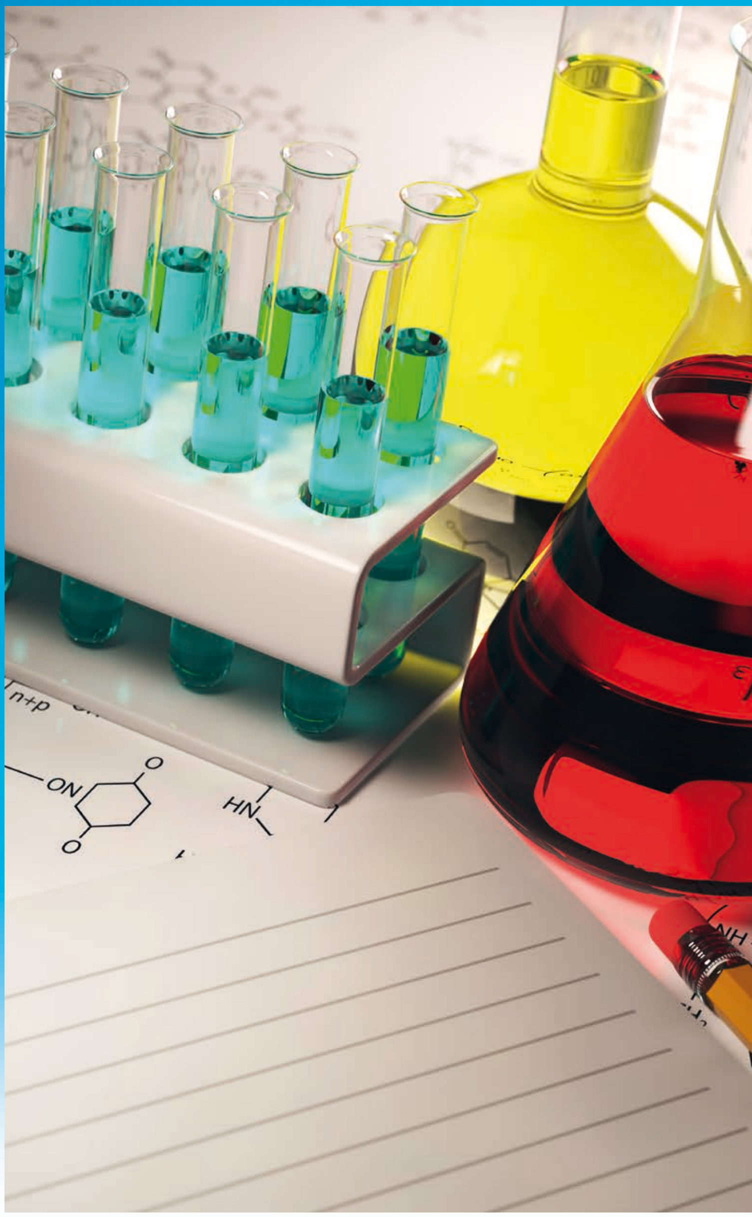
Density2Go



Hydrometers
Pycnometers
Digital Hydrometers

3 Ways to Measure Density

Know-How, Hints, and More

METTLER TOLEDO

Content

1. Introduction

The density of a substance provides information on its mass per unit volume: in other words, how tightly a substance's molecules are packed together.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

A beaker filled with water will weigh considerably less when compared to a beaker filled with mercury, a denser substance. Density is a physical property and is used as a unique identifier that allows users to monitor the quality of their products and their processes. For example, the density of water at 20 °C is known to be 0.998 g/cm^3: any deviation from this value would imply that the water sample contains impurities.

The use of hydrometers, pycnometers, and digital hydrometers are officially recognized for the density determination of liquids. They are used in quality and process control, where precise methods are needed and the recording of information such as date, calibration, and temperature are typically required.

This guide explains each measurement method and gives you additional information on how to achieve maximum accuracy with an optimized workflow.

