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G.L.A. WATER, INC.

Boiler Lay-up Procedures

There are many reasons for laying up a boiler (i.e., placing it out of service.) A primary influence revolves around the actual demand of the operation for steam. Since there are no practical means available for storing steam for an extended period of time, it must be generated, as it is needed. Consequently, if there are wide variations in a plant's demand for steam, boilers are often taken off-line or started up to fulfill the load requirements. This is particularly true for operations that are weekly or seasonal. Other potential reasons for taking a boiler out of service include scheduled downtime for an annual inspection and routine maintenance, an extended shutdown caused by equipment failure and repairs, and a long-term scheduled turnaround.

The Need for Proper Lay-up

Unless adequate precautionary measures are taken, more corrosion damage can occur to a boiler and its auxiliary equipment during idle periods of storage than during entire periods of operation. Corrosion, which is the deterioration of metal or its properties, can occur on both internal and external surfaces of a boiler (i.e. the waterside and the fire/gas side) when it's out of service for any length of time. Most corrosion in a steam-generating system is influenced by such factors as pH and dissolved gases, including oxygen, carbon dioxide, and ammonia. While these factors are typically very stringently monitored and controlled by both mechanical and chemical means during normal operation, they are more often than not neglected during downtime situations. The consequences of improper storage include not only the questionable reliability and availability of the steam-generating system when operation is resumed, but also a reduction in the life span of the equipment and an increase in maintenance and part replacement due to metal loss through corrosion.

Preparation For Lay-up

Selecting the proper method for storing the idle equipment during this time period can be just as important as selecting the proper chemical treatment program for normal operations. The lay-up procedures utilized, for the most part, will determine the rate of corrosion and the levels of corrosion by-products in the system once the equipment is placed back in service. If proper techniques for storage are followed during the outage, there will be minimal corrosion in the steam-generating system, and a fast, efficient start-up can be ensured. It should be understood that there are several different procedures for storing idle equipment, each with its own advantages. Consequently, before a certain lay-up technique is decided upon, a through understanding of both the nature and length of the shutdown and the necessity of the equipment to be brought back into service upon demand will determine the particular lay-up procedure to be utilized.

Lay-up Procedures

Storing a steam-generating system properly during periods of idle downtime should always be a carefully planned, prepared occurrence, and part of the standard procedures of the operation. As previously mentioned, the major factors that influence corrosion during storage include water, pH, and dissolved gases, particularly oxygen. In order to be successful, the various lay-up procedures used in the water treatment industry focus, therefore, on either control or elimination of these factors. Protection that involves removing the oxygen from the boiler water and maintaining an alkaline pH throughout the system to prevent corrosion is known as a *wet lay-up* procedure. *Dry lay-up* procedure, on the other hand, involves draining the boiler and its auxiliaries of all water and maintaining little, if any, humidity in the system.

The choice of protection, via either the wet lay-up or dry lay-up method, is dictated by the duration of the downtime period, the complexity of the system, and the degree of availability required for the equipment. *Wet* storage is typically used during short-term outages; however, it is the preferred method, regardless of shutdown duration, should the steam-generating system need to be available for immediate use. *Wet lay-up* is also the primary choice in complex systems should repairs to the operation not be necessary during the outage. *Dry* storage is usually the preferred treatment in all other situations, particularly during extended shutdown periods or if internal repairs are necessary. Steam plant outages are considered short-term if the operation is out of service for 1 month or less; long-term lay-ups involve downtimes exceeding 1 month. Whatever storage method is chosen, it is imperative to frequently monitor the system to ensure the efficacy of the lay-up procedure (i.e., that either an oxygen free, alkaline environment is maintained during wet storage, or that the system remains free of humidity during dry storage.) The procedures that are recommended in this article are a compilation of guidelines widely accepted and practiced in the industry. Additional plant experience, however, may dictate various modifications to the specific recommendations of the outage treatment programs, including the frequency of monitoring and degree of control, in addition to any special considerations that are made for particular plant equipment and mode of operation.

