ENVE 204

Lecture -2

Pipelines and Pipe Networks-I

(Pipelines connecting two reservoirs; Solution procedures for Type I, Type II, Type III problems)

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Friction Head Loss (hf) and Discharge (Q)Relationships

$$\mathrm{hf} = \mathrm{RQ}^{\mathrm{x}}$$

X:dimensionless

R:dimension depends on the friction equation and the unit system chosen.

Darcy-Weisbach Equation

$$hf = \frac{fL(Q/A)^2}{2gD} = \frac{fLQ^2}{2gDA^2} = \underbrace{\frac{fL}{2gDA^2}Q^2}_{R}$$

$$hf = RQ^2$$

Hazen Williams Equation

$$V = B.C.R_h^{0.63}.S^{0.54}$$

$$Q = A.Vh_f = \left[\frac{L}{C^{1.85}.D^{4.87}} \cdot \frac{7.88}{B^{1.85}}\right].Q^{1.85}$$

$$h_f = \underbrace{\left[\frac{L}{C^{1.85}.D^{4.87}} \cdot \frac{7.88}{B^{1.85}}\right]}_{R_{hazen\text{-}williams}}.Q^{1.85}$$

$$h_f = R_{Hazen-W}.Q^{1.85}$$

Manning's Equation

$$V = \frac{1}{n} . {R_h}^{2/3} . S^{1/2}$$

$$Q = A . \frac{B}{n} . {R_h}^{2/3} . S^{1/2}$$

$$h_f = \underbrace{\left[\frac{10.29}{B^2} . \frac{L . n^2}{D^{5.33}} \right]}_{R_{manning's}} . Q^2$$

$$h_f = R_{manning's} . Q^2$$

PIPELINES and PIPE NETWORKS

In general, when a number of pipes are connected together to transport water in a given project, they perform as a system that may include series pipes, paralel pipes, branching pipes, elbows, valves, meters & other devices.

If all elements are connected in series the arrangement is known as **pipeline** otherwise it is known as a **pipe network.**

3.1 Pipeline connecting two reservoirs

A pipeline is a system of one or more pipes connected in series and designed to transport water from one location (often a reservoir) to another.

Three principal types of pipeline problems:

TYPE 1: Flowrate (Q), pipe combinations are given → **Head (HL) Loss** determined

Directly solved

TYPE 2: Allowable total head loss (HL), pipe combinations are given → **Flowrate (Q)** determined

TYPE 3: Flowrate (Q) and allowable total head loss (HL) are given → **Diameter (D)** determined

Trial & Error

Calculations Involved in Pipeline Problems: Head Loss

3.2 Calculations Involved in Pipeline Problems

1. Head losses:

HL= Hm + Hf

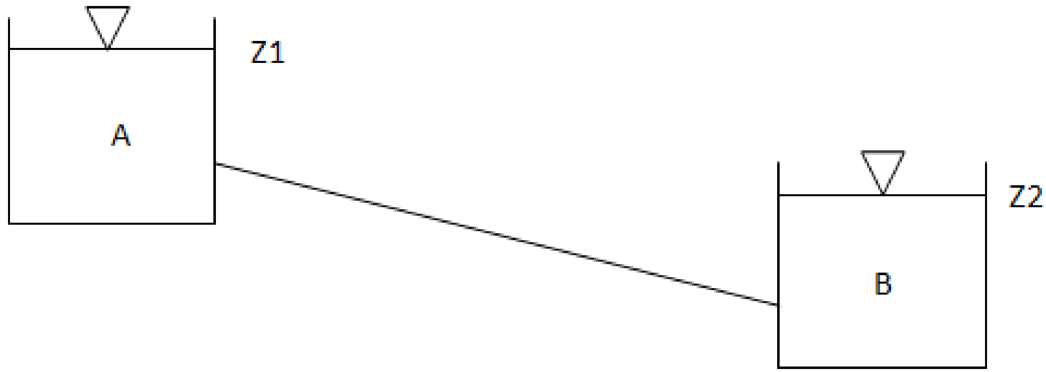
Hm= Total Minor Losses = $K\frac{V^2}{2g}$

