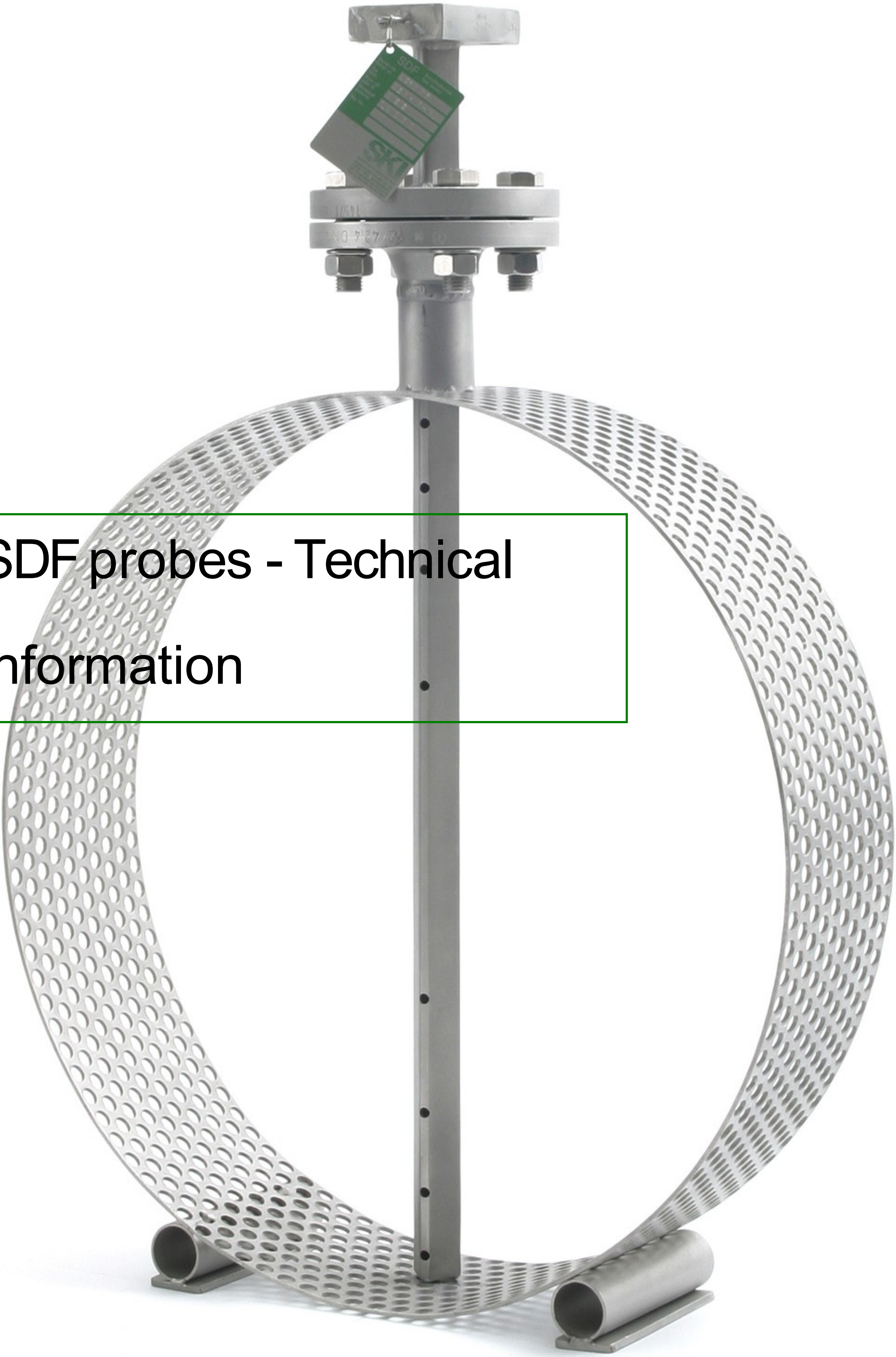
SKI
Kompetente Messtechnik



SDF probes - Technical information

Preamble

This collection of facts, figures, and background information regarding SDF probes has been compiled with several objectives in mind. Firstly it is intended to give readers not yet familiar with measuring operations using our SDF probes certain basic knowledge about:

- ➔ how these instruments actually function
- ➔ where they can be used and where not
- ➔ which elements and components are needed to use them
- ➔ what advantages SDF probes offer compared with other methods
- ➔ and many other questions besides.

Secondly it is intended to give our own staff, retailers, and those who frequently operate SDF probes a fund of hands-on knowledge that will be useful for their daily working needs. We at SKI have for many years done our best to ensure that computer support is made publicly available for more and more planning and working processes. Users of our Internet site for example can run our differential pressure calculation program or download numerous files illustrating products or listing engineering data.

We hope with this brochure to encourage and support the use of these online tools.

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The benefits and limitations of SDF probes

SDF probes are designed to determine flow velocities, volume flow rates, and mass flow rates of low-viscosity media in completely filled pipes and ducts. SDF probes use the principle of differential pressure; (see the Section entitled "A few words on the functional principle").

The characteristic advantages of SDF dynamic pressure probes are:

➔ They are quick and easy to install - even in existing pipework

➔ They ensure low lasting pressure losses and thus lower energy and running costs than most other flow measuring systems

➔ They are subject to virtually no wear and tear, thus ensuring a long useful life and extremely good transmission stability

➔ They need very little routine maintenance; (this applies to all media with the exception of especially sticky substances)

➔ SDF probes are available in all sorts of steel, alloy, and plastic; the right choice of material and design ensures extremely high resistance to the adverse effects of mechanical, chemical, and thermal stress

➔ High linearity

➔ They are largely insensitive to contamination and condensation

➔ The generous size ratio of chamber volume to measuring apertures ensures accurate geometric averaging of the flow velocity and thus a stable measuring signal

➔ Certified design accuracy, tested by approved certification offices

Typical uses

SDF probes are ideal for countless applications ranging across the whole spectrum of industrial flow measurement. Typical everyday areas of use are in measuring operations for:

➔ Air intake / exhaust quantities

➔ Compressed air, also for billing purposes

➔ Exhaust gases, also containing moisture and / or dust particles

➔ Natural gas, also at pressures exceeding 250 bar (including structural inspection)

➔ Flue gases from coke works and other sources

➔ Supply gases, also at low temperatures (<-100 °C)

➔ Flue gas quantities in large pipes

➔ Low-pressure vapor, waste vapor (also possible in existing ring chambers by means of an adjusting ring which can be fitted in place of the standard orifices)

- ➔ Medium-pressure vapor
- ➔ High-pressure vapor and live steam (by means of a flange, also by means of welded-in probes)
- ➔ Feed water and condensate in steam circuits
- ➔ Air quantities for regulating or distributing several partial flows (e.g. in drying systems, machines, etc.)
- ➔ Gases and liquids with calibration by an approved office (for highest possible accuracy and reproducibility; the probe is delivered in a pipe segment that has been duly accepted)

> This list is of course not complete. However, it does, we hope, offer an overview of the wide variety of application possibilities for SDF probes.

A few words on the functional principle

The functional principle of SDF flow probes is based on a simple but highly effective way of interpreting energy. Let us consider a rod-type probe comprising two symmetrical chambers when it is inserted in a flow of medium. Both chambers have a certain number of measuring apertures. The probe is then aligned in the medium in such a way that the flowing medium strikes the apertures of one chamber only. The apertures of the second chamber by way of contrast lie sheltered in the lee of the probe.

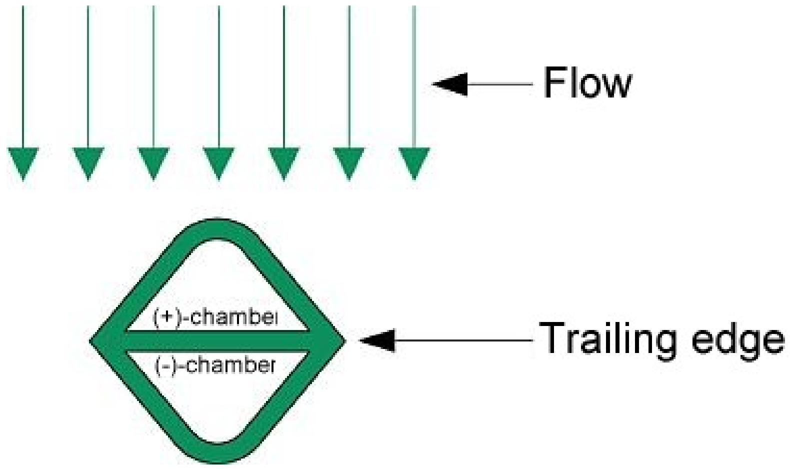


Figure 1: The symmetrical chambers of an SDF probe (cross-section view)

The first chamber, facing the flow, experiences overpressure and is therefore called the ⊕-chamber; the second chamber, turned away and sheltered from the flow, is called the ⊖-chamber.

The overpressure on the ⊕-chamber results from the static pressure in the pipe plus the additional pressure caused by the dynamic impounding of medium on the probe; (we shall for the sake of simplicity ignore other pressure components just now). On the ⊖-side the static pressure in the pipe is also present.

However, here there is no dynamic impounding pressure. Indeed, we have designed the exterior in such a way that the ⊖-chamber experiences underpressure.

Useful for our purposes is that as the medium's velocity increases the overpressure on the ⊕-chamber and the underpressure on the ⊖-chamber both increase by equal and measurable amounts.

If the velocity doubles, the dynamic impounding pressure on the ⊕-side and the underpressure on the ⊖-side both quadruple. The nature of the medium obviously also makes a difference, e.g. if the probe is exposed to a flow of air or a flow of water. The higher density of water causes a greater differential pressure - exactly proportionate to the amount by which the density of water is higher than the density of air.

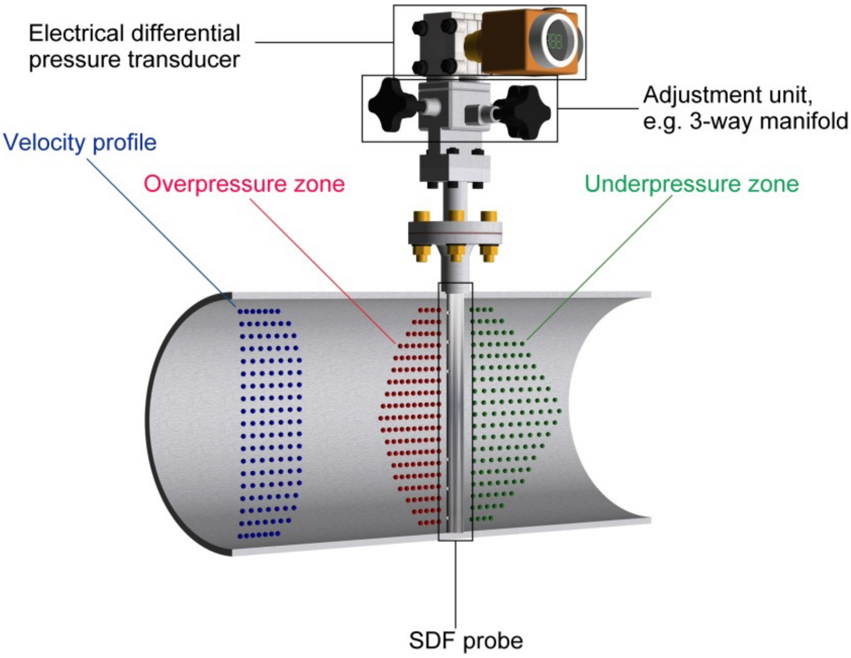


Figure 2: Pressure zones of an SDF probe in a flow of medium

To deduce the flow velocity of a particular medium therefore we must:

➔ measure the difference in pressure between the ⊕ and ⊖ chambers

➔ calculate the square root of this number

➔ adjust the result according to the density of the medium

Thus, having installed an SDF probe in a pipe we can determine the velocity of the medium by 1) measuring the differential pressure between the two chambers, then 2) calculating the square root of this, and then 3) adjusting this according to the density of the medium. All we need to know now is how to interpret what the probe tells us.

The answer is given in the following equation:

$$w = k * \sqrt{\frac{2 * \Delta p}{\rho}} \qquad \text{(Equation 1)}$$

This is the general equation for flow measurement using a dynamic pressure probe; it is used to determine flow velocity w - from differential pressure Δp, density ρ, and a special probe factor k.

The trick involved in obtaining an accurate measured value from a dynamic pressure probe is to determine what this k factor is.

Our computer-assisted calculation system determines this k factor fully automatically.

How accurate are SDF flow probes?

