

Heat, Burning Smells, Panel Buzz, Aluminum, and Backstabs

YES Electric • NEC 2026 with NEC 2023 numbers in parentheses

Draft 1 (October 2026). This chapter is under review. Code numbers are NEC 2026. Your local inspector may use an earlier edition, so ask your journeyman which one applies. Boxes marked "Picture coming" will get drawings and photos in a later version.

Phase 2, Troubleshooting and Service Calls.

Before this module: R2.1 (the service call routine), R2.2 (meters and testers, including the spot thermometer and clamp meter), R2.3 (dead outlets and mid-pointing), and R2.4 (breakers that trip). R-OLDHOUSE goes deeper on aluminum wiring and problem panels.

Code edition. Code references are NEC 2026. Where a section moved, the NEC 2023 number is in parentheses. The local inspector (the AHJ) may enforce an earlier edition, so ask your journeyman which one applies.

Learning Objectives

When you finish this module you will be able to:

1. Treat a warm device, a burning smell, or a buzzing panel as a stop-everything call, and find the hot connection.
2. Check torque on every termination in a panel and record how many were loose.
3. Identify aluminum branch-circuit wiring and use only the repairs the U.S. Consumer Product Safety Commission (CPSC) accepts as permanent.
4. Inspect a panel past the basics: double taps, shared neutral terminals, scorched bus, wrong breakers, open knockouts, water, and contamination.

Background: Why Connections Get Hot

Almost every heat call comes down to one bad connection. Current has to pass from one piece of metal to another at every screw terminal, wire connector, breaker clip, and lug. When the two pieces press together tightly over a large area, the connection has very low resistance and stays cool. When the pressure drops or the contact area shrinks, the resistance goes up. Current through resistance makes heat.

That heat makes the problem worse. The metal expands when it heats and shrinks when it cools. Each cycle can loosen the connection a little more. The surface of the metal oxidizes, and oxide conducts poorly. Resistance goes up again, so the next cycle is hotter. The Arc Guide describes this chain: loose connection, higher resistance, heat under load, thermal cycling that loosens it more, and then arcing (Part 10, "The 78% Torque Problem").

A breaker does not stop this. A loose connection at a receptacle can get hot enough to char the box while the circuit carries only 8 or 10 amps, well under what trips a 15 A breaker. The breaker protects the wire from too much current. It does not see a bad connection. (An AFCI may detect the arcing once it starts. R2.4 covers that.)

Where the heat starts

Location	Common cause	Where in this module
Receptacle or switch	Backstabbed (push-in) connection, loose screw, worn receptacle contacts	Part B, Part C
Wire connector in a box	Connector not twisted tight, wrong size, one wire not engaged	Part B
Aluminum branch wiring	Aluminum connections at devices, splices, and appliances	Part D
Breaker terminal	Under-torqued or over-torqued screw, two wires under a screw made for one	Part E
Breaker-to-bus clip	Breaker not fully seated, worn clip, wrong breaker type, tandems where not allowed	Part E
Neutral bar	Two neutrals under one screw, loose screw	Part E
Main lugs, meter base	Loose service conductor, water damage	Part E and R2.5
Dimmer	Overloaded or derated by broken tabs	R2.6
Light fixture box	Bulbs over the fixture's rating	R2.6

What the customer notices

The CPSC lists the trouble signs for aluminum wiring, and they fit any bad connection: cover plates on receptacles or switches that are hot to the touch, flickering lights, circuits that stop working, and the smell of burning plastic at outlets or switches (CPSC Publication 516, "Trouble Signs"). The CPSC also warns that failing aluminum connections often give no warning at all.

Hot vs warm

Device	Warm is normal	Not normal
GFCI receptacle	A little warm, from its electronics (Arc Guide, Symptom 6)	Hot enough that you pull your hand away
Dimmer	Warm; dimmers turn part of the power into heat (Kuhlman, p. 26)	Plate too hot to keep your hand on
Breaker	Slightly warm under load (Arc Guide, Symptom 2)	Hot, or much hotter than the breakers next to it
Plain receptacle or switch	Room temperature	Any warmth you can feel, any discoloration
Panel cover	Warm to the touch is normal (Arc Guide, Symptom 12)	Uncomfortably hot

Part A: The Stop-Everything Call

A warm device, a burning smell, smoke, a crackling sound, or a buzzing panel is an emergency until you prove it is not. The Arc Guide puts it plainly: a burning smell is always serious (Symptom 6).

Symptom

The customer reports one or more of these: a burning or "fishy" plastic smell, a receptacle or switch that is warm or hot, a cover plate that is discolored, a plug that is hard to pull or has melted prongs, sparks when something is plugged in, crackling, or a panel that buzzes or is hot.

Questions to ask the customer

1. "Where is the smell or heat strongest? Show me."
2. "When did you first notice it? Is it there all the time or only when something is running?"
3. "What is plugged in or running there? A space heater, a window AC, a hair dryer?"
4. "Has anything stopped working, or do lights flicker anywhere in the house?"
5. "Has anyone worked on wiring here? Did you notice it after a storm?"
6. "Did you hear a crackle or pop, or see sparks?"

Steps, in order

Step A1. Shut it down safely. 1. If you see smoke, flame, or glowing, get everyone out and call 911. Do not fight an electrical fire with water. 2. If there is a smell or heat but no smoke or flame, have the customer unplug whatever is plugged into the warm device, if they can do it without touching the hot plate. 3. Find the breaker for the circuit and turn it off. If you cannot identify the breaker quickly and the smell is strong, turn off the main breaker and tell the

customer why. 4. Do not open the device or the box while the circuit is on (Arc Guide, Symptom 6, Step 1).

Step A2. Scan before you open (only if no smoke and the circuit can safely run for a minute).

