York Resource Recovery Center Metal Spray Success

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Abstract
Early US waste-to-energy plants were constructed using conventional boilers designed for fossil fuels, gas, and oil. Combusting MSW exposed those boilers to high levels of sulfides and chlorides that caused accelerated corrosion problems. MSW fuel required higher amounts of excess air that resulted in high furnace gas velocities and metal erosion. Depending upon the individual design of each boiler, effects of higher upper furnace temperature, flame impingement, and flyash carry over were reported. This paper describes a test conducted to extend the useful metal life of superheater tubes by employing recently developed high velocity continuous combustion (HVCC) metal spray materials.

Introduction
The three combustion units at the York Resource Recovery Center use the Westinghouse Electric design (1987) consisting of an O'Connor Rotary Combustor fitted to a single-pass waste heat boiler. Several design aspects of the boilers and conditions of the operation cause severe metal wastage in the superheater compartments. Tube design, furnace gas temperature, steam temperature, and superheater metal material led to superheater tube failures after only six months of operation in 1998.

The boiler's radiant cross-sectional dimensions are 22 feet x 20 feet (6m x 6.7m) with a vertical height of 56 feet (17m). The rotary combustors penetrate the boilers near the bottom of the chamber. Flame impingement and high velocity furnace gas problems in the radiant section caused the original plant operator to protect a large area of the lower radiant section with refractory.

Combustion gas leaves the rotary combustor flowing into a single pass boiler, spirals up through the firebox, and makes a ninety-degree turn to pass through screen tubes and into the superheater compartment. Furnace gas temperature near the entrance of the screen tubes averaged a temperature of 1375°F (746 Celsius) through most of the normal operation while the lower furnace walls were refractory coated.

The original boilers were fitted with two superheater sections with pendants fabricated of 2 in. OD x .135 in. wall thickness, SA-213 T11 designed for 900°F and 1100 PSIG, steam temperature and pressure respectively, corresponding to a gas temperature of 1332°F (723 Celsius) and steam temperature of 810°F. The higher than expected upper furnace temperature was related to the refractory protection installed on the lower radiant water wall tubes.

Within six months of the initial plant start-up and operation, the
superheater tubes experienced failures. The former operator created a Task Force to review the premature superheater failures.

Three separate and independent engineering studies were conducted to evaluate present boiler conditions and design and what needed to be done to improve superheater metal life.

The Task Force concluded that superheaters would need to be reconfigured to address the effects of the suspected high furnace gas velocity which was believed to play an important role in tube corrosion and erosion. Operational limits were placed upon upper furnace temperature and higher excess air with better secondary air admission to reduce the failures rather than to undertake significant and more costly boiler modifications such as a suggested archway or second pass to correct the problem.

Superheater #2 was reconfigured and tube material was upgraded from carbon steel to T22 material. Tube wall thickness was increased to 0.280 in. The cross-sectional flow area through the compartment was increased by the reconfiguring the superheater pendants. Steam temperature was reduced by changing the original steam flow path and adding a second attemperator. These changes were made in an attempt to reduce gas velocity and superheater pendant metal temperature. Following the reconfiguration, no extensive follow-up testing was performed to evaluate the effectiveness of these changes. The following year, the remaining superheater was also reconfigured to further improve flow and temperature in the compartment. The final and present configuration of the superheaters is shown in Figure 2.

The new T22 material failed in less than two years of operation with the earliest of these failures occurring in the Finishing Superheater. At that time and without post modification testing data, the operator believed that the pendant reconfiguration had resolved the gas velocity problem in the compartment. However, the new failures were attributed to the corrosive effects of the furnace gas further aggravated by steam soot-blowing. The theory was further supported by the presence of deposits on the finishing superheater tubes thought to be low melting temperature eutectic mixtures.

In 1993, new finishing superheater pendants of Inco Alloy 800H were fabricated and installed. That alloy is considered to be extremely corrosion resistant. The Alloy 800H pendants failed in significantly less operational time than the previous T22 tubes. Subsequent superheater pendant replacements continue to be fabricated from T22 material and replaced at regular two-year intervals.

