SITRANS FS230 ultrasonic flowmeter

Overview

SITRANS FST030 with FSS200 and external DSL

SITRANS FS clamp-on ultrasonic flowmeters provide highly accurate measurement while minimizing installation time and maintenance expense.

Benefits

- Easy installation; no need to cut pipe or stop flow
- Minimal maintenance; external sensors do not require periodic cleaning
- No moving parts to foul or wear
- No pressure drop or energy loss
- Wide turn-down ratio
- Single or dual path with internal DSL, up to four paths with external DSL option

System performance	
Approvals	• ATEX Zone 2 (Sensors: Zone 0, 1, 2) • IIECEx Zone 2 (Sensors: Zone 0, 1, 2) • FM/FMc Class I Div. 2 (Sensors: Class I Div. 1)
Accuracy	± 0.5 ... 1 % for velocities above 0.3 m/s and >10 diameters straight run
Repeatability	± 0.25 % (based on ISO 11631)
Pipe size range	12.7 ... 10 m (0.5 ... 394")
Wall Thickness Range	0.64 ... 76.2 mm (0.025 ... 3.0")
Pipe material	Any sonically conductive material (steel, plastic, aluminum, glass, cement, ductile iron, copper)
Optional External DSL	Zone 0, 1, 2, Class 1 Div. 1 with transmitter in Zone 2 Class 1 Div 2 area

Optional External DSL

The optional external DSL allows for additional flexibility in application configurations. The External DSL benefits include:

- Measurement of 1-4 paths
- 2 x additional analog inputs, RTD or current
- Up to 150 m cable from DSL to transmitter (connection from zone 0,1 area to zone 2 area)

Applications

SITRANS FS230 standard functions are suitable for a wide variety of liquid applications, including the following:

- Water industry
  - Raw water
  - Potable water
  - Chemicals
- Wastewater industry
  - Raw sewage
  - Effluent
  - Sludges
  - Mixed liquor
  - Chemicals
- HVAC industry
  - Condensers
  - Hot and cold water systems
- Power industry
  - Nuclear
  - Fossil
  - Hydroelectric
- Processing industry
  - Process control
  - Batching
  - Rate indication
  - Volumetric and mass measurement

SITRANS FS230 hydrocarbon functions are ideal for applications carrying crude oil, refined petroleum or liquefied gas.

Standard volume (high end system)

- Standard (net) volume flow measurement
- Suitable for use in leak detection systems
- Mass flow output measurement
- Chemical and petrochemical processing
- Precise identification of interfaces on multi-liquid pipelines
- Product identification
- Standard density indication
- Applications with multiple liquids having a wide viscosity range
- Automatic gross volume compensation due to viscosity

SITRANS FS230 is ideal for most natural and process gas industry applications, including:

- Checkmetering
- Allocation
- Flow survey verification
- Lost and unaccounted for (LAUF) gas analysis
- Production
- Storage

The FS230 can be supplied with an external DSL option that allows for up to four paths with two additional analog inputs. The External DSL enclosure can be installed in a Zone 1 or Div 1 area near the sensors and measurement pipe using short sensor cables, with communication cable to transmitter up to 150 meters away.

Overview (continued)

System information and selection guide

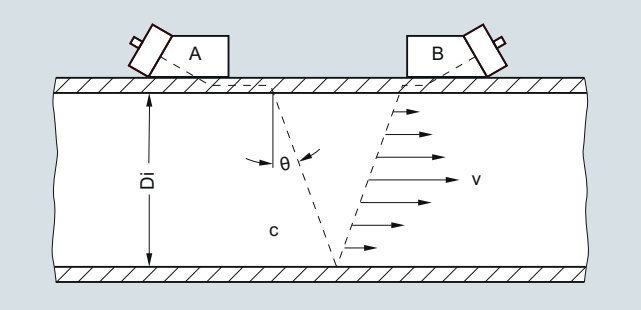
SITRANS FS clamp-on flowmeters	FS230 (Standard)	FS230 (Hydrocarbon)	FS230 (Gas)
Industry/Applications			
Water and aqueous solutions	X		
Utility district heating, cooling	X		
Chemical	X		
Hydrocarbons/petrochemical, multiple products or varying viscosity, liquefied gases, net and gross volume		X	
Hydrocarbons (single product with limited viscosity range) gross volume	X	X	
Very low flow (< 0.1 m/s) in small pipes	X		
High temperature applications < 232 °C (450 °F)	X	X	
Refrigeration liquids	X		
Food products	X		
Natural gas			X
Other gases i.e. propane, oxygen, argon etc.			X
Design			
Field clamp-on (non-intrusive)	X	X	X
Standard volume or mass flow; per API MPMS chapter 11.1		X	X
Interface detection		X	X
Standard density output		X	X
Temperature measurement	X	X	X
Analog input	X	X	X
Large graphical display	X	X	X
Configuration and diagnostic software PDM compatible	X	X	X
Number of acoustic paths and channels			
1-path	X	X	X
2-path	X	X	X
3-path (with external DSL)	X	X	X
4-path (with external DSL)	X	X	X
Size			
12.7 ... 10 000 mm (0.5" ... 394")	X		
38 ... 10 000 mm (1.5" ... 394")		X	
38 ... 1 200 mm (1.5" ... 48")			X
Approvals			
FM/FMc[1)]	X	X	X
ATEX	X	X	X
UL/ULc	X	X	X
IECEx	X	X	X