The Arc Guide recommends scanning while the loads are still running, then killing power before you open anything, because a connection only heats under load (Part 10, "Thermal Inspection Without a Camera"). If the smell is mild and there is no smoke, you may do this:

1. Set your spot (infrared) thermometer to °F.
2. Hold it about 6 to 12 in. from the face of the cover plate. Read the warm device and a similar device on the same wall that is not suspect.
3. Write both readings. A device noticeably hotter than its neighbor has a heating connection.
4. Turn the breaker off.

If the smell is strong or the plate is too hot to touch, skip the scan and turn the breaker off.

Step A3. Prove dead, then open. 1. Prove your meter on a known live outlet. Read the device dead (hot-to-neutral and hot-to-ground both 0 V). Prove the meter again. 2. Take the cover plate off and pull the device out by its strap. 3. Look before you touch the wires. Take a photo.

Step A4. Read the damage.

The Arc Guide gives this order of severity for visual signs of heat (Part 10):

What you see	What it means
Yellow or tan tint on the device plastic	Mild past heating. Look for the cause.
Brown discoloration	Repeated overheating. Likely a loose connection.
Black charring or melted plastic	Severe. Must be repaired now.
White, green, or dull film on the metal terminal that other terminals do not have	Oxidized, high-resistance connection
Melted or brittle wire insulation near the terminal	The connection got hot enough to damage the wire

Step A5. Find the cause, then fix. Use Parts B, C, and D below: backstab, loose screw or connector, aluminum, worn receptacle, overloaded device, wrong wire size for the breaker.

Step A6. Check the wire size against the breaker.

With the power off, read the size printed on the cable jacket or the wire insulation. Check it against the breaker (Arc Guide, Symptom 6, Step 3; NEC 240.4(D)):

Copper wire size	Maximum breaker
14 AWG	15 A
12 AWG	20 A
10 AWG	30 A

A wire on a breaker larger than this can overheat before the breaker trips. Turn the breaker off and leave it off. Write it up as a safety finding. The fix is the correct breaker size, or a larger wire if the load needs it (scope for the office).

Step A7. If the smell is at the panel.

The Arc Guide says to turn everything off and inspect, and that any burn marks in a panel mean stop work and tell the homeowner (Symptom 6, Step 4). Go to Part E. Panel repairs go to your journeyman.

Part B: Backstabbed Devices and Loose Connections

What a backstab is

A backstab, also called a push-in terminal, is a hole in the back of a receptacle or switch. You push a stripped wire in, and a spring clip holds it. It is faster than wrapping the wire under a screw, which is why production builders used it (Kuhlman, p. 27). The spring touches the wire at a small point. A screw terminal clamps the wire across its whole width.

Kuhlman's company teaches its electricians never to backstab (p. 27), and he says that when he finds a backstabbed outlet on a no-power call, the problem always turns out to be a backstab somewhere in the house (p. 27). The push-in holes on modern receptacles only accept 14 AWG solid copper; a 12 AWG wire will not fit (Kuhlman, pp. 13, 27). The 2026 NEC makes this a code rule: 406.10(3) allows devices with push-in terminals only on branch circuits of 15 A or less, connected with 14 AWG solid copper only. Older editions had no such section and left the limit to the device's UL listing. A backstabbed 12 AWG wire on a 20 A circuit, or a backstab on aluminum wire, is wrong under any edition.

At YES, wires go under the screw terminal. When you find a backstab, you move it.

Symptom

Dead outlets downstream of one device, intermittent power, a warm receptacle, a receptacle that works only when you wiggle the plug, a device with brown or black marks at the back.

Questions to ask the customer

1. "Does it work if you push or wiggle the plug?"
2. "Did it get warm, or did something plugged in here stop and start?"

3. "When was the house built, and have the outlets ever been replaced?"
4. "What gets plugged in here? Heaters and AC units load a receptacle hard."

Tests, in order

Test B1. Find the hot device (power on, under load, plate on). Use the spot thermometer as in Step A2, with the normal load running. Compare the suspect device to others on the same circuit.

Test B2. Voltage drop under load at the device. This finds a high-resistance connection before it fails. 1. Plug a known load, such as a 1,500 W heater on high, into the receptacle being tested. (Use the device downstream of the suspect one if you are checking a feed-through connection.) 2. Set the meter to AC volts. 3. Read hot-to-neutral at the panel side (at the first receptacle on the circuit, or at the breaker and neutral bar if your journeyman has the panel open). Then read hot-to-neutral at the loaded receptacle. Write both. 4. The difference is the voltage drop. The NEC informational note on branch circuits suggests no more than 3 percent drop, which is 3.6 V on 120 V (210.19 Informational Note). R2.2 teaches this test in depth. 5. A drop much larger than the wire length explains, or a drop that jumps when you move from one device to the next, points to a bad connection in between.

Test B3. Open it (power off). 1. Turn the breaker off and prove dead. 2. Pull the device out. Look for wires in the backstab holes, darkened insulation, a darkened or melted area around the holes, and loose screw terminals. 3. Tug each wire gently. A backstabbed wire that slides or a screw that turns with a little pressure is loose.

The fix

1. Release each backstabbed wire. Many push-in terminals have a small slot next to the hole: push a small screwdriver into the slot and pull the wire straight out. If the device has no release slot, twist the wire gently while pulling, or cut the wire off flush at the device and re-strip it, if there is enough length.
2. Look at the wire end. If the copper is dark, pitted, or the insulation is brittle near the end, cut back to clean copper and good insulation. Strip to the length shown on the device's strip gauge.
3. If the device shows any discoloration or melting, replace it. A heat-damaged device has weakened contacts and plastic.
4. Bend a hook in the wire with needle-nose pliers and wrap it clockwise under the screw, so tightening pulls the wire in (Arc Guide, Job 1).
5. Put only one wire under each screw unless the device is marked for two. If two hots or two neutrals need to connect to the device, splice them with a short pigtail and put only the pigtail on the device. NEC 110.14(A) says terminals for more than one conductor shall be identified for it.
6. Torque each terminal screw to the value on the device or its instructions (NEC 110.14(D)). If the device is not marked, 110.14(D) Informational Note No. 2 points to the UL torque tables in Informative Annex I, and says to contact the manufacturer.

