The AP series of reports is published by the Technical Publications Branch of the Information Services Division of the Office of Administration for the Office of Air and Water Programs, Environmental Protection Agency, to report the results of scientific and engineering studies, and information of general interest in the field of air pollution. Information reported in this series includes coverage of intramural activities and of cooperative studies conducted in conjunction with state and local agencies, research institutes, and industrial organizations. Copies of AP reports are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - as supplies permit - from the Air Pollution Technical Information Center, Environmental Protection Agency, Research Triangle Park, North Carolina 27711 or from the Superintendent of Documents.
CHAPTER 6

METALLURGICAL EQUIPMENT

FURNACE TYPES
JOHN A. DANIELSON, Senior Air Pollution Engineer

STEEL-MANUFACTURING PROCESSES
WILLIAM F. HAMMOND, Senior Air Pollution Engineer
JAMES T. NANCE, Senior Air Pollution Engineer
KARL D. LUEDTKE, Senior Air Pollution Engineer
JOEL F. NENZELL, Senior Air Pollution Engineer

IRON CASTING
WILLIAM F. HAMMOND, Senior Air Pollution Engineer
JAMES T. NANCE, Senior Air Pollution Engineer

SECONDARY BRASS- AND BRONZE-MELTING PROCESSES
WILLIAM F. HAMMOND, Senior Air Pollution Engineer
JAMES T. NANCE, Senior Air Pollution Engineer
EMMET F. SPENCER, Intermediate Air Pollution Engineer*

SECONDARY ALUMINUM-MELTING PROCESSES
WILLIAM F. HAMMOND, Senior Air Pollution Engineer
HERBERT SIMON, Senior Air Pollution Engineer
JOHN E. WILLIAMSON, Principal Air Pollution Engineer
JOEL F. NENZELL, Senior Air Pollution Engineer

SECONDARY ZINC-MELTING PROCESSES
GEORGE THOMAS, Senior Air Pollution Engineer

LEAD REFINING
JAMES T. NANCE, Senior Air Pollution Engineer
KARL D. LUEDTKE, Senior Air Pollution Engineer

METAL SEPARATION PROCESSES
JAMES T. NANCE, Senior Air Pollution Engineer
EMMET F. SPENCER, Intermediate Air Pollution Engineer*

CORE OVENS
GEORGE THOMAS, Senior Air Pollution Engineer

FOUNDRY SAND-HANDLING EQUIPMENT
EDWIN J. VINCENT, Intermediate Air Pollution Engineer†

HEAT TREATING SYSTEMS
JULIEN A. VERSSEN, Intermediate Air Pollution Analyst

*Now with FMC Corporation, 633 Third Avenue, New York, N. Y.
†Now with the Environmental Protection Agency, Research Triangle Park, N. C.
Control of the air pollution that results from the melting and casting of iron may be conveniently considered according to the type of furnace employed. The cupola, electric, and reverberatory furnaces are the types most widely encountered. The air pollutants are similar, regardless of the furnace used; the primary differences among the pollution control systems of the various furnace types are to be found in the variations in hooding, and the necessary preparation and treatment of the contaminated gases from the furnaces. Essentially, the air pollution problem becomes one of entraining the smoke, dust, and fumes at the furnace and transporting these contaminants to suitable collectors.

**CUPOLA FURNACES**

The most widely encountered piece of equipment in the gray iron industry is the cupola furnace. High production rates are possible and production costs per ton of metal are relatively low. Despite this, where the product permits, some gray iron foundries have substituted reverberatory furnaces for their cupolas rather than install the air pollution control equipment that cupolas require. Table 75 shows one manufacturer's recommendations for operating cupolas.

**The Air Pollution Problem**

Air contaminants emitted from cupola furnaces are (1) gases, (2) dust and fumes, and (3) smoke,
Table 75. GENERAL RECOMMENDATIONS FOR OPERATING WHITING CUPOLAS

