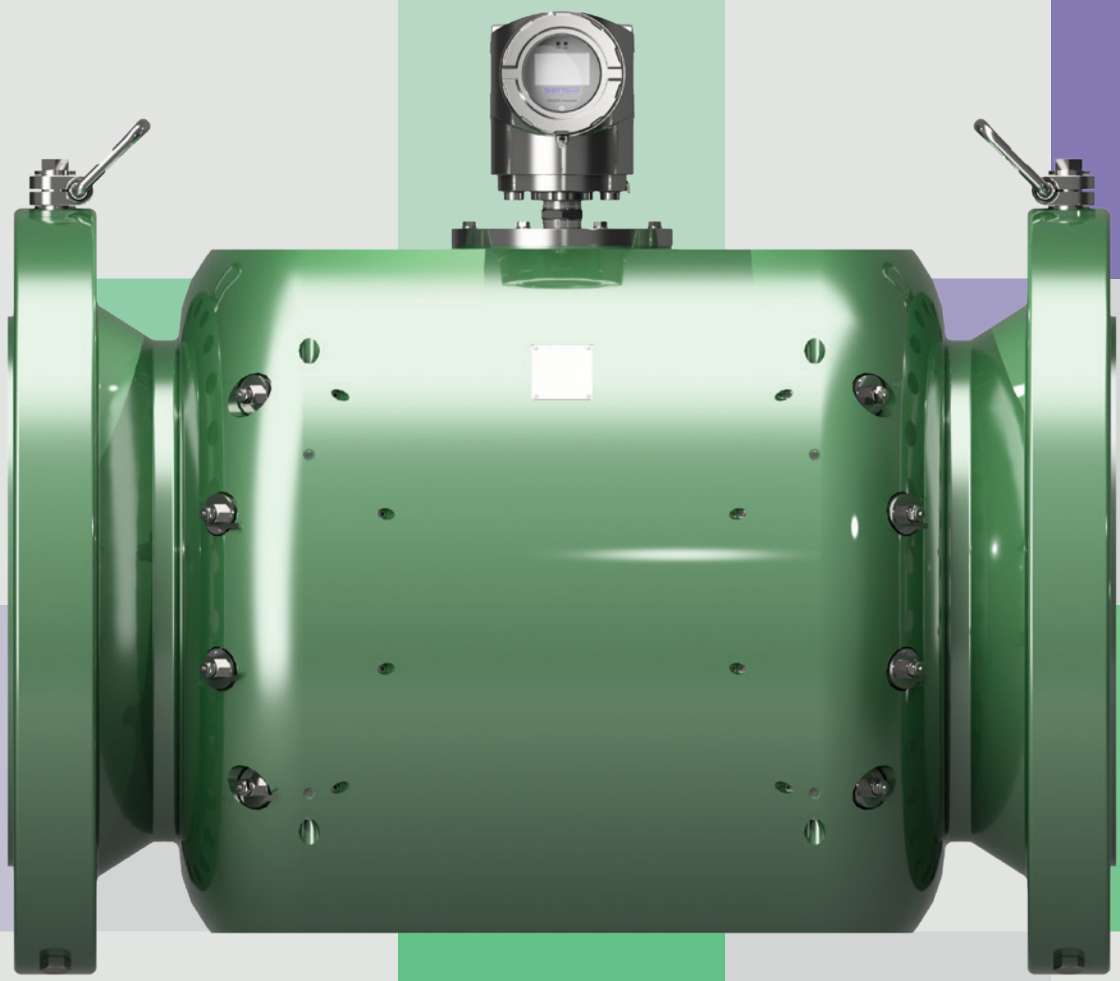
SENSIA

+ MEASUREMENT SOLUTIONS

CALDON LEFM 500 Series

Ultrasonic meters for carbon dioxide in the liquid and dense supercritical phase



INTELLIGENT ACTION

CALDON LEFM 500 Series

The CALDON LEFM 500 Series is the result of a coalescence of CALDON experience in both liquid and gas applications – utilizing core technology building-blocks that stem from decades of practical application and development.

CALDON's transducer technology, developed for challenging application conditions, has been adapted and optimized for use in CO_2 applications spanning the liquid and dense supercritical phase of the CO_2 phase diagram. Coupled with a digital electronic platform, the CALDON LEFM 500 Series is designed to meet the accuracy demanded of fiscal and custody transfer metering in CO_2 applications.

Many years of extensive modeling and testing experience enables Sensia to configure the 500 Series to meet the needs of particular CO_2 measurement applications, including but not limited to ship loading, large-scale import or export for pipeline transportation, and for high-pressure wellhead injection measurement. The adoption of well-established design, manufacturing, and calibration processes from the CALDON 200 and 300 custody transfer flow meters, ensures confidence and accuracy of the CALDON 500 Series.

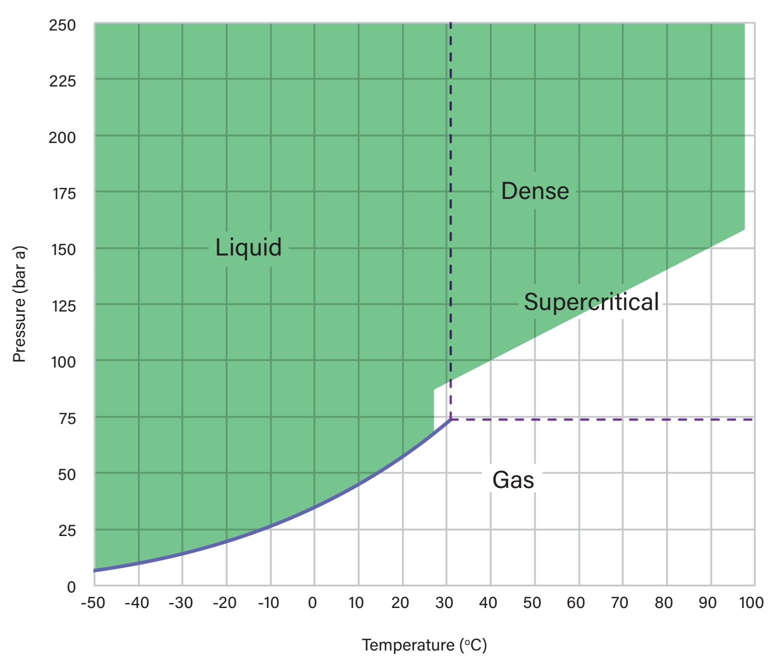
The development of the 500 Series [figure 1] has also been complemented by a long-term cooperation with SLB/OneSubsea to develop a subsea version of the CALDON meter [figure 2], which has been tested with pure CO_2 and CO_2/N_2 mixtures at temperatures and pressures spanning the gas, liquid and dense supercritical regimes. As a result of these parallel and cooperative developments, Sensia and OneSubsea can offer robust and highly accurate USMs and digital solutions to track CO_2 quantities from pipeline to pore.

