum is lighter and cheaper for big feeders. NEC 2026 110.14: terminals "shall be identified, installed, and used for the material of the conductor," copper and aluminum are not mixed in one terminal unless it is identified for that, and any inhibitor compound must be "identified for the use." Aluminum also has a lower pulling limit (Part D).
- **Real numbers for 4/0 THHN/THWN-2 copper** (Southwire SIMpull): 19 strands, about 0.627 inch across, 719 pounds per 1,000 feet. Cross-section area for fill: 0.3237 in² (NEC Chapter 9 Table 5).

Part B — Sizing & Derating

Ampacity is how many amps a conductor can carry continuously without overheating. You start from a table, then correct it for a hot room and adjust it for a crowded pipe.

Copper size	60°C	75°C	90°C
10 AWG	30	35	40
8 AWG	40	50	55
6 AWG	55	65	75
4 AWG	70	85	95
1/0	125	150	170
4/0	195	230	260
500 kcmil	320	380	430

NEC 2026 Table 310.16, copper, amps. Use the printed table on the job for any size not shown.

Step by step: sizing a conductor

- Find the termination temperature.** NEC 2026 110.14(C)(1): circuits of 100 A or less, or terminals marked for 14 through 1 AWG, use the **60°C column** unless the equipment is listed for higher. Over 100 A, or marked for conductors larger than 1 AWG, use the **75°C column**. In practice almost all commercial gear is 75°C.
 - Look up the ampacity** in the conductor's own temperature column (usually 90°C for THHN). You may start correction and adjustment from that number.
 - Correct for ambient temperature** above 30°C (86°F), using Table 310.15(B)(1)(1). For 90°C wire: 31–35°C × 0.96, 36–40°C × 0.91, 41–45°C × 0.87, 46–50°C × 0.82. For 75°C wire: 0.94, 0.88, 0.82, 0.75.
 - Rooftop raceways:** if a raceway runs less than 7/8 inch above a roof, add 33°C (60°F) to the outdoor temperature before you correct (310.15(B)(2)). XHHW-2 is exempt.
 - Adjust for crowding.** If more than three current-carrying conductors run together for more than 24 inches (310.15(C)(1)), multiply by: 4–6 = 80%, 7–9 = 70%, 10–20 = 50%, 21–30 = 45%, 31–40 = 40%, 41 and up = 35%. Spare conductors count. Each conductor of a parallel set counts.
 - Count the neutral right** (310.15(E)). It counts as current-carrying on a 2-wire circuit, on a circuit of two hots and a neutral from a 4-wire wye, and where most of the load is nonlinear (computers, LED drivers). The equipment grounding conductor never counts (310.15(F)).
 - Check the termination limit.** NEC 2026 310.15(A): the corrected and adjusted ampacity may not exceed the ampacity at the termination's temperature rating. 310.14(A)(2): "Where more than one ampacity applies for a given circuit length, the lowest value shall be used."
- **Worked example 1, a feeder.** Three 4/0 THHN copper phases, a neutral, and a ground in one EMT, in a 45°C (113°F) mechanical room, ordinary linear load of 230 A. Current-carrying conductors: 3 (the neutral only carries imbalance, the ground never counts), so no crowding adjustment. 90°C ampacity $260 \times 0.87 = \mathbf{226\ A}$. The 75°C lug limit is 230 A. The lowest is 226 A, which is less than the 230 A load. The 4/0 fails. Go up a size and run the numbers again.

- **Worked example 2, a crowded branch bundle.** Nine 10 AWG THHN current-carrying conductors in one conduit at 100°F (36–40°C): $40 \times 0.91 \times 0.70 = \mathbf{25.5\text{ A}}$ usable per conductor.
- **Worked example 3, conduit fill.** Three 4/0 THHN ($3 \times 0.3237 = 0.971\text{ in}^2$) plus a 4 AWG THHN ground (0.0824 in^2) = 1.054 in^2 . A 2-inch EMT allows 1.342 in^2 at 40 percent, so it fits at 78 percent of what's allowed.

Parallel conductors (NEC 2026 310.10(G))

Big feeders often run two or more sets of conductors in parallel, "electrically joined at both ends." Parallel sets are 1/0 and larger. Every conductor in a phase must be the **same length, same material, same size, same insulation type, and terminated the same way**. If the sets are in separate raceways, each raceway carries the same number of conductors with the same characteristics. Cut parallel sets to the same length, even if one run is shorter.