The accuracy of SDF flow probes was originally tested and documented in a series of trials conducted by the "Institute for Hydraulics" in Delft in the Netherlands. The institute's test-beds guarantee a level of precision that is unique and unparalleled in Europe. The institute tested several SDF probes designed for use in pipes of various internal diameters. Let us quote just a representative extract from our in-house report:

"Measuring the dependence of the k factor on the Reynolds number

> The dependence of the k factor on the Reynolds number is not a fixed constant; apparently it also depends on the test setup. In the trials on our probes a wide variety of curves were obtained for the k factor. As the Reynolds number was incremented the results for the k factor ranged widely - sometimes an increase, sometimes virtually unchanged, sometimes a decrease.
> However, in all cases the k factor results lay within the specified accuracy tolerances. In test series 6 a few measured values, apparently the result of incorrect measuring operations, were ignored."

To see the curve for the k factor for a larger range of Reynolds numbers one test series was conducted using an SDF-22 probe in a pipe with an internal diameter of 309 mm.

The results are shown in the following diagram:

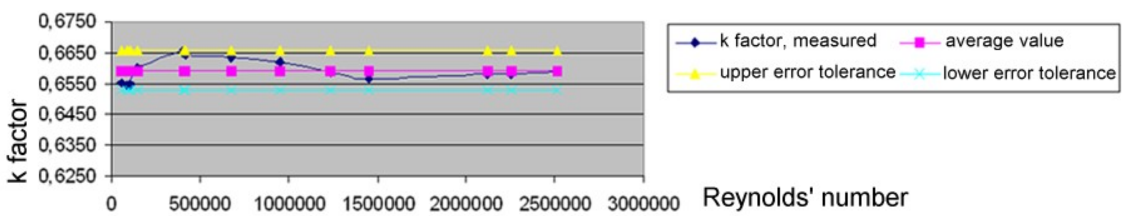


Figure 3: Dependency on the Reynolds number

As this diagram shows, the measured k factors - even in a larger range of Reynolds numbers - are still valid. Extrapolation into the range of smaller Reynolds numbers on the basis of the available measured results can only be made if an additional error can be accepted. To be able to make a reliable statement further test series are necessary. Extrapolation of the ranges of Reynolds numbers shown above into the range of larger Reynolds numbers on the basis of the measured results obtained is permissible. A restriction with respect to very large Reynolds numbers applies only in terms of the mechanical loads this would cause on the SDF flow probes.

Selection and specification of SDF flow measurement

Selection of an SDF probe with fixed basic design

The steps in designing an SDF flow probe according to the specific requirements of a particular measuring point assume that the basic decisions have already been reached. These basic decisions concern the design and fitting of the probe according to the medium (steam or other medium).

Step	The situation / selection step	Available options
1	Preselect the profile type according to internal diameter	Selection according to Figure 4
2	Acquire data regarding the medium, pipework, and flow and on this basis calculate the differential pressure	Approximation of maximum differential pressure
3	Choose probe material according to requirements of the medium and its condition	Standard material is 1.4571; for other materials see "Selection of suitable material"
4	Check the strength	Determine $\Delta p_{permissible}$ from Table 1. If $\Delta p > \Delta p_{permissible}$ increase the strength. Possible methods are: ➔ Choose a stronger profile ➔ Provide an end support Having chosen one or both of these options back to step 2.
5	Installation fittings: Installation type – Design of installation components – Nominal pressure PN – Material used for installation components	➔ Standard or special design? ➔ Installation component or weld-in probe? ➔ Installation component provided by customer (not recommended) ➔ Choice of material according to pipework material or other stipulations or directives ➔ Special features - sealing surface of flange, screw materials, etc.

Step	The situation / selection step	Available options
6	Connect differential pressure transducer and primary shut-offs	➔ Choose design of connections (observing permissible pressures and temperatures) ➔ Choose primary shut-off ➔ Stipulate material of primary shut-off
7	Specify accessories	Integrated pressure and / or temperature measurement, screw connections, 3-way or 5-way valves

Selection of basic design of SDF probe (I)

... According to the intended purpose

The first questions we have to consider are whether the probe needs to be frequently installed and uninstalled and whether or not the process would have to be interrupted to do so. This would be the case, for example, where the pipework is under high pressure or is carrying some hazardous substance.

SDF probes are normally installed in the pipe on a fixed basis and probe and pipe together form the measuring apparatus. The probe will only need to be removed - if at all - at relatively long intervals - for inspection purposes. Well over 90 percent of all SDF probes are installed once only and then never removed for the duration of the useful life of the whole pipework system.

Installation of this type means welding the probe into the pipe. In many cases work of this nature cannot be performed in the course of normal operation.

The process has to be interrupted.

The same applies of course when removing the probe - in particular in cases where the pipework is under pressure or is carrying a toxic or hazardous substance.

In certain exceptional cases, however, process interruption is simply unacceptable. For such special cases we offer our SDF ***"FASTLOK"*** series, a variant which can be installed and uninstalled during normal operation. Even welding work can - with a certain amount of extra preparation - be completed without requiring an interruption - even in Ex-Zone 0 (potentially explosive) pipework. However, this type of installation work must be performed by qualified specialists only.

... According to the medium to be measured

We must in this context distinguish between two further basic types, firstly SDF probes for gases and liquids and secondly SDF probes for saturated or overheated steam and vapor.
SDF probes intended for steam can be distinguished by the "D" in the 2nd position of their type code. Steam probes differ from other probe types by virtue of the condensate collectors they have fitted.
These condensate collectors thermally separate the process from the probe and the differential pressure connection. Without such collectors overheating would be inevitable and the electrical differential pressure transducer would be destroyed.

Selecting the profile type according to the internal diameter of the pipe and the expected stress

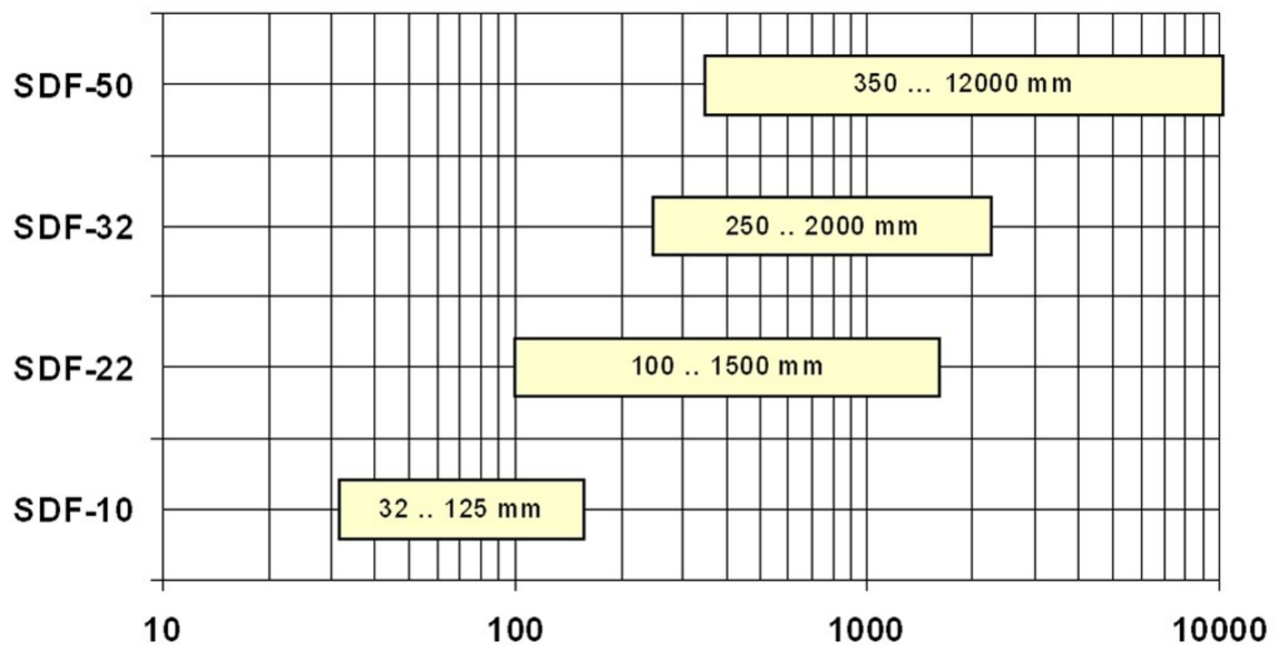


Figure 4: Recommended profile types for various ranges of diameter

With their different profile strengths SDF probes cover all diameter ranges from 40 mm up to over 10,000 mm. The graphic above illustrates the recommended application areas. The overlaps between the various profiles result from the fact that under certain loads more stable or otherwise more resistant probe variants are recommended.

End support - yes or no?

To protect SDF probes against mechanical overloading it may be necessary to fit a support for the probe on both sides of the pipe.

SDF probes are subject to the mechanical loads exerted by the force of the flowing medium's mass and also in some cases by their own inherent weight. This is unavoidable; it is a factor we take into account right from the planning phase. In situations where probes are exposed to unduly high loads the use of end supports can in fact quadruple their resistance to mechanical deformation.

For the mechanics specialists an SDF probe without end support is a "cantilever beam with line load". A probe with end support is a "constrained beam with movable bearing and line load".

Table 1 in the Annex explains the load limits of SDF probes in standard design depending on the pipe's internal diameter. Please carefully adhere to the limits listed in this table. Before beginning production of an SDF probe we carry out an in-house computerized check of the proposed design for its mechanical strength. However, if an end support does prove mechanically necessary, it is vitally important that it can indeed be fitted on site. With extremely long probes (pipework of >4 meters internal diameter) the calculations regarding bending may also have to take account of the probe's own inherent weight. Probes of this nature always need an end support.

An end support must satisfy the following demands:

- ➔ The probe must always be quick and easy to install - even in pipework with a large internal diameter
- ➔ The probe must be able to extend in its own longitudinal direction while permitting only minimum play in the medium's flow direction
- ➔ The end support must be suitable for the nominal pressure PN in question and as far as possible be made from the same material as the pipework itself (to ensure weldability)

Selecting a suitable material

SDF probes are normally manufactured completely from material 1.4571.

This material is extremely corrosion-resistant and can be used without problems under high pressures up to temperatures of 400 °C and under low pressures even up to 550 °C.

However, it is always absolutely necessary to check each application individually. In such cases please always consult us.

We can give you clear and unambiguous information and, so long as we know the general conditions and raise no objections, we accept responsibility for the stability of the material. All other appropriate materials above 1.4571 grade are available as options. The following section gives a brief overview of all the areas for which the principle materials are suitable.

Material 1.4571 (X6CrNiMoTi 17-12-2)

This material ensures good corrosion resistance in water and waste water - so long as the concentrations of chloride, salt, hydrochloric acid, and organic acids remain only low to medium. In the food and drinks industry its corrosion resistance is excellent. The surface is slightly rougher than e.g. material 1.4404; tempering colors from welding must not under any circumstances appear. The justification for using this grade of steel as opposed e.g. to 1.4404 is that it retains good strength characteristics at high temperatures. The tensile yield strength Rp0.2 at 550 °C is still over 60 percent of the value achieved at 100 °C. This material can be used at temperatures up to maximum 700 °C.

Material 1.4541 (X6CrNiTi 18-10)

The special quality of this material lies in its excellent resistance to inter-crystalline corrosion at temperatures above 550 °C. Its tensile yield strength Rp0.2 at 550 °C is higher than that e.g. of material 1.4571. It can be used continuously at temperatures up to maximum 850 °C in oxidizing atmospheres and up to maximum 750 °C in sulfurous oxidizing atmospheres. In other respects all the characteristics relevant for our purposes are similar to those of material 1.4571.

Material 2.4622 (X6CrNiTi 18-10) - Hastelloy C22

Hastelloy alloys are not actually counted as steels in the narrow sense of the term. Hastelloy C22 is very resistant to general corrosion, crevice corrosion, grain fracture and disintegration, and stress corrosion cracking. It is suitable for a wide range of applications wherever special demands are made as regards corrosion resistance. This alloy possesses for example outstanding creep strength characteristics - necessary in waste treatment, the chemicals industry, and for applications involving contact with seawater.

Material 2.4633 (NiCr25FeAlY) – Inconel 602

There are manufacturer-specific designations for this material, e.g. Inconel 602, alloy 602, or similar. Alloy 602 is extraordinarily resistant to oxidation at high temperatures and has very good corrosion resistance in carburizing, oxidizing, or chlorinating media. It also possesses excellent creep strength values at high temperatures. It can be used at temperatures up to maximum 1100 °C; its tensile yield strength Rp0.2 at 900 °C is higher than that of e.g. material 1.4571 at 500 °C. In other words alloy 602 is the right choice whenever there are unusually high demands regarding both chemical and thermal resistance.

