BULK FLOW METERS

FOR

WATER SUPPLY SYSTEM

PAKISTAN WATER OPERATORS NETWORK

(March-2022)

PREFACE

On behalf of All water utilities in Pakistan PWON is thankful to JICA for providing Support for ***Management of Water & Sanitation Services in Punjab against Covid-19*** through which lectures / webinars were arranged January 2022, to end March 2022, for ***Better Management of Water & Sanitation Services during Outbreak*** as well *as* ***Awareness & Preventive Measures against Covid-19*** *and* ***Preparation of in house Disinfection by Water & Sanitation Utilities.***

On demand of PWON members, lectures for capacity building of utilities in Pakistan about various important technical topics were also added along with above lectures / webinars / seminars. All these events were well participated and appreciated by all utilities

On demand of member utilities PWON has published these lectures for capacity building and references for improvement of their day to day working for the benefit of their consumers at large. This book on the topic of **BULK FLOW METERS FOR WATER SUPPLY SYSTEM** is published by PWON for the benefit of all its members

PWON is thankful to Capt. (R) Muhammad Hafeez for Preparing this valuable document.

Syed Zahid Aziz
CHAIRMAN
PWON, Pakistan

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1. MAIN COMPONENTS OF A WATER SUPPLY SYSTEM

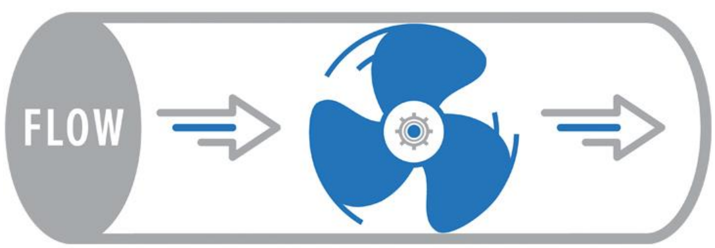
- Water Source
- Piping network & valves
- Flow measuring devices
- Consumer metering

2. POPULAR FLOW METERS

Mechanical flow meters;
- Woltmann,
- Paddle wheel & Propeller.

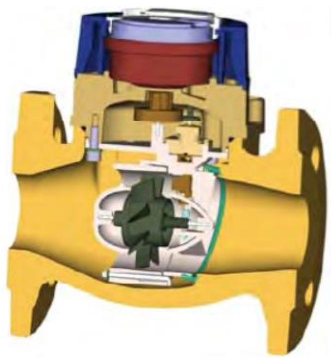
Electronic flow meters;
- Electromagnetic
- Ultrasonic

2.1 Mechanical flow meters



Mechanical flow meters are a family of devices where the measured fluid is mechanically displaced in the meter's body through a rotor to measure fluid flow velocity.

2.2 Woltmann Flow Meters



- Speed of water flowing through the pipe causes a wheel to rotate.
- The volumetric flow rate of the water is proportional to the rotational speed of the blades.
- Woltmann meters are simple to operate and maintain, and in service worldwide as a reliable, cost-effective method.

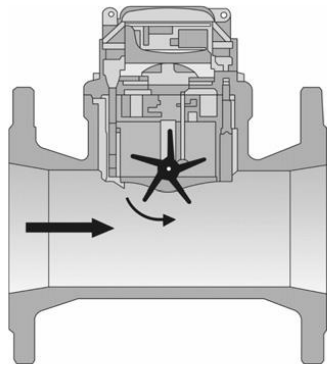
2.3 Advantages of WOLTMANN meters

- A moderate amount of solids in suspension can even be tolerated.
- The metering module may be replaced without affecting the meter accuracy, keeping the meter housing.
- Can be installed in, virtually, any position.

2,4 DISADVANTAGES of WOLTMANN water meters

- Performance is significantly affected with the velocity profile therefore, use of tranquilizing lengths of pipe **upstream of the meter** is often necessary.
- **Low sensitivity for low flow rates.**
- These meters are used around the world for diameters between 50 and 500 mm**.**
- The impact of **large suspended solids** could damage the metering module, making the installation of a strainer quite recommendable.

