BIE 5110/6110
Sprinkle & Trickle Irrigation
Fall Semester, 2004

Assignment #6 (100 pts)
Pump Characteristic Curves
Due: 20 Oct 04

Given:

- A graph of pump characteristic curves for Cornell Model 4HS
- Notice the abscissa scale and the note saying that the pump curves are "flat" from Q = 0 to Q = 100 gpm
- The desired operating point on your system curve is Q = 550 gpm at TDH = 72 ft
- The pump will take water from a large concrete-lined canal with water surface which can vary from 1,330 to 1,333 ft above mean sea level
- The suction side of the pump has a screen, 8.0 ft of 6-inch SDR41 IPS PVC pipe, and one 45-degree elbow
- The pump itself is located at an elevation of 1,338 ft above mean sea level
- The crop to be grown in the irrigated field is alfalfa

Required:

1. What is the nominal pump speed (RPM)?
2. What is the pump efficiency at the desired operating point?
3. What is the WHP at the desired operating point?
4. What is the calculated BHP at the desired operating point? Does it match the BHP value given by the manufacturer on the graph?
5. Select an impeller diameter (inches) from the options given on the graph
6. What is the required pump speed (RPM) such that the desired operating point is the actual operating point?
7. What is the required impeller trim (reduction in D) if the pump speed cannot be changed, such that the desired operating point is the actual operating point?
8. What is the $NPSH_r$ at the desired operating point?
9. What is the $NPSH_a$ at the desired operating point?
10. Do you expect the pump to cavitate at the desired operating point?

Solutions:

1. The nominal pump speed is listed on the Cornell sheet as 1200 RPM. The exact speed for the pump curves is 1175 RPM.
2. From the graph, at 550 gpm and 72 ft head, the efficiency is approximately 75%, to the nearest whole number; or more generally, the efficiency is between 74 and 75%.
3. At the desired operating point, the WHP is:

$$WHP = \frac{QH}{3956} = \frac{(550)(72)}{3956} = 10.0 \text{ HP}$$

   or, 7.46 kW.

4. The calculated BHP is:

$$BHP = \frac{WHP}{E_{pump}} = \frac{10.0}{0.75} = 13.3 \text{ HP}$$

   or, 9.94 kW. Interpolating on the graph, the BHP appears to be approximately 14 HP, or perhaps slightly less than 14 HP. Thus, the calculated value agrees fairly well with the graphical value, given the need for interpolation "by eye." Also, the 14 HP estimate is sufficient to determine a power unit (motor) to drive this pump.

5. Select the nearest pump curve which is above the desired operating point (unless a pump curve is only slightly below the desired operating point). In this case, choose the curve for the 14" nominal diameter.

6. For this, apply the procedure given in the lecture notes. Develop some points for the "equal efficiency" curve, and make them near the desired operating point such that the curve will intersect with the pump curve.

Q_1 (gpm)	H_1 (ft)
560	74.6
570	77.3
580	80.1
590	82.9
600	85.7

   After graphing the points from the above table, the intersection with the 14" pump characteristic curve is approximately:

H_3 = 77 ft
Q_3 = 568 gpm

Finally, reduce the pump speed as follows:

$$N_{new} = 1175\left(\frac{550}{568}\right) = 1138 \text{ RPM}$$

Note that the intersection (Q_3, H_3) is usually close to the actual operating point without a change in speed, N, and the value of Q_3 is not much different than Q_2. In this case, the adjustment in speed is slight and it might not be worth the expense to gear down to N_{new}; instead, it might be better to accept the actual operating point without changing speeds.

To know the actual operating point without changing speeds, we would need sufficient information to develop the system curve.

7. The intersection (Q_3, H_3) is already known from the previous calculations, so calculate the required impeller diameter straight away as follows:

$$D_{new} = 14\left(\frac{550}{568}\right) = 13.6 \text{ inches}$$

where it is assumed that the nominal diameter is the actual standard diameter. The table below the graph shows maximum impeller diameters, but to apply them it would be necessary to consult the manufacturer to be sure.

Note that the above impeller trim (0.4") is very slight.

8. Extrapolating in the manufacturer's curves, at the desired operating point, $NPSH_r \approx 5$ ft.

9. Determine $NPSH_a$ as given in the lecture notes:

Maximum static lift is given as:

$$(h_{lift})_{max} = 1338 - 1330 = 8 \text{ ft}$$

Average atmospheric pressure head:

$$(h_{atm})_{avg} = 10.3 - 0.00105\ (1{,}338)(0.3048) = 9.87 \text{ m } (32.4 \text{ ft})$$

Assuming a water temperature of 10°C:

$$h_{vapor} = 0.0623 \exp\left(\frac{17.27(10)}{10 + 237.3}\right) = 0.125 \text{ m } (0.411 \text{ ft})$$

From Table 8.5, the suction pipe has an ID of 6.301 inches. Then, pipe area is:

$$A_{pipe} = \frac{\pi(6.301/12)^2}{4} = 0.217\ ft^2$$

The flow rate is: Q = 550/448.86 = 1.23 cfs. And, the velocity head is:

$$\frac{V^2}{2g} = \frac{(1.23)^2}{2(32.2)(0.217)^2} = 0.500\ ft$$

Friction loss in the suction pipe, using Hazen-Williams:

$$h_f = 10.5\left(8.0\right)\left(\frac{550}{150}\right)^{1.852}\left(6.301\right)^{-4.87} = 0.12\ ft$$

Minor losses on suction side of pump: From Table 11.2 for a flanged "long-radius" 45-degree elbow, 6" nominal size, K_r = 0.17. Also from Table 11.2, for a "basket strainer," K_r = 0.85. Then,

$$\left(h_f\right)_{minor} = \left(0.17 + 0.85\right)\left(0.500\right) = 0.51\ ft$$

Notice that the minor losses are greater than the pipe friction losses (the pipe is only 8-ft long, and it is PVC, so it's smooth) . Note that the average velocity in the suction pipe is 5.67 fps, which is OK. Note also that the static lift will have a much greater influence on $NPSH_a$ than friction losses, and that the velocity head is on the same order of magnitude as the friction losses. Finally,

$$NPSH_a = 32.4 - 0.12 - 0.51 - 8.0 - 0.50 = 23.3\ ft$$

10. This pump installation will not be expected to cavitate because $NPSH_a \gg NPSH_r$.