Flow Measurement.

KRAL






Fuel Consumption Measurement for Diesel Engines.

Overview of Contents.

Why Measure Fuel Consumption.

Many opportunities for saving fuel and reducing emissions.

For many companies, the result of success is an increasing fuel requirement. Fuel consumption dominates operating costs.

In the case of a ship, for example, a reduction of fuel consumption is easily achieved by reducing speed. The table shows the potential for fuel saving very clearly.

Ship owners control the engine load to set the most efficient speed.

Engine manufacturers use KRAL fuel consumption measurement in test benches for research and development. Engines are optimized.

Test bench runs become shorter.
Railway companies train their drivers to drive to save fuel, and check locomotive contracts.

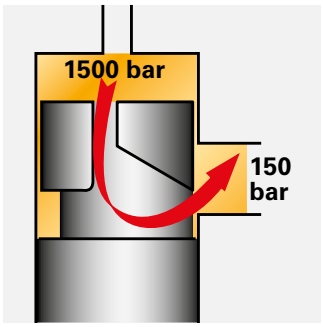
Independent power producers determine the guaranteed specific fuel consumption during the guarantee period. Afterwards, excessively high fuel consumption indicates that maintenance of the engine is necessary.

Besides measuring fuel consumption, the KRAL system provides other parameters such as fuel temperatures and forward and return flow quantities, from which the circulation rate can be calculated. This on-board monitoring helps with monitoring optimum operation of the engine.
This survey of applications shows many possible ways of using KRAL fuel consumption measurement. If you have challenging ideas about making your engine system more efficient, please let us share them.
Customer-specific developments are one of KRAL's strengths. Cooperation with KRAL as a partner leads to unique solutions.

Speed reduction.	Fuel saving.
2 %	4 %
4 %	8 %
6 %	12 %
8 %	16 %
10 %	19 %

Fuel is Becoming Ever More Valuable.

KRAL fuel consumption measurement takes account of effects of the engine system and provides very precise measured values, with compensation for errors.



Typical operating parameters for consumption measurement.	
Engine power:	300 kW, no top limit.
Number of engines:	1 to 32.
Fuels:	Diesel oil (LFO), marine diesel (MGO, MDO), heavy oil (HFO).
Temperature:	Up to 200 °C.
Pressure pulsation:	Up to 20 bar.
Vibration:	No effect on measurement.

Taking account of temperature differences.

The temperature of the fuel in the return line is up to 30 °C higher than in the forward line. Even in the case of heavy oil systems, in which the fuel is preheated in the booster module, temperature differences up to 20 °C occur.

KRAL fuel consumption measurement monitors the temperatures of the forward and return lines and calculates consumption at a freely selectable temperature level. 15 °C is commonly used internationally. The consumption value can then be displayed for a freely selectable temperature.

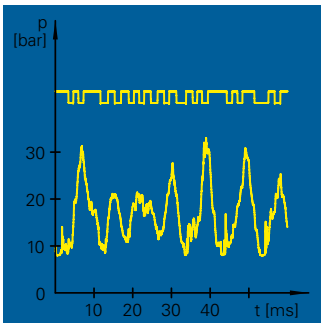
In this way, KRAL temperature compensation ensures very precise measured values for consumption.

Compensating for fuel pulsation.

The pistons of the injection pumps cause fluid pulsation in the low pressure fuel lines. This pulsation may cause:

- Pressure surges on the system components.
- The flow rate of the fuel varying at high frequency.
- A brief reversal of the flow direction of the fuel.

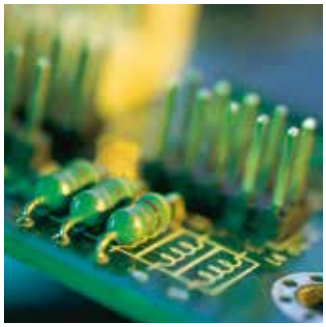
As a displacement meter, the measurement spindles of the KRAL flowmeter follow every movement of the fluid column. The functional principle does not depend on the direction of flow. Reverse flows of the fuel can therefore be measured. With KRAL pressure pulse compensation, reverse flows are monitored and compensated for in the measured value formation. Correct measured values in the specified flow direction are thus ensured.
The diagram above shows the



course of the output signal of a KRAL fuel consumption measurement. Each pulse represents, very precisely, a quantity of fuel. The different pulse lengths show variations of the fuel's flow rate. The flow rate varies with the pressure pulses which the injection pumps excite. The diagram clearly shows that the fuel does not flow evenly through the fuel line, but that very harsh conditions prevail there.

Fulfilling customer wishes.

More and more often, end users of diesel engines demand fuel consumption measurement.
Where the engine manufacturer leaves consumption measurement to its customers, there are always different views about the type of measurement and the interpretation of the measured values. By integrating fuel consumption measurement, the engine manufacturer can adjust it optimally to the manufacturer's engines.



Engine management.

Operators of large diesel engines want to know what high fuel consumption or specific fuel oil consumption (SFOC) is at different engine powers. Both values are given by the engine manufacturer.

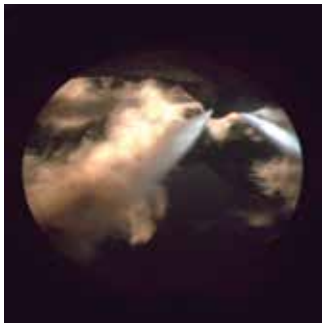
Deviations indicate poor engine tuning. Without reliable measurement, evaluating these values is guesswork. KRAL fuel consumption measurement, with KRAL electronic units, shows consumption as input for engine management.

Dual fuel systems.

Power plant operators buy the least expensive fuel type, or what is available. Modern diesel engines can therefore be operated with different fuel grades.

Ocean-going ships are driven by heavy fuel oil (HFO), and in certain regions must switch to marine diesel (MGO or MDO).

Viscosity has only a very slight effect on the measurement principle of the KRAL flowmeter. They work equally reliably at the clearly different operating temperatures of MDO and HFO. KRAL electronics take account of the different temperatures where conversion from volume to mass units or to a reference temperature is requested. KRAL fuel consumption measurement measures all fluid fuels for large diesel engines.



Measurement results for research and development.

Two goals of engine development are reduction of emissions and of fuel consumption. To achieve this, changes are made to the engine and its components. For example, the combustion chamber or turbocharger can be optimized.

The effect of the improvement on fuel consumption can be shown very precisely by KRAL fuel consumption measurement.

Multi-engine systems.

Where fuel consumption of several engines is to be measured, KRAL offers optimum solutions.

KRAL fuel consumption measurement can measure up to 32 engines. The measured values can be provided for data acquisition by the customer and displayed on a central display.

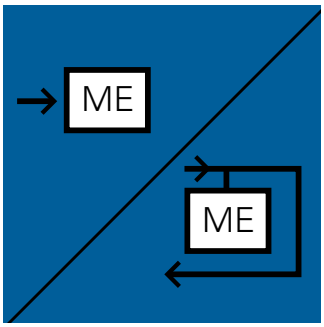
High System Precision.

KRAL flowmeter are the basis for maximum system precision.

Precise KRAL flowmeter.

With a measurement precision of ±0.1 %, reproducibility of 0.01 % and a measurement range of up to 100:1, calibration and testing institutes assess KRAL flowmeter as the most precise displacement meters for industrial applications. The measurement is independent of the flow direction. These unique properties mean that it is ideal for fuel consumption measurement.

Some system suppliers describe only their electronic system, without giving information about flowmeters. We at KRAL are convinced that precise meters are important, because they provide the input for the electronic system.



Single line measurement and differential measurement.

