STEAM MANUAL

STEAM TRAPS & ENERGY TRAPS

INTELLIGENT TRAP VALVE STATIONS

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CHAPTER I

STEAM: BASIC CONCEPTS

1.1 PHASE TRANSITION

Water steam is a thermal fluid that is widely used across the industry because of these notable properties:

» High energetic content

» Easy to transport

The combination of these two properties allows for the distribution of large amounts of energy from locations that are distant from the facilities, thus taking advantage of the steam's internal pressure to pump the fluid.

Water can exist in three different states: solid, liquid, and gas or steam. The process of moving from one state to another is called a phase transition, which is produced through the exchange of energy in the form of heat. When the change of state occurs from a solid to a gas, the process requires energy, and when the change occurs in the opposite direction, it releases energy.

Figure 1.1 shows the process of vaporizing water by adding heat where you can see the three different stages.

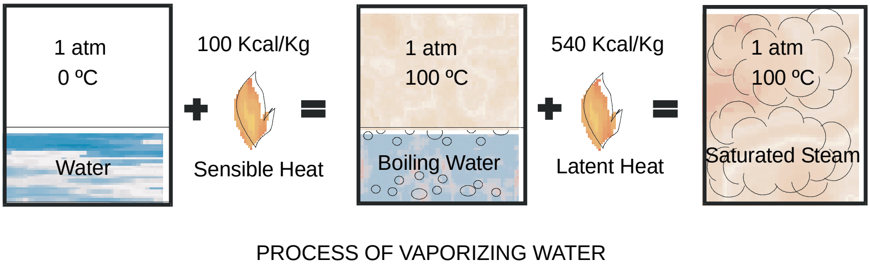


Figure 1.1

Stage 1: Consists of water in the form of a liquid at atmospheric pressure and zero degrees Celsius; as heat is added the water will rise in temperature until it reaches its boiling point, 100 degree Celsius. The amount of energy given in this process is called the sensible heat (head added to the liquid without a change in state); this amount depends on the pressure.

Stage 2: Heat added after the boiling point results in the vaporization of water, but the temperature remains constant while vaporization is occurring, meaning that water and steam are both present simultaneously. Energy absorbed in the formation of steam is known as latent heat; this amount depends on pressure.

Stage 3: UOnce all of the water has become vapor, any additional heat causes the temperature to rise and the result is ***superheated steam***.

Figure 1-2 shows the three stages of the vaporization process.

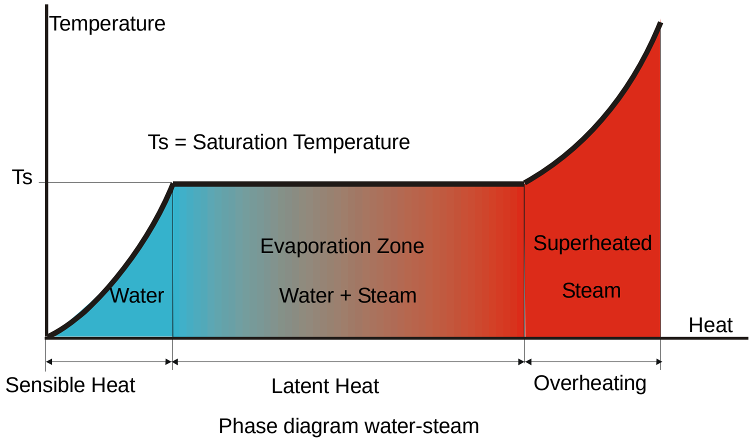


Figure 1.2

Note that the diagram of the water-steam phases is different for each pressure, therefore, representing this diagram for different pressure values on three-dimensional coordinates would provide us an area that varies on three magnitudes (pressure, temperature, and heat), where the latent heat and the saturation temperature change according to the pressure.

As shown, the total energetic content of the steam is:

Total Heat = Sensible Heat + Latent Heat + Overheating

Figure 1-3 shows the ***steam saturation curve***, which connects the boiling point of water with pressure. This variation can also be seen in the ***saturated steam chart*** included at the end of this chapter.

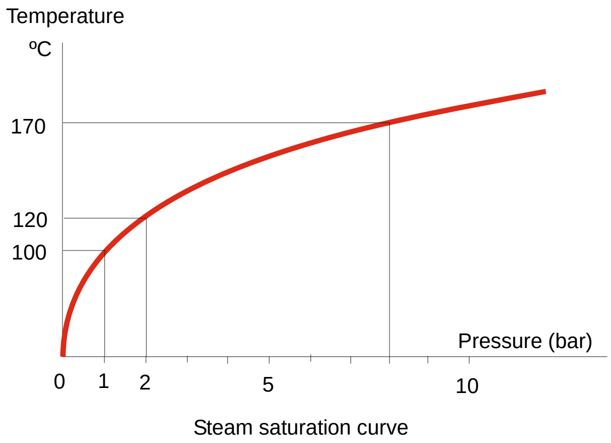


Figure 1.3

1.2 TERMINOLOGY

The following are some frequently used terms related to steam:

Saturated steam or live steam: Water steam at the boiling or saturation temperature.

Dry saturated steam: Water steam at the boiling temperature without any particles of water in the steam.

Superheated steam: Steam whose temperature is higher than the saturation point that corresponds to a given pressure.

Condensation: The inverse process of vaporization, which is the change of steam to water (condensate), releasing its latent heat during this process.

Manometric pressure: The pressure measurement that uses atmospheric pressure as a reference level, as indicated by a pressure gauge.

Absolute pressure: Pressure measured from zero, thus absolute pressure is the manometric pressure, plus one bar.

Working pressure or operating pressure: The manometric pressure of steam at the inlet to the steam trap.

Backpressure: Pressure at the outlet of the steam trap, which is pressure in the water return lines.

Differential pressure: The difference between operating pressure and backpressure, meaning, the pressure before the steam trap minus the pressure after.

Calorie (Cal): The amount of heat needed to raise the temperature of one gram of water from 14.5 degrees Celsius to 15.5 degrees Celsius.

Kilocalorie (Kcal): The amount of heat needed to raise the temperature of one Kilogram of water from 14.5 degrees Celsius to 15.5 degrees Celsius; equivalent to 1000 Cal.

Specific Heat: The amount of heat that is required to raise the temperature of one mass unit of a substance one degree Celsius. It is expressed as Kcal/Kg°C. The specific heat of water = 1 Kcal/Kg°C.

Specific Volume: The volume occupied by one mass unit of a substance. It is expressed as m3/Kg. The specific volume of steam is very large in comparison with that of water; for this reason, steam trap discharge is usually accompanied by a cloud of flash steam even when the steam trap is properly functioning.

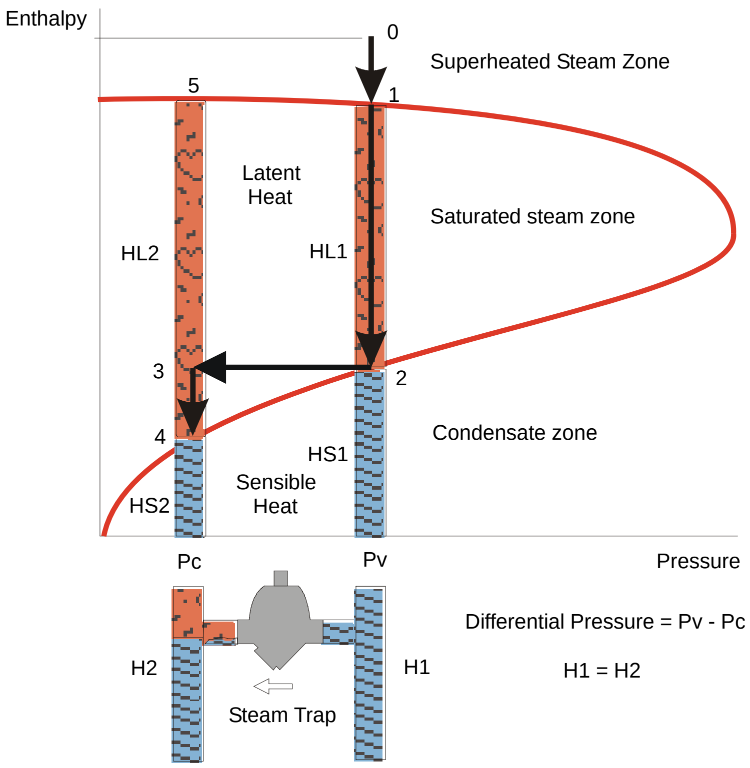
Revaporization: The processing of forming vapor as a result of a drop in pressure or the expansion of condensate. The revaporized steam is also called ***expansion steam*** or ***flash steam***. Even though it is not generated by added heat, its energetic content and all the rest of its properties correspond to the saturated steam at the same pressure. Regarding steam traps, it is essential to differentiate between live steam and flash steam.

1.3 FLASH STEAM

Temperature and pressure of saturated steam are related in that all pressures have different saturation temperatures. This connection, as well as its energetic content (enthalpy), specific volume, and other steam properties, can be checked by looking at the saturated steam chart or the saturation curve of steam.

The saturated steam table shows sensible heat (heat of the boiling water) rising as pressure rises, while latent heat (evaporation heat or heat lost during condensation) becomes less as the pressure increases.

Graphically representing the total heat of steam broken down into sensible heat and latent heat, (Figure 1-4) shows an easy explanation of the formation of expansion steam:



ENTHAPY-PRESSURE DIAGRAM FOR WATER-STEAM

Figure 1.4

As a result, point 1 shows the energetic content of the steam at the entrance of the equipment that consumes steam. The release of latent head is produced all along the path from 1 to 2. Upon reaching point 2, all of the steam has condensed without any theoretical variation of its temperature, reaching the steam trap in order to be removed.

The steam trap causes an abrupt change in pressure from Pv to Pc, path 2 to 3, while maintaining the steam's energetic content. Point 3 shows the state of the steam when exiting the steam trap. Now, the saturation point of the condensate at Pc pressure corresponds to point 4, whose energetic level is lower than the same at point 3. Therefore, point 3 has a mixture of condensate and steam, so the path from 3 to 4 represents the excess energy content in the condensate that is removed by the steam trap which partially revaporizes in order to reach an energy balance. Note that this excess energy originates from the expansion of condensate through the steam trap since there is no external heat provided.

In summary, there is always a discharge of condensate and expansion steam when a steam trap is working at the saturation temperature, in a way in that the energetic content of the liquid phase (condensate) is precisely the sensible heat of the condensate at the pressure of the collector, while the rest of energy from point 4 to 3 in the diagram's evaporation zone corresponds to the presence of a certain amount of expansion steam that is formed during this process.

The quantity of revaporized content that is formed by a unit of mass of the condensate that is removed, is the quotient between the enthalpy of path 3-4 and the enthalpy of path 5-4, which is the quotient of the steam's different enthalpies before and after the purgadorsteam trap (h2-h4) divided by the latent heat of evaporation at the outlet pressure of the steam trap (h5-h4):

$$\text{Revaporization per unit of mass} = (h2\text{-}h4) / (h5\text{-}h4)$$

It is fundamental to understand the physical process of the formation of expansion steam in order to assess the proper functioning of a steam trap, since it is not easy to distinguish between live steam and expansion steam, which can lead to serious diagnostic errors in steam traps, worsened by the increase in volume produced during the formation of expansion steam.

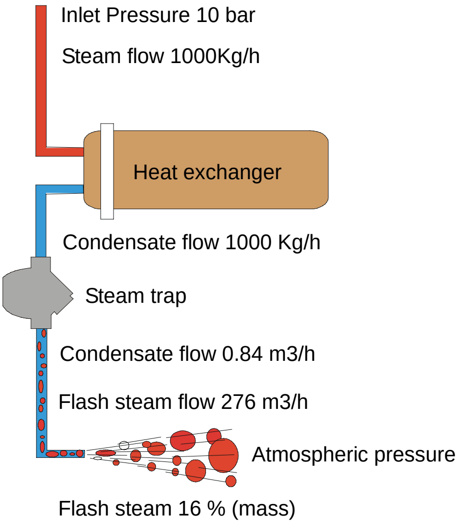


Figure 1.5

Figure 1-5 shows this aspect, demonstrating the condensate's large increase in volume when revaporizing at the exit of the steam trap.

Note that even though the mass of condensate is much higher than that of flash steam, the opposite observation can be made when comparing their volumes (276 m3/h of flash steam over 0.840 m3/h of condensate).

1.4 THE DIFFERENCE BETWEEN LIVE STEAM AND FLASH STEAM

The only difference between live steam and expansion steam lies in the process that created it, but once they become steam, both have the same chemical and physical properties. This makes visual detection of live steam leaks difficult when observing discharge from the steam traps. Diagnosis get more complicated in installation with hundreds or thousands of steam traps, where the discharge from some may locally alter the backpressure in the shared condensate collector; this makes it very difficult to distinguish live steam from expansion steam.

Ambient temperature and relative humidity of the air greatly affect the aspect of steam traps discharge; expansion steam is much more visible on cold and humid days than on warm and sunny days.

With experience, it is sometimes possible to differentiate live steam and expansion steam discharge with the naked eye,when there is a small amount of live steam. When observing steam trap discharge, the revaporized steam is always accompanied by some condensate, make for a more humid aspect than live steam. Revaporized steam is a little opaque and humid, while live steam is transparent and it discharges at a higher velocity and with more noise right at the exit of the steam trap (see figure 1-6). A precise assessment can only be made with the help of reliable detection equipment.

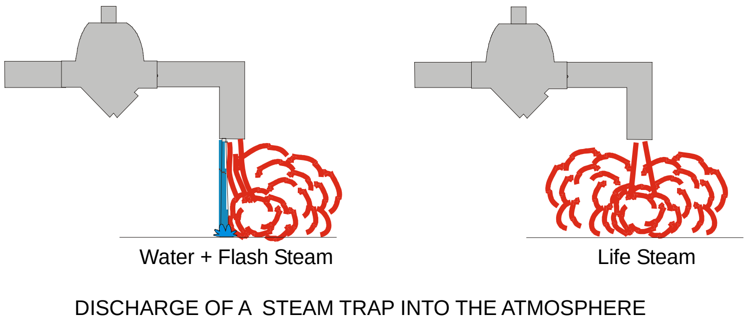


Figure 1.6

It is always important to reduce the amount of revaporized steam in draining stations, especially in large facilities where very large facilities or future expansions may cause high local backpressure which keeps the system from functioning properly and affects its energetic output.

Current techniques for saving energy and reducing atmospheric emissions have made it necessary in many processes to take partial advantage of the condensate's sensible heat in order to lessen the formation of revaporized steam.

Figure 1-4 shows that in order to reduce the formation of expansion steam, it is necessary to reduce the difference from point 3 to 4. This means lowering point 2, whose position depends on the operating pressure of steam, which is not easily modified since it is imposed by its own process, or by adjusting the temperature of the trap, which is only possible in thermostatic steam traps. Note that in practice, adjusting the steam trap´s discharge temperature requires that there is a functional external adjustment mechanism; without this feature, adjusting the discharge temperature would be a laborious, difficult, and generally impractical process.

The graph in figure 1-7 allows us to graphically calculate the amount of revaporized steam by mass unit in the expansion of condensate through a steam trap.

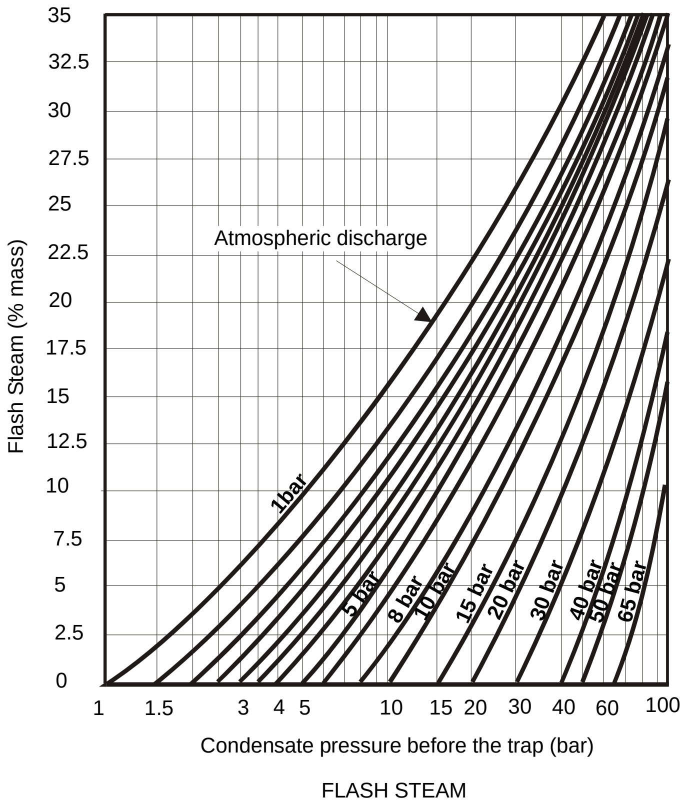


Figure 1.7

Ambient temperature and relative humidity of the atmosphere greatly affect the aspect of steam traps discharge. In very cold and humid winter days, expansion steam in steam trap discharge is easily visible, giving the impression that there is a large steam leak; on the other hand, hot and dry summer days greatly lessen the appearance of expansion steam.

1.5 PROBLEMS CAUSED BY EXPANSION STEAM

The partial revaporization of the condensate in the discharge of the steam trap is one of the sources for diverse types of serious problems, namely:

Operational Problems:

» Line cooling and a reduction in the efficiency of heating processes

» Appearance of thermal water hammering

» Difficulty in regulating processes of heat exchange

» Solidification of viscous products in process equipment and lines

Energetic and Environmental Problems:

» Increase in steam leaks

» Increase in CO_2 emissions into the atmosphere

» Difficulty in recovering condensate and residual energy

» Increase in noise and humidity in the processing units

Inspection and Mainaintance Problems:

» Difficulty in inspecting steam traps

» Increase in erosion of the condensate return network

» Increase in internal wear and tear of the steam traps

» Breakage of elements and gaskets produced by water hammering

» Increase in corrosion due to a more humid environment

All of these problems are generally caused by the elevation of backpressure in the water return collector, originated as a product of the enormous increase in specific volume experienced by the condensate upon becoming partially revaporized in the steam trap discharge (see figure 1-5).

Figure 1-8 shows a group of steam traps draining into a shared collector. If the discharge temperature of one of these steam traps is not properly controlled, it will create expansion steam in its discharge zone, which will put local pressure on the condensate manifold. This effect will be transmitted to nearby steam traps that, depending on the type of steam trap, will experience a large or small degree of change in their performance.

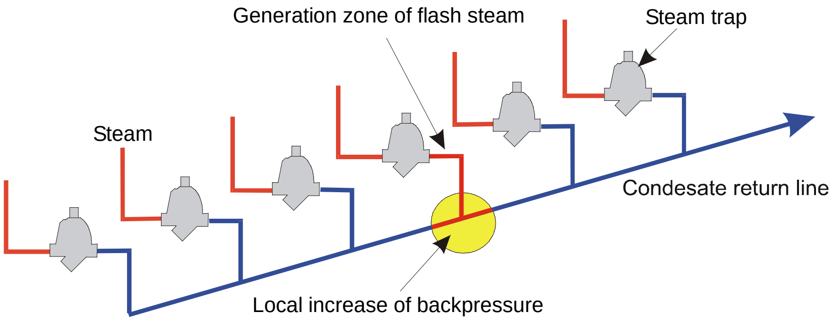


Figure 1.8

Once the problem appears, it will most likely expand rapidly throughout the entire condensate network unless it is effectively controlled. This problem occurs often with mechanical and thermodynamic steam traps as they do not allow for the control of discharge temperature.

Thermodynamic steam traps functioning at low pressures require that the backpressure does not exceed 60% of the inlet pressure; this is why a rise in backpressure immediately affects nearby steam traps that cannot work in these conditions and therefore remain in an open position, allowing live steam to escape into the collector. In other words, thermodynamic steam traps act as detonators of this problem, since they cause the issue and suffer the consequences which creates a vicious circle that is difficult to correct and has serious consequences.

In order to eliminate this problem, bimetal bi-thermostatic steam traps are used, with a balanced pressure valve and an external adjustment mechanism, which are capable of supporting very high backpressure and allow for the individual adjustment of the discharge temperature, without the need to interrupt normal operation.

The current commitment to efficiently utilize energy and reduce CO_2 emissions into the atmosphere has made it possible to apply technological solutions that have allowed for the development of the current concept of a smart steam trap, BiThermSmartWatchWeb, whose description and characteristics will be covered in a later chapter.

1.5 SATURATED STEAM TABLE

The following page shows the saturated steam table with useful information for calculations, such as specific volume, sensible enthalpy, total enthalpy, and latent heat of vaporization. Note that the last column of the table, latent heat of vaporization, is the difference between the steam's total enthalpy and water's total enthalpy at the boiling temperature of that pressure, as shown in figure 1-4.

It is interesting to point out that while the enthalpy of boiling water continuously grows as the pressure rises (see column 4 of the table), the same does not occur with the total enthalpy of steam (column 5) which reaches it maximum value at a pressure of 30 bars, then decreases when it passes the aforementioned pressure.

Latent heat of vaporization, which is primarily used in heat exchange processes, continuously decreases as the pressure increases, which is why steam consumption will be reduced if the operating pressure is kept low.

However, there is a minimum pressure as there is a need for the condensate to reach a certain heating temperature in the process, which depends on steam pressure (columns 1 and 2).

SATURARED STEAM TABLE

Abs. Press. (bar)	Manom. Pres. (barg)	Temprature °C	Spec.Vol. m3/Kg m3/Kg	Sensible heat Kcal/Kg	Latent Heat Kcal/Kg	Total Enthalpy Kcal/Kg
1,0	0	99,09	1,7250	99,12	539,4	638,5
1,5	0,5	110,79	1,1800	110,92	531,9	642,8
2,0	1,0	119,62	0,9016	119,87	525,9	645,8
2,5	1,5	126,79	0,7316	127,2	521,1	648,3
3,0	2,0	132,88	0,6166	133,4	516,9	650,3
3,5	2,5	138,19	0,5335	138,8	513,1	651,9
4,0	3,0	142,92	0,4706	143,6	509,8	653,4
4,5	3,5	147,20	0,4213	148,0	506,7	654,7
5,0	4,0	151,11	0,3816	152,1	503,7	655,8
5,5	4,5	154,71	0,3489	155,8	501,1	656,9
6,0	5,0	158,08	0,3213	159,3	498,5	657,8
6,5	5,5	161,15	0,2980	162,6	496,1	658,7
7,0	6,0	164,17	0,2778	165,6	493,8	659,4
7,5	6,5	166,96	0,2602	168,5	491,7	660,2
8,0	7,0	169,61	0,2448	171,3	489,5	660,8
8,5	7,5	172,11	0,2311	173,9	487,5	661,4
9,0	8,0	174,53	0,2189	176,4	485,6	662,0
9,5	8,5	176,82	0,2080	178,9	483,6	662,5
10	9	179,04	0,1981	181,2	481,8	663,0
11	10	183,20	0,1808	185,6	478,3	663,9
12	11	187,08	0,1664	189,7	475	664,7
13	12	190,71	0,1541	193,5	471,9	665,4
14	13	194,13	0,1435	197,1	468,9	666,0
15	14	197,36	0,1343	200,6	466	666,6
16	15	200,43	0,1262	203,9	463,2	667,1
17	16	203,35	0,1190	207,1	460,4	667,5
18	17	206,14	0,1126	210,1	457,8	667,9
19	18	208,81	0,1068	213,0	455,2	668,2
20	19	211,38	0,1016	215,8	452,7	668,5
21	20	213,85	0,09682	218,5	450,2	668,7
22	21	216,23	0,09251	221,2	447,7	668,9
23	22	218,53	0,08856	223,6	445,5	669,1
24	23	220,75	0,08492	226,1	443,2	669,3
25	24	222,90	0,08157	228,5	440,9	669,4
26	25	224,99	0,07846	230,8	438,7	669,5
28	27	228,98	0,07288	235,2	434,4	669,6
30	29	232,76	0,06802	239,5	430,2	669,7
33	32	238,08	0,06179	245,5	424,1	669,6
35	34	241,42	0,05822	249,4	420,1	669,5
38	37	246,17	0,05353	254,8	414,5	669,3
40	39	249,18	0,05078	258,2	410,8	669,0
45	44	256,23	0,04495	266,5	401,7	668,2
50	49	262,70	0,04024	274,2	393,1	667,3
55	54	268,69	0,03636	281,4	384,8	666,2
60	59	274,29	0,0331	288,4	376,6	665,0
65	64	279,54	0,03033	294,8	368,8	663,6
70	69	284,48	0,02795	300,9	361,2	662,1
75	74	289,17	0,02587	307,0	353,5	660,5
80	79	293,62	0,02404	312,6	346,3	658,9
85	84	297,86	0,02241	318,2	338,8	657,0
90	89	301,92	0,02096	323,6	331,5	655,1
95	94	305,80	0,01964	328,8	324,4	653,2
100	99	309,53	0,01845	334,0	317,1	651,1
110	109	316,58	0,01637	344,0	302,7	646,7
120	119	323,15	0,01462	353,9	288	641,9

CHAPTER 2

CONDENSATE AND STEAM NETWORKS

2.1 BASIC CONCEPTS

In simple terms, a steam network is a semi-closed circuit that consists of four basic components (figure 2.1):

» Steam Generators

» Steam Distribution Network

» Steam-Using Equipment

» Condensate Return Line

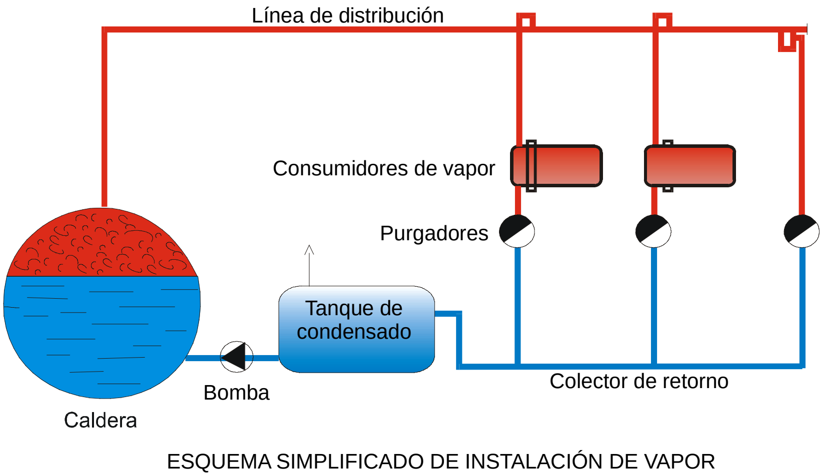


Figura 2.1

In a steam system, there are two distinctly different energetic levels that are always present; their boundary is established by the control elements known as steam traps and steam energy traps.

The saturated steam table shows that the energy per unit of mass (total heat of the steam) in the high energy zone is four or five time higher than that corresponding to the low energy zone (sensible heat of the condensate). In steam-using equipment, latent heat is released, producing the phase transition (steam condensation).

