SHIPCO® PUMPS

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PRIDE

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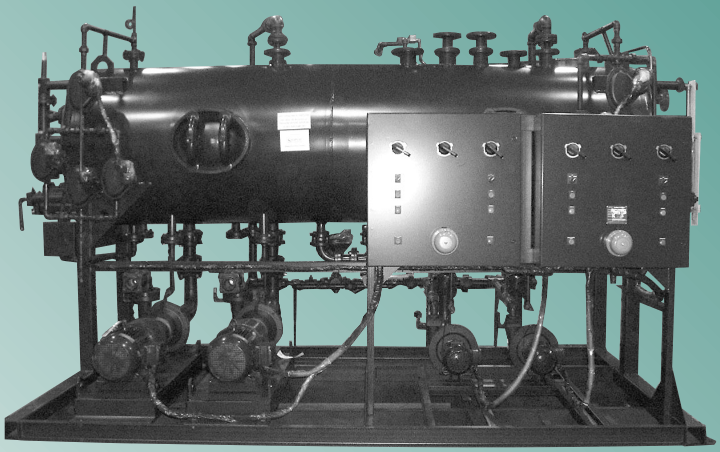


TYPE .005 DA-2C

Deaerating Boiler
Feed Pumps

SHIPCO® Deaerators can save you money!!!

SHIPCO® PUMPS are equipped with Mechanical Seals rated for temperatures up to 300˚F as standard.

SHIPCO®'s deaerators are designed to remove the non-condensable gases from boiler feed water. To understand the process, it is helpful to understand two basic gas laws. Henry's Law and Dalton's Law of Partial Pressures are primary rules to understand.

Henry's Law, credited to William Henry, an English Chemist (1775-1836), states that: "The solubility of gases in liquids is directly proportional to the pressure of the gas above the liquid." This law simply states that if the pressure of a gas above a liquid is increased more gas dissolves in the liquid. It is important to understand that there is constant motion of gas molecules dissolved in a liquid. The state of equilibrium is when the number of molecules leaving the surface area equals the number of molecules entering the surface area.

Henry's Law can literally be demonstrated with the effervescence that occurs when you open a carbonated beverage. The carbon dioxide in the beverage is forced into the liquid and bottled under pressure. When the cap is removed, the pressure is reduced and the dissolved carbon dioxide escapes from the liquid to reach an equilibrium at atmospheric pressure.

Oxygen is only slightly soluble in water. Carbon dioxide is more soluble in water and reacts with the water to form carbonic acid. The reaction that occurs is usually a result of the bicarbonate and carbonate alkalinity of the raw make-up water being heated. Heating the alkaline make-up water causes free carbon dioxide to be released which readily forms carbonic acid. It is important to eliminate the carbon dioxide from the feed water as a gas. Once carbonic acid is formed, it builds in concentration. The acid is more difficult to remove from the feed water than the gases. Carbonic acid can be credited with the thinning of pipes and the grooving that occurs along the bottom of return lines.

