DENSITY: A CORE PARAMETER AT KEY POINTS

For companies in the oil industry, improving productivity and product quality and increasing profits are always on the agenda. Measuring the density of crude oil and petroleum products throughout the oil recovery process, distillation, and processing contributes to achieving these goals.

Upstream research and crude oil analysis

Increasing the yield of crude oil from the reservoir is the number one priority. Knowing the properties of the crude oil in the ground is the solid basis for making major decisions on how to enhance the output.

A density measurement on live crude oil at reservoir conditions – up to 200 °C and 1400 bar – simulates in the laboratory the crude's behavior in the reservoir and delivers the information needed to make the choice of solvent for the extraction process. Knowledge of the crude oil properties and use of the right solvent leads to increased output and the ability to predict the potential output quantity of the drill hole reservoir based on hard facts instead of rudimentary assessments. Insights based on density results lead to the right choice of solvent and make it possible to increase the yield of crude oil to 80 % or even 90 %.

To evaluate the behavior of the crude oil in the reservoir the same reservoir conditions are simulated in the density meter and the bubble point is determined. To do this a small sample of crude oil (no more than a few milliliters) is filled into the measuring cell and the pressure in the density meter is slowly decreased until a large density change is detected at a certain pressure level. This is the bubble point.

It is not possible to use just any density meter for this measurement. It has to be a device which is capable of measuring at pressures slightly higher than below ground to keep the live crude oil in one phase. The temperature required for these measurements is also exceptional. Recommended for this type of measurement is DMA HPM from Anton Paar, a robust density meter which is thermostatted using a climatic chamber or an oven.

API characterisation

After exploration and before distillation, the characterisation of crude oil by its API grade is needed to define the optimum blending mixture as well as the refinery operating parameters and therefore the yield of production. The fastest way to ensure that crude oil complies with specifications according to regulations is to use a digital density meter such as DMA 4500 M, a rugged and die-hard workhorse which gives 5-digit density results according to ASTM D5002.

Accurate density measurement proves that the crude oil is clean, dry, and without sedimentation. A large advantage to using a digital instrument is that it removes the need for tempering the sample, doing manual corrections, and noting down the results. Results are typically available within minutes. As the amount of sample needed per measurement is small, this saves on the volume of solvent needed for cleaning. Implementing filling checks and having precise temperature control eliminates the errors which typically arise from manual measurement with conventional methods. A digital density meter is also able to measure at one specific temperature between 0 °C and 100 °C or automatically perform a temperature scan within a short time.

Fig. 1: Density meter: DMA 1001

Trading crude oil

When buying or selling crude it is important to make sure that the indication of quantity is correct. Density measurement is a reliable way to calculate the weight of crude oil from the given volume. From a known volume, DMA M density meters measure the density and apply a software-automated calculation to deliver the weight of the quantity to be traded. The measurement is performed at either 15 °C or 60 °F and the correct invoice is then just a few seconds away. DMA 4500 M covers all products, from light to heavy crude. For even higher accuracy, DMA 5000 M provides 6-digit results which leads to more accurate calculations and therefore to more profit. Dual control of the measurement is provided by a real-time camera monitoring the measuring cell plus an algorithm detecting filling errors automatically. This information is part of the final result that is stored on the instrument (ready for export or printing later on).

At the refinery

There is a need for density measurement whenever crude oil or the subsequent products are moved between processing steps in the refinery. In these cases the measurement may be needed at tanks or from containers and requires a portable or at least very lightweight density meter. To protect employees the device must be Ex-certified, as is the case with the portable density meter DMA 35 Ex Petrol. This lightweight device is intrinsically safe, specially designed for work on-site at tank farms and refineries, and is ASTM D7777 compliant. Measurement requires only one hand and is possible when wearing gloves. Its light weight makes it ideal for measuring hard-to-reach samples from tanks or similar containers. An RFID functionality means sample points can be scanned and the appropriate measurement settings implemented automatically.

