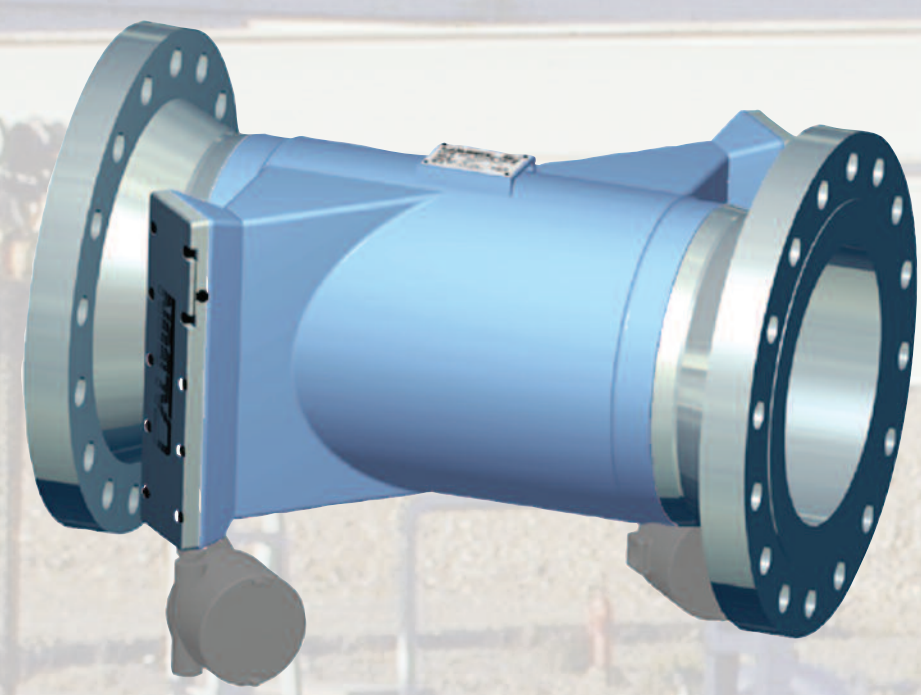
ULTRASONIC CUSTODY TRANSFER FLOW METER



PRODUCT INFORMATION

LEFM® 240C Four Path Ultrasonic Flow Meter

- **Measurement System Simplicity**
  - Large flow capacity
  - No moving components
  - Lowest system weight and installation envelope
- **Reduced Cost of Measurement & Ownership**
  - Stable measurement with flow rate and product change
  - Low pressure drop for lower pumping costs
- **Multi-Property Measurement**
  - Complete condition monitoring
  - Flow stream and performance diagnostics

ML122 Rev 4, May 2005

U.S. Patents: 5546813, 5597962, 5639972, 5705753; Korea Patent 208678, Canada Patent 2107.750; Taiwan Patents NI-080038, UM-119114. U.S. and foreign patents pending.

GENERAL DESCRIPTION

The Caldon LEFM 240C is a multi-path, high performance ultrasonic flow meter intended for applications which measurement accuracy, reliability, and immunity to fluid induced errors are critical. The LEFM 240C is ideally suited for custody measurement of crude oils, refined products, and petroleum blends where meter factor stability is of prime importance. The LEFM 240C will provide superior performance in many applications, including chemical, high temperature, low temperature, and aggressive fluids. The LEFM 240C flow measurement system consists of a meter body and a signal processing transmitter.

Within the meter body are eight fully integrated high performance ultrasonic transducers forming four chordal paths for accurate and stable flow measurement.