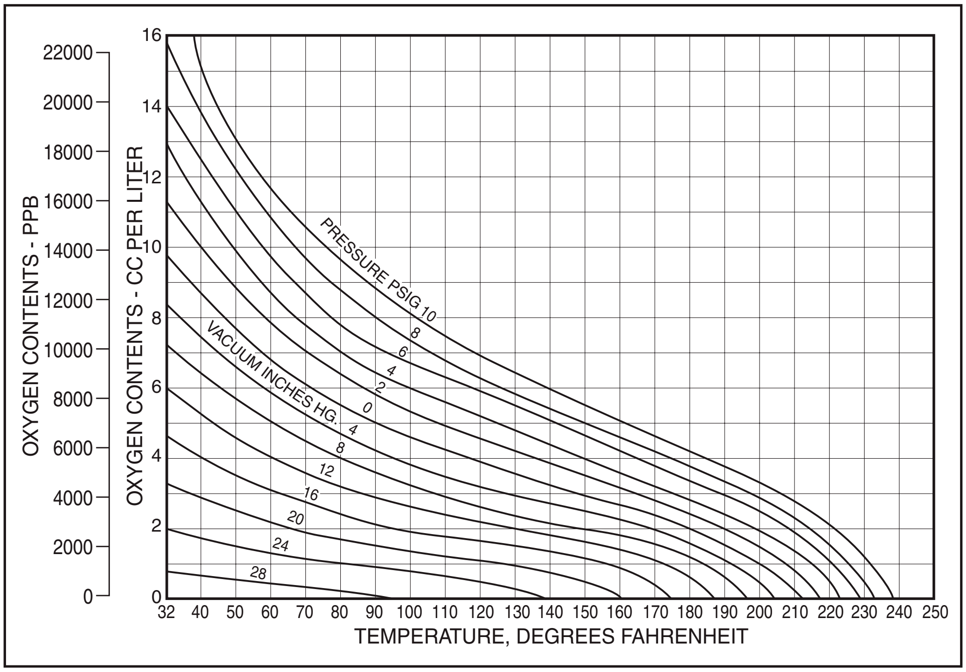
Our atmosphere is a mixture of different gases. Understanding Dalton's Law of Partial Pressures is important when a mixture of gases is present. Dalton's Law of Partial Pressures states that: "The total pressure exerted by a mixture of gases is equal to the sum of the partial pressures of the various gases comprising the mixture." This law simply states that each gas in a mixture acts as if it were alone in the space; however, the total pressure is the sum of all the partial pressures of all the gases in the mixture.

Our atmosphere is a mixture of gases. Understanding Henry's Law and Dalton's Law of Partial Pressures allows us to see that the dissolved gases in our make-up water are proportional to the partial pressures exerted by the gases in our atmosphere. Our air is about 20 percent oxygen. The amount of dissolved oxygen in make-up water is directly proportional to the partial pressure exerted by the oxygen (gas) in the atmosphere at a definite temperature and at a fixed volume.

Oxygen solubility in water is in direct relationship with the water temperature. (see chart)

Raising the temperature of feed water increases the speed of the molecules in it. Applying Henry's Law, the number of molecules leaving the surface area is greater than the number of molecules entering the surface area, lowering the concentration as heat is applied. This process is enhanced by increasing the surface area of the exposed feed water. This is accomplished by the use of spray nozzles and cascade trays.

Refer to the Oxygen Solubility Chart and note the oxygen solubility at 212°F at atmospheric pressure. The chart then shows pressures greater than atmospheric pressure and less than atmospheric pressure. In all cases, at the saturation temperature the



OXYGEN SOLUBILITY IN WATER AT VARIOUS TEMPERATURES AND PRESSURES

oxygen constant is zero. All deaerators, regardless of design, must conform to this physical law.

The design of a deaerator relies on expanding the surface area of the feed water to obtain the release of the non-condensable gases. The atmospheric design allows a free flow of gases while a pressurized design uses a restricted orifice method. The atmospheric design lends to the use of vent condensers for increased operating efficiency. Either design may obtain the desired results.

Steam is the gaseous form of water. Dalton's Law of Partial Pressures allows the definition of boiling point to be "The condition when the equilibrium vapor pressure of a liquid is equal to the prevailing atmospheric pressure." This means that the number of molecules leaving the surface area equals the number entering.

We are now ready to study the difference between deaerators operated at atmospheric pressure (14.92 PSI) and those operated at a gauge pressure above one (1) atmosphere. (Note: 5 PSIG is a nominal set operating pressure.) For our discussion we will refer to units operating at atmospheric pressure as "atmospheric" deaerators and those operating at pressures greater than one (1) atmosphere as "pressurized" deaerators.

An atmospheric deaerator now allows the free oxygen and carbon dioxide to be vented to the atmosphere and with the use of a vent condenser, capture the waste heat. An atmospheric deaerator has a saturation temperature of 212°F. A pressurized (5 PSIG) deaerator has a saturation temperature of 227°F. At either fixed temperature the solubility of O_2 is a constant.

