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.

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

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 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.

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

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 carries 20°C water at a discharge of 8.35 cubic-meters per second (cms), using the Hazen-Williams head loss model.

EXERCISE 4 Page 1 of 5 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).

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

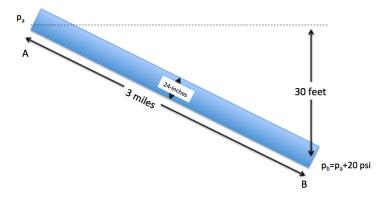


Figure 1: Pipeline Schematic

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

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

where;

D is the pipe diameter;

 k_s is the pipe roughness height;

L is the length of pipe;

q 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.

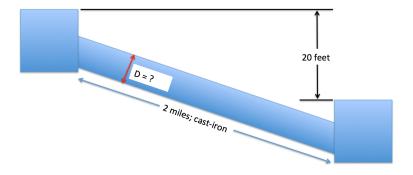


Figure 2: Pipeline connecting two reservoirs

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

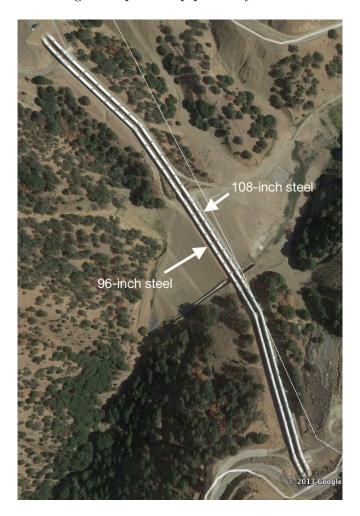


Figure 3: Parallel Pipeline System

The left pipeline is a 96-inch diameter steel pipe, whereas the right pipeline is a 108-inch diameter steel pipe. Water at 50^{o} F has kinematic viscosity of $1.45 \times 10^{-5} \ ft^{2}/s$. The sand roughness of ductile iron is $1.64 \times 10^{-4} \ ft$. 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.

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References

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

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