

## INTRODUCTION TO STEAM TRAPS

---

### WHAT IS A STEAM TRAP AND WHAT DOES IT DO?

A steam trap is an automatic valve that allows condensate, air and other non-condensable gases to be discharged from the steam system while holding or trapping the steam in the system. Several different types of steam trap technologies exist to accomplish this extremely critical and necessary task. Explained below are why steam traps are required, their primary applications, how each type functions, their advantages and disadvantages, and when each should be applied.

### WHY ARE STEAM TRAPS REQUIRED?

For any steam system to operate properly a method must be used to remove the condensate, air and other non-condensable gases such as carbon dioxide from the steam.

#### CONDENSATE:

When steam releases its heat energy in a heat exchanger making hot water, from a radiator heating a room, from a steam pipe transferring steam or from any process application, the steam reverts back to water. This water, technically referred to as *condensate*, must be separated from the steam and removed from the system or the system would back up with water. The removal of condensate from steam is considered the primary function of the steam trap.

#### AIR:

Air exists in all steam pipes prior to system start-up when the system is cold. This air must be bled out of the piping system so that the steam can enter and eventually reach the designated process applications. If the air is not removed, the steam will effectively be blocked from entering the steam pipes by the residual air. In addition to blocking the steam, air acts as an insulator to heat transfer. Even after the system is filled with steam, small amounts of air can re-enter the system through various paths such as boiler water make-up systems and vacuum breakers.

#### NON-CONDENSABLE GASES:

Gases other than air such as carbon dioxide exist inside steam systems. These non-condensable gases must also be separated from the steam and removed from the system for all processes to operate properly. In addition to inhibiting steam flow and proper heat transfer, carbon dioxide can be very corrosive to components in the system.

### STEAM TRAP GENERAL APPLICATION CATEGORIES:

---

#### DRIP APPLICATIONS:

Drip applications are by far the most common application for steam traps. This application refers to removing the condensate that forms in steam lines when steam loses its heat energy due to radiation losses. Traps used in these applications are referred to as *drip traps*. Generally speaking, traps used for these applications require relatively small condensate capacities and don't normally need to discharge large amounts of air. (Air removal is the primary function of air vents and process traps located throughout the system.) The most common trap choices for drip applications are *thermodynamic* for line pressures over 30 PSIG, and *float & thermostatic* for line pressures up to 30 PSIG. Inverted bucket traps are also commonly used for drip trap applications due to their ability to handle large amounts of dirt and scale often found in this type of application.

#### PROCESS APPLICATIONS:

Process trap applications refer to removing condensate and air directly from a specific heat transfer process such as a heat exchanger that could be making hot water or a radiator heating a room. Traps used in these applications are referred to as *process traps*. Generally speaking, traps used for process applications require larger condensate handling capability and also need to be able to discharge large amounts of air. The most common trap choices for process applications are *float & thermostatic* traps and *thermostatic* traps. Both are known for their excellent condensate and air handling capabilities. In contrast, thermodynamic traps and inverted bucket traps, which have poor air handling ability, would normally make a poor choice for process applications.

#### TRACING APPLICATIONS:

Steam tracing refers to using steam to indirectly elevate the temperature of a product using jacketed pipes or tubing filled with steam. A typical application would be wrapping a high viscosity oil pipeline with steam tubing. The steam inside the tubing heats the oil to lower its viscosity, allowing it to flow easily through the pipeline. Similar to any steam applications, a steam trap must be used on the end of the steam tubing to discharge unwanted condensate. Steam traps used in these applications are referred to as *tracer traps*. The most common trap choice for tracing applications is the *thermostatic* type.

# STEAM TRAP APPLICATIONS

## THERMOSTATIC & BI-METALLIC STEAM TRAPS

Thermostatic & Bi-Metallic steam traps operate under the direct influence of increasing or decreasing temperature within the body of the trap. These two different types of steam traps operate differently to suit specific applications.

### THERMOSTATIC STEAM TRAPS

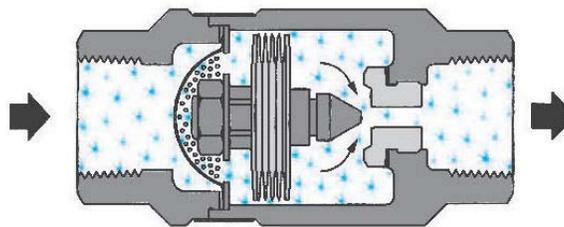
The bellows type thermostatic trap uses a fluid-filled thermal element (bellows) that operates under the principle of thermal expansion and contraction. The fluid vaporizes and expands as the temperature increases, causing the bellows to close the valve. As the temperature decreases, the fluid condenses and contracts, causing the bellows to open the valve. These traps provide excellent air handling capability and are used for drip, tracing and process applications. The main advantage of the thermal element is that on start-up loads, the trap is in the open position, allowing air and condensate to be rapidly removed from the system. Watson McDaniel thermal element traps offer wide operating pressure ranges, rugged welded stainless steel bellows, and various orifice sizes, making them a great choice for a majority of applications.