The measurement precision of fuel consumption measurement is determined by the number of flowmeters used. Where only one unit per engine is required, the high precision of the KRAL flowmeter can be fully exploited. Where two units are required, system measurement precision is reduced according to Gaussian error propagation.

One KRAL flowmeter will be sufficient if the fuel supply behind the tank branches into a ring line. Two flowmeters will be required if the return line leads directly into the tank, or each engine of a multi-engine system is measured.

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 %

*KRAL (red) other (black).

High system precision.

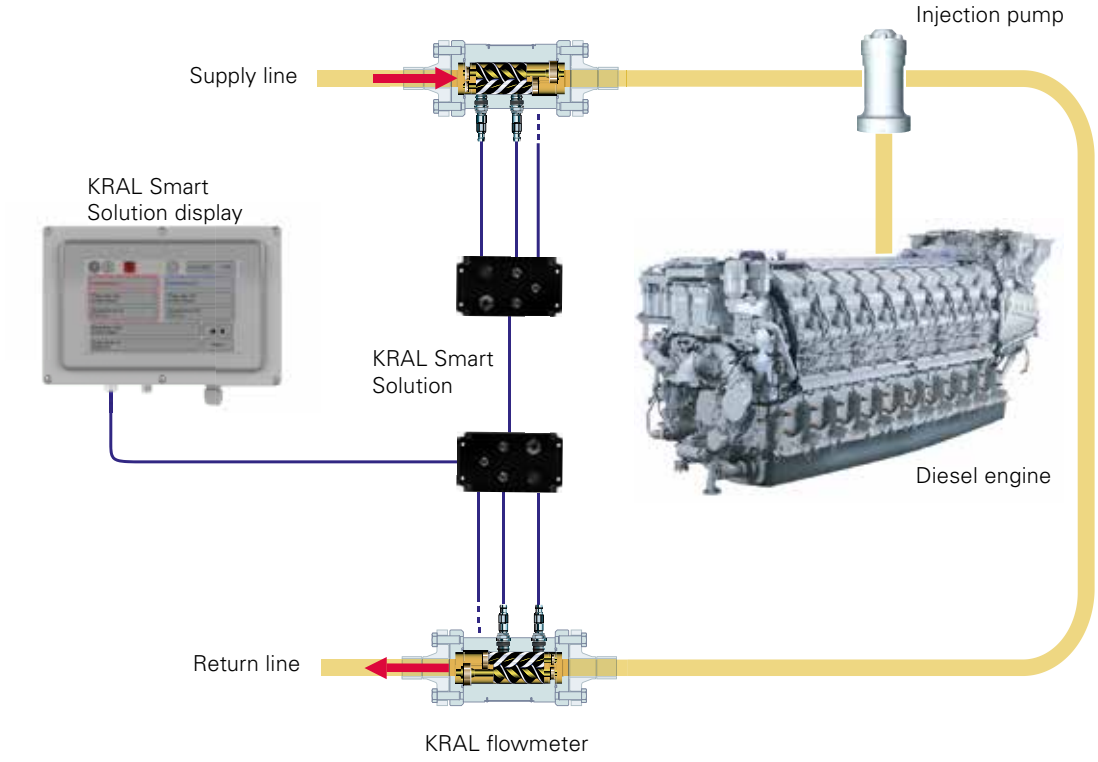
Where one measured value is calculated from several individual measured values, the error of the individual measurements is propagated according to the Gaussian error propagation law. The table shows the measurement errors of a system depending on the precision of the individual meters. The table values are calculated according to the error propagation law for two engine states: „idling“ and „full load“.

The calculated results show that the system error, for mathematical reasons, rises sharply even at a slight deterioration of the precision of the individual meters. Flowmeters with a measurement precision of 0.5 % and up are unsuitable for consumption measurements on engines which may be idled. A 10.3 % system error is not worth spending money on.

In contrast, KRAL flowmeters, because of their high measurement precision of 0.1 %, achieve optimum system measurement precision for both idle and full load.

Choose KRAL. Only highly precise KRAL flowmeters guarantee system measurement precision which stands the test in practical applications!

The solution, taking the KRAL flowmeter with KRAL Smart Solution display as an example.



A complete system from one source.

The benefit of the screw spindle principle is its insensitivity to vibration. There is no loss of precision.

High precision flowmeters.

Thanks to their high measurement precision of ±0.1%, KRAL flowmeter ensure system measurement precision of as high as ±0.4% at full load. The system precision increases with the circulation rate.

Measurement independent of direction.

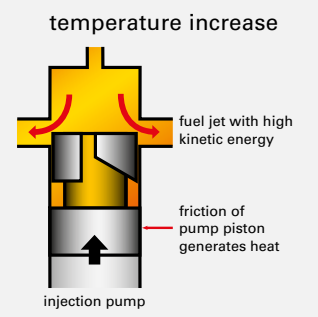
To detect the direction of flow, an additional flow direction sensor is required besides the flow sensor. A correct consumption value is only possible in this way.

Measurement with pressure pulsation.

Injection pumps cause pressure pulses in low pressure fuel lines, resulting in short term changes of the fuel's direction of flow. KRAL flowmeters in principle measure in both flow directions. Reverse flows are detected correctly and taken into account in the formation of measured values. The result is a very precise, variance-corrected measured value.

Variance-Corrected Measured Values.

Temperature compensation.



Density table of fuels (DIN 51757, method B).

T	$\rho_{LFO}(T)$	$\rho_{HFO}(T)$	rel. error LFO	rel. error HFO
[°C]	[kg/m³]	[kg/m³]	[%]	[%]
20	906.5	976.3	0.0	3.2
40	892.6	961.3	-1.5	1.6
60	878.6	946.2	-3.1	0.0
80	864.4	930.9	-4.6	-1.6
100	850.2	915.6	-6.2	-3.2
120	835.9	900.2	-7.8	-4.9

Temperature difference between forward and return flows.

If the temperature difference between the fuel supply and return line is ignored, the measured value will be incorrect.

In most diesel engine systems, the low pressure fuel system is designed as a ring line. This ensures that even in the case of rapid changes of engine load, enough fuel is available. These lines are also completly flushed, to ensure that there is fuel for injection without outgassing.

The kinetic energy of the returning fuel when the injection pump pistons are shut off, the friction of the injection pump pistons and the radiated heat of the engine are the reasons for a higher fuel temperature in the return flow.

In practice, the temperature differences are up to 30 °C. The fuel expands with increasing temperature. The volume changes.

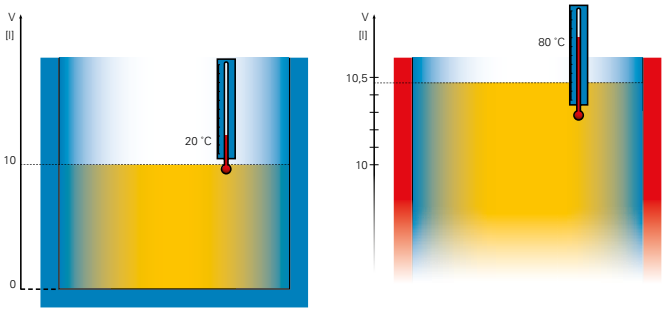
KRAL fuel consumption measurement measures the temperatures of the supply and return flows. Temperature compensation ensures that the difference between the forward and return flow quantities is calculated at exactly the same temperature. The highest measurement precision can only be guaranteed in this way.

Amazingly large effect.

The effect of temperature differences on the measurement precision of the whole system is unexpectedly large.

