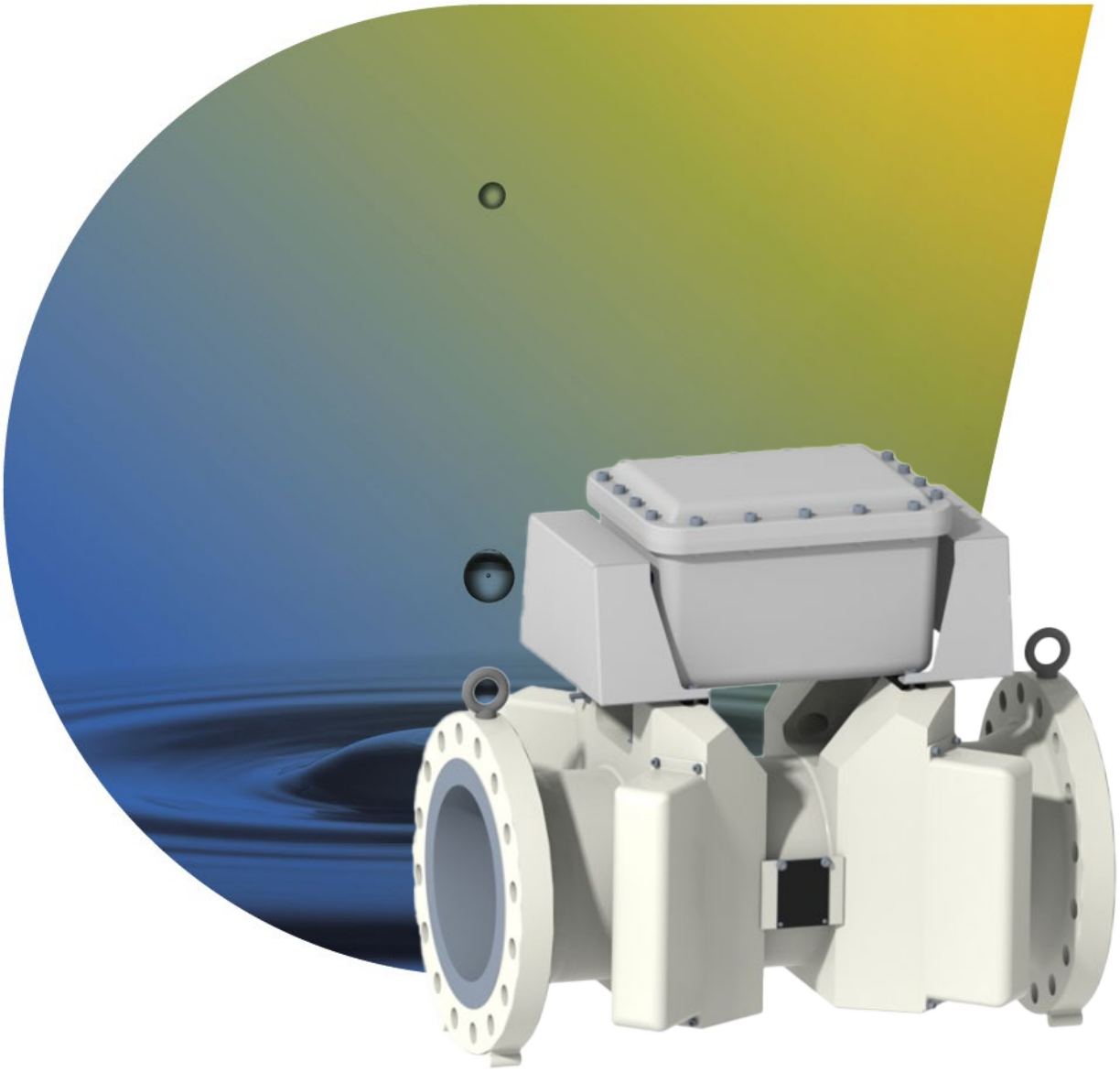
Faure Herman

Counting every drop



FH Sonic

User's manual

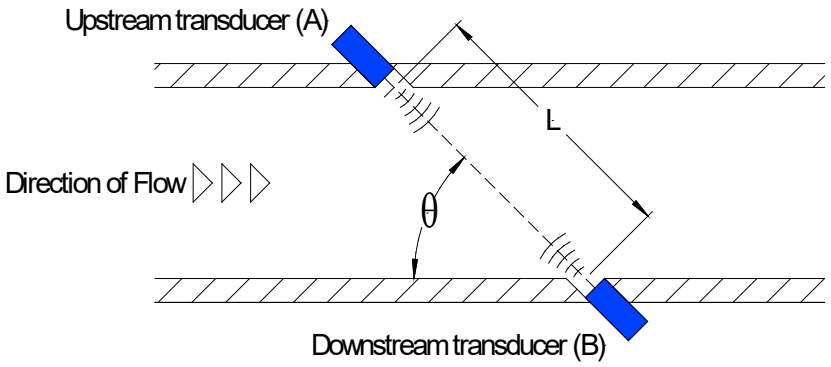
Contents

Chapter 1: general overview

The FH Sonic is a 5-paths Ultrasonic Flowmeter (UFM) developed to meet oil and petrochemical markets needs and requirements. The FH Sonic Ultrasonic flowmeters are suitable for use in hazardous area thanks to explosion proof certification in accordance with the requirements of ATEX/IECEx II 2 G (compatible with installation in zone 1).
By using the most innovative ultrasonic technology the FH Sonic product line successfully covers a wide range of applications and flow conditions including laminar and turbulent flow velocity profiles. The FH Sonic UFM are designed for process applications of liquids, crude or refined hydrocarbons, covering a viscosity range up to 500 cSt.
The integration of all components into a single integrated metering solution allows an especially comfortable installation and commissioning.
The FH Sonic does not generate any pressure drop. Its integrity is preserved even after being disturbed by gas pockets, solid bodies, spheres or scrapers.
Calibrated individually in Faure Herman facilities, the FH Sonic generates accurate measurements. FH Sonic installation and commissioning does not require specialist's intervention.

Measuring principle

The velocity of flow along the path between two paired transducers is determined by the "Transit Time" method based on the expression below:



$$V = \frac{L}{2.\cos\theta}\frac{\Delta T}{T_{AB}.T_{BA}}$$

where $\Delta T = T_{BA} - T_{AB}$

T_{AB}: transit time of the ultrasonic wave from the upstream to the downstream transducer
T_{BA}: transit time of the ultrasonic wave from the downstream to the upstream transducer

Remark: The expression above is independent of the velocity of sound in the product flowing in the pipe.
The velocity of sound is computed by the meter using the following expression:

$$c = \frac{L}{2}\left(\frac{1}{T_{AB}} + \frac{1}{T_{BA}}\right)$$

Size and Flowrate

FAURE HERMAN currently offers standard FH Sonic flowmeter sizes, from 6" (DN150) to 18" (DN450) with certificate in accordance with OIML R117:2019 (see metrological features below).
Other sizes can be studied upon request.
Refer to Appendix I for the dimensions and weight of each of these meters and their metrological features.

