

**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.

$$Q = 1.318C_hAR^{0.63}S^{0.54} \quad (1)$$

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 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.

$$Q = 0.849C_hAR^{0.63}S^{0.54} \quad (2)$$

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 carries 20°C 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).

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

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;  
 $\nu$  is the viscosity of liquid in the pipe;

- Find the viscosity for water at 50°F. Cite the source of your value.
- Find the sand roughness height of ductile iron pipe. Cite the source of your value.
- How deep is a column of water if the pressure at the bottom of the column is 20 psi?
- 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.

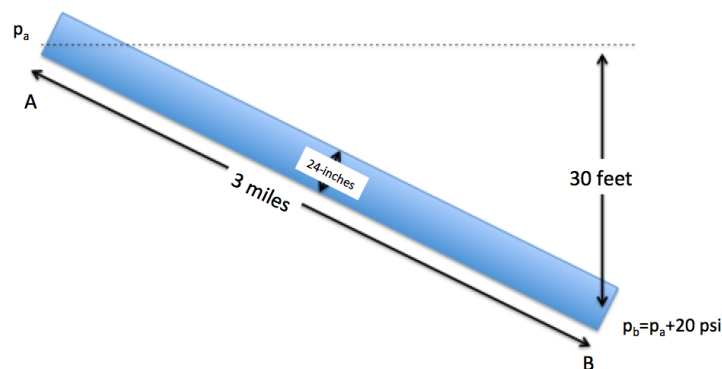


Figure 1: Pipeline Schematic

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

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

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;  
 $\nu$  is the viscosity of liquid in the pipe;

- Find the viscosity for water at 60°F. Cite the source of your value.
- Find the sand roughness height of cast-iron pipe. Cite the source of your value.
- 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.

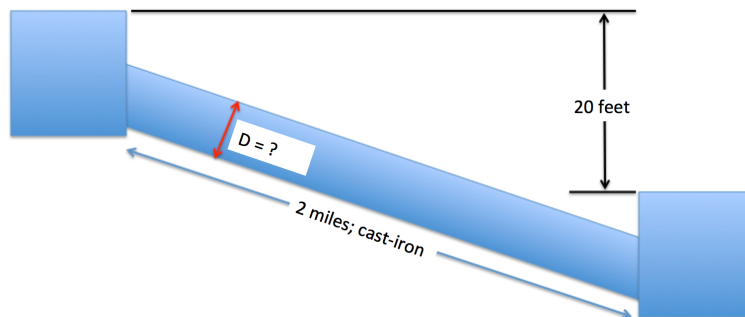


Figure 2: Pipeline connecting two reservoirs

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