STEAM TRAPS

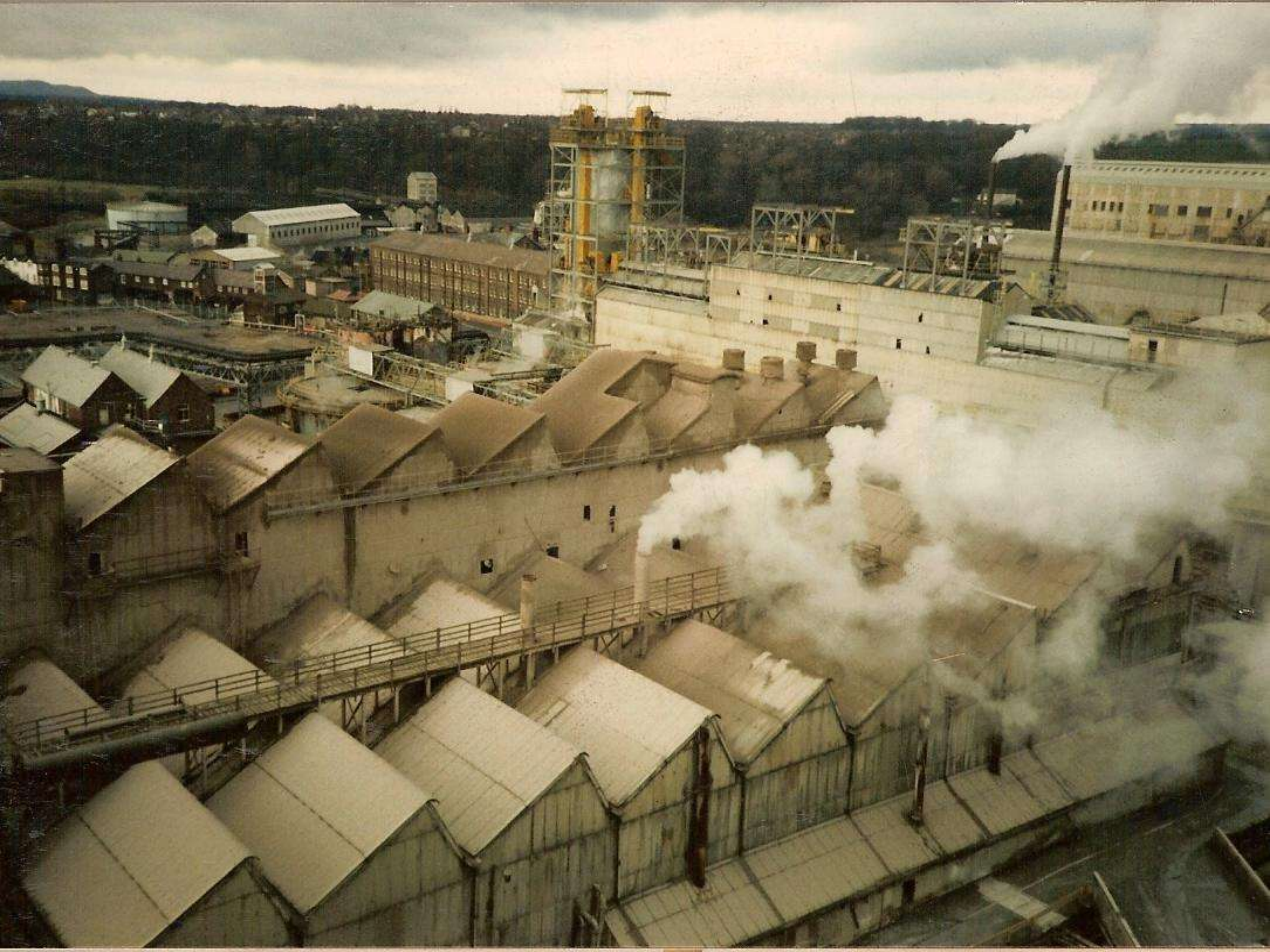
Steam Utilization

Steam is generated for the following plant uses:

Turbine drive for generating electricity, providing power for site equipment and lighting.

Process for direct contact with products, direct contact sterilization and noncontact for processing temperatures.

Heating and air conditioning for comfort and maintaining ambient storage temperatures.



Steam Utilization

The efficiency achievable with steam generation relies heavily on the system's ability to return condensed steam to the operating cycle.

Many of the systems described previously, return a significant portion of the condensed steam to the generation cycle.

Steam Production

When water is heated in a boiler, it begins to absorb energy. Depending on the pressure in the boiler, the water will evaporate at a certain temperature to form steam.

The steam contains a large quantity of stored energy which will eventually be transferred to the process or the space to be heated.

Steam Utilization

Sensible heat

When an object is heated, its temperature rises as heat is added. The increase in heat is called sensible heat. Similarly, when heat is removed from an object and its temperature falls, the heat removed is also called sensible heat.
Heat that causes a change in temperature in an object is called sensible heat.

Latent heat

All pure substances in nature are able to change their state. Solids can become liquids (ice to water) and liquids can become gases (water to vapour) but changes such as these require the addition or removal of heat.
The heat that causes these changes is called latent heat.

Steam Production

Steam can be generated at high pressures to give high steam temperatures.

The higher the pressure, the higher the temperature.

More heat energy is contained within high temperature steam so its potential to do work is greater.

Steam Utilization

Steam is one of the most widely used media to convey heat over distances.

Because steam flows in response to the pressure drop along the line, expensive circulating pumps are not needed.

Due to the high heat content of steam, only relatively small bore pipework is required to distribute the steam at high pressure.

The pressure is then reduced at the point of use, if necessary. This arrangement makes installation easier and less expensive than for some other heat transfer fluids.

Steam should be available at the point of use:

In the correct quantity

At the correct temperature and pressure

Free from air and incondensable gases

Clean

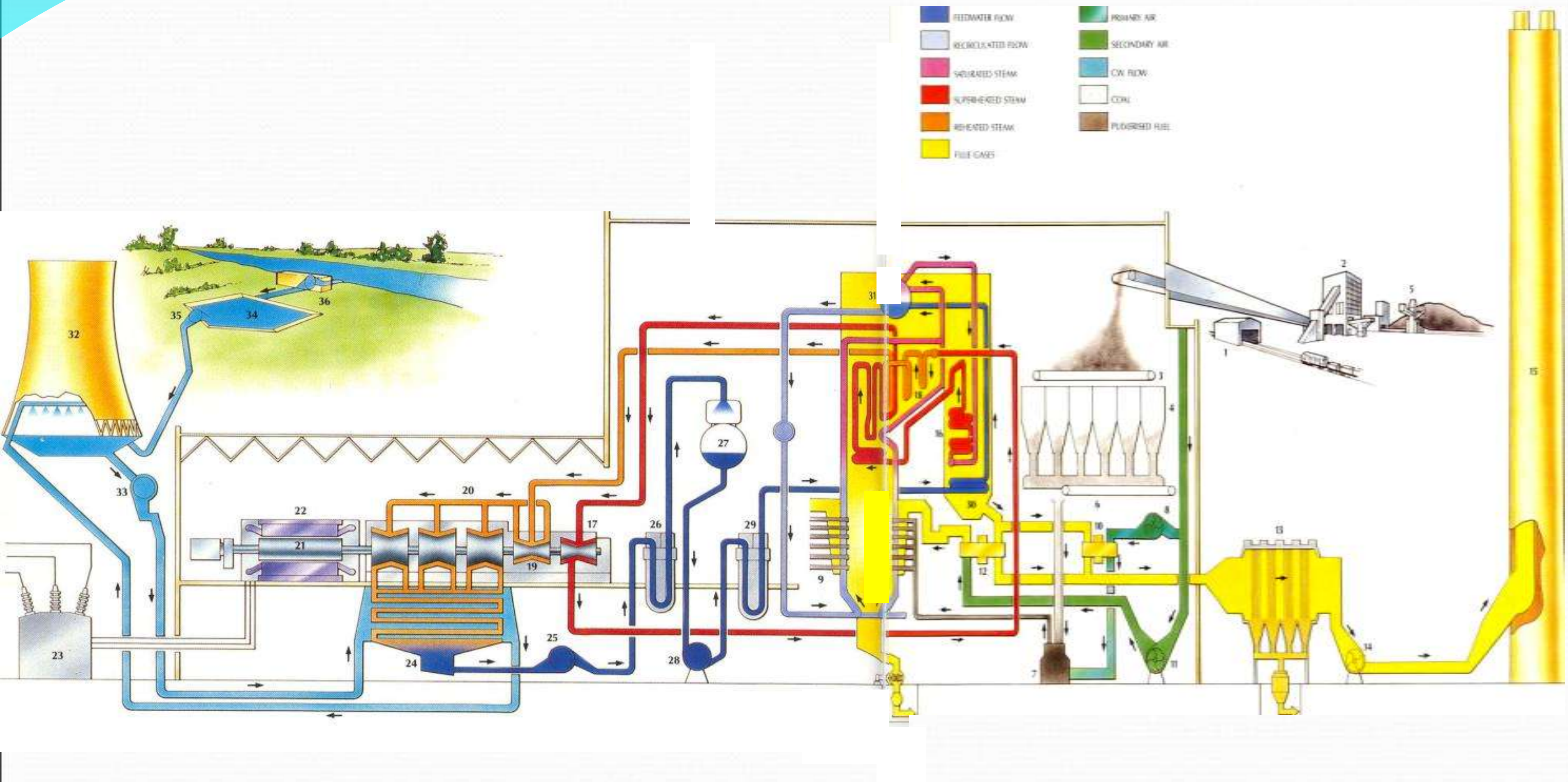
Dry

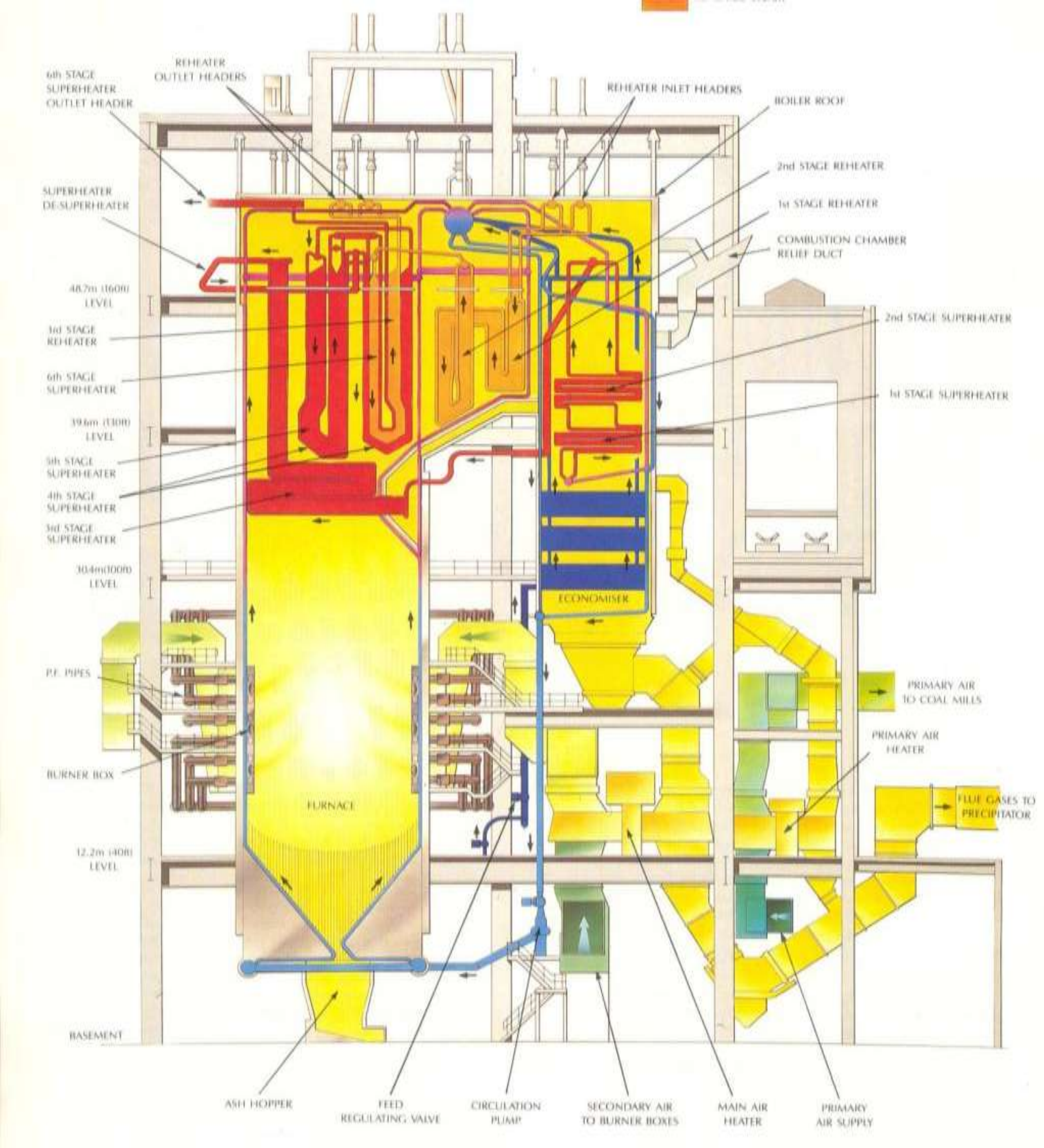
Enthalpy of vaporisation

Enthalpy of water, liquid enthalpy or sensible heat of water

This is the heat energy required to raise the temperature of water from a datum point of 0°C to its current temperature.

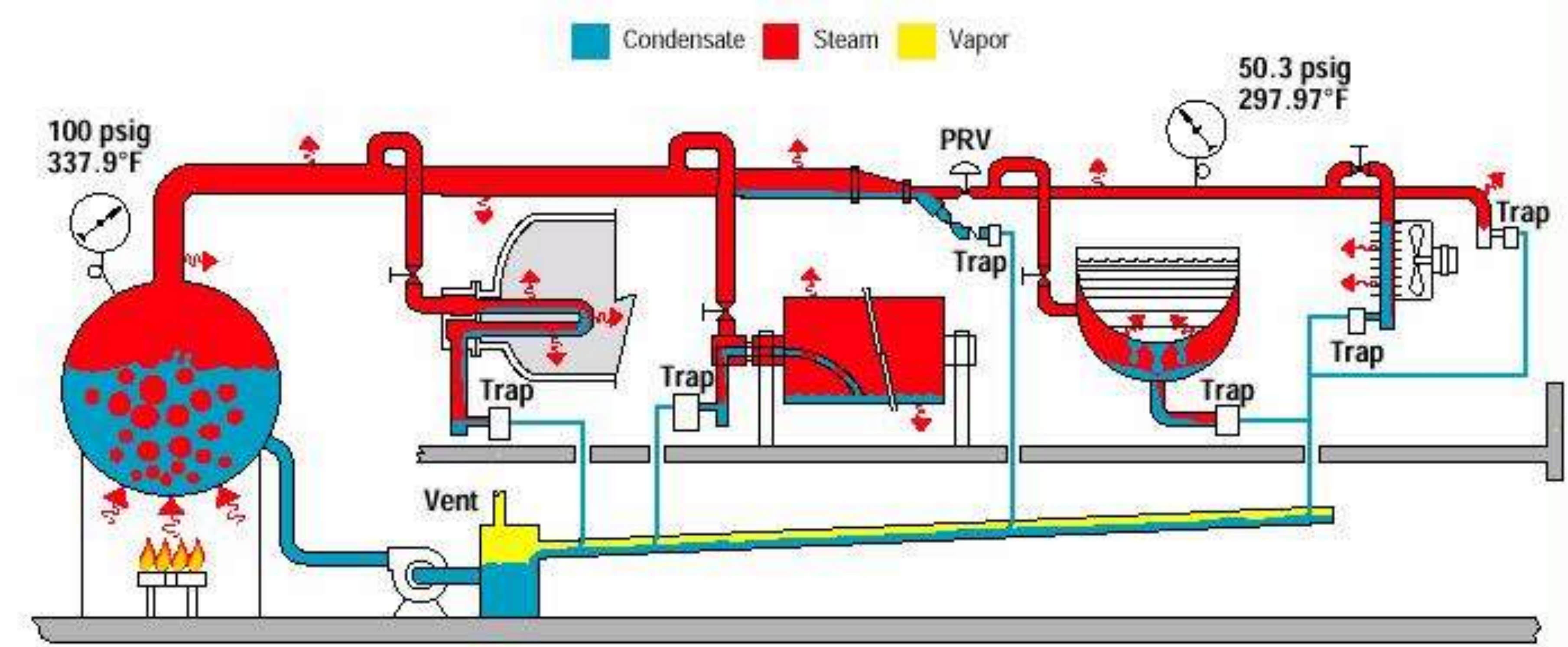
The enthalpy of vaporisation is the energy required to turn water into the gaseous form when it increases in volume by 1,600 times at standard temperature and pressure; this change in volume can be converted into mechanical work by engines and steam turbines


FEEDWATER FLOW
RECIRCULATED FLOW
SATURATED STEAM
SUPERHEATED STEAM
REHEATED STEAM
FLUE GASES
PRIMARY AIR
SECONDARY AIR
CW FLOW
COAL
PULVERISED FUEL



BOILER AND ASSOCIATED PLANT

The Steam "Loop"



Most industrial steam systems are closed systems.

