Bestobell Steam Division of Richards Industries

Presents

A Guide to Steam Traps and Their Effective Use

BESTOBELLSTEAM

Steam Traps and Steam Specialties

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Chapter 1

A Lesson on Steam Basics

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.

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 pound per degree **F**.

In order to raise 1 lb. of water 10ºF (from 70ºF to 80ºF, for instance), 10 BTUs 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. However, there is a limit to the amount of energy that can be expended to bring this water to the boiling point. This limit is known as the saturated water state.

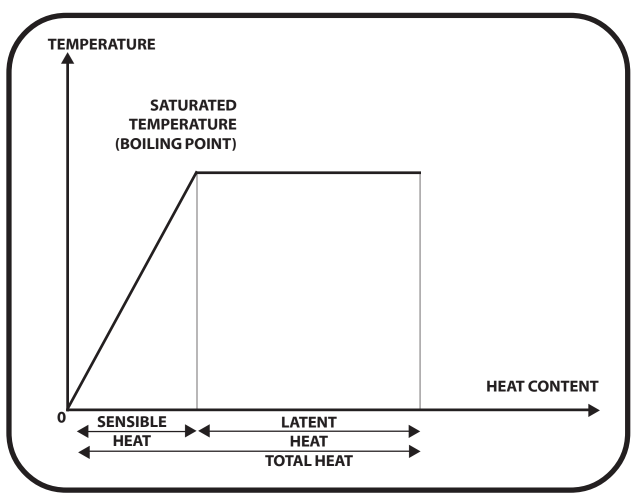


Fig. 1

Once the water has reached this saturation point, two things will simultaneously happen: the water will begin to boil and, the water temperature will stop increasing and will stabilize at a fixed temperature (212ºF under atmospheric conditions at sea level). The water in this saturated state has all the heat it can hold and still remain liquid; adding more heat changes the water from a liquid state to a vapor state and steam will form.

Up to its saturation point, the heat contained in water is known as **sensible heat**. Beyond the 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 the latent heat is known as the **total heat** or **enthalpy**. Enthalpy is defined as a measure of the amount of heat contained in a substance and is measured in BTUs (*See Fig. 1).*

The Steam Curve

Although water boils at 212ºF under atmospheric conditions (0 psig), the boiling point rises as the pressure on the water increases. If the water were under a pressure of 100 psig, the temperature of the water would have to increase to 338ºF before boiling occurred. The relationship between the boiling point or **saturation temperature** and pressure is shown on the **steam curve** (*Fig. 2).*

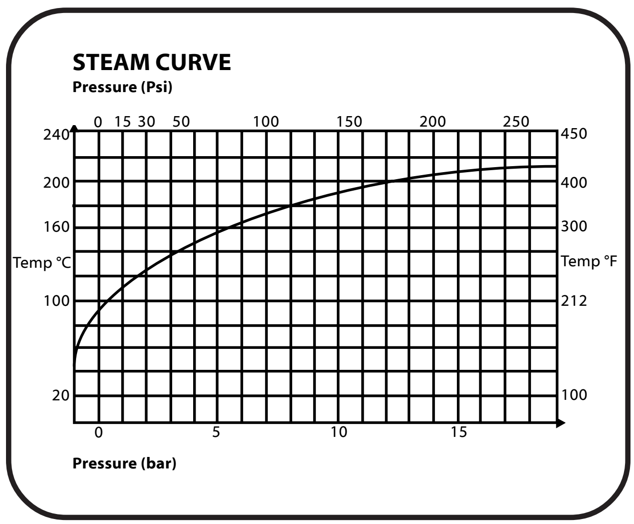


Fig. 2

The precise saturation temperature at a given operating pressure can be found in the steam tables (*Fig. 3).*

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

As an example, consider water at atmospheric pressure and 32ºF. 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 (212ºF), the sensible heat in one lb. of water equals 212ºF minus 32ºF or 180 BTU (180ºF x 1 BTU/lb/ºF = 180 BTU). From the steam table under sensible heat corresponding to 0 psig you will find 180 BTU/lb.

Any heat added to this 1 lb. of water will vaporize the liquid and will not further increase the 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. A greater amount of sensible heat is required to raise the 1 lb. of water to a saturated liquid state but a lesser amount of latent heat is necessary to convert the saturated liquid to a 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 systempressure, 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.

Steam Table

PRESSURE PSIG	Temperature °F	Sensible Heat (BTU/LB)	Latent Heat (BTU/LB)	Total Heat (BTU/LB)	Specific Vol. Dry Set (CU.FT./LB)
25* Hg	133.6	101.5	1018.1	1119.6	144.0
10* Hg	192.2	160.2	983.2	1143.4	39.2
5* Hg	203.0	171.0	976.5	1147.5	31.9
0	212.0	180.	970.6	1150.8	26.8
1	215.4	183.6	968.4	1152.0	25.2
2	218.5	186.8	966.4	1153.2	23.8
3	221.5	189.8	964.5	1154.3	22.5
4	224.5	192.7	962.6	1155.3	21.4
5	227.4	195.5	960.8	1156.3	20.4
6	230.0	198.1	959.2	1157.3	19.4
7	232.4	200.6	957.6	1158.3	18.6
8	234.8	203.1	956.0	1159.1	17.9
9	237.1	205.5	954.5	1160.0	17.2
10	239.4	207.9	952.9	1160.8	16.5
12	243.7	212.3	950.1	1162.3	15.3
13	245.8	214.4	948.6	1163.0	14.8
14	247.9	216.4	947.3	1163.7	14.3
15	249.8	218.4	946.0	1164.4	13.9
20	258.8	227.5	940.0	1167.6	12.0
25	266.8	235.8	934.6	1170.4	10.6
30	274.0	243.0	929.7	1172.7	9.46
40	286.7	256.1	920.4	1176.5	7.83
50	297.7	267.4	912.2	1179.6	6.68
60	307.4	277.1	905.3	1182.4	5.84
70	316.0	286.2	898.8	1185.0	5.19
80	323.9	294.5	892.7	1187.2	4.67
90	331.2	302.1	887.0	1189.1	4.25
100	337.9	309.0	881.6	1190.6	3.90
110	344.2	315.5	876.5	1192.0	3.60
120	350.1	321.8	871.5	1193.3	3.34
130	355.6	327.6	866.9	1194.5	3.12
140	360.9	333.2	862.5	1195.7	2.93
150	365.9	338.6	858.0	1196.6	2.76
160	370.7	343.6	853.9	1197.5	2.61
170	375.2	348.5	849.8	1198.3	2.48
180	379.6	353.2	845.9	1199.1	2.35
190	383.7	357.6	842.2	1199.8	2.24
200	387.7	362.0	838.4	1200.4	2.14
220	395.5	370.3	831.2	1201.5	1.96
240	402.7	378.0	824.5	1202.5	1.81
260	409.3	385.3	817.9	1203.2	1.68
280	415.8	392.3	811.6	1203.9	1.57
300	421.7	398.9	805.5	1204.4	1.47
400	448.1	428.2	777.4	1205.6	1.12
500	470.0	453.0	752.3	1205.3	0.902
600	488.8	474.8	729.1	1203.9	0.750
700	505.4	494.4	707.4	1201.8	0.641
800	520.3	512.5	686.6	1199.1	0.557
900	533.9	529.2	666.7	1195.9	0.490
1000	546.4	544.8	647.2	1192.0	0.437
1200	568.8	573.8	609.6	1183.4	0.357
1500	597.5	613.6	554.2	1167.8	0.274
2000	636.8	673.5	461.5	1135.0	0.186
2500	669.0	732.5	357.6	1090.1	0.129
3193*	705.6	896.0	0	896.0	0.0489

***Critical Point**

Fig. 3

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

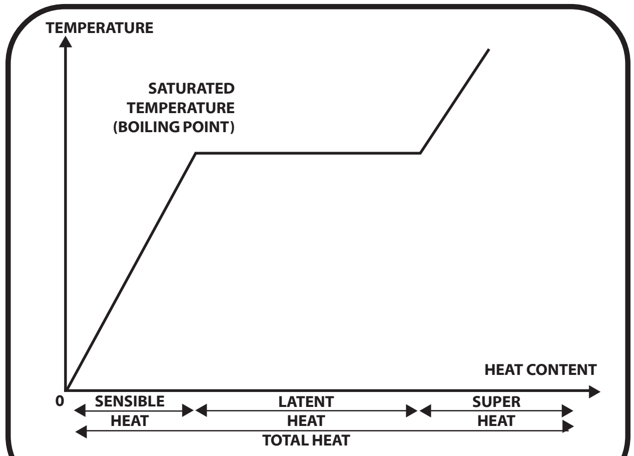


Fig. 4

Water can exist when the mass that is multiplied by 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 of that water. 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 **degree of superheat.**

The Use of Steam

Steam is used because it is a convenient and economical way of moving 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 known as **heat transfer**. In other words, the steam gives up its enthalpy to another 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 *(Fig. 5)*. As steam is

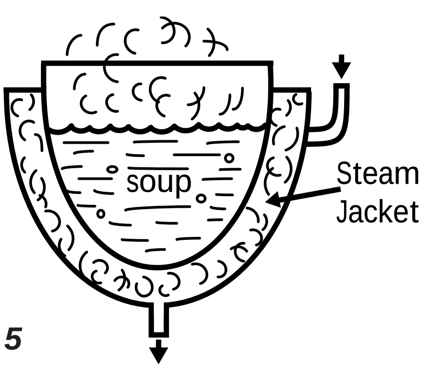


Fig. 5

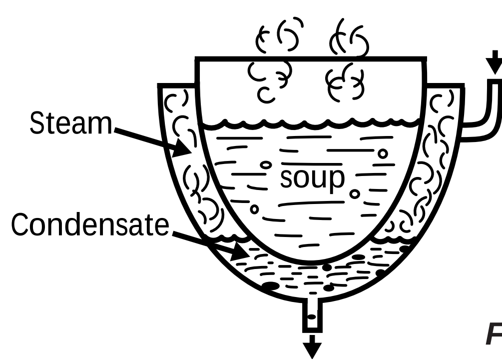


Fig. 6

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 total heat of the steam is reduced by the amount of the BTUs transferred and causes condensate (water) to form in the bottom of the jacket as the steam gives up latent heat *(Fig. 6)*. The soup then heats up to the required temperature as BTUs of latent heat are transferred to the soup through the metal kettle wall.

The FIRST RULE for the efficient use of steam: *The latent heat does the work.*

As the steam gives 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. 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, its temperature decreases. Steam, on the other hand, **does not** reduce in temperature as it uses its latent heat.

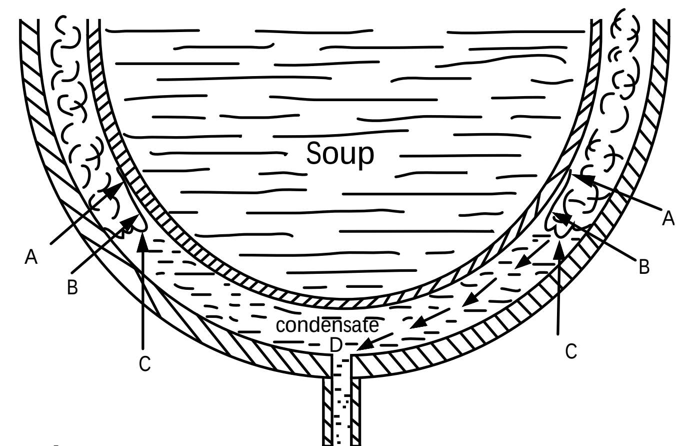


Fig. 7

If we have 30psig steam (274ºF), it contains 929 BTU/lbs. of latent heat. As it gives up heat to the kettle, the temperature of the condensate, as it forms, is also 274ºF, but it contains sensible heat of 243BTU/lb. Since condensate is heavier than steam, it falls to the bottom of the jacket as it forms. As shown in *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.

Halfway through the heating of the soup, the conditions may be as follows:

- Soup temperature: 150ºF
- Steam temperature: 274ºF (30psig)
- Condensate temperature at "C": 274ºF
- Condensate temperature at "D": 230ºF

The temperature difference between the steam and the soup is 124ºF (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 80ºF (230-150). The rate of heat transfer between the condensate and the soup and the quantity of heat that the condensate is able to transfer is very small compared to the quantity of heat available in the steam.

Note that a water film is forming at point "A" and is thickening at point "B" as the water begins to run down the walls of the jacket. Because the water has a very high resistance to heat transfer, this film forms an 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. As found in the steam table, 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).

Since saturation temperature is a function of pressure, another advantage of condensing steam, as a heat transfer medium is that 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 unlike any liquid; it is also easier to convey than a liquid.

The SECOND RULE for efficient use of steam: *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 point, 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 **cold start-up**. When the metal of the kettle has been warmed and the soup temperature begins to rise, the conditions gradually change. The temperature difference between the steam and soup gradually lessens, the rate of heat transfer gradually slows, the rate of steam consumption eases and the rate of condensation eases. These conditions are described as **hot running load**.

It is important to recognize that the difference between the starting load and the running load can be significant. Since the greatest amount of condensate is present at cold start-up, it is imperative that the system be sized so that the condensate drainage will occur as rapidly as possible. Since heat transfer occurs in direct proportion to the temperature difference, toward any surface or substance cooler than the steam itself, the condensate must quickly be removed from contact with the steam. This ensures that the condensate does not absorb heat or prevent the transfer of heat to the process. Insulation is often used to further prevent this from taking place.

Air and Non-Condensable Gases

Like condensate, air will blanket heat transfer surfaces *(Fig. 8)*, but it has a much greater resistance to heat flow. In addition, air 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 shutdown, 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, since water contains air, air is released when water is boiled. Since the density of steam and air are close under equal conditions, the air is pushed along with the steam.

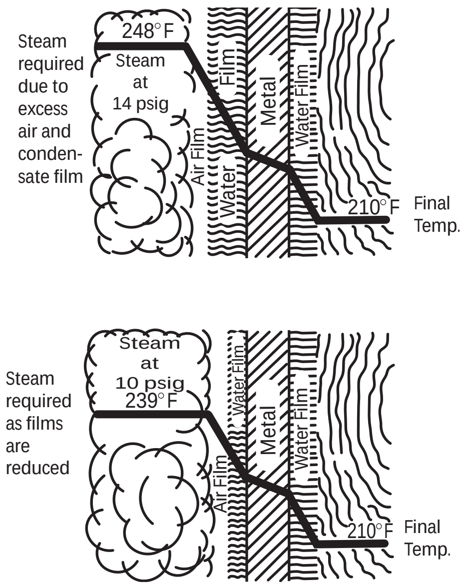


Fig. 8

In a steam system, the steam naturally flows toward the cooler heat transfer surfaces, and condenses into water and is carried to the drain by gravity. 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 and reduces the efficiency of heat transfer. While steam and condensate can push the air to the discharge from the process equipment, there are installations where the air can "pocket" and cannot get to the drain.

Let's look at an example:

> *With anymixture of gases, each gas exerts only a portion of the total pressure based on the amount of each gas present. 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 30psig (saturated temperature of 274*ºF). *However, due to the quantity of air in the system, the steam is actually at a pressure of 20 psig (258*ºF). *The system will beoperating 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 (Fig. 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.

Pressure psig	Temp. of Steam, No Air Present	Temp. of Steam Mixed with Various Percentanges 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

Fig. 9

How Does the Condensate Get Out?

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

If steam was not so costly to produce, and thus a valuable form of energy, it would be a simple matter to discharge the condensate. In our earlier example, we could have allowed it to drain out through a hole or pipe in the bottom of the soup kettle, but significant quantities of steam would be able to blow out also. It is essential that we find a way to discharge the condensate without losing any of the steam.

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

A flow restriction is necessary. This could be 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 potential solutions, although easy to understand and relatively inexpensive to install, have one major 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 startup 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 startup load and the equipment could become waterlogged, and reduce the amount of heat transfer surface available for contact with the steam. There is no regulating or adjusting feature available to compensate for the changing loads.

A globe valve or other type of flow regulating valve could be used and could work satisfactorily. During startup, 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 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 to precisely

match the load conditions – it would either be closed too much allowing the 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 such and automatic valve 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's performance. The steam trap is as crucial to the heating efficiency of a system as the steam control elements are on the inlet side of the equipment.

The Industrial Steam Cycle

In industrial plants, the steam supply circuit can be very complex *(Fig. 10)*. Steam is generated in a boiler which is usually gas, oil, or coal fired. The steam is generated at pressures corresponding to the maximum plant needs, and is distributed to various portions of the plant through steam mains. Where heat is required at the process areas, secondary piping systems carry it from the steam mains. 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' 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. We have already covered the basics of the steam system. Although simpler to explain, the condensate return system is equally important.

If the condensate is drained to the ground or to a sewer, there is little more involved than ensuring that the pipe size is large enough to carry off the amount of condensate formed. However, a condensate return system requires more condensation.

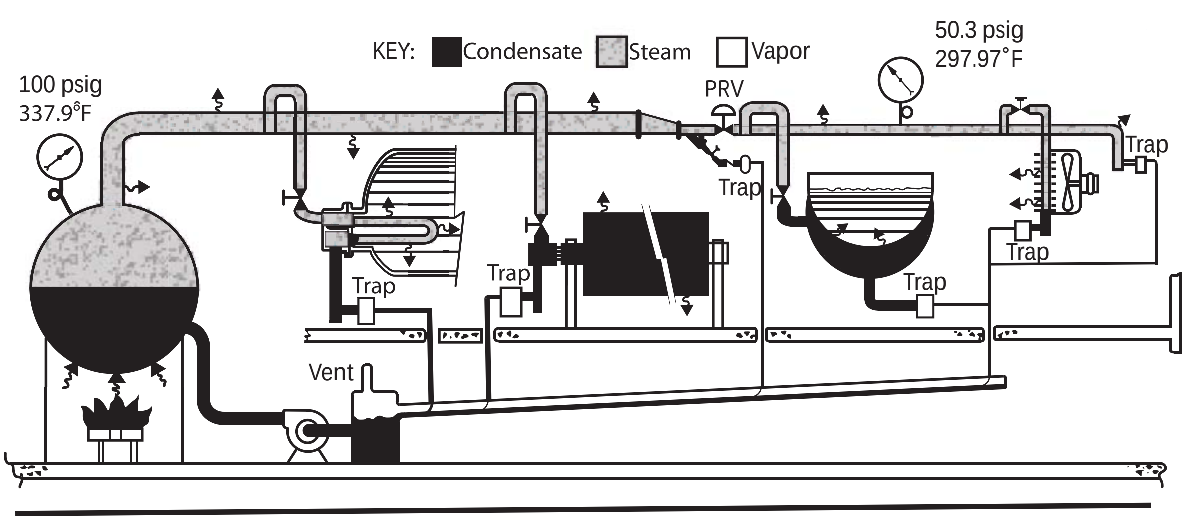
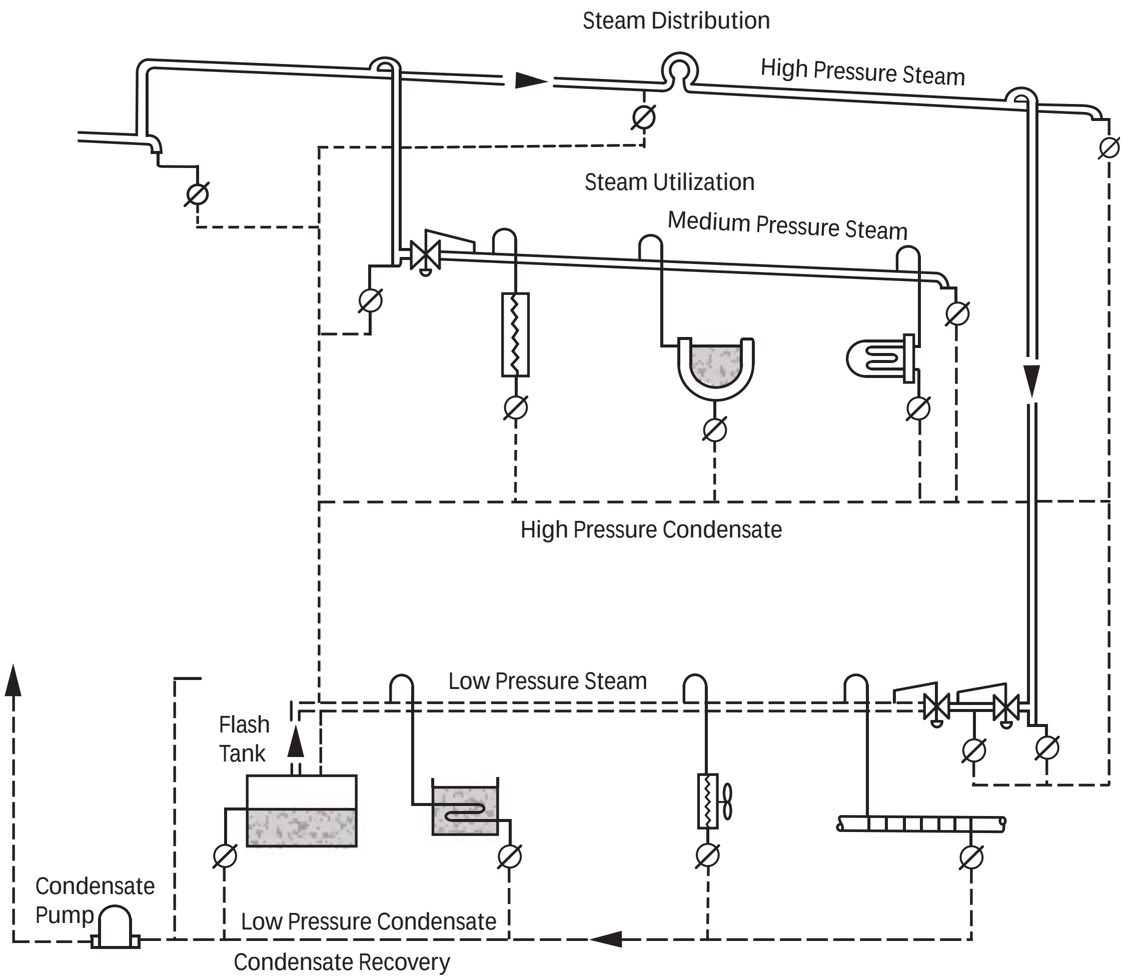


Fig. 10



Typical Steam Circuit

Flash Steam

In any piece of process equipment, the condensate initially forms at the saturation temperature, then decreases slightly in temperature 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, excess energy is contained in the condensate at the reduced pressures. Since this energy must be expended, some of the condensate is converted to vapor (or flash steam) as it discharges to the lower pressures *(Fig. 11)*.

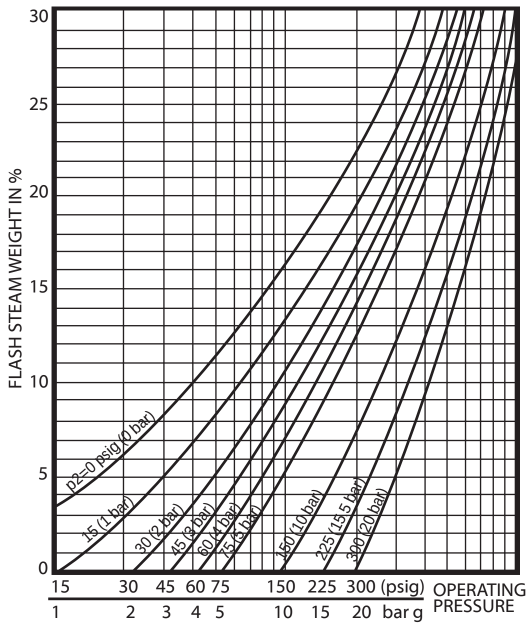


Fig. 11

For example: assume an inlet pressure of 100 psig (338ºF) and a return main pressure of 0 psig (212ºF). A pound of condensate at 100 psig saturated temperature contains sensible heat 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 flash steam

The formula for the calculation of flash steam is:

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

$$= \frac{309-180}{971} \times 100$$

$$= 13.3\%$$

P1= Inlet pressure (Operating pressure)
P2= Outlet pressure (Back pressure)

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.

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

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

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

The THIRD RULE for the efficient use of steam: *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 a number of 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:** 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 any type are able to differentiate between steam and condensate. They may differ in their operating principles and the source of energy used to make them operate, but they share some common characteristics.

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 in the design of the elements that control the discharge orifice.

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

Other traps operate in an intermediate range – wide open discharging condensate alternating with periods of being completely closed. The time between the cycles varies depending on 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 for the efficient use of steam: *There is no universal steam trap.*

TRUE COST TO GENERATE STEAM

"DIRECT"

Cost of Water

Cost of Chemicals (Deironizer-resin treatment to handle iron + softner)

Cost of Fuel (Coal-Gas-Oil)
Note: There are #2 and #6 oils. #6 has more BTUs but you have to use steam to keep it thin enough to burn.

Electrical costs to run blowers, dampner, etc.

"INDIRECT"

Depreciation of all the equipment involved with the operation of steam systems.

Cost of real estate (ground and building)

Maintenance (cost of maintaining steam system).

Operators (cost of operators and benefits).

Major repair of or replacement of equipment and parts.

Auxillary equipment (piping, traps, valves, controllers, etc.).

Cost of inspection (Hartford or other insurance company).

Insurance (interuptable insurance, workman's compensation, libality, etc.).

Cost of compliance to environmental regulatory agencies.

Note: Some companies burn paper or wood which have other problems that come into consideration.

Chapter 2

Types of Steam Traps

There have been many different types of steam traps made by an abundance of different manufacturers throughout the world since the first effective steam trap appeared in 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 those developed by a recognized leader in the manufacture of that particular type of steam trap. The traps will be described in no particular order and we will not go into the history and development of each steam trap.

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

Mechanical
- Ball float
- Float and thermostatic
- Open bucket
- Inverted bucket

Thermostatic
- Bellows
- Bimetal
- Liquid expansion

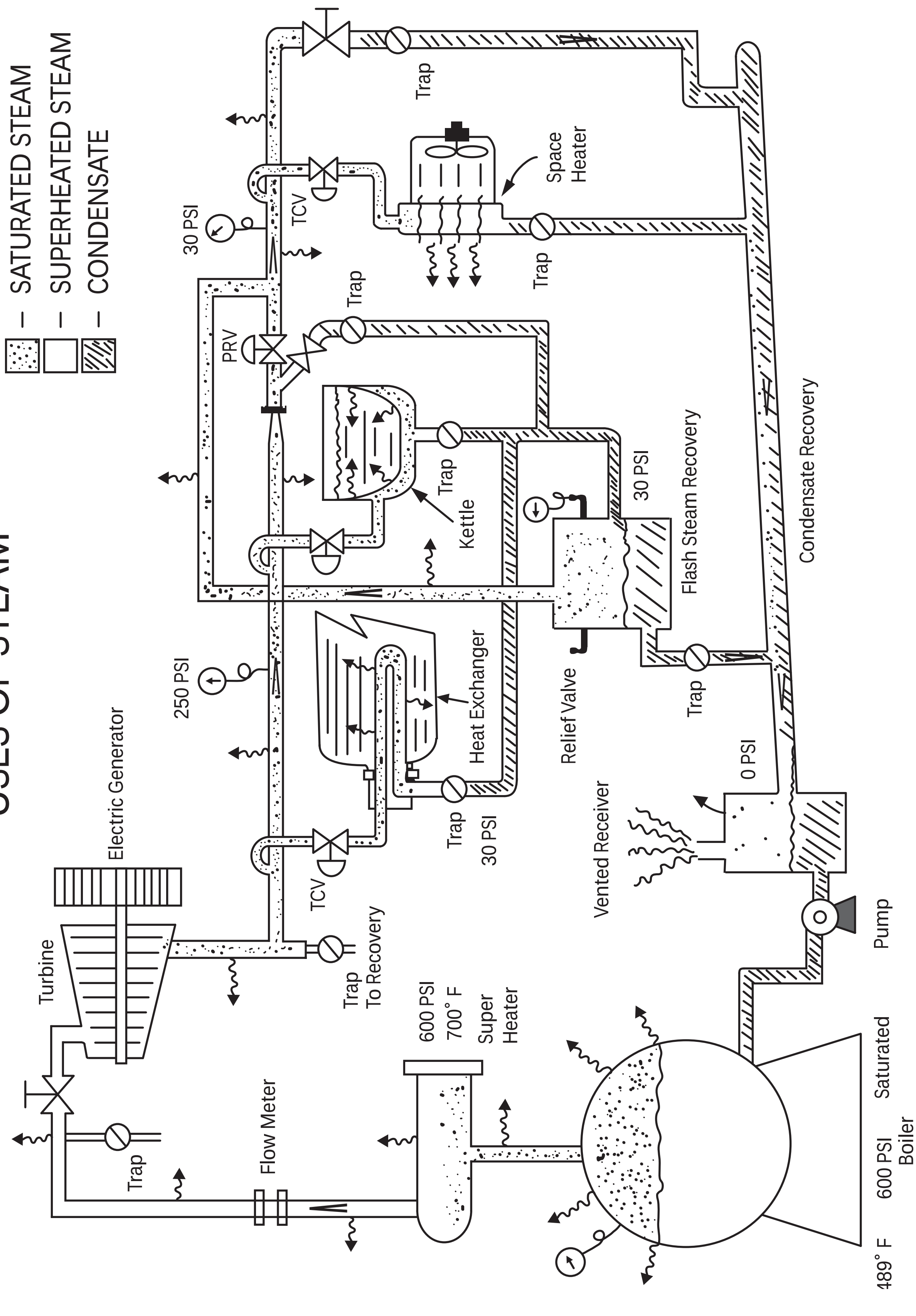
Thermodynamic
- Impulse
- Disc

Combination
- Thermostatic/Thermodynamic

Miscellaneous
- Labyrinth
- Orifice
- Wax-filled

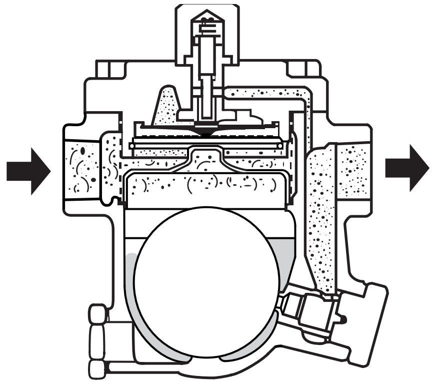
Each of these trap types will be covered in the following separate sections.

USES OF STEAM

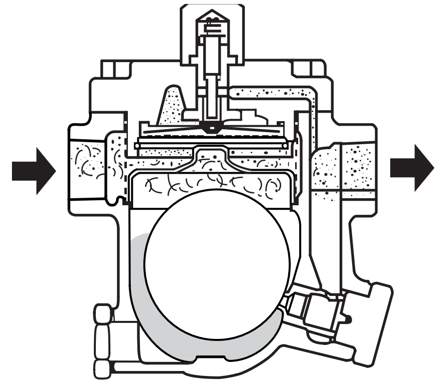


Mechanical

Ball Float

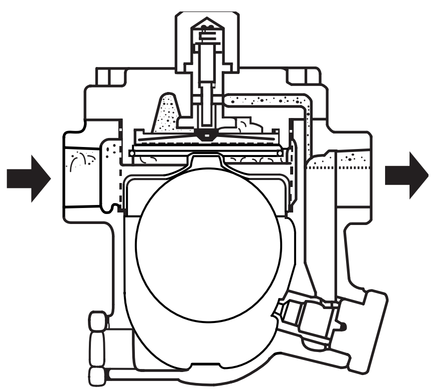


On start-up, the bimetallic plate in the cover is concave upward and keeps the vent valve bore open. This allows the air to flow out freely through the vent valve bore and results in faster start-up.



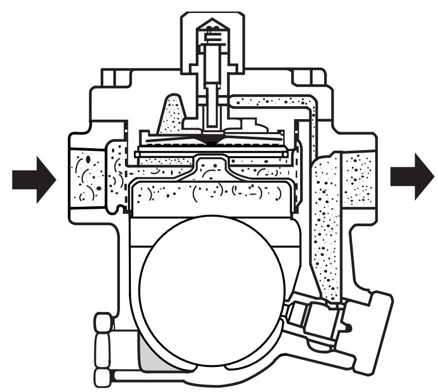
When condensate flows into the trap, the float rises due to buoyancy and allows the mixture of air and condensate to be discharged. The temperature of hot condensate causes the bimetallic plate to flex upward and close the air valve seat, sealing by pressure differential.

Air venting is now completed but condensate will continue to be discharged as long as condensation occurs.



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. 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.



Even with a very light load, the trap continuously discharges. If the inflow 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 temporary drastic increase in flow of condensate, the float immediately rises, allowing quick discharge. The trap then resumes normal continuous discharge.

Characteristics of Ball Float Traps

Plant Control

- Continuous discharge but still considered cyclic under low or intermittent loads (lift off lag)
- Same hot and cold capacity
- Rapid response to changing load
- Can operate on very low pressure differential
- Not for superheat applications
- Not freeze-proof (not self-draining)

Energy Control

- Possible steam loss through air (bimetal vent valve disc operates on temperature only)
- Water seal on discharge orifice – steam-tight until ball becomes scrateched, dented, or deformed to any degree.

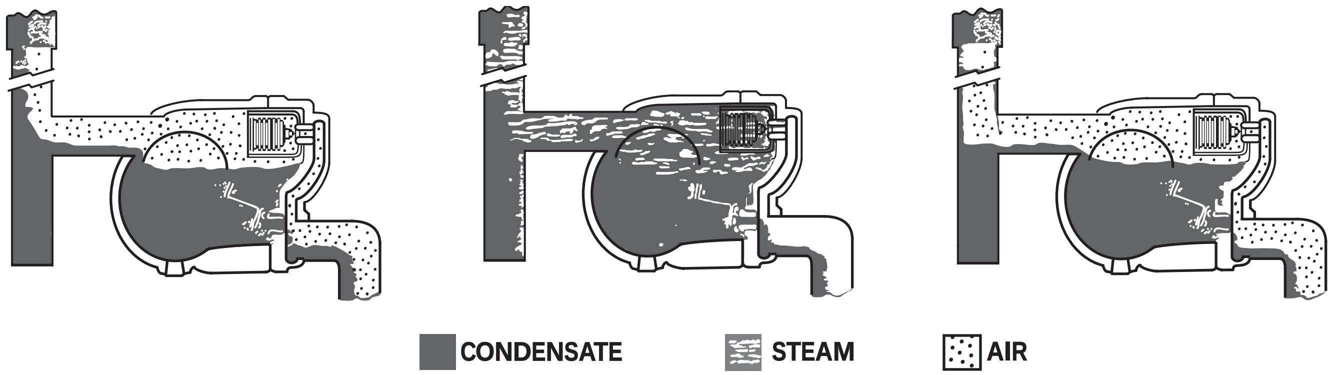
Installed Costs

- Mount in one position only
- Moderate to large in size and weight

Reliability

- Few moving parts
- Water hammer can damage float
- Can fail closed in over-pressure, or ball punctures and fills
- Normally fails open

Float & Thermostatic



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

When steam, or an overflow of condensate, reaches the trap, the thermostatic air vent closes. Condensate flows through the main valve which is regulated by the float to discharge condensate at the same rate as rate which condensate is flowing to trap (if the trap has a correctly sized orifice).

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

Characteristics of Float & Thermostatic Traps

Plant Control

- Continuous discharge, but still considered cyclic low or intermittent loads (lift off lag).
- Same hot and cold capacity
- Rapid response to changing load
- Can operate on very low pressure differential
- Not for superheat applications
- Not freeze-proof (not self-draining)

Energy Control

- Possible steam loss through air vent
- Water seal on discharge orifice – steam-tight

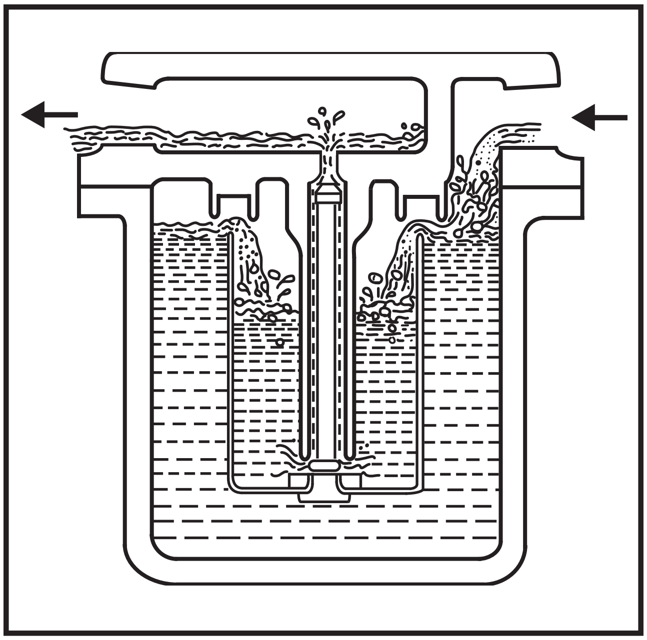
Installed Costs

- Mount in one position only
- Large size and weight
- Not for dripleg or tracer applications

Reliability

- Medium service life on low pressure, short lived on high pressure
- Thermostatic bellows air vent is thin walled and relatively fragile
- Water hammer can damage float
- Can fail closed in over-pressure conditions, or if ball seal fails and sinks
- Normally fails closed
- Time consuming to repair

Open Bucket



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

Characteristics of Open Bucket Traps

Plant Control

- Cyclic discharge
- Same hot and cold capacity
- Rapid response to changing load conditions
- Can operate on very low pressure differential
- Poor air handling capacity
- Not for superheat applications
- Not freeze-proof (not self-draining)

Energy Control

- Steam tight

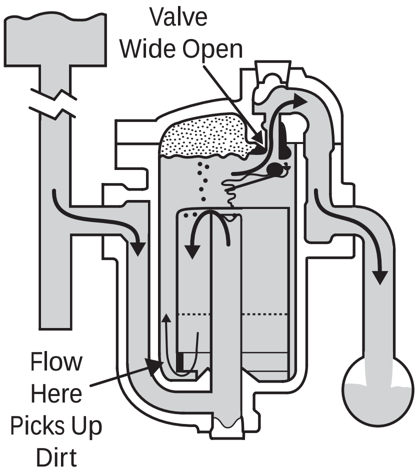
Installed Costs

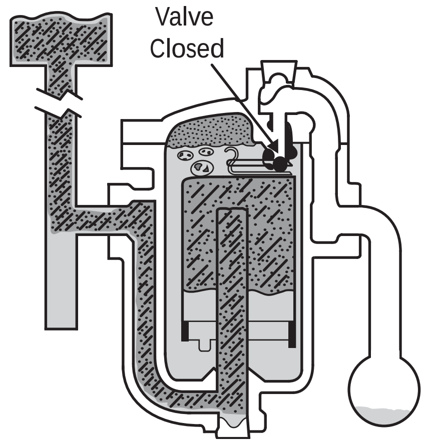
- Mount in one position only
- Very large size and weight
- Not for drip and tracer applications

Reliability

- Medium service life on low pressure applications, shorter lived on high pressure systems
- Resistant to water hammer
- Normally fails open

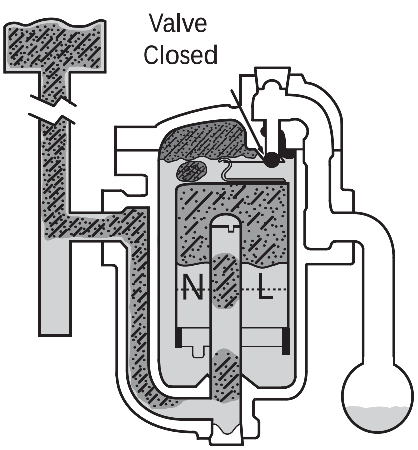
Inverted Bucket

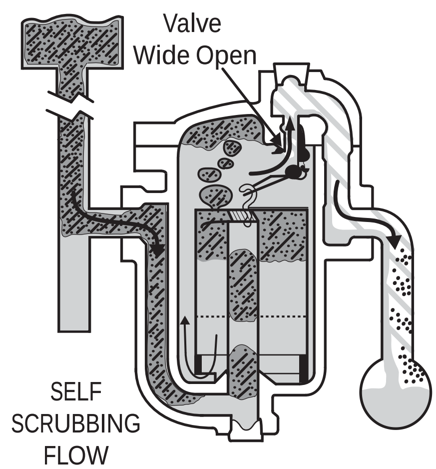




Steam trap is installed in drain line between steam heated unit and condensate return header. At this point, bucket is down and valve is wide open. As initial flood of condensate enters the trap and flows under bottom edge of bucket, it fills trap body and completely submerges bucket. Condensate then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

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.





