Technical Information

**Advanced technology for measuring flow in gases, liquids and steam**

# SDF Flow Sensors

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# Contents

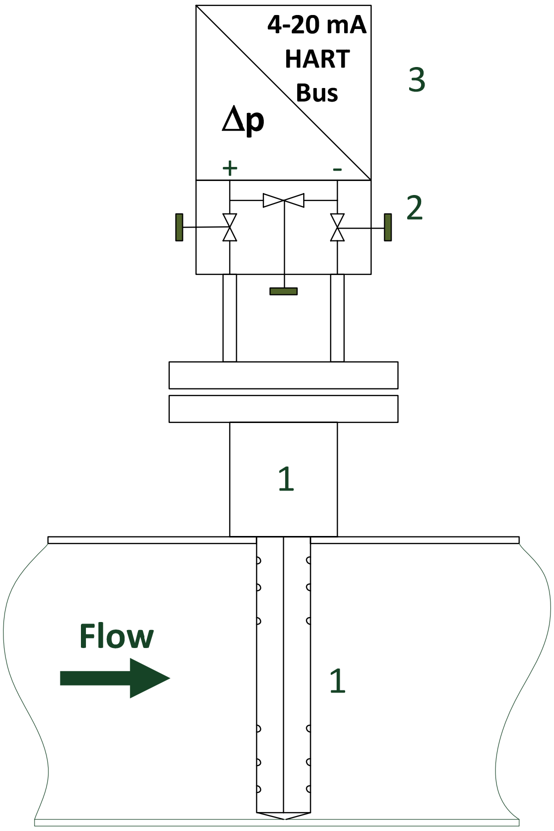
# Introduction

## Functions

A measurement with a differential pressure transducer always consists of a minimum number of components that are absolutely essential:

- the sensor itself, in our case an SDF sensor or a sensor in accordance with ISO5167;
- the transducer, known in common parlance as a "differential pressure transmitter" or more simply as a "transmitter";
- a display or control unit, which begins the process with the result of the measurement.

The accompanying illustration shows in more detail how this minimum configuration operates in practice:



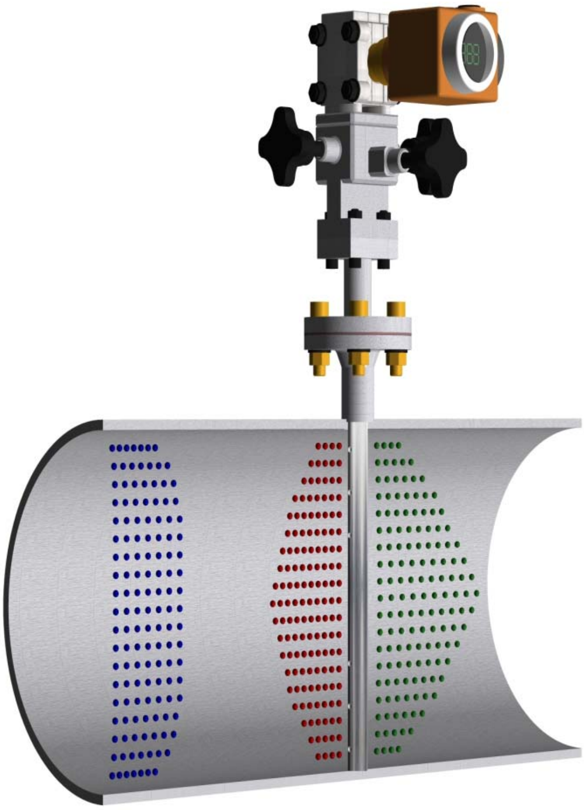

*Minimum configuration of a measuring station:*
*1. SDF flow sensor*
*2. Shut-off and adjustment valves (3 or 5-way valve block)*
*3. Electronic differential pressure transmitter*

The subsequent indicator or display device is not shown in this diagram. Anything could be located here, from a simple digital display and a process control system. More on this topic later.

The purpose of the adjustment valve is in the zero point calibration of the differential pressure transmitter. This is essential, especially when measuring small quantities.

**What exactly do these components do now?**

The diagram to the right shows a sensor which is mounted transversely in a pipe, in the direction of flow. An over pressure is produced on the upstream side, due to the congestion of the flowing medium, in addition to the static pressure already in the existing pipeline (shown in red in the illustration).



A negative pressure zone is produced at the back of the sensor ("downstream side") thanks to the external shape of the sensor profile (represented in green).

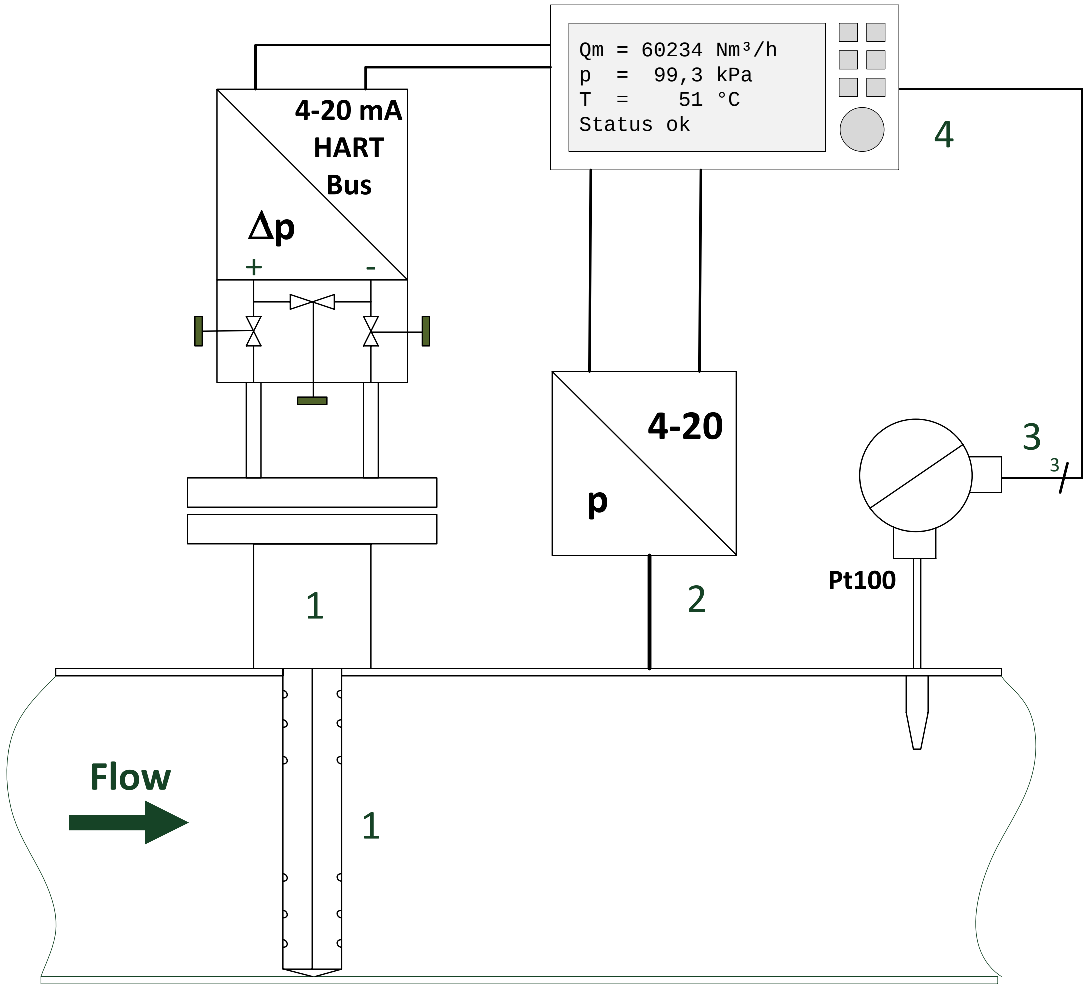
The (pressure) difference between these two sides is passed via the sensor out through the pipeline and led to the aforementioned differential pressure transmitters. Its task is to convert the differential pressure into an electrical signal that can be processed in due course with simpler means.