When water vaporizes to become steam in the boiler, the expansion pressurizes the system.

Steam is forced out of the boiler by its own pressure and is carried by piping to whatever devices are to be employed for heating or processing.

The pressure changes within the system provide transportation for the steam and also affect its physical properties.

Superheated Steam

If the saturated steam produced in a boiler is exposed to a surface with a higher temperature, its temperature will increase above the evaporating temperature.

The steam is then described as superheated by the number of temperature degrees through which it has been heated above saturation temperature.

Superheat cannot be imparted to the steam whilst it is still in the presence of water, as any additional heat simply evaporates more water.

The saturated steam must be passed through an additional heat exchanger. This may be a second heat exchange stage in the boiler, or a separate superheater unit.

The primary heating medium may be either the hot flue gas from the boiler, or may be separately fired.

Dryness fraction

Steam with a temperature equal to the boiling point at that pressure is known as dry saturated steam.

However, to produce 100% dry steam in an industrial boiler designed to produce saturated steam is rarely possible, and the steam will usually contain droplets of water.

It is convenient and helpful to think of the typical steam system as a loop with four distinct sections.

The first is **Generation**. During this stage - in the boiler - heat is applied to water to raise its temperature.

After the water has vaporized, the resulting steam moves into the second stage of the steam loop: **Distribution.**

This is simply the movement of the steam within a closed system to its point of use. The use, whatever that happens to be, is called **Heat Transfer**.

This is the third stage. In the heat transfer portion of the steam loop, the heat of the steam is transferred and put to work doing countless jobs.

As the steam gives up its heat through heat transfer or use, it condenses or changes its state - this time from a gas back into a liquid. This is called condensate.

It is very important to drain condensate from a steam system as quickly as possible.

This is the job of a simple device called a steam trap.

The fourth and final section of the steam loop is **Condensate Return**.

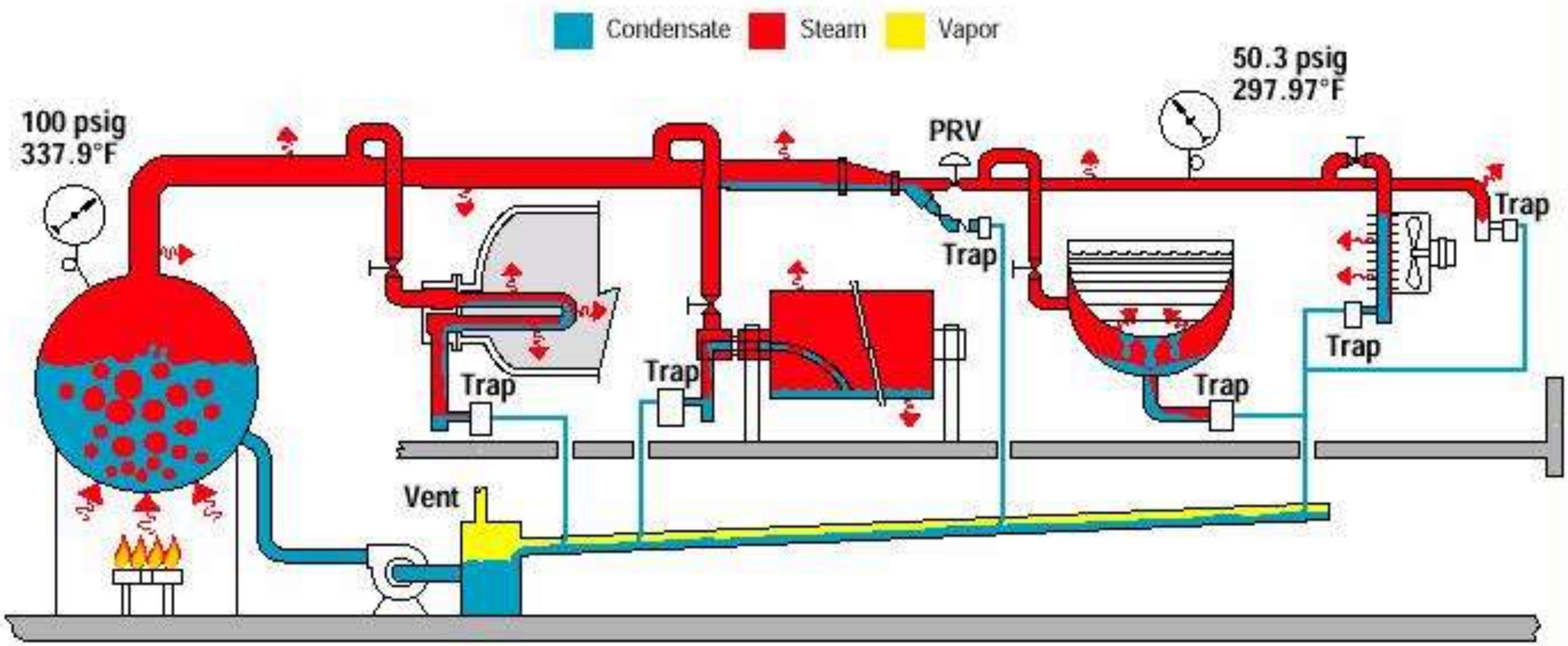
For many years, condensate was simply dumped on the ground or into a drain.

In recent times, cost pressures and environmental concerns have forced energy managers to rethink how they handle condensate.

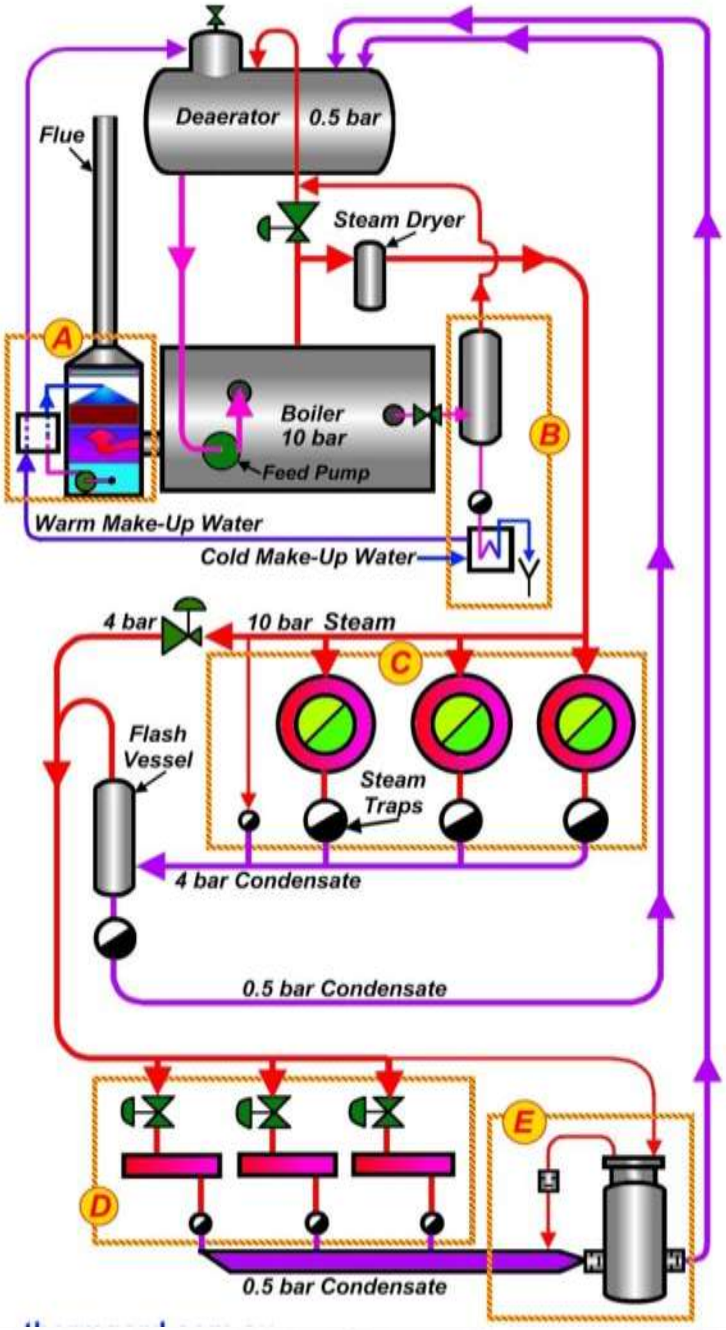
Condensate Return Systems provide excellent opportunities for substantial savings in energy, water and chemical costs.

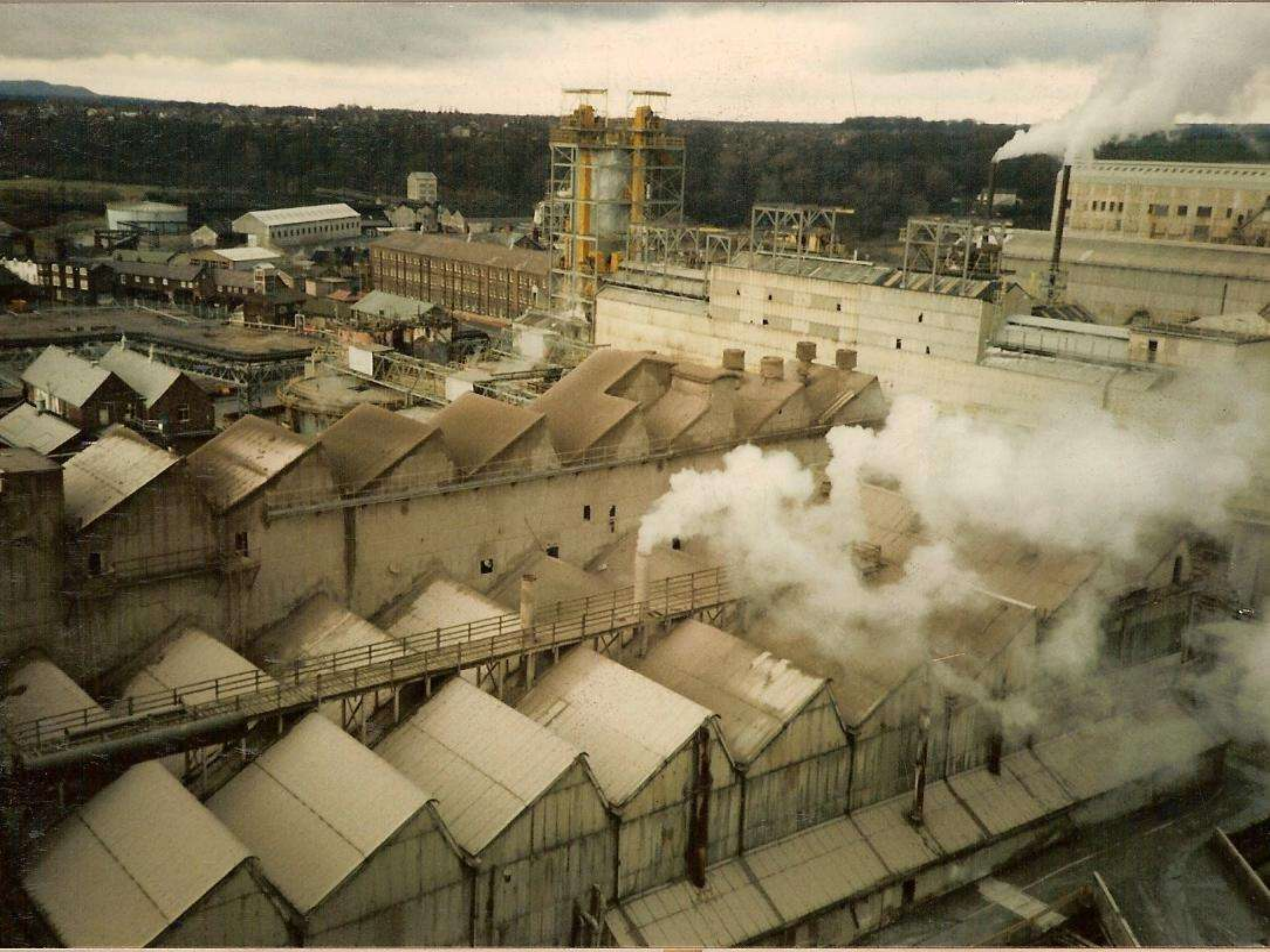
Improvements to a condensate return system often are also beneficial from the perspective of production efficiencies

Since condensate has already been through the steam system, it will take far less heat (and fuel) to turn it back into steam than it would to make steam of an equal quantity of cold water. That is why a growing number of steam users return the condensate back to the boiler where the whole process starts over. Hence, the concept of the steam "loop."



CLOSED LOOP STEAM AND CONDENSATE SYSTEM





The benefits of steam - a summary:

Inherent benefits	System benefits
Water is readily available Water is inexpensive Steam is clean and pure Steam is inherently safe Steam has a high heat content Steam is easy to control due to the pressure/temperature relationship Steam gives up its heat at a constant temperature	Small bore pipework, compact size and less weight No pumps, no balancing Two port valves - cheaper Maintenance costs lower than for dispersed plant Capital cost is lower than for dispersed plant SCADA compatible products Automation; fully automated boiler houses fulfil requirements such as PM5 and PM60 in the UK Low noise Reduced plant size (as opposed to water) Longevity of equipment Boilers enjoy flexible fuel choice and tariff Systems are flexible and easy to add to
Environmental factors	**Uses**
Fuel efficiency of boilers Condensate management and heat recovery Steam can be metered and managed Links with CHP/waste heat Steam makes environmental and economic sense	Steam has many uses - chillers, pumps, fans, humidification Sterilisation Space heating Range of industries

Conduction

When a temperature gradient exists in either a solid or stationary fluid medium, the heat transfer which takes place is known as conduction.

When neighbouring molecules in a fluid collide, energy is transferred from the more energetic to the less energetic molecules. Because higher temperatures are associated with higher molecular energies, conduction must occur in the direction of decreasing temperature.

Convection

The transfer of heat energy between a surface and a moving fluid at different temperatures is known as convection. It is actually a combination of the mechanisms of diffusion and the bulk motion of molecules.