Fill: 1 conductor 53%, 2 = 31%, 3 or more = 40% (Chapter 9 Table 1, or look it up in Annex C). Full fill steps are in Module 1.2.

Part C — Identify Every Conductor: The Color Code

COMMERCIAL CONDUCTOR COLOR CODE				
<i>(U.S. common practice — verify your local AHJ/POCO requirements)</i>				
	Phase A / B / C			Neutral Ground
120/208V (3-phase Wye)	A BLACK	B RED	C BLUE	NEUTRAL WHITE GND GREEN
277/480V (3-phase Wye)	A BROWN	B ORANGE	C YELLOW	NEUTRAL GRAY GND GREEN
High-leg (Δ) note: on a 120/240V high-leg delta, the high (stinger) leg = ORANGE (Phase B), NEC 110.15 / 230.56.				

120/208V (black/red/blue) vs 277/480V (brown/orange/yellow); white/gray neutral, green ground, orange high-leg.

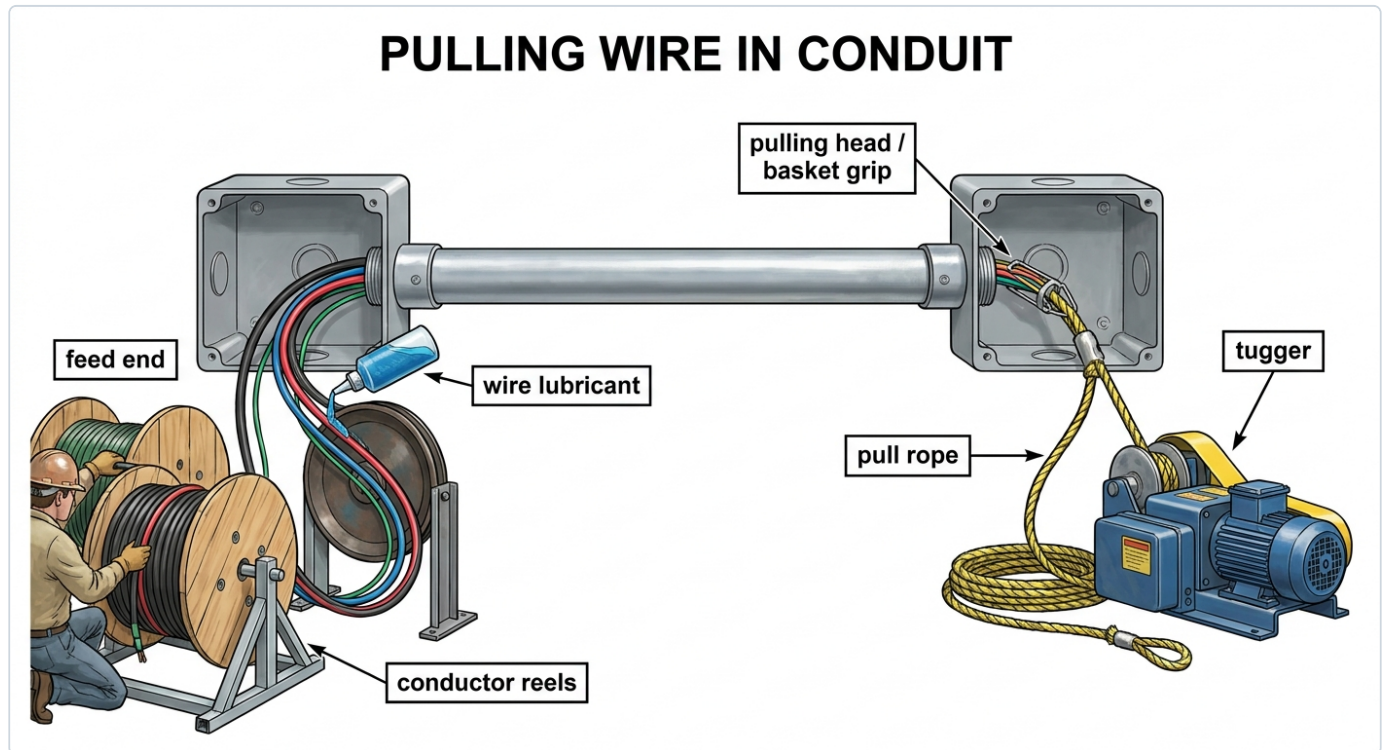
Conductor	Rule	NEC 2026
Neutral (grounded)	6 AWG and smaller: continuous white or gray, or three white or gray stripes. 4 AWG and larger may also be identified at the terminations.	200.7 (200.6 in 2023)
Equipment ground	Bare, or green, or green with yellow stripes. Green is never used for a hot or a neutral. 4 AWG and larger may be re-identified green at every accessible point.	250.119
High leg	Orange, "visible at all splices and" terminations.	110.15
Hots, more than one voltage system	Each hot identified "by phase or line and by nominal voltage system at all termination, connection, and splice points." The method is posted at each panelboard and "shall not be handwritten."	210.5(C)(2); feeders 215.12(C)(2)

