9

THE CONDENSATE RECOVERY SYSTEM

Steam will condense on any surface that has a lower temperature than the saturation temperature of the steam. The formed liquid from condensed steam is called **condensate**. Condensate starts to form as soon as the steam leaves the boiler. Steam headers and steam-using equipment will form condensate, which will require steam traps to provide a barrier that will separate the condensate from the steam. The trapped condensate needs to be collected, discarded, or pumped back into the boiler feed water system. This part of the steam system, called the condensate recovery system, has three fundamental purposes. It must:

- **Separate the condensate from the steam**
- **Collect the condensate**
- **Pump the condensate into the feed water tank or be discharged**

The condensate formed in both the steam distribution pipe work and in the process equipment is a convenient supply of useable hot boiler feed water. Although it is important to remove this condensate from the steam space, it is a valuable commodity and should not be allowed to run to waste. Returning all condensate to the boiler feed tank closes the basic steam loop and should be practiced wherever practical.

A general piping and instrumentation diagram of a typical condensate system is shown in Figure 9.1. Condensate recovery systems can be divided into the five subsystems listed below, with each subsystem requiring its own design considerations. Not all condensate recovery systems use all five subsystems, but all will have drain lines and steam traps.

Process Steam Systems: A Practical Guide for Operators, Maintainers, and Designers, First Edition. Carey Merritt.

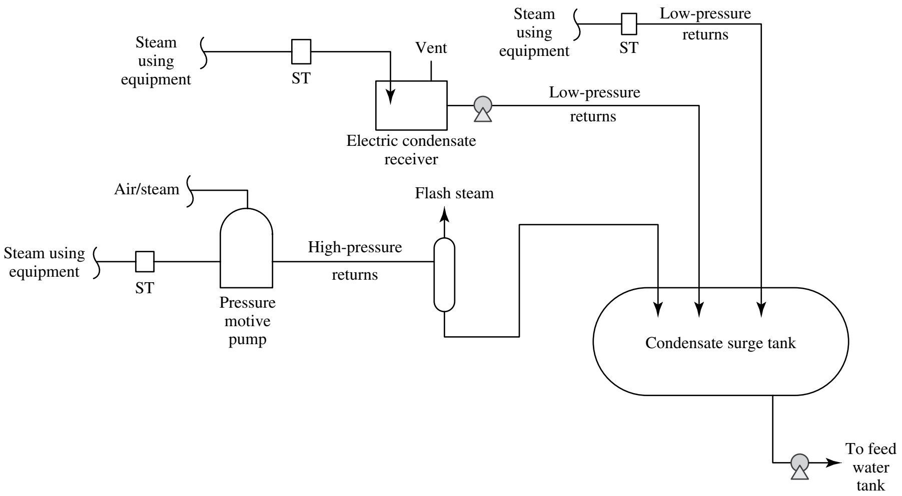


FIGURE 9.1 Condensate recovery system.

The five subsystems are:

a) Drain lines from the steam-using equipment to the traps carry pressurized high-temperature hot water.
b) Steam traps and trap discharge lines carry a two-phase mixture of flash steam and condensate.
c) Flash tanks that reduce the hot pressurized water to atmospheric or near-atmospheric pressure.
d) Condensate collection and pumped return systems utilizing electric or non-electric pumps.
e) Surge tank to accept the condensate from different sources and provide a means to store water for the feed water tank.

Example 9.1

A steam boiler produces 20,000 lb/h at 120 psig steam, and none of the condensate is returned back to the boiler. Consequently, the boiler uses 100% fresh makeup water at 70°F. A plant modification can be done for $100,000 that would allow 50% of the condensate to be returned to the boiler. Is the modification worth doing?

Answer: To determine the viability of this modification, you must determine the cost savings from returning the condensate and weigh that against the cost of the modification. You will also need to know the temperature of the condensate (if unknown, then assume it will be 200°F) and the cost of fuel (we assume natural gas at $5/million BTUs). First, determine the amount of heat energy required to heat the boiler water with and without the condensate. We know that 120 psig water will boil at 350°F.

Without condensate, 20,000 lb/h × 1 Btu/lb-F × (350 – 70°F) = 5,600,000 Btu/h. With 50% condensate, the new boiler water temperature can be calculated by adding the portions of each of the 100°F makeup water and the 200°F condensate. Therefore, the new boiler water temperature would be (100°F × 50%) + (200°F × 50%) = 150°F. So with 50% condensate returned, the heat energy needed to raise the boiler water from 150 to 350°F will be 20,000 lb/h × 1 Btu/lb-F × (350 – 150°F) = 4,000,000 Btu/h. Then the energy savings per hour is 1,600,000 Btu/h, and at $5/million Btu, we can save 1.6 × 5 = ***$8/h****. This doesn't seem like a lot, but annualized at 24/7, the saving is $70,080/year. Furthermore, if we take into account the efficiency of the boiler (around 80%), then this savings becomes even greater (i.e., $70,080/0.80 =* ***$87,600/year****). The actual savings would depend on how many equivalent rated hours of operation the boiler achieved in a year. When you consider that a steam system is designed to operate for 20 years, the modification maybe well worth doing.*

CONDENSATE LINE SIZING

Drain Lines to Traps. The condensate has to flow from the condensing surface to a steam trap. In most cases, this means that gravity helps to induce flow, since the heat exchanger steam space and the traps are at the same pressure. The lines between the drainage points and the traps should have a minimum slope of 1″ in 10 ft. Table 9.1 shows the water-carrying capacities of the pipes with such a gradient. It is important to allow for the passage of noncondensable gases to the trap and for the extra water to be carried at cold starts. **In most cases, it is sufficient to size the drain pipes on 1.5 to 2 times the condensate produced at full running load**.

TABLE 9.1 Condensate Flow versus Pipe Size (lb/h)[a]

Steel	Approximate Frictional Resistance			
Pipe	In Inches Water Column per 100 ft of Travel			
Size	1	5	7	10
½″	100	240	290	350
¾″	230	560	680	820
1″	440	1070	1,200	1,550
1 ¼″	950	2,300	2,700	3,300
1 ½″	1,400	3,500	4,200	5,000
2″	2,800	6,800	8,100	9,900
2 ½″	5,700	13,800	16,500	20,000
3″	9,000	21,500	25,800	31,000
4″	18,600	44,000	52,000	63,400

[a]Data from Spirax Sarco [13].

Trap Discharge Lines. At the outlet of steam traps, the condensate return lines must carry condensate, noncondensable gases, and flash steam released from the condensate. Where possible, these lines should drain by gravity to the condensate receiver, whether this be a flash recovery vessel or the vented receiver. When sizing return lines, two important practical points must be considered. First, one pound of steam has a specific volume of 26.8 ft^3 at atmospheric pressure. It also contains 970 Btus of latent heat energy. This means that if a trap discharges 100 lb/h of condensate from 100 psig to atmosphere, the weight of flash steam released will be 13.3 lb/h, having a total volume of 356.4 ft^3. It will also have 12,901 Btus of latent heat energy. This will appear to be a very large quantity of steam and may well lead to the erroneous conclusion that the trap is passing live steam (failed open).

Secondly, the actual formation of flash steam starts to take place downstream of the steam trap orifice where pressure drop occurs. From this point onward, the condensate return system must be capable of carrying some flash steam, as well as condensate. **Sizing of condensate return lines from trap discharges based totally on water is a gross error and causes lines to be drastically undersized for the flash steam**. This causes condensate lines to become pressurized, not atmospheric, which in turn causes a back pressure to be applied to the trap's discharge, which can cause equipment failure and water logging.