The relationship between differential pressure Δp and the flow rate to be measured v is described for a medium with the density ρ and for this type of flow sensor by the following equation:

$$v = k * \sqrt{\frac{2 * \Delta p}{\rho}}$$

More on that in subsequent sections.

## What makes up a complete measuring point?




**Fully configured measuring station (example):**

**1. Flow measurement device with SDF-sensor, 3-way valve block, differential pressure transmitter**
**2. Absolute pressure transmitter**
**3. Pt100 temperature sensor (built into the protective case)**
**4. Processor with compensation of the p and T influences on the medium's density**

The above-mentioned complete measuring point is required if the influences of pressure and temperature on the measurement are to be corrected. This involves correcting the properties of the medium as well as those of the pipe expansion for example, among other things.

# Features

## Consistently low pressure losses

In piping systems, pressure losses are, more often than not, undesirable side effects. Minimising these is one of the main requirements in the search for appropriate instruments. Therefore, devices with no narrowing of the pipe cross section are particularly useful. These include ultrasound measuring devices or magnetic-inductive flow meters. Both methods have limitations, however, which often exclude their use.

SDF sensors are very often installed where differential pressure transmitters can also be used according to ISO 5167 standards or to specific manufacturer standards. The following table shows the comparison of pressure losses and the resulting loss in the steam's working capacity between a typical measurement orifice and an SDF sensor in a very ordinary steam measurement. The example shows that the pressure losses costs a lot of power and therefore also a lot of money.

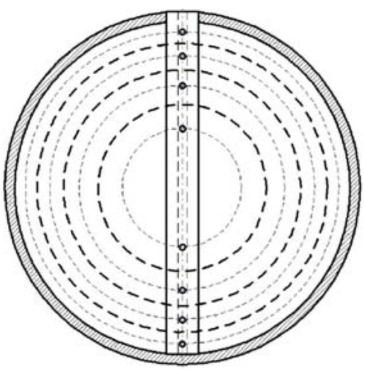
| | Orifice | SDF sensor | Unit |
|---|---|---|---|
| Max. differential pressure (1) | 200 | 23.55 | mbar |
| Constant pressure loss | 63 | 12 | % of (1) |
| Flow | 11562 | | kg/h |
| **Condition before the sensor** | | | |
| Absolute pressure | 400.0 | | kPa |
| Temperature | 150.0 | | °C |
| **Condition after the sensor** | | | |
| Absolute pressure | 387.4 | 399.7 | kPa |
| Temperature | 149.99 | 149.99 | °C |
| **Exergy loss per hour** | **19.35** | **0.43** | **kWh** |

## Averaging even during disturbed velocity distribution

In this section we show you the particular suitability of the SDF sensors in reducing the need for damping zones in comparison with other methods of measurement by

- geometric averaging of the velocity over the cross section v
- the special relationship between the size of the openings with the interior volume of the measuring sensor
- the completely symmetrical arrangement of the measuring holes on the front and the back.

One of the "secrets" of the SDF sensors is the arrangement of the measuring orifices. They are distributed over the sensor profile in such a way that a geometric averaging is carried out.



If we compare this behaviour of SDF-sensors with an ultrasonic flow meter for example, it quickly becomes clear that ultrasound machines measure each individual flow line the same – regardless of its actual predictive value of the flow rate. The ultrasound runs for a specified time through the internal diameter – the runtime of the ultrasound is a measure for the arithmetic mean of the flow velocity in the flow lines. This draws on the usual practice of unequal distribution of velocity after the inevitable systematic errors.

A second secret of the short inlet distances that can be achieved with SDF sensors, also in contrast to all other pitot sensors on the market, brings up an analogy to electrical engineering: the **characteristic ratio of the size of the port openings to the volume of the sensor** behaves hydraulically similarly to the way an electrical RC circuit behaves in electrical terms. A large volume buffers compensation flows, a large (flow) resistance reduces balancing processes using externally applied signal differences. In other words: different velocity distributions in a pipe lead to different dynamic conditions in the area of the measured orifices. These differences can lead to transient currents, which could in some cases even cause reverse flows from the sensor to filter out into the process. This eliminates or at least reduces the specific design of the SDF sensor with massive internal volume at comparatively minimal size of the measuring orifices. The same goes for pitot measurement sensors with slots on the upstream side – easy to produce, but metrologically wrong!

A third "secret" for accurate measurements in short damping zones has actually been common knowledge for some time now: the acquisition of a pitot sensor manufacturer by the ABB Group has made the fact that only such pitot sensors are able to measure accurately, and to determine the flow before and after the damming body with equal accuracy, more important. The idea of the "famous" static pressure which is apparently measured downstream, is nonsense, both in theory and in practice. A flow sensor must have the same number of orifices on both the upstream side and the outflow side, and these must also lie in the same flow line.

## High accuracy

In this section we will give you an insight into the results of hundreds of experiments on test rigs, in which SDF sensors were tested for the deviation of our stated flow rates from the real measured values.