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 header.

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. However, small amounts of steam do escape with each cycle before the valve is seated.

Characteristics of Inverted Bucket Traps

Plant Control

- Cyclic discharge
- Same hot and cold capacity
- Moderate response to changing load conditions
- Can operate on low pressure differentials
- Poor air handling capacity
- Not for superheat applications
- Not freeze-proof (not self-draining) (Stainless body designs expand when frozen but usually still operate.)

Energy Control

- Uses live steam to operate (approx. 2 lbs/hr.)
- Water seal on discharge orifice – steam-tight
- Small live steam loss with each cycle

Installed Costs

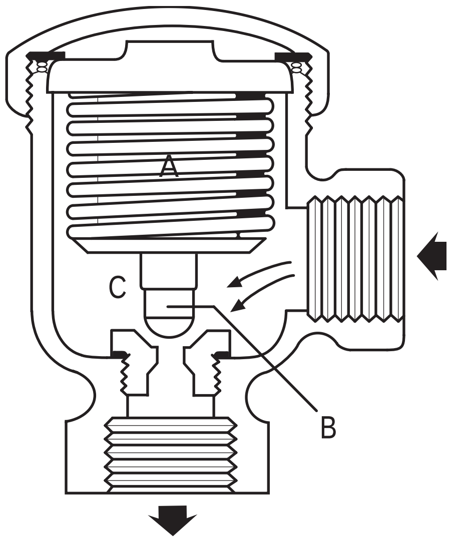
- Mount in one position only
- Moderate size and weight
- Not for tracer applications

Reliability

- Medium service life on low pressure applications, shorter lived on high pressure systems
- Relatively resistant to water hammer
- Can fail closed in over-pressure situations
- Can fail open on rapid pressure drop; or if condensate prime is lost
- Normally fails open

Thermostatic

Bellows (Balanced Pressure)



The bellows (A) is filled with a liquid having a lower boiling point than water. As assembled, valve is normally open. When steam or very hot condensate enters trap, bellows fill vaporizes to a pressure higher than line pressure. This forces valve (B) into seat orifice (C) to prevent any further flow. As condensate collects, it removes heat from bellows condensing the vaporized fill and lowering internal pressure. Line pressure will then compress bellows to open valve and discharge condensate. Valve opening automatically adjusts to load conditions from minimum on very light loads to full at maximum loads as the bellows fully contracts.

They do not have to be adjusted since the characteristics of the water-filled bellows match the saturated steam pressure/temperature curve.

Characteristics of Bellows Traps

Plant Control

- Continuous discharge (cyclic on low loads)
- Slightly higher cold capacity than hot
- Slow response to changing load conditions
- Can operate on low pressure differentials
- Excellent air handling capacity
- Not for superheat of acidic condensate applications
- Freeze-proof (self draining - some models)

Energy Control

- Steam tight

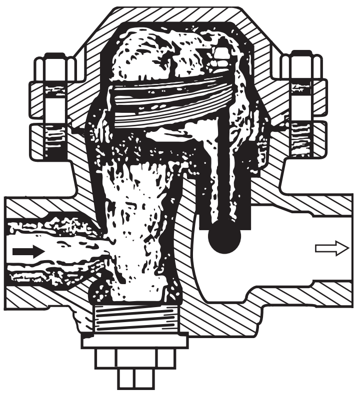
Installed Costs

- Mount in any position
- Small size and weight

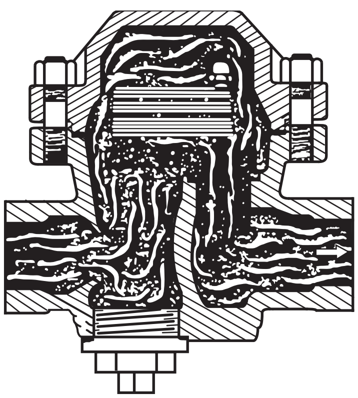
Reliability

- Limited service life due to thin bellow wall
- Bellows may be damaged by water hammer
- Fails open (liquid filled bellows)
- Fails closed (vacuum bellows)

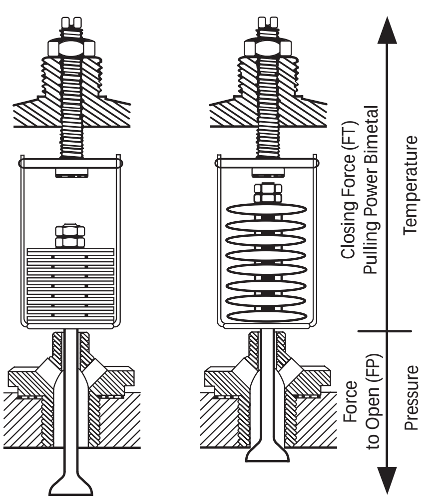
Bimetal



1. Stacked leaf beginning to open.



2. Stacked leaf full capacity flow.



3. Stacked Disc design

Stacked Cantilevered Leaf Design

Incoming steam contacts the bimetallic element and causes the bimetal to deflect and lift the valve stem, overcoming the line pressure and closing the valve. The power of the bimetal 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 pressure/temperature range.

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

1. When flow is released, the unbalanced pressure acts on the full valve area doubling its force and opens the orifice for full capacity flow.

Stacked Concentric Disc Design

The primary operating principle of any bimetallic steam traps is based on the simultaneous action of two opposite forces: one resulting from the working pressure (Opening Force Fp), and the second from the pull exerted by bimetallic elements 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.

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 bimetallic elements relax and the valve moves away from the seat, permitting and increase in condensate flow. The opening force Fp becomes greater than the closing force Ft. The trap begins to open.

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 backpressure, the inverted stem tip closes and acts as a check valve.

Characteristics of Bimetal Traps

Plant Control

- Continuous discharge
- Slow response to changing load conditions (stacked element types)
- Can operate over wide pressure range
- Very good in high pressure service (over 600 psi)
- Excellent air handling capacity
- Excellent on superheat
- Freeze-proof (self-draining)

Energy Control

- Steam tight
- Can be set to utilize sensible heat

Installed Costs

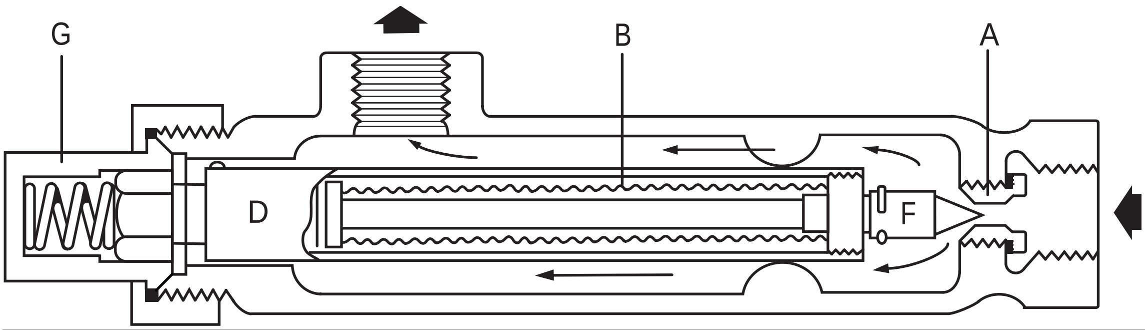
- Mount in any position
- Small size and weight
- Will act as check valve

Reliability

- Good service life over wide pressure range
- Resistant to water hammer
- Must be adjusted for high back pressure applications
- May require resetting due to wear (stacked disc type)
- Not good for process applications (stacked leaf type)
- Normally fails open
- Not good for contaminant laden condensate/steam
- Relatively simple to repair

Liquid Expansion

On start-up, the liquid expansion trap is wide open and continuously discharges air and cool condensate until the condensate reaches the predetermined temperature below 212ºF (100ºC). As the hot condensate flows over the thermostatic element, the liquid filling expands, pushing the plunger forward and the valve stem tip to its seat. This action throttles the flow and, at the set temperature, closes the trap. The trap is fitted with a relief spring, which prevents damage from over-expansion of the element or from water hammer.



***Key:* G--Adjustment B--Bellows F--Stem Tip A--Seat D--Thermostatic Element**

Characteristics of Liquid Expansion Traps

Plant Control

- Continuous discharge
- Slow response to changing load conditions
- Limited application range
- Good air handling capacity
- Not for superheat applications
- Not freeze-proof (not-draining)

Energy Control

- Steam tight
- Can be set to utilize sensible heat

Installed Costs

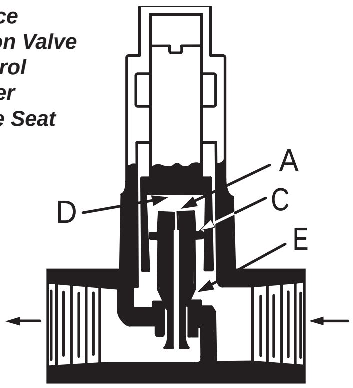
- Mount only in certain fixed positions
- Small size and weight

Reliability

- Medium service life
- Fair resistance to water hammer
- Not self-adjusting to pressure changes
- Not good for process applications
- Normally fails open
- Difficult to repair

Thermodynamic

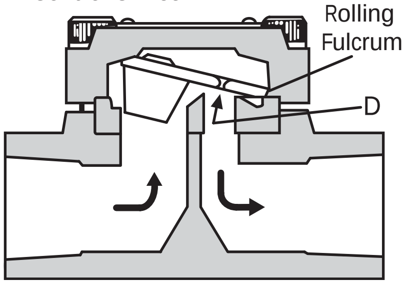
A: Orifice
C: Piston Valve
D: Control Chamber
E: Valve Seat



Impulse

Piston Valve Type
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 underside 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 reopens. The cycle is repeated.

D: Control Orifice



Lever Valve Type
On start-up, the 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 reopens.

Characteristics of Impulse Traps

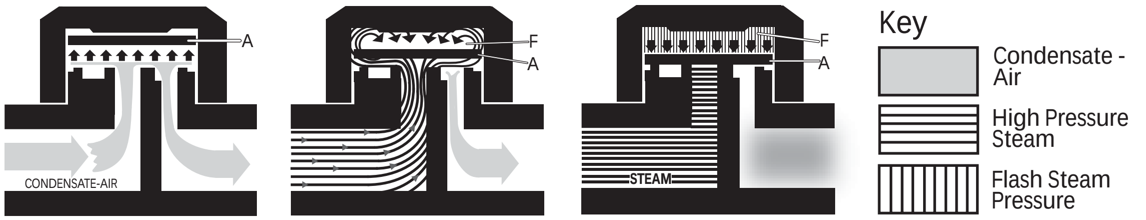
Plant Control
- Continuous discharge (cyclic on low loads
- Same hot and cold capacity
- Can operate over wide pressure range
- Fair air handling capacity
- Limited use on superheat
- Freeze-proof (self-draining)

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

Installed Costs
- Mount in horizontal position only
- Small size and weight

Reliability
- Limited service life
- Resistant to water hammer
- Not good on drip and tracing service
- Will not operate on greater than 40% back pressure
- Normally fails open

Disc



Start-up

Pressure of condensate or air lifts the disc (A) off its seats. Flow is across the underside of the disc to the outlet hole. Discharge continues until flashing condensate approaches steam temperature or until live steam passes through the orifice.

Closing

A high velocity jet of steam reduces pressure under the disc. At the same time, by recompression, steam builds up pressure in the control chamber (F) above the disc. This drives the disc to the seat assuring tight closure.

Closed

Steam pressure in the control chamber (F) 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 in the trap inlet it seals and condenses the steam in the control chamber (F) reducing its pressure. The disc (A) is lifted and condensate discharged when inlet pressure exceeds the reduced pressure in chamber (F).

Characteristics of Disc Traps

Plant Control

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

Energy Control

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

Installed Costs

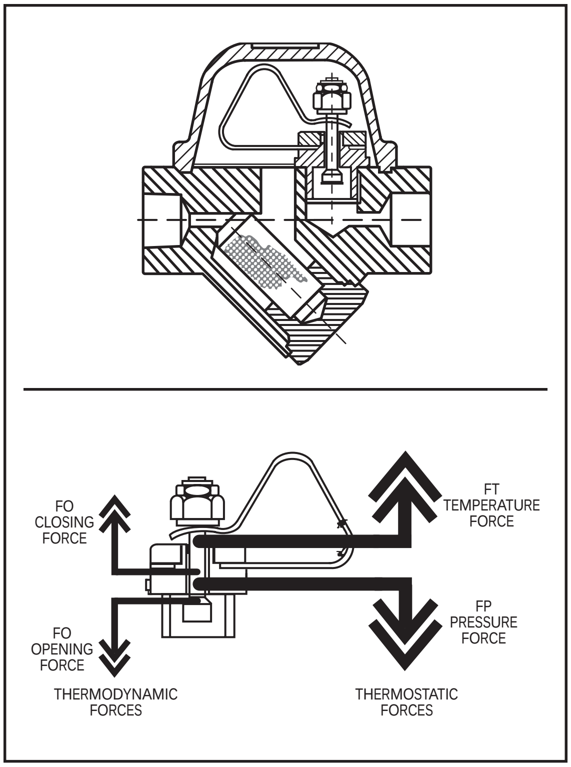
- Mount in any position
- Small size and weight

Reliability

- Short effective service life
- Resistant to water hammer
- Use limited to drip and tracing service
- Limited use on greater than 50% back pressure
- Fails open

Combination

Thermostatic/Thermodynamic



The Bestobell design brought about a new generation of thermostatic/thermodynamic steam traps offering advanced performance features and energy efficient operation. At the heart of every Bestobell steam trap is the unique delta-shaped element, a rugged single blade bimetal formed from high-grade stainless steels. Coupled with the valve seat and stem, the element forms a single moving part that is unaffected by wear and dirt. The design provides a sophisticated, force-balanced valve that prevents the loss of live steam. By utilizing both **thermostatic** and **thermodynamic** forces, the Bestobell steam trap assures optimal plant control.

The **thermostatic** effect combines a temperature closing force (**FT**) generated by the element, and a pressure opening force (**FP**) generated by the differential pressure across the seat. When condensate temperature approaches that of saturated steam, bimetal expansion raises the stem to close the control valve. Lower temperature condensate relaxes the bimetal to open the valve. With this valve opening, the system differential pressure then acts on the diameter of the plug providing an increase in opening force and discharge capacity.

The **thermodynamic** forces are introduced by way of a three stage orifice containing an expansion chamber formed between the seat and skirt of the valve stem. The controlled generation of flash steam within the chamber increases the intermediate pressure and resultant opening force (**FO**) on the valve to increase hot discharge capacity. When the temperature increases, the flashing takes place closer to the seat at the entrance to the expansion chamber. This causes a sudden reduction in the opening force allowing the closing force (**FC**) to take over and pull the valve tightly onto the seat. This assures tight shutoff preventing the loss of live steam.

Characteristics of Thermostatic/Thermodynamic Traps

Plant Control

- Modulating discharge
- Can operate over wide pressure range
- Rapid response to load changes
- Excellent air handling capacity
- Excellent on superheat service
- Freeze-proof (self-draining)

Energy Control

- Steam tight
- Can be set to utilize sensible heat

Installed Costs

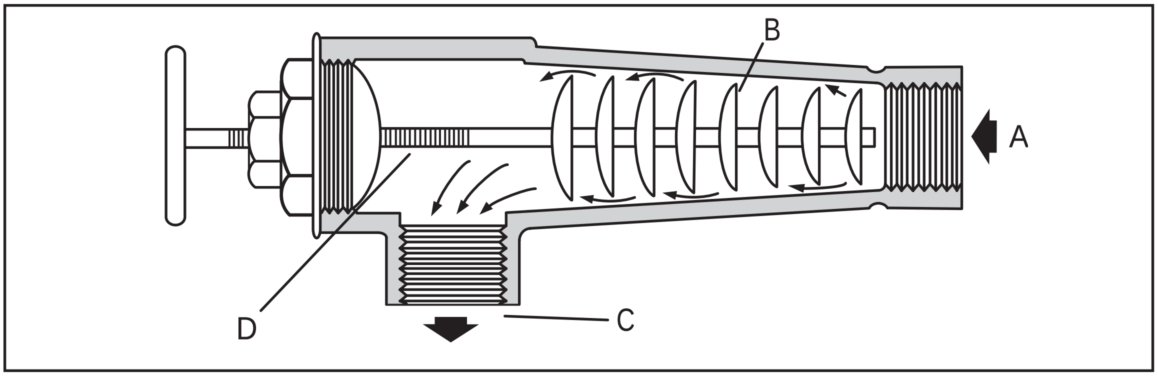
- Mount in any position
- Small size and weight
- Will act as check valve

Reliability

- Long service life over wide pressure range
- Resistant to water hammer
- Restricted operation on very high back pressures
- Limited application on very small differential pressures
- Fails open
- Freeze-proof (self-draining in vertical position)

Miscellaneous

Labyrinth



Condensate enters at **A**. The discs marked **B** are adjustable baffles increasing in diameter toward the outlet end of the trap. To move from one end to the other, the condensate flows past these restrictions, gradually losing pressure at each disc. This decreasing pressure results in some of the condensate flashing into steam in each of the chambers formed by the baffles. Because of this, the flow of condensate is slowed down, preventing live steam from escaping. Condensate is discharged from the trap at **C**.

The baffle plates can be pushed in or out (altering the clearances between the plates and the trap body) by adjusting spindle **D**.

Characteristics of Labyrinth Traps

Plant Control

- Continuous discharge
- Same hot and cold capacity
- Good air handling capacity
- Not for superheat applications
- Freeze-proof (self-draining)

Energy Control

- Live steam loss on low loads
- Not “true steam trap”

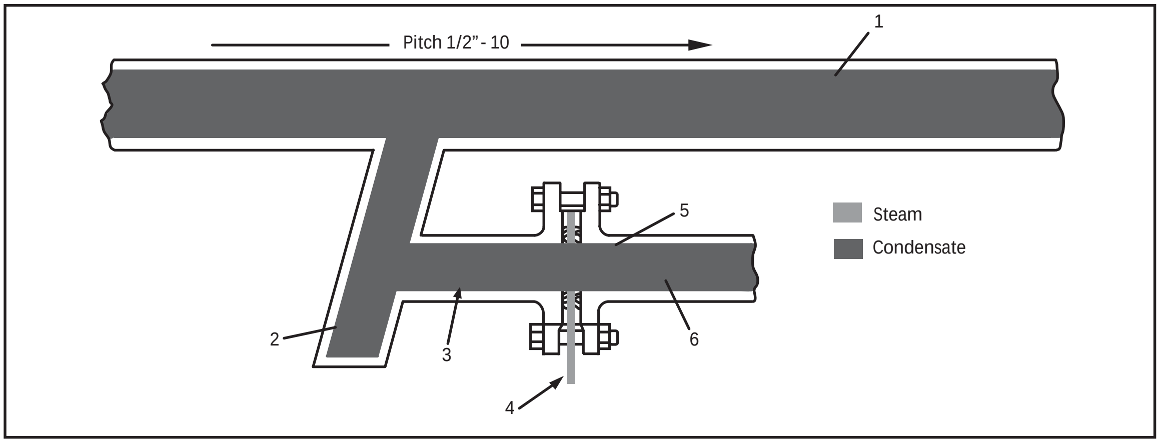
Installed Costs

- Mount in any position
- Small size and weight

Reliability

- No moving parts
- Must be adjusted for different pressure ranges
- Ineffective on low load applications
- Fails open

Orifice



As shown, the steam main (1) loses heat through radiation, etc., causing condensate to form. This accumulates at the bottom of the line and runs to the right due to the pitch of the pipe and gravity, until is spills into the drip leg (2) where it accumulates until it reaches a level sufficient to enter the drain line (3) and reaches equilibrium at a height above the middle of the orifice plate (4) and orifice (5). The balance of the steam main drip leg and drain line is steam filled.

This highly complex flow may be visualized with the help of the following idealization: consider the only water flowed through the system due to gravity. If the orifice had a safety factor of 1.5, then only two-thirds of the orifice would be filled and the equilibrium level would be slightly above the orifice center line. In actual conditions, only a small portion of steam (by weight) passes with the condensate. Since the specific volume of steam is large and the acceleration through the orifice causes turbulence, the steam and water are thoroughly mixed. Thus, with steam at saturation temperature, the orifice passes steam at a fixed rate (based on differential pressure) when no condensate is present at the orifice. At operating state, it passes full condensate production and steam at approximately 13% of the above steam flow rate. As condensate load increases, back up will result in lowering of temperature of discharge. This reduces the amount of restrictive flash steam allowing capacity to increase.

Characteristics of Orifice Traps

Plant Control

- Continuous discharge
- Same hot and cold capacity
- Excellent air handling capacity
- Not for superheat applications
- Freeze-proof (self-draining)

Energy Control

- Live steam loss on low loads
- Not “true steam trap”

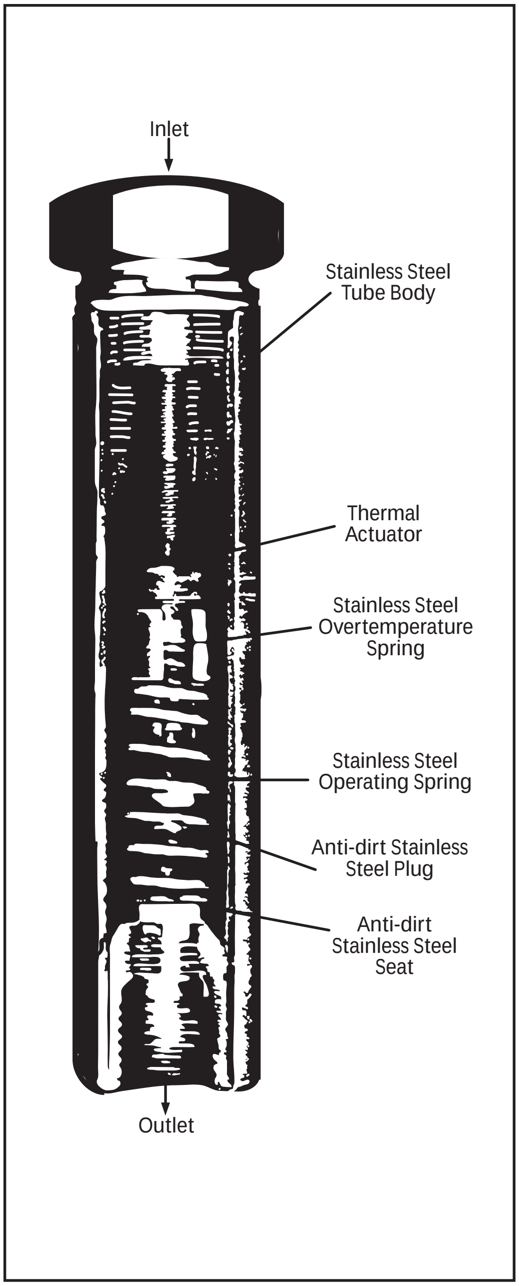
Installed Costs

- Mount in any position
- Small size and weight
- Must have accessory flanges

Reliability

- No moving parts
- Not good on fluctuating pressure or load applications
- Not good for process applications
- Ineffective on low load applications
- Fails open

Wax-filled



The hydrocarbon wax-filled device actuates the trap in response to changes in condensate temperature. The transition from solid to liquid phase causes a large change in volume, exerting a tremendous force over a narrow temperature band.

Cold Position

As temperature drops below preset temperature, the wax contracts (Fig. 1), allowing the trap to open. It remains open until the condensate temperature rises above preset temperature.

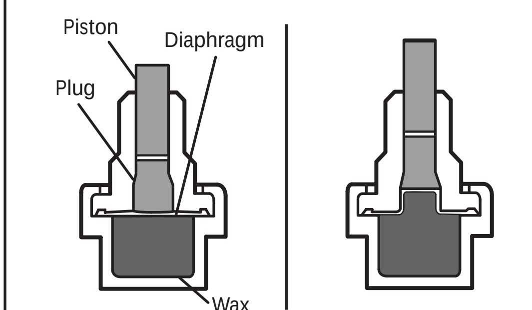


Figure 1 Figure 2

Hot Position

As condensate temperature rises, the wax expands (Fig. 2), closing the trap. It remains closed until condensate temperature drops below preset temperature.

Characteristics of Wax-filled Traps

Plant Control

- Continuous discharge
- Slow response to changing load conditions
- Limited applications range
- Good air handling capacity
- Not for superheat applications
- Freeze-proof (self-draining)

Energy Control

- Steam tight
- Can be set to utilize sensible heat
- Not “true steam trap”

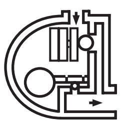
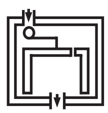
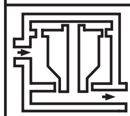
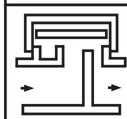
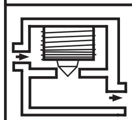
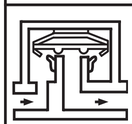
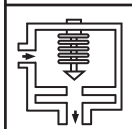
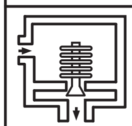
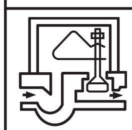
Installed Costs

- Mount in any position
- Small size and weight

Reliability

- Good service life
- Fair resistance to water hammer
- Not good for process applications
- Normally fails open

STEAM TRAP COMPARISON

		ADVANTAGES & DISADVANTAGES				
		PLANT CONTROL	ENERGY CONTROL	INSTALLED COST	RELIABILITY	MAIN APPLICATION
	**Float Type.** Float follows condensate level in chamber to open discharge valve. Opening increases with rising level in chamber giving modulated discharge. As operating presuure increases, valve size must be reduced as the buoyancy force from the float is fixed. A temperature sensitive valve may be fitted as an air vent.	**1.** Modulating **2.** Same hot and cold capacity. Size for start-up. **3.** Rapid air and CO_2 vent from separate valve. **4.** No superheat **5.** Select orifice for limited pressure range.	**1.** No steam loss when new **2.** Air vent can fail and lose steam	**1.** Large and heavy **2.** Horizontal mounting only **3.** No strainer or check valve	**1.** Wear on mechanical linkage and air vent **2.** Some dirt tolerance **3.** Sensitive to freezing **4.** Waterhammer damages float **5.** Replaceable seat	**1.** Process **2.** Space heating
	**Inverted Bucket Type.** Condensate flows around bucket to discharge through valve. Steam following condensate fills bucket, which rises to close valve due to its buoyancy. Steam escaping through bleed hole in bucket and condensing in body causes loss of buoyancy. Bucket fails to open valve as weight of bucket overcomes pressure valve. Steam is used to operate each cycle of the trap.	**1.** Cyclic **2.** Same hot and cold capacity. Size for start-up. **3.** Slow air and CO_2 venting. **4.** No superheat **5.** Orifice selection critical for narrow pressure range.	Steam loss each cycle from condensing action	**1.** Some versions light and compact **2.** Must be mounted vertically **3.** No strainer or check valve **4.** May require separate air vent or bypass	**1.** Low wear **2.** Dirt can block bleed hole **3.** Sensitive to freezing **4.** Replaceable seat on some versions **5.** Waterhammer can damage **5.** Susceptible to loss of prime	**1.** Process **2.** Drip leg (no superheat) **3.** Heating
	**Impulse Trap.** Condensate lifts piston to allow discharge. As steam dollows condensate into trap, it chokes flow through upper pilot orifice allowing pressure to build above the piston closing valve. There is always a small continuous steam loss through the pilot orifice.	**1.** Cyclic **2.** Same hot and cold capacity. Size for start-up. **3.** Slow air and CO_2 venting. **4.** Superheat OK **5.** Wide pressure range.	Steam loss each cycle and through pilot orifice	**1.** Compact **2.** Any mounting **3.** No check valve **4.** May require separate air vent or bypass	**1.** Low wear **2.** Dirt can foul pilot orifice **3.** OK freezing **4.** OK Waterhammer **5.** Replaceable seat	**1.** Drip leg **2.** Small process **3.** General
	**Disc Type.** As condensate is fully discharged, steam enters trap and flow velocity under disc rapidly increases. This reduces pressure below disc and pulls it down to close trap. Steam locked above disc cools, condenses, loses closing pressure and allows cycle to repeat. Steam is used to operate each cycle of the trap.	**1.** Cyclic **2.** Same hot and cold capacity. Size for start-up. **3.** Tendency to air lock. **4.** Superheat OK **5.** Wide pressure range.	**1.** Steam loss each cycle **2.** Loss increases with disc wear and fall in ambient temperature	**1.** Compact and light **2.** Horizontal mount preferred **3.** No check valve **4.** May require separate air vent	**1.** Disc wears **2.** Dirt increases steam loss **3.** OK freezing **4.** Can aggravate waterhammer **5.** Fixed seat	**1.** Drip leg **2.** Small process **3.** Tracing
	**Bellows Type.** Alcohol/water mixture sealed into bellows vaporizes as condensate approaches saturation temperature. Resulting expansion of bellows closes valve. Vaporization temperature increases as operating pressure compresses bellows, in rough approximation to steam curve.	**1.** Cyclic/Modulating **2.** Same hot and cold capacity. Size for start-up. **3.** Rapid air and CO_2 vent **4.** Limited superheat **5.** Modest pressure range.	**1.** Steam loss if blast discharge action **2.** Heavy loss if bellows fall	**1.** Compact and light **2.** Any mounting **3.** No strainer or check valve	**1.** Bellows can fracture **2.** Steam loss affected by dirt **3.** OK freezing **4.** Waterhammer can fracture bellows **5.** Fixed seat	**1.** Tracing **2.** Small process **3.** Radiators **4.** General
	**Capsule Type.** Operation is same as for bellows, but alcohol/water mix is contained within small, wafer-like element to reduce motion and improve cycle life.	**1.** Cyclic **2.** Same hot and cold capacity. Size for start-up. **3.** Rapid air and CO_2 vent **4.** Superheat possible **5.** Good pressure range.	**1.** Steam loss if blast discharge action **2.** Dirt in short travel valve can cause steam loss	**1.** Compact and light **2.** Any mounting **3.** No check valve	**1.** Limited cycle life of capsule **2.** Dirt can prevent short travel valve closing **3.** OK freezing **4.** Waterhammer may damage **5.** Fixed seat	**1.** Tracing **2.** Drip leg
	**Bimetallic - temperature sensing only.** Temperature sensitive bimetal stack closes valve. Individually adjusted to close at fixed temperature, it is therefore restricted to narrow operating pressure range unless re-adjusted.	**1.** Modulating **2.** Good cold, poor hot capacity **3.** Rapid air and CO_2 vent **4.** Superheat OK **5.** Must be set to line pressure	Steam tight at set pressure only	**1.** Compact **2.** Mount any position **3.** May require check valve	**1.** Disc wears **2.** Dirt increases steam loss **3.** OK freezing **4.** Can aggravate waterhammer **5.** Fixed seat	**1.** Tracing
	**Bimetallic - Thermostatic.** Operating pressure is applied across face of valve to oopose temperature closing force. This helps trap to follow steam curve, giving wider operating pressure range. Discharge capacity falls as condenate temperature rises towards saturation temperature, providing poor hot discharge.	**1.** Modulating **2.** Good cold, poor hot capacity **3.** Rapid air and CO_2 vent **4.** Superheat OK **5.** Good pressure range	**1.** Steam tight **2.** Wear in bimetal stack can cause steam loss	**1.** Compact **2.** Mount any position **3.** No extras required	**1.** Dirt in stack causes back up **2.** Wear in stack causes steam loss **3.** OK freezing **4.** Replaceable seat	**1.** Tracing **2.** Drip leg
	**Bimetallic-Thermostatic/Thermodynamic (Bestobell Design).** Same as bimetallic - thermostatic, but additional thermodynamic flow forces, develped in downstream expansion chamber, improve hot discharge capacity right up to saturation temperature.	**1.** Modulating **2.** Good cold, poor hot capacity **3.** Rapid air and CO_2 vent **4.** Superheat OK **5.** Good pressure range	**1.** Steam tight **2.** Does not utilize steam to function	**1.** Compact **2.** Mount any position **3.** No extras required **4.** No bypass required	**1.** Low wear **2.** Dirt resistant **3.** OK freezing **4.** OK Waterhammer **5.** Replaceable seat **6.** No Fatigue	**1.** Drip leg **2.** Process **3.** Heating **4.** General **5.** Tracing **6.** Subcooled tracing

Traps Should Be Selected and Sized Based On Capacity

A random Selection of ½" inverted bucket traps showed the following capacities at 40 psi differential pressure:

½"……………………….750 lb/hr
½"……………………….270 lb/hr
½"……………………….470 lb/hr
½"……………………….620 lb/hr
½"……………………….280 lb/hr
½"……………………….900 lb/hr

Even when using the same "type" of trap, you could easily disrupt your system by selecting a replacement trap based on pipe size. The traps could be too small and back up or too large and inefficient.

Chapter 3

Determining Condensate Loads

The total steam generation requirement is determined by the rate of steam consumption, or a plant's total steam load. As the steam is used, it is turned into condensate which must be rapidly removed to maximize the efficiency of the total steam system. It is critical that the steam traps are selected not only for their operating features, but for their ability to handle the required condensate loads.

The FIFTH RULE for the efficient use of steam: *a pound of steam equals a pound of condensate.*

The basic formula for the calculation of the condensate load in any steam system is:

$$C = \frac{(W)\,(Cp)\,(T2 - T1)}{h_{fg}} \qquad \textit{where}$$

C = Condensate load in lbs.
W = Weight of material to be heated in lbs.
Cp = Specific heat of material to be heated in BTU/lb/°F
T2 = Final temperature of material to be heated in °F
T1 = Initial temperature of material to be heated in °F
h_{fg} = Latent heat of steam used in BTU/lb.

The formula for the time required to achieve the final temperature of the material to be heated is:

$$t = \frac{\text{“}T}{°F/hr.} \qquad \textit{where}$$

t = Time required in hrs.

“T = Temperature rise in °F (T2 –T1)

°F/hr = Rate at which temperature rise occurs.

The rate at which condensate flows is then:

$$CR = \frac{C}{t} \quad \textit{where}$$

CR = Condensate rate in lbs./hr
C = Condensate load in lbs.
t = Time required in hrs.

Combining the three previous formulas gives:

$$CR = \frac{(W)\ (Cp)\ (\text{“}T)}{(h_{fg})\ (t)}$$

The basic formula **assumes 100% efficiency,** or that all of the heat available in the steam is transferred directly to the material to be heated. Because this condition rarely, if ever, occurs, a sizing factor is commonly applied to the answer to compensate. Bestobell typically uses a 1.5 factor for equipment with small steam spaces. **(Note: See appendix for useful charts applicable to this section).**

Insulated Steam Mains

Running Loads

The formula for calculating the running condensate load in insulated steam mains is:

$$C = \frac{(U)\ (A)\ (\text{“}T)\ (If)}{h_{fg}} \quad \textit{where}$$

CR = Condensate rate in lbs/hr.
U = Heat transfer coefficient in BTU/hr/sq.ft./°F (see Table 1)
A = Total area of heating surface in sq. ft. (external area of pipe in sq. ft. / ft. x length of pipe in ft.) (see Table 1A)
“T = Steam temperature minus air temperature in °F
If = Insulation factor (1 minus efficiency)
h_{fg} = Latent heat of steam in BTU/lb.

Example:

What is the calculated condensate for 100’ of 8" steam main operating at 150 psig with an ambient air temperature of 70ºF? Assume pipe insulation efficiency at 85%.

$$CR = \frac{(3.0)\ (2.258 \times 100)\ (365-70)\ (1-.85)}{858}$$

$$= \frac{(3.0)\ (225.8)\ (295)\ (.15)}{858}$$

$$= 34.94 \text{ lbs.}$$

The approximate condensate rate per foot of insulated steam main is shown in Table 1.