The NEC does not require black-red-blue or brown-orange-yellow. Those are trade conventions. The code requires that the building's method be posted, so **read the posted legend before you pull**, and keep A-B-C phasing consistent through the building.

Step by step: tagging a pull

1. At the reels, wrap phase tape on each conductor before the head goes into the pipe.
2. At the pull end, tape each conductor again before you cut the grip off.
3. Label the raceway at both ends with the feeder or circuit ID.
4. Re-identify a black 4 AWG or larger used as a ground with green tape at every accessible point.

Part D — STEP-BY-STEP: The Feeder Pull



Feed end (reels, sheave, lube) and pull end (tugger, rope, basket grip).

Know your equipment

- **Tugger.** A Greenlee 6001 Super Tugger is rated 6,500 lb max and 4,500 lb continuous. It runs on 120 V, 20 A, and needs $\frac{3}{4}$ -inch double-braided composite rope rated 26,000 lb. It has a force gauge, a high-force alarm, and a breaker that shuts it off at max. Leaf chains with serrated feet clamp it to the conduit.
- **Basket grip.** Kellems non-conductive grips are rated by cable diameter: 0.50–0.62 inch 800 lb, 0.63–0.74 inch 1,000 lb, 0.75–1.74 inch 1,200 lb, with a safety factor of 5. Southwire's conservative practice is to hold any basket grip to 1,000 lb. A pulling eye is limited to its maker's rating or 10,000 lb, whichever is less.
- **Swivel** between the grip and the rope keeps the rope from twisting.
- **Lubricant** must be compatible with the cable and the pipe, UL or CSA listed, and no wax or grease. Never thin it with water.

Step by step: plan the pull (do this on paper first)

1. Confirm the raceway is complete, every end reamed, bushings on, and no more than 360 degrees of bends between pull points (NEC 2026 358.24(B), 358.26 in 2023).
2. Measure the run. Order the run length plus 10 percent plus service loops.
3. Check the fill (Part B) and the jam ratio (below).
4. Figure the maximum allowed tension and the tension you expect (below).

5. Figure the lube: **gallons = 0.0015 × length in feet × conduit inside diameter in inches** (Polywater). Add up to 50 percent for dirty pipe, high fill, many bends, or heat. The rule of thumb is a gallon per 100 feet.
6. Pick the pull direction. Feed from the end that has the bends nearest the reels, so tension stays low at the bends.

The pulling numbers

- **Maximum conductor tension** (Southwire): 0.008 lb per circular mil × circular mils × number of conductors for copper. Aluminum is 0.006. The allowed tension is the **lower** of the conductor limit and the grip or eye limit.
- **Jam ratio:** 1.05 × conduit ID ÷ conductor OD. With three conductors, jamming is likely between 2.8 and 3.2 (NEC Chapter 9 Table 1, Informational Note 2). Southwire says the risk is significant at 2.9 to 3.0.
- **Friction** (Southwire Table 6, lubricated): nylon jacket in metal conduit $\mu = 0.4$, in PVC 0.35. Dry, μ "can exceed 1.0." "Pulls should never be stopped and restarted because the coefficient of static friction will always be higher."
- **Tension in a straight run:** $T_{out} = T_{in} + w \times \mu \times W \times L$, where W is the cable weight per foot and L the length.
- **Tension through a bend:** $T_{out} = T_{in} \times e^{(w \times \mu \times \text{angle in radians})}$. A 90 is 1.571 radians.
- **Weight correction** w for three cables lying cradled: $1 + (4/3) \times (d \div (D - d))^2$.
- **Sidewall pressure** at a bend, three cables cradled: $((3w - 2) \div 3) \times T \div R$, where R is the bend radius in feet. The limit is 500 lb per foot for 600 V cable.

