

I'm not a robot



Viscosity is one of the most important physical properties of fluids in a variety of industries from food and beverages to pharmaceuticals to oil and gas. Viscosity measures the resistance of a fluid to flow, which can affect the production process, product quality, and final performance of a material. To measure viscosity with precision, various tools have been developed, one of which is the rotational viscometer. This instrument is famous for its accuracy in measuring the viscosity of liquids that have non-Newtonian and Newtonian flow characteristics. This article will review the working principle, applications, and advantages of a rotational viscometer. A rotational viscometer is a tool that uses the principle of rotation to measure the viscosity of a fluid. This tool usually consists of two elements in the form of a spindle or rotating cylinder, with the fluid being measured filled into a container between the two spindles. Rotational Viscometers can measure variations in the viscosity of fluids ranging from liquid to semi-solid types. Rotational viscometers work on the basic principle of measuring the torque required to rotate a spindle or cylinder in a fluid. The tool consists of a spindle connected to a drive motor, as well as a sensitive torque measurement system. When the spindle is rotated in the fluid, the fluid provides resistance to the movement. The magnitude of this resistance depends on the viscosity of the fluid. The higher the viscosity, the greater the resistance the fluid gives to the spindle. Rotational viscometers generally have adjustable rotational speed settings, so they can be used to measure viscosity at various flow conditions. The viscosity of a fluid can be determined by measuring the torque required to rotate the spindle in the fluid at a specific speed. The relationship between torque and viscosity is often expressed as a constant speed. This type of viscometer is one of the most popular models of rotational viscometers. Using cones and plates to measure viscosity. The cone is rotated on a plate, with the liquid in between the two. It is highly sensitive and ideal for measuring the viscosity of small volumes of liquid. It consists of two concentric cylinders, in which the inner cylinder is rotated and the liquid is placed in the space between the two cylinders. It is a highly precise tool and is used in research as well as industrial applications. 1. Spindle Type L: Designed to measure the viscosity of low-viscosity liquids. 2. Spindle Type R: Suitable for measuring the viscosity of medium to high viscosity liquids. 3. Spindle Type H: Used for liquids with high viscosity. Example of using the right type of spindle for fluid viscosity measurement Food and Beverages Pharmaceuticals and Cosmetics Oil and Petrochemical Application Spindle Type Application Spindle Type Application Spindle Type Fruit Butter Honey Jam Lubricating Oil Jelly Honey Syrup Medicine Fuel Oil Sauce Antibiotic Creams Cooking Oil Yogurt Moisturizing Lotion Coatings, Paints Juice Shampoo, Conditioner Resin Epoxy Rotational viscometers have a wide range of applications in various industries, especially in production processes that require strict quality control of the viscosity of materials. Here are some of the main applications of this tool in this industry. Viscosity is an important parameter that affects the texture, taste, and stability of a product. In the manufacture of medicines and cosmetic products, viscosity affects the formulation, stability, and application of the product. In the oil and gas industry, viscosity is an important factor in the processing, transportation, and storage of crude oil and its derivative products. The viscosity of paints and coatings affects their application, spread ability, and finish. Rotational viscometers are often used in the development and production of paints to ensure the quality of the final product. Rotational viscometers have several advantages over other viscosity measurement tools. 1. Accuracy: Rotational viscometers provide highly accurate and repeatable measurements. 2. Versatility: They can measure a wide range of fluid types, from low to high viscosity. 3. Ease of Use: Despite having advanced technology, rotational viscometers are generally easy to use. 4. Ability to Measure Viscosity in Dynamic Conditions: Unlike static measurement methods, rotational viscometers can measure viscosity in dynamic conditions, where fluids are undergoing changes in velocity or force. 1. Limitations on Non-Newtonian Fluids: Rotational viscometers may not provide consistent results for non-Newtonian fluids, whose viscosity changes with the rate of shearing. 2. The Need for Regular Calibration: To stay accurate, rotational viscometers need to be calibrated regularly. 3. Cost and Maintenance: Rotational viscometers tend to be more expensive than other simple types of viscometers, such as capillary viscometers. Rotational viscometers are a very important tool in the industrial and research world for accurate viscosity measurements. With a simple but effective working principle, it provides flexibility and high precision in the measurement of different types of liquids. Its wide application in various industrial sectors confirms the importance of rotational viscometers in ensuring product quality and consistency, as well as in scientific research. In this modern era, where product quality is a top priority, rotational viscometers remain the tool of choice for reliable and accurate viscosity measurement. "Viscosity decreases as temperature is raised." Define Absolute Viscosity (Dynamic Viscosity) Absolute viscosity is a measurement of the internal flow resistance of a fluid. Its unit is poise or centipoise Define Kinematic Viscosity Kinematic Viscosity is refers to the ratio of Dynamic Viscosity to density. Its unit is stokes or centistokes List the types of liquids Newtonian Fluid -

fluid with constant viscosity. Eg: Water; Oil, benzene Non-Newtonian Fluid - fluid that is having a unique value for viscosity. Eg: slurries, pastes, gels, Polymer Solution What is viscometer? A fluid's thickness can be determined with the help of an instrument is called a viscometer. A viscometer provides readings mainly for a single flow pattern, i.e., laminar flow. The viscometers are classified into two types based on their operation. They are rotational viscometers and falling sphere viscometers. Rotational viscometers consist of a rotating spindle or rotor which is placed in a fluid sample and rotated at a known speed. Standard laboratory viscometers for liquids Capillary-tube Viscometer Falling sphere viscometers 2. Rotational viscometers Cup & Bob Viscometer Cone & Plate Viscometer Electromagnetic Spinning Sphere Viscometer Stabinger viscometer 3. Falling Ball Viscometer 4. Falling Piston Viscometer 5. Oscillating Piston Viscometer 6. Vibrational viscometers 7. Bubble Viscometer 8. Micro-Slit Viscometers Capillary-tube Viscometer Working Principle of Capillary-tube Viscometer The term "U-tube" viscometer is used to describe this kind of viscometer. It is used to calculate a Newtonian fluid's viscosity. A fluid whose viscosity is unaffected by shear force or rate. The main concept behind it is timing how long it takes a liquid to travel between two places or markers. Poiseuille's law provides the foundation for how the capillary tube viscometer functions. This method of measurement compares the time needed for a liquid with a given viscosity to flow through a capillary with a known diameter and length to the time needed for a determined quantity of fluid to do so (usually water). Capillary viscometers can detect viscosity at different shear rates, are economical, and only require small volumes of sample fluid. Formula of Capillary-tube viscometer

$$\eta = \frac{r^2 \rho t}{V} \cdot \frac{\Delta P}{L}$$

Where:

