

Flow measurement with primary element

Fuji Electric Corp. of America

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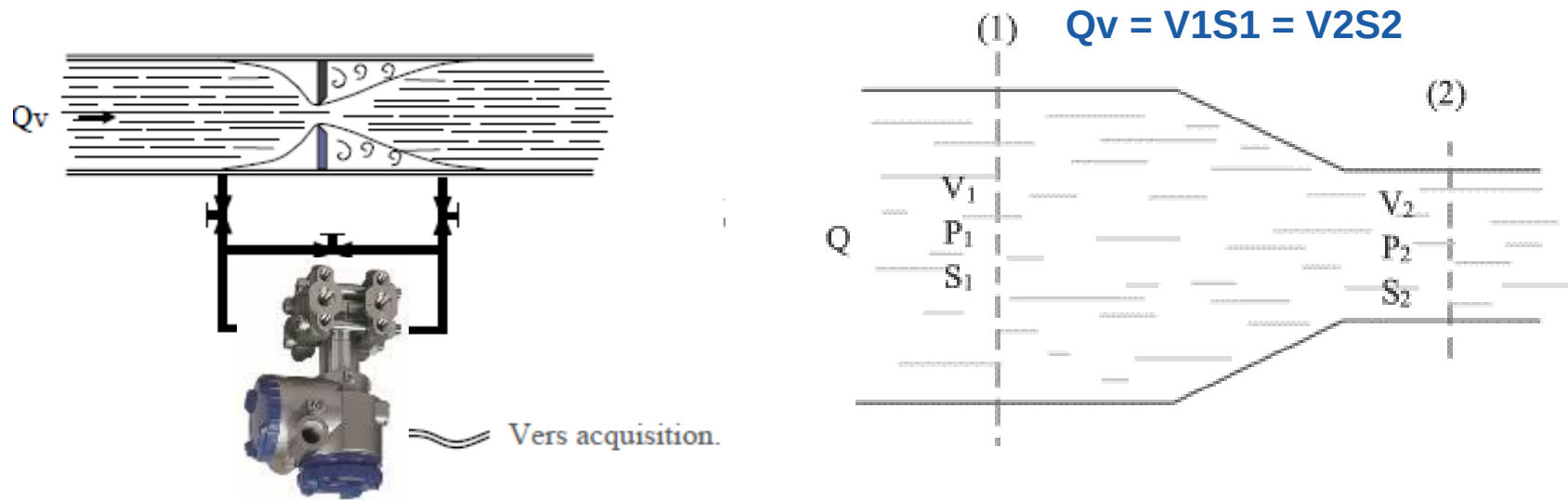
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Flow measurement with DP transmitter

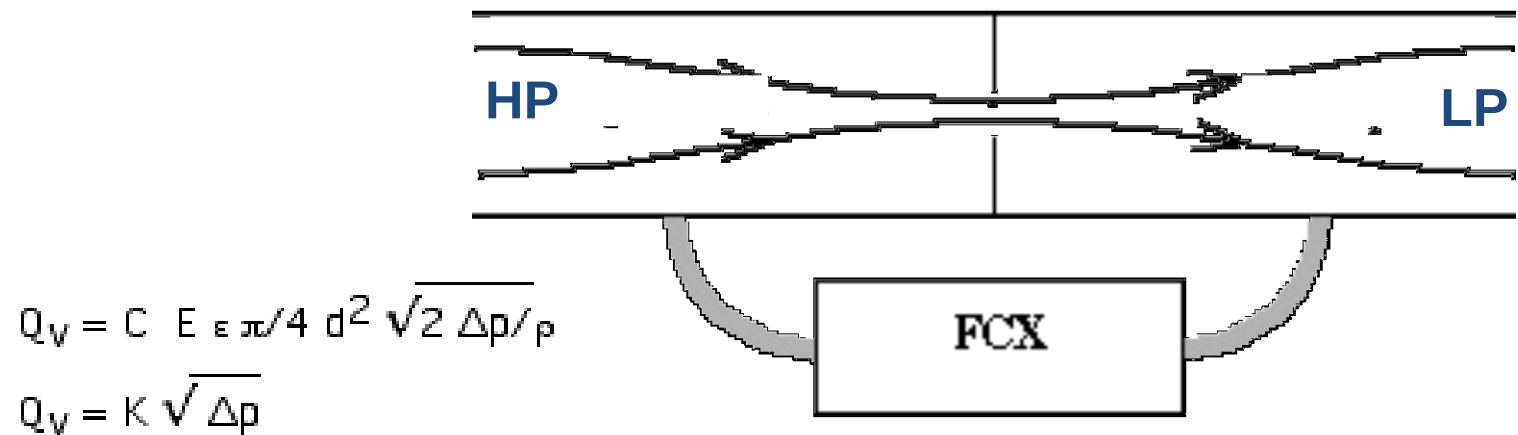
Measurement of a differential pressure: upstream and downstream of a primary element



- Increase the speed (Q_v)
- Increase the dynamical pressure
- Decrease of the static pressure

Primary Element

Volumetric flowrate is depending of the differential pressure square root made by the primary element



C = pressure lost coefficient determined by experimental test

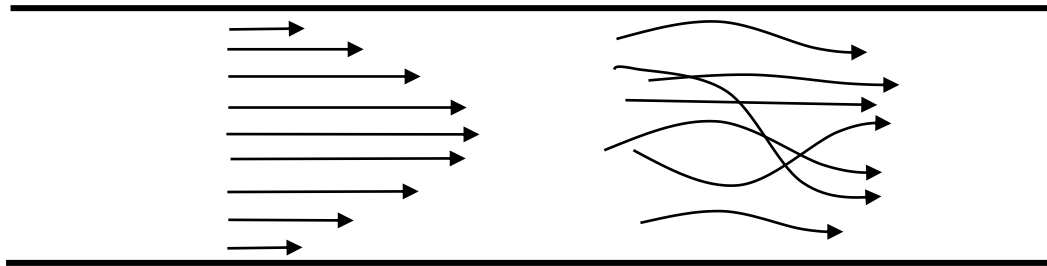
E = approach coefficient $E = 1/\sqrt{1 - b^4}$

ε = expansion coefficient

d = internal primary element diameter

D = Internal pipe diameter

Flow type



Laminar

Turbulent



So it is necessary to ensure to have the right straight length



What are the Primary Element ?

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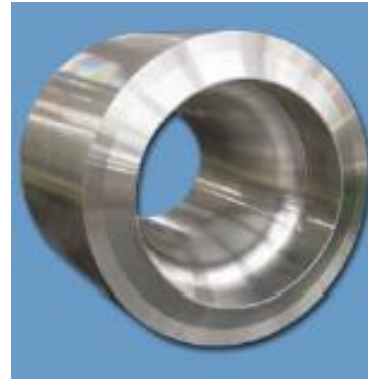
Primary elements



Venturi and micro-venturi



Nozzles



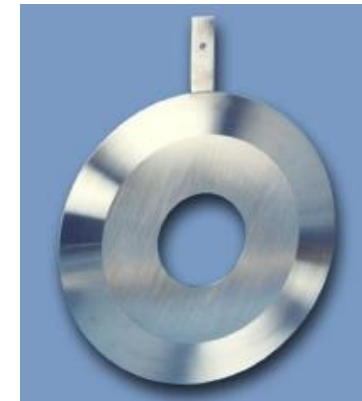
Pitot Tube



Wedges



Diaphragm



Orifice plate

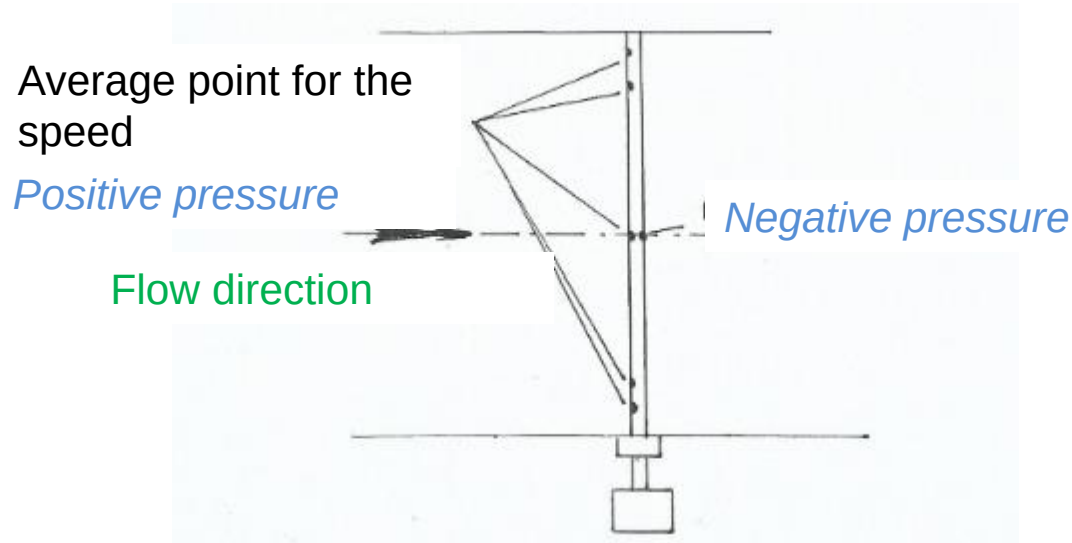


V-Cone

Pitot Tube

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Pitot tubes generates a differential pressure proportional to the dynamic pressure