Steam Pressure PSIG	“U”	STEAM MAIN SIZE								
		2”	4”	6”	8”	10”	12”	16”	20”	24”
10	2.5	.04	.08	.12	.15	.19	.22	.28	.35	.42
50	2.6	.06	.11	.17	.22	.27	.32	.41	.51	.61
75	2.7	.07	.13	.20	.26	.32	.38	.47	.59	.71
100	2.8	.08	.15	.22	.29	.36	.43	.54	.67	.80
150	3.0	.10	.18	.27	.35	.44	.52	.65	.81	.97
200	3.2	.11	.21	.31	.41	.51	.61	.76	.95	1.14
300	3.4	.14	.26	.39	.50	.63	.74	.93	1.17	1.40
450	3.6	.17	.32	.48	.62	.77	.92	1.15	1.44	1.73
600	3.8	.20	.39	.57	.74	.92	1.09	1.37	1.72	2.06
900	4.1	.28	.51	.75	.97	1.21	1.44	1.80	2.25	2.70

Table 1

Table 1 is based on 70ºF ambient temperature and assumes pipe insulation at 85% efficiency. To convert to 0ºF ambient temperature with a moderate wind, multiply by 1.5. To convert to a different insulation efficiency, divide values in the table by .15 and multiply by 1 minus the pipe insulation efficiency rating.

	PIPE SIZE								
	2”	4”	6”	8”	10”	12”	16”	20”	24”
Sq. Ft./Linear Ft.	0.622	1.178	1.734	2.258	2.815	2.34	4.19	5.24	6.29
Length/Sq. ft. surface	1.608	0.848	0.576	0.442	0.355	0.299	0.238	0.191	0.159
Wt. -lbs./ft. Sch. 40	3.65	10.79	18.97	28.55	40.48	53.60	83.00	123.0	171.0
Wt. -lbs./ft. Sch. 80	5.02	14.98	28.57	43.39	54.74	88.60	137.0	209.0	297.0
Wt. -lbs./ft. Sch. 160	7.45	22.60	45.30	74.70	116.0	161.0	245.0	379.0	542.0
Wt. -lbs/ft. XX Strong	9.03	27.54	53.16	72.42	--	--	--	--	--

Table 1A

Warm-Up Load

The formula for calculating the warm-up load in insulated steam mains is:

$$C = \frac{(W)\ (L)\ (Cp)\ (\text{“}T)}{hfg} \qquad \textit{where}$$

C = Condensate in lbs.
W = Weight of pipe in lb/ft. (See Table 1A)
L = Length of pipe in ft.
*Cp = Specific heat of pipe in BTU/lb/*ºF *(Use .115 for steel) – (See Table 6)*
“T = Final temperature minus starting temperature in ºF
hfg = Latent heat of steam in BTU/lb

Example:

What is the calculated condensate load to bring a steam main of 200’ of 10" schedule 40 steel pipe to operating conditions of 100 psig from an ambient temperature of 50ºF?

$$C = \frac{(40.48)\ (200)\ (.115)\ (338-50)}{881}$$

$$= 304.4 \text{ lbs.}$$

The condensate load in lbs. divided by the time required to bring the main to the final temperature gives the condensate rate in lbs/hr.

The approximate warm-up condensate load per foot of steel steam main is shown in Table 2.

Steam Pressure PSIG	“K”	STEAM MAIN SIZE (Sch. 40 Steel Pipe*)								
		2”	4”	6”	8”	10”	12”	16”	20”	24”
10	1.41	.07	.22	.39	.58	.83	1.09	1.69	2.51	3.50
50	1.31	.10	.31	.54	.82	1.16	1.53	2.37	3.52	4.90
75	1.28	.12	.35	.61	.92	1.30	1.72	2.66	3.95	5.50
100	1.26	.13	.38	.66	1.00	1.42	1.87	2.90	4.31	5.99
150	1.24	.14	.43	.75	1.13	1.60	2.12	3.27	4.87	6.77
200	1.22	.16	.47	.83	1.24	1.76	2.33	3.60	5.36	7.45
300	1.20	.18	.54	.95	1.44	2.04	2.69	4.16	6.19	8.61
450	1.18	.22	.64	1.13	1.70	2.40	3.18	4.91	7.31	10.17
600	1.16	.24	.71	1.25	1.89	2.68	3.54	5.47	8.14	11.32

Table 2

Table 2 is based on an ambient (starting) temperature of 70ºF. Multiply the value given by the “K” factor corresponding to the steam pressure to convert to an ambient (starting) temperature of 0ºF.

To convert to pipe other than schedule 40, divide the value given in Table 2 by the other pipe weight and multiply by the appropriate amount.

Steam Tracing Lines

The condensate load formed in steam tracing lines is determined by the amount of heat loss in the associated product line. The following formula can be used:

$$CR = \frac{(L)\ (U)\ (\text{“}T)\ (If)}{(s)\ (hfg)} \quad \textit{where}$$

CR = Condensate rate in lbs/hr
L = Product line length between traps in ft.
*U = Heat transfer coefficient in BTU/hr/sq ft/*ºF (*See Table 1)*
“T = Temperature difference between product line temperature and ambient temperature in ºF
If = Insulation factor (1 minus efficiency)
S = Length of product pipe per sq ft of surface (See Table 1A)

Example:

With a steam tracing pressure of 100 psig, what is the calculated condensate rate of 100’ of 16" insulated pipe to maintain a product temperature of 180ºF with a minimum ambient temperature of 20ºF? Assume pipe insulation efficiency of 80%.

$$CR = \frac{(100)\ (2.8)\ (160)\ (.20)}{(.238)\ (881)}$$

$$= 42.73 \text{ lbs/hr}$$

Note: A rule of thumb that may be used in sizing steam traps for tracing service or determining maximum trap spacing is:

CR = 50 lb/hr per 100’ of tracing line

Space Heating Equipment

The rule for sizing equipment which uses steam to heat air (such as unit heaters) is to determine the BTU/hr rating required and divide by the latent heat of the steam. The standard rating method for air heating units is based on BTU output of 2 psig steam with an entering air temperature of 60ºF. In order to use the rating data of the equipment and determine the condensate load, a conversion factor must be used if conditions are other than standard.

This conversion factor is shown in Table 3.

Steam Pressure PSIG	STEAM MAIN SIZE (Sch. 40 Steel Pipe*)										
	0	10	20	30	40	50	60	70	80	90	100
2	--	--	--	--	1.2	1.1	1.0	.9	.8	.8	.7
5	1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.0	.8	.8	.7
10	1.6	1.5	1.5	1.4	1.3	1.2	1.1	1.1	.9	.9	.8
15	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.1	1.0	1.0	.9
20	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.0	1.0	1.0
30	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.1	1.1	1.0
50	2.0	1.9	1.8	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.2
70	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.4	1.3
100	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.7	1.5	1.5	1.4

Table 3

The condensate rate is then determined by the following formula:

$$CR = \frac{(R)(K)}{hfg} \quad \text{where}$$

CR = Condensate rate in lbs/hr
R = Standard rating of the unit in BTU/hr
K = Conversion factor (Table 3)
hfg = Latent heat in BTU/lb

Example:

What is the condensate rate of a unit heater operating at 15 psig with a rating of 200,000 BTU/hr and 10ºF entering air?

$$CR = \frac{(200{,}000)(1.6)}{946}$$

$$= 338.3 \text{ lbs/hr}$$

If the unit is rated in cfm, the condensate load can be determined by the following formula:

$$CR = \frac{(F)\ (60)\ (Cp)\ (d)\ (\text{“}T)}{hfg} \qquad \textit{where}$$

CR = Condensate rate in lbs/hr
F = Air flow rate in cfm
60 = min/hr
*Cp = Specific heat of air in BTU/lb/*ºF *– (use .24)*
d = Density of air in lbs/cu ft – (use .075)
“T = Temperature rise through unit (outlet air temperature minus inlet air temperature) in ºF
hfg = Latent heat of steam in BTU/lb

Substituting values in the above formula reduces it to:

$$CR = \frac{(F)\ (60)\ (.24)\ (.075)\ (\text{“}T)}{hfg} \quad \textit{or} \quad \frac{(F)\ (1.08)\ (\text{“}T)}{hfg}$$

Example:

What is the condensate load from a 3000 cfm heater operating on 30 psig steam pressure with an outlet air temperature of 100ºF and an inlet air temperature of 60ºF?

$$CR = \frac{(3000)\ (1.08)\ (40)}{929}$$

$$= 139.5 \text{ lbs/hr}$$

Note: A general rule of thumb is $CR = \frac{(cfm)\ (\text{“}T)}{900}$

Process Air Heaters

These units differ from space heating equipment in that they generally operate at much higher temperatures and thus require greater steam pressures. In certain applications requiring extremely high temperatures, process air heaters may be mounted in series where the outlet air from one unit enters the next unit to be progressively heated.

The formula for calculating the total condensate rate is the same as the previous example except that the load is determined by the temperature rise through each individual coil. Although the flow rate (in cfm) through each coil in the series is the same, the air entering the first coil is cooler than when entering the second; therefore the temperature rise is greater through the first coil and the condensate load is greater.

In order to determine the approximate condensate load on each coil, use Table 4.

No. of Coils in Series	% Temperature Rise Across Each Coil			
	1st Coil	2nd Coil	3rd Coil	4th Coil
1	100	--	--	--
2	64	36	--	--
3	54	28	18	--
4	46	26	16	12

Table 4

Steam Radiation with Finned Tubes

This is generally a low pressure, low capacity application where a "rule of thumb" is suitable:

CR = .24 x sq ft EDR *or* $\frac{\text{square feet EDR}}{4}$

EDR = Equivalent Direct Radiation; 1 square foot EDR equals 240 BTU/hr

Note: A general rule of thumb is CR = 1.5 pph/lineal ft of finned *steel* pipe or CR = 2.2 pph/lineal ft of finned *copper* pipe.

Steam Radiation with Pipe Coils

In this application, bare pipe coils are mounted to give free convection of air. Steam flows through the coils while air flows over the coils with natural or forced circulation. The formula is:

$$CR = \frac{(A)\ (U)\ (\Delta T)}{hfg} \qquad \textit{where}$$

CR = Condensate rate in lbs/hr
A = Area of pipe coils heating surface in sq ft (obtain by multiplying length in ft by sq ft/linear ft from Table 1A)
*U = Heat transfer coefficient in BTU/hr/sq ft/*ºF *(Use 2 for natural circulation)*
ΔT = Steam temperature minus ambient air temperature in ºF
hfg = Latent heat of steam in BTU/lb
Example:

50 ft of 2" pipe coil mounted on a wall, has a surrounding ambient air temperature of 75ºF. What is the condensate rate using 15 psig steam?

$$CR = \frac{(50 \times .622)\ (2)\ (250\text{-}75)}{946}$$

$$= 11.5 \text{ lbs/hr}$$

Heating Liquids with Steam

The calculation of the condensate rate in these applications can be grouped into two main categories: batch heating where the product is in a container and heated at one time or continuous heating, where a flowing liquid is heated as it passes through the heat exchanger. The major difference between the two applications is that the condensate rate in batch heating is variable – very high at the beginning when the product is cold and low at the end of the cycle when the product has reached the desired temperature.

Shell and Tube Heat Exchangers

In these units, steam is flowing through tubes within a housing or shell into which the liquid to be heated is circulating. (The reverse can be true where steam is in the shell and the liquid is in the tubes). The formula for condensate rate is:

CR = (L) (60) (Cp) (W) (“T) *where*
hfg

CR = Condensate rate in lbs/hr
L = Flow in GPM
60 = Min/hr
*Cp = Specific heat of liquid in BTU/lb/*ºF *(See Table 5)*
W = Weight of liquid in lbs/gal (See Table 5)
“T = Temperature rise of liquid in ºF
hfg = Latent heat in BTU/lb

Example:

What is the condensate rate from heating #3 fuel oil flow from 60ºF to 180ºF using steam at 70 psig? Flow rate is 40 GPM.

CR = (40) (60) (.43) (7.3) (120)
899

= 1005.6 lbs/hr

When heating water with steam, the formula becomes simpler as the specific gravity of water is 1.0 and the specific heat of water is also 1.0. Water weighs 8.33 lbs/gallon, so combining all of these factors, the formula for heating water with steam is:

CR = Condensate rate in lbs/hr
L = Water flow in GPM
500 = 60 min/hr x 8.33 lbs/gal
T = Temperature difference in ºF
hfg = Latent heat of steam in BTU/lb

Example:

What is the condensate rate from heating 1 GPM of water from 90ºF to 200ºF using 20 psig of steam?

$$CR = \frac{(12)\ (500)\ (110)}{940}$$

$$= 702.1 \text{ lbs/hr}$$

Note: General rules of thumb to use for water and oil are:

Heating water with steam = $\frac{\text{GPM x ˝T}}{2}$

Heating oil with steam = $\frac{\text{GPM x ˝T}}{4}$

Note: To find the weight in lb/gal of a liquid, multiply the specific gravity of the liquid by 8.33.

Table 5

Liquid	Specific Heat BTU/lb./°F	Specific Gravity @ 70°F	Weight lb/gal.
Acetic Acid	.47	1.05	8.7
Alcohol	.65	.81	6.7
Benzene	.45	.84	7.0
Dowtherm A	.63	.99	8.2
Dowtherm C	.50	1.10	9.2
Ethylene Glycol	.58	1.11	9.2
Glycerine	.58	1.26	10.5
Kerosene	.47	.81	6.7
#3 Fuel Oil	.43	.88	7.3
#6 Fuel Oil	.40	.95	7.9
Sea Water	.94	1.03	8.6
Sulfur	.23	2.00	16.7
Water	1.00	1.00	8.33

Submerged Coils

Where submerged pipe coils are used to raise a liquid to the desired temperature, the formula is:

$$CR = \frac{(W)\ (Cp)\ (“T)}{(hfg)(t)} \quad \textit{where}$$

CR = Condensate rate in lbs/hr
W = Weight of liquid to be heated in lbs
*Cp = Specific heat of liquid to be heated in BTU/lb/*ºF *(See Table 5)*
“T = Final temperature minus starting temperature in ºF
hfg = Latent heat of steam in BTU/lb
t = Time to achieve final temperature in hrs. (See Chapter 3)

Example:

What is the condensate load from heating 800 gallons of parts cleaning fluid (sg = 1.02; Cp = .90) from ambient of 70ºF to 120ºF in 1 ½ hrs using 30 psig steam?

$$CR = \frac{(800 \times 1.02 \times 8.33)\ (.90)\ (50)}{(929)\ (1.5)}$$

$$= 219.5 \text{ lbs/hr}$$

When the size of the embossed coil or the length of the pipe coil is known, this formula can be used:

$$CR = \frac{(U)\ (A)\ (T_2 - T_1)}{(hfg)\ (t)} \quad \textit{where}$$

CR = Condensate rate in lbs/hr
*U = heat transfer coefficient in BTU/hr/sq ft/*ºF *(See Table 6A or 6B)*
A = surface area of heating coil or plate in sq ft (See Table 7)
T_2 *= mean temperature of heating surface or medium in* ºF
T_1 *= mean temperature of liquid being heated in* ºF
hfg = latent heat of steam in BTU/lb
t = time to achieve final temperature in hrs (See Chapter 3)

Table 6A: Pipe Coil "U" Values

Type of Service	Circulation	
	Natural	Forced
Steam to Water	50-200	150-1200
1-1.2" Tube Heaters	180	450
3/4" Tube Heaters	200	500
Steam to Oil	10-30	50-150
Steam to Boiling Liquid	300-800	--
Steam to Boiling Oil	50-150	--

Table 6B: Embossed Coil "U" Values

Type of Service	Circulation	
	Natural	Forced
Steam to Watery Solutions	100-200	150-275
Steam to Light Oil	40-45	60-110
Steam Medium Oil	20-40	50-100
Steam to Bunker C	15-30	40-80
Steam to Tar Asphalt	15-25	18-60
Steam to Molten Sulphur	25-35	35-45
Steam to Melted Paraffin	25-35	40-50
Steam to Food Syrups	20-40	70-90

Table 7: Square Foot Conversion For Pipe Coils

Pipe Size	Steel Pipe	Copper/Brass Pipe
1/2"	4.55	7.63
3/4"	3.64	5.09
1"	2.90	3.82
1-1/4"	2.30	3.05
1-1/2"	2.01	2.55
2"	1.61	1.91
2-1/2"	1.33	1.52
3"	1.09	1.27
4"	0.848	0.954

Sq. Ft. of Surface = lineal feet of pipe in coil divided by factor in table for given size and type pipe.

Steam Jacketed Kettles

In this application, product is heated in a cooking pot which is surrounded by a steam jacket. This unit is usually open on top: the product is usually not under any pressure. The formula to use to calculate the condensate rate is:

$$CR = \frac{(G)\ (s.g.)\ (Cp)\ (\text{“}T)\ (8.33)}{(hfg)\ (t)} \quad \text{or} \quad \frac{(G)\ (W)\ (Cp)\ (\text{“}T)}{(hfg)\ (t)} \quad \textit{where}$$

CR = Condensate rate in lbs/hr
G = Liquid to be heated in gallons
*s.g. = Specific gravity of liquid to be heated in BTU/lb/*ºF *(Table 5)*
*Cp = Specific heat of liquid to be heated in BTU/lb/*ºF *(Table 5)*
“T = Final liquid temperature minus initial liquid temperature in ºF
8.33 = Weight of water in lbs/gal
hfg = Latent heat of steam in BTU/lb
t = Time in hours (See Chapter 3)
W = Weight of liquid in lbs/gal (s.g. of liquid x 8.33)

Example:

40 gallons of soup is to be brought to boil in a jacketed kettle. It starts at 70ºF (s.g. = 1.15; Cp = .95). If the boiling occurs in 45 minutes, what is the condensate rate using steam at 30 psig?

$$CR = \frac{(40)\ (1.15)\ (.95)\ (142)\ (8.33)}{(929)\ (.75)}$$

= 74.2 lbs/hr

Sterilizers, Retorts, Autoclaves

These units heat materials for sterilizing, cooking, or curing by direct contact with the steam. The formula is:

CR = Condensate rate in lbs/hr
W = Weight of the material in pounds
*Cp = Specific heat of the material in BTU/lb*ºF
(See Table 8)
“T = Temperature rise of the material in ºF
hfg = Latent heat of steam in BTU/ lb
t = Time to achieve final temperature in hours
(See Chapter 3)

Solid	Spec. Heat BTU/lb/°F
Aluminum	.23
Asphalt	.40
Brass	.10
Brick	.22
Copper	.10
Glass	.20
Iron	.131
Lead	.03
Nickel	.11
Paper	.45
Plastic	.35
Rubber	.40
Silver	.057
Solder	.04
Steel	.115
Sugar	.30
Tin	.056
Wood	.45
Zinc	.095

Table 8

Example:

Calculate the condensate rate from sterilizing 40 pounds of steel surgical instruments at 205ºF for 30 minutes using steam at 100 psig (Assume instruments are at room temperature of 75ºF).

$$CR = \frac{(40)\ (.115)\ (140)}{(881)\ (.5)}$$

$$= 1.5 \text{ lbs/hr}$$

If the unit is constructed such that the steam does not come into direct contact with the material, the same formula is used for the amount of steam required. The time required to reach the required temperature will be longer and the total condensate load will be higher as a greater mass of equipment must be heated (i.e. the steam jacket).

Steam Jacketed Molding Presses – Platens

In this equipment, water is removed from material such as in laundry presses, glue is cured such as with plywood, rubber is cured, and plastic is molded and cured (Note: this application typically requires a blast discharge type trap). The formula for the approximate condensate rate is:

CR= (A) (R) *where*

CR = Condensing rate in lbs/hr
A = Area of platen in contact with the product in square feet
R = Rate of steam condensing in lbs/sq ft/hr – Use as an approximate rate

Example:

What is the corresponding condensate rate for a laundry flatwork ironer which measures 1’ x 3’?

CR = (1 x 3) (7)

= 21 lbs/hr

Rotary Dryers

In these units, product is heated to reduce moisture content by bringing it in contact with a steam filled rotating cylinder. The time the steam is in contact with the surface determines how much the moisture is reduced in the product. The speed of the cylinders is usually around 2-3 rpm. This gives a high surface velocity on the large drums used in paper production, for instance.

Note: Typically this is a difficult application for steam traps, unless the dryer rolls are small. A cascade condensate drainage system works well, due to its lack of sensitivity to the condensate temperature.

The formula used is:

CR = (A) (R) *where:*

CR = Condensate rate in lbs/hr
A= Surface area of cylinder in feet (Diameter x 3.14 x width)
R = Rate of steam condensing in lbs/sq ft/hr – Use 7 as an approximate rate

Example:

What is the condensate rate on a rotary paper dryer 6' in diameter and 15' in width?

CR = (6) (3.14) (15) (7)

= 1978.2 lbs/hr

These units contain a siphon drain in order to pickup condensate for removal from the drum. The discharge pipe then leaves the equipment through the rotary joint.

Steam Jacketed Dryers

Some product is dried by placing it in rotary drums which are heated with steam jackets. The moisture is removed from the product by raising it to the vaporizing point. To approximate the condensate rate, use the following formula.

$$CR = \frac{(K)\,(W1-W2) + (W1)\,(Cp)\,(\text{“}T)}{hfg} \qquad \textit{where}$$

CR = Condensate rate in lbs/hr
K = Approximate latent heat at atmospheric pressure required to vaporize the moisture removed from the product – Use 1000 BTU/lb
W1 = Initial weight of product in lbs/hr
W2 = Final weight of product in lbs/hr
Cp = Specific heat of moisture removed in BTU/lb/ ºF
“T = Final product temperature minus initial product temperature in ºF
hfg = Latent heat of steam in BTU/lb

Example:

A batch of wood chips is to be dried in 1 hour. The wet wood weighs 2000 lbs and has 60% water by weight. It is at 50 ºF ambient temperature and the dryer will use 120 psig steam. Calculate the condensate rate.

$$CR = \frac{(1000)\,(2000 - 800) + (2000)\,(1)\,(212-50)}{871}$$

$$= \frac{1{,}200{,}000 + 324{,}000}{871}$$

$$= 1749.7 \text{ lbs/hr}$$

Chapter 4

Steam Trap Installation And The Condensate Return System

To maximize the efficiency of the total steam cycle, careful consideration must be given to the proper installation of the steam trap and its associated equipment. A properly designed condensate return system is crucial to the overall steam system. If not properly designed, be prepared for problems such as back pressure build-up, "short-circuiting," and other situations which can affect the efficiency of the total system.

The SIXTH RULE for the efficient use of steam: *steam can't get in the equipment if the condensate can't get out.*

Steam Trap Installation

In designing an efficient and economic installation, you should consider the following:

Steam Supply Side

The steam supply to the equipment should take off from the top of the steam main so as to pick up only dry steam. This may also eliminate scale and condensate that could be present in the steam main, and keep it from getting into the control valve, the equipment, or the steam trap.

Gravity Drain

In order for the steam trap to discharge the condensate, it must enter at the inlet to the trap. Under pressure conditions, this does not cause much of a problem; however, in low pressure situations or when the steam to the equipment is shut off, it is important that gravity causes the condensate to flow through the equipment to the steam trap in order to drain the system. This prevents freeze-up and water hammer that could occur with the accumulation of condensate at low points in the equipment.

Trap Location

Wherever possible, the steam trap should be located approximately 2' from and below the discharge of the equipment. This provides sufficient space for the installation of all of the required accessories as well as a collecting pocket to help remove condensate from the equipment and supply it to the steam trap.

Strainers

Strainers, either built in or separate, are recommended with all steam traps. Strainers increase the life of steam traps by removing scale and dirt form the system. This scale and dirt, when discharged through the steam trap, can cause wear on the metal seating surfaces which will lead to premature loss of the trap's steam-tight property. Where 'Y' type strainers are used, strainer blow-down valves are recommended.

Isolating Valves

Install gate or ball valves before and after the steam trap to ease maintenance by isolating the trap form the rest of the system. The outlet valve can be eliminated when discharging condensate to the ground. If the trapped unit has a shut-off valve on the steam inlet, this can be used to isolate the steam trap.

Globe valves should not be used unless they are installed with the stem horizontal. Otherwise, a blockage of flow can be caused by the need for the water to rise above the elevation of the seat. In steam service, this can allow condensate to back up behind the seat.

Unions

Unions should be installed between the isolating valves and the steam trap so that the trap can be removed and replaced as required. This is especially important where non-maintainable traps are used. The spacing between unions should be standardized so that replacement assemblies can be made up ahead of time to allow the equipment back in service as quickly as possible. The union on the discharge side can be eliminated if the condensate is discharged to the ground.

Bypass Hook-ups *(Figure 1)*

In certain applications, such as cold start-up of steam mains at the beginning of the season, it may be practical to install a bypass valve manifold around the steam trap to provide additional capacity. The steam trap can then be sized for the normal running loads. Caution should be used in the installation of bypass valves as they could inadvertently be left open allowing large amounts of live steam to be lost when the running loads are achieved. Most steam trap manufacturers discourage the use of a bypass. *By selecting a trap design that provides for high cold start-up capacity, the bypass is not needed.*

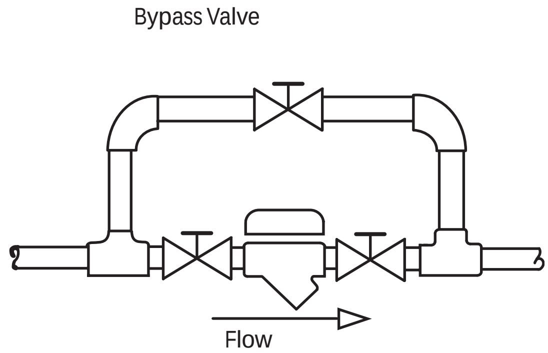


Fig. 1

Steam Traps in Parallel *(Figure 2)*

In some applications, such as the start-up situation above, parallel traps can be installed. One trap is sized for the normal running load. The second trap is sized to handle the start-up load. This should be valved in the same manner as the running load arrangement so that each trap can be maintained separately. Although the bypass trap installation is more expensive, it may be cost-effective in eliminating the possibility of live steam blowing through the bypass valve if left in the open position.

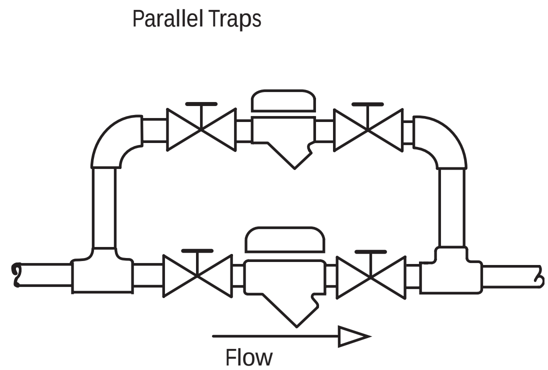


Fig. 2

Parallel traps can also be used in critical process applications where the unit cannot be shut down for servicing. One trap can be on stream while the parallel trap is being serviced.

Test Valves

A test valve can be used after the steam trap to determine the trap discharge characteristics and to see if the trap is worn or blowing through. It is also a convenient place to install a pressure gauge to check on the operating conditions of the return system. A small globe valve can be used for this purpose. Note: test valves are not used in closed return systems operating under a back pressure.

To check inlet conditions, the strainer blow-down valve can be used. The presence of large amounts of condensate can indicate a plugged trap, a trap too small to handle the load, or other problems. The strainer blow-down is also a convenient place to install a gauge to check inlet pressures.

Dirt Pockets

In certain applications, such as large steam mains where continuous formation of scale can cause problems in the system, a dirt pocket should be installed. The dirt pocket is an extension of the equipment's drainage line where scale and dirt can settle. The take off point for the steam trap is at some elevation above the bottom part of the dirt pocket so that no scale is transported into the steam trap installation. A blow down can be used to remove the scale from the dirt pocket.

Check Valves

Check valves are recommended whenever the condensate is "lifted" above the elevation of the steam trap's discharge. They prevent the back-flow and siphoning of condensate into the equipment from the return main which can occur when the equipment is shut down and draws a vacuum. Traps with a built-in check valve eliminate this requirement.

Sight Flow Indicators

Installing a sight flow indicator after the steam trap can allow a quick visual check on the trap's performance. It can be helpful to install a unit on the inlet side on a critical application to monitor whether condensate is backing up.

Some steam traps are available with built-in slight glasses for simplified installation.

Air Vents

Because air can accumulate at remote points, vents can be installed to bleed the air from the equipment to allow steam to fill the spaces. These are helpful because the condensate may not be able to "scrub" air out of these stagnant points and carry it to the steam trap for discharge. Most air vents operate thermostatically and will allow some live steam to discharge with the air before they can close.

Vacuum Breakers

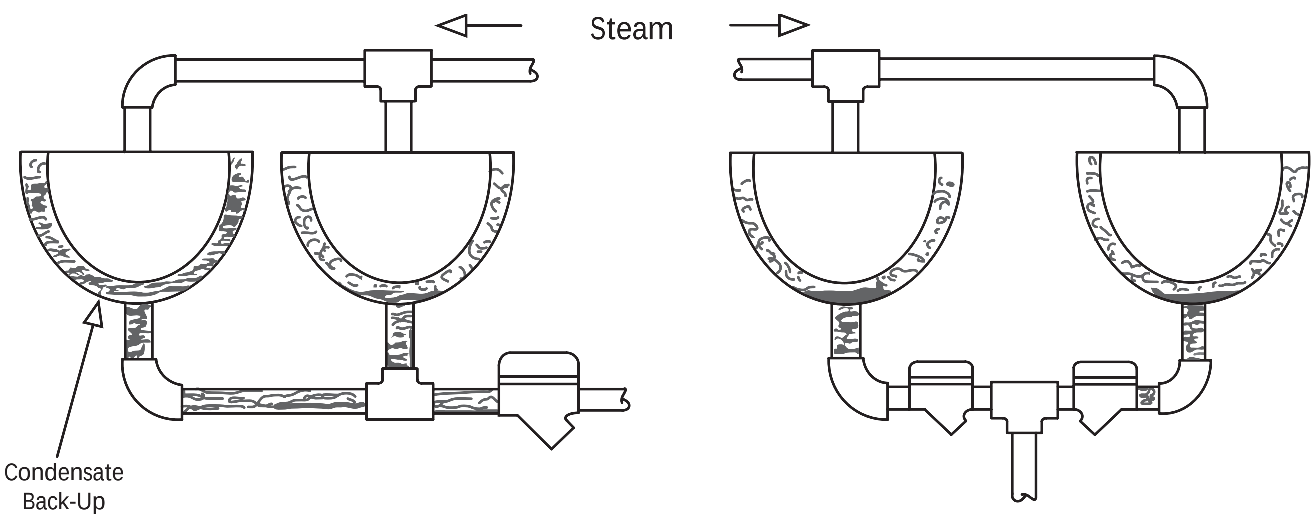
Whenever steam condensing equipment is shut down hot, the cooling creates a vacuum which can draw fluids into the system. These fluids could be air drawn through the return system, shut-off valves, or small pinholes in the piping. Corrosive process fluids surrounding submerged coils can be more damaging, and cause severe system damage. A vacuum could collapse copper heating coils or thin wall material requiring costly repairs.

A vacuum breaker will prevent these problems by introducing air into the equipment when a vacuum forms, but the following precautions should also be observed:

- A check valve may be used.
- The vacuum breaker line should be open to atmosphere. Connected to the return line, condensate could be drawn into the equipment on shut-down.
- The vacuum breaker should be installed at the lowest temperature point possible at the equipment outlet.

Short Circuiting/Group Trapping *(Figure 3)*

Short circuiting can be caused when two or more pieces of equipment discharge into a common steam trap (A). Because no two units generate condensate at the identical rate, steam would be introduced into the common discharge piping by the unit which exhausted condensate first. The presence of steam in the condensate piping would cause the steam trap to close even though the other unit may still contain some condensate. The steam trap is thus controlled by the piece of equipment with the smaller condensate rate which could eventually cause the other pieces of equipment in the system to become inoperative. Each piece of equipment should be sized and trapped individually (B).



A. Short Circuiting *B. Correct Installation*

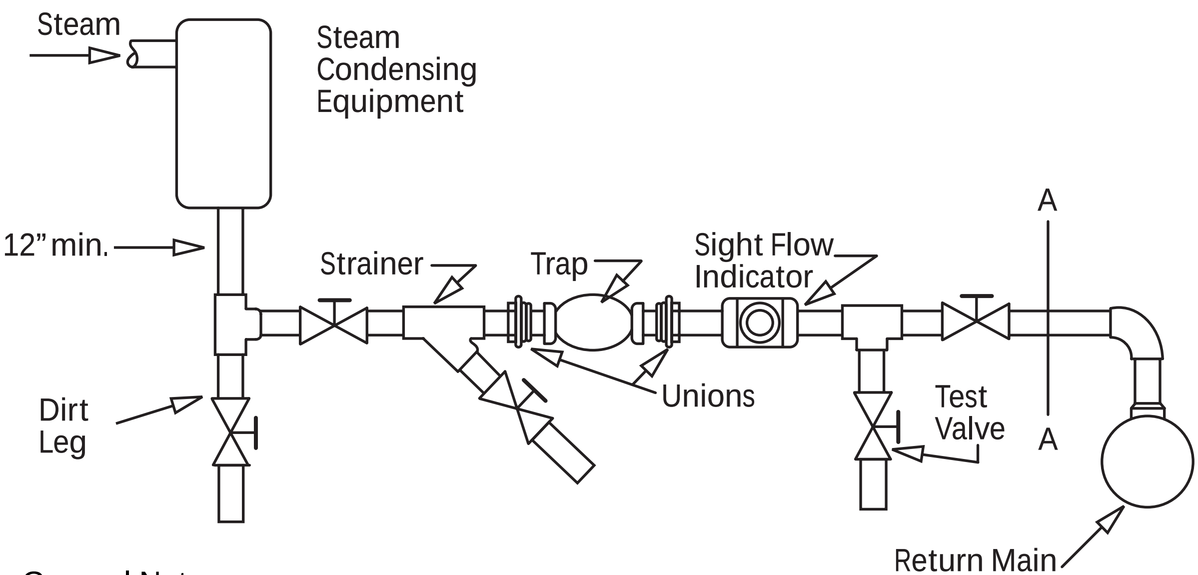
Figure 3

The SEVENTH RULE for the efficient use of steam: *trap each piece of equipment separately.*

Typical Steam Trap Hookups

Figure 4 shows a steam trap installation which illustrates all of the points brought up previously. All of the equipment is not required on every type of installation. Practical considerations of cost, steam conditions, equipment type, etc. will determine which of these features should be selected for a particular installation. *Figure 4A* shows piping for return to overhead return main from point A – A.

Figure 4: Non-Maintainable Steam Trap Installation



General Notes:

- Consideration must be given to the condensate return line in areas subject to freezing. In certain applications, it may be necessary to steam trace the line.
- If the steam trap is located a great distance from the equipment, air binding or steam locking may occur. A rise in elevation from the equipment to the steam trap can cause this condition also.
- The rule of thumb for calculating the back pressure of condensate lift installations is 1 psig back pressure for every 2 ft. of vertical lift. For low pressures, use 1 psig per foot for lift.
- All lines should be blown clean before installing steam traps.
- The line to the steam trap should not be insulated.

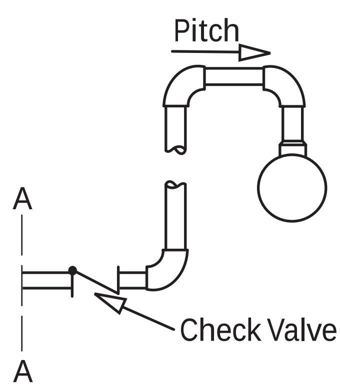


Fig. 4A

Steam Main Drip

The most common application for steam traps are steam main drips. The proper design of the drip pocket is essential to preventing water hammer and severe damage to equipment. The recommended construction of the drain pocket for a steam main is shown in *Figure 5.*

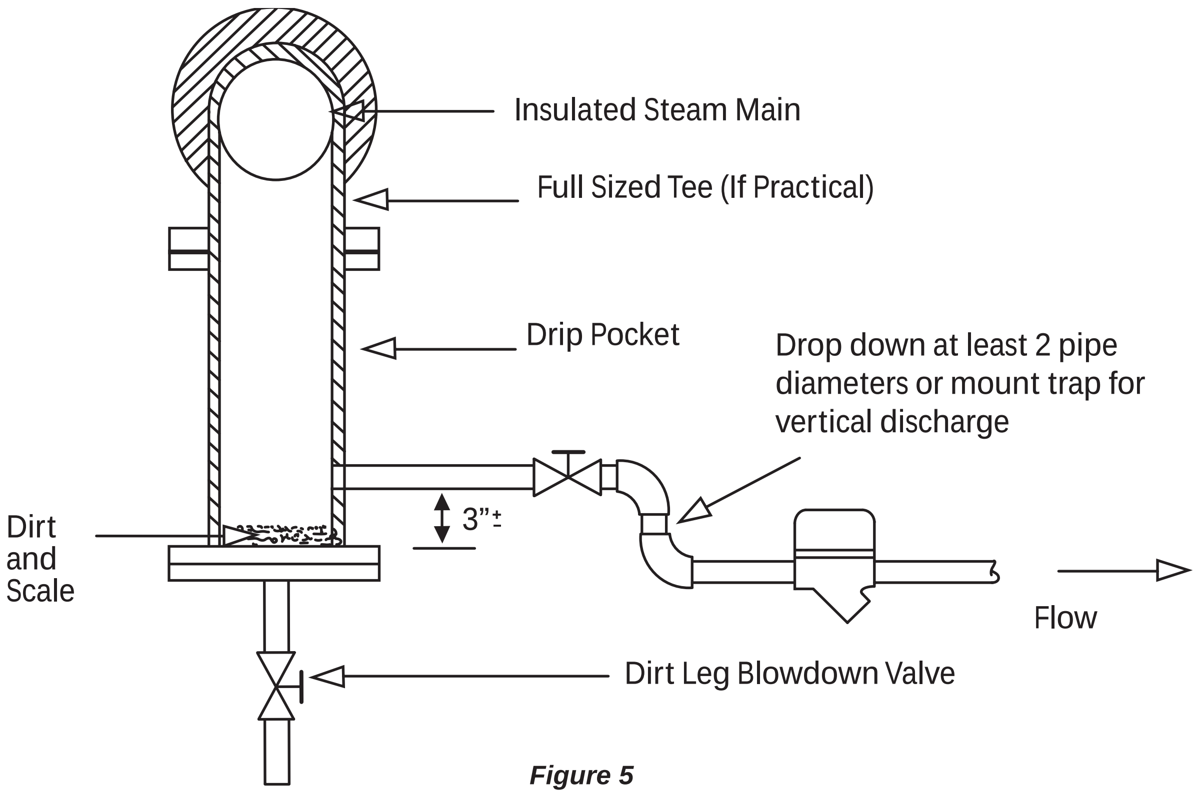


Figure 5

The tee or drop pocket installed in the steam main ideally should be the same diameter as that of the steam main. This ensures that the maximum amount of condensate is removed at the drainage point. If the steam trap is sized for running loads only, the collecting leg can be used to hold the initial load of condensate under warm-up conditions. However, selecting a trap design which automatically handles the cold start-up capacity alleviates concern.