When flash steam volume is not accounted for, a positive pressure can develop in the condensate return system by the flash steam. The condensate return line will follow the pressure/temperature relationship of saturated steam. So, trap testing showing elevated condensate return temperatures does not necessarily mean a trap has failed. When sizing condensate return lines, the volume of the flash steam must be considered. The following chart allows the lines to be sized considering flash steam. By determining the quantity of flash steam and sizing the return line for velocities between 4000 and 6000 ft/min, the two-phase flow within the pipe can be accommodated.

Draining condensate from traps serving loads at differing pressures to a common condensate return line can be accomplished. At the downstream or outlet side of the traps, the pressure must be at common pressure in the return line. This return line pressure will be the sum of at least three components.

1. The pressure at the end of the return line, either atmospheric or of the vessel into which the line discharges
2. The hydrostatic head needed to lift the condensate up any risers in the line
3. The pressure drop needed to carry the condensate and any flash steam along the line

Item 3 is the only one likely to give rise to any problems if condensate from sources at different pressures enters a common line. The return line should be sufficiently large to carry all the liquid condensate and the varying amounts of flash steam associated with it, without requiring excessive line velocity and excessive pressure drop.

Example 9.2 [7]

Size a condensate return line from a 160 psig steam system trap discharging 3000 lb/h hot condensate to 20 psig flash tank.

*Answer: Determine percent flash steam produced using Figure 2.6, flash steam chart. A steam pressure of 160 psig and a flash tank pressure of 20 psig will result in 12.4% of the condensate flashing to steam. Next, multiply the condensate load by the percent flash from step 1 to determine the flow rate of flash steam produced: 3000 lb/h × 0.124 = 372 lb/h. Now, from Figure 9.2, with the flash steam flow rate of 372 lb/h at "A," move horizontally to the right to the flash tank pressure of 20 psig at "B." Rise vertically to choose a condensate return line size that will give a velocity between 4000 and 6000 ft/min at "C." In this example, a **1.5 inch schedule 40 pipe** will have a velocity of approximately 5000 ft/min. If schedule 80 pipe is to be used, refer to table within body of chart. Multiply the velocity by the factor to determine whether the velocity is within acceptable limits.*

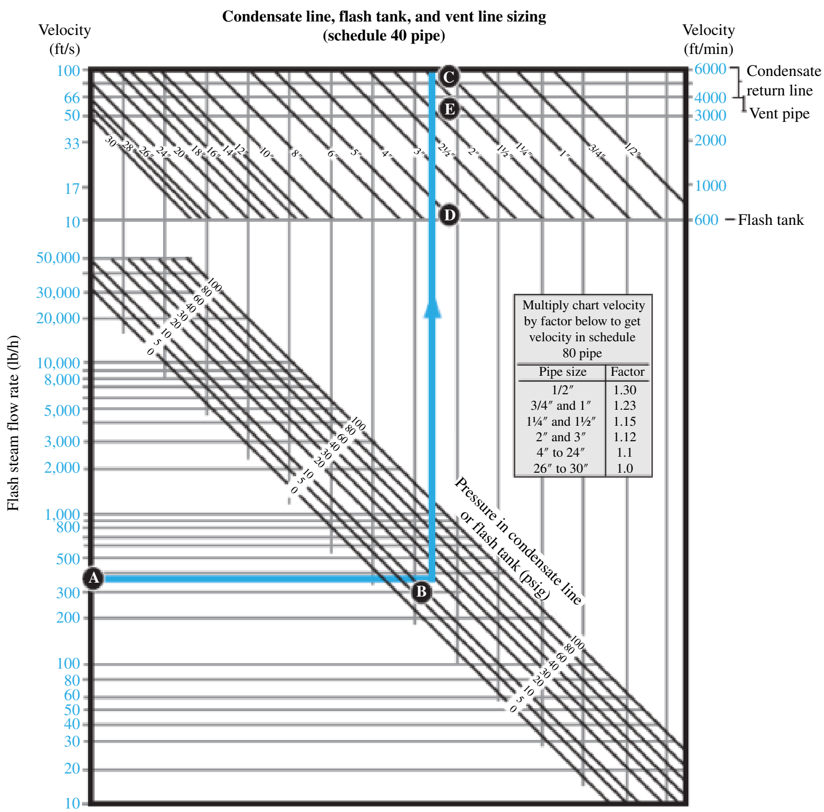


FIGURE 9.2 Condensate line sizing chart. Courtesy of Watson McDaniels Inc.

STEAM TRAP APPLICATIONS

Steam traps come in a variety of sizes and functionality. Applying the correct size, pressure rating, and type of trap is essential to a good condensate recovery system design. Incorrect application can lead to system heat transfer inefficiencies and wasted money. Likewise, trap location relative to the heat exchange equipment is essential to ensuring proper condensate draining. This discussion of steam traps reviews the type of steam traps and their proper usage. There is no such thing as a “universal” steam trap that is suitable for all applications. For this reason, you should familiarize yourself with each of the main steam trap groups and learn how to best take advantage of the merits of each type.

When the steam system is shut down, air will be drawn in to take up the space formerly occupied by steam. Since this air has to be removed from the system on startup, it is a considerable bonus if the steam traps have a good air venting capability. While this is the case with certain traps, other types are actually prone to “air binding”—a condition in which the trap remains closed when it should be opening to release condensate. There are three main steam trap groups.

Thermostatic Group

This group separates steam and condensate by the temperature difference of each that operates a thermostatic, valve-carrying element. Condensate must cool below steam temperature before it can be released.

Mechanical Group

Traps of this group operate an internal mechanical device, sensing the difference in density between steam and condensate. The movement of a “float” or a “bucket” operates a valve to discharge condensate.

Thermodynamic Group

This group works on the difference in kinetic energy or velocity between steam and condensate flowing through the trap. The most widely used types are thermodynamic disc models. In these traps, the valve consists of a simple disc that closes to high velocity steam but opens to lower velocity condensate.

Thermostatic Steam Trap Group

Balanced Pressure Type. A typical balanced pressure thermostatic steam trap is shown in Figure 9.3 [4]. The thermostatic element will expand and contract if pulled or pushed at the sealed ends. The element is filled with a liquid (alcohol mixture) that has a boiling point lower than that of water. Air and cooler condensate will be pushed out through the wide open valve. As the condensate gradually warms up, heat transfer will take place to the alcohol mixture inside the element. Before the condensate

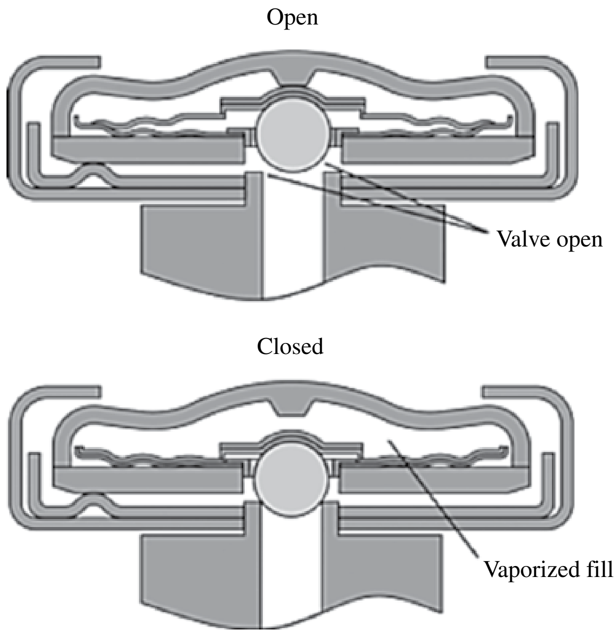


FIGURE 9.3 Balanced pressure thermostatic-type trap. © Spirax Sarco Inc. [42]

reaches steam temperature, the mixture reaches its boiling point. As soon as it boils, vapor is given off, increasing the pressure inside the element. The pressure inside the element exceeds the pressure in the trap body and the element expands, forcing the trap to close off flow. Eventually, the condensate in the trap body cools down, allowing element to contract and open the valve to condensate flow. Condensate is then discharged through the open valve, and the complete cycle is repeated. Thermostatic balanced pressure traps are small and light and have a large capacity for their size. This type of trap is unlikely to freeze when working in an exposed position. The balanced pressure trap automatically adjusts itself to variations of steam pressure up to the maximum pressure for which it is suitable. Trap maintenance is easy. The element and valve seat are detachable and can be replaced in a few minutes without removing the trap body from the line. The flexible element in this type of trap may be susceptible to damage by water hammer or corrosive condensate.