2.5 Paddle wheel flow meters



- One of the most popular cost effective flow meters for water or water like fluids.
- The flow is measured by an impeller placed on the top section of the meter (paddle wheel). This method also has similarities with single jet meters where water hits only part of the impeller and the rotation is perpendicular to the pipe axis.
- The rotor of the paddlewheel sensor is perpendicular to the flow and contact only a limited cross section of the flow

2.6 Main advantage of paddle wheel meters

- ❖ Water finds no obstacles in flowing through the meter, allowing large suspended solids to go through the meter without damaging the impeller.
- ❖ Higher-density solids, which could damage the impeller, will usually travel in the lower part of the pipe while the impeller is situated in the higher part.

2.7 Disadvantages of paddle wheel meters

- Very sensitive to the velocity profile
- Narrow measuring range
- Limited metering capacity at low flows.

2.8 Propeller Meter

- Propeller flow meters have a rotating blade, suspended by a single bearing, which faces into the flow.
- Those turns, or revolutions, equate to flow rate and volume over time.
- It should not be used in low flow situations because the resistance of the bearings interferes with the measurement of the flow.
- It also should not be used at high velocity because this can cause damage or wear to the propeller and bearings, resulting in inaccurate results.

2.9 STATIC OR ELECTRONIC FLOW METERS

- ❖ No moving parts
- ❖ more accuracy than mechanical meters if used in favorable conditions

TYPES

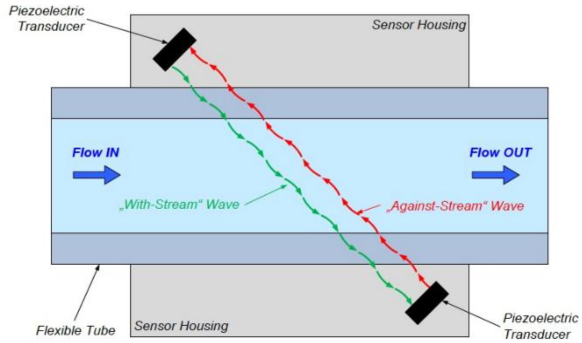
- ❖ Ultrasonic
- ❖ Electromagnetic

2.10 ULTRASONIC FLOW METERS

Two types based on sound waves responding to physical principles totally different in nature.

- **Transit time**
- **Doppler.**

2.11 Transit time ultrasonic meters



- ❖ Flow meter uses two ceramic piezoelectric transducers that can work both as emitters and receivers of sound waves.
- ❖ Ultrasonic signals (sound waves) moving in the direction of flow require less time to travel between the two transducers as compared to signals moving against the flow.
- ❖ The velocity of the fluid will be obtainable simply from the difference in transit times.

2.12 Measurement of flow rate: Transit time ultrasonic meters

Ultrasonic flow meters are designed to measure flow rate in pipes completely full of water.

The pipe diameter is fed into the flow meter — the unit calculates flow rate by simple calculation;

Q=Pipe's cross sectional area × Velocity measured by transducers.

2.13 Sources of Error in measurement

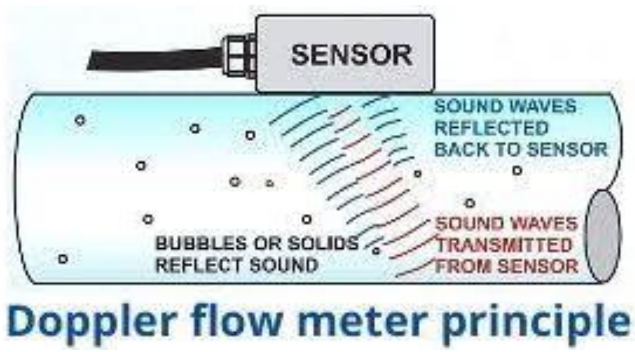
- ❖ Air at the top of the pipe or sediments resting at the bottom can cause deviations in the assumed cross sectional area.
- ❖ Additionally, air in the water can disrupt the transducer signal and give inaccurate readings.
- ❖ Use air valves to purge trapped air or other means available to ensure the pipeline is flowing full.
- ❖ One easy test is to feel the top and the bottom of the pipe. If the pipe is full the top should feel as cold as the bottom.

2.14 Metrology of transit time meters

- Not suitable for dirty waters.
- High sensitivity to flow distortions.
- Not suitable for Sedimentations: In the lower part of the pipe there are usually all types of deposits. These deposits notably attenuate the signal. They may considerably reduce the cross section of the pipe in such a way that the flowrate is incorrectly estimated from the average velocity.