As an alternative to measurements on-the-go with a portable device, it often makes sense to equip a small lab space for quick

Suitable density meters with their features				
	DMA 35 Ex Petrol	**DMA 1001**	**DMA 4100 M** **DMA 4500 M** **DMA 5000 M**	**DMA 4200 M**
Portable	✓			
Temperfect™			✓	✓
FillingCheck™		✓	✓	✓
U-View™		✓	✓	
Pulsed Excitation Method (see Infobox)		✓	✓	✓
Gesture control	✓		✓	✓
Accuracy	0.001 g/cm³	0.0001 g/cm³	0.0001 g/cm³ 0.00005 g/cm³ 0.0000007 g/cm³	0.0002 g/cm³
Temperature range	0 °C to 40 °C (32 °F to 104 °F)	15 °C to 40 °C (59 °F to 104 °F)	0 °C to 100 °C (32 °F to 212 °F)	-10 °C to 200 °C (14 °F to 392 °F)
ASTM standards	D7777	D4052, D5002	D4052, D5002	D4052, D5002, D8188
Other standards	IP 559	ISO 12185	ISO 12185	ISO 12185

density measurements on intermediate products with a small benchtop density meter such as DMA 1001. This density meter is compliant with ASTM D4052 and D5002 and delivers 4-digit accuracy. It is one of the most straightforward density meters available which is small and robust while still providing a range of features to ensure reliable and reproducible results, even outside the traditional lab space.

Quality control on final products

Density measurement is required again before the distillated products are treated and blended, put into storage, and transported and traded to other companies for further processing and sale. Making sure the refined product meets all requirements of the specification is what counts. The correct classification, done via a measurement of API gravity, is the basis for converting the volume into mass and vice versa before sale. This is best done with a 5-digit density meter, such as a DMA 4500 M, or even a 6-digit DMA 5000 M. With 5-digit accuracy the mass per barrel of the final product will be known accurate to 1.59 g, providing a good base for a beneficial deal.

Checking the density of products directly at the terminal is another job for a handheld density meter such as the intrinsically safe DMA 35 Ex Petrol which has all relevant unit conversions stored in its software. Results are recorded and transferred to a PC or printer later on.

Official certification of products requires a benchtop density meter under the steady environmental conditions of the laboratory to achieve the highest accuracy possible. Automating a digital density meter with a sample changer means measurements can be completed at night when everyone has gone home. Sample changers such as Xsample 630, which works with the DMA M series of density meters, cover a wide temperature range and allow measurements on a wide variety of products, including lubricants and waxes.

For converting volume to mass for the trading of bitumen/asphalt and other heavy petroleum products digital density measurement is a fast and accurate alternative to hydrometers and pycnometers. The DMA 4200 M density meter, for example, is a reliable tool for density measurement at elevated temperatures and pressures. It is compliant with both ASTM D4052, D5002, and the new ASTM 8188. This new ASTM method is an alternative to ASTM D70 and makes density checks on asphalt, asphalt binder, and bitumen 10 times faster and more accurate. The constant temperature control from the syringe to the inlet and outlet of DMA 4200 M ensures highly fluid bitumen/asphalt or residual fuel oil when filling.

With an additional filling device, DMA 4200 M can also be used to determine the density of LPG. A coupler is used to connect the container and fill liquefied propane, butane, and mixtures of these safely.

Fuel sold for use by ships should undergo a last quality check before the delivery is accepted by the ship operator. Low-quality fuels will harm the motors so having a density meter on-board makes sense. A DMA 4500 M on the ship will allow quick checks on the fuel before final delivery. Conditions on-board have to be taken into consideration, especially the lack of space, vibrations, and movement. However, despite being a high-precision device, the DMA M density meters have a heavy countermass for the oscillating measuring cell to ensure that the rolling movement and vibrations from the ship do not affect the measurement. If the density results show that the quality of the fuel is sufficient, the delivery can be accepted and the ship's tank filled.

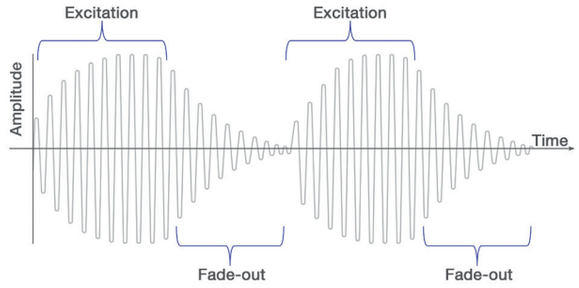

Fig. 2: The sequence of excitation and fade-out is repeated continuously.

An essential part of daily routines

The measurement of density and derived parameters such as API gravity is part of the work of tens of thousands of people every day in the crude oil and petroleum industry. Efficient measuring routines and precise and reliable results are provided by digital density measurement.

Pulsed Excitation Method

The Pulsed Excitation Method is patented (AT 516420 B1) and exclusively available from Anton Paar. With this method the U-tube is excited to oscillate and then the oscillation is allowed to fade out freely without being disturbed by external influences (see Fig. 1). The sequence of excitation and fade-out is repeated continuously. This results in:

- 3 times more information
- 2 times better viscosity correction
- Higher reproducibility
- Higher repeatability

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