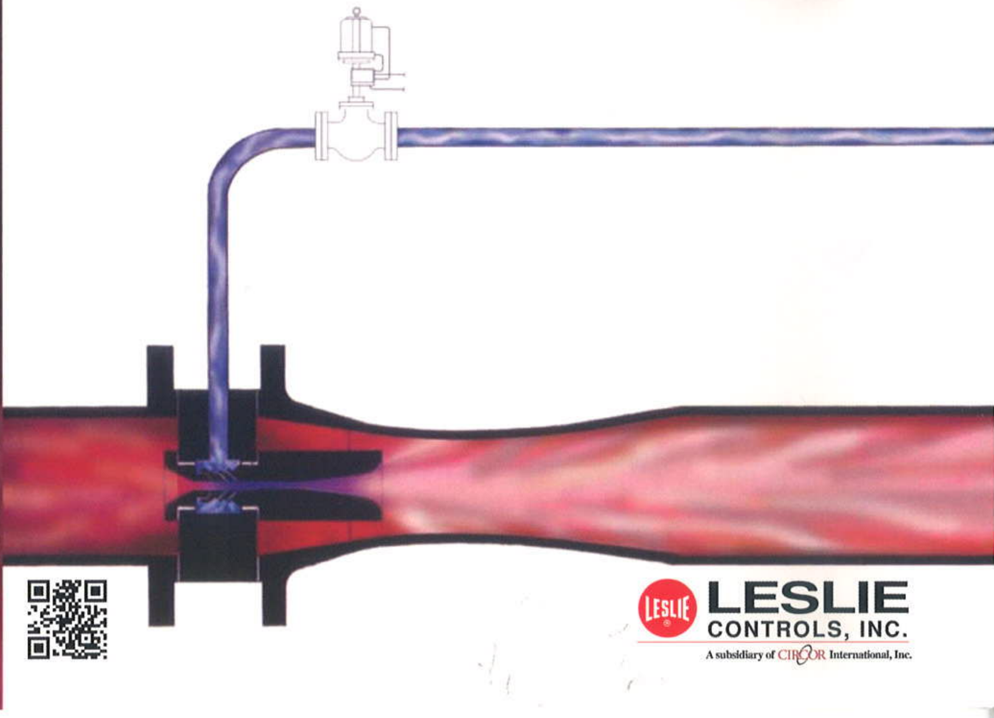
Steam desuperheating by spraywater injection in Process and Thermal Power Plants

STEAM
DESUPERHEATING
GUIDE



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The principle function of any desuperheater is to accelerate the phenomena of absorption of the spray water by the steam so that steady conditions of steam temperature are reached within a short distance from the outlet at all loads. This ensures that poor quality of steam or water droplets are not carried downstream in the steam pipeline. The purpose, therefore, is to develop methods by which heat transfer between steam and water can be hastened. The main purpose is to break spray water droplets into very fine particles at all loads to ensure increased surface area for water to come in contact with the steam is available, thereby increasing the rate of evaporation. It is very clear that the size of the water droplets should be smallest, utmost surface area available, absorption will be almost instantaneous and true temperature will be measured within the shortest distance.

In all instances for desuperheating, the nature of the downstream stream, and the avoidance of large spray water droplets that can be propelled at high speed to damage elbows, valve seats, heat exchanger tubes, or process material are very important factors while designing desuperheating system and equipment selection.

INTRODUCTION

For nearly three centuries, steam has been used to convey energy in the form of thermal energy from the place of its origin - the boiler - to its usage point: a steam engine, a turbine or a heat exchanger. For this reason, steam is generated in boilers at high pressure and temperature and subsequently expanded in equipments to obtain thermal or mechanical energy. In a condenser this reduced steam is converted back into its liquid phase and by means of boiler feed water pump this condensate is pressurized again and transported to the boiler.The water/steam cycle is closed.

Desuperheaters are employed to control superheat temperatures. However, they are not restricted to reduce steam temperatures only but are also used to reduce temperatures of other gases by injecting suitable liquid condensates.

For continuous plant operation, a number of auxiliary and emergency systems, like bypass systems, are installed to ensure smooth and continuous running of the plant and for every small component failure, the plant does not need to come to a standstill.

A typical thermal plant has complicated network of piping systems with a large number of other components. Desuperheaters are deployed to protect piping systems and components from excessive temperatures and/or to provide process steam at required temperatures.

For a number of operating conditions, superheated steam must also be reduced to desired pressure level. For better understanding the differentiation is furnished:

- Start-up and shut-down systems.
- System safety devices.
- Bypass systems.
- Connections of bypass systems.
- Heating processes.

DESUPERHEATER

Desuperheaters can be classified in two types: Direct contact and Non contact types. The temperature reduction can be performed in two ways:

- By water injection into the steam (direct contact) ***Figure 1.***
- Through heat exchanger (non contact type) ***Figure 2.***

DIRECT CONTACT:

This type of desuperheater has more advantages and is highly efficient since it utilizes not only the temperature difference but also the steam generating heat of the fluid.

This design usually is compact and does not require much maintenance. They recognize load variations very quickly and temperatures close to saturation can be maintained. Since the spray water is transformed into the steam, care should be taken to ensure water is clean and of good quality. This method is largely adopted universally.

NON CONTACT:

This type of desuperheater is highly inefficient owing to the low heat transfer coefficient between steam and the exchanger wall. This heat transfer becomes even less if the temperature difference between steam and water is small. *It ultimately requires large area, resulting in high capital cost.* Normally it is shell and tube type which requires maintenance frequently. In addition, frequent load changes are not recognized quickly. These desuperheaters are used where any form of cooling water

Figure-1: Desuperheating by spraywater injection into the steam.

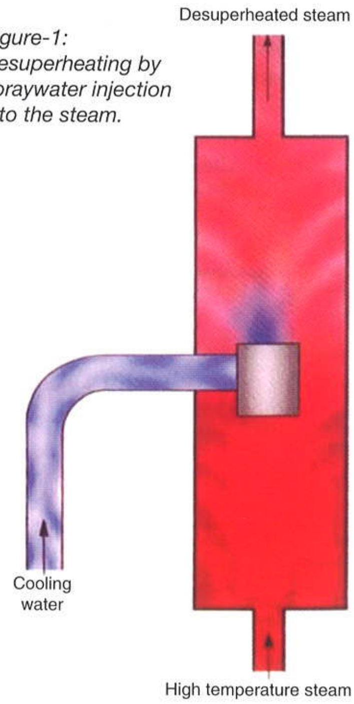
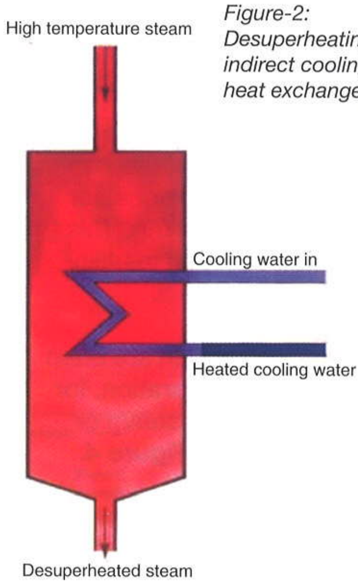


Figure-2: Desuperheating by indirect cooling in a heat exchanger.



