5.17 Coriolis Mass Flowmeters
for fuel consumption measurement

To manage fuel consumption responsibly, considering ecologic, economic and legal reasons, requires an innovative fuel management system.

With variable fuel prices and tight regulations on greenhouse gas emissions, fuel efficiency has become a major concern for the transportation industry and especially for the marine business. Approximately 50% of all operational costs of ships are fuel costs. To manage fuel consumption responsibly, considering ecologic, economic and legal reasons, requires an innovative fuel management system based on reliable, highly accurate and durable flow sensors.

Coriolis mass flowmeters are state of the art instruments using the Coriolis force to measure the mass flowrate of any kind of fluid with utmost precision. The fluid flows through vibrating tubes generating a Coriolis force that creates a phase shift of the vibration between inlet and outlet. As there are no moving parts in the fluid, no wear occurs, and maintenance is reduced to a minimum. In the past, flowmeters using vibrations onboard ships created issues.

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Coriolis mass flowmeters are available in multiple sizes

The new generation CoriolisMaster flowmeter, however, uses very high operational frequencies well away from any possible vibrational noise on board ships. It is therefore possible to gain DNV approval for the meters even for harsh environment areas onboard ships.

In addition, possible mechanical stress from installations has no influence as the stiff flowmeter housing is designed to decouple outer installation forces of up to 40 tons. Besides traditional current or pulse outputs, fast Modbus communication outputs are available, ensuring seamless integration with any kind of ABB fuel efficiency system. This data link provides direct access to all kinds of measurement values like flow, density, temperature and concentration as well as diagnostics information. Even remote access is possible.

Benefits
Marine fuel consumption measurement in accordance to SEEMP* guidelines using the CoriolisMaster flowmeter provides many benefits:

- Reliable and highly accurate mass flow measurement: 0.1% accuracy
- Working even under harsh vibrations
- Working at high frequencies of about 400 Hz, far away from noisy vibration frequencies on board (~10 to 200 Hz)
- No in- or outlet sections and inlet filters required
- Direct mass measurement eliminates pressure and temperature compensation

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Application benefits of
Coriolis mass flowmeter

CoriolisMaster mass flowmeters are in compliance with
marine class standards by operating at high frequences
far away from noise frequencies on board they are free of
disturbances.
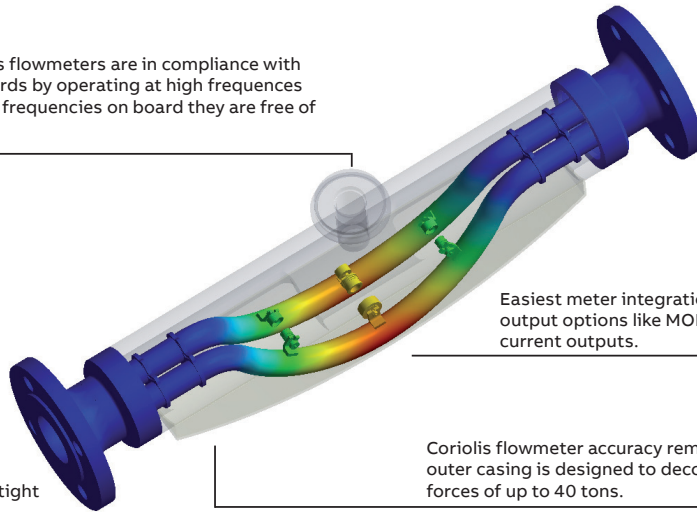
Easiest meter integration: Enabled by various
output options like MODBUS, pulses or classic
current outputs.

Coriolis flowmeter accuracy remains because its stiff
outer casing is designed to decouple outer installation
forces of up to 40 tons.

Easy retrofit even in tight
spaces due to small
compact flange to flange
dimensions.