Low cost solution for measurement in large diameter pipes or ducts

- ❖ Low permanent pressure lost – energy lost use is minimal
- ❖ Robust construction – long service life and virtually impossible to wear out
- ❖ Negligible wear – long term stability with Zero drift or degradation

Pitot Tube

**Pitot Tubes with FKC
for Flow measurement and corrected Flowrate (Nm³/h)**



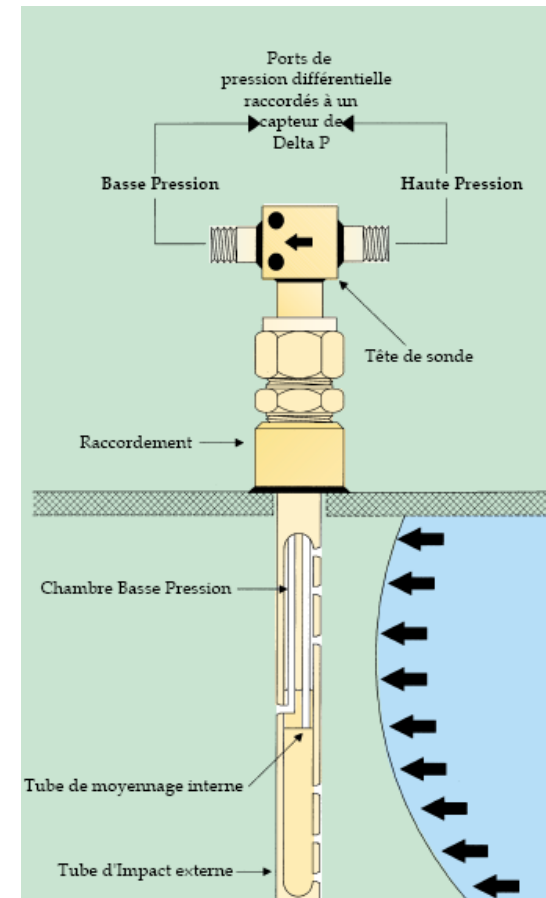
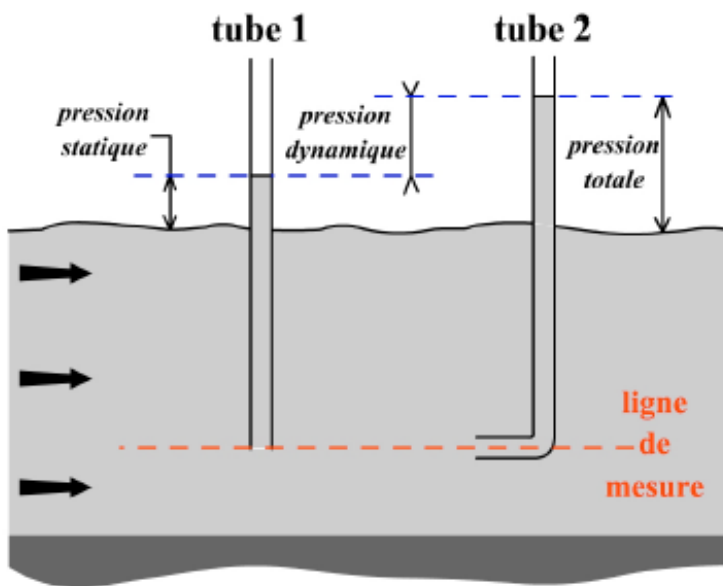
Single point 5 RB

Average 5RD



Pitot tube characteristics

- Rangeability: 10 : 1
- Accuracy $\pm 1 \%$ of real flow rate
- Maxi Temperature: 500°C
- DN50 to DN1500
- 316 L
- Be careful with loaded fluids → fooling !



What kind of fluids?

❖ 5RD Average

Water



Gas



Steam



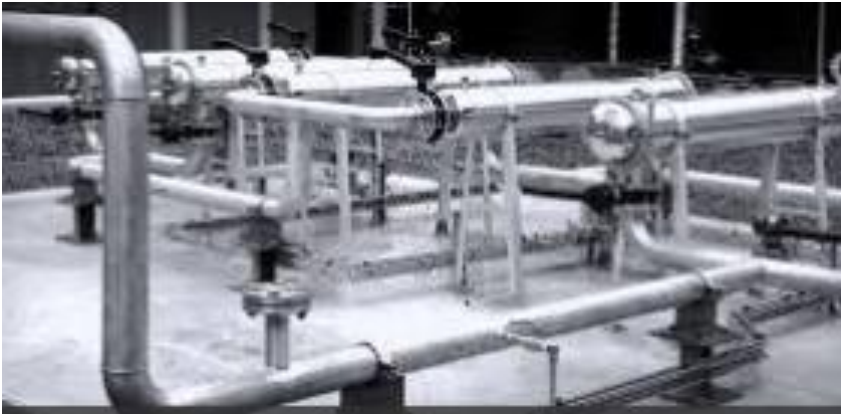
❖ 5RD Single point

Gas



What kind of pipe?

Circular pipe



To know the internal diameter
and the thickness of the pipe

Rectangular pipe



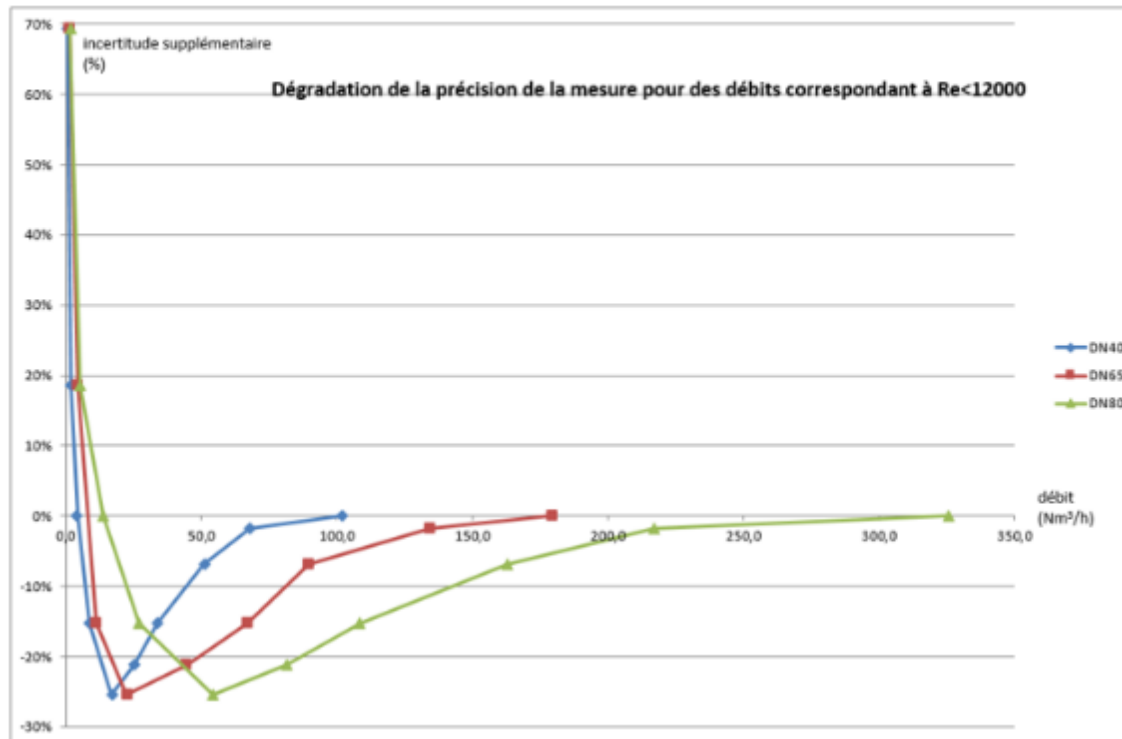
To know the internal length, height and
thickness of the duct

**IMPORTANT: Specify the pitot tube
localization: in the length or height**

Be careful if the pipe has a thermal protection !!!

