Digital Density Measurement Redefined

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Anton Paar's improved digital density meters open the door to new insights into many fields of application.

In 1967, digital density meters by Anton Paar revolutionised the formerly complicated and time-consuming ways of density determination. The measuring cell in Anton Paar's density meters was a U-tube made of glass. This U-tube, the heart of the instrument, was continuously excited and its oscillations were monitored electronically. The higher the density of the sample filled into the U-tube, the slower the oscillations. This oscillating U-tube principle led to fast, repeatable, and unbelievably precise density results with surprisingly small sample volumes. Within a short period of time, this new technology conquered the market in many fields of application. Nowadays, digital density meters are indispensable devices for the quality control of all kinds of liquid, paste-like, and even gaseous samples.

For many years this patented technology remained unchallenged until Anton Paar's ingenious research and development team realised that there was still potential for improvement. The U-tube is influenced by factors such as glass inhomogeneity, temperature changes, and the magnets attached to the glass cell to initiate the oscillations. The team worked hard and succeeded in eliminating these drawbacks. In 1997, in a first step, the development of an improved measuring cell made the magnets obsolete. In the next step, a reference oscillator was introduced which compensated the influence of temperature changes on the glass. Finally, in 2000, elaborate handicraft and machine processing were combined and influences on the glass cell were reduced to a minimum. Thus, optimum hardware was accomplished.

The more insight and awareness of the limitations the R&D team gained, the more their ambition was aroused. They saw that further improvement to the electronics was still possible. Until then, the U-tube was electronically excited, and the oscillating frequency measured. If the oscillating frequency was not identical to the U-tube's resonance frequency, the electronics fine-tuned the excitation until the resonance frequency was reached. As such, the system never was in equilibrium but in a continuous state of alignment – another influencing factor which had to be compensated.

The breakthrough could be achieved in 2015 with the Pulsed Excitation Method, in short: PEM. The U-tube is excited to oscillate with a series of impulses until a constant amplitude is reached (as can be seen in *Figure 1*). Then the excitation pulses are stopped. The properties of the U-tube during the fade-out period are monitored, and the amplitude is measured precisely before the next excitation impulse is initiated. Excitation and fade-out are repeated periodically. This way, even more precise results are delivered as the decay of the U-tube is not influenced in its resonance frequency movement at all.

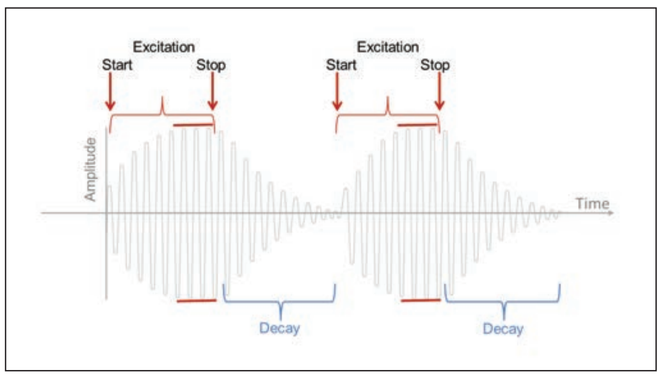

Figure 1. Principle of the Pulsed Excitation Method.

All for the Best

Thanks to this new Pulsed Excitation Method, considerable improvements of Anton Paar benchtop density meters *(Figure 2)* could be accomplished in several ways.

Highest precision can be achieved because the improved viscosity correction for highly viscous samples leads to more precise density results. PEM allows continuous monitoring of the correct functioning and immaculate state of the glass measuring cell. With PEM, the viscosity correction also works for density meters with a U-tube made from metal as is the case with DMA 4200 M. Thus, on top of their robust and reliable construction and design, Anton Paar density meters convince with a unique repeatability of better than $1*10^{-6}$ g/cm³.

A new insight for Newtonian fluids is now possible as PEM delivers the viscosity in addition to the density value with an accuracy of 5% in the range from 10 mPa.s to 3,000 mPa.s.

More confidence into measuring results originates from the fact that filling errors are detected more reliably as PEM allows monitoring the condition of the measuring cell. As a consequence, erroneous results due to bubbles or particles in the filled-in sample are eliminated. More certainty means more confidence.

The FillingCheck™ function makes it possible to detect filling errors, also in metallic U-tube oscillators. This is also valid for measurements up to 150°C. Detecting filling errors allows avoiding them.

Figure 2. The family of Anton Paar benchtop density meters and the portable DMA 35.

The Silent Assistants That Never Get Tired

With a sample filling device, be it a single or a multiple sample filling unit, the workload of the operator is made significantly easier. Productivity, quality and repeatability of measurement results can be enhanced. While one sample is being filled and measured by the respective instrument(s), the operator can dedicate the time to other tasks such as preparing the next sample to be filled and analysed. Filling conditions are exactly identical and not subject to human influences. Time can be saved and cross contamination minimised as most filling devices provide automatic cleaning and drying procedures. The quality can be monitored even more closely as samples can be determined around the clock - a multi-sample changer never gets tired!