The density table shows that fuel density falls by about 1.5 % per 20 °C temperature increase. In the case of an LFO system with a 40 °C temperature difference, that is about -3.1 %. For differential measurement in the whole system, Gaussian error propagation indicates an error of 8.5 %. In the case of HFO systems, despite fuel preheating in the booster module, a temperature difference of 20 °C and a density difference of about -1.6% occur. The result is a system error of 5 %. Precise measurements require highly precise KRAL flowmeters with temperature compensation.

Temperature-based volume expansion.



Pressure pulse compensation.

Variations of flow rate.

The fuel does not flow evenly through the lines. It pulses, and may even change its flow direction briefly. If this effect is ignored, the measured value for consumption will be incorrect.

The injection pumps cause pressure pulses. As the pump piston moves upward, it closes the volume above itself. The fuel is compressed in the pressure chamber to an injection pressure of about 1,500 bar. The end of injection is reached when the control edge of the pump piston releases the fuel line again. A fuel jet then shoots at high pressure back into the fuel line. A pressure wave in the forward and return lines is the result. The fuel is accelerated.

The precisely manufactured measurement spindles of KRAL flowmeters quickly follow the changes of the fuel flow rate.

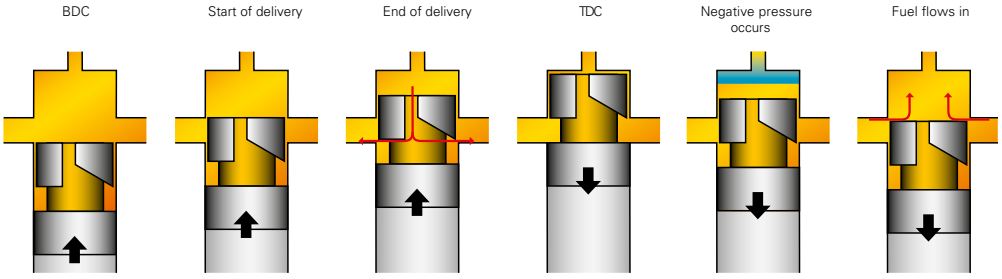
Reversal of flow direction.

In its downward movement, the pump piston creates suction on the fluid column. The result is a negative pressure.

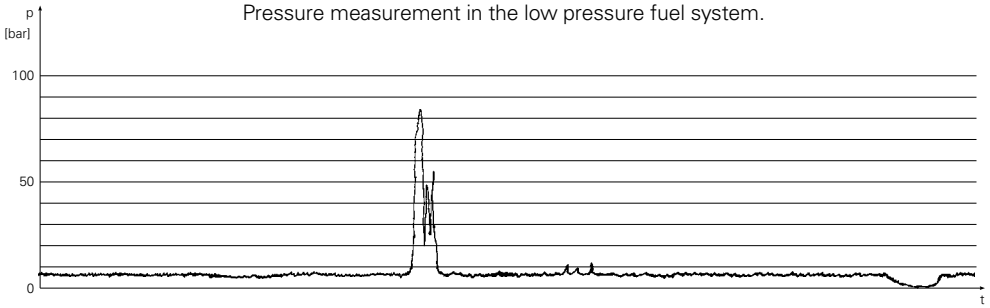
When the pump piston, in its downward movement, releases the fuel line, the pressure chamber fills rapidly with fuel because of the negative pressure. The fuel which flows in makes the forward flow faster and reduces the return flow. In the return line, the direction of flow may be reversed.

KRAL flowmeters in principle measure in both flow directions. Using a second sensor, the direction of rotation of the spindles and thus the direction of flow can be detected. For precise measurement of the small reverse flows, very precise flowmeters are necessary. KRAL flowmeters measure correctly and precisely.

Pump piston of the injection pump.



Pressure measurement in the low pressure fuel system.



System Variants.

Single line measurement and differential measurement.

Single line measurement.

In the simplest case, a KRAL flowmeter can be installed before the mixing tank. It should be noted that KRAL fuel consumption measurement then only measures the refilling of the mixing tank. Fuel consumption is not measured and displayed in real time. However, over a longer measurement period, fuel consumption is very precisely correct. Where more than one engine is supplied with fuel from the mixing tank, fuel consumption measurement is no longer related to an engine. The total consumption of all engines together is measured.

The benefits of this type of installation are the low system price and easy operating conditions. The system is inexpensive because only one KRAL flowmeter and one display and processing unit are required.

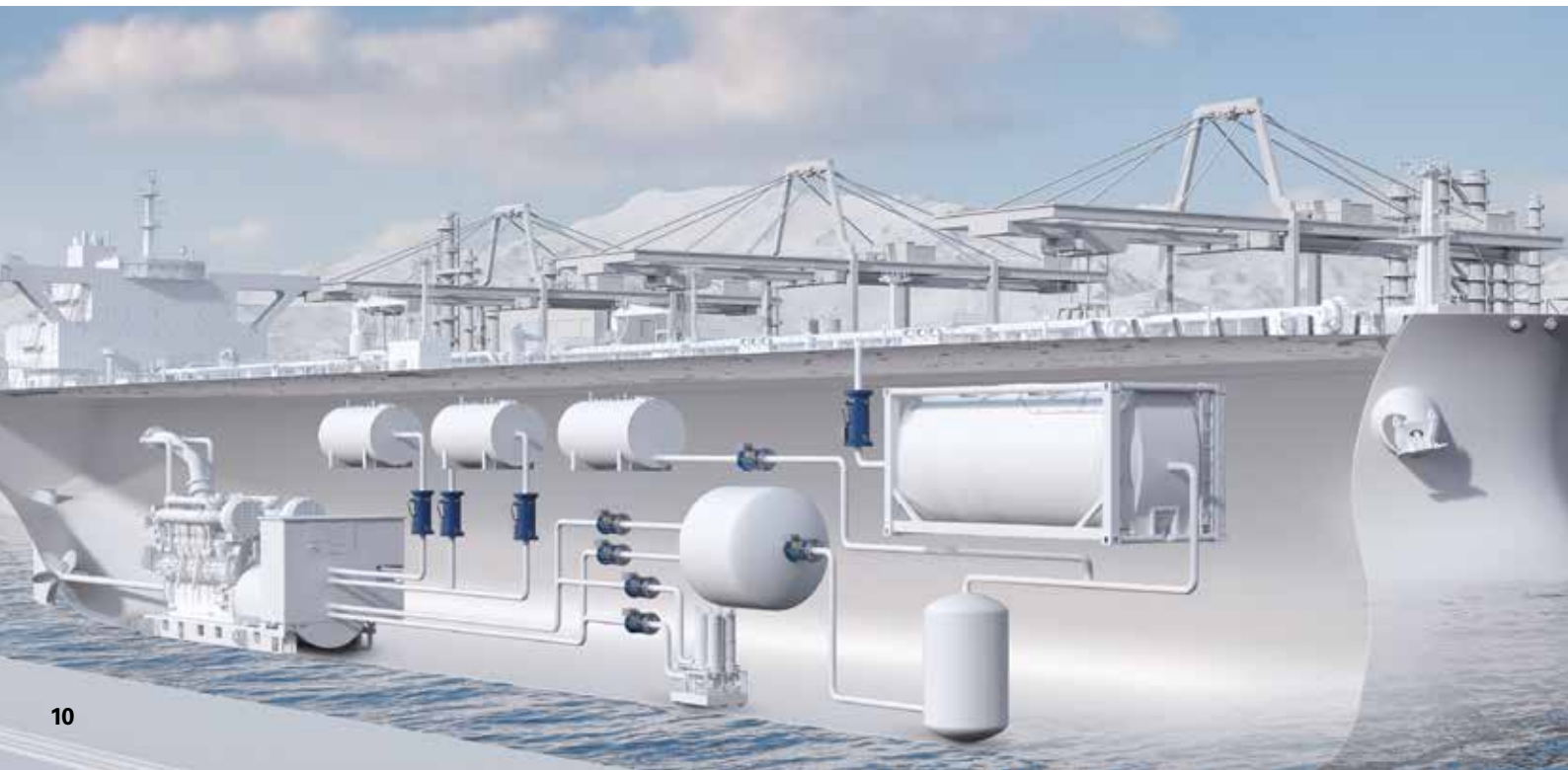
System measurement precision using one flowmeter is better than in the case of differential measurement.

