Session 2
Pump Selection

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Gresham, Smith and Partners
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Quick Refresh

- System Curves graphically show the relationship between flow rates and associated total dynamic heads (TDH)
- TDH is the amount of pressure required to push a certain flow rate through a given pipe network
- TDH is the sum of:
  - Static head loss – moving the water from one elevation to another
  - Friction head loss – dynamic losses related to flow rate, pipe diameter, pipe length, pipe roughness, fittings
Intermediate high point, 2 possible conditions:
- Pump to high point, gravity down back side (high static, low friction losses)
- Pump to discharge point, pressure entire length (low static, high friction losses)

**WHICH ONE GOVERNS?**
Advanced System Curves
Composite Curves

- Scenario 1 – pump to high point, then gravity flow down to discharge point
  - May have manhole at the top of the hill for free discharge and system ventilation
  - Behaves according to plan as long as the pumping rate is **less** than hydraulic capacity of gravity system

![Graph showing hydraulic gradeline, pressure flow, gravity flow, friction head, static head, and pipe length.](image-url)
Scenario 2 – pump to discharge point

- ARV/CAVV at the top of the hill for system ventilation and to prevent unintentional siphoning
- Behaves according to plan as long as the pumping rate is more than hydraulic capacity of gravity system
Advanced System Curves

Composite Curves

- Answer: Both scenarios govern, depending on flow rate
- You must plot both system curves independently, then combine into a composite curve
Advanced System Curves

Composite Curves

- **Total Dynamic Head, ft**
- **Flow Rate, gpm**

- **Design System Curves**
- **High static head, short pipe**
- **Low static head, long pipe**

- **Critical Flow Rate (Avoid)**
Advanced System Curves

Bracketing

- It is **impossible** to predict accurately the hydraulic behavior of a piping system at a given point in time.
- Therefore, we must evaluate a range of hydraulic behaviors by defining a low-head condition and a high-head condition. We can be confident that the system will behave within those boundary conditions.
Advanced System Curves
Bracketing

• Low Head Loss Curve
  • High wetwell level (at start of pumping cycle)
  • Low discharge level (if variable)
  • High Hazen-Williams C-factor (smooth pipe)
    • C = 140 is good for DIP
    • C = 160 may be appropriate for plastic pipe (caution!)

• High Head Loss Curve
  • Low wetwell level (at end of pumping cycle)
  • High discharge level (if variable)
  • Low Hazen-Williams C-factor (rough pipe)
    • C = 100 is too low for DIP
    • C = 120 is realistic
### Advanced System Curves

#### Bracketing

<table>
<thead>
<tr>
<th>Length</th>
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<tr>
<td>Diam</td>
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<tr>
<td>Area</td>
<td>0.50 ft2</td>
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<tr>
<td>Static Head</td>
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<td>C-factor</td>
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#### Low Head Loss Curve

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<thead>
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<th>Flow, gpm</th>
<th>Flow, ft3/sec</th>
<th>Velocity, ft/sec</th>
<th>Static Head, ft</th>
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**Graph Details:**
- **Static Head = 40 ft**
- **C = 140**

**Legend:**
- **FT** (feet)
**Advanced System Curves**

**Bracketing**

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<table>
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<th>Flow, gpm</th>
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<td>86</td>
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</table>
Pump Curves – Centrifugal vs. PD

![Graph showing performance of Positive and Centrifugal pumps.](image)
Pump Curves (centrifugal)

- Shows relationship between head (H) and pumping rate (Q) (inverse of system curves – pumping rate increases as head decreases)

- May also show:
  - Pump efficiency as a function of Q
  - Pump horsepower (brake) as a function of Q and H
  - NPSH_R as a function of Q (upcoming session)
  - Performance changes for different impeller diameters and/or pump speeds
Pump Curves (centrifugal)

- Pump Selection Example
  - Use System Curves developed earlier
  - Pump must deliver 600 gpm
Pump Curves (centrifugal)

Q Required = 600 gpm

Expected pump performance range

76 ft TDH

65 ft TDH

UNACCEPTABLE PUMP SELECTION
Pump provides required Q only when pumping against “best case” system curve—not realistic
Pump Efficiency

- More efficient pumps draw less horsepower
- Less horsepower may mean smaller motor ($Capital)
- Less horsepower draws less electricity
- Less electricity saves money ($O&M)

HOWEVER

- Efficiency is not the be-all, end-all criteria for selection
- Overall pump RELIABILITY is more important
- Pump downtime, repairs, and PM may dwarf electricity savings over time…
Pump Reliability
Pump Reliability

Moral of the story –

- Do not select a pump based ONLY on efficiency
- Best Efficiency Point flow rate ($Q_{BEP}$) is often more important, even at the expense of some efficiency
Example – Pump Selection

An irrigation pumping station is being designed to transport water from a reservoir to a downstream tank, as shown below. The maximum design flow is 4,000 gpm. Select the pump, given the following:

- Suction line is 100 ft of 18” diameter ductile iron pipe
- Forcemain is 5,000 ft of 18” diameter ductile iron pipe

