BOILER FEED & PUMP SIZING

Presented by Cleaver-Brooks Steve Connor and Grundfos’ Jim Swetye
TODAY’S AGENDA

• Brief review of a typical steam system
• The boiler size range, pressures and types we will be addressing today
• Methods and importance of capturing condensate for boiler feed
• Typical pumps used for boiler feed water discharge
• Typical piping methods used
• Pump sizing criteria
• Criteria for calculating the base flow for the pump
• Understanding TDH and NPSH
• Sizing a pump for a specific application (example)
• Reading the pump curve for final selection
• Summary and Q&A
## BOILER SIZES AND FEED PUMP SIZES

<table>
<thead>
<tr>
<th>Boiler HP Range</th>
<th>Boiler Pressure Range</th>
<th>Typical Feed Pump Type</th>
<th>Typical Max. Feed Pump Flow Range</th>
<th>Typical Max. Feed Pump Head</th>
<th>Where Used?</th>
</tr>
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<tbody>
<tr>
<td>100 to 1200</td>
<td>150 to 500 psi</td>
<td>Vertical inline multistage; regenerative turbines</td>
<td>10 to 125 gpm</td>
<td>1250 feet</td>
<td>General industry; institutional; universities; some commercial buildings</td>
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HORIZONTAL FIRETUBE BOILERS

The Dryback

- Two (2) Tubesheets
- Baffles
- Refractory Filled Door
- Tubesheet
WATERTUBE OR IWT
THE WATERTUBE BOILER

- Opposite of Firetube
- Water in the Tubes
- Natural and Forced Circulation
- Large Furnace
- Upper & Lower Drums or Headers
FLUE GAS SEALING

100% Membrane Construction

Adjacent fins of all furnace, and outside convection tube are continuously seal welded to form a pressure tight - water cooled panel.

Fins are dual-welded to tubes

Mineral Wool Insulation

Corrugated pebble grain aluminum lagging

Tangent Tube Furnace Design Also Available
CONDENSATE IS LIQUID GOLD!

A finite resource
CONDENSATE RETURN PUMPS
Use flash steam for heating or deaerating?

Why not recover the heat from the hot condensate?
HOT CONDENSATE RETURNED

Boiler Feed System

A vented receiver, wastes energy.

Deaerator

Pressurized receiver, saves energy.

Steam diffusing tube
Steam
H.P. Return
Vent
Exhaust Or
Flash Steam
To Boiler
Boiler Feed Water Pump(s)
Overflow Drainer
Make-Up Valve
Check Valve
Cold Make-Up Water
L.P. Condensate
Level control
PRV
SPRAY DEAERATOR

Spray cone
TRAY DEAERATOR
HIGH PRESSURE CONDENSATE RECEIVER

- Takes high pressure condensate directly from the user.
- No need to deaerate.
- Pump directly into boiler
- Feed the HPR from the DA
BOILER FEED WATER TANK OPTIONS

Spray DA

Tray DA

Column DA

HPCR

Vented Receiver
FEED WATER SYSTEMS

For multiple boiler Installations
METHOD 1 –
Direct feed for multiple boilers

- **Boiler A Controller**: 4-20mA signal directly to Grundfos E-pump instead of control valve
- **Boiler B Controller**: 4-20mA signal directly to Grundfos E-pump instead of control valve
METHOD 2 –
Booster sets for multiple boilers
STEAM BOILER PUMP APPLICATIONS AND TYPES

- Boiler feed pumps
  - Collection tank pumps
  - Water treatment pumps
  - Condensate return pumps
  - Deaerator tank recycle pumps
  - Deaerator vacuum pumps (vacuum deaerator tanks only)
  - Economizer pumps
SIZING COMPLEXITY FOR BOILER FEED PUMPS
Base flow = Boiler maximum capacity horsepower X 0.069 X C

- C = 1.5 for On/Off intermittent operation
- C = 1.15 for continuous feed operation
To the Base flow we MIGHT add if specified:

For Continuous Boiler Blowdown flow

• Approximately 5% to 10% of the pump’s flow rate at the Best Efficiency Point
**ADD FOR BYPASS RECIRCULATION FLOW**

Certain feed system control modes require the use of a bypass line back to the source tank – such as back to the deaerator tank.

