1. Introduction to Pitot Tube Flow Measurement

Pressure sensors are classified as Differential Pressure sensors for flow measurement.

The measuring principle of the pitot tube utilizes the differences between the pressure ridge on the upstream side of a bluff body and the static pressure on its down stream side.
.

ITABAR-pitot tube sensors, see sample Fig 1.1, are mainly used to measure the volumetric flow of liquids, gases and steam in closed pipes ranging from ½“ to 480“ (DN 20 to DN 12000).

Examples of their applications are precise volumetric flow measurement in batch processes, continuous measurement of liquid ingredients in the process industry, fuel, air, steam and gases as primary energy source as well as in control functions requiring a high degree of stability and repeatability.

Examplary in comparsion to almost all other flow measuring instruments is the ITABAR-sensor’s ease of installation. The installation consists of these steps: drilling of the pipe, weld-o-let is welded on to the pipe, ITABAR is inserted. Models Flo-Tap FT , see Fig 1.2, allows installation and removal without shutting the process down.

ITABAR-pitot tube sensors were developed with the goal of high reliability even under difficult conditions. ITABAR-pitot tube sensors are optimized in several ways with respect to fluid stream conditions. Advantages of the engineered sensor profile are their low permanent pressure loss as well as the constistent measurement accuracy over a wide range of Reynolds numbers.

For over two decades ITABAR-pitot tube sensors have been applied in the industrial world. Their examplary reliability and excellent long-term use record resulted in broad acceptance by customers. Many measurements by independent institutes are testimony to the ITABA-sensor’s high measuring accuracy.

Fig 1.1

Fig.: 1.2: Flo-Tap pitot tube sensor ITABAR FTM 20 for installation and removal under pressure

2. Measurement Principle of Pitot Tube Sensors

According to the continuity law derived by Bernoulli and the energy equation, the sum of the pressure energy and the potential and kinetic energy of a flowing fluid inside a pipe and in conditions of stationary and frictionless flow is the same at any time and in any part of the pipe.

$$p_{stat} + p_{dyn} = const \qquad \text{(Gl. 2.1)}$$

The factor p_{stat} is the static pressure equally distributed in all directions. The other term in the equation represents the dynamic pressure, effective in the flow direction, p_{dyn}.

For flowing fluids in horizontal pipes, with a small velocity compared to the Mach-number (Ma <<1), the dynamic pressure p_{dyn} of a fluid with a flowing velocity v, a density ρ and a resistance factor ζ is calculated as:

$$p_{dyn} = \zeta \frac{\rho}{2} v^2 \qquad \text{(Gl. 2.2)}$$

Inserting a fixed body into a flowing fluid causes the flow to dam up immediately upstream of the body and to be completely zero at S2 ,see Fig 2.1. At this point the total pressure p_{S2}:is

$$p_{S2} = p_{stat} + p_{dyn} \qquad \text{(Gl. 2.3)}$$

The apertures of the sensor's downstream side are only affected by the direction-independent static pressure p_{stat}. The difference in both pressures, the differential pressure Δp, is a measure of the velocity with which the inserted body is impacted, see Fig. 2.2.

$$\Delta p = p_{S2} - p_{S1} \qquad \text{(Gl. 2.4)}$$

Substituting Gl. 2 and 3 into 4 results in

$$\Delta p = \zeta \frac{\rho}{2} v^2. \qquad \text{(Gl. 2.5)}$$

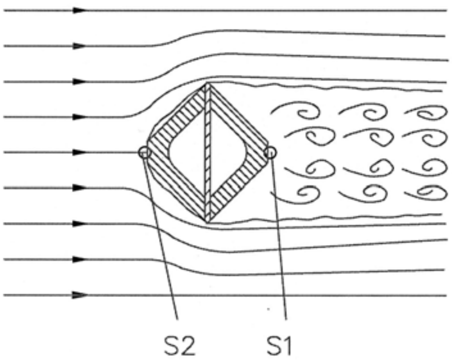

Fig. 2.1: Schematic representation of fluid flow pattern at location of ITABAR profile

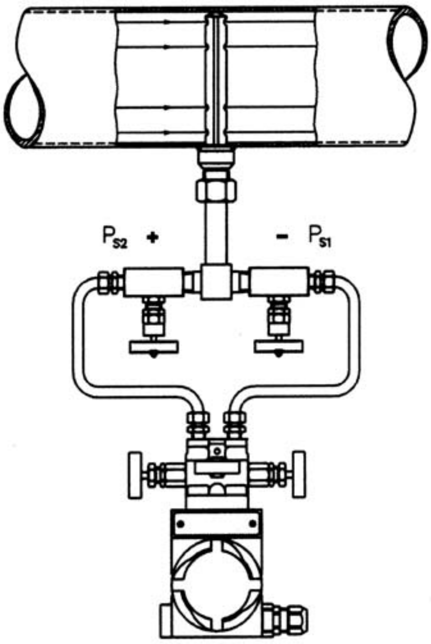

Fig. 2.2: Schematic representation of generating a differential pressure Δp

The volumetric flow can be calculated using the continuity law with a pipe area A and an average flow velocity. The following formulas can be derived

Volumetric flow for gases under standard conditions	$Q_{vn} = k*1{,}0159*A\varepsilon\sqrt{\frac{2\,\Delta p\;P_b\;Z_n\;T_n}{\rho_n\;T_b\;Z_b\;P_n}}$	2.7
Volumetric flow for gases under operating conditions	$Q_v = k*1{,}0159*A\varepsilon\sqrt{\frac{2\,\Delta p}{\rho_b}}$	2.8
Mass flow for gases and steam	$Q_m = k*1{,}0159*A\,\varepsilon\sqrt{2\,\Delta p\;\rho_b}$	2.9
Mass flow for liquids	$Q_m = k*1{,}0159*A\sqrt{2\,\Delta p\;\rho_b}$	2.10
Volumetric flow for liquids	$Q_v = k*1{,}0159*A\sqrt{\frac{2\,\Delta p}{\rho_b}}$	2.11

The following definitions apply :

		Units in equations				
		2.7	2.8	2.9	2.10	2.11
Δp	Differential pressure at sensor profile	Pa	Pa	Pa	Pa	Pa
ρ_n	Medium density at standard conditions	kg/Nm^3	---	---	---	---
ρ_b	Medium density at operating conditions	kg/m^3	kg/m^3	kg/m^3	kg/m^3	kg/m^3
ε	Expansion factor	1	1	1	---	---
A	Cross sectional area of the pipe	m^2	m^2	m^2	m^2	m^2
D_i	Pipe inside diameter	---	---	---	---	---
k	k-factor	1	1	1	1	1
P_b	Operating pressure	Pa	---	---	---	---
P_n	Absolute pressure of gas at standard conditions	Pa	---	---	---	---
Q_m	Mass flow	---	---	kg/s	kg/s	---
Q_v	Volumetric flow	---	m^3/s	---	---	m^3/s
Q_{vn}	Volumetric flow at standard conditions	Nm^3/s	---	---	---	---
T_b	Temperature of gases at operating conditions	K	---	---	---	---
T_n	Temperature of gases at standard conditions	K	---	---	---	---
Z_b	Real gas factor at operating conditions	1	---	---	---	---
Z_n	Real gas factor in standard conditions	1	---	---	---	---

The expansion factor needed to calculate the flow of gases and steam is computed as follows :

$$\varepsilon = 1 - \frac{\Delta p}{k(\ldots)\ \mathrm{P_b}} \left\{ \left(1 - \frac{2\ b}{\sqrt{\pi\ F}} \right)^2 0{,}31424 \quad - 0{,}\ 09484 \right\} \qquad \text{(Gl. 2.11)}$$

Symbol	Variable	Units
ε	Expansion factor	1
Δp	Differential pressure at sensor profile	Pa
P_b	Operating pressure	Pa
k	Isotropic exponent of gases (also: ratio of specific temperatures of ideal gases)	1
b	Width of sensor profile perperdicular to flow direction	m
F	Cross sectional area of pipe	m^2

For example: for one-atom (two-, three-atom) gases the isotopic exponent k of the gas has a value of k = 1.66 (1.4 und 1.3). The width of the sensor profile perpendicular to the flow direction depends on the sensor type (see page 13)

3. Required Fluid Conditions

Pitot tube sensors, such as orifice plates, flow nozzle or venturi tubes are classified as flow measuring devices which utilize differential pressure to measure volumetric flow. The technical descriptions in (German) DIN 1952 „Durchflussmessung mit Blenden, Düsen und Venturirohren in voll durchströmten Rohren mit Kreisquerschnitt“ are analogous to pitot tubes:

- The fluid has to completely fill the pipe so that the measured differential pressure is representative of the volumetric flow. Fluids in partially filled pipes can only be measured if a full pipe can be arranged (e.g. by means of a siphon)
- The fluid must be single-phase. Two-phase fluids (e.g. water-air mixtures) cannot be measured.

Fig. 3.1: Air purge unit LSP for automatic cleaning of pitot tubes used in gas and gas mixtures containing dust or bubbles

The average flow velocity v_m and the kinematic viscosity ν of the fluid to be measured in a given pipe size with an inside diameter d must reach a Reynold’s number value Re > 3150 according to the formula

$$\mathrm{Re} = \frac{v_m \, d_i}{\nu} \quad \text{(Gl. 3.1)}$$

meaning: the flow has to be sufficiently turbulent. Fluids of laminar nature cannot be measured with pitot tubes. Fluids may contain small particles or bubbles. The pressure generated in front of the sensor apertures causes a deflection of the particles or bubbles. Fluids which tend to cristalize will quickly plug the pressure tubes of the sensor and therefore cannot be measured with pitot tubes. Gases and gas mixtures containing dust can coat the sensor to an undesirable degree. To clean such dust desposits the air urge unit LSP (Fig 3.1) can be applied. This instrument will automatically flush out the sensor with air pressure in programmable intervals and durations . For flue gas mixtures a sensor version is recommended, which allows mechanical cleaning from both ends without having to take the sensor out of the pipe (see Fig 3.2)

In steam measurement applications condensate pots are used, inside of which a constant transition from steam to condensate and vice versa occurs. The pressure transfer is achieved via water columns.

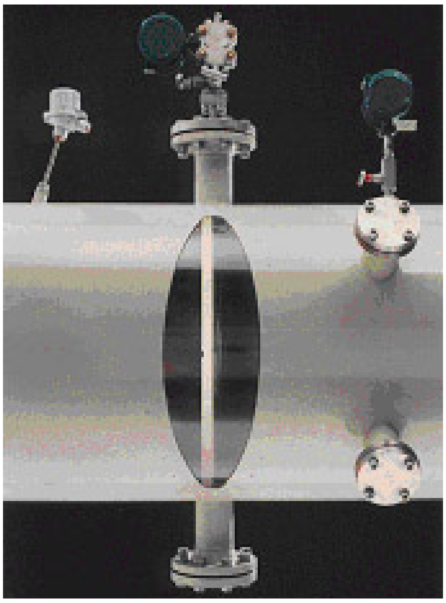

Fig. 3.2: Foto of sensor version IBF-100, developed specifically for flue gas measurement, installed in a (for demo purposes) transparent pipe. The sensor is accessible from both ends and allows mechanical cleaning without having to be taken out of the line.

4. Advantages of ITABAR-Pitot Tube Sensors

4.1 Advantages in Comparison to Orifice Plates

4.1.1 Lower Installation Costs

Compared to an orifice plate the ITABAR-sensor reduces material- and labor costs for the installation as well as operating expenses.

Part of the installation material costs of an ITABAR-sensor are the expenses for a weld boss and – depending on the sensor type – for a counter support fitting. The material costs for an orifice installation consist of two flanges and the necessary screws and hardware. The advantage in the ITABAR-sensors material costs are especially high for: large diameter pipes, pipe materials of exotic materials because of chemical compatibility issues, pipes for high pressure applications.

