The SEMASS Resource Recovery Facility (SEMASS) is a processed refuse fuel (PRF) waste-to-energy plant serving Southeastern Massachusetts. Using its PRF technology, Energy Answers Corporation developed the project in the early 1980's. The first two units have been in operation since 1988 and the addition of a third unit was completed in 1993. SEMASS is owned by the SEMASS Partnership, a Massachusetts limited partnership, between American Ref-Fuel of SEMASS, L.P. (Ref-Fuel), and ArkMass, Inc.

Each of the three units at SEMASS is capable of processing a nominal 1000 tons per day of municipal solid waste (MSW). Two condensing steam turbines receive the steam from all three boilers and develop a combined 80 MW of net power.

BOILER DESCRIPTION

The boilers at SEMASS are Riley Stoker (Babcock Borsig Power) type VR, balanced draft, natural circulation units. The boilers incorporate a welded membrane waterwall construction, generating bank, and two-stage pendant type superheater. These boilers are top-supported, two-drum, single-gas pass units. The design has a maximum continuous rating of 270,000 PPH at 650 psig and 750 °F superheater outlet conditions.

The boilers are fired on Refuse Derived Fuel (RDF) utilizing a Riley Stoker double Spreader Type Stoker (see Fig #1). The boiler can also fire No. 2 fuel oil through two John Zink, Inc. round burners mounted on the rear wall at the 131'-0" elevation.
Superheater Details

All three boilers have a two-stage pendant-type superheater suspended over the upper slope convection pass section of the boiler (see Fig Superhea#2). There are a total of 43 Low Temperature Superheater (LTSH) and 43 High Temperature Superheater (HTSH) assemblies. Each LTSH is constructed from a single tube circuit forming sixteen 16-vertical runs. The LTSH original material selection was 2\%\ W, 0.150" MWT, SA-210 Al on the rear 10-legs and 2\%\ W, 0.148" MWT, SA-213 T-22 on the front six legs. This has since been upgraded to 0.180" wall thickness on both materials. Each HTSH is constructed from a single tube circuit forming 10-vertical runs. The HTSH sections original material selection was 2\%\ W, 0.150" MWT, SA-210 Al on the front leg and 2\%\ W, 0.148" MWT, SA-213 T-22 on the rear nine legs. This has since been upgraded to all 2\%\ W, 0.203" MWT, SA-213 T22 material. Refer to Figure #2.

Deteriorating Superheater Life

Over the life of the SEMASS project, superheater life has fallen precipitously. The original set of superheater tubes at SEMASS, installed in 1988, lasted approximately seven years. The second set of superheaters, installed in 1996, lasted about three years. In late 1999, a third set of superheaters was installed in all three units. From this point on, superheater tubes have lasted only 12 to 18 months before exhaustion. Obviously, this trend has been a bit disconcerting to all involved.

Factors Affecting Superheater Life

Over the 13 year history of the SEMASS plant, availability rates have gone up significantly, thus allowing for significantly higher annual throughputs. Another factor we believe that has had a negative impact on the life cycle of our superheaters is the amount of Inconel and tile utilized on the furnace waterwalls.

Starting in the second year of SEMASS operation (1990), field applied Inconel was utilized on the waterwall tubes to protect the carbon steel from excessive wastage due to corrosion. During 1990, approx. 6% of the furnace waterwall surface area was covered with Inconel weld overlay. That percentage has steadily increased over the years with current Inconel coverage averaging nearly 68% in the three units.

In addition to the Inconel, SEMASS has also protected waterwall tubes from severe corrosion through the use of 2" thick silicon carbide ceramic tiles. This method of protection started in late 1998 with approx. 6% coverage and is currently at approx. 20% coverage of the furnace tubes. Consequently, nearly 88% of the furnace waterwall tubes are now either covered with Inconel or silicon carbide tile. All of the above factors have led to furnace exit gas temperatures that are 100 degrees F to 200 degrees Fahrenheit higher than originally designed.

Materials Test in Boiler #1 - 2001

In an effort to return our superheaters to a three yr. life, a test of higher alloy materials (SA213-TP310H, SB-423 Incoloy 825, and SB-423 Inconel 625 spiral weld overlay of SA213-T22 base material) was undertaken in our unit #1 Low Temp Superheater during the 2001 outage. The higher nickel content of these alloys was the primary consideration for these alloys (see Table #1).

In addition, in 2001, ARC started testing on a very limited basis, higher alloy materials in the High Temp Superheater.