- η = Viscosity
- r = Radius of the capillary tube
- ρ = Density of the liquid
- t = Time taken for the liquid to flow through the capillary
- V = Volume of the liquid
- L = Length of the capillary
- ΔP = Pressure difference across the capillary

Ostwald viscometer Ostwald viscometer Working Principle of Ostwald viscometer This viscometer is used to measure viscosity of fluids with a known density. This instrument is named after philosopher "Wilhelm Ostwald". Procedure for viscosity measurement:

- Fill the reservoir's tube with water until the mark point is reached (mark C) . Use a suction bulb to suction the liquid from the capillary tube and pull it to mark A . Note the time for the liquid falling from mark A (the starting time) to mark B using a stopwatch (ending time)
- Formula of Ostwald viscometers To calculate the viscosity of a liquid, we need to know its density and compare it to flow from mark A to mark B. If the density of the liquid is ρ_1 , then the formula for calculating the viscosity of the liquid is as follows:

$$\eta = \frac{\rho_1}{\rho_2} \times \left(\frac{t_1}{t_2} \right) \times \eta_0$$

Where:

- η = Viscosity of the liquid
- ρ_1 = Density of the liquid
- ρ_2 = Density of the standard liquid
- t_1 = Time taken for the liquid to flow from mark A to mark B
- t_2 = Time taken for the standard liquid to flow from mark A to mark B
- η_0 = Viscosity of the standard liquid

A modified version of Ostwald's viscometer, and it can test high viscosity liquids. This instrument is found by inventor Leo Ubbelohde There are two bulbs in this instrument; the first is the reservoir, and the second is the measuring bulb. A capillary tube joins the two bulbs together. In addition, there is a vent for air. The reservoir bulb is initially filled with liquid (large bulb located in the lower level). It is important to take precautions to keep the liquid from getting into the air hose. The viscometer is submerged in a liquid bath of the same temperature until its internal liquid reaches the same temperature as the bath. Afterward, a rubber tube attached to the air tube is used to suction the liquid to the measuring bulb. Once the liquid has been transferred, the rubber tube must be sealed to prevent it from leaking back into the reservoir. The liquid is then allowed to fall down when the rubber tube has been loosened. The time it takes for the liquid to cross the two marks at the top and bottom of the measuring bulb is used to calculate the flow rate. This viscometer gives accurate readings regardless of the amount of liquid being measured. Category of Ubbelohde Viscometer

There are two types of viscometers: direct flow and reverse flow. When measuring direct flow, viscometers place the reservoir below the lines; when measuring reverse flow, they place the reservoir above the markings. The marks will be concealed by the liquid, making it impossible to determine when a level has crossed the mark. In order to calculate the amount of opaque or staining liquids these classifications are required because the liquid will cover up the marks. This permits the viscometer to have several marks, allowing for the timing of the time needed to reach the third mark right away, producing two timings, and allowing for the computation of the determinability of the viscosity to be done later, ensuring reliable results. Formula of Ubbelohde viscometer Flow rate, $Q = VT/Q$ Q is inversely proportional to the time between the marks.

As is the hydrostatic pressure which is equal to the weight of the column of liquid above the point of measurement. This is equivalent to the pressure exerted by the column of liquid above the point of measurement. This is equivalent to the pressure exerted by the column of liquid above the point of measurement.

Differences

- Ostwald viscometer is appropriate for measuring liquids with low to moderate viscosity, whereas Ubbelohde viscometer is appropriate for measuring liquids with high viscosity. Advantages of Capillary Viscometer Accurately measure viscosities of a wide range of fluids Lightweight and portable Low cost Easy to use wide range of capillary tubes can be used with a single viscometer Disadvantages of Capillary Viscometer There is no one tube that works for every possible viscosity, and the simplest models can only be used with transparent fluids. One of the challenges is that capillary tubes are notoriously difficult to disinfect. Applications of Capillary Viscometer The viscosity of a large variety of fluids can be measured with a capillary viscometer. Typical examples include things like motor oil, adhesives, sealants, and lubricants. Falling sphere viscometers Working Principle Falling sphere viscometers The fluid is stationary in a vertical glass tube in the falling sphere

Stokes' law forms the basis of this viscometer. A sphere with known dimensions and density is allowed to float in the fluid. By measuring the time it takes to pass between two tube markers, one can determine the final velocity, if the choice is made properly. Electronic sensing is a practical solution for transparent fluids. If you know the terminal velocity, the size and density of the sphere, as well as its density, you can apply Stokes' law to calculate the fluid's viscosity. Formula in Falling Sphere Viscometers The terminal velocity, often referred to as the settling velocity, is attained when the frictional force combined with the buoyant force exactly balances the gravitational force. In other words, the net force acting on the sphere is zero and it falls at a constant rate. This is the principle behind the operation of the falling sphere viscometer. Advantages of Falling Sphere Viscometer Can be maintenance intensive Replacement parts can be costly Rotational Viscometer Working Principle of Rotational Viscometer These viscometers are suitable for both Newtonian and non-Newtonian systems. The fluid being measured for viscosity is sheared between two surfaces, one of which rotates and the other of which is stationary. The rotational deflection of the cylinder, which occurs when either the outer or inner cylinder rotates at a constant speed, serves as a gauge for the viscosity of the liquid. The sample is sheared in the area between the inner and outer walls of the cup. The sample causes the bob to turn because of a viscous drag. The ratio of the resultant torque to the sample's viscosity. Procedure in Rotational Viscometer Put the sample into the beaker, while tilting it to avoid air bubble that might affect result of viscosity. With the motor off, attached the spindle at a 45 degree angle to prevent air bubbles. Move the gear up and down until the fluid and is level with the spindle's immersion groove Operate and enter the key codes to start rotating the spindle and take the date on the screen displayed Advantages of Rotational Viscometer It is useful for describing shear-thinning and time-dependent behavior and can measure the viscosities of opaque, settling, or non-Newtonian fluids. The main disadvantage of rotational viscometer is that they cannot be used for very low viscosity fluids. Couette viscometer The Couette viscometer consists of two concentric cylinders. The inner cylinder is rotated by a motor at a constant speed. The viscous drag on the bob produced by the liquid results in a torque which is proportional to the viscosity of the liquid. Examples: Mac Michael Viscometer - Rotating cup and stationary bob Searle type Viscometer In searle type viscometer, the bob is rotated while the cup is kept constant. Examples: Stormer viscometer, Brookfield viscometer Couette Viscometer In this viscometer, the cup is rotated while the liquid's drag on the bob creates a torque that is inversely proportional to the liquid's viscosity. As shown below, the two cylinders are concentric and have an annular clearance that is filled with fluid.

