

AquaMaster4

Electromagnetic flowmeter insertion sensor



The ideal flowmeter for potable water distribution networks, survey and flow investigation and irrigation applications

Measurement made easy

—
Harness the power
of electromagnetic
flowmeters

Introduction

AquaMaster4 is a range of high performance electromagnetic flowmeters for the measurement of electrically-conductive fluids and are normally supplied as factory-configured, calibrated systems.

This Operating Instruction provides end-user details for AquaMaster4 insertion sensors.

For more information

Further publications for AquaMaster4 are available for free download from:
<http://new.abb.com/products/measurement-products>

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1 Health & Safety

Document symbols

Symbols that appear in this document are explained below:



DANGER – SERIOUS DAMAGE TO HEALTH

This symbol in conjunction with the signal word 'DANGER' indicates an imminent electrical hazard. Failure to observe this safety information will result in death or severe injury.



WARNING – BODILY INJURY

This symbol in conjunction with the signal word 'WARNING' indicates a potential electrical hazard. Failure to observe this safety information will result in death or severe injury.



CAUTION – MINOR INJURIES

This symbol in conjunction with the signal word 'CAUTION' indicates a potentially dangerous situation. Failure to observe this safety information may result in minor or moderate injury. The symbol may also be used for property damage warnings.



IMPORTANT (NOTE)

This symbol indicates operator tips, particularly useful information or important information about the product or its further uses. The signal word 'IMPORTANT (NOTE)' does not indicate a dangerous or harmful situation.

Safety precautions

Be sure to read, understand and follow the instructions contained within this manual before and during use of the equipment. Failure to do so could result in bodily harm or damage to the equipment.



WARNING – BODILY INJURY

Installation, operation, maintenance and servicing must be performed:

- by suitably trained personnel only
- in accordance with the information provided in this manual
- in accordance with relevant national and local regulations

Intended use

This insertion sensor is intended for the following uses:

- To measure the volumetric flow rate, flow velocity, volume flow (forward, reverse and net) and pressure (option) of a conductive fluid.

The insertion sensor has been designed for use exclusively within the technical limit values indicated on the identification plate and in the data sheets.

In terms of the measuring medium, observe following points:

- Wetted parts such as measuring electrodes, liner, insertion sensor tip must not be damaged because of the chemical and physical characteristic of the measuring medium.
- The information on the name plate must be observed.

Improper use

The following are considered to be instances of improper use of the insertion sensor:

- For use as a climbing aid – for example, for mounting purposes.
- Material application – for example, by painting over the nameplate or welding/soldering on parts.
- Material removal – for example, by spot drilling the housing.

Potential safety hazards

AquaMaster4 insertion sensor – electrical



WARNING – BODILY INJURY

To ensure safe use when operating this equipment, the following points must be observed:

- Up to 240 V AC may be present. Isolate the supply before removing the terminal cover.
- Normal safety precautions must be taken to avoid the possibility of an accident occurring when operating in conditions of high pressure and/or temperature.
- Risk of injury due to pressurized vessel. Installation, removal or adjustment of this insertion sensor can be dangerous. The instructions in this manual **MUST** be observed and followed carefully, especially with regard to use of the safety mechanism (see page 16). Incorrect procedures could cause the insertion sensor assembly to be expelled from a pressurized line with high force resulting in the potential for serious personal injury.

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

Safety standards

This product has been designed to satisfy the requirements of IEC61010-1:2010 3rd edition 'Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use' and complies with US NEC 500, NIST and OSHA.

This equipment complies with the requirements of CEI/IEC 61010-1:2010 'Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use' and complies with US NEC 500 and Occupational Safety & Health Administration. If the equipment is used in a manner NOT specified by the Company, the protection provided by the equipment may be impaired.

Waste Electrical and Electronic Equipment (WEEE)

WEEE EU Directive 2012/19/EU covers disposal and recycling of electronic equipment at the end of life for reasons of environmental protection.



For industrial installations, portable equipment is included. This means that when the AquaMaster4 transmitter is used with a portable insertion sensor, it is included in directive's scope and has the WEEE symbol (left) on its data label. Therefore, at the end of life, contact the supplier for specialist waste recycling. It must not be disposed of as municipal waste.

Permanent Industrial installations are not designated within this directive for recycling. At the point of supply the intended use is not always known, so the WEEE symbol is included on all remote forms of the AquaMaster4 transmitter.

Product recycling and disposal (Europe only)



Electrical equipment marked with this symbol may not be disposed of in European public disposal systems after 12 August 2005. To conform to European local and national regulations (EU Directive 2012/19/EU), European electrical equipment users can now return old or end-of-life equipment to the manufacturer for disposal at no charge to the user. 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.



IMPORTANT (NOTE)

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

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.

Product symbols

Symbols that may appear on this product are shown below:



Risk of electric shock.



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.



Protective earth (ground) terminal.



Functional earth (ground) terminal.



Direct current supply only.



Alternating current supply only.



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.



Recycle separately from general waste under the WEEE directive.

2 Insertion sensor overview

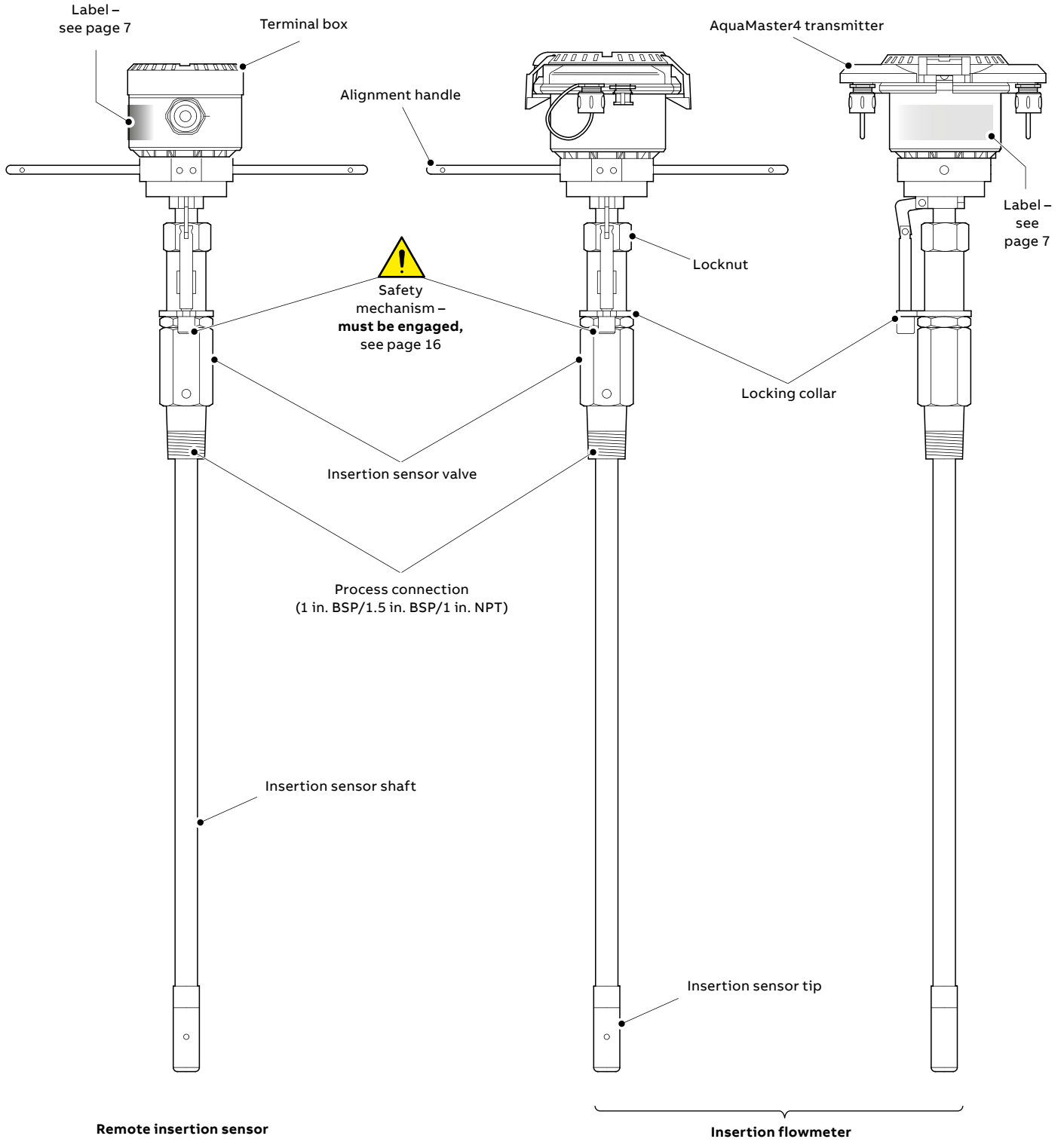
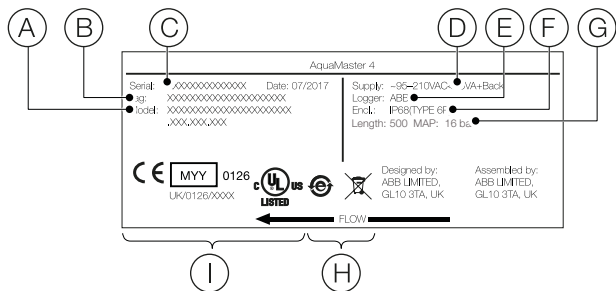


