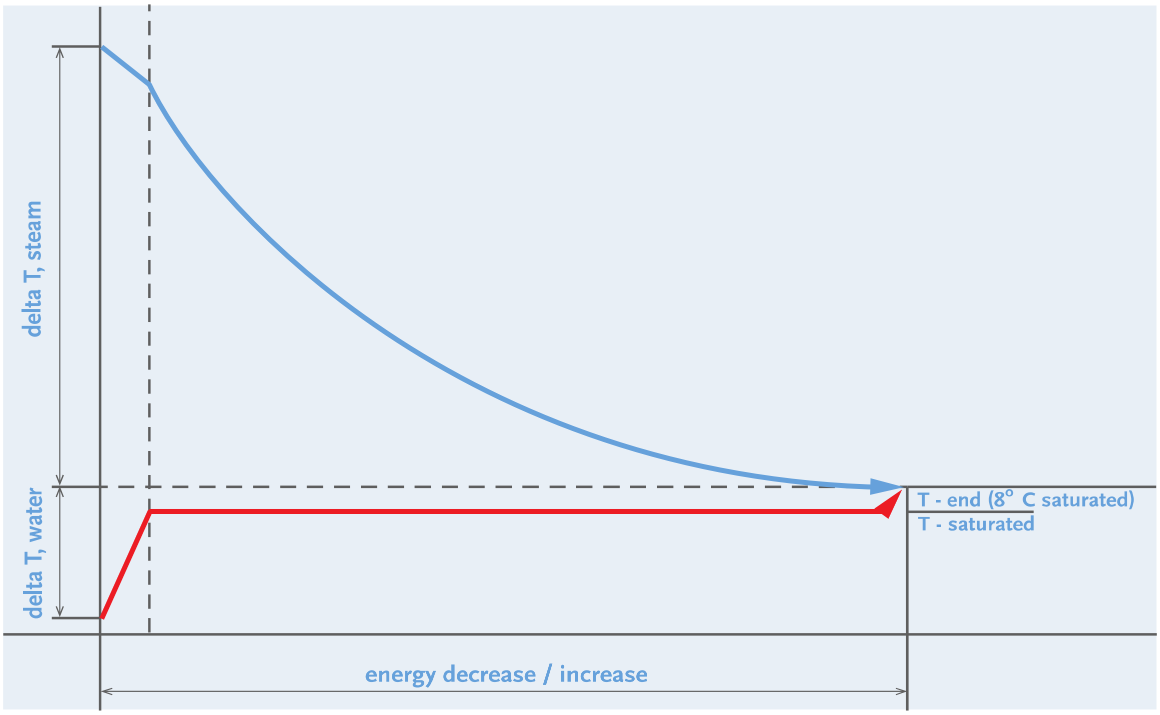
STEAM COOLING

Two shift operation power plants

Power stations that were originally designed for base load applications are now increasingly being asked to operate on a two shift, stop/start regime; this is more commonly known in the industry as dual shifting. The multiple start/stops that these stations are now experiencing is in some instances causing an increase of operational issues due to the to the constantly changing process parameters. For example dual shift stations will experience additional thermal stress in the headers, drums, high temperature piping, valves plus the auxiliary equipment leading to additional wear and tear of their systems and component parts. This is due to the more frequent use of the plant at severe service conditions. The consequences of the change in plant operation cannot be ignored. If the plant is not operated correctly or more importantly modified properly to handle these changes the lifetime of the components within the plant will decrease enormously.
The changing operational requirements of the plant require that the steam coolers, de-superheater valves, drains, feed water control valves, main steam isolation valves and the turbine quick closing valves are reviewed. These critical pieces of equipment have to be specifically designed to take the new dual shifting process requirements into consideration, once this has been done the operational performance of the plant can be improved and wear and tear of systems and components can be controlled and significantly reduced. Consequently as these pieces of equipment have been specifically designed for the new operating conditions of the station they are no longer a limiting factor to the start up time of the plant.
The following paper highlights some of the more common issues found in dual shifting power stations with special regards to steam control

