THE FLOW OF LIQUIDS THROUGH SUBMERGED ORIFICES

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The loss of head Δ h in a liquid, when flowing through a submerged orifice, has been measured by F. E. Giesecke. From his measurements two definite laws have been deduced: the loss of head or pressure difference is proportional to the square of the velocity; a fact which follows immediately from the principle of dimensional homogeneity; and in the second place the loss is an exponential function of the diameter D of the circular tube, Δ h being proportional to e^{-aD} where $a = 3.32$ and D is the diameter.

If the diaphragm is completely closed, the pressure will increase and a pressure wave will travel through the liquid column with the velocity of sound, but there is also another phenomenon recently observed by E. E. Ambrosius and J. C. Reed, namely the liquid returns at the diaphragm and moves along the wall of the tube in a direction opposite to the original motion in the center. If R is the radius of the tube and r the radius of the central veine, which flows in the original direction, then for laminar motion $r = R \cdot 0.71$, while for turbulent motion $r = R \cdot 0.766$. In the case of laminar motion it is shown that the velocity gradually dies down after the closing of the diaphragm according to the law: $\mu^2 = u_0^2 e^{-\frac{16\mu t}{\rho R^2}}$, where u is the average velocity within the veine of radius R, μ the viscosity, ρ the density and t the time, and u_0 a constant velocity. This expression and $r = R \cdot 0.71$ have already been verified by measurements of Ambrosius and Reed. When the diaphragm is suddenly closed, there is a pressure increase $p = um\sqrt{v_s}$, where m is the mass per unit volume, u the average velocity, V_s the velocity of sound in the liquid column; this pressure increase is the same when the liquid turns around and moves backward. This backward motion, obeying at first the exponential law, is unstable and soon breaks up in irregular turbulent motion.

From the submerged orifice there issues a jet, which seems to move in a sinus-oidal form, being accompanied by a system of vortices which finally in some distance from the orifice break up into turbulent motion. The system of vortices reminds me somewhat of the vortex ally of von Karman. But there may be vortex rings, whose axes are inclined toward the direction of the general motion. Or the issuing jet may describe a spiral motion. Indeed experiments have been made with a jet of smoke from a turpentine flame, which showed, from time to time, beautiful spiral motions of the form of a twisted elastic ribbon.