Differential measurement.

With most engines, the return flow of the fuel ring line leads back into the tank. The additional quantity which is more then the fuel consumption depends on the circulation ratio. The circulation ratio determines the circulated quantity as a ratio to fuel consumption. If the engine is at full load, 3.5 will be a typical value, which means that 3.5 times as much fuel circulates as the engine consumes.

For precise measurement, one KRAL flowmeter must be installed in the supply line and one in the return line. For each engine, two KRAL flowmeters are required. The difference between the supply and return flow quantities indicates the consumption of fuel. The difference is calculated in the KRAL processing units. Compensation for pressure pulses is controlled by KRAL pressure pulse compensation.
KRAL temperature compensation takes account of the temperature difference between the supply and return flows. Very precise, variance-corrected measured values are thus ensured.

The benefit of this type of installation is accurate, very fast consumption measurement. The measured value is immediately available in real time.

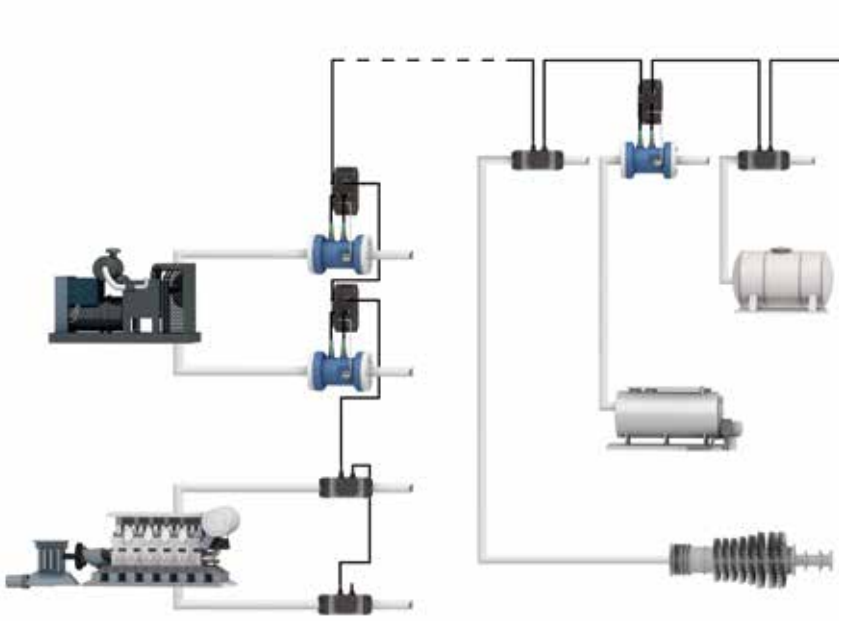


Picture: MAN AG.

Multi-engine systems.

Ships, power plants and diesel locomotives often have multiple engines. To keep control of total fuel consumption, operators often demand fuel consumption measurement which can measure many engines. Displaying all consumption values measured on one display is often required. Fuel consumption measurement of an engine in a multi-engine system can be implemented as single line measurement or differential measurement. As an example, the illustration shows a system with 3 engines and 3 differential measurement systems.

The KRAL display unit Smart Solution Display shows the consumption values for one engine. The KRAL Smart Solution can provide the consumption of up to 32 engines. KRAL electronic units support various output signals. Even complex KRAL fuel consumption measurement can therefore be integrated into the electronic system installed on board or in the control room.



Barges – Optimized, Cost-Efficient Systems.

Rising fuel prices force savings.

Fuel costs are reduced with KRAL technologies.

Whereas freight rates have hardly changed over the years, the price of fuel never ceases to rise. All opportunities for saving fuel must be used in order to keep the business profitable.

Check manufacturer's data.

When they invest in a tow boat, barge operators take note of the engine's guaranteed fuel consumption. Fuel costs rapidly overtake the price of the engine.

The electronic system of the engine indicates fuel consumption which is determined from the number of injection strokes and the injected quantity. The injected quantity varies. An average injected quantity can provide only a guideline value for fuel consumption. We at KRAL have measured differences from actual consumption of up to 20 %. KRAL fuel consumption measurement measures the actual flow directly in the fuel line.

KRAL flowmeters are precise to 0.1 %. For this precision class, the table of measurement errors on page 6 shows an error of only 0.4 % at full load. With precise measured values, guaranteed manufacturer's data can be checked.

Why rush it?

Arriving in the destination port before the agreed time is usually pointless, because the dock will still be occupied. Going at full throttle is almost always unnecessary. At high engine speed, consumption is disproportionately high. The fuel saving table on page 3 shows that even a small reduction of speed saves considerable quantities of fuel.

Again and again, captains are surprised that KRAL fuel consumption measurement shows changed consumption directly after operation of the speed regulator.

Favorable position in the river.

Resistance to motion depends on many factors, including the current and water depth. With KRAL fuel consumption measurement, it is possible to search systematically for the most favorable position in the river while consuming very little fuel.

With KRAL fuel consumption measurement, there are many opportunities for saving fuel. Barge operators have reported that the system pays for itself in less than a year – a worthwhile investment.

Information on the bridge and in the engine room.

For efficient movement, displaying fuel consumption on the bridge is enough. At engine inspections and for trouble shooting, the engineers on board use the fuel consumption value as an indicator of optimum engine tuning. As well as the consumption value, KRAL fuel consumption measurement also indicates the fuel temperatures and densities. Therefore, an additional display in the engine room has often been shown to be useful.

KRAL electronic units can be installed both on the bridge and in the engine room.

Optimized system solutions.

In contrast to ocean-going ships, tow boats run on MDO. The fuel is much cleaner than heavy oil and does not have to be preheated.

With such good operating conditions, the cost-optimized KRAL flowmeter of the OME series with the display unit Smart Solution display are outstandingly suitable.

The Smart Solution display exploits all the benefits of the KRAL flowmeter, and offers all necessary functions for differential measurement, including temperature and pressure pulse compensation.

Benefits of the KRAL flowmeter.

KRAL flowmeter generate the measured flow value in a very simple way. The operating principle of mechanical KRAL flowmeter is shown again and again to be an advantage in the harsh conditions of the fuel system. Tank levels and fuel consumption are shown in liter volume units. Metrologically, the aim is always to use a meter which determines the measured value directly, without conversion. KRAL flowmeters are positive displacement meters. The measured value is measured directly, without conversion.

OMP flowmeter with Smart Solution.

The simple, reliable measurement principle demands the highest manufacturing precision. With displacement meters, slippage and friction are the cause of measurement errors. KRAL has reduced these error sources to a minimum using state-of-the-art manufacturing methods. The opinion of national calibration and testing institutes is that KRAL flowmeters are the most precise displacement meters on the market. Metrologically, precision is shown by the high measurement precision over a wide measurement range with minimum loss of pressure.

Fishing Vessels – Save Fuel Even at Full Throttle.

Increased profit despite high fuel prices.

Fishermen in daily fight for survival.

The profitability of fishing companies is endangered by quota controls for fish catches and the increase of fuel prices.

Many fishermen have recognized the potential for fuel saving by careful movement. Unfortunately, some fishing companies have already invested in simple systems. However, these systems, which are known from the hobby field, mostly do not measure precisely. Without precise measurement, consumption can only be estimated. Non-professional installation also affects measurement precision and may even cause malfunctions.