2. Hydrometer

A hydrometer is an inexpensive instrument used to determine the density of liquids (see Figure 1). Made of blown glass, it consists of a bulbous bottom weighted with lead or steel shot and a long, narrow stem with a scale. The hydrometer is immersed into the sample liquid until it floats, and the density reading is taken by looking at the scale, where the level of the sample liquid aligns with a marking on the hydrometer scale.

Figure 1: Hydrometer.

Most hydrometers measure the specific gravity of samples: that is, the ratio of the density of a liquid sample to the density of water. In simple terms, a hydrometer tells the user if a liquid is more or less dense than water. It will float higher in a liquid with a greater density – such as one with sugar dissolved in it – compared to one with a lower density, such as water or alcohol.

Density and specific gravity are dependent on the surrounding temperature. When using a hydrometer, the user has two possibilities:

1. Use the hydrometer at its calibration temperature (usually 16 °C or 20 °C). However, depending on the sample volume, it can take some time for the sample to reach this temperature.
2. Simply record the measurement value at the surrounding temperature. Both measurement and temperature value have to be recorded. If needed, a correction factor can be applied later to obtain the temperature-corrected measurement value.

Because hydrometers are used in different industries, a variety of hydrometer scales exist [1]. For example, a juice or wine producer who is interested in the sugar content of their beverages might use a Brix hydrometer. On the other hand, a crude oil producer has no interest in determining sugar content: instead, they are more concerned with the API (American Petroleum Institute) gravity of their petroleum product, because it can give information on product composition and thus, appropriate storage and handling measures [2]. These crude oil producers would most likely use an API hydrometer to ensure quality of their products. Other typical hydrometer scales include Baumé and alcohol.

2.1 How to choose a hydrometer

There are several factors involved in choosing a suitable hydrometer:

- **Hydrometer scale:** Hydrometers can measure specific gravity, Brix, and more. Based on the sample, the user will need to know which scale fits their purposes.
- **Hydrometer measurement range:** Hydrometers are offered at specific measuring ranges, for example, a specific gravity range of 1.999 to 1.220. The user needs to know the expected value of their product and choose a range based on this.
- **Sample volume:** Hydrometers require a large sample volume ranging from 140–600 mL, making it less suitable for precious or toxic samples.
- **Calibration temperature:** Because the density of liquids changes with temperature, hydrometers are calibrated at specific temperatures, usually either 16 °C or 20 °C. Hydrometers are intended to be used at their respective calibration temperatures. However, because most measurements are taken at room temperature, a calculation is used to derive the correct density value. Many hydrometers come with a table that provides the appropriate correction factor at different temperatures.
- **Level of user training:** Although simple to use, the hydrometer requires basic user training. Users must be taught how to properly read the scale (should be read at the bottom of the meniscus) as well as the thermometer.
- **Whether it fits into the test cylinder:** The hydrometer is inserted into a test cylinder containing the sample of interest; therefore, it is important that it fits into the test cylinder and can float freely without touching the cylinder walls.

2.2 How to use your hydrometer

1. Sanitize the hydrometer and test cylinder.
2. Place the test cylinder on a flat, level surface. Placing it at eye-level will ensure the most accurate readings.
3. Fill the test cylinder with enough liquid to ensure the hydrometer will float.
4. Immerse the hydrometer into the test cylinder:
   - Spin it slowly, especially for viscous samples: This prevents bubbles from sticking to the bottom. of the hydrometer, which may affect readings.
   - Ensure the hydrometer is not touching the sides of the test cylinder and that it is floating in the sample liquid.
5. Take a reading by looking at the point where the level of the sample liquid aligns with the hydrometer scale. It is important to do so at eye level to ensure an accurate reading.

2.3 Calibration

Due to the measurement process, the glass hydrometer may corrode over time. This is caused by constant immersion in liquid samples normal cleaning and handling, and the natural aging process of glass. These processes wear down the hydrometer and result in small changes to its original dimensions. Despite not being visible to the naked eye, these changes may still affect the weight and displacement of the hydrometer.

Therefore, periodic calibration checks of the hydrometer are recommended to assure accurate results and traceability to international standards, as well as to comply with any internal requirements [3; 4]. Fortunately, one- and two-point calibration checks are simple and quick, and involve the use of samples with known specific gravities.