2.15 Doppler effect ultrasonic flow meters

- Wavelength of sound perceived by a stationary observer appears shorter when the source is approaching and longer when the source is moving away. This shift in frequency is the basis upon which all Doppler-shift ultrasonic flow meters work.
- The transducer sends an ultrasonic pulse or beam into the flowing stream. The sound waves are reflected back by particles, entrained air bubbles, or even by turbulence vortices.
- The frequency shift is proportional to the relative velocity of the particles and the emitter/receiver, and consequently to the flowrate.



2.16 Limitations of Doppler effect ultrasonic flow meters

- The Doppler meter does not really determine the velocity of the fluid, but rather the velocity of the suspended particles or bubbles. Sometimes these two velocities are quite different and can create important errors.
- Non uniformity of particle distribution in the pipe cross section may result in a incorrectly computed mean velocity.
- High sensitivity to flow distortions

2.17. Advantages of Doppler effect ultrasonic flow meters

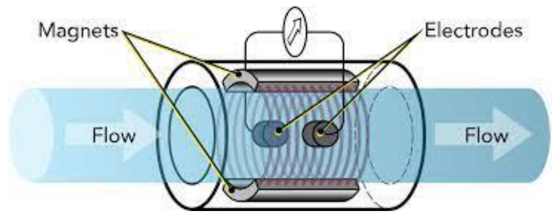
- Doppler meters may be used where other meters don't work.
- These are commonly used in dirty applications such as wastewater which ordinarily cause damage to conventional sensors.
- Can be installed outside the pipes
- Relatively low power consumption
- Ultrasonic flow meters installed on the outside of the pipes will not have any influence on pressure loss in the pipe.

2.18 Open channel Doppler flow meter

- ❖ Open channel measurement system that makes use of a pulsed Doppler transducer for velocity measurement.
- ❖ The velocity transducer also contains an integral hydrostatic level measurement transducer.
- ❖ The hydrostatic level transmitter signal is used by the display module to determine the cross-sectional area of the flowing media.
- ❖ The reflected Doppler signal is shifted from the transmitted frequency by approximately 6 Hz for every foot per second of velocity. Therefore, if the flow velocity is less than 1 ft/sec, ultrasonic flow metering is not practical.

2.19 Electromagnetic Flow Meters

2.20 Electromagnetic Flow Meters



The operation of electromagnetic meters is based in Faraday's induction law.
This law states that a voltage (E) appears between the ends of any conductor passing through a magnetic field.
The induced voltage is directly proportional to flow velocity (V), the length of the conductor (L) and the intensity of the magnetic field (B) that surrounds it.
The flow of the fluid creates an induced voltage which is proportional to the flow velocity

2.21Coating of the measuring tube

- Should the metering tube be metallic, it has to be coated with non-conductive material to avoid the electrodes being in short circuit.
- Coating of the measuring tube
- Hard rubber or ebonite, Polyurethane , Polytetrafluoroethylene (PTFE)
- GRP , Ceramics , Teflon/TFA

2.22 Effect of Conductivity of the fluid

- Conductivity (measure of water's capability to pass electrical flow).
- This ability is directly related to the concentration of ions in the water which come from dissolved salts and inorganic materials such as chlorides, sulfides and carbonate compounds). TDS=EC*K
- However, if the concentration of these elements is high, the meter will be inferring that everything flowing through the meter is water, and consequently the error will be considerable.

Air and sand with almost no conductivity will not present a problem, and the velocity of water will be used to calculate the flowrate

2.23 Working suitability of Electromagnetic Flow Meters

- Require the fluid to completely fill the pipe
- Very accurate
- Not recommended for fluids with high, very low, or variable conductivity
- Can be used on a wide range of pipe sizes

2.24 Metrology of electromagnetic meters: Velocity profile

- Electromagnetic meters are sensitive to velocity profile distortions, although this sensitivity is lower than for other types of meters.
- In most applications, a distance of five diameters of straight pipe upstream of the meter and three diameters downstream is enough to guarantee correct measurements
- (studies show that a shorter downstream distance may produce errors up to 5%).
- If the meter is installed downstream from a pump, the distance must be increased to eight diameters from the distorting element.