KRAL offers industrial precision metrology. If necessary, KRAL also helps with installation.

Saving fuel on the journey to the fishing grounds.

A practical example: a ship is approaching the fishing grounds at 12 knots (22.2 km/h) and fuel consumption of 330 l/h. With the KRAL system, fuel consumption can be compared with the engine speed. The optimum speed is thus determined. Throttling back by half a knot reduces fuel consumption by 30 l/h to 300 l/h. The journey takes only 5 minutes per hour longer, but the fuel saving is 10 %. That's a lot of money!

Saving fuel while fishing.

When it is catching, the vessel chases the shoals at high speed. It is known that high engine speeds cause maximum consumption. The captain watches the KRAL fuel display and reduces engine speed until the speed display responds. A clearly reduced consumption value is then already apparent. This saves about 1.5 % fuel.

These reductions are small, but soon add up. To see them, high-precision devices like the KRAL flowmeters are needed.

Paying for itself unexpectedly quickly.

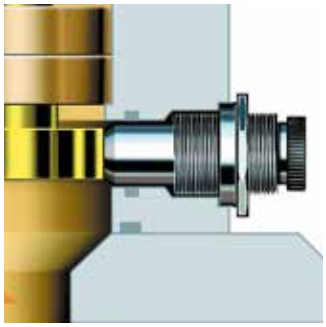
The decision for consumption measurement systems from the boat hobby field is made for price reasons. The investment will be futile, and will be regretted if the measured values are useless.

This is how a fisherman who has decided on the KRAL system calculates it: weekly fuel consumption is about 36,000 liters of gas oil. 1.5 % less fuel means 540 liters per week. KRAL consumption measurement pays for itself in 1.5 years.

KRAL systems in different variants.

OME series.

OMP series.



Electronic unit Smart Solution display.

- Evaluation of 2 sensor signals for detection of the flow direction possible.
- Temperature and pressure pulse compensation.
- Mass conversion.
- Easy installation with only one cable.
- Use of the full performance of the KRAL flowmeters.
- High-quality electronic components and evaluation algorithms.
- Clear, easy-to-read display.
- Up to 4 languages to choose from.
- Custom setting options.

Two series for different applications.

To suit different ambient conditions, KRAL has developed the OME and OMG series.

For fishing vessels, the OME series is usually adequate. E stands for „Economy". The OME series is limited for temperature to 125 °C, for pressure to 40 bar and for maximum flow to 525 l/min and is therefore most suitable for engines of fishing vessels. Its precision is uncompromisingly high.

KRAL OMP series are used, in particular, if the operating conditions are very harsh. Examples are high pressure pulsation in the fuel lines and temperature of 200 °C. For heavy fuel oil, KRAL recommends the OMP with hybrid bearings.

Sensors.

The flow measurement signal is monitored for each flowmeter by a flow sensor. Reverse flows, which are excited by pressure pulses of the injection pumps, are detected by a second sensor for each flowmeter.
KRAL flowmeter are ready to accommodate a temperature sensor. The fuel temperature is needed for temperature compensation and conversion to mass.

Yachts – Efficient, Fuel-Saving Engine Operation.

The engine is constantly monitored, whether moving slowly or at full speed.

Less load = lower consumption.

The good thing about yachts is that from a certain speed they plane on the water. Resistance to motion is thus reduced. This fuel-saving effect is shown in the diagram below.

With KRAL fuel consumption measurement, the minimum of the consumption curve can easily be found.

Reducing maintenance costs.

Fuel consumption is an important indicator of the state of the engine. With KRAL fuel consumption measurement, guesswork about engine power and fuel consumption is a thing of the past. With the reliable KRAL measurement system, rising fuel consumption is detected.

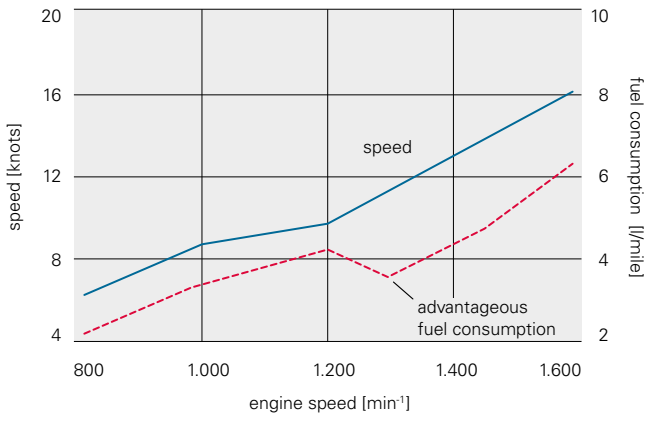
Integration into the electronic system on board.

KRAL provides electronic units which support numerous standard communication interfaces. This includes bus system like Modbus. The consumption value in particular, but also other measured values such as temperatures and quantities of fuel in the forward and return lines, can be transmitted to the bridge by the electronic system installed on board.

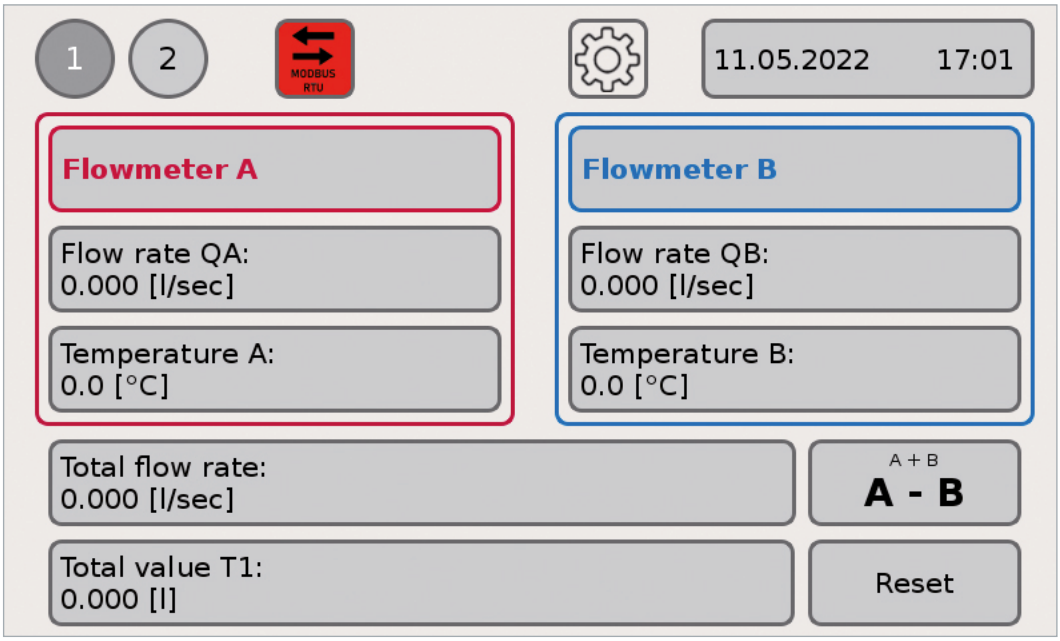
KRAL flowmeter installed in the engine room of a yacht.

Little space.

The space for fitting additional components is very limited in the engine room of a yacht. KRAL flowmeters are extremely compact. As positive displacement meters, they do not need flow conditioning after pipe bends or T-pieces. The small dimensions of the device correspond to the reduced mounting space required.



A flexible system for engine management.



Useful support through precise information.

All KRAL electronic units are especially suitable for fuel consumption measurement, provide precise information which the operator needs for fuel-saving, careful handling of the engine system.