<table>
<thead>
<tr>
<th>Cupola size</th>
<th>Shell diameter, in.</th>
<th>Min. thickness of lower lining, in.</th>
<th>Diameter inside lining, in.</th>
<th>Area inside lining, in.²</th>
<th>Melting rate, tons/hr, with iron-coke (after bed) ratios of</th>
<th>Bed coke height above tuyeres, in.</th>
<th>Coke and iron charges, lb</th>
<th>Limestone, lb</th>
<th>Air through tuyeres, cfm</th>
<th>Suggested blower selection</th>
<th>Discharge pressure, oz</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>27</td>
<td>4-1/2</td>
<td>18</td>
<td>254</td>
<td>3/4</td>
<td>28 to 44</td>
<td>20</td>
<td>120</td>
<td>150</td>
<td>4</td>
<td>570</td>
</tr>
<tr>
<td>1</td>
<td>32</td>
<td>4-1/2</td>
<td>23</td>
<td>415</td>
<td>1-1/2</td>
<td>36 to 42</td>
<td>35</td>
<td>210</td>
<td>280</td>
<td>7</td>
<td>940</td>
</tr>
<tr>
<td>2</td>
<td>36</td>
<td>4-1/2</td>
<td>27</td>
<td>572</td>
<td>1-3/4</td>
<td>36 to 42</td>
<td>45</td>
<td>270</td>
<td>360</td>
<td>9</td>
<td>1,290</td>
</tr>
<tr>
<td>3</td>
<td>41</td>
<td>7</td>
<td>27</td>
<td>572</td>
<td>1-3/4</td>
<td>36 to 42</td>
<td>45</td>
<td>270</td>
<td>360</td>
<td>9</td>
<td>1,290</td>
</tr>
<tr>
<td>4</td>
<td>46</td>
<td>7</td>
<td>32</td>
<td>804</td>
<td>2-1/2</td>
<td>40 to 46</td>
<td>65</td>
<td>390</td>
<td>520</td>
<td>13</td>
<td>1,810</td>
</tr>
<tr>
<td>5</td>
<td>51</td>
<td>7</td>
<td>37</td>
<td>1,075</td>
<td>3-1/4</td>
<td>40 to 46</td>
<td>85</td>
<td>510</td>
<td>680</td>
<td>17</td>
<td>2,420</td>
</tr>
<tr>
<td>6</td>
<td>56</td>
<td>7</td>
<td>42</td>
<td>1,385</td>
<td>4</td>
<td>40 to 48</td>
<td>110</td>
<td>660</td>
<td>880</td>
<td>22</td>
<td>3,100</td>
</tr>
<tr>
<td>7</td>
<td>63</td>
<td>9</td>
<td>45</td>
<td>1,590</td>
<td>4-1/2</td>
<td>42 to 48</td>
<td>130</td>
<td>780</td>
<td>1,040</td>
<td>26</td>
<td>3,600</td>
</tr>
<tr>
<td>8</td>
<td>66</td>
<td>9</td>
<td>48</td>
<td>1,809</td>
<td>5-1/2</td>
<td>45 to 51</td>
<td>145</td>
<td>870</td>
<td>1,170</td>
<td>29</td>
<td>4,100</td>
</tr>
<tr>
<td>9</td>
<td>72</td>
<td>9</td>
<td>54</td>
<td>2,290</td>
<td>7</td>
<td>45 to 51</td>
<td>185</td>
<td>1,100</td>
<td>1,480</td>
<td>37</td>
<td>5,200</td>
</tr>
<tr>
<td>10</td>
<td>76</td>
<td>9</td>
<td>60</td>
<td>2,827</td>
<td>9</td>
<td>45 to 51</td>
<td>225</td>
<td>1,350</td>
<td>1,800</td>
<td>45</td>
<td>6,400</td>
</tr>
<tr>
<td>11</td>
<td>84</td>
<td>9</td>
<td>66</td>
<td>3,421</td>
<td>10-1/2</td>
<td>45 to 51</td>
<td>275</td>
<td>1,650</td>
<td>2,200</td>
<td>55</td>
<td>7,700</td>
</tr>
<tr>
<td>12</td>
<td>90</td>
<td>9</td>
<td>72</td>
<td>4,071</td>
<td>12-1/2</td>
<td>47 to 53</td>
<td>325</td>
<td>1,950</td>
<td>2,600</td>
<td>65</td>
<td>9,200</td>
</tr>
<tr>
<td>13</td>
<td>96</td>
<td>9</td>
<td>78</td>
<td>4,778</td>
<td>15</td>
<td>47 to 53</td>
<td>385</td>
<td>2,300</td>
<td>3,090</td>
<td>77</td>
<td>10,700</td>
</tr>
<tr>
<td>14</td>
<td>102</td>
<td>12</td>
<td>78</td>
<td>4,778</td>
<td>15</td>
<td>47 to 53</td>
<td>385</td>
<td>2,300</td>
<td>3,090</td>
<td>77</td>
<td>10,700</td>
</tr>
<tr>
<td>15</td>
<td>108</td>
<td>12</td>
<td>84</td>
<td>5,542</td>
<td>17</td>
<td>47 to 53</td>
<td>445</td>
<td>2,670</td>
<td>3,560</td>
<td>89</td>
<td>12,500</td>
</tr>
</tbody>
</table>

*For long heats, use heavier linings.

