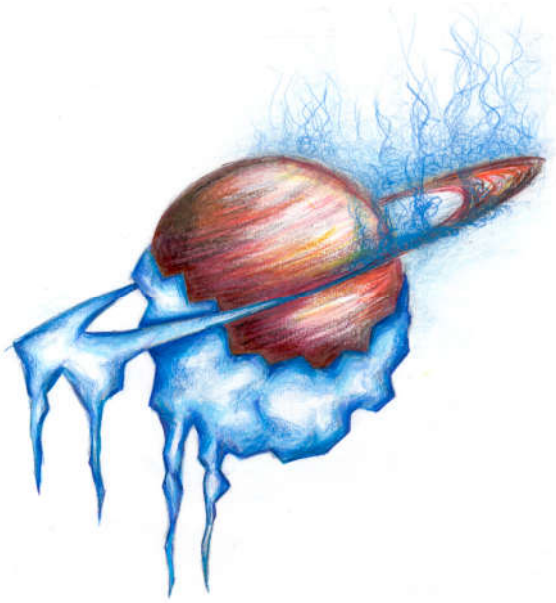
# Ice is from Venus



# Steam is from Mars

December 12, 2019

# Preface

After spending more than forty years in this business, it has become evident that the knowledge base of users and designers of steam systems is gradually diminishing. So, with the help of my friends and associates, I put this primary steam book together. This is but a general overview, and yet I hope with this straight forward approach, you will begin to understand the fundamentals as they apply to steam and steam systems.

For those of you who wish to broaden your knowledge of steam, its production, and its many uses, an advanced version is available. The advanced book is written in greater detail and is designed for the engineering community or individuals who wish to broaden their knowledge of steam and its many uses. For your copy, please e-mail us at Orders@EngineeredSolutionsCan.com.

If you require design assistance or clarification on any process, please contact us at Orders@EngineeredSolutionsCan.com, and one of our technicians will help you with your questions.

Please visit our web site Engineered Solutions and utilize the links to sites of related manufacturers of products used in steam and hydronic systems.

Bill Jefferson

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# ICE IS FROM VENUS
# STEAM IS FROM MARS

## Chapter One

In preparing this book, we made every effort to explain each point in non-technical language. Doing this means that some explanations will be longer than they would be if we used technical language and arithmetic formulas.

If some explanations seem to be labored or too elementary, please have patience and remember that others may appreciate and better understand the simplified approach.

STEAM WHAT IS IT?

We all know what happens when a kitchen kettle begins to boil; steam rushes from the spout, and when the lid doesn't fit tightly to the body, the cover starts to bounce up and down.

What happened inside the kettle between putting in the cold water and the steam leaving the spout?

As soon as you put the kettle of cold water on the stove heating element, the heat began to make its way through the metal of the kettle and into the water. The continuous flow of heat warmed up the water and made it hotter and hotter until the water began to boil.

As soon as the water began to boil, it had reached the stage where it could not take in any more heat. Since the kettle is still on the stove, it is still absorbing heat into the water. What happened then?

A change took place in the water. The extra heat that was trying to find room in the water was shot out immediately in the form of vapor. In other words, the excess heat began to evaporate or convert the liquid into a vapor.

This "Water Vapour" is what is commonly known as "**STEAM**"

If we left the kettle on the stove long enough, the water would continue to be vaporized by the incoming heat until all of the water turned into steam.

WHY DO WE USE STEAM?

Why do we use steam for heating factories or offices; for boiling jam or other prepared foods; for turning wet stock into paper; for heating the water that washes dirty clothes in laundries; for evaporating chemical solutions; for driving turbines, engines, and pumps; for doing the thousands of jobs in all branches of industry?

Why steam in particular? Why is it in such everyday use throughout the world?

Because there is such a common need for heat and pressure energy (or power energy, if you like) and steam happens to be such a convenient and economical way of conveying large quantities of heat and pressure energy from one place to another. Steam is inexpensive to produce and is a product made from water of which there is plenty in most parts of the world. Steam is easy to control and is a very versatile commodity.

For a straightforward demonstration of the heat and pressure energy in steam, let's go back to the kettle in the kitchen.

First, we will test the steam for temperature. If we were to stick one finger into the boiling water and another into the steam at the mouth of the spout, the second finger would hurt just as much as the other because the steam is precisely the same temperature as the boiling water.

Now let's test the steam for pressure energy. This time we don't need to scald ourselves. All we need do is watch the kettle lid bobbing up and down. It is the pressure energy in the steam, which is making the lid bounce.

## STEAM GENERATION

When we generate steam in a boiler, much the same thing happens as in the kitchen kettle, of course, on a much more elaborate scale and with variations. A boiler is the big brother of the kettle.

The most significant difference between the two is that the kettle has a spout - which isn't intended to be a funny remark, as you will presently realize.

At this stage, we bring in one or two technical terms, not because we cannot dodge them but because it will be much easier for you to understand and appreciate the great usefulness of steam once you have memorized these terms and what they represent.

Whenever you see these initials "Btu," you will know that they stand for "British Thermal Units," which is the engineer's unit of heat. A single Btu is the quantity of heat needed to raise the temperature of 1 pound of water through 1 degree Fahrenheit.

Let us put that in more simple language. Suppose we have a quantity of water which weighs precisely 1 pound (whether the water is cold or hot doesn't matter for the moment). We put a thermometer in the water and note the reading on the scale (which for our purpose is the Fahrenheit scale, signified from now on in the usual manner; by the symbol ° for degree and the capital letter F or, more simply: °F.)

Now we add heat to the water until the thermometer has moved up the scale one degree. The quantity of heat we have added to raise the temperature of that 1 pound of water by 1°F is 1 Btu.

If instead of raising the temperature of the water by 1°F we increase it by 4°F, we will have put in 4 Btu. If we increase the temperature of 4 pounds of water by 1°F, we will have put in 4 Btu and so on.

Now let's see what happens in the boiler during the process of generating steam.

The heat from the boiler furnace passes through the wall of the coils and into the water. We measure the quantity of heat passing into the water in these Btu's.

As happened in the kettle, the heat from the fire warms up the water; it becomes hotter and hotter until it boils. The fire is still supplying heat, so when the water reaches the boiling point, it then begins to evaporate into steam.

We will explain what has happened in the boiler:

SENSIBLE HEAT

Heat, which produces a rise in temperature when it enters a substance, is called Sensible Heat. Which, in our boiler, means this: the heat passing from the furnace and into the water making the water warmer is known as Sensible Heat. The full name is "Sensible Heat of Water."

Even if, when we start up the boiler, the water is cold, it must contain some heat. This initial heat also is known as Sensible Heat. Therefore, adding the initial heat in the water plus the quantity of heat, up to the moment of boiling is the total amount of Sensible Heat in the boiling water.

To make sure we completely understand, let's suppose that the temperature of the water in the boiler before we began to add heat was 50°F. Let us suppose too, that the temperature of the water when it started to boil was 212°F. That represents a temperature rise of 162 degrees (which means the water is 162 degrees hotter than when we started).

If you read again what we said about Btu's, you will realize that every pound of our boiler water has absorbed 162 Btu's in heating up from 50°F to 212°F. Which means that if the boiler holds 10,000 pounds of water (which is about 1,200 US gallons or1,000 Imperial gallons), the Sensible Heat added to the water to bring it to the boiling point is 1,620,000 Btu's (l pound has 162 Btu's, so 10,000 pounds has 1,620,000 Btu's).

Note particularly that this amount of heat is not the total amount of Sensible Heat in the boiling water. It is the amount of Sensible Heat added to the water to raise its temperature from 50°F to 212°F.

The total amount of Sensible Heat in the water at a temperature of 212°F is 180 Btu's per pound of water. Therefore, our 10,000 pounds of boiling water is holding 1,800,000 Btu of Sensible Heat.

If you are wondering why the boiling water (which is at 212°F) is holding a total of only 1,800,000 Btu's and not 2,120,000 Btu's, there is a simple explanation:

The freezing point of water is 32°F, and it is usual to assume that at that temperature, water does not (for practical purposes) contain any Sensible Heat. This means that in calculating the total amount of Sensible Heat in our boiling water, we start from 32°F, not from 0°F. Below 32°F, it isn't water. It's ice.

Therefore, from 32°F to 212°F, there is a temperature rise of l80 degrees, meaning there are l80 Btu's of Sensible Heat in every pound of our example boiler water and 1,800,000 Btu's of Sensible Heat in our 10,000 pounds of boiling water.

So remember, whenever you are calculating the total amount of Sensible Heat: start at 32°F, not at 0°F and also remember, not to get confused between the amount of heat added to the water and the total amount of heat which the water contains.

We are interrupting the story at this point to let you know what you have been reading is, perhaps, the first lesson to be learned about fuel economy. If you have to burn oil or gas or any other fuel to make something hotter, you will use less fuel if that something is already warm instead of stone cold. Remember, every time and all the time, you are thinking in terms of heat economy. The water in our boiler was at a temperature of 50°F before we began to add heat to it. If it had been 100°F when we started, we would have needed only 1,120,000 Btu's of Sensible Heat to bring our 10,000 pounds of water to the boiling point. Compared with the 50°F start, we would have used 500,000 Btu's less, meaning we would have used considerably less fuel to bring the water to the boiling point. The hotter you start, the less fuel you will use.

We are now at the stage where the water in our boiler is about to boil. What next?

LATENT HEAT

The water is at a temperature of 212°F, and heat still is absorbed into the water from the furnace. This extra heat is converting the water into steam.

Now, for a minute or two, we will imagine that our boiler has a spout like a kitchen kettle and that the spout is an outlet for the steam from the boiler.

Although more and more heat is passing into the water from the boiler, the water cannot be made any hotter than 212°F. So some of the water is now changing its state and turning into steam, and as we discovered when we scalded our fingers, the steam is the same temperature as the boiling water, so it too must be 212°F.

Heat, which produces a change of state without a change in temperature is known as Latent Heat.

Latent Heat is the extra heat put into the water which begun to boil and which converts water into steam - its full name is "Latent Heat of Vaporization of Water," but we'll be content with the first two words. The quantity of Latent Heat, as with any other kind of heat, is stated in Btu's.

TOTAL HEAT OF STEAM

As we stated in the beginning, steam is a good conveyer of heat and pressure energy. For the time being, we are concentrating on the heat portion.

We have seen that the steam generated in our boiler has two lots of heat and those quantities we express as so many Btu's. There is the Sensible Heat in the water to which we add the Latent Heat, which converts the water into steam.

The Total Heat in steam is Sensible Heat plus Latent Heat, which equals "Total Heat," as depicted in picture form in Fig. 1. You will see from the diagram that the quantity of Latent Heat is considerably more significant than the amount of heat sensible. In every 1 pound of our steam, which at present is at the temperature of 212°F, there are 180 Btu's of Sensible Heat and 970 Btu's of Latent Heat, making a Total Heat of 1,150 Btu's.

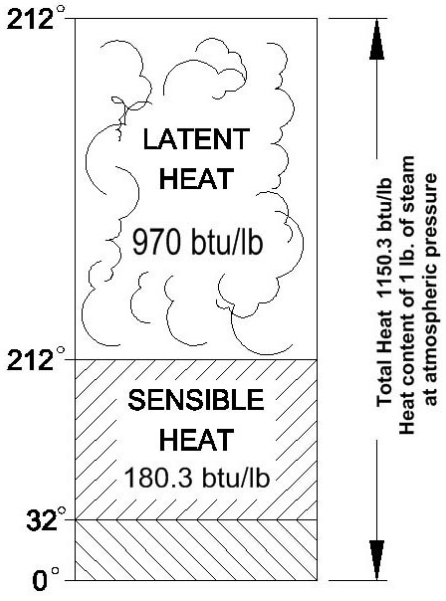



**Figure 1: Latent Heat "A"**

Whatever the quantity of that steam, the proportion remains the same. For instance, if instead of 1 pound, we had a quantity of the steam weighing 100 pounds, we take the figures given above then multiply them by 100. Which means that we would have at our disposal a Total Heat of 115,000 Btu's. This would be made up of 18,000 Btu's of Sensible Heat and 97,000 Btu's of Latent Heat.

It is important to remember that such a great proportion of the Total Heat of steam is Latent Heat. You will understand why when we get further into the book and talk about the use of steam.

STEAM PRESSURE

You will have heard about Atmospheric Pressure. In case you are not quite sure what it means, let us use a simple example.

If in imagination, you will allow yourself to be flattened by the pressure of a 100-ton Hydraulic Press, you will at once recognize it as an unpleasant experience.

Conversely, if we were to put you into a sealed vacuum chamber, which is devoid of air (of "atmosphere"), the effect would be the opposite of the hydraulic press, although the result would undoubtedly be no less messy. As the air (the "atmosphere" in your body) would exert a pressure outwardly in all directions, and you would tend to burst, whether you liked it or not.

The atmosphere exerts pressure on you and everything around you. This pressure is exerted equally in all directions.

This Atmospheric Pressure is equal to nearly 15 pounds on every square inch of surface. The actual figure is 14.7 pounds per square inch or, in short form, Lbs./sq. in.

The steam leaving the spout of the kitchen kettle (and out of the imaginary spout on our boiler) is exposed to the atmosphere and is therefore at this atmospheric pressure of 14.7 lbs./sq. in. The temperature of steam at this atmospheric pressure is the same as the temperature of boiling water at atmospheric pressure (212°F), and so long as there is an imaginary spout on top of our boiler through which the steam can pass through unhindered, everything is at atmospheric pressure and its specified temperature. To make this clear, we will repeat the figures: pressure inside and outside the boiler is 14.7 lbs./sq. in., steam pressure is 14.7 lbs./sq. in., the temperature of the water in the boiler is 212°F, and the temperature of the steam is 212°F.

Having helped us to explain what happens at atmospheric pressure, the imaginary spout on our boiler has served its purpose, and we can now dispense with it. We are still generating steam in the boiler, but there is no outlet for the steam to escape. What happens?

The boiler is now a closed vessel. So as more steam is generated inside this vessel, the steam, to find room for itself, must compress. Also, when it's now compressed, it tries to push out in all directions and exerts a pressure on everything surrounding it. Applying additional heat generates more steam, which becomes even more compressed, and its strength continues to increase, consequently exerting in all directions. So besides pressing on the inside surfaces of the boiler, the steam also creates pressure on the surface of the water.

These two things - the increasing pressure exerted by the steam and the effect of that rising pressure on the surface of the water - cause other things to happen. These other things have a significant bearing on the practical use of steam for process heat and space heating purposes. Properly understood, they would help you to use your steam to the best possible advantage.

As the pressure on the surface of the water increases, it has the effect of increasing the temperature at which the water boils. While at atmospheric pressure (14.7 Lbs./sq. in.) water boils when it reaches the temperature of 212°F, we find that at a pressure of, for example, 100 lbs./sq. in. the boiling point will have risen to 338°F.

You will see in Fig. 2 on the next page that to keep the water boiling and to give off steam at this higher temperature; we must supply a more significant proportion of Sensible Heat On the other hand, at the higher pressure and temperature, a reduced quantity of Latent Heat is needed to convert the boiling water into steam.

Please turn back to Fig. 1. which shows the heat content of steam at atmospheric pressure. Compare it with Fig. 2, which shows the changed heat content of steam at a higher pressure of 100 lbs./sq. in. You will see that while the Total Heat in each pound of the Fig. 2 steam has increased by 38.7 Btu's, the Sensible Heat has risen by 128.7 Btu's, and the Latent Heat has decreased by 90 Btu's.

Changes in the heat content of steam, such as have happened between Figs. 1 and 2 occur with every change of steam pressure.

As the steam pressure increases, there is more Total Heat available, but this increase becomes less and less as the pressure rises, resulting in more Sensible Heat, but less Latent Heat. As the steam pressure decreases, there is less Total Heat available, less Sensible Heat, yet more Latent Heat.

At the end of the section headed "Total Heat of Steam," we mentioned how important it is to remember that such a significant proportion of the Total Heat of steam is Latent Heat. So there it is - if there is one thing that we might single out from all the rest in this section on steam pressure - it is this: the lower the steam pressure, the higher the quantity of Latent Heat.

When you read the section headed "WHEN STEAM CONDENSES" in the next chapter, you will begin to realize why the Latent Heat is so essential in the general use of steam for process work and heating.

Please remember that we are still talking about steam as a conveyor and source of heat. When later we come to steam as a means of supplying power through engines, for example, we have to approach things from an entirely different angle.

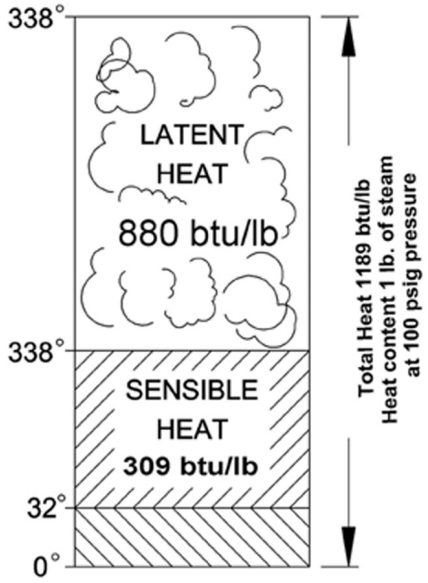



**Figure 2: Latent Heat "B"**

Now we must clarify one or two points on the general subject of pressure, in case you happen to be unfamiliar with them.

We express Steam pressures in pounds pressure per square inch and show them as Lbs./sq. in. or sometimes as p s i .

We show Steam pressures as either "gauge pressure" or "absolute pressure." The most common form shown is gauge pressure. "Gauge Pressure" is the pressure above atmospheric pressure. "Absolute pressure" begins at absolute zero, which is 14.7 p s i below atmospheric pressure. When specifying an absolute pressure, it is gauge pressure plus the pressure of the atmosphere. For example, 25 p s i absolute would be 10.3 p s i above atmospheric pressure.

Pressures below zero gauge, which is, below atmospheric pressure, generally are expressed in "inches of mercury vacuum." Abbreviated to "inches mercury" or signified by the letters "Hg," which are the chemical symbol of mercury.

Gauge pressure is the pressure shown on an ordinary pressure gauge on every boiler and which you will generally see scattered about on pipelines and equipment. As gauge pressure is the pressure above the atmospheric pressure, the "0" on the dial of the usual pressure gauge is 14.7 p s i Absolute. However, for all ordinary purposes, "0" is "Zero Gauge Pressure."

Throughout this book, whenever we refer to pressure in p s i g , we mean "gauge pressure," corresponding with the figures on the dial of the usual pressure gauge. In the odd case where we have to refer to "absolute pressure," this will be shown as so many p s i absolute and signified as p s i a.

HOW MUCH SPACE DOES STEAM OCCUPY?

The space a given weight of steam will occupy depends upon its pressure.

If we have 1 pound of water (which is something less than a pint) and convert all of it into steam, we will have exactly 1 pound of steam. To show you how the space occupied by steam (referred to as its "volume") varies according to the pressure at which it is supplied, we give you two examples:

At Atmospheric pressure (0 psig), 1 pound of steam occupies nearly 27 cubic feet of space

At a pressure of 100 p s i g , 1 pound of steam occupies only 4 cubic feet of space.

In each case, we start with precisely the same quantity of water, and in each case, we convert the water into precisely the same weight of steam. However, as the pressure increases, we find that less and less space is taken up by the steam, which is exactly what you would expect to find since the steam becomes more compressed as the pressure rises.

THE STEAM "READY RECKONER"

By this time, you probably think that all this stuff about Btu's and pressures and heaven knows what will give you a head as big as a boiler. Well, it won't if we can help it.

There is a chart that will show you at a glance the Temperature, the Sensible Heat, the Latent heat, the Total Heat, and the Volume of steam at any given pressure. This chart is better known as a "Steam Table."

To anybody who uses steam, beginner or old hand, these Steam Tables are handy. To those who intend to know as much as possible about steam and the marvelous things they can do with it, Steam Tables are indispensable.

Steam Tables are printed in various forms and by multiple publishers. For your use and convenience in going through this course, we have added a set of Steam Tables at the end of this chapter. It's a simplified version, but you will find all the information you'll need for quick reference while you are working your way through.

One other thing that will help you is the additional sheet at the end headed "WHAT IS IT?" This is a glossary of some of the technical terms you might come across in the industry and can be a quick reminder. We hope you will find this to be a useful time-saver.

HEAT AND TEMPERATURE

The words "heat" and "temperature" are commonly confused. So, to be quite sure you clearly understand the difference between “heat” and “temperature,” we include this brief explanation:

Heat is what makes things hotter, and the hotter a thing is, the higher its temperature.

As water will always flow from one level to a lower one, heat will always flow from a hotter substance to a cooler one.

To raise the temperature of anything, we must add to it heat, which derives from something else. The passage of heat out of one thing and into another is called "heat transfer."

The rate (or speed) at which heat is transferred out of one thing and into another is called "the rate of heat flow."

For example, if you put your warm hand on your cold foot, heat will flow out of your hand and into your foot. Between the two, there is what is called a "temperature difference." Meaning that there is heat transfer from your hand to your foot. The rate of heat flow between the two depends mainly on the temperature difference between the two.

Now, put a hot water bottle between your warm hand and your cold foot. The bottle is at a higher temperature than either your warm hand or your cold foot, so there will be heat transfer from the bottle to both the hand and the foot. The rate of heat flow from the bottle to your foot will be higher (faster) than from the bottle to your hand because of the more significant temperature difference between bottle and foot than between bottle and hand.

Heat transfer will continue from the bottle to the hand until the bottle has lost temperature, and the hand gained warmth to the point where they balance. During this gradual balancing of temperature, the rate of heat flow will have been gradually slowing down. When there is no longer a temperature difference between the bottle and the hand, heat transfer between them ceases.

In spite of this rambling description, perhaps you still imagine "temperature" to mean quantity of heat. Well, it does not. We must have a quantity of heat, of course, but that isn't quite the whole story. One more example to make this particular point clearer:

Think of our boiler holding 1,000 gallons of boiling water. Imagine that you could take a lump of white-hot metal, and could drop it into that mass of boiling water. Heat would at once begin to flow from the white-hot metal into the water because the metal ball would be at a temperature higher than that of the boiling water.

Nevertheless, that mass of water, although it would be at a lower temperature, would contain a far greater quantity of heat than was in the lump of white-hot metal.

Finally, a thing does not have to be hot, or even warm before it can be said to have temperature. A chunk of rock in your garden rockery has temperature. Coldwater coming out of your kitchen tap has temperature. Even when water begins to freeze, it has a temperature of 32°F.

Hopefully, this first chapter has given you, among other things, a rough idea of what happens when we generate steam and what you may expect to get out of steam in the way of heat. Chapter 2 deals with steam after it has left the boiler. Mainly it will be about the condensation of steam and the practical use of the heat in steam.

STEAM TABLES

The figures given in Steam Tables are not just the result of fancy arithmetic. They are the result of actual tests on steam. Different experimenters have obtained slightly different results, so you might pick up two sets of Steam Tables from separate publishers and find slight differences in the figures. However, the variations are so slight as to make no difference for our purposes.

The following Steam Table presents seven columns of figures, and as we said earlier, this is an abbreviated Steam Table. More complex tables are available, and some would believe the more detailed, the better, not so. For our purposes, we can get along quite nicely with this condensed version. The thing is, don't try to take it all in at once, take it in a bit at a time. Let's review the column subjects first:

The first column gives us "Gauge Pressure," expressed as PSIG. As previously mentioned, this is the pressure, as shown on a standard pressure gauge. As you go down the column, the pressures get higher, just as they do around the dial of a pressure gauge.

The second column gives us "Absolute Pressure," expressed as PSIA, which, also as previously mentioned, means 14.7 Lbs./sq. in. above the psig shown in the first column.

The third column shows the temperature of steam in degrees Fahrenheit at the different pressures. In each case, this temperature of the steam is also the temperature of boiling water at the same pressure.

The fourth column gives the number of Btu's of "Sensible Heat" in every 1 pound of steam at various pressures. They also represent the number of Btu's of heat in every 1 pound of boiling water at the same pressure.

The fifth column gives the number of Btu's of "Latent Heat" in every 1 pound of steam at various pressures.

The sixth column gives the number of Btu's of "Total Heat" in every 1 pound of steam at various pressures. As you will see, in every case, the figure is the Sensible Heat and the Latent Heat added together.

The seventh column shows us the Volume of every 1 pound of steam at the various pressures, which is the space occupied by the steam as measured in cubic feet.

Now, let's pick three separate lines from the Table as examples and see what they tell us. Read across from left to right in each case.

Let's start with 0 PSIG (column 1) and 14.7 PSIA (column 2). If we run across this line of figures from left to right, you will see that the temperature of steam and boiling water is 212°F. The Sensible Heat in one pound of steam and boiling water is 180 Btu's. The Latent Heat in one pound of steam is 970 Btu's. The Total Heat in one pound of steam is 1,150 Btu's. Also, the volume of space taken up by one pound of steam is 26.80 cubic feet.

For the second example, let's start with 114.7 PSIA. You will see some significant changes. Comparing steam at this pressure with steam at the pressures in the previous examples, we find these changes: the Temperature has gone up to 338°F. The Sensible Heat has gone up to 308.94 Btu's. The Latent Heat has gone down to 880.4 Btu's. The Total Heat has gone up to 1,189.4 Btu's, and the Volume has gone down considerably to just under 4 cubic feet (3.89 cubic feet).

Lastly, in the final line of the Table (which is for a gauge pressure of 600 PSIG), you will find that the same trend of changes has continued right up the scale of pressures. You can spot for yourself which of the changes are more dramatic than others.

WHAT KIND OF STEAM?

You may have, at some time or other, heard or read about what is called "saturated steam" or "dry saturated steam." In practice, there are two kinds of steam: there is this saturated or dry saturated steam, both commonly referred to as "steam," and there is "superheated steam." Throughout this chapter, we have been talking about "steam." The difference between this and "superheated steam" will be dealt with later on.

Dry Saturated Steam is steam at the temperature of boiling water at the particular pressure but which does not contain any free particles of water. However, in practice, steam does contain at least some tiny particles of water and so cannot indeed be described as dry saturated steam.

As such, it means that the figures in the Steam Tables would need altering somewhat for them to reflect an accurate picture of the everyday steam we use in the plant. However, assuming the steam we use in the plant is of reasonably good "quality," we can also safely assume the figures in the Steam Table to be correct enough for our purposes.

If your plant steam happened to be of "poor quality," that is very wet steam in which the suspended particles of water are bigger and more numerous. The figures in the Steam Table might then be a bit misleading in making calculations, but let's take it for granted that the following Steam Tables are a reliable guide to the properties of steam.