#### Operation:

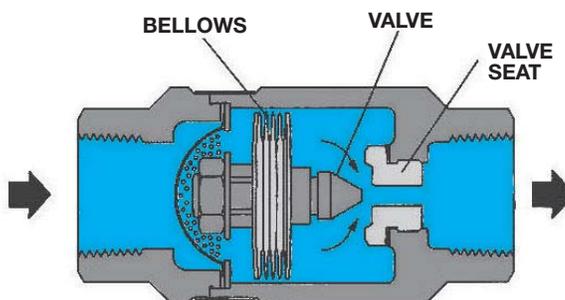
The operation of the thermal element is governed by the volumetric thermal expansion of the fluid inside the bellows as it changes states. There is no adjustment required for this trap as the fluid inside the bellows is chosen for its quick response to the change in temperature between steam and condensate at various pressures. The bellows is designed to follow the steam saturation curve, always discharging condensate a few degrees cooler than the steam temperature. During start-up, when the system is cold, the bellows is contracted and the valve plug is lifted off of the seat allowing air and condensate to be discharged from the system (Figures 1A & 1B). Throughout warm-up, air and condensate are allowed to escape from the system through the open orifice in the trap. As hot steam approaches the thermal element in the trap, the fluid inside the bellows vaporizes and expands, closing the valve tightly (Figure 1C). As long as steam is present, the valve will remain closed. Only when subcooled condensate or air is present will the valve open. The bellows will immediately expand and close the valve upon the reintroduction of steam.

Figure 1:

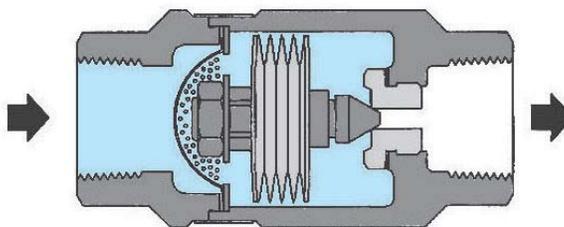
**A) AIR** (When air, which is cooler than steam, is present, the bellows is retracted and the seat is open, allowing large quantities of air to be discharged.)



**B) CONDENSATE** (When condensate, which is cooler than steam, is present, the bellows is retracted and the seat is open, allowing condensate to be discharged.)



**C) STEAM** (When steam reaches the trap, the bellows expands, which closes off the seat and prevents the steam from escaping.)



### BI-METALLIC STEAM TRAPS

The bi-metallic steam traps operate under the principle of thermal expansion of metals. Two dissimilar metals are joined into a series of discs and upon heating will deflect to provide movement to close off the valve. These traps are primarily used in steam tracing because of their ability to adjust condensate discharge temperature which may be desirable on certain tracing applications.

When cold condensate and air are present, the bimetallic trap remains open as the flow of air and condensate discharges from the system. When steam arrives to the trap, the discs deflect and pushes the plug onto the seat. The temperature at which the valve closes can be adjusted by turning a set screw located on the top of the valve.

# STEAM TRAP APPLICATIONS

## MECHANICAL STEAM TRAPS

Mechanical steam traps operate by use of a float device connected to a mechanical linkage that reacts upon changes in volume or fluid density. There are two main types of mechanical traps: the *float & thermostatic* (F&T) trap and the *inverted bucket* trap.

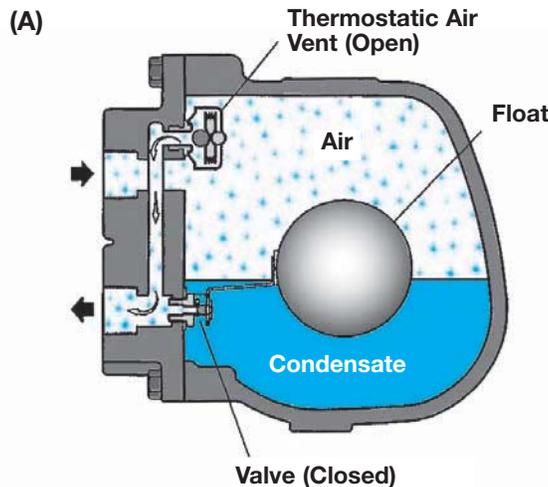
### FLOAT & THERMOSTATIC TRAPS

The float & thermostatic trap uses a float connected by a linkage to the valve plug to discharge condensate from the system. In addition, F&T traps contain a thermostatic air vent to allow the discharge of air from the system. For this reason, these traps have excellent air removal capability, which is advantageous during system start-up when large amounts of air are present in the system. Float & thermostatic steam traps are generally the primary selection for drainage of process heat transfer equipment.

#### Operation:

At start-up, air and condensate enter the steam trap. The air will be discharged through the open thermostatic air vent (**Figure 2A**). As the condensate level in the trap rises, it lifts the float which opens the valve to allow the discharge of condensate. When steam enters the trap, the thermostatic element expands and closes the air vent, preventing the steam from escaping (**Figure 2B**). As the condensate discharges through the seat orifice, the float lowers and shuts the valve (**Figure 2C**). The float is designed to shut the valve with a level of condensate above the seating orifice to prevent loss of any steam. The float modulates to maintain a constant equilibrium between the incoming and discharging condensate. Due to the balance of forces required between the incoming pressure and internal trap components, several orifice sizes are offered to accommodate various differential pressure ranges. These traps can be fitted with a steam lock release (SLR) orifice for high pressure and high temperature applications that exceed the pressure capability of a thermostatic air vent.