Liquid Expansion Thermostatic Steam Trap. (Fig. 9.4) A typical liquid expansion trap is operated by the expansion and contraction of a liquid-filled well that responds to the temperature difference between steam and condensate. As the temperature of the condensate passing through the trap increases, heat is transmitted to the well causing it to expand. This expansion acts on the piston, and the valve is pushed nearer and nearer to its seat, steadily reducing the flow of condensate. When steam reached the well, the valve is shut completely off. If the cooler condensate is formed, the valve will reopen and pass just this amount. This type of trap can be adjusted to discharge at very low temperatures, if so desired. Like the balanced pressure trap, the liquid

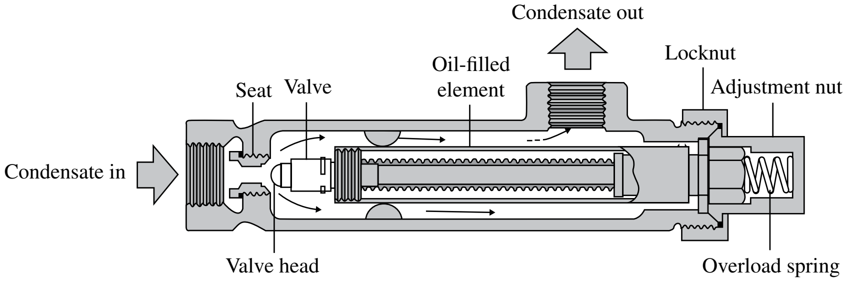


FIGURE 9.4 Liquid expansion thermostatic-type trap. © Spirax Sarco Inc. [42]

expansion trap is fully open when cold, giving good air discharge and maximum condensate capacity on startup loads. If the steam pressure at the trap is subject to wide and rapid variation, the element will not respond to the changes as quickly as that of a balanced pressure trap. The flexible tubing of the element can be destroyed by corrosive condensate. Since the liquid expansion trap discharges condensate at a temperature of 212°F or below, it should never be used on applications that demand immediate removal of condensate from the steam space.

Bimetal-Type Steam Trap. (Fig. 9.5) Condensate flow in this type of steam trap results from the bending of a composite strip of two metals that expand by a different amount when heated up. One end of the strip is fixed to the trap body, while the other end is connected to the valve. Air and condensate pass freely through the open valve until the bimetal strip approaches steam temperature. The free end will then bend downward and close the valve. The trap will remain shut until the body is filled with condensate that has cooled sufficiently to allow the strip to straighten and open the valve. Bimetallic traps are usually small in size and yet can have a large condensate discharge capacity. The valve is wide open when the trap is cold, giving a good air venting capability and maximum condensate discharge capacity under startup conditions. Bimetallic traps can be constructed to withstand water hammer, corrosive condensate, high steam pressures, and superheated steam. Bimetallic traps do not usually respond quickly to changes in load or pressure because the bimetal is relatively slow to react to variations in temperature. As condensate is discharged below steam temperature, water logging of the steam space will occur unless the trap is fitted to the end of a fairly long cooling leg.

Mechanical Group

Float and Lever Type. With a simple float and lever-type steam trap, the condensate enters the trap body through the inlet, and the ball lifts as the water level rises [4]. The float arm connects the ball to the outlet valve, which is gradually opened as condensate raises the ball. The position of the valve varies according to the level of water in the trap body, giving continuous condensate discharge on any load that falls within the maximum capacity of the trap. If the condensate load diminishes and steam reaches the trap, the float will drop to its lowest position. The valve is held firmly

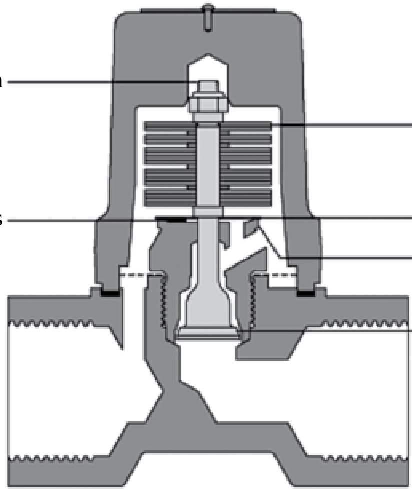


FIGURE 9.5 Bimetal-type steam trap. © Spirax Sarco Inc. [42]

against its seat and no steam can be wasted. The one major drawback with this trap is that air cannot be discharged through the main valve on startup. Unless some means is provided for releasing air from the system, condensate will be prevented from flowing into the trap, which then becomes "air bound." A design feature that allows for automatic air venting is the addition of a thermostatic element. This is, in fact, a thermostatic element of the type used in the thermostatic traps already explained in this section. These types of traps are called **float and thermostatic types** (Fig. 9.6). The thermostatic valve is wide open when the trap is cold, so that the air is readily discharged on startup. As soon as steam reaches the trap, the element expands and pushes the valve shut so no steam is able to escape. The float and lever trap gives continuous discharge of condensate at steam temperature. This makes it the first choice for applications where the rate of heat transfer is high for the area of heating surface available. It is able to handle heavy or light condensate loads equally well and it is not adversely affected by wide and sudden fluctuations of pressure. Floats, bellows, and the thermostatic elements, however, are susceptible to damage by water hammer. The materials of this type of thermostatic element cannot tolerate corrosive condensate, and they are not suitable for use on super heated steam, unless modified. A float trap can be damaged by freezing, and the body should be well insulated if it is to be placed in an outdoor location where freezing conditions exist.

Open Top Bucket Type. An open top bucket can be used to operate the valve instead of a ball float. The bucket will float in condensate when empty but sink by its own weight when full of condensate. When condensate enters, it first fills the body of the trap outside the bucket. The bucket floats and the valve is pushed up on to its seat. More condensate flowing into the body spills over into the bucket. When it is full enough, the bucket is sufficiently heavy to drop back to the bottom of the trap, drawing the valve away from its seat. The steam pressure on the condensate in the

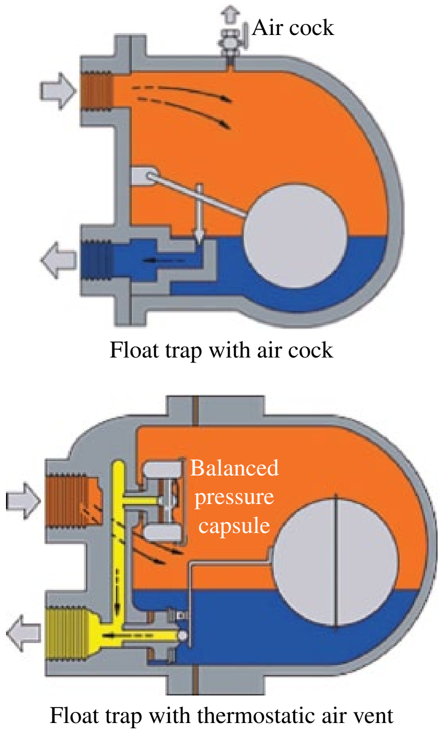


FIGURE 9.6 Float-type trap with manual and thermostatic-type air venting. © Spirax Sarco Inc. [42]

trap forces water out through the central tube, and the bucket becomes buoyant once again. The whole action is then repeated. It should be noted from this description that traps of this type have an intermittent blast discharge action. Open bucket traps are usually robust and can be made for use on high-pressure and superheated steam. They can withstand water hammer and corrosive condensate better than most types of mechanical traps, and there is little that can go wrong with the simple mechanism. This mechanical limitation means that open bucket traps tend to be rather large and heavy in relation to their discharge capacity. No provision is made for air venting unless either a manual cock or thermostatic air vent is fitted. This type of trap is susceptible to damage by freezing, and the body must be well insulated if it is placed outdoors.