● High vibration   ● No vibration

- Maintenance free: no moving parts in the fluid
- Real time density measurement for fuel quality
  control
- Minimum pressure drop through the meter
- DNVGL and BV certified
- MID / OIML R117 certified

Fuel consumption is energy consumption – en-
ergy is directly related to the mass of the fuel.
Therefore direct mass flow measurement is key
to highly accurate energy management.

Multiple applications of Coriolis flowmeters are
possible onboard ships to measure fuel consump-
tion. The below figure shows some typical exam-
ples.ABB experts are very experienced in select-
ing the right location and helping with selecting
the correct meter size.

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Typical installation with
Coriolis mass flowmeter
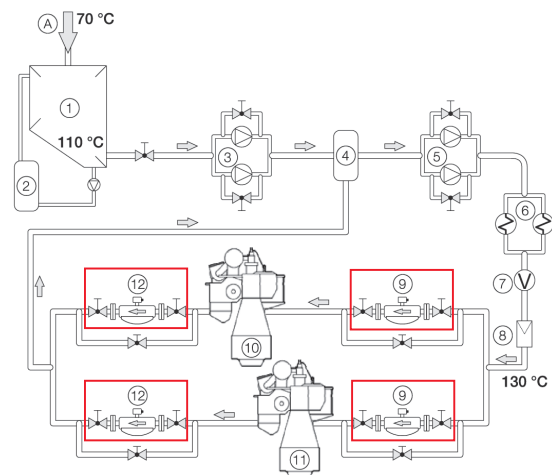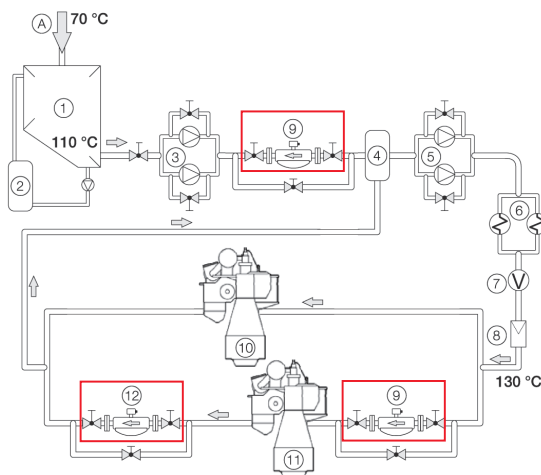
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Typical installations of Coriolis mass flowmeters onboard vessels

A From setting tank | 1 Service tank | 2 Boiler | Supply pumps | 4 Mixer | 5 Booster pumps | 6 Heater | 7 Viscorator | 8 Filter |
9 Flowmeter in supply line | 10 Main engine | 11 Auxiliary Engine | 12 Flowmeter in return line

CORIOLISMASTER FLOWMETER TYPES
CoriolisMaster FCB100

The FCB100 is specifically designed to make system integration as easy as possible. It provides a high-speed Modbus RS485 output as well as two digital outputs (pulse, frequency or logic output). It is available with an aluminum transmitter housing or an all stainless-steel solution.

The FCB100 comes with a SensorMemory concept, allowing for easy transmitter exchange. It is approved for various hazardous areas. Holds several Marine class approvals and fulfills many local requirements. Application software modules can be activated even after installation in the field.

CoriolisMaster FCB400

The FCB300 series provides a display, various analog and digital outputs as well HART, Modbus, Profibus DP, and various Ethernet (i.p.) communication. It comes with a SensorMemory concept, allowing for easy transmitter exchange. The series is approved for various hazardous areas, has several Marine class approvals and fulfills many local requirements. Application software modules can be activated even after installation in the field.
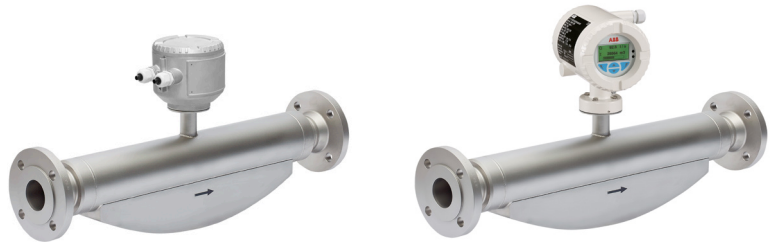
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Comparison between series FCx100 and FCx400

