per hour, and converting area in square feet to diameter in inches, gives

$$Q_t = 3600\,K\,\frac{\pi D_2^2}{4 \times 144}\sqrt{2gh_t}$$

or

$$Q_t = 19.635\,KD_2^2\sqrt{2gh_t} \qquad (52)$$

where

Q_t = rate of flow in cubic feet per hour.
D_2 = the diameter of the orifice or nozzle throat in inches.
K = flow coefficient including correction for velocity of approach.

Equation 52 is a general equation, expressing the flow of any fluid through an orifice or nozzle. Further use of it will be made as other types of flow are discussed.

The differential loss, h_t, is in terms of feet of the fluid flowing through the orifice or nozzle. In the case of a gas flowing, where it is customary to read the differential pressure in inches of water, feet of gas must be converted to inches of water. Since dry air at 32 F and 14.7 psi absolute pressure weighs 0.0807 lb per cu ft, the weight of a cubic foot of any other kind of gas under the same conditions is 0.0807 G, where G is the specific gravity of the gas referred to air. Water weighs 62.37 lb per cu ft at 60 F. Using also the relation of 12 in. in 1 ft,

$$h_t = \frac{h_w}{12} \times \frac{62.37}{0.0807G} \qquad (53)$$

in which h_w is the differential pressure in inches of water.

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

$$h_t = \frac{h_w}{12} \times \frac{62.37}{0.0807G} \times \frac{14.7}{P_t} \times \frac{T_t}{492} \qquad (54)$$

in which P_t and T_t are the absolute pressure and temperature of the flowing gas. Substituting this in Equation 52, and combining the constants,

$$Q_t = 218.44KD_2^2\sqrt{\frac{h_w T_t}{P_t G}} \qquad (55)$$

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,

$$Q_b = Q_t \times \frac{P_t}{P_b} \times \frac{T_b}{T_t} \qquad (56)$$

Equation 55 becomes

$$Q_b = 218.44KD_2^2\,\frac{T_b}{P_b}\sqrt{\frac{P_t h_w}{T_t G}} \qquad (57)$$

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

$$Q_b = 218.44\,KYD_2^2\,\frac{T_b}{P_b}\sqrt{\frac{P_t h_w}{T_t G}} \qquad (58)$$

In Equation 58, 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*

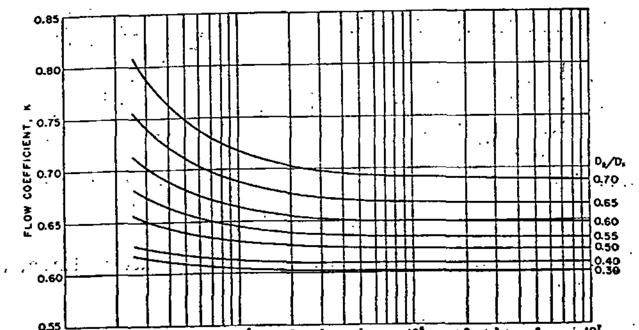

FIG. 7. FLOW COEFFICIENTS, K, FOR SQUARE-EDGED ORIFICE PLATES AND FLANGE TAPS IN SMOOTH PIPE

NOTE: From Table 6, Bibliography [H].

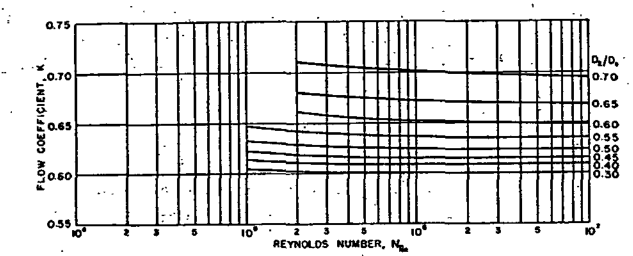

FIG. 8. FLOW COEFFICIENTS, K, FOR SQUARE-EDGED ORIFICE PLATES AND RADIUS TAPS IN SMOOTH PIPE

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

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