Figure 1 AquaMaster4 insertion sensor overview

3 Product identification

Nameplate

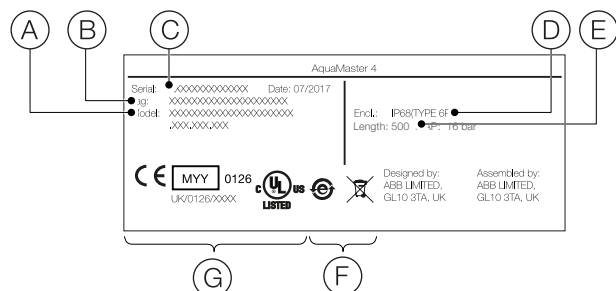
Integral insertion sensor



- (A) Model type/number
- (B) Insertion sensor-specific tag
- (C) ABB-defined product serial number
- (D) Power supply, min./max. voltage rating
- (E) Logger (shown if available)
- (F) Enclosure ingress protection rating
- (G) Insertion sensor length
- (H) Insertion sensor disposal categories
- (I) Applicable certification

Figure 2 Name plate – integral insertion sensor (example)

Remote insertion sensor



- (A) Model type/number
- (B) Insertion sensor-specific tag
- (C) ABB-defined product serial number
- (D) Enclosure ingress protection rating
- (E) Insertion sensor size/manifold absolute pressure (psig)/temperature
- (F) Insertion sensor disposal categories
- (G) Applicable certification

Figure 3 Name plate – remote insertion sensor (example)

4 Transport and storage

Inspection

Check the insertion sensor immediately after unpacking for possible damage that may have occurred from improper transport. Details of any damage that has occurred in transit must be recorded on the transport documents. All claims for damages must be submitted to the shipper without delay and before installation.

Transport

**WARNING – BODILY INJURY**

Life-threatening danger due to suspended loads. In the case of suspended loads, a danger of the load falling exists.

Remaining under suspended loads is prohibited.

Storing the insertion sensor

Bear the following points in mind when storing insertion sensors:

- Store the insertion sensor in its original packaging in a dry and dust-free location.
- Observe the permitted ambient conditions for transport and storage.
- Do not store the insertion sensor in direct sunlight.

Storage temperature

–20 to 60 °C (–4 to 140 °F)

The ambient conditions for the transport and storage of the insertion sensor must correspond to the ambient conditions for operation of the insertion sensor.

Adhere to the AquaMaster4 data sheet (DS/FET400-EN)!

5 Installation

General information

The following points must be observed during installation:

- Secure the insertion sensor against pipe vibration.
- Insertion sensors must be installed without mechanical tension (torsion, bending).
- Ensure temperature limits are not exceeded when operating the insertion sensor.
- Avoid vacuum shocks in the piping to prevent damage to the insertion sensor. Vacuum shocks can destroy the insertion sensor.
- Do not remove the sealing plugs in the cable glands until you are ready to install the electrical cable.
- The transmitter with a remote mount design must be installed at a largely vibration-free location.
- When installing the transmitter in a control cabinet, ensure adequate cooling is provided.

Pre-installation requirements

- Before installing a remote insertion sensor, check the cable is of sufficient length for application/site conditions.
- Use only a single cable length. If the cable is not of sufficient length do not extend it; replace it with new cable of sufficient length and pot the terminal housing at the insertion sensor end as detailed on page 16.

Installation requirements



CAUTION

- The installation conditions shown must be observed to achieve the best operational results.
- Care must be taken when unpacking and lifting the insertion sensor.

Fluid level

The insertion sensor pipe must always be completely full.

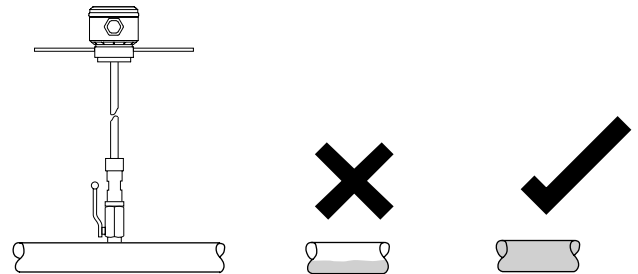


Figure 4 Fluid level in pipe

Extremes of temperature

Do not install the insertion sensor in a position that will expose it to extremes of temperature (for example, direct sunlight, frost and snow). Provide appropriate weather protection where necessary.

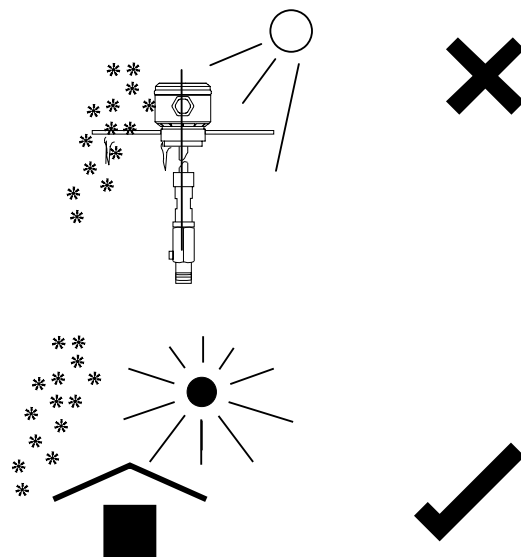


Figure 5 Extremes of temperature/adverse environments

...5 Installation

Seal materials/fluid temperatures

The flange seal material must be compatible with the fluid and fluid temperatures.

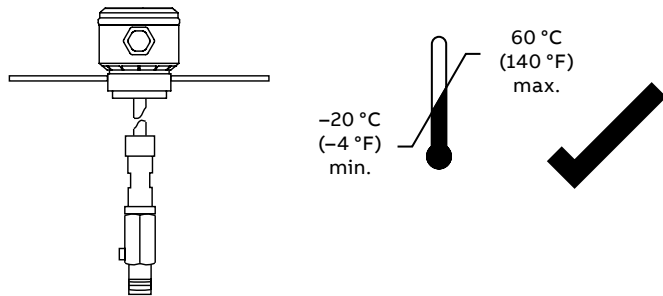


Figure 6 Within temperature limits

Pipeline forces/torque

The pipeline must not exert any forces and torques on the insertion sensor (for example, vibration).