Pitot tube accuracy with the flowrate

DN 40 à DN 80



Pitot tube only

Pressure transmitter only

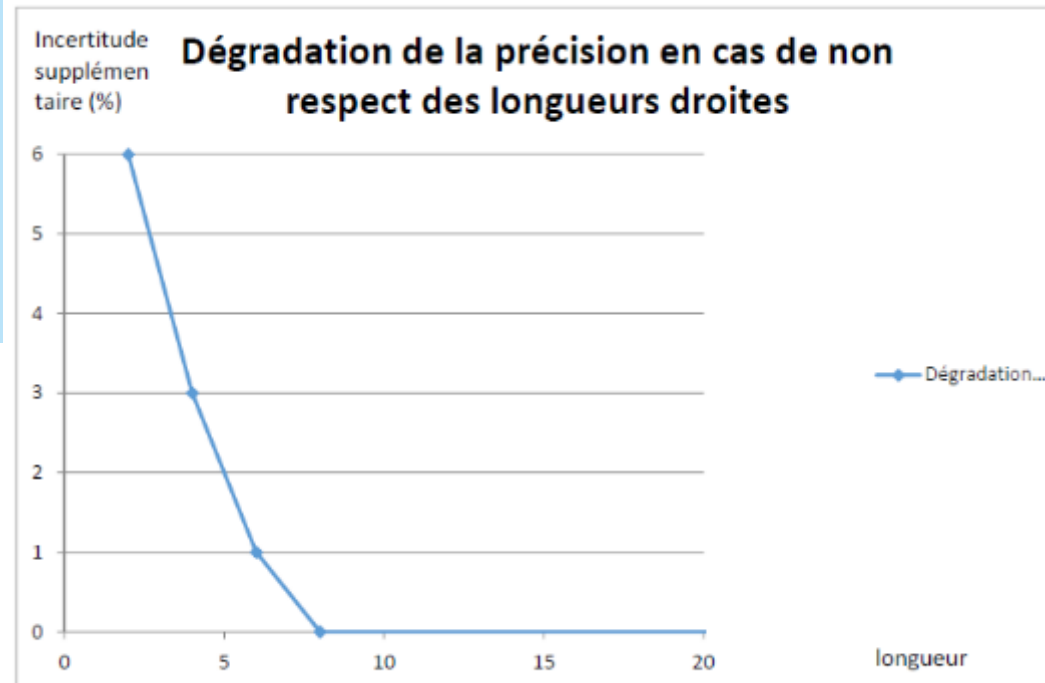
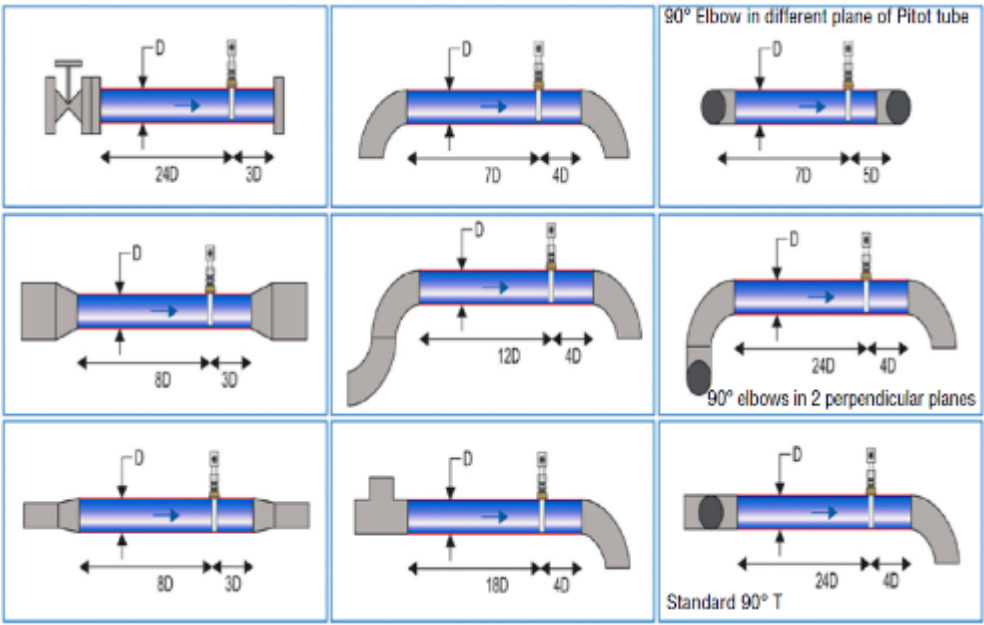
FKC11 and 22	Accuracy
50-100% of output	0,10% span
20-50 % of output	0,25% span
10-20% of output	0,50% span

Be careful to the minimal flowrate !!!

Straight length



5RB pitot tube is more sensitive to the straight length than 5RD pitot tube !!



No straight length, degraded accuracy !!!

Exemple of accuracy

URV transmitter :	1,74			
FKC11 et FKC22				
Flowrate	DP	Transmitter accuracy		Measurement accuracy
T/h or m3/h	mbar	% Span	mbar	%
1200	1,74	0,1	0,00174	0,1
900	0,98	0,1	0,00174	0,2
800	0,77	0,25	0,00435	0,6
600	0,44	0,25	0,00435	1,0
500	0,3	0,5	0,0087	2,9
400	0,19	0,5	0,0087	4,6
300	0,11	0,5	0,0087	7,9
200	0,05	0,5	0,0087	17,4
100	0,01	0,5	0,0087	87,0

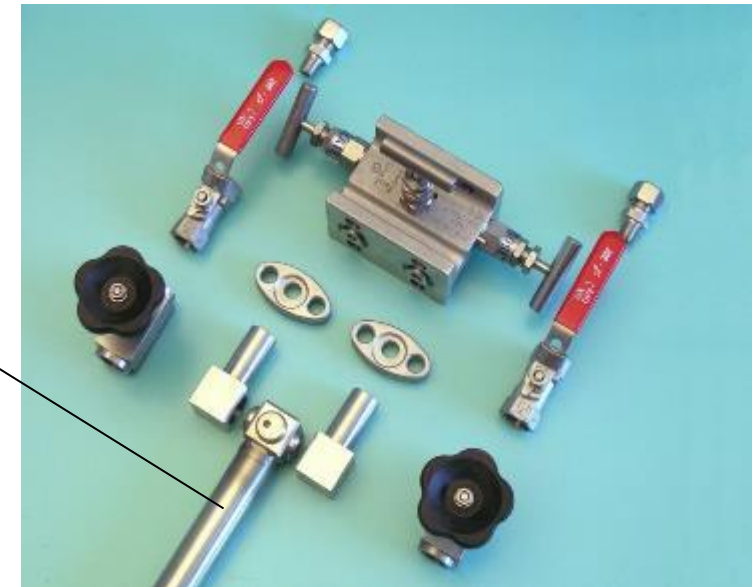
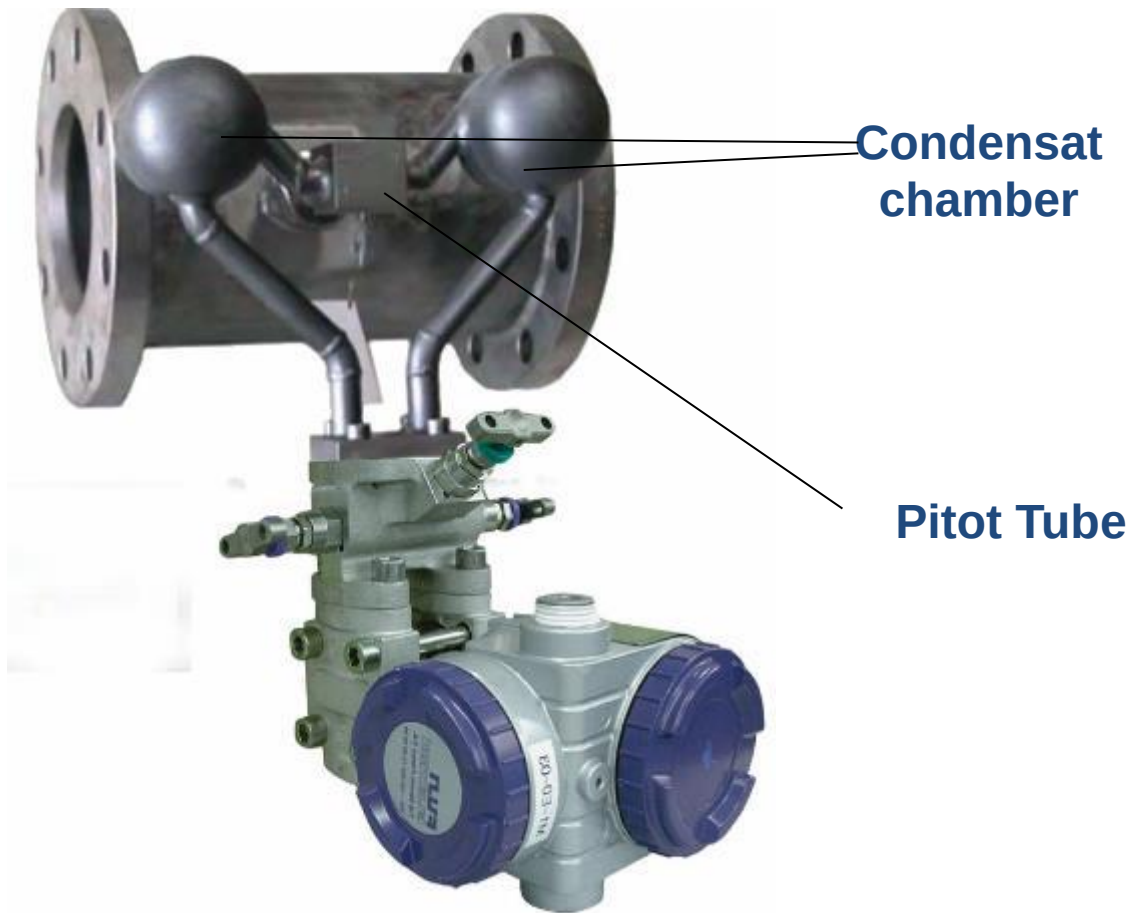
: **Imprecision** (Pitot (2%) + transmitter) : **10 % around at 300 m3/h**

Accuracy = Transmitter + Pitot + all element of the measurement chain

- Biogaz
- Boiler
- Incineration plant
- Cogeneration plant
- Compressor and HVAC
- Flow gas or atmospheric emission flue gas measurement
- Oxygenation of water treatment plant's aerating tank