Labor costs for an ITABAR-sensor or orifice plate installation must include the wages for the welders. The installation of a weld boss requires – depending on the sensor type – a weld seam of approx. 10 cm (4“). The installation of a DN100 /4“ (DN500/20“) requires a weld seam of approx. 36 cm /14“ (approx. 628“). The time needed to install an orifice plate is approx. 12 hours, as compared to approx.1.5 hours for an ITABAR-sensor. The ITABAR-sensor in this case saves 10.5 labor hours.

The total savings in material- and labor costs which can be realized by using an ITABAR-sensor are at least 25% in a 4“ pipe installation and at least 70% in a 20“ pipe installation.

4.1.2 Bi-Directional Flow Measurement

The profile of all ITABAR-pitot tube sensors is designed to be symmetrical to the plane between the pressure channels. This arrangement results in the same resistance values and thus the same k-factor with respect to the fluid properties during forward as well as reverse flow. The differential pressures generated by a given flow velocity are the same for flow in either direction. They only differ in the +/- sign

This constitutes an advantage over to the orifice plate, see Fig 4.1), which - because of its angled downstream corner – has different resistance values for forward and reverse flows. It would indicate widely different differerential pressures for the same flow velocity in opposite directions.

The differential pressure measurement and processing can be accomplished with either one or two signal converters. The use of two signal converters is justified in cases requiring a high resolution or if separate signals are needed for forward and reverse flow.

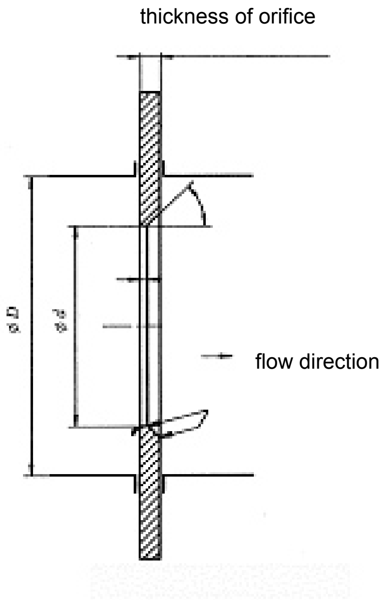

Fig. 4.1: Orifice plate for volumetric flow measurement

4.1.3 Shorter Up/Down Straight Pipe Run Requirements

In order to increase the ITABAR-sensor's measurement accuracy the dynamic and static pressures are measured at four points along the sensor profile and averaged. A non-symmetrical flow profile thus has a smaller influence on the measured result. This leads furthermore to shorter up/down stream straight pipe run requirements. For example: The ITABAR-sensor requires 7 straight pipe diameters downstream of a 90°-bend. An orifice plate requires 10 to 46 times as much depending on the β ratio.

4.1.4 Lower Permanent Pressure Loss

The sensor profile of the ITABAR-sensor is optimized with respect to the conditions of a flowing fluid and causes – in comparison to an orifice plate – a considerably smaller permanent pressure loss. The following application example is to illustrate this point: pipe size 10 inches (DN 250 PN 16); fluid: water; fluid temperature T = 68 °F (20 °C); operating pressure p = 29.01 psia (2 bar abs); volumetric flow Qv = 770 GPM (175 m3/h) and average flow velocity = 3.2 FPS (0,99 m/s).

Type	Ratio of diameters ß	D/ mm	d/ mm	Diff. Pressure/ mbar	Pressure loss/ mbar	Ratio of perm. pressure loss vs differ. pressure / %	Required up stream straight pipe run after 90°-bend	Required downstream straight pipe run before 90°-bend
ITABAR IBR-25	---	250,4	---	12,48	1,36	10,9	7 x DN	3 x DN
Orifice plate	0,25	250,4	62,6	2874	2730	95,0	10 x DN	4 x DN
Orifice plate	0,3	250,4	75,1	1386	1247	90,0	10 x DN	5 x DN
Orifice plate	0,35	250,4	87,6	748	636	85,0	12 x DN	5 x DN
Orifice plate	0,4	250,4	100,2	439	351	80,0	14 x DN	6 x DN
Orifice plate	0,45	250,4	112,7	274	205	74,8	14 x DN	6 x DN
Orifice plate	0,5	250,4	125,2	180	126	70,0	14 x DN	6 x DN
Orifice plate	0,55	250,4	137,7	123	80	65,0	16 x DN	6 x DN
Orifice plate	0,6	250,4	150,2	87	52	59,8	18 x DN	7 x DN
Orifice plate	0,65	250,4	162,8	63	35	55,6	22 x DN	7 x DN
Orifice plate	0,7	250,4	175,3	47	23,4	49,8	28 x DN	7 x DN
Orifice plate	0,75	250,4	187,8	35,5	16	45,1	36 x DN	8 x DN

As this example illustrates it is possible to reduce the permanent pressure loss of an orifice plate by selecting the proper diameter-ratio ß = d/D. The price to be paid for this is a considerable increase in longer straight pipe run requirements. The comparatively higher permanent pressure loss of orifice plates can be explained by their increased influence on the flow profile and related generation of eddy currents.

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In summary: Compared to orifice plates pitot tubes have the advantage of causing considerably lower permanent pressure losses while generating useful differential pressures. A further advantage is the need for shorter up/down stream straight pipe requirements.

The ITABAR-sensor's lower permanent pressure loss reduces the the energy- and thus operating costs of a measurement point considerably. In many applications the replacement costs of an ITABAR-sensor for an orifice plate are amortized within a very short time period

4.2 The ITABAR-Sensor Profile

4.2.1 Design Advantages For Flow Measurement

Unique Sensor Profile

The design of the ITABAR-sensor profile, see Fig. 4.2, is optimized with respect to fluid flow properties, and meets the technical challenges of accurate measurement as well as static and sensor-oscillating problems.It represents a forward step in technical development.

Excellent Linearity

A significant improvement in the sensor design with respect to the fluid properties is the shape of the sensor profile. The fluid separation takes place at the same spot on the sensor over a wide range of Reynols numbers, which results in minimal Reynold number dependency. This specially designed ITABAR-sensor profile achieves excellent linearity over a wide measuring range.

Examplary Reproducibility

The form design of the sensor profile not only improves the linearity but also the reproducibility of the measurement in cases of averaging within certain time intervals. The result is especially positive with shorter time intervals

Superior Averaging

In order to reduce the influences of in most cases less than ideal flow profiles, the differential pressures representing the local flow velocities are measured at four points, averaged and processed. Each of these four measuring points has pressure sensing apertures located opposite from each other. The positioning of these pressure apertures is designed for fluid flow profiles as they are encountered in real applications. .

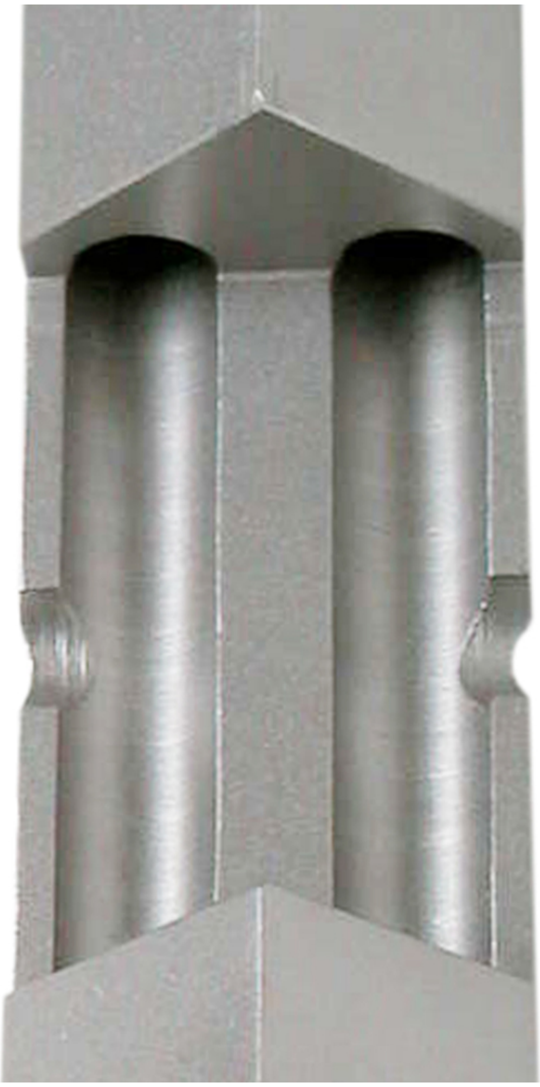


Fig.4.2: Sensor profile of pitot tube model 35/36 in a cut-away view to illustrate the two pressure channels near the pressure apertures.

Large Pressure Apertures and Pressure Channels

Large diameter pressure sensing apertures and pressure channels allow the long term uninterrupted use even in contaminated fluids. Condensate in form of drops can more easily flow off through the larger areas. A mechanical blockage of the pressure channels through condensate drops is thus eliminated. The table below lists the characteristic dimensions depending on the type of sensor.

	Sensor Type				
	15	20/21	25/26	35/36	65/66/100
Width of profile perpendicular to flow	11 mm	12 mm	25,4 mm	42 mm	56 mm
Height of profile in flow direction	10,5 mm	11 mm	23 mm	36 mm	50 mm
Diameter of pressure sensing apertures	4 mm	4 mm	8,5 mm	10 mm	16 mm
Area of pressure channel	28 mm^2	14 mm^2	62 mm^2	78 mm^2	113 mm^2

Very Good Mechanical Stability

The mechanical stability in situations of static and dynamic stress to the sensor profile is one of the most important criteria in the constructive design of the sensors.

The dislodging of a one-side mounted sensor profile through static stress caused by the flowing medium is inversly proportional to the 2nd degree axial area-momentum of the sensor.. For this reason the ITABAR-pitot tube sensor is designed with a very high 2nd degree axial area-momentum. Similar arguments are valid for a sensor’s resonance-frequency oscillations, which are determinant for dynamic stresses.

Commercially available pitot tubes made of only 1 mm thick stainless steel sheet metal have a low 2nd degree axial area-momentum. The mechanical stability of such thin-sheet sensors under static and dynamic stresses is lower compared to the ITABAR-sensor (e.g. as shown in Fig 4.2).

ITABAR-Sensors Are Better Than Any Cylindrical Sensor

Pitot tube sensors with a cylindrical sensor profile do not belong to the same class as ITABAR pitot tube sensors. The differences lie in the form and design of cylindrical sensors.

A typical cylinder-shaped sensor consists of a thin walled pipe with four sensing ports to measure the total pressure and one sensing port to measure the static pressure. The static pressure is lead to the outside via a thin pice of pipe located inside the sensor profile. The main disadvantages are measurement inaccuracies and poor reproducibility. The reasons for this are a weakly defined technical relationship to fluid flow properties and thus a Reynols number dependence. Contrary to a sharp-edged sensor profile design the fluid separation point is not fixed on the sensor (see Fig 4.3). As a result the resistance value c_w is very much Reynolds number dependent, see Fig. 4.4. A sensor's k-factor is derived from its resistance value as follows:

$$k = \sqrt{\frac{1}{c_w}}$$

For example a 10% change in the k-factor causes a change in the measured volumetric flow value of also 10%. For this reason a k-factor dependence on Reynolds numbers is not desirable.

Further disadvantages of cylindrical sensors are their lack of mechanical stability and their inaccurate performance in bi-directional flow measurement.

