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COMBINED CYCLE Journal
User Groups Gas Turbines HRSGs Controls

How to boost HRSG performance and increase your plant's bottom line

Posted on May 22, 2013 by Team CCJ

The performance thieves lurking in many heat-recovery steam generators sometimes can be eliminated with relatively little effort and at low cost, Lester Stanley, PE, told owner/operators attending HRST Inc's HRSG Spotlight Session at the 7F Users Group annual conference being held this week at the Hyatt Regency, Greenville, SC.

The ideas and experience offered by Stanley and colleague Bryan Craig, PE, during the four-hour workshop on Monday morning were of high interest, judging from the questions and floor discussion generated. That these attendees were a motivated group there was no doubt. All had to arrive a day early, pay an extra fee, and be in their seats by 8 a.m. to get maximum benefit from the program. Interestingly, there were about twice the number of users participating in the HRSG Spotlight Session than there were playing in the annual 7F Golf Tournament, which was held at the same time.

HRSGs and steam turbines have been the book-ends for the industry's most successful meeting of frame gas-turbine owner/operators for many years. Prior to 2011, the HRST's F-class workshops covered a wide variety of topics in nominal 15-minute increments. For the last three years, the boiler experts have focused on three subjects during each session to provide the level of detail necessary to facilitate implementation of initiatives suggested for improving efficiency, availability, and safety, while reducing emissions.

This year's topics were the following:

* HRSG performance thieves.

* Advanced inspection techniques.

* Inspection and maintenance of HRSG inlet and firing ducts, and gas-turbine diffuser ducts.

These subject areas were natural extensions of material covered in 2012 (superheater and reheater fatigue, economizer cracking, and drum-nozzle cracking) and in 2011 (flow-accelerated corrosion, desuperheater issues, and steam-drum cracking). The electronic links provided in this article connect to CCJ ON*site's* coverage of the 2011 and 2012 presentations, bringing the three years' worth of interrelated material together for you.

Stanley focused on these four performance thieves during his opening presentation:

* Gas baffling.

* Gas-side fouling

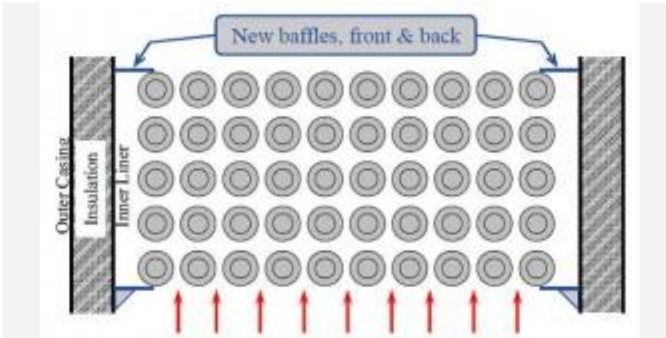
* LP economizer recirculation.

* Buoyancy instability/vapor locking.

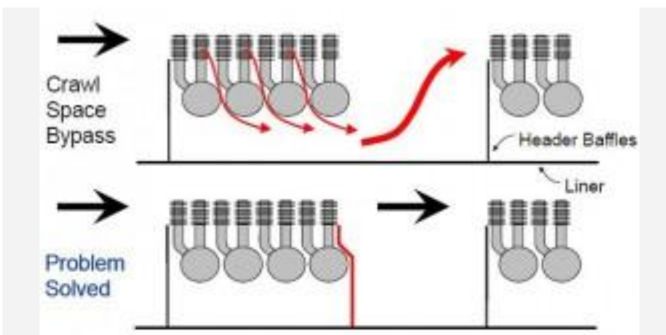
Baffles force turbine exhaust gas through the tube bundles, maximizing heat transfer and performance. Even gaps of only 2 in. between adjacent tube panels, between tube panels and the inner liner, and between headers in the crawl-space area can cause significant losses, Stanley told the group. Baffle integrity in evaporator and economizer sections is particularly important, he said.

Damaged or missing baffling is easy to identify during a gas-side inspection (Fig 1) and relatively easy and inexpensive to correct with standard carbon-steel components and conventional welding techniques (Figs 2 and 3). Perhaps the most costly component of baffle repair and/or replacement is the installation of scaffolding. Therefore, it makes good sense to do this work when cleaning tube panels, which also requires scaffolding.

