Contemporary Desuperheater Design

Desuperheaters are a vital part of power generation applications. This article shows how an enhanced design can extend product life and improve system performance and reliability in cycling service.

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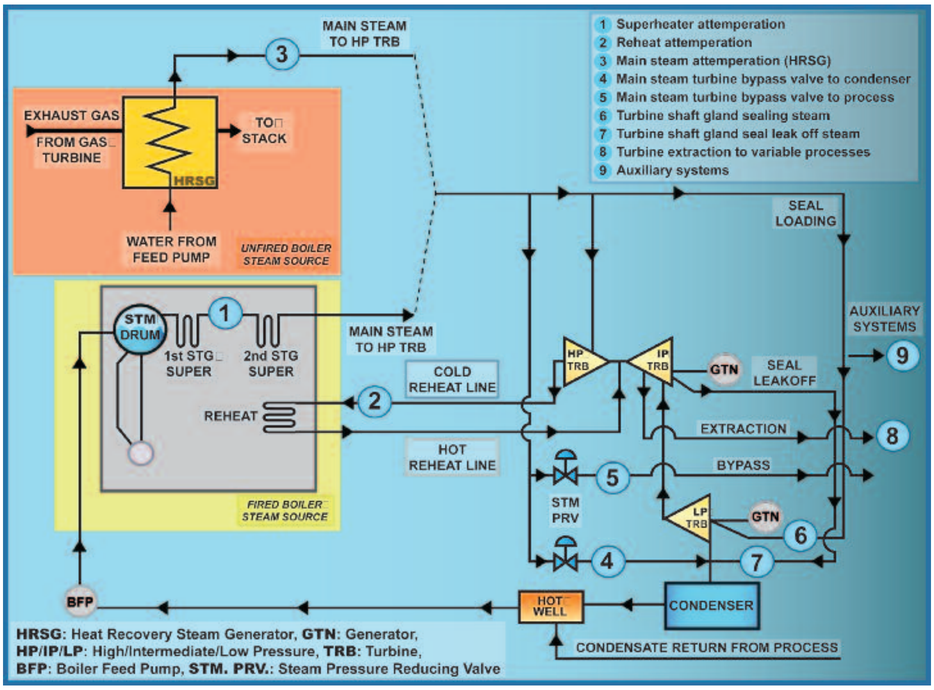

Figure 1. Typical power generation desuperheater applications.

Introduction

Multi-nozzle spray desuperheaters can be specified to control the temperature of superheated steam in a variety of power generation applications. Careful consideration must be given to the operating parameters and related system components required to achieve optimal steam attemperation at each individual desuperheating station. Improper specification can lead to costly problems, including extended startup and shutdown times, reduced process efficiency, and general wear of downstream piping and equipment. Contemporary desuperheaters designed to enable piping to withstand the thermal shocks and stresses experienced in cycling service can also be used in less demanding desuperheating applications throughout the plant, delivering bottom line benefits to power generators.

Attemperation Applications

Figure 1 provides an overview of typical attemperation applications in combined-cycle and conventional power generation plants. While desuperheaters are a critical system component for maintaining base-load plant efficiency and protecting equipment, a more challenging application is the control of steam temperature in cycling service which is characterized by high modulation of temperature. Examples of cycling service are shown at (1) the superheater attemperation of steam from fired boilers to high-pressure turbines in peaking plants and (3) the attemperation of steam from the heat recovery steam generator (HRSG) to the high-pressure steam turbine in combined-cycle plants.

Base-load plants operate at a relatively steady output where there is generally less requirement for modulation of the temperature; therefore a simple desuperheater, such as a fixed venturi type, can be used. Peaking stations and combined-cycle plants may cycle through startup and shutdown twice a day. Properly functioning desuperheaters can significantly reduce startup and shutdown times, thus saving large amounts of fuel. These systems may also be run at different outputs, increasing the importance of desuperheater rangeability in ensuring plant efficiency and cost savings.

System Design Considerations

Desuperheaters ultimately function as part of an engineered system and therefore careful consideration must be given to the operating parameters and supporting system components required for optimal steam attemperation. These include:

- Turndown: Ensure that the rangeability of the proposed/supplied equipment meets or exceeds the turndown required. The turndown ratio specifies the range of volume of flow (max:min) and is the most important specification in determining how consistently a desuperheater can produce suitable cooling droplets. Multi-nozzle desuperheaters are most effective in applications where the turndown ratio is between 6:1 and 40:1. An improperly specified turndown ratio can result in inaccurate readings throughout the system. Over-specification is a common but costly error, both from an initial cost and process efficiency standpoint.
- Pressure drop: Droplet size is inversely proportional to flow rate/pressure through the nozzles. The lower the flow, the larger and less effective the droplets are for desuperheating. A spray-type desuperheater can become ineffective if

the flow drops below 20% of the design value of the smallest nozzle.