TYPICAL APPLICATIONS OF DESUPERHEATERS IN PROCESS AND POWER PLANTS:

Various steam systems in process and power plants are interconnected by steam conditioning valves. The function of these valves is to reduce high pressure and temperature to the desired level. The pressure reduction can also be performed by an ordinary throttling valve equipped with actuating systems. The positioning of the valve is catered by the feedback system from the control loop. In the majority of cases, temperature has to be reduced as well to the desired level.

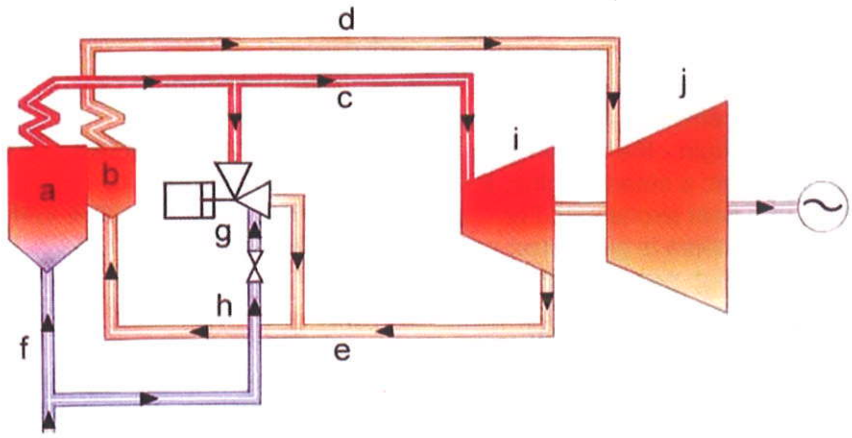
A distinct example for the application of steam conditioning valve is turbine bypass system.

During start-up and shut-down, as well as after turbine trip, full steam flow is handled by these bypass valves. These valves are subjected to live steam and their function is to reduce the steam condition of the superheater outlet to the turbine outlet condition.

There are basically two different applications:

- Bypass systems which are in operation only occasionally. Among them there are start-up and shut-down conditions and emergency conditions, for example after turbine trip. This is a typical application in utility power plants. ***Figure 3.***

- Bypass systems which are often or permanently in operation, for example for process steam or heating application. ***Figure 4.***



a = Boiler with superheater
b = Reheater
c = Life steam
d = Hot reheat
e = Cold reheat
f = Feed water
g = HP bypass valve
h = Spraywater valve
i = HP turbine
j = LP turbine

BASIC DESIGNS OF SPRAYWATER INJECTION:

Different designs have been developed for spray water injection for various applications. In order to develop a reliable design some basic principles are needed to be considered. A few decades back, pressure and temperature reduction had been exclusively assigned to two independent units: the pressure reducing valve and a separate desuperheater. Today, not only for economic but also for performance reasons, both these functions are employed by a single unit. By excellent designing, thermal stresses caused by spray water injection have to be avoided at all costs, especially for the pressure retaining parts.

Thermal stresses are secondary stresses which can exceed yield strength of the material by far and do not lead to immediate failure. They are subject to "low cycle

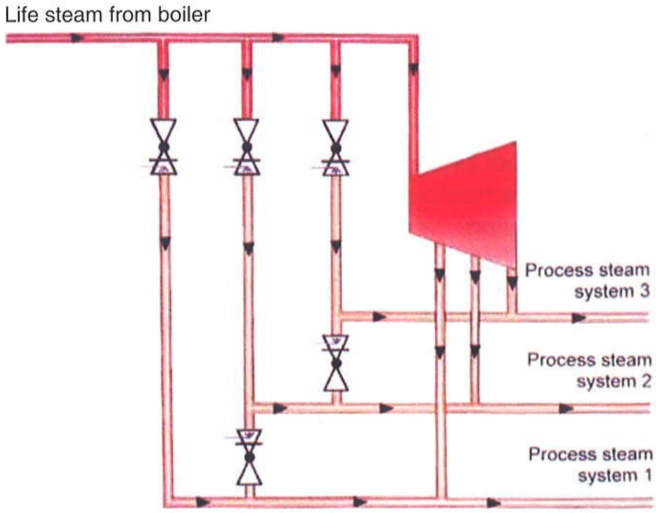


Figure-4: Turbine bypass system for process steam generation.

fatigue" and repeated exposure to thermal stresses eventually lead to cracks and major damage. Thermal stresses are created by temperature differences over the wall thickness and simultaneously restricted temperature expansion. The temperature differences can occur permanently or variable with time; for instance, during start-up conditions:

- Reducing the wall thickness to the allowable minimum
- Smooth wall thickness variation, for example using spheric valve body design.
- Reduction of forces induced from outside (pipe forces and vibrations) to reduce the collective stress level.

It is very important to avoid thermoshock stresses since they are created by the spray water coming in contact with the hot body wall. These stresses depend on the temperature difference between water and material. The good heat transfer coefficient between the spray water and the hot valve leads always to excessive thermoshock stresses followed almost immediately by formation of cracks and successive major damage. This problem is very common at high stressed valve portions due to collective primary and secondary stresses.

Thermoshock stresses can be safely avoided by appropriate designs, and spray water being injected into the valve should not touch hot valve internals. In many cases a separate perforated cylinder is incorporated in order to protect the pressure retaining parts of the valve body.

Due to a large variety of requirements with respect to steam conditioning systems, it is virtually impossible to cover all applications by a single design.

BASIC CONSIDERATIONS OF STEAM COOLING BY WATER INJECTION:

The change in the condition of steam and water can be demonstrated from ***Figure 5.***

In phase 1, water droplets in contact with the steam are heated by the surrounding steam till saturation is reached.
In phase 2, as saturation is reached, the water droplets start to evaporate with continuing heat consumption.
In phase 3, evaporation is complete. The saturated steam is further heated till equilibrium and the desired temperature t_2 is reached.

However, practically the above three phases will not succeed each other as stated above. There will be superposition of all three phases as well as parallel processes. This being a complicated thermodynamic process cannot be calculated simply and accurately. The most important factors are:

- The design of the spray water injection, to ensure smallest size of water droplets by high kinetic energy of the water and the steam. This will lead to the greatest surface area of water for heat transfer and in addition all thermoshock problems have to be avoided.
- The heat transfer coefficient is not constant throughout the process but varies with water droplet size, and the temperature difference between water and steam.
- Relative velocity between water and steam.

It is evident that the following conditions are not favorable for steam conditioning process:
- Low water velocity.
- Low steam velocity.
- Large amount of spray water in comparison to steam flow rate.
- Large temperature difference of spray water to saturation.
- Steam temperature desired close to saturation.

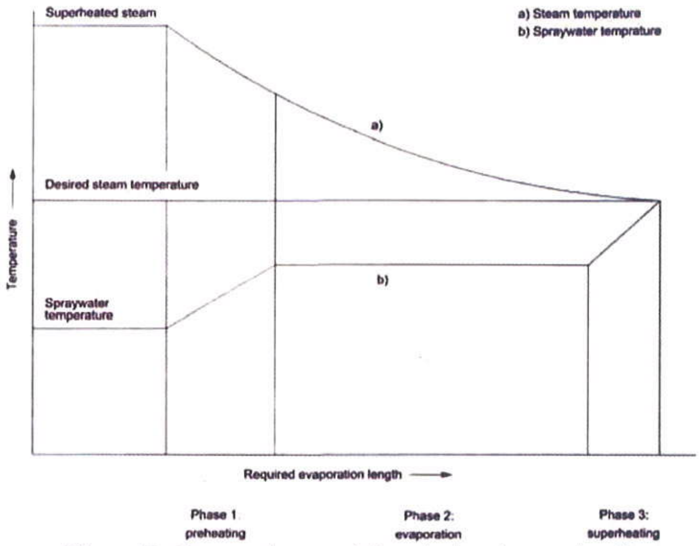


Figure-5 : Temperature variation during desuperheating.

