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CHAPTER 4

FLUID FLOW

Theory; Pressure Loss in Circular and Non-Circular Pipes; Compressible Fluids; Nozzles and Orifices; Steam Flow Measurement; Metering Liquids; Nozzle Coefficients and Expansion Factors; Pitot Tube; Installation of Nozzles and Orifices, Variable Area Flow Meters

THE flow of fluids is part of the branch of engineering science known as fluid mechanics, which will be discussed here insofar as it applies to the work of engineers in the fields of heating, ventilating, and air conditioning. Probably air is the most frequently handled fluid, but other gases and liquids are often involved. Compressible fluids (gases) and incompressible fluids (liquids) vary somewhat in behavior, though in cases where pressure and density changes are small, the gases may be treated as incompressible fluids.

THEORY OF FLUID FLOW

The following energy equation for one dimensional steady flow processes will serve as a basis for the theory of the flow of fluids. This equation is presented in several ways in various texts, but a suitable form is

$$\frac{V_1^2}{2g_c} + Ju_1 + p_1v_1 + Jq + \frac{g}{g_c}z_1 = \frac{V_2^2}{2g_c} + Ju_2 + p_2v_2 + W + \frac{g}{g_c}z_2 \qquad (1)$$

where

V = velocity in feet per second.
g = gravitational acceleration, in feet per (second) (second).
g_c = gravitational conversion factor = 32.174 (pounds mass per pound force) × ft per (second) (second).
J = mechanical equivalent of heat = 778 foot pounds per Btu.
u = internal energy, in Btu per pound of fluid.
p = pressure in pounds per square foot.
v = specific volume, in cubic feet per pound.
W = mechanical work done by the fluid in foot pounds per pound of fluid.
q = heat transferred to the fluid in Btu per pound of fluid flowing.
z = elevation above some arbitrary datum, in feet.
Subscript 1 refers to the entrance, subscript 2 to the exit.

Introducing the enthalpy h, which by definition is $u + \frac{pv}{J}$, expressed in Btu per pound of fluid, Equation 1 becomes

$$\frac{V_1^2}{2g_c} + Jh_1 + Jq + \frac{g}{g_c}z_1 = \frac{V_2^2}{2g} + Jh_2 + W + \frac{g}{g_c}z_2 \qquad (2)$$

The equivalent differential form for energy Equation 1 is

$$\frac{1}{2g_c}dV^2 + J\,du + d(pv) + \frac{g}{g_c}dz - J\,dq + dW = 0 \qquad (3)$$