MECHANICAL MEASUREMENTS

"VODOLEI" JET LEVEL GAUGE FOR WASTE-WATER DISPOSAL SYSTEMS

I. D. Vel't

UDC 681.121.4

A method for determination of the level of an electrically conductive liquid flowing through an open channel by measurement of the electrical resistance of a water jet striking the surface is examined.

The complexity of measurement of waste-water discharge makes it necessary to seek new methods and means. The physicochemical composition of discharge is extremely varied and constantly changing; as a rule, it has liquid, solid, and gas phases. The liquid phase (besides water) contains various petroleum products, alkalis, acids, salt solutions, alcohols, etc. The solid phase consists of diverse industrial and household waste, vegetation, dispersed sand and clay particles, and feces. The gas phase is made up of decomposition products.

Unfortunately, the selection of devices for measurement of the level and flow rate of such media is extremely limited; some are described in [1–7].

In our opinion, the resistive jet level gauge described here can compete with existing instruments in simplicity, reliability, and accuracy.

The “Vodolei” level gauge employs the dependence of the electrical resistance of a section of a water jet that falls from a certain height onto the surface of a liquid flowing through a channel. A diagram of the level gauge is presented in Fig. 1.

An electrode is placed at approximately the middle of the jet, which divides it into two sections: section $L_1$ from the electrode to the valve has a constant dimension and section $L_2$ from the electrode to the surface of the liquid flowing through the channel has a variable dimension, depending on the level of filling of the channel. The electrical resistances $R_1$ and $R_2$ of the corresponding sections of the jet are connected to a bridge circuit.

A low-level ac voltage is applied to the bridge diagonal between the valve, from which the water jet flows, and the grounded electrode. The measuring device is connected to the other diagonal of the bridge. The measure of waste-water level is the ratio of the voltages on the diagonals of the unbalanced bridge, which is recorded by the measuring device. The resistance $R$ of a jet section $L$ is determined by the formula

$$R = \frac{L}{\sigma S},$$

where $\sigma$ is the electrical conductivity of the jet liquid and $S$ is the cross-section of the jet.

Tap water has a conductivity $\sigma$ on the order of $10^{-3}$ S/m, so for a jet diameter of 20 mm and 10 mm, for example, the resistances are approximately 250 kΩ/m and 1.0 MΩ/m, respectively.

The resistance $R_g$ of the mass of liquid between the grounded electrode, which is on the bottom of the stream, and the contact of the jet with the stream of medium being measured can be estimated by the formula

$$R_g = \frac{1}{\sigma_g d},$$

where $d$ is the diameter of the contact surface of the jet with the stream in the channel, and $\sigma_g$ is the conductivity of the stream flowing through the channel (approximately $10^{-1}$ S/m). For a contact diameter of 20 mm, resistance $R_g$ is approximately
Fig. 1. Jet method for measurement of flow level in channel: 1) hose for water supply; 2) control valve and electrode No. 1; 3) sleeve electrode No. 2; 4) channel with water flowing through it; 5) grounded electrode No. 3; 6) low-frequency pulsed-voltage supply for bridge; 7) instrument transducer.

50–200 Ω, i.e., smaller than the jet resistance by three or four orders of magnitude. The conductivities of the level-meter jet and the measured stream could be the same, in which case a nonconstant jet diameter could cause a level-measurement error, which must be taken into account. To eliminate this error, the flow rate of the level-meter jet must be held constant or monitored by a flowmeter, and the level-measurement result must be corrected for the jet’s flow rate.

The level gauge consists of a cylindrical metal protective housing, whose lower part (facing the waste-water surface) is open. Inside the housing are the tap valve, measuring electrode, and bridge components. The housing also serves as a noise shield. Water is supplied to the valve through a rubber hose.

If the bridge is balanced, the ratio

\[ \frac{L_2}{L_1} = \frac{R_2}{R_1} = \frac{R_4}{R_3}. \]

Each particle of the liquid, with its own parameters (electrical conductivity, temperature, volume, air bubbles, velocity, and other physicochemical properties), and all particles together move continuously along the jet trajectory, passing first through section \( L_1 \) and then through \( L_2 \).

Therefore, if the signals are measured over a relatively long time interval (on the order of 1–5 sec), changes in the temperature, electrical conductivity, velocity, and cross-section of the jet will not affect the result of level measurement, since the jet resistance changes when these parameters change, but the ratio of the resistances of the jet sections remains constant.

The jet level gauge solves the problem of linear variation of the level of channel filling by continuously renewing the electrical contact between the measuring instrument and the medium being measured, which greatly improves measurement reliability.

If the bridge is not balanced, the level measure is the ratio of the voltages on the bridge diagonals.

In this case, the level is calculated as

\[ \frac{L_2}{L_1} = \frac{R_4 + U_s (R_3 + R_4)}{R_3 - U_s (R_3 + R_4)} \]

where \( U_s \) and \( U_p \) are the voltages on the measuring and powered diagonals, respectively.

It should be taken into account that the measured signal is of very low power, on the order of \( 10^{-8} – 10^{-10} \text{ V.A} \), and must be distinguished from electromagnetic noise of various types. The problem of selective measurement of such low-level signals is solved in electromagnetic flowmeters, in which the informative component of a low-power signal must also be separated from noise.