DESCRIPTION OF OPERATION

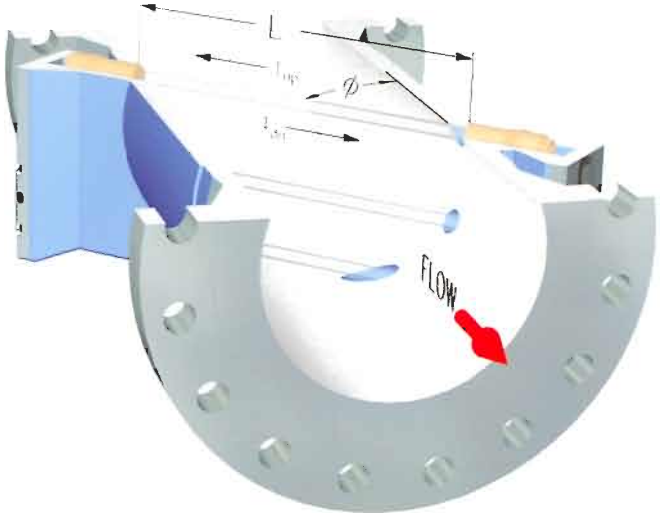
PRACTICE

Ultrasonic transducers within the wall of the meter are aligned diagonally across the flow stream. Sound pulses sent against the direction of the flow take more time to cross than sound pulses sent with the flow. The proportion of the fluid velocity that contributes to the time difference is related to the crossing angle, as is shown below.

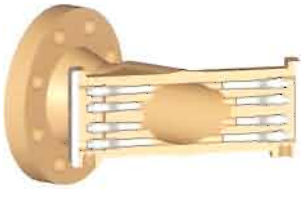
$$T_{dn} = \frac{L}{c + V\cos\phi} \qquad T_{up} = \frac{L}{c - V\cos\phi}$$

Where: L = Path Length
c = Velocity of Sound (VOS)
V = Average Velocity Along the Path
f = Angle of the Path to the Axis of Meter

The meter precisely measures the upstream and downstream transit times. The difference is directly proportional to the flow velocity. The equations are simple and determine the fluid velocity along the transmitted ultrasonic path:



$$V = \frac{L}{2\cos\phi} \times \frac{T_{up} - T_{dn}}{T_{dn} \times T_{up}}$$

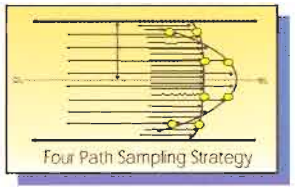


CHORDAL PATHS

The shape of the flow profile within the meter changes with the velocity and viscosity of the flow stream. A meter with a single acoustic path cannot differentiate between flow rate changes and flow profile changes and therefore, is incapable of high accuracy measurement. By using multiple acoustic paths, crossing the flow stream at different levels (chords), the shape of the flow profile can be determined allowing for accurate measurement. The Caldon LEFM 240C meter measures the flow stream velocity along four (4) chordal paths. The average fluid velocity is determined using a Gaussian Quadrature Integration technique that provides extremely accurate and predictable performance under a variety of conditions. The basic equation is given by:

$$Q = \sum_{i=1}^{4} k_{bi} V_i \bullet A$$

Where: Q = Volumetric Flow Rate
k_{bi} = Path Weighting Factor
V = Individual Path Velocity
A = Cross-sectional Area of Meter



METER CONSTRUCTION

The Caldon LEFM 240C Meter Body is designed and manufactured in accordance with ASME B-31.3 Process Piping Code or the Pressure Equipment Directive (PED) 97/23/EC and is suitable for handling pressurized liquid hydrocarbons. It has eight (8) piezoelectric transducer modules (typically 0.5MHz, 1.0 MHz or 1.6 MHz) forming four (4) chordal paths. These are mounted in pressure containing housings and can be replaced while the meter body is under operating conditions

ELECTRICAL APPROVALS

The meter meets the requirements of NFPA 70 for use in Class 1, Division 1, Groups C and D hazardous locations and is classified by UL/cUL. It meets the requirements for NEMA 4X and NEMA 7. It is certified by ATEX (CENELEC IIB) for use in EExd IIB flameproof applications and has an ingress protection rating of IP66.

