

HRSG preservation during shutdowns: a key issue often neglected

The preservation of HRSG fluid and steam systems during shutdown periods is an important objective at any power plant. However, this is often one of the most neglected aspects of HRSG operations. Improper layup will lead to increased corrosion, which can be the initiator of serious major failure mechanisms that will affect plant availability. Tetra Engineering has assisted plant owners and operators in developing practical preservation strategies tailored to the expected shutdown duration, equipment condition and available site infrastructure

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Plant preservation refers to a strategy used to limit corrosion and damage of power plant equipment during shutdown periods (or "layup"), including steam turbines, gas turbines, boilers, HRSGs and other steam-cycle BOP. The main objective is to isolate the critical equipment from corrosive environments. A well-considered and properly implemented preservation procedure protects plant reliability and ensures restart readiness during periods when the plant is not generating.

Why preservation matters more than ever

Preservation demand has increased in recent years as plant owners face greater uncertainty over when units may be required to operate. Although global electricity demand is increasing, the changing generation mix (increased generation by renewable sources) means that many fossil fuelled plants are operating less frequently. In some cases, operations have changed from baseload to cycling, and in others, plants are put on standby for extended periods before being called back into service. Protecting the boiler and steam cycle components from corrosion during these idle periods becomes increasingly important as the number and duration of the standby time grows.

The consequences of inadequate preservation

Without adequate preservation, boiler and steam-cycle components can be exposed to corrosive conditions on both the gas-side and waterside. General corrosion, pitting, crevice corrosion, and under-deposit corrosion are common corrosion mechanisms that occur during layup. General corrosion during layup is often responsible for generation of large quantities of iron oxides. A thin layer of corrosion over the huge surface area of



Figure 1. External boiler tube corrosion



Figure 2. Corrosion of HRSG pressure parts



Figure 3. Corrosion of steam turbine blades.



Figure 4. Internal boiler tube corrosion.

carbon steel creates a large volume of oxides. The oxides are transported to and deposited on heat transfer surfaces when the unit returns to operation. The deposits impede heat transfer and provide a crevice where chemical impurities can concentrate, further increasing corrosion.

Pitting requires a stagnant fluid and therefore virtually only occurs when the unit is shut down. Again, oxygen provides a corrosive environment, especially if chlorides are present. Pitting can progress rapidly enough to penetrate a tube wall in a few weeks. For cycling units, a more common and more insidious failure scenario is that a pit will form and grow partially through the tube wall while the unit is shut down and in layup. Upon return to

service, the pit acts as a stress riser and a corrosion-fatigue crack forms and grows. The corrosion-fatigue crack eventually causes failure of the tube.

Tetra recently had experience with an HRSG that had been relocated and left without any preservation for several years. Advanced corrosion of the boiler, including pressure parts, was evident (Figures 1 and 2).

Another instance showed heavy corrosion on turbine blades, see Figure 3, while other examples include severe internal boiler tube corrosion (Figure 4) and corroded external tube surface (Figure 5).

Clearly this is not the ideal condition of the equipment for reliable service and resulted in high costs to assess and, where necessary, repair the damage.

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Figure 5. Corroded external tube surface

What to consider when deciding on a strategy?

Deciding when standby should move into short-term preservation can be difficult and is highly dependent on the configuration and operating constraints of a given plant. If the unit is put out of service for more than one week then long-term wet or dry layup should be considered. At some plants, based on TETRA experience, the move from short to long term is often made several weeks or more after shutdown. While this is not ideal it is the reality, generally driven by operating constraints or availability of resources.

A preservation procedure should be based on general principles that are suitably adapted to the design and operating constraints of the specific site under consideration in keeping with the resources (time, money, manpower) available.

Guidelines for layup practice at thermal power plants have been issued by a number of industry organisations including ASME¹, EPRI² and VGB³, as well as OEMs.

These guidelines often provide useful high-level guidance, including on options such as wet and dry layup. However, they rarely give enough detail to define the best approach for a specific plant. The main challenge is therefore moving from the general guidance into a practical preservation strategy tailored to each given plant.

The choice of appropriate method is influenced by several factors, including:

- duration of shutdown;
- restart constraints;
- operating water chemistry and water treatment plant capabilities, availability of nitrogen or dehumidified air;
- piping layout and materials used in steam/water piping and tubing;
- condition of unit, particularly cleanliness of heat transfer surfaces;
- local environmental regulations concerning disposal of chemicals; and
- local climate, particularly humidity and likelihood of freezing over the year.

Various guidelines provide aids for choosing a layup strategy, whether wet or dry, given the particular plant operating constraints, design and local climate.

Finally, whatever the strategy chosen, planning should begin before shutdown. For example, any isolation points, temporary connections, drainage paths, monitoring

requirements and preservation equipment can be prepared while the unit is still operating.

