

Module 2.2 — Diagnostic Test Instruments

Step by step with the DMM, clamp meter, insulation tester, rotation meter, thermal imager, earth ground tester and power logger, with the pass/fail numbers for each.

Why this module. You cannot see voltage, current, or failing insulation, so your instruments do the seeing for you. Each instrument answers one question, and each has limits that can fool you or hurt you. This module walks step by step through the digital multimeter, clamp meter, insulation tester (megohmmeter), phase rotation meter, thermal imager, earth ground tester, power logger, and plug-in receptacle testers. Each procedure comes from the maker's manual and ends with the numbers that tell you pass or fail.

Part A — The Toolkit

COMMERCIAL TEST INSTRUMENTS				
 Digital Multimeter (DMM)		 Clamp-on Ammeter		 Megohmmeter (Megger) — insulation resistance
 Phase Rotation Meter		 Infrared (thermal) Camera		

DMM, clamp-on ammeter, megohmmeter, phase-rotation meter, infrared camera — each answers a different question.

Pick the instrument by the question you need answered. The models named below are common examples, not the only choices.

Question	Instrument	Example models
Is it live? What voltage? Open or short?	Digital multimeter (DMM)	Fluke 87V, 117
Is it live? (screening only, never proof of dead)	Non-contact voltage detector	Fluke 2AC
How much current? What inrush?	Clamp meter (AC/DC, flexible iFlex coil)	Fluke 376 FC, 381
Is the insulation good?	Insulation tester (megohmmeter, "megger")	Fluke 1507 / 1587 FC, Megger MIT
Is the grounding electrode good?	Earth ground tester	Fluke 1625-2
Which way will the motor turn?	Phase rotation indicator	Fluke 9040
Is a connection heating up?	Thermal imager	Fluke Ti series, FLIR
What is the load profile? Harmonics? Sags?	Power logger	Fluke 1736 / 1738
Is the receptacle wired right? Does the GFCI trip?	Plug-in tester (UL 1436)	Various

Part B — The Digital Multimeter (DMM)

CAT ratings: match the meter to where you use it

Meters are rated by measurement category (CAT) under IEC 61010-1. The category tells you how large a voltage spike (transient) the meter can survive without failing. A spike on a 480 V system can make a low-rated meter fail with an arc in your hand.

Category	Working voltage	Test transient	Test source resistance
CAT II	1000 V	6,000 V	12 Ω
CAT III	600 V	6,000 V	2 Ω
CAT III	1000 V	8,000 V	2 Ω
CAT IV	600 V	8,000 V	2 Ω

- **CAT IV** is the "origin of installation": the utility meter, service drop, and the run from meter to panel.
- **CAT III** covers switchgear, feeders, distribution panels, and lighting in large buildings.
- A CAT III 600 V meter is safer than a CAT II 1000 V meter. Its spike test uses a 2 Ω source instead of 12 Ω , which pushes 6 times the current through the meter (Fluke, "ABCs of multimeter safety").
- The Fluke 87V is rated "1000 V Overvoltage Category III ... 600 V Overvoltage Category IV." The Fluke 117 is 600 V CAT III. Use a 117-class meter for 120/208/277 V branch work. Use an 87V-class meter at 480 V gear and at the service.

- NFPA 70E-2024 110.6(B) requires test instruments to be "Rated for circuits and equipment where they are utilized," "Approved for the purpose," and "Used in accordance with any instructions provided by the manufacturer."

Step by step: the pre-use check

1. Inspect the leads for damaged insulation or exposed metal. OSHA 1910.334(c)(2) and 70E 110.6(D) both require a visual check "before each use."
2. Touch the probe tips together on ohms. Lead resistance should be 0.1 to 0.2 Ω . The 87V's REL button can zero it out.
3. Fit the probe tip caps for CAT III and CAT IV work. The Fluke 376 FC manual says not to use the probes there "without the protective cap of test probe installed."
4. Test the current fuse (87V): put a lead in the A jack with the dial on a non-current function. A good fuse makes the meter chirp and flash "LEAd." No chirp means a bad fuse. Replace it only with the fuse the manual lists.
5. When measuring, connect the common (black) lead first and the live (red) lead second. Remove the live lead first.