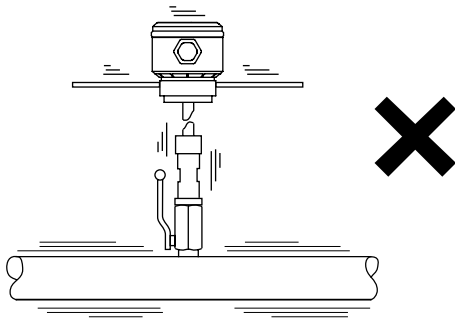


Figure 7 Vibration

Spillage onto the insertion sensor

Do not install the insertion sensor in an area where a spillage of any substance could damage the insertion sensor.

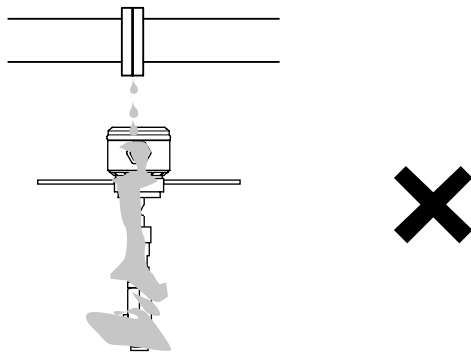


Figure 8 Spillage

Flow direction

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

- On the center line, or
- At the mean axial velocity point ($\frac{1}{8}$ pipe diameter)

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

Install the insertion sensor in the pipe so the flow direction arrow on the insertion sensor handle matches the pipe flow.

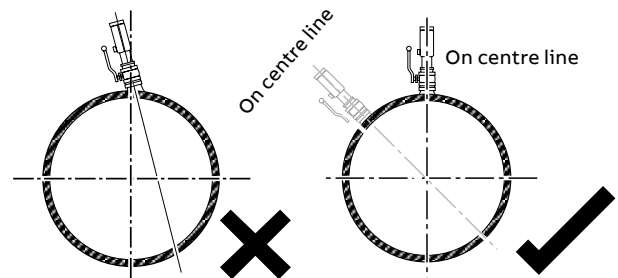
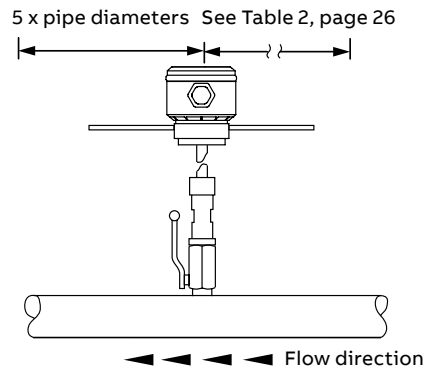


Figure 9 Flow conditions/orientation

Environmental rating

Ensure the level of IP rating is correct for the required meter installation application. IP68 (NEMA 6P) rated meters can be submerged continuously.

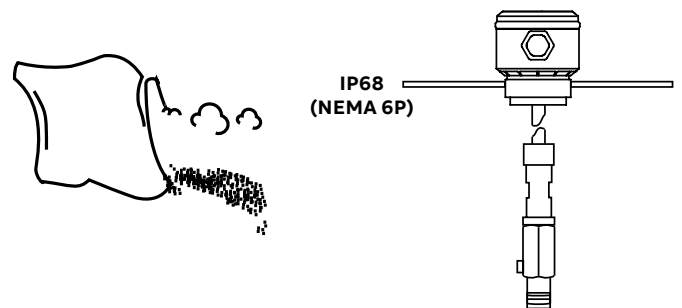


Figure 10 Environmental rating

Cable routing



IMPORTANT NOTE

Do not join signal cable to increase cable length. Use single lengths of cable only.

The cable to the insertion sensor must be installed neatly or within a conduit. Both loose or conduit installations must have a u-bend below terminal connection box height to enable any water to run off thus avoiding any capillary action into the insertion sensor.

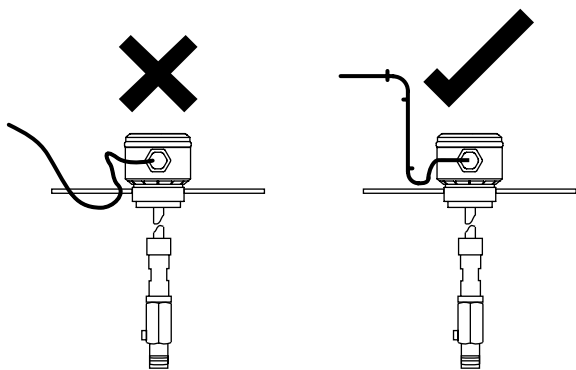


Figure 11 Cable routing to enable water run off

Observe the following points when routing signal cables:

- Keep the remote form insertion sensor cable as short as possible to avoid unnecessary electrical and magnetic pickup. Lengths* up to 150 m (492 ft) are permitted, but are more susceptible to unwanted pickup.
- Avoid routing the cable in the vicinity of electrical equipment or switching elements that can create stray fields, switching pulses and induction.
- Avoid running insertion sensor cables adjacent to those from other electromagnetic flowmeters, especially in the same cable ducts as unwanted magnetic coupling can induce unwanted signals and cause incorrect operation of the insertion sensor. Ideally adjacent cables should be >200 mm (8 in) apart.
- Do not damage the sheathing of the cable during installation.
- Ensure that a drip loop (water trap) is used when installing the connecting cables for the insertion sensor.

*Sensus™ cable is available in 5 and 20 m (15 and 65 ft) lengths.

Renewable energy cable is available as a 10 m (30 ft) length.

Localized heating/welding

The insertion sensor must not be submitted to localized heating during installation; remember this is a measuring instrument.

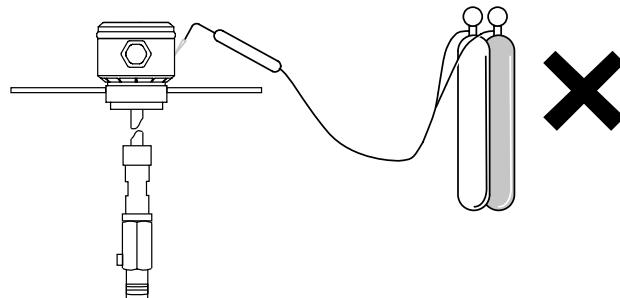


Figure 12 Localized heat

Tapping on pipelines

An insertion sensor 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 – RISK OF INJURY DUE TO PRESSURIZED VESSEL

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 insertion sensor. If the pressure is greater than 10 bar, installation (or removal) of a insertion sensor 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 insertion sensor, when the pressure can then be re-applied. In many instances, the removal of a insertion sensor from a line is more dangerous than the installation. For this reason, the insertion sensor is supplied complete with a safety mechanism (see page 16) that prevents rapid outward movement and potential injury to operators. It must be stressed that this is a problem with all insertion sensor types, not just the insertion sensor.