The outer cylinder rotates at a steady speed while the internal cylinder is fixed. It is determined how much force is required to shear the fluid between the cylinders. Cylinder's velocity can be adjusted to measure how the fluid's viscosity varies as the shear rate increases. For various fluids, various cylinders with a variety of radial clearances are employed. Formula in Rotational Viscometer The dynamic viscosity (η) can be estimated from the formula: where r_{bc} is the radius of the inner and outer cylinder respectively [m]; M is the shear torque on the inner cylinder [Nm]; w is the angular velocity [rad/s]; d is the immersion depth of the inner cylinder [m]; k is the viscometer constant [m³] $\eta = \frac{Mr_{bc}}{4\pi dw}$ These cylinders are used to measure the viscosity of fluids that are isotropic and shear thinning. Formula of Cone on Plate Viscometer The dynamic viscosity (η) can be estimated from the formula: where r is the radius of the cone [Nm]; M is the shear torque on the cone [Nm]; w is the angular velocity [rad/s]; α is the cone angle [rad]; k is the viscometer constant [m³] Advantage of Cone on Plate Viscometer Very little fluid sample volume is needed for the test The temperature of the fluid sample is adjusted while tests are being conducted. This also has running preheated or chilled external fluid through the viscometer plate. Electromagnetically Spinning Sphere Viscometer (EMS Viscometer) The electromagnetic interaction-driven spinning of a sphere is used by the EMS Viscometer to gauge the viscosity of liquids. A spinning magnetic field is created by two magnets connected to a rotor. In a little test tube is the sample (3) that needs to be measured (2). An aluminum spherical is located inside the tube (4). The tube is positioned so that the sphere is in the middle of the two magnets in a temperature-controlled space (1). Eddy currents are created in the sphere by the spinning magnetic field. The magnetic field and these eddy currents then interact through a Lorentz process, creating torque that rotates the sphere. The magnetic field's strength, rotational velocity, and viscosity of the sample surrounding the sphere all affect the torque. The torque is measured and the viscosity is calculated. The torque is linearly proportional to the viscosity of the sample. The torque is linear. This new measuring principle technique was found by Sakai et al. Advantages of EMS Viscometer over Capillary & Rotational Viscometer No cleaning is necessary Measurements can be carried out in a controlled environment There are no measuring errors due to evaporation. This is the ideal solution for samples that are only available in small quantities Quick temperature control of the small sample container No cleaning required after measurement. How EMS Viscometer is different from other rotational viscometers? Samples are inexpensive and disposable. In a sealed sample vessel, the measurements are carried out. Only very small sample quantities are needed for the EMS Viscometer (0.3 mL). Stabinger viscometer Working Principle of Stabinger viscometer Kinematic viscosity determination accuracy can be combined with a large measuring range by adapting the traditional Couette type rotational viscometer. Kinematic parameters can be obtained by integrated density measurement from the oscillating U-tube technique, where V is the Kinematic Viscosity [mm²/s] is the dynamic viscosity [mPa.s] ρ is the density (g/cm³) Working of Stabinger Viscometer The rotor is propelled by the shear forces of the rotating fluid & an eddy current brake is created by the copper

This enables a large measuring range from 0.2 to 30,000 mPa·s and a highly accurate torque resolution of 50 nNm with a single measuring system. Advantages of Stabinger Viscometer Kinematic viscometer with an integrated density measuring cell that is extremely precise. The temperatures range between 15°C and 100°C. This provides high efficiency with green and environmental protection, and does not require thermostat bath. Simply inject the sample using a syringe to begin the measurement. Simple cleaning and safe handling without leaks or breakage. Low maintenance. Factory-adjusted and ready for use right away. Application of Stabinger Viscometer Provide certified for density & Kinematic viscosity in analyzing diesel fuel. Determines the viscosity of crude oils in petroleum industry to determine when it's time for an oil change. Ensures the purity of jet fuel. To determine the viscosity of samples containing volatile ingredients. To the measurement of viscosity in lubricating oil. Falling Ball Viscometers Working Principle of Falling Ball Viscometers There are also many additional varieties of viscometers available, each based on a different measurement basis. The "Falling Ball Viscometer" is the instrument that is most frequently used in laboratories. A steel ball is dropped into a glass tube that has been filled with the fluid being evaluated. After that, the measurement is made by counting the time it takes the ball to fall between the first and second timing marks that are etched on the tube. The accuracy of the time measurement is 0.1 [s]. Additionally, the determination of viscosity changes under pressure can be done with this viscometer. Formula in Falling Ball Viscometer The dynamic viscosity can be estimated from the formula $F = \frac{4}{9} \frac{r^2 (\rho - \rho_f) g}{\eta}$ is the correction factor $F = 1 - 2.104(d/D) + 2.09(d/D)^3 - 0.9(d/D)^5$ where d is the diameter of the ball [m], D is the internal diameter of the tube [m] Falling Piston Viscometer Working Principle of Falling Piston Viscometer The founder of Falling piston viscometer is Austin Norcross. It is also known as the

