COOLED ATTEMPERATORS

TWO SHIFT OPERATION POWER PLANTS

Wind, solar power and other renewables energy generation creates a more flexible demand on gas fired power stations to balance the grid. To operate in a reliable, quick, modulating and start/stop regime, some improvements are necessary.

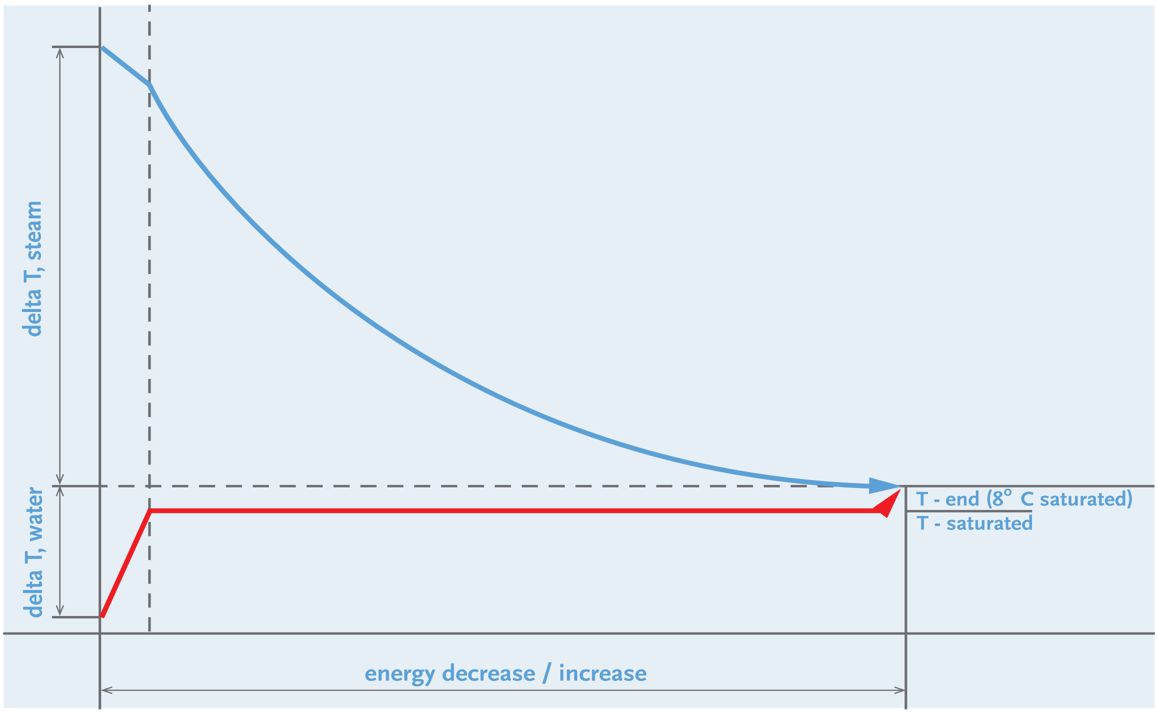
The start-up should be done as quick as possible to limit the costs and to supply as soon as possible to the grid. For all CCGT plants the demand to be reliable and the need to start quickly is the single most important driving factor.

MOST CRUCIAL

One of the most crucial components in an installation are the attemperators. The range ability, the capability to atomize the water droplets and to guarantee a good distribution makes the attemperator an installation component which have to be designed and chosen carefully.