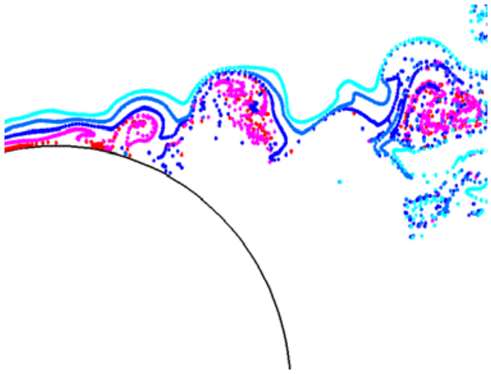


Fig. 4.3: Stream lines illustration at the separation area of a cylindrical shaped pitot tube sensor. Using a finite-element-method calculation, this computer graphic shows the fluid conditions at a Reynolds number Re = 20.000

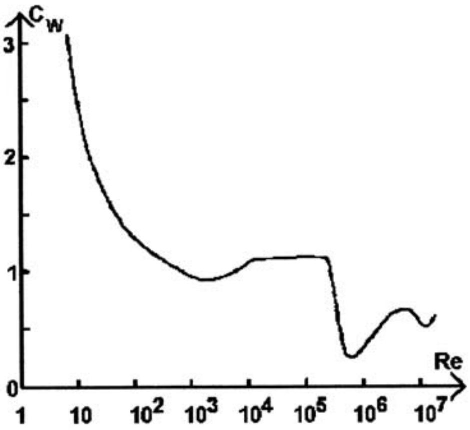


Fig. 4.4: Resistance value c_w of a cylindrical pitot tube sensor as a function of Reynolds number

4.2.2 Sensor Profile with Integrated RTD resitance thermocouple

In order to measure the fluid temperature all ITABAR-pitot tube sensors – with exceptions: IBFD-HT, IBFD-HTG and types –20/21 – can optionally be equipped with a RTD resistance thermocouple, see Fig 4.5. The advantages of the selected thermometer are as follows:

- The resistance thermometer is rod shaped, of robust design for long term use.
- A st steel (material 316 SS) tube provides a reliable protective cover for the the resistance thermometer.
- This version is designed with long term reliable components for industrial applications with increased challenges of oscillations.
- The temperature sensor is of 3-wire design in order to reduce the effective resistance.
- The resistance thermometer is usable in a temperature range from – 200 to + 500°C (-148°F to +842 °F).

The constructive solution of inserting the resistance thermometer is unique and convinces with the following advantages:

- The resistance thermometer is inserted into the sensor profile, see Fig 4.6 for a cross-sectional view of the sensor profile for a resistance thermometer assembly. With this method it is not a fluid wetted part, nor is it exposed to operating pressures.
- This design together with the rod-shaped version of the resistance thermometer allows for easy and quick installation and removel under pressure.

The temperature sensor is positioned along the sensor axis in between the two pressure channels. After all thermic adjustments in the vicinity of the temperature sensor it measures the fluid temperature along the pipe axis.

Fig 4.5: Pitot tube sensor type IBR with integrated resistance thermometer. Right side: opened junction box

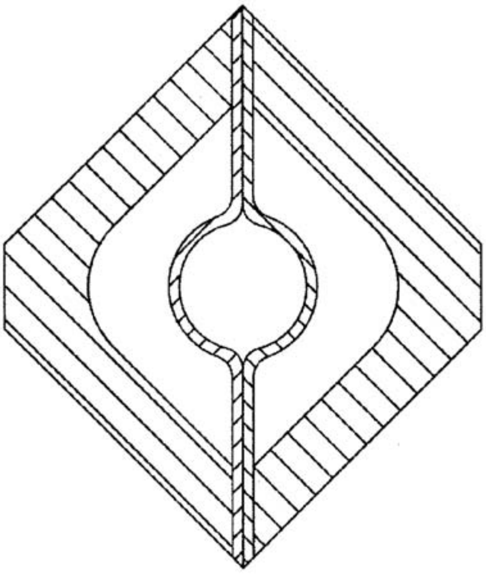


Fig. 4.6: Cross-sectional view of a type 25/26/35/36/65/66/100 sensor profile for insertion of a resistance thermocouple

4.3 Patented ITABAR-Sensor Series Flo-Tap

4.3.1 Retroactive Installation In Under-Pressure Conditions

The current level of technical development allows only a few flow measurement devices to be installed retroactively, when a process interruption is expensive and to be avoided. Some criteria to be considered as part of the flow meter selection process are: the type of fluid to be measured, the desired measurement accuracy as well as purchase and installation costs. The following table compares several competing flow metering technologies, which can be installed under pressure, with respect to these criteria:

Flow Measurement Instrument	Applicable fluids	Method applied to read average flow velocity	Accuracy	Purchase costs	Installation costs
Pitot tube sensor ITABAR, series Flo-Tap	Liquids, gases, steam	Averaging of four flow representative locations	± 0.5 % of rate	low	medium
Non intrusive ultra sound sensors (transit time)	Liquids with air- or gas content of < 3 Vol. %	Averaging along the ultrasonic beam between ultrasonic sensors	± 1-3 % of rate	high	low
Non intrusive ultra sound flow sensor (Doppler)	Liquids with evenly distributed air-,gas- or particles	Averaging along narrow ultrasonic beam	± 1 % of rate	medium	low
Electro-magnetic sensors (insertion type)	Liquids with conductivity > 5 µS	Localized measurement in vicinity of sensor electrodes	± 2-3 % of rate	low	medium

For many applications, which require an under-pressure installation, the ITABAR pitot tube series Flo-Tap is the first choice. A retroactive Flo-Tap-sensor installation under pressure is done in the following steps:

1. Welding of the assembly stud with assembly flange to the pipe, see Fig. 4.7a.
2. Assembly of isolation valve to the assembly stud, see Fig. 4.4a lower picture.
3. Installation of the tapping tool, see Fig. 4.7b.
4. Drilling of the pipe, see Fig.. 4.7 c.
5. Withdrawl of the tapping tool, see Fig. 4.7d.
6. Closing of isolation valve and removal of tapping tool, see Fig. 4.7e.
7. Assembly of Flo-Tap pitot tube sensor, opening of isolation vale and insertion of flow sensor profile, see Fig. 4.7f.

4.3.2 Removal without Process Shut-Down (Flo-Tap)

All Flo-Tap versions of the ITABAR-sensor allow the removal under pressure. These features are valuable in applications requiring

- a periodic check of the flow sensor’s measurement accuracy
- an exchange after extended service in abrasive fluids or
- cleaning during normal maintenance operations

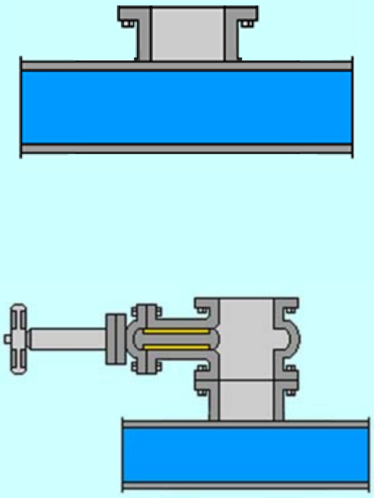


Fig. 4.7a: Welding of assembly weld boss with assembly flange to the pipe (above) and assembly of the isolation valve to the weld boss (below)

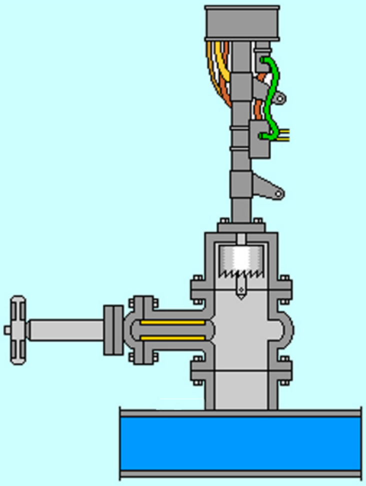


Fig. 4.7b: Installation of the tapping tool

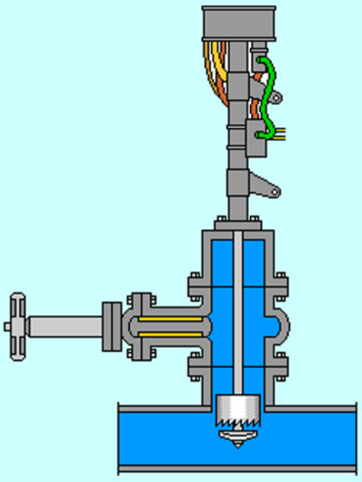


Fig. 4.7c: Drilling the pipe

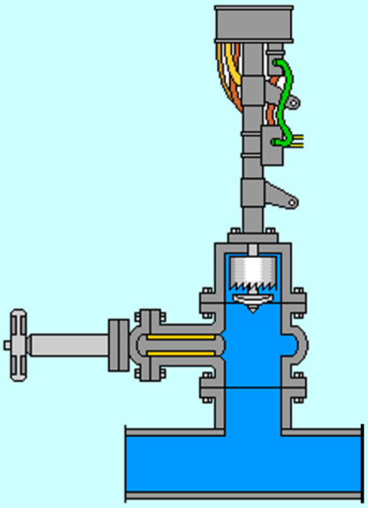


Fig. 4.7d: Pull back of tapping tool

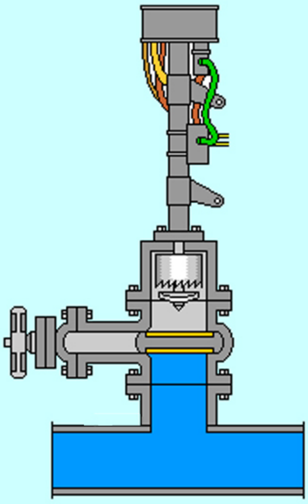


Fig. 4.7e: Closing of valve and removal of tapping tool

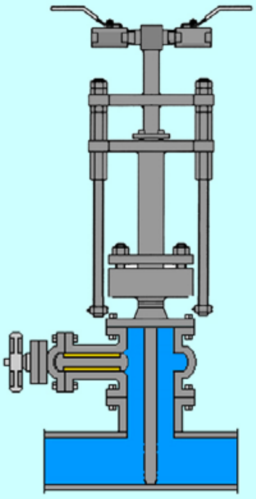


Fig. 4.7f: Assembly of Flo-Tap-pitot tube sensor, opening of the isolation valve and insertion of pitot tube sensor

4.3.3 Safe Operation with Second Packing Gland

The current level in technical design of Flo-Tap pitot tube sensors is marked by one packing gland on the far end of the process isolation valve (see Fig 4.9). This type of construction can lead to accidents in practical installations. .

Pitot tubes are often subjected to mechanical stresses with static and dynamic components under varying operating conditions. The forces impacting on the sensor profile can cause irregular or resonant oscillations. Depending on the amplitude and the frequency of this stress the material can weaken and the sensor can break.

For this reason a pitot tube sensor profile with only one single packing gland and because of its unsupported length is in danger of being damaged

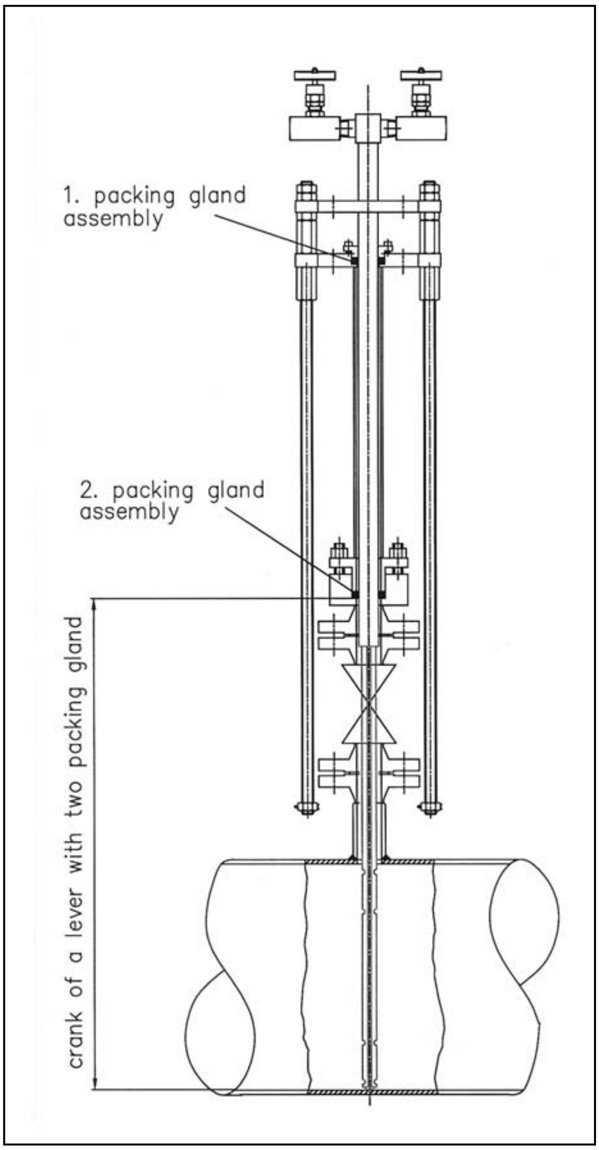
In order to avoid such accidents all ITABAR® Flo-Tap-sensors are equipped with two packing glands (see Fig 4.10). This measure increases a sensor's resonant frequency by such a magnitude that the material cannot easily weaken even in severe operating conditions.