Wet lay-up: General Discussion

To protect the equipment and assure minimal corrosion during downtime, proper wet storage uses a dual mechanism: the exclusion of oxygen and the maintenance of a high, alkaline pH. As will be discussed shortly, there are three basic procedures for storing a boiler wet: (1) Flooding of the

boiler with a prepared treatment solution; (2) Flooding the boiler with the continuous blowdown sourced from another operating boiler; and (3) Capping the partially filled boiler with a positive-pressure nitrogen or steam blanket. The selection of one of these procedures and the particular treatment chemicals is typically mandated by the type of auxiliary equipment (i.e., non-drainable superheaters) already present in the system, as well as by plant experience. The discussion that follows will first focus on those steps that should be taken to protect the boiler proper, with any special considerations to be noted for proper storage of steam-heating auxiliaries such as superheaters and reheaters. This will be followed by discussion of the procedures to protect any feed water auxiliaries such as deaerators and economizers.

Wet lay-up by Flooding with Prepared Treatment Solution

While wet lay-up procedures involving flooding of the boiler and its auxiliaries can be applied to any size and pressure of steam-generating system, these procedures are typically used in smaller low-to-medium-pressure operations. In this type of storage procedure, certain chemicals are added to the boiler water to scavenge oxygen and raise the pH; the boiler is then filled to the point of overflowing, and sealed. Flooding the boiler system for wet storage serves two major purposes. First, it will eliminate the possibility of a liquid-vapor interface that precludes the potential for waterline corrosion. Also, a steam drum filled with prepared water will prevent corrosion caused by condensation of steam either made acidic by carbon dioxide absorption, or containing dissolved oxygen. The various treatment chemicals that are used to prevent corrosion during wet storage can be classified as either non-volatile or volatile additives. The non-volatile material listed in table A are commonly used in low-medium pressure systems, where they are also part of the internal treatment during normal steaming operations. As seen in Table A, either sulfite (catalyzed or uncatalyzed) or erythorbate can be used for oxygen scavenging, and caustic (sodium hydroxide) is used to add hydrate alkalinity to elevate pH. It should be noted that the advantages in using erythorbate over sulfite for lay-up are that not only will it scavenge oxygen, but it will also promote a reducing, passivated environment in the system, providing additional protection against corrosion. These chemicals, when applied correctly and maintained at the proper levels, can provide effective protection against corrosion caused by both oxygen and low pH during wet standby. The addition of non-volatile chemicals for wet lay-up should occur only in systems that do not contain superheaters and reheaters, or in those operations where these auxiliaries are drainable. Otherwise, precipitations of the nonvolatile solids may subsequently occur on the auxiliary surfaces during start-up, leading to underdeposit corrosion, localized hotspots, turbine deposition, and erosion corrosion in the steam lines. In steaming operations that have nondrainable superheaters and reheaters, the selection of volatile treatment chemicals for corrosion protection during lay-up is recommended. Listed in Table A are possible volatile additives that can be used to scavenge oxygen (i.e. ammonia, morpholine, and cyclohexylamine) during storage. These additives are commonly used in systems with higher operating pressures. It should be noted that while no other treatment is required for wet lay-up, the standard levels of deposit and corrosion inhibitors used during normal steaming operations could be present. The common practices that are accepted and recommended in the industry for wet lay-up by flooding are:

(1) The lay-up solution containing the selected treatment from Table A should be prepared separately in a day tank or condensate receiver and added at the required concentration to the fill water that enters the boiler. In preparing this solution, the highest quality of water available to the operation should be used. Typically, either deaerated boiler feedwater or uncontaminated or polished condensate is suitable. For systems containing nondrainable steaming auxiliaries, water of demineralized quality necessary, again to preclude the presence of nonvolatile solids in the equipment during start-up. If the unit is to be drained and inspected prior to wet storage, it is recommended that the boiler be cleaned, if necessary, prior to laying it up. If the boiler has been drained, the storage solution should be added as the boiler is refilled with deaerated water. If the boiler is to be taken out of service but not drained, the chemical lay-up solution should be added at least 30 minutes prior to shutdown.