TRANSMITTER

CE 0891 Ex II 2 G EEx d IIB T6 TRL Certificate No. TRL04ATEX 11056X (TA = -50°C to 60 °C) US C entela. Certified Class I, Groups C and D

METER

CE 0035 CE 0891 Ex II 2 G EEx d IIB T5 TRL Certificate No. TRL04ATEX 110 68X (TA = -50°C to 93°C) US C entela. Certified CSA CL 1, Div 1 GP B,C,D TYPE 4X C US

SIZES, MAX. FLOW RATES, AND K FACTORS

Size		Nominal Maximum Flow BPH	K Factor P/Bbl	Nominal Maximum Flow m^3/h	K Factor P/m^3
Inches	DN				
4	100	2,050	2000	325	12600
6	150	4,650	1000	740	6300
8	200	8,150	500	1,290	3150
10	250	12,800	350	2,030	2200
12	300	19,300	250	3,070	1570
14	350	23,600	200	3,750	1000
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	1000	205,000	20	32,600	125

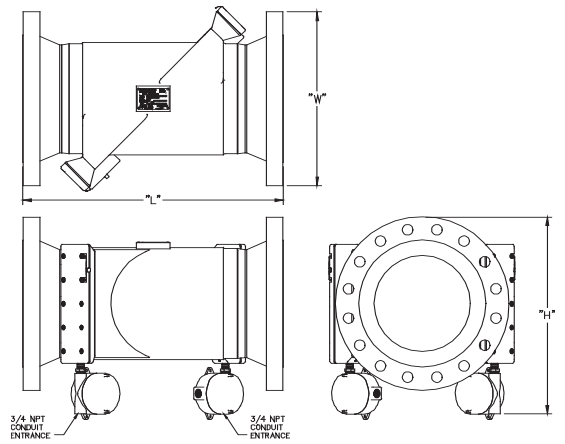
K Factor is based on ~ 1.1 KHz at max. nom. rate. Other K factors can be programmed but must be between 4Hz and 10 KHz at all operating flow rates.

STANDARD MATERIALS OF CONSTRUCTION		
Meter Body	**Stainless Steel**	**Carbon Steel**
Flanges	316 Forged Stainless Steel	Forged Carbon Steel – ASTM A105
Body	Cast Stainless Steel – CF8M (316)	Cast Carbon Steel – ASTM A216 Gr WCB
Manifold	304 Stainless Steel	304 Stainless Steel
Manifold Covers	316 Stainless Steel	316 Stainless Steel
Transducer Housings	316 Stainless Steel	316 Stainless Steel
Junction Boxes	Epoxy Painted Copper-Free Aluminum	Epoxy Painted Copper-Free Aluminum
Transmitter Enclosure		
GP - NEMA 4X	304 Stainless Steel	304 Stainless Steel
EX - NEMA 7	Copper-free Aluminum	Copper-free Aluminum

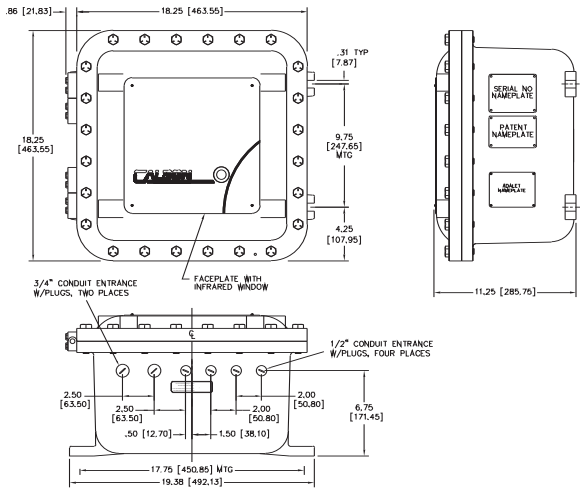
STANDARD END CONNECTIONS and MAXIMUM WORKING PRESSURES		
Maximum Working Pressure -20° F to 100° F (-29° C to 38° C)		
ANSI B16.5 Raised Face	**Stainless Steel**	**Carbon Steel**
Class 150	275 psi (18.96 Bars)	285 psi (19.65 Bars)
Class 300	720 psi (49.64 Bars)	740 psi (51.02 Bars)
Class 600	1,440 psi (99.29 Bars)	1,480 psi (102.05 Bars)
Class 900	2,160 psi (148.93 Bars)	2,220 psi (153.07 Bars)
Class 1500	3,600 psi (248.22 Bars)	3,705 psi (255.46 Bars)