CALCULATIONS FOR REQUIRED AMOUNT OF SPRAY WATER QUANTITY:

By energy balance the quantity of spray water can be calculated: (equation 1)

$$m_1 \times h_1 + m_w \times h_w = m_2 \times h_2 \quad (1)$$

and condition of continuity

$$m_1 + m_w = m_2 \quad (2)$$

follows

$$m_w = m_D \times (h_1 - h_2)(h_2 - h_w) \quad (3)$$

where

- m_1 inlet steam flow rate
- m_w required quantity of spray water
- m_2 total quantity of desuperheated steam
- h_1 enthalpy of inlet steam
- h_2 enthalpy of desuperheated steam
- h_w enthalpy of spray water

The values of enthalpy can be derived from steam tables against corresponding pressure and temperature conditions for inlet steam, desuperheated steam and spray water.
Equation (3) gives exact amount of spray water quantity for desired steam temperature to be maintained. However, depending upon the designs, only a certain amount of spray water injected will be converted into steam and a small quantity of water will remain unevaporated. This is precisely why some excess water is required to be sprayed for satisfactory performance.

CONTROL SYSTEM OF A STEAM CONDITIONING VALVE:

Figure 6 depicts the pressure and temperature control of a HP-bypass station. The upstream pressure is measured by two pressure gauges with attached transmitters. The maximum measured value is taken for further evaluation. By a 2 of 2 selection any malfunctioning in either can be detected by comparison with the set point in the control unit. For boiler start-up, the set point tracking system is activated in order to start the boiler according to a predetermined characteristic.

The temperature control system works in a similar fashion. Normally, pressure and control systems do not pose any problems.

Temperature measurement is much more critical:
A quick responding control system requires temperature gauges to be located close to the valve, and also incorporation of quick thermocouples. But on the other hand, to sense correct temperature, certain distance is required to enable all injected water droplets turn into steam and heat transfer in the pipe must be completed, otherwise water droplets may touch temperature gauges and thereby give false readings for measurement.

For conventional desuperheaters, it is advisable to position the temperature sensor downstream after the first bend at the inside radius in an elevated position (about 15 above horizontal). This makes sure that only the steam temperature is measured and water droplets not evaporated get carried to the outside radius of the bend by their kinetic energy.

There are also arrangements of steam conditioning valves, where to sense a correct temperature is almost impossible. For example, a LP-bypass valve located close to the condenser. In this type of

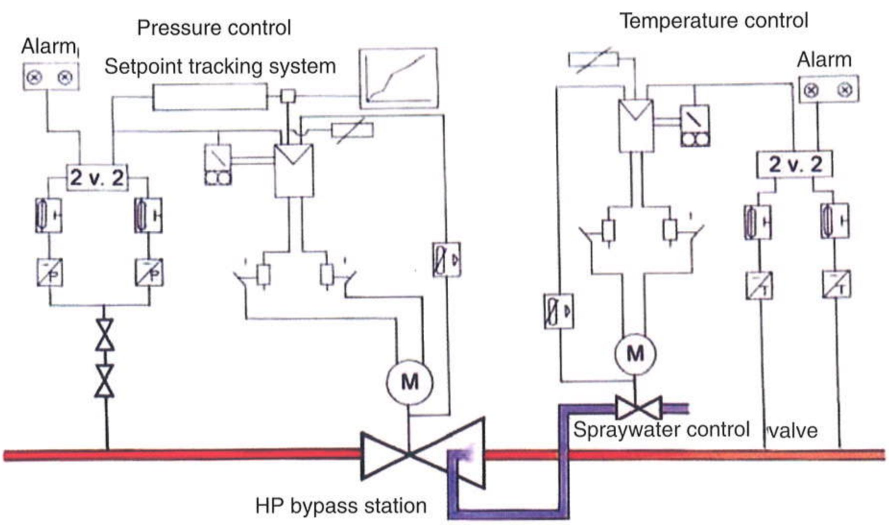


Figure-6: HP bypass control system.

installation, most cases operate with a large quantity of surplus amount of spray water.

However, this amount of spray water quantity can also be calculated as long as there is critical pressure drop across the valve since the flow rate depends only on the inlet pressure and temperature which can be measured easily, the water condition, and the flow area. For a given valve characteristic, the steam flow depends only from the valve stroke, which also can be calculated:

The steam flow is calculated:

$$m_D = m_D\,(p_1, t_1, A) \qquad (4)$$

and by the valve charactristic

$$m_D = m_D\,(p_1, t_1, h) \qquad (5)$$

Required spray water quantity according to equation (3)

$$m_w = m_D\,(h_1, h_2, h_w) \qquad (6)$$

Or ignoring the influence of specific heat

$$m_w = m_w\,(t_1, t_2, t_w) \qquad (7)$$

With equation (4) and (7) follows

$$m_w = m_w\,(p_1, t_1, h) \qquad (8)$$

Or for our example with constant downstream conditions

$$m_w = m_w\,(p_1, t_1, h) \qquad (9)$$

where

A	valve flow area
h	valve stroke
m_D	steam flow
p_1	inlet steam pressure
t_1	inlet steam temperature
m_w	spray water quantity
t_2	outlet steam temperature
h_1	inlet steam enthalpy
h_2	outlet steam enthalpy
h_w	spray water enthalpy
t_w	spray water temperature

DESIGNS PERTAINING TO DESUPERHEATERS AND STEAM CONDITIONING VALVES:

Most desuperheater designs can be incorporated in control valves without any major modifications, thus forming the steam conditioning valves. A large variety of designs are available in the market ranging from simple to complicated multi channel atomizing nozzles with steam extraction from the HP steam system.

In all instances of desuperheating the nature of the downstream steam and the avoidance of large water droplets that can be propelled at high speed to damage elbows, valve seats, heat exchanger tubes, or process material are important factors, in desuperheating-system design and equipment selection.

A primary aim in all this is to get thorough evaporation of spray water in a short distance , with accurate control of temperature at all loads and steam superheat conditions.

The object, therefore, is to design methods by which the heat transfer between steam and water can be speeded up. For a stable operating condition and in a long and straight downstream piping, a simple water nozzle will perform quite well, whereas at rapid changing conditions, and downstream conditions close to saturation a highly versatile and efficient desuperheater is required.

TYPES AND DESIGNS OF DESUPERHEATERS

MULTI NOZZLE DESUPERHEATER:

An insertion type compact unit, directly mounted on the steam pipe line and the control element is an integral part of the unit and does not need a separate spray water control valve.

Steam temperature is controlled by the positioning of the perforated plug within the nozzle head. The signal from the temperature control loop to the actuator positions the perforated plug to increase or decrease the amount of free flow area for the spray water. As the perforated plug is lifted from the seat, water flowing through the hollow plug turns upward and exits from the exposed orifices from the nozzle block. Full water/steam pressure differential is maintained at all flows for optimum efficiency. The unique design of the spray nozzles ensures the formation of hollow cone shaped misty spray which is readily absorbed into the superheated steam. Differential pressures of 4 to 25 bar between the coolant and steam can be accommodated by the unit with a maximum water inlet pressure of 42 bar. However, multistage trims are also available for any pressure drops.