(2) The boiler should be slowly filled to overflowing with deaerated water and the storage solution. For boilers coming off-line, this flooding step should be accomplished as the unit cools, but before the pressure drops to zero. Units being filled after being empty, it may be necessary to circulate the treatment solution prior to flooding the steam drum area. For adequate circulation and uniform distribution of the chemicals, the boiler should be allowed to operate for a short time (1 hour) with the steam drum vents open to purge the system of excess air, prior to filling the boiler entirely. Alternatively, circulation of treatment chemicals can be accomplished by means of a recir-culation pump between the bottom blowdown line and the feedwater line. However, to minimize potential leakage of oxygen through any pump seals, the pump should be used only as necessary. Frequent tests of the chemical treatment levels during the filling/flooding process should be made to ensure their proper concentrations, and adjusted as necessary.

(3) Once the chemicals are in the boiler and the unit is filled, all connections should be closed and checked for leaks, and a small

positive pressure applied to the system to compensate for any vacuum and to prevent air leakage as the unit cools to ambient temperature. This can be achieved by means of the boiler feedwater pump; by capping with a nitrogen blanket; or, as is typical with smaller operations, by using a surge tank attached to the highest steam drum vent line to maintain a head pressure on the boiler. This surge tank (usually a 55-gallon drum) contains the chemical treatment solution, and provides not only a storage reservoir for overflow as the boiler is filled and heated, but also a source of treatment as a vacuum is drawn on the system during cooling. The boiler system remains full and flooded at all times.

(4) The boiler water should be tested at least weekly as long as the unit is in storage to ensure that the levels of treatment (i.e., oxygen scavenger residual and pH/hydrate alkalinity) are within their recommended parameters. If possible, samples should be taken from a connection on the steam drum. Prior to sampling, the boiler water should be circulated, if possible, by an external pump, and the sample line flushed thoroughly, both done to ensure a representative sample of the internal chemistry. If additional chemicals are required, the boiler should be emptied only as much as required to inject the necessary treatment. You will need to circulate the chemicals, either with an external pump or by steaming the boiler for a short time. (If steaming, boiler water level should be dropped to normal operating conditions before firing, and subsequently raised to fill the unit.) Attention should be directed at all times during chemical addition to the proper maintenance of all system valves to prevent the potential addition of untreated water to the boiler.

Wet lay-up with Gas Blanket

A second type of wet storage used in the industry involves capping, or blanketing, a partially filled boiler and its auxiliaries with an inert gas or treated steam. This type of lay-up is commonly used in larger high-pressure systems, or in those operations that have nondrainable superheaters. By maintaining a positive pressure internally with the applied gas, the blanketing procedure minimizes corrosion by preventing the infusion of air into the system. For most operations that use the gas blanketing technique for lay-up, the boiler is filled to its normal operating level and then capped, or pressurized with the gas. This is commonly done in systems with nondrainable superheaters, which would not be flooded in this procedure. Some boiler operations incorporate the blanketing process in addition to the flooding procedure for wet storage. The preliminary procedures and treatment programs discussed in the flooding process for wet lay-up are similar to those incorporated in the blanketing method. Boiler system to be laid up should be treated chemically to prevent oxygen and low-pH corrosion. The blanket of inert gas or treated steam that supplements the process is simply to prevent air inleakage by placing a positive pressure on the system. In the gas blanketing process, nitrogen is frequently selected as the inert gas for pressuring the boiler. The nitrogen blanketing system may either be manual or automatic, with the use of a pressure-regulating valve. For operations that use this type of wet storage frequently, a two-stage pressure regulator is commonly used to introduce and maintain the nitrogen feed to the boiler system. Ideally, the gas should be fed to all partially filled steam drums and superheater headers through parallel supply lines to ensure complete capping of the operation. Typically, a 5-punnds-per-square-ince-gauge (psig) blanket of nitrogen is sufficient for pressurizing the boiler and preventing air ingress. During the lay-up process, if the boiler is to be brought off-line from operation, the nitrogen gas should be injected into the system before the steam pressure has decreased to atmospheric, usually about 25 psig. This will prevent the influx of atmospheric oxygen as the boiler cools. If an empty boiler is to be put into wet standby with a nitrogen blanket, it should first be filled to its normal operation level with water that has been treated with the appropriate level of oxygen-scavenging and pH elevation chemistries, then fired to 100 psig or 25% of operating pressure, with adequate venting (through the superheater outlet if applicable). The boiler is then capped with the gas as it cools. Throughout the storage period, the integrity of the gas blanket must be maintained through frequent monitoring of water chemistry and system pressure, checking of any seals and valves, and replacement of any faulty equipment. If the boiler system needs to be opened in any way during the shutdown (i.e., due to loss in positive-pressure of the blanket), it should be refired to drive off any oxygen that may have leaked back into the system, then pressurized and resealed. An alternative to using nitrogen to blanket the boiler is to use treated steam from an operating boiler. In this procedure, the steam to be used for capping must be sufficiently protected against oxygen and low-pH corrosion with volatile additives, prior to its injection into the idle boiler or its auxiliaries. This will help to minimize potential corrosion should any of the steam condense on the internal surfaces. A 5-to10-psig blanket of steam properly maintained throughout the lay-up period is sufficient to prevent air inleakage. As with the other wet storage programs discussed here, the internal water chemistry needs to be monitored frequently and properly controlled, all valves and seals maintained properly closed.