Table 1 shows the recommended length for collecting legs for various diameter pipes.

Table 1 Based on Warming Loads of 0 °F to 212 °F									
Steam Main Size	2”	4”	6”	8”	10”	12”	16”	20”	24”
Length of Leg	24”	24”	24”	24”	24”	24”	28”	30”	36”

Where it is not practical to install a tee equal in diameter to the steam main, a reduced size leg can be installed. Over 6,” a collecting leg of one-half of the pipe size can be utilized as long as it is not less than 6" in diameter.

The take-off to the steam trap should be at a point approximately 3" above the lower level of the collecting leg and drain to the steam trap by gravity. A dirt leg blown-down valve can be installed on the bottom of the collecting leg to remove the scale and dirt that accumulates.

Steam main drip locations are recommended at every horizontal or vertical change of direction of the steam main, and in front of all equipment such as control valves, pressure reducing valves, or steam main shutoff valves because these are natural collecting points.

Consideration must be given to the amount of condensate that can form in a steam main between the drip points. It is impractical to space the drip pockets more than 250 feet apart since the large amount of condensate carried between these drip pockets may be too great a quantity to be removed at the take off points. Spacing should be reduced as the steam main size increases because the mass of condensate carried along in large mains under high pressure has a significant amount of energy (water hammer) that could cause damage to the system.

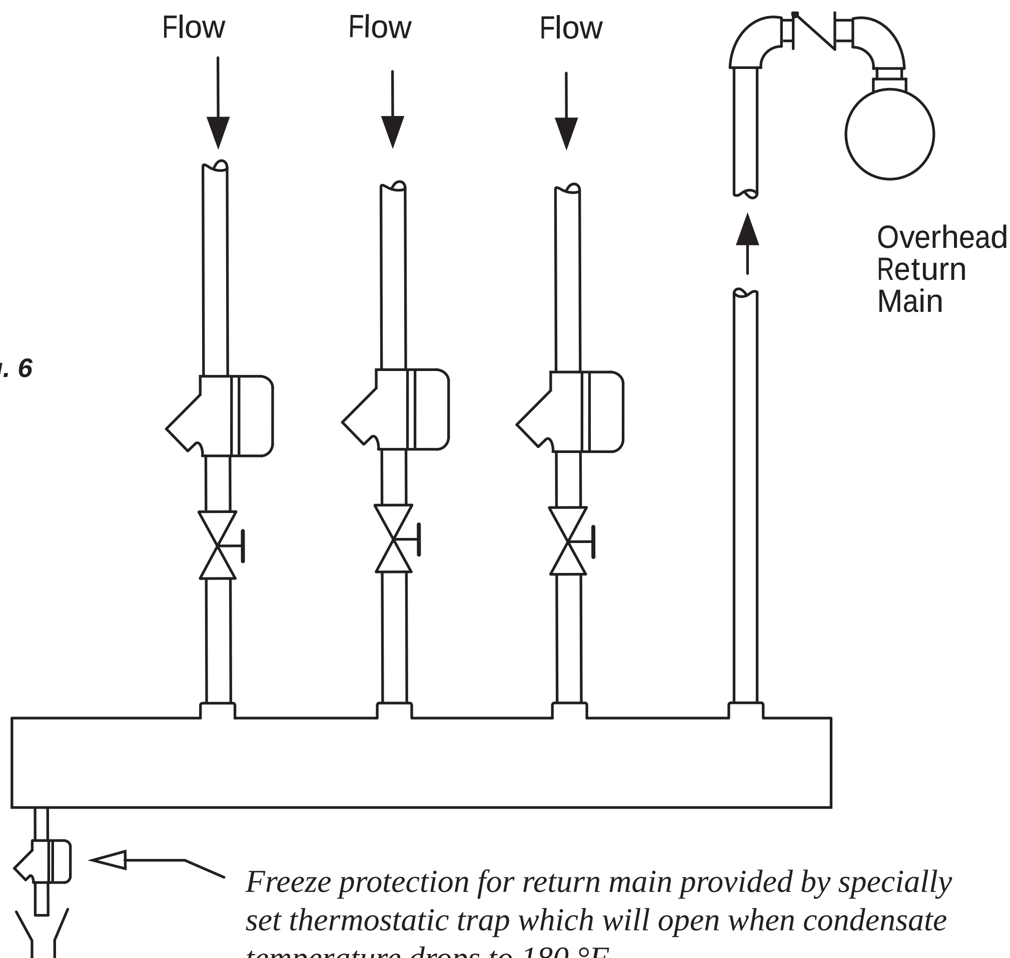
A rule of thumb for spacing the drip pockets is the higher the pressure or the larger the main, the closer the spacing.

The condensate load forms at a continuous uniform rate and the trap should be selected with a continuous discharge capacity equal to the load. If the trap is selected for running loads, a sizing factor should be applied (1.5 times the calculated load) to ensure adequate capacity for rapid drainage of the drip pocket. This assures that if loads change significantly, condensate will never exceed the calculated capacity of the pocket or trap.

Steam Tracing

Figure 6 shows a typical steam tracing line. This is a relatively simple steam trap installation with the steam trap station as an extension of the tracing line itself. Steam tracing, like main drip service, is generally a light, continuous load application that requires traps of small capacity.

Fig. 6



Freeze protection for return main provided by specially set thermostatic trap which will open when condensate temperature drops to 180 °F.

Because many steam tracing systems utilize stainless steel, copper, or other piping which does not produce scale, the strainer can be eliminated.

The maximum length of the steam tracing line is based upon the diameter of the tracing pipe, but the maximum tracer length should be kept below 400’. In smaller tracing sizes such as ½” and ¾” OD tubing, this limitation drops to 200’ as the condensing rate is such that the steam supply would be exhausted before reaching the end of the tracer.

Whenever small diameter pipe or tubing is used, care must be taken to ensure that low points do not form. These low points can cause accumulation of condensate and prevent the flow of steam throughout the total effective length of the tracer. Where tracing is used on horizontal product lines, it should not be coiled around the pipe because this will cause low points at the bottom of each coil. Coiled tracers can be used in a vertical product line where gravity drainage will not cause plugs of condensate to form. Coiled tubing is used to heat instruments, valves, and non-product lines where moderate heating is required.

If it is not possible to maintain temperature with a single external tracer line, more than one line can be evenly spaced around the product line. In this situation, each tracer line should be individually trapped (*See Fig. 7A).*

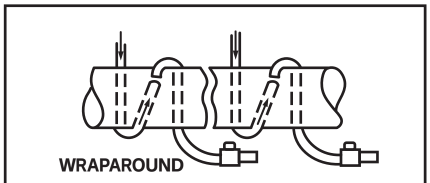


Fig. 7A

For internal tracing *(Fig. 7B)* where the product flows around the tracing line, or for jacketed tracing *(Fig. 7C),* condensate loads are usually greater since larger diameter pipe is frequently used.

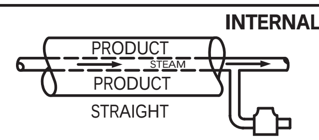


Fig. 7B

Since many tracing lines are subject to freezing conditions, consideration must be given to gravity drainage to the steam trap. This prevents condensate being left in the line after the steam is shut off. Consideration should also be given to the drainage of condensate after the steam trap so that it cannot accumulate and freeze. In general, freeze-proof (self-draining) steam traps should be selected for tracing applications.

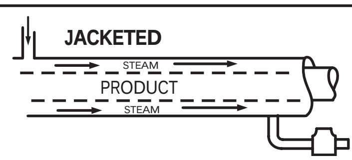


Fig. 7C

The discharge from steam tracers is sometimes collected into a common header and returned to mains at an elevation higher than the steam trap. In these installations, a temperature actuated mechanism should be fitted to the header to drain it when the system is shut down. A setting of 180 ºF is recommended. A Bestobell Model DM10E is suitable.

Remember: the lift leg must be able to drain to prevent freezing.

Space Heating Equipment

Space heating equipment like unit heaters, air preheaters, and air handling units can discharge condensate at a widely varying rate. When the unit is cold, start-up loads are at a high rate and require rapid drainage of condensate as well as accumulated air. The efficiency of the unit is dependent upon how fast the initial condensate load can be removed.

Unit heaters generally operate at relatively low pressures of 30 psig or less. A negative pressure at the trap on start-up can result from these low operating pressures due to the rapid high condensate rates. In order to facilitate good drainage form the equipment, a vertical leg should be installed on the bottom of the equipment which is long enough to provide a hydraulic head. This leg should be at least 12" in length.

Figure 8 shows a unit heater with the return discharging below the elevation of the steam trap. If the unit heater has a modulating valve on the inlet, consideration must be given to the pressure differentials across the steam trap so that there is always enough steam pressure to remove condensate. This is vital if the unit is discharging to an overhead return main.

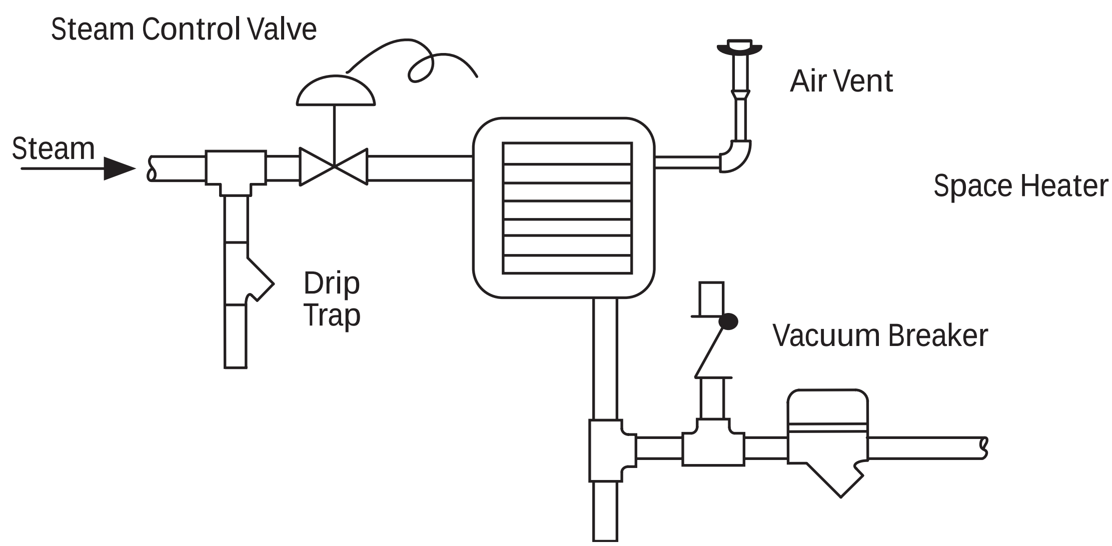


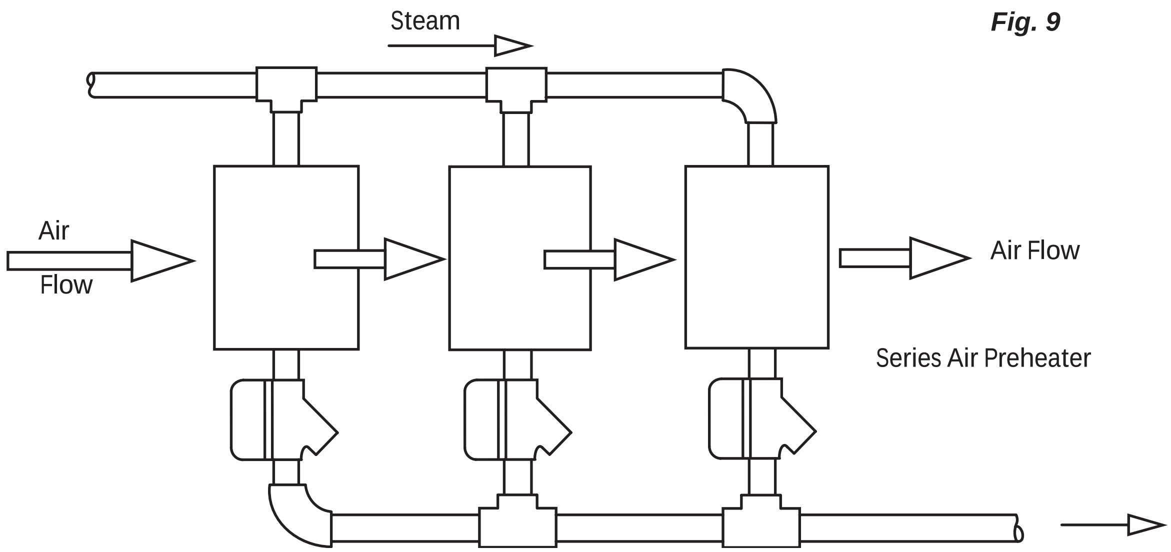
Fig. 8

An optional vacuum breaker helps in reducing the possibility of negative pressure on start-up. The installation of a vacuum breaker is vital whenever steam is controlled to the unit heater with a modulating control valve. The vacuum breaker allows drainage of condensate from steam space by gravity whenever the modulating valve throttles down. When the control valve decreases steam flow, the condensing steam remaining in the heater can generate a vacuum as it collapses.

An air vent installed at the opposite corner from the inlet steam supply helps remove air from the remote areas of the equipment. Otherwise, air might not be carried to the steam trap and this could reduce the effective output of the unit heater.

Figure 9 shows a series air preheater with individual traps handling the discharge from each of the sections. No special consideration has to be given to this type of installation because it generally operates at relatively high pressures.

Fig. 9



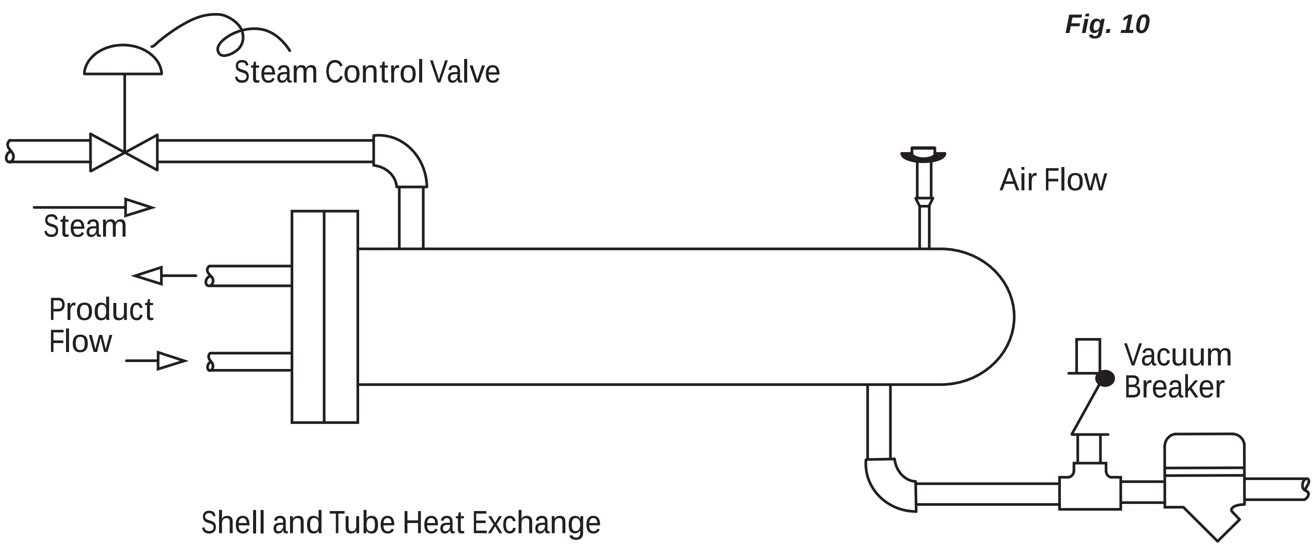
Series Air Preheater

Shell and Tube Heat Exchangers

Shell and tube heaters normally operate at relatively high pressures and utilize a temperature control valve on the steam inlet side. There can be fluctuating pressures in the steam supply and at the inlet to the steam trap.

Figure 10 shows a typical shell and tube heater installation. Note the optional vacuum breaker installed to allow free drainage of condensate when the steam is off. The air vent is used to remove the air that may be introduced through the opening of the vacuum breaker or from the steam supply.

Fig. 10



Shell and Tube Heat Exchange

Submerged Coils

In these applications, tanks or vats are used in batch heating large quantities of liquid. The discharge of condensate from these tanks can be through a gravity drain exiting the side or bottom of the tank through a sealed penetration fitting. Where penetration of the tank is not allowed (as in toxic chemicals), discharge of condensate from the coil is accomplished through the use of a lift fitting which forms a water seal at the base of the coil.

Figure 11 shows a vat with a steam coil discharging through a lift fitting which removes condensate out through the top of the tank. A problem could occur if the coil size is so large that steam could bubble up through the vertical column of water leading from the bottom of the coil to the steam trap. The presence of steam at the trap would cause it to close even though the coil contained a significant amount of water. When the coil was completely water logged, the steam in the rising pipe would condense, allowing the steam trap to open and discharge condensate from the coil. This would cause intermediate operation and unsatisfactory heating of the process fluid.

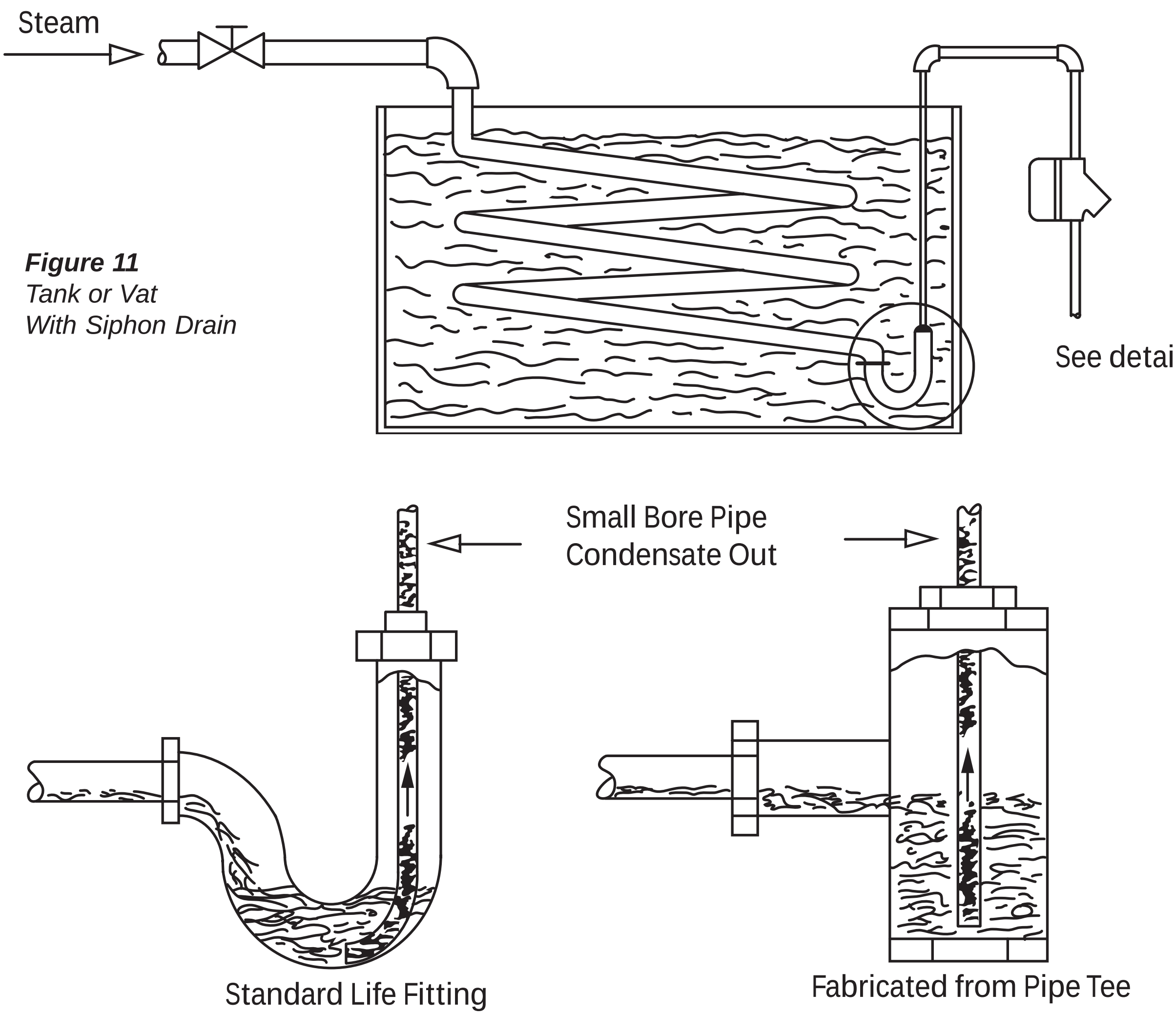


Figure 11
Tank or Vat
With Siphon Drain

In order to effectively remove the condensate from the tank, the coils should slope down to a lift fitting at the lowest point. The lift fitting shown allows condensate to accumulate at the bottom of the coil. A small diameter pipe is installed into the bottom of this fitting, and a water seal forms over the inlet. Steam pressure will blow the condensate up through the pipe to the steam trap which is able to operate on a normal basis and keep the unit operating efficiently.

Where the coil of a material that is resistant to chemical attack by the liquid is used, the internal siphon tube can be a common material because it will not come into contact with the process fluid. The steam trap should be sized to handle the condensate load with a sizing factor of 3 to 1 because there are occasions of cyclic action such as when the coil exhausted completely of condensate after the liquid reached the required temperature.

Steam Jacketed Kettles

In these kettles *(Figure 12)*, steam is introduced to a jacket surrounding the cooking pot. Normally, the condensate drains to a low point at the bottom of the jacket and it is removed.

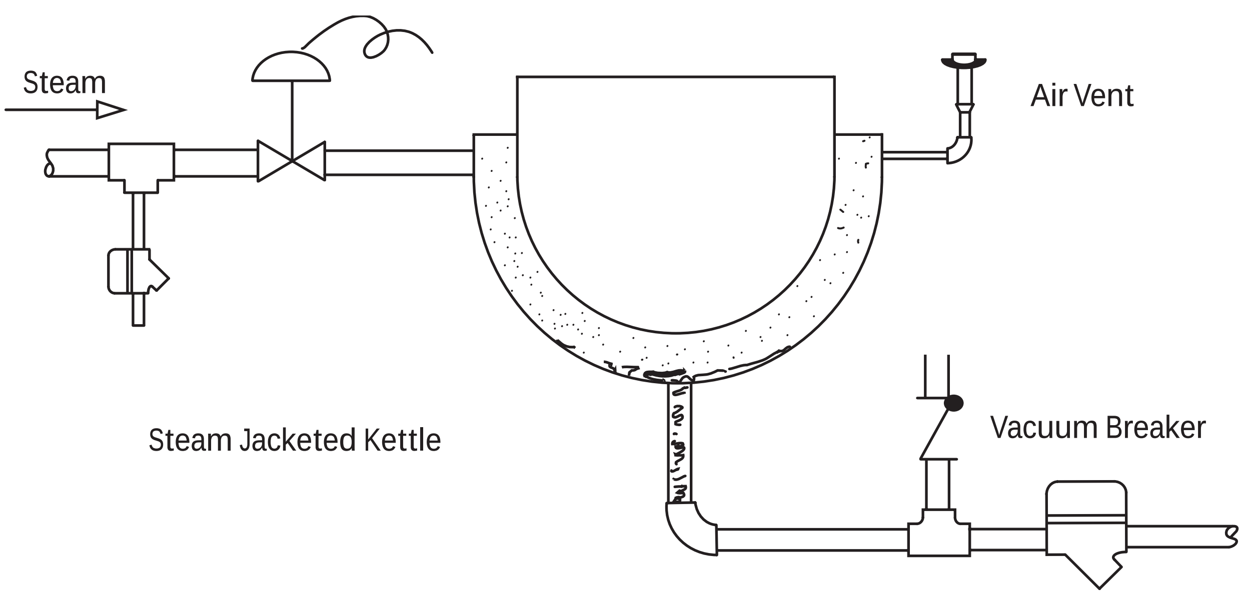


Fig. 12

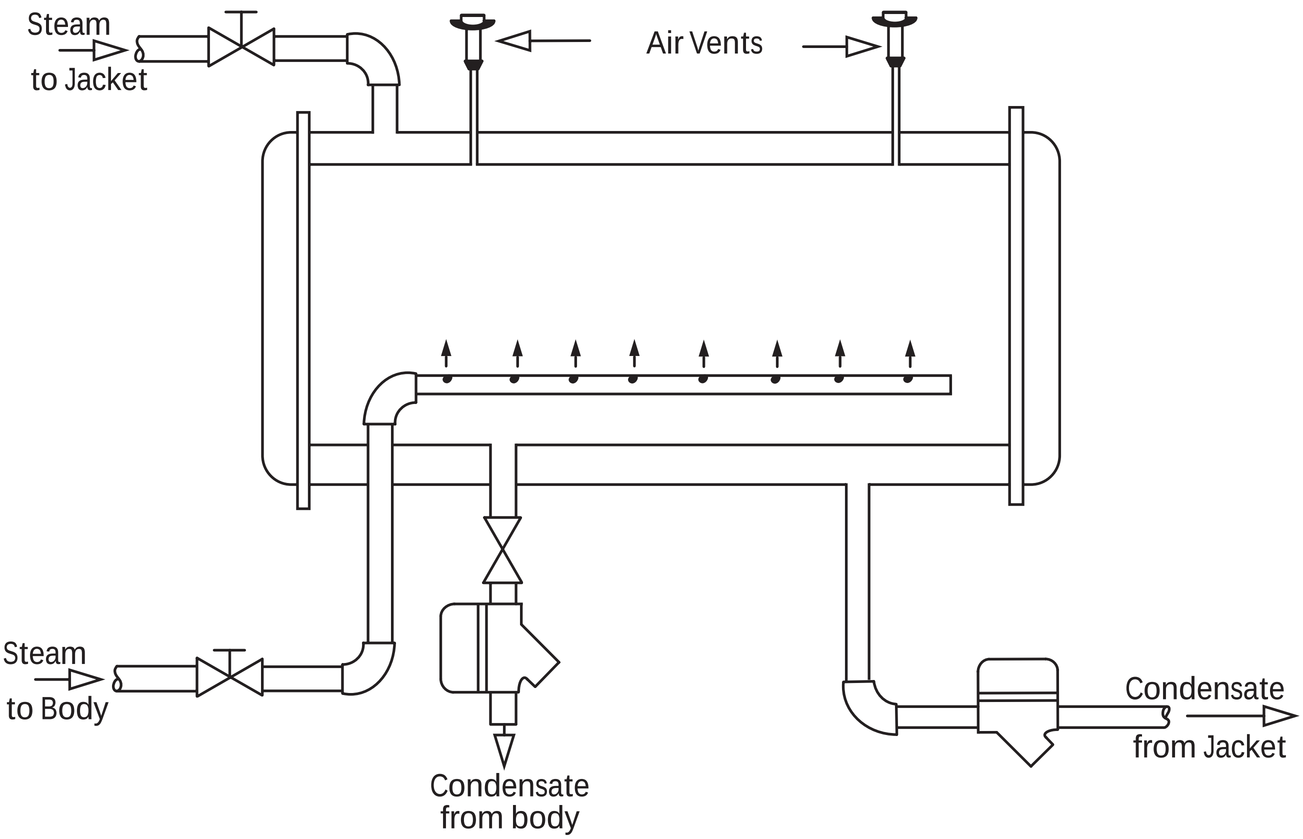
In order to increase the efficiency of this application, an air vent should be installed at the corner opposite the steam supply. In this application, the steam trap requires no special installation considerations.

Sterilizers, Retorts, Autoclaves

In these applications, steam is injected into a container where it comes into direct contact with the material to be heated. They are generally lower pressure applications. The major problem is in handling the large amounts of air in the vessel at start-up. Multiple air vents may be needed in order to remove the air as rapidly as possible in conjunction with the steam pressure build up.

Figure 13 shows a typical installation.

Fig. 13



The condensate drains to the bottom of the equipment and is gravity fed to the outlet pipes leading to the steam trap. Because both the equipment and the material to be heated are cold on star-up, there is little pressure to force the condensate through the steam trap. A hydraulic head of approximately 2' in front of the steam trap will facilitate drainage.

This installation does not require any special consideration unless the product being heated could produce dirt or particles that could plug the steam trap. A strainer would then be necessary (Note: in this application, a self-draining trap is desirable as this prevents condensate contaminated with bacteria from remaining in the chamber).

Rotary Dryers

This application is most likely the most difficult to successfully trap.

Figure 14 illustrates a typical installation.

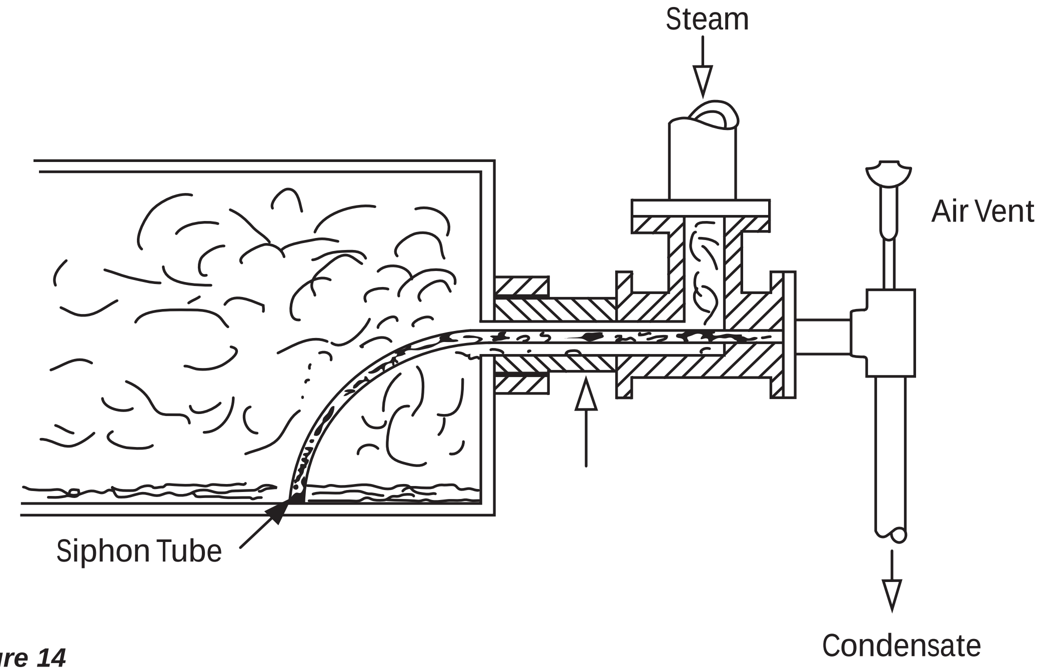


Figure 14
Rotary Drying Cylinders

The steam is introduced through a rotary joint and fills the inside of the revolving cylinder. As condensate forms, it falls by gravity to the bottom of the cylinder where it is collected by a siphon pipe to be discharged out through the rotary joint to the steam trap. The major problem faced in trying to effectively trap the installation is that as the siphon pipe empties of condensate, steam is introduced to the steam trap and it closes. Because the siphon pipe is completely surrounded by steam, the condensation rate in this siphon pipe is very slow. This causes slow reaction of the steam trap. This can be effectively handled by the using an auxiliary “steam lock” release. Steam locking occurs when the steam in the line to the steam trap blocks the flow of condensate. The steam lock release device is a needle valve which can be adjusted to discharge just enough steam to allow response to the conditions at the inlet side to siphon pipe. Once the needle valve is adjusted to balance the discharge at a continuous rate, it generally doe not have to be readjusted. The discharge from the steam lock release valve can be piped to the condensate return system.

A steam trap with a rapid response time is recommended if the steam lock release valve is not used. A cascade type condensate discharge system is popular for this application.

Sizing Condensate Return Lines

Careful consideration must be given to the condensate return pipe size to ensure efficient steam trap operation. Too small of a return line can lead to sluggish operation, high back pressures, water hammer, or system water logging even though the trap may be of the proper size and type to do the job. In general, it is not possible to hurt performance by having the return piping too large, but economics must be considered. Also, when initially installing the system, it is advisable to design with future expansion in mind.

Condensate system design should take into consideration: capacity, velocity, and pressure drop. For most applications, a maximum velocity of 5000 ft/min is used. Pressure drop is a function of the length of return piping and pipe diameter.

Two-phase flow (flash steam and condensate) will occur in the return system piping. As the condensate travels, however, natural cooling will reduce or eliminate the flash steam volume. It is difficult to calculate where all the flash vapor will condense. Most return systems have traps discharging into them at various points along their total length. This may mean that the return line must be increased as additional traps discharge into it before it gets to the end. Except in special circumstances, it is not advisable to discharge both high pressure and low systems in the same return main.

In determining return main sizes, only the flash steam volume is calculated because it is so much greater than the water volume. The formula used will determine the volume of flash steam that can be carried off by various size pipes at a specified set of inlet to outlet conditions.

The EIGHTH RULE for the efficient use of steam: *the condensate return piping can't be too big.*

$$\text{Capacity} = \frac{\text{cu. ft./ft. pipe area} \times \text{lbs/cu ft. flash vapor} \times \text{ft/hr}}{\%\text{flash steam}}$$

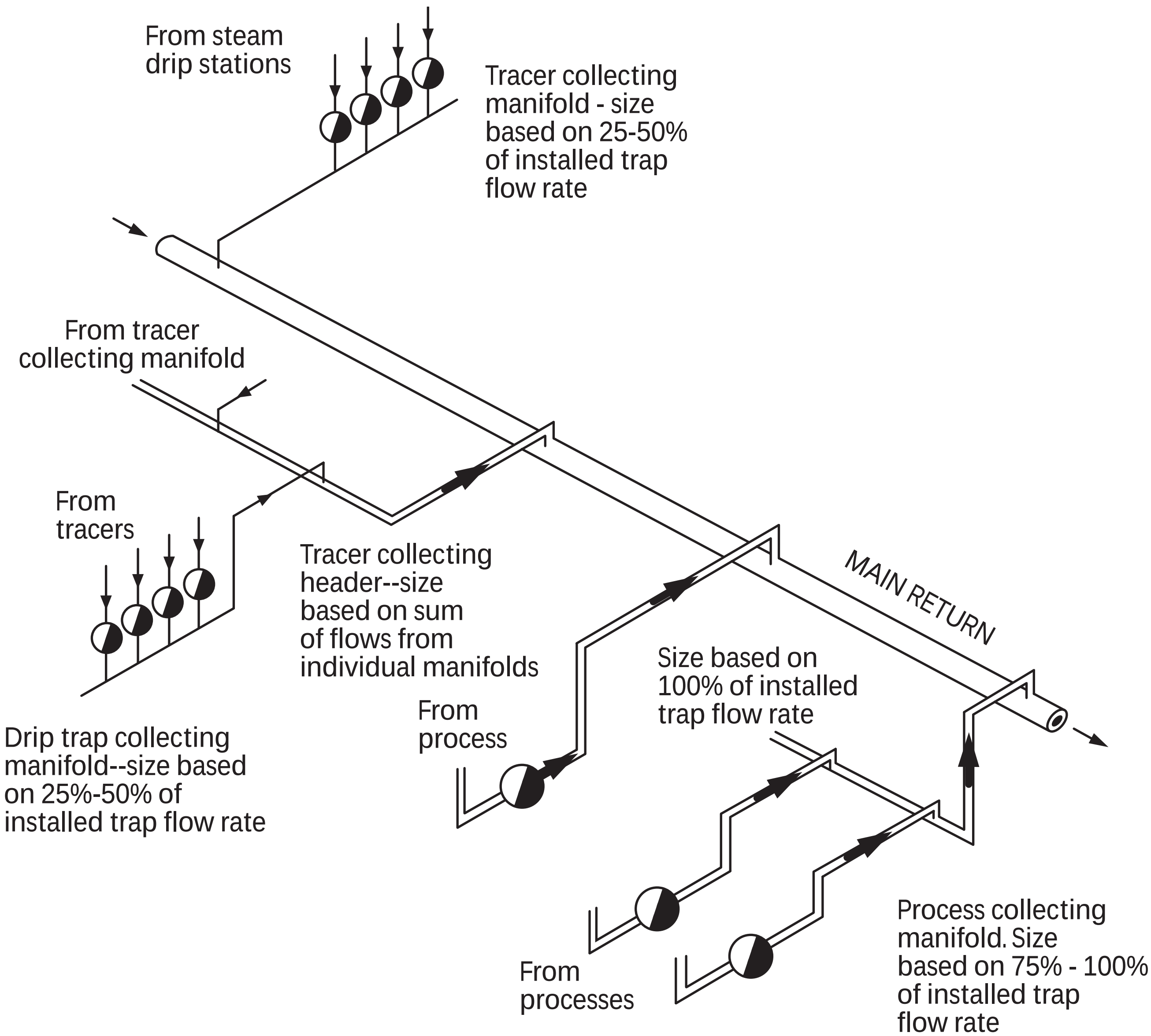
Example:

What capacity would a 4" schedule 40 pipe have handling steam traps with 300 psig inlet pressure if the return were under 20 psig pressure?

