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μFM-TOP™ Microflows Meter
Manual and Automatic Models

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μFM-TOP™ Microflows Meter
Manual Model

μFM-TOP™ Microflows Meter
Auto Model with dual sensors

The μFM-TOP™ (later in the text as μFM-TOP) Microflows Meter is a novel instrument designed for measurements of very low flow rates of fluids, from few mL/min to well below μL/min range. The minimum flow rate is limited only by the time allowed. Although the main purpose is determination of gas flow rates, flow rates of many liquids compatible with the used construction materials can be measured as well.

In principle, the flow rate measurement is similar to the well-known soap bubble flowmeter with several exceptions. A thick borosilicate glass capillary tube is being used instead of a typical glass tube of relatively large internal diameter. When the diameter of the glass tube gets sufficiently small, then it is no longer possible to form a film but rather a short column of liquid. Since for very small flow rates the method of generating of a liquid film in a typical bubble soap meter by squeezing the rubber bulb is not quite doable, a different approach has been employed to overcome this problem and other limitations. The characteristic feature of a soap bubble flowmeter is that the film is formed at the bottom and it travel upward during measurements but in this design, the short column of liquid is formed at the top and it travels downward. A typical soap bubble flowmeter is usually open to atmosphere and does not has any valves. The µFM-TOP can be envisioned as a three valve system, two at the top and one at the bottom.

Two specially designed upper and lower adapters attach the glass capillary to the stand vertical column. The upper adapter has the gas input port, on/off ball (shutoff) valve, and the top valve in form of a lever to access the top of the capillary. The lower adapter also has a movable lever that allows for temporary blocking of flow at the bottom of the glass tube. When the on/off ball valve and the upper lever are opened and the lower lever is closing the glass tube output, the user can apply a drop of liquid to the conically shaped upper end of the glass tube. The on/off valve should be held in the opened position before the upper lever is being closed. Simultaneous closing of the on/off valve and opening of the lower lever allows the gas to flow through the capillary. The progress of flow can be observed visually when the formed column of liquid is moving downward. The flow rate is determined by measurement of time that front of the formed liquid column passes through a certain distance.

Various glass (or plastic) tubes can be used with different internal diameters. The tubes do not need to have any scale imprinted on them, as there is a precision metal ruler in mm units attached to the stand. The dual scale ruler is scaled in mm and in 0.5 mm increments. Two movable blocks, which are attached to the stand, are used to facilitate determination of the start and end distance for the falling column of liquid. Basically, they help transferring the position of the meniscus from the liquid to the ruler to obtain better accuracy of the distance readings. For low flow rates, a height gauge can be utilized if higher resolution is required.

Knowing the internal diameter **d [mm]** of the capillary, the distance **h [mm]** traveled by the column of water, and the time **t [min]** of the passage, it is trivial to determine the flow rate **f [mL/min]**.

$$f\,[mL/min] = \frac{\pi \cdot d^2 \cdot h}{4000 \cdot t}$$

There are two main versions of the meter, manual and automatic. The manual version, like a typical bubble soap meter, requires attention of the user in determining the start and end of the time of passage through a certain distance and subsequently calculating the rate. If the bubble or liquid column traverse at a moderate speed, it is easy to use a timer. However, when the liquid moves through a certain distance for many minutes or hours, then the determination of start and stop time may not be so accurate. The far more convenient solution is to determine the time electronically in an automated fashion.

To achieve the automated operation, the proprietary design of optical sensor was undertaken. The sensor is housed in the self-centering holder, which can be moved along the glass tube and held in place. Its position can be read on the precision ruler attached next to it with the help of a bit different design of the moving block for easier readout of the position. There are two such sensor assemblies in the regular μFM-TOP Microflows Meter, the upper and lower, as shown on the above photo. In special versions, quadruple sensors can be used. The overall operation of liquid column forming is the same as in the manual version.

In the auto versions, the user needs to enter the height location of the sensors among other parameters or use the same experiment definition template if there there no changes. The signals from the sensors are processed by electronics and transferred to personal computer via USB port. The provided PC software (any Microsoft Windows OS) processes the received information, calculates time of passage, flow rate(s), displays the results on screen, and records the results in text format.

The main objective of the design was to enable flow rate measurements well below the range that is offered by other electronic and manual devices. One very important advantage here is that this meter does not need any significant overpressures like they are common in low-flow mass flow controllers, micro-machined or on-chip devices. This is advantageous in many biological processes. The pressure differential for driving the gas flow is on the level of Pascal(s) (standard atmospheric pressure = 101 325 Pa), and this would be quite challenging to achieve otherwise. The cost of the equipment is below the sophisticated flow/mass measurement setups.

Due to the very low flow rates capabilities, measurements of gas permeability through "tough" samples can be attempted at much lower pressures. For example, for measurements of gas permeability through rock-core samples, the high pressure chambers, like Hassler cells might not be necessary to be used. Study of gas transport rates through membranes or determination of leak rates from devices under pressure are the main areas of applications. Since the liquid column can also move upward if the driving pressure falls below atmospheric or temperature decreases, visual observation can be used to study samples in a closed sample chambers if usage of a pressure transducer is not feasible. Using two such systems, one with "sample" and another one as 'empty" can be used for figuring out non-sample effects. Plurality of applications can be addressed if this flow detection device(s) can be combined with some of gas (Helium) pycnometers with open architecture design. Special adapters for studying of permeability through membranes, films, rock cores can be provided and such pycnometer combined with the μFM-TOP Microflows Meter can serve as a very effective and inexpensive setup.