Wet Lay-up by Cascading Blowdown.

A third procedure that can be used for wet storage of a boiler involves distributing clean (i.e., minimal suspended material) continuous blowdown from a properly treated operating boiler into a bottom blowdown connection of the boiler to be stored. This technique is

referred to as a *lay-up by cascading blowdown.*
In the cascading-blowdown method of storage, the treated water from operating boilers circulates through the idle unit and is allowed to overflow through an open steam vent to an appropriate disposal site. By keeping the stored boiler completely filled with warm, treated water, the system is protected internally against corrosion, both from a chemical standpoint and because oxygen ingress is prevented. The warmth provided by circulating water may also be enough not only to keep the idle boiler from freezing but also to keep the fireside dry. Efforts should be made to keep the furnace area tightly sealed during this type of storage to prevent the intrusion of moist air and resulting corrosion on the fireside. The cascading method is typically applied to medium-and high-pressure boiler systems that use solubilizing programs for deposit protection under normal operating conditions. Boilers that use precipitating programs, such as conventional phosphate treatments, should not be sourced for blowdown, as these sludges may deposit out in the idle unit due to reduced circulation rates. Additionally, this type of lay-up is not recommended for steam-generating systems that contain nondrainable superheaters due to the potential for solid deposition of any nonvolatile treatment chemicals when the steaming operation is resumed.

Wet Lay-up of Boiler Auxiliaries

The proper storage of auxiliary equipment in a steam-generating system is just as crucial as the proper storage of the boiler itself. In many situations, the recommended procedures for laying up the auxiliaries parallel those used for treating the boiler. The various types of supplemental equipment and their respective practices for proper wet lay-up are as follows:

Feedwater Heaters. The tube sides (watersides) of any feedwater heaters should be protected during lay-up by flooding with a treatment program similar in chemistry to that of the boiler itself. The shell side can be protected by one of three methods: steam blanketing to 5 – 10 psig; nitrogen blanketing to 5 – 10 psig, after thorough drying of the shell side; or flooding with treated condensate The applicable condensate treatments are similar to those discussed earlier for nondrainable auxiliaries – superheaters – the chemistry to scavenge oxygen and elevate pH should be from the list of volatile components in Table A. For feedwater heaters made of steel, the level of oxygen scavenger in the condensate should be the same as listed in Table A, and the pH should be maintained at a minimum of 10.5. In copper-bearing equipment, it is recommended that half of the typical level of volatile oxygen scavenger be used, and pH be controlled at 9.5 with volatile amine.

Deaerators and deaerating Heaters.

Typically, many facilities will steam blanket an empty deaereator during shutdown. However, if steam is not readily available, the deaerator may be filled with feedwater or condensate treated in the same fashion as the associated boiler or feedwater heater. A nitrogen blanket may also be incorporated into this latter protection technique.

