Custom High-Temperature Load Cells: Why Catalog Ratings Stop Working Above 400 °F (204 °C)

A case study in evidence-based force instrument design

Engineering teams sourcing instrumentation for downhole and aerospace joints often assume a catalog load cell can be pushed past its published temperature rating as long as the steel load-bearing element itself can tolerate the heat. The assumption stops at the wrong material. The question this case study addresses is which components in a load cell actually set its temperature limit, and what changes when an application moves into ultra-high-pressure, high-temperature (ultra-HPHT) territory above 400 °F (204 °C) or 20 000 psi (138 MPa).

A recurring request at Morehouse's calibration laboratory involves customers asking whether an existing catalog load cell can serve in a downhole or high-temperature aerospace joint, or whether the application requires a purpose-built cell. Working through these requests with metrology engineers and design staff surfaces the same set of pain points on nearly every application:

- Catalog load cells are compensated only from roughly 60 °F to 160 °F (16 °C to 71 °C) and begin reading erratically above about 175 °F (79 °C), often well before the steel element itself is stressed.
- The components that actually fail first — gauge backing, bonding adhesive, wire insulation, solder, and potting — are rarely called out on a datasheet, so the true limit is easy to miss.
- Bolt preload and clamping force on a hot joint do not stay where they were set; nickel-alloy fasteners relax and creep as temperature climbs, so the joint's actual load has to be measured, not assumed.
- The customer needs a clear answer on what is achievable before committing to a custom build, and a calibration baseline defensible enough to support that answer once the part is deployed.

With these considerations in mind, Morehouse applies the same evaluation framework to every high-temperature load cell request: identify what is actually setting the temperature limit, confirm the geometry matches the load path, and build the calibration baseline the application will need once it is in service.

NON-METALLIC COMPONENTS SET THE REAL TEMPERATURE LIMIT

The load-bearing steel element is rarely the constraint on a load cell's operating range. The non-metallic parts are: the gauge backing, the bonding adhesive, the wire insulation, the solder, and the potting. When heat softens the adhesive, strain no longer transfers cleanly from the element to the gauge, and the output becomes a number the customer cannot defend. Polyimide-backed foil gauges hold to about 392 °F (200 °C) in continuous service. Above 400 °F (204 °C), the design has to move to specialty gauge systems, inorganic or ceramic bonding, hermetically sealed housings, and cable built for the soak. Each of those choices affects temperature effect on zero, temperature effect on output, and creep — a cell designed for the heat controls all three; a catalog cell pushed past its rating controls none of them.

GEOMETRY HAS TO MATCH THE LOAD PATH

For bolted and threaded joints in downhole and aerospace hardware, a donut load cell (through-hole, ring, or load washer) puts the hole where the force already is: the bolt, stud, rod, or tool string passes through the center, and the cell measures axial force directly at the joint in a compact, low-profile package. That geometry matters most on a hot joint, because bolt preload does not stay where it was set — nickel-alloy fasteners relax and creep as temperature climbs, so measuring the clamping force at the joint beats assuming it holds. Wells above 300 °F (149 °C) are classified as high pressure, high temperature (HPHT); wells above 400 °F (204 °C) or 20 000 psi (138 MPa) as ultra-HPHT. Getting a cell into that territory takes gauge systems rated for the soak, thermal compensation matched to the working range, hermetic sealing against pressure and media, and lead wire that survives the trip.

CALIBRATION UNCERTAINTY COMPOUNDS WITH HEAT, SO THE BASELINE HAS TO START LOW

A custom cell is only as good as its calibration. Every custom load cell Morehouse builds is calibrated in-house on deadweight primary standards, which apply force through calibrated masses corrected for local gravity and air buoyancy, at an expanded uncertainty of 0.002 % of applied force (k = 2, approximately 95 % coverage probability) — 10 to 50 times lower than the uncertainty of a typical calibration performed with secondary standards. That baseline matters because every downstream claim about the customer's process rests on it, and uncertainty never gets smaller as conditions get harsher. Start with a low-uncertainty baseline and there is margin left for the thermal effects the environment will add; start with a sloppy baseline and the heat only compounds the doubt.

THE MOREHOUSE IMPACT

This framework gives customers a straightforward path from application question to a build they can defend once it is in service. Three actions carry the most weight:

1. **Define the real operating envelope first.** Capacity and load direction (compression, tension, or both), operating temperature and soak duration, and the pressure and media the cell will see set every material and sealing decision that follows.
2. **Size the geometry to the joint, not the catalog.** Bore diameter, outside diameter, height limits, mounting details, and cable exit and routing determine whether a donut or through-hole design will actually fit the joint it has to measure.
3. **Calibrate on a primary standard before it ships.** A cell calibrated on Morehouse deadweight primary standards carries an uncertainty low enough to leave margin for the thermal effects the application will add in service — a benefit a catalog cell or a secondary-standard calibration cannot match.

SAFETY CONSIDERATIONS

Getting the temperature rating right is not solely a measurement-accuracy question. Several of the same variables also affect whether the assembly holds up in service:

- **A rating pushed past its limit does not fail gracefully.** Pushing a catalog cell past its rated temperature does not fail gracefully — the output drifts and becomes a number that cannot be defended, well before the steel element itself is at risk.
- **Setup and alignment errors are common on small washer and through-hole cells.** Small washer load cells are notorious for misalignment errors and reading changes between rotations; a top alignment fixture with a loading ball, a centered base adapter, and an alignment plug keep the load on the loading line and reduce the setup variability.
- **Hermetic sealing has to match the pressure and media, not just the temperature.** A cell rated for the soak temperature but not for the surrounding pressure and media will fail at the seal, not the gauge.
- **Confirm what is achievable before committing to the build.** Morehouse reviews the operating parameters, states plainly what is achievable, and will say so if a catalog part genuinely solves the problem instead of a custom one.

CUSTOM LOAD CELL SOLUTIONS BY MOREHOUSE

Custom high-temperature load cells can be difficult to spec correctly, but Morehouse is here to help. Send us your capacity and load direction, operating temperature and soak duration, pressure and media, envelope and mounting details, and your accuracy requirement — we will tell you what is achievable and quote the build with calibration included. Contact us at (717) 843-0081 or sales@mhforce.com for a consultation.