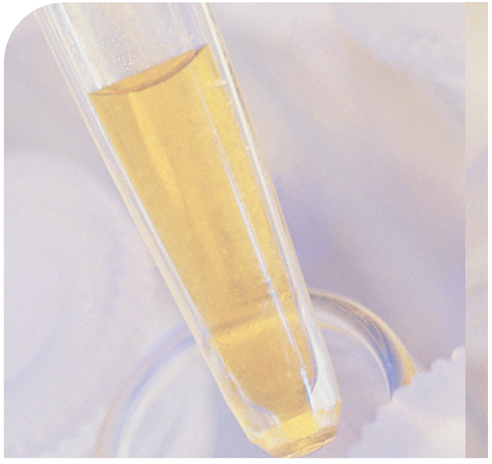

Laboratory Products Focus

THE MANY AGES OF DENSITY

Sarah Knights

Sources tell us that in the 4th century AD the principle of measuring density by immersing an object in fluid was already in use. The Arabic scientist Alhazen in the 11th century describes such an instrument, and states a table of densities. The instrument was a spindle engraved with a scale from which the density and thus the concentration could be read. Today this is known as an areometer.

"CRUDE OILS AND PETROLEUM PRODUCTS ARE COMPLEX MIXTURES, WHICH MAKES THEIR CHARACTERISATION VERY COMPLICATED"

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In the 15th century, weighing gold in air and then in water was a common practice among jewelers in Europe. Galileo Galilei had some ideas for refining this practice, and wrote a book called "The Little Balance". In this book he describes an instrument that is still used for high-precision density measurement today: the hydrostatic balance. Again, an object is immersed in fluid, but here the object is attached to a highly sensitive balance, and the density values are read from the movement of the counterweight.

In the 1960s, density measurement entered the digital era when an Austrian company, Anton Paar GmbH, launched the first digital density meters. These instruments, using a new measuring principle which was groundbreaking at the time, have since revolutionized density measuring practice and tens of thousands of density meters are now in use worldwide.

Figure 1. The first digital density meter: DMA 02

OSCILLATION BRINGS RESULTS

With a digital density meter, the sample is filled into a U-shaped tube mounted on a countermass. The U-tube is electronically excited and oscillates. Much like a sound fork used by musicians, this oscillation emits a tone. The frequency or tone of each substance is different - depending on the substance's density. Using this 'oscillating U-tube principle', the density can be precisely determined from the recorded frequency.

Density expresses the relationship "mass per unit volume" of a substance. The most commonly derived reading from density is specific gravity, which, though dependent on temperature and reference material, can be loosely defined as the measured density divided by the density of water. Various concentrations can be calculated from the density and specific gravity.

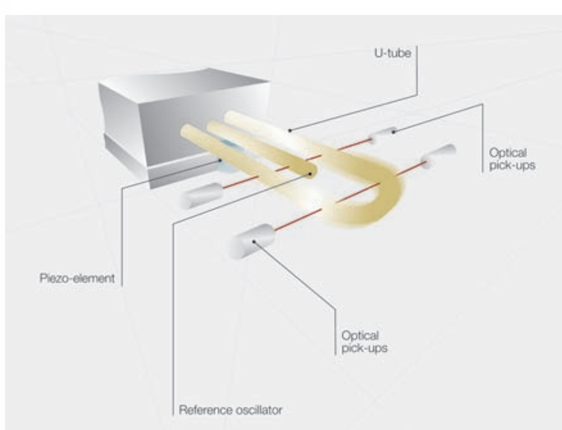

Figure 2. The U-tube principle

PREPARING FOR ACCURACY

As the density of a substance is influenced by its temperature, a digital density meter must include accurate thermostatting, typically via Peltier elements. To ensure precise results, high-end density meters require only one adjustment with air and water, for example at 20 °C, which is then valid for the whole measuring temperature range. The accuracy of a digital density meter can range from 0.001 g/cm^3 to 0.000005 g/cm^3, depending on the model. The formula below is a basic formula for calculation of Density:

$$\rho = A \times P^2 - B$$

ρ = Density P = *Period* A,B = *Coefficients*

PETROLEUM: DENSITY CONVERTED TO API AND SG

Crude oils and petroleum products are complex mixtures, which makes their characterisation very complicated. They are frequently characterised via their physical properties and an important property is the density (or specific gravity, SG). There are digital density meters available for practically all density measurement situations in this industry. Measuring the density of liquefied petroleum gas (LPG), bitumen and related products poses significant challenges. Here, external cells are required which can withstand high pressure (e.g. up to 1400 bar, 20,300 psi) and which have integrated Peltier thermostats to control the temperature up to 200 °C.

