Gas Custody Transfer Calibration

Using multi-variable temperature / pressure calibrators for flowmeter calibration

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Introduction

Gas custody transfer flow computers require special calibration to perform at optimum accuracy. In custody transfer applications where the buying and selling of commodities like natural gas is involved, calibration checks are performed frequently as a matter of fiduciary responsibility. For the purpose of this white paper, the use of gas custody transfer flow computers in the natural gas transmission industry is referenced.

Flow computers need multiple calibrations in a single device. In the normal application 3 measurements are made, volumetric flow, static (line) pressure and temperature. A calculation is performed using this data to determine the actual mass of the gas flowing through the pipeline.

Recently, several calibrator manufacturers have released new model calibrators that target this application. These are referred to as Multi-Variable Temperature/Pressure Calibrators. These differ from the typical multi-function calibrator in that they are primarily pressure calibrators intended for field use with highly accurate performance.

For these temperature/pressure calibrators special features that support the complete calibration of natural gas multi-variable electronic flowmeters and other types of flow computers have been added. These calibrators have special features like

- an internal pressure range
- integral electric pump for generating test pressure signals
- external pressure module interface
- precision RTD probe connection

All of the calibrations required for the flow computer can be performed with just one instrument.

What this means is that a single small kit replaces a list of equipment that includes difficult to use items like dead weight testers, analog or digital thermometers and a digital test gauge. This is an opportunity for a huge increase in productivity without any sacrifice in performance or reliability.

These calibrators are available with built-in ranges up to 300 psi/20 bar. However, for this application, a low pressure range of no more than 30 psi/2 bar is the most appropriate. Since they have an accuracy specification as a percent of full scale, it is important to closely match the full scale of the calibrator to the scale of the application in order to get good performance. See the section below on understanding and calculating system accuracy.

In addition to the calibrator itself, an external pressure module with a higher range and a high pressure calibration pressure source will be needed. An accessory RTD probe is also required. These calibrators are often available in a kit that includes all of these except the high pressure source.

The sources can take the form of so-called Nitrogen packs with a high pressure cylinder. A good alternative is a high pressure pneumatic test pump capable of generating up to 2000 psi / 140 bar. Using a gas is necessary because it eliminates contamination of the flowmeter with liquids from a test pump.

Since users often already have such sources available, they can continue to use what they have used in the past as a source.

Gas custody transfer flow computer operational theory

Custody transfer flow computers are called by a variety of names including electronic flowmeters (EFMs) and multi-variable flow computers, but they all feature some common principles of operation.

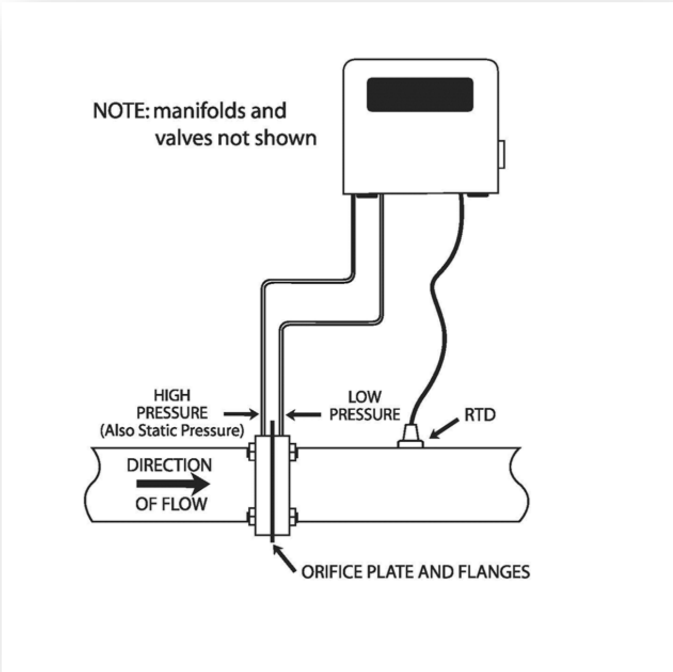

Figure 1 - Typical flowmeter installation

1. Volumetric flow measurement uses some type of flow restriction such as an orifice plate to generate a pressure drop. The differential pressure is measured by the flow computer as the primary measurement. It is based on the principle that flow velocity is proportional to the square root of the pressure drop. The volumetric rate is essentially calculated from the velocity by knowing the diameter of the pipe in which the gas is flowing.

