AquaProbe FEA100/FEA200
Electromagnetic flowmeter insertion-type flow sensors

Maximum performance, minimum hassle

Measurement made easy

—
AquaProbe
FEA100/FEA200
flow sensor

Introduction

The AquaProbe FEA100/FEA200 flow sensor is designed for measurement of the velocity of water. The flow sensor is available in four standard lengths and can be installed in any pipeline of internal diameter from 200 mm (8 in) to 8000 mm (360 in), through a small tapping.

The flow sensor is designed for use in survey applications such as leakage monitoring and network analysis and in permanent locations where cost or space limitations preclude the use of conventional closed pipe meters.

This User Guide provides installation, connection, security, start-up and basic setup details for the flow sensor only. The AquaProbe sensor is available for operation with either a WaterMaster transmitter (FET100) or an AquaMaster3 transmitter (FET200).

For more information

Further publications are available for free download from www.abb.com/flow or by scanning this code:

	Search for or click on

Data Sheet
AquaProbe FEA200
Insertion-type electromagnetic
   flow sensor with AquaMaster3
   transmitter
	DS/FEA200

Data Sheet
AquaProbe FEA100
Insertion-type electromagnetic
   flow sensor with WaterMaster
   transmitter
	DS/FEA100

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User Guide Supplement WaterMaster FEX100–MB Electromagnetic flowmeter | MODBUS RS485 Physical Layer	COI/FEX100/MOD
MODBUS Tables Supplement WaterMaster Electromagnetic flowmeter	COI/FEX100/MOD/TBL
User Guide Supplement WaterMaster Electromagnetic flowmeter | PROFIBUS RS485 Physical Layer (FEX100-DP)	IM/WMPBS
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ScrewDriver profiling and configuration software	Search for or click on
User Guide ScrewDriver 7 Diagnostic and Flow-Profiling Software for ABB Flowmeters	IM/SDR

Contents

1   Health and safety

Information in this manual is intended only to assist our customers in the efficient operation of our equipment. Use of this manual for any other purpose is specifically prohibited and its contents are not to be reproduced in full or part without prior approval of the Technical Publications Department.

1.1 Health and safety

Health and safety

To ensure that our products are safe and without risk to health, the following points must be noted:

- The relevant sections of these instructions must be read carefully before proceeding.

- Warning labels on containers and packages must be observed.

- Installation, operation, maintenance and servicing must only be carried out by suitably trained personnel and in accordance with the information given.

- Normal safety precautions must be taken to avoid the possibility of an accident occurring when operating in conditions of high pressure and/or temperature.

- Chemicals must be stored away from heat, protected from temperature extremes and powders kept dry. Normal safe handling procedures must be used.

- When disposing of chemicals ensure that no two chemicals are mixed.

Safety advice concerning the use of the equipment described in this manual or any relevant Material Safety Data Sheets (where applicable) may be obtained from the Company, together with servicing and spares information.

1.2 Electrical safety – CEI/IEC 61010-1:2001-2

This equipment complies with the requirements of CEI/IEC 61010-1:2001-2 'Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use' and complies with US NEC 500, NIST and OSHA.

If the equipment is used in a manner NOT specified by the Company, the protection provided by the equipment may be impaired.

1.3 Product symbols

One or more of the following symbols may appear on the equipment labeling:

Protective earth (ground) terminal.

Functional earth (ground) terminal.

Direct current supply only.

Alternating current supply only.

Both direct and alternating current supply.

The equipment is protected through double insulation.

This symbol, when noted on a product, indicates a potential hazard which could cause serious personal injury and/or death.
The user should reference this instruction manual for operation and/or safety information.

This symbol, when noted on a product enclosure or barrier, indicates that a risk of electrical shock and/or electrocution exists and indicates that only individuals qualified to work with hazardous voltages should open the enclosure or remove the barrier.

This symbol indicates that the marked item can be hot and should not be touched without care.

This symbol indicates the presence of devices sensitive to electrostatic discharge and indicates that care must be taken to prevent damage to them.

This symbol identifies a risk of chemical harm and indicates that only individuals qualified and trained to work with chemicals should handle chemicals or perform maintenance on chemical delivery systems associated with the equipment.

This symbol indicates the need for protective eye wear.

This symbol indicates the need for protective hand wear.

Electrical equipment marked with this symbol may not be disposed of in European public disposal systems. In conformity with European local and national regulations, European electrical equipment users must now return old or end-of-life equipment to the manufacturer for disposal at no charge to the user.

Products marked with this symbol indicates that the product contains toxic or hazardous substances or elements. The number inside the symbol indicates the environmental protection use period in years.

1.4 Product recycling information (Europe only)

ABB is committed to ensuring that the risk of any environmental damage or pollution caused by any of its products is minimized as far as possible. The European Waste Electrical and Electronic Equipment (WEEE) Directive that initially came into force on August 13 2005 aims to reduce the waste arising from electrical and electronic equipment; and improve the environmental performance of all those involved in the life cycle of electrical and electronic equipment.

In conformity with European local and national regulations, electrical equipment marked with the above symbol may not be disposed of in European public disposal systems after 12 August 2005.

NOTICE

For return for recycling, please contact the equipment manufacturer or supplier for instructions on how to return end-of-life equipment for proper disposal.

…1   Health and safety

1.5 Information on ROHS Directive 2011/65/EU (RoHS II)

ABB, Industrial Automation, Measurement & Analytics, UK, fully supports the objectives of the ROHS II directive. All in-scope products placed on the market by IAMA UK on and following the 22nd of July 2017 and without any specific exemption, will be compliant to the ROHS II directive, 2011/65/EU.

1.6 Chemical reagents

> ⚠ **WARNING**
>
> To familiarize yourself with handling precautions, dangers and emergency procedures, always review the Material Safety Data Sheets prior to handling containers, reservoirs, and delivery systems that contain chemical reagents and standards. Protective eye wear and protective hand wear is always recommended when contact with chemicals is possible.

1.7 Safety precautions

Please read the entire manual before unpacking, setting up, or operating this instrument.

Pay particular attention to all warning and caution statements. Failure to do so could result in serious injury to the operator or damage to the equipment.

To ensure the protection provided by this equipment is not impaired, do not use or install this equipment in any manner other than that which is specified in this manual.

1.8 Safety conventions

> ⚠ **WARNING**
>
> In this manual, a warning is used to indicate a condition which, if not met, could cause serious personal injury and/or death. Do not move beyond a warning until all conditions have been met.
>
> If a warning sign appears on the instrument itself, refer to Precautionary Labels – UL Certification and Electrical Safety – CEI/IEC 61010-1:2001-2 for an explanation.

> ⚠ **CAUTION**
>
> A caution is used to indicate a condition which, if not met, could cause minor or moderate personal injury and/or damage to the equipment. Do not move beyond a caution until all conditions have been met.

Note.
A note is used to indicate important information or instructions that should be considered before operating the equipment.

1.9 Safety recommendations

For safe operation, it is imperative that these service instructions be read before use and that the safety recommendations mentioned herein be scrupulously respected. If danger warnings are not heeded to, serious material or bodily injury could occur.

