PREVENTION OF FUSED DEPOSITS ON INCINERATOR LOWER SIDE WALLS

E. R. KAISER
New York University
Bronx, New York

ABSTRACT

Where fused accumulations of glass, ash, and residue metal occur on the lower side walls of municipal incinerators, the movement of grates and burning refuse is obstructed. The chilling of the wall surfaces near the burning refuse is the basic principle employed for preventing such deposits.

Discussed are the fusion characteristics of glass and the ash from major refuse components. A successful method of fusion control that can be installed in existing furnaces, the use of steam spray nozzles, is described in detail, together with test data and costs.

INTRODUCTION

Modern incinerator art has progressed in the direction of larger furnaces, continuous refuse feeding, and 24-hour operation. At the same time the calorific value of municipal refuse has increased. One result of this combination of events has been the need for special means to prevent the adhesion of ash, glass and included metal on the lower areas of the furnace side walls where the walls are in contact with the hotter parts of the fuel bed.

Fireclay refractories are widely used in the walls and arches of incinerator furnaces. Problems with growing ash and slag deposits are minor when the furnaces are operated only 8 hours a day. Continuous operation raises the wall temperatures and permits viscous flow of glass to continue. As the deposits build up, the heat loss through the outside of the walls decreases, promoting further rise in the fireside surface temperatures of the deposits.

Silicon carbide shapes, with forced air cooling of the rear surfaces, are used in some incinerator furnaces to reduce or prevent these deposits [1]. Water-tubed wall surfaces are used in European refuse-fired boilers for the same purpose [2]. In both cases the objective is to prevent a chilled surface that will provide a weak bond, if any, with molten or tacky ash and glass particles that come into contact with it.

TEST FURNACE

Opportunity to investigate the deposit phenomena and to undertake corrective action was found at the Oceanside Refuse Disposal Plant, Town of Hempstead, Nassau County, New York. The refuse received there is from a predominantly residential community. The Plant has three furnaces, two of which are rated at 300 tons of refuse per day, and one at 150 tons per day. The two larger units, Furnaces 1 and 2, include 450 psig boilers, which supply steam to a turbine for electric generation and to water desalinization equipment.

Furnaces 1 and 2 are identical and are fired by Flynn and Emrich rocking grate stokers, 4 sections long (44 ft),
and 10 ft wide. Underfire blower air is supplied to the lower three stoker sections; overfire air is supplied through sidewall and arch ports. These two furnaces are capable of operation at 400 tons per day and are operated at those rates for lengthy periods with good burnout.

Furnace walls and arch are composed of fireclay refractory shapes. The side walls are suspended fireclay-shape construction. The lower sidewalls are 7.5-inch fireclay shapes faced on the inside with 1/4 inch silicon carbide tiles (Detrick), anchored in the fireclay shapes. The outer surface of the wall was cooled by natural upward air convection between the wall and the plate steel sheathing. During the test period the steel panel was removed, which probably increased the wall cooling slightly. Fig. 1 is a longitudinal cross-section of Furnace 1, the test furnace. The wall area on which heavy deposits grew is outlined, together with the normal contour of the fuel bed.

The experience was similar on both side walls of Furnaces 1 and 2. As shown in Figure 2a, the deposits grew from the wall in the fuel-bed zone. Starting with a clean wall, there was a noticeable deposit after 8 hours of operation. Continued build-up forced a shutdown after about 30 hours of operation.

As the deposits grew, they restricted the action of the stoker grates. The refuse flow was also impeded, causing the bed to thicken ahead of the deposits, and to avalanche into the void created behind the deposit zone. After the furnace cooled for 5 to 8 hours, the mass usually loosened at the wall and could be pried off. The mass was partially fused, strong and dense. It was held together with refuse wires, pipe, and metal that were imbedded in it. Visual observation of the adherent clinkers on the lower side walls showed many pieces of clear and colored glass from bottles and other sources that had broken into shards. The glass had obviously softened and deformed in the heat and adhered to the silicon carbide wall. The SiC had acquired a light brown silica surface from oxidation.

