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# Reference Handbook

9.2 Version for Computer-Based Testing

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**Circular Pipe Head Loss Equation (Head Loss Expressed in Feet)**

$$h_f = \frac{4.73 L}{C^{1.852} D^{4.87}} Q^{1.852}, \text{ where}$$

- $h_f$  = head loss (ft)
- $L$  = pipe length (ft)
- $D$  = pipe diameter (ft)
- $Q$  = flow (cfs)
- $C$  = Hazen-Williams coefficient

**Circular Pipe Head Loss Equation (Head Loss Expressed as Pressure)**

U.S. Customary Units

$$P = \frac{4.52 Q^{1.85}}{C^{1.85} D^{4.87}}, \text{ where}$$

- $P$  = pressure loss (psi per foot of pipe)
- $Q$  = flow (gpm)
- $D$  = pipe diameter (inches)
- $C$  = Hazen-Williams coefficient

SI Units

$$P = \frac{6.05 Q^{1.85}}{C^{1.85} D^{4.87}} \times 10^5, \text{ where}$$

- $P$  = pressure loss (bars per meter of pipe)
- $Q$  = flow (liters/minute)
- $D$  = pipe diameter (mm)

**Values of Hazen-Williams Coefficient  $C$**

|                                |     |
|--------------------------------|-----|
| Pipe Material                  | $C$ |
| Ductile iron                   | 140 |
| Concrete (regardless of age)   | 130 |
| Cast iron:                     |     |
| New                            | 130 |
| 5 yr old                       | 120 |
| 20 yr old                      | 100 |
| Welded steel, new              | 120 |
| Wood stave (regardless of age) | 120 |
| Vitrified clay                 | 110 |
| Riveted steel, new             | 110 |
| Brick sewers                   | 100 |
| Asbestos-cement                | 140 |
| Plastic                        | 150 |

**TRANSPORTATION**

U.S. Customary Units

- $a$  = deceleration rate (ft/sec<sup>2</sup>)
- $A$  = absolute value of algebraic difference in grades (%)
- $e$  = superelevation (%)
- $f$  = side friction factor
- $\pm G$  = percent grade divided by 100 (uphill grade "+")
- $h_1$  = height of driver's eyes above the roadway surface (ft)
- $h_2$  = height of object above the roadway surface (ft)
- $L$  = length of curve (ft)
- $L_s$  = spiral transition length (ft)
- $R$  = radius of curve (ft)
- $SSD$  = stopping sight distance (ft)
- $t$  = driver reaction time (sec)
- $V$  = design speed (mph)
- $v$  = vehicle approach speed (fps)
- $W$  = width of intersection, curb-to-curb (ft)
- $l$  = length of vehicle (ft)
- $y$  = length of yellow interval to nearest 0.1 sec (sec)
- $r$  = length of red clearance interval to nearest 0.1 sec (sec)

**Vehicle Signal Change Interval**

$$y = t + \frac{v}{2a \pm 64.4 G}$$

$$r = \frac{W + l}{v}$$

**Stopping Sight Distance**

$$SSD = 1.47Vt + \frac{V^2}{30 \left( \left( \frac{a}{32.2} \right) \pm G \right)}$$