Steam cooling, The Theory

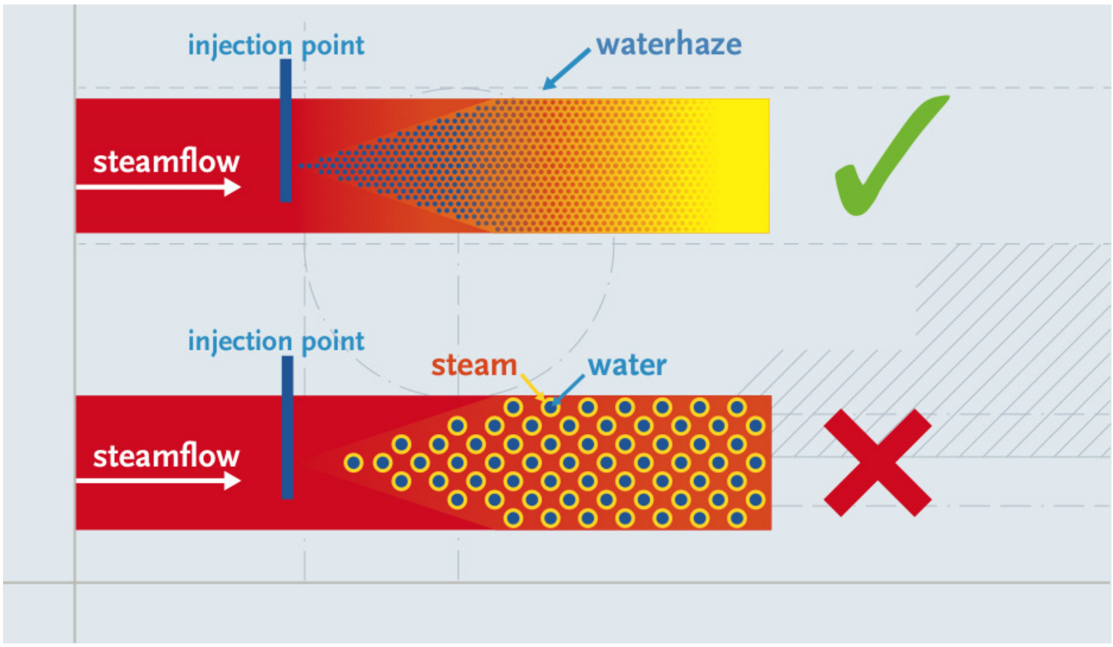
Steam cooling is the opposite process of super heating and is in fact the destruction of Heat, however this function is crucial in steam boilers and other process installations.
As the cooling water is brought into the superheated steam, it will quickly reach its boiling point and will start to evaporate. The energy needed to do so is taken from the steam around the water and the temperature of the steam is effectively reduced. The graph below details two lines, with the blue line indicating the steam temperature, while the red line represents the water temperature.



Graph showing the temperatures of water and steam during the steam cooling process.

1. The droplet size of the injected water should be maintained as small as possible.
If the water droplets brought into the steam process line are as small as possible then the effective combined heat exchanging surface is maximised. This results in quick cooling taking place whereby the chance of thermal shock is significantly reduced. There are several methods of creating small droplets. Furthermore, the temperature of the cooling water should be as high as possible as this helps the evaporation process.

Schematics regarding evaporation



2. The cooling water has to be injected into a turbulent steam flow with a minimum velocity of 8 m/sec.
The turbulence will assist the droplets in evaporating. It "agitates" the droplets and prevents them from staying in a straight flow line.

3. The cooling water has to be injected throughout the whole flow, so all the steam can be cooled to the pre-set or desired temperature
Care should be taken to avoid injecting only into the centre of the process medium which could give the effect of a two phase flow. Unequal distribution of droplets by means of too narrow a spray pattern could lead to a two phase flow condition known as **stratification.** This effect has been known to give some spurious temperature readings downstream of the device ultimately leading to poor temperature control. If you have temperature control problems please contact AVS.