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<th>Method #</th>
<th>Name</th>
<th>Pump Speed Type</th>
<th>Duty</th>
<th>Is orifice flow by-pass line required?</th>
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<td>On/Off control and fixed speed pumps</td>
<td>Fixed</td>
<td>Intermittent</td>
<td>No</td>
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<tr>
<td>2</td>
<td>Feed control valve and fixed speed pumps</td>
<td>Fixed</td>
<td>Continuous</td>
<td>Yes</td>
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<td>Variable</td>
<td>Continuous</td>
<td>Yes</td>
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RECIRCULATION FLOW

- The solid curve below shows the minimum flow rate as a percentage of the nominal flow rate in relation to the liquid temperature.
- Ignore the dotted line which indicates a pump with special high-temperature construction.
CALCULATING REQUIRED 
FEED PUMP HEAD

Pressure in DA tank

Elevation of DA tank

Friction loss - suction side

+ Suction side head

+ Discharge side head

= Total Dynamic Head

Elevation of boiler

Friction loss - discharge side

Safety factor
FEED VALVE IMPACTS
PUMPING HEAD CALCULATION
CALCULATING THE HEAD FOR THE FEED PUMP

1) At the duty point flow rate:
Head in feet = Boiler operating pressure $\times 2.31 \times 1.03 \div$ Liquid Specific Gravity
Example: Head = 130 psi $\times 2.31 \times 1.03 \div 0.953 = 324$ feet

2) At shutoff head (dead head):
Head in feet = Pressure relief valve setting $\times 2.31 \times 1.03 \div$ Liquid Specific Gravity
Example: Head = 160 psi $\times 2.31 \times 1.03 \div 0.953 = 400$ feet
NPSH –
FORMULA FOR CALCULATION

To avoid cavitation, NPSHa must be greater than NPSHr

**NPSHr** is obtained from the pump curve

Add two to four feet of safety factor to the NPSHr stated on the curve

**NPSHa** is calculated:

+ Absolute pressure in deaerator tank

± Elevation of minimum water level in tank above feed pump

- Vapor pressure of water in deaerator tank

- Suction line friction loss

= Net Positive Suction Head Available
NPSH AND ELEVATION

Deaerator tank

Minimum water level in DA tank

Difference in elevation

Location of eye of lowest impeller

Boiler feed pumps
Critical suction line considerations here
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1. Base flow calculation equation
   Boiler maximum capacity horsepower X 0.069 X C = Base flow rate
   C = 1.50 for On/Off intermittent operation
   C = 1.15 for continuous feed operation

2. Determine BASE head for feed pump
   Formula based on Safety Valve setting:
   Pump head in feet = Maximum pressure X 2.31 X 1.03 ÷ Liquid Specific Gravity

3. Head components on suction side of piping system
   Pressure above atmospheric on deaerator converted to feet of head =
   Elevation difference between minimum deaerator water level and pump inlet =
   Suction pipe friction loss =
   Suction fitting friction loss =
   Suction line valves and strainer friction loss =
   Total =

4. Head components on discharge side of piping system
   Friction loss through discharge piping =
   Friction loss through discharge fittings =
   Friction loss through feed valve =
   Elevation of boiler maximum water level above pump =
   Total =

5. NPSHa equation
   \[ \pm \text{Elevation}^{**} + \text{Absolute pressure} - \text{Vapor Pressure} - \text{Suction Line Friction} = \text{NPSHa} \]
   (Feet) \quad (\text{psi} \times 2.31 \text{ Feet}) \quad (\text{psi} \times 2.31 \text{ Feet}) \quad (\text{Feet}) \quad (\text{Feet})