Materials Test in Boiler #2 - 2002

In 2002, ARC started testing Heavy Wall T-22 material High Temp Superheaters in Boiler #2. These superheaters had roughly twice the tube wall thickness of the regular superheaters and an outside diameter that was 1/4" larger in order to keep the ID of the tube steady.

Test Material locations

In Boiler #1, SEMASS installed a LTSH that had the first 12 tube runs made of SA-213-TP310H material. (See figure #3) The last four tube runs were made of SA-210 material (original design). In addition, we had three pendants with SB-423 Incoloy 825 utilized in the 3rd and 4th tube runs, and three more pendants with Inconel 625 weld overlay on SA-213 T22 tubes in the 3rd and 4th tube runs.
LTSH Results 2001

After nine months of operation, the LTSH tubes (685°F steam temp.) made with SA-213-TP310 H stainless steel, as shown in table #2 below, had average metal wastage rates that were 50% lower than the comparable SA-213 T22 pendants installed at the same time in unit #2, 1.5 mils/month vs. 3 mils/month. The Incoloy 825 tubes showed slightly less wastage than the TP310H tubes (1.1 mils vs. 1.5 mils). The superheater tubes overlaid with Inconel 625 looked essentially like new after nine months and showed no measurable metal wastage.

LTSH Results 2002

Evaluation after 18 months showed that all of the corrosion rates had accelerated somewhat, but the conclusions were essentially the same. The SA-213-TP310 H stainless steel still had average metal wastage rates that were 41% lower than the comparable SA-213 T22. The Incoloy 825 tubes had corrosion rates that were 58% less than the T22 tubes and Inconel clad tubes still had no measurable wall loss.

Economic Considerations – year two

The purchase price of the low temperature superheaters utilizing 75% stainless steel tubes was approximately 2.5 times the cost of a T-22 superheater. However, when you factor in the labor costs for installing the superheater, the net increase in costs of an installed stainless steel superheater versus the T-22 superheater, is only a factor of 1.6. Consequently, with an increased life factor of 1.7, it still makes sense to purchase the stainless steel unit over the T-22 superheater. That is;

Annualized cost factor = cost factor / life factor.

So the St. St. annualized cost factor would be:

Annualized StSt Cost Factor = 1.6/1.7 = 0.94

The total installed costs of an Incoloy 825 superheater are approximately 1.9 times the cost of an installed T-22 superheater. So as with the stainless steel pendant, it appears to make sense to make the investment in higher grade tube material because the cost ratio of 1.9 is still less than the projected lifetime ratio of 2.4. The annualized Cost Factor would be:

Annualized Incoloy Cost Factor = 1.9/2.4 = 0.79

Finally, the Inconel 625 overlay tubes are the most expensive to install with a cost ratio(installed) of 2.4 but with a projected lifetime ratio of greater than 4.0, it still makes sense to invest in the higher nickel content in order to achieve a lower annualized cost.

Annualized Inconel 625 Cost Factor = 2.4/4.0 = 0.60

HTSH Results

In April of 2002 we added another twist to the tube metals evaluation. In the High Temperature Superheater in boiler #2 we replaced the 203 MWT SA-213 T22 tubes with heavy wall 300 MWT SA-213 T22 tube material. The tubes were also increased in outer diameter to 2-1/2" (from 2-1/4") to make the Inside Diameter of these new heavy wall tubes essentially the same as the old Inside Diameter.

Corrosion rate data after 6 months of operation are presented in table #4. This data indicates that overall, even though the corrosion rate appears to be a little faster on the heavy wall tubing, the relative life is about 25% longer on the 300 MWT tubing.

Economic Considerations – HTSH

The installed cost of the heavy wall High Temperature Superheater is approximately 10% higher than the normal wall HTSH, or a cost factor of 1.1 The annualized cost factor for the Heavy wall HTSH would then be:

Annualized HW Cost Factor = 1.1/1.25 = 0.88

Summary

Based on the data from 18 months of LTSH service at SEMASS, it appears that utilizing the higher alloy tube materials, Stainless Steel 310 H, Incoloy 825 and Inconel 625 overlay, all are more cost effective than the T-22 material. And as found after 9 months of testing, the highest grade material after 18 months of
service, (Inconel 625 overlay) had the lowest overall annualized cost. The only drawback for the Inconel overlay tube material was that it took 4 years to recover your initial investment on a simple payback basis.

