

Identify, correct HRSG gas-side corrosion problems

By Bryan Craig, HRST Inc

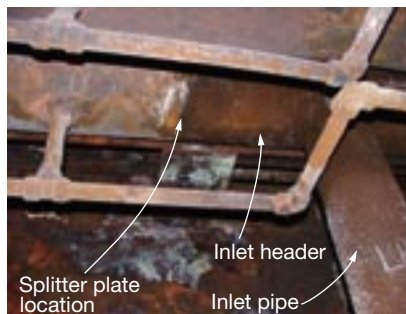
Gas-side corrosion affects all heat-recovery steam generators (HRSGs). Consequences range from unsightliness and reduced performance to reliability problems and potential safety hazards. Presented here are thumbnail sketches of several corrosion mechanisms that you may find when inspecting your boilers. They explain how to identify the different types of corrosion, the consequences of inaction, problem correction, and when to call for outside assistance. In most cases, a relatively small investment is all it takes to assure long life for your HRSG and maximize its availability.

1. Dewpoint corrosion

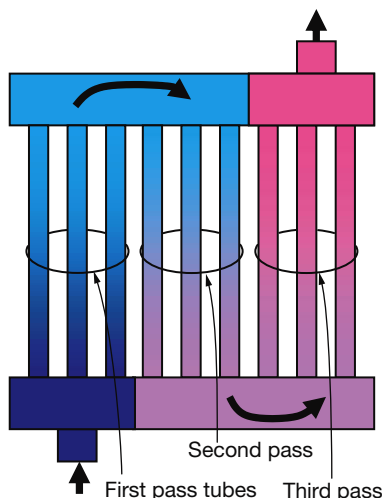
Moisture contained in gas-turbine (GT) exhaust gas will condense on HRSG heat-transfer surfaces when that metal is below the gas dewpoint temperature, which typically ranges from 112F to 120F. Dewpoint corrosion usually is found in low-pressure (l-p) economizers and condensate heaters that receive water from a relatively cool source—the condenser hotwell, for example.

Piping, headers, and tubes in these HRSG components operate very close to the water temperature—especially in upper and lower crawlspaces, where there is relatively little gas flow and heat transfer. The inlet piping, headers, and tubes are at the lowest temperature and most likely to show signs of attack.

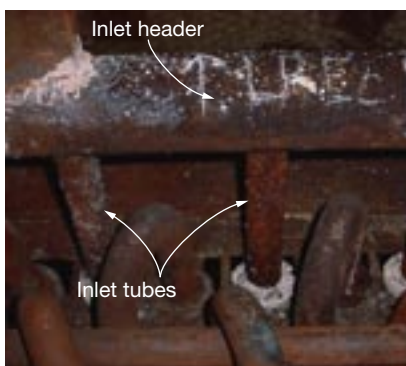
Some OEMs (original equipment manufacturers) specify



1. Dewpoint corrosion attacks cool feedwater inlet components



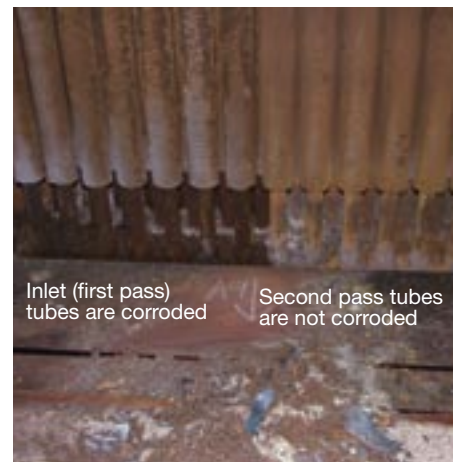
2. Damage is in evidence where first-pass tubes intersect with inlet header and metal is coolest; there's no dewpoint corrosion of second-pass tubes



3. Inlet tubes and header exhibit wastage; other tubes are not corroded

alloy materials to protect against corrosion. Others provide a recirculation system or external heat exchanger to increase the temperature of incoming feedwater. However, many HRSGs in service were built with carbon-steel materials in areas where metal temperature is well below the gas dewpoint. Do you have one of these units?

What to look for. Dewpoint corrosion is easy to identify visually

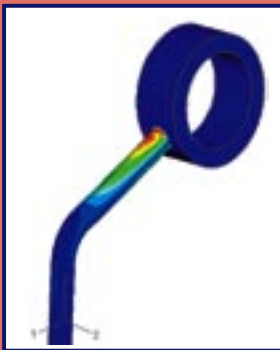


given access to the gas side of the HRSG where feedwater enters. Compare the condition of inlet pipes, headers, and tubes to that of nearby piping, headers, and tubes: If components at the feedwater inlet exhibit greater material wastage, dewpoint corrosion is the likely cause (Figs 1-3).

