

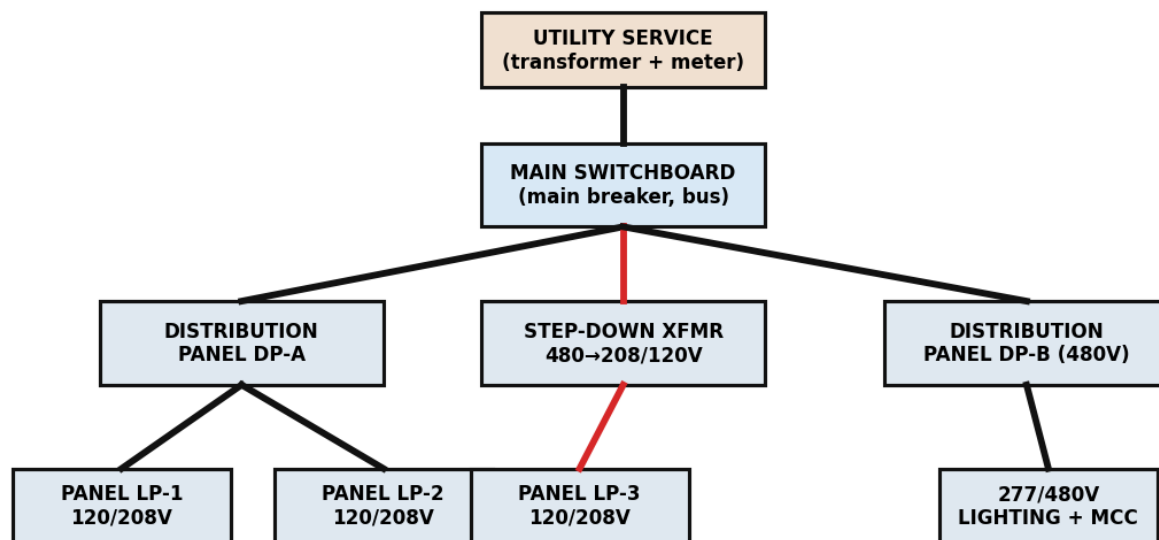
Module 1.5 — Distribution, Switchboards & Transformers

The big iron: interrupting ratings, service disconnects, ground-fault protection, transformer protection — plus step by step setting a switchboard and connecting and grounding a dry-type transformer.

Why this module. This is the big iron: the gear that carries, divides, and transforms the building's power. It handles the most energy on the job, so it is the highest-stakes gear to install and the most dangerous to work on. This module covers the ratings and code rules, then walks through setting a switchboard and connecting a dry-type transformer step by step, following the manufacturers' instruction bulletins (Schneider QED-2 switchboards and Schneider/Eaton dry-type transformers).