[1)] Nema 4X associated equipment in DIV 2 connected to DIV 1 sensors and DIV 1 external DSL.

Function

Operating Principle

The SITRANS FS system is a transit-time ultrasonic meter that provides exceptional performance using a non-intrusive clamp-on approach. Ultrasonic sensors transmit and receive acoustic signals directly though the existing pipe wall, where the fluid refraction angle is governed by Snell's law of refraction.



Clamp-on sensor mounted in a reflect configuration

The beam refraction angle is calculated as follows:

$\sin\theta = c / V_\phi$

c = Velocity of sound in fluid

V_φ = Phase velocity (a constant in the pipe wall)

The flowmeter automatically compensates for any change in fluid sound velocity (or beam angle) in response to variations in the average transit time between sensors A and B. By subtracting the computed fixed times (within the sensors and pipe wall) from the measured average transit time, the meter can then infer the required transit time in the fluid (T_{Fluid}).

The sound waves traveling in the same direction as the flow ($T_{A,B}$) arrive earlier than sound waves traveling against the direction of flow ($T_{B,A}$). This time difference (Δt) is used to compute the line integrated flow velocity (v) as shown in the equation below:

$v = V_\varphi / 2 \cdot \Delta t / T_{Fluid}$

Once the raw flow velocity is determined, the fluid Reynolds Number (Re) must be determined to properly correct for fully developed flow profile. This requires the entry of the fluid's kinematic viscosity (visc) as shown in the equations below, where Q represents the final flow profile compensated volumetric flow rate.

$Re = Di \cdot v / visc \cdot Q = K(Re) \cdot (\pi / 4 \cdot Di^2) \cdot v$

v = Flow velocity

$visc = \mu / \rho$ = (dynamic viscosity / density)

K(Re) = Reynolds flow profile compensation

In wetted type ultrasonic flowmeters the meter constants are configured prior to leaving the factory. As this is not possible with clamp-on meters, the settings must be made by the customer at the time of installation. These settings include pipe diameter, wall thickness, liquid viscosity, etc.

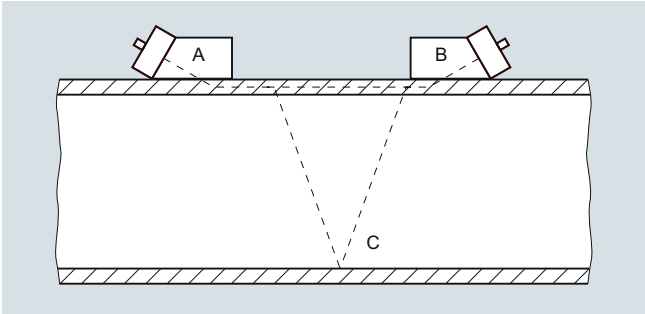
SITRANS clamp-on flowmeters that include temperature sensing can be configured to dynamically infer changes in fluid viscosity for the purpose of computing the most accurate flow profile compensation (K_{Re}).

Ultrasonic sensor types

Two basic types of clamp-on sensors can be selected for use with the SITRANS F S flowmeter. The lower cost "universal" sensor is the most common type in the industry and is suitable for most single liquid applications where the sound velocity does not vary much. This sensor type can be used on any sonically conductive pipe material (including steel) making it well suited for portable survey applications. Universal sensors are selected based on the pipe diameter range alone, so wall thickness is less important to the selection process.

The second sensor type is the "WideBeam" sensor (called high precision), which utilizes the pipe wall as a kind of waveguide to optimize the signal to noise ratio and provide a wider area of vibration. This makes this kind of sensor less sensitive to any change in the fluid medium.