Consequences. Dewpoint corrosion has caused numerous tube failures in HRSGs. Experience indicates that carbon-steel tubes operating in a condensing envi-

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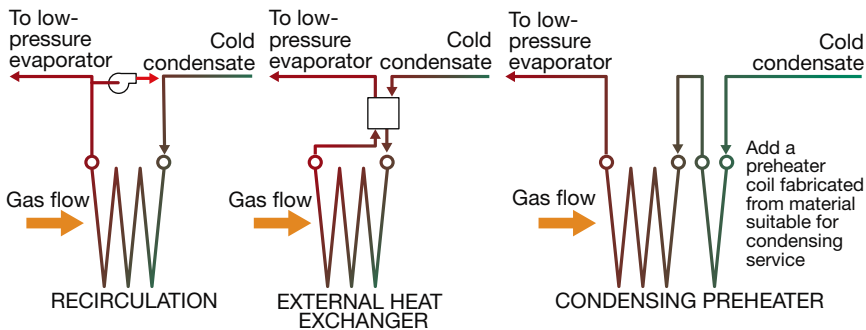
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4. Alternatives for maintaining inlet feedwater temperature above the GT exhaust gas dewpoint

ronment have a service life ranging from two to 15 years. Actual water inlet temperature, operating hours, the presence of ammonia salts, and other variables determine the actual service life.

Corrective action. Prevent carbon-steel components from operating below the GT exhaust-gas dewpoint. If your system is equipped with a recirculation system or other means for maintaining feedwater inlet temperature above the dewpoint, make sure it is operating properly. If no such system is installed, consider retrofit of a recirculation system, an external heat exchanger, or a preheat coil designed for condensing service to prevent corrosion (Fig 4).

2. Offline corrosion

This is a relatively recent phenomenon because HRSGs are more likely to spend extended periods offline today than in the past. The large “thermal mass” of HRSG components causes them to lag behind naturally fluctuating ambient temperatures. If a period of relatively cool weather is followed by warm humid conditions, HRSG metal surfaces may remain below the ambient dewpoint for several days, causing the metal to “sweat” like a cold beverage on a summer day (Fig 5). This, of course, increases the corrosion rate of those surfaces.

What to look for. HRSGs that operate in a cycling mode typically exfoliate more fin scale than those in base-load service (Fig 6). The scale is flaky in appearance and may fill the gaps between the fins. It also finds its way to access lanes and lower crawl-space floors—often resulting in



5. Condensate drips from lower reheater header while unit is shut down



6. Scale between fins is a consequence of offline corrosion



7. Offline corrosion causes debris to accumulate in lower crawl-space

deep piles of debris (Fig 7). Often, offline corrosion is most severe in the middle of the HRSG or one or two access lanes upstream of the stack.

Consequences include reduced performance caused by fouling of heat-transfer surfaces. Such performance reduction often is difficult to quantify, and in some instances may be less than expected considering the appearance of the finned tubes. Debris tends to foul surfaces in low-velocity zones—for example, the “dead spot” on the downstream side of each tube, where little heat transfer occurs.

Additionally, reduced heat-transfer in one section typically is offset by increased heat transfer downstream, because those tubes see hotter gas than they would normally. However, cleaning of fouled heat-transfer surfaces by CO₂ blasting or other methods still may be warranted based on performance improvement.

Be sure to collect and dispose of corrosion products that pile up on the floor of the HRSG. This debris usually is absorbent and hygroscopic. Thus any moisture that enters the HRSG casing is retained, accelerating corrosion of the floor liner, drain piping, and casing penetration seals.

Correction action. Clean heat-transfer surfaces and floors annually or more frequently. Offline corrosion can be prevented or reduced by maintaining a low-humidity environment in the boiler while offline—provided the problem is severe enough to justify the cost. This can be accomplished by adding heat or by dehumidification. In either case, a stack damper or balloon is recommended to seal off the space being conditioned.

3. High-temperature oxidation

Two important points to remember here: Metal oxidizes rapidly when exposed to excessive temperatures, and practical temperature limits for oxidation resistance vary with the alloy. High-temperature oxidation typically is a threat to liner systems,