Inverted Bucket Type. A trap that is more commonly used than the open bucket is the inverted bucket pattern. In this type, the operating force is provided by steam entering an inverted bucket and causing it to float in the condensate with which the trap is filled. When steam is turned on, the bucket is at the bottom of the trap and the valve is wide open. Air is discharged through a small hole in the top of the bucket. Condensate enters the trap and the water level rises both inside and outside the bucket. The bucket remains at the bottom of the trap, and the water is able to pass away through the wide open valve. When steam reaches the trap, it enters the bucket and makes it float upward, shutting the valve through a lever arrangement. The steam

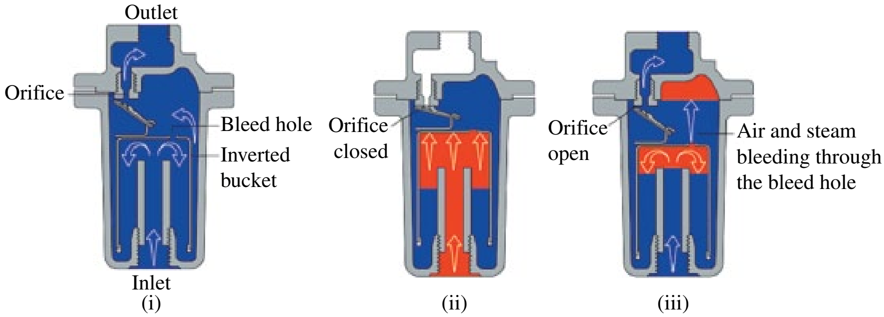


FIGURE 9.7 Inverted bucket trap operation. © Spirax Sarco Inc. [42]

in the bucket will slowly escape via the small vent hole, collecting at the top of the trap. If it is replaced by more steam, the trap remains closed. If condensate enters, the bucket will sink, pulling the valve open (Fig. 9.7). Like the open bucket trap, this type has an intermittent blast discharge action. The inverted bucket trap can be made to withstand high pressures and can be used on superheated steam if a check valve is fitted on the inlet. It has a reasonably high degree of tolerance to water hammer conditions, and there is little to go wrong with the simple bucket and lever mechanism. There should always be enough water in the trap body to act as a seal around the lip of the bucket. If the trap loses this water seal, steam can blow to waste through the outlet valve. If an inverted bucket trap is used on an application where fluctuation of the pressure can be expected, a "check valve" or a "nonreturn valve" should be fitted on the inlet line in front of the trap. The inverted bucket trap is likely to suffer damage from freezing if placed outdoors in an exposed position.

Thermodynamic Group

Thermodynamic Disc Type. (Fig. 9.8) The construction of the thermodynamic disc type of steam trap is extremely simple [4]. A typical trap consists of only a body, a top cap, and a free-floating disc. This disc is the only moving part of the trap. An annular groove is machined into the top of the trap body, which forms the seat face. The faces of the seat and of the disc are carefully ground flat, so that the disc seats on both rings at the same time. This seals off the inlet from the outlet and is essential if a tight shutoff is to be achieved. On startup, air and cool condensate reach the trap, passing up the inlet orifice. Air and condensate flow radially outward from the center of the disc into the space between the seat rings and are discharged through the outlet passage. The temperature of the condensate gradually increases and as this passes through the trap inlet, some of it flashes into steam. The resulting mixture of flash steam and condensate flows radially outward across the underside of the disc, and because flash steam has a larger volume than the same weight of condensate, the speed of flow increases steadily as more and more flash steam is formed. In order to understand what happens next, it is necessary to have a basic grasp of what is known as "Bernoulli's theorem." This simply states that in a moving fluid, the total pressure is the same at all points. This total pressure is the sum of the static and dynamic pressures of a fluid. The static pressure is that which would be measured by a pressure gauge, while the dynamic pressure is that which would be produced by the individual fluid particles if they were to be brought to rest by hitting an obstruction. The dynamic pressure increases as the speed of the particles increases.

If we apply this theorem to the thermodynamic disc trap, we can appreciate that the dynamic pressure of the steam and condensate flowing under the disc will increase as the speed of flow increases. Since the total pressure must remain constant, the static pressure falls as the dynamic pressure rises. The flash steam exerts a static pressure on the whole of the top surface of the disc. This builds up until it is sufficient to overcome the inlet pressure that acts only on a small section in the middle of the disc. When this happens, the disc snaps shut against the seat rings preventing further flow through the trap. The disc remains firmly against its seat until the flash steam above it condenses. This relieves the pressure acting on the top of the disc, allowing it to be raised again by the inlet pressure. If there is no condensate waiting to be discharged when the trap opens, a small amount of high-pressure steam will enter the control chamber and cause the disc to seat very quickly. The addition of a strainer helps to prevent the possibility of dirt particles either blocking the small outlet holes of the trap or preventing the disc from giving a tight shutoff. Thermodynamic disc traps can operate within their whole working range without any adjustment or change of valve size. They are compact, simple, and lightweight and have a large condensate handling capacity for their size. This type of trap can be used on high-pressure and superheated steam and is not damaged by water hammer or vibration. They are usually stainless steel construction that offers a high degree of resistance to corrosive condensate. As the disc is the only moving part, maintenance can easily be carried out without removing the trap from the line. The disc prevents any return flow of condensate through the trap, cutting out the need for a separate check valve. When it fails to open, the disc moves rapidly up and down, giving off a “clicking” sound. This sound is an audible warning that tells us trap maintenance is required. Thermodynamic traps will not work positively on very low inlet pressures or high back pressures.

Sizing a steam trap can also be done by applying some basic information [4].

Required information

1. The steam pressure at the trap—after any pressure drop through control valves or equipment.
2. The lift, if any, after the trap. Rule of thumb: 2.3 ft head = 1 psi back pressure.
3. Any other possible sources of back pressure in the condensate return system. For example, condensate taken to a pressurized DA tank or back pressure due to discharges of numerous traps close together into small-sized return.
4. Quantity of condensate to be handled. Obtained from calculation of heat load.
5. *Safety factor*—These factors depend upon particular applications. **Rule of thumb**: Use a factor of 2 on everything except temperature-controlled air heater coils and converters and siphon applications.

