Interface, Inc. | 7401 E. Butherus Dr. | Scottsdale, AZ 85260
480-948-5555 | gen@interfaceforce.com | www.interfaceforce.com

Temperature Compensation of High Temperature Load Cells

L. Clegg 11-06-2014

The temperature rating of a strain gage type load cell is primarily dependent upon the materials selected for its construction. While the load bearing element is normally good for a relatively wide temperature range, the non-metallic materials in a load cell are quite sensitive to temperature extremes and must be properly selected. This includes strain gage materials, adhesives, and insulations. Most Interface load cell models are rated for an upper operating temperature limit of 200°F. Special models can be made to operate as high as 500°F.

With any set of materials, performance at temperature extremes is nearly always compromised to some extent, relative to performance at nominal temperatures. There are four parameters of interest in examining temperature performance of high temperature cells.

A) Temperature Effect on Zero

The change in zero balance that is due to a change in ambient temperature. It is normally expressed as the slope of a chord spanning the compensated temperature range.

B) Temperature Effect on Output

The change in output that is due to a change in ambient temperature. It is normally expressed as the slope of a chord spanning the compensated temperature range.
Note that output is defined as a net value, as the zero load signal is always subtracted from the loaded signal.

C) Creep

The change in load cell signal that occurs with time while under load, and with all environmental conditions and other variables remaining constant. It is normally expressed in units of % of applied load over a specified time interval.

D) Zero Return

The degree to which the initial zero balance is maintained after application and release of a load, while environmental conditions and other variables remain constant.

Temperature Effect on Zero

This effect is illustrated by the following example data on 5 load cells from a common load cell family. These load cells are rated for -65 to 300°F. It is readily seen that the temperature characteristic is basically linear but not perfectly linear, and that some cells are more linear than others.

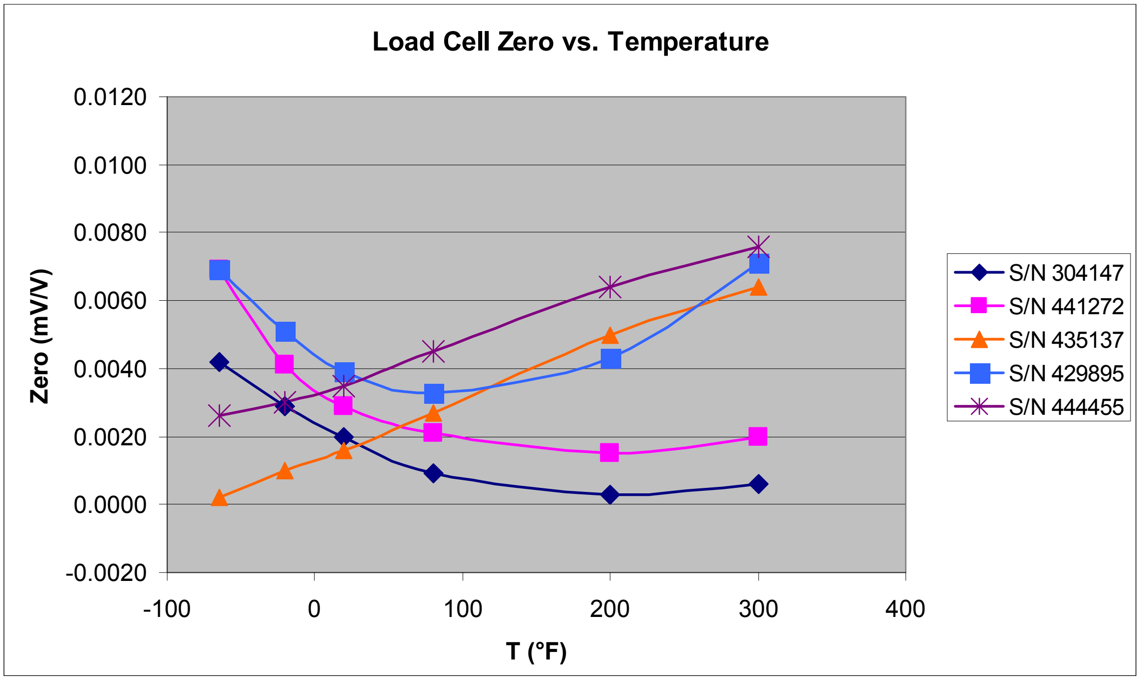
The curves serve to illustrate the effect of manual compensation. Each of these cells has already been through a compensation procedure and therefore meets its specification in the present condition. The procedure has the effect of rotating a curve. While an individual curve can be rotated either clockwise or counterclockwise, the nonlinearity of the curve is not easily improved. Note that if we were to see curves for these cells in their uncompensated condition, they would be on a larger vertical scale and would appear to be much more linear. In effect, we have magnified the apparent nonlinearity by rotating the curves in the compensation process.

So it is seen that some of the curves are better for one application than another. For example, if the region of interest is between 80°F and 300°F, S/N 441272 is ideal. If on the other hand, the entire region of -65°F to 300°F is the primary interest, then S/N 429895 may be best unit. We note that S/N 441272 could be returned to the compensation procedure and have its curve rotated counterclockwise until it would be very similar to S/N 429895.

S/N 444455 and S/N 435137 fortunately have very linear curves, and each could have its curve rotated to have minimal deviation over the entire temperature range if that were a priority. Do not let the scale of these curves fool you, the compensation is already quite good and further improvement does not come free of cost, as additional time-consuming testing is involved.