Current superheater pendants are installed with tube shields, 10-gauge 310SS 360-degree wrap, on two of the inlet and outlet tubes. These shields generally afford good protection over the first year and then require replacement. The replacement shields never fare as well.

The current superheater configuration in the gas flow path is arranged as Primary I, Finishing, Intermediate and Primary II. Two attemperators are used. One is placed between Primary II and the Intermediate and the second is located between the Intermediate and Finishing. Both are controlled by the main steam outlet temperature. Figure 2 depicts the present configuration of the two
attemperators and Table 1 provides the inlet and outlet temperatures and pressures for reference.

Inspection of the superheaters over the years continually showed wear rates of as high as 8 to 10 mils per month. This was particularly the case for leading tubes of each superheater pendant that were located in the proximity of the sootblower path and the pendant tubes attached to the steam header with the higher temperature. The nominal .280" wall tubes wear to the permissible minimum wall tube thickness of 90 mils in a twenty-four month operating period even with the 10-gauge 310SS shielding described previously.

In 1999 and again in 2003, two independent engineering companies conducted tests on the York boilers and then simulated conditions in the superheaters using both physical and computer modeling. Their recommendations to reduce superheater metal wastage were twofold: 1.) install an arch in the radiant section to increase turbulence, thereby reducing the overall furnace gas velocity, and 2.) to reconfigure the steam flow path leaving the drum to create parallel feed to each superheater header to reduce overall metal temperature by improving steam flow.

Following these two recommendations, a return on investment analysis was performed and the operator could find no promising maintenance cost savings between the capital investment required to complete the modifications over the maintenance cost associated with the current two-year replacement schedule. Additionally, the recommendations simply provided no guarantee of extending the useful life expectancy of the superheaters and did not adequately address the question of the overall effects of corrosion in metal wastage.

In 2003, six superheater pendants (two each for the Primary I, Finishing and Intermediate) were fabricated using spiral wound Inconel 625 overlaid tubes. The two pendants were placed near the center of the superheater banks where the highest metal loss rates were regularly detected. After approximately six months of operation, corrosion and spalling of the inconel coating on the Finishing superheater test pendants were observed. Large divots of the overlay were missing at the end of one year. The highest metal losses were measured on the pendant tubes attached to the hottest steam header and indicated that metal temperature was directly related to the performance of the protecting material. Primary I test pendants fared slightly better since steam temperature and pressure was slightly lower and the corresponding metal temperature of the tube was also lower.

Over the years, different companies representing various metal spray applicators have visited our site to discuss the application and use of their products in our superheaters. We generally provide them a six-foot length of 2 inch OD T22 tube material certified for use in our boilers and the applicator would coat it with a 30-mil application of their product at their facility. Our normal practice is to use such test pieces as a repair replacement tube during maintenance outages. When the tube of an installed pendant shows excessive wear, it is repaired using the test piece. A note is made of its date of installation, location, provider, and then we periodically monitor its performance.
None of the many coatings and sprays tested over the years demonstrated enough promise to be considered as viable for permanent use in our superheaters until we installed a test pendant coated with Amstar AmS 888 material.

In August 2005, three different vendors had provided samples with spray coatings. Each applicator had applied 30 mils of recently developed proprietary metal spray coatings to the standard T22 tube material applied using high velocity thermal spray techniques.

The AmS 888 cladding is a nickel chrome material designed for service in very high corrosive and erosive environments operating at high temperatures. According to the manufacturer, general laboratory development tests (alternating reducing / oxidizing, sulfurdation) demonstrated a twelve-fold improvement over wrought Inconel 625 [1].