SDF sensors provide, in comparison with the standard measuring orifices and nozzles in accordance with ISO 5167, a highly linear output signal. This means that regardless of the flow velocity and the media properties, the transfer characteristic of an SDF sensor remains stable under all specified conditions. This is not the case for most orifices and nozzles according to ISO 5167. The problems are shown in the following table: if an orifice measurement deviates from its design point, the system-related measurement errors increase considerably. The same problem arises with nozzles. Among the sensors according to ISO 5167 only the traditional Venturi tube is as free from the influence of the Reynolds number as an SDF sensor.

Sample application of steam ID=250 mm, design data: pressure = 4bar abs., temperature = 150°C, air regulator opening d = 120 mm (b = 0.48). The information available through the ISO 5167 deviation with the application of the transfer coefficient C from the design point on the respective operating point:

| Differential pressure | Indicator qm | True value qm | Error rate |
|---|---|---|---|
| 12,5 | 2891 | 2975 | 2.85% |
| 25 | 4088 | 4201 | 2.69% |
| 50 | 5781 | 5919 | 2.33% |
| 100 | 8176 | 8307 | 1.58% |
| 200 | 11562 | 11562 | 0.00% |
| 400 | 16352 | 15818 | -3.38% |

The errors quoted here do not include the already existing measurement uncertainty of an ISO5167 differential pressure transmitter. These errors must be counted in addition to the aforementioned linearity errors.

In comparison, here are the uncorrected measurement errors of an SDF sensor in a test run with a national calibration laboratory (*):

**Ergebnis der Kalibrierung**
*Calibrationresul*

| Ausg. mA Soll mA | Ausg. mA Ist mA | Dichte kg/m3 | Soll-Volumen l | Messzeit s | Impulse [mA] | Soll-Masse kg | Belastung t/h | Messabw. % |
|---|---|---|---|---|---|---|---|---|
| 4,3946 | 4,3916 | 999,70 | 805,74 | 379,25 | 83276 | 805,498 | 7,65 | -0,77 |
| 4,7659 | 4,7715 | 999,70 | 756,01 | 183,35 | 43743 | 755,783 | 14,84 | 0,73 |
| 5,5979 | 5,6053 | 999,70 | 817,22 | 95,00 | 26625 | 816,975 | 30,96 | 0,46 |
| 8,6691 | 8,6346 | 999,70 | 8679,00 | 345,28 | 149067 | 8676,396 | 90,46 | -0,74 |
| 11,8055 | 11,7827 | 999,70 | 8819,00 | 209,87 | 123642 | 8816,354 | 151,23 | -0,29 |
| 15,3691 | 15,3442 | 999,70 | 8493,00 | 138,76 | 106458 | 8490,452 | 220,28 | -0,22 |
| 18,4921 | 18,5254 | 999,70 | 8508,00 | 109,05 | 101010 | 8505,448 | 280,79 | 0,23 |

(*) In this case, we point out that manufacturers repeatedly present various measuring instruments with exaggerated accuracy test results that were not produced at accredited facilities. Thus, these results are not verifiable. We argue that in many cases they also can not be confirmed. We would therefore like to take this opportunity to point out that our testing and calibration results come from PTB-accredited test facilities and can withstand any investigation!

## Large dynamic range

Manufactured using the above calibration, a wide range of flow measurement using an SDF sensor becomes possible. Thanks to the high linearity of an SDF sensor this measurement method surpasses others considerably.

Consider the example of a vortex meter, as used in many applications. It has the reputation of having an extremely wide measuring range. An unsubstantiated legend, as it turns out on closer inspection. On the home page of a well-known manufacturer of such devices, the following equation is given to determine the minimum flow rate.

$$\text{DN } 40\ldots300 \rightarrow v_{\text{min.}}{}^{*} = \frac{7}{\sqrt{\rho\ [\text{kg/m}^3]}}\ [\text{m/s}]$$

For water, this results in a minimum velocity of 0.22 m/s. Converted to the mass flow, a vortex frequency counter, in our above calibration measurement, could not achieve a flow rate below 39 t/h anymore. In our example, the measurable vapour mass flow ends at 1800 kg/h. An SDF sensor with measuring range switch thus offers up to five times higher dynamic than a vortex frequency counter in a relevant technical field. The same is true in comparison with many other methods of measurement.

## Long-term accuracy

To function properly, measuring orifices need the edge radii to adhere to the orifice plate. These radii are enlarged by the medium coating them. The result: the orifices become inexact and ultimately imperceptibly useless.

In comparison: on a type 22 SDF sensor an unrealistic 10% will be removed from the outer section due to abrasion, which produces an additional deviation of 0.49% on the measurement value. In other words – normal wear and tear shows no detectable effect on the measurement result.

## Versatility

SDF sensors can be used universally. Basically, they can be used anywhere where other differential pressure transmitters would also be considered suitable. This applies not only to orifice plates, nozzles and traditional venturi pipes according to ISO5167, but "V Cones" and other exotic devices, to which special properties are attributed.

Specifically, the fields of application include

- technical and natural gases, even those with high steam content (such as biogas and landfill gas), contaminated by dust or corrosive elements
- liquids (such as boiler feed water, condensate and thermal oil)
- steam, even at very high pressures and temperatures.

SDF sensors are not suitable for pastes, sludges and adhesive media. In conductive water SDF sensors are suitable, especially for small diameters but magnetic inductive measuring devices are, in economic and technical measurement terms, the device of choice.

## Suitable materials

| Material | Use/application |
|---|---|
| 1.4571 | Standard materials of SDF sensors (optional: materials for weld-on mounting parts) |
| 2.4816 (Inconel 600) | High temperature materials for temperatures of up to 900°C |
| 2.4633 (Inconel 602) | High temperature materials for temperatures of up to 1150°C with high resistance to corrosion, but unsuitable for air over 1000°C |
| 1.4539 | Corrosion resistant austenitic steel – use for wetted parts in SDF sensors |
| P235GH | Material for welded attachments for mounting an SDF sensor in the pipe. Continuous operation up to 400°C |
| 1.5415 (15/16 Mo 3) | Temperature-resistant steel boiler (suitable up to 530°C wall temperature) |
| 1.7335 (13CrMo4-5 | Alloy steel stable at high temperatures (suitable up to 560°C wall temperature) – the use of SDF-weld-on components in high-temperature steam measurements |
| 1.7380 (10CrMo9-10) | Alloy steel stable at high temperatures (suitable up to 590°C wall temperature) – use for SDF weld-on components in high-temperature steam measurements |
| 1.4923 (X22CrMoV 12-1) | Extremely high temperature resistant stainless steel for live steam applications with operating temperatures over 600°C |
| 1.4841 (X15CrNiSi 25 20) | Heat-resistant stainless steel suitable for temperatures in a range from 900 to 1120°C, including air |

