Group Four
Transducers Inc

Understanding the Group 4 Corner Adjusted Load Cell

A calibration technique was developed by the writer about thirty years ago which provided load cells for multi-cell weighing platforms which eliminated the time consuming corner or shift error adjustment after scale assembly.

Moreover, the calibration technique allowed the substitution of a defective load cell with another "corner adjusted" load cell without having to readjust the scale corners. However, recalibration of the scale after the load cell replacement was required which to some extent defeated the original purpose of the "corner adjusted" load cell.

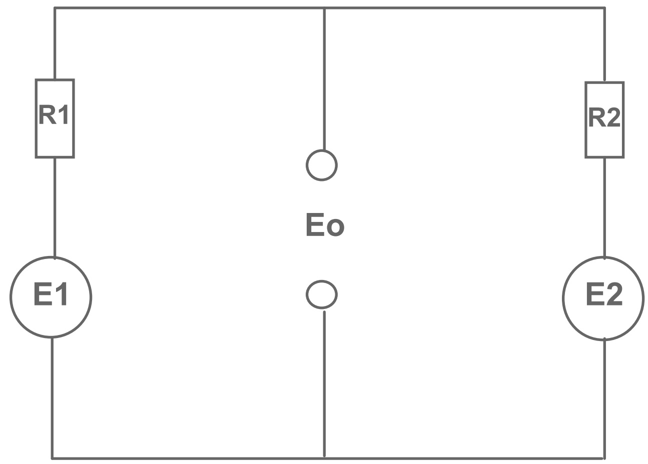
The G4 calibration technique provides a "corner adjusted" load cell which avoids the need for scale recalibration after a defective load cell is replaced.

To understand the G4 calibration method it will be instructive to first review the predecessor technique for an understanding of that method and the reason for its limitations.

A Hypothetical Two Load Cell System:

The Thevenin equivalent circuit for a two load cell system is shown below with voltage generators E1 and E2, source resistances (R-W) R1 and R2 and the scale output voltage Eo.

The expression for the scale output voltage is shown in equation (1) *[A]* below. Note that the contribution to the output voltage Eo from load cell No. 1 is developed by the voltage divider R2/(R1+R2) and that from load cell No. 2 by the voltage divider R1/(R1+R2). That is to say that load cell No. 1 loads load cell No. 2 by virtue of the former's source resistance and vice versa.



[A]

$$E_0 = \frac{E_1R_2 + E_2R_1}{R_1 + R_2}$$

It should be noted that the load cell source resistances are never the same. The strain gages have finite trim resistance tolerances and the trimmed resistances actually change during the gage application process.

When the applied load is totally on load cell No. 1, the scale output voltage is:

[B]

$$E_0 = \frac{E_1R_2}{R_1 + R_2}$$

And when the applied load is totally on load cell No. 2 the scale output is:

[C]

$$E_0 = \frac{E_2R_1}{R_1 + R_2}$$

Since R1 and R2 are <u>never equal</u> the scale output voltage in each load position will never be equal and hence the need for a load cell calibration technique which avoids this problem without having to adjust the sensitivity of each load cell in the field.

The method developed at HBM can be illustrated by rewriting equation *[A]* and by dividing the numerator and denominator by the product R1R2:

[D]

$$E_0 = \frac{E_1R_2 + E_2R_1}{R_1 + R_2} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_2}}{\frac{R_1 + R_2}{R_1R_2}}$$

Note that the numerator on the far right contains two terms each containing terms that pertain only to load cell No. 1 or load cell No. 2. Making each of these terms equal to a standard value results in the following:

[E]

$$\frac{E_1}{R_1} = \frac{E_2}{R_2} = \frac{E_s}{R_s}$$

$$\textit{where : s signifies some standard value,} \left[mV/V/\Omega \right]$$

The units of these terms are mV/V/Ω or "millivolts per volt per ohm", a new term required for this form of calibration.

Now, if each load cell is calibrated to the "standard value' the scale will be automatically cornered upon scale assembly. That is, if the load is fully on load cell No. 1 the scale output will be $\frac{E_1}{R_1}$ and if the load is fully on load cell No. 2 the scale output will be $\frac{E_2}{R_2}$. But in view of eq. *[E]* above, these values are equal and hence the scale is "cornered".

The above analysis was performed on a hypothetical two load cell scale. The equation for the four load cell scale is:

[F]

$$E_0 = \frac{E_1R_2R_3R_4 + E_2R_1R_3R_4 + E_3R_1R_2R_4 + E_4R_1R_2R_3}{R_2R_3R_4 + R_1R_3R_4 + R_1R_2R_4 + R_1R_2R_3}$$

And for the "n" load cell scale it is:

[G]

$$E_0 = \frac{E_1R_2R_3..R_n + E_2R_1R_3..R_n + ..E_nR_1R_2..R_{n-1}}{R_2R_3..R_n + R_1R_3..R_n + R_1R_2..R_{n-1}}$$

Returning to eq. *[E]* the prior method adjusted values of E_1 and E_2 by adding series resistance in the excitation leads of the load cells. This had the disadvantage of affecting the TCS adjustment of the load cell unless adjustments were made for the additional resistance in the excitation leads.

