



## EMCO Primary Elements for Flow Measurement

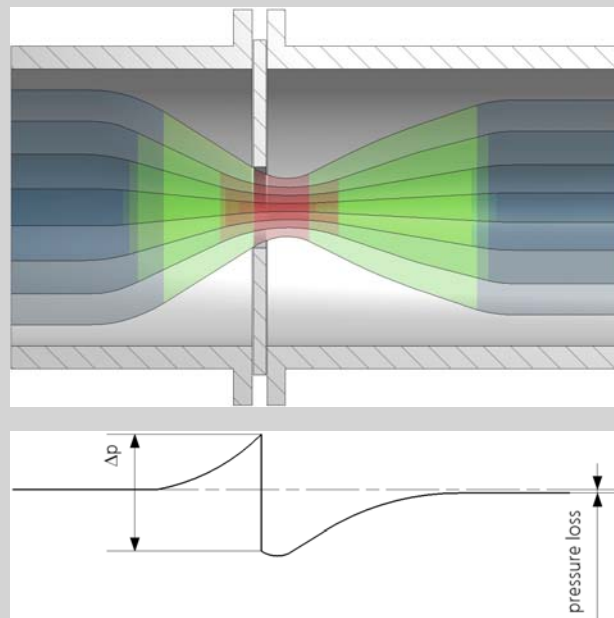
### Introduction

EMCO primary elements measure the flow of liquids, gases and steam according to the differential pressure principle. The primary elements are widely used in many industries including power stations and other thermal installations, chemical - and petrochemical, off shore- and water industry.

### Principle of measurement

Flow measurement according to the differential pressure principle is based upon the law of energy balance developed by Bernoulli. The sum of dynamic and static energy remains constant in a circular pipe where the fluid is fully contained.

The fluid must be in one phase and changes of flow shall be slowly i.e. without pulsation.



A restriction (an orifice plate or similar) in a pipe will change the combination of energy. The velocity in the throat will increase and consequently the pressure will decrease. The pressure before and after the restriction is measured and the applied differential pressure is an expression of flow velocity.

Between the differential pressure DP and flow Q there is a square root relationship which is expressed in the following formula:

$$Q = \alpha \times \epsilon \times \frac{\pi}{4} \times d^2 \times \sqrt{2 \times \Delta P \times \rho_1}$$

This formula can be reduced to:

$$Q = K \times \sqrt{\Delta P}$$

In the constant K many factors are contained f.i. the geometrical shape of the restriction, the pressure tapping, ratio of diameters and the condition of fluid characterised by the pressure, temperature, viscosity, density and other factors known by experience.





## EMCO Primary Elements for Flow Measurement

### Calculation and Manufacturing Standards

EMCO primary elements are calculated and constructed according to international standards.

Usually ISO 5167 "Measurement of fluid flow by means of orifice plates, nozzles and venturi tubes inserted in circular cross section conduits running full", ISO/TR 15377 or the American standards ASME MFC-3M, ASME MFC-14M or the German standard DIN 1952 "Durchflussmessung mit Blenden, Düsen und Venturirohren in voll durchstromten Rohren mit Kreisquerschnitt DIN 19205?19215, VDI/VDE 2040/41 are used.



Upon request primary elements are manufactured according to other American standards such as L.K. Spink, AGA No. 3, R. W. Miller : Flow measurement Engineering Handbook and Shell Flow meter Engineering Handbook.

### Accuracy

Equipment for flow measurement according to the principle of differential pressure consists of two elements:

The primary element and the differential pressure transmitter and signal conditioning electronics elements.

The overall accuracy of the flow meter depends of the accuracy of the individual parts plus the use of the correct physical values, i.e. pressure, temperature, density and for gasses expansion factors.

The accuracy is calculated according to ISO 5168.

The accuracy of the primary element can be divided into two groups:

### Basic tolerance and additional tolerance

The basic tolerance depends on the construction of the individual primary element (orifice plate, venturi, nozzle). The basic tolerance for an orifice plate varies with the diameter ratio "b" which is equal to d/D.

For orifice plates the basic tolerance is 0,5% for "b" less than 0,6 and equal to "b" at greater diameter ratio. For venturi nozzles the tolerance is  $(1,2 + 1,5 \times b^4)$  %. For classical venturi tubes the tolerance for the machined type is 1 % and for the welded sheet type 1,5 % and for "as cast" type 0,7 % These values are taken from the ISO standard whereas the ASME standard states more conservative figures.