Step by step: using each function

- **Volts AC or DC:** red lead in V, black in COM. The 87V's input looks like 10 M Ω across the circuit (high impedance).
- **Low-pass filter (87V):** the manual warns: "Do not use the Low Pass Filter option to verify the presence of hazardous voltages." Read unfiltered first. Use the filter only to read the output of a variable frequency drive (VFD).
- **Auto-V / LoZ (117):** drops the input to about 3 k Ω "to reduce the possibility of false readings due to ghost voltages." A ghost voltage is voltage coupled from a live wire running next to a dead one in the same raceway. Fluke notes it "can be 80-85% of what the hard voltage should be." LoZ loads the circuit, so keep it off sensitive control electronics. The 87V has no LoZ setting.
- **Continuity and ohms:** circuit dead and discharged. The 87V catches opens and shorts as short as 1 ms. The 117 beeps below 20 Ω and stays quiet above 250 Ω . An ohms reading is the "total resistance of all paths between the probes," so lift one end of the part you are testing.
- **Capacitance:** dead and discharged. If the display shows "diSC," charge is still present. The 117 has a low-impedance capacitance mode (LCAP) for cables that carry ghost voltage.
- **MIN MAX:** records minimum, maximum and average. The 87V can catch peaks at 100 ms or 250 μ s response. Use it to catch a voltage sag when a motor starts.
- **Input Alert:** a lead left in the A jack while you touch a live circuit "acts like a short circuit" and blows the fuse. The 87V beeps to warn you.

STEP-BY-STEP: reading a circuit's voltage signature

1. Prove the meter on a known live source.
2. Set the DMM to AC volts with the leads in V and COM.

3. At the device, measure **Hot to Neutral**, **Hot to Ground**, and **Neutral to Ground**.
4. Compare to the healthy pattern and the table below.
5. Prove the meter again on the known source.

READING A HEALTHY vs. OPEN-NEUTRAL 120V CIRCUIT (DMM)

HEALTHY 120V

Hot → Neutral	120 V
Hot → Ground	120 V
Neutral → Ground	~0 V

OPEN NEUTRAL (under load)

Hot → Neutral	0 V
Hot → Ground	120 V
Neutral → Ground	~120 V
= the neutral is broken downstream	

Healthy 120V (H-N 120, H-G 120, N-G ~0) vs. open neutral (H-N 0, H-G 120, N-G ~120).

H-N	H-G	N-G	What it means
120	120	About 0 to 2 V under load	Healthy circuit
0	120	About 120	Open neutral
0	0	0	Open hot, OR a blown meter fuse or a lead in the wrong jack. Re-prove the meter before you believe it
120	0	120	Hot and neutral reversed, or an open equipment grounding conductor. Confirm against a known ground
120	120	Exactly 0 on a loaded circuit	Possible bootleg ground (neutral jumped to the ground terminal). See Part H

Part C — The Clamp-On Ammeter

A clamp meter reads current without opening the circuit. The jaws sense the magnetic field around the conductor. AC-only clamps use a current transformer (CT) and cannot read DC. AC/DC clamps use a Hall-effect sensor, which also picks up the earth's magnetic field and must be zeroed before a DC reading.

Step by step (Fluke 381 and 355 manuals)

1. Remove the test leads from the meter. Keep your fingers behind the tactile barrier on the jaw.

2. Select A~ (AC) or A= (DC).
3. For DC: close the empty jaws, let the reading settle, and press ZERO.
4. Clamp ONE conductor and center it on the jaw alignment marks. Fluke: "place only ONE conductor into the clamp." Two conductors carrying current in opposite directions cancel and read near zero.
5. With an iFlex coil, the arrow points toward the load. Do not wrap it around bare live conductors without extra precautions.
6. Stay inside the range. The 376 FC jaw reads up to 999.9 A AC/DC; the iFlex reads up to 2500 A AC.

Inrush current

Arm INRUSH with the load off, clamp the conductor, then start the load. The meter samples over 100 ms, "approximately 400 samples," and holds the peak.

