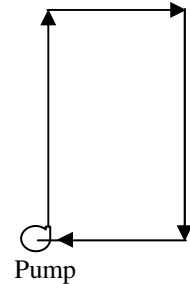


EN -644 - Two-Phase Flow and Heat Transfer

Assignment -2

1. Solving real life reactor problems are tedious and time consuming. However, to illustrate the principles involved, let us look at a closed loop constructed of a pipe with diameter $d = 2.5$ cm and a total length of 20 m driven by a centrifugal pump as shown in the figure. The fluid circulated is water of density 1000 kg/m^3 and viscosity 10^{-3} Pa.s at a rate of 1.5 kg/s .



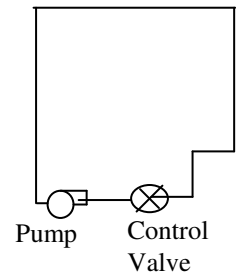
- (a) Calculate the frictional pressure drop in the total circuit.
- (b) The next task is to choose a pump. Calculate the head required to be developed by the pump
- (c) To be conservative, add an additional 30% on the estimated head. If the market offers two pumps of the following given characteristics, which one would you choose? The characteristics are:
 Pump-A $H \text{ (m)} = 10 - 700,000 Q^2$ where Q is flow rate in m^3/s
 Pump-B $H \text{ (m)} = 12 - 700,000 Q^2$ where Q is flow rate in m^3/s
- (d) Assuming that the actual circuit behaves ideally with no error (30% accounted in part c is not there), estimate the actual mass flow rate the pump will circulate
- (e) Assuming that the desired flow rate is 1.5 kg/s , estimate the friction loss coefficient K for the valve that has to be installed in the circuit.
- (f) Now imagine that the circuit you engineered is working fine. Suddenly due to pump malfunction, it seized (got jammed) instantly and so the head developed is zero. Now the circulating fluid would slowly come to rest. You are asked to estimate the time required for the flow to reduce to 1% of the design flow rate. During this process, for simplicity, assume that the friction factor is a constant and equal to the design value (though it will change in reality)
2. The forced circulation loop (sketched in the figure) in a Test Facility has the following specifications.

Working Fluid: Water at 20°C . (Assume density = 1000 kg/m^3)

Mass flow rate desired: 0.15 kg/s to 1.5 kg/s

Diameter of pipe: 24 mm.

The pump employed has a shut-off head of 30 m and has a characteristic given by the expression, $H \text{ (m)} = 30 - 2.22 \times 10^6 \times [Q(\text{m}^3/\text{s})]^2$.



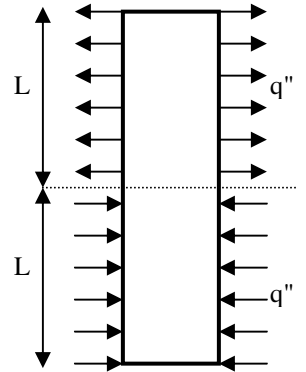
- (a) State whether the pump can deliver the desired flow range. The friction factor in pipe may be assumed as 0.03 and the closed loop equivalent length (including minor losses) is 24 m.
- (b) Assuming that the flow is controlled by a throttle valve, what should be the range of K_{valve} to get the desired flow range.
3. Consider the flow of water in a channel of 0.1 cm diameter entering at 12 m/s and 50°C .
 - (a) Compute the frictional pressure gradient, assuming that the channel is smooth.
 - (b) For data given in part (a), assuming that the channel is adiabatic, compute (a) the temperature gradient along the channel due to the shear work at the wall. Proceed systematically from the relevant governing equation. Comment at what heat flux on the wall (if it is also heated by uniform heat flux), the frictional energy deposition shall be within 1% and hence for heat flux above this value the frictional contribution can be neglected.
 - (c) You are now asked to develop a model in which the shear work on the wall (assumed to be thin) is split between the ambient and the fluid, unlike in part (b) where, all the work was ploughed back into the fluid as heat. For this you may assume that the channel wall is at a temperature T_w . The wall temperature will be decided in such a way that the heat flux to the wall and the ambient will add up to shear work. Mathematically set up the equations for the same. For the data given in Problem 1, compute the split at the entrance. You may note that the heat transfer is by forced convection in the inside and free convection on the outside. Use suitable correlations for both. Ambient may be assumed to be at 30°C .

4. Consider a loop constructed with pipe of length $4L$ and diameter d as shown in the figure. In the bottom half of the loop fluid is heated by uniform heat flux q'' and the fluid is cooled in the top half of the loop in a similar fashion. Show that under steady natural circulation conditions, the non-dimensional velocity, $Re = \frac{\rho v d}{\mu}$, is equal to $\frac{Gr}{128}$,

where $Gr = \frac{g \beta \Delta T_f d^3 \rho^2}{\mu^2}$ and ΔT_f is the increase in temperature of the fluid in the

heating section. You may assume that (a) the length of the horizontal sections are short and therefore are negligible, (b) Flow is single-phase and laminar and (c) Boussinesq approximation is valid.

5. Consider a loop shown below. The data for the loop are given in the following table.
- Compute the mass flow rate and temperature distribution in the loop. I
 - Now assume that the heat removed is equal to heat generated and assume that the heat removed per unit length is constant (i.e., heat removed is also at constant heat flux) Calculate the circulating flow rate. Compare this with the one obtained in part (a) and comment.



Acceleration due to gravity	9.81 m/s ²
Volumetric Expansion Coefficient	4.158 X10 ⁻⁴ /K
Density	996 kg/m ³
Power	1000 W
Length (L)	Refer Figure
Diameter(d)	0.04 m
Dynamic Viscosity	7.953X10 ⁻² Pa-s
Specific Heat	4177.8 J/kg-K
Coolant Temperature	30 °C
Friction factor	0.079Re ^{-0.25}
Heat transfer coefficient in Cooler	200 W/m ² -K

