A GUIDE TO STEAM TRAPS

The purpose of this guide is to discuss the steam system and the application of steam traps to assist in the control and operation of steam systems. Utilizing the techniques involved in maximizing steam system efficiency through the understanding of steam trap selection and application can make a direct and substantial contribution to company profits through energy conservation.

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WHAT IS STEAM?

Steam is a convenient and economical way of conveying large quantities of energy from one place to another. It is versatile and easy to control, made from a plentiful commodity - water - to which heat is added to convert it to a vapor state - steam.

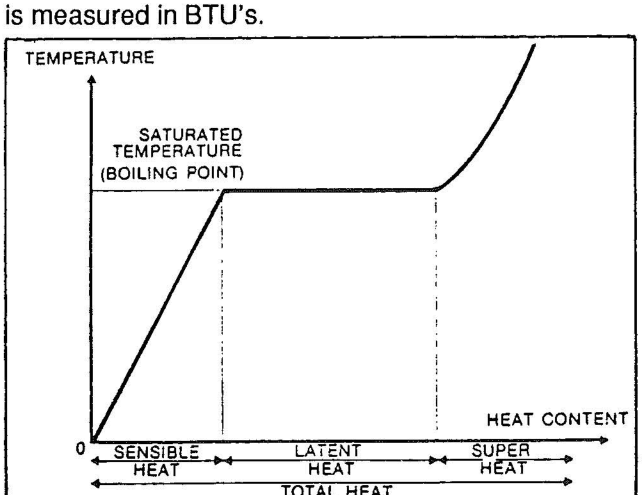
To understand steam, we must understand several terms.

The common unit for measuring heat energy is the **British Thermal Unit (BTU)**. When heating fluid there is a definite relationship between the amount of heat added and the temperature rise. This ratio is called the specific heat. For water, the specific heat is 1 BTU per lb. per degree F.

In order to raise 1 lb. of water 10 degrees F *(from 70 to 80 degrees F, for instance),* 10 BTU's of heat energy is needed. To bring water to a boil, it is necessary to bring it from its' initial temperature to the boiling point corresponding to the pressure that the water is under. There is a maximum amount of energy that can be put into the water to bring it to the boiling point, or saturated water state, however...

If we continue to add heat, once the water has reached this saturated condition, two things will happen. First, the water will begin to boil (vapor will begin to form) and, second, the water temperature will stop increasing and stabilize *(at 212 degrees F under atmospheric conditions).* The water in this saturated state has all the heat it can hold and remain liquid; adding more heat changes the water from the liquid state to a vapor state - steam is forming.

The heat contained in the water, at any temperature, is called **sensible heat.** Once the liquid has reached its' saturated state, any additional heat which produces the constant temperature phase change is termed the **latent heat of vaporization.** The sum of the sensible heat and latent heat in the steam vapor is the **total heat** or **enthalpy.** Enthalpy may be defined as a measure of how much heat a substance contains. It is measured in BTU's.



As water and steam are heated they absorb heat. Over the different portions of the heating cycle, this heat is identified by the following definitions.

Sensible Heat (Heat of the liquid) the heat required to raise the temperature of a unit mass of water from freezing point to saturated temperature (boiling point).

Latent heat (Heat of the vapor) the heat required to convert a unit mass of water at saturated temperature to dry steam at the same temperature.

Total heat (The total heat in the steam at any time) it is the total of the sensible heat, the latent heat and the super heat.

THE STEAM CURVE

Although water boils at 212 degrees F under atmospheric conditions (0 psig) the boiling point rises as the pressure on the water rises. If the water were under a pressure of 100 lbs. per square inch gage (psig), the temperature of the water would have to be raised to 338 degrees F before boiling could occur. This relationship between the boiling point or saturation temperature and pressure is shown on the steam curve Figure 2, below.

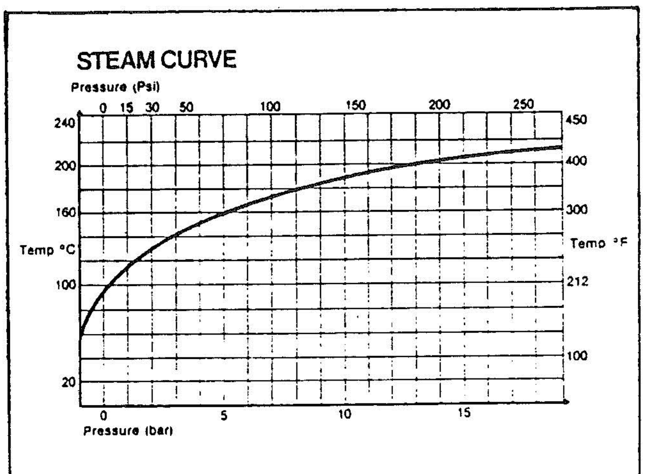


Figure 2.

When water is heated in an open container it will boil at 100 degrees C/212 F. If it is heated in a closed container the pressure will increase and the boiling action will occur at a higher temperature. The relationship between boiling point (more correctly called the saturation temperature) and pressure is shown on the steam curve. The exact saturation temperature at any operating pressure can be obtained by reference to steam tables.

The exact saturation temperature at any operating pressure is shown in the **steam tables** (Figure 3).

The steam table shows the relationships between the system pressure, saturation temperature, sensible heat, latent heat and total heat.

Take, as an example, water at atmospheric pressure and 32 degrees F. There is no heat content (0 BTU/lb.) - the enthalpy is zero. As we add heat to this water, the temperature rises. The slope of this line is the **specific heat capacity** of the liquid. When the saturated liquid state is reached (212 degrees F), the sensible heat in one lb. of water equals 212 degree F minus 32 degrees F or 180 BTU (180 degrees F x 1 BTU/lb./F = 180 BTU). From the steam table under sensible heat corresponding to 0 psig you will find 180 BTU/lb.

STEAM TABLE

	Pressure	Temperature F	Sensible Heat BTU/lb.	Latent Heat BTU/lb.	Total Heat BTU/lb.
Inches of	(15	179	147	991	1138
Vacuum	(10	192	160	983	1143
	5	203	171	976	1147
psig	0	212	180	971	1151
	1	215	183	969	1152
	3	221	190	964	1154
	5	227	196	960	1156
	10	239	207	952	1159
	15	250	218	946	1164
	20	258	227	940	1167
	25	266	236	934	1170
	30	274	243	929	1172
	35	280	250	924	1174
	40	286	256	920	1176
	45	292	263	915	1178
	50	297	267	912	1179
	55	302	273	908	1181
	60	307	277	905	1182
	65	311	281	903	1184
	70	316	286	899	1185
	75	320	290	896	1186
	80	323	294	893	1187
	85	327	298	890	1188
	90	331	302	887	1189
	95	334	305	884	1189
	100	338	309	881	1190
	110	344	316	876	1192
	120	350	322	871	1193
	130	355	328	867	1195
	140	360	333	863	1196
	150	365	339	858	1197
	175	377	350	848	1198
	200	387	362	838	1200
	225	397	372	830	1202
	250	406	381	821	1202
	300	422	399	805	1204
	400	448	428	778	1206
	500	470	453	752	1205
	600	489	475	729	1204
	800	520	512	687	1199
	1000	546	545	647	1192
	1250	574	581	600	1181
	1500	599	614	554	1168
	1750	618	644	509	1153
	2000	637	674	461	1135

Additional heat added to the 1 lb. of water will vaporize the liquid. This occurs with no further increase in temperature. When the 1 lb. of water has completely vaporized, a certain amount of latent heat has been added. The **saturated vapor** (or steam) at this point has enthalpy (total heat content) equal to the sensible heat plus the latent heat.

From the steam table, the total heat contained in the 1 lb. of steam formed equals 1151 BTU *(180 BTU sensible heat plus 971 BTU latent heat).*

At a pressure of 100 psig, you will note that the relationship between the sensible heat, latent heat and total heat changes from the example given at 0 psig. It requires a greater amount of sensible heat to raise the 1 lb. of water to a saturated liquid state but a lesser amount of latent heat to convert the saturated liquid to saturated vapor. The total heat energy in the 1 lb. of water increases slightly to 1190 BTU. Thus, the temperature at which the transition from liquid to gas occurs varies depending on the operating system pressure as does the total heat of the steam. To find the total amount of heat energy, multiply the total steam mass of the system by the total heat at the system pressure as determined from the steam table.

One additional property of steam to be considered is superheat. This is the amount of heat required to raise a unit mass of steam from saturation temperature to any greater temperature (Figure 4).

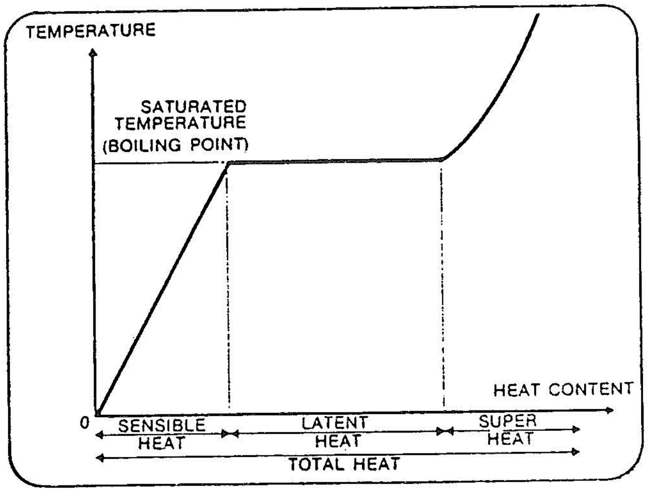


FIGURE 4

Water can exist when the mass times the total heat does not equal the amount shown in the steam table at any given pressure. The temperature of that water will not exceed the saturation temperature. Conversely, when energy exceeding the total heat as shown in the steam table is added, raising the temperature above the saturation point, all of the mass is converted to steam vapor and no water in the liquid state can exist. The amount of temperature above the saturation point for any given pressure is called the **degrees of superheat.**

THE USE OF STEAM

Steam is used because it is a convenient and economical way of conveying large quantities of energy from one place to another. To utilize this energy, we must remove some of the heat and transfer it to some process. This exchange of energy is **heat transfer.**

In other words, the steam gives up its' enthalpy to some other medium. This exchange occurs in various types of equipment or heat exchangers. A typical example would be a jacketed kettle used to heat soup for cooking.

The soup is placed in a container which is surrounded by a steam space (Figure 5).

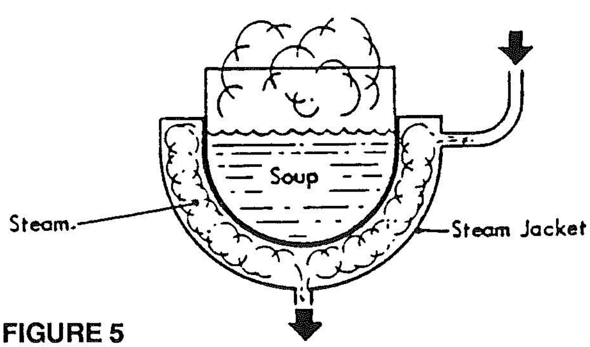


FIGURE 5

As steam is introduced to the steam jacket, heat transfer occurs through the metal wall of the kettle to the soup as the metal wall and the soup are cooler than the steam. The BTUs transferred reduces the total heat of the steam by the amount transferred which causes condensate to form in the bottom of the jacket (Figure 6).

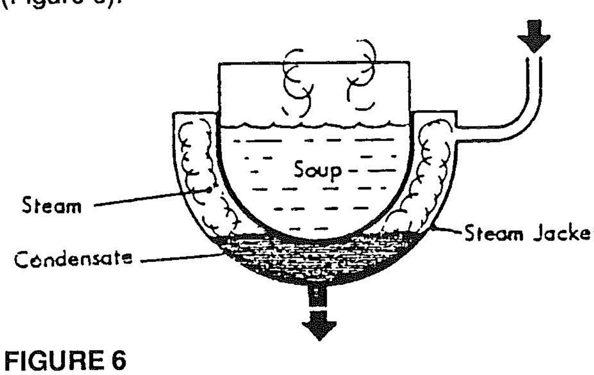


FIGURE 6

This condensate (water) forms as the steam gives up latent heat through heat transfer. BTUs of latent heat have been transferred through the metal kettle wall to the soup which in turn causes the soup to heat up to the required temperature.

