Application Guidelines *are offered by* **INDUSTRIAL STEAM** t*o assist in the application, sizing and selection of deaeration and feed water conditioning systems.*
If you have questions on any of the topics discussed or questions about the information provided, please contact one of the people in our sales or engineering groups for assistance.

Pumps Selection & Sizing

The objective when sizing boiler feed pumps is to find the pump which will operate under the conditions required. The pump selection should consider first cost, reliability and electrical consumption.

There are seven steps involved in pump selection.

1. Determine the number of pumps required
2. Determine if modulating feedwater or on-off feedwater control will be used.
3. Calculate the head required for each boiler feed pump.
4. Calculate the flow rate of each boiler feed pump.
5. Determine if recirculation is required to protect the pumps and if so, which type is appropriate.
6. Choose the pump which satisfies the required conditions
7. Will the pump satisfy ASME boiler feed pump sizing requirements?

1. Select the Number of Pumps

The number of pumps is based on the load conditions. If the steam plant is “base loaded” with very little load swing, one pump may be used to serve multiple boilers. This is usually the most cost effective approach if the loads are relatively constant. The first cost will usually be lower since in many cases, one large pump is less expensive than several smaller ones.

If the loads vary widely, multiple pumps are appropriate. The recommendation is to install one pump per boiler. This will usually provide acceptable performance. In Summary;

- if Boiler(s) Base Loaded - 1 pump to carry load,
- if 2 or more boilers ***w/Variable Loads*** - choose at least one pump for each boiler

Multiple Pumps may be the best investment for the project because:

1. 3 or 4 Smaller pumps may cost less initially than 2 larger pumps.
2. Smaller pumps will usually have smaller motors, which will result in less power consumption in cases when the average load is much lower than the peak.
3. Multiple pumps provide greater flexibility & redundancy.

2. Should modulating, or on-off, boiler feedwater control be used?

The Second Step is to determine if modulating feedwater control be used, or should the project use on-off control for the boiler feed pumps.

We recommend modulating feedwater control for all steam boilers. This will eliminate one of the biggest causes of pump problems and poor deaerator performance. If you use on-off pump control to control the boiler water level the boiler is subjected to feedwater surges which are two to three times the peak boiler capacity.
On-off pump control results in:

1) Disruption of the natural boiler circulation and firing rate.
2) Overload the deaerator for short periods of time by withdrawing two to three times the normal Deaerator capacity when the pumps cycle on-off.
3) Requires feed pumps which are oversized for the boiler load.
4) Oversized feed pumps use more electrical horsepower which costs more to operate.
5) The Pump may run off the right side of the curve if the pump is operated at a lower pressure than it was sized for, or it is operated with an unrestricted discharge when large load demands occur. This can result in cavitation and damage to the pump.

Generally on-off pump control is used in order to reduce the first cost of the system. It is also used if the customer chooses turbine type pumps. Outside of the first cost reason for on-off pump control, there is no reason to use it.

3. Calculate the discharge head for the boiler feed pump.

The Third Step is to calculate the discharge head of each boiler feed pump. The boiler feed pump must overcome the boiler operating pressure as well as any and all pressure losses in the piping to the boiler. Following is a suggested list of the pressure drops to consider when sizing the boiler feed pumps.

The Total Pump Discharge Pressure must overcome the following:

System Pressure - The pressure required by the steam distribution system.
Non-return valve loss - how much drop occurs across the non-return valve, the boiler must operate at a pressure high enough to overcome this and satisfy the system pressure requirements.
Economizer - The pressure drop across the water side of the economizer.
Super Heater - The pressure drop across the water side of the superheater.
Modulating Level Control Valve - The pressure drop across the level control valve. (not required with on-off pump control)
Feed stop & check loss - Drop across the feedwater stop and check valves (if used).
Piping Loss to Boiler
Height to boiler water level - The drum may be substantially higher than the boiler feedwater pumps. The pumps must be able to lift the water up to the drum level.

Total Discharge Pressure -The sum of all pressure drops the feed pump must satisfy.

After the total pressure drop is calculated, it must be converted to feet of discharge head in order to select the pump. The correction factor of 2.31 converts psig to feet of head. We correct for the density of boiling water (227 ^{0}F) by dividing the head by .96, which is the specific gravity of water at 227 ^{0}

$$TDH = \frac{\text{total discharge pressure (psig)} \times 2.31}{.96}$$

An Example: Calculate Pump Discharge Head

STEP #1- The Total Pump Discharge Pressure;

System Pressure	150 psi (required by system)
Non-return valve loss	5 psi (boiler operates at 155 psig)
Economizer	0 psi
Super Heater	0 psi
Modulating Level Control Valve	20 psi
Feed stop & check loss	7 psi
Piping Loss to Boiler	5 psi
Height to boiler water level	0 psi
Pump discharge pipe loss	5 psi
Total Discharge Pressure=	**192 psi**

STEP #2- The Total Pump Discharge Head (TDH) is;

$$TDH = \frac{\text{pressure (psig)} \times 2.31}{.96}$$

$$TDH = \frac{192 \text{ psig} \times 2.31}{.96}$$

TDH = 462 (ft) TDH

4. Calculate the Net Flow Rate of each Boiler Feed Pump.

The Third Step is to calculate the flow required for each boiler feed pump.

