APPROVED SOLUTION

Design Problem 2 – Hydraulics & Pump Characteristics

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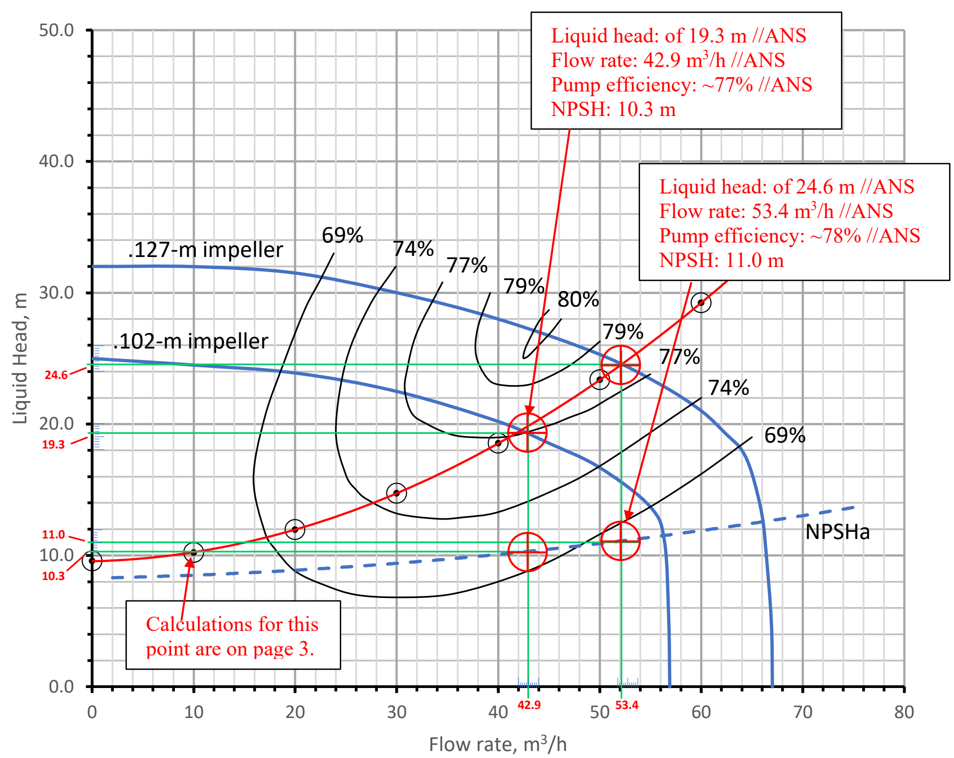
Objective

The objective is to determine the operating point for a pump-pipe system using the pump characteristic curve, and to implement the solution in CHEMCAD. This exercise accompanies the pump video by Jacques Chaurette.

Problem Statement, Part 1

A process liquid is pumped from a storage tank to a distillation column using a centrifugal pump. The pump characteristic curve is shown below. 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.

Generate and plot the system curve on the given axes, and use the plot to determine the operating point, pump efficiency, and NPSH for the 0.102-m and .127-m impellers.



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Problem Statement, Part 2

In this part of the problem, your job is to use CHEMCAD to simulate the pump and pipe system described earlier in CHEMCAD. Your instructor will provide you with two items to help you do this: (1) 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 the PowerPoint. Follow the instructions in the PowerPoint carefully and use the results, along with the results from part one, to complete the data table below to compare the CHEMCAD result to your calculations. Note: Details of the CHEMCAD simulation such as feed composition are provided in the PowerPoint slide deck.