The FIRST RULE for the efficient use of steam **is that it is the latent heat that does the work.**

As the steam proceeds to give up its latent heat, condensate forms at the bottom of the jacket and must be drained as quickly as possible in order to maximize the efficiency of the system. If the condensate is not removed rapidly, it will cover part of the heating surface and reduce the area through which heat transfer can take place from the steam to the soup. Although the hot condensate is capable of giving up heat equal to the difference in temperature between the soup and the condensate, as it transfers heat it reduces in temperature. Steam, on the other hand, as it gives its latent heat, does not reduce in temperature.

If we use steam at 30 psig (274 degrees F), it contains 929 BTU/lb. of latent heat. As it gives up heat to the kettle, the temperature of the condensate, as it forms, is also 274 degrees F. But it contains sensible heat of only 243 BTU/lb. As the condensate forms, it, being heavier than steam, falls to the bottom of the jacket (Figure 7).

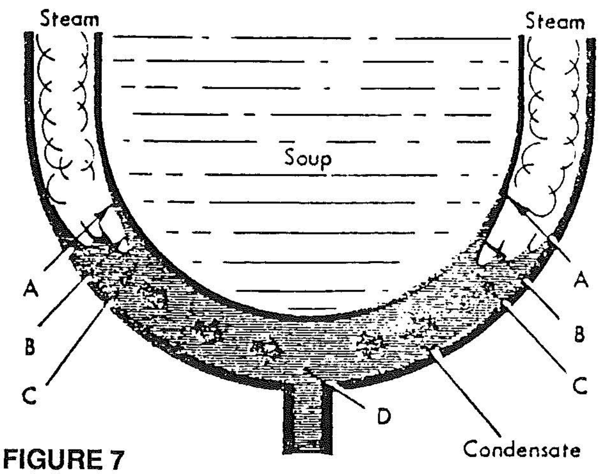


FIGURE 7

At point 'C', the condensate temperature is roughly equal to the steam temperature, but at point 'D' it is cooler because it is farther away from contact with the steam.

The conditions at a stage about half way through the heating of the soup could be as follows:

- Soup temperature - 150 degree F
- Steam temperature - 274 degree F (30 psig)
- Condensate temperature at 'C' - 274 degree F
- Condensate temperature at 'D' - 230 degree F

The temperature difference between the steam and the soup is 124 degrees F (274-150). The temperature difference between the condensate at 'C' and the soup is about the same, but between the condensate at 'D' and the soup, the temperature difference is only 80 degrees F (230 - 150). The rate of heat transfer between the condensate and the soup would be very much lower than that between the steam and the soup and thus the quantity of heat that the condensate is able to give up is very small compared to the quantity of heat available in the steam.

Note also that a water film is forming at point 'A' and is getting thicker at point 'B' as the water begins to run down the walls of the jacket. Because water has a very high resistance to heat transfer, this film forms a definite obstruction to the effective heat transfer from the steam to the soup. Heat transfer is the amount of heat that will flow from one substance to another and is a direct function of the temperature difference between the two. The temperature of a saturated liquid and a saturated vapor are the same. However, as sensible heat is removed from the liquid, its temperature will drop, thus the factor causing heat flow - temperature difference - will decrease as heat is removed, whereas removing latent heat from steam will merely condense some of it but leave the system at the initial temperature difference. In the case of steam at atmospheric pressure there is roughly 5.4 times more latent heat available for transfer at a constant temperature difference than the entire amount of sensible heat (971 divided by 180 = 5.4).

There is another advantage of condensing steam as a heat transfer medium. Since the saturation temperature is a function of pressure, the temperature can be controlled in a heat exchanger by controlling the pressure. When the exchanger is full of steam at a given pressure, the temperature on all contact surfaces is the same. Steam provides uniform, flexible temperature control in heat transfer equipment like no liquid can. It is also easier to convey than a liquid.

So the SECOND RULE is that **the temperature difference between the steam and the product to be heated determines the rate of heat transfer and the output of a particular process.**

STARTING LOAD AND RUNNING LOAD

At the initial stage of operation of the soup kettle, the temperature difference between the hot steam, the cold metal and the cold soup was the greatest. At this stage, the greatest rate of heat transfer took place, the greatest quantity of steam per minute was used and the greatest quantity of condensate per minute was formed. This condition is described as the **starting (or start-up) load.** When the metal of the kettle has been warmed and the soup becomes warmer, the conditions gradually change. The temperature difference between the steam and the soup gradually lessen; the rate of heat transfer gradually slows; the rate of steam consumption eases; the rate of condensation eases. These conditions are described as **running load.** It is important to recognize that the difference between the starting load and the running load can be significant. It is therefore important that the system be sized such that the condensate can be drained from the equipment as rapidly as possible. Because heat transfer takes place towards any surface or substance which is cooler than the steam itself, in direct relationship to the temperature difference, the condensate must be removed from contact with the steam so that it does not absorb heat or prevent the transfer of heat to the process.

Insulation is used to reduce or prevent the heat transfer from taking place on non-productive surfaces.

AIR AND NON-CONDENSABLE GASES

Like condensate, air will blanket heat transfer surfaces (Figure 8) but its resistance to heat flow is much greater. Air also reduces the temperature of the steam in a steam/air mixture as dictated by **Dalton's Law of Partial Pressure.** Air enters a steam system in two ways. First, during shut-down, the steam in the line and equipment condenses. The drastic change in volume leaves the system under a vacuum. Vacuum breakers then open to allow air to enter the steam system to prevent the pipes from collapsing. Air can also enter through valves, joints and so on.

Second, air is also contained in water. When water is boiled, the air is released and carried with the steam. The density of steam and air are quite close under the same conditions, thus the air is pushed along with the steam.

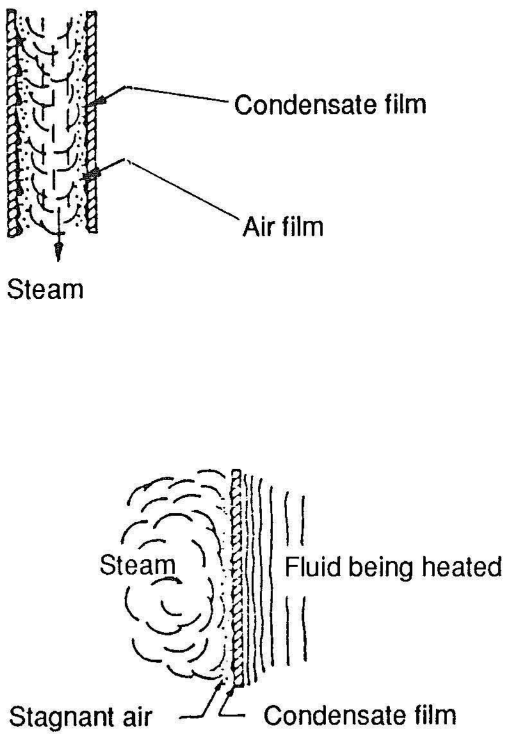


FIGURE 8

In a steam system, the steam naturally flows towards the cooler heat transfer surfaces, condenses and the water is carried by gravity to the drain. The air is carried along with the steam to the heat transfer surface; however, air does not condense so it is left there when the steam condenses. This film of air acts as an insulating blanket reducing the heat transfer efficiency. Steam and condensate can push the air to the discharge from the process equipment but there are installations where the air can "pocket" and cannot get to the drain.

Pressure psig	Temp. of Steam, No Air Present	Temp. of Steam Mixed with Various Percentages of Air (by Volume)		
		10%	20%	30%
10.3	240.1	234.3	228.0	220.9
25.3	267.3	261.0	254.1	246.4
50.3	298.0	291.0	283.5	275.1
75.3	320.3	312.9	304.8	295.9
100.3	338.1	330.3	321.8	312.4

FIGURE 9

As previously mentioned, air reduces the temperature of the steam as determined by Dalton's Law of Partial Pressures. Because the density of air and steam are very close, they mix. With any mixture of gases, each gas exerts only a portion of the total pressure based on the amount present. Thus, for example, if a mixture of gases is two-thirds steam and one-third air by weight, and the pressure in the system is 30 psig, the steam is at 20 psig and the air at 10 psig.

Because the pressure in any system is the total of the mixture, we would assume that the steam is at 30 psig (saturated temperature of 274 degrees F). But because of the quantity of air in the system, the steam is actually at a pressure of 20 psig (258 degrees F).

The system will be operating at a greatly reduced output because the latent heat available is based on the steam pressure of 20 psig instead of 30 psig. The mixture of steam and air has reduced the output of the unit because it has reduced the temperature (Figure 9).

Air and non-condensable gases must be removed from the equipment or from the steam by the use of deaerators in the boiler feed water system.

HOW DOES THE CONDENSATE GET OUT?

To this point, we have described the conditions on the steam side of the process and the formation of condensate in the heat transfer process. It is evident that something must be done to get rid of the condensate and the air and non-condensable gases to assure efficiency in the process by keeping the heating surfaces blanketed with steam.

It would be a simple matter to discharge the condensate if it were not for the fact that the steam is very costly to produce. We could allow it to drain out through a hole or pipe in the bottom of the soup kettle as in the example, but significant quantities of steam would be able to blow out also. It is therefore necessary to find some way to discharge the condensate without letting out any of the steam.

Several options are available to control the flow of condensate from the kettle.

Some sort of restriction to flow is necessary such as a reduced size outlet pipe, an orifice in the discharge pipe, or a valve which can be regulated to adjust the rate of discharge.

All of these possible solutions, although easy to understand and relatively inexpensive to install, have one main drawback - the question of sizing for the rate of flow. If we use a small discharge pipe or an orifice, the most obvious question is "For which load do we size?" If we size for the start-up load, which is significantly larger than the running load, the kettle will get up to temperature rapidly. But when we approach the running load conditions, this oversizing will allow large amounts of steam to escape with the condensate. On the other hand, if we size for running loads, the arrangement will not have enough capacity to handle the start-up load and the equipment could become **water logged,** and reduce the amount of heat transfer surface available for contact with steam. There is no regulating or adjusting feature available to compensate for the changing loads.

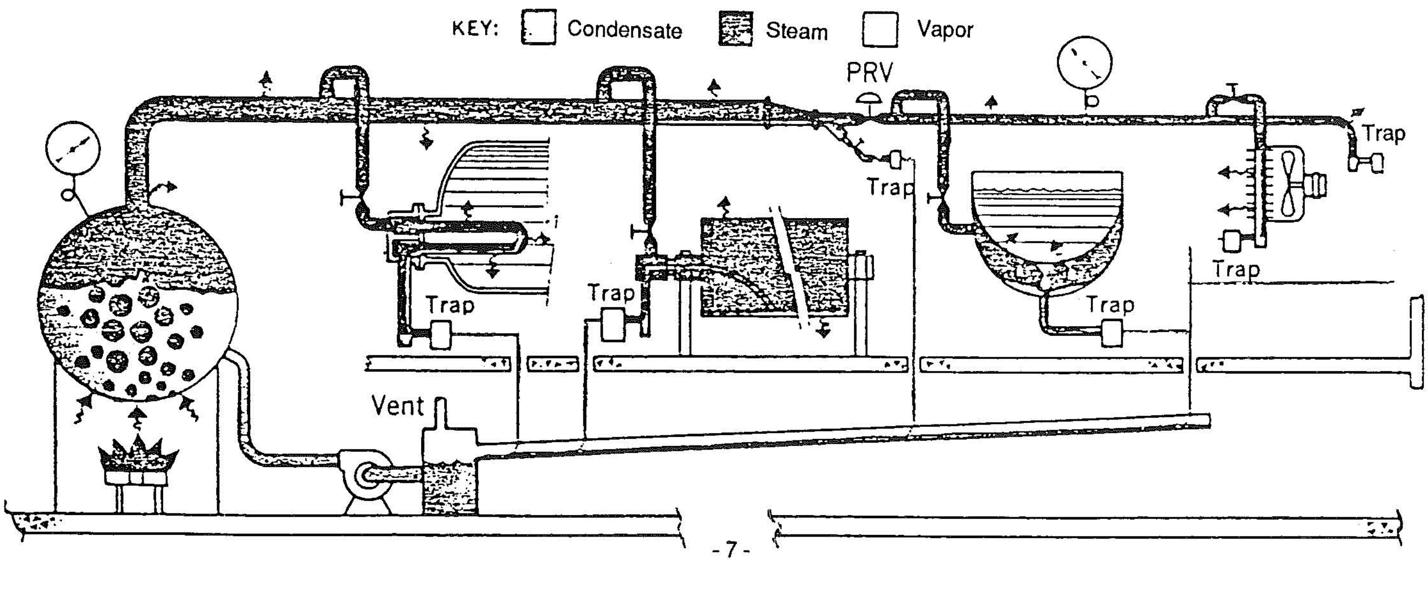
A valve such as a globe valve or other type of flow regulating valve could be used and could work satisfactorily. During start-up, the valve could be opened a large amount in order to handle the high starting condensate load. As the load diminished due to the drop in temperature difference between the steam and the product being heated, the valve could be gradually closed. At each stage a balance between the discharge capacity of the valve and the condensate load would be possible. This would require the use of an operator in constant attendance and even then there would be the probability that the valve would never be adjusted exactly right to match the load conditions - it would either be closed too much allowing condensate to back up or open too much allowing steam to escape.