To scope the small degree of error that these curves represent, consider S/N 444455 as a load cell with 4 mV/V rated output. Then the slope of the chord from -65 to 300°F is

$$\frac{0.0042\ \text{mV/V}}{4\ \text{mV/V}\ \ (365\ \text{F}^\circ)} = 0.0003\ \%\text{RO}/^\circ\text{F}$$



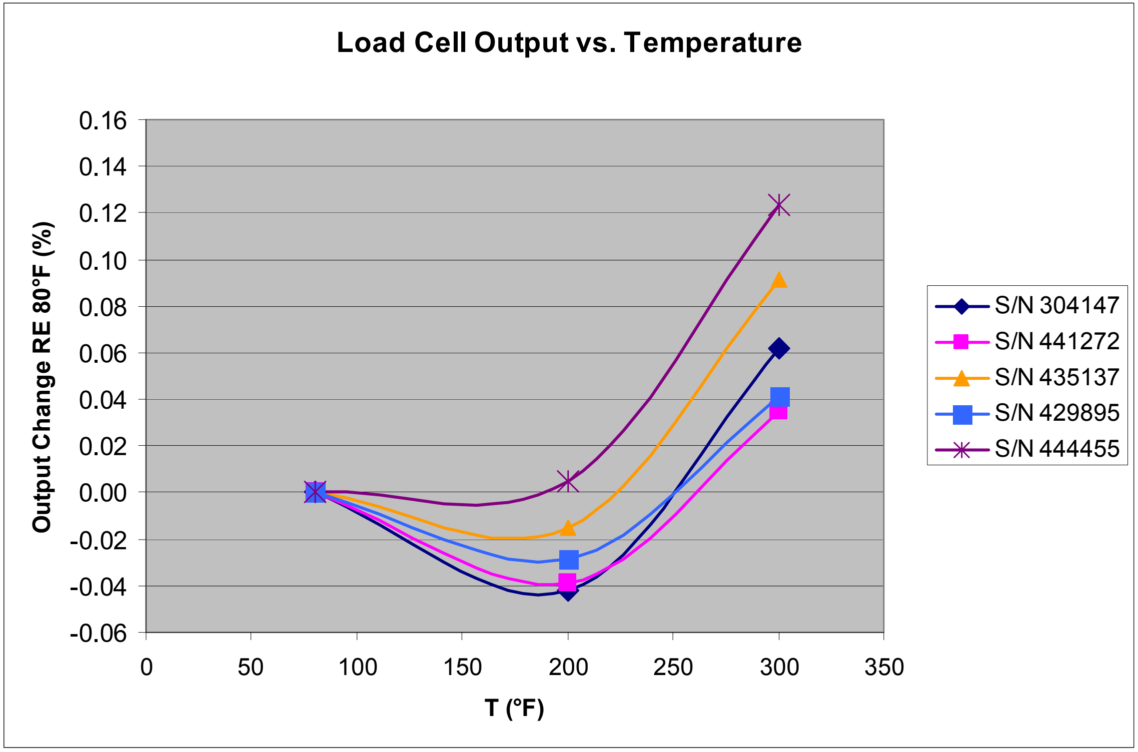
Temperature Effect on Output

This effect is illustrated by the following example data on the same 5 load cells that are rated for -65 to 300°F. Again, the load cells are already compensated in their condition as presented on this small vertical scale. The characteristic is basically linear, but not perfectly linear. In this case the performance of all 5 units is similar due to the common materials in their construction for this particular model. We know that other models may have different shaped curves, as well as some unit-to-unit variation.

Temperature effect on output is a relatively constant percentage of load for all loads from zero to rated load. Therefore, for small loads, it is more forgiving than temperature effect on zero which is expressed as a function of the rated load rather than of the actual load.

Just as temperature effect on zero curves can be rotated in a compensation procedure, so likewise can temperature effect on output curves. The latter are more costly to adjust and to test because of the need to stabilize test temperatures for long times with equipment capable of applying and releasing loads at the test temperatures.

It is seen from the examples that performance can be good or better depending, on the range of the chord of interest.



Creep and Zero Return

Here we describe a test that critically reveals the capability of a load cell to operate at elevated temperatures. In the below plot, the lower curve is a monitor of chamber temperature. The upper curve is a monitor of load cell signal, beginning at zero load. Note the scale compression on the vertical axis so that we can see both the zero and loaded signals in one view.

The test begins at 80°F and then is soon stabilized for an hour at 200°F. A load is applied for a few minutes and then released. The item of interest is the return to zero. As seen in the plot, it is very good.

Next the temperature is stabilized at 250°F, and the load is applied and released. The return to zero is again quite good. The temperature is then stabilized at 280°F, and the load applied and released. At this temperature the behavior has changed. First, note that the signal under load is slipping with time. Then note that when the load is released the zero signal has decreased by the same amount that it the signal slipped under load. The important point here is that even given 2 hours for the zero to recover it did not. In other words, the zero shift was permanent.

The “slipping” could be mistaken for creep, but it is not creep because it is permanent, whereas creep is recoverable.

To verify what was observed, the load application was repeated. The same slipping and zero shift was observed the second time. From this we conclude that this particular load cell will not be stable at 280°F. This is not alarming because this load cell was made to be rated for 200°F. Thus we see that it performed with a margin of safety up to 250°F, but clearly cannot operate above 250°F. This test was intended to demonstrate expected behavior when a temperature rating is exceeded, whatever that rating may be. Had the 5 load cells shown in the previous sections of this report been subjected to this test, they would have shown no zero shift at 280°F because they are rated for 350°F. Thus we see how important it is that load cells are not used above their temperature rating.