SENSIRION
THE SENSOR COMPANY

Application Note for SDP3x Series differential pressure sensors

Compensation of pressure drop in a hose

Summary

The Sensirion differential pressure sensors of the SDP3x series are not designed to be used with tubes. However in laboratory conditions, when testing or evaluating the sensor, there might be instances where connecting the SDP3x with tubes is the most convenient setup. In this case the pressure drop occuring in the hose has to be taken into account and can already be significant above a few centimeters.

A tube with an inner diameter of 1.8mm is recommended.

1. Theory

In some situations, hoses are connected to the inlet and outlet port of the SDP3x differential pressure sensor in order to test or evaluate the sensor or an application.

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 fig. 1).

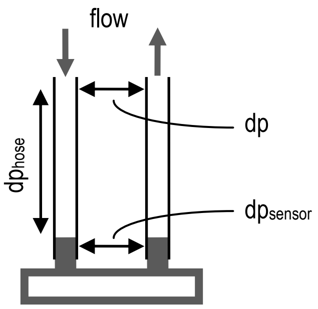

*Fig. 1 Pressure drop in a system with connecting hose (**$dp = 2 \times dp_{hose} + dp_{sensor}$**)*

2. Tubing recommendation

The outside diameter of the SDP3x pressure ports is only 2mm, making relatively rigid tubing with inner diameter of approximately 1.8mm a suitable choice. Because the ports are not designed to be used with tubes, the connection between the tube and the sensor will not be very sturdy and has to be handled with care.

A possible tube model to connect to the SDP3x is Legris "1025P03 00 18" semi-rigid polyamide (PA) tubing.

We recommend using only very short tubes of a few centimeters in length, as there will be a significant drop of pressure within the hoses.

When using the SDP3x connected with tubing, it should only be used to measure **changes in differential pressures** and not the absolute value of the pressure difference itself. Or alternatively, the differential pressure value read by the sensor needs to be compensated with the calculated pressure drop in the tubes.

3. 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.

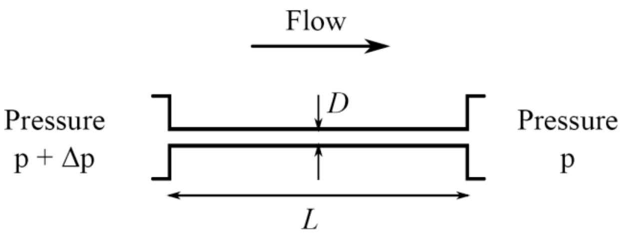

Fig. 2 Pressure drop Δp in a hose of length L and inner diameter D

Each differential pressure 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).

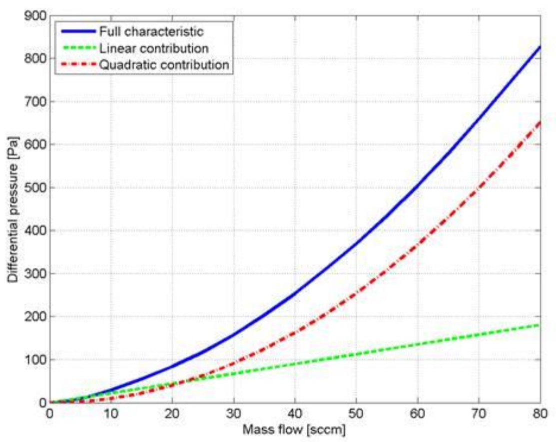

Fig. 3 Correlation of dp vs. flow for SDP3x (blue solid line)

With the SDP3x 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

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

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

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

$$m_c = 4.79\times 10^{-7}\ \frac{\text{kg}}{\text{s}}$$

$$\Delta p_c = 101\text{Pa}$$

with

L	=	length of hose (sum of hose length to and from sensor) in meter[1] [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[2] [Pa]
p_{abs}	=	absolute air pressure in hose in bar[3]
m_c	=	massflow
Δp_c	=	dp sensor constants where the linear and quadratic contribution to the dp vs. flow relationship of the SDP3x sensor are equal

Example of pressure drop compensation

Let us assume the following:

L	=	10 cm
D	=	1.8 mm
p_{abs}	=	1 bar
T	=	25 °C
$\boldsymbol{\Delta p_{sensor}}$	=	**250 Pa**

From the formulas above we derive that:

η_{air}	=	1.8447×10^{-5} Pa·s
ρ_{air}	=	1.1686 kg/m^3,
ε	=	- 2.09%
$\boldsymbol{dp_{eff}}$	=	**255.3 Pa**

[1] 1 m = 3.2808 ft = 39.4 inch
[2] 1 Pa = 0.004 inch Water column
[3] 1 bar = 100'000 Pa = 0.986923 atm = 14.50377 psi

Example plots for the hose-induced sensor deviation

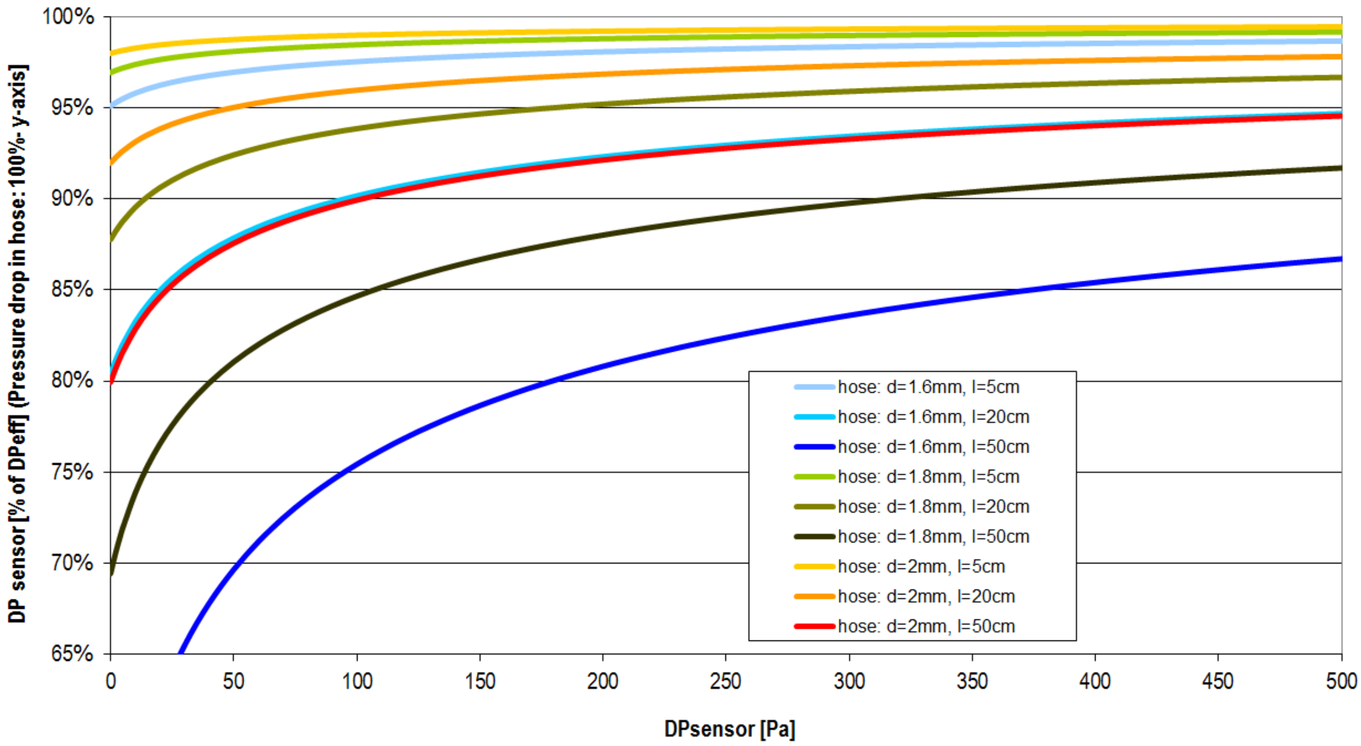

Fig. 4 Example of differential pressure drop in hoses with various lengths and inner diameters.

Important notice

Generally tubes should only be used to connect with the SDP3x in laboratory conditions, they must be very short, and only used to measure changes in the differential pressure. Tubes should be avoided when particularly small pressure differences (0-50 Pa) are the object to be measured. It is strongly recommended to refrain from using tubes for the final product design.

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Revision history

Date	Version	Author	Changes
May 2016	V0.1	PHA	Initial draft based on AN for SDP600 series
July 2016	V0.2	ANB	Update of pictures and some formulas

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