STEAM COOLING, THE THEORY

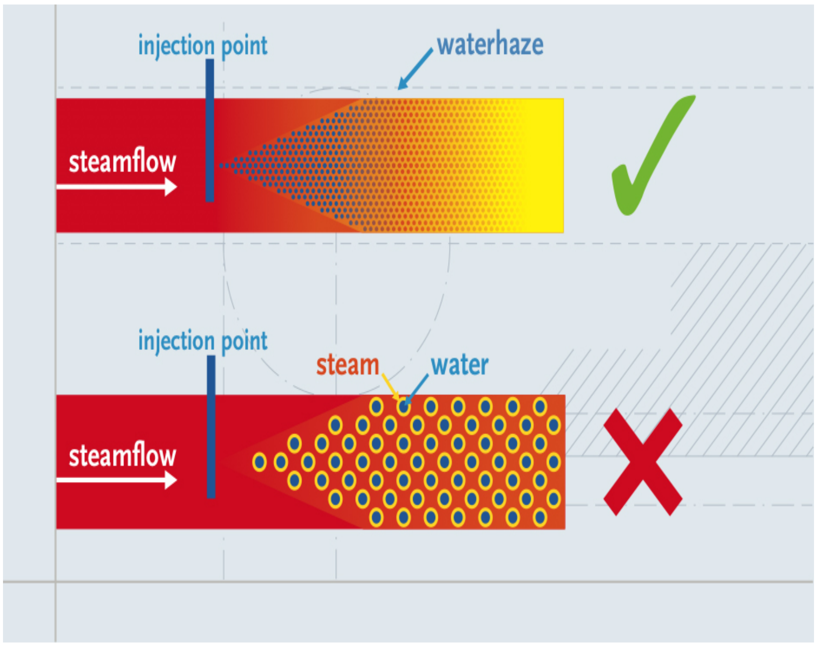
Steam cooling is done by cooling water which is brought into the superheated steam. It will quickly reach its boiling point and will start to evaporate. The energy needed to do so is taken from the steam around the water and the temperature of the steam is effectively reduced. The graph below details 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, the effective combined heat exchanging surface is maximised. This results in quick cooling. 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 high as this helps the evaporation process.



Schematics regarding evaporation

pressure drop at point of injection

2. THE COOLING WATER HAS TO BE INJECTED INTO A TURBULENT STEAM FLOW WITH A MINIMUM VELOCITY OF 10 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

Injection of small droplets in the centre of the turbulent flow gives the best distribution of the drop lets and avoids impeachment on the wall.

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.

FROM BASE LOAD OPERATION TO START UP

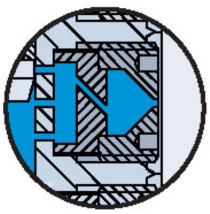
Installations running on base load do have a fairly constant set of process conditions. The attemperators are also running on a similar constant load condition. A basic old style cooler design for these applications will work.

If an installation is starting and stopping (dual shifting) the attemperation requirements are far more onerous, For instance the required cooling range ability is very high. Starting from an absolute minimum up to the maximum process conditions the cooling water has to be sprayed correctly.

HOW TO CREATE SMALL DROPLETS? THIS REQUIRES ENERGY.

BY MEANS OF A PRESSURE DROP

Pressure drop creates small droplets. This pressure drop should take place at the point of injection.



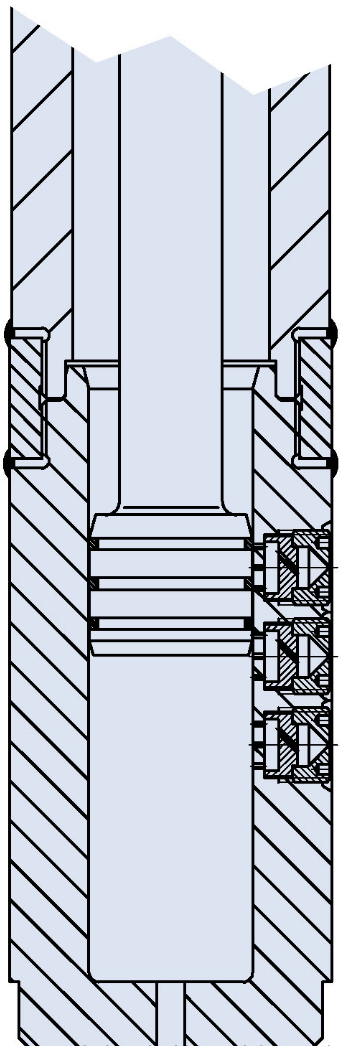
typical spray nozzle

By using a spray nozzle, the pressure drop is used to create an additional swirl. If the first nozzle has a small CV value fine cooling can be achieved. Single nozzle coolers are limited in their range ability in these instances.