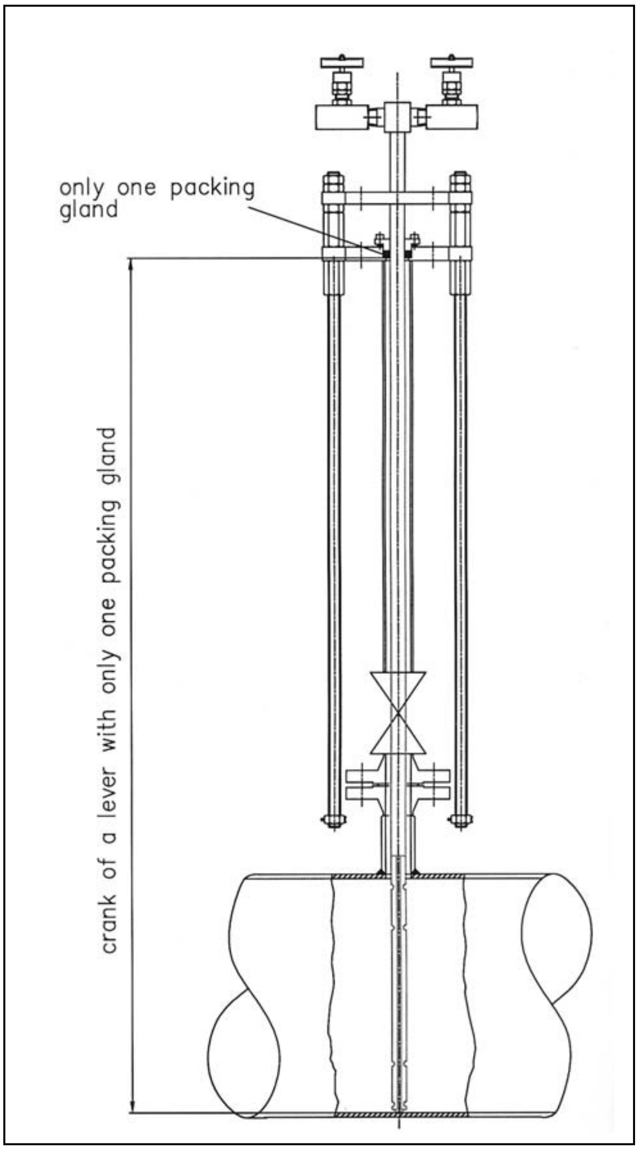
Intra Automation GmbH has this design patented and is the only manufacturer of pitot tube which are equipped with a second packing gland.

ITABAR® models FTM, FTH, FTMD and FTHD are all equipped as standard with a pair of threaded rods (mat 316 SS) (see Fig. 4.8). A wrench is required to remove and install the sensor. The emoval/installation is made faster and easier with a threaded wheel. The housing is made of aluminum, the wheel of carbon steel.

Fig. 4.8: ITABAR® Flo-Tap-sensor with second packing gland

Construction of Wet-Tap Pitot Tubes





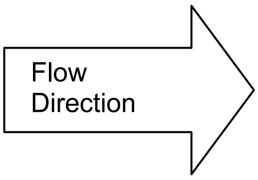


Fig. 4.9: ITABAR pitot tube with two packing glands. The short leverage practically eliminates the danger of the sensor breaking.	Fig. 4.10: Conventional pitot tube without prevention of material weakening. The long leverage increases the likelihood that the sensor might break

5. Specifications for ITABAR- Flow Sensors

The selection of the proper pitot tube sensor can be made quickly and reliably by this manufacturer if the operational data about the existing pipe line, the fluid and the desired version are made available according to the table below.

General Information:

Customer:
Reference-Nr.:
Installation-Nr.:

Pipeline:

Material:
Nominal pressure: psig
Pipe inside diameter: inches
Pipe wall thickness: inches
Thickness of pipe insolation: inches

Fluid:

Name: liquid ☐ steam ☐ gas ☐
Isotropic exponent:
Compessability factor:
Flow direction: horizontal ☐ vertical ☐

Physical values :	Minimum:	Operating Condition:	Maximum:	Unit
Flow				
Temperature				
Pressure abs. ☐ rel. ☐				
Std density				
Operating density				
Dynamic viscosity				

Desired version:

Special pipe assembly with threaded weld-o-let : ☐
Special pipe assembly with flanged version: ☐ DIN-Flanges: ☐ ANSI-Flanges ☐
Wet-tap version of ITABAR-sensor required: ☐
Compact version (if technically possible): ☐

6. Specification of Pitot Tube Sensors

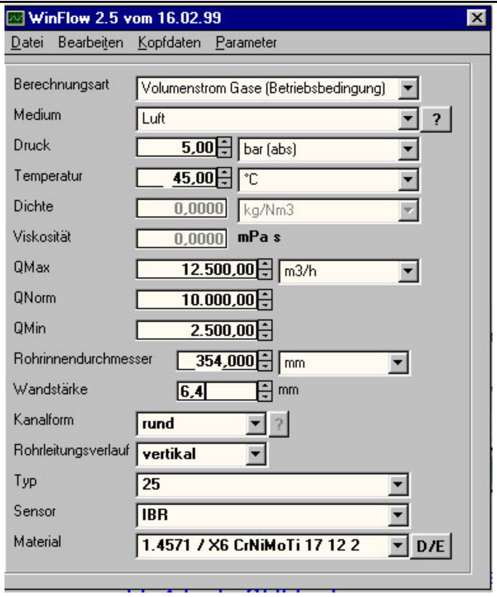
Specifying a pitot tube sensor starts with the selection of a fitting version for a specific application

For a better understanding the meaing of the sensor-version nomenclature will be explained in the following. Pitot tube sensors which start with the letter „IB..“ are designed for fixed (installation not under pressure) installations. The letter „R“ („F“, „G“) indicates a threaded (flanged, welded) process connection between the pipe and the sensor’s assembly components. All sensors, which are used to measure steam have the letter „D“ at the end of the model name. The additions „HT“ or „HTG“ stand for „High Temperature“. Pitot tube sensor series „Flo-Tap“ is indicated by the letter „FT’ at the beginning of the model name. They can be installed and removed under pressure conditions (wet-tap design). The letters „N“ („M“, and „H“) signify their possible use in low („N“) and medium and high operating pressure applications, with „D“ for steam use. Model series 21,26,36 and 66 differ from series 20,25,35 and 65 in that they come with a counter-end support, which serves to avoid mechanical stress caused by high flow velocities and high impact pressures or sensor-resonance oscillations.

Sections 7.1 and 8.1 cover in detail the selection criteria for the various ITABAR- sensor model series, depending on the speficic operating pressure, operating temperature and the desired assembly and installation design.

The WINFLOW sizing and model selection program serves to calculate and configure a pitot tube sensor. The WINFLOW program (program window see Fig 6.1) calculates the following as a function of the parameters for a specific measurement point:

- the differential pressures generated under varying operating conditions,
  - the permanent pressure loss caused by the sensor,
  - the sensor resonance and – if need be – it recommends a sensor with counter support,
  - the sensor oscillating frequency at operating conditions,
- the maximum allowable differential pressure,
- the maximum allowable flow for the selected sensor,
- the average flow velocity and
- the viscosity and density of commonly measured fluids under operating conditions.



Berechnungsart: Volumenstrom Gase (Betriebsbedingung)
Medium: Luft
Druck: 5,00 bar (abs)
Temperatur: 45,00 °C
Dichte: 0,0000 kg/Nm3
Viskosität: 0,0000 mPa s
QMax: 12.500,00 m3/h
QNorm: 10.000,00
QMin: 2.500,00
Rohrinnendurchmesser: 354,000 mm
Wandstärke: 6,4 mm
Kanalform: rund
Rohrleitungsverlauf: vertikal
Typ: 25
Sensor: IBR
Material: 1.4571 / X6 CrNiMoTi 17 12 2

Fig. 6.1: The program window of WINFLOW

The WINFLOW program can be ordered at no charge by any customer and in the desired format. The selection process can also be done by this manufacturer if the customer has furnished all required information mentioned in chapter 5 „Specifications for ITABAR flow Sensors.

The order specifications are selected via a simple to use order specification key, which has the same format for all sensors and which shows the variety of the in modules constructed versions. It enables a sensor specific selection for almost any application.

6.1 Compact or Separate Version?

The compact or the separate versions describe the assembly of the sensor components. In the compact version the pitot tube sensor, a separate 3-or 5-way manifold and a transmitter are assembled together into one compact unit (see Fig 6.1). In the separate version the transmitter and the sensor are separated from each other and are connected via conduit-pipes , (see Fig. 6.2.)

Fig. 6.1: Example of a compact version with flange plate, 3-way manifold and DP transmitter

Fig. 6.2: Example of a separate version with 3-way manifold and DP transmitter

The compact version (see Fig 6.1) offers obvious cost advantages compared to the separate version (see Fig 6.2). Assembly- as well as material expenses are eliminated for:

- two ball valves
- two conduit fittings
- one mounting bracket for the DP transmitter
- the fixed conduit and
- two conduit fittings on the DP transmitter
- Assembly time

7. Pitot Tubes for Liquids and Gases

7.1 Selection Criteria

The following table allows the selection of a model series depending on the given measurement task, the operating pressure, the operating temperature as well as the desired installation and assembly design.

Installation / Removal **with** Process Shut Down	**IBR**	**IBF**	**IBF-100**
			
Measurement task:			
Measurement of liquids, gases and gas mixtures	x	x	---
Measurement of flue gases	x	x	x
Possible operating pressures:			
6 bar, 16 bar (87, 232 psig)	x	x	x
40 bar, 63 bar (580, 914 psig)	x	x	---
100, 160, 250, 320 ,400 bar (1450, 2321, 3626, 4641, 5801 psig)		x	---
Max. operating temperature			
200° Celsius / 25 bar (392 °F / 363 psig)	x		
1175° Celsius (2147 °F), material dependent	---	x	x
Materials of installation parts:			
Carbon steel, 316 SS	x	x	x
1.4462 Duplex, 1.4539, Hastelloy C4, Incoloy 800, Inconel, Monel, PVDF	---	x	x
Sensor materials			
316 SS - Standard	x	x	x
1.4462 (Duplex), Inconel, Monel,	---	x	---
1.4539, Hastelloy C4, Incoloy 800, Inconel 600, PVDF	---	x	x
3.7035 (Titanium Gr.2)	---	x	---
Construction design features:			
Threaded connection with weld boss and locking nut for installation of sensor to pipe	x	---	---
Flanged connection to install sensor on pipe	---	x	x
Counter support with threaded removable blind flange for ease of sensor cleaning	---	---	x

	FTN	FTM	FTH
Installation / Removal Under Pressure (Wet-Tap)			
Measurement task:			
Measurement of liquids, gases and gas mixtures	x	x	x
Measurement of flue gas	x	x	x
Possible operating pressures			
6 bar / 87 psig	x	x	x
16 bar, 40 bar (232, 580 psig)	---	x	x
63 and 100 bar (914 and 1450 psig)	---	---	x
Max. operating temperature:			
200° Celsius (392 °F)	x		
300° Celsius (572 °F)	---	x	X
400° Celsius (752 °F)	---	---	X
Materials of assembly parts			
Carbon steel, 316 SS	x	x	x
1.4462 Duplex, 1.4539, Hastelloy C4, Incoloy 800, Inconel, Monel	---	---	x
Sensor material:			
Carbon steel, 316 SS (Standard)	x	x	x
1.4462 Duplex, 1.4539, Hastelloy C4, Monel	---	---	x
3.7035 (Titanium Gr.2)	x	x	x
Design features :			
Threaded connection with weld-o-let and locking nut for installation of sensor to pipe	x	---	---
Threaded connection with weld-o-let and lock ring for installation of sensor to pipe	---	x	---
Flanged connection to mount sensor to pipe	---	---	x
Protective safety chain during removal	x	---	---
Threaded rods for easy removal (safety chain required)	---	x	x
Option: threaded with hand wheel	---	x	x