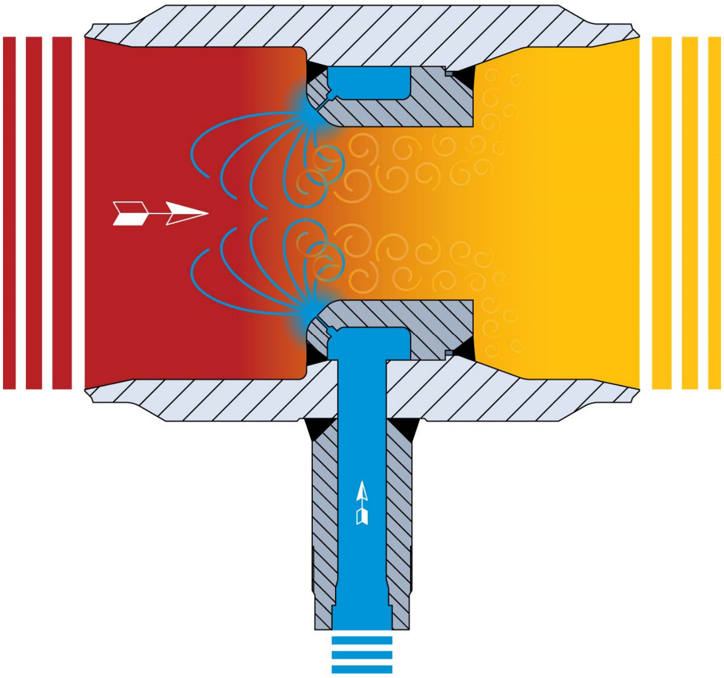
4. Sufficient superheated temperature
Steam cooling cannot be done till approx. 8 deg C above saturation, due to the influence of the wall temperature.

If the above 4 conditions are fulfilled then good steam cooling can take place

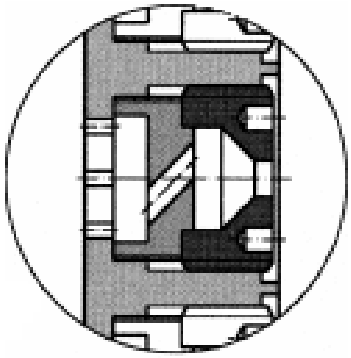
We have already *discussed the need for small droplets to achieve a maximised surface area which will assist rapid evaporation.*

How to create small droplets? This requires energy.

1. By means of a pressure drop

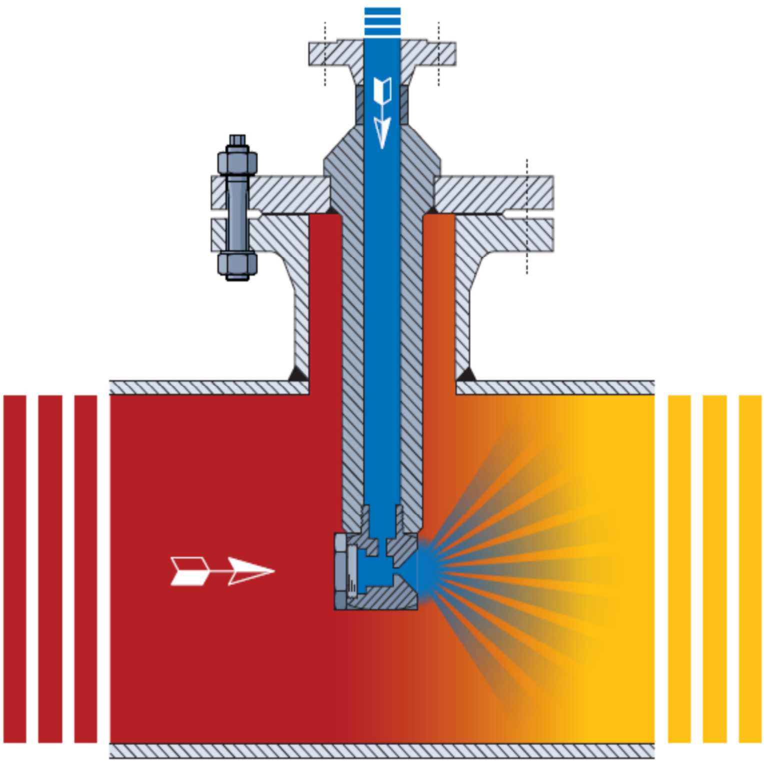


Venturi cooler with a single nozzle injection.
The venturi increases the velocity and the turbulence.
The cooling water flow is controlled by a separate control valve.