## Comparison and interchangeability with sensors according to ISO5167

| Criterion | Orifices | Nozzles | Traditional Venturi | SDF sensors | Accuflo |
|---|---|---|---|---|---|
| **Pressure loss** | High | High | Low | Low | Low |
| **Accuracy** | Limited | Limited | High | High | Very high |
| **Long-term stability** | Low | Given | Very high | Very high | Very high |
| **Price** | Low | High | Very high | Low-medium | High |
| **Installation** | Complex | Complex | Complex | Easy-medium | Medium Plug’n Play |
| **Dynamics** | Limited | Limited | High | High | Very high |
| **Standardisation** | Yes | Yes | Yes | No | No |
| **Calibration** | Complex | Complex | Complex | Possible | Standard |

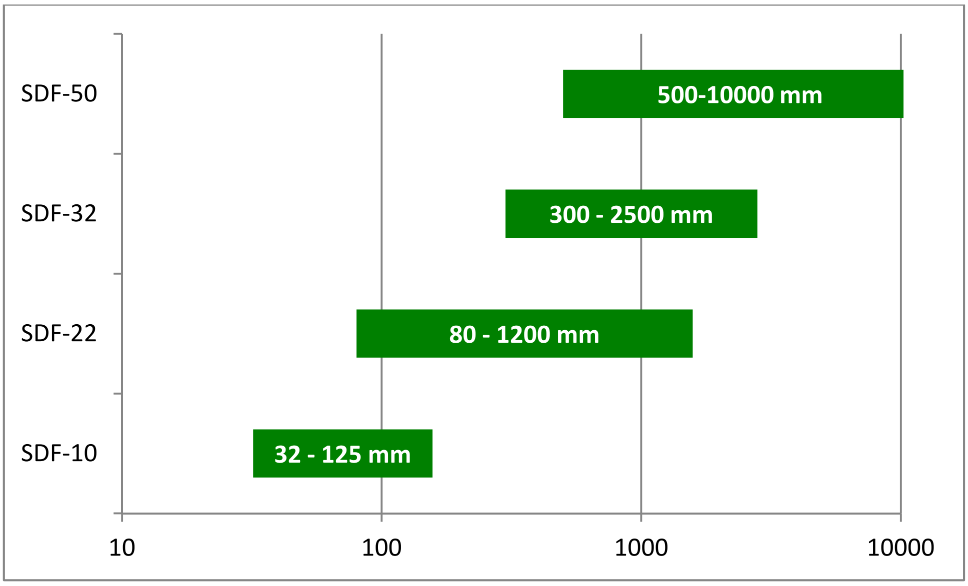
# The system

## Selecting the appropriate type of sensor

In this section we will show you how to select a suitable SDF-type sensor based on the essential features of your application. In most cases, this specification can be performed very quickly and easily. If you are still unsure, please contact our specialists who are always happy to advise you.

### Which sensor type for which pipe?

The sensors – in other words, the size of the wetted profile, depends primarily on the inner diameter of the pipeline, but the mechanical loading of the sensor by the flow and the resulting mechanical stresses must also be taken into account. The chart below shows the diameter ranges for the use of individual sizes:




Attached you will find the table "Maximum permissible differential pressure (in mbar)" (page 3), with whose help the smallest yet most appropriate SDF flow sensor for a specific application can be determined.

### Design/layout of a SDF sensor

In this section we will show you an example of the composition of an order reference code for the SDF sensors, allowing you to even specify the correct sensor in most cases.

Typically the order reference code of an SDF sensor reflects the sensor completely. Conversely, you can therefore find out what constitutes a sensor, just by studying the order reference code. Therefore, the best way to explain the composition of an SDF sensor is to use a concrete example of an order reference code:

### SDF-F-107.1 mm-3.6 mm/50 mm-S-C-0-PN16-FPK-DE3-T1-V

Such a sensor is a typical sensor, used for the measurement of gases and liquids. The order reference code can be understood with the help of the table "Order reference codes for standard sensors with flange (SDF-F)," on page 3.

| | | |
|---|---|---|
| **1** | **SDF** | Product ID |
| **2** | **F** | **Basic design**: here "F" stands for a sensor which is mounted by means of a flange on a counter flange welded to the pipeline. |
| **3** | **107.1mm** | The **inner diameter of the pipeline** |
| **4** | **3.6mm/50mm** | The figure on the left represents the **wall strength** of the pipeline; the figure on the right represents the strength of a potentially available **insulation**. If there is no insulation, this figure is absent. |
| **5** | **S** | This letter represents the **material of the sensor** itself. "S" stands for standard material 1.4571. |
| **6** | **C** | The **pipeline material**: here “C” stands for the “material group 2”, i.e. the simple carbon steels (e.g. P235 GH). The “E” stands for weld-on components made of stainless steel Mat.Nr. 1.4571 (material group 1). We manufacture the weld-on components from the raw material. |
| **7** | **0** | **End support**: “0” stands for “no end support” |
| **8** | **PN16** | **Pressure stages in plain text** |
| **9** | **FPK** | **Connecting the primary barrier.** This is required to be able to shut off the line upon removal of the electrical differential pressure transmitter. Here the downwardly facing, comfortable flange version (“FPK”) was chosen, which also allows for the installation of a thermometer in the sensor. |
| **10** | **DE3** | **Type of primary barrier chosen**: “DE3” stands for a stainless steel three-way valve block with double-sided 7/16“-UNF cadmium-plated carbon steel screws. |
| **11** | **T1** | **Accessories**: here “T1” stands for an integrated Pt100 resistance thermometer in 3-conductor version with replaceable measuring insert without electric transmitter in the connection head. |
| **12** | **V** | **Pipeline route:** “V” = vertical, “H” = horizontal |

Using this system, the code

**“SDF-DF-10-54.5mm-2.9mm-S-C-0-PN16-KT-FWC-0-H”**

describes a standard steam sensor with flange connection on a horizontally-running carbon steel pipeline DN50 PN16, including compact mounting of the differential pressure transmitter on a carbon steel five-way block, which itself is directly mounted on the condensation vessel integrated on the connecting head. This version is readily available for temperatures up to 300°C – also with custom valves for higher temperatures.

