APPROVED SOLUTION

Design Problem 2 – Hydraulics & Pump Characteristics Part 2 - CHEMCAD

1. Objective
2. Problem statement
3. Submission requirements
4. Supporting Calculations

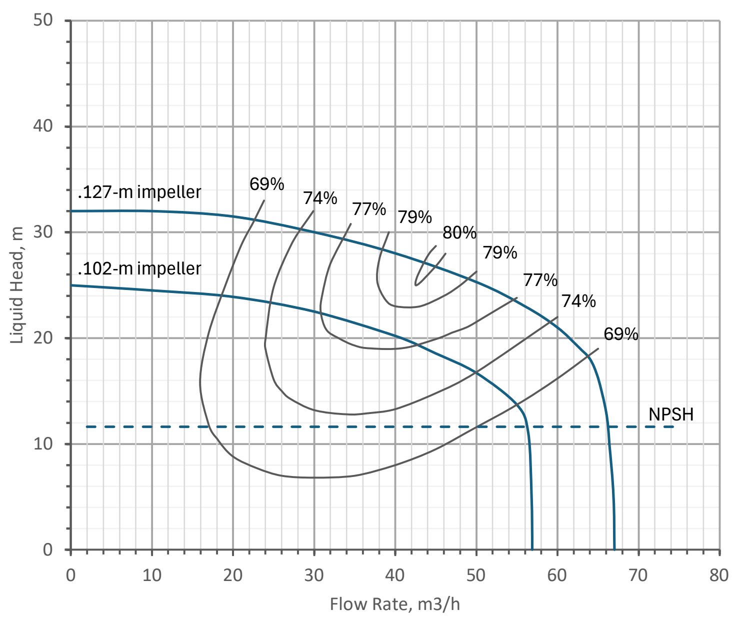
Objective

The objective is to use CHEMCAD to determine the operating point for a pump-pipe system using the pump characteristic curve and to optimize the pipe diameter.

Problem Statement

This exercise accompanies the pump video by Jacques Chaurette. Watch the video before doing the lab. The video illustrates several properties of pumps that we will simulate in this lab.

Recall that in lab 2, you calculated the optimum pipe diameter for a process liquid pumped from a storage tank to a distillation column through a pipeline using a centrifugal pump. The pump characteristic curve is shown below. The characteristic curve describes the ability of the pump to generate pressure as a function of the flow rate through the pump. In this case, the flow rate is throttled by the frictional elevation losses in the upstream pipeline as well as the external pressure increase.



The pipeline is 100 m long and is 80 mm-internal-diameter commercial carbon steel pipe. Miscellaneous losses from fittings and valves are equivalent to 600 pipe diameters. The storage tank operates at atmospheric pressure and the column at 1.7 bara. The lowest liquid level in the tank is 1.5 m above the pump inlet, and the feed to the column is 3 m above the pump inlet. The density of the fluid is 868 kg/m^3 and its viscosity is 0.631 mNs/m^2. While the actual physical pipeline diameter is 80 mm, the optimal diameter is 73 mm when pump efficiency is accounted for. However, we will use the 80 mm pipe because that is the closest standard size to the optimal.

In this lab, your job is to use CHEMCAD to simulate the pump and pipe system described in Design Problem 2. Your instructor will provide you with two items to help you do this: (1) a PowerPoint slide deck that has instructions for how to build the process, and (2) an Excel file that has the pump characteristic curve in it. The Excel file is explained in PowerPoint. Follow the instructions in PowerPoint carefully and use the results to complete the data table below. Note: Details of the CHEMCAD simulation such as feed composition are provided in the PowerPoint slide deck.