There was another and much more serious disadvantage, however. Returning to eq. *[D]* it is certainly true that corner adjustment has been achieved and that a load cell can be replaced with the same standard mV/V/Ω calibration without destroying the scales corner adjustment.

However, when a "corner-adjusted" load cell is replaced the overall scale calibration will be changed. Returning again to eq. *[D]*, assume, for example, that load cell No. 1 is replaced by a load cell No. 3 that has a bridge resistance that is 5 per cent higher than the previous resistance. While $\frac{E_3}{R_3}$ is set to the standard value and the scale is still "cornered", the R_3 value now in the denominator is 5 per cent higher then the R_1 value it replaced and therefore the denominator is correspondingly different, affecting the overall scale calibration quite significantly. So, while the scale corner adjustment was maintained after the load cell replacement, the scale calibration was significantly altered and the scale must be recalibrated.

The above calibration technique was termed "the mV/V/ohm" method. It set the mV/V/ohm or short circuit current of each load cell to a standard value. The load cell terminal resistances were taken as they were received at calibration and the mV/V level of each load cell was allowed to vary over a rather wide range in order to make the mV/V/ohm ratios equal to the "standard" value.

The G4 Approach:

The above shortcoming is eliminated in the G4 mV/V/Ω -mV/V calibration process. Referring to the hypothetical two load cell scale diagram below, each load cell is calibrated to a standard mV/V/Ω value (the short circuit current) by inserting a resistor and in series with the signal terminals of each load cell.

Now:

[H]

$$\frac{E_1}{R_1 + r_1} = \frac{E_2}{R_2 + r_2} = \frac{mV/V}{\Omega} = \text{Standard Value}$$

But in addition to that calibration step, the mV/V level of each load cell is <u>also</u> adjusted to a standard value by adding a resistor r_{p1} and r_{p2} across the signal terminals using the equation below:

[I]

$$E_s = \frac{E_1 r_{p1}}{R_1 + r_1 + r_{p1}} = \frac{E_2 r_{p2}}{R_2 + r_2 + r_{p2}} = mV/V = \text{Std. Value}$$

These resistors do not affect the mV/V/Ω calibration because, by definition, the mV/V/Ω value is the short circuit current of the load cell.

Now both the mV/V/Ω <u>and</u> the mV/V values of each load cell have been set to standard values. When a load cell is replaced <u>the scale corner adjustment and the scale calibration will have been preserved.</u>

This is clearly an improvement over the prior approach where scale recalibration is necessary after replacing a "corner adjusted" load cell, a rather time consuming effort, especially on high capacity floor scales and motor truck scales.

G4 Corner Adjustment Approaches The Ideal:

Referring to eq. *[H]* and augmenting it slightly:

[J]

$$\frac{E_1}{R_1 + r_1} = \frac{E_2}{R_2 + r_2} = \frac{E_s}{R_s} = \frac{mV/V}{\Omega}$$

Here Es and Rs are standard values of 2.00 mV/V and 1000 ohms, respectively and they establish the standard mV/V/Ω value of 0.002.

Also the standard mV/V value is established by the equation:

[K]

$$E_s = \frac{E r_p}{R_1 + r_1 + r_p}$$

Generalizing eq. *[H]* by dropping the numerical subscripts and setting it equal to eq. *[K]* divided by Rs results in:

[L]

$$\frac{E}{R+r} = \frac{E_s}{R_s} = \frac{Er_p}{(R+r+r_p)R_s}$$

Simplification of equation *[L]* results in the following:

[M]

$$R_s = \frac{r_p(R+r)}{R+r+r_p}$$

This equation states a very important result. The parallel combination of the original load cell source resistance R plus the resistance added to achieve the standard mV/V/Ω value and the r_p resistance added to achieve the standard mV/V value is equal to the standard resistance value, normally 1000 ohms in most G4 load cells.

<u>Now the source resistance of all</u> mV/V/Ω-mV/V calibrated <u>1,000 ohm G4 load cells is 1,000.0 ohms, indeed an important result as shown below.</u>

Now eq. *[F]* for the four load cell scale reduces to:

[N]

$$E_0 = \frac{E_1 + E_2 + E_3 + E_4}{4}$$

No load cell source resistance values appear in the equation. The load cell outputs behave as ideal load cells with identical mV/V output values (within calibration tolerances) and identical source resistances which causes the scale output to be simply the <u>average of the four load cell outputs, the ideal case</u>. Of course, this follows for the "n" load cell system, as well.

Conclusions:

The G4 mV/V/Ω -mV/V calibration method is superior to the mV/V/ (only) approach. It results in load cells with very closely matched mV/V output values and virtually identical source impedances. As a result, the output of any multi-load cell system utilizing these load cells is simply the average of the individual load cell output signals.

Load cells can be replaced without affecting either the scale corner adjustment or the scale calibration.

HARRY E. LOCKERY MEE, PhD
harryl@group-4.com
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