VDC100 OCM

Viscosity Density Cell

Temperature Controlled Measurement Cell for Viscosity and Density Measurement

Features

- Determines viscosity, density, permittivity, conductivity and viscosity index
- Precise and stable temperature control
- High sensitivity, low drift
- Withstands contaminations
- Viscosity error: $<\pm 1\%$ (0.3 to 100 mPas)
- Density error: $<\pm 0.2\%$ (0.5 to 1.8 g/cm^3)
- Temperature error: $<\pm 0.01\,°C$
- Measurement rate up to 4 samples/s
- Compact and robust design
- Easy to install
- High pressure version available
- Operated with MFA200 Resonance Analyzer

Applications

- Oil condition monitoring
- Fuel quality control
- Analysis of process media
- Monitoring of mixing processes

The viscosity and density measuring cell VDC is a precise measuring device for monitoring physical fluid parameters such as viscosity (dynamic and kinematic), density, permittivity and electric conductivity.
The integrated high precision temperature control enables not only the accurate determination of the strongly temperature dependent viscosity but also the acquisition of parameters derived from the viscosity such as the viscosity index.
The extraordinary performance is achieved by a combination of a patented evaluation technology with established quartz tuning fork resonators.
Due to the high sensitivity and long-term stability, the VDC100 OCM is particularly suitable for oil condition monitoring.
With a measurement rate of up to 4 measurements per second, fast changes can be resolved sufficiently.

1 Specifications

Ambient Temperature $T_{amb} = 24°C$, Measurement Rate $f_m = 1$ sample/s, liquid not conductive, unless otherwise noted.

Description		min	typ	max	Unit
General					
Measurement Rate [1]	f_m	0.1		4	s^{-1}
Sample Volume				0.5	ml
Ambient Temperature [2]	T_{amb}	10		40	°C
Particle Size				500	µm
Measurement Range					
Viscosity (dynamic)	η	0.2		200	mPa s
Density	ρ	0.4		1.8	g/cm^3
Conductivity	σ			30	µS/m
Permittivity (relative)	ε_r			20	
Temperature Range					
Control Range [3]	T_{cell}	0		100	°C
	$T_{cell} - T_{amb}$	-30		+70	°C
Heat Flow [3]	steady state			10	W
	during temperature change			30	W
Trueness					
Viscosity [4 5]	$\eta = (1 .. 100)$ mPa s $\rho = (0.5 .. 1.5)\ g/cm^3$		0.4	1	$\%_{reading}$
	otherwise		TBD		
Density [4 5]	$\eta = (1 .. 100)$ mPa s $\rho = (0.5 .. 1.5)\ g/cm^3$		0.04	0.2	$\%_{reading}$
	otherwise		TBD		
Conductivity			TBD		
Permittivity (relative)			TBD		
Temperature				0.01	°C
Noise					
Viscosity [6]	$\eta = (0.3 .. 100)$ mPa s $\rho = (0.5 .. 1.5)\ g/cm^3$		< 0.12		$\%_{reading}$
	otherwise		TBD		
Density [6]	$\eta = (0.3 .. 100)$ mPa s $\rho = (0.5 .. 1.5)\ g/cm^3$		< 0.03		$\%_{reading}$
	otherwise		TBD		
Temperature			$< \pm 0.003$		°C

Permitted media: liquid hydrocarbons (oils, fuels).
Cleaning agents: cleaner's naphtha, air.

[1] This parameter is determined by the Resonance Analyzer (see MFA Datasheet).
[2] Non condensing.
[3] When $T_{cell} < T_{amb}$, sufficient cooling is required at the bottom (see Fig. 4).
[4] Valid for Newtonian liquids only. For further details see section 3.
[5] The accuracy is influenced by the reference liquids. See section 3.
[6] Error propagation depends on the fluid. More detailed information is given in section 3, Fig. 2 and 3.

2 Concept

Viscosity is a strongly temperature-dependent variable. In the case of oils and lubricants, chemical changes and impurities not only lead to an aging-related change in viscosity but also to a change in the temperature response. Not self-tempering systems (e.g. practically installable screw-in solutions), measure at varying process temperatures and extrapolate the results to a reference temperature at which the values can be compared. This conversion is a critical source of error in oil condition monitoring systems.

With the measuring cell VDC, these sources of error can be consistently eliminated. Precise temperature control and high measurement accuracy make the VDC particularly suitable for condition monitoring of oils in sensitive applications. The advantages of this concept are:

- Precise measurement of viscosity and density independent of the process temperature.
- Extrapolation to a reference temperature is omitted.
- Consequently, unknown temperature responses of fluid parameters do not impair the accuracy.
- Long-term stability of temperature measurement reduces the risk of misinterpretation.
- The temperature responses (e.g. the viscosity index) of the fluid can actively be measured by performing automated temperature cycles.

