Application Note for SDP800 Series differential pressure sensors

Compensation of pressure drop in a hose

Summary

The Sensirion differential pressure Sensors of the SDP800 series are often connected to a hose in order to measure differential pressure at a distant location. This application note gives a short explanation of how the pressure drop in a hose needs to be compensated for an accurate differential pressure measurement.

1. Theory

In some applications, hoses are connected to the inlet and outlet port of differential pressure sensors in order to measure differential pressure at distant locations.

According to Hagen-Poiseuille law, a hose acts as a linear flow restrictor for air flowing through the hose, inevitably generating a pressure drop between the hose inlet and outlet. In a static differential pressure sensor no flow is generated, because the membrane separates the high from the low pressure side. However, Sensirion's differential pressure sensor measures the differential pressure by means of a small flow through the sensor. This small flow leads to a pressure drop in the hose.

The Sensirion differential pressure sensor measures only the pressure drop applied directly at its port inlet and outlet. The pressure drop of the hose itself is not measured (refer to figure 1). For hoses of 6 mm or larger inner diameter, the pressure drop of the hose is relatively small compared to the differential pressure, which the user wants to measure with the sensor. *However, for long hoses (> 1 m) or hoses with small inner diameters (≤ 4 mm) the pressure drop of the hose might not be negligible any more.* In these cases the following formulas allow to compensate for the pressure drop of the hose.

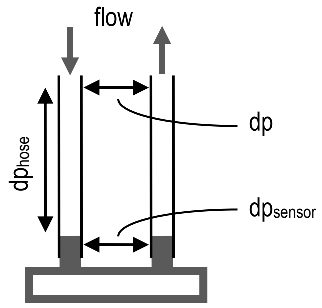

Fig. 1 Pressure drop in a system with connecting hose ***($dp = 2 \times dp_{hose} + dp_{sensor}$)***

2. Pressure drop in a hose

How to calculate the pressure drop of the hose

According to the Hagen-Poiseuille law, the pressure drop Δp of non-turbulent air or gas in a long narrow hose with circular cross section, is (see fig. 1&2):

- proportional to the Length L and flow m and,
- inversely proportional to the 4th power of the diameter D.

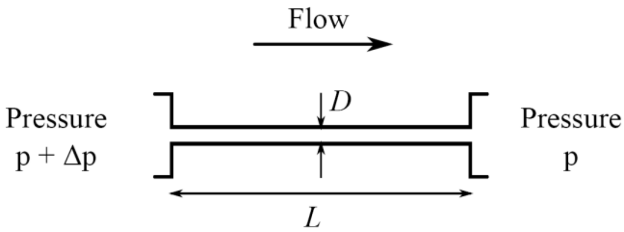

Fig. 2 Pressure drop Δp in a hose of length L and inner diameter D

Each DP sensor model has its own flow vs. dp characteristic, which depends on the combination of linear and orifice type inner sensor flow path design (fig 3).

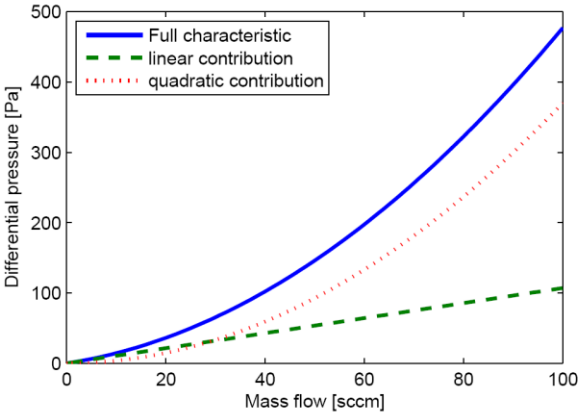

Fig. 3 Correlation of dp vs. flow for SDP800 (blue solid line)

With the SDP800 differential pressure sensor output measured at the end of the hose we can calculate the effective differential pressure at the beginning of the hose with the following formula:

$$dp_{eff} = \frac{dp_{sensor}}{1+\varepsilon}$$

whereas

$$\varepsilon = -\frac{64}{\pi}\frac{L}{D^4}\frac{\eta_{air}}{\rho_{air}}\frac{m_c}{\Delta p_{sensor}}\left(\sqrt{1+\frac{8\Delta p_{sensor}}{\Delta p_c}}-1\right)$$

$$\eta_{air} = (18.205 + 0.0484 \times (T[°C]-20)) \times 10^{-6}\,\frac{\mathrm{Pa}}{\mathrm{s}}$$

$$\rho_{air} = (1.1885 \times p_{abs}[\mathrm{bar}]) \times \frac{293.15}{(273.15+T[°C])}\,\frac{\mathrm{kg}}{\mathrm{m}^3}$$

$$m_c = 6.17 \times 10^{-7}\,\frac{\mathrm{kg}}{\mathrm{s}}$$

$$\Delta p_c = 62\mathrm{Pa}$$

With

L = length of hose (sum of hose length to and from sensor) in meter [m]

