g = acceleration of gravity, ft/sec^2 (taken as 32.174 ft/sec^2 in making conversions).
h_f = head loss due to friction, ft of liquid
ϵ = absolute roughness in feet—see **page 3-5**
h_v = Velocity head—ft of liquid
k = kinematic viscosity, centistokes = $\frac{z}{s}$
υ = kinematic viscosity,—ft^2/sec
L = length of pipe including equivalent length for loss through fittings—ft
m = hydraulic radius = $\frac{\text{flow area}}{\text{wetted perimeter}}$ = ft
(use in calculating flow in open channels or unfilled pipes)
ρ = density at temp. and press. at which liquid is flowing, lb/ft^3
gpm = flow of liquid, gallons per minute.
μ = absolute or dynamic viscosity, lb-sec/ft^2
V = velocity of flow, ft/sec
s = density, g/cm^3 (water at 4°C or 39.2°F = 1.000)
z = absolute or dynamic viscosity—centipoises

3

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:

$$h_f = 0.002083\ L\left(\frac{100}{C}\right)^{1.85} \times \frac{\text{gpm}^{1.85}}{d^{4.8655}}$$

This formula is basis a fluid having a kinematic viscosity, υ = 0.000 012 16 ft^2/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**

Type of pipe	Values of C: Range—High = best, smooth, well laid—Low = poor or corroded	Values of C: Average value for clean, new pipe	Values of C: Commonly used value for design purposes
Cement—Asbestos	160-140	150	140
Fibre	—	150	140
Bitumastic-enamel-lined iron or steel centrifugally applied	160-130	148	140
Cement-lined iron or steel centrifugally applied	—	150	140
Copper, brass, lead, tin or glass pipe and tubing	150-120	140	130
Wood-stave	145-110	120	110
Welded and seamless steel	150-80	130	100
Interior riveted steel (no projecting rivets)	—	139	100
Wrought-iron, Cast-iron	150-80	130	100
Tar-coated cast-iron	145-50	130	100
Girth-riveted steel (projecting rivets in girth seams only)	—	130	100
Concrete	152-85	120	100
Full-riveted steel (projecting rivets in girth and horizontal seams)	—	115	100
Vitrified, Spiral-riveted steel (flow with lap)	—	110	100
Spiral-riveted steel (flow against lap)	—	100	90
Corrugated steel	—	60	60

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

* Multiplier to correct friction loss tables (in previous editions—14th Edition and earlier); cannot be used with tables in this book which are based on the Darcy-Weisbach-Colebrook formula.

** **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 calculat

To illustrate the application of the f
calculating the total system head for a
example is offered:

Problem—referring to the accompan
takes water (68°F) from a sump and d
4″ diameter schedule 40 steel pipe. Th
feet long and includes a foot valve and
charge line includes two standard 90 d
check valve and an open wedge—disc
find the suction lift (h_s) and the disch
of flow is 200 gpm.

Solution

(a) SUCTION LIFT—Data from tabl

Velocity head $= \frac{V^2}{2g}$

Pipe friction loss $h_f = 2.25$ ft per 1
The resistance coefficient for the
K = 1.3 and for the long-radius elbow

The head loss due to pipe friction

$h_f = 2.25 \times \frac{5}{100}$

The head loss in the foot valve an

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

Total suction lift (h_s) = (28.62 –

(b) DISCHARGE HEAD—The head
4″ discharge line will be:

$h_f = 2.25 \times \frac{125}{100}$