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Rockwell Automation + Schlumberger

CALDON® ULTRASONICS

LEFM® 2xxCi Family of Ultrasonic Flowmeters with G3 Transmitters

User Manual & Safety Manual

Manual No. IB1402 Rev 17

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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 2xxCi. 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 Sensia's Measurement Systems division, Caldon Ultrasonics.

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

Section 1

Introduction

Equipment Description

The LEFM 2xxCi[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 2xxCi can be configured to indicate direction of flow via either a quadrature pulse output or a digital signal.

The LEFM 2xxCi 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 2xxCi provides easy-to-interpret diagnostic information via Modbus communications and the local display.

This manual provides detailed instructions on the installation and operation of the flowmeter including 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 2xxCi 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 display and acoustic data processing electronics.

Typically, the transmitter is mounted to the meter body and tested 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 or extreme vibration at the meter body. This manual covers three different models or configurations. These models are described as follows:

> **Models 2xxCi and 2xxCiRN**: For the models 220Ci, 220CiRN, 240Ci, 240CiRN, 280Ci and 280CiRN, the transmitter is mounted to the meter body (refer to Section 2 for meter body installation and Section 3 for transmitter installation). This model has a factory installed seal between the transmitter and the meter body.
>
> **Models 2xxCi-R**: The character "R" indicates that the transmitter is mounted remotely from the meter body (see Section 3 for transmitter installation). This model has a factory installed seal between the transmitter and a junction box for terminating cables from the meter body.
>
> **Models 2xxCiLT-R**: The "LT" indicates that the meter is built for low temperature operation. In this case, the meter body is likely to see extreme temperatures (see Section 3 for transmitter

[1] The term 2xxCi encompasses all versions of the liquid ultrasonic flowmeters. Specifically, the 220Ci (two path), 240Ci (four path) and 280Ci (8 path) models are covered. Further, different meter body configurations are covered. These include the full bore version and the reduced bore version (RN model).

installation) and the design has reduced volume electrical compartments. Further, the design uses rigid conduit to put the hazardous location seals in a benign environment.

This model has a factory installed seal between the transmitter and a junction box for terminating cables from the meter body. Additionally, the meter body has factory installed seals.

Models 2xxCi-R and 2xxCiLT-R require that the transmitter be mounted separately from the meter body. In those instances the transmitter(s) and meter body are shipped separately.

LEFM 2xxCi Meter Body

The meter body or *metering section*, as it is sometimes referenced, contains up to eight pairs of acoustic transducers and a temperature sensor (RTD). Refer to Figure 1-1 below for a depiction of the meter body and transmitter assembly.

The meter body is a specially designed section of pipe that contains multiple pairs of housings that are positioned to provide acoustic paths[2] typically at a 45° 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 between 1.0 and 3.5 MHz). The transducer modules may be removed from their housings for maintenance while the meter body is installed without affecting the pressure boundary.

The 2xxCiRN meter has a specially designed reducer section in the meter body. This reducer design allows the meter to operate linearly at low Reynolds Numbers (e.g., high viscosities) and to prove better against displacement provers (e.g., ball provers and small volume piston provers).

[2] 8 paths for the 280Ci, 4 paths for the 240Ci and 2 paths for the 220Ci meters

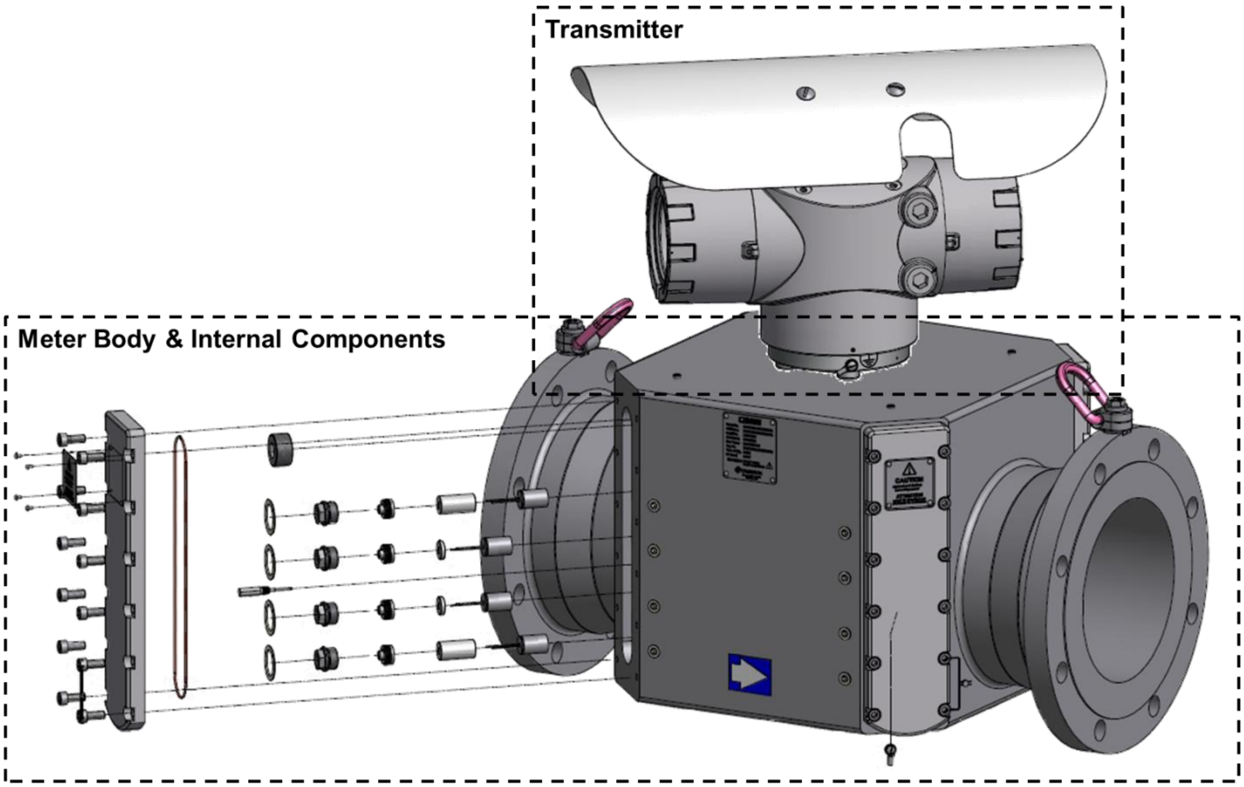


Figure 1-1 Example of 2xxCi Meter Body and Transmitter Assembly (shown with optional sunshield)

G3 Transmitter

The transmitter houses the display that provides readouts of flow data including flow rate, total flow volume, fluid 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
- Compute flow
- Compute gross to net flow conversions
- Generate pulse outputs and analog outputs

The transmitter offers the following inputs/outputs:

- Three analog inputs (optional; choose from 4-20 mA). Choose from the following:
  - Product temperature
  - Product pressure
  - Product density
  - Product viscosity
- Two analog outputs (optional; choose from 4-20 mA)
  - Flow

  - Any Modbus Register (See Modbus manual)
- Communications
  - Up to three RS485 ports (half duplex) – Modbus RTU
  - Ethernet port (via Copper or Fiber) with Modbus TCPIP
  - Optional HART channel (operates on second analog output)
- Digital Outputs
  - Status (Qty 4)
  - Standard volume pulse outputs (Qty 4)

The K-factors used to configure transmitters at the factory are listed below in Table 1-1 and Table 1-2. The user may configure the K-factor to meet their needs.

Table 1-1 Standard K-Factors, 220Ci, 240Ci, and 280Ci Meters

Size		Maximum Flow BPH	K-Factor (P/bbl)	Maximum Flow m^3/h	K-Factor (P/m^3)
Inches	DN				
4	100	2,050	2,000	325	12,600
6	150	4,650	1,000	740	6,300
8	200	8,150	500	1,290	3,150
10	250	12,800	350	2,030	2,200
12	300	19,300	250	3,070	1,570
14	350	23,600	200	3,750	1,000
16	400	28,700	150	4,560	940
18	450	41,000	100	6,500	630
20	500	50,000	85	7,900	530
24	600	72,000	60	11,500	380
26	650	87,000	45	13,900	280
28	700	100,000	40	16,200	240
30	750	115,000	35	18,700	220
32	800	130,000	30	21,300	185
34	850	150,000	25	24,200	165
36	900	165,000	25	27,200	145
40	1,000	205,000	20	32,600	125

Table 1-2 Standard K-Factors, 240CiRN and 280CiRN Meters

Size		Maximum Flow BPH	K-Factor (P/bbl)	Maximum Flow m^3/h	K-Factor (P/m^3)
Inches	DN				
6	150	3,210	2,000	510	12,600
8	200	5,660	2,000	900	12,600
10	250	8,870	1,000	1,410	6,300
12	300	12,710	500	2.020	3,150
14	350	15,100	350	2,400	2,200
16	400	19,900	350	3,165	2,200
18	450	25,540	250	4,060	1,570
20	500	31,075	200	4,940	1,000
24	600	45,230	150	7,190	940
26	650	54,665	100	8,690	630
28	700	63,690	100	10,125	630
30	750	73,540	85	11,690	530
32	800	83,760	85	13,315	530
34	850	95,145	60	15,125	380
36	900	106,940	60	17,000	380

Model Numbers

Meter Body Model Number - 2xxCi and 2xxCiRN Models Only

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, flange rating/style, and enclosure type.

MODEL NUMBER CODE: LEFM 2BC-X-D-E-F-G-H-J-K-L-M-N-P-Q-R

B = 20 FOR 2 PATH METERS
B = 40 FOR 4 PATH METERS
B = 80 FOR 8 PATH METERS

C = Ci-G3 FOR INTEGRAL ELECTRONICS
C = Ci-R-G3 FOR REMOTE ELECTRONICS AND 1 J-BOX PER MANIFOLD
C = CiRN-G3 FOR INTEGRAL ELECTRONICS WITH REDUCED BORE
C = CiRN-R-G3 FOR REMOTE ELECTRONICS WITH REDUCED BORE AND 1 J-BOX PER MANIFOLD
C = Ci-RB-G3 FOR REMOTE ELECTRONICS AND 1 J-BOX FOR WHOLE METER
C = CiRN-RB-G3 FOR REMOTE ELECTRONICS WITH REDUCED BORE 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 = A FOR WELDED MANIFOLDS
H = B FOR MANIFOLDS INTEGRAL WITH METER BODY
H = C FOR MANIFOLDS INTEGRAL WITH METER BODY AND SEAL OFF BLOCK
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 = A FOR WELDED DESIGN TRANSDUCER HOUSING
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 = L FOR LIQUID TRANSDUCER HOUSINGS

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

Example for a carbon steel 280Ci meter with Schedule 40, 150# flanges with raised faces and with the G3 electronics mounted directly the meter body:

280Ci-G3-04-40-CF-150-A-W-L-A-N-A-1-L

Meter Body Model Number - 2xxCiLT-R Low Temperatures Models Only

The model number for the low temperature application is different, but it still includes information that 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: 2XXCi-LT-SCH-N-H**-WYZ-M-P-X

XX = 20 FOR 2 PATH METERS
XX = 40 FOR 4 PATH METERS
XX = 80 FOR 8 PATH METERS

SCH = PIPE SCHEDULE (TYPICALLY ONE OF 10, 30, 40, 60, 80, 100, 120, 160, XS AND XXS)

N = ASME FLANGE RATING (CLASS 150, 300, 600, 900, OR 1500)

H** = NOMINAL PIPE SIZE

H01 = 6 INCH	H02 = 8 INCH	H03 = 10 INCH	H04 = 12 INCH
H05 = 14 INCH	H06 = 16 INCH	H07 = 18 INCH	H08 = 20 INCH
H09 = 24 INCH	H10 = 26 INCH	H11 = 28 INCH	H12 = 30 INCH
H13 = 32 INCH	H14 = 34 INCH	H15 = 36 INCH	

W = BRAND OF HAZ LOC SEAL
- W = D FOR BARTEC GLAND
- W = E FOR HAWKE GLAND
- W = F FOR CMP GLAND
- W = G FOR PEPPERS GLAND
- W = C FOR QUINTEX GLAND

Y = R IF 90º ELBOW IS USED IN THE CONDUIT
Y = S IF NO 90º ELBOW IS USED IN THE CONDUIT

Z = T IF A TEE IS USED IN THE CONDUIT
Z = N IF NO TEE IS USED IN THE CONDUIT

M = C FOR CARBON STEEL
M = S FOR STAINLESS STEEL
M = D FOR DUPLEX STEEL

P = 2 FOR TWO TRANSDUCER PORTS PER MANIFOLD
P = 4 FOR TWO TRANSDUCER PORTS PER MANIFOLD

X = G3 FOR THE G3 TRANSMITTER

Example for a 12 inch stainless steel 280Ci meter using Bartec seals, elbows and no tee in the conduit, built as a Schedule 40 meter with 150# flanges:

280Ci-LT-40-150-H04-DRN-S-4-G3

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 EXd IIB APPROVAL
Y = C FOR ATEX EXd IIB + H_2 APPROVAL
Y = D FOR ATEX EXd IIC APPROVALS
Z = 0 FOR NO IEC APPROVAL
Z = B FOR IECEX EXd IIB APPROVALS
Z = C FOR IECEX EXd IIB + H_2 APPROVALS
Z = D FOR IECEX EXd IIC APPROVALS

Flow Meter Specifications

Table 1-3 LEFM 2xxCi Transmitter Specifications

Material	
Standard	Aluminum
Corrosion Resistant	Stainless Steel
Size and Weight (if delivered separate from the meter body)	
	14"x 8" x 6" = 152mm x 356 mm x 203 mm
Net Weight	15 lb. (6.1 kg) Aluminum – Transmitter only Note – When attached to an aluminum junction box, the total could surpass 135 lbs (61 kg), depending on the junction box brand 40 lb. (15.9 kg) Stainless Steel – Transmitter only
Power Requirements – DC Power	
Voltage Req'd	24 VDC (18 VDC to 30 VDC)
Current Draw	0.25 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)
Rated Current Draw	0.14 A
Nominal Power Consumption	7.3 W
Pulse Outputs/Alarm	
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 (3 total)	
	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 for DC applications, 2000 meters for AC applications, limited to 1600 m for functional safety applications (Contact Sensia for applications at higher elevations)

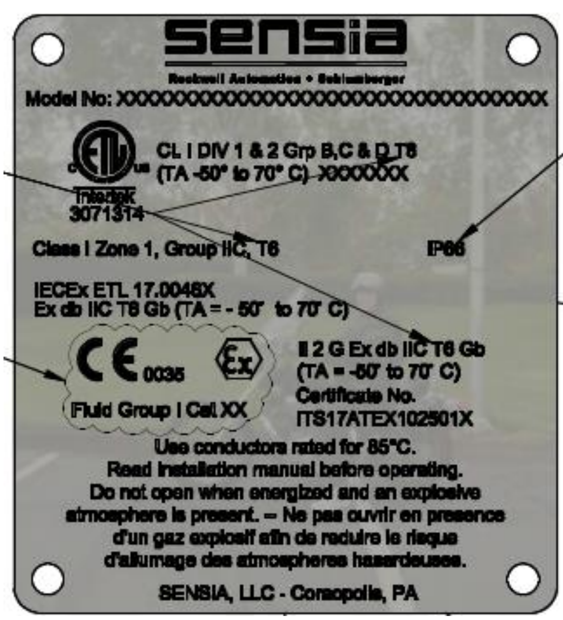
The intended use of this transmitter is a permanently connected installation, Equipment Class II, Pollution Degree 2, Continuous operation.

Table 1-4 LEFM 2xxCi, 2xxCi-R, and 2xxCiLT-R Meter Body Specifications

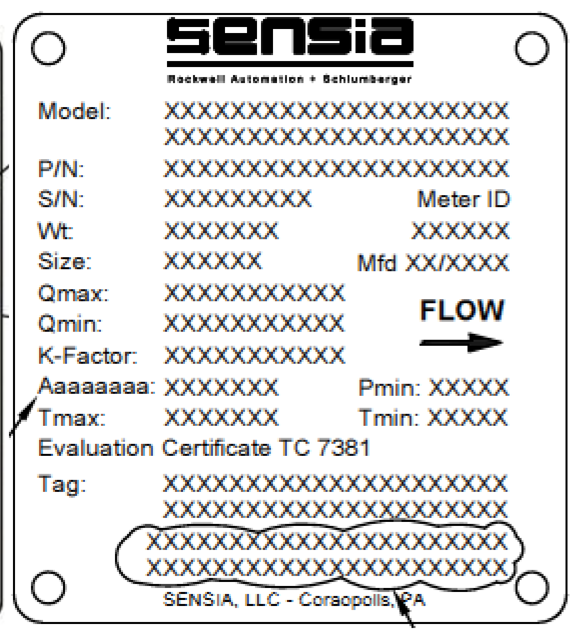
Material	
Standard Custom	Stainless steel, Carbon steel, Duplex, Super Duplex, Inconel, Hastelloy
Operating Temperature	Note – For storage temperature, the meter body limits have been set by the limiting ambient rating of any seal/gland or J-box that could be used with the flow meter. Check Safe Operation Manual for Operation Within Electrical Certification.
Operating Pressure	Maximum working pressure is listed on the meter nameplate (Surge pressures in excess of the flange maximum working pressure rating must be evaluated.)

Meter Markings

Meter Body Approvals Nameplate Example



Meter Body Serial Number Nameplate Example



Section 2

Meter Body Installation

The LEFM 2xxCi 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 integral to the meter body or mounted remotely from the meter body. This section describes the installation procedure for the typical case where the transmitter is mounted to the meter body (Model 2xxCi). Section 3 describes the installation of remote mounted transmitters, which are typically used in extreme environmental conditions (for example, high or low pipe temperatures). Remote mounting of the electronics is for Models 2xxCi-R, 2xxCiRN-R and 2xxCiLT-R.