7.2 Illustration of Sensor Heads and Assembly Parts

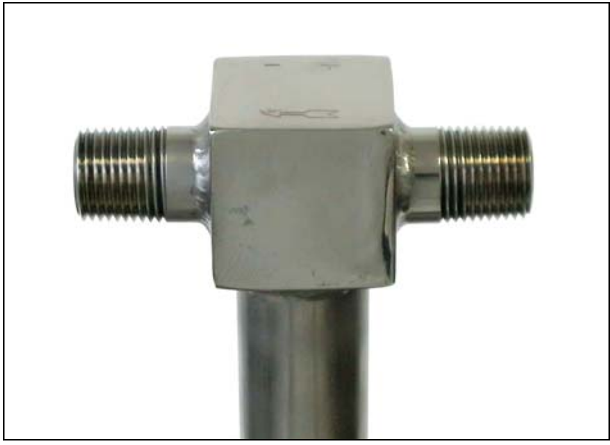


Fig. 7.1: Sensor head with ½ " NPT, only for gases and liquids

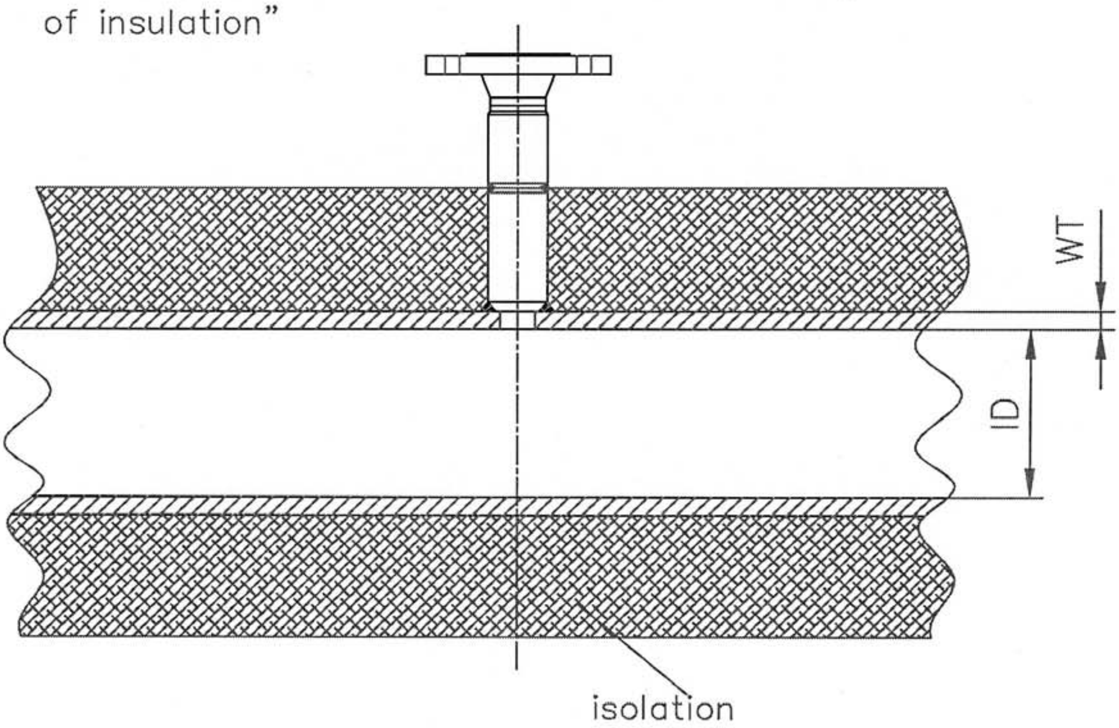
Fig. 7.2: Sensor head with flange plate to direct-mount a 3-way manifold. Limited use w/out pipe insulation,
gase to pressure$_{max}$ = 63 bar (914 psig) and temp$_{max}$ = 200 °C (392°F)
liquids to pressure$_{max}$ = 63 bar (914 psig) and temp$_{max}$ = 150°C (302°F)

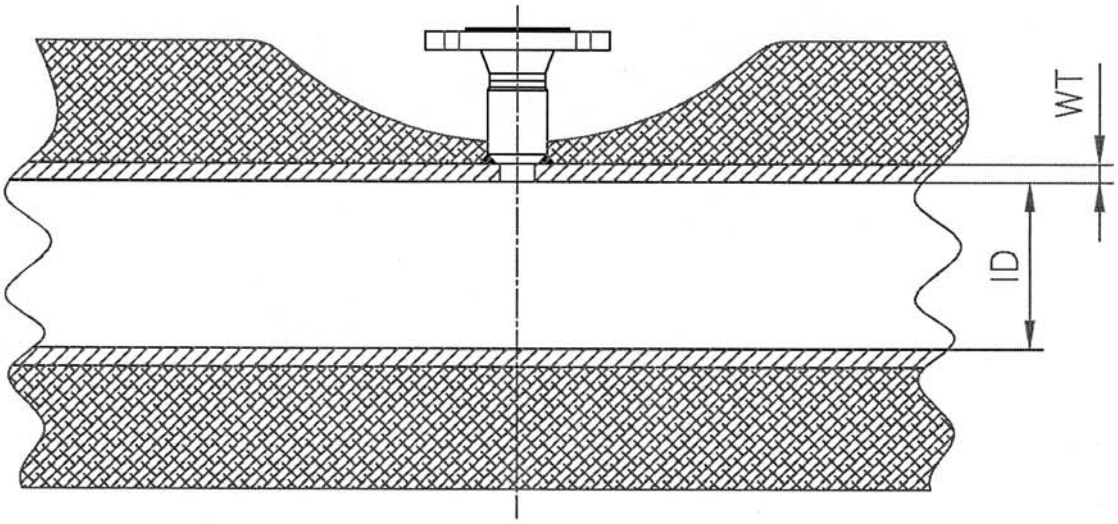
Fig. 7.3: Threaded weld boss for IBR-25/26 mat. Carbon steel, 316 SS

Fig. 7.4: Installation stud in weld-o-let version

7.9 Considerations of Heat Insulation in Order Codes

"Installation stud extention – so that fitting is outside of insulation"



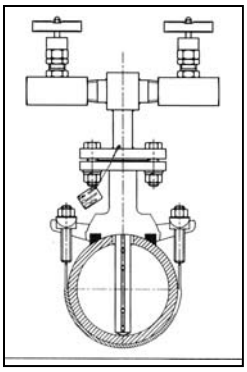


"If an extention is not included, the isolation must be reduced – increased insulation effort"

7.10 Saddle Flange Version for Cast / Pig Iron, Steel and AZ Pipes (Asbestos – Cement Pipe)

The saddle flange version is a special assembly version for pitot tubes in cast iron, steel and asbestos-cement pipes. Common pipe diameters are between 2 1/4“ to 20“ (DN 65 to DN 500). Larger pipes can be realized upon customer request.

The picture to the right shows an example for a pitot tube sensor model IBF-25 in saddle flange version. This version consists of a drill-clamp with flange PN 4 / 58.0 psig (gas) / PN 16 / 232.1 psig (water) and at least one saddle clamp.



This assembly version is not available for pitot tube sensors with counter support.

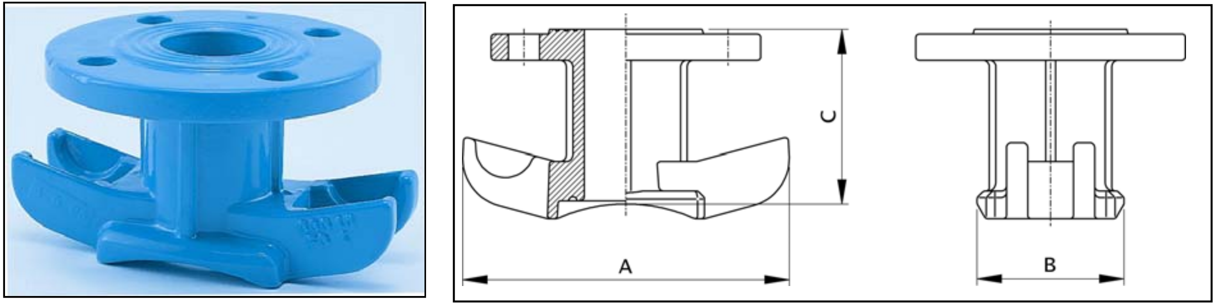


Fig 7.6: Universal drill-clamp with flange pipe size 2“ DN 40/50 PN 4 / 58.0 psig (gas) / PN 16 / 232.1 psig (water)

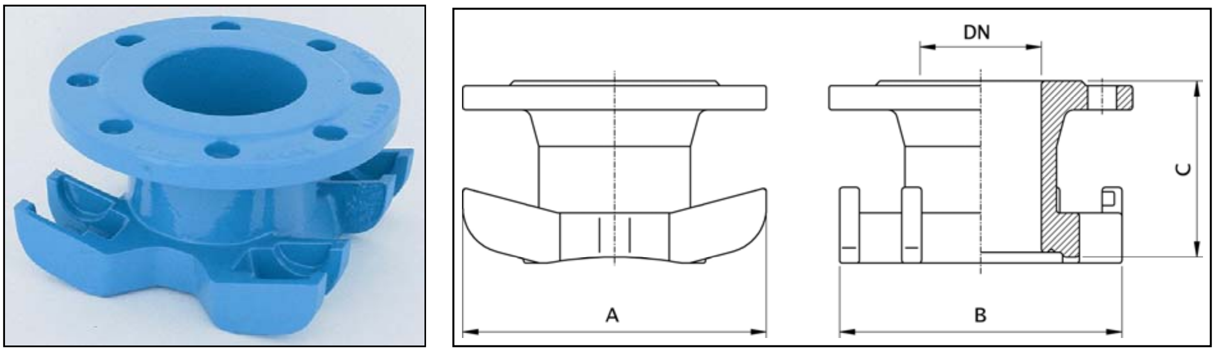


Fig 7.7: Double saddle clamp- drill-clamp with flange pipe size 3“ DN 80 PN 4 / 58.0 psig (gas) / PN 16 / 232.1 psig (water)

Fig 7.8: saddle clamp, fully vulcanized

Fig 7.9: saddle clamp, stainless, acid-resistant steel (304 SS)

	Saddle clamp, fully vulcanized	Saddle clamp st steel (304 SS)	Saddle clamp for AZ pipe
Figure:	7.5	7.6	n/a
Use for pipe types:			
- Welded pipe according DIN 2060	x	x	---
- Welded pipe with PE-cover to DIN 30670	x	x	---
- Cast pipe to DIN 28610 bituminized	x	x	---
- Cast pipe to DIN 28610 with PE-cover to DIN 30674 T 1	x	x	---
- Cast pipe to DIN 28610 with ZM-cover	x	x	---
- Asbestos-cement pipe 10 bar (145 psig)	---	---	x
- Asbestos-cement pipe 12.5 bar (181.3 psig)	---	---	x
- Asbestos-cement pipe 16 bar (232.1 psig)	---	---	x
Pipe outside diameter	87 – 470 mm (3.4 – 18.5“)	75 – 582 mm (2.9 – 22.9“)	97 – 494 mm (3.8 –19.4“)
Width of saddle:	70 mm (2.7“)	65 mm (2.6“)	90 mm (3.5“)
Material of saddle :	St steel, fully vulcanized	1.4301	1.4301
Saddle seal:	NBR	NBR	NBR
Order code (x= pipe outside diameter in mm):	HB1-x	HB2-x	HB3-x