7. Fold the wires back into the box without forcing the device in. If the box is too full to close without force, it may be overfilled (NEC 314.16; R1.3).
8. Power on. Test with your receptacle tester and repeat Test B2 under load. The drop should now be small.

Loose wire connectors in boxes

Kuhlman's photos show burned splices from connectors that were never made tight, which "happens a lot" (pp. 123, 125). He notes that in a proper box the heat stays contained, and usually all that happens is loss of power downstream (p. 125).

1. Power off, prove dead.
2. Tug every wire in every connector. Any wire that moves, any connector that spins without the wires turning, means remake it.
3. Cut off any blackened copper. Strip to the connector's instructions.
4. Use a connector listed for the number and size of wires.
5. Twist on until the wires twist together inside, then tug each wire.

When you find one backstab

The Arc Guide says that when you find one backstabbed outlet, assume the whole house was done that way (Part 10, "Backstabbed Outlets"), and Kuhlman's experience matches (p. 27). Do not move every device in the house on your own. Write it up as a recommendation: "Receptacles and switches in this house are backstabbed. Recommend moving all connections to screw terminals." The office prices it (R3.1).

Field photo coming: Re-shoot of a burned backstab: a 15 A receptacle pulled from its box, back side facing the camera, with one push-in hole browned and the plastic around it slightly melted, the black wire's insulation darkened for about 1/2 in. from the end. Beside it, a new receptacle with the same wires hooked clockwise under the brass and silver screws. Shoot with a ruler or a wire stripper in the frame for scale.

Part C: Worn Receptacles and Melted Plugs

Symptom

Plugs fall out of the receptacle, a plug is warm or its prongs are discolored, or the receptacle face is browned around one slot.

Questions to ask the customer

1. "What is usually plugged in here?" A heater, window AC, or microwave on an old receptacle is the common pattern.
2. "Is the plug of that appliance warm when you unplug it?"

Tests

1. With the normal load running, use the spot thermometer on the plug and the receptacle face.
2. Look at the plug blades. Discolored or pitted blades mean the receptacle contacts are not gripping.
3. Power off. Pull the receptacle and check the terminals as in Part B.

The fix

1. Replace the receptacle with a new tamper-resistant receptacle of the right rating (15 A or 20 A to match the circuit). Tamper-resistant receptacles are required in dwelling units by NEC 406.26 (2023: 406.12), and receptacle replacements must meet the current requirements of 406.12(D) (2023: 406.4(D)). R1.4 covers those replacement rules.
 2. If the appliance plug is damaged, tell the customer to stop using it until the cord or plug is replaced. Do not repair the customer's appliance.
 3. If the appliance is a space heater or AC that runs for hours, recommend a dedicated circuit if the clamp reading (R2.1, Check 4) shows the circuit near its rating.
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Part D: Aluminum Branch-Circuit Wiring

Background

A copper shortage in the mid-1960s led builders to use aluminum wire for ordinary 15 A and 20 A circuits, not just for dryers and ranges. The CPSC says homes built before 1965 are unlikely to have aluminum branch wiring, and that cables installed from 1965 to the mid-1970s, including in additions and rewired circuits, may contain it (CPSC Publication 516, June 2011, p. 1).

A CPSC-sponsored survey by Franklin Research Institute found that homes built before 1972 and wired with aluminum were 55 times more likely to have one or more outlet connections reach "fire hazard conditions" than homes wired with copper (Publication 516, p. 1). The survey defined fire hazard conditions as cover plate screws reaching 149°C (300°F), sparks from the receptacle, or charred material around it. The survey only looked at connections at outlets.

The CPSC says the fire hazard happens at connections: receptacles, switches, junction boxes, and major appliances such as dishwashers and furnaces. Several processes at the connection raise the resistance over time, and the damage adds up (p. 1).

Identifying aluminum branch wiring

1. Look at the cable jacket where you can see it: unfinished basement, attic, garage, crawl space, or at the panel. Aluminum cable is marked "AL" or "ALUMINUM" on the jacket every few feet. A flashlight held at a low angle helps you read embossed letters (Publication 516, p. 2).

2. Read the whole marking. If it also says "CU-clad" or "copper-clad," the wire is copper-coated aluminum, which is not covered by the CPSC repair recommendations (p. 2).
3. Look at the wire size compared to the breaker. Aluminum branch circuits were sized at 12 AWG for 15 A circuits and 10 AWG for 20 A circuits, where copper would be 14 and 12 (p. 2, footnote 2). A 15 A breaker with what looks like 12 AWG wire is a clue.
4. With the power off and a device pulled, look at the bare conductor. Aluminum is dull silver-gray. Copper is orange-pink.
5. At the panel, look at the branch breaker terminals. Many breakers are marked "AL/CU." That marking does not tell you what wire is in the house; look at the wire.

Large aluminum conductors for services, dryers, and ranges are common and are not what this section is about (Publication 516, p. 2, footnote 3). Those are covered in R1.5 and R-SERVICE.

Picture coming: Aluminum branch wiring ID panel, three parts. Left: a section of NM cable with "ALUMINUM 12 AWG WITH GROUND TYPE NM" embossed on the jacket, a flashlight beam shown raking across it at a low angle. Middle: bare conductor ends side by side, one dull silver-gray labeled "aluminum," one orange-pink labeled "copper," and one silver with an orange core visible at the cut end labeled "copper-clad aluminum: not covered by CPSC repair." Right: an AlumiConn connector in a receptacle box with an aluminum circuit wire and a copper pigtail in separate ports, the pigtail going to the receptacle's screw terminal.

