LITREMETER
Specialist flow measurement engineering

VFF Flowmeters for Chemical Injection

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VFF Overview

Advantages of the measurement principle

- Very low flow measurement (0.01 USgph 0.038 l/h on 2cSt, ultimately 0.0001 l/min, 0.01 l/hr, 0.002 USgph)
- Ultra high pressure capability (60,000psi, 4000bar if required)
- Low pressure drop (<0.1 bar)
- Low maintenance
- Single moving part
- Tolerant of particulate up to 150 microns
- Large viscosity range
- Measures pulsing flow accurately
- Preserves molecular integrity of fluid
- Highly durable
- Proven over 25 years
- Positive displacement

Technology Comparison

Key Property	Coriolis	Rotary Piston	Gear	Turbine
Very low flow measurement, 0.0001 l/min		√		
Tolerant of particulate up to 150 microns	√	√		√
Low pressure drop		√		√
Single moving part	√	√		√
Large viscosity range including methanol	√	√		
Measures pulsing flow accurately		√	√	
Preserves molecular integrity of fluid	√	√		√
Pressure independent including over 6,000 psi /400 bar	√	√		√
Up to 2500 bar		√		√

Used worldwide, thousands of chemical injection points are monitored today using VFF flowmeters.

Chemical Injection

Chemical injection is the process designed to assist in the production of oil. Various chemicals are injected into the crude oil to provide a degree of protection. For example a scale inhibitor will prevent the build-up of scale on the pipes and fittings used to transport the oil on its journey to the refinery.

Flowmeters are used to monitor and control the amount of chemicals added to the crude oil. Biocide prevents the build-up of organisms in the pipe. Corrosion inhibitor is the most popular additive to be measured. There are various types depending on the type of main liquid. Pour point depressant is added to reduce the pour point thereby making the oil easier to flow through the main pipelines. Most of the chemicals added tend to be at low flow rates of the order of 0.01 to 30 litres per hour (typical LF05 flow rate range). LDHI or Low Dosage Hydrate Inhibitor has the highest injection rate sometimes up to 17,000 litres per hour (V270). It is designed to inhibit water based mixtures which would otherwise have a tendency to freeze. Methanol is often used with the same effect. More exotic chemicals are used for similar purposes all with the intention of reducing cost on the way to the refinery.

It is a little known fact that flowmeters are used to measure these chemicals which contribute 30% of the cost of running an offshore platform. Control systems are often manually set from the flowmeter displayed value (either locally or from the SCADA system) and there is a trend towards automation of this process using control valves such as a SkoFlo. A typically turndown ratio of 500:1 is measurable with the VFF positive displacement flowmeters. Often the systems are relatively slow dynamically and need only slight adjustments from day-to-day which is why manual control is still so popular.

It is important that the flow measurement system for the chemicals is able to cope with the pulsing nature of the pumps used and also with the high pressures that are encountered. These can be up to 1035bar/15000psi/15ksi in modern systems injecting subsea. Topsides injection is at lower pressures typically from 200 to 6000 psi. There is also a trend towards measuring the chemicals subsea i.e. underwater rather than when the crude oil reaches the surface. Not only does the flowmeter have to work at high internal pressures of over 10,000 psi, 690bar but also with external pressures up to 345bar/5000psi.