...5 Installation

Dimensions

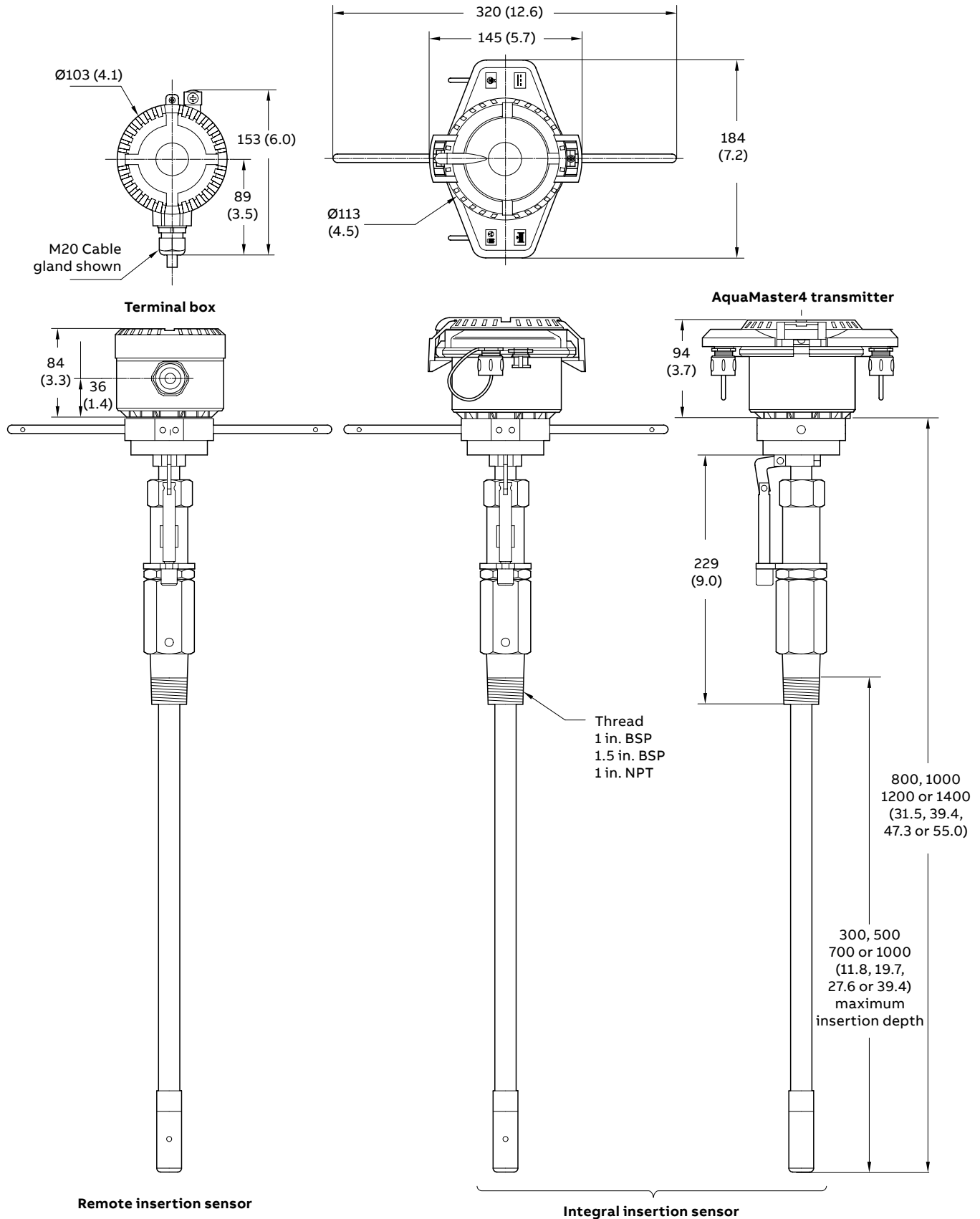


Figure 13 AquaMaster4 A-insertion sensor dimensions

Setting up

The basic equation for volume measurement using the insertion 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 below (as applicable). The pipe diameter must be accurately determined, see page 14 for use of gauge.

i IMPORTANT (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).

Centre line method

- 1 Determine the internal diameter D of the pipe, in millimeters, by the most accurate method available.
- 2 Determine the profile factor F_p from Figure 14.
- 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 14)

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

F_i = 1.021

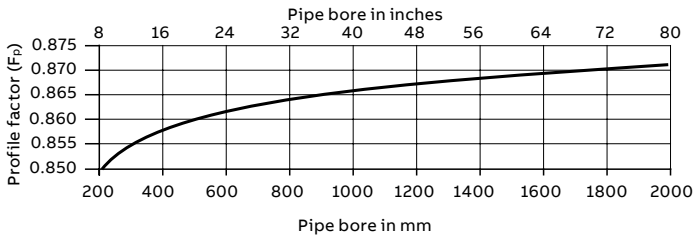


Figure 14 Profile factor vs velocity for pipe sizes 200 to 2000 mm (8 to 80 in)

Mean axial velocity method (1/8 Diameter)

- 1 Determine the internal diameter D of the pipe, in millimeters, by the most accurate method available.
- 2 A profile factor F_p 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

Partial velocity traverse

Refer to page 28 for the procedure.

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 Instruction manual: OI/FET400-EN.

Menu entries must be made for:

- Profile Factor F_p
- Insertion Factor F_c
- Insertion sensor pipe bore (mm)

...5 Installation

Measuring the internal diameter of the pipe

When a standard full-bore electromagnetic insertion sensor is manufactured, it is usually supplied in a nominal bore size of a round figure anywhere between 15 and 2000 mm (for example 600 mm, 700 mm). Rarely are insertion sensors 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 insertion sensor, 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 ($\pi \times$ 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 insertion sensor (pipe-bore gauging tool) for this purpose – see Figure 15.

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 center line 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 insertion sensor fully into its fitting and close the valve fully.



Figure 15 Pipe-bore gauging tool

Connections



DANGER – SERIOUS DAMAGE TO HEALTH

- The mains/line-powered transmitter option is not fitted with a switch – an isolator such as a switch or circuit breaker conforming to local safety standards must be fitted to the final installation. It must be fitted in close proximity to the transmitter, within easy reach of the operator and marked clearly as the isolator for the transmitter.
- Remove all power from supply, relay, any powered control circuits and high common mode voltages before accessing or making any connections.
- All connections to secondary circuits must have insulation to required local safety standards. After installation, there must be no access to live parts. Use screened cable for signal inputs and relay connections. Route signal leads and power cables separately, preferably in an earthed (grounded) flexible metal conduit.



WARNING – BODILY INJURY

- If the transmitter is used in a manner not specified by the Company, the protection provided by the equipment may be impaired.
- Replacement of the internal battery must be carried out by an approved technician only.
- The transmitter conforms to Installation Category II of IEC 61010.
- All equipment connected to the transmitter’s terminals must comply with local safety standards (IEC 60950, IEC61010-1).

- If the insertion sensor is ordered with cable, the cable is potted at the (remote) insertion sensor and is connected to the transmitter using the supplied plug.
- If the insertion sensor is ordered without cable, the insertion sensor is supplied part-potted (up to the terminal block). Connections must then be made and the enclosure must be fully potted.

Insertion sensor terminal box connections



DANGER – SERIOUS DAMAGE TO HEALTH

- Make connections only as shown in Figure 17.
- Maintain environmental protection at all times.
- Conduit connections must provide cable entry sealing.

To make insertion sensor terminal connections:

- 1 Unscrew and remove the insertion sensor terminal housing cover.
- 2 Remove foil screens.
- 3 Twist the three screen wires together and sleeve them.
- 4 Twist cable pairs together.
- 5 Power up and check all connections.
- 6 Pot the terminal block (see page 16).
- 7 Refit the cover.

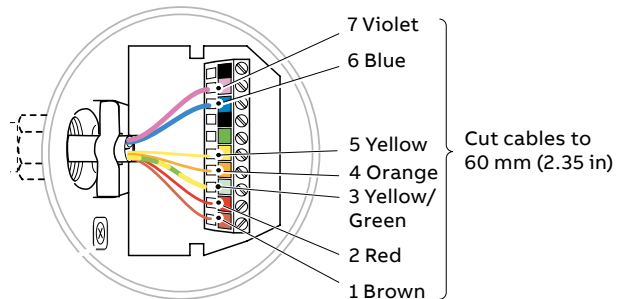


Figure 17 Cable connections at insertion sensor terminal block

Grounding



IMPORTANT NOTE

Only to be installed in metallic pipelines for electrical screening.