†Weight of bed coke varies as square root of blast pressure. Recommend blowers with 20-oz discharge pressure when air weight control is used.

‡Additional pressure capacity may be required when auxiliary equipment is added to the blast systems or when piping is long or complicated.
and oil vapor. The following is a typical cupola combustion gas analysis: Carbon dioxide, 12.2 percent; carbon monoxide, 11.2 percent; oxygen, 0.4 percent; nitrogen, 76.2 percent. Twenty to thirty percent by weight of the fumes are less than 5 microns in size. A particle size analysis of the dust and fumes collected from gray iron cupolas is shown in Table 76, as are some emission rates. Tables 77 and 78 show micromerograph and spectrographic particle size analysis of two samples taken from the hoppers of a bag filter serving a gray iron cupula furnace. Dust in the discharge gases arises from dirt on the metal charge and from fines in the coke and limestone charge. Smoke and oil vapor arise primarily from the partial combustion and distillation of oil from greasy scrap charged to the furnace.

Hooding and Ventilation Requirements

One way to capture the contaminants discharged from a cupola furnace is to seal the cupola top and vent all the gases to a control system. A second method is to provide a vent in the side of the cupola a few feet below the top of the burden and vent the gases to a control system. The control system consists of an afterburner, a gas-cooling device, and a dust collector, which is either a baghouse or an electrical precipitator. The system must be designed to exhaust enough gas volume to remove all the products of combustion from the cupola and to inspire sufficient air at the charge opening to prevent cupola gas discharge at that point. In addition, the exhaust gas volume must be sufficient to remove the products of combustion from the afterburner section. In cupolas of large diameter (over 36 in.), enclosure of the charge opening with refractory-lined or water-cooled doors is usually necessary. These doors are pneumatically operated to open only during the actual dumping of a charge into the cupola.

Even though a closed top cupula is equipped with a door to cover the charge opening, it is common practice to design the ventilation unit to provide at least 250 fpm average indraft velocity across the full open area of the charge opening.

Air Pollution Control Equipment

Collection efficiencies of several small-scale control devices on gray iron cupolas are shown in

### Table 76. DUST AND FUME EMISSIONS FROM GRAY IRON CUPOLAS

<table>
<thead>
<tr>
<th>Test No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cupola data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside diameter, in.</td>
<td>60</td>
<td>37</td>
<td>63</td>
<td>56</td>
<td>42</td>
<td>60</td>
<td>48</td>
</tr>
<tr>
<td>Tuyere air, scfm</td>
<td>-</td>
<td>1,950</td>
<td>7,500</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Iron-coke ratio</td>
<td>7/1</td>
<td>6.66/1</td>
<td>10.1/1</td>
<td>6.5/1</td>
<td>9.2/1</td>
<td>9.6/1</td>
<td>7.4/1</td>
</tr>
<tr>
<td>Process, wt, lb/hr</td>
<td>8,200</td>
<td>8,380</td>
<td>39,100</td>
<td>24,650</td>
<td>14,000</td>
<td>36,900</td>
<td>16,300</td>
</tr>
<tr>
<td><strong>Stack gas data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume, scfm</td>
<td>8,300</td>
<td>5,520</td>
<td>30,500</td>
<td>17,700</td>
<td>20,300</td>
<td>21,000</td>
<td>8,430</td>
</tr>
<tr>
<td>Temperature, °F</td>
<td>1,085</td>
<td>1,400</td>
<td>213</td>
<td>210</td>
<td>430</td>
<td>222</td>
<td>492</td>
</tr>
<tr>
<td>CO₂, %</td>
<td>-</td>
<td>12.3</td>
<td>2.8</td>
<td>4.7</td>
<td>5.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CO₂, %</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>12.7</td>
<td>11.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>N₂, %</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>67.5</td>
<td>67.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Dust and fume data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of control equipment</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Baghouse</td>
<td>Elec precip afterburner</td>
<td>Baghouse</td>
<td>Elec Precip</td>
</tr>
<tr>
<td>Concentration, gr/scf</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlet</td>
<td>0.913</td>
<td>1.32</td>
<td>0.413</td>
<td>1.33</td>
<td>2.973</td>
<td>0.392</td>
<td>1.522</td>
</tr>
<tr>
<td>Outlet</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.051</td>
<td>0.0359</td>
<td>0.0456</td>
<td>0.186</td>
</tr>
<tr>
<td>Dust emission, lb/hr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlet</td>
<td>65</td>
<td>62.4</td>
<td>108</td>
<td>7.7</td>
<td>6.24</td>
<td>8.2</td>
<td>13.2</td>
</tr>
<tr>
<td>Outlet</td>
<td>197</td>
<td>184.7</td>
<td>148.4</td>
<td>70.6</td>
<td>110</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Control efficiency, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle size, wt %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 5 μ</td>
<td>18.1</td>
<td>17.2</td>
<td>23.6</td>
<td>25.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5 to 10 μ</td>
<td>6.8</td>
<td>8.5</td>
<td>4.5</td>
<td>6.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10 to 20 μ</td>
<td>12.8</td>
<td>10.1</td>
<td>4.8</td>
<td>2.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>20 to 44 μ</td>
<td>32.9</td>
<td>17.3</td>
<td>3.9</td>
<td>10.0a</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>&gt; 44 μ</td>
<td>29.3</td>
<td>46.9</td>
<td>57.9</td>
<td>55.7b</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>3.34</td>
<td>2.78</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