In the petroleum industry density is frequently quoted at 15 °C or 60 °F (=15.56 °C), although the measurement is performed at a higher or lower temperature. The conversion of the measured density at any temperature into the density at 15 °C or 60 °F is carried out automatically within the density meter. API gravity and specific gravity are also converted automatically from the density result. The following standard methods for density measurement are documented for petroleum products: ASTM D 4052, ASTM D 5002, DIN 51757 and DIN ISO EN 12185. These requirements are fulfilled by laboratory density meters.

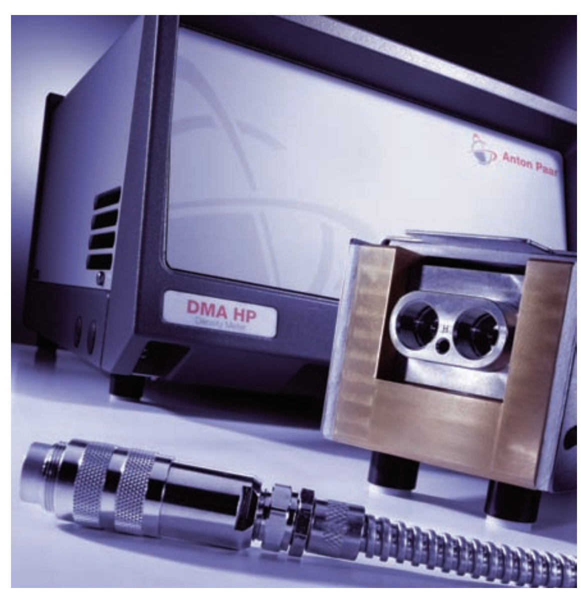

Figure 3. Density measurement with external cell which can withstand high pressure

Figure 4. Density measurement of liquefied petroleum gas

Filling the petroleum samples is an issue which may require additional apparatus. Samples with low viscosities can usually be measured directly. The sample temperature is controlled by an integrated Peltier thermostat and the measurement is carried out at a temperature beween 0 and +90 °C (32 to 194 °F). However, samples with high viscosities (e.g. up to 35,000 mPa.s) or samples with volatile components are best filled into the density meter under pressure. This is only available with high-end sample changers. Some sample filling systems also allow multiple measurements from the same vial and recovery of the sample. Measurement is completed within 1 to 4 minutes and the amount of sample required is low (typically 1 mL).

Digital density meters are typically adjusted using two pure substances (liquid or gas) with precisely known density at the measuring temperature and measuring pressure. For most measuring tasks air and distilled water can be used. For extreme situations (high/low temperature or pressure) other substances, such as nitrogen or n-undecane, may need to be used.

PHARMACEUTICALS: NOW WITH APPROVAL

Digital density measurement became extremely attractive for the pharmaceutical industry on January 1st 2006. This was the date that the United States Pharmacopeia and National Formulary officially approved specific gravity measurements using a density meter. The ruling made measurements with a laboratory density meter fully compliant with USP 29 - <841>, something which was previously reserved only for measurements with a pycnometer.

Measurement with a digital meter requires a typical sample volume of 1 mL. The results are given as specific gravity and density. The instruments typically have a built-in thermostat, precluding any influence the ambient temperature may have on the sample. If fully automated measurements are needed, this requires the use of a sample changer, which typically results in a total measurement time of 2 to 4 minutes, depending on the model and sample handling system used. One significant benefit of using a density meter is that the values are determined automatically within the instrument. This means that the results are not user-dependent, removing the need for skilled operators assigned to this task.