What the CPSC accepts as a permanent repair

The CPSC approves only three methods for a permanent repair (Publication 516, p. 3):

Method	What it is	Who does it
1. Replace with copper	New copper branch circuits; the aluminum is abandoned in the walls. The CPSC calls this the best method.	Scope for the office. A rewire.
2. COPALUM	A copper pigtail is joined to the aluminum with a COPALUM crimp sleeve, using a dedicated power tool and die. Every aluminum connection in the house is repaired, including outlets, switches, dimmers, fixtures, appliances, and junction boxes (p. 4).	Only electricians trained by the manufacturer (TE Connectivity) may install COPALUM (p. 5).
3. AlumiConn	A copper pigtail joined to the aluminum with an AlumiConn set-screw connector. The CPSC calls it the next best option if COPALUM is not available (p. 6).	A qualified electrician, with careful workmanship (p. 6). At YES, a journeyman, or you with a journeyman's sign-off.

What the CPSC does not accept as a permanent repair

Method	What the CPSC says
Pigtailing with twist-on connectors	In CPSC-sponsored tests, substantial numbers overheated severely. Some twist-on "repairs" may fail more often than the original connections. Not a solution (p. 7).
CO/ALR switches and receptacles	Perform better than non-CO/ALR devices but failed in lab tests with aluminum wire typical of existing homes, and are not available for all parts of the system. At best an incomplete repair (p. 8).
Other crimp connectors, including hand-crimped ones	Not evaluated for copper-to-aluminum; CPSC strongly recommends against (p. 6).

The CPSC allows AL/CU twist-on pigtails or CO/ALR devices only as an emergency, temporary repair of a failed aluminum termination, followed as soon as possible by a complete repair using a recommended method (p. 8). If you make a temporary repair, write it on the job board as temporary, with the recommendation for a complete repair.

The Arc Guide lists purple twist-on connectors and CO/ALR devices with antioxidant compound as fixes (Part 2, Part 5). That conflicts with the CPSC publication. Follow the CPSC.

Why this is a code issue too

NEC 110.14 says terminals and connectors shall be identified for the conductor material, dissimilar conductors shall not touch in a terminal or connector unless it is identified for that purpose, and terminals used to connect aluminum shall be so identified (110.14 and 110.14(A)). NEC 110.3(B) says listed equipment shall be installed according to its instructions. Those two rules are why the connector's own instructions control the repair.

Step by step: one aluminum-to-copper pigtail with AlumiConn

Do this only with your journeyman's sign-off and only after you have practiced on scrap. The steps follow King Innovation's UL-listed installation instructions for the 3-port AlumiConn (document 50100-46 REV Q, 06/23).

Safety: Turn the breaker off and prove dead with live-dead-live. The connector's instructions say to turn off power before installing or removing it. Aluminum branch circuits in older houses often have splices in boxes you do not expect; confirm every wire in the box is dead, not just the one you are working on.

1. Pull the device out of the box. Take a photo of the wiring.
2. Disconnect the aluminum wires from the device.
3. Look at each aluminum conductor. If it is nicked, scored, or blackened, cut back to clean, round conductor. Aluminum is soft and breaks after repeated bending, so handle it gently and do not over-strip.

4. Cut a copper pigtail of the same circuit size as the original design (12 AWG copper for a circuit that was 12 AWG aluminum on a 15 A breaker is acceptable; 14 AWG copper also matches a 15 A breaker under 240.4(D)). Leave about 6 in. so the pigtail reaches the device.
5. Strip each conductor 5/16 in. (AlumiConn instructions, step 1).
6. Insert each conductor into its own port, fully seated (step 2). One conductor per port only.
7. Tighten each set screw with a torque screwdriver to the value for that conductor (step 3):

Conductor	AlumiConn set-screw torque
12 AWG solid aluminum	10 in-lb
10 AWG solid aluminum	15 in-lb
Any solid or stranded copper	15 in-lb

1. Do not over-torque. The instructions warn that not following the torque values can cause failure.
2. Close the lid and check that the latch is fastened (step 4).
3. Connect the copper pigtail to the device's screw terminal. Torque to the device's value.
4. The connector is rated 300 V, 105°C, for 12–10 AWG solid aluminum and 18–10 AWG solid and stranded copper. It is listed to UL 486C. Do not reuse a connector once installed.
5. The connector ports already contain a corrosion inhibitor (product sheet). Use any other compound only if the connector's instructions call for it; 110.14 requires compounds to be identified for the use.
6. Repeat for every aluminum connection in the box, including the neutral and the ground if they are aluminum.
7. Fold the connectors and wires into the box. AlumiConn connectors are larger than twist-ons. If the box is now too full (314.16), add a box extension or a larger box.
8. Power on and test.

What to recommend

1. One failed connection on an aluminum-wired house means every aluminum connection in the house is a risk. The CPSC says every aluminum-to-aluminum and aluminum-to-copper connection should be repaired for the full benefit (p. 4).
2. Write the job board finding: "Aluminum branch-circuit wiring identified (jacket marking photo). Failed connection at [location] repaired with AlumiConn copper pigtail. Recommend whole-house repair by CPSC-recommended method (COPALUM or AlumiConn at every connection, or rewire)." The office prices it.
3. Tell the customer in plain words: "Your house has aluminum wiring, which was common in the late '60s and early '70s. The wire itself is fine inside the walls. The weak spots are where it connects to outlets, switches, and lights. I fixed the one that failed. The government's safety agency recommends fixing every connection, and the office will send you options."

Part E: Panel Heat, Buzz, and Inspection

Symptom

The panel buzzes or crackles, the panel cover or a breaker is hot, there is a burning smell at the panel, or a breaker crackles when you switch it.

Questions to ask the customer

1. "Is the buzz there all the time or only when something big is running? Which appliance?"
2. "Has any breaker been tripping or been hard to reset?"
3. "Have you seen water near the panel or the meter? Any leaks in that wall?"
4. "Has anyone added breakers or circuits recently?"
5. "Do any lights in the house flicker or go bright and dim?" If yes, also work R2.5.