2.25 Metrology of electromagnetic meters: Suspended solids

- Abrasive solids in suspension may result in wear in particular areas.
- The diameter of the electromagnetic meter must allow a velocity ranging from 1 to 5 m/s in normal operating conditions.
- Higher velocities may lead to an excessive wear of the coating.
- Lower velocities may favor solid depositions.

2.26 Entrapped air

- The magmeter cannot distinguish entrained air from the water; therefore, air in the pipes will be accounted for as water.
- If the trapped air is not homogeneously dispersed, but takes the form of air slugs or large air bubbles (the size of the electrode), this will make the output signal noisy or even disrupt it.
- Therefore, in applications where air entrainment is likely, the meter should be sized so that the flow velocity under normal flow conditions is 6-12 ft/sec.

2.27 Lime scale

- lime scale or Material build-up on the electrodes and the tube can electrically isolate the electrodes from the process fluid.
- May even lead to reducing considerably the cross section of the meter.

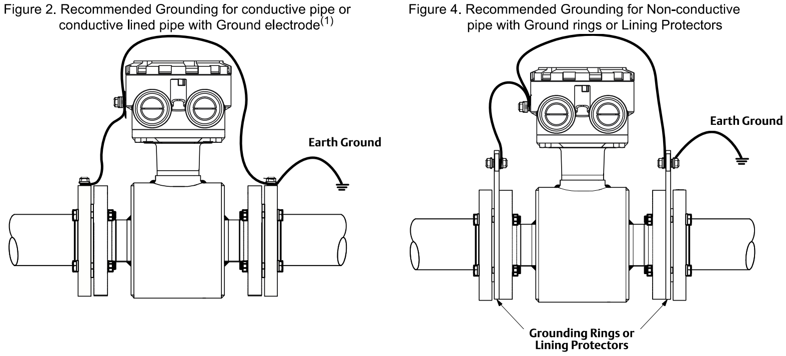
- This can also cause a loss of signal or a measurement error, either by changing the diameter of the flowtube.
- Naturally, the best solution is prevention. One preventive step is to size the meter such that, under normal flow conditions, the flowing velocity will be relatively high: at least 6-12 ft/sec, or as high as practical considering the possibility of erosion and corrosion.

2.28 Grounding of the meter

- Proper installation and grounding of magnetic flowmeters is important for accurate, reliable measurement performance. Stray AC or DC currents through the fluid or instrument can produce noise signals that may in turn interfere with the relatively low flow signals generated. **It is essential for abrasive flow.**
- Manufacturers provide a variety of elements (ground straps, ground electrode, ground rings, lining protectors) and directions for the standard grounding

Figure 2. Recommended Grounding for conductive pipe or conductive lined pipe with Ground electrode[1]

Figure 4. Recommended Grounding for Non-conductive pipe with Ground rings or Lining Protectors

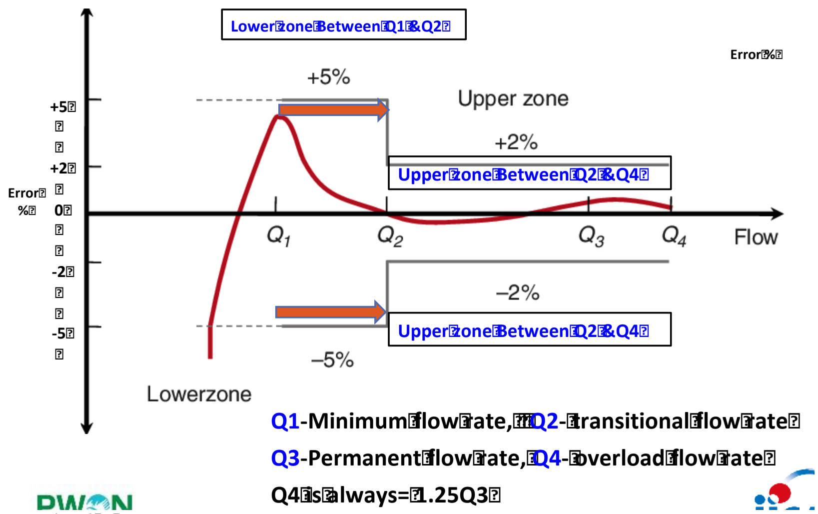


3. Cost & pressure loss comparison of flowmeters

Flowmeter	Recommended Service	Pressure Loss	Relative Cost
Turbine	Clean water	High	Medium
Electromagnetic	Clean, dirty conductive water	None	High
Ultrasonic (Doppler)	Dirty water	None	High
Ultrasonic (Time-of-travel)	Clean water	None	High