# Engineering Data

## Steam Tables

| Pressures | | Temperature | Heat in BTU'S per One Pound of Steam | | | Volume |
|---|---|---|---|---|---|---|
| PSIA | In. of Mercury | Deg. F | Sensible | Latent | Total | Dry Sat Cu. Ft./Lb |
| 5 | 19.79 | 162 | 130.1 | 999.7 | 1129.8 | 73.42 |
| 10 | 9.580 | 193 | 161.1 | 981.9 | 1143.0 | 38.37 |
| 14 | 1.410 | 210 | 177.6 | 972.2 | 1149.8 | 28.00 |
| PISG | PSIA | | | | | |
| 0 | 14.7 | 212 | 180.33 | 970.0 | 1150.3 | 26.79 |
| 1 | 15.7 | 215 | 183.70 | 967.9 | 1151.6 | 25.19 |
| 2 | 16.7 | 219 | 186.89 | 966.0 | 1152.9 | 23.78 |
| 3 | 17.7 | 222 | 189.93 | 964.1 | 1154.0 | 22.52 |
| 4 | 18.7 | 224 | 192.83 | 962.3 | 1155.1 | 21.39 |
| 5 | 19.7 | 227 | 195.61 | 960.5 | 1156.1 | 20.38 |
| 6 | 20.7 | 230 | 198.28 | 958.8 | 1157.1 | 19.46 |
| 7 | 21.7 | 232 | 200.84 | 957.2 | 1158.0 | 18.62 |
| 8 | 22.7 | 234 | 203.31 | 955.6 | 1158.9 | 17.85 |
| 9 | 23.7 | 237 | 205.69 | 954.1 | 1159.8 | 17.14 |
| 10 | 24.7 | 239 | 207.99 | 952.6 | 1160.6 | 16.49 |
| 11 | 25.7 | 242 | 210.21 | 951.2 | 1161.4 | 15.89 |
| 12 | 26.7 | 244 | 212.37 | 949.8 | 1162.1 | 15.34 |
| 13 | 27.7 | 246 | 214.46 | 948.4 | 1162.8 | 14.82 |
| 14 | 28.7 | 248 | 216.50 | 947.0 | 1163.5 | 14.33 |
| 15 | 29.7 | 250 | 218.47 | 945.7 | 1164.2 | 13.88 |
| 16 | 30.7 | 252 | 220.40 | 944.5 | 1164.9 | 13.46 |
| 17 | 31.7 | 254 | 222.27 | 943.2 | 1165.5 | 13.06 |
| 18 | 32.7 | 255 | 224.10 | 942.0 | 1166.1 | 12.68 |
| 19 | 33.7 | 257 | 225.88 | 940.8 | 1166.7 | 12.33 |
| 20 | 34.7 | 259 | 227.62 | 939.6 | 1167.3 | 12.00 |
| 22 | 36.7 | 262 | 230.99 | 937.4 | 1168.4 | 11.38 |
| 24 | 38.7 | 265 | 234.21 | 935.2 | 1169.4 | 10.83 |
| 26 | 40.7 | 268 | 237.30 | 933.1 | 1170.4 | 10.33 |
| 28 | 42.7 | 271 | 240.27 | 931.0 | 1171.3 | 9.88 |
| 30 | 44.7 | 274 | 243.13 | 929.0 | 1172.2 | 9.46 |
| 32 | 46.7 | 277 | 245.89 | 927.1 | 1173.0 | 9.08 |
| 34 | 48.7 | 279 | 248.57 | 925.3 | 1173.8 | 8.73 |
| 36 | 50.7 | 282 | 251.15 | 923.4 | 1174.6 | 8.41 |
| 38 | 52.7 | 284 | 253.66 | 921.7 | 1175.3 | 8.10 |
| 40 | 54.7 | 287 | 256.09 | 919.9 | 1176.0 | 7.83 |
| 42 | 56.7 | 289 | 258.46 | 918.3 | 1176.7 | 7.57 |
| 44 | 58.7 | 291 | 260.76 | 916.6 | 1177.4 | 7.32 |
| 46 | 60.7 | 293 | 263.00 | 915.0 | 1178.0 | 7.10 |
| 48 | 62.7 | 296 | 265.18 | 913.4 | 1178.6 | 6.88 |
| 50 | 64.7 | 298 | 267.31 | 911.9 | 1179.2 | 6.68 |
| 52 | 66.7 | 300 | 269.39 | 910.4 | 1179.8 | 6.49 |
| 54 | 68.7 | 302 | 271.43 | 908.9 | 1180.3 | 6.31 |
| 56 | 70.7 | 304 | 273.41 | 907.4 | 1180.8 | 6.15 |
| 58 | 72.7 | 305 | 275.35 | 906.0 | 1181.4 | 5.99 |
| 60 | 74.7 | 307 | 277.26 | 904.6 | 1181.9 | 5.84 |
| 65 | 79.7 | 312 | 281.84 | 901.2 | 1183.0 | 5.49 |
| 70 | 84.7 | 316 | 286.21 | 897.9 | 1184.1 | 5.18 |
| 75 | 89.7 | 320 | 290.39 | 894.8 | 1185.1 | 4.91 |
| 80 | 94.7 | 324 | 294.39 | 891.7 | 1186.1 | 4.67 |
| 85 | 99.7 | 328 | 298.23 | 888.8 | 1187.0 | 4.45 |

**Table 1: Steam Table**

# Engineering Data

## Steam Tables

| Pressures | | Temperature | Heat in BTU'S per One Pound of Steam | | | Volume |
|---|---|---|---|---|---|---|
| PSIG | PSIA | Deg. F | Sensible | Latent | Total | Dry Sat Cu. Ft./Lb |
| 90 | 104.7 | 331 | 301.93 | 885.9 | 1187.8 | 4.24 |
| 95 | 109.7 | 335 | 305.50 | 883.1 | 1188.6 | 4.06 |
| 100 | 114.7 | 338 | 308.94 | 880.4 | 1189.4 | 3.89 |
| 105 | 119.7 | 341 | 312.28 | 877.8 | 1190.1 | 3.74 |
| 110 | 124.7 | 344 | 315.51 | 875.3 | 1190.8 | 3.60 |
| 115 | 129.7 | 347 | 318.64 | 872.8 | 1191.4 | 3.46 |
| 120 | 134.7 | 350 | 321.69 | 870.3 | 1192.0 | 3.34 |
| 125 | 139.7 | 353 | 324.65 | 868.0 | 1192.6 | 3.23 |
| 130 | 144.7 | 356 | 327.54 | 865.6 | 1193.2 | 3.12 |
| 135 | 149.7 | 358 | 330.35 | 863.3 | 1193.7 | 3.02 |
| 140 | 154.7 | 361 | 333.09 | 861.1 | 1194.2 | 2.93 |
| 145 | 159.7 | 363 | 335.77 | 858.9 | 1194.7 | 2.84 |
| 150 | 164.7 | 366 | 338.38 | 856.7 | 1195.1 | 2.76 |
| 160 | 174.7 | 370 | 343.44 | 852.5 | 1196.0 | 2.61 |
| 170 | 184.7 | 375 | 348.30 | 848.5 | 1196.8 | 2.47 |
| 180 | 194.7 | 380 | 352.96 | 844.6 | 1197.5 | 2.35 |
| 190 | 204.7 | 384 | 357.45 | 841.4 | 1198.9 | 2.24 |
| 200 | 214.7 | 388 | 361.79 | 837.7 | 1199.4 | 2.14 |
| 210 | 224.7 | 392 | 365.99 | 834.0 | 1200.0 | 2.04 |
| 220 | 234.7 | 395 | 370.05 | 830.4 | 1200.5 | 1.96 |
| 230 | 244.7 | 399 | 373.99 | 826.9 | 1200.9 | 1.88 |
| 240 | 254.7 | 403 | 377.82 | 823.5 | 1201.3 | 1.81 |
| 250 | 264.7 | 406 | 381.54 | 820.2 | 1201.7 | 1.74 |
| 260 | 274.7 | 409 | 358.16 | 816.9 | 1202.1 | 1.68 |
| 270 | 284.7 | 413 | 388.69 | 813.7 | 1202.4 | 1.62 |
| 280 | 294.7 | 416 | 392.14 | 810.5 | 1202.7 | 1.57 |
| 290 | 304.7 | 419 | 395.50 | 807.5 | 1203.0 | 1.52 |
| 300 | 314.7 | 422 | 398.79 | 804.4 | 1203.2 | 1.47 |
| 310 | 324.7 | 425 | 402.01 | 801.4 | 1203.4 | 1.43 |
| 320 | 334.7 | 428 | 405.15 | 798.5 | 1203.6 | 1.39 |
| 330 | 344.7 | 430 | 408.24 | 795.6 | 1203.8 | 1.35 |
| 340 | 354.7 | 433 | 411.26 | 792.7 | 1204.0 | 1.31 |
| 350 | 364.7 | 436 | 414.22 | 789.9 | 1204.1 | 1.27 |
| 360 | 374.7 | 438 | 417.13 | 787.1 | 1204.2 | 1.24 |
| 370 | 384.7 | 441 | 419.99 | 784.3 | 1204.3 | 1.21 |
| 380 | 394.7 | 443 | 422.80 | 781.6 | 1204.4 | 1.18 |
| 390 | 404.7 | 446 | 425.25 | 779.0 | 1204.2 | 1.15 |
| 400 | 414.7 | 448 | 427.94 | 776.3 | 1204.2 | 1.12 |
| 450 | 464.7 | 460 | 440.80 | 763.5 | 1204.3 | 1.00 |
| 500 | 514.7 | 470 | 452.76 | 751.3 | 1204.1 | 0.90 |
| 550 | 564.7 | 480 | 463.99 | 739.6 | 1203.6 | 0.82 |
| 600 | 614.7 | 489 | 474.59 | 728.3 | 1202.9 | 0.75 |

**Table 2: Steam Table continued**

# Chapter Two

In the first chapter, we gave you a brief picture of what is the composition of steam. Having produced steam, what exactly do we have?

By now, you will have firmly fixed in your mind the primary process of steam making and the "ingredients" used in the making. These "ingredients" can be summed up in one word, "heat." The steam we have made is, in fact, a reservoir of heat in a convenient form.

We intend to use this steam to carry out some process or service which requires heat. Let's see what happens.

## CONDENSATION OF STEAM

When giving up the heat in steam, condensate must form. You scalded your finger when you stuck it into the steam coming out of the kettle spout, just as much as was the other finger which you stuck into the boiling water. We gave the reason that both steam and boiling water were as hot as each other. This is true. Conversely, we will explain now what happens when the steam scalded your finger.

The steam is hotter than your flesh, immediately gave up some of its heat to your finger. It was this heat transfer from the steam to your finger that made you jump. Probably you noticed that your finger, besides painful, was wet. The steam had to give up some of its heat to your cooler finger, and to do so; it had to condense. In other words, the steam that encountered the cooler surface of your finger changed back into hot water and instantly became boiling water, or instead water at boiling temperature.

As soon as steam leaves the source of heat, which generated it from boiling water, it immediately begins to give up its heat to any surface or substance, which is colder than itself. In giving up its heat, it changes back into water, which is at the same temperature. Now we know from the first chapter that boiling water can contain only Sensible Heat. Therefore, the heat given up by the steam in the act of condensing must be the Latent Heat. That, then, is the first and most important thing that we learn about the use of steam for all heat purposes. It is the latent heat of steam that does the work.

Let’s suppose we are boiling soup in a large restaurant. Saucepans aren't big enough, so we use vats designed for cooking large batches of products that are consumed daily, such as in large restaurants or hospitals, or canned and bottled for sale in grocery stores. These cooking vats have a steam jacket surrounding the exterior of the pan. These massive pots are known as kettles in the industry.

Soup is in the kettle, and we introduce steam into the jacket. The steam proceeds to give up its Latent Heat, first to the metal wall of the kettle, then to the soup. The hot water of condensation runs down the wall to the bottom of the jacket. If we left this condensate there to collect, we would find that the water level in the jacket would rise, and the space available for steam would get smaller and smaller. Eventually, the jacket would be completely full of water, and there would no longer be room for the steam to be in contact with the heating surface.

That, of course, wouldn't do at all, so the jacket must be kept drained of this condensation.

Let us suppose that even with a drainage point on the jacket, there are times when the condensing steam in the jacket is forming water at a rate faster than the water is leaving through the drain hole. At such times, there will be water at the bottom of the jacket waiting to be discharged. The jacket will become partially water-logged.

All or most of this water will be at its boiling point. In other words, it will be as hot as the steam which is still entering the jacket. That being so, why should we be so worried about getting rid of this water? Why can't it be as useful as the steam in supplying heat to the soup?

Let's look at our steam tables. Imagine we are using steam at 30 psig gauge pressure. In condensing, every 1 Lb. of the steam gives up about 929 BTU's of Latent Heat. The water of condensation, although at the same temperature, has in it only 243.13 BTU's of Sensible Heat. Even, in theory, the very most we could get out of the water would be only one-quarter of the number of BTU's that we have available in the Latent Heat of the steam. In practice, we would get even less, as you will realize from the following section on "Heating Surface."

Although the Sensible Heat in the condensate is usable, it is far better to remove the water as quickly as possible from the jacket and make room for more steam with its much higher proportion of Latent Heat. There are other and better uses for the Sensible Heat in the condensate, and these issues will be talked about later. So far as our soup kettle is concerned, the main thing is to make the best use of the jacketed space by giving the steam full scope to transfer its mass of Latent Heat to the soup.

If we didn't do this but allowed the condensate to stay at the bottom of the jacket, what would happen? Firstly, we would be wasting steam (we will learn how later) and secondly, the customers would be waiting for their soup, which wouldn't do at all. The soup would take longer to heat up for the following reasons:

HEATING SURFACE

The metal surface of the kettle between the soup and the jacket is what we call the "heating surface." This "heating surface" is the area that has to be in constant contact with the source of heat, which in this case, is steam.

To transfer as much heat as possible and as quickly as possible from the steam and into the soup, we must utilize every square inch of this heating surface.

It should be clear that if we cover up portions of the heating surface, we will reduce the area through which heat can flow from the steam to the soup. That is precisely what we will be doing if we allow condensate to collect in the bottom of the jacket. Part of the heating surface will be covered by water, which means we will be unable to transfer the required amount of heat to the product in a given amount of time.

Let's run through these conditions in light of the information given in the previous chapter.

Comparing the conditions of a partially water-logged jacket with no water lying in the jacket, this is what we find:

The steam is capable of giving up to the soup the same quantity of Latent Heat, the temperature difference between steam and soup is unchanged; the rate of heat flow from the steam to soup also is constant. What is different is the area through which the heat can pass from the steam to the soup. In the partially waterlogged jacket, reducing the area of heating space, so within a given time, we are unable to transfer as much heat from the steam to the soup.

The hot condensate lying in the jacket is only capable of giving up its Sensible Heat to the soup, and as we have discussed, the quantity of Sensible Heat passing through is quite small in comparison to the Latent Heat of the steam. Moreover, when this hot condensate is giving up its Sensible Heat, it has nothing else left, in the way of heat, to give up, and therefore, it will cool off. It would cool right down to the soup temperature was it not for the fact that the steam above it is transferring and, in a way, wasting some of its valuable Latent Heat in keeping the water hot in the upper portion.

We hope this is giving you a clear idea of why the soup would take longer to heat up if the steam jacket was partially water-logged. To be sure we are not missing anything, we have included two illustrations.

In Figs. 3 "A" & "B" you will see a sectional view of a steam-jacketed kettle which we have been using for our soup. In Fig. 3 "A," the jacket is completely filled with steam, which is in contact with the whole heating surface. In Fig. 3 "B," you see condensate lying in the bottom of the jacket and covering a portion of the heating surface.

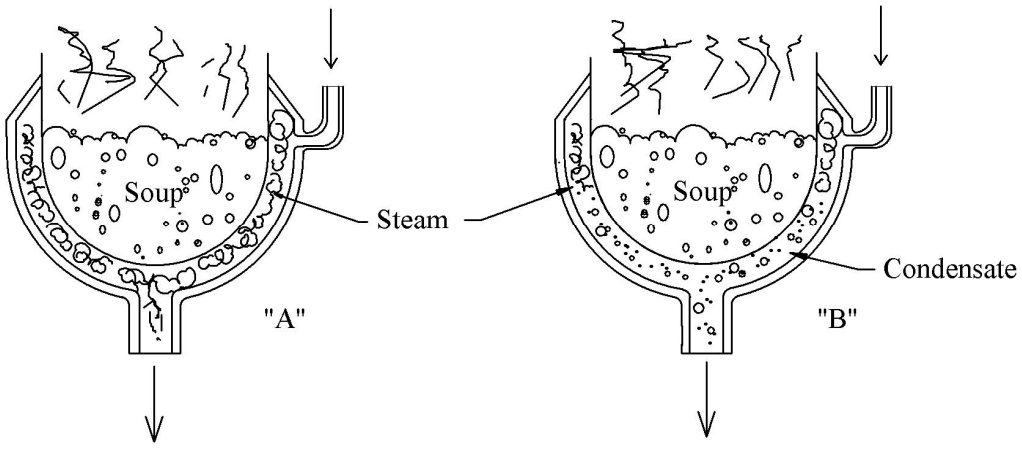



**Figure 3: Soup Kettles "A" & "B"**

Now let's look at Fig. 4 “C.” In this close-up view, you can see more clearly the soup, the metal wall of the kettle, the steam in the jacket, and the condensate, which is lodging in the bottom of the jacket and covering the lower part of the heating surface.

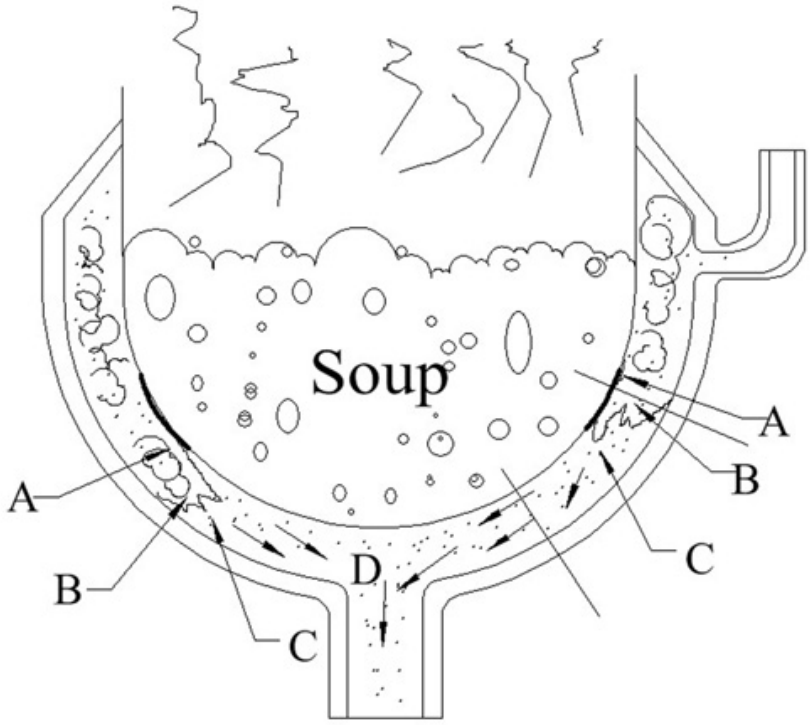



**Figure 4: Soup Kettle "C"**

We said that in theory, the very most in the way of heat we could get out of the condensate would be only a quarter of the number of BTU’s that are available in the Latent Heat of the steam, and we said that in practice we would get even less. Fig. 3 and our Steam Table tell us why. However, there is still more explanation needed: the steam we are using is at 30 psig pressure. Every 1 pound of steam which condenses in the jacket is giving up 929 BTU of Latent Heat. The condensate, when formed, has only 243 BTU’s of Sensible Heat to the pound.

We ask you to note the words "when formed" because not all the condensate, which is lodging at the bottom of the jacket will be at the temperature of 274°F, and not all of it will contain Sensible Heat at the full value of 243 BTU’s per lb.

At 'C' in Fig. 4 the water is being kept at the boiling point by being in direct contact with the steam, so its temperature will be about 274' F. But at 'D' its temperature may not be more than about 220' F. There are two reasons:

(1) Because this is the point farthest from the source of heat, the heat from the steam has to follow the path of the little arrows down through the water to get to ' D . '

(2) The withdrawal of heat from the water and into the soup keeps the water cool since having given up a quantity of its Sensible Heat; the Condensate has little or no reserve of heat left, which is of any real value in heating the soup. Even as the Sensible Heat content of the water at ' C ' will be about 243 BTU/lb. at 'D,' it may not be more than 188 BTU/lb.

Consider the conditions at a stage halfway through the heating up of the soup. This, roughly, is the sort of situation you could expect:

| | |
|---|---|
| Soup temperature: 150°F | Steam Temperature: 274°F |
| Condensate temperature at C : 274°F | Condensate Temperature at D: 220°F |

The temperature difference between steam and soup is 124°F (274 minus 150 = 124). The temperature difference between the condensate at ' C ' and the soup is about the same. However, between the condensate at 'D' and the soup, the temperature difference is only 70°F (220 minus 150 = 70). So quite obviously, the rate or speed of heat transfer between the bulk of the condensate and the soup must be lower than between the steam and the soup. Also, the quantity of heat that the condensate is capable of giving up is small in relation to the amount of heat available in the steam.

Summing up, all of this water lying in the bottom of the jacket is slowing down the operation of the kettle because the bulk of the condensate has comparatively little heat to give up and because it is slower in transferring it to the soup.

As the soup becomes hotter, this situation gradually worsens. The temperature difference between the bulk of the condensate and the soup becomes so small that there is very little heat transfer at all.

THE WATER FILM

That isn't all. Please look again at Fig. 4. When the steam encounters the cooler metal surfaces of the jacket, it gives up its Latent Heat and condenses. This condensation takes place in the form of a film on the metal surfaces. As the film thickens, the water begins to run down the walls. During the whole of the operation, the metal surfaces blanketed by this film of water, indicated by the slightly thicker line at 'A' in Fig. 4. As we get nearer the water laying in the bottom of the jacket, the film of water on the walls increases in thickness, this is marked 'B' in Fig. 4.

We have exaggerated the thickness for illustration purposes. You mightn't think so, but water is a relatively poor conductor of heat, and although the water film, even at its thickest, may be no thicker than a hair, it is a very definite obstruction to the transfer of heat from the steam to the soup. This is conveyed more vividly when we explain that a film of water only one-hundredth of an inch thick (0.01") offers the same resistance to heat flow as a solid wall of iron 1" thick or a solid wall of copper 5" thick.

So, this very thin film of water does put up a powerful resistance to the transfer of heat, and quite obviously, the thinner we can keep it, the better the heat will transfer through to the product.

Let us give you a storybook example to show the effect of this film of water. Suppose we have a flock of sheep in a field. On the other side of the road is another field offering some particularly luscious grazing. The sheep twitch their noses and decide that they are going to get into that other field. To do so, they have to get through a thick thorn hedge and cross the road. If we think of the sheep as the heat in our steam, the thorn hedge as our film of water, the road as our metal wall of the kettle, and the luscious field as our soup, you will have a clear picture of what happens in the soup kettle. The sheep dash the thorn hedge, but what an awful time they have getting through it. Once through though, they get across the road quite easily and into the lovely new pasture. Had it not been for the obstruction of the thorn hedge, they would, of course, have arrived in the new field in a fraction of the time taken.

Sorry to drag sheep into it, but we want you to clearly understand that anything which obstructs the passage of heat from the steam must slow down the operation. Look again at Fig. 4, heat transfer from the steam to the soup around that part of the kettle at point 'B' will be considerably slower than it is higher up the kettle wall. Because the film of water at ' B ' has thickened as the condensate running down the side has accumulated.

What we have been saying in the last few pages is of the utmost importance in steam trapping practice. In general, the conditions in the soup kettle, which we have been using as our example, apply to many types of steam-heated process equipment. The conditions we have described are the cause of wasted steam and delayed output, and they are directly traceable to faulty or inadequate drainage of condensate from the steam space of the process equipment.

## "STARTING LOADS" AND "RUNNING LOADS"

When we first put the soup into the pan, everything was cold. When the steam was turned on, the first thing it had to do was to warm up the metal of the pan. Then it had to start warming up the soup.

In this early stage of the operation, the temperature difference between the hot steam and the cold metal and cold soup is at its highest. In other words, at this early stage of the operation, the most significant quantity of heat per minute is consumed, so the highest volume of steam per minute is used, and the highest amount of condensate formed.

We label these conditions as the "starting conditions" or the "starting load" of steam and or condensate.

When the metal of the kettle is warmed, and the soup begins to heat up, the conditions gradually change. The temperature difference between steam and soup gradually diminishes; the rate of heat flow gradually slows down; the rate of steam consumption eases, as does the rate of condensation, of course.

These conditions are the "running conditions," or the "running load" of steam or condensate.

Why it is necessary to understand and remember these changing conditions during the heating operation will presently become clear:

HEAT LOSSES

Pause for a moment and look again at Fig. 3 “A” and “B.” So far, we have been concentrating on the passage of heat from the jacket to the soup. What else must we consider?

Sometimes fortunately and sometimes, unfortunately, steam gives up its heat in all directions. It is fortunate in, say, a submerged tank heating coil, where the product surrounds the steam heating surface, and we want the heat in all directions, but in equipment such as our soup pan, we need the temperature in one direction only, towards the soup.

As we know, when the steam was turned on to the soup kettle, it had first to warm up the metal; this is referred to as heating by "conduction" because the metal is acting as a conductor for the heat. Besides heating the metal in the direction of the soup (the inner wall), it also heated the metal in the direction of the fresh air around the outer wall of the kettle. Heating anything outside of the kettle is technically known as heating by "radiation" and or "convection.

If you hold your hand a few inches away from the kettle, it will pick up the radiated heat from the kettle wall; the heat which is given up to the fresh air is wafted about by convection currents. The significant point we want to make here is: <u>any heat from the steam in the jacket which doesn't go to warm up the soup is a heat LOSS.</u>

What does this mean? It merely means that in the soup kettle and similar kinds of steam-using equipment, a quantity of our steam has no useful purpose. If it isn't used to warm up the soup or whatever it happens to be that we are heating, then the heat is entirely wasted.

The worst thing is this: When the soup is good and hot, there is as much or more steam transferring to warm up the air surrounding the kettle as is being used to keep the soup hot! You see, as the soup became hotter and hotter, the temperature difference between steam and soup got less and less. So there was less and less heat transmission from the steam to the soup. However, the temperature difference between the steam and the air outside the jacket remained more or less the same. Therefore, heat transmission to the surrounding air was as high at the finish of the soup batch as it was at the beginning.

This brings us now to the point we made a little earlier, under "condensation of steam" about wasting steam due to the partial waterlogging of the steam jacket.

In the soup kettle and any other kind of steam-using equipment, the heat used in warming the metal of the equipment and the heat which may be lost to the surrounding atmosphere during the normal course of operation are referred to as "standing losses." In other words, they are wastages of the heat supplied by the steam which we have to accept whether we like them or not.