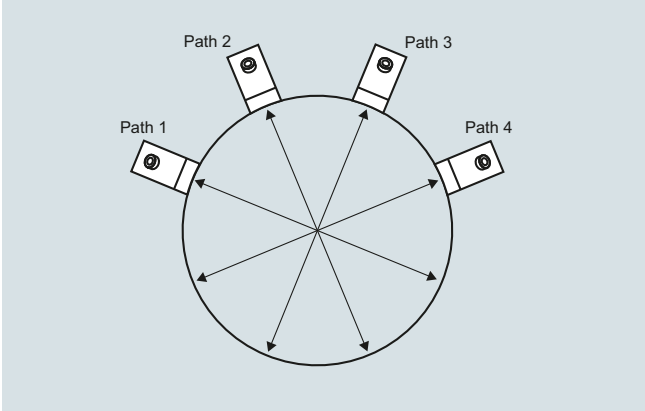
The WideBeam sensor is designed for steel pipes, but can also be used with aluminum and titanium. It is the preferred sensor for HPI applications. Note that unlike the universal type, this sensor selection is dependent only on the pipe's wall thickness.



Multi-path flowmeters

For improved flow profile averaging, redundancy or better cost per measurement, clamp-on meters can be supplied with 1, 2, 3 or 4 path measurement systems.

In the standard FS230 systems, these can be installed on a single pipe as shown below (four paths on same pipe).



Four path installation example

Function (continued)

SITRANS meter family description

SITRANS FS230 clamp-on flowmeters

The FS230 system is a basic function, permanent (or dedicated) Clamp-on meter that is available with a full range of safety approvals and I/Os. This meter can be used in a wide range of applications.

FST030 transmitter standard flow functions

When configured with standard flow functions, the FST030 transmitter is typically programmed with a fixed viscosity and specific gravity entry, which can limit the mass flow and volumetric flow accuracy when highly variable (multi-product) liquid properties flow through the same pipeline.

It will have the ability to accommodate clamp-on RTDs, or analog input from a temperature transmitter.

FST030 hydrocarbon flow functions

When configured with hydrocarbon functions, the FST030 can be used for applications that will flow a wide range of viscosity with a standard volume (mass) and interface detection functions available. All functions rely on a variable referred to as "LiquIdent (TM)", which is used to infer the liquid's viscosity and density. This variable represents the measured liquid sonic velocity compensated by the operating temperature and pressure, so for a given liquid product the measured LiquIdent (TM) output will remain constant over a wide range of pressure or temperature.

Standard volume description:

This LiquIdent (TM) variable can also be used to identify the liquid flowing through the pipe as well as it's physical properties (density, viscosity and compressibility) at base conditions. With this information the meter can be configured to output a temperature and pressure compensated (standard) volume flow rate using the API MPMS chapter 11.2.1 methods as shown below.

Correction for temperature:

Compute thermal expansion coefficient (α_b):

$\alpha_b = KO / \rho_b^2 + K1 / \rho_b$

where: KO and K1 are constants dependent on type of liquid and ρb is the liquid density at base conditions

Compute temperature correction factor (K_T):

$K_T = \rho_b * EXP (- \alpha_b \Delta T (1 + 0.8 \alpha_b \Delta T))$

where: ΔT = (T – base temperature)

Correction for pressure:

Compute compressibility factor (F):

$F = EXP(A + B T + (C + D T) / \rho_b^2$

where: A, B, C and D are constants, and "T" is liquid temperature

Compute pressure correction factor (K_p):

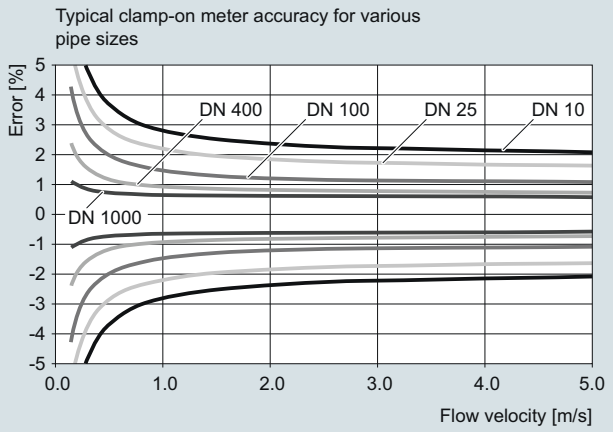
$K_p = 1 / (1 – F (P_{act} – P_{base}) * 10^{-4})$

Final volume correction: $Q_{std} = Q_{act} * K_t * K_p$

Available outputs from this meter include: API, standard density, mass flowrate, standard volume flowrate and liquid identification.