> ⚠ **WARNING**
>
> The installation of the instrument should be performed exclusively by personnel specialized and authorized to work on electrical installations, in accordance with relevant local regulations.

1.10 Service and repairs

None of the instrument's components can be serviced by the user. Only personnel from ABB or its approved representative(s) is (are) authorized to attempt repairs to the system and only components formally approved by the manufacturer should be used. Any attempt at repairing the instrument in contravention of these principles could cause damage to the instrument and corporal injury to the person carrying out the repair. It renders the warranty null and void and could compromise the correct working of the instrument and the electrical integrity or the CE compliance of the instrument.

If you have any problems with installation, starting, or using the instrument please contact the company that sold it to you. If this is not possible, or if the results of this approach are not satisfactory, please contact the manufacturer's Customer Service.

1.11 Potential safety hazards

The following potential safety hazards are associated with operating the analyzer:

• Electrical (line voltage)

• Potentially hazardous chemicals

2   System schematic

AquaMaster3 FET200
Transmitter

WaterMaster FET100
Transmitter

or
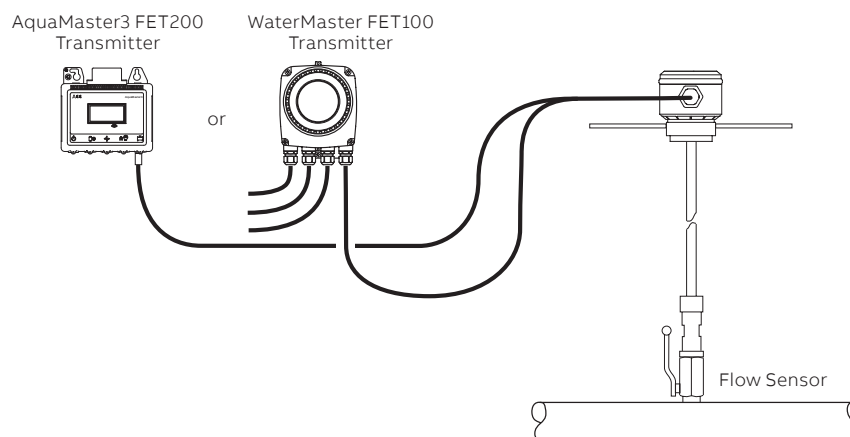
Flow Sensor

Figure 1   System schematic

⚠ CAUTION

Care of the Equipment

- The tip of the flow sensor is a precision-built part of the equipment and must be handled with care.

- When the flow sensor is not in use, fully retract the tip of the flow sensor and replace the end-cap.

- When removing / inserting the flow sensor into the pipeline, ensure that the valve is fully open.

- Damage to the flow sensor affects the performance.

- Physical damage to the flow sensor invalidates the warranty.

- Do not clean the electrodes.

3   Mechanical installation

3.1 Location – Environmental conditions

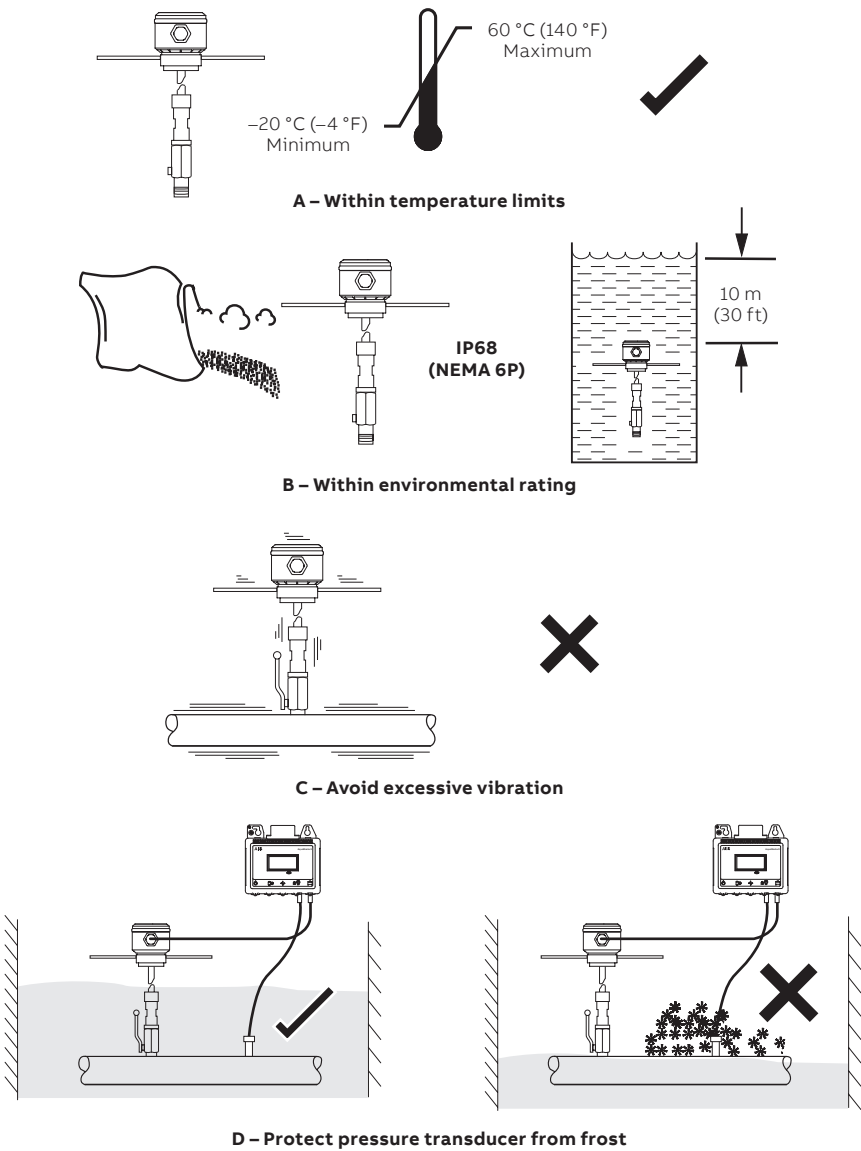A – Within temperature limits

B – Within environmental rating

C – Avoid excessive vibration

D – Protect pressure transducer from frost

Figure 2   Environmental requirements

...3   Mechanical installation

3.2 Use

An insertion probe is inserted into a flow-line through a small tapping and a valve fitted to the line. The tapping can be as small as one inch BSP or larger. Such a tapping is common on pipelines and, if one does not exist where it is required to make the installation, it is very inexpensive to fit one, online and under pressure, and there are many specialist companies that do this type of work.

⚠ **WARNING**

It is important to note that putting any type of device into a pressurized vessel (the pipe) can be dangerous. If the pressure in the line is high (typically 5 bar or more), care must be used in both installing and removing the probe. If the pressure is greater than 10 bar, installation (or removal) of a probe is not recommended. Instead the pressure should be removed from the line for the short period of time it takes to install or remove the probe, when the pressure can then be re-applied. In many instances, the removal of a probe from a line is more dangerous than the installation. For this reason, AquaProbe is supplied complete with a safety device that prevents rapid outward movement and potential injury to operators. It must be stressed that this is a problem with all probe devices, not just AquaProbe.