These "standing losses" can be quite significant, or they can be quite small, depending upon the steps taken to reduce them. Let's suppose, as an example, that when things are going well, the standing losses from our soup kettle are equal to 54 pounds of steam per hour and that from start to finish, it takes 20 minutes to get the batch of soup ready for the customers. This means that per batch of soup, the standing losses are equal to 18 pounds of steam. Now let us suppose that because of partial waterlogging of the steam jacket due to sluggish drainage of the condensate, the batch takes 30 minutes instead of 20 minutes. The standing losses for the batch then will be equal to 27 pounds of steam, which means that the extra 10 minutes taken to finish the batch have required 9 pounds of additional steam.

Look at it the other way around; suppose it has been normal for each batch of soup to take 30 minutes, but due to an improvement in the way the condensate is discharged from the jacket, we find that we can cut the batch time down to 20 minutes. In that case, we will be saving or gaining 9 pounds of steam on every batch.

A gain of 9 pounds of steam may not seem much. However, imagine that instead of being in the restaurant kitchen, we are in a jam factory, and at this jam factory there are 20 steam-jacketed boiling kettles very similar to the one in the restaurant, and each kettle does 30 batches of jam a day which totals 600 batches a day. We find that by improving the kettle condensate drainage, we can, among other things, reduce the standing losses of heat by, say, 5 pounds of steam per kettle per batch. On the day's work, a saving of 3,000 pounds of steam. If at this plant, the fuel costs are $8.00 per 1,000 pounds of steam, the cash saving per day is $24.00.

Over the year, the factory will have saved over $8,000.00 by merely reducing the standing heat losses per kettle per batch by as little as 5 pounds of steam.

## REDUCING HEAT LOSSES

So, heat flow from steam is not a one-way affair. It would be nice if the heat flowed only in the direction we wanted it to, but instead, it will flow towards any surface or substance which is cooler than the steam itself. Generally speaking, it wants to flow in all directions at once; slower or faster in some directions according to whatever changes there might be in the temperature difference between the steam and all points north, south, east, and west.

In trying to reduce heat losses from steam-heated equipment, there are two ways open to us:

1. we can prevent as much as possible the passage of heat in an unwanted direction, or

2. we can cut down as much as possible the duration of the time during which the heat is flowing in this undesired direction.

For example, 1: We can install insulation (lagging) on those surfaces through which we don't want the heat to flow away from our steam. Even using the very best kind of lagging, some heat will still get away from us. Nevertheless, lagging will be useful in keeping most of the temperature where we want it, inside the unit.

For example, 2: We can do everything possible to remove whatever may be causing delay or hold up during the heating operation. Partial waterlogging of the restaurant soup kettle was a case in point; the sluggish discharge of condensate meant that the soup took longer to heat up, so the heat losses from the kettle were going on much longer and so were higher than they ought to have been. We improved the condensate drainage and shortened the heating uptime, thereby reducing the heat losses.

THE HEAT CIRCUIT

So far, in this chapter, we have seen what happens when steam gives up its heat and, in doing so, condenses. We now know why it's necessary to remove the condensate from the unit in which we are using the steam.

We have seen how heat from the steam can escape without doing any useful work, and we have noted the two main ways of reducing these heat losses.

During the course of this book, we will be referring to all these lessons again and with many significant variations.

Before we end this chapter, we should consider what is called the "heat circuit" of the plant, which will bring us up-to-date with a general representation of what happens or should occur in the average plant where we generate steam and use it for process and heating purposes.

After we generate steam in the boiler, we conveyed the steam through piping to the places where the steam heat is required. There will first be a main pipe or pipes leading from the boiler in the general direction of the various pieces of equipment which use the steam. From the main or mains will be branch pipes to the individual pieces of equipment.

When we open, the boiler valve immediately steam rushes from the boiler and through the main. The pipe being cold absorbs heat from the steam. The main pipeline will become warmer. The heat will then transfer to the cooler surrounding air. Here is where we find our first heat loss. For as long as there is steam in the main, the loss is continuous. It is one of those "standing losses" we mentioned earlier.

As we now know, the thing to do is to insulate the piping and so reduce this standing loss. The better the insulation, the smaller the amount of heat is lost. Indeed good insulation is essential; inferior insulation may even increase the heat loss. You see, if a pipe is insulated with inferior insulating material, the rate of heat loss will still be high. By protecting the pipeline, we have added to the overall diameter, effectively increasing the surface area through which heat can escape and might result in an increase in the standing heat loss.

However, big or little, this quantity of lost heat from the pipe has to be supplied by the steam. In providing it, the steam condenses to water. The waterfalls to the bottom of the pipe and is carried along by steam flow to low points in the main. What happens to this condensate will be described later.

The steam has now reached the branch piping. When we open a steam valve on a piece of equipment, the steam enters and again encounters surfaces cooler than itself. The steam proceeds to give up its heat and condenses; at this point, the conditions are identical or very similar to those in the restaurant soup kettle of our example. Condensate collects at the bottom of the equipment.

As we open, additional valves on the other steam-using equipment, this same event occurs.

The position now is that there is a continuous flow of steam coming out of the boiler. To maintain the steam supply, we must generate more steam. We accomplish this by feeding the boiler more fuel and more water. The boiler also needs makeup water, which replaces the vaporized steam we produced.

You'll remember from the previous chapter the vital point about fuel economy: if instead of feeding the boiler with cold water we feed water which is already hot, we will use less fuel in bringing the water to the boiling point and turning it into steam.

However, hot water doesn't grow on trees. How or where can we get a supply without having to use more fuel in making the water hot before we put it into the boiler?

Perhaps you have already spotted the answer. The condensate, which has formed in the steam main and branch pipes and the various pieces of steam-using equipment, is hot water. We know from our previous lessons that one pound of water, when evaporated, gives us one pound of steam and that when steam condenses, it turns back into one pound of water, which is as hot as the steam.

In other words, the quantity of hot condensate in the steam pipes and steam-using equipment is, for all practical purposes, the same as the quantity of water which we vaporized in the boiler in supplying the steam. Besides, it is at the same temperature as the steam.

Here is the ready-made answer to the question of providing hot water to make up for that which was evaporated in the boiler.

In some way or another, we must get the hot condensate out of the steam piping and steam-using equipment and return it to the boiler.

That is our heat circuit. We will describe practical applications in the next chapter.

One more subject we should touch upon in the present chapter is "superheated" steam.

SUPERHEATED STEAM

So far, when we have spoken of "steam" we have meant "saturated steam."

Having made in our boiler some steam with its full quota of Sensible Heat and Latent Heat, what happens if we add even more heat to the steam?

The steam generated in the boiler, even though it may be of good quality, is moisture-laden. If of poor quality, it will be definitely wet.

By adding more heat to the steam, the first thing that will happen is that the moisture in the steam will evaporate. This first heat added to the steam will be a small quantity of "latent heat of evaporation."

Next, if we continue to add heat, the temperature of the steam will rise. So as we learned in chapter 1, heat, which raises the temperature, is “Sensible Heat.” Thus, the heat which brings about this rise in temperature will be Sensible Heat, and only the Sensible Heat content of our steam will increase.

What we now have superheated steam; steam, which is at a temperature higher than the saturation temperature. Although saturated steam is always at the temperature equivalent to its pressure (see your steam tables), the temperature of superheated steam does not bear any realation to its pressure.

You might think that superheated steam was a far superior article to saturated steam, and for some jobs, it is. However, with very few exceptions, heating process applications are carried out far more efficiently and far more economically with saturated steam than with superheated steam. We will shed more light on this subject in upcoming chapters.

We are placing a glossary here to help refresh your understanding of these terms as they are used extensively through the book.

## A GLOSSARY OF TECHNICAL TERMS

| | |
|---|---|
| ABSOLUTE PRESSURE | the pressure reading which begins at 14.7 Lbs/sq. in. below atmospheric pressure and indicated by psia |
| ATMOSPHERIC PRESSURE | the pressure exerted by the atmosphere; this is 14.7 Lbs/sq. in. |
| BTU | is defined as the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit. |
| CONDENSATE | when steam gives up its latent heat, it condenses. The water of condensation is generally called “condensate.” |

| | |
|---|---|
| CONDUCTION | heating by “conduction” is when heat is transferred from one thing to another as a result of both things being in direct contact (heat is conducted from one to the other). When you stick a poker into the fire, and it gets hot, it has been heated by “conduction.” |
| CONVECTION | heating by “convection” is when heat is carried from one place to another by being wafted along in currents of air (or water, or any other fluid). If the room you are in is warmer because of a fire in the next room, the heat has been carried there on “convection currents.” |
| DRAINAGE POINTS | the outlet for condensate from a steam pipe or a piece of steam-using equipment. |
| DRY SATURATED STEAM | steam at the temperature of boiling water at a particular pressure, but which does not contain any free particles of water. It is the ideal "quality" of steam rarely found in practice. Also, look at Saturated Steam. |
| GAUGE PRESSURE | any pressure above atmospheric pressure. It is the pressure registered on an ordinary pressure gauge and indicated by psig |
| HEATING SURFACE | the surface of a steam-heated pipe or a piece of steam heating equipment which is in direct contact with the steam |
| LAGGING | the heat insulating material used for the surface of piping or equipment. This serves to reduce the standing losses of heat from the steam. |
| LATENT HEAT | the heat, which produces a change of state without producing a change of temperature. In steam, it is the extra heat added to boiling water, which has converted the water into steam. |
| Lbs/sq.in | when pressures are given in pounds pressure per square inch of surface, usually given as so many Lbs/sq. in. |
| PSI | another way of saying pounds per square inch or lbs/sq. in. and it this designation that we will continue to use. Therefore, "psig" will represent "gauge" pressure, and "psia will represent "Absolute" pressure. To convert gauge pressure to absolute pressure add 14.7 psi |

| | |
|---|---|
| RADIATION | when heat is transferred from one area to another while the two areas are separated. The transfer is by direct waves of heat and does not require currents of air to act as a carrier for the heat. When warming your hands in front of a fire, they are being heated by “radiation.” |
| SATURATED STEAM | generally referred to simply as "steam." It is steam, which is generated in contact with water. Also, look under "Dry Saturated Steam." |
| SENSIBLE HEAT | the heat, which produces a rise in temperature when it enters a substance. In steam generation, it is the heat that has been added to water to bring it up to a boiling point. |
| SUPERHEATED STEAM | “saturated” steam from the boiler to which extra heat has been added in a separate apparatus known as a superheater. It is dry steam, and its temperature is higher than the temperature of saturated steam at the same pressure. |
| TOTAL HEAT OF STEAM | Sensible Heat and Latent Heat added together |
| VOLUME OF STEAM | the space occupied by a given weight of steam at a given pressure |

In the previous chapter, we began talking about the "heat circuit" of the plant. Fig. 5 shows this at a glance.

First, there is a boiler generating steam. Then there is the main header carrying the steam from the boiler in the direction of the steam-using equipment. From this main pipework, there is branch piping to engines, processing equipment, heating system, and so on. Thus describes the steam supply portion of our circuit.

However, this is only the midpoint in our system. If we are to make the maximum use of the fuel, we are burning in the boiler. Then we must complete our heat circuit.

Following the arrows in Fig. 5, we see another set of branch piping going away from the pieces of process equipment and the heating system. This branch piping is taking away the condensate, which, as you know, is the water left behind by the steam when it has given up its Latent Heat. As you read in chapter two, this water, although it has plenty of useful heat, can do more harm than good in most of the steam spaces of the equipment, so we must get rid of it.

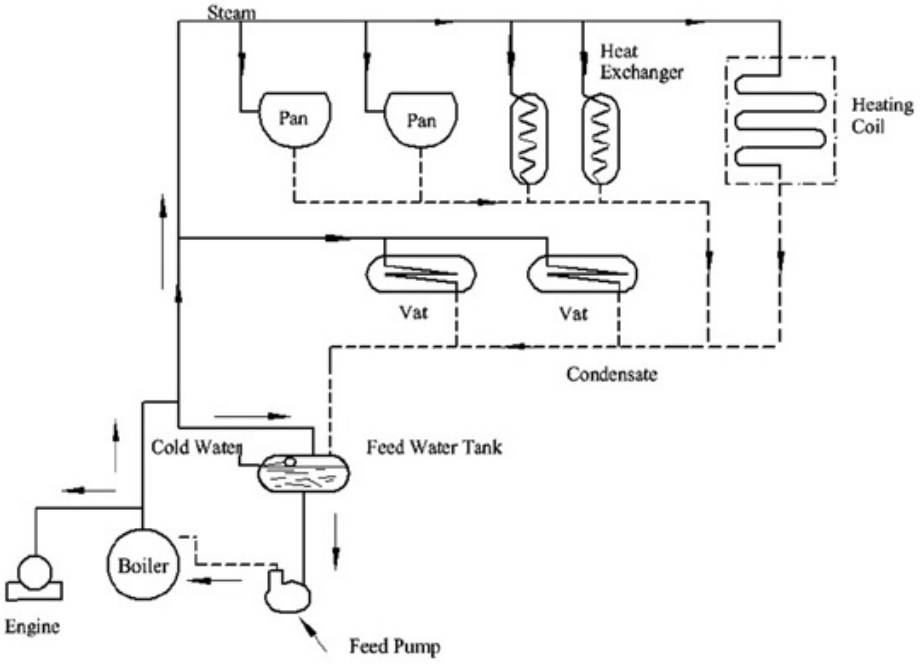



**Figure 5: Heating Circuit**

If we were to throw the water away, it would be like throwing fuel away. Besides, we know that we need a supply of water for the boiler, and here is water, which is already hot, and there's practically enough of it to keep the boiler supplied.

We now refer to this as a "Condensate Return System." The first part of this system is the branch piping going away from the process equipment and heating system. The piping connects into the main return line, which carries the collected condensate back to the boiler feed tank and finally into the boiler itself.

HOW DO WE GET THE CONDENSATE OUT?

What we have given you is only a broad picture of our heat circuit. Now we will go over it in more detail.

The previous two chapters have taken us part of the way. If, for the time being, you will imagine that the restaurant soup pan in chapter two represents all the process and heating equipment in Fig. 5, we have reached the stage in our heat circuit where the steam has completed its work, and what is remaining is hot condensate.

The next step is to get the water out of the steam spaces of the equipment

The restaurant soup kettle shows a single outlet at the bottom through which the condensate could flow. If we connected some piping from the outlet to the main condensate return pipe, we would get the water out of the steam space and return it to the boiler-house.

However, since there is nothing to stop the steam, we would be losing steam at the same time. The drain outlet at the bottom of the steam space, not only is an outlet for condensate. It is also an outlet for steam. Therefore, we have to find a way of discharging the condensate without letting any steam escape from the heating surface chamber.

The first thing that comes to mind is a plug cock or valve, which we could open or close. We could open the valve to remove the condensate and close it to keep the steam from escaping. Let's try it on our soup kettle.

We turn on the steam to the jacket of the kettle. Since everything is cold, the steam condenses rapidly; we now need to contend with our startup load of condensate. Now we open the valve at the drain outlet fully to allow easy discharge of the starting load of water. For the short time that the kettle and soup are cold, the steam will condense at a rapid pace. Condensate will form at its highest rate during this stage, so the valve could probably remain wide open.

After a short period, the kettle and soup will begin to heat up. The transfer rate will start to slow down, and there will be less condensate. Soon we see live steam leaving the valve as well as water. We then close the valve just enough to pass the water but retain the steam.

In theory, I suppose, we might be lucky and do it right on the first try, but we won't rest for long. Soon, we will have to re-adjust the valve to leave an opening, which will allow the smaller amount of water to pass, but no steam.

As we said, in theory, we might be lucky enough to do precisely what we aim to do. In practice, however, it would be practically impossible. Even with the most skilled and knowing touch on a valve, we would waste steam or hold back water. The chances are we would either lose a great deal of steam or cause waterlogging of the equipment.

We could, of course, shut down the valve just a bit more than we need to. This would prevent a lot of the steam wastage. However, unfortunately, it also would prevent some of the condensate from getting out, resulting in partial waterlogging of the steam space, and we already know this is undesirable.

CAN WE USE A CRACKED VALVE?

We might try another alternative. Instead of fiddling about with the valve to keep step with the changes in the rate of condensation in the steam space, we could set the valve so that it is just cracked open.

Before we go on, perhaps we ought to explain what a “cracked valve” means. The term "cracked valve" means a valve that is set so that the valve opening is no more than a crack. In other words, the head is just off its seating, leaving a small aperture or, if you like, a small orifice.

If we were to use a cracked valve for draining the condensate, what would happen? First, air and condensate are discharged through the partly open valve. There would be the heavy starting conditions during which condensate will be squirting out of the valve as fast as it could go, but not fast enough to prevent waterlogging. The valve hole would be small enough to prevent steam from escaping, but not big enough to let condensate out as quickly as it’s formed.

At some point during the running conditions (depending on the amount the valve is cracked open), the outlet would be just right, letting out condensate at the same rate at which it was formed and yet still preventing steam from escaping. Unfortunately, that happy state would last only for a few moments. As the condensate load got lighter and lighter, when we were nearing the finish of the operation, the valve opening would easily pass all the formed condensate, and it would also pass and waste live steam.

CAN WE USE AN AUTOMATIC VALVE

You will realize from what we have said that the use of a hand-operated valve or plug cock, or a cracked valve as a means of discharging condensate is both crude and wasteful.

The hand adjusted valve must have an operator attending to it when he ought to be doing other and much more useful jobs. Even under the best conditions, either we will waste live steam or production will be slowed down due to periods of partial waterlogging or possibly both.

The cracked valve doesn't need an operator, but, as already expressed, it provides for only a fixed rate of condensation, and there is no such thing. The valve opening is right only at one stage of condensation; at all other times, it is wrong. Again, wasting steam and product output will slow down.

What we are looking for is something that will discharge condensate at the rate at which it's formed at any stage of the operation and which will not pass live steam.

The only answer is a valve that automatically opens to release condensate and closes to prevent the passing of live steam from the system. The name for an automatic valve that will give us these results is a "Steam Trap."

Steam traps are not new; they have been in use since before we were born. However, before anybody can begin to think and talk sensibly about steam traps and their great importance in steam economy and plant output, it is necessary to know quite a bit about steam itself and what happens when it gives up most of its heat and turns back into hot water.

ABOUT STEAM TRAPPING IN GENERAL

One thing which may have been impressed upon you during this description of steam, the restaurant soup kettle, condensation, and waterlogging, is the extent to which equipment efficiency and output depend on something which is not generally a part of the equipment. Assuming that the restaurant soup kettle was of average design and workmanship and if its design and workmanship had been twice as good or even if the kettle had been gold-plated and diamond-studded, it would have been just the same.

The efficiency of the best piece of steam-heated equipment ever made must finally be dependent upon the effectiveness of its condensate drainage provisions. If the condensate drainage is sluggish, heating efficiency inevitably must suffer.

Given this, it seems very strange that there are not more makers of steam-heated apparatus who supply their equipment complete with the correct steam trapping arrangement. In many cases, a first-class piece of equipment goes out with nothing but a drain hole to encourage proper drainage. It's become the responsibility of somebody else to stick on a bit of piping and a steam trap. No wonder that new and expensive steam-heated equipment sometimes fails to give the expected performance.

Then there is the question of fuel economy. Good steam trapping is well up on the list of things that will yield substantial savings of fuel. It would be correct to say a fuel economy campaign begins with a better knowledge of steam trapping methods and a better appreciation of their prime importance in the economical working of steam-heated apparatus. Some of the most significant individual examples of fuel-saving had their beginning in a reorganization of the steam trapping installation.

What a pity that all the bad or poor steam-trapping installations in the country cannot be transformed overnight into proper installations. The result in real fuel economy and plant output would be awe-inspiring.

## ABOUT STEAM TRAPS IN PARTICULAR

As we now know, the job of the steam trap is to discharge condensate without allowing live steam to escape. Its role is also to remove air and non-condensibles during start-ups. All steam traps are designed to do just that, but they don't all do it the same way.

If the conditions in steam-heated equipment didn't differ much, then probably one steam trap design would cover them all. However, the conditions in steam-heated equipment vary a great deal. Therefore, there have to be enough different steam trap types to include these variations.

That is one of the first things to remember about steam traps. You can't switch a trap from one piece of equipment to another and expect it to work correctly on both if the conditions vary. When you want to replace a faulty trap in a hurry, it isn't much good going to the stock room and taking a trap at random from the shelves. You are also asking for trouble if you order steam traps merely by size, as you would a pair of shoes. If you think that a particular trap at your facility is letting you down because it isn't large enough to handle the load of condensate. You may not help matters (in fact, you may make them worse) by putting in another trap only because it looks bigger. For many jobs, steam traps no larger than a teacup may be a far better choice than one as large as a giant crockpot. Just because certain traps work well indoors, it doesn't follow that it will work well outdoors in a variety of weather conditions. Just because a steam trap works well when fitted near the condensate outlet it doesn't follow that it will work even passably when installed on the end of a piece of piping several feet away from the condensate outlet.

We have mentioned these few points so that you will understand at the start why there are so many different types of steam traps. Each is right for some jobs, but not one of them is right for <u>all</u> jobs.

Before we go on to describe the various types of steam traps and how they work, we will have to say a word or two about the effect of air in steam traps. Unless we do this, our descriptions of the traps may not give you an entirely clear idea of the advantages and drawbacks of the different types.

## AIR IN STEAM TRAPS

The question of air or non-condensable gasses in steam equipment is a crucial one and one which will be explained in detail later.

For the moment, we want to mention the air which gets inside the steam traps themselves.

When the steam supply is turned off, the entire steam system will begin to fill with air. The air gets in through valves and joints; through vents and open-ended pipes; and so on. The air gets into the steam piping, the empty steam spaces of process equipment, the heating system; in fact, it gets into every place where steam would be when the plant was operating. So, naturally, it also gets inside the steam traps.

Please bear that in mind, unless we do something with the air, it can seriously interfere with the operation of practically every steam trap. It can cause traps to air bind, keeping them closed when they should be opening to release condensate. This results in water being held back in the equipment, creating waterlogging, the same unsatisfactory condition which we described earlier.

Because air is as common as breathing, there is a tendency for some people to ignore its presence in steam equipment. However, it would be best if you didn't ignore it unless you are prepared to overlook the harm it can do.

Having mentioned that the air which can become locked in particular types of steam traps is something to be reckoned with; we will turn now to a description of the steam trap types in general use.

## STEAM TRAP TYPES

A steam trap is an automatic valve that discharges condensate, air, and non-condensibles from a system while trapping or holding back steam. They fall into 3 major categories:

Thermostatic Thermodynamic Mechanical

The traps in all groups can automatically tell the difference between steam and condensate, but each group goes about it differently from the other.

## THERMOSTATIC GROUP

The traps in this group open or close in direct response to the temperature inside their bodies. The valve mechanism is operated by a thermostatic element that does not move until the temperature reaches a predetermined point. There are two primary types of thermostatic steam traps: Bimetallic and Balanced Pressure.

## THERMODYNAMIC GROUP

Essentially, a thermodynamic steam trap is one that is a time-sensitive cycle device that responds to imbalances of pressure applied to a grooved free moving disc.

## MECHANICAL GROUP

As the name suggests, the traps in this group do the job mechanically. They are open to condensate and close to steam by the action of a float, which may be a closed ball float or one shaped like an upside-down bucket. The movement of the float operates a valve. There are two main types of mechanical steam traps: Float & Thermostatic and Inverted Bucket.

Some users swear by mechanical traps and wouldn't have a thermostatic or thermodynamic trap if offered to them for free. Others always insist on the handy little thermostatic or thermodynamic traps and would scrap all mechanical traps if they had their way.

Both ideas are wrong. Fortunately, the largest group of users has the right idea. They choose their steam trap types according to the nature of the job and the conditions under which we expect the trap to work. That's the only way to get the full benefit from a steam-trapping installation.

Before you can choose the correct trap for each job, you must have at least a good knowledge of the different types, their advantages and limitations, and the way they react to certain conditions. By the time you get through this first book, we hope you will be able to regard yourself as an expert on steam trapping matters.

A steam trap is a separating trap. That is, it can separate condensate and steam. When a steam trap discharges condensate, it does so from one pressure to a lower pressure. If the pressure at the outlet side of the trap were the same as or higher than the pressure at the inlet side, the trap wouldn't be able to work. With pressure at the inlet, which is higher than the pressure at the outlet, condensate not only will be discharged but also will quickly travel. Depending on how much greater the inlet pressure is than the outlet pressure, the condensate when leaving the steam trap can move quite a long way and in an upward direction as well as on the level. We will explain all this in detail later on. For the moment, remember that the pressure at the inlet must be more significant than the pressure at the outlet, or the steam trap won't work. In the ordinary course of things, you couldn't, for instance, expect the steam trap to return its condensate directly into the boiler because the pressure in the boiler would be equal to or greater than the pressure at the steam trap. What does happen, in most cases, is that the condensate from the steam trap returns via the condensate return main to the boiler feed-water tank and then pumped into the boiler utilizing the boiler feed pump.

The thing to do for the moment is to become familiar with steam trap terms by understanding the differences between the types and how to take advantage of the merits of each.

Some traps discharge their condensate in a continuous flow. The flow will vary from a trickle to a gush according to the rate at which condensate is forming in the steam space of the unit. When traps work in this fashion, we refer to them as "continuous discharge traps."

Some traps get rid of their water in another way. They discharge condensate in periodic rushes or cycles. After each cycle, which is like a blast, the trap shuts off entirely until there is a fresh collection of condensate, after which there is another cycle or blast as the trap opens wide again. The periods between cycles and the length of the cycles vary according to the rate at which condensate is forming in the equipment. When they work in this fashion, we refer to the traps as "blast discharge traps."

Certain traps can operate either as a continuous discharge or as a blast discharge trap, depending on the conditions under which they happen to be working. You may hear some people say that they dislike blast discharge traps because of the noise. They prefer quieter continuous discharge traps.

You will hear others say that they prefer blast discharge traps because of unmistakable open or shut action. They are suspicious of the "dribbling" of a continuous discharge trap.

A sensible attitude comes somewhere between these likes and dislikes. The experienced steam trap user knows that in some places, the noise of a blast discharge trap might be undesirable, but that in many other areas, the noise wouldn't matter at all. He knows, too, that the dribble-to-gush action of the continuous discharge trap is in the nature of the trap. He knows that in some jobs the sudden discharge and sudden shut-off of the blast discharge trap might show an advantage over a continuous release; but that on other jobs the smoother conditions, with the constant discharge trap are just what is wanted and that a quick blast and shut-off would be a drawback.

The next chapter will give a full description of each type of steam trap in the thermostatic, thermodynamic, and mechanical group.

We hope you're not beginning to think to yourself that steam trapping is a complicated business. It need not be, much of it is just plain common sense. There are some things you must know and remember if you are going to get the most out of your steam trapping. By learning these features and acting accordingly, your rewards are in fuel economy, better plant operation, and output and less maintenance.