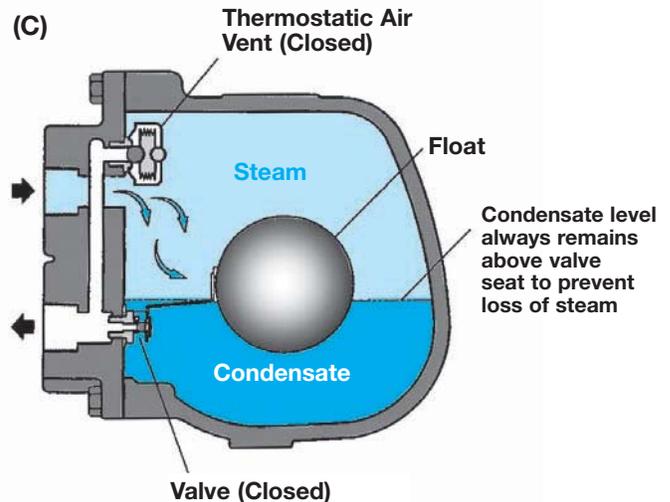
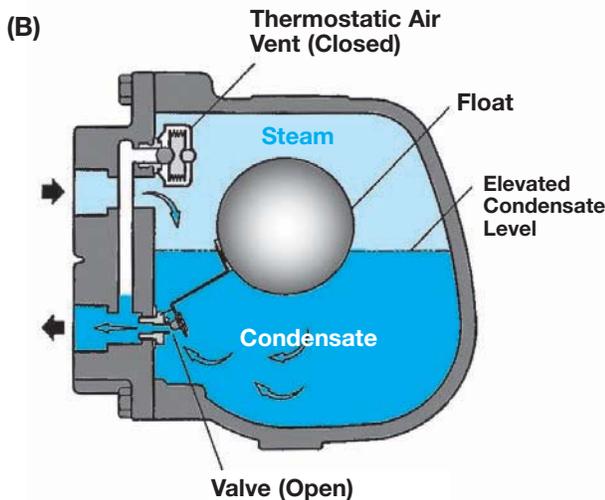
Figure 2:



**A)** When cold air enters the trap during start-up, the thermostatic air vent is open, allowing the discharge of large quantities of air from the system.

**B)** When condensate enters the trap, the float lifts, opening the valve, and discharges the condensate.

**C)** When steam is present, and no condensate is entering the trap, the valve and thermostatic air vent remain closed, trapping steam in the system.



### INVERTED BUCKET TRAPS

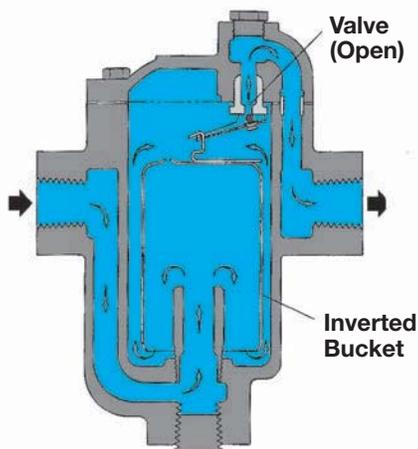
The inverted bucket trap uses an inverted bucket as a float device connected by a linkage to the valve plug. The varying densities between condensate and steam are used to create a buoyancy force on the bucket to open and close the valve. These traps are primarily used in drip applications on steam mains and steam supply lines. They are generally not used in process applications due to their poor air handling capability. Bucket traps are extremely rugged and resistant to waterhammer and also resistant to any dirt and scale that may be present in the system.

#### Operation:

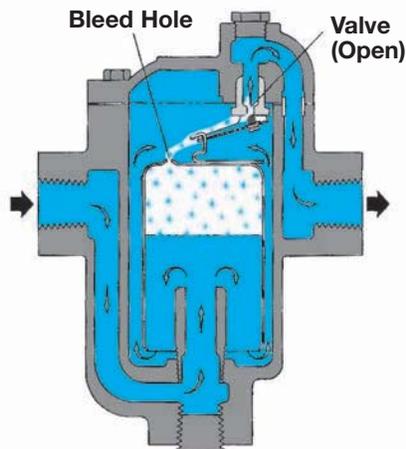
Upon start-up, the trap fills with condensate. Due to the weight of the bucket, it rests on the bottom of the trap keeping the valve open to let condensate flow out (**Figure 3A**). In the top of the bucket there is a small orifice (bleed hole) to allow air to escape the bucket and exit through the outlet (**Figure 3B**). When steam arrives through the inlet of the trap, it fills the inverted bucket. The density differential between the steam and the condensate causes the bucket to become buoyant and rise to the top of the trap, closing the valve (**Figure 3C**). As steam condenses and/or is bled through the small orifice, the bucket loses buoyancy as it becomes filled with condensate; this causes it to sink to the bottom of the trap. This opens the valve allowing condensate to escape from the system (**Figure 3A**). The small orifice in the top of the bucket is imperative for venting air from the system; however, it will also bleed steam once the air has been completely removed. The bucket trap must contain a certain amount of water (prime) in order to operate. Without this prime, the bucket will not be able to float and rest on the bottom of the trap, keeping the valve in the open position, allowing steam to escape (**Figure 3D**). Due to the balance of forces required between the incoming pressure and internal trap components, several orifice sizes are offered to accommodate various differential pressure ranges.

**Figure 3:**

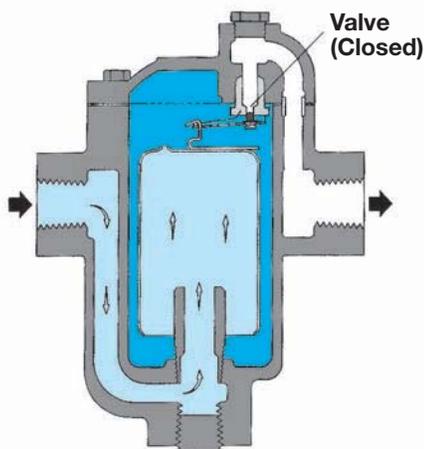
**(A) Discharging Condensate**



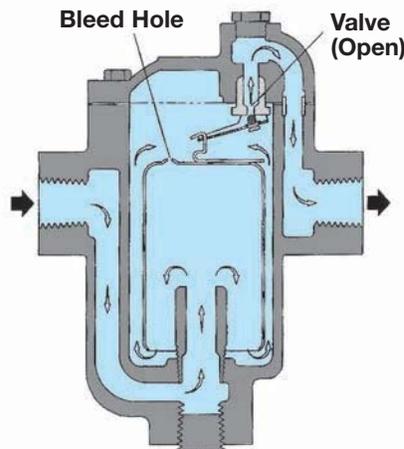
**(B) Expelling Air**



**(C) Trapping Steam**



**(D) Potential Failure Mode**



**A)** With condensate completely filling the trap, the bucket is in the down position with the valve open, allowing condensate to be discharged.