The answer then is a valve which will automatically open to release condensate and close to prevent steam from escaping. The name for an automatic valve of this type is a **steam trap.**

The steam trap is an integral part of any steam system as the efficiency of the condensate drainage system is dependent upon the steam trap doing its' job. It is as critical to the heating efficiency of a system as is the steam control elements on the inlet side of the equipment.

THE INDUSTRIAL STEAM CYCLE

In industrial plants, the steam supply circuit can be very complex (Figure 10). Steam is generated in a boiler which is usually gas, oil or coal fired. The steam is generated at pressures corresponding to the maxi-



mum plant needs, and is distributed to various portions of the plant through steam mains. At the process areas where the heat is required, it is taken off from the steam mains by secondary piping systems.

In some cases, it is run through pressure reducing valves to reduce the pressure and temperature of the steam. After going through the processing equipment and giving up its latent heat, the condensate formed is either discharged to the ground or returned to the boiler where it is reheated to steam and recirculated.

The system consists of two main components - the **steam supply system** and the **condensate return system.** The basics of the steam system have been covered up to this point. The condensate return system is a more simple system to explain but is nearly as important.

If the condensate is drained to the ground or to a sewer, there is little to the system except to insure that the pipe size is large enough to carry off the amount of condensate formed. A condensate return system requires more consideration.

FLASH STEAM

In any piece of process equipment when the steam condenses, the condensate initially forms at the saturation temperature, then has a slight temperature reduction before leaving the equipment. The condensate is discharged to a lower pressure system through a device such as a steam trap.

This hot condensate contains a significant amount of energy in the form of sensible heat. When the differential pressures (difference between inlet and outlet pressures) are great enough, too much energy is contained in the condensate at the reduced pressures. Because this energy must be used in some way, the excess converts some of the condensate to vapor as it discharges to the lower pressures (Figure 11).

For example, assume an inlet pressure of 100 psig (338 degrees F) and a return main pressure of 0 psig (212 degrees F). A pound of condensate at 100 psig saturated temperature contains 309 BTU/lb. A pound of condensate at 0 psig saturated temperature can only contain 180 BTU/lb. The difference of 129 BTU is in the form of latent heat at 0 psig and thus turns a portion of the discharged condensate into vapor called **flash steam.**

The formula for the calculation of flash steam is:

$$\%\ \text{Flash Steam (wgt)} = \frac{\text{Sen. Ht. @P1-Sen. Ht. @P2}}{\text{Latent Heat @P2}} \times 100$$

= 309-180 x100

= 971

= 13.3%

P1 = Inlet pressure (operating pressure)

P2 = Outlet pressure (back pressure)

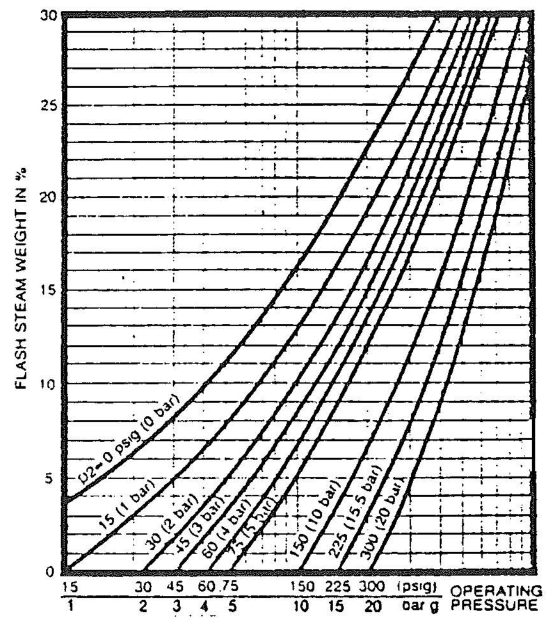


FIGURE 11

There is also a significant volumetric increase in the discharge of hot condensate. In the example shown, the volumetric increase is approximately 1500 to 1.

$$\text{Increase} = \frac{\text{volume (cu. ft./lb.) of vapor at P2}}{\text{volume (cu. ft./lb.) of water at P1}}$$

$$1506 = \frac{26.8}{.0178}$$

This factor must be taken into account when sizing the return mains.

The THIRD RULE of steam trapping is **when high pressure and temperature condensate is discharged to a lower pressure, the reduction in pressure produces flash steam.**

THE FUNCTION OF THE STEAM TRAP

The definition of a steam trap can be given as "A device which automatically opens to permit the discharge of air and non-condensable gases and condensate at, or below, saturated steam temperature and closes to prevent or limit the passage of steam."

In order to understand the operative principles of steam traps, it is necessary to define the following terms:

Operating Pressure the pressure at the inlet to a steam trap.

Back Pressure the pressure at the outlet of a steam trap.

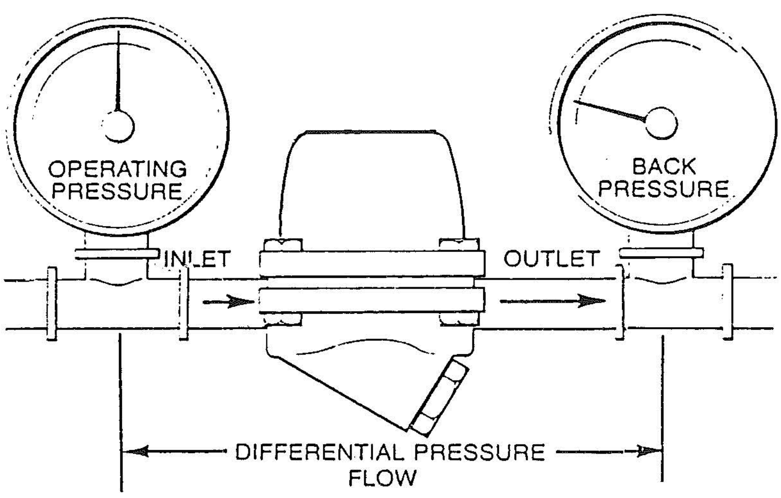
Differential Pressure this is the difference between the operating pressure and the back pressure.

Operating Temperature the temperature measured at the inlet of a steam trap under operating conditions.

Maximum Operating Temperature the maximum temperature allowed at the inlet of a particular steam trap (as specified by the manufacturer).

Saturated Temperature the temperature at which steam is formed, which varies according to pressure.

Maximum Operating Pressure the maximum pressure allowed at the inlet to a particular steam trap (as specified by the manufacturer).



Steam traps of almost any type are able to tell the difference between steam and condensate. They share certain characteristics but differ in their operating principles and the source of energy used to make them operate.

All steam traps contain an orifice, the size of which determines the condensate capacity or the amount of water that is able to pass through the trap at any set of operating conditions. The main difference between the types of traps is the design elements used to control the discharge orifice.

Some steam traps discharge condensate in a continuous flow which can vary according to the rate at which condensate if forming. They are referred to as **continuous discharge traps.**

Other traps operate in an intermediate fashion - wide open discharging condensate alternating with periods of being completely closed. The time between the cycles varies according to the type of steam trap and the operating conditions. The time that the trap is fully open varies according to the condensate conditions at the inlet of the trap. Traps that operate in this fashion are referred to as **blast discharge traps** or **cyclic traps.**

There are applications where operating characteristics are useful in helping to select the most efficient steam trap for a particular job. No one has yet designed the "perfect" steam trap - that is, a trap which is exactly right for every installation regardless of pressure, temperature, condensate load, discharge characteristics, or whatever.

The FOURTH RULE is **there is no universal steam trap.**

There have been many different types of steam traps made by many different manufacturers throughout the world since the first effective steam trap appeared about 1870. Many of these variations will not be covered so that we can concentrate on the types of steam traps that are commonly in use today in industrial and commercial applications.

The illustrations used and the operating principles described for each type of steam trap will be that developed by a recognized leader in the manufacture of that particular type of steam type.

The traps will be described in no particular order and we will not go into the history and development of the steam trap.

Steam traps can be classified into five (5) categories:

Steam Traps

1. Mechanical
   a. Ball float
   b. Float and thermostatic
   c. Open bucket
   d. Inverted bucket

2. Thermostatic
   a. Bellows
   b. Bi-Metal
   c. Liquid expansion

3. Thermodynamic
   a. Impulse
   b. Disc

4. Combination
   a. Thermostatic/thermodynamic

5. Miscellaneous
   a. Labyrinth
   b. Orifice
   c. Wax filled

Each of these trap types will be covered in the following separate sections.

Mechanical- Ball Float

a. Ball Float

Plant control

1. Continuous discharge
2. Same hot and cold capacity
3. Rapid response to changing load conditions
4. Can operate on very low pressure differential
5. Not for superheat applications
6. Not freeze-proof (self-draining)

Energy Control

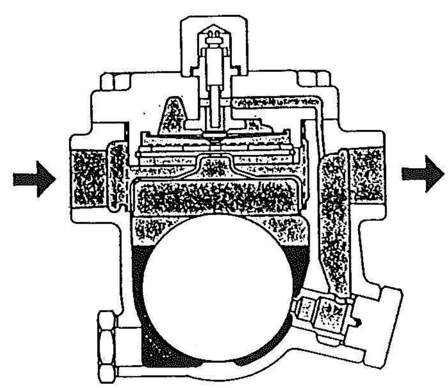
1. Water seal on discharge orifice - steam tight

Installed Cost

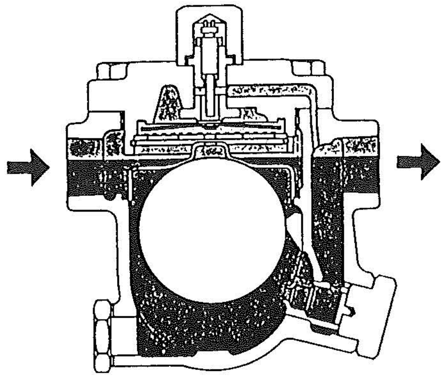
1. Mount in one position only
2. Moderate size and weight

Reliability

1. Few moving parts
2. Water hammer can damage float
3. Can fail closed in over-pressure situations
4. Normally fails open

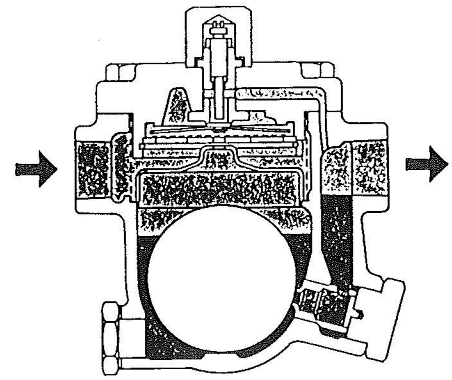


On start-up the bi-metallic plate in the cover is concave upward and keeps the vent valve bore open. This allows the air to flow out freely through the vent valve bore and results in faster start-up.



