CALDON ULTRASONICS

LEFM 3xxCi Family of Gas Ultrasonic Flowmeters with G3 Transmitter

User Manual & Safety Manual

Manual No. IB1406 Rev. 15

Manual No. IB1406, Rev. 15
August 2021

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Important Safety Information

Terms Used in this Manual

WARNING

This symbol identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss.

CAUTION

This symbol indicates actions or procedures which if not performed correctly may lead to personal injury or incorrect function of the instrument or connected equipment.

Note – Indicates actions or procedures which may affect instrument operation or may lead to an instrument response which is not planned.

Personal Safety

CAUTION

OPERATORS SHOULD NOT REQUIRE ACCESS TO THE INTERIOR OF THE FLOWMETER. ONLY QUALIFIED PERSONNEL SHOULD SERVICE THE LEFM 380Ci. DO NOT ATTEMPT TO DISASSEMBLE THE INSTRUMENT OR OTHERWISE SERVICE THE INSTRUMENT UNLESS YOU ARE A TRAINED MAINTENANCE TECHNICIAN.

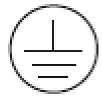
If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment's safety features may be impaired. Sensia is not responsible for damages or injuries sustained as a result of inappropriate use.

Before performing system verification and repair procedures, contact the Measurement division, Sensia.

For additional information or assistance on the application, operation or servicing, call the Sensia office nearest you or visit www.SensiaGlobal.com.

Symbols Marked on Equipment

 Attention! Refer to manual

 Protective (earth) ground

Section 1

Introduction

Equipment Description

The Caldon© LEFM 3xxCi[1] ultrasonic flowmeter is a highly sophisticated bidirectional flow measurement system that employs ultrasonic transit time to measure fluid velocity and volumetric flow rate. Its advanced signal and data processing circuitry help ensure high accuracy and repeatability. The LEFM 3xxCi can be configured to indicate direction of flow via either a quadrature pulse output or a digital signal. It can also be configured to output positive flow pulses on one channel and negative flow pulses on the other.

The LEFM 3xxCi also contains an automatic fault detection system for verifying performance and alerting personnel when abnormal operating conditions are detected. For ease of troubleshooting, the LEFM 3xxCi provides easy-to-interpret diagnostic information via Modbus communications and the local display.

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This manual provides detailed instructions on the installation and operation of the flowmeter to include the viewing of flow parameters and interpretation of diagnostic data viewed via the transmitter's display. Users who require a more detailed view of diagnostic acoustic data can access the data via Sensia's LEFMLink software. The operation of this software is outside the scope of this manual. See the LEFMLink User Manual for details.

The LEFM 3xxCi flowmeter has two basic components or subsystems:

- A meter body, including up to eight pairs of transducers forming acoustic paths and a temperature sensor
- A transmitter(s) containing a readout display and acoustic data processing electronics

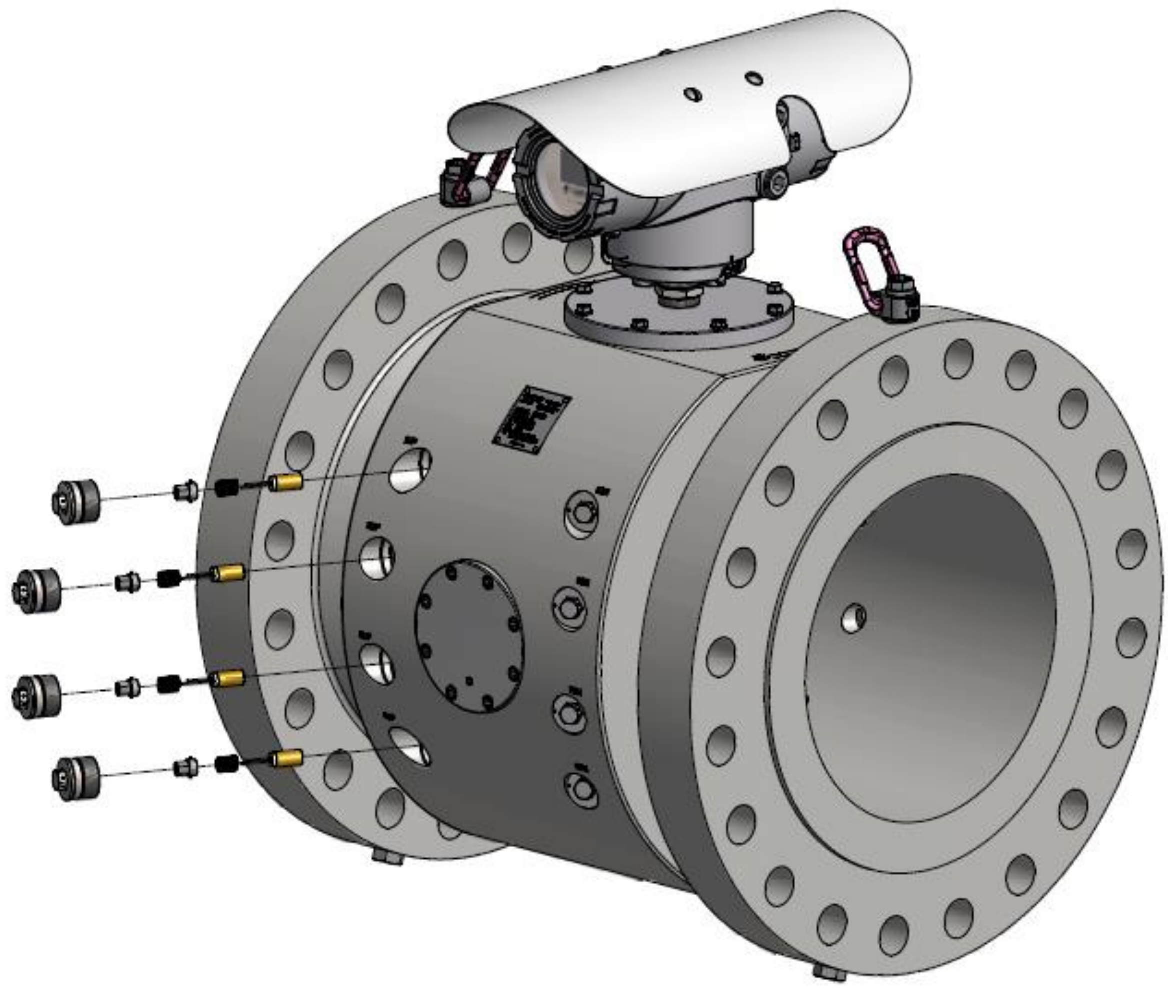
The meter design typically mounts the transmitter to the meter body at the factory and the assembly is shipped as one instrument, ready for installation. Remote-mount units are available, particularly when there are extreme temperatures at the meter itself. This manual covers three different configurations. These are described as follows:

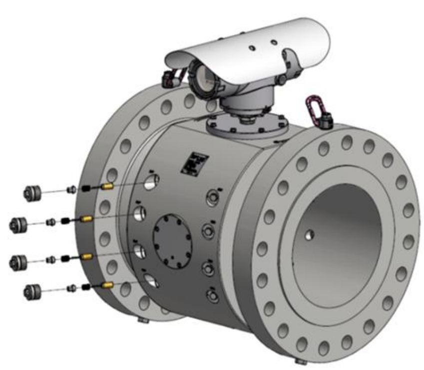
[1] The term 3xxCi encompasses all versions of the gas ultrasonic flowmeters. Specifically, the 340Ci (4-path), and the 380Ci (8-path) models are covered. Further, different meter body configurations are covered.

Model 34xCi: Transmitter mounted to the meter body. This model has a factory installed seal between the transmitter and the meter body.

Model 380Ci: Transmitter mounted to the meter body. This model has a factory installed seal between the transmitter and the meter body. Refer to Figure 1.1 below for a depiction of the meter body and transmitter assembly.

Model 3xxCi-R/RB: Transmitter mounted remotely from the meter body. This model has a factory installed seal between the transmitter and a junction box for terminating cables from the meter body. The 3xxCi-R/RB model requires that the transmitter be mounted separately from the meter body. In those instances, the transmitter(s) and meter body are shipped separately.





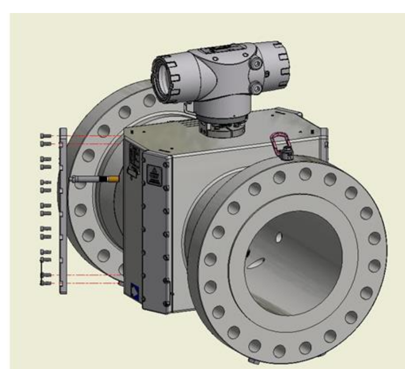


Figure 1.1 LEFM 380Ci Meter Body and Transmitter Assembly, NextGen (left) shown with optional sunshield and Legacy (right)

LEFM 3xxCi Meter Body

The meter body contains up to eight pairs of acoustic transducers and a temperature sensor (RTD).

The meter body is a specially designed section of pipe that contains pairs of transducer housings that are positioned to provide acoustic paths at a 65° angle to the flow direction. They are spaced in accordance with the Gaussian Method of flow integration. The transducers are installed inside these housings.

Each transducer module contains a piezoelectric crystal which transmits and receives acoustic energy in the form of ultrasonic pulses (typically 200 kHz). A distinguishing design feature is that the transducer modules may be removed from their housings for maintenance while the meter body is in the pipeline without affecting the pressure boundary (i.e. no special extraction tools required).

The meter body comes in 2 styles: The legacy meter style which has a manifold design that groups sets of transducers and transformers and the NextGen meter style which is reduced weight and has individual transducer ports. Figure 1.1 shows the NextGen meter (left) and Legacy meter (right). If there are any questions about which design you may have, please contact Sensia for assistance.

LEFM 3xxCi Transmitter

The transmitter houses the display, which shows the flow data, including flow rate, total flow volume, gas properties, analog input data, alarm indication, fault detection, and acoustic diagnostic information.

The transmitter performs all control and timing for the generation and measurement of acoustic pulses. Acoustic processing is performed by specialized proprietary boards that are designed to achieve high sampling rates, provide stable ultrasonic signals, and eliminate zero drift. The circuit boards within the transmitter are programmed to perform the following functions:

- Step through the ultrasonic path cycles
- Provide gain control for each ultrasonic path
- Compute flow
- Generate pulse outputs and analog outputs

The transmitter offers the following inputs/outputs:

- Standard volume pulse output
- The K-factors used to configure transmitters at the factory are listed in Table 1.1. The user may configure the K-factor as needed.
- Analog Inputs (up to 3)
    - Product temperature
    - Product pressure
- Analog Outputs (up to 2)
    - Flow (forward or reverse)
    - Temperature
    - Pressure
- Communications
    - RS-485 ports (half duplex; up to 3) – Modbus RTU
    - Ethernet port (via Copper or Fiber) with Modbus TCPIP
    - Optional HART channel (operates on second analog output)

- Digital Outputs (4)
  - Status
  - Standard volume pulse outputs

Table 1.1 Nominal K-Factors

Size		Maximum Flow	K-Factor	Maximum Flow	K-Factor
In.	DN	CFH	(P/CF)	m^3/h	(P/m^3)
4	100	29,000	240	810	8900
6	150	65,000	110	1845	3900
8	200	114,000	63	3,230	2230
10	250	180,000	40	5,090	1416
12	300	254,000	28.3	7,200	1000
14	350	307,000	23.5	8690	829
16	400	402,000	17.9	11,400	632
18	450	511,000	14.1	14,500	498
20	500	632,000	11.4	17,900	402
24	600	913,000	7.9	25,900	278
26	650	1,203,000	6.0	34,100	210
28	700	1,405,000	5.1	39,800	180
30	750	1,623,000	4.4	46,000	160
32	800	1,857,000	3.9	52,600	140
34	850	2,106,000	3.4	59,600	120
36	900	2,371,000	3.0	67,100	100

Model Number

Meter Body Model Numbers

The model number defines construction and features. From the model number, a user can identify and verify the component type, meter size, piping thickness, construction material, ANSI rating, and enclosure type.

MODEL NUMBER CODE: LEFM 3BC-D-E-F-G-H-J-K-L-M-N-P-Q-R

B = 80 FOR 8 PATH METERS
B = 40 FOR 4 PATH METERS

C = Ci-G3 FOR INTEGRAL ELECTRONICS
C = Ci-R-G3 FOR REMOTE ELECTRONICS AND 1 J-BOX PER MANIFOLD
C = Ci-RB-G3 FOR REMOTE ELECTRONICS AND 1 J-BOX FOR WHOLE METER

D = NOMINAL PIPE SIZE (e.g., 04 = 4 INCH, 16 = 16 INCH ....)

E = PIPE SCHEDULE (SCHEDULE 5 THRU 160 AND XXS)

F = CF FOR FORGED CARBON STEEL
F = CC FOR CAST CARBON STEEL
F = SF FOR FORGED STAINLESS STEEL
F = SC FOR CAST STAINLESS STEEL
F = DF FOR FORGED DUPLEX STEEL
F = DC FOR CAST DUPLEX STEEL
F = LF FOR FORGED LOW TEMPERATURE CARBON STEEL
F = LC FOR CAST LOW TEMPERATURE CARBON STEEL
F = HF FOR HASTELLOY
F = IF FOR INCONEL FORGED

G = ASME FLANGE RATING (CLASS 150, 300, 600, 900, 1500, 2500)

H = B FOR MANIFOLDS INTEGRAL WITH METER BODY
H = D FOR SPLIT MANIFOLDS INTEGRAL WITH METER BODY
H = E FOR SINGLE TRANSDUCER ENCLOSURES INTEGRAL WITH METER BODY

J = W FOR WELD NECK RAISED FACE FLANGES
J = R FOR WELD NECK RTJ FACE FLANGES
J = O FOR OTHER FLANGE VARIETY
J = S FOR SLIP-ON FLANGES

K = L FOR LOCTITE E40 EXP POTTING MATERIAL

L = B FOR SECONDARY SEAL DESIGN TRANSDUCER HOUSING IN ACCORDANCE WITH ISA 12.27.01 (DUAL SEAL)
L = C FOR DOUBLE O-RINGS

M = N FOR NO PRESSURE PORT OPTION
M = P FOR PRESSURE PORT OPTION

N = A FOR ALUMINUM MANIFOLDS COVERS
N = S FOR STAINLESS STEEL MANIFOLDS COVERS

P = 1 FOR ONE TRANSMITTER
P = 2 FOR TWO TRANSMITTERS

Q = G FOR GAS TRANSDUCER HOUSINGS

R = "BLANK" FOR NO CUSTOM OPTION
R = C FOR CUSTOM OPTION

Example: For a forged carbon steel 380Ci meter that has a head mounted electronics, 6 inch NPS, Schedule 40, 150# weld neck flanges with raised faces, no pressure port, aluminum manifold covers, having the secondary seal design and having no other custom features – the model code would be: LEFM380Ci-G3-06-40-CF-150-B-W-L-B-N-A-1-G

Transmitter Model Number

The model number for the transmitter includes information that defines construction and features.

MODEL NUMBER CODE: G3MFFFCCPSEXYZ

MATERIAL

M = A, ALUMINUM
M = S, STAINLESS STEEL

FREQUENCY

FFF = 020 FOR 200KHZ
FFF = 100 FOR 1 MHZ
FFF = 160 FOR 1.6 MHZ
FFF = 250 FOR 2.5 MHZ
FFF = 350 FOR 3.5 MHZ
FFF = 500 FOR 5.0 MHZ
FFF = BBD FOR A BROADBAND DESIGN

COMMUNICATIONS

CC = HC FOR TWO RS-485 PORTS, ONE HART PORT, AND ONE COPPER ETHERNET
CC = SC FOR THREE RS-485 PORTS (ONE MASTER) AND ONE COPPER ETHERNET (LEGACY = S2)
CC = HF FOR TWO RS-485 PORTS, ONE HART PORT, AND ONE FIBER ETHERNET
CC = SF FOR THREE RS-485 PORTS (ONE MASTER) AND ONE FIBER ETHERNET

POWER OPTIONS

P = D FOR DC POWER – 24 VOLTS
P = A FOR AC POWER – 120/230 VAC

SUNSHIELD OPTIONS

S = Y FOR WITH SUNSHIELD
S = N FOR WITHOUT SUNSHIELD

ENTRY PORT

E = 1 FOR NPT PORTS 3/4 INCH NPT
E = 2 FOR M25 PORTS
E = 3 FOR SPECIAL

APPROVALS

X = 0 FOR NO CSA APPROVAL
X = C FOR CSA APPROVAL
Y = 0 FOR NO ATEX APPROVAL
Y = B FOR ATEX EX db IIB APPROVAL
Y = C FOR ATEX EX db IIB + H_2 APPROVAL
Y = D FOR ATEX EX db IIC APPROVALS
Z = 0 FOR NO IEC APPROVAL
Z = B FOR IECEX EX db IIB APPROVALS
Z = C FOR IECEX EX db IIB + H_2 APPROVALS
Z = D FOR IECEX EX db IIC APPROVALS

Flowmeter Specifications

Table 1.2 LEFM 3xxCi Transmitter Specifications

Material	
Standard	Aluminum
Corrosion Resistant	Stainless Steel
Size and Weight (if delivered separate from the meter body)	
Size	14"x 8" x 6" = 152mm x 356 mm x 203 mm
Net Weight	15 lb. (6.1 kg) Aluminum 40 lb. (15.9 kg) Stainless Steel Note – When attached to a junction box, the total could surpass 135 lbs (61 kg), depending on the junction box material
Power Requirements – DC Power	
Voltage Req'd	24 VDC (18 VDC to 30 VDC)
Current Draw	0.3 A at 24 VDC
Power Consumption	6 W
Power Requirements – AC Power	
Voltages	120 (60 Hz) / 230 (50 Hz) VAC
Voltage Range	(108 VAC to 253 VAC)
Frequency Range	(47 Hz to 63 Hz)
Current Draw	0.06 A at 120 VAC / 0.03 A at 230 VAC
Power Consumption	7.3 W
Pulse Outputs	
Pulse/Direction Outputs (4 Total)	0-5 V or 0-12 V
Alarm Status (4 Total)	5V or 12 V = normal operation 0V = alarm condition
Communications	
RS485 (up to 3 total)	2 Wire – Modbus RTU
Ethernet	Copper or Fiber
HART	Optional
Analog Outputs (2 total)	
	4-20 mA (max load 650 Ohms)
Analog Inputs (4 total)	
	Three 4-20 mA Meter body RTD is standard

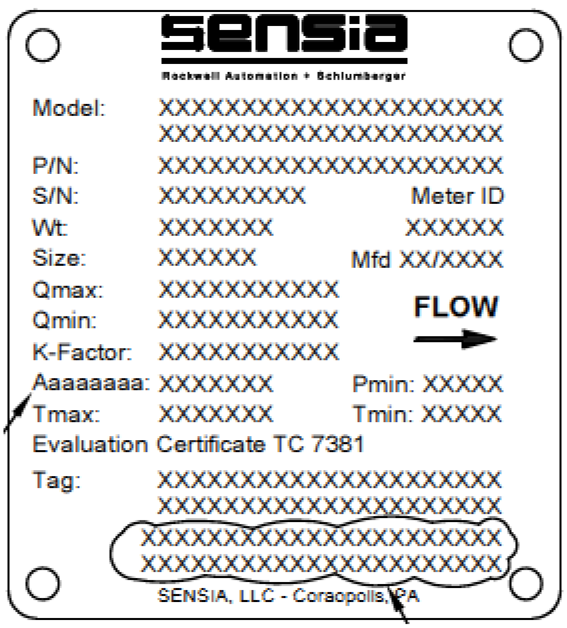
Environment Requirements	
Storage Temperature	-58°F (-50°C) to 185°F (85°C)
Operating Temperature	-58°F (-50°C) to 158°F (70°C)
Altitude	Up to 5000 meters (16400 feet) for DC applications, 2000 meters for AC applications, limited to 1600 m for functional safety applications (Contact Sensia for applications at higher elevations)

This transmitter is intended for use in a permanently connected installation, Equipment Class II, Pollution Degree 2, Continuous operation.

Meter Markings

Meter Body Approvals Nameplate Example

Meter Body Serial Number Nameplate Example



Section 2

Direct-Mount Meter and Transmitter Installation (Model 3xxCi)

The LEFM 3xxCi flowmeters are designed for use with a broad range of process and environmental conditions. Durable construction permits conventional installation practices. The flowmeter body is typically fabricated of stainless steel, carbon steel, or duplex steel, depending on customer requirements. The flowmeter is designed to be as strong as or stronger than pipe and flanges of the same schedule, pressure class, and material. For site stress analysis, the meter can be conservatively treated as equivalent pipe.

Installation procedures vary, depending on whether the transmitter is attached directly to the meter body, or mounted remotely from the meter body. This section describes the direct-mount installation in which the transmitter is mounted directly to the meter body (Model 3xxCi). Section 1 addresses the remote-mount installation method in which the transmitter is mounted separately from the flowmeter, typically due to extreme environmental reasons (for example, high or low pipe temperatures). Remote mounting of the electronics is for Model 3xxCi-R/RB.

Flowmeter Body Installation – Best Practices

CAUTION

The weights of the flowmeter body are listed on customer specific General Arrangement Drawing. Never use the transmitter, conduit or junction boxes for lifting or maneuvering the meter body. These components are not designed for the forces required to move the meter body and could be damaged.

CAUTION

If the equipment is likely to come into contact with aggressive substances, then it is the responsibility of the user to take suitable precautions that prevent it from being adversely affected, thus ensuring that the type of protection is not compromised.

No external supports or special mounting pads are required or recommended for the LEFM meter body. However, the piping immediately upstream and downstream of the flowmeter should be well supported in accordance with good piping practices and site seismic requirements.

Lifting/Hoisting the Meter Body

WARNING	**If the swivel hoist rings have been used previously, inspect them for signs of wear, corrosion, or stress. If the rings appear damaged or corroded, DO NOT USE.**

Hoist Ring Installation

1. Before installing hoist rings, refer to your company's hoisting and rigging standards. If no such company standards exist, refer to the Department of Energy (DOE) STD-1090-2011(Hoisting and Rigging Standard). Additional information can be found in OSHA 29 CFR 1926.251 (Rigging Equipment for Material Handling) and 1926.552 (Material Hoists, Personnel Hoists, and Elevators).
2. Identify the assembled weight of the meter body from the serial tag or by referencing the GA drawing.
3. Place the meter on a stable surface or platform capable of supporting its assembled weight.

