Application of Boiler Feed Pumps in Combined Cycle, Thermosolar, & Biomass
Historical Perspective

In the days of coal-fired power plants...

- Feed Pumps were Barrel Pumps
- Turbine Drive or Geared FC Drive
  - High Speed 4500 to 6000 RPM
  - 4-6 Stages
- Booster Pumps Common
- Base Loaded, Steady State Operation
- For a 500 MW Plant:
  - Two 50% Pumps, ~4500 GPM Each
  - 7500 Feet TDH Subcritical
  - 11,500 Feet TDH Supercritical
Barrel (Diffuser)

To 21,000 GPM, 12,000 Feet, 7000 PSIG, 6000 RPM
Current Market

Natural gas is dominant…

- Combined Cycle (GT + HRSG)
- Primarily Ring Sectional Pumps, Some Horizontally Split
- Motor Drive, Direct or via Fluid Coupling
  - Two-Pole Speed Nominal 3580 RPM for 60 HZ
  - 7-13 Stages
- Booster Pumps are Rare
- Daily Cycling
- For a 500 MW Plant:
  - Four 100% Pumps per HRSG, ~1500 GPM Each
  - 5000 to 6000 Feet TDH
Current Market

Thermosolar & Biomass

- Pumps are Similar to CC for Largest Thermosolar & Biomass Plants
- Plant Size, and thus Pump Size, Varies Significantly
- Smallest Biomass Plants Approaching “Industrial” Size Boilers & Pumps
- Pump Manufacturers Need Wide Range of Products
Ring Section

To 5000 GPM, 8000 Feet, 4000 PSIG, 5000 RPM
Horizontally Split

To 5000 GPM, 7500 Feet, 4000 PSIG, 6000 RPM
Requirements & Features

- Rapid Start-Up & Daily Cycling
  - No Warming

- Thermal Transients
  - Axisymmetric Design
  - Uniform Wall Thickness

- High Interstage Takeoffs (25% of Suction Flow)
  - Ability to “Mix” Hydraulics within Pump
  - Thrust Balance Important
Other Considerations

- Combined Cycle focused on Low Initial Cost
- Thermosolar focused on Power Consumption
  - Virtually all are Variable Speed (VFD or FC)
- Low NPSHa for Thermosolar & Biomass
- Plants run with Minimal Staff
  - Instrumentation for Remote Operation
  - Trust to OEM for Guidance
Low NPSHa

Impact of NPSHa

- \( N_{ss} = \frac{N \times Q_{eye}^{.5}}{NPSHr^{.75}} \)
- Reasonable Value \( \sim 10,500 \)
- Reasonable NPSHa/NPSHr Margin \( \sim 1.8 \)
- Double Suction Available
- Booster Pumps Available but Not Common
Suction Performance

LOW Nss  IMPELLER A

HIGH Nss  IMPELLER B

This area unstable for high Nss imp.

RESULTANT IMPACT ON NPSHR

Q (FLOW)

LOW

HIGH

NPSHR

Experience In Motion
Efficiency vs. Stage Count

Impact of Specific Speed

- \[ N_s = \frac{N \times Q^{0.5}}{H_{stg}^{0.75}} \]
- Too Low >>> Low Efficiency
- Too High >>> Unstable Curve Shape
Impact of Variable Speed

Proposed Performance

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Boiler Water</th>
<th>Speed (RPM)</th>
<th>3560</th>
<th>Capacity (gpm)</th>
<th>1330</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity (cSt)</td>
<td>0.2</td>
<td>First Stage Design</td>
<td>Single Suction</td>
<td>Efficiency</td>
<td>82.1%</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>0.90</td>
<td>Stage Count</td>
<td>11</td>
<td>NPSHr (ft)</td>
<td>32.3</td>
</tr>
</tbody>
</table>

Curves are approximate. Pump is guaranteed for one set of conditions. Capacity, head, and efficiency guarantees are based on drop test and when handling clear, cold, fresh water at a temperature of not over 85 degrees.

Experience

SERVICE
Questions?