** Elevation of deaerator tank minimum water level above pump's first impeller
SPECIFICATION FOR EXERCISE

a) Control Method: Continuous duty fixed speed pump with bypass line and feed valve
b) Boiler maximum capacity = 250 HP
c) Boiler safety valve setting = 125 psig
d) Pressure safety factor = 3% above boiler’s safety valve setting
e) Boiler operating pressure = 100 psig
f) Continuous Boiler Blowdown flow - Required
g) Bypass recirculation flow – Required
h) Altitude – Sea level
i) Pressure in deaerator tank above atmospheric pressure = 5 psi (14.7 + 5 = 19.7 psi absolute)
j) Height of deaerator tank minimum water level above pump’s first impeller = 10 feet
k) Friction line loss through suction piping = .5 foot
l) Friction loss through suction side fittings = .5 foot
m) Friction loss through suction side valves = None
n) Friction loss through suction side strainer = 1 feet
o) Friction loss through discharge piping = 1 foot
p) Friction loss through discharge side fittings = 1 foot
q) Pressure drop across feed valve – 15 psi
r) Elevation of boiler maximum water level above pump’s discharge port = 5 feet
s) Liquid Specific Gravity = 0.953
t) Temperature of water in deaerator tank = 227 degrees F
u) Vapor pressure in deaerator tank = 19.7 psi
v) Pump materials all 316 stainless steel to resist treatment chemicals
w) Mechanical seal to be silicon carbide/silicon carbide/EPDM to withstand liquid temperature
CONTROL METHOD:

Fixed speed pumps with feed valve and recirculation line
### STEP 1 – Determine control method

Feed valve controlled system with a continuous duty fixed speed pump has been specified.

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STEP 2 –
Calculate the BASE feed pump flow rate

The formula for this calculation is:

- Boiler maximum capacity in horsepower \times 0.069 \times C
- The maximum capacity in boiler horsepower is 250
- The C factor is 1.15 for continuous duty

Therefore:

\[ 250 \times 0.069 \times 1.15 = 20 \text{ gpm} = \text{BASE flow rate} \]
STEP 3 – Continuous Boiler Blowdown Flow

**Determination:**

1. The BASE flow rate has been established at 20 gpm

2. We will on next slide need to add for bypass flow, which can add 10 to 20 percent to the BASE flow rate

3. Blowdown flow is to be approximately 10 percent of flow at pump’s Best Efficiency Point

4. So the total boiler blowdown flow required is approximately 3 gpm
**STEP 4 – Add for by-pass flow**

- Control is via feed valve with fixed speed pump and for continuous duty
- A bypass will be required

- Solid curve to right shows minimum flow rate as a percentage of nominal flow rate in relation to liquid temperature
- Ignore dotted line which indicates a pump with special high-temperature construction

- At 227°F, we require a bypass flow that is about 20% of BEP flow.
- Presuming we can find a pump with BEP at about 25 or so gpm, the bypass flow must be about 5 gpm
STEP 5 –

Calculate total flow required

- **BASE flow** = 20 gpm
- **Blowdown flow** = 3 gpm
- **Recirculation flow** = 5 gpm
- **Total flow required** = 28 gpm

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STEP 6 –
Calculate BASE pumping head

Boiler operating pressure setting + 3%

Formula: BASE head in feet = Boiler operating pressure X 2.31 X 1.03 ÷ Specific Gravity

BASE head = 100 psi X 2.31 X 1.03 ÷ 0.953 = 250 feet
STEP 7 –
Add for suction piping system head components

From specification:
Absolute pressure on deaerator tank = 19.7 psi X 2.31 = - 46 feet
Water elevation above first impeller = - 10 feet
Friction loss through suction piping = + .5 feet
Friction loss through suction fittings = + .5 feet
Friction loss through suction side valves and strainer = + 1 feet
Total = - 54 feet
STEP 8 –