The transformation of energy in the system is produced in a continuous cycle which is why the overall energy efficiency is much higher the less energy that is recycled through it, taking maximum advantage of the steam's energy before sending it to the condensate zone.

From a functional point of view, it is also necessary to minimize the injection of steam energy in the condensate zone in order to prevent serious problems from appearing in the system (water hammer, high backpressure, cavitation in the boiler supply pumps, etc.).

In addition, raising the energy efficiency of the steam system reduces the amount of fuel needed to generate steam, which reduces CO_2 emissions and therefore the amount of air pollution.

As a result, it is essential to establish a physical barrier between the two energetic levels in the steam system, keeping energy from passing from the high-energy zone to the low energy zone.

Now, steam condenses when releasing energy and the condensate that is formed in the area from the heat exchange must be removed in order to keep the heat exchange area exposed to steam, thus, maintaining a high heat exchange rate since the rate of the condensate's heat exchange is 100 times less than that of steam.

All of this leads to the need to remove the condensate that is produced in the steam zone, or the high energy level zone, simultaneously preventing steam from moving to the condensate zone, or the low energy level zone. This essential mission is carried out by means of a wide variety of old mechanical devices known as ***steam traps*** and more efficient elements as ***steam energy traps***.

Note that even though these terms are often confused, this manual distinguishes between ***steam traps*** and ***steam energy traps***, since their application not only affects the performance and functionality of the system but it also affects other relevant aspects, including the system's energy efficiency, the emission of greenhouse gases, and the maintenance of the steam system. Finally, the perfection of the concept of the ***steam energy traps*** has lead to the development of modern ***intelligent energy traps***.

2.2 DIFFERENCES BETWEEN STEAM TRAPS AND STEAM ENERGY TRAPS

When referring to draining elements in steam systems, it is normal to use ***steam traps***. However, when referring to energy efficiency in steam networks it is more appropriate to use ***steam energy traps***.

There is a great difference between these two concepts.

The ***steam trap***, or simply ***trap***, is adrain component that is activated by changes in the state of the fluid (water or steam), but it lacks the capacity to control the residual energy of the condensate.

The ***steam energy trap*** is an automatic valve that is driven by the energetic level of the fluid, and therefore has the ability to control the steam energy and residual energy of the condensate.

The essential difference between a trap and an energy trap is precisely this energetic control characteristic that is only found with the energy trap. This is why the energy efficiency of the energy controller is higher than that of the trap.

Observe figure 2-1 in order to put this into context. The boiler (steam generator) is connected to the steam-user equipment by two lines: the steam distribution line (high energy level), and the condensate return line. Both zones are separated by a barrier that comes in two different forms:

» ***Physical barrier of phase transition*** created by ***steam traps***, which releases condensate at the saturation temperature (highest residual energy), producing the most amount of flash steam possible in its discharge. This raises backpressure and it may cause strong thermal water hammer in the condensate return line.

» ***Energy barrier*** generated by ***steam energy traps*** that efficiently regulates the residual energy of the condensate, reducing the amount of flash steam in the discharge; this also reduces backpressure and prevents thermal water hammer in the condensate return line.

Now, it is interesting to see the ***saturation temperature*** column and the ***sensible heat of the liquid*** column in the saturated steam table (section 1.5) as they are almost identical for each pressure. This means that the steam energy traps must be able to regulate the condensate's evacuation temperature in order to create the energetic barrier.

Therefore, the concept of ***steam energy trap*** is always accompanied by the concept of a ***thermostat***.

In order to assess the differences that exist between the concepts of a trap and an energy trap, we must analyze the processes that occur in each of them (Figure 2.2).

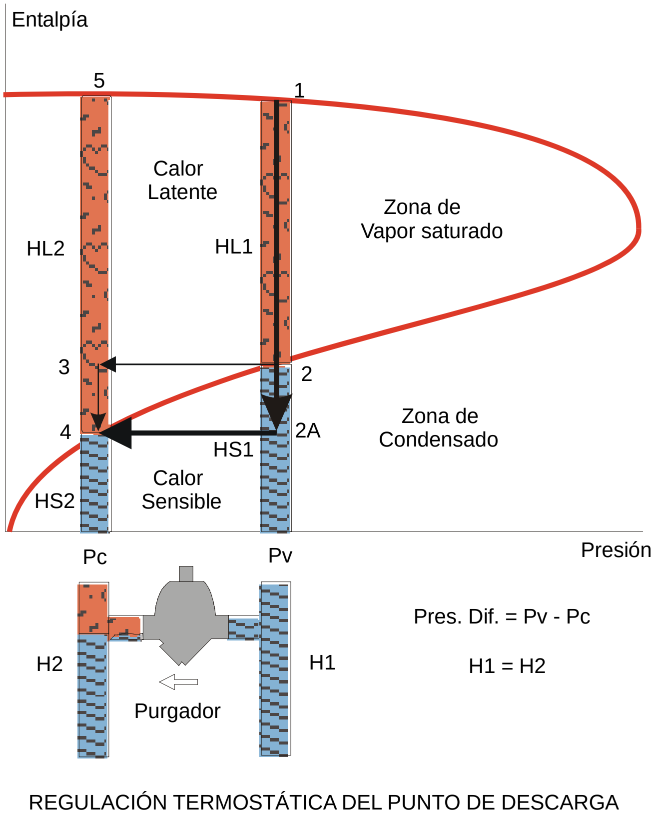


Figura 2.2

- ***Discharge process in steam traps:*** Once the live steam has released its latent heat (HL1), it condenses and reaches point 2 (physical barrier of the change from steam to water). At this point, the trap opens and sends all of the residual energy of the condensate to the return line, (point 3). At the Pc pressure in the return line, a part of this residual energy (section 3 to 4) revaporizes a certain amount of the evacuated condensate, producing destructive consequences.

- ***Discharge process in steam energy traps:*** The temperature control in the opening of the steam energy trap allows us to adjust point 2 to position 2A, which is more favorable for each process as it takes advantage of the residual energy of the condensate, increasing energy efficiency and preventing the previously mentioned unfavorable consequences.

Note that when there is an excess of residual energy discharged into the return line, this excess energy is usually spread out along the same line or it is removed through an atmospheric vent in the condensate tank. On the other hand, circulating flash steam and condensate at high speeds produces erosion and damages piping, elbows, and valves.

A simple calculation in a low pressure system demonstrates that using residual energy (section 3 to 4) accounts for 8 % of the steam energy (section 1 to 2), meaning that there is an 8 % savings in the consumption of steam, which also saves the same amount of treated water consumed.

As a result, using energy controllers instead of steam traps in large steam networks that have thousands of drain points (eg. refineries, petrochemical industry, …) generates the following advantages:

» Increase in energy efficiency (8 %)

» 8 % reduction in the consumption of treated water

» Reduction in CO2 emissions (2.3% using fuel oil)

» Reduction of backpressure in the condensate return line

» Prevention of thermal water hammer

» Reduction in maintenance costs (less erosion on valves, energy controllers, accessories, …)

2.3 CONDENSATE AND STEAM NETWORK COUPLING

A condensate network is coupled with the steam network when the pressure in the condensate return line follows the steam system's variations; this phenomenon is common in large facilities that have thousands of working steam traps.

Section 2.1 showed the need to establish a barrier between the high and low energy zones (steam and condensate), which is created by steam traps and steam energy traps.

This aspect offers a different definition of the term steam trap and ***steam energy trap**, **as elements that are able to produce the largest load loss possible without affecting the proper functioning of the steam and condensate systems***.

To clarify this concept, understand that during start-up of the facility, the condensate is very cold and the steam energy trap barely holds any fluid back, and as the condensate gets hotter the steam energy trap begins to shut off (increasing the load loss) until the live steam arrives and it closes entirely (100% load loss).

As for thermodynamic and inverted bucket steam traps, this process is not continuous but rather intermittent. Each time the steam trap opens the load loss is small and it unfavorably increases the pressure in the condensate return line. The increase in backpressure and the trap's deterioration over time will increase the rate of discharges, which will also reduce the load loss generated by the trap.

Network coupling is produced by an error or inefficiency of the elements (steam traps and steam energy traps) that are meant to create the energy barrier between the system's condensate and steam zones. In this circumstance, pressure in the condensate return line increases as it tries to balances with that of the steam. This reduces the differential pressure in steam traps and steam energy traps which cause serious problems in the system's operations (lack of condensate evacuation capacities, strong thermal water hammer, high steam consumption, impossibility of recovering condensate, etc.).

Obviously, the solution to this problem is to raise the load loss in steam traps and steam energy traps until they reach the highest amount compatible with each application. This is a conceptually simple solution; however it is practically impossible when using steam traps. In the case of steam energy traps, on the other hand, this is possible by simply changing the position of point 2 (Figure 2-2). This reduces the condensate's discharge temperature, which reduces the formation of flash steam and backpressure in the condensate return line, lowering network coupling.

Two important conclusions are gathered from this:

» *Steam Traps contribute to network coupling*

» *Steam Energy Traps reduce network coupling*

In practice, adjusting the discharge temperature is only functional if the steam energy trap has an external adjustment mechanism. This way, we can dynamically act on the energy trap as we directly and immediately verify the results in the process and its effects over the condition of the network.

Note that this external adjustment mechanism is able to function while the steam energy trap is in operation, as the contrary would not allow for dynamic action and it would lose its purpose.

The external adjustment mechanism working in BiTherm traps (Bi-Thermostatic steam energy traps) allows for other notable advantages such as the ability to make repairs without needing replacement parts or having to stop the energy trap from functioning.

All of this significantly reduces maintenance costs.

2.4 STEAM TRAPS OR STEAM ENERGY TRAPS?

Now that we see the differences of the concepts of steam traps and steam energy traps, it is worth understanding the situations in which one concept should be used over the other.

The diversity of the processes and applications that require steam, translates into demands that are very flexible, and sometimes contradictory, which require different types of steam traps and steam energy traps in order to perform the best for the needs of the specific service (in some cases, using both concepts can yield acceptable results).

For example, for the proper functioning of a rotating cylinder dryer in a paper or textile industry, it may be necessary to leak a small continuous amount of steam while non-critical tracer applications require condensate discharge temperature to be 40 degree below the steam's saturation temperature. Between both examples, there is a large variety of applications where it is necessary to analyze the process in order to decide which is the most appropriate element to use.

To clarify, the average temperature of the condensate that reaches the steam trap or steam energy trap in all heat exchange processes is around 10 degrees Celsius less than the steam's saturation temperature. This fact allows using thermostatic steam traps without the risk of retaining condensate in the heat exchange equipment. However, certain applications require lower condensate evacuation temperatures in order to compensate for oversized heat exchangers, which greatly reduces the consumption of steam.

However, the steam trap or the steam energy trap should not be thought of as an isolated component, but rather as a piece that it integrated in the system which is used to prevent negative effects caused by the various parts that are connected to the system.

In effect, a steam facility can have applications that use superheated steam (turbines, cylinder dryers, etc.) and others that use saturated steam (heat exchangers, tanks, tracing lines, etc.). Additionally, the steam used goes through a wide range of pressure and temperature. Sometimes the condensate from various applications is driven by the same return line. All of this produces strong interactions which can create serious operational problems.

Using certain steam traps (thermodynamic, labyrinth, and inverted bucket) produces continuous or intermittent discharges of certain amounts of live steam with an elevated energetic level (point 1, figure 2-2) in the condensate return line (the energetic content of the live steam is situated above point 1 in superheated steam applications); these discharges are accompanied by high temperature condensate that produces additional flash steam in the condensate return line.

Therefore, indiscriminate use of steam traps leads to the existence of a mix of condensate, flash steam, and live steam in the condensate return line, whose varying energetic levels cause serious operational and economic consequences.

On the contrary, the use of steam energy traps prevents the possibility of discharging live steam and it controls the condensate's evacuation temperature, limiting the formation of flash steam in the return line.

In conclusion, all of the characteristics of each process should be analyzed in detail, there must be energetic balance in all applications, the energetic level and the required energy must be evaluated and compare to the supplied energy, and finally, the optimum residual energy of the condensate must be determined.

All of this information is necessary for determining the position of point 2 (figure 2-2). The operational temperature of the steam energy trap will not only determine the performance of the entire facility, but it will also determine its energy efficiency and future maintenance costs.

Analyzing all of this information will provide the suitability for use of steam traps or steam energy traps.

The condensate return line in large facilities (refineries, petrochemical plants, etc.) is very sensitive to persistent problems caused by backpressure and thermal water hammer. In order to avoid this without increasing the diameter of the return line, steam energy traps must be used in place of steam traps so that the energy of the condensate may be controlled.

As a general rule, steam energy traps should be used in all applications that require precise energy control or a continuous control of residual energy from the condensate, limiting the use of steam traps to applications where it is essential to guarantee the total absence of condensate before the steam trap.

Finally, the steam energy trap may also be utilized, in unique ocasions, as a steam trap when it is important to make sure that there is a small controlled live steam leak, which would require the discharge temperature to be raise to the steam's saturation point.

2.5 THE IDEAL STEAM ENERGY TRAP

From a practical point of view the steam energy trap has to be able to carry out the following functions:

» Evacuate condensate without loss of steam

» Evacuate incondensable air and gas

Now, from an operational stand point, the energy controller should posses additional services, such as:

» High reliability

» High energy efficiency

» Energetic control of condensate

» Easy maintenance, preferably without interrupting service

» Strength and versatility

» Auto detection of changes in its work condition

» High quality

Obviously in practice it is difficult to fulfill all of these conditions, thus, the real steam energy trap has to get as close as possible to the ideal in order to fulfill those previously listed characteristics that are essential for the particular service provided, sacrificing the less influential ones.

Over the decades, traps and energy traps have been slowly developing their mechanics. On 1996, the addition of micro-electronics in the bithermostatic energy trap has given birth to the patented ***BiTherm SmartWatchWeb*** or ***Smart Energy Trap***, a strong energy regulator that completely resolves all of the problems that come from the size and complexity of facilities and the continuous rising of the price of the energy. The Smart Energy Trap (chapter 5) can reduce between 8 % and 15 % of steam consumption in facilities (chapter 9).

Historical outline:

Bitherm has pioneered the design and manufacture of smart energy traps. The first smart traps (see www.bitherm.com SmartWatch steamwatch and International Patent No. PCT / ES97 / 00181, US 6,338,283 B1, ES9601878, ES9700044, ...) combines a bi-thermostatic trap with an electronic device with microprocessor capable of monitor up to four independent parameters. Thus, the genuine smart energy trap is able to evaluate the energy efficiency of the trap, identify any trouble either in the trap or in the electronic system. The smart energy trap incorporates an external adjustment device which allows to solve any problem without interruption of work, resulting in the most suitable to prevent and solve critical problems in the facilities (backpressure, water hammer, energy savings, simplified maintenance, reduction of CO2 emissions, prevention of pollution, etc.).

CHAPTER 3

STEAM TRAPS

3.1 INTRODUCTION

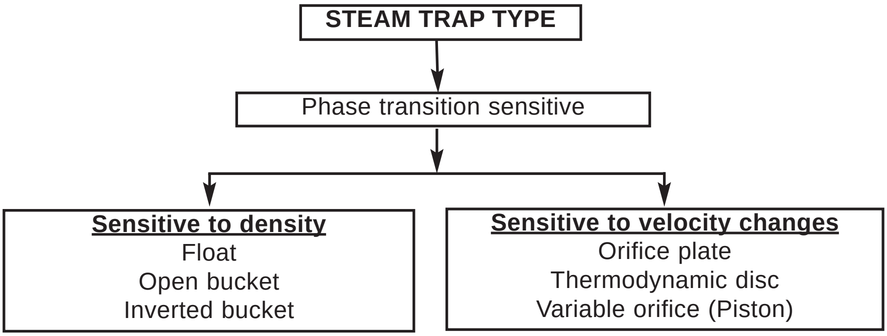
As mentioned in chapter 2, the ***steam trap*** is an automatic mechanical draining element that does not have the ability to regulate the temperature of the condensate discharge.

Its operation does not depend on the energycontent of condensate, but rather the physical state of the fluid (liquid or steam). This mean, in the best case, the trap opens in the presence of condensate, whatever its energy content may be, and it closes when there is steam. In other situations, the trap closes only after having lost a quantity of live steam (control steam).

Since the appearance of the orifice plate, the first steam trap in history, other trap designs have been appearing with the purpose of improving performance.

3.2 STEAM TRAP CLASSIFICATION

A commonality in all steam traps is their sensitivity to phase transitions. However, they are different in the way in which the phase transitions are detected. Taking into account their work, steam traps can be classified in the following way:



Density sensitive steam traps are based on the buoyancy of a float, open or closed, which moves a valve depending on the level of condensate on the inside of the trap.

The group of stream traps that are sensitive to changes in the velocity of fluid is based on the large difference between the specific volume of condensate and that of steam. Steam passes through a hole at a much higher velocity than that of condensate; this fact means that there are differences in pressure which are used to control the trap's opening and closing.

Taking into account the design of the steam trap valves, they can be classified in the following way:

» Differential pressure valve

» Balanced pressure valve

» Pilot valve

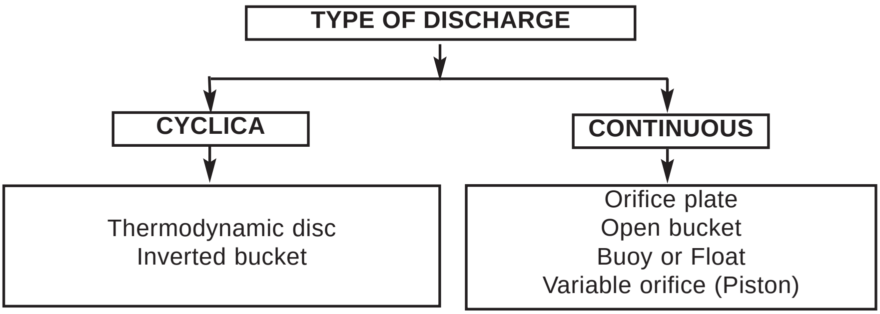
The valve cone of the balanced pressure valve is submerged in a uniform pressure field where the sum of the forces on the valve cone is null. Because of this, the balanced pressure valve can work independently of the backpressure present in the trap's discharge. This type of valve is ussually applicable with certain float traps.

The differential pressure valve uses the difference of the inlet and outlet pressure to regulate the cone. This fact must be highly considered when sizing the steam trap.

Pilot valve uses a small valve which acts on a larger or main valve. Pilot valve traps are usually used to evacuate large volumes of water or under extreme differential pressure situations.

3.3 CYCLICAL AND CONTINUOUS TRAPS

According to the way in which they function, traps can be classifieds as shown:



Note that the production of condensation in industrial processes occurs continuously, without abrupt fluctuations, which means that there are more advantages to continuous discharge systems than cyclical ones.

The evacuation capacity of continuous discharge traps automatically adjusts as long as condensate is being produced. This creates a dynamic balance that prevents sudden pressure oscillations in the condensate return line.

On the other hand, cyclical discharge traps must be oversized in order to compensate in the active part of the cycle for the capacity lost in the passive part of the cycle. Discharging intermittently provokes pressure and backpressure oscillations that can affect other traps and produce strong water hammering.

In a cyclical system, it is normal to lose live steam before the trap closes. When it opens, a cyclical system should quickly eliminate the condensate that has accumulated; this causes a drop in the pressure before the element and a slight drop in temperature. At the same time, the discharge produces a rise in backpressure, reducing the pressure difference that acts on the trap.

In summary, the obvious advantages of the continuous discharge system over the cyclical one are:

» Balance between production and condensate evacuation

» Smoother working installation

» Higher energy efficiency

» Improved control of the system's operation

» Improved control of steam leaks

» Lower network coupling

» Higher differential pressure in the system

3.4 ORIFICE PLATE

This may be considered the first steam trap in history. It is very simple (figure 3-1), being just a metal plate with a hole that is calibrated depending on the volume of condensate to be evacuated.

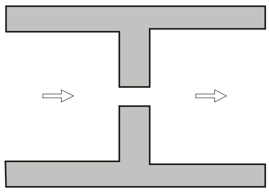


Figure 3.1

In reality, the orifice plate cannot be considered a true steam trap, since it does not include a valve but rather a fixed orifice that results in a load loss, which increases with the flow volume or the phase transition of the fluid (liquid - steam).

Live steam that passes through the orifice at a high speed produces a load loss that partially stops the flow, and to a certain extent, reduces the large steam losses that are possible if the equipment is not properly measured.

The advantages of this element are:

» Maximum simplicity

» Large pressure range

» Limited maintenance

Its disadvantages are clear:

» Very critical sizing

» Limited flexibility

» Large loss of live steam

» Increase in backpressure in the condensate return line

3.4 FLOAT TRAP

This was the first automatic drain element used in the industry; it uses a valve is regulated by the water level (Figure 3-2).

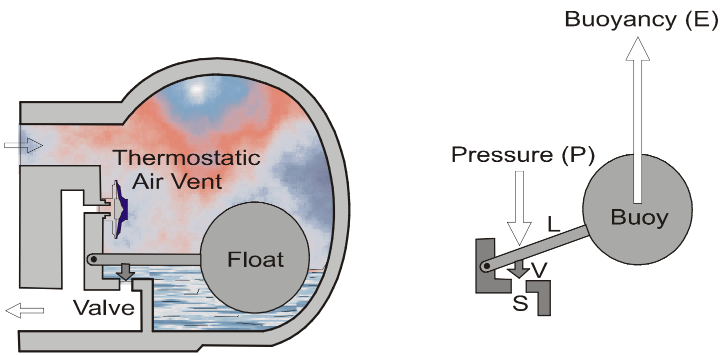


Figure 3.2

Its mechanics is made up of a long lever (L), joined at one of the ends, and a closed buoy or float on the other side, which provides the buoyancy (E). Somewhere in the middle is the valve (V) with an area (S). The level of the liquid causes the valve to open and close.

On one side, the cone valve is subject to the bouyancy force (E), transmitted by the buoy, and on the other side, the differential service pressure. So therefore, in order for the valve to work, there must always be enough bouyancy force reserved to open the valve when it experiences the highest differential pressure for closing. This can be explained as:

$$E \times L > P \times S$$

That is why it is always important to consider the area of the discharge orifice and the maximum working differential pressure. In order to evacuate large amounts of water, we would need an orifice with a large diameter with requires an increase in the size of the float or the arm of the lever, thus, the size of the trap itself.

For evacuating incondensable gases it is common to use a thermostatic air vent in the form of a capsule, bellows or bimetallic, or even a small manual air extractor valve. The thermostat has to be bimetallic if it works with superheated steam. Some substitute the automatic vent for a small internal by-pass hole that, inconveniently, releases live steam continuously.

It is necessary to consider the following aspects when sizing a float trap:

» Maximum differential pressure. This should not exceed the amount as indicated by the manufacturer.

» Minimum differential pressure. It should evacuate the maximum working load upon start-up and in a continuous cycle.

» Maximum working pressure. The maximum amount as indicated by the manufacturer

» Type of air vent required.

These traps usually come equipped with an external lever that lifts the float and opens the internal valve when necessary; however, it is important to note that this lever is in no way an external adjustment mechanism of the water flow, but rather an element that voids the float, making it an open by-pass.

A specific type of these traps is known as a free float. In this model, the float is not rigidly connected to any element; but instead, it freely floats on the inside of the trap. The valve seat is located in the lower part of the body and it is closed when the float descends to its lowest point, closing the discharge orifice.

The range of differential pressure of the free float trap is less than the conventional float trap because the force of the float is not amplified by the lever's effect.

The advantages characteristic of floats traps are:

» They withstand variations in condensate load and differential pressure

» Continuous evacuation at the condensate's saturation temperature

» Easily discharge dirty and oily condensate

Its main disadvantages are:

» Traps are robust, heavy, and costly. High indirect steam loss

» Mounting position is fixed

» Lacks a filter and a check valve

» Sensitive to freezing and water hammers

» Does not allow for variations in its discharge temperature

3.5 INVERTED BUCKET TRAP

This trap uses the same physical principle of the float trap, but different from it, the valve (V) is driven by a float that is in the shape of an inverted cylinder (C) with a small orifice (D) at the top (figure 3-3).

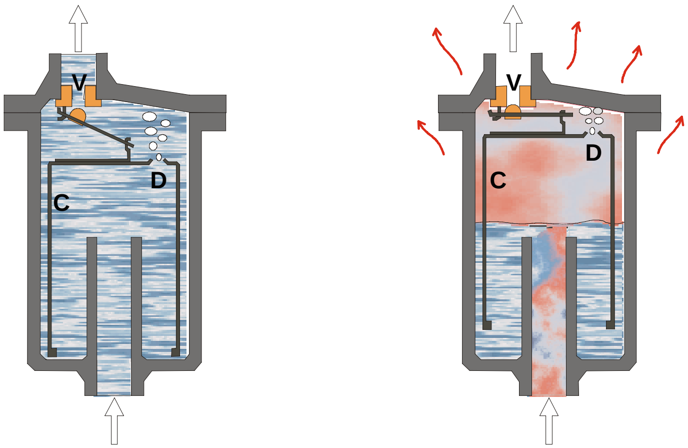


Figure 3.3

Figure 3-4 explains how the trap works:

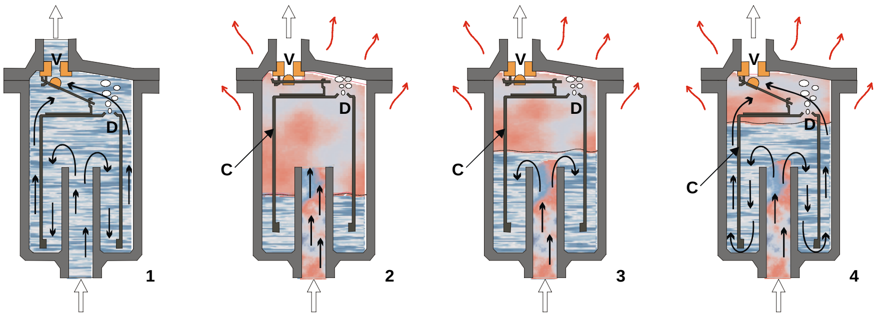


Figura 3.4

1. The inverted bucket rests at the bottom and the valve (V) and remains open, allowing condensate and incondensable gas to escape.

2. As steam reaches the trap, it starts displacing the condensate from the inside of the inverted bucket, pushing it down; with this, the bucket's (C) hydrodynamic push progressively increases until it starts to float and closes the valve.

3. The inverted bucket (C) has a small orifice (D) nearatits top that has an important role in the trap's operation. When the trap releases heat into the atmosphere, the steam held between the bucket (C) and the body of the trap starts condensing as it is replaced by steam or incondensible gas retained in the interior of the bucket; this allows for more condensate to enter the trap, raising its level in the interior of the inverted bucket (C). The gradual filling reduces buoyancy while the process continues.

4. The weight of the inverted bucket (C) overpowers its buoyancy and it drops, returning to step one.

Therefore, the discharge of this type of trap is intermittent and it always requires a hydraulic seal in the lower part so that the bucket acts as a floating device. If the steam is superheated, or if the trap experiences a large decompression, the water seal may be lost, resulting in a large leak of live steam. However, with low levels of superheat, these circumstances can be avoided by installing a check valve at the inlet of the trap.

