VESSEL FUEL MEASUREMENT & MANAGEMENT SYSTEM (VFMMS)

Reference: - June 2012

TECHNICAL APPROACH

Kral Fuel Flowmeters

History:

The Kral Flowmeter was developed over 20 years ago a solution to an internal requirement. Kral needed a precision flowmeter as part of their production test stands, but could not find a meter that would meet their demands of accuracy, turn-down ration and robustness.

The experience gained over the 30 years of manufacturing positive displacement pumps, provided the idea of turning around the working principle of the pumps. Instead of a motor driving the pump spindles, Kral used the flowing liquid to rotate the spindles.

This concept provided and ideal solution to assure precision and reduce pressure drop even in very diverse operating conditions.

Robust and Precise:

In most flow measuring instruments, robustness and precision are mutually exclusive, however the Kral OMG Series offers both. At Kral, our core competence in profiling screw spindles guarantees precise measuring chambers in the meter. Therefore extremely accurate measurements are possible and the OMG meter's operation is smooth and responsive.

This has allowed us to create a selection of OMG Flowmeters that are suitable for a wide variety of applications and operating conditions:

❖ Flow Range:	0.03 to 2,000 GPM
❖ Max Pressure:	3600 psig
❖ Temperature Range:	-4 to 400F
❖ Viscosity Range:	1 to $1x10^2$ cSt
❖ Liquid:	Chemically neutral, slightly lubricating Clean, non-abrasive.
❖ Accuracy:	0.1% of Rate
❖ Casing	Cast Iron EN-GJS-400
❖ Spindles	Nitrided Steel
❖ Ball Bearings:	Bearing Steel
❖ Seals:	Viton

Wide Range of Applications:
As a "PD" Meter, the OMG Series covers a wide range of Viscosities and has a turn-down ratio of 100:1

Compact Design:
The Axial arrangement of the measurement system allows laminar flow with no change in direction making it a very compact design.

Fast Response Measurement:
The fast response spindles can follow any rapid fluctuations in the flow caused by pulsations.

High Accuracy:
Because of the precision measurement chamber, extremely accurate measurements are possible

Minimal Pressure Loss:
The precision screw design of the Flowmeter operates with minimal friction and pressure loss

Multiple Connections:

- NPT Pipe Thread
- "G" Thread
- DIN Flange, ANSI, SAE & JIS
- Custom

No Flow Conditioning:
The OMG operating principle is insensitive to flow disturbances. Flow conditioning is not required. Valves and pipe elbows are allowed close to the Flowmeter. This allows for easy installation in tight spaces.

Robust and Precise:
The rigid casing protects the precisely manufactured spindles. That is why the OMG offers both fobustness and precision.

Bi-Directional Flow Measurement:
Because of the operating principle, bi-directional flow can be measured. Using a flow direction sensor, a change of flow direction or brief reverse flow can be detected and measured.

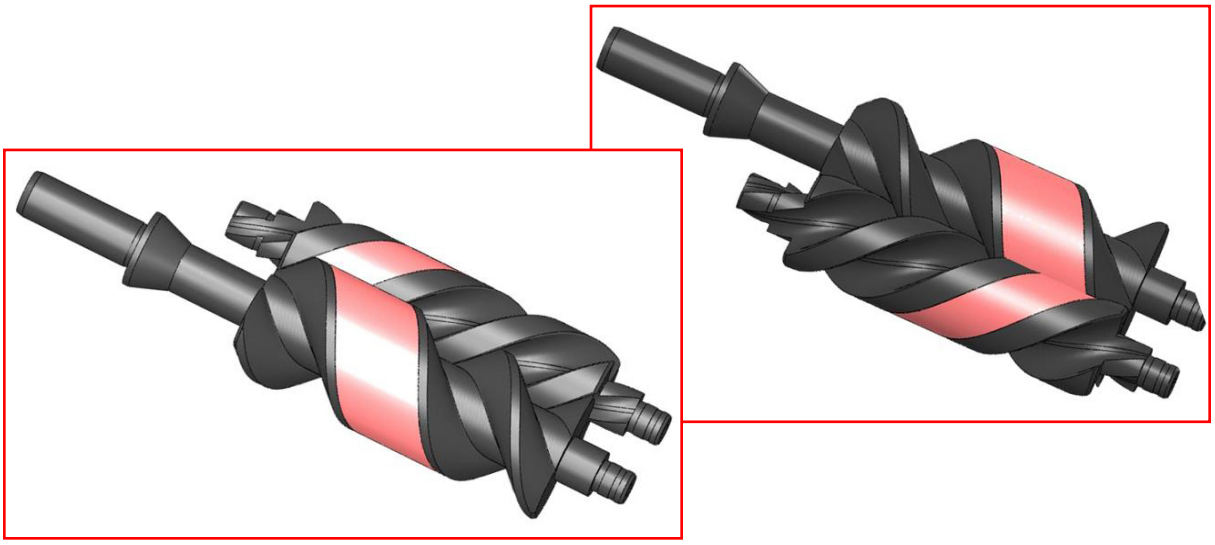
Temperature Compensation:
Temperature sensors on each meter provide accurate data to allow for any temperature corrections to be calculated for a specific volume and volume comparisons.

