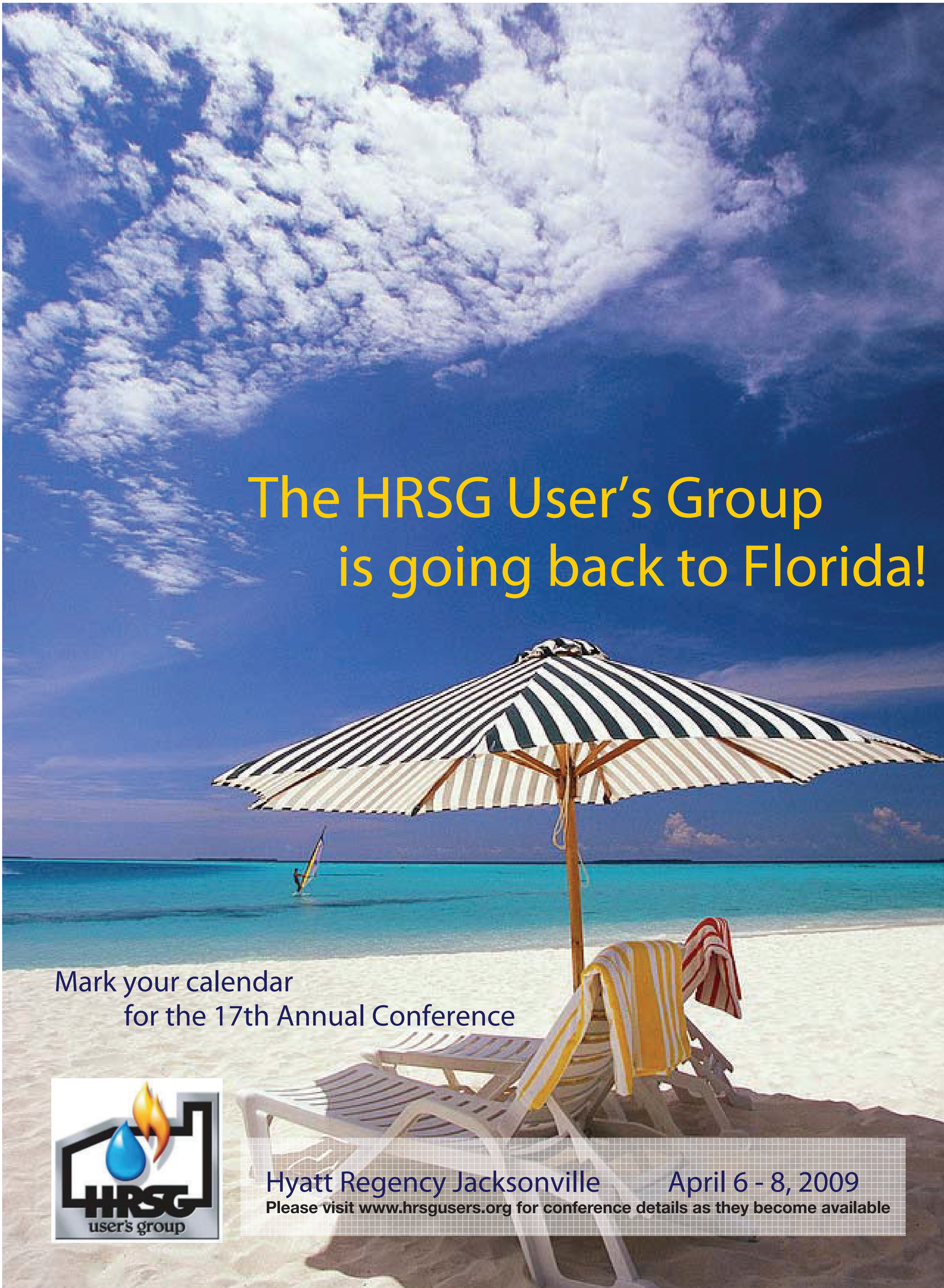
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Layup strategies for maintenance outages and when not dispatched

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Today's challenging business environment, coupled with the volatility in natural-gas prices, has many merchant-plant owner/operators wondering when they will be dispatched next. Such uncertainty increases the complexity of decision-making regarding wet versus dry layup. The fact that many HRSGs designed for base-load service are forced to cycle also impacts the type of layup. Reason is that these units often are not equipped with stack dampers, nitrogen purge systems, steam sparging, and/or systems for circulating boiler water when off line; and implementation of preferred layup practices may be impractical.