In addition to the tolerances mentioned above, the manufacturing and the installation tolerances are not taken into account.

During manufacturing of the primary elements special care is taken of the bore of the orifice plates, the sharp edge and the surface of the upstream side of the plate.

Special jigs are to be used to ensure narrow tolerances. In the case that the sharp edge is rounded slightly the discharge coefficient C will change resulting in an error in flow reading.

When installing a primary element in a pipe run, the minimum requirement for the straight pipe run up and down stream must be taken into consideration. Up-stream disturbances influence the symmetrical flow profile and lead to incorrect flow measurement. Examples of disturbances are 90° elbow, two 90° elbows in two planes, control valves and thermowells.

The most common used instrument for measuring the differential pressure is the dP cell ? differential pressure transmitter. Due to the square root relationship between differential pressure and flow it is very important to choose an instrument which is very accurate especially when a wider rangeability is required.





## EMCO Primary Elements for Flow Measurement

The most common used instrument for measuring the differential pressure is the dP cell - differential pressure transmitter. Due to the square root relationship between differential pressure and flow it is very important to choose an instrument which is very accurate especially when a wider rangeability is required.

In some cases the use of only one transmitter is not sufficient when a wide rangeability and high accuracy is required. By using two transmitters or more the range is divided and each transmitter covers a fraction of the total range.

In addition to that the signal conditioning equipment switches between the transmitters according to the actual flow rate.

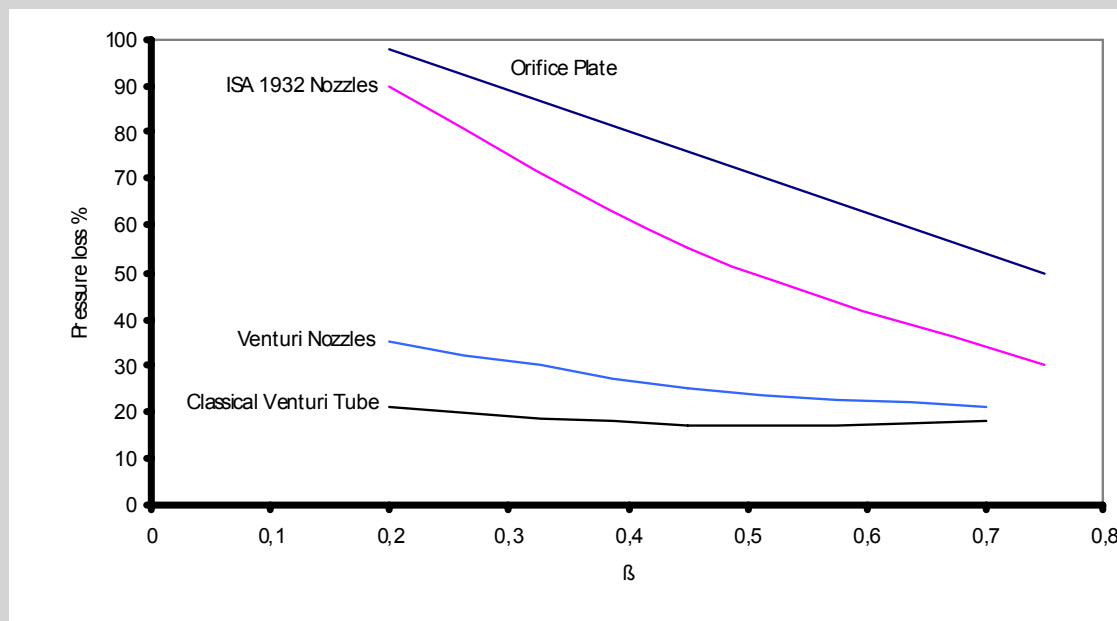
The multi variable transmitter offers a gigantic step forward for flow measurement using primary elements. This transmitter combines 4 instruments into 1 unit. The transmitter not only measure the differential pressure, but also the static pressure and can convert the signal from a external temperature sensor, and the transmitter also has a flow computer for calculation of mass flow. The flow computer performs a dynamic correction on constants.

With a total accuracy (orifice plate and transmitter) of 1 % a rangeability of approximately 10 : 1 is achievable.