In the HTSH application, it appears that investing in the heavier wall material does have a net payback with an annualized cost benefit that is slightly better than the annualized cost benefit of the stainless steel superheater in the LTSH application.

**Future Plans**

Based on the testing performed in both units #1 and #2 at the SEMASS facility. American Ref-Fuel Corp. has purchased one full set of Inconel 625 overlay LTSH pendants for installation in the #3 boiler as well as a heavy wall HTSH. In boiler #2, ARC has purchased a Stainless Steel LTSH with a Heavy Wall HTSH. In boiler #1, we will continue the Stainless Steel Superheater testing of the LTSH (3rd year of testing) and replace the 210 wall MWT HTSH with a heavy wall set of HTSH pendants.

**References:**


**Table 1: Material Comparison [1,2]**

<table>
<thead>
<tr>
<th>ALLOY</th>
<th>SA213-T22</th>
<th>SA213-TP310H</th>
<th>SB-423 Incoloy 825</th>
<th>SB-423 Inconel 625</th>
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<tbody>
<tr>
<td>Ni</td>
<td>---</td>
<td>20</td>
<td>38-46</td>
<td>58(min)</td>
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<tr>
<td>Cr</td>
<td>1.9-2.6</td>
<td>24-26</td>
<td>19.5—23.5</td>
<td>20.0-23.0</td>
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<tr>
<td>Mo</td>
<td>0.87—1.13</td>
<td>---</td>
<td>2.5—3.5</td>
<td>8.0-10.0</td>
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<tr>
<td>Fe</td>
<td>Balance</td>
<td>Balance</td>
<td>22.0 min</td>
<td>5.0(max)</td>
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<tr>
<td>Co</td>
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<td>---</td>
<td>---</td>
<td>1.0(max)</td>
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<tr>
<td>W</td>
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<tr>
<td>Si</td>
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<td>0.75</td>
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<td>Mn</td>
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<td>1.0</td>
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<tr>
<td>C</td>
<td>0.15</td>
<td>0.04-0.08</td>
<td>0.05</td>
<td>0.10</td>
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<td>Nb</td>
<td>10xCmin-1.10 max</td>
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<td>3.15—4.15</td>
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<tr>
<td>Al</td>
<td>---</td>
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<td>0.20</td>
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<td>Ti</td>
<td>---</td>
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<td>0.6—1.2</td>
<td>0.40(max)</td>
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<td>V</td>
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<td>Cu</td>
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<td>1.5—3.0</td>
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<tr>
<td>P</td>
<td>0.030</td>
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<td>---</td>
<td>0.015</td>
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<tr>
<td>S</td>
<td>0.030</td>
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<tr>
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### Table 2: 2001 AVERAGE LTSH WASTAGE RATES
(data taken after 9 months of service)

<table>
<thead>
<tr>
<th>Material Type</th>
<th>SA 213-T22</th>
<th>TP310H St. St.</th>
<th>Incoloy 825</th>
<th>Inconel 625</th>
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<tbody>
<tr>
<td>Wastage Rate</td>
<td>3.0 mils/mo.</td>
<td>1.5 mils/mo.</td>
<td>1.1 mils/mo.</td>
<td>No measurable loss</td>
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<tr>
<td>Relative Life Factor</td>
<td>1</td>
<td>2</td>
<td>2.7</td>
<td>4+</td>
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### Table 3: 2002 AVERAGE LTSH WASTAGE RATES
(data taken after 18 months of service)

<table>
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<tr>
<th>Material Type</th>
<th>SA 213-T22</th>
<th>TP310H St. St.</th>
<th>Incoloy 825</th>
<th>Inconel 625</th>
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<tbody>
<tr>
<td>Wastage Rate</td>
<td>6.0 mils/mo.</td>
<td>3.6 mils/mo.</td>
<td>2.5 mils/mo.</td>
<td>No measurable loss</td>
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<tr>
<td>Relative Life Factor</td>
<td>1</td>
<td>1.7</td>
<td>2.4</td>
<td>4+</td>
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### Table 4: 2002 AVERAGE HTSH WASTAGE RATES
(data taken after 6 months of service)

<table>
<thead>
<tr>
<th>Material Type</th>
<th>T22 203 MWT</th>
<th>T22 300 MWT</th>
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</thead>
<tbody>
<tr>
<td>Wastage Rate</td>
<td>6.2 mils/mo.</td>
<td>7.2 mils/mo.</td>
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<tr>
<td>Relative Life Factor</td>
<td>1</td>
<td>1.23</td>
</tr>
</tbody>
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