Calculating Pipe Size

Friction Loss Characteristics

Sizing for any piping system consists of two basic components: fluid flow design and pressure integrity design. Fluid flow design determines the minimum acceptable diameter of pipe and pressure integrity design determines the minimum wall thickness required. For normal liquid service applications an acceptable velocity in pipes is 2.15 ±0.9 (m/s), with a maximum velocity of 2.15 (m/s) at discharge points.
Pressure drops throughout the piping network are designed to provide an optimum balance between the installed cost of the piping system and the operating cost of the pumps.
Pressure loss is caused by friction between the pipe wall and the fluid, minor losses due to obstructions, change in direction, etc. Fluid pressure head loss is added to elevation change to determine pump requirements.

Darcy–Weisbach equation

In fluid dynamics, the Darcy–Weisbach equation is a phenomenological equation, which relates the head loss — or pressure loss — due to friction along a given length of pipe to the average velocity of the fluid flow. The equation is named after Henry Darcy and Julius Weisbach.

Pressure loss form

The Darcy–Weisbach equation can be written in terms of pressure loss Δp:

$$\Delta p = f \cdot \frac{L}{D} \cdot \frac{\rho V^2}{2}$$

where the pressure loss due to friction Δp is a function of:

- L/D, the ratio of the length to diameter of the pipe;
- ρ, the density of the fluid;
- V, the mean velocity of the flow;
- f, a (dimensionless) coefficient of laminar, or turbulent flow.

Colebrook equation

The Colebrook equation is an implicit equation that combines experimental results of studies of turbulent flow in smooth and rough pipes. It was developed in 1939 by C. F. Colebrook. The 1937 paper by C. F. Colebrook and C. M. White is often erroneously cited as the source of the equation. This is partly because Colebrook in a footnote (from his 1939 paper) acknowledges his debt to White for suggesting the mathematical method by which the smooth and rough pipe correlations could be combined. The equation is used to iteratively solve for the Darcy–Weisbach friction factor *f*. This equation is also known as the Colebrook–White equation.

$$\frac{1}{\sqrt{f}} = -2 \cdot \log\left[\frac{2.51}{(R_e \cdot \sqrt{f})} + \frac{k}{3.72 \cdot d_i}\right]$$

where:

- *f*, is the Darcy friction factor;
- k, Roughness height, (m, ft);
- d_i, Hydraulic or inside diameter, (m, ft);
- Re is the Reynolds number.

Solving Colebrook Equation

Due to the implicit nature of the Colebrook equation, determination of a friction factor requires some iteration or a numerical solving method. Colebrook equations can be solved within a worksheet using circular reference. It is found that the Colebrook equation converges to its reasonably precise value within tens of iterations and it needs only 12 iterations for an 8 digit result. Within hundred iterations it reaches a maximum of fifteen-digit precision. However, the accuracy is limited by the accuracy of the experimental data which is at best about ±2%.

Approximations of the Colebrook equation

Goudar-Sonnad equation

The Goudar equation is the most accurate approximation to solve directly for the Darcy–Weisbach friction factor *f* for a full-flowing circular pipe. It is an approximation of the implicit Colebrook–White equation. The equation has the following form:

$$a = \frac{2}{ln(10)}$$

$$b = \frac{\varepsilon/D}{3.7}$$

$$d = \frac{ln(10)Re}{5.2}$$

$$s = bd + ln(d)$$

$$q = s^{(s/(s+1))}$$

$$g = bd + ln\frac{d}{q}$$

$$z = ln\frac{q}{g}$$

$$D_{LA} = \frac{g}{g+1}z$$

$$D_{CFA} = D_{LA}(1 + \frac{z/2}{(g+1)^2 + (z/3)(2g-1)})$$

$$\frac{1}{\sqrt{f}} = a[ln(\frac{d}{q}) + D_{CFA}]$$

where *f* is a function of:

- ε , Roughness height, (m, ft);
- *D* , Pipe diameter, (m, ft);
- Re, Reynolds number, (unitless).

Comparisons by the author's shows error compare to Colebrook-White equation of 1.04^{-10} %.

Reynolds Number

Reynolds number can be defined for a number of different situations where a fluid is in relative motion to a surface (the definition of the Reynolds number is not to be confused with the Reynolds Equation or lubrication equation). These definitions generally include the fluid properties of density and viscosity, plus a velocity and a *characteristic length* or *characteristic dimension*. This dimension is a matter of convention - for example a radius or diameter is equally valid for spheres or circles, but one is chosen by convention. For aircraft or ships, the length or width can be used. For flow in a pipe or a sphere moving in a fluid the internal diameter is generally used today. Other shapes (such as rectangular pipes or non-spherical objects) have an *equivalent diameter* defined. For fluids of variable density (e.g. compressible gases) or variable viscosity (non-Newtonian fluids) special rules apply. The velocity may also be a matter of convention in some circumstances, notably stirred vessels.

Flow in a pipe

$$\mathrm{Re} = \frac{QD_H}{\nu A}$$

where:

- D_H is a characteristic linear dimension, (traveled length of fluid) (m);
- ν is the kinematic viscosity, ($\nu = \mu / \rho$) (m^2/s);
- Q is the volumetric flow rate, (m^3/s);
- A is the pipe *cross-sectional* area, (m^2).

Due to the complexity of the Colebrook–White equation, the following tables on pages 48-67 have been derived from the Goudar-Sonnad equation. Values shown in these tables are rounded to two decimal places and figures shown can be up to +/- 1% of the actual values.
Getting the true value pressure losses is almost impossible to calculate due to the complexity of a pipe system with fittings, valves, internal beads, internal gaps between fitting joints etc, and the turbulent influences these all have on water flow.