WARNING	**Failure to properly stabilize and support the meter body during installation or removal could allow the meter to shift or roll, posing a hazard that may result in equipment damage or serious injury, up to and including death.**

4. Remove the plug bolts and sealing washers from the tapped holes on top of each meter body end flange and set them aside. The plug bolts will be replaced after the hoist ring is no longer required, as shown in Figure 2.1.

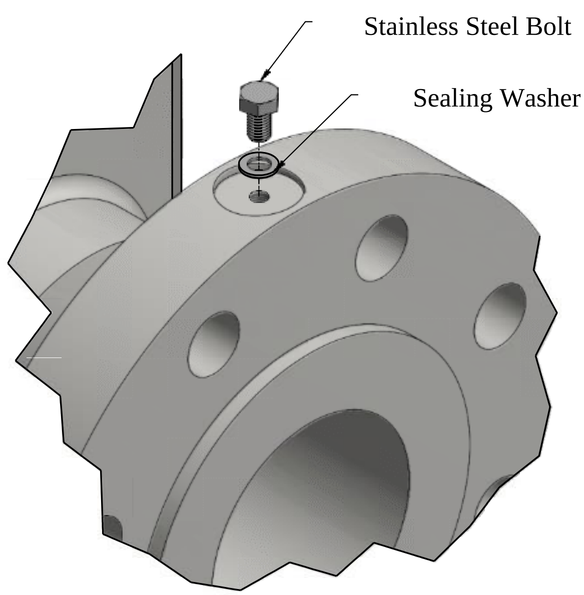


Figure 2.1 Stainless steel bolt and washer in tapped hole of meter body end flange

5. Use only Sensia swivel hoist rings (ordered separately; see Table 2.1) in the meter body end flanges. DO NOT USE the following:
    a. Eyebolts
    b. Other hoist rings with the same screw size
    c. Heavy-duty hoist rings
6. Screw the swivel hoist rings into the tapped holes. To ensure the hoist rings hold their rated load, the base of the hoist ring must be in full contact with the surface of the tapped holes before attempting to lift/hoist the meter body.
7. Torque the swivel hoist ring attachments to the site recommended limit for that bolt size. DO NOT over-torque.
8. Verify that the rings move freely in all directions.

Table 2.1 Hoist Ring Rated Weights and Part Numbers

Rated Weight (lbs)	Rated Weight (kg)	Thread	Sensia Part No.
1385	628	M8	9A-8504651
1980	898	M10	9A-8504652
2970	1347	M12	9A-8504653
4400	1996	M16	9A-8504655
7700	3493	M20	9A-8504657
9900	4491	M24	9A-8504659
14740	6686	M30	9A-8504661
17600	7983	M36	9A-7983553

Sling Attachment

WARNING

Ensure that the meter body is detached from all piping, pipe fittings, and/or meter tubes before lifting/hoisting the meter. Failure to take this precaution may result in damage to equipment and/or personal injury, up to and including death.

WARNING

Failure to properly stabilize and support the meter body during installation or removal could allow the meter to shift or roll, posing a hazard that may result in equipment damage or serious injury, up to and including death.

WARNING

NEVER attempt to thread one sling through both hoist rings. DO NOT exceed an angle of 90 degrees between the slings. Choose slings that exceed the swivel hoist ring load rating. Failure to follow these precautions may result in hoist ring failure, equipment damage, or serious personal injury, up to and including death.

1. Select two slings of equal length that exceed the load rating for the weight of the assembled meter body.
2. Visually inspect the slings for signs of wear, abrasion, or other damage. DO NOT USE if damage is detected.
3. Attach the slings to the hoist rings, ensuring that the angle between the slings is 90 degrees or less (see Figure 2.2). DO NOT wrap slings around the meter body or the transmitter enclosure.

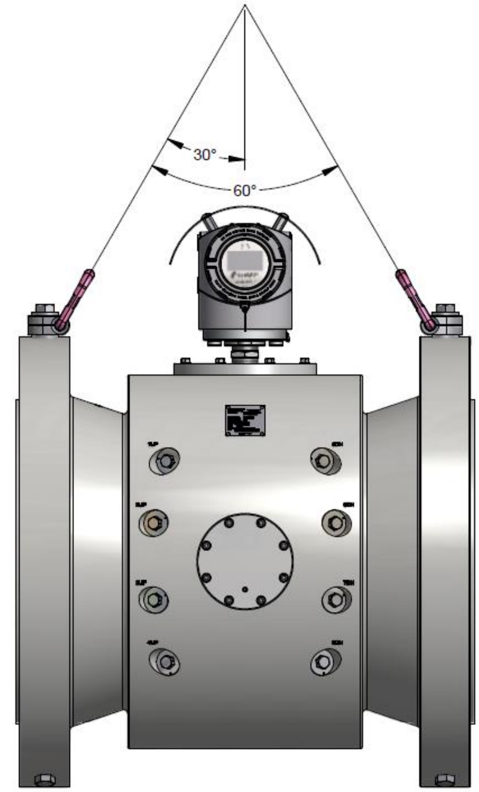


Figure 2.2 The angle (shown here at 30° from vertical and 60° total) may range from 0° to 45° (from vertical) or 0° to 90° (total). The angle must be chosen so that lifting method does not interfere with the electronics unit

4. To avoid damaging the transmitter enclosure, ensure that the slings do not come into contact with it. Consider using a spreader bar (as shown in Figure 2.3), in order to ensure that the angle between the slings does not exceed 90 degrees.

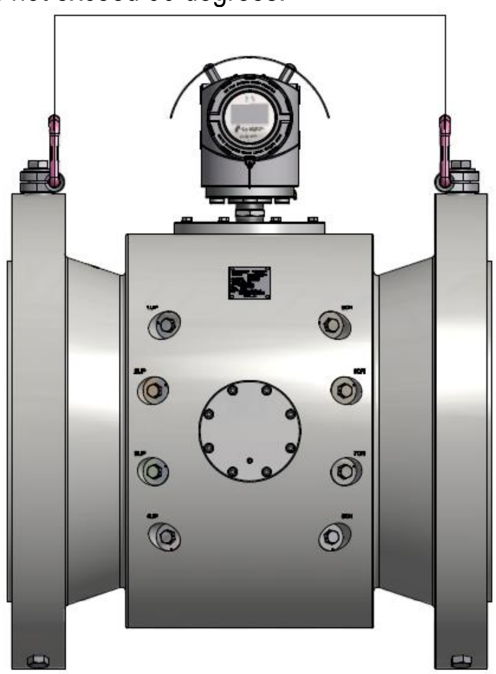


Figure 2.3 Hoist rings used at 0° with a lifting bar above the electronics unit allow for uniform lifting.

CAUTION

To avoid damaging the swivel hoist rings, never use cables, hooks, or chains to lift the meter body. Lift the meter gradually. Exposing the swivel hoist rings to shock loads can result in damage to the hoist ring. DO NOT USE any swivel hoist ring exposed to shock loads.

5. After lifting, remove the swivel hoist rings and store away from exposure to moisture, extreme temperatures, and other adverse conditions.
6. Reinsert the plug bolts into the tapped holes to protect them from debris and corrosion.

Meter Installation

Install the flowmeter so that:

- The acoustic paths are horizontal (with the transmitter and nameplate on top) to decrease the likelihood of debris accumulating in the sensor wells.
- The meter is not located at a low point in the system which could allow liquid accumulation.
- The flow arrow indicates the flow direction for positive flow.
- All wiring to the transmitter is routed in shielded conduit / armored cable that meets site environment specifications.
- All power connections on site shall go through an equipment switch or circuit breaker employed as a disconnecting device. This switch shall be easily accessed and be marked as the disconnecting switch for the transmitter. This switch shall meet the requirements of IEC 60947-1 and IEC 60947-3 and site electrical codes.
- If using DC power, power cable must be installed in separate conduit from all other cabling. This is to meet requirements of IEC 61000-4-4 (2004-07).
- 380Ci Installations: Upstream of the meter there should be at least 5 diameters of straight pipe of the same nominal diameter as the meter. If a straightening/conditioning element is used, 10 diameters of straight pipe between the conditioner and flowmeter are recommended with an additional 5 diameters upstream of the flow conditioner. Downstream of the meter, there should be at least 3 diameters of straight pipe of the same nominal diameter as the meter. Refer to
- Figure 2. for details.
- 340Ci Installations: Upstream of the meter there should be at least 10 diameters of straight pipe of the same nominal diameter as the meter. If a straightening/conditioning element is used, 10 diameters of straight pipe between the conditioner and flowmeter are recommended with an additional 5 diameters upstream of the flow conditioner. Downstream of the meter, there should be at least 3 diameters of straight pipe of the same nominal diameter as the meter.
- Process temperature and pressure should be measured within 2 to5 diameters downstream of the meter. The pressure measurement may be made at the downstream spool ahead of the temperature measurement or optionally at the meter body itself.

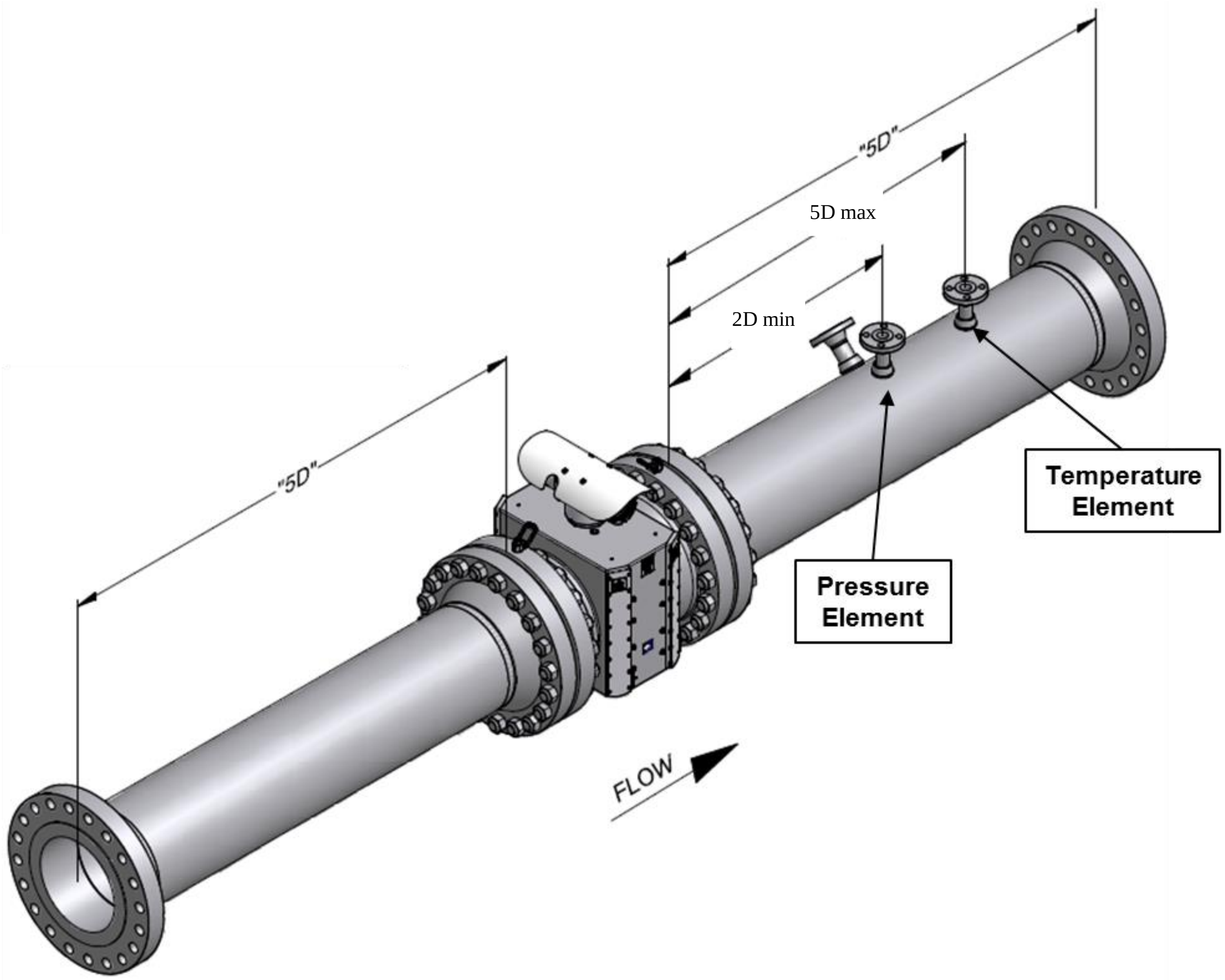


Figure 2.4 Best Practice for 380Ci Installation

Note: For 340Ci Installation: The Upstream pipe length should be 10D with a flow conditioner or 20D of straight pipe.

- By following the recommended installation practices detailed below, the LEFM 380Ci has been approved by NMi (Certificate Number T10504 for pipe sizes 4 to 42 inches).
- The meter meets the performance requirements of OIML R137 Class 0.5 and ISO 17089 Class 1.
- The accuracy specifications for the meter following calibration are as follows:

  Linearized meter factor less than or equal to +/- 0.1% of measured value relative to calibration facility (between Q_t and Q_{max})

  Linearized meter factor less than or equal to +/- 0.2% of measured value relative to calibration facility (between Q_{min} and Q_t)

Table 2.2 Flow Ranges for the 3xxCi Meter

Pipe Size In.	DN	Q_{max} (cfh)	$Q_{overrange}$ (cfh)	Q_t (cfh)	Q_{min} (cfh)	Q_{max} (m³/hr)	$Q_{overrange}$ (m3/hr)	Q_t (m3/hr)	Q_{min} (m3/hr)
4	100	28,700	34,440	2,870	574	813	975	81	16
6	150	65,200	78,240	6,520	1,304	1,850	2,216	185	37
8	200	114,000	136,800	11,400	2,280	3,230	3,874	323	65
10	250	180,000	216,000	18,000	3,600	5,100	6,116	510	102
12	300	254,000	304,800	25,400	5,080	7,190	8,631	719	144
14	350	307,000	368,400	30,700	6,140	8,690	10,432	869	174
16	400	402,000	482,400	40,200	8,040	11,400	13,660	1,138	228
18	450	510,000	612,000	51,000	10,200	14,400	17,330	1,444	289
20	500	632,000	758,400	63,200	12,640	17,900	21,475	1,790	358
24	600	913,000	1,095,600	91,300	18,260	25,900	31,024	2,585	517
26	650	1,203,000	1,443,600	120,300	24,060	34,100	40,878	3,407	681
28	700	1,405,000	1,686,000	140,500	28,100	39,800	47,742	3,979	796
30	750	1,623,000	1,947,600	162,300	32,460	46,000	55,150	4,596	919
32	800	1,857,000	2,228,400	185,700	37,140	52,600	63,101	5,258	1,052
34	850	2,106,000	2,527,200	210,600	42,120	59,600	71,562	5,964	1,193
36	900	2,371,000	2,845,200	237,100	47,420	67,100	80,567	6,714	1,343

380Ci Upstream Condition Requirements for Calibrated Meters (Pipe Sizes ≥ 6 in.)

To meet the requirements of the Measurement Instruments Directive (Directive 2004/22/EC) and OIML R-137, one of the following installation configurations must be used:

Inlet piping configuration No. 1: 5D

- Measuring installations using the LEFM 380Ci with 5 diameters or more of straight pipe upstream (without a flow conditioner) and 3 diameters downstream are suitable for accuracy class 0.5 and accuracy class 1.0 in piping arrangements that cause only mild disturbances excluding expanders where the upstream pipe is smaller than the meter diameter. Examples of permitted pipe arrangements upstream of the 5 diameters are bends, tees and reducers, including single bends and out-of-plane combinations.

Inlet piping configuration No. 2: 10D

- Measuring installations using the LEFM 380Ci with 10 diameters or more of straight pipe upstream (without a flow conditioner) and 3 diameters downstream are suitable for accuracy class 0.5 and accuracy class 1.0 in piping arrangements that cause only mild disturbances including expanders where the upstream pipe is smaller than the meter diameter. Examples of permitted pipe arrangements upstream of the 10 diameters are bends, tees, expanders, and reducers, including single bends and out-of-plane combinations.

Inlet piping configuration No. 3: 15D

- Measuring installations using the LEFM 380Ci with 15 diameters or more of straight pipe upstream (without a flow conditioner) and 3 diameters downstream are suitable for accuracy class 1.0 in piping arrangements that cause severe disturbances including combinations of out-of-plane bends in combination with partial blockage of the pipe. An example of a severe disturbance would be a 50% open gate valve installed between out-of-plane bends.

Inlet piping configuration No. 4: 15D (with flow conditioner)

- Measuring installations using the LEFM 380Ci with 15 diameters or more of straight pipe upstream inclusive of a flow conditioner with its inlet located 10 diameters from the meter, and with 3 diameters downstream are suitable for accuracy class 0.5 and accuracy class 1.0 in piping arrangements that cause severe disturbances including combinations of out-of-plane bends in combination with partial blockage of the pipe. An example of a severe disturbance would be a 50% open gate valve installed between out-of-plane bends.

For all above configurations, the internal diameter of the pipe sections must be the same as the inlet and outlet diameter of the meter. The pipe sections shall be considered identical if their diameters differ by no more than 3%. For unidirectional flow, the temperature sensor well should be installed downstream of the meter. The distance from the downstream flange face to the temperature sensor well should be between 2 and 5 internal diameters. For bi-directional flow installations, temperature sensor well should be located at between 3 and 5 diameters from the flange of the meter.

340Ci Upstream Condition Requirements for Calibrated Meters (Pipe Sizes ≥ 6 in.)

To meet the requirements of the Measurement Instruments Directive (Directive 2004/22/EC) and OIML R-137, one of the following installation configurations must be used:

Inlet piping configuration No. 1: 10D

- Measuring installations using the LEFM 340Ci with 10 diameters or more of straight pipe upstream (without a flow conditioner) and 3 diameters downstream are suitable for accuracy class 0.5 and accuracy class 1.0 in piping arrangements that cause only mild disturbances excluding expanders where the upstream pipe is smaller than the meter diameter. Examples of permitted pipe arrangements upstream of the 10 diameters are bends, tees and reducers, including single bends and out-of-plane combinations.

Inlet piping configuration No. 2: 15D (with flow conditioner)

- Measuring installations using the LEFM 340Ci with 15 diameters or more of straight pipe upstream inclusive of a flow conditioner with its inlet located 10 diameters from the meter, and with 3 diameters downstream are suitable for accuracy class 0.5 and accuracy class 1.0 in piping arrangements that cause severe disturbances including combinations of out-of-plane bends in combination with partial blockage of the pipe. An example of a severe disturbance would be a 50% open gate valve installed between out-of-plane bends.

For all above configurations, the internal diameter of the pipe sections must be the same as the inlet and outlet diameter of the meter. The pipe sections shall be considered identical if their diameters differ by no more than 3%. For unidirectional flow, the temperature sensor well should be installed downstream of the meter. The distance from the downstream flange face to the temperature sensor well should be between 2 and 5 internal diameters. For bi-directional flow installations, temperature sensor well should be located at between 3 and 5 diameters from the flange of the meter.

Uncalibrated Meters

Some customers may request to have a meter delivered without calibration. In these instances, it is expected that the general performance requirements of AGA 9 and ISO17089 (Class 1) will apply as per Table 2.3 below.

Table 2.3 Uncalibrated Meter Performance

	Flows between Q_t and Q_{max}		Flows between Q_{min} and Q_t	
Pipe Sizes	Maximum (Permissible) Error	Max Peak-to-Peak Error	Maximum (Permissible) Error	Max Peak-to-Peak Error
4 to 10 NPS	+/-1.0%	1.0%	+/-1.4%	1.4%
12 and larger	+/-0.7%	0.7%	+/-1.4%	1.4%

Section 3

Remote-Mount Meter and Transmitter Installation (Model 3xxCi-R/RB)

CAUTION

The physical properties, acoustic properties, and calibration of the meter body are pre-programmed into the transmitter; therefore, the meter body and transmitter are manufactured as a matched set and must be installed as a pair. Failure to install transmitters and meter bodies as matched sets can result in erroneous flow measurements.

Should a customer receive multiple meter bodies and transmitters in one shipment, the installer must verify that each transmitter is installed with the meter body for which it was programmed.

CAUTION

If the equipment is likely to come into contact with aggressive substances, then it is the responsibility of the user to take suitable precautions that prevent it from being adversely affected, thus ensuring that the hazardous location protection is not compromised.

Note – All wiring between the transmitter and the meter body must be routed through grounded metal conduit or equivalent. All wiring to the transmitter is to be routed in shielded conduit that meets site environment specifications.

This section describes the installation procedure for installing the transmitter separately from the meter body. Refer to Figure 3.1 for the remote mounted transmitter configuration. The transmitter may be mounted according to this section within 100 meters (~300 feet) of the meter body. For distances further than 100 meters, contact Sensia.