Measurement of steam flowrate with a pitot tube



Pitot tube with remote transmitter

**Pitot tube with a remote
erection**

Differential pressure transmitter



Pressure transmitter

Biogaz flow measurement with Pitot tube



Differential pressure XTR

Temperature measurement

Absolute pressure XTR

Pitot tube



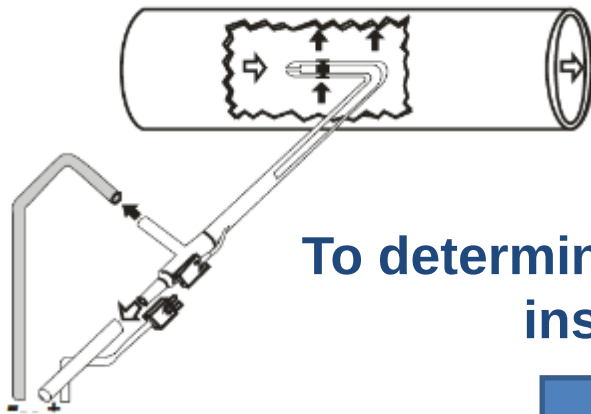
Automatic unclogging cabinet system – Pitot tube

Air injection with programming time in the 5RD and 5RB pitot tubes



For loaded fluids

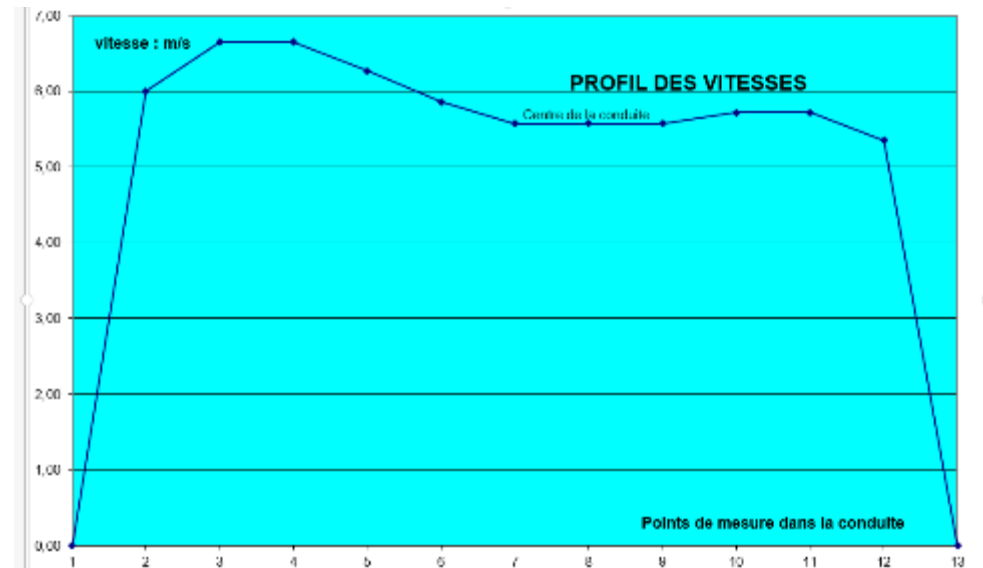
Velocity profile



To determine the velocity profile
inside the pipe



Check and/or verify the
precise localization of the
pitot tube inside the pipe ...



Standard NF X10-112

Can be made by FEF

V-Cone

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Technical datasheet – V-Cone



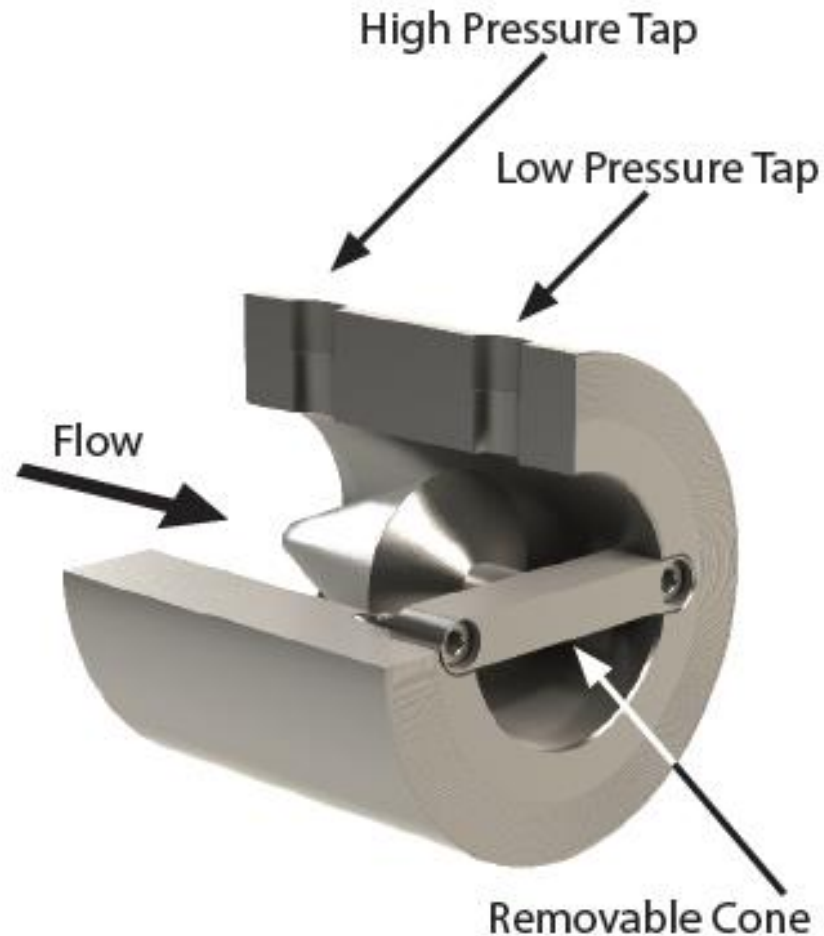
- ❖ Liquid, gas and steam measurement for **high loaded and high viscosity** fluid. For example: waste water, oil...
- ❖ **Straight length very low (3D/1D)**
- ❖ Flow profile very stable, High accuracy (< 1% of the flow) and reputability: 10:1
- ❖ No corrosion of the cone by abrasion
- ❖ Many FCX working for « subsea » flowrate measurement (oil&gas application)
- ❖ Measurement in 2 ways

- **Accuracy:** to $\pm 0.5\%$ of rate
- **Turndown:** from 10:1
- **Repeatability:** $\pm 0.1\%$

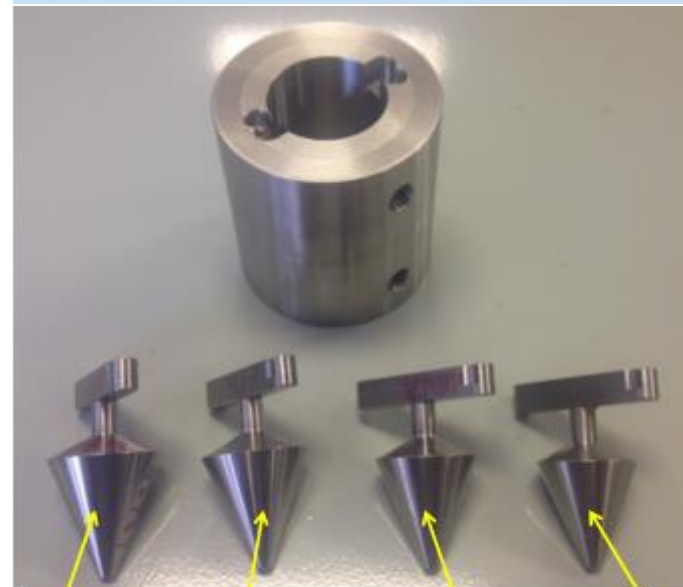


- ❖ All and each V-Cones are supplied with standard water calibration.
- ❖ $\pm 0.5\%$ Accuracy for all V-Cones calibrated over the total Re Range of the application for a 10:1 turndown.
- ❖ $\pm 1.0\%$ Accuracy for all V-Cones operated above 20,000 Re but not calibrated over the total Re application range.
- ❖ Meters operated below Re 8,000 may require a high viscosity calibration.
- ❖ Stated accuracy is valid through all the Turndown of the meter.