3.3 Location – Flow conditions

The flow sensor can be installed in one of two positions in the pipe:

• on the centerline, or,
• at the mean axial velocity point (⅛ pipe diameter).

It can also be traversed across the pipe to determine the velocity profile.

Note.
Ensure the sensor is installed in the pipe so the flow direction arrow on the flow sensor case matches the pipe flow.
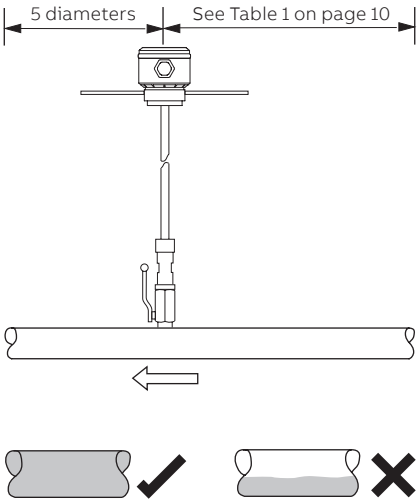

Figure 3   Flow conditions

...3 Mechanical installation

...3.3 Location – Flow conditions

3.3.1 International standard for flow measurement

ISO 7145 '(BS 1042) Measurement of fluid flow in closed conduits 'Part 2 Velocity area methods' describes methods of calculating volumetric flow from velocity measurements.

Section 2.2: 1982 'Method of measurement of velocity at one point of a conduit of circular cross section' describes the inference of volumetric flow from measurement of velocity at a single point. Several conditions must be fulfilled to validate the method, that uses calculations based on empirical data.

Where the validating conditions can be met, the method described in "Location – Flow conditions" on page 9 is the most practical. It is possible to measure the velocity either on the centre line, which reduces sensitivity to positional errors, or at the assumed point of mean flow velocity.

Table 1 is an extract from ISO 7145 (BS 1042): Section 2.2: 1982 and is reproduced with the permission of BSI. Complete copies of the standard can be obtained by post from:

BSI Publications
Linford Wood
MILTON KEYNES
MK14 6LE
United Kingdom

Note.
Where the above ideal conditions cannot be achieved, the flow profile must be tested for symmetry in order to obtain reliable flow results.

3.3.2 Velocity limitations

All insertion flow sensor devices are susceptible to the vortex shedding effect that can cause severe vibration of the flow sensor, resulting in damage and/or measurement instability. Electromagnetic devices with no moving parts, such as the flow sensor, are less susceptible to this effect than mechanical devices.

Figure 5 on page 11 shows the maximum permissible velocities, depending on the flow sensor's location.

This information is provided as a guide only. Some installations may experience unwanted vibration resonance that may further limit the maximum velocity at which the flow sensor can be used.

Table 1   Straight pipe lengths

Type of disturbance upstream from the measuring cross-section	Minimum upstream straight length*	
	For a measurement at the point of mean axial velocity	For a measurement on the axis of the conduit
90° elbow or a t-bend	50	25
Several 90° coplanar bends	50	25
Several 90° non- coplanar bends	80	50
Total angle convergent 18 to 36°	30	10
Total angle divergent 14 to 28°	55	25
Fully opened butterfly valve	45	25
Fully opened plug valve	30	15

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* Expressed in multiples of the diameter of the conduit.
Downstream from the measurement cross-section, the straight length shall be at least equal to five duct diameters whatever the type of disturbance.
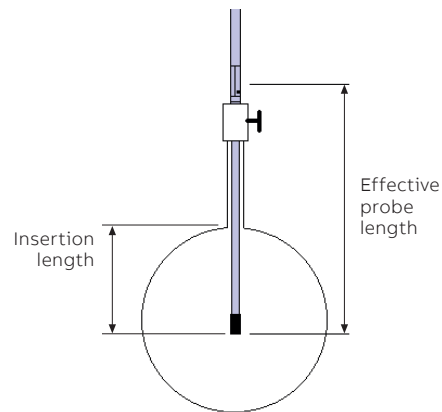
Figure 4   Maximum permissible velocity for different pipe sizes

It is important to add the external length from the fixing point to the insertion length. Failure to do this can give incorrect information from the graphs, resulting in vortex shedding affecting AquaProbe.

Examples:

• A 600 mm pipe with the probe mounted on the centerline has an insertion length of 300 mm.

• A typical valve is approximately 250 mm high and the distance to the support point inside the probe is approximately 100 mm therefore, in this example, the total effective length is 650 mm.
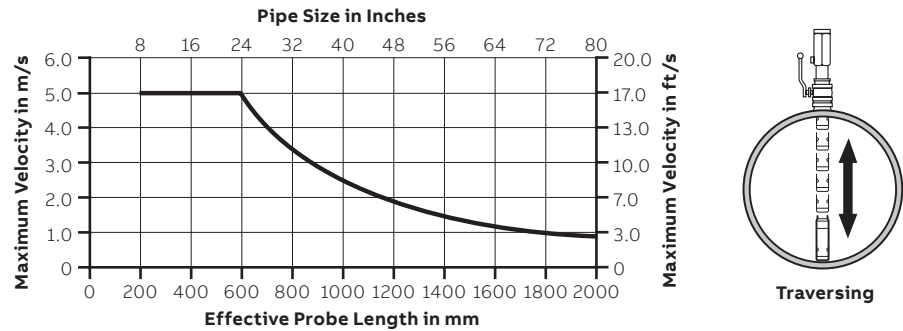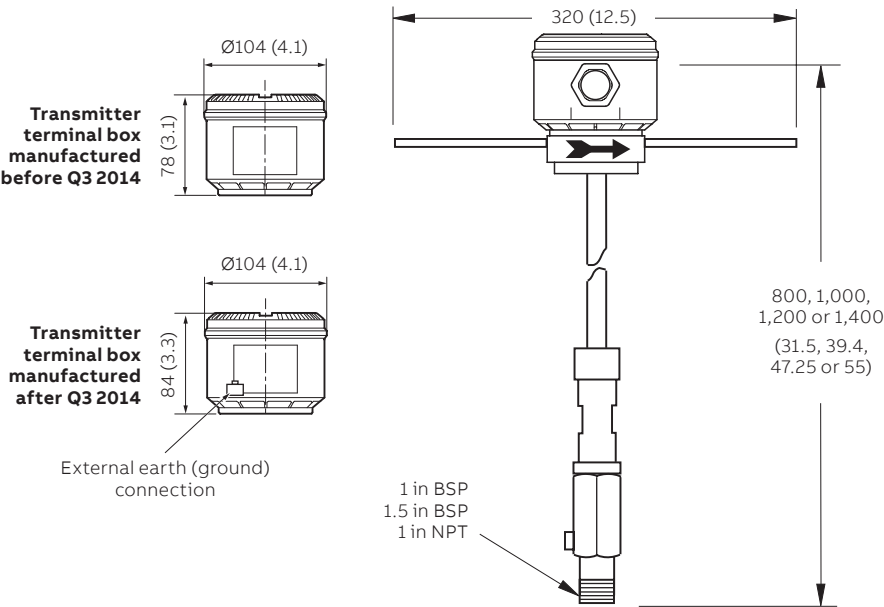
• Max velocity at 650 mm is 3.6 m/s.