VFF Datasheet

Model:	LF05, LF15, MF30, VFF4, VFF8, HF20 & HF60 Rotary Piston Positive Displacement Flowmeters
Body:	207bar (3000 psi) or 414bar (6000 psi) body provided in 316L stainless steel with ½", ¾" or 1" NPT female process connections in-line. Higher pressure versions available with connections to suit e.g. AE MP 3/8"OD tube. Alternate materials are available such as titanium, duplex and super duplex. Optional Swagelok, hub or flange connections.
Rotor:	The rotor is provided in either anti galling stainless steel (AG, Nitronic 60) or Titanium (Ti) with a 316SS or Ti encapsulated magnet depending on the application. An optional coating is available on the rotor & chamber which can double the maximum flow rate and increases the low flow capability (AGPVD & TiPVD). Titanium is only PVD coated and the LF05 only uses TiPVD.
Seal:	There is a single FPM O-ring seal between the top cap and body. Other elastomers are available e.g. FFKM, FEP covered silicon and in higher pressure versions use PTFE and Inconel.
Pick-up / Transmitter / Pulse Output:	There is one reed switch installed in a SS housing which is O-sealed to the meter body providing a rating of IP68. The optional display is mounted on this housing or remotely. The reed switch outputs in pulses per litre are approximately LF05: 1200, LF15: 500, MF30: 200, VFF4: 80, VFF8: 45, HF20: 20, HF60: 7. Typical reed switch life is 30 years at continuous maximum operating flow rate.
Pressure rating:	207, 414, 690, 1035, 1380, 2500 and 4000 bar. (3000, 6000, 10000, 15000, 20000, 36000 and 60000 psi) depending on size
Temperature rating:	-40°C to +60°C (subject to chemical compatibility, pressure rating and location of the display), higher temperature sensor (+150°C) available. With an integral mounted Exd display instrument, temperature rating is -20 - 55°C.
Viscosity range:	0.8 to 2000 cSt or greater. The normal meter maximum flow rate applies for viscosities from 1.2 to 30 cSt. For higher viscosities up to 2000+ cSt a reduced maximum flow rate may apply.
Flow rate range:	

With AGPVD option	Flow range (for examples of minima see table at foot of page)			
LF05 TiPVD	0-30 l/hr	0-0.5 l/min	7.9 USG/hr	45 USGPD
LF15	0-90 l/hr	0-1.5 l/min	23.8 USG/hr	570 USGPD
MF30	0-180 l/hr	0-3 l/min	47.2 USG/hr	1,134 USGPD
VFF4	0-480 l/hr	0-8 l/min	127 USG/hr	3,040 USGPD
VFF8	0-960 l/hr	0-16 l/min	252 USG/hr	6,040 USGPD
HF20	0-2400 l/hr	0-40 l/min	640 USG/hr	15,200 USGPD
HF60	0-7200 l/hr	0-120 l/min	1920 USG/hr	45,600 USGPD
Larger sizes, such as V125, available. Lower flow LF03 available Q1 2014, see website for details.				

Filtration:	A 100 micron filter is advisable for 100% long life serviceability. If filtration is not possible, consult Litre Meter.
Accuracy:	A calibration certificate is provided based on a representative viscosity fluid for the application. The calibration certificate confirms the flowmeter accuracy. Improved system accuracy can be provided typically ±0.5% to ±1% of actual reading where the linearisation signal processing facility of the display instrument is employed.
Optional Display, remote or head mounted:	Exd display of rate and total, 24Vdc, 3 or 4 wire with Optional HART, MODBUS or Fieldbus comms. ATEX, IECEx, INMETRO, FM or UL. Coated aluminium or stainless. See separate FPodExd data sheet. Loop powered version available soon.
Operating & Maintenance Manual	LM0333 (LM0620 for FM approved versions) with Quick Start Information detailed in LM0548.
Conformity:	These products conform to PED (Litre Meter are approved to Module H up to 2500bar, -40 to 100°C and 6" size) and EMC. Hazardous Area approved as standard.

	Meter Rotor Maximum	LF05 TiPVD 30 l/hour	Turndown	Meter Rotor Maximum	LF15 AGPVD 90 l/hour	Turndown	Meter Rotor Maximum	MF30 AGPVD 180 l/hour	Turndown	Meter Rotor Maximum	VFF4 AGPVD 500 l/hour	Turndown
Standard		min. flow			min. flow			min. flow			min. flow	
minimum	Water	0.600	50 : 1	Water	1.7	52.9 : 1	Water	10	18 : 1	Water	15	33.3 : 1
	1.5cSt	0.300	100 : 1	3cSt	0.5	180 : 1	3cSt	2.4	75 : 1	3cSt	3.5	143 : 1
	2.5cSt	0.200	150 : 1	10cSt	0.4	225 : 1	10cSt	1.5	120 : 1	10cSt	2	250 : 1
	10cSt	0.100	300 : 1	50cSt	0.1	900 : 1	50cSt	1	180 : 1	50cSt	1.6	313 : 1
	50cSt	0.060	500 : 1	250cSt	0.02	4500 : 1	250cSt	0.3	600: 1	250cSt	1.25	400 : 1
Optional		min. flow			min. flow			min. flow			min. flow	
minimum	Water	0.400	75:1	Water	1	90 :1	Water	8	22.5 : 1	Water	9	55.5 : 1
at extra	1.5cSt	0.220	136 : 1	3cSt	0.3	300 : 1	3cSt	1.8	100 : 1	3cSt	2	250 : 1
cost	2.5cSt	0.080	375 : 1	10cSt	0.2	450 : 1	10cSt	0.8	225 : 1	10cSt	1.6	313 : 1
£350	10cSt	0.020	1500: 1	50cSt	0.08	1125 : 1	50cSt	0.6	300 : 1	50cSt	1	500 : 1
	50cSt	0.012	2500 : 1	250cSt	0.008	11250 : 1	250cSt	0.2	900 : 1	250cSt	0.8	625 : 1