Materials of Construction : available in carbon steel and stainless steel (AISI 316 or equivalent), other materials upon request.

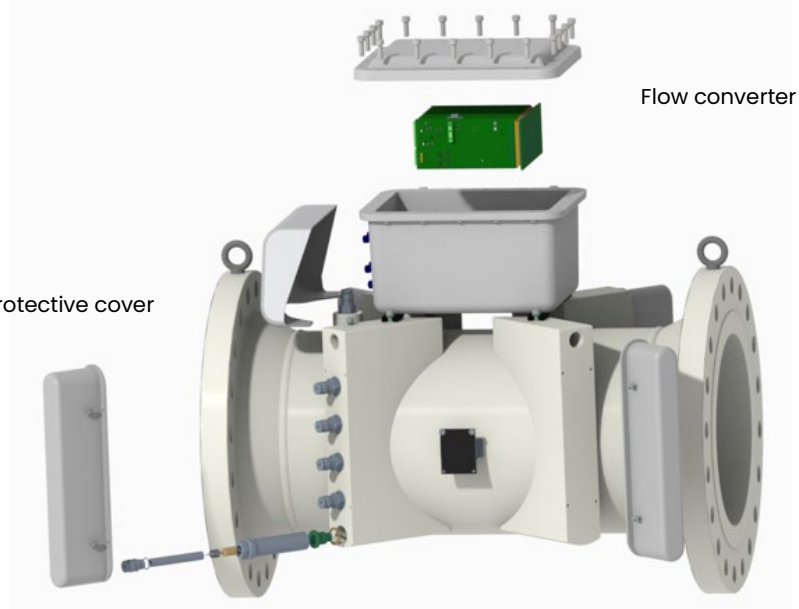
The FH Sonic bodies cover the following sizes and pressure ratings:

- Diameters: DN150 to DN450 (6" to 18") (others upon request)
- Flanges: ANSI #150, 300, 600 or 900

Constitutive parts

The FH Sonic provides a compact and integrated metering solution, consisting of:

- Flanged body in either carbon steel, stainless steel, or other optional materials,
- 11 ultrasonic transducers interchangeable under service conditions,
- Explosion proof flow converter
- Up to 2 PT1000 sensors
- Totalizer (optional)



Under standard conditions, the FH Sonic is delivered with :

- Individual calibration certificate
- User's manual
- ATEX / IECEx certificates upon request.

FH Sonic inputs-outputs

The FH Sonic integrates the following I/O ports:

- 2 x pulses outputs
- 2 x independent and configurable 4-20mA analogue outputs are available for either flowrate, VOS, VOF or volume reading
- 2 x digital outputs
- 1 Ethernet link (Modbus TCP) for remote Web HMI
- 1 x RS485 serial port (Modbus RTU)
- 1 x RS422 serial port

Maximum line pressure

The FH Sonic is designed for a maximum fluid pressure of 150 bar (1,450 psi), equivalent to #900.
The FH Sonic complies with Pressure Equipment Directive 2014/68/EU.

Pressure drop

The FH Sonic is a real full bore flowmeter that generates no more pressure drop than an equivalent length of straight pipe.

Power supply

The FH Sonic must be powered by a Class 2 24Vdc power supply 3A min - Consumption: 42 W.

Protection for hazardous area

The FH Sonic can be used in hazardous areas classified as Zone 1 IIB T6 or T4, according to its ATEX marking II 2 G – II B T4 or T6, based on:

- Protection of ultrasonic transducers by encapsulation:
  - Ex mb IIC T6 Gb / Tamb : -50°C to +70°C
  - Ex mb IIC T4 Gb / Tamb : -50°C to +115°C
- Protection of FLAMEPROOF HOUSING FOR TRANSDUCERS FHP101 & FHP101C:
  - Ex db IIB T6 …. T4 Gb / Tamb : -50°C to +120°C
- Protection of Coffret type EJB:
  - Ex db IIB + H2 T6 Gb / Tamb : -40°C to +60°C

Protection of Class 2 power supply and the instrumentation cables: the protection must be made according to local standards and rules. In particular, the cables must correspond to one of the following standards: IEC 60092-300 series / NEK600, BS 6883 / 7197, NF M 87-202.
Ensure that any personnel that works on the transducer housings or the electronic enclosure is correctly trained and qualified according to EN and IEC 60079-14, and that the local regulations in force will be strictly followed.

Remark: The FH Sonic is delivered with ATEX/IECEx certificates upon request

Other characteristics

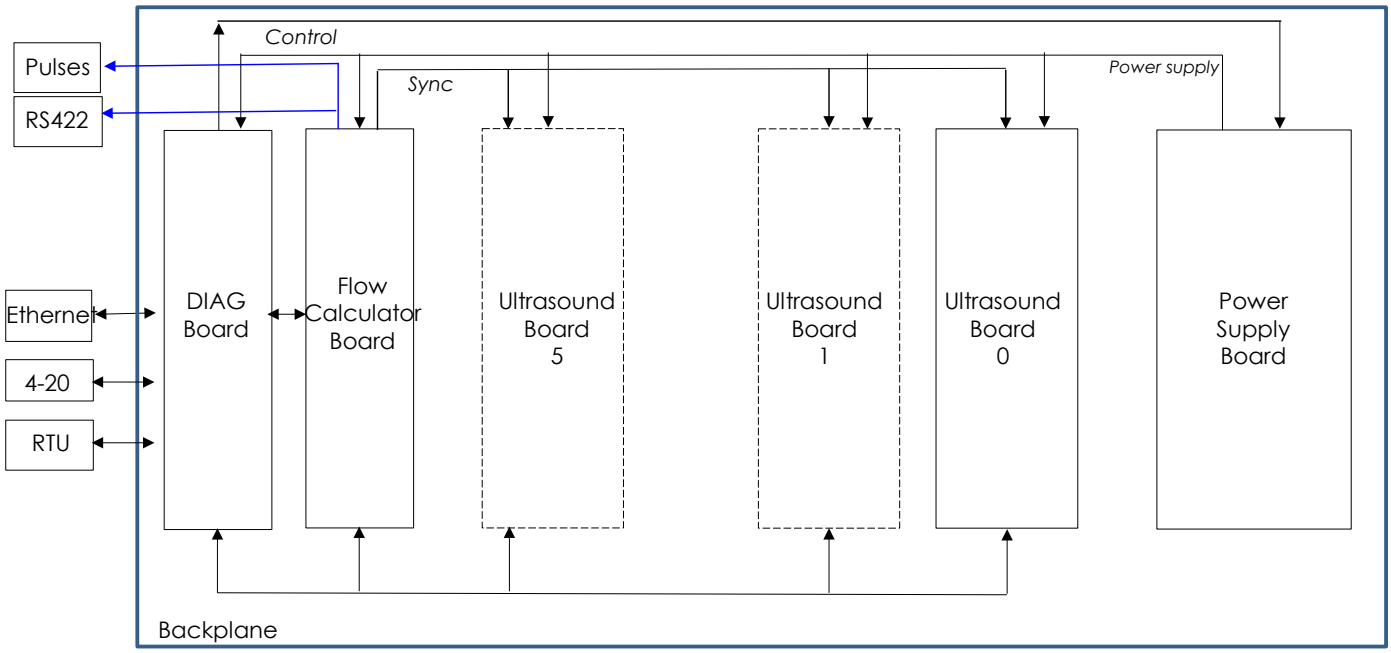
- Repeatability: according to OIML R117-1, API MPMS 4.8, customer specifications
- Ambient temperature: from -40 to +60 °C (-40 to +140 °F)
- For high ambient temperatures, the electronic enclosure must be protected from direct sun rays.
- Fluid temperature: from -50 to +115 °C (-58 to +239 °F)
- Fluid kinematic viscosity: from 0.2 to 500 cSt
- Ingress Protection: IP66
- Available flanges: #150 (ISO PN 20), #300 (ISO PN 50), #600 (ISO PN 100), #900 (ISO PN 150)