Add for discharge piping system head components

From specification:
Friction loss through discharge piping = + 1 foot
Friction loss through discharge fittings = + 1 foot
Friction loss through feed valve is 15 psi X 2.31 = + 35 feet
Elevation of boiler maximum water level above pump = + 5 feet
Total = + 42 feet
STEP 9 –

Sum of all head components

BASE head with safety factor = + 250 feet
Suction side piping system head = - 54 feet
Discharge side piping system head = + 42 feet

Total = + 238 feet
STEP 10 –  
Pressure safety valve considerations

At shutoff head (dead head):
Head in feet = Pressure relief valve setting X 2.31 X 1.03 ÷ Liquid Specific Gravity
Example: Head = 125 psi X 2.31 X 1.03 ÷ 0.953 = 312 feet

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STEP 11 –
Determine deaerator tank water temperature

From specification: 227°F
STEP 12 –
NPSHa calculation

NPSHa equation:

± Elevation + Absolute pressure – Vapor Pressure – Suction Line Friction = NPSHa

10 feet + (19.7 psi X 2.31) - (19.7 psi X 2.31) - 2 feet = NPSHa
10 feet + 46 feet - 46 feet - 2 feet = 8 feet NPSHa
STEP 13 – Preliminary pump selection

Conditions of Service:
Flow = 28 gpm
Head = 238 Feet

Does this 10 stage pump pump meet the required flow and head conditions of service?

YES
STEP 14 –
Pressure safety valve considerations
STEP 15 –
Check NPSHa vs NPSHr

Conditions of Service:
Flow = 28gpm
Head = 238 Feet
NPSHa = 8 Feet

- Pump meets or exceeds flow/head requirement
- Low-NPSHr first stage = 4 feet required
- NPSHr safety factor = 2 to 4 feet
- Target NPSHr = 8 feet
- NPSHa = 8 feet

Does NPSHa equal or exceed NPSHr?
YES
**STEP 15 – NPSH - Continued**

Conditions of Service:  Flow = 28 gpm  Head = 238 Feet  NPSHa = 8 Feet  
The NPSHa is equal to or exceeds the NPSHr of 8 feet

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STEP 16 –
Check material compatibility

- Pump materials: 316 stainless steel
- Mechanical seal materials: Silicon carbide/silicon carbide/EPDM
### STEP 17 – Final pump selection

Pump meets all specification requirements

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- Virtual Classroom
  - Self-Paced
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SUMMARY

- Steam condensate is a very valuable commodity which needs to be saved and used as much as possible.
- Most commonly used boilers for process are industrial firetubes and watertube boilers, IWT,s.
- High pressure condensate flash steam can be used for various purposes such as unit heaters or the DA.
- Condensate can be returned to vented receivers or pressurized deaerators (Spray, Tray & Column).
- Sometimes high pressure condensate receivers are employed. Save considerable losses.
- Boiler feed pump selection involves 17 decision points which need to be carefully considered.
- Calculating the pump’s base flow rate differs when the pump operates continuously (15% safety factor) or on/off (50% safety factor).
- Sometimes the base flow rate needs to include for continuous pump re-circulation and maybe for continuous blow down.
- Total Dynamic Head (TDH) is the pressure the pump must overcome to get water in the boiler, and includes the positive pressure at the pump’s inlet after suction pipe losses, and the piping losses through the discharge piping before overcoming the boiler’s operating pressure.
- Net Positive Suction Head (NPSH) is the pressure required at the pump’s suction to mitigate cavitation.
- NPSHA is the NPSH available after all the friction losses on the suction side have been determined in light of the pump’s minimum and maximum flow rates.
- The seal selection for the pump is very important and can vary based on the boiler’s operating pressure/temperature, chemicals in the feed water, etc.
QUESTIONS?

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