**B)** Small amounts of air will pass thru the bleed hole on top of the bucket and be discharged. (Note: Large amounts of air will lift the bucket and close off the trap, temporarily air locking the system.)

**C)** When steam enters the trap, the inverted bucket will fill with steam and float, closing off the valve, preventing steam from escaping.

**D) Potential Failure Mode:** Bucket traps must maintain a water prime to function properly. If the prime is lost, the bucket will remain in the down position with the valve open, and live steam will be discharged from the system.



## THERMODYNAMIC STEAM TRAPS

### THERMODYNAMIC STEAM TRAPS

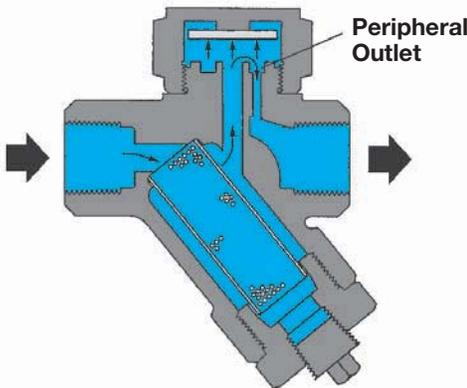
Thermodynamic steam traps operate in a cyclic on/off process using the thermodynamic properties of flash steam as it flows through the trap. Thermodynamic traps use only one moving part, the valve disc, which allows condensate to escape when present and closes tightly upon the arrival of steam. These traps have an inherently rugged design and are commonly used as drip traps on steam mains and supply lines. Their solid construction and single moving part make them resistant to waterhammer and are freezeproof when installed vertically. Thermodynamic traps will only discharge small amounts of air and therefore are typically not used in process applications.

#### Operation:

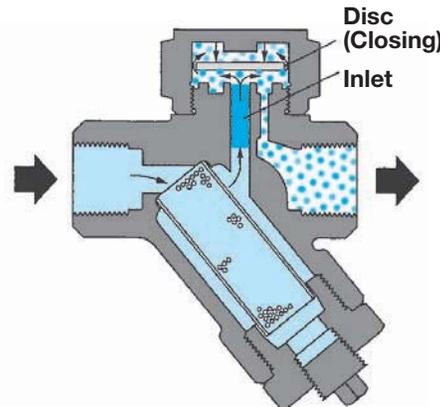
As inlet pressure to the trap increases, the disc lifts off the seat and allows the unwanted condensate to escape through the peripheral outlet surrounding the inlet (**Figure 4A**). As hot condensate reaches the disc chamber, it creates flash steam in the chamber (**Figure 4B**). This flash steam travels at high velocity from the inlet to the outlets, creating a low pressure area under the disc. Some of the flash steam bypasses the disc and enters the top of the chamber, creating a buildup of pressure above the disc. This differential pressure causes the disc to close against the seat, trapping the steam (**Figure 4C**). The flash steam above the disc is the only force opposing the pressure from the inlet condensate, keeping the valve closed. As heat transfer takes place in the upper chamber, the flash steam condenses and the pressure above the disc reduces. When the pressure above the disc falls to a point that is less than the pressure of the incoming condensate, the disc will lift again and repeat the cycle (**Figure 4A**). Cycle time is dependent on steam temperature, and more importantly, ambient temperature outside the trap. Since the amount of time the valve is closed is primarily dependent on the heat transfer from the flash steam to the ambient environment, frequent cycling of the valve can occur in cold or wet environments. Applying an insulating cap over the cover of the trap will reduce the cycle rate.

Figure 4:

(A) Valve Disc (Open)



(B) Valve Disc (Starting to Close)



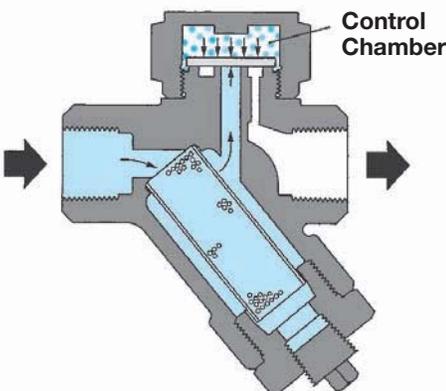
A) When condensate is present, trap is in the full open position discharging condensate.

B) When steam enters the trap, the disc begins to close with the formation of flash steam above the disc.

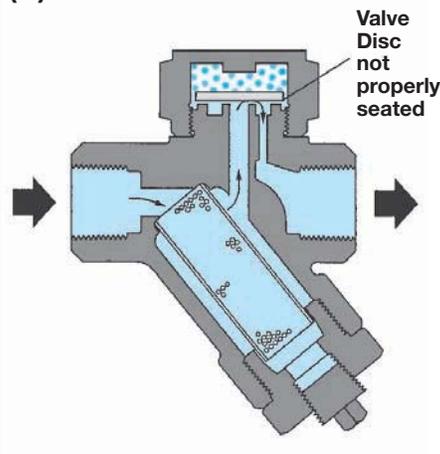
C) Trap will remain closed, trapping steam in the system until the flash steam above the disc condenses, due to ambient heat loss.

D) **Potential Failure Mode:**  
A possible failure mode for thermodynamic traps is the disc not seating properly due to dirt or scale on the flat seating surface, causing the loss of steam.