- Back-up battery allowing data and parameter storage for up to 10 years
- Material used for the meter body: stainless steel or carbon steel (other materials may be available upon request)
- Material used for electronic enclosure: Copper-free cast aluminum (stainless steel may be available upon request)

Chapter 2: product overview

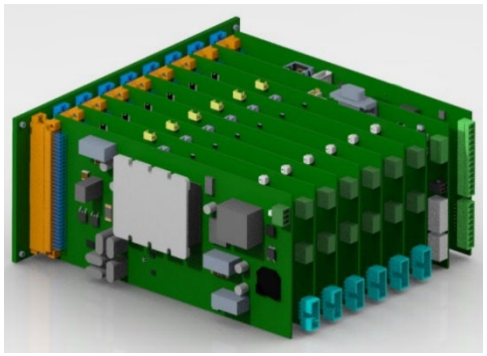
Electronics architecture

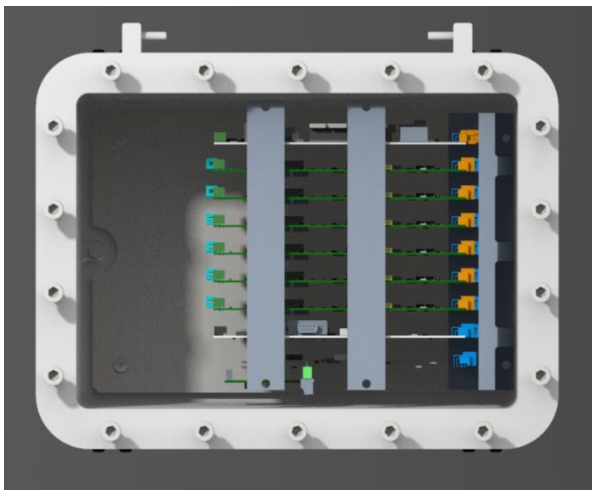
The FH Sonic Electronics architecture is the following :



The FH Sonic electronics are based on :

- 5 Ultrasound boards, number 1 to 5, each driving a chord composed of a transducer pair
- 1 Ultrasound board, number 0, driving the vertical diagnostic transducer
- 1 Power supply board
- 1 Flow Calculator board
- 1 Diag board
- 1 Backplane





Chapter 3: commissioning

Reception and storage

⚠ Check the general appearance of the packaging and FH Sonic in order to identify possible damages inflicted during transportation.

⚠ Remove the equipment from its packaging, check its general condition and verify the presence of this manual and the calibration certificate.

- Before installing the equipment, it is recommended to keep it in its original packaging.
- Protection covers equipped on flanges of the FH Sonic must be removed only for its installation on the pipe.
- Store the FH Sonic in a dry and clean place. The storage temperature should be maintained between -50 and +80 °C (-58 and +176 °F)
- In case of extended storage (typically more than one year), it is recommended to re-calibrate the meter prior to the installation.

⚠ If the equipment is damaged and/or the documentation is not complete, contact the Support Department immediately by email :

Email: services@faureherman.com

FH Sonic handling

Like any measurement device, the FH Sonic must be handled with great care.
The handling must be done as follows:

- With lifting rings fitted on the FH Sonic
- With straps on both sides of the flowmeter body when there are no lifting rings

FH Sonic position on metering line

The FH Sonic can be installed horizontally, or vertically if the flow is upward.

In all cases, the primary direction of flow shown on the nameplate must be observed.

FAURE HERMAN recommends an upstream flow conditioner followed by a minimum straight length of 10D (10 times the pipe diameter) depending on upstream flow disturbances. The downstream recommended minimum straight length is 5D.
20D upstream straight section is also acceptable upon FH operating conditions analysis.

Please, contact FAURE HERMAN to determine the most suitable flow conditioner for your application.

Preparation for installation

Before integrating the meter into the measuring line, check the following points:

- No significant deposits or pollution in the upstream pipe section.
- Respect of primary flow direction (plate).
- Matching of flange dimensions and joint faces, between upstream/downstream piping and equipment.
- Matching of internal diameter of upstream pipe with internal diameter of meter body
- Alignment of the meter with upstream/downstream pipes and absence of obstacles to the flow
- Orientation of electrical I/O.

Like all measuring instruments, the FH Sonic must be handled with care

Properties of the measured fluid

The reliability of measurements can be seriously impacted by the presence of gas and/or solid particles in the measured liquid.
The presence of gas, in the form of bubbles, emulsion or pocket can results in a significant degradation of performance. It is therefore recommended to ensure that there is no risk of gas injection/generation upstream of the measurement and to install a purge or degassing system upstream of the meter if necessary. For an installation in elevation, it is strongly recommended not to position the meter in a "high" area where a gas pocket could form due to gravity and/or volume contraction during a stop.

Installing the FH Sonic

- Check that meter and pipe are correctly aligned.
- Before installing the meter on the pipe, carefully check the cleanliness of flanges in order to obtain an absolute tightness between meter and pipes.
- Check that the meter positioning does not cause any traction effort on flanges and cables.