The automatic deaeration in this kind of trap is slow due to the fact that the deaerating orifice (D) is small in order to avoid more loss of live steam. As well as in float traps, inverted bucket traps also rely heavily on the size of the valve's orifice

(V) and determine the maximum working differential pressure for the trap. Consequently, the indications listed in float traps should be taken into consideration when sizing these types of elements.

The advantages characteristic of the inverted bucket trap are:

» Simplicity, with few cases of mechanical failure

» Highly resistant to water hammers

» Easily discharges dirty and oily condensate

» Low maintenance

Its main disadvantages are:

» Robust, heavy, and expensive. High indirect steam loss

» Mounting position is fixed

» Slow air venting

» Sensitive to freezing

» Does not allow for variations in its discharge temperature

» Expensive to repair, generally cannot be done while in use.

» Only allows the steam to get slightly superheated

3.6 THERMODYNAMIC DISK TRAP

This trap is notably mentionable since it has been the most used trap in the past, and it is currently considered a true "trap" from the economic stand point due to its low energy efficiency.

From an operational point of view, it is very bad to use thermo-dynamic disk traps since their steam losses create high local backpressure in the return line, negatively affecting the entire facility's operation.

Its design is very simple; it included a body (A), a cap (B), and a disk (C). (Figure 3-5)

The body has two concentric annular seats, an interior one (D) around the inlet orifice (E) and the other on the exterior (F).

Between the two anular seats, there is a semicircular canal that links the orifice (S) with the trap's outlet. The cap has a protusion(H) in the middle that helps form a control chamber between the disk and the cap when the disk is in the highest position (open trap).

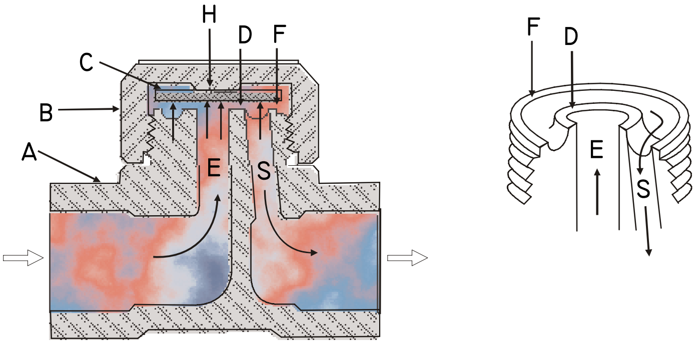


Figure 3.5

Its operation is based on the Bernoulli principle. When the trap is closed, the disk is in the lowest position, closing the two concentric seats, leaving the control chamber closed. When the system is cold started, the trap discharges the condensate formed in the pipes. Once the condensate is discharged, stream reaches the trap; at this moment, when the steam goes from inlet (E) to the outlet (S), under the disk, the high speed movement generates an increase in dynamic pressure of the fluid current, which leads to the reduction in static pressure under the disk (Figure 3-6A) since the sum of both, the total pressure, sure remain constant according to the Bernouilli principle.

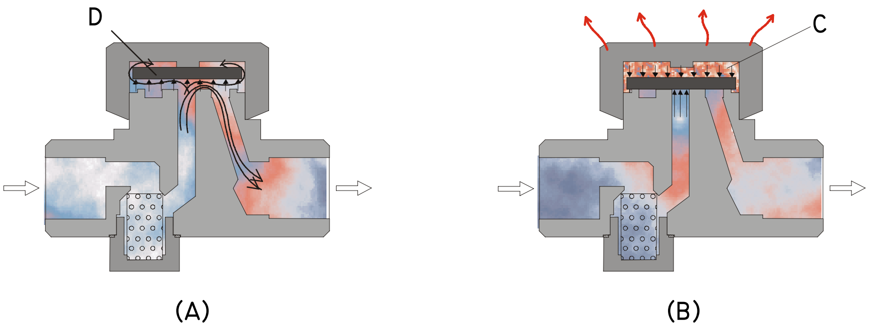


Figure 3.6

At the same time, a small amount of steam fills the small control chamber that is formed between the disk and the cap. The steam in the control chamber decelerates, and according to the Bernouilli principle, this creates an increase in static pressure. As a consequence of this, the disk violently descends against the trap seat, closing it. In this position, the control chamber and the inlet and outlet holes are closed off to one another by the disk (Figure 3.6B)

In this situation, the disk is being pushed by imbalanced pressure forces since its sides are subject to the following:

a) The entire upper side of the disk faces the pressure of the control chamber trying to close the trap.

b) On the bottom side of the disk, the pressure of steam and the condensate's backpressure push against the parts that coincide with the orifices (E) and (S), trying to open trap.

In this imbalanced pressure situation, the closing force prevails until the control chamber pressure lowers enough do to the condensation of the steam retained inside, caused by heat transmission in the air around the trap's cover. Therefore, the disk will open again and repeat the cycle.

Is it important to note that the trap acts as a timer in that its discharge is cyclically produced in the time that it take the retained steam to condense in the control chamber, independently of the condensate's influx. This means than in cold areas or on rainy days, the speed at which it opens increases dramatically and causes large energy losses. This fact is easily proven by letting a few drops of water fall on top of the trap's cover. Protective caps are installed in order to reduce energy loss in humid climates.

Be advised that operation of this trap is sometimes mistakenly explained, affirming that the closing is produce by flash steam inside the trap. This is incorrect since it is live steam escape, not flash steam that generates this closing action when passing through the trap (see test published in Petrogas, September 1979, page 43.)

The advantages characteristic of the thermodynamic disk trap are:

» Large pressure range

» Robust design

» Not sensitive to freezing or water hammers

» Works with superheated steam

» Low price

Its main disadvantages are:

» Low energy efficiency and a cyclical loss of steam, above all, in applications with small volumes of condensate (line and tracing drains)

» Increased backpressure in condensate return lines

» Does not allow backpressure to be higher than 60% in low pressures (80% in medium to high pressures)

» Very sensitive to adverse climate conditions (rain and wind increase the steam loss)

» The disk and the seat deteriorate quickly from the violent closing of the trap which increases the steam loss

» Low air venting capacity

» Subject to failures from buildup.

As it is shown, the disadvantages of the thermodynamic disk trap continuously have an effect on its excessive energy consumption, since it has one of lowest energy efficiencies.

3.7 THERMODYNAMIC PISTON TRAPS

The mechanism behind the thermodynamic impulse trap is made up of a cylindrical piston (P), that has a center orifice (O) along its symmetry axis, connecting the inlet to the outlet of the trap (Figure 3-7).

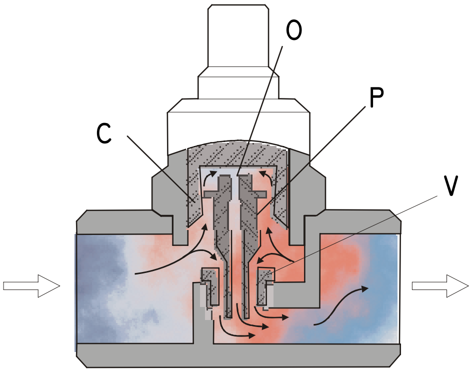


Figure 3.7

The piston has a horizontal circular wing close to its upper part and it can move up and down within the cylinder, which has a conic interior (C). The lower part of the piston closes the outlet orifice of the main valve.

The condensate that reaches the trap then borders the upper circular wing of the piston, and it passes through the center orifice. When the condensate passes through the narrow area produced by the horizontal wing of the piston, it causes a load loss and consequently reduces the pressure in the upper control chamber, on top of the piston. This way, the pressure beneath the piston's circular wing becomes higher than the pressure above the same wing, making the piston lift up, opening the main valve.

When steam reaches the trap, the piston's center orifice generates some resistance due to the increase in steam flow speed with respect to the flow of condensate; this causes the pressure in the upper control chamber to increase and the piston lowers, blocking the passage around the main valve (V).

The section that is open between the piston and the guide cylinder varies with the movement of the former as a result of the piston's conic shape, which acts as a variable size nozzle. This gives the trap some flexibility when reacting to flow volume variations, thus making it a regulating body since the open section of the main valves depends on the piston's vertical position at every moment, and this will depend on the condensate flow volume in the trap.

It is important to note that the trap must always be mounted vertically in order to not interfere with the upward and downward motion of the piston.

In order to have more operational flexibility, the trap usually has an adjustment screw on top which changes the position of the conic guide cylinder in order to vary the volume, and with it, the pressure of the upper control chamber.

Evidently, the trap never blocks steam as a result of the piston's center orifice and this steam leak (control steam) is precisely what makes the trap work. This fact must be taken into consideration when inspecting this type of trap with ultrasound equipment, since logically, the results will always detect an internal steam leak.

The advantages of this type of trap are:

» Small and robust construction

» Discharges air and incondensable gases

» Operates in a wide range of pressures and flow volumes

» Can be used with superheated steam

The disadvantages of this type of trap are:

» Live steam losses and low energy efficiency

» Increased backpressure and water hammers in return lines

» Fast internal wear and tear from erosion

» Sensitive to backpressure. Does not allow backpressure to exceed 40% of the working pressure.

» Prone to drain blockage from dirt buildup

3.8 THE CURRENT USE OF STEAM TRAPS

The use of steam traps has been declining over time due to the appearance of steam energy traps with higher energy efficiency.

The need to reduce CO_2 emission, a topic closely linked to increasing energy efficiency, has permanently tipped the scale in favor of steam energy traps, setting aside steam traps for use in minor applications where the requirements of the process prefer this type of equipment.

In conclusion, the appearance of the modern smart energy traps has made an unstoppable path towards logical and intelligent energy use.

CHAPTER 4

ENERGY TRAPS

4.1 INTRODUCTION

As mentioned in chapter 2, an energy trapis a mechanic element that drains automatically and has the ability to control the temperature of the condensate discharge.

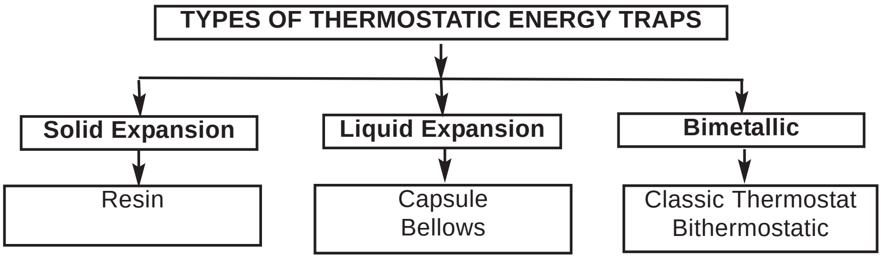
Its operation exclusively depends on the energy content of the condensate, and its regulating elements do not use control steam in order to function with high energy efficiency.

Contrary to what occurs with steam traps, the internal elements of the energy traps do not usually come in direct contact with steam and the condensate's flow velocity through the valve is very low compared to that of a regular steam trap; because of this, there is much less erosion, and as a consequence, energy traps last much longer in comparison with steam traps.

4.2 CLASSIFICATION OF ENERGY TRAPS

The direct relationship between the energy content of saturated steam and the saturation temperature leads to the use of thermostatic elements for controlling the operation of the energy trap.

The most common types of thermostatic energy traps are:



According to the valve design, energy traps can be placed into two categories:

» Differential Pressure Valve

» Balanced Pressure valve

Regarding the way they function, energy controllers can be classified as:

» Cyclical discharge

» Continuous discharge

4.3 AUTOMATIC AIR VENTING

An interesting characteristic that is common in all thermostatic energy traps is the ability to automatically vent. As a result, the mixture of steam and air or incondensable gas, like all mixtures of gas, follows Dalton's law. Because of this, the total pressure of the mixture is the sum of the partial pressures of its components.

So, the steam's saturation temperature in the mixture corresponds to only the partial pressure of the steam in it.

Therefore, a thermostatic energy trap that is subject to the action of the mixture of steam and incondensable gases will sense a temperature that is lower than if all of the fluid was steam.As a result, the energy trap will open itself and create an automatic vent for incondensable gases.

As the proportion of steam in the mixture increases, its temperature rises and the thermostat progressively moves the energy trap valve until it is shut, once all of the incondensable gases have been completely evacuated.

In steam traps, automatic air venting is achieved by adding an internal thermostat. Figure 4.1 shows a float trap whose air vent valve (V) is driven by the thermostat (T). Occasionally, the thermostat is disregarded and an internal bypass is used as an automaticair venting element; although, in this case it should be called constant air venting since it has continuous leak of live steam in the absence of incondensable gases.

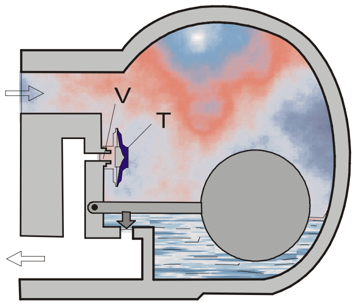


Figure 4.1

In energy traps, the use of a thermostat to control the evacuation of condensate simultaneously implies its automatic air venting characteristic.

4.4 LIQUID EXPANSION THERMOSTATIC ENERGY TRAP

This energy trap includes a thermostat (T) constructed with a capsule or bellows made of stainless steel, hastelloy, or another corrosion resistant material (Figure 4-2), which drives the cone (C) of the valve (V).

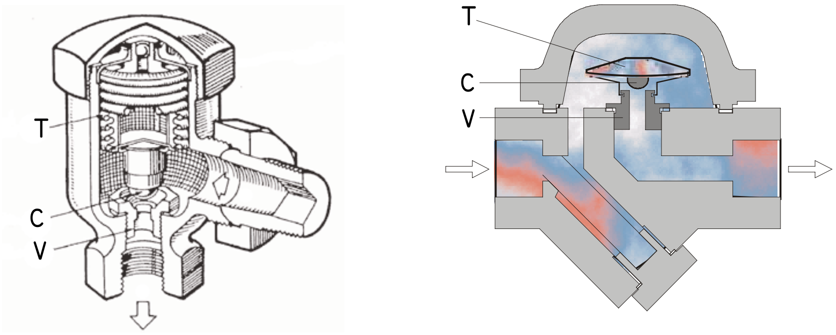


Figure 4.2

Generally, the interior of the capsule or bellows contains an azeotrope of water and alcohol; this way, the saturation curve of the mix follows one that is parallel to that of water but just a few degrees below, as a result of the proportion of alcohol in the mix.

Its operation is very simple: when there is steam or condensate that has a temperature close to steam, the liquid inside of the thermostat (T) evaporates, causing it to expand, pushing the cone (C) which closes the energy trap's valve (V).

In the presence of subcooled condensate (below the saturation temperature of the fluid inside the thermostat), the liquid inside the thermostat condenses and as a result shrinks /contracts the thermostat and opens the valve.

The advantages characteristic of liquid thermostatic energy traps are:

- » Large evacuation capacity
- » Quick and accurate response
- » Works in any position
- » Automatic air venting
- » Not sensitive to dirt
- » Resistant to freezing

» Allows high backpressure

» Follows the saturation curve of steam

Its main disadvantages are:

» Fragility of the thermostatic element

» Low resistance to water hammers and superheated steam

» Costly maintenance (expensive and short-lasting spare parts)

4.5 CLASSIC BIMETALLIC THERMOSTATIC ENERGY TRAP

This type uses a thermostat with bimetallic plates (T) that react according to the differences in the condensate's temperature, transmitting its movement to the cone (O) of the energy trap's valve (V) (Figure 4-3).

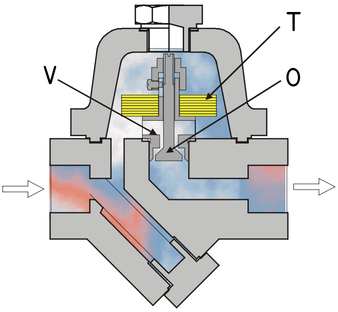


Figure 4.3

It is a very robust and versatile energy trap as it allows for the discharge temperature to be adjusted to the ideal amount for the service provided or in order to optimize the steam network's energy efficiency.

Its operation is the following: when cold condensate reaches the energy trap, the bimetallic plates move towards a flat position, allowing for the cone to move open, which is pushed by the fluid's own pressure.

As the condensate rises in temperature, each pair bimetallic plates start to curve and expand against one another expanding like a bellows, pushing the valve cone close against the opposing force of the pressure. The position of the valve cone, thus the opening of the valve, continually depends on the balance of opening (pressure) and closing (thermal) forces.

When the temperature reaches up to a few degrees below the corresponding saturation point of the steam, the cone hermetically seals. The closing point depends on the adjustment set on the thermostat, which can be modified by the user.

Note that the closing is produced on the outlet side of the energy trap, where flash steam is formed and the velocity of the fluid flow is higher. Because of this, the cone valve is subject to intense erosion which reduces the life of the energy trap. Some manufacturers have designed a stepped nozzle, in attempt to distribute the pressure jump that occurs between the inlet and outlet in stages, thus, reducing the level of erosion.

In reality, the bimetallic plates are not a spring, although they act as one. Their deformation is an intrinsic property of bimetal which takes a curved shape depending on the temperature. Bimetal's operation range is maintained at all times in the elastic part of the material, far from the plastic part, in order to avoid permanent deformations.

Each bimetallic plate is made of two alloy layers that have different thermal expansion coefficients and high levels of Cr and Ni to prevent corrosion. Therefore, bimetallic plates always last much longer than the rest of the parts of the energy trap.

This type of energy trap uses a differential pressure valve and an annular chamber on the outlet side where the condensate expands. This creates and additional opening pressure force which increases the pressure difference that initially pushed against the cone valve. This reduces the bimetal's thermal hysteresis at the expense of increasing the erosive actions of the mixture of condensate and flash steam on the cone valve.

The advantages characteristic of the classic bimetallic energy trap are:

» High reliability, versatility, and energy efficiency

» Continuous discharge and high range of pressure

» Very robust and resistant to water hammers

» Not sensitive to corrosive condensate or freezing

» Automatic air venting and large cold-start capacity

» Works with superheated steam

» Operates in any position

Its main disadvantages are:

» Sensitive to dirt

» Slow response to abrupt system or pressure changes

4.6 BIMETALLIC BI-THERMOSTATIC ENERGY TRAP

This is the most modern bimetallic energy trap and it is characterized by the incorporation of two opposing bimetallic thermostats and a balanced pressure valve.

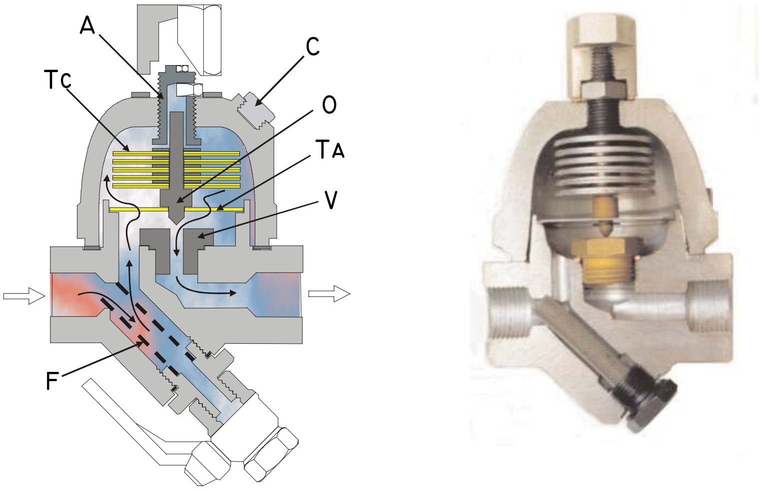


Figure 4.4

As shown in figure 4.4, the internal energy trap regulator is composed of the following parts: an upper thermostat made of various pairs of bimetallic plates (closing thermostat Tc), a lower small single-plated thermostat (opening thermostat Ta), a cylindrical cone valve (O), valve seat (V), and an external adjustment mechanism (A).

This energy trap uses a connection (C) for the SmartWatch monitoring system,"Y" filter (F), which has the option of being equipped with a drain and test valve, and a removable top cover that allows for external adjustments while the energy trap is in operation.

Note that the ascending vertical movement of the upper thermostat (Tc) is restricted by the adjustment mechanism (A), therefore, when it expands it moves the cone valve (O) downward vertically. The lower thermostatic plate (Ta), rectangular with two opposing sides circularly shaped, is simply supported by the edge of the circular sides in a way that, as shown in the figure, does not block fluid from moving towards the upper thermostat, always keeping the thermostats submerged in condensate to be discharged. When the lower thermostatic plate (Ta) expands, it curves downward allowing the cone (O) to move down as well.

The following explains its operation:

With the arrival of cold condensate, the upper thermostat (Tc) contracts and the lower thermostatic plate (Ta) is flat, keeping the valve (V) completely open, allowing condensate to be freely evacuated.

As long as the condensate increases in temperature, the lower thermostat (Ta) curves itself downward allowing the cone (O) to lower, and the upper thermostat continues to expand, and therefore pushes the cone (O) downward. As a result, the cone (O) moves closer to the orifice of the valve (V), constricting the condensate's pathway.

When the temperature of the condensate reaches the amount as adjusted on the energy trap, the cone (O) closes the valve (V) completely.

When the condensate's temperature lowers a little, the upper thermostat (Tc) slightly contracts and partially releases the closing force; at the same time, the lower thermostat (Ta) slightly reduces its curvature, lifting up the cone (O) and opening the valve (V).

Taking into account that the influx of condensate is a continuous process, the small temperature variations maintain a dynamic balance between both thermostats, which adjust the energy trap's discharge,to thecondensate production capacity in the line. So, the energy trap perfectly adapts to the conditions of the process of forming condensate, preventing abrupt or intermittent discharges that would typically cause water hammers in the condensate networks. Also when controlling the energy trap's discharge temperature, the amount of flash steam produced is reduced so, as thus the level of backpressure that is present in the return line, avoiding the most serious and common cause of malfunctioning in condensate networks.

The dynamic balance point or point of operation mentioned is easily adjusted by an external adjustment mechanism (A), without the need to stop the flow of steam nor interrupt the operation of the energy trap.

Note that the cone valve as well as the thermostats are completely submerged in the fluid, which means that the resulting pressure forces acting on themare null. That is to say, the valve is a balanced pressure valve, therefore, the energy trap's capacity to operate and regulate is not affected by variations in the differential pressure nor backpressure. In addition, its internal elements are subject to much weaker mechanical stress than in the classic bimetallic energy trap.

The lower thermostat plays a very important role during the cold-start of the energy trap; in fact, the cone valve can shut against excessive increases in the temperature of condensate in the transitory systembecause of the thermal inertia of the thermostats. Once the valve (V) shuts, pressure forces act upon the cone which keep it from opening, but when the temperature of the energy trap drops slightly due to the transmission of heat with the exterior, the lower thermostat (Ta) enters into action and lifts the cone (O) from the valve (V), reestablishing the balance of forces in the cone valve as well as the operation of the energy trap. This quick situation only occurs in cold starts during the transitional system.

The bi-thermostatic energy trap includes four elements that make them not sensitive to dirt:

» "Y" Filter, with the option of including a cleaning and test valve

» Full bore valve that prevents any obstruction

» 1 mm spacers between the pairs of bimetallic plates in order to eliminate the tightening of the bimetallic packet from particle buildup between plates

» External adjustment mechanism that allows for an occasional internal blow with the energy trap's steam, without interrupting its service

All aspects considered, the bi-thermostatic energy trap brings enough characteristics together in order to be currently considered one of the most robust, versatile, efficient, reliable, and low maintenance cost energy traps.

The advantages characteristic of the bimetallic bi-thermostatic energy trap are:

» Highly reliable, versatile, and energy efficient

» External adjustment mechanism, very low maintenance costs

» Continuous discharge and a wide range of pressure

» Very robust, durable, and resistant to water hammers

» Not sensitive to dirty or corrosive condensates

» Not sensitive to freezing

» Automatic air-venting and a large cold-start capacity

» Supports extremely superheated steam and very high backpressure

» Operates in any position (cone valve is guided by two separate points)

Its main disadvantages are:

» Produces a slight delay when there are abrupt system or pressure changes (this is not an important issue since the working conditions do not experience sudden variations in the grand majority of applications)

4.7 CLASSIC BIMETALLIC vs. BIMETALLIC BI-THERMOSTATIC

Although both types of energy traps have already been described in sections 4.5 and 4.6, given that the differences between the two have serious repercussions on operational, energy, and maintenance areas, the most relevant differences are analyzed below:

The first significant difference is found in the type of valve:

The classic bimetallic energy trap uses a differential pressure valve while the bimetallic bi-thermostatic incorporates a balanced pressure valve (Figure 4-5).

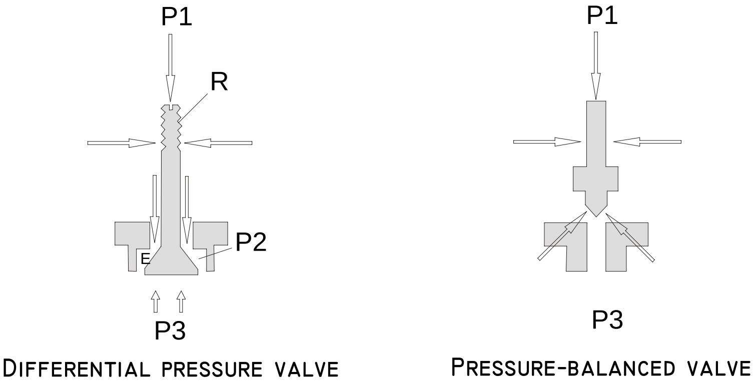


Figure 4.5

In the figure on the left, it shows that the cone closes the valve on its lower surface, or the outlet side; as well, the cone valve is subjected to different pressure forces (P1, P2, and P3), depending on the zone considered; the variable pressure forces (P2) are generated by the condensate in the annular expansion chamber (E) over the cone valve and its magnitude depends on the degree of expansion. The resulting opening forces or differential pressure on the cone valve is P1 + P2 - P3; this differential pressure limits the energy trap´s range of operation.

Due to the increase in the volume of flash steam, the mixture of condensate and flash steam in the annular chamber (E) flows at a high velocity, subjecting the cone valve to intense erosion.

On the other hand, in the balanced pressure valve (figure on the right), the cone closes the valve on its upper surface, the inlet side. In addition, it is completely subject to a uniform pressure (P1), in an area where there is no flash steam, and thus, where the fluid's velocity is low and the erosive action of the condensate on the cone is minimal. Consequently, the lifespan of the bi-thermostatic energy trap is around three times longer than that of the classic bimetallic energy trap.

Because the resulting forces of pressure on the cone are null, the bi-thermostatic energy trap allows for super elevated backpressure.

Different from the cone of the classic bimetallic energy trap, the cone of the bi-thermostatic energy trap does not include a threaded area, keeping the cone from being fragile or even breaking.