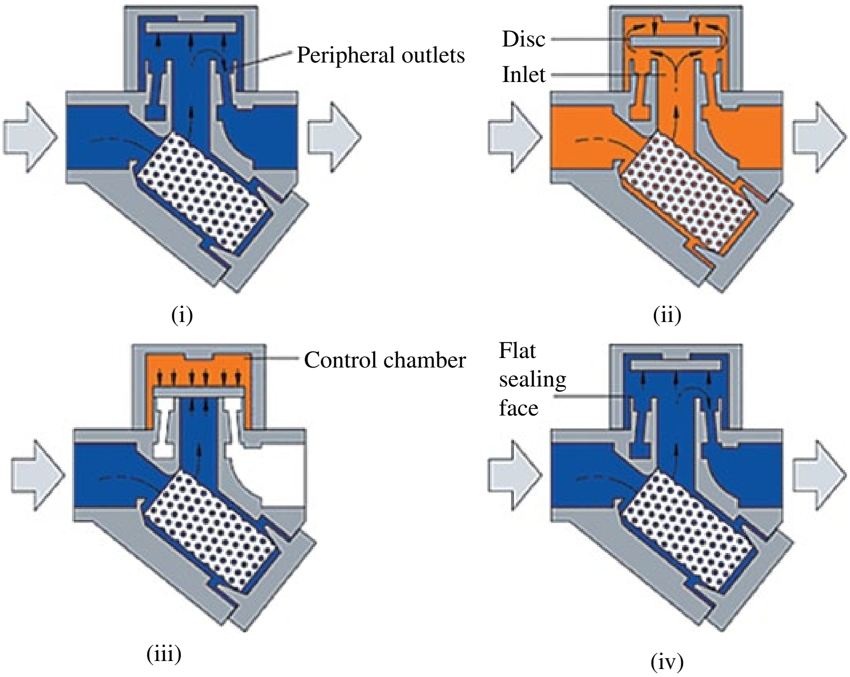


FIGURE 9.8 Thermodynamic-type trap shown with integral strainer. © Spirax Sarco Inc. [42]

Example 9.3

A trap is required to drain 45 lb/h of condensate from a 6″ insulated steam main, which is supplying steam at 100 psig. There will be a lift after the trap of 20 ft:

Supply pressure = 100 psig
Lift = 20 ft = 9 psig
Therefore, differential pressure = 100 – 9 = 91 psig
Quantity = 45 lb/h
Mains drainage factor = 2
Therefore, sizing load = 90 lb/h

Answer: A small reduced capacity thermodynamic steam trap will easily handle the 90 lb/h sizing load at a differential pressure of 90 psi.

If maximum steam system efficiency is to be achieved, the best type of steam trap must be fitted in the most suitable position for the application in question, the flash steam should be utilized, and the maximum amount of condensate should be recovered (Fig. 9.9).

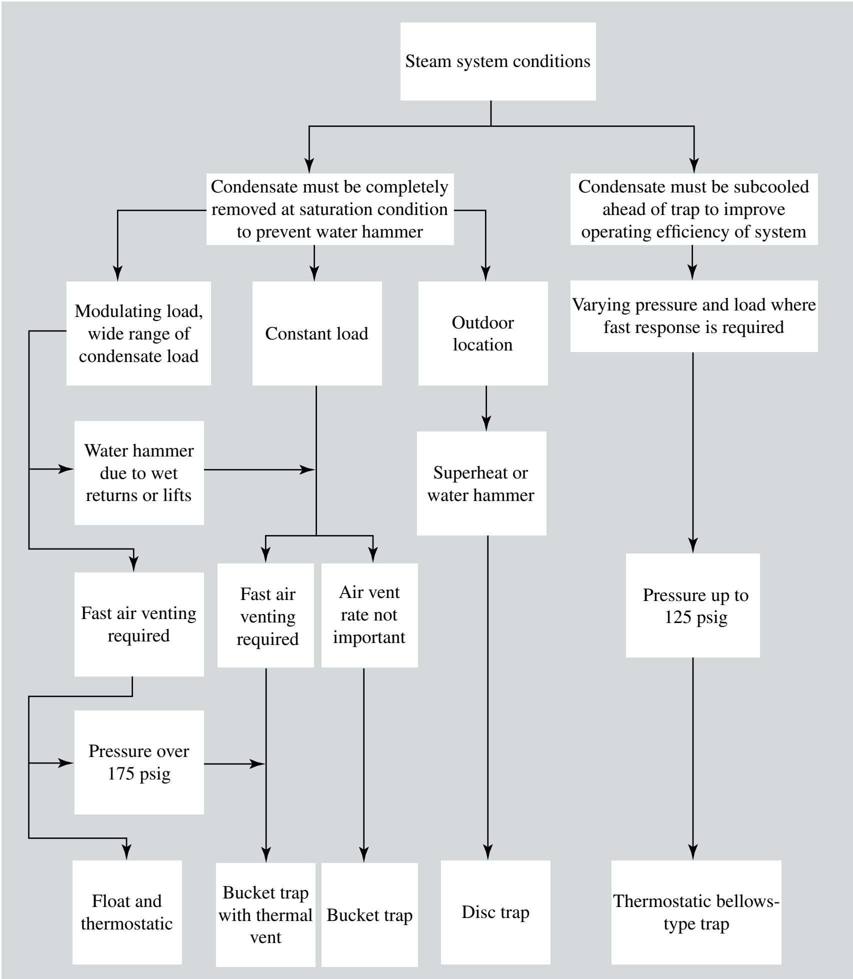


FIGURE 9.9 Steam trap selection flow chart. Courtesy of Xylem Inc.

FLASH STEAM UTILIZATION

We discussed in Chapter 2 that hot pressurized water can flash to steam when it is depressurized. Hot pressurized condensate discharged from a steam trap will create flash steam. If the flash steam is to be recovered and utilized, it has to be separated from the condensate. This is best achieved by passing the mixture of flash steam and condensate through what is known as a "flash tank" or "flash vessel." A typical flash tank is shown in Figure 9.10. These vessels are usually ASME Section VIII pressure vessels rated for 50 psig or less.

The size of the vessel has to be designed to allow for reduced steam velocity so that the separation of the flash steam and condensate can be accomplished

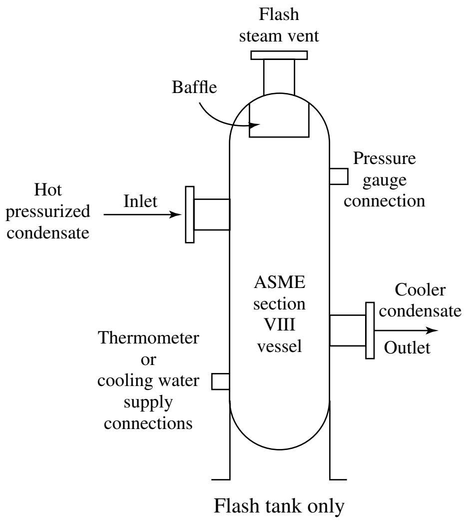


FIGURE 9.10 Typical flash tank design.

adequately. It must also prevent carryover of condensate into the flash steam recovery system. The target velocity is 10 ft/s to ensure proper separation. The condensate drops to the bottom of the flash tank where it is discharged directly into the condensate collection system. The flash steam outlet connection is sized so that the flash steam velocity through the outlet is approximately 60 ft/s. The condensate inlet should also be sized for less than 100 ft/s flash velocity.

How to Size Flash Tanks and Vent Lines

Whether a flash tank is atmospheric or pressurized for flash recovery, the procedure for determining its size is the same. The most important dimension is the diameter. It must be large enough to provide adequate separation of the flash and condensate to minimize condensate carryover. Figure 9.11 can be used to size the tank and openings.

Example 9.4
Size a flash recovery vessel receiving condensate from a 160 psig steam trap discharging 3000 lb/h into the condensate return system at 20 psig.