Standard Output Signal:
The flow sensor output signal is an industry standard square wave.

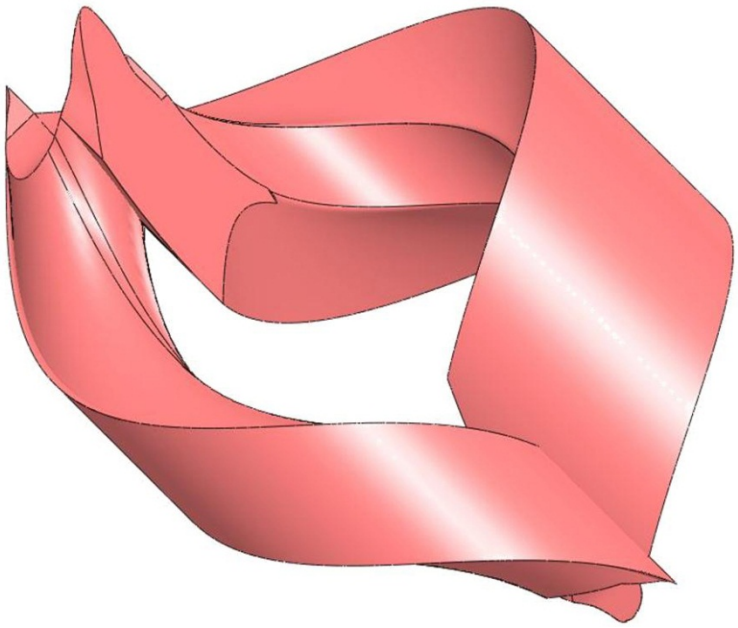
A dry sleeve seals the meter completely, for troublefree sensor installation and verification.

Measurement Concept:

- The “Division” of liquid medium into countable volume



- “Countable” liquid volume within the set of spindle screws



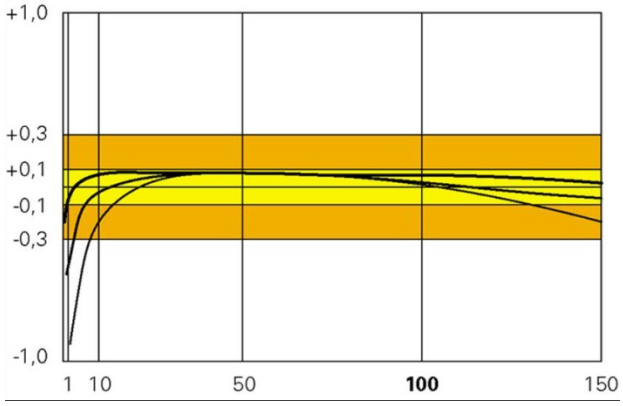
Calibration:

All Kral Flowmeters are factory calibrated to a national traceable standard. This confirms the accuracy. Since the K-Factors are all predetermined, no field calibration is necessary.