General installation guidelines for transit time clamp-on sensor

- Minimum measuring range: 0 to ± 0.3 m/s velocity (see meter accuracy graph below for more detail)
- Maximum measuring range: 0 to ± 12 m/s (± 30 m/s for high precision sensors). Final flow range determination requires application review



- Pipe must be completely full within the sensor installation volume for accurate flow measurement
- Typical MINIMUM straight pipe requirements are: 10 Diameters upstream/5 Diameters downstream. Additional straight run is required for double out-of-plane elbows and partially open valves.
- Sensors should be installed at least 20° off vertical for horizontal pipes. This reduces the chance of beam interference from gas buildup at the top of the pipe
- Operation inside the Reynolds transition region, between 1000 < Re < 5000 should be avoided for best accuracy
- Submersible and direct burial installations can be accommodated. Consult sales representative for details
- Ultrasonic coupling compound is provided with all sensor orders. Insure that a permanent coupling compound is used for long term installations
- Refer to the "Sensor type selection guide" to insure proper application of the equipment

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Function (continued)

Sensor type selection guide

	Standard sensor supported in MLFB		
Considerations for sensor selection	**High precision**	**Universal**	Notes
Media			
General survey (clean liquids) on non-steel pipes		**X**	
General survey (clean liquids) on a limited range of steel pipes	**X**		
Moderately aerated liquid or slurry, up to 121 °C (250 °F)	**X**		
Permanent installation on steel pipe (clean liquids and gases)	**X**		
Installation in offshore or corrosive environment	**X**[1)]	**X**[2)]	Sensor size C/D/E come standard as corrosion resistant. Size A and B optional stainless steel
Liquid temperature greater than 120 °C (248 °F)	**O**	**X**	FSS200 high temperature metal block sensors (up to 232 °C (450 °F))
Operation on single pipeline flowing multiple products	**X**	**O**	
Pipe material			
Steel	**X**		
Steel pipe with diameter/wall thickness ratio <10	**O**	**X**	
Non-steel pipe material (copper, ductile iron, cast iron, etc.)	**O**	**X**	High precision sensors can also be used on plastic and aluminum pipes in special cases
Wall thickness > 31.75 mm (1.25")	**O**	**X**	

O = not suitable X = preferred choice

1) For steel and stainless steel pipes only

2) Not preferred for steel pipes

Definitions

Sensor chart	Description
FSS200	Formerly 1011 clamp-on sensors of the 1010 systems
Standard	Standard system sensor, selectable as part of a configured product
Special	Sensors available for non-standard applications and pipes. Contact tech support for application use
Corrosion resistant	Stainless steel metal parts on all Size C, D and E and all high temperature sensors
Aluminum	Aluminum metal parts on all HP and Universal size A and B (Corrosion resistant on request for size B)
Spare	Not available as part of a configured product, must be ordered separately
CE	Transmitter and sensors certified for sale in the EU
Trackless mount	Sensors fixed only by straps, no other mounting (spacer bar as an option) - not recommended
Tracks	Permanent installation for universal size A/B, high precision size A/B and all sizes of high temperature. Tracks always come as dual-part for either direct or reflect mounting, and always with straps.
Frames	Three sizes, for permanent installation for universal size C/ D/ E, and for high precision size C/D. For universal and high precision size B available for pipes > 125 OD (Spare)
T1	Usable from -40 ... +120 °C (-40 ... +248 °F), but best for Ø temperature below 80 °C (< 176 °F), standard
T2	Usable from -40 ... +120 °C (-40 ... +248 °F), but best for Ø temperature above 80 °C (> 176 °F)
Submersible	Sensors can be used submerged; adding Denso for supplemental protection is recommended

Function (continued)