The CALDON LEFM 500 Series includes four-path (540Ci), two independent four-path meters in one body (544Ci), eight-path (580Ci), two independent eight-paths in one body (588Ci) and Self Verifying Meter (589Ci) variants configured to meet the application demands in terms of redundancy, measurement uncertainty, and verification requirements.

All 500 Series variants utilize the same transducers and digital electronics platforms common with the long-established and field-proven 200 and 300 Series meters. The 540Ci four-path meter is a conventional Ultrasonic Meter (USM) which generally requires the use of a flow conditioning device. The 580Ci eight-path meter is a high-performance meter, less susceptible to fluid-dynamic installation effects than the 540Ci. The 580Ci can achieve high accuracy in compact installations with a minimum upstream straight length of five pipe diameters with no need for flow conditioning. For pay/check functionality or 100% redundancy a 544Ci or 588Ci can be delivered.

The 589Ci compliments the performance of the 580Ci with highly sophisticated yet easy to use Self Verifying Meter (SVM) technology, which delivers an uncertainty output in quantitative terms alongside the measurement result.

The first of its kind, SVM technology enables a meter to be continuously verified in-situ. Eliminating the need to install complex calibration systems, costly master meters, or remove meters for elapsed-time based recalibration.



CALDON LEFM 500 Series meters can be applied across the dense supercritical and liquid regions as indicated in the phase diagram above

Building on our track record of ultrasonic metering excellence

CALDON technology has been at the forefront of high-performance ultrasonic metering for over 50 years.

When high accuracy, reliability and critical performance is required, CALDON delivers. Pioneering the use of USMs in some of the most challenging applications such as safety-critical nuclear feed water measurement, high viscosity crude oil custody transfer (overcoming limitations at low Reynolds numbers) and cryogenic applications such as liquefied natural gas (LNG).

CALDON's continual developments and decades of experience reinforce our ability to deliver optimized solutions for demanding applications. Today the stage is set for a new challenge – reliable, accurate measurement of CO_2 within the Carbon Capture, Utilization and Sequestration (CCUS) chain.

CCUS will be a key contributor to achieving the global goal of net zero. However, as contractual commitments, regulations, standards and technology continue to evolve, it is not only important that we accurately capture and measure CO_2, but utilize methods that minimize the carbon footprint of the transportation and sequestration life cycle.

Although various technologies, including ultrasonic, Coriolis and differential pressure meters can be considered for CCUS processes, misconceptions about metering suitability arises when solely focusing on the commercial and technical comparisons of the meters themselves.

When the measurement system is evaluated holistically, considering the operational implications and carbon equivalence of multiple meter runs, valves, potential leak points, space, weight, verification techniques and pressure loss, the benefits of using ultrasonic metering technology within metering systems become very significant.

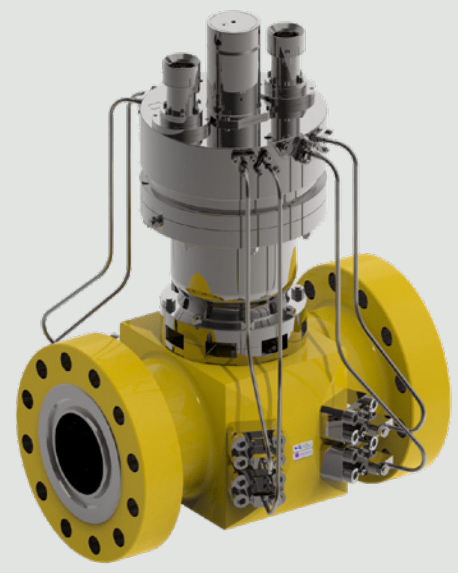
Owing to its non-intrusive, full-bore design and high rangeability, ultrasonic metering technology is ideal for high-capacity applications such as CO_2 pipeline transportation and sequestration. The CALDON 500 Series technology provides a significant opportunity for system complexity reduction. A single-stream ultrasonic metering system can often serve the same function as that of other technologies which rely on multiple streams to achieve the same rangeability. Ultrasonic metering technology offers additional significant advantages over other metering technologies, such as reduced pressure loss.

Benefits include, but are not limited to: reductions in CAPEX and OPEX, system footprint and weight, reduction in potential leak points and pressure drop potential, reduced system connections and operating equipment, and simplified maintenance regimes due to the reduction in number of streams.

CALDON USMs combine high accuracy and robust design with the digital features expected from a modern metering technology.

Figure 1: LEFM 500

Figure 2: Subsea Ultrasonic Meter



Key application considerations – system design and operation

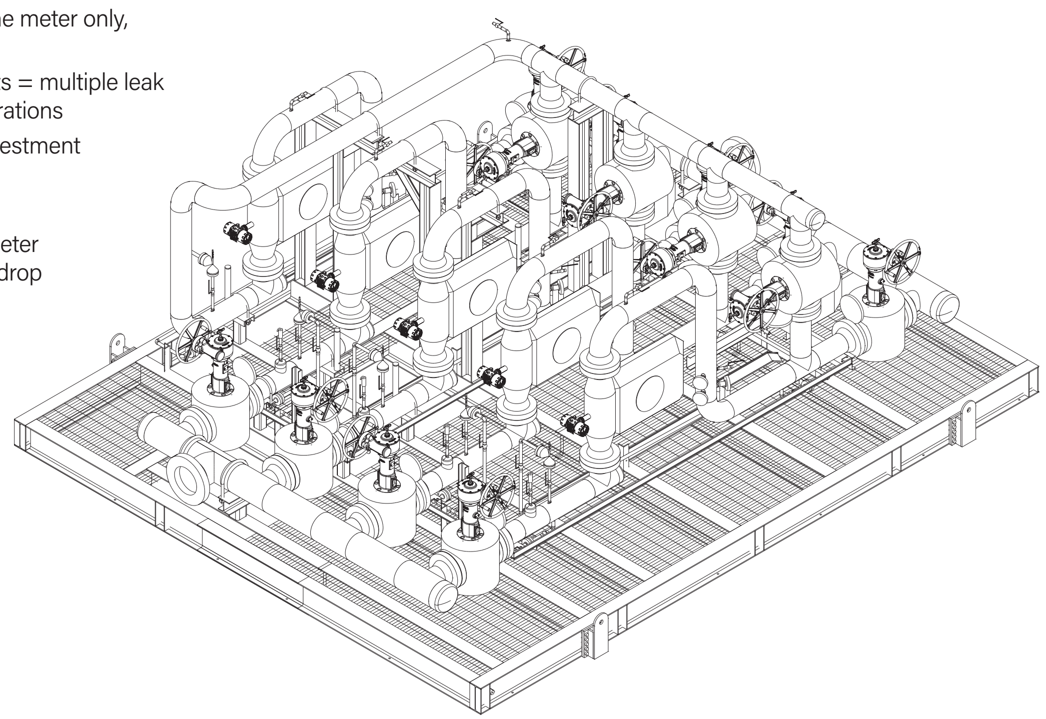
When evaluating liquid and dense supercritical phase CO_2 applications, it is important that we not only compare the features of the primary elements but also their impact on the resulting metering system, taking configuration, operability and performance into consideration.