A 4" schedule 40 pipe internal area is 12.730 square inches; therefore, the cu ft/ft equals

$$\frac{12.730 \text{ sq in} \times 12 \text{ in/ft}}{1728 \text{ cu in/cu ft}}$$

$$= .0884$$


From steam
drip stations
Tracer collecting
manifold - size
based on 25-50%
of installed trap
flow rate
From tracer
collecting manifold
From
tracers
Tracer collecting
header--size
based on sum
of flows from
individual manifolds
MAIN RETURN
Size based on
100% of installed
trap flow rate
From
process
Drip trap collecting
manifold--size based
on 25%-50% of
installed trap flow rate
Process collecting
manifold. Size
based on 75% - 100%
of installed trap
flow rate
From
processes

From the steam tables, the specific volume of steam at 20 psig is 12.0 cu. ft/lb.

Steam velocity = 5000 ft/min x 60 min/hr = 300,000 ft/hr.

$$\%\text{flash steam} = \frac{\text{sensible heat @ inlet} - \text{sensible heat @ outlet}}{\text{latent heat @ outlet}}$$

$$= \frac{399 - 227}{940}$$

$$= 18.3\%$$

Solving the equation gives:

$$\frac{.0884\text{ cu. ft}}{\text{ft}} \times \frac{\text{lbs}}{12.0\text{ cu ft}} \times \frac{300{,}000\text{ ft}}{183}$$

$$= 12{,}076\text{ lbs/hr}$$

The tables on the following pages give the approximate values using the above formula. To use the tables, find the flow rate in the column under the inlet-outlet pressures. The pipe size will be shown in the left hand column. Remember that the values given are for flash steam velocities of 5000 ft/min which may be too high for the application. A larger diameter pipe will reduce the velocities.

Some other factors to consider when sizing the condensate return system are:

- The condensate velocity is determined primarily by the differential pressure across the steam trap orifice, the temperature of the condensate, and the space into which the trap discharges.
- Increasing the return piping size can reduce back pressure and flash steam velocity.
- Cold condensate (no flashing) will be many times greater than hot condensate flow.
- Insulated returns will increase the time it takes for flash steam to dissipate.
- Lifts or vertical rises of the condensate line increase back pressure.

Condensate Return Line Sizes
Approximate Capacities per 100 Feet of Sch. 40 Pipe @ 5000 ft./min.

Supply Pressure PSIG	5	15	15	30	30	30	60	60	60	60	Pipe Area In Square Inches
Return Pressure PSIG	0	0	5	0	5	10	0	5	10	20	
1/2” Pipe	1424	601	1348	362	630	1010	235	365	519	986	.304
3/4” Pipe	2510	1059	2376	638	1110	1779	414	644	915	1738	.533
1” Pipe	4070	1717	3853	1034	1800	2886	672	1045	1484	2819	.864
1-1/2” Pipe	9592	4048	9080	2438	4243	6801	1584	2463	3497	6644	2.036
2” Pipe	15807	6670	14962	4018	6992	11207	2610	4059	5763	10949	3.355
2-1/2” Pipe	22557	9519	21352	5734	9979	15993	3725	5793	8225	15624	4.788
3” Pipe	34830	14698	32969	8855	15408	24694	5752	8945	12700	24125	7.393
4” Pipe	59972	25308	56769	15247	26530	42520	9905	15402	21867	41541	12.730
5” Pipe	94253	39774	89218	23962	41696	66826	15567	24207	34367	65286	20.006
6” Pipe	136112	57438	128841	34604	60213	96504	22480	34957	49630	94280	28.891
8” Pipe	235691	99460	223100	59921	104265	167105	38927	60533	85940	163256	50.027
% Flash	1.65	3.91	2.29	6.49	4.90	3.78	9.99	8.44	7.35	5.32	

Condensate Return Line Sizes
Approximate Capacities per 100 Feet of Sch. 40 Pipe @ 5000 ft./min.

Supply Pressure PSIG	100	100	100	100	100	150	150	150	150	150	150
Return Pressure PSIG	0	5	10	20	30	0	5	10	20	30	50
1/2” Pipe	176	262	356	602	937	143	207	275	440	644	1195
3/4” Pipe	311	462	628	1060	1652	253	365	485	776	1135	2106
1” Pipe	505	749	1018	1720	2679	410	592	786	1259	1841	3415
1-1/2” Pipe	1190	1766	2400	4053	6315	966	1395	1853	2968	4340	8048
2” Pipe	1962	2911	3955	6680	10406	1593	2299	3054	4890	7152	13262
2-1/2” Pipe	2800	4154	5644	9532	14851	2273	3281	4358	6979	10207	18925
3” Pipe	4324	6414	8715	14719	22930	3510	5067	6730	10776	15760	29222
4” Pipe	7445	11045	15007	25334	39483	6044	8724	11588	18555	27137	50317
5” Pipe	11701	17358	23585	39830	62052	9500	13711	18212	29162	42649	79079
6” Pipe	16898	25067	34060	57520	89610	13719	19801	26300	42113	61591	114198
8” Pipe	29261	43406	58978	99601	155169	23756	34288	45541	72923	106651	197746
% Flash	13.29	11.77	10.71	8.72	7.10	16.37	14.90	13.87	11.91	10.33	7.89

Condensate Return Line Sizes
Approximate Capacities per 100 Feet of Sch. 40 Pipe @ 5000 ft./min.

Supply Pressure PSIG	300	300	300	300	300	450	450	450	450	450	600	600	600	600	600
Return Pressure PSIG	0	10	20	30	50	0	10	20	30	50	0	10	20	30	50
1/2” Pipe	104	189	286	396	651	87	155	230	312	494	77	135	199	266	413
3/4” Pipe	183	333	505	698	1148	154	273	406	550	870	136	238	350	469	728
1” Pipe	297	540	819	1133	1862	249	443	658	892	1412	221	387	568	762	1181
1-1/2” Pipe	701	1274	1931	2670	4388	588	1045	1552	2104	3328	521	913	1340	1795	2783
2” Pipe	1156	2100	3183	4400	7231	970	1723	2558	3467	5484	858	1504	2208	2959	4587
2-1/2” Pipe	1650	2997	4542	6280	10319	1384	2459	3650	4947	7826	1225	2147	3151	4222	6546
3” Pipe	2548	4627	7013	9696	15934	2138	3797	5636	7640	12084	1891	3315	4865	6520	10108
4” Pipe	4388	7968	12076	16696	27436	3681	6538	9705	13154	20807	3257	5709	8377	11226	17404
5” Pipe	6896	12523	18979	26240	43119	5785	10276	15253	20674	32700	5119	8973	13166	17644	27353
6” Pipe	9959	18085	27408	37893	62268	8355	14840	22027	29856	47223	7392	12958	19013	25480	39501
8” Pipe	17245	31316	47460	65616	107824	14467	25697	38143	51698	81772	12800	22438	32923	44121	68400
% Flash	22.55	20.17	18.30	16.79	14.47	26.88	24.58	22.77	21.31	19.08	30.38	28.15	26.38	24.97	22.81

Chapter 5

Steam Trap Maintenance And Trouble Shooting

Because a properly functioning steam trap should drain condensate as it forms without the use or loss of steam, it is important to recognize when it has reached its effective service life.

Generally, traps fail in the open position although some traps will fail closed. If the trap fails open, it may be difficult to recognize, as it generally will not affect the equipment on which it is installed. This is because it is not holding back any condensate; steam is allowed to flow freely and therefore the heat transfer rates are great. A steam trap that is failed closed is easier to spot because the condensate backup will cause the equipment to become cool due to waterlogging.

Most steam traps gradually lose their steam-tight integrity over a period of time because of metal to metal seat and orifice contact. Periodic attention and inspection will help detect when they have reached the point where they are blowing live steam and require maintenance or replacement.

We can break down trap maintenance into 4 major categories:

- Steam Leakage
- Steam Blow-through
- Restricted Discharge
- Fail Closed

Steam Leakage

The most common failure of steam traps is worn internals. Even when the trap is in the "closed" position, the loss of water seal allows steam flow through the valve assembly, progressively more rapid wear, and loss of greater amounts of live steam.

Certain types of traps, such as disc traps, wear very rapidly once the initial leakage occurs. This affects their ability to stay closed after condensate is discharged and the "shot gunning" or rapid cycling causes a significant amount of live steam loss. These traps should be replaced or repaired as soon as possible after the initial leakage is detected.

In some traps containing auxiliary air vents, steam leakage can be traced to failure or wear on the thermostatic element. These built-in air vents can sometimes be adjusted to reduce or eliminate the steam leakage, but frequently the wear is severe enough to require replacement.

Some thermostatic steam traps can be adjusted if steam leakage occurs. If the leakage is caused by wire-drawing or severe wear on the seat assembly, it must be replaced.

Free float traps can leak steam after a period of time due to the indentations formed on the float preventing a tight seal on closure.

Summarizing the causes of steam leakage common to all steam traps:

- valve assembly wear
- wire-drawing or other defects on the valve seat
- scale or rust affecting the closure of the valve assembly

Steam Blow-Through

Steam blow-through is usually attributed to severely worn internals, but other factors can also cause this condition.

- Large pieces of scale or other obstructions can get into the operating parts of the trap preventing closure.
- Physical damage could also cause steam blow-through. Bellows thermostatic traps are particularly sensitive to damage by water hammer, which can cause them to become completely inoperative in the open position.

Certain types of steam traps, such as the inverted bucket trap can fail in the open position if their "prime" is lost. The bucket, which controls the valve mechanism, must be surrounded by water in the body of the steam trap so that it can become buoyant. If there is no prime, the bucket stays open and steam will blow through the discharge orifice. This condition can also occur if the trap is subject to super-heat conditions, which could cause the water in the body of the trap to flash off and allow the bucket to drop open.

Very high backpressure situations can cause a disc trap to remain open blowing live steam. It is possible that the high back pressures can be caused by too many traps discharging into too small a return which allows back pressure to build up and causes traps to remain open for longer than normal periods. This blows additional live steam into the return system and creates accelerating problems.

Summarizing the problems common to steam blowing:

- foreign materials trapped between the valve and seat
- wire-drawn or seriously worn valve seat
- physical damage to the internals of the steam trap
- high return main back pressure

Restricted Discharge

In the case of sluggish discharge, the steam trap is not able to discharge enough to allow the steam condensing equipment to operate at capacity. The most obvious cause to this problem is that the steam trap is not sized large enough to handle the load or is misapplied. A check on the operating conditions would help to isolate this problem. Check inlet pressures, return pressures and condensate load.

If the trap is equipped with a strainer, it is possible that it is plugged and requires blow-down.

Sluggish operation can also be caused by large quantities of air, which the trap is incapable of handling, or steam locking which could be a function of improper installation. The internals of the trap could also be restricted due to an accumulation of dirt and scale.

In review, common causes of insufficient discharge are:

- partial blockage of the strainer
- steam locking or air binding
- increase in back pressure or reduction in inlet pressure from design
- the wrong type or size of trap selected for the application
- incorrect installation procedures
- return piping inadequately sized

Fail Closed

A plugged trap is generally easy to detect in that the system is cold. Several factors can contribute to the inability of the trap to operate.

Mechanical traps can become damaged and cause them to remain closed. Collapsed floats can cause the unit to become inoperative. Bucket and float traps can also remain closed if the pressure exceeds the design pressure of the valve assembly. This will cause blockage of flow and can only be cured by installing the proper set of internals.

Traps can steam lock or air bind and fail closed. Bucket traps can air bind if the vent in the top of the bucket is plugged.

There are occasions when the type and size of the steam trap is correct, but the system is at fault. The return line pressures could exceed the inlet pressures preventing the flow of condensate from the equipment. This can happen in the case of unit heaters, for instance, where a regulating valve is installed on the inlet of the equipment and drops to a pressure lower than the return line pressure causing water logging of the equipment.

A plugged system can be as easy to repair as blowing down the strainer. In certain cases, excessive amounts of dirt and scale can be present in the line, which can completely plug the strainer and prevent condensate flow.

Common causes of traps failing in the closed position are:

- plugged strainers
- over pressure of the system beyond the design ratings
- elevated return pressures
- steam locking or air binding
- damaged internals

Chapter 6

Determining Steam Trap Capacity

Steam trap capacity is a function of:

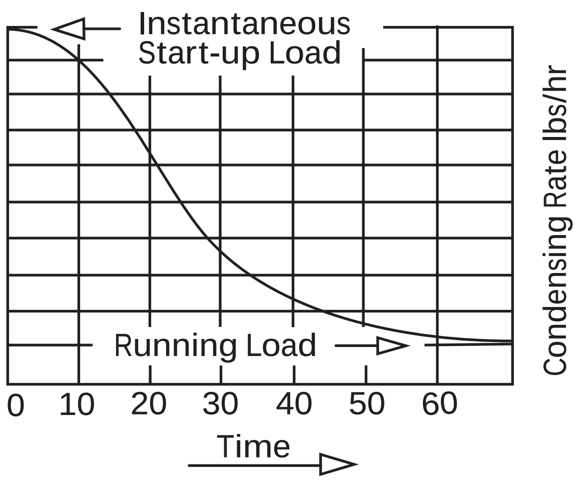
- the trap's effective discharge orifice area
- the inlet and outlet pressures
- temperature of the condensate
- the operating principal

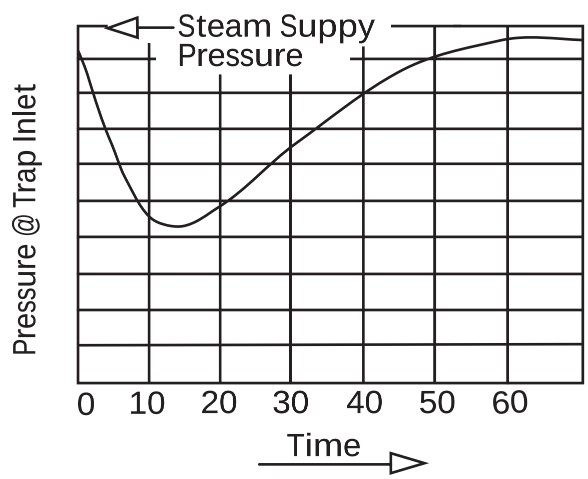
To properly select a steam trap for a particular application, these factors must be considered along with the characteristics of the steam condensing equipment.

Most steam trap manufacturers rate their steam traps on the basis of continuous discharge capacity. As an example: if a steam trap is rated at 1000 pounds per hour at some set of operating conditions, it means that if the inlet pressure and outlet pressure stayed exactly stable for one hour, the condensate remained stable at the rated temperature and no other factor such as air in the condensate came into play, the steam trap would discharge the specified load. This condition seldom, if ever, occurs in real application; therefore, the steam trap rating should be considered more instantaneous than continuous. This is one of the reasons that sizing factors are utilized.

Most steam condensing equipment discharges condensate at a point below saturated temperature. This difference between the condensate temperature and saturation temperature is called "suppression." Many manufacturers have determined that this suppression is approximately 30ºF. It is therefore practical to select a steam trap whose capacity is rated at 30ºF under saturation temperature in order to more closely balance the requirements of the equipment with the performance of the trap. Complicating the problem are variations in the load from start-up conditions to hot running conditions.

The following graph shows the typical discharge rates of a piece of steam condensing equipment from start-up to hot running load. At any particular point on the graph, there is an instantaneous condensate discharge rate for maximum efficiency. The steam trap should be able to handle the condensate load through this complete range of capacity. It is normal for the steam trap to need to discharge continuously as the condensate is continuously forming.





Notice that, as the condensation rate changes, there may also be a change in the operating pressures, which are a function of the condensing rate. On start-u, when the equipment is cold, the steam can condense so rapidly that it could lose a significant amount of pressure across the steam trap and the ability of the steam trap to discharge.

Certain types of steam traps, such as the inverted bucket trap, bellows thermostatic trap, or disc trap, generally operate with the valve mechanism in the wide open position; that is, no restriction in the orifice. The effective area of the orifice is the diameter of the hole. Other types of traps, such as bimetallic thermostatic traps, utilize an annular orifice – a tapered valve piece operating in a fixed diameter orifice.

The first category of trap is cyclic and has little or no modulating control possible. The second type of trap can have a modulating flow effect. In the wide open position, the effective orifice area of both type traps, when equal, will give the same discharge rate. The difference in the operating principles usually does not have an effect until the hot running loads are achieved because the steam trap is normally wide open up to that point.

The discharge capacity of the blast or cyclic trap is a function of the number of cycles per hour that the trap achieves whereas the modulating trap, which generally does not close, has a capacity equal to the sum of the effective orifice areas over the operating period. In order to select the properly sized trap of any type, consider the instantaneous condensate load required at any period throughout the operating cycle.

A rule of thumb is that 1/2 to 4/5 of the total start-up load can occur in 1/3 of the start-up time.

The peak load often reaches ten times the normal running load and occurs immediately after start-up in such pieces of equipment as oil tanks and autoclaves. It is not necessarily practical to size the steam trap for this very high load; bypass valves or bypass high capacity steam traps may be utilized to help get the equipment up to normal temperatures quickly without running the risk of oversizing the trap.

It is difficult to calculate the actual instantaneous condensate loads but familiarity with the above suggestions can help ineffectively trapping the installation (*Note: refer to Chapter 3 for calculations of steam and condensate loads*).

The NINTH RULE for the efficient use of steam: *select the trap that most closely fits all of your operating conditions.*

Reducing Steam Usage

To maximize energy savings, the lowest practical steam pressure should be used. This reduces the condensate temperature, flash steam loss, and extends equipment life due to less wear on the installed equipment. The cost of steam leaks, which may develop, is also reduced.

Insulation is recommended on all steam supply piping to reduce the radiation losses and lower condensate loads. The steam trap should be left uninsulated for ease of maintaining and testing, unless it's necessary to protect the trap from freezing.

Periodic inspection of all of the elements in the system will uncover sources of steam loss such as leaking joints, leaking valve packing, broken lines, and missing or loose insulation.

Steam traps should be periodically checked to ensure that they are operating at maximum efficiency. An industrial contact pyrometer can be used to check the inlet and outlet temperatures across equipment and steam traps. A cold reading on the pyrometer indicates the need for strainer maintenance, a check of the trap sizing or other conditions. A high temperature on the discharge side of the steam trap could indicate that the steam trap is no longer maintaining its steam tight integrity or that return line conditions are abnormally high.

An ultrasonic leak detector is a valuable tool used to locate the presence of live steam in the return system caused by steam traps worn or blowing through. It is sometimes difficult to pick up live steam loss in a closed return system without some device, which is specifically designed to accomplish this purpose. Pyrometers are not able to detect live steam loss until the loss becomes excessive due to the insulating effect of the thickness of the pipe wall,scale or paint on the pipe, or poor contact on the return line surfaces. A steam trap preventive maintenance program is recommended. The periodic checking of traps can pick up problems before they escalate to major energy loss.

A final rule—

The TENTH RULE for the efficient use of steam: *see rule FOUR:*

THERE IS NO UNIVERSAL STEAM TRAP!!!

Chapter 7

Technical Information

Over the years, much data has been accumulated and many articles have been written concerning all of the factors that affect steam supply and condensate return systems. It is helpful to understand as much of this information as possible as it can be used to maximize the efficiency of the systems on which steam traps are installed. Much of the information available to us is edited from the numerous articles and technical data, which have been published throughout the years by steam trap manufacturers, steam users, and other authorities in the field of steam thermodynamics.

Water Hammer

Moving water contains a great deal of energy because of its weight and velocity. If this mass of water is suddenly stopped or reaches a change of direction, the energy of movement (kinetic energy) has to be dissipated in some way. Because the moving water is being transported in a confined space, the energy will be transmitted to any obstacle in its path and into the walls of the space.

There are three primary conditions for water hammer in both steam mains and return lines. They are:

- presence of condensate
- high live steam or flash steam velocity
- change of direction or obstruction in the line

Normally, all three of these conditions must exist if water hammer is to occur, therefore, the proper handling of the condensate is critical in preventing potential damage.

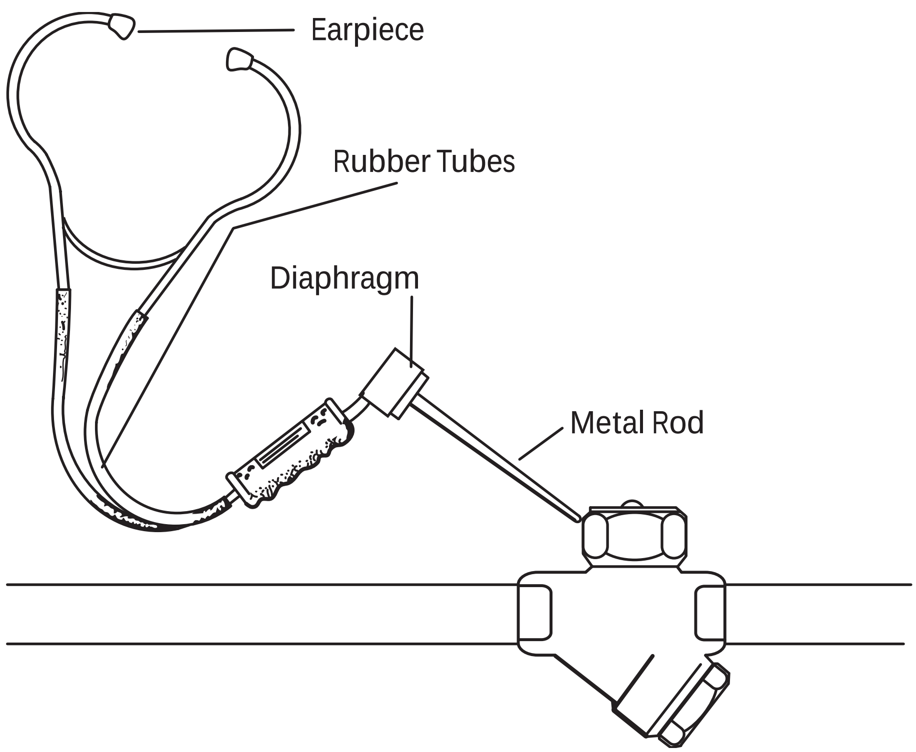
In steam supply lines, condensate forms primarily from radiation losses. This condensate is carried along in the steam main until it reaches obstruction. These obstructions take the form of horizontal or vertical changes of direction of the steam main, shutoff valves, control valves, or similar pieces of equipment. Because of the high velocities associated with the flow of live steam (approximately 5000 feet per minute or 60 miles per hour), the condensate can reach high velocities as it is carried along by the flowing steam. Water hammer canoccur when this mass of water reaches some obstruction.

In the case of condensate return systems, water is always present. In these return systems, flash steam is released from the condensate and flows at a velocity considerably higher than that of the water.

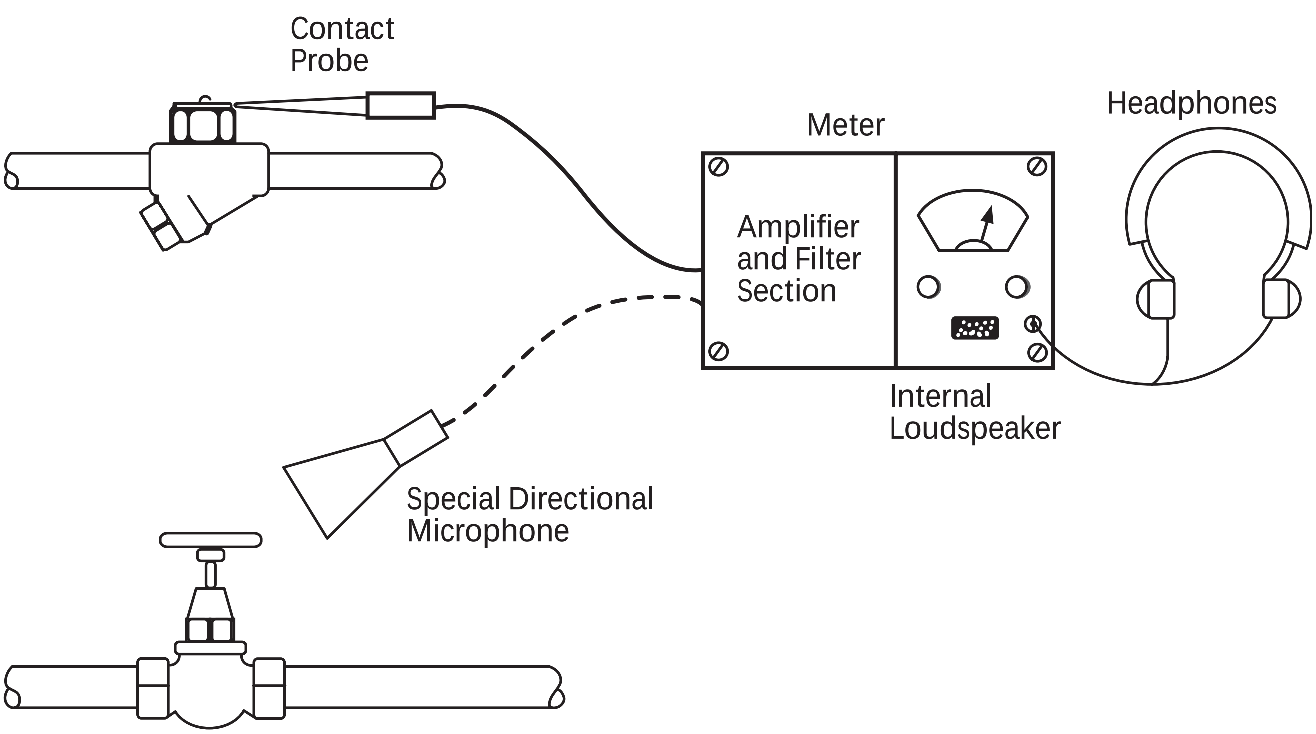
Certain types of steam condensing equipment are more susceptible to water hammer than others due to the configuration of the steam coils and the associated problem of removing the condensate from the equipment. In applications such as submerged steam heating coils, air handling units, or any equipment by the incoming steam flow can fill the coil and act as a piston delivering energy to a change of direction such as a steam trap at the discharge of the equipment.

The main points to consider, then, for the prevention of water hammer are:

- steam control valves should be opened slowly to gradually increase the flow of condensate that might be present in the system
- drain pockets should be adequately sized and located to prevent large quantities of condensate from forming at any one point
- the steam trap should be selected for resistance to water hammer as well as prevention of water hammer
- discharge should be piped in such a way as to eliminate back flow into the equipment; this may necessitate the installation of check valves
- if there are long lengths of discharge pipe, it should be pitched downward as steeply as possible; return lines should be as short as possible
- if the condensate is lifted after the trap, there must be sufficient pressure to move it out of the equipment
- the condensate return main must be adequately sized to handle the maximum load
- condensate from different line pressure systems should not be discharged into a common return line which can cause back pressure that slows condensate flow
- avoid high velocity flow in the return mains by removing flash steam from the system with a flash tank or utilizing large return lines
- when a series of steam units are started up from a common steam main, water hammer can be prevented by opening the last unit in line first and starting up the units in reverse order



Stethoscope



Ultrasonic Leak Detector

Pipeline Corrosion and Deaeration

The possibility of corrosion exists in all steam and condensate return systems due to dissolved gases in the water used. Most steam systems require continual makeup water to replace losses from the unrecovered condensate leaks, etc. The supply water usually contains carbonates and bicarbonates which, if not removed before entering the boiler, will be thermally decomposed to CO_2, gas, carbonate and hydroxide ions. These carbonates and hydroxides will raise the alkalinity with the CO_2 being discharged into the system. As the condensate forms in the steam system, the CO_2 will be dissolved in the condensate and can form carbonic acid. Carbonic acid within the condensate will have a corrosive effect on the pipework and associated equipment. Oxygen is introduced into the return systems at any location where the condensate is exposed to atmospheric pressures.

Return line failures due to corrosion can be properly handled only by feed water treatment and deaeration. The following design practices will help to slow down the corrosion process:

- do not use piping systems of dissimilar metals which can intensify the rate of corrosion at the connecting point
- horizontal pipes are generally subject to more severe attack than vertical lines because of the possibility of incomplete drainage of condensate
- systems that operate intermittently allow more severe corrosion to occur. In these systems, the condensate can dissolve large quantities of CO_2 that have accumulated in the system during operation. Precautions should be taken to remove this CO_2. Proper drainage, frequent air venting during operation and air venting before shutdown are essential.

For efficient and economical operation of a steam generating system, deaeration will increase equipment life, reduce replacement costs, and lower maintenance costs. Deaeration consists primarily of oxygen and CO2 removal. Removing these gases will also improve the heat transfer rates and lead to energy savings.

Chemical control of the boiler makeup water can also be utilized to minimize corrosion along with the removal of the aggressive substances in the steam and condensate.

Condensate Recovery Factor

The two primary reasons for the installation of a condensate recovery system are the utilization of the heat energy in the returned condensate and the cost of makeup water and its associated treatment.

In certain types of applications, it is virtually impossible to collect and return the condensate. This is the case where the steam is injected directly into liquids or where the discharged condensate may be polluted by the process. Installations at remote distances from the boiler plant may make it impractical to install return systems.

In justifying a condensate recovery system, a balance must be drawn between the savings in recovered heat, water and water treatment versus the cost of the piping system, associated receivers, and pumping equipment to return the condensate to the boiler house.

Flash Tanks and Flash Steam Recovery

Hot condensate under pressure being released to a lower pressure revaporizes into flash steam. This flash steam contains heat energy. If this condensate is to be returned, its temperature must be reduced to approximately 180ºF in order for it to be pumped into the boiler without causing cavitation damage to the boiler feed pumps.

The flash steam forms with the same identical values as that of live steam at the same pressure. That is, part of the heat energy is in the form of sensible heat with the excess in the form of latent heat causing some of the hot condensate to convert to steam vapor. The latent heat content of this flash steam may be used for other low pressure applications such as space heating, preheating water and oil, etc.

Figure 1 shows a typical flash system tank with live steam makeup.

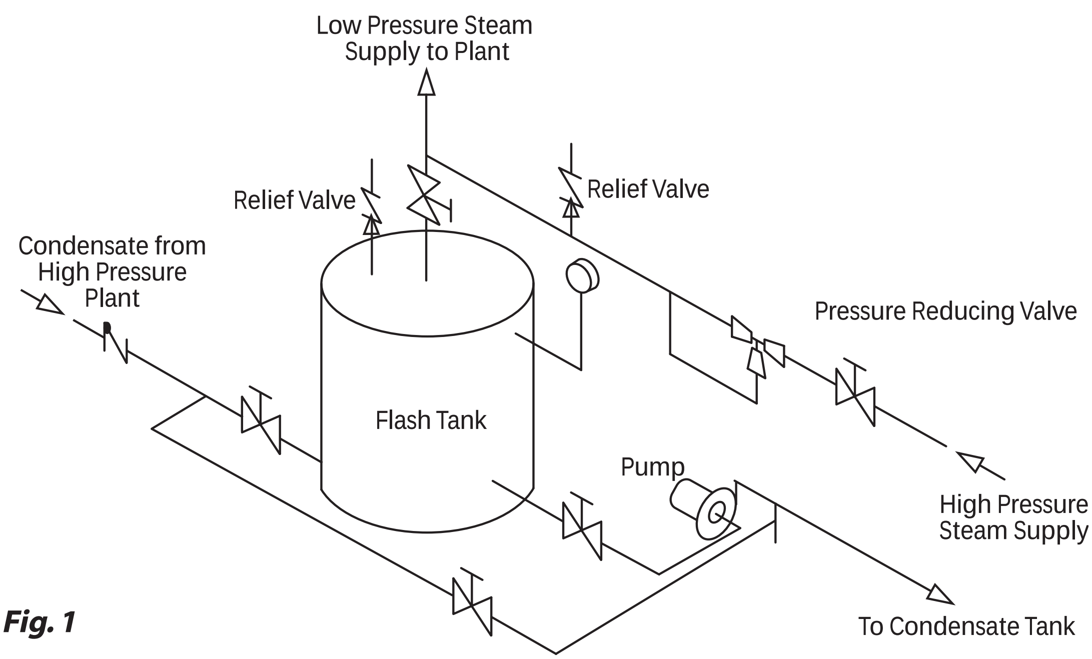
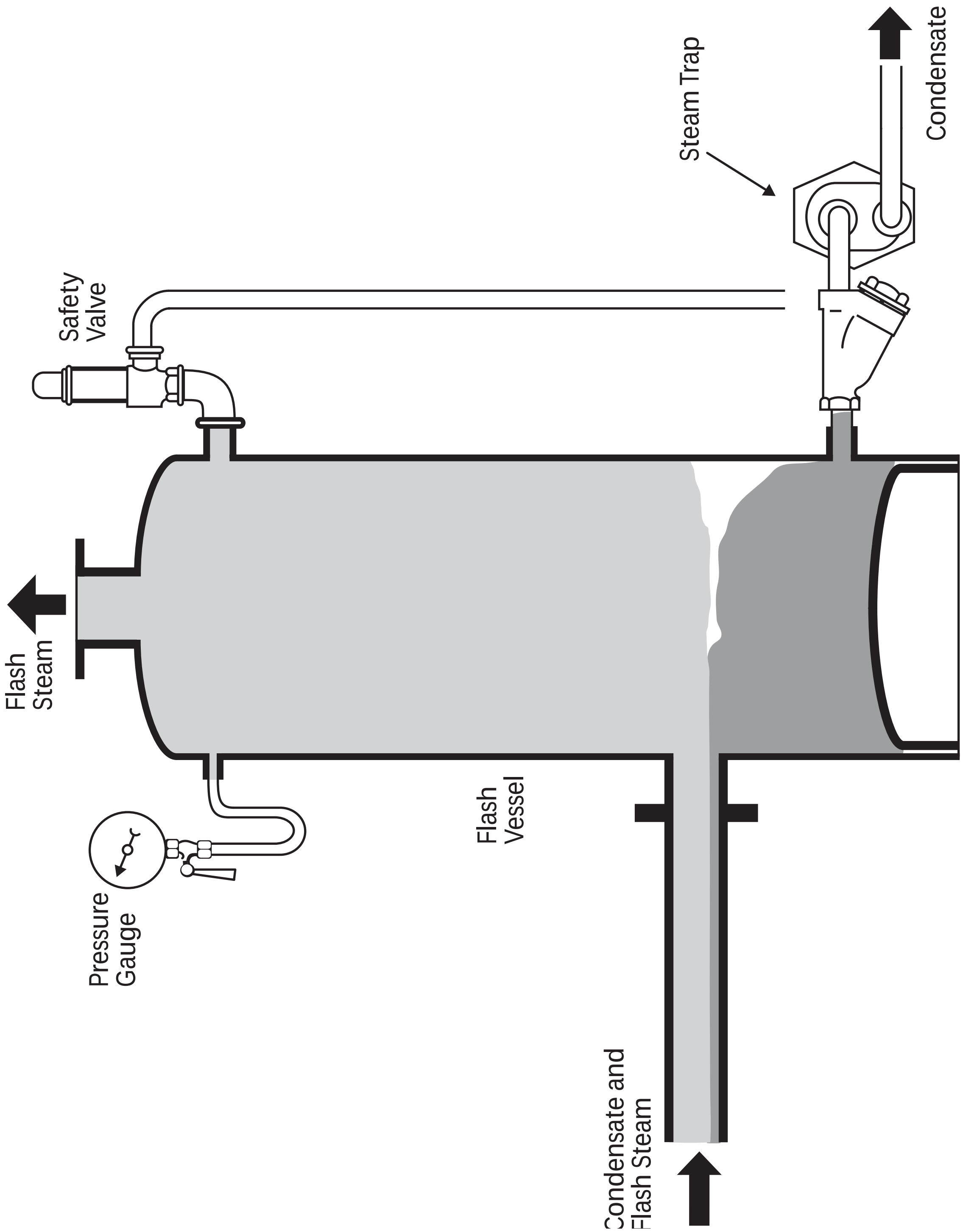
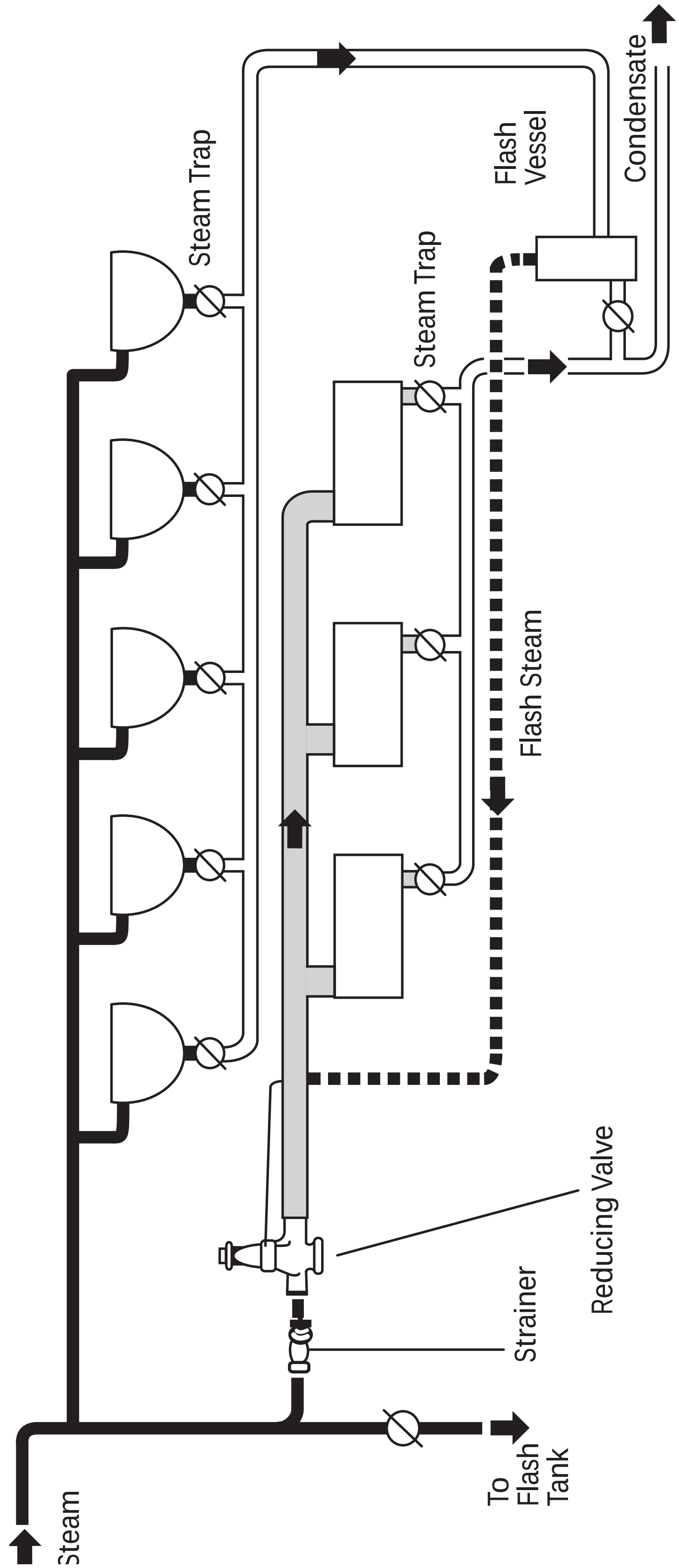


Fig. 1


Flash Steam
Pressure Gauge
Safety Valve
Flash Vessel
Condensate and Flash Steam
Steam Trap
Condensate


Steam Trap
Steam Trap
Flash Vessel
Condensate
Flash Steam
Reducing Valve
Strainer
Steam
To Flash Tank

When the condensate returned to the flash tank is from a high pressure system, a significant amount of flash steam can be generated and the pressure of the flash steam can be above atmospheric pressure. It is possible to combine this flash steam with controlled high pressure live steam to create a secondary steam system utilizing some of the heat from the condensate.