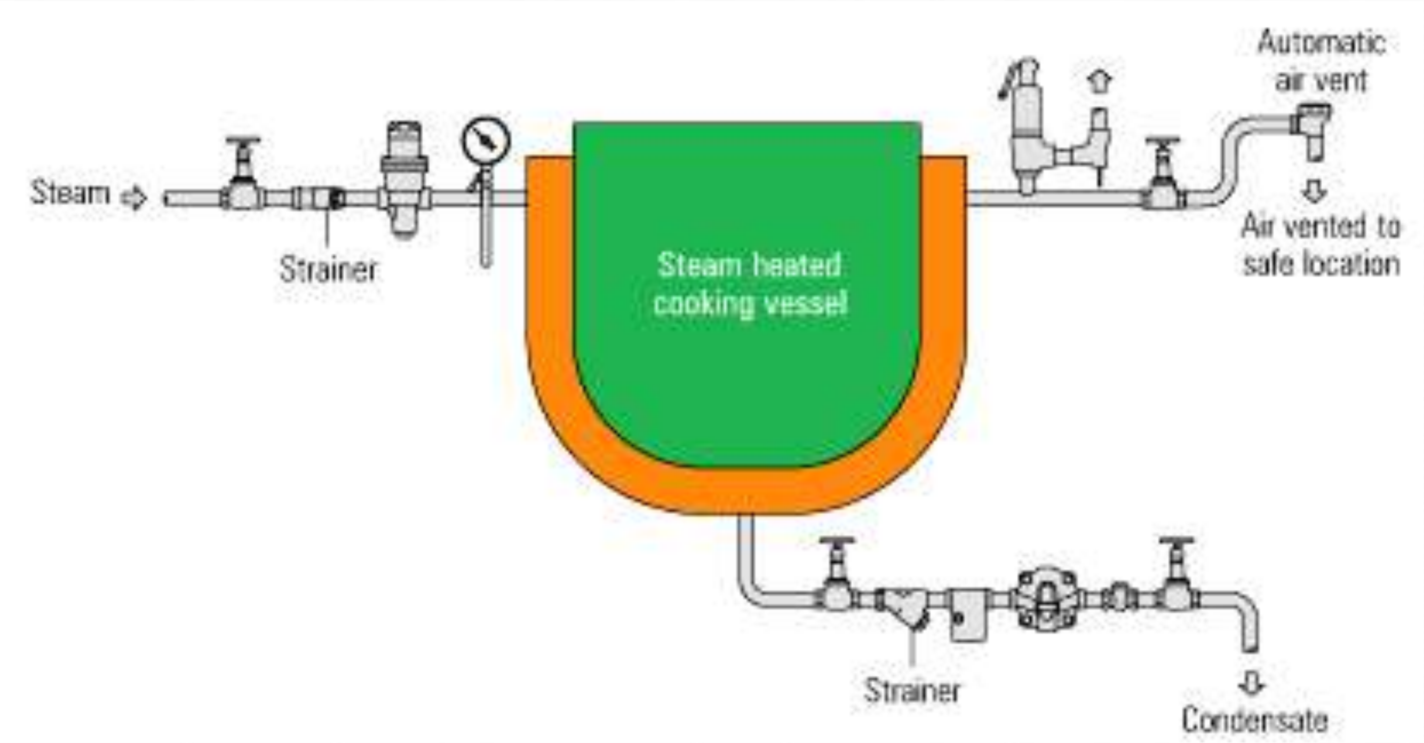
Radiation

The heat transfer due to the emission of energy from surfaces in the form of electromagnetic waves is known as thermal radiation. In the absence of an intervening medium, there is a net heat transfer between two surfaces of different temperatures. This form of heat transfer does not rely on a material medium, and is actually most efficient in a vacuum.

Process Equipment

Steam jackets

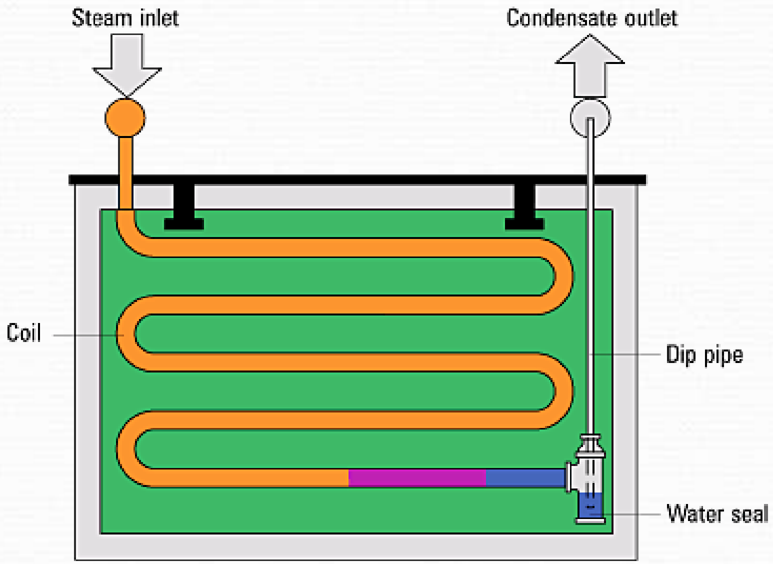
The most commonly used type of steam jacket consists simply of an outer cylinder surrounding the vessel. Steam circulates in the outer jacket, and condenses on the wall of the vessel. Jacketed vessels may also be lagged, or may contain an internal air space surrounding the jacket. This is to ensure that as little steam as possible condenses on the outer jacket wall, and that the heat is transferred inwards to the vessel.

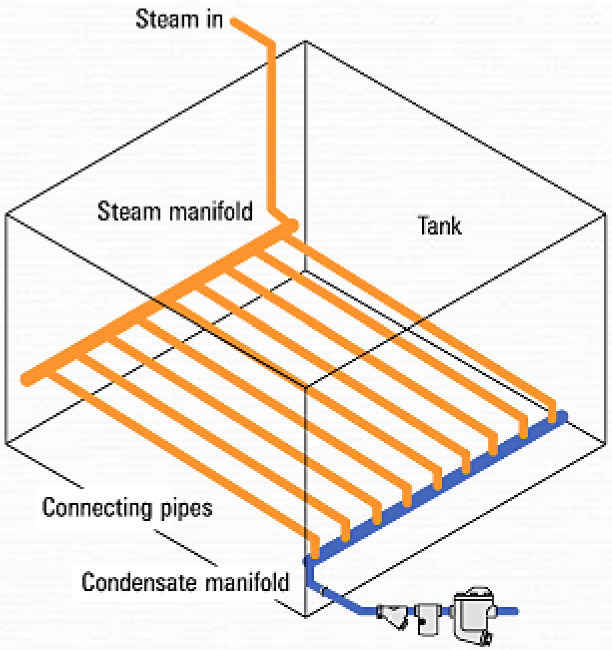


Steam process equipment with an automatic air vent and strainers

Submerged steam coils

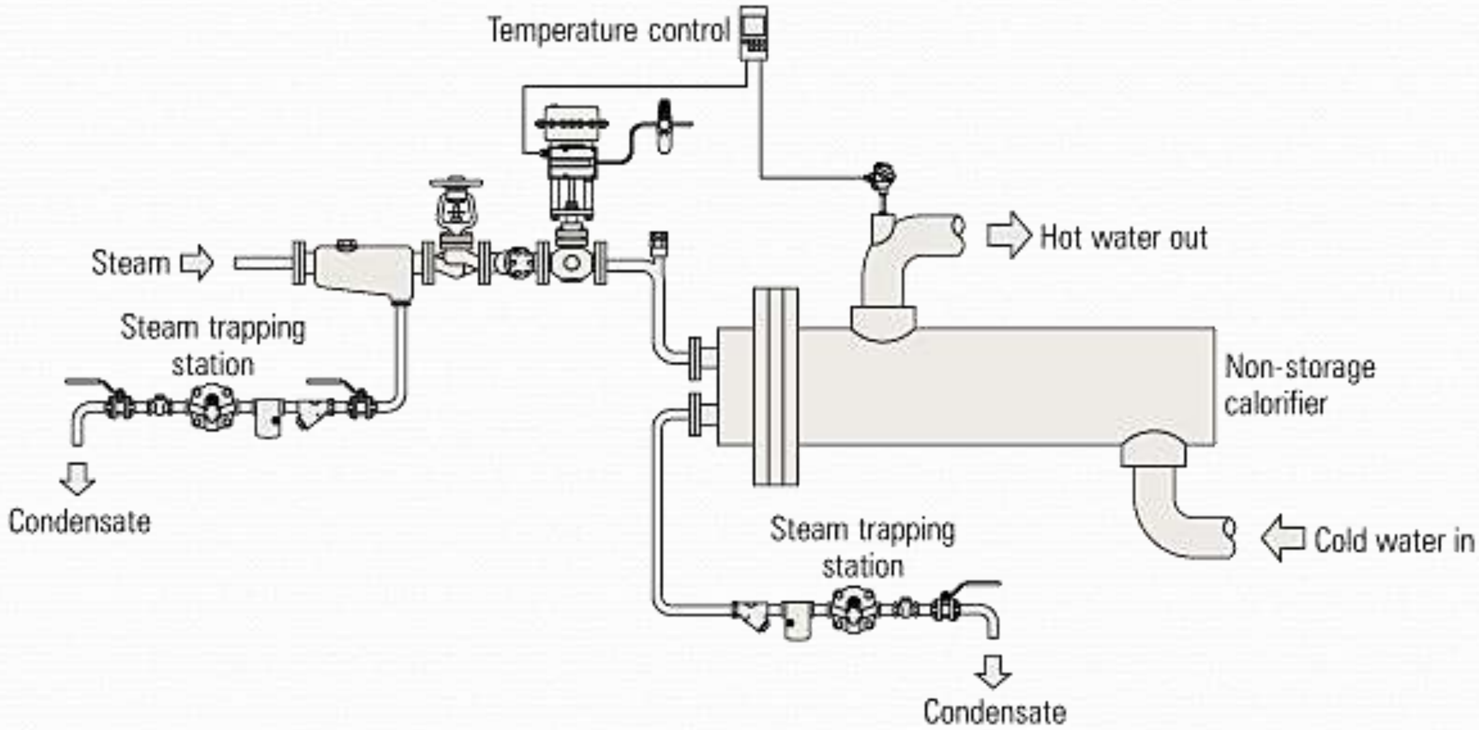
The use of tank coils is particularly common in marine applications where cargoes of crude oil, edible oils, tallow and molasses are heated in deep tanks. Many of these liquids are difficult to handle at ambient temperatures due to their viscosity. Steam heated coils are used to raise the temperature of these liquids, lowering their viscosity so that they become easier to pump.





A Non-storage calorifier installation

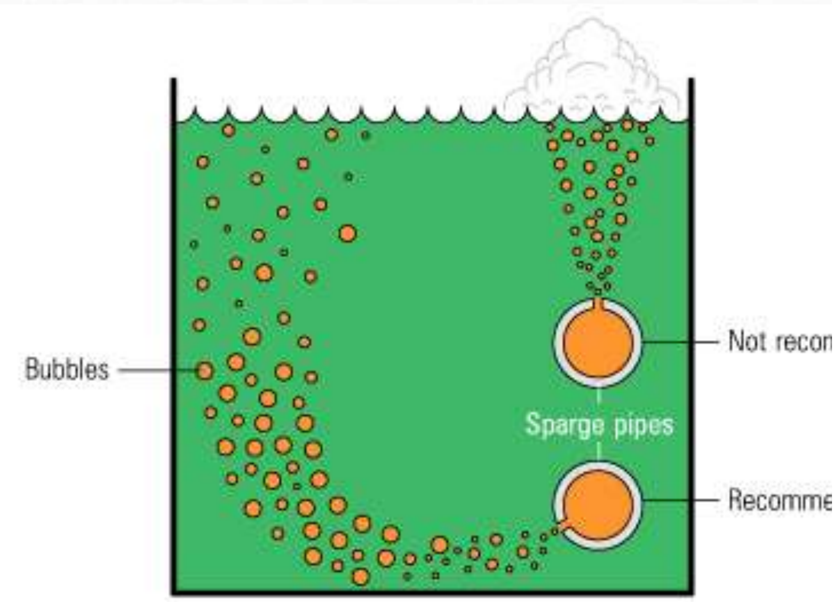
Steam provides heat to transfer to an enclosed hot water circulation system.

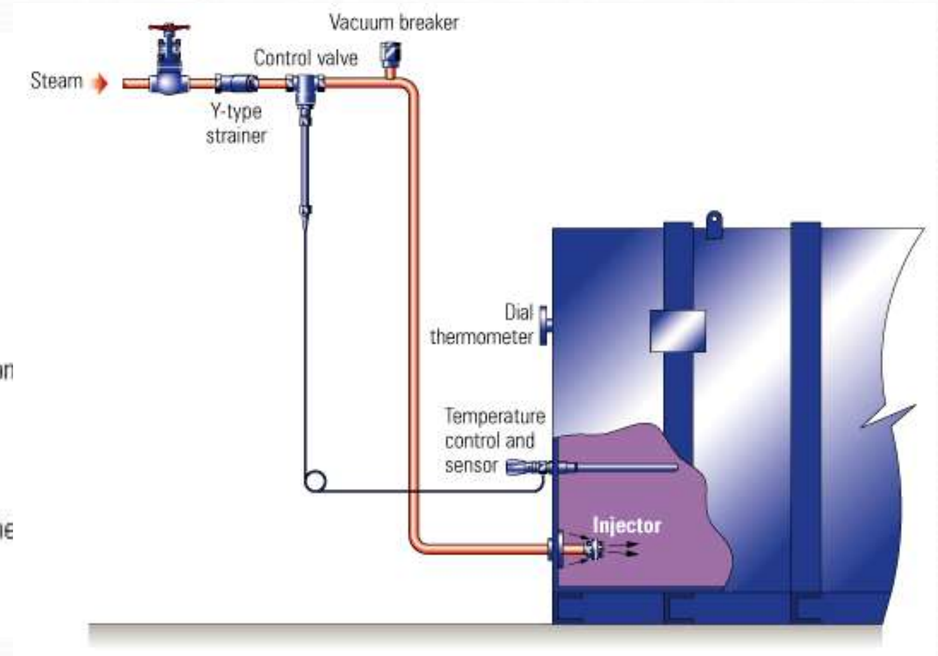


Heating Vats and Tanks by Steam Injection

Direct steam injection involves the discharge of a series of steam bubbles into a liquid at a lower temperature. The steam bubbles condense and give up their heat to the surrounding liquid.

Heat is transferred by direct contact between the steam and the liquid, consequently this method is only used when dilution and an increase in liquid mass is acceptable. Therefore, the liquid being heated is usually water. Direct steam injection is seldom used to heat solutions in which a chemical reaction takes place, as the dilution of the solution would reduce the reaction rate and lower the productivity.