To receive the fullest benefit from this book, try to use a mentor who can help you understand these principals, and answer your questions. If you are unable to find such a person and need answers to any issues that may arise, send us an e-mail to Orders@EngineeredSolutionsCan.com, and we will do our best to provide you with a useful response.

THERMOSTATIC GROUP

The traps in the thermostatic group depend for their operation on the fact that virtually all materials expand when they are heated and contract when they are cooled.

The Thermostatic Group of steam traps are in two main sections titled: Balanced Pressure and Bi-Metallic.

BALANCED PRESSURE THERMOSTATIC

The main component of this style of trap is the thermostatic element, sometimes also referred to as the bellows. It is either a chamber formed from a corrugated metal tube or one that is formed from seam welded stainless steel discs (as shown in our figure 6) or from seam welded stainless steel diaphragms sealed at each end.

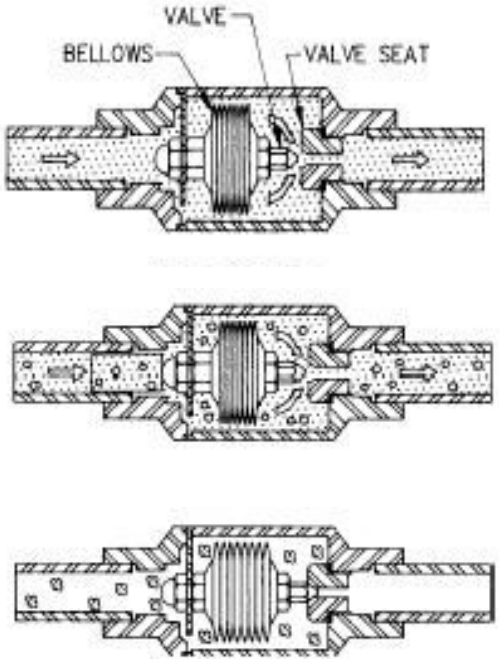



**Figure 6 Balanced Pressure Thermostatic**

On the bottom of the element is a valve head which is free to enter the valve seat orifice when the element expands toward it. The top of the element is held rigid, so any movement of the bellows due to expansion or contraction must take place at the free end.

we charge the element with an alcohol mixture which has a lower boiling point than water (generally 10°F to 15°F below the boiling point of water), but, like water, will rise with the operating pressure and will follow the steam chart (Table 1 on page 20 at a constant temperature below that of steam. That is: it's balanced with the system operating pressure, which exerts itself equally on the element. So, condensate close to the temperature of steam will cause some of the alcohol mixture to change state and flash into a vapor, which in turn causes the element to expand until movement is stopped by the element head, making contact with the valve seat. The pressure inside the bellows will then hold the element valve head firmly in the seat orifice until the condensate cools enough to allow the alcohol mixture to condense back into a liquid and the element to contract.

Let's look at the trap in operation. Before starting your system, the element head is completely removed from the trap orifice leaving the trap in the open position. Steam is turned on, and the air in the system is pushed forward and exhausted through the open orifice. Following the air is cool condensate, which releases through the open orifice.

As the condensate warms, it transfers some of its heat to the alcohol mixture inside the element, and as the condensate continues to become hotter, the temperature of the alcohol mixture inside the element rises with it. Before the exiting condensate has reached steam temperature, the alcohol mixture reaches its boiling point; some of it flashes into a vapor and expands the element forcing the element head onto the seat orifice.

The trap is now closed, and the steam following the hot condensate cannot escape.

Presently the condensate surrounding the element cools, allowing the alcohol mixture inside the bellows to cool and its vapor to condense, which relieves the pressure in the element. The element can contract and draw the element head away from the seat orifice, releasing the cooled condensate, repeating the cycle.

The system operating pressure makes absolutely no difference to this trap's operation so long as it is, of course, within the limit of the trap's operating pressure and temperature range. It is the temperature that operates this trap, and because it always closes below steam temperature, regardless of the pressure, steam should not escape while it is functioning correctly.

Balanced Pressure Thermostatic advantages:

This type of trap automatically adjusts itself to variations of steam pressure.

These traps are relatively small in size, yet have a large condensate handling capacity.

When the trap is cold, the valve is wide open. Meaning:

(a) the trap discharges air on startup

(b) the condensate discharge capacity of the trap is greatest when the amount of discharged condensate is the greatest

(c) when installed correctly, condensate will drain freely from the trap, and it's considered freeze-proof when installed vertically outdoors

Besides being able to remove air on startup, this trap will continue to release any air which reaches it during normal operations.

It is an easy trap to maintain. When it is necessary to renew the thermostatic element and the valve seat, the job of taking out the old and putting in the new is a matter of minutes, and with most selections, it is not necessary to remove the trap from the piping. When replacing the element and the valve seat, you have renewed all working parts, and the trap is as good as new.

Balanced Pressure Thermostatic disadvantages:

A cycling trap any condensate that forms while the trap is in its closed position cannot discharge until the condensate within the trap cools sufficiently for it to open again. Cycles are short, but the nature of its operation, this trap retains some condensate.

These are not the most robust of steam traps, and models using a corrugated thermostatic element are susceptible to damage by water hammer. However, those using either a welded stainless steel or welded diaphragm style element can withstand moderate water-hammer.

BI-METALLIC EXPANSION THERMOSTATIC

Bi-metallic steam traps utilize the opposing expansion of two dissimilar metals to create element movement; some manufacturers use stacked bi-metal discs on a centre stem while others use bi-metal strips, each too much the same effect. The higher the temperature, the greater the element movement or force generated will be.

Since a bi-metal element is only sensitive to temperature, it is necessary to set this trap to close at a specific temperature. To attain some variance to this, set the temperature based upon the operating pressure, the element head is located downstream of the seat so that the system pressure will oppose the pull of the element. That is: the system pressure will push against the element head, increasing the necessary force required by the element to draw it closed. The greater the system pressure, the higher the temperature needed to bring the head into the closed position.

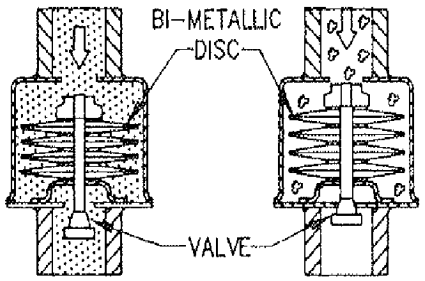


**Figure 7 Bi-Metal Thermostatic**

With careful attention to design details, it is
now possible to manufacture a bi-metallic trap that will remain relatively balanced over a short pressure range. The elements in these traps are usually not a simple bi-metallic lever or arm with a valve on one end, but rather an arrangement of bi-metallic disks or spokes which exert a graduated force on the valve when the operating pressure and temperature vary.

Bi-Metal Thermostatic advantages:

These are robust steam traps and can withstand moderate water-hammer.

When the trap is cold, the valve is wide open. Meaning:

(a) the trap can discharge air on startup

(b) the condensate discharge capacity of the trap is most significant when the discharge amount of condensate is at its coolest

(c) when installed correctly, condensate will drain freely from the trap, and it's freeze-proof when installed outdoors

Because the closing temperature is adjustable, the Bi-Metal traps are sometimes utilized as a temperature control device.

Bi-Metal Thermostatic disadvantages:

Unless the closing temperature is set below 212°F, there will always be steam lost during start-up, and since most applications are above 0 psig, this would result in the holding back of condensate and flooding of equipment and piping unless a long cooling leg was installed before the trap. If we were to select this trap for operation at 50 psig, we know from our steam table that we would have to sub-cool the condensate by at least 86°F (298°F for 50 psig steam minus the 212°F setpoint). If we were to set the closing temperature higher than 212°F, say 250°F, to lessen the sub-cooling, then, on start-up, steam would whistle through until the system pressure rose to at least15 psig. This one major flaw excludes this style of steam trap from consideration for most applications.

THERMODYNAMIC

This type of trap depends on a principle that is as old as steam itself, but before World war II never was incorporated in steam trap design.

We will try to explain this principle by describing a straightforward experiment. As shown in fig. 8 below, we take an ordinary spool, preferably one from which the thread has been removed, and place a thin cardboard disc with a pin through the centre on the bottom of the spool so that the pin sticks up through the centre hole.

The pin is to keep the disc from moving sideways. Now, if we blow hard into the open end of the spool, the cardboard will stick tight to the bottom and cannot be blown off. What happens is the air is blown out between the disc and the spool so quickly that it creates an area of reduced pressure between the disc and the spool. Since we have atmospheric pressure pushing up on the disc, and this reduced pressure zone above it, the disc is held close to the bottom of the spool.

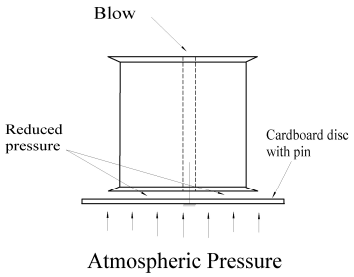



**Figure 8 Spool**

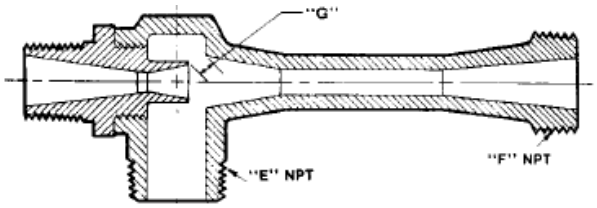



**Figure 9 Suction Tee**

This is an example of Bernoulli's Effect, the same principle that led to airplane flight, and you don't have to understand it, just to believe it completely. You cannot have flow without subsequent pressure drop.

Perhaps another example will make this clearer. In fig. 9, we show what is commonly known as a suction tee, syphon, or sometimes an educator. You may have seen this device used for emptying laundry tubs, barrels, or any standing water or liquid. When attached to a cold water tap, water from the tap runs straight through the fitting and draws in the liquid being syphoned through the centre connection "E" and discharging it along with the flowing tap water.

The same basic principle that worked for the thread spool and cardboard disc applies here as well. When the water is forced through the restriction orifice “G,” it must speed up, and it is this speeding up that reduces the pressure, allowing atmospheric pressure acting on the water in the tub to push it up to connection “E” through a connecting hose or pipe. Hopefully, you can see from these examples that reduced pressure occurs whenever we have a fluid moving.

We use this same principle on the thermodynamic steam trap. Here, we replace the cardboard of our spool experiment with a solid stainless steel disc "A," and the spool tube by the inlet tube "B." When this disc is seated on "B," it also closes off the outlet "E." Now, when air, steam, or condensate enters the trap through "B," the pressure raises the disc and opens the outlet "E." Air and condensate flow fairly slowly across the underside of the disc from inlet to outlet. Because the flow is relatively slow, the pressure on the underside of the disc is not reduced too greatly, and the pressure of the entering fluid keeps the disc raised.

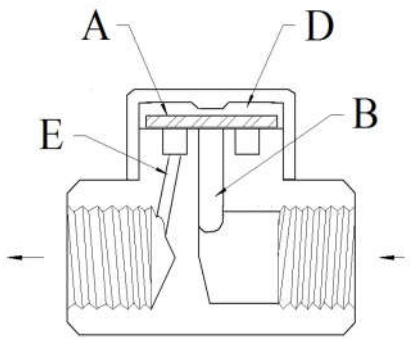



**Figure 10 Thermodynamic Steam Trap**

However, when condensate immediately in front of the steam reaches the trap, this slightly lower pressure causes some of this condensate at steam temperature to flashback into steam. We know from our earlier lessons that the water temperature cannot exceed the boiling point, and we know from our steam table that if the pressure drops, even slightly, the boiling point drops with it. While we will deal with this in more detail in Chapter 9, suffice to say right now, some of this condensate will flash into steam when it enters a lower pressure. As we also know from our steam tables, this flash steam takes up much more space than water. To escape this expanded steam must travel across the underside of the disc much more quickly, and the pressure on the underside of the disc is reduced even more. While this is going on, some of this flash steam finds its way around the disc into the chamber “D” above the disc and applies its pressure down onto the disc’s upper surface. Effectively, we now have a higher pressure on the top of the disc than on the bottom. The disc snaps tightly onto its seat, closing off both inlet "B" and outlet "E." Immediately the flow across the disc and seat stops. The full line pressure exerts itself upon the portion of the disc, which covers the inlet port, but this upward force on this small area is not immediately sufficient to offset the lower pressure pushing down over the entire upper surface of the disc.

Therefore, the disc is held onto its seat until the flash steam in the upper chamber starts to condense and loses enough of its pressure that the system pressure on the smaller area below is enough to overcome it, lifting the disc and repeating the cycle.

Thermodynamic Steam Trap Advantages:

Thermodynamic steam traps are small and robust, meaning that they will radiate less heat than larger traps and can withstand moderate water hammer.

Most thermodynamic traps will operate on all pressures from 10 to 600 psig (depending on the model) without any adjustment.

Thermodynamic steam traps have only one moving part, so there is very little to wear out.

When installed correctly, this trap is self-draining and can be installed outdoors.

These traps will vent air under slow start-up conditions.

Efficient operation can usually be determined by listening to the distinct snapping action of the disc on each cycle.

Thermodynamic Steam Trap Disadvantages:

Generally, the steam pressure at this style of trap should not be below 10 psig, and although some manufacturers specify acceptable operating pressures as low as 3 psig, this style of steam trap functions much better at higher pressures and should only be considered for those applications.

The pressure at the trap outlet must not exceed 50% of the supply pressure, so care must be used when selecting for discharge into pressurized returns.

This type is typically not manufactured in sizes above 1”.

The thermodynamic is a cycling trap, which will hold condensate back while the trap is in the closed position.

Over-sizing will cause a rapid cycle (sometimes referred to as machine-gunning), which will shorten the life cycle and cause steam loss.

This style of steam trap does not respond well to the rapid fluctuation of condensate loads.

This style of a steam trap will air bind on a quick start-up. On a quick start-up, forcing air to travel at steam velocity, and it will cause this trap to cycle, and as air does not condense, the time between cycles tends to be quite long, delaying start-up times and retarding condensate removal.

MECHANICAL GROUP

There are two basic types of mechanical steam traps: Float and Thermostatic (mechanism style or free float style) and Inverted Bucket

Sometimes the ball float lever-type steam traps are referred to as closed float traps or F&T float traps. However, as there are different kinds of "floats," it is just as well to be clear on this point.

These float traps, outwardly, vary quite a lot in shape and size according to the manufacturer, but the mechanical movement inside is pretty much the same in all of them (with some slight variations). A simple illustration of this mechanical movement would be the float valve in a toilet where there is a plastic arm with the valve at one end and a plastic float at the other. The float rises and falls with the level and in doing so, shuts or opens the valve, which controls the amount of water entering the tank.

This said we would explain the difference in the operation of the various types of float traps in general use.

FLOAT AND LEVER TYPE

A simple example of this type is shown in Fig. 11. With a continuous discharge action, condensate from the equipment being drained enters the trap at "A." In the diagram the float "B" is seen at its lowest position, however when condensate enters the trap, the float, being buoyant, rises with the level of the condensate.

The float arm "C" connects the float and the outlet valve "D," so as the float rises, the movement gradually opens the valve and allows some of the condensate out through the “D” outlet valve orifice. If condensate is entering the trap quicker than it is being discharged, the float will continue to rise with the condensate level, thus lifting the valve head further from the seat orifice, which allows more water to leave the trap cavity.

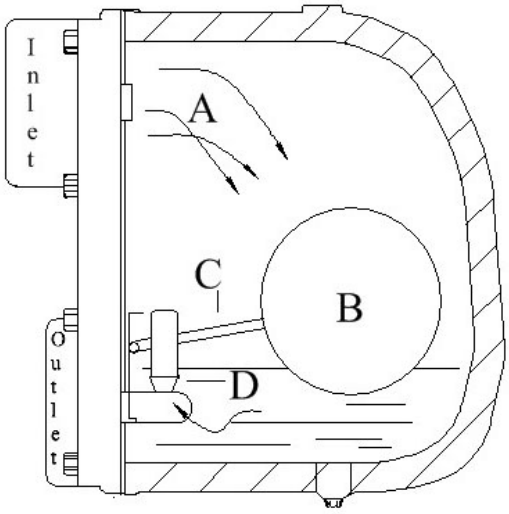



**Figure 11 Float & Lever Trap**

Until there is as much condensate leaving through the orifice as entering, the float will rise to its limit of travel. If, when the float reaches the limit of travel, the amount of condensate entering through "A" is still greater than the amount leaving; then the trap is too small for the job.

Assuming, however, that the trap is correctly sized and there isn't any pipe scale or foreign substance obstructing the valve head and seat, at some point, the float stops rising. This happens when the flow of condensate leaving the trap matches the flow into it.

Eventually, as the steam demand diminishes, the flow of condensate into the trap will ease off. When that happens, the water level inside the trap will begin to fall. The float will lower, and with it, the outlet valve head will begin to close. When the flow of condensate to the trap increases again, the float will rise with the rising water level; the outlet valve head will open wider, and the flow of water from the trap will increase.

As you will perceive, the position of the valve head varies according to the level of condensate in the trap body, and the amount of valve opening varies according to the amount of condensate flowing into the trap. The discharge sometimes is a dribble and sometimes a gush, but so long as condensate is coming into the trap, there will be a continuous discharge from it. If at any time there isn't any condensate entering the trap, the float will be at its lowest level, the outlet valve will be closed, and steam will be unable to escape.

We have detailed how Fig. 11 deals with condensate, but we haven't said anything about air discharge. Without something with which to release the air (which is <u>always</u> present when starting), condensate would be unable to flow into the trap as the trap would be air-bound.

Fig.12 example takes us a step further, a float trap, which, in some respects, is similar to Fig. 11 but has one significant improvement. Installed inside the trap is an automatic air venting device, doing away with any need for somebody to manually look after an air valve.

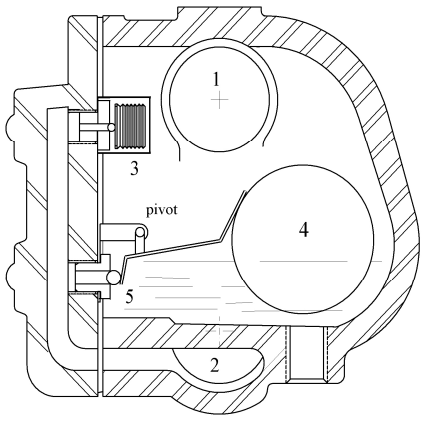



Fig. 12, shows the condensate inlet marked as # 1 . The inlet is on the top side of the body, so that condensate entering the trap falls to the bottom; the float #4 and valve head #5 are connected to a mechanism lever which in turn is attached employing a pivot pin to a seat bracket which is being held in place on the trap cover by the seat. Before starting, the float is at its lowest position, and valve # 5 is closed. When steam is turned on, there has to be, as we have already explained, an outlet for the air which is inside the trap. The device marked # 3 serves as the method to remove this unwanted air.

**Figure 12: Float & Thermostatic Steam Trap**

Item #3 is a thermostatic air vent which has a valve head and seat and functions the same as the balanced pressure steam trap we read about earlier. The air vent is wide open when everything is cold, hence when the steam is turned on, the steam pushes the cooler air through the pipe and into the trap, through the open thermostatic air vent, down the cored passage in the cover and out at the port marked # 2 . This air vent remains open until steam reaches the trap. As soon as steam is present, the thermostat #3 expands and pushes the valve head into the seat, thus shutting off against the steam. Air is automatically discharged from the trap, and any chance of air binding is eliminated.

Following this air is condensate, and as described before, the water level in the trap rises and lifts the float. This movement lifts the valve #5 away from its seat, and the condensate is discharged through #2. Let's see what happens under various conditions:

If there happens to be a large quantity of condensate, but no steam entering the trap, #5 is open, and #3 is open, so that condensate has a chance of getting away through the thermostatic air vent as well as directly through the main outlet valve.

If condensate and steam are entering the trap together, the main outlet valve will be open to discharge condensate. The steam will not be able to escape as the main valve seat is always underwater and is sealed off against the steam and since steam is now present in the trap, the air vent (#3 ) has expanded and closed its valve, so there's no chance of steam escaping there either.

If steam only is reaching the trap, the water level in the trap will be at its lowest. Therefore, the float will be at its lowest position holding the valve head (#5) against its seat below the waterline, and the air vent (#3) will remain closed, so nothing is being discharged. If at any time, air reaches the trap, it will collect at the top, and its cooling effect will contract the thermostatic element of the air vent (#3), which will allow the air to discharge automatically.

From this, you will see that whatever the conditions, this trap will get rid of condensate and air but will not release live steam.

Now we ought to summarize the advantages of the float type traps illustrated by Figs. 11 and 12.

Float Trap Advantages:

Whether the condensate load is heavy or light, this type will work equally well.

Oversizing does not affect its operation, and it isn't affected by vast and sudden changes of pressure within its operating range.

A float and thermostatic steam trap automatically discharges air on start-up and will release any non-condensables that may form during operation.

Because the float and thermostatic trap discharges condensate immediately, it is the best selection for those applications where loads are fluctuating, and this alone will encompass most process applications.

Float Trap Disadvantages:

As with all mechanical traps, the energy required to pull the disc away from the discharge orifice is determined by the orifice diameter, the differential pressure across it, and the available energy generated by the buoyancy of the float, the length of the float arm and the fulcrum point. Within any specific size of the mechanical trap, the float, float arm and fulcrum point remain fixed, so the only way we can adjust the energy required to pull the disc away from the seat is by changing the diameter of the seat orifice. Therefore, mechanical traps must have different sizes of valve seats for different pressures; each size of valve seat or discharge orifice is suitable only for a limited steam pressure range.

Because of its water prime, do not install this trap outdoors or anywhere where freezing might occur.

While most float and thermostatic steam traps can withstand slight water hammer, they are not considered to be a robust trap and should not be selected where water hammer is known to exist.

This style of trap is quite bulky compared to those previously mentioned, with the larger body surface, which radiates more heat, we lose more BTUs which cost money!

FREE FLOAT TYPE

Fig 13 Is the simplest example of a free-float trap. Condensate from the process drains entering the trap at " A . " When the water in the trap is at the lowest level, the float "B" is at rest on the stop "C" and covers outlet orifice "D." As condensate enters, the water level rises, as does the float, the condensate can flow freely flow out through valve orifice "D."

When the flow of condensate to the trap eases off, the water level in the trap falls, and the float drops with it, covering the outlet orifice "D." When steam follows the condensate, the float seals off the valve orifice, and the steam cannot escape as the pressure in the system holds the float against the valve orifice.

More condensate entering the trap raises the float gradually uncovering the outlet orifice so condensate may leave the trap. Depending on the rate of condensation in the equipment, the flow of condensate from the trap will vary from a lot to none at all. So, as in the previous float and lever style, the free float type also has a "continuous" discharge action. Air is discharged through the automatic thermostatic air vent at the top of the trap to eliminate any air binding.

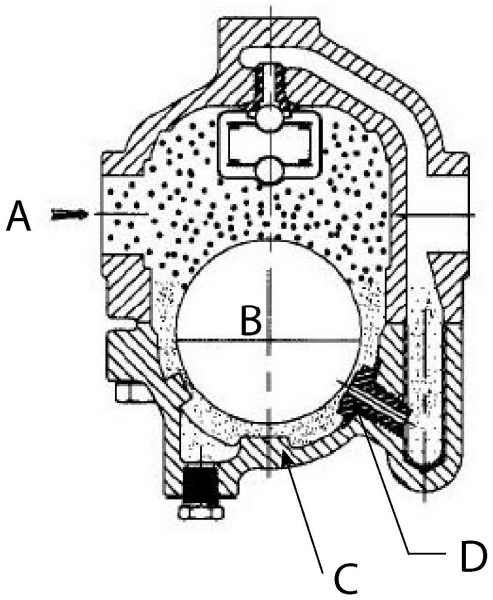



**Figure 13: Free Float trap**

Free Float Advantages:

This trap has all the advantages of the lever type float trap but does not have mechanical moving parts. So there is less to go wrong mechanically.

Float Trap Disadvantages:

All the disadvantages of the lever float trap, plus this style is more susceptible to a build-up of debris in the bottom of the trap stopping the float from seating properly.

MECHANICAL GROUP - BUCKET TYPE

In the bucket trap, the valve of the trap is operated not by a closed float as in those we have just described, but by a float shaped like an open bucket with straight sides.

There are two kinds of bucket type traps. One is called the open-top bucket trap, which was replaced in the marketplace by the second type, The Inverted Bucket trap. Although there is still one source of the open bucket traps today, I have not seen one in operation in the past forty years, so we can skip this and talk entirely about the most commonly used style.

INVERTED BUCKET TYPE

Let's experiment with a cup and a washbasin. Fill a washbasin with water, hold the cup upside down and place the open end carefully and evenly into the water. Push the cup down towards the bottom of the basin.

Now, do you feel the cup pushing upward against your hand?

That "pushing upward" is what happens inside the inverted bucket trap. Steam provides the operating force by entering the overturned bucket and causing it to float.

If you take your hand away from the overturned cup in the washbasin, it will at once bob up to the top of the water. Whereas with the bucket of the trap, steam inside the bucket is doing the pushing up.

As you can see, the effect of this imprisoned air in the cup gives you a fair idea of how a collection of air in certain types of steam traps air bind the trap and temporarily stop it from working. Put the cup upside down into the water as you did just now. Instead of taking your hand away, slowly tilt the cup. Some of the air will escape with a plop. Now, take your hand away quickly, and the rest of the air will force itself out, and the cup will fall to the bottom of the washbasin.

This little experiment is worth doing because it is a simple but convincing demonstration that air is real and something that you must never overlook in connection with steam trapping and steam jobs.

If we review fig. 14 below, this is what happens when steam is turned on to the equipment: on start-up, the bucket "A" is down and the valve head "B" (which is operated by the movement of the bucket through a lever arrangement) is open, away from the seat orifice. First, any air entering the bucket slowly leaks out through a small vent hole "C" in the 'top' of the inverted bucket. The air is forced out by the pressure behind the condensate, which is coming to the trap. The air, after passing through the little hole "C" is now in the upper part of the trap cavity and is discharged through "B" out of the trap.

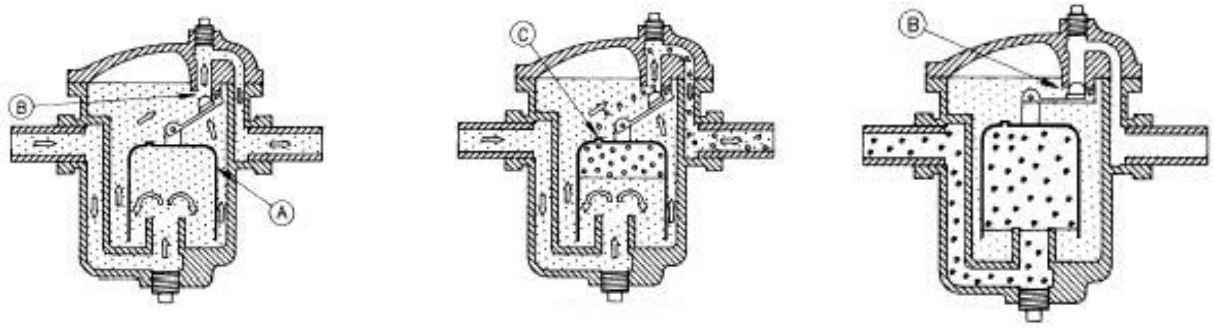



**Figure 14: Inverted Bucket Trap**

Condensate enters the trap raising the level of the water within the trap both inside and outside of the bucket. The bucket, being heavier than water and with all of the air exhausted, is at its lowest position, the valve head is away from the seat orifice, discharging all the condensate.