Defining the nominal pressure PN

The nominal pressure PN is a rated value defined for the pipework being used. If the nominal pressure PN for the pipework is not yet known we need to resort to the appropriate tables. The nominal pressure PN must not be equated with the maximum permissible pressure. As the temperature rises, the maximum permissible pressure decreases substantially. The nominal pressure PN indicated refers to ambient temperature only.

The stabilizing zones needed

Some background information

The accuracy data indicated for each and every flow measurement always refers to test-bed conditions. In test-bed conditions a characteristic flow velocity distribution prevails over the whole cross-section of the pipe. For this distribution to form the flow needs two prerequisites: an undisturbed course and sufficient turbulence.

Each change in direction in the flow, however small and apparently insignificant, causes a "distortion" of the flow profile. When we talk about “flow profile” we mean the distribution of velocity over the whole cross-section of the pipe.

Each stationary flow is subject to two conditions:

1. What flows into a pipe must also flow out again.
   This condition is known as “continuity”.
2. The energy contained in a flow can change its form but never its absolute quantity. This condition is known as the “conservation of energy“. This is often also called the *Bernoulli condition*.

If we consider a simple right-angled pipe elbow, the problem becomes clearer; the medium as it flows round the curve must - depending on which course it takes - travel a longer or shorter distance. The inside lane slows down; the outside lane accelerates. Given the inertia of the flowing mass this velocity distribution is retained for a while after passing the elbow. But the story is not finished there.

According to Newton a body is forced into orbital motion by its acceleration towards the center of this orbit. In other words a flow is also produced transverse to the main flow direction. This is, we realize, all rather complicated.

However, since this flow is itself subject to the continuity condition, the same volume must flow towards the center of orbit as flows away from it.

This straightforward 90° elbow we have considered here in our example thus causes a different distribution of the velocities in the main flow direction and in the circular flow transverse to this main flow direction.

Give the flow time to calm down and stabilize.

In this context time means distance. And this in turn means straight pipe sections. What happens in a straight pipe section?

Forced industrial flows are normally turbulent flows.

Turbulence means that the flow contains a significant proportion moving transverse to the main flow direction. This transverse flow causes an exchange of material and energy. Medium from zones

under high pressure penetrates into zones under lower pressure. The tendency is always towards an equalization of pressure - and thus also of velocity. The sum of potential (pressure) and kinetic energy must, according to Bernoulli's conservation of energy condition, remain constant.
This is good news for us - because the more turbulence there is, the shorter the stabilizing zone needed to allow reliable flow measurement.

Why do SDF probes with short inlet sections cope better than other measuring systems? (I)

One of the "secrets" of pitot tube sensors is the arrangement of the measuring apertures. These are distributed over the probe profile in such a way as to permit geometric averaging.

If we map the pipe cross-section onto the SDF probe a number of rings are formed all with an equal surface area. The probe's measuring apertures are located on the geometric middle lines of these rings (i.e. the "center of gravity lines"). Each flow line that strikes the probe thus obtains its appropriate weighting.

If we compare the behavior of SDF probes with e.g. a conventional ultra-sonic device, the ultra-sonic method accords each flow line exactly the same weighting as all the others. The sonic signal passes for a certain period of time through the internal diameter of the pipe. In geometric terms the cross-section is subdivided into rings not of equal surface area but of equal width. However, this classic method of arithmetic averaging inevitably leads to incorrect measuring results. This is especially so if the profile is uneven - and that will in most applications be the case.

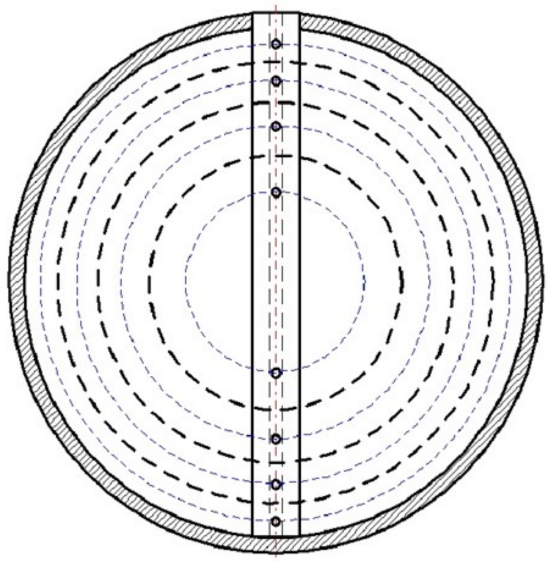


Figure 5: Location of measuring apertures - geometric averaging brings maximum accuracy

Why do SDF probes with short inlet sections cope better than other pitot tube sensors? (II)

Especially significant for the functioning of pitot tube sensors is the characteristic ratio between the volume of the probe interior and the size of the holes. This ratio should, for the purposes of measuring accuracy, be as large as possible.

For the purposes of reliability, however, there are certain limits; we can only make the measuring apertures so small without risking congestion by contaminants. And conversely we should not be misled into thinking that the bigger the holes the greater the probe's reliability. That is most certainly not true. In practice apertures of approximately 2.5 to 8 mm have proven to be the best choice. The basic approach is thus to have the afore-mentioned ratio between probe chamber size and probe apertures as large as possible but within reason.

The wisdom of this approach can be explained by considering one simple aspect; in an extreme scenario pressure differences would cause unwanted flows of medium between the apertures from a point of high pressure to points of lower pressure.

The smaller the flow resistance from outside to inside the probe, the greater these equalizing flows would become. However, the larger the apertures, the lower this resistance becomes.

The probe would thus need a very large interior volume in order to prevent even a relatively small amount of medium from slipping through the apertures. However, increasing this volume is for obvious reasons also subject to certain limits.

It comes down therefore to finding the right compromise - one that reduces the equalization flows inside the probe to a negligible amount.

This amount depends in turn on the pressure differences at the apertures; and the more the flow profile in a pipe is disturbed, the greater these differences will be.

In other words - there is only so much we can do to ensure the absolute accuracy of any probe. Minimizing all the unwanted factors as far as possible, e.g. by using very short inlet sections and coping as best one can with substantial disturbance - is one of the arts in designing reliable pitot tube sensors. SDF probes - with their unique design and enormous interior volume - keep a short nose ahead of the rest of the field.

That this is more than just a novelty on our part is a fact known and appreciated by numerous users who cannot implement standardized inlet and outlet sections and who have had salutary experiences using other measuring systems or pitot tube sensors.

Intelligent installation

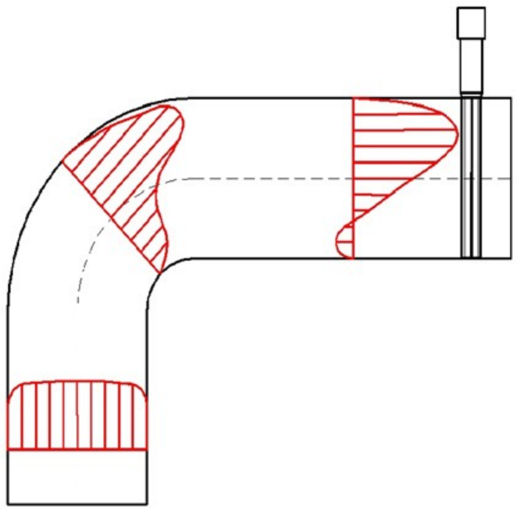


Figure 6: "Intelligent installation" - how installation takes proper account of velocity distribution

In simple applications it should be sufficient to keep a "watchful eye" on the pipework to see approximately how the velocity profile in the flow direction might be distorted. We take this "previous history" of the flow into account by confronting the probe as comprehensively as possible with the disturbances that actually emerge in the velocity distribution.

The adjacent Figure shows how it is possible by simply observing the expected distribution to raise the level of measuring accuracy compared with other setups. However, with complex changes of direction upstream from the measuring probe, this approach is less precise; and there may be yet more surprises waiting round the corner downstream.

Modifying the k factor

In situations where the inlet and outlet sections are substantially shorter than the recommendations as per DIN 1946 the most reliable method for determining the actual flow velocity in gas ducts is to perform a calibration measurement on site. With other media such checks using anemometer, Prandtl pitot tube, or similar apparatus are not advisable - because of the temperature and pressure conditions and the health risks involved.

The procedure is based on the formula for differential pressure probes:

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

The k factor defines the interplay between the probe, the pipe (of which the probe has, with its installation, become part), and the flowing medium. Since all other variables are a matter of physics, it is only the k factor that can actually define this interplay.

The k factor set on leaving our factory represents the ideal values we have determined in test-bed trials. The real k factor is the lever that can be used to correct any deviation between the test-bed and the specific measuring setup on site.

If you have a choice we recommend that you correct the k factor using a Prandtl, pitot, or similar system.

These measuring probes are not recommended for stationary, industrial use because of the low differential pressures and other characteristics. However, for calibration measurements on SDF probes they are very suitable because the influences of medium density that affect other measuring methods here cancel one another out. This simplifies the whole procedure substantially.

To perform a calibration measurement we must do two things:

1.) We must see as much of the flow as possible; i.e. the more measuring points at which information can be acquired the better. Ideal is if we can measure in at least two axes.

2.) We must weight the results in such a way that each measuring point is accorded exactly the significance it deserves. This can be achieved by arithmetical post-processing or by choosing the appropriate measuring points.

In practice it is easier to stipulate the measuring points in advance in such a way that weighting is then automatically correct. Of course it makes good sense if for the duration of the measuring operation conditions remain virtually constant.

Pronounced fluctuations in excess of 10 percent of flow rate lead to individual measured results that no longer agree.

Frequently asked questions about SDF probes

Why do I need a three-way or five-way manifold?

Three-way or five-way manifolds are used primarily for the zero-point adjustment of electrical differential pressure transducers. This is done by opening the middle valve of the 3-way manifold and then closing the process valves. As a result both chambers of the transducer are short-circuited and subject to the same pressure. This status can now be set as zero-point. This zero-point adjustment cannot be performed in the laboratory or at the manufacturer's works; it is an absolutely indispensable step concluding the installation of a differential pressure transducer at its intended location in the system. This adjustment is a routine maintenance task which must be performed at regular intervals and in addition after any heavy, asymmetrical overload on the transducer.

Can an SDF probe measure in both flow directions?

The unequivocal answer is yes. Any SDF probe can be used to measure in both directions - without the need for any additional constructional measures. We merely recommend using at least two transducers - one for each flow direction. The inactive transducer in each case assumes negative saturation; i.e. its output delivers a current of less than 4 mA, which means "no flow". The active transducer then delivers the plausible flow signal or differential pressure signal.

Although a solution with just one transducer and a zero-point at approximately 12.00 mA would theoretically be possible, this is in practice not advisable. In such a setup small deviations in the "0" position at 12 mA would lead to errors in identifying the flow direction. Using two transducers we can exclude this risk by suppressing small, negligible quantities.

I have ordered an SDF probe, type XX. What size should I drill the holes for fitting the installation components?

Our answer to this question is that each and every probe represents a unique and individual case. However, for standard nominal pressures (PN16) the following hole sizes apply:

Probe type	Main support	End support		
		Welding nipple / Cap	Mating flange	closed
SDF-M-10	21 mm	17 mm	--	16 mm
SDF-F-10	17 mm			
SDF-DF-10	17 mm			
SDF-M-22	37 mm	28 mm	36 mm	30 mm
SDF-F-22 SDF-DF-22	38 mm	28 mm	36 mm	30 mm
SDF-F-32 SDF-DF-32	38 mm	36 mm	38 mm	38 mm
SDF-F-50 SDF-DF-50	71 mm	54 mm	70 mm	

My measuring operation has produced a value that is too low. I am working at 100 percent of the design rating for mass flow (or for standard volume flow); the pressure is slightly lower than the design pressure. What could be causing this?

At lower pressure the medium expands more than at the higher design pressure. In other words, its density decreases. If you take a good look at the differential pressure formula (see Equation 1) you will notice that although density and velocity are inversely proportionate to one another their effects on the differential pressure are not the same. Whereas differential pressure increases in linear proportion to density it increases as the **square** of flow velocity.

As a result of the lower pressure the differential pressure exceeds the design value.

However, since the differential pressure transducer has been set for the design value it will be unable to cope with this higher value.

One remedy is to recalculate the differential pressure on the basis of the modified values for absolute pressure and reset the end value of the measuring range on the differential pressure differential pressure.

What influence does the pipe's internal diameter have on the measured result?

Internal diameter has a big influence. At a constant flow velocity the volume / mass flow increases with internal diameter by the square. For this reason, as recommended in the relevant standards, we must, in designing SDF probes, also take account of the expected thermal expansion of the pipework. It is also very important of course that the customer be extremely careful in measuring the real internal diameter of the pipe; failure to do so leads inevitably to substantial measuring errors.

Must one take account of the pipework's thermal expansion in calculating differential pressure?

The answer is yes. For more detailed information please refer to the preceding question and answer.