Figure 5   Maximum permissible velocity for different insertion lengths
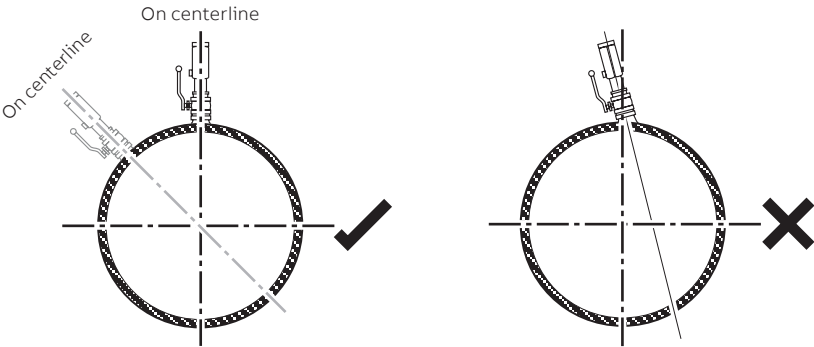
...3 Mechanical installation

3.4 Location – Mechanical

Note.
Pipeline recommended to be metal for electrical screening.

Dimensions in mm (in)

Ø104 (4.1)

Transmitter terminal box manufactured before Q3 2014

78 (3.1)

Ø104 (4.1)

Transmitter terminal box manufactured after Q3 2014

84 (3.3)

External earth (ground) connection

320 (12.5)

800, 1,000, 1,200 or 1,400

(31.5, 39.4, 47.25 or 55)

1 in BSP
1.5 in BSP
1 in NPT

A – Clearance dimensions

On centerline

On centerline

B – Orientation

Figure 6   Mechanical requirements

3.5 Safety

> ⚠ **WARNING**
>
> The flow sensor is provided with a safety mechanism (see Figure 7 A) that must be attached to its securing collar as shown in Figure 7 B. This prevents rapid outward movement by the flow sensor if nut ① is released.

Note. To ensure maximum safety, the positioning collar **MUST** be tightened in place using a 4 mm hexagon key
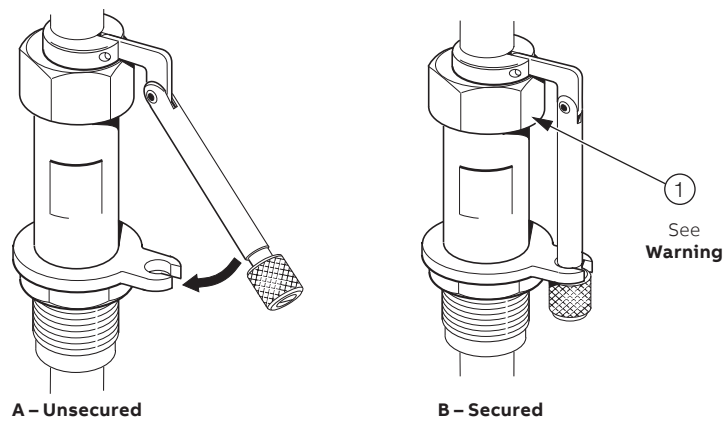

A – Unsecured   B – Secured

Figure 7   Safety mechanism

...3   Mechanical installation

3.6 Installing the flow sensor

> ⚠ **WARNING**
>
> When inserting or removing the flow sensor suitable restraining equipment must be used to prevent the flow sensor being forced out under pressure. Ensure that the valve is fully open.

Dimensions in mm (in)
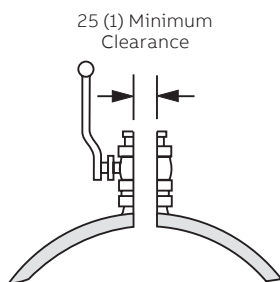
25 (1) Minimum
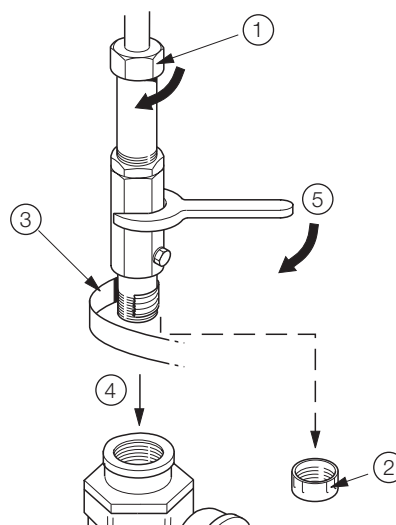Clearance

Figure 8   Insertion bore clearance

Figure 9   Installing the flow sensor

Referring to Figure 9:

① Tighten the nut (hand-tight only).

② Remove the cap.

③ Apply PTFE tape.

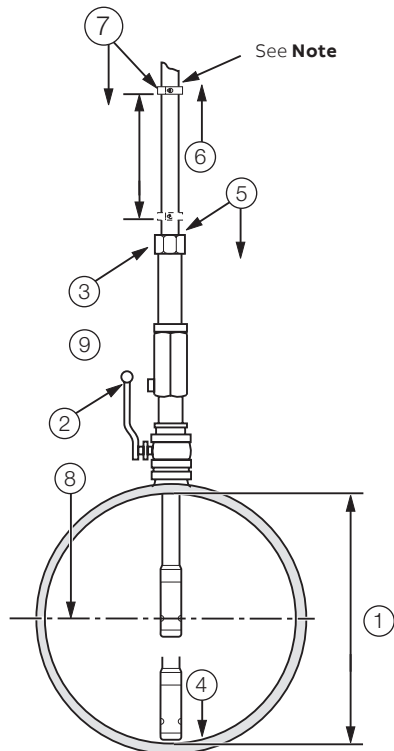④ Insert the flow sensor into the valve.

⑤ Tighten firmly.

3.7 Setting the insertion depth

3.7.1 Centerline method for pipe diameters ≤1 m (≤40 in)

> ⚠ **WARNING**
>
> When inserting or removing the flow sensor suitable restraining equipment must be used to prevent the flow sensor being forced out under pressure. Ensure that the valve is fully open.

Note. Safety restraint omitted for clarity.

Figure 10   Setting the insertion depth – centerline method for pipe diameters 1 m (40 in)

Referring to Figure 10:

1. Determine the internal diameter (D).
2. Open the valve fully.
3. Slacken the nut.
4. Insert the flow sensor into the valve.
5. Slide the positioning collar down to the nut and lock in place.
6. Retract the flow sensor fully.
7. Unlock, slide the positioning collar down and lock at the distance:

$$\frac{D}{2} + 30 \text{ mm (1.181 in)}$$

8. Insert flow sensor to position the collar depth.
9. Tighten to 40 N·m (30 ft.lbf).

…3   Mechanical installation

…3.7 Setting the insertion depth

3.7.2   Centerline method for pipe diameters >1 m ≤2 m (>40 in ≤80 in)

⚠ **WARNING**

When inserting or removing the flow sensor, suitable restraining equipment must be used to prevent the flow sensor being forced out under pressure. Ensure that the valve is fully open.