One-point calibration checks typically involve the use of distilled water, which has a known specific gravity of 1.000. If a hydrometer has been correctly calibrated, floating it in distilled water will give a specific gravity reading of 1.000 at the calibration temperature. If the hydrometer reads higher or lower, add or subtract the amount of error from your sample readings.

For example, if the hydrometer reads the specific gravity of distilled water as 1.001 at its reference temperature, simply add 0.001 to future sample readings. To check that the hydrometer reads correctly in its range and scale of use, a two-point calibration check is recommended: this ensures that the markings on the hydrometer scale are not too close or far apart. This time, dissolving a known mass of solute, such as sugar, in a defined mass of solvent, such as water is recommended [5; 6]. For example, dissolving 10 g of sugar in 90 g of water should yield a solution with a specific gravity of 1.040.

Ideally, the measurement of this second point will be off from its target by the same amount as the first point: using the example above with the expected deviation of 0.001 for all readings, this would mean that if target value of the second reading was 1.050, then the expected reading should be 1.051.

If the deviation of the second reading differs from the deviation of the first, then the user must calculate and apply a point-slope correction to all subsequent readings with the hydrometer. Often, when a calibration check produces unexpected results, the simplest solution is replacement of the hydrometer.

2.4 Tips and hints

Typically made of glass, hydrometers are fragile and can break easily. A protective case is recommended to store the hydrometer.

Furthermore, results must be accurate to be trustworthy, and the accuracy of a hydrometer depends on three main factors [1]:

- Cleanliness: After each use, the hydrometer and test cylinder must be cleaned thoroughly using an appropriate cleaning solvent. This ensures that the surface and stem of the hydrometer are free of any film or buildup from previous sample that readings remain accurate.
- Temperature stabilization: Because specific gravity is dependent on the surrounding temperature, the hydrometer and sample liquid should be at the same temperature. This prevents inaccurate readings.
- Immersion: The test cylinder should have an inside diameter approximately 25 mm greater than the outside diameter of the hydrometer. This ensures that the hydrometer can float properly in the sample liquid without touching the test cylinder walls.

The hydrometer method is generally a suitable choice for viscous samples, as its cylindrical shape makes it easy to clean after the measurement.

Summarized in the table below are several important points when considering measurement with a hydrometer:

Suitable sample types	Viscous, non-viscous, non-toxic
Level of user training required	Medium
Single measurement cycle duration	10–30 minutes
Accuracy	0.01 to 0.001 g/cm^3 depending on hydrometer

2.5 Relevant standards and norms

Norm	Description	Applicable Industries
ASTM D287	Standard Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)	Petrochemical
ASTM D1429	Standard Test Method for Specific Gravity of Water and Brine	All
ISO 387	Hydrometers – Principles of construction and adjustment	All
ISO 649	Laboratory glassware – Density hydrometers for general purposes	All

3. Pycnometer

Typically made of glass, a pycnometer (see Figure 2) is a flask of a pre-defined volume used to measure the density of a liquid. It can also be used to determine the density of dispersions, solids, and even gases. Pycnometers can be a very precise method when performed correctly, with accuracy up to 10^{-5} g/cm^3 – this correlates to the accuracy (number of decimal places) of the digital balance used. A thermometer is also required to measure the temperature. User training is required to guarantee accurate measurements with the pycnometer.

Figure 2: Pycnometer.

In this guide, we will focus on measurement of liquids using a pycnometer. Essentially, glass pycnometers measure the unknown mass of a liquid – this mass is then divided by the known volume of the pycnometer to determine the density of a liquid:

$$\text{Density} = \frac{(M2\text{–}M1)}{\text{Flask Volume}}$$

where M1 is the weight of the glass pycnometer without a sample, and M2 is the weight of the glass pycnometer with the sample.

Density is dependent on temperature. During measurement, the pycnometer and sample liquid should be kept at the calibration temperature (delivered on the certificate with the pycnometer): this requires temperature stabilization of the sample and can take a long time. Furthermore, no air should be trapped in the liquid, as this may affect the measurement.