My measuring operation has produced a value that is too low. We have saturated steam at a certain pressure / certain temperature. What could be causing this?

One of the biggest mistakes in flow measurement in steam pipes is to assume automatically that saturated steam conditions prevail in the pipe in question. In fact saturated steam status as a stable operating point only really occurs in theory. It is a serious mistake simply to assume that at a pressure and temperature combination that would normally produce saturated steam that in fact saturated steam is actually present. It might just as easily be saturated water or a mixture of the two (wet steam). If the temperature rises even only slightly above saturation temperature the situation changes; then there will most certainly be pure steam (i.e. superheated dry steam). Or, the converse, if the temperature drops below saturation temperature or if the pressure exceeds saturation pressure then there will most certainly be water.

We have often experienced situations in practice where as a result of pressure losses and mistaken basic assumptions the actual status of the steam is a long way off the assumed saturation. Measuring errors in such circumstances may be quite pronounced. Our recommendation is therefore to be absolutely clear about whether the "saturated steam" assumption is really justified. Precise steam flow measurement also requires pressure and / or temperature measurement and a suitable computing module such as our µFLOW-WT flow calculator.

Our air quantity measurement shows incomprehensible fluctuations and deviations. We measure fresh air / hot exhaust gases. What could be causing this?

Condensate might be accumulating in the differential pressure pipes and not be able to drain off.
Please observe our advisory notes on installation - in particular the following rules:

➔ The differential pressure pipe must rise from the probe to the transducer by an exactly consistent incline.

➔ Its internal diameter must for safety reasons be larger than 8 mm throughout; the internal diameter must have these minimum dimensions to prevent congestion caused by the dominating force of adhesion between condensate and pipe.

➔ If it is not possible to satisfy these prerequisites please consider fitting insulation or heating to the differential pressure pipes to prevent condensation.

A routine inspection has revealed that the probe is heavily corroded in the vicinity of the pipe wall. What could be causing this?

The pipe wall might be much cooler than the temperature of the medium. This will cause the temperature in the chimney to fall below dewpoint. The condensate contains acidic constituents which trickle down the wall onto the probe. The area of the probe where this acidic condensate is continuously penetrating the material needs special protection. The standard material 1.4571 or the usual alternatives such as 1.4539 cannot in the long term really cope with this stress.
Please contact us and we can propose a solution to the problem.

Our system works in a dusty environment, 3000 mg/m³. Can you recommend a suitable solution?

Such environments are no problem for our air purging unit (LSE-HD). Please refer to the relevant data sheet on our Internet site:
http://www.ski-gmbh.com/online/04_pages_english/produkte/luftspueleinrichtung.htm

Our system works with air at a temperature of 650 °C. Is standard material 1.4571 suitable for this environment?

In purely mechanical terms this temperature is not a problem - so long as the probe is not being overloaded by its own inherent weight and the flow velocity is not unreasonable. However, the mechanical strength at 650 °C is only half as high as indicated in Table 1; (see Annex). This should not be forgotten. You should also remember that the normal resistance of many materials is also reduced in an oxidizing atmosphere. Air itself at very high temperatures may become an extremely aggressive medium.

The stabilizing zone upstream / downstream from the SDF probe in our system is shorter than you recommend. Can we still expect reasonable results?

The answer is basically yes - so long as you can exactly quantify the disturbance caused by these shorter inlet sections. Generally you can do this by analysing the velocity distribution in the pipe section under observation and then according to the findings finely adjusting the measuring setup installed in the pipe on a fixed basis.

This analysis is one of the standard services offered by SKI. Please call us; we can help you find the right solution to this problem or we can have our experts carry out this service for you.

What influence does the water vapor constituent have on the results of air quantity measurement ? How can I calculate this constituent?

The influence of water vapor makes itself felt in various ways. Firstly it affects the density. This aspect can in many cases be ignored, so long as air temperature and ambient temperature are close together. It does, however, become a problem when the temperature rises. With rising temperature the air's capacity for absorbing water vapor also increases. Since water vapor at ambient pressure has a lower density than air the medium expands substantially. Thus at constant air quantity the flow velocity increases; and since precisely flow velocity is the dominating influence on differential pressure, the differential pressure increases too. The consequence is substantial deviation between dry gas status and moist gas status. How to calculate this change in status is no trivial matter; it is too complicated to explain here.

To estimate the extent of the error, SKI can calculate the condition of your gas; this is one of the standard services offered by SKI. Please ask us; we can make you an offer.

When using orifices one must take account of the compressibility of the gas. Is this also the case with SDF probes?

The answer here is a definite "maybe". At low pressure the compressibility of gas is virtually negligible. However, at high pressure and high flow velocity the compressibility of the gas may have substantial effects. We always take account of this phenomenon therefore in all differential pressure calculations - even though in many applications involving gaseous media this is not significant.

How big is the measuring ratio (the "dynamic range") of an SDF probe?

Above the critical Reynolds number (approximately 10,000) the dynamic range of a probe is about 1:35 to 1:50; this is without the restrictions involving the accuracy of transmission. But this is just half the story. The other half concerns the limits of the electrical differential pressure transducer being used. These limits can only be influenced by using several transducers with one and the same SDF probe. The measuring range is then divided into a number of sub-ranges. Each such sub-range is then optimally covered by one transducer.

For a better understanding of this topic let us return to equations 1 and 2; the differential pressure is proportionate to the square of the flow velocity. This means that at 20 percent flow velocity (referred to maximum velocity) we have 4 percent differential pressure (referred to maximum differential pressure).

Everything now depends on which sub-range the connected transducer is covering and how exactly it is operating at this point. Clearly each case requires individual analysis. Other imponderables must also be taken into account. The influence of the pipe wall on flow characteristics is relatively low in a very large pipe compared, for example, with a DN50 pipe. We should therefore expect better results regarding dynamics from a large pipe than from a smaller pipe.

Our rule of thumb is that generally the permissible measuring ratio with just one transducer can be stretched up to maximum 1:6 / 1:7. To work with ratios above this and obtain results of sufficient quality that need no further correction you will certainly need luck on your side.

The measuring ratio can be further stretched by adding a second transducer for the lower measuring range. Theoretically in favorable cases a dynamic range of up to 1:50 could be obtained. Generally, however, the ceiling in practice is around 1:25. It all depends on the circumstances of each individual case.

What is it that actually determines the accuracy of an SDF probe?

- ➔ The inlet sections and any individual adjustments that may have been made
- ➔ The quality of the differential pressure transducer that is connected
- ➔ The precision of the data defining the pipework
- ➔ The manufacturing precision of our SDF probe
  (each probe is specifically checked and certified)
- ➔ The probe must have been correctly installed and the transducer correctly connected; (these steps are explained in detail in our operating instructions)
- ➔ The exactness of the differential pressure calculation; we guarantee this so long as the input data is correct and our calculation program (available via the Internet) is used;
  (see "Calculation for SDF probes via the Internet")

What does an accuracy indication of "1%" mean ? Exactly how exact is an SDF probe?

The indication "1% maximum deviation" refers to the transmission coefficient of an SDF probe across the velocity range we specify. This coefficient (the often cited "k factor") has been determined in a series of test-bed trials in accredited test laboratories (e.g. "Institute for Hydraulics" in Delft, Netherlands).

We would warn users, however, not to view this value in isolation. The test-bed conditions include ideal installation and setup (which in practical terms in industry do not always apply). At the end of a measuring chain the measured results may thus often be subject to substantial deviation. Such deviations have absolutely nothing to do with the probe. They usually result from uncertainties concerning the pipework and the stabilizing zones needed.

A probe manufacturer advertises with an accuracy of 0.6%. Why do SDF probes reach a value of only 1%?

The answer is quite simple; the performance data for SDF probes is provable, documented, and certified. Official documentation in our possession referring to the said competitor states perfectly clearly that the figure of 0.6 percent refers not to the product's accuracy but to the reproducibility of measured results obtained with it. Anyway, it is not our style to use one of our publications to reprimand competitors for spreading untruths.
Our latest results show, by the way, that SDF probes far outperform the said competitor in all areas. In official trials with critical pipes in the DN50 to DN200 range our SDF probes achieved accuracy levels of 0.5 percent. Our results do not rely on generous interpretation; they are provable, officially certified, reproducible, and comprehensible for everyone.

One of your competitors has a so-called "ImproveIt" program for improving accuracy with very short inlet sections. What do you say to that?

That's a nice advertising trick. A program like that would at a stroke make all simulations and test-beds superfluous. Anyone who has even seen the calculation matrix used in a flow simulation program knows what immense influence even the tiniest objects can have in fluid dynamics. Even welds or sediments downstream from a probe can adversely affect results if the distance is not sufficient for the disturbance to stabilize. To estimate the effects of a simple, known disturbance in qualitative terms is one thing but to make a quantitative statement about a more complicated disturbance, e.g. downstream from a U or S bend, is altogether a different matter - comparable to the attempts of ancient alchemists to turn all manner of cheap material into gold.

What is the smallest internal diameter of a pipe in which an SDF probe can be used?

With an SDF-10 probe the internal pipe diameter can be as little as 40 mm; and if the probe has been individually calibrated the internal diameter can be even less. However, the probe must have been calibrated in a special measuring section. If this is not the case, the influence of the pipework on the measured results cannot be reliably quantified.

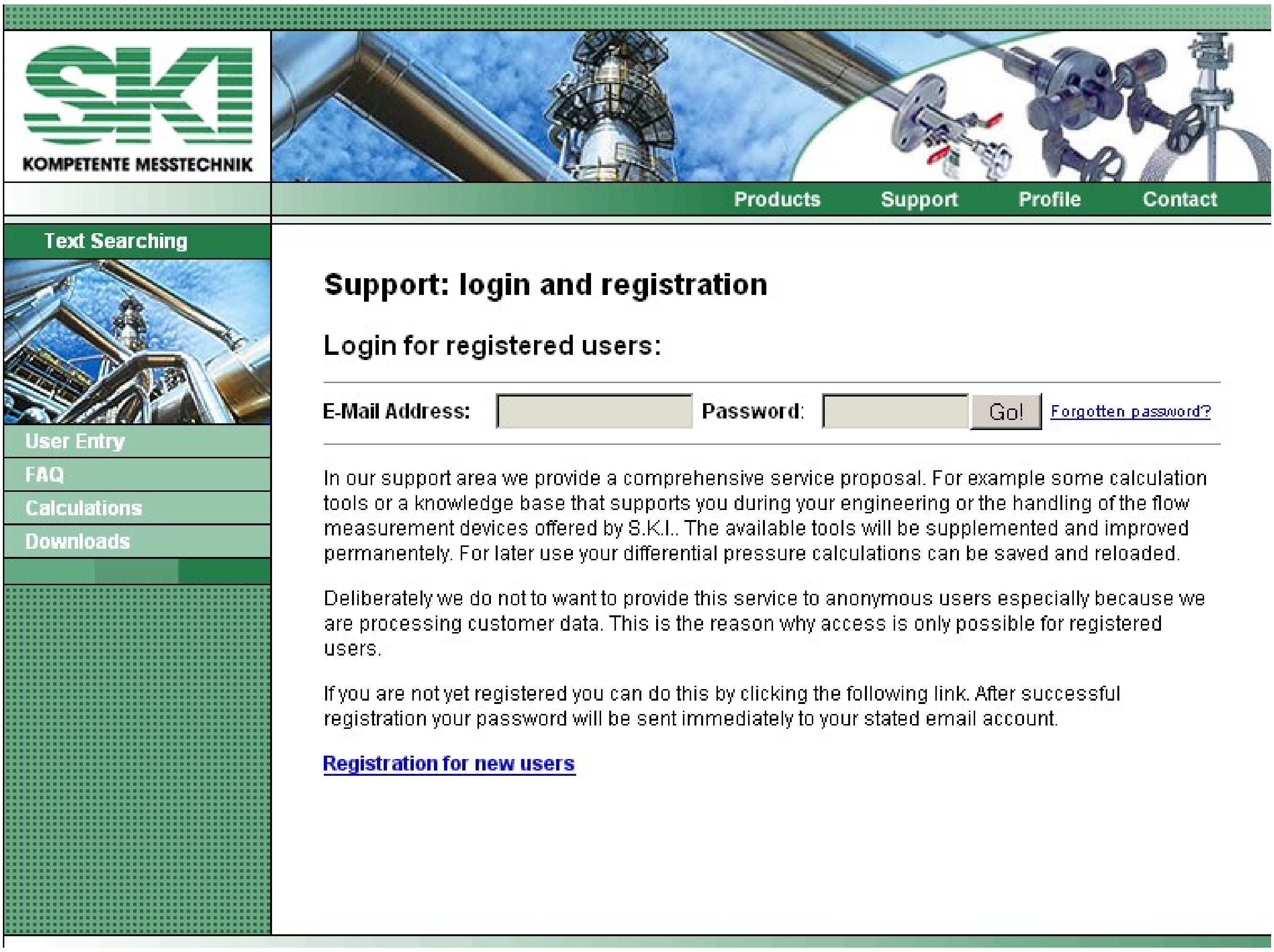
Calculation of SDF probes via the Internet

