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 petro-chemical, 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.

![Diagram of flow measurement](image)

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 \( \Delta P \) and flow \( Q \) there is a square root relationship which is expressed in the following formula:

\[
Q = \alpha \times \varepsilon \times \frac{\pi}{4} \times d^2 \times \sqrt{2 \times \Delta P \times \rho_1}
\]

the formula can be reduced to:

\[
Q = K \times \sqrt{\Delta P}
\]

In the constant \( K \) many factors are contained f.i. the geometrically 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.
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", or the American standard ASME MFC-3M 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 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 "β" which is equal to d/D.

For orifice plates the basic tolerance is 0.6% for "β" less than 0.6 and equal to "β" at greater diameter ratio. For venturi nozzles the tolerance is (1.2 + 1.5 x β^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 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. The smart transmitter offers higher accuracy than the traditional analogue transmitter.

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 newly developed 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. 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.

![Pressure loss graph](image)

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.
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. Is this 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 dimension less Reynolds Number which is a relationship between flow velocity V, inner pipe diameter D and cinematic viscosity γ.

\[ \text{Re} = \frac{V \times D}{\gamma} \]

At low Reynolds No., Re less than 2300, the flow is laminar. Orifice plates are following the standards 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. Is 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.
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 downstream 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 downstream of the primary element.

Worst case is 90° elbows in 2 plans plus a high "β" 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 pots placed in the same horizontal height. The differential pressure transmitter is mounted below the primary element.

The condensing pots 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 x 2 mm and in a material suitable for the service condition. The primary element is normally supplied with isolating valves.
Primary Element Types

EMCO Orifice Plates for Insertion between Flanges

EMCO orifice plates are manufactured according to ISO 5167, ASME MFC-3M, DIN 1952 and DIN 19206 with a concentric, eccentric bore or as segmental orifice. The edge of the orifice plate is made sharp during a special manufacturing process.

Other shapes are available to suit specific applications including 1/4 circle and double bevelled.

The orifice plates are mounted between flanges with RF or RTJ facing according to ANSI B 16.36 or DIN 19214 standards.

The pressure tappings are in the orifice flanges or in the main pipe.

The orifice plates are suitable for pressure ratings up to PN400 or ANSI 2500 lbs and are available in sizes up to DN 1000 (40").

The orifice plates are normally made from AISI 316 stainless steel sheets, but are also manufactured in more exotic materials like Monel, 254 SMO, Hastelloy, Duplex, Titanium and Zirconium.

Advantages: High accuracy, low price.

EMCO Orifice Plate with Carrier Rings

EMCO orifice plate with carrier rings, type MRK consists of a plate fixed between two carrier rings. The pressure tappings are connected each to their separate carrier ring, which ensures that the pressure measured before and after the orifice is an average, resulting in a better accuracy. EMCO orifice plate type MRK is mounted between flanges with flat or raised face according to flange standards and suitable for pressure ratings up to PN 160 or equivalent. The orifice plates are made in sizes ranging from DN 50 to 1000 and in materials according to customers’ requirement, usually carrier rings in steel and orifice plates in stainless steel.

Advantages: High accuracy, orifice plate exchangeable.
EMCO Orifice Plate with Corner Single Pressure Tappings

EMCO orifice plate with corner tappings, type MEF is made in one piece and is for insertion between flanges with flat or raised face or recess according to flange standards.

EMCO orifice plate type MEF can be delivered in pressure ratings up to PN 100 or equivalent and are made in sizes ranging from DN 50 - 1000 in materials according to customers’ requirement, usually in stainless steel.

Advantages: Good accuracy, very favourable price.

EMCO Orifice Plate with Carrier Rings for Weld Ends.

EMCO orifice plate with carrier rings, type MRS consists of two pipes with carrier rings in-between which the orifice plate is secured by welding. EMCO orifice plate type MRS is all-welded and made to DIN 19215 specifications. The welded pressure tappings are connected to each of their carrier ring, which ensures, that the pressure before and after the orifice plate is an average, which results in higher accuracy.