Wafer-Cone



Accuracy: $\pm 1.0\%$ of rate
Turndown: 10:1
Repeatability: $\pm 0.1\%$
Line Sizes: 1" to 6"
Standard Beta Ratios: 0.45 through 0.85
Head Loss: % of dP, varies with beta ratio
Piping Requirements: 1-3 diameters upstream and
1 diameter downstream of the cone



$\beta = 0.45$

$\beta = 0.50$

$\beta = 0.55$

$\beta = 0.60$

V-Cone

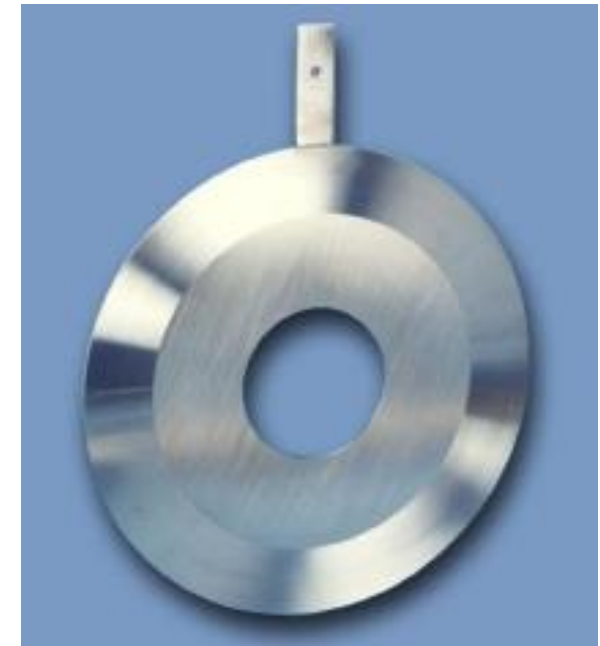
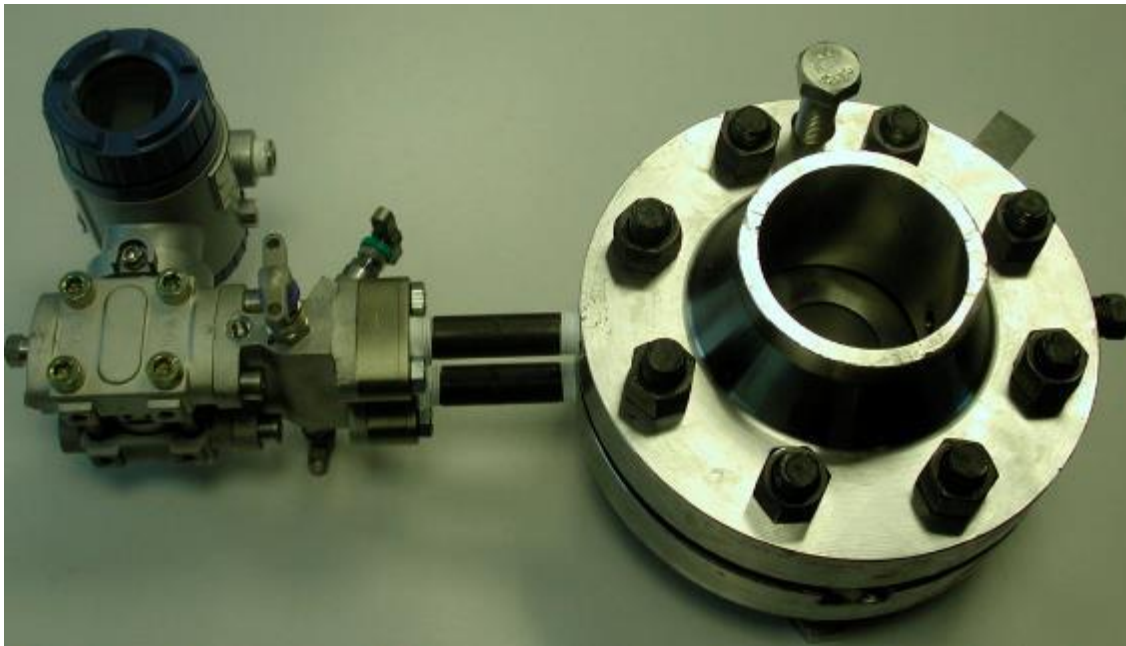


Orifice plate

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Technical specification: Orifice plate

- Accuracy: 1,5 % or flow (ISO 5167)
- Rangeability: 6 : 1
- Excellent repeatability
- Connection clogging because of high loaded fluid
- High pressure lost

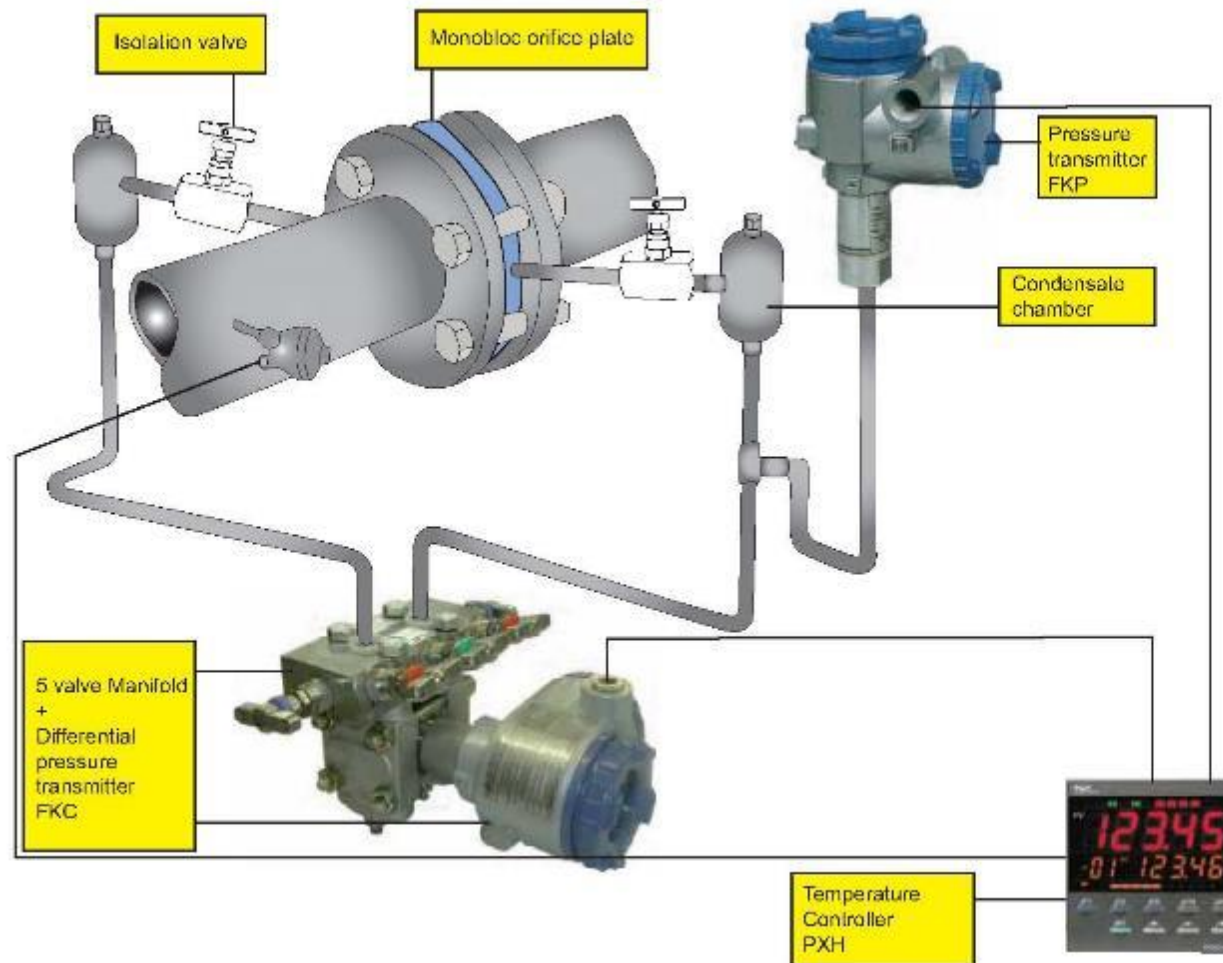


Integrated orifice

- **Measurement of low flowrate (liquid or gas)**
- Assembly with flange upon request



Steam flowrate with orifice plate



Fuji Electric



Straight length: Orifice plate

Diam- eter ratio β	Upstream (inlet) side of orifice plate																								Down- stream (outlet) side of the orifice plate	
	Single 90° bend Two 90° bends in any plane $(S > 30D)^a$		Two 90° bends in the same plane: S -configur- ation $(30D \geq S > 10D)^a$		Two 90° bends in the same plane: S -configur- ation $(10D \geq S)^a$		Two 90° bends in perpen- dicular planes $(30D \geq S \geq 5D)^a$		Two 90° bends in perpen- dicular planes $(5D > S)^{a, b}$		Single 90° tee with or without an extension Mitre 90° bend		Single 45° bend Two 45° bends in the same plane: S -configur- ation $(S \geq 2D)^a$		Concentric reducer $2D$ to D over a length of $1,5D$ to $3D$		Concentric expander $0,5D$ to D over a length of D to $2D$		Full bore ball valve or gate valve fully open		Abrupt symmetrical reduction		Ther- mometer pocket or well ^c of diameter $\leq 0,03D^d$		Fittings (columns 2 to 11) and the densi- tometer pocket	
1	2		3		4		5		6		7		8		9		10		11		12		13		14	
—	A ^e	B ^f	A ^e	B ^f	A ^e	B ^f	A ^e	B ^f	A ^e	B ^f	A ^e	B ^f	A ^e	B ^f	A ^e	B ^f	A ^e	B ^f	A ^e	B ^f	A ^e	B ^f	A ^e	B ^f	A ^e	B ^f
$\leq 0,20$	6	3	10	9	10	9	19	18	34	17	3	9	7	9	5	9	6	9	12	6	30	15	5	3	4	2
0,40	16	3	10	9	10	9	44	18	50	25	9	3	30	9	5	9	12	8	12	6	30	15	5	3	6	3
0,50	22	9	18	10	22	10	44	18	75	34	19	9	30	18	8	5	20	9	12	6	30	15	5	3	6	3
0,60	42	13	30	18	42	18	44	18	65 ^h	25	29	18	30	18	9	5	26	11	14	7	30	15	5	3	7	3,5
0,67	44	20	44	18	44	20	44	20	60	18	36	18	44	18	12	6	28	14	18	9	30	15	5	3	7	3,5
0,75	44	20	44	18	44	22	44	20	75	18	44	18	44	18	13	8	36	18	24	12	30	15	5	3	8	4