(C) Valve Disc (Closed)



(D) Potential Failure Mode



### Selection & Sizing of Steam Traps & Safety Factors:

The type of steam trap to choose for a particular application can depend on several variables, making it difficult to effectively cover every factor involved in making a proper decision. However, the guidelines below should assist you in making a proper and logical selection.

For any type of **process applications**, such as making hot water in a heat exchanger, we generally want a steam trap that is very good at discharging air as well as condensate. Therefore, a float & thermostatic (F&T) trap is typically the first choice of steam trap. However, thermostatic steam traps, such as the WT3000 and WT4000, which have been designed for process applications, also do an excellent job and are very commonly used. Both types of traps will generally satisfy most process applications.

For **drip applications**, such as draining steam mains over 30 PSIG, thermodynamic traps are normally considered the first choice. In drip applications it's not as critical of a requirement to remove air from the system since this is normally the function of separate thermostatic air vents placed in strategic places in the piping system and the process traps. However, for steam systems up to 30 PSIG, F&T traps are normally recommended. For steam systems that are known to contain large amounts of scale and dirt, bucket traps are recommended because they are less prone than thermodynamic and F&T traps to failure from this type of situation.

For **tracing applications**, the most commonly used steam trap is the thermostatic type. Thermostatic traps are the most thermally efficient of all traps and lend themselves perfectly to this type of application.

### The capacity of steam traps:

The capacity charts for steam traps give the maximum condensate flow in pounds per hour at a given pressure or pressure differential. When selecting the proper size of steam trap, the normal condensate rate (load) should be known and then multiplied by an appropriate safety factor.

### Why safety factors need to be considered:

A safety factor is required because the amount of condensate generated and the steam pressure are not always constant in any steam system. For example, when the system is cold and steam first starts to flow thru the pipes, steam is condensing very quickly because of the massive heat required to heat all the cold surfaces as well as to overcome the radiation losses. To compound this issue further, the steam pressure in the system, which is being relied upon to push the condensate thru the steam trap into the return line, is extremely low before the system comes up to full pressure. Therefore, we have a condition in which the condensate in the system is being generated at a maximum rate and the steam pressure used to push the condensate out of the system, is at a minimum. If we sized the traps for the normal running loads and normal system pressures, these traps would be severely undersized for the start-up condition. If supervised start-ups of the steam system are being done then sizing the steam traps for start-up conditions may be less of an issue. When performing a supervised start-up of a cold system, the condensate drain valves that are strategically placed throughout the system are manually opened. This helps drain the massive amount of condensate that is generated by the cold piping system, relying less on the steam traps. Therefore, the steam traps selected for the system can be more properly sized for the actual normal running load if supervised start-ups are performed.

### Recommended Steam Trap Selection & Safety Factors for Sizing:

APPLICATIONS	PRIMARY TRAP CHOICE	SAFETY FACTORS & SPECIAL NOTES
Drip Trap on Steam Mains $\leq$ 30 PSIG	Float & Thermostatic	Trap should be sized for 2X normal capacity at full differential pressure
Drip Trap on Steam Mains $>$ 30 PSIG	Thermodynamic	
Steam Tracing, Non-critical	Thermostatic	Thermostatic traps are suitable for the majority of steam tracing applications; for critical steam tracing applications, where no back-up of condensate can be tolerated, thermodynamic traps should be used.
Steam Tracing, Critical	Thermodynamic	
Process applications up to 450 PSIG	Float & Thermostatic	For steam systems with <u>constant</u> pressure: Trap should be sized for 2X normal capacity at full differential pressure. For steam systems with <u>modulating</u> pressure: When draining condensate from heat exchangers operating up to 30 PSIG, steam traps should be sized for full capacity at 1/2 PSI differential pressure. When draining condensate from heat exchangers operating at over 30 PSIG, steam trap should be sized for 2.5X normal condensate load at full differential pressure.

## DRIP LEG DESIGN

---

**PURPOSE:** Drip Legs are used for removing entrained moisture from steam transmission and distribution lines to ensure high quality steam for use in various plant applications, while also preventing damaging and dangerous waterhammer.

**OPERATION:** As steam travels at high velocity through piping, moisture forms as the result of piping heat losses and/or improper boiler control resulting in condensate carryover. Drip legs are therefore located at points where condensate may accumulate to allow for drainage by gravity down to a steam trap for proper discharge from the system. Since condensate drains by gravity, drip legs must be located on the bottom of piping and designed with diameters large enough to promote collection.

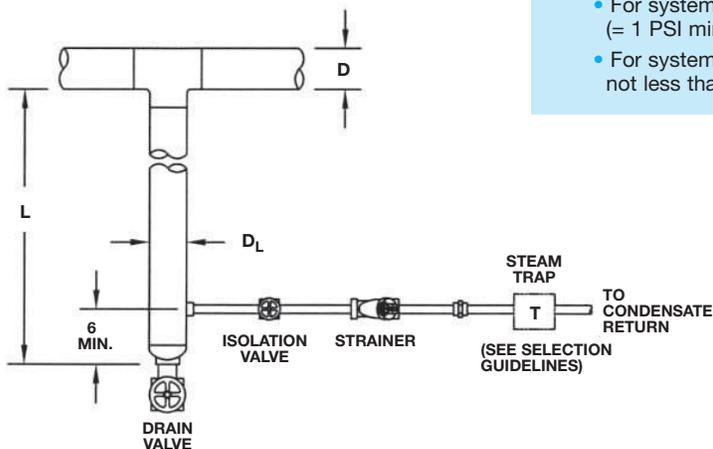
### **INSTALLATION GUIDELINES:** (see Figure 5)

