Basics of Steam
&
Steam Trap Guidelines

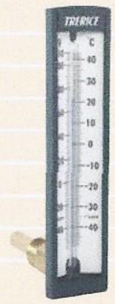
Corporate Office: 428 Jones Blvd. · Pottstown, PA 19464 · 610-495-5131

Steam & Condensate

Introduction

Pressure / Temperature Relationship of Steam

Steam is created when water is heated to its boiling temperature until enough heat energy is absorbed to transform the water from a liquid to a gas. The temperature at which water boils is 212˚F; however, this is the boiling point of water at 0 psig, or atmospheric pressure. A unique property of steam is that there is a direct relationship between the pressure at which it is generated and the temperature at which it boils. The boiling temperature increases as steam pressure increases. If steam is generated at a pressure higher than 0 psig, the temperature at which the water boils will be higher than 212˚F. An abbreviated version of the Saturated Steam Table is included to show the exact boiling temperature at various steam pressures. (The complete steam table is available in Engineering Section.)



Steam Pressure (psig)		Temperature (˚F) Steam	Temperature (˚F) Boiling Water
0 psi	=	212˚ F	212˚ F
1 psi	=	215˚ F	215˚ F
4 psi	=	224˚ F	224˚ F
10 psi	=	239˚ F	239˚ F
50 psi	=	298˚ F	298˚ F
100 psi	=	338˚ F	338˚ F
150 psi	=	366˚ F	366˚ F
200 psi	=	388˚ F	388˚ F
300 psi	=	421˚ F	421˚ F

Steam Supplies Heat at a Constant Temperature

Steam does not reduce its temperature when it releases its heat; it just simply changes from a gas back into water at the same temperature. For example, steam at 50 psig (is at 298˚F; refer to steam chart above) will condense back to water at 298˚F when it releases its heat energy. In contrast to steam, water reduces in temperature when it gives up its heat.

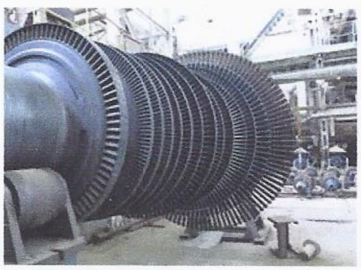
What is saturated steam?

Steam that is generated under pressure inside the boiler, while in the presence of boiling water, is referred to as **Saturated Steam**. If additional heat is later added to the saturated steam to increase its temperature, it is then referred to as Superheated Steam. Superheated steam is used in power generation and saturated steam is used for heating. When saturated steam releases its energy, it condenses back to water. This hot water at or near boiling temperature is referred to

Heating Properties: The energy absorbed by water at its boiling point to transform it from a liquid to a gas is known as **Latent Heat**. This Latent Heat is then released by the steam when used for heating. Steam is very efficient in transferring heat to other processes. Steam, being a gas, allows it to surround any surface it needs to transfer its heat energy into. When steam transfers its heat, it condenses back into water, which will be drained away and sent back to the boiler in order to be used again (referred to as Condensate Recovery).

Where else is steam used?

Hospitals and pharmaceutical manufacturers may use steam for the sterilization of medical instruments and production of medicines, while the petrochemical industry may use steam for processing gasoline from crude oil. Steam is essential in large scale food processing & manufacturing applications. Large cities, such as New York, have centralized steam systems for heating large apartment complexes.



Steam Turbines in Power Plants

Steam exhaust from power plants

Steam used in cities for heat

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.

WHY ARE STEAM TRAPS REQUIRED?

For any steam system to operate properly the condensate, air and other non-condensable gases such as carbon dioxide must be removed from the steam system. This is the purpose of the steam trap.

CONDENSATE:

When steam releases its heat energy, the steam reverts back to water. This occurs in a heat exchanger making hot water, in a radiator heating a room, or in a steam pipe transferring steam. This water, technically referred to as *condensate*, must be removed from the system or the system would back up with water. The removal of condensate from the steam system 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 thru various paths such as boiler water make-up systems, vacuum breakers and air vents.

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 steam pressures over 30 PSIG, and *float & thermostatic* for 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 pipeline containing high viscosity oil with tracing tubing. The steam inside the tubing heats the oil to lower its viscosity, allowing it to flow easily thru 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 *tracing traps*. The most common trap choice for tracing applications is the *thermostatic* type.

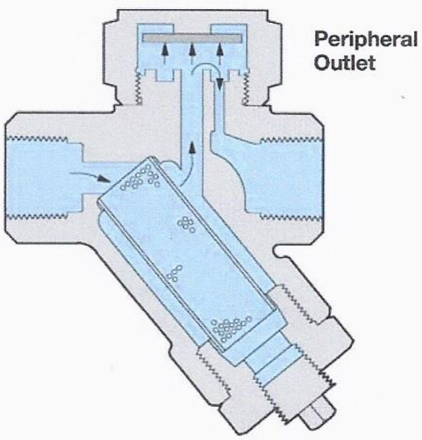
THERMODYNAMIC TRAPS

Thermodynamic traps use only one moving part, the valve disc, which allows condensate to be discharged 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 freeze-proof when installed vertically. Thermodynamic traps will only discharge small amounts of air and therefore are typically not used in process applications. Since Thermodynamic traps rely on steam velocity to operate, they are not intended for low pressure service (below 30 PSI).

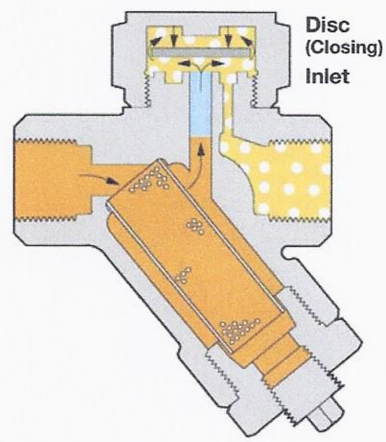
Operation:

The inlet pressure to the trap pushes the disc off the seat and allows unwanted condensate to be discharged through the peripheral outlet surrounding the inlet (**Figure A**). As hot condensate reaches the disc chamber, flash steam is created that travels at high velocity from the inlet to the outlet creating a low pressure area under the disc and higher pressure above the disc (**Figure B**). This differential pressure causes the disc to close against the seat and trap the steam in the system (**Figure C**). The steam pressure above the disc creates a force holding the disc closed. Heat transfer takes place through the cap and the steam pressure above the disc begins to reduce. When the downward force created by the steam pressure above the disc falls below the force created by the incoming condensate, the disc is pushed off its seat and the process repeats itself (**Figure A**). Cycle time is dependent on steam temperature, and more importantly, ambient temperature outside the trap. Since the amount of time the valve remains closed is primarily dependent on the heat transfer from the steam above the disc 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.

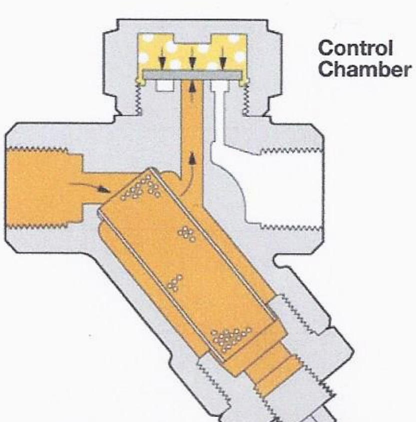
A) Valve Disc (Open)



B) Valve Disc (Starting to Close)



C) Valve Disc (Closed)



A) When condensate is present, trap remains in the open position allowing condensate to discharge.

B) When steam enters the trap, it creates an internal pressure above the disc that instantly forces the disc and seat to close tightly, preventing steam from escaping.

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

Watson McDaniel

THERMOSTATIC STEAM TRAPS

Operation:

The bellows type thermostatic trap contains a fluid-filled thermal element (bellows). The operation of this 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 operation of the bellows follows 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 retracted and the valve plug is lifted off the seat allowing air and condensate to be discharged from the system. As hot steam approaches the thermal element in the trap, the fluid inside the bellows vaporizes and expands, closing the valve tightly. As long as steam is present, the valve will remain closed. Only when subcooled condensate or air is present will the valve open.

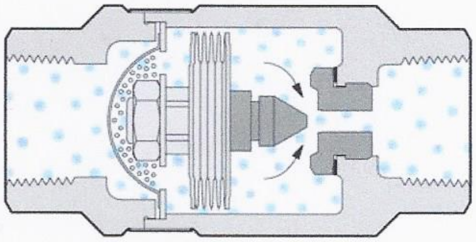
Watson McDaniel thermal element traps offer wide operating pressure ranges, rugged welded stainless steel bellows, and various orifice sizes, making them a great choice for a majority of applications.

Sub-cool:

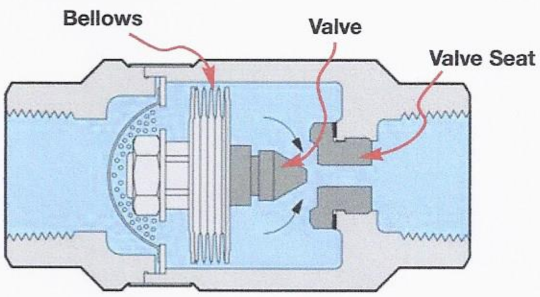
The sub-cooling of condensate prior to discharge can have certain beneficial effects. In the majority of tracing applications, the sub-cooling of condensate is highly desirable because of the additional energy that is extracted from the Hot condensate. If the trap did not sub-cool condensate, this energy would be wasted.