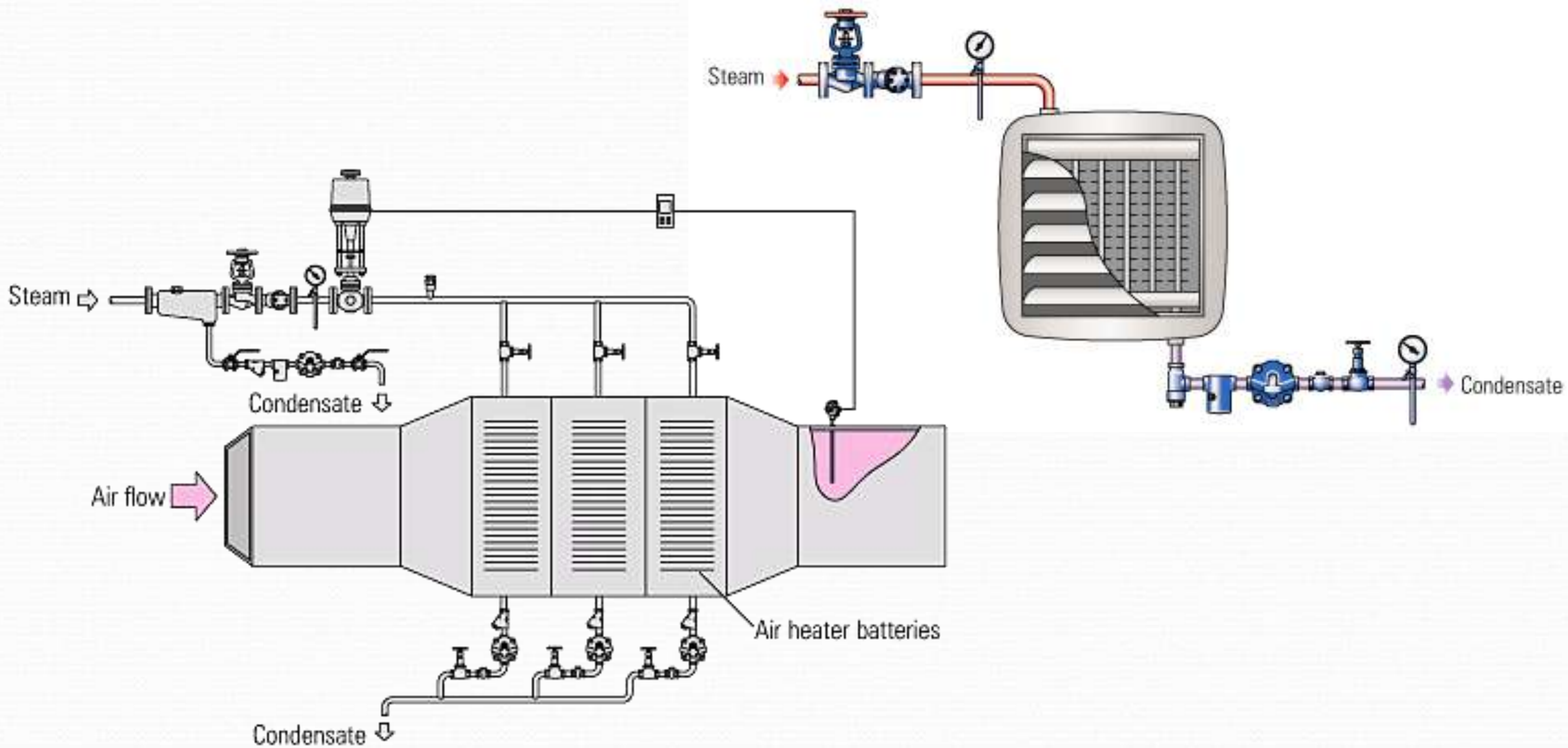




Heater batteries

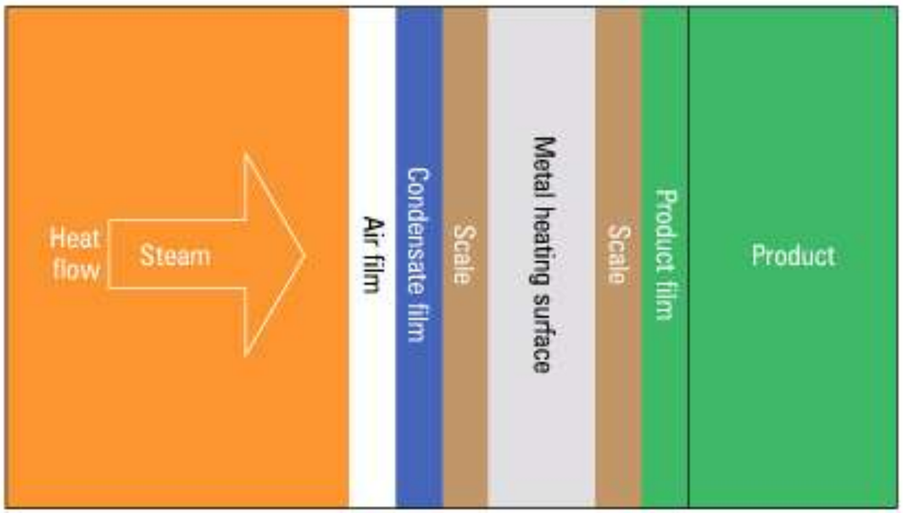
Unit heaters

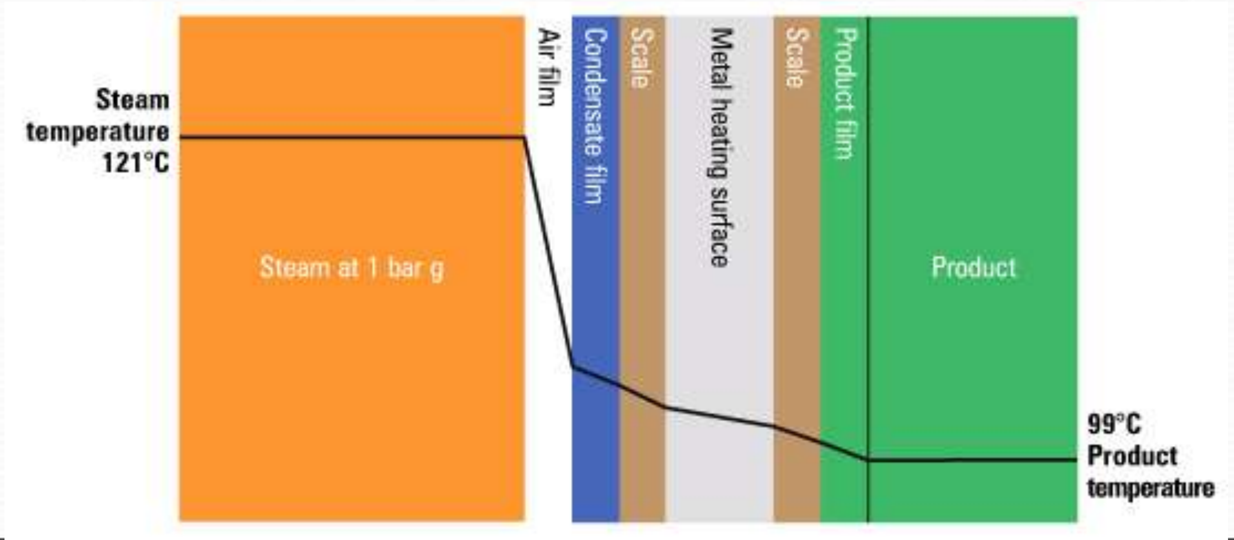
These consist of a heater battery and fan in one compact casing. The primary medium (steam) condenses in the heater battery, and air is warmed as it blows across the coils and is discharged into the space.



Barriers to heat transfer

The metal wall may not be the only barrier in a heat transfer process. There is likely to be a film of air, condensate and scale on the steam side. On the product side there may also be baked-on product or scale, and a stagnant film of product.

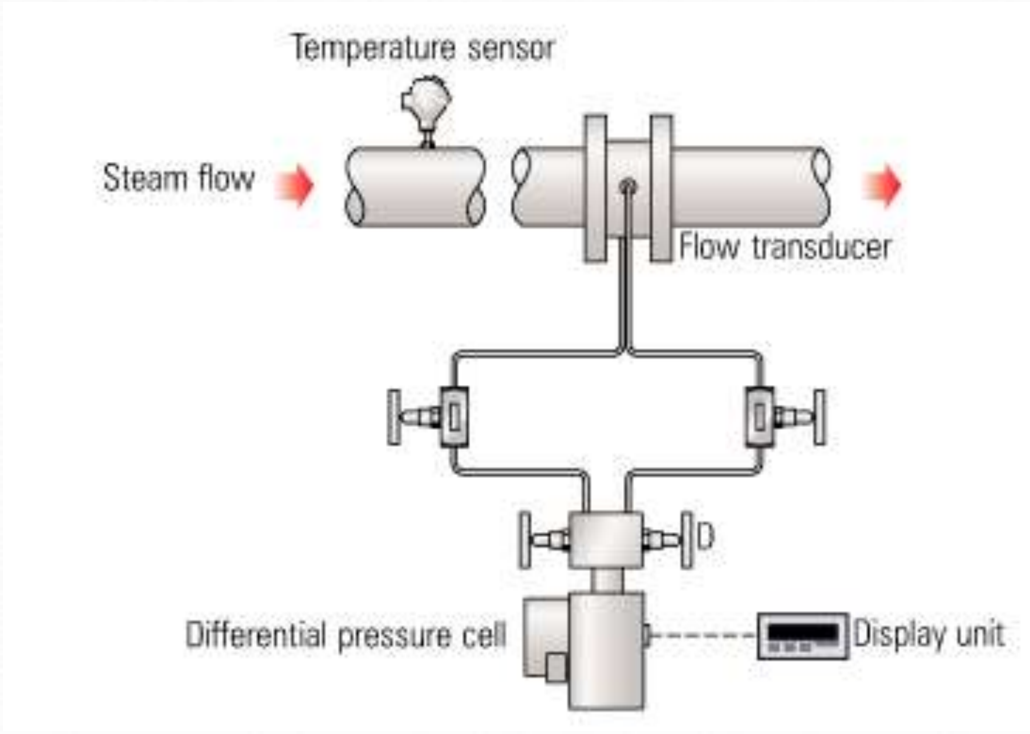




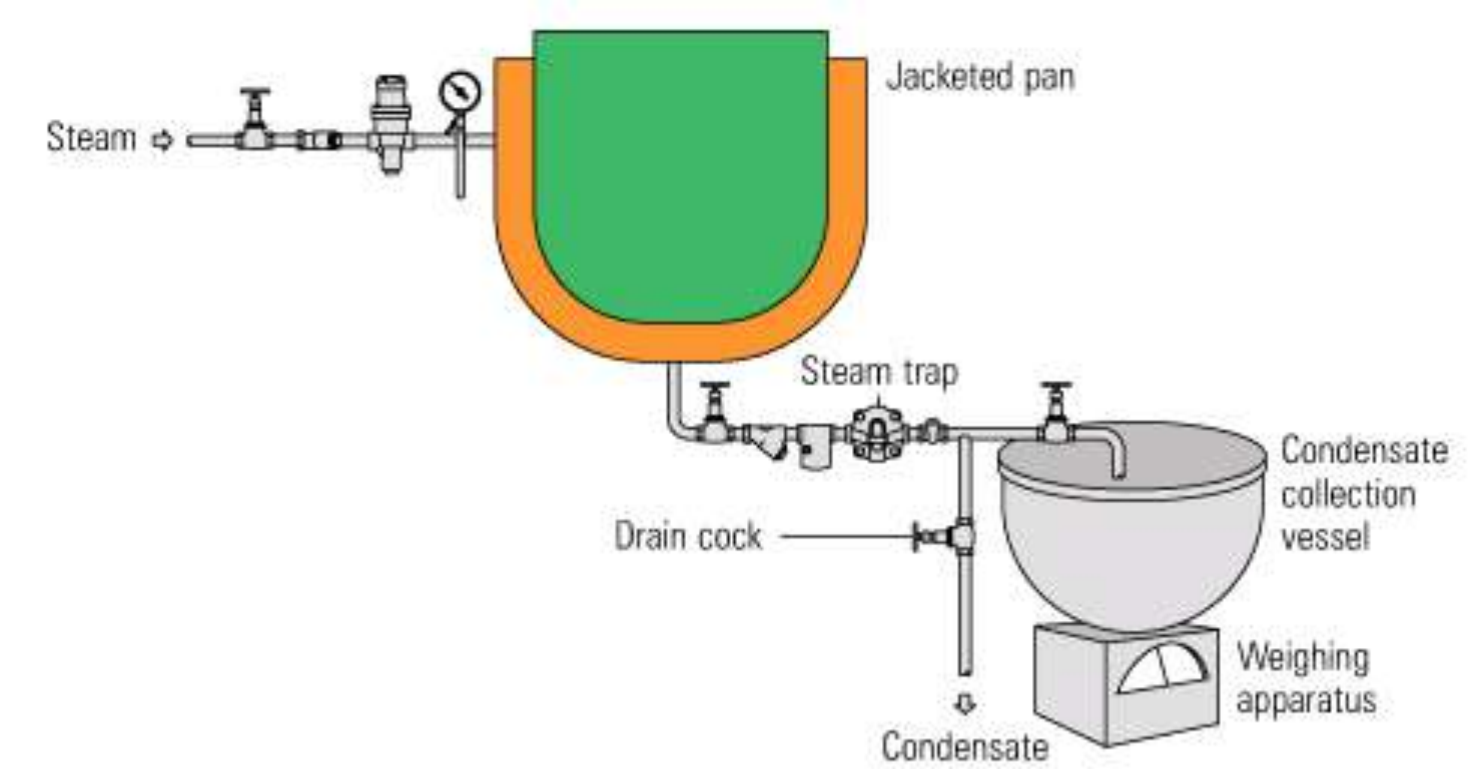
Measurement of Steam Consumption

By a steam flowmeter

The use of a steam flowmeter may be used to directly measure the steam usage of an operational item of plant. This may be used to monitor the results of energy saving schemes and to compare the efficiency of one item of plant with another. The steam can then be costed as a raw material at any stage of the production process, so that the cost of individual product lines may be determined.