In addition to the CAPEX and OPEX considerations, potential leak points, the impact of leakage, system complexity, and the operational carbon footprint of the system should be considered. Systems with higher permanent pressure loss will result in greater energy consumption and a larger associated carbon footprint where the latter seems counterproductive to the ultimate goal.

By means of example we can consider a large CO_2 metering application involving transfer of CO_2 at a transportation hub. Here we compare two modern technologies, USMs along with Coriolis metering and their impact to the overall system design and operation. For this example, we have used a transfer rate of 60 million tonnes per annum (MTPA) at a pressure of 160 bar(g) and conditions ranging between -5 degC (with a density of ~1025 kg/m^3), and 30 degC (with a density of ~858 kg/m^3).

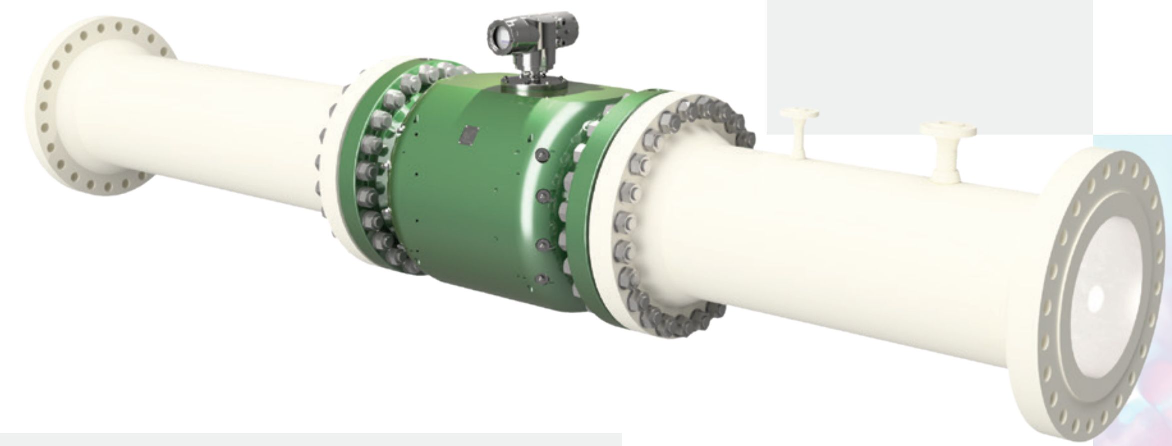
Coriolis-based measurement system
To handle the flow capacity requires a metering system with 4 parallel operating streams (and usually a 5th spare/standby or master meter stream, to cater for equipment failures or in-situ verification). Key characteristics of this system include:

+ > 35 m/s tube velocities in the Coriolis meter
+ ~ 3.3 bar pressure loss (across the meter only, not including other components)
+ Multiple streams and components = multiple leak points and maintenance considerations
+ Significant CAPEX and OPEX investment
+ Large complex system requiring above-ground infrastructure
+ Series operation with a master meter (if required) will double pressure drop



CALDON LEFM 500 Series, single stream solution

+ Single stream full bore 24″ USM operating at < 12 m/s
+ 5-diameter minimum upstream straight length and no flow conditioner, resulting in negligible system pressure drop (~0.09 bar)
+ One stream, one set of instrumentation and no requirement for complex headers and valving arrangements thus reducing potential leak points
+ A second full bore USM can be added in series for comparison and/or redundancy with negligible pressure loss
+ Meter location flexible, i.e. where advantageous can be installed in a pit avoiding any expensive above ground infrastructure
+ The CALDON SVM 589Ci provides the opportunity for reduction or removal of time based verification, avoiding the requirement to break and depressurize the CO_2 pipeline



Comparison of power consumption and CO_2 equivalence of pressure loss
The following comparison looks at the impact of pressure loss on power consumption[1] and expresses the power as a CO_2 equivalent[2] value. This calculation addresses the pressure loss across the meters only, and the contrast will be even more significant when system components (valves and headers) are also considered.

+ The power consumption calculated for the Coriolis pressure loss of 3.3 bar and a throughput of 60 MTPA is 8,196,791 kWh per annum
+ The power consumption calculated for the 24″ USM pressure loss of 0.09 bar and a throughput of 60 MTPA is 223,549 kWh per annum
+ The power consumption that can be avoided by adopting the 24″ ultrasonic solution is therefore 7,973,242 kWh per annum
+ The CO_2 equivalent value corresponding to 7,973,242 kWh avoided is 5,650 metric tons of CO_2 per annum. This is equivalent to greenhouse gas emissions associated with burning 31.2 railcars' worth of coal or the electricity used by 1,099 homes

[1] A pump efficiency of 85% and motor efficiency of 92% are assumed in this calculation.
[2] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Key application considerations: calibration, verification and flow computation

Mass flow computation

USMs are volumetric devices and require density information from an external source to compute mass flowrate. The density can be calculated from CO_2 composition using the AGA 8 Part 2 (2017) standard calculations on board a Sensia Scanner 3100 flow computer, a Sensia-Swinton Technology Virtual Flow computer or a device of the customer's choice.

Flow calibration and verification

Although certain meter types are more or less reliant on the similarity of calibration and application conditions, no meter type is completely independent of fluid property and process conditions. With due care in design, both ultrasonic and Coriolis technologies can be relatively insensitive to fluid properties and application conditions.

However, it should be noted that accuracy figures are usually quoted at reference conditions and no matter which technology is selected, additional uncertainty is incurred when operating with fluids, temperatures and pressures different from those used at calibration.

USMs are often used in conditions that are not exactly matched by the calibration conditions. ISO and API standards recognize the dependence of the USM on Reynolds number, and the suitability of calibration over an appropriate Reynolds number range. ISO 12242 (ultrasonic transit time meters for liquids) and ISO 21903 (dynamic measurement of LNG) recognize the need to calibrate with alternative fluids, and allow for extrapolation of calibration results where required.

For CALDON USMs Sensia employ a well-established calibration method for fluids and conditions that cannot be replicated in calibration laboratories, such as LNG. Meters are calibrated using a surrogate fluid (such as a light hydrocarbon oil at the independently ISO 17025 accredited CALDON Ultrasonic Meter Technology Centre).

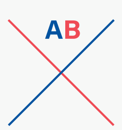
The Sensia calibration methodology has been independently reviewed by NMi, a recognized world leader in flow meter certification and the weights and measures authority of the Netherlands. The report produced by NMi, documents the uncertainty method and provides example results[1]. Applying the documented methodology to calibration of 500 Series meters for CO_2 applications, the evaluation of the uncertainty owing to calibration using a surrogate fluid results in a contribution to the overall uncertainty of < 0.3%.