Note – For installation in North America, conductor insulation for cabling must be rated for a voltage of 300V and a minimum temperature as follows. For all other installations – adherence to local code is advised:

- For units rated with Ta max = 70°C: “Use conductors for 85°C”
- For units rated with Ta max = 110°C: “Use conductors for 125°C”
- For units rated with Ta max = 125°C: “Use conductors for 140°C”
- For units rated with Ta max = 140°C: “Use conductors for 155°C”

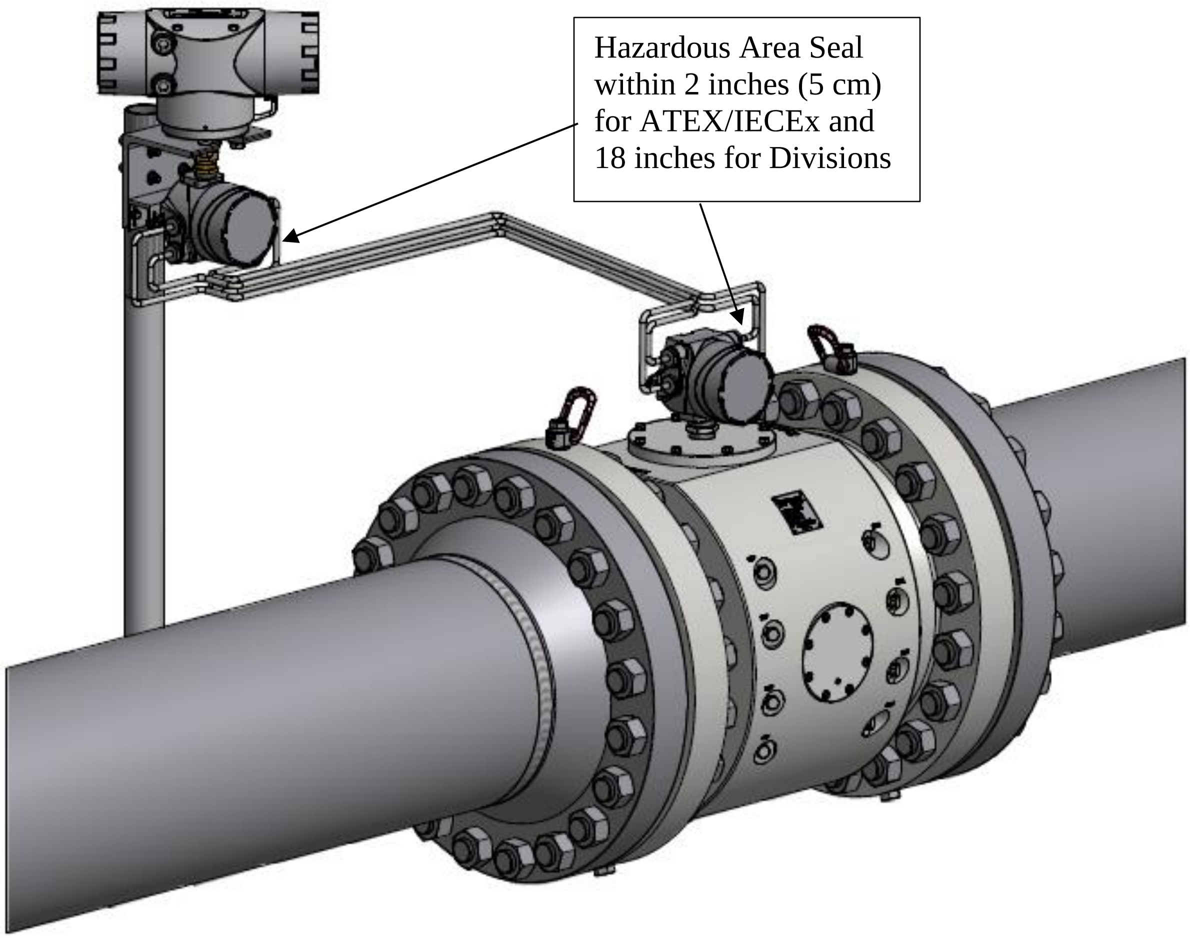


Figure 3.1 Remote Installation of Transmitter from Meter Body (shown with optional sunshield and swivel hoist rings)

The installation requires field wiring to connect the meter body terminations to the transmitter. The meter body is installed with junction boxes (J-Box) for the field terminations. The transmitter and its junction box must be mounted according to site seismic rules/guidelines. There is a pole mounting hardware kit as an option for remote mounting the transmitter.

Remote Mount Terminations Procedure (External Junction Box Only)

The terminations discussed in this section are within the junction boxes associated with the meter body and transmitter. For all other terminations (e.g., power, serial communications etc.) refer to Section 4, Transmitter Installation Procedure.

Meter Body to Transmitter Terminations

WARNING

Before terminating wires, open the power supply circuit breaker. Failure to do so can result in electrical shock and/or explosion.

1. For ATEX/IECEx installations, install hazardous area seals within 2 inches (5 cm) of the meter body junction boxes. For Divisions installations, install hazardous area seal within 18 inches of the meter junction boxes. For ATEX, see the certificate for the conditions for safe use. Install hazardous area seals at the entry point to transmitter junction box. There is a factory installed hazardous area seal installed between the factory delivered junction box and the transmitter. Hazardous area equipment entry must be suitable to Ex db IIC.

WARNING

If ATEX approved glands are to be used, they shall be types that include compound filled seals around individual cores. (Refer to EN 60079-14 clause 10.4.2).

2. Route the transducer and RTD cable(s) from the meter body junction boxes through the hazardous area cable/conduit to the transmitter junction box (bottom entry port) and make termination connections according to Table 3.1.

Important	**All equipment should be installed by a licensed electrician in accordance with NEC/CEC or local codes. At a minimum, install a disconnect switch in series with the transmitter power input.**

Note – Ensure that cables routed from the junction boxes to the transmitter do not exceed a bend radius of 14 inches (35.5 cm).

Table 3.1 LEFM 380Ci-R Transducer and RTD Terminations (See Figure 3.2)

Transducer Cable Identification	G3 J-Box Termination		Meter Body Junction Box	
Wire Name	**Terminal**	**Pin**	**Device**	**Pin**
RTD (+)	TB5	1	TB5	1
RTD (-)		2		2
RTD (+)		3		3
RTD (-)		4		4
Power Supply Common		5		-
Chassis Ground		6		-
GSS (+) - NextGen Meter Only		7		-
GSS (-) - NextGen Meter Only		8		-
1 UP (+)	TB1	1	TB1	1
SHIELD		2		-
1 UP (-)		3		3
2 UP (+)		4	1A - Upstream JBOX-TB1	4
SHIELD		5		-
2 UP (-)		6		6
3 UP (+)		7	1A - Upstream JBOX-TB1	7
SHIELD		8		-
3 UP (-)		9		9
4 UP (+)		10	1A - Upstream JBOX-TB1	10
SHIELD		11		-
4 UP (-)		12		12
5 UP (+)	TB3	1	TB3	1
SHIELD		2		-
5 UP (-)		3		3
6 UP (+)		4	2A - Upstream JBOX-TB1	4
SHIELD		5		-
6 UP (-)		6		5
7 UP (+)		7	2A - Upstream JBOX-TB1	7
SHIELD		8		-
7 UP (-)		9		8
8 UP (+)		10	2A - Upstream JBOX-TB1	10
SHIELD		11		-
8 UP (-)		12		12
1 DN (+)	TB2	1	TB2	1
SHIELD		2		-
1 DN (-)		3		3
2 DN (+)		4	1B - Upstream JBOX-TB1	4
SHIELD		5		-
2 DN (-)		6		6
3 DN (+)		7	1B - Upstream JBOX-TB1	7

Transducer Cable Identification	G3 J-Box Termination		Meter Body Junction Box	
Wire Name	Terminal	Pin	Device	Pin
SHIELD		8		-
3 DN (-)		9		9
4 DN (+)		10	1B - Upstream JBOX-TB1	10
SHIELD		11		-
4 DN (-)		12		12

5 DN (+)	TB4	1	TB4	1
SHIELD		2		-
5 DN (-)		3		3
6 DN (+)		4	2B - Upstream JBOX-TB1	4
SHIELD		5		-
6 DN (-)		6		6
7 DN (+)		7	2B - Upstream JBOX-TB1	7
SHIELD		8		-
7 DN (-)		9		9
8 DN (+)		10	2B - Upstream JBOX-TB1	10
SHIELD		11		-
8 DN (-)		12		12

To validate a meter's installation, perform the procedures in Section 4, Meter Installation Check-out. For troubleshooting information see Section 8, Troubleshooting and Diagnostics.

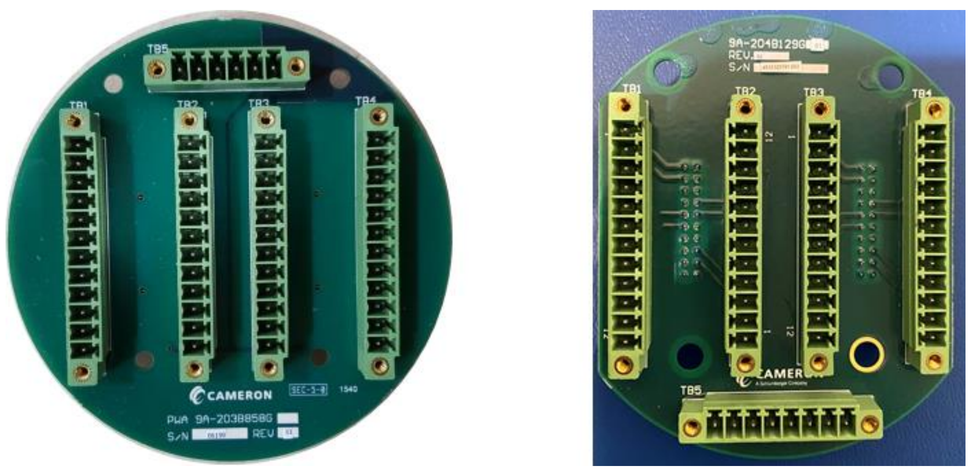


Figure 3.2 Locations of Terminals on Electronics MXR Board for Legacy (left) and NextGen (right) meters

Remote Mount Transmitter Installation Procedure

It is recommended that the transmitter be mounted at a convenient working height. The recommended height from the floor to the bottom of the transmitter is 4.5 feet (1.4 meters). While an installation in direct sun is acceptable, an installation in the shade will increase the life of all components.

1. Uncrate the transmitter (note the “unpacked weight” of the transmitter as listed in Table 1.2 for proper handling).
2. Consider site seismic requirements.
3. Determine the orientation that will best accommodate connections to the meter body as well as the transmitter display view angle.
4. Use the indicated mounting points for mounting the units. Use ½ inch bolts/hardware (or equivalent) on all mounting points for the explosion proof (NEMA 7) transmitter. Cover bolts are metric (M12 x 1.75 x 50 mm). Use 19 mm socket/wrench.

Transmitter Connections – All Models

CAUTION

The physical properties, acoustic properties, and calibration of the meter body are pre-programmed into the transmitter; therefore, the meter body and transmitter are manufactured as a matched set and must be installed as a pair. Failure to install transmitters and meter bodies as matched sets can result in erroneous flow measurements.

Transmitter Installation Procedure

Important **All equipment should be installed by a licensed electrician in accordance with NEC/CEC or local codes. At a minimum, install a disconnect switch in series with the transmitter power input.**

Note

- All wiring to and from the transmitter must be routed through grounded/shielded metal conduit or equivalent that meets site environment specifications.
- All power connections from site shall go through a properly rated equipment switch or circuit breaker employed as a disconnecting device (see Section 1, Table 1.2 for ratings). This switch shall be easily accessed for and be marked as the disconnecting switch for the transmitter. This switch shall meet the requirements of IEC 60947-1 and IEC 60947-3 and site electrical codes.

Note – For installation in North America, conductor insulation for cabling must be rated for a voltage of 300V and a minimum temperature as follows. For all other installations – adherence to local code is advised:

- For units rated with Ta max = 70°C: “Use conductors for 85°C”
- For units rated with Ta max = 110°C: “Use conductors for 125°C”
- For units rated with Ta max = 125°C: “Use conductors for 140°C”
- For units rated with Ta max = 140°C: “Use conductors for 155°C”

Transmitter Location

To ensure that the proper supply voltage reaches the transmitter, the distance between the transmitter and its power source must be less than that given in the below table (based on the wire gage used):

Wire Gage	Max Distance (Meters)	Max Distance (Feet)
12	1082.2	3550.4
14	679.7	2229.8
16	429.0	1407.3
18	269.1	882.9
20	169.1	554.6
22	106.3	348.6
24	66.9	219.6

Transmitter Terminations

WARNING

Before inspecting components, open the power supply circuit breaker. Failure to do so can result in electrical shock and/or explosion.

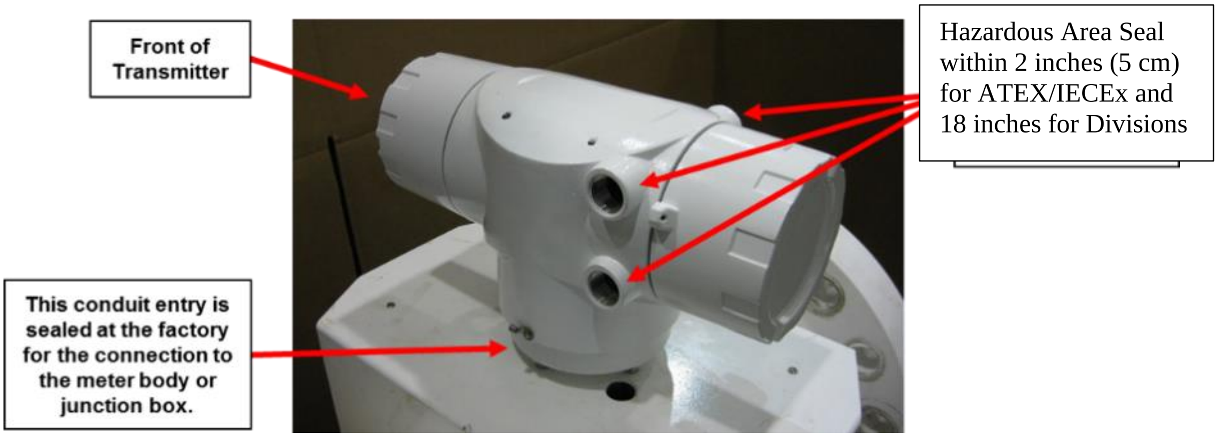


Figure 4.1 Fully Assembled Transmitter

The four conduit entries at the rear of the transmitter are for user connections. For ATEX/IECEx installations, a hazardous area conduit seal is required within 2 inches (~5 cm) of the device on every entry used. For Divisions installation, a hazardous area conduit seal is required within 18 inches of the device on every entry used. Unused entries must have plugs installed to be wrench tight with at least 5 threads fully engaged for a ¾ inch NPT connection or 8 threads for a straight thread connection.

WARNING

If ATEX approved glands are to be used, they shall be types that include compound filled seals around individual cores. (Refer to EN 60079-14 clause 10.4.2).

The wires should then be routed so that the terminations can be made. The terminations are made under the rear cover at the terminal blocks. Refer to Figure 4.2 for the location of the transmitter terminations on the IOP terminal blocks and an identification of the pin numbers. The inside of the rear cover has a diagram of the user connections.

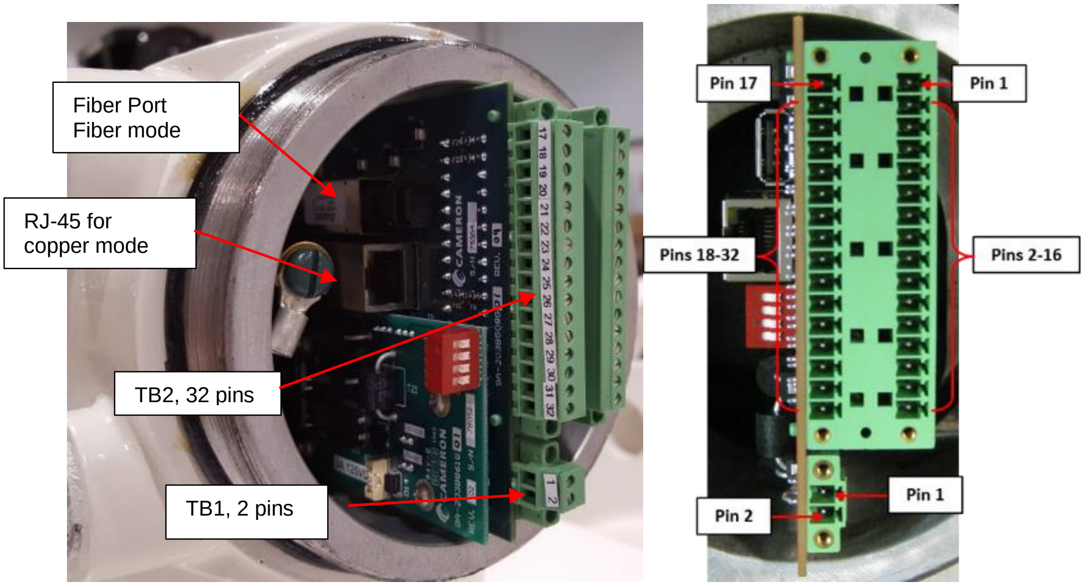


Figure 4.2 User Terminations, Rear View

Power Terminations (Terminal Block 1) – Recommended 16 to 20 AWG wire[2]

TB1 contains the power terminations, described below in Table 4.1 and Figures 4.3 through 4.5.

DC Power	
TB1, Pin 1	+24 VDC
TB1, Pin 2	(RETURN)
AC Power	
TB1, Pin 1	+120/230 VAC
TB1, Pin 2	(RETURN)

Table 4.1 - Power Terminations

The schematics for the power terminations are shown below in Figure 4.3 and Figure 4.4.

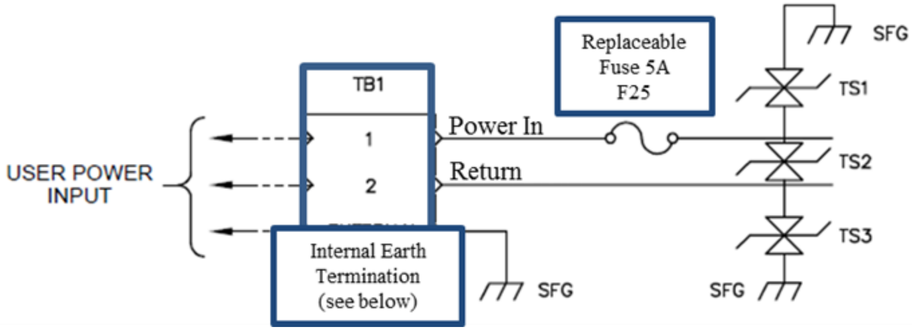


Figure 4.3 - DC Power Terminations

[2] 14 AWG is allowable.

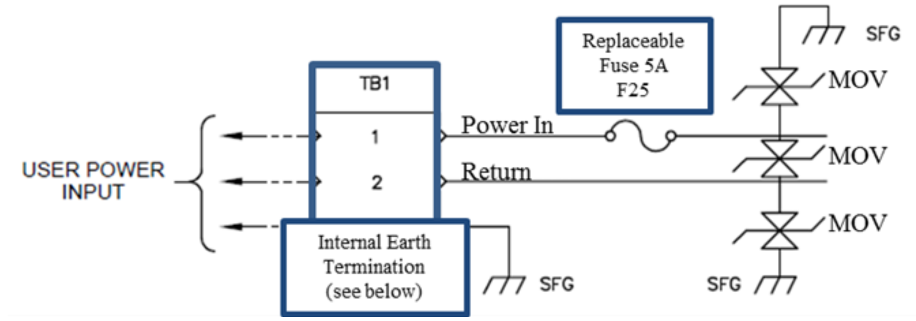


Figure 4.4 - AC Power Terminations

User 1 and User 2 Inputs/Outputs

There are two groups of inputs/outputs in this transmitter. The groups are organized as User 1 and User 2. Each user group is galvanically isolated from the other user group and from the incoming power supply. Inputs/outputs within a user group have a common isolated ground. Accordingly, all inputs/outputs will be listed according to the user group.

Analog Inputs (Terminal Block 2) – Recommended 16 to 28 AWG wire

TB2 contains the transmitter's analog inputs, described below in Table 4.2. A typical schematic for the analog inputs, including a depiction of the terminal block 2 configurations, is shown below in Figure 4.5.

Table 4.2 Analog Inputs (User 1)

Analog Input 1	TB2, Pin 3	4 to 20 mA (+)
	TB2, Pin 4	4 to 20 mA (-)
Analog Input 2	TB2, Pin 5	4 to 20 mA (+)
	TB2, Pin 6	4 to 20 mA (-)
Analog Input 3	TB2, Pin 7	4 to 20 mA (+)
	TB2, Pin 8	4 to 20 mA (-)

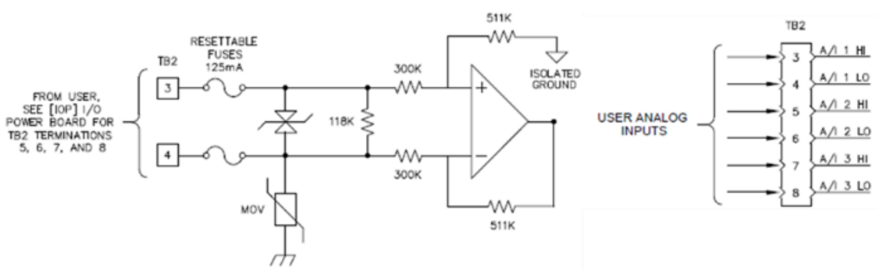


Figure 4.5 Typical Analog Input

Analog Outputs (Terminal Block 2) – Recommended 16 to 28 AWG wire

TB2 contains the transmitter's analog outputs, described below in Table 4.3. A typical schematic for the analog outputs, including a depiction of the terminal block 2 configuration, is shown below in Figure 4.6.

Table 4.3 Analog Outputs (User 1)

Analog Output 1	TB2, Pin 9	4 to 20 mA (+)
	TB2, Pin 10	4 to 20 mA (-)
	TB2, Pin 11	Ground
Analog Output 2	TB2, Pin 25	4 to 20 mA (+)
	TB2, Pin 26	4 to 20 mA (-)
	TB2, Pin 27	Ground

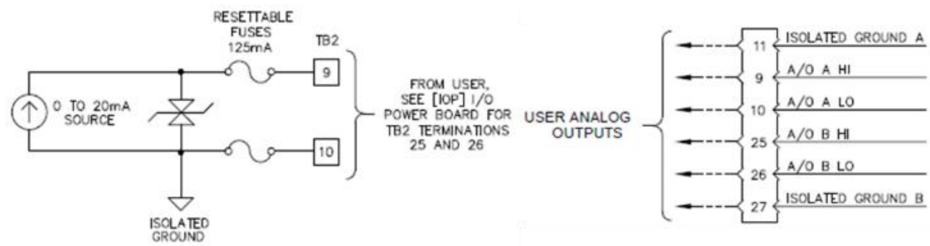


Figure 4.65 Typical Analog Output

Optional HART (Terminal Block 2) – Recommended 16 to 28 AWG wire

TB2 contains the transmitter's analog outputs, described below in Table 4.3. Note that HART bus connections are made to the Analog Output 2 terminals. HART does not interfere with the analog function.