Worked example 1 (Fluke inrush note). A load runs at 8 A and starts at about 5 times that, 40 A, on a 20 A breaker. The breaker holds because its time-current curve lets a short surge pass. The same note gives three-phase motor inrush as 500 to 1200 percent of running current, lasting 75 to 150 ms.

Low current and balance

- **Low current:** loop the wire N turns through the jaw and divide the reading by N. Fluke example: 10 turns, 400 mA displayed, 40 mA actual.
- **Balance:** clamp phases A, B and C, then the neutral. Percent imbalance = largest deviation from the average $\div$ the average $\times$ 100.
- **Neutral:** a high neutral reading when the three phases are balanced suggests harmonic current. Confirm it with a power logger harmonic study (Part I) before you act on it.

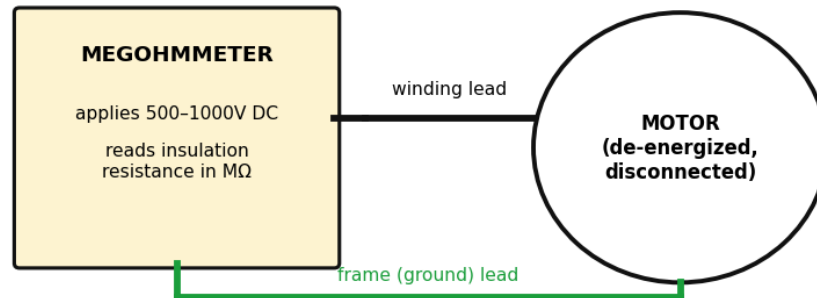
Worked example 2. A feeder reads A = 90 A, B = 100 A, C = 110 A. Average = 100 A. Largest deviation = 10 A. Imbalance = $10 \div 100 = 10$ percent.

Part D — STEP-BY-STEP: The Megohmmeter ("Megger")

A DMM's ohms function uses a few volts, which cannot find weak insulation. An insulation tester applies 500 to 1000 V DC (or more) and reads the leakage as megohms (M Ω , millions of ohms). NEC 2026 110.7 (Wiring Integrity) requires completed wiring to be "free from short circuits, ground faults, or any connections to ground other than as required or permitted." The insulation test is how you prove it.

INSULATION RESISTANCE TEST (Megohmmeter / "Megger")

Tests the insulation between the WINDINGS and the FRAME — one lead on a winding, one on the frame.



HIGH MΩ (e.g. >1 MΩ + per the spec) = good insulation. LOW / falling MΩ = moisture or breakdown → the motor will fail.

One lead on a winding, one on the frame. High megohms = healthy; low/falling = moisture or breakdown.

Test voltage and minimum readings

NETA ATS Table 100.1 (from the public 2013 edition; confirm against the edition in your project spec):

Equipment voltage rating	Minimum DC test voltage	Minimum insulation resistance
250 V	500 V	25 MΩ
600 V	1,000 V	100 MΩ
1,000 V	1,000 V	100 MΩ
5,000 V	2,500 V	1,500 MΩ
15,000 V	2,500 V	5,000 MΩ

- Transformers 0 to 600 V (NETA Table 100.5, same 2013 edition): test at 1,000 V DC. Minimum 100 MΩ for liquid-filled, 500 MΩ for dry-type.
- The Fluke 1587 FC tests at 50, 100, 250, 500 or 1000 V at about 1 mA. It will not start a test if more than 30 V is present, and it discharges loads up to 1 μF in under 0.5 s.

Motor acceptance (IEEE 43-2013, one-minute reading corrected to 40 °C)

Winding type	Minimum one-minute insulation resistance
Random-wound motors, and motors rated below 1 kV	5 MΩ
Form-wound windings built after 1970	100 MΩ
Windings built before 1970, and field windings	kV + 1 MΩ (rated kV plus 1)

- **Polarization index (PI)** = the 10-minute reading ÷ the 1-minute reading. IEEE 43 minimum: 1.5 for Class A insulation, 2.0 for Class B and higher. PI is not useful when the 1-minute reading is above 5,000 MΩ.
- **Dielectric absorption ratio (DAR)** = the 60-second reading ÷ the 30-second reading. The 1587 FC times both automatically.
- Megger's older rule of thumb: "one megohm for each 1,000 volts of operating voltage, with a minimum value of one megohm."