Materials Overview

Material Nr.	Temperaturerrange	Use	Use
316 SS (Standard)	800°C 1472°F *(for pressure retaining parts: 450°C 842°F)*	Extraction facilities, dryers, mixing- and batching facilities, evaporators, distilleries, and other	The Cr-Ni-Mo alloyed material is very resistant against reducing organic and inorganic acids, as well as against halogen-containing media. This steel is furthermore less susceptible to selective corrosion. The titanium stabilized material exhibits slightly better heat properties with somewhat less resistance to acids.
1.4462 (st steel) Duplex	500°C 932°F	Sea water desalination plants, petro-chem industry, off-shore technology, evaporators, extraction facilities, distilleries, dryers	Good mechanical properties combined with high resistance against general corrosion, tear- and oscillation corrosion.
1.4539 (st steel)	450-800°C 842-1472°F	Flue gas sulfur elimination (srubbers), below dew point	The material is a highly acid resistant specialty steel with particularly good resistance to sulfuric and phosphoric acid at concentrations of up to 70% and operating temperatures of up to 80°C. Furthermore this material is resistant against concentrated organic acids, even at high temperatures, as well as against salt- and soda solutions. The steel is especially insensitive to selective corrosion and tear corrosion.
2.4610 NiMo16Cr16Ti Hastelloy C4	650-1040°C 1202-1904°F	Flue gas sulfur elimination (srubbers), chlorine gas	Excellent stability in the chemical process industry against strong oxidizing media, hot contaminated mineral acids, solvents, chlorine- and chlorine contaminated media (organic and inorganic), anhydrous bleach acid, formic acid, distilled vinegar , Essighydrid-, seawater, and The alloy exhibits great ductile strength and resistance to corrosion even in temperatures of 650 – 1040°C. Resistant to build-up of Korngrenzkariben and is therefore in most cases usable without heat treament after welding.
1.4876 X10NiCrAiTi3320 Incoloy 800	900°C 1652°F	Hydrogen facilities	This alloy is resistant against corrosion from hydrogen and hydrogen sulfides as well as against tension corrosion.
2.4816 NiCr15Fe Inconel 600	1175°C 2147°F	air heaters	Excellent oxidation resistance up to 1175°C with superb general resistance to corrosion. Maintains high stability up to approx. 650°C. Good mechanical properties even in low temperatures. Because of its resistance to chloride-corrosion this alloy is also used in nuclear reactor components. Can be welded w/out heat treatment.
3.7035 Ti-50° B 348 Gr.2 Titan Gr.2	300°C 572°F *(for pressure retaining parts: -10 - +250°C 14 - +482°F)*	Sea water desalination plants, petro-chem industry, food industry, evaporators, extraction facilities, distilleries, dryers	Good mechanical properties combined with high resistance against general corrosion, tear- and oscillation corrosion. Low density and excellent to be welded.

Materials Overview

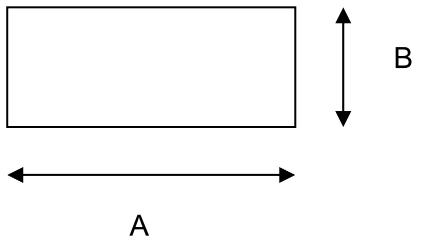
Material Nr.	Temperature range	Use	Use
2.4360 NiCu2Ofe Monel	425-550°C 797-1020°F	Extraction facilities, dryers, mixing – and batching plants, evaporators distilleries, sea water desalination plants	The Cr-Ni-Mo alloyed material is very resistant against reducing organic and inorganic acids, as well as against halogen-containing media. This steel is furthermore less susceptible to selective corrosion. The titanium stabilized material exhibits slightly better heat properties with somewhat less resistance to acids.
PVDF	-40 bis +120°c -40°F to +248°F	Chemical plants, flue gas cleaning (scrubbers), filter technology	Well suited for many agressive acids, many solvents and cleaning agents, hot water resistant
1.5415 16 Mo 3	530°C 986°F	High pressure steam applications	
1.7335	570°C 1058°F	High pressure steam applications	
1.7380 10 CrMo 4 4	600°C 1112°F	High pressure steam applications	
1.4903 10 CrMoVNB 91	650°C 1202°F	High pressure steam applications	High pressure steam, energy and environmental technologies, chemicals/ petro-chem, oil- and gas industries, cryogenics, food and beverage industry, plastics

Technical Specifications

Sensor materials		**Comercial designation**	**AISI**	**UNS**
	1.4571	316Ti (standard)		S31635
	1.4462	Duplex	316 Ti	S31803
	1.4539			N08904
	2.4610	Hastelloy C4		N06455
	1.4876	Incoloy 800		N08811
	2.4816	Inconel 600		N06600
	2.4360	Monel		N04400
	PVDF			-
	1.5415	15 Mo 3		K12020
	1.7335	13 CrMo 44		K11562
	1.7380	10 CrMo 910		-
	1.4903	X 10 CrMoNVb		-
	3.7035	Titan Gr. 2	B 348 Gr.2	-

Pipe inside diameter	1 ½“ – 480“ (DN 20 - DN 12000)
Max. operating pressure	PN 400 / 5801 psig (depending on sensor type)
Max. operating temperature	1200°C (2192°F) (depending on sensor material)
Accuracy	± 0,3 % of full scale

- Lower permanent pressure loss (energy savings)
- Use from Re=3150
- Direct mass flow measurement (integrated temperature and flow measurement)
- Direct-mount of electr. DP transmitter
- Little danger of contamination due to large pressure sensing apertures
- ITABAR-flow-sensors with certified accuracy, tested at water calibration facility ABB Göttingen/Gerrnany. All sensor types from DN400 (16“) through DN1600 64“) were calibrated and tested – see test protocols.
- Material certificates available in 3.1B und 3.1A
- Flo-Tap-versions allow installation and removal under pressure (wet-tap)
- Flow measurement in rectangular or square vessels is possible



Substitiute diameter

$$D_{ER} = 2 * \sqrt{\frac{A * B}{\pi}}$$

The sensor is always made for the longer side to better cover the flow profile.

- Shorter straight pipe run requirements as compared to orifice plates and nozzle.

Selection of Sensor Orientation

1. Gases, if possible the sensor should be inserted into the pipe from the top or from the side. In case the gas contains moisture, liquid drops can migrate back into the measurement chambers. If the sensor is installed into the bottom of a pipe an increase in the liquid column can cause measurement errors.

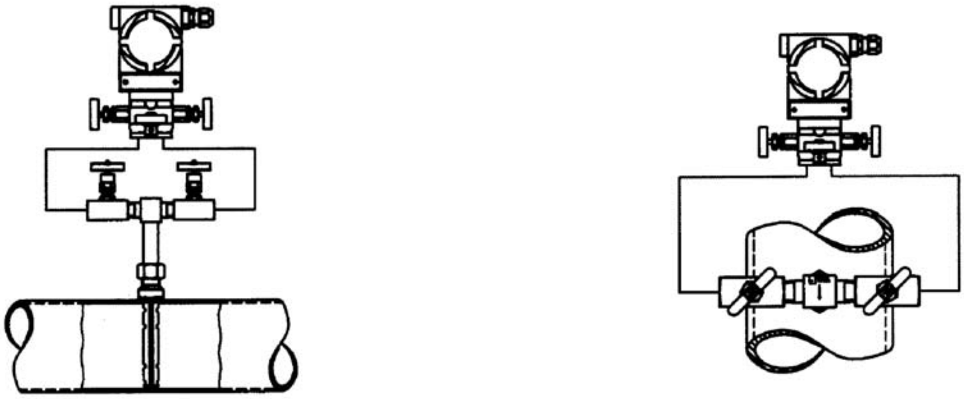


Fig. 7.10: Recommended orientation for measurement of gases

2. Liquids, sensor installation from side or from below into pipe, never from above (as opposed to gases). Air bubbles rise and cause measurement errors, transmitter always below the pressure connections.

Fig. 7.11 Recommended sensor orientation for liquid measurement

3. Steam, the sensor is always to be inserted from the side into a pipe, the transition between the aggregate conditions steam and water must be allowed to take place freely, the transmitter is to be installed below the pressure process connections. The water columns of the condensate pots must be located above the transmitter at exactly the same hydrostatic level.

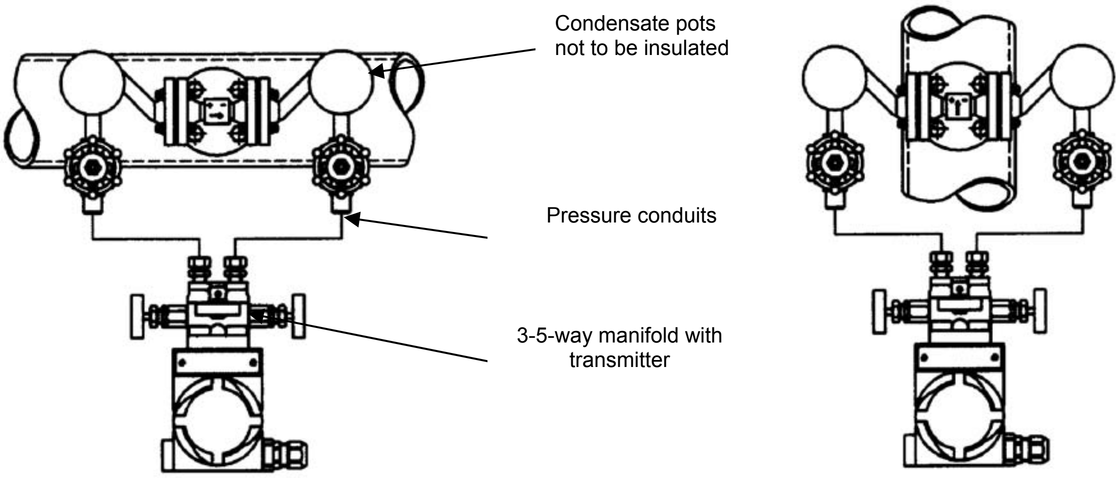


Fig. 7.12: Recommended sensor orientation for steam measurement

Important: When measuring steam never insert the sensor from the top into a pipe !

Calibration of ITABAR-Flow-Sensors

In order to achieve the highest accuracy for the ITABAR-flow-sensors, they were tested on a PTB tested and approved calibration facility. The objective was to determine the absolute measurement error at minimum as well as maximum flow.

The measuring turn-down was 1:5, the Reynolds number influence was to be determined and to be integrated into the Winflow Program, so that the user can demand the highest performance from the product.

Tested pipe diameters inches (mm)	Sensor type
ID 12.047 (306 mm)	IBF-26/36/66
ID 15.748 (400 mm)	IBF-26/36/66
ID 19.685 (500 mm)	IBF-26/36/66
ID 23.543 (598 mm)	IBF-26/36/66
ID 39.291 (998 mm)	IBF-26/36/66
ID 63.307 (1608 mm)	IBF-26/36/66

Intra-Automation manufactured several different pieces of pipe for these tests, which could be inserted into the hydraulic test stand. The pipe-layout was measured with a tolerance of ± 1 mm.

The conversion from the differential pressure into a mA signal was done with a DP transmitter manufactured by Endress + Hauser, which was calibrated ± 0,1 % of full scale.