The measurement of viscosity and density in the VDC100 OCM is based on a vibration method using a piezoelectric quartz tuning fork resonator. These kinds of resonators have been used in electronics for decades as clock sources and are characterized by their extraordinary long-term stability and their low sensitivity to external vibrations, temperature changes and mounting conditions.

Time-harmonic voltages applied at the electrodes of the sensor crystal cause mechanical vibrations. Changes of the impedance spectra of the sensors due to the action of fluid forces are mapped to the mechanical fluid parameters. However, a part of the electrical field also penetrates the liquid and therefore also electrical fluid parameters (permittivity and conductivity) influence the measured frequency spectrum. With appropriate coating of the sensor surface this influence can be reduced, but not completely eliminated. Using our patented signal processing routines implemented in the resonance system analyzer MFA200, which together with the VDC100 OCM forms the complete measuring system (see Figure 1), all relevant data of the resonator are recorded simultaneously, and the electrical and mechanical influences are completely separated from each other. Cross-sensitivities of density and viscosity on the electrical parameters are thus avoided.

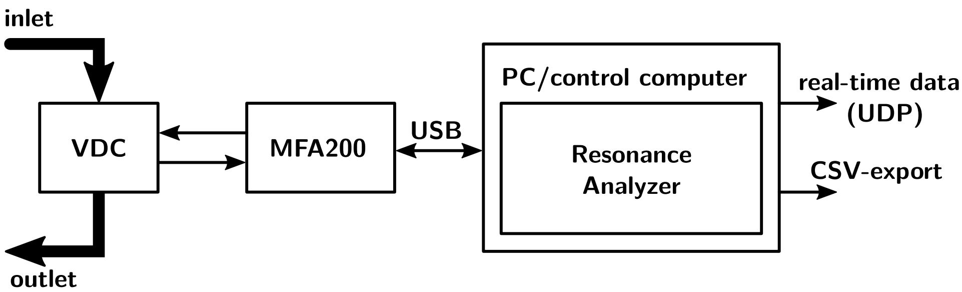


Figure 1: Block diagram of the measuring arrangement.

Depending on the particular application, different tuning fork resonators can be used in the VDC measuring cell. In addition to different resonance frequencies and resonator sizes, electrode material and passivation layers can also be adjusted to the meet different chemical or rheological requirements. The measuring cell in the version VDC100 OCM is designed for the measurement of liquid hydrocarbons (i.e. oils and fuels). To operate the VDC100 OCM, it is connected to the universal resonance system analyzer MFA 200 which handles the signal processing and temperature control. The operation of the system as well as the visualization of the measurement results can be realized with a graphical user interface (Resonance Analyzer Software) on a PC (or an embedded computer such as the Raspberry Pi). Integration into various development environments (e.g., in MATLAB, LabVIEW) is also possible.

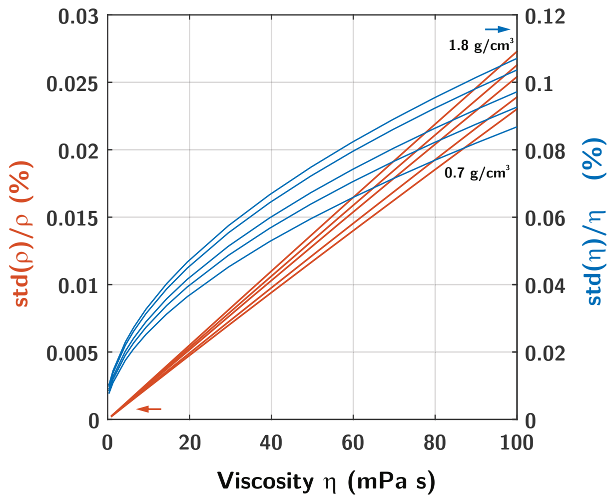


Figure 2: Standard error percentage due to the measurement noise on density ρ and viscosity η as a function of ρ and η. The curves are plotted for the non-conducting fluids with density values of 0.7, 0.9, 1.1, 1.5, 1.8 g/cm^3. The sampling rate is 1 sample/s.