Safety before you open a panel

1. Stand to the side of the panel, not in front of it, when you open the door and remove the dead front.
2. Wear safety glasses. Follow your journeyman's and R1.1's PPE for opening a live panel.
3. Keep the working space clear (NEC 110.26).
4. Remember that the service conductors and the line side of the main breaker stay live with the main off. Only the utility can de-energize them (Arc Guide, Job 4).
5. If you see heavy charring, melted plastic, or an arcing sound when you open the door, close it if you can do so without reaching in, back away, and call your journeyman. Do not remove the dead front on a panel that is actively arcing.

Test E1. Listen and locate (power on, dead front on)

The Arc Guide says a faint hum is normal, but a loud buzz or one that changes with load is a problem (Symptom 12).

1. Put your ear near the panel without touching it. Is the buzz from one area or general?
2. Have the customer turn on the big loads one at a time: dryer, range, AC, water heater. Note whether the buzz changes.

Test E2. Thermal scan (power on, under load)

1. With the dead front on and the normal load running, use the spot thermometer on the face of each breaker. Write the reading next to the breaker number.
2. Compare each breaker to breakers of the same size carrying similar load. The Arc Guide says a single breaker running much hotter than its neighbors points to a loose terminal or an overloaded circuit, and a hot spot on the bus points to a poorly seated breaker (Symptom 12; Part 10).

3. Clamp the hot breaker's circuit with your clamp meter and compare to the breaker rating. A breaker at or near its rating will run warm. A breaker that is hot on a light load has a bad connection.
4. Kuhlman also checks the main breaker by touch for heat, because stab-on main breakers can fail at the bus connection (p. 95).

Test E3. Crackling breaker

Kuhlman says that when a breaker's connection to the bus has broken down, you can often hear crackling when you switch it on and off, and that sound means the breaker is melting or falling apart (p. 33). Stop switching it. Turn off the main and inspect (Test E4).

Test E4. Open inspection (main off)

Safety: With your journeyman. Turn off the main breaker. Prove dead at the branch breakers' terminals and the bus with live-dead-live. Treat the main lugs and line side as live.

1. Take the dead front off. Photograph the whole interior before you touch anything.
2. Look at each breaker where it clips to the bus. Pull any breaker that showed heat or crackling and inspect its clip and the bus stab. Kuhlman's photos show a breaker and the bus beneath it burned by a bad connection over years (pp. 108–109).
3. Look at every terminal on every breaker, every neutral bar screw, and the ground bar.
4. Go through the panel defect list below and mark each one you find.

Panel defect list

Defect	What to look for	Why it matters	Code
Double-tapped breaker	Two wires under one breaker terminal	The terminal is made for one wire unless the breaker is marked for two; the extra wire loosens (Kuhlman, p. 34)	110.14(A) (terminals for more than one conductor shall be identified); 110.3(B)
Two neutrals under one screw	Two white wires under one neutral-bar screw	When one circuit is worked on, the other neutral loosens. Each neutral needs its own terminal.	408.41
Wrong-brand or wrong-type breaker	Breaker brand or type not on the panel's label	The breaker's clip may not grip the bus correctly. The panel label lists the breakers allowed.	110.3(B)
Tandem breakers where not allowed	Twin (half-size) breakers in a panel or position not rated for them	Kuhlman has seen twins melt from improper use, especially several side by side (p. 35). The panel label shows which positions take tandems (p. 34).	110.3(B); 408.54 (panelboard limits the number of OCPDs to its rating)
Scorched or pitted bus	Dark marks, pits, or melted plastic at a breaker position	A breaker clipped onto damaged bus will heat again. That position is done.	110.12(B)
Loose terminals	Screws that turn when you torque-check	Heat source	110.14(D)
Breaker too large for the wire	E.g., 20 A breaker on 14 AWG	Wire overheats before trip	240.4(D)
Open knockouts, missing filler plates	Holes in the cabinet or dead front	Fingers, rodents, and debris can get in	110.12(A)
Paint, plaster, drywall dust, or debris inside	Overspray on the bus, plaster on terminals	Contamination of busbars and terminals is not allowed	110.12(B)
Water or rust	Rust lines, white corrosion, water stains running down from the top	Kuhlman shows a panel where years of water ruined the bus, neutral bar, and all breakers. He says to check the meter outside, where it starts (p. 107). Water often follows service entrance cable from the meter or weatherhead into the panel (pp. 40–42).	110.12(B)
	Neutrals and grounds on one	Puts neutral current on metal parts. R1.6 covers it.	250.24, R1.6

Defect	What to look for	Why it matters	Code
Neutral and ground joined in a subpanel	bar, or bonding screw in, in a panel fed from another panel		
Federal Pacific Stab-Lok, Zinsco, other problem brands	Label and breaker style	Known failure histories. R-OLDHOUSE covers them.	—
Blocked working space	Shelves, appliances, pipes in front	Unsafe to service	110.26
Panel in a closet, bathroom, or over stairs	Location	Not permitted for new work	240.24

Picture coming: Panel defect sheet: one residential panel drawn with the dead front off and seven numbered callouts. 1: a breaker with two wires under one screw. 2: two white wires under one neutral-bar screw. 3: a breaker of a different color and shape than the others, labeled "brand not on panel label." 4: a scorched, blackened bus stab where a breaker has been pulled. 5: an open knockout in the side of the can. 6: a rust line running down from the top entry. 7: white paint overspray on the bus. A legend at the bottom lists each defect in one line.

Test E5. Torque check every termination

The Arc Guide reports that in an IAEI-reported observation, 78 percent of experienced electricians under-torqued connections (Part 10). Whatever the exact number, loose terminals are common in panels. A torque check finds them.

