SIEMENS

APPLICATION DATA

AD353-124
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Procidia Control Solutions
Orifice Flowmetering
Pressure/Temperature Compensation

This application data sheet describes pressure and temperature compensation methods needed to ensure orifice flowmeter accuracy. A configuration can be developed within a Siemens 353 controller[1] to perform the flow measurement compensation.

An orifice flowmeter can be used to accurately measure gas flow. However, when gas pressure varies or gas temperature varies, measurement compensation must be applied. Without compensation, changes in pressure and temperature can cause large errors in the flow measurement.

Figure 1 shows a length of pipe with an orifice flange union and an orifice plate. Also shown are three transmitters for measuring: differential pressure (ΔP) across the orifice plate, gas pressure in the line, and gas temperature in the line. The ΔP generated by the plate is proportional to the density of the gas and the square of the volumetric flow rate. Pressure and temperature measurements are used to infer gas density and to compensate the ΔP measurement so that the final measurement value responds only to changes in flow.

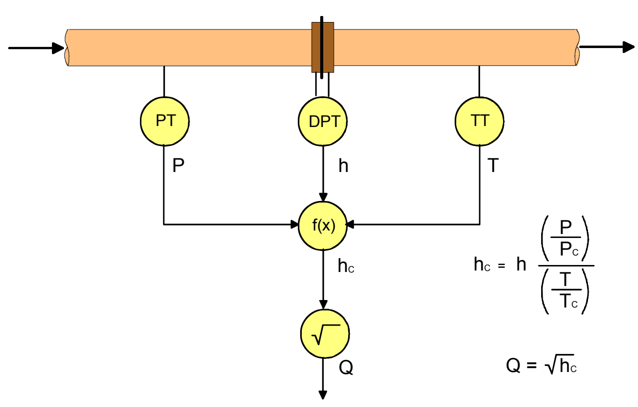

Figure 1 Pressure and Temperature Compensation of an Orifice Meter

[1] See Applications Support at the back of this publication for a list of controllers.

Pressure and temperature compensation is a mathematical operation that corrects the measured differential pressure at actual operating conditions to an equivalent differential pressure at calibrated conditions. Calibrated conditions are the specific operating pressure and temperature that were used to size the orifice plate. The correction is based on equivalent mass flow at the two sets of operating conditions.

Compensated flow measurement Q is proportional to the square root of the corrected differential pressure across the orifice plate. Therefore, the pressure and temperature corrections must occur before the square root is extracted, as show in Figure 1.

Design

The vast majority of gas flowmeters are calibrated to provide a signal that represents standard volume flow. Standard volume flow is proportional to mass flow and is based on the density of the gas at standard reference conditions (usually 14.7 psia and 60ºF). Although most flowmeters operate at pressures and temperatures that are considerably different from standard reference conditions, it is customary to convert the actual volume flow to an equivalent mass flow in standard volume units.

For standard volume flow, the following engineering equation is used to correct the differential pressure from actual conditions to calibration conditions.

Standard Volume Flow:

$$hc = h\frac{\left(\dfrac{P}{Pc}\right)}{\left(\dfrac{T}{Tc}\right)}$$

where:
- h = differential pressure
- P = line pressure (absolute)
- T = line temperature (absolute)
- c = calibration conditions subscript

The Siemens 353 series of controllers allow all input signals to be scaled in engineering units. However, in many cases it is desirable to display the pressure in units of psig and the temperature in units of ºF or ºC. The following example illustrates the procedure for pressure/temperature compensation in the 353.

Orifice Calibration Conditions:

Full scale flow:	15,000 SCFM
Full scale ΔP:	100“H_2O
Line pressure:	125 psig (139.7 psia)
Line temperature:	110ºF (570ºR)
Barometer:	14.7 psia

Transmitter Ranges:

DPT: 0 to 100“H_2O
PT: 0 to 200 psig (14.7 to 214.7 psia)
TT: 0 to 150ºF (460 to 610ºR)

The configuration for this example is shown in Figure 2. ΔP, pressure, and temperature input signals are connected to three analog input blocks (AIN1, AIN2, and AIN3). Each analog input block scales the 4-20 mA input for the units of the transmitters. Scalar function blocks SCL1 and SCL2 scale the pressure and temperature signals for absolute units.

The divider block DIV1 computes the pressure compensation P/Pc and the divider block DIV2 computes the temperature compensation T/Tc. The resultant signals are then divided by function block DIV3. The ΔP signal (0-100”H_20) is scaled to a normalized signal by SCL4. A normalized signal is required in order to calculate the square root in function block SRT1.

The output of the square root extractor is scaled in SCL3 to represent the actual flow units of 0 – 15,000 SCFM. In this configuration example, the three transmitter inputs and the computed flow signal are displayed using an ODA (operator display, analog) function block. This block processes all four variables and routes them to a single faceplate for display. If flow is being controlled, the output of SCL3 can be connected as the process variable in an ODC (operator display for controllers) loop in the 353.