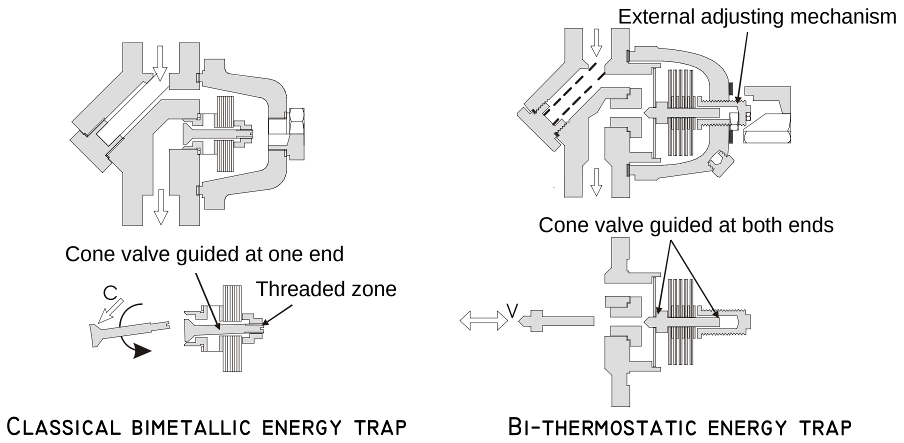


Figure 4.6

In the classic bimetallic energy trap, the thermostat exerts a closing force against the cone which is being pushed at all times by the opposing pressure forces that open the valve.

In the bi-thermostatic energy trap, none of its thermostats are found subject to pressure forces. This gives this energy trap a much larger working pressure range and a much longer lifespan.

There are balanced pressure energy traps where the lower thermostat (Ta) is substituted for a spring. However, different from this one, which provides a force that is proportional to the deformation, the advantage of the bimetallic thermostat is that it provides a force that is proportional to temperature for the entire range of operation.

Figure 4-6 shows differences in guiding. The cone is guided by only one side in the classic bimetallic energy trap, while the bi-thermostatic one is guided by both. This means that although both energy traps can work in any position, the classic design of the cone remains subject to asymmetrical wear and tear when it is installed horizontally.

Repair of the bi-thermostatic energy trap typically consists of a simple external adjustment in order to compensate for possible erosion on the valve cone. However, unlike the classic bimetallic energy trap whose repair requires the replacement of the entire bimetallic regulator, if necessary, the bi-thermostatic energy trap allows for the replacement of any of its internal pieces since they are all independent (Figure 4-6) and they can be replaced separately, greatly reducing maintenance costs.

The mere inspection of the state of wear and tear in the valve is impossible in a classic bimetallic energy trap without disassembling the regulator itself. On the other hand, the bi-thermostatic energy trap has easy access to all of its parts once the cover is removed, without the need to use tools or remove the regulator adjustment as it remains in the adjustment screw that is secured to the cover.

Finally, as it is logical, the direction of the flow in an energy trap is indicated on its own body and it should not be inverted as the energy trap would become blocked. But if this occurs unintentionally, the bi-thermostatic energy trap is so reliable that it will continue to function in this situation, though the closing action of the valve would be produced in the outlet side like in the classic bimetallic energy trap except that the thermostat would now be located on the outlet side.

4.8 TRAP VALVE STATION

The trap valve station is an element that is widely used in new projects for its reduced size, low cost, and easy mounting.

Generally, a TVS (Figure 4-7) is made up of a combination of all of the elements that form a classic drain station, including:

- Inlet and outlet isolation valves
- Drain Valve
- Test Valve
- Universal connection
- Energy trap (or steam trap) with universal connector

Bitherm trap valve stations incorporate additional elements that introduce significant improvements to their performance, such as:

» SmartWatch monitoring device connection

» "T" filter

» Inlet pressure connection

» Outlet pressure connection

» External adjustment mechanism

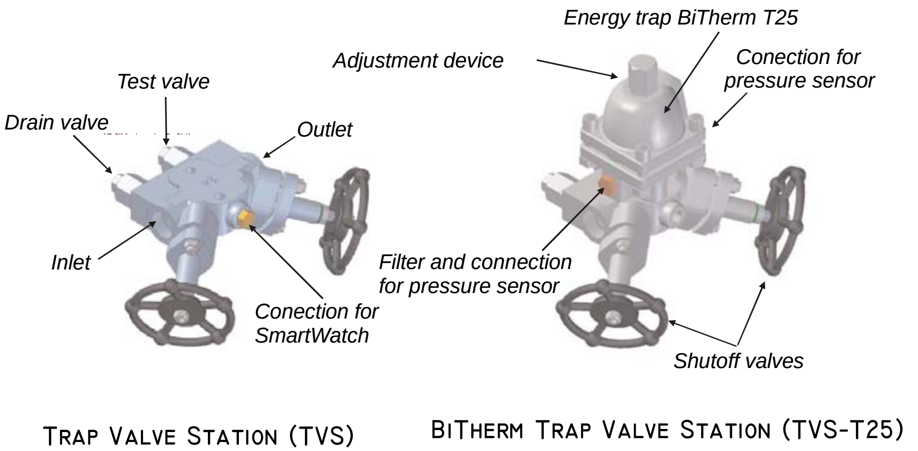


Figure 4.7

The isolation valves in the BiTherm Trap Valve Stations use piston valves, giving them two clear advantages over needle valves:

» Minimizes sensitivity to solid particles

» Piston slipping, without rotating, keeping the dirt from depositing between the packing rings and damaging the seal's surface, guaranteeing a long life without leaks

CHAPTER 5

INTELLIGENT ENERGY TRAPS AND VALVES

5.1 INTELLIGENT ENERGY TRAP

The genuine Intelligent Energy Trap, known as *SmartWatchWeb™* (in short SWW), was internationally patented by BiTherm on 1996. SWW basically consists of three main elements (figure 5.1):

a) Bi-Thermostatic Energy Trap with external adjustment mechanism

b) Non-invasive Electronic Monitor Device (SWW)controlled by microprocessor

c) Graphical User Interface (GUI)

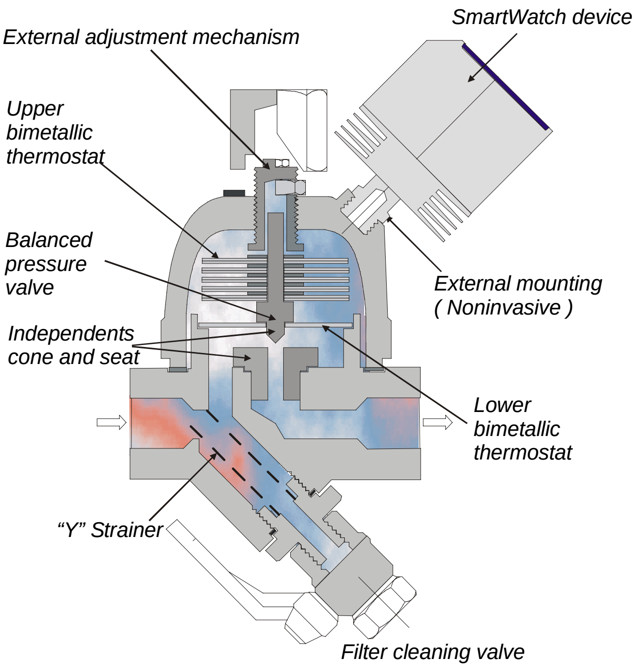


Figure 5.1

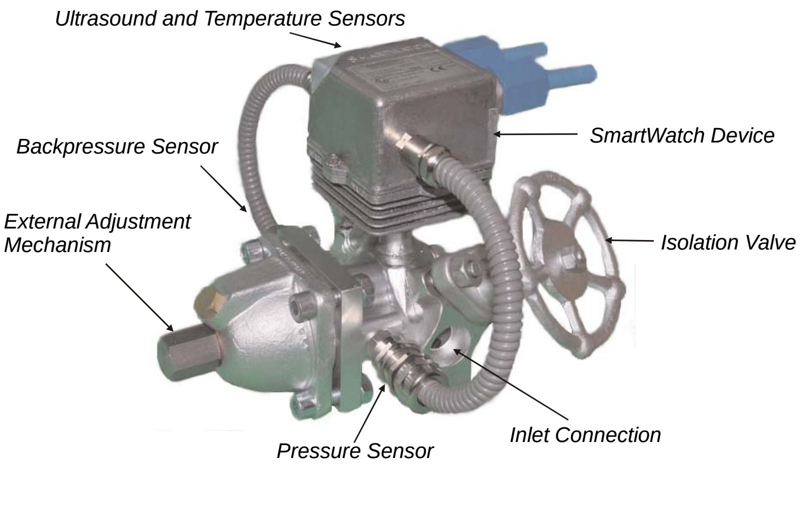
Experience shows that correct setting of a Bi-thermostatic Energy Trap (point 2 in Figure 2-2) is essential for reducing steam consumption and eliminates operational problems in steam networks. Well, the monitoring system includes two sensors (ultrasoundand temperature) that noninvasively maintain continuous surveillance of the working point of the Energy Trap, identifying the emergence of internal or externalsteam leakage, obstruction or blockage, inappropriate temperature or low energy efficiency.

Additionally the monitoring system has two auxiliary channels for pressure probes, which properly positioned in some Energy Traps (conveniently distributed throughout the facility), allows knowing a map of pressure and/or backpressure, in order to prevent the occurrence of problems operating along the steam/condensate network. This is essential to prevent operative problems as well as to increase recovery of residual energy and condensate recovery rate.

Although the monitoring system can be applied on any type of steam trap its maximum potential is obtained when applied on bi-thermostatic energy trap because any incident detected by the system can be corrected immediately by mean of its external adjustment mechanism, neither interrupting its service nor costly repair.

5.2 INTELIGENT TRAP VALVE STATION (ITVS)

Just as the trap, Trap Valve Station (TVS) can become intelligent by simply adding the *SmartWatchWeb*™ monitoring system



BiTherm Intelligente Trap Valve Station (ITVS)

Figure 5.2

As shown in Figure 5.2, Intelligent Trap Valve Station (BiTherm ITVS) has all necessary connections to monitor the four parameters controlled by the *SmartWatchWebTM* system (ultrasound, temperature, pressure and backpressure); thus it is possible to monitor the steam/condensate network without the need for subsequent connections into pipes.

It is interesting to note that it is not necessary install a pressure sensor per steam trap to get reliable map of back pressure along the whole condensate network, but installing only a few pressure sensors conveniently distributed along the network is enough to get that goal.

Although the possibility of monitoring is not addressed in new projects, the use of monitorable BITHERM Trap Valve Stations brings great value to the project since it allows this future option, reducing installation costs.

5.3 DESCRIPTION AND ARCHITECTURE OF THE SWW SYSTEM

SmartWatchWebTM is a digital monitoring system based on microprocessor. Their devices are organized in a hierarchical structure, which exchange information bidirectionally via a field data bus. These electronic devices are divided into three basic levels:

» At the lowest level of the system there are the field devices that incorporate or are connected to the corresponding sensors.

» The second level consists of control units or concentrators that collect information from the field devices and transmit it to the next level.

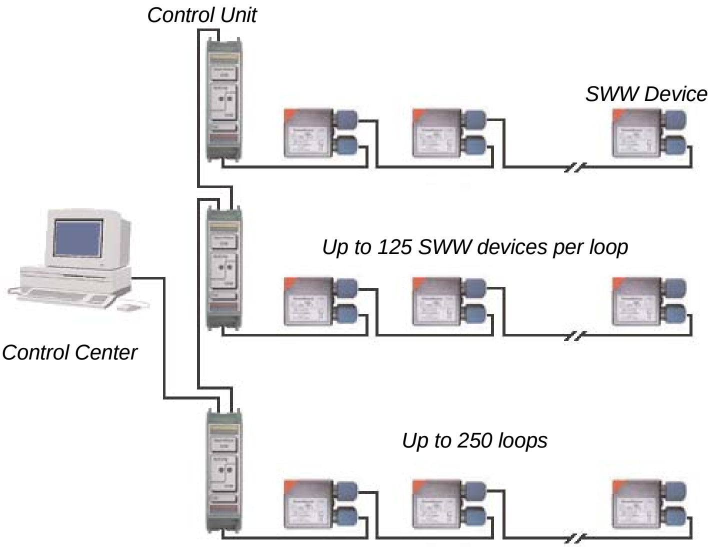
» The third level is the control center where all information is managed.

Depending on the physical media used the system supports two possible options:

» Wired data bus RS-485 (Figure 5.3)

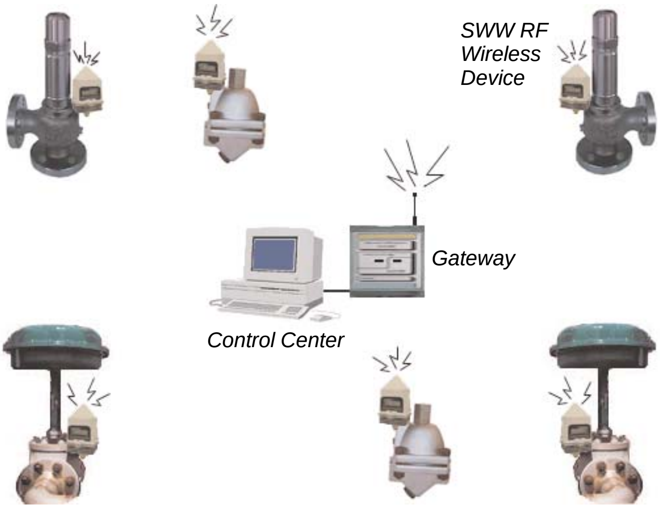
» Wireless network (Figure 5.4)

The wired data bus can cover a distance of 1200 meters (limitation imposed by the RS-485 specification, which can be expanded conveniently by placing control units or installing signal amplifiers) and supports up to 125 field devices, four channels per device , i.e.up to 500 sensors. The range of the wireless network depends on factors such as location of antennas, power emitted by antennas, absorption of radiated power by nearest elements to antennas (ground, concrete pillars, etc.) so it is advisable to conduct a radiofrequency survey on site before deploying a wireless network in order to detect potential problems and to locate radio transmitters conveniently.



WINDOWS PC PLATFORM WITH WIRED DATA BUS RS-485

Figure 5.3



SMARTWATCH WIRELESS NETWORK)

Figure 5.4

Bidirectional communication between system elements is half duplex type and is performed by mean of standard open protocols (MODBUS RTU, TCP / IP, ZigBee, ISA100, etc). System management is done through an intuitive graphical interface.

Considering the structure and implementation of the control center, the system can be installed on two different platforms:

» Local System *SmartWatch™* (SW) on Windows platform (Figure 5.3)

» Remote system *SmartWatchWeb™* (SWW) on a Web platform, based on LAMP technology (Linux, Apache, MySQL, PHP) (Figure 5.5)

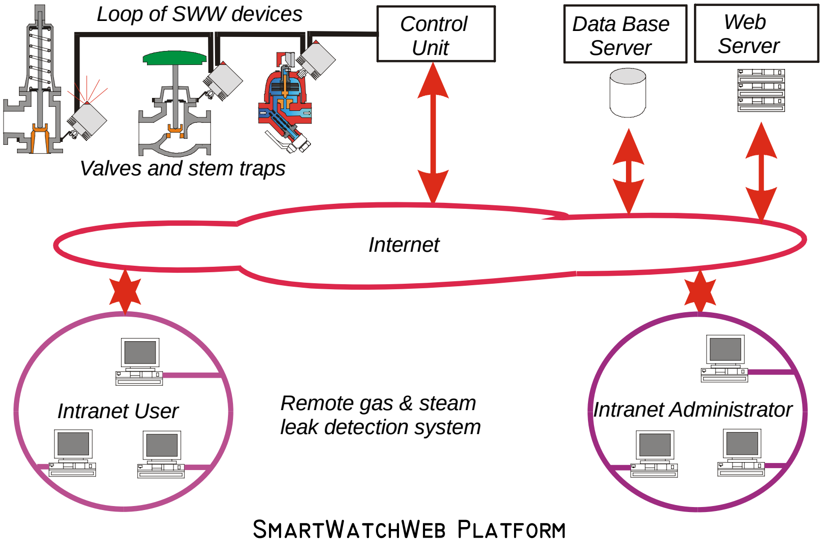


Figure 5.5

Mention that *SmartWatchWeb™* technology won two Gold Medals at the International Exhibition of Inventions of Geneva (Switzerland) in 2004 and 2005, Special Mention of the International Jury, and GarcíaCabrerizo Foundation's Award for the Spanish Invention in 2004. In addition, *SmartWatchWeb™* system has intrinsic safety certificate, ATEX marking II 1 G, [Ex ia] IIC T4 and IECEX [Ex ia] IIC T4, therefore it can be used in potentially explosive atmospheres (Zone 0, Div 1).

System management, either locally or remotely, is performed through an intuitive graphical interface (Figure 5.6), which allows knowing all the information generated by field devices, interact bidirectionally with them, and get a wide variety of reports about operating, energy efficiency, emissions, etc.

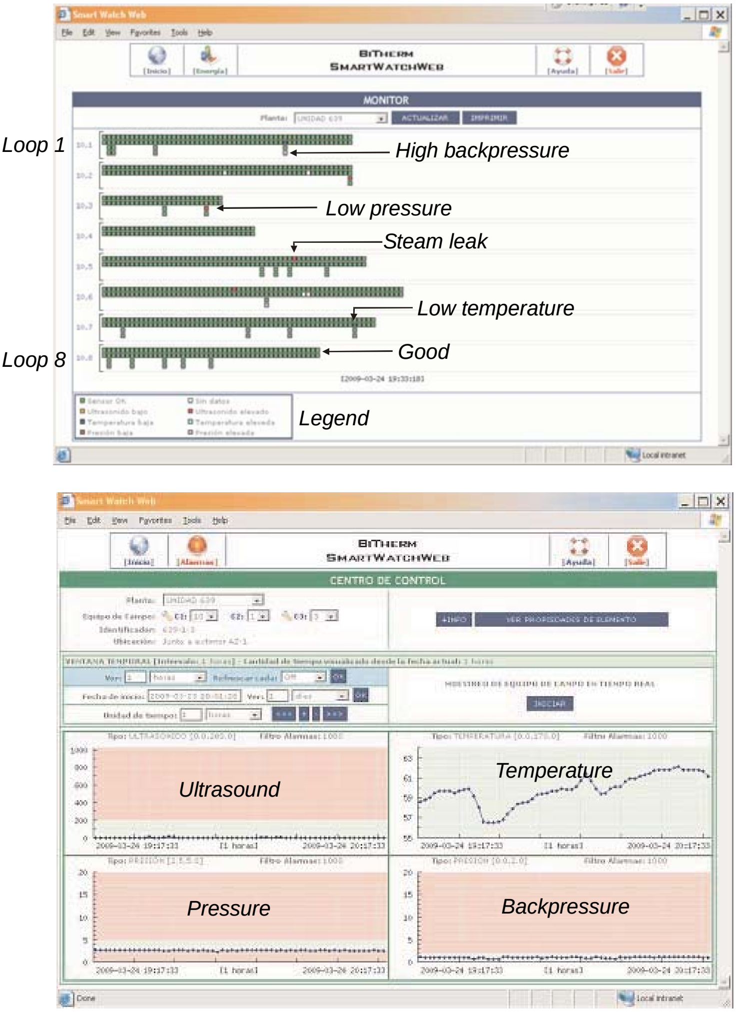


Figure 5.6

5.4 ADVANTAGES OF INTELLIGENT ENERGY TRAPS

Given that conventional steam trap is an automatic valve, operated without auxiliary power, ie, an automatic valve that indirectly controls steam energy, it is understood that the great contribution of intelligent energy trap is exactly to put in hand of the user all the information needed, not only for to make rational use of energy and eliminate their loss but also to improve the operating conditions, reduce costs (operating, inspection and maintenance), and increase safety and reliability of the network of steam / condensate.

The main advantages of intelligent energy traps are:

» Self-diagnostic capability

» Continuous detection of steam leaks (internal and/or external)

» Continuous monitoring of energy efficiency

» External adjustment mechanism and repair without service interruption

» Continuous monitoring of pressure/backpressure of the steam/condensate network

» Adjustment mechanism to reduce flash steam

» Prevention of thermal water hammers

» Reduction of costs (operation, inspection and maintenance)

» Very long lasting life (about three times longer than conventional steam traps)

» Reduction of greenhouse gas emissions

5.5 INTELLIGENT VALVES

The concept of intelligent energy traps can be applied in monitoring valves as well as gas leak detection on safety valves and automatic on-off valves.

The *SmartWatch™* device is externally attached to these valves with non-intrusive clamps or collars, but without dismantling the valves or interrupting their operation (Figure 5.7).

The *SmartWatchWeb™* system can configure a powerful monitoring and surveillance network of steam leaks, process gas leaks, and hazardous gas leaks on valves in order to improve safety, reliability, and reduce operation costs.

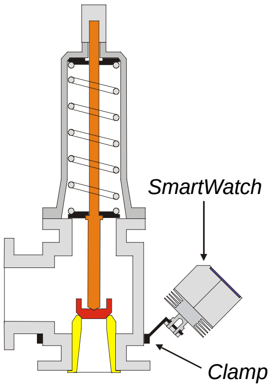


Figure 5.7

The system monitors continuously, detecting any leakage of gas as soon as it occurs; once the leak has been detected, the control center automatically transmits the alarm to the appropriate departments, which can then act immediately and take the corrective action in order to eliminate hazardous situations and reduce the risk of accidents (Figure 5-8).

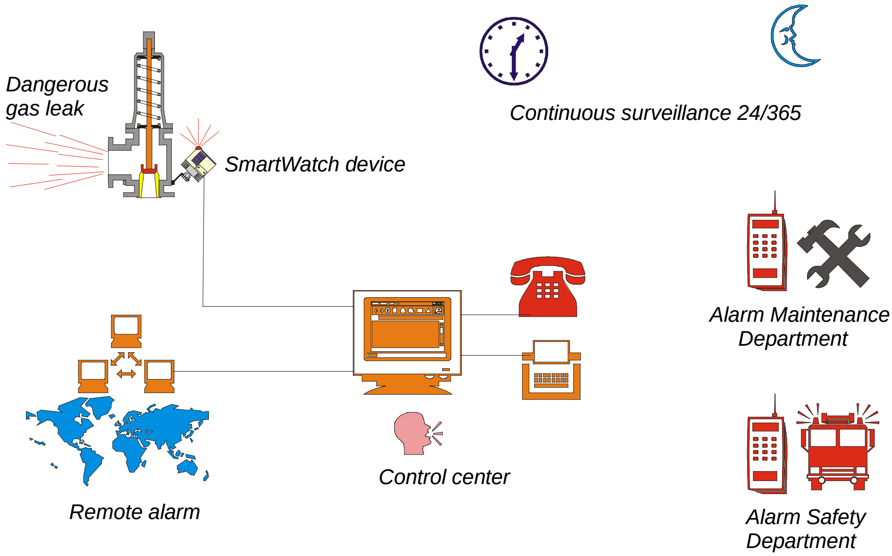


Figure 5.8

Therefore, the following objectives are achieved:

» Detection of internal and external leakage of process gases in order to reduce production costs

» Fast detection of hazardous gas leaks in order to significantly improve safety conditions on facilities

» Reduction of inspection costs

» Reduction of deterioration from gas and steam leaks in valves on account of fast leak detection (reduction of maintenance costs)

Figure 5-9 shows the application of *SmartWatchWeb™* in monitoring automatic on-off valves for instant detection of process gas leaks that otherwise could be burned on flare without identification. Thus, process losses are reduced and therefore, so are production costs as well as inspection costs and maintenance costs.

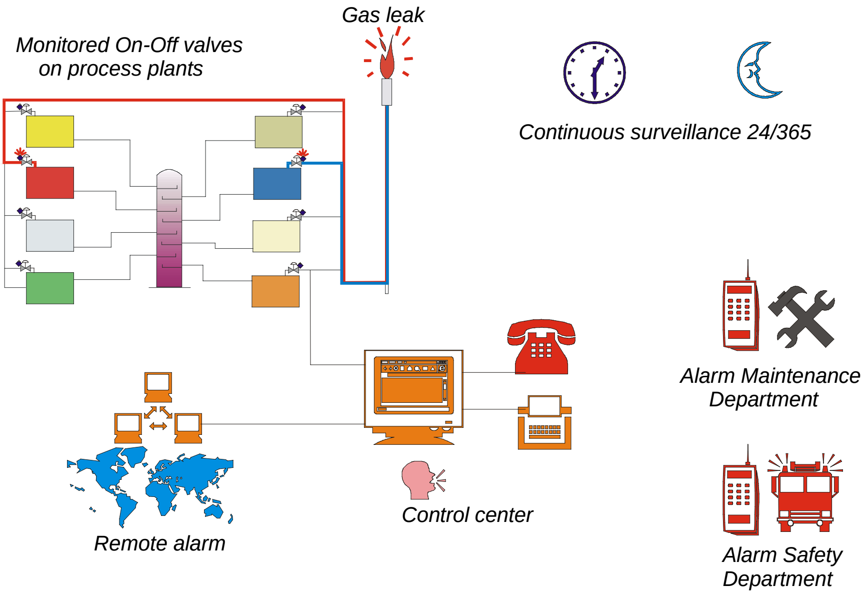


Figura 5.9

A remarkable feature of the *SmartWatchWeb™* system is its ability to integrate multiple types of sensors in a common architecture that can grow as new needs arise. Therefore, steam traps, valves and other equipment can share a common architecture, simplifying operations and reducing costs.

5.6 STEAM SAVING WITH ENERGY TRAPS

Experience shows that the correct setting of the operating point of the energy trap (point 2 of the curve in Figure 2-2) leads to significant energy savings.

In petrochemical plants and refineries, the vast majority of traps are installed in low flow applications (tracers, drip legs, ...) where an optimal adjustment of the working point of the energy trap reduces up to 8% steam consumption.

CHAPTER 6

DESIGN OF STEAM AND CONDENSATE NETWORKS

6.1 INTRODUCTION

The high energy content of steam and its easy transformation into other forms of energy makes steam an element that is widely used in a large amount of industrial applications.

Steam is most widely used as a thermal carrier in industrial processes that require heat input as in heat exchangers, heating radiators, piping for product lines, etc.

Another application that is very economically important consists in converting its internal energy into mechanical energy for moving turbines, which is then converted into electric energy by alternators. In other applications, this mechanical energy is used to directly drive pumps or compressors.

Steam's internal energy can be converted into kinetic energy which is used, among other applications, in steam ejector based on the Venturi effect.

Other applications use steam as a chemical compound in chemical reactors, which is involved in the reaction or is used as a means of agitating tanks and mixers.

Logically, different points of use of steam are usually placed far from others and at a distance from where steam is produced, which is why it is absolutely essential to have a distribution pipe network that carries it to each equipment that requires steam. Figure 2-1 is a visual representation of a typical steam facility.

First, there is a boiler that converts chemical energy from the fuel into heat energy. By means of an interchanging pipe system, the heat is transferred to the water that is contained inside the boiler until it causes the water to evaporate.

The steam generated is sent to the various points of use through a pipe system that makes up the distribution network.

The energy content of the steam is extracted by adequate equipment using methods that are the most appropriate for each process, thus, causing the steam to condense as a result of this release of energy.

The water formed is evacuated to a tank through another pipe network that makes up the condensate return line system. At this point, it is pumped back into the boiler where it will restart the same cycle.

The diagram described corresponds to a closed system where water changes to steam then back to water again, repeating this cycle without losing mass. Different from this, if condensate produced in the steam using equipmentis not sent back to the boiler, but instead it is evacuated to the outside of the facility, this corresponds to an open circuit system.