**Suction Minor Losses**
- 1 x 1.00 for entrance loss
- 2 x 0.39 for 90° bend
- 1 x 0.23 for plug valve

**Discharge Minor Losses**
- 6 x 0.36 for 90° bend
- 1 x 0.22 for plug valve
- 1 x 1.20 for swing check valve
- 1 x 0.50 for exit loss

El = 6122 ft
Example – Pump Selection

Determine pipeline velocities from \( v = \frac{Q}{A} \):

\[ v_{12} = 7.52 \text{ ft/s}, \quad v_{18} = 6.68 \text{ ft/s} \]

Calculate minor losses

\[ H_m = \Sigma K \times \frac{V^2}{2g} \]

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Total = 2.01

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<td>Swing check valve</td>
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<td>1.20</td>
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<tr>
<td>Tee (branch flow)</td>
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<tr>
<td>Exit loss</td>
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</table>

Total = 5.16

Suction minor losses:

\[ H_m = 2.01 \times \frac{5.04^2}{2(32.2)} = 0.8 \text{ ft} \]

Discharge minor losses:

\[ H_m = 5.16 \times \frac{5.04^2}{2(32.2)} = 2.0 \text{ ft} \]
Example – Pump Selection

High Head Loss (C=120)
Pipe friction losses:

Manning Equation: \[ H_f = \frac{3.022 \times V^{1.85} \times L}{C^{1.85} \times D^{1.165}} \]

Suction losses at 4,000 gpm:
\[ H_f = \frac{3.022 \times 5.04^{1.85} \times 100}{120^{1.85} \times 1.5^{1.165}} = 0.5 \text{ ft} \]

Discharge losses at 4,000 gpm:
\[ H_f = \frac{3.022 \times 5.04^{1.85} \times 5000}{120^{1.85} \times 1.5^{1.165}} = 22.1 \text{ ft} \]
Example – Pump Selection

High Head Loss Curve static head (lowest water level in reservoir):

\[ \text{Static Head} = \text{Discharge Piping} - \text{Source Water Surface Elevation} \]

\[ \text{Static Head} = 6230ft - 6127ft = 103ft \]

Total dynamic head required at 4,000 gpm (high head loss):

\[ \text{TDH} = H_{\text{static}} + H_{\text{minor}} + H_{\text{friction}} \]

\[ \text{TDH} = 103ft + (0.8ft + 2.0ft) + (0.5ft + 22.1ft) = 128.4ft \]
Example – Pump Selection
Pump Selection

Hydraulic Institute Standards 9.6.3 (2012)

- Preferred Operating Range (POR)
  - Generally 70% - 120% of $Q_{BEP}$
  - Optimum Performance
  - Minimal Vibration *(Shake)*
  - Minimal NPSH Margin *(Rattle)*
  - Maximum Service Life *(Less Roll)*
Pump Selection

Hydraulic Institute Standards 9.6.3 (2012)

- Allowable Operating Range (AOR)
  - Defined by manufacturer (not always clear on pump curve)
  - Region outside of POR
  - More Noise *(Rattle)*
  - More Vibration *(Shake and Roll)*
  - Reduced Service Life *(unhappy client)*
  - **Do not go beyond AOR limits**
POR and AOR, Illustrated

- **70% of \( Q_{BEP} \)**
- **120% of \( Q_{BEP} \)**
- **Yellow region is AOR by Mfgr**
- **BEP**

Graphical representation showing the performance characteristics of a pump or motor, with shaded regions indicating the operational ranges for POR and AOR.
Single Pump Selection

AOR/ POR ✔
Q_{BEP} ✔
Efficiency ✔
Impeller Size ✔
Horsepower ✗

2000 gpm @ 85 ft TDH

Graph showing various parameters like US GPM, NPSHR, BHP, and their relationship with TOTAL and Q_{BEP}.
Pump Arrangement

- **Series**
  - Discharge of Pump 1 connected to Suction of Pump 2
  - Same pumping rate, doubles head

- **Parallel**
  - Pumps 1 and 2 operate independently and discharge to a common manifold
  - Suctions for Pumps 1 and 2 may or may not be common
  - For identical pumps, double pumping rate @ same head
  - For dissimilar pumps, add pumping rates @ same head (if possible)
Pump Curves (centrifugal)

Series Operation
- two pumps
- Head is added by each pump, without an increase in flow

Parallel Operation
- similar pumps
- The flow of both pumps are added together to form new curve

Flowrate

Head

one pump

two pumps
Parallel Pump Selection

Triplex station (2 duty, 1 standby) must discharge peak flow rate of 660 gpm against the high and low system curves shown. Identify pump selection for the specs.

Rated Duty Point 330 gpm @ 120 ft TDH (AOR)
Parallel Pump Selection

Triplex station (2 duty, 1 standby) must discharge peak flow rate of 660 gpm against the high and low system curves shown. Identify pump selection for the specs.

Rated Duty Point 330 gpm @ 120 ft TDH (AOR)

Selection Duty Point = Q gpm @ 95 ft TDH.
Pump Selection Considerations

- Develop system hydraulics for worst/best cases – but don’t select pumps based on worst case (i.e. C ≤ 100) – use as a check
- Make preliminary selection with ‘runout’ condition within POR
- Make final selection on the basis of least NPSH<sub>R</sub> (next session)
- Avoid speeds greater than 1200 rpm if possible
Questions/Discussion