Superheaters and Reheaters

As discussed earlier, the presence of auxiliary equipment such as superheaters and reheaters in the same steam-generating system can dictate that special precautions be taken for proper wet storage. If the equipment is nondrainable, then only volatile chemicals for oxygen control and pH adjustment should be used in the deaerated demineralized water or condensate used to flood the auxiliary. The recommended procedure to flood this equipment is by backfilling then discharging backfill into the boiler. In a steam-generating system coming off-line, to ensure complete filling, the superheater flooding should ideally occur before the superheater reaches atmospheric pressure. If this is not feasible, it is recommended that nitrogen be admitted while the boiler is cooling down, and a positive pressure (5 psig) be maintained. If the boiler should then have to be opened, the superheater can be flooded with chemically treated lay-up solution prior to opening. Additionally, the nondrainable units can be capped with a nitrogen blanket at 5 psig after flooding. The treatment conditions used in superheater and reheater wet storage protection should be the same as the dosage and residual levels carried in the companion boiler. In low-pressure operations using softened feedwater and nonvolatile treatment programs for both normal operations and wet storage, the proper way to protect a nondrainable superheater is to blanket the auxiliary and the space above the normal drum water level with nitrogen. It is essential that precautions be made to ensure that none of the lay-up solutions enter this type of superheater. For systems containing drainable steaming auxiliaries, this equipment can be flooded with the same solution used to protect the boiler. The boiler water / lay-up solution should contain minimal sludge or suspended matter. Very often it is recommended to drain the boiler entirely and refill it and the superheater with a treatment solution using the best quality water available to the operation.

Dry Lay-up: General Discussion
An alternative method to laying up an idle boiler wet with the proper treatment is to store it dry. By keeping the boiler metal surfaces free of any moisture containing dissolved oxygen, the corrosion process can be prevented during shutdown. Dry storage of a boiler and its auxiliaries is typically recommended for an extended outage of 1 month or more in duration, and also when time will be available to prepare the unit for operation. Dry lay-up may also be the storage procedure of choice if the potential for freezing conditions exists during the shutdown. The dry lay-up procedures to be discussed here are commonly recommended for the waterside of low-and-intermediate-pressure industrial boilers. Dry storage is seldom used in high-pressure utility systems, owing to the complexity of their steam circuits and the ensuing difficulties in maintaining all internal surfaces completely moisture free. When implementing proper dry lay-up, it is imperative that the boiler to be stored is clean and free of all moisture-retaining deposits. These deposits can provide the potential for underdeposit corrosion. If deposits are present, the boiler should first be chemically cleaned and then passivated before storing Such requirements may be so demanding at times that dry lay-up may not actually be practical for boilers containing deposits. Dry storage techniques fall into two general categories, open and closed, and commonly practiced procedures and recommendations for storing a boiler and its auxiliaries will be discussed next.

Dry Lay-up – Open Boiler
The primary objective in dry lay-up is the elimination of moisture, and as long as the metal surfaces remain dry, no significant corrosion will occur. For a boiler that is to be stored dry, particular attention must be paid in order to maintain low humidity in the air (less than 60% relative humidity), and to prevent water leakage into the unit and sweating of the surfaces. Dry storage of a boiler that is to remain open is typically used in low-pressure systems utilizing the following procedures:
(1) The boiler should be drained completely once it has cooled, thoroughly cleaned on both waterside and fireside, and inspected. (2) All internal surfaces should next be dried thoroughly. If possible, compressed air should be used to blow out all water from horizontal and nondrainable boiler tubes and superheater tubes. Complete drying can also be aided by circulating warm air through the unit either via a blower or with the use of heating devises such as heat lamps or resistance heaters. Typically, these devises are placed in either the boiler drum or furnace areas. Application of heat to the metal surfaces prevents the possibility of condensation in the system, as air contacting the metal will be heated enough to reduce it humidity to below 60% saturation. (3) All apertures such as manheads, handhole plates, furnace doors, and stack dampers should be left open. (4) All feedwater valves, nonreturn valves, blowdown valves connected to an operating system, and steam shutoff valves should be properly sealed and leak-free to prevent the intrusion of water into the unit. To ensure against leakage, these lines may be flanged closed. (5) The boiler should be periodically inspected for condensation, which is removed by heating the wet surfaces or blowing warm air over them.