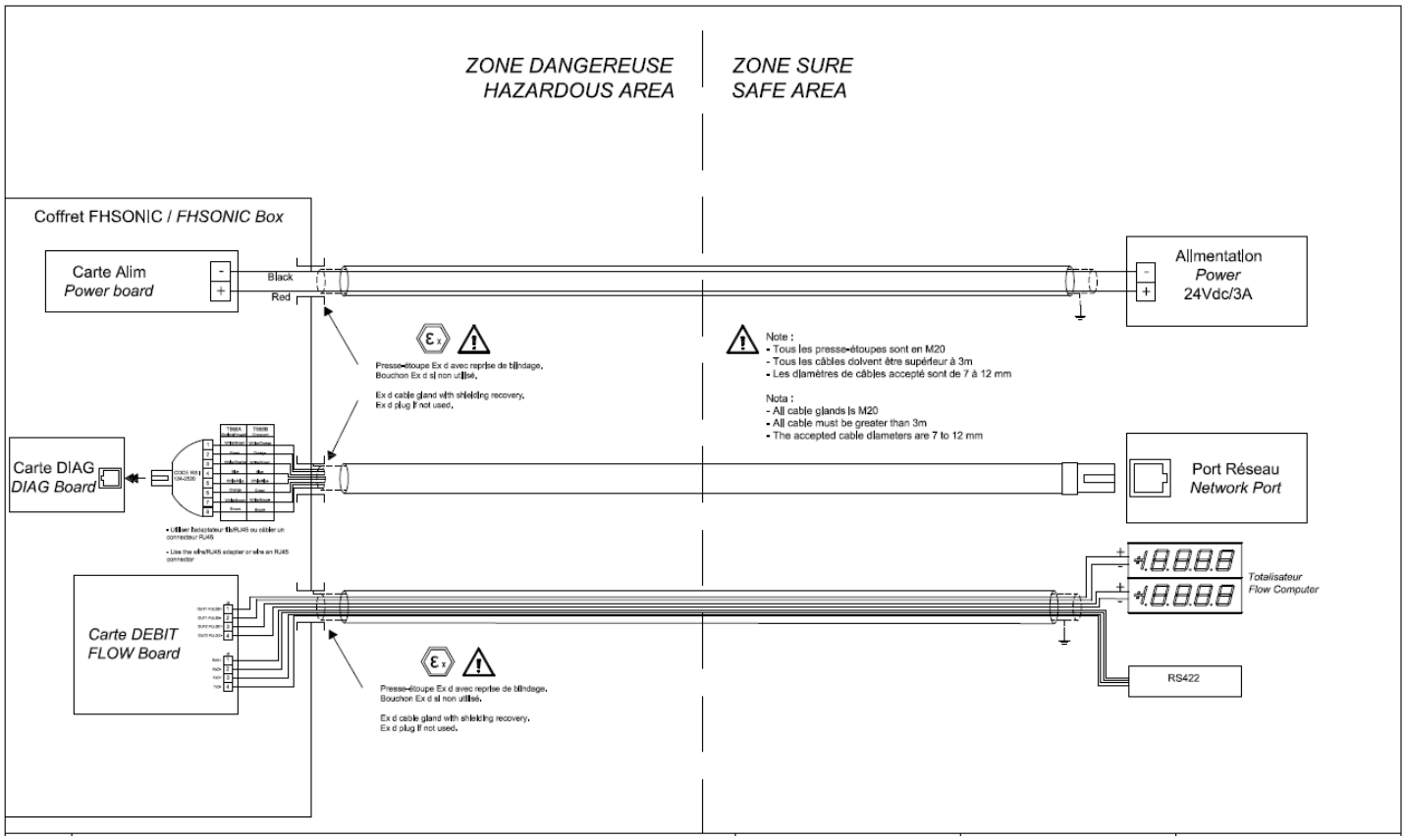
Cabling the FH Sonic

Please follow the instructions in the following chapter

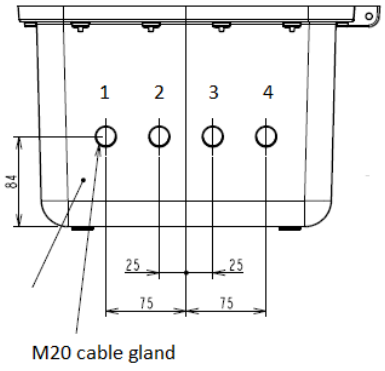
Please refer to the EJB enclosure instruction manual for all openings and closures.

Chapter 4: FH Sonic installation

Customer wiring scheme



The Customer cables exit through M20 cable gland as in the drawing below on the flow converter enclosure



M20 cable gland

1. Cable gland for 24Vdc power supply cable
2. Cable gland for multi-pair cable :
   - 2 digital outputs
   - 2 4-20mA or HART outputs
   - 1 RS485 serial link for Modbus RTU
3. Cable gland for Ethernet link
4. Cable gland for Pulse outputs and RS422 link

Connecting the Power supply cable

24Vdc power supply : 2 wires to be connected to Customer power supply

Connecting the multi-pair cable

Digital outputs : 2 pairs of wires to be connected to Customer equipment
4-20mA outputs : 2x2 or 2x3 wires to be connected to Customer equipment
Modbus RTU (RS485) : 3 wires to be connected to Customer equipment

Connecting the Ethernet cable

Ethernet/Modbus TCP : RJ45 connector to be connected to Customer router or switch

Connecting the Pulse outputs

Pulse outputs : 2 pairs of pulse outputs to be connected to Customer flow computer
RS422 : 4-wires to be connected to Customer equipment for Metrological Data reading

Earthing the meter to the pipe

As the meter's electronics are floating-potential designed, the meter can be connected to the pipe without risk of damage in case of pipe with cathodic protection.

Setting the FH Sonic's parameters

The FH Sonic parameter setting is described in the next chapter.

On site Commissioning

Ensure that measurement is not altered by gas pockets, bubbles or suspended particles. (Gas pockets, bubbles and suspended particles impede the propagation of ultrasonic waves. If present in excessive quantities, they may compromise the validity of the measurement.

Chapter 5: configuration of the FH Sonic

The parameter setting of the FH Sonic is performed with a PC connected by Ethernet to the meter and the use of the *Putty* application as a serial console.

Meter data checking

Display the configuration of the flowrate calculation :

- *"aff g m"*

Zeroing

To do a zeroing procedure, there is 3 steps :

- Zeroing measurement
- Modify zeroing settings
- Zeroing verification

Zeroing measurement

A command on the diag board, will record the deltaT average on the chosen period:

- *"config g 0 xx"* with xx as the chosen period in second
- After the period, the command *"config g 0 0"* will display the recorded deltaT average.