When steam enters the trap, it fills the inverted bucket, which then floats. Remember the air in the overturned cup pushing the cup against your hand? This upward movement closes the valve head "B" against the seat orifice. The trap is now shut, the steam cannot escape.

The steam trapped inside the bucket will gradually condense, and some will slowly escape out through "C" just like the air did previously, as this condensing and escaping steam is replaced by condensate, the bucket sinks, repeating the cycle.

Yes, like the thermostatic and thermodynamic, this too is a cycling steam trap, sometimes referred to as having a blast discharge and sometimes also referred to as a lift trap. However, don't be fooled by these terms, effectively, all cycling traps have a blast discharge, and it isn't the trap that lifts the condensate, it is the pressure of the system which will push it up, if necessary. There will be more on this later.

Inverted Bucket Trap Advantages:

It is a robust trap and can withstand moderate water hammer conditions.

The seating mechanism is at the top of the trap and is less susceptible to fouling due to scale and rust deposits than other types of traps.

Inverted Bucket Trap Disadvantages:

This style of trap consumes steam to perform its cycle.

It does not vent air well on start-up. Although this trap will vent air, it does so slowly and, on start-up, air from the system, arriving much more quickly than it can escape through the bucket vent hole, raises the inverted bucket and forces the trap to cycle and this air cycle is slower than a steam forced cycle as the air is not able to condense. Therefore, the time taken to start-up is longer than with traps that readily vent air.

To properly function, there must always be a water seal or prime around the lip of the bucket. The trap can lose this prime if the pressure were to drop suddenly; some of the prime could flash into steam, allowing the bucket to fall and steam to escape until the condensate replaces the prime.

Because this trap retains a prime, do not use outdoors or where freezing may occur.

Like the float traps, this style of trap is quite bulky and as well as consuming steam to perform its cycle; it also has a large body surface through which to radiate heat.

What we have described in this chapter are the main types of steam traps you are most likely to come across. There are many modifications to the operating principles we have discussed, but you won't go wrong if you make yourself familiar with the main points brought out in this chapter.

Know the characteristics of the general run of steam traps and then match them as closely as possible with the aspects of the jobs where you are applying them. That is the basis of good steam trapping.

Starting in the next chapter, we will try to show you how to sort out the characteristics of any condensate draining job, and how to decide which trap or traps will match best to them.

## Chapter Five

### THE DRAINAGE POINT

Whatever type of steam trap used, you should always remember that the trap does not draw the condensate to it.

For good steam trapping, you must always be sure that the condensate can find its way quickly to the trap. Unless you do this, you will never have good condensate drainage.

We all know that water will run downhill without any assistance, other than gravity, of course. Well, it's precisely the same in a piping system. For the moment, let us think of water in a pipe. If the pipe slopes, the water will run through it in the direction of the drop. As long as the pipe is the least bit off of the horizontal plane, the water will flow in the downward direction until it reaches the lowest point in the piping, where it will begin to collect.

Therefore, if water collects at the lowest point of a pipe system, that point is the place to drain away the water.

That may seem quite elementary, but you would be surprised just how many times this simple fact is ignored.

There is a tendency to think that because of the pressure in a steam system, condensate will behave differently from water, which collects when not under pressure. Believe this statement and use it as a rule. Water will always accumulate at the lowest point regardless of the system pressure. As elementary as this may seem to you, it is essential knowledge for anyone trying to determine the best location for their steam traps.

#### Draining Steam Mains

With steam-heated equipment of any kind, the makers provide a connection for condensate drainage. However, in the case of steam mains and branch piping, you have to make your drain connections - commonly referred to as "main drips."

A hole of any sort will let condensate out, but as shown in figure 15, if it is too small, some or most of the condensate may pass by.

We have assumed, for this particular exercise, all we need for adequate condensate drainage is a 1/2" steam trap. However, although a 1/2" steam trap may be large enough for the job, we show that only a portion of the condensate traveling along the bottom of the main at this point will reach the trap to be discharged if only a 1/2" drain opening is used. The steam piping is almost always pitched downward in the direction of flow, and as well as flowing by gravity in the direction of this downward pitch, condensate is also pushed along by the steam flowing above it, gaining in speed as it moves along.

The 1/2" pipe feeding the steam trap is satisfactory, but the 1/2" hole in the bottom of the main is too small to catch all of the condensate rushing along the bottom of the main. This hole collects only a small portion of the water, most of which sweeps right across the opening and continues along the main. RESULT: improper drainage practice.

Also, as depicted, much like the water that is pushed by wind across an ocean, lake, pond, or puddle, it cannot travel as fast as the wind and ripples, and then waves start to develop.

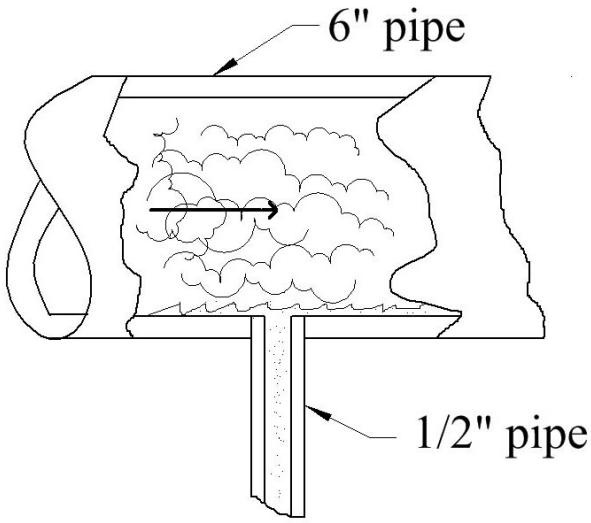



**Figure 15: Main Drip**

The proper way to install a drip leg shown in Fig. 16. Install a full-size T-fitting in the main providing a gap sufficient for the fast-moving condensate to fall into and also act as a dirt collecting pocket. All of the condensate moving along the main to that point will drop into the pocket and find its way quickly discharging through the 1/2" pipe to the trap. Result: excellent drainage. A properly installed drip station is as much a part of a proper trapping installation as the steam trap selection itself.

Before we begin to talk about the correct selection of steam trap types for particular applications, there is something else to be considered when planning any steam trap installation: the importance of dealing with the dirt and scale present in every system.

Dealing With Dirt

Steam traps are automatic valves, not just metal boxes, and like any automatic device, they need occasional attention. How often they need attention depends mainly on how well or how poorly we protect them from foreign matter in the form of pipe scale, rust, grit, or just plain dirt.

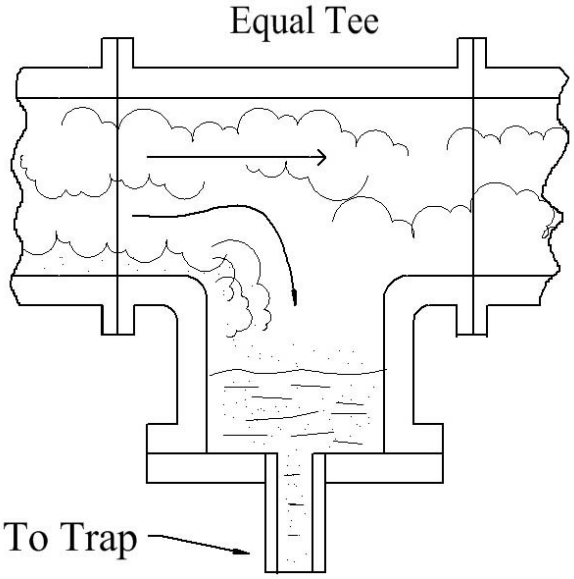



**Figure 16: Equal Tee Main Drip**

In new piping systems, it is not uncommon to find stray bits of casting sand, packing, jointing, solder, welding slag, even nuts and bolts left in the piping.

With older piping systems, there are often rust and scale deposits that have built up in the pipes, and from time to time, bits come loose and flow along with the steam and condensate. Without proper protection, these deposits come to rest in the equipment and steam traps.

Some of this dirt may pass through the trap without consequence, but sooner or later, some will get caught between the valve head and seat of the trap, keeping them open and allowing live steam to pass. Besides this waste of steam and fuel, eventually, the trapped dirt will cause permanent damage to the trap due to "wire drawing." Wire drawing is the erosive result of steam traveling at high velocity across the valve head and seat. Once the head and seat have been etched in this manner, they will never seal tightly again, and there will be a permanent and gradually worsening steam loss until the valve head and seat are replaced.

The point to remember here is that dirt, scale, or any foreign matter inside a steam trap or valve can cause steam wastage and undue wear.

Dirt collection pockets (fig. 17 below left) used to be installed in front of steam traps and valves, and we wouldn't dissuade anyone from continuing the practice, however, unless it is routinely emptied, a dirt pocket will fill and then all of the overflow dirt will go directly into the trap or valve it was designed to protect. Also, while a dirt pocket will likely collect most of the dirt traveling with the condensate. The speed of the condensate rushing into the trap when it is discharging may still carry pieces of dirt across the top of the pocket. Any foreign substance entrained with the much faster-moving steam would easily bridge the gap and move on to a valve or equipment downstream.

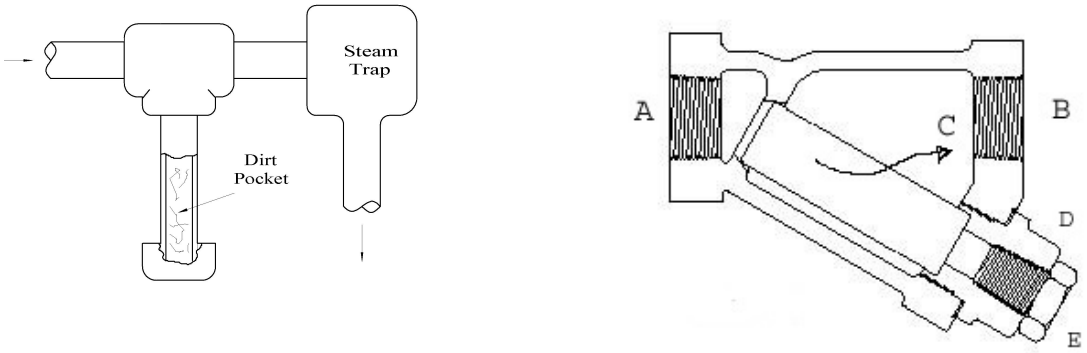



**Figure 17 Dirt Pocket & Strainer**

These days, it is much more common to fit a Y pattern pipeline strainer (fig. 17 above right) immediately in front of every steam trap and control valve. The direction of flow is from "A" to "B," and all flow must pass through the cylindrical screen "C." Following the arrow in the diagram, you will see that although steam and water will readily pass through to "B," the screen will hold back any dirt larger than the selected screen openings. By removing cover "D," the screen can be removed periodically for inspection and cleaning, and most 'Y' strainers also come complete with a plugged connection "E" on the cover.

This plug can be removed for draining prior to screen removal or replaced with a hand-operated ball or gate valve for periodic blow-down, hopefully decreasing the number of times the screen must be removed for inspection and cleaning.

Simple and inexpensive, Y strainers are a valuable part of any steam trap installation, and even though some steam traps have a built-in strainer or integral screen, it is still good piping practice to install a separate strainer.

## CHOOSING THE RIGHT STEAM TRAP

Even though any steam trap will function if the conditions are within its pressure/temperature range and condensate discharge capacity, it isn't enough to merely have a working steam trap; we are aiming to get the utmost heat efficiency and product output from the equipment it is draining.

Just grabbing any old steam trap without consideration of the job at hand can lead to much disappointment and considerable dismay to say nothing of production ability and energy conservation.

The following is a list of some points to consider when deciding on the correct steam trap to select for a given job. It would be a good idea to memorize this list, or at least keep it handy.

(a) What is the highest rate of condensate?

(b) What is the lowest rate of condensation?

(c) What is the steam pressure at the drainage point (i.e., at the trap inlet)?

(d) Is there any pressure above atmospheric at the outlet side of the trap (i.e. are you lifting the condensate or feeding into a pressurized return)?

(e) Are we returning condensate under vacuum, (i.e., does the trap discharge into a condensate return pipe which is under partial vacuum)?

(f) Are we dripping a main? If so, how often does the system shut down and start-up (i.e., daily, weekly, monthly, seasonally, or annually)?

(g) Are we draining condensate from a piece of equipment? If so, is there a manual or automatic control valve controlling the flow of steam to the equipment?

(h) Are we draining condensate from more than one piece of steam heating equipment into one steam trap?

(i) Is air of any consequence likely to be present?

(j) Must the condensate be discharged immediately, or would it be desirable to make some use of some of the Sensible Heat before discharging the condensate?

(k) Are we lifting condensate to an overhead return or discharging into a pressurized return?

(l) Is water hammer present in the supply piping?

(m) Is this an indoor or outdoor application (i.e., is freezing a consideration)?

(n) Is vibration or movement of the equipment a consideration?

(o) Is the supply steam superheated?

We will go through the above list with you item by item and explain as we go along. We are getting into the meat of the book now, so follow carefully and pay attention.

GETTING TO KNOW THE CONDENSATE RATES items "a" and "b."

Before we can begin to consider the type and size of steam trap required for any job, we must know the volume of condensate at a given time.

Most manufacturers of steam-heated equipment will supply reliable figures on the condensation rate of their equipment. However, on retrofit or old installations, it is not uncommon for us to have to calculate this for ourselves by determining the product to be heated and the amount of product to be heated within a specific time frame.

The following formulae will allow you to determine the steam load requirement for any steam heating applications; you are likely to run across. These are used not just for the sizing of steam traps to suit the equipment, but also for the sizing of control valves, steam supply, and condensate return lines. We will deal with all aspects in later lessons.

The formula for determining the amount of steam to heat liquids is usgpm x 8.3 (weight in pounds of each gallon) x 60 (to get from pounds per minute to pounds per hour) x SG (specific gravity of the liquid) x SH (specific heat of the liquid) x required temperature rise in °F = Btu/hr required ÷ latent heat of steam = lbs/hr of steam required.

$$\frac{\text{Usgpm} \times 8.3 \times 60 \times \text{SG} \times \text{SH} \times \text{\^{}T}}{\text{Latent Heat}} = \text{Lbs/Hr}$$

The formula for determining the amount of steam to heat gases is: SCFM (standard cubic feet per minute) x 60 (to get to standard cubic feet per hour) x 1.08 (constant in our formula) x SG (specific gravity of the gas) x SH (specific heat of the gas) x required temperature rise in °F = Btu/hr required ÷ latent heat of steam = lbs/hr of steam required.

$$\frac{\text{SCFM} \times 60 \times 1.08 \times \text{SG} \times \text{SH} \times \text{\^{}T}}{\text{Latent Heat}} = \text{Lbs/Hr}$$

We list these and other formulas on our website under **Tools**. For a complete listing go to:

www.EngineeredSolutionsCan.com

http://www.engineeredsolutionscan.ca/web/calc/index.html

If you have the necessary information, but find the method of calculating the steam load too laborious, e-mail us at orders@engineeredsolutionscan.com

Failing this, on existing applications where not all of the information is readily available, you can always try “the boy and the bucket” method by collecting discharged condensate in a bucket or barrel and note the weight of water collected within a specific amount of time. For example: if in a test lasting 5 minutes, you find that you have collected 10 gallons of water, the rate of condensation in lbs/hr is determined by multiplying our collected water (10 gallons) by its weight per gallon of 8.3 lbs. and multiplying that sum by the number required to get up to an hour (i.e., 60 minutes per hour ÷ by our 5 minute test period = 12) or 10 (gallons collected) x 8.3 (pounds per gallon) = 83 lbs. collected in 5 minutes x 12 (to get to an hour) = 99.6 or approx. 100 lbs/hour steam consumption for this piece of equipment.

THE QUESTION OF PRESSURE AND TRAP CAPACITY “c” “d” and “e.”

In chapter three, we broached this subject when we explained that when a steam trap discharges, it does so from one pressure to a lower pressure. For a steam trap to operate, there must be a higher pressure at its inlet than there is at its outlet.

Aside from making it possible for the trap to work, the difference between the inlet and outlet pressures, known as the "differential pressure," is one of the three factors that determine the "capacity" of a steam trap. Meaning the quantity or volume of condensate which the trap is capable of discharging in a given time, usually expressed as “pounds per hour.”

The discharge capacity of a steam trap is governed by:

(a) the differential pressure,

(b) the diameter of the trap discharge orifice and

(c) the temperature of the condensate

**It should be clearly understood that the size of a steam trap body or the diameter of the inlet and outlet connections have little to do with the condensate handling capacity of the trap or the eventual sizing of a trap.**

The amount of condensate that a steam trap is capable of discharging will increase as the differential pressure increases and will decrease as the differential pressure decreases. Let's examine differential pressure in little more detail.

DIFFERENTIAL PRESSURE

When a steam trap is discharging condensate to the atmosphere, the pressure at the outlet of the trap is, of course, atmospheric pressure; and when we say "discharging to the atmosphere," we don't necessarily mean straight from the trap into the open air. If the trap is discharging condensate into a length of piping, short or long, which is continually pitched in the direction of flow and eventually open to atmosphere, it is considered to be “discharging to atmosphere." If then, the pressure at the inlet to this trap is 50 psig, the differential pressure across the trap is 50 psi.

If the trap is discharging into a pipe that is under pressure, referred to as “back pressure,” of say, 5 p s i and the pressure at the trap inlet is still 50 p s i g ; the differential pressure will be 50 minus 5 = 45 psi. So, to find the pressure difference across the trap, the "differential pressure," you subtract the pressure at the trap outlet from the pressure at the trap inlet.

Taking this one step further, let’s now think of a trap, still with a 50 psig inlet pressure and discharging into a pipe eventually open to atmosphere, but this time the pipe rises 20 feet vertically to get to the overhead return which is pitched downward in the direction of flow. The pressure exerted by the weight of water in a vertical pipe is equal to 1 psi for every 2.31 feet of rise. Therefore, in this instance, there is backpressure at the trap outlet due to the vertical lift. For ease of calculating, it is common practice to figure on 1 psi of backpressure for every 2 feet of lift, and this is quite acceptable for rises that are not too excessive. So, getting back to our example, even though we are feeding into an atmospheric return, we now know the 20 ft. the lift will cause a back pressure of approximately 10 p s i (20 divided by 2 = 10), and the differential pressure across the trap will be 40 p s i , 50 minus 10 = 40.

If besides rising 20 feet above the trap outlet, the pipe was under a further back pressure of 5 p s i , the differential pressure would be that much less. This time the total back pressure would be 10 + 5 = 15 p s i , and the differential pressure at the trap would be 50 minus 15 = 35 p s i

Let’s consider one last example. This time, our trap is discharging into a return, which is at a pressure below atmospheric pressure (a partial vacuum), so the differential pressure must be increased by a pressure equal to the negative pressure. For our example, the trap outlet pressure is 15" of mercury vacuum, which your steam table shows is equivalent to about 7½ psi below atmospheric pressure (more precisely, 7.35 psia). After all, if a perfect vacuum is 30” of mercury (more accurately, it’s 29.96” of mercury) or 0 psia, then, 15” of mercury vacuum would have to be half of the atmospheric pressure. This time, instead of subtracting from the inlet pressure, we add the 7½ psi to get a differential pressure of 57½ p s i

The second of the three points governing the condensate discharge capacity of a steam trap is:

THE SIZE OF THE DISCHARGE ORIFICE

Besides being one of the three things that determine the condensate discharge capacity of the trap, in mechanical steam traps, the diameter of the discharge orifice (the "valve seat area"), also often fixes the maximum pressure at which the trap can operate.

First, let's be sure we are thinking of the same thing in talking about a trap discharge on a mitered seat. There are two openings. The smaller one is the actual "discharge orifice," and the other is the "valve seat area."

In chapter four, the steam trap diagrams, in most instances (balanced pressure thermostatic, float and thermostatic and inverted bucket) show the valve head on the steam pressure side of the trap. In these cases, the valve, when closed, will be held on its seat by the steam pressure.

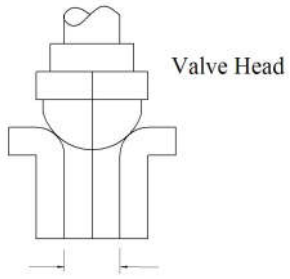


**Figure 18: Orifice**

According to the particular type of trap, the thermostatic element or the float or bucket operating mechanism must have enough power to pull the valve head away from the seat against this differential pressure. In the mechanical float and inverted bucket steam traps, this power is a fixed amount. For those who want a complete explanation, we give the following:

The maximum operating differential pressure for single-seated mechanical steam traps is determined by dividing the available mechanical power (expressed in pounds of force) by the seating area in square inches or conversely, we determine the required operating force by multiplying the maximum operating differential pressure by the valve seat area in square inches.

You may need to read that bit two or three times before you grasp it. Perhaps it will help actually to go through the calculation. If the valve seat is1/8" and our maximum differential pressure is 125 psi, we could determine the necessary pounds of force to be applied by the float mechanism by taking the valve seat area in square inches ($R^2$ determines our area) which is pi (3.142) times the radius (radius is half of the 1/8" or 0.125" diameter) squared or 0.0625 x 0.0625 x 3.142 = 0.01227 sq. inches x 125 = 1.53 Meaning, the fixed operating power produced by the mechanism (determined by the float buoyancy, float arm length, and fulcrum point) would have to be in excess of 1.53 pounds of force to overcome a differential pressure of 125 psi across a 1/8" diameter seat. Don't sweat it; you're never likely to need this formula. Steam trap manufacturers list their trap capacities for different mechanisms at various operating differential pressures; we want you to understand why there are different seat sizes for different pressure ranges.

In the case of the traps with the valve at the outlet side of the valve seat, the situation is different. In such a case the steam pressure pushing to open the valve, so the maximum pressure at which the trap can close is that at which the operating power is just greater than the steam pressure multiplied by the area of the seat orifice (the miter, in this case, doesn't have any effect).

The third of the three points governing the condensate discharge capacity of a steam trap is:

THE TEMPERATURE OF THE CONDENSATE

You might think that if you put a steam trap on test, pumping cold water through it, that the amount of this water the trap can pass at any given pressure difference between inlet and outlet and in a given time would be its maximum discharge capacity, effectively, the boy and the bucket method using cold water. Well, you would be wrong. The published capacity of a steam trap is rarely expressed in cold water figures. To demonstrate why we will go back into the kitchen.

We have a kettle of water on a gas burner. The water is boiling vigorously; we turn off the gas, and almost instantly, the water stops boiling. Immediately we shut off the source of heat the slight pressure that had developed inside the kettle drops.

As we shut off the gas, did you notice that through the vent in the kettle lid, a little puff of steam shoots out? Because of that quick, though slight, drop in pressure, some of the water, though no longer at the boiling point, came out of the lid vent in the form of "flash steam." We will explain all about flash steam or re-evaporation in chapter 9, but for the moment, we want you to realize that what happened to the water in the kettle also happens to condensate when a steam trap discharges it.

Condensate in a steam trap is usually at a temperature above the atmospheric boiling point, and when the condensate passes through the valve seat of the trap, its pressure quickly reduces. Consequently, we generate a certain amount of this flash steam (the amount of flash will depend upon the temperature and the pressure inside the trap as well as the trap discharge pressure).

Now, this is what we are leading to because steam takes up more space than condensate; the flash steam tends to choke the discharge orifice of the trap. The result of this choking is a reduction of the orifice area available to condensate. We will give you just one example to make this point clear.

We have a trap on a test, and we discharge cold water through it. The pressure at the trap inlet is 50 psig, and in one hour, the trap discharges 1,000 lbs. of the water. The test unit temperature is raised to 263°F (35°F below the 50 psig boiling point), and the trap passes only 740 lbs/hr. When the temperature is raised to 25°F below steam temperature only 500 lbs/hr passes, and when the water is still hotter at 20°F below steam temperature, the trap passes only 380 lbs/hr of water.

The same trap and the corresponding pressure difference across the trap, but you see quite clearly, how the discharge capacity is affected by the initial temperature of the condensate. You see how misleading it can be to base the condensate handling capacities of traps on cold-water figures.

Once again, don't sweat it, we're just trying to make a point for your understanding, for the ease of selection, steam trap manufacturers list their trap capacities at various operating differential pressures and have already considered the flash steam effect.

All we have said in this chapter emphasizes the point that the size of the trap body and the pipe connection sizes have little to do with the amount of condensate the trap is capable of handling. As we have said before, you can have a trap no bigger than a teacup discharging more condensate per hour than a trap as big as a cooking pot. It depends on the traps, the jobs, and the conditions.

To ensure you never choose a trap with, say, ½" connections just because it has to go on a ½" drain pipe, here is some interesting data. We looked at random through our own and other steam trap manufacturer's catalogs and found the following ½" traps for sale:

| | | | | |
|---|---|---|---|---|
| 1/2" | Inverted | Bucket . . . . | 750 | lbs. per hour |
| 1/2" | Inverted | Bucket . . . . | 270 | lbs. per hour |
| 1/2" | Inverted | Bucket . . . . | 470 | lbs. per hour |
| 1/2" | Inverted | Bucket . . . . | 620 | lbs. per hour |
| 1/2" | Inverted | Bucket . . . . | 280 | lbs. per hour |
| 1/2" | Inverted | Bucket . . . . | 900 | lbs. per hour |

**Table 3: Capacity Comparison at 40 psi differential pressure**

All the same type, all are working at the same pressure, all the same, pipe connections, but with discharge capacities from as little as 270 and as much as 900 lbs/per hour! Select your trap for the service, not by the pipe size.

When suiting a trap to a particular job, it is necessary to see that its maximum condensate discharge capacity is more than the condensate load to be handled. The margin to allow varies according to the piece of equipment and the type of steam trap selected. Always base the condensate load on the peak demand, which, as we explained earlier, occurs mostly on startup. Another point to remember is that under starting conditions when the rate of condensation is high, the pressure at the trap is often considerably lower than the normal running pressure.

# Chapter Six

In chapter five, we set out fifteen points, which generally have to consider when deciding on the correct type of steam trap to use for any given situation and dealt with the first five. Let's now continue with the next point on the list:

## DRIPPING STEAM MAINS item "f."

We touched on this briefly in the last chapter, and now we'll deal with it in somewhat greater detail.