3.1 How to choose a pycnometer

There are several factors involved in choosing a suitable pycnometer [7; 8]:

- **Measurement scale:** The pycnometer allows for accurate density measurements. If another measurement scale such as Brix or % alcohol is needed, the user must consult a concentration table: with this, the user can look up the density value obtained during the measurement and its corresponding value on the measurement scale of interest.
- **Sample volume:** Pycnometers are available in different sizes, ranging from 10–250 mL. If you are working with a precious or toxic sample, purchasing a pycnometer of small volume is recommended.
- **Thermometer accuracy:** Some pycnometers are delivered with thermometers; other times, a thermometer must be purchased separately. Each thermometer has a certain scale and accuracy, and using a thermometer with a wide margin of error may result in measurements that are outside the required accuracy.
- **Level of user training:** To ensure accurate measurements, the pycnometer must be filled properly and be allowed to equilibrate to its calibration temperature: it is a precise method that is affected by minute details and can take a long time. Proper filling and use requires extensive user training.
- **Calibration temperature:** Because the density and volume of liquids change with temperature, pycnometers are calibrated at specific temperatures and are intended to be used at these temperatures: this results in long measurement times as the pycnometer and sample must be brought to the calibration temperature. Measurement outside this temperature requires knowledge of the volume expansion coefficient of the sample liquid. In general, no correction is necessary if the temperature stays within ±0.5 °C of the calibration temperature.
- **Standard compliance:** Different pycnometers are available for compliance with specific standards and norms, which often list the required pycnometer volume and temperature range.

The accuracy of measurements directly correlates with the accuracy (number of decimal places) of the digital balance used: a digital balance with an accuracy of 0.0001 g is more accurate than one with an accuracy of 0.01 g.

3.2 How to use your pycnometer

1. The flask volume is known (delivered with each newly-purchased pycnometer).
2. Place the empty pycnometer on a balance. Measure its weight (M1).
3. Rinse the pycnometer 1–3 times with the sample liquid to ensure only the sample of interest is measured.
4. Fill the pycnometer with the sample liquid.
5. Insert the glass stopper so that any excess fluid flows out of the narrow orifice in the stopper.
6. If there are air bubbles in the stopper, repeat steps 3–4 until no air bubbles are present.
7. Place the pycnometer in a thermostatic bath at the pycnometer's calibration temperature. Allow the sample liquid temperature to reach the pycnometer's calibration temperature.
8. Take the pycnometer out of the thermostatic bath.
9. Dry the exterior of the pycnometer using a paper towel or cloth, ensuring that it is completely dry.
10. Determine the weight of the filled pycnometer (M2).
11. Calculate the density of the sample liquid using the following equation:

$$\text{Density} = \frac{(M2-M1)}{\text{Flask Volume}}$$

To calculate another scale, a concentration table with values corresponding to specific densities and temperatures is required.

3.3 Calibration

The calculation of the density of a sample liquid is highly dependent on the volume of the pycnometer. The purpose of a calibration check, or a verification, is to ensure that no shift in the certified volume of the pycnometer has occurred. The test should be performed when there is doubt about the accuracy of the certified values. The simplest way to check a pycnometer calibration is to fill it with a known liquid, such as distilled water. Then follow the directions as outlined in the section "How to use your pycnometer" above to verify the volume of your pycnometer.

3.4 Tips and hints

The pycnometer can be used for samples of a small quantity (10 mL), though they are also available in larger volumes (around 250 mL). Because of the way the pycnometer is constructed, only a small surface area of the sample liquid is exposed to the air – this prevents evaporation of the sample, as well as absorption of moisture from the surrounding air – making the pycnometer a suitable choice for precious or toxic samples, especially in comparison to the hydrometer.