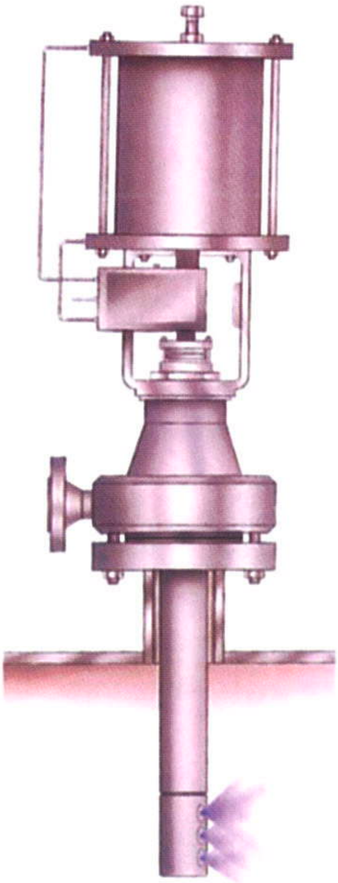


Figure-7: Multi nozzle desuperheater

Multi-orifices of varying sizes aim at modified linear characteristics, however by adjusting the Cv values of nozzles any characteristic can be achieved and the fineness of the droplet size allows application at steam velocities as low as 10 mts/sec. Temperature control within 5.5° c (10° f) of saturation is possible and the steam temperature can be held within 2.3° c (5° f) of the set value. High turndowns are available for this design. ***Figure 7.***

VARIABLE NOZZLE DESUPERHEATER:

This desuperheater also does not need any separate spray water control valve as the control element is an integral part of the desuperheater. It is also a probe type, which is directly mounted on the steam pipe line. Significant turndowns of 40:1 can be achieved. It has advantages over multiple fixed spray nozzles, such as collision between single spray cones resulting in larger spray water droplets and longer evaporation time, provides accurate control of steam temperature by introducing spray water through a nozzle of advanced design. Water pressure above steam pressure is used to produce a thin film of conical spray water which instantaneously evaporates as it is injected into the steam flow. The amount of spray water being injected is being controlled by the modified equal percentage plug. As per the signal from the temperature control loop, the positioning of the plug varies the nozzle area and the water which enters into the cage has about 10 to 12 water inlet orifices, which are progressively uncovered as per the lift of the plug. Water flow is controlled at the point of the injection into the steam. It utilizes constant differential pressure at all flow conditions to create a fine conical spray which is injected into the main steam line resulting in excellent attemperation at all times. Steam velocities as low as 10 mts/sec can be allowed for these units and temperature control and accuracy are very similar to Multi nozzle type desuperheaters. ***Figure 8.***

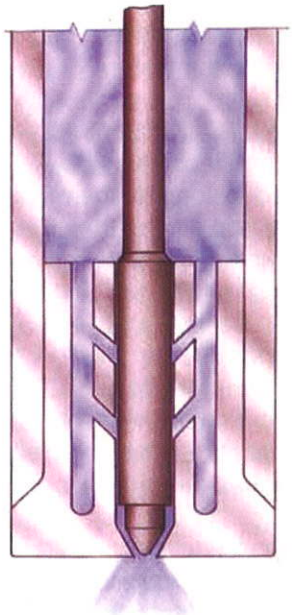


Figure-8:
Variable nozzle desuperheater

VENTURI DESUPERHEATER:

These units consist of a De Laval nozzle which utilizes a part of the incoming steam flow to create a reduced pressure zone into which spray water is drawn and atomized by steam energy, and then exits in a short expanding throat which allows pressure recovery.

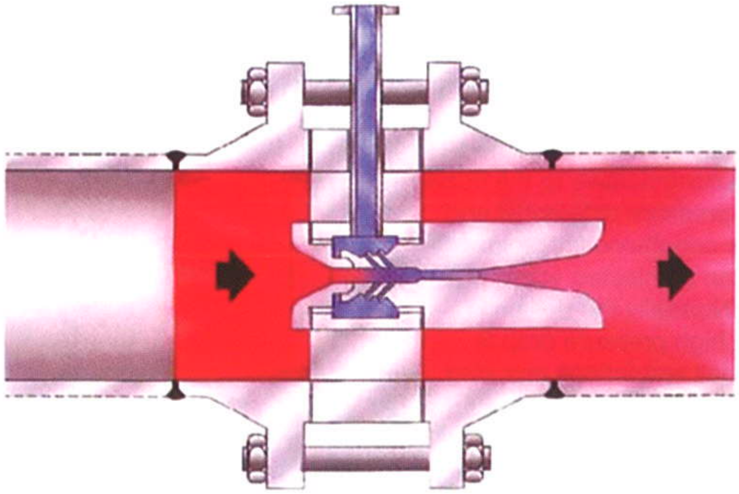


Figure-9: Attemperator desuperheater

They create very high velocities and turbulence to help mix the cooling liquid and vapors enabling desuperheating to take place. Water entering the desuperheater is preheated in a circulatory chamber around the water diffuser tube and is introduced in many small jets to assist final atomization by the steam flow through the center of the throat. When leaving the throat, the mixture of steam and water enters the venturi section for turbulent mixing prior to entering the main steam line in a fog like condition. The mixture is ejected such that no contact is made with the external venturi (sleeve) ensuring maximum operational effectiveness with minimum pipeline erosion.

The desuperheating performance will remain constant at all loads from 100% or less, because of the atomizing steam effect of the steam jet. The venturi desuperheater will operate successfully at quite low velocities of steam line flow, even when the main steam flow falls to a very low point. This desuperheater is unique such that the spray water can be supplied to the unit at the same pressure as the inlet steam. It is, however, desirable to allow an excess water pressure of about 2 bar ahead of the cooling water control valve. High turndowns are possible depending on installation. ***Figures 9 & 10.***

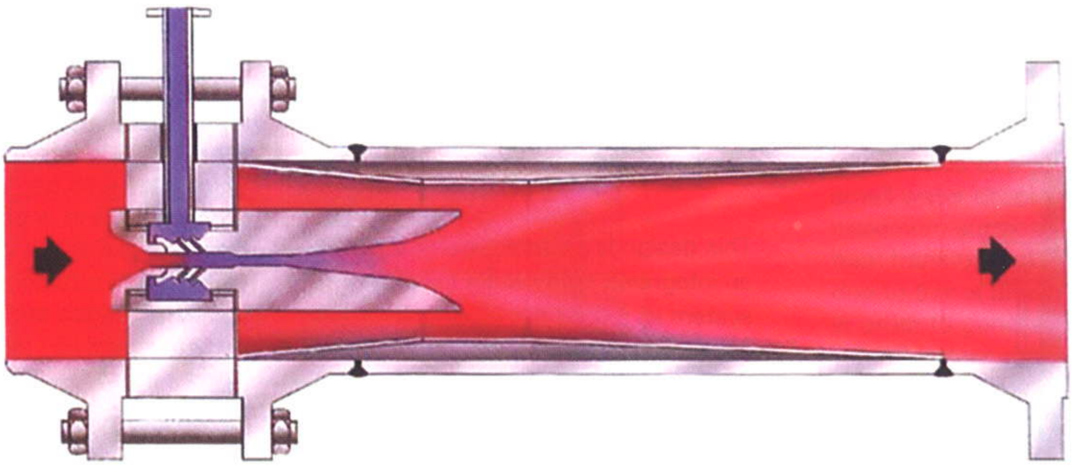


Figure-10: Venturi Desuperheater

SIMPLE MECHANICAL NOZZLE SPRAY DESUPERHEATER:

The simplest and most basic form of desuperheater involves the use of high spray water pressure fed through a control valve to the nozzle to create pressure differential and derive the conditions for rapid evaporation of injected water droplets. Normally the design is such that high pressure drop is across small restrictions ensuring the water to flash. As water enters the steam flow, small water droplets are formed which can easily absorb the heat from the high pressure stream - resulting in good vaporization. However, as the steam temperature or flow drops, the spray water control valve starts to throttle the flow. As the nozzle has a fixed orifice, the pressure differential will not be maintained and it will reduce proportional to the square of the reduction in flow in accordance with Bernouli's law. With lower pressure at the nozzle, the degree of flashing across the restrictions is also reduced and as a result fine water droplets are no longer formed and in the extreme a steady flow of water is injected in the steam pipe line. This ultimately leads to poor vaporization and bad temperature control. The steam will be wet and the pipework will suffer from extensive damage due to thermal cracking. These units find their application in relatively steady flows for steam and water and have very poor rangeability. ***Figure 11.***

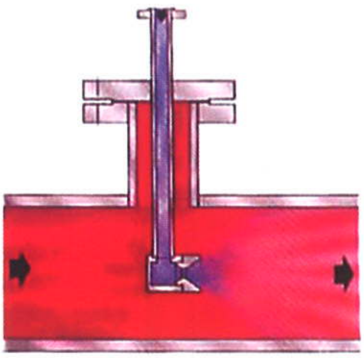


Figure-11: Simple mechanical nozzle spray desuperheater

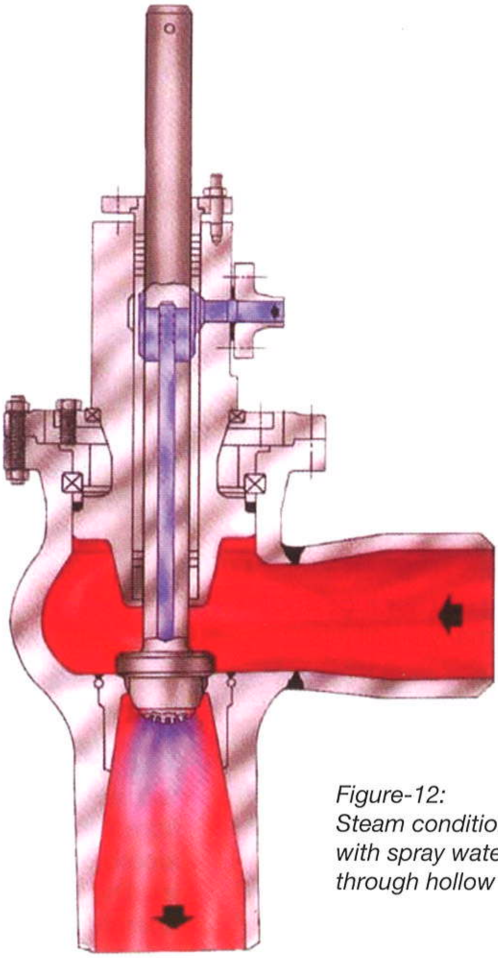


Figure-12: Steam conditioning valve with spray water injection through hollow stem

STEAM CONDITIONING VALVE WITH SPRAY WATER INJECTION THROUGH HOLLOW STEM:

This design is a classic example of an integrated spray water injection system as it does not exist as a separate desuperheating unit. The spray water is injected through a hollow stem and through a perforated plug. The water is sprayed into the steam just downstream of the valve throttling area. This will ensure an excellent heat transfer area since the water is introduced into the steam at very high velocities and turbulence resulting in instantaneous evaporation, turbulence resulting in instantaneous evaporation, However, higher spray water pressures are required in these designs. Recommended spray water pressures should be in the range of 50% of steam pressure at valve inlet + 15 bar. The evaporation time is less and is complete shortly downstream at the valve outlet; especially if additional pressure reducing stages are incorporated (approximately 5° in diameter).

Care has to be taken in these designs that thermoshock problems are avoided at all costs - considering this, the amount of spray water quantity which is being injected is limited to 20% of the inlet steam flow. ***Figure 12.***

STEAM CONDITIONING VALVE WITH SPRAY WATER INJECTION NEAR THE CONE THROUGH A SEPARATE NOZZLE:

The basic idea of this injection type is based on the design indicated in the above figure. It is more utilized in smaller valve sizes in Z-shapes or cast steel valves in globe shape and not for high pressure drops. ***Figure 13.***

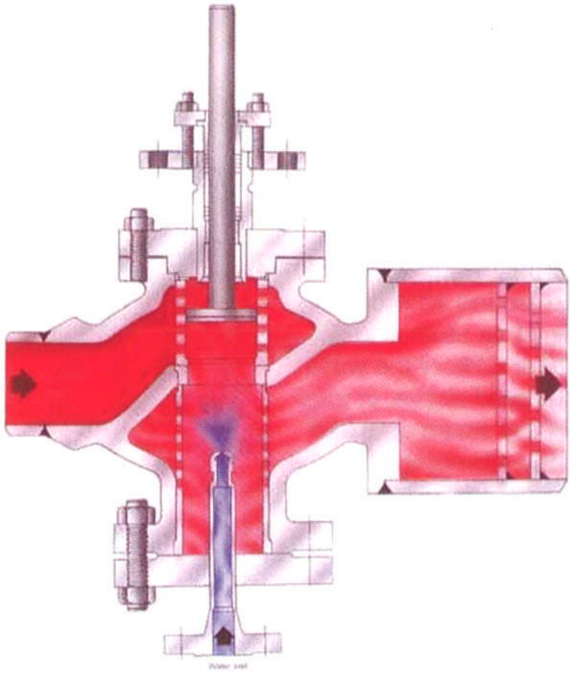


Figure-13: Steam conditioning valve with spray water injection near the cone through a separate nozzle

All the above designs discussed require an evaporation distance which varies with desuperheater designs and operating conditions. A standard approximation resulting from the evaluation of many applications with steam conditioning valves is shown in the following diagram:

- V characteristic value
- r vaporization heat
- h_w enthalpy of water
- h_1 inlet steam enthalpy
- h_2 outlet steam enthalpy
- h enthalpy of water at saturation point.