**REFRACTORY TEMPERATURES**

The investigation comprised several phases, the first of which was the measurement of the temperatures and heat flux at the wall surface where the deposits were formed.
Temperatures of the arch, the inner face of the furnace refractory, the back face of the silicon carbide, and the outside of the fireclay shapes, were measured by Cr-Al Type K thermocouples attached to a 16-point recorder. For simplicity only two thermocouples, one on the wall and one in the arch, are shown in Fig. 1. In one case the temperature record was continuous from the start of the fire until the forced shutdown because of the deposits.

Fig. 3 presents typical findings of the temperatures beginning with the start of operation. The arch thermocouple 14 in a suspended SiC well indicates the combined temperatures that result from gas flow past the well and radiation exchange between the flames and furnace surfaces visible to the well. The erratic fluctuations reflect the unsteady burning that is characteristic of refuse burning. Thermocouple 14 temperatures were up to 500 F above those of the control thermocouple, also shown in Fig. 1, because the latter was influenced by radiation exchange to the boiler above it.

The cross-hatched range of wall surface temperatures in Fig. 3, measured in the deposit area, shows a rising and high range during the first 8 hours while the wall was comparatively clean. During the succeeding hours the trend was downward as the deposit grew and “insulated” the wall thermocouples. After 26 hours the deposit had thickened enough to cause the fire to become unmanageable, as shown by the arch temperatures and the declining wall temperatures. Between the 8 and 24 operating hours, the fireside surface of the deposit itself was undoubtedly 1600 to 2000 F or hotter.

Fig. 3a. FIG. 2b.
WALL PROFILE BEFORE STEAM SPRAYS
WALL PROFILE AFTER STEAM SPRAYS

Heat flux through the wall at the deposited zone was calculated as 1284 Btu per sq ft-hour when \( t_1 = 1455 \) F, \( t_2 = 419 \) F and \( k = 9.3 \). In still air at 70 F, cooling by natural convection from a vertical wall at 419 F is given as 1235 Btu per sq ft-hour [3] which is a fair check on the calculated heat flow.

**FUSION RANGE OF RESIDUE**

Several samplings and analyses of refuse from the Oceanside Plant indicated that the source ingredients of the incinerator residue are typically as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>42%</td>
</tr>
<tr>
<td>Metals</td>
<td>33%</td>
</tr>
<tr>
<td>Ash, other inerts</td>
<td>25%</td>
</tr>
</tbody>
</table>

Glass bottles and larger glass pieces decrepitate in the uneven heating of the fire. Metals partially oxidize and some non-ferrous metals melt. An appreciable fraction falls through openings in the grates.

The tendency for bottle glass shards to become tacky was investigated by heating shards in alundum boats in an electric muffle furnace. The specimens were surrounded by air and were held at selected temperatures for 30 minutes. Beginning at 1275 F, fire polishing of sharp edges was noted. At 1300 F and higher, the shards softened and fused to each other and to the boat. A one-gram piece of glass was laid on a sample of the silicon carbide (SiC) from the incinerator wall and held at 1600 F for 30 minutes. On removal from the furnace the fused button of glass was tightly adherent, despite crazing on cooling. It should be noted that the SiC has acquired a sand-colored SiO₂ film beforehand from its service in the incinerator.

ASTM fusion temperatures were also determined for glass and the ash from refuse components, as reported in Table I below. In the test procedure, the finely pulverized
powder is molded into small pyramids, dried, and heated at a prescribed rate in an oxidizing atmosphere. The pyramids deform by gravity as they soften. The temperature at the first deformation is reported, as are the temperatures when the pyramid has slumped into fused buttons of height H and width W, and finally as a thin fluid layer. These oxide mixtures do not have sharp melting temperatures as do the purer metals and oxides also reported.

By comparing the “welding” temperatures of glass with the somewhat higher initial deformation temperatures, one may infer that sintering of glass and other ash will occur at temperatures below the ASTM initial deformation temperatures. This will be particularly true when hot glass and ash are pressed against the wall by the forces produced by the stoker and the weight of the burning refuse.

**FIRE TEMPERATURES**

Observations were made with an optical pyrometer looking downward at an angle into fissures in the fuel bed. Temperatures up to 2500 F were noted, with many readings in the range of 1800 to 2400 F. The temperatures are high enough to melt all metals and ash mixtures except steel, bones and clam shells.