Net Pump Flow Rate = Boiler Evaporation Rate + Catch Up Capacity

1. Boiler Evaporation Rate
   a. Boiler Capacity = System Load + Blowdown + Steam to DA
   b**. Boiler Evaporation Rate = Boiler Capacity(pph)/500**
2. Capacity for "**Catch up**"
   a. On-off pump control - add 100% to evaporation rate (turbine pumps), (75% for centrifugal pumps)
   b. Modulating feedwater control - add 25% to evaporation rate
3. Flow required to provide ***Minimum Flow Protection*** (not required for on-off pump operation)
   a. Pump off when boiler off, boiler has maximum 4 to 1 turndown
   Instantaneous Recirc rate = manufacturers recommendation
   b. Pump always operates, or boiler has greater than 4 to 1 turndown
   Continuous Recirculation Rate = 20% of Best Efficiency Flow Rate

An Example: Calculate Pump Net Flow Rate

One pump will be sized to serve one boiler with the following conditions:

- **34,000 pph load**
- **3% Surface Blowdown Rate**
- **Modulating feedwater control (25% catch up capacity required)**
- **The deaerator is sized for 34,000 pph, and requires 8% of it's capacity in steam**

1. Boiler Capacity = System Load + Blowdown + Steam to DA
Boiler Capacity= 34,000 pph + (3% x 34,000 pph) + (8% x 34,000 pph)
= 34,000 pph + 1,020 pph + **2,720 pph**
= 37,740 pph

2. Boiler **Evaporation Rate** = Boiler Capacity(pph)/500
= 37,740 pph / 500
= 75.5 gpm

3. Capacity for "**Catch up**"
a. On-off pump control - add 100% to evaporation rate
b. Modulating feedwater control - add 25% to evaporation rate
Catch up capacity = 25% x evaporation rate
= 25% x 75.5 gpm
= 18.8 gpm

Net Pump Capacity = Boiler Evaporation Rate + Catch-up Capacity
= 75.5 gpm + 18.8 gpm
= 94.3 gpm

We know that we need a pump which will produce at least 94 gpm. To compensate for minimum flow requirements we will probably look for a pump with a capacity that is 10 to 20 gallons higher than the Net Pump Capacity. We must also consider the minimum flow requirement of the pump if modulating feedwater control is used.

Minimum Flow - Minimum flow is the lowest flow rate at which there is sufficient flow thru the pump to allow it to operate without damage caused by overheating. There are two minimum flow rates which are commonly referred to.

Instantaneous Minimum Flow - applies when it is impossible for the pump to operate with the feedwater control valve closed.
1. Published by pump vendors
2. Requires the pumps be turned off when the boiler cycles off, (interlock to stop pump if burner stops)

Continuous Minimum Flow - applies when the pump may be required to operate "on the by-pass" when flow to the boiler stops. Calculate Continuous Minimum Flow :
1. Determine Flow at peak pump efficiency
2. The continuous minimum flow is equal to 20% of the Flow at peak pump efficiency.

5. Provide for minimum flow protection for the boiler feed pumps.

Gross Pump Capacity = Net Pump Capacity **+** ***Minimum Flow***

> *"The total pump capacity must satisfy the boiler evaporation rate, the capacity required to catch up and the minimum flow requirements of the boiler feed pumps*

Pump Protection: If the boilers use modulating feedwater control, protection for the pumps is provided by recirculation of the minimum flow amount back to the deaerator to insure the pump always has sufficient flow to prevent overheating during periods of low flow. Let's assume this system will never operate with the burner off or the feed water valve closed. As a result, we will use the instantaneous minimum flow for these pumps.

The conditions for the pump using the two previous examples are **94 gpm @ 462' TDH.** A review of the Industrial Steam pump curves shows that the VC90 can make the 94 gpm capacity, but the NPSH is excessive, so we will review the next larger pump. The VC100 will easily satisfy the flow requirement at a reasonable NPSH. The instantaneous minimum flow for the VC100 is 13.5 gpm.

The Gross Pump Capacity is:

Gross Pump Capacity = 94.3 gpm + 13.5 gpm = 107.8 gpm

6. Select the pump.

The pump should be rated at 108 gpm and 462' TDH. The pump selected is:

VC100-7 (7 stage), with 20 hp motor. The pump requires 4' NPSH

7. Does the pump satisfy the ASME boiler feed pump capacity requirement? This calculation is also appropriate when sizing pumps for solid fuel fired boiler applications.

The ASME code requires that the boiler feed pump be able to put water in the boiler at the evaporation rate at a pressure which is 3% greater than the highest setting of the safety valves. If the boiler in this example is designed for 150 psig operating pressure, the safety valves could be set at 175 psig. To determine if the pump selection meets this requirement, recalculate the discharge pressure required and use the actual evaporation rate for the rated flow.

The Total Pump Discharge Pressure;

Safety valve set point	175 psi (required by system)
3% excess pressure	6 psi
Non-return valve loss	5 psi (boiler operates at 155 psig)
Economizer	0 psi
Super Heater	0 psi
Modulating Level Control Valve	20 psi
Feed stop & check loss	7 psi
Piping Loss to Boiler	5 psi
Height to boiler water level	0 psi
Pump discharge pipe loss	5 psi
Total Discharge Pressure=	**223 psi**

The Total Pump Discharge Head (TDH) is;

$$TDH = \frac{223\ psig \times 2.31}{.96}$$

TDH = 537 (ft) TDH, the flow rate is 76 gpm. Does the chosen pump satisfy these conditions? This selection point falls above the curve for the VC100-7. As a result, we must go to the next larger pump in this application. The pump chosen would be a **VC100-8**, (8 stage), **with 25 hp motor.**

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are published by:
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