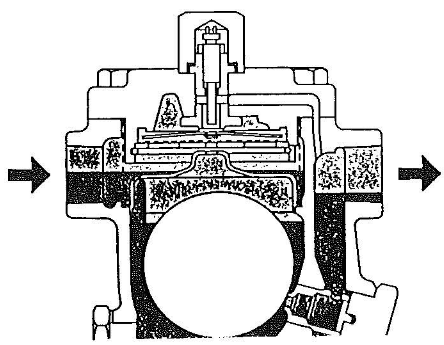
During normal operation an increase in the condensation rate causes the condensate level in the trap to rise. The float, therefore, rises and enlarges the opening of the orifice allowing more condensate to flow out. On the contrary, when the condensation rate decreases, the opening of the orifice also decreases, allowing less condensate discharge.

In this manner condensate discharge is performed continuously without time lag, and is self-regulated in accordance with the condensation rate. This results in the most efficient operation of the equipment.



When condensate flows into the trap, the float rises due to buoyancy and allows the mixture of air and condensate to be discharged. The temperature of hot condensate causes the bi-metallic plate to flex upward and close the valve seat, sealing by pressure differential.

Air venting is not completed but condensate will continue to be discharged as long as condensation occurs.



Even with a very light load the trap continuously discharges. If flowing in of condensate should stop, the float seals the orifice with no steam leakage because the orifice is always situated below the condensate level (water seal).

When there is a temporary drastic increase in flow of condensate, the float immediately rises, allowing quick discharge. The trap then resumes normal continuous discharge.

Mechanical- F & T

b. Float & Thermostatic

Plant Control

1. Continuous discharge
2. Same hot and cold capacity
3. Rapid response to changing load conditions
4. Can operate on very low pressure differential
5. Not for superheat applications
6. Not freeze-proof (self-draining)

Energy Control

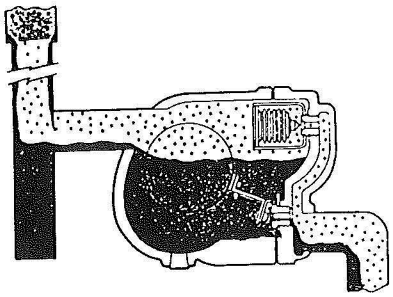
1. Possible steam loss through air vent
2. Water seal on discharge orifice - steam tight

Installed Cost

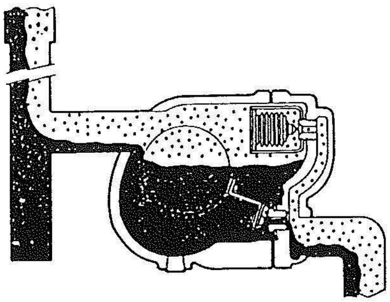
1. Mount in one position only
2. Large size and weight
3. Not for drip and tracer applications

Reliability

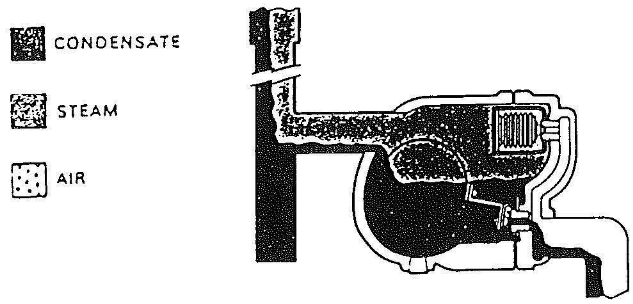
1. Long service life on low pressure
2. Water hammer can damage float
3. Can fail closed in over-pressure conditions
4. Normally fails closed



1. On start up, main float-actuated valve is normally closed. Air is pushed through open thermostatic air vent by steam pressure. When condensate reaches trap (above), float opens the main valve to permit flow. Remaining air continues to discharge through open vents.



2. When steam reaches trap, thermostatic air vent closes in response to higher temperature. Condensate continues to flow through main valve which is positioned by float to discharge condensate at same rate as rate at which condensate is flowing to trap.



3. Air from system will now begin to accumulate in top of trap. When temperature of air drops a few degrees below saturated steam temperature at existing pressure, thermostatic air vent opens and discharges air.

Mechanical - Open Bucket

c. Open Bucket

Plant Control

1. Cyclic discharge
2. Same hot and cold capacity
3. Rapid response to changing load conditions
4. Can operate on very low pressure differential
5. Poor air handling capacity
6. Not for superheat applications
7. Not freeze-proof (self-draining)

Energy Control

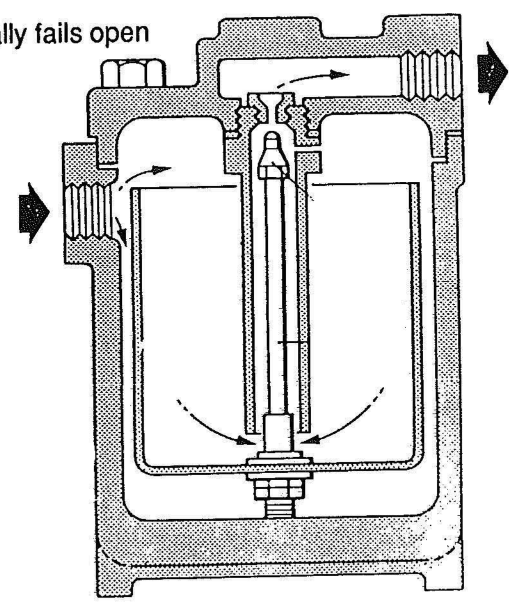
1. Steam tight

Installed Cost

1. Mount in one position only
2. Very large size and weight
3. Not for drip and tracer applications

Reliability

1. Long service life on low pressure applications
2. Resistant to water hammer
3. Normally fails open



These traps operate only as the condensate is received. After the trap chamber is filled, the condensate overflows into the bucket, which drops and opens the valve seat orifice. After condensate is discharged, the bucket again floats and the valve closes.

Mechanical - Inverted Bucket

d. Inverted Bucket

Plant Control

1. Cyclic discharge
2. Same hot and cold capacity
3. Moderate response to changing load conditions
4. Can operate on very low pressure differential
5. Poor air handling capacity
6. Not for superheat applications
7. Not freeze-proof (self-draining)

Energy Control

1. Uses live steam to operate (approx. 2 lbs/hr.)
2. Water seal on discharge orifice - steam tight

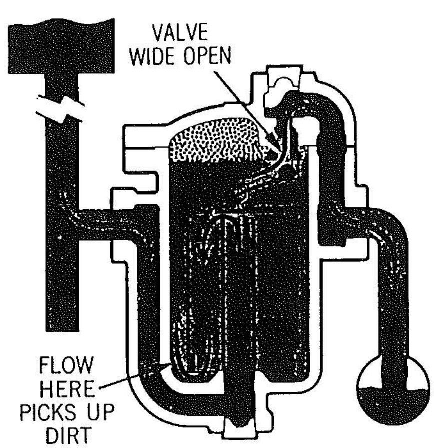
Installed Cost

1. Mount in one position only
2. Moderate size and weight
3. Not for tracer applications

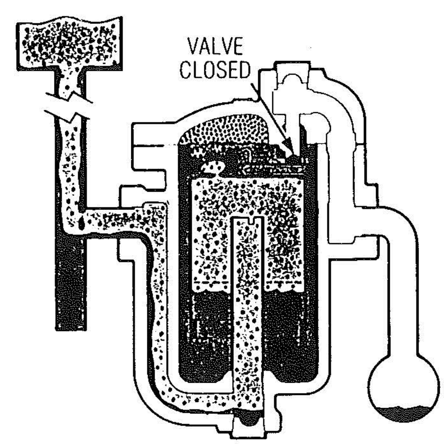
Reliability

1. Long service life on low pressure applications
2. Resistant to water hammer
3. Can fail closed in over - pressure situations
4. Can fail open (lose prime) on rapid pressure drop
5. Normally fails open

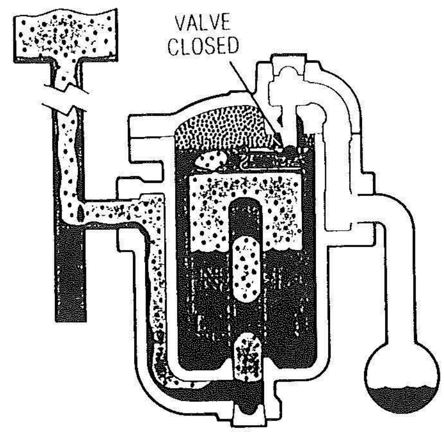
KEY Steam Condensate Air Flashing Condensate



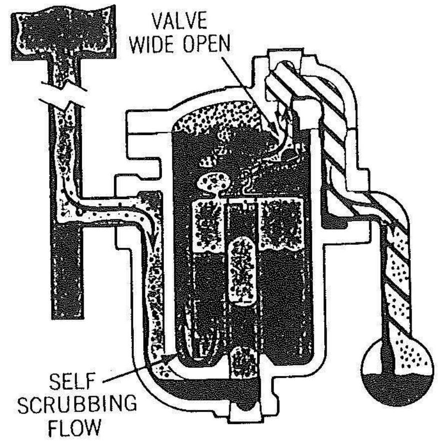
1. Steam trap is installed in drain line between steam heated unit and condensate return header. At this point, bucket is down and valve is wide open. As initial flood of condensate enters the trap and flows under bottom edge of bucket, it fills trap body and completely submerges bucket. Condensate then discharges through wide open valve to return header.



2. Steam also enters trap under bottom edge of bucket, where it rises and collects at top, imparting buoyancy. Bucket then rises and lifts valve toward its seat until valve is snapped tightly shut. Air and carbon dioxide continually pass through bucket vent and collect at top of trap. Any steam passing through vent is condensed by radiation from trap.



3. When entering condensate brings the condensate level slightly above the neutral line, the bucket exerts a slight pull on the lever. The valve does not open, however, until the condensate level rises to the opening line for the existing pressure differential between the steam and the condensate return headers.



4. When the condensate level reaches opening line the weight of the bucket, times leverage, exceeds the pressure holding valve to its seat. Bucket then sinks and opens trap valve. Any accumulated air is discharged first, followed by condensate. Discharge continues until more steam floats bucket at which time cycle begins to repeat.