Worked example 3. A 460 V random-wound motor must read at least 5 MΩ at 40 °C under IEEE 43. The kV + 1 formula would give only 1.46 MΩ, but that formula applies to older and field windings, so the 5 MΩ minimum governs.

Step by step: testing a motor or cable

1. Lock out and do live-dead-live (Part G).
2. Isolate the item. At a VFD, lift the motor leads at the drive. Rockwell says not to megger motor leads "without disconnecting the motor leads at the motor lead terminals on the drive." ABB says not to Hi-Pot or Megger "any part of the ACx 600." Yaskawa: "Do not perform a withstand voltage test on any part of the drive." Also lift surge protective devices (SPDs), electronic trip units, and control wiring.
3. Check the tester's battery and fuse. Select the test voltage from the NETA table above.
4. Connect the line lead to the conductor and the earth lead to the frame or equipment grounding conductor. Test each phase to ground with the other phases grounded. On cable, also test phase to phase.
5. Apply the voltage for 60 seconds and record the reading. For PI, run 10 minutes.
6. Record the winding temperature and the humidity.
7. Discharge for "about four times as long as test voltage was applied." Leave large windings shorted until you re-energize. Megger: "Never connect a Megger insulation tester to energized lines or equipment." OSHA 1910.333(b)(2)(ii)(C) also requires stored energy to be released.
8. Correct the reading to a base temperature and compare it to earlier readings.

Temperature correction (Megger, "A Stitch in Time")

Insulation resistance roughly halves for each 10 °C rise in temperature and doubles for each 10 °C drop. IEEE 43 corrects to 40 °C. Megger's tables correct to 20 °C. Always write down which base you used.

Measured	At	Corrected to 20 °C	Math
50 MΩ	40 °C	About 200 MΩ	Two 10 °C drops: $50 \times 2 \times 2$
2.0 MΩ (Class A)	40 °C	9.6 MΩ	Megger Table II factor 4.80: 2.0×4.80

A reading that keeps falling from test to test means trouble, even if it is still above the minimum.

Part E — Phase Rotation & Infrared

Step by step: phase rotation (Fluke 9040)

Rotation must be known before you connect a three-phase motor. A pump or compressor run backward can be damaged.

1. Use the CAT III/IV alligator clips. The 9040's self-retaining probes are rated only 1000 V CAT II.
2. This is a live test. Wear the PPE the arc flash label calls for (Module 2.1).
3. Prove each lead with your DMM first. The manual warns: "The rotary indicator lights even if the neutral conductor, N, is connected instead of L1, L2, or L3."
4. Connect L1, L2 and L3 of the tester to phases A, B and C on the line side of the disconnect.
5. Read the clockwise (CW) or counterclockwise (CCW) indicator.
6. To reverse a motor, swap any two motor leads with the circuit locked out.

Step by step: thermal (infrared) scanning

A loose or failing connection runs hot before it fails. Scan panels, lugs, breakers and motors under load. The hot spot becomes your next work order (predictive maintenance, Module 2.8).

1. Scan under load. NETA ATS calls for scans "during periods of maximum possible loading." FLIR's summary of NFPA 70B-2023 gives a floor of "no less than 40 percent of normal circuit loading" and says to document the loading.
2. Remove covers so you can see the connections. Follow Module 2.1 for PPE when covers are off energized equipment.
3. Set emissivity. Emissivity is how well a surface gives off heat: polished copper is 0.07, oxidized copper 0.6 to 0.7, black oxidized copper 0.78 to 0.88, and paint 0.90 to 0.95. Readings on surfaces below 0.6 are unreliable. Aim at insulation or put a piece of electrician's tape on the part, set emissivity to 0.95 and enter the reflected temperature. Expect about ± 2 °C.
4. Compare like parts under like load (phase A lug to phase B and C lugs) and compare each to ambient air.
5. Clamp and record the amps with each image. Heat rises roughly with the square of the current.
6. Classify the finding with the table below. NETA asks for an imager that resolves 1 °C at 30 °C, and a follow-up scan within 12 months of acceptance.