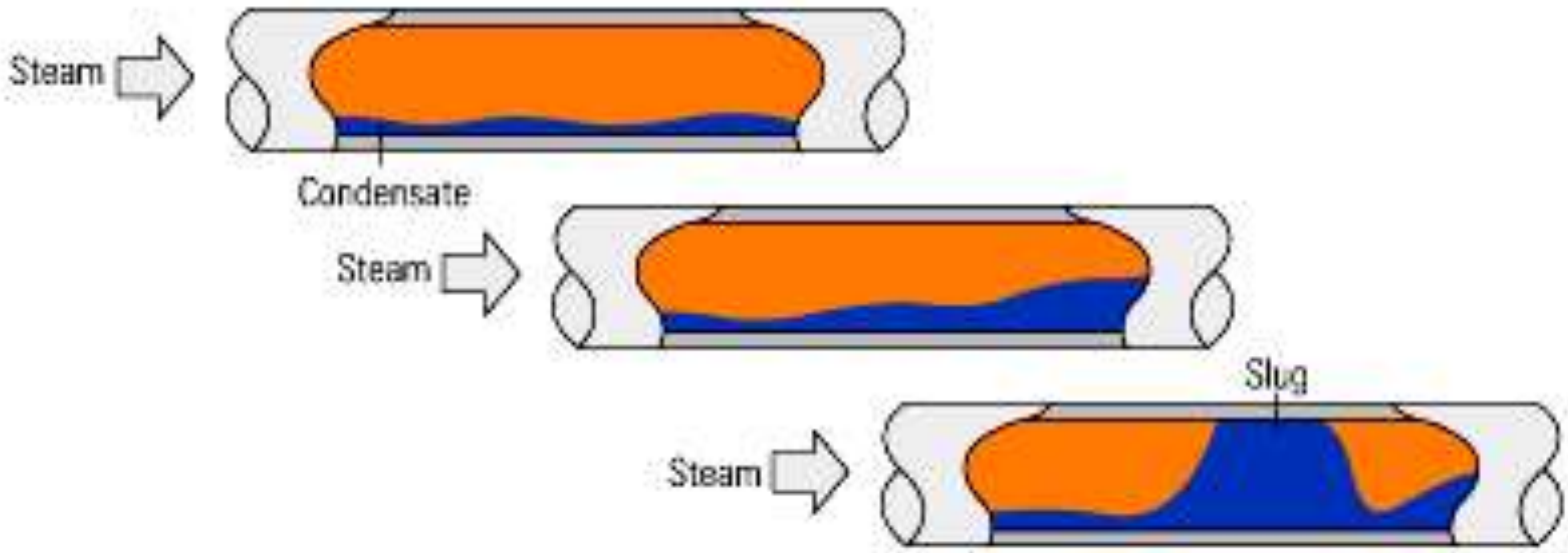


By collecting the condensate



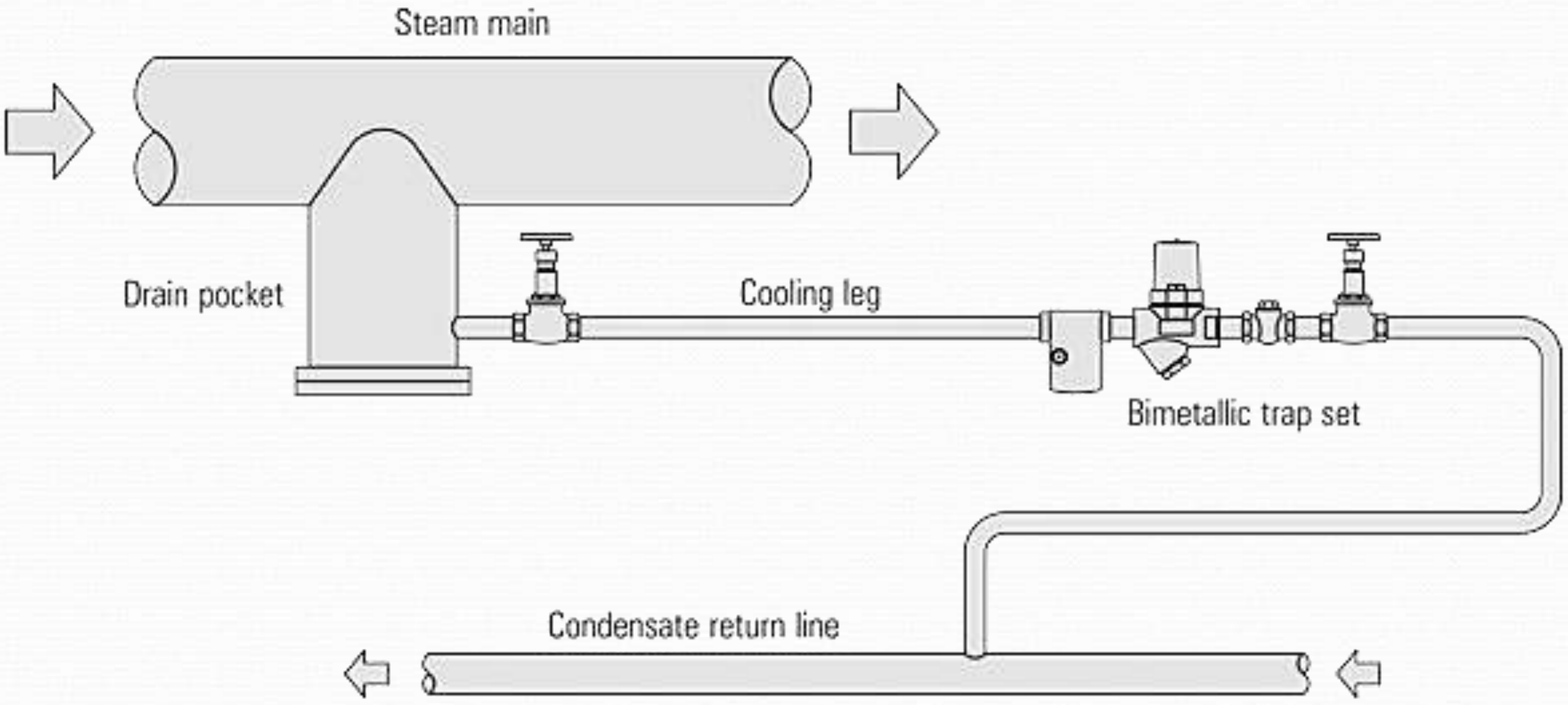
Waterhammer

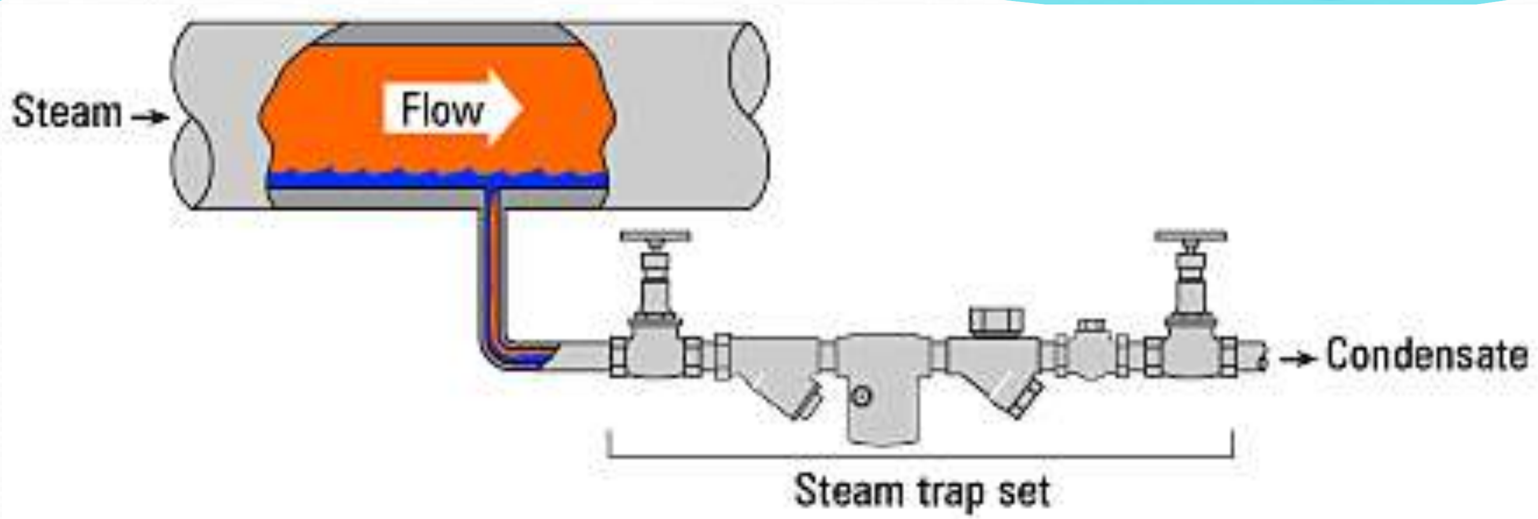
As steam begins to condense due to heat losses in the pipe, the condensate forms droplets on the inside of the walls. As they are swept along in the steam flow, they then merge into a film. The condensate then gravitates towards the bottom of the pipe, where the film begins to increase in thickness. which will be carried at steam velocity along the pipework (25 - 30 m/s).

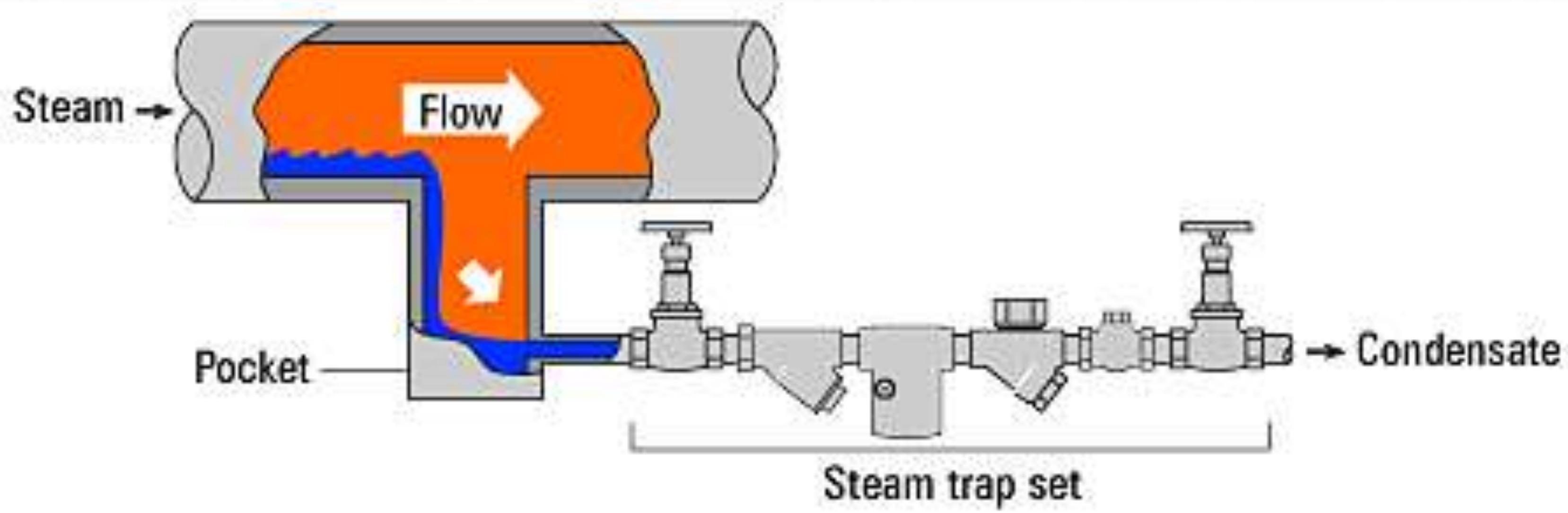


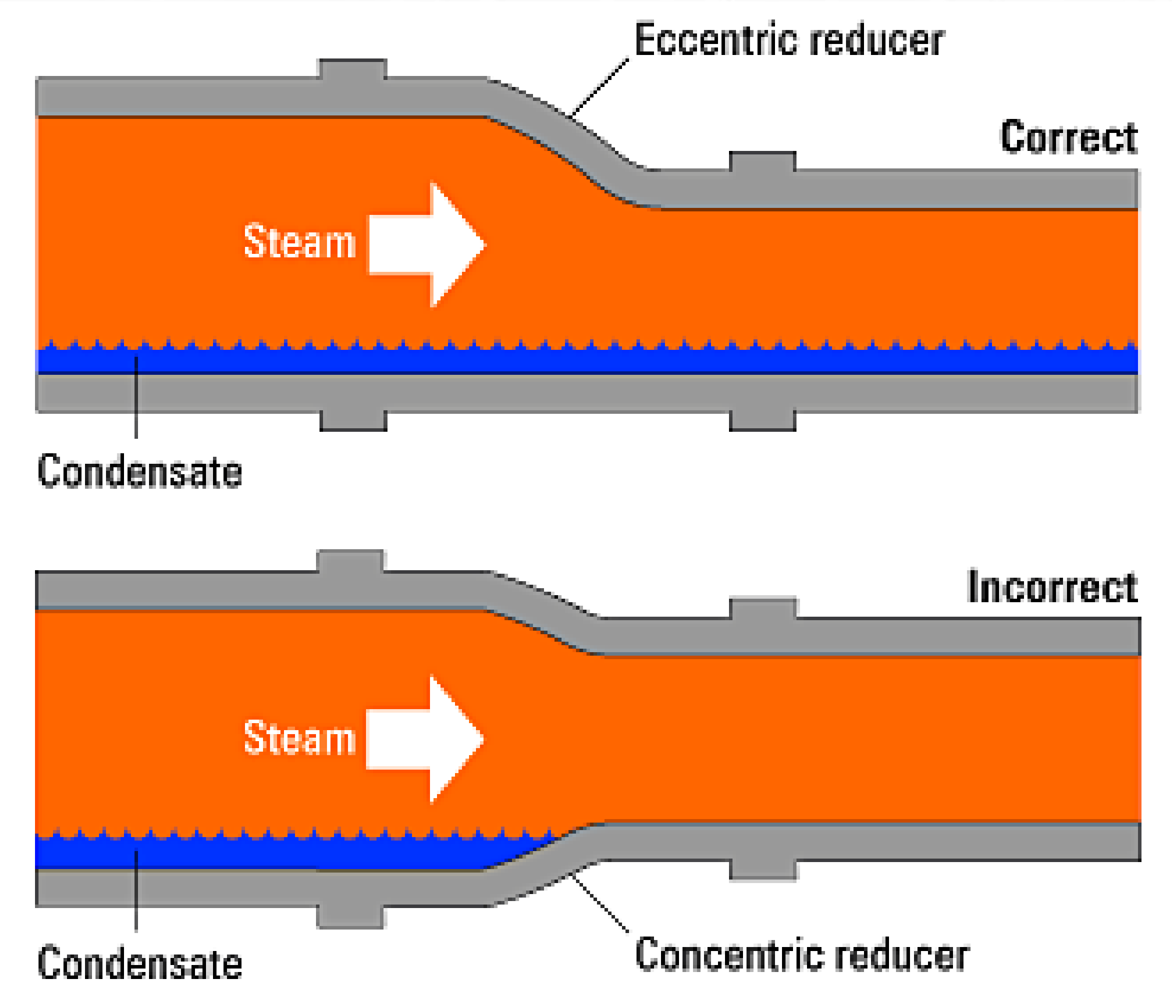
The noise and vibration caused by the impact between the slug of water and the obstruction, is known as waterhammer.