The accuracy of venturis and nozzles is inferior to orifice plates.

### Permanent pressure loss

The previous mentioned transformation of energy in a restriction from pressure to velocity and back to pressure results in a permanent pressure loss. The pressure loss depends on the chosen primary element, and  $\beta$  value.



The permanent pressure loss for orifice plates, is between 35 and 80% of the calibrated span of the transmitter. Thanks to the square root relationship between differential pressure and flow, the drop in the permanent pressure loss is also the square root to the measured differential pressure. F.i. at 2/3 flow the pressure loss is reduced to the half.

The divergent in a classical venturi tube and short venturi nozzle results in a higher pressure recovery without turbulence resulting in a considerably lower pressure loss. It is 7-10% for classical venturi tube, whereas for venturi nozzle it is 10-15% of the calibrated span.





## EMCO Primary Elements for Flow Measurement

### Correction for physical and mechanical factors

The calculation of the bore "d" is normally based upon International Standards ISO 5167 and ASME. In order to use the discharge coefficients C mentioned in the standards, the physical properties of the fluid must be constant. If this is not the case the discharge coefficient C must be corrected. This is easily done with modern micro-processor technology in multi variable transmitter, in flow computer or in the main process control computer.

The need for correction depends on the required accuracy plus the magnitude of the variations. Most common is flow correction for gas and steam flow. The change in gas temperature from 20 to 26 degrees Celsius, which is equal to 2% of the absolute temperature, results in an error of 1%. More rarely it is necessary to correct for specific gravity of a liquid.

### Viscosity

A fluid can flow in a pipe run in two forms, laminar and turbulent. By laminar flow the velocity profile forms a parabola whereas by turbulent flow the profile has a "flat front" almost covering the whole cross section area of the pipe.

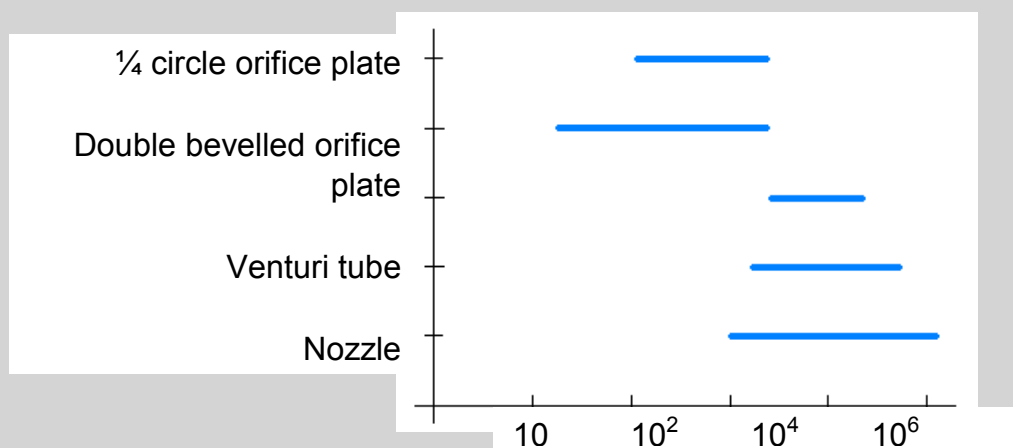
The velocity profile depends on the dimensionless Reynolds Number which is a relationship between flow velocity V, inner pipe diameter D and cinematic viscosity  $\gamma$

$$Re = \frac{V \times D}{\gamma}$$

At low Reynolds No., Re less than 2300, the flow is laminar in the pipe.

Orifice plates are following the ISO 5167 standard when Reynolds No is higher than 5000 at max. flow. This gives a margin of safety for turbulent flow through the restriction at reduced flow.

For viscous liquids - low Reynolds No - other discharge coefficients and shape of the orifice plates must be used. If high accuracy required it is recommended to calibrate at service condition. In the chart below, the range of the different primary elements can be seen.



For correct calculation of the bore "d", calculated from a computer programme, it is recommended to use our questionnaires. The standards refer to the primary elements with inner pipe diameter greater than 50 mm and less than 1200 mm. For primary elements with inner pipe diameter less than 50 mm a wet calibration must be foreseen if high accuracy is required. In many modern process plants with high pressures and high velocities the calculated Reynolds No. is higher than specified in the standards. However the standards say in the appendix that this may only lead to a slight increase in inaccuracy.