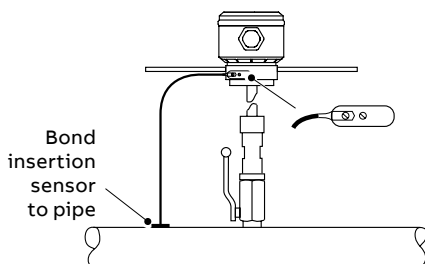


Figure 16 Grounding for electrical screening
Cable connections at the remote insertion sensor

...5 Installation

Potting the remote insertion sensor terminal housing



WARNING

- Power up and check all connections before potting.
- Pot the remote insertion sensor terminal box connections immediately on completion (after power-up and check) to prevent the ingress of moisture.
- Potting materials are toxic. Read the manufacturers' instructions carefully before preparing the potting material and use suitable safety precautions.
- 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).

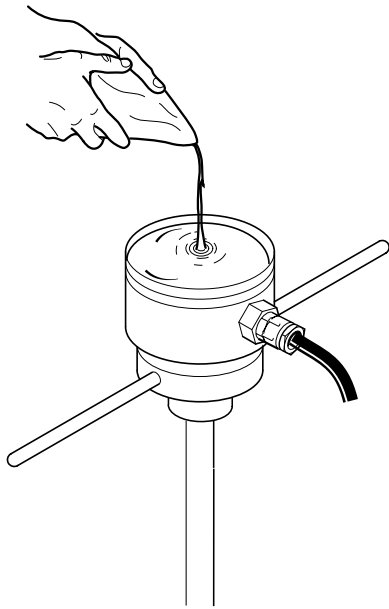


Figure 18 Potting the remote insertion sensor terminal housing

Pipeline preparation



CAUTION

- Prepare the main or pipeline into which this insertion sensor is to be installed prior to installation.
- Installation must be performed only by suitable experienced/qualified personnel in accordance with relevant safety requirements.

Safety mechanism



WARNING

- The insertion sensor is provided with a safety mechanism that must be attached to its securing collar (A) as shown in Figure 19 (**Secured position**). This prevents rapid outward movement by the insertion sensor if nut (B) is released.
- To ensure maximum safety, the positioning collar (C) **MUST** be tightened in place using a 4 mm hexagon key.

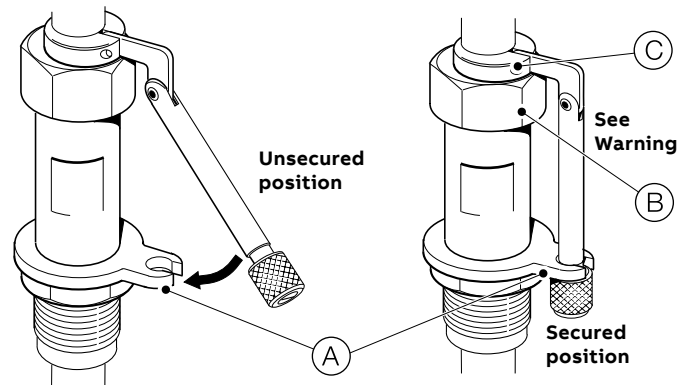


Figure 19 Safety mechanism

Inserting/Removing the insertion sensor



WARNING – PRESSURIZED EQUIPMENT

When inserting or removing the insertion sensor, the safety mechanism (see page 16) must be **fitted and engaged** to prevent the insertion sensor being forced out under pressure. Ensure the valve is fully open.

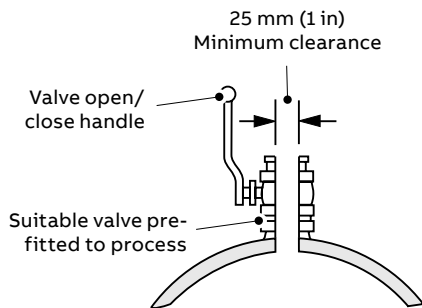


Figure 20 Insertion bore clearance

Referring to Figure 21:

- 1 Tighten nut (A) (hand-tight only).
- 2 Remove cap (B).
- 3 Apply PTFE tape (C).
- 4 Insert insertion sensor (D) into the valve (E).
- 5 Tighten firmly (F).

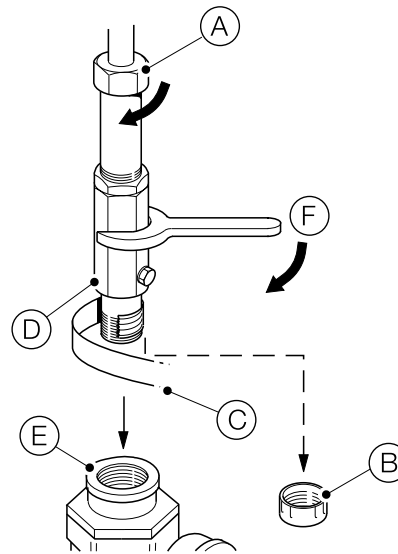


Figure 21 Installing the insertion sensor

...5 Installation

Setting the insertion depth

Centre line method for pipe diameters ≤ 1 m (≤ 40 in)



WARNING – PRESSURIZED EQUIPMENT

- When inserting or removing the insertion sensor, the safety mechanism (see page 16) must be **fitted and engaged** to prevent the insertion sensor being forced out under pressure. Ensure the valve is fully open.
- Safety restraint omitted for clarity.

Referring to Figure 22:

- 1 Measure internal diameter (D) of the pipe – see page 14.
- 2 Open valve (A) fully with valve lever (B).
- 3 Slacken nut (C).
- 4 Lower insertion sensor (D) into valve (A).
- 5 Slide positioning collar (E) down to nut (C) and lock in place using a 4 mm hexagon key (see page 16).
- 6 Retract insertion sensor shaft (F) fully.
- 7 Unlock positioning collar (E), slide down and lock at the distance:
 $\frac{D}{2} + 30$ mm (1.181 in.)
- 8 Lower insertion sensor until positioning (E) collar contacts nut (C), with sensor tip at the required depth (G).
- 9 Tighten nut (C) to 40 Nm (30 ft lbf).

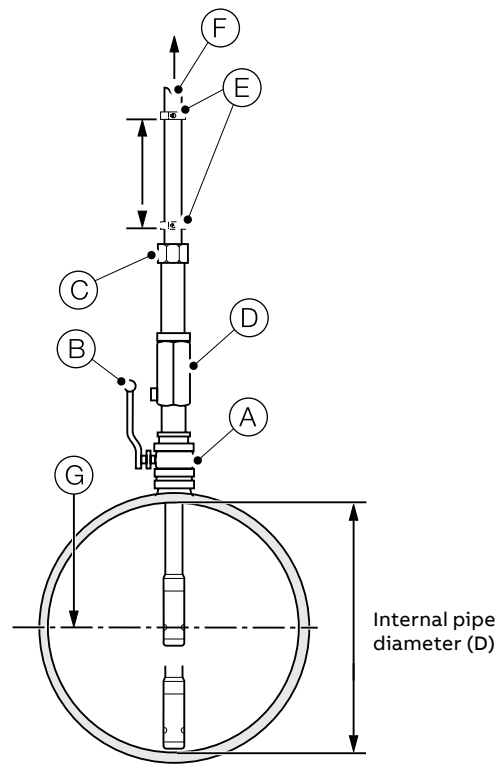


Figure 22 Setting the insertion depth – center line method for pipe diameters ≤ 1 m (≤ 40 in)

Centre line method for pipe diameters >1 m ≤2m (>40 in ≤80 in)

**WARNING – PRESSURIZED EQUIPMENT**

- When inserting or removing the insertion sensor, the safety mechanism (see page 16) must be **fitted and engaged** to prevent the insertion sensor being forced out under pressure. Ensure the valve is fully open.
- Safety restraint omitted for clarity.