The display shows the information content, using the example of the KRAL Smart Solution display.

Flow rate Q shows the fuel consumption with the unit. The indication "A-B" indicates a differential measurement between supply and return flow. The measuring unit can be chosen from a wide variety of SI, UK and US units.
Obviously, fuel consumption is compared with the expected values from the manufacturer's data. Where fuel consumption is higher than expected, this indicates incorrected engine tuning. Maintenance is then advisable.

Displays give information about the operating parameters in the fuel lines where the supply flowmeter (flowmeter A) and return flowmeter (flowmeter B) are installed. QA is the measured supply flow fuel rate, QB is the return flow rate. QA shows whether the fuel feed pump is supplying the specified quantity. The temperatures are those of the fuel in the supply and return flow lines. The engine manufacturer provides these values, too.

A captain once confirmed to KRAL: „With the KRAL system, it's as if you had a microscope installed in the engine room. Its precise measurements give us information about the engines, which after all are the heart of the ship."

High reliability in operation.

KRAL flowmeters, as positive displacement meters, provide the highest measurement precision in harsh operating conditions. To avoid blockage because of contamination of the fuel line, KRAL optionally offers an external bypass.

Diesel Trains and Diesel Locomotives – Reducing Operating Costs.

Many solutions for train drivers, control room operators and railway engineers.

Energy-saving driving.

Railway companies look for effective opportunities for reducing energy costs.

Training train engineers in energy-saving operation is an obvious idea. The most helpful solution is a measuring instrument which shows energy consumption to the train operator. Power meters are a simple matter in electric locomotives. In the case of a diesel locomotive, fuel consumption must be measured and displayed. Because of the harsh operating environment of the railway, measuring fuel consumption is metrologically a greater challenge than power measurement in an electric locomotive.

Calculating section profiles.

If a railway operation service is to be offered to a region, the costs must be known precisely.

Service providers acquire knowledge about what operation on the various sections costs. For this purpose, the railway operators determine fuel consumption on defined sections. A mountain section is more expensive to operate than the same distance on the plain.

KRAL can record fuel consumption values over long periods. The measured values are transmitted to the operator's electronic system via appropriate interfaces.

Different load ranges.

Diesel locomotives in passenger transport in particular have many stops. The locomotive is rapidly accelerated, then runs at reduced load and coasts to the next station. The load profile of the engine rarely shows full load. Partial load ranges and idling predominate.

In this operating mode, utmost measurement precision of the individual flowmeters is important, to obtain good system measurement precision. KRAL precision meters fulfill this requirement entirely (page 6).

KRAL

Cost-efficient, compact and accurate fuel consumption measurement.

OME flowmeter.

OME compact flowmeter measures in both flow directions. The sensor technology recognizes a reverse of flow direction which can happen due to heavy pulsation from engine. The OME flowmeter is designed and constructed as a compact version to fit in locomotives with low space and harsh environment. Included is also temperature measurement with PT-100 sensor being able to compensate volume due to different medium temperature at inlet and outlet.

Display unit BEA 89.01.

Smart Solution with display is designed for fuel consumption measurement in case of circulation before engine with inlet and outlet flowmeter. All signals (pick-up sensor for flow rate and direction, temperature) from both flowmeters will be connected to the Smart Solution display. A lot of necessary and important data will be calculated, like volume compensation due to temperature, correction of reverse flow and consumption measurement (subtract of corrected return from inlet flow). A Modbus interface (485) is available as an output signal.

Consumption measurement solution.

All components are coordinated on each other with respect to sensors, signals, calculations and display. A system which is designed and constructed for your requirement on fuel consumption measurement.

Engine Test Benches – Quick, Reliable Measurements.

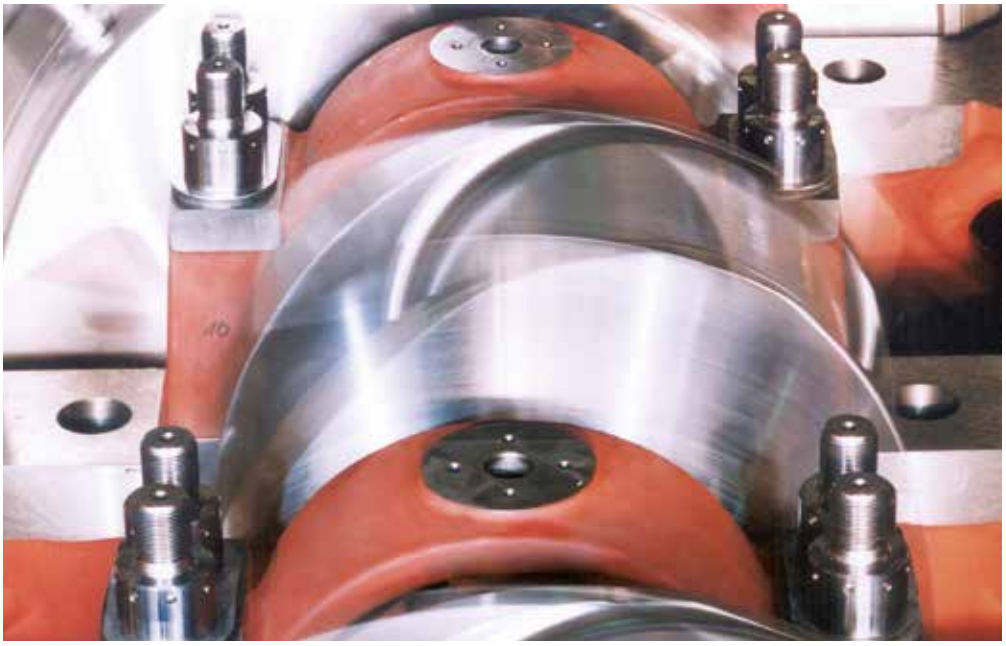
Efficient test bench runs using KRAL flowmeters.

Test bench runs made shorter.

To determine the power of an engine, the mass flow of the fuel into the engine must be known (page 18).

Fuel scales are very precise measuring devices for engine test benches. To achieve the highest measurement precision, a long measurement time with the scales is required. Some measurement concepts even require multiple measurements followed by averaging. Long measurement times and multiple measurement cycles consume a lot of fuel. Test bench runs are therefore expensive. This applies in particular where new, extremely expensive fuel types are being researched.

For a first estimate, this expensive precision is often unnecessary. The scales have a measurement error of about 0.03 %. KRAL flowmeters reach about 0.1 %, and in the system typically below 1 % (page 6), but indicate measured values immediately. Short measurements, still with excellent precision, save a lot of money.



Picture: Caterpillar Motoren Rostock GmbH.

Measurement of mass.

For power measurement and to determine the specific consumption of fuel, the fuel mass flow is required.

KRAL fuel consumption measurement can be designed for mass measurement if desired. For this purpose, temperature sensors are integrated in the KRAL flowmeter. The KRAL electronic units have up to 2 density tables. The mass is calculated from the temperature and density.

Low operating costs are good sales arguments for engines.

Measurement of fuel consumption is an important parameter for operating motors efficiently. Since in many cases consumption data is part of the contracts when they are concluded, fuel consumption measurement becomes particularly important.

Engine manufacturers use KRAL systems in the test area of engine development and on acceptance test benches. KRAL flowmeters fulfill the highest demands for precision and reproducibility of the measured values during the acceptance run.

Measurement log at a mouse klick.

The test bench measurement and log printout are started and saved by a mouse click. The engine operator and manufacturer use the acceptance log to judge guarantee questions.

KRAL fuel consumption measurement is important for documenting the necessary head start over the competition regarding fuel consumption and engineering. It offers certainty, to minimize or exclude later guarantee claims from the onset.