Note. Safety restraint omitted for clarity.

Figure 11   Setting the insertion depth – centerline method for pipe diameters >1 m 2 m (>40 in. 80 in)
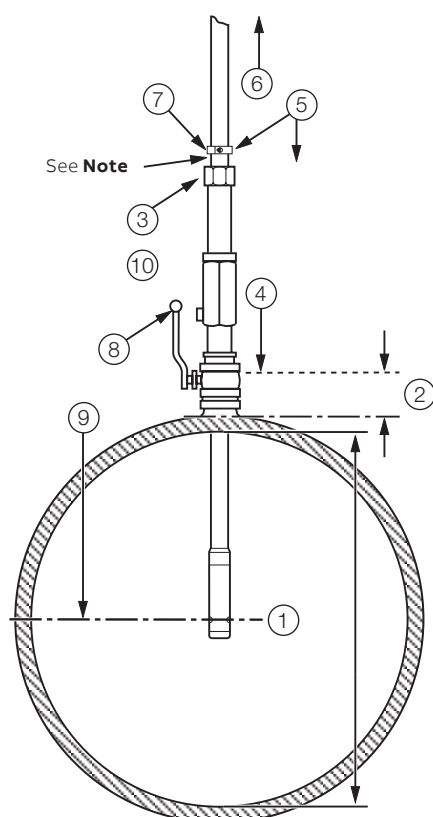
Referring to Figure 11:

① Determine the internal diameter (D).

② Measure to the top of the valve plate (VP).

③ Slacken the nut.

④ Lower the flow sensor to touch the valve plate.

⑤ Slide the positioning collar down to the nut and lock in place.

⑥ Retract the flow sensor fully.

⑦ Unlock, slide the positioning collar down and lock at the distance:

$$\frac{D}{2} + VP + 30 \text{ mm (1.181 in)} + \text{pipe thickness.}$$

⑧ Open the valve fully.

⑨ Insert flow sensor to position the collar depth.
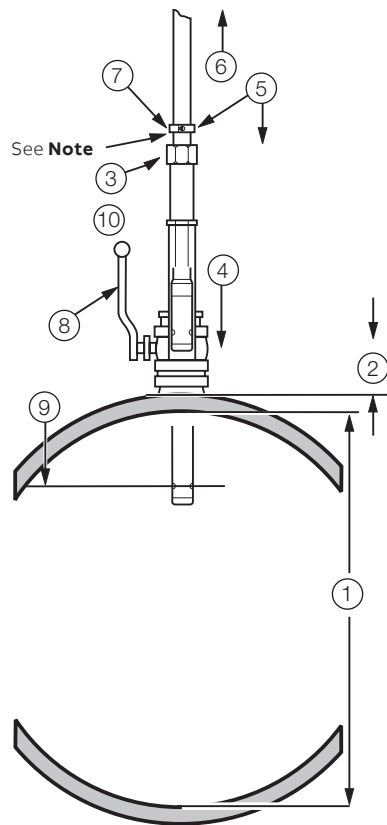
⑩ Tighten to 40 N·m (30 ft.lbf).

3.7.3 Mean axial velocity method

⚠️ **WARNING**

When inserting or removing the flow sensor suitable restraining equipment must be used to prevent the flow sensor being forced out under pressure. Ensure that the valve is fully open.

Note. Safety restraint omitted for clarity.

Figure 12   Setting the insertion depth – mean axial velocity method

Referring to Figure 12:

1. Determine the internal diameter (D).
2. Measure to the top of the valve plate (VP).
3. Slacken the nut.
4. Lower the flow sensor to touch the valve plate.
5. Slide the positioning collar down to the nut and lock in place.
6. Retract the flow sensor fully.
7. Unlock, slide the positioning collar down and lock at the distance:

   $\dfrac{D}{8}$ + VP + 30 mm (1.181 in.) + pipe thickness.

8. Open the valve fully.
9. Insert flow sensor to position the collar depth.
10. Tighten to 40 N·m (30 ft.lbf).

...3   Mechanical installation

3.8 Flow sensor alignment

> ### ⚠ WARNING
>
> When inserting or removing the flow sensor suitable restraining equipment must be used to prevent the flow sensor being forced out under pressure. Ensure that the valve is fully open.

Note. Safety restraint omitted for clarity.

Figure 13   Flow sensor alignment

Referring to Figure 13:

① Slacken the nut.

② Align parallel to the pipe (within 2°) – measurement error due to misalignment (of <2) is <0.15 %.
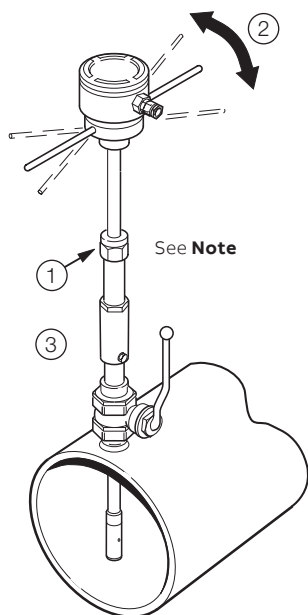
③ Tighten to 40 N·m (30 ft.lbf).

4   Electrical installation

4.1 Sensor terminal box connections – WaterMaster FET100 Transmitter

⚠ CAUTION

- Make connections only as shown.

- Remove foil screens

- Twist the three screen wires together and sleeve them.

- Twist cable pairs together

- Maintain Environmental Protection at all times.

- Conduit connections must provide cable entry sealing.

S1 Violet (Screen)
E1 Violet (*Signal)
E2 Blue (*Signal)
S2 Blue (Screen)
3 Green (Sleeve)
D2 Yellow
D1 / TFE Orange
SCR (Screen)
M2 Red
M1 Brown

Cut cables to
60 mm (2.35 in)

*Inner wire

**Figure 14   Cable connections at flow sensor terminal block –
WaterMaster FET1 Transmitter**

...4   Electrical installation

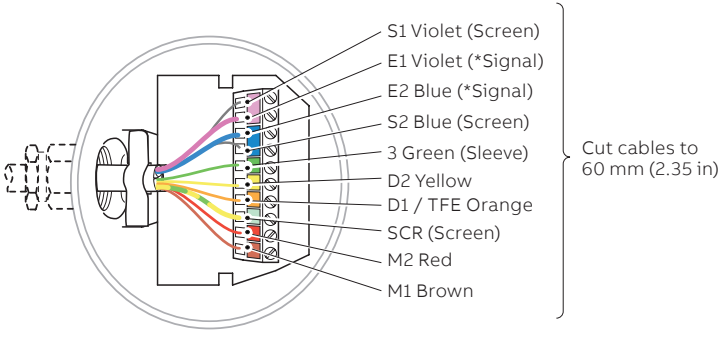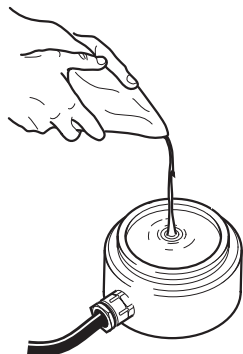## 4.2 Environmental protection

Figure 15   Potting the terminal box – WaterMaster FET1 Transmitter

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⚠ WARNING

- Potting materials are toxic – use suitable safety precautions.