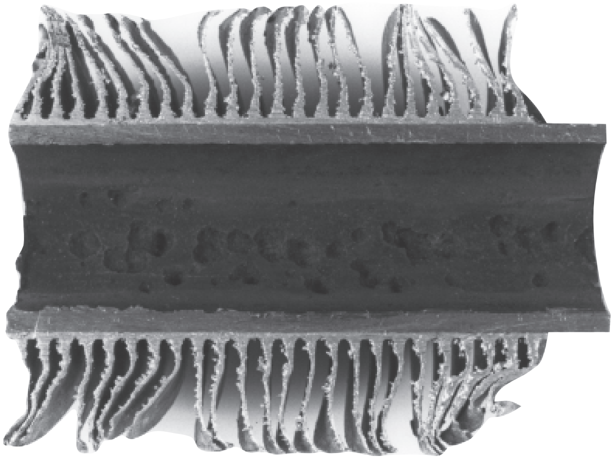
Having reviewed the specific gas laws that apply to the deaeration process, we are now ready to look at the mechanical processes of deaeration. The Oxygen Solubility Chart is again referred to for our discussion. The amount of dissolved oxygen in feed water is a function of temperature. Maintaining saturation temperature is accomplished by injecting steam into the feed water. The steam is injected below the water line, causing the bubbles to agitate the deaerated water to prevent reabsorption. The steam then enters the open area of the storage receiver. The free steam is now in contact with the cascading water from the tray section of the deaeration column. This water is at saturation temperature and being deaerated a second time. Free steam continues rising to the spray section of the Deaeration Dome. Here the feed water enters the Dome through a spray nozzle and is raised to saturation temperature.

In atmospheric units, the temperature sensing element controlling the steam inlet valve is located below the water line. This location ensures a steam flow at the various load swings. The steam is in sufficient supply to effect an instantaneous temperature change to the saturation temperature. The release of the non-condensable gases is accomplished at this point.

With atmospheric units, a shell and tube vent condenser is installed on the vent connection of our atmospheric style deaerators. The steam vapor is condensed and the latent heat is used to preheat the incoming feed water. The vent is sized to allow a free venting of the uncondensable gases. Under operating conditions, only trace amounts of steam appear to flow from the vent line.

