

About the Calibration of Rotameter

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Abstract

This work on basis of literary studies and analysis of the author are examined the principle of action and characteristics of rotameter. Also is shown the procedure for calibrating the rotameter under certain conditions. There have been made some experimental studies on the determination of the calibration curve of the flowmeter.

Keywords

rotameter, flow meter, calibration

1. Introduction

The amount of a substance (liquid or gas), passing per unit time through a cross-section is called a flow rate. We measure quantity of substance in [2] volume flow Q [m^3/s] or mass flow Qm [kg/s]. Devices for measuring the flow (flow rate) are called flow meters. Quantity counters are devices that measure the amount of the substance (fluid) passed through a cross-section per unit time. According to the principle of operation, the flow meters are [1]: variable pressure drop, variable level, with constant pressure drop, velocity, power, electromagnetic, thermal, and others.

2. Design and Working Principle of Rotameter

The Rotameters are one of the most common flow meters. They belong to the group of devices working with a constant pressure drop.

Figure 1 shows a principle scheme of a rotameter. Its main elements are a vertically positioned conical transparent tube (1) and float (2). The input of the unit is supplied with fluid (liquid or gas) at a pressure P_0 .

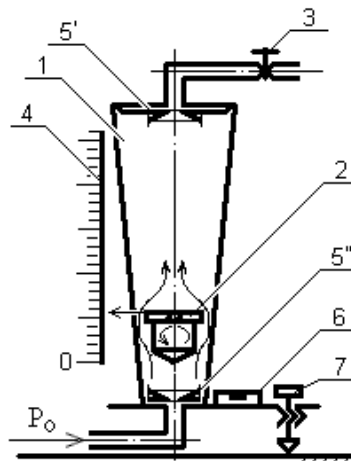


Fig. 1. Principle scheme of rotameter

In the absence of flow, when the throttle valve (3) is closed, the float is located in the lower end position, completely closing the tube, and its upper surface should show zero mark on the scale (4). When opening the throttle conditions are created for fluid flow, the flow forces overcoming the weight of the float and move vertically upwards. It opens passage section with an annular space defined by the difference of the diameters of the float and the tube for the particular position of the float. In the actual design the pipe and the scale are interchangeable depending on the scale of the device and the type of measured fluid. Because of the sloping grooves on the flange of the float, the flow giving the latter rotary motion and it centered on the axis of the tube, thereby avoiding friction between solids

and improves the sensitivity of the device. Plastic sleeves (5) and (5') limiting the movement of the float in the end positions and protect the tube from a hard impact at hopping pressure. The vertical position of the pipe is achieved by means of the spirit level (6) and adjustable feet (7).

The construction drawing of the laboratory Rotameter LD, designed to measure the flow of fluids (liquids and gases), is shown in Figure 2.

In accordance with the principle of operation of the rotameters, a major part of the structure is a vertically extending conical transparent tube (3) with a small cone extending upwards in which a float (15) is placed which, in the absence of flow through the rotameter, under its gravity lies on the plastic sleeve (14) near the lower end of the tube and almost completely closes its light section. When the fluid passes through the pipe in the bottom-up direction, the float is forced to lift, opening a smaller or larger ring gap, depending on the momentary consumption. With a set (constant) flow, the float occupies an equilibrium position along the height of the pipe as determined by its forces. Thus, the height h on which the float is located, measured on a scale on the tube, gives an idea of the flow rate.

