Open-book, Open-notes (8 pages {double-sided}, 3 questions); Time allowed: 90 minutes

Questions 1-2 refer to the pump station/reservoir/pipeline system diagrammed below.

**Pump Station Flow Schematic**

- **Suction line:**
  - DI (ε=0.0048 in)
  - 12 in ø
  - 225 ft long

- **Discharge line:**
  - DI (ε=0.0048 in)
  - 14 in ø
  - 3000 ft long

- **Pump Stations:**
  - Goulds 3410 8x10-17-H-L, 1185 rpm, 16.5 in impellor
  - Goulds 3410 4x6-13-S, 1775 rpm, 11 in impellor

- **Bypass valve**
Goulds Pumps
ITT Industries

Centrifugal Pump Characteristics

Model: 3410
Size: 8×16-17H-L
Imp. Dwg: D02342A/D03039A
Pattern: 63019/63066
Eye Area: 91.4 in²

Model: 3410
Size: 4×8-13-S
Imp. Dwg: D02497A/D03557A
Pattern: 63847/63653
Eye Area: 26.54 in²
1. Determine the flowrate in the pipeline (gpm) and total shaft power consumption (kW) for the operating scenarios listed below. A sheet of blank graph paper is attached. (45 points)

\[1 \text{ kW} = 737.6 \text{ ft} \cdot \text{lb/sec} \quad \{1 \text{ cfs} = 448.8 \text{ gpm}\]

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Pumps Operating</th>
<th>Flow (gpm)</th>
<th>Shaft Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>All</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>L #1, L #2, S #3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>L #1, S #3</td>
<td></td>
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</tr>
</tbody>
</table>
(Work space for #1)
2. Will the pump station operate with sufficient NPSH? (25 points)
3. Diagrammed below is a simple WDS and the topography (dash-dot lines) of the area. Assume all pipes have Hazen-Williams $C = 130$; pipe diameters are given in inches and lengths in feet next to each pipe. The numbers next to nodes indicate nodal demand in gpm. Applicable codes state that pressure in the WDS must be maintained in the range 35-80 psi. Characteristic curves for the system’s high service pump and the available model of booster pump are given below. You may assume that available pressure reducing valves decrease pressure by 25 psi. Indicate on the diagram the necessary locations for booster pumps and pressure reducing valves.

(30 points)

Hazen-Williams Eqn:  

$$Q = 0.285 \ C \ D^{2.63} \left( \frac{H_f}{L} \right)^{0.54}$$  \[ Q \text{ = gpm, } D \text{ = in, } [H_f, L] = \text{ ft} \]

![Diagram of WDS and Topography](image-url)
{Work space for #3}