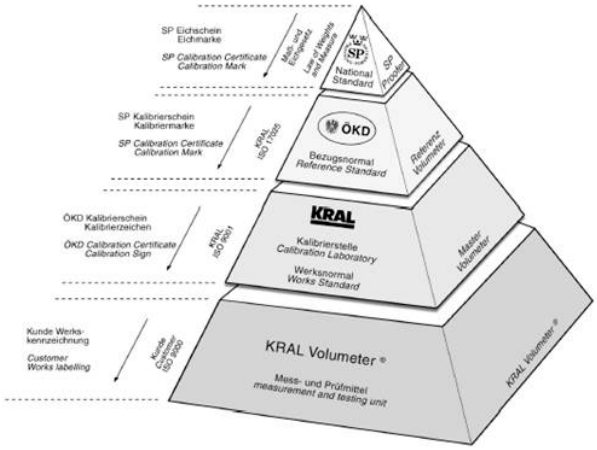
The K-Factors (number of pulses/liter) are linearized using 7 points over the operating flow range, used in conjunction with temperature compensation; the accuracy can be maintained over the operating flow range.

General Linearity Characteristics

Accuracy



Operating Flow Range



This "Accuracy" and "Precision is very important for Fuel Consumption Measurement since it allows for the reduction of the impact of errors

$$C = Q_{supply} - Q_{return}$$

$$\Delta C = \sqrt{\left(\frac{\delta C}{\delta Q_{supply}} \Delta Q_{supply}\right)^2 + \left(\frac{\delta C}{\delta Q_{return}} \Delta Q_{return}\right)^2}$$

$$\frac{\Delta C}{C} = f_R(Q) \sqrt{\frac{Q_1^2 + Q_2^2}{(Q_1 - Q_2)^2}}$$

Why is Gaussian Error Propagation important in fuel consumption measurements?

Measurement errors* in differential measurement.

Idling		Full load	
Single flow measurement	System	Single flow measurement	System
0,1 %	2,2 %	0,1 %	0,4 %
0,3 %	6,2 %	0,3 %	1,0 %
0,5 %	10,3 %	0,5 %	1,8 %
1,0 %	20,5 %	1,0 %	3,6 %
3,0 %	61,0 %	3,0 %	10,8 %

* Measurement errors vary with the circulation rate. Here: idling 20, full load 4. Upon request we will gladly calculate your application.

- A meter that has a 1% error factor will have a system error of over 20.5% at idle and a over a 3.6% system error at high idle.
- This will be especially important as reporting requirements are increased in order to monitor fuel consumption as it relates to exhaust emissions output.

Economic Impact of the Error:

Economics of the Error Propagation Factor

Meter with a **1% Error Factor** Test Engine: Caterpillar 3512B @ 40gph @1325 rpm

Burn Rate	Error Factor	Fuel not Recorded	Cost per Gal	Cost of Fuel / Hr	Total Hrs/ Year	Cost of 1% Error
3 Gal / Hr @ Idle	Idle: 20.5%	.615 gph	$3.65	$2.24	2500	**$5,600.00**
40 Gal /Hr @ 73%Load	Load: 3.6%	1.44 gph	$3.65	$5.26	2500	**$13,150.00**

KRAL Meter with a **.1% Error Factor** Test Engine: Caterpillar 3512B @ 40gph @1325 rpm

Burn Rate	Error Factor	Fuel not Recorded	Cost per Gal	Cost of Fuel / Hr	Total Hrs/ Year	Cost of .1% Error
3 Gal / Hr @ Idle	Idle: 2.2%	.066 gph	$3.65	$0.24	2500	**$ 600.00**
40 Gal /Hr @ 73% Load	Load: .04%	.160 GPH	$3.65	$0.58	2500	**$1,450.00**

- Over the lifetime of an engine 80% of the costs are fuel costs.

  Tracking and managing those costs will be critical to making successful management decisions, especially in light of rising fuel cost and regulatory demands for emissions compliance.

Kral BEM500 Electronic Display:

The Kral BEM500 Series Electronic Display offers a management system that

- Provides a 4-Line display
- Calculates temperature variation on fuel volume
- Linearizes over 7 points across the fuel flow range
- Provides multiple analog and pulse outputs
- Offers a RTU Modus interface protocol to easily transfer data to shipboard data management systems

Data Management System:

It has been our experience at Eco Star Collaborative, that Krill Systems, Inc has provided an extremely reliable and flexible Data Management and Acquisition Platform that easily communicates with the RTU Modbus signal provided by the Kral BEM500.