Registration

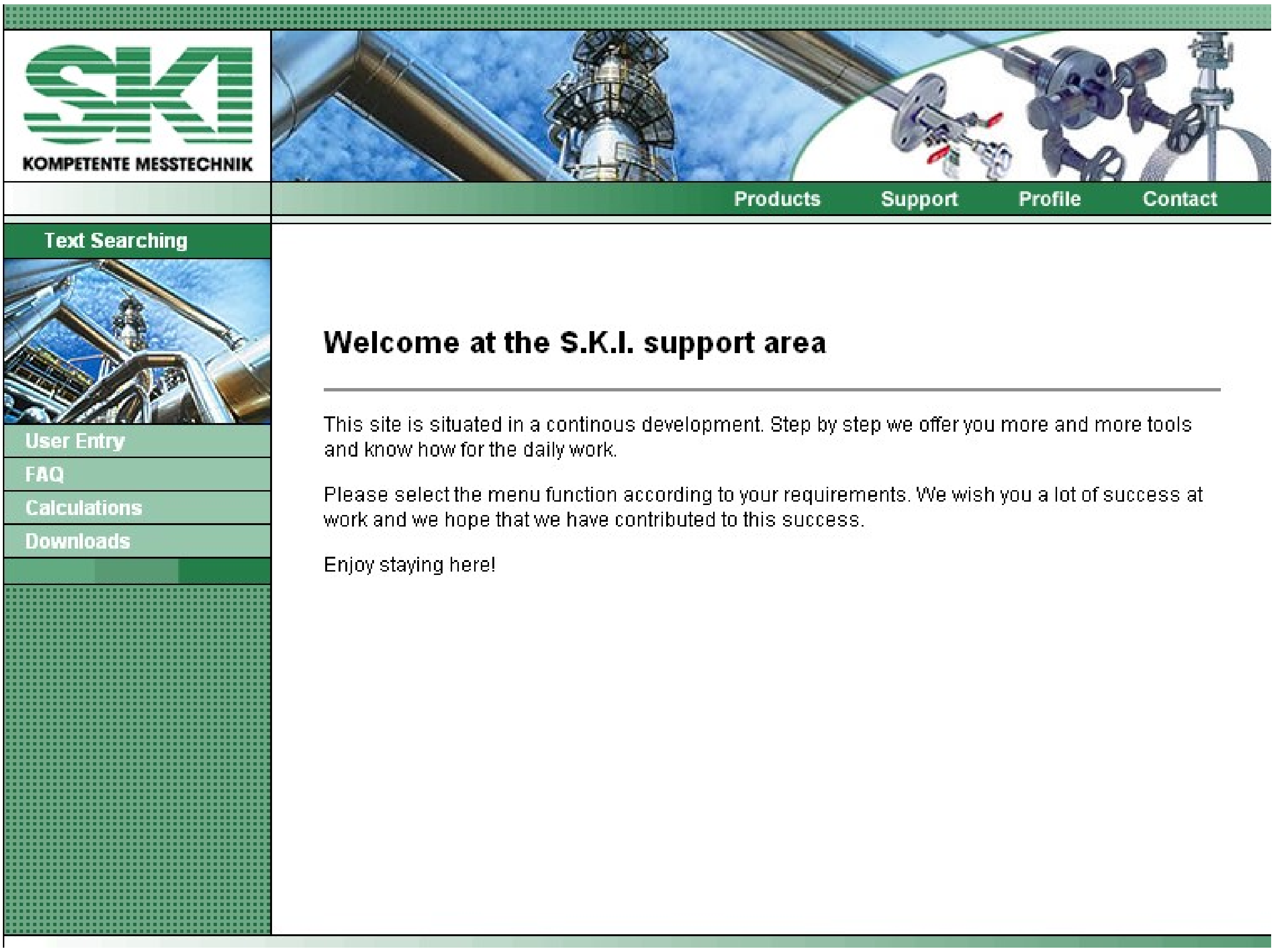
To use our differential pressure calculation program you must first register with us as a user. Click on the link "New users please register here" and complete the registration form that appears. Please do not use any special characters - not even in proper names. If you do the form will be keep being redisplayed and you will be unable to complete registration.

After just a few minutes you will receive an automatically generated e-mail providing a link for activating your user access. Please keep a note of the password supplied or set your browser to remember it for you.

And please note that, as with many other applications, your browser must have cookies activated. If cookies are not activated your user registration will not be saved on your computer.



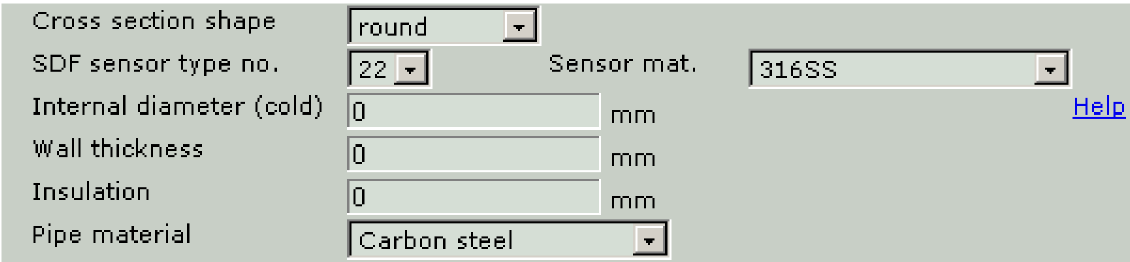
If you are a registered user you will be asked to enter your e-mail address and the password you have received (as shown in the previous screenshot). If you then click on "Go!" your browser will switch to the internal support level. By clicking on the menu item "Calculations" listed down the left-hand margin you can now navigate to the calculation form.



Calculating the differential pressure for an SDF probe

The input form is divided into a number of sections. In the header section you can enter information about yourself, your customer, the project, and the measuring point, plus your comments about the measuring point.

Immediately below the header section begins the section for data describing the combination of the pipe and the SDF probe you have chosen.



Basically this section, like the other sections, should be self-explanatory. Please note that results will only be exact if calculation takes account of the pipe's thermal expansion. This is why we have added "cold" in brackets after the internal diameter. Here you should enter the pipe's internal diameter at 20 °C. To enable the program to calculate the thermal expansion you must of course also enter the materials of which the probe and the pipe are made.

The third section in this form is for the medium; here you must enter the characteristics of the medium to be measured.

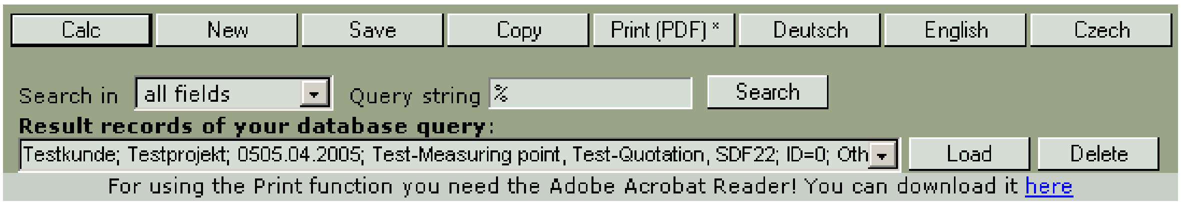
This section comprises a number of dropdown lists from which you can choose - gas, other media, etc.

The next section in the form is for the status and process data and for the calculated results. With most media all the fields (except those for flow, pressure, and temperature) are completed automatically as you enter information elsewhere in the form.

For more detailed information please refer to the following examples.

Actual density				kg/m^3
Temperature				C
Absolute pressure				kPa abs
Kinem. viscosity				m^2/s Help
Actual volume flow				m^3/h
k-factor (cold)	0			
k-factor (warm)	0.0000	0.0000	0.0000	
Internal diameter (warm)	0.0	0.0	0.0	mm
Expansion factor	1.0000	1.0000	1.0000	
flow velocity	0.00	0.00	0.00	m/s
Reynoldsnumber	0	0	0	
Calculated diff.pressure	0.00	0.00	0.00	mbar
Remaining pressure drop	0.00	0.00	0.00	mbar

The last section always looks the same; this is the navigation section; here you can control how the calculation program functions.



We do not really need to explain all the details of this section. Feel free to experiment a little; you cannot do any damage. Just a few words of explanation:

- If you click **"Calculate"** the program attempts to update all the fields in the form that you have not been able to complete. To do this the program draws on data you have entered so far.
- If you click **"New"** the program creates a new probe calculation.
- If you click **"Save"** the program saves your work. Important! When you create a new probe calculation the old one is not saved automatically.
- If you click **"Copy"** you make a copy of the current calculation. This is a good idea, for example, if you have a number of similar but not identical measuring points in a project.
- If you click **"Print (PDF)"** you generate a PDF document in your browser. You can save this on

your computer, send it by e-mail, or print out a hard copy on paper.

- By clicking on **"German"**, **"English"**, or **"Czech"** you choose the language for the input form and for the PDF document.
- In the **"Search in"** line you can search for one or more calculations.

  If you know only part of the search term you can enclose this in "%" signs.

  Example: **Search in | All fields | Search string | %waste% |**

  will find all terms such as: "waste", "waste-to-energy power plant", "hazardous waste incineration" etc.

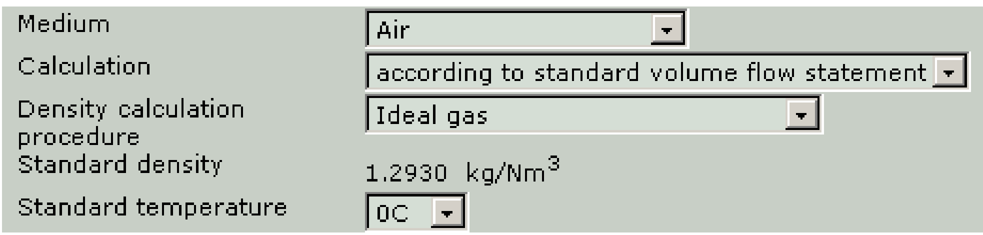
  The search results are listed in the subsequent combo box:

  Just select the data set you want, press **"Load"** to import it into your form or press **"Delete"** to remove the data set from the database. This delete process cannot be reversed.

Example 1: Calculation for air

If you have selected "Gas" as category, the field "Medium type" now provides a list of gases whose values are already stored in the program. If you want to measure a gas that is not included in this list, please select "Medium type" "Other gas" and in the field immediately to the right enter the actual name of the medium. In such cases you will also have to enter the medium data by hand.

The following screenshot shows how the area of the screen describing the medium changes when you enter for example "Medium type" "Air" and "Calculation" "According to standard volume flow data".



Medium	Air
Calculation	according to standard volume flow statement
Density calculation procedure	Ideal gas
Standard density	1.2930 kg/Nm^3
Standard temperature	0C

The form now includes a number of additional input fields. The differential pressure of a gaseous medium can be calculated from the data for velocity, mass flow, volume flow, or the standard volume flow. The calculation procedures involved are all slightly different. The program must therefore be told which data it should expect. In this example we have decided to base calculations on a standard volume flow. You can now see in the form how the subsequent input fields also change. We shall discuss this in more detail later.

The menu item "Density calculation" comprises a dropdown list with the options "Ideal gas" and "Real gas as per Redlich-Kwong". The specialists among our readers will know what this means. For other readers "Ideal gas" is the right choice here.

Standard density is a value listed in the relevant specialist literature; in our example, for air, this is 1.293 kg/Nm³. This value is based - as indicated by the last item "Reference temperature" “0 °C” - on the standard conditions valid in Germany, i.e. 0 °C and 101.325 kPa absolute pressure. In other countries other reference temperatures may apply; this can be set as required.