First, if we are to remove condensate that is forming in the steam piping, as we must, then, as water always runs downhill, a drip station must be located at every low point in the steam system and at intervals of no more than 100 feet on long horizontal runs.

You may ask, "if we are already removing condensate at all the low points, why must we also have drip stations along the horizontal runs"?

Well, as mentioned in the previous chapter, condensate travels along the bottom of the horizontal pipe following the pitch and being pushed along by the much faster-moving steam above it. Steam pipes commonly are sized for velocities between 5,000 and 10,000 fpm (feet per minute) or, if it makes it clearer, between almost 60 and 120 mph (miles per hour). By not removing the condensate, it will gradually build up, infringe upon the space available for the steam and force the steam to travel even faster. The steam flow won't decrease. Therefore it must increase in velocity if it is to get through the decreasing opening. Waves of condensate will form, ever-increasing in size until the entire internal diameter of the pipe is bridged. At that point, we have a slug of water traveling at steam velocities (much like a cannonball or missile) until it hits an obstruction (an elbow, strainer, control valve, or piece of equipment) with sometimes devastating force. We can easily avoid this type of "Water Hammer" with proper trap placements.

Aside from the condensing start-up rate and the running condensate load, to select the ideal steam trap, we also need to know how frequently the steam system is shut down and started up because each time this cycle repeats, we must discharge the air that has filled the system. If the steam system is being shut down and fired up annually or seasonally, substantial volume air removal may not be a primary consideration, but when shutting the system down daily, weekly, or even monthly, air removal starts to increase in importance when considering the correct steam trap selection. To assist you in future drip trap selections, we have included a chart showing both start-up and running condensate loads per 100 foot run of various insulated pipe sizes at different operating pressures.

Since the draining of condensate from steam mains is critical, we recommend that a fail-open trap be selected, and both the balanced pressure thermostatic and float and thermostatic steam traps can fail closed. So, for low-pressure mains, our first choice is the inverted bucket steam trap, and for higher pressures, let's say 50 psig or greater, we could comfortably choose either the inverted bucket or thermodynamic type.

If air removal is a concern, the preferred method of speeding up air removal on the inverted bucket and thermodynamic steam trap installations is to install an air vent off the top of the trap inlet piping and discharge it into the return piping, allowing the air to by-pass the trap altogether.

The most common device for this purpose is a balanced pressure thermostatic air vent, which, in operation, is precisely the same as a balanced pressure thermostatic steam trap but, when installed as described above, will discharge air and close to steam. Just like a steam trap, it is wide open on start-up and closes automatically as steam approaches.

On steam mains, we recommend that an air vent, as described above, also be installed at the end of each run to facilitate the removal of air on start-up.

FLUCTUATING CONDENSATE LOADS item "g."

As you know, in most instances of heating with steam, the highest rate of condensation occurs when starting up because the rate of heat transfer from the steam to the equipment and the product it is heating has the highest temperature difference during this period.

When the medium has heated to its normal maximum working temperature, the condensation rate generally is at its lowest, because the temperature difference is at its lowest and, consequently, the rate of heat transfer from the steam is at its lowest.

On some jobs, the heating equipment is on a continuous process, and the change from a heavy starting load to a lighter running load may happen only once or twice a day.

Whereas on other jobs, the equipment is on a batch process like our soup kettle example in Chapter 2, and it will happen on each batch.

You get similar action in domestic hot water heaters where there are periods when everybody wants hot water at once. During morning and evening in hotels and apartment buildings, end of shifts at industrial facilities and throughout the day at schools and hospitals. The heat exchanger sees a sudden demand for steam with which to heat the inrush of cold make-up water.

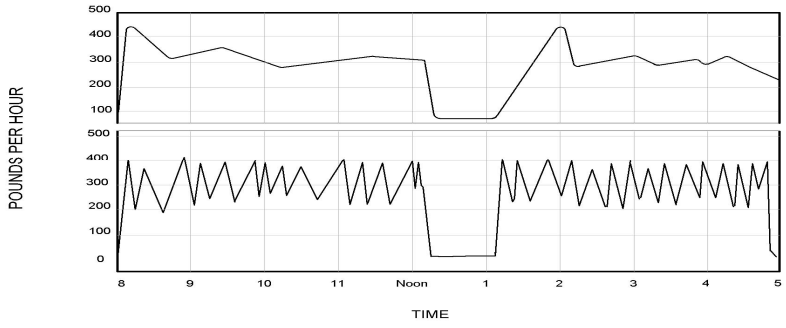



**Table 4: Chart Recordings of Fluctuating Loads**

Let's examine the two charts in table 4.

The upper chart shows what happens in a unit working on a continuous process. At 8 a.m., when we start the unit, we have the peak load of about 450 lbs/hr of condensate to handle; by 8:30, the equipment is up to its normal operating temperature, and the condensation rate has fallen to 300 lbs/hour. There is a sharp drop in consumption around noon when they break for lunch hour, another peak start-up load 450 lbs/hr after the lunch break, and by 1:45 p.m. we are back on the lighter running load again.

The lower chart shows what happens in a unit working on a batch process. Here we can see that each time product is heated our steam consumption at the peak rate of 400 lbs/hr, consumption then drops to around 200 lbs/hr probably when the kettle empties then rises to 400 lbs/hr again at the start of each of the next batches except for the lunch break, of course. Clearly, the quicker we can heat up, the more batches of the product we can produce.

A good rule of thumb would be to always select a modulating steam trap for a modulating condensate load, and the float & thermostatic steam trap is the only true modulating steam trap. After all, spending good money selecting the proper equipment and temperature controls to ensure appropriate process control, and we know that a cycling trap will hold back condensate for the length of its off-cycle, meaning that it could interfere with the already paid process control.

So, always use the Float and Thermostatic steam trap for modulating or even on/off loads unless there are conditions present that prevent this selection. If so, our next choices in order of preference would be thermostatic and then inverted bucket.

GROUP TRAPPING VERSUS INDIVIDUAL TRAPPING item “h.”

The description "group trapping" is applied to installations where the drains of several pieces of steam equipment connect to a single steam trap. This could be some laundry presses or boiling pans; several ironing beds or drying machine cylinders; several heating coils or unit heaters. No matter what, avoid this as it’s an incorrect practice.

Whatever the group might be, each piece of steam equipment, or compartment thereof, should have its own steam trap. This is known as "individual trapping," and you should accept as one of the golden rules of good steam trapping. Hang the expense; if you fail to follow this rule, the likely result will be poor heat up, erratic operating temperatures, uneven heat transfer and impeded output.

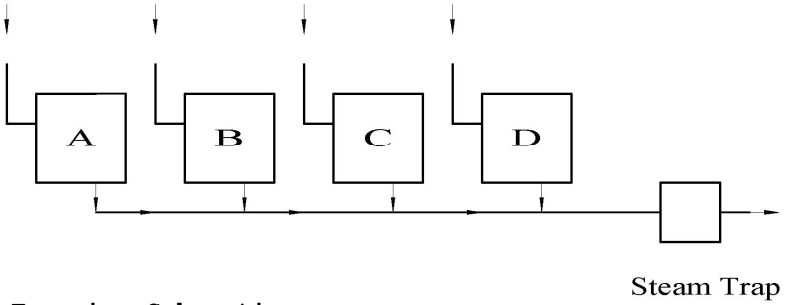



**Figure 19 Group Trapping Schematic**

Let's review the fig. 19 for an explanation:

Let's suppose that units "A," "B," "C," and "D" in our diagram are boiling pans, all working on an equal steam supply pressure. The pans "A," "B" and "C" have been going for a while and are up to temperature, so we consume little steam, the rate of condensation is low, and steam has likely found its way to the steam trap. In contrast, pan "D" is just being started up, and because of this, the rate of steam consumption is high which means that it needs to get rid of its condensate quickly to make room for the steam following it, but it cannot, even though it is the closest pan to the steam trap.

Mainly because the trap is closed, the steam is blocking the way - commonly referred to as "Steam Lock" - locking out boiling pan "D" and the other pans for that matter. Moreover, the trap will stay closed until the steam locking condenses or is by-passed. When that locking steam does condense, the trap will open and start to discharge condensate, but steam from one of the already hot units will find its way to the steam trap and close it again before pan "D" will have had a chance to rid itself of condensate.

So it doesn't matter whether it was "A," "B," "C," or "D" which was being started up, the same scenario would take place; steam from the units which had reached temperature and were condensing at their lightest rate, would enter the trap and close it just when the freshly-started unit had its largest volume of condensate to discharge. Whenever you have two units or more in parallel discharging into a single steam trap, one of them will remove all of its condensate to the trap before another, and the trap will close, steam locking the trap and ceasing all further condensate removal until the steam lock is condensed or by-passed around the trap.

Steam trap selection is not an issue here; there is no fault assigned to the trap. It is merely doing what it was designed to do, pass condensate and hold back steam.

However, you might say "suppose the four units "A," "B." "C" and "D" are exactly the same and always started up together; wouldn't the conditions change simultaneously? Also, in that case, wouldn't a single trap of the right type and size cope with the condensate from all the units"? A fair question and our answer is:

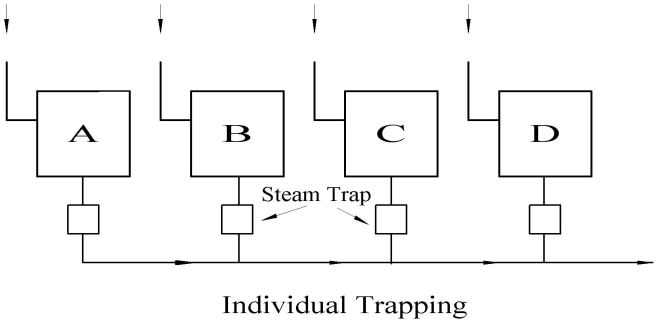
If all four units were started simultaneously, all contained the exact same product, volume, and starting temperature. If the heating surfaces of all the units were in precisely the same state of cleanliness or dirtiness. If the temperature surrounding all the units were the same, that is none subject more than others to cooling draughts from doors or windows. If the drainpipe arrangements and the distances from drain holes to the trap were all identical....if all these conditions were met, then, I suppose, there is a chance that one trap would do the job. But I wouldn't bet on it and certainly wouldn't install it that way.

Fig. 20 shows the correct hook-up. Each boiling pan has its own trap.

Each unit drains directly into its own steam trap, and each steam trap drains into a common condensate return line. No matter how widely the conditions may vary from one unit to another, each trap will cope with the needs of the particular pan, and each pan can perform without interference from conditions in any of the others.

While we're on the subject, group trapping is not the only example of "Steam Locking," and this phenomenon probably bears further scrutiny.

Take our advice, study, and understand it. It is a common problem that can be the cause of inefficient operation, and yet we can avoid it easily.




Individual Trapping

**Figure 20: Individual trap schematic**

Fig. 21 depicts a further example of steam locking showing a steam-heated unit drained by a float & thermostatic steam trap. It is the correct selection, but there is 15 feet of 1" pipe between the outlet of the equipment and the steam trap draining it.

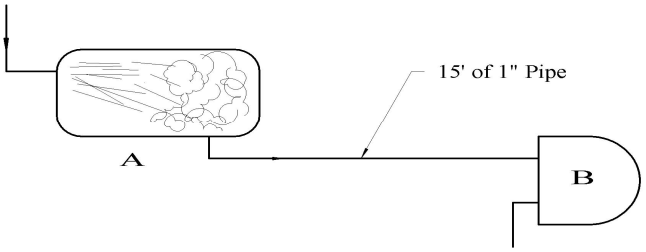



**Figure 21: Steam locking**

When first turning on the steam, everything is cold. Air and condensate from the unit are forced by the steam pressure to the trap and are discharged. Steam follows, and the trap does what it's expected to do, it closes. The pipe from "A" to "B" now is full of steam.

For an experiment to depict what transpires next, take a drinking straw, hold it upright with your thumb or finger sealing off the bottom. Now try and pour water into the top of the straw. Oh yeah, you better perform this experiment over a sink. You will find that water cannot enter the straw because the trapped air is blocking the way.

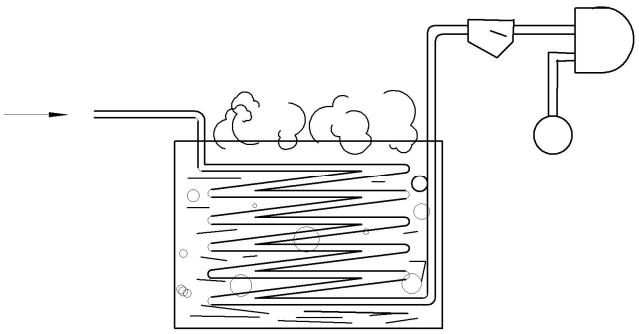


**Figure 22: Steam Locking From Lift**

What happens when steam fills the pipe "A" to "B" in fig. 21. Until the steam condenses, it acts similarly to the air, except that instead of an air-lock, we have a steam-lock, meaning that while we are locked closed, any condensate that forms cannot drain away from the piece of steam equipment.

In this instance, install the steam trap as close as possible to the unit to avoid the detrimental effect of steam locking.

To avoid this, the only other way to ease the effect of the steam-locking is to install a by-pass around the steam trap using an adjustable globe style valve. The valve will allow the trapped steam to escape and speed up the process cycle. Alternatively, select a steam trap fitted with an anti-steam-locking device – depending on the manufacturer, this is either a fixed internal by-pass orifice or an adjustable needle valve fitted into the trap.

Figure 22 is an example of an unavoidable steam locking installation since the coil design dictates that the trap must be at the top. On an initial start-up, steam pushes air through the trap, followed by condensate, which in turn is followed by the steam, which forces the trap to close. Steam now fills the vertical pipe feeding to the trap and blocks the path of any forming condensate. Condensate collects at the bottom of the coil and slowly rises up the vertical lift as the locked steam condenses.

On installations such as this, it is essential that the rising pipe is of the smallest diameter capable of handling the maximum condensate load, and if the trap time cycle is still unacceptable, then a trap by-pass valve or steam lock release must be installed.

AIR IN STEAM SPACES item "i."

Air will always fill the steam equipment when the steam is turned off, and when turned back on, the steam will push the air and non-condensable gases in front of it toward the steam trap.

In chapter 3, we spoke briefly about the air in steam spaces that can result in steam traps becoming air-bound. In chapter 4 we showed clearly which types of traps are subject to air-binding and those which will not air-bind.

Before we go into the main question of the effect of air on the working of the equipment itself, we ought to say something more about traps which can suffer from the impact of air in the system.

Preventing Air-Binding of Steam Traps

Inverted bucket traps may not air-bind completely, but as you read in chapter four, they release air very slowly due to the necessarily small vent hole in the bucket, and it isn't the system pressure which pushes the air out of the bucket because the system pressure fills the trap body encompassing the bucket. The only force available to push the air out of the inverted bucket opening is the buoyancy of the trapped air trying to rise versus the weight of the bucket trying to sink. Fig. 23 will make this point clearer.

To alleviate this problem, mount an optional internal air vent on the bucket. While this allows a larger opening to vent air quicker, even with this optional air vent, air removal through this style of steam trap is still painstakingly slow.

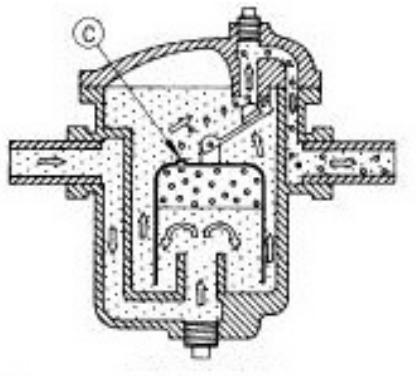



**Figure 23: Venting Air within an Inverted Bucket Trap**

Now we will continue with the main subject of this section; the effect of air on the operation of the equipment itself and the correct methods of dealing with this air.

It is as important to eliminate air from steam spaces of all types of equipment as it is to discharge the condensate. The removal of air is essential for the following three reasons:

1. Air will reduce steam temperature.
2. Air will reduce the rate of heat transfer.
3. Air will impede with heat distribution within the equipment.

Now let's deal with each of these points.

### Effects of Air on Steam Temperature

In any mixture of gases and vapors, each exerts a partial pressure. The partial pressures of these separate gases make up the total pressure of the mixture. The amount of partial pressure exerted by each gas or vapor separately depends upon the proportion of it, which is present in the mixture.

To better explain, suppose we have a mixture of steam and air with a total pressure of 30 psia (absolute), and this mixture is two-thirds steam and one-third air. That being so, the steam exerts a partial pressure of 2/3 of 30 psia, which is 20 psia, and the air exerts a partial pressure of 1/3 of 30 psia, which is 10 psia.

All of the heat in this mixture (above ambient temperature) must come from the steam as the air will contribute nothing, and herein lays the trouble. Instead of the steam having the apparent pressure of 30 psia, it has only an effective pressure of 20 psia, and if we look at our Steam Table in chapter one, we will see that while the temperature of saturated steam at 30 psia is 250°F, at 20 psia the temperature is only 227°F. So, although you would expect a reading of 250°F from the total pressure, the actual temperature of this steam/air mixture is 227°F or 23° less. Meaning, of course, that the heat transfer rate is less than your design or size of your equipment.

From this example, you now know that if the pressure and the proportion of air and steam are known, you can calculate the mixture's temperature. Alternatively, more importantly, if you know the pressure and the temperature, which is much more likely, you can determine the amount of air in the mixture.

### Effect of Air on Heat Transfer

This whole question of air in steam spaces may be new to you, or you may have already been aware of it. In any case, please keep firmly in your mind that this problem is a very real one and that unless equipment users do something about the air, it will most certainly affect the output of their equipment.

To examine the effect of air on heat transfer, let's see what happens when we start up a piece of steam-heated equipment. Remember that the steam space is full of air.

The steam enters the unit and tries to displace the air. The air tries to find an outlet and most pushes towards the drainage point or points. The remainder will compress in the remote reaches of the unit and onto the points of condensation (i.e., the heat transfer surfaces of the unit). The steam will condense on these surfaces, but as the air cannot condense, it forms a thin film over the heating surface. This film of air is a very definite obstruction to the transfer of heat from the steam to the product surfaces of the unit.

A thin layer of air, only one-thousand of an inch thick, can offer the same resistance to the flow of heat as a layer of iron more than 4" thick, or a layer of copper more than 19" thick.

The selected steam trap must discharge the air pushed towards the drainage points. Our first choice would be a Float and Thermostatic model as they release air quickly and remove condensate without any back-up. Our second choice would be the balanced pressure thermostatic type which backs up condensate during their off-cycle, but vent air quickly. Our last desperate selection would be an inverted bucket trap with an external air vent, as described previously. However, none of these selections can do anything to aid in the removal of air trapped in pockets within the equipment. For this, we need to install strategically located balanced pressure thermostatic air vents. Often, equipment manufacturers will correctly install vent connections immediately opposite the steam inlet connections where the air will tend to collect, and just as often they don't. In these instances, you must either create a connection for the air vent or chronically suffer through with a cold spot on your heating surface.

Do Air and Steam Tend to Separate or Mix?

Both happen. After turning on the steam, while most of the air is being pushed out through the correctly selected steam trap, some will blend with the steam on its way to the trap, and air will continue to enter the equipment amid the new steam flowing in. Unfortunately, there is almost always some air in steam, no matter how diligent we have been with its removal. If it is turbulent within the heating space, and it likely is, any air trapped in pockets will eventually blend in with the steam. As the steam condenses, some air becomes separated and finds its way to the steam trap for eventual removal and some deposits itself on the condensing surface retarding heat transfer. You cannot prevent this entirely, but you must endeavor to limit it through good steam trapping and air venting practices.

Air is heavier than steam under similar conditions of temperature and pressure. Steam in the open will always float upward. While the water of condensation will fall. Confirming that steam is lighter, and water is heavier than air. However, this is not necessarily the case with a mixture of steam and air as the relative densities of steam and air are so close that in a mixture, the slightest turbulence will cause them to flow together. So in steam spaces, the tendency is for air to be carried by the steam in the direction in which the steam is flowing. This direction is always:

1. Towards the drainage point
2. Towards the remote parts of the steam space
3. Towards the heating (condensing) surfaces

These facts have a significant bearing on the efficient removal of air from steam spaces.

How to Deal with Air

Air which is present in the equipment can be released by a hand air cock when the steam is turned on, but manual air cocks aren't very efficient for this purpose as they will also vent the blended air and steam. The amount of steam wasted in this manner would depend entirely upon someone's idea as to how long the cock should be left open.

When it comes to dealing with air mixed in with steam, a manual air cock won't do. The only way to effectively remove air from steam-heated equipment is to provide something which will discharge the air automatically. As mentioned previously, the most common device for this purpose is a balanced pressure thermostatic air vent. It is wide open on start-up, closes on the approach of steam, and as air (which separates from the steam during the running period) cools the element; it will open until steam approaches to close it again.

As you have read, air will tend to collect at locations to which it flows smoothly. If you are familiar with the internal shape and construction of the steam-heated unit, you can, without too much difficulty, decide at which point or points the most significant quantity of air will collect. Find these natural collecting points and install air vents.

To refresh your memory, we should mention again that in Chapter 5, we set out fifteen things that generally need to be kept in mind when deciding on the correct type of steam trap to use for a given job.

Since then, we have taken each of those items in turn and discussed them in detail. Let's continue.

USING SENSIBLE HEAT item "j."

With the majority of steam-heated equipment, it is desirable, and most frequently essential, to discharge condensate as soon as it forms. Although the Sensible Heat in the condensate is usable heat, it is generally necessary to immediately remove the water from the steam space to allow the incoming steam to make use of the entire heating surface to transfer its mass of Latent Heat to the product.

Although we are discharging the hot condensate as soon as it forms because we have no more use for it in the steam space, that doesn't mean we are going to throw it away. To do so would be wasting heat.

It was once quite common to let this hot, treated water pour down the drain, and even today, it's not that uncommon to witness good clean condensate going to waste.

Hot condensate is two things: It is water, which costs money to purchase and treat, and it is heat, which takes fuel to produce and money to purchase. In reality, hot condensate is money, and surely only politicians would pour money down the drain.

Hot condensate is a ready-made heating medium, with several excellent and practical uses, not the least of which is getting it back to the boiler as hot as possible. Later in the book, we will say more on this subject and give detail to some other uses for this hot condensate, but for now, the question we are dealing with is whether some application can be made of the Sensible Heat in the condensate before discharging the water from the steam space. This will affect the choice of a steam trap, and the answer is that it depends on the kind of steam-heated equipment and the requirements of the process.

When the primary consideration is to obtain the maximum rate of heat transfer from the steam to the substance, then generally, condensate should be discharged from the steam space continuously, and as soon as it forms and a Float and Thermostatic steam trap would be our first choice.

However, when the primary consideration is economy of heat usage rather than the maximum rate of heat transfer, then sometimes before discharging the condensate, proper use can be made of some of the Sensible Heat. Note that we said some of the Sensible Heat because you cannot release condensate any cooler than the product you are heating.

On jobs where heat economy is more important than rapid heat transfer and equipment output, the best way of taking heat from the condensate and the steam is to control the discharge of the condensate according to the needs of the particular job.

For example, suppose we have a tank or vat fitted with a steam-heated coil. There will, of course, have to be a steam trap on the discharge end of the coil outside the tank. If the trap is a low-temperature discharge type, we will be able to utilize both the Latent Heat of the steam and some of the Sensible Heat of the condensate. Also, if the trap was not just temperature sensitive but also adjustable, we could set the condensate discharge temperature to satisfy our requirements. For this, we would select a bi-metal steam trap with an external temperature adjustment feature.

This steam trap selection can sometimes accomplish two things:

One, it holds back condensate long enough for it to give up some of its Sensible Heat to the process, and two, the trap can sometimes act satisfactorily as a crude product temperature controller.

Understand that this is not a common practice and is only practical for specific applications, such as large storage containers/vessels with internal pipe coils or external wrap around coils where the purpose is not so much to heat the product but to hold it at temperature.

As you may know, there are also instances where open tanks of water or product are heated through the direct injection of the steam into the water. In this circumstance, all of the available Latent Heat of steam and Sensible Heat of condensate enters directly into the water or product. If we take care to ensure that steam does not bubble up past the water and escape, this is the most efficient way to heat, but not always the most practical. After all, you are now adding volume to your product, and your product will be absorbing chemicals from the treated steam and condensate as well as any system deposits that they carry. So remember, by not returning condensate to the boiler, it must be replaced, processed through a water softener, chemically treated, and, of course, heated.

LIFTING CONDENSATE item “k.”

There are two main methods available in returning hot condensate to the boiler room for re-use by the boiler. One approach is using a “gravity return” system; the other is to pump it back utilizing a condensate pumping unit, a “pumped return” or “flooded return” system.

A Gravity Return system is more economical and is the method most widely used in multi-story buildings. Picture a multi-story building with the boiler situated on the lowest level feeding steam up through the supply mains and out to the various pieces of steam heating equipment. Condensate discharges from the traps into return piping, which drops down into return mains located on the ceiling of the floor below, continually flowing down to the boiler feed tank in the boiler room.

Single story buildings are somewhat different. The supply steam mains are usually overhead delivering steam throughout the plant, and the return mains are often beside them, returning the condensate to the boiler feed tank. Our problem is that most of our steam-heated equipment is located down at floor level or close to it, so we must find a way to get the condensate up to those overhead returns.

As we mentioned briefly in chapters 3 and 4, the steam pressure which forces the condensate through the steam traps can also push the condensate up a vertically rising pipe.

Remember? For every p s i of steam pressure at the steam trap, condensate can be lifted to a height of approximately 2 feet (actually 2.31 feet). So if the steam pressure at the steam trap is 20 psig, the condensate could be lifted to a height of approximately 4O feet. If the steam pressure at the trap were to be 50 psig, it would be possible to lift the condensate to a height of about 100 feet. We wouldn't need a pump. So remember, it isn't the steam trap that's doing the lifting; it's the steam pressure at the trap that pushes the condensate upward.

Because of this, you may feel that lifting condensate to overhead returns after steam traps is a reasonable and acceptable practice, but it isn't. Many problems can result if the application has an interruptible steam supply as many do. You can consider your steam supply interruptible if you are making use of a temperature regulator, control valve, or an automatic on/off valve. Even a manual valve to control the flow of steam to your specific piece of equipment, as a throttled steam supply, can mean that you do not always have the necessary pressure at the steam trap to perform the lift.

The best principle to adhere to in steam trapping is: **do not lift condensate and do not feed into a pressurized return**. So, if you are unable to feed your condensate down into a gravity return, you must drop your condensate into a vented condensate return pumping unit and pump the condensate up into the overhead return line. If you adhere to this one principle, you will experience few, if any, steam trap installation problems in your career.