While it's important to have your HRSG available for service when needed, it's also important to prevent offline damage. Sometimes these objectives are not completely aligned. Keep in mind that idle HRSGs, if not properly "parked," may deteriorate more rapidly than if they were in service—even during outages lasting less than two weeks.

Thus goal-setting is an important part of layup planning. Goals of a proper layup for most users include the following:

- Prevent corrosion on both the water and gas sides of the HRSG.
- Maintain maintenance availability as needed.
- Restart the HRSG as fast as possible.
- Achieve the desired water chemistry quickly upon restart.

Impacts of improper layup

Water side. How would you know if your HRSG layup was done correctly or incorrectly? Simple: Oxygen pitting, corrosion fatigue, and/or underdeposit corrosion will surface—eventually. Because most modern HRSGs do not have mud drums, the only convenient way to confirm that proper procedures are being followed is to visually inspect the water side by crawling through the steam drums during overhauls.

Expect to find at least some oxygen pitting of the drum if a nitrogen purge system is not installed (refer to article on p 2 of this issue for more detail). It is the first component exposed to ambient air when drum vents are opened.

Corrosion fatigue and underdeposit corrosion can be difficult to identify without a videoprobe and/or tube sampling. They occur most often in the lower sections of the HRSG's pressure parts. That's where the highest stresses are found in many top-supported designs and where deposits accumulate.

The gas side is much easier to inspect. Poor layup procedures are confirmed by tube and fin corrosion, external pipe and hanger corrosion, particulate emissions on restart, increased gas-side pressure drop, and reduced thermal performance. Systematic removal of selected roof and floor seals for inspection is valuable for identifying corroded or thinned piping before it leaks.

Water-side layup options

Short-term wet layup. The ASME "Consensus Document for the Lay-up of Boilers. . ." defines "short-term wet storage" as less than seven days. Options for short-term wet layup include (1) "bottling-up" your HRSG—that is, not allowing drum pressure to fall below 25 psig (a common OEM trigger point for opening drum vents), and (2) use of nitrogen to purge and blanket the steam spaces, including superheaters and reheaters.

Industry experience indicates that a practical timeline for the "bottling-up" option typically is less than 72 hours. Actual limit differs among HRSGs and depends on ambient conditions, degree of tightness of vents and drain valves, whether a stack damper is installed and the stack is insulated up to the damper, etc. HRSGs are unique; and even multi-pressure sister units will decay to 0 psig at different rates. It takes an astute operator to closely monitor pressure and valve-in nitrogen at the optimum time.

Stack dampers generally help enable the wet-layup option and are a worthwhile investment. They block the natural stack draft and prevent hot air from escaping/cold air from entering the HRSG, which would accelerate cooling and condensation. Stack dampers usually are butterfly or double-louver type capable of remote, quick response. Their installed cost can be $150,000 to $250,000 for an F-class HRSG; and actuator maintenance is an ongoing annual expense.

Duct balloons are another option. Recently this technology has advanced from manual insertion and inflation to full automation. Stack balloons serve the same purpose as dampers at much lower installed cost.

Keep in mind that the amount of nitrogen required for a wet layup will be high if you're filling the superheater and reheater panels. An option to reduce nitrogen volume, especially during long-term wet storage, is to back-fill superheater and reheater harps with demineralized water. Caution: Experts do not recommend filling superheaters with water pushed through the economizer and evaporator because it results in "cycling up" or concentrating salts and chlorides in the drum water to levels higher than they are in the feedwater.