Straight length according to ISO 5167

Diaphragm installation



Diaphragm installation



Exemple of installation



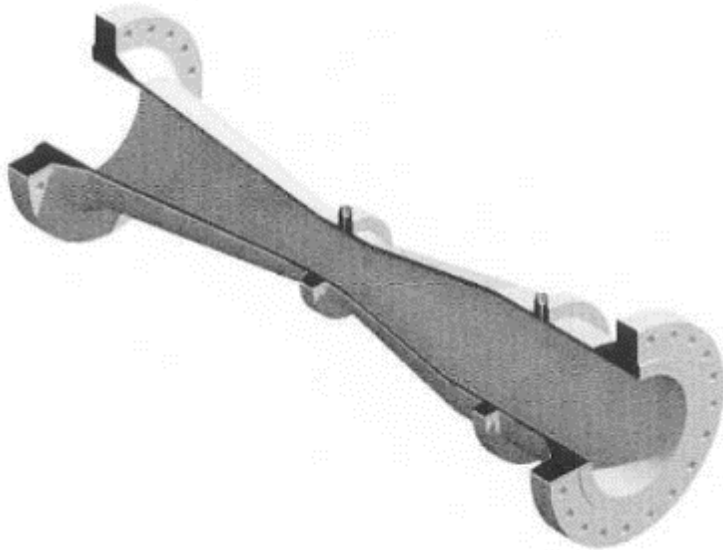
Exemple of installation



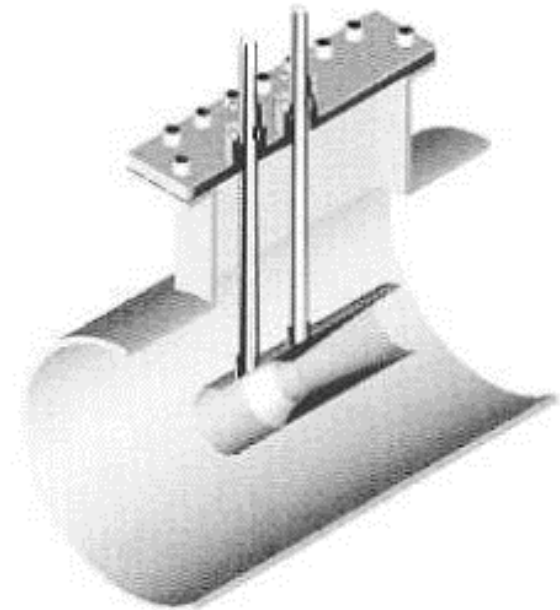
Venturi and micro venturi

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Venturi & Micro-venturi, the difference



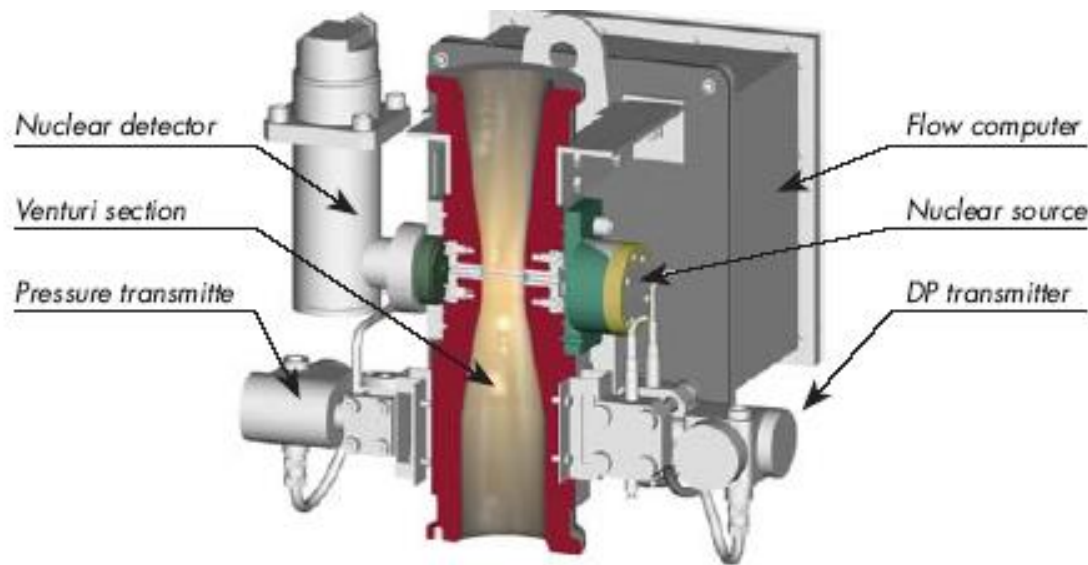
Venturi



Micro venturi

Technical datasheet - Venturi

- Accuracy: 1,5% of maximal flow
- Rangeability: 6 : 1
- Low pressure lost
- Recommended for high viscosity and high loaded fluid



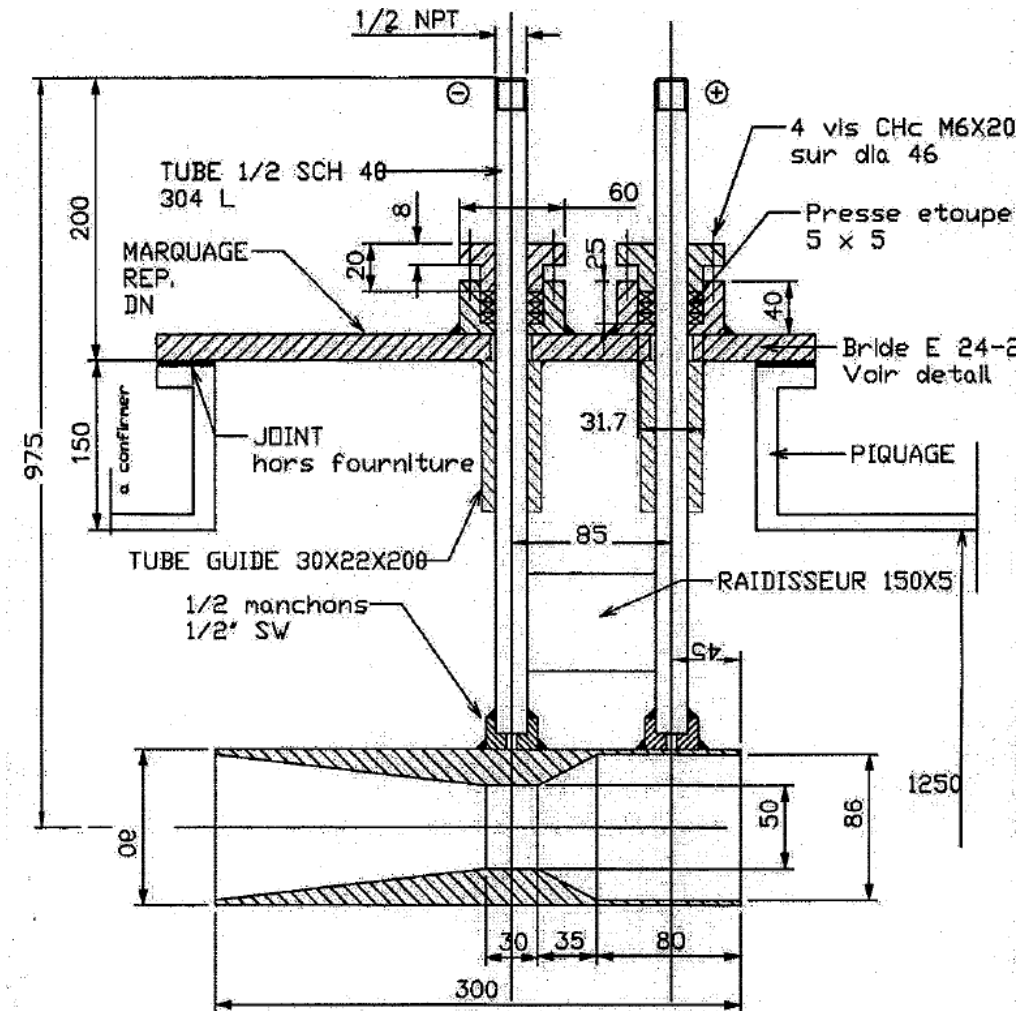
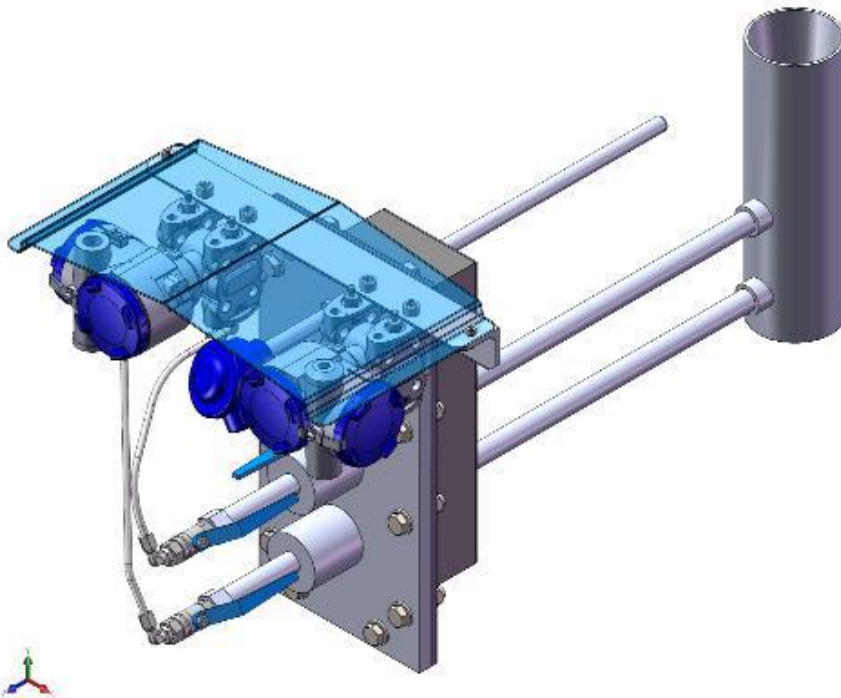
Straight length – Venturi