Unfortunately, this is not always practical, and lifting of the condensate is sometimes unavoidable. In these instances, you can effectively lift the condensate if you have sufficient uninterruptible steam pressure at the steam trap to perform the necessary lift. A few steam trap installations where the steam is uninterruptible are main drips, unit heaters (where the fan turns off and on, not a steam valve), platen presses, and rotating cylinders such as corrugators. Just remember, few if any steam systems run 24 hours a day, 365 days a year so when the steam is shut off, each of these steam trap stations represent low spots in the system where condensate will collect, and they must be drained manually or automatically at shut down or start-up.

Positioning Your Steam Trap

It is always preferable to fit the steam trap close to and below the actual drainage point of the unit.

In some cases, however, this isn't possible. An example would be a coil heated tank, where the discharge pipe is not through the side of the tank but rises from inside of the tank. (refer to "steam locking" fig. 22 on page 70). In such cases, the steam trap has to be fitted clear of the liquid at the top of the rising pipe.

Also, note here that there is no improvement in condensate lifting ability when we attach the trap to the top position of a lifting installation. Whether the trap is at the bottom or the top of the lift, the pressure difference across the trap will remain the same.

Fig. 24 depicts a simple example of an installation where we lift condensate a higher level return line with the steam trap in the normal position at the bottom of the rising pipe. Immediately after the steam trap, we show a check valve to prevent condensate from running back through the trap and into the unit when the steam is turned off.

Our condensate is discharged into the top of the overhead return so the condensate can fall to the bottom of the return line, and any flash steam can expand into space above the condensate, thus reducing the likelihood of any water hammer.

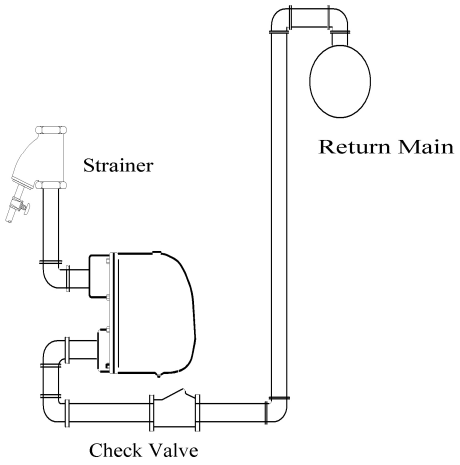



**Figure 24: Lift after trap**

Check Valves

A check valve, used in conjunction with a steam trap, is recommended when you are lifting to an overhead or a pressurized return. Attach the check valve at the discharge of the steam trap to prevents condensate from running back into the steam space of the heated unit when steam is off.

WATER HAMMER item "l"

We already touched on this, but it certainly bears repeating. Since moving condensate has both weight and velocity, it has energy. This means that if the water suddenly stopped, the energy of its weight and movement has to dissipate in some way, and this won't happen without having done something.

When an obstacle suddenly stops moving water in its path, some of the energy will transmit to the obstacle, and some will make the water shoot away in all directions. If the moving water is in a confined space, its energy will transmit to the obstacle and the walls of the space.

Now imagine a slug of his water traveling quickly and meeting an obstacle. Two things happen: the pipe and fittings are stressed, which generates a banging noise. Often the sound as loud as if a hammer had hit the pipe, hence the moniker "water-hammer."

If the velocity is high enough, the condensate is now moving along the inside of a pipe at steam velocities of 50 to 100 miles an hour. Even more, if the volume of water is large enough, the amount of energy given up may be so great as to rupture valves and pipe fittings and possibly cause serious injury to anyone in the general vicinity.

To express just how dangerous water hammer can be, I would like to relate an occurrence at a local utility. A high-pressure underground steam main feeding a building under construction had been turned off at the manhole containing the pressure regulator that provided low-pressure heating steam to that building.

It turned cold overnight; then, the contractor decided to turn on the steam for heating. Someone was sent down into the manhole to open the isolation valve to the building; the mechanic did so and started to climb back out. Unknown to anyone, a support bracket on the supply main feeding steam to the regulator had broken, allowing the pipe to sag since there had been no steam flow, condensate had pooled at this low point.

As soon as he opened the isolation valve, low-pressure steam started to rush through the pressure regulator into the building, and that pool of water in the supply piping was pushed along at steam velocity on its way to the pressure regulator, reaching it at about the same time the worker was exiting the manhole. This slug of water blew the top cover off of that 6" regulator and propelled it skyward through the still open manway narrowly missing the worker who had just that instant cleared the manhole and stepped aside. If that broken pipe hangar had been a few hundred feet closer to that pressure regulator, that worker would likely never have lived to tell the story.

This tale not only points out the hazard presented by this form of water hammer and the need to prevent it, but also the dangers of starting up a system too quickly.

Also, a pipe is a terrific transmitter of noise, so even if the velocity is low, the volume of water is small, and the damage of no consequence, the noise generated can carry through the piping system for great distances disturbing office staff, tenants, patients, or even worse, management.

Triggering Water hammer can be achieved in many ways, and the source of trouble is often some distance from the point at which the hammering takes place, or the damage occurs.

When faced with a water hammer condition, it is always best to find the cause of the problem and either correct the piping arrangement or install drip traps where necessary to resolve the issue.

In trying to eliminate water hammer at the source, you might consider some of the following:

Supply Steam Lines

1. Are the operators in the habit of opening valves too quickly instead of admitting steam gradually? If this is happening, the condensate may not be getting to the drain trap quickly enough to prevent partial choking of the pipe.

2. Are drip trap stations located at all low points, and do all of these drip stations have adequate drain pockets for the condensate to accumulate?

3. Are the strainers installed before the traps or within the steam traps clean?

4. Are the traps the correct type and working properly? Remember, we prefer fail open steam traps for this service, usually inverted bucket or, for high-pressure service, thermodynamic.

5. If the traps discharge into an overhead or pressurized return line, are check valves installed at the trap discharge? If so, are they in good order and properly installed? If not, condensate may be able to return through the trap into the main when steam is off, forming a slug of water that picks up when turning on the steam.

6. Are vacuum breakers installed on the system allowing the removal of free-standing condensate from the system, when the system is calling for steam, the steam cavities are free from cooler condensate? A common form of water hammer is live steam coming into contact with cooler condensate, maybe the most common example: discharging condensate from a high-pressure system into a flooded lower pressure return.

Individual Pieces of Steam Equipment

1. Are you lifting the condensate, and is your steam supply interruptible? If so, you must avoid the lift by draining the condensate down into a condensate pumping unit. As well as affecting your heat transfer, temperature control and production efficiency, the backing up of condensate can result in mild to severe forms of water hammer. Steam coming in contact with cooler condensate can sometimes be expressed as mildly as an annoying clicking sound and occasionally severe enough to make the equipment bounce around. Remember, **do not lift the condensate and do not feed into a pressurized return**.

2. Is a vacuum breaker installed after the steam control valve? If not, a vacuum could form and prevent condensate from draining away, resulting in the same symptoms just described above. One of the best ways to create a vacuum is to fill a space with steam, don't install a vacuum breaker, and then let the steam condense; you run this risk as soon as you start to restrict the flow of steam into a heating space. A vacuum breaker allows air into the steam space to beak any formed vacuum. **Install A vacuum breaker after each control valve that could interrupt the flow of steam into a piece of equipment**.

Condensate Return Lines

1. Do you have any steam traps discharging into a pumped return? If so, flash steam from the discharged condensate will expand as soon as it enters the lower pressure return line. This immediate expansion will quickly push the condensate away, and just as quickly, the flash steam will condense in the cooler condensate and collapse, allowing the condensate to come back together with a hammering effect.

2. Do you have any steam traps discharging into the bottom or side of a gravity return? If so, this creates a similar form of water hammer.

3. Are your return lines sized adequately for the volume of condensate and flash steam they're required to handle? If not, you could experience the same form of severe water hammer that can appear in improperly installed or drained steam supply mains. If there is not adequate space for the flash steam, it will have to travel faster, and it can pick up waves of condensate that eventually bridge the inside diameter of the return pipe – sometimes to devastating effect.

4. Do you have any lifts in your gravity returns? If so, you will likely have water hammer caused by the flash steam trying to get by the condensate collecting at the bottom of the lift. Gravity returns should always be pitched downward in the direction of flow. No lifts!!

If, after eliminating every possible cause of water hammer at the source, there is still reason to suspect its presence, then consideration should be given to it when selecting your steam trap. Most modern steam traps can withstand mild forms of water hammer, but as discussed in chapter 4, some can withstand it better than others.

OUTDOOR INSTALLATIONS item “m.”

When selecting steam traps to be installed outdoors in climates subject to freezing temperatures at any time during the year, take care to choose a steam trap that will remain unaffected if frozen when the steam supply is interrupted or shut-off.

Both the inverted bucket and float & thermostatic steam traps operate with a prime (i.e., they always have a water seal within the trap cavity), and as the water expands when it freezes, these traps could suffer body damage when the enclosed condensate freezes. Consequently, don’t select these traps for outdoor use. If they are, protect them from freezing damage by suitable tracing or thermal drain plugs installed on the drain connection on the body.

When installed correctly, thermodynamic and balanced pressure thermostatic steam traps will not retain any condensate and are deemed satisfactory for outdoor use.

VIBRATION item “n”

Any mechanical trap will be adversely affected by vibration, and therefore you should avoid selecting an inverted bucket or float & thermostatic steam trap. Balanced pressure thermostatic and thermodynamic would be the preferred selections.

SUPERHEATED STEAM item “o”

Although saturated steam is always at the temperature equivalent to its pressure, the temperature of superheated steam bears no relation to its pressure.

What has that to do with steam traps or steam trapping? Refer to your steam tables at the end of chapter one. Saturated steam at a pressure of 100 psig has a temperature of 338°F. If we put this saturated steam into a superheater, it is still 100 psig when it comes out at the other end but at a temperature higher than 338°F. If the steam is given, say, 100 degrees of superheat, we then have steam at 100 psig with a temperature of 438°F.

Now, consider a float and thermostatic steam trap. Suppose we have one of these traps designed to work at any pressure up to a maximum of about 125 psig. This means that the trap ordinarily is not expected to come up against temperatures higher than about 353°F.

However, in our scenario, the trap has to face a temperature that is 85 degrees higher than its design maximum because superheated steam, not condensate, will be in the trap as condensate cannot exist if the temperature is higher than its flashpoint. Even allowing that the trap will, in practice, withstand temperatures higher than its design maximum of 353°F, an excess of the order of 85°F could be more than the element or body components could withstand. When selecting for superheated steam service, make sure that the steam trap design criteria falls within your service conditions.

Avoid inverted bucket steam traps as their condensate prime would evaporate when superheated steam made it to the trap, the bucket would drop and live superheated steam would be exhausted to the return system.

We have only dealt briefly with superheated steam, as there is no need to dwell on it in this primary book. But it should be made clear that for most heating and process applications, saturated steam does a better job than superheated steam.

## THERMOSTATIC TEMPERATURE CONTROL

Let's start with a simple building heating system. We design heating systems to maintain a determined minimum indoor temperature when the outdoor conditions are at their expected worst. Meaning that the heating system will have a heat output capability well above our normal requirements, and without some form of temperature control, the heating system will try to maintain this output even with milder outdoor temperatures.

Remember what we said under "Heat and Temperature" in chapter one and under "Heat Losses" in chapter two: heat will always flow from a warmer substance to a cooler substance. In our example, heat from a warm room or building will always want to flow to the cooler outside air.

The extent of this heat loss from a building depends mostly on the difference between indoor temperatures and outdoor temperatures (that and the effectiveness of your insulation). If we design our heating system to maintain an indoor temperature of 70°F when the outdoor temperature is 0°F, if uncontrolled, it will still want to maintain that temperature difference of 70 degrees even when the outdoor temperature rises. If the outside temperature increases by 10 degrees, the inside temperature will increase to 80°F unless there is something like a thermostat to control it.

In our example, when installing a thermostatic temperature controller set to maintain an inside temperature of the required 70°F on the steam supply to the building. When the outside temperature rises, the temperature controller will modulate or throttle the flow of steam entering the heating system.

As discussed in chapter 6, it is essential to recognize that there is a definite relationship between good temperature control and proper steam trap selection. A Float & Thermostatic steam trap that releases condensate immediately will allow a modulating temperature controller to do its job appropriately.

It is important to remember that regardless of the temperature controller selected, the temperature variations which take place will ultimately depend on the speed at which the heating equipment responds to the adjustments of the temperature controller and on how quickly the controller sensor can sense and react to product output temperature changes.

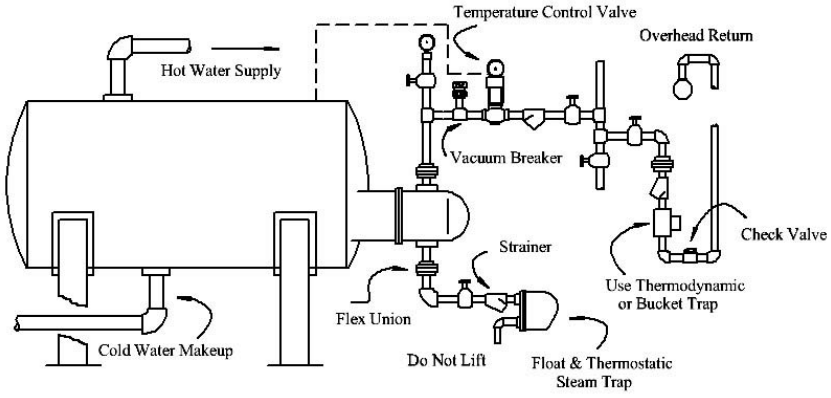



**Figure 25: Thermostatic Temperature Control**

In fig. 25, we show a direct-acting temperature regulating valve controlling the supply of steam to a heating coil in a storage tank, the connecting piping, the steam traps, and associated valves. We show a domestic hot water storage heater, which is simply a closed tank for heating water and holding it ready for use (much like your electric or gas-fired hot water heater at home). The heating coil is a series of pipes or tubes more commonly known as a steam tube bundle into which you feed steam while allowing the condensate to drain away. What we have is a heat exchanger within a water storage tank. This simple diagram will help you to visualize that the type of steam trap fitted on the heater in our example is the best choice where we control the steam supply.

Imagine, installing an inverted bucket trap to remove the condensate. Since it is a cycling trap, it must close each time steam enters and stay closed until that steam has dissipated. There is a temperature regulator on the steam supply line to the exchanger, which is supposed to control the temperature of the water in the tank at 180°F but is having difficulty as condensate is starting to accumulate in the tube bundle taking away valuable space meant for steam. As the hot water temperature drops, the regulator opens to allow more steam into the heating space, but with little effect while the trap remains closed.

When all of the trapped or locked steam is eventually condensed or released, the bucket trap will open and start to discharge all of the condensate that had been flooding the tube bundle. Allowing higher pressure steam to enter from the regulator, which is still open farther than need be due to the waterlogging of the closed steam trap. This higher pressure than necessary steam overheats the water causing the regulator to start to close just as steam reaches the bucket trap, and the cycle repeats itself, creating temperature variations (hunting) in time with the steam trap cycle. A not so uncommon example of a wrongly selected steam trap being responsible for poor temperature control.

The same conditions can occur even if the proper steam trap is selected, but 1) it is installed far enough away to cause steam locking, 2) the condensate is discharged into an overhead return, or 3) by discharging the condensate into a pressurized return.

Remember, when you have an interruptible steam supply, **do not lift condensate and do not feed into a pressurized return**.

On such installations, there are times when waterlogging will be unavoidable. On low loads, the steam pressure in the steam space will be reduced by the control valve until it is insufficient to overcome the head of water in the rising pipe. Example: if the condensate pipe rises to a height of 12 feet, there will need to be a pressure of at least 6 psig at the trap to raise the condensate. The steam pressure may be well more than this some times, but will at times, certainly under light load conditions, be too low to provide the energy needed to overcome the lift or backpressure. At such times condensate will begin to fill up the steam space of the heater, and the cycle we described before repeats its self.

So far, we have only been describing the effects of poor trap selection, and installation has on temperature control.

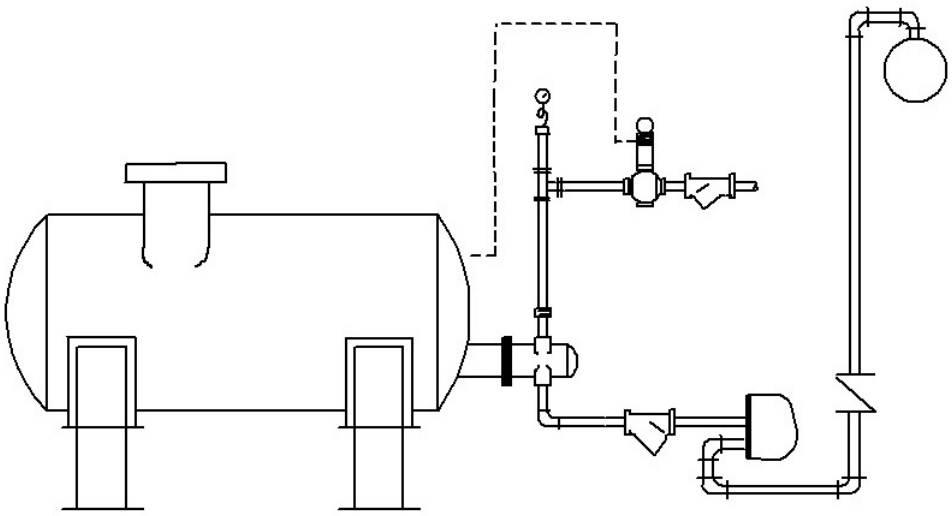


**Figure 26: Water Logging**

Is anything else detrimental taking place? Yes. Whenever steam comes in contact with cooler condensate (as is the case when you waterlog or flood a steam space), it begins to implode or collapse on the condensate sometimes resulting in a mild crackling or clicking sound, sometimes resulting in a more violent banging and crashing or even bouncing around of the equipment. Water hammer! So even the mild hammer indicated by crackling can result in damage to equipment welds and connections and bulging or collapsing of tube bundles.

Geez, anything else? Unfortunately, yes. Without going into a detailed analysis, suffice it to say that as condensate cools, its ability to absorb the ever-present air increases, and as condensate absorbs air, it becomes acidic and will start to pit or corrode the heating surfaces in which it contacts. The cooler it gets, the more acidic or corrosive it becomes.

Of course, there is a simple solution. Is it starting to sink in? Whenever you have an interruptible steam supply, **do not lift condensate and do not feed into a pressurized return**.

If lifting the condensate or feeding into a pressurized return is unavoidable and pumping the condensate is not a viable option, there is one last option to be considered. The control valve could be sized and selected for installation on the condensate outlet of the heating space before the inlet to the float & thermostatic steam trap. This means pressure will always be on the equipment and available to overcome the lift or backpressure.

In this position, the valve controls the product temperature by controlling the condensate discharge. When demand is low, it holds the condensate back, reducing the heating surface exposed to steam. When demand increases, the valve will open wider to release more condensate, thus increasing the heating surface exposed to steam.

You may be asking yourself: 'why is it necessary to have a steam trap if the regulator is controlling condensate discharge'? The control valve may, under sudden or heavy load conditions, open sufficiently to allow steam to reach the outlet. The steam trap can then close to prevent steam loss.

Of course, if this hook-up were the answer to all of our problems, it would have become the standard hookup for all steam control valve applications, and it has not. Some of the issues that exist with this arrangement:

1. Although less air would enter the equipment because the vacuum breaker wouldn't open (under this arrangement, it would always be under pressure) air would still be present, and the condensate would again become corrosive affecting both the equipment and the return piping.

2. Water hammer could still be an issue as the condensate is released from the heating space.

3. The product temperature control will likely suffer somewhat as most of the heat transferred will be from the steam exposed portion of the heating surface, not its entirety.

You're better off to stick with the tried and true way. Control the steam entering the equipment and discharge the condensate down into a gravity return or a vented condensate pumping unit.

We cover the subject of temperature control in greater detail in the advance steam book.

# Chapter Nine

Thus far, this is what this book has aimed to do:

1. To explain clearly and simply the basic principles of steam and steam usage, which form the ground-work of the whole subject.

2. To give reasons why we must remove condensate and air from steam-heated equipment and the best methods of removing them.

3. To correctly guide you in choosing the type of steam trap best suited to the conditions of a particular job.

Step by step, we produced steam and found out how much heat we can expect from it. We conveyed the steam to the piece of equipment in which it is used. We made proper arrangements for venting air and clearing the condensate from the steam space of the equipment.

We can, therefore, now picture ourselves as having traveled step by step from the boiler room and arriving at the outlet side of the steam trap on our steam-using equipment.

## THE HANDLING OF CONDENSATE

For the moment, we will assume that we have not connected the outlet of the steam trap to the return piping. We can see the hot condensate discharging from the open outlet. If we know the steam pressure in the equipment, the steam tables in chapter one will tell us the temperature of the condensate and will indicate how much sensible heat it is likely to contain.

However, besides hot water, we can see steam coming out of the trap outlet. Yet we know that the trap is in good working order and cannot be leaking steam. What then is this steam, and how is it formed?

Please refer to your steam tables in chapter one. We will assume that the steam pressure in our steam-using equipment is 200 psig. According to the steam tables, condensate from steam at this pressure should have a temperature of 388°F, and every pound of the water should contain about 362 Btu's of sensible heat.

However, if we were to place a thermometer in the steam or condensate near the outlet of the steam trap instead of 388°F, the thermometer reading is 212°F, the highest temperature it could be at atmospheric pressure. So according to our steam table, instead of every pound of condensate containing 362 Btu's of sensible heat it now contains only 180 Btu's at atmospheric pressure. What happened to the missing 176 degrees and the182 Btu's?

The 176 degrees of temperature and the 182 Btu's of heat per pound are all in the steam, which we see rising above the condensate. That steam is "re-evaporation steam" or, as it is more commonly known, "Flash Steam."

FLASH STEAM

Flash steam has become an important commodity in modern steam utilization. It is a valuable by-product of condensate recovery. Ever since the first day we used steam under pressure, there has been flash steam. However, until recent years, it was mostly regarded as normal waste and ignored as a source of usable heat. So, before we proceed to talk about any other aspect of condensate handling, we ought to take a good look at flash steam and give it its proper place in the scheme of things.

We made a brief reference to flash steam in chapter 5, in the section dealing with the effect of condensate temperature on the discharge capacity of steam traps. We used the simple example of boiling water in a kettle on a gas burner. When we turn off the gas, the water almost instantly stops boiling. As soon as we shut off the source of heat, the pressure inside the kettle drops very slightly. As we shut off the gas, we notice that through the vent in the kettle lid, a little puff of steam shoots out. Because of that quick, though small drop in pressure, some of the water, no longer at boiling point, came out of the lid vent in the form of flash steam.

As you have learned from our study of chapter one and the steam tables, as the pressure of steam increases, there is a corresponding rise in the boiling point temperature. It follows then that a drop in pressure will result in a lower boiling point temperature. Whatever the pressure may be, this principle always applies; water stays as water until its temperature reaches boiling point; beyond that, any extra heat turns the water into steam. This is the reason for the existence of flash steam.

We are getting back to our question, where did our temperature and Btu's go? Moreover, our short answer (into the steam), what happened is our excess sensible heat gave up its energy in the form of steam. Also, we can figure out just how much: we know we dropped about182 Btu's of sensible heat (361.79 Btu/lb. at 200 psig less 180.33 Btu/lb. at 0 psig or atmosphere = 181.46 Btu/lb. dropped) and we know that the steam we have generated at 0 psig has 970 Btu's of latent heat, so 181.46 Btu's/lb. given up divided by 970 Btu's/lb. of steam = 18.7, or 18.7% of our condensate turned into flash steam. The formula is relatively simple, but for convenience, the following flash steam table gives you a quick reference as to what percentage of condensate reverts to steam under specific conditions.

Table 5 shows how much flash steam will be given off by condensate released from higher pressure to lower pressure. For example, the flash steam we see coming away from the condensate at the open outlet of our steam trap is forming at the rate of 18.7% of the quantity of condensate. If the equipment is discharging condensate at the rate of 500 lbs/hr, we will generate flash steam at the rate of 93.5 lbs/hour.

Another example: if we discharge the same 200 psig condensate at the rate of 500 lbs/hr to a discharge pressure of 60 psig, the amount of flash steam generated will be 9.3% or 46.5 lbs/hr. per the flash steam table, or using our steam tables (361.79 Btu/lb. at 200 psig less 277.26 Btu/lb. at 60 psig = 84.53 Btu/lb. dropped) and we know that the steam we have generated at 60 psig has 904.6 Btu's of latent heat per pound, so 84.53 Btu's/lb. given up divided by 904.6 Btu's/lb. of steam = 9.3, or 9.3% of our condensate turned into flash steam.

| Percent Flash | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Initial Steam Pressure PSIG | Flash Steam 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 | 18.7 | 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 | 24.0 | 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 pressures | | | | | | | | | | | |

**Table 5: Flash Steam Table**

We should understand that flash steam has precisely the same properties as live steam from the boiler or any other source at the same pressure, and it is just as valuable as live steam for use in steam-heated process equipment and space heating.

So, rather than vent this rich source of heat to waste, we should find a way of catching the flash steam and putting it to useful work in equipment which operates at a steam pressure lower than that of the first piece of equipment.

If we connect a piece of piping from the outlet of the steam trap to some collecting vessel, we shall catch the flash steam. Then if we connect the collecting vessel to process or heating equipment which is working at a pressure lower than the starting pressure of 200 psig, we shall be able to use the flash steam, saving an equal amount of live steam.

Fig. 27 on the next page depicts a flash tank explicitly designed for that purpose. The Flash Tank is a straightforward device. Essentially it is a collecting chamber with three primary connections:

'A' is the condensate inlet to which the discharge piping of the steam trap on the steam-using equipment is connected.

'B' is the outlet for flash steam and is connected to the lower pressure steam system using the flash steam.

'C' is the outlet for the residual condensate from the flash tank and is connected to another steam trap for discharge into an even lower pressure flash tank or a condensate return system. The other two connections are for the pressure gauge and the safety valve, the latter set to blow off at the maximum allowable operating pressure of the low-pressure system we are feeding.

Understand that even after flashing has taken place, the condensate leaving the flash tank will still be at steam temperature; only now it will be at the lower pressure system steam temperature. For example, if the described flash tank is feeding into an 80 psig steam system, the residual condensate leaving the flash tank will have a temperature of 324°F, and every pound of condensate will still contain 294 Btu's of sensible heat so, although we have flashed off and saved some beneficial steam. The condensate still has more Btu's to give, if we have an even lower pressure steam system, the correct thing to do would be to connect the outlet of our flash tank steam trap to another lower pressure flash tank and so on until it is no longer practical to do so.

So that you have a clear idea of the kind of arrangement we are describing, Fig. 28 shows it to you in picture form. Process equipment is working at a steam pressure of 200 psig. The steam trap on this equipment connects to a flash tank, which connects to an 80 psig system. The condensate discharged by the steam trap on this lower pressure equipment is tied in with the discharge of the flash tank steam trap, and all of this condensate is either conveyed to another lower pressure flash tank or the condensate return system.