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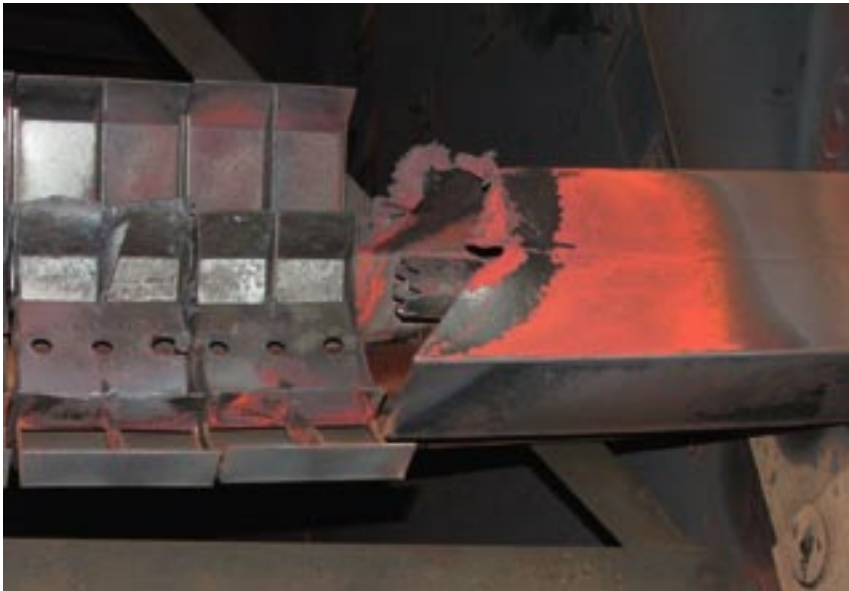
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8. High-temperature oxidation damaged this igniter box

fin tips, duct-burner components, and baffles (Figs 8, 9). For example, inlet ducts and firing ducts experience temperatures that are too high for carbon steels commonly used for other components and must be fabricated from stainless steel. By contrast, high-temperature oxidation of pressure parts is highly unlikely because these components have material strength limits that require operating temperatures to be below those at which oxidation becomes a factor.

High-temperature oxidation occurs in HRSGs for these reasons:

- **Incorrect material selection.** Specifically, the temperature is as expected, but the material is not suitable for use at that temperature (Fig 10). This can occur because of an engineering error, or a material mix-up in the fabrication shop or during field installation.

- **Temperature exceeds the designer's expectation.** This rarely occurs in HRSGs without duct firing because GT exhaust temperature is very predictable. Units with duct firing may have areas where temperatures exceed the designer's expectation because of unaccounted-for radiation from burner flames, poor fuel-gas flow distribution, and poor exhaust gas flow distribution. The last is most common.

What to look for. Conspicuous



9. Oxidized burner components require replacement



10. Incorrect material use was cause of high-temperature corrosion here



11. Conspicuous color changes in liner system help identify problem

color changes in a liner system can indicate a problem (Fig 11). For example, if a duct liner is silver in color except for a few red sheets or washers, it may be that the wrong material was used for those parts. Note that a red color is not necessarily bad; some liner materials are supposed to be red. Focus your attention on color variations.

A magnet often can provide a quick verification as to whether a material is what it's supposed to be. However, this doesn't always work, because multiple grades of both magnetic and non-magnetic materials are used in HRSGs. Consider sending a small sample to a metallurgical lab to learn exactly what materials were used.

Perhaps the most obvious sign of high-temperature oxidation is burned-up, swollen, sagging, or crumbling metal. Such conditions generally indicate the presence of flow distribution problems in supplementary-fired units. Keep in mind that duct burners require a relatively uniform GT exhaust gas flow profile across the burner grid for trouble-free operation.

Consequences. High-temperature oxidation can lead to component failure and other operational problems if the cause of the problem is not addressed. The specific consequences depend on the component affected. For example, in liner systems, high-temperature oxidation may result in (1) loss of insulation, (2) hot spots, (3) excessive pressure drop through the SCR (selective catalytic reduction) because catalyst is blinded by liberated insulation, etc.

Corrective action depends on why high-temperature oxidation occurred in the first place. Components failing because incorrect materials were used in their fabrication obviously must be replaced. For local areas where gas temperature exceeds the designer's expectations, corrective action specific to the situation can be identified by way of an engineering evaluation. Consider calling in the OEM or a third-party expert to conduct the sophisticated analysis required.



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4. Casing penetrations

Pipe penetrations that pierce the HRSG casing represent a unique challenge—actually two challenges because roof and floor penetrations each are subject to their own set of corrosion problems.

Roof casing penetrations

Roof penetrations can allow rain-



12. Rainwater leaking in through penetration seal corroded economizer vent pipe



13. Leakage through riser penetration reaches tube bundle below



14. Measure thickness of drain-pipe wall to determine corrosion rate. Access is easier if penetration seal is removed from casing exterior

water to leak into the HRSG (Figs 12, 13), corroding the pipe and surrounding liner plate, when the seal at the penetration/roof joint is inadequate.

What to look for. Check areas where penetrations come through the roof following a heavy rain to see if water pools, which means that the potential for leakage exists. Additionally, penetrations that do not seal properly—for example, fabric seals with loose band clamps—are problematic. If there is access to the spaces above the tube bundles inside your HRSG, look for pipe and liner corrosion near liner penetrations.