The flexibility and adaptability of the Krill System coupled with the wide range of sensor data it can provide, will allow the vessel operator to easily access information enabling both the Vessel Captain and shore side personnel the ability to make accurate decisions and develop data models for future planning.

Installation Configurations:

Typical Commercial Vessel / Generator Arrangement generally includes two main engines for propulsion and a generator to meet hotel and electrical demands. The model below represents what a normal configuration would be on engines with supply fuel flow of less than 300 gph, using differential flow measurement with temperature compensation.

Systems can be arranged to accommodate many different vessel configurations including propulsion engines, diesel generators, and boilers. Pricing models can be developed for each of the vessel configurations as required.

Differential Fuel Mgmt	Main Engine Fuel Monitoring OMG20 FCM Arrangements - For Differential Fuel Measurement, 2 Meter Groups per Engine	
OMG 20 Flowmeters	OMG 20.6150743 (K1, P=2) Max Nom Flow 480 gph End Connections UOD 000 (G 3/4" 250Bar Class) 2 x Pick-Up Sensors BEG 43D Factory Installed Temperature Sensor EET21 Factory Installed Pre-Wired UZA 11 Junction Box for BEM500 Display	4 Units
BEM 500 Display Unit	Kral BEM500 Display Module Standard Design In Plastic Housing - IP65 2 Pulse inputs, Power Supply, 24VDC Text Display 4 Lines to 20 Signs, Operator Guidance in Clear Text, BUS Interface (Modbus), Serial Interface RS232 or RS485, 2 Linearization Tables, Pressure Pulse Compensation, 2 Temperature Inputs, (PT 100), 2 Analog Outputs (4-20mA or 0-10v), 2 relays (for by pass messages), company settings The OMG Series Meter is an ABS Class Certified Flowmeter. It is manufactured with a Steel Body	2 Units

Installation and Installation Kits including any by-pass requirements can be offered separately.

KRAL
Pumpen·Volumeter

Volumeter selection	OMG 20.610043

OMG 20 Series Selection Guide

Number of pick ups: 2

Liquid: Diesel fuel

Series: OMG

Size: 20

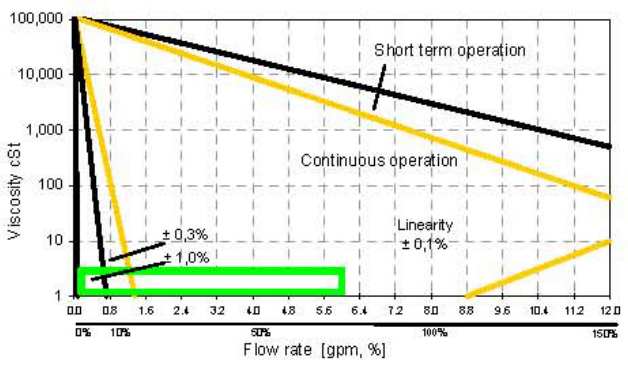
K-factor: K1

Pick up: BEG 43

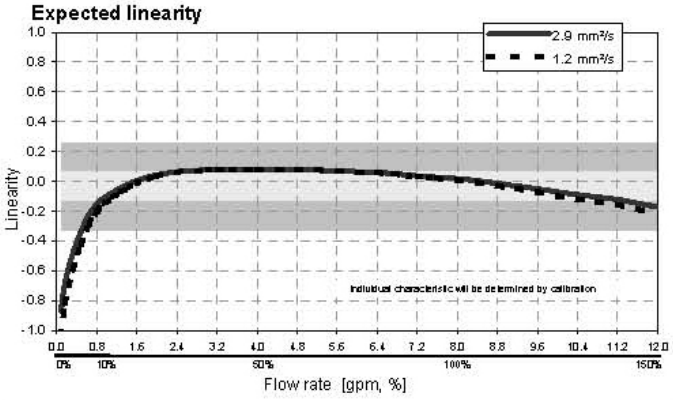
		Customer data min.	Customer data max.	Device data min.	Device data max.	Pick up data min.	Pick up data max.
Flow rate	gpm	0.15	6.00	0.1	12.0		
Pressure	psig	15.0	60.0	0.0	3600.0	0.0	3600.0
Viscosity	cSt	1.2	2.9	1.0	1,000,000		
Temperature	°F	32.0	32.0	-4.0	400.0	-4.0	210.0
Pressure loss	psig	0.0064	3.0738				