The principle of viscosity measurement based on a piston and cylinder combination. This viscometer is durable, sensitive industrial device and robust measuring measure. The piston is pulled through the clearance (gap) between the piston and the cylinder wall by means of a lifting mechanism. The assembly is held up briefly before falling to shear the liquid. The viscometer is sensitive enough to measure viscosity of liquids. The duration of fall is related to fluid viscosity. The viscosity controller determines viscosity from fall time. The controller can set time-of-fall to centipoise/cup seconds (also known as efflux cups). Advantages of Falling Piston Viscometer This instrument is common for industrial application since it is easy to repeat, requires no upkeep, and is unaffected by flow rate or outside vibrations. The operating concept is flexible and adaptable and it is perfect for environments involving process control. Oscillating Piston Viscometer Working Principle of Oscillating Piston Viscometer A measurement chamber and a piston with magnetic effect make up the sensor. A sample is initially delivered into the thermally controlled measuring chamber where the piston is located in order to obtain measurements. Electronics use a regulated magnetic field to move the piston in an oscillatory motion inside the measurement chamber. The piston's journey places a shear stress on the liquid (or gas), and the viscosity is calculated by timing the piston's movement. According to Newton's Law of Viscosity, the viscosity is calculated using the construction parameters for the annular gap between the piston and measurement chamber, the strength of the electromagnet field, and the piston's journey distance. Advantages of an oscillating piston flowmeter Installation can be carried out in either a vertical or horizontal position, or even at an angle. It is not necessary to run straight pipes before and after the flowmeter. Viscosity fluctuations do not significantly affect the oscillating piston flowmeter. It is therefore perfect for applications where the temperature is variable. It has a lengthy operating life under normal working conditions. Disadvantages of oscillating piston flowmeter The liquid must be clear and free of suspended particulates, which could jam or harm the piston. The liquid must always be flowing so as to prevent the piston from sticking. Applications of oscillating piston flowmeter Oscillating piston flowmeters are used in many laboratory applications for small sample volumes and micro-sampling viscosity measurement have been developed using the oscillating piston viscometer technology. It has been modified to assess viscosity at high temperatures and pressures in both laboratory and process settings. The viscosity sensors have been used for a broad range of industrial applications, including small size viscometers for use in compressors and engines, flow-through viscometers for dip coating processes, in-line viscometers for use in refineries, and many more. The use of oscillating piston viscometers in academic laboratories studying gas viscosity is growing as a result of improvements in sensitivity brought forth by modern electronics. Vibrational Viscometers Vibrational viscometers measure the damping of an oscillating electro-mechanical resonator to determine a fluid's viscosity. The resonator often oscillates transversely or in torsion (as a cantilever beam or tuning fork). The amount of damping imposed on the resonator increases with viscosity.

Advantages of Vibrational Viscometer Quick and accurate measuring is feasible. Because vibration approach just slightly perturbs the sample liquid, there is little energy delivered to it. Because of the oscillator's low thermal capacity, interference from the measurement with the sample substance can be minimized. Disadvantages of Vibrational Viscometers The lack of a specified shear field in the vibrational instrument renders it unsuitable for measuring the viscosity of a fluid whose flow behavior is not known. Rugged industrial systems called vibrating viscometers are used to detect viscosity in a process environment. A vibrating rod is the sensor's active component. The viscosity of the fluid in which the rod is submerged affects the vibration's amplitude. Application of Vibrational Viscometers These viscosity meters can measure high-viscosity fluids (up to 1,000 Pa-s), including those containing fibers, and clogging fluid. These viscometers are currently regarded by many industries as the most effective way to test the viscosities of slurries, suspensions, and emulsions. The test is simple and requires no special test cells. The test is also applicable to fluids that are too viscous to be measured by conventional viscometers. The kinematic viscometers are used to measure the viscosity of liquids like resins and varnishes may be swiftly determined. Since the time needed for an air bubble to rise is directly inversely correlated with the viscosity of the liquid, the viscosity is lower the faster the bubble climbs. The "bubble seconds," which can subsequently be translated to stokes, are calculated using the Direct Time Method using a single 3-line time tube. Application of Bubble Viscometer Bubble Viscometer can be used in kinematic viscosity of well-known liquids like resins and varnishes may be efficiently determined. Micro-Slit Viscometers Viscosity measurements is performed utilising flow through a slit. To overcome the wall shear stress in a viscous flow through a circular pipe, pressure is necessary. Slit flow simulates actual application flow circumstances, such as drug injection or inkjetting, and has the advantage of not requiring entrance or exit pressure drop corrections. Advantages of Micro Slit Viscometer • Calculates the absolute viscosity of fluids, including Newtonian and non-Newtonian. • An enclosed system eliminates sample evaporation and air interaction. • Measuring is possible with small sample volumes. • Laminar flow is enabled by low Reynolds numbers even at high shear rates. Application of Micro Slit Viscometer Micro slit viscometer is used for measuring blood viscosity over a Wide-Ranging Shear Rate Frequently asked questions about Viscometers What is meant by Rheometer? A rheometer is a device used to measure the response of a dense fluid (a liquid, suspension, or slurry) to applied forces. How rheometer differ from viscometer? Rheometers measure a fluid's response to applied shear or stress, which may reveal information about the elasticity and viscosity of the material. The material's flow behavior is measured by viscometers. Both instruments have a similar design, but the rheometer is used to study the material's response to a range of stresses, while the viscometer is used to study the material's response to a single stress. Industries that use rheometers include the chemical industry, the food industry, the paint industry, the petroleum industry, and the pharmaceutical industry. Industries that use viscometers include the chemical industry, the food industry, the paint industry, the petroleum industry, and the pharmaceutical industry. What are the errors and factors affecting viscometer? Error in Viscosity are caused by Alignment If the surface tension of the fluid allows sample to "leak" out of the flow cell, the inaccuracy caused by misalignment towards the unbonded edges of the capillary (from left to right) can be rather severe. Factors Affecting Viscosity Molecule size: Solutions with large particles exhibit high viscosity. That is, the viscosity is directly proportional to the size of the molecules. Molecules Shape: Spherical molecules exhibit low viscosity due to their shape. Force: Large intermolecular forces result in more viscous materials. Temperature: A gas becomes more viscous as its temperature rises. With an increase in temperature, fluid viscosity decreases. Why measuring viscosity is important? Viscosity is utilized to characterize a product constituent. A lot of typical polymers for these ingredient classes are frequently chosen or specified based on their viscosity in their solutions in different solvents.