Flow Meter Body Installation – Best Practices

CAUTION

The weights of the flow meter body are listed in Error! Reference source not found.**,** Error! Reference source not found.**,** Error! Reference source not found.**, and** Error! Reference source not found.**. 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. See Section 1 for LEFM weight and size information.

Install the flowmeter so that:

- The acoustic paths are horizontal (with the transmitter and nameplate on top) to decrease the likelihood of debris or air (gas) accumulating in the sensor wells.
- The flow arrow should be pointing in the direction of “positive” flow.
- The amount of entrained gas that reaches the meter is kept to a minimum (2% or less, as a rule of thumb). Although ultrasonic meters can provide accurate measurement when a small volume of entrained gas exists in the flow stream, performance is improved by eliminating entrained gas. Certain operations can introduce air into the flow stream. Various types of leaks in a liquid handling system can draw air into the flow stream. Also, pressure loss through a system can allow gas to

break out (flash). By being aware of these conditions/operations, an operator can help prevent the accumulation of gas in the flow stream. Slugs of gas in the flow stream do not damage the meter; however continuous presence of gas will give a fault indication. In the worst case, all the sensors will stop indicating and no measurements will be made.

- All wiring to the transmitter is routed in shielded conduit/armored cable 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 1.3 for ratings). 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).
- In order to limit uncertainty caused by hydraulic effects, it is recommended that the installation of the LEFM2xxCi models use the guidelines in the following subsections.

LEFM 220Ci(-R), 220CiRN(-R), and 220CiLT

- The adjoining straight pipe should be of the same schedule as the meter. Temperature elements and pressure connections should be located downstream of the meter. It is recommended that the meter be installed downstream of a 10-diameter pipe section that includes a flow conditioning element at its inlet. For effective flow conditioning, it is generally recommended that there be an additional straight pipe of approximately 5 diameters in length located upstream of the flow conditioner. Downstream of the meter there should be an uninterrupted pipe at least 2 pipe diameters in length. Refer to Figure 2-1 for details.
  If a flow conditioning element is not used, additional uncertainty can be limited by using a straight pipe upstream at least 20 pipe diameters in length and applying strict rules to avoid the introduction of swirl upstream of that length. Typically, this will dictate specific requirements for the combination of fittings that can be used for a further 30 diameters upstream. For less demanding uncertainty requirements or when the meter is calibrated in situ, the installation recommendations can be relaxed. For application specific recommendations or more detailed installation guidance, please consult Sensia.

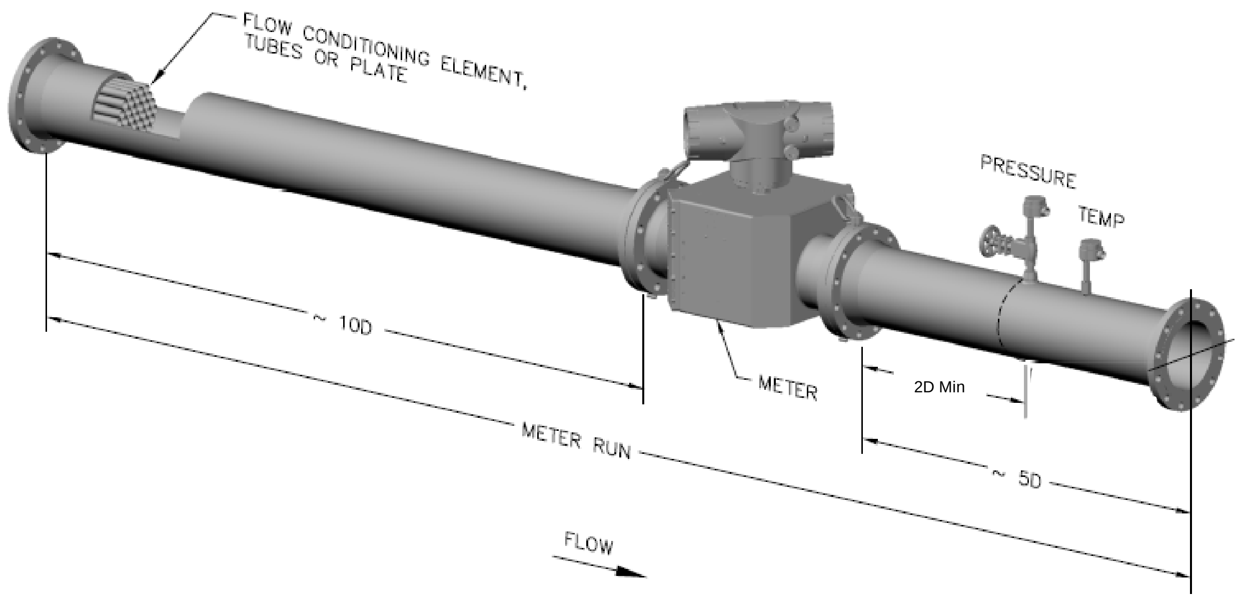


Figure 2-1 220Ci Best Practice for Installation Hydraulics

LEFM 240Ci(-R), LEFM 240CiRN(-R), and LEFM 240CiLT

- The adjoining straight pipe should be of the same schedule as the meter. Temperature elements and pressure connections should be located downstream of the meter. It is recommended that the meter be installed downstream of a 10-diameter pipe section. If using a flow conditioner, it should be installed at the inlet of the 10-diameter pipe section upstream of the meter. For effective flow conditioning, it is generally recommended that there be an additional straight pipe of approximately 5 diameters in length located upstream of the flow conditioner. Downstream of the meter there should be an uninterrupted pipe at least 2 pipe diameters in length. Refer to Figure 2-2 for details.
  If a flow conditioning element is not used, additional uncertainty can be limited by using a straight pipe upstream at least 20 pipe diameters in length and applying strict rules to avoid the introduction of swirl upstream of that 20 D length. Typically, this will dictate specific requirements for the combination of fittings that can be used for a further 30 diameters upstream. For less demanding uncertainty requirements or when the meter is calibrated in situ, the installation recommendations can be relaxed. For application specific recommendations or more detailed installation guidance, please consult Sensia.

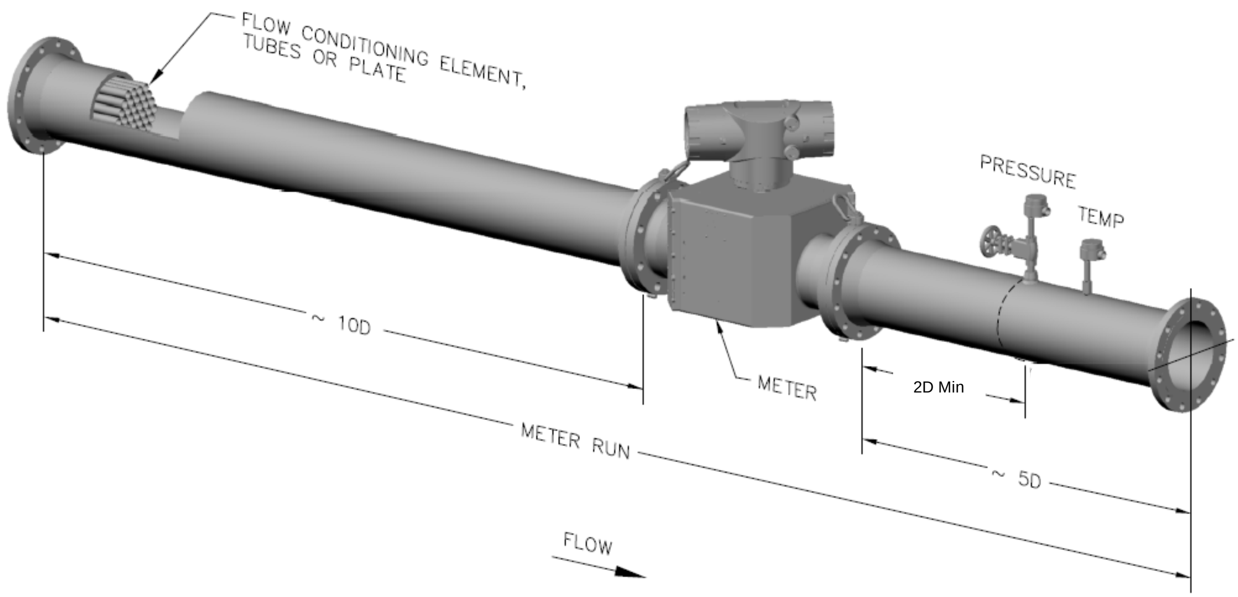


Figure 2-2 240Ci and 240CiRN Best Practice for Installation Hydraulics

LEFM 280Ci(r), 280CiRN-(R) and 280CiLT

- The adjoining straight pipe should be of the same schedule as the meter. Temperature elements and pressure connections should be located downstream of the meter. The LEFM 280Ci, 280Ci-R, and 280CiLT do not normally require the use of a flow conditioning element. An uninterrupted upstream pipe 5 pipe diameters in length is adequate in most applications. In situations where there is a constriction upstream of the meter that is smaller than the diameter of the meter run piping (such as a reduced bore valve), it is recommended that this be separated from the meter by a pipe at least 15 pipe diameters in length. Downstream of the meter there should be an uninterrupted pipe at least 2 pipe diameters in length prior to any installed pressure or temperature elements. Refer to Figure 2-3 for details. For application specific recommendations or more detailed installation guidance, please consult Sensia.

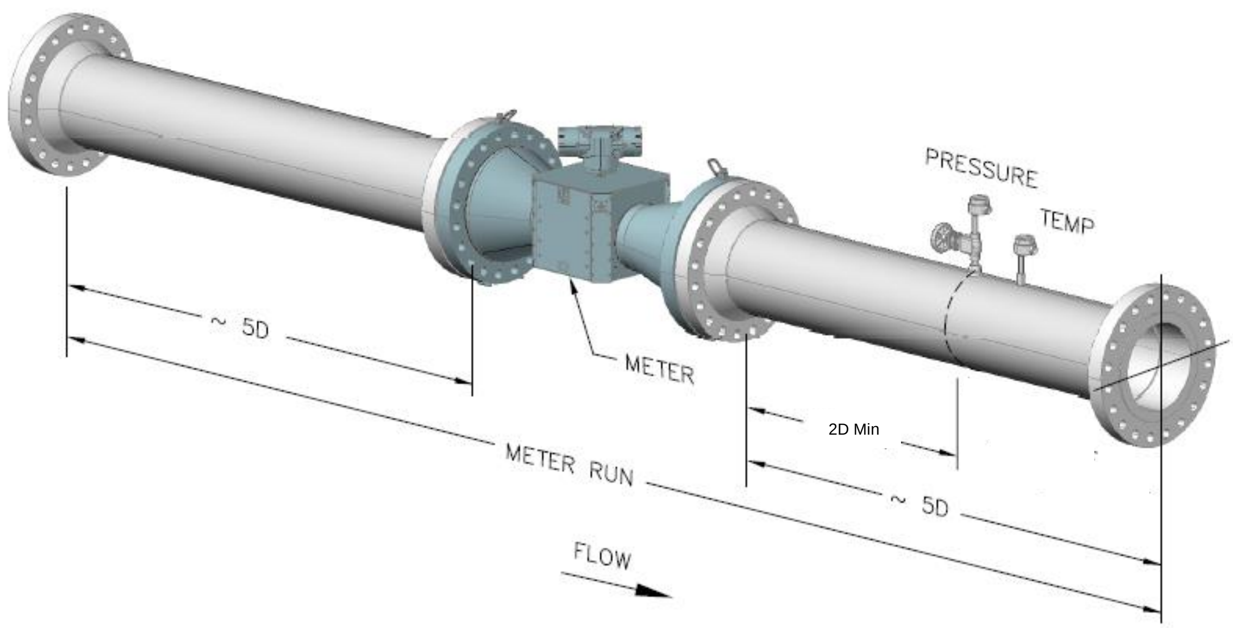


Figure 2-3 280Ci and 280CiRN Best Practice for Installation Hydraulics

Section 3

Installing Transmitter Remotely–Models 2xxCi-R & 2xxCiLT-R Only

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 – Conductor insulation for cabling must be rated for a voltage of 300V and a minimum temperature as follows:

- 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”

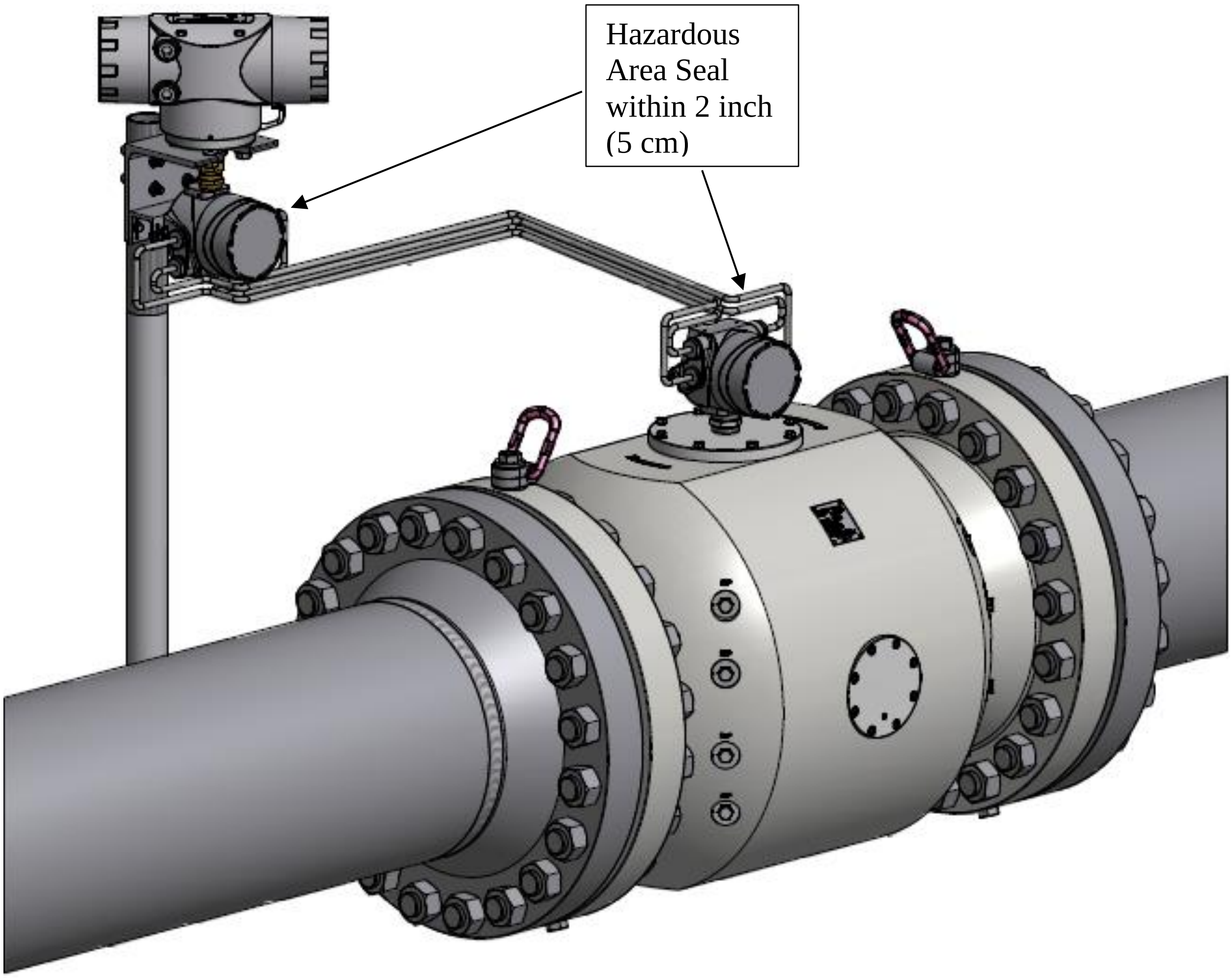


Figure 3-1 Remote Installation of Transmitter from Meter Body. NextGen meter body design shown with single junction box.