A

nozzle is a piece of equipment that optimises the creation of fine droplets. Nozzles can be used as single injection points or can be brought together in a multi nozzle injection cooler.

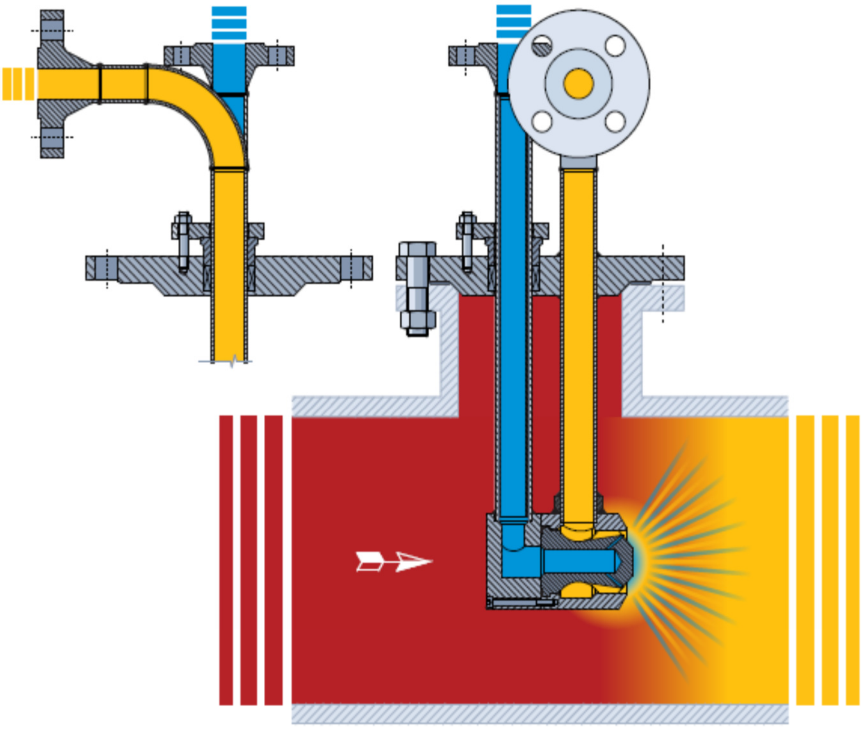


If water is pushed through a hole its velocity will create small droplets.

A single point nozzle injection. The cooling water flow is controlled by a separate control valve.

2. Steam atomising using the velocity of critical expanding steam

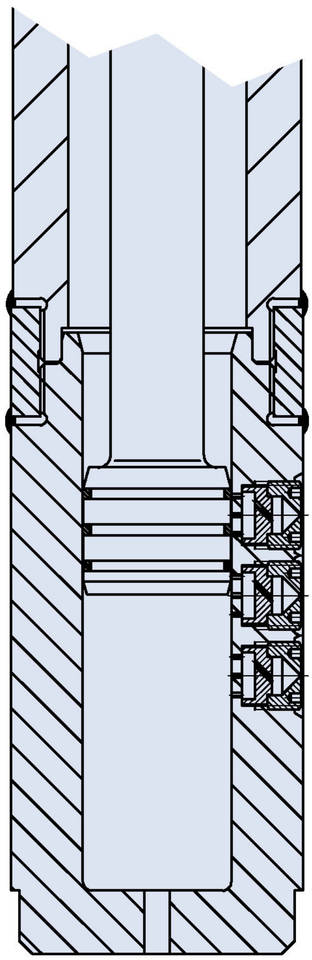
The velocity of critical expanding steam can be used to atomise cooling water.
This method is good at creating fine droplets over the full range.



Steam is brought into the outer ring, feeding into a number of bores. Critical expansion will take place creating high velocity steam. From the inside of the core, cooling water is injected through small bores into the high velocity steam. The water flow is controlled by a separate control valve

The cooling water is atomised and will cool the steam downstream.