	Series FCx100	Series FCx400
LCD indicator	no	yes, illuminated
Outputs	Modbus 2 digital outputs (impulse, frequency contact output)	Up to 5 modular inputs / outputs freely selectable and adjustable*, HART, Modbus, PROFIBUS DP
DNVGL Certified	yes	yes
SmartSensor Concept	yes	yes
Ambient temperature	- 40° C to 70° C	- 40° C to 70° C
Custody transfer	yes, in accordance with MID/OIML R175	yes, in accordance with WID/OIML R117
SIL2	no	yes
Power supply	11 to 30 VDC	11 to 30 VDC 110/230 VAC
Max. power consumption	5 W (normal: 2 to 3 W)	20 W (normal: 4 to 5 W)
DensiMass concentration	yes (Version FCx150)	yes (Version FCx450)
FillMass filling software	yes (Version FCx150)	yes (Version FCx450)
VeriMass verification	yes	yes

*Details available in the data sheet

VERIMASS
Integrated device verification and diagnosis

VeriMass offers many features to verify the performance of the meter. The built-in erosion monitoring function creates a "fingerprint" of the measuring device in the specific application as a basis for automatic, continuous monitoring. As this feature focuses on erosion and coating of the meter, long term trends are identified. The health status of the meter as well as the erosion monitor status can be combined in a verification report print out, documenting required meter checks.

Measuring Principle
For cost and material balance calculations, mass flow information is preferred in technical processes because it is independent of physical influences when compared with volume flow information. Pressure, density, temperature and viscosity do not change the mass. Therefore, the mass flow rate is the favored measured variable. Mass can only be measured indirectly, e.g. with the help of Newton's second law of motion, which states that a force acting on a mass produces acceleration $(F=ma)$.

How can the mass of a liquid be determined using this relationship? One can accelerate the liquid in a rotating (or oscillating) system and measure the inertial effects. The physical effect was discovered by the French mathematician Gustave-Gaspard Coriolis in 1835.

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CoriolisMaster - common built in diagnostics and verification

Diagnostics & Verification*

Sensor Element Failures
– Sensor Memory failure
– Sensor hardware
– Sensor connection issues
– Zero point plausibility check

Health Status and meter diagnostics

Electronic Failures
– Internal electronics check
– Data Security Check
– Safety check according to SIL
– User configuration check
– Check of external wiring using simulation

Meter performance monitor in situ
– Based on specific meter technology
– Coriolis: Erosion Monitor checking
– Erosion
– Coating
– Other meter integrity issues

Online monitoring of meter performance incl. in situ verification

Meter verification report generation
– DTM based verification
– Report generation
– Alarm history
– Event history
– Trend indication

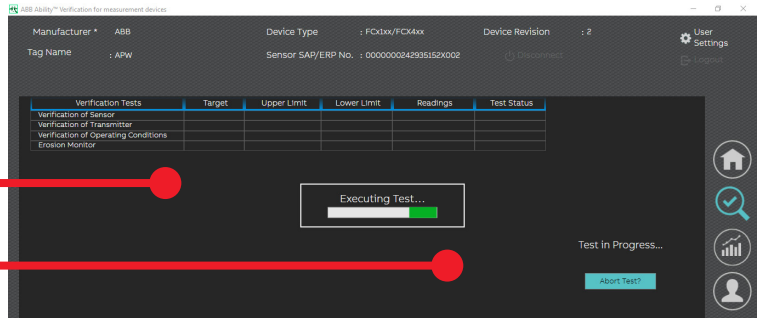**Meter verification and report generation**
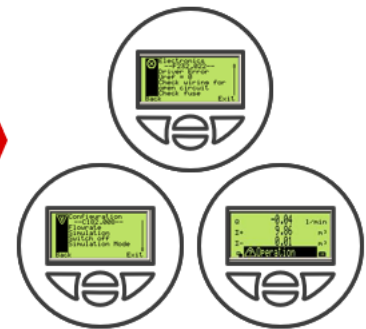
VeriMass