Part A — The Distribution Tree

THE COMMERCIAL DISTRIBUTION TREE



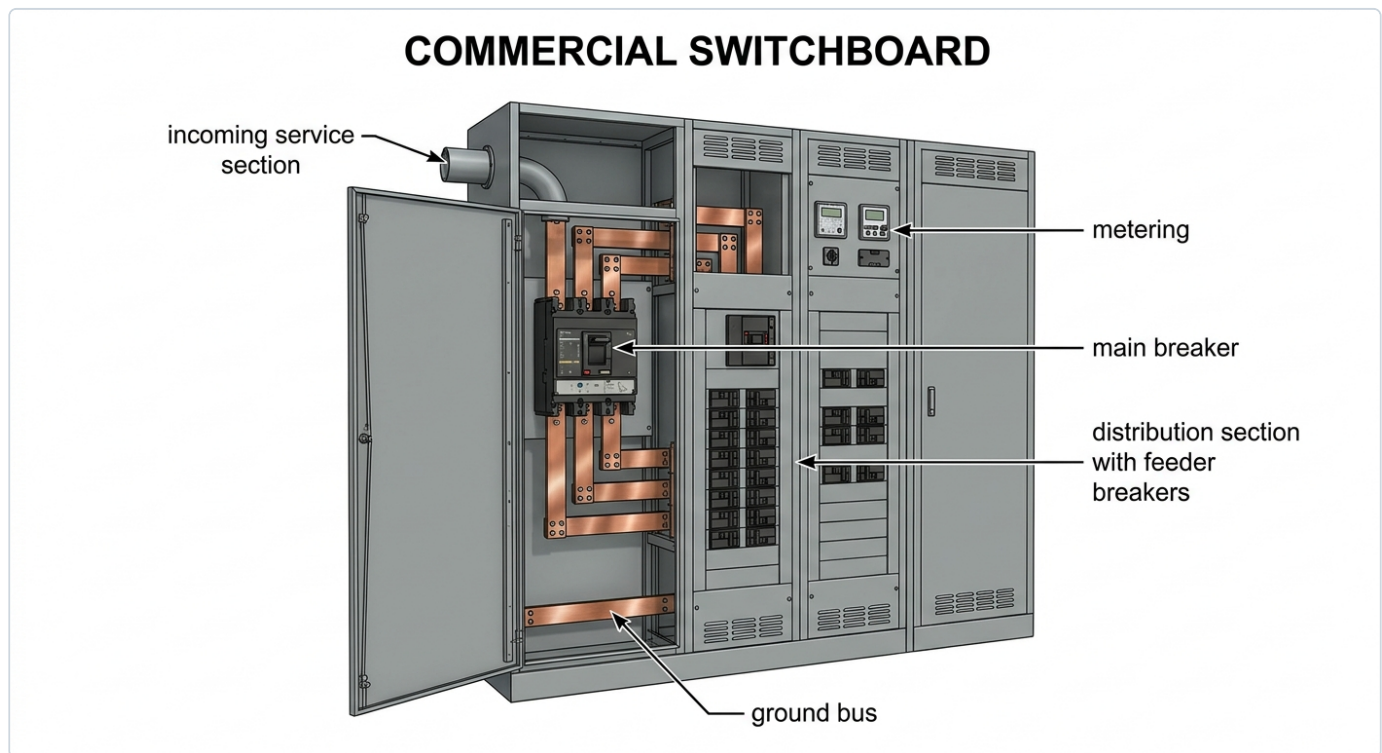
Power steps DOWN as it branches: service → switchboard → distribution panels (and step-down transformers) → branch panels → loads. Higher voltage (480V) is carried as far as possible to save copper, then transformed to 208/120V near the loads that need it.

Service → main switchboard → distribution panels & step-down transformers → branch panels → loads.

Power steps down as it branches. You carry high voltage a long way (less current, less copper) and transform it near the loads.

- **Switchboard** (NEC 2026 Article 100): "A large single panel, frame, or assembly of panels on which are mounted ... switches, overcurrent protective devices (OCPDs) ... buses, and usually instruments."
- **Switchgear**: "An assembly completely enclosed on all sides and top with sheet metal ... containing primary power circuit switching, interrupting devices, or both." Switchgear is heavier, with draw-out breakers and higher short-circuit ratings (Module 1.5B).
- **Interrupting rating** (110.9): every breaker and fuse must be rated "at least equal to the available fault current at the line terminals of the equipment." The switchboard's short-circuit rating must also be at least the available fault current (408.6). This is the rating that trips people up on old or upgraded services.
- **Labels at the service**: service equipment in non-dwellings is field-marked with the available fault current and the date the calculation was done (110.24(A)). A switchboard fed by a feeder is marked with where its power comes from, not handwritten (408.4(B)).

Part B — Switchboards & Switchgear



Incoming service, main breaker, copper bus, feeder-breaker distribution, metering, ground bus.

Topic	NEC 2026	Rule
Number of service disconnects	230.71	"Each service shall have only one service disconnect unless the requirements of 230.71(B) are met." Two to six are allowed only in separate enclosures, or one per vertical section with barriers, or one per switchgear compartment
Grouping	230.72(A)	Disconnects "shall be grouped. Each disconnect shall be marked to indicate the load served"
Location	230.70(A)	A readily accessible location outside, or inside nearest where the service conductors enter. Marked "SERVICE DISCONNECT"
Ground-fault protection (GFPE)	230.95	Required on solidly grounded wye services over 150 V to ground and not over 1000 V phase-to-phase, for each service disconnect rated 1000 A or more . Pickup no more than 1200 A, and no more than 1 second at 3000 A or more (230.95(C), 230.95(A) in 2023). Performance-tested by primary injection when installed, with a written record (230.95(E), 230.95(C) in 2023)
Arc energy reduction	240.87	A breaker that can be set to 1200 A or more needs an arc-reduction method (zone interlocking, differential relaying, a maintenance switch with a status light, active mitigation, or an instantaneous trip), tested by primary injection
Bonding	250.24(C); 408.10(C)	An unspliced main bonding jumper at the service. "All sections of a switchboard or switchgear shall be bonded together"

Worked example 1. A 480Y/277 V, 2000 A service switchboard. 277 V is over 150 V to ground and 2000 A is over 1000 A, so it needs GFPE (230.95), set no higher than 1200 A pickup. Its main can be set to 1200 A or more, so it also needs arc energy reduction (240.87). Both get primary-injection tests with written records, and the board gets its arc-flash and fault-current labels (110.16, 110.24). Primary-injection testing is usually done by a third-party testing firm. Your crew finishes torque, megger, and bonding before the tester arrives.