Depending on the requirements, several options of Xsample sample changers offer improved automatic filling. Table 1 gives an overview of their characteristic features.

The single sample units Xsample 320 and Xsample 330 allow automatic filling by means of a peristaltic pump. Single samples with higher viscosities that are best introduced with a syringe can be accommodated with the Xsample 340 single sample device. Up to two cleaning agents avoid carry-over if samples with different properties are filled in succession. Xsample 610 allows effortless filling of heavy duty single samples. With temperatures up to 95°C, highly viscous samples and even samples that are solid at room temperature can be handled.

For unattended filling of multiple samples 24 hours a day, Xsample 520 is well-suited for similar samples that are measured consecutively when sample recovery is not necessary. In case of different samples, Xsample 530 scores with up to three cleaning liquids to avoid cross contamination, with moderate maintenance requirements, robust design and high resistance to chemicals. Xsample 530 distinguishes itself with its optional sample recovery – no sample goes down the drain, no money is wasted.

Xsample 630 holds the pole position among the Xsample family for multiple samples and offers everything you could possibly ask for. Improved heating to temperatures up to 95°C and short heating periods result in enormous time savings. Xsample 630's increased performance in magazines with up to 56 positions allows measurements of challenging petrochemical samples, waxes, food, and flavour samples according to ASTM standards.

Table 1. Sample changers and their respective properties.

Type	Sample filling	Magazine positions	Max. sample viscosity	Samples per hour	Sample recovery	Automatic cleaning & drying
Xsample 320	Single from vial	n/a	3,000 mPa.s	30	No	No
Xsample 330	Single from vial	n/a	3,000 mPa.s	15	Yes	Yes (2 cleaning agents)
Xsample 340	Single with syringe	n/a	36,000 mPa.s	12	No	Yes (2 cleaning agents)
Xsample 520	Multiple from vial	Up to 96	3,000 mPa.s	30	No	No
Xsample 530	Multiple from vial	Up to 154	36,000 mPa.s	16	Optional	Yes (up to 3 cleaning agents
Xsample 610	Single with syringe	n/a	10,000 mPa.s at 95°C	8	No	Yes (2 cleaning agents)
Xsample 630	Multiple from vial	Up to 56	36,000 mPa.s at 95°C	8	No	Yes (up to 3 cleaning agents)

An Amazingly Wide Range of Applications

Be it the chemical industry, alcoholic and non-alcoholic beverages, pharma and petro industries, density measurement nowadays serves as a means of fast and reliable quality control worldwide.

Density measurement is helpful at all stages of production to determine the quality of incoming raw materials, to monitor the manufacturing progress all the way to the final product where density measurement ensures that only product with the correct composition is delivered to the end user or consumer. The sugar content of soft drinks, the concentration measurement of sulphuric acid, the state of charge of batteries, the right composition to fulfil the standards required for biodiesel, the conversion of volume-to-weight for products quantified by weight while the products are filled, paid and even taxed by their volume, and the concentration of salt solutions for roads and pathways to help commuters in the wintertime to arrive safely at their final destination are only a few examples.

Density meters, with or without a suitable filling device, can be combined with other measuring instruments or modules for the simultaneous determination of multiple parameters. In these measuring systems, usually a DMA M density meter acts as the master instrument that gets commands from a PC and forwards them to the respective instruments or modules. The combination of instruments for analysing the required parameters leads to custom-tailored measurement solutions for many industries.

A Modulyzer, the combination of a DMA 4500 M density meter, an Abbemat 550 refractometer, an MCP polarimeter, rounded off with an Xsample 530 multiple sample changer, represents an acknowledged measuring system, especially for the flavour and fragrance industry as valuable sample can be recovered. With this system, the density, refractive index, and optical rotation can be measured simultaneously. A Modulyzer is shown in *Figure 3*.

Figure 3. A Modulyzer system, with Xsample and waste vessel.

A Partnership That Pays Off

Any good product requires careful supervision with adequate instrumentation from the very beginning all the way through the production process to the final product. Many years of experience in numerous fields of application are the foundation for a long-term partnership between industry and instrument manufacturer. As the technology leader, Anton Paar always proudly aims to provide the best solution for the respective application requirements. All critical instrument components, the oscillating U-tubes among them, are made in-house.

Upon request, calibration according to ISO 17025 for traceability of density meters to the International System of Units (SI) is available to make sure that measurement results are globally comparable and true.

Last but not least, the worldwide distribution and service support network render Anton Paar a worthwhile partner for a wide range of industries for many years to come.

For more information www.anton-paar.com