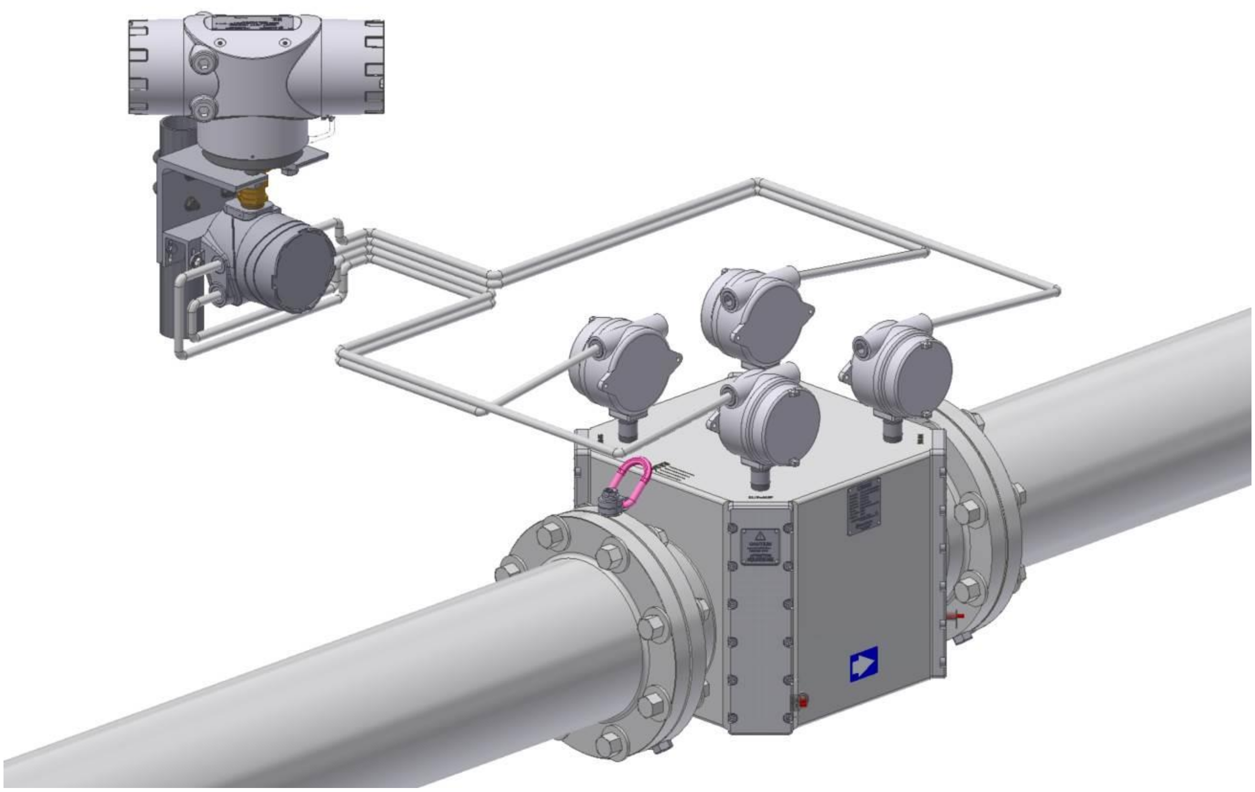


Figure 3-2 Remote Installation of Transmitter from Meter Body. Legacy meter body design shown with 4-junction box configuration.

There are two junction box configurations for the remote mount connection to the meter body: 1) junction boxes mounted above each manifold (Figure 3-2) and 2) a single junction box mounted in the center of the meter (Figure 3-1).

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. Install hazardous area seals within 2 inches (5 cm) of the meter body 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 d 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:
   - Multiple J Box on meter configuration: Table 3-1, Table 3-2, and **Error! Reference source not found.**. Refer to Figure 3-3 for meter body junction box locations. If the meter body does not include junction boxes, route the cables directly from the meter body. Refer to Figure 3-4 for this configuration.
   - Single J-Box on meter configuration: Table 3-4. Refer to Figure 3-1 for meter body junction box location.

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

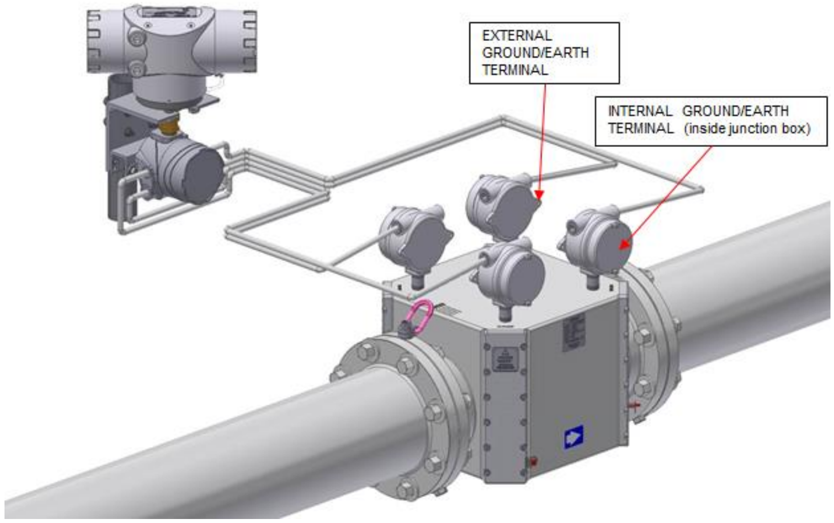


Figure 3-3 LEFM 2xxCi-R or LEFM2xxCiLT-R Meter Body Junction Box Locations

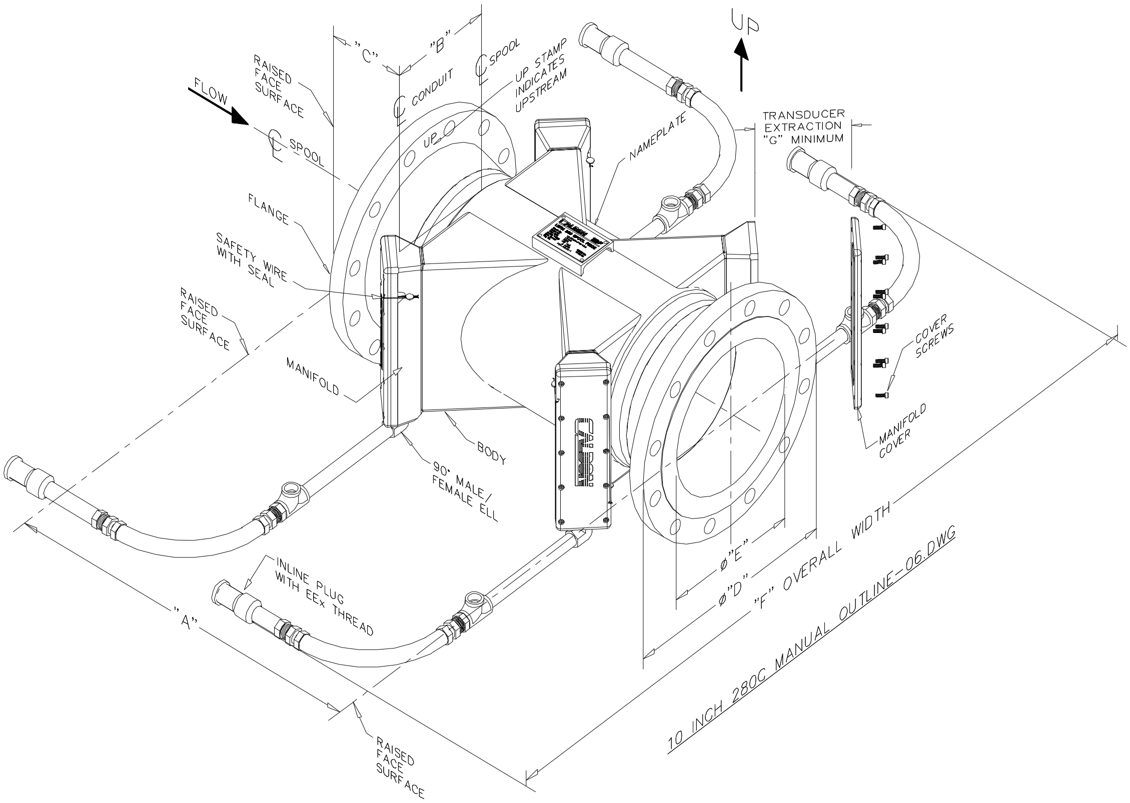


Figure 3-4 LEFM 2xxCiLT-R Meter Body Termination Locations with built in connectors (no junction boxes)

Note – Cables and Connectors are pre-made for field connections.

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.**

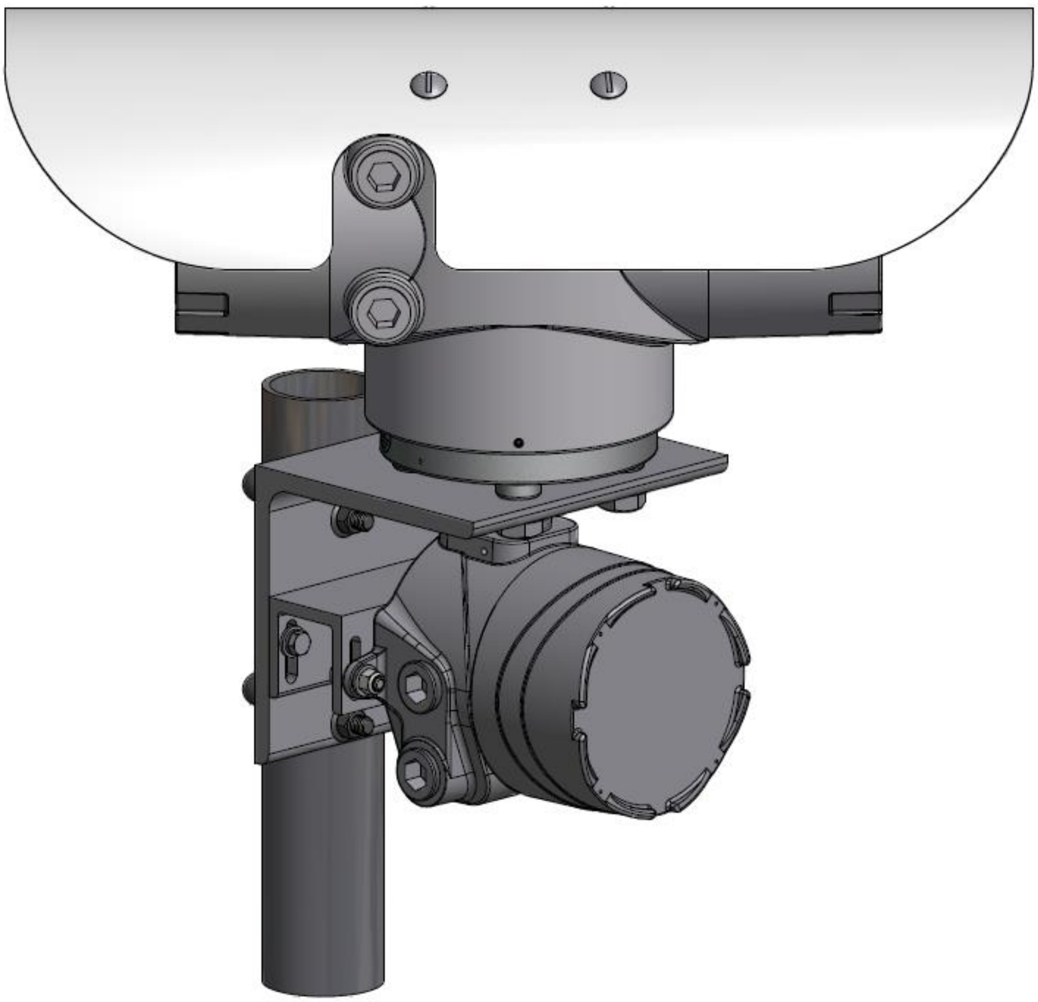


Figure 3-5 LEFM 2xxCi Remote Mounted Transmitter

Table 3-1 LEFM 220Ci(RN) Transducer and RTD Terminations (See Figure 3.5)

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

Note – 22 to 24 AWG twisted pair wires are recommended. On the LEFM 220CiLT with built in connectors, all terminations are made in the connectors.

Table 3-2 LEFM 240Ci(RN) Transducer and RTD Terminations (See Figure 3.5)

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

Table 3-3 LEFM 280Ci(RN) Transducer and RTD Terminations

Transducer Cable Identification	G3 J-Box Termination		Meter Body Junction Box	
Wire Name	Terminal	Pin	Device	Pin
RTD (+)	TB5	1	1B - Upstream JBOX-TB3	9
RTD (-)		2		10
RTD (+)		3		11
RTD (-)		4		12
1 UP (+)	TB1	1	1A - Upstream JBOX-TB1	1
SHIELD		2		-
1 UP (-)		3		2
2 UP (+)		4	1A - Upstream JBOX-TB1	3
SHIELD		5		-
2 UP (-)		6		4
3 UP (+)		7	1A - Upstream JBOX-TB1	5
SHIELD		8		-
3 UP (-)		9		6
4 UP (+)		10	1A - Upstream JBOX-TB1	7
SHIELD		11		-
4 UP (-)		12		8
5 UP (+)	TB3	1	2A - Upstream JBOX-TB1	1
SHIELD		2		-
5 UP (-)		3		2
6 UP (+)		4	2A - Upstream JBOX-TB1	3
SHIELD		5		-
6 UP (-)		6		4
7 UP (+)		7	2A - Upstream JBOX-TB1	5
SHIELD		8		-
7 UP (-)		9		6
8 UP (+)		10	2A - Upstream JBOX-TB1	7
SHIELD		11		-
8 UP (-)		12		8
1 DN (+)	TB2	1	1B - Upstream JBOX-TB1	1
SHIELD		2		-
1 DN (-)		3		2
2 DN (+)		4	1B - Upstream JBOX-TB1	3
SHIELD		5		-
2 DN (-)		6		4
3 DN (+)		7	1B - Upstream JBOX-TB1	5
SHIELD		8		-
3 DN (-)		9		6
4 DN (+)		10	1B - Upstream JBOX-TB1	7
SHIELD		11		-
4 DN (-)		12		8
5 DN (+)	TB4	1	2B - Upstream JBOX-TB1	1
SHIELD		2		-
5 DN (-)		3		2
6 DN (+)		4	2B - Upstream JBOX-TB1	3
SHIELD		5		-
6 DN (-)		6		4

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

Table 3-4 LEFM Transducer and RTD Terminations - Single Meter Body J-Box Configuration

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		4
SHIELD		5		-
2 UP (-)		6		6
3 UP (+)		7		7
SHIELD		8		-
3 UP (-)		9		9
4 UP (+)		10		10
SHIELD		11		-
4 UP (-)		12		12
5 UP (+)	TB3	1	TB3	1
SHIELD		2		-
5 UP (-)		3		3
6 UP (+)		4		4
SHIELD		5		-
6 UP (-)		6		6
7 UP (+)		7		7
SHIELD		8		-
7 UP (-)		9		9
8 UP (+)		10		10
SHIELD		11		-
8 UP (-)		12		12
1 DN (+)	TB2	1	TB2	1
SHIELD		2		-
1 DN (-)		3		3

Transducer Cable Identification	G3 J-Box Termination		Meter Body Junction Box	
Wire Name	Terminal	Pin	Device	Pin
2 DN (+)		4		4
SHIELD		5		-
2 DN (-)		6		6
3 DN (+)		7		7
SHIELD		8		-
3 DN (-)		9		9
4 DN (+)		10		10
SHIELD		11		-
4 DN (-)		12		12
5 DN (+)	TB4	1	TB4	1
SHIELD		2		-
5 DN (-)		3		3
6 DN (+)		4		4
SHIELD		5		-
6 DN (-)		6		6
7 DN (+)		7		7
SHIELD		8		-
7 DN (-)		9		9
8 DN (+)		10		10
SHIELD		11		-
8 DN (-)		12		12

Note – 22 to 24 AWG twisted pair wires are recommended. On the LEFM 280CiLT with built in connectors, all terminations are made in the connectors.

To validate a meter's installation, perform the procedures in Section 4, Meter Installation Check-Out. For troubleshooting information, refer to Section 1, Troubleshooting and Diagnostics.

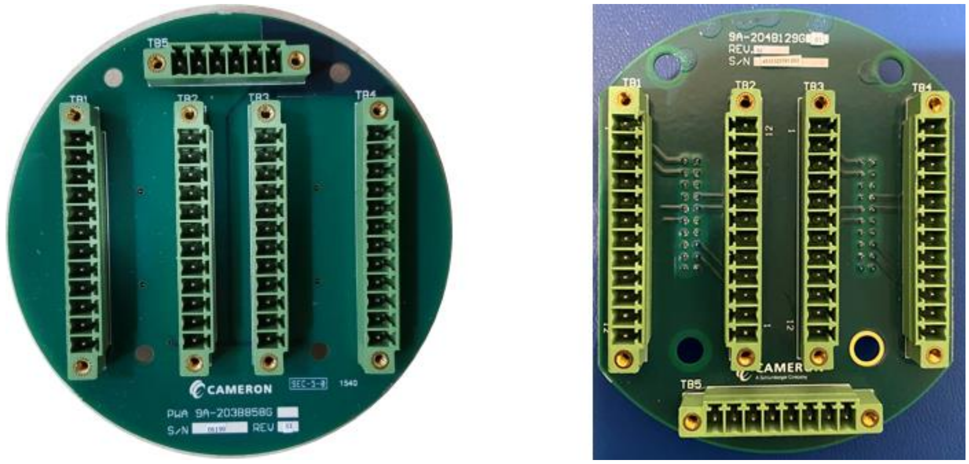


Figure 3-6 - Locations of Terminals on Remote Interface Board for Legacy (left) and NextGen (right) meter bodies.

Remote Mount G3 Transmitter Installation Procedure

<u>2xxCi-R Remote Mount G3 Transmitter</u>

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).

1. Uncrate the transmitter (note the "unpacked weight" of the transmitter as listed in Table 1-3 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 (bottom side of G3 bottom port) for mounting the units. Select bolts/hardware appropriate for the unit's weight. The bottom cover bolts are 0.5 inch x 13 x1.5 inches long.

Section 4

Transmitter Connections – All Models

CAUTION

Models 2xxCi-R and 2xxCiLT-R Only: 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 Class 1 Div I installations conductor insulation for external circuits must be rated for a voltage of 300V and a minimum temperature of at least 85ºC.

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.