First measured values within seconds.

KRAL flowmeters are positive displacement meters. The two spindles, with the case, enclose a precisely known fuel volume. The KRAL catalogue gives the volume which flows through the meter at each rotation. Spindle rotation is monitored via a pole wheel and a sensor.

The electronic system requires only 2 pulses to form the measured value. With 2 pulses, the part of a total spindle rotation and thus the volume flow are known. That is why this simple functional principle provides measured values within such a short time.

Picture: Caterpillar Motoren Rostock GmbH.

Measurement logs of constant quality.

In serial test bench acceptance, it is important that fuel consumption measurement meets the highest demands for precision and reproducibility of the measured values during the test bench acceptance run.

National calibration and testing institutes confirm that KRAL flowmeters are very precise positive displacement meters. The reproducibility of an individual flowmeter is about 0.01 %! Measurement precision and reproducibility ensure measurement logs of constant quality.

Consumption measurement for engines.

With various design sizes, KRAL flowmeters cover a large flow range from 0.1 to 5,000 l/min.

Oil Drilling Platform – Plant Design to Customer's Wishes.

Proper fuel balance in multi-engine systems.

More than just measuring fuel consumption.

Devices for fuel consumption measurement extend from cheap systems for hobby applications to professional solutions. Professional systems are characterized by robust components, high measurement precision and data interfaces which meet industry standards. Few manufacturers offer systems which can measure and display the consumption of multiple engines and can pass on the measured values. For multi-engine systems, KRAL GmbH is the leader.

KRAL multi-engine systems measure up to 32 engines. A unique feature is the integration of KRAL flowmeter for measurement tasks other than fuel consumption measurement. A typical and very useful example is the integration of a transfer meter.

The KRAL transfer meter measures the fuel which is being put in the tank. Knowledge of the transferred fuel, consumption of the individual engines, and consumption of the whole system enable to prepare a fuel balance. Important questions such as: Was more put in the tank than was consumed, are all engines running economically, does the fuel consumption of the whole system correspond to the original profitability calculation, are clearly answered.

Project business.

No multi-engine system is like another. KRAL systems analysts discuss the whole fuel system with the client. After the analysis, KRAL presents proposals about the system layout and measurement concept.

If required, KRAL helps with installation and commissioning. KRAL trains the operator's staff if required.

Unique and flexible.

KRAL flowmeters are highly precise. The KRAL electronic units are specially matched to the flowmeters. The unique technology, together with professional KRAL measurement experts, forms the basis for successful project execution.

With these assets, KRAL takes a special position in the market.

What is the KRAL Smart Solution?

The Smart Solution is a compact electronic unit to which a KRAL flowmeter is connected. The Smart Solution processes the signals that the KRAL flowmeter generates with its integrated sensors in such a manner that measured values are available and can be passed on via the Modbus.
Up to 32 Smart Solution electronic units can be switched in series and thus save a multitude of cabling and their installation in comparison to conventional measured data acquisition.

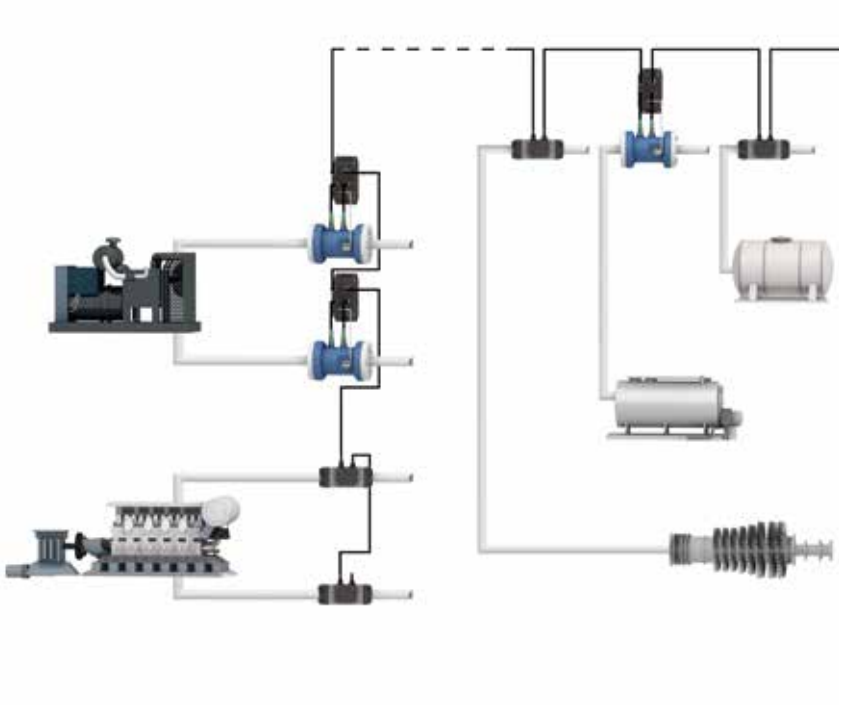
Smart Solution features.

- Individual combination of single line and differential measurement.
- Calculation of volume compensation by temperature measurement.
- Handling of pulsations due to reverse flow recognition and correction.
- Up to 32 flowmeters on one Modbus line.
- Prepared data and information for performance and condition monitoring.

A clear benefit which saves a lot of money.

The benefit of the KRAL multiengine system is obvious:

- The engines are operated cost-effectively at the optimum operating point, at the lowest specific fuel consumption.
- Consumption above the specified value indicates that engine maintenance is required.
- Fuel theft is detected by comparing the quantity put in the tank with consumption.



Ocean-Going Shipping – Safe and Profitable.

Profitable operation despite rising oil prices and more stringent exhaust gas regulations.

Matching speed and consumption optimally to each other.

Ship owners which have introduced a policy of reducing the speed of their ocean-going ships save about 6 % of fuel. The percentages are impressive, showing the immense potential for savings.

A large ship owner, with 80 ships, needs about 1.6 million tonnes of bunker fuel per year. A 6% saving is 96,000 tonnes. At a price of US$ 650 per tonne of IFO 380, that is US$ 65 million. This saving can be achieved by using KRAL fuel consumption measurement. The systems for all 80 ships have paid for themselves within a month

Reducing emissions.

For efficient engine operation with low emissions, electronic control and monitoring systems are required.

Leading engine manufacturers and suppliers of engine control systems use the KRAL fuel consumption signal. With the precise measured value, they determine the specific fuel oil consumption (SFOC) and the fuel conversion efficiency (FCE).

Measuring different fuels.

In SECAs (Sulfur emission control areas), ocean-going ships are driven by MDO. In these protected areas, stricter limits for sulfur content apply. The limits cannot be achieved in HFO operation. Therefore, there is a changeover over hours to MDO, in a blending process.

KRAL flowmeters measure irrespective of the viscosity of the fuel. KRAL systems are therefore suitable for HFO, MDO and the continuous mixing stages.

Safe operation with heavy oil.

Again and again, dockyards and ship owners are amazed that KRAL offers fuel measurement systems for heavy oil. The idea that precise meters are incompatible with high temperatures and abrasive heavy oil components is still widely held.

KRAL has many years of experience with heavy oil pumps and flowmeters. The technologies are long established and tested.

Precision measurement suitable for heavy oil.

Other providers of systems for fuel consumption measurement mainly advertise their pretty electronic displays. The flowmeters which measure the fuel are often not mentioned at all. It is not the electronic display but the flowmeter which decides how useful the measurement is.

The cases of KRAL flowmeters are of nodular cast iron, which is suitable for heavy oil. The steel spindles are nitrated. The flowmeters are equipped with steel ball bearings as standard, but hybrid bearings with ceramic balls are also used for HFO if required. KRAL flowmeters are always installed behind the filter of the booster module. This filtering protects the injection pumps and therefore also the flowmeters.