Technical Description

Each flowmeter is functionally identical in that each is designed to provide an indication of flow rate and total and a HART signal (or others). They are designed for installation in a hazardous area.

Each flowmeter has a rotor, a pressure balanced chamber (PBC) in most cases, a sensor and an electronics to interpret the raw output from the sensor. The sensor, electronics and its enclosure are identical for all meters although they are individually calibrated. The size of rotor and PBC varies with the flow duty required.

Measurement Principle:

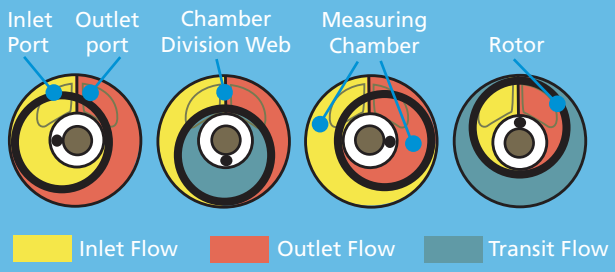

Figure 1 Measurement Principle

The flow causes the rotor to move within the measuring chamber. This movement is sensed, giving an output representing an increment of volume flow. The rotor is basically a disc shape with an annular groove on its underside capable of holding and transporting flow from the chamber inlet to the outlet. Some fluid is also transported in a cavity formed between the rotor outside wall and the chamber wall. A centre 'peg' under the rotor is constrained to run in a circular groove in the body.

A web (or plate) in the body is engaged with a slot in the rotor and this modifies the rotation to that of an oscillation as flow passes. It is this oscillation that produces the compartmentation of the fluid into 'positively displaced pockets'. The top of the rotor is equipped with a powerful magnet directly above the 'peg' that is on the underside and so this also has a circular path which allows it to engage and disengage a reed switch sensor located in the top cap above.

A volt-free contact closure output signal is given for each oscillation which represents a volume increment. The fluid is transported in a 'positive' manner at all times. The typical metering repeatability is better than 0.2% and a meter accuracy of 1% actual reading is usually obtained over a substantial flow range. For lowest flows the meter will under-read the actual flow in a consistent manner. This allows an improved wide-range system accuracy to be gained by the use of a linearising electronics instrument such as the Litre Meter FPod.

Materials used these vary according to the duty but can include:

- 316 stainless steel, duplex or super duplex stainless steel S32760 (F55) – as specified for each project and used on all the main bodies and hubs. Also: F51, F53, 6%Moly, titanium
- Stainless steel 316 — used for the caps, PBCs, rotors and all external parts including the mount
- Chemraz 526, 555, FFKM or FPM – used as the seal material for the PBC and/or cap – as specified for each project
- FPM – used on external/environmental seals – will not be in contact with process fluid
- A4-80 and A4-100 — used on bolting the cap to the body
- Inconel — used on the C ring seal between body and cap for high pressure variants
- PVD used on rotor and PBC

LF15 PVD coated rotor in stainless steel Pressure Balanced Chamber (PBC) with lid (left)

Litre Meter has now introduced a superior stainless steel rotor which has had a Physical Vapour Deposition (PVD) coating applied. The low friction properties provide extended low flow ability whilst the hardness improves wear resistance.

Extensive testing has been performed by Litre Meter and by a customer who installs these meters subsea. This customer required testing to reflect exceptional lifetime needs. Three meters were calibrated by Litre Meter before shipment and then again after 300,000,000 cycles. This represented a year's service at twice maximum flow rate. The outcome of the test was that the meters performed better after the 300,000,000 cycles than before. They had enhanced minimum flow rate capability and showed no change in the accuracy/linearity over the initial calibration. Subsequently a further 1.5 years has been added to this test, with no detriment to the original low flow performance.