viscosity, as a characteristic of a suspension or solution and in determining invertiveness. Whether particles in a suspension will settle at a specific rate, for instance. It also has a significant effect on determining the quality of various fluids used in various applications. What are the need in measurement of viscosity? Uses include determining inherent viscosity. Determining light flows. Controlling polymerization, determining the flow of various solvents through HPLC or GC pumps. Determining or researching the physical characteristics of liquids. What is meant by Dip Cups? These cups help paint makers and users quickly estimate efflux times for paints and comparable fluids. What is meant by Flow Curves? Flow curves are used to apply a known shear stress to a fluid and measure the resulting shear rate. The shear stress is the force applied to the fluid divided by the area of the fluid. The shear rate is the change in velocity of the fluid divided by the distance between the fluid layers. A constant measurement temperature. The liquid's Newtonian flow behavior? What is meant by Efflux time? It is the amount of time needed to drain the vessel's contents. Viscosity, a measure of a fluid's resistance to flow, is a crucial property in various industries such as chemical, pharmaceutical, food, and cosmetics. Accurate viscosity measurement is essential for ensuring product quality, optimizing production processes, and meeting regulatory requirements. Rotational viscometer, specifically designed to measure the viscosity of a wide range of fluids, have become an indispensable tool in these industries. Rotational viscometers are versatile instruments that determine the viscosity of fluids by analyzing the torque and angular velocity generated by a rotating element within the fluid. These instruments provide valuable information about the fluid's rheological properties, enabling researchers and engineers to understand the material's behavior under various conditions. In this blog post, we will delve into the inner workings of the rotational viscometer, exploring its underlying principles, various types, and the fundamental role it plays in accurately determining the viscosity of both Newtonian and non-Newtonian fluids. Back to top A. The Principle of a Rotational Viscometer The rotational viscometer's principle work is based on the principle of measuring the torque and angular velocity generated by a rotating element within a fluid. This interaction between the fluid and the rotating element provides valuable information about the fluid's rheological properties, which in turn can be used to determine its viscosity. 1. What is the Principle of a Rotational Viscometer? Rotational viscometry works by measuring how much resistance a rotating element faces as it moves through a fluid. This resistance is directly related to the fluid's viscosity, and it is expressed in terms of torque and angular velocity. By analyzing the relationship between torque and angular velocity, rotational viscometers can provide quantitative information about the fluid's viscosity. 2. The Relationship Between Shear Stress, Shear Rate, and Viscosity The relationship between shear stress, shear rate, and viscosity is fundamental to understanding fluid behavior. Shear stress is the force applied to the fluid, shear rate is the rate at which the fluid layers move relative to each other, and viscosity is the fluid's resistance to flow. These three quantities are essential for understanding the behavior of fluids under various conditions, and they form the basis for rotational viscometer measurements. 3. The Relationship Between Shear Stress, Shear Rate, and Viscosity The relationship between shear stress, shear rate, and viscosity is described by the following equation: $\eta = \tau / \dot{\gamma}$, where η represents viscosity, τ is shear stress, and $\dot{\gamma}$ is shear rate. In this context, viscosity is defined as the ratio of shear stress to shear rate, and it is expressed in units such as pascal-seconds (Pa-s) or centipoise (cP). 4. Viscosity Classification: Newtonian and Non-Newtonian Fluids Fluids can be classified based on their viscosity behavior as either Newtonian or non-Newtonian. Newtonian fluids exhibit a linear relationship between shear stress and shear rate, where the viscosity remains constant regardless of the applied force. Examples of Newtonian fluids include water, glycerin, and many oils. Non-Newtonian fluids, on the other hand, display a more complex relationship between shear stress and shear rate, where the viscosity changes as the applied force changes. Non-Newtonian fluids can be further divided into several categories, such as shear-thinning, shear-thickening, and time-dependent fluids. Examples of non-Newtonian fluids include blood, paint, and toothpaste. 5. Types of Rotational Viscometer There are several types of rotational viscometers, including coaxial cylinder viscometers, cone-and-plate viscometers, and rotating spindle viscometers. Each type of viscometer has its own advantages and limitations, and the selection of the appropriate viscometer will depend on the specific requirements of the measurement. Understanding the principles of rotational viscometry and the different types of fluids is crucial for selecting the appropriate measurement technique and ensuring accurate viscosity determination using the ASTM rotational viscometer or other rotational viscometers. Back to top Rotational viscometers are widely used in various industries to measure the viscosity of fluids, a crucial property that affects flow characteristics and material behavior. The rotational viscometer is a specialized instrument used to measure the viscosity of fluids. It is based on the principle of measuring the torque and angular velocity generated by a rotating element within a fluid. This interaction between the fluid and the rotating element provides valuable information about the fluid's rheological properties, which in turn can be used to determine its viscosity. 1. What is the Principle of a Rotational Viscometer? Rotational viscometry works by measuring how much resistance a rotating element faces as it moves through a fluid. This resistance is directly related to the fluid's viscosity, and it is expressed in terms of torque and angular velocity. 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Shear stress is the force applied to the fluid, shear rate is the rate at which the fluid layers move relative to each other, and viscosity is the fluid's resistance to flow. These three quantities are essential for understanding the behavior of fluids under various conditions, and they form the basis for rotational viscometer measurements. 3. The Relationship Between Shear Stress, Shear Rate, and Viscosity The relationship between shear stress, shear rate, and viscosity is described by the following equation: $\eta = \tau / \dot{\gamma}$, where η represents viscosity, τ is shear stress, and $\dot{\gamma}$ is shear rate. In this context, viscosity is defined as the ratio of shear stress to shear rate, and it is expressed in units such as pascal-seconds (Pa-s) or centipoise (cP). 4. Viscosity Classification: Newtonian and Non-Newtonian Fluids Fluids can be classified based on their viscosity behavior as either Newtonian or non-Newtonian. Newtonian fluids exhibit a linear relationship between shear stress and shear rate, where the viscosity remains constant regardless of the applied force. Examples of Newtonian fluids include water, glycerin, and many oils. Non-Newtonian fluids, on the other hand, display a more complex relationship between shear stress and shear rate, where the viscosity changes as the applied force changes. Non-Newtonian fluids can be further divided into several categories, such as shear-thinning, shear-thickening, and time-dependent fluids. Examples of non-Newtonian fluids include blood, paint, and toothpaste. 5. Types of Rotational Viscometer There are several types of rotational viscometers, including coaxial cylinder viscometers, cone-and-plate viscometers, and rotating spindle viscometers. Each type of viscometer has its own advantages and limitations, and the selection of the appropriate viscometer will depend on the specific requirements of the measurement. 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Common types include coaxial cylinder, cone-and-plate, and rotating spindle viscometer. Setting the rotational speed: This should be set according to the appropriate procedures for the specific fluid. The rotational speed is chosen to ensure the fluid is subjected to the appropriate shear rate. Measuring the torque and angular velocity: This is done using a transducer or sensor. The relationship between these two quantities is crucial for determining viscosity. Calculating the viscosity: The viscosity is calculated using the rotational viscometer equation: $\eta = (\tau / \dot{\gamma})$ where η is the viscosity, τ is the shear stress, and $\dot{\gamma}$ is the shear rate. This equation is also known as the rotational viscometer formula.