Table 4.4 Optional HART Output

HART	TB2, Pin 25	4 to 20 mA (+)
	TB2, Pin 26	4 to 20 mA (-)
	TB2, Pin 27	Ground

Digital Outputs (Terminal Block 2) – Recommended 16 to 28 AWG wire

TB2 contains the transmitter's digital outputs, described below in Table 4.5. The voltages, +V, for the digital signals are active, selectable as either 5 volts or 12 volts, and electrically isolated. The output impedance is 249 ohms. These outputs are intended for high-impedance (1 MΩ) devices.

Pulse B can be configured to indicate volume or flow direction. The desired function is selected by a Modbus register. Refer to either the Modbus manual or the LEFMLink manual for changing parameters.

Table 4.5 LEFM 3xxCi Digital Signals

Signal	Pulse Description	Voltage Description	Terminal			
			User 1		User 2	
Pulse A (Volume)	Pulse A precedes Pulse B by 90 degrees = forward flow	—	TB2	Pin 12 (+) Pin 16 (-)	TB2	Pin 28 (+) Pin 32 (-)
	Pulse B precedes Pulse A by 90 degrees = reverse flow					
Pulse B (Volume)/ Direction	Pulse B precedes Pulse A by 90 degrees = reverse flow	0V = forward flow	TB2	Pin 13 (+) Pin 16 (-)	TB2	Pin 29 (+) Pin 32 (-)
	Pulse A precedes Pulse B by 90 degrees = forward flow	+V = reverse flow				
Status A	—	0V: alarm condition	TB2	Pin 14 (+) Pin 16 (-)	TB2	Pin 30 (+) Pin 32 (-)
		+V: normal operation				
Status B	—	0V: alarm condition	TB2	Pin 15 (+) Pin 16 (-)	TB2	Pin 31 (+) Pin 32 (-)
		+V: normal operation				

Note: Pulse A can be dedicated to positive flow only, while Pulse B is dedicated to negative flow.

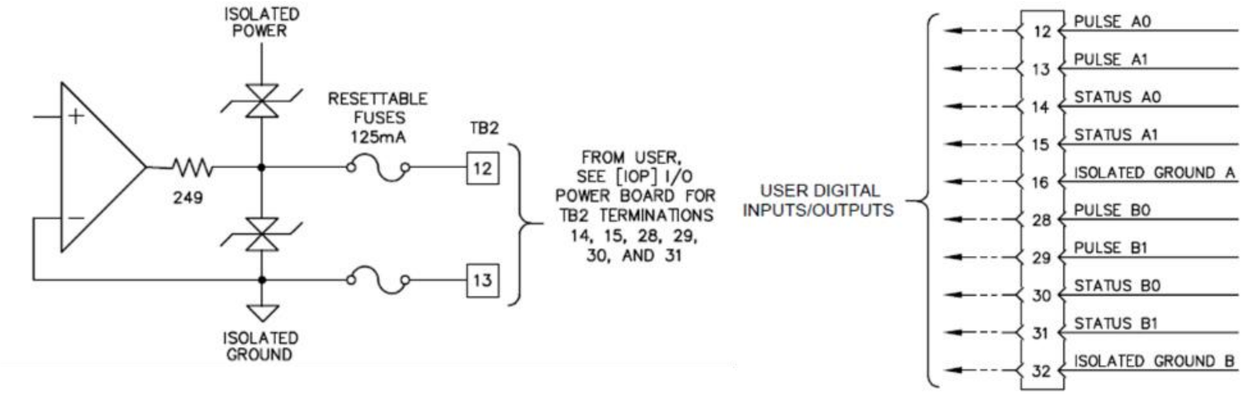
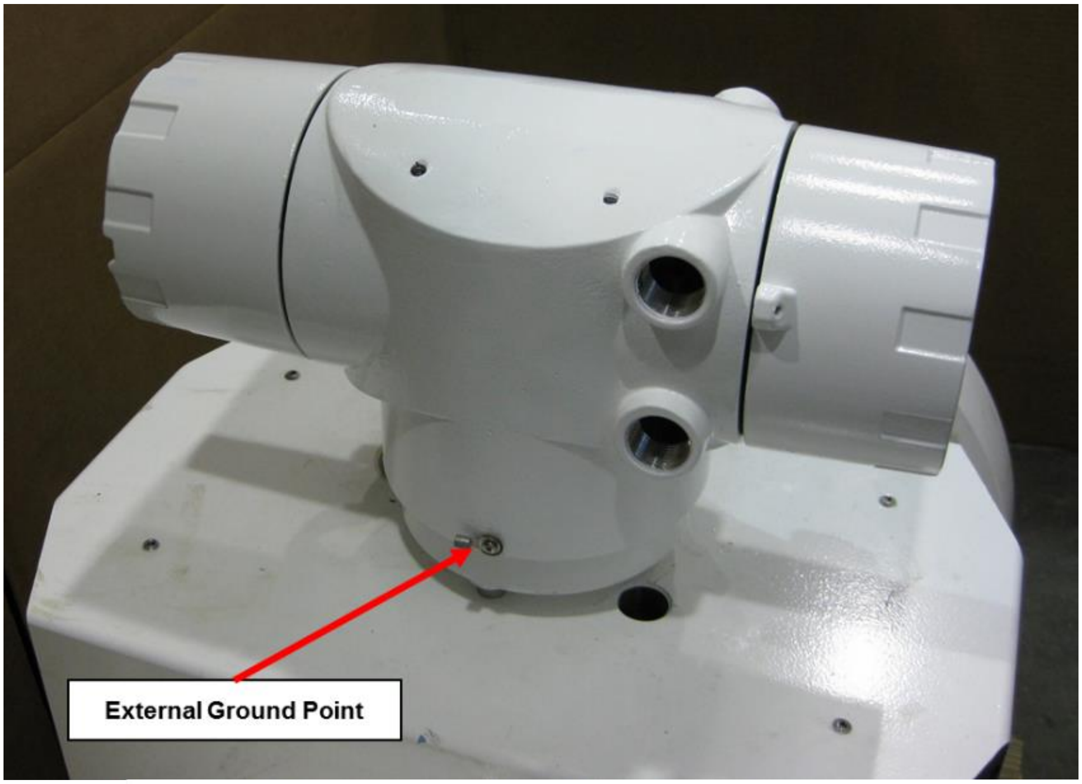


Figure 4.7 Typical Digital Signals

Grounding – Recommended 18 AWG wire (internal) and 16 AWG wire (external)

There are earth points on the inside of the junction box at the meter body (if remote mount) and on the outside of the enclosure. There are grounding points on the inside and outside of the transmitter enclosure. Refer to Figure 4.9 for the location of the external earth point. For ATEX applications, both earth points should be used. Follow all other site guidelines regarding grounding/earthing.



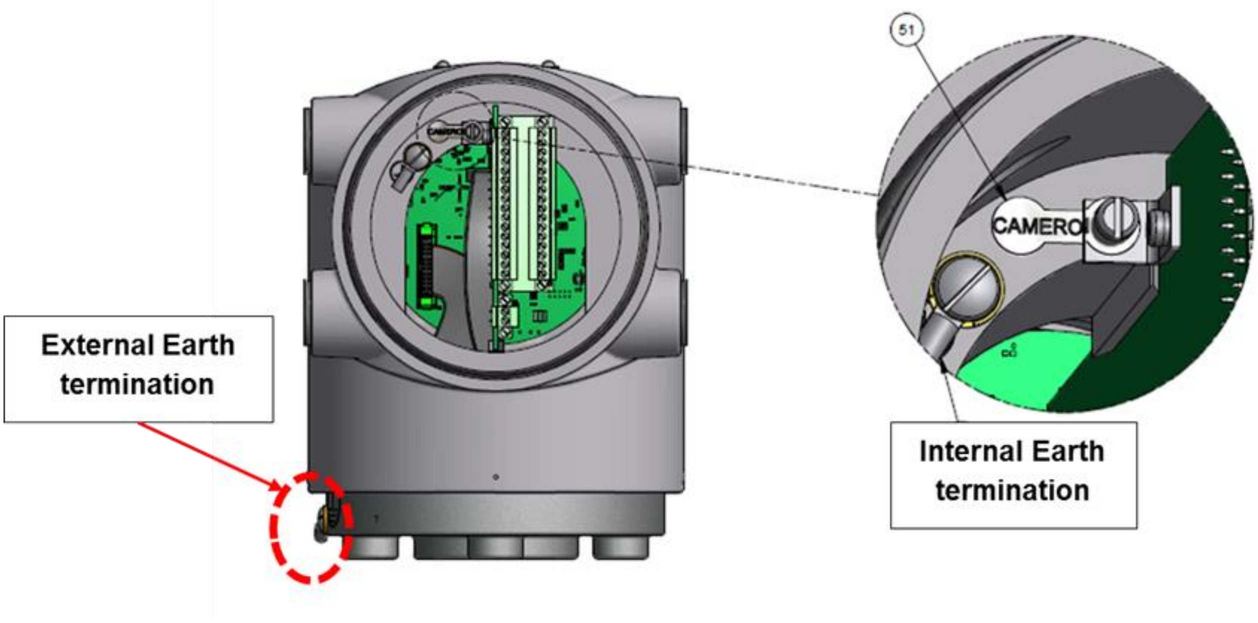


Figure 4.9 Earth Points, Transmitter Body

Refer to Table 4.6 for isolated ground connections to be made by user.

Table 4.6 Ground Connections

Terminal	Description
TB2, Pin 11	Isolated ground for User 1
TB2, Pin 16	Isolated ground for User 1
TB2, Pin 21	Isolated ground for User 2
TB2, Pin 22	Isolated ground for User 2
TB2, Pin 27	Isolated ground for User 2
TB2, Pin 32	Isolated ground for User 2
TB2, Pin 23	Chassis ground
TB2, Pin 24	Chassis ground

Note – Do not connect the isolated grounds to the chassis earth; this defeats the isolation the electronics provide. Generally, User 1 and User 2 grounds are not connected to each other. These grounds are intended for separate users. These isolated grounds should be connected as appropriate to the ground where the signals are going.

Communications

The LEFM transmitter supports remote data communications via its three serial communications ports and Ethernet communications (RJ45 or fiber modem). Figure 4.10 shows the locations of the RJ45 (copper) and the MT-RJ (Fiber) connections on the IOP board. Note that the Ethernet connection is electrically isolated from both User groups (e.g., independently isolated).

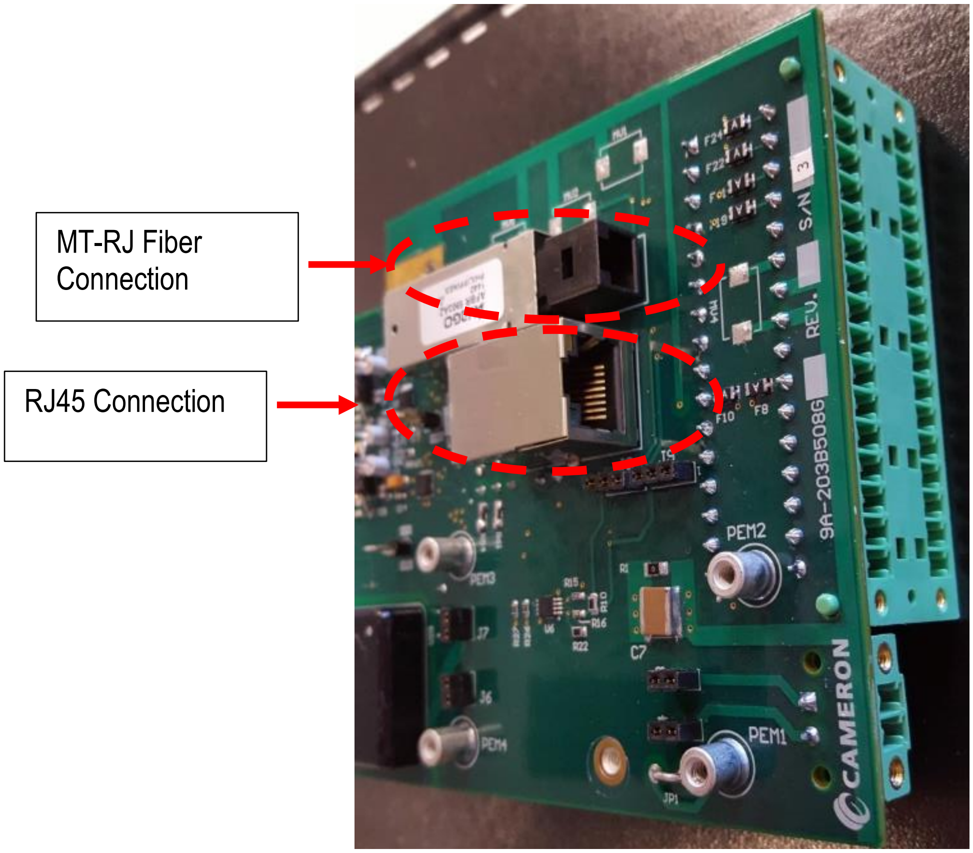


Figure 4.10 Ethernet Locations

Serial Communications – Recommended 16 to 28 AWG wire

The serial communications are Half-Duplex (two-wire). Terminations for serial communications are provided in Table 4.. A typical schematic showing the serial communications is shown below in Figure 4..

Table 4.7 Terminations for Serial Communications

Port Name	Termination		User
COM1	TB2, Pin 1	Transmit/Receive (-)	1
	TB2, Pin 2	Transmit/Receive (+)	1
COM2	TB2, Pin 17	Transmit/Receive (-)	2
	TB2, Pin 18	Transmit/Receive (+)	2
COM3 (Not available with optional HART)	TB2, Pin 19	Transmit/Receive (-)	1
	TB2, Pin 20	Transmit/Receive (+)	1

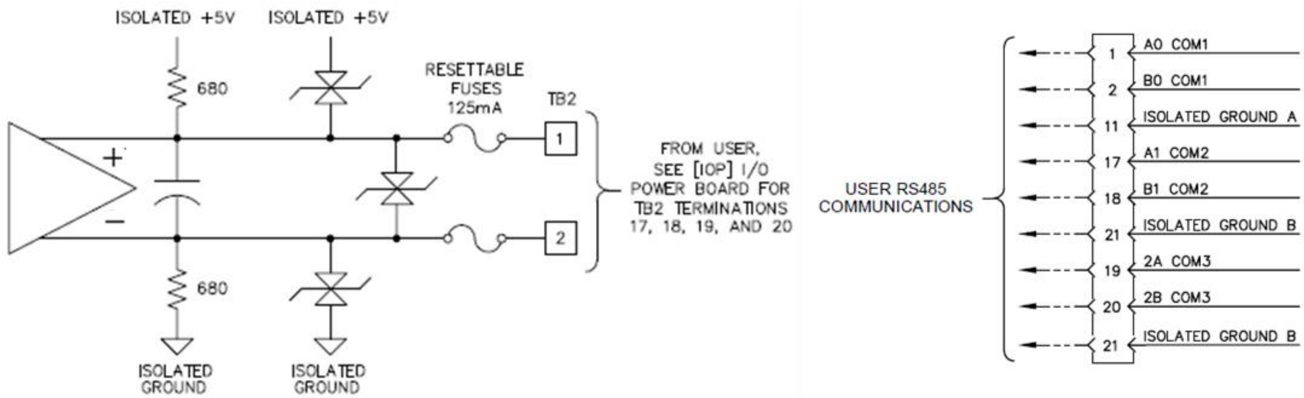


Figure 4.6 Typical Serial Communications

Meter Installation Check-Out

WARNING

Never open the transmitter when it is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so can result in electrical shock or an explosion.

To validate a meter's installation, perform the following procedure. For troubleshooting information, see Section 8, Troubleshooting and Diagnostics.

Verify the meter is oriented with the transmitter on top of the meter body and the upstream hydraulics is adequate. Verify the upstream pipe diameter is concentric with the meter body.

1. Verify all field terminations have proper continuity and isolation from each other and earth. Verify connections are good with respect to insulation.
2. Verify electronics turn on. The two LEDs on the display should be lit and the display is working.
3. Verify Modbus communications are operational. (Use LEFMLink software to test Modbus communications on the RS-485 connection or the Ethernet connection).
4. Verify meter operation according to Section 6, Operations.
5. Use LEFMLink software to force outputs (current and pulses). Verify forced outputs are within 0.1% on current and within 0.01% on pulse frequency. For more information on forced outputs, see the LEFMLink software manual.

Note – Always return the meter to normal operation following the use of forced outputs in Output Test mode.

6. If the pipe is pressurized, use LEFMLink software or Modbus communications to verify the following:

    a. Signals have Rejects < 2% and a Signal to Noise Ratio > 40.
    b. Standard deviations of Paths 1 and 4 are less than 6% (for flowing conditions).
    c. Standard deviations of Paths 2 and 3 are less than 4% (for flowing conditions).

Section 5

Understanding Flow Calculations

Measuring Flow Velocities

LEFM ultrasonic flowmeters use pairs of ultrasonic transducers to send acoustic pulses to one another along a measurement path. The measurement path is at an angle to the fluid flow. The acoustic pulse's transit time depends upon both the velocity of sound (VOS) in the fluid and the velocity of the fluid along the path. The transit time is shorter for pulses that travel downstream with the flow than for pulses that travel upstream against the flow.

$$T_D = \frac{\ell_P}{C_f + V_P}$$

$$T_U = \frac{\ell_P}{C_f - V_P}$$

where T_D = downstream transit time

T_U = upstream transit time

ℓ_p = path length

C_f = velocity of sound in fluid

V_p = flow velocity along the ultrasonic path

V = flow velocity along the pipe axis

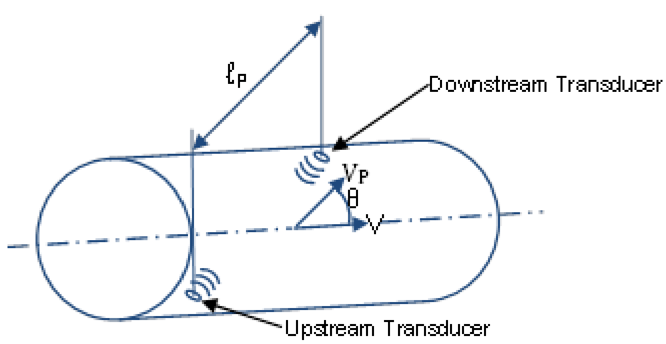


Figure 5.1 Flow Velocities along the Ultrasonic Path and the Pipe Axis

When pulses travel upstream and downstream at the same time, the above equations may be treated as if they are performed simultaneously, and solved for the two unknowns, C_f and V_P.

Solving for V_p and taking into account path angle θ

$$V = \frac{\ell_P}{2\,\mathrm{Cos}\,\theta} \bullet \frac{T_U - T_D}{T_D\,T_U}$$

Using this method, the velocity measurement V_p is independent of the velocity of sound. Consequently, the velocity measurement is unaffected by variations in flow, temperature, density, chemical composition, etc.

Measuring Flow Rate

LEFM Ultrasonic Flowmeters can measure velocities along multiple acoustical paths arranged across the flow pattern in the pipe. The accuracy and repeatability of the flow measurement increases with the number of paths. The acoustic paths of the 380Ci are arranged into two planes. The plane is oriented at an angle Θ (path angle) with respect to the centerline of the pipe. Refer to Figure 5.2 for the acoustical path configuration.

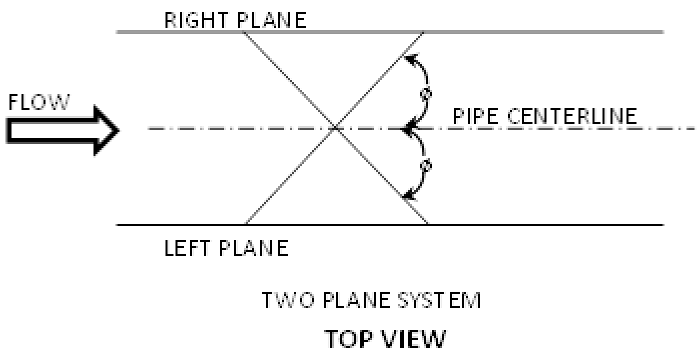


Figure 5.2 Acoustical Path Configuration

During manufacturing, precision measurements of inside diameter (ID), path lengths and path angles are taken and inserted into the equation for volume flow rate. For maximum accuracy, the LEFM 3xxCi automatically compensates for pipe thermal expansion and contraction.

Gross Flow Rate to Net Flow Rate Conversion (Hydrocarbon Gas)

The calculation of volumetric flow rate and total at standard (base) conditions is done externally by a flow computer which meets the current API/AGA/ISO standards for calculation of gas volumes from linear pulse output meters (AGA-7 & AGA-8). The LEFM 3xxCi measures and outputs flow rate and volume at “as measured” (actual) conditions. The output from the LEFM must be sent to a suitable flow computer to calculate the volume at “base” conditions; the values upon which custody transfer or allocation transactions are typically based. The Sensia Scanner family of EFM/RTU flow computers may be used for this function.

Operations

Definitions

SNR – Signal to Noise Ratio

Gain – Required gain to amplify signal

Rejects – Percentage of Data Rejects due to low SNR

VOS – Velocity of Sound

IOP – Input Output and Power Board

CTC – Control and Timing Card

MXR – Multiplexer, Transmitter and Receiver Card

Normal Operating Conditions

If the LEFM is properly installed, the display will begin working when power is supplied to the unit. Two LED indicators, one showing a valid power connection and the other showing the meter is in a "RUN" mode, will illuminate, and the display will show readouts of flow total, flow rate, fluid properties and basic acoustic diagnostic information. If more detailed diagnostic data is needed beyond what is available via the display, consider accessing transmitter diagnostic data via the LEFMLink software.