TOILETRIES: KEEPING THE VOLUME IN CHECK

As density measurement with digital meters provides results in minutes, digital measurement comes into its own in the production of toiletries such as toothpaste and hair gel. Liquid products are filled by volume and correct filling can be ensured by measuring the density and the weight. Even the density of pressurised liquids (aerosols) can be determined by using additional filling apparatus.

Digital meters can also be found in use in the production of essential oils and food flavourings. Measurement of the specific gravity of starting or gain materials and finished products is required to maintain a constant quality of the products. If the product is alcohol-based, such as essences and extracts, digital density meters can also be routinely used to measure the alcohol content via the distillate gravity. This is then converted to %alc, v/v or w/w using built-in tables in the meter. Sometimes, knowledge of both the density and refractive index is elemental for identifying or characterising the samples in which case a refractometer/density meter pairing can be used. In the case of density measurement alone, the required sample volume is typically 1 mL, simultaneous density and refractive index measurement requires approximately 2 mL when filled manually or 5 mL when using a sample handling apparatus.

Figure 5. The DMA 4500 density meter

INTO THE FUTURE

Apart from the applications described above, the digital density meter has found its place in measuring alcohol concentrations and determining the density and concentrations and of a range of substances such as milk, juice, molasses, salad oil and beer wort.

Applications in the chemical industry include the monitoring of reactions in solution, determining the etching bath concentration and density measurement of acids and bases.

Instrument manufacturers are of course working with industrial partners to develop new applications and improve the handling and accuracy of existing ones. In a world defined by the rising demand for consistent quality and traceable documentation, digital density meters have become part of the setup no laboratory can do without.

Compact & Flexible Heater Shaker

Radleys has announced the introduction of the new generation Metz Heater Shaker™ - designed to fulfil the heating/agitation needs of scientists in the fields of chemical synthesis, combinatorial chemistry, process development and optimisation.

Shaking can be preferable to stirring in applications including parallel organic synthesis, solid phase chemistries, sample concentration and incubations as it has less physical effect on the contents whilst offering excellent mixing.

Offering heating and shaking in a single compact unit the Metz Heater Shaker fits easily onto any bench or into any fumehood. Reactions or incubations are performed in a removable reaction block that fits securely into the heated platform which rotates in a circular orbit for efficient mixing of the reactants. The new Metz Heater Shaker is flexible, accommodating reaction blocks that accept different size tubes or multiple micro titre plates. Reaction blocks can also be customised to accept vessels for your specific application. Ruggedly constructed the Metz Heater Shaker is designed to provide many years of reliable service.

Operating the Metz Heater Shaker as a stand-alone unit is extremely simple. Using an easy to operate, back-lit Touch Control front panel, setting the temperature (ambient +5°C to 150°C) and agitation speeds (from 100 to 600rpm) just takes moments. Alternatively for unattended operation, heating and shaking cycles can be controlled by externally as part of an automated system through the RS232/RS485 ports. When integrated within robotic workstations, an auto-park feature ensures that Metz Heater Shaker platform always stop on the same X-Y coordinate for accurate alignment.

Circle no. 47

Environment-Friendly and Economic Cooling

Julabo presents the new FL line, the latest generation of chillers for routine cooling applications in laboratories and industry. 20 different models with numerous features and air or water-cooled options offer the ideal solution for any application. Compact chillers with cooling capacities up to 1.7 kW are ideal for typical lab applications as they can be placed under or on top of the lab bench. More powerful models with up to 11 kW of cooling capacity are designed with small footprints. The working temperature range covers –20°C to +40°C, the PID controller enables a temperature stability of ±0.5°C. Four different pump types with flow rates of up to 60 l/min respectively and 6 bar pressure will meet any requirement. All units have an LED temperature display integrated into a splash waterproof keypad for easy cleaning. A RS232 interface, as well as an analog alarm output are located on the front panel and the lift-up cover placed on the top gives easy access to the filling port. An additional hinged tray serves as a compartment for the operating manual and other documents. The removable venting grid allows for easy cleaning of the condenser. All models include an easily visible level indicator. Models with a pump pressure of more than 1 bar additionally display the pump pressure on a gauge and feature a pump pressure bypass to adjust the pump capacity. Venting slots are exclusively located on the front and back and therefore allow placing the units directly next to each other.

Circle no. 48