Equations

$$fL/D = (1/M_1^2)[1 - (P_2/P_1)^2)] - \ln(P_1/P_2)^2 \quad (1)$$

where: $r = P_2/P_1$

$$fL/D = 1/M_1^2[1 - 1/r^2] - \ln r^2 \quad (2)$$

$$r^2M_1^2(fL/D) = r^2 - 1 - r^2M_1^2\ln r^2 \quad (3)$$

$$r^2 = r^2M_1^2[(fL/D) + \ln r^2] + 1 \quad (4)$$

$$r^2 = M_2^2[(fL/D) + \ln r^2] + 1 \quad (5)$$

$$M + V_g/V_s \quad (6)$$

$$V_g = W/\rho\ A \text{ or } V_g = 0.0509W/d^2\ \rho \quad (7)$$

$$V_s = 223(kT/Mw)^{0.5} \text{ or } V_s = 68.0(P_1/\rho)^{0.5} \quad (8)$$

$$V_g = (W/A)\ (ZRT/PMw) \quad (9)$$

$$M = (W/A)\ (ZRT/PMw)(1/233)(Mw/t)^{0.5} \quad (10)$$

$$M = 0.0001336(W/PA)(ZRT/MW)^{0.5} \quad (11)$$

$$S_{60g} = \rho_{60g}/\rho_{60a} = M_g/M_a \quad (12)$$

$$Z = F_1\{1/[1 + (C_6P_{10}/T^{3.825})^{1.785S_g} + F_2F_3\} + F_4F_5 \quad (13)$$

where:

$$F_1 = P(0.251S_g - 0.150) - 0.202S_g + 1.106$$

$$F_2 = 1.4\exp[-0.0054(T - 460)]$$

$$F_3 = C_1P^5 + C_2P^4 + C_3P^3 + C_4P^2 + C_5P$$

$$F_4 = (0.154 - 0.152S_g)P^{(3.18S_g-1)}\exp(-0.5P) - 0.02$$

$$F_5 = 0.35(0.6 - S_g)\exp[-1.039(P - 1.8)^2]$$

$$C_1 = 0.001946$$

$$C_2 = -0.027635$$

$$C_3 = 0.136315$$

$$C_4 = -0.23849$$

$$C_5 = 0.105168$$

$$C_6 = 3.44 \times 10^8$$

$$1/f^{0.5} = -0.8686 \ln[(e/3.7D) + 2.51/R_ef^{0.5}] \quad (14)$$

$$X_i + 1 = X_i - F(X_i)/F'(X_i) \quad (15)$$

where:

$$i = 1,2,3,\ldots i_{max}$$

$$F'(r^2) = -2/r^3 + 2M_1^2/r \quad (16)$$

$$F'(r^2) = 2r - 2M_2^2/r^2 \quad (17)$$

$$F'(f) = -0.5/f^{0.5} - 0.4343/f \quad (18)$$

$$Mw = \Sigma W_i/\Sigma(W/Mw)_i \quad (19)$$

$$T = \Sigma W_iT_i/\Sigma W_i \quad (20)$$

$$\mu = \Sigma X_i\mu_i(Mw)_i^{0.5}/\Sigma X_i(Mw)_i^{0.5} \quad (21)$$

accurate than other methods.

The Newton-Raphson method is employed to solve the iterative process of the friction factor from the ratio of the inlet and outlet pressures. The program is based on assumptions that the flow of gas through the discharge lines is isothermal, and that either the inlet or exit pressure is known.

The mach numbers are evaluated at both the inlet and outlet. The types of pipe fittings are incorporated in the program for selection.

The program displays a message if the exit mach number is greater than 0.7, signifying that the outlet gas velocity is too close to sonic velocity (the pipe size is too small). A larger pipe size is then selected and the program proceeds to calculate the Reynolds number, the friction factor, and the pressure drop in the pipe system.

The algorithm. Compressible flow calculations using Lapple's derivations are used to determine either the exit pressure for a given inlet pressure, or the inlet pressure for any known discharge pressure.

Isothermal conditions, based on the inlet pressure, can be expressed as shown in Equation 1. (See boxes for equations and nomenclature.) When $r = P_2/P_1$ is substituted, Equations 2, 3, and 4 result.

For isothermal conditions based on the outlet pressure, if M_2 is the mach number at the outlet, and since $M_1 = M_2/r$, the result is Equation 5.

The mach number is evaluated from the ratio of the actual gas velocity to the sonic velocity, resulting in Equation 6.

The actual gas velocity can be expressed by Equation 7.

The sonic velocity is expressed as Equation 8.

The density of the gas is expressed as $\rho = PM_w/ZRT$.

For an ideal gas where $Z = 1.0$, the actual gas velocity can be calculated by Equation 9.

If Equations 8 and 9 are substituted into Equation 6, the expression for the mach number becomes Equation 10. Equation 11 is a simplification of Equation 10 using consistant units.

Compressibility factor. Compressibility factors (Z) are available in charts or tables, as a function of pseudo-reduced temperatures and pressures, T_r and P_r. Use of these charts is often time consuming and sometimes requires difficult calculations.

Computer programs[8,9] for calculating Z have been developed solely as a function of the temperature and pressure of the gas.

Numerical methods, within certain limitations, have also been used to determine Z.

However, the method proposed here is a modified form of that developed by Awoseyin.[10] This method gives a compressibility factor to within 5% for natural hydrocarbon gases with specific gravities between 0.5 and 0.8, and for pressures up to 5,000 psia.

The specific gravity of a gas, S_{60g}, is the ratio of the gas density at 60° F. and 1 atmosphere (14.7 psia), ρ_{60g}, to the density of air, ρ_{60a}, under the same conditions.

The specific gravity can be expressed as Equation 12.

Specific gravity can also be determined by dividing the molecular weight of the gas, M_g, by the molecular weight of air, M_a.

The compressibility factor, Z, can be expressed as Equation 13.

Friction factor. Various forms of friction-factor equations have been derived involving both explicit and implicit derivations.[11,12] However, the well known Colebrook-White method[13] is employed, and can be obtained from the Moody diagram.

The Darcy friction factor (which has a value equal to four times that of the Fanning friction factor) can be expressed as in Equation 14. Solving