In Batch style process applications such as jacketed kettles, plating tanks and heating of outdoor storage tanks, the sub-cooling of condensate is generally not a factor to consider since the amount of condensate back-up requires less than 1% of the heat transfer surface area and is therefore considered negligible. So a heat exchanger with 50 square feet of surface area requires only ½ a square foot of surface area to sub-cool the condensate. In a Continuous process application that exhibit rapid changes in steam pressures, steam traps requiring sub-cool could lead to additional condensate back up. This scenario is typical in instantaneous hot water heaters using a shell & tube heat exchanger with temperature control valves. The steam pressure in the heat exchanger can drop extremely fast when the water demand changes. In this case, additional sub-cooling of the condensate is required before it will discharge. In some cases, this may be acceptable, but in general, only F&T traps are recommended for process with rapid changes in steam pressures since they always discharge condensate immediately as it is formed. In addition, traps that sub-cool condensate have a softer discharge since less flash steam is generated in the return line.

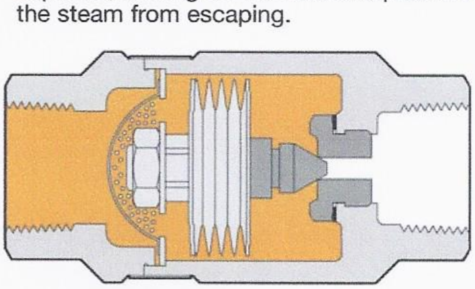
A) AIR When air, which is cooler than steam, is present, the bellows is retracted and the seat is open, allowing large quantities of air to be discharged.



B) CONDENSATE When condensate, which is cooler than steam, is present, the bellows retracts and the seat opens, allowing condensate to be discharged.



C) STEAM When steam reaches the trap, the bellows expands, closing off the seat and preventing the steam from escaping.



Introduction

FLOAT & THERMOSTATIC TRAPS

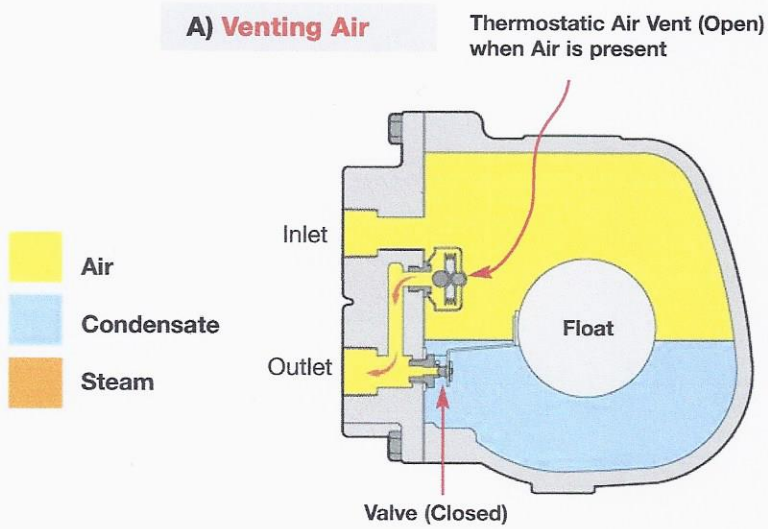
F&T steam traps are the most common trap type used for process applications. They use a float-operated valve mechanism to discharge condensate as it is formed, and an air vent for discharging air at start-up; both very important requirements for process applications. The WFT and FTT-Series with Iron bodies, are suitable for most general purpose process applications up to 250 PSIG. The 3/4" WFT and FTT are often used for drip applications. The FTE-Series has extremely high capacity. The FT600 Series available with Cast Steel or Stainless Steel bodies; often required in Chemical and Petrochemical refineries and other industries.

F&T Traps are classified as mechanical style traps and require the buoyancy of the float, and a lever mechanism to lift the valve disc off the seat orifice. Larger seat orifices and higher steam pressures require additional buoyancy and mechanical force for the trap to open. Select a trap model with an equal or higher PMO rating than the steam pressure, or the trap will not open. F&T traps are not self-draining and are therefore subject to freezing in cold climates. Freeze protection valves are available to fully drain most model F&T traps during shut down periods.

Operation:

At start-up, air and condensate enter the steam trap. The air will be discharged through the open thermostatic air vent (**Figure A**). 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 B**). As the condensate discharges through the seat orifice, the float lowers, and shuts the valve (**Figure C**). The float closes the valve with a level of condensate above the seating orifice to prevent loss of any steam. The float level rises and falls to modulate the seat opening in order 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) to be used when the steam trap is physically positioned above the condensate collection point. For superheated steam applications, the thermostatic air vent is replaced with a live orifice air vent.

A) Venting Air

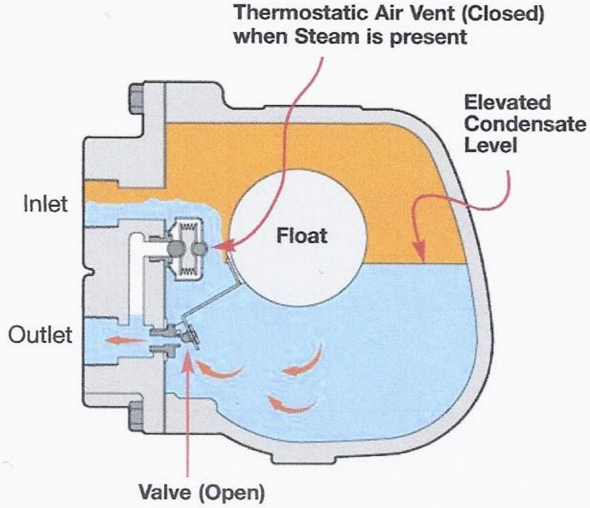


A) When cold air enters the trap during start-up, the thermostatic air vent is open, allowing the discharge of large quantities of air from the system.

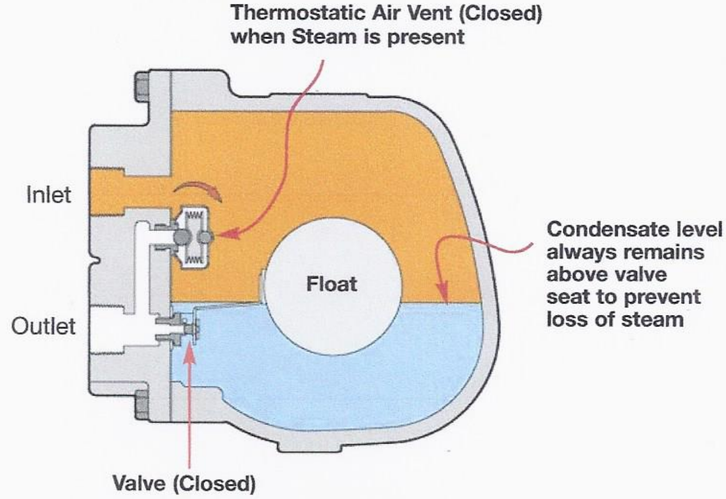
B) When condensate enters the trap, the float lifts which opens the valve, allowing condensate to discharge.

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.

B) Discharging Condensate



C) Closed (Trapping Steam)



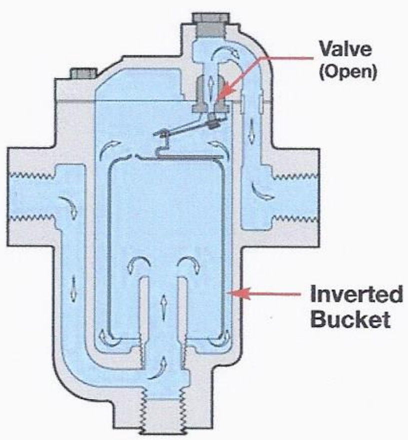
Introduction

INVERTED BUCKET TRAPS.

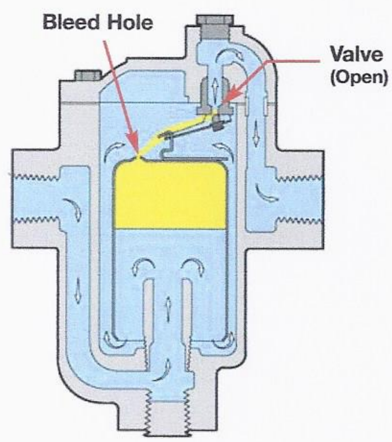
Operation:

Due to its weight, the inverted bucket within the trap will rest on the bottom of the trap body keeping the valve open and allowing condensate to be discharged (**Figure A**). In the top of the bucket there is a small bleed hole which allows air to escape from inside the bucket and exit through the outlet port (**Figure B**). When steam arrives through the inlet of the trap, it fills the inverted bucket which makes it buoyant and rise to the top of the trap, closing the valve (**Figure C**). As steam condenses and/or is bled through the small bleed hole in the top of the bucket, the bucket loses buoyancy which causes it to sink to the bottom of the trap. The valve then opens allowing condensate to be discharged from the system (**Figure A**). The bucket trap must maintain a certain amount of water (prime) in order to operate. If the trap loses its prime, the bucket will not be able to float when steam enters; keeping the valve in the open position which allows steam to escape (**Figure D**). Due to the balance of forces required between the incoming pressure and internal trap components, several orifice sizes are required to accommodate various differential pressure ranges. For this reason care must be used to select a trap model with an equal or higher PMO rating than the steam pressure.