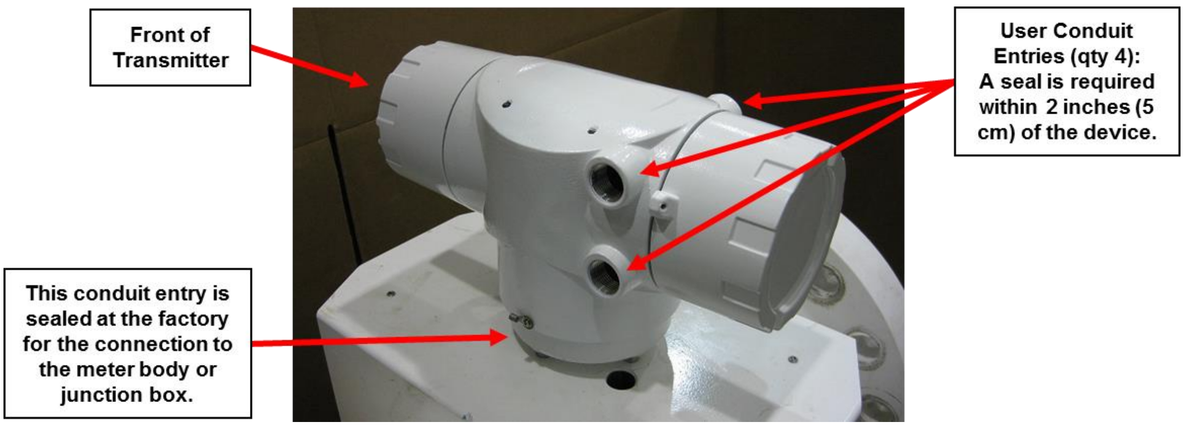


Figure 4-1 Fully Assembled Transmitter

The four conduit entries at the rear of the transmitter are for user connections. A hazardous area conduit seal is required within 2 inches (5 cm) 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 an M25 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.

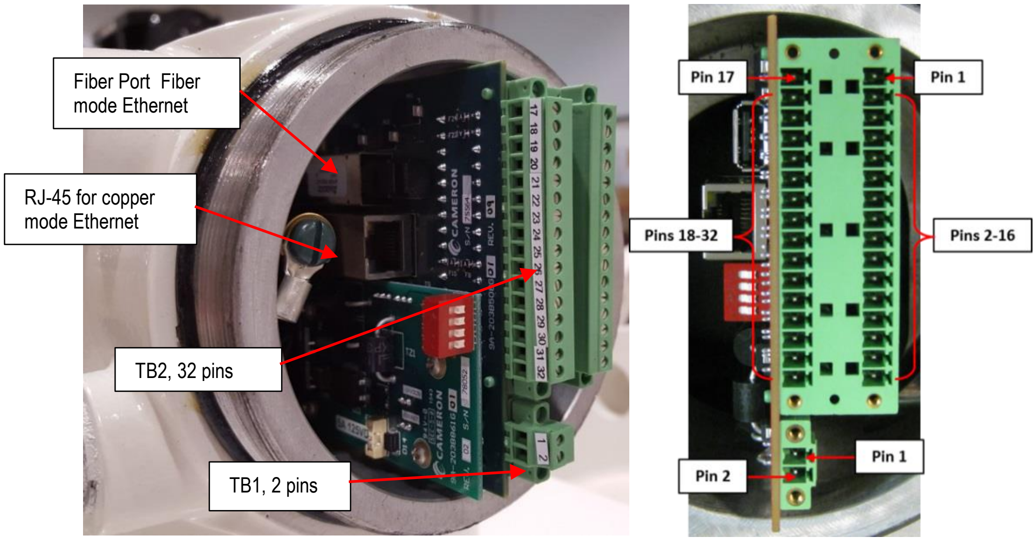


Figure 4-2 User Terminations, Rear View

Note – Conductor insulation for external circuits must be rated for a voltage of 300V and a minimum temperature of 90ºC.

Power Terminations (Terminal Block 1) – Recommended 16 to 20 AWG wire[3]

TB1 contains the power terminations, described below in Table 4-1.

Table 4-1 Power Terminations

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

The schematics for the power terminations are shown below in Figure 4-3 and Figure 4-4.

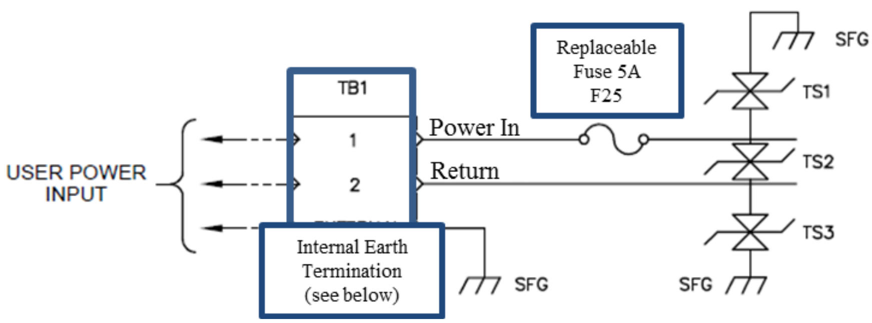


Figure 4-3 DC Power Terminations

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3 14 AWG is allowable.

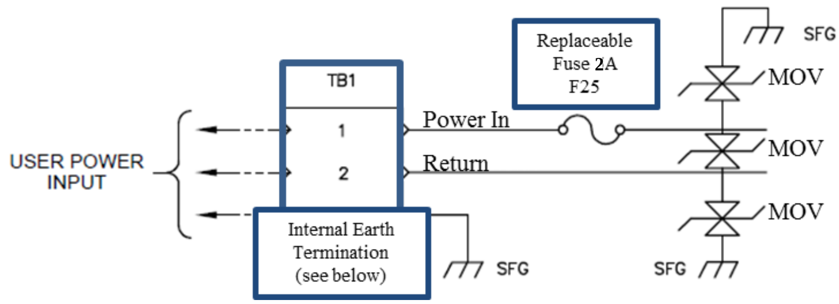


Figure 4-4 AC Power Terminations

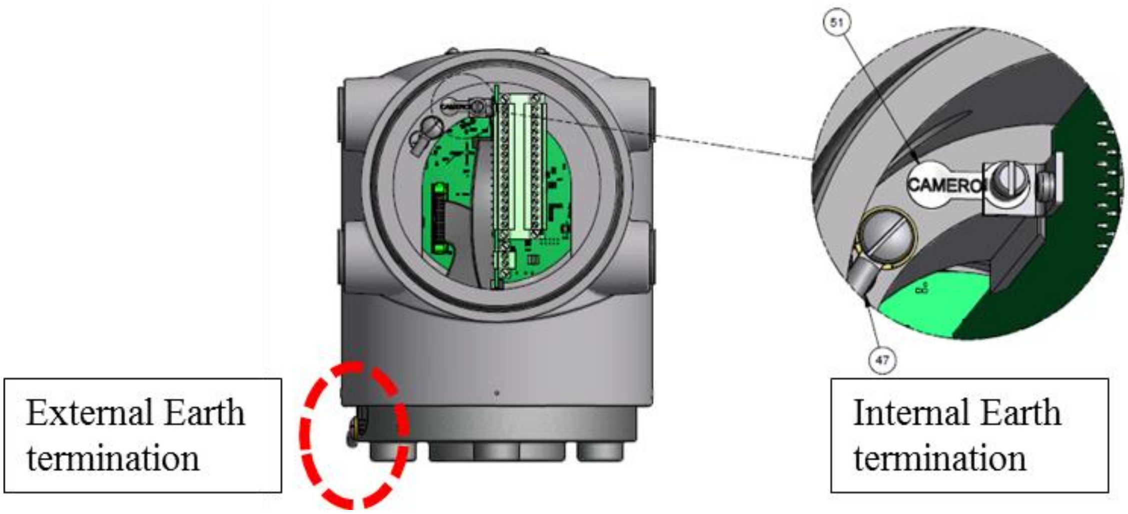


Figure 4-5 Power Terminations
(TB1 has terminals 1 and 2 only –Safety earth/ground shown two places above)

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) – Recommend 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 4-6.

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 (-)

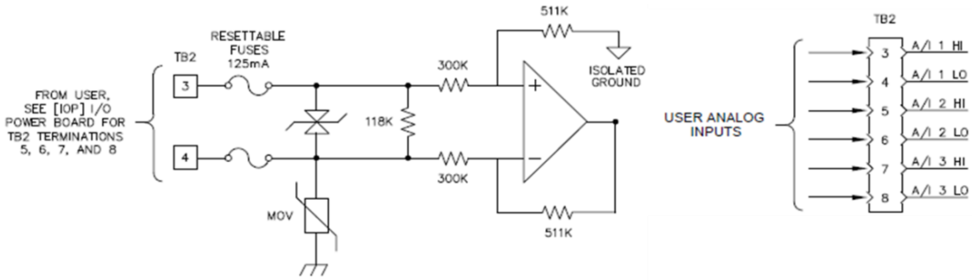


Figure 4-6 Typical Analog Input

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 4-7.

Table 4-3 Analog Outputs (User 2)

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

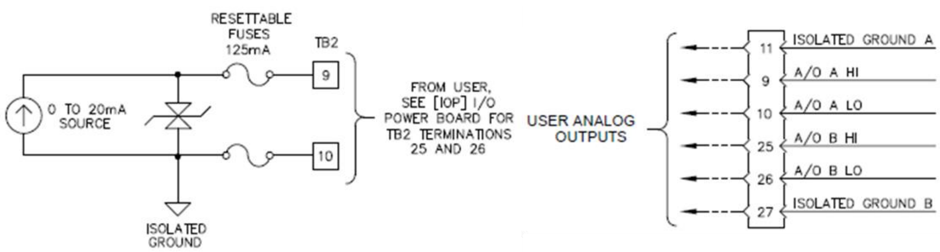


Figure 4-7 Typical Analog Output

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

TB2 contains the transmitter's analog outputs, described below in Table 4-3. 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 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 2xxCi 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 may be configured to positive flow only with Pulse B assigned to negative flow.

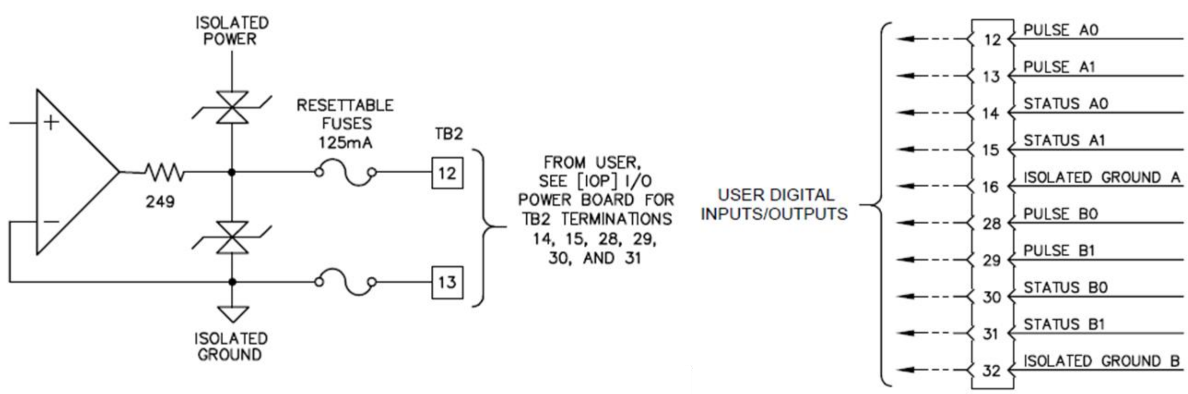
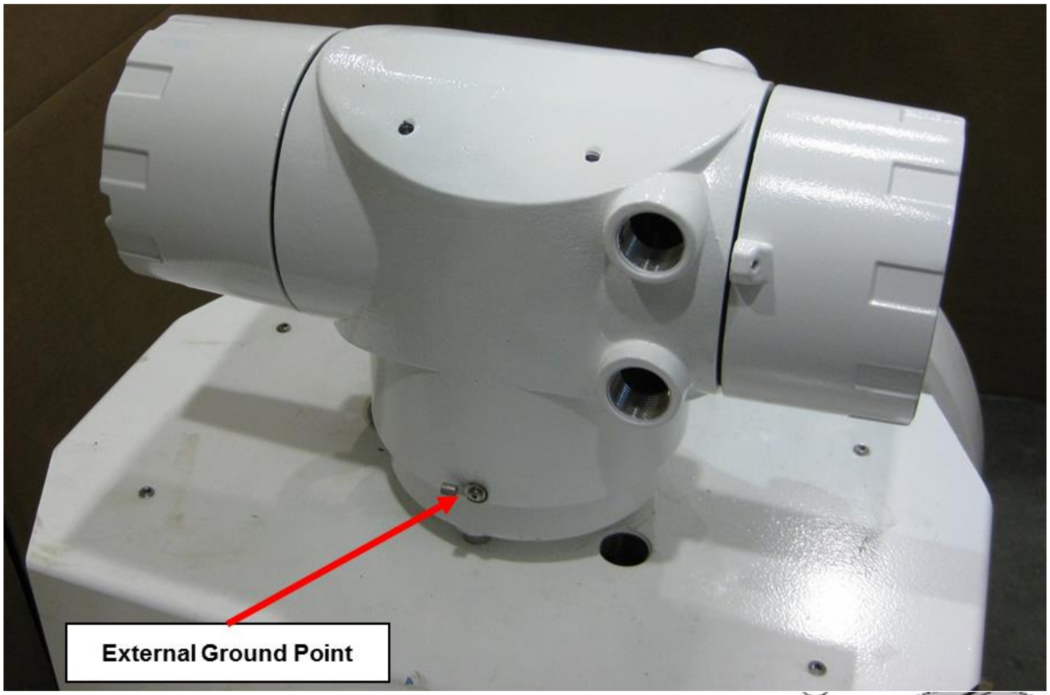


Figure 4-8 Typical Digital Signals

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 earth point. For ATEX applications, both earth points should be used. Follow all other site guidelines regarding grounding/earthing.



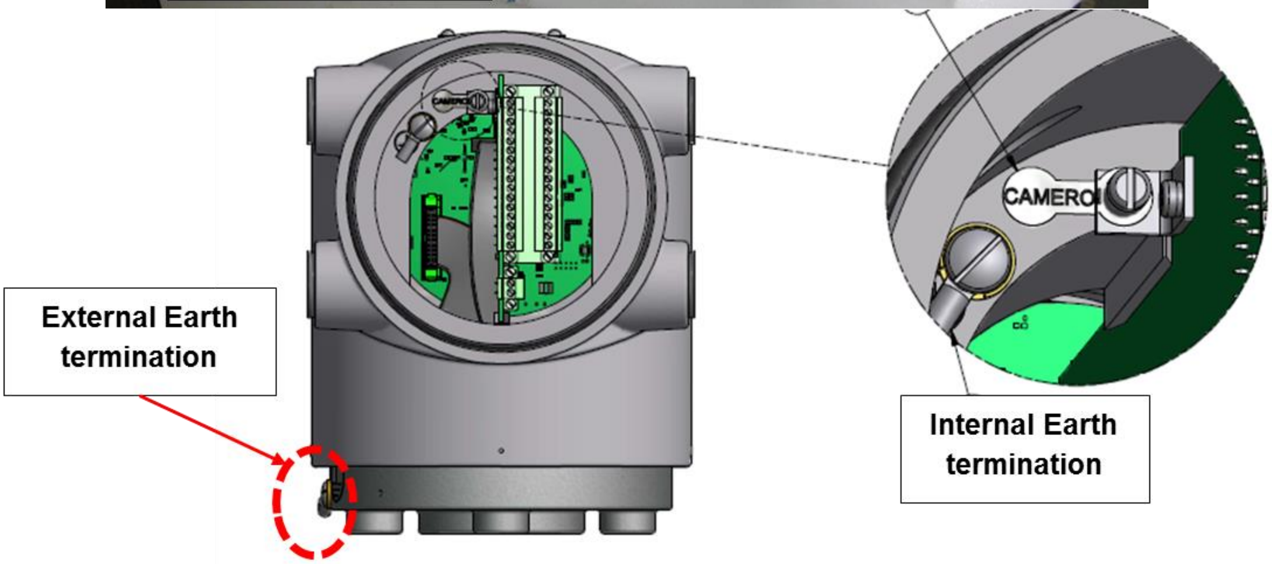


Figure 4-9 Earth Points, Transmitter Body

Refer to Table 4 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 earth ground; 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.

Remote Data Communications

The LEFM transmitter supports remote data communications via its three serial communications ports and Ethernet communications (RJ45 or fiber modem). Figure 4-8 shows the locations of the RJ45 (copper) and the MT-RJ (Fiber) connections on the IOP board. If the Fiber option is chosen the RJ45 port is disabled. Note that the Ethernet connection is electrically isolated from both User groups (e.g., independently isolated).

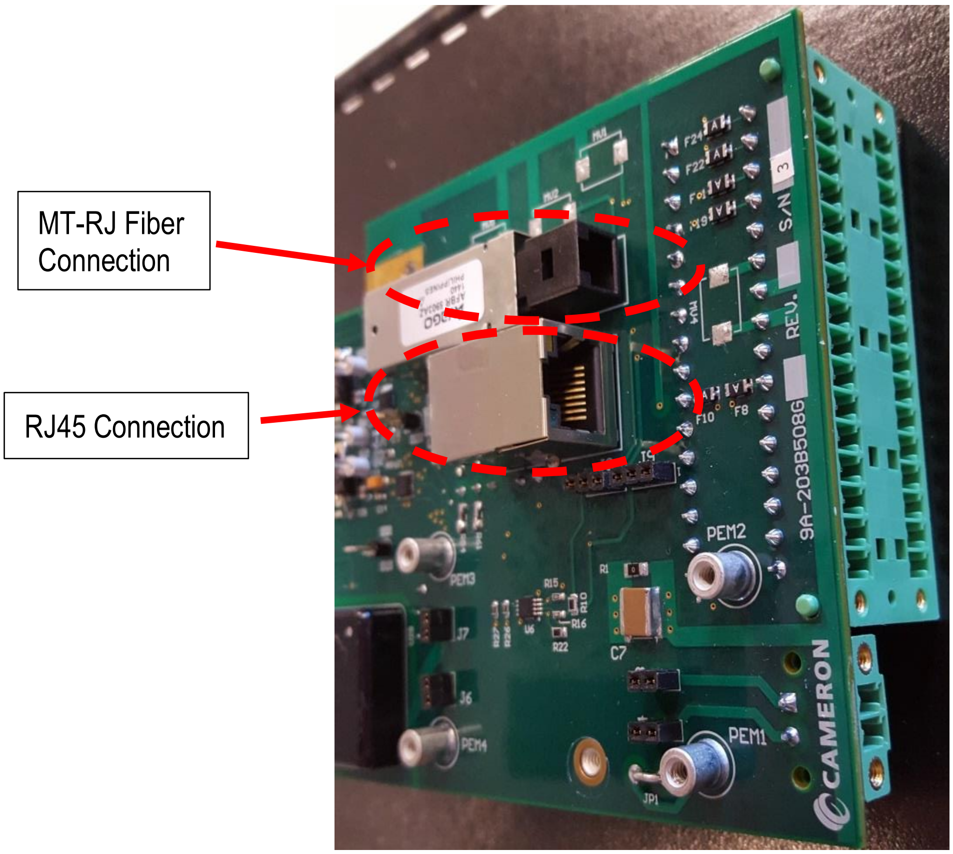


Figure 4-8 Ethernet Locations

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 4-9.