As stated above, pressure and temperature compensation must occur before the square root is extracted. If a square root function is included in the differential pressure transmitter, it must be turned off. If the square root extractor can not be turned off, the input signal must first be normalized for a range of 0 – 1.0 and then squared by connecting the normalized signal to two inputs of a multiplier function block (MUL_). In cases where the calibration range of the pressure transmitter is less than 50 psig, an absolute pressure transmitter is recommended.

Applications

For applications requiring only pressure compensation, the temperature is assumed to be constant at the value used for calibration (Tc). The compensation equation is then derived by using a value of 1 for the ratio T/Tc. Likewise, for applications requiring only temperature compensation, the compensation equation is then derived by using a value of 1 for the ratio P/Pc.

Although most applications require standard volume (mass) flow, some applications require actual volume flow. For example, the performance of centrifugal and axial compressors is related to the actual volume flow at the compressor inlet. The compensation procedure for actual volume flow is identical to the procedure for standard volume flow except that the pressure and temperature corrections are inverted as follows:

$$hc = h\frac{\left(\frac{T}{Tc}\right)}{\left(\frac{P}{Pc}\right)}$$

Pressure and temperature compensation for other head-type flowmeters (e.g. flow nozzles, venturis) is identical to the procedure shown here for an orifice flowmeter. These compensation calculations are also applicable to other types of volumetric flowmeters (e.g. vortex shedding meters, turbine meters). However, the square root extractor is required only for head-type flowmeters.

American Gas Association

Several American Gas Association Reports have been issued concerning calculating the volume flow of natural gas using an orifice meter (Report #3) or a turbine meter (Report # 7). The Siemens 353 controller has built-in function blocks AGA3 and AGA7 that provide these calculations. Although similar to what has already been discussed, these blocks also compensate for the flowing compressibility of natural gas based on the actual composition of the gas. The 353 also includes an AGA8 function block that provides this capability in accordance with AGA Report #8.

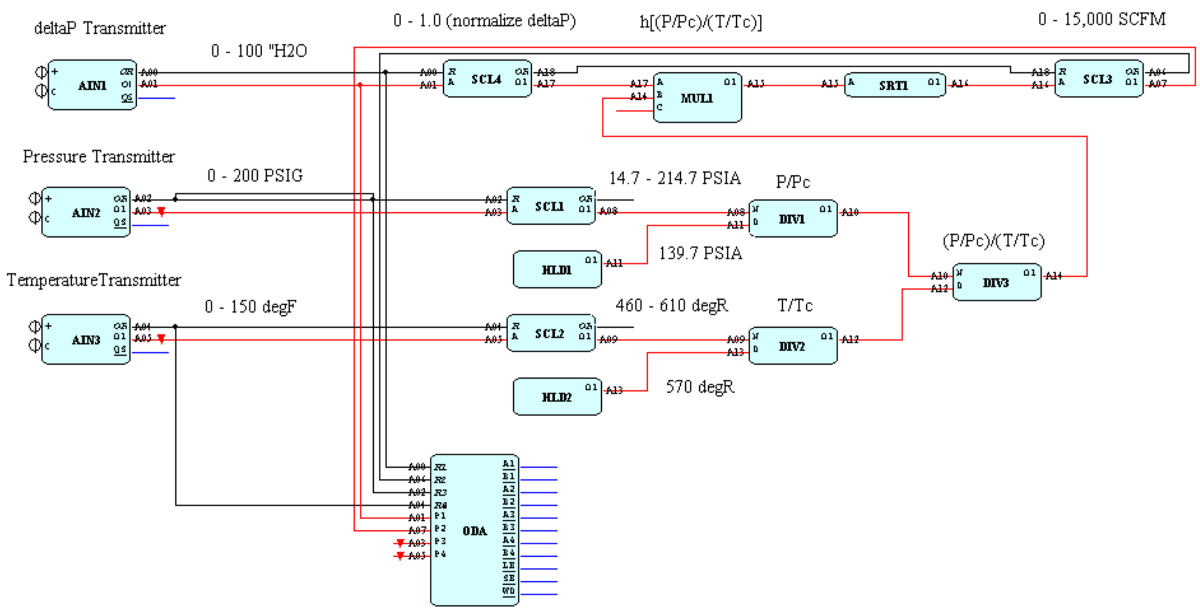

Figure 2 Pressure/Temperature Compensation (CF353-124)

Application Support

User manuals for controllers and transmitters, addresses of Siemens sales representatives, and more application data sheets can be found at www.usa.siemens.com/ia. To reach the process controller page, click **Process Instrumentation** and then **Process Controllers and Recorders**. To select the type of assistance desired, click **Support** (in the right-hand column). See AD353-138 for a list of Application Data sheets.

The configuration(s) shown in this publication were created in Siemens i|config™ Graphical Configuration Utility. Those with CF353 in parenthesis in the Figure title are available using the above navigation, then click **Software Downloads** > **353 Orifice Flowmetering, Pressure/ Temperature Compensation (Reference AD353-124)**.

The configuration(s) can be created and run in a:

- Model 353 Process Automation Controller
- Model 353R Rack Mount Process Automation Controller*
- i|pac™ Internet Control System*
- Model 352*Plus*™ Single-Loop Digital Controller*

* Discontinued model