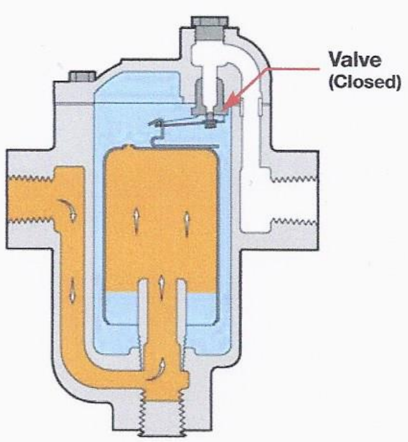
A) Discharging Condensate



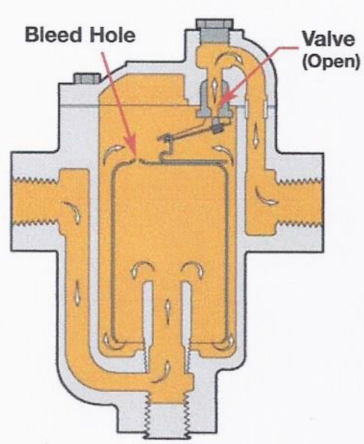
B) Discharging Air



C) Closed (Trapping Steam)



D) Potential Failure Mode
Loss of Prime



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 fills with steam and floats to the surface, 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.

Air
Steam
Condensate

Steam Trap Selection Guidelines

Steam Traps for Drip Applications: "Drip traps"

Drip applications refer to draining condensate that forms in distribution piping as steam is transported from the boiler to where it is to be used. Eliminating this condensate protects valves and piping from wiredrawing and water hammer Because condensate loads tend to be low, steam traps with smaller orifices are typically selected for extended service life. It is reasonable to consider a single trap that can operate over a wide pressure range in order to simplify selection and reduce inventory. Other factors to consider when selecting drip traps: materials, repairability, efficiency, reliability, installation orientation, personal preference/experience, as well as the trap's ability to handle freezing climates, superheated steam, or pipe scale and debris.

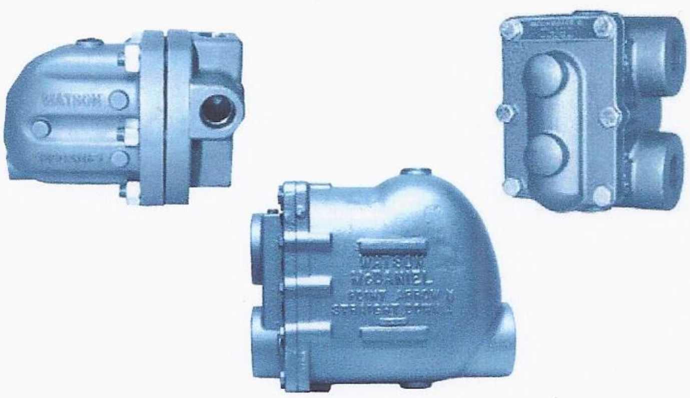
Steam Traps for Tracing Applications: "Tracing Traps"

Tracing Applications refer to using steam to elevate the temperature of a product, process, or piece of equipment by using tubing or some type of jacketing device filled with steam. These applications are commonly used to promote flow of heavy fluids or prevent pipelines and equipment from freezing. The relatively small traps used for these applications are referred to as "Tracing traps". A Non-Critical Tracing application may benefit from a thermostatic steam trap which sub-cools and backs up some condensate - an adjustable bimetal trap offers additional temperature control. Thermodynamic traps are ideal for Critical Tracing applications where condensate back-up is not permitted.

Steam Traps for Process Applications: "Process Traps"

Process applications refer to draining condensate from the actual process using the steam. These require steam traps with relatively high condensate capacity. In the majority of process applications, it is important to discharge air present in the system during start-up so the steam can quickly enter the system. Although separate air vents can be used for this purpose, it makes sense to select a trap which has air venting capability, in addition to discharging varying condensate loads. The trap must have enough capacity to discharge the condensate even when the differential pressure across the trap is low. These low pressure conditions commonly occur in process heating applications where control valves are used to regulate the flow of steam into the equipment. However, if the trap is significantly oversized it may cause it to wear out more quickly and allow steam to pass into the condensate return. The most common trap type for process applications is the Float & Thermostatic style.

Most Common Types of Steam Traps



Most Common Use:
Process Applications from low pressure HVAC models for residential heating to Industrial cast steel and stainless steel models for Chemical and Petro-Chemical plants up to 450 PSI. Suitable alternative for drip applications to 200 psig.

F&T (Float & Thermostatic) Traps:

Float & Thermostatic Steam Traps contain a float-operated valve to continually discharge condensate and a thermostatic air vent which discharges air. Body materials available are Cast Iron, Ductile Iron, Cast Steel, & Stainless Steel for pressures up to 450 psig. *(F&T traps are referred to as mechanical traps.)*

Typical Applications: F&Ts are the most commonly used trap for both batch type processes and continuous process applications with rapidly changing pressures and loads.

Advantages: F&Ts quickly respond to load and pressure changes, discharge large amounts of air present at start-up which allow steam to quickly enter the system, continuously discharge condensate as it forms and offer a wide range of capacities for any process application.

Other Factors to Consider: F&Ts narrow operating pressure ranges require more care during selection. Since they are not self-draining, they are subject to freezing. Trap body must be installed vertically for proper operation.

Steam Trap Selection Guidelines

Most Common Use:
General service drip & tracing applications above 30 psig, as well as high-pressure drip applications with superheat.

Thermodynamic Traps:

The Thermodynamic Trap is simple and compact with a single moving part (disc) which opens to discharge condensate and closes in the presence of steam. Body materials available are Stainless and Alloy Steels for pressures up to 3,600 psig.

Typical Applications: Widely used on higher pressure drip applications and critical tracing applications (where condensate back-up is not permitted).

Advantages: Rugged design, operation is easy to check due to distinct cyclic operation, relatively small with lower capacities, single model operates over wide pressure range in contrast to mechanical traps, excellent for superheated steam, self-draining when mounted vertically to prevent freezing.

Other Factors to Consider: Limited air venting, wet climates can increase cycle rates, sensitive to excess back pressure, blast discharge may not be preferred in some systems

Most Common Use:
Industrial style Thermostatic Traps are extremely versatile. Their use can range from general service drip & tracing applications to small-to-medium batch process heating applications.

Thermostatic Traps:

A Thermostatic Trap contains a heavy-duty, industrial-purpose welded stainless steel thermal element designed to control condensate discharge by sensing the temperature difference between steam and cooler condensate. Body materials available are Cast Iron, Stainless and Alloy Steels with thermal element designs available for pressures up to 650 psig. The WPN Series Bi-metallic design will handle presssures up to 2,260 psig.

Typical Applications: Extremely versatile and energy efficient, these traps are suitable for a wide range of applications. Thermal element designs are suitable for applications ranging from general service drip and tracing applications to small-to-medium batch style processes. Bi-metal designs can be used in high pressure, superheated drip applications or in lower pressure tracing applications.

Advantages: Self-draining when mounted vertically to prevent freezing, single model operates over wide pressure range in contrast to mechanical traps, small and compact with similar capacities to larger mechanical traps (F&Ts & IBs), superior air venting capabilities, welded stainless steel thermal element and bimetal elements are extremely rugged, moderate discharge due to reduced flash steam, choose between fail-open or fail-closed bellows.

Other Factors to Consider: Some condensate back-up can be expected, thermal element design not recommended for superheated applications.

Most Common Use:
Used on drip applications where excessive dirt and debris may be of significant concern. They can serve as alternatives to F&T's in process applications where air venting is not required by the steam trap.

Inverted Bucket Traps:

The Inverted Bucket Trap uses an inverted bucket as a float device to control the opening and closing of the plug and seat to discharge condensate. Body materials available are Cast Iron and Stainless Steel for pressures up to 450 psig. *(IB traps are referred to as mechanical traps.)*

Typical Applications: These traps have a discharge orifice positioned at the top of the trap body which make them ideal for drip applications on systems containing excessive pipe scale and debris. They may be considered for process applications where air venting is less of a concern or handled by a separate air vent.

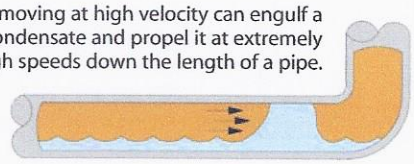
Advantages: Rugged and simple design, top-mounted discharge orifice less susceptible to failure from dirt and debris, service life often exceeds other style traps.

Other Factors to Consider: Limited air venting capabilities, can lose its prime causing it to fail, narrow operating pressure ranges require more care during selection, not self-draining therefore subject to freezing, single position installation, fixed orifice on bucket allows small steam leakage, physical size can be large and require additional support.