Answer

1. *Determine the percent flash steam produced using Figure 2.6. With a steam pressure of 160 psig and a flash tank pressure of 20 psig, 12.4% of the condensate will flash off.*
2. *Next, multiply the condensate load by the percent flash from step 1 to determine the flow rate of flash steam produced: 3000 lb/h × 0.124 lb/h = 372 lb/h.*

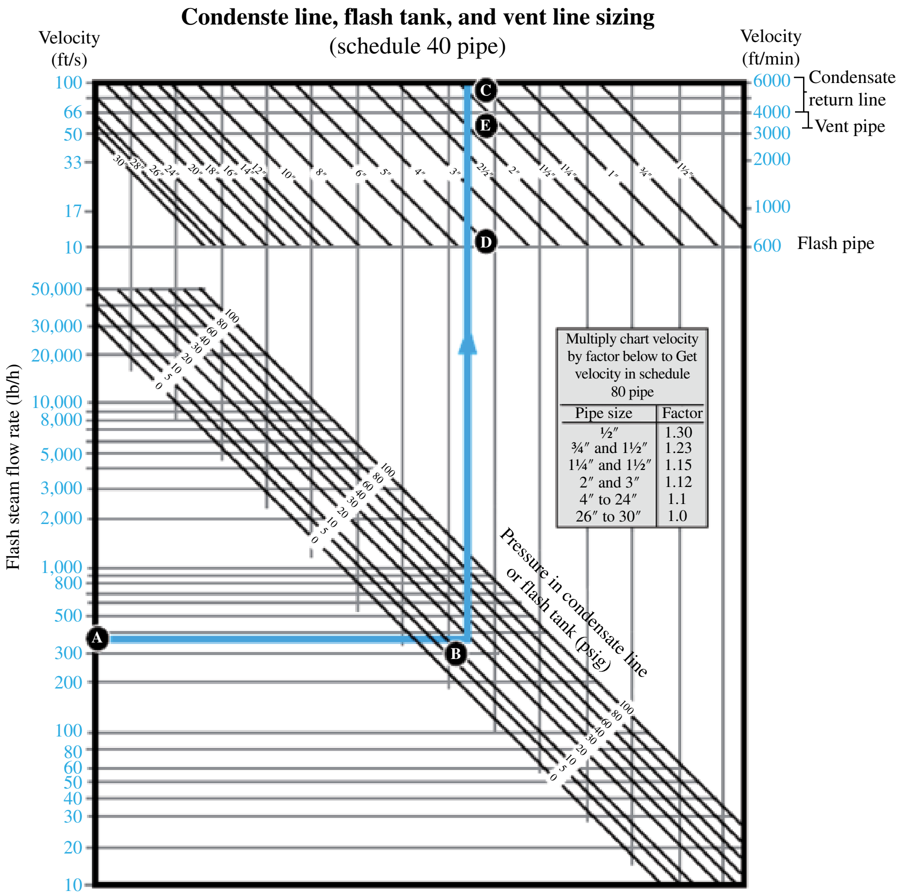


FIGURE 9.11 Flash tank design graph. Courtesy of Watson McDaniels Inc.

3. *Using the calculated flash steam quantity of 372 lb/h, enter Figure 9.11 at "A" and move horizontally to the right to the flash tank pressure of 20 psig at "B." Rise vertically to the flash tank diameter line (600 ft/min) at "D." The tank diameter of 5″ is required.*
4. *From point "D," continue to rise vertically to "E" to determine the size of vent pipe to give a velocity between 3000 and 4000 ft/min. In this case, 2″ schedule 40 pipe connection is required.*
5. *The condensate inlet connection size can also be determined using the same graph. As in step 4, find the vertical line to determine the vent connection size and continue up the graph until the vertical line intersects the horizontal 100 ft/s velocity line (actually 6000 ft/min). "C'" The graph shows that an 1.5″ condensate line connection is adequate.*

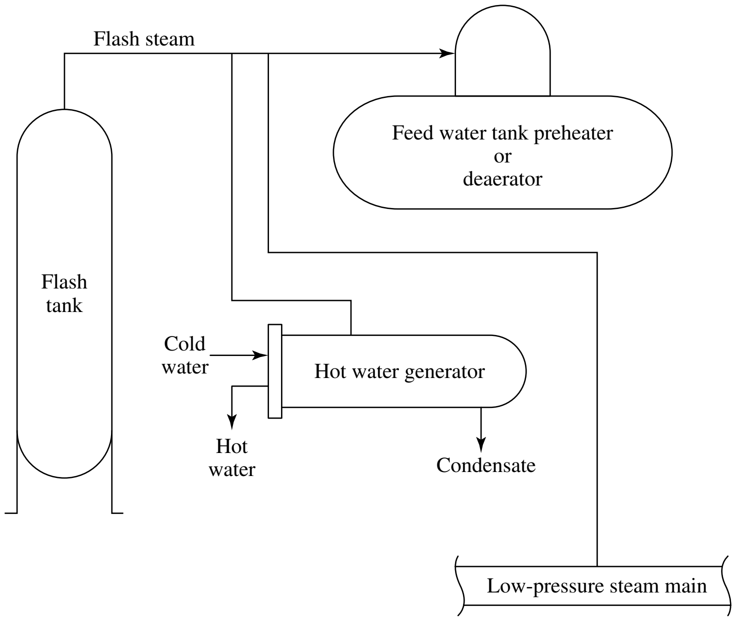


FIGURE 9.12 Flash steam recovery.

The answer is a vessel that has a diameter of 24″ and has a 10″ vent with an 8″ condensate inlet connection. Generally, a flash tank will have a 2:1 height to width aspect ratio. Therefore, this vessel would likely be a 48″ × 24″ vessel.

In an efficient and economical steam system, this so-called flash steam will be utilized on any load that will make use of low-pressure steam. Sometimes, it can be simply piped into a low-pressure distribution mainly for general use. Flash steam can be used wherever low-pressure steam is needed. Preheating process fluid, pressurizing a feed water deaerator, or using the steam to make hot water are some typical applications for flash steam utilization. The flow diagram in Figure 9.12 shows flash steam usage for a variety of applications.

Flash steam recovery is simplest when being recovered from a single piece of equipment that condenses a large amount of steam, such as a large steam kettle or process heat exchanger. The flash steam recovery system by design will apply a back pressure to the equipment being utilized as the flash steam source. Only as a last resort should flash steam be vented to atmosphere and lost.

CONDENSATE COLLECTION

The trapped condensate must be collected and pumped back to the feed water system if it is to be reused. Condensate collection will vary in design and is dependent on the size of the steam system. Smaller steam plants (i.e., 100 hp and smaller) may have the condensate flow directly back to the feed water tank. Likewise, if the feed tank is located close to the steam-using equipment, the condensate may also be sent directly to the feed water tank. In these applications, it is recommended that the feed water tank be oversized at least 50% to account for slugs of condensate returning, which may create a water inventory problem on startup. Remember that as a steam system is allowed to cool down, the steam will condense in the steam piping and sit there until the system is either drained manually or repressurized. Large low-pressure steam systems will often see significant amounts of condensate slug back to the feed water or surge tank during startup after a system shutdown. Steam systems having a large distribution network will utilize a series of condensate collectors and a surge tank. The condensate collectors or drainers as they are sometimes called are usually located near the steam traps. They are usually small (i.e., 15 gallon or less) and will cascade to the condensate surge tank. The surge tank is used as the common collection tank and typically fed directly to the boiler feed tank or deaerator.

Electric Condensate Return System

When using electric pumps to lift the condensate, packaged units comprising of a receiver tank (usually vented to atmosphere) and one or more motorized pumps are commonly used. It is important with these units to make sure that the maximum condensate temperature specified by the manufacturer is not exceeded, and the pump has sufficient capacity to handle the load. Condensate temperature usually presents no problem with returns from low-pressure steam systems. There, the condensate is often below 212°F, and a little further subcooling in the gravity return lines and the pump receiver itself provides little difficulty in meeting the maximum temperature limitation.