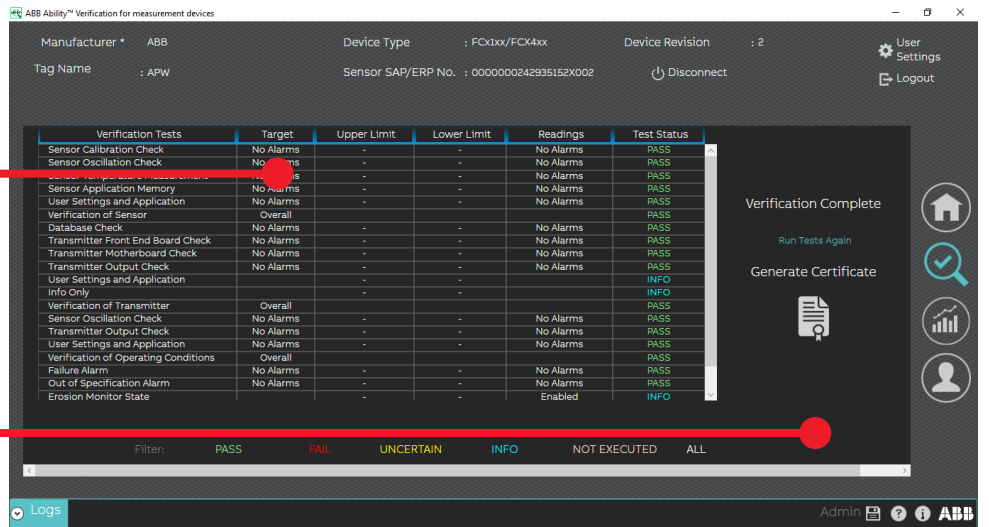Diagnosis and VeriMass
verification report

Verifying

- Sensor
- Transmitter
- Operating Conditions
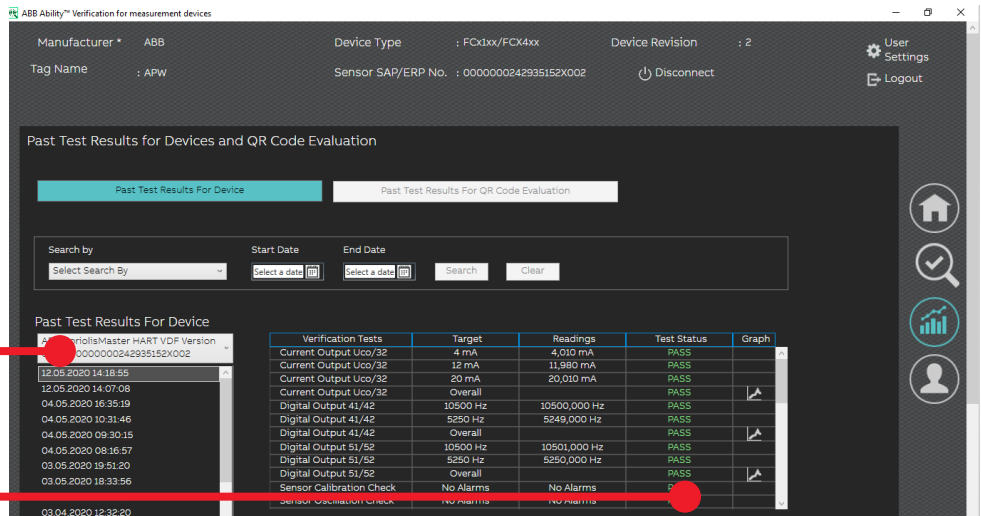- Erosion Monitor