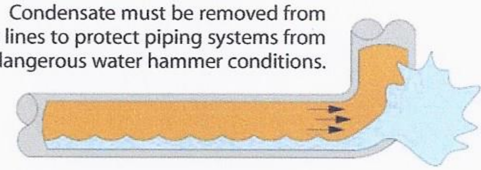
DRIP Applications • Sizing a Trap for Draining a Steam Main

Drip applications refer to the removal of condensate formed in steam lines due to the radiant heat loss of the hot steam pipes to surrounding air and are required for the protection of the steam system. (Drip Traps remove the condensate from the steam lines where the process traps remove condensate being generated by the actual process.) Drip traps should be placed 150 to 300 feet apart on straight runs of piping, before elevation changes, and before critical equipment such as Regulators and Control Valves. See description below of typical drip leg configurations.

Steam moving at high velocity can engulf a slug of condensate and propel it at extremely high speeds down the length of a pipe.



Condensate must be removed from steam lines to protect piping systems from dangerous water hammer conditions.



Why Condensate Safety Load Factors and Warm-up Loads need to be considered:

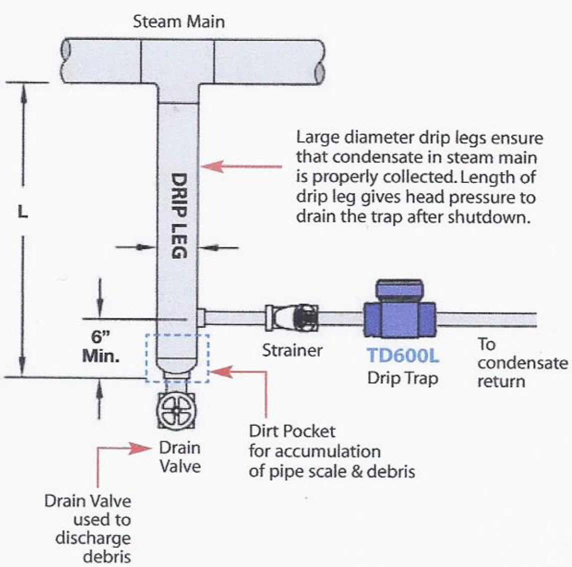
During start-up, when the piping system is cold and steam begins to flow thru the pipes, steam is condensing very quickly because of the energy required to heat all the cold surfaces. Furthermore, the steam pressure in the system which is required to push the condensate through the steam trap into the return line, is low before the system comes up to full pressure. Therefore, condensate 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 the traps are sized for the normal running loads and normal system pressures, then they would be undersized for the start-up condition.

In a supervised start-up, condensate drain valves located throughout the system, are manually opened to drain excessive condensate generated by the cold piping system; relying less on the steam traps. Therefore, the steam traps selected for a system with a supervised start-up can be more closely sized for the actual normal running load.

Drip Leg in a Steam Main

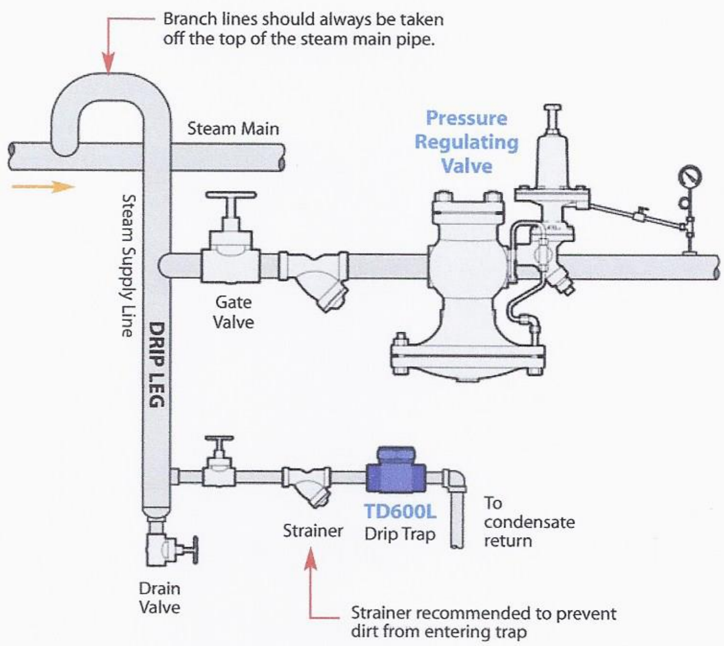
Drip Leg Design Criteria:

- For systems with automatic start-up, L to be 28" minimum (= 1 PSI minimum head pressure)
- Drip leg diameter should be equal to steam main diameter (up to 4" in size)



Drip Leg Before Regulator or Control Valve

Drip Legs should be installed directly ahead of regulators and control valves to minimize erosion to valve trim and flooding of valve bodies.



Steam Trap Selection Guidelines • DRIP Applications

Sizing Example: Size a drip trap for an 8" steam main with 100 psig steam pressure. Traps should be placed every 200 ft. A 2x safety factor based on Warm-Up load will be used.

- Based on Warm-Up Load Chart: **100 lbs/hr** of condensate is generated per 100 feet length of pipe.
- Warm up load for 200 ft. length is therefore, **200 lbs/hr** (2 x 100 lbs/hr)
- If a 2x safety factor based on warm-up load is used, we require a trap with a capacity of **400 lbs/hr**
- Actual running load for 100 ft. length = 41 lbs/hr
- Actual running load for 200 ft. length = **82 lbs/hr**

Warm-Up Loads in Pounds of Condensate per hour per 100 ft. of Steam Main

Outside Temperature at 70˚F															
Steam Pressure (PSIG)	Pipe Size														0˚F Correction Factor †
	2"	2 1/2"	3"	4"	5"	6"	8"	10"	12"	14"	16"	18"	20"	24"	
20	8.4	13.4	17.5	24.9	33.8	44	66	93	124	146	191	241	284	396	1.37
60	11.0	17.5	22.9	32.6	44	57	86	122	162	192	250	316	372	518	1.29
100	12.8	20.3	26.6	37.8	51	67	100	142	188	222	290	366	431	600	1.26
125	13.7	21.7	28.4	40	55	71	107	152	200	238	310	391	461	642	1.25

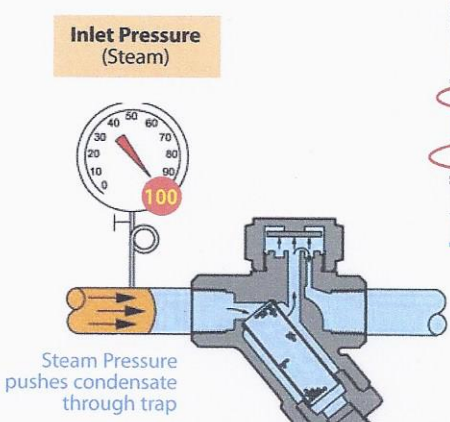
Running Loads in Pounds of Condensate per hour per 100 ft. of Steam Main

Outside Temperature at 70˚F															
Steam Pressure (PSIG)	Pipe Size														0˚F Correction Factor †
	2"	2 1/2"	3"	4"	5"	6"	8"	10"	12"	14"	16"	18"	20"	24"	
20	8	9	11	14	17	20	26	32	38	42	48	51	57	68	1.50
60	10	12	14	18	24	27	33	41	49	54	62	67	74	89	1.45
100	12	15	18	22	28	33	41	51	61	67	77	83	93	111	1.41
125	13	16	20	24	30	36	45	56	66	73	84	90	101	121	1.39

† For outdoor temperatures of 0˚F, multiply load value selected from table by correction factor shown.

Trap Selection: Reference the TD600S Series Capacity Chart below based on inlet steam pressure. Enter the chart under 100 psig inlet pressure to compare the capacities of different models.

The 1/2" TD600LS will be capable of discharging 375 lbs/hr of condensate at 100 psig steam pressure. The capacity is slightly less than the load calculated based on warm-up load with 2x safety factor, however, this trap selection would be a suitable choice since its capacity is well in excess of what is actually required. These loads are indicative of drip applications and lend support as to why only reduced capacity 1/2" TD600L or 3/4" TD600L traps are required for the majority of drip applications.



CAPACITIES – *Condensate (lbs/hr)*

Size	Model Code	Steam Inlet Pressure (PSIG) 3.5	5	10	15	20	25	30	40	50	75	100
1/2" 1"	TD600LS-12-N TD600LS-14-N	180	185	190	195	200	215	220	230	250	310	375
3/4"	TD600LS-13-N	300	315	350	380	415	440	470	515	580	710	825
1/2"	TD600S-12-N	300	315	350	380	415	440	470	515	580	710	825
3/4"	TD600S-13-N	415	430	475	520	565	610	650	720	825	1020	1185

Watson McDaniel

Steam Trap Selection Guidelines • DRIP Applications

Thermodynamic

The Thermodynamic Disc (TD) Steam Trap is simple and compact and one of the primary choices for drip applications over 30 psig. The TD600 Series with integral one piece body-seat design, are the most economical and commonly used for pressures up to 600 psig. The 1/2" & 3/4" TD600**L** will meet the capacity needs of most drip applications ("S" models have integral strainers). The TD600 Series cannot be welded in-line. The TD700S & TD900S Series are both in-line repairable and can be welded into the pipeline.

