

Fig. 5 .... Typical Herschel Type Venturi Tube

Assuming an incompressible fluid (liquid or slow moving gas), uniform velocity profile, frictionless flow, and no change in elevation, Equations 6 and 7 of Chapter 6 may be combined to give for the Venturi and nozzle,

$$w = \rho V_1 A_1 = \rho V_2 A_2 = A_2 \sqrt{\frac{2g_c\rho(p_1 - p_2)}{1 - \beta^4}} \qquad (4)$$

where

w = flow rate, pounds per second.
V = velocity of the stream, feet per second.
A = flow area, square feet.
g_c = gravitational conversion factor = 32.174 (pounds mass per pound force) × feet per (second) (second).
ρ = density of fluid, pounds per cubic foot.
p = absolute pressure, pounds per square foot.
$\beta = \frac{D_2}{D_1}$ for the Venturi and $\frac{d}{D}$ for the nozzle as shown in Figs. 5 and 6.

Subscript 1 refers to the entering conditions.
Subscript 2 refers to the throat conditions.

Since flow is not frictionless, a correction factor C is introduced to account for friction losses. If the fluid is at a high temperature, an additional correction factor (F_a) is included

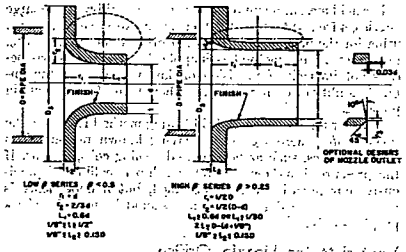

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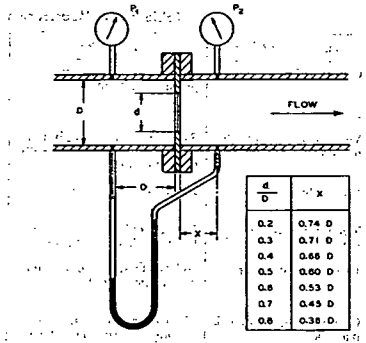
Fig. 6 .... Dimensional Relations of ASME Long-Radius Flow Nozzles for Code Tests (The use of either a recess or bevel at nozzle outlet is optional)



d/D	x
0.2	0.74 D
0.3	0.71 D
0.4	0.68 D
0.5	0.60 D
0.6	0.53 D
0.7	0.45 D
0.8	0.38 D

Fig. 7 .... Sharp Edge Orifice with Vena Contracta Pressure Tap Locations[33]

to account for thermal expansion of the primary element (Reference 34). Since this amounts to less than one percent at 500 F, it may be omitted for most usage. Equation 4 then becomes

$$w = CA_2 \sqrt{\frac{2g_c\rho(p_1 - p_2)}{1 - \beta^4}} \qquad (5)$$

and

$$Q = CA_2\sqrt{2g_c h_f/(1 - \beta^4)} \qquad (6)$$

where

Q = discharge rate, cubic feet per second.
h_f = loss of head, feet of fluid.

The factor C is a function of geometry and Reynolds number. Values of C for the Venturi tube are shown in Fig. 9. Values of C for the flow nozzles of Fig. 6 with pressure differences taken by wall taps are shown in Fig. 10. The approach factor referred to in Fig. 10 is the quantity $1/\sqrt{1 - \beta^4}$.

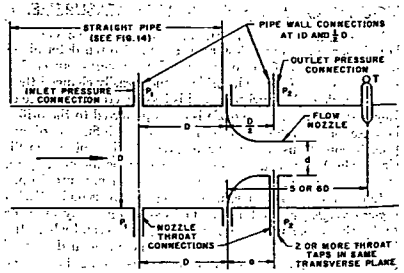


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Fig. 8 .... Location of Pressure Taps Used with Flow Nozzles