One click verification

Detailed results
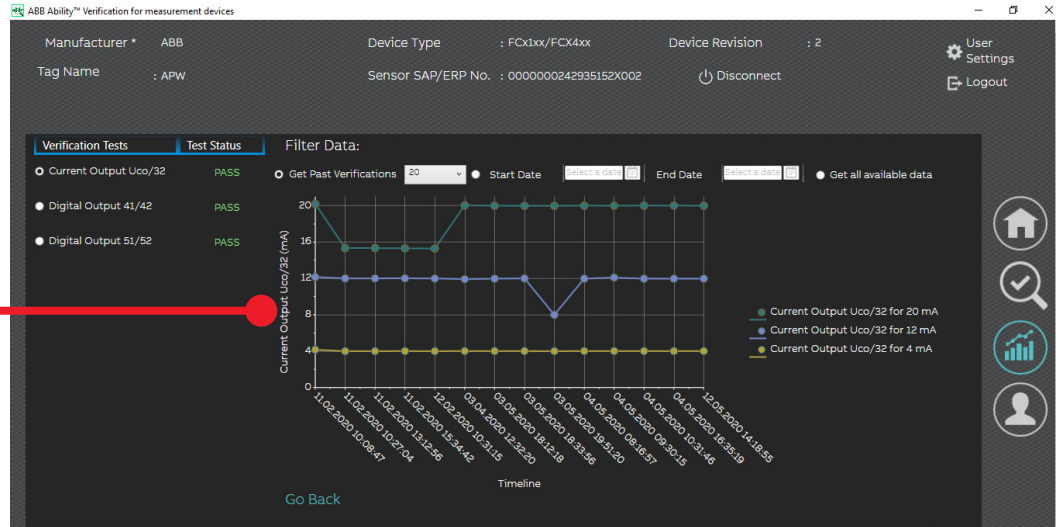
Generates Verification Report

Archive of former verifications

Former results

Trends for a specific device

A mass m is located at point A at an average distance r from the center on a rotating disk with an angular velocity ω which is to be moved radially towards B at a radius R, that is to a location with a higher rotational velocity and angular momentum (mv). The higher velocity requires an acceleration, which requires a force. The inertial force that opposes the change in velocity is the Coriolis force Fc:

$$\vec{Fc} = -\,2\,m(\vec{\omega} \times \vec{V})$$

v is the velocity of the mass on the way from A to B.

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Rotating disk
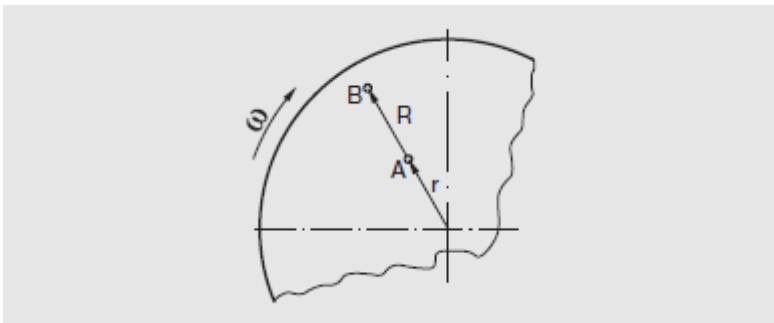
These principles are transferred to a liquid filled pipe. Measuring principle: When a fluid mass flows through a curved vibrating tube, opposing Coriolis forces are generated that bend or twist the tube. These very small meter tube distortions are measured by optimally located sensors and evaluated electronically. The measured phase shift between the sensor signals is proportional to the mass flow rate. As a result, Coriolis flowmeters directly measure the mass flow rate of a fluid.

This measuring principle is independent of density, temperature, viscosity, pressure and conductivity. The meter tubes always vibrate at resonance. The resonant frequency depends on the meter tube geometry, its material properties and the density of the fluid medium vibrating in the meter tube. A temperature sensor permits compensation for any changes in tube stiffness. In summary, it can be stated that the Coriolis mass flowmeter can be used to simultaneously measure the mass flow rate, density and temperature of fluid.