Service boards come with a removable neutral link so the neutral can be isolated for megger testing, with the bonding strap on the line side of the link. A utility metering section is either "hot sequence" (meter ahead of the main) or "cold sequence" (main ahead of the meter). Get the local utility's metering spec before the gear is submitted.

Part C — STEP-BY-STEP: Setting a Switchboard

The steps follow the Schneider QED-2 instruction bulletin 80043-055-16. Other makers' bulletins follow the same order. Read the one that shipped with your gear; NEC 110.3(B) makes it enforceable.

1. **Receive.** Check the packing list and inspect every section the day it arrives. File any damage claim with the carrier and tell the rep. Let cold gear warm to room temperature before you unwrap it.

2. **Store.** Clean, dry, at or below 75 percent humidity, heated. Even outdoor-rated gear is not built for outdoor storage. Cover the openings and keep about 200 W of heat per section.
3. **Rig.** Crane or forklift, spreader bar, rated shackles, skates. Keep sections upright. On NEMA 1 sections up to 3000 A with lifting straps, use rated chains with safety hooks or shackles, never through the strap holes, with a spreader beam and at least 45 degrees to the top. Heavier and outdoor sections are slung around the section or lifted with forks under the whole section, balanced and strapped.
4. **Check the location.** Working space per 110.26 (Module 1.1). $\frac{1}{2}$ inch behind rear-ventilated or outdoor boards, 30 inches if rear access is required. Room at or below 40°C. 3 feet to a combustible ceiling (408.18(A)).
5. **Check the pad.** Smooth and level. Embedded channels must be level over their length and flush with the floor, or the frame twists and the bus won't line up. Conduits stub 2 inches above finished floor. Raceway fittings may rise no more than 3 inches above the enclosure bottom (408.5). Add spare conduits before the pour.
6. **Prepare.** Clean the pad, remove the shipping stringers, cut and reinstall bottom closure plates. On boards deeper than 24 inches the center base channel can come out, **except on a seismic job.**
7. **Set and level one section at a time.** Lower each section over the conduit stubs inside its available conduit area, level it, and **splice the through-bus to the previous section before you set the next one.**
8. **Join the sections.** Remove the lifting straps on the sides that join. Six $\frac{3}{8}$ -16 $\times$ 1 inch bolts through the front and rear corner channels. Outdoor boards add the top cap and roof gasket.
9. **Anchor every section** through the $\frac{3}{4}$ -inch base-channel holes, with anchors specified by the engineer (hardware is not furnished). Seismic jobs: use all the anchor points the certificate calls for, Belleville washers "TOP" side up, and top restraint if required.
10. **Splice the bus, never energized.** The U-shaped connector slot points down around the insulating tube. Re-wrap insulated bus. Conical washers go convex ("Top") side against the bolt head and nut. Torque every bolt to the table with a calibrated wrench (NEC 2026 110.14(D)), then stripe it.
11. **Bring in conduit** only in the available conduit area, with hubs, locknuts, and bushings. Bond every hub. Never hang conduit or busway from the roof of the board. All conductors of a circuit, including the neutral, go through the same opening in steel (300.20(A)).
12. **Pull and terminate.** Use the largest bend radius you can, pad cable at sharp edges, strip to the full barrel depth without nicking. Wire-brush aluminum and apply compound right away. Compression lugs come off to crimp and go back on at torque. Set-screw torque is marked on the device. Size conductors over 100 A from the 75°C column (110.14(C)(1)(b)). Where the bulletin calls for it (long unsupported cables at high fault current), lash the cables with $\frac{1}{2}$ -inch sisal rope at 11-inch centers.
13. **Ground and bond.** Grounding electrode conductor to the ground-bus connector. Main bonding jumper on service boards only. A non-service board gets an equipment grounding conductor and no bonding jumper.