   The measured pressure drop (differential) is typically 200 inches of water column ("WC) or higher.

2. To convert volumetric flow to mass flow you need to know the mass per volume of the flowing media. The flow computer calculates that using 2 additional measurements, plus a range of factors/constants based on the flowing media. The 2 additional measurements are the static pressure of the gas in the pipeline and the temperature of the gas in the pipeline.

The static pressure in these applications ranges widely from a low of about 300 psi / 20 bar to a high of about 1500 psi / 100 bar.

The temperature of the gas is usually at ambient, so it is within the range of normal environmental conditions.

3. A final consideration about flow computers is how they are typically installed and used.

   Industrial applications use either the analog output of the flowmeter (4 to 20 mA) or a digital output like the HART signal to get data from the flowmeter to a control system or data acquisition system.

   This is generally not used in gas pipeline applications. Instead, the flowmeter is a specialized device that operates standalone to measure and record the total mass flow through the pipeline. The total is periodically “downloaded” from the flowmeter to be used in an accounting of gas flow and custody transfer.

   The flowmeter may be packaged with other electronic devices to be able to perform this function or it may be purpose manufactured, which is the most common type.

How to calibrate the flow computer

Each flow computer manufacturer has created a proprietary method of calibration, but they all use the same general technique, which will be described here.

In these proprietary calibrations, the manufacturer has provided a software application, which runs on a notebook computer (PC). The PC is connected to the serial port or USB port of the flow computer. In this way, the software both instructs the user to connect appropriate signals to the flow computer (either pressure or temperature) and communicates that information to the flow computer so that any calibration errors are corrected.

NOTE

This procedure is a generic description of the calibration process. The actual procedure will vary based on the original equipment manufacturer's design and instructions and on local process and policy.

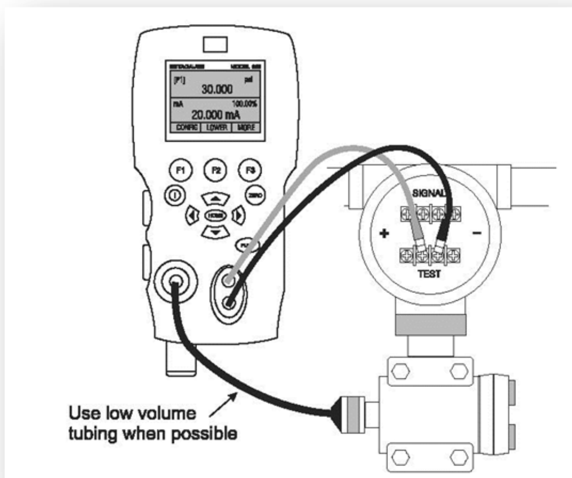

Figure 2 - Typical Calibrator Connection

Detailed Procedure

NOTE

The detailed procedure is based on the use of a particular model of calibrator. Some details of the procedure may be different based on what manufacturer or model of calibrator is used.

Setup

1. Turn on the calibrator and use the calibrator's SETUP function to select the appropriate display and function setup for the flow computer calibration. The proper setup will provide a display of all three signals to be calibrated.
    - internal sensor pressure (volumetric flow calibration)
    - external sensor pressure (static pressure correction factor)
    - RTD temperature measurement (temperature correction factor)

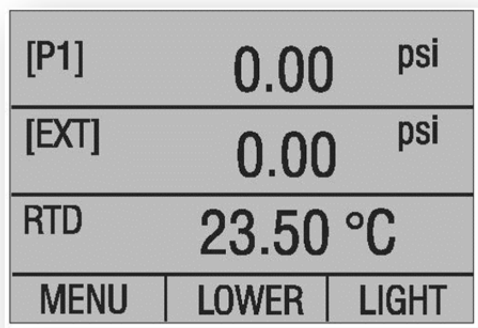

Figure 3 - Calibrator Setup Display

2. Set the upper display (internal pressure sensor) to use inches of water column (in H_2O 60°F) as the engineering unit, the middle display (external pressure module) to use psi as the engineering unit and the bottom display (RTD) to use °F as the engineering unit.
3. Connect the external pressure module and the RTD probe to the calibrator. If necessary, zero both pressure displays while vented to atmosphere.
4. Isolate the flow computer from the process. (It is normally installed with a 5 valve manifold. Closing the valves on the process side of the manifold will isolate it from the process). Be sure to follow local policy and procedure when performing this step.