End connections: G 3/4" 250 bar

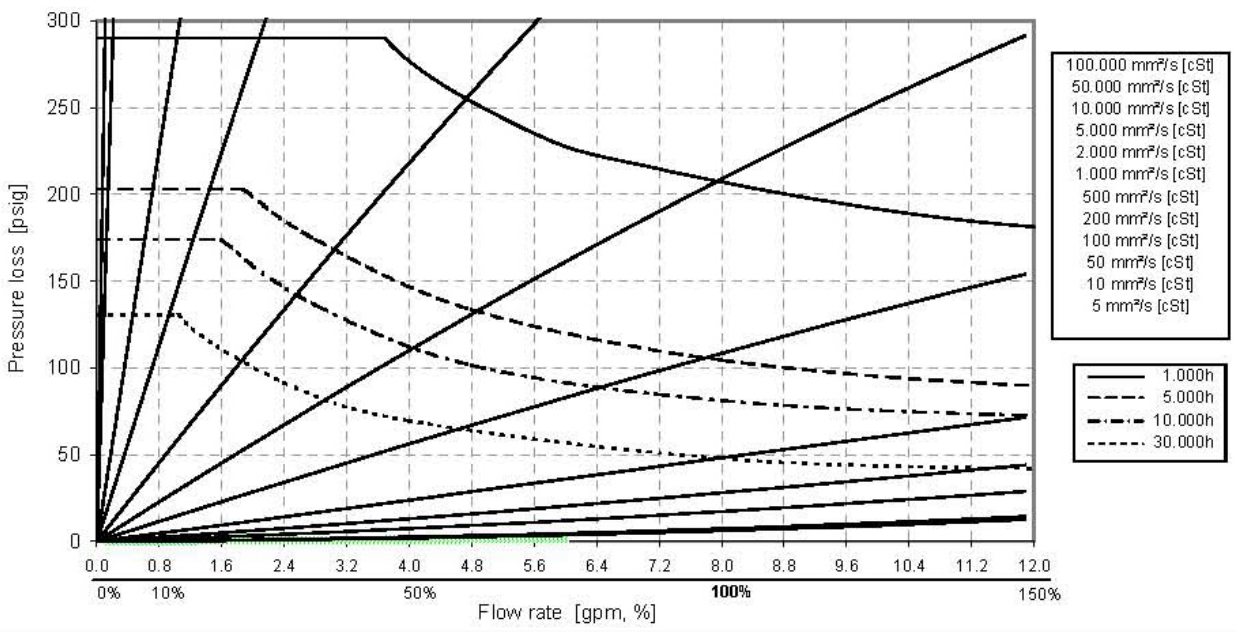
Operating range



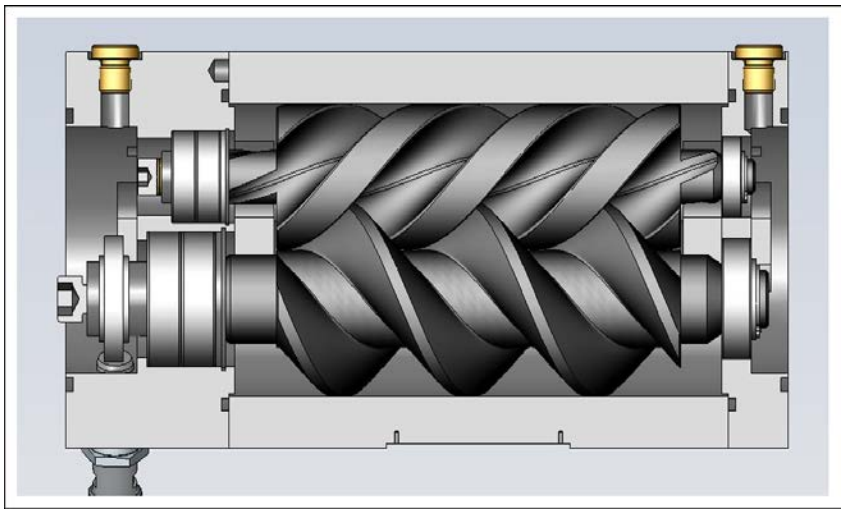
Expected linearity

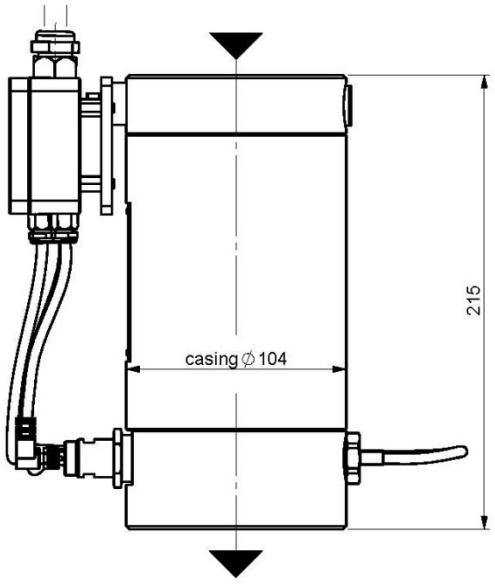


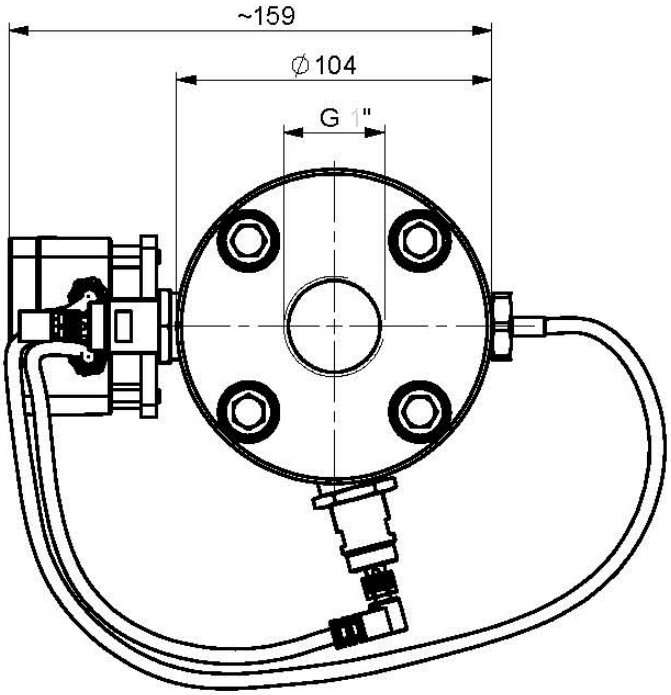
Load rating

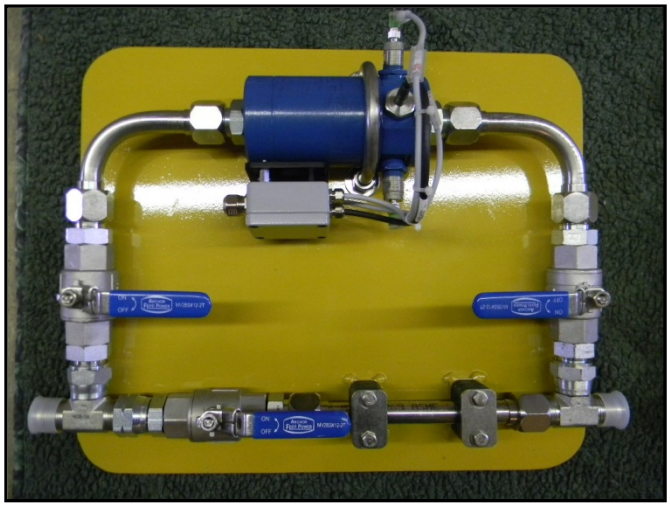


OMG Series Meter Drawings & Typical Installation Photo with optional bypass:









Thank you for your consideration of the Kral Flowmeters for your application. If you have any questions please do not hesitate to give me a call or send an email.

Respectfully submitted,

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