WARNING

Except when troubleshooting, do not remove the enclosure covers from the transmitter. The diagnostic information is easily read from the display with the covers in place.

Display LEDs

The typical statuses of the LEDs are as follows. (Refer to Section 8, Troubleshooting and Diagnostics for troubleshooting information.)

Table 6.1 LED Diagnostics

LED Number	Color (Typical)	Indication	Normal State
1	Green	Power on	On
2	Green	Operation	On

Display

The transmitter has a 400x240 pixel LCD. The display shows the meter's indicated flow, totalized flow, fluid properties, and diagnostics data.

A user can touch the IR sensor to change the displays. As the user touches the IR sensor, the display will move to the next display. Refer to Figure 6.1 for a typical display sequence. If the user stops interacting with the IR sensor, the current screen will remain on the display for 2 minutes (nominal). The display will revert back to the main screen (display #1) after 2 minutes.

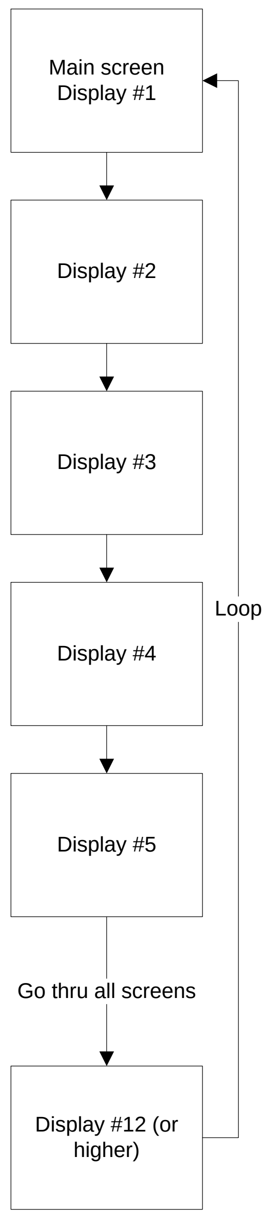
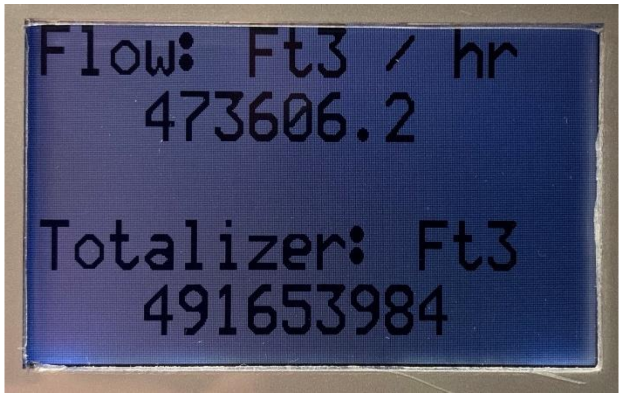


Figure 6.1 Display Sequence

Display 1—Main Display Data



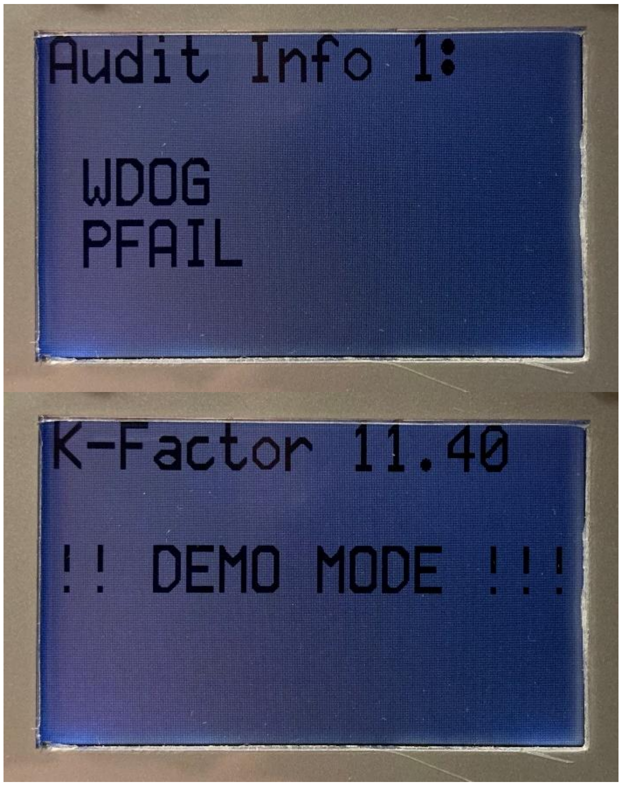
Flow rate units:
Cubic meters/hour –M3/H
Cubic meters/second – M3/S
Cubic feet/sec – CFS

Figure 6.2 Display 1 – Main Display Data

Display 2 — Process Properties

Figure 6.3 Display 2 – Process Properties

Display 3 — Persistent Alarm Summary



Kfactor for the meter shown
Alarms that require user acknowledgement are shown.

These alarms include:
EXE_CKSUM - Executable checksum
CFG_CKSUM - Configuration checksum
NVRAM – "Nonvolatile memory error"
WDOG – "Watch dog reset"
OSCTEST – "Clock accuracy test failure"
PFThresh – "Meter performance failure"
MBTemp "Meter body temperature out of range"

K-factor for the meter shown
If in Demo Mode this is shown

Figure 6.4 Display 3 – Alarm Summary

Display 4—Acoustic Path Data

(Two screens, first for paths 1 through 4 and the second for paths 5 through 8)

Figure 6.5 Display 4 – Acoustic Path Data

Display 5—Acoustic Path Data

(Two screens, first for paths 1 through 4 and the second for paths 5 through 8)

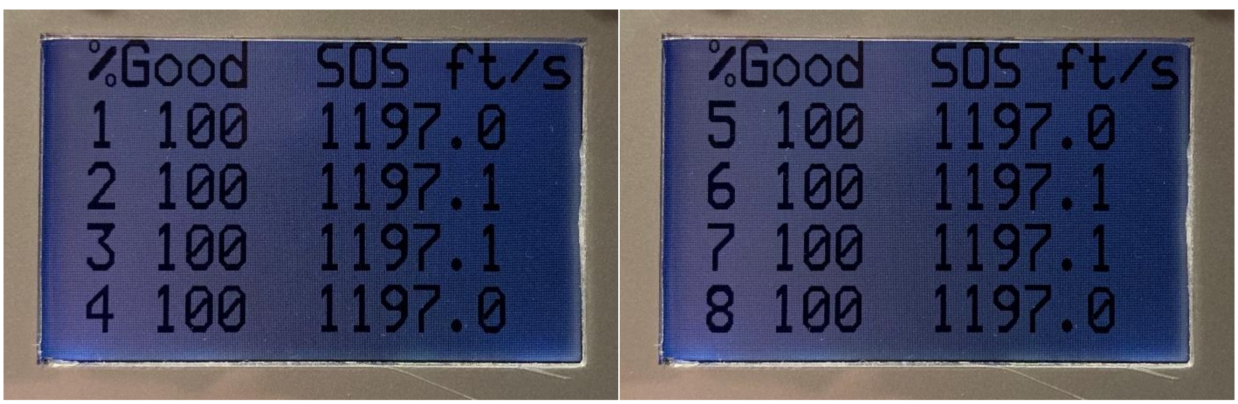


Figure 6.6 Display 5 – Acoustic Path Data

Display 6 —Velocity Data

(Two screens, first for paths 1 through 4 and the second for paths 5 through 8)

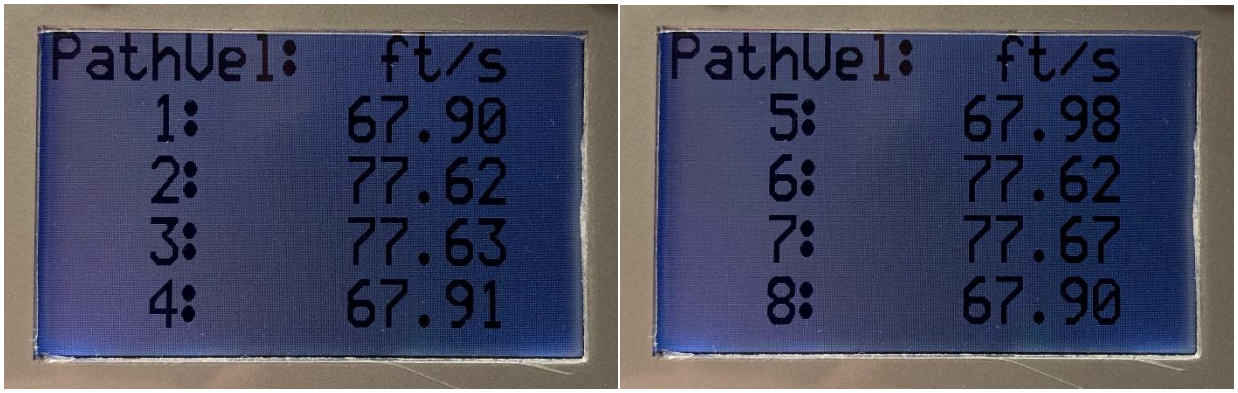


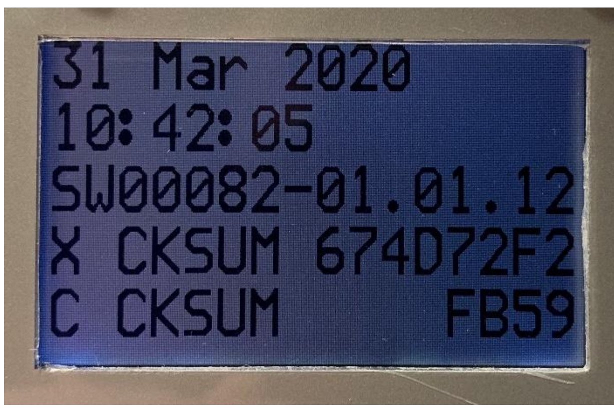
Figure 6.7 Display 6 – Velocity Data

Display 7 —Analog Inputs

Analog Input Measured Channels. States are OK or OOR (out of range)

Figure 6.8 Display 7 – Analog Inputs

Display 8 —Software Information



Software version
(example is SW00082)
Revision
(example is 01.01.12)

Executable checksum
(example is 674D72F2)

Configuration check sum
(example is FB59)

Figure 6.9 Display 8 – Software Information

Section 7

Maintenance

WARNING

Service should be performed on the LEFM 3xxCi only by qualified personnel.

Introduction

The troubleshooting and maintenance procedures in this section may be incorporated into the customer's standard maintenance program. The procedures should be performed only by a trained maintenance technician. For additional assistance from Sensia, please contact:

Measurement Field Service Group
3600 Briarpark Drive
Houston, TX 77042 USA
Tel: +1 281-582-9549

7.1 General Inspections – Preventative Maintenance Procedures

CAUTION

Wear an ESD protective wrist strap to avoid damaging any components.

WARNING

Never open the transmitter or the meter body manifold when the instrument is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so may result in electrical shock and/or an explosion.

The following procedure covers the inspection of the transmitters, transducers, and metering sections.

Enclosure Inspection (perform bi-annually or according to site guidelines)

Perform the following inspections on each enclosure:

1. Verify that the transmitter enclosure and the meter body have suffered no structural damage. Report any damage to the proper maintenance supervisor.
2. Remove dust, dirt, and other soiling from the enclosure. Use a damp cloth to clean surfaces.
3. Remove access covers.
    a. Inspect gaskets. Clean gaskets and mating surfaces on the enclosure with water if they are dirty.
    b. Contact Sensia if there is any corrosion on the mating surfaces.

   c. Verify that gaskets compress when the cover is installed.
   d. Lubricate the cover threads with petroleum jelly for the aluminum enclosures and anti-seize on stainless steel enclosures.

4. Inspect the enclosure mounting.

Internal Electronics Inspection

5. Put on an ESD (Electrostatic Discharge) protective wrist strap. Connect the ESD protective wrist strap to a known earth ground.
6. Inspect cable entry points to assure that cable insulation is free from damage.
7. Inspect cable connections for tightness. If connections are fouled or corroded, clean with electronic contact cleaning fluid.
8. Inspect all internal connections and terminals for tightness. If connectors and terminals are fouled or corroded, clean with electronic contact cleaning fluid.
9. Inspect the display for damage.

7.2 Transmitter Troubleshooting

Perform the following inspections on the transmitter to isolate a problem.

WARNING

Never open the transmitter when the instrument is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so may result in electrical shock and/or an explosion.

CAUTION

Wear an ESD protective wrist strap to avoid damaging any components.

1. With the unit energized, verify that power is being supplied to the meter and that the meter is operating.
2. When the flowmeter is operating normally, the LEDs (LED 1 & 2) should be illuminated.

Always verify that the “Power On” LED (LED 1) is active before troubleshooting a component.

Troubleshoot an error condition by checking the following lights in the order listed:

1. **If LED1 is out:**
   Implies that the 24 VDC power has failed. All the LEDs and the display should be off in this instance. Investigate the cause (e.g., loss of power to site). Another possibility is that extreme power surges damaged the protection circuits in the IOP. Check the IOP for fuses that may be blown and replace as necessary. The IOP also has surge protection circuitry that may be damaged.

   If LED2 is on and the display is on but the power LED is off then this indicates that the supply voltage is outside of the allowable input range and the meter should not be used.

2. **If LED2 is out and LED1 is lit:**

   This implies the transmitter is powered but not running. Observe the display. If serial or Ethernet communications are functioning, confirm that the device has a valid setup file (Note – the software will not run if the setup file is corrupted). A bad setup file is annunciated on the display and in the Modbus registers. If the setup file is acceptable, then review the power supply voltages on the MXR and CTC (via Modbus registers). If these power supply values are within specification, then contact Sensia's Measurement Systems division.

7.3 Circuit Board Replacement

The transmitter comprises three basic subassemblies. Refer to Table 7.1 for a description of each subassembly's components.

Table 7.1 Circuit Boards

Circuit Board Name	Description/Function
Input/output and Power Supply (IOP)	Provides galvanically isolated digital outputs, analog output/input and communications. Converts 24 VDC power to internal voltages, which are passed to the CTC/MXR to power the electronics. Provides fused connection to power (Fuse F25).
CTC and Display	Performs all flowmeter processing. Contains the display and communicates with the MXR and IOP.
Acoustic Board (MXR)	Interfaces with transducers, excites and receives acoustic signals.

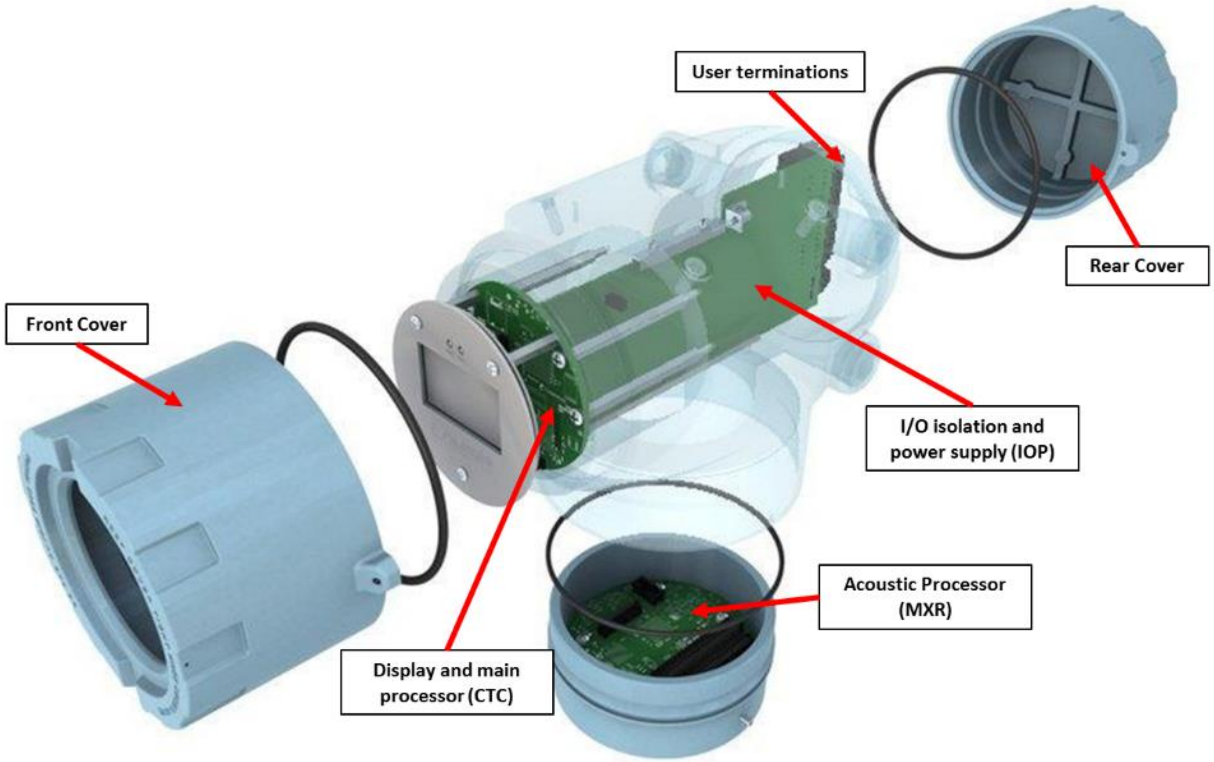


Figure 7.1 Transmitter Components

7.4 IOP – Input/Output and Power Supply Board or Power Fuse Replacement

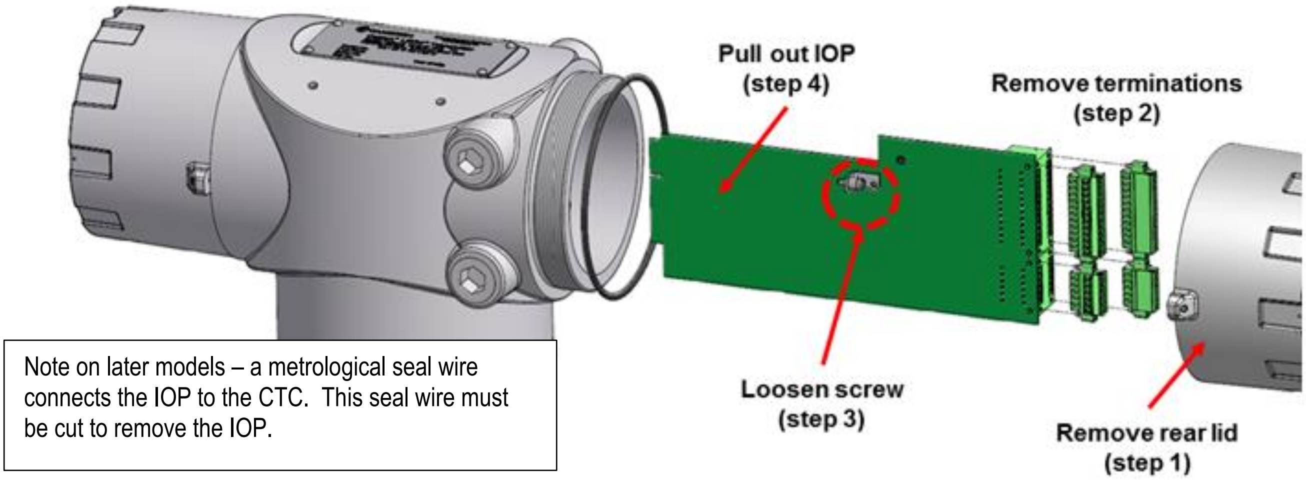


Figure 7.2 Disassembly Views for IOP Replacement

WARNING

Never open the transmitter when the instrument is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so may result in electrical shock and/or an explosion if in a hazardous area.

If any component on the IOP assembly fails (other than the fuse), the entire assembly is to be replaced. To replace the IOP, perform the following steps, referring to Figure 7.2 for hardware locations.

1. Loosen the 2 mm hex set screw on the rear enclosure. Unscrew and remove the rear lid of the enclosure.

CAUTION

Use proper grounding straps on personnel before handling any circuit boards.

2. Remove all user terminations or terminal blocks such that the board can be fully accessed.

   See Section 7.5 for removal/reinstallation of the enclosure's front cover. For later models, there is a metrological seal that connects the IOP to the CTC (plastic wire). This wire must be cut to remove the IOP.
3. Viewed from the back, there is a screw towards the top of the IOP that holds the IOP to the enclosure. Loosen the screw until it is disengaged (a captive screw).
4. Grasp the edges of the IOP and gently pull the IOP out of its connection with the CTC board. If the IOP fuse **only** needs to be replaced, proceed to the next step. If the entire IOP needs to be replaced, skip to step 7.

5. Locate the IOP/F25 fuse. (Note – the fuse protects the electronics from errant wiring of power to 120/230 VAC). The F25 fuse is on the same side of the IOP board as the plug-in connectors, near the power inputs (TB1). Refer to Figure 7.3 below.

