PREVENTING MOISTURE-INDUCED FAILURES IN ELECTRIC HEATERS

DE14

TEMPCO

Moisture is the most common—and the most preventable—cause of Ground Fault Interrupter (GFI) trips, failed high potential (hi-pot) tests, and premature heater failures (electrical short). The root of the issue is the insulation system most industrial electric heaters rely on: compacted magnesium oxide (MgO). MgO is hygroscopic; when it absorbs water, insulation resistance collapses and the heater can smoke at start-up, trip GFIs, or fail dielectric tests. Understanding the physics, electrical testing, and conditioning methods will restore performance and extend heater life.

MOISTURE ABSORPTION

Under dry conditions, MgO provides excellent thermal conductivity and very high insulation resistance (often >100 MΩ/ft). When it absorbs moisture, the MgO hydrates ($MgO + H_2O \rightarrow Mg(OH)_2$), creating leakage paths from element to sheath and slashing resistance by orders of magnitude. Practically, you'll see smoke or outgassing on first energization (that's moisture and binders leaving the assembly), GFI/ground-fault trips, and failures to pass hi-pot. These symptoms are especially common after storage, overseas shipment, or idle periods in humid plants.

Where the moisture comes from

1. **Storage and climate**: Humidity greater than 60%, temperatures near the dew point, and long idle periods allow MgO to wick moisture through microscopic seal imperfections. Large bundles and high-voltage designs (480 V) are more susceptible.
2. **Thermal cycling**: Cooling creates slight negative pressure inside the heater, pumping ambient moisture inward.
3. **Logistics**: Long shipments (especially overseas) and humid shop floors frequently precede GFI trips, smoke on first power-up, and hi-pot failures.

ELECTRICAL TESTING REQUIRED

Megohm testing (preferred): Use a 500 or 1000 VDC megohmmeter from element to sheath at room temperature. As a rule of thumb, new heaters should measure ≥10 MΩ; anything below ~1 MΩ warrants immediate conditioning. Trend resistance over time; rising values during a low-power warmup confirm drying.

Dielectric (hi-pot) testing: Align your in-house test with UL/CSA guidance. Typical one-second AC test voltages for strip-style heaters are:

- **≤250 V rated**: 1250 VAC
- **251 V rated**: 2 × rated voltage + 1000 V, with a maximum allowable (compensated) leakage of 4 mA per 100 in^2.

Excess moisture is a frequent root cause of hi-pot failures – even with otherwise sound construction.

CONDITIONING (BAKE-OUT) PROCEDURES

The objective is to reverse moisture and bake off absorbed water without damaging seals or terminations. Effective programs combine temperature, time, and controlled power.

Field oven bake-out (uninstalled or removable heaters):

- 121–204 °C (250–400 °F) for overnight is a proven, low-risk starting point.
- Heavier masses and wetter heaters need more time; plan 6–40 hours depending on size and starting resistance.
- Verify by re-megging to spec (≥5–10 MΩ depending on design/voltage) and rechecking stability after 24–48 h.

In-place electrical bake-out (installed heaters):

- Start at reduced voltage/power (≈25–50% rated) and gradually ramp while monitoring current and insulation resistance.
- Many SCR power controllers include a low-voltage "heater bake-out" / soft-start feature that automatically ramps until the heater dries, then switches to normal control. This approach minimizes nuisance trips and blown fuses during first energization.

Temperature profile optimization:

- **A conservative, component-friendly ramp**: 80 °C (initial outgassing) → 150 °C (primary dehydration) → ≈200 °C (completion).
- Chemically, $Mg(OH)_2$ begins decomposing ~330 °C and completes back to MgO near 430 °C; practical field conditioning stays lower to protect seals and terminations, so expect longer dwell times.

PREVENTATIVE MEASURES

- **Specify and store for dryness:** For heaters stored longer than 30 days or exposed to high humidity, mandate pre-installation conditioning. Store in climate-controlled areas, keep original moisture-barrier packaging intact, and add desiccant for extended holds.
- **Periodic inspection:** For critical lines, schedule quarterly megger checks and trend results to trigger conditioning before trips or failures.
- **Align test procedures:** Match your incoming and field hi-pot protocols to UL/CSA expectations to avoid over-stressing wet but otherwise healthy heaters—and to get a consistent read on true failures.
- **Always ground the sheath:** A solid equipment ground gives leakage a safe path, protecting personnel and sensitive electronics if a fault occurs. Heaters can be built with ground leads/terminals—use them.

QUICK ENGINEER'S CHECKLIST

1. **On receipt:** Keep packaging sealed; store ≤55% RH. If storage >30 days, tag for conditioning before install.
2. **Before power-up:** Megger at 500–1000 VDC, element → sheath. If <1 MΩ, condition; target ≥10 MΩ for new builds.
3. **If installed/wet:** Use controller bake-out (low-voltage ramp) or energize at reduced power; watch IR trend upward.
4. **If removable/wet:** Oven bake 121–204 °C; re-meg and re-check after 24–48 h.
5. **Verify:** Align hi-pot levels with UL/CSA; confirm leakage criteria; ensure ground continuity.

By adopting these practices—accurate diagnostics, controlled conditioning, and moisture-aware storage/testing—you'll eliminate the most common avoidable failure mode in industrial heaters and keep your lines running.