QED-2 hardware	Torque
Lugs with $\frac{1}{4}$ / 5/16 / $\frac{3}{8}$ / $\frac{1}{2}$ inch socket	180 / 250 / 340 / 450 lb-in (some lugs marked 620)
$\frac{1}{2}$ in. carriage bolt, hex nut, conical washer (bus joint)	720-840 lb-in (60-70 lb-ft)
$\frac{3}{8}$ in. bolt, conical washer, Keps nut	175-225 lb-in
$\frac{1}{2}$ in. bolt, conical washer, Keps nut	250-350 lb-in
Ground-bus splice, $\frac{1}{4}$ -20 thread-forming	100 lb-in
Ground bar slotted screw, 14-10 AWG / 6-1/0	20 / 45 lb-in

Schneider QED-2 bulletin 80043-055-16, pp. 53-54. **Worked example 2:** a $\frac{1}{2}$ -inch socket lug at 450 lb-in is $450 \div 12 = 37.5$ lb-ft; a $\frac{1}{2}$ -inch carriage-bolt joint at 720-840 lb-in is 60-70 lb-ft.

Pre-energization checkout (from the 23-step QED-2 list)

1. Torque every field splice and lug. Check the bus supports for damage.
2. Remove shipping foam from the devices. Exercise every breaker and switch by hand.
3. Remove CT shorting screws, and confirm every CT has a burden connected.
4. Adjustable trips ship at the lowest setting. Set them per the coordination study.
5. Verify the main bonding jumper on a service board.
6. **Megger the bus** at 500 or 1000 V DC. First remove trip rating plugs marked for removal during dielectric tests, open control and metering disconnects, and lift the neutral from any surge protector. With the neutral isolated and all devices open, test phase to phase, phase to ground, phase to neutral, and neutral to ground. Under one megohm, "the system may be unsafe and must be investigated." Record every reading.
7. Vacuum it out. "Do not use an air hose."
8. Covers on, no pinched wires, doors closed.

Energize (QED-2 p. 40)

1. No load connected. Control power on. Doors closed. Qualified persons present in the right PPE.
2. Close the main. Then each feeder breaker. Then each downstream panel. Then the loads.

After energizing: don't re-torque the bus. QED-2: bus joints are maintenance-free. "Do not retighten them after the pre-energizing checkout." Inspect no more than yearly, and use an infrared scan to find a bad joint.

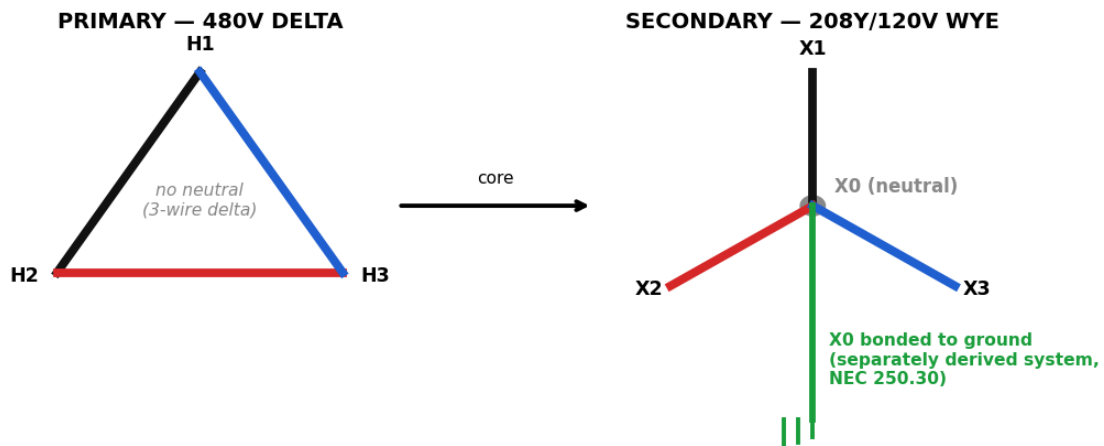
Common mistakes setting gear

- Setting the next section before splicing the bus to the last one.
- Leaving lifting straps on the sides that join.
- Pulling the center base channel on a seismic job. Installing Belleville washers upside down.

- Hanging conduit from the roof of the board. Running a neutral through a separate knockout.
- Leaving CT shorting screws in, or trips at their shipping minimum.
- Meggering with trip plugs and electronic modules still in. Cleaning with compressed air.
- Storing material in the dedicated space above the board (110.26(E)).