The user can then choose to continue using the current zeroing setting if the deltaT average is sufficient or chose to modify the zeroing setting

Modify zeroing setting

A command set on the diag board will allow zeroing setting modifications.
First step, modify zeroing setting in the diag board configuration:

- *"config c n 0 xxxx"* with "n" as chord number and "xxxx" as new zeroing value in pico-second.

When all needed zeroing setting have been modified, a command will transfer this new zeroing setting on Flow Calc board to a new record in the zeroing history:

- *"config u f"*

Verify zeroing setting

Display the parameters of the chords, including L et Daxe, thresholds, gains, zeros, synchro (delay of firing) :

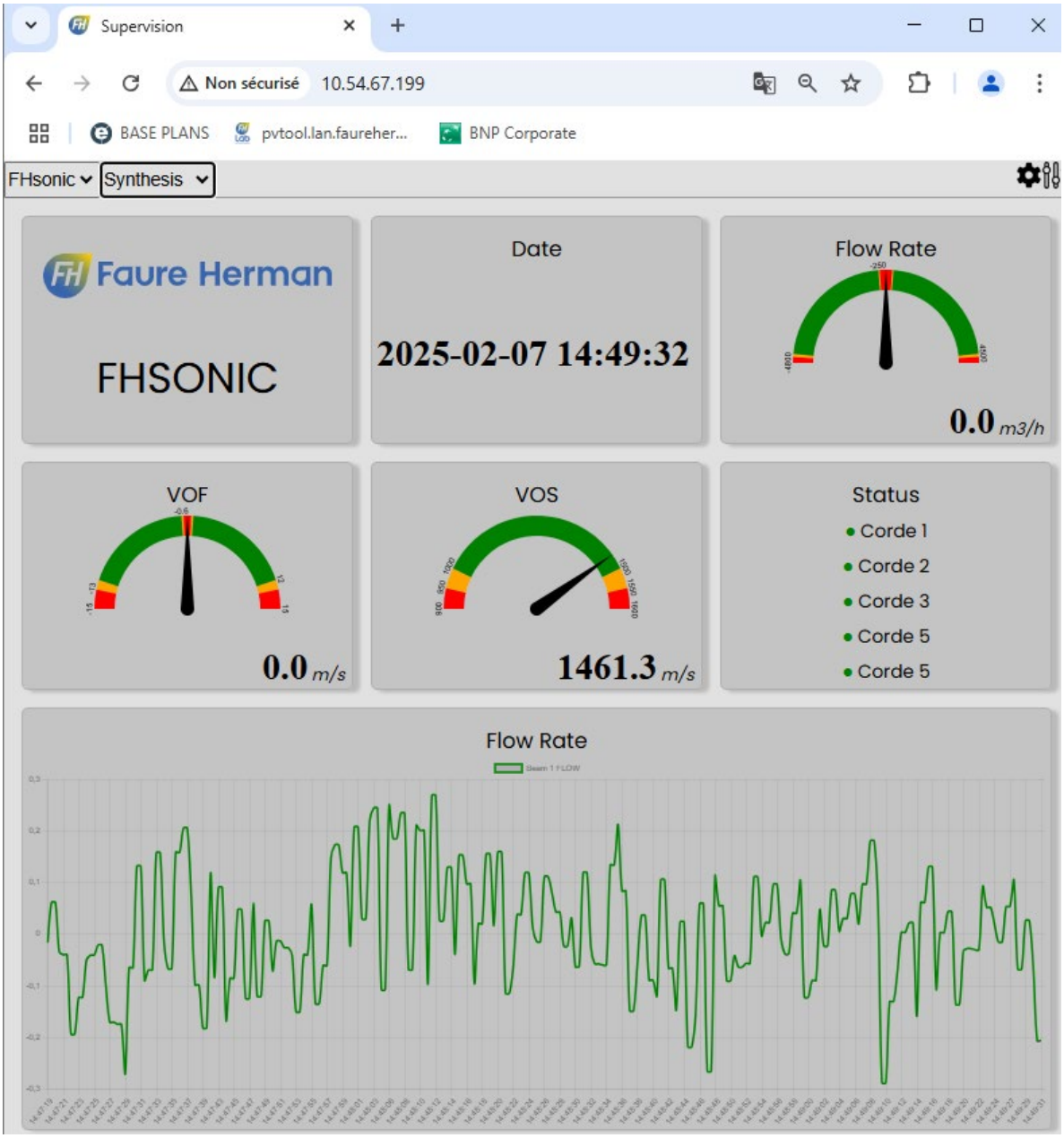
- *"aff q p"*

Chapter 6: FH Sonic HMI

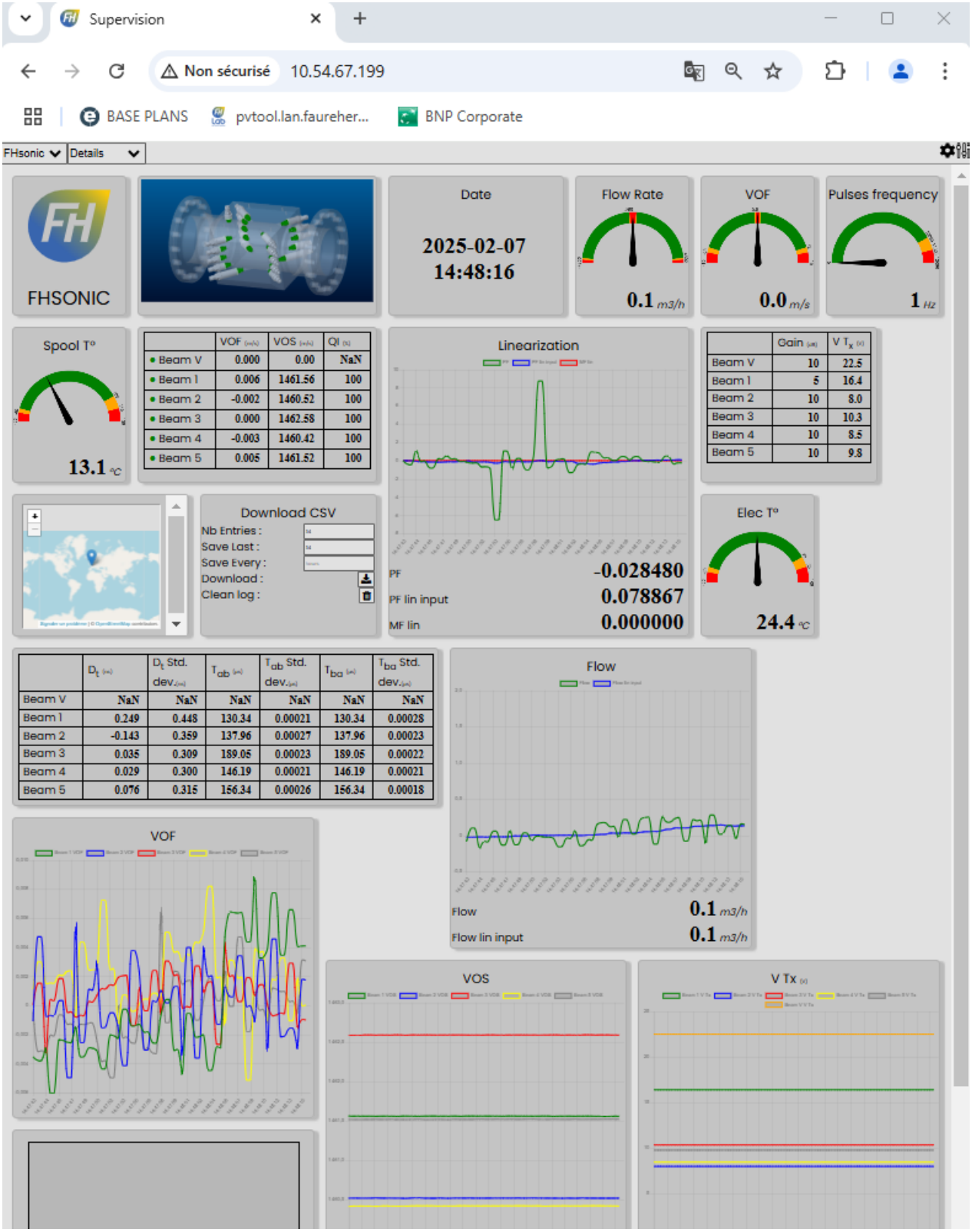
FH Sonic HMI is a Web HMI developed on Javascript.
It displays different data and signal visualizations from the meter.
They are grouped into several pages, 'Synthesis', 'Details', 'Diag' and 'US signal' which are only available depending on the user's access right.