Referring to Figure 23:

- 1 Measure internal diameter (D) of the pipe – see page 14.
- 2 Measure from the top of the pipe to the top of the valve plate (VP) (item A).
- 3 Slacken nut (B).
- 4 Lower insertion sensor (C) until it touches valve plate (D).
- 5 Slide positioning collar (E) down to nut (B) and lock in place using a 4 mm hexagon key (see page 16).
- 6 Retract insertion sensor shaft (F) fully.
- 7 Unlock positioning collar (E), slide down and lock at the distance:

$$\frac{D}{2} + VP + 30 \text{ mm (1.181.in.)} + \text{pipe thickness}^*$$
- 8 Open valve (D) fully with valve lever (G).
- 9 Lower insertion sensor until positioning (E) collar contacts nut (B), with sensor tip at the required depth (H).
- 10 Tighten nut (B) to 40 Nm (30 ft lbf).

*Refer to pipe supplier/manufacturer specification.

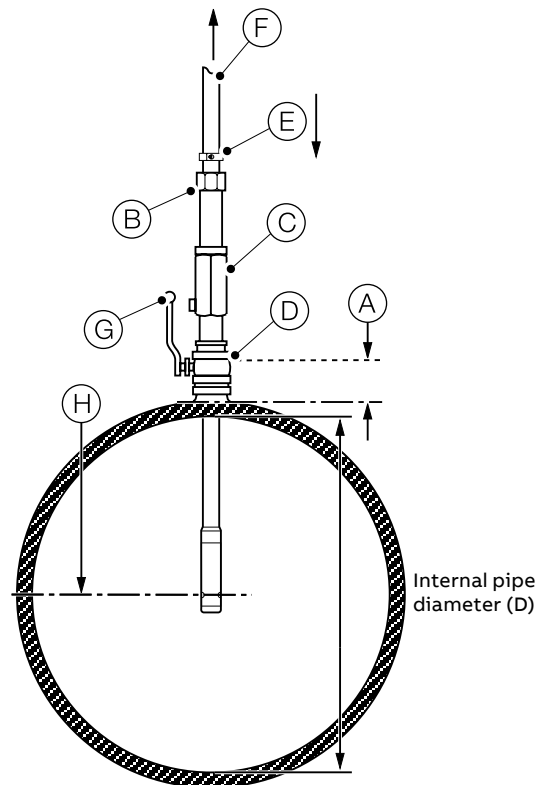


Figure 23 Setting the insertion depth – center line method for pipe diameters >1 m ≤2 m (>40 in. ≤80 in)

...5 Installation

Mean axial velocity method (1/8 Diameter)



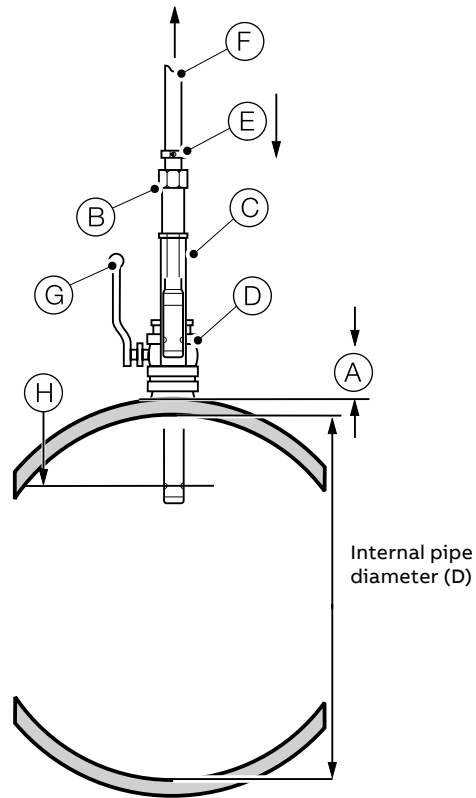
WARNING – PRESSURIZED EQUIPMENT

- When inserting or removing the insertion sensor, the safety mechanism (see page 16) must be **fitted and engaged** to prevent the insertion sensor being forced out under pressure. Ensure the valve is fully open.
- Safety restraint omitted for clarity.

Referring to Figure 24:

- 1 Measure internal diameter (D) of the pipe – see page 14.
- 2 Measure from the top of the pipe to the top of the valve plate (VP) (item A).
- 3 Slacken nut (B).
- 4 Lower insertion sensor (C) until it touches valve plate (D).
- 5 Slide positioning collar (E) down to nut (B) and lock in place using a 4 mm hexagon key (see page 16).
- 6 Retract insertion sensor shaft (F) fully.
- 7 Unlock positioning collar (E), slide down and lock at the distance:
 $\frac{D}{8} + VP + 30 \text{ mm (1.181.in.)} + \text{pipe thickness}$
- 8 Open valve (D) fully with valve lever (G).
- 9 Lower insertion sensor until positioning (E) collar contacts nut (B), with sensor tip at the required depth (H).
- 10 Tighten nut (B) to 40 Nm (30 ft lbf).

*Refer to pipe supplier/manufacturer specification.



**Figure 24 Setting the insertion depth
– mean axial velocity method**

Insertion sensor alignment



WARNING – PRESSURIZED EQUIPMENT

- When inserting or removing the insertion sensor, the safety mechanism (see page 16) must be **fitted and engaged** to prevent the insertion sensor being forced out under pressure. Ensure the valve is fully open.
- Safety restraint omitted for clarity.

Referring to Figure 25:

- 1 Slacken nut (A).
- 2 Align insertion sensor parallel (B) to the pipe (within 2°) – measurement error due to misalignment (of <math><2^{\circ}</math>) is <math><0.15\%</math>.
- 3 Tighten nut (A) to 40 Nm (30 ft lbf).

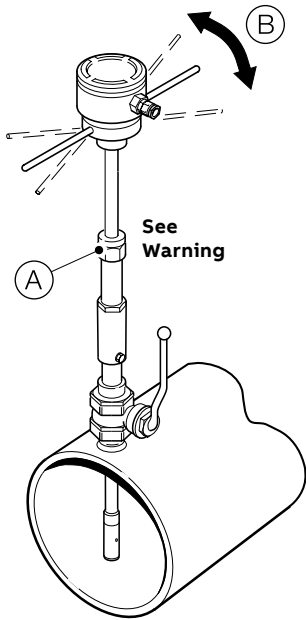


Figure 25 Insertion sensor alignment

6 Commissioning

Safety instruction

**WARNING**

Risk of burns due to hot measuring media.
The insertion sensor surface temperature may exceed 70 °C (158 °F), depending on the measuring medium temperature! Before starting work on the insertion sensor, make sure that it has cooled sufficiently.

If there is a chance that safe operation is no longer possible, take the insertion sensor out of operation and secure it against unintended startup.

Checks prior to commissioning

The following points must be checked before commissioning the insertion sensor:

- The wiring must have been completed as described in the Installation section on page 15.
- The insertion sensor must be grounded correctly.
- The ambient conditions must meet the requirements set out in the technical data.
- The power supply must meet the requirements printed on the identification plate.
- Checking the correct insertion sensor to transmitter assignment (remote flowmeter only – see page 8 for insertion sensor label information).

**IMPORTANT (NOTE)**

The Flow Settings > Mains Noise Rejection Frequency (Hz) setting must match the mains frequency supplied at the point of installation – refer to Operating Instruction OI/FET400-EN.