At the York facility, six tubes fabricated from 2-inch OD T22 material coated with 30mils of three types of metal sprays were tested. Two tubes were coated with Amstar AmS 888, a product exclusively produced by Specialty Metals. Four other tubes were coated by two other independent vendors and bore Colmonoy 88 in their descriptions. Colmonoy 88 is a commercially available product that has been successfully used in many waste-to-energy plants internationally. It should be noted that aftermarket vendors applied the material, not the manufacturer of Colmonoy 88. The six test tubes were installed in the superheater of our #1 Boiler in August 2005.

One of each of the three varieties was installed as the leading tube in the Intermediate Superheater. Our intermediate banks have fifty-two (52) total pendants and are cleaned by two steam sootblowers that enter from opposite sides of the compartment and have overlapping spray at the center. Tubes observed to have the highest rates of metal wear are located in this overlapping area and are likely to fail first. A coated tube was installed in Pendant #26, the Amstar AmS 888 tube in Pendant #28, and the second type of coated tube as Pendant #30. Therefore, each of the three coatings was applied by a different vendor.

A second set of similar test tube sections was installed as the leading tube in the pendants located in the Finishing Superheater. This bank is comprised of twenty-six pendants and shares the same overlapping sootblower problem as in the Intermediate Bank. A coated tube was installed in Pendant #14, the Amstar AmS 888 tube in Pendant #16, and the other coated tube in Pendant #18. Figure #3 shows exact locations of the six installed test pieces.

Previous measurements of metal loss on the leading tubes in both the Intermediate and Finishing Superheaters approached 10 mils per month. The superheater flu gas lanes generally foul in approximately eight weeks due to the amounts of entrained fly ash carried by flue gas with a velocity of over 50 ft / sec. Superheaters are cleaned off-line using water. These eight-week cleaning cycles affords the opportunity to inspect the progress of the test sections on a somewhat regular basis.

The six test sections performed without noticeable metal loss or problem from installation in August 2005 until May 25, 2006, some ten months later.
The boiler was stopped for a regular cleaning cycle and the test pendants were inspected as routinely done.

The Amstar coated tubes installed in both the Finishing and Intermediate superheaters showed no visible signs of failure and thickness testing verified that the metal spray remained at full 30-mil thickness. The two tube sections coated with other products provided showed signs of early failure. Spalling, surface pitting, and measurable metal loss were noted.

Similar observations and readings were made when Unit #1 was cleaned in July, September, and November. The pendants were removed as part of the routine two-year replacement of superheaters in January 2007. The Amstar AmS 888 test sprayed tubes remained impervious to the erosion and corrosion present in the boiler for the entire sixteen month test.

One Amstar AmS 888 test section was returned to service in the newly installed Finishing Superheater in January 2007 and will continued to be monitored at regular intervals over the next two years.

The second Amstar AmS 888 test section was returned to the applicator for further evaluation and test reports indicate that our observations at the plant were correct. No thinning of the 30-mil coating occurred and the surface of the tube appeared to show no visible change or corrosion under microscopic inspection in the lab.

Conclusion

Amstar believes that their spray application process yields a superior product to either hand or machine welding of NiCr alloys because the spray deposited coating material is fully amorphous (no crystal grain boundaries with no microscopic elemental segregation / concentration), which is different from coatings produced using a welding process. For Amstar AmS 888 metal spray coatings, no intergranular corrosion occurs.

Our tests are not an endorsement of Amstar, their products or application methods. Nor, do we endorse the use of any metal spray products of any other manufacturer.

Our tests demonstrate that the new technology of Amstar metal spray has been effective at the York facility on tests sections installed in our superheater application.

Metal spray and its technology has continued to evolve over recent years and facilities with similar metal wastage problems such as the ones that are experienced in our boilers should consider their use. If metal wastage of boiler heat transfer surfaces is related to erosion from high velocity furnace gas or to corrosion created by the ill effects of sulfur and chlorine in furnace gas, then the technology of high velocity metal sprays may be a solution.

References


Figure 1. York Boiler Configuration
Figure 2. York Superheater Configuration

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Table 1. Superheater Steam Flow Path Temperatures & Pressures
Figure 3. Test Tube Location Map August 2005