On high-pressure systems, the gravity return lines often contain condensate at just above 212°F, together with some flash steam. If a flash tank is not used, then the condensate must be cooled to less than 200°F or pump cavitation will likely occur. Uninsulated condensate piping to the collector can provide some condensate cooling. The condensate water must remain in the receiver for an appreciable time if it is to cool sufficiently, or the pump discharge may have to be throttled down to reduce the pump's capacity to avoid cavitation. In some cases the pumps are supplied coupled to receivers and the static head above the pump inlet is already fixed by the pump manufacturer, it is only necessary to ensure that the pump set has sufficient capacity at the water temperature expected at the pump. Pump manufacturers usually have a set of capacity curves for the pump when handling water at different temperatures and these should be consulted. Condensate receivers that receive hot pressurized condensate and have to pump the condensate with low-lift requirements will be highly susceptible to pump cavitation. The receiver must be vented or a flash tank used in front of the receiver to reduce the condensate to atmospheric pressure. Typical condensate receivers are shown in Figures 9.13 and 9.14.

FIGURE 9.13 Small electric condensate return system. © Roth Pump Co.

FIGURE 9.14 Larger condensate tank. © Shippensburg Pump Co.

Pressure Motive Condensate Pump

Condensate can also be moved by the use of nonelectric condensate pumps, such as the pressure motive pump. The pressure motive pump, sometimes called a **pump trap**, is essentially an alternating receiver that can be pressurized, using steam, air, or other gas. The gas pressure displaces the condensate (which can be at any temperature up to and including boiling point). Check valves at the inlet and outlet of the pump body ensure condensate can enter and exit the receiver at the right time.

When the receiver is full of condensate, an internal float mechanism opens the steam or pressurized supply gas valve. This pressurizes the receiver and forces the inlet check valve to close and opens an exhaust check valve. The pressurizing gas forces (i.e., pumps) the condensate out of the receiver. When the receiver is emptied, the float falls and closes the pressurized gas supply allowing the discharge check valve to close and the inlet check valve to reopen. The pressurized gas is vented to atmosphere or to the space from which the condensate is being drained as the receiver fills with condensate. When the pressures are equalized, condensate can flow by gravity into the pump body to refill it and complete the cycle. As the pump fills by gravity only, there can be no cavitation and this pump readily handles boiling water or other liquids compatible with its materials of construction. A summary of its operation is shown in Figure 9.15.

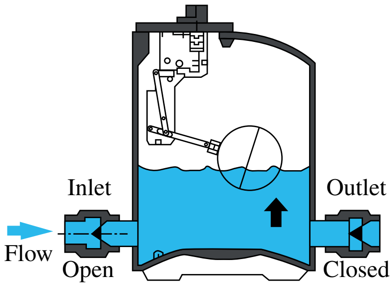
The capacity of the pump depends on the filling head available, the size of the condensate connections, the pressure of the operating steam or gas, and the total head through which the condensate is lifted. This will include the difference in elevation between the pump and the final discharge point, any pressure difference between the pump receiver and final receiver, friction in the connecting pipe work, and the force necessary to accelerate the condensate from rest in the pump body up to velocity in the discharge pipe. Tables listing capacities under varying conditions are usually provided in the equipment manufactures catalog bulletins.

Pressure Motive Pump Installation Requirements

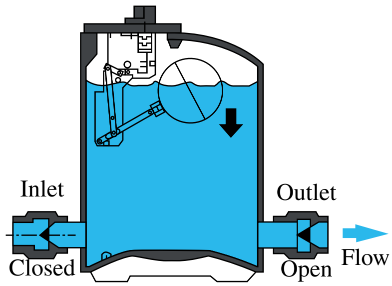
Depending upon the application, the pressure motive pump body is piped so that it is vented to atmosphere or, in a closed system, is pressure equalized back to the space that it drains. This allows condensate to enter the pump, but during the short discharge stroke, the inlet check valve is closed and condensate accumulates in the inlet piping.

To eliminate the possibility of condensate backing up into the steam space, reservoir piping must be provided above the pump with volume as specified by the manufacture. A closed system requires only a liquid reservoir. In open systems, the vented receiver serves this purpose as it is always larger in order to also separate the flash steam released.

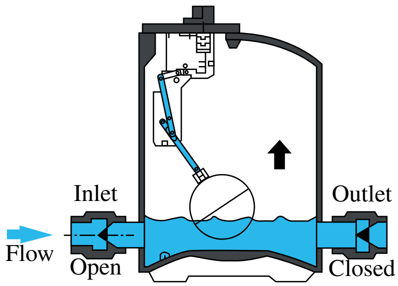
Vented or Open Systems. Condensate from low-pressure steam systems may be piped directly to a small-sized pressure motive pump only when 50 lb/h or less of flash steam is vented through the pump body. This does not eliminate the requirement that there must be enough piping to store condensate during the brief discharge cycle. In many low-pressure systems, the reservoir may be a section of large horizontal pipe that is vented to eliminate flash steam. In higher-pressure, high-load



1 Condensate flows from the receiver tank through the inlet check valve and fills the pump tank. During the filling cycle, the float inside the tank rises



2 When the pump tank has filled to the trip point, the mechanism triggers, opening the motive gas inlet valve and simultaneously closing the vent valve. This allows motive pressure to enter the pump body, which drives the condensate through the outlet check valve into the condensate return line. During the discharge cycle, the liquid level and the float inside the pump tank drop



3 At the lower trip point, the mechanism triggers and the motive gas inlet valve to the pump tank closes and simultaneously the vent valve opens. The fill and discharge cycle then repeats itself

FIGURE 9.15 Steam pressure motive pump operation. © Watson McDaniels Inc.

systems, the larger quantity of flash released requires a vented receiver with piping adequate to permit complete separation. To prevent carryover of condensate from the vent line, the receiver should be sized to reduce flow velocity to about 10 ft/s (Fig. 9.16).