Part D — Transformers

STEP-DOWN TRANSFORMER: 480V DELTA → 208Y/120V WYE



WYE gives you BOTH voltages: 208V phase-to-phase (X1-X2) for 3-phase loads, and 120V phase-to-neutral (X1-X0) for receptacles & lighting.

480V delta primary → 208Y/120V wye secondary; X0 bonded to ground (separately derived).

Topic	NEC 2026	Rule
Overcurrent protection	450.5(B), Table 450.5(B) (450.3(B) in 2023)	Primary only: 125% of rated primary current (9 A or more). With primary and secondary protection: primary up to 250%, secondary 125%. Next standard size permitted on the primary
Ventilation	450.11 (450.9 in 2023)	Ventilating openings not blocked. Clearances marked on the unit. Tops marked to prohibit storage
Nameplate	450.13	kVA, voltages, impedance (25 kVA and up), clearances, insulation class
Wiring space	450.14	Bending space per 312.9 (312.6 in 2023)
Disconnect	450.16	In sight of the transformer, or remote and lockable open with its location marked on the transformer
Indoor dry-type	450.21	112.5 kVA or less: 12 inches from combustibles unless there is a barrier
New system grounding	250.30(A)	System bonding jumper at the transformer or the first disconnect, not both; grounding electrode conductor; supply-side bonding jumper

- **%Z** (percent impedance) sets the voltage drop under load and the available secondary fault current (about secondary full-load amps $\div$ %Z). That is the number the downstream panel's rating must beat (Module 1.5C).

Worked examples: a 75 kVA, 480 V delta to 208Y/120 V transformer

- **Worked example 3, primary protection only.** Primary full-load current = $75,000 \div (480 \times 1.732) = 90.2$ A. Maximum primary breaker = $1.25 \times 90.2 = 112.8$ A, so the next standard size, **125 A**.
- **Worked example 4, primary and secondary protection.** Primary up to $2.5 \times 90.2 = 225$ A. Secondary full-load current = $75,000 \div (208 \times 1.732) = 208.2$ A, and secondary protection up to $1.25 \times 208.2 = 260$ A, so a **250 A** secondary main.
- **Worked example 5, fault current.** Nameplate impedance 3.5 percent: $208.2 \div 0.035 \approx$ **5,950 A** available at the secondary terminals with an unlimited supply. The panel it feeds must be rated above that.
- **Worked example 6, taps.** The supply measures 492 V, which is 480×1.025 . On the normal tap the secondary would read $208 \times 492 \div 480 = 213.2$ V. De-energize, move to the +2.5% (492 V) tap, and re-measure for 208 V.

STEP-BY-STEP: Connecting a Dry-Type Transformer

Steps follow Schneider bulletin 43006-850-01 and Eaton manual PUB53311.

1. **Receive and store.** Check the packing list and the nameplate against the drawings. Store indoors, dry, heated, vents covered. If it sat somewhere damp, megger it before you energize.

2. **Rig.** Keep it upright on its pallet. Forks fully under. With a crane, use a spreader and lift from the core-bracket holes with cables at least 60 degrees from horizontal.
3. **Locate.** Ventilated, at or below 40°C ambient. Keep the clearances on the nameplate (rear clearance is 3 to 6 inches on many styles, 12 inches on some). Avoid corners, which trap heat and amplify hum.
4. **Mount** through the four base holes on the floor, a wall bracket, or a trapeze, with anchors and rod picked by the engineer of record. Check the bracket's weight rating against the unit.
5. **Float the core.** Loosen the four isolation-pad nuts one full turn so the core sits on its vibration pads. Leaving them tight transmits hum into the building.
6. **Install the ground bar** on the stamped holes, paint scraped, never over a vent. All grounds and bonds at one point.
7. **Bring conduit in** only in the marked entry area, below the top terminal board, so heat doesn't exhaust up the raceway. Avoid top entry. Use flexible conduit at the enclosure so vibration doesn't travel.
8. **Terminate the primary first** (H1-H2-H3) per the nameplate. The lugs are rated 90°C, but size conductors from the 75°C column. Clean the contact faces, apply joint compound, torque with a calibrated wrench. Insulate unused tap leads.
9. **Set the taps de-energized** to the measured supply. "Do not change taps while the transformer is energized." Clean any varnish off the tap contacts.
10. **Energize the primary with the secondary open.** Measure secondary line-to-line and line-to-neutral, then de-energize. Open-circuit secondary voltage should be no more than 110 percent of rated.
11. **Land the secondary** (X1-X2-X3) and the neutral on X0.
12. **Ground the new system** (250.30). Set the system bonding jumper from X0 to the ground bar **at the transformer or at the first disconnect, not both**. Run the grounding electrode conductor to building steel or the electrode. Run a supply-side bonding jumper with the secondary conductors.
13. **Pre-commissioning tests:** remove packing and temporary braces, vacuum, check torque and bonding. Insulation resistance winding to winding and winding to ground at 1 megohm or more, then ground each winding for 1 minute to discharge it. A turns-ratio test on all taps should agree within 0.5 percent across phases. Contact resistance on bolted joints: investigate any joint more than 50 percent above the lowest.
14. **Energize** per NFPA 70E. De-energize at any sign of arcing. Record line-to-line, line-to-neutral, and line-to-ground on both sides, and check phase rotation for motor loads.