	Excel/Plot	CHEMCAD
0.102-m impeller		
Flow Rate, m^3/h	19.3 //ANS	19.4 //ANS
Liquid head, m	42.9 //ANS	42.5 //ANS
Efficiency, %	77 //ANS	77.1 //ANS
NPSH, m	10.3 //ANS	11.7 //ANS
0.127-m impeller		
Flow Rate, m^3/h	24.6 //ANS	24.4 //ANS
Liquid head, m	53.4 //ANS	52.6 //ANS
Efficiency, %	78 //ANS	77.7 //ANS
NPSH, m	11.7 //ANS	11.7 //ANS

Submission Requirements for Parts 1 and 2

1. Sketch of the system curve on the same axes as the characteristic curve, with a minimum of six points added to the plot and a "smooth" curve added to the points.

2. PDF of plot and completed table with signed cover sheet. You may use the Microsoft Word document in Canvas, along with drawing tools, to make a sketch of the plot and to complete the table, and then convert this to pdf for your submission

3. Supporting calculations in Excel and CHEMCAD in Canvas.

Supporting Calculations *(Use space below for hand calculations if needed. Append additional sheets as necessary)*

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Solution

Use Equation 12-12 on page 492 to calculate the static and dynamic head terms. Dynamic head terms are the flow-dependent terms and the static head terms remain constant with respect to flow. Static head includes elevation and pressure terms, and kinetic energy and frictional losses contribute to dynamic head. The static and dynamic heads are calculated below, with the sample calculation of dynamic head at one flow rate. The sample calculation is for 10 m^3/h.

<u>Static head terms:</u>

The static head is the same at all flow rates.

$$\text{Difference in elevation} = \Delta z = 3.0 - 1.5 = 1.5\text{m}$$

$$\text{Difference in pressure} = \Delta P = (1.7 - 1.01325)\times 10^5 = 0.7\times 10^5\ \tfrac{\text{N}}{\text{m}^2}$$

$$\text{Expressed as head of liquid} = (0.7\times 10^5\ \tfrac{\text{N}}{\text{m}^2}) / (868\tfrac{\text{kg}}{\text{m}^3}\times 9.8\tfrac{\text{m}}{\text{s}^2}) = 8.1\text{m}$$

$$\text{Total static head} = 1.5\,\text{m} + 8.1\,\text{m} = 9.6\text{m}$$

<u>Dynamic head terms, for fluid flow rate of 10 m^3/h</u>:

The dynamic head calculation is repeated for other flow rates to determine the points shown in the plot.

$$\text{cross-sectional area of pipe} = \frac{\pi}{4}(0.080\text{m})^2 = 5.03\times 10^{-3}\,\text{m}^2$$

$$\text{velocity} = \frac{\left(10\,\tfrac{\text{m}^3}{\text{h}}\right)\times\left(\tfrac{1\text{hr}}{3600\text{s}}\right)}{5.03\times 10^{-3}\,\text{m}^2} = 0.5526\ \text{m/s}$$

$$\text{Reynolds number} = \frac{.080\times .5526\times 868}{0.000631} = 68,675$$

$$\text{relative roughness} = 0.000046 / 0.080 = 0.000575$$

$$\text{friction factor} = 0.0055\ \text{(read from fig 12-1)}$$

$$\text{equivalent pipe length} = 100\text{m} + 600\times 0.080\text{m} = 148\text{m}$$

$$\text{frictional head from eq 12-7} = \frac{2\times .0055\times(.5526\,\tfrac{\text{m}}{\text{s}})^2\times 148\,\text{m}}{0.080\,\text{m}\times 9.8\,\tfrac{\text{m}}{\text{s}^2}} = 0.6\underline{3}7\,\text{m}$$

$$\text{kinetic energy term} = \frac{\tfrac{1}{2}(0.5526\,\tfrac{\text{m}}{\text{s}})^2}{9.8\,\tfrac{\text{m}}{\text{s}^2}} = 0.01\underline{5}6\,\text{m}$$

$$\text{total dynamic head} = 0.64\,\text{m} + 0.02\,\text{m} = 0.6\underline{5}3\,\text{m}$$

$$\text{total head} = 0.6\underline{5}3\,\text{m} + 9.\underline{6}\,\text{m} = 10.\underline{2}\,\text{m}$$

This last result is plotted as the second point in the plot.