- For drainage of steam transmission and distribution lines, drip legs should be located at bends in piping (direction changes), low points, end of line, and in straight run of piping every 200 feet.
- For protection of equipment such as regulators and control valves, drip legs should be installed directly ahead of the regulating or control valve line.
- Proper steam trap selection for drip applications is dependent upon application requirements, such as pressure, number of and distance between installed steam traps, ambient conditions, start-up requirements, etc. A commonly accepted practice is to use float & thermostatic (F&T) steam traps for low pressure steam systems up to 30 PSIG, and thermodynamic steam traps for steam pressures over 30 PSIG.
- Because condensate drainage from steam systems is dependent upon gravity, drip leg diameter is critical for optimum removal – larger is better. Collection leg diameter ( $D_L$ ) is recommended to be the same size as the steam main ( $D$ ), up to 4". For steam mains above 4", the collection leg diameter may be half the diameter of the main, but not less than 4". The length ( $L$ ) of the drip leg for systems with automatic start-up should be a minimum of 28" to provide approximately 1 PSI head pressure. The length ( $L$ ) of the drip leg for systems with supervised start-up should be  $1.5 \times D_L$ , but not less than 8".
- Consider low-cracking pressure (1/4 PSI opening pressure) check valves after steam traps when discharging into condensate return lines. Check valves eliminate the possibility of condensate backing up through the steam trap into the system.
- A drain valve is included at the bottom of the collection leg for manual discharge of condensate during supervised start-up. The drain valve should be located at least 6" below the steam trap line.
- An isolation valve and strainer should be installed before the steam trap. The isolation valve simplifies maintenance of the trap and the strainer protects the trap from any dirt, debris or scale in the line.

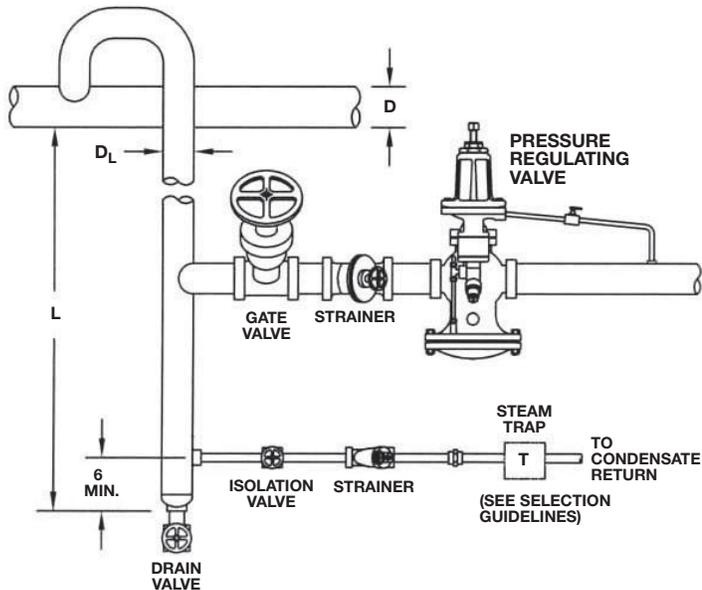
Figure 5:

### DRIP LEG DESIGN CRITERIA:

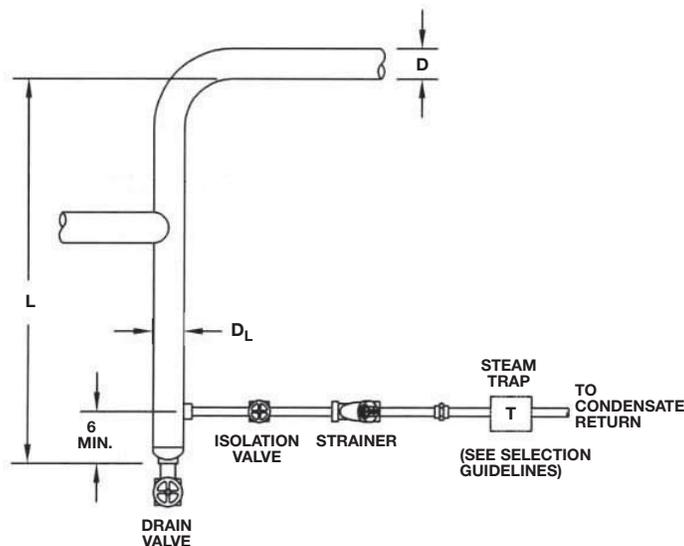
- 1) Locate prior to valves, bends in pipe (direction changes), low points, end of line and straight piping runs (max. 200 ft. apart).
- 2) Diameter:
  - Drip leg diameter ( $D_L$ ) to be equal to steam main diameter ( $D$ ) for steam main sizes up to 4"
  - Drip leg diameter ( $D_L$ ) may be half the steam main diameter ( $D$ ) for steam main sizes over 4", but not less than 4"
- 3) Length ( $L$ ):
  - For systems with automatic start-up,  $L$  to be 28" minimum (= 1 PSI minimum head pressure)
  - For systems with supervised start-up,  $L$  to be  $1.5 \times D_L$ , but not less than 8"