A transformer secondary is a new system. Re-ground it (250.30). Skip the X0 bond and grounding electrode conductor, and the new system has no ground reference, so faults won't clear. Bond it at both the transformer and the first disconnect, and neutral current flows on the ground path.

Back-feeding. Only feed a transformer backward if it is marked bi-directional. Never connect the supply to the H0 or X0 of a wye winding. Expect higher inrush, use time-delay protection, and size the primary at 250 percent with secondary protection.

Common transformer mistakes

- Changing taps with it energized.
- Leaving the isolation-pad nuts tight.
- Ground bar over a vent. Conduit entering above the terminal board.
- Sizing conductors from the 90°C lug rating.
- Not discharging the windings after an insulation test.
- Bonding X0 at both ends, which creates a parallel neutral path.
- Storage on top, or set closer to the wall than the nameplate clearance (450.11).

Safety. Splicing, terminating, and testing are done de-energized: follow the NFPA 70E (2024) Article 120 steps to an electrically safe work condition, with your own lock and tag at every point where the gear can be energized (OSHA 1926.417). Use a rated voltage tester proved live-dead-live, and consider backfeed from generators, tie breakers, and transformers. The shock boundaries for 151–750 V are 3 ft 6 in (limited approach, fixed parts) and 1 ft (restricted). Read the arc-flash label before any energized work; switchboards carry much more incident energy than panelboards.

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

- **408:** 408.4(B), 408.5, 408.6, **408.10** (408.3) bus and bonding, 408.18, 408.20 • **110.9, 110.16, 110.24, 110.26.**
- **230.70, 230.71, 230.72** service disconnects • **230.95(C), (E)** ((A), (C)) GFPE • **240.87** arc energy reduction.
- **450.5** (450.3) protection • **450.11** (450.9) ventilation • **450.13, 450.14, 450.16, 450.21 • 250.24, 250.30.**

Hands-On Field Exercise

- Rig a switchboard section (or training unit) with a spreader bar at 45 degrees or more. Set, level, and splice it to the next section. Torque a bolted bus joint to the table and stripe it.
- Megger a board at 1000 V DC with the neutral isolated and record every reading.
- On a dry-type transformer: loosen the pad nuts one turn, set the +2.5% tap for a measured 492 V supply, energize with the secondary open and measure, then land the secondary, X0, and the system bonding jumper.
- Size the primary and secondary protection for a 75 kVA transformer, and figure its secondary fault current.
- Decide whether a 480Y/277 V service needs GFPE (230.95) and arc energy reduction (240.87).

Sources used in this module (public documents)

- NFPA 70, National Electrical Code 2026 (free read-only access at [nfpa.org](https://www.nfpa.org)).
- Schneider Electric, Power-Style QED-2 Switchboards Instruction Bulletin 80043-055-16; Dry-Type Transformers Instruction Bulletin 43006-850-01: [se.com](https://www.se.com)
- Eaton, Switchboards—Low Voltage Consulting Application Guide (Tab 21); Low-Voltage Dry-Type Distribution Transformers IOM PUB53311: [eaton.com](https://www.eaton.com)
- NFPA 70E, 2024 edition, Article 120 and Tables 130.4 and 130.7. OSHA 29 CFR 1926.417 and 1910.333: [osha.gov](https://www.osha.gov)

Next: Modules 1.5B Switchgear & 1.5C Transformer Masterclasses.