From Base Load operation to start up



Installations running on base load do have a fairly constant set of process conditions.
The implication is that the coolers are also running on a similar constant load condition.
A basic old style cooler designed for these applications will work.
Old style coolers are based on a perforated tube with simple holes. As long as the pressure drop is high enough and there is enough turbulence from the steam flow the cooler can work satisfactory.

However if an installation is starting and stopping every day the cooling requirements are far more onerous, For a start the required valve rangeability is very high. Starting from an absolute minimum up to the maximum process conditions, through all these conditions the cooling water has to be sprayed properly.

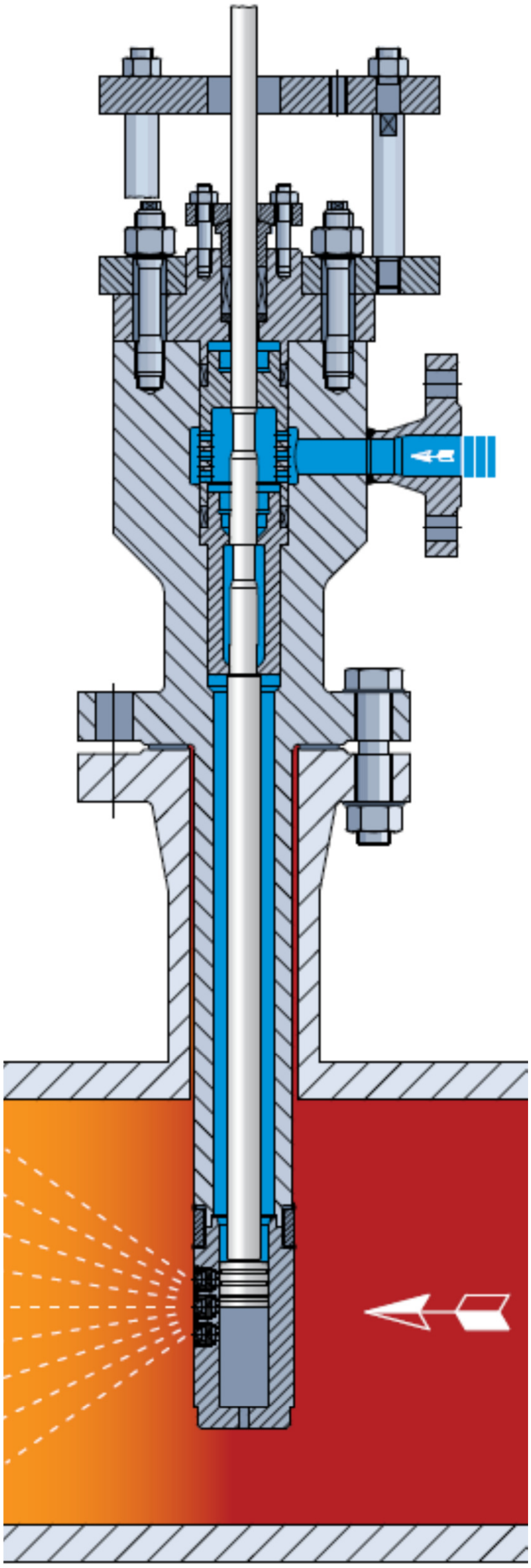
The requirements can be fulfilled by different types of coolers.

The steam assisted atomising units perform well in these circumstances.
However single nozzle coolers are limited in their range ability in these instances.

A attemperator with a number of nozzles will give the best result. For this design a piston with piston rings opens the nozzles one by one. At a minimum flow only one small nozzle can atomize really small mass flows, at maximum capacity all nozzles (up to 24) can spray an impressive amount of cooling water. In all cases the water droplet size remains at its optimal size.

Multi nozzle coolers

The multi nozzle cooler is based on the use of a set of nozzles to be opened one by one. When pushing down the plug will open the different nozzles in turn. A continuous and fine cooling spray based on the correct pressure drop is the result.