Thermostatic - Bellows

a. Bellows (Balanced Pressure)

Plant Control

1. Continuous discharge (cyclic on low loads)
2. Same hot and cold capacity
3. Slow response to changing load conditions
4. Can operate on very low pressure differential
5. Excellent air handling capacity
6. Not for superheat applications
7. Not freeze-proof (self-draining)

Energy Control

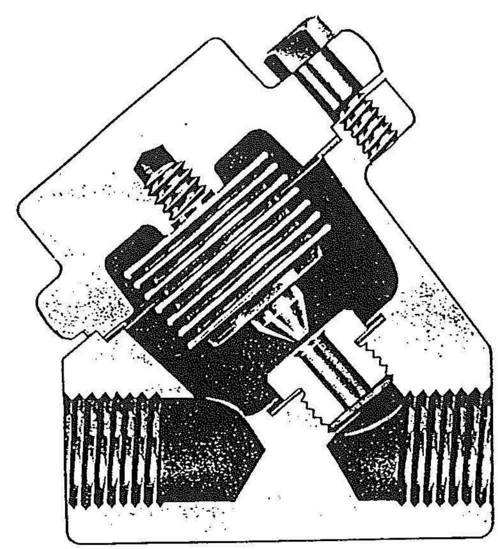
1. Steam tight

Installed Costs

1. Mount in any position
2. Small size and weight

Reliability

1. Limited service life
2. Bellows may be damaged by water hammer
3. Fails open (liquid filled bellows)
4. Fails closed (vacuum bellows)



The bellows is partially filled with distilled water under high vacuum and is compressed by the pressure difference. The valve is now open for discharge. When steam enters, vapor pressure inside the bellows equals trap pressure, permitting spring action of bellows to close valve fast. Just a slight temperature differential causes instant trap action on light or heavy loads. They do not have to be adjusted since the characteristics of the water filled bellows match the saturated steam pressure- temperature curve.

b. Bi-Metal - (Stacked Leaf or Stacked Disc)

Plant Control

1. Continuous discharge (cyclic on low loads)
2. Slow response to changing load conditions (stacked leaf type)
3. Can operate over wide pressure range
4. Very good in high pressure service (over 600 psig)
5. Excellent air handling capacity
6. Excellent on superheat
7. Not freeze-proof (self-draining)

Energy Control

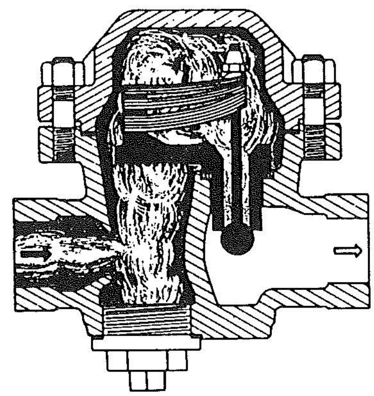
1. Steam tight
2. Can be set to utilize sensible heat

Installed Costs

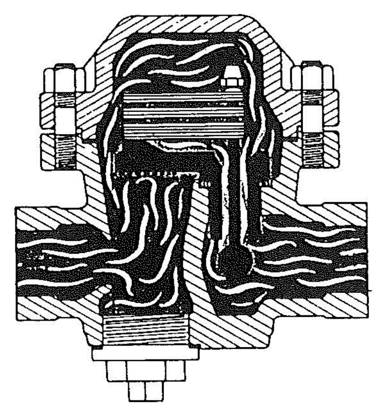
1. Mount in any position
2. Small size and weight
3. Will act as check valve

Reliability

1. Good service life over wide pressure range
2. Resistant to water hammer
3. Must be adjusted for high back pressure application
4. May require resetting due to wear (stacked disc type)
5. Not good for process applications (stacked leaf type)
6. Normally fails open



Incoming steam contacting the bi-metallic element causes the bimetal to deflect and develops the thermal power to act on the valve steam, overcomes line pressure and closed the valve tight. The power of the Bi-metal element increases or decreases as a function of the relative temperature of Saturated Steam. The same element operates efficiently at any pressure within its given range.

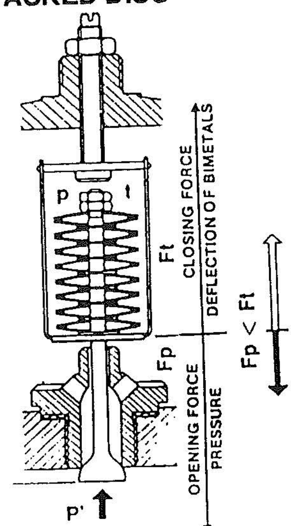


STACKED LEAF

Cooler condensate gradually reduces the pull until the unbalanced pressure on the valve cracks the orifice and releases the flow.

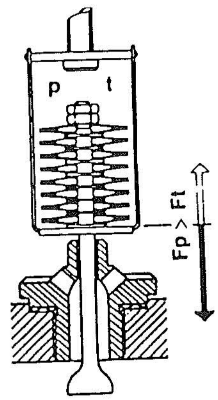
The operating principle of bi-metallic steam traps is based on the simultaneous action of two opposite forces; one resulting from the working pressure (open force Fp), and the second from the push exerted by bi-metallic strips that deflect as a result of changes in the working temperature (closing force Ft). The extent of the valve opening is determined by the predominance of one of these forces (Fig 1). *See next page.*

STACKED DISC



Inverted valve acting as a check valve in case of back pressure P'.

FIGURE 1



Modulating movement of the inverted valve according to P and T variations.

FIGURE 2

Thus; as condensate temperature increases, force Ft increases, overcoming force Fp and drawing the valve closer to its seat, reducing the condensate flow. As closing force Ft becomes more important than the opening force Fp the trap begins to close.

Conversely, with the arrival of cooler condensate at the trap, the bi-metallic strips relax and the valve moves away from the seat, permitting an increase in condensate flow. The opening force Fp becomes greater than the closing force Ft. The trap begins to open (Fig. 2).

As a result, condensate is discharged continuously at the rate at which it is formed and not discharged into the condensate system in slugs. This permanent valve equilibrium allows the trap to respond quickly to any pressure or flow variations.

In case of sudden back pressure, the inverted valve closed (Fig. 1) and acts as a check valve.

Thermostatic - Steam Efficient Design

c. Thermostatic - Diaphragm (balanced pressure)

Plant Control

1. Continuous discharge
2. Same hot and cold capacity
3. Fast response to changing loads
4. Can operate over wide pressure range
5. Excellent air handling capacity
6. Not for superheat application
7. Not freeze-proof (self-draining)
8. Short operating stroke for greatest efficiency
9. Positive seating without the use of a guide
10. No restriction of condensate flow

Energy Control

1. Steam tight

Installation Costs

1. Mount in upright position
2. Small size and weight
3. Union nut and tail pieces

Reliability

1. Long service life
2. Diaphragm may be damaged by water hammer
3. Fails open (recommended for comfort heating)

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Thermostatic - Liquid Expansion

d. Liquid Expansion

Plant Control

1. Continuous discharge
2. Slow response to changing load conditions
3. Limited application range
4. Good air handling capacity
5. Not for superheat applications
7. Not freeze-proof (self-draining)

Energy Control

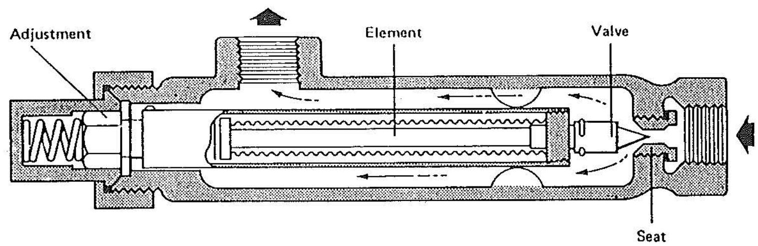
1. Steam tight
2. Can be set to utilize sensible heat

Installed Costs

1. Mount in any position
2. Small size and weight

Reliability

1. Good service life
2. Fair resistant to water hammer
3. Not self-adjusting to pressure changes
4. Not good for process applications
5. Normally fails open



This is one of the simplest thermostatic traps and is shown diagrammatically in Fig 1. An oil filled element expands when heated to close the valve against the seat. The adjustment allows the element to be moved relative to the seat which effectively alters the temperature of the trap discharge.

The problem is that the temperature of steam varies with pressure. The trap, on the other hand, can only be set to operate at a fixed temperature. Fig. 2 shows the saturation curve for steam together with the response line of the liquid expansion trap and illustrates the problem. At pressure P1 condensate would have to cool by only a small amount and trapping would be acceptable. However, if pressure is increased to P2 then condensate has to cool appreciably before passing through the trap and serious waterlogging will take place. At reduced pressure P3 the trap will blow live steam.

Thermodynamic - Impulse

a. Impulse

Plant Control

1. Continuous discharge.(cyclic on low loads)
2. Same hot and cold capacity
3. Can operate over wide pressure range
4. Fair air handling capacity
6. Limited use on superheat
7. Freeze-proof (self-draining)

Energy Control

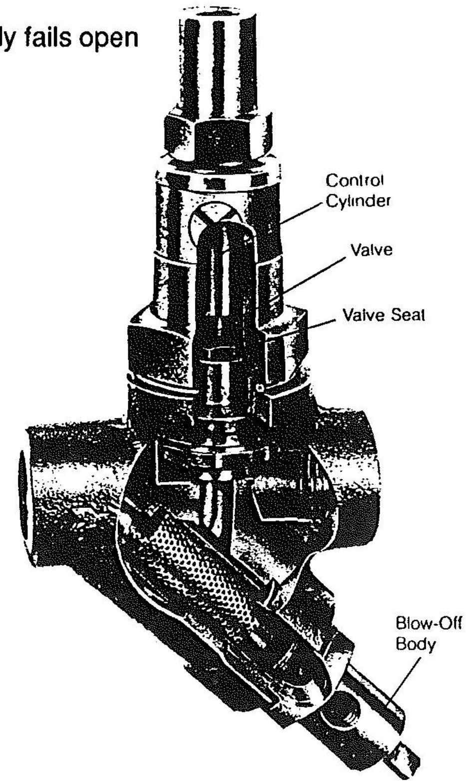
1. Live steam loss on light loads (approx. 2 lbs/hr.)
2. Does not give tight shut off

Installed Costs

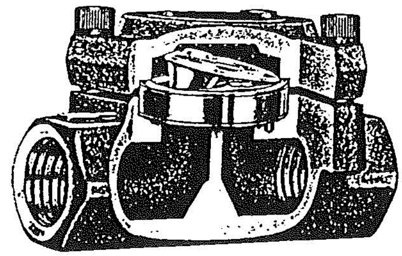
1. Mount in horizontal position only
2. Small size and weight

Reliability

1. Limited service life
2. Resistant to water hammer
3. Not good on drip and tracing service
4. Will not operate on greater than 40% back pressure
6. Normally fails open



On start-up, flow of air and cool condensate lifts the piston valve permitting discharge at full capacity. As condensate temperature approaches steam temperature, flashing occurs in the orifice in the piston valve. This chokes the flow and increases the pressure in the control chamber. The pressure build-up overcomes the forces on the under side of the piston valve snapping it closed to prevent steam loss. A slight drop in condensate temperature reduces flashing in the orifice. Chamber pressure decreases and the piston valve re-opens. The cycle is repeated.



On start-up, flow of a high volume of air and cool condensate tilts open the lever valve to permit discharge at full capacity. As steam temperature condensate reaches the trap flashing begins in the orifice of the valve and pressure builds up in the chamber above the valve. The valve closes as the pressure increases. A small "control flow" of steam temperature condensate and flash steam continues to reach the chamber permitting the trap to respond immediately to inlet conditions. A slight drop in condensate temperature reduces flashing in the orifice. Pressure in the control chamber drops and the valve re-opens.

Thermodynamic

b. Disc

Plant Control

1. Cyclic discharge
2. Same hot and cold capacity
3. Can operate over wide pressure range (except very low)
4. Poor air handling capacity
5. Limited use on superheat
6. Freeze-proof (self-draining)

Energy Control

1. Live steam loss on all loads (approx. 2 lbs/hr.)
2. Can cause high return line pressures

Installed Costs

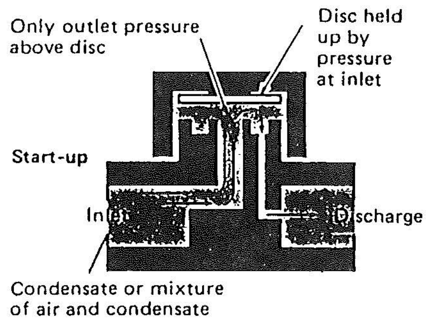
1. Mount in any position
2. Small size and weight

Reliability

1. Short effective service life
2. Resistant to water hammer
3. Use limited to drip and tracing service

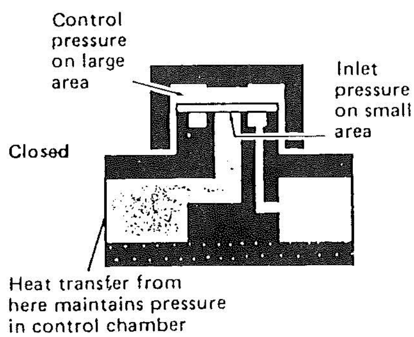
4. Limited use on greater than 50% back pressure

5. Fails open



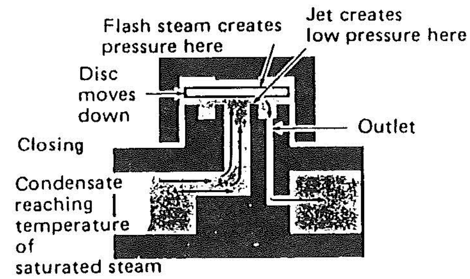
Start-up

Pressure of condensate or air lifts the disc off its seats. Flow is across the underside of the disc to the three outlet holes. Discharge continues until flashing condensate approaches steam temperature.



