CHME 302 CHEMICAL ENGINEERING LABOATORY-I

EXPERIMENT 302-II
HEAD LOSS IN PIPES AND FITTINGS

OBJECTIVE

The goal of this experiment is to determine the local (minor) and linear (major) head losses to investigate how they are influenced by the flow speed.

THEORY

Viscous flow in a pipe can be characterized based on the Reynolds number, *Re*, which is the ratio of flow inertia to the viscous effects.

$$Re = \frac{\rho V D}{\mu} \quad (1)$$

where ρ is the fluid density, V is the average fluid velocity, D is the diameter of the pipe and μ is the fluid viscosity. In a steady incompressible pipe flow, the viscous effects as well as other irreversibilities can be incorporated into the Bernoulli equation in terms of a head loss. In general, losses in a straight pipe due to its surface roughness and length are referred to major losses, H_{major}, and losses associated with other effects (i.e. fittings, junctions, elbows, throttles, etc.) are referred to minor losses, H_{minor}. When viscous effects are considered, extended Bernoulli equation is expressed by

$$\frac{P_o}{\rho g} + \frac{V_1^2}{2g} + z_o = \frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 + H_{major} + H_{minor} \quad (2)$$

The magnitude of both major and minor losses is proportional to the velocity head ($V^2/2g$).

$$H_{major} = f\left(\frac{l}{D}\right)\left(\frac{V^2}{2g}\right) \qquad H_{minor} = \sum k_i \left(\frac{V^2}{2g}\right) \quad (3)$$

where f is the friction factor, l is the length of the pipe, g is the gravitational acceleration, and k_i is the loss coefficient for i^{th} component within the pipe system.

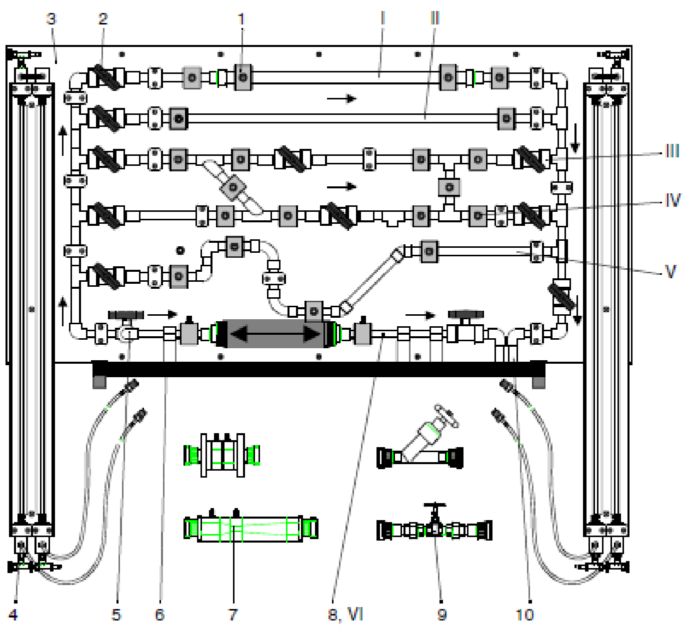
SETUP DESCRIPTION

The set-up is designed to demonstrate the head losses in pipes. The apparatus enables the following instruction capabilities:

- Minor head loss through sudden contraction and sudden expansion (Section I)
- Major head loss through a pipe (Section II)
- Minor head loss through pipe branches (Section III and IV)
- Minor head loss through elbows (Section V)

- Minor head loss through various objects: valves, Venturi, nozzle, orifice (Section VI)

The unit, shown in figure, is suited on the top of the hydraulic bench in order to make use of water supply and volumetric measurement facilities of the bench. The hydraulics bench unit provides the basic services for the pumping and volumetric measurement of the water supply in a certain period of time. A calibrated level indicator (11) allows measuring the amount of water circulated through the meters in the period.