1. Main off, branch terminals proven dead, line side treated as live.
2. Read the torque value printed on each breaker or on the panel label. Values differ by brand, breaker type, and wire size. Do not use a value from memory.
3. Set your torque screwdriver to the label value.
4. Apply torque to each breaker terminal smoothly until the driver clicks or slips. If the screw turned before the click, it was loose. Mark it.
5. Do the same for the neutral bar and ground bar screws, using the value on the panel label.
6. Record: total terminals checked, number that turned, which ones.
7. Do not tighten past the value. The Arc Guide warns that over-torque is also a failure mode, crushing strands, especially aluminum (Part 10).
8. Main lugs and service conductors are not part of your torque check unless your journeyman is doing service work with the service de-energized.

The fixes

Finding	Fix
Loose terminal, no heat damage	Torque to the label
Terminal or wire heat damage	Cut the wire back to clean copper; replace the breaker
Double-tapped breaker	Add a breaker for the second circuit, or splice the two wires with a pigtail to one wire under the terminal (Kuhlman, p. 34). Some breakers are marked for two conductors; read the label (Kuhlman notes certain Square D models, p. 34).
Two neutrals under one screw	Move one neutral to an open terminal on the bar (408.41)
Wrong breaker	Replace with a breaker listed on the panel label
Scorched bus position	Do not reuse that position. If the damage spreads past one position, the panel needs replacing. Scope for the office.
Water damage	Find and stop the water source (meter, weatherhead, cable entry). Damaged breakers, bus, or bars need replacing. Escalate.
Problem brand panel	Recommend replacement (R-OLDHOUSE)

Worked Examples

Example 1: "The outlet behind the couch smells like something burning"

Intake. A space heater runs on that outlet most evenings. The customer smelled hot plastic last night and unplugged the heater. The house was built in 1988.

Step A1. No smoke. The heater is unplugged. You find the circuit's breaker (breaker 12) using the tracer.

Step A2. With the heater plugged into the suspect receptacle for two minutes on high, the plate reads 104°F; the next receptacle on the wall reads 74°F. You turn off breaker 12.

Step A3-A4. Proven dead. The receptacle is backstabbed: hot and neutral in, hot and neutral out. The incoming hot's push-in hole is brown and the plastic is soft. The wire insulation is darkened 3/8 in. back.

Fix. Cut both blacks back to clean copper. Install a new 15 A tamper-resistant receptacle. Wires hooked clockwise under the screws, torqued to the value on the package. Breaker is 15 A on 14 AWG; correct.

Verify. Heater on high, 10 minutes: plate 76°F. Voltage drop from the first receptacle on the circuit to this one under the heater load: 2.1 V.

Document and recommend. Photo of the burned backstab and the repair. "House receptacles are backstabbed. Recommend moving all to screw terminals." Customer told the heater draws about 12.5 A, and a dedicated circuit is an option for the office to price.

Example 2: "Switch plate in the hall is warm and the light flickers" (1970 house)

Intake. Built in 1970. The hall switch plate feels warm; the hall light flickers sometimes.

Identify. In the attic you see NM cable marked "ALUMINUM 12 AWG WITH GROUND." The hall circuit is on a 15 A breaker.

Open. Breaker off, proven dead. The switch is an older non-CO/ALR switch. The aluminum wire under the brass screw is dark and the screw head is discolored.

Fix with journeyman's sign-off. Two AlumiConn pigtails: aluminum line to a copper pigtail, aluminum switch leg to a copper pigtail. 5/16 in. strip, aluminum set screws at 10 in-lb, copper at 15 in-lb. New switch on the copper pigtails, torqued to its label. The ground is copper; it stays as is.

Verify. Light on for 15 minutes, plate at room temperature, no flicker.

Document and recommend. "Aluminum branch wiring, whole house. Failed switch connection repaired with AlumiConn. Recommend whole-house repair by CPSC-recommended method." The customer gets the plain-words explanation from Part D.

Example 3: "The panel is buzzing"

Intake. The buzz started a week ago and gets louder when the dryer runs. No flicker reported.

E1. Buzz localized to the lower left of the panel. Louder with the dryer on.

E2. Spot thermometer, dryer running: the 30 A two-pole dryer breaker reads 131°F; the other two-pole breakers read 85–90°F. Clamp on the dryer circuit: 22 A on each leg. That is under the breaker rating, so heat from load alone does not explain the reading.

E4 with journeyman. Main off. The dryer breaker is loose on the bus; it rocks when touched. Pulled, its clip and the bus stab show dark pitting. One terminal screw turned a quarter turn before clicking during the torque check.

Fix. The journeyman decides the bus pitting is limited to one stab. The dryer circuit moves to a different two-pole position with a new breaker of the listed type. The damaged stab is left empty with a filler. Torque check of every terminal: 38 terminals checked, 5 turned before clicking.

Document and recommend. Photos of the pitted stab and old breaker. "Panel bus damaged at one position from a loose breaker. Recommend monitoring; if more damage is found, recommend panel replacement." Record the 5 of 38 loose terminals.