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

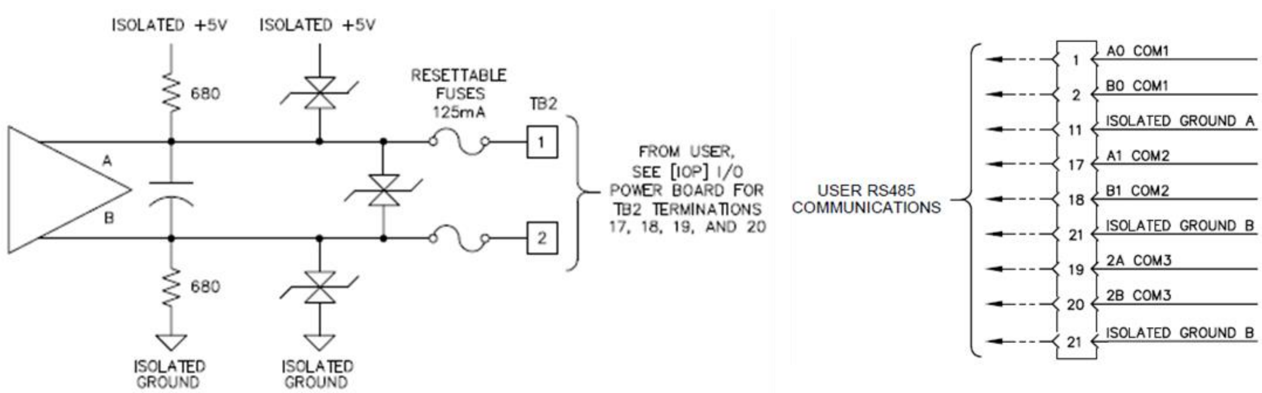


Figure 4-9 Typical RS485 Communications

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 1, 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 Output Test Mode below or consult the LEFMLink software manual.

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

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

    a. Signals have Percent Good > 98% 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).

Output Test Mode

The Output Test mode is used during field testing or verification checks. This output test is best done using the Sensia provided software – LEFMLink.

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

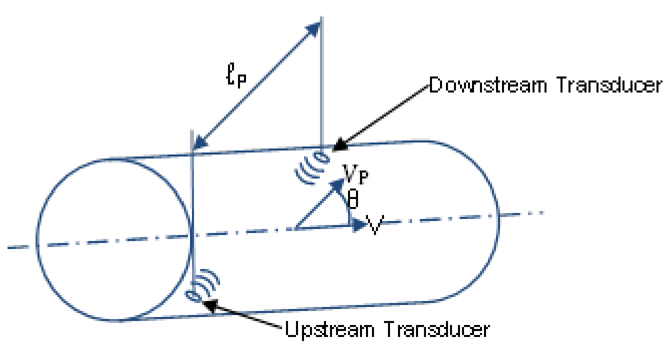


Figure 5-1 Flow Velocities along the Ultrasonic Path and the Pipe Axis

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 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 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 two-plane configuration of the 280Ci has the acoustic paths arranged into two planes (orthogonal to each other). The plane is oriented at an angle (path angle) with respect to the centerline of the pipe. Refer to Figure 5-2.

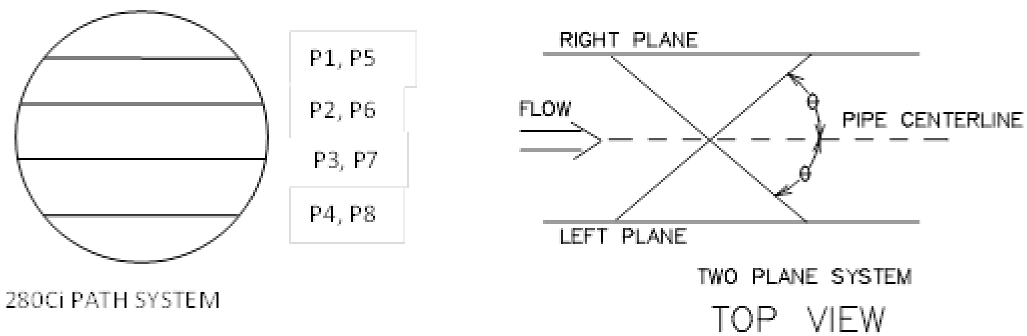


Figure 5-2 Acoustical Path Configurations

The 240Ci uses only paths 1 through 4 built into one plane. The 220Ci uses only 2 paths that are set at mid-radius chord.

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 2xxCi automatically compensates for pipe thermal expansion and contraction.

Likewise, net flow is available when fluid temperature and pressure are continuously monitored. Correction factors that take into account the changes in fluid expansion due to pressure and temperature may be applied to the flow rate equation.

Gross Flow Rate to Net Flow Rate Conversion

Net volumetric flow rate is calculated by correcting gross volumetric flow rate to standard product conditions of 60°F and 0 psig (default, other values can be used).

Net Flow Rate = Gross Flow Rate • $[K_{net,temp} \bullet K_{net,pres}]$

The LEFM 2xxCi computes a temperature correction factor and pressure correction factor. Typically, these factors are based on the following references:

> *API Chapter 11.1, Volume I, November 1984 (API Standard 2540), Table 6A – Generalized Crude Oils and JP-4, Correction of Volume to 60° Against API Gravity at 60°*
>
> *API Chapter 11.2.1, Manual of Measurement Standards, March 1990, Compressibility Factors for Hydrocarbons: 0-90° API Gravity Range*

Inputs required for gross to net conversions include:

- Gross flow rate
- Product temperature
- Product pressure

The LEFM has only one analog input. Therefore, to input all three variables, some values must be sent via Modbus registers. The specific gravity used for the gross to net conversions can be either an analog input entered via Modbus registers, or a value that is automatically computed by the LEFM. The automatic calculation is based on API tables, sound velocity, temperature and pressure.

Section 6

Operations

Definitions

SNR – Signal to Noise Ratio

Gain – Required gain to amplify signal

%Good – Percentage of Data accepted by the processor

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 1, 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. Refer to Figure 6-1 for a typical display sequence.

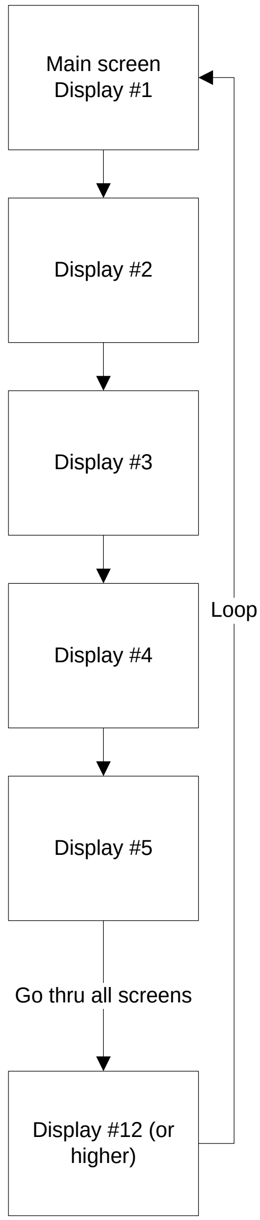
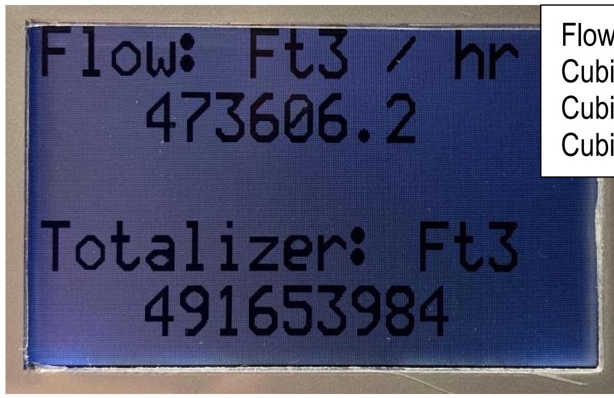


Figure 6-1 Display Sequence

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

Alarm Conditions

The LEFM 2xxCi'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 flow meter), 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 – Operating normally
F-PATH – Failed paths (flow is computed with a possibility of lesser accuracy)
F-VOS – Fall Sound Velocity (path sound velocity spread is out of range for normal flow rates)
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.

Display 2 — Process Properties

Figure 6-3 Display 2 – Process Properties

Display 3— Alarm Summary

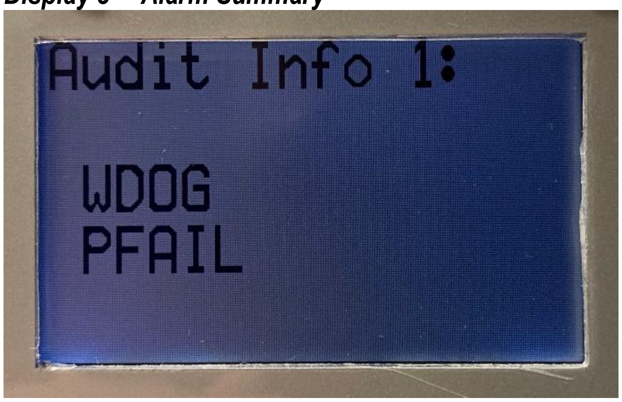


Figure 6-4 Display 3 – A

Kfactor for the meter shown

Also alarms that require user acknowledgement are shown below. These alarms require "Write Protection" to be disabled (see Section 9)

These alarms include:

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

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)

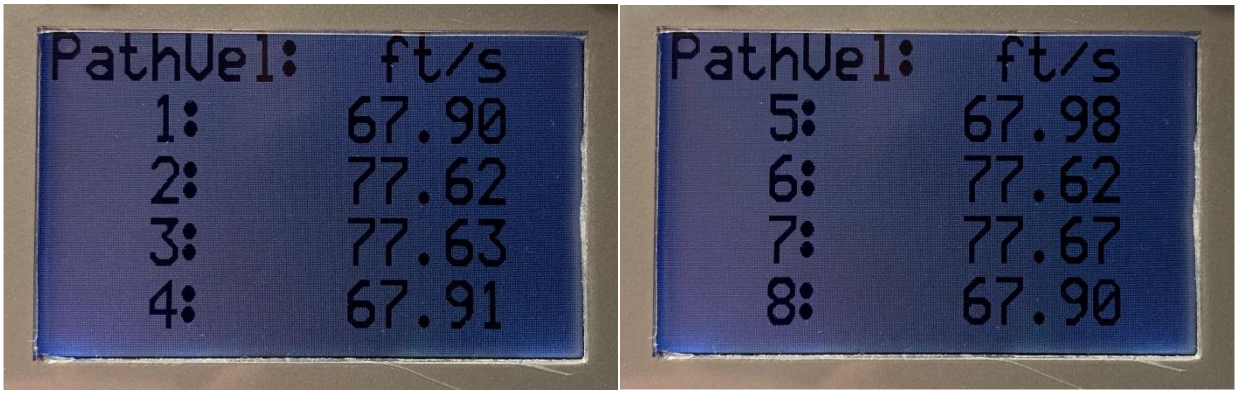


Figure 6-7 Display 6 – Velocity Data

Path Alarm Conditions

The following codes (described in the LEFM Modbus manual) are used to indicate the status of each ultrasonic path:

Normal – Path is operating normally

Invalid – Path is rejecting data due to low signal-to-noise ratio, irregular statistics, or failing cross-correlation tests

VOS – Path sound velocities are inconsistent with thresholds (typically, a spread of 0.2% or less between paths is acceptable)

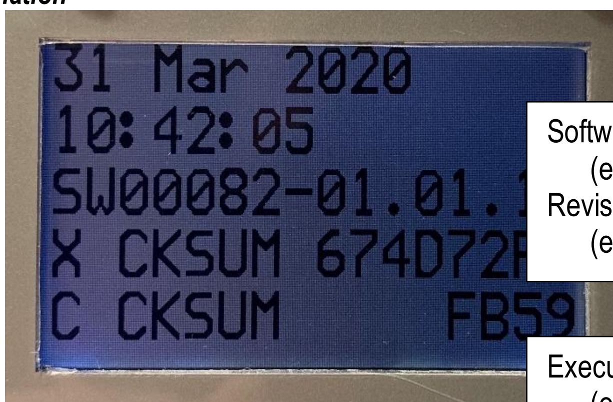
VOT – Path velocity is inconsistent at low flow rates

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 SW00070)
Revision
(example is 01.01.01)

Executable checksum
(example is 2F20ABEC)

Configuration check sum
(example is 7467)

Figure 6-9 Display 8 – Software Informatio

Section 7

Maintenance

WARNING

Service should be performed on the LEFM 2xxCi 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:

Sensia Ultrasonics Technology Center
1000 McClaren Woods Drive
Coraopolis, PA 15108 USA
Tel 724-218-7800

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 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.

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 flow meter processing. Contains the display and communicates with the MXR and IOP.
Acoustic Board (MXR)	Interfaces with transducers, excites and receives acoustic signals.

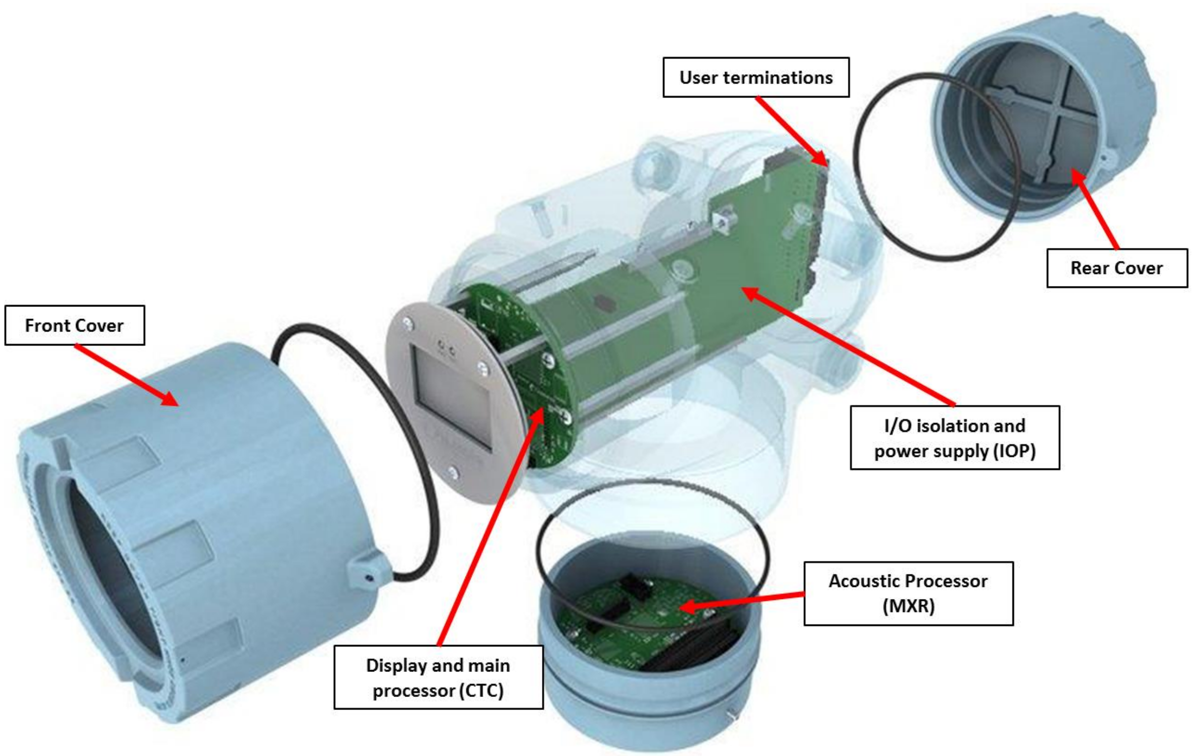


Figure 7-1 Transmitter Components

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

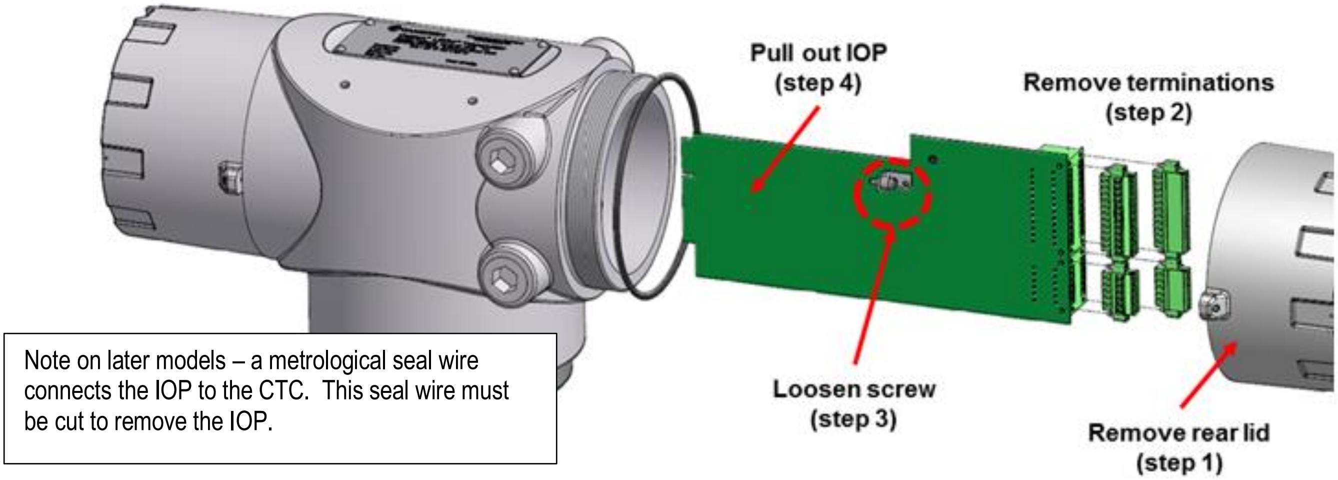


Figure 7-2 Disassembly Views for IOP Replacement

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 2mm 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.