It is evident that the closed system is more efficient than the open one, since the residual energy of the condensate (sensible heat) is returned and reused in the boiler. However, the presence of steam loss through leaks and vents or the existence of equipment in the facility that uses steam mass (ejectors, bubble agitators, soot blowers, mixers, deaerators, etc.) make the facilities, in practice, not closed entirely but rather almost closed.

The loss of water mass in an open system can be more problematic than the energy cost of steam in areas that are difficult to supply.

During the start of a facility, the equipment and pipes may contain air. The air or other non-condensable gases produced in the steam generation process reduce the steam's temperature, and they are poor heat transmitters, making it necessary to be evacuated through adequate air vents.

The steam distribution and condensate return network, subject to environmental conditions, release heat to the outside through transmission and radiation, resulting in energy loss or auto-consumption, which can be reduced by thermally isolating pipes, equipment, and accessories.

The circulation of steam and condensate through the inside of the piping is slowed down by the friction of the walls of the pipes, causing a loss of pressure. In the steam, this pressure loss translates into a decrease in temperature as shown in the steam saturation curve (Figure 1-3). This pressure loss by friction is known as a ***pressure drop***.

The temperature differences on the piping create expansions and contractions, generating considerable mechanical stress on the structure. This stress is strong enough to cause breakage and therefore must be avoided. In order to do this, expansion joints and dilatation lira are used in those sections where the installation itself is unable to absorb the expansions.

The differences in circulation velocity between steam and condensate are capable of producing obstructions in the pipes known as water hammers (mechanical); the mix of condensate and flash steam originating from different pressures of steam can also cause water hammers (thermal), which significantly damage all of the facility's elements, causing breakage and leaks. Water hammers are heard as loud metallic cracks or hammer blows in the pipes.

6.2 GENERAL STEAM DISTRIBUTION LINES

The design of steam distribution lines must take the following factors into consideration:

» Auto consumption of steam. Energy loss

» Sizing and flow velocity

» Structural calculations: mechanical stress, expansions, etc

The sizing of a steam distribution network always begins with the understanding of steam consumption for each piece of equipment that makes up the facility. The calculations must always include an adequate safety factor that gives certain flexibility to the operation of all of the equipment and the facility as a whole. It is recommended to size the network with at least 20% of the capacity reserved for future expansions or modifications.

Additionally, identifying the network layout allows us to first estimate the approximate diameter required, which will be explained in a later section. Now, the network itself consumes its own steam because of releasing energy to the outside. These losses depend on thermal insulation and the surface of the pipes. Auto-consumption must be taking into account, increasing the total steam flow transported by the pipes, thus resulting in a recalculation of the distribution network's final diameter.

It is very common to use different steam pressures in different equipment at the same facility. Because of this, steam is often generated at pressures that surpass the working amount, only to be lowered at the points of use. This is usually beneficial since there is a pressure margin for future needs, which also means a reduction in the diameters of pipes, valves, or network accessories (reduction in installation and maintenance costs), although their thickness increases (rise in costs), which is why it is necessary to determine the most favorable solution.

It is also important to recall that the correct choice of working pressure in heat exchanging equipment influences its thermal efficiency; this can be seen in the enthalpy-pressure curve shown in figure 1-4. Note that as long as the pressure increases, so does the sensible heat of the liquid; at the cost of lowering the latent heat of vaporization used in the heat exchange processes, therefore requiring more steam in order to produce the same amount of energy. However, the pressure of steam must not drop below a certain limit in order to guarantee the process of heat transmission.

This minimum limit is theoretically fixed by the process's temperature that determines the saturation temperature of steam, and with it, the theoretic pressure threshold. Twenty percent above this amount is usually enough to achieve favorable conditions for transmitting heat with high thermal efficiency.

For calculations of steam facilities, this manual uses simple and quick graphics, based on empirical laws that are widely confirmed by experience, which offer real solutions that are very close to those gathered through more elaborate methods.

6.3 NETWORK AUTO-CONSUMPTION

The least favorable situation or the case that has the most auto-consumption is produced during the start-up of the facility, since the pipes are cold and must warm-up until they reach the system's temperature.

After this temperature, the pipes continue releasing energy through conduction, convection and radiation to the outside, but the condensation generated by these energy losses is generally much less than during the facility's start-up.

The amount of steam needed to put a facility into operation comes from the following equation:

$$Qs = P * (Ts - Ta) * Cp / CL$$

Where:

- Qs = Amount of steam in Kg
- P = Total weight of the pipes and accessories in Kg
- Ts = Steam temperature in Celsius
- Ta = Outside air temperature in Celsius
- Cp = Specific heat of steel = 0.114 Kcal / ºC Kg
- CL = Latent heat of the steam in Kcal / Kg

This amount of steam Qs will correspond to an hourly flow rate, increasing as the heating time or start-up time gets shorter.

It is not advisable to heat the facility quickly as this may cause water hammers and reduce the thermal and mechanical stress that is experienced during start-up. The heating velocity is controlled by how fast the steam valves are opened.

If "tr" (minutes) is the time it takes for the facility to be ready to work or for the system to be in operation, the required hourly flow rate Q (Kg/h) of steam is given by the following expression:

$$Q = Qs * 60 / tr$$

6.4 DIAMETER OF STEAM PIPES

The diameter of the pipes is relative to the steam flow rate, the flow velocity, and the specific volume of steam, therefore, everything depends on the pressure and temperature of steam since specific volume is a function of these variables.

The average flow velocity of a fluid through a tube is expressed by the mass conservation equation or the continuity equation:

$$Q = d * V * S$$

Where:

V = Velocity of steam in m / s

Q = Steam flow rate in Kg / h

d = Density of steam in Kg / m3

Ve= Specific Volume in m3 / Kg

S = Section of the pipe in m2

If S = 3.14 D2/ 4 the result is:

$$V = 353{,}7 * Q * Ve / D^2$$

And D represents the diameter of the pipe in mm.

This expression shows the relationship that exists between the diameter of the pipe and the flow velocity through it. In situations of fixed pressure, temperature, and steam flow rate, the flow velocity increases at a quadratic proportion as the diameter of the pipe decreases.

Excessive flow velocity can cause serious problems such as pressure drops, water hammers, erosion, … . Experiments confirm that the optimal flow velocities for the size of saturated steam distribution lines are as follows:

Steam Pressure (bar)	**Optimal Steam Velocity (m/sg)**
1,1 - 1,5	25
1,5 - 3	30
3 - 6	35
6 - 13	40
13 - 26	50
26 - 100	55

In short piping sections, the velocities can be slightly higher than those shown. When the pipes transport superheated steam, higher velocities are used (in this case it is common to use velocities that are 10% higher).

With the help of Figure 6-1 and by using the flow velocity appropriate for each pressure, one can easily find the adequate diameter to move a determined steam flow rate. The chart is valid, including calculations of superheated steam pipes by simply identifying the steam's temperature and pressure in the upper part of the chart.

Using the concept of velocity refers to the average velocity in a section of a pipe, without taking into account the velocity characteristics that correspond to its distribution through each section of the pipe.

The following example clarifies the use of this chart.

In an attempt to find the pipe section that is necessary for a distribution line with the following information:

Superheated steam flow rate:	30 Tm/h
Steam temperature:	300 ºC
Absolute pressure of steam:	16 bar.

Enter horizontally with steam temperature at the top of the chart until it crosses with the pressure curve. Continue vertically downward until it crosses with the line of the required steam flow rate, reaching one specific point. From here, continue horizontally until the rising vertical line from the lower part of the graph by using the steam velocity selected in the previous table. The intersection point shows the diameter needed for the pipe. If the point is in between two lines, the larger diameter of the two is used.

In this example, the diameter required is 200 mm (8"), for a steam flow velocity of 44 m/s.

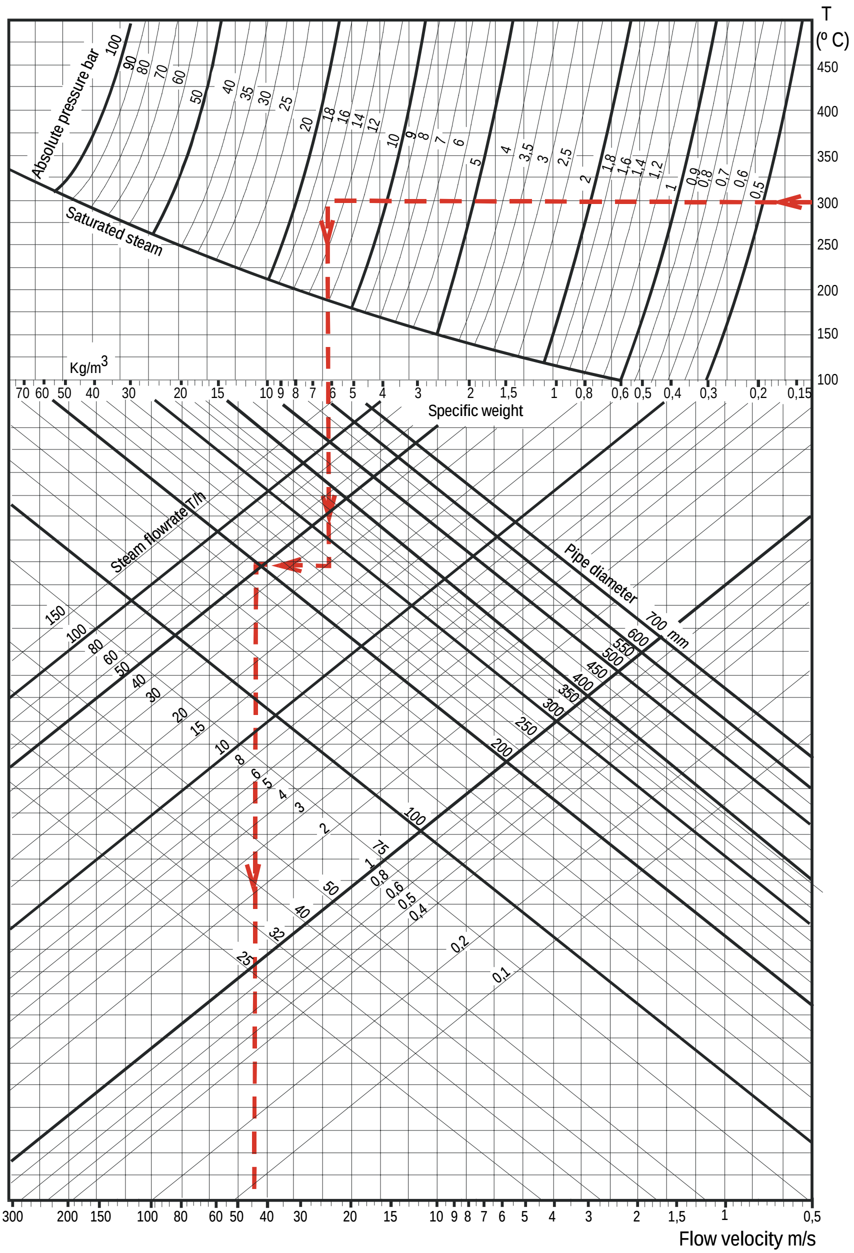

T (º C)
Absolute pressure bar
Saturated steam
Kg/m3
Specific weight
Steam flowrate T/h
Pipe diameter
700 mm
Flow velocity m/s

Figure 6.1

Once the pipe diameter is determined, other important aspects of the design of the facility must be taken into consideration, whether they are mechanical, thermal, operational, structural, or other aspects, such as:

» Pressure Drops

» Pipe dilatation

» Slopes

» Thermal loss and insulation

» Draining and Venting Points

» Structural strength calculations

6.5 CONDENSATE RETURN LINES

The condensate return lines have a few similarities and differences with regards to the steam's distribution lines.

The first difference that can be observed is that one drives steam while the other, condensate; this gives them different flow velocities to take into account when sizing the corresponding sections of pipes.

However, the condensate return line does not only move water but also flash steam. This is a consequence of the differential pressure in the diverse draining systems, causing the formation of a certain amount of flash steam (see section 1.3).

Note that the flash steam has the same properties as live steam; the only difference between them is how they originate, so, in order to size the condensate return line, it can be considered a transversal double-sectioned pipe. Water will circulate through the bottom section and low pressure steam will circulate through the upper section.

Now, experience shows that fairly good results come from sizing return lines as if they were steam distribution lines (first, disregarding water flow as an approximation of the actual solution) only by taking into account the following observations:

» Use the maximum amount of flash steam formed for the flow design

» Use a flow velocity of 15 m/s for this flash steam

» Prove the validity of this simplification

Actually, in order to find the exact size of the section needed for the condensate return line, the water flow section must be calculated first, and then the steam phase section.

Due to the differences in viscosity between both phases, the flow velocity of each must be different; when significant, this difference can cause little waves along the surface of the separation of the phases (Figure 6-2), and eventually cause momentary blockage of the entire pipe section, primarily in direction or section changes, which results in undesirable water hammers that are harmful to the facility. In order to avoid water hammers, the appropriate flow velocities should be around 2 m/s for liquid and between 15 and 20 m/s for steam.

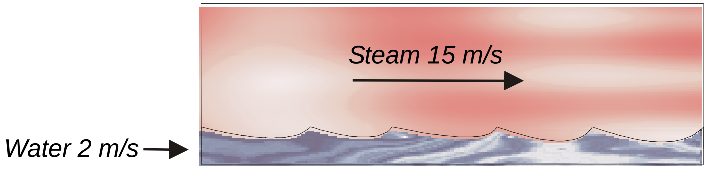


Figure 6.2

Now, with such a low flow velocity for the steam phase and the large volume that represents a small percentage of revaporized water compared with the total flow volume in the return line, the section that is needed to move the additional liquid turns out negligible in front of the section required for the steam phase. The commercial pipe diameter available determines the closest choice because of excess in the market-excess that is usually much larger than the section needed to drive the liquid phase.

Because of all of this, it seems practical to utilize the calculation simplification hypothesis mentioned, since, in practice the results rarely differ from those obtained with the most precise calculations.

Use chart 1-7 to calculate the amount of flash steam.

6.6 PRESSURE DROPS

Pressure drops in fluids moving through a turbulent pipe can most frequently be calculated using the Darcy Equation:

$$Pc = k * (L * d * V^2) / (D * 10^4 * 2g)$$

Where:

Pc = Pressure drop (Kg/cm^2) or (bar)

k = Friction Coefficient

L = Piping length (m)

D = Piping diameter (m)

d = Steam density (Kg/m^3)

V= Flow velocity (m/s)

g = acceleration of gravity (9,81 m/s^2)

The factor of 10^4 is introduced in order to represent the result in Kg/cm2 (in bars approximately).

The following equation is use frequently:

$$Pc = k_V * (d * V^2) / (10^4 * 2g)$$

The coefficient k_V is commonly used in valves and accessories, which represent concentrated pressure drops. Usually, all concentrated pressure drops are grouped together in the coefficient k_V, as the sum of all of the individual k_V.

The total pressure drop happens to be the sum of all of the concentrated pressure drops plus that caused by the piping itself.

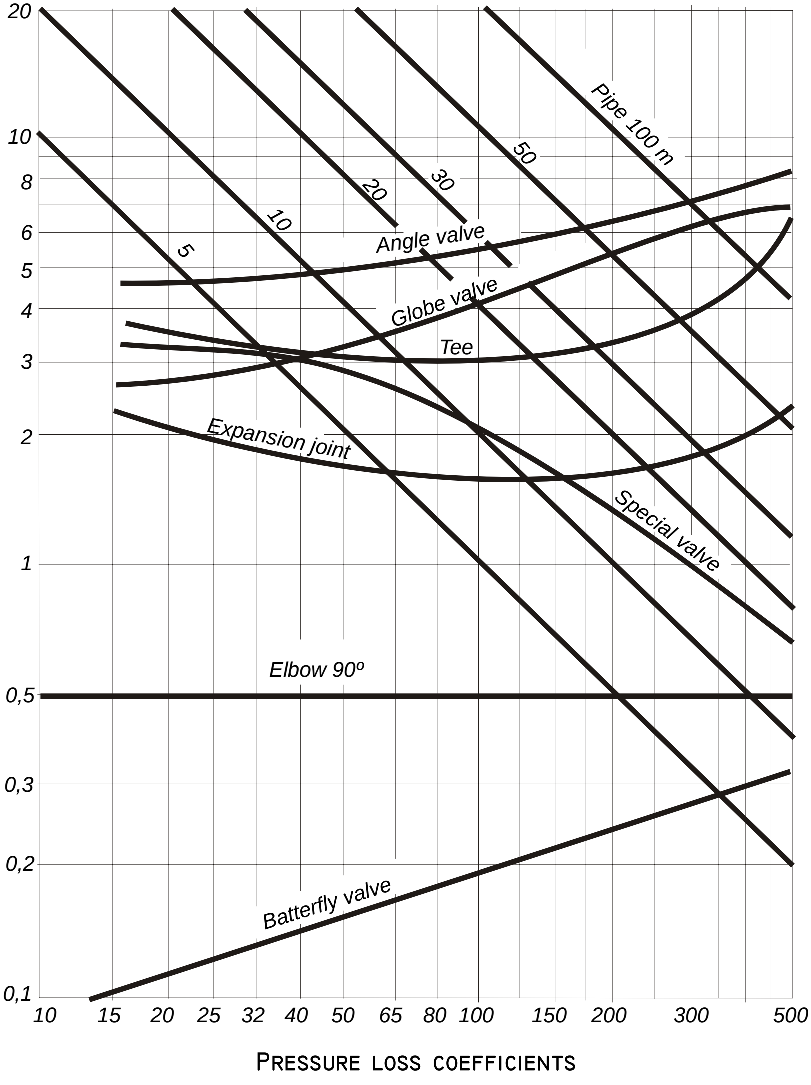
In order to apply these formulas, the pipe friction coefficient (k) must be known, which depends on the relative roughness of the pipe and the Reynolds number. Common in all practical cases, for turbulent flow and from Reynolds in the order of 10^6, the friction coefficient (k) takes an almost constant value. An average acceptable value is k = 0.0206.

A sufficiently approximated calculation can be carried out with the help of the graphs in Figures 6-3 and 6-4, as described below:

» Use the graph in Figure 6-3 to obtain the pressure drop coefficients (k) for the piping, valves, and accessories.

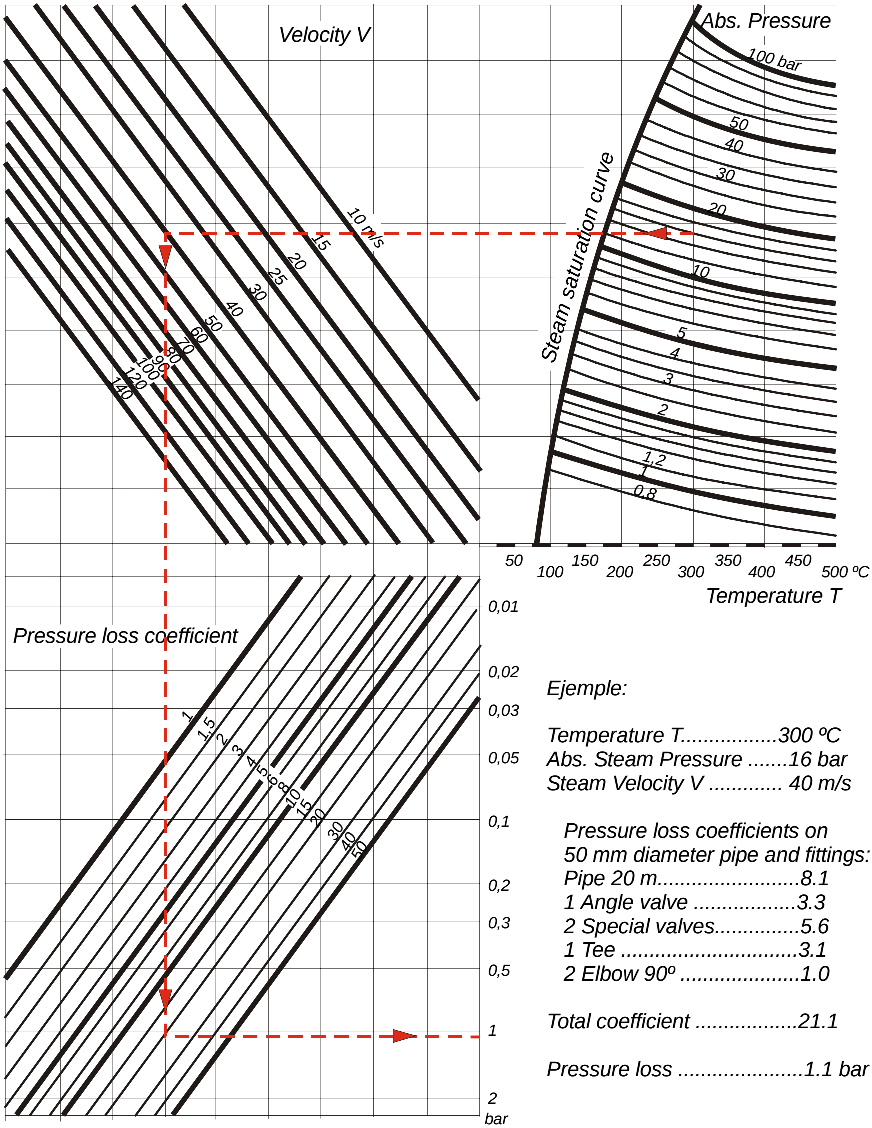
» Add all of the coefficients corresponding to all of the elements that make up the steam distribution line in order to determine the total pressure drop coefficient.

» Use the total pressure drop coefficient obtained before, and apply it to the graph in Figure 6-4 to finally find the total pressure drop (in bars).



20
10
8
6
5
4
3
2
1
0,5
0,3
0,2
0,1
10 15 20 25 32 40 50 65 80 100 150 200 300 500
Pipe 100 m
50
30
20
10
5
Angle valve
Globe valve
Tee
Expansion joint
Special valve
Elbow 90º
Batterfly valve
PRESSURE LOSS COEFFICIENTS

Figure 6.3



PRESSURE LOSS IN STEAM PIPES

Figure 6.4

6.7 PIPE EXPANSION

During the start-up of the steam facility, the pipes expand as they continue getting closer to the temperature of a continuous regimen. The increase in length of the pipes caused by the temperature can be determined by using the graph in Figure 6-5, applicable for steel pipes commonly used in facilities (carbon content between 0.1% and 0.2%).

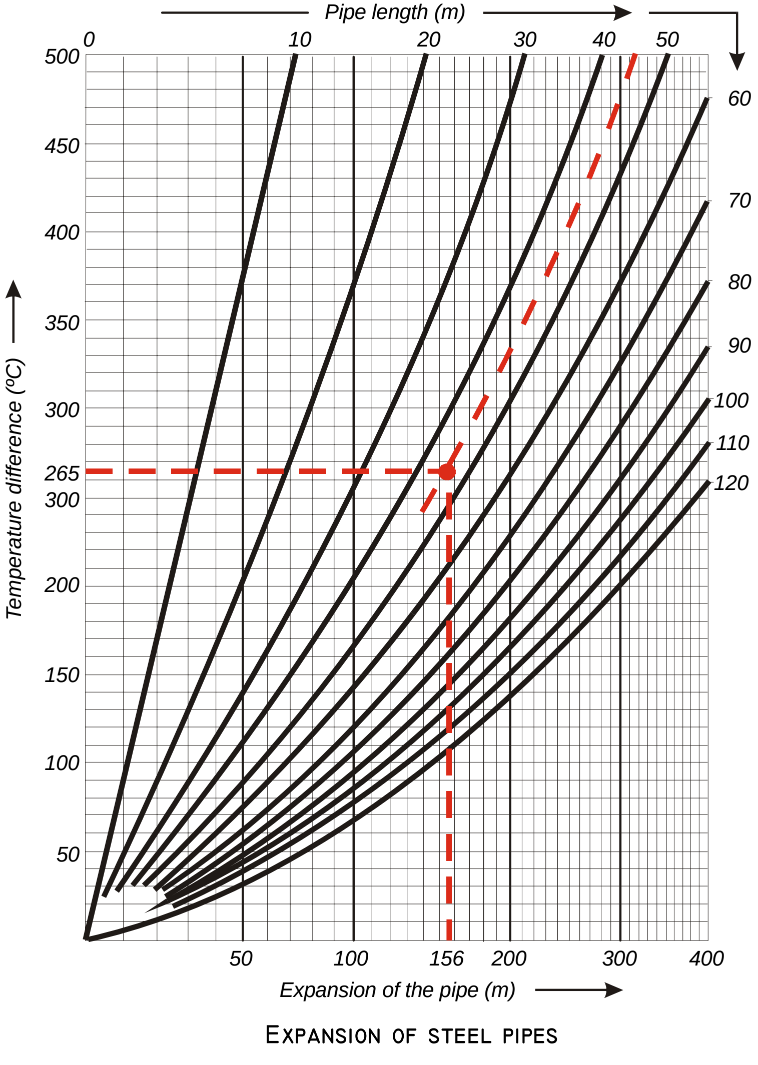


Figure 6.5

This heat expansion, or dilatation, is absorbed by various types of compensators, some of which are pre-manufactured and must be selected using the manufacturer's directions, and others are constructed out of piping elements such as elbows and liras.

In the situation that the pipes change direction, the elbows can be sized in a way that they absorb the dilatation experienced by the pipes in accordance with the following expression, valid for pre-compressed elbows with 50% of the expansion absorbed.

$$L = 0{,}063\ (f * D)^{1/2}$$

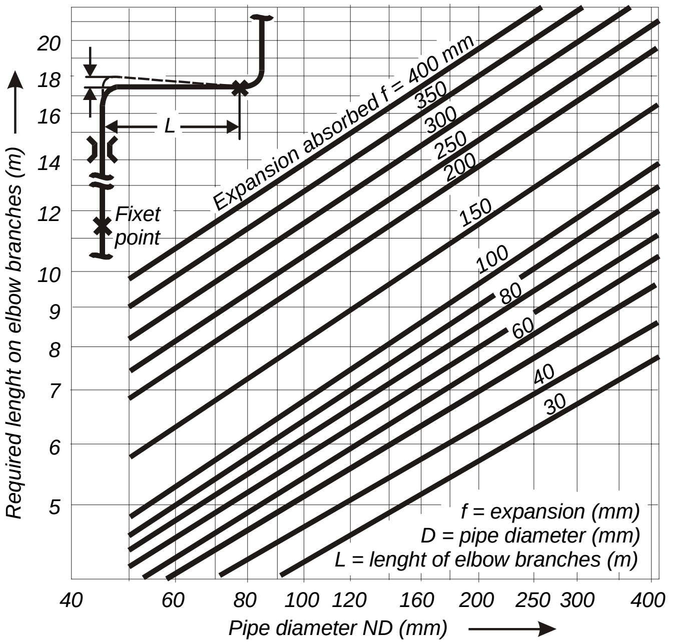
Where:

L = Length of the elbow arms (m)

f = Dilatation absorbed by the elbow (mm)

D = Diameter of the exterior of the pipe (mm)

This expression is represented graphically in Figure 6-6.