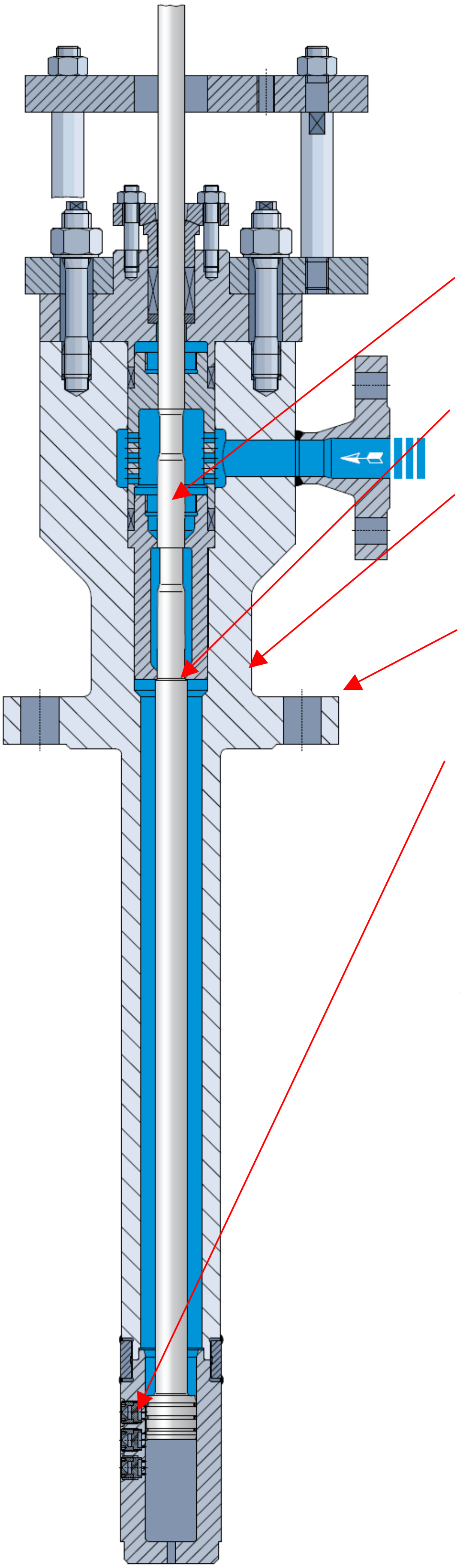
A cooler with a number of nozzles will give the best result. For this design a piston with piston rings opens the nozzles one by one.

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 optimum.

A limitation is found in the pressure drop over the nozzle. Pressure drop creates fine droplets; too much pressure drop creates additional wear and tear. This can be an important issue especially for the hot reheat attemperators.



nozzle head with multiple nozzles



The multi nozzle attemperator is based on the use of a set of nozzles which opens one by one. When pushing down the plug the different nozzles will open one after the other. A continuous and fine cooling spray based on the correct pressure drop is the result.

BENEFITS

1. 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.

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

3. The valve body, located in the steam flow, will be subject to 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.

4. Different connection flanges in EN/DIN and ANSI are available to suit your installation.

5. A multi nozzle head with a selection of different nozzle sizes to create the best possible capacity and characteristic.

6. The cooler can be fitted with a pneumatic, an electrical or a hydraulic actuator.

EXAMPLE

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, Jammed seat and multi nozzle spray head.*

HIGH CYCLE ATTEMPERATOR

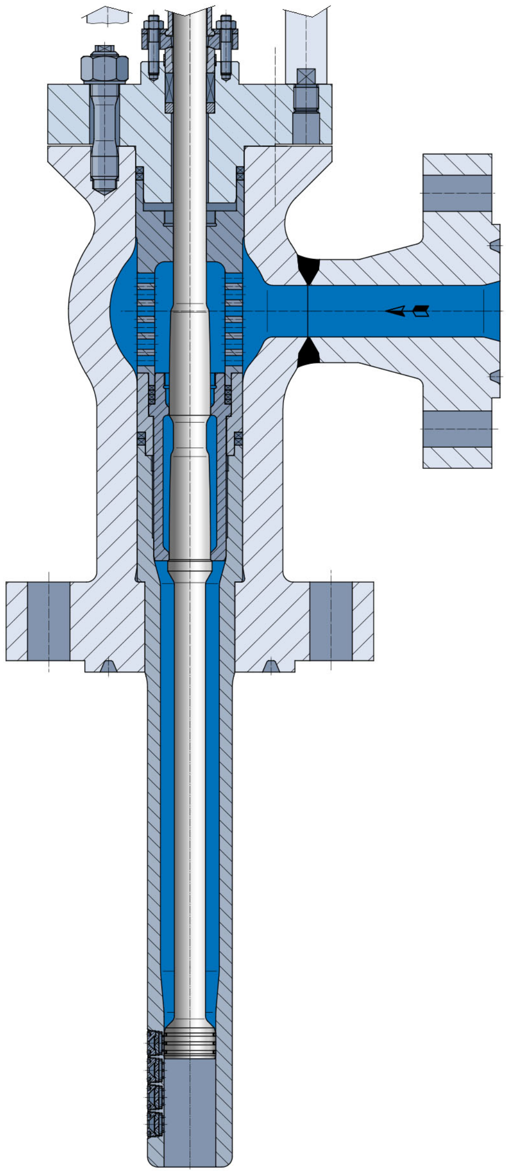
There are applications for steam coolers in very complex situations. One common example is if a cooler is not working continuously and only has to function occasionally. This can occur for example during start up and shut down or in case of an emergency to protect the main steam lines. In this instance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