- Read the manufacturers instructions carefully before preparing the potting material.

- The remote sensor terminal box connections must be potted immediately on completion to prevent the ingress of moisture.

- Check all connections before potting – see "Electrical installation" on page 19.

- Do not overfill or allow the potting material to come into contact with O-rings or grooves.

- Do not let potting material enter conduit, if used.

4.3 Sensor terminal box connections – AquaMaster3 FET200 Transmitter

With AquaMaster3 FET2 transmitter the sensor terminal box is factory-wired, potted and terminated with a plug for easy connection at the transmitter.

5   Setting up

5.1 Introduction

The basic equation for volume measurement using the flow sensor is:

$$Q = A \, F_i \, F_P \, V$$

Where: Q = flow rate

F_i = insertion factor

F_P = profile factor

V = velocity

A = area

The profile factor and insertion factor must be determined as detailed in "Centerline method" on page 21 and "Mean axial velocity method (⅛ diameter)" on page 22 as applicable. The pipe diameter must be accurately determined, see "Measuring the internal diameter" on page 30 for use of gauge.

Note. Due to software configuration, all calculations are in metric units. Therefore if using an imperial pipe, the diameter MUST be converted into millimeters (1 in. = 25.4 mm, for example, a 36 in pipe = 914 mm).

5.2 Centerline method

1 Determine the internal diameter D of the pipe, in millimeters, by the most accurate method available.

2 Determine the profile factor Fp from Figure 16.

3 Calculate the insertion factor

$$F_i = \frac{1}{1 - (38/(\pi D))}$$

Example – for a pipe of internal diameter 593 mm (23.35 in.):
F_P = 0.861 (derived from Figure 16)

$$F_i = \frac{1}{1 - (38/(\pi 593))}$$
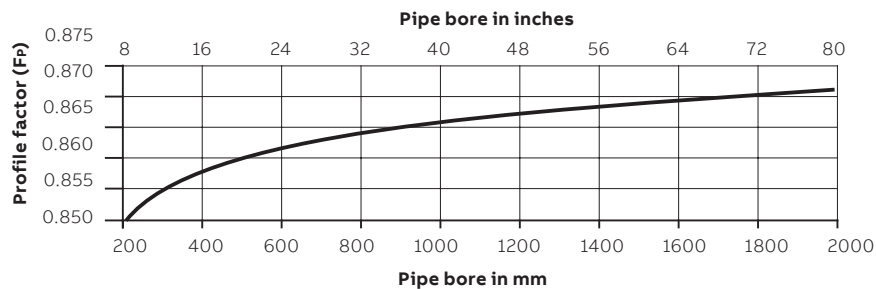
F_i = 1.021

Figure 16   Profile factor vs. velocity for pipe sizes 200 to 2,000 mm (8 in to 80 in)

...5 Setting up

5.3 Mean axial velocity method (⅛ diameter)

1 Determine the internal diameter D of the pipe, in millimeters, by the most accurate method available.

2 A profile factor Fp of 1 must be used.

3 Calculate the insertion factor

$$F_i = \left[1 + \frac{12.09}{D} + \frac{1.3042}{\sqrt{D}} \right]$$

Example – for a pipe of internal diameter 593 mm (23.35 in):

$F_P = 1$

$$F_i = \left[1 + \frac{12.09}{593} + \frac{1.3042}{\sqrt{593}} \right]$$

$F_i = 1.074$

5.4 Partial velocity traverse

Refer to "Partial velocity traverse" on page 28 for the procedure.

5.5 Transmitter setup

The transmitter can be set up to display point velocity, mean velocity or flow rate, as required. For full programming details refer to the relevant user guide:

WaterMaster FET100:
- User Guide – OI/FET100
- Programming Guide – IM/WMP
- User Guide Supplement, PROFIBUS RS485 Physical Layer – IM/WMPBS
- User Guide Supplement, PROFIBUS FEX100-DP Parameter Tables – IM/WMPBST

AquaMaster3 FET200:
- User Guide – OI/FET200
- Programming Guide – COI/FET2XX
- MODBUS Tables Supplement – COI/FET2XX/MOD/TBL

Menu entries must be made for:
- Profile Factor F_P
- Insertion Factor F_C
- Flow sensor pipe bore (mm)

6 Specifications

6.1 FEA100/FEA200 flow sensor

Maximum insertion length
- 300 mm (12 in)
- 500 mm (20 in)
- 700 mm (25 in)
- 1,000 mm (40 in)

Pipe sizes
- 200 to 8,000 mm (8 to 320 in) nominal bore

Protection
- IP68/NEMA 6P (Indefinite submersion down to 10 m [30 ft])

Weight
- <3.5 kg (7.7 lb)

Accuracy

Velocity
- ±2 % of rate or ±2 mm/s (±0.08 in/s) whichever is the greater

Volume
- Refer to ISO 7145-1982 (BS 1042 section 2.2) for details

Flow condition
- Fully developed profile in accordance with ISO 7145-1982 (BS1042 section 2.2.)

Pressure limitations
- 20 bar (295 psi)

Max. Pressure
- 20 bar (295 psi)

Pressure equipment Directive 97/23/EC
- This product is applicable in networks for the supply, distribution and discharge of water and associated equipment and is therefore exempt

Conductivity
- >50 μS/cm

Connections
- 1 in BSP
- 1 in NPT
- 1.5 in BSP

Potable Water Approvals for wetted parts
- WRAS
- NSF - 61
- ACS

Approvals, certifications and safety


NSF
Certified to NSF/ANSI/CAN 61 - G

...6   Specifications

6.2 Maximum flow

The maximum velocity depends upon the actual insertion length. Typical insertion lengths are 0.125 and 0.5 × pipe diameter.

The graph is a guide* to the maximum allowable velocity for different insertion lengths.

*The graph is intended as a guide only. Factors that influence the maximum insertion length into the pipe include: flow sensor mounting components, for example, standoffs, bushes and valves; other influences include pipeline vibration, fluid vibration and pump noise.
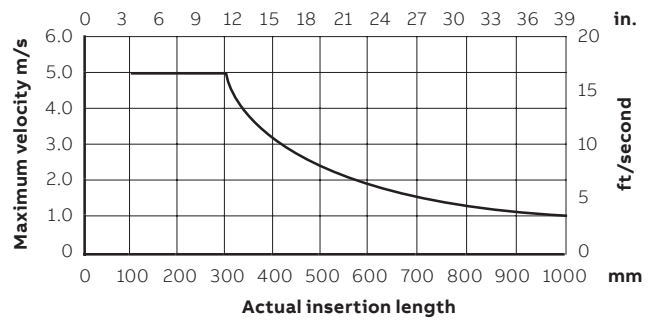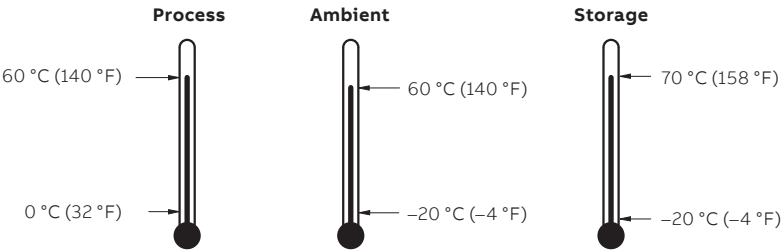