1. Failed baffle was designed to prevent turbine exhaust gas from bypassing heat-transfer surface by flowing between adjacent panels



2. Sidewall baffles, relatively easy to install, prevent gas from taking the path of least resistance between the tube bundle and inner liner



3. Header baffles stop hot gas from bypassing the tube bundles via the crawl space

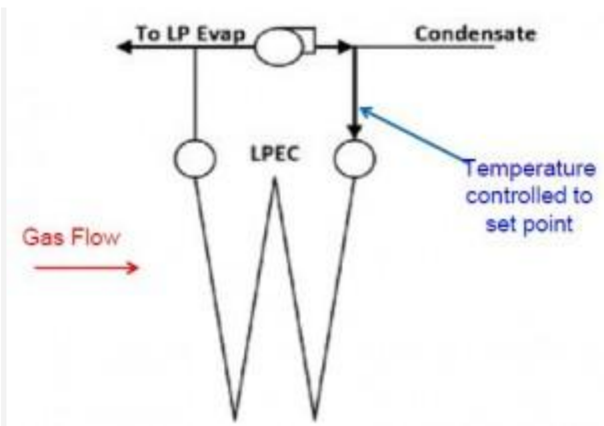
Stanley noted that thermal performance loss is not the only adverse impact of ineffective baffling; it has been known to contribute to flow-accelerated corrosion (FAC) as well. Also, when baffles in the firing-duct area are not in good condition, duct-burner flames can be disrupted and tubes and the SCR can suffer thermal damage—all in addition to performance loss.

Though baffle work is relatively simple to do, if your unit has excessive gaps in many locations, the plant maintenance budget might not be able to swallow the whole refurbishment project in one gulp. Stanley discussed one such case where performance modeling provided justification and prioritization of the work. Some gap locations create more performance decrease than others, he said. In the real-world example described, Stanley said that the annual benefit of coil-to-coil baffle fixes in all six access lanes of an F-class HRSG was about $1 million. However, baffle restoration in only two of the lanes produced 60% of that benefit making the investment decision an easy one. In this case, the plant reported a 2 MW increase in output after repairs were made.

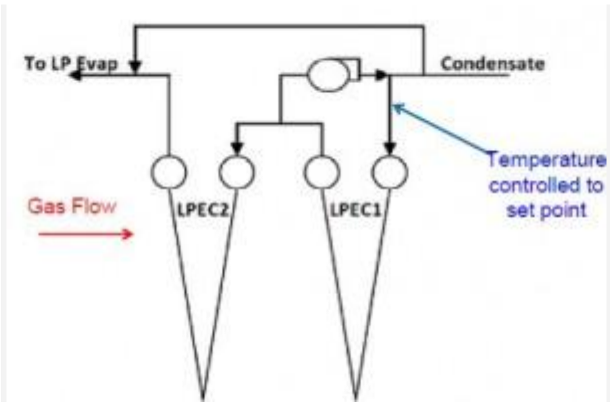
Gas-side fouling, as most attendees knew, can be caused by one or more of the following: rust, ammonia salts, sulfur compounds, and liberated insulation. They also were aware that the consequences of fouling include an increase in gas-turbine backpressure, a thermal-efficiency penalty, and the release of particulates up the stack, especially at startup. But many were not sure of the financial impact of fouling. Stanley worked up a short calculation that showed gas-turbine power production decreased by 0.105% for each 1-in.-H_2O increase in backpressure. For a 7FA with a nominal rating of 183 MW at ISO conditions, this translates to a “de-rate” of 192 kW. In addition, fouling reduces HRSG thermal efficiency because it reduces heat transfer and steam production.

Someone asked about the optimal time for cleaning fouled heat-transfer surfaces. Stanley said this was an economic decision and could be different for every plant. He added that high backpressure often drives the decision, to avoid the consequences of an unnecessary turbine trip. Next, the boiler expert suggested that plants develop their thermal-performance and backpressure yardsticks to determine the optimal time for cleaning. Stanley pointed out that rust is relatively easy to remove, SCR ammonia salts not so. Regarding the latter, he warned about the difficulties in cleaning tube bundles after they had bridged over—that is, totally packed to the fin OD with ammonia salts. “Clean before crisis,” Stanley urged.