### Design calculations

When pre-calculating an SDF sensor essentially two points need to be clarified:

1. How much differential pressure must the SDF sensor bear, depending on the specific application data?
2. Is the chosen sensor adequate for this differential pressure? Is the differential pressure high enough for the electrical differential pressure transmitter?

Calculating the differential pressure can be carried out very easily and elegantly with the help of a calculation programme, which is always available on the internet. This calculation programme can be found at http://www.ski-gmbh.com by selecting "Support/Calculations" from the menu. To use the programme you need to register by entering your email address and name. Once you create your own password, you can do your own calculations, save them and access them again, as long as you are connected to the internet.

You can also calculate the differential pressure with the help of the equations in the table "Equations for simple design calculations" on page 3. For rough calculations, it is sufficient to take the transfer coefficient of the chosen SFG sensor from the table 'Table of transfer coefficients of SDF sensors (k factors)' on page 3.

The results should be checked against the table "Permissible maximum differential pressure (in mbar)" (page 3), which can be found in the appendix to this document.

**Important note:**

**For use with high pressure (e.g. with gases and steam with 20 bar or greater line pressure) and high flow rates or with very large pipes (inner diameter > 2000mm), please contact us during the design phase!**

## Process with extremely short damping zones

### Using two sensors

Short inlet and outlet routes are "slow burners" in flow measurement, especially in larger pipelines. Therefore, we have carried out many experiments in this area and can demonstrate conclusive results. Clear operational rules can be derived from these experiments. We attempted to solve the problem of finding a reproducible solution even under difficult conditions when using a short damping zone. We compared the results of an SDF sensor in the same flow but at three different installation points:

1. the optimal placement with a x10 inner diameter (ID) as a damping zone in front of the measuring point and x5 ID as a damping zone behind;
2. the placement with a x5 ID inlet section and without an outlet section (x0 ID)
3. the placement without an inlet section (x) ID) and with a x5 ID outlet section

The following table shows a selection of the results we obtained:

| Damping zones | Attempt 1 | Attempt 2 | Attempt 3 |
|---|---|---|---|
| | * ID | | |
| Inlet | 10 | 5 | 0 |
| Outlet | 5 | 0 | 5 |
| | | | |
| **Mass flow in t/h** | Deviation in % | | |
| 20 | 0.36 | -0.60 | 1.43 |
| 50 | 0.20 | -1.17 | 0.92 |
| 140 | -0.39 | -1.26 | 0.70 |
| 270 | -0.77 | -1.51 | 0.50 |

**The conclusion of this experiment is: using two crosswise SDF flow sensors, in the absence of an inlet section, produces a measurement value with an accuracy of +/-2% in the flow ratio of minimum to maximum flow rate in the range of 1:13!**

## Start-up calibration

While deviating significantly from the DIN 1946-recommended inlet and outlet sections, an on-site calibration is the most reliable method to determine the actual flow rate in gas channels. In other media, checking with an anemometer, pitot tube or the like is not advisable, due to the temperature and pressure conditions and the associated health risks.

The procedure uses the following basic formula for the differential pressure sensors:

$$v = k * \sqrt{\frac{2 * \Delta p}{\rho}}$$

Here, the k-factor characterises the interaction of the sensor, pipe (whose component the sensor has become after being mounted) and the streaming media. Since all other factors are pure physics, only the k-factor closely reflect this interaction. The factory-made k-factor corresponds to the ideal values determined by our bench tests.

The real k-value is the lever for a correction of the deviation between test and measurement of the specific arrangement. If you have a choice, we recommend the correction of the k-factor using a pitot or Prandtl pipe or similar procedures. These measuring sensors are not designed or recommended for stationary industrial applications due to their low differential pressures and other aspects. For the calibration of SDF sensors, however, they are well suited, because the influences of the media in both density measurement methods cancel each other out. This simplifies the procedure considerably.

To perform a calibration measurement, we must do two things:

1. We must have as many views of the flow as possible, i.e. the more measurement points taken, the better. It is best when at least two axes are measured.
2. We need to weight the results in a way that each point is given its due importance. This can be done by calculation or by selecting the measuring point.

In practice, it is easier to fix the measurement points in advance, so that the weighting then happens of its own accord. Of course it makes sense to keep the operating conditions almost constant during the measurement process. Considerable fluctuations of more than 10% of flow rate lead to individual measurements which cannot be compared with each other.

# Illustrations and tables

## Equations for simplified design calculation

| Simplified differential pressure equations | |
|---|---|
| **Basic equation** | $v = k * \sqrt{\frac{2 * \Delta p}{\rho}}\ mit\ [\Delta p] = Pa\ (1)$ |
| **Speed** | $\Delta p = \frac{\rho}{2} * \left(\frac{v}{k}\right)^2\ mit\ [\Delta p] = Pa\ (2)$ |
| **Volume flow** | $\Delta p = \rho * \left(\frac{25 * \dot{V}}{k * ID^2}\right)^2\ (3)$ |
| **Mass flow** | $\Delta p = \frac{1}{\rho} * \left(\frac{25 * \dot{m}}{k * ID^2}\right)^2\ (4)$ |
| **Special case of standard volume flow for gases** | $\Delta p = \frac{\rho_N * T_B}{p_B} * \left(\frac{15{,}23 * \dot{V}_N}{k * ID^2}\right)^2\ (5)$ |
| **Unit** | |
| **Speed** | $[v] = m/s$ |
| **Volume flow, standard volume flow** | $[\dot{V}] = m^3/h\ , [V_N] = Nm^3/h$ |
| **Mass flow** | $[\dot{m}] = kg/h$ |
| **Pressure** | $[p] = kPa\ abs.$ |
| **Temperature** | $[T] = K$ |
| **Differential pressure** | $[\Delta p] = mbar$ |
| **Inner diameter** | $[ID] = mm$ |
| **Ratios for SDF sensors in ISO 5167 notation** | |
| **Orifice ratio** | $\beta = \sqrt{1 - \frac{4 * br}{\pi * D}}$ |
| **Flow coefficient** | $C = \left[\frac{1 - \beta^4}{\beta^4} * (0{,}668 - 1{,}4 * (\beta^2 - 1)^2\right]^{0,5}$ |
| **Differential pressure formula for mass flow** | $dp = \frac{1}{\rho} * \left[0{,}9003 * \frac{\sqrt{1 - \beta^4} * \dot{m}}{C * d^2}\right]^2$ |