This HMI is generated through the Diag board.
The address to enter on the user's web browser (Chrome, Edge and Firefox are accepted) is the IP address of the Diag Board.
The layout of each page is configurable

Page 'Synthesis' example



Page 'Details' example



	VOF	VOS	QI
Beam V	0.000	0.00	NaN
Beam 1	0.006	1461.56	100
Beam 2	-0.002	1460.52	100
Beam 3	0.000	1462.58	100
Beam 4	-0.003	1460.42	100
Beam 5	0.005	1461.52	100

	Gain	V Tx
Beam V	10	22.5
Beam 1	5	16.4
Beam 2	10	8.0
Beam 3	10	10.3
Beam 4	10	8.5
Beam 5	10	9.8

	D_t	D_t Std. dev.	T_{ab}	T_{ab} Std. dev.	T_{ba}	T_{ba} Std. dev.
Beam V	NaN	NaN	NaN	NaN	NaN	NaN
Beam 1	0.249	0.448	130.34	0.00021	130.34	0.00028
Beam 2	-0.143	0.359	137.96	0.00027	137.96	0.00023
Beam 3	0.035	0.309	189.05	0.00023	189.05	0.00022
Beam 4	0.029	0.300	146.19	0.00021	146.19	0.00021
Beam 5	0.076	0.315	156.34	0.00026	156.34	0.00018

Chapter 7:
spare parts and Maintenance

The FH Sonic is a maintenance-free instrument, mainly because it does not have any moving parts. However, users may occasionally need to replace transducers, gaskets or electronics.
Warning: The replacement of any parts requires turning OFF the power supply. Once power supply is off, wait at least one minute before opening the converter's enclosure.

Spare parts

To reduce the downtime period due to either transducer, gasket or electronics failures, Faure Herman recommends the following spare parts:

- US transducer pairs — Article code : SI1760TXP0-X0_CM (x2)
- PT1000 transducer — Article code : U11081
- Complete electronics set — Article code : 510141
- Gaskets

Important: The replacement of the electronics must be done by a FAURE HERMAN technician or trained by FAURE HERMAN personnel with qualification following IEC and EN 60079-14.

Removing and replacing the transducers or gasket

In case of failed chord, identify the missing ultrasonic path and the failed transducer(s) by checking Web HMI page. One path corresponds to two transducers.
The replacement can be done on load

- To determine the failed transducer, measure its capacitance on the connector at the end of its cable.
- The value must be between 500 and 700pF for each transducer.

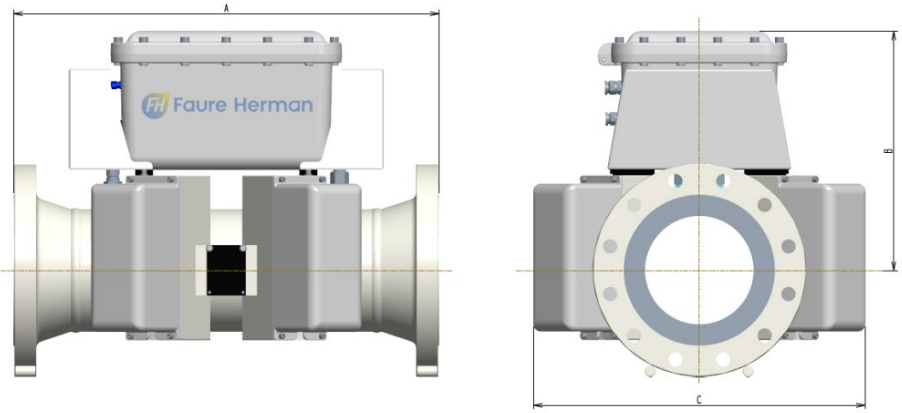
Refer to FAURE HERMAN FH Sonic US Transducers and PT1000 sensor replacement manual **TEC 23.07.07**.

Performing a zeroing procedure

- If possible, reduce the flow as soon as possible while maintaining the pipe at the operating pressure or at least 4 bars.
- Close the nearest upstream and downstream valves if possible. The pressure shall remain at the previously established value.
- Allow a few minutes (depending on the installation and the diameter of the pipe) for flow disturbances to stabilize.
- Perform the zeroing operation by using a PC connected to the meter through Ethernet link or RS422 link.