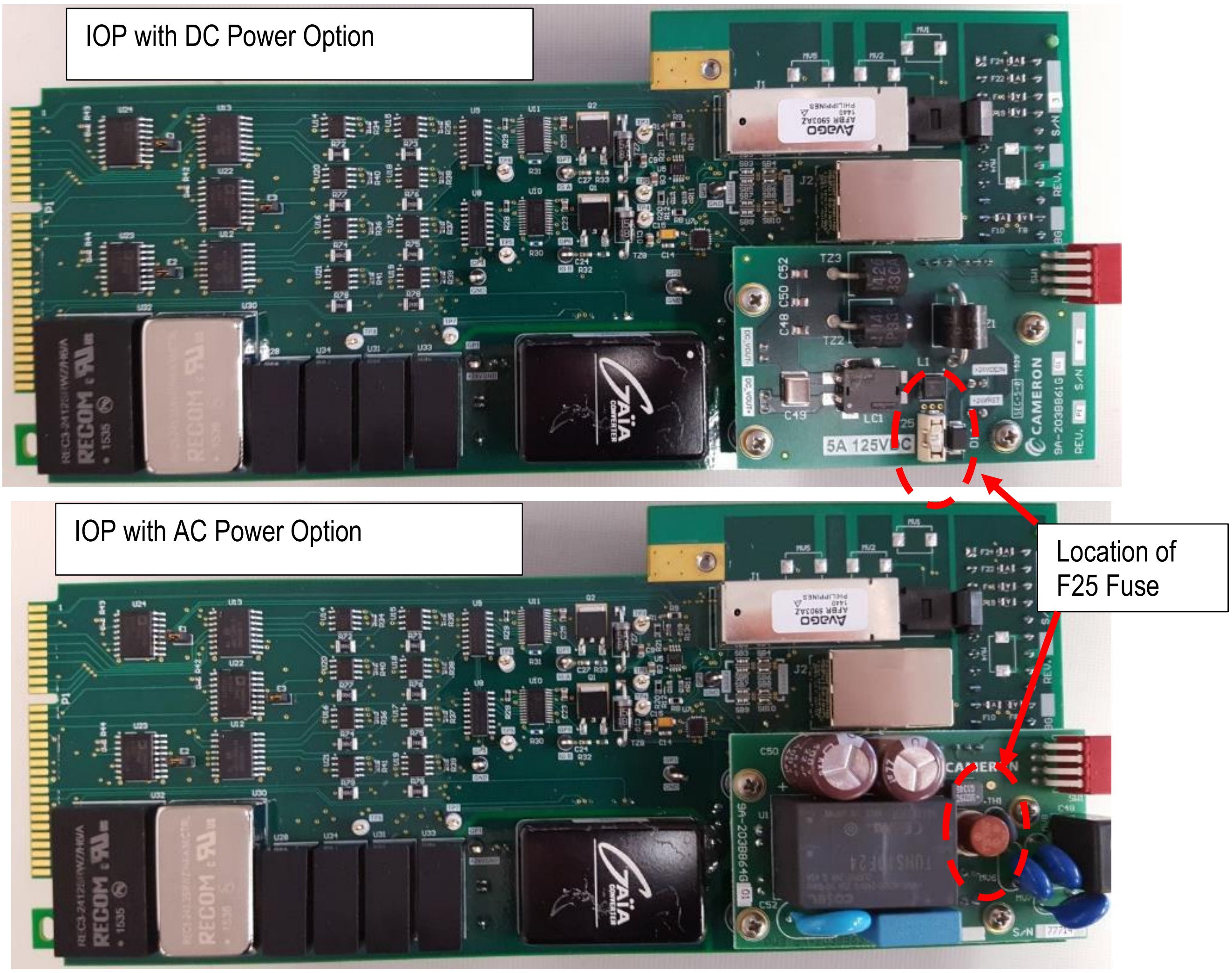


Figure 7.3 Location of IOP/F25 Fuse

6. Remove the F25 fuse with tweezers or needle nose pliers.

   DC Option: Only use Littelfuse Series 454 - Part Number 0454-005 (5 amp rating) as a replacement fuse. Skip to step 8.

   AC Option: Only use Littelfuse Series - Part Number 37412000430 (2 amp rating) as a replacement fuse. Skip to step 8.

7. Remove the new IOP from its packaging. Place the old IOP into this packaging for proper storage.

8. Align the IOP with card guides. Slide the IOP down the guides until it engages the connector of the CTC. Firmly push the IOP so that the connector seats (DO NOT FORCE).

   See Section 7.5 for removal/reinstallation of the enclosure's front cover. For later models, there is a metrological seal that needs to be reinstalled to connect the IOP to the CTC (plastic wire).

9. Viewed from the back, tighten the screw that holds the IOP to the enclosure.

10. Reattach all user terminations or terminal blocks. Confirm that all connectors' flanges are tightened and all terminations are in a secure condition.
11. Screw the rear lid of the enclosure back on. This should be hand tight with at least 8 full turns of the lid. Tighten the setscrew on the lid.

7.5 CTC and Display Replacement

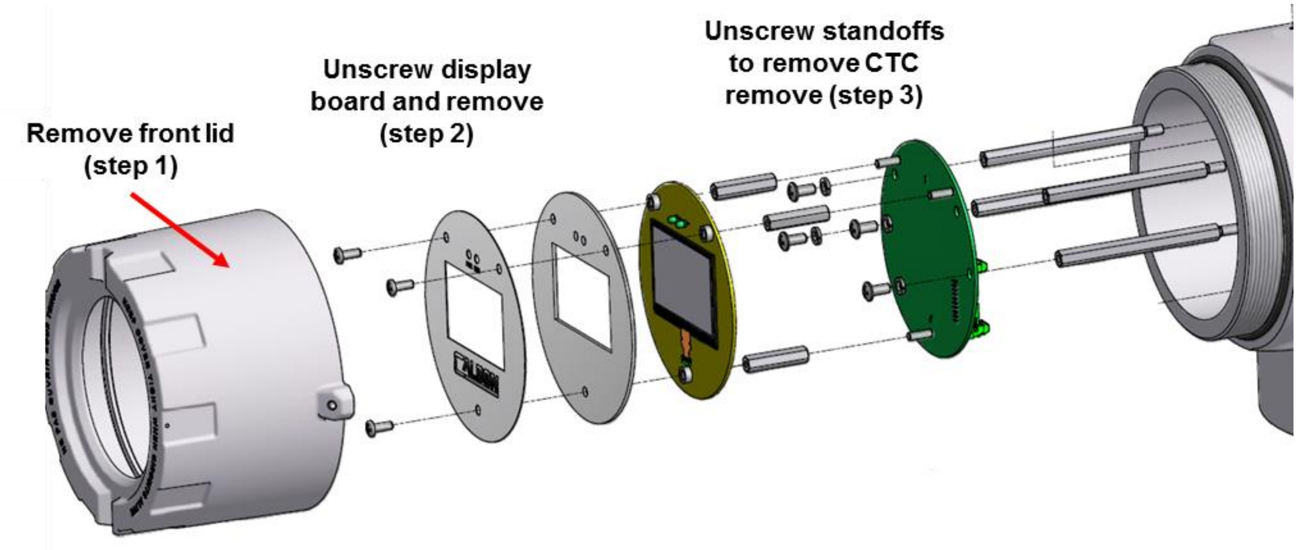


Figure 7.4 Disassembly Views for CTC and Display Replacement

WARNING

Never open the transmitter when the instrument is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so may result in electrical shock and/or an explosion if in a hazardous area.

WARNING

The transmitter has a real time clock that has battery backup. It is recommended to replace the complete circuit board if the battery ever fails. Do not replace the battery alone. It must be replaced with the identical battery and it must never be changed in a hazardous location area.

The CTC and Display assembly consists of two component boards. The individual component boards are not designed for individual replacement. Rather, if any component on the CTC and Display assembly fails, the entire assembly is to be replaced.

To replace the CTC and Display assembly, perform the following steps, referring to Figure 7.4 for hardware locations.

1. Loosen the 2mm hex set screw on the front enclosure. Unscrew and remove the front cover from the transmitter.

CAUTION

Use proper grounding straps on personnel before handling any circuit boards.

2. Unscrew the Display board from the CTC. Grasp the edges of the Display and gently pull to lift it from the CTC. If the display is faulty, replace the Display and skip to step 6. Otherwise, put Display into an anti-static bag for later use.
3. Unscrew the four screws to free the CTC assembly from the transmitter body and lift the assembly from the enclosure. On the rear of the CTC, disconnect the ribbon cable from connector P1.

   For newer versions of the IOP (see previous section) – there may be a metrological seal wire (plastic) connecting the IOP and the CTC. This plastic wire will need to be cut/broken.
4. Remove the new CTC from its packaging. Place the old CTC into this packaging for proper storage.
5. Connect the ribbon cable to the back of the CTC card. Gently press the CTC assembly onto the IOP connector. Refer to Figure 7.5 below for a view of the routing path.

   For newer versions of the IOP (see previous section) – there may be a metrological seal wire (plastic) to be reinstalled to reconnecting the IOP to the CTC.

CAUTION

Ensure the ribbon cable is routed to the right side of the IOP board when looking from the CTC end of the enclosure. If not routed properly, the ribbon cable can get pinched by the IOP/CTC connector.

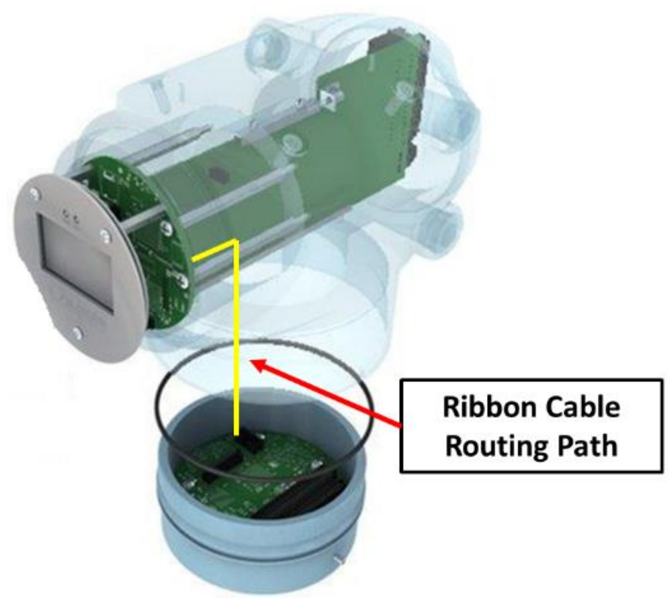


Figure 7.5 MXR-CTC Ribbon Cable Routing Path

Reinstall the four screws that were removed in step 3, screwing them into the holes provided in the CTC board.

6. Reattach the display by aligning the connector on the rear of the display board to connector P2 on the CTC.
7. Reinstall the three screws that secure the Display Board to the CTC.

8. Screw the front lid of the enclosure back on. This should be hand tight with at least 8 full turns of the lid. Tighten the 2 mm hex set screw on the lid.

CAUTION

Following replacement of the CTC board, the "safe mode" readout may appear in the transmitter display. This is an indicator that the configuration data has not been uploaded to the transmitter. See Reprogramming the Transmitter in Section 8 for instructions on downloading the configuration file.

7.6 MXR Replacement

WARNING

Never open the transmitter when the instrument is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so may result in electrical shock and/or an explosion if in a hazardous area.

If any component on the MXR assembly fails, the entire assembly is to be replaced. To replace the MXR, perform the following steps, referring to Figure 7.6 for hardware locations.

Phase 1 – Disconnecting the Ribbon Cable from the CTC

Note – The ribbon cable must be removed from the CTC card to disassemble the enclosure. So the first steps are merely to remove the ribbon cable. Follow Section 7.5, steps 1 through 3 in order to disconnect the ribbon cable.

Phase 2 – Removing the Top Portion of the Transmitter to Expose the MXR

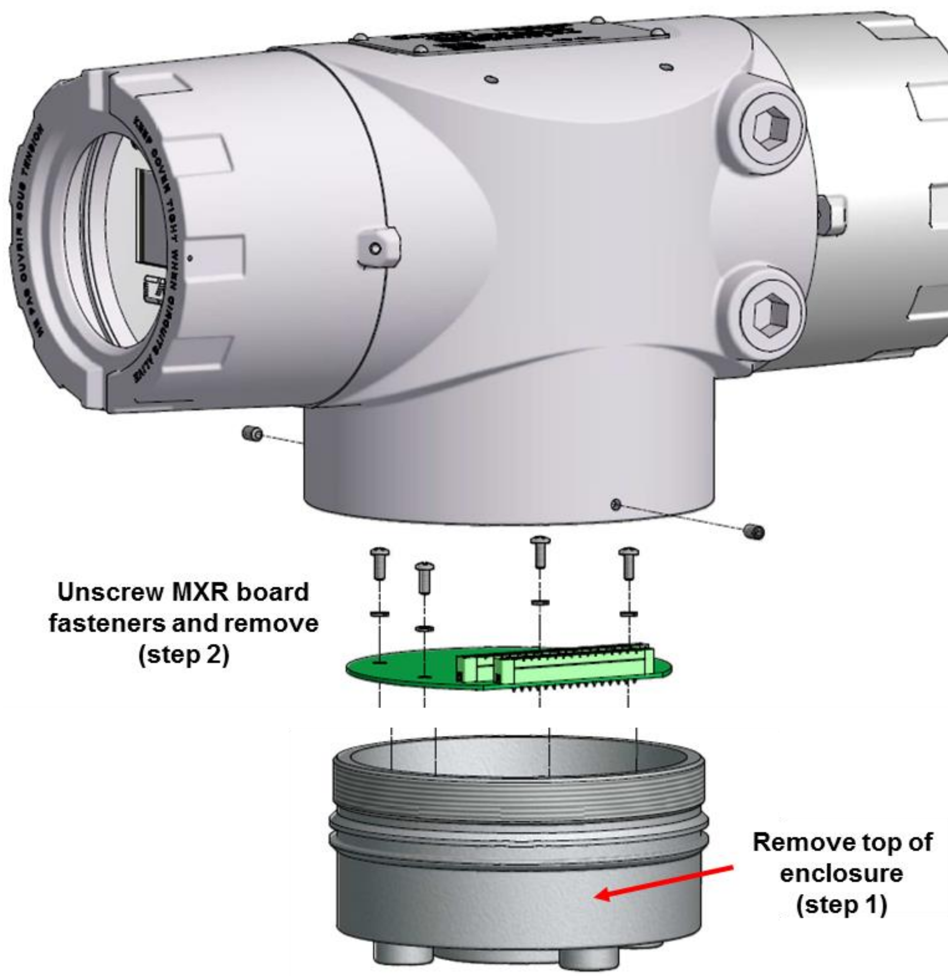


Figure 7.6a Disassembly Views for removing MXR

Figure 7 Disassembly Views for removing MXR

1. Loosen the two setscrews on the top of the enclosure. Unscrew and remove the top lid of the enclosure. Note – this may require disconnecting any conduit attached to the transmitter (in order to spin the head).

CAUTION	**Use proper grounding straps on personnel before handling any circuit boards.**

2. For MXR shown in Figure 7.6a, loosen the transducer wires connector flanges (two connectors) and disconnect both connectors. Push the transducer wires/connectors to the side so that the MXR can be removed. Remove ribbon cable from P1 connector. For MXR shown in Figure 7.6 b, disconnect both ribbon cables coming from the pipe nipple. Slide the ribbon cables to the side so that the MXR can be removed.

3. Remove the MXR board fasteners (qty 4). Grasp the edges of the MXR and gently pull to lift it from the enclosure.
4. Remove the new MXR from its packaging. Place the old MXR into this packaging for proper storage.
5. Align the MXR onto its standoffs in the top lid of the enclosure and reinstall the four screws that were removed.
6. Reattach the ribbon cable and the transducer wire connectors. Tighten the connector flange screws and inspect/confirm the wire terminations have not been loosened.
7. Screw the top lid of the enclosure back on with at least 8 full turns of the enclosure. Once fully threaded on, reinstall the setscrews. Turn the enclosure to face the proper direction and tighten the setscrews. Note – the setscrews can only fully tighten if the enclosure has been threaded to the bottom range of its threads.

Phase 3 – Reconnecting the Ribbon Cable to the CTC

Follow Section 7.5, CTC and Display Replacement, steps 5 through 8, to reconnect the ribbon cable to the CTC.

7.7 Transducer Installation

WARNING

Never open the manifold / transducer cover when the instrument is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so may result in electrical shock and/or an explosion.

Manifold O-rings should NOT be installed or replaced without appropriate guidance from Sensia.

Should a transducer fail, install a replacement using the following procedure, referring to Figure 7.8 and Figure 7.9 Transducer Replacement (Single Transducer Enclosure Style Meter) Figure 7.9 for hardware locations and descriptions:

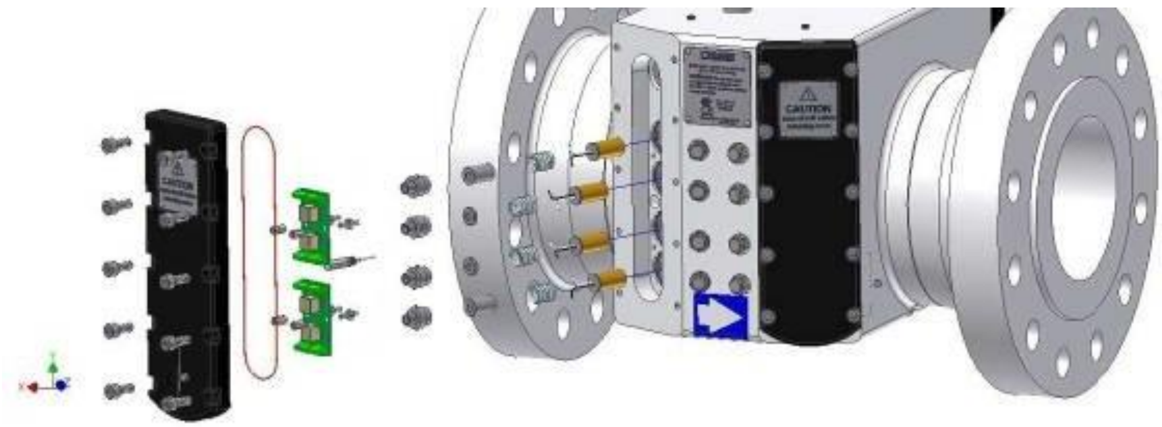


Figure 7.8 Transducer Replacement (Manifold Style Meter)

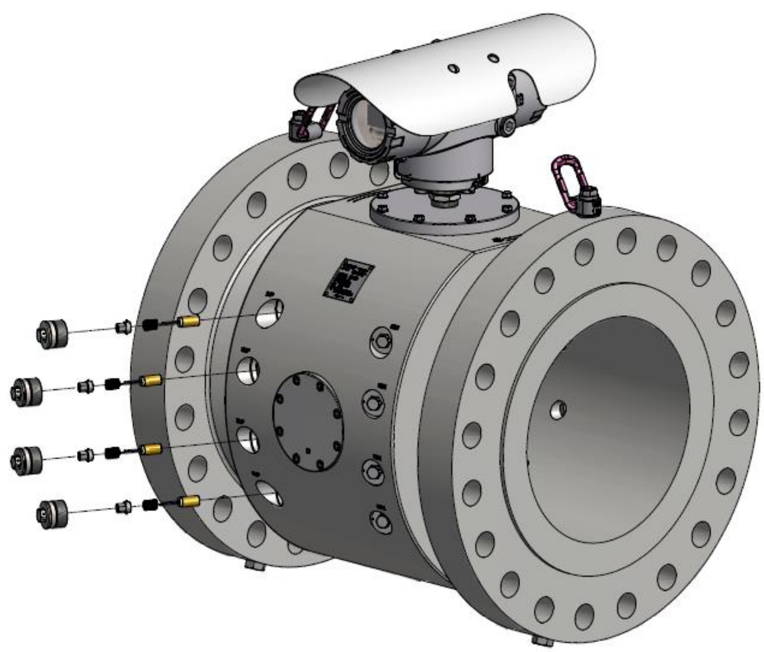


Figure 7.9 Transducer Replacement (Single Transducer Enclosure Style Meter)

1. Remove the socket head screws (M6 hex wrench) from the manifold cover and remove the manifold cover to reveal the transducer wiring, transformers, and transducer housings. Alternatively, for the single transducer enclosure style meter, remove the transducer cover.

Note – Removal of the covers requires the removal of the security seal. Once the cover is re-installed, a new seal should also be installed.

2. For manifold style meters disconnect the transducer leads from the transformer terminal block. If necessary, remove the transformer circuit board, shown below in Figure 7.10. For the single transducer enclosure style meter, the solder joint must be cut to remove the transducer.

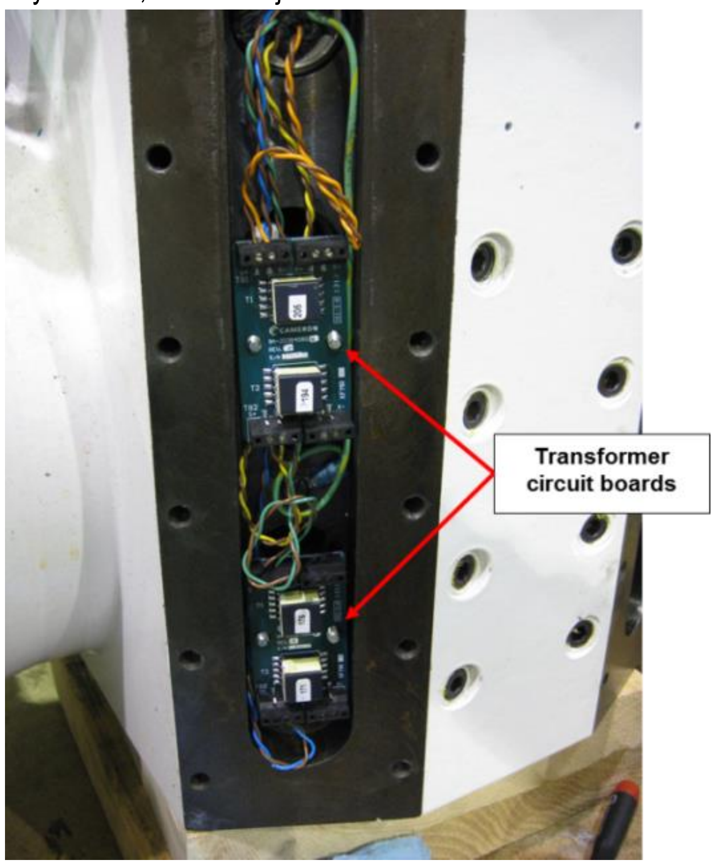


Figure 7.10 Transformer Circuit Boards

Remove the compression plug retaining the transducer by pushing in and turning clockwise to release (pliers might be helpful to get a grip on the knurled head). Figure 7.11 shows the notches that will need to be aligned before the transducer can be re-installed (pins on the sides of the compression plug go into the notches).

Refer to Figure 7.12 for a view of the transducer being removed.