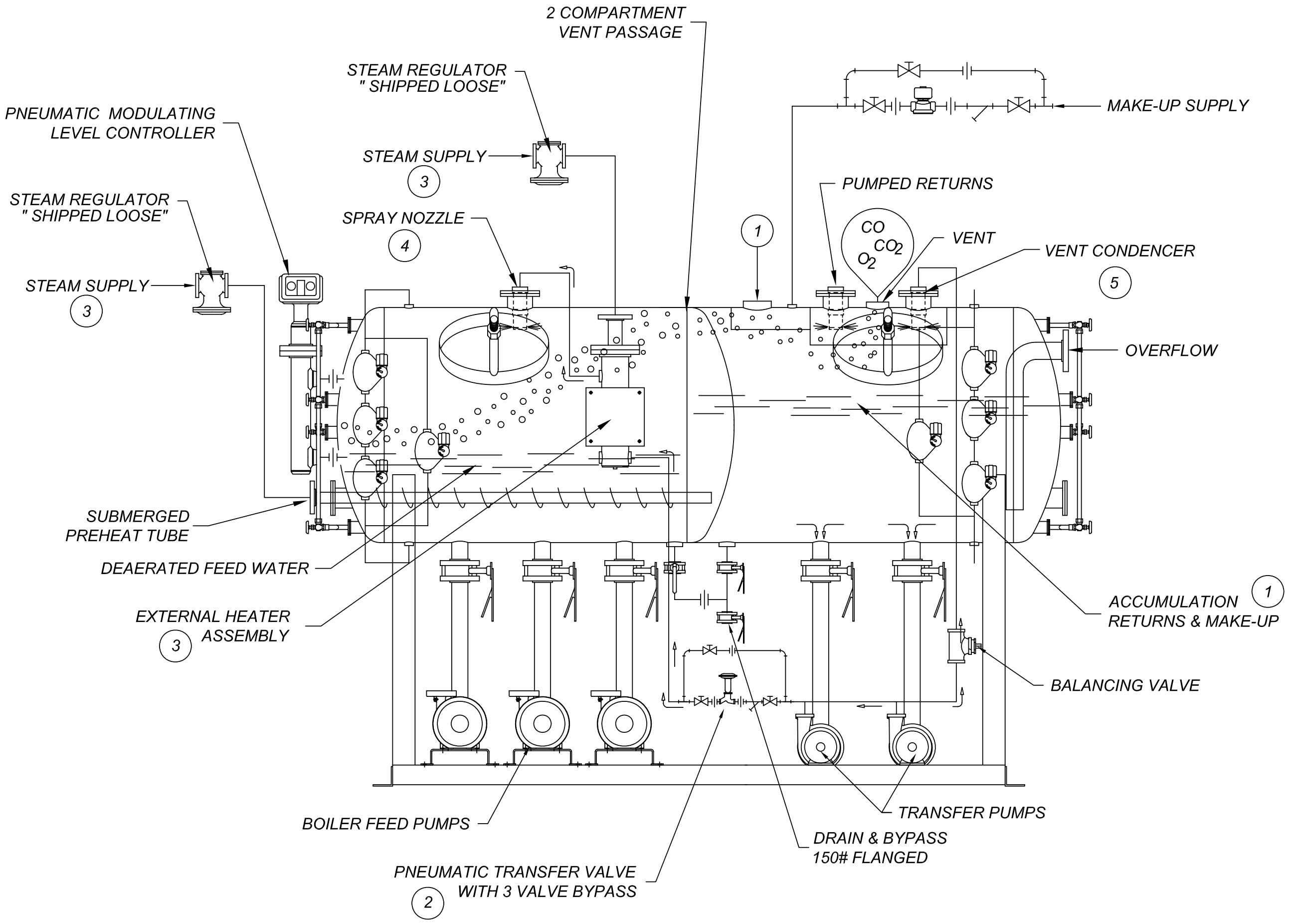
Pressurized units are controlled by a steam pressure pilot. The internal working pressure of the receiver is maintained at 5 PSIG. The steam temperature and pressure are in direct relationship, hence you maintain saturation temperature.

It is a commonly recognized fact that using a deaerator can save hundreds of dollars and lower fuel costs. Using atmospheric deaerator designs results in the greatest overall operating efficiency.



OXYGEN PITTING IS A COSTLY PROBLEM!
PROPER WATER TREATMENT UTILIZING MECHANICAL DEAERATION IS VERY INEXPENSIVE WHEN COMPARED TO REPLACING EQUIPMENT PREMATURELY!

MECHANICAL DEAERATION IS A COST EFFECTIVE MEANS TO ACHIEVE EFFICIENT BOILER PLANT OPERATION.



SHIPCO® HAS A FIVE-STEP APPROACH.

1. Incoming returns and make-up water are introduced into the accumulation section which helps increase the temperature of the make-up water.
2. The blended water in the accumulator section is then transferred into the external heating assembly by a continuously running transfer pump through a modulating transfer valve.
3. Steam is directly injected into the external heating assembly where the transferred water is heating to the saturation level.
4. From the heating assembly the water travels through the stainless steel spray nozzles. The fine spray provides the increased surface area for heat absorption and release of the now condensable gases.
5. Gases released through the spray nozzle then can flow freely through the compartment divider plate and over to the accumulator compartment vent condenser which assures a minimum vent loss.

SHIPCO® DEAERATORS CAN SAVE YOU MONEY BY REMOVING “AIR”.

SHIPCO® DEAERATORS CAN SAVE YOU MONEY COMPARED TO REDUCED CAPACITY OF THERMAL EQUIPMENT.

SHIPCO® DEAERATORS CAN SAVE YOU MONEY BY REMOVING BARRIERS TO EFFECTIVE HEAT TRANSFER.