TD600L

TD600LS

TD700S

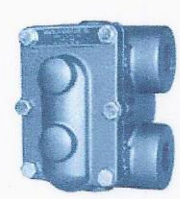
TD900S

Fully In-line Repairable

Float & Thermostatic

The Float & Thermostatic (F&T) Steam Trap is the primary choice for process applications. However, for drip applications, they can be effectively used for pressures up to 125 psig on the WFT Series & 225 psig on the FTT Series; for higher pressures, the larger body sizes required make F&T traps a less economical and desireable solution for drip service. The 3/4" WFT-125, or 1/2" & 3/4" FTT-225 will meet the capacity needs of most drip applications. Other PMO (maximum operating pressure) ranges available. For drip applications, select a PMO that meets or exceeds the maximum pressure in the main steam distribution piping.

FTT
In-line Pipe Connection



WFT
Parallel Pipe Connection

Thermostatic

Thermostatic Steam Traps are extremely versatile and can be used on a wide variety of applications from general service drips to small-to-medium batch type processes. Using a welded stainless steel thermal element to control condensate discharge, these traps allow condensate to subcool, making them extremely energy efficient. As a result, the condensate discharged generates less flash steam which reduces back pressure build-up in condensate return lines. A single model will operate from 0 to 650 psig which simplifies selection. The WT2001, with stainless steel body and non-repairable design, is the most commonly used. The WT3001 and WT2501 have the same internals as the WT2001, however, their 4-bolt cover allows them to be in-line repairable. The WT3001 has a stainless steel body while the WT2501 is cast iron.

The WPN Series (not shown), uses a bi-metal element suitable for pressures to 2,260 psig, and will handle superheated steam.

WT2501
Repairable
(Cast Iron)

WT2001
Non-Repairable
(Stainless Steel)

Inverted Bucket (IB)

Inverted Bucket Traps are extremely rugged and have a discharge orifice mounted at the top of the trap body, making them less susceptible to failure from dirt and debris when compared to other trap types. The IB models selected are suitable choice for most drip applications.

Stainless Steel

Cast Iron

Universal Quick-Change

The all stainless steel universal style steam traps feature a permanent installation of the universal connector with a 2-bolt mounting arrangement for the universal steam trap module, allowing the steam trap to be removed and replaced in minutes. These Quick-Change Steam Traps should be considered for all drip applications.

- Thermodynamic
- Float & Thermostatic
- Thermostatic
- Inverted Bucket

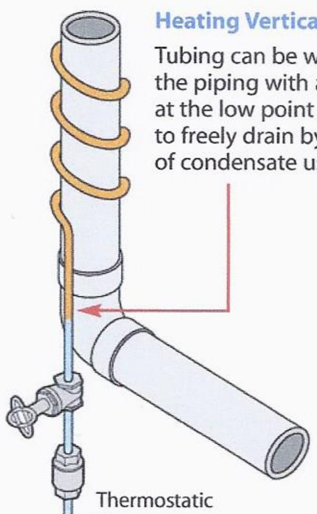
Tracing Applications

Steam tracing refers to using steam to indirectly elevate the temperature of a product or process by using tubing or some type of jacketing device filled with steam. In a typical steam tracing application, stainless steel or copper tubing is filled with steam and is coiled or wrapped around the outside of a pipe or tank containing material that requires heating. The steam inside the tubing transfers its heat to the material in the pipe or tank; to stop it from freezing or to lower its viscosity to allow it to flow more easily. A steam trap is required for tracing to remove the condensate and air from the system. The most common trap choice for tracing applications is the Thermostatic type. Depending on the particular tracing application, it is often desirable to have some amount of condensate backup in the tubing.

Steam Tracing Applications:		Primary Trap Choice	Special Notes
Typical Service:	Some condensate back-up preferable	• 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.
Critical Service:	No back-up of condensate permitted	• Thermodynamic	

Heating Vertical Pipelines

Tubing can be wrapped around the piping with a steam trap installed at the low point to allow condensate to freely drain by gravity. Partial back-up of condensate using thermostatic trap.

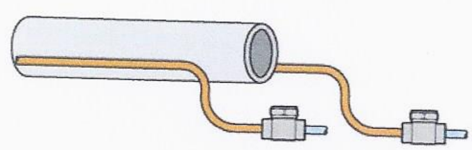


Thermostatic Trap

WT2000 Thermostatic
(5°F - 10°F subcool)

Heating Horizontal Pipelines

Tubing should not be wrapped around horizontal pipelines or condensate will collect at low points. After shutdown, condensate retained in the system could potentially freeze. Therefore, tracing tubing should be run parallel to any piping and sloped slightly towards the steam trap to promote condensate drainage.

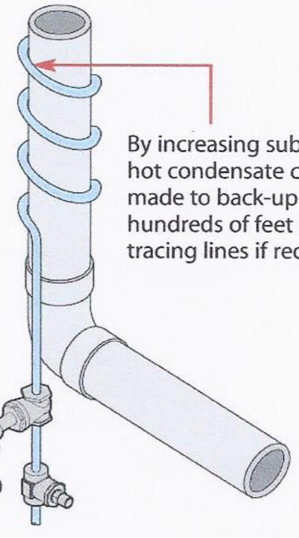


Thermodynamic Traps

TD600

Bi-Metal Steam Trap with Adjustable Discharge Temperature (WT5000)

For applications where overheating of product fluids in a pipeline may be a concern, an Adjustable Bi-Metal Steam Trap, such as the WT5000 (shown), should be considered. The discharge temperature of the condensate can be manually adjusted to control the amount of condensate back-up in the tracing tubing. This technique can be used to control the temperature of the product in the pipeline.



By increasing subcool, hot condensate can be made to back-up into hundreds of feet into tracing lines if required.

WT5000

WT5000 Bi-Metal

Process Steam Trap Selection Guidelines

This guide is intended to provide the user with a "starting point" for the selection of Watson McDaniel steam traps. Steam trap selection can appear to be overwhelming given the range of applications and trap choices available. Selection criteria for a specific application may include pressure & temperature ratings, capacity, physical size & weight, and materials.

Batch Process - Steady Demand

Batch type processes typically have steady demand as a batch of products is heated to a certain temperature. They tend not to experience rapid changes in steam pressure and steam flow. Common examples of such processes are: **• Unit Heaters • Storage Tank Coils • Jacketed Vessels • Pipe Coils**

The primary steam trap type for process equipment is a Float & Thermostatic. The **WFT** & **FTT** Series in Cast Iron and Ductile Iron are the most cost-effective solutions to most applications. The **FTE** Series is for higher capacity applications. The **FT600/601** Series traps are available in Cast Steel or Stainless Steel which may be specified for refineries and higher pressure applications. Since rapid pressure changes do not typically occur with batch processes, Thermostatic Bellows traps can also be selected. The **WT2000, WT3000** & **WT4000** Series have Stainless Steel bodies and may be preferred for outdoor applications to Cast Iron F&T traps, particularly when a potential for freezing exists.

Continuous Process - Varying Demand • Heating Processes (high to ultra-high capacity)

These applications use steam to heat a continuous flowing product. The modulation of the control valve results in rapid change in steam pressure and flow. Common examples of such processes are:

• Heat Exchangers • Air Handling Coils • Instantaneous Water Heaters

The primary steam trap type for process equipment is a Float & Thermostatic. The **WFT** & **FTT** Series in Cast Iron and Ductile Iron are the most cost-effective solutions to most applications. The **FTE** Series is for higher capacity applications. The **FT600/601** Series traps are available in Cast or Stainless Steel which may be specified for refineries and for higher pressure applications.

Safety Load Factors (SLF's) and appropriate rules to size steam traps

The largest condensate load occurs when the maximum steam pressure is present in the Heat Exchanger (HX). However, if the steam trap is selected based on the maximum condensate load at maximum pressure, it will not be adequately sized at lower differential pressures. This is because the capacity of a steam trap depends on the differential pressure across the trap (less pressure means less capacity) and trap capacity decreases **at a significantly faster rate** than condensate load when the steam pressure drops. When temperature control valves are used to control steam flow to a HX, the pressure may reduce to 0 psig or less. The pressure available to discharge condensate would then be based on head pressure of the drop leg. A drop leg length of 14" will produce a head pressure of ½ psig.

Use the following rules and safety factors for the three categories of process applications. This should assure the trap has adequate capacity at lower differential pressure and not be drastically oversized when operating at full pressure.