Summarized in the table below are several important points when considering measurement with a pycnometer:

Suitable sample types	Viscous, non-viscous, toxic, non-toxic
Level of user training required	High
Single measurement cycle duration	30–60 minutes
Accuracy	Up to 0.00001 g/cm³ depending on balance used

3.5 Relevant standards and norms

Norm	Description	Applicable Industries
ASTM D1429	Standard Test Method for Specific Gravity of Water and Brine	All
DIN ISO 3507	Laboratory glassware - Pycnometers	All
OIML G 14	Density measurement	All

4. Digital hydrometer

Handheld digital hydrometers, or digital density meters, are used to determine the density of liquids quickly and automatically. Density determination using digital meters is based on two factors:

1. The oscillation, or vibration, of a U-shaped glass tube (U-tube).
2. The relationship between the liquid sample mass and the frequency of oscillation of the U-tube.

Filling the U-tube with sample liquid affects its frequency of oscillation: due to factory adjustment with samples of known densities, this frequency of oscillation can be directly correlated with the density of any liquid sample with an accuracy of 0.001 g/cm^3.

Handheld digital density meters measure the sample at ambient temperature. If a result is needed at a certain temperature, the digital density meter can also apply a correction factor to the measured result to compensate the result to a defined temperature [9]. Each measurement takes only a few seconds, allowing users to move on to the next sample.

Figure 3: A digital hydro-meter. In this case, the METTLER TOLEDO Density2Go instrument.

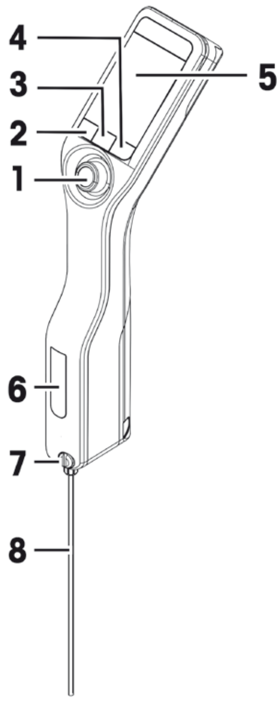
4.1 How to choose a digital hydrometer

There are several factors involved in choosing a suitable digital density meter:

- **Digital density meter scale:** Digital density meters offer a wide range of measurement scales in the same instrument. Scales offered include density, Brix, % alcohol, API gravity, and many more – including user-defined concentration units. The user does not need to calculate any results or look up values in a concentration table, as the instrument performs the calculation automatically.
- **Digital density meter measurement range:** Digital density meters cover a wide density range (0–3 g/cm^3). Normally, only one digital density meter is required to cover the sample measurement range.
- **Sample volume:** Digital density meters require a sample volume of 2–5 mL, making them suitable for precious samples. Because the sampling tube can be dipped directly into the sample, use of a digital density meter minimizes direct user contact with the sample, making it especially suitable for measurement of toxic samples.
- **Level of user training:** Digital density meters are easy to use, and menus are self-explanatory. Density meters such as METTLER TOLEDO's Density2Go line provides onscreen directions that guide the user through each step, minimizing the need for user training.
- **GLP compliance:** For companies that follow Good Laboratory Practice (GLP), raw data and results must be documented. Many digital density meters offer method and results storage, as well as the possibility to print or export results to the PC.
- **Barcode and RFID reader:** Users can scan in the sample ID using barcodes or RFID tags: this allows quick identification of the sample, and the user can measure the sample directly after. METTLER TOLEDO's DensitoPro model comes with a built-in barcode and RFID reader for this purpose.

4.2 How to use your digital hydrometer

In this section, we will refer to the use of a METTLER TOLEDO Density2Go handheld density meter:



1. Ensure that the U-tube of the Density2Go handheld density meter is clean by checking the measurement cell window (6).
2. Immerse the filling tube (8) into the sample liquid.
3. Tip up on the joystick (1). The U-tube will fill with the sample liquid automatically.
4. Tip down on the joystick to empty the sample into the waste beaker. The U-tube will empty the sample liquid automatically.
5. Perform steps 3–4 one more time to rinse the cell again. This ensures that only the sample of interest will be measured.
6. Tip up on the joystick again to fill the U-tube with sample liquid.
7. With the sample in the U-tube, press the "OK" key to start the measurement.
   - The sample temperature is detected simultaneously
   - If a temperature correction is needed, the instrument will apply the correction factor automatically
8. Tip down on the joystick to empty the sample into the waste beaker.