Important design features to note:

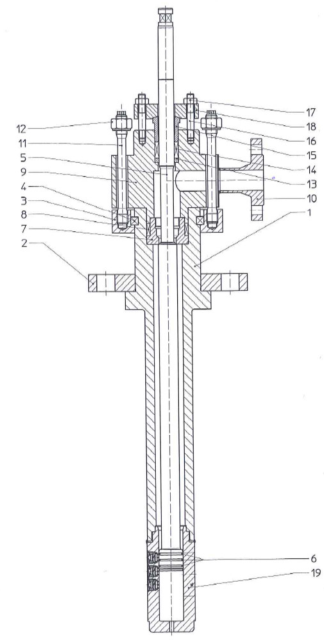
First of all, the valve body, located in the mass flow will create bending forces. **HORA** manufacture the body of the valve in a one piece forging and it can be forged in various materials such as F1, F11, F22 and P91.

Hora have located the injection water seat outside of the hot part of the cooler.

If the cooling water pressure is very high it is possible to install additional pressure reducing stages. This feature is designed to always maintain an optimum pressure drop over the nozzle.

A number of these coolers have been fitted to a coal fired power station in The Netherlands, The coolers, fed from the main feed water pump at 220 barg are cooling the hot reheat at 50 barg. The 170 bar pressure drop is handled by three control stages and the nozzle head. The coolers are performing very well.

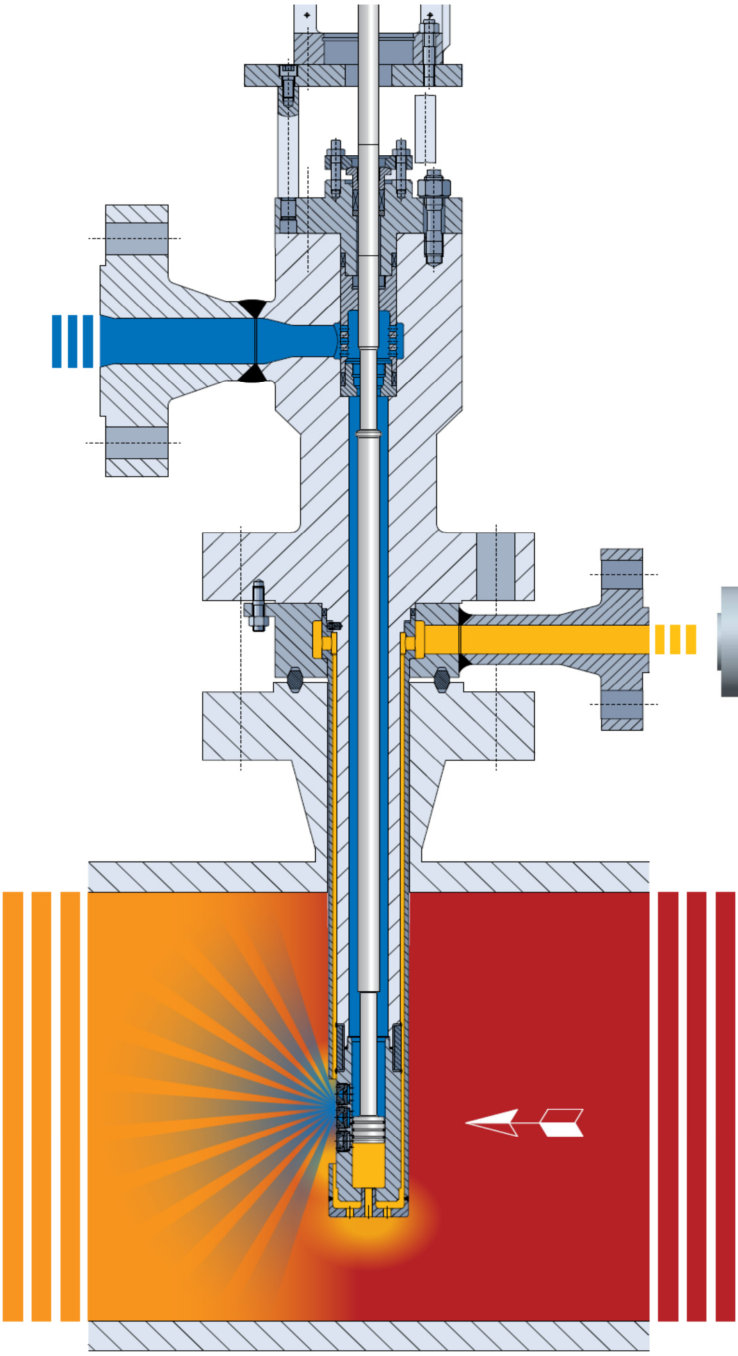
***left: HORA** standard cooler with two additional stages, single forged body and multi nozzle head. Jammed seat,*



