Fundamentals of Water System Design

17, 18, 24, 25 January 2007
Chapter 8: Matching Pumps to Systems

1. Matching the Pump to the System
2. Parallel Pumping
3. Series Pumping
4. Standby Pumps
5. Trimming Pump Impellers
6. Two-speed Pumping
7. Variable-speed Pumping
8. Source Distribution Pumping
Typical System Curve

- Total System Pressure
- System Design Pressure & Flow
- Friction Pressure
- System Curve
- Independent Pressure
- System Flow
Pump Curve and System Curve

- Pump Curve
- Operating Point
- System Curve

Total Pressure vs. Flow Rate
Shift of System Curve

- Anticipated Operating Point
- Actual Operating Point

Total Pressure vs. Flow Rate
Pump Curve for Parallel Operation

Paralleled Pump Curve

Single Pump Curve

© 2007 ASHRAE Hong Kong Chapter
Operating Conditions for Parallel Pump Installation

- Each Pump Operates At This Point — Both Pumps On
- System Operating Point — Both Pumps On
- Single Pump and System Operating Point — (Single Pump On)
Piping Schematic of Parallel Pumps
Pump Curve for Series Operation

Pressure

Flow

Pump Curve For Series Operation

Single Pump Curve

X_1

X_2

Y_1

Y_2
Operating Conditions for Series Pump

- Pump Curve Series Operation
- System Operating Point — Both Pumps On
- Single Pump and System Operating Point — (One Pump On)
- Each Pump Operates At This Point — Both Pumps On

Pressure vs. Flow Rate

© 2007 ASHRAE Hong Kong Chapter
Piping Schematic of Series Pumps
Standby Pump
Pump Affinity Laws

Speed Change

Flow: \[ Q_2 = Q_1 \left( \frac{N_2}{N_1} \right) \]

Pressure: \[ p_2 = p_1 \left( \frac{N_2}{N_1} \right)^2 \]

Power: \[ P_2 = P_1 \left( \frac{N_2}{N_1} \right)^3 \]

Impeller Diameter Change

Flow: \[ Q_2 = Q_1 \left( \frac{D_2}{D_1} \right) \]

Pressure: \[ p_2 = p_1 \left( \frac{D_2}{D_1} \right)^2 \]

Power: \[ P_2 = P_1 \left( \frac{D_2}{D_1} \right)^3 \]
Pump Operating Points

- NEW PUMP CURVE WITH IMPELLER TRIMMED TO ACTUAL SYSTEM CONDITIONS
- POINT 4
- ORIGINAL PUMP CURVE
- POINT 1
- POINT 4A
- DESIGN SYSTEM CURVE
- POINT 3
- ACTUAL SYSTEM CURVE
- POINT 2
- 100% DESIGN FLOW
- POINT 5
- 50% DESIGN FLOW
- SYSTEM FLOW
- SYSTEM AND PUMP PRESSURE
- NOTE B
- NOTE A
Two-Speed Pumping

- System and Pump Head
- Pump Curve @ 24 rps
- Design Point
- System Curve B
- Pump Curve @ 16 rps
- Point 1
- 50% Design Head
- System Curve A
- Point 2
- 100% Design Flow
- Independent Head
- System Flow
Typical Impeller Performance Curve

Recommended Selection Range
150 x 200 x 240 mm Pump Unit
@ 24 rps

© 2007 ASHRAE Hong Kong Chapter
Two-Speed Pumping Example

Variable Volume System
Two Equal Size Pumps $P_1 = P_2$
C/W Two-Speed Motors 16/24

<table>
<thead>
<tr>
<th>Flow (L/s)</th>
<th>Pres. (kPa)</th>
<th>Eff. (%)</th>
<th>Power (kW)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point A</td>
<td>61.6</td>
<td>78.8</td>
<td>85</td>
<td>5.6</td>
</tr>
<tr>
<td>Point B</td>
<td>78.1</td>
<td>99</td>
<td>82</td>
<td>9.7</td>
</tr>
<tr>
<td>Point C</td>
<td>104.4</td>
<td>152</td>
<td>79</td>
<td>20.5</td>
</tr>
<tr>
<td>Point D</td>
<td>133.1</td>
<td>225</td>
<td>84</td>
<td>36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flow</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>16</td>
</tr>
<tr>
<td>58</td>
<td>27</td>
</tr>
<tr>
<td>78</td>
<td>57</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
Typical Direct Return System
Pressure Loss With Two-Way Valves

- Total System Pressure Loss
- Flow Pressure Loss: Equipment Room, Piping, Coils, Balance Valves, etc.
- Pressure Absorbed By Control Valve
- 35 L/s: 330 kPa
- 69 L/s: 300 kPa
- 60 kPa
- 270 kPa
- 240 kPa
- 60 kPa
- Total Pressure, kPa

Flow, L/s
Proportional Controller and AFD

A.C. Power
Adjustable Frequency Drive
Pump/Motor

Hard-wired Sensor Wires
P.I.D. Controller
△P Sensor/Transmitter

Hard-wired Sensor Wires
△P
Supply
Return

© 2007 ASHRAE Hong Kong Chapter
Measuring \( \Delta p \) in Direct Return System

End of last riser, or highest pressure drop
Differential Pressure Control Curve Above Piping Friction Loss

![Differential Pressure Control Curve](image_url)

- Total Pressure, kPa
- Flow, L/s
- Control Curve
- Piping Pressure Loss Change
- Maintained Differential Pressure Across Sub-circuits

© 2007 ASHRAE Hong Kong Chapter
Measuring $\Delta p$ in Reverse Return System

Central or typical zone
Pressure Reduction With Change in Pump Speed

© 2007 ASHRAE Hong Kong Chapter
Pumping Power Reduction With Change in Pump Speed

© 2007 ASHRAE Hong Kong Chapter
Primary-Secondary Pumping Concept

Distribution Pump 1

Load
Pump 2

Common Pipe
(decoupler)

Source
constant flow

B
variable flow

Load
Primary-Secondary Variable Speed Pumping
Distributed Variable Speed Pumping