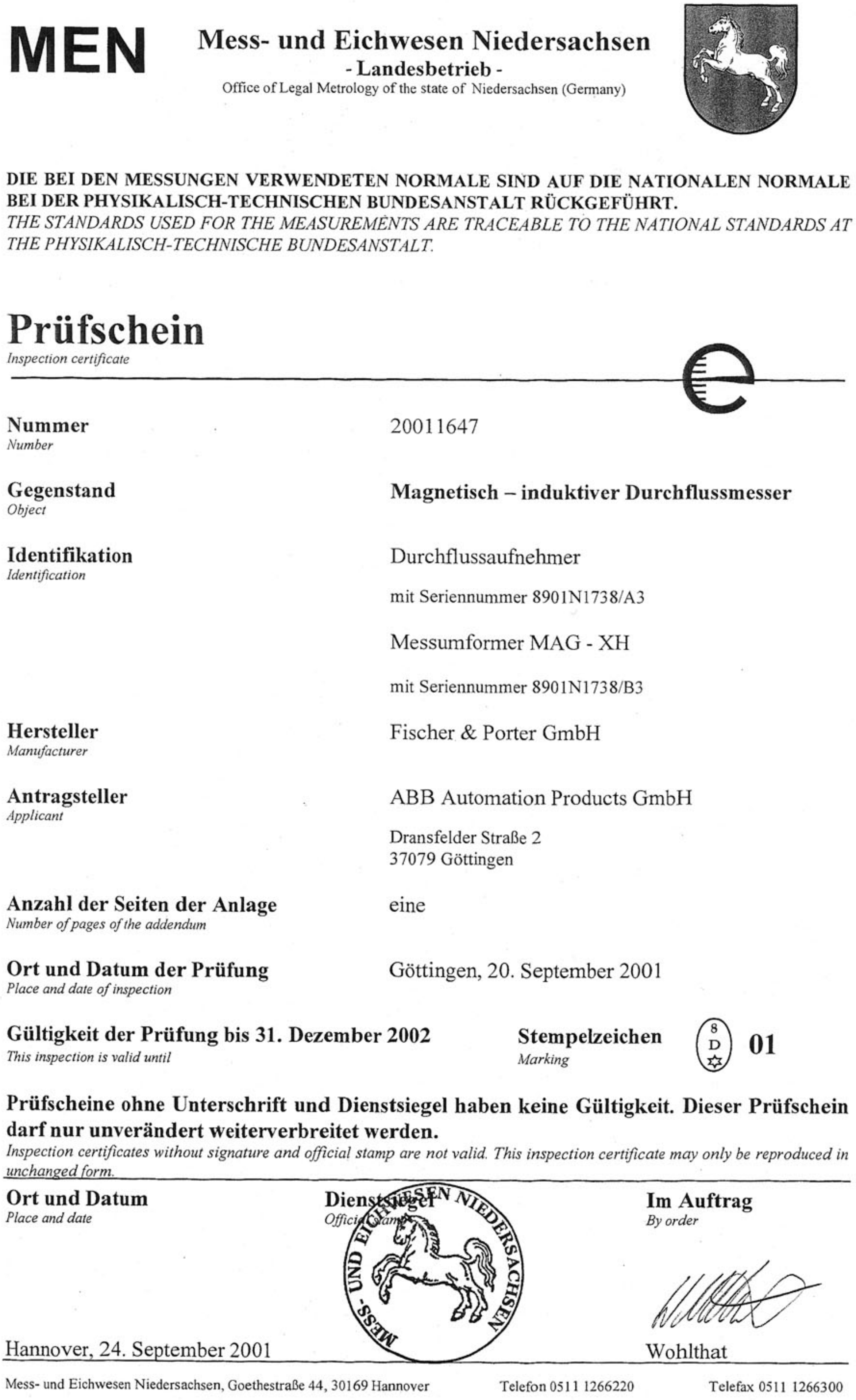
The water temperature and the pressure were read at the calibration stand. The output signal of the electrical DP transmitter was transmitted in the form of pulses to the ABB computer and were compared directly with the calibration standard values.

Six measurements were automatically taken at every flow range in intervals of 100 seconds. The measurement errors at each interval were averaged.

With the help of these calibrations it was possible to reach an accuracy of ± 0,3 % for all ITABAR-sensors. In the ongoing manufacturing process the width of all sensors is manufactured with and checked for a tolerance as listed in the following table

Sensor types	Manufacturing tolerance
IBR/IBF-15	± 0,05 mm
IBR/IBF-20/21	± 0,05 mm
IBR/IBF-25/26	± 0,05 mm
IBR/IBF-35/36	+ 0 mm - 0,1 mm
IBR/IBF-65/66/100	+ 0 mm - 0,1 mm

Against this background Intra-Automation guarantees an accuracy of ± 0,3 % for ITABAR-flow-sensors.



MEN **Mess- und Eichwesen Niedersachsen**
- Landesbetrieb -
Office of Legal Metrology of the state of Niedersachsen (Germany)

DIE BEI DEN MESSUNGEN VERWENDETEN NORMALE SIND AUF DIE NATIONALEN NORMALE BEI DER PHYSIKALISCH-TECHNISCHEN BUNDESANSTALT RÜCKGEFÜHRT.
THE STANDARDS USED FOR THE MEASUREMENTS ARE TRACEABLE TO THE NATIONAL STANDARDS AT THE PHYSIKALISCH-TECHNISCHE BUNDESANSTALT.

Prüfschein
Inspection certificate

Nummer *Number*	20011647
Gegenstand *Object*	**Magnetisch – induktiver Durchflussmesser**
Identifikation *Identification*	Durchflussaufnehmer mit Seriennummer 8901N1738/A3 Messumformer MAG - XH mit Seriennummer 8901N1738/B3
Hersteller *Manufacturer*	Fischer & Porter GmbH
Antragsteller *Applicant*	ABB Automation Products GmbH Dransfelder Straße 2 37079 Göttingen
Anzahl der Seiten der Anlage *Number of pages of the addendum*	eine
Ort und Datum der Prüfung *Place and date of inspection*	Göttingen, 20. September 2001

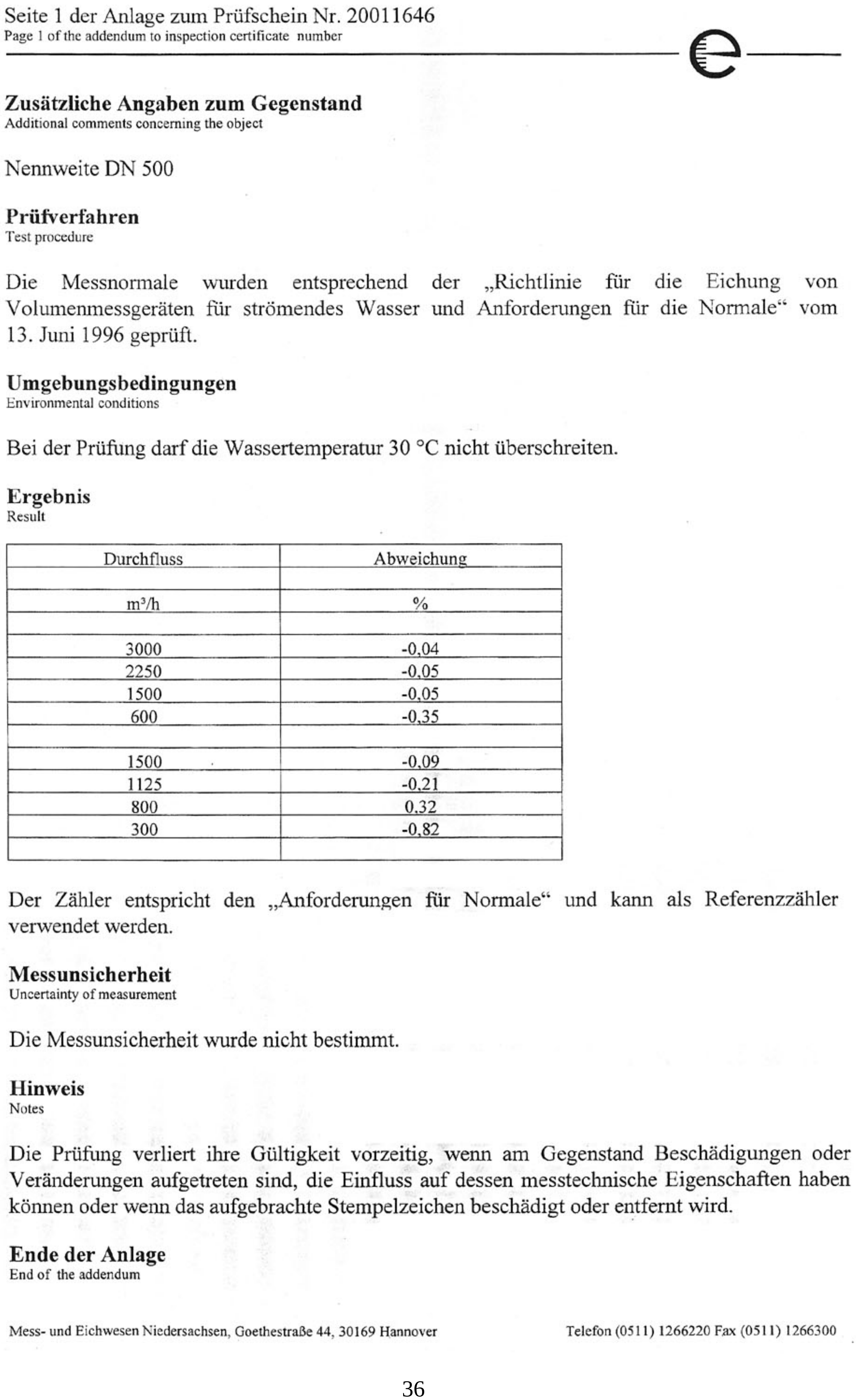
Gültigkeit der Prüfung bis 31. Dezember 2002
This inspection is valid until

Stempelzeichen 8 D ✡ **01**
Marking

Prüfscheine ohne Unterschrift und Dienstsiegel haben keine Gültigkeit. Dieser Prüfschein darf nur unverändert weiterverbreitet werden.
Inspection certificates without signature and official stamp are not valid. This inspection certificate may only be reproduced in unchanged form.

Ort und Datum *Place and date*	**Dienstsiegel** *Official stamp*	**Im Auftrag** *By order*
Hannover, 24. September 2001		Wohlthat

Mess- und Eichwesen Niedersachsen, Goethestraße 44, 30169 Hannover   Telefon 0511 1266220   Telefax 0511 1266300



Seite 1 der Anlage zum Prüfschein Nr. 20011646
Page 1 of the addendum to inspection certificate number

Zusätzliche Angaben zum Gegenstand
Additional comments concerning the object

Nennweite DN 500

Prüfverfahren
Test procedure

Die Messnormale wurden entsprechend der „Richtlinie für die Eichung von Volumenmessgeräten für strömendes Wasser und Anforderungen für die Normale“ vom 13. Juni 1996 geprüft.

Umgebungsbedingungen
Environmental conditions

Bei der Prüfung darf die Wassertemperatur 30 °C nicht überschreiten.

Ergebnis
Result

Durchfluss	Abweichung
m³/h	%
3000	-0,04
2250	-0,05
1500	-0,05
600	-0,35
1500	-0,09
1125	-0,21
800	0,32
300	-0,82

Der Zähler entspricht den „Anforderungen für Normale“ und kann als Referenzzähler verwendet werden.

Messunsicherheit
Uncertainty of measurement

Die Messunsicherheit wurde nicht bestimmt.

Hinweis
Notes

Die Prüfung verliert ihre Gültigkeit vorzeitig, wenn am Gegenstand Beschädigungen oder Veränderungen aufgetreten sind, die Einfluss auf dessen messtechnische Eigenschaften haben können oder wenn das aufgebrachte Stempelzeichen beschädigt oder entfernt wird.