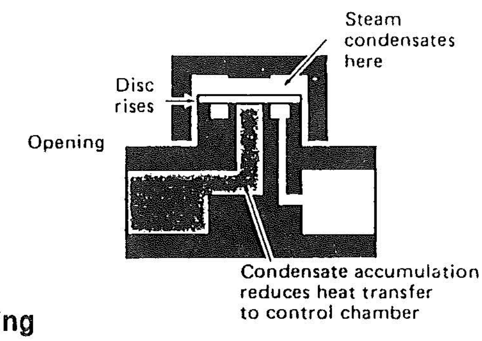
Closing

A high-velocity jet of flash steam reduces pressure under the disc and at the same time, by recompression, builds up pressure in the control chamber above the disc. This drives the disc to the seats assuring tight closure without steam loss.



Closed

Flash steam pressure in the control chamber, acting over the total disc area, holds the disc closed against inlet pressure acting over the smaller inlet seat area.



Opening

As soon as condensate collects it reduces heat transferred to the control chamber. Pressure in the chamber decreases as steam trapped there condenses. The disc is lifted by inlet pressure and condensate is discharged.

Combination

a. Thermostatic/Thermodynamic

Plant Control

1. Modulating discharge
2. Can operate over wide pressure range
3. Rapid response to load changes
4. Excellent air handling capacity
5. Excellent on superheat service
6. Freeze-proof (self-draining)

Energy Control

1. Steam tight
2. Can be set to utilize sensible heat

Installed Costs

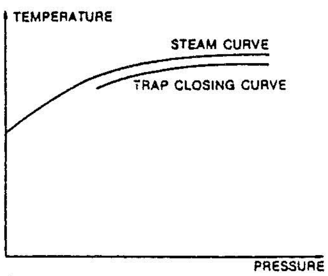
1. Mount in any position
2. Small size and weight
3. Will act as check valve

Reliability

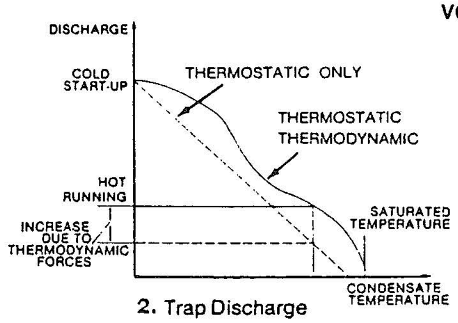
1. Long service life over wide pressure range
2. Resistant to water hammer
3. Restricted operation on very high back pressures
4. Limited application on very small differential pressures

5. Fails open

The robust single blade bi-metal which replaces the stack is resistant to the ingress of dirt so eliminating problems of wear and loss of setting.



1. Trap Closure



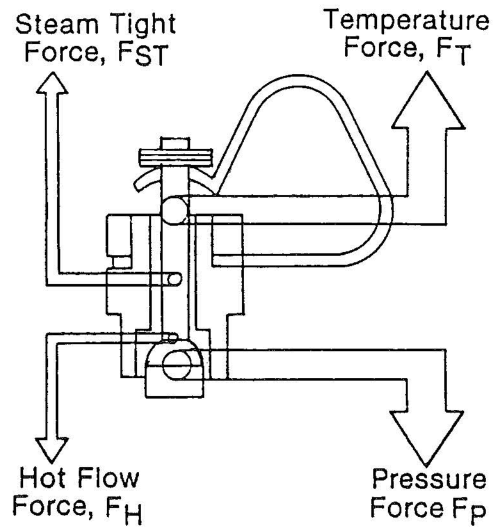
2. Trap Discharge

The single blade bi-metal is combined with a (3) three stage valve orifice system containing an expansion chamber formed between the seat and skirt of the valve steam which introduces thermodynamic forces in the valve.

The higher intermediate pressure on the valve face resulting from the (3) three stage orifice increases the opening force on the valve compared with a pure bi-metallic thermostatic trap. The controlled generation of flash steam within the expansion chamber increases the intermediate pressure and resultant opening force on the valve.

These additional hot flow opening forces, increase the hot discharge capacity and reduce discharge velocity through the valve seat. This extends seat life.

As condensate temperature increases and discharge reduces, the flashing takes place closer to the seat at the entrance to the expansion chamber. At very low loads, well below normal service conditions, the flashing occurs in the inlet passage, causing choking of the flow and a drop in intermediate pressure. This causes a sudden reduction in the opening force allowing the vi- metal closing force to take over and pull the valve tightly onto the seat. This action will only occur under abnormally dry line conditions and provides additional security against live steam loss. In normal use where there is always condensate forming from the process vessel, steam main or heater the modulating action matches discharge rate with condensing rate without fully closing the trap. The closing force is called the steam tight force.



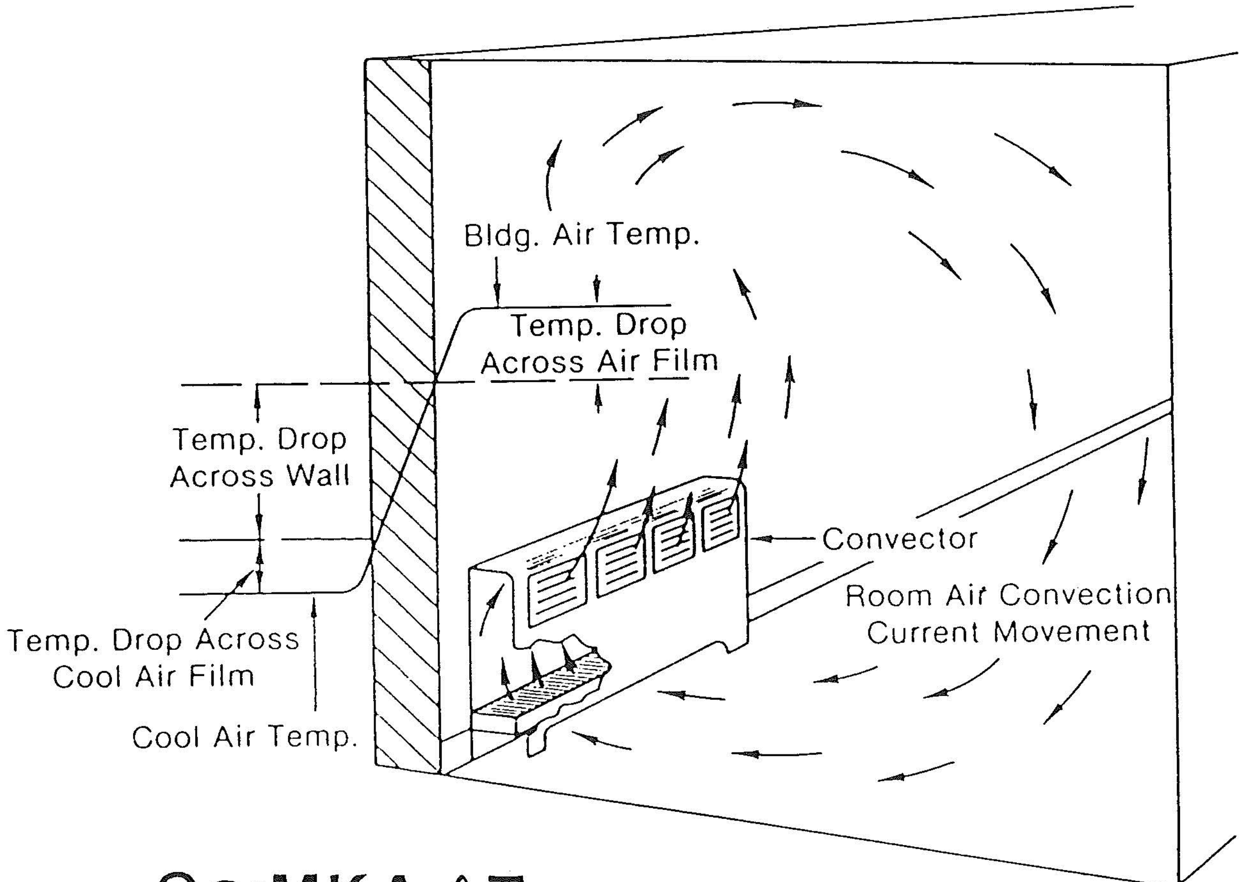
1. The thermostatic forces ensure that the third generation trap is self adjusting to operating pressure within its working range.

2. The modulating discharge enhanced by the thermodynamic flow forces enable third generation bi-metallic traps to be applied not only to tracing and drip legs but also to high capacity process and heating applications.

Heat Transfer

See next page.

Heat Transfer



$$Q \approx MKA\Delta T$$

Q = BTU/HR

M = Mass rate of flow (lb/hr)

K = Resistance factor - Various films opposing energy flow 1) water films 2) air films

A = Area feet squared of heating surface

ΔT = Temperature difference driving force in heat transfer moves hot to cold.

STEAM TRAP INSTALLATION

A. General Notes

1. **Steam Supply** - Take off from the top of the steam main so as to pick up dry steam only.

2. **Gravity Drain** - In order for the steam trap to drain the equipment, it is important that the condensate flow by gravity through the equipment to the steam trap. If possible, the return lines should drain away from the steam trap.

3. **Trap Location** - The steam trap should be located approximately 2' from and below the discharge of the equipment.

4. **Strainers** - Recommended with all steam traps as they increase trap life by removing scale and dirt from the system. Where 'Y' type strainers are used, blow-down valves are recommended.

5. **Isolating Valves** - Gate or ball valves should be installed before and after the steam trap to facilitate maintenance by isolating the trap from the rest of the system.

6. **Unions** - Install between the isolating valves and the steam trap so that it may be removed and replaced as required.

7. **Bypass Hook-ups** - In certain applications, such as cold start-up of the steam mains at the beginning of the season, it may be practical to install a bypass valve manifold around the steam trap so as to give additional high capacity. A steam trap may be used in place of the valve.

8. **Dirt Pockets** - Where formation of scale can cause problems in the system, a dirt pocket should be installed. A blow down valve will remove the scale from the dirt pocket.

9. **Check Valves** - Recommended whenever the condensate is "lifted" above the elevation of the discharge of the steam trap. They prevent the back-flow and siphoning of condensate from the return main equipment. Not necessary with steam traps with built-in check valve.

10. **Air Vents** - Installed to vent large quantities of air from the equipment.

11. **Vacuum Breakers** - Will eliminate problems by introducing air to prevent a vacuum from forming in equipment when it cools. The following precautions should be observed:
a. A check valve may be used.
b. The vacuum breaker line should be open to atmosphere. Connected to the return line, condensate could be drawn into the equipment on shut-down.
c. The vacuum breaker should be installed at the lowest temperature point such as at the equipment outlet.

12. **Short Circulating/Group Trapping** - Can be caused when (2) two or more pieces of equipment discharge into a common steam trap. Each piece of equipment should be sized and trapped separately.