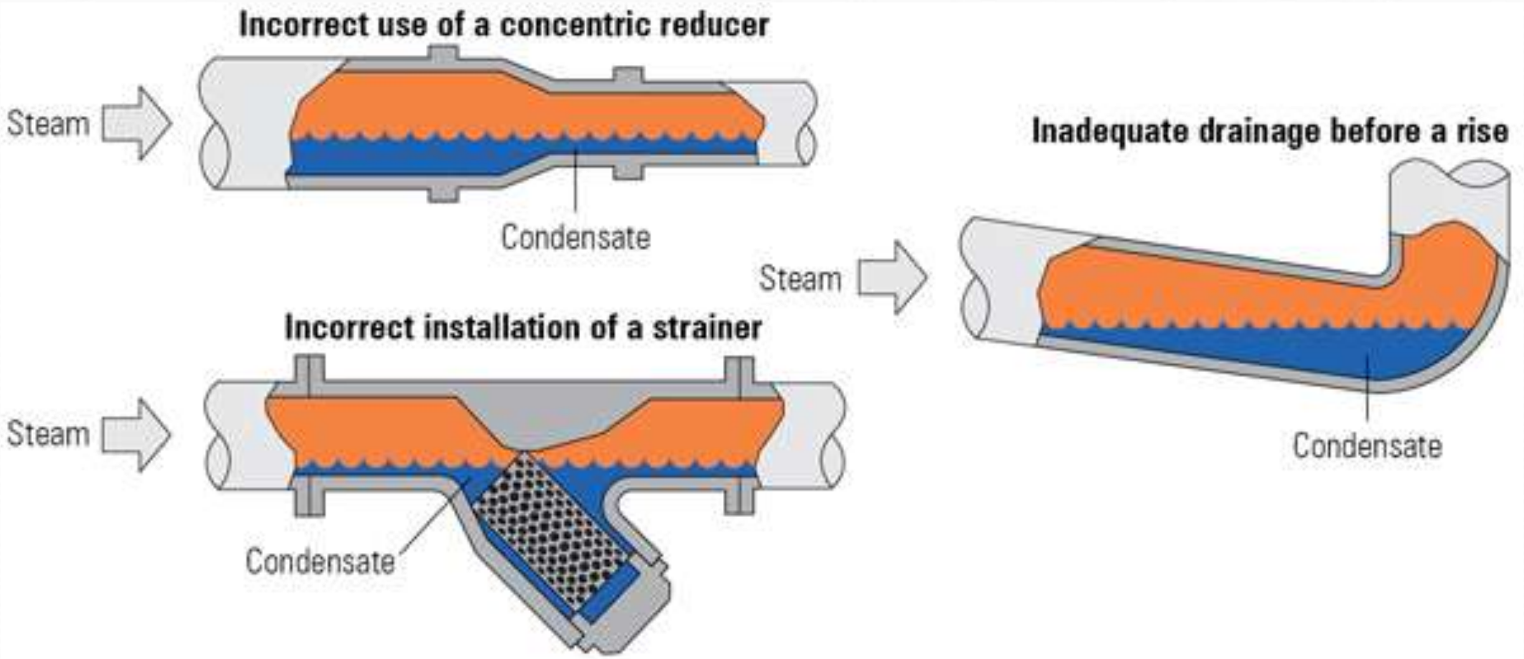
Condensate removal from pipework

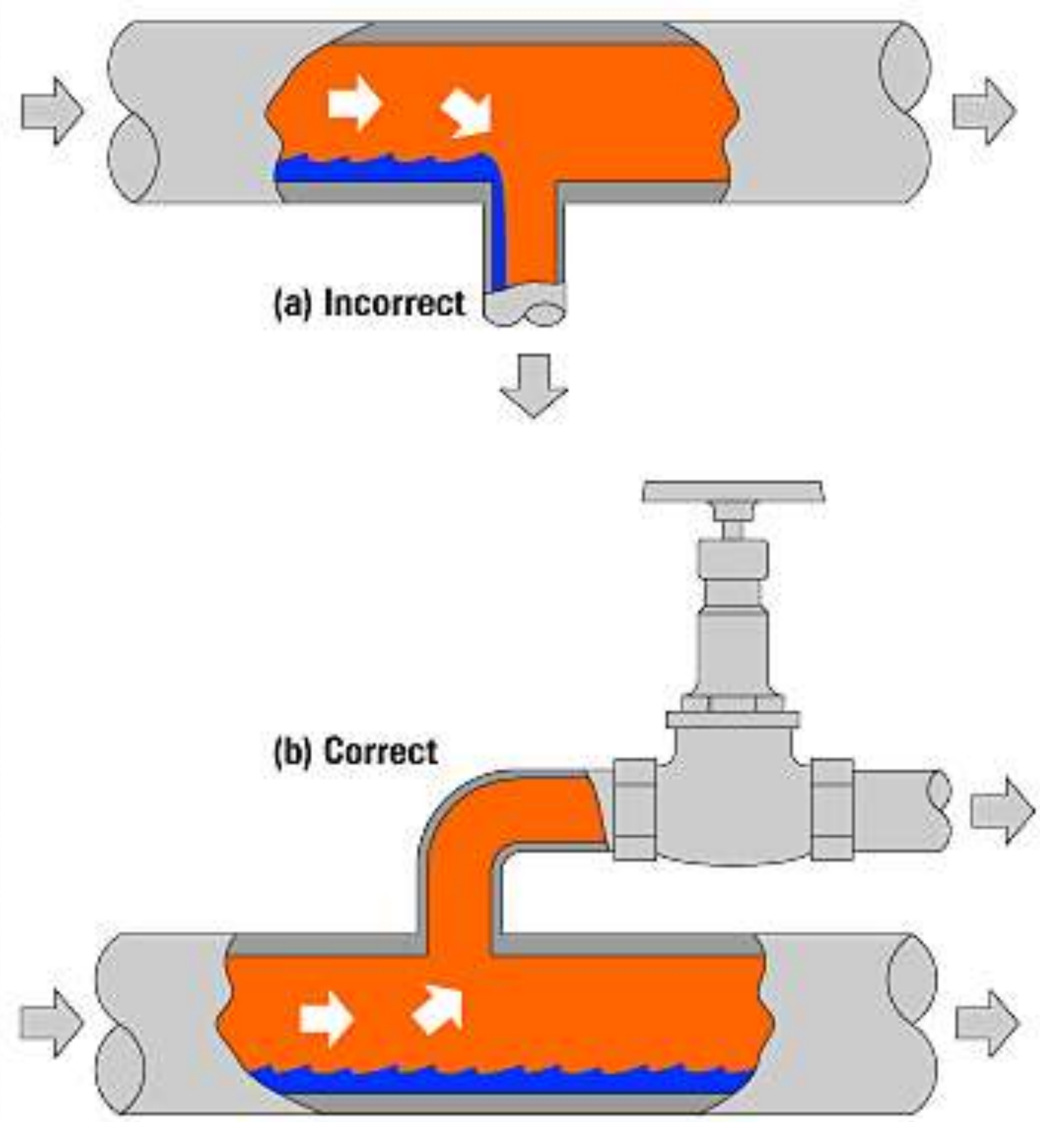



Steam
Flow
Condensate
Steam trap set


Steam
Flow
Pocket
Condensate
Steam trap set


Eccentric reducer
Correct
Steam
Condensate
Incorrect
Steam
Condensate
Concentric reducer


Incorrect use of a concentric reducer
Steam
Condensate
Inadequate drainage before a rise
Steam
Condensate
Incorrect installation of a strainer
Steam
Condensate



(a) Incorrect
(b) Correct

Steam Trap Types

Thermostatic

Mechanical

Thermodynamic

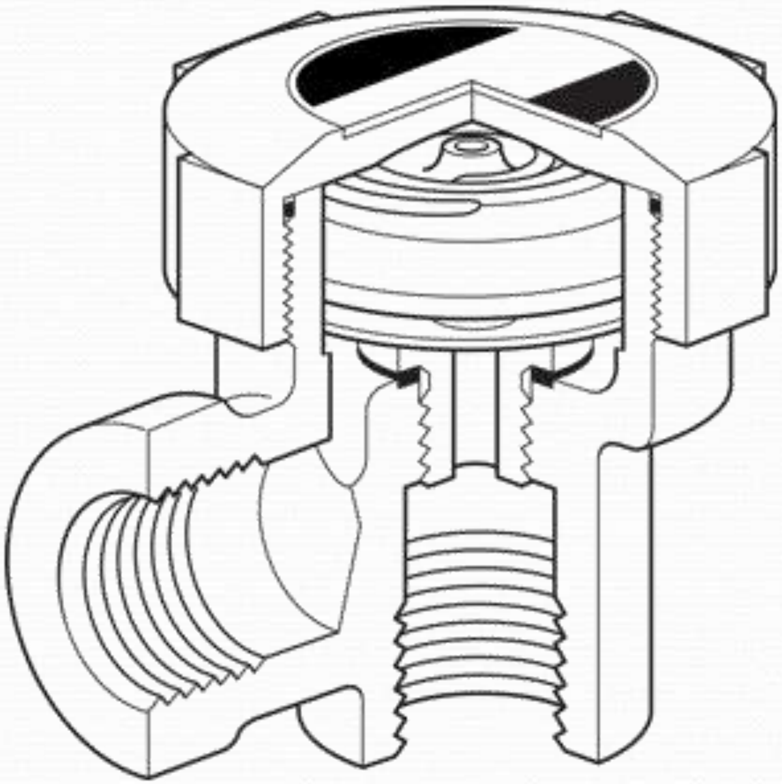
Thermostatic types

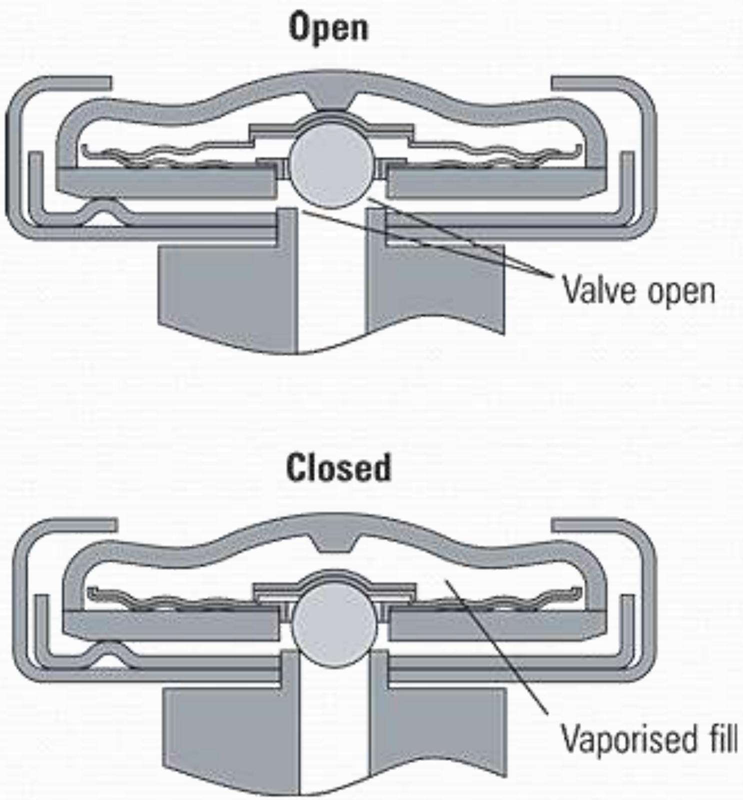
Balanced pressure

Liquid expansion

Bi-metalic

Balanced pressure steam trap with replaceable capsule



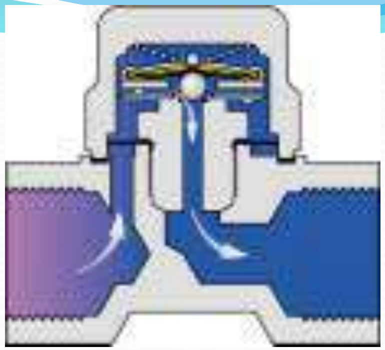


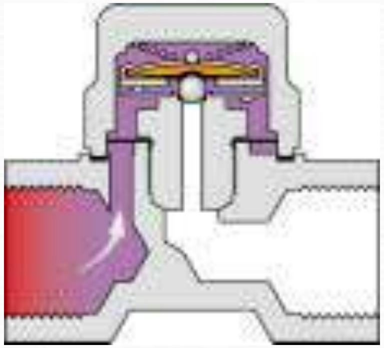
How the balanced pressure thermostatic steam trap works

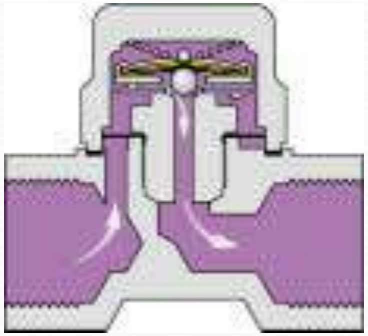
At the heart of the balanced pressure thermostatic steam trap is a stainless steel capsule - filled with deionised water and alcohol. For further details see the note under Product range and options.

On start-up, cold air and condensate enter the trap. As the capsule is also cold, the valve is open and the air and condensate are discharged (**1**). The capsule warms up as the condensate approaches steam temperature. Its liquid filling boils, and the resultant vapour pressure acting on the diaphragms pushes the valve head towards the seat (**2**), fully closing at the selected discharge temperature before any steam is lost.

As the condensate within the trap cools, the vapour filling condenses and the internal capsule pressure falls. The valve reopens, discharges condensate and the cycle repeats (**3**).







Advantages of the balanced pressure steam trap:

Small, light and has a large capacity for its size.

The valve is fully open on start-up, allowing air and other non-condensable gases to be discharged freely and giving maximum condensate removal when the load is greatest.

This type of trap is unlikely to freeze when working in an exposed position (unless there is a rise in the condensate pipe after the trap, which would allow water to run back and flood the trap when the steam is off).

The modern balanced pressure trap automatically adjusts itself to variations of steam pressure up to its maximum operating pressure.

Trap maintenance is simple. The capsule and valve seat are easily removed, and replacements can be fitted in a few minutes without removing the trap from the line.

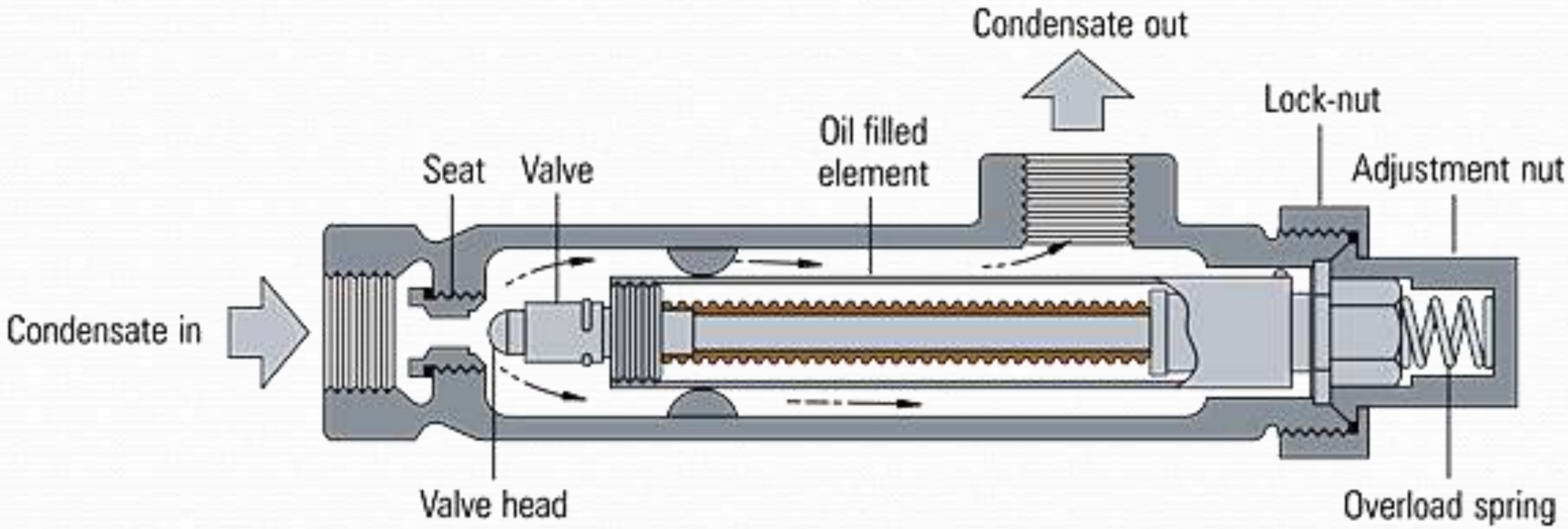
Disadvantages of the balanced pressure steam trap:

The older style balanced pressure steam traps had bellows which were susceptible to damage by waterhammer or corrosive condensate.

Welded stainless steel capsules introduced more recently, are better able to tolerate such conditions.

In common with all other thermostatic traps, the balanced pressure type does not open until the condensate temperature has dropped below steam temperature (the exact temperature difference being determined by the fluid used to fill the element). This is clearly a disadvantage if the steam trap is chosen for an application in which waterlogging of the steam space can not be tolerated, for example; mains drainage, heat exchangers, critical tracing.

Liquid expansion steam trap



Liquid expansion steam trap
This is one of the simplest thermostatic traps.
An oil filled element expands when heated to close the valve against the seat.

The adjustment allows the temperature of the trap discharge to be altered between 60°C and 100°C, which makes it ideally suited as a device to get rid of large quantities of air and cold condensate at start-up.

Advantages of the liquid expansion steam trap:

Liquid expansion traps can be adjusted to discharge at low temperatures, giving an excellent 'cold drain' facility.

Like the balanced pressure trap, the liquid expansion trap is fully open when cold, giving good air discharge and maximum condensate capacity on 'start-up' loads.

The liquid expansion trap can be used as a start-up drain trap on low pressure superheated steam mains where a long cooling leg is guaranteed to flood with cooler condensate.

It is able to withstand vibration and waterhammer conditions.

Disadvantages of the liquid expansion steam trap:

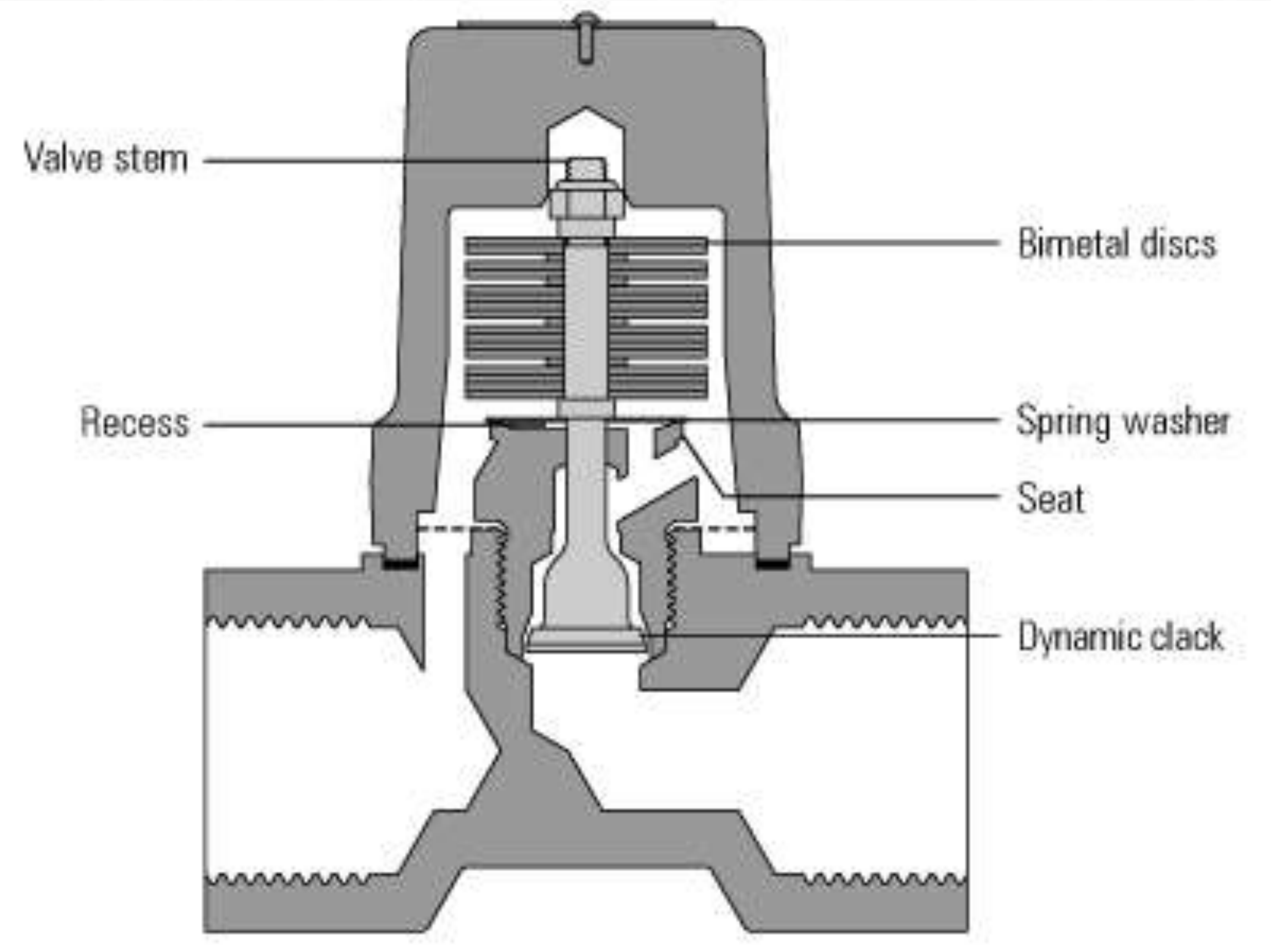
The flexible tubing of the element can be destroyed by corrosive condensate or superheat.

