8, respectively. Additional specifications are given in References 2, 3, and 4 at end of chapter.

The measurement of flow in head meters is dependent upon observations of a static pressure difference between two parts of the system. In general, there exists a reduction in area, either by a smooth contour as in the case of a Venturi or flow nozzle, or by a vena contracta following an orifice. In either case, the flow will be given by a suitable modification of Equations 47 and 48. Adding a correction term, these become

$$w = \frac{A_2 C}{\sqrt{1 - \beta^4}} \sqrt{2g\rho\Delta p} \tag{49}$$

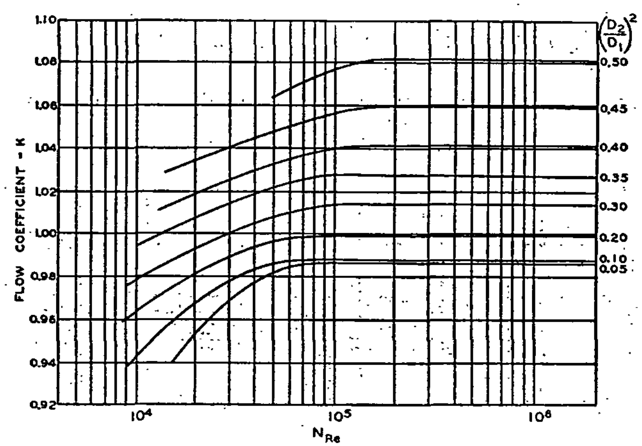

FIG. 12. FLOW COEFFICIENT FOR INTERNATIONAL STANDARDS ASSOCIATION FLOW NOZZLE AS A FUNCTION OF AREA RATIO $(D_2/D_1)^2$ AND THE REYNOLDS NUMBER N_{Re}
NOTE: From Reference 3. Used by permission of *A.S.M.E.*

and

$$Q = \frac{A_2 C}{\sqrt{1 - \beta^4}} \sqrt{2gh_t} \tag{50}$$

In all cases, A_2 refers to the minimum area of the Venturi, nozzle, or orifice. The correction factor C is introduced to account for any loss due to departure from isentropic flow, and for any deviation between the downstream measured pressure and the actual pressure at the minimum section. Since these corrections are usually dependent on configuration, as described by the ratio of upstream to minimum area A_1/A_2, it is often convenient to introduce a combined flow coefficient, K which is

$$K = \frac{C}{\sqrt{1 - \beta^4}} \tag{51}$$

so that

$$w = KA_2\sqrt{2g\rho\Delta p} \tag{52}$$

and

$$Q = KA_2\sqrt{2gh_t} \tag{53}$$

The coefficients K and C will be determined by the area ratio A_1/A_2, or by the diameter ratio D_1/D_2 and the Reynolds number. Extensive data are available from various sources.[2, 4] Figs. 9, 10, 11, 12 show representative values of K based on N_{Re}, the Reynolds number, and the ratio of diameter of the orifice or nozzle throat to pipe diameter.

In any specific application, numerical values for areas, densities, and pressure units can be substituted in Equations 52 and 53 to obtain compact working formulas. In cases where the tests are run under non-standard

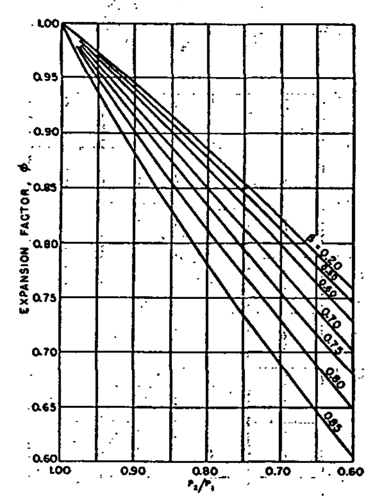

FIG. 13. RELATION OF EXPANSION FACTOR, ϕ, FOR NOZZLES TO DIAMETER RATIO AND PRESSURE LOSS FOR AIR AND OTHER DIATOMIC GASES

conditions, care must be taken that proper adjustment be made in computing flow rates.

In measuring the flow of compressible fluids, the approximate Equations 52 and 53 must be corrected for density variations. The need for such correction is evident by comparing Equations 35 and 38 with Equation 47. Introducing a multiplicative correction factor ϕ the equation for flow with no loss becomes:

$$w = \frac{A_2\phi}{\sqrt{1 - \beta^4}} \sqrt{2g\rho_1(p_1 - p_2)} \tag{54}$$

By comparison with Equation 35,

$$\phi = \sqrt{\frac{k}{2}\,\frac{p_2}{p_1}\,\frac{M_2^2(1 - \beta^4)}{(p_1/p_2) - 1}} \tag{55}$$

From Equations 34 and 35,

$$M_1^2/M_2^2 = \beta^4(p_2/p_1)^{2/k} \tag{56}$$