6.3 Wetted materials

Body
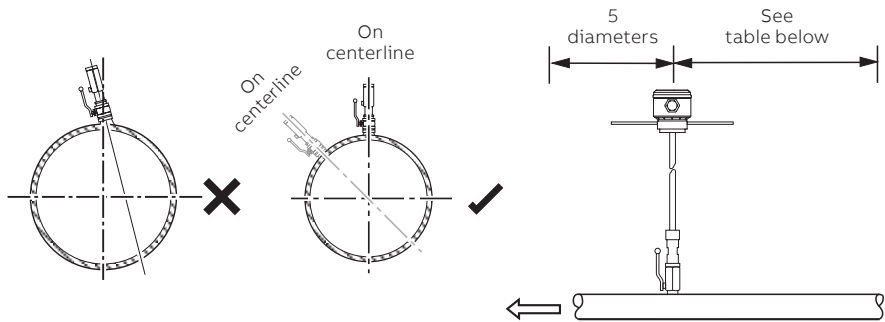
Stainless steel

Flow Sensor

Suitable for potable water (WRAS listed)

Electrodes – stainless steel 316L

Seals

Suitable for potable water (WRAS listed)

Temperature Ranges

6.4 Limits of upstream disturbance

	Minimum upstream straight length*	
Type of disturbance upstream from the measuring cross-section	**For a measurement at the point of mean axial velocity**	**For a measurement on the axis of the conduit**
90° elbow or a T-bend	50	25
Several 90° coplanar bends	50	25
Several 90° non-coplanar bends	80	50
Total angle convergent 18 to 36°	30	10
Total angle divergent 14 to 28°	55	25
Fully opened butterfly valve	45	25
Fully opened plug valve	30	15

Note.

This table is an extract from ISO7145 (BS 1042): Section 2.2: 1982 and is reproduced with the permission of BSI. Complete copies of the standard can be obtained by post from:

BSI Publications
Linford Wood
MILTON KEYNES
MK14 6LE
United Kingdom

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*   Expressed in multiples of the diameter of the conduit.
Downstream from the measurement cross-section, the straight length must be at least equal to five duct diameters whatever the type of disturbance.

Appendix A

A.1 Velocity profiles background

Figure 17 is a vector diagram showing a fully developed turbulent profile of the flow within a pipe. Such diagrams illustrate the distribution of flow within the pipe. Known as the Flow Profile, it is highest in the center falling to zero at either side on the pipe wall. If there is sufficient upstream straight pipe, it can be assumed that there is a profile of this form. In this case if, for example, the pipe is 600 mm in diameter, the velocity at the centerline is 2 m/s and the flow is 487 L/s
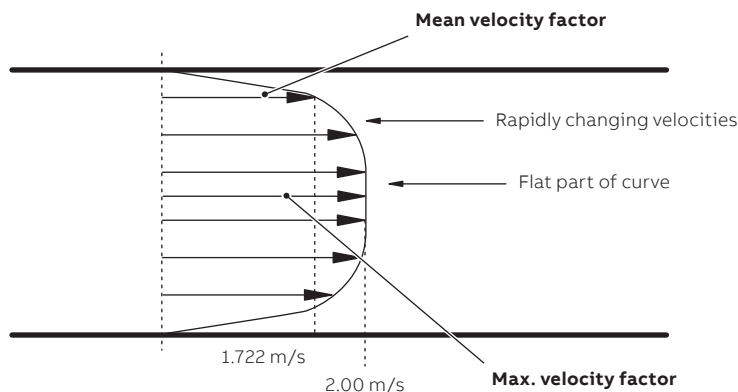

Figure 17   Turbulent flow profile

As the volume flow is known, the mean velocity in the pipe can be calculated – note that it is actually 1.722 m/s lower than the velocity measured on the centerline. Careful Investigation of this profile or vector diagram reveals that the mean velocity of 1.722 m/s occurs at a point 72.5 mm or ⅛ of the pipe's diameter in from the edge of the pipe. This point is referred to as the point of mean velocity (for a fully developed turbulent flow profile only). This is true (provided the profile **is** turbulent **and** fully developed) for all pipes of all sizes and at all flow rates, and is recognized in the British Standard referred to previously. Therefore, the best position to measure velocity is at the Point of Mean Velocity, i.e., ⅛ of the diameter in from the edge of the pipe. By placing the probe at this point a straightforward calculation of volume flow can be performed – but there is more to be considered.

The Point of Mean Velocity is on the knee of the curve (the velocity at this point is changing rapidly with distance) so it is necessary to position the probe extremely accurately in order to measure the correct velocity. If the probe is inserted accurately to 72.5 mm, it is therefore measuring the mean velocity of 1.722 m/s which, when multiplied by the area, gives a volume flow of 487 L/s. If the probe is inserted to 74 mm instead of 72.5, the velocity measurement is 1.85 m/s instead of the expected 1.722. Multiplying this figure by the area results in a volume flow of 523 L/sec – an error of 7.4 %.

On-site it can be very difficult to locate a probe exactly, so this sort of error is quite common. With devices other than AquaProbe, working under any degree of pressure in the line, inserting a probe to within 10 mm of its intended location is often accepted. Using the calculation above, this produces an error of approximately 15 %. This can be reduced significantly by using the following method.

Referring to Figure 17, in the middle of the pipe, near the centerline, the profile is relatively flat, i.e., the flow velocity does not change very much with distance into the pipe. Therefore, if the velocity is measured on the centerline, measurement errors due to positional errors (i.e., not locating the probe where required) are very small; hence most users will try to use the centerline measuring position. However, as explained previously, this process gives us the wrong answer,

Fortunately there is a mathematical relationship between the velocity at the centerline and the mean velocity within the pipe – the **Profile Factor (Fp)**. The value of Fp can be calculated by an equation (below) or obtained from a graph – see Figure 18.