4.Accuracy requirement

4.1 Understanding accuracy curves



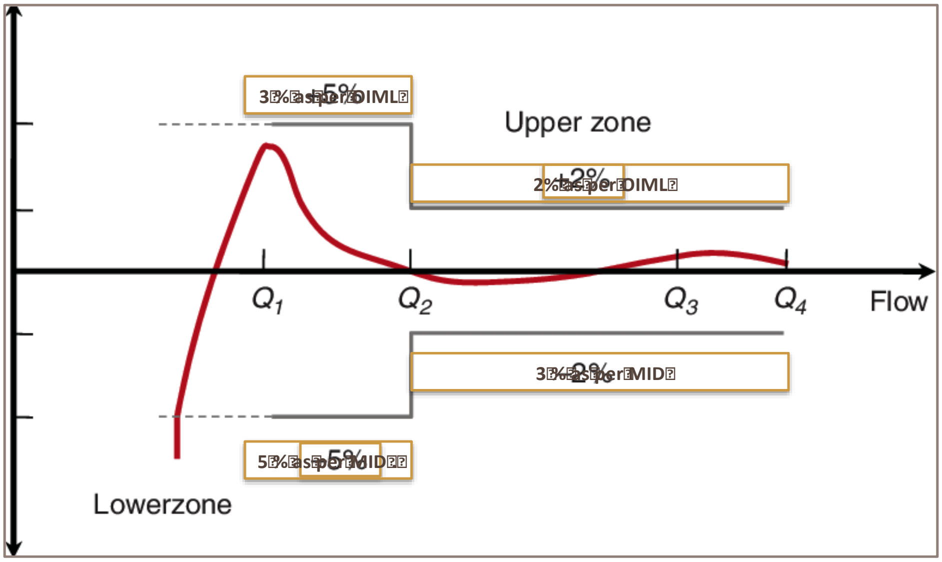
4.2 maximum permissible errors OIML water meters

- Accuracy class 1
- The MPE for the upper flow rate zone is ±1 %, for temperatures from 0.1 °C to 30 °C, and ±2 % for temperatures greater than 30 °C.
- The MPE for the lower flow rate zone is ±3 % regardless of the temperature range.
- Accuracy class 2
- The MPE for the upper flow rate zone is ±2 %, for temperatures from 0.1 °C to 30 °C, and ±2 % for temperatures greater than 30 °C.
- The MPE for the lower flow rate zone is ±5 % regardless of the temperature range.

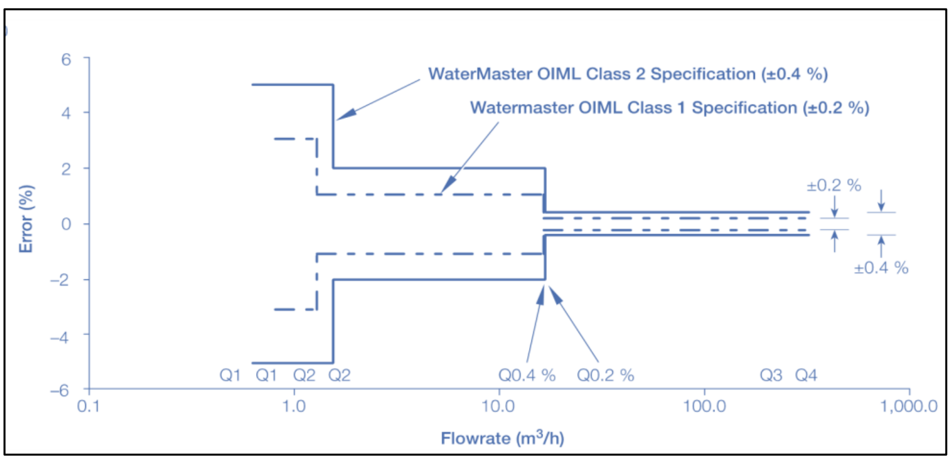
4.3 maximum permissible errors Measuring Instrument Directive (MID)

- ❖ The MPE, positive or negative, on volumes delivered at flow rates between the transitional flow rate (Q2) (included) and the overload flow rate (Q4) is **2 % for water having a temperature ≤ 30 °C, and** 3 % for water having a temperature > 30 °C.
- ❖ Flow rates between the minimum flow rate (Q1) and the transitional flow rate (Q2) (excluded) is 5 % for water having any temperature.