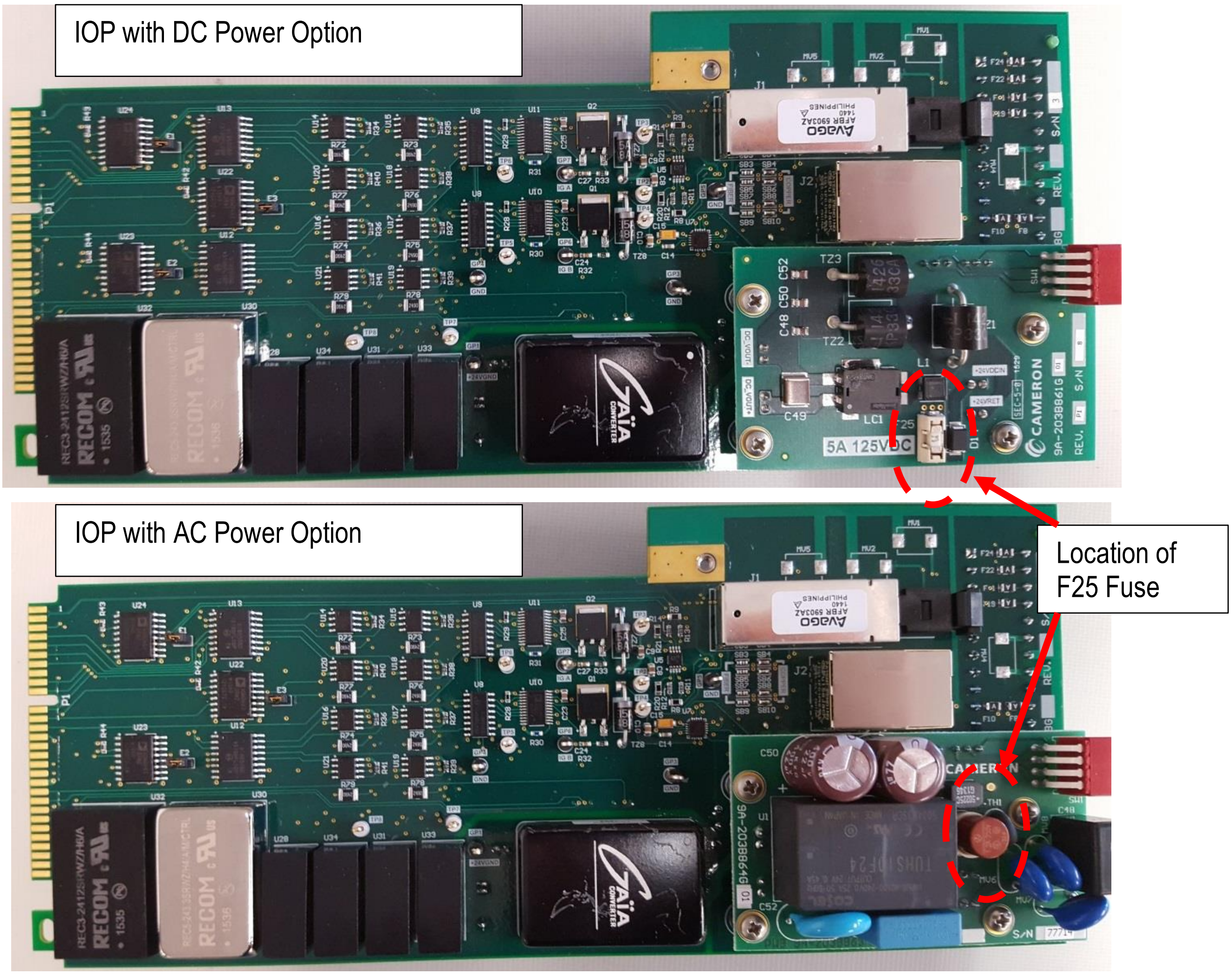


Figure 7-3 Location of IOP/F25 Fuse

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 9.

   AC Option: Only use Littelfuse Series part number 37412000430 (2 amp rating) as a replacement fuse. Skip to step 9.

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).

Again, 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 set screw on the lid.

7.5 CTC and Display Replacement

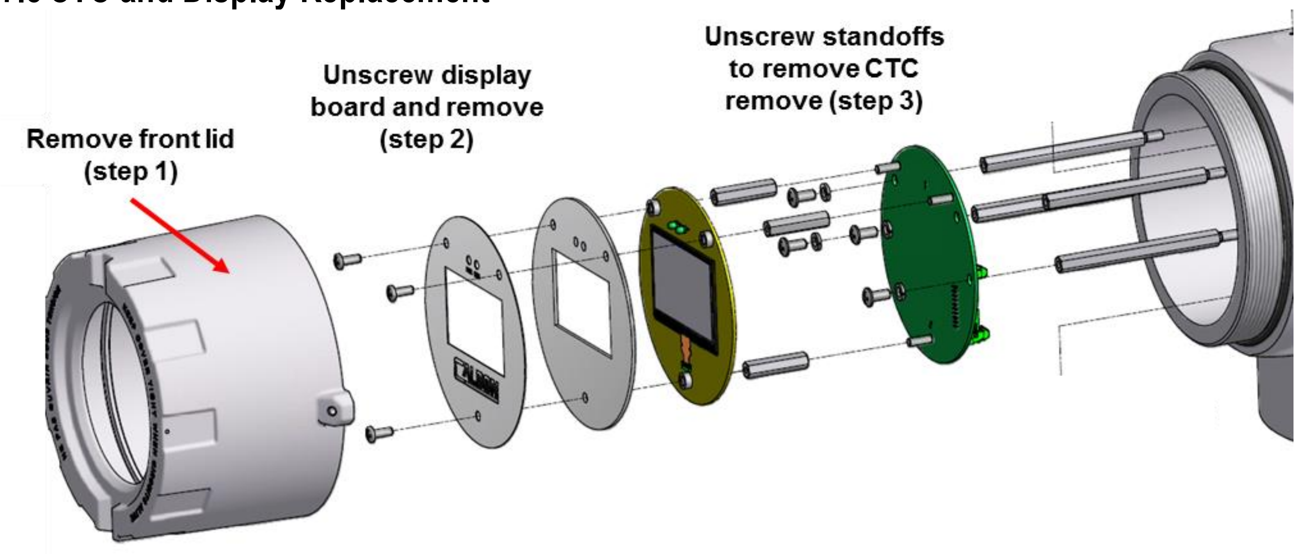


Figure 7-4 Disassembly Views for CTC and Display Replacement

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, discard 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.

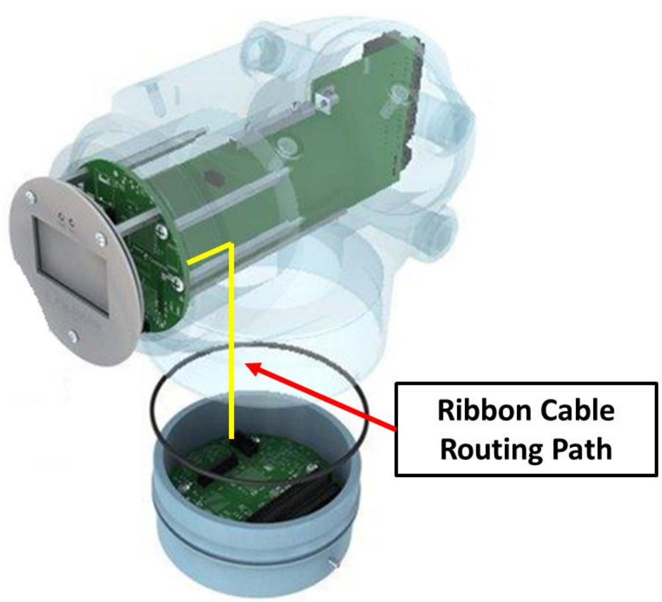


Figure 7-5 MXR-CTC Ribbon Cable Routing Path

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 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, CTC and Display Replacement, steps 1 through 3 in order to disconnect the ribbon cable.

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

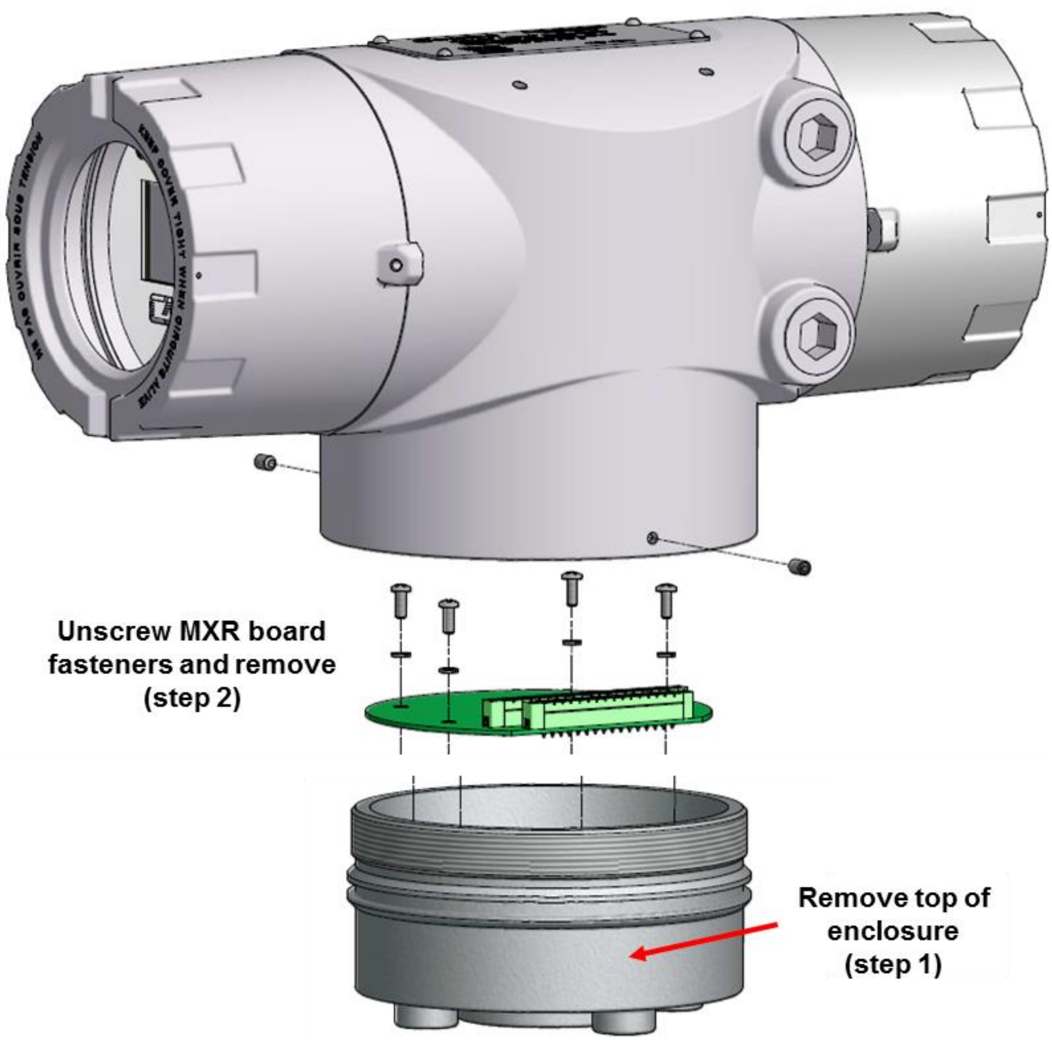


Figure 7-6 Disassembly Views for removing MXR

1. Loosen and remove the two set screws 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. 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.
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 set screws. Turn the enclosure to face the proper direction and tighten the set screws. Note – the set screws 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 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 employees.

Should a transducer fail, install a replacement using the following procedure, referring to Figure 7-7 below for hardware locations and descriptions:

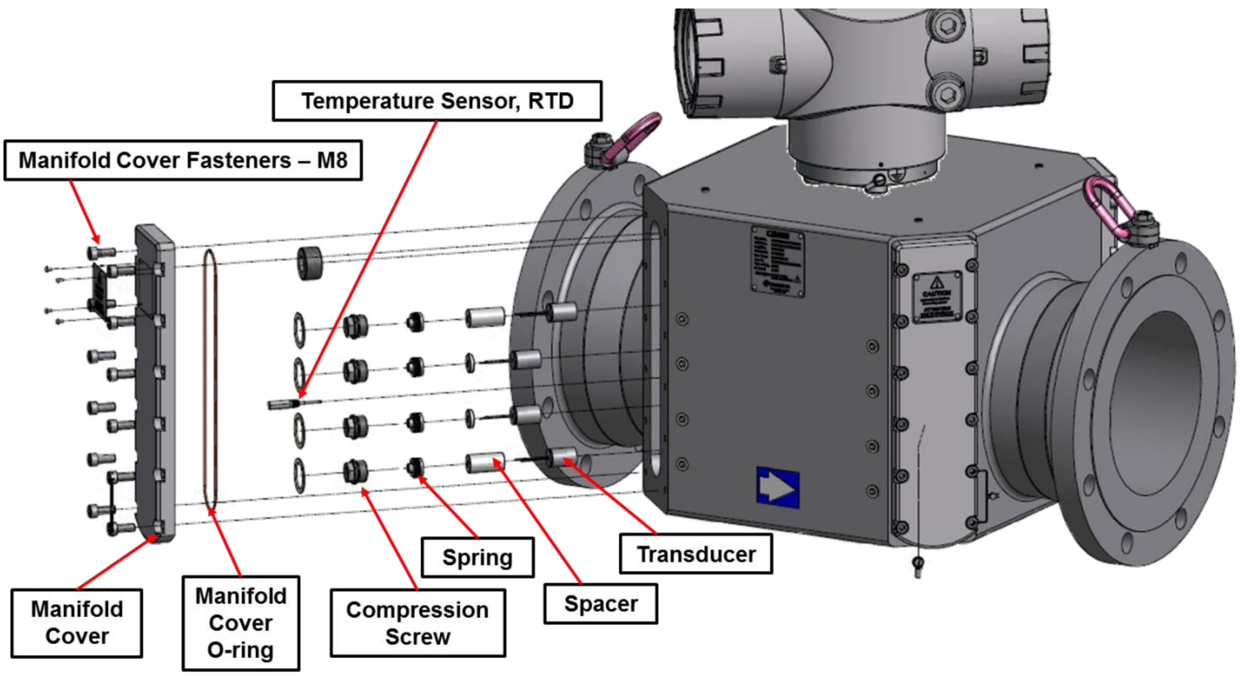


Figure 7-7 Transducer Replacement (note – image is for a 0.5 inch transducer housing)

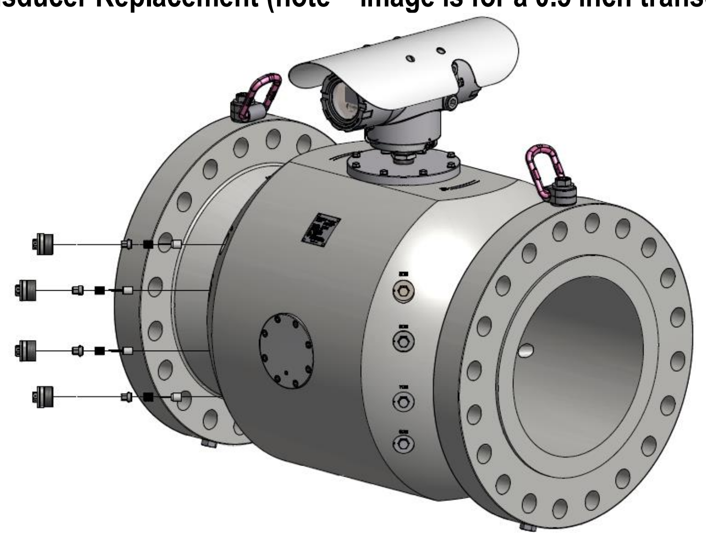


Figure 7-8 Transducer Replacement

1. For Remote Mount Meters, Disconnect the failed transducer from the terminals in the junction box (note upstream and downstream junction boxes).
2. For Manifold Style Meters use an M5 hex wrench, remove the socket head screws from the manifold cover and remove the manifold cover to reveal the transducer internals. For single transducer covers remove the cover using a socket. Disconnect the failed transducers wire terminations.