SHIPCO® DEAERATORS CAN SAVE YOU MONEY COMPARED TO LOST PRODUCTION TIME AND EXPENSIVE REPAIR OR REPLACEMENT OF PREMATURELY CORRODED BOILERS, BOILER TUBES, CONDENSATE RETURN LINES, HEAT EXCHANGERS, OR PROCESS EQUIPMENT.

Deaerator Selection & Sizing

Selection is based on gallons per minute (GPM), pounds per square inch (PSIG), net positive suction head (NPSH) and receiver size.

Determine GPM of Boiler Feed Pump

The evaporation rate of one boiler horsepower is .069 gallons per minute.

Other conversion equivalents: One boiler horsepower equals 33,475 BTU/hr. or 34.5 lbs./hr. or 139.4 sq. ft. EDR.

Boiler feed pumps for on-off operation are sized at two (2) times this evaporation rate.

Boiler feed pumps for continuous operation (generally 15 motor HP and larger) are sized at one and a half ($1^1/_2$) times this evaporation rate. In addition, extra flow for recirculation with deaerator boiler feed pumps may have to be added. The SHIPCO® centrifugal Model "P" and "D" pumps do not require any additional flow. SHIPCO® pumps with motors 5 HP and less have a bleed line that serves this function, and in pumps with motors $7^1/_2$ HP and larger a bypass orifice is used in a recirculation line for this purpose.

Boiler feed pumps are sized based on the maximum number of boilers each pump is feeding.

Determine PSIG of Boiler Feed Pump

The deaerator boiler feed pumps are sized to overcome the **operating** pressure of the boiler + friction loss in pipe + valve loss + feed valve loss (if any) + stack economizer (if any) + vertical lift from pump to boiler + safety margin of approximately 10 PSIG. The amount of these values added together, are normally expressed in feet of head. To convert feet of head to PSIG, 2.31 ft. = 1 PSIG.

Generally, the feed valve loss is 20 PSIG and the stack economizer loss is 20 PSIG when estimating the pump discharge pressure. Stack economizer requires a continuously running pump in the system.

The standard rules of thumb are:

- High-pressure boilers running on–off from a boiler level controller add 20 PSIG to the operating pressure (not the design pressure).
- High-pressure boilers running continuously pumping through a modulating valve add 30 PSIG to the operating pressure (always better to get pressure drop through valve).
- High-pressure boilers running continuously pumping through a modulating valve and a stack economizer add 50 PSIG to the operating pressure.
- Low-pressure boilers (running between 1 to 15 PSIG) generally use pumps with a discharge pressure of 20 PSIG.

If the boilers run at more than one pressure setting (like a night setback), an additional pump(s) is needed to handle this pressure and the steam control regulator must be sized for this nighttime low-pressure setback.

Determine GPM of Transfer Pump

The transfer pumps are sized for continuous operation on the surge tank. The pumps feed water over to the Deaeration chamber on the unit based on the rating of the deaerator. In addition, the pumps will also supply water continuously to the vent condenser in the surge chamber.

The sizing of each transfer pump is sized at $1^1/_2$ times the rated capacity of the deaerator unit. For example, 10,000 lbs/hr deaerator would have a pump rated for 30 GPM or 10,000 divided by 500=20 GPM and then multiply by (1.5)=30 GPM pumping rate.

Determine PSIG of Transfer Pump

The transfer pump is factory selected to allow water to feed the Deaeration chamber based on the factory selected modulating valve size. Typically a modulating valve is selected by SHIPCO® to bypass 100% of the load with a 10 PSIG drop across the valve; therefore, the transfer pump's discharge pressure is rated for 25 PSIG.

Determine NPSH

NPSH stands for Net Positive Suction Head. The **available NPSH** is essentially the measure of how close the water in the suction passage of the pump is to boiling, with the attendant formation of steam within the impeller, thus diminishing the pump's performance.

Since we have a deaerator where the water is at the saturation point or boiling point, the **available NPSH** is at zero, located at the bottom of the steam manifold.