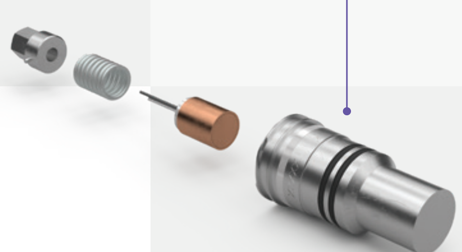
[1] NMi Report CPC 10200742 evaluation of the calibration method applied to LEFM ultrasonic flow meters for high Reynolds numbers and extreme temperatures.

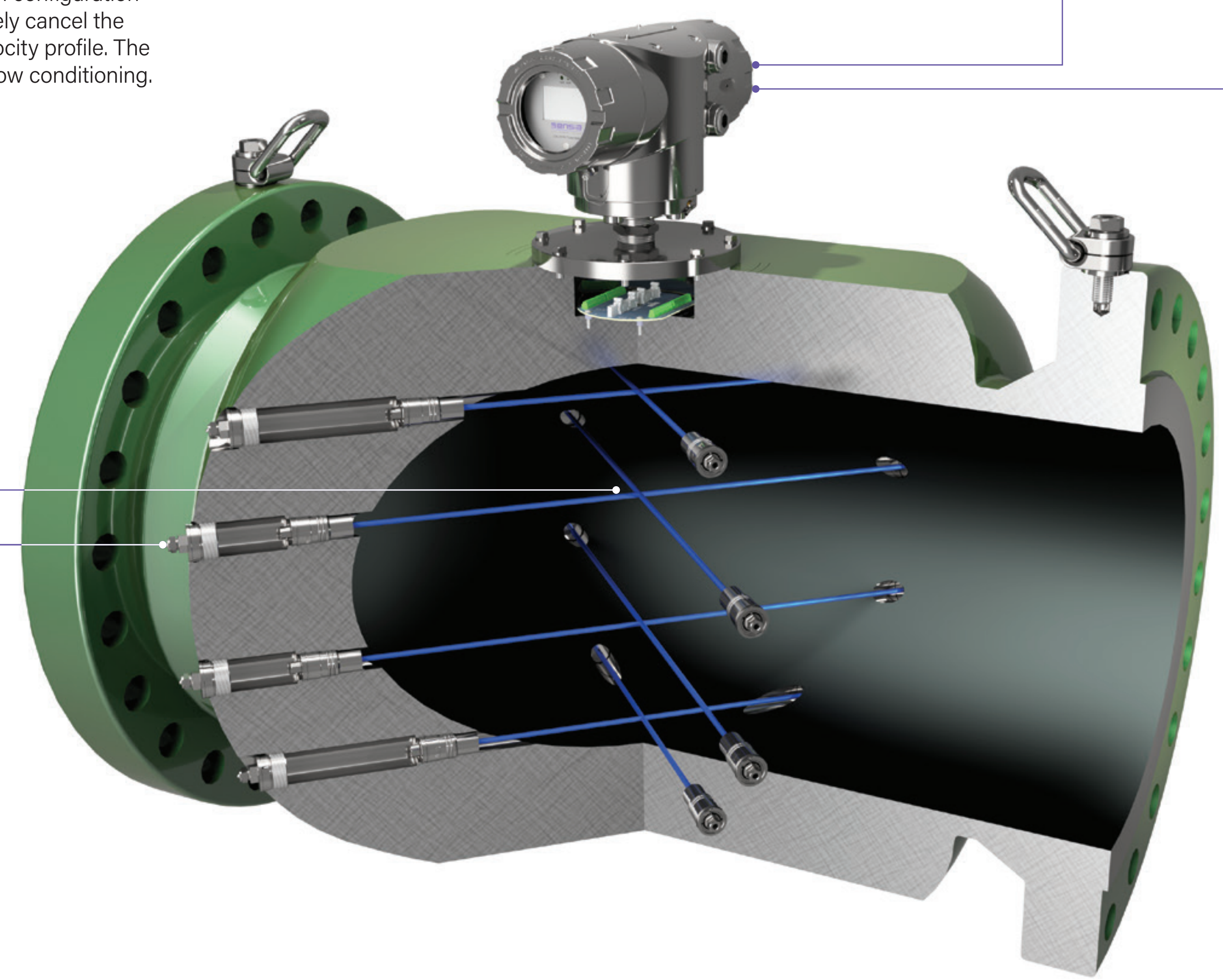
Accuracy, reliability and high integrity, without exception

Built upon proven ultrasonic technology
For over 50 years, CALDON ultrasonic flow meters have provided the industry with highly accurate, reliable, and low cost-of-ownership measurement solutions. CALDON technology is well-proven with installations dating back to the 1970s and is utilized globally across a wide range of liquid and gas applications. The 500 Series uses the same meter design elements, transducers, and electronics technology as our field-proven 200 and 300 Series custody transfer USMs.

Low installation uncertainty
The CALDON LEFM 580Ci and CALDON SVM 589Ci employ our proven eight-path configuration for their primary measurements. The eight-path configuration uses crossed paths (AB) in each of four chordal planes to effectively cancel the effect of non-axial velocities and accurately integrate the axial velocity profile. The meter requires a minimum of 5D upstream without the need for flow conditioning.







Transducer technology:

+ Transducers that are isolated from the process and outside the pressure boundary for ease of service, if required.
+ No recalibration or zeroing required if a transducer is replaced
+ In-house transducer manufacturing and testing for maximum quality control

CALDON USM ADVISOR is an intuitive, intelligent and automated Condition-Based Monitoring system. For CALDON SVM 589Ci model the Advisor screens, warning limits and reports include additional features using the SVM's quantitative evaluation of measurement uncertainty in % or volumetric terms.

Comprehensive I/O
The CALDON 500 Series is equipped with a broad range of I/O which can be configured to suit the needs of the operator.