Since the liquid expansion trap discharges condensate at a temperature of 100°C or below, it should never be used on applications which demand immediate removal of condensate from the steam space.

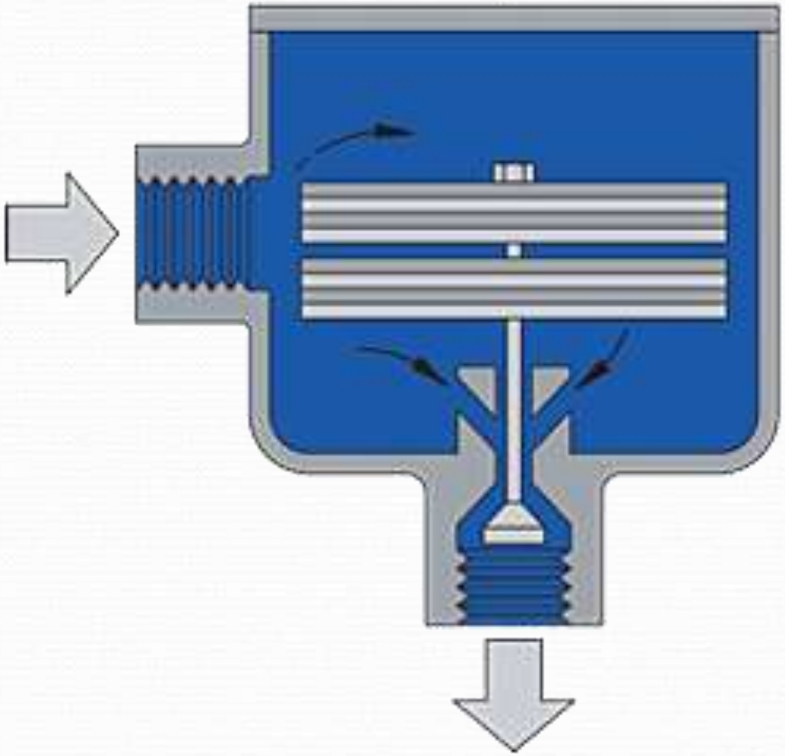
If the trap is to be subjected to freezing conditions the trap and its associated pipework must be well insulated.

The liquid expansion trap is not normally a trapping solution on its own, as it usually requires another steam trap to operate in parallel.

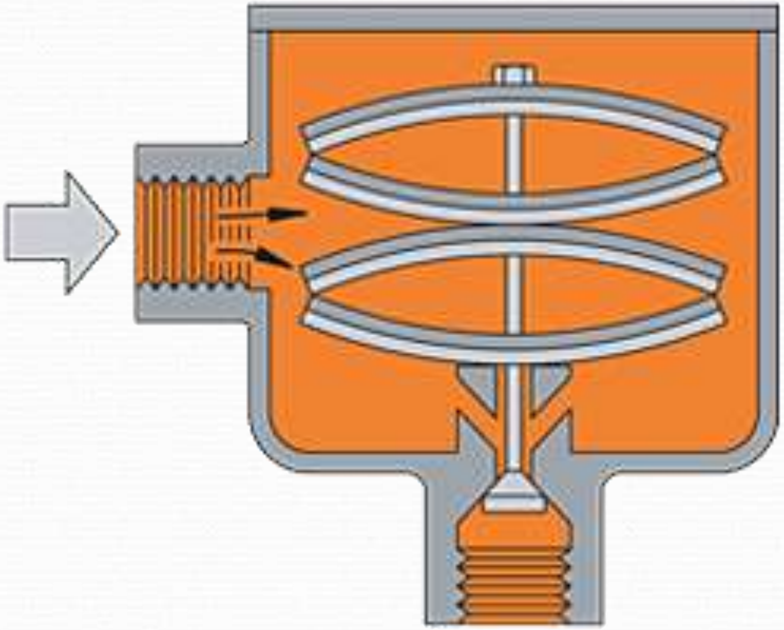
Bi-metalic steam trap



Open



Closed



Advantages of the bimetallic steam trap:

Bimetallic steam traps are usually compact, yet can have a large condensate capacity.
The valve is wide open when the steam trap is cold, giving good air venting capability and maximum condensate discharge capacity under 'start-up' conditions.

As condensate tends to drain freely from the outlet, this type of steam trap will not freeze up when working in an exposed position. The bodies of some bimetallic steam traps are designed in such a way that they will not receive any damage even if freezing does occur.

Bimetallic steam traps are usually able to withstand waterhammer, corrosive condensate, and high steam pressures.

The bimetal elements can work over a wide range of steam pressures without any need for a change in the size of the valve orifice.

If the valve is on the downstream side of the seat, it will tend to resist reverse flow through the steam trap.

Maintenance of this type of steam trap presents few problems, as the internals can be replaced without removing the trap body from the line.

Disadvantages of the bimetallic steam trap:

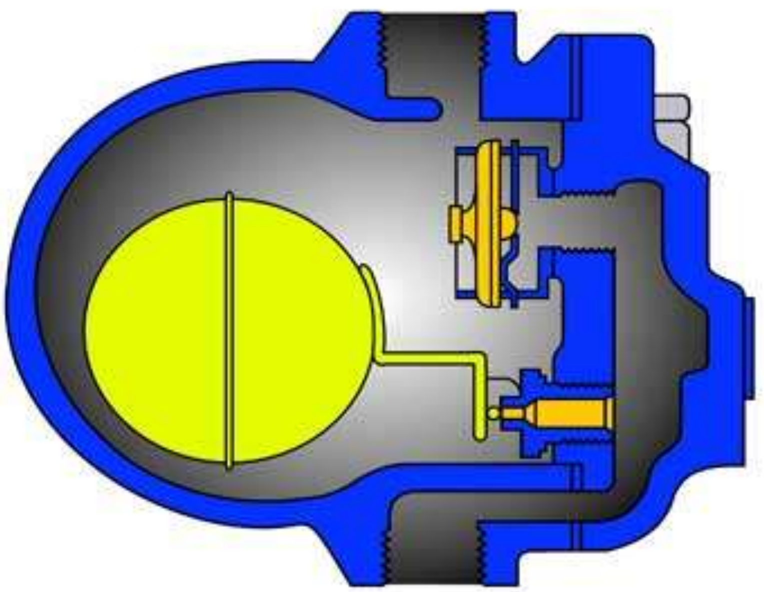
As condensate is produced, waterlogging of the steam space will occur unless the steam trap is fitted at the end of a long cooling leg.
It may be necessary to increase the length of cooling leg to meet this condition.

Bimetallic steam traps are not suitable for fitting to process plants where immediate condensate removal is vital for maximum output to be achieved.
This is particularly relevant on temperature controlled plants.

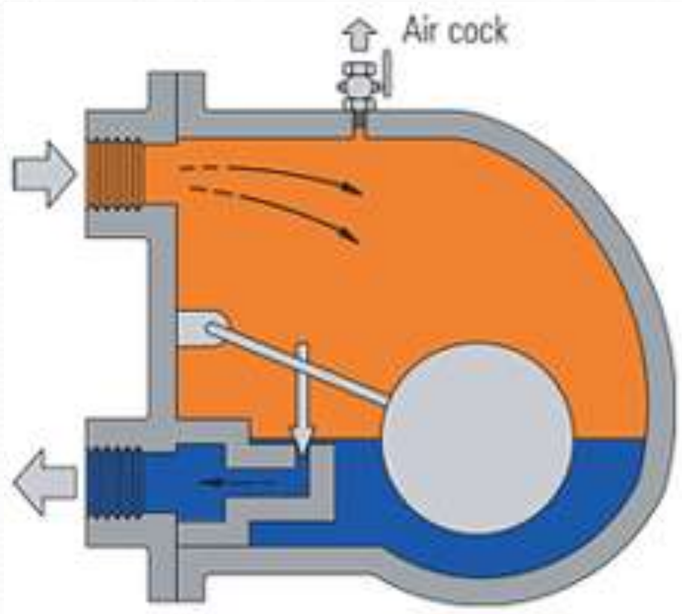
Some bimetallic steam traps are vulnerable to blockage from pipe dirt due to low internal flow velocities.

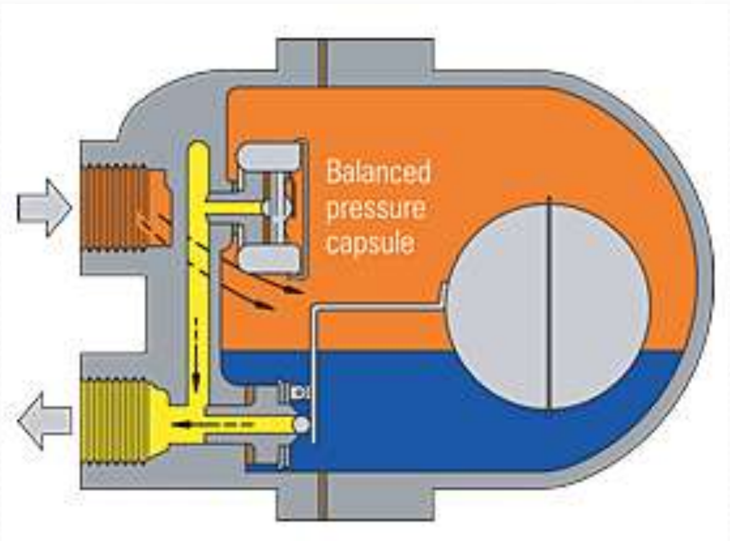
Bimetallic steam traps do not respond quickly to changes in load or pressure because the element is slow to react

Ball float steam trap



Ball float steam trap





The ball float type trap operates by sensing the difference in density between steam and condensate. In the case of the trap shown condensate reaching the trap will cause the ball float to rise, lifting the valve off its seat and releasing condensate. As can be seen, the valve is always flooded and neither steam nor air will pass through it, so early traps of this kind were vented using a manually operated valve at the top of the body. Modern traps use a thermostatic air vent, as this allows the initial air to pass whilst the trap is also handling condensate.

Advantages of the float steam trap

The trap continuously discharges condensate at steam temperature. This makes it the first choice for applications where the rate of heat transfer is high for the area of heating surface available.

It is able to handle heavy or light condensate loads equally well and is not affected by wide and sudden fluctuations of pressure or flowrate.

As long as an automatic air vent is fitted, the trap is able to discharge air freely.

It has a large capacity for its size.

The versions which have a steam lock release valve are the only type of trap entirely suitable for use where steam locking can occur.

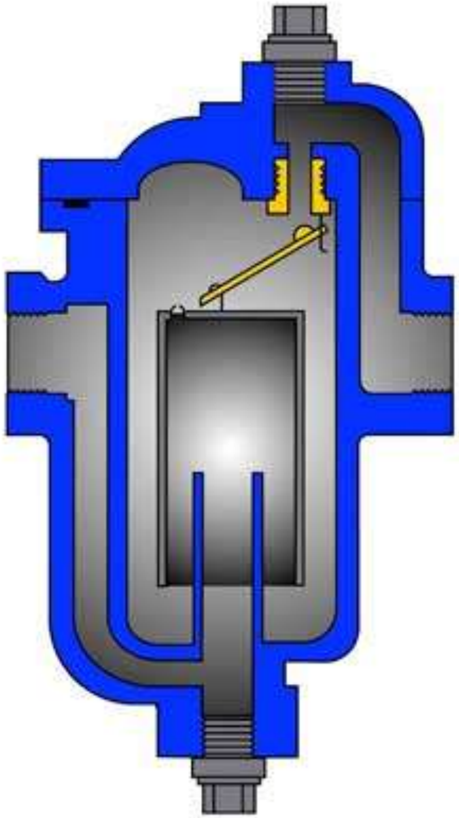
It is resistant to waterhammer.

Disadvantages of the float steam trap

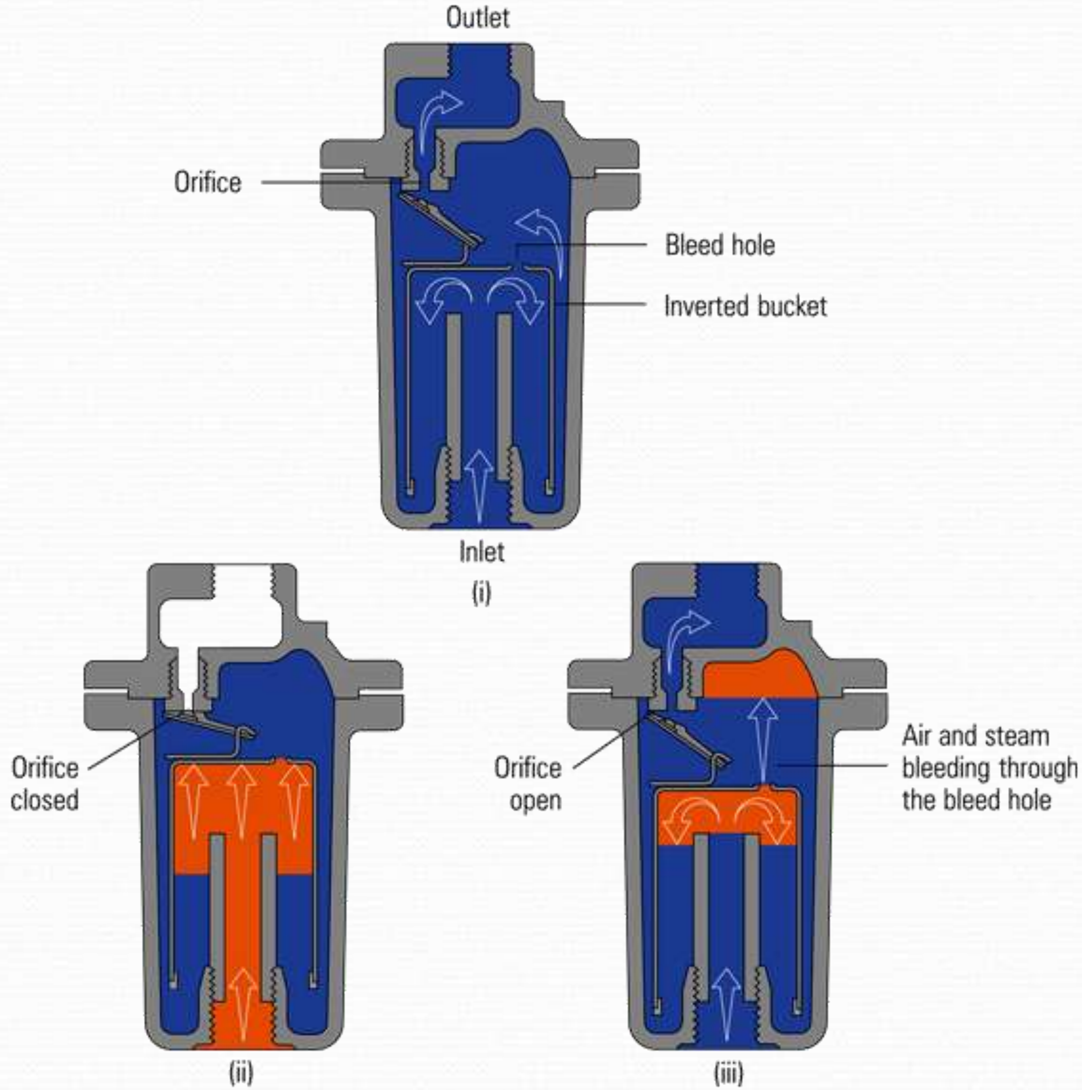
Although less susceptible than the inverted bucket trap, the float type trap can be damaged by severe freezing and the body should be well lagged, and / or complemented with a small supplementary thermostatic drain trap, if it is to be fitted in an exposed position.

