Dealing effectively with deposits on cold-end heat-transfer surfaces

Sometimes you pay for oversights and poor design decisions for the entire life of a plant. Consider tube spacing in heat-recovery steam generators (HRSGs), for example. Tight spacing minimizes capital cost, but it can adversely impact efficiency and availability, and increase maintenance. More generous spacing raises first cost slightly but can save money in the long term.

Special attention should be given to HRSG performance goals, and the impact of tube cleaning on them, at the design stage, says Jeff Daiber of Vogt Power International Inc, Louisville. Fin density, tube pitch, fins per inch, and tube arrangement in evaporator and downstream sections of the HRSG vary, but most cleaning technologies only can penetrate effectively the first four rows of tubes. If fin design is high-density, cleaning can push the salts and debris further back into the tube bank and trap it there. Occasionally, plugging of the tube bank occurs, irreversibly increasing backpressure and reducing heat transfer.

CO_2 pellet blasting of boiler tubes, while rated highly for its effectiveness in cleaning heat-transfer surfaces downstream of the SCR and for the small, dry waste streams it creates compared to other cleaning methods, is not necessarily a slam dunk, adds Daiber. Pellet velocity and density, technician experience, and other variables impact cleaning effectiveness.

According to the "HRSG Users Handbook" (visit www.hrsgusers.org for more information), the most significant fouling occurs downstream of the selective catalytic reduction system (SCR) installed to minimize NO_x emissions. Rust particles fill the gaps between tube fins, reducing heat-transfer efficiency.

Additionally, ammonia salts—primarily ammonium bisulfate and ammonium sulfate—precipitate in the gas turbine (GT) exhaust stream and collect on the finned tubes. They form when sulfur in the fuel (even natural gas contains trace amounts) combines with unreacted ammonia from the SCR.

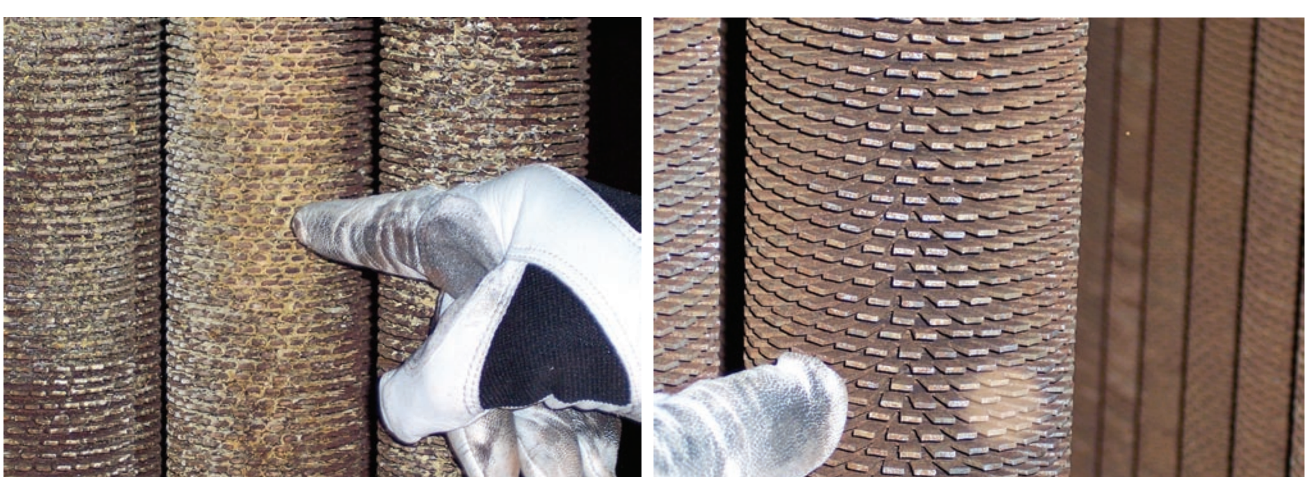
Quantity of ammonia salts depends on the type of fuel, amount of SO_3 in the exhaust gas, presence of ammonia slip, and local temperature. Precipitation is most likely where the gas temperature is below 400F, so deposition is greatest in tube sections closest to the stack.

Higher-than-normal GT backpressure probably is the best online indicator of tube fouling. Manometers can be installed across each tube bank to measure and track the module-by-module backpressure increase. Higher-than-normal stack temperature also can be an indicator of fouling, the temperature rising with increased fouling because of reduced heat transfer. Another indicator is a decrease in water temperature at the economizer exit. But keep in mind that it is difficult to use such indicators to quantify fouling because of the substantial influence of ambient conditions on GT and HRSG performance.

Use of cryogenic cleaning is common in the gas-turbine-based sector of the electric power industry. Generally it is effective for removing both "loose" material lodged between fins and contaminants tightly bonded to the metal surface with a combination of impact energy, temperature differential, and gas expansion. Applications beyond HRSG finned tubes include GT compressor and turbine blades, steam-turbine blades, generator rotors and windings, motors, and other equipment.