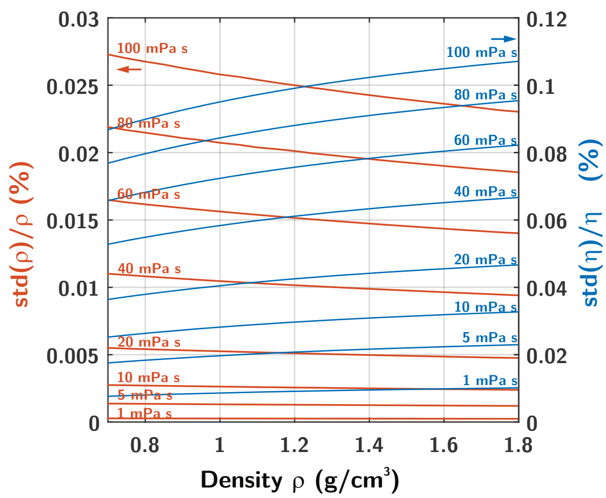


Figure 3: Standard error percentage due to the measurement noise on density and viscosity for non-conducting fluids and a sample rate of 1 sample/s.

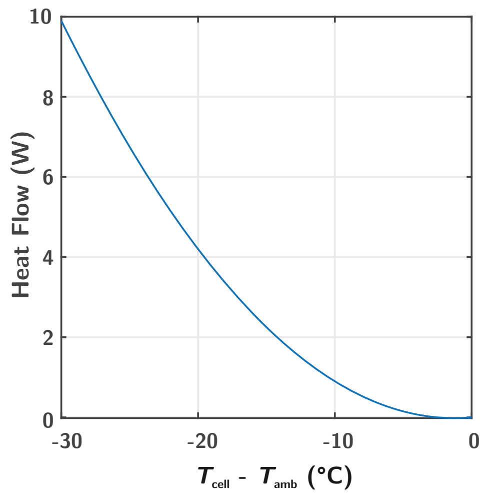


Figure 4: Heat flow at the bottom of the housing in cooling mode (steady state).

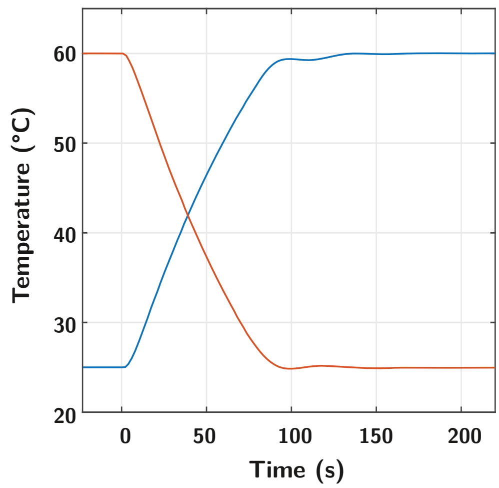


Figure 5: Step response of the temperature control for steps from 25°C to 60°C, and vice versa.

3 Measurement and Calibration Principle

The electrical measurement of the mechanical fluid parameters viscosity and density is performed using a resonant piezoelectric element, which serves for excitation and readout of the vibration simultaneously. The functional principle is shown in Figure 6.

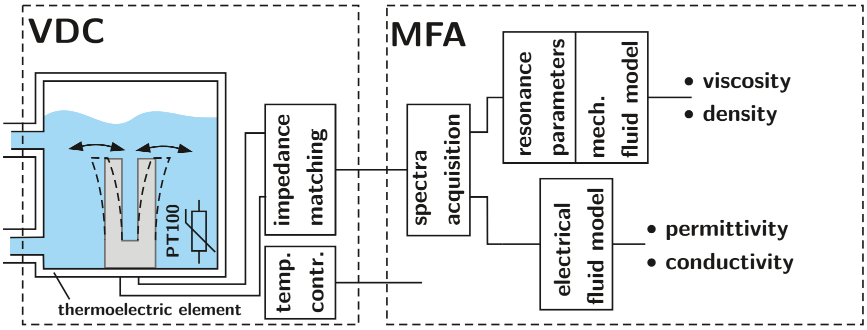


Figure 6: Working principle of the sensor setup.

The electrical and mechanical fluid properties are reflected in the measured frequency responses. The fluid forces acting on the vibrating sensor element affect the resonant frequency (f) and the bandwidth (B). By means of a fluid-mechanical model these resonance parameters are uniquely mapped to accelerated mass and dissipative damping, which correspond to density and viscosity for Newtonian fluids (as shown in Figure 7).

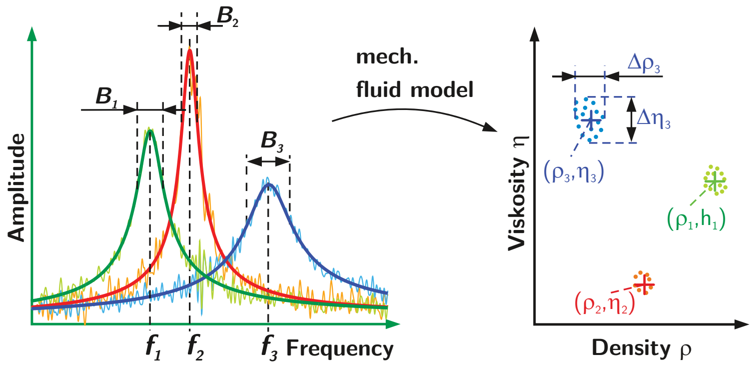


Figure 7: Determination of fluid parameters of Newtonian liquids using spectral analysis.