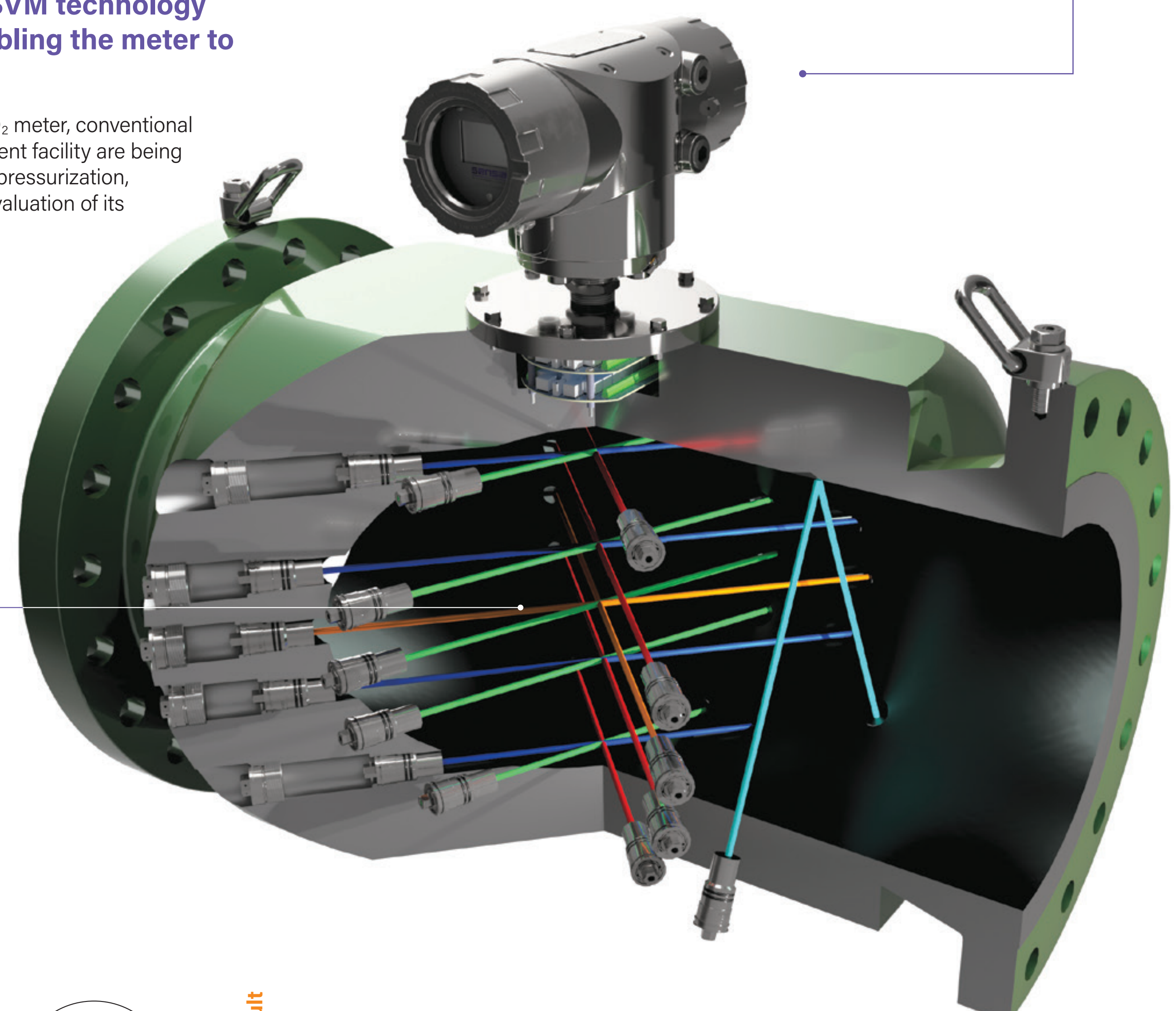
Communications	RS485 (up to 3 in total) Modbus RTU
	Ethernet (copper and fiber)
	HART (optional)
Pulse outputs/alarm	Pulse direction/outputs (4 total)
	Alarm status (4 total)
Analog inputs	3 total
Analog outputs	2 total

INTELLIGENT ACTION

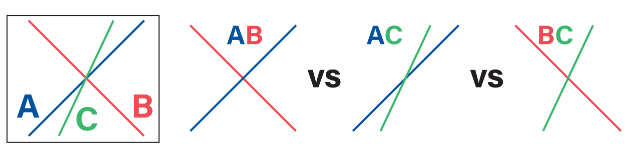
Quantitative and continuous self-verification with CALDON SVM 589Ci

Ultrasonic flow meters are well known for their advanced diagnostic capabilities, which can be utilized to alert a user to a change in meter behavior or process condition. Using the CALDON LEFM 580Ci as the underlying technology for flow rate measurement, our CALDON SVM technology enhances, and surpasses, existing capabilities by enabling the meter to continuously quantify its measurement uncertainty.

In the absence of any proven in-situ methods to verify the performance of a CO_2 meter, conventional approaches, such as master meters or removal for recalibration at an independent facility are being considered. These however, will increase leak points and/or require pipeline depressurization, the SVM solves this critical operational challenge by delivering a quantitative evaluation of its performance through a live uncertainty output.

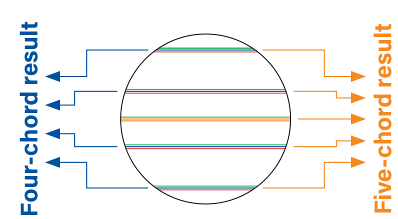


Three paths per chordal plane:
Axial velocity verification

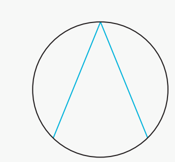


The axial velocities measured on multiple chordal planes are the primary input to an USMs calculation of flowrate. Use of a pair of crossed paths on each chordal plane (paths A and B as used in the eight-path meter) enables the cancellation of the unwanted components of non-axial velocity. The addition of the third (C) path enables the uncertainty of the axial velocity measurements to be determined on each chordal plane by a patented method that compares the axial velocity values from the AB, AC and BC path combinations.

Four-chord versus five-chord:
Velocity profile verification
The integration of the velocity profile in a chordal USM is achieved by calculating a weighted average of the chordal axial velocities. SVM technology incorporates a fifth measurement plane on the diameter. This enables the computation of a four-chord (eight-path) weighted average velocity and a five-chord (ten-path) weighted average velocity using a distinct set of weighting factors. Comparison of the four- and five-chord results obtained by this patented method enables quantification of the uncertainty associated with averaging the velocity profile.



Uncertainty totalization
SVM technology enables the simultaneous calculation of measurement uncertainty alongside each flow measurement calculation – updated once per second. In addition to the continuous and instantaneous output of uncertainty in terms of volumetric flowrate or a relative percentage value, SVM totalizes uncertainty values internally. This powerful feature means that measured volume totals and corresponding uncertainty totals can be read at intervals – e.g. daily or weekly – with the measurement uncertainty stated in volumetric terms alongside the transaction volume.



Vertical path:
Cross-sectional area verification
The CALDON SVM 589Ci incorporates a pair of transducers that are used to form a vertical path with a reflection point at the top of the measurement cross-section. This path is not used for velocity measurement, its purpose is to enable the SVM to verify the cross-sectional area and detect if there is any gaseous-phase fluid in the measurement section, even if the quantity of that gaseous phase is very small. Combined with the measurements from the chordal paths, the measurement results from the vertical path are used to quantify uncertainty in the cross-sectional area of the measurement section.

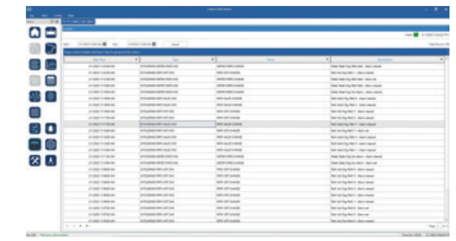
CALDON USM Advisor software

CALDON USM Advisor is an automated and intuitive Condition-Based Monitoring system which continuously monitors the health of CALDON 500 Series flow meters. Multiple ultrasonic flow meters can be monitored simultaneously, locally or remotely from anywhere in the world.