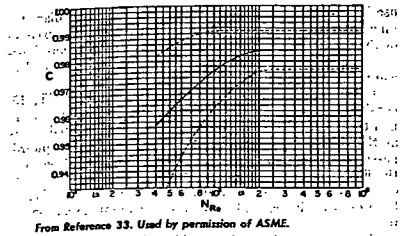

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Fig. 9 .... Flow Coefficients for Herschel Type Venturi Tube

(The tolerance limits are shown by dotted lines)

The jet passing through a plate orifice contracts to a minimum area at the *vena contracta*, which is located a short distance downstream from the orifice plate. The contraction coefficient, the energy loss coefficient, and the approach factor may be combined into a single constant K, which is a function of geometry and Reynolds number. The orifice flow rate equations then become

$$w = KA_2\sqrt{2g_c\rho(p_1 - p_2)} \qquad (7)$$

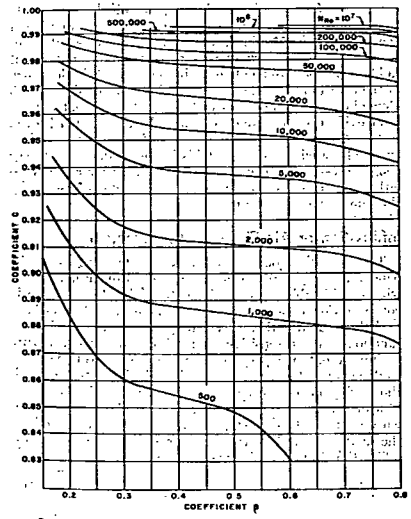

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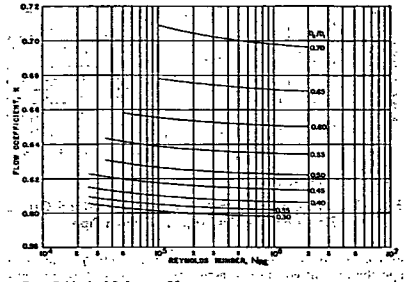
Fig. 10 .... Discharge Coefficients for ASME Long-Radius Flow Nozzles with Pressure Taps Located One Pipe Diameter Preceding and One-Half Pipe Diameter Following the Inlet Face of the Nozzle

(Velocity of approach factor not included)



From Table 6 of Reference 33.

Fig. 11 .... Flow Coefficients K for Square-edged Orifice Plates and Vena Contracta Taps, in Smooth Pipe

and

$$Q = KA_2\sqrt{2g_c h_f} \qquad (8)$$

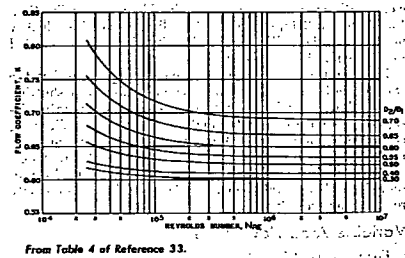
where

A_2 = orifice area, square feet.
$p_1 - p_2$ = pressure drop in pounds per square foot as obtained by the pressure taps.

Values of K are shown in Figs. 11, 12, and 13 and apply only to the following positions of the pressure taps: Vena contracta taps for Fig. 11 as shown in Fig. 7; flange taps for Fig. 12 located 1 in. before and after the orifice; and radius taps for Fig. 13 located one pipe diameter upstream and one-half pipe diameter downstream.

In the installation of Venturi tubes, orifices, and nozzles, care must be taken in regard to upstream and downstream flow conditions. Recommended practice, with reference to fittings and valves, is shown in Fig. 14. If these conditions cannot be met, some flexibility is possible by introducing straightening vanes, as described more fully in Reference 33.

If gas flow is being measured, and the pressure drop is more than a few percent of the initial pressure, it may be necessary to make an allowance for compressibility effects. Consider for the cases of the Venturi and nozzle a compressible, but adiabatic and frictionless flow. Since the flow is isentropic, p



From Table 4 of Reference 33.

Fig. 12 .... Flow Coefficients K for Square-edged Orifice Plates and Flange Taps in Smooth Pipe