7 Operation

Refer to Instruction manual OI/FET400-EN for insertion sensor operation.

8 Diagnostics

Refer to Instruction manual OI/FET400-EN for insertion sensor diagnostics.

9 Maintenance



CAUTION – INSERTION SENSOR CARE

- The tip of the insertion sensor is a precision-built part of the equipment and must be handled with care.
- When the insertion sensor is not in use, fully retract the tip of the insertion sensor and replace the end-cap.
- When removing/inserting the insertion sensor into the pipeline, ensure that the valve is fully open.
- Damage to the insertion sensor affects the performance. Physical damage to the insertion sensor invalidates the warranty.

10 Spare parts

Part number	Description
3KXF208400L0100	AM4 battery pack 10 lithium D cells
3KXF208400L0200	AM4 battery pack 50 lithium D cells
3KXF208400L0300	AM4 display protective cover
3KXF208400L0400	AM4 display protective cover NFC 5 m (15 ft. approx) cable
3KXF208400L0500	AM4 display cover NFC 20 m (66 ft. approx) cable
3KXF208400L0600	AM4 rs485 lead MIL connectors Modbus™
3KXF221400L0100	FEW4 sensor cable 5 m (15 ft approx)
3KXF221400L0200	FEW4 sensor cable 10 m (30 ft. approx)
3KXF221400L0300	FEW4 sensor cable 20 m (66 ft. approx)
3KXF221400L0400	FEW4 sensor cable 30 m (98 ft approx)
3KXF221400L0500	FEW4 sensor cable 50 m (164 ft approx)
3KXF221400L0600	FEW4 sensor cable 100 m (300 ft. approx) junction box/MIL
3KXF221400L0700	FEW4 sensor cable 150 m (450 ft. approx) junction box/MIL
3KXF221400L0800	FEW4 sensor cable 500 m (1640 ft. approx)
3KXF221400L0900	FEW4 junction box & cable – M20 to MIL
3KXF208400L0700	AM4 Sensus cable 5 m (15 ft.) approx
3KXF208400L0800	AM4 Sensus cable 20 m (66 ft.) approx
3KXF208400L0900	AM4 renewable energy cable 10 m (30 ft. approx)
3KXF208400L1000	AM4 pulse output cable 1 m (3 ft. approx)
3KXF208400L1300	AM4 pressure transducer 10 bar 10 m (30 ft. approx)
3KXF208400L1400	AM4 pressure transducer 10 bar 20 m (60 ft. approx)
3KXF208400L1500	AM4 pressure transducer 16 bar 1 m (3 ft. approx)
3KXF208400L1700	AM4 pressure transducer 16 bar 10 m (30 ft. approx)
3KXF208400L1800	AM4 pressure transducer 16 bar 20 m (60 ft. approx)
3KXF208400L2100	AM4 pressure transducer 20 bar 10 m (30 ft. approx)
3KXF208400L2200	AM4 pressure transducer 20 bar 20 m (60 ft. approx)
3KXF208400L2500	AM4 pressure transducer 40 bar 10 m (30 ft. approx)
3KXF208400L2600	AM4 pressure transducer 40 bar 20 m (60 ft. approx)
3KXF221400L1100	FEW4 term box potting compound 200 g
3KXF221400L1200	FEW4 ball valve stainless steel 1½ in. BSP
3KXF221400L1300	FEW4 bush stainless steel 1½ in. M x 1" BSP
3KXF221400L1400	FEW4 ball valve stainless steel 1½ in. NPT
3KXF221400L1500	FEW4 bush stainless steel 1½ in. M x 1 in. NPT
3KXF221400L1600	FEW4 Aquaprobe seal replacement kit
3KXF208400L2700	AM4 transmitter seal kit
3KXF208400L2800	AM4 battery connector kit
3KXF221400L1700	FEW4 pre-amp board and potting kit
3KXF208400L2900	Aquamaster 4 – demo kit
3KXF221400L1800	FEW4 terminal box maintenance kit
3KXF208400L3000	AM4 anti-tamper security kit
3KXF208400L3100	AM4 remote transmitter mounting bracket kit
3KXF221400L1900	FEW4 earth strap kit

Table 1 Spare parts

11 Recycling and disposal

Disassembly



WARNING

Risk of injury due to process conditions
The process conditions, e.g. high pressures and temperatures, toxic and aggressive measuring media, can give rise to hazards when dismantling the insertion sensor.

- If necessary, wear suitable personal protective equipment during disassembly.
- Before disassembly, ensure that the process conditions do not pose any safety risks.
- Depressurize and empty the insertion sensor/piping, allow to cool and purge if necessary.

Disposal

This product and its packaging are manufactured from materials that can be recycled by specialist recycling companies.

Note the following points when disposing of the product:

- This product is not subject to WEEE Directive 2012/19/EU or relevant national laws (for example, ElektroG in Germany).
- The product must be surrendered to a specialist recycling company. Do not use municipal garbage collection points.
- According to WEEE Directive 2012/19/EU, only products used in private applications may be disposed of at municipal garbage collection points.
- If it is not possible to dispose of old equipment properly, ABB Service can take receipt of and dispose of returns. Contact your local ABB Sales or Service representatives for a quotation.



IMPORTANT (NOTE)

Products that are marked with this symbol may not be disposed of through municipal garbage collection points.

12 Specification

Mounting

Integral transmitter

On insertion sensor

Remote transmitter

Off insertion sensor

Insertion details

Size range

300 to 1000 mm (12 to 40 in)

Pipe sizes

200 to 8000 mm (8 to 320 in) nominal bore

Pressure limitations

20 bar (295 psi) absolute

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.

Insertion sensor body material

316L stainless steel

Insertion sensor tip material

PEEK

Terminal box material for remote insertion sensors

Polycarbonate

Threaded connection

1 in. BSP

1 in. NPT

1½ in. BSP

Pressure tapping provision

½ in. BSP

Environmental and process conditions

Ingress rating

IP68 (NEMA 6P) to 10 m (33 ft.)

Temperature ranges

Ambient: -20 to 60 °C (-4 to 140 °F)

Process: 0 to 60 °C (32 to 140 °F)

Conductivity

>50 µS/cm

Metrological performance and certifications

Accuracy

±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.)

Maximum flow

The maximum velocity depends upon the actual insertion length. Typical insertion lengths are 0.125 and 0.5 x pipe diameter. Figure 26 is a guide* to the maximum allowable velocity for different insertion lengths.

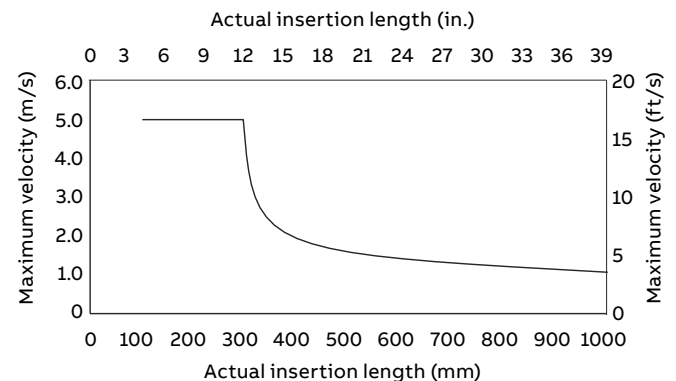


Figure 26 Maximum allowable velocity for different insertion lengths

Potable water approvals for wetted parts

WRAS

* Figure 26 is intended as a guide only. Factors that influence the maximum insertion length into the pipe include: insertion sensor mounting components (for example, standoffs, bushes and valves) pipeline vibration, fluid vibration and pump noise.

13 Appendix

Declarations of conformity



IMPORTANT (NOTE)

All documentation, declarations of conformity, and certificates are available in ABB's download area: www.abb.com/flow.