In attemperators with a screwed on nozzle head the thermal shock will damage the construction. After a limited number of cycles the attemperator will fail.

A significant improvement is made with the introduction of the high cycle attemperator design.

In this design the mast and nozzle configuration is integrated. The wall thickness con be reduced and the resistance against thermal shock in increased significantly. This design represents "state of the art" performance.

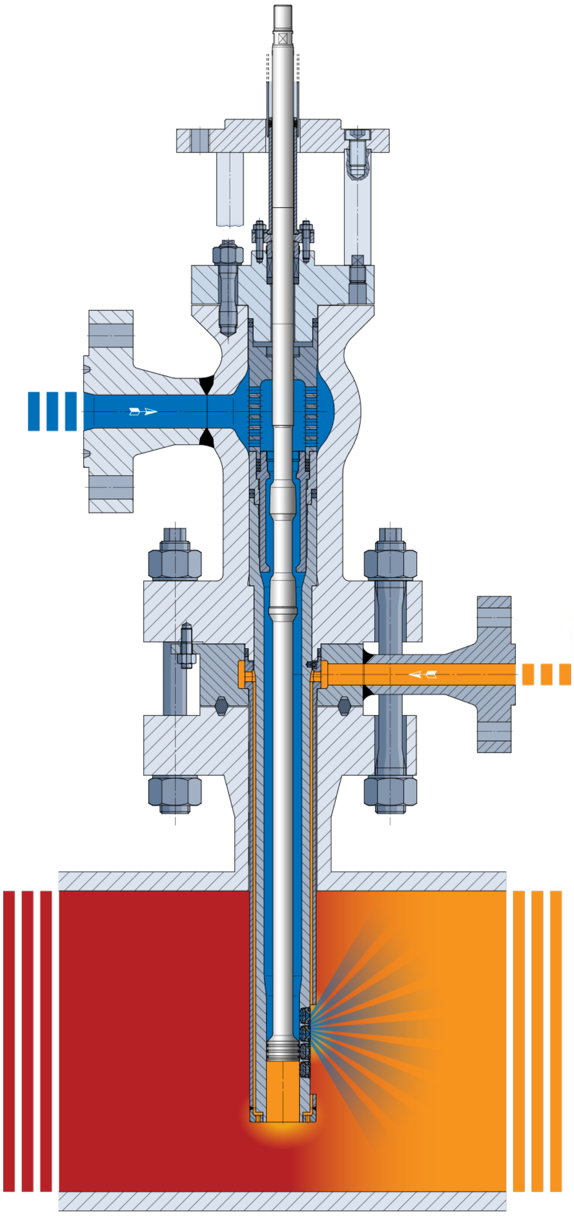
Fine droplets over the full range ability, superior cooling and a long life cycle. Ideal for frequent starting and stopping.