- **Outlet superheat:** Outlet superheat should be composed of less than 8% spray water. More than 8% spray water increases the risk of impurities being introduced into the system.
- **Pipe length:** Desuperheaters should only be installed in straight sections of pipe with no flow disruptions in order to achieve required cooling. There should be two to eight pipe diameters upstream of the desuperheater and twelve to twenty pipe diameters downstream. To ensure accuracy, the temperature of the desuperheated steam should be measured at a distance from the desuperheater that conforms with OEM guidelines (approximately 30 ft).
- **Minimum steam velocity:** To ensure the proper mixing of spray droplets with the superheated steam, the steam should be flowing at a minimum of 10 m/s (33 ft/s). If the flow of the steam is below this minimum, fallout can occur, leading to the accumulation of water and eventually to stress cracking.

When Desuperheaters Fail

Desuperheaters are a critical system component for maintaining efficiency and protecting equipment. The following are the most commonly experienced problems in desuperheating applications.

- **Startup overspray:** To compensate for temperature spikes experienced during turbine startup, desuperheaters need to spray heavily to keep steam at optimal operating levels. In conventional desuperheaters, this can result in "wet" steam, or overspray, which can have damaging effects on the tube-to-header joints and tubes within the superheaters.
- **High demand at low loads:** Exhaust temperature is often equal to, or greater than, the rated output, resulting in the steam being superheated beyond the specified control point. Desuperheaters have to spray to near saturation just to achieve the desired steam temperature, resulting in "wet" steam, which can damage steam turbines when more than 8% of the steam is spray water.
- **Leakage:** Leakage is lost efficiency during regular operation and can be damaging in other ways – such as quench cooling of select tubes, piping, or headers and/or the buildup of water in piping that can cause water hammer at the next startup.
- **Nozzle failures:** Enlarged, eroded nozzles on a desuperheater reduce the amount of atomization of the spray water. This decreases the surface area of the spray droplets, which reduces attemperation efficiency. Water droplets can form, causing thermal gradients in the piping. This forces the boiler to work harder and use more fuel than necessary. In the reverse scenario where the nozzles are obstructed, spray water will not be atomized and will be introduced into the steam as large water droplets. Spray water that does not mix or evaporate properly can damage the system.
- **Thermal liner failure:** If the liner fails, it can cause damage by impinging on the pipe with spray water and causing steam purity issues. Liner debris can travel downstream and damage equipment. Solid impurities in the steam can build up around thermosensors and in the superheater tubes, causing overheating, inefficiency, carryover damage and corrosion. Carryover can also erode turbine nozzles and blades, causing them to warp and become imbalanced. Warped turbine blades will increase the vibration and load on the turbine rotors, drastically reducing plant efficiency.

Enhanced Design Elements

Contemporary desuperheaters offer enhancements that can be leveraged to extend product life and improve system performance. Several of these associated with Hora Power Technology's Multi-Nozzle Spray Desuperheater (HPT-MNSD) (www.hora.de) are listed below:

- **Seat position:** In a conventional multi-nozzle spray desuperheater, where the seat is located inside the lower part of the valve body, energy can be wasted on heating cooling water trapped above the seat and piston. The seat can also become distorted, causing the valve to leak and producing pitting, pipe cracking and flashing downstream of the desuperheater. The HPT-MNSD locates the seating above the steam pipe, outside of the flow path and heat-affected zone. This protects the seal from distortion, helps to ensure proper shut off, eliminates the constant heating of cooling water trapped above the seat and piston, and minimizes the thermal stresses to piping caused by unequal expansion. This seat position ensures a more efficient

Preventive Maintenance

On a newly installed desuperheater, whether new or reconditioned, it is recommended that operators perform an inspection and collect baseline data after 12 to 18 months of operation. If no damage or loss of efficiency is detected, re-inspection after 5 years should be acceptable. Operators should rely on operational data in order to determine the appropriate timeframe for inspection and replacement of desuperheaters.

While the best prevention is a properly designed system, should degradation of performance occur, the following inspections should be performed:

Online Inspection

- Measure steam temperature drop across the desuperheater when spray is not required; temperature should be zero.
- Ensure that steam temperature immediately downstream is within acceptable, measurable range of saturation; +10°F for a Hora Power Technology Multi-Nozzle Spray Desuperheater (HPT-MNSD) (www.hora.de).
- Verify that the piping adheres to OEM guidelines, which should be at least two to eight pipe diameters upstream and twelve to twenty diameters downstream, in a straight pipe run.
- Ensure that the steam pipe slopes downward immediately after the desuperheater at an angle conforming to the original system design, that it has a drip leg equipped with a level switch or steam trap to prevent water or condensate buildup, and that the blowdown mechanism is functioning correctly.
- Verify that the downstream thermocouple location adheres to OEM guidelines and that water is fully evaporated when it reaches the thermocouple.
- Verify that the control valve position has not changed significantly. As the desuperheater shuts off, the control valve should approach shutoff decisively–it should not cycle or hunt. The HPT-MNSD does not require a separate control valve.