## EMCO Primary Elements for Flow Measurement

### Installation of primary elements

The primary element must be mounted in a straight pipe run of the same size. It is of greatest importance for correct flow measurement that the straight pipe run up and down-stream are following the standards. The length of straight pipe run depends on two things, the diameter ratio and the disturbance upstream.

The requirement is at least 10 times the upstream inner diameter and 4 times down stream of the primary element.

Worst case is 90° elbows in 2 plans plus a high "b" which requires 80 times inner pipe diameter of straight pipe run. Although 20?30 times is the most common requirement.

Is the required straight pipe run not available a flow straightener can be used. Different types are available each with its advantages and disadvantages. The most common is the "Bundle of Tubes" which consists of usually 19 tubes fastened together and to the main pipe. The length of the tubes depends on D ? the inner diameter of the pipe.

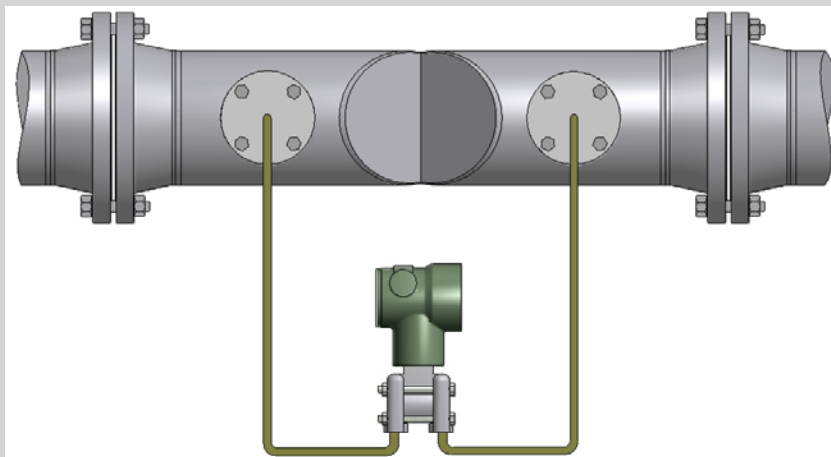
The inner roughness of the pipe has to be small in order not to influence the flow profile. The consideration is mainly necessary in the smaller sizes.

Installation of a primary element must be as far away as possible from any pulsation. For liquid flow measurement the liquid shall run full in the pipe.

The connecting tubes between the pressure tubes and the differential pressure transmitter shall always be mounted with a fall.

By air and gas flow measuring the best place to mount the transmitter is above the primary element allowing any condensation to run backwards into the main pipe.

By liquid flow measuring it is best to mount the transmitter below the primary element enabling any air or gas to escape into the main pipe.



By steam flow measuring it is recommended to use condensing chambers placed in the same horizontal height. The differential pressure transmitter is mounted below the primary element.

The condensing chambers should be half filled with water and the pressure of the water column on the plus and minus side of the transmitter is the same and has consequently no influence on the accuracy.

The "+" side of the orifice plate is connected to the "+" side of the DP-transmitter and the two "-" sides are connected. The impulse lines must be installed with a slope, to let captured air escape. The impulse lines should not be less than 12 mm and in a material suitable for the service condition. The primary element is normally supplied with single or double isolating valves.



## EMCO Primary Elements for Flow Measurement

### PITOBAR Averaging Pitot tube

For flow measurement of liquid, steam and gasses.

The PITOBAR is mounted diametrically across the pipe.

The probe of the PITOBAR has holes spaced centrally within concentric rings of equal areas.

Sizes from DN 50 (2") to DN 8000 (320") and pressure ratings up to PN 400 (2500 lbs).

The PITOBAR has a flange mounting style for easy and correct mounting.

The PITOBAR averaging pitot tube is manufactured from solid bar in a great variety of machinable materials reaching from stainless steel to Hastelloy, 254 SMO, Inconel, Titanium and Duplex steel

Simple construction but still strong and ridged for high flow velocities and high differential pressures.



### EMCO Orifice Plates

For flow measurement of liquid, gas and steam.

For insertion between flanges with pressure tapplings in the flanges or in the orifice plate itself.

Orifice plate with carrier rings with annular chamber.