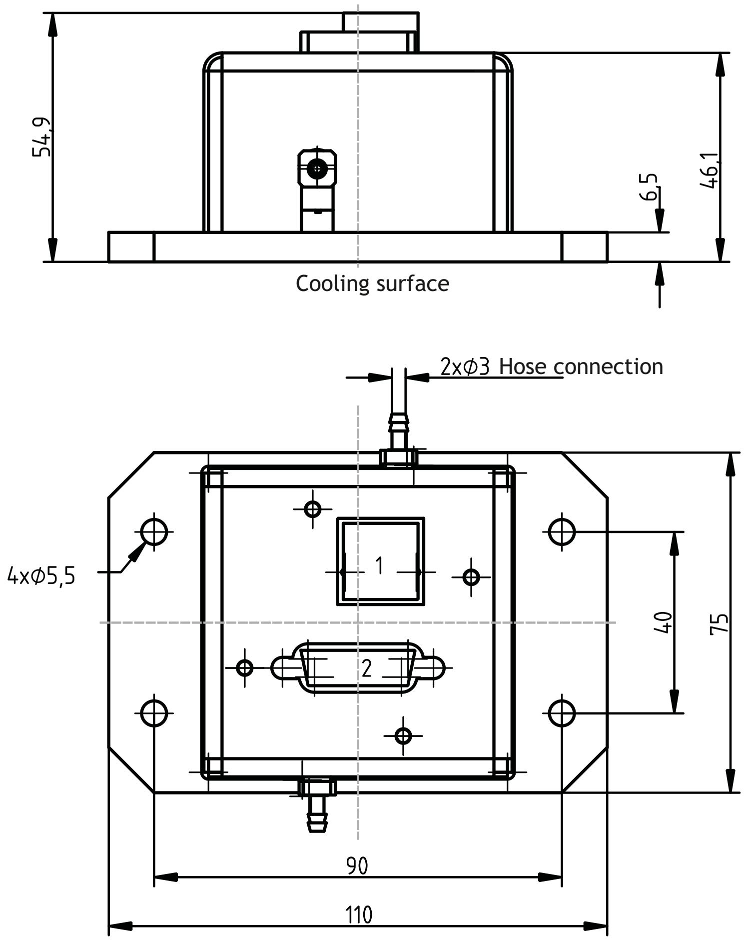
For non-Newtonian fluids apparent parameters are obtained. The apparent viscosity typically shows frequency (shear rate) dependent components. Furthermore, partial elastic fluids (i.e. viscoelastic) influence the apparent density. Please note that these effects do not impact the precision and repeatability of the given results.

The effects of the electrical fluid properties (permittivity and conductivity) are unambiguously separable from the mechanical components and are available as additional parameters. The fluid mechanical model contains several parameters which are subject to fabrication tolerances and therefore not known ad hoc with sufficient accuracy. These parameters are determined for each sensor element in the course of a calibration process which is performed by Microresonant using certified viscosity and density standards (Cannon, NIST traceable). Subsequently, the validity of the calibration is verified at more than 10 viscosity and density points using additional standard liquids. All determined deviations were within the bounds stated in the specifications on page 1. The specified measurement uncertainties include both, calibration and model errors[1]. The accuracies of the certificate values are, according to the manufacturer, about 0.3% for the viscosity and about 0.05% for the density. The Figures 2 and 3 show the effects of measurement noise on the relative standard deviations of density and viscosity results for a sampling rate of 1 value/s. The scattering of the calculated values ($\Delta\rho$ and $\Delta\eta$) due to the measurement noise increases with viscosity[2], with only small influence of the density. The error propagation follows a well-defined function and reduces by a factor of $\sqrt{k}$ when the averaging time by is increased by the factor k. In case of fluids containing conductive components, the standard errors are slightly increased.

[1] Basically, it is not possible to distinguish between calibration and model errors; the uncertainty of the certificate values is thus partially included.

[2] This is a fundamental property of the resonant measurement principle

4 Dimensions



All dimensions in mm, scale 1:2.
Alternative inlet and outlet connectors available.

Note: All electrical connections of the device to the universal resonance analyzer MFA only.

Revision History

09/2018 Preliminary Revision

Specifications subject to change without notice.

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