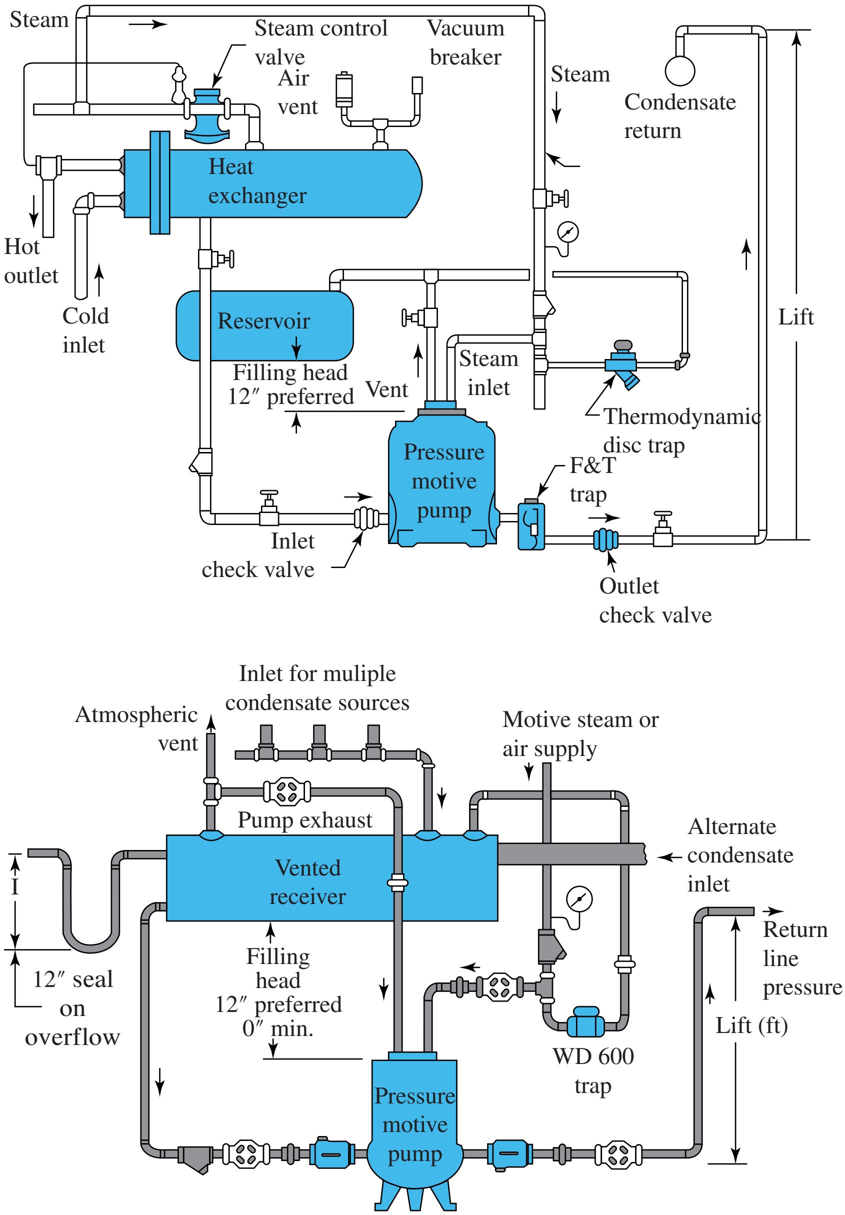


FIGURE 9.16 Installation of PMP in open and closed loop systems. © Watson McDaniels Inc.

Closed Loop Systems. It is often advisable where larger condensate loads are being handled to dedicate a pressure motive pump to drain a single piece of equipment. The pump exhaust line can then be directly connected to the steam space of a heat exchanger or, preferably with air-heating coils, to the reservoir. This allows condensate to drain freely to the pump inlet and through a steam trap at the pump outlet. Only liquid is contained in the reservoir of a closed loop system. The pressure motive pump functions as a pumping trap, and the steam supply must be greater than the return line pressure.

Pumped Condensate Return Line Installation

Finally, the condensate is often pumped from the receiver(s) to the boiler plant. These pumped condensate lines carry only water, and high water velocities can often be used so as to minimize pipe sizes. The extra friction losses entailed must not increase back pressures to the point where the pump capacity is affected. Velocities in pumped returns should be limited to 6–8 ft/s. Electric pumps are commonly installed with pumping capability of 2.5 or 3 times the rate at which condensate reaches the receiver. This increased instantaneous flow rate must be kept in mind when sizing the delivery lines. Similar considerations apply when steam-powered pumps are used or appropriate steps taken to help attain constant flow along as much as possible of the system.

Where long delivery lines are used, the water flowing along the pipe as the pump discharges attains a considerable momentum. As the end of the discharge cycle when the pump stops, the water tends to keep moving along the pipe and may pull air or steam into the delivery pipe through the pump outlet check valve. When this bubble of steam reaches a cooler zone and condenses, the water in the pipe is pulled back toward the pump. As the reversed flow reaches and closes the check valve, water hammer often results. This problem is greatly reduced by adding a second check valve in the delivery line some 15 or 20 ft from the pump. If the line lifts to a high level as soon as it leaves the pump, then adding a vacuum breaker at the top of the riser is often an extra help. However, it may be necessary to provide means of venting from the pipe at appropriate points, the air which enters through the vacuum breaker.

The practice of connecting additional high-pressure steam trap discharge lines into the pumped main is to be avoided whenever possible. **The flash steam that is released from this hot condensate leads to a thermal shock wave creating a banging noise within the piping commonly associated with steam hammer**. The traps should discharge into a separate gravity line that carries the condensate to a vented receiver. If this is impossible, an alternative method is to pipe the trap discharge through a sparge or diffuser inside the pumped return line. A typical diffuser installed in a return line is shown in Figure 9.17. The trap most suitable for this application would be the float and thermostatic type due to its continuous discharge. This is very much a compromise and will not always avoid the noise although it should reduce the severity.

SURGE TANK APPLICATION

In nearly all steam-using plants, condensate must be pumped from the location where it is formed back to the boiler house and be lifted into a boiler feed tank or deaerator. If multiple condensate collectors are used, it is often necessary to cascade the combined pump discharges to a surge tank. A surge tank is a tank located

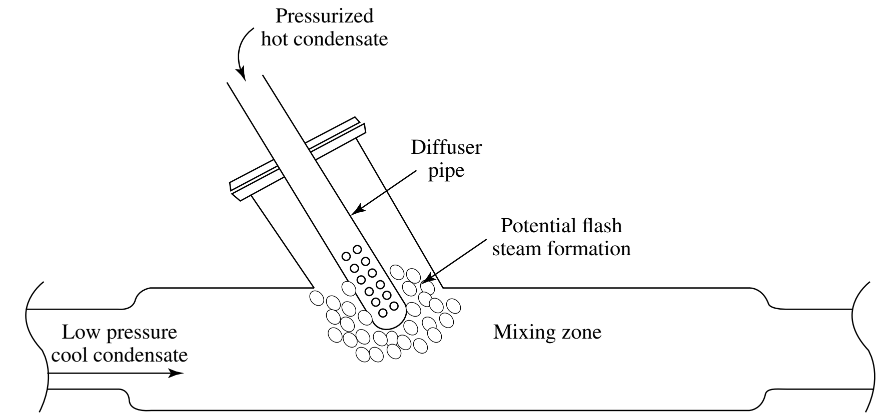


FIGURE 9.17 Hot condensate diffuser connection in a return line.

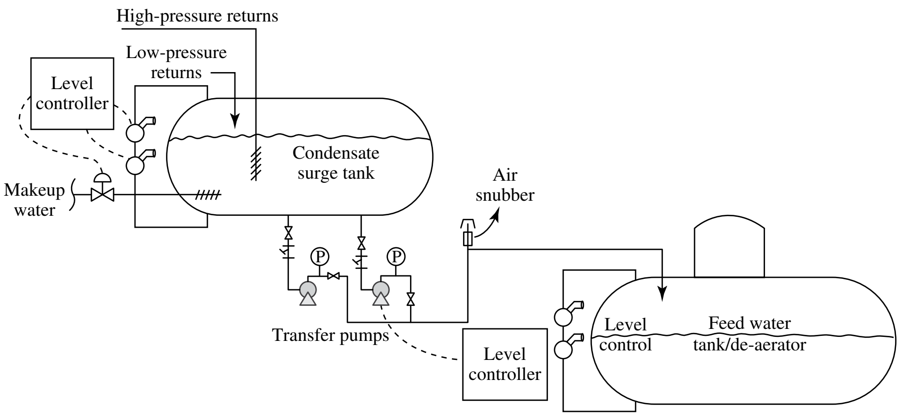


FIGURE 9.18 Surge tank piping integration with the feed water tank.

between the boiler house and condensate collectors. Its main function is to act as a means to level out the flow of condensate and fresh makeup water to the feed water system. Typically, a surge tank is about half the size of the feed water tank and will have transfer pumps that come on and off based on the feed water tank level. Surge tanks can be ASME code or noncode tanks but generally are made of stainless steel to handle the low pH condensate water. If the surge tank is located near several steam-using pieces of equipment, the trapped condensate lines can cascade directly to a flash tank bolted directly on the top of the surge tank and let the low-pressure condensate gravity drain directly into the surge tank. If the surge tank is located relatively close to the feed water tank, then the flash steam can be used to preheat fresh makeup water or pressurize the feed water DA. A flow diagram is shown in the following. Since the surge tank is a condensate collector, the only level control is to allow fresh makeup water in on a low-level signal (Fig. 9.18).