FIGURE 1

B. Typical Steam Trap Hook-ups

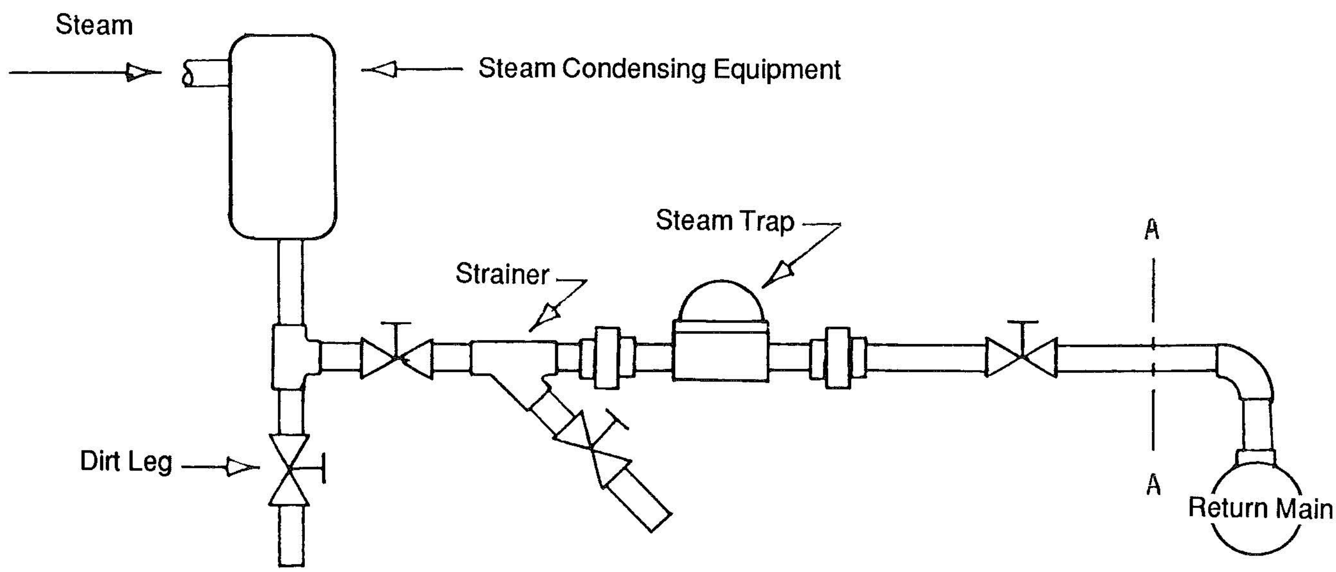


Fig. 1 shows a steam trap hook-up using a separate 'Y' type strainer. The trap can be either maintainable or throw-away.

FIGURE 1a

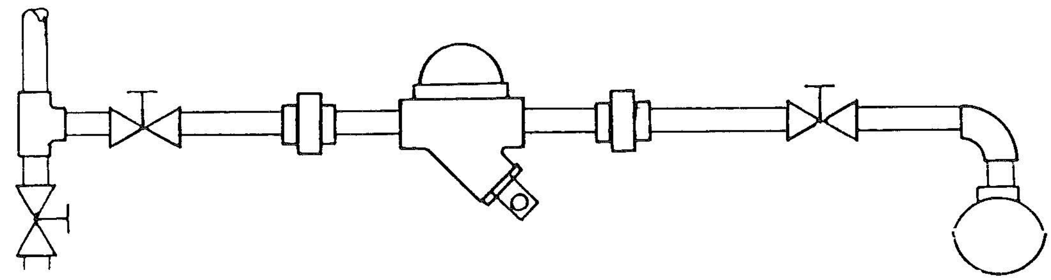


Fig. 1a shows an integral strainer trap. In both cases the trap should be installed with 2 unions (1 optional) and isolating valves.

FIGURE 1b

In Fig. 1b the trap is discharging to an overhead return which requires a check valve to prevent back flow.

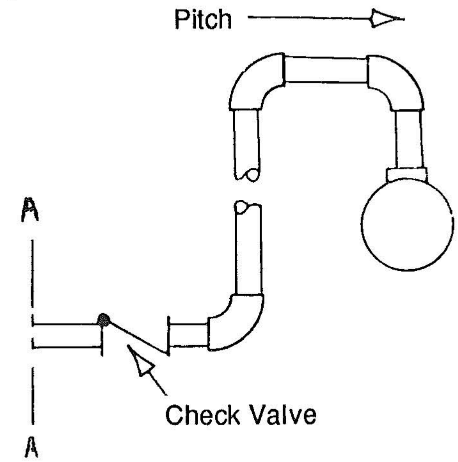


FIGURE 2

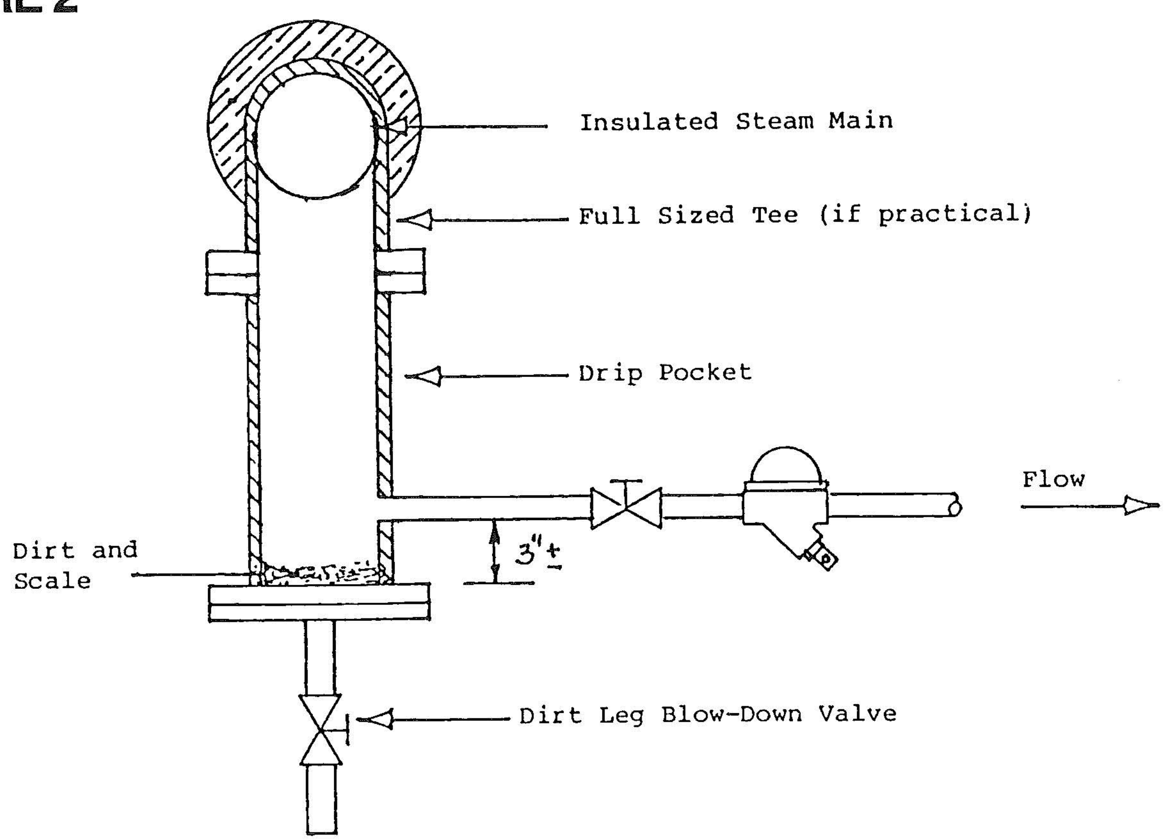


Fig. 2 illustrates a typical drip pocket or dirt leg installed on a steam main. The steam trap is installed 3" or so above the bottom of the leg.

FIGURE 3

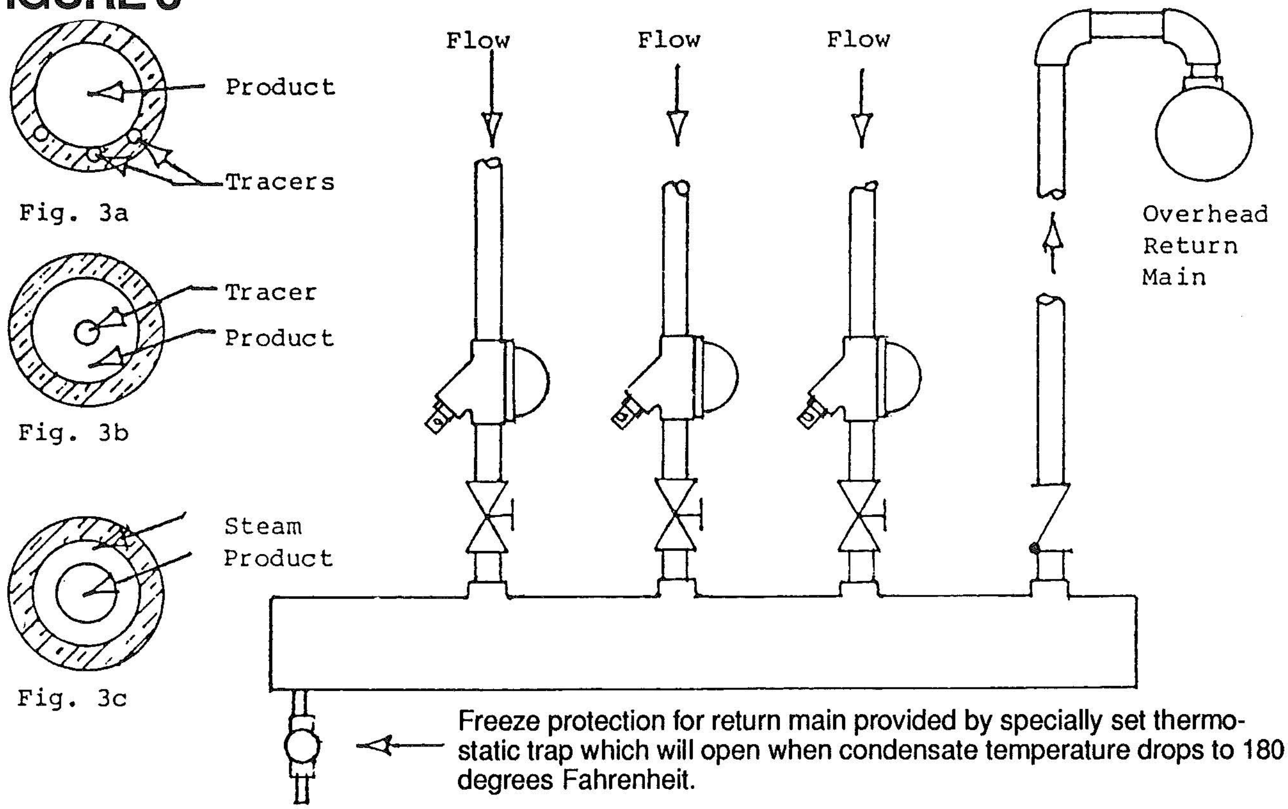


Fig. 3 shows several traps discharging into a common heater which then discharges to an overhead return. This is typical in refineries and chemical plants having lines run in overhead racks.