A pump with a level control can be used to remove the condensate from the flash tank for return to the boiler. There are steam traps available that will maintain a liquid level in the flash tank.

Some flash tanks or condensate receivers utilize a cold water spray to condense flash steam and thus save the steam vapor that could be vented to atmosphere. A thermostat, sensing the steam temperature in the condensate receiver, can be used to control the amount of spray water that needs to be added to reduce or eliminate flash steam.

In some systems, a cascade principal can be used to utilize the flashing condensate discharge from a high pressure system to generate the steam required in a secondary system where less heat is required by the process.

Sensible Heat

There are installations and applications where high heat content is not required or where energy can be conserved by the use of certain steam trap designs.

Examples of applications where high heat content is not always required are: preventing fire water mains from freezing and heating instrument boxes. Temperatures below the saturation point may be sufficient.

Special installations may also make use of sensible heat to reduce energy costs. An example is shown below in *Figure 2.*

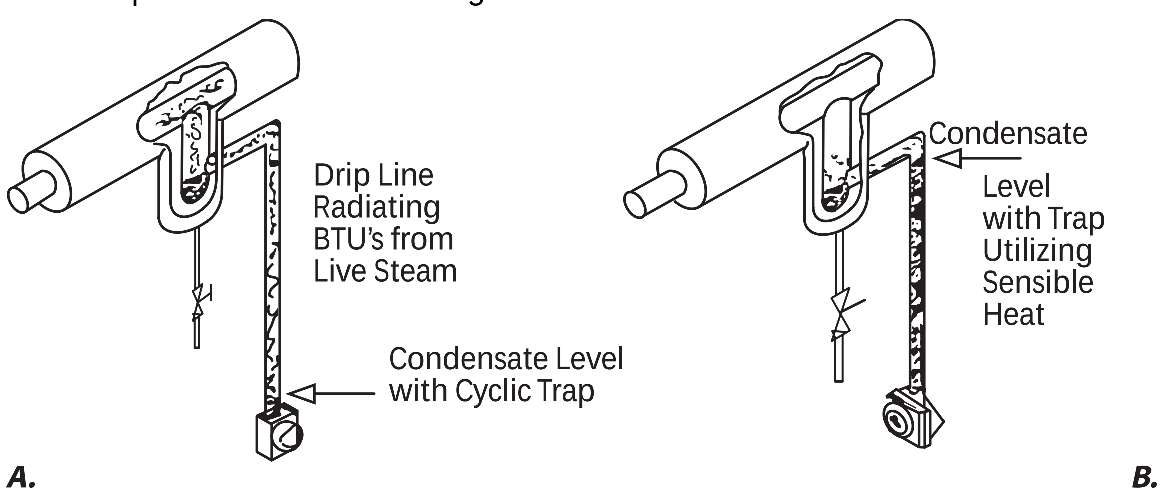


Fig. 2

The traced product lines and steam mains are in overhead racks with the steam traps installed at ground level. If a cyclic trap were installed, steam would be present up to the inlet of the trap (A). The length of the vertical leg would then produce radiation losses, which would add to the total condensate load. If the leg were partially full of hot condensate at a temperature lower than the live steam, savings could be realized in an amount at least equal to the radiation loss equivalent to the length of the leg. Many large processing plants such as oil refineries and chemical plants utilize this type of installation. Even if only 1000 BTU per hour per installation were saved, the cost savings over a one year period would be considerable.

In order to make use of the sensible heat concept, a special steam trap must be installed. This trap should not be confused with traps, which are designed for the rapid removal of condensate. Steam traps utilizing the sensible heat are set to "undercool" to as much as 90ºF under saturation temperatures. This undercooling causes condensate to be stored at the inlet to the steam trap preventing live steam from occupying that space and thus reducing radiation losses (*Figure 2B*). The line must be long enough to allow for this undercooling so that condensate does not back up into the steam main or tracer. An additional benefit of discharging subcooled condensate is the reduction of valve wear and extended steam trap life.

Thermostatic traps are best suited for the utilization of sensible heat. Some thermostatic traps can be factory calibrated to maximize the efficiency on any specific application, particularly bimetallic trap designs.

Appendix

Ten Tips For Understanding Your Steam System

#1 **Latent** Heat does the work…

#2 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…

#3 When high pressure and temperature condensate is discharged to a lower pressure, the reduction in pressure **produces** Flash steam…

#4 A pound of steam **equals** a pound of condensate…

#5 Steam can't get **in** the equipment if the condensate can't get **out**…

#6 Condensate only gets to the trap by **gravity**…

#7 Trap **each** piece of equipment separately…

#8 The condensate piping **can't** be too big…

#9 Select the trap that most closely fits **all** of the operating conditions…

#10 Locate the trap at the **lowest** point after the equipment outlet…

Glossary of Technical Terms

Absolute Pressure: pressure exerted by vapor or liquid.

Air Vent: device to release quantities of air from remote points or stagnant corners of steam condensing equipment.

Atmospheric Pressure: pressure exerted by the atmosphere; equals 14.7 psi at sea level.

BTU (British Thermal Unit): the measure of heat energy defined as the amount of heat required to raise one pound of water at atmospheric pressure 1ºF.

Back Pressure: pressure at the steam trap discharge.

Bernoulli's Theorem: the principle of conservation of energy applying to a constricted fluid. Fluid going from a high pressure to a lower pressure through an orificewill increase in velocity. High velocity flow across a surface creates a lower pressure area.

Blast Discharge Trap: steam trap that operates in an intermediate fashion – wide open discharging condensate alternating with periods of being completely closed.

Centigrade: temperature measuring scale based on the freezing point of water at 0ºC and the boiling point of water at 100ºC. Also called Celsius.

Condensate: condensed steam; water.

Conduction: heat transfer by direct contact.

Continuous Discharge Trap: steam trap discharging condensate in a continuous flow.

Convection: heat transfer by direct contact.

Cyclic Trap: see *Blast Discharge Trap.*

Dalton's Law of Partial Pressures: "in a mixture of gases in a given volume, each gas exerts the same pressure that it would if it occupied the same volume alone. The total pressure exerted by the mixture of gases is equal to the sum of the pressures each would exert if it occupied the volume alone."

De-aerator: device used to remove entrained air from water.

Degrees of Superheat: temperature difference between the superheated steam and dry saturated steam.

Differential Pressure: difference between the operating pressure and back pressure

Dry Saturated Steam: steam at the boiling temperature and pressure containing no water droplets.

Enthalpy: total heat equal to the sum of the sensible heat, latent heat, and the superheat.

Fahrenheit: temperature measuring scale based on the freezing point of water at 32ºF and the boiling point of water at 212ºF.

Flash Steam: steam formed when hot condensate is discharged from a high pressure to some lower pressure.

Gauge Pressure: pressure above atmospheric.

Heat Exchanger: device in which heat transfer takes place.

Heat Transfer: exchange of enthalpy from cooler to hotter material.

Heat Transfer Coefficient: rate of conductance or rate of heat flow.

Horsepower: equal to 2545 BTU/hr.

Insulation: material used to reduce or eliminate heat loss.

Kilowatt: equal to 3415 BTU/hr.

Kinetic Energy: energy of motion.

Lagging: see *Insulation.*

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

Modulating Discharge Trap: steam trap discharging condensate at a rate varying with the load.

Natural Process Undercooling: the reduction in condensate temperature below saturation due to the .temperature differential between the condensate and the process. The longer the condensate remains in contact with the heat transfer surfaces, the cooler it will be when it reaches the trap.

One Pipe Heating System: radiator heating system where steam and condensate flow within the same piping, the pitch of the piping allowing gravity drainage of the heavier condensate.

Operating Pressure: pressure at the steam trap inlet.

Orifice: an opening through which fluid passes.

PSI: pounds per square inch.

PSIG: pounds per square inch gauge.

Radiation: heat transfer by absorption of electromagnetic waves.

Running Load: rate at which condensate forms when temperature difference is constant.

Saturated Steam: see *Dry Saturated Steam.*

Saturated Water: water at the boiling point containing only sensible heat.

Second Law of Thermodynamics: "heat cannot of itself pass from a colder to a hotter body."

Sensible Heat: heat required to raise the temperature of a unit mass of water from the freezing point to the boiling point.

Specific Heat: ratio between the heat added and the temperature rise; the amount of heat a substance can hold relative to water.

Specific Heat Capacity: rate at which heat is absorbed.

Specific Gravity: ratio of the density of any substance compared to the density of the water.

Specific Volume: volume that a pound of steam occupies at a corresponding pressure.

Start-up Load: rate at which condensate forms when temperature difference is greatest.

Steam Curve: curve showing the relationship between the pressure, boiling temperature, sensible heat, latent heat, and total heat.

Steam Locking: condition where steam is preventing condensate from reaching the steam trap.

Steam Table: table giving the relationship between the pressure, boiling temperature, sensible heat, latent heat, and total heat.

Steam Trap: a device that automatically opens to permit the discharge of air and non-condensible gases and condensate at, or below saturated steam temperature and closes to prevent or limit the passage of steam.

Strainer: device used to filter dirt and other particles from condensate system.

Sub-cooling: reducing the temperature of the condensate before it is discharged to allow for the use of sensible heat or the reduction of flash steam vapor. Also called "under-cooling."

Superheated Steam: dry saturated steam at a temperature above the boiling temperature and pressure.

Suppression: the temperature at which a steam trap operates relative to the saturated steam temperature.

Temperature: degrees of hotness or coldness.

Thermal Efficiency: heat energy converted to work as a percentage of the total heat energy put into the steam.

Thermostatic Dead Band: the differential between the temperature at which thermostatic steam Trap closes and the saturated steam temperature through the traps' operating pressure Range.

Total Heat: see *Enthalpy.*

Under-Cooling: see *Sub-Cooling.*

Universal Steam Trap: a fairy tale!

Vacuum Breaker: device to prevent damage to equipment due to vacuum formed when hot process equipment cools.

Warming Load: see *Start-up Load.*

Waterhammer: damaging effect of "slug" or mass of water traveling in steam lines at high velocity reaching obstructions; or change of direction delivering its' inertial force to the obstruction.

Waterlogged: condensate back-up.

Wet Steam: steam which carries water droplets in suspension.

For
Future
Additions

Conversion Factors

To Convert	Into	Multiply By	To Convert	Into	Multiply By
atmospheres	ft. of water (at 4°C)	33.90	Feet of water	atmospheres	0.02950
atmospheres	in. of mercury (at 0°C)	29.92	Feet of water	inches of Hg	0.8826
atmospheres	pounds/sq. inch	14.70	Feet of water	pounds/sq.ft.	62.43
			Feet of water	PSI	0.4335
Btu	foot-lbs	778.3	Feet/min.	feet/sec	0.1667
Btu	horsepower-hrs	3.931×10^{-4}	Feet/min.	miles/hr.	0.01136
Btu	kilowatt-hrs	2.928×10^{-4}	Feet/sec.	miles/hr.	0.6818
Btu/hr.	foot-pounds/sec	0.2162	Feet/sec.	miles/min.	0.01136
Btu/hr.	horsepower-hrs	3.931×10^{-4}	Foot-candle	lumen/sq meter	10.764
Btu/hr.	watts	0.2931	Foot-pounds	Btu	1.286×10^{-3}
Btu/min	foot-lbs/sec	12.96	Foot-pounds	hp-hrs	5.050×10^{-7}
Btu/min	horsepower	0.02356	Foot-pounds	kilowatt-hrs	3.766×10^{-7}
Btu/min	kilowatts	0.01757	Foot-pounds/min	Btu/min	1.286×10^{-3}
Btu/min	watts	17.57	Foot-pounds/min	foot-lbs/sec	0.01667
Btu/min	tons of refrigeration	200.0	Foot-pounds/min	horsepower	3.030×10^{-5}
Btu/hr	tons of refrigeration	12000.0	Foot-pounds/min	kilowatts	2.260×10^{-5}
Btu/sq ft min	watts/sq in.	0.1221	Foot-pounds/sec	Btu/hr	4.6263
			Foot-pounds/sec	Btu/min	0.07717
Candle/sq. in	Lamberts	.4870	Foot-pounds/sec	horsepower	1.818×10^{-3}
Cubic feet	cubic inches	1728.0	Foot-pounds/sec	kilowatts	1.356×10^{-3}
Cubic feet	cubic yards	0.03704			
Cubic feet	gallons (US liquid)	7.48052	Gallons	cubic feet	0.1337
Cubic feet	pints (US liquid)	59.84	Gallons	cubic inches	231.0
Cubic feet	quarts (US liquid)	29.92	Gallons	cubic yards	4.951×10^{-3}
Cubic feet/min	gallons/sec	0.1247	Gallons	liters	3.785
Cubic feet/min	pounds of water/min	62.43	Gallons (Br. Imp)	gallons (US)	1.20095
Cubic feet/sec	millions gals/day	0.646317	Gallons (US)	gallons (Imp)	0.83267
Cubic feet/sec	gallons/min	448.831	Gallons of water	pounds of water	8.3453
Cubic inches	cubic feet	5.787×10^{-4}	Gallons/minute	cu.ft/sec.	2.228×10^{-3}
Cubic inches	cubic yards	2.143×10^{-5}	Gallons/minute	cu.ft/hr.	8.0208
Cubic inches	gallons	4.329×10^{-3}			
Cubic yards	cubic feet	27.0	Horsepower	Btu/min.	42.44
Cubic yards	cubic inches	46,656.0	Horsepower	foot-lbs./min.	33000.0
Cubic yards	gallons (US liq.)	202.0	Horsepower	foot-lbs/sec.	550.0
Cubic yards	pints (US liq.)	1615.9	Horsepower	kilowatts	0.7457
Cubic yards	quarts (US liq.)	807.9	Horsepower	watts	745.7
Cubic yards/min	cubic feet/sec.	0.45	Horsepower-boiler	Btu/hr	33479
Cubic yards/min	gallons/sec.	3.367	Horsepower-boiler	kilowatts	9.803
			Horsepower-hrs	Btu	2547.0
Degrees (angle)	seconds	3600.0	Horsepower-hrs	foot-lbs	1.98×10^{6}
Degrees/sec.	revolutions/min	0.1667	Horsepower-hrs	kilowatt-hrs	0.7457

Conversion Factors (continued)

To Convert	Into	Multiply By
Inches-water (4°C)	ounces/sq.in.	0.5781
Inches of water	pounds/sq.ft.	5.204
Inches of water	pounds/sq.ft.	0.03613
Kilometers	miles	0.6214
Kilometers	yards	1094.0
Kilowatts	Btu/min	56.92
Kilowatts	foot-lbs/min	4.426×10^{-4}
Kilowatts	foot-lbs/sec	737.6
Kilowatts	horsepower	1.341
Kilowatts	watts	1000.0
Kilowatt-hrs	Btu	3413.0
Kilowatt-hrs	foot-lbs	2.655×10^{6}
Kilowatt-hrs	horsepower-hrs	1.341
Kilowatt-hrs	pounds of water evaporated from and at 212°F	3.53
Kilowatt-hrs	pounds of water raised from 62° to 212°F	22.75
Lumens/sq.ft.	foot-candles	1.0
Lumen	spherical candle power	.07958
Lumen	watt	.001496
Lumen/sq.ft.	lumen/sq.meter	10.76
Lux	foot candles	0.0929
Meters	feet	3.281
Meters	yards	1.094
Miles/hr	feet/min	88.0
Miles/hr	feet/sec	1.467
Miles/hr	miles/min	0.1667
Miles/min	feet/sec	88.0
Miles/min	miles/hr	60.0
OHM (internatl).	OHM (absolute)	1.0005
Ounces	pounds	0.0625
Pounds	ounces	16.0
Pounds of water	cu. feet	0.01602
Pounds of water	cu. inches	27.68
Pounds of water	gallons	0.1198

To Convert	Into	Multiply By
Pounds of water/ minute	cu ft/sec	2.670 x 10-4
Pounds/cu.ft.	pounds/cu. in	5.787 x 10-4
Pounds/cu.in.	pounds/cu. ft.	1728.0
Pounds/sq. ft.	atmospheres	4.725 x 10-4
Pounds/sq. ft.	feet of water	0.01602
Pounds/sq. ft	inches of Hg	0.01414
Pounds/sq. ft.	pounds/sq. in.	6.944 x 10-3
Pounds/sq. in.	atmospheres	0.06804
Pounds/sq. in.	feet of water	2.307
Pounds/sq. in.	inches of Hg	2.036
Pounds/sq. in.	pounds/sq. ft.	144.0
Revolutions	degrees	360.0
Square Feet	square inches	144.0
Watts	Btu/hr.	3.4129
Watts	Btu/hr.	0.05688
Watts	foot-lbs/min	44.27
Watts	foot-lbs/sec	0.7378
Watts	horsepower	1.341 x 10-3
Watts	kilowatts	0.001
Watt-hours	Btu	3.413
Watt-hours	foot-pounds	2656.0
Watt-hours	horsepower-hrs	1.341 x 10-3
Watt-hours	kilowatt-hrs	0.001

SPECIFIC HEATS

Table I

Various Solids

Material	B.t.u. per Lb. per °F	Material	B.t.u. per Lb. per °F
Aluminum	.22	Ice, 32F	.49
Andalusite	.17	Iridium	.03
Antimony	.05	Iron, cast	.12
Apatite	.20	Iron, wrought	.12
Asbestos	.20	Labradorite	.19
Augite	.19	Lava	.20
Bakelite, wood filler	.33	Lead	.03
Bakelite, asbestos filler	.38	Limestone	.22
Barite	.11	Magnetite	.16
Barium	.07	Magnesium	.25
Basalt rock	.20	Malachite	.18
Beryl	.20	Manganese	.11
Bismuth	.03	Marble	.21
Borax	.24	Mercury	.03
Boron	.31	Mica	.21
Cadmium	.06	Molybdenum	.06
Calcite, 32-100F	.19	Nickel	.11
Calcite, 32-212F	.20	Oligloclose	.21
Calcium	.15	Orthoclose	.19
Carbon	.17	Plaster Paris	1.14
Carborundum	.16	Platinum	.03
Cassiterite	.09	Procelain	.26
Cement, dry	.37	Potassium	.13
Cement, powder	.20	Pyrexglass	.20
Charcoal	.24	Pyrolusite	.16
Chalcopyrite	.13	Pyroxylin Plastics	.34-.38
Chromium	.12	Quartz, 55-212F	.19
Clay	.22	Quartz 32F	.17
Coal	.26-.37	Rock Salt	.22
Cobalt	.11	Rubber	.48
Concrete, stone	.19	Sandstone	.22
Concrete, cinder	.18	Serpentine	.26
Copper	.09	Silk	.33
Corundum	.10	Silver	.06
Diamond	.15	Sodium	.30
Doomite rock	.22	Steel	.12
Fluorite	.22	Stone	.20
Fluorspar	.21	Stoneware	.19
Galena	.05	Talc	.21
Garnet	.18	Tar	.35
Glass, common	.20	Tellurium	.05
Glass, crystal	.12	Tin	.05
Glass, plate	.12	Tile, hollow	.15
Glass, wool	.16	Titanium	.14
Gold	.03	Topaz	.21
FGranite	.19	Tungsten	.04
Hermatite	.16	Vanadium	.12
Hornblende	.20	Vulcanite	.33
Hypersthene	.19	Wood	.32-.48
Ice, - 112F	.35	Wool	.33
Ice, - 40F	.43	Zinc blend	.11
Ice, - 4F	.47	Zinc	.09

SPECIFIC HEATS

Table II
Various Liquids

Liquid	B.t.u. per Lb. per °F	Liquid	B.t.u. per Lb. per °F
Acetone	.51	Fuel Oil, sp. gr. 86	.45
Alcohol, ethyl 32F	.55	Fuel Oil, sp. gr. 81	.50
Alcohol, ethyl 104F	.65	Gasoline	.53
Alcohol, methyl 40-50F	.59	Glycerine	.58
Alcohol, methyl, 60-70F	.60	Kerosene	.48
Ammonia, 32F	1.10	Mercury	.033
Ammonia, 104F	1.16	Naphthalene	.41
Ammonia, 176F	1.29	Nitrobenxole	.36
Ammonia, 212F	1.48	Olive oil	.47
Ammonia, 238F	1.61	Petroleum	.51
Anilin	.52	Ptoassium hydrate	.88
Benzol	.42	Sea water, sp. gr. 1.0235	.94
Calcium Chloride, sp. gr. 1.20	.73	Sesame oil	.39
Castor Oil	.43	Sodium chloride	.79
Citron Oil	.44	Sodium hydrate	.94
Diphenylamine	.46	Soybean oil	.47
Ethyl ether	.53	Toluol	.36
Ethylene Glycol	.53	Turpentine	.41
Fuel oil, sp. gr. 96	.40	Water	1.00
Fuel oil, sp. gr. 91	.44	Xylene	.41

Table III
Gases and Vapors

Gas or Vapor	Specific Heat, B.t.u. per Lb. per °F at Constant Pressure	Specific Heat, B.t.u. per Lb. per °F at Constant Volume	Gas or Vapor	Specific Heat, B.t.u. per Lb. per °F at Constant Pressure	Specific Heat, B.t.u. per Lb. per °F at Constant Volume
Acetone	.35	.315	Ether	.48	.466
Air, dry, 50F	.24	.172	Hydrochloric acid	.19	.136
Air, dry, 32-392F	.24	.173	Hydrogen	3.41	2.410
Air, dry, 68-824F	.25	.178	Hydrogen sulphide	.25	.189
Air, dry, 68-1166F	.25	.184	Methane	.59	.446
Air, dry, 68-1472F	.26	.188	Nitrogen	.24	.170
Alcohol, C_2H_5OH	.45	.398	Nitric oxide	.23	.166
Alcohol, CH_3OH	.46	.366	Nitrogen tetroxide	1.12	1.098
Ammonia	.54	.422	Nitrous oxide	.21	.166
Argon	.12	.072	Oxygen	.22	.157
Benzene, C_6H_6	.26	.236	Steam, 1 psia 120-600°F	.46	.349
Bromine	.06	.047			
Carbon dioxide	.20	.150	Steam, 14.7 psia 220-600°F	.47	.359
Carbon monoxide	.24	.172			
Carbon disulphide	.16	.132	Steam, 150 psia 360-600°F	.54	.421
Chlorine	.11	.082			
Chloroform	.15	.131	Sulphur dioxide	.15	.119

SPECIFIC HEATS

Table IV
Foodstuffs

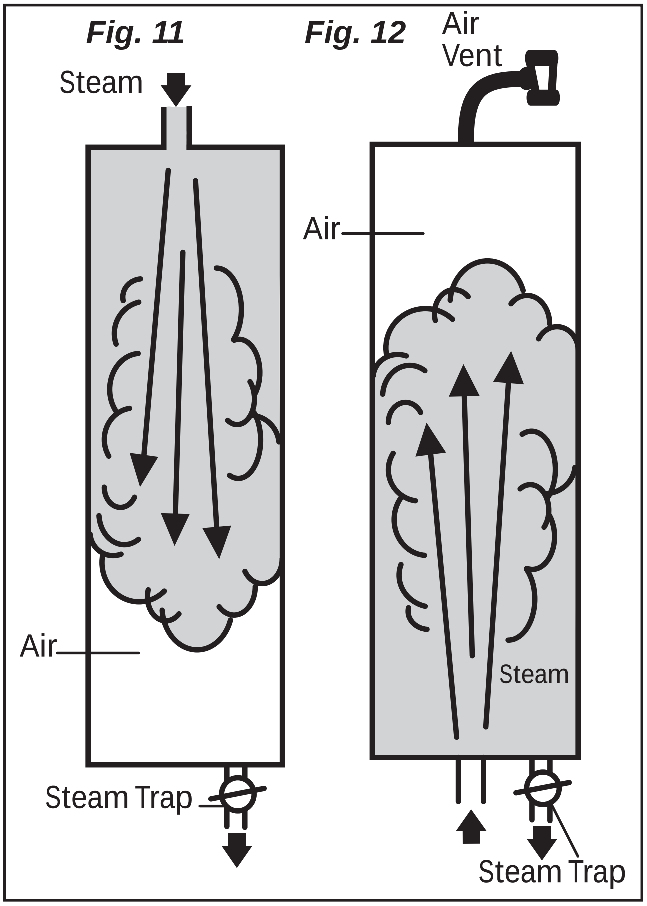
Food	Specific Heat, B.t.u. per Lb. per °F Above Freezing	Specific Heat, B.t.u. per Lb. per °F Below Freezing	Food	Specific Heat, B.t.u. per Lb. per °F Above Freezing	Specific Heat, B.t.u. per Lb. per °F Below Freezing
Apples	.87	.42	Eggs	.76	.40
Apricots, fresh	.88	.43	Eggplant	.94	.45
Artichokes	.87	.42	Endive	.95	.45
Asparagus	.94	.45	Figs, fresh	.82	.41
Asparagus beans	.88	.43	Figs, dried	.39	.26
Avocados	.72	.37	Figs, candied	.37	.26
Bananas	.80	.40	Flounders	.86	.42
Barracuda	.80	.40	Flour	.38	.28
Bass	.82	.41	Frogs legs	.88	.44
Beef, carcass	.68	.48	Garlic	.79	.40
Beef, flank	.56	.32	Gizzards	.78	.39
Beef, loin	.66	.35	Goose	.61	.34
Beef, rib	.67	.36	Gooseberry	.86	.42
Beef, round	.74	.38	Granadilla	.84	.41
Beef, rump	.62	.34	Grapefruit	.91	.44
Beef, shanks	.76	.39	Grapes	.86	.42
Beef, corned	.63	.34	Grape juice	.82	.41
Beets	.90	.43	Guavas	.86	.42
Blackberries	.87	.42	Guinea hen	.75	.38
Blueberries	.87	.42	Haddock	.85	.42
Brains	.84	.41	Halibut	.80	.40
Broccoli	.92	.44	Herring, smoked	.71	.37
Brussels sprouts	.88	.43	Horseradish, fresh	.79	.40
Butter	.30	.24	Horseradish, prepared	.88	.43
Butterfish	.77	.39	Ice Cream	.74	.40
Cabbage	.94	.45	Kale	.89	.43
Candy	.93	.-	Kidneys	.81	.40
Carp	.82	.41	Kidney beans, dried	.28	.23
Carrots	.91	.44	Kohlrabi	.92	.44
Cauliflower	.93	.44	Kumquats	.85	.41
Celery	.94	.45	Lamb, carcass	.73	.38
Chard	.93	.44	Lamb, leg	.71	.37
Cherries, sour	.88	.43	Lamb, rib cut	.61	.34
Cherries, sweet	.84	.41	Lamb, shoulder	.67	.35
Chicken, squab	.80	.40	Lard	.54	.31
Chicken, broilers	.77	.39	Leeks	.91	.44
Chicken, fryers	.74	.38	Lemons	.91	.44
Chicken, hens	.65	.35	Lemon juice	.92	.44
Chicken, capons	.88	.44	Lettuce	.96	.45
Clams, meat only	.84	.41	Lima beans	.73	.38
Coconut, meat and milk	.68	.36	Limes	.89	.43
Coconut, milk only	.95	.45	Lime juice	.93	.44
Codfish	.86	.42	Litchi fruits, dried	.39	.26
Cod Roe	.76	.39	Lobsters	.82	.41
Cowpeas, freash	.73	.39	Loganberries	.86	.42
Cowpeas, dry	.28	.22	Loganberry juice	.91	.44
Crabs	.84	.41	Milk, cow	.90	.47
Crab apples	.85	.41	Mushrooms, fresh	.93	.44
Cranberries	.90	.43	Mushrooms, dried	.30	.23
Cream	.90	.38	Muskmelons	.94	.45
Cucumber	.97	.45	Nectarines	.86	.42
Currants	.97	.45	Nuts	.28	.24
Dandelion greens	.88	.43	Olives, green	.80	.40
Dates	.20	.007	Onions	.90	.43
Eels	.77	.39	Onions, Welsh	.91	.44

SPECIFIC HEATS

Table IV
Foodstuffs (continued)

Food	Specific Heat, B.t.u. per Lb. per °F Above Freezing	Specific Heat, B.t.u. per Lb. per °F Below Freezing	Food	Specific Heat, B.t.u. per Lb. per °F Above Freezing	Specific Heat, B.t.u. per Lb. per °F Below Freezing
Oranges, fresh	.90	.43	Reindeer	.73	.37
Orange juice	.89	.43	Rhubarb	.96	.45
Oysters	.84	.41	Rose Apple	.89	.43
Peaches, Georgia	.87	.42	Rutabagas	.91	.44
Peaches, N. Carolina	.89	.43	Salmon	.71	.37
Peaches, Maryland	.90	.43	Sand dab, California	.86	.42
Peaches, New Jersey	.91	.44	Sapodilla	.91	.44
Peach juice, fresh	.89	.43	Sapote	.73	.37
Pears, Bartlett	.89	.43	Sauerkraut	.93	.44
Pears, Beurre Bosc	.85	.41	Sausage, beef and pork	.56	.32
Pears, dried	.39	.26	Sausage, bockwurst	.71	.37
Peas, young	.85	.41	Sausage, bologna	.71	.37
Peas, medium	.81	.40	Sausage, frankfurt	.69	.36
Peas, old	.88	.43	Sausage, salami	.45	.28
Peas, split	.28	.23	Sardines	.77	.39
Peppers, ripe	.91	.44	Shad	.76	.39
Perch	.82	.41	Shrimp	.83	.41
Persimmons	.72	.37	Spanish mackerel	.73	.39
Pheasant	.75	.36	Strawberries	.95	.45
Pickerel	.84	.41	Strawberry juice	.79	.39
Pickles, sweet	.82	.41	String beans	.91	.44
Pickles, sour and dill	.96	.45	Sturgeon, raw	.83	.41
Pickles, sweet mixed	.78	.29	Sturgeon, smoked	.71	.37
Pickles, sour mixed	.95	.45	Sugar apple, fresh	.79	.39
Pig's feet, pickled	.50	.31	Sweet potatoes	.75	.38
Pike	.84	.41	Swordfish	.80	.40
Pineapple, fresh	.88	.43	Terrapin	.80	.40
Pineapple, sliced or crushed	.82	.41	Tomatoes, red	.95	.45
			Tomatoes, green	.96	.45
Pineapple juice	.90	.43	Tomato, juice	.95	.45
Plums	.89	.43	Tongue, beef	.74	.38
Pomegranate	.85	.41	Tongue, calf	.79	.40
Pompano	.77	.39	Tongue, lamb	.76	.38
Porgy	.81	.40	Tongue, pork	.74	.39
Pork, bacon	.36	.25	Tongue, sheep	.69	.36
Pork, ham	.62	.34	Tripe, beef	.83	.41
Pork, loin	.66	.35	Tripe, pickled	.89	.43
Pork, shoulder	.59	.33	Trout	.82	.41
Pork, spareribs	.62	.34	Tuna	.76	.39
Pork, smoked ham	.65	.35	Turkey	.67	.35
Pork, salted	.31	.24	Turnips	.93	.44
Potatoes	.82	.41	Turtle	.84	.41
Prickly pears	.91	.43	Veal, carcass	.74	.38
Prunes	.81	.40	Veal, flank	.65	.35
Pumpkin	.92	.44	Veal, loin	.75	.38
Quinces	.88	.43	Veal, rib	.73	.37
Rabbit	.76	.39	Veal, shank	.77	.39
Radishes	.95	.45	Veal, quarter	.74	.38
Raisins	.39	.26	Venison	.78	.39
Raspberries, black	.85	.41	Watercress	.95	.45
Raspberries, red	.89	.43	Watermelons	.94	.45
Raspberry juice, black	.91	.44	Whitefish	.76	.39
Raspberry juice, red	.93	.44	Yams	.78	.39

Effects of Air in Steam Space



When the steam is turned off to all or part of a steam system, air fills the void that is generated due to the condensing of the steam. There isn't a system in operation that is totally leak-free.

When the system is turned back on line, it is crucial that air is removed from both the lines and equipment as soon as possible for the following reasons:

- air reduces the temperature of steam
- air reduces the heat transfer rate
- air and CO_2 mix with water and can cause corrosion problems.

Air Reduces Steam Temperature

In a mixture of two separate gases, each exerts a partial pressure. The total pressure of the mixture is the combination of these partial pressures. The amount of partial pressure exerted by each depends upon the proportion of it which is present in the mixture.

Suppose we have a mixture of 2/3 steam and 1/3 air, resulting in a total pressure of 150 psig for the steam and air mixture. Now the total heat available for heat transfer in the mixture must all come from the steam. The air doesn't contribute any of the enthalpy. Instead of having a temperature associated with 150 psig, 365°F steam, the temperature of the 150 psig air and steam mixture will only have a temperature associated with 100 psig (2/3 of the total), 338°F steam. The temperature will be much less than the pressure gauge would lead you to believe.

Air Reduces Heat Transfer

Air is one of the best insulating mediums. Some of the air that is not removed on start-up will collect and form an air film on the heat transfer surface. A .001 inch air film offers the same resistance to heat transfer as a 1.6 inch thick iron plate. If air is discharged quickly, start-up times will be increased significantly.

Corrosion Problems

Air along with CO_2 gas released in the boiler can cause corrosion problems. CO_2 gas, when dissolved in subcooled condensate forms carbonic acid and if it is not discharged or taken care of through proper feed water treatment, can be corrosive to the equipment upstream of the trap.

A steam trap can discharge air only if the air is allowed to reach it. There are many pieces of steam equipment in industry where the steam inlet and condensate discharge are on the same side (See *Figure 12*).

Here it is impossible for the air to reach the trap. In this case, it is best to have a separate thermostatic air vent located where the incoming steam front can push the air out. As soon as the air vent senses steam temperatures, it will shut.

Recommended Velocities and Pressure Drops

Service	Velocities	Pressure Drops
Saturated Steam		
Vacuum	2000 - 4000 fpm	1/4 - 1/2 psi/100’
0 - 15 psig	2000 - 5000 fpm	1/4 - 1/2 psi/100’
15 - 100 psig	2000 - 7500 fpm	1/2 - 1.5 psi/100’
Over 100 psig	2000 - 9000 fpm	1/2 - 2 psi/100’
Superheated Steam		
0 - 100 psig	2500 - 10000 fpm	1/2 - 1.5 psi/100’
100 - 500 psig	2500 - 12000 fpm	1 - 2 psi/100’
Condensate		
Boiler Feed Pump Suction	1.5 - 2.5 fps	
Condensate Pump Suction	1.5 - 3.0 fps	
Condensate Pump Discharge	3.0 - 7.5 fps	
Boiler Feed Pump Discharge	4.0 - 10 fps	
Hot Water		
Heating Systems	Max. 4 fps for quiet flow	
Pump Suction Lines	1.0 to 8.0 fps	
Pump Discharge Lines	5.0 to 15.0 fps	
Cooling Water Systems	5.0 to 15 fps	

Approximating Steam Flow

TABLE 1
REASONABLE STEAM VELOCITY THROUGH PIPES
(Based on design of many systems. To be used when exact data is not known.)

TABLE 1	Psig	Service	Reasonable Velocity (FPM)
Saturated Steam	0-25	Heating Mains	4000-6000
	25-up	Miscellaneous Process Piping	6000-8000
Superheated Steam	200-up	Boiler & Turbine Leads	10000-15000

NOTE: The velocity through pipe is lower than it would be through a valve of equivalent size since the velocity is held low to prevent noise, undue friction, and erosion.