Diagnostic health data is transferred from the meter and stored in the CBM database and is automatically evaluated against customizable warning and alarm limits. CALDON USM Advisor either works with a permanent connection to the meter or can be periodically connected to access data stored within the meters integral SD card for traceability, auditability and general convenience.

Easy-to-use, icon-driven user interface
Easily monitor the active and historical health status of multiple ultrasonic flow meters from a single overview.

You can also drill down to all available information using an icon-driven interface to get a more intelligent and detailed insight into a specific ultrasonic flow meter in as few as three clicks.

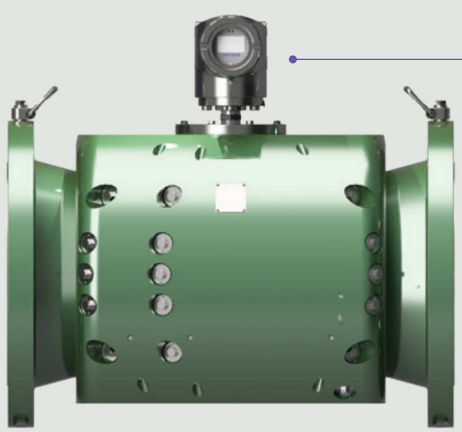


Complete audit trail data integrity
Guaranteed coverage of historical data is provided by the meter's on-board storage of up to 10 years of key diagnostic data. Advisor software uses an SQL database that retains every minute of data that is transferred from the meter, providing long-term records limited only by the storage capacity of the host computer.

Customizable multidimensional fingerprinting
Optimize your decision-making by fingerprinting meter behavior during normal operation under changing process conditions (flow velocity, temperature, pressure, and speed of sound).

Intuitive displays
CALDON USM Advisor provides access to intuitive displays and graphs that report the uncertainty data that is unique to SVM as well as the full complement of standard diagnostics.

Features unique to SVM
When connected to an SVM flow meter, Advisor displays, warnings and reports include unique features based on the meter's determination of live uncertainty.



Communication (ethernet and serial)
The diagnostic software can be used with serial communication or ethernet (copper and fiber both available). Ethernet is preferred delivering additional features such as worldwide monitoring, simultaneously analyzing multiple meters and retrieving historical data from the SD card (backfill).

Dimensions and weights

Dimensions & Weights for LEFM 540, 544, 580, 588, SVM 589Ci[1]

Nominal Pipe Size, in [mm]	Flange ANSI Class	Width (W), in [mm]	Height (H), in [mm]	Length (L), in [mm]	Meter Weight, lbm [Kg]
4" [100mm][2]	150	14.0 [356]	20.0 [508]	21.00 [533]	481 [218]
	300	14.0 [356]	20.0 [508]	21.75 [552]	500 [227]
	600	14.0 [356]	20.0 [508]	23.50 [597]	531 [241]
	900	14.0 [356]	20.5 [521]	24.50 [622]	564 [256]
	1500	14.0 [356]	21.0 [533]	25.25 [641]	600 [272]
6" [150mm][3]	150	15.5 [394]	22.0 [559]	24.00 [610]	641 [291]
	300	15.5 [394]	22.0 [559]	24.75 [629]	679 [308]
	600	15.5 [394]	23.0 [584]	26.75 [679]	762 [345]
	900	15.5 [394]	23.5 [597]	28.50 [724]	833 [378]
	1500	15.5 [394]	23.5 [597]	31.00 [787]	948 [430]
8" [200mm][4]	150	17.0 [432]	23.5 [597]	26.75 [679]	797 [361]
	300	17.0 [432]	24.0 [610]	27.50 [699]	852 [386]
	600	17.0 [432]	25.0 [635]	29.75 [756]	982 [445]
	900	18.5 [470]	26.0 [660]	32.00 [813]	1,115 [506]
	1500	19.0 [483]	26.0 [660]	36.00 [914]	1,324 [600]
10" [200mm][4]	150	20.0 [508]	27.0 [686]	28.75 [730]	1,326 [602]
	300	20.0 [508]	27.5 [699]	30.00 [762]	1,414 [641]
	600	20.0 [508]	28.5 [724]	33.25 [845]	1,653 [750]
	900	21.5 [546]	29.5 [749]	35.75 [908]	1,811 [821]
	1500	23.0 [584]	30.0 [762]	41.25 [1,048]	2,244 [1,018]
12" [250mm][5]	150	22.0 [559]	29.5 [749]	31.75 [806]	1,712 [776]
	300	22.0 [559]	30.0 [762]	33.00 [838]	1,834 [832]
	600	22.0 [559]	30.5 [775]	35.50 [902]	2,100 [953]
	900	24.0 [610]	31.5 [800]	39.00 [991]	2,385 [1,082]
	1500	26.5 [673]	33.0 [838]	45.50 [1,156]	3,107 [1,409]
14" [300mm]	150	23.8 [603]	31.0 [787]	34.00 [864]	2,119 [961]
	300	23.8 [603]	32.0 [813]	35.25 [895]	2,288 [1,038]
	600	23.8 [603]	32.0 [813]	37.50 [953]	2,577 [1,169]
	900	25.3 [641]	33.0 [838]	41.25 [1,048]	2,907 [1,319]
	1500	29.5 [749]	35.0 [889]	48.00 [1,219]	3,967 [1,799]
16" [350mm]	150	27.0 [686]	35.0 [889]	35.75 [908]	3,151 [1,429]
	300	27.0 [686]	35.0 [889]	37.25 [946]	3,362 [1,525]
	600	27.0 [686]	36.0 [914]	40.25 [1,022]	3,809 [1,728]
	900	27.8 [705]	36.0 [914]	43.25 [1,099]	4,113 [1,865]
	1500	32.5 [826]	38.5 [978]	50.75 [1,289]	5,573 [2,528]
18" [400mm]	150	29.3 [743]	36.0 [914]	38.75 [984]	3,740 [1,696]
	300	29.3 [743]	37.0 [940]	40.25 [1,022]	4,024 [1,825]
	600	29.3 [743]	37.5 [953]	43.25 [1,099]	4,582 [2,079]
	900	31.0 [787]	38.5 [978]	46.25 [1,175]	5,130 [2,327]
	1500	36.0 [914]	41.0 [1,041]	54.00 [1,372]	7,045 [3,196]
20" [450mm]	150	32.0 [813]	38.5 [978]	41.13 [1,045]	4,788 [2,172]
	300	32.0 [813]	39.5 [1,003]	42.50 [1,080]	5,120 [2,322]
	600	32.0 [813]	40.0 [1,016]	46.25 [1,175]	5,881 [2,668]
	900	33.8 [857]	41.0 [1,041]	49.75 [1,264]	6,561 [2,976]
	1500	38.8 [984]	43.5 [1,105]	58.25 [1,480]	8,960 [4,064]
24" [600mm]	150	37.0 [940]	43.5 [1,105]	45.75 [1,162]	7,115 [3,227]
	300	37.0 [940]	44.5 [1,130]	48.50 [1,232]	7,652 [3,471]
	600	37.0 [940]	45.0 [1,143]	52.25 [1,327]	8,795 [3,989]
	900	41.0 [1,041]	47.0 [1,194]	57.25 [1,454]	10,541 [4,781]
	1500	46.0 [1,168]	49.5 [1,257]	66.25 [1,683]	13,920 [6,314]

Footnotes:

1 Tabulated weights and dimensions are approximate and are confirmed during the sales and order processes. Consult Sensia for model 588 weights and dimensions. Meter images shown in this brochure are 580Ci and 589Ci. Design details vary with model and meter size.