The following diagram can be applied for all the above stated and discussed designs. In any case, the shortest distance of straight pipe should not be less than 10° diameter at the outlet of the desuperheater. However, to exactly derive at straight length requirements, various factors are required to be considered - which are not discussed in this paper. ***Figure 14.***

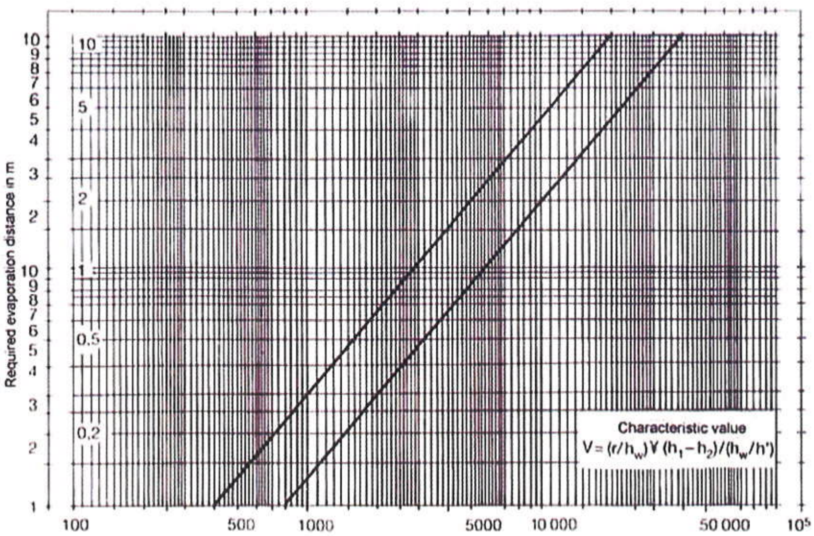


Figure-14: Required evaporation distance

DESUPERHEATER DESIGNS USING ATOMIZING STEAM:

It is very well accepted and known that the most efficient method for complete and rapid spray water evaporation is to utilize atomizing steam. Normally a small amount of steam is accelerated to sound velocity and even further to supercritical velocity in a Laval nozzle. At the outlet of the nozzle where steam velocity is maximum, spray water is injected. The high velocity of steam and spray water leads to a formation of very small water droplets which have maximum surface area required for heat transfer and the evaporation due to this is almost instantaneous. In order to generate high steam velocity, atomizing steam at high pressure is required. The pressure drop over the Laval nozzle has to be at least critical. Usually the atomizing steam flow is not controlled by a separate control valve, but is calculated for the maximum operating conditions by adequate designing of the flow areas. It has been proved by experience that about 20% of the water flow rate, in terms of mass flow, is adequate for excellent water atomization.

A typical HP bypass valve requires about 20% of spray water which corresponds to around 20% of the steam flow. At an atomizing steam flow rate of 20% of the water quantity, as indicated above, in total a flow of 4% of the steam quantity is required for the atomizing steam. This results in a rangeability of about 25:1.

STEAM ATOMIZING NOZZLE:

This is a unique design of Laval nozzle. The spray water coming from the external spray water control valve is injected into the Laval jet. The outlet is covered by highly energized steam and this unique design prevents water droplets to touch hot body walls which may lead to thermoshock problems. Due to its excellent designing no thermal sleeves are required. ***Figure 15.***

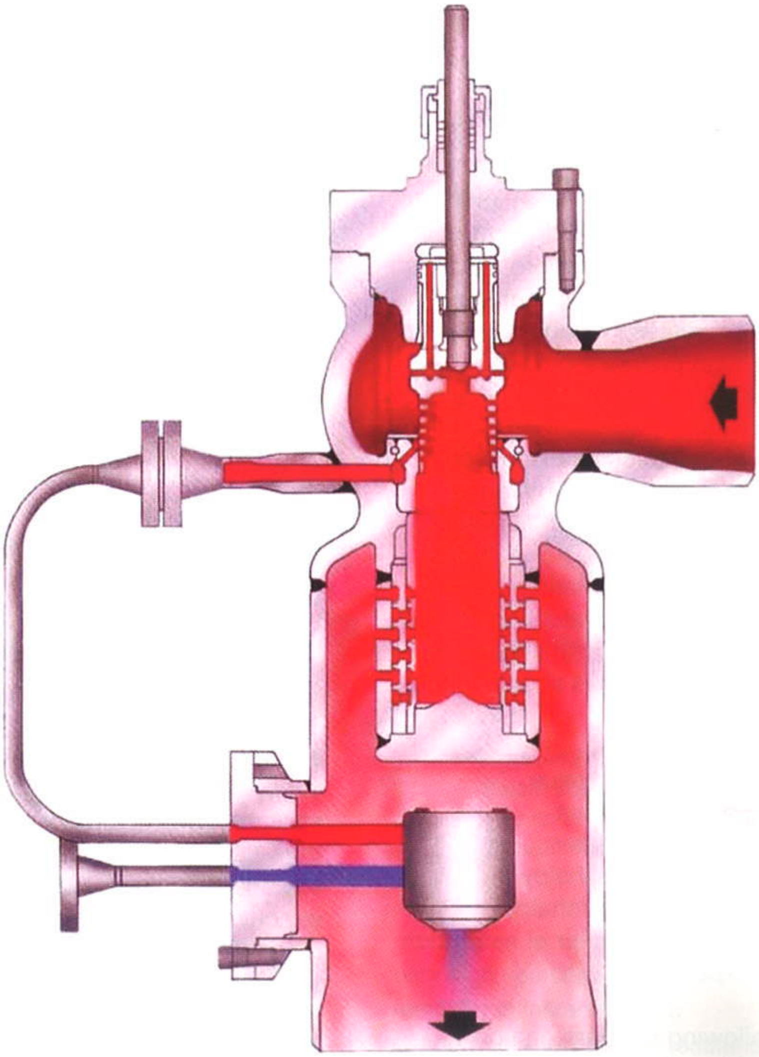


Figure-16: Steam conditioning valve with atomizing nozzle at the valve outlet

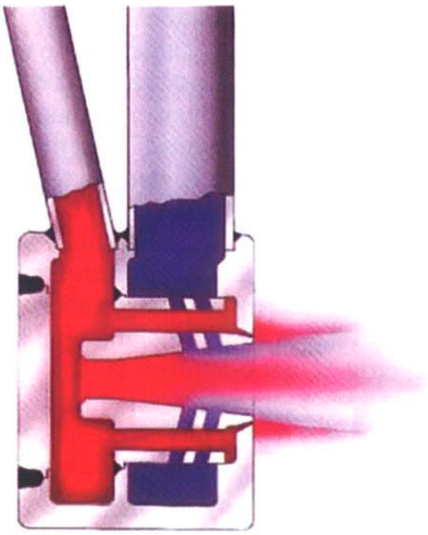


Figure-15: Steam atomizing nozzle

STEAM CONDITIONING VALVE WITH ATOMIZING NOZZLE AT THE VALVE OUTLET:

This design incorporates a separate atomizing nozzle at the outlet of the valves. The atomizing steam is extracted from the high pressure side of the valve shortly downstream of the valve seat.

At the point of extraction, the pressure throttling process is not initiated and the atomizing steam is transported to the desuperheating (Laval jet) nozzle by an external line. No additional atomizing steam valve is required. ***Figure 16.***

STEAM CONDITIONING VALVE WITH ATOMIZING NOZZLE INCORPORATED IN THE PRESSURE REDUCING STAGE AT THE VALVE OUTLET :