Various physical designs of pump have various **NPSH requirements**. In order for any pump to operate successfully, the NPSH **available** must be **greater** than the NPSH **requirements.** With a deaerator the only way you can increase the NPSH available is to elevate the tank a greater distance than the pump requires. For example, a pump with an NPSH requirement of 4 ft. must be elevated at least 4 ft. plus a safety factor (usually 1 to 2 ft.). The SHIPCO® model "P" pump requires only 2 ft. of NPSH at the best efficiency point; therefore, our standard elevation is 4 ft. or 48 inches.

Suction strainers hurt NPSH calculations since you can't measure the pressure drop through a strainer. In addition, if it works it will destroy the pump by causing it to run dry. For this reason suction strainers are **never** used with centrifugal pumps like the SHIPCO® model "P" or "D" pumps. Suction strainers are only used when turbine pumps are supplied since even a little dirt and debris will cause this style of pump to go bad due to the close tolerances within the design. The standard rule of thumb is to add one additional foot of stand elevation to compensate for this suction strainer.

Determine Receiver Size

The receiver size on a two-compartment deaerator is based on the total load of all boilers being fed by the unit at any one time. The receiver size is generally based on 20 minutes of net storage or 10 minutes in each chamber.

[1] When should a single-compartment .005 DA deaerating heater be used?
A good general rule is to select a single-compartment .005 DA unit on systems having 80% or more make-up.

[2] When should a two-compartment .005 DA-2C [or two-tank .005 DA-2T] deaerating heater be used?
Use a two-compartment .005 DA-2C [or a two-tank .005 DA-2T] design on systems having more than 20% return condensate.

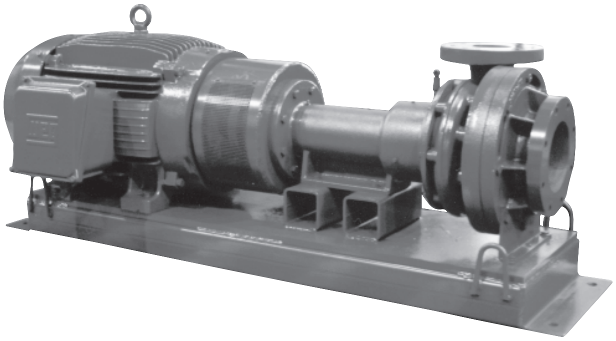
It is no secret that constant balanced flows provide the best results when deaerating feed water. The two-compartment [or two-tank design] allows the system to intermittently return condensate to the accumulator compartment. The capacity of the accumulator is such that it has ample capacity for storing the condensate from the system. The system lag time for returning condensate to the accumulator will determine the required size of the accumulator compartment. A good general rule is to size the compartment for a minimum 10 minutes of storage.

The condensate is blended with any required make-up water in the accumulator compartment. This feed water is then transferred to the deaeration compartment by the transfer pump through a modulating transfer valve. This balanced flow enables the steam control valve to maintain the constant temperature critical for good deaeration.

Good engineering practice has shown from experience that the percentage of make-up required in a given system will determine the style of deaerator to be used. Systems requiring less than 80% make-up should have an accumulator. The intermittent return condensate is collected and blended with the make-up water to be deaerated on a balanced demand based on system load. This will assure an ample quantity of deaerated feed water.

Boiler Feed Pumps

Shipco® offers a wide variety of boiler feed pump types with various models and styles designed specifically to pump hot condensate over a wide range of flow and pressure applications. Pumps are centrifugal single or multi-stage and can be vertical or horizontal flange mounted with 1750 RPM or 3500 RPM motors in single or three phase. Pumps are low NPSH designed bronze fitted with removable wear ring and impeller and equipped with industry standard motors that can be purchased locally.