## Typical constant pressure losses for SDF sensors

| SDF type | 10 | 22 | 32 | 50 |
|---|---|---|---|---|
| Inner diameter in mm | Pressure loss in % of the differential pressure | | | |
| 50 | 29 | - | - | - |
| 100 | 15 | 29 | - | - |
| 150 | - | 19 | - | - |
| 200 | - | 15 | 19 | - |
| 250 | - | 12 | 16 | - |
| 300 | - | 10 | 13 | 21 |
| 400 | - | 7 | 10 | 15 |
| 500 | - | 6 | 8 | 12 |
| 600 | - | 5 | 6 | 10 |
| 700 | - | 4 | 6 | 9 |
| 800 | - | 4 | 5 | 8 |
| 900 | - | 3 | 4 | 7 |
| 1000 | - | 3 | 4 | 6 |

For example, a SDF-22 sensor for a diameter DN300, for which a maximum differential pressure of, for example 28.63 mbar was calculated, will produce a constant pressure loss of approximately 10% at this work point, equal to 2.8 mbar.

## Maximum permissible differential pressures (in mbar)

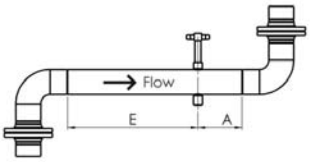
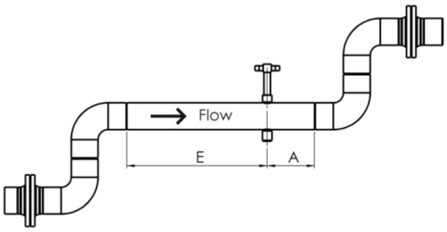
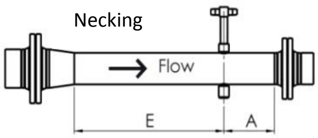
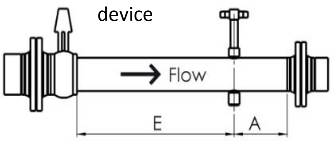
| Type | SDF-10 | | SDF-M-22 | | SDF-F-22 | | SDF-32 | | SDF-50 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | without | with | without | with | without | with | without | with | without | with |
| | end support | | | | | | | | | |
| 40 | 2214 | 55350 | | | | | | | | |
| 50 | 1417 | 35424 | | | | | | | | |
| 65 | 838 | 22671 | | | | | | | | |
| 80 | 554 | 13415 | | | | | | | | |
| 100 | 354 | 8856 | | | | | | | | |
| 125 | 227 | 5668 | 4800 | | 907 | | | | | |
| 150 | | | 3333 | | 630 | | | | | |
| 200 | | | 1875 | | 354 | | | | | |
| 250 | | | 1200 | | 227 | | | | | |
| 300 | | | 833 | 1940 | 157 | 2519 | 280 | | | |
| 350 | | | 612 | 1425 | 116 | 1851 | 206 | | | |
| 400 | | | 469 | 1091 | 89 | 1417 | 157 | 2519 | | |
| 500 | | | 300 | 698 | 57 | 907 | 101 | 1612 | | |
| 600 | | | 208 | 485 | 39 | 630 | 70 | 1120 | 176 | 2821 |
| 700 | | | 153 | 356 | | 463 | 51 | 823 | 130 | 2073 |
| 800 | | | 117 | 273 | | 354 | 39 | 630 | 99 | 1587 |
| 1000 | | | 75 | 175 | | 227 | 25 | 403 | 63 | 1016 |
| 1250 | | | | 112 | | 145 | | 258 | 41 | 650 |
| 1500 | | | | 78 | | 101 | | 179 | 28 | 451 |

## Table of transfer coefficients of SDF sensors (k factors)

| ID | SDF-10 | SDF-22 | SDF-32 | SDF-50 |
|---|---|---|---|---|
| 50 | 0.5284 | | | |
| 65 | 0.5962 | | | |
| 80 | 0.6244 | | | |
| 100 | 0.6420 | 0.5284 | | |
| 125 | 0.6522 | 0.5889 | | |
| 150 | | 0.6172 | | |
| 200 | | 0.6420 | | |
| 250 | | 0.6522 | 0.6378 | |
| 300 | | 0.6574 | 0.6480 | |
| 350 | | 0.6604 | 0.6538 | |
| 400 | | 0.6623 | 0.6574 | 0.6384 |
| 450 | | 0.6636 | 0.6598 | 0.6453 |
| 500 | | 0.6644 | 0.6615 | 0.6501 |
| 600 | | 0.6656 | 0.6636 | 0.6560 |
| 700 | | 0.6662 | 0.6648 | 0.6594 |
| 800 | | 0.6667 | 0.6656 | 0.6616 |
| 900 | | 0.6669 | 0.6661 | 0.6630 |
| 1000 | | 0.6672 | 0.6665 | 0.6640 |
| 1100 | | 0.6673 | 0.6667 | 0.6647 |
| 1200 | | 0.6674 | 0.6669 | 0.6653 |
| 1300 | | 0.6675 | 0.6671 | 0.6657 |
| 1400 | | 0.6676 | 0.6672 | 0.6660 |
| 1500 | | 0.6676 | 0.6673 | 0.6663 |
| 1600 | | | 0.6674 | 0.6665 |
| 1700 | | | 0.6675 | 0.6667 |
| 1800 | | | 0.6675 | 0.6668 |
| 1900 | | | 0.6676 | 0.6669 |
| 2000 | | | 0.6676 | 0.6670 |
| 2500 | | | | 0.6674 |
| 3000 | | | | 0.6676 |

## Inlet and outlet sections

In general, for the proper function of SDF sensors, the following damping zones must be kept in front of and behind of a deviation from the straight uninterrupted pipe route.

| Pipe route | Inlet | Outlet |
|---|---|---|
|   | 7*ID | 3*ID |
|   | 10*ID | 3*ID |
|   | 7*ID | 3*ID |
|   | 20*ID | 5*ID |

