FIRESIDE TUBE CORROSION IN AN INDUSTRIAL RDF-FIRED BOILER — KODAK'S EXPERIENCE

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Discussion by

Richard Engdahl
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Mr. Blakely's contribution is beautifully detailed and is thus extremely helpful to all who are struggling with the problems of tube maintenance in waste burners. The unusually high concentration of corrosive halides in some of the wastes fired appear to accelerate corrosion rates.

One critical detail that ought to be added to make this splendid paper even more helpful is to give some estimate of combustion intensity or heat release rate. The reference to flame impingement on the walls gives the reader the impression that this undesirable feature is not simply an effect caused by tangential firing but also because volume heat release (or release rate per unit area of waterwall surface) is too high! A clue to the severity of this parameter is the poor showing of castable refractory on studded wall tubes from 1976 to 1979 as shown in Table 1. This is much worse performance than is the common experience in many municipal waste burners both here and abroad. The obvious failure of this method of wall protection at Kodak must be related somehow to "excessive" heat release rates.

It will be interesting to have a tabulation for the various waste-burning conditions, some figure for total heat release in the furnace: for example, Btu/cu ft in the total volume between the grate and the lower tip of the superheater, or Btu/ft² waterwall surface. Then the range of those rates should be compared to similarly calculated rates in various municipal waste burners. It is my impression that such comparisons may show the Kodak boiler to be subjected to much more intense firing than has been found prudent for MSW.

This paper gives a helpful summary of important ways that the furnace differs from design predictions: (a) a single fireball does not occur; (b) excess air is much higher than predicted; (c) wide swings occur in oxygen concentration.

Then the important conclusion is: "with the above conditions, it is impossible to prevent particle and flame impingement on the furnace walls."

The waste-to-energy industry will mature more rapidly if designers and owners would follow Mr. Blakely's suggestion in his last sentence: "sharing of such problems as well as successful solutions will continue to be beneficial to Kodak and other resource recovery facility operators."

Discussion by

Edward H. Hohman
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Gaithersburg, Maryland

INTRODUCTION

The author has prepared and presented an informative paper about Kodak's corrosion research and materials testing on a full-size industrial boiler. The boiler is
used to dispose of industrial solid waste and wastewater sludge and produce steam for manufacturing plants. It has been in operation since 1970, and the author believes it to be the first use of a tangentially-fired, suspension-fired boiler for 100% firing of prepared refuse and sludge.

REFUSE AND SLUDGE CHARACTERISTICS

The waste being fired is identified as shredded industrial refuse, including photographic scrap material, and wastewater sludge. It is mentioned that silver chloride and bromide are present in the refuse and sludge. However, other characteristics of the materials are not identified.

It would be valuable for the author to add information such as refuse particle size, and lead, sodium, potassium, chlorine, bromine and sulfur concentrations in the refuse and sludge. This would make it possible to compare these wastes with municipal solid waste or refuse-derived fuel.

SLUDGE DRYING AND BOILER FEED SYSTEM

One of the interesting features of the plant is that sludge is cofired with refuse. For many years, cofiring has been suggested as a solution to the two major problems of solid waste disposal and sludge disposal. However, cofiring is not widely practiced in the United States, which indicates that it is not that easy or economical to accomplish. One major issue is sludge drying and sludge handling in the semi-dry state.

Kodak apparently has a successful sludge drying, conveying and boiler feeding system. The author should expand the discussion to include any significant operating experiences or problems in his response paper. This could also be the subject of a future paper.

BOILER DESIGN AND OPERATION

One conclusion of the paper is that the boiler design and operation results in flame and burning particle impingement, which brings corrosive compounds in contact with the waterwalls and superheater pendants. Another finding is that the excess air is much higher, 75–100% than the 30% originally expected, which presumably increases the wall scouring and removal of protective oxide coatings.

It appears that a tangentially-fired boiler may not be optimum for this application, or perhaps the higher excess air is at fault. Another possibility is the wrong refuse particle size. As noted in the paper, recent dedicated RDF boilers are semi-suspension types having travelling grates. The author should respond.

CORROSION PROTECTION

Kodak has tried most corrosion protection methods, beginning with weld overlays in 1975. Reportedly, neither the castable or brick refractory nor the plasma-sprayed coatings lasted very long. The shields required continual replacement. Kodak is now back to using weld overlays.

Several RDF plants are also using weld overlay for corrosion protection. Are there any operating comments in the year the material has been in use on the Kodak boiler? Are there any other corrosion methods, such as use of concentric tubes, being contemplated in the future?

Discussion by

H. H. Krause
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Columbus, Ohio

The author is to be commended for presenting a well-documented account of the corrosion experience in their waste-fired boiler. The paper does an excellent job of reconstructing in detail the 20 year history of problems and their solutions in addition to discussing causes and mechanisms involved in the various aspects of the corrosion. I was on site during the Battelle corrosion probe studies mentioned in the paper, and recall seeing large pieces of paper and other carbonaceous material burning in contact with the furnace wall tubes at that time. The existence of such local reducing conditions contributed to the severe tube wastage by a synergistic action of CO and HCl, which was not fully appreciated at that time. European experience with waste-fired units had shown higher corrosion rates in areas where CO was high, and British boilers burning coal with more than 0.3% chlorine had similar problems.

In the early 1980s, Brooks and Meadowcraft\(^1\) conducted a laboratory study of the corrosion of mild steel

exposed to simulated flue gases containing high levels of CO and SO₂. At 752°F (400°C) the corrosion followed a parabolic rate curve that leveled off at a maximum metal loss of only 5 mils (127 μm). However, when 400 ppm HCl was added to the flue gas mixture, the corrosion rate curve became linear with time, at a slope of 45 mils/year (1.14 mm/year). Reduction of iron oxide scales by CO, allowing greater penetration by HCl and disruption of the scale layer by formation of FeCl₂ at the metal surface appear to be the mechanisms involved.