4. **Data Analysis** The data obtained from the rotational viscometer diagram should be carefully analyzed for errors and outliers. Appropriate statistical methods are used to analyze the data, and the viscosity of the fluid can be calculated as a function of shear rate, temperature, or other relevant factors.

5. **Rotational Viscometer Calibration** Rotational viscometer calibration is crucial for ensuring accurate and consistent measurements. A properly calibrated viscometer is essential for reliable results. This can be achieved using appropriate calibration techniques, such as using a calibration fluid with a known viscosity or utilizing a viscometer with a built-in calibration system.

6. **Reporting Results** The results of the rotational viscometer measurements should be reported in a clear and concise manner. This includes providing the measured viscosity, the shear rate, the temperature, and any other relevant parameters. The results should be compared to the expected values to ensure the accuracy of the measurements.

7. **Advantages and Limitations** Rotational viscometers have several advantages and limitations. They are widely used in various industries to measure the viscosity of fluids due to their versatility and effectiveness. However, like any measurement technique, they come with their own set of advantages and limitations that must be considered when selecting the appropriate viscometer for a specific application. Let's explore the key advantages and limitations of rotational viscometers.

1. **Advantages of Rotational Viscometers** Versatility: Rotational viscometers are available in a wide range of configurations, including coaxial cylinder, cone-and-plate, and rotating spindle designs, which allow them to be used for measuring the viscosity of a diverse range of fluids, from low-viscosity liquids to high-viscosity materials. Precision and Accuracy: Rotational viscometers are capable of providing precise and accurate viscosity measurements, making them suitable for quality control, process optimization, and research applications. Shear Rate Control: Many rotational viscometer designs allow for the control and adjustment of the shear rate applied to the fluid, enabling the measurement of both Newtonian and non-Newtonian fluid behavior. Continuous Measurement: Rotational viscometers can provide continuous viscosity measurements, allowing for the monitoring of changes in fluid properties over time, which is particularly useful for process control and stability testing.

2. **Limitations of Rotational Viscometers** Sample Volume Requirements: Rotational viscometers typically require a minimum sample volume to ensure proper immersion of the rotating element, which can be a limitation for applications where sample volume is restricted. Maintenance and Calibration: Rotational

Researchers require regular maintenance and calibration to ensure accurate and reliable performance, which can add to the overall cost of ownership and operation. In conclusion, rotational viscometers offer a range of advantages that make them a popular choice for viscosity measurements in various industries. However, it is important to understand their limitations and to carefully consider the specific requirements of the application when selecting the appropriate viscometer for a given task. Back to top