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

---

3. Remove the transducer internals using an O-ratchet T-socket head (½-in. socket for the ½-in. or 12.5-mm transducer housing and ¾-in. (19-mm) socket for the 1-in. or 25-mm transducer housing). Typically 4-in. to 10-in. meter bodies contain ½-in. transducer housings; 12-in. and larger meter bodies contain 1-in. housings. Figure 7-9 reflects an installed transducer once the manifold cover is removed, while Figure 7-10 shows the compression screw removed, revealing the transducer internals.

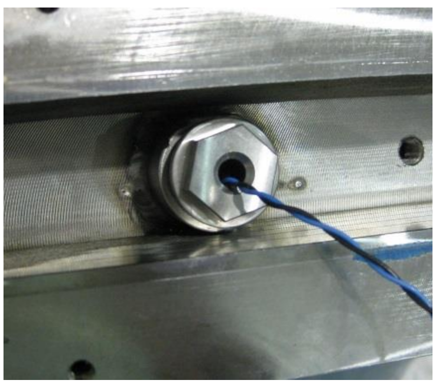


Figure 7-9 Transducer

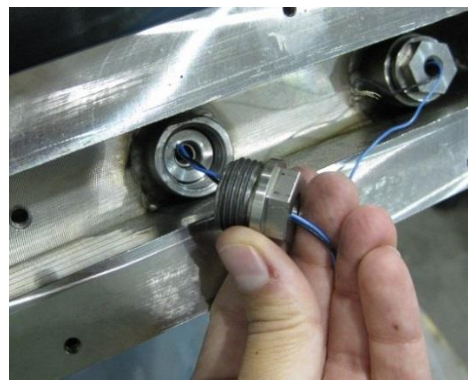


Figure 7-10 Transducer, Compression Screw Removed (1 inch housing shown)

WARNING

Note – Meters with transducer housings using O-rings have retaining system that must never be tampered with. Only Sensia technicians may remove these components – as they are pressure containing.

Note - See Figure 7-11 for details on the retaining system. See Figure 7-12 for an example of the warning sticker located on the face of the meter. The transducer housings are pressurized and contain two locking rings to keep the housing in place. Specialized tools and Sensia trained personnel are required to remove the housing.

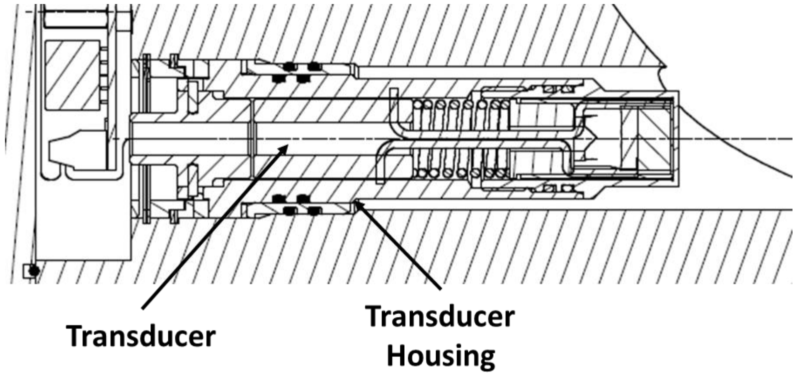


Figure 7-11 Transducer Housings

Figure 7-12 Retaining Ring Warning Sticker

4. Remove the failed transducer.
5. Using a flashlight, verify the transducer housing is clean and free from dirt.
6. Re-install the transducer internals as follows, referring to Figure 7-13 and Figure 7-14.
    a. (0.5 inch housings) Thread the wires of the transducer though the compression spring and the spacer. (1.0 inch housings) Thread the wires of the transducer though the spacer and then through compression spring.
    b. Apply Sensia brand silicone lubricant to the transducer face. For cryogenic transducers use Sensia's metal foil couplant.
    c. Insert the transducer and components into the housing until the parts bottom out.
    d. Route the wires though the compression screw and then apply lubricant to the threads.
    e. Screw into the transducer housing and tighten. This will energize the spring.

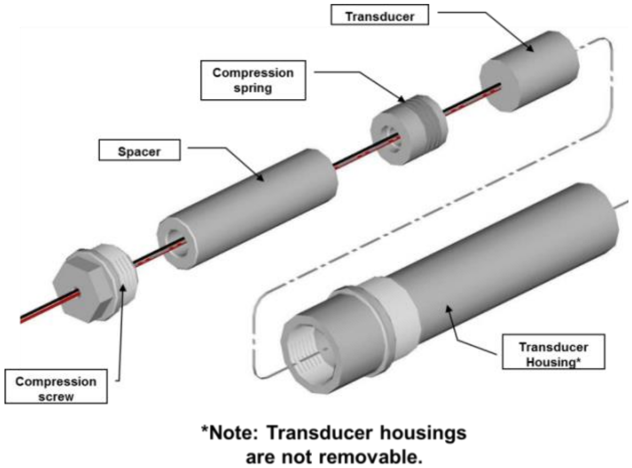


Figure 7-13 Transducer Assembly Construction (shown components are for 1.0 inch housing)

Figure 7-14 Transducer Internals (shown components are for 1.0 Inch housing – note that the spacer is next to the transducer)

7. Connect the new transducer to the terminals.
8. Re-install the manifold and junction box cover.
9. Torque the socket head screws to between 100 and 180 in-lbs (11.3 to 20.3 nm).

Note – The LEFM 2xxCi system may require that the acoustic performance is verified when a transducer is replaced or re-coupled (see Section 8, Troubleshooting and Diagnostics).

7.8 Analog Input Verification

The LEFM 2xxCi may have an analog input (for example, temperature, pressure, or density). 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 of the engineering units. 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.

Section 8

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.

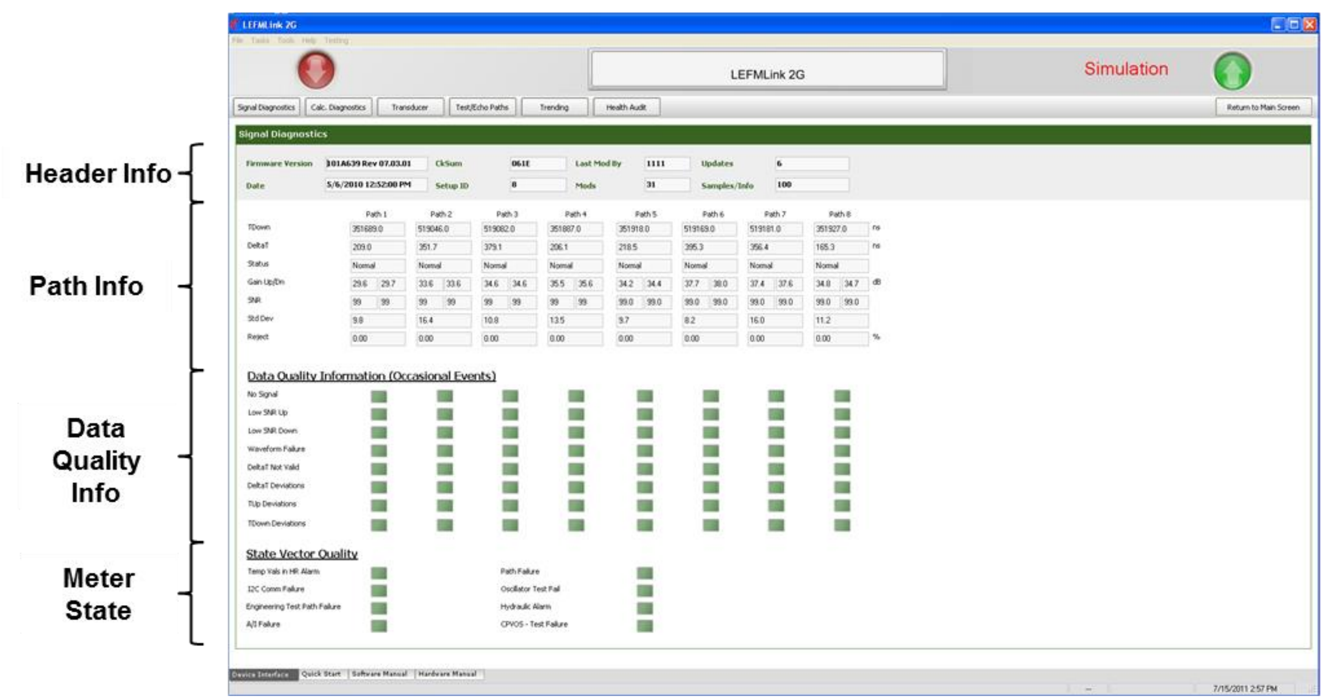


Figure 8-1 Diagnostic Screen

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
% Good (Performance)	0 to 100%	95 to 100%
Gain	0 to 88dB	20 to 60dB
SNR	0 to 100	20 to 999

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.

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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, up to 0.2% 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 at 5 volts or 12 volts)
   - "ALARM" – 1 or more paths failed; flow is computed with a lower accuracy (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 Status

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

1. Verify that the meter body is full of liquid. If the pipe is not filled, it may cause the top path to 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 8, Reprogramming the Transmitter.
4. Check the acoustic signal. Check path gains via Modbus or LEFMLink Software. If the path gains are high (65dB 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 is not full of liquid.
   - The line pressure is too low for the vapor pressure.
   - The cable/wire from the meter to the transmitter is damaged.
   - The transducer has failed.
5. Check the transducers for failure. The LEFM has a diagnostic capacity for determining which transducer(s), if any, needs attention. Normally, the gains for the upstream and the downstream are equal. However, if a transducer fails due to wiring, coupling, etc., one transducer will have a higher gain. Using the regular acoustic paths, follow these steps to determine which transducer has failed:
   a. Review the SNR for each path (paths 1 through 8). The SNR should be greater than 40 (or greater than 20 for high viscosities).
   b. Review the gains for each acoustic path (both upstream and downstream). The gains should be between 10dB and 85dB. Upstream and downstream gain should nominally be within 3 dB of each other.
   c. Review the percent good data for each path. The percent should be between 90 and 100%.

Remember the following troubleshooting tips:

- If all paths fail, the meter has no liquid or an electronics hardware failure has occurred.
- If a path has 0% good 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 is full of liquid.
  2. Check the continuity of transducer cable in the manifold.
  3. If a signal is present, consider investigating the ultrasonic transducer or replacing the acoustic coupling. Refer to Section 7, Maintenance.

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.
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.

Section 9

LEFM 2xxCi and 2xxCi-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 2xxCi 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 CTC board (front of the transmitter) can be engaged, preventing configuration changes. The transmitter with the cover removed is shown in Figure 9-1 below. If the electronics has switch SW1-4 (top-most switch) configured to the left (closed), the transmitter is write-protected, and the parameters cannot be reprogrammed (irrespective of passwords). Using this switch together with the seal wire on the transmitter or seals on the circuit boards enables full metrological control of the system.

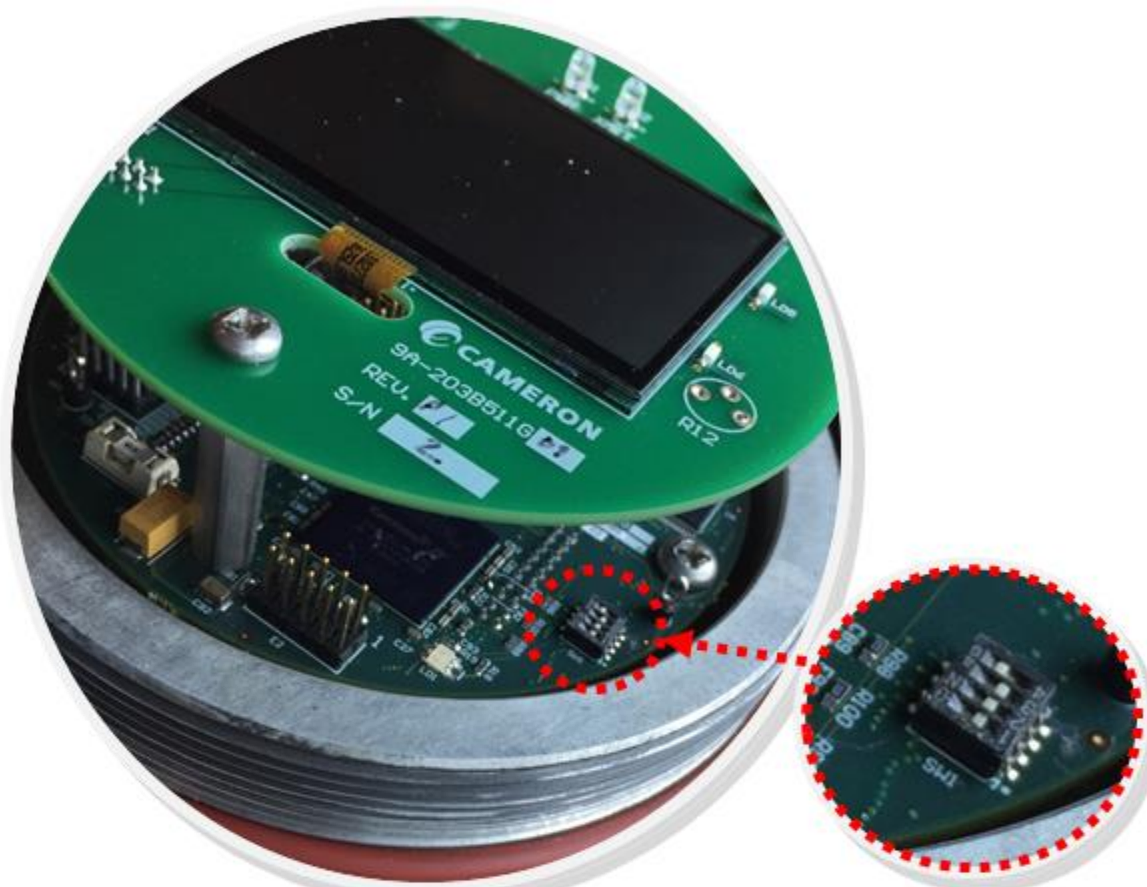

Figure 9-1 Transmitter, Cover Removed - SW1-4 set to prevent configuration changes (shown without tamper evident seal for clarity)

Figure 9-2 shows the optional seal wire on the transmitter (wire goes from the front cover to the back cover). This seal can be applied by the user – if desired. The rear entry can also have a seal wire attached (but this is optional, see Figure 9-3).

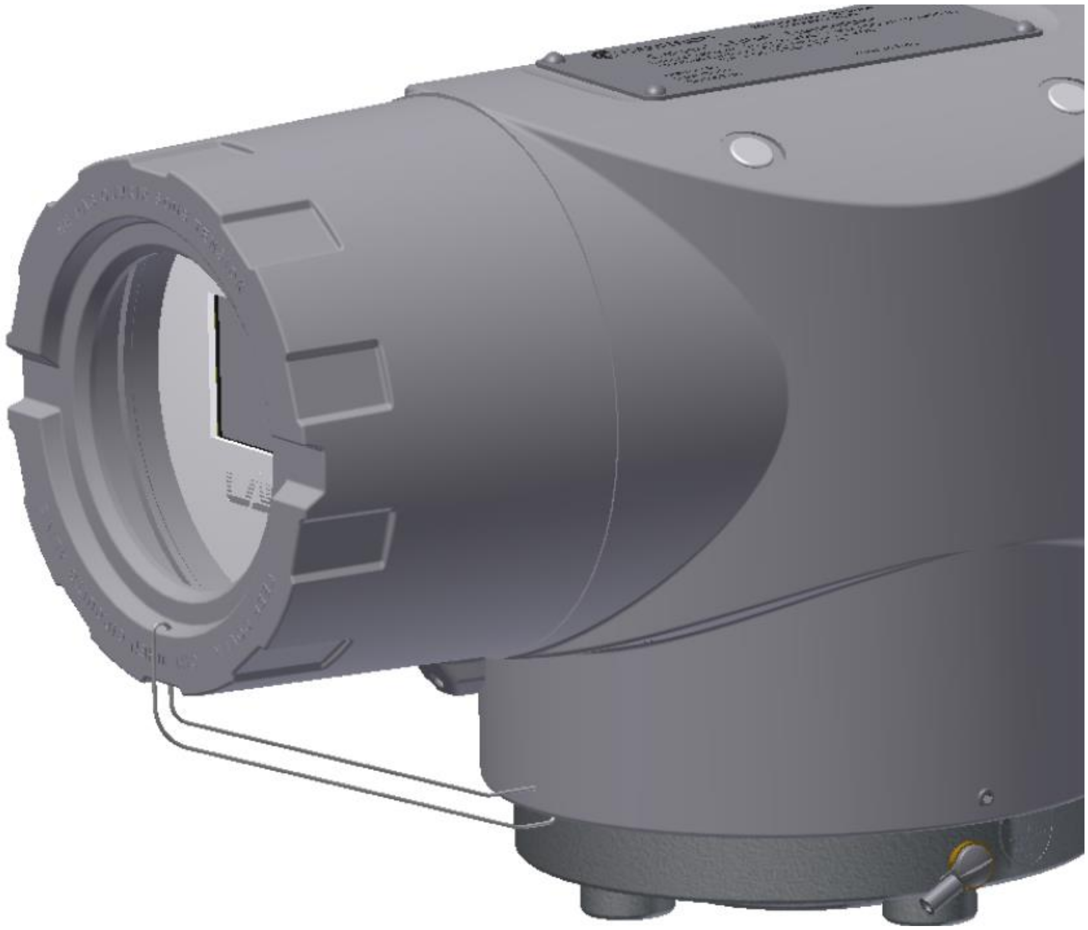

Figure 9-2 Seal Wire on Transmitter Enclosure

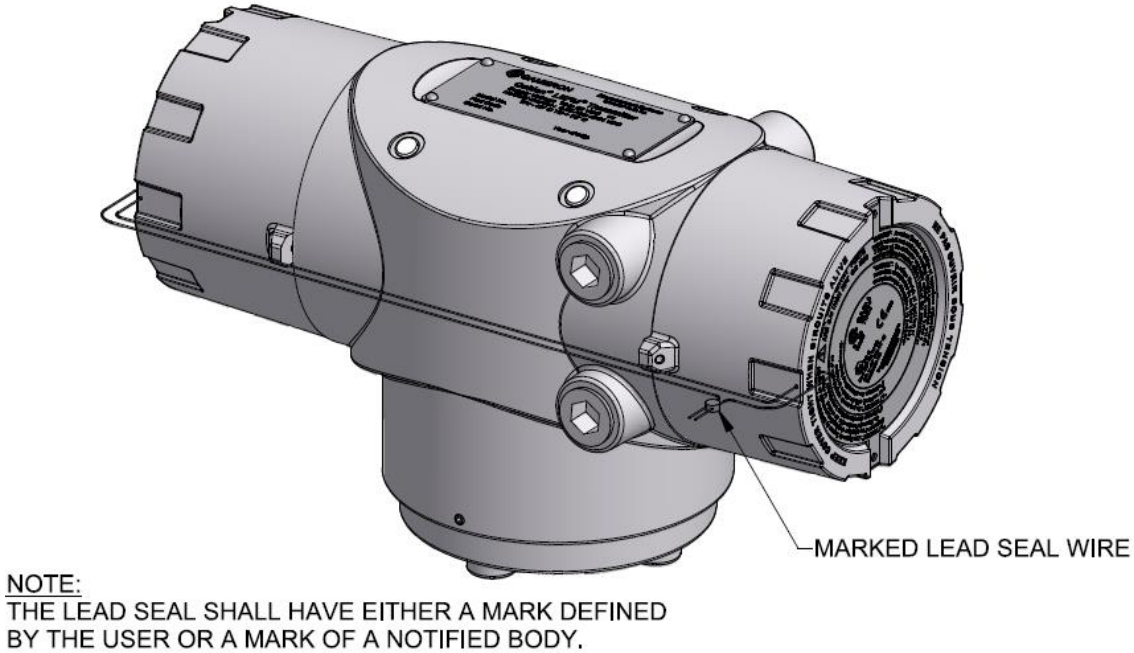

Figure 9-3 Seal Wire on both ends of Transmitter

Each of the accessible circuit boards has tamper evident seals as a tamper evident precaution (particularly in applications where the seal wire is not selected). Figure 9-4 below shows the locations of the two tamper evident seals on the IOP.