Common Mistakes

1. **Opening a hot device with the power on.** Turn off the breaker first, every time.
 2. **Replacing a burned device and leaving the backstab method in place.** Move every wire to the screw terminal.
 3. **Putting a burned wire end back under the screw.** Cut back to clean copper first.
 4. **Treating aluminum wiring with purple twist-ons or CO/ALR devices as a permanent fix.** The CPSC says those are temporary at best (Publication 516, pp. 7–8).
 5. **Doing COPALUM without manufacturer training.** Only trained installers may (Publication 516, p. 5).
 6. **Skipping the AlumiConn torque values.** Under- and over-torque both cause failure. Use a torque screwdriver.
 7. **Torquing to a number from memory.** Use the value printed on the breaker, panel, device, or connector.
 8. **Over-tightening "to be safe."** Over-torque crushes strands and cracks devices.
 9. **Ignoring two neutrals under one screw.** 408.41 requires one neutral per terminal.
 10. **Reusing a scorched bus position.** The next breaker will heat too.
 11. **Forgetting the line side is live.** The main lugs and service conductors stay live with the main off.
 12. **Fixing the panel and ignoring the water source.** The meter and the service entrance cable are often where the water starts (Kuhlman, pp. 40–42, 107).
 13. **Upsizing a breaker on a wire that was overheating.** That removes the wire's protection.
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Field Exercise

Part 1: Torque check a training panel. 1. With your journeyman, turn off the training panel's main breaker. Prove dead at the branch breakers and the bus with live-dead-live. Treat the line side as live. 2. Read the torque values from every breaker and the panel label. Write them in a table: breaker number, wire size, label torque. 3. Torque-check every branch breaker terminal and every neutral and ground bar screw. 4. Record the total number checked and how many turned before the driver clicked. Report the result to your journeyman as "X of Y were loose."

Part 2: Inspect a scrap panel. 1. Your journeyman gives you a scrap panel with defects planted. 2. Using the panel defect list in Part E, find and list every defect. For each, write what it is, why it matters, and the fix, in one line each. 3. Your journeyman tells you how many you missed.

Part 3: Aluminum identification and pigtail. 1. From a set of cable scraps, sort them into copper NM, aluminum NM, and copper-clad aluminum by reading the jacket markings and looking at the cut ends. 2. Make up a copper pigtail onto a 12 AWG solid aluminum scrap using an AlumiConn connector, following the manufacturer's instructions step by step: 5/16 in. strip, one

conductor per port, fully seated, 10 in-lb on the aluminum, 15 in-lb on the copper, lid latched. 3. Your journeyman checks the strip length, seating, and torque with their own driver. Then do it twice more until it passes all three checks. 4. Explain in two sentences why a purple twist-on or a CO/ALR device is not the permanent repair, and cite CPSC Publication 516.

Part 4: Thermal scan of a live panel. 1. On a live training panel (or a customer panel with your journeyman), turn on loads on several circuits. 2. With the dead front on, use the spot thermometer on the face of every breaker. Write each reading. 3. Clamp the circuits on the three warmest breakers and compare current to rating. 4. Say which breaker is warmest, whether the current explains it, and what you would check next.

Pass standard. All parts done with live-dead-live before touching any terminal; loose-terminal count recorded; every planted defect found or missed defects explained; three AlumiConn pigtails passing the journeyman's checks; thermal scan readings and clamp readings written and explained.

NEC 2026 Cross-References

Section	What it says	How it applies here
110.3(B)	Listed or labeled equipment shall be installed and used per its listing and instructions	Aluminum connectors, breakers allowed in a panel, tandem positions
110.12(A)	Unused openings shall be closed	Open knockouts and missing breaker fillers
110.12(B)	Internal parts shall not be damaged or contaminated by paint, plaster, corrosive residue, or deteriorated by corrosion or overheating	Painted bus, water damage, scorched parts
110.14	Connectors and terminals identified for the conductor material; dissimilar metals not to touch unless identified; compounds identified for the use	Aluminum to copper connections
110.14(A)	Terminals for more than one conductor and terminals for aluminum shall be identified	Double taps; aluminum at devices
110.14(B)	Splices made with devices identified for the use; free ends insulated	Wire connectors in boxes
110.14(D)	Tightening torque as indicated on equipment or instructions; approved means such as torque tools; Annex I torque tables where the manufacturer gives none	Every termination you touch
110.26	Working space about electrical equipment	Blocked panels
210.19 Informational Note	Branch circuit voltage drop of 3 percent and total of 5 percent for reasonable efficiency (advisory, not a requirement)	Voltage drop test for high-resistance connections
240.4(D)	14 AWG copper at 15 A, 12 AWG at 20 A, 10 AWG at 30 A	Wire too small for its breaker
240.24	Breakers readily accessible; not in clothes closets, bathrooms, or over stairs	Location findings
314.16	Box fill	AlumiConn and pigtails add volume
406.10(3)	Push-in (backstab) terminals only on branch circuits of 15 A or less, with 14 AWG solid copper only (new in 2026; earlier editions left this to the UL listing)	Backstabs on 20 A circuits or on 12 AWG are not allowed
406.12(D) (2023: 406.4(D))	Receptacle replacements	Replacing heat-damaged receptacles
406.26 (2023: 406.12)	Tamper-resistant receptacles in dwellings	Replacement receptacles
408.36	Panelboard protected by an OCPD not greater than its rating; Exception No. 2 for existing residential service panelboards	Panel ratings during inspection

Section	What it says	How it applies here
408.41	Each grounded conductor terminates in its own terminal	Two neutrals under one screw
408.54	Panelboard has a physical means to prevent more OCPDs than it is rated for	Tandems in panels not rated for them

End-of-Chapter Checklist

Heat or smell call - ☐ Got everyone out and called 911 if there was smoke or flame. - ☐ Turned off the circuit (or the main) before opening anything. - ☐ Scanned with the spot thermometer under load first, if it was safe. - ☐ Proved dead with live-dead-live before opening. - ☐ Photographed the damage before touching it. - ☐ Read the damage level: tan, brown, black, melted. - ☐ Checked wire size against the breaker.

Devices and connections - ☐ Moved backstabbed wires to screw terminals. - ☐ Cut wire back to clean copper and good insulation. - ☐ Replaced any heat-damaged device. - ☐ One wire per terminal unless marked for more; pigtails otherwise. - ☐ Torqued to the device's value. - ☐ Reran the voltage drop test under load.