Several factors mitigate against a high degree of fusion:

- Residue on or near the grate is cooled by underfire air flowing through the grate.
- Much of the ash is not released from associated combustibles until the zone of peak temperatures have been passed.
- High fusion constituents such as sand, lime and iron oxide would act as dry barriers to fusion.

Nevertheless, the effect of these mitigating factors is not enough to prevent a small but important portion from being in a tacky condition and adhering to the walls.

**SIDEWALL STEAM JETS**

As an expedient to stop the residue fusion on the lower

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**FIG. 3 TYPICAL TEMPERATURE-TIME LOG FOR TEST FURNACE 1**

139
TABLE I
ASTM FUSION TEMPERATURES OF RESIDUE CONSTITUENTS
AND MELTING POINTS OF PURE METALS AND OXIDES, DEG F

<table>
<thead>
<tr>
<th>Mineral Source</th>
<th>Initial Deformation</th>
<th>Softening H=W</th>
<th>H=W/2</th>
<th>Fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear glass</td>
<td>1480</td>
<td>1600</td>
<td>1680</td>
<td>1840</td>
</tr>
<tr>
<td>Brown glass</td>
<td>1620</td>
<td>1700</td>
<td>1740</td>
<td>2080</td>
</tr>
<tr>
<td>Green glass</td>
<td>1640</td>
<td>1720</td>
<td>1800</td>
<td>2080</td>
</tr>
<tr>
<td>Ash from:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Garbage, less bones</td>
<td>2020</td>
<td>2100</td>
<td>2140</td>
<td>2200</td>
</tr>
<tr>
<td>Cardboard, corrug.</td>
<td>2060</td>
<td>2120</td>
<td>2160</td>
<td>2240</td>
</tr>
<tr>
<td>Misc. paper</td>
<td>2160</td>
<td>2260</td>
<td>2300</td>
<td>2480</td>
</tr>
<tr>
<td>Grass and dirt</td>
<td>2080</td>
<td>2200</td>
<td>2240</td>
<td>2320</td>
</tr>
<tr>
<td>Textiles</td>
<td>2040</td>
<td>2120</td>
<td>2180</td>
<td>2240</td>
</tr>
<tr>
<td>Heavy plastics, leather, rubber</td>
<td>2100</td>
<td>2160</td>
<td>2220</td>
<td>2300</td>
</tr>
<tr>
<td>Bones and clam shells</td>
<td>&gt;2800</td>
<td>&gt;2800</td>
<td>&gt;2800</td>
<td>&gt;2800</td>
</tr>
</tbody>
</table>

Melting Points, deg F

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>2795</td>
</tr>
<tr>
<td>FeO</td>
<td>2588</td>
</tr>
<tr>
<td>Fe₃O₄</td>
<td>2800</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>2849</td>
</tr>
<tr>
<td>Lead</td>
<td>622</td>
</tr>
<tr>
<td>Tin</td>
<td>449</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃</td>
<td>3713</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>3713</td>
</tr>
<tr>
<td>SiO₂</td>
<td>&gt;2930</td>
</tr>
<tr>
<td>Zinc</td>
<td>769</td>
</tr>
</tbody>
</table>

Wall face temperatures were lowered by the steam jets. A typical temperature log is included in Fig. 3. The fuel bed behavior was improved and became more uniform. The steam pressure of the boiler was easier to maintain within the desired limits.

No visible effect of the jets on the flames, appearance of the fire, or burnout of refuse near the walls has been noted. The previous deterioration of the wall was stopped by the steam, and has shown no noticeable change in over a year of use. Furnace 2 was equipped with the same system, with the same result.

Steam consumption was calculated by the Grashof formula, with an assumed orifice coefficient of 0.75.

\[ w = 3600 kA (0.0165) p^{0.97} \]

where \( w \) = steam flow, lb per hr, \( k \) = orifice coef. 0.75 assumed, \( A \) = area of orifice, 0.01226 sq in., \( p \) = steam pressure increased the height of clean wall surface. Optimum results were obtained with the nozzles angled 6 to 8 degrees toward the walls, and a manifold pressure of 60 psig. Calorimeter tests showed that the steam entering the manifold was 98 percent saturated. Between the boiler and the throttle valve, the steam supply had lost 44 Btu per lb.