Sensor availability guide

Sensor models	Availability												
	Standard	Spare only	ATEX/FM/FMc/IECEX	Corrosion restistant	Trackless	Tracks	Frames	High precision mount	T1 best use < 80 °C (176 °F)	T2 best use > 80 °C (176 °F)	Submersible	Catalog
FSS200 Universal Sensor -40 … 120 °C (-40 ... +248 °F) Polyetherimide - stainless steel housing CE IP68												
A1 Universal for pipe OD – 5.8 … 50.8 mm (0.23" … 2")		X	X	X	X[1)]	X					X	
A2 Universal for pipe OD – 12.7 … 50.8 mm (0.5" … 2")	X		X	X	X[1)]	X					X	X
B1 Universal for pipe OD – 12.7 … 76 mm (0.5" … 3")		X	X	X	X[1)]	X	X				X	
B2 Universal for pipe OD – 12.7 … 76 mm (0.5" … 3")		X	X	X	X[1)]	X	X				X	
B3 Universal for pipe OD – 19 … 127 mm (0.75" … 5"")	X		X	X	X[1)]	X	X				X	X
C1 Universal for pipe OD – 51 … 254 mm (2" … 10")		X	X	X	X		X				X	
C2 Universal for pipe OD – 51 … 254 mm (2" … 10")		X	X	X	X		X				X	
C3 Universal for pipe OD – 51 … 305 mm (2" … 12")	X		X	X	X		X				X	X
D1 Universal for pipe OD – 102 … 508 mm (4" … 20")		X	X	X	X		X				X	
D2 Universal for pipe OD – 152 … 610 mm (6" … 24")		X	X	X	X		X				X	
D3 Universal for pipe OD – 203 … 610 mm (8" … 24")	X		X	X	X		X				X	X
*E1 Universal for pipe OD – 254 … 3048 mm (10" … 120")		X	X	X	X		X				X	
*E2 Universal for pipe OD – 254 … 6096 mm (10" … 240")	X		X	X	X		X				X	X
*E3 Universal for pipe OD – 304 … 10007 mm (12" … 394")		X	X	X	X		X	X			X	
FSS200 High Precision Sensor -40 ... +120 °C (-40 ... +248 °F) Polyetherimide - stainless steel housing T1/T2 CE IP68												
A1H (High Precision) for pipe WT - 0.64 ... 1.0 mm (0.025" ... 0.04")		X	X	X	X[1)]	X			X		X	X
A2H (High Precision) for pipe WT - 1.0 ... 1.5 mm (0.04" ... 0.06")	X		X	X	X[1)]	X			X		X	X
A3H (High Precision) for pipe WT - 1.5 ... 2.0 mm (0.06" ... 0.08")	X		X	X	X[1)]	X			X		X	X
B1H (High Precision) for pipe WT - 2.0 ... 3.0 mm (0.08" ... 0.12")	X		X	X	X[1)]	X	X		X	X	X	X
B2H (High Precision) for pipe WT - 3.0 ... 4.1 mm (0.12" ... 0.16")	X		X	X	X[1)]	X	X		X	X	X	X
B3H (High Precision) for pipe WT - 2.7 ... 3.3 mm (0.106" ... 0.128")		X	X	X	X[1)]	X	X		X	X	X	X
C1H (High Precision) for pipe WT - 4.1 ... 5.8 mm (0.16" ... 0.23")	X		X	X	X		X	X	X	X	X	X
C2H (High Precision) for pipe WT - 5.8 ... 8.1 mm (0..23" ... 0.32")	X		X	X	X		X	X	X	X	X	X
* D1H (High Precision) for pipe WT - 8.1 ... 11.2 mm (0..32" ... 0.44")	X		X	X	X		X	X	X	X	X	X
* D2H (High Precision) for pipe WT - 11.2 ... 15.7 mm (0.44" ... 0.62")	X		X	X	X		X	X	X	X	X	X
* D3H (High Precision) for pipe WT - 7.4 ... 9.0 mm (0..293" ... 0.354")		X	X	X	X		X	X	X	X	X	X
* D4H (High Precision) for pipe WT - 15.7 ... 31.8 mm (0..62" ... 1.25")	X		X	X	X		X	X	X	X	X	X
FSS200 High Temperature Universal Sensor -40 ... +230 °C (-40 ... +446 °F)												
High Temperature size 1 ... 230 °C (Ø 12.7 ... 100 mm)		X	X	X		X						
High Temperature size 2 ... 230 °C (Ø 30 ... 200 mm)	X		X	X		X						X
High Temperature size 3 ... 230 °C (Ø 150 ... 610 mm)	X		X	X		X						X
High Temperature size 4 ... 230 °C (Ø 400 ... 1200 mm)	X		X	X		X						X
High Temperature size 2A ... 230 °C (Ø 30 ... 200 mm)		X	X	X		X						
High Temperature size 3A ... 230 °C (Ø 150 ... 610 mm)		X	X	X		X						
High Temperature size 4A ... 230 °C (Ø 400 ... 1200 mm)		X	X	X		X						

[1)] Usable, but not recommended for selection.

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Function (continued)

Sensor mounting availability guide

	Sensor		
	FSS200 Dedicated Universal	**FSS200 Dedicated High precision**	**FSS200 High temperature Universal**
Mounting			
Trackless[1)]	**X**	**X**	
Tracks universal dedicated	**X**		
Tracks HP dedicated		**X**	
Frames universal dedicated	**X**		
Frames HP dedicated		**X**	
Tracks high temperature universal			**X**
High precision mounting single enclosure		**X**	
High precision mounting dual enclosure		**X**	
SpacerBar	**X**	**X**	
Straps	**X**	**X**	**X**
Denso	**X**	**X**	

1) Usable but not recommended