Can be supplied with mating flanges, bolts, nuts and gaskets.

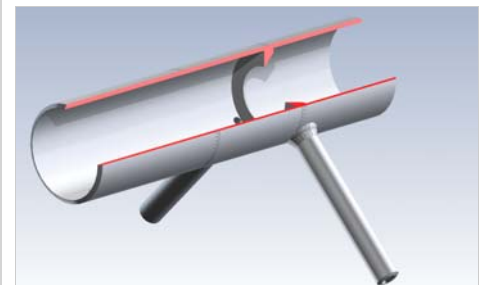
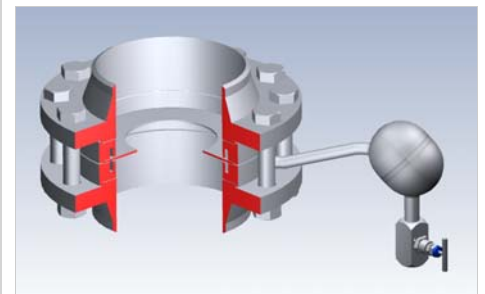
Shown with condensing chambers for steam flow measurement.

Orifice plate in all welded construction.

Materials for high temperature and high pressure.

With single pressure tapplings or annular chambers.

Process connections are butt weld ends.





## EMCO Primary Elements for Flow Measurement

### EMCO Venturis and Nozzles

Classical venturi tubes are manufactured in 3 different versions: machined, welded sheet, and as cast.

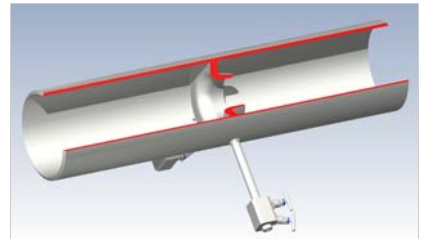
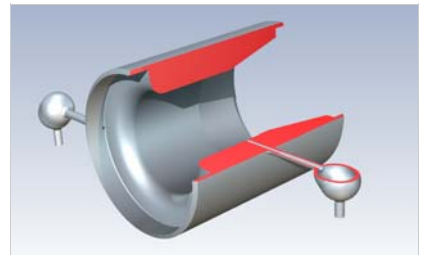
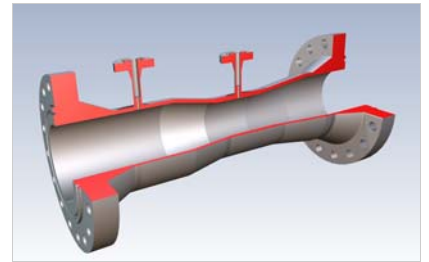
Process connections are flanges, butt weld ends or hubs for clamp connections.

With single pressure tapings or annular rings.

Supplied in many exotic materials including 13CrMo4-5, 10CrMo9-10 and F91.

ISA 1932 nozzle with single pressure tapings or annular chambers.

Offers higher accuracy but has also higher pressure loss than the venturi nozzle.



### EMCO Meter Runs

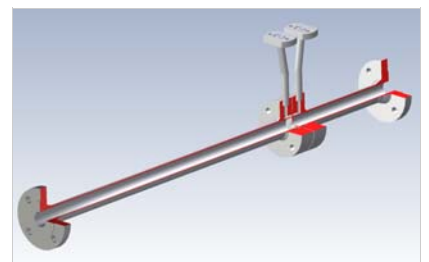
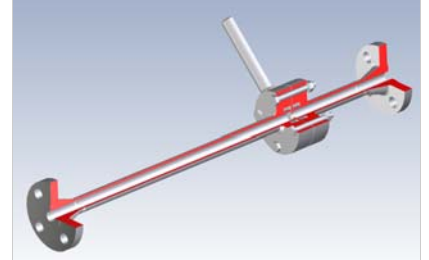
Meter runs are used in pipe sizes up to DN 50 (2")

The orifice plate is fixed between carrier rings.

The meter run is made from high precision cold drawn pipes to insure high accuracy.

Meter runs type CompaQ are constructed in the same way as standard meter runs, but have mounting flanges for direct manifold and/or transmitter mounting.

This solution offers a full flow meter package.



### Accessories

Condensing chambers in many materials to suit the process conditions.

Strength calculations to PED or ASME standards.

Primary shut off valves with a full choice of connections.