EXPANSION ABSORBED BY CARBON STEEL ELBOWS
50% PRECOMPRESSED

Figure 6.6

When the current elbows in the facility's layout cannot absorb the dilatation, it is necessary to employ expansion compensators or liras. For liras, they can be shaped like a "swan's neck" or a "double elbow".

Liras in the form of a "swan's neck" are used more than the "double elbow" because of their ability to absorb expansions with low levels of stress. Despite that the exact calculation must be confirmed with specialized methods, Figure 6.7 represents the absorption capacity of this type of lira (for elevated temperature differences, the values obtained from the graph should be lowered by 20%).

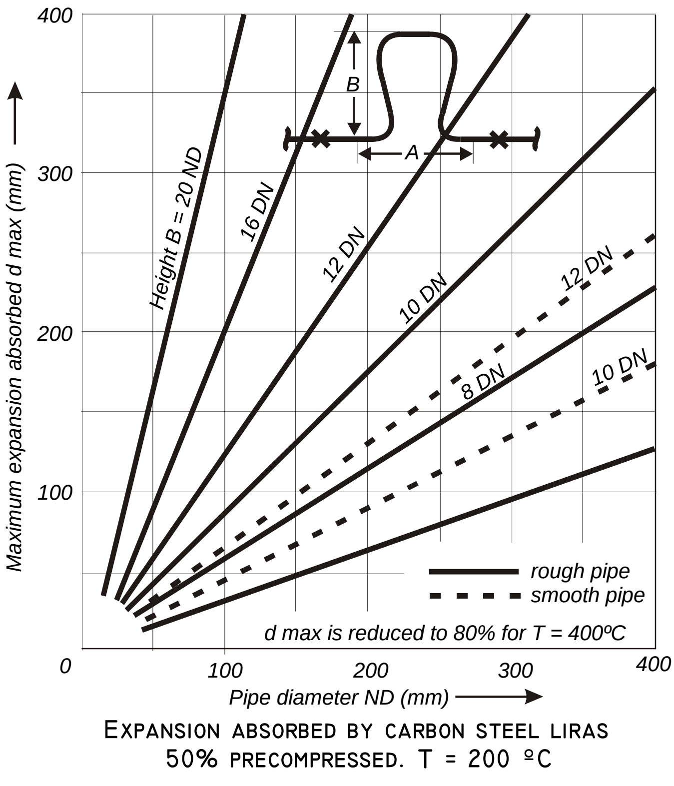


Figure 6.7

Finally, the pipe must be fixed at specific anchor points so that the expansion is produced in the desired direction in such a way that the compensator can function properly. These anchor points are equidistant from the dilatation compensator.

6.8 SLOPES

All of the piping in the facility should have a positive slope in the direction of the flow in order to allow it to be emptied by gravity. This helps prevent possible water pockets caused by the pipe deflection produced between two consecutive piping supports.

The pipes are usually angled with a 2% gradient; any less will allow for the formation of the aforementioned water pockets, which cause corrosion in the pipes. If there is a negative gradient (an upward slope), the condensate may flow backwards due to the force of gravity, opposite that of steam, potentially causing water hammers due to blocking the pipes; this is most common with small diameter pipes, damaged heat insulators, or in low pressure steam facilities.

6.9 SUPPORTS

Its purpose is to rigidly support the pipes, or to allow for them to expand longitudinally or laterally, thus, helping the mission of the elbow and lira dilatation compensators. The large variety of current pipe supports can be separated into three types:

» Normal supports

» Anchors

» Lateral guide supports

Normal Supports:

They are regularly spaced along the pipes and allow for longitudinal movement and sometimes, lateral movement. They are frequently used in the shape of even rollers (cylinders) that allow for lateral movement, arranged over beam supports or suspended by a roof or another fixed structure.

Anchors:

Their purpose is to provide pipe immobilization at fixed points. They are made of flanges that are secured by screws that connected the pipe to an adequate fixed structure. Their calculation must consider resistance in order to support the forces not only from the pipe's weight, but also from the thermal mechanical stress that cause heat expansion in the pipes and any other additional load that may act on them during the facility's service, as well as start-up and shut-down.

Lateral Guide Supports:

As the name indicates, lateral guide supports allow for the pipe to move laterally, but they also leave the pipes free to move longitudinally.

6.10 THERMAL WATER HAMMERS

In general, a water hammer is understood as a sudden and significant pressure increase or pressure wave that usually reaches values of around 150% of the normal operating pressure. This pressure wave displaces at the velocity of sound inside the fluid, which can cause elastic deformations, plastic deformations, and breakage in the facility's elements.

Water hammers are recognized by loud cracks, metallic hits, noises, and vibration in the facility. They must be separated into two different classes of water hammers, although they can sometime occur simultaneously.

» Hydraulic water hammers in liquid facilities

» Thermal water hammers in steam and condensate lines

The first are generally caused as a result of the sudden opening or closing of valves or when the valves themselves operate very quickly.

The second type of water hammers are cause by sudden condensation of steam bubbles inside a mass of condensate with a much lower temperature, thus, producing what can be considered an "implosion". These implosions get stronger the larger the bubbles are or the faster their condensation occurs (larger temperature difference between flash steam and condensate).

It is not easy to calculate the overpressure produced in thermal water hammers, but it is obvious that their intensity depends on the size of the steam bubbles, the velocity of water and steam, and their temperature difference.

Thermal water hammers can occur as a result of inadequate sizing of equipment or piping, poor selection of draining devices or defective steam traps and energy traps, internal steam leaks in the draining devices, improper installation or placement of these elements, or a combination of all of these.

In any case, water hammers must be avoided starting at the design of the facility with respect to a series of regulations, some of which are listed below:

» Limit the use of steam traps to when they are absolutely necessary

» Install energy traps before pipe elevations

» Install energy traps at the lowest point of the facility

» Transport condensate originating from steam of a very different pressure in independent lines; if this is not possible, water hammer compensators should be installed and strategically placed

» Avoid condensate elevations after the draining elements, and when it is inevitable, use water hammer compensators if water hammers occur

» In order to reduce the potential intensity of water hammers, equip the discharge pipe with holes or openings that distribute the steam in small bubbles in situations where the return line arrives to a condensate tank at a lower level than the liquid

Preventing thermal water hammers:

The best way to prevent thermal water hammers is with the use of intelligent energy traps. With them, internal steam leaks can be detected immediately and its energy efficiency can be monitored and adjusted, which effectively prevents the occurrence of water hammers.

CHAPTER 7

DESIGN OF DRAINING STATIONS

7.1 INTRODUCTION

In general, the basic objective of draining stations is to discharge the condensate that has formed in the distributions lines or in the processing equipment without letting any live steam escape.

However, as indicated in Chapter 2, draining stations currently perform other important control operations related to increasing energy efficiency, reducing CO2 emissions into the atmosphere, improving facility reliability, etc.

The following aspects must be taken into account in order to ensure that the drain stations can complete their objective:

» Mounting and placement position (of the drain station)

» Selecting the type of draining element (steam trap or energy trap)

» Sizing the draining element

» Constructing drain stations

7.2 SELECTING DRAINING POINTS

The location of draining points is critical in ensuring that the stations produce the desired results.

In steam distribution lines, the draining points have to be spread throughout the entire facility, with the objective of draining all of the low points and/or where condensate is expected to have accumulated because of an interruption in steam flow (ex. before shut-off valves); It is also necessary to anticipate automatic air venting points located at the highest points or where non-condensable gases are expected to have accumulated in the distribution network and the processing equipment. In terms of tracing lines and steam jacketed piping, the drain points must be distributed throughout the facility. Obviously, process equipment has draining points situated along their lower section.

So, in a non-exhaustive summary, the following indicates the most characteristic places where drain points should be installed (Figure 7-1):

» A thermostatic deaerator should be installed at the highest point of the steam facility (various locations for large facilities)

» Located at distances of 30 to 50 meters from each other along straight steam distribution pipe sections, tracing line sections, or in steam jacketed pipe sections

» Before vertically ascending pipe sections

» Before dilatation liras in piping

» In all of the water pockets or low points of the facility

» In front of automatic valves in steam distributions pipes

» At the end of steam lines

» After each process equipment that uses steam

» Thermostatic deaerators should be installed at the high points of process equipment with large steam chambers (autoclaves, etc)

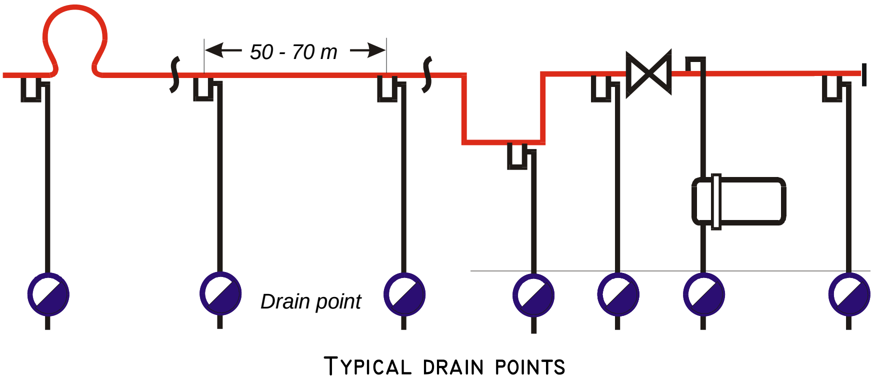


Figure 7.1

7.3 SELECTING THE TYPE OF DRAINING ELEMENT

Selecting the type of drain element is primarily determined by the characteristics of the processing equipment for draining or the application; but other aspects must be considered, such as the characteristics of the facility, work and environment conditions, energy efficiency, reliability and availability, ease of inspection and maintenance, robustness, lifespan, resistance to failures, and finally, its cost.

Therefore, the first decision to make is in selecting the type of drain element; there are two basic options:

» Steam Trap

» Energy Trap

It is usually recommended to use steam traps when it is necessary to ensure that there is absolutely no condensate in front of the trap, without considering the facility's energy efficiency. In this situation, the effects of the rise in flash steam in the discharge of the trap should be assessed in order to prevent any consequences (backpressure, thermal water hammers). Thermodynamic disk traps are used to evacuate small and medium steam flows, while inverted bucket traps and float traps are used for large steam flows.

It is recommended to use energy traps when it is necessary to increase the energy efficiency of a facility by reducing steam consumptions, and with it, CO_2 emissions as well as improving the operation of condensate return lines, avoiding backpressure and thermal water hammers. The evolution of thermostatic energy traps always provides a satisfactory solution for each application; to evacuate small and medium steam flows, bimetallic and bi-thermostatic energy traps are used, while multi-element thermostatic energy traps are used for large steam flows. For tracing applications, the most appropriate type is the bimetallic thermostatic energy trap, preferably the bi-thermostatic energy trap due to its external regulation mechanismthat allow for the most benefits.

When choosing the drain element, an aspect that should be considered is the method to be employed for future inspection and maintenance. The rising use of intelligent energy traps simplifies the inspection tasks and reduces energy and maintenance costs. However, even when the use of intelligent steam traps is not anticipated, it is advisable to design a drain stations in a way that allows for an easy incorporation of additional elements for future monitoring (SwartWatch connection, pressure and backpressure sensor connections), and in this way the costs would be reduced when the conventional stations are updated to intelligent draining stations.

Just as the energy trap is implicitly related to its automatic air-venting capacity, when steam traps are used, thermostatic air-venting elements should be included in order to prevent possible blockage caused by air or non-condensable gases. It is recommended to avoid using internal by-bass orifices as automatic air vents, since they create a continuous steam loss that is injected into the return lines, causing problems.

Sizing the Drain Element:

Once the type of draining element has been decided, it needs to be sized; in order to do this, the following aspects must be taken into account:

» Maximum pressure and temperature of the design

» Maximum operational differential pressure

» Minimum operational differential pressure

» Maximum steam flow to be evacuated in low differential pressure conditions

» Optimal condensate evacuation temperature

» Safety factor

» Type of connection

The design's maximum pressure and temperature determine the materials of the draining element in accordance with the manufacturer's instructions.

The draining element must be able to function properly up to the maximum operational differential pressure. Note that energy traps may lose steam when the differential pressure exceeds the maximum amount indicated by the manufacturer; on the contrary, float traps and inverted bucket traps remain blocked when the differential pressure exceeds the amount indicated by the manufacturer.

The size of the draining element is imposed by the maximum steam flow to evacuate, including safety factors and in situations of minimum differential pressure. It is not advisable to utilize exaggerated safety coefficients since over-sizing is harmful to the element's regulatory operation and it reduces its lifespan. It is worth pointing out that steam traps require greater safety factors than energy traps, since the latter have an intrinsic safety coefficient that superimposes the one measured by the user. Typical values for this coefficient are from 2.5 to 3 for steam traps and 1.5 to 2 for energy traps.

When considering the discharge capacity of a draining element, the steam flow curves provided by the manufacturer have to be used. There is no uniformity in the way of presenting these curves, and therefore, while some offer cold condensate flow information, others refer to condensate flow at the condensate's boiling temperature; figure 7-2 represents the form of a typical condensate flow graph.

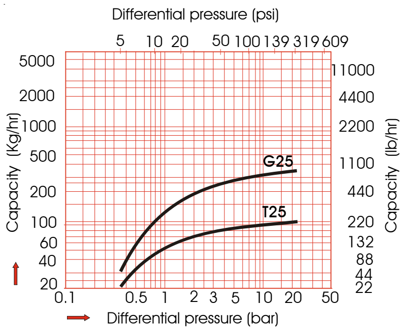


Figure 7.2

In the absence of other information, it must be assumed that the maximum evacuation capacity at the saturation temperature is usually approximately 70% of the draining element´s maximum cold discharge capacity. The standard is very different in energy traps since its intrinsic safety coefficient is higher and the maximum cold evacuation steam flow is usually between 3 and 4 times more than the amount that corresponds to the saturation temperature; because of this, the safety factor must be reduced when sizing energy traps.

The average temperature of the condensate produced in a heat exchanger is between 10 and 20 degrees lower than the saturation of steam (this is precisely the situation where it is possible to successfully use energy traps in process equipment and reduce steam consumption). Therefore, it is advisable to try to adapt the energy trap's characteristics to those of the process in order for both to work under the best conditions possible.

As shown, for small steam flows, drip legs, and tracing lines it is recommended to exclusively use thermostatic energy traps, bimetallic bi-thermostatic energy traps in particular, due to their robustness, evacuation temperature regulation, operation and design characteristics that are not only adaptable to each application but also to each draining point. It is suggested to discharge condensate between 10 ºC and 40 ºC below the steam's saturation point for drip legs and tracing lines. On regular tracing lines, it is highly recommended to adjust the condensate discharge temperature 40 ° C below the steam saturation temperature.

The bimetallic bi-thermostatic energy trap offers an interesting characteristic by providing an energy trap that appears to have been specially manufactured for each individual draining point (external adjustment mechanism), even though it is mass produced.

The internal elements of a draining element, the cone valve and seat, are subject to very severe work conditions that cause considerable wear and tear. Therefore, it is important to guarantee that the internal pieces are of the highest quality, requiring special steel that is highly durable and resistant to wear and tear, preferably, with its surface coated with special materials such as titanium nitride, tungsten carbide, or similar materials. This considerably lengthens its operational lifespan.

Take into account that a draining element with a robust design that uses special materials in the components will mean a higher purchasing price, but this is thoroughly compensated by its high reliability, long life, and energy savings.

The draining element's possibility of including an external adjustment mechanism raises the final price, but the enormous advantages in energy savings, easy maintenance, versatility, etc, offered by this mechanism undoubtedly put to rest any economic comparisons with elements that lack the mechanism.

Occasionally the draining element must withstand temperatures below zero. This is the case for facilities with intermittent operations, which can leave them filled with condensate when the outside temperature is below zero degrees. In these situations, the draining element is required to be durable enough to support freezes, setting aside those that are constructed from iron casts or that have sensitive internal elements. Additional, in this situation the drain element design must favor auto-draining the facility into the atmosphere; this will keep a facility safe against freezes.

In situations where thermal water hammers are expected to form from discharging condensates of different pressures to a shared condensate return line, sensitive elements of the energy traps should be discarded, such as floats and capsules or liquid expansion bellows. Here, the most adequate are the bimetallic followed by the inverted bucket elements.

It is preferable to use float traps or inverted bucket traps when the condensate is very dirty or oily. In the situation that another type of element is used, it is convenient to have a filter (a "Y" filter if possible) with a drain valve to help clear any potential obstruction of the element.

Ideally, the draining element has a good air-venting capacity during start-up and regular operation. The most common automatic air-venting mechanism is the thermostat, which should be bimetallic due to its robustness against liquid expansion.

Some float traps have permanent venting holes with the purpose of creating automatic air venting. These types of vents must only be used in applications that require it in order to avoid the formation of a "steam jam", like draining rotating cylinder dryers with a siphon. In all other situations, this type of vent is a source of unnecessary energy loss.

Lastly, choosing the type of connection has an impact on future steam leaks in the facility. There is no doubt that the most dependable connection against leaks is welding, although the flanged connection offers high reliability and easier maintenance. In tracing facilities with a large number of draining stations, it is normal to use the threaded, the cheapest but with frequent leaks throughout pipe accessories such as connecting nuts. Angular and non-standardized connections should be avoided as they implicate a dependency on a manufacturer.

Although it is risky to provide recommendations regarding the type of draining element for each application, the following shows certain guidelines that help facilitate the selection, limiting the wide variety of possibilities, in descending order of priority:

Application: Tracing, radiators, and jacketed pipes

» Bi-thermostatic with external temperature adjustment

» Bimetallic

» Thermostatic

» Other type

Application: Drip legs and line ends

» Bi-thermostatic with external temperature adjustment

» Bimetallic

» Thermostatic

» Float

» Inverted Bucket

» Other type

Application: Steam blowers and turbine protectors

» Bi-thermostatic with external temperature adjustment

» Inverted bucket when the superheated steam level allows

» Thermodynamic

» Impulse

» Other type

Application: Tanks, water heaters, heat exchangers

» Bi-thermostatic with external temperature adjustment, when steam flow allows

» Thermostatic, when the steam flow allows, and/or multi-element

» Float

» Inverted Bucket

» Other type

Application: Autoclaves and sterilizers

» Float

» Inverted Bucket

» Thermostatic, when the steam flow allows

» Thermodynamic

» Other type

Application: Air heaters

» Bi-thermostatic with external temperature adjustment

» Bimetallic

» Thermostatic

» Float

» Other type

Application: rotating cylinder dryers

» Special energy traps and automatic wastepipe valves

» Float

» Inverted Bucket

» Other type

Application: Vulcanizers and flat presses

» Inverted Bucket

» Float

» Thermodynamic

» Bi-thermostatic with external temperature adjustment, when steam flow allows

» Thermostatic

» Other type

Application: Air heaters and hot air dryers

» Bimetallic

» Thermostatic

» Float

» Inverted bucket

» Other type

Application: Evaporators and beer distilleries

» Float

» Inverted bucket

» Bimetallic

» Thermostatic

» Other type

Application: Steam irons and laundry grills

» Bi-thermostatic with external temperature adjustment, when steam flow allows

» Float

» Inverted bucket

» Thermodynamic

» Other type

Other than a few exceptions, note that thermodynamic traps rarely appear in the previous recommendations due to the fact they have very low energy efficiency as a consequence of its principle of operation.

Recall that the size of the draining element is not determined by the diameter of the connection, but rather the diameter of the internal orifice of the valve, which is sized for the maximum steam flow to evacuate and the minimum possible differential pressure.

In the petrochemical industry, the two most expansive applications are tracing or heavy material heating and drip legs in steam distribution lines. In both cases, the operation steam flows in a continuous regimen are almost always less than 50 Kg/h (generally they do not exceed 10 Kg/h). So, in situations of the reduced flow as mentioned, any small steam leak results in an extremely high percentage of energy loss; therefore, it is essential to use draining elements that thoroughly guarantee that the steam is hermetically sealed and that the condensate discharge is carried out by controlling its temperature, which leads to the necessity to use bi-thermostatic energy traps in both applications.

In order to facilitate the selection of BiTherm energy traps, use the computer tool "Energy Trap Selection Software", available in the following link:

http://www.smartwatchweb.com

7.4 CONSTRUCTION OF DRAINING STATIONS

The construction of a draining station differs according to its application; the following are the most common:

Automatic Air Venting Points:

Air venting points are located at the highest points of the facility, close to steam generators when possible. They are constructed by implanting a 1 to 2 meter long pipe section, 3/4" to 1" in diameter, at an ascending angle, with a thermostatic energy trap or air vent at the end. At the outlet of the energy trap, a piece of pipe in the shape of a swan's neck is connected in order to prevent dripping on the energy trap itself. The air-venting pipe and the energy trap itself must remain without thermal insulation in order to assist their air-venting function.

Drip Legs in Steam Distribution Lines:

Drip legs are designed in such a way that gravity causes the condensate to enter in order to be removed by the draining element (Figure 7-3).

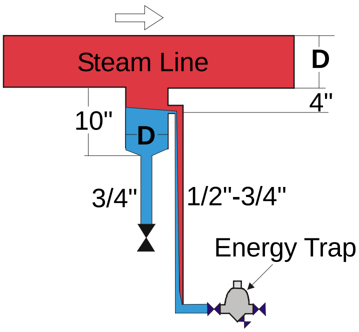


Figure 7.3

As a general rule, the depth of a drip leg usually spans between 250 mm and 700 mm (the depth increases as the differential pressure drops) and its section, up to 4", typically coincides with the diameter of the pipe itself. Beyond 4", the drip leg diameter is slightly reduced. The largest section of the drip leg must never exceed 10", no matter the situation.

At the bottom of the drip leg, a descending vertical connection is implanted with a draining and cleaning valve; this valve is 3/4" in drip legs up to 2", 1" in drip legs that measure 2.1/2" or 3", 1.1/2" for diameters larger than 3" but less than 10", and 2" for drip legs with diameters 10" and above.

At 3/4 of the height of the drip leg from its base, a horizontal draining pipe is implanted and measures 1/2" or 3/4" according to the user's standard.

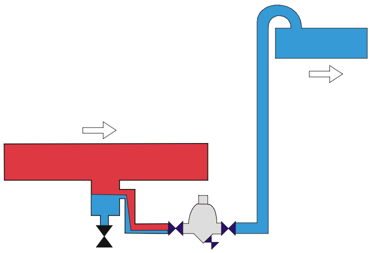
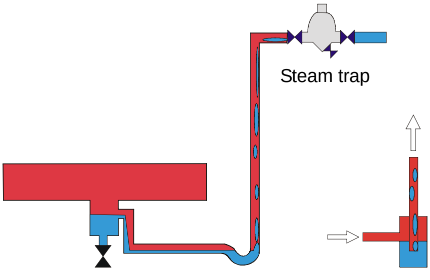

Wrong elevation of condensate after a trap

Figure 7.4



Correct elevation of condensate after a trap

Figure 7.5

When condensate has to be elevated after the draining element, up to the return line, it is advisable to do so in accordance with the diagram in Figure 7-4.

If condensate is elevated before the draining element, a small siphon should be placed before the elevation in order to prevent water hammers (Figure 7-5).

In addition to the draining element, draining stations must contain elements that make the maintenance process easier (filters, isolation valves, and when necessary, bypass valves), but the current tendency is to use compact draining stations known as TVS (Trap Valve Stations) which, in addition to the draining element, incorporate all of the previously mentioned valves as shown in Figure 7-6.


Figure 7.6

Tracing Lines:

Any section of a tracing line must not exceed 100 meters in length. Steam distribution stations and energy traps alike must be grouped in manifolds in order to make their maintenance easier (Figure 7-7).

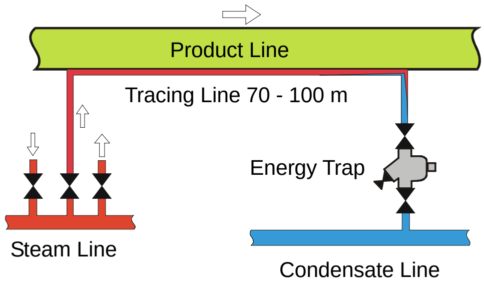


Figure 7.7

Jacketed Lines:

Jacketed lines are commonly used for transporting substances that require high temperatures in order to remain in the liquid state with an adequate viscosity. In this case, tracing is very critical and condensate temperatures have to be kept monitored.

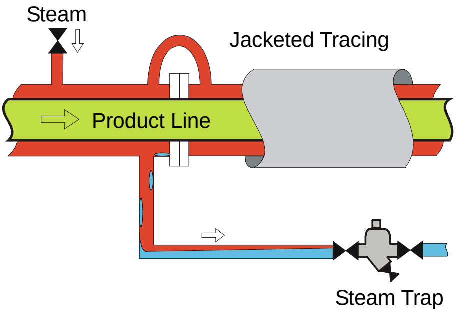
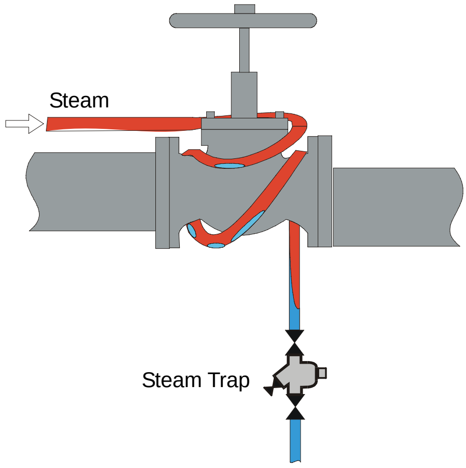


Figure 7.8

Valve and Instrumentation Tracing:

This method applies the same goals mentioned in the previous paragraph; however, in this case it is carried out by wrapping a copper pipe around the valves or instruments to be heated (Figure 7-9).



Valve and Instrument Tracing

Figure 7.9

Process Equipment Draining:

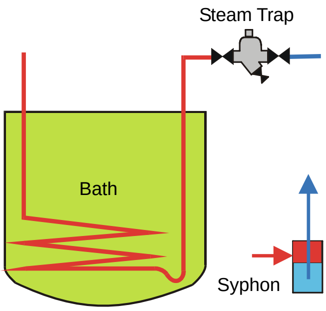


Figure 7.10

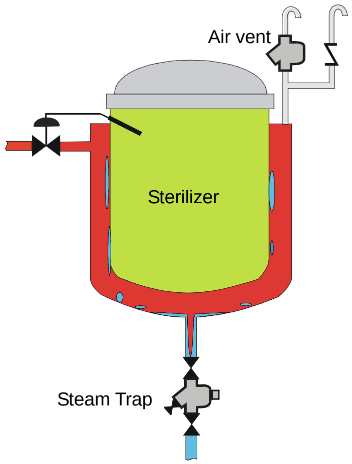


Figure 7.11

When draining process equipment, the drip leg must have a vertical descending distance between the equipment and the energy trap of between 300 and 700 mm, selecting the drain pipe diameter and the diameter of the energy trap itself in accordance with the capacity of condensate to be evacuated, differential pressure, design safety factor, and any other condition imposed by the design.

In situations where there are special conditions like bottom coils with condensate elevations before the energy trap (Figure 7-10), bottom siphons need to be used in order to prevent water hammers.