4.4 Comparison of permissible errors of OIML and MID for class 1 meters



4.5 Electronic & Mechanical meters performance curves



4.6 Choosing Right Specifications

- Don't depend upon manufacturers quotations
- Consult OIML/ISO or MID docs. for right specifications

4.7 Accuracy Class of Flow Meters Required in water utilities

- As the Q3 (permanent flow rate) of most of the Bulk flow meters used in Utilities is more than 100 M^3/h (for1, 2 CFS & 4 CFS tubewells) therefore, these fall in accuracy class-1 as per OIML/ISO

4.8 Choosing a Right Flow Meter

- Simply matching the existing pipe size is not recommended.
- Don’t choose on cost alone.
- Know your flow rate : minimum and permanent flow.
- Opt for the widest turndown ratio of the maximum and minimum flow rates a flow meter can measure within its specified accuracy range.
- Pay attention to installation: It is important to consider exactly where and how the device will be installed, as this can significantly affect both accuracy and efficiency.
- Pick the flow meter that will offer the best accuracy for the application :

4.9 Choosing Q3: Permanent Flow Rate

Let us consider 200mm pipe for 2 cusec flow.
Permanent flow rate is 204 m^3/h.
As per OIML/ISO, Q3 will be chosen from below table;

4.1.3 The value of Q_3 , expressed in m^3/h, shall be chosen from the following list:

1	1.6	2.5	4	6.3
10	16	25	40	63
100	160	250	400	630
1 000	1 600	2 500	4 000	6 300

The list may be extended to higher or lower values in the series.

So any Q3 may be chosen that is greater than 204 m^3/h

4.10 Choosing Q^3/Q^1

- If Q_3/Q_1 is chosen as 80, the Q1 will be 400/80=5 m^3/h
- And if you chose the ratio as 160, Q1 will be 2.5 m^3/h.
- If you want Q1 still lesser the ratio may be taken as 200(Q1 will be 2 or even 400(Q1 will be 1).

4.1.4 The value of the ratio Q_3/Q_1 shall be chosen from the following list:

40	50	63	80	100
125	160	200	250	315
400	500	630	800	1 000

The list may be extended to higher values in the series.

5. How you make the final decision?

Values taken from actual brochures of manufacturers

Size(mm)	Q3/Q1 (R)	Q1 (m3/h)	Q3 (m3/h)	Accuracy class	Type
200	**200**	**5**	**1000**	1	Electromagnetic
200	**1000**	**1**	**1000**	1	Electromagnetic
200	**100**	**4**	**400**	1	Voltmann
200	**160**	**3.9**	**630**	1	Electromagnetic
200	**80**	**3.13**	**250**	1	Electromagnetic
200	**250**	**2.52**	**630**	1	Electromagnetic

As Q4 is=1.25Q3=204*1.25=255m3/h therefore, meter will be chosen that has more flow range than 250m3/h.

5.1 must required specifications

Parameter	Requirement
measurement	No reverse flow
Accuracy Class	Class 1 or 2 ?
Material	Carbon steel, SS
Protection Class	IP-68
Power supply	Replaceable/Non replaceable battery as per section 2.2 of OIML
Liquid Temperature	up to 50° C
Maximum working pressure:	10 bar
Flow rate ratio (R)	Q_3/Q_1=?
Permanent flow rate (m^3/hr.)	Q_3=?
Compliance	ISO 4064
Certification:	OIML: R49 (International Organization for legal Metrology) or DIRECTIVE 2014/32/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

5.2 Ingress Protection (IP 65-68 & 69)

IP 65	Protected from total dust ingress & **protected from low pressure water jets from any direction.**
IP 68	Protected from total dust ingress & **protected from continuous immersion in water at specified pressure**. Typically, the equipment is hermetically sealed.
IP-69	Protected from total dust ingress & **protected from steam jet cleaning.**