D. Applications of Rotational Viscometers

Rotational viscometers have found widespread application across numerous industries due to their versatility, accuracy, and ability to provide valuable insights into the rheological properties of fluids. 1. Quality Control and Process Monitoring: Rotational viscometers are extensively used in quality control applications, where they play a crucial role in ensuring the consistency and stability of various products. In the food, cosmetic, and pharmaceutical industries, rotational viscometers are employed to monitor the viscosity of products throughout the manufacturing process, ensuring that the final product meets the required specifications. 2. Research and Development: Rotational viscometers are also widely used in research and development, particularly in the study of complex fluids and materials. They enable scientists to investigate the structure-property relationships and optimize their performance. 3. Lubricant and Fuel Testing: In the automotive and industrial machinery sectors, rotational viscometers are utilized to assess the viscosity characteristics of lubricants, greases, and fuels. This information is crucial for predicting the performance, efficiency, and lifetime of these critical components, helping to ensure proper lubrication, reduce wear and tear, and maintain optimal engine or machinery operation. 4. Coating and Ink Formulation: The viscosity of coatings, paints, and inks is a crucial parameter that determines their flow, spreadability, and application properties. Rotational viscometers are employed in the development and quality control of these materials, enabling formulators to optimize the viscosity for desired application characteristics, such as spraying, brushing, or printing. In the biomedical and pharmaceutical industries, rotational viscometers are used to characterize the rheological properties of various fluids, such as blood, synovial fluids, and drug formulations. This information is essential for understanding the behavior of these complex fluids in the human body and for the development of effective and safe pharmaceutical products. 6. Food and Beverage Processing: The food and beverage industry relies heavily on rotational viscometers to monitor the viscosity of a wide range of products, from sauces and dressings to fruit juices and dairy products. Maintaining the optimal viscosity is crucial for ensuring product quality, consistency, and shelf life. 7. Polymer and Composite Manufacturing: In the polymer and composite industries, rotational viscometers are used to monitor the viscosity of molten polymers and resin systems. This is essential for ensuring proper mixing, casting, and curing, which directly impacts the mechanical properties and performance of the final products. 8. Petrochemical and Refining: In the oil and gas industry, rotational viscometers are used to measure the viscosity of crude oil, refined petroleum products, and lubricants. This information is critical for optimizing refining processes, ensuring proper flow, and maintaining the performance of industrial machinery. 9. Environmental Monitoring: Rotational viscometers are also used in environmental monitoring applications, such as measuring the viscosity of water, wastewater, and various industrial effluents. This helps in assessing water quality, detecting leaks, and monitoring the performance of industrial processes. 10. Material Science and Engineering: Rotational viscometers are used in material science and engineering to study the rheological properties of various materials, including polymers, composites, and biological fluids. This information is essential for understanding the behavior of these materials under different conditions and for optimizing their performance in various applications. 11. Pharmaceutical Development: In the pharmaceutical industry, rotational viscometers are used to monitor the viscosity of various formulations, including injectables, emulsions, and suspensions. This is crucial for ensuring the stability, efficacy, and safety of the final product. 12. Food Safety and Quality Assurance: Rotational viscometers are used in food safety and quality assurance to monitor the viscosity of various food products, ensuring that they meet the required specifications and are safe for consumption. 13. Cosmetics and Personal Care: In the cosmetics and personal care industry, rotational viscometers are used to monitor the viscosity of various products, including lotions, creams, and shampoos. This is essential for ensuring the proper texture, spreadability, and performance of the final product. 14. Industrial Process Optimization: Rotational viscometers are used in industrial process optimization to monitor the viscosity of various fluids, ensuring that the process is running efficiently and producing high-quality products. 15. Research and Development in Materials Science: Rotational viscometers are used in research and development in materials science to study the rheological properties of various materials, including polymers, composites, and biological fluids. This information is essential for understanding the behavior of these materials under different conditions and for optimizing their performance in various applications. 16. Quality Control in Manufacturing: Rotational viscometers are used in quality control in manufacturing to monitor the viscosity of various products, ensuring that they meet the required specifications and are consistent in quality. 17. 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This information is essential for understanding the behavior of these polymers under different conditions and for optimizing their performance in various applications. 20. Quality Control in Chemical Manufacturing: Rotational viscometers are used in quality control in chemical manufacturing to monitor the viscosity of various products, ensuring that they meet the required specifications and are consistent in quality. 21. Research and Development in Biotechnology: Rotational viscometers are used in research and development in biotechnology to study the rheological properties of various biological fluids, including cell suspensions and tissue extracts. This information is essential for understanding the behavior of these fluids under different conditions and for optimizing their performance in various applications. 22. 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This information is essential for understanding the behavior of these materials under different conditions and for optimizing their performance in various applications. 28. Quality Control in Pharmaceutical Packaging: Rotational viscometers are used in quality control in pharmaceutical packaging to monitor the viscosity of various packaging materials, ensuring that they meet the required specifications and are consistent in quality. 29. Research and Development in Food Packaging: Rotational viscometers are used in research and development in food packaging to study the rheological properties of various packaging materials, including films and containers. This information is essential for understanding the behavior of these materials under different conditions and for optimizing their performance in various applications. 30. 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(c-26)/(n(6+1)-4)). Calibration is a key part of ensuring measurement accuracy, including trimment constant calibration and measurement process calibration. The calibration of the instrument needs to be carried out under constant temperature conditions with standard viscosity liquid to establish the torque-viscosity correspondence. The in-line calibration criteria need to be adjusted in real time in combination with process parameters (e.g., melt temperature, pressure). Modern smart viscometers have integrated automatic calibration functions, such as TOV viscometers with temperature/pressure double compensation and gain adjustment, which can control the measurement error in industrial fluids to less than 1%. Application and maintenance Rotational viscometers play a key role in industrial production. In the petroleum industry, it strictly follows the GBT 10247-2008 standard to test the viscosity of lubricating oil to ensure the lubrication performance of equipment. In the food and chemical industries, online viscometers are used to monitor the viscosity of products in real time, and to detect quality changes and adjust the process parameters accordingly. To ensure the accuracy of the measurement results, the instrument must be calibrated regularly and maintained properly. Calibration and maintenance: The instrument must be calibrated regularly and maintained properly. Calibration: The instrument must be calibrated regularly and maintained properly. Maintenance: The instrument must be calibrated regularly and maintained properly.

The article discusses the importance of rotational viscometers in various industries and provides detailed information about their application, maintenance, and calibration. It highlights the benefits of modern smart viscometers, such as automatic calibration functions and real-time monitoring capabilities. The article also emphasizes the need for regular calibration and maintenance to ensure accurate measurements and reliable operation.

Because they work with both Newtonian and non-Newtonian fluids, they are extremely versatile. Whether you're in R&D or routine quality control, understanding Rotational Viscometry 1. Shear Stress and Shear Rate These are the key concepts behind how viscosity is calculated. Shear stress is the force per area, and shear rate is how fast one fluid layer moves over another. Their ratio gives you viscosity: Viscosity (η) = Shear Stress (τ) / Shear Rate ($\dot{\gamma}$) Understanding this relationship allows you to assess how fluids respond under different processing or flow conditions. This is especially important in dynamic environments. 2. Newtonian vs Non-Newtonian Fluids Newtonian fluids have constant viscosity – like water or mineral oil. Non-Newtonian fluids change viscosity when stirred or stressed, like ketchup or paint. This matters when choosing your spindle and speed settings. Accurate viscosity classification helps ensure product performance stays consistent under real-world viscometer types: Spring-type: Uses a spring to measure deflection. Simple, affordable, and common in quality control. Servo-motor type: Feedback controls spindle speed and wider range of viscosity measurements. Coaxial cylinder: Concentric cylinders rotate relative to each other. Good for low viscosity fluids. Cone and plate: A flat cone rotates against a curved plate. Excellent for very low viscosity fluids, like oils. If you're selecting your first instrument, explore our rotational viscometer collection to compare configurations. Inside a Rotational Viscometer: Key Components - Spindle: The part that rotates in the sample. Available in disk, cone, cylinder, or vane shapes. - Motor: Controls speed and applies torque. - Torque Sensor: Measures resistance to rotation. - Temperature Control: Maintains consistent sample temperature, which is critical for accurate results. High-performance systems like those from Qualitest, as Rotational Viscometers supplier are designed for reliable, repeatable measurements, even under challenging conditions. Choosing the Right Spindle and Torque Model Rotational viscometers often use one of three torque model types: - L-model (Low): For low-viscosity fluids like solvents and juice. - R-model (Regular): For medium-viscosity materials like creams and paint. - H-model (High): For thick substances like peanut butter or ointments. Spindle size and speed also matter. Use a larger spindle and higher speed for thinner fluids. For thick materials, go with a smaller spindle and slower rotation. Need help matching spindle to application? Check out our viscometer product specs for compatible ranges and sample types. How to Perform a Viscosity Test (Step-by-Step) 1. Prepare your sample, make sure it's free from bubbles or clumps. 2. Select the spindle and speed based on expected viscosity. 3. Insert the spindle slowly to avoid trapping air. 4. Wait for the measurement to stabilize. 5. Start the measurement and watch for stable torque readings. 6. Record results once the reading is consistent. Tip: Keep torque between 10% and 100% of full-scale range (FSR) for valid results. Calibration & Standards Rotational viscometers require regular calibration to ensure accuracy. Our instruments are factory-calibrated and meet international standards. We provide comprehensive training and support to ensure you get the most out of your investment. Applications of Rotational Viscometers a. Food & Beverage: Monitor sauce texture or creaminess. b. Pharmaceuticals: Measure consistency in gels and suspensions. c. Cosmetics: Ensure lotions spread properly. d. Paints & Coatings: Control flow and finish. e. Lubricants: Confirm proper engine or machinery performance. Our instruments are widely trusted across these sectors for their reliability and ease of use. Learn more about our full selection at Qualitest. How to Select the Right Viscometer Ask yourself: 1. What viscosity range am I measuring? 2. Do I need precise shear control or basic readings? 3. Will the sample be tested in a lab, field, or inline? 4. Is the fluid temperature-sensitive? 5. How much sample volume do I have? Answering these helps match your needs with the right model. At Qualitest, we offer state-of-the-art materials testing and quality control instruments with the highest spec-to-price ratio. If you can find a similarly featured product at a lower price, let us know. Conclusion A rotational viscometer helps you control