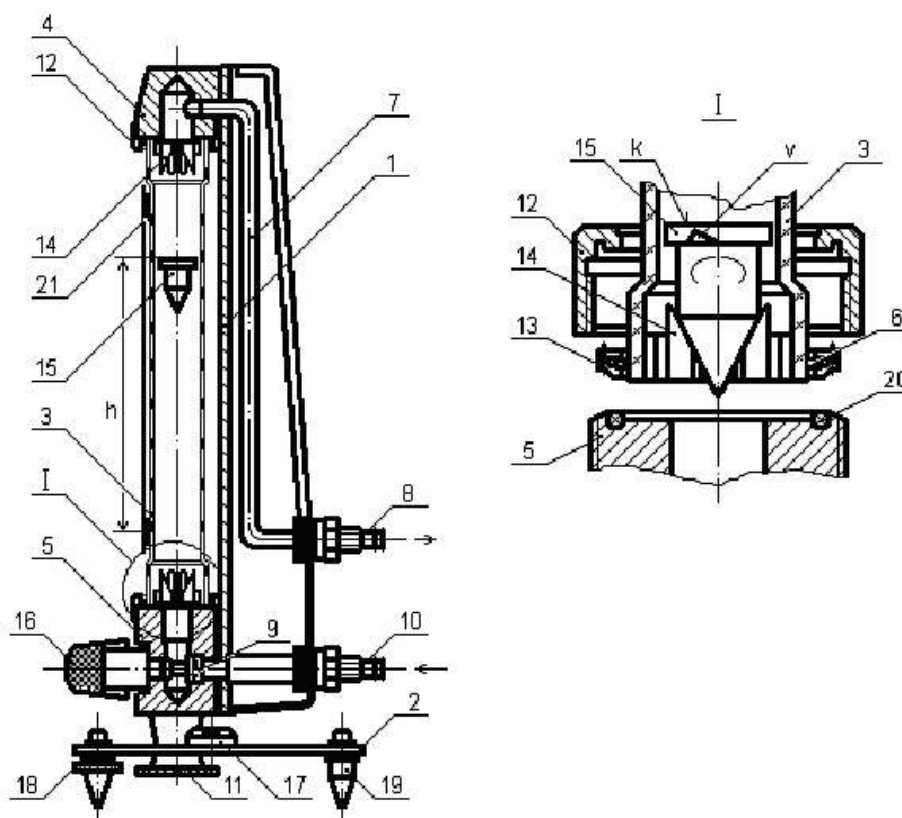


Fig. 2. Construction drawing of laboratory Rotameter LD

The rotameter body consists of two parts - upper (4) and lower (5) heads with central holes and external thread connected to each other by the plate (1). The lower head is attached to the base (2) by screw and a nut (11). To the base are mounted three legs - one non-adjustable (19) and two adjustable (18) by means of which the conical pipe in operation is set vertically to the indications of the circular fluid level (17). The set of the rotameter contains a number of conical tubes of different diametrical dimensions each of which corresponds of a certain measuring range (see Table 1). When installed, the appropriate float is placed inside the selected pipe, in the widened and end portions - plastic sleeves (14), and the nuts (12) and the sealing groups (13), all oriented in the manner shown in the figure, are hopped on the pipe. The tubes are of a length such that they enter a small gap between the heads (4) and (5). With the nuts (12), the sealing groups (13) are tightened to the base, which leads to deformation of the rubber O-rings (6) and (20) and to the sealing of the node. The measured flow is fed to the nozzle (10) (rotor inlet). On its way, the flow meets the conical valve (9), which allows (by rotating the handle (16)) to control the flow. Upon encountering the float (15), the flow raises it and

causes it to rotate due to the unsymmetrical cutout of the surrounding surface of its flange. The purpose of the rotary motion is to entrain a thin layer of fluid that centers the float along the pipe axis and prevents direct contact and friction between them, thereby improving the sensitivity of the device. The purpose of the sleeves (14) is to avoid damaging the pipe and flooding the float in the event of sudden drops in the flow. The upper head (4), by means of the pipe (7), is connected to the nozzle (8) (rotameter outlet). For connection to the inlet and outlet of the rotameter, glands and a flexible hose with inner diameters d are used. When measured, the position of the float (size h) is determined by the float's forehead (surface k) and the conditional scale on the pipe. If necessary, other scales (21) from the set are calibrated for specific fluids and placed on the pipes by means of spring plates. The axial position of these scales is determined according to the benchmarks applied on them and the pipes.

3. Experimental Stand

The technical resources are:

1. Laboratory Rotameter LD:

- measured substances: liquids and gases;
- accuracy class: 2.5 (compared to the upper limit of the range);
- operating temperature: $-30\text{ }^{\circ}\text{C} \div +120\text{ }^{\circ}\text{C}$;
- scale length: 200 mm;
- cone pipe no G15, designed for water flow rate of 5 to 60 l/h
- connectivity: flexible piping (hoses).

2. Sight

- target volume: $V = 1.190\text{ l}$ (from the upper surface of the spindle of the crane to the mark on the throat).

3. Stopwatch

- division value: 0.01 s.

4. Thermometer

- range: 0 to $30\text{ }^{\circ}\text{C}$;
- division value: $1\text{ }^{\circ}\text{C}$.

The calibration procedure is as follows:

Specifies constant values of flow rate by maintaining constant hydrostatic pressure at the entrance of rotameter:

$$p = \rho \cdot g \cdot H, \quad (1)$$

where ρ is density of the fluid, g – gravitational acceleration, and H – height of the column of fluid.

Flow rate Q is determine by expression:

$$Q = \frac{V}{t}, \quad (2)$$

where V is the volume of sight (a measure of volume), and t is the time for filling the volume V . It is measured with a stopwatch.

Scheme of the experimental stand is shown in Figure 3. The names of elements and their purpose are as follows: LD - undergoing for calibration laboratory rotameter; 1 - tube with a scale (S) for calibration; 2 - valve for the flow rate through the rotameter; 3 - container of calibration fluid (tap water); 4 - barrier for smoothing the waves in the container (3); 5 - overflow for maintaining a constant level of water in the container (3); 6 - sight (a measure of the volume with a volume V_6); 7 - tap of sight; 8 - a mark on the neck of sight defining the volume V_6 ; 9 - a flexible connecting tube (hose) with an internal diameter d , approximately equal to the diameter of the jet with a height l in sight; 10 - thermometer; 11 - container for measuring the temperature T of the water; H - height difference, the height of the water column (the difference between the water levels at the inlet of a rotameter, and the free surface in the container (3).