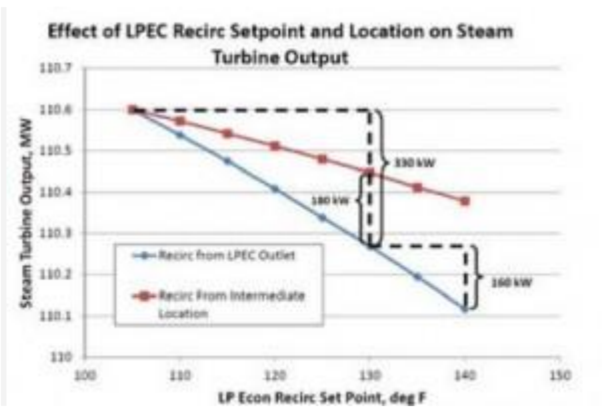
The next 10 minutes or so was dedicated to a review of the types of cleaning, the effectiveness of various media, and the advantages of so-called deep cleaning—a process developed by HRST Inc. Stanley said that, in general, best results in the cleaning of fouled finned-tube surfaces have been achieved using CO_2 and compressed-air blasting, perhaps in series. Water deluge or hydroblasting can do the job in some instances, he continued, but waste collection and disposal would likely militate against the use of water.



4. Corrosion is controlled in some LP economizers by recirculating a portion of the water exiting that heat exchanger back to the inlet to stay above the dew-point temperature



5. A more efficient recirculation scheme is to recirculate warm water from an intermediate header, if installed



6. The output penalty associated with recirculation may be such that replacement of a corroded harp is the more economic approach

The next performance thief

Stanley discussed was LP economizer recirculation. Bryan Craig wrote in a recent issue of HRST's *Boiler Biz* that recirculation often is used to raise the temperature of condensate entering the LP economizer above the turbine-exhaust dew point to minimize corrosion of panels in the back end of the unit. However, this comes with a cost. Recirculating water flow to increase the inlet temperature reduces overall output from the HRSG in a small, but measurable way, he stated. The amount of performance reduction depends on the water-temperature set point, and also the location from which the recirc flow is taken.

Some LP economizers recirculate a portion of the flow from the economizer outlet back to the inlet to achieve temperature control (Fig 4); others recirculate from an intermediate point within the economizer, design permitting (Fig 5). HRST engineers have concluded that if recirc must be used, it is more efficient to take the flow from an intermediate point than from the economizer outlet. The temperature set point also comes into play: Reducing the set point improves efficiency.

Craig used Fig 6 to illustrate this point. The chart is based on a typical F-class HRSG with a 12-row LP economizer and a condenser hotwell temperature of 105F. If recirc flow is taken from the economizer outlet, reducing the temperature set point from 140F to 130F increases steam-turbine output by 160 kW. Assuming the plant operates 5000 hr/yr and is paid $50/MWh for the electricity it produces, the 10-deg-F reduction in the set point is worth $40,000 yearly. For the 130F set point, extracting recirc flow from the midpoint of the economizer increases steamer output by another 180 kW, more than doubling the annual revenue gain to $85,000.

Eliminating recirc altogether, and allowing cold water to enter the LP economizer, increases steam-turbine production by 330 kW, which is worth about $82,000 per year. This suggests it may make sense to forego recirculation and plan on replacing the last one, two, or three rows of LP economizer surface every eight years or so, give or take a couple of years. Also worthwhile considering: The first time you replace the back-end surface, switch to an alloy material suitable for the wet environment and eliminate the need to do it a second.

Buoyancy instability. Stanley began the final segment of his presentation by reviewing the performance. Nearly all economizers have some down-flowing tubes, he said; most have down-flow in half the tubes. Buoyancy instability causes flow to stagnate in some of the down-flow tubes, or to reverse direction. When water does not flow as designed, the effective heat-transfer surface is reduced and heat absorption decreases.

Also, stagnant and reverse-flow tubes become hotter than neighboring tubes increasing the level of stress. The risk of this happening is greatest at low loads. Hundreds of thermal cycles can occur within a day, leading to fatigue failures in less time than you might think. Modification of flow circuitry can correct the issue. If a performance assessment advises that buoyancy instability is a problem early in the life of a unit, changing the location of splitter plates in the upper header should be considered to optimize the flow pattern. Stanley said the relocation of splitter plates is not as difficult as it might appear. In some cases, he said, it can be easier than plugging economizer tubes.

Buoyancy instability in return-bend economizers causes water in some circuits to flow very slowly or not at all, others to flow quickly. If the gas temperature is above the saturation temperature, stagnant tubes will vapor-lock—that is a steam bubble trapped in the return bend will block flow, generally until unit load is high enough to clear it. It is difficult to modify existing systems to correct this problem.