DIMENSIONS AND WEIGHTS

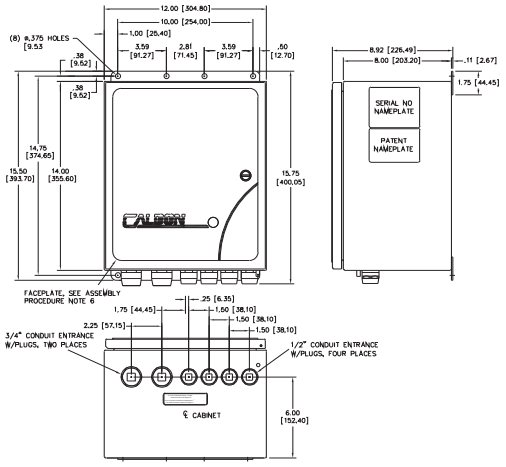
Pipe Size	ANSI Class	L		W		H		Un-Packed Weight	
Inches (DN)		Inches	(mm)	Inches	(mm)	Inches	(mm)	lbs.	(kg)
4 (100)	150	18.0	(457)	9.0	(229)	13.5	(344)	100	(45)
	300	18.8	(477)	10.0	(254)	14.0	(357)	117	(53)
	600	20.5	(521)	10.8	(273)	14.4	(366)	151	(68)
	900	21.5	(546)	11.5	(292)	14.8	(376)	169	(77)
	1500	22.3	(565)	12.3	(311)	15.2	(385)	213	(97)
6 (150)	150	20.5	(521)	11.0	(279)	15.4	(390)	166	(75)
	300	21.3	(540)	12.5	(318)	16.1	(409)	200	(91)
	600	23.2	(590)	14.0	(356)	16.9	(428)	278	(126)
	900	25.0	(635)	15.0	(381)	17.4	(441)	336	(152)
	1500	27.5	(699)	15.5	(394)	17.6	(447)	446	(202)
8 (200)	150	24.0	(610)	13.5	(343)	17.6	(447)	308	(140)
	300	24.8	(629)	15.0	(381)	18.4	(466)	364	(165)
	600	27.0	(686)	16.5	(419)	19.1	(485)	470	(213)
	900	29.3	(743)	18.5	(470)	20.1	(511)	580	(263)
10 (250)	150	26.0	(660)	16.0	(406)	19.9	(506)	481	(218)
	300	27.2	(692)	17.5	(445)	20.7	(525)	559	(254)
	600	30.5	(775)	20.0	(508)	21.9	(557)	757	(343)
	900	33.0	(838)	21.5	(546)	22.7	(576)	897	(407)
12 (300)	150	29.5	(749)	19.0	(483)	22.4	(569)	687	(312)
	300	30.7	(781)	20.5	(521)	23.2	(588)	807	(366)
	600	33.2	(844)	22.0	(559)	23.9	(607)	977	(443)
	900	36.8	(934)	24.0	(610)	24.9	(633)	1177	(534)
14 (350)	150	32.0	(813)	21.0	(533)	24.0	(611)	900	(408)
	300	33.2	(844)	23.0	(584)	25.0	(636)	1040	(472)
	600	35.5	(902)	23.8	(603)	25.4	(646)	1240	(562)
	900	39.3	(997)	25.3	(641)	26.2	(665)	1480	(671)
16 (400)	150	33.5	(851)	23.5	(597)	26.4	(671)	1056	(479)
	300	35.0	(889)	25.5	(648)	27.4	(696)	1276	(579)
	600	38.0	(965)	27.0	(686)	28.2	(715)	1556	(706)
	900	41.5	(1054)	27.8	(705)	28.5	(725)	1766	(801)
18 (450)	150	37.0	(940)	25.0	(635)	28.2	(716)	1170	(531)
	300	38.5	(978)	28.0	(711)	29.7	(754)	1510	(685)
	600	41.0	(1041)	29.3	(743)	30.3	(770)	1820	(826)
	900	44.5	(1130)	31.0	(787)	31.2	(792)	2230	(1012)
20 (500)	150	39.4	(1000)	27.5	(699)	29.8	(757)	1310	(594)
	300	40.8	(1035)	30.5	(775)	31.3	(795)	1750	(794)
	600	43.5	(1105)	32.0	(813)	32.0	(814)	2130	(966)
	900	48.0	(1219)	33.8	(857)	32.9	(836)	2610	(1184)
24 (600)	150	44.0	(1118)	32.0	(813)	34.0	(865)	1610	(730)
	300	45.2	(1149)	36.0	(914)	36.0	(915)	2250	(1021)
	600	48.5	(1232)	37.0	(940)	36.5	(928)	2750	(1247)
	900	55.5	(1410)	41.0	(1041)	38.5	(979)	4090	(1855)
26 (650)	150	43.5	(1105)	34.3	(870)	36.2	(919)	1790	(812)
	300	48.5	(1232)	38.3	(972)	38.2	(969)	2400	(1089)
28 (700)	150	45.9	(1165)	36.5	(927)	38.3	(973)	1970	(894)
	300	51.5	(1308)	40.8	(1035)	40.4	(1027)	2770	(1256)
30 (750)	150	48.8	(1239)	38.8	(984)	39.7	(1007)	2160	(980)
	300	54.5	(1384)	43.0	(1092)	41.8	(1061)	3100	(1406)
32 (800)	150	51.4	(1305)	41.8	(1060)	42.2	(1071)	2450	(1111)
	300	57.5	(1461)	45.3	(1149)	43.9	(1115)	3450	(1565)
34 (850)	150	53.8	(1366)	43.8	(1111)	44.2	(1122)	2600	(1179)
	300	60.2	(1530)	47.5	(1207)	46.0	(1169)	3810	(1728)
36 (900)	150	56.4	(1432)	46.0	(1168)	46.3	(1176)	2880	(1306)
	300	63.0	(1600)	50.0	(1270)	48.3	(1227)	4150	(1882)