In process equipment with large spaces for steam and/or frequent starts and stops, it is necessary to prevent automatic air venting at the equipment's high points in order to avoid the presence of non-condensable gases that would reduce the stea-m's partial pressure (Dalton's Law), along with its saturation temperature, affecting the thermal efficiency of the heating process. A thermostatic energy trap can be used as an automatic air vent. Note that in these situations it is not sufficient to have an energy trap with automatic air venting capabilities located at the bottom, since the air and non-condensable gases in the upper area of the equipment would never reach the bottom energy trap, making it necessary to install an air vent at the top. The air vent must be installed at end of the vertical ascending pipe at least 1 meter in length, coming to an end in the shape of a swan´s neck behind the energy trap, without any thermal insulation.

If the condensate flow to be evacuated in the equipment is unknown, follow the rule of selecting the energy trap diameter that is one step lower than the diameter of the equipment's outlet pipe. For example, a 2" energy trap is used if the equipment outlet is 2 1/2".

Finally, the collective draining of process equipment through a single draining element must be avoided (Figure 7-12) given that if it malfunctions, it simultaneously affects all of the process equipment, and also, in certain conditions could cause a backflow of condensate and non-condensable gases towards any one of these pieces of equipment, which would result in a loss of efficiency, thermal water hammers, and unexpected corrosion.

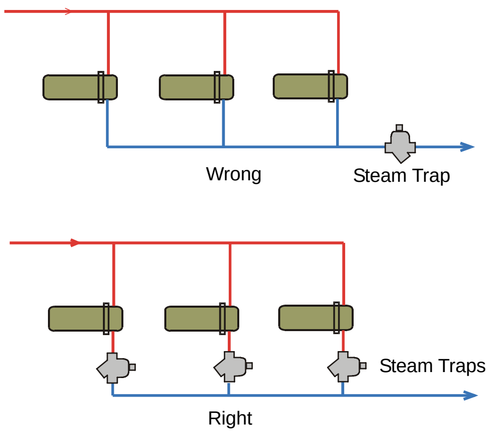


Figure 7.12

7.5 MOUNTING OF DRAINING ELEMENTS

The mounting position of a draining element is determined by its principle of operation; in general, follow the rules below:

» Thermodynamic, labyrinth, or impulse steam traps must be installed horizontally with the disk or upper cap at its highest position. If they are installed in another position, they lose more energy and deteriorate quicker.

» Float or inverted bucket steam traps can only be installed in whichever position that allows the flotation mechanism to move vertically with no restrictions. If they are installed in another position, the trap is no longer operational.

» Thermostatic energy traps can be mounted in any position as they are exclusively controlled by the temperature of the condensate, and the mobile parts of the valve are guided along their entire path.

Draining stations are usually mounted in groups in a compact design, but it is worth considering easy access and handling at each draining element in order to be able to easily carry out future inspection and maintenance operations.

In some applications it may be useful to install a sightglass upstream of the draining element in order to be able to observe its operation; but, it must be taken into account that the sightglass is an element that requires maintenance to clean the dirt from its window. However, the same effect may be achieved through the use of monitoring the drain element just as described in section 8.3.

Due to the evolution of the draining station inspection systems, the use of ultrasound makes it unnecessary to install test valves on the draining stations themselves.

In the same way, the problems generated by improper maneuvering of by-pass valves (pressurization in return lines), together with the advances in the energy trap design with external adjustment mechanisms, are contributing to eliminations of by-pass valve, except in process equipment drains or highly critical drains where they must be conserved for reasons of reliability.

Check valves, when necessary, must be of the highest quality and the lowest pressure drop, especially in low differential pressure systems in order to not cause any serious problems that keep the energy trap from operating, a very common situation in petrochemical facilities.

In areas where the meteorological conditions are not favorable, it is expected that wind, rain, or freezes will have an effect on the draining stations' operation and energy losses. Thus, when using thermodynamic steam traps, which are very sensitive to adverse environmental conditions, or mechanical steam traps (float or inverted bucket), which are large and have internal steam chambers, they must be protected with adequate metal caps in order to keep the rain from falling directly on them, since their operation would be seriously affected resulting in excessive increases in energy loss and backpressure in the entire facility.

Remember that draining elements must not be thermally insulated since this could invalidate its automatic venting capacity and reduce its evacuation capacity. However, the rest of the pipes and valves that compose the draining station must be thermally insulated.

Preventing freezes is extremely important for maintaining the facility, especially when its operation is intermittent. If this is not anticipated, it may result in serious damages. For this, plan on locating generously oversized drains in various low points of the facility, as well as to avoid the elevation of condensates in all of the draining stations, designing their own structure with atmospheric draining valves that remain open during the periods when there is risk of freezes in all of the draining stations that are susceptible to being affected, thus, draining the condensates into the atmosphere. After the freeze risk period is over, the valves will be closed in order to recover the residual energy of the condensates.

An alternative system for preventing freezes, more costly but undoubtedly more worthwhile, is to substitute the manual draining valves for thermostatic valves, preset at a temperature of 60 to 70 degrees; they remain closed during normal operation and they automatically open when there is a risk of a freeze so that the draining station can be emptied and avoid damages. For this purpose, thermostatic energy traps with an external temperature adjustment mechanism are very useful in that they make this task much easier.

When there is a risk of a freeze, horizontal pipe sections must be avoided before and after the energy trap by using slopes. All of the pipes that drain into the atmosphere must be as short as possible.

During the draining of equipment with automatic steam supply control, a vacuum can even be formed when the steam retained inside the equipment condenses while the control valve is closed. In such situations, it is necessary to anticipate the use of a vacuum breaker valve with a connection to the outside air on the draining side of the process equipment.

Always when possible, draining element discharge must be sent to the main condensate return tank; when the condensate is elevated at the outlet of the draining element, 1 bar of backpressure for approximately every 7 meters of elevation must be taken into account (theoretically it would be 1 bar for every 10 meters of elevation, but in practice the previously mentioned amount is used in order to factor in the presence of a certain amount of flash steam that coexists with the condensate as well as the increased local backpressure that is produced). To avoid backflow, use high quality check valves that have small pressure drops.

In process equipment with automatic steam supply control when there is expected to be a differential pressure that is too low to evacuate condensates because of its excessive elevation, it is necessary to install a safety draining system, made up of a secondary energy trap mounted in parallel with the first, discharging into the atmosphere or an atmospheric tank to recover the condensate.

CHAPTER 8

INSPECTION OF DRAINING STATIONS

8.1 INTRODUCTION

The inspection of draining stations is meant to detect any type of anomaly whether it is operational, related to efficiency, or of any other nature. Among the most frequently detected issues during the inspection process are: internal or external steam leaks, inadequate design or sizing, defective mounting, inadequate discharge temperatures, obstructions, blockages, thermal water hammers, and excessive backpressure.

Statistically, more than 80% of the incidents detected are related to steam leaks and energy efficiency, while the rest are operational. Frequently, more than 20% of draining stations have steam leaks or low energy efficiency, which is inconsistent with rational energy use and sustainable development.

Establishing an effective inspection and intensive, preventive, and corrective maintenance system considerably reduces all of the previously mentioned incidents and is especially useful in reducing steam leaks, optimizing energy efficiency, and reducing greenhouse gas emissions in steam networks.

The following table shows the approximate amount of incidents in draining stations in relation to the frequency of inspection and maintenance:

Frequency of inspection and preventive maintenance of draining stations	Typical failure rate
24 months	30 %
18 months	25 %
12 months	15 %
6 months	7 %
3 months	5 %
1 month	3 %
1 day (continuous monitoring)	< 0,2 %

Logically, the percentage of incidents decreases as the frequency of inspection increases.

The choice of draining element also has a great influence on the facility's energy efficiency, but looking at the previous table, this undeniable objective can only be guaranteed through the implementation of continuous monitoring and an intensive maintenance program (see chapter 9).

8.2 MOST COMMON INCIDENCES AND SOLUTIONS

The following are the most common incidents and solutions in draining stations:

Draining element is cold or does not drain:

» Verify that there is steam in the line

» Confirm that the filter is in good condition, inside or upstream of the draining station, as well as possible obstructions in the line caused by a broken element in the isolation valves, etc.

» Confirm that value of the real differential pressure as well as the steam trap or energy trap's adequacy to work under such pressure (sometimes a larger orifice is used to replace the internal valve of a float trap in order to increase its discharge capacity; this can have completely negative outcomes since the float will remain permanently blocked if the admissible differential pressure limit for this orifice is exceeded).

» Verify the movement of the mechanism that drives the valve of the energy trap. In float traps or inverted bucket traps, verify that there are no cracks or holes that would reduce its buoyancy.

» Check if the automatic thermostatic air-venting device is obstructed or deteriorated, as this could produce blockage caused by non-condensable gases.

Draining element has an insufficient discharge capacity

» Verify the size of the draining element.

» Confirm that the internal automatic air-venting device is functioning correctly.

» In thermostatic energy traps, modify its adjustment (if it has an adjustment mechanism).

» In steam traps with intermittent discharge, check that the discharges are cyclical, and if not, the steam trap is inadequate.

Draining element with an internal leak

» Verify the differential pressure and check that it is adequate for the draining element being used.

» Check the wear and tear of the internal parts or for an object that could be blocking it.

» Confirm that there are no leaks in the gasket between the body and valve seat.

» In inverted bucket traps check for hydraulic seal and replace it in case missed by closing its output valve for several minutes and cooling the trap's body.

» In liquid expansion thermostatic energy traps, check for some stiffness of the thermostat (bellows or capsule); if there is none, it could be due to the loss of internal liquid from a perforation in the thermostat.

Draining element with an unjustified leak:

» Confirm if the real differential pressure is within the limits of the draining element being used. If it is required, change the type of draining element or reduce backpressure.

» In steam traps with automatic air venting, verify the integrity of the thermostat or the venting element.

» In bimetallic energy traps, verify that the thermostat plates are in the correct order; they must be grouped in pairs and the side facing outwards on both plates must be the metal with a higher heat dilatation coefficient. To make this process easier, the manufacturer generally labels the side with the higher dilatation coefficient.

» In BiTherm bi-thermostatic energy traps, the lower thermostat, made up of a single extended bimetallic plate, must have its labeled side facing towards the valve seat.

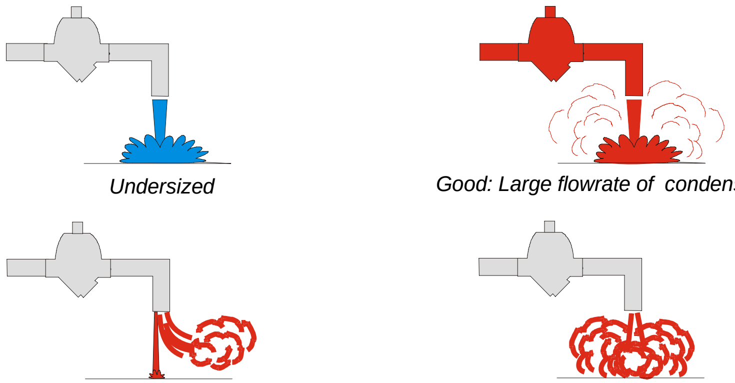
8.3 METHODS FOR THE INSPECTION OF DRAINING STATIONS

The verification of draining stations should not only confirm the status of all of the elements (draining elements, isolation valves, bypass valves, …) but also its adequacy and sizing for each application, as well as its energy efficiency.

This verification usually requires a certain level of experience and the combination of different inspection methods, as described below:

Direct visual inspection:

Observing the atmospheric discharge of a draining element (Figure 8-1) requires a certain level of experience to be able to distinguish between live steam and flash steam.



MORE FREQUENT FAILURES IN DRAINING ELEMENTS

Figure 8.1

The presence of flash steam in a draining element's discharge is natural and it does not mean that there is a live steam leak. However, the formation of flash steam is significantly reduced in tracing applications since it takes advantage of using part of the condensate's sensible heat in order to increase energy efficiency-a currently undeniable objective.

Generally, when a completely transparent stream of steam can be observed at the drain's exit, it is without a doubt live steam, but if it is accompanied by drops of water and it is slightly opaque, it could be flash steam formed from a properly functioning energy trap. In-between cases are difficult to specify and experience is necessary to make a proper diagnosis.

Visual inspection must take the following circumstances into consideration:

» When the energy traps discharges into a return line instead of the atmosphere, a test valve is required in order to carry out the visual inspection.

» In steam traps, the test valve should always be installed just after the trap.

» In energy traps, the draining valve can be before or after. When the test valve is placed before the energy trap, it provides the advantage of verifying if live steam or condensate is reaching the element. Therefore, a few drops of water should escape immediately followed by steam if the energy trap is working properly; on the contrary, if dry steam is all that escapes, it is a sign that the energy trap is leaking live steam, since there cannot be flash steam before it. Note that if the test valve is mounted after the energy trap, it is natural for it to release flash steam, even though it is functioning properly, which makes it difficult to make the correct diagnosis.

» In the case of steam traps that intermittently discharge (thermodynamic and inverted bucket traps), a test valve after the trap can verify if the operation is intermittent; in any other case, the trap is leaking steam.

» In the case of steam traps that continuously discharge (float), the valve after the trap always discharges flash steam, sometimes mixed with live steam; this is why visual diagnosis can be inaccurate.

It must be taken into account that the visual inspection method is not highly recommended since the draining element's real working conditions are changed when the test valve is opened, eliminating backpressure.

It is common and widely known that draining elements that work correctly when they discharge into the atmosphere are partially blocked or leak steam when they are reconnected to the condensate return line.

Visual inspection with a sightglass

Inspections of draining station using sightglasses substitutes the test valve of the visual inspection for a glass viewer located in the pipe before or after the steam trap or energy trap.

There are three types of sightglasses:

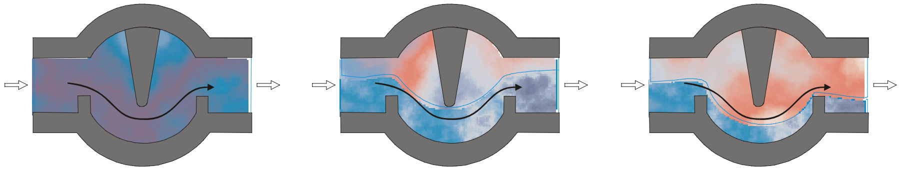
» Simple

» Syphonic

» Electronic

The simple sightglass is generally installed after the draining element and only allows for the verification of discharge but it is usually not possible to differentiate between live steam or flash steam.

The syphonic sightglass (Figure 8-2) is a simple sightglass that incorporates an internal siphon. It is installed before the draining element, and therefore, it is possible to identify the phase transition of the fluid (condensate or live steam) since there will never be flash steam before the draining element.



IMAGES ON A SHYPHON SIGHTGLASS INSTALLED BEFORE A DRAINING ELEMENT

Figure 8.2

In the siphonic sightglass, three different situations can be seen (Figure 8-2):

- Sightglass is entirely inundated: the draining element is flooded with condensate due to a lack of discharge capacity, obstruction, or blockage.
- The liquid level seen in the viewer of the sightglass reaches the highest point of the central separator of the two sides of the siphon: the draining element is working properly, without loss of steam.
- The liquid level seen in the viewer of the sightglass does not reach the highest point of the siphon separator: the draining element leaks steam, which increases as the distance between both levels increases.

The usefulness of sightglasses is limited to low pressure applications and has the disadvantage of getting dirty quickly, losing its transparency due to the progressive build up of oxide particles on its glass, invalidating its usefulness and increasing maintenance costs.

A more sophisticated type of sightglass is electronic, which consists of a small recipient with an internal electrode. In the presence of condensate, the electrode closes the electrical circuit by conductivity, and it opens it when there is a steam leak. The signal is isolated by exterior measuring equipment that is connectable to the recipient; however, its is almost never used due to its high costs and low reliability, since the electrode short-circuits when it is recoated with a layer of iron oxide (magnetite) which invalidates its diagnostic purpose.

Inspection using time measurement

This method is only applicable in steam traps that operate in cycles, as these are the basis for obtaining a time measurement between two consecutive discharges of the trap. A chronometer is not necessary; it is sufficient to count 101, 102, 103, … in order to achieve a sufficiently valid duration of the trap cycles in seconds.

If there are no cycles, these three situations may occur:

» The trap is cold, out of service, or blocked.

» The trap is inundated with condensate and it discharges condensate at a low temperature, either as a result of under sizing or excessive backpressure.

» The trap leaks steam and has a very elevated temperature.

If the trap opens cyclically, verify that the duration of these cycles are not excessively short. In thermodynamic disk traps, the duration of the cycles must not be less than 30 seconds; if not, the shorter the cycle is, the more deteriorated the internal valve will be and the larger the energy loss will be.

Inspection using temperature

Inspecting draining elements exclusively using temperature measurements usually produces errors, since it can only be applied correctly with additional information that is not typically available to the person performing the inspection. For this method of diagnosis to be reliable, the following facts must be understood:

» The type and operation of the draining element (continuous or intermittent discharge, super-cooled or saturation temperature discharge), which determines the discharge temperature adjustment limitations.

» The type of service (turbine protection, drip leg, process equipment, normal tracing, critical tracing, tank heating, …) determines the optimal discharge temperature of the draining element for each application.

» Inlet pressure of the draining element: This value may vary due to the action of regulator valves at entrances to equipment or because of variations in consumption. For example, in low-pressure steam networks, this value can fluctuate between 2.5 bar and 4 bar, altering the steam's saturation temperature.

» Outlet pressure of the draining element: this is usually unknown since it is not enough to know the pressure in the steam line, but rather the amount of pressure right at the energy trap's outlet, where there may be large variations due to the formation of local flash steam. Its value modifies the energy trap's discharge temperature.

The variations of outlet pressure can depend on multiple causes that are difficult to identify (internal leaks, insufficient sizing of local return line, elevated discharge temperature forming excessive flash steam, partial obstruction of the return line or stop valve, manual draining of water, inadequate regulation of the energy trap for its service, type of draining element itself and the nearest draining elements, …).

When there is doubt about the existence of leaks, various temperature measurements must be taken: before, on, and after the draining element. If the draining station is operating correctly, the backpressure is less than the pressure of steam, and therefore, the outlet temperature is lower. If the temperature of the inlet is correct and there is not thermal jump because the inlet and outlet of the draining stations, there must be internal steam leaks.

In summary, diagnosis through the exclusive use of temperature measurement can be erroneous if all of the previously mentioned variables are not taken into account.

Inspection using ultrasound

This method is quick and very reliable for detecting internal steam leaks in draining stations. It consists of capturing the ultrasound generated by the passing of steam or gas through an orifice.

In effect, gas or steam that flows at a high velocity through a narrowing generates noise along a wide range of frequencies, highlighting the harmonic that corresponds to a narrow frequency range around 39 KHz (+/- 2 KHz).

In order to apply this method, it is recommendable to understand how the draining element operates, its discharge type (continuous or cyclical), and how to choose the sensitivity of the instrument that corresponds to the pressure of the steam of the draining element; next, firmly apply the contact probe on the draining element in order to read the diagnosis on the LCD screen.

Figure 8-3 shows the BiTherm LeakTector LT3-EX ultrasound detector, with a contact probe, an optional directional probe for detecting compressed gas leaks, a discontinuous sensitivity selector, and a rechargeable battery. This equipment has the intrinsic safety certificate according to ATEX II 1G, "Ex ia IIC T4 Ga", for use in potentially explosive environments, and its elevated sensitivity makes it capable of diagnosing very small steam leaks.

The reliability of this method depends on the quality of the ultrasound detector, the adjustment mode of its measurement scales, and the user's experience level. To avoid diagnosis errors and to make use easier, avoid using continual scale selectors as the sensitivity adjustment depends on the expertise of the operator and the results are not always reliable.

Note that the ultrasound method losses reliability when the local backpressure is very high after the draining element and the differential pressure is reduced to a

Figure 8.3

low value; in this situation, the steam's velocity can be so low that it does not generate an ultrasound, invalidating this method of detection.

When in doubt, such as in draining elements with large steam flows where there is a large amount of flash steam produced which can create its own ultrasound that can be misinterpreted as a live steam leak, two readings must be taken: one over the draining element itself, and another 1 to 2 meters downstream. When comparing both measurements, if the ultrasound level detected is similar at all of the points, there is most likely a steam leak; on the contrary, if the ultrasound weakens downstream, it is produced by flash steam and not by the passing of live steam, which can be interpreted as an acceptable condition.

In energy traps with small steam flows, temperature measurements are generally dismissed since ultrasound detection is sufficiently reliable.

Inspection using the SmartWatchWeb™ remote monitoring system:

The *SmartWatchWeb™* monitoring system, an essential part of modern intelligent energy traps and valves (Chapter 5.3), combines the measurement of up to four parameters (ultrasound, temperature, pressure, and backpressure) in order to remotely analyze the operation and energy efficiency of the draining stations in real time.

Therefore, it is not a simple inspection method but rather a technology that provides the analysis and diagnostic tools necessary to implement the ***"Intensive Maintenance"*** methodology in steam networks (Chapter 9).

The measurements are automatically taken at regularly programmed intervals (usually every 5 seconds), saving all of the information gathered in a local or remote server, accessible to any authorized user.

The upper part of figure 8-4, shows a screen of the system's graphic interface; in it, the draining elements are grouped in loops. Each loop consists of 4 small colored icons, all of which correspond to a monitored parameter (row 1-ultrasound, row 2-temperature, row 3-pressure, and row 4-backpressure). The color of each icon easily identifies the status of the corresponding parameter.

Note that there is only a small number of icons that fall into rows 3 and 4 of the loops; this is because a lesser number of pressure and backpressure sensors is enough to obtain a pressure map of the steam/condensate network.

The measurements taken are kept in a history record, allowing for the analysis of the evolution of any incident in monitored draining elements as well as the verification of its correct interpretation; this way, the diagnosis obtained is highly reliable.

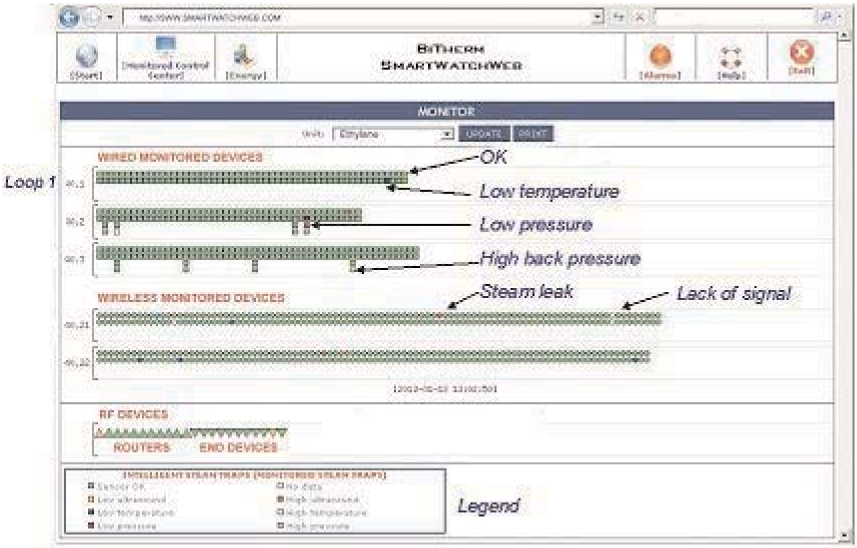
Clicking on any colored icon will provide the information that corresponds to the draining element it represents, as shown in the lower section of figure 8-4.

This new screen of the graphic interface allows for the analysis of the evolution of the monitored parameters in the draining elements for any time range selected.

The combination of all of the information and the availability of measurement records makes it possible to have an accurate analysis, eliminating the diagnostic errors described in all of the previously mentioned methods when evaluated individually. In effect, the variations detected in each parameter remain registered and their analysis allows for the identification of any incident; in addition, adequately setting the alarm thresholds, the system carries out a predictive analysis of incidents, making it possible to avoid failures and extend the life of the draining elements considerably.

It is generally not required to check all of the individual information of each element being monitored unless it is necessary to do a full analysis. The interface has a button that performs an instantaneous audit in all of the elements being monitored and it generates a list of all of the incidents detected so that they may be repaired immediately.

Lastly, there is an alarm screen that makes it possible to analyze any of them throughout time in order to improve the facility's future operations.


BiTherm
SmartWatchWeb
MONITOR
WIRED MONITORED DEVICES
Loop 1
OK
Low temperature
Low pressure
High back pressure
WIRELESS MONITORED DEVICES
Steam leak
Lack of signal
RF DEVICES
ROUTERS
END DEVICES
Legend

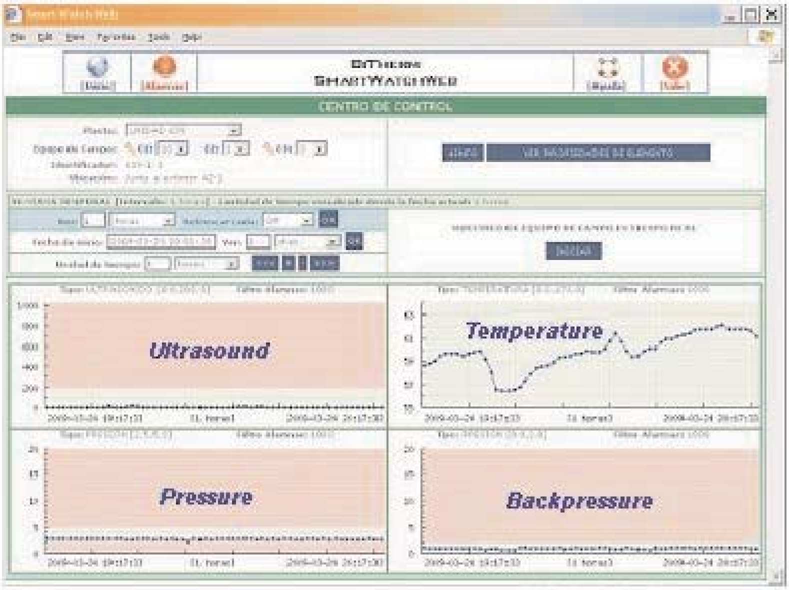

BiTherm
SmartWatchWeb
CENTRO DE CONTROL
Ultrasound
Temperature
Pressure
Backpressure

Figure 8.4

8.4 PURGE STATION INSPECTION PROTOCOL

Recommended action protocol for performing purge station inspection is summarized below.

There are two cases:

Unmonitored purge stations

It is advisable to carry out a periodic inspection at least once every six months in order to reduce energy and maintenance costs. The recommended inspection procedure is as follows:

1. Check the appearance of all the elements of the purge station (isolation valves, filter, steam trap, accessories, connections, identification tag of the purge station, etc.) and take note any deficiencies observed in them.

2. Check and record the data of the steam trap (identification tag number, brand, model, size, connection type, steam inlet pressure, outlet pressure, type of application, etc.).

3. Check the condition of the inlet and outlet isolation valves. If either of them is closed, the diagnosis is "*out of service*".