Appendix I: dimensions, weight and metrological features vs meter size

Dimensions and weight



Meter size		A #150-#300		A #600 - #900		B		C		Approx. Weight	
"	mm	"	mm	"	mm	"	mm	"	mm	lbs	kg
6	150	26	660								
8	200	30	762			16.8	428	23.4	594	661	300
10	250	32	812								
12	300	35	889			18.3	466	23.4	596	838	380
14	350	37	940								
16	400	40	1016			19.8	505	26.5	675	1212	550
18	450	43	1092								

Metrological features

Meter size		Qmin (V = 0.5 m/s)		Qmax (V = 12 m/s)		Minimum Measured Quantity	Minimum Reynolds Number	Typical Kfactor	
"	mm	m^3/h	BPH	m^3/h	BPH	m^3		p/m^3	p/Bbl
6	150	33	208	804	5,063	2	5000	30000	4,7770
8	200	53	333	1 394	8,768	2	5000	25000	3,975
10	250	92	579	2 198	13,825	5	5000	16000	2,544
12	300	130	818	3 120	19,624	5	5000	10000	1,590
14	350	157	987	3770	23,712	5	6000	9000	1,431
16	400	205	1,289	4925	30,977	5	6000	7500	1,192
18	450	258	1,623	6235	39,217	5	6000	5500	874

For process application, higher Qmax could be performed upon request.

Appendix II: operating restrictions & recommendations

Nominal operating conditions of the equipment are specified on its nameplate.
This domain is mainly defined in terms of:

- Minimum/Maximum – Flowrate
- Maximum – Pressure
- Minimum/Maximum – Temperature

Flowrate restrictions specify the equipment's optimal performance range (measurement accuracy and repeatability).
Pressure and temperature restrictions involve the equipment's mechanical dimensions and define the authorized operating range.

Remark: When operating temperature is higher than the indicated value, the maximum authorized pressure shall be reduced, in strict application of the ASME B31.3 or NF EN 1759-1 Standard

Gasket

Be sure to use gaskets that are suitable for flange types and comply with ASME B16.20 and ASME B16.21 or NF EN 1514 and NF EN 12560.

⚠ **Never reuse used seals.**

Flange bolting

The material of flange bolting shall be chosen in ASTM A 193 B7 (rods) and ASTM A 194 2H (nuts) according to EN ISO 898-1 standard for temperature between -45°C and +480°C.

Tightening torque

Size & Torque values Uncoated bolts				Size & Torque values Coated bolts			
M	N.m	NPS	ft-lb	M	N.m	NPS	ft-lb
14	110	1/2	60	14	85	1/2	45
16	160	5/8	120	16	130	5/8	90
20	350	3/4	210	20	250	3/4	160
24	550	7/8	350	24	450	7/8	250
27	800	1	500	27	650	1	400
30	1,150	1 1/8	750	30	900	1 1/8	550
33	1,550	1 ¼	1,050	33	1,200	1 ¼	800
36	2,040	1 ⅜	1,400	36	1,600	1 ⅜	1,050
39	2,650	1 ½	1,800	39	2,050	1 ½	1,400
42	3,350	1 ⅝	2,350	42	2,550	1 ⅝	1,800

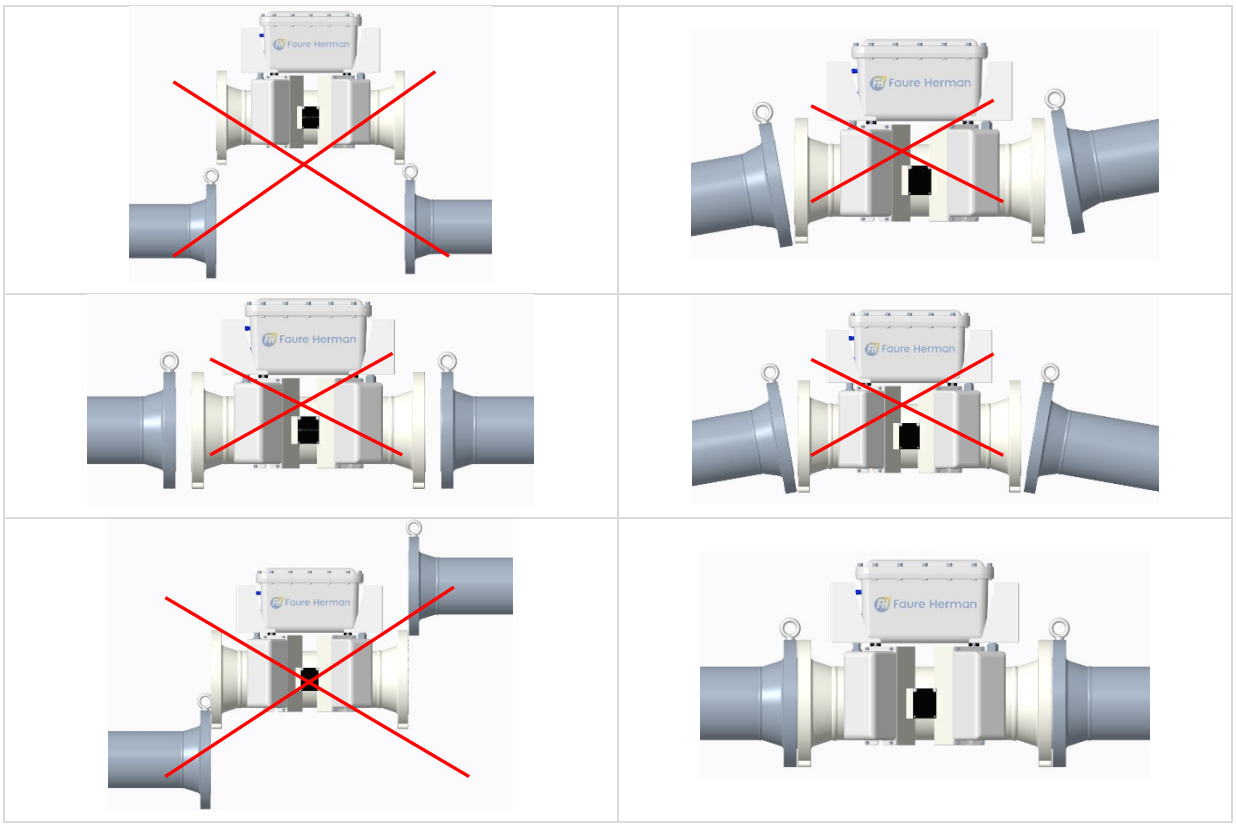
Recommended tightening torque for Klingersil gasket type

When the meter is associated with one or more upstream and/or downstream pipes on delivery (e.g. spool piece integrating a flow conditioner), the tightening of the relevant bolts must be checked before commissioning.
A label is fixed to the flanges at the factory before delivery.

Equipment installation

Before installation, keep the equipment in its original packaging, sheltered from bad weather and possible impacts.
The mechanical installation of the equipment on the measurement line shall not generate excessive stresses. Specifically, the alignment of upstream and downstream flanges shall avoid the transmission of stresses on the equipment body.
The equipment shall be installed by means of the suitable tools.