product performance and production consistency. When you choose the right type, set it up correctly, and follow a solid procedure, you'll get data you can trust. Whether you're making yogurt, paint, or pills — viscosity matters. Ready to find the right instrument for your needs? Keep this guide handy and revisit it whenever your testing requirements change. Or explore Qualitest's rotational viscometers for dependable, user-friendly solutions built for your lab or factory floor. Although there are two setups available to measure viscosity with a rotational viscometer – spring-type instruments and servo motor instruments – we only cover spring-type instruments here. How do these work? The rotation of the spindle deflects a spring. Optical sensors detect the deflection and the viscosity of the sample is then calculated from it.[2] The test sequence is the following: The user attaches a spindle to the rotational viscometer, sets a speed, and receives the dynamic viscosity and the torque (mostly in %). The resulting driving torque depends on the rotational speed ω , the spindle geometry, and the sample viscosity. In case of low-viscosity substances, the spring needs to be sufficiently sensitive, whereas for samples in the high-viscosity range, a more robust spring is required. Different instrument models are available that have different spring types to cover a broad range of applications. There are three different rotational viscometer models: Spring type to measure low-viscosity samples ("L-type") Spring type to measure medium (regular)-viscosity samples ("R-type") Spring type to measure high-viscosity substances ("H-type") There are two types of spring-type viscometers:[3] Dial reading: The torque value in % is shown by the pointer on the dial. To convert the torque % reading to viscosity in mPa·s, the dial reading has to be multiplied by the appropriate factor for the spindle and speed in use (Equation 1). Equation 1: Formula for the calculation of the apparent viscosity if using a dial reading instrument. Digital reading: The viscosity is automatically calculated and displayed on a screen for every spindle/speed combination. There are no further calculations necessary. Viscosity measurement is important for various liquid and semi-solid materials we know from daily life (Figure 1). You can use a spring-type rotational viscometer for countless applications in various industries, particularly the chemical, petrochemical, food, beverage, personal care, and pharmaceutical ones. Figure 1: Samples with increasing viscosity. Viscosity measurement from low-viscosity to high-viscosity liquids is possible with spring-type rotational viscometers. Depending on the viscosity of the sample, you need to use a certain instrument with the accurate torque range (Table 1). The L-model is suited for the measurement of low-viscosity samples, such as solvents, oils, juices, ink, and mouthwash. The R-model is suited for the measurement of medium-viscosity samples, such as paints, coatings, adhesives, and dairy products. The H-model is suited for the measurement of high-viscosity samples, such as mayonnaise, peanut butter, pastes, and ointments. Table 1: Overview of torque models and their typical applications Chemicals & petrochemicals Food & beverage Pharma & cosmetics Application Torque Application Torque Application Torque Solvents, inks L Juices L Mouthwash L Oils, lubricating oils L Dairy R Shower liquid L Liquid wax L Dressing, sauces R Shampoo, lotion, cream R Paints, coatings R Blancmange, vanilla sauce R Detergents R Adhesives, epoxies R Chocolate and cocoa products H Ointments, gels H For each torque model, different spindles exist so that samples with different viscosities can be measured. Usually, interchangeable spindles in the form of disks and cylinders are used. They are fixed on the coupling of the instrument. For a given viscosity, the flow resistance is related to the spindle's speed of rotation and its shape and size. The flow resistance increases with the speed and size of the spindle. What does that mean? The lowest viscosity range can be covered by measuring with the biggest spindle at maximum speed. The highest viscosity range can be covered by measuring with the smallest spindle at the lowest speed. For a better reproducibility, you should use the same spindle/speed combination for multiple tests.[4] The maximum measurable viscosity of the spindle at a given speed is called the full-scale range (FSR).[5] In other words, the FSR is the maximum viscosity that can be measured with the chosen spindle/speed combination. The minimum viscosity that can be measured is one tenth of the full-scale range. By knowing the FSR of the spindle/speed combination, you can determine whether that spindle/speed combination fits to the viscosity of the sample. If the viscosity of the sample is unknown, the viscosity is tested by taking the smallest spindle first and replacing it in ascending order by the next largest spindle until a valid measurement result is achieved. To obtain a valid measurement, the torque value must be between 10 % and 100 %.[6] If the torque value is higher than 100 %, you need to use a smaller spindle. If the torque value is lower than 10 %, you need to use a bigger spindle. The higher the torque value, the better the accuracy – since the accuracy of the measuring system depends on the full-scale range (usually 1 % of FSR). An overview of typical available spindle types for rotational viscometers is shown in table 2. Spindle Absolute / relative Defined gap / shear-rate calculation Sample types Particles Sample volume Temperature equilibration Cleaning Liquid bath Peltier-tempered Standard Relative No Liquids

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