The Nature of Incinerator Slags

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Abstract

Slag samples taken from three incinerators operated by the City of New York were investigated. The slags selected were taken from the point of greatest build-up immediately above the air-cooled silicon-carbide wall. Investigation included: a) Fusion point and fluidity characteristics, b) Petrographic examination and c) Chemical analysis. Results reported showed considerable variation in all properties determined undoubtedly due to the nature of the refuse charged in each incinerator. At the same time, it is felt that this information is an excellent basis for future investigations and will be of value in studying slag-refractory reactions.

Introduction

In order to stimulate interest by operations, designers, contractors and suppliers in the improvement of incinerator refractory design and performance, the Refractories and Furnace Construction Subcommittee concluded that an understanding of operating environments is essential. As a first step towards this, we agreed to determine the nature and range of composition of incinerator slags. It is obvious that slag composition will vary according to the nature of the refuse charged and will differ widely from one installation to another. New York City Incinerators offer a wide range of refuse composition, and, therefore, we concluded that an investigation of slags from some of these incinerators would be of value.

Slag Sampling

Slags were taken from three incinerators operated by the City of New York. The slags selected were taken from the point of greatest build-up attached to the fire clay refractory immediately above the air-cooled silicon-carbide wall regardless of the location along the length of the grate. All three incinerators were of similar construction and were all of the traveling grate type.

Exact locations of the slag samples are shown in Figs. 1, 2 and 3. These figures also illustrate the location and nature of the slag, and the fly ash build-up in each case.
Slags investigated in this report are designated:
Sample B - Gansevoort  Furnace 4 Right Wall
Sample D - S. W. Brooklyn  Furnace 1 Left Wall
Sample F - Greenpoint  Furnace 2 Left Wall
The actual sample pieces evaluated are shown in Figs. 4, 5 and 6. These were selected to have adequate areas as dense as possible, as far away from the refractory brick as possible to avoid effects of brick contamination.

The following properties were investigated by the Research Laboratories of the Norton Company, Worcester, Massachusetts:

1. Fusion point and characteristics
2. Chemical analysis
3. Petrographic examination

**Fusion Tests**

Samples for this test were taken from the thickest and most uniform section of the slag samples. The locations are shown in Figs. 4, 5 and 6. Four cubes (approx. ½ in. face) were cut from each sample as close to one another as possible.

The cubes were placed (with the face closest to the refractory lining down) on 2 in. square aluminum oxide plates, placed in an electric resistance heated furnace and one from each sample removed immediately on attaining the following temperatures:

- 1175 C (2140 F)
- 1200 C (2190 F)
- 1250 C (2280 F)
- 1300 C (2370 F)

In addition, as sample D appeared extremely fluid at the lowest temperature, further tests of this sample were run at:

- 1120 C (2050 F)
- 1150 C (2100 F)
FIG. 7 illustrates the nature and texture of these slag cubes before testing. Figs. 8, 9 and 10 show the degree of fusion and fluidity of each slag sample at the temperatures indicated. Figs. 11 and 12 permit comparison of the fusion characteristics of these three slags.

**Chemical Analysis**

Wet Chemical Analysis were run on slag taken adjacent to the fusion samples with the following results:

<table>
<thead>
<tr>
<th></th>
<th>Sample B</th>
<th>Sample D</th>
<th>Sample F</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>43.01%</td>
<td>49.91%</td>
<td>45.99%</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>24.85%</td>
<td>8.73%</td>
<td>21.47%</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>6.00%</td>
<td>12.78%</td>
<td>7.78%</td>
</tr>
<tr>
<td>TiO₂</td>
<td>3.31%</td>
<td>2.40%</td>
<td>3.00%</td>
</tr>
<tr>
<td>CaO</td>
<td>9.28%</td>
<td>11.03%</td>
<td>9.50%</td>
</tr>
<tr>
<td>MgO</td>
<td>2.47%</td>
<td>2.54%</td>
<td>2.65%</td>
</tr>
<tr>
<td>Na₂O</td>
<td>3.28%</td>
<td>3.31%</td>
<td>3.16%</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.73%</td>
<td>2.27%</td>
<td>1.09%</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>2.05%</td>
<td>2.40%</td>
<td>2.00%</td>
</tr>
<tr>
<td>BaO</td>
<td>0.66%</td>
<td>0.45%</td>
<td>0.62%</td>
</tr>
<tr>
<td>SO₃</td>
<td>N.V.*</td>
<td>1.59%</td>
<td>0.32%</td>
</tr>
<tr>
<td>ZnO</td>
<td>1.17%</td>
<td>2.49%</td>
<td>0.46%</td>
</tr>
<tr>
<td>Total</td>
<td>97.95%</td>
<td>99.90%</td>
<td>98.04%</td>
</tr>
</tbody>
</table>

*N.V. - None visible on 1 gram sample.*
Severe problems were encountered in the analysis because of the high iron content. Balance to 100 per cent in each case was not determined but is probably made up of trace materials including Pb, Mn, Cu, Ni, Sn, and Cr.

**Petrographic Analysis**

Samples were examined petrographically and the following observations reported:

**Sample B**
Mostly opaque glass with about 5 per cent crystalline with well developed fine lath shaped crystals of about 50 microns. Under transmitted light the glass appears transparent brown with some 5 to 10 micron spherical black particles.

**Sample D**
Muddy brown glass matrix, almost opaque, with about 5 per cent crystals approx. 150 microns in size. The crystals are larger and more blocky than B. There are fewer fine black particles than B.

**Sample F**
Transparent colorless glass matrix with approx. 10 per cent black spherical particles 5-10 microns in size and about 5 per cent lath shaped crystals about 50 microns in size.

Sample D is quite different from B because it is mostly a muddy brown glass with a few large blocky shaped crystals.

Samples B and F have finer crystal development and crystals are long and narrow. Sample B also has a more transparent brown glass matrix and very small spherical black particles. Sample F on the other hand has a large number of these small black particles in an almost colorless glass matrix. The black particles appear metallic and are magnetic in character. They are probably free iron on Magnetite.

**Discussion**

The purpose of this paper is to form a basis for better understanding of slag conditions in incinerators. Sufficient information regarding operating conditions and refuse composition is not yet known to permit satisfactory conclusions to be drawn. Therefore, I do not propose to discuss the results of this investigation in detail. However, a few general comments are in order:

1. Slag D has a substantially lower fusion point than the other two slags, undoubtedly due to the much lower alumina level.

2. While there is a marked similarity in chemical composition between Samples B and F, Sample F appeared to be more magnetic. Assuming this to be due to magnetic iron oxide, this would account for the higher fusion point and lower fluidity of Sample F. This also may indicate a reducing condition in the area of slag deposition in the incinerator.

3. Substantial variation can be expected from one incinerator to another in the amount present of such compounds as Al₂O₃, K₂O, SO₃, Fe₂O₃ and ZnO, all of which can have a marked influence on the physical and chemical properties of the slag.

**Acknowledgment**

The author wishes to express his sincere thanks to the personnel of the Department of Sanitation, Bureau of Waste Disposal, City of New York, for their cooperation in obtaining the slag samples, and for permission to present the information in this paper.