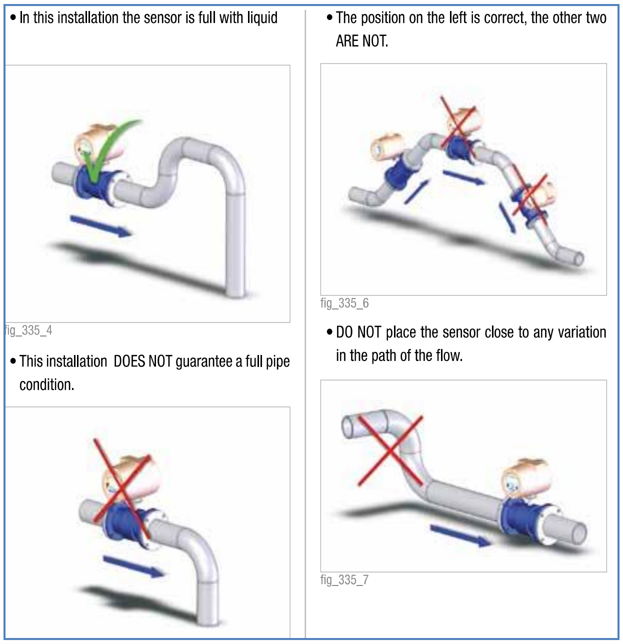
5.3 POWER SUPPLY: OIML/ISO

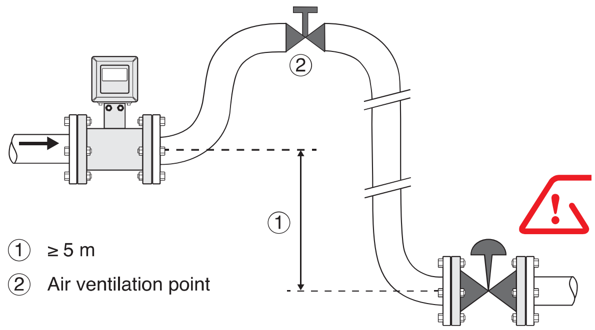
- A water meter with electronic devices shall be designed such that in the event of an external power supply failure (AC or DC), the meter indication of volume just before failure is not lost, and remains accessible for a minimum of one year.
- *Note:* Compliance with this requirement does not necessarily ensure that the water meter continues to register the volume consumed during a power supply failure.
  The manufacturer shall ensure that the expected lifetime of the battery is such that;
- meter functions correctly for at least one year longer than the operational lifetime of the meter.
- A low battery or exhausted battery indicator or a meter replacement date shall be indicated on the meter. If the register display gives an indication of “low battery”, there shall be at least 180 days of useful life for the register display from the time “low battery” indication is displayed to end of life.

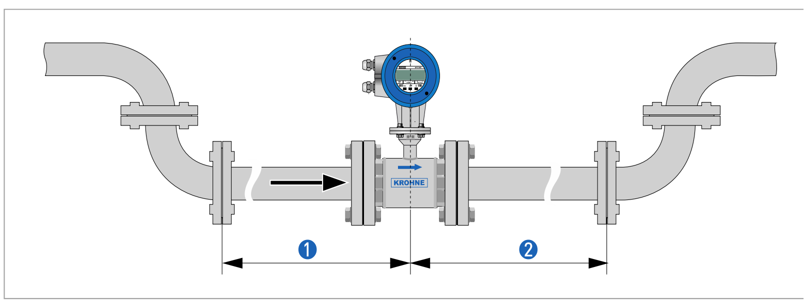
5.4 Installation conditions: OIML/ISO

- The water meter shall be installed such that it is completely filled with water under normal conditions.
- A water meter shall be able to withstand the influence of disturbed velocity fields as defined in the test procedures in OIML R 49-2:2013.
- Any specific flow conditions, including straightener and/or straight lengths in the upstream or downstream pipeline, to be used shall be prescribed by the manufacturer so that the indications of the installed water meter meet the requirements with respect to MPEs and according to the accuracy class of the meter.

6. Installation conditions







1 ≥ 5DN
2 ≥ 2DN

References:

- *JE VAN ZYL: Introduction to Integrated water Meter Management Edition 1*
- *ISO 4064-1:2014 - Water meters for cold potable water and …*
- *OIML R-49-1,2,3 Edition 2013 (E).https://www.oiml.org*
- *DIRECTIVE 2014/32/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 February 2014*

Directive 2004/22/EC Directive