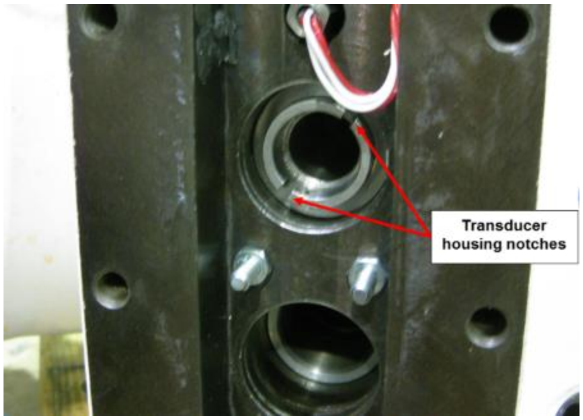


Figure 7.11 Transducer Housing

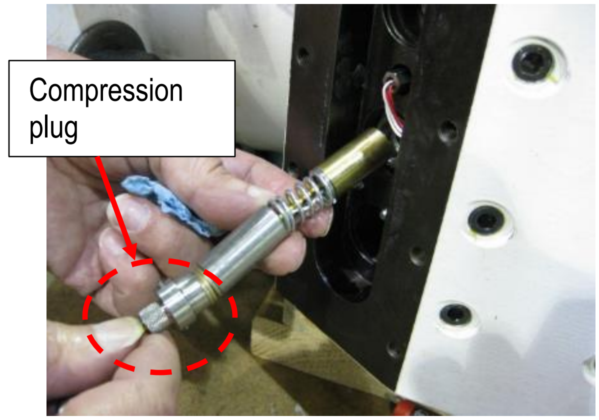


Figure 7.12 Transducer Removal

WARNING

Do not remove the transducer housing retaining components. The mechanical hold downs must not be modified particularly while the meter is under pressure.

Note – The transducer housings use a retaining system of components. If removing a transducer, site personnel should never attempt to remove the retaining rings located around the transducer. This maintenance shall only be done by Sensia trained technicians. See Figure 7.13 for details.
The transducer housings are pressurized and use two locking rings to keep the housing in place. Specialized tools and trained personnel are required to remove the housing.

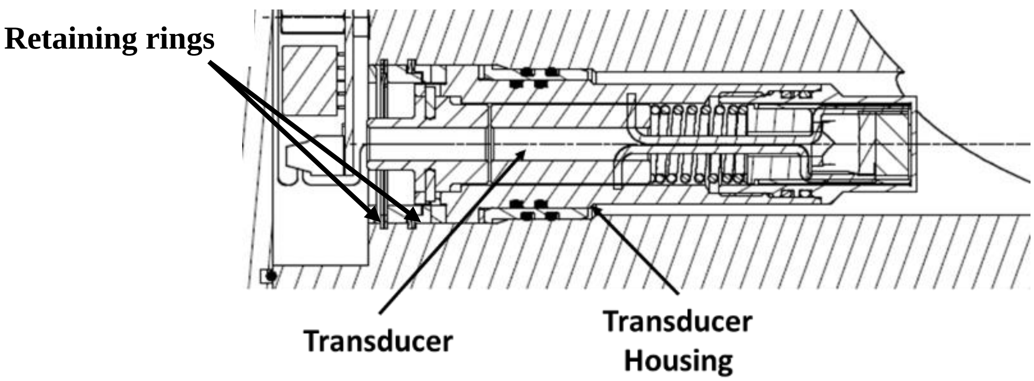


Figure 7.13 Transducer Housings

3. Remove the transducer internals by a steady pull on the transducer wires.
4. Verify the transducer housing is clean and free from dirt. Clean as necessary.
5. Re-install the transducer internals as follows, referring to Figure 7.14.
    a. Route the wires of the new transducer though the compression spring, the spacer, and the compression plug.
    b. Apply silicone grease to the transducer face.
    c. Insert the transducer and components into the housing until the parts bottom out.
    d. Re-install the compression plug by pushing it in and rotating it counter clockwise to secure the transducer assembly in the housing notches.

Figure 7.14 Transducer Internals

6. On manifold style meters connect the new transducer leads to the transformer terminals and reinstall the transformer circuit board if it was removed. For single transducer port meters, solder the wires to the existing wire harness; ensure the joint is covered with shrink tubing.
7. Re-install the cover(s).
8. On Manifold style meters Torque the socket head screws to 100 and 180 in-lbs (11.3 to 20.3 nm).

Note – The LEFM 3xxCi system may require that the acoustic performance be verified when a transducer is replaced or re-coupled. Refer to Section 8, Troubleshooting and Diagnostics.

7.8 Analog Input Verification

The LEFM 3xxCi may have an analog input (for example, temperature, or pressure). The input signal is conditioned before it is converted to a digital input.

The input is scaled linearly to convert the user input of 4-20 mA (or 0-20 mA) to maximum and minimum values. Analog input ranges can only be adjusted via the LEFMLink software interface (see the LEFMLink manual for instructions).

Failed inputs result in readouts at their lowest range. For example, a 4-20 mA pressure input scaled to 0-1000 psig will go to 0 psig if the input is removed.

7.9 Analog Output and Pulse Output Verification

The digital output channels consist of an analog output and a pulse output. The current output channel has a 0-20 mA range. The pulse output has a range of 0 to 5V or 0 to 12V. There are no adjustments to be performed for the analog or pulse outputs. The analog output can be mapped to any Modbus input register for maximum flexibility. By default, the analog output is mapped to read flow.

Force Output (Analog)

The analog output is scaled linearly between its maximum and minimum values. Use the force output function of LEFMLink software to test the scaling of the analog output with input site devices. See the LEFMLink manual for detailed instructions.

Force Output (Pulse)

Similar to calibrating the analog outputs, a fixed frequency may be forced out of the transmitter pulse output. To verify the pulse output using a forced output, follow the instructions in the LEFMLink Manual.

Troubleshooting and Diagnostics

Diagnostics

The LEFM transmitter display provides basic diagnostic information. Additionally, more detailed diagnostics are available via software download with serial ports or an Ethernet port. The transmitter's serial and Ethernet ports use the Modbus protocol. Sensia's LEFMLink software allows the user to interface with the transmitter via Modbus.

Note – Modbus registers can be edited to change the configuration of many LEFM parameters. However, these instructions are outside the scope of this manual. Throughout this section, values such as path SNR (Signal to Noise Ratio), Gain, etc. are discussed in reference to the LEFMLink Software. Modbus register addresses will not be addressed.

Online configuration is not permissible when using the device as a functional safety device and the configuration should be locked as per Section 9.

The following screen capture depicts the interface software. The layout of the LEFMLink software may vary. Please refer to the LEFMLink manual for more information.

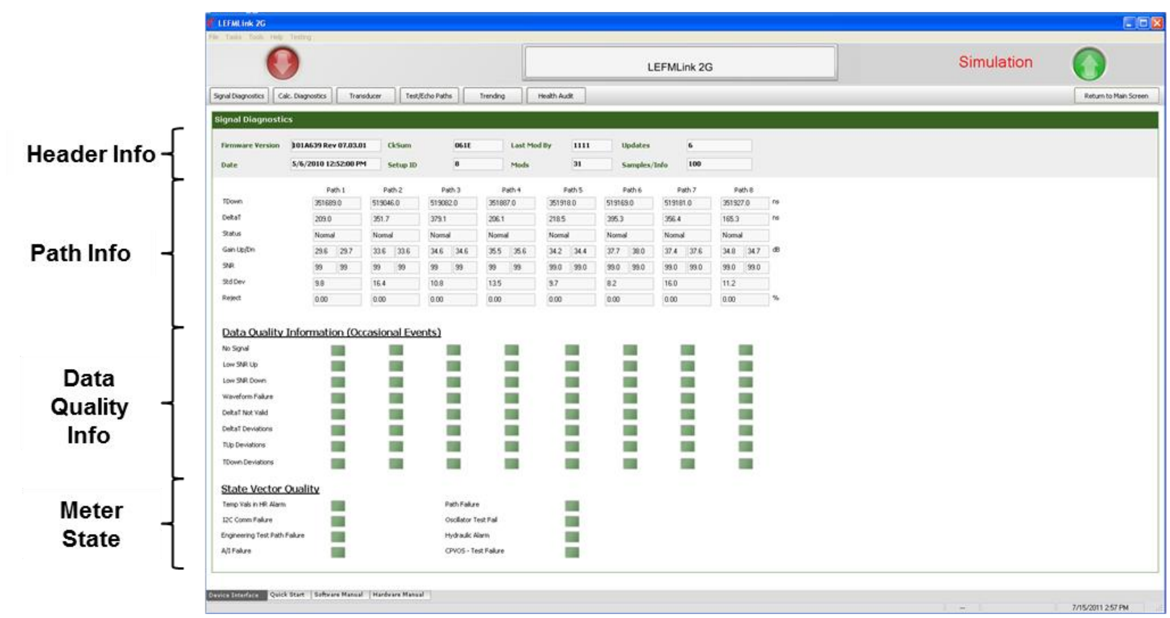


Figure 8.1 Diagnostic Screen

In order to access the above screen shown in Figure 8.1, click on the Signal Diagnostics tab.

For troubleshooting ultrasonic signals, the most frequently used diagnostic parameters are shown below in Table 8.1.

Table 8.1 Acoustic Signal Diagnostics

Diagnostic Parameter	Range	Typical Values for Normal Operation
Rejects (%)	0 to 100%	0 to 5%
Performance (%)	0 to 100%	95 to 100%
Gain	20 to 70dB	20 to 60dB
SNR	0 to 4000	20 to 500

Alarm Conditions

The LEFM 3xxCi's automatic fault detection system is specially designed to verify the performance of the transducers and transmitter electronics and to alert personnel when abnormal operating conditions are detected.

It detects faults in three basic steps:

1. The system checks the data quality for ultrasonic paths and evaluates the data against thresholds. Data evaluation is based on signal to noise ratio (SNR), cross-correlation tests, and signal statistics.
2. The transmitter confirms the self-consistency of the sound velocities computed by each path.
3. The transmitter confirms the velocity profile parameters. The parameters are FR (Flatness Ratio), Swirl, Plane Balance (relative results of the two planes of the flowmeter), and AR (Asymmetry Ratio or the balance between the top of the meter and the bottom of the meter).

The transmitter outputs the current status via the Ethernet port, serial port, and digital outputs. The displayed status may be any of the following:

- NORMAL
- F-PATH Failed paths (flow is computed with a possibility of lesser accuracy)
- F-VOS Failed Sound Velocity (path sound velocity spread is out of range)
- F-PROFILE Failed Profile (one or more of the velocity profile tests out of range)

Note – 1, 2, 3, 4, or 5 path failures lose no accuracy for custody transfer applications when operating conditions do not change significantly.

Automatic Fault Detection

The LEFM transmitter continuously checks the data quality of each acoustic path for detecting faults. Each time the signal is sampled, the transmitter tests the signal as follows:

1. The LEFM checks the quality of data collected from the ultrasonic signals and evaluates it against pre-set thresholds. The data is evaluated based on SNR, cross-correlation tests, and signal statistics.
    - The LEFM verifies whether the path's SNR is higher than its threshold value.
    - The LEFM correlates the Upstream Signal with the Downstream Signal to test for "cycle skipping." The processor rejects data that does not pass this correlation test.
    - The LEFM verifies the computed transit time and Delta T are acceptable.

Note – The LEFM will reject data occasionally; this will not influence the operation. If an ultrasonic path rejects data continuously, the LEFM will alert the operator with an "ALARM" status and an error code.

2. The processor outputs the individual path status codes through a digital output and Modbus. LEFMLink software interprets these codes and displays a text message. The individual path status codes are:
    - Path operating normally
    - Invalid or Pre-Valid, the processor is still searching and validating data for the path.
    - Path sound velocities are inconsistent with thresholds (typically a 0.15% spread between paths is acceptable).
    - Path velocity inconsistent at low flow rates
3. The processor outputs the current meter status through a digital output and Modbus. The meter status is identified as one of the following:
    - "NORMAL" (status bit is at 5 volts or 12 volts)
    - "ALARM" – 1 or more paths failed; flow is computed with a slightly greater uncertainty (status bit is at 0 volts)
    - "ALARM" – All Paths Failed; flow is set to zero (status bit setting is the same as for "NORMAL"). Note, the software can be configured to go to zero flow when only one or two paths function.

Path Performance Status

When the path status indicates a failure ("Pre-Valid" or "Invalid") the percentage of good data that has been accepted fails to meet LEFM thresholds. Use the following troubleshooting sequence to pinpoint the cause.

1. Verify that the meter body is pressurized. If there are liquids in the line, bottom paths may fail.
2. Verify continuity of all cable connections.
3. Check the display. If the display reports "Configuration File Needed" or "Flowmeters", the transmitter needs to be reprogrammed or the CTC board requires replacement. Refer to Section 7, Reprogramming the Transmitter.

4. Check the acoustic signal. Check path gains via Modbus or LEFMLink software. If the path gains are high (65 dB or higher), the signals may be too weak to be detected. Weak signals can be caused by any of the following (listed from most likely to least likely):
    - The line contains liquid.
    - The line pressure is too low.
    - The cable/wire from the meter to the transmitter is damaged.
    - The transducer coupling needs to be replaced (with grease couplant only).
    - The transducer has failed.
5. Review the SNR for each path (paths 1 through 8).
6. Review the gains for each acoustic path (both upstream and downstream). The gains are typically between 20 dB and 70 dB. Gain is dependent on pressure, composition, velocity, and temperature. It will vary as conditions change. Upstream and downstream gain should nominally be within 12 dB of each other.
7. Review the performance data for each path. The percent accepted data should be between 95 and 100%.

Remember the following troubleshooting tips:

- If all paths fail, the meter has low pressure, significant liquid, or an electronics hardware failure has occurred.
- If a path has 0% accepted valid data, the transmitter cannot lock onto a signal. The cables or transducers should be investigated for potential failure.
- If an acoustic signal does not exist, or if SNR has degraded from installation, follow the checklist below:
    1. Verify the pipe contains no liquid.
    2. Check the continuity of transducer cable in the manifold.
    3. If a signal is present, consider reseating the ultrasonic transducer or replacing the acoustic coupling. Refer to Section 7.7.

Reprogramming the Transmitter

Before each transmitter leaves the factory, it is preprogrammed to work with the meter body with which it will be installed. This information is stored within a configuration file that is maintained by Sensia. The file includes the following information:

- Pipe size
- Pipe transducer frequency
- Acoustic path lengths
- Calibration constant
- Alarm settings
- K-factor
- Analog input/output scaling

Should the processor in the transmitter fail and require replacement, the transmitter must be reprogrammed with the appropriate configuration file using Caldon's LEFMLink software (for PC). The procedure is as follows:

1. Download the LEFMLink User Manual from Sensia's Measurement Systems website for reference.
2. Connect the serial interface cable between a COM port on the PC and the transmitter.
3. Select the appropriate Modbus ID and baud rate using LEFMLink software. All transmitters are initially programmed with a Modbus ID of 1, and a baud rate of 19200 with RTU Slave Mode.
4. Select the configuration file for the meter.
5. Send the configuration file. The transmitter will be reprogrammed.

LEFM 3xxCi and 3xxCi-R Metrological Seals

CAUTION

The physical properties, acoustic properties, and calibration of the meter body are pre-programmed into the transmitter; therefore, the programming of the transmitter must be controlled. Failure to control transmitter's programming can result in erroneous flow measurements outside the stated accuracy.

As a precaution the LEFM 3xxCi design allows for seals to control programming the transmitter or altering the meter body.

To ensure control of the electronics programming, a switch on the front of the transmitter can be engaged, preventing configuration changes. The transmitter with cover removed is shown in Figure 9.1 below. If the electronics switch SW1-4 is configured to the left (closed), the electronics cannot be reprogrammed (irrespective of passwords). Using this switch combined with the seal wire on the transmitter enables full metrological control of the system.

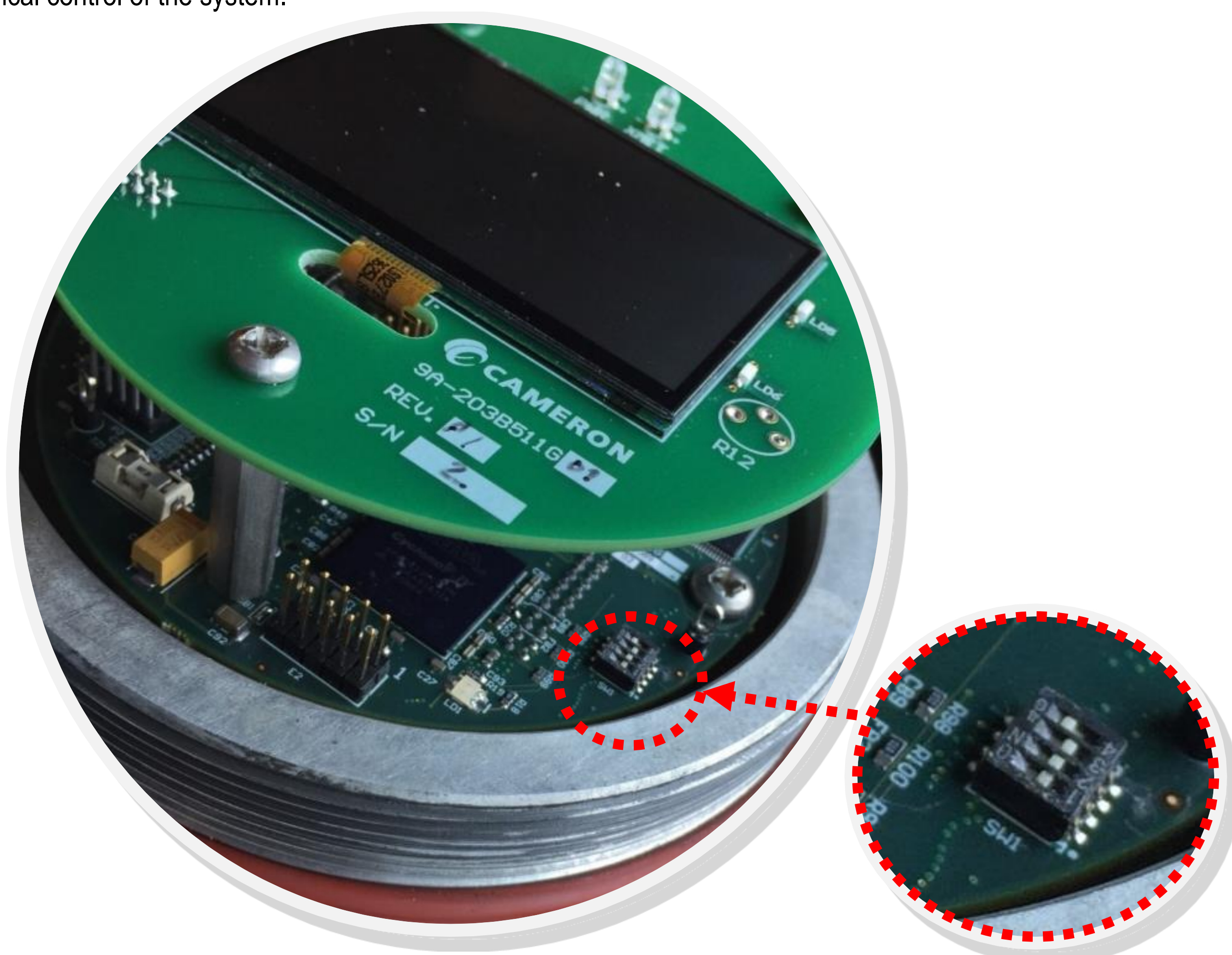


Figure 9.1 Transmitter, Front Cover Removed – SW1-4 Set to prevent changes

(shown without tamper evident seal for clarity)

Figure 9.2 shows the seal wire on the transmitter (wire goes from the front cover to the main body). A properly installed wire seal prevents undetected entry into the transmitter.

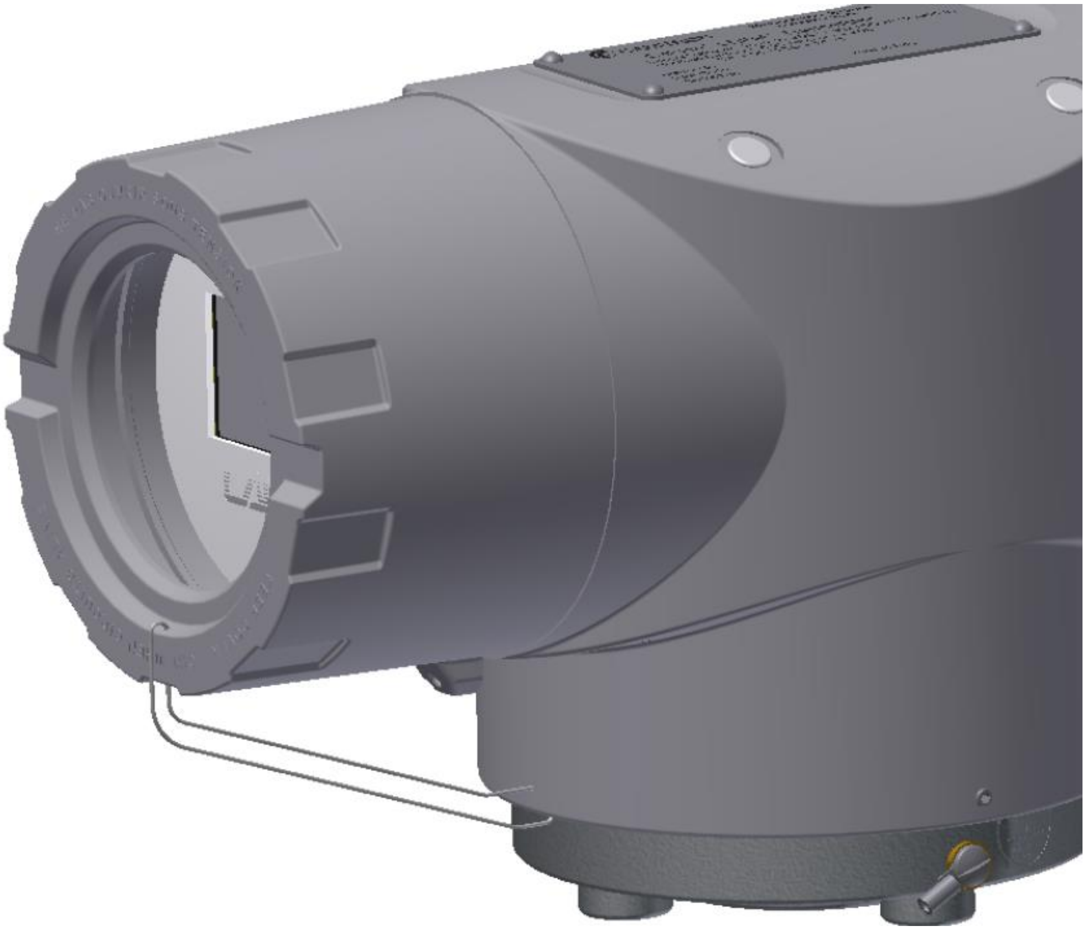


Figure 9.2 Front Lid only - Seal Wire on Transmitter Enclosure

The circuit boards also have a tamper evident seal. Figure 9.3 shows the seal between the IOP and the CTC (the enclosure is not shown for clarity). The front lid seal and lid must both be removed to in order to access this seal.