Hf=Total Friction Losses = $\frac{fLV^2}{2gD}$

$$\mathbf{HL} = K\frac{V^2}{2g} + \frac{fLV^2}{2gD}$$

Head Losses in Reservoir Problems:

If the discharge is to another reservoir:



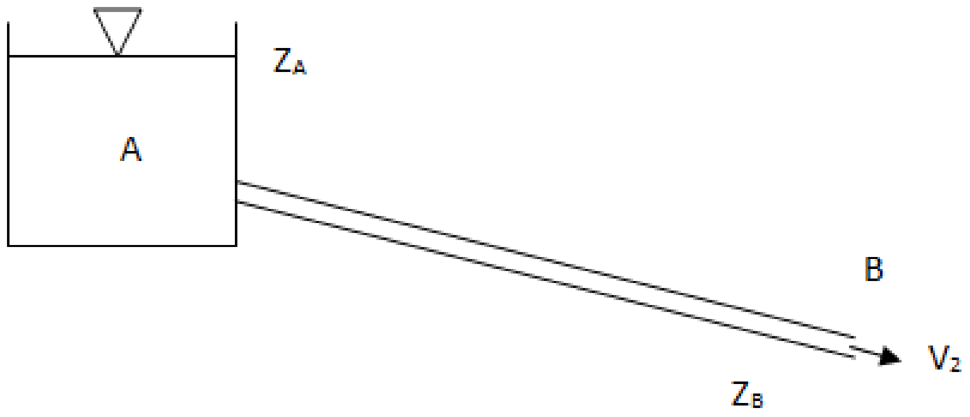
$$z_A + \frac{v_A^2}{2g} + \frac{P_A}{\gamma} = z_B + \frac{v_B^2}{2g} + \frac{P_B}{\gamma} + h_L$$

- Reservoirs are open to the atmosphere gauge pressures are equal to zero → $\frac{P_A}{\gamma}, \frac{P_B}{\gamma} = 0$
- Reservoir cross sectional area is so big compared to the cross sectional area of the pipes, velocity in reservoirs become negligible and taken as zero → $\frac{v_A^2}{2g}, \frac{v_B^2}{2g} = 0$
- Total Head for reservoir A and B is elevation head (surface elevation)

$$z_A = z_B + h_L$$

Head Losses in Reservoir Problems:

If the discharge is a free jet to atmosphere:



$$z_A = z_B + \frac{v_B^2}{2g} + h_L$$

$$h_L = z_A - z_B - \frac{v_B^2}{2g}$$

Calculations Involved in Pipeline Problems: Friction factor

2. Friction Factor (f)

<u>If diameter and flowrate is known (TYPE 1);</u>

- find velocity
- calculate Re
- use one of the methods listed below
  - graphical solutions (Moody diagram) or
  - implicit equation (colebrook-white) or
  - explicit equation (Jain equation)

Two Reservoir Example Problem

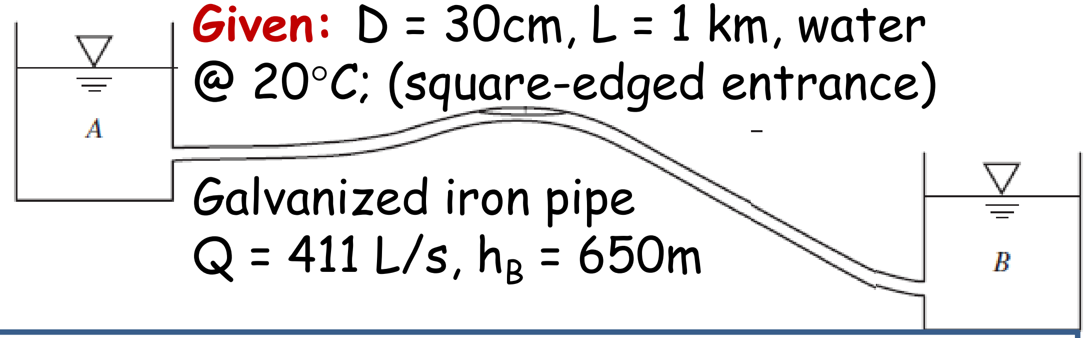
(Find the head loss given pipe size, material, and flow rate.)

