ES5-P2

February 16, 2025

0.1 ES5-Problem 2

The figures below show the analysis for the problem

14. Water is to be pumped at a rate of 70 liters per second in a 1-kilometer meter long, 200 millimeter diameter pipeline between two reservoirs with an elevation difference of 20 meters. The roughness height of the steel pipe is 0.045 millimeters.

A: i = 30 m
A: ii = 16 m
A: iii = 26 m

The Reynolds number for water is computed from

$$Re = \frac{VD}{\nu} \tag{3}$$

The kinematic viscosity of water in the system is

$$\nu = 1 \times 10^{-6} \mathrm{m}^2/\mathrm{s} \tag{4}$$

The Jain equation (Jain, 1976) that directly computes friction factor from Reynolds number, diameter, and roughness is

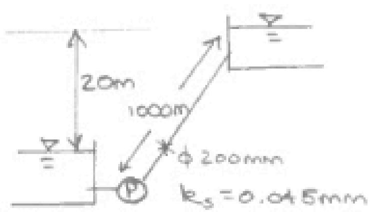
$$f = \frac{0.25}{[log(\frac{k_s}{3.7D} + \frac{5.74}{Re^{0.9}})]^2} \tag{5}$$

The Darcy-Weisbach head loss equation (for pipe losses) is

$$h_{loss} = f \frac{L}{D} \frac{V^2}{2g} \tag{6}$$

Using the description and these equations

a) Sketch the system – show the two reservoirs and the pump on the sketch.



+6

b) Convert the pipe diameter into meters (you will need this value below).

$$200\text{mm} \frac{1\text{m}}{1000\text{mm}} = 0.2\text{m}$$

+2

c) Convert the flow rate into cubic-meters-per-second (you will need this value below).

$$70.0 \text{ lps} \frac{1\text{m}^3}{1000 \text{ L}} = 0.07 \text{m}^3/\text{s}$$

+2

d) Determine the pipeline velocity (in meters per second).

$$A = \frac{\pi D^2}{4} = \frac{\pi (0.2)^2}{4} = 0.0314 m^2 \quad V = \frac{Q}{A} = \frac{0.07 m^3/s}{0.0314 m^2} = 2.229 m/s$$

+2

e) Compute the Reynolds number for the system.

$$Re = \frac{(2.229 m/s)(0.2 m)}{1 \cdot 10^{-6} m^2/s} = 4.458 \cdot 10^5$$

f) Compute the friction factor from the Jain equation.

$$f = \frac{0.25}{\left[\log_{10}\left(\frac{0.045}{3.7(200)} + \frac{5.74}{(4.458 \cdot 10^5)^{0.9}}\right)\right]^2} = 0.0158$$

g) What is the pipe head loss in the system at 70 liters per second?

$$h_L = f \frac{L}{D} \frac{V^2}{2g} = 0.0158 \left(\frac{1000 m}{0.2 m}\right)\left(\frac{(2.229 m/s)^2}{2(9.8 m/s^2)}\right) = 20.02 m$$

h) What is the static lift (in meters of head)? (CHANGES FOR DIFFERENT VERSIONS

20m (30m) (16m) (26m)

A. A:. A:. A::

i) What is the sum of the frictional loss and the static lift (in meters of head)?

h_T = STATIC + h_L

A. 20+20.02 = 40.02 m

A:. 16+20.02 = 36.02 m

A:. 30+20.02 = 50.05 m

A:: 26+20.02 = 46.02 m

Select a pump from one of the four on Figure 7 below. Indicate the operating point on the pump you select.

j) Which pump and operating impeller speed did you choose?

A. PUMP II, 4350RPM

A:. PUMP II, III, IV; ANY RPM

A:. PUMP III, 4350RPM

A:: PUMP IV, 4050RPM

k) Estimate the required NPSH for the pump you choose.