Let us now enter a few sample values for a fictitious waste air pipe with internal diameter 1286 mm. The measuring range is to be 0 to 60000 Nm³/h for temperature range -10 to +35 °C and absolute pressure roughly equal to ambient or atmospheric pressure. To determine the minimum differential pressure value you should use the highest pressure and the lowest temperature possible; to determine the maximum differential pressure value you should use the lowest pressure and the highest temperature possible. After entering all the above data our form should look like this:

Differential Pressure Calculation for SDF-Sensors

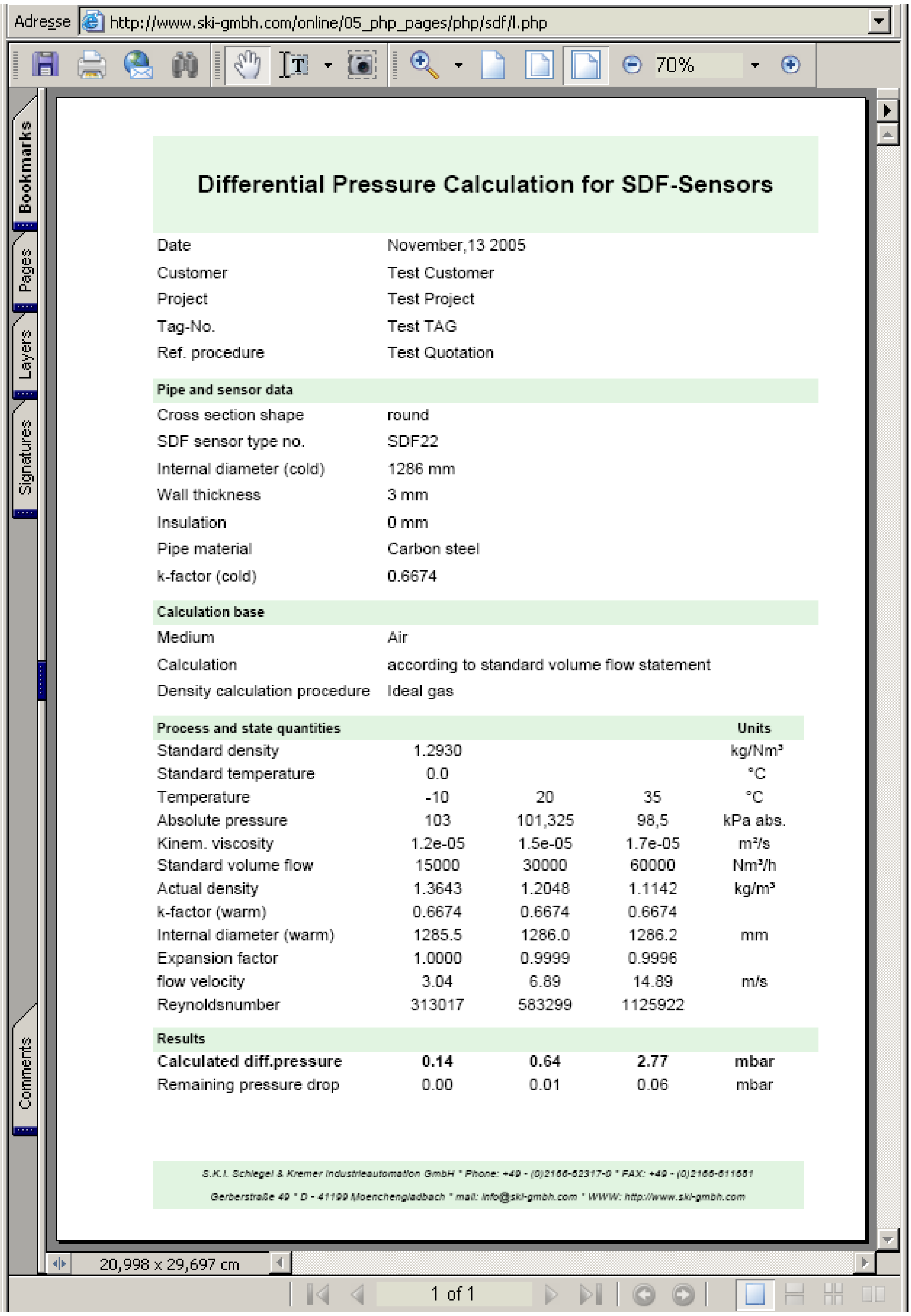
Date	November,13 2005			
Customer	Test Customer			
Project	Test Project			
Tag-No.	Test TAG			
Ref. procedure	Test Quotation			
Additional note (max. 255 char.)				
Cross section shape	round			
SDF sensor type no.	22	Sensor mat.	316SS	
Internal diameter (cold)	1286 mm			Help
Wall thickness	3 mm			
Insulation	0 mm			
Pipe material	Carbon steel			
Type of medium	Gas			
Medium	Air			
Calculation	according to standard volume flow statement			
Density calculation procedure	Ideal gas			
Standard density	1.2930 kg/Nm^3			
Standard temperature	0C			
Temperature	-10	20	35	C
Absolute pressure	103	101,325	98,5	kPa abs
Kinem. viscosity	-1.0e+00	-1.0e+00	-1.0e+00	m^2/s
Standard volume flow	15000	30000	60000	Nm^3/h
k-factor (cold)	0			
k-factor (warm)	0.0000	0.0000	0.0000	
Internal diameter (warm)	0.0	0.0	0.0	mm
Expansion factor	1.0000	1.0000	1.0000	
Actual density	0.0000	0.0000	0.0000	kg/m^3
flow velocity	0.00	0.00	0.00	m/s
Reynoldsnumber	0	0	0	
Calculated diff.pressure	0.00	0.00	0.00	mbar
Remaining pressure drop	0.00	0.00	0.00	mbar

If you click on the "Calculate" button the calculated values are displayed:

Differential Pressure Calculation for SDF-Sensors

Date	November,13 2005			
Customer	Test Customer			
Project	Test Project			
Tag-No.	Test TAG			
Ref. procedure	Test Quotation			
Additional note (max. 255 char.)				
Cross section shape	round			
SDF sensor type no.	22	Sensor mat.	316SS	
Internal diameter (cold)	1286 mm			Help
Wall thickness	3 mm			
Insulation	0 mm			
Pipe material	Carbon steel			
Type of medium	Gas			
Medium	Air			
Calculation	according to standard volume flow statement			
Density calculation procedure	Ideal gas			
Standard density	1.2930 kg/Nm^3			
Standard temperature	0C			
Temperature	-10	20	35	C
Absolute pressure	103	101,325	98,5	kPa abs
Kinem. viscosity	1.2e-05	1.5e-05	1.7e-05	m^2/s
Standard volume flow	15000	30000	60000	Nm^3/h
k-factor (cold)	0.6674			
k-factor (warm)	0.6674	0.6674	0.6674	
Internal diameter (warm)	1285.5	1286.0	1286.2	mm
Expansion factor	1.0000	0.9999	0.9996	
Actual density	1.3643	1.2048	1.1142	kg/m^3
flow velocity	3.04	6.89	14.89	m/s
Reynoldsnumber	313017	583299	1125922	
Calculated diff.pressure	0.14	0.64	2.77	mbar
Remaining pressure drop	0.00	0.01	0.06	mbar

If you click on the "Save" button your calculation will be saved; if you then also click on the "Print (PDF)" button the following display appears in your browser.



Differential Pressure Calculation for SDF-Sensors

Date	November,13 2005
Customer	Test Customer
Project	Test Project
Tag-No.	Test TAG
Ref. procedure	Test Quotation
Pipe and sensor data	
Cross section shape	round
SDF sensor type no.	SDF22
Internal diameter (cold)	1286 mm
Wall thickness	3 mm
Insulation	0 mm
Pipe material	Carbon steel
k-factor (cold)	0.6674
Calculation base	
Medium	Air
Calculation	according to standard volume flow statement
Density calculation procedure	Ideal gas

Process and state quantities				**Units**
Standard density	1.2930			kg/Nm³
Standard temperature	0.0			°C
Temperature	-10	20	35	°C
Absolute pressure	103	101,325	98,5	kPa abs.
Kinem. viscosity	1.2e-05	1.5e-05	1.7e-05	m²/s
Standard volume flow	15000	30000	60000	Nm³/h
Actual density	1.3643	1.2048	1.1142	kg/m³
k-factor (warm)	0.6674	0.6674	0.6674	
Internal diameter (warm)	1285.5	1286.0	1286.2	mm
Expansion factor	1.0000	0.9999	0.9996	
flow velocity	3.04	6.89	14.89	m/s
Reynoldsnumber	313017	583299	1125922	
Results				
Calculated diff.pressure	**0.14**	**0.64**	**2.77**	**mbar**
Remaining pressure drop	0.00	0.01	0.06	mbar

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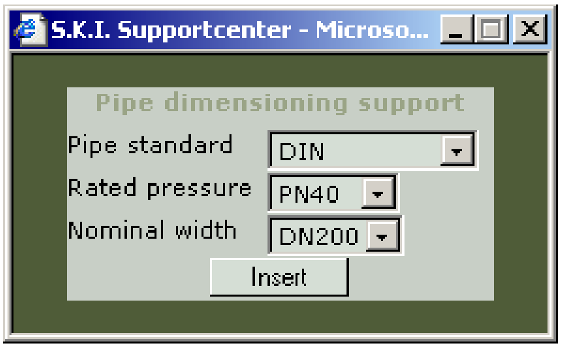
If you click on the "Back" button of your browser (top left) you return to the input form.

Example 2: Calculation for steam

If you have understood our first example for gas and air, the mathematics in our second example, the design for a steam probe, will seem much easier; the differential pressure calculation program here offers fewer options and - except for pressure, temperature, and flow rate - does everything automatically. “Density calculation” is performed automatically using the IAPWS-97 algorithm and produces results of the highest theoretically conceivable precision.

Let us imagine we want to fit an SDF-DF-22 probe in a pipe with DN200 nominal width and PN40 nominal pressure. The pressure is between 17 and 25 bar overpressure, the temperature is between 183.4 and 245.6 °C, and the flow rate is 0 to 40 t/h.

We enter these values one after the other; we can if we wish use the "Help" button on the right of the row "Internal diameter (cold)“. If you are using Microsoft’s Internet Explorer as your browser, a small window will now open in which you can select the pipe to be specified.



If having specified the pipe in question you now click on the "Insert" button, the pipe’s internal diameter and wall thickness will be inserted in the form automatically.

The input form should now look like this (or at least very similar):

Differential Pressure Calculation for SDF-Sensors

Date	November,14 2005			
Customer	Test Customer			
Project	Test Project			
Tag-No.				
Ref. procedure	Test Quotation			
Additional note (max. 255 char.)				
Cross section shape	round			
SDF sensor type no.	22	Sensor mat.	316SS	
Internal diameter (cold)	206.5	mm		Help
Wall thickness	6.3	mm		
Insulation	0	mm		
Pipe material	Carbon steel			
Type of medium	Other fluids			
Medium	Steam			
Calculation	acc. to mass flow statement			
Temperature	183.4	224.5	245.6	C
Absolute pressure	2600	2200	1800	kPa abs
Kinem. viscosity	0.0e+00	0.0e+00	0.0e+00	m^2/s
Mass flow	10000	20000	40000	kg/h
k-factor (cold)	0			
k-factor (warm)	0.6437	0.6437	0.6437	
Internal diameter (warm)	206.4	206.4	206.4	mm
Expansion factor	1.0000	1.0000	1.0000	
Actual density	0.0000	0.0000	0.0000	kg/m^3
flow velocity	0.00	0.00	0.00	m/s
Reynoldsnumber	0	0	0	
Calculated diff.pressure	0.00	0.00	0.00	mbar
Remaining pressure drop	0.00	0.00	0.00	mbar

If now, to conclude, you click on the "Calculate" button the following screen should appear:

Pipe material	Carbon steel			
Type of medium	Other fluids			
Medium	Steam			
Calculation	acc. to mass flow statement			
Temperature	183.4	224.5	245.6	C
Absolute pressure	2600	2200	1800	kPa abs
Kinem. viscosity	1.7e-07	1.5e-06	2.2e-06	m^2/s
Mass flow	10000	20000	40000	kg/h
k-factor (cold)	0.6437			
k-factor (warm)	0.6437	0.6437	0.6437	
Internal diameter (warm)	206.9	207.1	207.1	mm
Expansion factor	1.0000	0.9999	0.9991	
Actual density	-9999.9999	10.7540	8.0906	kg/m^3
flow velocity	0.09	15.34	40.76	m/s
Reynoldsnumber	115178	2039035	3834644	
Calculated diff.pressure	0.09	30.53	162.34	mbar
Remaining pressure drop	0.01	4.30	22.86	mbar

On closer inspection we see a large and confusing negative value for “Operating density” in the first column. This value is intended to draw our attention to the implausibility of some value we have entered. In our example this is caused by the temperature - pressure pair we have entered, namely 183.4 °C and 26 bar absolute.

In this status of course we would not have steam but water. This input is not compatible with "Steam" as selected medium. The display "-9999.9999" acts as an error message.

You will obtain the same error message if conversely you set "Water" as “Medium type” and the program calculates a status where steam must exist.

In our example the answer is thus to increase the temperature up to the saturated steam line. At the pressure we have chosen this lies above 226.05 °C; this can be calculated incidentally very easily using the tool provided via the following link: http://www.ski-gmbh.com/online/05_php_pages/php/sdf/steamcalc.php.