Determine the water surface elevation in reservoir "A."

Energy Eq'n: $h_A - h_B = h_L$

$h_L =$

$h_L =$



Given: D = 30cm, L = 1 km, water @ 20°C; (square-edged entrance)

Galvanized iron pipe

$Q = 411$ L/s, $h_B = 650$m

Calculations Involved in Pipeline Problems: Type 2

<u>If flowrate is not known (TYPE 2);</u>

- assume complete turbulence conditions in which Re is so big and becomes neglicible
- graphical solution ➔ by using e/D value ➔ find friction factor
- explicit equation ➔ by neglegting Re number in Jain equation ➔ calculate friction factor by using following formula, $f_{old} = \frac{1.325}{\left[\ln\left(\left(\frac{e}{D}\right)/3.7\right)\right]^2}$
- calculate flowrate and then velocity and Re number by using friction factor found in previous step
- recalculate friction factor by using Jain Equation, $f_{new} = \frac{1.325}{\left[\ln\left(\frac{e/D}{3.7}+\frac{5.74}{N_R{}^{0.9}}\right]^2}$
- If $|fnew - fold| < 0.001$, stop the iteration and find the flowrate by using new friction factor.

Two Reservoir Example Problem

(Find the <u>flow rate</u> given pipe size, material, and head loss.)

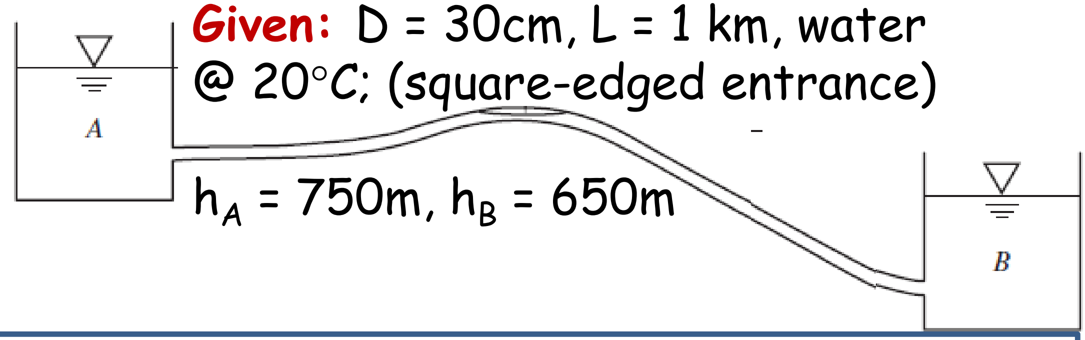
Determine the flow rate in the galvanized iron pipe.

$h_A - h_B = 100m = h_L$

$h_L = h_e + h_f + h_d$

$h_L = [f(L/D)+\sum K](V^2/2g)$

Given: D = 30cm, L = 1 km, water @ 20°C; (square-edged entrance)



$h_A = 750m$, $h_B = 650m$

Calculations Involved in Pipeline Problems: Type 3

<u>If diameter is not known (TYPE 3);</u>

- Write all equations in a form that diameter and f are the main parameters
- assume diameter
- calculate Re, friction factor and diameter
- assume a new diameter
- If $|Dnew - Dold| < 0.01$, stop the iteration, recalculate flowrate, head loss and friction factor with the final diameter

Two Reservoir Example Problem

(Find the pipe size given material, flow rate, and head loss.)

Determine the galvanized iron pipe size required.

$h_A - h_B = 100\text{m} = h_L$

$h_L = h_e + h_f + h_d$

$h_L = [f(L/D)+\sum K](V^2/2g)$

Given: L = 1 km, Q = 411 L/s, water @ 20°C; (square-edged entrance)

$h_A = 750\text{m}$, $h_B = 650\text{m}$