ADVANTAGES OF FLAT-FLAME COMBUSTION OF LIQUID FUEL IN GLASSMAKING FURNACES

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Heat transfer from the flame to the melt is intensified and the uniformity of melt heating is improved by creating a horizontal flame and increasing the area of coverage of the melt surface by the flame [1, 2]. This is accomplished in practice by installing 3-4 or more circular-flame burners under the burner inlet. However, in this case only 45-55% of the melt surface in the heating zone is covered, whereas up to 75% coverage is ensured with the provision of an intermediate flame between burners [3].

Flame coverage by the melt and the levelness of the flame can be further improved through flat-flame combustion of liquid fuel [4]. The advantages of this method of combustion include more uniform heating of the melt with a 2-2.5-fold reduction in the number of burners under the inlet, as well as elimination of flame overshooting with a furnace of any size. The installation of two burners provides for a total width of the flat flames at the burner outlet that is close to the width of the inlet, so that contact of the relatively cold air with the melt is practically eliminated, cooling of the top layers of the melt is reduced, and the surface of contact of the atomized fuel with air is increased. The latter helps shorten the flame and change the character of heat liberation along the flame length and width compared to the case with circular flames.

The present work reports the results of studies of heat transfer from circular and flat single fuel-oil flames conducted on an experimental combustion stand at the Anzhero-Sudzha Glass Plant. We studied local and total heat transfer from circular and flat flames at a low rate of fuel supply, flame and melt temperature fields, concentration fields (soot, CO₂, O₂), flame length, and fuel combustion efficiency.

The test stand, built by the glass plant for the State Scientific-Research Institute of Glass (GIS), is a combustion chamber equipped with a two-section radiant air preheater with automatic heating permitting air to be preheated to 700°C. Also part of the stand is a fuel supply system with gravimetrically-calibrated NSh-40 pumps with thyristor drive to maintain a specified fuel flow rate, and a system of air and waste-gas ducts with plate dampers. The combustion chamber is 4.2 m long, 2.3 m wide, and 1.65 m high, measured from the floor to the roof in the center of the chamber.

In practice, the combustion chamber is one section of a regenerative furnace designed on a 1:2 scale. The cross section of the channel through which air is delivered for combustion is 0.256 m², with a burner-inlet width of 0.915 m. Located under the chamber is a five-section water cooler-calorimeter covered with a 65-mm-thick layer of high-alumina brick and a 20-25-mm-thick layer of glass. The cooler is designed to withdraw and measure the heat received by the melt.

The chamber walls and roof are lined with 500- and 300-mm-thick dinas beams, respectively. The roof is insulated with a layer of ultra-lightweight brick 115 mm thick. Holes for conducting measurements have been left in one of the side walls.

To ensure that the experiment approximated radiative transfer in a glassmaking furnace in accordance with the data obtained earlier [1], approximate equality of the determinative criteria of Boltzmann (Bo-0.0512-0.0792) and Buger (Bu-0.125-0.29) relative to heat loss through the lining and melt was observed, as well as approximate equality of the radiative characteristics and temperatures of the lining and melt. To satisfy conditions of the similitude of flame processes [5], approximate equality of the nozzle discharge velocities of the fuel-air stream on the stand and in an actual furnace was also maintained.
TABLE 1

<table>
<thead>
<tr>
<th>Shape of flame</th>
<th>Fuel consumption, kg/h</th>
<th>Pressure in front of burner, MPa</th>
<th>Unit consumption of atomized fuel, kg/kg</th>
<th>Temperature, °C</th>
<th>Air-fuel ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>76.7</td>
<td>0.01</td>
<td>0.06</td>
<td>1138</td>
<td>1064</td>
</tr>
<tr>
<td>Circular</td>
<td>76.7</td>
<td>0.03</td>
<td>0.07</td>
<td>1132</td>
<td>1093</td>
</tr>
<tr>
<td>Flat</td>
<td>102</td>
<td>0.09</td>
<td>0.11</td>
<td>1313</td>
<td>1305</td>
</tr>
<tr>
<td>Circular</td>
<td>102</td>
<td>0.10</td>
<td>0.12</td>
<td>1355</td>
<td>1249</td>
</tr>
<tr>
<td>Flat</td>
<td>118.8</td>
<td>0.09</td>
<td>0.09</td>
<td>1376</td>
<td>1418</td>
</tr>
<tr>
<td>Flat</td>
<td>118.8</td>
<td>0.10</td>
<td>0.10</td>
<td>1406</td>
<td>1333</td>
</tr>
</tbody>
</table>

Fig. 1. Distribution of incident thermal fluxes \( q_i \) 1, temperature of the melt 2, and maximum flame temperature 3 along the flame axis: -) flat flame; --) circular flame.

Fig. 2. Thermal flows incident to the melt in cross sections of the combustion chamber: numbers beside curves denote numbers of furnace cross sections; FF) flat flame; CF) circular flame.

During the experiment,* incident local radiant flux and effective heat flux on the melt surface were measured with a thermocouple probe: total heat transfer from the flame to the melt, the temperature fields of the gas space and melt—by means of an extraction thermocouple and a PR-30/6 thermocouple with open junctions; \( \text{CO}_2 \) and \( \text{O}_2 \) content of the combustion products—by means of GKhP-3m and VTI gas analyzers. Rate of flow of water to the hearth calorimeter was determined by means of a normal diaphragm with a DT-150 differential manometer; temperature difference between the calorimeter inlet and outlet was measured with a differential KhA thermocouple; roof temperature—with a PR-30/6 thermocouple embedded 2–5 mm from the inside surface of the roof.

The experiment was conducted using M-100 fuel oil at a temperature of 75–80°C before the nozzle. Fuel and atomizer pressure, the temperature of the fuel oil, and fuel oil flow rate were kept constant during the experiment.

In the study, we used a pneumatic-mechanical burner [4] on which we created a round or flat flame by changing the discharge nozzle. Compressed air was used as the atomizer. The round and flat flames were compressed at the same fuel and atomizer consumptions. Table 1 shows basic heat-engineering characteristics of the experiment. Results of tests at a fuel consumption of 102 kg/h at the burner are shown in Figs. 1–4.

The following was established in comparing the geometric and aerodynamic characteristics of the flames. The lengths of the circular and flat flames, judged by observing their luminous parts, were 2.8 and 2 m at a fuel consumption of 76.7 kg/h, and 3.6 and 2.5 m at a fuel consumption of 102 kg/h, respectively.

The length \( l_f \) of the circular and flat flames may be evaluated for test-stand conditions from an earlier-derived [5] empirical relation with the introduction of coefficient \( K_a \), accounting for the effect of excess air, corrected on the basis of the data obtained:

\[
l_f = K_a \frac{0.2}{8_d} \omega_0^{0.34} \rho_e^{0.83}.
\]

* GIS researchers M. A. Pryanishnikov, G. P. Vdovina, and V. N. Safre and plant workers also participated in the experiment.