TELEDYNE HASTINGS INSTRUMENTS

APPLICATION NOTES

Improving Accuracy in Analog Mass Flow Measurements
5^{th} Order Polynomial Curve Fitting

Analog thermal mass flow instruments perform very accurate and repeatable measurements.

These instruments are calibrated to meet an accuracy/linearity specification such as +/- 1% Full-scale. In a typical calibration, ten or twenty representative data points are recorded and analyzed and uncertainties are calculated for each data point referenced to a precision measurement standard.

Careful examination of an analog mass flow instrument's calibration data will reveal its output is not a purely linear expression. The sources of non-linearity include random and predictable errors. This presents an opportunity to improve the accuracy of the measurements.

A series of polynomial coefficients can be derived from the calibration data which, when applied to measurements, can reduce predictable uncertainties dramatically. This is the same methodology used by most digital mass flow instruments. It can be applied real-time to analog instruments interfaced with computers, or manually if post-processing is acceptable.

An instrument supplied with a 5^{th} order polynomial fit is delivered with a standard calibration report *and* a supplemental polynomial analysis. The supplement contains two sets of five coefficients (standard and normalized) derived from an analysis of the calibration data. It includes a restated calibration report certifying the resultant uncertainites.

In order to realize the accuracies stated in the polynomial analysis, it is necessary to "plug-in" the output voltages and the coefficients to a 5^{th} order polynomial calculation for each measurement.

There are two methodologies available:

Standard Fit

$$Flow = C_1V + C_2V^2 + C_3V^3 + C_4V^4 + C_5V^5$$

Flow = Indicated Flow
V = Output Voltage
C_1 thru C_5 are the standard 5^{th} order polynomial coefficients

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Normalized Fit

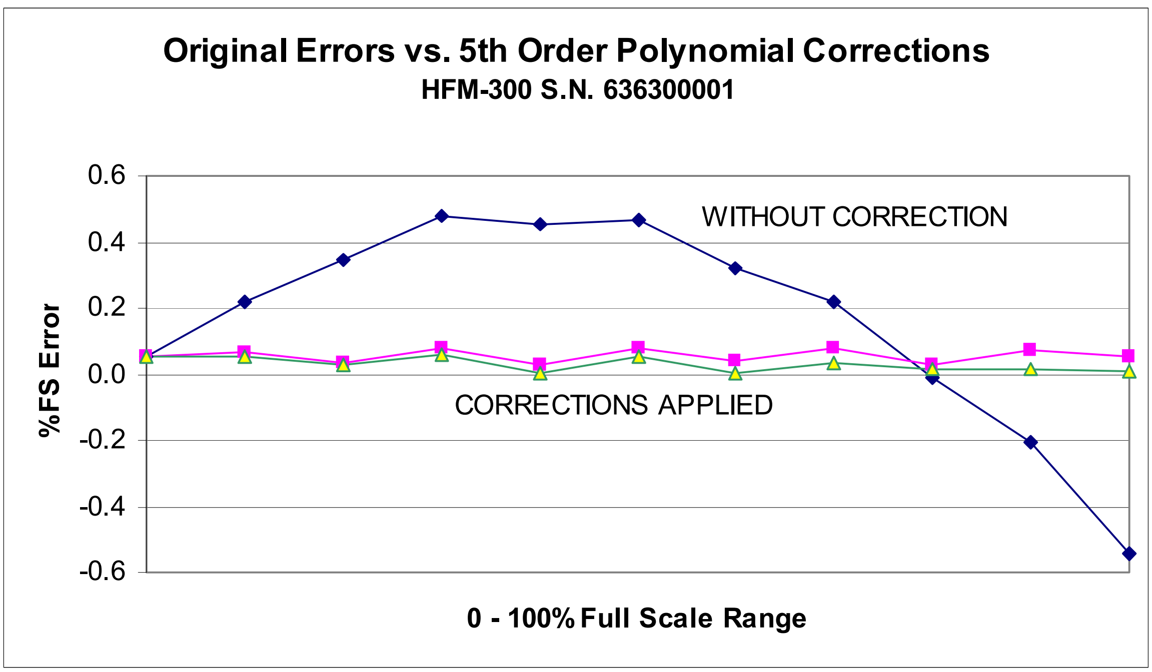
$$F = \frac{V}{5\ volts}$$

$$Flow = \left[N_1F + N_2F^2 + N_3F^3 + N_4F^4 + N_5F^5\right] \cdot Full\ Scale\ Flow$$

Flow = Indicated Flow
V = Output Voltage
N_1 thru N_5 are the normalized 5th order polynomial coefficients

Both methods provide a significant improvement over the original calibration's uncertainties.

The following example is from an actual calibration for an HFM-300 with a manufacturer's accuracy/ linearity specification of +/- 0.75% F.S.:



The uncertainty remaining is mainly attributable to the uncertainty associated with the reference standard(s).