Worked example 4: three 4/0 THHN through 100 ft of 2-inch EMT with two 90s

Layout: 30 ft, 90°, 40 ft, 90°, 30 ft. Basket grip, lubricated.

- $d = 0.627$ in., $D = 2.067$ in. $D \div d = 3.30$, so the cables lie cradled. Jam ratio $1.05 \times 3.30 = 3.46$, outside the danger band.
- $w = 1 + 1.333 \times (0.627 \div 1.440)^2 = 1.25$. Weight $W = 3 \times 0.719 = 2.16$ lb/ft. $\mu = 0.4$.
- Limits: conductors $0.008 \times 211,600 \times 3 = 5,078$ lb. The grip is 1,000 lb. So the allowed tension is **1,000 lb**.
- First 30 ft: $1.25 \times 0.4 \times 2.16 \times 30 = 32$ lb. First bend: $32 \times e^{(1.25 \times 0.4 \times 1.571)} = 32 \times 2.19 = 71$ lb. Next 40 ft: $+43 = 114$ lb. Second bend: $\times 2.19 = 250$ lb. Last 30 ft: $+32 =$ **282 lb at the tugger**. Well under 1,000.
- Sidewall pressure at the second bend (radius $9\frac{1}{2}$ in. = 0.79 ft): $0.58 \times 250 \div 0.79 =$ **185 lb/ft**, under 500.
- **The same pull dry** ($\mu = 1.0$): each bend multiplies by 7.1, and the tension climbs to about **4,930 lb**, five times the grip rating and almost the conductor limit. Lube took the pull from 4,930 lb to 282 lb.
- Lube: $0.0015 \times 100 \times 2.067 = 0.31$ gallon. Bring a gallon.

Step by step: the pull

1. **Set the reels** on jack stands at the feed end, "just enough to clear the ground." Feed off the **bottom** of the reel so the cable curves one way only. Follow the rotation arrow, pull the lagging nails, and line the reels up with the conduit mouth. Put a sheave or feeding tube at the mouth.
2. **Mount the tugger** at the pull end. Chain it to the conduit with the serrated feet, or set the boom with a nose coupling that matches the conduit size. Line it up so the rope comes straight out. Test the force gauge. Rope off an exclusion zone.
3. **Get a line in.** Push a fish tape, or blow a string through with a vacuum/blower and a foam "mouse." Use the string to pull in the $\frac{3}{4}$ -inch rope. Tie on the swivel.
4. **Make the head.** Stagger the conductor ends, slide them into the basket grip, and smooth the mesh from the shoulder toward the tail. Tape from 3 inches onto the grip to 3 inches onto the cable, two or three layers. Kellems says the tape is "required to insure maximum reliability and guard against accidental release." Attach the swivel to the rope.
5. **Lube.** Put about two-thirds of the lube into the conduit ahead of the cable. The feeder lubes the head and keeps lubing the cable the whole pull, top and bottom.
6. **Pull.** Crew: a reel tender, a feeder at the mouth, a spotter at the pull end, and the tugger operator, all on radios on one channel. The operator runs only on "pull" and stops on any "stop" from anyone. The feeder keeps the conductors parallel. A crossover forms a bulge that jams. Keep it moving; if it stops, re-lube and back off before restarting.
7. **Finish.** Stop with 3 to 6 feet of tail at the pull end. Leave the service loop at the reel end. Cut, cap, and tag phases. Wipe the lube off the jackets.

Rope safety (Greenlee). Never wrap the rope around your hands or body. Never stand in line with the rope or in the spent coils. Nobody stands under a vertical pull. Keep everyone not needed out of the area. A rope that breaks under load whips back. Test the air in a manhole or pull pit before anyone goes in.

LARGE CONDUCTOR TERMINATIONS



Mechanical set-screw lug (torqued) vs. compression lug (crimped, with die marks).

Weakest-link rule — NEC 2026 110.14(C), verbatim

"The temperature rating associated with the ampacity of a conductor shall be selected and coordinated so as not to exceed the lowest temperature rating of any connected termination, conductor, or device." 90°C wire on a 75°C lug is sized from the **75°C column**. A #6 THHN is 75 A at 90°C but only 65 A at 75°C. The lug is the limit.