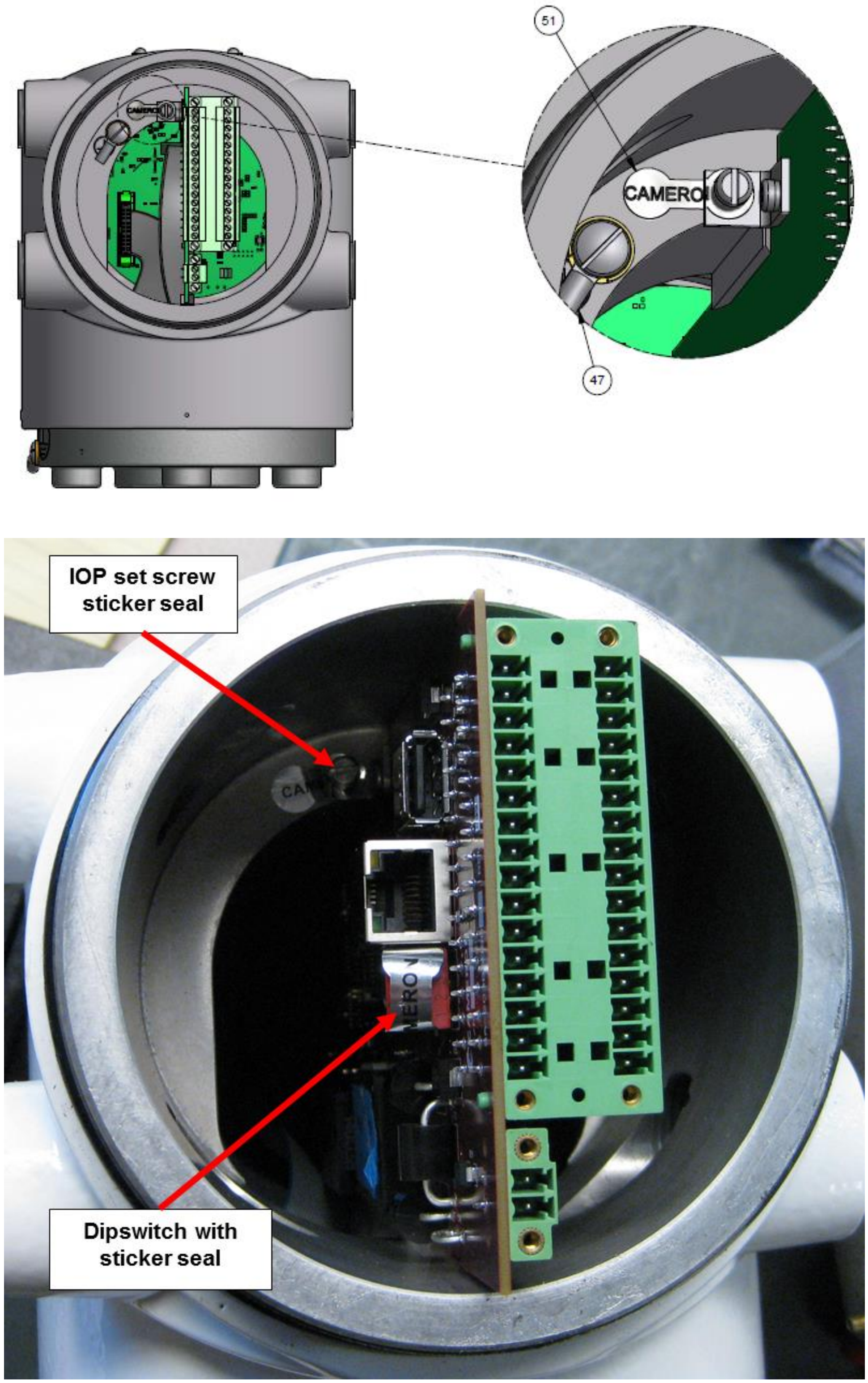

Figure 9-4 IOP Tamper Evident Seals

Further, the meter body has a seal wire on the fasteners for the manifold cover. The seal wire allows the meter owner to verify if there has been any tampering with the meter body. Refer to Figure 9-5.

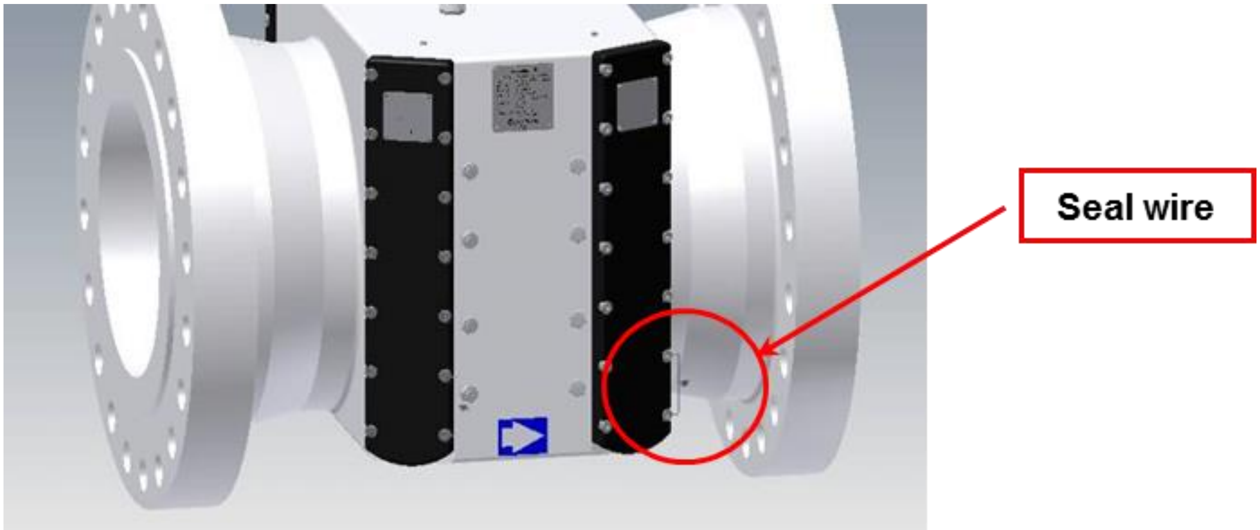

Figure 9-5 Seal Wire on Meter Body

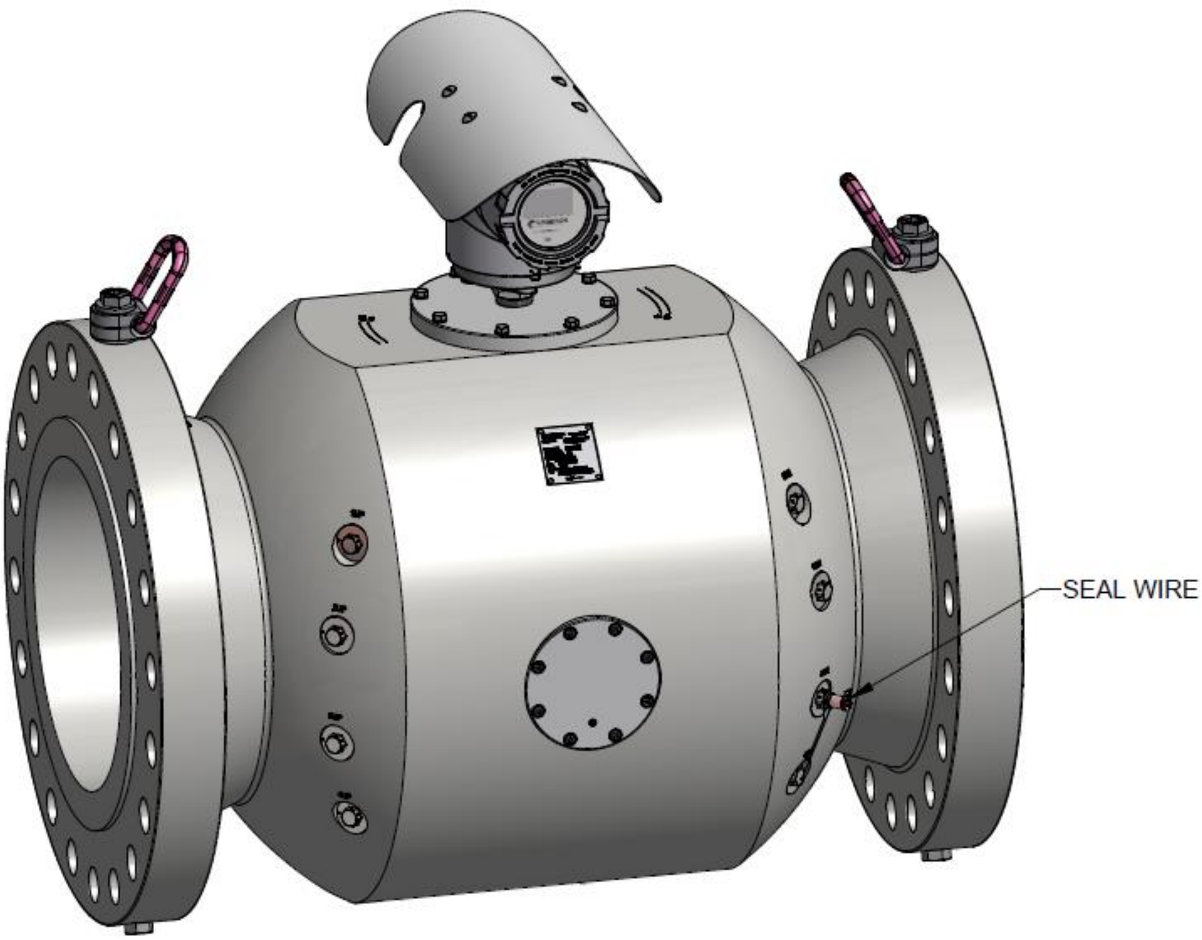

Figure 9-6 Seal Wire on Meter Body (Single Transducer Cover Style)

The remote mount configuration, shown in Figure 9-7 has seal wires for all the junction boxes used in the system.

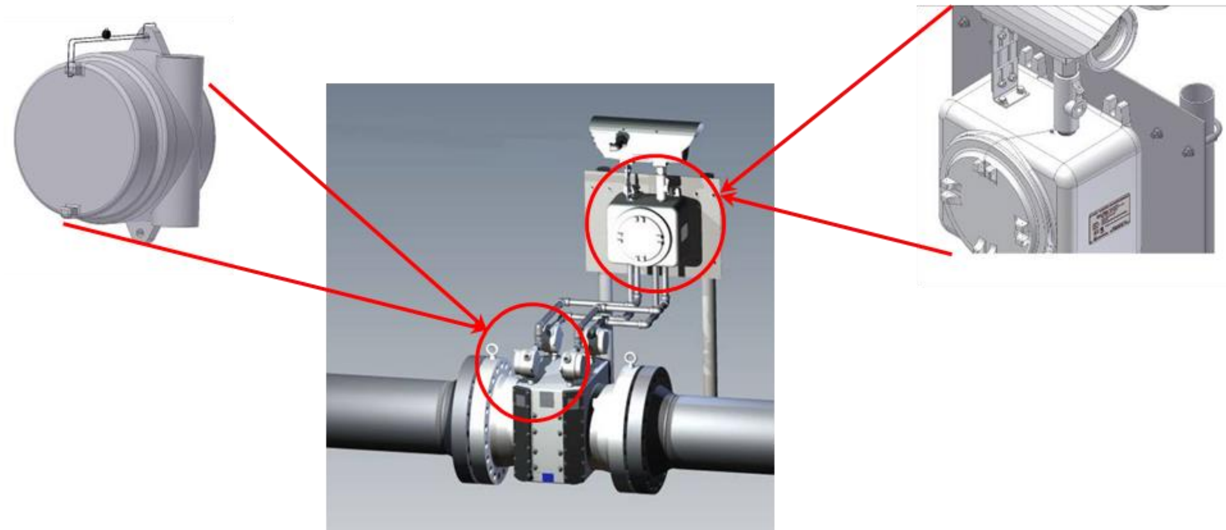

Figure 9-7 Seal Wires for Junction Boxes

Section 10

Secondary Seals and Seal Failure Indication

Secondary Seals

The 2xxCi LEFM flowmeter has a version that is designed to comply with the requirements of ISA standard 12.27.01-2003, “Requirements for Process Sealing between Electrical Systems and Flammable or Combustible Process Fluids”.

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

The vent hole can also be delivered with an additional visual indication of a seal failure. In this optional configuration, if a seal were to fail, then vent hole has a plunger that deploys at the location of the failure. Refer to Figure 10-1 below.

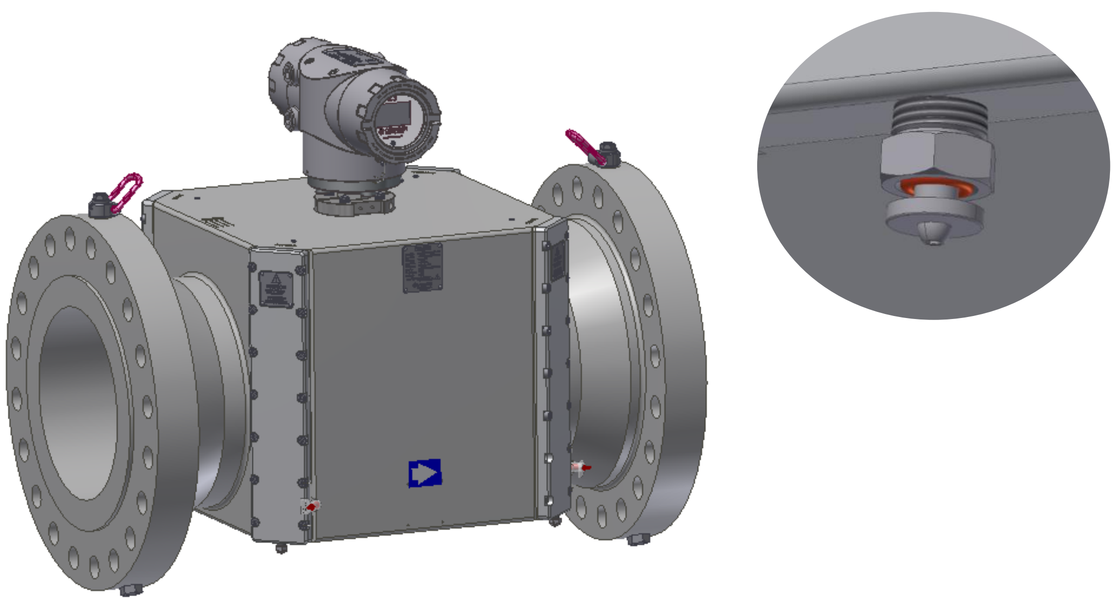

Figure 10-1 Primary Seal Failure Indication

Section 11

Recommended Spare Parts

Transducer Equipment

Qty: 2	Transducer (appropriate frequency)
Qty: 1	Transducer Grease (small tube)
Qty: 16	Transducer Cryogenic Couplant (2xxCiLT-R Only)

Electronic Equipment

Qty: 1	Display Board
Qty: 1	CTC Board
Qty: 1	IOP Board
Qty: 1	MXR Board
Qty: 1	Transducer Interface Board

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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