FIGURE 4

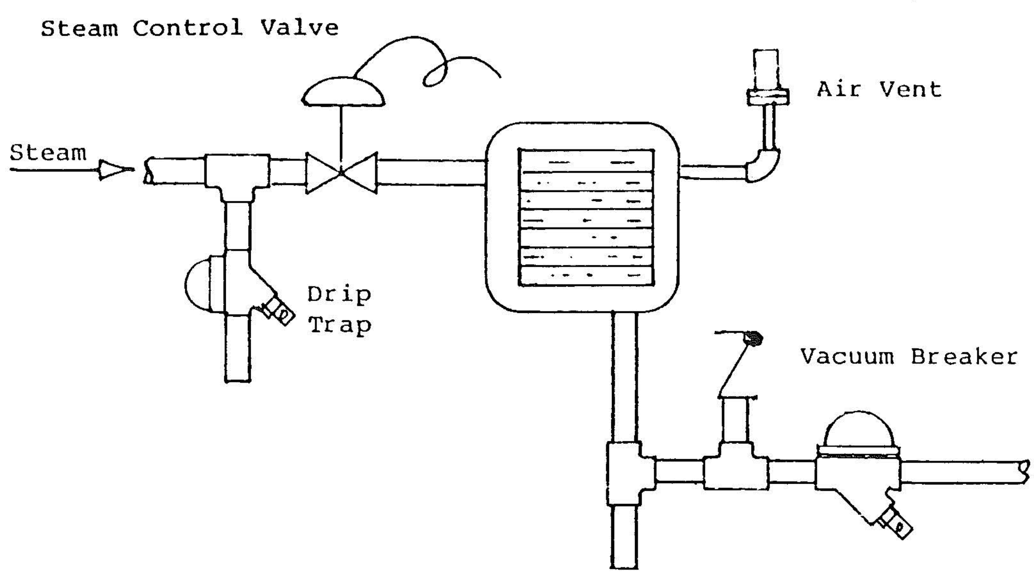
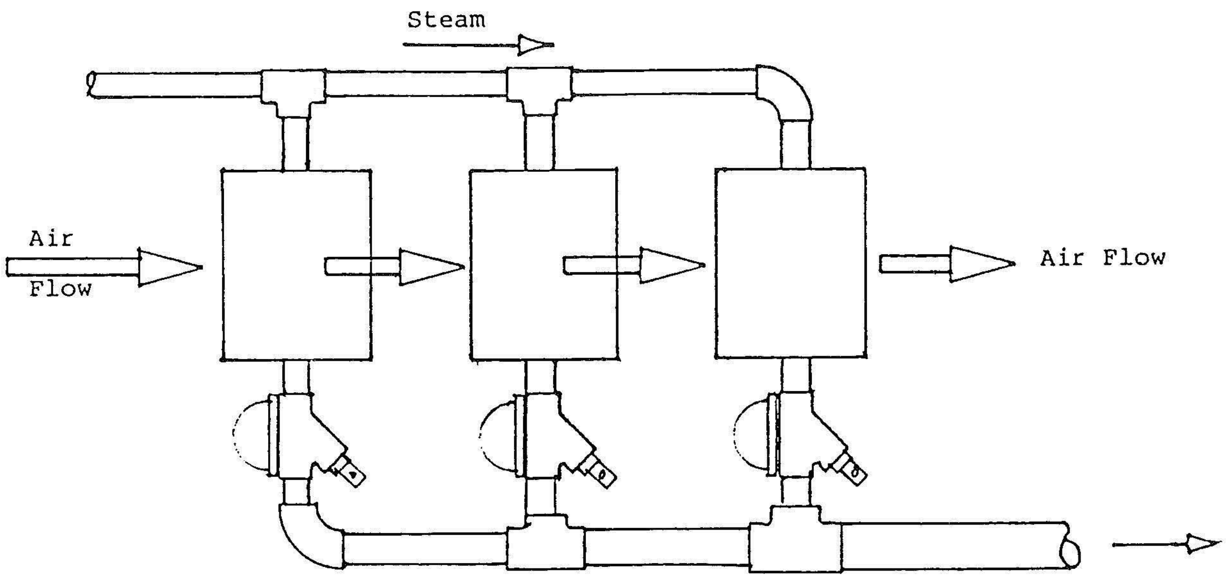


Fig. 4 shows an air heater utilizing a steam control valve. Note the use of both an air vent and a vacuum breaker.

FIGURE 5



The air in Fig. 5 is being progressively heated through units in series. Trap each unit separately; calculate the trap size of each unit individually.

FIGURE 6

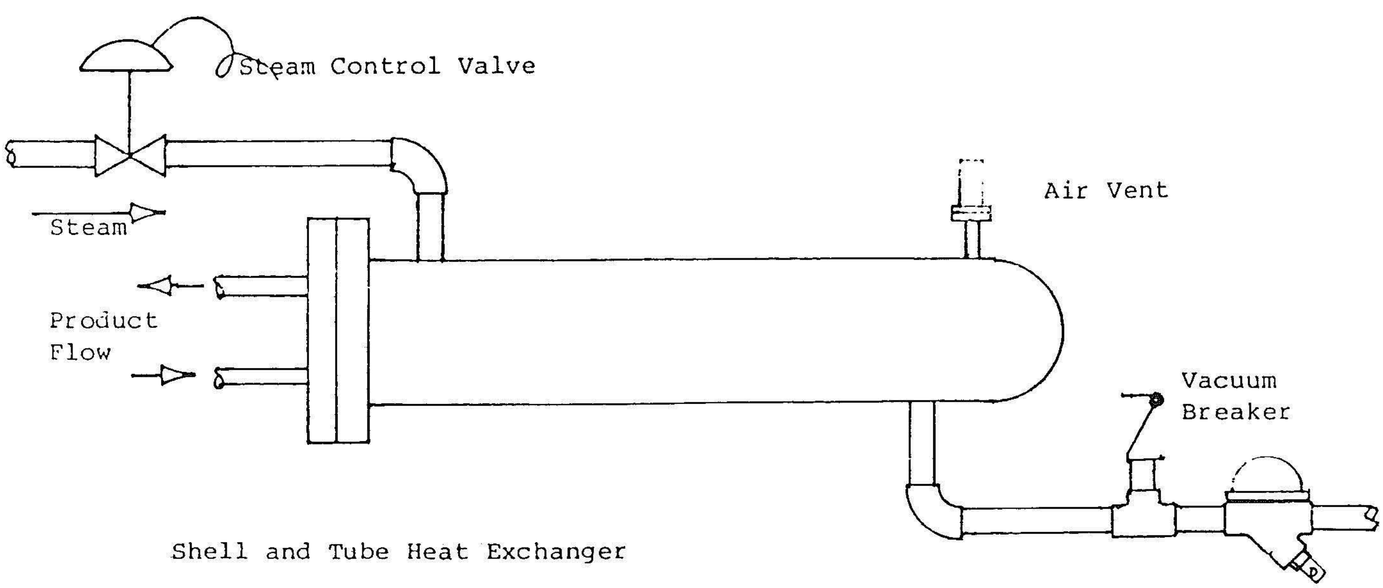
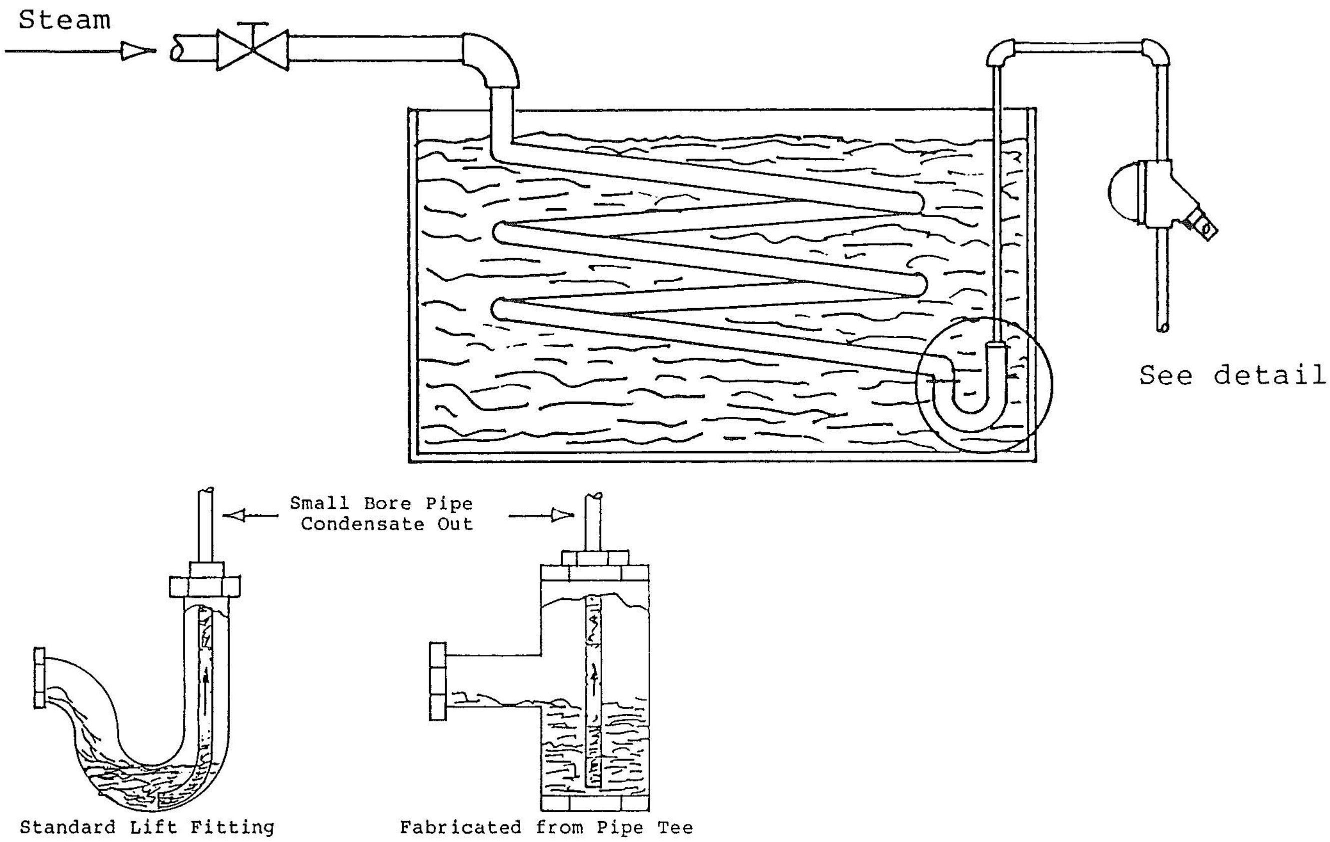


Fig. 6 shows the recommended steam trap installation on a shell and tube heater.

FIGURE 7



The "lift fitting" in Fig. 7 is for those applications where the steam trap is locked above the low point in the system where the condensate collects.

FIGURE 8

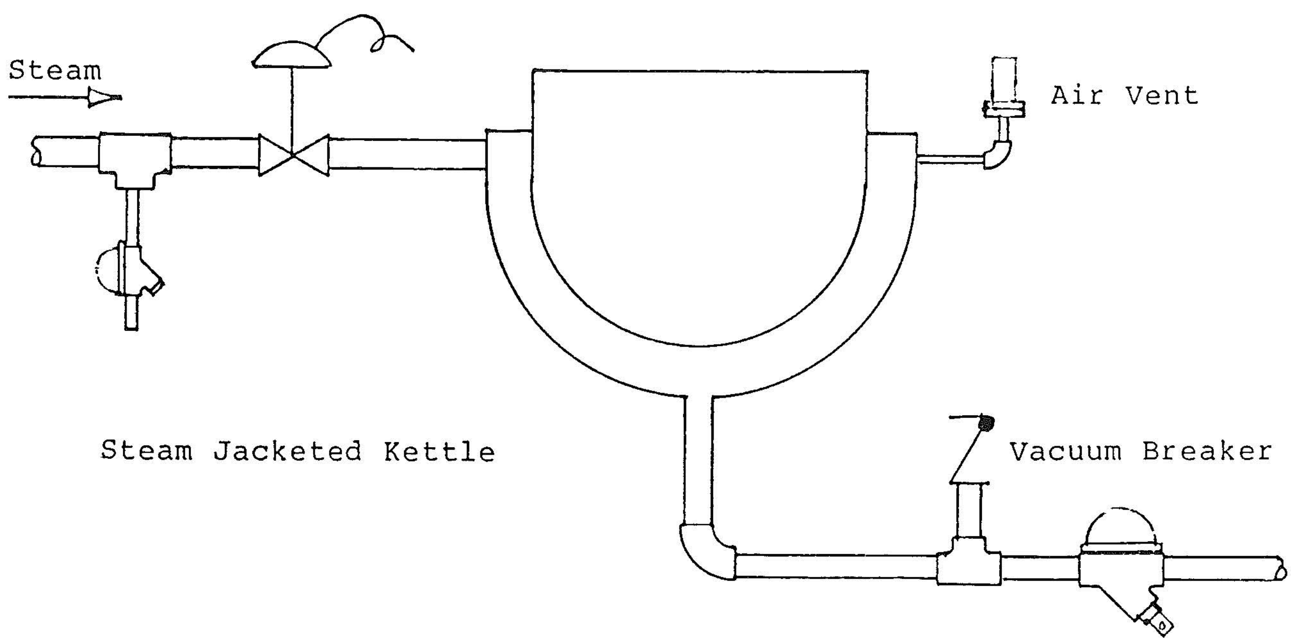


Fig. 8 shows a steam jacketed cooking kettle with both a vacuum breaker and air vent.

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