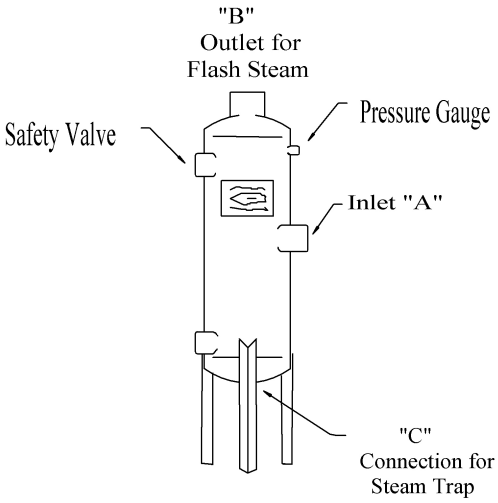



**Figure 27: Flash Tank**

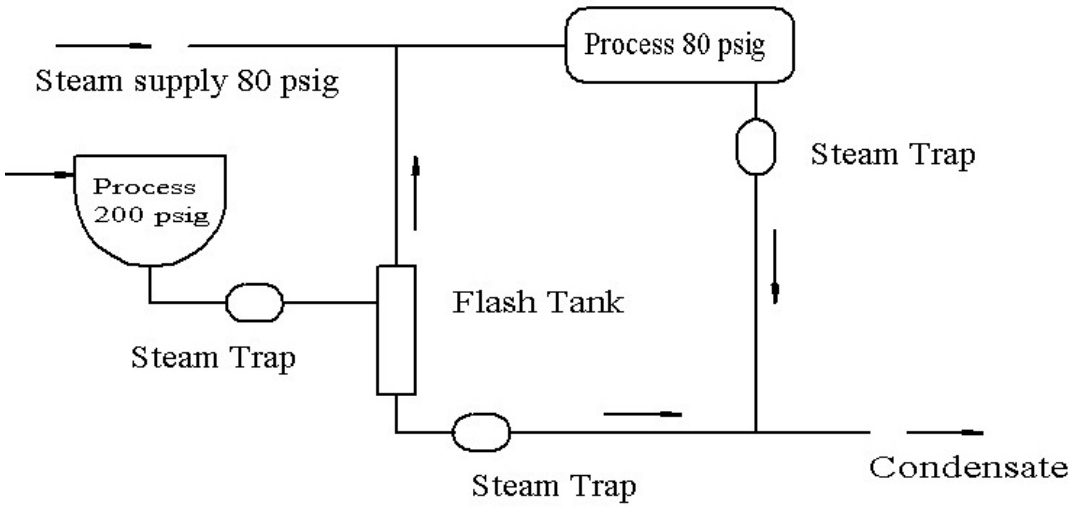



**Figure 28: Flash System**

In fig. 29 below “A” displays the practical example of a laundry ironing machine. The steam-heated bed is at high pressure, and the steam-heated roller is at lower pressure while “B” shows the same layout, but here the high-pressure equipment is an evaporator, and the lower-pressure equipment is a unit heater. There are many more examples of flash steam systems, all embodying more or less the same simple arrangement.

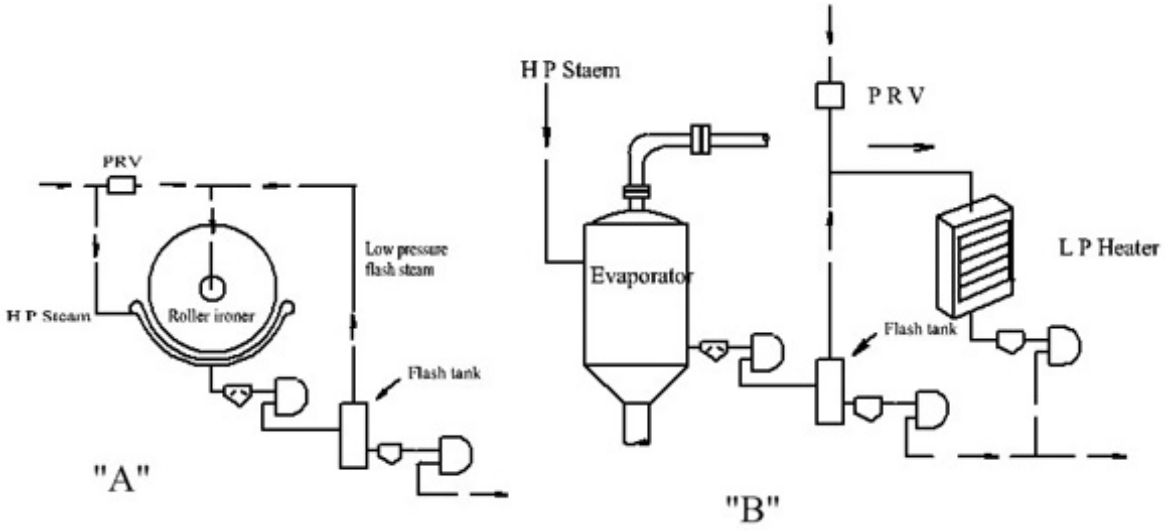



**Figure 29: Flash Systems "A" & "B"**

Understand that wherever there are varying steam pressures in use within an establishment, there is likely an opportunity to cut down live steam consumption by utilizing a flash steam system, and most flash steam systems will recover their installed cost within one year.

To determine your cost recovery time, determine the amount of flash steam recovered per hour (either from the formula issued or by using the flash steam table), multiply that by the hours per day the equipment is in use times the number of days per year the equipment is in use. The result is the annual savings in pounds of steam. Since steam costs expressed in $ per 1,000 pounds, divide that sum by 1,000 and multiply the answer by the cost of your steam. If the installed cost of your flash steam system was $10,000 and your annual steam savings were $30,000, your payback period would be 4 months or 1/3 of a year.

Some flash steam systems can be more elaborate than what we have described, but in most instances, a flash tank, some piping, an additional steam trap, strainer, and isolation valves are all that is required.

Figure 30 shows an example of the "Flash and Flash Again" system. The first stage is precisely the same, as shown in Fig. 28 with an added second stage of flash recovery to supply recovered flash steam to a 5 psig system. The steam trap on the original equipment connects to a flash tank that feeds recovered flash steam to the intermediate pressure equipment operating at 80 psig. The steam trap on the intermediate pressure equipment connects to a second flash tank, which in turn connects to a 5 psig low-pressure system. The condensate from the second flash vessel and the condensate from the low-pressure equipment is combined and discharged to the return system.

Using our flash steam table, we can determine in this example that we are recovering 7½% of our condensate volume in the first stage and 10% of our condensate volume in our second stage.

Many steam users have still not realized the possibilities of flash steam recovery, yet it is one of the simplest and least expensive ways of saving steam that we know of, and we suggest to all of our readers that the subject is well worth careful study in relation to their steam system.

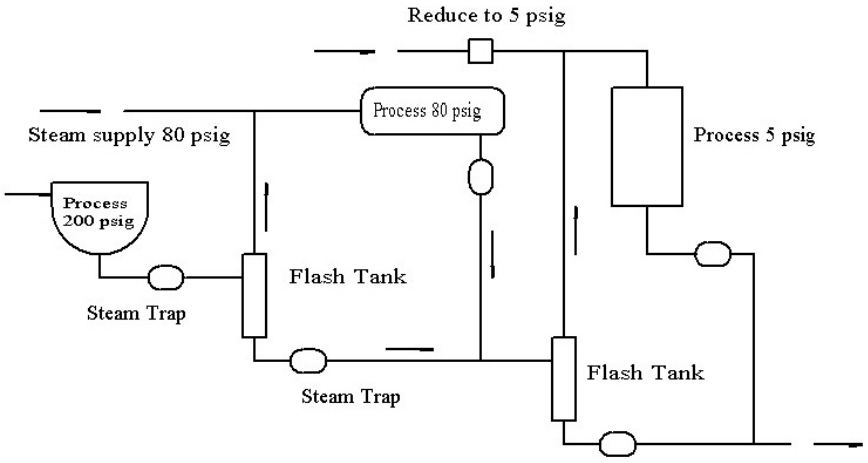



Figure 30: Flash and Flash Again System

Having introduced the subject of flash steam as part of the subject of condensate handling, we can now get back to the main theme. How is the "Flash" pressure controlled?

The amount of flash steam formed will vary with the volume of condensate. If, as usual, the volume of flash steam is insufficient to satisfy the consumption of the equipment accepting the flash, the pressure will fall or droop. So conversely, if the amount of flash steam is higher than the consumption rate of the equipment, the pressure will rise. So, to meet these conditions, we need a make-up pressure reducing valve to add steam from the high pressure main to keep the pressure steady when there is insufficient flash. In the unlikely event the flash recovered is more significant than our consumption and the pressure rises high enough, the safety valve will pop, and the excess flash steam will discharge to the atmosphere. In some of these specific instances, install a back pressure regulator to exhaust the excess flash steam before the pressure rises high enough to pop the safety valve.

Having pointed out the tremendous benefit of recovered flash steam, you may need to remind yourself that **when the steam supply is interruptible, you must not feed into a pressurized return or lift the condensate**. Discharging into a flash tank is the same as feeding into a pressurized return and fraught with precisely the same problems. Therefore, it is only condensate from steam traps with an uninterrupted steam supply should be considered for flash steam recovery. For example, steam traps dripping steam mains; on corrugators; presses; irons; rotating cylinders; autoclaves; vulcanizers; turbines; etc.

CONTINUING THE HEAT CIRCUIT

It is vital to bear in mind the fundamental basis of the "heat circuit" described in chapter two. An understanding of the heat circuit is necessary if steam is used efficiently and economically. The heat circuit is the supplying of heat to make steam (boiler), the delivery of that heat to the steam handling equipment (steam mains). The extraction of heat from the steam at the points of usage (heat exchange equipment), the returning of the residual heat in the form of condensate to the starting point (condensate return), and the delivery of the recovered condensate into the boiler (boiler feed).

The value that you get from the heat in the circuit increases as your knowledge of heat usage increases. The more you put the methods and suggestions offered in these chapters to practical use, the greater the value you will receive from the heat in your steam circuit.

Putting the heating circuit in its very simplest terms:

(a) You store heat in the form of steam (latent heat).

(b) You extract that stored heat at the point of use, and what remains is hot water (sensible heat).

(c) You return the hot water to the starting point into the circuit.

(d) The next stage is crucial. The amount of "profit" you get from the latent heat depends entirely on how efficiently you use the steam.

We explained in chapter seven how you could, in certain circumstances, make use of some of the “Sensible Heat” in condensate before discharging it through the steam traps. Having removed the condensate, you can, in some instances, extract more latent heat from it in the form of flash steam and having done that you can then send the condensate, still hot, back to the boiler feed tank.

But there is something else we should undoubtedly do in helping to maintain the temperature of condensate en route to the feed tank. Just as it is necessary to lag (insulate) steam mains to reduce the heat loss as much as possible, it is essential to lag condensate return mains for the same reason.

So, just as it is more economical to use high pressure to transmit steam throughout your system. With higher steam pressures, the steam is more compressed; as a result, the steam pipe is smaller. The smaller diameter pipe is less expensive to purchase and install and has less area to lose heat. It can sometimes be more economical to utilize condensate return pumping units to pump back condensate and get away with a smaller pipe than would be necessary with a gravity return.

ECONOMICS OF CONDENSATE USAGE

In considering the economics of condensate usage and the advantages to be gained by installing a condensate return system, it is essential to understand the heat contents of steam and the water of condensation thoroughly. Unless you know these basic principles, you cannot begin to assess the savings made possible by putting in the right kind of condensate return system.

From all the information given thus far, you can work out examples of fuel savings as a result of returning condensate for boiler feed. Also, when we discharge condensate to drain, freshwater must be consumed as make-up in the boiler; this freshwater has to be processed through a water softener, chemically treated (to protect the boiler, steam piping, and equipment) and then heated. If you are on municipal water, you have to purchase the water and pay for the drainage processing, and even if you're on a well, river, or lake, you have to pay for the pumping of it. Nothing comes for free, no matter what those television commercials say.

So, if our make-up water temperature is 50°F and if we are producing steam at a pressure of 100 psig, we would have to add 1,171 Btu's to each pound of make-up water fed to the boiler (don't trust me, check your steam tables).

On the other hand, if instead of running it to waste, we return our hot condensate for use as boiler feed, we can assume, for the sake of comparison, the returned condensate temperature to be about 180°F. Meaning that instead of 1,171 Btu per pound of water make-up, our fuel need only provide 1,041 Btu per pound with which to turn the water into steam. So the immediate saving of returning condensate is 130 Btu per pound of steam generated, which translates into a saving of more than 10% on fuel consumption alone to say nothing of the previously detailed associated costs.

Consult your steam table and play along, to determine the 1,171 required Btu's to convert our make-up water to 100 psig steam we took the 1,189 total Btu's in 100 psig saturated steam less the 18 Btu's contained in our 50°F make-up water (50 minus 32) remember, Btu's get counted up from 32°F. To get the required Btu's to convert our returned condensate to 100 psig steam, we took that same 1,189 total Btu's less the 148 Btu's retained in our returned condensate.

It would be most unusual to waste all of the condensate at a plant, but frequently we find condensate from one or two pieces of equipment or from one or two areas being discharged to the drain because it seemed too expensive to run the condensate back to the boiler room. This thinking can often be proven misguided when comparing the cost of installing a condensate pumping unit to the accumulated losses of dumping the condensate for the number of years the pump would run.

There are applications where the concern of condensate contamination dictates that it not be returned to the boiler for fear of system damage. Cross-contamination can be a concern when heating corrosive chemicals or detergents, and resultant system damage can be catastrophic. In these instances, it is recommended to either install a sensor in conjunction with a dump valve in the return line to dump the condensate and trigger an alarm in the event of sensed cross-contamination or process the condensate to be drained through a heat exchanger to recover most of the heat is lost.

On the matter of condensate handling in general, there may be a few points which we haven't fully covered or about which you would like to have more information. It is not possible within the scope of this primary book to deal with every problem likely to arise in connection with individual installations, but we hope we have been successful in giving you a general grasp of the significant savings to be gained from the efficient use of condensate.

We welcome your questions on any points concerning flash systems and condensate return systems. May we re-emphasize the importance of going over the earlier chapters again and again so that you will become thoroughly familiar with the basic principles of steam and condensate usage.

An index, along with a listing of diagrams and tables are located at the end of this book to act as a quick reference to subjects you may need to look up in the future.

## BY-PASSES AROUND STEAM TRAPS

The habitual use of a by-pass around a steam trap can result in a significant waste of steam. Often you may hear that the by-pass "helps the trap" or that "the trap works better that way." Maybe so, if the wrong size or type of steam trap is installed or located incorrectly. However, if the equipment is correctly trapped, there is often no need at all for the regular use of a by-pass.

As an emergency device, a by-pass around a steam trap is a sound engineering practice, but do not rely on it as a standard means of discharging condensate or air.

Aside from possibly being the source of lost steam, the habitual use of by-passes around steam traps can aggravate peak load problems if they exist. When they are not left open permanently, by-passes are opened most often during start-up periods, and it is during these start-up periods that peak demands are on the boilers. Steam needlessly lost through open by-passes only adds to the start-up demands of the steam-heated equipment, which intensifies any troubles associated with peak load conditions.

## MAINTENANCE

Steam traps are automatic valves or condensate controllers, and as such, they should have the same care and maintenance as your control valves and regulators.

First, you should start by making sure that your traps are of the right type and size for the application, appropriately located, installed with inlet strainers, and, in some cases, with discharge check valves.

A steam trap maintenance record can be a valuable check on trap performance. The next page shows a typical record sheet of the kind used by many maintenance engineers.

Some companies can perform steam Trap Surveys, but it is our recommendation here that you save the expense and take on this responsibility yourself. Don’t forget they are in the business to sell traps.

By cataloging and checking your steam trap population annually on a rotating basis as part of your planned maintenance, you will minimize your steam losses and indicate trouble spots that need addressing.

# *Trap Survey Summary Report*

Status Code

| ***ID No*** | ***Location*** | ***Size*** | ***Description*** | ***Status*** | ***Replacement Model*** | |
|---|---|---|---|---|---|---|
| 1 | Boiler room | 1" | Sarco FT-125 F&T | | 1" Watson WFT-125-14-N | |
| 2 | Boiler Room | 3/4" | Sarco B1X-125 Bucket | | ¾" Watson IB1031-13-N | |
| 3 | Boiler Room | 3/4" | Sarco B1X-125 Bucket | | ¾" Watson IB1031-13-N | |
| 4 | Maintenance Shop | 3/4" | Sarco TD-52 Thermodynamic | | Watson TD-600 | |
| 5 | Drip at W.D. Station | 3/4" | Miyawaki Bucket | | Watson TD-600 | |
| 6 | Office | 1/2" | Dunham Bush | | | |
| 7 | Drip at PRV Station | 3/4" | Sarco TD52 Thermodynamic | | Watson TD-600 | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |
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| 17 | | | | | | |
| 18 | | | | | | |

**Table 6: Steam Trap Survey Report**

Remember that strainers are installed before traps and valves to collect dirt and therefore need to be cleaned from time to time. We recommended that strainers should be cleaned within one month of installation and once a year afterward, also as part of your planned maintenance.

To clean a strainer, unscrew the end cap and withdraw the cap and screen. Empty the scale and wash the filter in clean water. Examine the screen to make sure that it is not damaged and then replace it.

TESTING STEAM TRAPS

If the trap discharges to atmosphere, this is relatively simple as the discharge can be seen; remember, there will be flash steam and vapor coming off of the condensate, so don't get misled into thinking that the presence of some steam means the trap is leaking. If we connect, the traps to a return line, and use sight glasses, the discharge again can be seen. If you are unable to see the trap discharge, then the best method of checking is to install a steam trap block and test valve. This valve will allow the operator to turn the test valve one-quarter turn and have the condensate discharge directly to the floor for easy observation. In some areas installing a test, valve is impractical, and if so, the only accurate method of testing the trap is by utilizing both a pyrometer to check temperatures and a sonic detector to check velocities.

There are also permanently installed steam trap monitoring devices available from most steam trap manufacturers, but be careful in their application. These devices are expensive to purchase and install and will only indicate fail open conditions. If the trap fails closed, the monitor will indicate it is still functioning correctly.

The following notes explain the things to look for when troubleshooting suspected faulty traps of different types. We assume that the method of installation is following the recommendations made in this course.

BALANCED PRESSURE THERMOSTATIC TRAPS

Symptom – Steam blowing

Make sure that it is live steam and not flash steam (re-evaporated condensate).

Shut off steam and cool the trap thoroughly with cold water to contract the element.

Remove the cap. Depending on the type of trap, the element may be either removed with the cap or held in the body by a holding plate and exposed ready for removal when the cap is taken off.

Examine the valve seat for scale and grit. If finding either, this is probably the cause of the trouble. Examine the valve and seat for possible damage or wiredrawing before replacing the element and cap. On heating systems or equipment which may have been lying idle for some time, the valve and seat may become coated with oxide. Finding such coatings, clean the valve head, and seat carefully. Do not use a medium or coarse grit as any marring of the surface will result in leakage.

If the valve and seat are clean, examine the element. If corrugated, the corrugations should be evenly rounded, or if it is a welded or diaphragm type, the element should be firm. Take the element between the thumb and first finger and test for any elongation. It should not be possible to compress it. Flabbiness of the corrugated element or flexing of a welded element indicates that it has lost its charge and requires replacement.

If you have a corrugated type of element suffering from flattened out corrugations, it is an unmistakable sign of damage due to water hammer, and you must either find the source of the hammer and eliminate it or install a thermostatic trap that can withstand the mild abuse.

NOTE: I should mention that elements of some Balanced Pressure Traps type have an enclosed metal shield, and it is not possible to examine the corrugations or flex of the element without removing the shield. We suggested to readers that rather than attempt to remove the protection of a suspected faulty element, they should return the element intact to the manufacturer for inspection.

Symptom - Trap won't release condensate.

Shut off steam, cool the trap, and remove the element as described previously.

(1) Flabbiness or elongation of the element may be causing the element to remain on its seat. Replace the element and seat.

(2) Elongation of the element and bursting of the top or bottom joints of the tubing can be a sign that superheat is or was present and is often accompanied by some scaling of the tubing of the element. If subjected to superheat, install a more suitable trap.

(3) If the element is in the closed position when it loses its charge, the system pressure will invade the element and keep the trap in the closed position.

## Inverted Bucket Traps

Symptom - Trap won't discharge condensate

1. Check steam pressure and the maximum working pressure of the trap. If the steam pressure is higher than the trap working pressure, the valve could be held on its seat by excess differential pressure. Replace the trap with one of the correct pressure range.

2. Remove the cover of the trap and examine the air vent hole in the top of the bucket. If this hole is choked or plugged, the trap will airlock and fail closed. Clean the vent hole, replace the cover, and test.

3. Examine the valve seat. If choked or plugged, clean out, replace the cover, then test.

Symptom - Trap passes Steam

1. Remove the cover and examine the valve and seat for scale or grit or damage by wire-drawing. If the valve head or seat is damaged, replace it with the appropriate kit.

2. If the trap is working on a light load, the trouble may be due to the loss of the bucket water seal caused by a sudden flashing off of prime when the trap opened. A trap of the correct size will not usually lose its water seal, so if this is a recurring problem, it may require the selection of a trap with less capacity.

3. Superheat can also result in a loss of prime. If superheat is present, fit a check valve before the trap.

4. Water-hammer may when very severe, cause damage to the mechanism or bucket, causing the valve to fail to seat and steam to blow. If the mechanism is damaged, install new parts and, of course, the cause of the water-hammer should be found and eliminated.

General

The frequency of discharge of an inverted bucket trap depends on the maximum designed pressure of the trap in relation to the pressure at which it is working as well as on the rate of condensation from the unit.

If a trap suitable for a maximum operating pressure of 200 psig is draining equipment working at 20 psig, it may discharge more frequently than would one designed for a maximum pressure of, say 30 psig, depending upon the percentage of full load at which the trap must operate.

FLOAT - THERMOSTATIC STEAM TRAPS

Symptom - Trap Won't Release Condensate

Compare the steam pressure at the trap against the maximum working pressure of the trap. If the steam pressure is higher than the designed pressure of the trap, this could cause the valve to be held on its seat and lock the steam trap.

1. Turn off steam and remove the cover of the trap. Examine ball float to find if it is perforated and full of water. If waterlogged or damaged, install a new float. Waterlogged, dented, or dislodged floats are indications of water hammer, once again, determine the source of the hammer and correct it.

2. Examine the thermostatic air vent element. If this is operational, the trap should have discharged condensate through the vent. If the element looks expanded or the valve closed, the element is faulty and replace with a new one.

Symptom - Trap Gives a Blast Discharge instead of a Continuous Discharge

This may be quite normal on low loads due to the float valve closing tight after releasing condensate and being held closed until sufficient condensate collects to give enough flotation to the ball for it to overcome the pressure on the valve. When the float rises, it pulls the valve head from the seat giving the blast effect.

If, however, blast discharging occurs on a steady load and is accompanied by signs of water-logging, it may be that the ball float is defective, causing the main valve to remain closed, and the thermostatic air release is acting as a balanced pressure thermostatic trap. In such a case, examine the trap as described above.

Symptom - Trap Blows Steam

First, make sure that the trap is blowing steam and not passing high-temperature condensate, which is flashing.

(1) Turn off steam and remove the cover of the trap.

(2) Examine the main valve and seat and the air vent for scale or damage, which may have caused the blow. If either is faulty, replace them with new ones.

(3) Check the thermostatic air vent in the same manner as instructed to deal with balanced pressure thermostatic steam traps.

FLOAT TRAP WITH STEAM LOCK RELEASE

Symptom - Trap will not release condensate

(1) Check the steam pressure at the trap against the designed maximum working pressure of the trap. If the steam pressure is greater, then the trap design pressure, install a trap suitable for the working pressure.

(2) Check the steam lock release valve setting to make sure that this is right. Incorrect setting of the steam lock release may cause the trap to steam lock or air bind, either of which would result in condensate being held up.

(3) Dismantle the trap and examine the working parts as described earlier.

Symptom - Trap Blows Steam

Check the steam lock release setting on the valve. If this is too wide open, adjust it back until the trap discharges continuously without steam locking.

If this does not cure the trouble, dismantle the trap and examine the float and float valve and fit replacements as necessary.

THERMODYNAMIC STEAM TRAP

Symptom - Trap Blows Steam

(1) Much like the float and thermostatic steam trap, this trap discharges condensate almost at steam temperature and will generate more flash steam than a thermostatic or a bucket trap, and therefore you must take care not to confuse flash steam with escaping live steam. If you can hear a sharp, clean cycle, the trap is not likely leaking steam.

(2) If the trap is blowing live steam, unscrew the cap and examine the disc and seat surface for scale or damage. A piece of pipe scale or dirt may prevent the disc from seating totally and if this condition persists, wiredrawing of the disc or seat may result. If this is the case, the disc and seat are lapped but take care not to remove no more than .005" of material from the disc, and .010" from the seat surface.

(3) This trap may also blow steam if the differential pressure across the trap is insufficient. If this condition cannot be corrected (by cleaning the strainer, for example), a more suitable trap should be selected.

Symptom - Noisy Operation

(1) Although this trap is not completely silent in operation, there should only be an occasional click as the trap cycles. A chattering or machine-gunning noise from the trap indicates the disc is fluttering and can be indicative of the trap being oversized.

(2) This same machine gun effect can be caused by an obstruction (such as an elbow or a check valve) immediately downstream of the trap. When the high-velocity jet of condensate meets the obstruction, a pressure wave bounces back to the trap, and the disc bounces on its seat. There should be an unobstructed run of at least 12" downstream of the trap.

General

You can install the thermodynamic steam trap in any position, but like most other traps, it should not be connected directly on the end of a long horizontal length of pipe. Stratification of steam and condensate can occur with this arrangement, and since steam and condensate could reach the trap together, there may be enough condensate mixed with the steam to keep the trap open and allow it to blow steam. Provide a pressure drop before the trap inlet to ensure positive operation.

With this book, we have tried to show how steam can be used more efficiently by understanding its properties, by improving heat transfer, by reducing heat losses, by speeding up steam-heating of processes, by utilizing flash steam and by making proper use of every drop of hot condensate.

May we end with an invitation to you to make use of our Advisory Service on any matter concerning your steam-using methods and equipment?

We welcome all inquiries send an e-mail to below address with all questions

Orders@EngineeredSolutionsCan.com

If you require a more personal touch, we can always arrange for a representative in your area to visit you. Help is just around the corner, except for those of you out in the boondocks, of course.

We extend an invitation to you to visit our web site which not only gives you a detailed view of all the products we represent but an engineering section which could be of value to you.

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**or contact us by phone at 905-832-0909**

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