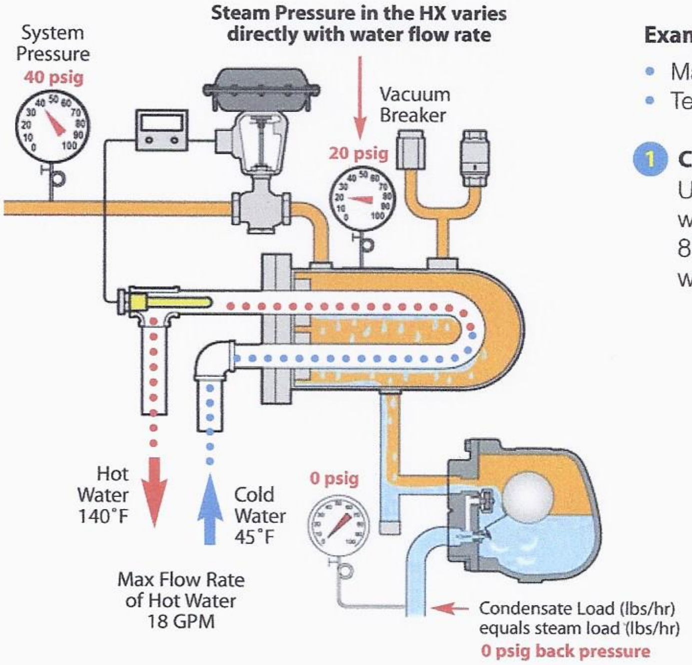
I For applications **NOT** containing a Temperature Control Valve and operate at fairly constant steam pressures; select a steam trap that will handle **2X the maximum condensate load at the maximum differential pressure**.
For Example: if a process will generate 5,000 lbs/hr at 50 psi differential pressure, then choose a trap that can handle 10,000 lbs/hr at 50 psi.

II For applications **WITH** a Temperature Control Valve and steam pressures **OVER 30 PSI**; select a steam trap that will handle **2.5X the maximum condensate load at the maximum differential pressure**.
For Example: if a process is expected to generate 5,000 lbs/hr at 50 psi differential pressure, then choose a trap that can handle 12,500 lbs/hr at 50 psi.

III For applications **WITH** a Temperature Control Valve and steam pressures **UNDER 30 PSI**; calculate the maximum condensate load at the maximum differential pressure; select a steam trap that will handle this **maximum amount of condensate at ½ psi differential pressure**. *For Example:* if a process is expected to generate 5,000 lbs/hr at 15 psi differential pressure, then choose a trap that can handle 5,000 lbs/hr at ½ psi differential pressure. The purpose of the ½ psi differential pressure is to allow condensate to properly drain when system pressure goes into vacuum. This assumes the installation of a vacuum breaker and a drop leg of at least 14" in length (for ½ psig) below the HX to give proper condensate head pressure to the steam trap, and trap discharge to atmospheric pressure (0 psig).

PROCESS Applications • Sizing a Trap for Heat Exchanger Application

Goal: Select appropriate model and size steam trap for Process Water Heating application using a Shell & Tube Heat Exchanger in which a maximum of 18 GPM of water is being heated from 45-140°F. Steam Pressure to the control valve is 40 PSI. The trap is discharging to a condensate return line at atmospheric pressure (0 psig back pressure)



Example: Conditions of Service at Max Load

- Maximum water load to be heated = **18 GPM**
- Temperature Rise: (140°F - 45°F) = **95°F**

1 Calculate Maximum Condensate Load

Using the formula below, to approximate steam load based on water flow rate (GPM) and temperature rise, a Steam Flow of 855 lbs/hr is required; therefore, 855 lbs/hr of condensate will likewise be generated.

$$\textbf{Steam (lbs/hr)} = \frac{\textbf{GPM x Temp. Rise (°F)}}{2}$$

$$= \frac{18 \times 95°F}{2} = 855 \text{ lbs/hr}$$

Steam Flow (lbs/hr) = Condensate Load (lbs/hr)

Condensate (lbs/hr) = 855 lbs/hr

2 Determining the Differential Pressure (ΔP) Across the Trap at the Maximum Condensate Load

In order to size the steam trap, we must first know the pressure in the HX at the Max Condensate Load. This steam pressure is determined by the physical size of the HX. (*note that a larger HX uses lower steam pressure while a smaller HX requires a higher steam pressure to heat the same flow of water*). If the pressure of the HX is not known, assume 50% of the Pressure at the inlet of the control valve is required in the HX to heat the maximum flow of 18 GPM of water. We therefore have (40 psig x 0.5 = 20 psig) **20 psig steam pressure at 855 lbs/hr.**

3 The Condensate Load at 0 psig Steam Pressure and Conditions at other Water Flow Rates

The steam trap cannot be selected solely based the condensate load at the maximum steam pressure because it will be undersized at lower steam pressures (when there is much less force to push the condensate thru the trap). Lower steam pressures occur when less water is being heated. If the steam pressure and condensate load is known at the lowest pressure, the trap can be selected based on that operating point, and it would be adequately sized at higher pressures. In this particular application, we have a gravity return line at 0 psig back pressure.

Load Chart Based on HX Size to Heat 18 GPM of Water using 20 psig Steam Pressure

	Flow Rate Water (GPM)	Steam Flow (required) (lbs/hr)	Steam Temperature (required) in HX (°F)	Steam Pressure (required) in HX (PSIG)	Actual Pressure in the HX (PSIG)	Trap Differential Pressure (PSI)	Condensate Flow (lbs/hr)
At maximum Flow Rate of 18 GPM	**18**	**855**	259	20	**20** steam	**20**	**855**
Flow Rate of Water at 0 psig Steam Pressure	**12.9**	**614**	212	0	**0** steam	**1/2** psi 14" drip leg	**614**
At Flow Rate of 10 GPM of Water	**10**	**475**	185	-6 vacuum	**0** steam & air mixes together	**1/2** psi 14" drip leg	**475**

For this size HX, when water flow rate is 12.9 GPM, the steam temperature required is 212°F, therefore, the steam pressure is 0 psig. At flow rates below 12.9 GPM, the steam pressure would need to go into vacuum or mix with air drawn in thru the vacuum breaker in order to achieve the proper temperature.

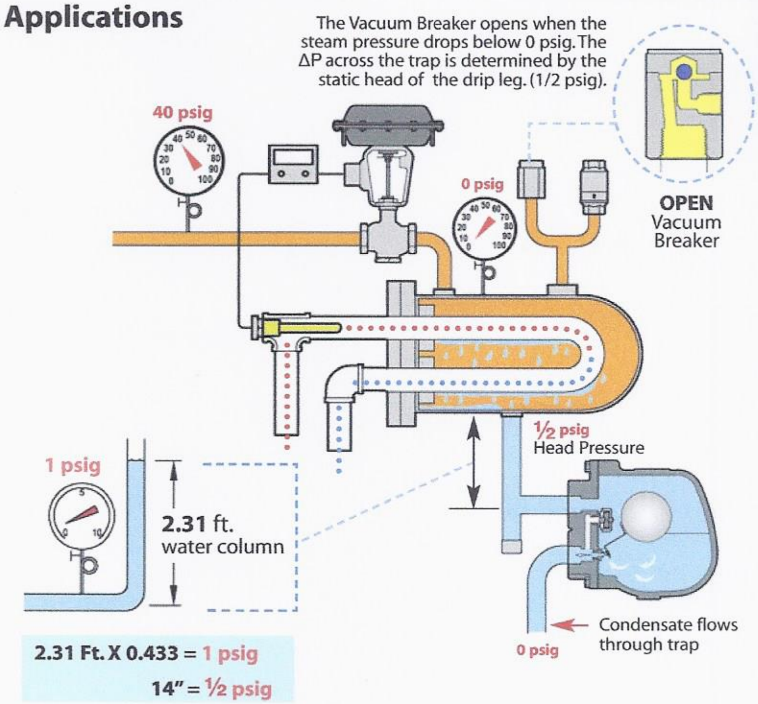
Steam Trap Selection Guidelines • PROCESS Applications

4 Using Safety Load Factors to size Steam Traps

The largest condensate load occurs when the maximum steam pressure is present in the HX. However, if the steam trap is selected based on the maximum condensate load at maximum pressure, it will not be adequately sized at lower differential pressures. This occurs because the capacity of a steam trap decreases *at a significantly faster rate* than condensate load when the steam pressure drops. When temperature control valves are used to control steam flow to a HX, the pressure may reduce to 0 psig or less. The pressure available to discharge condensate would then be based on static head pressure of the drip leg. A drip leg length of 14" will produce a static head pressure of 1/2 psig.

In this application, 614 lbs/hr of condensate is being generated at 0 psig steam pressure. See Load Chart.

The appropriate safety load factor for this application is 2.5X the maximum condensate load of 855 lbs/hr. Therefore, select a steam trap based on:
2.5 x 855 = 2,138 lbs/hr at a differential pressure of 20 psi.



5 Selecting the Steam Trap

The steam trap should be sized for a condensate load of 2.5 x 855 = **2,138 lbs/hr at 20 psi differential pressure.** The HX is assumed to have **20 psig** steam pressure at the maximum water usage of **18 GPM**. However, when selecting the PMO (maximum operating pressure) for the trap, assume the actual pressure could reach nearly the full line pressure of **40 psig**. Therefore, select a trap with a PMO of at least **40 psig**.

Referring to the WFT Capacity chart below, we must select a **WFT-075** model with a PMO of 75 psig. Enter the **20 psi** column inside the **WFT-075** section and scroll down until a condensate load greater than **2,138 lbs/hr** is found. The capacity of **3,850 lbs/hr** is the first condensate load greater than **2,138 lbs/hr**.

For this application, the **WFT-075-15-N** will be capable of discharging the calculated condensate loads of **2,138 lbs/hr** at **20 psi ΔP** and 614 lbs/hr at **½ psi ΔP**.