The sharp edge of the orifice can be hardened with stellite for greater durability, when used for abrasive media. The orifice plate is welded into the pipe system and is delivered with weld connection according to relevant standards, usually DIN 2559 or ANSI B 16.25.

The orifice is made in pressure ratings up to PN 640 and in sizes ranging from DN 50 to 500, in steel and heat resistant steel, usually St35.8, 15Mo3, 13CrMo44, 10CrMo910 and WB 36.

Advantages: Great accuracy, no risk of leakage.
EMCO Orifice Plate with Single Pressure Tappings.

EMCO orifice plate with corner taps type MES consists usually of two pipes of pipes in which the orifice plate is fastened by welding. The orifice plate is made according to DIN 19215. The sharp edge of the orifice plate can be hardened with stellite for greater durability when used for abrasive media. The orifice plate is welded into the pipe system and is delivered with weld connections according to relevant standards, usually DIN 2559 or ANSI B 16.25.

The orifice plate is made in pressure ratings up to PN 640 and in sizes ranging from DN 50 to 500 and in steel and heat resistant steel, usually St 35.8, 15Mo3, 13CrMo44, 10CrMo910 and WB 36.

Advantages: Good accuracy, great durability, no risk of leakage.

EMCO Meter Run with Carrier Rings

EMCO Meter Run with carrier rings type MSRS and type MSRF consist of an upstream and a downstream pipe, the orifice plate is fixed between the two carrier rings. The annular rings appears when the pipes are put into the carrier rings.

The pipe and the carrier ring are welded together. The pipes are calibrated precision tubes, which, if required, can be honed for better accuracy. The pressure tappings are connected each to their separate carrier ring which ensures that the pressure measured before and after the orifice plate is an average, resulting in higher accuracy.

EMCO Meter Run type MSRS has weld ends and type MSRF has flanged connection according to standards required by the customer.

EMCO Meter Run is designed for pressures up to max. PN 100 and in sizes from DN 15-50. They are normally made from carbon steel and stainless steel, but other materials can be offered according to the requirements.

Advantages: Higher accuracy, orifice plate exchangeable, no risk for increased inaccuracy due to incorrect installation.
**EMCO Meter Run type CompaQ**

EMCO meter run with carrier rings, type CompaQ is supplied with mounting plates for direct differential pressure transmitter and 3 way-manifold mounting.

EMCO meter run type CompaQ, is manufactured with an upstream and a downstream pipe, two carrier rings, the orifice plate, and a mounting plates for 3 way-manifold and transmitter.

Apart from the compact mounting of the transmitter the construction is similar to EMCO meter run type MSRF.

However, they are offered in sizes from DN 15-100.

Advantages: High accuracy, more simple detail engineering due to the supply of an assembled unit. Very easy installation.

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**EMCO venturi nozzle**

EMCO venturi nozzle type VES is produced according to DIN 19215. The venturi is made from bar stock or thick walled pipe. Pressure tappings, condensing pots and valves if required, are welded to the nozzle.

EMCO venturi nozzles type VES are supplied with weld end connections according to DIN 2559 and ANSI B 16.25 standards. The venturis are designed for pressure class up to PN 640 and in sizes from DN 50 - 500.

The most common materials are steel and heat resistant steels i.e. St 35.8, 15Mo3, 13CrMo44, 10CrMo44 but also in more exotic materials such as X20CrMoV121, WB 36, F91 and F92.

Advantages: Fair accuracy, low pressure loss, high degree of resistance towards wear and abrasive media’s, no risk of leakage.
EMCO Classical Venturi Tube type KVR

EMCO classical venturi tube is produced in 3 different models: machined, as cast or welded sheet. The venturi tube consists of a cylindrical pipe, a convergent, a cylindrical throat and a divergent with an angle between 7 and 15 degrees.

The classical venturi tube is used when a very small pressure loss is required and a fair accuracy is acceptable. The pressure loss is roughly 5% - 10% of the differential pressure measured. Required straight length of pipe up stream is very limited.