Ende der Anlage
End of the addendum

Mess- und Eichwesen Niedersachsen, Goethestraße 44, 30169 Hannover Telefon (0511) 1266220 Fax (0511) 1266300

Calibration faciltiy / Fa. ABB Göttingen (Germany)

Test Protocol

Calibration Facility: ABB Göttingen, PTB-tested / Test Stand PS 0014
Pipe ID : 306 mm / Medium : Water

Type Test	Operating temperatur	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-26	20°C	100	1000	27,632	27,594	0,1388
IBF-26	20°C	100	1000	27,616	27,615	0,0035
IBF-26	20°C	100	1000	27,662	27,652	0,0345
IBF-26	20°C	100	1000	27,563	27,555	0,0284
IBF-26	20°C	100	1000	27,598	27,608	0,0395
IBF-26	20°C	100	1000	27,599	27,547	0,1882
Average	▨	**100**	▨	**27,612**	**27,595**	**0,0721**

Type Test	Operating temperatur	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-36	20°C	100	1000	27,613	27,564	0,1807
IBF-36	20°C	100	1000	27,520	27,489	0,1125
IBF-36	20°C	100	1000	27,614	27,576	0,1400
IBF-36	20°C	100	1000	27,644	27,546	0,3531
IBF-36	20°C	100	1000	27,580	27,577	0,0130
IBF-36	20°C	100	1000	27,697	27,505	0,6983
Average	▨	**100**	▨	**27,611**	**27,543**	**0,2496**

Type Test	Operating temperatur	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-66	20°C	100	1000	27,499	27,432	0,2464
IBF-66	20°C	100	1000	27,451	27,425	0,0933
IBF-66	20°C	100	1000	27,436	27,457	-0,0774
IBF-66	20°C	100	1000	27,503	27,495	0,0274
IBF-66	20°C	100	1000	27,448	27,453	-0,0164
IBF-66	20°C	100	1000	27,618	27,569	0,1793
Average	▨	**100**	▨	**27,493**	**27,472**	**0,0754**

Test Protocol

Calibration Facility: ABB Göttingen, PTB-tested / Test Stand PS 0014
Pipe ID : 400 mm / Medium : Water

Type Test	Operating temperatur	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-26	9°C	100	2000	55,840	55,908	-0,1209
IBF-26	9°C	100	2000	55,635	55,788	-0,2743
IBF-26	9°C	100	2000	55,975	56,016	-0,0724
IBF-26	9°C	100	2000	55,909	56,001	-0,1648
IBF-26	9°C	100	2000	55,775	55,815	-0,0726
IBF-26	9°C	100	2000	55,673	55,779	-0,1914
Average		**100**		**55,801**	**55,884**	**-0,1493**

Type Test	Operating temperatur	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-36	3°C	100	2000	56,205	56,141	0,1135
IBF-36	3°C	100	2000	56,034	56,068	-0,0618
IBF-36	3°C	100	2000	56,050	56,028	0,0391
IBF-36	3°C	100	2000	56,197	56,260	-0,1111
IBF-36	3°C	100	2000	56,256	56,254	0,0039
IBF-36	3°C	100	2000	56,202	56,209	-0,0127
Average		**100**		**56,157**	**56,160**	**-0,0048**

Type Test	Operating temperatur	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-66	3°C	100	2000	55,622	55,641	-0,0337
IBF-66	3°C	100	2000	55,657	55,659	-0,0022
IBF-66	3°C	100	2000	55,713	55,644	0,1240
IBF-66	3°C	100	2000	55,505	55,583	-0,1405
IBF-66	3°C	100	2000	55,625	55,485	0,2523
IBF-66	3°C	100	2000	55,373	55,499	-0,2272
Average		**100**		**55,583**	**55,585**	**-0,0045**

Test Protocol

Calibration Facility: ABB Göttingen, PTB-tested / Test Stand PS 0014
Pipe ID : 499 mm / Medium : Water

Type Test	Operating temperatur	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-26	8,2°C	100	3000	83,285	83,387	-0,1220
IBF-26	8,2°C	100	3000	83,443	83,831	-0,4628
IBF-26	8,2°C	100	3000	83,196	83,369	-0,2071
IBF-26	8,2°C	100	3000	83,323	83,543	-0,2684
IBF-26	8,2°C	100	3000	83,138	83,358	-0,2684
IBF-26	8,2°C	100	3000	83,012	83,358	-0,4155
Average		**100**		**83,233**	**83,475**	**-0,2899**

Type Test	Operating temperature	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-36	8,2°C	100	3000	83,297	83,333	-0,0422
IBF-36	8,2°C	100	3000	83,170	83,130	0,0484
IBF-36	8,2°C	100	3000	83,723	83,097	-0,4502
IBF-36	8,2°C	100	3000	83,116	83,109	0,0079
IBF-36	8,2°C	100	3000	83,253	83,221	0,0375
IBF-36	8,2°C	100	3000	83,074	83,164	-0,1080
Average		**100**		**83,105**	**83,176**	**-0,0844**

Type Test	Operating temperature	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-66	7,0°C	100	3000	83,512	83,602	-0,7078
IBF-66	7,0°C	100	3000	83,482	83,629	-0,1754
IBF-66	7,0°C	100	3000	83,802	83,830	-0,0330
IBF-66	7,0°C	100	3000	83,696	83,636	0,0715
IBF-66	7,0°C	100	3000	83,596	83,760	-0,1957
IBF-66	7,0°C	100	3000	83,683	83,701	-0,0219
Average		**100**		**83,629**	**83,693**	**-0,0770**

Test Protocol

Calibration Facility: ABB Göttingen, PTB-tested / Test Stand PS 0014
Pipe ID : 599 mm / Medium : Water

Type Test	Operating temperature	Time sec	m^3 /h	Test m^3	Test Norm m^3	Error %
IBF-26	6,0°C	100	4000	110,96	111,03	-0,0597
IBF-26	6,0°C	100	4000	110,93	111,10	-0,1550
IBF-26	6,0°C	100	4000	111,13	111,18	-0,0431
IBF-26	6,0°C	100	4000	110,86	111,08	-0,1973
IBF-26	6,0°C	100	4000	110,98	111,07	-0,0833
IBF-26	6,0°C	100	4000	111,09	111,12	-0,0208
Average		**100**		**110,99**	**111,10**	**-0,0932**

Type Test	Operating temperature	Time sec	m^3 /h	Test m^3	Test Norm m^3	Error %
IBF-36	2,4°C	100	4000	110,45	110,33	0,1116
IBF-36	2,4°C	100	4000	110,44	110,26	0,1615
IBF-36	2,4°C	100	4000	110,44	110,32	0,1081
IBF-36	2,4°C	100	4000	110,50	110,32	0,1640
IBF-36	2,4°C	100	4000	110,41	110,28	0,1215
IBF-36	2,4°C	100	4000	110,40	110,47	-0,0623
Average		**100**		**110,44**	**110,33**	**0,1007**

Type Test	Operating temperature	Time sec	m^3 /h	Test m^3	Test Norm m^3	Error %
IBF-66	5,0°C	100	4000	110,97	111,05	-0,0760
IBF-66	5,0°C	100	4000	110,68	110,90	-0,2060
IBF-66	5,0°C	100	4000	110,87	111,01	-0,1260
IBF-66	5,0°C	100	4000	110,65	111,05	-0,3622
IBF-66	5,0°C	100	4000	110,86	111,07	-0,1870
IBF-66	5,0°C	100	4000	111,13	111,09	0,0414
Average		**100**		**110,86**	**111,03**	**-0,1526**

Test Protocol

Calibration Facility: ABB Göttingen, PTB-tested / Test Stand PS 0014
Pipe ID : 999 mm / Medium : Water

Type Test	Operating temperature	Time sec	m^3/h	Test m^3	Test Niorm m^3	Error %
IBF-26	12,5°C	100	5000	139,99	140,14	-0,1067
IBF-26	12,5°C	100	5000	139,96	140,12	-0,1144
IBF-26	12,5°C	100	5000	139,82	139,92	-0,0685
IBF-26	12,5°C	100	5000	139,79	139,99	-0,1409
IBF-26	12,5°C	100	5000	139,51	139,78	-0,1954
IBF-26	12,5°C	100	5000	139,77	139,86	-0,0617
Average		**100**		**139,81**	**139,97**	**-0,1146**

Type Test	Operating temperature	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-36	16,5°C	100	5000	138,02	137,75	0,1985
IBF-36	16,5°C	100	5000	138,36	138,51	-0,1087
IBF-36	16,5°C	100	5000	138,72	139,09	-0,2662
IBF-36	16,5°C	100	5000	139,54	139,37	0,1195
IBF-36	16,5°C	100	5000	138,92	139,56	-0,4613
IBF-36	16,5°C	100	5000	139,66	139,68	-0,0181
Average		**100**		**138,87**	**138,99**	**-0,0899**

Type Test	Operating temperature	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-66	13,5°C	100	5000	138,32	138,70	-0,2685
IBF-66	13,5°C	100	5000	138,41	138,65	-0,1771
IBF-66	13,5°C	100	5000	139,11	138,69	0,3033
IBF-66	13,5°C	100	5000	138,86	138,63	0,1674
IBF-66	13,5°C	100	5000	139,10	138,60	0,3640
IBF-66	13,5°C	100	5000	138,50	138,78	-0,2013
Average		**100**		**138,72**	**138,68**	**0,0313**

Test Protocol

Calibration Facility: ABB Göttingen, PTB-tested / Test Stand PS 0014
Pipe ID : 1608 mm / Medium : Water

Type Test	Operating temperature	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-26	12,5°C	100	5500	153,47	153,21	0,1698
IBF-26	12,5°C	100	5500	153,99	153,14	0,5586
IBF-26	12,5°C	100	5500	153,60	153,20	0,2594
IBF-26	12,5°C	100	5500	153,63	153,25	0,2465
IBF-26	12,5°C	100	5500	153,88	153,30	0,3813
IBF-26	12,5°C	100	5500	153,32	153,18	0,0879
Average		**100**		**153,65**	**153,21**	**0,2839**

Type Test	Operating temperature	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-36	11,5°C	100	5500	154,61	154,45	0,1015
IBF-36	11,5°C	100	5500	153,68	154,28	-0,3892
IBF-36	11,5°C	100	5500	154,23	154,22	0,0042
IBF-36	11,5°C	100	5500	154,28	154,26	0,0130
IBF-36	11,5°C	100	5500	153,49	154,33	-0,5445
IBF-36	11,5°C	100	5500	154,16	154,69	-0,3376
Average		**100**		**154,08**	**154,37**	**-0,1922**

Type Test	Operating temperature	Time sec	m^3/h	Test m^3	Test Norm m^3	Error %
IBF-66	11,5°C	100	5500	152,45	152,02	0,2856
IBF-66	11,5°C	100	5500	151,83	151,84	-0,0073
IBF-66	11,5°C	100	5500	152,35	151,95	0,2642
IBF-66	11,5°C	100	5500	152,13	151,94	0,1247
IBF-66	11,5°C	100	5500	152,36	152,03	0,2180
IBF-66	11,5°C	100	5500	152,49	151,86	0,4153
Average		**100**		**152,27**	**151,94**	**0,2168**

Approvals and Test Certificates

The following tables shows the currently valid approvals and test certificates :

Sensor Type	Test Method	Result	Approval/Test Agency	Location	Date of Test
IBF-100	Sample design test to TA Luft 1986, 13. BImSchV und 17. BImSchV	Test passed	TÜV Rheinland Sicherheit und Umweltschutz GmbH	D-Köln	12.5.1999
IBF-20	Measurement accuracy	±0,5% of rate for all measured values	NMI Nederlands Meetinstituut	NL-Dordrecht	24.3.2000
IBF-25	Measurement accuracy	±0,68% of rate for all measured values	PIGSAR Ruhrgas AG (national authorized)	D-Dorsten	24.11.1999
IBF-25/26	Sample design test to TA Luft 1986, 13. BImSchV und 17. BImSchV	Test passed	TÜV Rheinland Sicherheit und Umweltschutz GmbH	D-Köln	12.5.1999
IBF-35/36	Sample design test to TA Luft 1986, 13. BImSchV und 17. BImSchV	Test passed	TÜV Rheinland Sicherheit und Umweltschutz GmbH	D-Köln	12.5.1999
IBFD-26-HTG	Test according to TRD 110 and TRD 110 Anlage 1	Test passed	VdTÜV	D-Essen	7.12.1995
IBR-25/26	Sample design test to TA Luft 1986, 13. BImSchV und 17. BImSchV	Test passed	TÜV Rheinland Sicherheit und Umweltschutz GmbH	D-Köln	12.5.1999
IBR-35/36	Sample design test to TA Luft 1986, 13. BImSchV und 17. BImSchV	Test passed	TÜV Rheinland Sicherheit und Umweltschutz GmbH	D-Köln	12.5.1999