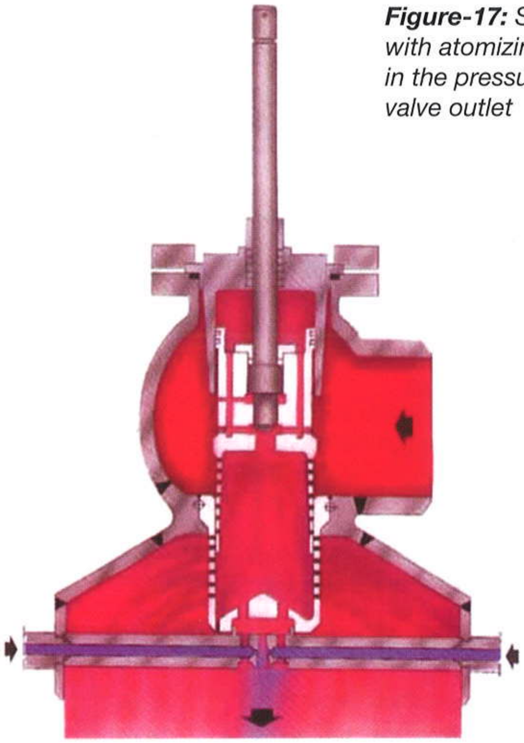


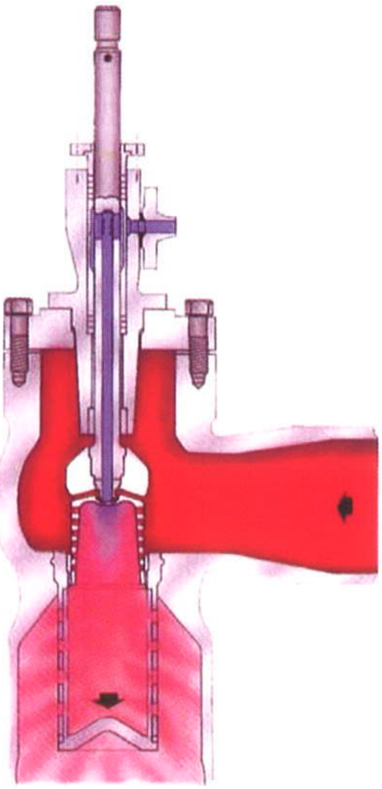
Figure-17: *Steam conditioning valve with atomizing nozzle incorporated in the pressure reducing stage at the valve outlet*

In this design the atomizing nozzle is incorporated in the pressure reducing stage (silencer) at the valve outlet. The Laval nozzle is not of straight type by is a ring nozzle and for this particular application creates a circular Laval jet. The spray water is transported through channels in the pressure reducing plate and injected into the Laval ring nozzle.

No external line for atomizing steam is required and can only be utilized if additional pressure reducing stages are required (as silencers). At critical pressure drop over the valve seat the pressure of the atomizing steam is about 50% of the inlet steam pressure. In view of this, this design requires twice the critical pressure drop over the valve. This is normally the case in HP-bypass applications. ***Figure 17.***

STEAM CONDITIONING VALVE WITH ATOMIZING NOZZLE INCORPORATED IN THE VALVE CONE :

The basic idea is same as that indicated in ***Figure 12*** and in addition atomizing steam is utilized, extracting the steam just downstream the valve seat portion. The steam is expanded in Laval ring nozzle as shown in ***Figure 18***. The spray water is transported through the hollow stem, and injected close to the nozzle outlet. Together with the main steam flow though the cage type cone this design provides excellent water evaporation. However, it requires considerable high spray water pressure. Also the spray water quantity is limited to 20% of the steam flow.
Figure 18.



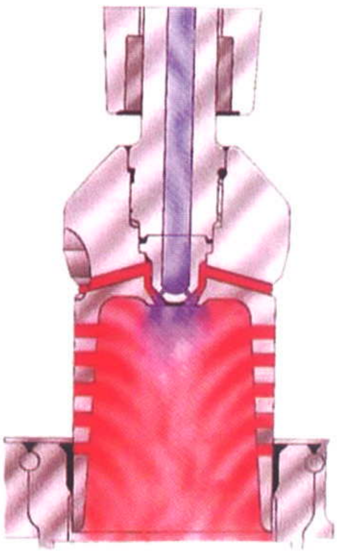


Figure-18:
Steam conditioning valve with atomizing nozzle incorporated in the valve cone

HP-BYPASS VALVE WITH SPRAY WATER INJECTION THROUGH HOLLOW STEM:

This design is exclusively utilized and developed for HP-bypass valves with code safety function for the boiler. According to German standard, TRD a combined HP-bypass and safety valve can be utilized without additional safety valves. This valve must tend to fail open in case of signal failure and as a result the steam flows through the valve in opening direction.

The valve cone features a two-stage pressure reduction by a special design of the flow passage. The spray water is transported through the hollow stem. It is injected into the steam after the first critical pressure reduction. In this portion the steam has almost sound velocity. This unit utilizes the whole steam flow for atomizing and the steam velocity remains critical at all operating conditions.

For the above desuperheating designs which use atomizing steam outlet temperatures as close as 3 c above saturation can be achieved depending on operating conditions and the temperature sensors can be located at a straight distance of 3 to 4 times outlet size measured from the valve outlet.
Figure 19.

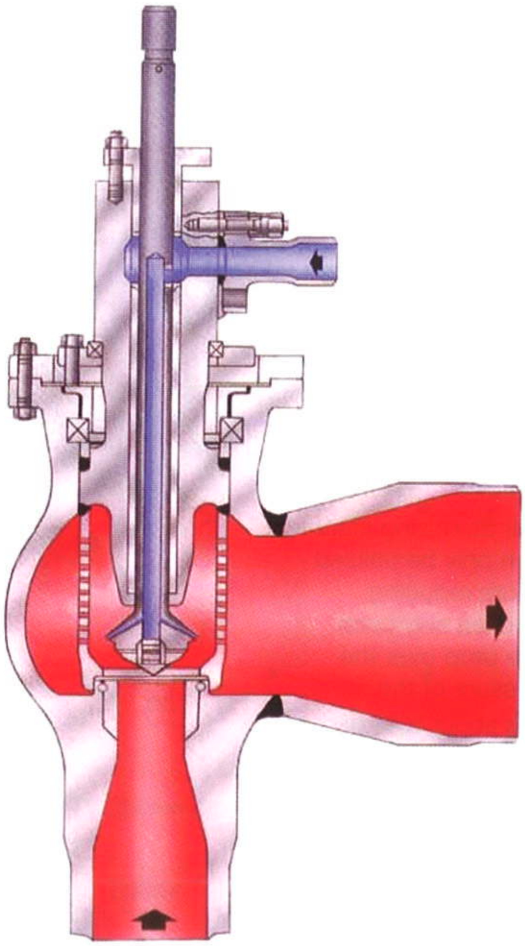


Figure-19: *HP-bypass valve with spray water injection through hollow stem*

SMART COMBINATION OF VARIOUS COMPONENTS YIELDS TO EFFICIENT DESUPERHEATING:

a) It is advisable for the upstream control valve to have a higher rangeability than the desuperheater. Normally these valves should operate between the control range of 8% to 90% of full flow. Over sizing reduces the range ability and should be avoided.

b) Piping from the pressure control valve should be long enough to ensure flow entering the desuperheater is laminar, however should not be excessively long. If desuperheater and valve are very near or valve is situated near a bend or a wall, noise and vibration may occur. It is advisable to have elastic supports and not fixed supports and these supports should be on the pipe rather than the valve to reduce stresses on the valve body. In case of support on the valve body the stresses induced into the body by the piping are higher. The basic idea is to have the valve stronger than the piping.

c) Distance to the temperature sensor is of prime importance. It is advisable to have undisturbed straight length of 9 to 10 meters, as a rule of thumb, before placement of temperature sensors. It is best to locate the sensors after the first bend at the inside radius in an elevated position (about 15° above horizontal). This method ensures that the correct temperature is measured and the water droplets in the pipe line are carried to the outside radius of the bend by their kinetic energy.

d) Temperature sensors and / or thermocouples should be quick enough to respond as per the changes in process parameters. Temperature measurement in much more delicate and care should be taken that correct measurements are recorded even at low loads.

e) As indicated above time lag for temperature transmission is not recommended. Electronic temperature transmitters are best devices for rapid transmission. Mercury filed systems are slowly being phased out since they have limitations and are adopted for distances less than 6 to 8 meters.

f) Advanced temperature controllers with adequate proportional range are recommended to cover the full operating range of the desuperheating system.