- Never use a hammer or impact wrench.
- No equipment element is designed to contribute to the tightening of connecting rods.
- Specific tools shall be used, when necessary, for the spacing between upstream and downstream flanges.



Removal from measurement line

The equipment is designed to operate under pressure and must be depressurized and drained before being removed from the measurement line.

Important: Ensure that the line is completely depressurized before loosening the connecting bolts, and that the liquid will be completely collected in a retention tank (or equivalent).

Flow Conditioning

The performance of ultrasonic flowmeters can be affected by fluid stream rotation and asymmetry in the upstream flow profile. These factors are often caused by the pipe configuration (e.g., elbows, diameter reductions, etc.) and upstream accessories such as valves, filters, and pumps. Flow conditioning devices must be installed upstream of the meters to reduce the effect of these disturbances (API MPMS 5.8, ISO 12242).

FAURE HERMAN can integrate these devices with its meters as long with upstream and downstream piping, to ensure compliance with applicable standards recommending straight upstream and downstream lengths (respectively 10 x DN and 5 x DN).

It is strongly recommended to calibrate meters equipped with these straight lengths with or without a flow conditioning device.

Appendix III: safety Information

Important information to read before installation

This manual contains important safety instructions. It is essential that you read and understand the operations to be performed before installing, connecting and commissioning the equipment.
Failure to follow these instructions and warnings may result in damage to the equipment and/or danger to operating personnel.

Personnel requirements

Ensure that operators and maintenance personnel have all safety equipment applicable to the area of operation (safety glasses, hearing protection, safety shoes, etc.) and are trained for the activities involved.
Unauthorized personnel must not have access to installation and/or maintenance operations on the equipment.

Risks resulting from failure to follow instructions and warnings

Failure to follow these instructions and warnings may:

- Expose personnel to mechanical, electrical and/or chemical hazards
- Damage the equipment (meter)
- Pollute the environment by releasing harmful or polluting substances

Safety instructions

Power supply must be disconnected and possibly meter depressurized before any work is performed to avoid electrical and pressure-related hazards.
The safety instructions in this manual as well as all safety regulations and recommendations in force in the country of installation must be observed.

Operating conditions

Operating range indicated on the meter's nameplate must be strictly observed. The reliability and performance of the equipment are only guaranteed if it is installed and operated as specified in this manual.
Installation, operation and maintenance of the equipment must be carried out using the appropriate tools. Never use hammers or tools that may generate sparks or damage the electrical protection of the equipment (enclosure, cable glands, conduit, etc.). If impact wrenches are used, make sure to respect the torque values specified in this manual.
Installation, service and maintenance of the equipment must be performed by qualified personnel.
All spare parts must be approved by FAURE HERMAN.

For any further information concerning the installation, use or maintenance of the equipment, please contact the Support Service by mail to : sales@faureherman.com

Repair and maintenance

Repairs and modifications to the equipment are only possible after formal agreement from FAURE HERMAN. The use of spare parts not recognized by FAURE HERMAN releases FAURE HERMAN from its responsibility for all consequences linked to this original modification.

Return

Contact FAURE HERMAN before returning the equipment to the factory.
If the meter has been used to measure dangerous, toxic or corrosive liquids, the operator must make sure that it has been properly rinsed and decontaminated before being returned to the factory.

Appendix IV:
ATEX & IECEx Installation

This equipment is ATEX (Directive 2014/34/EU) certified and IECEx complies with the essential health and safety requirements for the design and construction of equipment intended for use in potentially explosive atmospheres.
Ensure that the equipment is used in full compliance with the instructions given in the certificates and the nameplate.
This equipment incorporates ATEX / IECEx certified components relating to the design and construction of equipment for use in potentially explosive atmospheres (Directive 2014/34/EU).

General safety information

The equipment must remain de-energized during the installation and maintenance phases.
For safe operation, the equipment must be used in accordance with the criteria defined by the ATEX / IECEx certificate and nameplate. Be sure to observe all instructions concerning the equipment and components contained in this manual.
The equipment must be installed and used only in areas that comply with its protection rating as specified on the rating plate.
If the equipment is connected to other electrical systems, check that the electrical protection systems are fully compatible.

Risk Analysis (Directive 2014/68/EU)

Suitable Resistance	Requirement
Excessive temperature and pressure.	Consideration of temperature and pressure limits by design. Limitations are indicated on the equipment plate. It is the user's responsibility to install suitable devices to limit pressure and temperature.
Influence of wind/snow.	No influence given the small surfaces.
Earthquakes	The equipment is not intended for be use in seismic zones. If this is not the case, it is the user's responsibility to provide the appropriate protection devices.
Reaction of the supports, fixings and piping.	The equipment is intended to be connected to other piping and does not have any specific supports.
Thermal fatigue.	Design according to ASME B31.3. Material selection.
Mechanical fatigue.	Measuring instrument. It is the user's responsibility to provide a stress-free installation.
Vibrations.	Measuring instrument. It is the user's responsibility to provide an isolated installation far from sources of vibration.

Handling and Operations	Comments
Closing and opening.	The equipment does not have an opening or closing mechanism.
Hazardous emissions from valves.	The equipment does not have a valve.
Access to the interior.	The equipment has no access (manhole cover ...).
Surface temperature.	It is the user's responsibility to report hot surfaces.
Decomposition of unstable fluid.	The equipment is used during fluid transfer, not for storage.
Handling.	Equipment with a mass of more than 30 kg is equipped with lifting rings for safe handling.
Purge and Venting	**Comments**
Water hammer	Measuring instrument. It is the user's responsibility to install devices to prevent water hammer.
Collapse under the effect of the vacuum.	Minimum operating pressure greater than 1 bar.g indicated on the plate. The equipment is not designed to operate under vacuum.
Corrosion and Chemical attack	**Comments**
Uniformly generalized	Consideration of a corrosion allowance. Choice of materials and application of paints adapted to the environment. It is the user's responsibility to periodically check the condition of his installation.
Selective.	Choice of materials.
Galvanic.	Choice and compatibility of materials. It is up to the user to put in place the appropriate devices (grounding braid, cathodic protection ...).
By differential ventilation.	Choice of materials. Keeping equipment full of liquid.
Cavernous by inter granular puncture.	Choice of materials. Compliance with NACE MR0175 requirements if applicable.
Ammonia.	Choice of materials.
Under stress.	Choice of materials. Compliance with NACE MR0175 requirements if applicable.
Wear	**Comments**
Corrosion erosion.	Choice of materials. Application of a corrosion allowance. Application of paints adapted to the environment.
Corrosion cavitation.	Choice of materials. Measuring instrument. It is the user's responsibility to install devices to avoid cavitation.
Abrasion	Choice of materials. Application of a corrosion allowance. It is the user's responsibility to periodically check the condition of the equipment.

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