For the LF15 on 10 cSt fluid the flow range is now from 0.5 to 90 l/hr rather than 0.5 to 45 l/hr. The coating also improves low flow ability. The LF15 can now measure down to less than 0.2 l/hr on 10cSt and less than 1 l/hr on water. As an example on one of the larger meters the HF66 minimum on water improved from 5 l/min down to 0.2 l/min. To ensure the lowest possible rate measurement the LF05 uses a titanium rotor which is also PVD coated.

Typical VFF construction with Exd Instrument

What is 'PVD'

Litre Meter manufactures the Nitronic rotor as normal. Coatings are applied by physical vapour deposition. A hard metal chromium nitride base layer provides surface hardness and appropriate support for the carbon (WC/C) which is laid over. The WC/C coating provides excellent protection against adhesive wear and its low coefficient of friction reduces the risk of surface fatigue (pitting) and fretting corrosion. Simultaneously, the layer of chromium nitride increases the corrosion resistance of components. The result is that the tribological properties and functional reliability are improved.

What's a pressure balanced chamber?

Extensive testing by Litre Meter in 2005 proved that leaks occur over the top of the rotor at higher pressures. This is due to minute distortions of the cap. For example at 700bar the cap moves by just 0.02mm in the centre. Increasing the bulk of the cap still produces this movement. The effect on meter performance was the creation of a leak path for fluid that avoided the positive displacement of the rotor. This was equivalent to about a 3% inaccuracy at 700bar. As a result of this Litre Meter designed a special pressure balance chamber (PBC) for its VFF flowmeter so it could operate at extreme pressure and at low-flow rates. The pressure balance chamber acts as a barrier, protecting the internal measurement components of the instrument from the high pressure conditions, preventing them from expanding and contracting under the immense pressure.

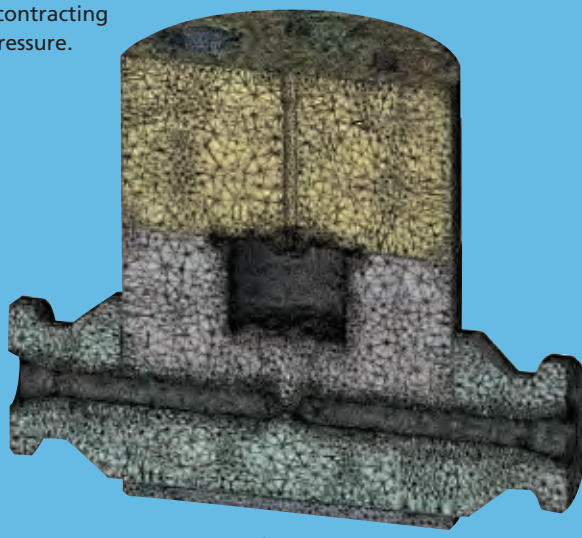

Figure 2 FEA mesh analysis of a 1035bar VFF

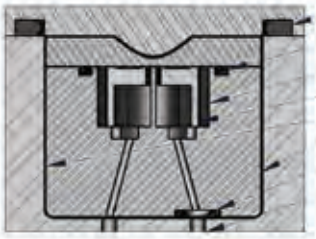

Figure 3 Pressure Balanced Chamber design

Key benefits

- No distortion of the chamber at higher pressures
- No measurement inaccuracy due to pressure
- Enables selection of optimal materials for the chamber to match the rotor i.e. PVD coated stainless steel
- Enables selection of optimal materials for the pressure vessel. i.e. super duplex stainless steel
- Enables construction of a duplex and super duplex bodied flowmeter – duplex material does not lend itself to the tolerances required in machining the chamber
- Enables simple swap out if required. LF03, LF05 and LF15 are interchangeable. Flowmeter body can remain in line whilst metering element is upgraded

Sensor:

The VFF series utilises a simple reed switch sensor. It is provided encapsulated in plastic. Two important tests have been carried out on the sensor:

- Two of our standard reed switches were set running on a dual input instrument. Each ran faultlessly for over a year at 500 Hz. That is 15 billion cycles each, equivalent to 30 years running at max frequency for a VFF
- A test in 2007 successfully showed that the sensor can work at an external pressure of 1000bar with no further protection although it is not in contact with the fluid at any time
- The same sensor is used by several companies for subsea versions of the VFF meter. Extensive vibration and shock tests have been performed

Instrumentation:

The rotor oscillation is detected by a single reed-switch. The pulse is received by the electronics within the display housing. They are pre-programmed to each flowmeter and should not be swapped with other bodies without prior consent from the manufacturer. There are two basic types of instrument certification: either Exi or Exd. The Exd versions vary depending on the materials of construction and on the certifying authority. The Exi versions are generally in plastic or aluminium housings. The Exd is more prevalent in chemical injection applications.

In older Exd versions within the enclosure there is also [1] a galvanic isolator providing protection to the flowmeter, [2] a HART transmitter providing a 4-20mA signal proportional to flow rate and [3] a PCB which linearises the incoming pulses, drives the display and provides a 0-72mV output to the HART transmitter. The flowmeter is pre-wired. Later Exd versions have a true HART output, large LCD display and linearisation. Some versions are pure two wire.

Mount:

Litre Meter have designed the flowmeter itself for optimal use of material. On all meters with hubs (such as Grayloc, Destech, Galperti) a mount has been added to the base of the design to provide a stable base and a place for the customer to attach the meter to the installation. For units without hubs various threaded holes are provided on the underside for mounting.

Sizes:

In order of flow capacity the following flowmeter sizes may be used: LF05, LF15, MF30, VFF4, VFF8, HF20, HF40, HF60, HF66, V125 etc. These are rated to 8, 23, 127, 1280 and 1920 US gallons per hour etc. See separate tables. The minimum flow rate measurable depends on the viscosity of the fluid. However all units will measure at least a 10:1 turndown from the specified maximum application flow rate. Some will have over 100:1 or 1000:1 turndown ability.

Flow Meter

Meter	Materials	Pressure	Rotor	Sealing	Electronic Mount	Line Size	Connection Type	Optional
LF03	Blank	207bar	AG	V	HD	½"	NPT	LF
LF05	DX	414bar	AGPVD	E	HV	¾"	AEMP	
LF15	SDX	690bar	TiPVD	N	FP	1"	ANSI150	
MF30		1035bar		PTFE		3/8"	ANSI300	
VFF4		1380bar		K		9/16"	ANSI….	
VFF8				CH		¾"	API10000	
HF20				M		1 ½"	Grayloc	
HF40						2"		
HF60	Example code: LF05/690bar/TiPVD/V/HV/9/16"AEMP					3"		
HF66								
V125								
V270								

Ordering Codes:

Blank	316L Stainless Steel	AG	AG stainless			NPT	NPT
DX	Duplex	AGPVD	PVD coated AG			AEMP	Autoclave
SDX	Super duplex	TiPVD	PVD coated Titanium			ANSI150	Wafer
			V	FPM		ANSI300	Wafer
			E	EPDM		ANSI….	Wafer up to 2500#
			N	Nitrile		API10000	API wafer
			PTFE	PTFE		Grayloc	Hub
			K	FFKM		Destec	Hub
			CH	Chemraz®		Galperti	Hub
			M	Metal - e.g Inconel			
					HD	Wall mount	Low Flow calibration
					HV	Meter mount	
					FP	FlowPod mount	

This is not a comprehensive list.
Simplified for illustration purposes.

Instrument

Electronics	Input	Linearisation	Pulse Output	Analogue Output	Digital Comms	Approval	Mounting	Material
FPOD	RS	10	OC	I	H1	ATEX	V	Blank
					H2	UL	VX	SS
					FF1	IECEx	VXI	
Example Code: FPOD-RS-10-OC-I-H1-ATEX-V-SS					FF2	FM	VXO	
							H	
							R	

Ordering Codes:

H1	HART	V	Vertical	
H2	HART	VX	Consult Factory	
FF1	Foundation Fieldbus	VXI	Consult Factory	
FF2	Foundation Fieldbus	VXO	Consult Factory	
		H	Horizontal	
		R	Remote	
			Blank	Aluminium
			SS	SS316L

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