Where the torque number lives

NEC 2026 110.14(D): "Tightening torque values for terminal connections shall be as indicated on equipment or in installation instructions provided by the manufacturer. An approved means shall be used to achieve the indicated torque value." Look in this order:

1. The label on the breaker, switch, or lug.
2. The wiring and torque diagram inside the panel door or on the gear.
3. The installation bulletin for that gear.
4. The number molded next to each port on a multi-tap connector.
5. Only if none of those exists: Informative Annex I of the NEC, and call the manufacturer.

Socket (hex) size on the lug	Schneider QED-2 switchboard lug	NEC Annex I Table I.3 (fallback)
¼ in.	180 lb-in	200 lb-in
5/16 in.	250 lb-in	275 lb-in
⅜ in.	340 lb-in	375 lb-in
½ in.	450 lb-in	500 lb-in

Schneider bulletin 80043-055-16, Table 6; NEC Informative Annex I, Table I.3. The two columns are different on purpose: the manufacturer's number wins. Some torque charts posted online match neither; don't use them.

Worked example 5. A 4/0 copper in a QED-2 lug with a ⅜-inch hex: **340 lb-in**, which is $340 \div 12 = 28.3$ lb-ft. The same screw with no marking anywhere: Annex I gives 375 lb-in. Set a click wrench in lb-in so you don't convert wrong.

Mechanical (set-screw) lug, step by step

1. Verify the gear is de-energized (Part F).
2. Mark the strip length on the insulation: the barrel depth plus about ⅛ inch.
3. Strip with a cable stripper, not a knife. Nicked strands reduce the copper and make a hot spot. Wire-brush the strands.
4. For aluminum: brush it bright, apply a thin coat of the listed anti-oxidant compound, and use a lug marked AL.
5. Insert fully. No insulation under the screw. No bare copper showing past the barrel.
6. Set the torque tool to the marked value. Tighten until it clicks. Do not go past it.
7. Mark the screw head with a paint pen, and write the value and date in the torque log.

Compression (crimp) lug, step by step (Burdny HYDENT)

1. Match the connector marking to the conductor size and stranding class.
2. Mark the strip length against the barrel. Strip without nicking. Wire-brush.
3. Match the **die index number and color** on the connector to the die. Copper examples: 1/0 = index 12 pink, 2/0 = 13 black, 3/0 = 14 orange, 4/0 = 15 purple, 250 kcmil = 16 yellow, 500 kcmil = 20 brown.
4. Put the dies in the tool. Insert the conductor fully and check the inspection window.
5. Crimp a terminal starting at the tongue end and working toward the wire. Crimp a splice from the middle outward, alternating sides. Use the number of crimps in the catalog, and run the tool through a full cycle on every crimp.
6. Inspect: the die index embossed on the crimp matches the connector, the count is right, and every crimp is inside the color bands.
7. Aluminum: brush, apply the compound, and line the dies up between the knurls.

Splicing

- **Insulated multi-tap (for example NSI Polaris).** Brush the conductors. Strip to the length on the sheet (for example 11/16 inch on a #6 connector, 1 inch on a 3/0). One conductor per port, with the insulation at least $\frac{3}{8}$ inch inside the port. Torque each port to the value molded beside it. A 3/0 connector takes 250 lb-in on 3/0 and 110 lb-in on #4.
- **Split bolt.** Torque to the split-bolt column of Annex I if there's no maker's number (for example 500 lb-in for 3/0–4/0). Then insulate it.
- **Every splice and free end** must be insulated equal to the conductor (NEC 2026 110.14(B)). Splices buried underground must be listed for that.

Torque is the law (NEC 110.14(D)). A loose lug runs hot, degrades, and arcs. The NEMA bulletin on torque tools says: do not re-torque after installation. Annex I says checking torque later "is not a reliable means of determining the values of torque applied at installation." To check a suspect connection, de-energize and apply a tool set to 90 percent of the spec. In service, an infrared scan finds loose connections without touching them.

Part F — Safety

- **OSHA 1926.416(a):** no work near a part of a power circuit you could contact unless it is de-energized and grounded or guarded. Before work, find out by asking, looking, and testing whether live circuits are within reach.
- **OSHA 1926.417(b):** de-energized circuits "shall be rendered inoperative and shall have tags attached at all points where such equipment or circuits can be energized."
- **NFPA 70E 2024 Article 120:** identify every source, open the disconnects, look to confirm the blades are open, release stored energy, lock and tag, and test each conductor at the point of work with a meter checked on a known live source before and after.
- **Pulling into a live panel:** push the fish tape from the panel toward the first box, not into the panel, and cover the bus with a rubber blanket. Pulling lube is water-based and conducts.