4.3 Calibration

To verify that the adjustment of the digital density meter is correct, METTLER TOLEDO Density2Go handheld density meters offers a simple, built-in test method on the instrument. In this test method, expected values of known reference standards can be stored: this makes it quick and easy for users to verify their adjustment values.

If a test with a known standard passes, the screen will flash green, signifying that the cell is clean and the adjustment is correct.

If a test with a known standard fails, the screen will flash red. If this happens, check if the correct standard has been used, and if needed, repeat the test with the correct standard. If the test continues to fail, the most likely cause is improper or insufficient cleaning of the U-tube, resulting in leftover sample remaining in the cell. In this case, the following steps are recommended:

1. Clean the U-tube with an appropriate solvent. It may be necessary to clean the U-tube multiple times to ensure all sample is removed.
2. Perform the test again.

If the test continues to fail, repeat the test twice and compare all three results. If the results are not the same, clean the measuring cell and perform tests until the test passes or the results of three consecutive tests are the same. If the test continues to fail and the results of three consecutive tests are the same, restore the factory adjustment data and repeat the test.

4.4 Tips and hints

Digital density meters offer a quick, accurate way to perform density measurements with minimal user training: measurements can be performed within minutes, and results are operator-independent.

To ensure accurate results, the following is recommended:

- Periodic calibration checks.
- Filling the U-tube two times before measurement ensures that only the sample of interest is measured.
- When measuring two completely different samples, such as juice and petroleum, the user should rinse with a solvent before moving on to the next sample.
- When measuring two similar samples, such as two different types of juice, rinsing with a solvent before moving on to the next sample is not necessary.

Because the U-tube always contains residue from the last sample, there is a risk that the U-tube can be damaged by the sample. To prevent such damages, the following is recommended to ensure longevity of the U-tube and the instrument:

- Clean the U-tube at the end of each sample series with a cleaning solvent that dissolves the sample.
- Ensure that the cleaning solvent can be dissolved in water.
- If the cleaning solvent cannot be dissolved in water, the use of alcohol as a cleaning solvent is recommended.
- After use of the cleaning solvent, flush the U-tube three times with water.
  - This step ensures that only water (instead of chemicals) remain in the U-tube.

Summarized in the table below are several important points when considering measurement with a digital density meter:

Suitable sample types	Viscous, non-viscous, toxic, non-toxic
Level of user training required	Low
Single measurement cycle duration	1–3 minutes
Accuracy	0.001 g/cm^3

4.5 Relevant standards and norms

Norm	Description	Applicable Industries
ASTM D7777	Density, Relative Density, or API Gravity of Liquid Petroleum by Portable Digital Density Meter	Petrochemical
IP 559	Determination of density of middle distillate fuels – Hand held oscillating U-tube density meter method	Petrochemical
ISO 15212	Oscillation-type density meters	All

5. Which method is best for me?

To understand which method will best suit your purposes, let's first summarize each measurement method, including their strengths and their weaknesses:

Hydrometers	Measuring principle	Strengths	Weaknesses
	• Glass body inserted into sample • Glass body floats at a certain level due to buoyancy and mass of hydrometer, dependent on sample density • Level of equilibration gives the density on the calibrated scale	• Simple, inexpensive • Used for a quick check of an approximate density value	• User-dependent results • Takes a long time to equilibrate the temperature • Small measuring range (typically takes 20 hydrometers to cover a wide range) • Large sample volume required (140 mL to 600 mL) • Difficult to clean • Not suitable for GLP • Breakable • Sample must be removed from sample container and poured into the hydrometer