4. Check the status of the bypass valves (if any) and, if open, the diagnosis is *"bypass purge"*

5. Check that the purge element is not blocked; if its temperature is close to the environment and the purge station does not have a filter cleaning valve, the diagnosis is "blocked" or "flooded". If the purge station has a filter cleaning valve, open it to blow the filter and check if it works out the problem. If the situation persists, the diagnosis is *"blocked"* or *"flooded"*.

6. If the purge station is operational, apply the contact probe of the ultrasonic detector to the steam trap body to verify its operation. If the leak detector shows high ultrasound it must be ensured that it is generated by the purge element and does not come from backgorund noice as structural vibrations, high level of flash steam, bypass leakage or from another near purge element. To do this, the probe of the detector must be applied in elements close to the one inspected to try to identify the source of ultrasound. In areas with presence of structural vibrations you must reduce the sensitivity of the detector and ensure that the ultrasound method is applicable; otherwise replace this method of verification with another. Once the validity of the method is guaranteed and assured that the ultrasound is caused by the purge element, several cases may occur:

» Continuous ultrasound < 20% of the scale. Diagnosis = *"partial leak"*.

» Continuous ultrasound> 20% of the scale. Diagnosis = "*continuous leak"*.

» Discontinuous ultrasound with cycle > 30 sg in thermodynamic vapor traps. Diagnosis = *"Acceptable"*.

» Discontinuous ultrasound with cycle between 5 and 30 sg in thermodynamic steam traps. Diagnosis = *"low performance"*.

» Discontinuous ultrasound with cycle <5 sg in thermodynamic steam traps. Diagnosis = *"partial leak"*.

7. When the desired temperature is not reached in the process, it must be analyzed if the purge station is well dimensioned and its adjustment is correct.

8. Finally record all the data collected in the field in an appropriate steam trap management application, for example TrapHelp or SmartWatchWeb, in order to easily obtain fault statistics, repair lists, energy losses due to failure, failure types , distribution by types, etc.

9. Generate the final inspection report with recommendations to improve energy efficiency, reliability, operation and future maintenance of the installation.

Monitored purge stations (SmartWatchWeb)

In this case the inspection of the purge station is carried out continuously and automatically; however, it is recommended to carry out an ocular inspection on a regular basis, for example every six months, to rule out possible incidents that cannot be detected by the monitoring system itself (disassembly of sensors from their original fixation, etc.).

It is important to note that all possible faults in purge stations will be detected and recorded by the monitoring system provided that the thresholds of the monitored parameters have been correctly adjusted (ultrasound, temperature, pressure and back pressure), otherwise the parameters will remain measured but the alarms will not be real.

The correct setting of thresholds must be done by analyzing the application of each purge station to adapt them to each particular case in order to maximize its energy efficiency and optimize the operation of the installation.

The adjustment of monitored parameter thresholds should be set as indicated below; however, these criteria will be modified according to the particular characteristics of each application and experience:

Ultrasound threshold:

In 8-bit resolution sensors (SWW-10 devices) the default basic threshold will be set to a digital value of 50. In case of structural noise the threshold will be set 50 digital units above the average level of ultrasonic noise detected by the system. In special cases, the threshold must be set according to the temperature threshold.

In 10-bit sensors (new SWW-11 devices) the default basic threshold will be set to a digital value of 200. In case of structural noise the threshold will be set to be set to 200 digital units above the mean ultrasonic noise level detected by the system. In special cases, the threshold must be set according to the temperature threshold.

Temperature threshold:

It must be set according to the application. However, if the temperature is measured outside the steam trap, it must be taken into account that the internal temperature could be about 60 °C higher. In this case, the minimum temperature threshold will be the operating temperature minus 60 °C.

In the SWW-11 sensors, it is also possible to set a maximum temperature threshold; this maximum must be about 10 ° C. However, the difference between external and internal temperature in the steam trap must also be taken into account. Setting the maximum temperature threshold is important to lengthen the life of the steam trap as it reduces the formation of flash steam in the trap, what means reduction wear by erosion reducing maintenance costs.

In other applications, the same criteria will be used, adapting the thresholds to the steam temperature in the process.

Pressure threshold:

The maximum inlet pressure threshold must be set at a high value, without exceeding the maximum pressure that the purge element can withstand.

The minimum inlet pressure threshold must be set by default to a value 20% below the nominal steam pressure.

Back pressure threshold

The maximum outlet pressure threshold must be set according to the maximum permissible backpressure value at each purge station, which depends on the existing backpressure and type of steam trap. For example, in low pressure applications (3.5 bar) this threshold will be 2.5 bar for thermostatic steam traps and 1.5 bar for thermodynamic steam traps; in this way, a minimum differential pressure compatible with the type of steam trap will be guaranteed to avoid operating problems.

Obviously the minimum output pressure threshold is zero.

El umbral de presión de mínima de salida se debe habitualmente en cero.

8.5 MAINTENANCE OF PURGE STATIONS

Maintenance of purge stations will depend on the inspection plan established by the user; The longer the period between two consecutive inspections, the greater the deterioration of the purge elements and the greater the cost of spare parts.

In monitored purge stations, all anomalies are detected as soon as they appear and can be repaired in less than 24 hours, this produces maximum benefits not only in energy efficiency but in maintenance costs.

Thus, experience has shown that the purge elements multiply their useful life when any detected incipient leak is repaired in less than 24 hours.

Repairs must always use original parts; avoiding repairing damaged parts unless they are subjected to the same thermal and surface treatments to which they were submitted by their manufacturer.

Whenever a vapor ramp is disassembled it is advisable to replace all existing gaskets between joint surfaces to prevent further leakage.

In order to reduce repair costs and improve the operation of the installation, it is advisable to use, whenever possible, balanced pressure bithermostatic traps and external adjustment mechanism. This considerably lengthens useful life and greatly reduces consumption of spare parts since their repairs are carried out by means of a simple external adjustment, which is carried out without interruption of service and does not require any spare parts.

CHAPTER 9

ENERGY EFFICIENCY AND MAINTENANCE

9.1 INTRODUCTION

The relationship that exists between the correct functioning of the draining elements and energy efficiency of the steam network has already been mentioned in previous chapters. However, there are some very common applications (tracing) where energy traps can act as a direct energy saving element, by simply adjusting its discharge temperature to 40 °C below the steam saturation temperature.

In other cases, it is possible to apply this concept although the discharge temperature is adjusted closer to the values of the steam saturation temperature, such as draining drip legs in distribution lines where there is a vertical distance from the drip leg to the draining element greater than 2 meters; in this case it is possible to reduce the discharge temperature so that it is able to retain a small column of water (less than 1 m height) upstream of the steam trap, which reduces conduction energy losses to the outside in the affected area due to the fact that the heat transmission coefficient of water-metal-air is a hundred times smaller than the heat transfer coefficient of steam-metal-air. Additionally, this practice extends the life of steam traps and reduces backpressure in the return line.

When discussing the topic of saving energy in steam networks, the energy efficiency of draining elements must be considered, which depends on its own energy consumption as well as its direct and indirect energy losses associated with the type of draining element.

Furthermore, any equipment requires maintenance in order to keep it functioning properly, but in the case of equipment that handles energy, such as draining stations, their maintenance must be focused on optimizing energy efficiency.

Until the birth of modern intelligent energy traps, the maintenance of draining stations was corrective, with periodic survey campaigns being conducted, (yearly or bi annually) to detect incidents and steam leaks to be subsequently repaired.

The need to reduce energy consumption, increase efficiency of production processes, and reduce greenhouse gas emissions requires the use of ever more advanced technologies, which when applied to the field of draining elements has led to the development of intelligent energy traps.

The use of such intelligent energy traps provides real-time operating data, eliminating the need for long and laborious field surveys; this has substantially modified the classical concept of draining station maintenance, leading to a new concept known as "Intensive Maintenance".

9.2 DIRECT AND INDIRECT ENERGY LOSS

All draining elements have certain energy self-consumption. Of course, it depends on its size, the physical phase of the fluid inside (steam or condensate), its working principle, material and thickness of its body, and operation temperature.

This self-consumption can be in the form of live steam, or steam which is condensed inside the draining element due to energy loss. The first form is a direct energy loss, easily observable and measurable, while the second form due to self-consumption is more subtle and can be qualified as indirect loss (Figure 9-1).

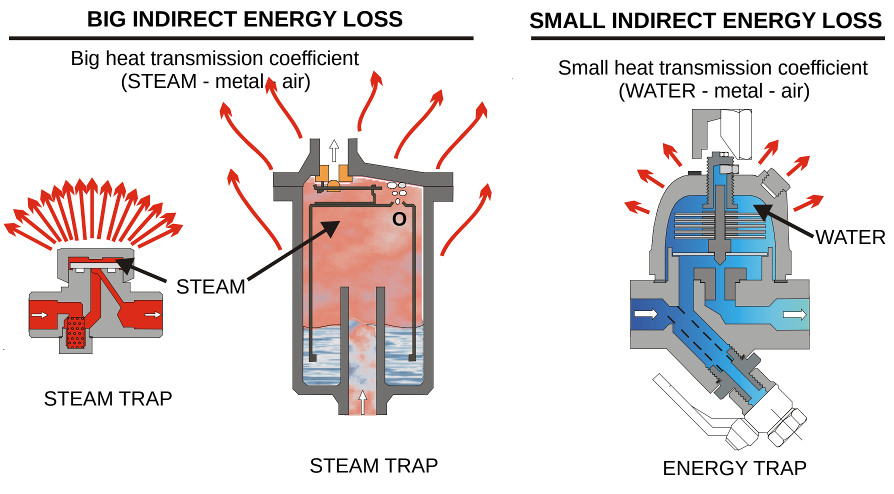


Figure 9.1

For example, direct energy loss is the live steam that escapes in each cycle of a thermodynamic steam trap, while indirect loss is due to the condensation of steam inside an inverted bucket steam trap.

In humid, cold or windy climates, the size of the trap has a significant influence on its self-consumption of energy. Of all atmospheric phenomena, rain is the most influential on the energy losses of draining elements; they can be multiplied by 5 to 10 times with respect to a dry day on thermodynamic steam traps (disk type).

Atmospheric phenomena strongly affect steam traps containing live steam inside, while they have a small influence on thermostatic energy traps which only contain hot condensate. Obviously the condensation of steam inside the steam trap represents an indirect energy loss that is much stronger than the energy loss due to sensible heat transfer on thermostatic traps that only contain hot condensate. This happens in float and inverted bucket traps where steam is always present; this steam continuously condenses through heat transfer to the outside which constitutes an indirect loss of energy.

Indirect loss is particularly relevant in the thermodynamic disk trap whose upper control chamber retains a small amount of steam, which aims to provide the closing force; the heat transfer toward outside under the influence of the weather (rain, cold and wind) causes the condensation of steam retained in the control chamber and the steam trap opens. This occurs even when there is no condensate to evacuate, discharging live steam into the return line.

To mitigate this energy loss, steam traps can be covered by a cap that protects them from the rain; remember that steam traps must never be thermally isolated in order not to hinder its automatic air venting ability.

Thermostatic energy traps are much less sensitive to indirect energy losses because there is only condensate inside and their efficiency is usually affected only around 15%.

Another interesting aspect is the volume of the trap; the more voluminous it is, the greater its indirect energy loss. Sizing of the internal valve must also be considered because an oversized valve worsens its regulatory ability and causes more wear and tear, increasing energy and maintenance costs.

It is common to think that the losses of any small steam trap (1/2 ") are negligible because they are generally used to drain a low flow rate, the order of 10 kg / h. But this is misleading, because individually a typical loss around 20 kg/h to 30 kg/h is small in absolute value, but since the number of elements in this situation can rise to several hundred or thousands of elements the resulting amount is considerable. Note that the average flow rate of tracing points is around 10 Kg/h. Therefore, a loss of steam from 20 to 30 kg / h represents a huge energy waste from 200% to 300%. Therefore, in practice, using intelligent energy traps is possible to save a gigantic amount of energy on steam facilities where there are thousands of draining elements (tracing and drip legs).

9.3 PRESURIZATION OF RETURN LINES

Pressurization of return lines has strong impact on the efficiency of the steam network. Return lines lead the condensate evacuated through draining elements and the residual energy of the condensate to the boiler to be transformed back into steam using part of the sensible heat of the liquid.

Internal steam leaks through draining elements produce a pressure increase in return lines, which causes serious problems affecting both the operation of the facility as its energy efficiency.

The most important problems caused by pressurization of return lines are:

» Difficulty to return condensate to the boiler

» Reduction of discharge capacity of draining elements

» Modify the discharge temperature in thermostatic energy traps

» If backpressure exceeds 60% of the inlet pressure, it causes great loss of energy in thermodynamic traps.

» Increase the temperature in the return lines and thus energy losses by conduction, convection and radiation into the atmosphere

» It favors cavitation in boiler feed pumps

» It causes thermal water hammers and thus the occurrence of leaks in valves and fittings

» It reduces the overall energy efficiency of the steam network by recirculation of energy

Pressurization of the return lines is a spontaneous phenomenon associated with the flash steam formed in condensate discharge of draining traps (see section 1-3).

Pressurization of the return lines is the most common problem that is present in large facilities, such us refineries and chemical plants, where a huge amount of draining elements exists.

Pressurization of the return lines increases not only because of the presence of internal leaks of live steam but also because of the flash steam. The formation of flash steam depends on the condensate discharge temperature. It is obvious that the influence on the backpressure in the return lines depends on the type of draining element.

However, during the return lines design, sometimes the type of draining element is not considered. This results in a bad calculation of the return lines backpressure which causes serious problems in the whole network, mainly when large steam network are involved with low operating pressures (For example, tracing lines using 3,5 bar steam pressure).

In accordance with section 6.5 in this manual, the theoretic amount of flash steam that the return line will drive has to be considered to calculate the return line. In this calculation, it is required to consider a flow velocity of 15 m/s for the mentioned flash steam.

However, even in the situation that there is not any steam leak, the formation of flash steam does not only depend on the condensate discharge temperature but also on the small amounts of live steam put inside the return line. These small amounts are used as the control steam that some steam traps need to work properly (thermodynamic steam traps, inverted bucket steam traps, impulse steam traps, etc). The mentioned small live steam injections allow certain amount of condensate to revaporize inside the return line, and this live steam is very difficult to estimate.

On the contrary, thermostatic energy traps reduce the return line backpressure because of their less discharge temperature. That means reduce the residual energy discharged to the return line.

In summary, theoretical calculations for sizing the return lines are valid when they correspond to draining elements discharging at the saturation point. Pressurization will be lower when using thermostatic energy traps, and will be higher to the theoretical when using steam traps.

In the practice, frequently it happens that facilities are extended in the future but the return line remains changeless. This, as well as the aged deterioration, worsens the design situation to a situation where the network collapses. So, it is necessary to discharge the condensate to the atmosphere, meaning huge energy losses.

One of the most harmful features of the pressurization of return lines is that it expands quickly along the whole network, although the effect begins in lonely points, the discharge of steam traps affects other nearby. This results in increasing steam leaks what means there is a multiplier effect that quickly expands along the whole return line.

Thermostatic energy traps help to reduce this effect, due to the fact that the local backpressure in the return line hinders and restricts the discharge of other nearby energy traps, avoiding that the effect quickly expands.

9.4 INTENSIVE MAINTENANCE OF DRAINING STATIONS

In large facilities, the classical preventive and corrective maintenance system of draining points is very laborious process due to the thousands of elements to check. The process consists of two sequential steps. First, all the elements of each draining station have to be periodically inspected what will end in making an inspection report. Second, repair of all incidences that were mentioned in the report.

It is recommended to divide the entire population of elements to be inspected in smaller groups in order to make easier the inspection. However, the inspection and repair of thousands of draining elements take long time, and this fact leads to big delays between the inspection of one draining element and its repair. The intensive maintenance substantially modifies this work scheme because the use of intelligent energy traps eliminates the periodically and manual inspection, providing on real time all information about any incidence.

The main feature of the intensive maintenance is to join the concepts of predictive, preventive and corrective maintenance in only one process, in which all anomalies are detected as soon as they appear, and so they can be repaired in less than 24 h to optimize the human resources.

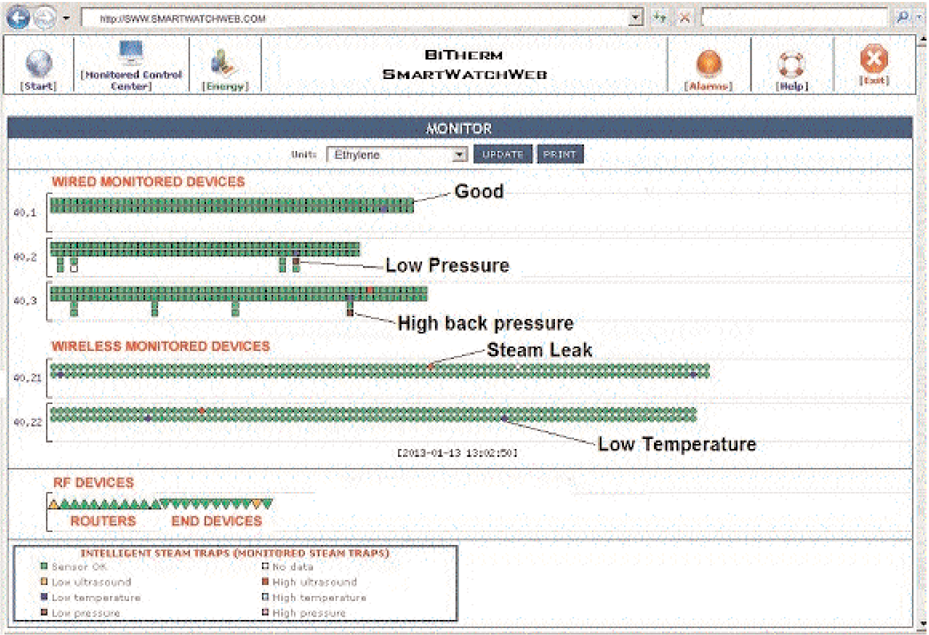


Figure 9.2

Figure 9-2 shows one of the multiples tools provided by the intensive maintenance graphical interface, where the incidences are easily identified by colours.

As it is shown in this figure, this online intensive maintenance interface can also handle the classical maintenance of non intelligent draining stations.

All information, regarding both types of draining stations, is recorded in the server and it can be queried by the customer. The interface allows the customer to make instantaneous energy audits, make all kind of reports, etc. For example, figure 9-3 shows a report of the status of all draining elements, this report can be filtered by the type of incidence.

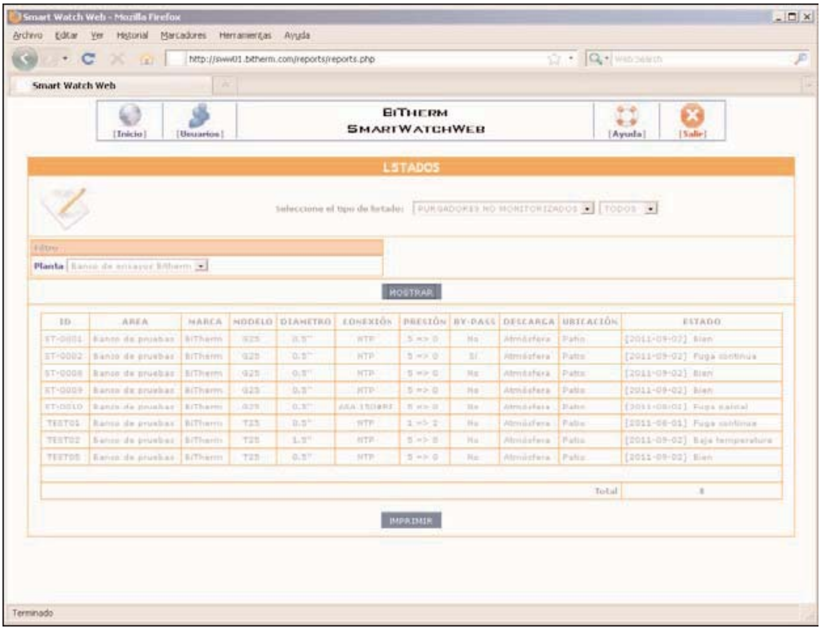


Figure 9.3

9.5 BENEFITS OF THE INTENSIVE MAINTENANCE

The experience shows that all elements subject to intensive maintenance multiplies their lifespan by 2 or 3 times respect to the one achieved by the classical maintenance scheme, because the internal leaks not detected on time are very erosive and destroy the internal of the draining stations.

The intensive maintenance of draining stations adds the following goals to those expected from the classical maintenance:

» Predict, prevent and/or correct any incidence in draining stations, focusing on multiple aspects (operational, energetic, etc)

» Reduce maintenance costs (they can be considered negligible because the benefits of the intensive maintenance are much higher than that of total maintenance costs)

» Increase reliability and availability of the steam and condensate network

» Increase safety of facilities and people

9.6 INTENSIVE MAINTENANCE AND ENERGY EFFICIENCY

Environmental aspects and the efficient use of scarce resources, for example water, will impulse the energetic performances in the world during the next years. In the Climate Summit in Cancun, it was agreed that the global average temperature has not to exceed 2ºC in the year 2050, and to achieve this goal all required actions to reduce the greenhouse gas emissions have to be taken. The most outstanding action that can be taken is regarding energy efficiency because it contributes to reduce CO_2 emissions and the consumption of products with high energy value in the market, as well as water that is a scarce resource in the world.

In the following years, all countries have to take actions to achieve this commitment especially since the 1st of January, 2012. This year, Kyoto Protocol finishes. The UE is leading environmental actions in the world. The UE has taken on the firm commitment from all their Members to achieve a 20% improvement in energy efficiency and reduce 20% CO_2 emissions in 2020 regarding those of 2008. Presumably, similar actions and even more strict will be agreed in coming Climate Summits. The visible effects of the climate change (heavy flooding, large tornadoes, etc) will impulse new actions to reduce greenhouse gas emissions. Energy efficiency is the simplest and most profitable tool to achieve this goal, recognized by the International Agency of Energy, followed by renewable energies, CO_2 capture and storage, and Nuclear Energy.

Large energetic facilities should anticipate the coming changes, in an intelligent way, improving profitably the energy efficiency of those processes for reducing emissions. As it is known, Petrochemical facilities consume huge amount of steam, meaning energy, mainly generated from fossil fuels. Energy efficiency of steam networks is strongly conditioned by steam energy degradation, which is handled by thousands of draining elements, so considering all these elements as one only equipment, then becomes one of the most important steam consuming equipment in these facilities. Additionally, steam leaks and energy inefficiency in draining elements result in huge energy losses, increase of consumption of treated water, increase of production and maintenance costs, as well as huge CO_2 emissions to the atmosphere.

Currently, without any doubt, Intensive Maintenance applied in steam networks is the tool that can have most impact for energy saving, to produce increases in energy efficiency between 8% and 15% and the corresponding greenhouse gas emissions reduction.

For example, figure 9-4 shows the energy graphic of the graphical interface to manage “***Intensive Maintenance***”.

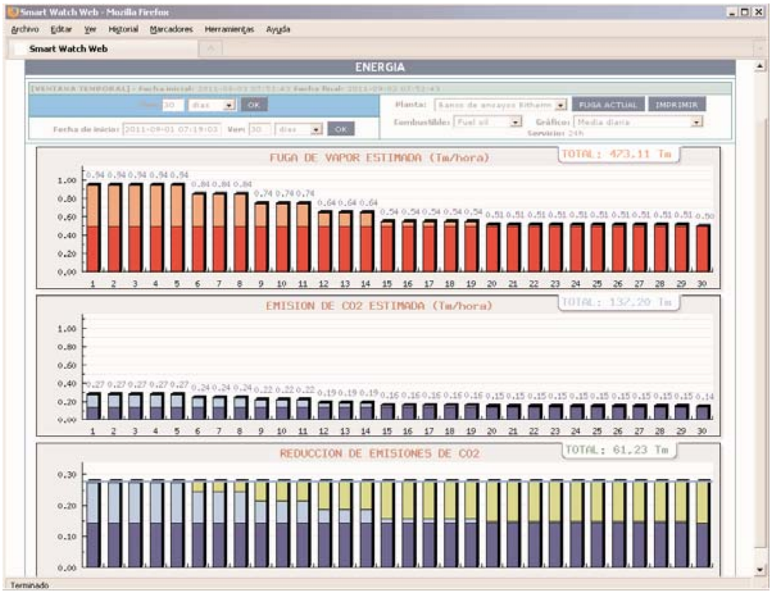


Figure 9.4

Each bar represents the daily steam leak in draining stations. The bottom part of that bar, with a more intense colour, corresponds to non monitored draining stations. The upper part of that bar, with a less intense colour, corresponds to intelligent draining stations.

The upper chart shows the typical evolution of steam leaks after implementing the Intenisve Maintenance in the facility. The chart in the middle shows the evolution of CO_2 emissions, and the bottom chart shows the initial base line (top horizontal line) and the evolution (green area) and accumulated amount of CO_2 emissions reduction, in the selected period. The following example gives an idea of the economical repercussion of this subject:

The energetic cost of refining crude represents between 50% and 60% of the total cost, in Europe. 25% of this energy corresponds to steam consumption. So, steam consumption means a percentage between 12,5% and 15% of the total cost of refining crude. Due to the fact that this steam is handled by draining elements, it is obvious that a 15% increase of its energy efficiency will reduce between 1,87% and 2,25% of the total refining cost (here it is not considered the additional benefit of reducing CO_2 emissions).

Draining elements are the direct responsible for energy efficiency in the steam facility as well as they are involved in the following aspects:

» Influence the increase of backpressure in return lines

» Influence in the occurrence of thermal water hammers

» Influence in the occurrence of thermal water hammers

» Affect the lifespan of the facility: pipelines, accessories, …

» Control the energetic degradation of steam and, so, influence in the generation of CO2 emissions

» Contribute to the general thought about the right use of energy

The following information highlights the importance of this matter:

One steam leak (42 Kg/h) in a small draining element (1/2” size) installed in a low pressure steam line, represents an energy cost of 368 tons of steam per year and 103 Tons of CO_2 emissions to the atmosphere per year.

In order to estimate steam leaks occurring in draining elements, it can be used the software "Simulation of steam leaks" in the following website:

http://www.smartwatchweb.com

9.7 ADVICES ABOUT REPAIRING OF DRAINING STATIONS

It is worth to recall that all repairs have to be done by using the original spare parts from the supplier, in all cases, avoiding repair the damaged pieces unless they are thermally treated, and coated as they were originally.

It is advisable to replace all gaskets between the bonding surfaces after disassembling a draining element in order to avoid future steam leaks.

It is advisable to use bithermostatic energy traps, whenever possible, which is a balanced pressure energy trap and with external adjustment mechanism in order to reduce repair costs and improve operation in the facility. Using this type of energy trap considerably lengthens lifespan and highly reduces the use of spare parts, as its repairs can be done by only using the external adjustment without interrupting steam in the facility.

Awards

Gold Medal at the International
Exhibition of Inventions of Geneva
(Switzerland - 2004)

Gold Medal at the International
Exhibition of Inventions of Geneva
(Switzerland - 2005)

Commitment to mitigation of Global Warming and Climate Change

Special Mention from the International
Jury at the International Exhibition of
Inventions of Geneva (Switzerland - 2004)

Headquarters:

Madrid - Spain

Factory:

Murcia - Spain