D = diameter of the tube in meter [m]

η_{air} = viscosity of air at temperature T in Celsius [°C]

ρ_{air} = density of air at temperature T in [°C]

Δp_{sensor} = dp reading of sensor in Pascal [Pa]

p_{abs} = absolute air pressure in hose in bar

m_c, Δp_c = massflow and dp sensor constants where the linear and quadratic contribution to the dp vs. flow relationship of the SDP800 sensor are equal

Example of pressure drop compensation

Let us assume the following:

L = 3m

D = 5mm

p_{abs} = 1 bar

T=25 °C, Δp_{sensor} = 250 Pa

From the formulas above we derive that:

η_{air} = 1.8447x10^{-5} Pa·s

ρ_{air} = 1.1686kg/m^3,

ε = -1.82%

dp_{eff} = 254.6 Pa

Which hose lengths and inner diameter to use

As a rule of thumb the effect of pressure drop in the hose can be neglected if the error is less than 5%. Therefore, appropriate hose inner diameters are 6 mm or larger.

Example plots for the hose-induced sensor deviation

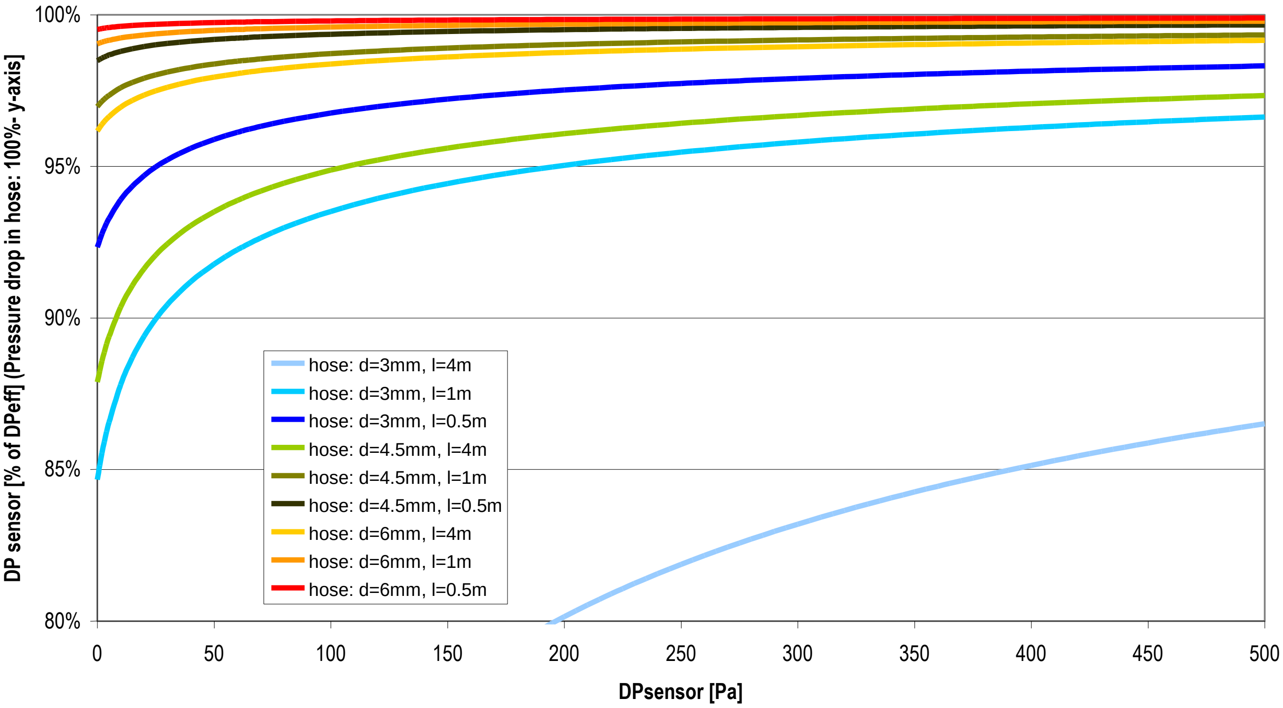

Fig. 4 Example of differential pressure drop in hoses with various lengths and inner diameters.

Revision history

Date	Version	Author	Changes
21.02.2019	V1.0	ANB	Initial release

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