Differential pressure calibration (volumetric flow)

1. The differential pressure calibration is performed using atmospheric pressure as a reference, so the low pressure connection of the flow computer is vented and the high pressure connection is connected to the port on the calibrator.
2. Connect the notebook PC to the flow computer serial or USB port. Use the PC to initiate the calibration process.

3. The PC will instruct the user to apply one or more test pressures to the flow computer. For example, on a device with a full scale differential measurement of 200" WC, the test pressures may be 0, 100 and 200" WC. In each case, it is not necessary to provide the exact pressure called for since the user will also be prompted to enter the actual pressure applied at each test point.
4. Set the calibrator pressure/vacuum control to the pressure mode (+) and close the vent valve. Press the PUMP button until the desired pressure is generated. The vernier or fine pressure control at the bottom of the calibrator can be used to adjust the pressure up or down in small amounts. NOTE: 200" WC is approximately 7.2 psi. Since the pump can easily exceed this pressure, it may be best to apply repeated short presses of the PUMP button to allow for better control. The rate of pressure increase will be affected by the volume of the test system with faster increases when the volume is lower.
5. When the differential calibration is complete, open the calibrator vent control and disconnect the calibrator from the flow computer.

Static pressure calibration

1. For the static pressure calibration, the test pressure will normally be applied to either the same high pressure port or both the high and low pressure ports simultaneously. Refer to the manufacturer's instructions for details on the exact method of connection to perform this test. Connect the external module to the appropriate port on the flow computer and to the high pressure test source. NOTE: if the source has 2 ports, one can be connected to the external pressure module and the other to the port on the flow computer.
2. The PC will instruct the user to apply one or more test pressures to the flow computer. For example, on a device with a full scale static pressure measurement of 1500 psi, the test pressures may be 0, 750 and 1500 psi. In each case, it is not necessary to provide the exact pressure called for since the user will be prompted to enter the actual pressure applied at each test point.
3. Use the high pressure test source to generate the called for pressures and enter observed data when prompted.
4. When the calibration is complete, carefully vent the system and disconnect the external module and pressure source.

Temperature calibration

1. Calibration of the temperature measurement on the flow computer is done with a single temperature point at the pipeline operating temperature.
2. A test thermowell is provided adjacent to the in service measuring RTD connected to the flow computer. Insert the calibrator probe into the test thermowell and allow time for the measurement to reach a stable value. NOTE: this can be done prior to the pressure calibrations if local conditions permit. That allows sufficient time to reach stability.
3. This calibration is based on the concept that the same temperature is measured at both thermowells and, therefore, the measured values should be identical. The PC will prompt the user to enter the value observed on the calibrator.
4. Remove the RTD from the test thermowell. The calibration is complete.

Wrap up

1. Follow local policy and procedures and manufacturer's instructions for returning the flow computer to service.

System Accuracy Determination

In order to effectively calibrate an instrument, the calibrator used must be more accurate than the instrument by some factor. The factor will vary according to the application, but it should be as large as is practical. The minimum factor is generally considered to be 3 times.

The rationale behind this comes from a technique for the statistical analysis of the error in a system. This technique is called Root Square Sum or RSS. To determine the error in a system you take the square root of the sum of the errors squared for all elements in the system. Note that this is not the maximum possible error in a system, but is the largest error which is statistically likely.

This formula describes the calculation, where E_t is the total error and E_1, etc. are the errors of the individual components of the system.

$$E_t = \sqrt{E_1^2 + E_2^2 + \cdots + E_n^2}$$

By using a ratio of four, the effect of the error in the calibrator is reduced to a small percentage of the error of the instrument under test and can therefore generally be disregarded. As an alternative to having a calibrator with the appropriate ratio, users may elect to de-rate the performance of the instrument to a value four times that of the calibrator.

For example, using a calibrator with ±0.05% accuracy would yield an instrument accuracy of ±0.2%. Due to the continual advances in instrument technology, calibration technology may, from time to time, fail to provide the necessary ratio to enable users to calibrate to the manufacturer's rated specification.

Summary

While the flow computers used for gas custody transfer application require regular calibration checks to maintain a high level of conformance to fiduciary requirements, new technologies and products from calibration manufacturers address the needs of the industry to be able to perform these tasks with confidence and improved productivity.

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