aFrom 20 to 50 μ.
bGreater than 50 μ.
An afterburner is generally installed in a cupola furnace control system for two reasons. The high carbon monoxide content of the cupola effluent presents a definite explosion hazard; this hazard can be avoided by burning the carbon monoxide to carbon dioxide. Secondly, the afterburner burns combustion particulates, such as coke breeze and any smoke and oil vapors that may be distilled from the furnace charge. This combustion of oil vapors prevents later condensation on the surface of the filter bags and their resultant blinding. While afterburners may be installed as separate units, the common practice is to use the upper portion of the cupola between the charging door and the cupola top as the afterburner. When this is done, the height of the standard cupola must usually be increased to give a volume sufficient to provide adequate residence time to complete the combustion in the afterburner.

An afterburner should be designed with heat capacity to raise the temperature of the combustibles, inspired air, and cupola gases to at least 1,200°F. The geometry of the secondary combustion zone should be such that the products to be incinerated have a retention time of at least 1/4 second. A luminous flame burner is desirable, since it presents more flame exposure. Enough turbulence must be created in the gas stream for thorough mixing of combustibles and air. In large-diameter cupola furnaces, stratification of the gas stream may make this a major problem. One device, proved successful in promoting mixing in large-diameter cupolas, is the inverted cone shown in Figure 179. The combustion air is inspired through the charging door and, if necessary, may also be inspired through openings strategically located in the cupola circumference, above the charging opening.
**Form NO. 79—In stock and for sale by Ross-Martin Co., Tulsa, W-14719**

**State:**

- **IOWA**
- **CHARLES CITY (FLOYD)**

**Twp. & Rge.:**

- **T-95N, R-16W**

**Commenced:**

- **AUG–OCT 1963**

**Varner Well Co.**

**Logged: **

- **Oct 8, 1963 Northup**

**Remarks:**

- **EL 1013’**
- **TD 185’**
- **Screen 135’-185’**
- **T-25-117**

---

**Flowing: T.D. 185’ Pumped at 600 gpm W. 37’ dh**

---

**TL-888**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>150</td>
</tr>
<tr>
<td>200</td>
</tr>
</tbody>
</table>

**Soil & Groundwater:**

- **Sand, calc., gravel, sand, clay, water.**
- **Till, gravel, sand, clay, water.**
- **Det. Gypsum, 60', S115’.**

**Casing:**

- **6 3/4”**

---

**Remarks:**

- **EL 1013’**
- **TD 185’**
- **Screen 135’-185’**
- **T-25-117**

---

**Flowing:**

- **T.D. 185’ Pumped at 600 gpm W. 37’ dh**

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**TL-888**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>150</td>
</tr>
<tr>
<td>200</td>
</tr>
</tbody>
</table>

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---

**Remarks:**

- **EL 1013’**
- **TD 185’**
- **Screen 135’-185’**
- **T-25-117**

---
<table>
<thead>
<tr>
<th>Twp.</th>
<th>Rge.</th>
<th>Commenced</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-3-2</td>
<td>12-16</td>
<td>Jan. 15, 1907</td>
<td>Jan. 25, 1907</td>
</tr>
</tbody>
</table>

**Casing Record**

- 70' of 3" Casing from 112' to 185'
- 61' of 2 1/2" Casing from 185' to 246'
- 97' of 2" Casing from 246' to 343'

**Logging**

- From 721' to 1011' by

**Remarks**

- 100' of mudstone, 30' of shale, 40' of sandstone, 30' of shale, 30' of sandstone

**Note:** Stanbrook places base on gravel and claystone.
<table>
<thead>
<tr>
<th>Column A</th>
<th>Column B</th>
</tr>
</thead>
<tbody>
<tr>
<td>TD 80</td>
<td>PL 45/8</td>
</tr>
</tbody>
</table>