As with all mechanical type traps, different internals are required to allow operation over varying pressure ranges.

Inverted bucket trap



Inverted bucket trap



Advantages of the inverted bucket steam trap

The inverted bucket steam trap can be made to withstand high pressures.

Like a float-thermostatic steam trap, it has a good tolerance to waterhammer conditions.

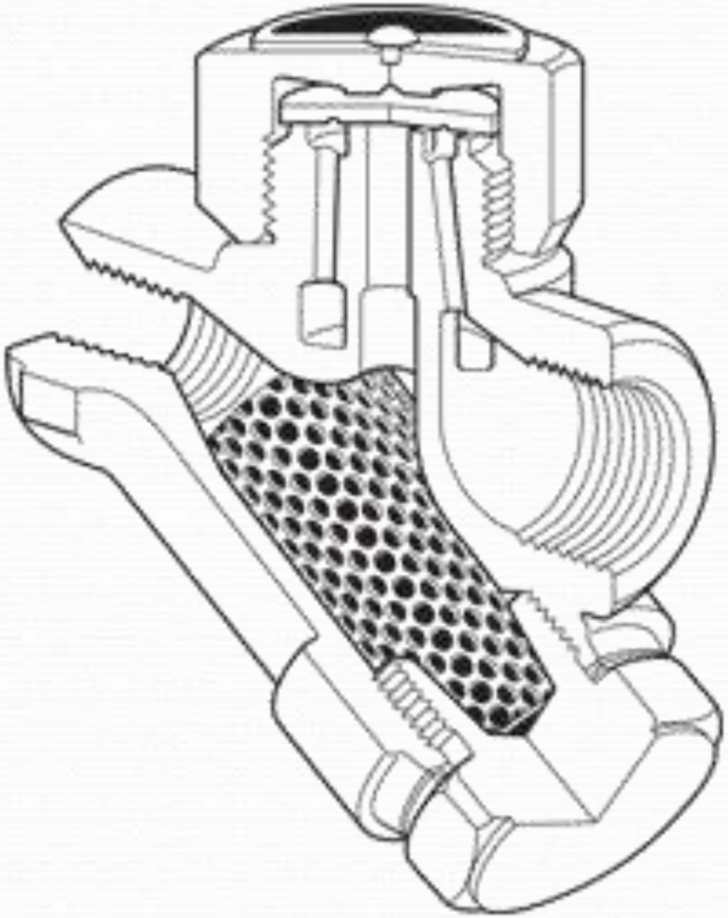
Disadvantages of the inverted bucket steam trap

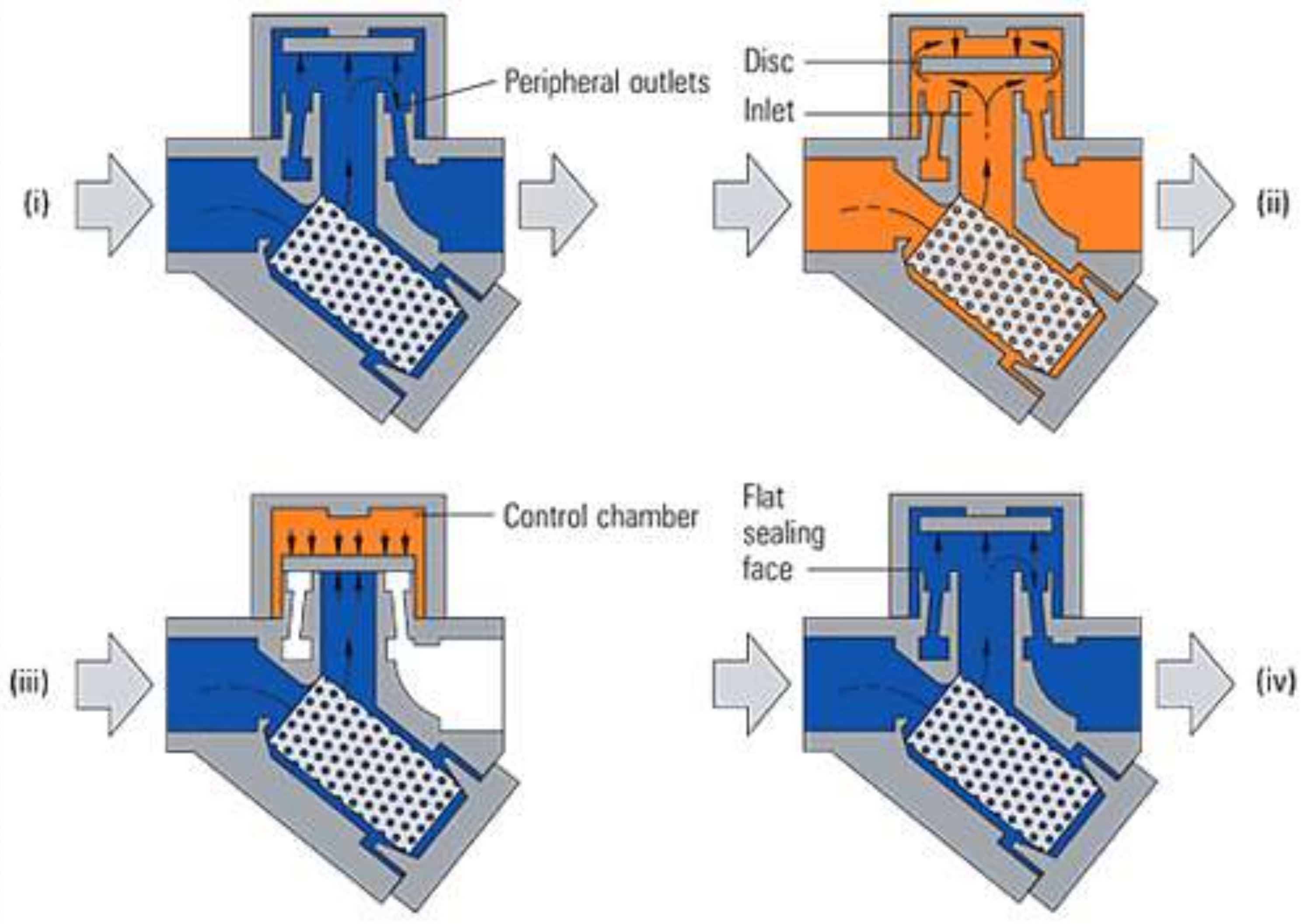
The small size of the hole in the top of the bucket means that this type of trap can only discharge air very slowly. The hole cannot be enlarged, as steam would pass through too quickly during normal operation.

There should always be enough water in the trap body to act as a seal around the lip of the bucket. If the trap loses this water seal, steam can be wasted through the outlet valve. The bucket loses its buoyancy and sinks, allowing live steam to pass through the trap orifice.
Only if sufficient condensate reaches the trap will the water seal form again, and prevent steam wastage.

he inverted bucket trap is likely to suffer damage from freezing if installed in an exposed position with sub-zero ambient conditions. Suitable lagging can overcome this problem if conditions are not too severe.

Thermodynamic steam trap





Peripheral outlets
Disc
Inlet
(i)
(ii)
Control chamber
Flat
sealing
face
(iii)
(iv)

Advantages of the thermodynamic steam trap

Thermodynamic traps can operate across their entire working range without any adjustment or change of internals.

They are compact, simple, lightweight and have a large condensate capacity for their size.

Thermodynamic traps can be used on high pressure and superheated steam and are not affected by waterhammer or vibration. The all stainless steel construction offers a high degree of resistance to corrosive condensate.

Thermodynamic traps are not damaged by freezing and are unlikely to freeze if installed with the disc in a vertical plane and discharging freely to atmosphere. However, operation in this position may result in wear of the disc edge.

As the disc is the only moving part, maintenance can easily be carried out without removing the trap from the line.

The audible 'click' which occurs as the trap opens and closes makes trap testing very straight forward.

Disadvantages of the thermodynamic steam trap

Thermodynamic steam traps will not work positively on very low differential pressures.

They are subjected to a minimum inlet pressure (typically 0.25 bar g)

Thermodynamic traps can discharge a large amount of air on 'start-up' if the inlet pressure builds up slowly.

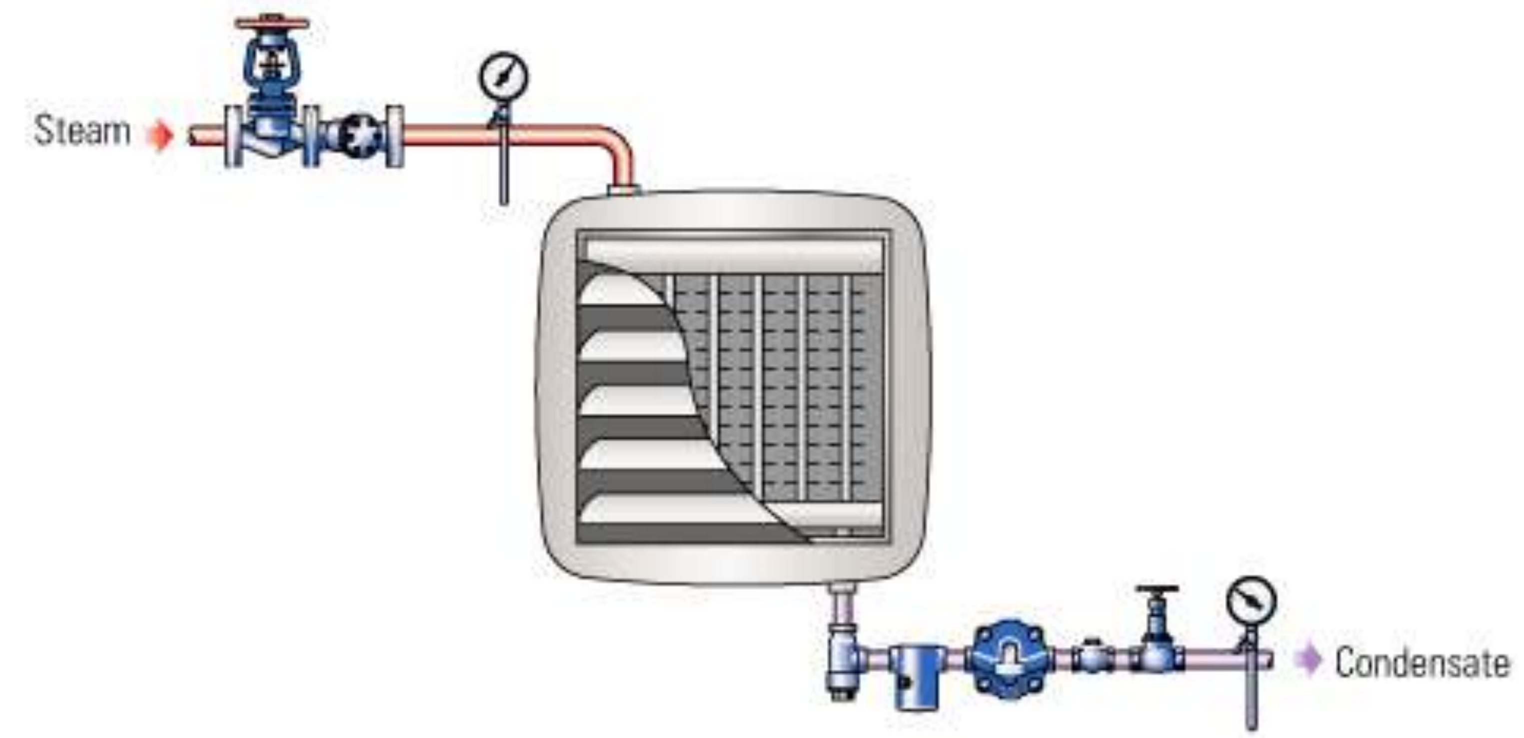
Rapid pressure build-up will cause high velocity air to shut the trap in the same way as steam, and it will 'air-bind'.

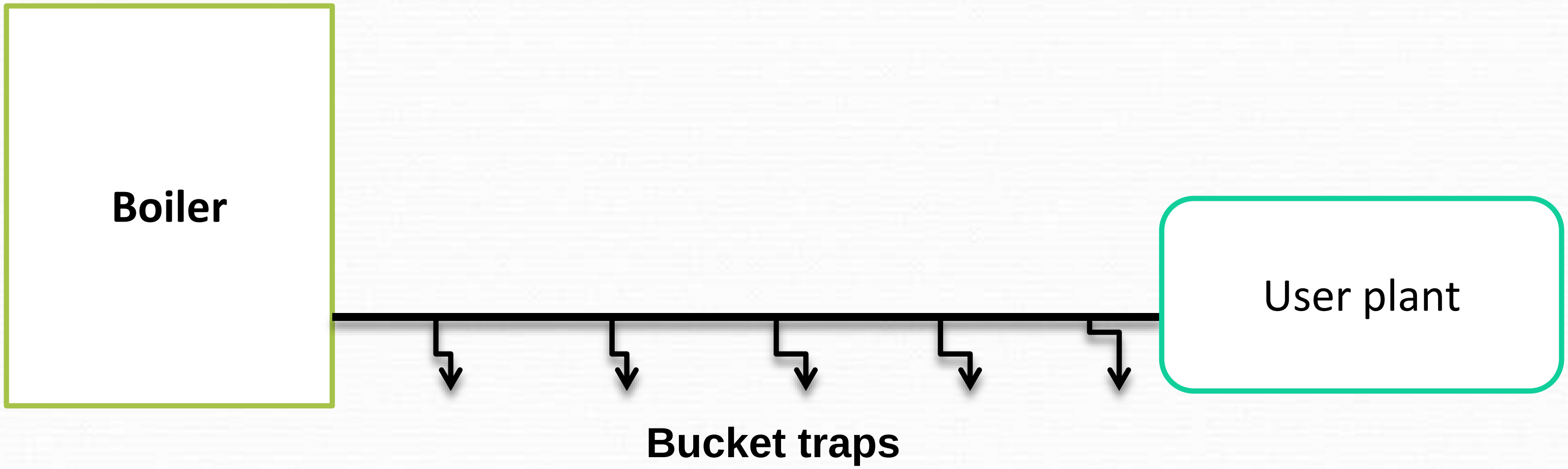
The discharge of the trap can be noisy and this factor may prohibit the use of a thermodynamic trap in some locations, e.g. outside a hospital ward, operating theatre, lecture areas etc

If noise is a problem, it can easily be fitted with a diffuser which considerably reduces the discharge noise.

Unit heaters

These consist of a heater battery and fan in one compact casing. The primary medium (steam) condenses in the heater battery, and air is warmed as it blows across the coils and is discharged into the space.




Boiler
User plant
Bucket traps