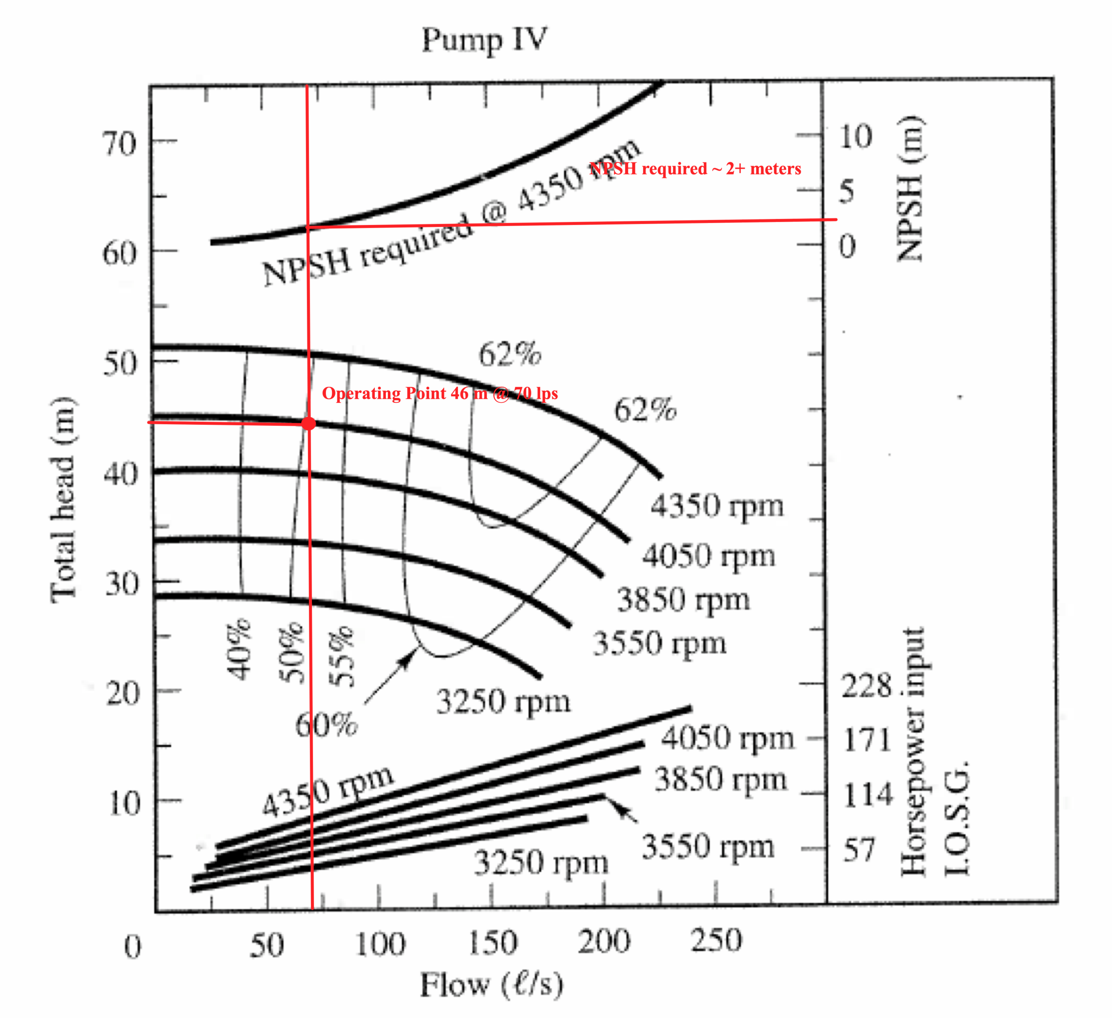
A. ~4 m

A:. ~3 m

A:. ~3 m

A:: ~2 m

The solution to the problem is to use the static lift of 26 meters. (The A:: answer) Pump IV @ 4050 RPM is best choice , NPSHr is 2 meters based on pump curve.


Pump IV
NPSH required @ 4350 rpm
NPSH required ~ 2+ meters
Operating Point 46 m @ 70 lps
62%
62%
4350 rpm
4050 rpm
3850 rpm
3550 rpm
3250 rpm
40%
50%
55%
60%
4350 rpm
4050 rpm
3850 rpm
3550 rpm
3250 rpm
Total head (m)
70
60
50
40
30
20
10
0
50
100
150
200
250
Flow (ℓ/s)
10
5
0
NPSH (m)
228
171
114
57
Horsepower input
I.O.S.G.

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