Advantages of this medium beyond its dry waste stream include no particles to plug GT cooling-air passages, no solvent to penetrate and concentrate in surface cracks, no drying time as required by a liquid medium, etc.

CO_2 blasting is art, not science. Cleaning effectiveness, says Bob Fidler, who heads up Bob Fidler



Dirty finned tube shows high degree of surface fouling (left); results after CO_2 blasting are at right.

Services Inc (BFS, www.bfsinc.org), Apple Valley, Calif, depends on the nozzles that direct the dry ice on the surface being cleaned and the knowledge and experience of the cleaning crew. BFS, one of several companies providing this service, is a relative newcomer to the electric power business.

The editors ran into Fidler at the vendor fair for the recent 7EA Users Group conference in San Francisco (see meeting report elsewhere in this issue) where he was touting the company's recent successes in cleaning two F-class HRSGs for one power producer in the West and the GT compressors for another.


Fidler

The affable Fidler is bullish on his company's achievements. If you have the time, he's happy to turn back the clock to 1965 when he started building his resume in industrial cleaning. In brief: Started in refineries and learned how to deal with all manner of cleaning challenges. In the mid 1980s he got his first experience in CO_2 blasting, using a prototype trailer-mounted system designed to remove paint from jet fighters and helicopters.

Fidler formed his own firm in 1992, got licensed in California as a General Engineering Contractor, acquired the necessary certifications and permits for handling and disposing of asbestos and other hazardous wastes, etc. BFS needs all this paper because its business involves a significant amount of work in process plants using a variety of media—including sand/grit blasting, high-pressure water, and chemical cleaning in addition to CO_2 blasting. The firm also does coatings to facilitate future cleaning.

In sharp contrast to the trailer-mounted CO_2 systems of yesteryear, Fidler says the firm's proprietary "guns" for shooting dry ice at deposits and efficiently removing them are all that he has to pack for any job today. He buys the ice and rents a compressor and other equipment when he gets to the plant. Thus response time almost anywhere in the US is within 48 hours, usually 24.

The two HRSGs the firm just cleaned represented a two-week effort. First unit took about nine days working top to bottom/row by row through special windows in the casing installed by the plant a few years ago. Once familiar with the design idiosyncrasies of the Vogt-NEM boiler, and after having developed an effective cleaning technique for it, BFS was able to do the second unit in half the time. In sum, 18 drums of waste were removed. Photos show both the initial condition of tubes and after cleaning.

The editors followed up with a phone call to the plant and spoke with the maintenance manager. They learned the following: The 2 × 1 combined cycle began commercial operation in June 2000. In 2005, plant operations personnel observed that deposits on the external surfaces of finned tubes in the downstream half of the low-pressure-boiler section and in the preheater bundle could limit load that summer if corrective measures were not taken. However, cleaning was not possible at that time.

After consulting with the HRSG supplier, personnel raised the GT backpressure trip setting, thereby enabling near rated output under most ambient conditions. Meanwhile, deposition on the tube bundles was increasing. Two negatives associated with the high-backpressure condition:

- Back-of-the-envelope calculations revealed an increase in plant heat rate of about 50 Btu/kWh.
- An increase in NO_x production. Apparently, flow disruptions attributed to high backpressure adversely impacted the ability of the ammonia reagent to properly mix with the exhaust gas—in particular, at low loads.

The maintenance manager characterized the external tube deposits as primarily of the "gooey" type, rather than cementitious. A practical test program revealed that they dissolve in water—particularly hot water. So after the 2005 summer peak had passed, plant personnel tried to remove the deposits by pressure washing from the front and back of the bundles. Predictably, only the first three front and back rows of the 15-row bundle came clean.

Next step was to cut windows into the casing to access all tubes in all rows of the 70-ft-tall bundles from the side. Then a contractor was hired to pressure wash the tubes. The service firm used water containing dissolved soda ash as the working fluid in the high-pressure system. A 20-ft lance is required to reach the center point of the heat-transfer section; the other half is accessed from the other side of the boiler.

Handling the waste stream created by the water wash was difficult at best. It was an extremely messy situation, according to the maintenance department. That's why a few months ago, when backpressure started creeping up to the turbine trip point once again, the plant turned to CO_2 as the cleaning medium.

In terms of cleaning effectiveness, the maintenance manager thought the water and CO_2 might have been on equal footing. But there was no way to really tell at this time: You can't see the level of cleanliness in the middle of the bundle and the plant does not yet have instrumentation installed to monitor the pressure drop across individual tube bundles. Only information available is the pressure drop from the GT outlet to the stack—a variable influenced by much more than tube fouling.

CO_2 probably will be cleaning medium of choice next time high backpressure threatens a turbine trip. But job will be easier, faster, and probably less expensive, according to the maintenance manager, because of lessons learned. Under consideration is training plant personnel for this job. Scuttlebutt is that another western combined cycle handles CO_2 blasting on staff with reasonable success. CCJ