Coefficients for these taps have been adopted by the *International Standards Association*, but are not used commercially in America.

It will be noted that the location of the downstream pressure tap of the vena contracta arrangement is variable. Vena contracta is the term applied to the minimum cross-section of the jet from the orifice, where the static pressure is at a minimum. Its location, and the location of the downstream vena contracta tap, vary with the ratio of orifice to pipe diameter, and with rate of flow, as shown in Fig. 17; the tap is generally located in accordance with the mean curve in the figure.

Similar precautions are required when using flow nozzles and Venturi tubes. In many cases, these will be supplied ready for installation. In such cases, the manufacturer's instructions should be followed with care

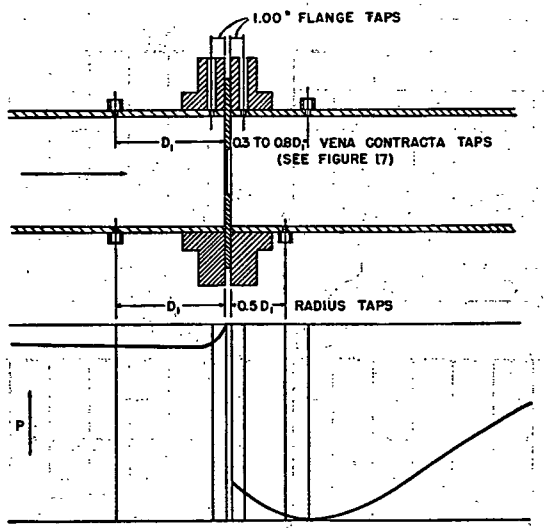


FIG. 16. RELATIVE LOCATION OF FLANGE, RADIUS AND VENA CONTRACTA TAPS

in order to avoid serious errors. Further information on such systems is given in References 2, 3, and 5.

Pitot Tube

In certain cases, such as in rectangular ducts, it is impracticable to use standard orifices, and consequently, either a specially designed orifice must be calibrated, or an independent flow device must be used. In either case, the Pitot tube is useful. It consists essentially of an inner bent tube with its open end pointing upstream so as to measure total pressure, and an outer tube having small holes on the side for communicating static pressure to a manometer. (See Fig. 3, Chapter 49). The difference in liquid level in the manometer will be proportional to the square of the velocity, for incompressible flow, so that in general

$$V = \sqrt{2gh_t} \tag{63}$$

For compressible flow, the differential head is to be divided by the correction F_c from Equation 64,

$$F_c = 1 + \tfrac{1}{4}M^2 + \tfrac{1}{40}M^4 \tag{64}$$

where

$$M^2 = 2\,\frac{p_0 - p}{kp} \tag{65}$$

In the use of a Pitot tube system, care is required in obtaining correct total and static pressures. The total pressure tube must be smoothly constructed, and should point directly upstream. The static pressure tap must be located so that local flow interferences will not reduce the value. In any case, it is better to obtain an independent calibration, or use a specially designed and manufactured probe. A number of such Pitot tube probes are available, and can be used without calibration.

In using Pitot tubes to obtain flow rates, it is necessary to make a traverse of the pipe and thereby to obtain one of the profiles of Fig. 5.

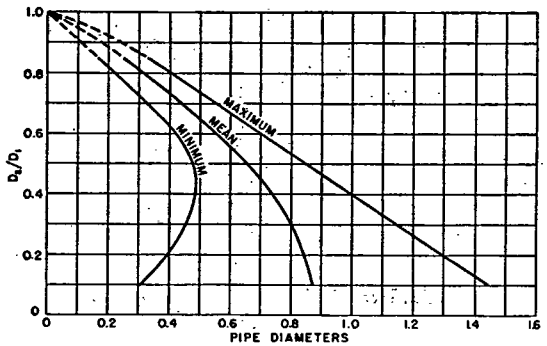


FIG. 17. LOCATION OF VENA CONTRACTA IN RELATION TO RATIO OF ORIFICE TO PIPE DIAMETER AND TO RATE OF FLOW

In rectangular ducts or near valves or fittings, a disturbed flow pattern would be obtained, and therefore, in such cases, a fairly complete survey should be made. The flow in such cases will be computed from the average of the local velocities, as obtained by Equation 63.

Variable Area Flow Meters

For permanent installations where high precision, ruggedness, and ease of operation are important, the variable area flow meter has proved very satisfactory. Its most frequent use is in measurement of liquids or gases in small diameter pipes. For ducts or pipes over 6 in. in diameter, the expense of this meter may not be warranted. In large systems, however, the meter might be placed in a by-pass line and used in conjunction with an orifice.

In its most common form, the variable area meter, Fig. 18, consists essentially of a float which is free to move vertically in a transparent tapered tube. The fluid to be metered enters at the narrow bottom end of the tube and moves upward, passing at some point through the annulus