PROPER DRIP LEG DESIGN



DRIP LEG BEFORE REGULATING OR CONTROL VALVES



DRIP LEG AT ABRUPT CHANGES IN DIRECTION OR ELEVATION

# STEAM TRAP APPLICATIONS

## PROCESS STEAM TRAP – GRAVITY DRAINAGE OF HEAT TRANSFER EQUIPMENT

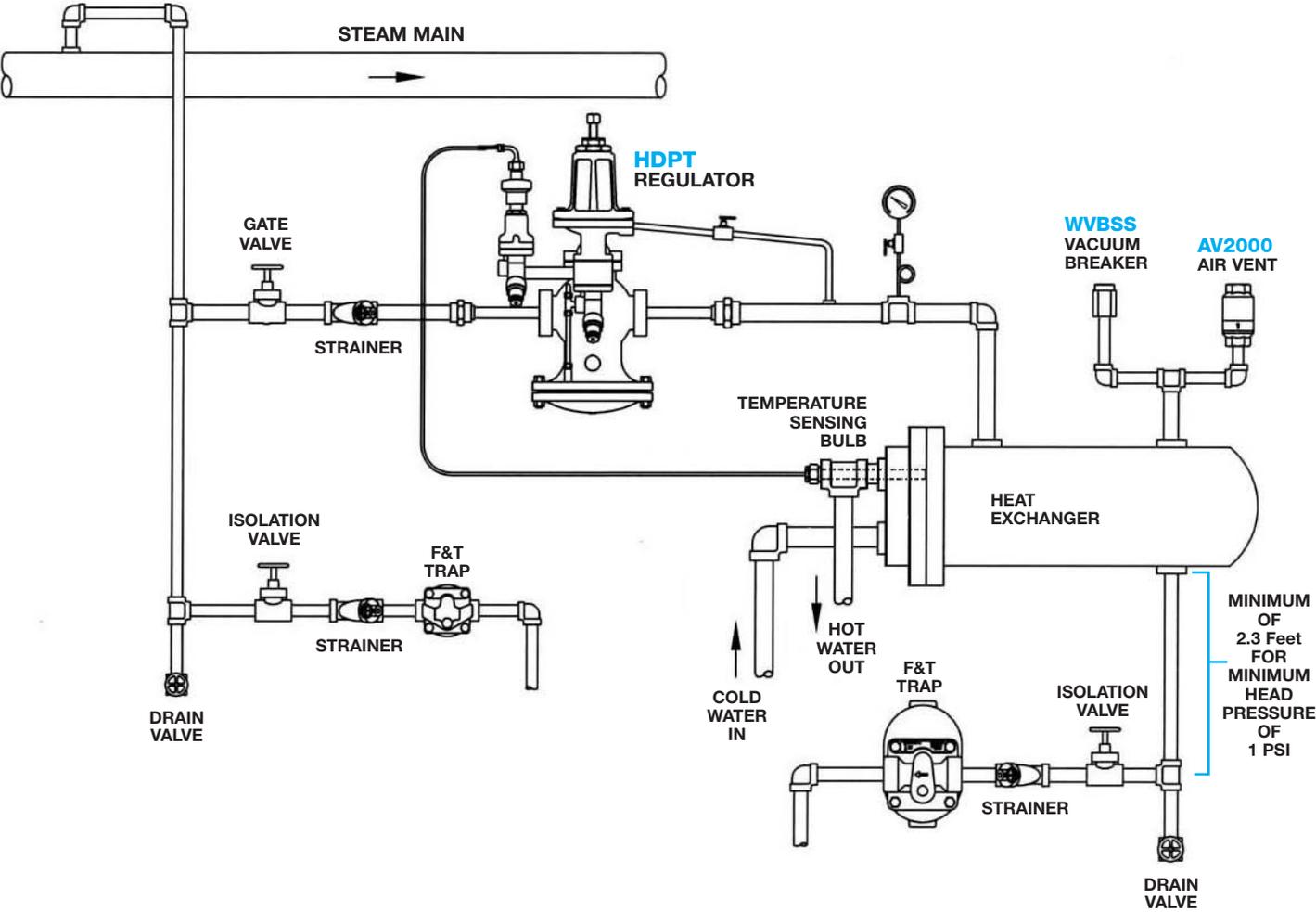
**PURPOSE:** For removing condensate from below steam heat transfer equipment to ensure optimum heating under various load conditions.

**OPERATION:** Steam used to heat product such as water in a heat exchanger condenses to liquid after passing through the heat exchanger and releasing its heating energy. To ensure optimum heating, this condensate is removed through an adequately sized drip leg and steam trap properly selected for the application and installed below the equipment. A Float and Thermostatic (F&T) steam trap is often an appropriate choice due to its modulating discharge and air venting capability.

### **INSTALLATION GUIDELINES: (see Figure 6)**

- Selection and sizing of the process steam trap is critical to proper operation. A safety load factor (SLF) is applied to accommodate load variations and surges, as well as high start-up requirements. Consult appropriate sections of this catalog or the factory for guidelines regarding proper process steam trap selection and sizing.
- The collecting leg to the process trap should be no smaller than the designed condensate outlet of the heat transfer equipment. Note that some steam trap technologies such as thermostatic require extended distance between the heat exchanger and steam trap to allow for back-up of subcooled condensate.
- The process trap should be located at least 2.3 feet (28") below the condensate outlet of the heat exchanger to provide a minimum of 1 PSI head pressure.
- The drip leg and steam trap prior to the regulating valve protect the valve from condensate, as well as ensure the best quality steam for heat transfer. Note the take-off from the top of the steam main to avoid condensate that would collect on the bottom of the main piping.
- The vacuum breaker and auxiliary air vent located at the top of the heat exchanger vessel promotes proper drainage and optimum heat transfer. The vacuum breaker allows system equalization with atmospheric air to allow gravity condensate drainage when vacuum is formed from condensing steam. The air vent improves heat-up times and overall heat transfer by expelling accumulated air on start-up.
- Consider low-cracking pressure (1/4 PSI opening pressure) check valves after steam traps when discharging into condensate return lines. Check valves eliminate the possibility of condensate backing up through the steam trap into the system.
- An isolation valve and strainer should be installed before any steam trap. The isolation valve simplifies maintenance of the trap and the strainer protects the trap from any dirt, debris or scale in the line.