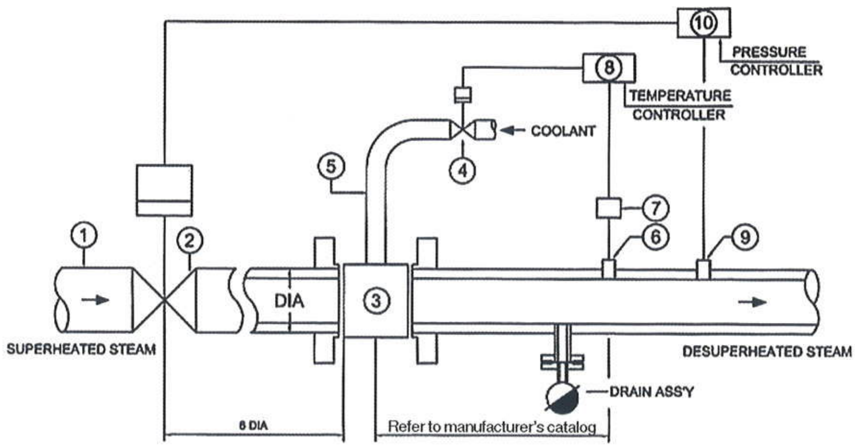
g) Range ability of spray water control valve should be higher than that of desuperheater and pressure reducing valve. High pressure drops should be avoided and careful designing is envisaged to avoid flashing, cavitation and reduce wear on the trim parts.

h) It is recommended to have pressure sensors located as close to the point of usage as possible, downstream of the desuperheater.

i) Efficient pressure controllers are recommended to maintain desired set point to ensure there is no hindrance for temperature control. They should have sufficient proportional range and should respond quickly as per the load demands.

j) For highest efficiency it is always advisable to locate the entire desuperheating system as near to the point of usage as possible. The piping should be properly insulated to ensure no heat losses in the atmosphere takes place, thereby reducing the efficiency of the desuperheater.

k) Final important point is that water should be clean and pure to avoid any clogging in the nozzles. Water pressure should be high but not to an extent that it cavitates in the spray water control valve. Water temperature should be high as it readily breaks into small particles for rapid heat transfer as the surface tension of the water decreases as temperature increases.



1	Steam piping	6	Temperature sensor
2	Pressure reducing valve	7	Temperature transmitter
3	Desuperheater designs	8	Temperature controller
4	Coolant control valve	9	Pressure sensor
5	Coolant piping	10	Pressure controller

Figure-20 : Smart combination of various components yields to efficient desuperheating

IMPORTANT FACTORS IMPROVING STEAM DESUPERHEATING PERFORMANCE:

1) As discussed earlier, direct contact desuperheaters are a combination of mass transfer and heat transfer phenomena. These processes are not instantaneous but require time. They are affected and dominated by total surface area, density, viscosity, velocity, pressure, temperature and enthalpy of both steam and spray water.

2) The desuperheating system consists of various individual components and not only desuperheater. To obtain the best results in terms of efficiency and costs as mentioned earlier over sizing should be avoided. In fact, if a desuperheater is oversized to cater to future requirements and is designed and subjected to function, it is bound to fail as it will operate at low rates leading to innumerable problems like erosion, wire drawing etc.

3) It has to be ensured that the spray water should be sufficiently clean to avoid any deposits in the desuperheating nozzle if water evaporates there partly. Although the washing of the spray water is undoubtedly effective in clearing away most deposits, others have been known to adhere tightly, admittedly not hampering the performance significantly.

4) Very few processes are harmed by a slight amount of superheat. It is always recommended to avoid desuperheaters operate close to saturation temperatures. Large amounts of uncontrolled spray water droplets will cause more harm than to accept a few degrees of superheat in steam flow. For conventional simple desuperheating system, it is recommended to have 5 to 10°c of superheat in the steam for full operating range indicates the possibility of spray water control valve constantly going on increasing the spray water quantity without realizing that the main line is being flooded with subsequent danger of thermal shock and water hammer. Far more complicated and excellent designs are required to ensure satisfactory performance of the desuperheaters very close to saturation temperatures, however downstream safeguards are necessary to dispose of excessive water, just as in simpler terms.

5) It is of prime importance that sufficient tapping of downstream piping of the desuperheating system is available. Unevaporated water tends to collect on the pipe wall and move forward and downward. A collecting tee or branch with a trap is ideal to eliminate water as soon as possible, with good general trapping practice.

6) If the temperature difference between steam and water is more than a few hundred c or if the pipe wall is over 1/2 inch thick then it is advisable to incorporate thermal sleeves / liners. Mostly they are avoided because of their cost and overall inconvenience. Thermal sleeves allows hot steam to flow past the liner and keep it at operating temperature. The thermal shield is thin enough to keep thermal stresses low even if water droplets impinge on it, and even if cracks form on it, the main wall is left intact.

7) Irrespective of steam flow or the pressure of water or steam, the desuperheater nozzle has to break up water droplets into fine particles for instantaneous evaporation. Size of a water droplet is very important and larger droplets may remain in suspension for a long time in the downstream piping before evaporating, or they may fall out and impinge on the pipe wall. Once on the wall, drops can form a film of water which is not readily controllable, heat transfer will be lower and thermal effects on the pipe wall may be undesirable, in addition to heavy damage done by drops striking the wall. In view of this, large water droplets injected into the steam pipe lines should be avoided by all means.

SUMMARY

There are varieties of steam conditions valves and desuperheater designs available to meet almost all the requirements.

The operating conditions and the (downstream) piping system have to be carefully checked in order to select the most suitable and economic desuperheating system.

PRINCIPLES USED IN CONTACT TYPE DESUPERHEATING

Procedure	Equipment	Moving Mechanical Parts	Pipe Line Pressure drop	Purpose	Conclusion	Configuration	Approximate Cost
Procedure-I Treat this steam to ensure it is readily received by the water	Single & Double Venturi Desuperheater	None	High	Steam Pressure reduction at the point of water injection	Significant velocity difference between steam and water for rapid heat transfer (steam velocity high while water velocity low) Turbulence due to steam pressure reduction results in complete mixing of water particles with steam. Water entrained is promoted to flash in the low pressure zone.	Pipe Line	High
	Pressure Reducing cum Desuperheating Station	Yes	High			Reduciing Valve	Very high
Procedure-II Treat the water to ensure it is readily received by the steam	Multinozzle & Variable nozzle Spray Desuperheater	Yes	Nil	To inject water at high pressure	Small water particles are created for maximum surface area to ensure excellent interaction with steam. Significant velocity difference between steam and water for rapid heat transfer.	Pipe Line	Moderate
	Laval Jet Atomizing Desuperheater	None	Nil	To increase Velocity of water	Significant velocity difference between steam and water for rapid heat transfer ensures good "brushing action" for smaller water particles.	Pipe Line	Moderate
	Preheater	None	Moder-ate	Preheating	Water vaporizes quickly when in contact with steam. Higher temperature of water ensures it evaporates quickly.	Pipe Line	Moderate
	Simple Mechanical Spray Desuperheater	None	Nil	To inject water at high pressure	Small water particles are created for maximum surface area to ensure excellent interaction with steam. Significant velocity difference between steam and water for rapid heat transfer.	Pipe Line	Very low

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