Pycnometers	Measuring principle	Strengths	Weaknesses
	• Glass beaker of defined volume • Weighed without sample (M1), then with a sample (M2) • Density calculated based on the following formula: $\text{Density} = \frac{(M2 - M1)}{\text{Flask Volume}}$	• Inexpensive • Directly related to the definition of density (mass divided by volume): ideal for academia/education	• User-dependent results • Pycnometers are calibrated for a certain temperature, e.g. 20 °C, so measurements are only valid at that temperature! Sample must be equilibrated to the calibration temperature. • Density must be calculated • Typical sample volume required is 25 mL • High level of user training required to ensure accurate, trustworthy measurements • Sample must be removed from sample container and added to pycnometer

Digital hydrometer	Measuring principle	Strengths	Weaknesses
	• Oscillating U-tube	• Easy to use • Small sample volume • Automatic measurement means results are operator-independent • Built-in temperature compensation • Offers storage of up to 1100 results and the possibility to connect to PC software for data management • Sample can be measured directly from the sample container	• More expensive in comparison to hydrometers or pycnometers

Depending on your sample of interest as well as the accuracy and ease of use and accuracy required for the measurement, you may arrive at a different recommended technique. Please refer to the table below which technique would best suit your needs:

	Which sample types are suitable?	**Minimum sample volume required**	**Instrument accuracy**	**Does the instrument comply with GLP?**	**Which measurement scales does the instrument offer?**	**Level of user training required**	**Approximate time taken for a single measurement cycle**
Hydrometer	Viscous Non-viscous Nontoxic	140–600 mL	0.01 to 0.001 g/cm^3 depending on hydrometer	No	Density Specific Gravity Brix Ethanol (Alcohol)	Medium	10–30 minutes
Pycnometer	Non-viscous Toxic Precious	10–250 mL	Up to 0.00001 g/cm^3 depending on balance used	No	Density	High	30–60 minutes
Digital hydrometer	Viscous Non-viscous Toxic Precious	2–5 mL	0.001 g/cm^3	Yes	Density Specific Gravity Ethanol (Alcohol) Brix API Baumé H_2SO_4 Plato Proof (US and IP) User-defined concentration	Low	1–3 minutes

6. Works cited

1. W.W. Grainger, Inc. How to Use a Hydrometer. [Online] [Cited: February 10, 2018.] https://www.grainger.com/content/supplylink-how-to-use-hydrometer.

2. American Society for Testing and Materials. ASTM D287-12b, Standard Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method). www.astm.org. [Online] 2012. [Cited: February 10, 2018.] https://www.astm.org/Standards/D287.htm. ASTM D287.

3. Robinson, Allan. Hydrometer Calibration Procedures. Sciencing. [Online] April 24, 2017. [Cited: February 10, 2018.] https://sciencing.com/hydrometer-calibration-procedures-5501425.html.

4. Calibration of hydrometers. Lorefice, Salvatore and Malengo, Andrea. 17, Torino, Italy : Institute of Physics Publishing, August 25, 2006, Measurement Science and Technology, pp. 2560–2566.

5. Colby, Charles. Calibrate Your Hydrometer and Fermenter. Brew Your Own. [Online] [Cited: February 10, 2018.] https://byo.com/article/calibrate-your-hydrometer-and-fermenter-techniques/.

6. Goldman, Jester. Calibrating Your Hydrometer. Craft Beer & Brewing Magazine. [Online] December 2, 2016. [Cited: February 10, 2018.] https://beerandbrewing.com/calibrating-your-hydrometer/.

7. Engineering360. Pycnometers Information. Engineering360. [Online] [Cited: February 12, 2018.] https://www.globalspec.com/learnmore/sensors_transducers_detectors/density_specific_gravity_sensing/pycnometers.

8. Density measurement. International Organization of Legal Metrology. Paris, France : s.n., 2011. OIML G 14.

9. American Society for Testing and Materials. Standard Test Method for Density, Relative Density, or API Gravity of Liquid Petroleum by Portable Digital Density Meter. West Conshohocken, PA : s.n., 2012. ASTM D7777.

Good Measuring Practices
Five Steps to Improved Measuring Results

The five steps of all Good Measuring Practices guidelines start with an evaluation of the measuring needs of your processes and their associated risks. Using this information, Good Measuring Practices provide straight forward recommendations for selecting, installing, calibrating and operating laboratory equipment and devices.

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