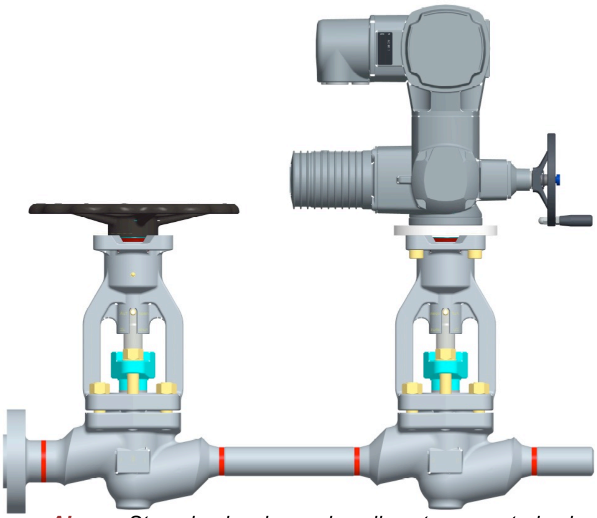


HORA high cycle attemperator

THE COOLED ATTEMPERATOR SOLUTION

To reduce thermal stress in the spray attemperator the temperature differential between the 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.





Above: *Stop-check valve and cooling steam control valve block.*

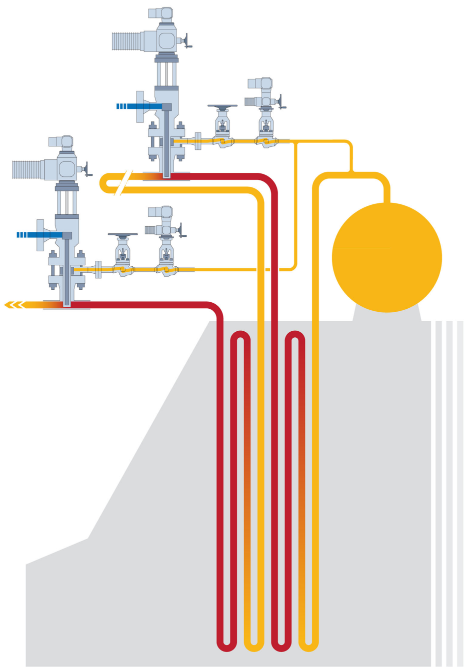
A LIFE TIME EXPECTANCY OF MORE THAN 25 YEARS OR › 100.000 CYCLES SHOULD BE ACHIEVABLE.

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 to the 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.

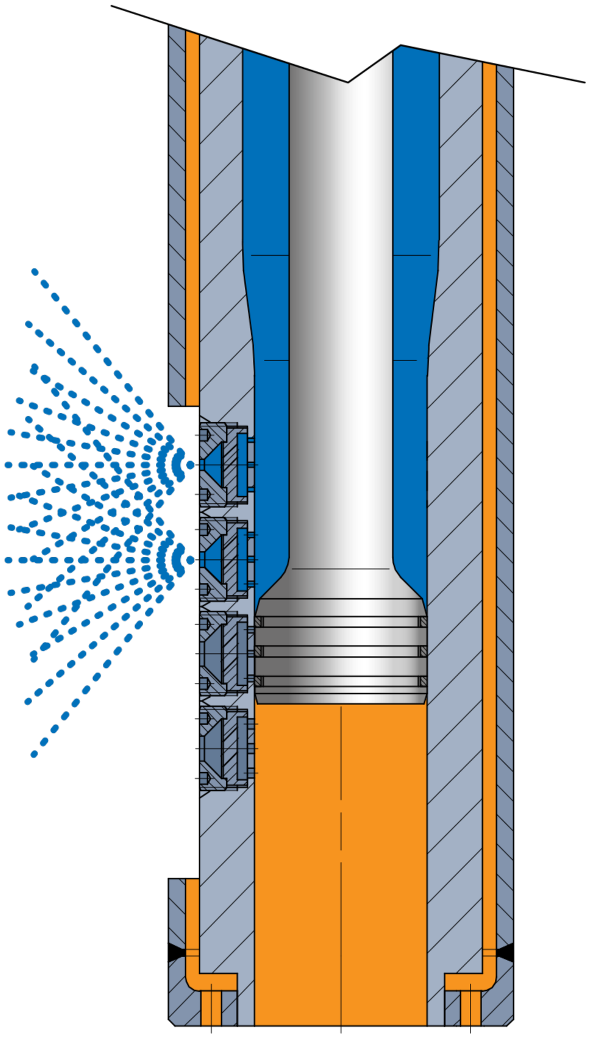
Above: *Attemperator with steam control block.*

RIGHT:

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



Cooling steam from overflow line



RIGHT:
Cooling steam flow path shown in yellow

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