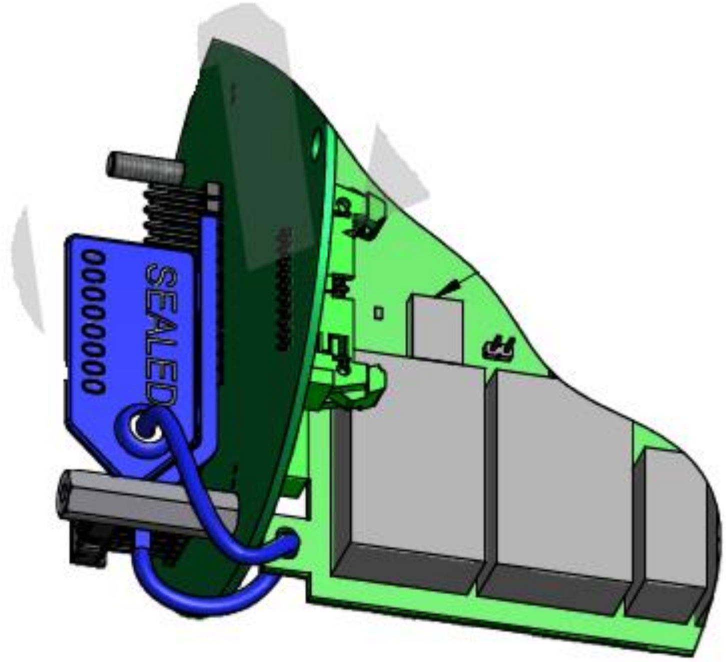


Figure 9.3 IOP Tamper Evident Seals

The meter body has a seal wire on the fasteners for the manifold cover or on the transducer cover. The seal wire allows the meter owner to verify if there has been any tampering with the meter body. Refer to Figure 9.4 or Figure 9.5.

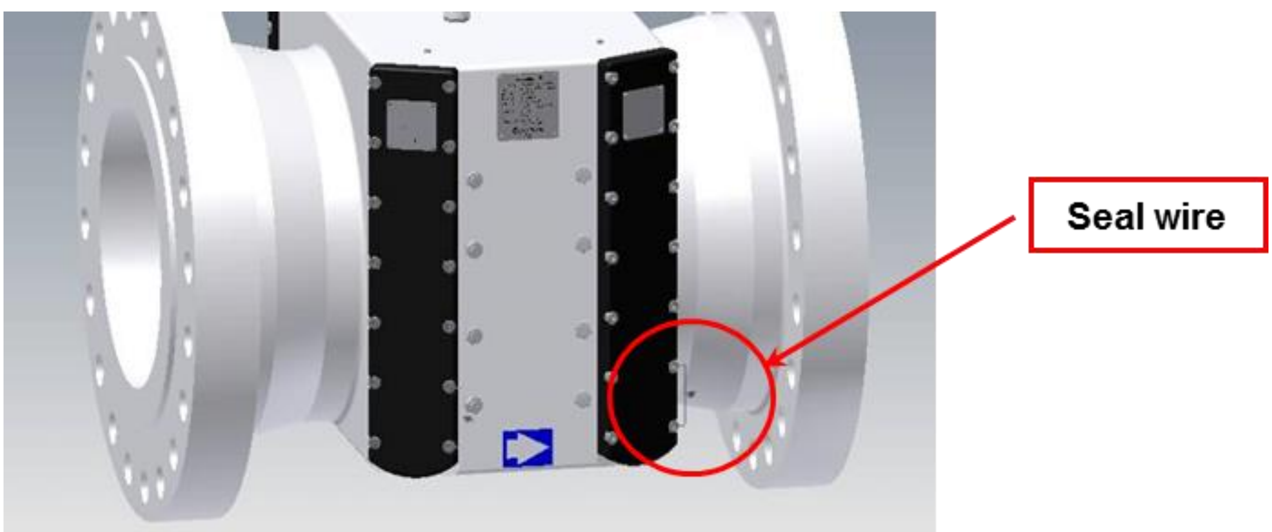


Figure 9.4 Seal Wire on Meter Body

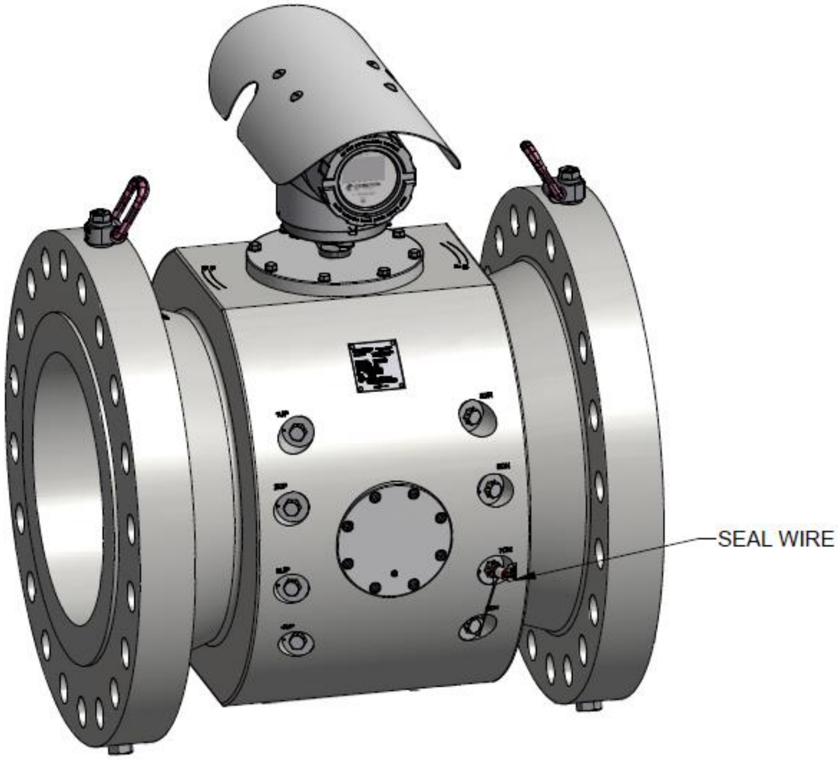
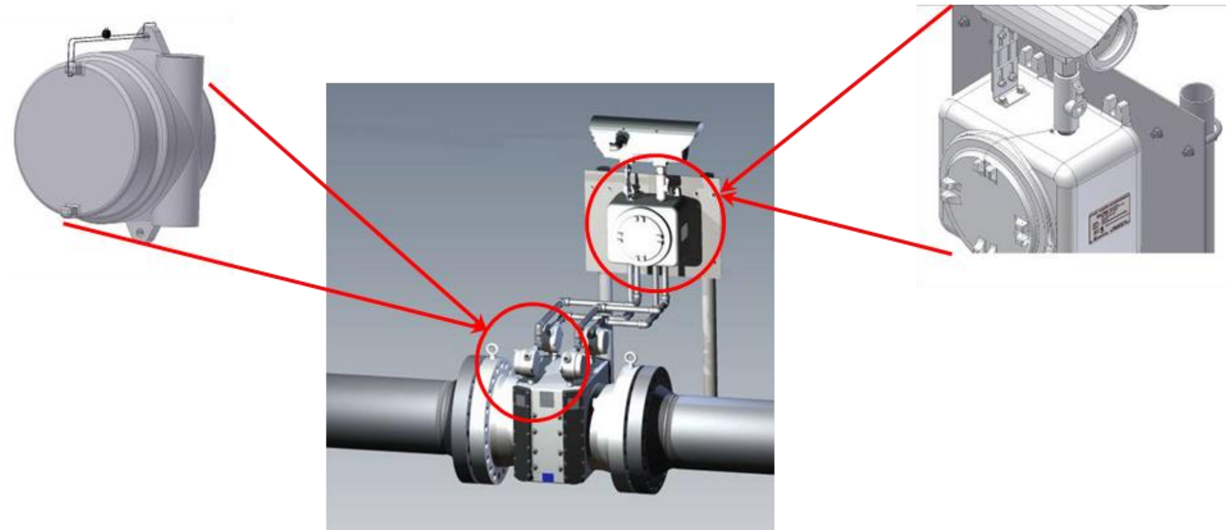


Figure 9.5 Seal Wire on Meter Body

The remote mount configuration, shown in Figure 9.6, has seal wires for all the junction boxes used in the system.



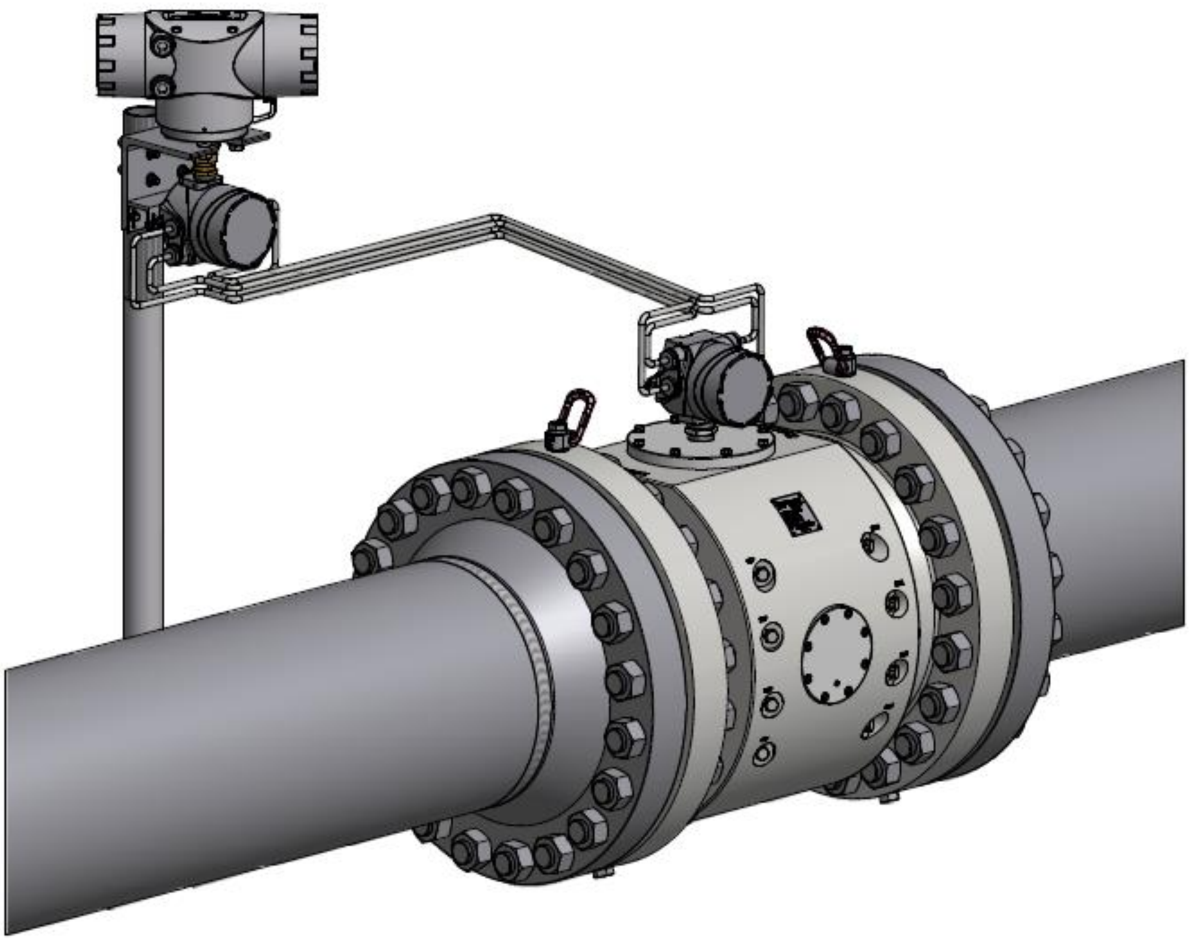


Figure 9.6 Seal Wires for Junction Boxes

Section 10

Secondary Seals and Seal Failure Indication

Secondary Seals

Some versions of the 3xxCi LEFM flowmeter have been designed to comply with the requirements of UL standard 12.27.01, "Requirements for Process Sealing between Electrical Systems and Flammable or Combustible Process Fluids". Specifically, the meter has an indication when an O-ring fails to meet its specifications.

All transducer housings have been designed and built with 2 sets of seals. The first and primary seal set retains the process gas. If the first seal set were to fail, the secondary seal exists to prevent gas from entering into the electrical compartments and to redirect that gas out through a vent.

For meters built to comply with UL 12.27.01, a special vent has been designed to vent gas if all seals were to fail – this provides a visual indication of a seal failure. If a seal were to fail, the vent has a plunger that deploys at the location of the failure. Refer to Figure 10.1 below.

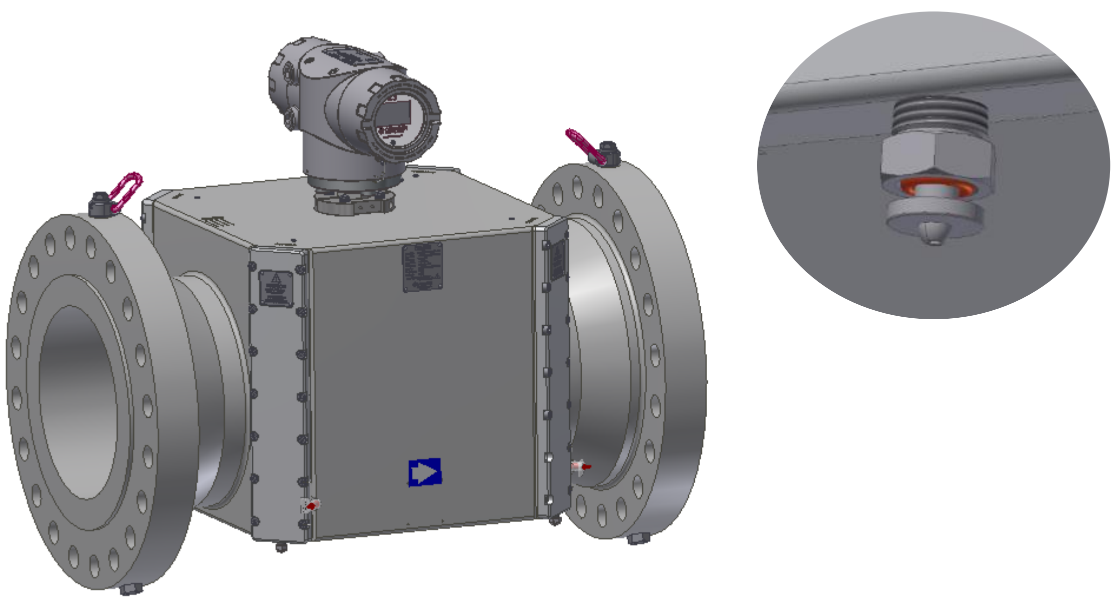


Figure 10.1 Primary Seal Failure Indication

Section 11

Recommended Spare Parts

Transducer Equipment

Qty: 2	Transducer (9A-101A850G24 or equivalent)
Qty: 1	Transducer Couplant (small tube)

Electronic Equipment

Note: The CTC card, MXR Card and the IOP Card can be customized for a given customer. Please contact Sensia to order spares with your meter's model code or serial number. Sensia can then send the correct group number to your site.

Qty: 1	Display Board (9A-203B511G01)
Qty: 1	CTC Board (9A-203B502G0x)
Qty: 1	IOP Board (9A-203B508G0x)
Qty: 1	MXR Board [Legacy] (9A-203B505G0x)
Qty: 1	MXR Board [NextGen] (9A-204B020G0x)
Qty: 1	Transformer Board [Legacy] (9A-203B408G01)
Qty: 1	Transformer Board [NextGen] (9A-204B029G01)

Installation Equipment (Optional)

Qty: 2	Hoist Rings (See Section 2 for part numbers)

Note – The printed circuit boards contain electrolytic capacitors. To ensure proper operation of these components, perform a functional test on them at least once every 5 years. Contact Sensia for instructions.

Section 12

Functional Safety

This section of the manual is relevant where the LEFM is being used in accordance with the SIL Certification only. For guidance or to report any safety related failure, contact Sensia:

Sensia Ultrasonics Technology Center
1000 McClaren Woods Drive
Coraopolis, PA 15108 USA
Tel 724-218-7800
Email ms-services@sensiaglobal.com

Safety Function

The functional safety aspects covered in this manual are:

- Continuous self-diagnostic
- Output via current output 4 to 20 mA

The LEFM measures volumetric flowrate and generates a proportional analogue signal which is output in the form of a 4 to 20 mA current.

The error state for the output is indicated by a current output of 3.6 mA.

It is user responsibility to program the logic solver to detect any failures (high or low) regardless of the effect, safe or dangerous, on the safety function. If a fault occurs that causes the output to indicate a fault, then the following scenarios apply:

- If the value is between 3.95 and 20.5 mA then the meter will indicate the corresponding flowrate.
- The max current output value is clamped at 20.5 mA. Anything over 20.5 mA indicates a fault.
- If the system tries to produce a value < 3.95 mA then it will display 3.8 mA, the meter will continue to operate however the output is out of range.
- A value of ≤ 3.6 mA indicates that the meter is in failure.
- If the value is 0 mA then there is no power and the meter is not measuring.

The HART protocol is only to be used for setup, calibration, and diagnostic purposes, not for safety critical operation.

The following values are specific to the safety function and does not reflect the metrological performance of the flow meter.

Safety Accuracy = 2%
Safety Response Time = 1 second
Worst case internal fault detection time = 1 hour
Diagnostic test interval = 1 second

Firmware

The firmware version is preset before the LEFM leaves the factory and should only be changed under the direct guidance of Sensia.

The latest Firmware version for new shipped meters will be SW000082 Rev. 01.01.12. The display Checksum for this firmware version is 674D72F2.

The current firmware version can be checked by the following methods:

1. Checking the transmitter display. Display 8 of the default cycle shows software information including checksum.
2. Connect to external software and check displayed version, e.g. LEFMLink2G or USM Advisor.
3. Get the executable checksum via Modbus to verify.

Standards

- IEC 61508, Functional safety of electrical/electronic/programmable electronic safety-related systems, 2010.

Related Documents

- IB1504, LEFM G3 Modbus User Manual.
- SEN 20-05-127 R001 V2, FMEDA Report.
- IB0910, LEFMLink2G User Manual
- USM Advisor User Manual

Definitions

Abbreviation	Term	Definition/Description
SIL	Safety Integrity Level	One of four levels which corresponds to a value range of the safety integrity. Within safety integrity SIL 4 is the highest level with SIL 1 the lowest level.
SIS	Safety-Instrumented System	A system composed of any combination of sensor(s), logic solver(s), and final element(s), including communication and ancillary equipment designed specifically for the purpose of executing Safety Instrumented Functions (SIF),

MTBF	Mean Time Between Failure	Mean Time Between Failures
MTTF	Mean Time to Failure	Mean Time to Failure
MTTR	Mean Time to Restoration	Mean Time to Restoration consisting of: - Time of detecting an incident. - Time to start repairing. - Actual repair time. - Time of restoring the service of the repaired component.
LEFM	Leading Edge Flow Meter	Instrument that uses ultrasonic signals to measure flow rate.
Diagnostics	Diagnostics	Data produced surplus to primary flow measurement to allow advanced analysis of system and hydraulic performance.

Useful Lifetime

The useful life of the electronics is based on which components contribute to dangerous undetected failures as determined by FMEDA. The component of concern has been determined to be a capacitor and given a useful lifetime of 90,000 hours. Further details can be found in the FMEDA report conducted by Exida, report number SEN 20-05-127 R001 V2. Please contact Sensia to obtain a copy of this report if required.

Component	Useful Life
Capacitor (electrolytic) – Aluminum electrolytic, non-solid electrolyte	Approx. 90,000 hours

Proof Test

A proof test can be carried out by the user to determine that the safety function is operating as intended and if not then the system should be returned to “as new” condition by repair. This is a requirement of IEC 61508.

Frequency of proof tests should be determined by the end user however it is recommended that these tests are carried out whenever a change is made to the process that may impact the flowmeter.

A suggested proof test is included in the FMEDA report conducted by Exida which will detect 84% of Dangerous Undetected Failures.

Report number SEN 20-05-127 R001 V2. Please contact Sensia to obtain a copy of this report if required.

Functional Safety Parameters

The Caldon G3 electronics are classified as a Type B element according to definitions in IEC 61508-2 and have a Hardware Fault Tolerance of zero (HFT-0). The product has a systematic capability of defined as SC 2.

The device has a Safe Failure Fraction of between 60% and 90% as determined during FMEDA, this is dependent on the connected logic system being programmed to detect over-scale and under-scale currents. This is a responsibility of the end user to ensure this is implemented to meet the SFF.

Note: When used as a functional safety device the Caldon G3 electronics are limited to an altitude of 1600 meters as per the FMEDA analysis. This supersedes any other guidance in this manual for non-functional safety applications.

Refer to the FMEDA report conducted by Exida for full failure rate details. Report number SEN 20-05-127 R001 V2. Please contact Sensia to obtain a copy of this report if required.

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