NETA ATS Table 100.18 (from the public 2013 edition; confirm against the edition in your project spec):

ΔT between like parts, like load	ΔT above ambient	Action
1 to 3 °C	1 to 10 °C	Possible deficiency; investigate
4 to 15 °C	11 to 20 °C	Probable deficiency; repair as time permits
—	21 to 40 °C	Monitor until corrective measures can be done
Over 15 °C	Over 40 °C	Major deficiency; repair immediately

Worked example 4. Phase B's lug reads 12 °C hotter than A and C at the same load. 12 °C falls in the 4 to 15 °C row: probable deficiency, repair as time permits. Record the amps and the image, and write the work order to repair that connection with the equipment de-energized. Do not re-torque connections on a schedule; find the bad ones by scanning.

Part F — The Earth Ground Tester

A megger does not test a ground rod. Ground electrode resistance is measured with an earth ground tester such as the Fluke 1625-2. NEC 2026 250.53(A)(2) Exception: "If a single rod, pipe, or plate grounding electrode has a resistance to earth of 25 ohms or less, the supplemental electrode shall not be required." If a second rod is needed, rods must be "not less than 1.8 m (6 ft) apart" (250.53(A)(3)).

Step by step: fall-of-potential (3-pole) test

1. Disconnect the electrode from the system for this method. The tester can put out 250 mA, so wear gloves and keep people clear of the leads and stakes.
2. Drive the current stake 100 ft or more from the electrode, in a straight line.
3. Drive the potential stake at 62 percent of that distance (the 62 percent rule, for a single electrode in uniform soil).
4. On the 1625-2, select RE 3-pole (or 4-pole), wire it as the display shows, and press START TEST. Read RE. Check the stake resistances (RS and RH) in the menu.
5. Move the potential stake 3 ft closer and test, then 3 ft farther and test.
6. If the three readings agree, record the result. If they do not, move the current stake farther out and repeat.

Worked example 5. Current stake at 100 ft. Potential stake at 62 ft, with checks at 59 ft and 65 ft. Suppose all three readings come out near 18 Ω . They agree, so you record 18 Ω , and a single

rod at 18 Ω meets the 25 Ω exception. If the 59 ft and 65 ft readings differ widely from the 62 ft reading, the stakes are too close and the current stake goes farther out.

- The 1625-2 manual wants the spikes more than 20 m apart. If moving one spike changes RE, move it farther. Keep the spike wires apart from each other.
- The 4-pole method cancels the test lead resistance. Selective mode (one clamp) tests a rod that is still connected to the system.
- **Stakeless (two clamps, at least 15 cm apart)** needs a low-resistance parallel path back through other grounds. Fluke example: 40 utility poles at 20 Ω each in parallel = 0.5 Ω . It does not work on a single-electrode site (a lone generator or transformer), or before the utility is connected. A stakeless reading under 1 Ω probably means you measured a hard-wired metal loop, not the earth.

Part G — Live-Dead-Live with Your Meter

NFPA 70E-2024 110.6 covers test instruments. 110.6(E), Operation Verification, applies at 50 V or more: the instrument must be "verified on any known voltage source before and after an absence of voltage test." Older Fluke articles cite this rule by its old number, 110.4(A)(5).

1. Select the meter by voltage and CAT rating (110.6(B)).
2. Inspect the meter and leads (110.6(D)).
3. Prove it on a known source (110.6(E)).
4. Test every phase-to-phase and every phase-to-ground combination at the point of work. A non-contact detector tests only phase to ground.
5. Prove it again on the same known source.
6. If a reading looks like a ghost voltage, switch to LoZ. If the voltage stays under LoZ, treat it as real backfeed. OSHA 1910.333(b)(2)(iv)(B) requires the test to catch "induced voltage or unrelated voltage backfeed." Over 600 V, OSHA requires the tester to be checked "immediately before and immediately after this test."