Having made this correction things look much better:

Temperature	226.06	224.5	245.6	C
Absolute pressure	2600	2200	1800	kPa abs
Kinem. viscosity	1.3e-06	1.5e-06	2.2e-06	m^2/s
Mass flow	10000	20000	40000	kg/h
k-factor (cold)	0.6437			
k-factor (warm)	0.6437	0.6437	0.6437	
Internal diameter (warm)	207.1	207.1	207.1	mm
Expansion factor	1.0000	0.9999	0.9991	
Actual density	13.0040	10.7540	8.0906	kg/m^3
flow velocity	6.34	15.34	40.76	m/s
Reynoldsnumber	1021122	2039035	3834644	
Calculated diff.pressure	6.31	30.53	162.34	mbar
Remaining pressure drop	0.89	4.30	22.86	mbar

Now you can save your calculation and / or print it out.

Annex:

Procedure for selecting and designing an SDF probe

- **Step 1**: Select the most suitable probe type and mechanical design according to three criteria:
    - Specific requirements (standard design or FASTLOK)
    - Medium (steam or other media)
    - Internal diameter (choice of profile)

  The most important points to be clarified here are: design, type of profile, installation method, end support.
- **Step 2**: Calculate the differential pressure for the selected probe from the available data on flow and medium.

  Note: In the early phase of project planning it is often not yet possible to issue an exact statement regarding the pipework and flow. In such cases the measuring point can only be designed and budgeted subject to certain reservations.
- **Step 3**: Check the feasibility of the measuring setup, in particular the compatibility of decisions taken in step 1 with results calculated in step 2.
    - Strength check: will the probe mechanically withstand the differential pressure that will occur? If it will not, then e.g. an end support can be provided; this can quadruple the probe's stability. If not even that is enough, you will have to use a stronger profile, e.g. instead of an SDF-22 perhaps an SDF-32 or even an SDF-50 probe.
    - This is especially important with FASTLOK probes on which the free length between the clamping positions is more than twice as much as with standard SDF probes.
    - If after repeating step 1 or 2 new decisions have been taken, of course a new calculation is required and then another repeat run of step 3.
- **Step 4**: Stipulate the probe's secondary features:
    - Material of which probe is made
    - Material of which installation components are made
    - Nominal pressure PN and special design features of the installation components
    - Differential pressure connection
    - Primary shut-offs
    - Integrated accessories
    - Pipe routing
- **Step 5**: Perform final calculation of differential pressure taking account of all influencing variables and check for mechanical stability and for oscillations.
- **Step 6**: Specify and select the most suitable electrical differential pressure transducer.

Details of how to modify the k factor

➔ Insert the calibration tube into the flow and measure the velocity in several different flow lines. The choice of measuring point depends on the immersion depth of the calibration assembly.

To properly perform this calibration the following equipment is recommended:

Tool	Purpose
Calibration probe (Prandtl pitot tube, vane-type anemometer, etc.), possibly with electronic evaluation or conversion devices	To take point-by-point measurements of the velocity
Tape measure	To survey and measure the pipework
Checklist, writing utensils, and pad	To record the raw values measured
Possibly a sliding protective sleeve for the calibration probe	To seal off the calibration probe against ambient effects
Water-proof marker-pen	To mark the immersion depths
Multimeter with DC input, 0 to 20 mA	To measure any output signals from the Δp transducer belonging to the SDF probe Ggf.
Sponge or other such "cleaning aid"	To erase old immersion markings on the calibration probe
Safety gloves	To protect against hot gases and heated calibration probe (only limited protection)

➔ Ensure that the apertures for the calibration assembly are available and correctly designed and constructed. Ensure that any significant overpressure or underpressure that may be present cannot escape through the calibration apertures. This would otherwise lead to substantial measuring errors and make the whole procedure a waste of time. The customer for his part must also pay particular attention when preparing the setup.

In some cases calibration measurements have failed simply because it was not possible to ensure the hermeticity of the muffs connecting the test pieces. In other cases errors in the installation of the SDF probe had to be corrected before calibration could start. A lack of adequate preparation can not only cause a lot of general Irritation but also, if plant has to be shut down and muffs have to be disconnected and rewelded, incur substantial extra costs.

➔ The immersion depths for the tip of the calibration assembly are calculated according to the afore-mentioned principle of geometric averaging. Normally you will have to push the calibration assembly and its tip through a certain length of bushing and possibly also through a pipe wall of uncertain thickness. Carefully measure the overall distance for all such external components. It is only after these components that the actual flow begins. The immersion depths are calculated according to the formula $T_i = h + ID * t_i$, where “h” is the height of the muff up to the inside edge of the pipe and “ID” is the internal diameter of the pipe.

The values of factor t_i can be taken from the following table:

Number of measuring points	t.1	t.2	t.3	t.4	t.5	t.6	t.7	t.8	t.9	t.10
6	0,955	0,855	0,705	0,295	0,145	0,45				
8	0,970	0,895	0,805	0,675	0,325	0,195	0,105	0,030		
10	0,975	0,920	0,855	0,775	0,655	0,345	0,225	0,145	0,080	0,025

➔ Before calibration the immersion depths can be marked on the calibration assembly relative to its tip. This facilitates the task appreciably.

➔ Enter the velocity or differential pressure of the calibration assembly in a table. In the same table in a separate column assign each test point the current measured value indicated by the SDF probe. The following table is a simple example of how measured values can in practice be acquired and entered.

No.	Calibration assembly		SDF probe	
	Value	Units	Value	Units
1				
2				
...				

Table 1: Maximum permissible differential pressure for SDF probes

Maximum permissible differential pressure for SDF probes [mbar]										
Nominal width (mm)	SDF 10	SDF-M-22		SDF-F-22		SDF-F-32		SDS-F-50		
		without	with	without	with	without	with	without	with	
	End support									
40	5887									
50	2278									
65	1059									
80	637									
100	386	10666		1497						
125		5495		771						
150		3474		488						
200		1807	4250	254	4250	663	10194			
250		1120	2635	157	2635	397	6109			
300		766	1801	107	1801	267	4100			
350		557	1311	78	1311	193	2966			
450		334	786	47	786	115	1762	348	4573	
500		270	635	38	635	92	1420	278	3651	
600		187	439	26	439	64	980	190	2491	
700		137	322	19	322	47	717	138	1811	
800			246	15	246	36	548	105	1378	
900			194	12	194	28	432	83	1084	
1000			157		157	23	350	67	876	
1000			130		130	19	289	55	722	
1200			109		109	16	243	46	606	
1300			93		93	13	207	39	515	
1400			80		80	12	178	34	444	
1500			70		70	10	155	29	387	
1600			61		61	9	136	26	339	
1700			54		54	8	121	23	301	
1800			48		48	7	108	20	268	
1900			44		44	6	97	18	240	
2000			39		39	6	87	17	217	

Table 2: Ordering code for standard probes with flange mounting

Ordering code for standard probes with flange mounting													
SDF-	-	-	-	-	-	-	-	-	-	-	-	-	
													Pipeline mounting
	F												Flange
	FX												Flange, special version
													Type of profile
		10											Internal diameter: 35-125 mm
		22											Internal diameter: 100-1500 mm
		32											Internal diameter: 400-2500 mm
		50											Internal diameter: 400-6500 mm
													Internal diameter
													Value with unit
													Wall thickness/ +Isolation
													Value with unit
													Wetted parts' material
					S								1.4571 (316Ti)
					R								1.4539 (Alloy 904L), with instrument connection R or X
					H								2.4602 (Hastelloy C22), with instrument connection R or X
					HT								2.4816 (Inconel 602), with instrument connection R or X
					X								Special version
													Mounting parts' material
						C							Carbon steel
						E							1.4571 (316Ti)
						X							Special version
													End support
							0						Without
							SC						Pipe thread with hood, carbon steel
							SE						Pipe thread with hood, 1.4571
							GF						With flange
							GG						Closed end support
							X						Special version
													Pressure gauge
													PN16, 300lbs or similar

Ordering code for standard probes with flange mounting

SDF-	-	-	-	-	-	-	-	-	-	-	-	Description
												Instrument connection
									N2			Nipple, ½-14-NPT male thread
									N4			Nipple, ¼-18-NPT male thread
									R2			Nipple, R½“ male thread
									R4			Nipple, R¼“ male thread
									R			Small pipe, 12 mm O.D.
									S			Hose stem 10,5×1,5
									FP			Flange plate for mounting of a 3-way manifold
									FPK			Flange plate for mounting of a 3-way manifold, rotated 90° e.g. for installation of Pt100 directly into the probe
									FPX			Special direct mounting device, e.g for multi-position tap
									X			Special version
												Primary shut-off
										0		Without
										KE		Ball valves PN40, 1.4401, max. 200°C
										AC		Shut-off valves PN420, ½“ NPT, carbon steel, max. 200°C
										AE		Shut-off valves PN420, ½“ NPT, 1.4571, max. 200°C
										ACH		Shut-off valves PN420, welding output, carbon steel, max. 450°C
										AEH		Shut-off valves PN420, welding output, 1.4571, max. 550°C
										DE1		3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF cadmium-plated, transmitter side metric stainless steel (only with FP)
										DE2		3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF stainless steel, transmitter side metric stainless steel (only with FP)
										DE3		3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF cadmium-plated, transmitter side 7/16-UNF cadmium-plated (only with FP)
										DE4		3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF stainless steel, transmitter side 7/16-UNF stainless steel (only with FP)
										X		Special version
												Special accessoried (multiple choice)
											0	Without

Ordering code for standard probes with flange mounting

SDF-	-	-	-	-	-	-	-	-	-	-	-	-	
											VC		1 pair of screw joints for pipe connection 12 mm, carbon steel
											VE		1 pair of screw joints for pipe connection 12 mm, 1.4571
											UC		Multi-position tap PN100 with scavenging connection, carbon steel, max. 200°C
											UE		Multi-position tap PN100 with scavenging connection, 1.4571, max. 200°C
											CH		One-sided purging apertures for compressed air connection (R1/8“)
											IH		Inspection and purging apertures (reasonable only with an end support)
											DSE1		3-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side metric stainless steel
											DSE2		3-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side 7/16-UNF stainless steel
											FSC1		5-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, carbon steel, max. 200°C, screws: transmitter side metric stainless steel
											FSC2		5-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, carbon steel, max. 200°C, screws: transmitter side 7/16-UNF cadmium-plated
											FSE1		5-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side metric stainless steel
											FSE2		5-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side 7/16-UNF stainless steel
											PC		Integrated pressure measurement for transmitter with screw adaptor end, shut-off with manometer shut-off valve PN400, carbon steel, max. 120°C, pressure measurement in mounting part, extra neck extenstion of 50 mm necessary (without transmitter)
											PE1		Integrated pressure measurement for transmitter with screw adaptor end, shut-off with manometer shut-off valve PN400, stainless steel, max. 120°C, pressure measurement in mounting part, extra neck extenstion

Ordering code for standard probes with flange mounting

SDF-	-	-	-	-	-	-	-	-	-	-	-	-	
													of 50 mm necessary (without transmitter)
											PE2		Integrated pressure measurement for transmitter with screw adaptor end, shut-off with manometer shut-off valve PN400, stainless steel, max. 120°C, pressure measurement in flow sensor's flange (without transmitter)
											T1		Integrated temperature measurement with Pt100, Class B, without transmitter, max. PN40
											T2		Integrated temperature measurement with Pt100, Class B, with transmitter 4-20 mA, max. PN40
											T3		Integrated temperature measurement with Pt100, Class B, with transmitter 4-20 mA, Ex-proof, max. PN40
												/	Integrated temperature measurement, thermowell made of 1.4571, measuring length for 22/32/50 probes: 1/3 I.D. + Isolation + 280 mm
											X		Special version
													Pipe run
												H	Horizontal
												V	Vertical (as well as diagonal run)

Table 3: Ordering code for standard probes with welding socket

Ordering code for standard probes with welding socket													
SDF-	-	-	-	-	-	-	-	-	-	-	-	-	
													Pipeline mounting
	M												Welding socket with cutting ring joint
	MX												Welding socket with cutting ring joint, special version
													Type of profile
		10											Internal diameter: 35-125 mm
		22											Internal diameter: 100-1500 mm
													Internal diameter
													Value with unit
													Wall thickness/ +Isolation
													Value with unit
													Wetted parts' material
					S								1.4571 (316Ti)
													Mounting parts' material
						C							Carbon steel
						E							1.4571 (316Ti)
						X							Special version
													End support
							0						Without
							SC						Pipe thread with hood, carbon steel
							SE						Pipe thread with hood, 1.4571
							X						Special version
													Pressure gauge
													PN16, 300lbs or similar
													Process connection
									N2				Nipple, ½-14-NPT male thread
									N4				Nipple, ¼-18-NPT male thread
									R2				Nipple, R½" male thread
									R4				Nipple, R¼" male thread
									R				Small pipe, 12 mm O.D.
									S				Hose stem 10,5×1,5
									FP				Flange plate for mounting of a 3-way manifold
									FPK				Flange plate for mounting of a 3-way manifold, rotated 90° e.g. for installation of Pt100 directly into the probe