Aluminum - ☐ Identified aluminum by jacket marking, wire size vs breaker, and conductor color. - ☐ Checked for "CU-clad" marking. - ☐ Used only a CPSC-recommended method for a permanent repair (COPALUM by a trained installer, AlumiConn, or rewire). - ☐ Followed AlumiConn instructions: 5/16 in. strip, one conductor per port, 10 in-lb on 12 AWG Al, 15 in-lb on 10 AWG Al and copper, lid latched. - ☐ Marked any twist-on or CO/ALR fix as temporary on the job board. - ☐ Recommended whole-house repair.

Panel - ☐ Listened for buzz and noted whether it changes with load. - ☐ Spot-scanned every breaker under load and clamped the warm ones. - ☐ Stopped switching any breaker that crackled. - ☐ Inspected with main off and line side treated as live. - ☐ Worked the full panel defect list. - ☐ Torque-checked every terminal and recorded X of Y loose. - ☐ Found the water source, if any.

Close out - ☐ Job board card with photos, readings, cause, fix, verification. - ☐ Recommendations written for the office with no prices.

Sources

- U.S. Consumer Product Safety Commission, Repairing Aluminum Wiring, Publication 516, June 2011. <https://www.cpsc.gov/s3fs-public/516.pdf>. Pages cited: 1 (history, 55-times survey, fire hazard conditions definition, 1965–mid-1970s), 2 (trouble signs, identification, CU-clad note, wire sizes, larger conductors excluded), 3 (three approved permanent repairs, rewire), 4–5

- (COPALUM, trained installers only), 6 (AlumiConn, other crimp connectors), 7 (twist-on pigtails), 8 (CO/ALR, temporary repairs).
- King Innovation, 3 Port AlumiConn® Aluminum to Copper Lug, UL-listed installation instructions and product sheet, document 50100-46 REV Q, 06/23. <https://www.kinginnovation.com/-/media/inriver/50100-46-AW%20AlumiConn%20REV%20Q.pdf>
 - Jesse Kuhlman, Residential Electrical Troubleshooting (2019). Pages cited: 13 and 27 (backstabs, 14 AWG only), 26 (warm dimmers), 33 (crackling breaker, bus breakdown), 34 (double taps, two-wire Square D note, tandem breakers and panel labels), 35 (twin breakers melting), 40–42 (water entering through SE cable and the meter), 95 (stab-on main breaker failures), 107 (water-ruined panel), 108–109 (burned breaker and bus), 123 and 125 (burned splices). All paraphrased. No photos reproduced.
 - Arc Workforce, Residential Electrical Field Guide. Symptom 2, Symptom 6, Symptom 12, Job 1, Job 4, Part 10 ("The 78% Torque Problem," "Backstabbed Outlets," "Panel Inspection," "Aluminum Wiring," "Thermal Inspection Without a Camera"). Where the Arc Guide's aluminum advice conflicts with CPSC Publication 516, this chapter follows the CPSC.
 - YES Electric commercial course, Module 2.4 (panel inspection, IR scanning) and Module 2.8 (retorquing).
 - NFPA 70, National Electrical Code, 2026 edition, sections listed above.
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Videos to watch

These videos are made by other electricians and companies, not YES Electric. Watch each one after you read the section it goes with. Where a video does something differently from this module, the caution line says so. Follow this module and your journeyman, not the video. Click a title to open it on YouTube.

Section	Video
Part B Backstabbed devices; Part C Worn receptacles and melted plugs	The Shocking Truth Behind Melting Outlets: Backstabbed Fire Risk Sherwood Park Electrician Halo Power Solutions • 10:09 On a real AFCI-tripping call the electricians find a backstabbed receptacle feeding a portable air conditioner, with a discolored neutral and a melted, bowed plug, and rewire it on the screw terminals. Caution: Canadian (Alberta) contractor; the receptacles and 120 V circuits are the same as ours. Some joking and brand talk.
Part D Step by step: aluminum-to-copper pigtail with AlumiConn	Aluminum Wiring Repair - How to Install AlumiConns to Fix Aluminum Wire Hazards Permanently Aluminum Wiring Repair • 9:27 A master electrician strips the aluminum without nicking it, inserts aluminum and copper into an AlumiConn, torques each set screw with a torque screwdriver to the package value, tug-tests, and folds it into the box. Caution: Canadian (Calgary). Use the torque values on the AlumiConn package for the wire sizes you have; do not memorize the '10 in-lb' he mentions. The narrator also sells aluminum-wiring repair.
Part D Step by step: AlumiConn (manufacturer)	nVent KING INNOVATION AlumiConn Installation nVent KING INNOVATION • 2:01 The manufacturer's own two-minute AlumiConn installation clip. Caution: No spoken transcript was available; content not vetted beyond the title and description. Check the package instructions for strip length and torque.
Part E, Test E5 Torque check every termination	Checking an Old Electrical Panel For Loose Connections With a Wiha Torque Screwdriver Benjamin Sahlstrom • 8:03 With the panel main off, a licensed electrician sets a torque screwdriver to the 36 in-lb on Square D QO breakers and finds most existing terminals were under-torqued. Caution: He notes the line lugs at the top stay live. Use the value printed on each breaker, not 36 in-lb from memory.
Part E, Test E2 Thermal scan (power on, under load)	How to inspect an electric panel with an infrared camera Structure Tech Home Inspections • 8:14 A home inspector loads the house, scans the open panel with a thermal camera, explains why AFCI/GFCI breakers and SPDs run warm, and uses a clamp meter to check a hot breaker. Caution: He uses about 70 F above ambient as a concern level; follow the module's hot-versus-warm guidance. Home inspector, not an electrician.

Background: Why connections get hot; Part C

[3 Reasons Why Your Outlet Burned... and How to Prevent an Electrical Fire!](#)

Top Homeowner • 4:59

Explains three common causes of a burned receptacle (loose or backstabbed connection, undersized wire, overload) and says to find the cause before replacing the device.

Caution: Homeowner channel, no field footage. It says garages 'typically need heavier gauge wire'; the real rule is wire size matched to the breaker.