COMPENSATED LEVEL GAUGE

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Measurement of displacements with a high degree of accuracy, e.g., with an accuracy needed in measuring changes in a liquid level, is associated with certain difficulties.

The level gauge shown diagrammatically in Fig. 1, is based on the principle of measurement of displacements of a float whose position is affected by changes in the level or density of a liquid. It can be used in measuring the level of a liquid in open vessels with a high degree of accuracy over a wide range of the parameter concerned. Changes in the level, density, or interface of liquids in tank 1 act on float 2 joined by rope 3 through pulley 4 to drum 15; this drum is mounted on the output shaft of reduction gearing 14 of a servomechanism. A float displacement interferes with the balance of the two-arm lever 7 mounted on knife-edge support 6. The left-hand arm of this lever is connected, through a pulley to the float and the servomechanism drum; whereas the right-hand arm is balanced by spring 11 and joined to core 10 of a differential transformer-type displacement transducer.

The lever is balanced by regulating spring tension by screw 12. The lever unbalance, caused by a change in liquid level or medium density, moves the core together with the excitation winding \( \omega_1 \) relative to measuring windings \( \omega_2 \) and \( \omega_3 \) connected in opposition. This changes the output signal \( E_1 \) applied to phase-sensitive amplifier 9. The amplifier feeds the control winding of reversing motor 13 which drives the reduction gearing input shaft.

The scale pointer 16 is connected to one of the reduction gearing output shafts. For transmitting readings over a distance, the device is fitted with another differential transformer-type displacement transducer whose core 18 is linked to the reduction gearing. The secondary device 17 is connected to the same reduction gearing shaft.

Mechanical stops 5 and 8 are provided to eliminate the effect of lever vibrations.

After neglecting the masses of the core 10 and rope we obtain:

\[
F_1 = \gamma_f v_f; \quad F_2 = cx_1, \tag{1}
\]

where \( F_1 \) is the force acting on the left-hand lever arm; \( F_2 \) is the force acting on the right-hand lever arm; \( \gamma_f \) is the average float density; \( v_f \) is the float volume; \( c \) is the spring rigidity; and \( x_1 \) is the spring displacement.

The float reacts to changes in the level or density by a displacement thereby disturbing the lever balance. The force acting on the left-hand arm after the float is immersed into the medium is found from

\[
F'_1 = \gamma_f v_f - \gamma_1 k_1 v_f, \tag{2}
\]

where \( \gamma_1 \) is the liquid density and \( k_1 \) is the coefficient determining the depth of immersion of the float into the liquid below the mark \( \nabla_1 \).

Equation (2) shows that a change in force \( F'_1 \) is caused by a change of the second term in its right-hand part due to changing density \( \gamma_1 \) and \( k_1 \).

Following a change in the position of the interface between two liquids with different \( \gamma_1 \) and \( \gamma_2 \) (if \( \gamma_1 < \gamma_2 \)) the float immerses deeper into the liquid with density \( \gamma_2 \) where it remains after the lever has been balanced by regulating spring 11.

The force acting on the left-hand arm of the lever is determined by

\[
F'_1 = \gamma_f v_f - \gamma_1 v_f (1 - k_2) + \gamma_2 v_f k_2, \tag{3}
\]

where $\gamma_2$ is the liquid density below boundary $\nabla_2$ and $k_2$ is the coefficient determining the depth of immersion of the float below mark $\nabla 2$.

Equation 3 shows that $F_1'$ depends on $k_2$, which, in turn, depends only on the position of interface $H_2$. A change in $F_1'$ and $F_1$ unbalances the lever causing a displacement of the core. These equations show that a change in the force acting on the left-hand lever arm may be caused by an insignificant change in the liquid level or density.

The highly sensitive instrument can measure small deviations of the parameter being monitored. A high sensitivity of the device is due to a number of factors: its measuring system is balanced electrically and compensated by a mechanical transmission system.

The use of a lever with a changing arm ratio and the absence of friction in knife-edge supports during small changes in the parameter being monitored can result in a considerable displacement of the transducer core.

The sensitivity of the transformer-transducer is determined by:

$$s = \frac{\Delta E_1}{\Delta x_c},$$

where $\Delta x_c$ is the change in core displacement, and $\Delta E_1$ is the change in the transducer signal due to core displacement by $\Delta x_c$.

A change in the displacement of the sensing element is described as a function of core displacement by the following relation:

$$\Delta y = \frac{l_1}{l_2} \Delta x_c,$$

where $\Delta y$ is the change in the sensing element displacement and $l_1/l_2$ is the lever arm ratio.

Equation (4) changes the description of the sensing element displacement to