Inspection checklist (what the foreman and inspector check)

1. Conductor size and insulation match the drawings. Wet-location type where required (310.10(C)).
2. Fill 40 percent or less and 360 degrees or less of bends. Bushings on and ends reamed.
3. Phase tape at both ends. Legend posted and not handwritten. Neutral white or gray (200.7). Ground green or re-identified (250.119). High leg orange (110.15).
4. No insulation damage. No crossed conductors at the mouth. Lube wiped off.
5. Lugs marked for the conductor material. Correct strip length. No cut strands. Torque mark on each screw and a torque log with the tool's calibration date.
6. Crimps: die index matches, count matches, inside the bands.

7. Before energizing: insulation resistance test phase-to-phase, phase-to-ground, phase-to-neutral, and neutral-to-ground with the neutral isolated and surge protectors disconnected. Schneider's switchboard bulletin says a reading "less than one megohm" must be investigated.
8. Parallel sets: same length, size, material, insulation, and termination. Same conductor count in each raceway (310.10(G)).

Common mistakes and what they cause

Mistake	What happens
Knife-stripping and nicking strands	Less copper, a hot spot at the lug
"Snug by feel"	Under-torque runs hot. Over-torque strips the screw or crushes strands
Standard lug on fine-strand flex cable	Strands squeeze out and the connection loosens
No brushing or compound on aluminum	Oxide film, heating
Pulling dry or stopping mid-pull	Tension climbs as much as ten times
More than 360 degrees between pull points	High sidewall pressure, jams
Three conductors at a jam ratio of 2.8–3.2	Conductors wedge in a bend
Untaped basket grip	The grip slips and a vertical pull drops
Citing 2023 numbers on a 2026 job	200.6 vs. 200.7; 358.26 vs. 358.24(B)

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

- **310.16** ampacity • **310.15** correction and adjustment • **310.14(A)(2)** lowest value governs • **310.10(C)** wet locations • **310.10(G)** parallel.
- **110.14** terminals, splices, **(C)** temperature limits [quoted], **(D)** torque [quoted] • Informative Annex I torque tables.
- **200.7** (200.6) neutral identification • **250.119** ground • **110.15** high leg • **210.5(C)**, **215.12(C)** posted legend.
- **358.24(B)** (358.26) 360° • **Ch. 9 Tables 1, 4, 5 / Annex C** fill.

Hands-On Field Exercise

- Work the pull math for three 4/0 through 100 feet of 2-inch EMT with two 90s, wet and dry. Figure the lube.
- Run the full **pull procedure**: reels, tugger, rope, swivel, taped basket grip, lube, radios.
- Size a load at 90°C, then check it against a 75°C lug. Derate nine conductors at a hot ambient.

- Find the torque number for three different lugs using the five-place search order, then terminate a 4/0 in a mechanical lug to torque and mark it.
- Crimp a 500 kcmil compression lug with the right die and find the die marks.
- Splice with a multi-tap connector, torquing each port to its molded value.

Sources used in this module (public documents)

- NFPA 70, National Electrical Code 2026 (free read-only access at [nfpa.org](https://www.nfpa.org)): 110.14, 110.15, 200.7, 210.5, 215.12, 250.119, 310.10, 310.14, 310.15, 310.16, 358.24, Chapter 9, Informative Annex I.
- Southwire Power Cable Installation Guide, and SIMpull THHN/THWN-2 product data: [southwire.com](https://www.southwire.com)
- Polywater, Cable Lubricant Application Guide: [polywater.com](https://www.polywater.com)
- Greenlee 6001 Super Tugger specifications and boom mount instruction manual: [greenlee.com](https://www.greenlee.com)
- Hubbell Kellems, Installation of Non-Conductive Pulling Grips (309-20-069).
- Burndy, Medium & Large HYDENT Crimp Instructions. NSI Industries, Polaris installation instructions.
- Schneider Electric QED-2 Switchboards bulletin 80043-055-16: [se.com](https://www.se.com)
- NEMA Technical Services Bulletin 120, Using Torque Tools for Terminating Building Wire: [nema.org](https://www.nema.org)
- NAVEDTRA 14026 and 14027, Construction Electrician Basic and Intermediate.
- OSHA 29 CFR 1926.416 and 1926.417: [osha.gov](https://www.osha.gov). NFPA 70E, 2024 edition.

Next: Module 1.4 — Branch Circuits, Feeders & Panelboards.