Torque information



IMPORTANT (NOTE)

The specified torques are valid only for greased threads and piping that is not subject to tensile stress.

Torque values are specific to the flange material types identified.

Insertion sensor length	Maximum tightening torque/Nm (ft lbf)
300 (12 in)	40 (30)
500 (20 in)	40 (30)
700 (28 in)	40 (30)
1000 (40 in)	40 (30)

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 on page 10 is the most practical. It is possible to measure the velocity either on the center line, which reduces sensitivity to positional errors, or at the assumed point of mean flow velocity.

Table 2 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.



IMPORTANT NOTE

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

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

* 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.

Table 2 Straight pipe lengths –insertion sensor

Velocity limitations



IMPORTANT NOTE

See also page 25 for maximum flow values for insertion sensor.

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

Figure 27 shows the maximum permissible velocities, depending on the insertion 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 insertion sensor can be used.

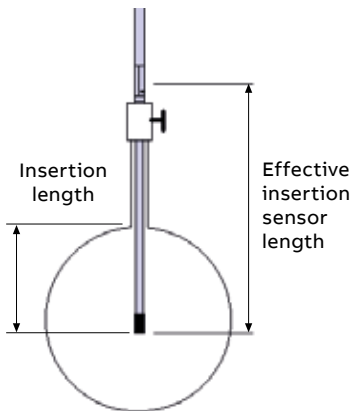


Figure 27 Maximum permissible velocity for different pipe sizes

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 the insertion sensor.

Examples:

- A 600 mm (24 in) pipe with the insertion sensor mounted on the center line has an insertion length of 300 mm (12 in).
- A typical valve is approximately 250 mm (10 in) high and the distance to the support point inside the insertion sensor is approximately 100 mm (4 in) therefore, in this example, the total effective length is 650 mm (26 in).
- Max velocity at 650 mm is 3.6 m/s.

Velocity profiles background

Figure 28 shows 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 center line is 2 m/s and the flow is 487 l/s

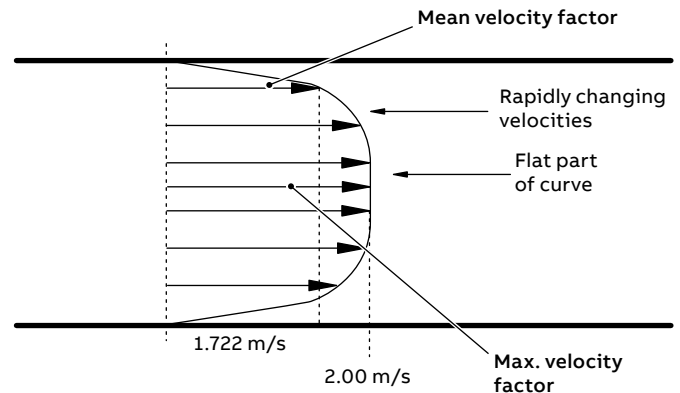


Figure 28 Turbulent flow profile

As the volume flow is known, the mean velocity in the pipe can be calculated – note that it is actually 1.722 m/sec lower than the velocity measured on the center line. Careful investigation of this profile or vector diagram reveals that the mean velocity of 1.722 m/sec occurs at a point 72.5 mm or $\frac{1}{8}$ th 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. $\frac{1}{8}$ th of the diameter in from the edge of the pipe. By placing the insertion sensor at this point a straightforward calculation of volume flow can be performed – but there is more to be considered.

...Appendix

Velocity profiles background

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 insertion sensor extremely accurately in order to measure the correct velocity. If the insertion sensor 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 insertion sensor 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 an insertion sensor exactly, so this sort of error is quite common. With insertion sensors other than this insertion sensor, working under any degree of pressure in the line, inserting an insertion sensor 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 28, in the middle of the pipe, near the center line, 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 center line, measurement errors due to positional errors (i.e. not locating the insertion sensor where required) are very small; hence most users will try to use the center line measuring position. However, as explained previously, this process gives us the wrong answer. Fortunately there is a mathematical relationship between the velocity at the center line and the mean velocity within the pipe – the Profile Factor (F_p).

The value of F_p can be calculated by an equation (below) or obtained from a graph – see Figure 29.

F_p is calculated as follows:

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

where:

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

and:

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

and:

$$R_e = \frac{D_p v}{\mu}$$

key:

D = pipe diameter

ρ = fluid density

v = average fluid velocity

μ = fluid viscosity

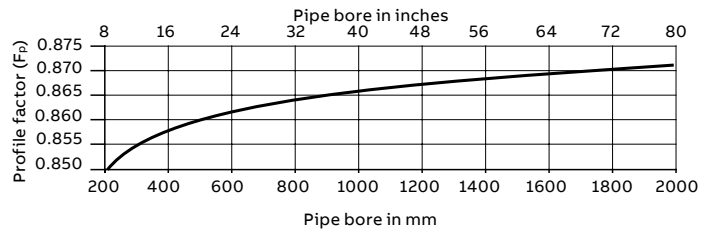


Figure 29 Profile factor vs flow velocity for pipe sizes 200 to 2000 mm (8 to 78 in)

When the insertion sensor insertion position is determined, the effect of putting the insertion sensor into the pipe (see page 27) must be calculated.

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

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

Testing the flow profile for symmetry

If there is any doubt as to the symmetry of the flow profile (see page 10), a Partial Velocity Traverse must be carried out.

This procedure involves comparing the value of velocity at two points at equal distances from the center line.

It is normal to compare the flow velocities at insertion depths of $\frac{1}{8}$ and $\frac{7}{8}$ of the pipe diameter as these points are always on the 'knee' of the profile.

Partial velocity traverse

Determine the internal diameter D of the pipe, in millimeters, by the most accurate method available. If the insertion sensor insertion length is greater than the internal diameter of the pipe, proceed with the Single Entry Point Method. If the insertion sensor's insertion length is less than the internal diameter of the pipe, proceed with the Dual Entry Point Method.

Single entry point method

- 1 Insert the insertion sensor to a depth of $\frac{1}{8}$ the pipe diameter – see "Mean axial velocity method (1/8 Diameter)" on page 13.



IMPORTANT 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 Instruction manual (OI/FET400-EN) and enter an Insertion Factor of value equal to F_i .
- 4 Record the flow velocity reading.
- 5 Insert the insertion sensor to a depth of $\frac{7}{8}$ 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 Instruction manual (OI/FET400-EN) and enter an Insertion Factor of value equal to F_i .
- 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 on page 13 can be used, or
 - if the calculated ratio is not between 0.95 and 1.05, re-site the insertion sensor for optimum accuracy.

Dual entry point method

Refer to page 16 and fit a second mounting boss directly opposite the one already fitted.



IMPORTANT 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 insertion sensor to a depth of $\frac{1}{8}$ the pipe diameter through the original mounting boss.
- 2 Calculate the insertion factor.
- 3 Refer to the Instruction manual (OI/FET400-EN) and enter a Insertion Factor of value equal to F_i .
- 4 Record the flow velocity reading.
- 5 Insert the insertion sensor to a depth of $\frac{1}{8}$ 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 on page 13 can be used or
- if the calculated ratio is not between 0.95 and 1.05, re-site the insertion sensor for optimum accuracy

Full velocity profile

For installations with very poor and asymmetric velocity profiles (for example as rejected, see **Single Entry Point Method, step 9**) a full velocity profile provides an improved accuracy of reading. To facilitate this ABB have developed ScrewDriver software for the PC that calculates F_i and F_p for any measured velocity profile – see IM/SDR section 'ABB Flow Profiling'.

Acknowledgments

- MODBUS is a registered trademark of the Modbus-IDA organization.
- Sensus is a registered trademark of Sensus USA, Inc.

Notes

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