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AN AUTOMATIC ELECTRICAL SWITCH WHICH USES A MODIFIED FORM OF PITOT TUBE

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The pitot tube has found many useful applications in the measurement of rates of flow of liquids and gases through various channels, such as the speed of air in wind tunnels, and rates of flow through oil and gas pipelines. The present paper is not concerned primarily with the rates of flow, but with a method of controlling the rate of flow.

The problem, as presented to the writer, consisted of designing an apparatus that would close an electrical circuit when water ceased to flow in the cooling system of a Diesel-controlled pipeline station. The desirable features to be attained were three in number: the apparatus should be as simple as possible—free of moving parts, it should be rugged and sturdy, and it should require little or no attention after being set in operation.

Let v represent the velocity of flow through a pipe P, the energy conditions at any cross section of P are, in view of Bernoulli's equation:

$$U = gx + p/d + v^2/2, \qquad (1)$$

where U represents the total energy of the fluid at the cross section S, g is the acceleration of gravity, p is the pressure of the region S, and d is the density of the fluid. The first term on the right represents the potential energy, the second term represents the energy due to the pressure p, and the third term represents the kintic energy. Dividing through by g, Eq. (1) becomes:

$$U/g = H = x + p/gd + v^2/2g, \qquad (2)$$

in which each term may be considered as representing a height. The first term on the right represents the static head, the second term, the pressure head, and the third term, the velocity head.

Now, imagine the pipe P cut at the cross section S and connected again with a T-joint. In the T-joint are mounted two small tubes, t_1 and t_2. The mouth of t_1 is parallel to the direction of flow, displaced 180° from the velocity vector v through P, and is thus subjected to the three pressures; namely, the static head, pressure head, and the velocity head. The mouth of t_2, on the other hand, is perpendicular to the direction of flow through P, and will be subjected only to the static head and pressure head, since there will be no component of the velocity head at right angles to itself. Therefore, there will be an excess of pressure in t_1 over that of t_2 by an amount equal to the velocity head, $v^2/2g$.

The other ends of t_1 and t_2 are brought through part of the T-joint which is perpendicular to P, and each hermetically connected to a mercury manometer. The mercury manometer is essentially a U-tube; however, it is modified in design. It consists primarily of two limbs, one movable, and the other immovable, each mounted on the same panel.

The immovable limb is a piece of iron pipe about 2 feet in length, mounted in a vertical position on the right side of the panel. Iron is used in this part of the manometer since it will not amalgamate appreciably with the mercury. The movable limb consists of a piece of pyrex glass tubing about one and a half times as long as the vertical limb, mounted on a sub-panel which in turn is pivoted close to the base of the vertical iron limb. The glass limb of the manometer can thus be rotated about the pivot as axis, making an angle theta with the horizontal. The angle theta is made adjustable by means of a wing-nut on the sub-panel which passes through a slotted-arc on the main panel.

The lower ends of both limbs of the manometer are hermetically connected by means of a piece of flexible rubber tubing. A tungsten electrode is sealed into the glass tube about two-thirds of the way from its junction with the vertical iron tube.

A suitable amount of mercury is placed in the manometer system, and the open ends of the glass and iron tubes of the manometer are hermetically connected to t_1 and t_2 respectively by means of flexible rubber tubing. The assembly of the automatic switch is thus complete with the tungsten electrode and iron pipe constituting the members with which electrical contact is made when the mercury rises in the glass tube. Two wires are soldered to these members and connected to two binding posts mounted at the top of the panel for convenience of installation of the apparatus.

The height to which the mercury rises in the iron limb of the manometer is directly proportiinal to the square of the velocity v, whereas the depression of the mercury column in the glass tube varies inversely as the angle theta and directly as v^2. When the flow in the pipe P ceases so, that the velocity v becomes zero, the mercury will then rise in the glass tube and make contact with the sealed in tungsten electrode, and thus complete the circuit between the binding posts at the top of the panel.

Thus, for a given value of the rate of flow, the angle theta may be adjusted so that electrical contact is made when the velocity decreases to a given minimum value, or, when it becomes zero, depending of course upon which function may be desired. The control circuit may be used in a variety of ways to regulate the velocity of flow between certain limits, or, to control other equipment which in turn depends upon the rate of flow in the pipe P for its operation. These suggested operations may be accomplished by means of suitable magnetic relays and auxiliary apparatus. The instrument is analogous therefore, to the photoelectric cell, since it may be employed to function similarly for a variety of like purposes.

It is thus seen that the instrument not only satisfies the original problem, but should find many useful applications not only in the pipeline station but in power plants, refineries, pumping stations, and power-controlled equipment in general. It should also prove quite useful in the laboratory where the rates of flow are involved. Moreover, the time and cost of construction should prove to be small, since the parts are few and easily obtained.