

CE 3372 – Water Systems Design
Exercise Set 4

Purpose: Review and application of head loss models used in water transmission and distribution system analysis

Exercises

1. Equation 1 is the Hazen-Williams discharge formula in US Customary Units.

$$Q = 1.318C_h A R^{0.63} S^{0.54} \quad (1)$$

where;

Q is the discharge in ft^3/sec ;
 A is the cross section area of pipe in ft^2 ($A = \frac{\pi D^2}{4}$; D is the pipe diameter.);
 C_h is the Hazen-Williams friction coefficient (depends on pipe roughness);
 R is the hydraulic radius in ft ; and
 S is the slope of the energy grade line ($\frac{h_f}{L}$); L is the length of pipe.

- (a) Look up the Hazen-Williams loss coefficient (C_h) for enamel coated, steel pipe and cite your data source.
- (b) Estimate the head loss in a 10,000 foot length of 5-foot diameter, enamel coated steel pipe that carries 60°F water at a discharge of 295 cubic-feet per second (cfs), using the Hazen-Williams head loss model.

2. Equation 2 is the Hazen-Williams discharge formula in SI Units.

$$Q = 0.849 C_h A R^{0.63} S^{0.54} \quad (2)$$

where;

Q is the discharge in m^3/sec ;
 A is the cross section area of pipe in m^2 ($A = \frac{\pi D^2}{4}$; D is the pipe diameter.);
 C_h is the Hazen-Williams friction coefficient (depends on pipe roughness);
 R is the hydraulic radius in m ; and
 S is the slope of the energy grade line ($\frac{h_f}{L}$); L is the length of pipe.

- (a) Look up the Hazen-Williams loss coefficient (C_h) for Acrylonite Butadiene Styrene (ABS) pipe and cite your data source.
- (b) Estimate the head loss in a 3,050 meter length of 1.5-meter diameter, ABS pipe that carries water at a discharge of 8.35 cubic-meters per second (cms), using the Hazen-Williams head loss model.

3. Equation 3 is an explicit formula (based on the Darcy-Weisbach head loss model and the Colebrook-White frictional loss equation) for estimating discharge from head loss and material properties (Swamee and Jain, 1976).

$$Q = -2.22D^{5/2} \times \sqrt{gh_f/L} \times [\log_{10}\left(\frac{k_s}{3.7D} + \frac{1.78\nu}{D^{3/2}\sqrt{gh_f/L}}\right)] \quad (3)$$

where;

Q is the discharge in L^3/T ;
 D is the pipe diameter;
 h_f is the head loss in the pipe;
 g is the gravitational acceleration constant;
 L is the length of pipe;
 k_s is the pipe roughness height;
 ν is the viscosity of liquid in the pipe;

- (a) Find the viscosity for water at 50°F. Cite the source of your value.
- (b) Find the sand roughness height of ductile iron pipe. Cite the source of your value.
- (c) How deep is a column of water if the pressure at the bottom of the column is 20 psi?
- (d) Estimate the discharge in the 3 mile long, 24-inch diameter, ductile iron pipeline connecting points A and B depicted in Figure 1. Point A is 30 feet higher in elevation than point B. The pressure at point B is 20 pounds per square-inch (psi) greater than the pressure at point A.

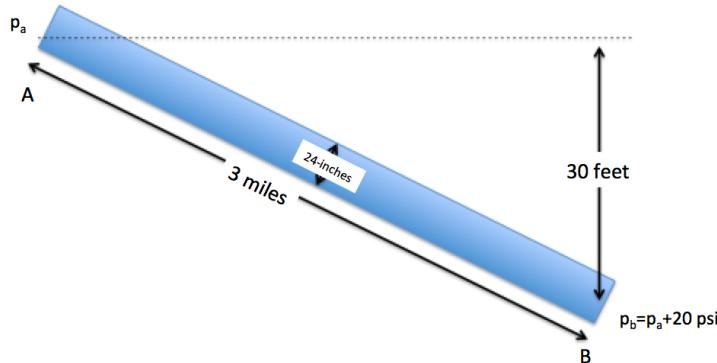


Figure 1: Pipeline Schematic

4. Equation 4 is a formula to estimate the required pipe diameter for a particular discharge, head loss, and roughness (Swamee and Jain, 1976).

$$D = 0.66[k_s^{1.25} \times \left(\frac{LQ^2}{gh_f}\right)^{4.75} + \nu Q^{9.4} \times \left(\frac{L}{gh_f}\right)^{5.2}]^{0.04} \quad (4)$$

where;

D is the pipe diameter;
 k_s is the pipe roughness height;
 L is the length of pipe;
 g is the gravitational acceleration constant;
 Q is the discharge in L^3/T ;
 h_f is the head loss in the pipe;
 ν is the viscosity of liquid in the pipe;

- (a) Find the viscosity for water at 60°F. Cite the source of your value.
- (b) Find the sand roughness height of cast-iron pipe. Cite the source of your value.
- (c) Estimate the diameter of a cast-iron pipe needed to carry 60°F water at a discharge of 10 cubic-feet per second (CFS) between two reservoirs 2 miles apart with an elevation difference between the water surfaces in the two reservoirs of 20 feet as depicted in Figure 2.

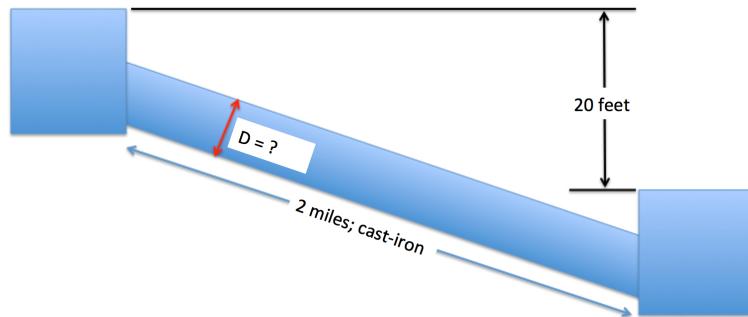


Figure 2: Pipeline connecting two reservoirs

5. Figure 3 is an aerial image of a parallel pipeline system in California.



Figure 3: Parallel Pipeline System

The left pipeline is a 96-inch diameter steel pipe, whereas the right pipeline is a 108-inch diameter steel pipe. Water at 50°F has kinematic viscosity of $1.45 \times 10^{-5} \text{ ft}^2/\text{s}$. The sand roughness of ductile iron is $1.64 \times 10^{-4} \text{ ft}$. If the head difference for the one-mile long pipelines between the thrust blocks is 120 feet, determine the discharge in each pipe in cubic-feet-per-second.

References

Swamee and Jain, A. K., 1976. Explicit equations for pipe-flow problems. ASCE J. of Hyd. Div., 102(HY5) pp. 657-664