Density of the water is $\rho = 1\text{ kg/dm}^3$; value of the gravitational acceleration is $g = 9.80665\text{ m/s}^2$; displacement $H = 1,800\text{ mm}$; volume of the sight $V_6 = 1,190\text{ l}$; internal diameter of the tube (9) is $d = 5\text{ mm}$; height of the column of liquid in sight volume $l = 264\text{ mm}$.

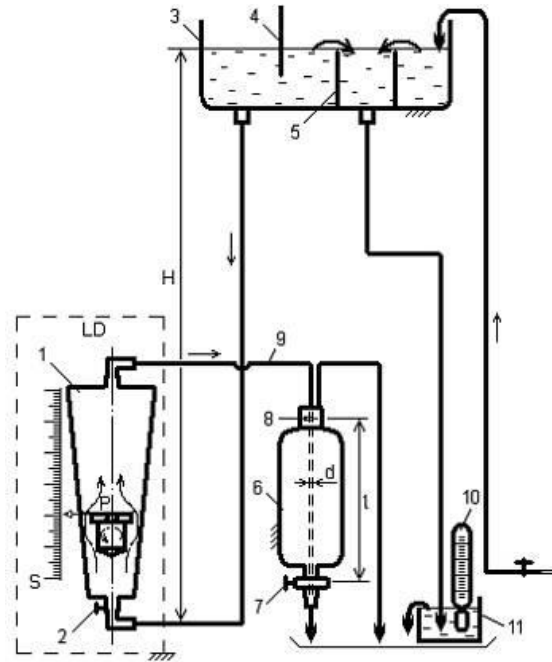


Fig. 3 Scheme of experimental stand

4. Experimental Results

Data from the experiment are recorded in Table 1, and then made the following calculations (experiments were carried out ten times and then the numerical results were averaged):

- determines the ΔV of the water column in the sight by the expression:

$$\Delta V = \frac{\pi d^2}{4} \cdot l, \quad [\text{dm}^3] \quad (3)$$

- determine the reduced with ΔV volume V'_6 by the expression:

$$V'_6 = V_6 - \Delta V, \quad [\text{dm}^3] \quad (4)$$

- for each of the calibration points is calculated flow rate Q_i by the following formula:

$$Q_i = \frac{V'_6}{t} \cdot 3600, \quad [\text{dm}^3/\text{h}] \quad (5)$$

- calculation of the differences ΔQ , in dm^3/h , for flow rates between neighbors calibration points;
- determines the average values of the division, in dm^3/h , for the intervals between the calibration points by the expression: Average value = $\Delta Q/10$.

Table 1 shows the experimental data about the graphical representation of the calibration of the Rotameter LD (Figure 4).

Table 1. Experimental data of the calibration of the Rotameter LD

no.	Mark	t [s]	Q [dm^3/h]	ΔQ [dm^3/h]	Average value, [dm^3/h]
1	10	685.28	6.22	4.64	0.46
2	20	392.4	10.86	5.11	0.51
3	30	266.84	15.97	5.11	0.51
4	40	202.1	21.08	5.21	0.52
5	50	162.03	26.29	5.37	0.54
6	60	134.56	31.66	5.75	0.58
7	70	113.87	37.41	5.77	0.58
8	80	98.65	43.19	5.96	0.60
9	90	86.68	49.15	7.00	0.70
10	100	75.88	56.14	7.00	0.70

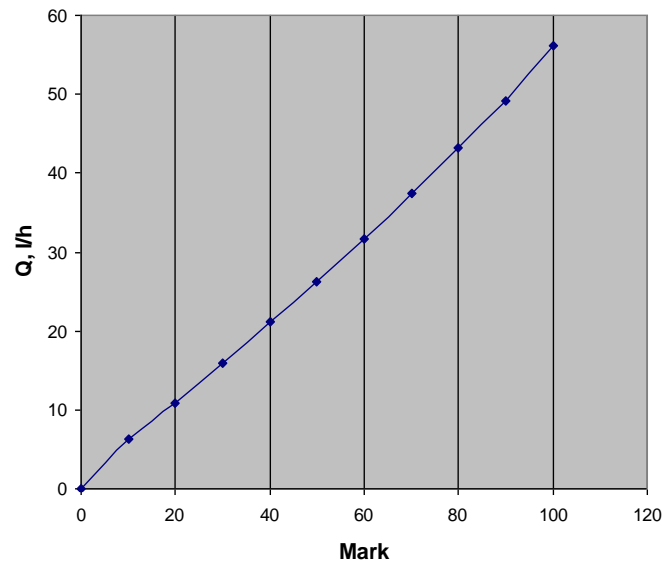


Fig. 4. Graphical representation of the calibration curve

5. Conclusion

The purpose of this work is to shown one of the methods for calibration of the rotameters.

There are some results from these experiments. Calibration curve for the rotameter is linear model. It also shows that the replicated points show very little deviation.

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