2 Tabulated 4 in. dimensions and weights are for the 540 model only. Consult Sensia for 4 in. model 544 and 580 weights and dimensions. 589 not available in 4 in. size.

3 Tabulated 6 in. dimensions and weights are for the 540 model only. Consult Sensia for 6 in. model 544, 580 and 589 weights and dimensions.

4 Tabulated 8 and 10 in. dimensions and weights are for the 540, 544 and 580 models. Consult Sensia for 8 and 10 in. model 589 weights and dimensions.

5 Consult Sensia for 12 in. model 589 weights and dimensions for Class 900 and 1500 ANSI flange size.

Installation

To limit uncertainty caused by pipe fittings and fluid dynamic effects to levels consistent with custody transfer requirements, we recommend installing the flow meter in compliance with the following guidelines.

For application-specific recommendations or more detailed installation guidance, contact Sensia.

CALDON LEFM 540Ci/544Ci

The adjoining straight pipe should be of the same schedule as the meter. It is recommended that the 540Ci meter be installed downstream of a 10 diameter pipe section that includes a flow conditioning element at its inlet. For effective flow conditioning, we recommend an additional straight pipe of minimum 5 diameters in length upstream of the flow conditioner. If a flow conditioning element is not used, additional uncertainty can be limited by using a straight pipe upstream of approximately 20 pipe diameters in length and avoiding the introduction of swirl upstream of that length.

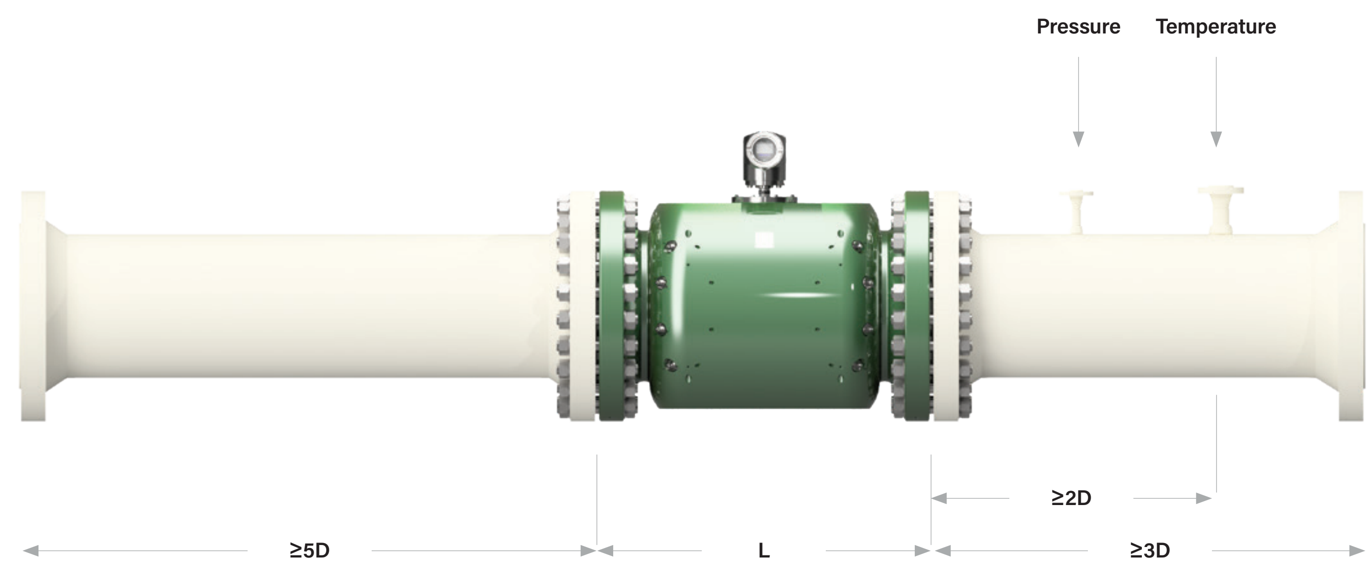
Downstream of the meter there should be a straight length of pipe at least 3 pipe diameters prior to any bends, tees, reducers, expanders or valves etc. In uni-directional applications, temperature elements and pressure connections should be located downstream of the meter. Intrusive temperature elements should be at a distance of at least 2 pipe diameters from the meter. Non-intrusive pressure connections may be located within 2 diameters of the meter.

CALDON LEFM 580Ci/CALDON SVM 589Ci

The adjoining straight pipe should be of the same schedule as the meter. Owing to the eight-path primary measurement, the 580Ci or 589Ci does not normally require the use of a flow conditioning element. An uninterrupted upstream pipe 5 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 or strainer), 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 a straight length of pipe at least 3 pipe diameters prior to any bends, tees, reducers, expanders or valves etc. In uni-directional applications, temperature elements and pressure connections should be located downstream of the meter. Intrusive temperature elements should be at a distance of at least 2 pipe diameters from the meter. Non-intrusive pressure connections may be located within 2 diameters of the meter.

CALDON LEFM 580Ci, CALDON LEFM 588Ci and CALDON SVM 589Ci recommended installation



Specifications

Meter body with integral transmitter		
Class	II 2 G, Ex db IIC Gb T6	Class I, Div. 1, Groups B,C, and D T6
Temperature degF [degC]	−58 to 158 [−50 to 70]	−58 to 158 [−50 to 70]

Meter body with remote transmitter[1]		
Class	II 2 G, Ex db Gb T4	Class I, Div. 1, Groups B,C, and D T3C
Temperature	−58 to 257 [−50 to 98]	−58 to 257 [−50 to 98]

Standard materials of construction	
Meter body and flanges	Carbon steel and INCONEL® (stainless steel standard under -46 degC)
Transducer housings	Stainless steel
Junction boxes and transmitter enclosure	Copper-free aluminum (stainless steel optional)

Consult Sensia for other material options.

Standard end connections and maximum working pressure

ANSI B16.5 raised Face	Stainless steel, psi [bar]	Carbon steel, psi [bar]
Class 150	275 [19.0]	285 [19.6]
Class 300	720 [49.6]	740 [51.1]
Class 600	1,440 [99.3]	1,480 [102.1]
Class 900	2,160 [148.2]	2,220 [153.2]
Class 1500	3,600 [248.2]	3,705 [255.3]

Consult Sensia for other material options.