Dry Lay-up of a Closed Boiler.
An alternative method of dry storage is to keep the empty boiler system closed and sealed from the environment. This type of lay-up is particularly recommended for operations where the plant atmosphere may contain fumes and/or abrasive dust, which could enter a dry boiler that is stored open. Additionally, closed dry lay-up is generally useful in naturally humid coastal environments. There are three possible methods for preparing and storing a boiler dry and closed: the use of desiccants, a nitrogen blanket, or a steam blanket.

Closed dry lay-up with the use of desiccants.
Following the proper procedures for draining and drying the boiler, desiccants, which are porous hygroscopic chemical drying agents, can be placed into the shutdown unit to absorb water and thus control relative humidity and prevent corrosion. The typical desiccants used (silica gel, quicklime [calcium oxide], and activated alumina [bauxite], and their recommended treatment levels are listed in Table B.
In most installations, silica gel is the preferred desiccant due to its ease of handling, its high moisture-absorbing capacity per unit volume, and the fact that it's easily regenerated by heating. Additionally, silica gel is available with a color indicator (cobalt chloride) that will show the degree of moisture absorption. Indicator will change from cobalt blue to pale pink as gel saturation increases. For infrequent dry lay-ups of limited duration, and those not requiring a desiccant change, quicklime is typically the most economical drying agent. The additional storage procedures involved with the use of desiccants are: (1) Once the boiler has been completely dried, trays or pans of the selected desiccant should be distributed throughout the boiler drums or, in the case of a firetube boiler, on top of the flues. Space should be allowed in the trays to accommodate approximately 50% swelling of the desiccant through absorption. (2) All manholes, handholes, vents, and connections on the boiler should next be tightly closed to prevent inleakage of moist air. The boiler may be pressurized with a nitrogen blanket of 5 psig if desired at this point, as an additional precaution against air intrusion. (3) The condition of the boiler waterside and the desiccant should be examined periodically, such as every 6 – 8 weeks. The internal metal surfaces should be inspected for signs of active corrosion; if the desiccant is

saturated and exhausted, it should be replaced (in the case of quicklime) or reactivated (silica gel or alumina). If nitrogen has been used to pressurize the boiler, proper safety precautions must be taken to completely vent the nitrogen before the unit is entered. It should be noted that although this method of dry storage can be very effective if properly implemented, it does present some problems. Maintenance of airtight seals on all of the boiler openings is difficult. Inspections during the shutdown period will admit moist air. A failure to detect that the capacity of the desiccant is spent means that it likely will no be replaced, rendering the boiler subject to corrosion by humid air until the next opening. Great care must be taken to properly seal the system and maintain a low relative humidity there during this type of dry lay-up.

Closed Dry Lay-up – Nitrogen Blanket

A second technique for storing a boiler system dry and closed is with the use of a nitrogen blanket. This is typically used for long storage in intermediate-and-high-pressure operations. By displacing the boiler atmosphere with an inert gas such as nitrogen and keeping the system closed and sealed under a positive-pressure, an oxygen-free environment will be maintained in the boiler, thereby providing corrosion protection. When a nitrogen blanket is used for storage, very often the accepted practice is to actually drain the boiler under a nitrogen overpressure as it comes off-line, before the boiler pressure has dropped completely. The points to inject nitrogen for the complete removal of water will depend largely on the system design; typically, addition of gas through the steam vents will suffice. During the draining operation, all low-point drain areas should be checked frequently to ensure removal of as much water and moisture as possible. Once the boiler has been emptied, all connections and valves should be tightly sealed or blanketed, and the boiler is then pressurized to 3 – 5 psig with the nitrogen to prevent the ingress of air. It should be emphasized that nitrogen will not sustain life. When this type of storage is used, all nitrogen must be completely purged from the boiler prior to entry by any plant personnel whenever the unit is opened.