Part H — What Simple Testers Cannot Tell You

- **Non-contact voltage detector** (Fluke 2AC, 90 to 1000 V AC): its sheet says it is "NOT suitable to determine if a circuit is hazardous." It can miss voltage in shielded cable, through thick insulation, when you are insulated from ground, at recessed sockets, or with a weak battery. Some detectors fail on metal-sheathed cable and on ungrounded circuits (UFC 3-560-01).
- **Three-light receptacle tester:** the package says it "will not detect two hot wires... combination of defects... reversal of grounded and grounding conductors." IEEE 1100 says it "cannot be relied upon to indicate correct wiring." A bootleg ground with reversed polarity reads correct on a three-light tester and on an H-N / H-G / N-G check. Find it by testing to a known earth ground.

- **GFCI tester (UL 1436):** press the device's own TEST button first; it must trip. Reset, then hold the tester button for at least 6 seconds. The tester "will not trip GFCI outlets installed without a ground wire," so on 2-wire circuits use the device TEST and RESET buttons only.

Part I — The Power Logger

A power logger records voltage, current, power and harmonics over days, so you can see what happens when no one is watching.

Step by step: setting up a Fluke 1736/1738

1. Read the panel and nameplates to determine the system type (for example, 3-phase wye).
2. Power the logger.
3. Under Change Configuration, set the study type, topology, nominal voltage, and CT/PT scaling.
4. Open the Configuration Diagram.
5. Plug in the voltage leads and the current probes, probe A to input A.
6. Put the iFlex probes on so "the arrow on the probe points to the load."
7. Connect voltage N, A, B, C, wearing the PPE for the panel.
8. Confirm the voltages and currents look right on screen.
9. Run "Verify Connection" to fix rotation, mapping and probe polarity. Most sites are clockwise.
10. Watch Live-Trend, then leave it to log. A full IEEE 519 harmonic report needs the 1738 or a license upgrade.

Part J — Calibration and Care

- NETA ATS-2013 5.3: field instruments are calibrated every "12 months maximum," traceable to NIST, with dated labels and records.
- UFC 3-560-01 5-7.1: calibration "not to exceed 12 months." Under 5-7.2, DMMs used only to check for presence or absence of voltage need no annual certification, but they must come out of service on any display fault and be recertified after repair. Analog low-voltage multimeters are not allowed.
- Torque wrenches (ISO 6789): default recalibration at 5,000 cycles or 12 months, and after any overload of 25 percent or more. Tolerance is ± 4 or ± 6 percent depending on the wrench type. A calibrated torque wrench is the "approved means" that NEC 2026 110.14(D) requires to reach the marked torque.

Part K — Reading the Results

Instrument	Reading	What it means	Source
DMM	Volts on high impedance, about 0 on LoZ	Ghost voltage	Fluke 117 manual
DMM	N-G exactly 0 on a loaded circuit	Possible bootleg ground	EC&M
Clamp	High neutral with balanced phases	Suspect harmonics; confirm with a logger	Part I
Megger	Below 5 MΩ at 40 °C (random-wound, under 1 kV)	Do not energize	IEEE 43
Megger	PI below 2.0, Class B or higher	Moisture or contamination	IEEE 43
Megger	Falling trend, still above minimum	Plan the repair	Megger
Megger, 600 V cable	Below 100 MΩ at 1,000 V DC	Fails acceptance	NETA ATS-2013 Table 100.1
Ground tester	25 Ω or less, single rod	No supplemental electrode required	NEC 250.53(A)(2) Exception
Ground tester (stakeless)	Under 1 Ω	Probably a hard-wired loop	Fluke
Thermal imager	ΔT over 15 °C versus like part	Repair immediately	NETA ATS-2013 Table 100.18

Part L — Common Mistakes

Mistake	Result	Rule or source
CAT II or unrated meter or leads at 480 V gear	Meter fails with an arc on a spike	Fluke; 70E 110.6(B)
Lead in the A jack while reading volts	Short circuit through the meter	87V manual
Blown fuse or wrong jack	Reads 0 V on a live circuit	Caught by 70E 110.6(E) re-prove
Low-pass filter on when checking for voltage	Under-reads	87V manual
Two conductors in the clamp	Reads near 0	Fluke 355 manual
DC clamp not zeroed	Offset error	Fluke 381 manual
Meggering through a VFD	Destroys the drive	Rockwell, ABB, Yaskawa
No discharge after a megger test	Shock from stored charge	Megger; OSHA 1910.333
Bare copper scanned at default emissivity	A hot joint reads cool	Fluke
Stakeless test on a single-electrode site	Meaningless number	Fluke
Non-contact detector used to prove dead	Misses live voltage	Fluke 2AC sheet
Using a megger on a ground rod	Wrong instrument	Use an earth ground tester