EMCO venturi tubes type KVR are supplied with weld ends, flanges or clamp connections according to European or American standards. They are designed for pressures up to PN 400 (class 2500 lbs) and in sizes from DN 50-1200. Larger sizes on request. EMCO venturi tubes are made in steel and stainless steel or materials according to customers requirements.

Advantages: Very low pressure loss, fair accuracy.

EMCO ISA 1932 Nozzle with Carrier Rings

EMCO nozzle type DRS is designed according to ISO 5167 and DIN 19215. The nozzle consists of two carrier rings in-between the nozzle and secured by welding. The upstream, downstream pipes and tappings are joined to the carrier rings by welding.

The pressure tappings are connected to each of their carrier ring, which ensures that the pressure measured before and after the nozzle is an average, resulting in higher accuracy.

EMCO nozzle type DRS is provided with weld ends according to International Standards usually DIN 2559 or ANSI B 16.25. The nozzles are designed for pressure class up to PN 640 and in sizes from DN 50-500 (2"-20"). They are commonly produced in carbon steel and heat resistant steels like St 35.8, 15Mo3, 13CrMo44, 10CrMo910.

Advantages: Good accuracy, high degree of resistance towards wear and abrasive media’s, no risk of leakage.
EMCO ISA 1932 Nozzle with Single Pressure Tapping

EMCO norm nozzle with single pressure tappings type DES is manufactured acc. to ISO 5167 and DIN 19215. The nozzle is made from a thick walled pipe and bar stock material. The tappings, upstream and downstream pipe are joined together by welding.

EMCO nozzle type DES is provided with weld ends according to International Standards usually DIN 2559 or ANSI B 16.25. The nozzles are designed for pressure class up to PN 640 and in sizes from DN 50-500 (2"-20"). They are commonly produced in carbon steel and heat resistant steels like St 35.8, 15Mo3, 13CrMo44, 10CrMo910. Advantages : Good accuracy, high degree of resistance towards wear and abrasive media’s, no risk of leakage.

EMCO ASME Flow Nozzle

EMCO ASME flow nozzle type LRN is manufactured according to ASME MFC-3M. The nozzle is made from bar stock material. The pressure tappings, which are the D and D/2 type, are normally not a part of the supply.

EMCO nozzle type LRN is for insertion between flanges according to ANSI B 16.5
The nozzles are designed for pressure class up to 2500 lbs and in sizes from 2"-20".
The ASME flow nozzle is made in 2 different models : High $\beta$ ratio nozzle and low $\beta$ ratio nozzle
They are commonly produced in stainless steel AISI 316.
Advantages : Strictly according to American standards.
EMCO Flow straightener

EMCO flow straightener is used to improve the flow profile before the fluid reaches the primary element.

EMCO flow straightener type FR20 is designed and manufactured according to ISO 5167.

The EMCO straightening vane consists of 19 tubes mounted in parallel and fixed together.

The flow straightener is supplied for pressure ratings up to PN 640 and in sizes from DN 50-400. The flow straightener is manufactured in materials according to the requirements of the customer, usually the main pipe is in steel or AISI 316 stainless steel.

Advantages: Possibility of reducing straight pipe lines before entering the primary element.

EMCO Accessories

EMCO range of products also include accessories for the primary elements.

It comprises pressure tapping with weld ends, threads or flange connections. Condensing chambers, shut of valves and orifice flanges.

Engineering

Design and engineering of our primary elements are based on recognised international standards including DIN, TRD, VDI/VDI and ASME. Our work is supported by CAD and computer programmes developed by our engineers.

We continually strive to provide high quality sensors with design innovations to meet our customers’ requirements.

Manufacturing

We stock raw material with traceable material certificates acc. to EN 10204 - 3.1B, 3.1C - or 3.1A.

Weldings are done by qualified welders according to ASME IX or EN standards.

The instruments can be non destructive examined NDE according to ASME or EN-standards. Heat treatment of the primary elements is available to comply to NACE MR-01-75.