Closed Dry Lay-up – Steam Blanket

Prolonged storage of a boiler may also be accomplished by maintaining it sealed and drained under a treated steam blanket of 5 – 10 psig pressure. Again, the overpressure on the boiler prevents oxygen inleakage; any condensed steam is periodically removed through traps on the mud drum and lowest header. Maintaining the proper level of volatile oxygen scavenger and pH-elevation chemical in the system used for storage ensures adequate corrosion protection in any condensate that forms during the storage. Vents should also be installed in the dead-end areas of the boiler to allow for removal of noncondensable gases. One advantage of this type of lay-up is that it keeps the steam system relatively hot. If all dampers and openings to the furnace are kept tightly sealed, the warmth of the boiler can minimize corrosion on the fireside by preventing condensation there.

Dry Lay-up – Boiler Auxiliaries

The same procedures applied to boiler can be followed for much of auxiliary equipment in a steam-generating system, particularly for economizers, deaerators, and feedwater heaters. Deaerators are commonly segregated from the boiler proper and steam-or nitrogen-blanketed, no matter what the lay-up choice for the rest of the equipment. As with wet storage, particular attention must be paid to the proper dry storage of superheaters. Drainable superheaters can be easily and completely emptied of water and moisture during shutdown, and adequately protected by any of the dry lay-up procedures discussed. With nondrainable superheaters, any condensate collecting in the lower bends of the tubes will cause rapid corrosion, despite adequate protection of the boiler itself. Again, warm air blown through the tubes will dry the superheater initially. To insure complete drying and prevent possible condensation on both sides of the superheater tubes, a series of small heaters should be installed in the furnace and equally spaced across the width of the superheater bank. Maintenance of these heaters offers an additional protective measure against corrosion, whether the boiler is left open and dry, or closed and dry.

Lay-up of the Fireside

Whenever a boiler is to be stored, considerations must be made not only to protect the waterside, but also the fire or gas side. Primary concern is to protect the internal surfaces of the boiler and any steaming auxiliaries form corrosion, particularly during extended storage. The main objective, therefore, is to keep all metal surfaces dry. Proper storage of the fireside area mandates that all surfaces be cleaned prior to lay-up. Fireside deposits, particularly in the economizer, convection, and air heater sections, will absorb moisture. When the firebox has cooled, and metal surface temperatures drop below the dew point, condensation will occur. If the deposits are acidic in nature, such as those produced from burning high-sulfur fuel, corrosive acids will be produced when the deposit absorbs moisture. The pH of such deposits may be as low as 2.5, and can cause severe destruction of the fireside during an extended outage. The proper procedures for storing the fireside area during lay-up therefore focus initially on neutralizing and removing the deposits and then on maintaining the area moisture-free. In preparing for lay-up of the fireside, it is advisable to change fuel sources, if a high-sulfur fuel is burned, for 1 week prior to shutdown. Switching to a low-sulfur natural gas or number 2 oil during the last week of operation may help to remove corrosive

deposits from the fireside before boiler is taken off-line. Additionally, before shutdown, all soot blowers should be operated, beginning with the blower farthest from the stack. This will help to minimize the presence of corrosive deposits. Once the boiler is off-line and the water temperature has dropped below 140°F, the fireside should be completely washed down. This includes all external surfaces, economizer, air heater, and induced draft (ID) fan on the flue gas side. In washing this equipment, a rinse of warm fresh water of neutral pH should be used first (to prevent the formation of hydroxide gels in the deposit), followed by a high-pressure alkaline wash. Typically, a 1% to 5% solution of soda ash is sufficient to dislodge the deposits and neutralize their acidity. Following the cleaning, all wash water should be drained from the equipment, and all areas of the fireside thoroughly dried by circulating warm air though the unit, or with a light firing of a sulfur-free fuel, or with heat lamps. It is imperative that all moisture be removed from the refractory and insulation, and that the relative humidity of the air be maintained as low as possible. If the fireside is to remain open during the shutdown, warm air should be circulated through the system to keep the metal surfaces above the dew point. If the firebox is to be closed during lay-up, it should be sealed tightly to prevent the ingress of moist air; desiccants may be used as discussed earlier to maintain enclosed area free of humidity.