Consequences. Pipe and liner failure can result from this type of corrosion; but not likely, based on field experience. In some cases, rainwater leakage into offline HRSGs has led to the mistaken diagnosis of a pressure-part leak. Such improper conclusions waste outage time and resources.

Corrective action. This is a relatively easy problem to fix and should be addressed. Rainwater pools can be corrected by boring holes through stiffeners or other structure to allow water to drain away. Periodically remove debris from drain holes. Repair or replace leaking penetration seals.

Floor casing penetrations

Floor penetrations are at low spots where debris and moisture conducive to pipe corrosion can accumulate. Drain penetrations can be particularly problematic because there normally is no flow through the drains during operation to maintain warmth. Thus that portion of the drain pipe inside the penetration seal may be cooled to below the gas dewpoint when cool ambient temperatures prevail, creating a corrosion site.

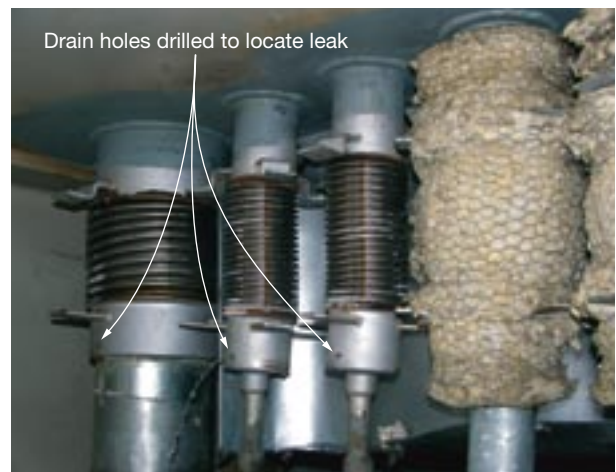
What to look for. Remove a

few drain penetration seals from suspect locations and inspect the pipe both visually and with ultrasound (Fig 14). This is relatively easy with clamped-on fabric penetration seals, but is more challenging with stainless steel bellows.

Visually inspect pipe penetrations from inside the HRSG casing, to ensure they are protected from debris ingress by a functional liner “donut” (metal flashing around the pipe). If there are no donuts, or if some are out of position so that you can see into the insulation space around the pipe, check for debris, moisture, and pipe corrosion.

Consequences. Drain-pipe failures caused by external corrosion of drain pipes inside the penetration seal are common.

Corrective action. Bore a small hole through the metal ring at the bottom of a fabric or metal-bellows penetration seal (Fig 15), permitting a small amount of exhaust gas to leak through and warm the pipe.



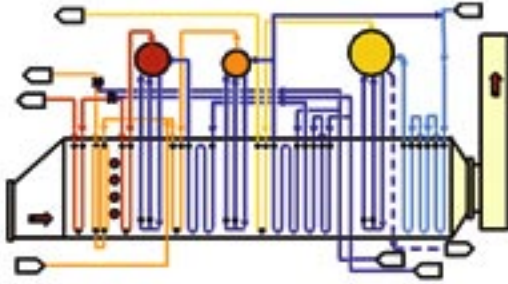
15. Drill holes in base of penetration seals to detect leaks. Allow holes to remain, enabling GT exhaust gas to heat seal and minimize opportunity for corrosion

Controlled-leakage mechanical seals do not require this. Repair or replace failed and missing liner donuts.

5. Stack corrosion

Stack corrosion is not unusual, particularly in HRSGs that are offline for extended periods. During operation, the exhaust gas temperature typically is high

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16. Corroded stack base. Numbers on wall are ultrasonic thickness measurements. Material wastage is significant

17. Inspector found approximately 8 in. of standing water in stack base



enough to keep the stack dry and minimize corrosion. However, it is relatively common to see standing water in the back of a stack during an outage. This virtually guarantees rapid corrosion attack.

Most—perhaps all—HRSG stacks have low-point drains. But they often plug with debris.

In addition, stack drains normally come with a blind flange or a valve to seal the stack drain during operation. Occasionally, these drains are not opened when the unit is out of service because of oversight or concerns over effluent discharge. In other instances, the drain is not at a true low point, or there is improper

ly sloped piping that prevents water from draining as intended.

What to look for. Inspect for standing water or mud in the stack base. If water is not present, check for signs of a previous waterline. Heavy scaling on the stack interior near the base is an indicator of previous corrosion. If stack-wall corrosion appears to exist, check metal thickness in the affected area and above it (Fig 16).

Consequences. Most stacks in the US are self-supporting—that is they rely on the stack shell for structural integrity rather than on external supports. This means that significant corrosion of the stack wall could result in failure.

Corrective action. Avoid having standing water in the stack base (Fig 17). Check stack drains open when the unit is offline and verify that drain piping is sloped properly. Remove any debris that could restrict flow of rainwater from the drain. Shovel any loose debris out of the stack base. CCJ OH