***left:** budget version, based on "slip on" flanges, however still with a multi nozzle head and a valve body in one piece. Note seats outside steam flow*

The “cooled attemperator” or “cooled desuperheater”

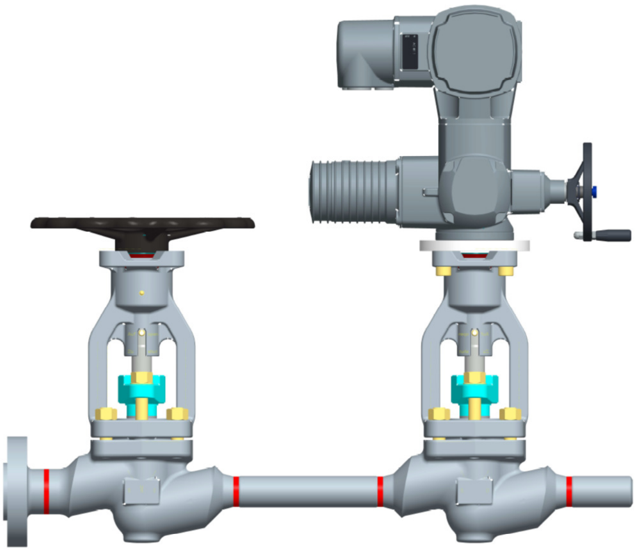
There are applications for steam coolers in very complex situations. One common example is if an attemperator is not working continuously and only has to function occasionally. This can occur for example during start up and shut down or in case of an emergency to protect the main steam lines.
In this instance the nozzle section will become very hot. The moment the cooler is required to start, thermal shock will occur and the cooler could be permanently damaged. In practice a very limited number of cycles can be expected before the cooler is damaged.



attemporator with steam control block

The solution:

To avoid thermal stress in the spray cooler the temperature differential between the