The large amount of lead found to be associated with chlorine in the tube deposits also could contribute to corrosion by forming a low-melting point eutectic mixture with the iron chloride on the surface of the metal. The composition 37 mole percent PbCl₂-63 mole percent FeCl₃ melts at 347°F (175°C) and could flux protective oxides from the surface and attack the substrate metal.

**AUTHOR’S REPLY**

The author is pleased that the reviewers (and audience) believe the paper will help others who are looking for better understanding of boiler tube fireside corrosion causes and preventative methods which successfully resist aggressive furnace conditions.

To Richard Engdhal

Regarding combustion intensity or heat release rates for Kodak’s boiler under various waste burning conditions, a review of the boiler’s maximum design criteria compared with spreader-stoker boilers firing municipal RDF shows the following:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Kodak-RDF(1)</th>
<th>MSW(2)(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stoker grate area heat release, Btu/hr/ft²</td>
<td>1,000,000</td>
<td>700-750,000</td>
</tr>
<tr>
<td></td>
<td>kJ/hr/m²</td>
<td>11.3 × 10⁶</td>
</tr>
<tr>
<td>Waterwall area heat release, Btu/hr/ft²</td>
<td>50,000</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>kJ/hr/m²</td>
<td>0.57 × 10⁶</td>
</tr>
<tr>
<td>Furnace volumetric heat release, Btu/hr/ft³</td>
<td>20,000</td>
<td>8000-16,000</td>
</tr>
<tr>
<td></td>
<td>kJ/hr/m³</td>
<td>540</td>
</tr>
</tbody>
</table>

These are gross, average numbers calculated for boiler design maximum refuse firing conditions. I cannot confirm or deny the reviewer's belief that flame impingement may be related to waterwall surface area heat release rates, due to lack of published numbers from the reference papers. I believe that such gross average values do not reflect what observation of the furnace interior and measurement of gas temperatures indicate—that the most amount of heat released from refuse combustion occurs within several feet (1-2 m) of the stoker grate. This is true even in Kodak’s boiler with “full suspension” firing of the RDF, which inherently causes the particles to burn while moving in the furnace gas. Macroscopic particles such as RDF have substantial momentum, which tends to carry them in the directions induced by the high velocity combustion air injection streams. However, no practical amount of air can deflect all the refuse from striking the furnace walls when there is a large horizontal component to the refuse particles’ motion. This is based on observations of the furnace and numerous modifications to the retrofit combustion air and refuse injection nozzles Kodak has made since 1986.

To H. H. Krause

The corrosivity of carbon monoxide (CO) gas as a significant factor in Kodak’s boiler fireside wastage problems is not clear. Prior to overfire air nozzle retrofits, black char deposits were commonly seen on tubes in the lower furnace corners. Flue gas probes determined that high carbon monoxide and low oxygen concentrations occurred within 1 ft (0.3 m) of the walls, around 2 ft (0.6 m) above the grate. However, these waterwall tubes were noticeably thicker than sidewall tubes at the same elevations, (Fig. 2 of the paper). The sidewall’s middle tubes, (such as #28), had less char content in their fireside deposits and were exposed to furnace gas with higher oxygen and lower CO concentrations (and high temperature) than the corner tubes, (such as #40), yet their fireside wall thicknesses were noticeably thinner, (again, Fig. 2). I believe that if CO gas contributes to fireside corrosion of carbon steel boiler tubes, it may be significant when the furnace gas temperatures are relatively high compared with the surface deposits, metal, and internal fluid temperatures. The presence of HCl gas may be responsible for accelerating the corrosion of the tubes beyond that caused by CO gas alone, as you suggest.

To Edward Hohman

Kodak’s general refuse is the major category of solid wastes burned in the subject boiler. This RDF stream was sampled over several weeks in 1983 to show average values as follows:
RDF Size: 94 wt% less than 2 in. \times 2 in. (51 mm \times 51 mm) mesh with 65 wt% less than 0.75 in. \times 0.75 in. (19 mm \times 19 mm)
HHV, dry: 7500 Btu/lb (17,400 J/g)
Moisture Content: 6 wt%
Ash Content: 6 wt%
Sulfur: 0.6 wt%  Sodium: 0.4 wt%  Lead: 0.01 wt%
Chlorine: 1600 ppm
Composition: 59 wt% paper, 16 wt% cardboard, 11 wt% plastics, 14 wt% other, (wood, rubber, cloth, metal, etc.)

Flash-dried sludge "as fired" is a granular powder and has:

HHV: 4300 Btu/lb (10,000 J/g)
Moisture Content: 5–15 wt%
Ash Content: 20–50+ wt%

The above values indicate orders of magnitude for the categories shown. Variations in feed streams occur with time, which may be expected for solid wastes. These numbers agree fairly closely with the original values used for the original boiler predicted performance calculations.

As for significant experiences or problems in feeding, flash-drying, and cofiring Kodak’s industrial waste water treatment plant sludge, the operation of this system has many advantages and disadvantages. For Kodak, this capability has been an attribute to sludge incineration capacity and flexibility since 1970. However, it does complicate the boiler’s design, operation and maintenance. Functionally it has performed well overall.

It may make sense for some companies and communities to consider this capability when investigating ways to manage their solid wastes and wastewater (sewage) sludges, but it is just one of many options possible. Each situation has its own set of needs and circumstances which must be reviewed along with the available methods to satisfy those requirements. Kodak’s desire to recover precious metals (a finite resource) from scrap and wastes resulting from manufacturing photographic products includes burning these materials. Providing this capability has been a long-standing commitment by Kodak to the responsible management of these resources.

REFERENCES