Ordering code for standard probes with welding socket

SDF-	-	-	-	-	-	-	-	-	-	-	-	-	
									X				Special version
													Primary shut-off
										0			Without
										KE			Ball valves PN40, 1.4401, max. 200°C
										AC			Shut-off valves PN420, ½“ NPT, carbon steel, max. 200°C
										AE			Shut-off valves PN420, ½“ NPT, 1.4571, max. 200°C
										ACH			Shut-off valves PN420, welding output, carbon steel, max. 450°C
										AEH			Shut-off valves PN420, welding output, 1.4571, max. 550°C
										DE1			3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF cadmium-plated, transmitter side metric stainless steel (only with FP)
										DE2			3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF stainless steel, transmitter side metric stainless steel (only with FP)
										DE3			3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF cadmium-plated, transmitter side 7/16-UNF cadmium-plated (only with FP)
										DE4			3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF stainless steel, transmitter side 7/16-UNF stainless steel (only with FP)
										X			Special version
													Special accessoried (multiple choice)
											0		Without
											VC		1 pair of screw joints for pipe connection 12 mm, carbon steel
											VE		1 pair of screw joints for pipe connection 12 mm, 1.4571
											UC		Multi-position tap PN100 with scavenging connection, carbon steel, max. 200°C
											UE		Multi-position tap PN100 with scavenging connection, 1.4571, max. 200°C
											CH		One-sided purging apertures for compressed air connection (R1/8“)
											IH		Inspection and purging apertures (reasonable only with an end support)
											DSE1		3-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side metric

Ordering code for standard probes with welding socket

SDF-	-	-	-	-	-	-	-	-	-	-	-	-	
													stainless steel
											DSE2		3-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side 7/16-UNF stainless steel
											FSC1		5-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, carbon steel, max. 200°C, screws: transmitter side metric stainless steel
											FSC2		5-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, carbon steel, max. 200°C, screws: transmitter side 7/16-UNF cadmium-plated
											FSE1		5-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side metric stainless steel
											FSE2		5-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side 7/16-UNF stainless steel
											T1		Integrated temperature measurement with Pt100, Class B, without transmitter, max. PN40
											T2		Integrated temperature measurement with Pt100, Class B, with transmitter 4-20 mA, max. PN40
											T3		Integrated temperature measurement with Pt100, Class B, with transmitter 4-20 mA, Ex-proof, max. PN40
												/	Integrated temperature measurement, thermowell made of 1.4571, measuring length for 22/32/50 probes: 1/3 I.D. + Isolation + 280 mm
											X		Special version
													Pipe run
												H	Horizontal
												V	Vertical (as well as diagonal run)

Table 4: Ordering code for steam probes with flange mounting

Ordering code for steam probes with flange mounting													
SDF-	-	-	-	-	-	-	-	-	-	-	-	-	
													Pipeline mounting
	DF												Flange
	HF												Welded construction, special version
	DFX												Flange, special version
													Type of profile
		10											Internal diameter: 35-125 mm
		22											Internal diameter: 100-1500 mm
		32											Internal diameter: 400-2500 mm
		50											Internal diameter: 400-6500 mm
													Internal diameter
													Value with unit
													Wall thickness/ +Isolation
													Value with unit
													Wetted parts' material
					S								1.4571 (316Ti), max. 450°C
					15								1.5415 (15Mo3), max. 540°C
					35								1.7335 (13CrMo44), max. 540°C
					80								1.7380 (10CrMo910), max. 600°C
					X								Special version and other materials
													Mounting parts' material
						C							Carbon steel
						E							1.4571 (316Ti)
						15							1.4571 (316Ti)
						35							1.5415 (15Mo3)
						80							1.7380 (10CrMo910)
						X							Special version and other materials
													End support
							0						Without
							SC						Pipe thread with hood, carbon steel
							SE						Pipe thread with hood, 1.4571
							GF						With flange
							GG						Closed end support
							X						Special version and other materials

Ordering code for steam probes with flange mounting

SDF- - - - - - - - - - - - -	
	Pressure gauge
	PN16, 300lbs or similar
	Process connection
NT	Steam version with condensate pots (1.5415), max. 540°C
ET	Steam version with condensate pots (1.4571), max. 450°C
MT	Steam version with condensate pots (1.7335), max. 540°C
HT	Steam version with condensate pots (1.7380), max. 600°C
NFP	Steam version with condensate pots (1.5415), max. 540°C with flange plate for direct mounting of a 3-way manifold, without primary shut-off
NFPX	Steam version with condensate pots (1.5415), max. 540°C with special mounting device for e.g. welded valve manifold, without primary shut-off
X	Special version
	Primary shut-off
0	Without
AC	Shut-off valves PN420, carbon steel, with graphite packing, max. 300°C
AE	Shut-off valves PN420, 1.4404, with graphite packing, max. 300°C
ACH	Shut-off valves PN420, welding output, Carbon steel, max. 450°C
A5H	Shut-off valves PN420, welding output, 1.5415, max. 550°C
AEH	Shut-off valves PN420, welding output, 1.4404, max. 550°C
DE1	3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF cadmium-plated, transmitter side metric stainless steel (only with FP)
DE2	3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF stainless steel, transmitter side metric stainless steel (only with FP)
DE3	3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF cadmium-plated, transmitter side 7/16-UNF cadmium-plated (only with FP)
DE4	3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF stainless steel, transmitter side 7/16-UNF stainless steel (only with FP)

Ordering code for steam probes with flange mounting

SDF-	-	-	-	-	-	-	-	-	-	-	-	-	
										X			Special version
													Special accessoried (multiple choice)
											0		Without
											VC		1 pair of screw joints for pipe connection 12 mm, carbon steel
											VE		1 pair of screw joints for pipe connection 12 mm, 1.4571
											DSE1		3-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side metric stainless steel
											DSE2		3-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side 7/16-UNF stainless steel
											DWC1		3-way manifold for welding PN400 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, carbon steel, max. 200°C, screws: transmitter side metric stainless steel
											DWC2		3-way manifold for welding PN400 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, carbon steel, max. 200°C, screws: transmitter side 7/16-UNF cadmium-plated
											DWE1		3-way manifold for welding PN400 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side metric stainless steel
											DWE2		3-way manifold for welding PN400 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side 7/16-UNF stainless steel
											FSC1		5-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, carbon steel, max. 200°C, screws: transmitter side metric stainless steel
											FSC2		5-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, carbon steel, max. 200°C, screws: transmitter side 7/16-UNF cadmium-plated
											FSE1		5-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side metric stainless steel

Ordering code for steam probes with flange mounting

SDF-	-	-	-	-	-	-	-	-	-	-	-	-	
											FSE2		5-way manifold PN420 with ½"-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side 7/16-UNF stainless steel
											FWNC1		5-way manifold PN400 for welding with ½"-NPT socket connections for direct mounting to electrical d/p transmitter, carbon steel, max. 200°C, screws: transmitter side metric stainless steel
											FWNC2		5-way manifold PN400 for welding with ½"-NPT socket connections for direct mounting to electrical d/p transmitter, carbon steel, max. 200°C, screws: transmitter side 7/16-UNF cadmium-plated
											FWHC1		5-way manifold PN400 for welding with ½"-NPT socket connections for direct mounting to electrical d/p transmitter, carbon steel, max. 550°C, screws: transmitter side metric stainless steel
											FWHC2		5-way manifold PN400 for welding with ½"-NPT socket connections for direct mounting to electrical d/p transmitter, carbon steel, max. 550°C, screws: transmitter side 7/16-UNF cadmium-plated
											FWNE1		5-way manifold PN400 for welding with ½"-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side metric stainless steel
											FWNE2		5-way manifold PN400 for welding with ½"-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side 7/16-UNF stainless steel
											FWHE1		5-way manifold PN400 for welding with ½"-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 550°C, screws: transmitter side metric stainless steel
											FWHE2		5-way manifold PN400 for welding with ½"-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 550°C, screws: transmitter side 7/16-UNF stainless steel
											PC		Integrated pressure measurement for transmitter with screw adaptor end, shut-off with manometer shut-off valve PN400, carbon steel, max. 120°C, pressure measurement in mounting part, extra neck extenstion of 50 mm necessary (without transmitter)
											PE1		Integrated pressure measurement for transmitter with screw adaptor end, shut-off with manometer shut-off valve PN400, stainless steel, max. 120°C, pressure measurement in mounting part, extra neck extenstion of 50 mm necessary (without transmitter)

Ordering code for steam probes with flange mounting

SDF-	-	-	-	-	-	-	-	-	-	-	-	-	
											PE2		Integrated pressure measurement for transmitter with screw adaptor end, shut-off with manometer shut-off valve PN400, stainless steel, max. 120°C, pressure measurement in flow sensor's flange (without transmitter)
											T1		Integrated temperature measurement with Pt100, Class B, without transmitter, max. PN40
											T2		Integrated temperature measurement with Pt100, Class B, with transmitter 4-20 mA, max. PN40
											T3		Integrated temperature measurement with Pt100, Class B, with transmitter 4-20 mA, Ex-proof, max. PN40
												/	Integrated temperature measurement, thermowell made of 1.4571, measuring length for 22/32/50 probes: 1/3 I.D. + Isolation + 280 mm
											X		Special version
													Pipe run
												H	Horizontal
												V	Vertical (as well as diagonal run)

Table 5: Ordering code for FASTLOK probes

Ordering code for FASTLOK probes												
SDF-	-	-	-	-	-	-	-	-	-	-	-	
												Pipeline mounting
	AL											FASTLOK L – without draw-out mechanism, max. PN2
	AS											FASTLOK S – with draw-out mechanism, max. PN6
	AN											FASTLOK N – with draw-out mechanism, max. PN16
	AM											FASTLOK HD – with draw-out mechanism, max. PN64
	AX											Special version
												Type of profile
		10										Internal diameter: 35-125 mm
		22										Internal diameter: 100-1500 mm
		32										Internal diameter: 400-2500 mm
		50										Internal diameter: 400-6500 mm
												Internal diameter
												Value with unit
												Wall thickness/ +Isolation
												Value with unit
												Wetted parts' material
					S							1.4571 (316Ti)
					R							1.4539 (Alloy 904L), with instrument connection R or X
					H							2.4602 (Hastelloy C22), with instrument connection R or X
					HT							2.4816 (Inconel 602), with instrument connection R or X
					X							Special version
												Mounting parts' material (welding nipple)
						C						Carbon steel
						E						1.4571 (316Ti)
						X						Special version
												Packing gland's material
							G					Graphite
							U					Urethane
							X					Special version
												Process connection
								N2				Nipple, ½-14-NPT male thread
								N4				Nipple, ¼-18-NPT male thread
								R2				Nipple, R½“ male thread
								R4				Nipple, R¼“ male thread
								R				Small pipe, 12 mm O.D.

Ordering code for FASTLOK probes

SDF- - - - - - - - - - - -	
S	Hose stem 10,5×1,5
FP	Flange plate for mounting of a 3-way manifold
X	Special version
	Primary shut-off
0	Without
KE	Ball valves PN40, 1.4401, max. 200°C
AC	Shut-off valves PN420, ½“ NPT, carbon steel, max. 200°C
AE	Shut-off valves PN420, ½“ NPT, 1.4571, max. 200°C
DE1	3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF cadmium-plated, transmitter side metric stainless steel (only with FP)
DE2	3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF stainless steel, transmitter side metric stainless steel (only with FP)
DE3	3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF cadmium-plated, transmitter side 7/16-UNF cadmium-plated (only with FP)
DE4	3-way manifold, 1.4404. max. 200°C, screws: process side 7/16 UNF stainless steel, transmitter side 7/16-UNF stainless steel (only with FP)
X	Special version
	Special accessoried (multiple choice)
0	Without
VC	1 pair of screw joints for pipe connection 12 mm, carbon steel
VE	1 pair of screw joints for pipe connection 12 mm, 1.4571
UC	Multi-position tap PN100 with scavenging connection, carbon steel, max. 200°C
UE	Multi-position tap PN100 with scavenging connection, 1.4571, max. 200°C
CH	One-sided purging apertures for compressed air connection (R1/8“)
DSE1	3-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side metric stainless steel
DSE2	3-way manifold PN420 with ½“-NPT socket connections for direct mounting to electrical d/p transmitter, 1.4404, max. 200°C, screws: transmitter side 7/16-UNF stainless steel
X	Special version
	Pipe run
H	Horizontal
V	Vertical (as well as diagonal run)

List of figures

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