0.102-m impeller			
Diameter, m	0.08 (By Hand)	0.08 (CC)	Opt:
Flow Rate, m^3/h	42.1		
Liquid head, m	19.3		
Efficiency, %	77		
NPSH, m	11.6		
Purchase Cost, $			
0.127-m impeller			
	Hand/Plot, .08 m	CC, .08 m	Opt:
Flow Rate, m^3/h	52.1		
Liquid head, m	24.3		
Efficiency, %	78		
NPSH, m	11.6		
Purchase Cost, $			

Submission Requirements

1. Completed table with signed cover sheet. You may use the fillable form in Canvas to complete the table.

3. Answers to the questions in PowerPoint slide 18.

3. Single PDF bundle of coversheet, table, and questions and CHEMCAD file submitted in Canvas.

Completed table and answers to questions follow below

0.102-m impeller			
Diameter, m	0.08 (By Hand)	0.08 (CC)	Opt: 0.0773
Act. Flow Rate, m^3/h	42.1	42.4	40.2
Liquid head, m	19.3	19.4	20.0
Efficiency, %	77	77.2	77.9
NPSH, m	11.6	11.6	11.6
Purchase Cost, $ (Feb 2025)	5,405	8,591	8,539

0.127-m impeller			
Diameter, m	0.08 (By Hand)	0.08 (CC)	Opt: 0.0720
Act. Flow Rate, m^3/h	52.1	52.5	44.0
Liquid head, m	24.3	24.4	27.0
Efficiency, %	78	77.7	80.0
NPSH, m	11.6	11.6	11.6
Purchase Cost, $ (Feb 2025)	5,654	9,200	8,969

Answers to questions in PowerPoint Slide 18 **APPROVED SOLUTION**

Question 1: Run the simulation and record your results in the .102-m section of the fillable table under "0.08 (CC)."

Solution:

The answers are recorded in the attached table.

Question 2: We never specified the flow rates of the "free streams," but CHEMCAD was able to calculate them. Explain how this happened. Discuss with other cadets in class.

Solution:

CHEMCAD finds the intersection of the system curve and the characteristic curve to determine the flow rate.

Solution:

Question 3: Change the pressure of the third node by +/- .2 bar and describe what happens to the "free" feed flow rate of the feed. What happened to the pressure in the flash drum when you did this? When finished, change the pressure back to 1.7 bar.

Solution:

Increasing the pressure of the third node from 1.7 to 1.9 bar increases the pressure in the flash vessel to 1.9 bar and decreases the flow rate from 42.47 to 39.20 m^3/h. Decreasing the pressure of the third node from 1.7 to 1.5 bar decreases the pressure in the flash vessel to 1.5 bar and increases the flow rate from 42.47 to 45.37 m^3/h.

Question 4: Change the elevation of the third node by +/- 1 m and describe what happens to the flow rate of the feed. Why did this happen? Explain. By what amount should the elevation be changed to reduce the feed flow rate by half?

Solution:

Increasing the elevation from 3 m to 4 m reduces the flow from 42.47 to 42.16 m^3/h. Decreasing the elevation from 3 m to 2 m increases the flow from 42.47 to 43.74 m^3/h.

Changing the elevation changes the hydrostatic pressure that the pump is pushing against, which changes the static head term in the system curve. Increasing the static head shifts the system curve upward and to the left, which decreases flow at the intersection point. Decreasing the static head shifts the system curve downward and to the right, which increases the flow at the intersection.

Increasing the elevation from 3 m to 14.55 m decreases the flow rate from 42.24 to 21.15 m^3/h.

Question 5: Change the pressure on the first node from 1.01 to 0.11 bar, run the simulation, and observe and explain the change in the NPSHa. Change the pressure on the first node once again to 0.01 bar and describe what happens. When finished, change the pressure back to 1.01 m

Solution:

Changing the pressure on the first node from 1.01 to 0.11 bar changes the NPSHa from 11.7 to 1.06 m. This is because feed pressure has been lowered to a value much closer to the saturation vapor pressure of the feed is about 0.015 bar.

Further decreasing the pressure to 0.01 bar causes cavitation in the pump because the inlet pressure is now below the saturation vapor pressure of 0.015 bar.

Question 6: Use the sensitivity analysis technique introduced in lesson 5 to optimize the efficiency of the pump by varying the pipe diameter. Record your results in the “Opt” column of the .102-m section of the fillable table.

Solution:

The answer is recorded in the attached table.

Question 7: Add the 0.127-m characteristic curve to the pump and repeat question 1.

Solution:

The answers are recorded in the attached table.

Question 8: Determine the purchased cost of the pumps in February 2025 and add your results to the table. In addition, use the costing figures in your textbook to determine the purchased cost for the “by hand” calculations.

Solution:

The answers are recorded in the attached table.