The pump design typically furnished on deaerators is a multi-stage, AWF style of pump. This pump is centrifugal, bronze-fitted design. Pump typically used for applications with flows up to 500 GPM and pressures up to 340 PSIG. Pump types (such as 221 AWF, 231 AWF, 616 AWF, etc.) selected depend on the design operating conditions–flow rate, discharge pressure and NPSH requirements; impellers trimmed to operating conditions. Pumps come standard with an ASA flanged suction and discharge. Pumps also have coupling guards. Pumps are furnished with bleed lines, sometimes called seal flushing lines, to help prevent the pump from vapor binding and to allow pump operation against a dead shut-off for a period of time without burning mechanical seals. Silicon carbide/Viton seals provided are for temperatures up to 300°F. All pumps come equipped with an automatic flow control valve for balancing or throttling pump to the designed condition point.

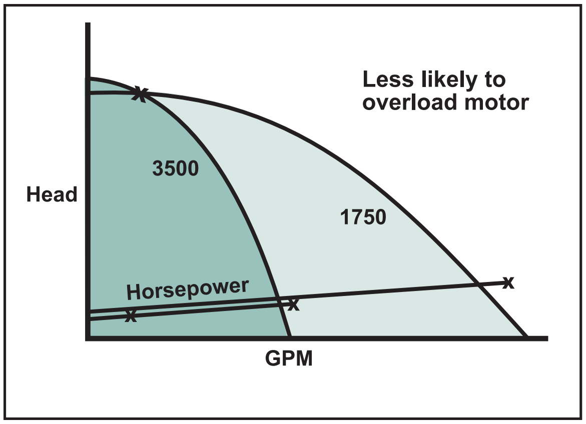
On all deaerator applications where pump is running continuously, an additional stainless steel bypass orifice must be installed when motor horsepower exceeds 7 1/2 HP.

Why Do We Recommend 3500 RPM Centrifugal Pumps for Most Boiler Feed Applications?

1) More efficient than 1750 RPM for most condensate and boiler feed applications.
2) Operating and repair costs are lower because pumps are more efficient and the motors and parts are less expensive.
3) Less likely to overload motor than 1750 RPM pumps because of much steeper head—capacity, characteristic especially for small capacities. If actual head on the pump is lower than the design head, the pump will operate at higher capacities with accompanying higher power. The 3500 RPM pump maximum load is lower.

4) Just as durable as 1750 RPM centrifugal pumps for the same head and capacity. Centrifugal pumps are not subject to the wear problems of regenerative turbine pumps which are frequently chosen to run at 1750 RPM because of this inherent limitation.

5) NPSH requirements are low for the lower capacities and can be further reduced by use of the "P" modification for higher capacities where the NPSH available is unusually low.



Are Suction Strainers Necessary on Centrifugal Pumps?

It is often asked whether a pump suction strainer is necessary or recommended. The purpose of a suction strainer is to act as a particulate strainer or filter ahead of the pump. This prevents large particles from entering the pump.

Before the introduction of the low-flow/high-head multi-stage centrifugal type pump, turbine type pumps were used almost exclusively for on/off boiler feed service for steam boilers. Back in the 1920s, a turbine pump was the only pump available for high-pressure pump applications since multi-stage, centrifugal pumps were not yet available. The turbine pump impeller was designed with very close tolerances within the pump. Any grit or sediment that entered the pump would result in accelerated erosion of these close-tolerance areas, leading to premature pump wear and loss of performance. These pump characteristics made the use of a strainer a necessity with a turbine type pump.

During the 1960s, ITT Domestic® and other manufacturers introduced multi-stage, centrifugal pumps into the high-pressure steam market. Then during the 1980s, manufacturers such as Grundfos, Gould, etc., started marketing multi-stage, centrifugal pumps and offering the pumps to boiler manufacturers who make feed tanks but not pumps. This strategy caused the boiler manufacturers to start specifying multi-stage, centrifugal pumps in lieu of turbines because the manufacturers now had a source for pumps.

Centrifugal pumps, by their design, are more durable. A centrifugal pump does not have the same close tolerances of a turbine pump—it has a more robust design that enables grit and sediment to pass through without clogging the impeller volute area. Therefore, the use of a suction strainer is neither mandatory nor recommended. Instead, an inlet basket on the return piping into the receiver and a wye strainer on the make up water piping are recommended.