**Important note: please consult us if you are dealing with shorter damping zones than the ones shown here.**

## Ordering codes for standard sensors with flange mounting (SDF-F)

| SDF | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **Pipe mounting** |
| | F | | | | | | | Basic price (up to max. PN64, SDF-32 max. PN40, SDF-50 max. PN16) |
| | F | | | | | | | Basic price (PN100) 1.4571 * only |
| | F | | | | | | | Basic price (PN160) 1.4571 * only |
| | FX | | | | | | | Special model |
| | | | | | | | | **Profile type** |
| | | 10 | | | | | | Inner diameter: 35 - 125 mm |
| | | 22 | | | | | | Inner diameter: 100 - 1200 mm |
| | | 32 | | | | | | Inner diameter: 400 - 2500 mm |
| | | 50 | | | | | | Inner diameter: 400 - 6500 mm |
| | | | | | | | | **Inner diameter (number values with unit)** |
| | | | | | | | | Price per 100 mm |
| | | | | | | | | **Wall strength / + insulation (number values with unit)** |
| | | | | | | | | Price per 100 mm (up to max. PN64) |
| | | | | | | | | Price per 100 mm (PN100/160) |
| | | | | | | | | **Special materials for media-touched components (factors)** |
| | | | | | S | | | Mat.Nr. 1.4571 (316 Ti) |
| | | | | | 41 | | | Mat.Nr. 1.4541 (only with process connection "R", "N2" o. "X") |
| | | | | | R | | | Mat.Nr. 1.4539 (only with process connection "R" o. "X") |
| | | | | | H | | | Hastelloy C22) (only with process connection "R" o. "X") |
| | | | | | HT | | | Inconel 602 (only with process connection "R" o. "X") |
| | | | | | X | | | Special materials |
| | | | | | | | | **Mounting components materials (without end support) PN16/40: Typ10=DN15; Typ22=DN32; Typ32=DN40; Typ50=DN80 PN64/100/160: Typ10=DN25; Typ22=DN40; Typ32=DN40; Typ50=DN80** |
| | | | | | | C | | Flange, carbon steel, PN16 |
| | | | | | | C | | Flange, carbon steel, PN40 |
| | | | | | | C | | Flange, carbon steel, PN64/100 |
| | | | | | | E | | Flange, 1.4571, PN16 |
| | | | | | | E | | Flange, 1.4571, PN40 |
| | | | | | | E | | Flange, 1.4571, PN64/100 |
| | | | | | | X | | Special model |
| | | | | | | | | **End support** |
| | | | | | | | 0 | Without |
| | | | | | | | SC | End support with carbon steel R1"plug (max. PN40 180°C) |
| | | | | | | | SC | End support (pipe thread & cap) carbon steel (max. PN40 180°C) |
| | | | | | | | SE | End support (pipe thread & cap) 1.4571 (max. PN40 180°C) |
| | | | | | | | GF | End support with flange, carbon steel, PN16 |
| | | | | | | | GF | End support with flange, carbon steel, PN40 |
| | | | | | | | GF | End support with flange, carbon steel, PN64/100 |
| | | | | | | | GF | End support with flange, 1.4571, PN16 |
| | | | | | | | GF | End support with flange, 1.4571, PN40 |
| | | | | | | | GF | End support with flange, 1.4571, PN64/100 |
| | | | | | | | GG | Closed end support, carbon steel, max. PN100 |
| | | | | | | | GG | Closed end support, 1.4571, max. PN100 |
| | | | | | | | X | Special model |

| | |
|---|---|
| | **Pressure stages (e.g. "PN16", "300 lbs." or similar)** |
| | **Process/differential pressure connections** |
| N2 | Nipple with 1/2-14-NPT external thread |
| N4 | Nipple with 1/4-18-NPT external thread |
| R2 | Nipple with R1/2" external thread |
| R4 | Nipple with R1/4" external thread |
| R | Spouts 12mm |
| S | Hose stem 10.5 x 1.5mm |
| FP | Flange plate for assembly of a 3-way valve block (only without integrated temperature recording) |
| FPD | Double-flange for the construction of two 3-way valve blocks (only without integrated temperature recording) |
| FPK | Flange plate for constructing a 3-way valve block but rotated by 90°, for integrated temperature recording for example |
| FPX | Special direct mounting device, for reversing tap mounting |
| X | Special model |
| | **Initial barrier** |
| 0 | no initial barrier |
| KE | Ball valves PN40 of 1.4401 (max. 200°C) |
| AC1 | Stop valves PN420 DN5, carbon steel, 1/2" NPT (max. 200°C) |
| AE1 | Stop valves PN420 DN5, 1.4404, 1/2" NPT (max. 200°C) |
| DE1 | 3-way valve block, materials 1.4401 (max. 200°C)<br>Screws: process-relevant 7/16-UNF cadmium-plated, differential pressure transmitter-relevant, metric, stainless steel (only with flange plate) |
| DE2 | like 'DE1', but with process-relevant screws 7/16-UNF stainless steel |
| DE3 | like 'DE1', but with differential pressure transmitter-relevant screws 7/16-UNF cadmium-plated |
| DE4 | like 'DE2', , but with differential pressure transmitter-relevant screws 7/16-UNF stainless steel |
| FE1 | 5-way valve block, material 1.4401 (max. 200°C),<br>Screws: process-relevant 7/16-UNF cadmium-plated, differential pressure transmitter-relevant, metric, stainless steel (only with flange plate) |
| X | Special model, see extra brochure if required |
| | **Accessories (multiple selection possible; separate with "/")** |
| 0 | without |
| VC | 1 pair of fittings for 12 mm pipe connection, carbon steel |
| VE | 1 pair of fittings for 12 mm pipe connection, 1.4571 |
| UC | Reversing tap PN100 with rinsing connection made of carbon steel (max. 200°C) |
| UE | Reversing tap PN100 with rinsing connection made of 1.4571 (max. 200°C) |
| CH | One-sided cleaning ports for compressed air supply (R1/8") |
| IH | Inspection and cleaning ports (only advisable with end support) |
| FTGE | Sensor tip, guide, made of 1.4571 in the end support with rubber rings for the medium of water (max. 80°C) (needed in addition to the normal end support) |
| X | Special model, see extra brochure if necessary |
| | **Pipe route** |
| H | Horizontal |
| V | Vertical (also on a slanting route) |