Recommended flow velocity range[2]	
Min velocity, m/s [ft/s]	1 [3.3]
Max velocity, m/s [ft/s]	15 [49.2]

Indicative maximum and minimum flow rates[3]

Nominal size, inch [mm]	Volumetric m³/hr		Mass kg/s		MTPA	
	Min	Max	Min	Max	Min	Max
4 [100]	24	359	6	90	0.2	2.8
6 [150]	55	828	14	207	0.4	6.5
8 [200]	94	1,414	24	353	0.7	11.1
10 [250]	150	2,246	37	561	1.2	17.7
12 [300]	211	3,161	53	790	1.7	24.9
14 [350]	255	3,818	64	954	2.0	30.1
16 [400]	336	5,033	84	1,258	2.6	39.7
18 [450]	424	6,357	106	1,589	3.3	50.1
20 [500]	527	7,908	132	1,977	4.2	62.3
24 [600]	759	11,378	190	2,845	6.0	89.7

Operation and performance	540Ci	544Ci	580Ci	588Ci	SVM 589Ci
Nominal pipe sizes, inch [mm]	4 to 48 [100 to 1,200]	8 to 48 [200 to 1,200]	4 to 48 [100 to 1,200]	8 to 48 [200 to 1,200]	8 to 48 [200 to 1,200]
Accuracy: Linearity at reference calibration conditions	± 0.15% over recommended flow velocity range		± 0.1% over recommended flow velocity range		
Typical rangeability (flow rate or velocity turndown corresponding to stated linearity)[4]	15:1				

Footnotes:
1 SVM 589Ci model not available with remote mount electronics.
2 Operation within this range is recommended but not limiting. Higher and/or lower velocities can be accommodated upon review by Sensia.
3 Tabulated values per meter size are indicative. Higher and/or lower flowrates can be accommodated. Please consult Sensia for an appropriate meter sizing. Tabulated rates are based on the recommended flow velocity range for meters of schedule 120 wall thickness, and a nominal density of 900 kg/m³.
4 Rangeability can be extended upon review of application conditions and accuracy requirements. Meter operation is bi-directional and can span from zero flow to velocities greater than the recommended maximum.

General specifications: Electronics	
Power requirements—DC power	
Voltage required, V DC	24 (18 to 30)
Current draw at 24 V DC, A	0.25
Power consumption, W	6
Power requirements—AC power	
Voltage, V AC	120 (60 Hz); 230 (50 Hz)
Voltage range, V AC	108–253
Frequency range, Hz	47–63
Current draw, A	0.14
Protection	Ingress Protection (IP) 66; National Electrical Manufacturers Association (NEMA) type 4 and 4X
Relative humidity, %	0–95
Operating temperature, degF [degC]	−58 to 158 [−50 to 70]
Local display, px	400 × 240 LCD showing flow, diagnostics data, and alarms
Analog inputs (three), mA	4–20 configurable
RTD input	Meter body temperature
Analog outputs (two), mA	4–20 (configurable 650-ohm maximum load)
Digital outputs	
Flow	Four pulse output channels
	Programmable K-factor
	Programmable configuration
	1. Dual frequency set-up, 50/50 duty cycle
	Channel B lags channel A by 90° for forward flow
	Channel B leads channel A by 90° for reverse flow
	2. Frequency and direction, 0 duty cycle
	Channel B indicates flow direction
	Forward flow = 0
	Reverse flow = high (5 or 12 V DC)
	3. Alternating, forward-flow frequency on
	Channel A only reverse-flow frequency
	On channel B only 50/50 duty cycle
Alarm status	Four outputs, 0–5 or 0–12 V DC selectable (0 V = alarm)
Communication	Three serial or two serial and HART protocol
	Ethernet (copper and fiber optic)

Count on CALDON

Backed by more than 50 years of experience and a history of technological firsts, CALDON have become the benchmark around the world for high accuracy measurement by ultrasonic technology. Our CALDON flow meter series accommodates the most extensive range of applications, including but not limited to gas mixtures, refined products, high-viscosity crude oils, cryogenic fluids such as LNG and carbon dioxide in the liquid, dense supercritical phase.

We are happy to work with our valued customers in applying our unrivaled capabilities to solve their application challenges. The CALDON LEFM 500Ci is another major step-change in high accuracy ultrasonic metering technology.

2024
First Subsea ultrasonic meter for gas, liquid, Carbon Capture and Storage. Jointly developed by SLB and Sensia.

2023
First USM for dense, supercritical and liquid phase CO_2, the CALDON LEFM 500 Series.

2021
First self-verifying high accuracy meter.

2020
CALDON USM Measurement Advisor; continuous, remote monitoring of multiple ultrasonic flow meters worldwide in combination with SQL database storage.

2016
First microbore subsea chemical injection metering valve using ultrasonic metering technology jointly developed with SLB/Cameron.

2010
First eight-path custody transfer gas USM with patented non-wetted transducers, OIML R137 Class 0.5 with 5D, no flow conditioner and a proprietary coating for the internal meter I.D. and transducer faces for long term performance.

2008
LEFM 280CiRN: Approval for custody transfer of heavy, viscous crude oils up to 3,000 mm^2/s according to OIML R117 Class 0.3. Enhanced repeatability and provability versus conventional full bore USMs.

2007
World class hydrocarbon flow facility opened, accredited to ISO 17025 accredited by NVLAP and CMC certified by VSL.

2005
Pioneered the use of ultrasonic technology for high accuracy cryogenic fluids with first LNG installation.

2003
First application for custody transfer of Liquid hydrocarbons.

1995
First military-specification flow meter.

1994
First measurement uncertainty recapture uprate at nuclear facilities.

1989
CALDON formed by Mr Cal Hastings. CALDON obtains Westinghouse Leading Edge Flow Meter technology in a full technology transfer acquisition.

1974
First crude oil application.

1970
First nuclear reactor coolant application.

1965
Westinghouse develop the LEFM product line, the first to use a chordal multipath design based on Gaussian integration, and predecessor to the CALDON product line.

Solving challenges from the reservoir to refinery. One challenge at a time.

We collaborate with all stakeholders to make the production, transportation and processing of oil & gas simpler, safer, more secure, more productive and better understood from end-to-end. Sensia is making the advantages of industrial-scale digitalization and seamless automation available to every oil & gas company.

Now every asset can operate more productively and more profitably.

US Patent No. 9,304,024: Acoustic flow measurement device including a plurality of chordal planes each having a plurality of axial velocity measurements using transducer pairs.

US Patent No. 10,288,462: Acoustic flow measurement device including a plurality of chordal planes each having a plurality of axial velocity measurements using transducer pairs.

US Patent No. 10,928,230: Acoustic flow measurement device including a plurality of chordal planes each having a plurality of axial velocity measurements using transducer pairs.

US Patent No. 10,393,568: Ultrasonic meter employing two or more dissimilar chordal multipath integration methods in one body.

US Patent No. 11,549,841: Ultrasonic meter employing two or more dissimilar chordal multipath integration methods in one body.

US Patent No. 9,170,140: Ultrasonic flow meter with internal surface coating and method.

US Patent No. 10,107,658: Ultrasonic flow meter with internal surface coating and method.

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