METER BODY



EX TRANSMITTER



GP TRANSMITTER

EX - Explosion Proof
Unpacked Weight: 120 lbs. (54.5 kg)
Use 1/2 inch bolts/hardware (or equal) on all mounting points for the Explosion Proof (NEMA 7) transmitter. Cover bolts are metric (19 mm).
Available with high quality offshore paint specification

GP - NEMA 4X
Unpacked Weight: 30 lbs. (13.6 kg)
Use 1/4 inch bolts/hardware (or equal) on at least the 2 top and 2 bottom mounting points for the NEMA 4X transmitter

PERFORMANCE SPECIFICATION - LEFM 240C

GENERAL PERFORMANCE

Linearity (Accuracy):	+/- 0.15% or better over Nominal Flow Range
Repeatability:	0.02% (API MPMS definition)
Flow Range:	Nominal 10:1 or greater dependent on flow conditions
Velocity Range:	Nominal 1 to 40 ft/s (0.3 to 12 m/s)
Meter Factor Uncertainty:	0.027% (Due to proving repeatability; API Proving definition)
Long Term Stability:	Accuracy unaffected by usage; SD 0.02% for conditions within Nominal Flow Range

EXTENDED PERFORMANCE

High Viscosity Performance:	Contact Caldon for viscosities and flow rates resulting in very low Reynolds numbers as this may increase uncertainty depending on site conditions.