Saturated steam was available from the incinerator boilers at 450 psig. The affected wall zone was 18 ft long. The fixed grate trunnions along the sidewalls provided opportunity for mounting a steam pipe above the grate. The pipe assembly used is shown in Fig. 1; the positioning sleeves are shown in Fig. 4. The 1.5-inch pipe was schedule 80, with welded connections. The steam nozzles were 1/8 inch drilled holes, spaced 6 inches apart, more or less, for a total of 36 holes.

From the start the system proved effective. The new wall profile is shown in Fig. 2b. Increasing the steam pressure increased the height of clean wall surface. Optimum results were obtained with the nozzles angled 6 to 8 degrees toward the walls, and a manifold pressure of 60 psig. Calorimeter tests showed that the steam entering the manifold was 98 percent saturated. Between the boiler and the throttle valve, the steam supply had lost 44 Btu per lb.

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Steam consumption was calculated by the Grashof formula, with an assumed orifice coefficient of 0.75.
press., 74.7 psia, 60 lb per sq in. gage. The steam flow per nozzle was 35.8 lb per hr. The total steam consumption for two side walls was 35.8 \times 2 \times 36 = 2580 \text{ lb per hr.}

As the steam output of the boiler is about 75,000 lb per hr average, the sidewall nozzles consumed about 3.4 percent of the steam output. The gain in furnace performance and steadier steam production more than made up for the steam consumption by the jets. Jet steam added only about 11 percent to the water vapor in the flue gases, and 1.2 percent to the total volume of flue gas.

**COST OF STEAM SYSTEM**

Installation of piping and brackets was made by the regular maintenance crew, at not in excess of $1000 per furnace. The incremental cost of steam at the Oceanside Plant is negligible.

In the case of an incinerator plant that has no waste heat boiler, and an oil-fired package steam generator must be acquired and installed, the cost of steam would be $1.75 to $2.00 per thousand pounds. With two 300 T/d incinerators in operation and a steam consumption of 2600 \times 2 = 5100 \text{ lb per hr}, the steam cost would be

\[
\frac{5200 \times 24 \times 2}{1000 \times 300 \times 2} = 0.42 \text{ a ton of refuse}
\]

The objective of the steam jets is to increase the availability, and hence the tonnage throughput, of the incinerator furnaces. Other benefits are reduced refractory and stoker maintenance. Where the increase in furnace availability is 10 percent by use of the steam, the increased throughput offsets the steam cost.

Steam flow protects the steam jet manifold and brackets from overheating. Where steam is available from the start of burning, as from an auxiliary boiler, the piping and brackets would probably have a life of at least one year. At Oceanside the piping did not receive steam until about 30 minutes after the fires were ignited, or until the boiler steam pressure developed. Despite the initial overheating and the shock of steam cooling, the pipe replacement was only partial after six months. The original brackets are still in use.

**CONCLUSION**

Important for high furnace availability is the prevention of massive formations of sintered glass, ash and metal on the lower walls of large incinerators. While the steam jets are highly effective, it is hoped that research and development will continue on the application of other techniques of fusion control on the lower side walls of refractory furnaces. The recirculation of cooled flue gas to the affected zone may also be a feasible approach. Applications of forced-air-cooled silicon carbide to wall areas are known to be effective slag deterrents, and are readily incorporated into a boiler system.

**ACKNOWLEDGMENT**

This investigation was supported in whole by Public Health Service Research Grant No. SW00035 from the National Center for Urban and Industrial Health.

Successful application of the steam jet system of wall cooling to the furnaces at Oceanside was largely due to the splendid cooperative effort by the Town of Hempstead's operating staff, the personnel of Charles R. Velzy Associates, consulting engineers, and N.Y.U. personnel, especially Charles Zimmer, N.Y.U. Senior Technician.

Ash analyses and fusion temperatures were determined by the Fuel Engineering Company of New York from samples taken at the Oceanside Plant.

**REFERENCES**