## Summary of the general specification data of SDF sensors

- Suitable for the measurement of gases, fluids and steam
- Two-chamber profile, symmetrical construction
- Two-way operation is possible
- Inherent vortex damping ("Karmann'sche Wirbelstraße" theory)
- Measurement area: depends on the lowest differential pressure; recommendation:
  - Gases: smallest measurement area $\Delta p_{FS,min}$= 1mbar
  - Steam and liquids: smallest measurement area $\Delta p_{FS,min}$= 5-10 mbar
- Pipe diameter from DN40 to DN11000
- Materials
  - Wetted parts: 1.4571 (standard); optional: Hastelloy C22, Inconel 602, Monel, 1.4871, 15 Mo 3, 1.4922/P91/P92 – other materials available on request
  - Mounting components: P235GH (standard); optional: 1.4571, 15/16 Mo 3, 1.7380, 1.4922 – other materials available on request
- Temperature of the medium to be measured: -180°C to 1100°C
- Pressure stages: PN16 (standard) to PN420 (3000 lbs.); special pressures available on request
- Conforms to DGRL 97/23/EG
- Max. measurement deviation: typically 1% of the measurement value in the specified dynamic range
- Dynamic:
  - Max. 1:10 with a measuring transmitter
  - Max. 1:40 in split range operating mode (max. deviation in the range 1:10 less than 1% of the measurement value)
- Connections:
  - ½"-14-NPTM (standard for gases and liquids)
  - Flange connection for direct mounting of a differential pressure transmitter (optional)
  - Condensation vessel with welded connection (standard for steam)
  - Compact head with integrated condensation vessels (optional for steam)
- Mounting in the pipeline: materials depending on pipeline material, construction:
  - Weld-on connection piece with cutting ring fitting
  - Mounting flange depending on pressure stage
- Contamination of the measurement materials:
  - Dry dust: max. 100 mg/m³
  - Max. 10 g/m³ dust when using an air purging system LSE-HD (consult manufacturer for higher dust load)
  - Acidic components in the material to be measured: adapt the material to the wetted parts
- Particular qualities/features:
  - High accuracy and excellent dynamics
  - Consistently low pressure losses
  - Low procurement and installation costs
  - Easy to retrofit
  - Two-way operational mode
  - Robustness and insensitivity to contamination of the material to be measured

# FAQs

## The evaluation unit can only calculate the flow rate in relation to a deviation from the design point. How should the transfer equation look under these circumstances?

The amount of the mass flow to be determined depends, for compressible media, not only on the measured differential pressure, but also on pressure and temperature which affect the density of the medium. If a measurement is designed, then you determine the differential pressure around a specific pressure-temperature-value pair. If the signal now deviates in practice from this pair of values, a correction must be made. This correction is relatively complicated and generally should be left to a special process computer. Only for measurements with idealised gases (i.e. all gas measurements with pressures that are not too high), the correction can be made using the following formulas:

$$\boldsymbol{qV_N} = \sqrt{\frac{p * T_D * \Delta p}{p_D * T * \Delta p_D}} * qV_{N,D} = \sqrt{\frac{\boldsymbol{p * T_D}}{\boldsymbol{p_D * T}}} * \boldsymbol{qV_{N,D}} * \sqrt{\frac{\boldsymbol{i_{\Delta p} - 4mA}}{\boldsymbol{16\ mA}}}$$

If the differential pressure transmitter square roots already, then this results:

$$\boldsymbol{qV_N} = \sqrt{\frac{\boldsymbol{p * T_D}}{\boldsymbol{p_D * T}}} * \boldsymbol{qV_{N,D}} * \frac{\boldsymbol{i_{\Delta p} - 4mA}}{\boldsymbol{16\ mA}}$$

The index “D” stands here for design data (“design”), the values without index “D” stand for currently measured operating values. $i_{\Delta p}$ is the flow measured by the differential pressure transmitter.

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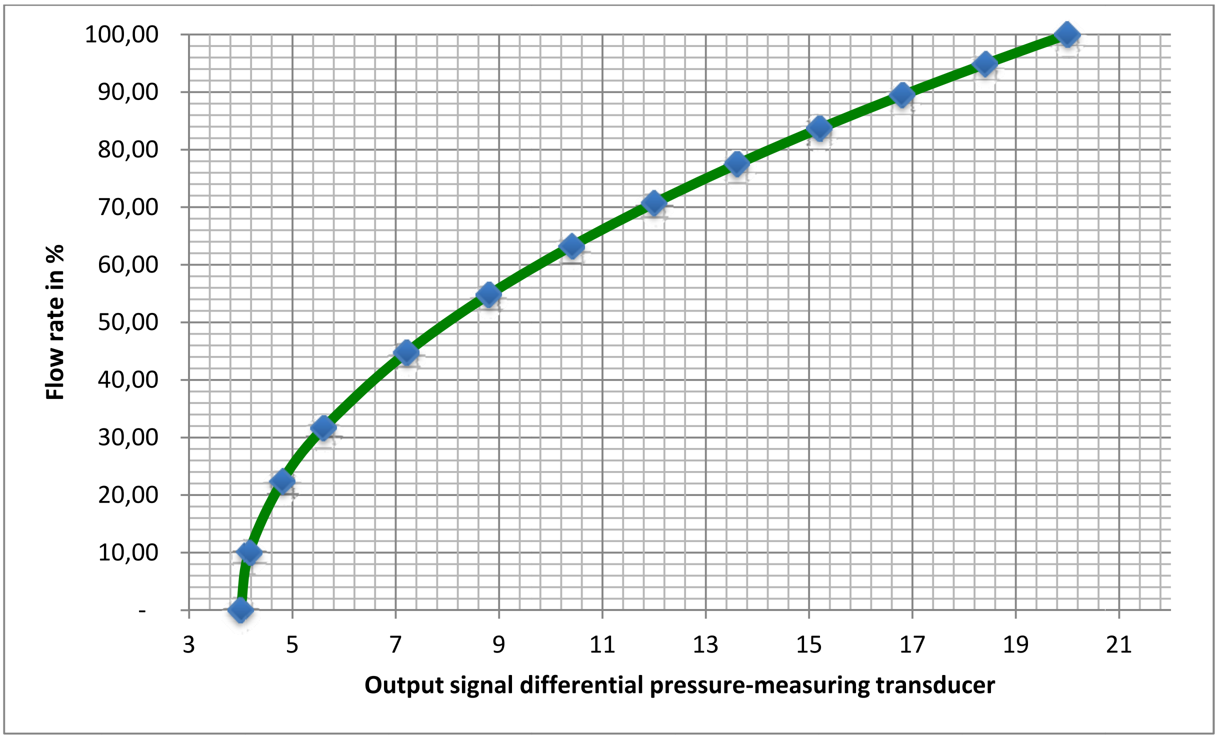
## How does the transfer curve of the output signal appear as a function of the mass flow?

The curve is derived from the "mother of all differential pressure equations", which was given at the beginning of this document.

$$v = k * \sqrt{\frac{2 * \Delta p}{\rho}}$$

When applied to the context of the current output of a differential pressure transmitter for flow rate, a characteristic curve is produced.




When using a root-extracting transmitter the transmission characteristic is of course a straight line.

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