CUSTODY TRANSFER CERTIFIED

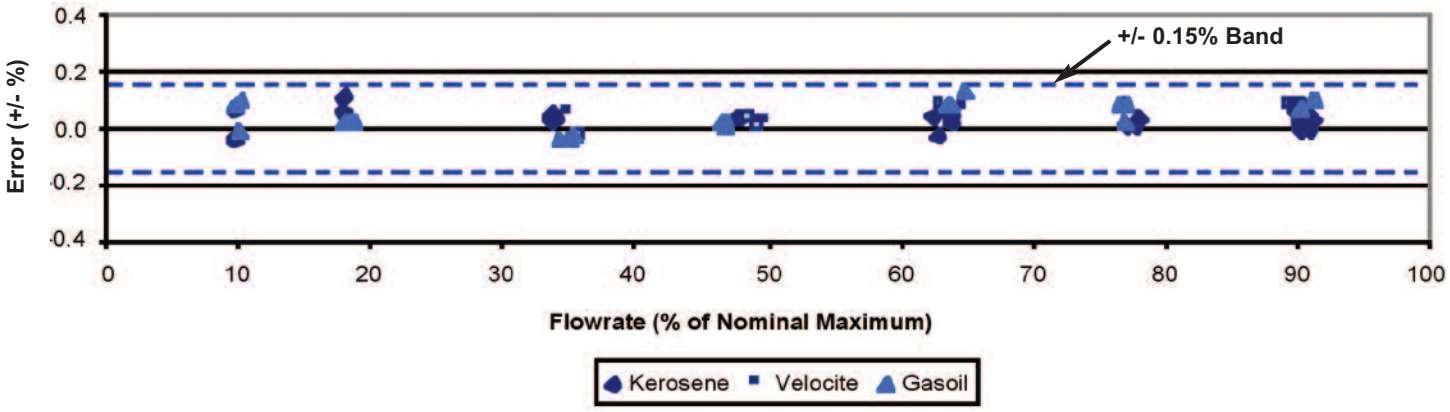
Organization for Legal Metrology:	OIML R 117 Edition 1995 (E)
Field of Application:	Accuracy Class 0.3 (Measuring Systems for Pipeline and Ship Loading)
Certification:	NMi (Dutch Weights and Measures) Test Certificate TC3499R01

WATER IN OIL

For water volumes up to 10% and velocities above 6.5 ft/s (2.0 m/s), the meter will measure the total volume with no change in performance. Below 6.5 ft/s (2.0 m/s) the performance depends on the separation of the water. Contact Caldon for special applications outside these ranges.

Typical Performance Curve

Error vs. Flow Rate



GENERAL SPECIFICATIONS

Power Requirements

Voltage (+/- 10%):	120VAC 240VAC 24VDC
Power - with heaters	80 W

Operating Temperatures

Interconnect Cable:	-40°F (-40°C) to 140°F (60°C)
Transmitter (Operating):	-30°F (-35°C) to 140°F (60°C)
Transmitter & Manifold (ATEX):	-58°F (-50°C) to 140°F (60°C)
Meter:	-328°F (-200°C) to 465°F (241°C)

(Inform Caldon of actual operating temperature range prior to ordering)

Relative Humidity

Meter:	0-100% Relative Humidity
Transmitter:	0-95% Relative Humidity

Pulse Output

A-1,2:	0-5V (Continuous 50/50 duty cycle, Programmable K Factor)
B:	Leads A-1 by 90° elect. deg. (for flow direction)
Alarm Status:	0 or 5V

Analog (I/O)

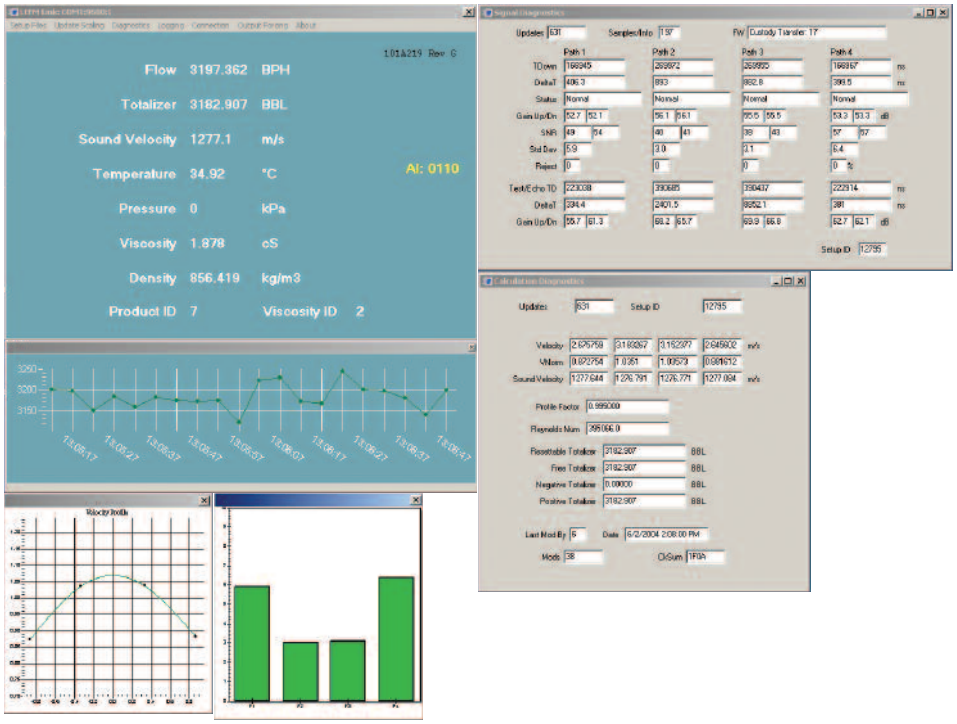
Input:	Up to 3 - Temperature, Pressure, and Density
Output:	Up to 4 - Flow rate, Viscosity, Density, Temperature, VOS (Velocity of Sound), Signal Gain, Signal Noise Ratio and Signal Rejects