1. Annular chambers with pressure tapping nipples.

2. Ball cocks for shutting off part sections.
3. Back wall
4. Double pressure gauge
5. Inlet
6. Tubular steel frame with suction pads
7,9. Measurement objects
8. Adjustable measuring section
10. Drain
I-VI. Measuring sections

EXPERIMENTATION

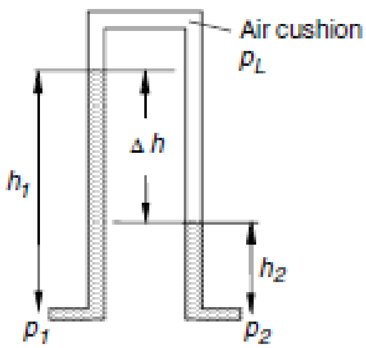
Notes on Safety

The set-up is kept in perfect condition from a safety point of view. To maintain this state and ensure safe operation, the following points should be observed:

- Pull the power cord before working on the electric circuits.
- Any modifications and repairs to the electrical equipment must only be carried out under the supervision of the lab technician and/ or the academic staff.
- In the event of obvious defects (e.g. split insulation on the electric wires), operation of the system is potentially fatal. In such cases, shut down the system immediately.
- Never allow the electrical components to come into contact with water.
- Never operate the submergible pump with the tank empty.

Procedure

For all experiments, volumetric flow rate should be determined. It can be estimated with the aid of the volumetric tank. Measure the flowrate by using bucket and stopwatch.



Double pressure gauge is suitable for measuring both differential pressures and gauge pressures in mm water column. When the vent valve at the top of the double pressure gauge is closed, differential pressure can be obtained as follows

$$\Delta p = \rho g \Delta h \qquad 4$$

where ρ is the liquid density and g is the gravitational acceleration.

During the measurements, the zero position of the pressure gauge should be in the center of the scale to obtain the maximum possible span. The level can only be increased by the vent valve (at the top). If it is too high, the pipe network must be drained.

1. Make sure that auxiliary valve allows flow through the tank pump.
2. Connect stop-cocks for the focused configuration by setting appropriate ones in parallel to the pipe and make sure that all others are set in perpendicular position to the pipe so that they won't allow flow.
    a. Long pipe (Section II on flow friction apparatus)
    b. Expansion-contraction (Section I on flow friction apparatus)
    c. Elbows (Section V on flow friction apparatus)
    d. Separation (Section III and IV on flow friction apparatus)
3. Switch on the pump and slowly open the main cock of the tank.
4. Connect pressure gauges to the desired measuring points.
    a. Make sure that double pressure gauge's vent valve at the top is closed and vent valves at the bottom are open.
    b. Slowly open ball cock in inlet of the appropriate measurement section
    c. Close the pipe section drain when there are no air bubbles in the connecting valves
    d. Simultaneously close the drain valve(s) on the double pressure gauge.
    e. The level can be increased by venting the double pressure gauge (If the level is too high, the double pressure gage should be drained and steps ***a-e*** should be repeated.)
5. Measure the volumetric flow rate using the tank if necessary.

Major Loss through a pipe

Measure major head loss for a pipe using the table provided in the data sheet at the back of this booklet. Record the data for at least 5 different values of volumetric flow rate, which can be set by adjusting the inlet valve of the appropriate section of the pipe setup (Section II).

Length = 800mm
Diameter = 17mm

Minor Losses

1) Measure minor head loss through sudden expansion and sudden contraction at the same volumetric flow rate using the table provided in the data sheet at the back of this booklet. Volumetric flow rate can be set by by adjusting the inlet valve of the appropriate section of the pipe setup (Section I).
   Expansion Diameters: from 17mm to 28,4 mm
   Contraction Diameters: from 28,4mm to 17mm

2) Measure minor head loss through branches at the same total volumetric flow rate using the table provided in the data sheet at the back of this booklet. Volumetric flow rate can be set by adjusting the inlet valve of the appropriate section of the pipe setup (Section III or IV).
   Angle: 45^o

3) Measure minor head loss through elbows at the same total volumetric flow rate using the table provided in the data sheet at the back of this booklet. Volumetric flow rate can be set by adjusting the inlet valve of the appropriate section of the pipe setup (Section V).

Analysis

- Estimate the Reynolds number and comment on whether the flow in the pipe is laminar or not.
- Using the Bernoulli equation, obtain expressions for either the friction factor (*f*) or head loss coefficient (*k*).
- Estimate the friction factor (for major loss experiment) or the loss coefficient (for minor loss experiment) using the experimental data.
- Plot the *f* vs *Re* number curve for the pipe.
- Calculate the coefficient for measured object.