Diameter ratio β	Single 90° bend ^a		Two or more 90° bends in the same plane or different planes ^a		Reducer 1,33D to D over a length of 2,3D		Expander 0,67D to D over a length of 2,5D		Reducer 3D to D over a length of 3,5 D		Expander 0,75D to D over a length of D		Full bore ball or gate valve fully open	
1	2		3		4		5		6		7		8	
	A ^b	B ^c	A ^b	B ^c	A ^b	B ^c	A ^b	B ^c	A ^b	B ^c	A ^b	B ^c	A ^b	B ^c
0,30	8	3	8	3	4	d	4	d	2,5	d	2,5	d	2,5	d
0,40	8	3	8	3	4	d	4	d	2,5	d	2,5	d	2,5	d
0,50	9	3	10	3	4	d	5	4	5,5	2,5	2,5	d	3,5	2,5
0,60	10	3	10	3	4	d	6	4	8,5	2,5	3,5	2,5	4,5	2,5
0,70	14	3	18	3	4	d	7	5	10,5	2,5	5,5	3,5	5,5	3,5
0,75	16	8	22	8	4	d	7	6	11,5	3,5	6,5	4,5	5,5	3,5

Straight length according to ISO 5167

Technical datasheet - Micro venturi

- Rangeability: 6 : 1
- Accuracy: 1,5 % of flow
- **Low pressure lost**

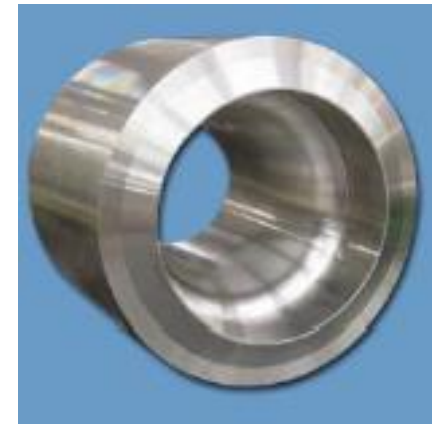
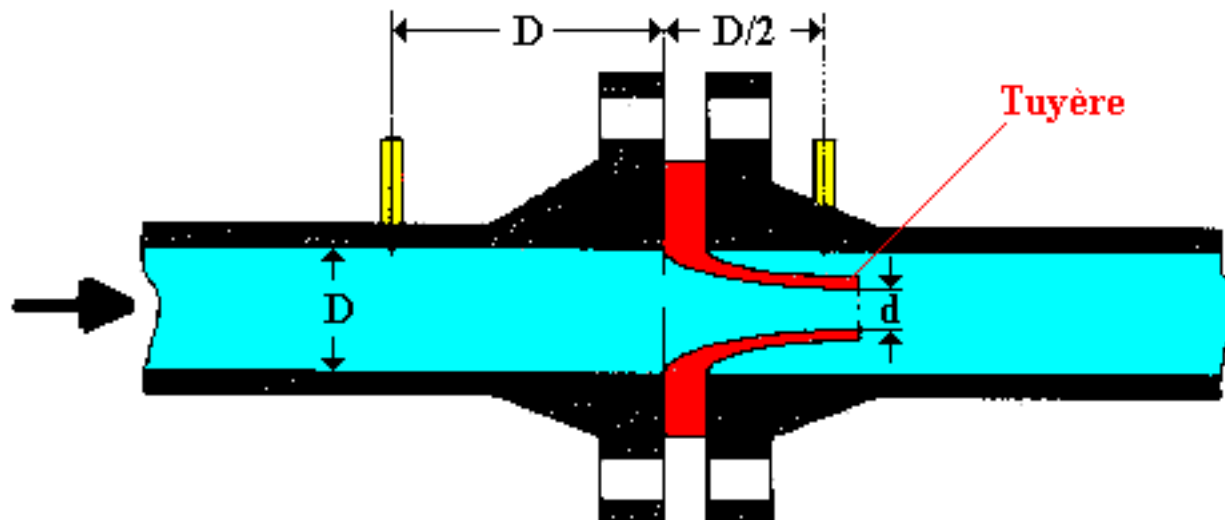


Nozzle

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Technical datasheet - Nozzle

- ❖ Recommended for high Reynolds number > 50000 , for exemple : steam with high temperature. **DO NOT USE THIS PRIMARY ELEMENT FOR SLUDGE**
- ❖ Accuracy: 1,5 % of flow (ISO 5167)
- ❖ Rangeability: 6 : 1



Straight length - Nozzle

Diam- eter ratio β^a	Upstream (inlet) side of the primary device																				Downstream (outlet) side of the primary device	
	Single 90° bend or tee (flow from one branch only)		Two or more 90° bends in the same plane		Two or more 90° bends in different planes		Reducer 2D to D over a length of 1,5D to 3D		Expander 0,5D to D over a length of D to 2D		Globe valve fully open		Full bore ball or gate valve fully open		Abrupt symmetrical reduction		Thermometer pocket or well ^b of diameter ≤ 0,03D		Thermometer pocket or well ^b of diameter between 0,03D and 0,13D		Fittings (Columns 2 to 8)	
	2		3		4		5		6		7		8		9		10		11		12	
1	A ^c	B ^d	A ^c	B ^d	A ^c	B ^d	A ^c	B ^d	A ^c	B ^d	A ^c	B ^d	A ^c	B ^d	A ^c	B ^d	A ^c	B ^d	A ^c	B ^d	A ^c	B ^d
0,20	10	6	14	7	34	17	5	e	16	8	18	9	12	6	30	15	5	3	20	10	4	2
0,25	10	6	14	7	34	17	5	e	16	8	18	9	12	6	30	15	5	3	20	10	4	2
0,30	10	6	16	8	34	17	5	e	16	8	18	9	12	6	30	15	5	3	20	10	5	2,5
0,35	12	6	16	8	36	18	5	e	16	8	18	9	12	6	30	15	5	3	20	10	5	2,5
0,40	14	7	18	9	36	18	5	e	16	8	20	10	12	6	30	15	5	3	20	10	6	3
0,45	14	7	18	9	38	19	5	e	17	9	20	10	12	6	30	15	5	3	20	10	6	3
0,50	14	7	20	10	40	20	6	5	18	9	22	11	12	6	30	15	5	3	20	10	6	3
0,55	16	8	22	11	44	22	8	5	20	10	24	12	14	7	30	15	5	3	20	10	6	3
0,60	18	9	26	13	48	24	9	5	22	11	26	13	14	7	30	15	5	3	20	10	7	3,5
0,65	22	11	32	16	54	27	11	6	25	13	28	14	16	8	30	15	5	3	20	10	7	3,5
0,70	28	14	36	18	62	31	14	7	30	15	32	16	20	10	30	15	5	3	20	10	7	3,5
0,75	36	18	42	21	70	35	22	11	38	19	36	18	24	12	30	15	5	3	20	10	8	4
0,80	46	23	50	25	80	40	30	15	54	27	44	22	30	15	30	15	5	3	20	10	8	4