However, pushing water through the drums to the superheater is becoming more common at plants that operate on all-volatile treatment (AVT). This approach may be acceptable if you take care not to thermally shock a hot superheater and are sure to consider pipe support issues—

Alternatives for maintaining your HRSG dry

Method	Advantages	Disadvantages
Nitrogen	■ Effective ■ No foreign chemicals introduced	■ Low-oxygen environment may be hazardous to personnel ■ Difficult to confirm that all spaces are filled with nitrogen (not air) unless cap is installed as pressure decays ■ Large volume of inert gas required ■ Does not remove standing water
Desiccant trays	■ Proven traditional method ■ Easy to source material (silica gel, quick lime, activated alumina); rule of thumb is 5 lb silica gel/100 ft^3 of volume	■ Need to handle chemicals ■ Damp chemical is corrosive if spilled in drum ■ Air circulation through HRSG is not accomplished naturally ■ Requires frequent checking
Dehumidified air	■ Successful in humid climates ■ Clears small pockets of water surprisingly fast (within hours) ■ Simple and effective ■ No foreign chemicals introduced	■ Equipment intensive; requires blowers, flexible ducting ■ Seal must be maintained with relative humidity of <30% re-established ■ Constant use of blowers
Vapor corrosion (phase) inhibitors	■ Simple to add ■ Chemicals are water soluble	■ Require flush and refill ■ Personnel should not enter drums until after a flush, refill, and startup ■ Handling and introduction of foreign chemicals ■ Do not clear residual water pockets ■ Difficult to confirm dispersion throughout HRSG

especially large-bore superheater and reheater piping that normally is filled with steam, not water.

Finally, if you fill the superheater and reheater with water, you must drain them completely prior to restart. This may be difficult and, depending on the elevation of the blowdown tank, it may be necessary to pressurize the system. A cost-saving option for nitrogen users: Depending on consumption, it may be less expensive to install an N_2 generator instead of buying bottled nitrogen. If you're considering a nitrogen generator, remember that it must be able to make a gas that's 99.6% pure according to ASME specifications. Even very small quantities of impurities can defeat the purpose of a nitrogen blanket.

Long-term wet layup

For long-term wet storage—defined as from seven to 30 days—you must have the capability to heat boiler water to maintain pressure in the bottled-up unit. The most practical options are steam sparging and gas-side heating. Sparging can reduce thermal cycling stress on high-pressure heavy-wall components and allow faster restart times.

An added benefit: Heat is radiated from the water inside the tubes to the gas side and minimizes—possibly prevents—condensation.

Risks to use of steam sparging can be water hammer, chemistry dilution (or concentration), and increased thermal stresses in low-pressure thin-wall components during restart. A poorly designed sparging system can cause heat stratification and high-stress events in evaporator tube bundles. If heat is used to reduce the possibility of freeze damage, factor the risk of gas-side stratification into your design.

Vapor corrosion inhibitors (VCIs), another option for minimizing corrosion, are not commonly used in HRSGs because they must be thoroughly flushed from the system after use.

The takeaway from the foregoing is that wet-layup program selection is an individual plant's choice with consideration given to HRSG design, climate (freeze risk), estimate of offline duration and confidence in that estimate, availability of auxiliary steam sources, required maintenance, and—most importantly—cost.

O&M practices contributing to success. If you opt for wet layup, here are a few beneficial O&M practices to consider prior to shutdown:

- Short intermittent blowdowns before shutdown remove solids and corrosion products from the HRSG, eliminating possible sites where under-deposit corrosion might occur.
- Raising drum level minimizes the amount of purge nitrogen required.
- Adding nitrogen (or VCIs) as close to zero pressure as possible is ideal, but not practical. Best practice: Inject nitrogen when drum pressure is in the range of 2 to 5 psig.
- Maintain stable boiler-water chemistry; addition and circulation of chemicals with the HRSG off line is challenging. Avoid use of hydrazine or other oxygen scavengers during offline periods—this to minimize the potential for flow-accelerated corrosion (FAC) on restart. Changing from a normally oxidizing environment to a reducing environment weakens and cracks the protective layer.
- Minimize system leakage by use of good maintenance on vents, drains, and block valves. A tight system prevents costly nitrogen loss.