Offline Inspection

- Remove the desuperheater and assembly and inspect for cracking.
- Inspect for signs of distortion or cracking of the liner and piping.
- Inspect for pits or wear on the inside surface of piping downstream of the desuperheater.
- Inspect spray nozzles for evidence of plugging, nicks, or ovality or other erosion of nozzle apertures.

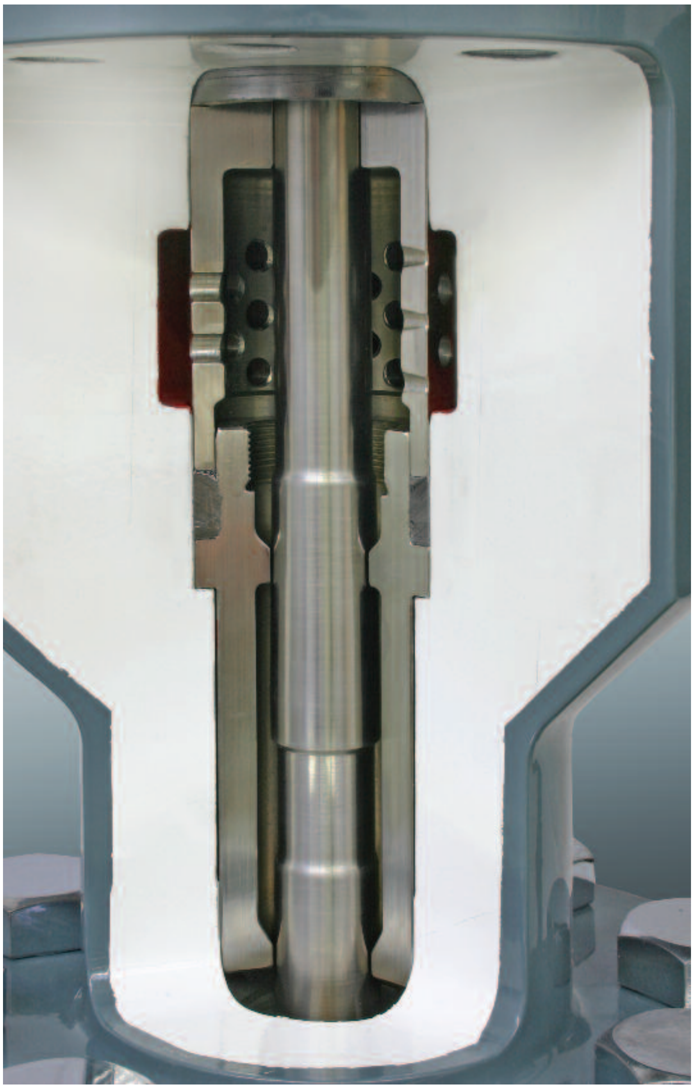

Figure 2. Cut-away of stem with one parabolic lobe.

Figure 3. Cut-away showing nozzles, plug and stem.

process, less desuperheater leakage, and less thermal stress to piping.

- One piece forging: The one-piece forging of the HPT-MNSD is ideal for use at the high temperatures and pressures demanded in cycling service. The rugged construction, free of welded connections, ensures prolonged maintenance-free operation as the HPT-MNSD will experience less cracking in high-pressure/temperature and vibration conditions that may damage desuperheaters of welded design.
- Stem plug: The stem seat and plug design on the HPT-MNSD enables it to withstand greater pressure drops than conventional desuperheaters. Typical overhaul of a conventional desuperheater usually involves replacement of the seat and costly nozzle spray head due to erosion failure caused by excessive cooling water pressure. Spray water pressure across the nozzles must exceed the steam line pressure by enough pressure to ensure optimal water atomization. If spray water pressure exceeds steam line pressure by more than 450 psi, the HPT-MNSD can drop the water pressure by as much as 400 to 600 psi per pressure drop stage up to 3 stages across a lobed stem with corresponding landings. This ensures that the pressure drops to a viable level before it reaches the nozzles thus avoiding nozzle erosion, significantly extending spray head service life, and reducing maintenance costs.
- Fewer system components: Neither a thermal liner nor a cooling water control valve are required to support the HPT-MNSD. With a pressure-reducing parabolic lobe design, the HPT-MNSD stem does not require a spray water control valve; a spray water isolation valve is sufficient.

The enhanced design elements of contemporary desuperheaters, such as the HPT-MNSD, can be used in cycling service and less demanding applications to extend product life, improve system performance and reliability, and reduce the cost of the engineered system and subsequent maintenance.

About the author

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