Available preservation methods

Long term preservation can be done either wet or dry. Dry preservation requires draining the unit whilst wet preservation entails keeping the system filled with water and adjusting the chemistry before shutdown.

There are several options available depending on the plant's design and resources available, Tetra Engineering has categorised typical methods as follows:

- dry nitrogen blanketing (DNB);
- active dehumidification/drying (ADD);
- passive dehumidification/drying (PDD);
- wet preservation (WP); and
- chemical surface protection (CSP).

These are each described in detail below.

Dry nitrogen blanketing (DNB)

Dry nitrogen blanketing can be used for steam-side and water-side areas, as well as other fluid systems. It involves draining the components and filling the protected volume with nitrogen, which significantly reduces steel corrosion. Complete drying is not essential, but it is recommended that the volume is dried as far as is practicable before introducing nitrogen.

For larger protected volumes, inherent leakage usually means that an on-site nitrogen generator is required. A purity of 99.5% at a positive pressure of 0.5 barg is generally sufficient for effective protection; higher purities typically require more costly generators to deliver the same volume flow rate. Safety considerations limit use to areas where any entry into enclosed space is strictly controlled.

This is not to be confused with nitrogen blanketing in wet preservation, where nitrogen is used only to fill sections of the boiler that are not filled with water (such as the drums above waterline).

Active dehumidification/drying (ADD)

Steel corrosion rates are strongly influenced by the relative humidity, as shown in Figure 6. Maintaining relative humidity below 60% is essential and reducing it to 40% or lower greatly decreases the risk of corrosion.

The presence of airborne chlorides and other contaminants, such as sulphates, will increase corrosion rates for a given level of humidity. This implies effective humidity control in coastal or industrial sites is particularly important.

Protection with dry or dehumidified air, generated by industrial rotating desiccant dehumidifiers or similar, offers the advantage of relative simplicity and good corrosion protection if done correctly. The key is to have a flow path through the protected systems from the outlet of the dehumidifier through the system and back into the unit, which operates continuously. This requires installation of temporary ductwork and selection of suitable inlet and

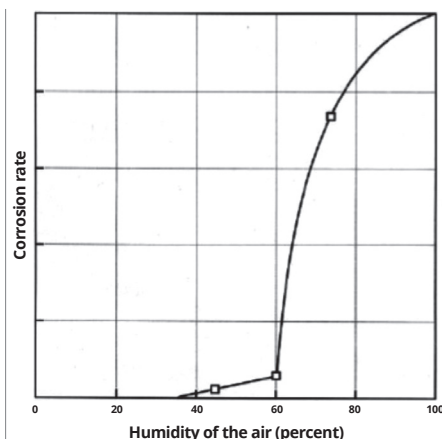


Figure 6. Corrosion rate of steels vs humidity in air⁴

outlet points for the ducts into the system to be preserved (such as HRSG waterside).

Passive dehumidification/drying (PDD)

For less critical systems, or where ADD is difficult to implement, potentially because of limited flow paths, equipment distance, or the cost of additional dehumidifiers, protection can be achieved by drying the unit. The required level of effort can be adjusted according to available resources and the importance of the equipment.

The most comprehensive approach involves hot draining the unit on the waterside, then drying with a temporary dehumidifier and sealing after desiccants such as quicklime or silica gel have been placed in the protected areas. Monitoring of the relative humidity can be performed and if required, further drying can be achieved with another temporary dehumidifier installation. The benefit of hot draining is that water is removed while the metal temperatures remain high, allowing residual moisture to evaporate and internal surfaces to dry. With fewer resources available, the system can be hot drained and then sealed after the use of desiccants or a portable heater to blow hot/warm air into the space until the relative humidity reaches the 40% target. The simplest method involves hot draining and then leaving the system open to air where possible to allow natural circulation. This is often the only practical option for complex, widely distributed systems such as piping.

Wet preservation

Wet preservation involves keeping the water circuits and vessels filled while adjusting the chemistry prior to shutdown. This typically includes increasing boiler water pH to approximately above 9.6 and maintaining a sufficient oxygen scavenger residual or applying a film-forming substance (FFS). Areas that cannot be kept filled are generally protected with a nitrogen cap.

To ensure mixing and uniform chemistry, the water should be recirculated at regular intervals, for example weekly, with sampling and additional dosing as required. This is difficult to implement for certain sections of the boiler such as evaporators. Installing temporary jockey pumps or injecting nitrogen into the downcomers are two methods that can be used in many cases to create a circulating flow. The preservation

Summary of typical boiler/HRSG preservation methods		
Method	Best suited to	Main consideration
DNB	Boilers, HRSG pressure parts, piping	Requires sealed envelope
ADD	Turbines, gas paths, large volumes	Requires airflow path
PDD	Less critical/complex systems	Less positive control
Wet	Shorter outages/rapid restart	Chemistry & recirculation
CSP	Local/small, difficult areas	Compatibility & cost

chemistry is managed using the same basic controls applied during operation, including oxygen removal, feedwater and boiler water pH control, treatment of insoluble material, and blowdown to control dissolved material.