CAPACITIES – *Condensate (lbs/hr)*

Model Code	PMO (PSIG)	Pipe Size	Orifice Size	Differential Pressure (PSI) 1/4	1/2	1	2	5	10	15	20	30	40	50	75
WFT-015-13-N	15	3/4"	0.250	390	490	620	780	1050	1320	1500					
WFT-015-14-N	15	1"	0.250	390	490	620	780	1050	1320	1500					
WFT-015-15-N	15	1¼"	0.312	610	770	960	1210	1630	2040	2330					
WFT-015-16-N	15	1½"	0.500	1420	1910	2570	3460	5120	6890	8190					
WFT-015-17-N	15	2"	0.625	2260	2950	3860	5040	7170	9360	10930					
WFT-030-13-N	30	3/4"	0.228	330	420	530	670	930	1180	1350	1500	17[illegible]			
WFT-030-14-N	30	1"	0.228	330	420	530	670	930	1180	1350	1500	172[illegible]			
WFT-030-15-N	30	1¼"	0.228	330	420	530	670	930	1180	1350	1500	1720			
WFT-030-16-N	30	1½"	0.390	930	1240	1650	2190	3210	4280	5060	5700	6750			
WFT-030-17-N	30	2"	0.500	1420	1910	2570	3460	5120	6890	8190	9760	11020			
WFT-075-13-N	75	3/4"	0.166	175	225	295	385	545	705	825	920	1075	1200	1305	1525
WFT-075-14-N	75	1"	0.166	175	225	295	385	545	705	825	920	1075	1200	1305	1525
WFT-075-15-N	75	1¼"	0.312	640	850	1130	1500	2180	2900	3420	3850	4540	5110	5600	6610
WFT-075-16-N	75	1½"	0.312	640	850	1130	1500	2180	2900	3420	3850	4540	5110	5600	6610
WFT-075-17-N	75	2"	0.422	1020	1340	1760	2310	3330	4380	5140	5760	6770	7590	8290	9730

Up to 15 PSI

Up to 30 PSI

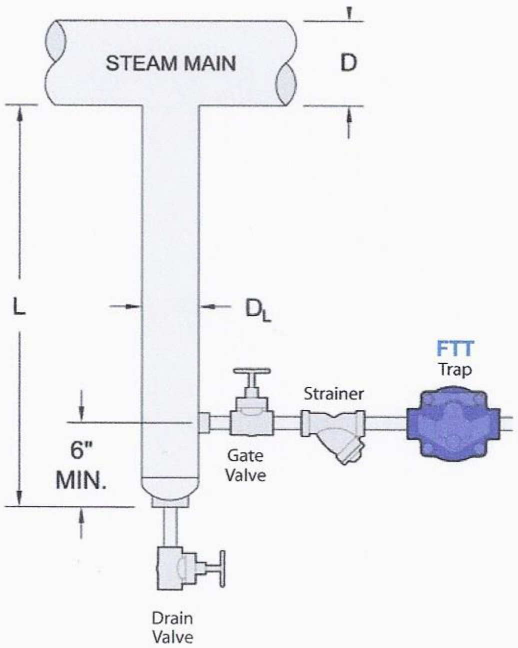
Up to **75 PSI**

This 3/4" trap can discharge 855 lbs/hr at 20 psi but is drastically undersized at 1/2 psi

1¼" trap is able to handle the condensate load of 614 lbs/hr at 1/2 psi. (see Load Chart to left)

The actual load is only 855 lbs/hr. However, with 2.5X SLFs applied, this larger trap was selected since it has adequate capacity at lower pressures.

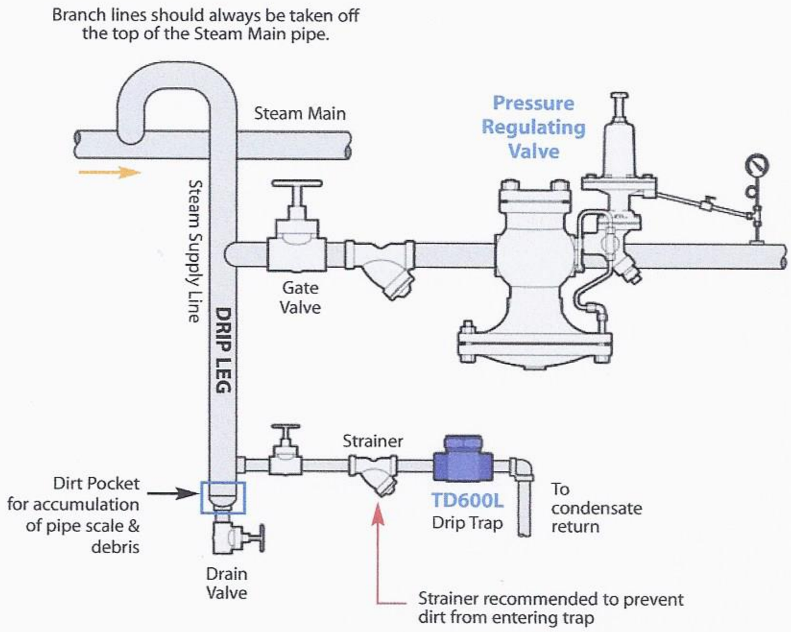
Figure 1: Proper DRIP LEG Designs



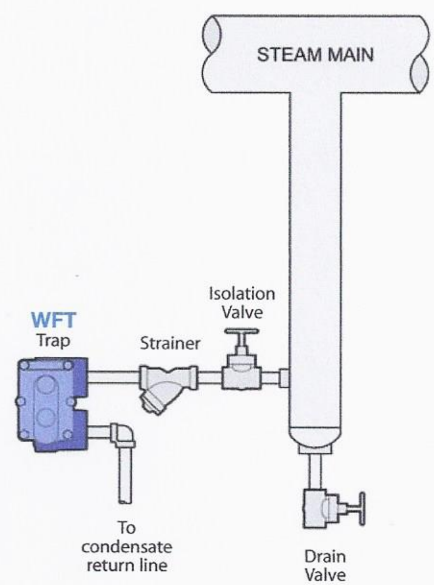
DRIP LEG DESIGN CRITERIA:

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 x D_L, but not less than 8"

DRIP LEG
Before Regulator or Control Valve

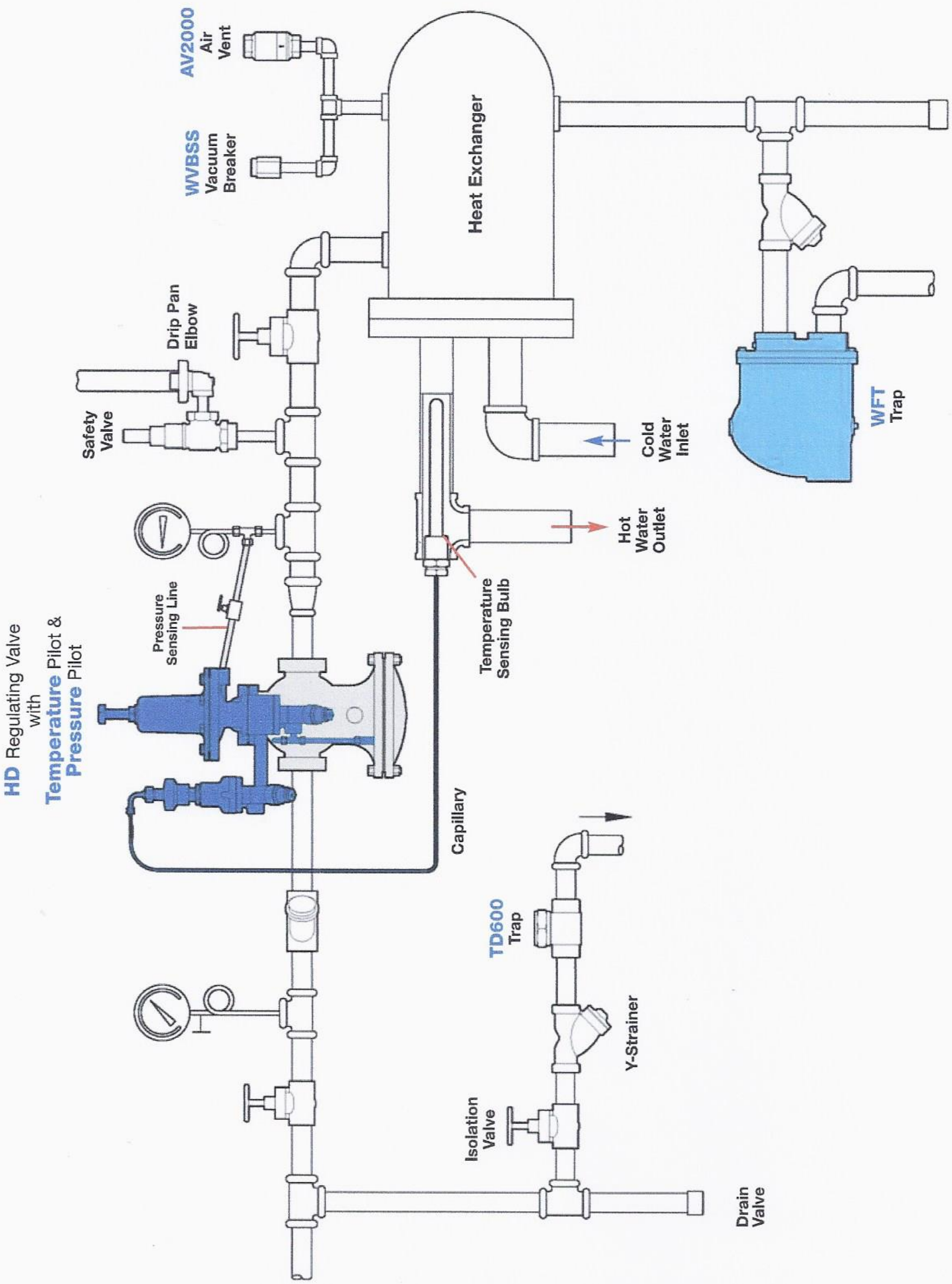


DRIP LEG
Draining Steam Main



PROCESS TRAP GUIDELINES – Gravity Drainage

Figure 2:



Shell & Tube Heat Exchanger with Gravity Drainage of Condensate

CAPACITY FORMULAS FOR STEAM LOADS

Definition of Terms and Units:

Q_S = Steam Load or Steam Capacity (lbs/hr)
E = Heat Load (Btu/hr)
m = Amount of water to cool per time (lbs/hr)
C_P = Specific Heat of fluid being heated (Btu/(lb-°F))
C_{P1} = Specific heat of solid being heated (Btu/(lb-°F))
ΔT = Temperature rise (°F)
ΔT_1 = Condensate Temp. - Temp. Set Point (°F)
ΔT_2 = Temperature difference (°F)
(Temp. set point - temp. of cooling water)

LH = Latent Heat of Saturated Steam (Btu/lb)
s.g. = Specific gravity of fluid
Q_W = Flow rate of water (GPM)
Q_L = Flow rate of liquid (GPM)
Q_{air} = Flow rate of air (CFM or ft³/min)
G = Volume of liquid to be heated (gallons)
t = Time to heat product (hours)
W = Weight of material (lbs)
p_{air} = Density of air (lb/ft³)
500 = 60 min/hr x 8.33 lbs/gal (convert GPM of water to lbs/hr)

APPROXIMATE FORMULAS	EXACT FORMULAS
When Heating Water with Steam $Q_S = \frac{Q_W}{2} \times \Delta T$	$Q_S = \frac{Q_W \times \Delta T \times 500}{LH}$
When Heating Fuel Oil with Steam $Q_S = \frac{Q_L}{4} \times \Delta T$	$Q_S = \frac{Q_L \times \Delta T \times C_p \times 500 \times s.g.}{LH}$
When Heating Air Coils with Steam $Q_S = \frac{Q_{air}}{900} \times \Delta T$	$Q_S = \frac{Q_{air} \times 0.24 \times p_{air} \times 60(min/hr) \times \Delta T}{LH}$
When Heat Load (Btu/hr) is Known $Q_S = \frac{E}{1000}$	$Q_S = \frac{E}{LH}$

When Boiler Output (H.P.) is Known

Q_S = Boiler H.P. x 34.5

Heating Water in Open-Top Tank with Direct Steam Injection

$$Q_S = \frac{G \times \Delta T \times 8.33\ (lbs/gal)}{LH \times t}$$

When Square Feet Equivalent Direct Radiation (EDR) is Known

$$Q_S = \frac{EDR}{4}$$

Heating Liquid in Jacketed Kettles

$$Q_S = \frac{G \times s.g. \times C_P \times \Delta T \times 8.33\ (lbs/gal)}{LH \times t}$$

Condensate Cooling using Water

Step 1: $E = m\Delta T_1$
Step 2: $Q_S = E/\Delta T_2$
Step 3: Water required: $Q_W(GPM) = Q_S/500$

Heating Solids by Direct Steam Injection into Chamber (Platens, Autoclaves, etc.)

$$Q_S = \frac{W \times C_{p1} \times \Delta T}{LH \times t}$$

How to Size Condensate Return Lines

The sizing of condensate return lines presents several problems that differ from those of sizing steam or water lines. The most significant of these is the handling of flash steam. Although a return line must handle both water and flash steam, the volume of flash steam is many times greater than the volume of condensate. For the values in Chart CG-26 the volume of flash steam is 96% to 99% of the total volume. Consequently, only flash steam is considered in Chart CG-26.

Condensate return lines should be sized to have a reasonable velocity at an acceptable pressure drop. Chart CG-26 is based on having a constant velocity of 7,000 feet per minute or below, using Schedule 40 pipe. Additional factors that should also be considered—depending on water conditions—are dirt, fouling, corrosion and erosion.

For a given supply pressure to the trap and a return line pressure, along with an assumed pressure drop per 100 feet of pipe (ΔP/L) and knowing the condensate flow rate, the proper pipe diameter can be selected from Chart CG-26.

How to Use Chart CG-26

Example 1: A condensate system has the steam supply at 30 psig. The return line is non-vented and at 0 psig. The return line is to have the capacity for returning 2,000 lbs/hr of condensate. What must be the size of the return line?

Solution: Since the system will be throttling the condensate from 30 psig to 0 psig, there will be flash steam (assuming no subcooling), and the system will be a dry-closed (not completely full of liquid and not vented to atmosphere) return. The data in Chart CG-26 can be used. A pressure of 1/4 psig per 100 feet is selected. In Chart CG-26 for a 30 psig supply and a 0 psig return for ΔP/L = 1/4, a pipe size for the return line of 2" is selected.

Example 2: A condensate return system has the steam supply at 100 psig and the return line is non-vented and at 0 psig. The return line is horizontal and must have a capacity of 2,500 lbs/hr. What size pipe is required?

Solution: Since the system will be throttling non-subcooled condensate from 100 psig to 0 psig, there will be flash steam, and the system will be a dry-closed return. Selecting a pressure drop of 1 psi per 100 feet yields from Chart CG-26 a non-recommended situation (a). Select a pressure drop of 1/4 psi per 100 feet and then a 2-1/2" pipe can be used for this system.

Chart CG-26. Flow Rate (lbs/hr) for Dry-Closed Returns

ΔP/L psi/100'	Supply Pressure = 5 psig Return Pressure = 0 psig			Supply Pressure = 15 psig Return Pressure = 0 psig			Supply Pressure = 30 psig Return Pressure = 0 psig			Supply Presssure = 50 psig Return Pressure = 0 psig		
D, in	1/16	1/4	1	1/16	1/4	1	1/16	1/4	1	1/16	1/4	1
1/2	240	520	1,100	95	210	450	60	130	274	42	92	200
3/4	510	1,120	2,400	210	450	950	130	280	590	91	200	420
1	**1,000**	**2,150**	**4,540**	**400**	**860**	**1,820**	**250**	**530**	**1,120**	**180**	**380**	**800**
1-1/4	2,100	4,500	9,500	840	1,800	3,800	520	1,110	2,340	370	800	1,680
1-1/2	3,170	6,780	14,200	1,270	2,720	5,700	780	1,670	3,510	560	1,200	2,520
2	**6,240**	**13,300**	**a**	**2,500**	**5,320**	**a**	**1,540**	**3,270**	**a**	**1,110**	**2,350**	**a**
2-1/2	10,000	21,300	a	4,030	8,520	a	2,480	5,250	a	1,780	3,780	a
3	18,000	38,000	a	7,200	15,200	a	4,440	9,360	a	3,190	6,730	a
4	**37,200**	**78,000**	**a**	**14,900**	**31,300**	**a**	**9,180**	**19,200**	**a**	**6,660**	**13,800**	**a**
6	110,500	a	a	44,300	a	a	27,300	a	a	19,600	a	a
8	228,600	a	a	91,700	a	a	56,400	a	a	40,500	a	a

ΔP/L psi/100'	Supply Pressure = 100 psig Return Pressure = 0 psig			Supply Pressure = 150 psig Return Pressure = 0 psig			Supply Pressure = 100 psig Return Pressure = 15 psig			Supply Pressure = 150 psig Return Pressure = 15 psig		
D, in	1/16	1/4	1	1/16	1/4	1	1/16	1/4	1	1/16	1/4	1
1/2	28	62	133	23	51	109	56	120	260	43	93	200
3/4	62	134	290	50	110	230	120	260	560	93	200	420
1	**120**	**260**	**544**	**100**	**210**	**450**	**240**	**500**	**1,060**	**180**	**390**	**800**
1-1/4	250	540	1,130	200	440	930	500	1,060	2,200	380	800	1,680
1-1/2	380	810	1,700	310	660	1,400	750	1,600	3,320	570	1,210	2,500
2	**750**	**1,590**	**a**	**610**	**1,300**	**a**	**1,470**	**3,100**	**6,450**	**1,120**	**2,350**	**4,900**
2-1/2	1,200	2,550	a	980	2,100	a	2,370	5,000	10,300	1,800	3,780	7,800
3	2,160	4,550	a	1,760	3,710	a	4,230	8,860	a	3,200	6,710	a
4	**4,460**	**9,340**	**a**	**3,640**	**7,630**	**a**	**8,730**	**18,200**	**a**	**6,620**	**13,800**	**a**
6	13,200	a	a	10,800	a	a	25,900	53,600	a	19,600	40,600	a
8	27,400	a	a	22,400	a	a	53,400	110,300	a	40,500	83,600	a

[a] For these sizes and pressure losses the velocity is above 7,000 fpm. Select another combination of size and pressure loss.