# Rosemount 3051S MultiVariable™ Accuracy

## Understanding the Sensitivity of the Coefficients

The Accuracy of a DP flowmeter is a combination of many different factors. The DP transmitter accuracy, the accuracy of the primary element, and the uncertainty of the fluid density are just a few. The total flow uncertainty can be divided into six main components.

1. Discharge Coefficient *Cd* (the primary element itself)
2. Gas Expansion Factor *Y1*
3. Pipe Diameter *D*
4. Bore Diameter *d*
5. Fluid Density *ρ*
6. DP Uncertainty *ΔP*

The uncertainties of these different components can not be combined by a simple root sum of squares because they do not all have the same effect on the flow rate accuracy. In other words, a 1% error in the discharge coefficient will not cause the same amount of error in flow rate as a 1% error in the measured DP.

The amount of error caused by a % change in any of the six components is determined by its sensitivity coefficient (*X*). The sensitivity coefficient can be found by taking the partial derivative of the flow equation with respect to the term whose sensitivity is to be found. In other words, think of the sensitivity coefficient as the power to which the term is raised in the DP flow equation.

$$Q_m = N C_d Y_1 E d^2 \sqrt{\rho \, \Delta P}$$

The discharge coefficient $C_d$ and the gas expansion factor $Y_1$ are raised to the first power, so their sensitivity coefficients ($X_{Cd}$ and $X_{Y1}$) are 1. That means a 1% error in either one will cause a 1% error in the flow rate.

The pipe diameter is a little more complicated since it only shows up in the velocity of approach factor *E.*

$$E = \frac{1}{\sqrt{1 - \left(\frac{d}{D}\right)^4}}$$

It turns out that the sensitivity coefficient depends on the beta ratio $X_D = \frac{-2\beta^4}{1-\beta^4}$.

The greater the beta ratio, the greater the sensitivity. The sensitivity coefficient is between 0 and 1, so a 1% error in pipe I.D. will cause 0 to 1% error in the measured flow, depending on beta.

The bore or throat diameter (*d*) should have a sensitivity of at least 2, because d is raised to the 2nd power in the equation. But it also appears in the velocity of approach factor E. This raises the sensitivity to between 2 and 3.

$$X_d = \frac{2}{1-\beta^4}$$

Again, the greater the beta ratio, the greater the sensitivity. A 1% error in measuring or manufacturing the bore will cause 2-3% error in the measured flow. This is why so much care is taken machining and measuring the bore or throat of a DP flowmeter.

Both density and differential pressure are under the square root (raised to the $^1/_2$ power) in the DP flow equation. This means that their sensitivity coefficients (*Xρ* and *XΔP*) are $^1/_2$. This is an inherent benefit of all DP flowmeters. A 1% error in either density or DP measurement will only cause 0.5% error in the flow rate.

The total flow uncertainty is determined by doing a root sum of squares of all the components only **after they have all been multiplied by their sensitivity coefficients**. In using the example values above, the total flow uncertainty would be calculated as follows:

$$U_{Qm} = \sqrt{\begin{matrix}(1 \times 0.6)^2 + (1 \times 0.1)^2 + (0.3 \times 0.4)^2 \\ +(2.3 \times 0.07)^2 + (0.5 \times 0.1)^2 + (0.5 \times 0.2)^2\end{matrix}}$$

TABLE 1. DP Flow Coefficient Sensitivity

| Coefficient | Symbol | Sensitivity Symbol | Sensitivity Value | Typical Uncertainty(1) |
|---|---|---|---|---|
| Discharge Coefficient | Cd | $X_{Cd}$ | 1 | 0.60% |
| Gas Expansion Factor | Y1 | $X_{Y1}$ | 1 | 0.10% |
| Pipe Diameter(2) | D | $X_D$ | 0.3 | 0.40% |
| Bore Diameter(2) | d | $X_d$ | 2.3 | 0.07% |
| Fluid Density(3) | $\rho$ | $X_\rho$ | 0.5 | 0.10% |
| Differential Pressure | $\Delta P$ | $X_{\Delta P}$ | 0.5 | 0.20% |
| | | | Total Flow Uncertainty | 0.65% |

(1) *Typical uncertainty when used with 3051SMV*

(2) *Depends on Beta Ratio, Beta = 0.6*

(3) *Calculated from Static Pressure, Temperature and Compressibility Factor uncertainty for gasses, or from Equation of State uncertainty for liquids.*

*Standard Terms and Conditions of Sale can be found at www.rosemount.com/terms_of_sale*
*The Emerson logo is a trade mark and service mark of Emerson Electric Co.*
*Rosemount and the Rosemount logotype are registered trademarks of Rosemount Inc.*
*PlantWeb is a registered trademark of one of the Emerson Process Management group of companies.*
*All other marks are the property of their respective owners.*

© October 2009 Rosemount Inc. All rights reserved.

**Emerson Process Management**
**Rosemount Measurement**
8200 Market Boulevard
Chanhassen MN 55317 USA
Tel (USA) 1 800 999 9307
Tel (International) +1 952 906 8888
Fax +1 952 949 7001

**Emerson Process Management**
Blegistrasse 23
P.O. Box 1046
CH 6341 Baar
Switzerland
Tel +41 (0) 41 768 6111
Fax +41 (0) 41 768 6300

**Emerson FZE**
P.O. Box 17033
Jebel Ali Free Zone
Dubai UAE
Tel +971 4 811 8100
Fax +971 4 886 5465

**Emerson Process Management Asia Pacific Pte Ltd**
1 Pandan Crescent
Singapore 128461
Tel +65 6777 8211
Fax +65 6777 0947
Service Support Hotline : +65 6770 8711
Email : Enquiries@AP.EmersonProcess.com



EMERSON
Process Management