Figure 6:



### SHELL AND TUBE HEAT EXCHANGER

# STEAM TRAP APPLICATIONS

## PROCESS STEAM TRAP – SYPHON DRAINAGE OF HEAT TRANSFER EQUIPMENT

---

**PURPOSE:** For removing condensate from steam heat transfer equipment when the steam trap is to be installed *above* the point where condensate will collect.

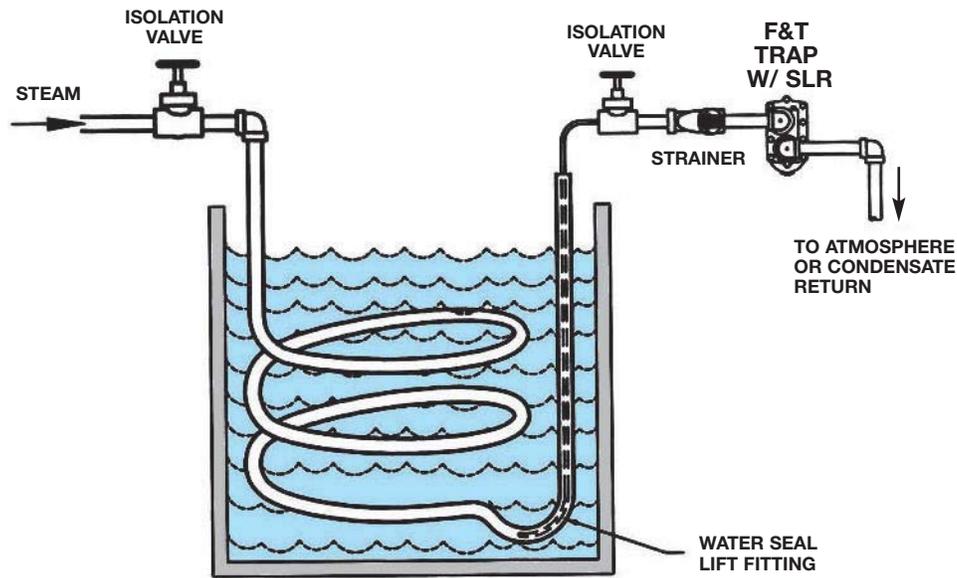
**OPERATION:** When steam is used to heat liquid in a tank with a submerged coil or a rotary drum dryer, gravity drainage to the steam trap is not possible. For these applications, it may be necessary to install the steam trap above the drain point of the equipment by creating a syphon lift to allow for proper condensate drainage.

### **INSTALLATION GUIDELINES:** (see Figure 7)

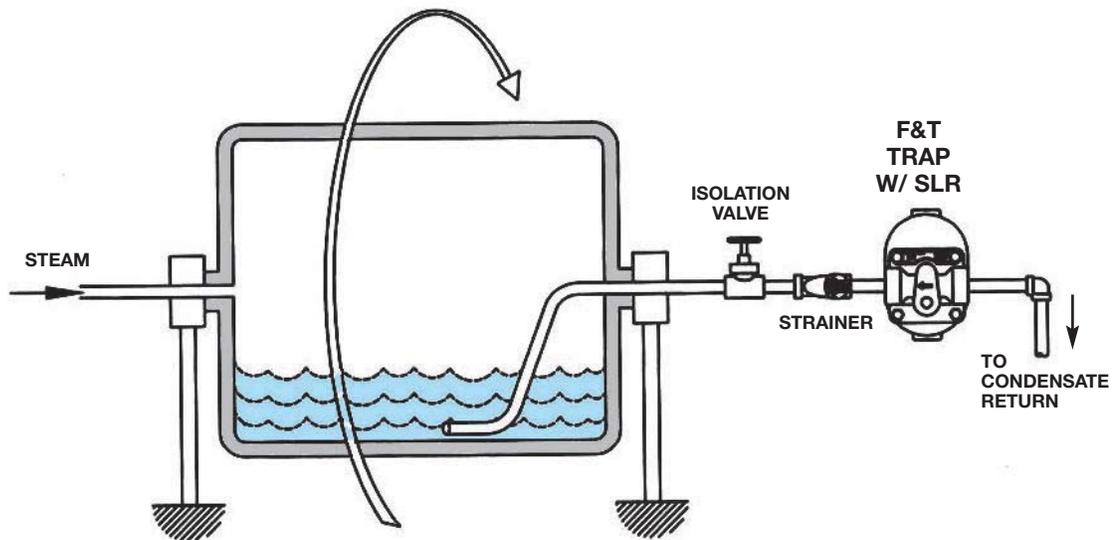
- There are two critical requirements to ensure proper operation of syphon lift process drainage systems: A water seal lift fitting and a steam trap with a function to prevent steam lock (often referred to as Steam Lock Release or SLR).
- The lift fitting on a submerged coil provides a water seal to stop steam from pushing past the condensate and reaching the steam trap, preventing a vapor-lock condition of the trap.
- Steam Lock Release (SLR) is provided on the steam trap to ensure the syphon lift remains continuous by preventing steam from becoming trapped – or locked – between the cavity of the steam trap and incoming condensate. The SLR function allows any small portion of trapped steam to be automatically removed from the system, allowing continuous drainage.
- Consider low-cracking pressure (1/4 PSI opening pressure) check valves after steam traps when discharging into condensate return lines. Check valves eliminate the possibility of condensate backing up through the steam trap into the system.
- An isolation valve and strainer should be installed before any steam trap. The isolation valve simplifies maintenance of the trap and the strainer protects the trap from any dirt, debris or scale in the line.

## PROCESS STEAM TRAP – SYPHON DRAINAGE OF HEAT TRANSFER EQUIPMENT

Figure 7:



SUBMERGED COIL FOR HEATING LIQUID



ROTARY DRUM DRYER