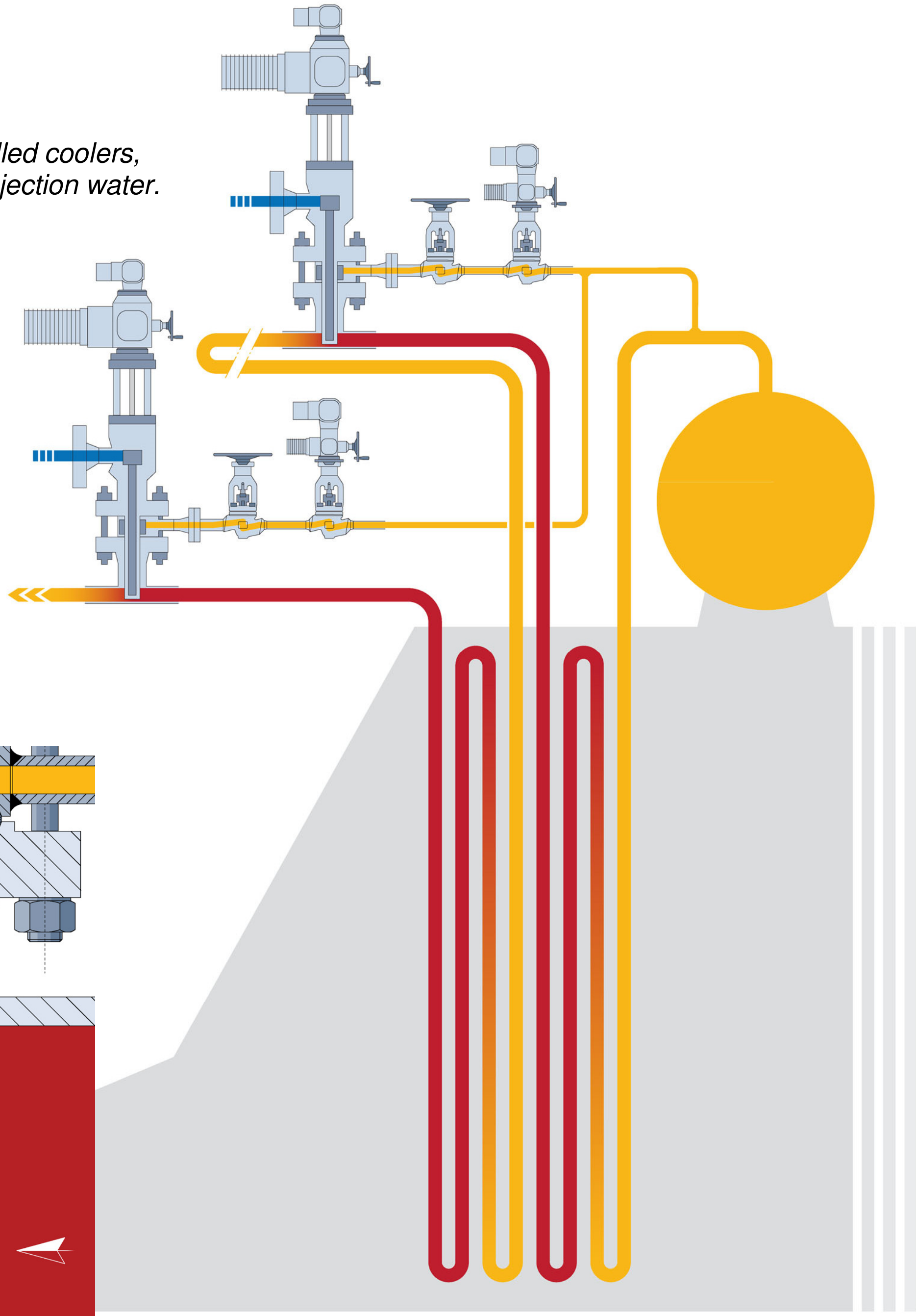


Stop-check valve and cooling steam control valve block

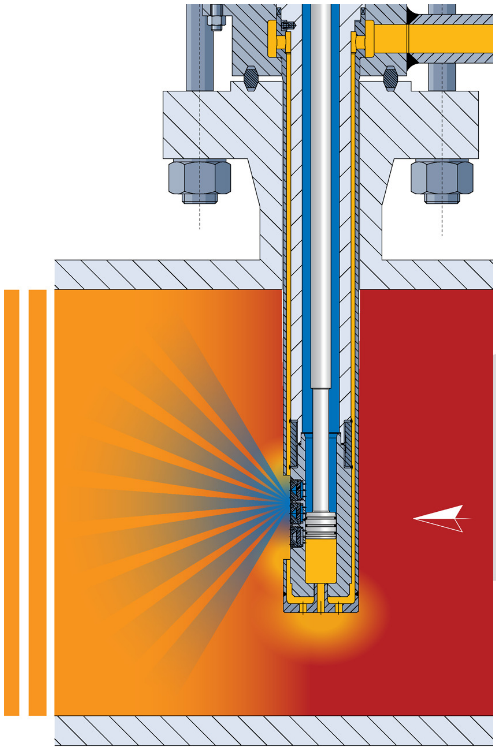
cooling water and the steam temperature should be significantly reduced. A partial solution could be found by increasing the spray water temperature.
However, a reduction of the body temperature of the cooler to the saturated steam temperature will bring the temperature differential between injection water and cooler body temperature down to figures which will not lead to thermal shock. The cooler is now suitable for numerous starts and stops.

A life expectancy of more than 25 years should be achievable.
Number of possible cycles. > 100.000

A limited amount of saturated steam bypasses the super heater and is brought into a “cooling jacket”. This steam cools the valve body keeping it on saturated temperature. The saturated steam then leaves the jacket and will mix up with the super heated steam. The saturated steam flow to the cooler is controlled by a small control valve and a manual stop check valve.



Right:
HRSG schematic with the installed coolers, cooling steam and preheated injection water.



Left:
Cooling steam flow path shown in Orange

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