Chemical surface protection (CSP)

Chemical surface protection during preservation can be achieved using a vapour phase inhibitor (VPI) or, for the water/steam side, film-forming substances. The idea is that these chemicals stick onto the metal surfaces and form a protective film which inhibits corrosion. VPI products are typically supplied in bags or pouches that are suspended or mounted within the equipment to be protected. The required quantity depends on the enclosed volume and equipment geometry. For larger spaces or long piping runs, certain VPI products may instead be applied by fogging. VPI is generally most practical for relatively small, enclosed volumes, such as tanks and vessels, or where other preservation methods are impractical; however, its cost per unit protected volume or surface area can be relatively high. FFS products are typically introduced during operation as part of the water chemistry treatment programme to establish a protective film on internal surfaces. Prior to restart, compatibility of any VPI product with the normal operating water chemistry should be confirmed.

Choosing the right method

In practice, there is no “one size fits all” solution and choosing the most appropriate preservation strategy is dependent on several factors. Wet preservation is generally better suited to shorter outages where rapid return to service is important, while dry methods become more attractive as shutdown duration increases or when systems must be opened and drained for repair purposes. Among dry methods, DNB offers particularly robust protection for steam and waterside systems, including complex circuits, but depends on maintaining nitrogen pressure and becomes less attractive where leakage is a concern, although this can be factored into the strategy. ADD is more flexible for turbines, gas paths and other spaces where a suitable airflow path can be established, with the additional advantage that its effectiveness can be readily monitored, whereas PDD is generally reserved for less critical or complex systems where the cost or complexity of active protection is not justified. CSP can work well for smaller areas or where drying or nitrogen protection is not practical, but the cost can make it less suitable for larger systems.

One important factor, particularly for the ADD and PDD approaches, is whether it is possible to achieve good draining of all sections targeted for preservation. Residual standing water significantly delays achievement of the target humidity and may leave local areas inadequately protected.

The various methods, area suitability and considerations are summarised in the table, left. Ultimately, the preferred method is therefore site specific, primarily influenced by shutdown duration, restart time as well as component size, available equipment and the level of protection justified for the equipment to be preserved. Whatever method is selected, the effectiveness should be verified, meaning that regular monitoring of relevant parameters (relative humidity, nitrogen pressure or oxygen concentration, water chemistry) should be an integral part of the preservation activity.

Case study

Tetra Engineering has worked with numerous power plants to develop site-specific preservation strategies. In one recent case, a strategy was developed for a large coastal combined cycle plant facing a six-month shutdown, where local high humidity and airborne chlorides increased the risk of corrosion. Rather than applying one method throughout, Tetra Engineering assessed each component separately and selected the approach that best matched its preservation needs.

Steam and gas turbines were assigned active dehumidification (Figure 7) because their high value justified a high level of protection and existing dehumidification equipment was already available.

HRSG pressure parts were assigned dry nitrogen blanketing because the interconnected waterside volumes could be easily drained and sealed. It was more practical to use active dehumidification for HRSG gas paths because of their large volumes and accessible ducting routes.

Steam, feedwater and condensate piping were also assigned nitrogen blanketing where continuous sealed envelopes could be established, with passive drying or local chemical protection used where the use of nitrogen was impractical due to leakage, access or geometry.

It was suggested that certain electrical systems continue operation at minimum load rather than full layup because maintaining the system online reduced condensation risk and simplified the restart, which was a key consideration of the client.

The recommended strategy also established preservation limits and monitoring requirements for each system, allowing operators to confirm that acceptable conditions are maintained throughout the shutdown.

The result was a practical mixed method strategy in which the resources were focused where equipment value and corrosion consequences were highest, while keeping restart constraints at the forefront.

References

¹ASME, *Consensus for the lay-up of boilers, turbines, turbine condensers, and auxiliary equipment*, CRTD Vol 66, 2002.
²EPRI, *Cycling, startup, shutdown, and layup fossil plant cycle chemistry guidelines for operators and chemists*, TR-107754, 1998.
³VGB, *Guideline for the preservation of power plant systems*, VGB-R116He, 1981.
⁴R. Winston Revie (ed), *Uhlig's corrosion handbook* (ECS series of texts and monographs 51), 3rd edition, Wiley, May 2011.



Figure 7. Dehumidifier ducting to steam turbine for preservation. Photo: Tetra Engineering