Communication

ModBus RTU:	RS 232 - Up to 25 ft (8 m) RS 485 - Up to 3,900 ft (1,200 m)

DIAGNOSTIC TOOLS

LEFM Link is a PC based software that enables the user to view operating parameters to validate the accuracy of the meter. Further, it can provide a continuous audit of the meter. The flow profile signature can be recorded at calibration and compared at installation to track variations that could affect the accuracy of the meter. It can also be used to track other changes in the process conditions that can affect accuracy, such as wax build-up within the meter body and the effect of drag reducing agents (DRA) on the flow characteristics. Acoustic transducer signal gains, signal-to-noise ratios and sample statistics enhance the analysis, and provide for continuous fault finding of the meter. Through LEFM Link it is possible to remotely scale the analog inputs and outputs, and force the pulse and analog outputs for troubleshooting.



BASIC ORDER INFORMATION

LEFM 240C- 6- 40- SS- 150- EX

Meter Size, Inches

Schedule:
40
STD
80
100
120
160
XXS
0.625
0.750
0.875

Material
SS = Stainless Steel
CS = Carbon Steel
DS = Duplex Stainless Steel

ANSI Flange Rating
150
300
600
900
1500

Enclosure Type
GP = NEMA 4X
EX = Aluminum, Explosion Proof
ES = Stainless, Explosion Proof

ADDITIONAL OPTIONS

Analog Inputs

There are up to 3 inputs. Each input can be assigned one of the following:

Pressure (4-20mA)
Fluid Temperature
Density

Analog Outputs (Galvanically isolated)

There are up to 4 outputs. Each output can be assigned to any one of the following:

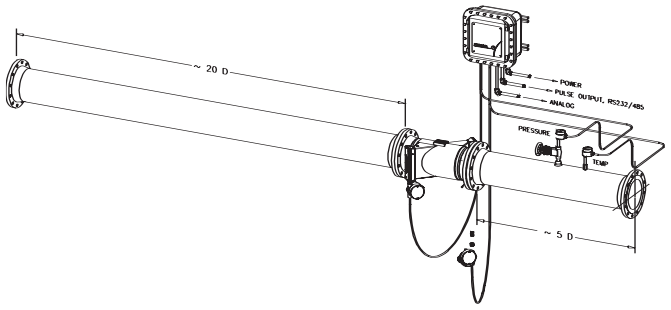
Flowrate (Actual)
Viscosity
Density
VOS
Gain
SNR
Temperature
Signal Rejects

Power Supply

120VAC
240VAC
24VDC

INSTALLATION

Following some basic minimum installation requirements ensures the best possible performance for the LEFM 240C. The meter should have upstream straight pipe of the same schedule as the meter. Process temperature and pressure should be measured downstream of the meter. It is recommended that the LEFM 240C meter be installed downstream of at least 20 diameters of straight pipe of the same nominal diameter as the meter or 10 diameters downstream of a straightening / conditioning element. There should be at least 3 to 5 diameters of straight pipe of the same nominal diameter as the meter downstream. These conditions minimize the possibility of significant flow profile distortions and swirl. Where installation guidelines cannot be met, consult with Caldon to determine acceptable application options.



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