Below is a list of considerations regarding the use of suction strainers with centrifugal pumps:

- **Suction Losses:** The addition of a strainer in the suction line of a pump increases the losses in the suction line, thereby decreasing the NPSH available to the pump. As the strainer fills with particles, the pressure drop across the strainer increases, further reducing the NPSH available. This situation becomes more critical as the temperature of the pumped water increases. When a feed water pump is pumping from a deaerator, the water is already at the flash point, and any increase in the suction losses could lead to a flashing condition and pump cavitations.
- **Increased system maintenance:** Because of the reason stated above, it is important that the strainer screen be checked and cleaned regularly. If the installation is in a remote area and maintenance checks are rare, a clogged strainer will eventually lead to pump failure and a low water condition in the boiler.
- **Can particles get into the pump without a strainer?** Shipco® recommends use of inlet strainers on all deaerators and boiler feed tanks to help prevent particles from getting into the pump. In addition the suction piping typically extends 2" to 3" up into the receiver (often referred to as a vortex breaker). This extension helps prevent any sediment and large particles from leaving the tank through the suction opening. In Shipco® deaerators, the water entering the deaerator must travel through a series of spray valves, baffles, trays and other restricted flow paths before deaeration is complete and the water is ready for use. The number and size of the particles that will make it through this path and into the storage area are limited.

As the engineering community continues to improve its understanding of the functions of centrifugal and turbine pumps, engineers are starting to remove requirements for suction strainers from specifications.

Shipco® believes that any benefit of a suction strainer is far outweighed by the risks, which can lead to pump failures and other system problems.

Why Inject Steam Below the Water Line of the Storage Section in Our Deaerator Designs?

Injecting steam into the storage section (also referred to as water reserve) of deaerators provides several advantages over other designs. Primarily, it helps prevent the reabsorption of oxygen into the deaerated water since steam injected below the water line keeps the water in the storage section in constant agitation. It provides a heat source for load swings that enables the storage section to operate as a steam accumulator if a rapid load swing should occur. Finally, it keeps the water in the storage section moving, which prevents chlorides from becoming stagnant.

In a system *without a surge tank but large quantities of uncontrolled returns*, the addition of make-up water, when required, will create a load swing that will be the difference in temperatures between the hotter system returns and the colder make-up water. An advantage of SHIPCO®'s design is that the deaerator has some stored energy in reserve in the storage section creating the capability to continuously scrub water in the storage section to prevent re-absorption of oxygen. When a sudden change in pressure occurs, steam will be released from the storage water, helping maintain the level of deaeration desired.

For deaerator designs where steam is only injected above the water line in the storage section, any oxygen that is re-absorbed into the effluent cannot be released without agitation and the water temperature in the storage section reaching the saturation point (i.e., boiling point). The saturation temperature throughout the depth of the storage section varies. For example, the saturation temperature is higher at the bottom of the receiver than at the water surface. At the bottom of the receiver, the saturation temperature depends on both the internal tank pressure plus the pressure generated by the weight of the water from the surface to the bottom of the tank.

While various designs exist within the industry, most deaerator manufacturers use the same or similar type of steam control valves since steam control valves are very responsive to detecting pressure changes inside the storage tank

Our goal in manufacturing deaerators is to provide a reliable unit that will meet or exceed customer requirements. Supporting this goal, we are fortunate to have an independent, third-party test of our .005 "dome-style", pressurized deaerator that confirms our design of injecting steam below the water line produces results that exceed rated performance. The test shows that the highest reading for dissolved oxygen was only 5 parts per billion (ppb) — below the industry-standard rating of 7 ppb for a .005-rated deaerator.

(Note: We recommend using a surge tank to lessen the effects of load swing in a system when condensate returns are 20 percent or more of system load. With a surge tank, make-up water is mixed with system returns for a blended effluent that is pumped to the deaerator by transfer pumps.)

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