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

- **110.7 Wiring Integrity:** wiring "free from short circuits, ground faults, or any connections to ground other than as required or permitted." The insulation test proves it.
- **250.53(A)(2) Exception:** single rod, pipe or plate at 25 Ω or less needs no supplemental electrode (same location in 2023). **250.53(A)(3):** rods at least 6 ft apart. There is no 250.56 in the 2026 NEC. Over 1000 V, 270.53 carries the same rule.
- **230.95(E) Performance Testing:** ground-fault protection of equipment is "performance tested when first installed on site" by primary current injection, with a written record. **240.67(C)** requires the same for arc energy reduction.
- **110.14(D):** "An approved means shall be used" to reach marked torque values.
- NFPA 70E-2024 **110.6** Test Instruments and Equipment: (A) qualified persons, (B) rated and approved, (D) inspect before each use, (E) verify on a known source before and after. OSHA **1910.334(c):** qualified persons, visual inspection "before the equipment is used," and "rated for the circuits and equipment to which they will be connected."

Hands-On Field Exercise

- DMM: prove on a known source, measure H-N, H-G and N-G on a healthy 120 V circuit, prove again, and record all three. Then diagnose an open neutral by its signature.
- Clamp: read A, B, C and N on a feeder and calculate percent imbalance. Capture one motor's inrush.
- Megger: test a disconnected 460 V motor at 1,000 V DC for 1 minute, phase to frame. Pass is 5 MΩ or more corrected to 40 °C. Discharge for at least 4 minutes. Record temperature and humidity.
- Phase rotation: prove each lead with the DMM, then confirm A-B-C rotation at a disconnect.
- IR: scan a loaded panel, find the hottest lug, record the amps, and classify it with the ΔT table.
- Ground: set up a fall-of-potential test with the 62 percent rule and the two 3 ft check readings.
- GFCI: test with the device button, then the plug-in tester, on a grounded receptacle.

Sources used in this module (public documents)

- NFPA 70, National Electrical Code 2026, and NFPA 70E 2024 (free read-only access): [nfpa.org](https://www.nfpa.org)
- OSHA 29 CFR 1910.333 and 1910.334: [osha.gov](https://www.osha.gov)
- Fluke user manuals: 80 Series V (87V), 110-117, 374/375/376 FC, 381, 355, 393 FC, 1587 FC, 9040, 1625-2 and supplement, 1736/1738, 2AC instruction sheet, i800 instruction sheet: [fluke.com](https://www.fluke.com)
- Fluke application notes and articles: "ABCs of multimeter safety," ghost voltage (117), inrush current, Hall-effect and CT clamp meters, emissivity, thermography reflectivity, ground electrode impedance, stakeless measurement, absence-of-voltage testing: [fluke.com](https://www.fluke.com)
- Megger, "A Stitch in Time: The Complete Guide to Electrical Insulation Testing": [megger.com](https://www.megger.com)
- IEEE 43-2013, Recommended Practice for Testing Insulation Resistance of Electric Machinery: [ieee.org](https://www.ieee.org)
- ANSI/NETA ATS-2013 Acceptance Testing Specifications (public copy posted at danville-va.gov)
- Rockwell Automation knowledge base 42078: rockwellautomation.com; ABB ACS 600 hardware manual; Yaskawa V1000 installation manual.
- FLIR, documenting thermography findings within NFPA 70B-2023: [flir.com](https://www.flir.com)
- EC&M, "Three-lamp circuit tester" and "Failures in outlet testing exposed": ecmweb.com
- UL 1436 receptacle and GFCI tester instructions (manufacturer packaging).
- UFC 3-560-01 Electrical Safety, O&M: [wbdg.org](https://www.wbdg.org)
- Norbar, torque wrench calibration: norbarusa.com; AWS, ISO 6789:2017 white paper: awstorque.co.uk

Next: Module 2.3 — Troubleshooting Branch Circuits & Devices.