TABLE 2
FLOW OF SATURATED STEAM

Pressure Psig →	5	25	50	75	100	150	200	250	300	400	500	600
Pipe Size ↓	LBH of Saturated Steam at 6000 FPM Velocity Through Iron or Steel Pipe SCHEDULE 80 PIPE											
1/2	30	55	90	120	150	210	270	340	400	520	660	790
3/4	50	100	160	220	280	400	510	620	740	970	1220	1460
1	90	170	270	370	460	660	840	1030	1230	1610	2025	2440
1 1/4	160	300	480	660	830	1170	1500	1840	2190	2870	3610	4340
1 1/2	220	420	660	900	1140	1620	2070	2530	3010	3950	4980	5980
2	370	700	1110	1510	1900	2700	3460	4230	5030	6610	8310	10000
2 1/2	525	1000	1590	2160	2730	3880	4960	6070	7230	9480	11900	14400
3	820	1560	2480	3370	4260	6040	7730	9460	11300	14800	18600	22400
3 1/2	1110	2100	3330	4540	5730	8130	10400	12700	15200	19900	25000	30000
4	1430	2720	4310	5870	7410	10500	13500	16500	19600	25700	32400	38900
5	2270	4300	6830	9290	11700	16600	21300	26100	31000	40700	51200	61600
6	3250	6160	9780	13300	16800	23900	30500	37300	44400	58300	73400	88300
8	5690	10800	17100	23300	29400	41800	53500	65400	77800	102000	129000	155000
10	8960	17000	26900	36700	46300	65700	84100	103000	122000	161000	202000	243000
12	17200	24000	38100	51900	65500	93000	119000	146000	173000	227000	286000	344000

EXAMPLES:

1. How many LBH of steam at 25 psig can pass through a 2" heating main at 6000FPM? Read horizontally (Table 2) on the 2" pipe line until under the column for 25 psig. The answer is 700 LBH.
2. How many LBH of steam at 200 psig can pass through a 3" process line at 6000FPM? Read horizontally (Table 2) on the 3" pipe line until under the column for 200 psig. The answer is 7730 LBH.

NOTE: If actual velocity is known, adjust the table to obtain actual flow. In example 1, if customer knows that the velocity is closer to 8000 FPM than 6000 FPM, the formula would be

$$\text{table flow} \times \frac{\text{actual velocity}}{\text{table velocity}} = \text{actual flow or } 700 \times \frac{8000}{6000} = 933 \text{ LBH}$$

Condensate Rates In Lbs/Hr for Jacketed Kettles -- Hemispherical Condensing Surface
"U" Value Assumes an Average of 175 btu/hr/sq ft/°F, 50°F Starting Temperature

Kettle Diameter	Heat Transfer Surface Sq. Feet	U.S. Gallons Water in Hemisphere	U.S. Gallons Water per inch of height above hemisphere	STEAM PRESSURE								
				5 psig 227°F	10 psig 240°F	15 psig 250°F	25 psig 267°F	40 psig 287°F	60 psig 307°F	80 psig 324°F	100 psig 338°F	125 psig 353°F
18”	3.50	7	1.10	113	122	129	142	158	174	188	201	214
19”	3.90	8	1.20	126	136	144	159	176	194	210	223	238
20”	4.35	9	1.35	140	152	161	177	196	217	234	249	266
22”	5.30	12	1.65	171	185	196	216	239	264	285	304	324
24”	6.30	16	1.95	203	220	233	256	284	314	339	361	385
26”	7.40	20	2.30	239	258	274	301	334	369	398	424	452
28”	8.50	25	2.65	274	297	314	346	383	423	457	487	519
30”	9.80	31	3.05	316	342	363	399	442	488	527	562	599
32”	11.20	37	3.50	362	391	414	456	505	558	603	642	684
34”	12.60	45	3.95	407	440	466	513	568	627	648	722	770
36”	14.10	53	4.40	455	492	522	574	636	702	759	808	862
38”	15.70	62	4.90	507	548	581	639	708	782	845	900	959
40”	17.40	73	5.45	562	607	644	708	785	867	936	997	1063
42”	19.20	84	6.00	620	670	710	781	866	956	1033	1100	1173
44”	21.10	97	6.60	681	736	781	859	952	1051	1135	1209	1289
46”	23.00	110	7.20	743	803	851	936	1037	1145	1237	1318	1405
48”	25.30	123	7.85	817	883	936	1029	1141	1260	1361	1450	1546
54”	31.70	178	9.90	1025	1108	1175	1292	1432	1581	1709	1820	1940
60”	39.20	245	12.30	1266	1368	1450	1595	1768	1952	2109	2246	2395
72”	56.40	423	17.70	1823	1970	2088	2296	2546	2811	3037	3235	3449

TYPICAL STEAM CONSUMPTION RATES

	Operating pressure PSIG	Lbs per hr	
		In Use	Maximum
BAKERIES			
Dough room trough, 8 ft long	10	4	
Proof boxes, 500 cu ft capacity		7	
Ovens: Peel or Dutch Type	10		
White bread, 120 sq ft surface		29	
Rye bread, 10 sq ft surface		58	
Master Baker Ovens		29	
Century Reel, w/pb per 100 lb bread		29	
Rotary ovens, per deck		29	
Bennett 400, single deck		44	
Hubbard (any size)		58	
Middleby-Marshall, w/pb		58	
Baker-Perkins travel ovens, long tray (per 100 lbs)		13	
Baker-Perkins travel ovens, short tray (per 100 lbs)		29	
General Electric		20	
fish Duothermic Rotary, per deck		58	
Revolving ovens: 8-10 bun pan		29	
12-18 bun pan		58	
18-28 bun pan		87	
BOTTLE WASHING	5		
Soft drinks, beer, etc.: per 100 bottles/min		310	
Milk quarts, per 100 cases per hr		58	
CANDY and CHOCOLATE	70		
Candy cooking, 30-gal cooker, 1 hour		46	
Chocolate melting, jacketed, 24” dia		29	
Chocolate dip kettles, per 10 sq ft tank surface		29	
Chocolate tempering, tops mixing, each 20 sq ft active surface		29	
Candy kettle per sq ft of jacket	30		60
Candy kettle per sq ft of jacket	75		100
CREAMERIES and DAIRIES	15-75		
Creamery cans 3 per min			310
Pasteurizer, per 100 gal heated 20 min			232
DISH WASHERS	10-30		
2-Compartment tub type			58
Large conveyor or roller type			58
Autosan, colt, depending on size		29	117
Champion, depending on size		58	310
Hobart Crescent, depending on size		29	186
Fan Spray, depending on size		58	248
Crescent manual steam control	30		
Hobart model AM-5	10		
Dishwashing machine	15-20	60-70	
HOSPITAL EQUIPMENT	40-50		
Stills, per 100 gal distilled water		102	
Sterilizers, bed pan		3	
Sterilizers, dressing, per 10” length, approx.		7	
Sterilizers, instrument, per 100 cu in approx.		3	
Sterilizers, water, per 10 gal, approx.		6	
Disinfecting Ovens, Double Door:	40-50		
Up to 50 cu ft, per 10 cu ft approx.		29	
50 to 100 cu ft, per 10 cu ft approx.		21	
100 and up, per 10 cu ft, approx.		16	

TYPICAL STEAM CONSUMPTION RATES

	Operating pressure PSIG	Lbs per hr	
		In Use	Maximum
HOSPITAL EQUIPMENT (Continued)			
Ovens: Peel or Dutch Type	40		
For bottles or pasteurization		51	69
Start with water at 70 F, maintained for20 minutes at boiling at a depth of 3”			
Instruments and Utensils:	40		
Start with water at 70F, boil vigorously for 20 min:			
Depth 3 1/2”: Size 8 X 9 X 18”		27	27
Depth 3 1/2”: Size 9 X 20 X 10”		30	30
Depth 4”: Size 10 X 12 X 22”		39	39
Depth 4”: Size 12 X 16 X 24”		60	60
Depth 4”: Size 10 X 12 X 36”		66	66
Depth 10”: Size 16 X 15 X 20”		92	92
Depth 10”: Size 20 X 20 X 24”		144	144
LAUNDRY EQUIPMENT	100		
Vacuum stills, per 10 gal		16	
Spotting board, trouser stretcher		29	
Dress finisher, overcoat shaper, each		58	
Jacket finisher, Susie Q, each		44	
Air vacuum finishing board, 18” Mushroom Topper, ea.		20	
Steam irons, each		4	
Flat Iron Workers:	100		
48” X 120”, 1 cylinder		248	
48” X 120”, 2 cylinder		310	
4-Roll, 100 to 120”		217	
6-Roll, 100 to 120”		341	
8-Roll, 100 to 120”		465	
Ship Equipment	100		
Single cuff, neckband, yoke No. 3, each		7	
Double sleeve		13	
Body		29	
Bosom		44	
Dry Rooms	100		
Blanket		20	
Conveyor, per loop, approx.		7	
Truck, per door, approx.		58	
Curtain, 50 X 114		29	
Curtain, 64 X 130		58	
Starch cooker, per 10 gal cap		7	
Starcher, per 10-in. length approx.		5	
Laundry presses, per 10-in. length approx.		7	
Handy irons, per 10-in. length approx.		5	
Collar equipment: Collar and Cuff Ironer		21	
Deodorizer		87	
Wind Whip, Single		58	
Wind Whip, Double		87	
Tumblers, General Usage Other Source	100		
36”, per 10-in. length approx.		29	
40”, per 10-in. length approx.		38	
42”, per 10-in. length approx.		52	
Vorcone, 46” X 120”		310	
Presses, central vacuum, 42”		20	
Presses, steam, 42”		29	

TYPICAL STEAM CONSUMPTION RATES

	Operating pressure PSIG	Lbs per hr	
		In Use	Maximum
PLASTIC MOLDING			
Each 12 to 15 sq ft platen surface	125	29	
PAPER MANUFACTURE			
Corrugators per 1,000 sq ft	175	29	
Wood pulp paper, per 100 lb paper	50	372	
RESTAURANT EQUIPMENT	5-20		
Standard steam tables, per ft. length		36	
Standard steam tables, per 20 sq ft tank		29	
Bain Marie, per ft length, 30” wide		13	
Bain Marie, per 10 sq ft tank		29	
Coffee urns, per 10 gal, cold make-up		13	
3-compartment egg boiler		13	
Oyster steamers		13	
Clam or lobster steamer		29	
Steam Jacketed Kettles	5-20		
10 gal capacity		13	
25 gal stock kettle		29	
40 gal stock kettle		44	
60 gal stock kettle		58	
Plate And Dish Warmers	5-20		
Per 100 sq ft shelf		58	
Per 20 cu ft shelf		29	
Warming ovens, per 20 cu ft		29	
Direct vegetable steamer, per compartment		29	
Potato steamer		29	
Morandi Proctor, 30 comp., no return		87	
Pot sink, steam jets, average use		29	
Silver burnishers, Tahara		58	
SILVER MIRRORING			
Average steam tables	5	102	
TIRE SHOPS	100		
Truck molds, large		87	
Truck molds, medium		58	
Passenger molds		29	
Sections, per section		7	
Puff Irons, each		7	

BtuH Heat Loss Calculating Guide for Approximating Heater Size

Guide intended only for approximating heater size, not to replace a precise heating survey. Table below indicates approximate Btu/hr heat loss per cu. ft. of interior space, at 0°F outdoor temperature. Multiply appropriate BtuH figure from the table by cubic volume of area to be heated to get total heat loss at 0°F. If minimum outdoor temperature expected is higher or lower than 0°F, multiply total BtuH heat loss at 0°F by the correction factor shown at the bottom of the table. Dividing answer (BTU/hr) by latent heat value of steam supplied to heaters will give approximate steam requirement in lbs/hr.

Type of Building	Major Qualifications	Minor Qualifications	Multiply Volume By
FACTORIES and WAREHOUSES, 65°F Inside	One Story	Skylight in Roof No Skylight in Roof	5.8 5.3
	No Skylights	Two Story Three Story Four Story Five Story Six Story	4.3 4.0 3.8 3.6 3.4
PUBLIC GARAGES, 60°F Inside	All Walls Exposed	Skylight in Roof No Skylight in Roof Heated Space Above	5.5 5.1 4.0
	Warm Party Walls on Both Long Sides	Skylight in Roof No Skylight in Roof Heated Space Above	4.7 4.4 3.0
	One Long Warm Party Wall	Skylight in Roof No Skylight in Roof Heated Space Above	5.0 4.9 3.4
STORES, 70°F Inside	All Walls Exposed	Flat Roof Heated Space Above	6.9 5.2
	Warm Party Walls on Both Long Sides	Flat Roof Heated Space Above	5.8 4.1
	One Long Warm Party Wall	Flat Roof Heated Space Above	6.3 4.7

CORRECTION FACTORS	**Min. Design Temperature**	**Correction Factor**	**Min. Design Temperature**	**Correction Factor**	**Min. Design Temperature**	**Correction Factor**
	+50°F	0.29	+20°F	0.72	-10°F	1.14
	+40°F	0.43	+10°F	0.86	-20°F	1.28
	+30°F	0.57	0°F	1.00	-30°F	1.43

Heat Loss From Storage Tanks and Product Correction Factors

Heat loss expressed as U (BTU/hr. sq. F)
$\triangle$T = Product temperature minus air temperature.

Surface Condition	Still Air	10 mph	15 mph	20 mph	25 mph	30 mph
	General Range of $\triangle$ T = 60°F					
Uninsulated	1.8	4.1	4.7	5.2	5.7	6.1
1” Insulation	0.18	0.20	0.20	0.21	0.21	0.21
1 1/2” Insulation	0.13	0.14	0.14	0.14	0.14	0.14
2” Insulation	0.10	0.11	0.11	0.11	0.11	0.11
	General Range of $\triangle$ T = 100°F					
Uninsulated	2.1	4.4	5.1	5.7	6.1	6.5
1” Insulation	0.18	0.20	0.20	0.21	0.21	0.21
1 1/2” Insulation	0.13	0.14	0.14	0.14	0.14	0.14
2” Insulation	0.10	0.11	0.11	0.11	0.11	0.11
	General Range of $\triangle$ T = 200°F					
Uninsulated	2.7	5.1	5.7	6.4	6.8	7.4
1” Insulation	0.19	0.21	0.21	0.22	0.22	0.22
1 1/2” Insulation	0.13	0.15	0.15	0.15	0.15	0.15
2” Insulation	0.11	0.11	0.11	0.11	0.11	0.11

A k value of 0.23 was used in calculating U for insulated tanks.

Calculated from data in Oil and Gas Journal’s “The Refiner’s Notebook,” No. 125, by Prof. W. L. Nelson.

Product correction factors. Apply to uninsulated U values only.

Product	Approximate Product Temp. 75 F	150 F	250 F
Watery solutions	1.00	1.00	1.00
Gasoline, Kerosene, etc.	0.90	0.90	0.90
Light oils	0.80	0.85	0.90
Medium oils	0.70	0.75	0.80
Heavy oils	0.60	0.65	0.70
Asphalts, Tars, etc.	0.50	0.55	0.60
Gases or Vapor spaces	0.50	0.50	0.50

U values as listed for insulated tanks, apply to all products without correction.

ORDINARY RANGES OF U FOR GENERAL SERVICE

Under special conditions higher or lower values may be realized. Overall coefficients U expressed in Btu/(hr)(sq ft)(°F)

Type of Heat Exchanger	State of Controlling Resistance: Free Convection U	State of Controlling Resistance: Forced Convection U	Typical Fluid	Typical Apparatus
Liquid to liquid	25 - 60	25 - 60	Water	Liquid-to-liquid heat exchanger
Liquid to liquid	5 - 10	5 - 10	Oil	
Liquid to gas	1 - 3	1 - 3	....	Hot-water radiators
Liquid to boiling liquid	20 - 60	20 - 60	Water	Brine coolers
Liquid to boiling liquid	5 - 20	5 - 20	Oil	
Gas to liquid	1 - 3	1 - 3	....	Air coolers, economizers
Gas to gas	0.6 - 2	0.6 - 2	....	Steam superheaters
Gas to boiling liquid	1 - 3	1 - 3	....	Steam boilers
Condensing vapor to liquid	50 - 200	50 - 200	Steam to water	Liquid heaters and condensers
Condensing vapor to liquid	10 - 30	10 - 30	Steam to oil	
Condensing vapor to liquid	40 - 80	40 - 80	Organic vapor to water	
Condensing vapor to liquid	----	----	Steam-gas mixture	
Condensing vapor to gas	1 - 3	1 - 3	....	Steam pipes in air, air heaters
Condensing vapor to boiling liquid	40 - 100	40 - 100	....	Scale-forming evaporators
Condensing vapor to boiling liquid	300 - 800	300 - 800	Steam to water	
Condensing vapor to boiling liquid	50 - 150	50 - 150	Steam to oil	
Condensing vapor to boiling liquid	----	----	Steam to organic liquid	Steam jacketed tubes

TEMP. RISE °F	U.S. GALLONS OF WATER HEATED PER HOUR -- FOR FUEL OIL, USE HALF THE LBS. PER HOUR OF STEAM LISTED																	
	25	50	75	100	150	200	300	400	500	750	1000	1500	2000	3000	4000	5000	7500	10000
	POUNDS OF STEAM PER HOUR REQUIRED																	
10						17	25	33	42	63	83	120	167	250	330	420	620	830
20					25	33	50	67	83	125	167	250	330	500	670	830	1250	1670
30				25	37	50	75	100	125	190	250	370	500	750	1000	1250	1900	2500
40			25	33	50	66	100	130	170	250	330	500	660	1000	1300	1700	2500	3300
50		21	31	42	63	84	125	170	210	310	420	630	840	1250	1680	2100	3100	4200
60	12	25	37	50	75	100	150	200	250	370	500	750	1000	1500	2000	2500	3700	5000
80	16	33	50	67	100	130	200	270	330	500	670	1000	1340	2000	2700	3300	5000	6700
100	21	42	63	83	120	170	250	330	420	630	830	1250	1700	2500	3300	4200	6300	8300
120	25	50	75	100	150	200	300	400	500	750	1000	1500	2000	3000	4000	5000	7500	10000
140	29	58	88	117	175	230	350	470	580	880	1170	1750	2340	3500	4700	5800	880	11700
160	33	66	100	133	200	270	400	530	660	1000	1330	2000	2700	4000	5300	6600	1000	13300
180	37	75	113	150	225	300	450	600	750	1125	1500	2200	3050	4500	5950	7500	13000	14950
200	42	84	126	165	250	330	500	660	840	1260	1660	2500	3400	5000	6600	8300	12600	16600

NOTE: For other liquids, use chart value and multiply by specific gravity and then multiply by specific heat for selected liquid.

Correcting for Superheated Steam

Steam flow and condensate amounts are normally calculated assuming saturated steam is used, but if superheated steam is supplied, and the tables are not available, the following correction factors will adjust flow rates calculated using standard formulae:

W = N x Fs

W = flow in pounds per hour of superheated steam
N = saturated steam flow from calculations using latent heat (hfg) of saturated steam at known pressure
Fs = superheat factor

Superheat Factor

“Fs” = 50°F Superheat — .96
100°F Superheat — .94
150°F Superheat — .90
200°F Superheat — .87
250°F Superheat — .84

TABLE I

FLASH TANK AREA IN SQ. FT. = DIAMETER X LENGTH OF HORIZONTAL TANK FOR 1000 LBS. CONDENSATE PER HOUR BEING DISCHARGED

Steam Pressure PSIG	Flash Tank Pressure PSIG										
	0	2	5	10	15	20	30	40	60	80	100
400	5.41	4.70	3.89	3.01	2.44	2.03	1.49	1.15	.77	.56	.42
350	5.14	4.45	3.66	2.84	2.28	1.91	1.38	1.07	.70	.51	.37
300	4.86	4.15	3.42	2.62	2.11	1.75	1.26	.96	.62	.44	.31
250	4.41	3.82	3.12	2.39	1.91	1.56	1.11	.85	.52	.37	.25
200	3.98	3.40	2.80	2.12	1.68	1.37	.97	.72	.43	.28	.18
175	3.75	3.20	2.61	1.95	1.57	1.26	.87	.64	.38	.23	.15
160	3.60	3.08	2.50	1.86	1.46	1.19	.80	.59	.34	.21	.12
150	3.48	2.98	2.41	1.80	1.40	1.14	.77	.56	.31	.19	.10
140	3.36	2.86	2.31	1.72	1.35	1.08	.72	.52	.29	.16	.08
130	3.24	2.76	2.23	1.65	1.29	1.02	.67	.49	.26	.14	.07
120	3.12	2.65	2.15	1.57	1.22	.97	.64	.44	.23	.12	.04
110	2.99	2.52	2.05	1.50	1.15	.91	.58	.40	.20	.09	.02
100	2.85	2.41	1.92	1.40	1.07	.85	.53	.36	.16	.06	
90	2.68	2.26	1.81	1.30	.99	.77	.48	.31	.13	.05	
80	2.52	2.12	1.67	1.18	.90	.68	.42	.25	.09		
70	2.34	1.95	1.55	1.08	.81	.61	.35	.20	.04		
60	2.14	1.77	1.39	.96	.70	.52	.27	.14			
50	1.94	1.59	1.22	.81	.58	.41	.20	.08			
40	1.68	1.36	1.02	.67	.44	.30	.11				
30	1.40	1.10	.81	.50	.29	.16					
20	1.06	.81	.55	.28	.12						
12	.75	.48	.28								
10	.62	.42	.23								

TABLE II

VENT LINE SIZE FOR HORIZONTAL FLASH TANKS

Area in Sq. Ft.*	Vent Pipe Size
Less than 3.2	1”
3.2 to 5.5	1 1/4”
5.5 to 7.4	1 1/2
7.4 to 12.0	2”
12.0 to 17.5	2 1/2”
17.5 to 27	3”
27 to 36	3 1/2”
36 to 47	4”
47 to 73	5”
73 to 106	6”
106 to 140	7”
140 to 185	8”
185 to 300	10”
300 to 420	12”

***Area in sq. ft. equals diameter of tank in feet multiplied by length of tank in feet.**

TABLE III

PERCENT FLASH

Steam Pressure PSIG	Flash Tank Pressure										
	0	2	5	10	15	20	30	40	60	80	100
5	1.7	1.0	0								
10	2.9	2.2	1.4	0							
15	4.0	3.2	2.4	1.1	0						
20	4.9	4.2	3.4	2.1	1.1	0					
30	6.5	5.8	5.0	3.8	2.6	1.7	0				
40	7.8	7.1	6.4	5.1	4.0	3.1	1.3	0			
60	10.0	9.3	8.6	7.3	6.3	5.4	3.6	2.2	0		
80	11.7	11.1	10.3	9.0	8.1	7.1	5.5	4.0	1.9	0	
100	13.3	12.6	11.8	10.6	9.7	8.8	7.0	5.7	3.5	1.7	0
125	14.8	14.2	13.4	12.2	11.3	10.3	8.6	7.4	5.2	3.4	1.8
160	16.8	16.2	15.4	14.1	13.2	12.4	10.6	9.5	7.4	5.6	4.0
200	18.6	18.0	17.3	16.1	15.2	14.3	12.8	11.5	9.3	7.5	5.9
250	20.6	20.0	19.3	18.1	17.2	16.3	14.7	13.6	11.2	9.8	8.2
300	22.7	21.8	21.1	19.9	19.0	18.2	16.7	15.4	13.4	11.8	10.1
350	24.	23.3	22.6	21.6	20.5	19.8	18.3	17.2	15.1	13.5	11.9
400	25.3	24.7	24.0	22.9	22.0	21.1	19.7	18.5	16.5	15.0	13.4

Percent flash for various initial steam pressures and flash tank pressures.

Flash Steam Systems

Condensate discharging from a high pressure to a lower pressure results in the production of "flash steam." This flash steam must be separated from the condensate in order to be able to pump the condensate back to a receiver or the boiler. In order to do this, condensate is discharged into what is called a flash tank. The dimensions of this tank are such that an adequate surface area of exposed condensate is provided so that the flash steam separates from the condensate, without carryover of water droplets.

The flash steam can either be vented to atmosphere or piped into a low pressure steam system. This would provide usable heat to a system requiring low quality steam for applications such as building heat or tracing.

To find the correct square feet of area, which must be provided as a water surface, enter Table 1 at the pressure of the condensate through the steam traps. Move horizontally to the pressure desired at the flash tank or in the system (vented will be 0 psig). Read required square feet needed for each 1000 lbs/hr of condensate flow. Figure total condensate load, divide by 1000 and multiply figure found in chart by result. Answer will be total area of condensate to expose. For a horizontal tank, the answer equals diameter times length.

Based on total area answer found above, read from Table 2 the vent size required necessary to handle the flash steam flow to atmosphere.

If flash steam is going to a steam system, size piping according to standard practice for flow and velocities expected.

Table 3 provides a quick method for determining the percentage of flash steam produced or available from condensate discharge. Enter chart on vertical line at condensate and steam pressure before the steam trap, and move horizontally to the column with the correct flash tank pressure for your application. Read the percentage of flash steam produced at the junction of the two scales.

Steam Loss Table

STEAM LOSS THROUGH ORIFICES DISCHARGING TO ATMOSPHERE

Orifice Diameter	Steam Loss, lb/hr, when steam gauge pressure (psig) is:												
	2	5	10	15	25	50	75	100	125	150	200	250	300
1/32	0.31	0.49	0.70	0.85	1.14	1.86	2.58	3.3	4.02	4.74	6.17	7.61	9.16
1/16	1.25	1.97	2.8	3.4	4.6	7.4	10.3	13.2	16.1	18.9	24.7	30.4	36.2
3/32	2.81	4.44	6.3	7.7	10.3	16.7	23.2	29.7	36.2	42.6	55.6	68.5	81.5
1/8	4.5	7.9	11.2	13.7	18.3	29.8	41.3	52.8	64.3	75.8	99.0	122.0	145.0
5/32	7.8	12.3	17.4	21.3	28.5	46.5	64.5	82.5	100.0	118.0	154.0	190.0	226.0
3/16	11.2	17.7	25.1	30.7	41.1	67.0	93.0	119.0	145.0	170.0	222.0	274.0	326.0
7/32	15.3	24.2	34.2	41.9	55.9	91.2	126.0	162.0	197.0	232.0	303.0	373.0	443.0
1/4	20.0	31.6	44.6	54.7	73.1	119	165	211	257	303	395	487	579
9/32	25.2	39.9	56.5	69.2	92.5	151	209	267	325	384	500	617	733
5/16	31.2	49.3	69.7	85.4	114	186	258	330	402	474	617	761	905
11/32	37.7	59.6	84.4	103	138	225	312	399	486	573	747	921	1095
3/8	44.9	71	100	123	164	268	371	475	578	682	889	1096	1301
13/32	52.7	83.3	118	144	193	314	436	557	679	800	1043	1286	1529
7/16	61.1	96.6	137	167	224	365	506	647	787	928	1210	1492	1774
15/32	70.2	111	157	192	257	419.8	580	742	904	1065	1389	1713	2037
1/2	79.8	126	179	219	292	476	660	844	1028	1212	1580	1949	2317

For Example:

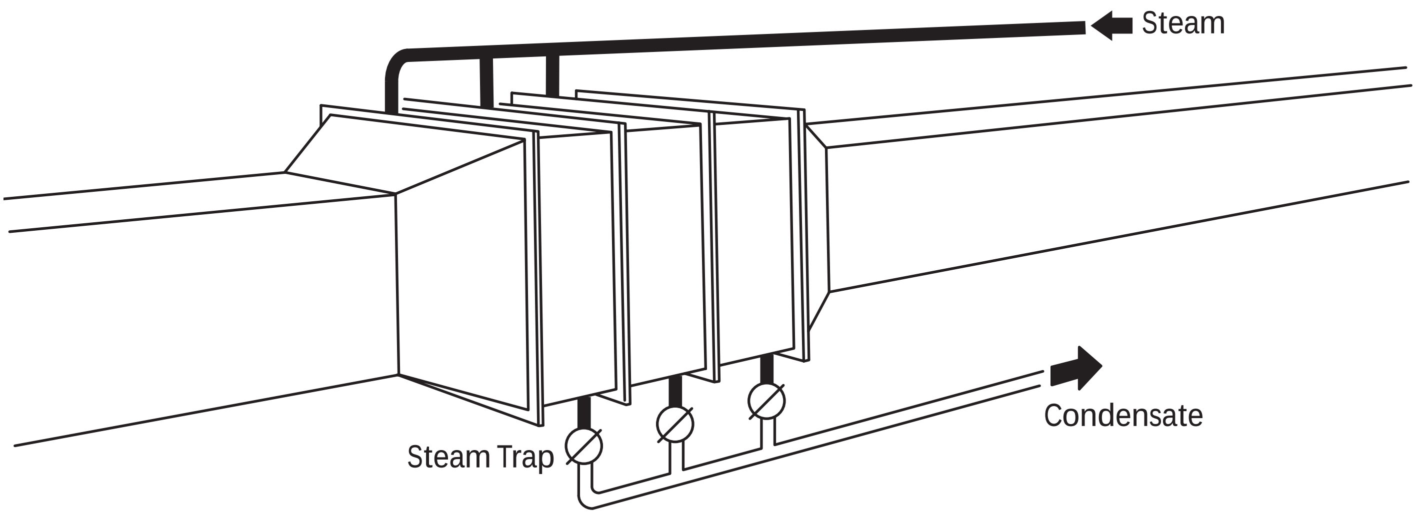
Diameter of Leak:____________ Steam Loss/hr (from chart):_______________

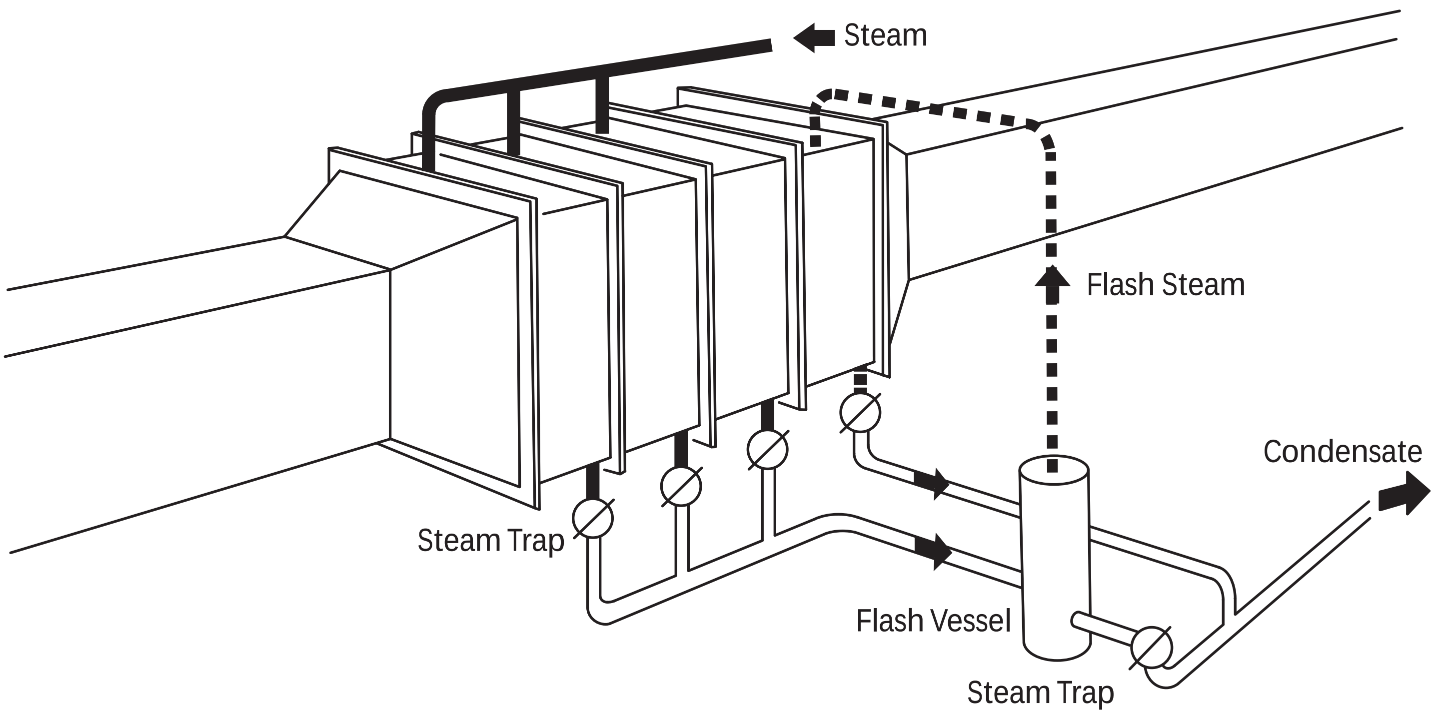
Pressure:___________ lbs Steam Loss/Day (24 hrs. x lbs/hr):_________lbs/da

Steam Cost/1000 lbs.: $_______ Steam Cost/lb
(Steam Cost/1000 lbs. x .001): $_______/year

_________X ___________ = $ ___________ /day x 365 days/yr = $_________ /year

If you had a steam leak 1/16” Dia. at 75 psi, checking the chart, you are losing 10.3 lbs/hr X 24 hrs/day = 247.2 lbs/day. For this calculation, steam costs are $3.50/1000 lbs or $0.0035/lb. Therefore, 247.2 lbs/day X $0.0035/lb = $0.87/day. For a yearly figure, $0.87/day X 365 days/year = $317.55/year.


