Friction

\[ g = \text{acceleration of gravity, ft/sec}^2 \text{ (taken as 32.174 ft/sec}^2 \text{ in making conversions)} \]

\[ h_f = \text{head loss due to friction, ft of liquid} \]

\[ \varepsilon = \text{absolute roughness in feet — see page 3-5} \]

\[ h_v = \text{Velocity head — ft of liquid} \]

\[ k = \text{kinematic viscosity, centistokes} \]

\[ \nu = \text{kinematic viscosity, — ft}^2/\text{sec} \]

\[ L = \text{length of pipe including equivalent length for loss through fittings — ft} \]

\[ m = \text{hydraulic radius} = \frac{\text{flow area}}{\text{wetted perimeter}} = \text{ft} \]

(\text{use in calculating flow in open channels or unfilled pipes})

\[ \rho = \text{density at temp. and press. at which liquid is flowing, lb/ft}^3 \]

\[ \mu = \text{absolute or dynamic viscosity, lb-sec/ft}^2 \]

\[ V = \text{velocity of flow, ft/sec} \]

\[ s = \text{density, g/cm}^3 \text{ (water at 4°C or 39.2°F = 1.000)} \]

\[ z = \text{absolute or dynamic viscosity — centipoises} \]

HAZEN AND WILLIAMS

Although the Darcy-Weisbach/Colebrook method (on which the tables in this book are based) offers a rational mathematical solution to friction loss calculations (since it can be applied to any liquid except plastics and those carrying suspended solids) some engineers prefer to use one of the many empirical formulas that have been developed for water flowing under turbulent conditions.

Of these, the most widely used and accepted is the Hazen and Williams empirical formula since it is convenient to use and experience has shown that it produces reliable results. In a convenient form it reads:

\[ h_f = 0.002083 \times \left( \frac{L}{C} \right)^{1.85} \times \frac{\text{gpm}^{1.85}}{d^{4.8655}} \]

This formula is based on a fluid having a kinematic viscosity, \( \nu = 0.000 \ 012 \ 16 \text{ ft}^2/\text{sec} \) (1.130 centistokes) or 31.5 SSU which is the case for water at 60°F. But since the viscosity of water can vary appreciably from 32°F to 212°F the friction can decrease or increase as much as 40% between the two temperature extremes. However, this formula can be used for any liquid having a viscosity in the range of 1.130 centistokes.

Values of \( C \) for various types of pipe with suggested design values are given in the following table with corresponding multipliers that can be applied, when appropriate, to obtain approximate results.
### Hazen and Williams—Friction Factor C**

<table>
<thead>
<tr>
<th>Type of Pipe</th>
<th>Range—High = best, smooth, well laid—Low = poor or corroded</th>
<th>Average Value for clean, new pipe</th>
<th>Commonly used value for design purposes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement—Asbestos</td>
<td>160–140</td>
<td>150</td>
<td>140</td>
</tr>
<tr>
<td>Fibre</td>
<td>—</td>
<td>150</td>
<td>140</td>
</tr>
<tr>
<td>Bituminous-enamel-lined iron or steel centrifugally applied</td>
<td>160–130</td>
<td>148</td>
<td>140</td>
</tr>
<tr>
<td>Cement-lined iron or steel centrifugally applied</td>
<td>—</td>
<td>150</td>
<td>140</td>
</tr>
<tr>
<td>Copper, brass, lead, tin or glass pipe and tubing</td>
<td>150–120</td>
<td>140</td>
<td>130</td>
</tr>
<tr>
<td>Wood-stave</td>
<td>145–110</td>
<td>120</td>
<td>110</td>
</tr>
<tr>
<td>Welded and seamless steel</td>
<td>150–80</td>
<td>130</td>
<td>100</td>
</tr>
<tr>
<td>Interior riveted steel (no projecting rivets)</td>
<td>—</td>
<td>139</td>
<td>100</td>
</tr>
<tr>
<td>Wrought-iron, Cast-iron</td>
<td>150–80</td>
<td>130</td>
<td>100</td>
</tr>
<tr>
<td>Tar-coated cast-iron</td>
<td>145–50</td>
<td>130</td>
<td>100</td>
</tr>
<tr>
<td>Girth-riveted steel (projecting rivets in girth seams only)</td>
<td>—</td>
<td>130</td>
<td>100</td>
</tr>
<tr>
<td>Concrete</td>
<td>152–65</td>
<td>120</td>
<td>100</td>
</tr>
<tr>
<td>Full-riveted steel (projecting rivets in girth and horizontal seams)</td>
<td>—</td>
<td>115</td>
<td>100</td>
</tr>
<tr>
<td>Rolled Spirally riveted steel (flow with lap)</td>
<td>—</td>
<td>110</td>
<td>100</td>
</tr>
<tr>
<td>Spiral-riveted steel (flow against lap)</td>
<td>—</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>Corrugated steel</td>
<td>—</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

| Values of C | 150 | 140 | 130 | 120 | 110 | 100 | 90 | 80 | 70 | 60 |

*Multiplier (Basis C = 100) ...*: 47, 54, 62, 71, 84, 1.0, 1.22, 1.50, 1.93, 2.57

** Note: the Hazen Williams friction factor "C" must not be confused with the Darcy-Weisbach-Colebrook friction factor "f"; these two friction factors are not in any way related to each other.

Friction—head loss—sample calculation:

To illustrate the application of the formula, a problem calculating the total system head for a given example is offered:

**Problem**—referring to the accompanying data, a system takes water (68°F) from a sump and discharges through 4" diameter schedule 40 steel pipe. The system includes a foot valve and a charge line which includes two standard 90° check valves and an open wedge—disc. The suction lift is 200 gpm.

**Solution**

(a) **SUCTION LIFT**—Data from table 3-8

Velocity head = \( \frac{V^2}{2g} \)

Pipe friction loss \( h_f = 2.25 \text{ ft per 100 ft} \)

The resistance coefficient for the 4" pipe is \( K = 1.3 \) and for the long-radius elbow \( K = 1.0 \) and the long-radius elbow

The head loss due to pipe friction

\[
h_f = K \frac{V^2}{2g} = (1.3 + 0.27)
\]

The total suction lift \( h_s \) is

\[
h_s = (28.62 - 1)
\]

(b) **DISCHARGE HEAD**—The head losses in the foot valve and charge line

\[
h_f = 2.25 \times \frac{225}{100} = 5
\]

Total suction lift \( h_s \) is

\[
h_s = 28.62 - 5 = 23.62
\]

3-8