specific consumption of ladle refractories equal to 1.7-3 kg/ton of steel. At Magnitogorsk they have increased the throughput capacity of steel melting bays by 3% with a reduction in the ladle stock of 11%.

LITERATURE CITED


PROCEDURE FOR INTENSE GUNITING OF THE MAIN ROOFS OF STEEL-MAKING FURNACES

A. S. Freidenberg and V. A. Perepelitsyn

Guniting of the main roofs of steel-making furnaces is usually performed locally; for the most part it ensures only equal strength of all sectors of the roof lining. At present guniting permits a small (15-20%) increase in the roof strength [1]. This is due to the fact that with the ordinary guniting regime (once for every one or two melts) the rate of accretion of the gunite layer is much less than the rate of its disintegration.

We have performed special investigations on guniting of the main roof of a duo-bath furnace of the Magnitogorsk Metallurgical Combine throughout the entire campaign (3-4 times per melt).

The roof was gunitied by a BM-60 machine operating cyclically with an output of 5-6 tons/h. On account of organizational factors in the steel-making shop, we were unable to constantly effect guniting 3-4 times per melt (virtually the entire finishing period). For this purpose it was necessary to use continuous guniting machines with an output of at least 25 tons/h.

Figure 1 shows a sample of a roof gunitied by this procedure; Table 1 gives the chemical composition of samples selected at different distances from the working surface.

A microscopic examination of a sample revealed that the working zone (15-18 mm) of the PShS roof refractory contains a multilayer gunite sector 40-55 mm thick, the boundaries between which could not be visually determined owing to sintering, but could be noted from:

(i) the sharp increase in the large (up to 2 mm) open and shallow silicate-healed pores, oriented in the form of chains parallel to the grain boundaries, i.e., perpendicular to the temperature gradient; (ii) the appearance of large (up to 1 mm) grains of chromite present in the mass used for guniting, made of ground spent PShS artifacts; (iii) the position of the elongated chromite grains in the gunite layer perpendicular to the surface being gunitied; (iv) the sharp decrease of the silicate content in the gunite layer at the boundary with the

<table>
<thead>
<tr>
<th>Distance from working zone, mm</th>
<th>Color of sample</th>
<th>SiO₂</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>MnO</th>
<th>Cr₂O₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Black with metallic luster</td>
<td>1.30</td>
<td>50.86</td>
<td>13.59</td>
<td>3.09</td>
<td>21.10</td>
<td>0.69</td>
</tr>
<tr>
<td>3</td>
<td>The same</td>
<td>1.78</td>
<td>53.91</td>
<td>11.75</td>
<td>3.80</td>
<td>19.78</td>
<td>0.77</td>
</tr>
<tr>
<td>8</td>
<td>&gt; &gt;</td>
<td>3.50</td>
<td>40.32</td>
<td>11.73</td>
<td>3.64</td>
<td>25.80</td>
<td>0.96</td>
</tr>
<tr>
<td>10</td>
<td>&gt; &gt;</td>
<td>2.48</td>
<td>37.22</td>
<td>23.15</td>
<td>3.36</td>
<td>22.53</td>
<td>0.73</td>
</tr>
<tr>
<td>12</td>
<td>Black</td>
<td>5.56</td>
<td>30.73</td>
<td>13.59</td>
<td>6.28</td>
<td>28.06</td>
<td>0.85</td>
</tr>
<tr>
<td>13</td>
<td>&gt; &gt;</td>
<td>5.62</td>
<td>27.13</td>
<td>9.12</td>
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<td>36.30</td>
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<tr>
<td>10</td>
<td>Brown</td>
<td>5.32</td>
<td>18.01</td>
<td>7.36</td>
<td>5.57</td>
<td>47.89</td>
<td>0.42</td>
</tr>
</tbody>
</table>

TABLE 1. Chemical Composition of a Sample of the Roof Lining

Eastern Institute of Refractories. Translated from Ogneupory, No. 6, pp. 22-25, June, 1981.
Fig. 1. Sample of PShS refractory from roof of steel-making furnace after intense guniting.

Fig. 2. Change in $R(\theta)$, $T_{mk}(\bullet)$, $P_t(\mathbb{1})$, percentages by weight of iron oxides $M_1 (\Delta)$ and silicates $M_2 (\square)$ of PShS refractories and gunite coating over vertical section of gunited lining after service for 707 melts.

working zone, causing migration of the melt into the cooler sectors of the working zone; (v) the sharp decrease of the fine-grained chromite content in the gunite layers.

The inner gunite layers exhibit layered, linearly oriented chains of micropores filled with silicates and a layered local concentration of silicates.

The working zone of the PShS artifacts and the gunite layers have a number of common structural features: The principal minerals in these regions are solid solutions of periclase (70-75%) saturated with ferrochrome spinel; the chromite grains are saturated with iron oxides only at the surface; the crystals of the former periclase are present in intimate intergrowth with chromite relics and form a concretion of large (up to 1.5 mm) elongated prismatic crystals; the bulk of the silicates of the gunite layers is present in the form of accumulations in the pores and as elongated inclusions between the crystals of periclase-based solid solutions. This process has a beneficial effect on intergrowth of crystals of the gunite sector and the PShS refractory, particularly in the direction of the temperature gradient; the microcracks in the gunite layer and the working zone are for the most part located horizontally and are filled with silicates; the greatest amount of silicates filling the cracks is present in the working zone of the PShS refractory. This indicates that after formation of a thick multilayered gunite sector the silicate melt becomes viscous as a result of the marked decrease in temperature in this zone; after formation of the gunite sector the working zone of the PShS refractory approximates in structural characteristics and functions to the transitional zone of the artifact.

We determine the temperatures of the onset of melting* of the material of the different zones, $T_{mk}$, approximating in value to its refractoriness, the true porosity $P_t$, and reflection coefficients of periclase† and the products of its replacement by iron oxides, $R$; we also investigated the distribution of iron oxides and silicates in the hot zones of PShS refractory and in cross sections of the gunite sector. Figure 2 shows the change in these properties of PShS refractory and the gunite layers deposited on it after service of the lining roof for 707 melts. The properties of the gunite coating are similar to those of the working zone of the PShS refractory.

Petrographic investigations showed that formation of horizontal microcracks, partly or completely filled with silicates (principally of monticellite composition), in the working zone of the PShS refractory is due both to first- and second-order thermal stresses and to loads of other origin (thrust forces, fatigue phenomena, etc.). Filling of the microcracks by silicate melts leads to their distinctive "healing" (Fig. 3), preventing formation of cleavage faces in the refractory.

* Determined by the procedure of the Scientific-Research Institute of Metallurgy [2].
† Determined by means of an Nu-2E microscope in the Petrographic Laboratory of the Eastern Institute of Refractories [3].