Fp is calculated as follows:

$$F_\rho = 1 - \left[\frac{(r - Y_b)}{r} \right]^{\frac{1}{n}}$$

Where:

$$Y_b = r \left[\frac{2n^2}{(n + 1)(2n + 1)} \right]$$

And:

$$n = 1.66 \log (R_e)$$

And:

$$R_e = \frac{D\rho v}{\mu}$$

D = Pipe diameter

ρ = Fluid density

v = Average fluid velocity
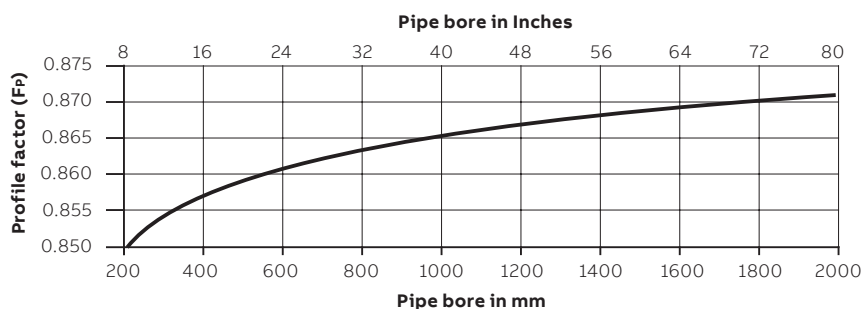
μ = Fluid viscosity

Figure 18   Profile factor vs. flow velocity for pipe sizes 200 to 2,000 mm (8 to 78 in)

…Appendix A

…A.1 Velocity profiles background

When the probe insertion position is determined, the effect of putting the probe into the pipe (see "Velocity limitations" on page 10) must be calculated.

The blockage or insertion effect is termed the **Insertion Factor (Fi)**. This is a mathematical relationship and can be calculated from the formula:

$$F_i = \frac{1}{1 - (38/(\pi D))}$$

A.2 Testing the flow profile for symmetry

If there is any doubt as to the symmetry of the flow profile (see "Location – Flow conditions" on page 9), a Partial Velocity Traverse should be carried out. This procedure involves comparing the value of velocity at two points at equal distances from the centerline.

It is normal to compare the flow velocities at insertion depths of ⅛ and ⅞ of the pipe diameter as these points are always on the 'knee' of the profile.

A.2.1 Partial velocity traverse

Determine the internal diameter D of the pipe, in millimeters, by the most accurate method available. If the flow sensor insertion length is greater than the internal diameter of the pipe, proceed with the Single Entry Point Method detailed in "Single entry point method" on page 28. If the flow sensor's insertion length is less than the internal diameter of the pipe, proceed with the Dual Entry Point Method detailed in "Dual entry point method" on page 29.

A.2.2 Single entry point method

1   Insert the flow sensor to a depth of ⅛ the pipe diameter – see Figure 12 on page 17.

Note.
Due to software configuration, all calculations are in metric units. Therefore if using an imperial pipe, the diameter **MUST** be converted into millimeters (1 in = 25.4 mm, for example, a 36 in pipe = 914 mm).

2   Calculate the insertion factor

$$F_i = \left[1 + \frac{12.09}{D} + \frac{1.3042}{\sqrt{D}} \right]$$

3   Refer to the relevant user guide* and enter an Insertion Factor of value equal to Fi.

4   Record the flow velocity reading.

5   Insert the flow sensor to a depth of ⅞ the pipe diameter.

6   Calculate the insertion factor.

$$F_i = \left[1 + \frac{12.09}{D} + \frac{1.3042}{\sqrt{D}} \right]$$

7   Refer to the relevant user guide* and enter an Insertion Factor of value equal to Fi.

8   Record the flow velocity reading.

9   Calculate the ratio of the two values recorded.

   – if the calculated ratio is between 0.95 and 1.05, the flow profile is acceptable and the procedure detailed in "Centerline method" on page 21 can be used,

   or

   – if the calculated ratio is not between 0.95 and 1.05, re-site the flow sensor for optimum accuracy.

*WaterMaster FET100 (OI/FET100) or
AquaMaster3 FET200 (OI/FET200)

A.2.3 Dual entry point method
Refer to "Installing the flow sensor" on page 14 and fit a
second mounting boss directly opposite the one already fitted.

Note.
Due to software configuration, all calculations are in metric
units. Therefore if using an imperial pipe, the diameter
MUST be converted into millimeters (1 in = 25.4 mm, for
example, a 36 in pipe = 914 mm).

1 Insert the flow sensor to a depth of ⅛ the pipe diameter
   through the original mounting boss.

2 Calculate the insertion factor.

$$F_i = \left[1 + \frac{12.09}{D} + \frac{1.3042}{\sqrt{D}} \right]$$

3 Refer to the relevant user guide* and enter a Insertion Factor
   of value equal to Fi.

4 Record the flow velocity reading.

5 Insert the flow sensor to a depth of ⅛ the pipe diameter
   through the second mounting boss.

6 Record the flow velocity reading.

7 Calculate the ratio of the two values recorded

   – if the calculated ratio is between 0.95 and 1.05, the flow
     profile is acceptable and the procedure detailed in
     "Centerline method" on page 21 can be used

     or

   – if the calculated ratio is not between 0.95 and 1.05,
     re-site the flow sensor for optimum accuracy

*WaterMaster FET100 (OI/FET100) or
AquaMaster3 FET200 (OI/FET200)

A.3 Full velocity profile

For installations with very poor and asymmetric velocity
profiles (for example as rejected in "Single entry point method"
on page 28) a full velocity profile provides an improved
accuracy of reading. To facilitate this ABB have developed
ScrewDriver software for the PC that calculates Fi and Fp for
any measured velocity profile – see IM/SDR section 'ABB Flow
Profiling'.

Appendix B – Measuring the internal diameter

When a standard full-bore electromagnetic flowmeter is manufactured, it is usually supplied in a nominal bore size of a round figure anywhere between 15 and 2,000 mm (for example 600 mm, 700 mm). Rarely are flowmeters precisely this nominal size, but it is not important as the wet flow calibration (performed on ABB's UKAS-approved and traceable flow rigs in the UK) compensates for small deviations in size. In the case of a probe, clearly it can't be tested in the pipe in which it is to be finally installed. It is therefore not possible to take account of the difference between the nominal or expected internal diameter of the pipe and its actual value.

Since the relationship between the point velocity measurement and the flow depends on the area of the cross section of the pipe (π × the radius squared), an error in the value of the internal diameter of the pipe causes a much greater error in the volume flow measurement due to the 'square effect'. Therefore it is essential, whenever possible, to measure the internal diameter accurately to eliminate this extra source of errors. ABB supply an internal pipe-measuring probe (pipe-bore gauging tool) for this purpose. The tool is used as follows:

1 Fit the tool into the back of the valve, so that the red line on top of the fitting and the handle of the tool is in line longitudinally with the centerline of the pipe.

2 Open the valve and push the tool in gently until it touches the other side of the pipe.

3 Back off the tool a small amount and rotate the handle through 180° so it is again in line with the longitudinal axis of the pipe.

4 Push the tool down again carefully until it touches the wall of the pipe. Now, slide the small collar on the tool down to touch the top of the fitting.

5 Pull the tool back carefully until it touches the top of the pipe. During this withdrawal, take care not to touch the sliding collar. This distance between the top knife-edge of the sliding collar and the top of the fitting is the internal diameter of the pipe. Measure this distance using a good quality tape rule.

6 Once the diameter has been measured and recorded, push the measuring tool back into the pipe a little then turn it through 180° so that the handle is once more in line with the longitudinal axis of the pipe and in the same direction as the red line on the top fitting.

7 Retract the probe fully into its fitting and close the valve fully.

Pipe alignment

Figure 19   Pipe-bore gauging rod

Acknowledgements

Notes

Notes

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www.abb.com/contacts

For more product information, visit:
www.abb.com/measurement