

Also, since the gas flowing is not necessarily at 32 F and 14.7 psi, it is necessary to apply Charles' and Boyle's laws to the density of the gas and therefore:

$$h_t = \frac{h_w}{12} \times \frac{62.37}{0.0807G} \times \frac{14.7}{P_t} \times \frac{T_t}{492} \quad (50)$$

in which P_t and T_t are the absolute pressure and temperature of the flowing gas. Substituting this in Equation 48, and combining the constants,

$$Q_t = 218.44KD_t^2 \sqrt{\frac{h_w T_t}{P_t G}} \quad (51)$$

Then, to correct the value of Q_t to any other standard conditions of pressure P_b and temperature T_b , using the gas laws,

$$Q_b = Q_t \times \frac{P_t}{P_b} \times \frac{T_b}{T_t} \quad (52)$$

Equation 51 becomes

$$Q_b = 218.44KD_t^2 \frac{T_b}{P_b} \sqrt{\frac{P_t h_w}{T_t G}} \quad (53)$$

Finally, since gases expand under the conditions of reduced pressure downstream from the orifice or nozzle, an expansion factor, Y , must be added. The final formula, then, is

$$Q_b = 218.44KYD_t^2 \frac{T_b}{P_b} \sqrt{\frac{P_t h_w}{T_t G}} \quad (54)$$

In Equation 54, all the data must be observed at the time of measurement except K and Y . These must be obtained from charts, tables, or formulas, derived from or based on the results of a great many experiments, the results of which have been collected by a joint committee of the *American Gas Association* and the *American Society of Mechanical Engineers*^{2,3}. The report of the two associations gives orifice coefficients as a function of the Reynolds number and of the ratio of orifice to pipe diameter, for pipes 2 to 12 in. and 14 in. in diameter, and for four different types of pressure taps in use in the United States. The coefficients are higher for the smaller pipe sizes. This is an effect of the turbulence produced by the roughness of the pipe surface, a given roughness being relatively greater with a small pipe than with a large one.

Space does not permit presenting all the coefficient data that are available. However, if the pipe is smooth drawn tubing, the effect of roughness is negligible, and the coefficients for the largest size of pipe apply also to smaller pipes. Figs. 7, 8, and 9 show these coefficients, N_{Re} , being the Reynolds number referred to the diameter of the orifice or throat of the nozzle, in feet.

Pressure Taps—Location and Types

The different sets of pressure taps are called flange taps, radius taps, vena contracta taps, and pipe or full-flow taps. The relative locations of the first three of these are shown in Fig. 10, and the need for different coefficients for the different taps is indicated by the course of the change in pressure of the flowing fluid shown in the lower part of the figure. Pipe taps are located $2\frac{1}{2}$ pipe diameters upstream and 8 pipe diameters downstream, both measured from the upstream face of the orifice plate,

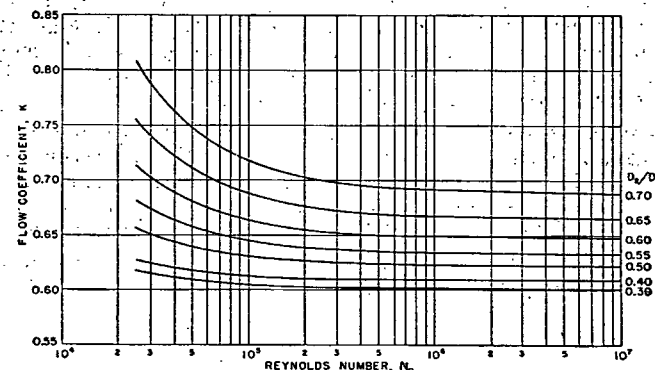


FIG. 7. FLOW COEFFICIENTS, K , FOR SQUARE-EDGED ORIFICE PLATES AND FLANGE TAPS IN SMOOTH PIPE

NOTE: From Table 6, Bibliography [H].

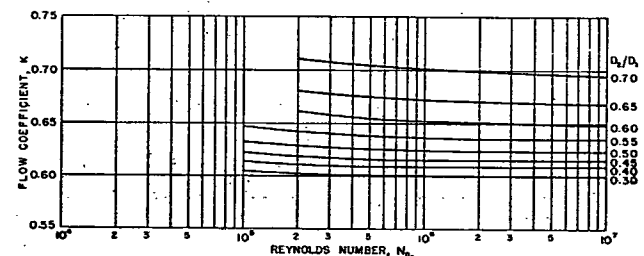


FIG. 8. FLOW COEFFICIENTS, K , FOR SQUARE-EDGED ORIFICE PLATES AND RADIUS TAPS IN SMOOTH PIPE

NOTE: From Fig. 36d, Bibliography [K].

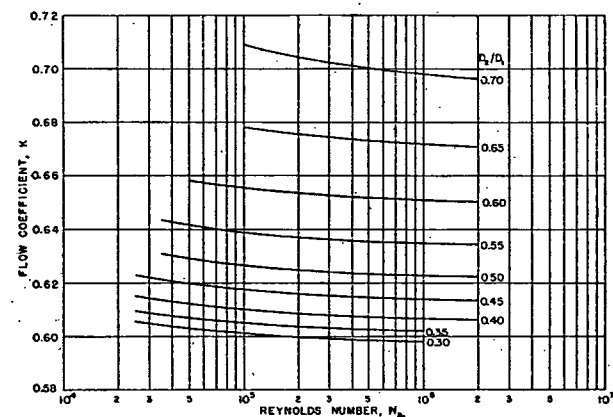


FIG. 9. FLOW COEFFICIENTS, K , FOR SQUARE-EDGED ORIFICE PLATES AND VENA CONTRACTA TAPS, IN SMOOTH PIPE

NOTE: From Table 7, Bibliography [H].