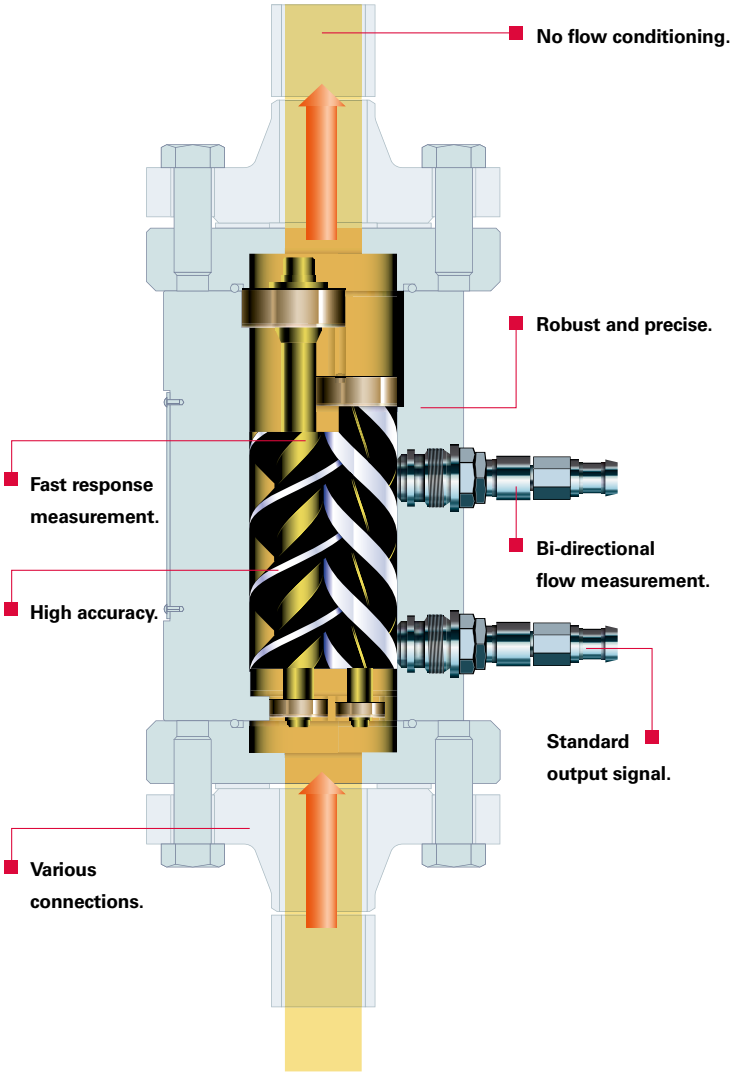
Temperature compensation.

Fuel is bunkered in volume units. Specific fuel consumption is a mass unit. Using the temperature sensor and density table, the measured values of the KRAL flowmeter can be converted into mass units and displayed.

Even in the case of preheated heavy oil, there are temperature differences between the forward and return flows. With KRAL temperature compensation, the temperature differences are taken into account in the precise measured value formation (page 8). Temperature compensation is a function of the KRAL electronic units.

High precision measuring chamber.

KRAL has great skill in spindle production. The spindles are precision parts.
They are the basis of very precise fuel measurement.



Pressure pulse compensation.

Injection pumps cause pressure pulses in the fuel lines, which may cause a reversal of the direction of flow (page 9). With the flow direction sensor in addition to the flow sensor, a second signal of the spindle rotation is monitored. From the phase difference, the KRAL electronic system detects the direction of rotation of the spindles. Flows in the wrong direction are measured correctly and used to calculate the consumption value precisely.

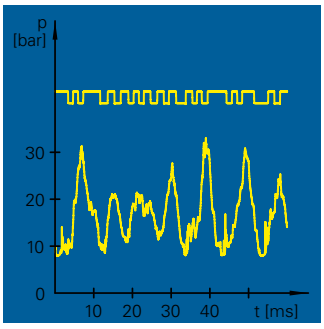
Power Generation Plants – High Energy Yield From Fuel.

By generating your own power, keep your operating costs under control.

Precise measurement of energy yield.

About 80 % of the investment and operating costs of power generation plants are fuel costs. The aim is efficient operation, particularly in the case of multiengine systems. The energy yield is therefore a decisive buying criterion, and is monitored attentively at acceptance, after commissioning, during the guarantee period and in operation.

Power plant operators determine the energy yield by measuring fuel consumption and the generated power. Both values can easily be read on the appropriate instruments in the control room, with KRAL providing the fuel consumption display. Specific fuel consumption is given in grams per kilowatt-hour (g/kWh). The KRAL flowmeters indicate the volume flow. The measurement of mass is described on page 7.



Measurement with pulsating fuel.

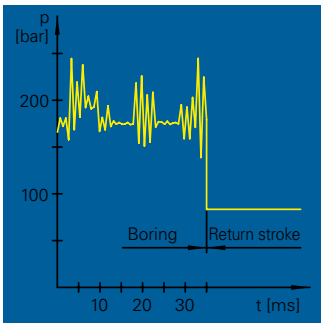
The pistons of the injection pumps force fluid pulses (pages 4 and 9). The pulses may cause a reversal of the fuel's direction of flow. Where this affect is not taken into account, incorrect measurements occur. KRAL pressure pulse compensation takes account of the reverse flows to form the measured value correctly.

Proof of fuel when power is sold to the public grid.

Independent power producers sell power which exceeds their own requirements to the public grid. In some countries, the fuel which is used for this purpose is funded by the government.

The responsible authority calculates the publicly used fuel on the basis of the specific fuel consumption of the engines. Engine manufacturers determine this value on acceptance test benches according to applicable standards. However, fuel consumption in actual use is higher than under test bench conditions. The additional consumption is therefore not funded by the government.

With KRAL fuel consumption measurement, the actual consumed quantity can be logged and submitted for funding. With the considerable additional funding, KRAL fuel consumption measurement pays for itself within about a year.



Measurement in harsh operating conditions.

KRAL flowmeters are very robust precision devices. These properties are usually mutually exclusive. KRAL has specialized in this unique combination.

KRAL flowmeter are extremly robust. But the precision measurement mechanism, too, has been designed so as to easily resists stresses such as plant vibration and fuel pulsation.

Protection of the environment is supported.

In some countries, protection of the environment is supported. There are high charges for operation of power and emergency power units with diesel engines. This includes units such as aircraft starting devices at airports. Usually, an hour counter shows the duration of operation. The authorities assume that the unit is operated at full load. They therefore assume maximum fuel consumption of the engines. Actually, power units do not operate at full load, but typically at 70 to 80 %. Realistically, much less fuel is used than theoretical calculations show.

Where fuel consumption is measured with the KRAL system, and lower consumption is thus proved, the system pays for itself through lower environmental protection charges.

Things may get worse.

The operating conditions in power stations set very high requirements for meters and sensors. KRAL also has many years of experience in other harsh applications. One example is the hydraulic system of tunnel borers.

The position of the drill head is measured using KRAL flowmeters. The movement of the drill head is determined by the stroke of the hydraulic cylinder. The stroke is determined by KRAL flowmeters, by measuring the quantity of fluid which flows into the cylinder. The impacts acting on the drill head as it bores into the rock are transmitted to the flowmeter via the hydraulic fluid.

The pressure pulses and pressure level are shown in the diagram.
In this application KRAL flowmeters are shown to be very robust and reliable. This makes all users in harsh operating conditions feel safe when they choose KRAL.

Flow Measurement.

KRAL

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