Boiler Start-up after Lay-up

As with lay-up, proper start-up of a steam-generating system requires careful, well-coordinated operational procedures. If the boiler has been laid up wet, the chemical concentrations of oxygen scavenger should be returned to normal operating levels, and the pH/hydrate alkalinity reduced if necessary before the equipment is returned to service. This is usually accomplished by partially draining the boiler then making up to the normal operating level with fresh water. If any superheaters have been stored wet, they should be drained (or blown out with air) before start-up. The boiler should then be brought up slowly to completely dry out the superheater before standard operation is resumed. When the dry lay-up method is used, any trays of desiccant must be removed from all locations in the equipment. If nitrogen has been used to store the boiler dry, it should be completely vented from the system. The boiler should be filled to its normal operating level with deaerated, treated feedwater, and then brought into service.

Disposal of Cleaning & Lay-up Chemicals

Current government regulations and environmental and safety considerations warrant the proper disposal of any cleaning or storage chemicals used in the lay-up process. Provisions must be made in compliance with all applicable local, state, and federal regulations for the safe handling and legal disposal of any chemical used during storage. Adequate safety equipment should be worn and safety precautions observer during the application and disposal of the treatment materials, particularly hydrazine and nitrogen. Such compounds should be completely purged from the boiler area prior to entry.

Summary

The proper storage of an idle boiler and its auxiliary equipment is essential to the continued, efficient operation of any steam-generating system. While many plants devote the time and resources necessary to provide adequate control against corrosion and deposition during operational periods, many will let this protection lapse during downtime. Failure to adequately store a boiler during lay-up can result in accelerated corrosion by oxygen and low pH of both the waterside and fireside of the equipment, completely offsetting the conscientious efforts to maintain a well-run operational water treatment program. Indeed, both research and plant experience have shown that much, if not the majority, of the corrosion in a steam-generating operation occurs while the system is idle and improperly stored. The goals of proper lay-up are to minimize corrosion of the boiler and auxiliary metal surfaces by either oxygen or low pH. The decision by the plant to store the system wet, by treating the water in the steam equipment with oxygen scavenging and pH-elevation chemicals; or to store it dry, by draining the system and minimizing the level of humidity present, is dependent upon the reasons for the outage, the length of downtime, the complexity of the system, and the necessity of the equipment for start-up. Whatever the decision, affording the time and treatments necessary to accomplish these goals will ensure the maximum operating efficiency of the steam-generating system.

See TABLE A and B on page 8

Disclaimer

TABLE A

Minimum Treatment Levels of Various Chemical Additives for Wet Lay-up

Chemical	*Purpose*	*Boiler Level, mg/L (ppm)*
Nonvolatile		
Uncatalized or catalyzed sodium sulfite	Scavenge oxygen	200 as SO_3
Sodium erythorbate	Scavenge oxygen	200 as $C_6H_8O_6$
Sodium hydroxide	Elevate pH	400 of P alkalinity as
	$CaCO_3$, or as needed to	
	Adjust pH to 10.0	
Volatile		
Uncatalized or catalyzed hydrazine	Scavenge oxygen	200 as N_2H_4
Carbohydrazide	Scavenge oxygen	200 as N_2H_4
Hydroquinone	Scavenge oxygen	200 as $C_6H_4(OH)_2$
Methylethylketoxime	Scavenge oxygen	5 – 10 as C_4H_8NOH residual
Ammonia	Elevate pH	10 as NH_3, or as needed to
	Adjust pH to 10.0	
Cyclohexylamine	Elevate pH	50 as $C_6H_{11}NH_2$, or as needed
	To adjust pH to 10.0	
Morpholine	Elevate pH	50 as C_4H_8ONH, or as needed
	To adjust pH to 10.0	

TABLE B

Recommended Treatment Levels of Various Chemicals for Dry Lay-up

Chemical	*Dosage, lb/100ft$_3$ of Boiler Volume*
Quicklime	6.5
Silica gel	16.5
Activated Alumina	27.0