Steam
Condensate
Steam Trap


Steam
Flash Steam
Condensate
Steam Trap
Flash Vessel
Steam Trap

TABLES

TABLE I. THE PROPERTIES OF SATURATED STEAM AND WATER*

PRESSURE		TEMPERATURE °F	HEAT BTU/LB.				VOLUME CU. FT./LB.		ENTROPY BTU/°F.ABS./LB.		
VAC IN. HG.	PSI ABS.		SENSIBLE	LATENT	TOTAL	GIBBS	LIQUID	VAPOUR	LIQUID	EVAP.	TOTAL
29 • 5	• 245	58 • 8	26 • 8	1060 • 5	1087 • 3	0 • 6	• 0160	1257	• 053	2 • 045	2 • 098
29 • 25	• 367	70 • 2	38 • 3	1053 • 8	1092 • 1	1 • 3	• 0161	860	• 075	1 • 989	2 • 064
29	• 490	78 • 9	47 • 0	1049 • 2	1096 • 1	2 • 0	• 0161	656	• 091	1 • 948	2 • 039
28 • 75	• 612	85 • 8	53 • 8	1045 • 2	1099 • 0	2 • 7	• 0161	532	• 104	1 • 916	2 • 020
28 • 5	• 735	91 • 6	59 • 6	1041 • 9	1101 • 5	3 • 4	• 0161	447	• 114	1 • 890	2 • 004
28 • 25	• 857	96 • 6	64 • 6	1039 • 3	1103 • 9	4 • 0	• 0161	387	• 123	1 • 868	1 • 991
28	• 979	101 • 0	69 • 0	1036 • 7	1105 • 7	4 • 6	• 0161	341	• 131	1 • 849	1 • 980
27 • 75	1 • 102	105 • 0	72 • 9	1034 • 6	1107 • 5	5 • 1	• 0162	305	• 138	1 • 832	1 • 970
27 • 5	1 • 224	108 • 6	76 • 6	1032 • 4	1109 • 0	5 • 6	• 0162	276	• 145	1 • 816	1 • 961
27 • 25	1 • 347	111 • 8	79 • 6	1030 • 6	1110 • 5	6 • 1	• 0162	252	• 150	1 • 803	1 • 953
27	1 • 469	114 • 9	82 • 9	1028 • 9	1111 • 8	6 • 6	• 0162	233	• 156	1 • 790	1 • 946
26 • 5	1 • 714	120 • 5	88 • 4	1025 • 7	1114 • 1	7 • 5	• 0162	201	• 165	1 • 768	1 • 933
26	1 • 958	125 • 3	93 • 2	1022 • 8	1116 • 0	8 • 3	• 0162	177	• 174	1 • 748	1 • 922
25 • 5	2 • 203	129 • 7	97 • 6	1020 • 3	1117 • 9	9 • 0	• 0163	159	• 181	1 • 732	1 • 913
25	2 • 448	133 • 6	101 • 5	1018 • 1	1119 • 6	9 • 8	• 0163	144	• 188	1 • 716	1 • 904
24 • 5	2 • 693	137 • 3	105 • 2	1015 • 9	1121 • 1	10 • 5	• 0163	132	• 194	1 • 702	1 • 896
24	2 • 938	140 • 7	108 • 7	1013 • 9	1122 • 6	11 • 2	• 0163	121	• 200	1 • 689	1 • 889
23 • 5	3 • 183	143 • 8	111 • 8	1012 • 1	1123 • 9	11 • 9	• 0163	112	• 205	1 • 677	1 • 882
23	3 • 428	146 • 8	114 • 7	1010 • 3	1125 • 0	12 • 5	• 0163	105	• 210	1 • 666	1 • 876
22 • 5	3 • 672	149 • 5	117 • 4	1008 • 8	1126 • 2	13 • 1	• 0163	98 • 4	• 214	1 • 657	1 • 871
22	3 • 917	152 • 1	120 • 0	1007 • 2	1127 • 2	13 • 7	• 0164	92 • 6	• 218	1 • 647	1 • 865
21 • 5	4 • 162	154 • 6	122 • 5	1005 • 8	1128 • 3	14 • 2	• 0164	87 • 5	• 222	1 • 638	1 • 860
21	4 • 407	157 • 0	124 • 9	1004 • 2	1129 • 1	14 • 7	• 0164	82 • 9	• 226	1 • 629	1 • 855
20	4 • 896	161 • 4	129 • 3	1001 • 7	1131 • 0	15 • 8	• 0164	75 • 1	• 233	1 • 614	1 • 847
19	5 • 386	165 • 4	133 • 3	999 • 4	1132 • 7	16 • 8	• 0164	68 • 7	• 240	1 • 599	1 • 839
18	5 • 876	169 • 2	137 • 1	997 • 1	1134 • 2	17 • 7	• 0164	63 • 3	• 246	1 • 586	1 • 832
17	6 • 365	172 • 7	140 • 6	995 • 0	1135 • 6	18 • 5	• 0165	58 • 8	• 252	1 • 573	1 • 825
16	6 • 855	175 • 9	143 • 8	993 • 1	1136 • 9	19 • 3	• 0165	54 • 8	• 257	1 • 562	1 • 819
15	7 • 344	178 • 9	146 • 8	991 • 3	1138 • 1	20 • 0	• 0165	51 • 4	• 261	1 • 552	1 • 813
14	7 • 834	181 • 9	149 • 8	989 • 4	1139 • 2	20 • 8	• 0165	48 • 4	• 266	1 • 542	1 • 808
13	8 • 324	184 • 7	152 • 7	987 • 7	1140 • 4	21 • 6	• 0165	45 • 7	• 270	1 • 533	1 • 803
12	8 • 813	187 • 3	155 • 3	986 • 1	1141 • 4	22 • 3	• 0166	43 • 3	• 274	1 • 524	1 • 798
11	9 • 303	189 • 8	157 • 8	984 • 7	1142 • 5	23 • 0	• 0166	41 • 2	• 278	1 • 516	1 • 794
10	9 • 793	192 • 2	160 • 2	983 • 2	1143 • 4	23 • 7	• 0166	39 • 2	• 282	1 • 508	1 • 790
9	10 • 28	194 • 5	162 • 5	981 • 8	1144 • 3	24 • 3	• 0166	37 • 5	• 286	1 • 500	1 • 786
8	10 • 77	196 • 8	164 • 8	980 • 4	1145 • 2	25 • 0	• 0166	35 • 9	• 289	1 • 493	1 • 782
7	11 • 26	198 • 9	167 • 0	979 • 1	1146 • 1	25 • 6	• 0166	34 • 4	• 292	1 • 487	1 • 779
6	11 • 75	201 • 0	169 • 1	977 • 7	1146 • 8	26 • 2	• 0166	33 • 1	• 295	1 • 480	1 • 775
5	12 • 24	203 • 0	171 • 0	976 • 5	1147 • 5	26 • 8	• 0167	31 • 9	• 298	1 • 474	1 • 772
4	12 • 73	204 • 9	172 • 9	975 • 3	1148 • 2	27 • 4	• 0167	30 • 7	• 301	1 • 468	1 • 769
3	13 • 22	206 • 8	174 • 8	974 • 0	1148 • 8	27 • 9	• 0167	29 • 7	• 304	1 • 462	1 • 766
2	13 • 71	208 • 6	176 • 6	972 • 9	1149 • 5	28 • 5	• 0167	28 • 7	• 307	1 • 456	1 • 763
1	14 • 20	210 • 3	178 • 4	971 • 7	1150 • 1	29 • 0	• 0167	27 • 7	• 310	1 • 450	1 • 760

**The Tables giving the properties of saturated steam and water and the properties of superheated steam are based on the values given in the 1939 Callendar Steam Tables by permission of Messrs. Edward Arnold and Co.*

TABLE I. THE PROPERTIES OF SATURATED STEAM AND WATER *CONTINUED*

PRESSURE		TEMPER-ATURE °F	HEAT BTU/LB.				VOLUME CU. FT./LB.		ENTROPY BTU/°F.ABS./LB.		
PSI GAUGE	PSI ABS.		SENSIBLE	LATENT	TOTAL	GIBBS	LIQUID	VAPOUR	LIQUID	EVAP.	TOTAL
0	14 • 69	212	180 • 2	970 • 6	1150 • 8	29 • 9	• 0167	26 • 8	• 312	1 • 445	1 • 757
1	15 • 7	215 • 4	183 • 6	968 • 4	1152 • 0	31 • 0	• 0167	25 • 2	• 317	1 • 435	1 • 752
2	16 • 7	218 • 5	186 • 8	966 • 4	1153 • 2	32 • 1	• 0168	23 • 8	• 322	1 • 425	1 • 747
3	17 • 7	221 • 5	189 • 8	964 • 5	1154 • 3	33 • 0	• 0168	22 • 5	• 326	1 • 416	1 • 742
4	18 • 7	224 • 5	192 • 7	962 • 6	1155 • 3	34 • 0	• 0168	21 • 4	• 331	1 • 407	1 • 738
5	19 • 7	227 • 4	195 • 5	960 • 8	1156 • 3	34 • 9	• 0168	20 • 4	• 335	1 • 399	1 • 734
6	20 • 7	230 • 0	198 • 1	959 • 2	1157 • 3	35 • 8	• 0168	19 • 4	• 339	1 • 391	1 • 730
7	21 • 7	232 • 4	200 • 6	957 • 6	1158 • 2	36 • 7	• 0169	18 • 6	• 342	1 • 384	1 • 726
8	22 • 7	234 • 8	203 • 1	956 • 0	1159 • 1	37 • 5	• 0169	17 • 9	• 346	1 • 376	1 • 722
9	23 • 7	237 • 1	205 • 5	954 • 5	1160 • 0	38 • 3	• 0169	17 • 2	• 349	1 • 370	1 • 719
10	24 • 7	239 • 4	207 • 9	952 • 9	1160 • 8	39 • 1	• 0169	16 • 5	• 352	1 • 363	1 • 716
11	25 • 7	241 • 6	210 • 1	951 • 5	1161 • 6	39 • 8	• 0169	15 • 9	• 356	1 • 356	1 • 712
12	26 • 7	243 • 7	212 • 3	950 • 1	1162 • 3	40 • 6	• 0170	15 • 3	• 359	1 • 350	1 • 709
13	27 • 7	245 • 8	214 • 4	948 • 6	1163 • 0	41 • 3	• 0170	14 • 8	• 362	1 • 344	1 • 706
14	28 • 7	247 • 9	216 • 4	947 • 3	1163 • 7	42 • 0	• 0170	14 • 3	• 365	1 • 338	1 • 703
15	29 • 7	249 • 8	218 • 4	946 • 0	1164 • 4	42 • 7	• 0170	13 • 9	• 367	1 • 333	1 • 700
16	30 • 7	251 • 7	220 • 3	944 • 8	1165 • 1	43 • 4	• 0170	13 • 4	• 370	1 • 328	1 • 698
17	31 • 7	253 • 6	222 • 2	943 • 5	1165 • 7	44 • 1	• 0170	13 • 0	• 373	1 • 323	1 • 696
18	32 • 7	255 • 4	224 • 0	942 • 4	1166 • 4	44 • 8	• 0170	12 • 7	• 375	1 • 318	1 • 693
19	33 • 7	257 • 2	225 • 8	941 • 2	1167 • 0	45 • 4	• 0171	12 • 3	• 378	1 • 313	1 • 691
20	34 • 7	258 • 8	227 • 5	940 • 1	1167 • 6	46 • 1	• 0171	12 • 0	• 380	1 • 308	1 • 688
21	35 • 7	260 • 5	229 • 2	939 • 0	1168 • 2	46 • 8	• 0171	11 • 7	• 382	1 • 304	1 • 686
22	36 • 7	262 • 3	230 • 9	937 • 8	1168 • 7	47 • 4	• 0171	11 • 4	• 385	1 • 299	1 • 684
23	37 • 7	263 • 7	232 • 6	936 • 7	1169 • 3	48 • 1	• 0171	11 • 1	• 387	1 • 295	1 • 682
24	38 • 7	265 • 3	234 • 2	935 • 8	1169 • 8	48 • 7	• 0171	10 • 8	• 389	1 • 291	1 • 680
25	39 • 7	266 • 8	235 • 8	934 • 6	1170 • 4	49 • 3	• 0171	10 • 6	• 391	1 • 287	1 • 678
26	40 • 7	268 • 3	237 • 3	933 • 5	1170 • 8	49 • 8	• 0172	10 • 3	• 393	1 • 283	1 • 676
27	41 • 7	269 • 8	238 • 7	932 • 6	1171 • 3	50 • 3	• 0172	10 • 1	• 395	1 • 279	1 • 674
28	42 • 7	271 • 4	240 • 2	931 • 6	1171 • 8	50 • 8	• 0172	9 • 87	• 397	1 • 275	1 • 672
29	43 • 7	272 • 6	241 • 6	930 • 6	1172 • 2	51 • 3	• 0172	9 • 66	• 399	1 • 271	1 • 670
30	44 • 7	274 • 0	243 • 0	929 • 7	1172 • 7	51 • 8	• 0172	9 • 46	• 401	1 • 267	1 • 668
31	45 • 7	275 • 4	244 • 4	928 • 7	1173 • 1	52 • 3	• 0172	9 • 27	• 403	1 • 263	1 • 666
32	46 • 7	276 • 7	245 • 9	927 • 6	1173 • 5	52 • 8	• 0172	9 • 08	• 405	1 • 260	1 • 665
33	47 • 7	278 • 1	247 • 2	926 • 7	1173 • 9	53 • 3	• 0172	8 • 90	• 407	1 • 256	1 • 663
34	48 • 7	279 • 4	248 • 5	925 • 8	1174 • 3	53 • 8	• 0173	8 • 73	• 409	1 • 252	1 • 661
35	49 • 7	280 • 7	249 • 8	924 • 9	1174 • 7	54 • 3	• 0173	8 • 56	• 410	1 • 249	1 • 659
36	50 • 7	281 • 9	251 • 1	924 • 0	1175 • 1	54 • 8	• 0173	8 • 40	• 412	1 • 246	1 • 658
37	51 • 7	283 • 2	252 • 4	923 • 1	1175 • 5	55 • 3	• 0173	8 • 25	• 414	1 • 242	1 • 656
38	52 • 7	284 • 4	253 • 7	922 • 1	1175 • 8	55 • 8	• 0173	8 • 11	• 416	1 • 239	1 • 655
39	53 • 7	285 • 6	254 • 9	921 • 3	1176 • 2	56 • 4	• 0173	7 • 97	• 417	1 • 236	1 • 653
40	54 • 7	286 • 7	256 • 1	920 • 4	1176 • 5	56 • 9	• 0173	7 • 83	• 419	1 • 233	1 • 652
41	55 • 7	287 • 9	257 • 3	919 • 5	1176 • 8	57 • 4	• 0173	7 • 70	• 420	1 • 230	1 • 650
42	56 • 7	289 • 0	258 • 5	918 • 6	1177 • 1	57 • 9	• 0174	7 • 57	• 422	1 • 227	1 • 649
43	57 • 7	290 • 1	259 • 6	917 • 9	1177 • 5	58 • 4	• 0174	7 • 45	• 424	1 • 224	1 • 648
44	58 • 7	291 • 3	260 • 8	917 • 0	1177 • 8	58 • 9	• 0174	7 • 33	• 425	1 • 221	1 • 646
45	59 • 7	292 • 4	261 • 9	916 • 2	1178 • 1	59 • 3	• 0174	7 • 22	• 427	1 • 218	1 • 645
46	60 • 7	293 • 5	263 • 0	915 • 4	1178 • 4	59 • 8	• 0174	7 • 10	• 428	1 • 216	1 • 644
47	61 • 7	294 • 5	264 • 1	914 • 6	1178 • 7	60 • 4	• 0174	6 • 99	• 430	1 • 212	1 • 642
48	62 • 7	295 • 6	265 • 2	913 • 8	1179 • 0	60 • 9	• 0174	6 • 89	• 431	1 • 210	1 • 641
49	63 • 7	296 • 6	266 • 3	913 • 0	1179 • 3	61 • 4	• 0174	6 • 78	• 433	1 • 207	1 • 640
50	64 • 7	297 • 7	267 • 4	912 • 2	1179 • 6	61 • 9	• 0174	6 • 68	• 434	1 • 204	1 • 638
51	65 • 7	298 • 7	268 • 4	911 • 5	1179 • 9	62 • 4	• 0174	6 • 59	• 435	1 • 202	1 • 637
52	66 • 7	299 • 7	269 • 4	910 • 7	1180 • 1	62 • 9	• 0175	6 • 50	• 437	1 • 199	1 • 636
53	67 • 7	300 • 7	270 • 4	910 • 0	1180 • 4	63 • 4	• 0175	6 • 41	• 438	1 • 197	1 • 635
54	68 • 7	301 • 7	271 • 5	909 • 2	1180 • 7	63 • 8	• 0175	6 • 32	• 439	1 • 195	1 • 634
55	69 • 7	302 • 7	272 • 5	908 • 5	1181 • 0	64 • 2	• 0175	6 • 24	• 441	1 • 192	1 • 633

TABLES

TABLE I. THE PROPERTIES OF SATURATED STEAM AND WATER *CONTINUED*

PRESSURE		TEMPER-ATURE °F	HEAT BTU/LB.				VOLUME CU. FT./LB.		ENTROPY BTU/°F.ABS./LB.		
PSI GAUGE	PSI ABS.		SENSIBLE	LATENT	TOTAL	GIBBS	LIQUID	VAPOUR	LIQUID	EVAP.	TOTAL
56	70 • 7	303 • 6	273 • 5	907 • 8	1181 • 3	64 • 6	• 0175	6 • 16	• 442	1 • 189	1 • 631
57	71 • 7	304 • 6	274 • 4	907 • 2	1181 • 6	65 • 0	• 0175	6 • 08	• 443	1 • 187	1 • 630
58	72 • 7	305 • 5	275 • 3	906 • 5	1181 • 8	65 • 4	• 0175	6 • 00	• 444	1 • 185	1 • 629
59	73 • 7	306 • 5	276 • 2	905 • 9	1182 • 1	65 • 8	• 0175	5 • 92	• 446	1 • 182	1 • 628
60	74 • 7	307 • 4	277 • 1	905 • 3	1182 • 4	66 • 2	• 0175	5 • 84	• 447	1 • 180	1 • 627
61	75 • 7	308 • 3	278 • 0	904 • 7	1182 • 7	66 • 6	• 0176	5 • 77	• 448	1 • 178	1 • 626
62	76 • 7	309 • 2	279 • 0	904 • 0	1183 • 0	67 • 0	• 0176	5 • 70	• 449	1 • 176	1 • 625
63	77 • 7	310 • 0	280 • 0	903 • 2	1183 • 2	67 • 4	• 0176	5 • 63	• 451	1 • 173	1 • 624
64	78 • 7	310 • 9	280 • 9	902 • 6	1183 • 5	67 • 7	• 0176	5 • 56	• 452	1 • 171	1 • 623
65	79 • 7	311 • 8	281 • 8	901 • 9	1183 • 7	68 • 1	• 0176	5 • 50	• 453	1 • 169	1 • 622
66	80 • 7	312 • 7	282 • 8	901 • 2	1184 • 0	68 • 4	• 0176	5 • 43	• 454	1 • 167	1 • 621
67	81 • 7	313 • 5	283 • 7	900 • 5	1184 • 2	68 • 8	• 0176	5 • 37	• 455	1 • 165	1 • 620
68	82 • 7	314 • 3	284 • 5	900 • 0	1184 • 5	69 • 1	• 0176	5 • 31	• 456	1 • 163	1 • 619
69	83 • 7	315 • 2	285 • 3	899 • 4	1184 • 7	69 • 5	• 0176	5 • 25	• 458	1 • 160	1 • 618
70	84 • 7	316 • 0	286 • 2	898 • 8	1185 • 0	69 • 8	• 0176	5 • 19	• 459	1 • 158	1 • 617
71	85 • 7	316 • 9	287 • 2	898 • 0	1185 • 2	70 • 1	• 0176	5 • 13	• 460	1 • 156	1 • 616
72	86 • 7	317 • 7	288 • 0	897 • 5	1185 • 5	70 • 5	• 0176	5 • 08	• 461	1 • 154	1 • 615
73	87 • 7	318 • 5	288 • 7	897 • 0	1185 • 7	70 • 8	• 0177	5 • 02	• 462	1 • 152	1 • 614
74	88 • 7	319 • 3	289 • 4	896 • 5	1185 • 9	71 • 2	• 0177	4 • 97	• 463	1 • 150	1 • 613
75	89 • 7	320 • 1	290 • 3	895 • 8	1186 • 1	71 • 5	• 0177	4 • 92	• 464	1 • 148	1 • 612
76	90 • 7	320 • 9	291 • 2	895 • 1	1186 • 3	71 • 9	• 0177	4 • 87	• 465	1 • 146	1 • 611
77	91 • 7	321 • 7	292 • 0	894 • 5	1186 • 5	72 • 2	• 0177	4 • 82	• 466	1 • 145	1 • 611
78	92 • 7	322 • 4	292 • 9	893 • 9	1186 • 8	72 • 5	• 0177	4 • 77	• 467	1 • 143	1 • 610
79	93 • 7	323 • 2	293 • 7	893 • 3	1187 • 0	72 • 8	• 0177	4 • 72	• 468	1 • 141	1 • 609
80	94 • 7	323 • 9	294 • 5	892 • 7	1187 • 2	73 • 1	• 0177	4 • 67	• 469	1 • 139	1 • 608
81	95 • 7	324 • 7	295 • 3	892 • 1	1187 • 4	73 • 4	• 0177	4 • 63	• 470	1 • 137	1 • 607
82	96 • 7	325 • 5	296 • 1	891 • 5	1187 • 6	73 • 8	• 0177	4 • 58	• 471	1 • 135	1 • 606
83	97 • 7	326 • 2	296 • 8	890 • 9	1187 • 7	74 • 1	• 0177	4 • 53	• 472	1 • 133	1 • 605
84	98 • 7	326 • 9	297 • 6	890 • 3	1187 • 9	74 • 5	• 0177	4 • 49	• 473	1 • 132	1 • 605
85	99 • 7	327 • 7	298 • 3	889 • 8	1188 • 1	74 • 8	• 0177	4 • 45	• 474	1 • 130	1 • 604
86	100 • 7	328 • 4	299 • 1	889 • 2	1188 • 3	75 • 1	• 0178	4 • 41	• 475	1 • 128	1 • 603
87	101 • 7	329 • 1	299 • 8	888 • 7	1188 • 5	75 • 5	• 0178	4 • 37	• 476	1 • 126	1 • 602
88	102 • 7	329 • 9	300 • 6	888 • 1	1188 • 7	75 • 8	• 0178	4 • 33	• 477	1 • 124	1 • 601
89	103 • 7	330 • 5	301 • 3	887 • 5	1188 • 8	76 • 2	• 0178	4 • 29	• 478	1 • 123	1 • 601
90	104 • 7	331 • 2	302 • 1	887 • 0	1189 • 1	76 • 5	• 0178	4 • 25	• 479	1 • 121	1 • 600
91	105 • 7	331 • 9	302 • 8	886 • 4	1189 • 2	76 • 9	• 0178	4 • 21	• 480	1 • 119	1 • 599
92	106 • 7	332 • 6	303 • 5	885 • 8	1189 • 3	77 • 2	• 0178	4 • 17	• 480	1 • 118	1 • 598
93	107 • 7	333 • 3	304 • 2	885 • 3	1189 • 5	77 • 6	• 0178	4 • 14	• 481	1 • 117	1 • 598
94	108 • 7	333 • 9	304 • 9	884 • 8	1189 • 7	77 • 9	• 0178	4 • 10	• 482	1 • 115	1 • 597
95	109 • 7	334 • 6	305 • 6	884 • 2	1189 • 8	78 • 2	• 0178	4 • 07	• 483	1 • 113	1 • 596
96	110 • 7	335 • 3	306 • 3	883 • 7	1190 • 0	78 • 6	• 0178	4 • 03	• 484	1 • 111	1 • 595
97	111 • 7	335 • 9	307 • 0	883 • 2	1190 • 2	78 • 9	• 0178	4 • 00	• 485	1 • 110	1 • 595
98	112 • 7	336 • 6	307 • 7	882 • 6	1190 • 3	79 • 3	• 0178	3 • 96	• 486	1 • 108	1 • 594
99	113 • 7	337 • 3	308 • 3	882 • 2	1190 • 5	79 • 6	• 0178	3 • 93	• 486	1 • 107	1 • 593
100	114 • 7	337 • 9	309 • 0	881 • 6	1190 • 6	79 • 9	• 0178	3 • 90	• 487	1 • 105	1 • 592
102	116 • 7	339 • 2	310 • 3	880 • 6	1190 • 9	80 • 5	• 0178	3 • 83	• 489	1 • 102	1 • 591
104	118 • 7	340 • 5	311 • 6	879 • 6	1191 • 2	81 • 2	• 0179	3 • 77	• 491	1 • 099	1 • 590
106	120 • 7	341 • 7	313 • 0	878 • 5	1191 • 5	81 • 8	• 0179	3 • 71	• 492	1 • 096	1 • 588
108	122 • 7	343 • 0	314 • 3	877 • 5	1191 • 8	82 • 4	• 0179	3 • 65	• 494	1 • 093	1 • 587
110	124 • 7	344 • 2	315 • 5	876 • 5	1192 • 0	83 • 0	• 0179	3 • 60	• 495	1 • 091	1 • 586
112	126 • 7	345 • 4	316 • 8	875 • 5	1192 • 3	83 • 6	• 0179	3 • 54	• 497	1 • 087	1 • 584
114	128 • 7	346 • 5	318 • 0	874 • 5	1192 • 5	84 • 2	• 0179	3 • 49	• 499	1 • 084	1 • 583
116	130 • 7	347 • 7	319 • 3	873 • 5	1192 • 8	84 • 8	• 0179	3 • 44	• 500	1 • 082	1 • 582
118	132 • 7	348 • 9	320 • 5	872 • 5	1193 • 0	85 • 4	• 0180	3 • 39	• 502	1 • 079	1 • 581
120	134 • 7	350 • 1	321 • 8	871 • 5	1193 • 3	86 • 0	• 0180	3 • 34	• 503	1 • 076	1 • 579
122	136 • 7	351 • 2	322 • 9	870 • 8	1193 • 6	86 • 6	• 0180	3 • 30	• 505	1 • 073	1 • 578
124	138 • 7	352 • 3	324 • 1	869 • 8	1193 • 9	87 • 2	• 0180	3 • 25	• 506	1 • 071	1 • 577
126	140 • 7	353 • 4	325 • 2	868 • 9	1194 • 1	87 • 7	• 0180	3 • 21	• 508	1 • 068	1 • 576
128	142 • 7	354 • 5	326 • 4	867 • 9	1194 • 3	88 • 3	• 0180	3 • 16	• 509	1 • 066	1 • 575
130	144 • 7	355 • 6	327 • 6	866 • 9	1194 • 5	88 • 9	• 0180	3 • 12	• 510	1 • 063	1 • 573

TABLE I. THE PROPERTIES OF SATURATED STEAM AND WATER *CONTINUED*

PRESSURE		TEMPER-ATURE °F	HEAT BTU/LB.			VOLUME CU. FT./LB.		ENTROPY BTU/°F.ABS./LB.		
PSI GAUGE	PSI ABS.		SENSIBLE	LATENT	TOTAL	LIQUID	VAPOUR	LIQUID	EVAP.	TOTAL
132	146 • 7	356 • 7	328 • 8	865 • 9	1194 • 7	• 0180	3 • 08	• 512	1 • 060	1 • 572
134	148 • 7	357 • 8	330 • 0	865 • 0	1195 • 0	• 0180	3 • 04	• 513	1 • 058	1 • 571
136	150 • 7	358 • 8	331 • 1	864 • 1	1195 • 2	• 0181	3 • 00	• 514	1 • 056	1 • 570
138	152 • 7	359 • 9	332 • 2	863 • 3	1195 • 5	• 0181	2 • 96	• 516	1 • 053	1 • 569
140	154 • 7	360 • 9	333 • 2	862 • 5	1195 • 7	• 0181	2 • 93	• 517	1 • 051	1 • 568
142	156 • 7	361 • 9	334 • 3	861 • 6	1195 • 9	• 0181	2 • 89	• 518	1 • 049	1 • 567
144	158 • 7	362 • 9	335 • 4	860 • 7	1196 • 1	• 0181	2 • 86	• 520	1 • 046	1 • 566
146	160 • 7	364 • 0	336 • 4	859 • 9	1196 • 3	• 0181	2 • 82	• 521	1 • 044	1 • 565
148	162 • 7	365 • 0	337 • 5	858 • 9	1196 • 4	• 0182	2 • 79	• 522	1 • 042	1 • 564
150	164 • 7	365 • 9	338 • 6	858 • 0	1196 • 6	• 0182	2 • 76	• 523	1 • 040	1 • 563
155	169 • 7	368 • 3	341 • 1	856 • 0	1197 • 1	• 0182	2 • 68	• 526	1 • 034	1 • 560
160	174 • 7	370 • 7	343 • 6	853 • 9	1197 • 5	• 0182	2 • 61	• 529	1 • 029	1 • 558
165	179 • 7	372 • 9	346 • 1	851 • 8	1197 • 9	• 0183	2 • 54	• 532	1 • 024	1 • 556
170	184 • 7	375 • 2	348 • 5	849 • 8	1198 • 3	• 0183	2 • 48	• 535	1 • 018	1 • 553
175	189 • 7	377 • 5	350 • 9	847 • 9	1198 • 8	• 0183	2 • 41	• 538	1 • 013	1 • 551
180	194 • 7	379 • 6	353 • 2	845 • 9	1199 • 1	• 0184	2 • 35	• 540	1 • 009	1 • 549
185	199 • 7	381 • 6	355 • 4	844 • 1	1199 • 5	• 0184	2 • 30	• 543	1 • 004	1 • 547
190	204 • 7	383 • 7	357 • 6	842 • 2	1199 • 8	• 0184	2 • 24	• 546	• 999	1 • 545
195	209 • 7	385 • 7	359 • 9	840 • 2	1200 • 1	• 0184	2 • 18	• 548	• 995	1 • 543
200	214 • 7	387 • 7	362 • 0	838 • 4	1200 • 4	• 0185	2 • 14	• 551	• 990	1 • 541
210	224 • 7	391 • 7	366 • 2	834 • 8	1201 • 0	• 0185	2 • 04	• 556	• 981	1 • 537
220	234 • 7	395 • 5	370 • 3	831 • 2	1201 • 5	• 0186	1 • 96	• 561	• 972	1 • 533
230	244 • 7	399 • 1	374 • 2	827 • 8	1202 • 0	• 0186	1 • 88	• 565	• 964	1 • 529
240	254 • 7	402 • 7	378 • 0	824 • 5	1202 • 5	• 0186	1 • 81	• 570	• 956	1 • 526
250	264 • 7	406 • 1	381 • 7	821 • 2	1202 • 9	• 0187	1 • 74	• 574	• 947	1 • 523
260	274 • 7	409 • 3	385 • 3	817 • 9	1203 • 2	• 0187	1 • 68	• 578	• 941	1 • 519
270	284 • 7	412 • 5	388 • 8	814 • 8	1203 • 6	• 0188	1 • 62	• 582	• 934	1 • 516
280	294 • 7	415 • 8	392 • 3	811 • 6	1203 • 9	• 0188	1 • 57	• 586	• 927	1 • 513
290	304 • 7	418 • 8	395 • 7	808 • 5	1204 • 2	• 0189	1 • 52	• 590	• 920	1 • 510
300	314 • 7	421 • 7	398 • 9	805 • 5	1204 • 4	• 0189	1 • 47	• 593	• 914	1 • 507
310	324 • 7	424 • 7	402 • 1	802 • 6	1204 • 7	• 0190	1 • 43	• 597	• 908	1 • 505
320	334 • 7	427 • 5	405 • 2	799 • 7	1204 • 9	• 0191	1 • 39	• 601	• 901	1 • 502
330	344 • 7	430 • 3	408 • 3	796 • 7	1205 • 0	• 0191	1 • 35	• 604	• 895	1 • 499
340	354 • 7	433 • 0	411 • 3	793 • 8	1205 • 1	• 0191	1 • 31	• 607	• 890	1 • 497
350	364 • 7	435 • 7	414 • 3	791 • 0	1205 • 3	• 0192	1 • 27	• 611	• 883	1 • 494
360	374 • 7	438 • 3	417 • 2	788 • 2	1205 • 4	• 0192	1 • 24	• 614	• 878	1 • 492
370	384 • 7	440 • 8	420 • 0	785 • 4	1205 • 4	• 0193	1 • 21	• 617	• 872	1 • 489
380	394 • 7	443 • 3	422 • 8	782 • 7	1205 • 5	• 0193	1 • 18	• 620	• 867	1 • 487
390	404 • 7	445 • 7	425 • 6	779 • 9	1205 • 5	• 0194	1 • 15	• 623	• 862	1 • 485
400	414 • 7	448 • 1	428 • 2	777 • 4	1205 • 6	• 0194	1 • 12	• 626	• 856	1 • 482
410	424 • 7	450 • 5	430 • 8	774 • 8	1205 • 6	• 0195	1 • 09	• 629	• 851	1 • 480
420	434 • 7	452 • 8	433 • 4	772 • 2	1205 • 6	• 0195	1 • 07	• 632	• 846	1 • 478
430	444 • 7	455 • 1	436 • 0	769 • 6	1205 • 6	• 0195	1 • 04	• 635	• 841	1 • 476
440	454 • 7	457 • 3	438 • 5	767 • 1	1205 • 6	• 0196	1 • 02	• 637	• 837	1 • 474
450	464 • 7	459 • 5	441 • 0	764 • 5	1205 • 5	• 0196	1 • 00	• 640	• 832	1 • 472
460	474 • 7	461 • 7	443 • 4	762 • 1	1205 • 5	• 0196	• 979	• 643	• 827	1 • 470
470	484 • 7	463 • 8	445 • 9	759 • 5	1205 • 4	• 0197	• 959	• 645	• 823	1 • 468
480	494 • 7	465 • 9	448 • 3	757 • 1	1205 • 4	• 0197	• 939	• 648	• 818	1 • 466
490	504 • 7	467 • 9	450 • 6	754 • 7	1205 • 3	• 0198	• 920	• 650	• 814	1 • 464
500	514 • 7	470 • 0	453 • 0	752 • 3	1205 • 3	• 0198	• 902	• 653	• 809	1 • 462
510	524 • 7	472 • 0	455 • 3	749 • 9	1205 • 2	• 0199	• 885	• 655	• 805	1 • 460
520	534 • 7	474 • 0	457 • 6	747 • 5	1205 • 1	• 0199	• 868	• 657	• 801	1 • 458
530	544 • 7	475 • 9	459 • 8	745 • 2	1205 • 0	• 0199	• 852	• 660	• 796	1 • 456
540	554 • 7	477 • 8	462 • 0	742 • 8	1204 • 8	• 0200	• 835	• 662	• 792	1 • 454
550	564 • 7	479 • 7	464 • 2	740 • 5	1204 • 7	• 0200	• 820	• 664	• 789	1 • 453

TABLE I. THE PROPERTIES OF SATURATED STEAM AND WATER *CONTINUED*

PRESSURE		TEMPER-ATURE °F	HEAT BTU/LB.			VOLUME CU. FT./LB.		ENTROPY BTU/°F.ABS./LB.		
PSI GAUGE	PSI ABS.		SENSIBLE	LATENT	TOTAL	LIQUID	VAPOUR	LIQUID	EVAP.	TOTAL
560	574 • 7	481 • 6	466 • 8	738 • 1	1204 • 5	• 0200	• 805	• 667	• 784	1 • 451
570	584 • 7	483 • 4	468 • 0	735 • 8	1204 • 4	• 0201	• 791	• 669	• 780	1 • 449
580	594 • 7	485 • 2	470 • 1	733 • 5	1204 • 2	• 0201	• 776	• 671	• 776	1 • 447
590	604 • 7	487 • 0	472 • 2	731 • 3	1204 • 1	• 0201	• 763	• 673	• 773	1 • 446
600	614 • 7	488 • 8	474 • 2	729 • 1	1203 • 9	• 0202	• 750	• 676	• 768	1 • 444
610	624 • 7	490 • 5	476 • 3	726 • 8	1203 • 7	• 0202	• 738	• 678	• 764	1 • 442
620	634 • 7	492 • 3	479 • 4	724 • 5	1203 • 5	• 0203	• 726	• 680	• 761	1 • 441
630	644 • 7	494 • 0	481 • 4	722 • 3	1203 • 3	• 0203	• 714	• 682	• 757	1 • 439
640	654 • 7	495 • 7	483 • 5	720 • 1	1203 • 1	• 0203	• 703	• 684	• 754	1 • 438
650	664 • 7	497 • 3	484 • 6	718 • 0	1202 • 9	• 0204	• 692	• 686	• 750	1 • 436
660	674 • 7	499 • 0	486 • 1	715 • 8	1202 • 7	• 0204	• 681	• 688	• 747	1 • 435
670	684 • 7	500 • 6	488 • 6	713 • 7	1202 • 5	• 0204	• 670	• 690	• 743	1 • 433
680	694 • 7	502 • 2	490 • 1	711 • 5	1202 • 2	• 0205	• 660	• 692	• 740	1 • 432
690	704 • 7	503 • 9	492 • 5	709 • 4	1202 • 0	• 0205	• 650	• 694	• 736	1 • 430
700	714 • 7	505 • 4	494 • 9	707 • 4	1201 • 8	• 0206	• 641	• 696	• 733	1 • 429
710	724 • 7	507 • 0	496 • 2	705 • 2	1201 • 5	• 0206	• 632	• 697	• 730	1 • 427
720	734 • 7	508 • 5	498 • 4	703 • 1	1201 • 3	• 0206	• 623	• 699	• 727	1 • 426
730	744 • 7	510 • 0	500 • 6	701 • 0	1201 • 0	• 0207	• 614	• 701	• 723	1 • 424
740	754 • 7	511 • 5	501 • 9	698 • 9	1200 • 8	• 0207	• 605	• 703	• 720	1 • 423
750	764 • 7	513 • 0	503 • 0	696 • 7	1200 • 5	• 0208	• 596	• 705	• 716	1 • 421
760	774 • 7	514 • 5	505 • 2	694 • 7	1200 • 2	• 0208	• 588	• 707	• 713	1 • 420
770	784 • 7	516 • 0	507 • 3	692 • 8	1200 • 0	• 0208	• 580	• 708	• 711	1 • 419
780	794 • 7	517 • 5	509 • 2	690 • 7	1199 • 7	• 0209	• 572	• 710	• 707	1 • 417
790	804 • 7	518 • 9	510 • 0	688 • 6	1199 • 4	• 0209	• 564	• 712	• 704	1 • 416
800	814 • 7	520 • 3	512 • 7	686 • 6	1199 • 1	• 0209	• 557	• 714	• 700	1 • 414
850	864 • 7	526 • 9	521 • 3	676 • 5	1197 • 5	• 0211	• 522	• 722	• 686	1 • 408
900	914 • 7	533 • 9	529 • 8	666 • 7	1195 • 9	• 0213	• 499	• 730	• 671	1 • 401
950	964 • 7	540 • 3	537 • 3	656 • 9	1194 • 0	• 0215	• 462	• 738	• 657	1 • 395
1000	1014 • 7	546 • 4	544 • 7	647 • 2	1192 • 0	• 0217	• 437	• 745	• 644	1 • 389
1050	1064 • 7	552 • 3	552 • 9	637 • 8	1190 • 0	• 0218	• 414	• 753	• 630	1 • 383
1100	1114 • 7	557 • 9	559 • 1	628 • 3	1187 • 9	• 0220	• 394	• 760	• 617	1 • 377
1150	1164 • 7	563 • 4	566 • 2	619 • 0	1185 • 7	• 0222	• 375	• 766	• 606	1 • 372
1200	1214 • 7	568 • 8	573 • 3	609 • 6	1183 • 4	• 0223	• 357	• 773	• 593	1 • 366
1250	1264 • 7	573 • 9	580 • 3	600 • 2	1181 • 0	• 0225	• 341	• 780	• 581	1 • 361
1300	1314 • 7	578 • 9	587 • 3	590 • 9	1178 • 5	• 0227	• 325	• 786	• 569	1 • 355
1350	1364 • 7	583 • 7	594 • 2	581 • 8	1176 • 0	• 0229	• 311	• 792	• 558	1 • 350
1400	1414 • 7	588 • 4	600 • 0	572 • 6	1173 • 3	• 0231	• 298	• 798	• 547	1 • 345
1450	1464 • 7	593 • 0	607 • 8	563 • 3	1170 • 5	• 0233	• 285	• 804	• 536	1 • 340
1500	1514 • 7	597 • 5	613 • 6	554 • 2	1167 • 8	• 0235	• 274	• 810	• 525	1 • 335
1550	1564 • 7	601 • 8	619 • 2	545 • 2	1165 • 0	• 0237	• 264	• 816	• 514	1 • 330
1600	1614 • 7	606 • 1	626 • 8	536 • 0	1162 • 0	• 0239	• 254	• 821	• 503	1 • 324
1700	1714 • 7	614 • 3	638 • 4	517 • 7	1155 • 8	• 0243	• 234	• 832	• 482	1 • 314
1800	1814 • 7	622 • 1	650 • 0	499 • 0	1149 • 1	• 0248	• 215	• 843	• 461	1 • 304
1900	1914 • 7	629 • 6	661 • 5	480 • 4	1142 • 2	• 0253	• 200	• 853	• 441	1 • 294
2000	2014 • 7	636 • 8	673 • 0	461 • 5	1135 • 0	• 0258	• 186	• 863	• 421	1 • 284
2100	2114 • 7	643 • 7	685 • 4	442 • 0	1127 • 1	• 0263	• 173	• 874	• 400	1 • 274
2200	2214 • 7	650 • 3	696 • 9	422 • 1	1118 • 9	• 0268	• 161	• 884	• 380	1 • 264
2300	2314 • 7	656 • 8	708 • 3	401 • 5	1110 • 0	• 0274	• 150	• 894	• 360	1 • 253
2400	2414 • 7	663 • 0	720 • 6	380 • 2	1100 • 5	• 0281	• 139	• 904	• 338	1 • 242
2500	2514 • 7	669 • 0	732 • 0	357 • 6	1090 • 1	• 0289	• 129	• 914	• 317	1 • 231
2600	2614 • 7	674 • 8	744 • 3	333 • 7	1078 • 6	• 0297	• 120	• 925	• 296	1 • 220
2700	2714 • 7	680 • 4	758 • 6	308 • 0	1066 • 2	• 0306	• 111	• 935	• 272	1 • 207
2800	2814 • 7	685 • 8	772 • 8	279 • 2	1051 • 5	• 0318	• 102	• 947	• 244	1 • 191
2900	2914 • 7	691 • 0	787 • 0	246 • 9	1034 • 4	• 0332	• 0936	• 960	• 214	1 • 175
3000	3014 • 7	696 • 1	805 • 2	207 • 4	1012 • 7	• 0349	• 0847	• 975	• 180	1 • 155
3193*	3208*	705 • 6*	896 • 0*	0	896 • 0*	• 0489*	• 0489*	1 • 052*	0	1 • 052*

**The values at the critical point were obtained by extrapolation.*

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