HYDRAULICS–1

The line between a low-pressure booster pump and a high-pressure boiler feed pump contains a running length of 65 ft of 6-in schedule-40 steel pipe, four long radius 90° elbows, a swing check valve, and a fully open gate valve. The feed pump is 12 ft higher than the booster pump in elevation. The flow rate is 740 gpm of 250°F water. The known pressures are

<table>
<thead>
<tr>
<th></th>
<th>Pressure before booster pump</th>
<th>Pressure before boiler feed pump</th>
<th>Pressure after boiler feed pump</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>37 psia</td>
<td>95 psia</td>
<td>1350 psia</td>
</tr>
</tbody>
</table>

(a) What is the pressure at the discharge of the booster pump?
(b) What is the brake horsepower requirement of the motor for the boiler feed pump if the pump’s efficiency is 62%?

HYDRAULICS–2

A centrifugal pump has the following operating characteristics based on operation at 1800 rpm, 14.7 psia, and 85°F water.

<table>
<thead>
<tr>
<th>Q (gpm)</th>
<th>H (ft)</th>
<th>NPSHR (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>550</td>
<td>50.0</td>
<td>8.0</td>
</tr>
<tr>
<td>600</td>
<td>47.5</td>
<td>9.5</td>
</tr>
<tr>
<td>650</td>
<td>45.0</td>
<td>11.1</td>
</tr>
<tr>
<td>700</td>
<td>42.1</td>
<td>13.0</td>
</tr>
<tr>
<td>750</td>
<td>39.1</td>
<td>15.0</td>
</tr>
<tr>
<td>800</td>
<td>36.0</td>
<td>17.2</td>
</tr>
</tbody>
</table>

(a) Tabulate the H and NPSHR characteristics as a function of Q if the pump is turned at 2000 rpm.
(b) Will the pump operate satisfactorily at 1800 rpm under the following conditions?
   • 5000 ft altitude
   • 90°F water
   • 9-ft static discharge head
   • 7-ft suction lift
   • 650-gpm flow rate
   • 10-ft friction loss in suction line

HYDRAULICS–3

In order to maintain the original appearances of a historic building, it has been decided to renovate the original hot-water radiator heating system. The building has a design heating load of 400,000 Btu/hr, which is satisfied by convective heat transfer from radiators throughout the building. Water leaves the boiler at 220°F saturated liquid and returns at 190°F. The hot water system has the following characteristics.

pipes
- 2½-in steel, schedule-40
- 225 linear feet (exclusive of minor losses)

minor losses (all fittings are screwed)
- 8 90° regular elbows
- 1 swing check valve
- 2 gate valves (normally open)
- boiler heating coils head loss: 12 ft

pump
- pump efficiency: 55%
- motor efficiency: 75%

(a) What hydraulic horsepower is required?
(b) What is the motor’s nameplate rating (in watts)?

HYDRAULICS–4

A pump was originally chosen based on an NPSHR of 21 ft for a given flow rate of 850 gpm of hot water. The water was to flow through 90 ft of 6.00-in (inside diameter) pipe (Darcy friction factor of 0.02) prior to entering the pump. Water entering the pump is currently at 180°F and 14.1 psia, and cavitation in the pump inlet is being experienced.

It has been proposed to enclose the inlet pipe with a larger diameter pipe for its entire 90 ft of run, and cold water circulated countercurrently through the outside pipe. The temperature at the pump inlet would be
1. (a) 

For 6-in pipe,
\[ D = 0.5054 \text{ ft} \]
\[ A = 0.2006 \text{ ft}^2 \]
\[ Q = (740) \left( 0.002228 \frac{\text{ft}^3}{\text{sec}} \right) \left( \frac{1 \text{ gal}}{1 \text{ min}} \right) \]
\[ = 1.649 \text{ ft}^3/\text{sec} \]
\[ v = \frac{Q}{A} = \frac{1.649}{0.2006} = 8.22 \text{ ft/sec} \]

For water at 250°F,
\[ \nu = 0.269 \times 10^{-5} \text{ ft}^2/\text{sec} \]
\[ \rho = 58.8 \text{ lbm/ft}^3 \]

The equivalent length of pipe is
\[ L_e = 65 + (4)(5.7) + 3.2 + 63 = 154 \text{ ft} \]

For the steel pipe,
\[ \epsilon = 0.0002 \]
\[ \frac{\epsilon}{D} = 0.0002 \times 0.5054 = 0.0004 \]
\[ N_{Re} = \frac{vD}{\nu} = \frac{(8.22)(0.5054)}{0.269 \times 10^{-5}} = 1.54 \times 10^6 \]
\[ f = 0.016 \]

The friction loss is
\[ h_f = \frac{fLv^2}{2Dg} = \frac{(0.016)(154)(8.22)^2}{2(0.5054)(32.2)} \]
\[ = 5.12 \text{ ft} \]

The booster pump discharge pressure is
\[ p = 95 + \frac{(12 + 5.12)(58.8)}{144} = 102.0 \text{ psia} \]

(b) \[ P = \dot{m} \Delta h \]
\[ = (1.649)(58.8) \left( \frac{1350 - 95}{58.8} \right)(144) \]
\[ = (0.62)(550) \]
\[ = 874 \text{ hp} \]

2. From affinity laws,

(a) \[ Q \propto n \]
\[ H \propto n^2 \]
\[ \text{NPSHR} \propto n^2 \]

The ratio of speeds is
\[ \frac{n_{\text{new}}}{n_{\text{old}}} = \frac{2000}{1800} = 1.11 \]

These values can be graphed if necessary.

(b) For water at 90°F,
\[ \rho = 62.11 \text{ lbm/ft}^3 \]
\[ h_{vp} = 1.61 \text{ ft} \]

At 5000 ft,
\[ p_a = 12.225 \text{ psia} \]
\[ h_a = \frac{(12.225)(144)}{62.11} = 28.34 \text{ ft} \]

The net positive suction head is
\[ \text{NPSHA} = 28.34 + (-7) - 1.61 - 10 \]
\[ = 9.73 \text{ ft} \]

Since 9.73 < 11.1,

\[
\boxed{\text{Operation is not ok.}}
\]

Notice that the discharge head is not considered.