Dry layup

Dry layup of the water side generally is preferred for outages lasting longer than 30 days, when there is significant freeze risk, or when maintenance is required. Of particular importance is the need to completely drain the unit and to keep it dry. Draining "hot" is very popular today and beneficial for getting all the low points dry. To do this, open drains and vents at approximately 50 psig, taking care to avoid flashing steam on open systems or overfilling the blowdown tank. Keep surfaces dry using a nitrogen blanket (1-5 psig), desiccant, dehumidified air, and/or VCI powder (table gives advantages and disadvantages of each).

Dehumidification is the best alternative from a safety perspective, particularly if you intend doing maintenance on the water side. For maximum effectiveness on the water side, blow dehumidified air in the drums and allow it to vent out flow paths in the economizers and superheaters. For long-term dry storage (several months), consider removing large valves in superheaters and economizers to get a large open flow area.

On the gas side, blow in dehumidified air up high on the HRSG, near the stack; draw air back to the dehumidifier from a low point near the front of the unit.

When selecting a dehumidification system, opt for absorption over refrigeration. Former involves the use of desiccant in a slowly rotating bed or wheel, which is why this arrangement often is referred to as a "dryer." Problem with the latter is that air leaves the dehumidifier cooler than the ambient air which can cause unintended condensation in the HRSG. This is especially important if your plant is in a high-humidity environment.

Regardless of the method for maintaining the unit dry, the big challenge of dry layup is complete drainage. How can you be sure all water is out of the unit? Many economizer drains do not offer proof of flow; the drains may be clogged, perhaps never opened (in a multi-pass arrangement); or worse, some areas of the HRSG may not be drainable.

Low spots in headers, such as chemical clean-out connections, are a prime example of non-drainable areas. Not only are the low areas incapable of being drained, they are the locations where corrosion products will accumulate, fueling underdeposit corrosion. Cycling the economizer drains monthly at 100-200 psig as pressure decays helps push out corrosion products. But this takes a toll on gate valves.

Gas-side layup

Gas-side corrosion can be problematic for HRSGs in cycling service. Layup of the gas side historically has been given less consideration than it has for the water side, but that may be changing. In the first half of 2008 alone, HRST Inc, Eden Prairie, Minn, was hired to clean 10 HRSGs.

Recall that as ambient temperature increases during the daylight hours, the cooler HRSG components, with their considerable thermal inertia, lag behind, and moisture condenses on metal surfaces. Condensation typically occurs when the relative humidity is more than 35%.

Also, when HRSG internal surfaces are cooler than ambient temperature, reverse draft through the stack occurs. Air entering through the stack exits via the gas turbine, open gas-side manways, and other leakage points.

Dewpoint corrosion of tubes, fins, headers, and casing can cause many problems—including particulate emissions at restart, piping and hanger corrosion, increased gas-turbine backpressure, and reduced heat transfer in the HRSG.

Corrosion can be minimized either by removing oxygen or moisture from ambient air; the latter usually is easier. In either case, it is important to minimize the amount of air that must be handled and conditioned. This requires blocking air flow through the stack with a damper or balloon.

Options for minimizing dewpoint corrosion include adding heat (1) by injecting sparging steam on the water side, and (2) installing portable heating coils or radiant heaters on the gas side. Another practical option is dehumidification. In many cases, a combination approach may be required.

Finally, some plants that clean tube panels early in an outage see residual deposits "growing" as they absorb moisture. A good strategy for a long outage may be to inspect the HRSG during the first five days of the outage, engage heating or dehumidification, clean as close to restart as possible, and return to the heating or dehumidification plan if startup is delayed. CCJ