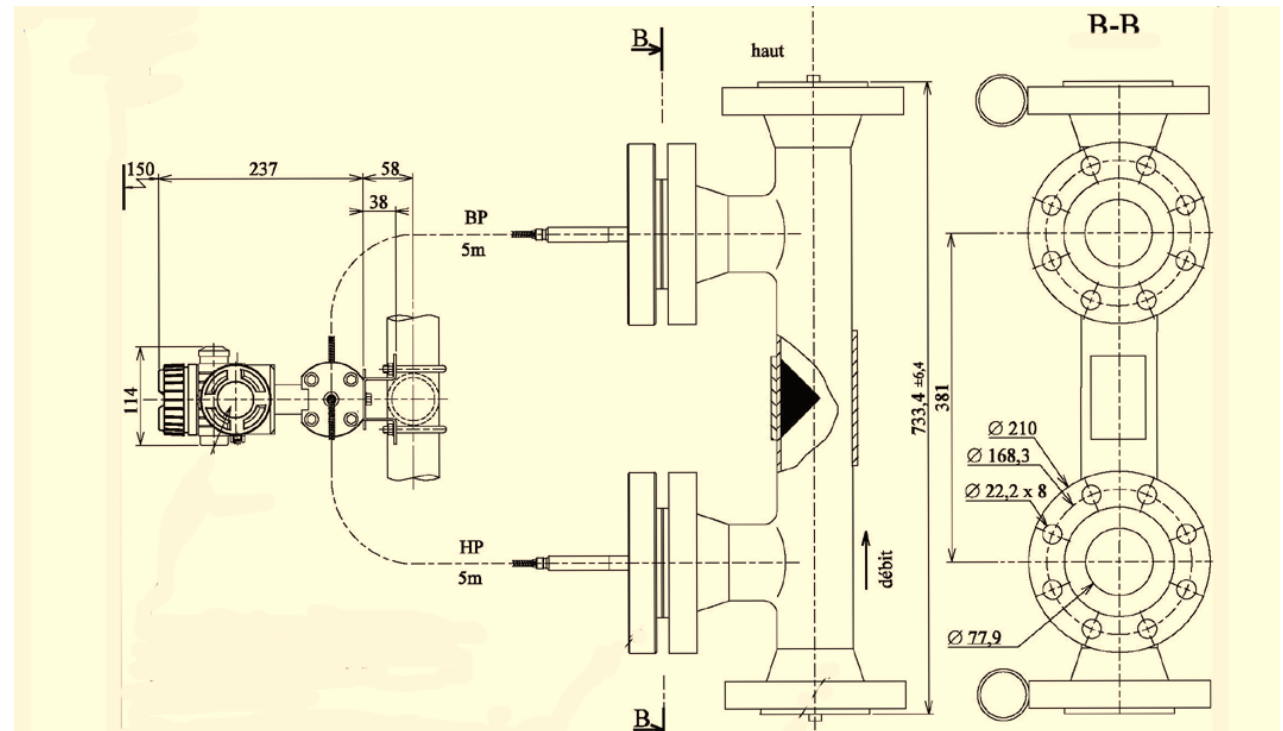
Straight length according to ISO 5167

Wedges

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Flowrate measurement with a wedges

Measurement for high viscosity or high loaded fluid



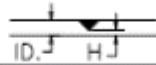
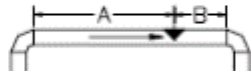
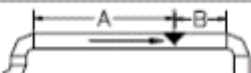
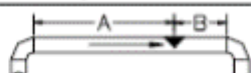
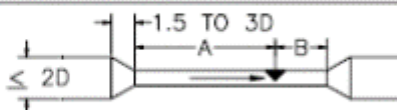
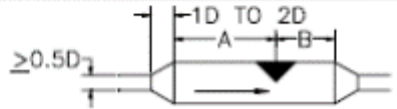
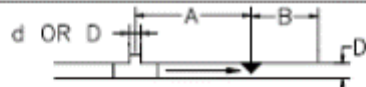
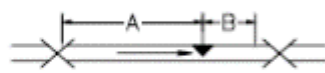
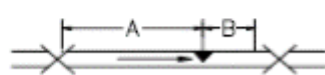
Technical datasheet - Wedges

- ❖ Accuracy: $< 1\%$ of maximal flow
- ❖ Repeatability: $\pm 0,2\%$
- ❖ Correct measurement with a low Reynolds (< 300)
- ❖ **Low pressure lost**
- ❖ **Measurement for fluid with high viscosity**
- ❖ Dual measurement



Oil&Gas application

Straight length – Wedges

DISTANCES (DIMENSIONS A & B) EXPRESSED IN NOMINAL PIPE DIAMETERS		ACCURACY: CALIBRATED $\pm 0.5\%$ UNCALIBRATED $\pm 3\%$				
UPSTREAM DISTURBANCE		DIMENSION	COIN RATIO (H/ID.) 			
			.2	.3	.4	.5
 Single Elbow	A	7	9	10	12	
	B	4	4	4	4	
 Two elbows in the same plane	A	10	12	14	16	
	B	4	4	4	4	
 Two elbows in different planes	A	20	22	24	30	
	B	4	4	4	4	
 Reducer	A	9	11	14	16	
	B	4	4	4	4	
 Expander	A	9	10	12	14	
	B	5	5	5	5	
 Tee connection with different diameters	A	7	9	10	12	
	B	4	4	4	4	
 Globe valve fully opened	A	10	12	14	16	
	B	4	4	4	4	
 Gate valve fully opened	A	7	7	9	10	
	B	4	4	4	4	

Exemple of measurement with a wedges



Conclusion

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Some advises...



- DP transmitter must be in square root or the PLC

Do not put the square root function on both

- The range of the pressure transmitter is according to the primary element calculation so to the flowrate

The URV is link to the maximum flowrate calculated

- Caution during the installation of the primary element (for example not in the right direction)
- BE careful to the clogging of the primary element

Primary element comparison

	DIAPHRAGM	VENTURI	NOZZLE	PITOT
Pressure lost	High pressure lost	Low pressure lost	Low pressure lost	Low pressure lost
Accuracy	According to a standard	According to a standard	According to a standard	No standard. Accuracy at 1,5%
	(ISO 5167) around 1,5%	(ISO 5167) around 1,5%	(ISO 5167) around 1,5%	Very dependant of the flow
Erection	Need to cut the pipe and weld the flange	Need to cut the pipe and weld the flange	Need to cut the pipe and weld the flange	Easy. No big works: No weld etc..
DN limits	According to the standard: DN > 50mm	According to the standard: DN between 200 mm and 1200 mm	According to the standard: DN between 50 mm and 630 mm	According to the standard: DN between 25mm and 6000 mm
Conclusion	Frequent use due to its price	Median use because of the cost of the erection	Rare. Very expensive for erection	Very often. Erection and price very interesting

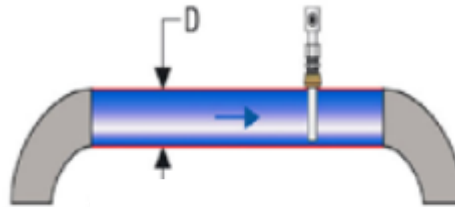
Primary element comparison

	Nozzle	Orifice plate (single hole)	Orifice plate (multi hole)	V-Cone	Pitot	Micro- venturi	Venturi
Price	+++	++	+	++++	+	+++	+++
Efficiency on loaded fluid	+	+	+	+++	+	++	++
Straight length	+++	++++	+	+	++	+	+++
High viscosity	+	+	+	++++	+	++	+++
Erection parameters	++	++	++	++	+	+++	++

+ Low
 ++++ High

Straight length - Comparison

Example: Pipe with 1 elbow downstream and upstream
Beta : 0,50



Primary Element	Pitot *	Orifice plate Single hole	Orifice plate Multi hole *	Venturi	Micro venturi *	Nozzle	Wedge	V-Cone
Straight length	7D/4D	22D/6D	2D/2D	9D/3,5D	3D/2D	14D/6D	12D/4D	3D/1D 0D/0D ¹

* Not included to ISO5167

¹ According to manufacturer McCrometer

Important technical point !!

- Technical information datasheet
- Minimum required technical data:
 - ❖ Internal diameter, thickness, thermal protection or other
 - ❖ Nominal Pressure
 - ❖ Nominal temperature
 - ❖ Fluid type
 - ❖ **Maximal REAL flowrate !**
 - ❖ Density if non standard
- Check straight length
- Check connection and erection
- DP pitot tube calculation note



Selection table – Primary element

Elément déprimogène – Tableau de sélection
Primary element – Selection table

Information générale / General information

Nom du client / Customer name

Nom du projet / Project name

Sélection du déprimogène / Primary element selection

Tube de pitot moyenné / Average Pitot tube ☐ Tube de pitot monopoint / Single point Pitot tube ☐

V-Cone ☐ Tuyère / Nozzle ☐ Débitmètre à coin / Wedge flowmeter ☐

Orifice intégré / Integrated orifice plate ☐ Venturi ☐ Micro venturi ☐

Plaque à orifice / Orifice plate ☐ Diaphragme monobloc / Monoblock orifice ☐

Chambre annulaire / Annular chamber ☐

Veuillez spécifier / Please specify : Simple orifice / Single orifice ☐ Multi orifice / Multi orifice ☐

Fluide / Fluid

Nom : Liquide ☐ Vapeur ☐ Gaz ☐

Direction du fluide : Horizontale ☐ Verticale ☐

Tuyauterie / Pipe Information

Matière / Material : Pression Nominale / Operating Pressure : mbar

Classe DIN : / Schedule : Classe ANSI : / lbs

Diamètre interne / Internal diameter mm

Épaisseur tuyauterie / Pipe Wall thickness mm

Épaisseur calorifuge / Heat insulator Thickness mm

Longueur interne / Internal length mm Hauteur interne / Internal height mm

New table to be filled and sent to FEF

Valeurs physiques Physical values	Minimum	Nominal	Maximum	Unités <i>Units</i>
Débit / Flowrate				
Température / Temperature				
Pression / Pressure abs. ☐ Rel. / Gauge ☐				
Densité / Density				

Autres informations / Other informations

Version vissée / Screwed version : ☐ Type de raccordement / Connection type : ☐

Version à brides / Flange version : ☐ Extractible / Extractable : ☐

Brides DIN / Flange DIN : / PN : Brides ANSI / Flange ANSI : / lbs

Modèle compact / Compact model : ☐ Modèle déporté / Remote model : ☐

Montage si canalisation rectangulaire / Erection type if rectangular pipe :

Dans la hauteur / In the height : ☐ dans la longueur / In the length : ☐

Thank You

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