A granular briquette resistance furnace for the electrothermic dry distillation of zinc ores

Milton E. Countryman

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A GRANULAR BRIQUET RESISTANCE FURNACE FOR THE
ELECTROTHERMIC DRY DISTILLATION OF ZINC ORES.

—By—

Milton E. Countryman.

A
THESIS
submitted to the faculty of the
SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI
in partial fulfillment of the work required for the
DEGREE OF
MASTER OF SCIENCE.

Rolla, Missouri,
1925.

Approved: 

B. W. O'Hara
Acting Superintendent of the Mississippi Valley Experiment Station of the U. S. Bureau of Mines.
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P R E F A C E.

This thesis is presented to the faculty of the School of Mines and Metallurgy of the University of Missouri in partial fulfillment of the work required for the degree of Master of Science. It describes experiments carried on at the Mississippi Valley Experiment Station of the United States Bureau of Mines, Department of the Interior, cooperating with the School of Mines and Metallurgy of the University of Missouri, which had for their purpose the development of a "granular briquet resistance furnace" for the electrothermic dry distillation of zinc ores.

Acknowledgements are due to Mr. B. M. O'Harrar, Acting Superintendent of the Mississippi Valley Station of the United States Bureau of Mines, for his advice and supervision in this investigation; to Mr. William Kahlbaum, Research Metallurgist of the Missouri School of Mines and Metallurgy, with whom the writer was associated in the investigation; and to Mr. O. W. Holmes, Chemist of the staff of the State Mining Experiment Station, for the analytical work connected with the investigation.
A GRANULAR BRIQUET RESISTANCE FURNACE FOR THE

ELECTROTHERMIC DRY DISTILLATION OF ZINC ORES.

-By-

Milton E. Countryman.

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INTRODUCTION.

In current retort smelting practice for the reduction of zinc ores, the ores, if carbonates, are calcined to remove carbon dioxide; or, if sulphides, are roasted to remove sulphur. The sulphur must be eliminated as completely as possible, usually to less than one per cent. This means that the roast must be continued for a long time at a high temperature, with resulting high costs and small capacity per furnace. The roasted ore is mixed with about fifty per cent of its weight of reducer, which may be fine coke, anthracite, or non-bituminous coal. This mixture is charged into horizontal fire clay retorts. The retorts used in this country are about eight inches in internal diameter by four feet in length and hold from fifty to sixty pounds of ore. The diameter of the retort is limited by the time required for the heat to penetrate to the center of the charge; the length by the strength of the retort, which at the high temperature employed
cannot support the weight of the charge if the span is more than about fifty inches. The retorts are heated externally by coal, natural gas, or producer gas to a temperature of 1200°C. or more. The zinc oxide is reduced to zinc, which is volatile at this temperature and passes into a conical fire clay condenser attached to one end of the retort, where it condenses to liquid zinc and is removed. Twenty-four hours are required for distillation, and because of the low heat conductivity of the retort walls and of the ore charge itself, the heat efficiency even of the most modern regenerative furnaces is only about twelve per cent. The retorts have a short life, thirty to sixty days, at the high temperature required; zinc losses are heavy, usually ten per cent or more; and the proportion of impurities in the retort charge must be carefully controlled to prevent the rapid corrosion of retorts.

For these reasons, much work has been done in an effort to find cheaper and more efficient methods of recovering zinc from its ores. Various methods have been proposed for smelting in the blast furnace. Some of these contemplated the production of zinc vapor and its condensation to liquid; others attempted to produce liquid zinc directly by smelting under pressure. It is now realized that fundamental difficulties render these proposals impracticable.
The electric furnace for zinc smelting offers obvious advantages which can be enumerated as follows:

1. High thermal efficiency, the heat being communicated directly to the ore to be smelted, and not from the outside through a fire clay wall.

2. Better control of temperature, and the easier attainment of high temperatures.

3. Possibility of using larger units, with longer life and reduced operating costs.

4. Possibility of treating complex ores which cannot be treated in the present retort.

The first electric furnace for the smelting of zinc ores was designed in 1895 by E. R. and A. H. Cowles. Since that time many different types of furnaces and various methods of operation for the electric smelting of zinc ores have been tried, but up to the present time none of them have been put into commercial operation except in Norway and Sweden, where electrical power is exceptionally cheap. The processes used there involve a larger consumption of electrical power than would be permissible in the United States, where the cost of power is higher.

One of the chief difficulties to overcome in the electric melting of zinc is the tendency of the zinc to condense as blue powder rather than as liquid zinc; this blue powder must be redistilled or melted to convert it into marketable form, thus entailing a further power consumption.

The Fulton Electrothermic Dry Distillation Process.²

The Fulton electrothermic dry distillation process is the process that offers the most promise of commercial success under conditions existing in this country. It is economical of power, makes high recoveries of the zinc, can treat complex ores, and recovers most of the zinc as the liquid rather than as blue powder. In this process the roasted zinc ore is mixed with about seventy per cent of its weight of fine coke and about twenty per cent of its weight of coal tar pitch and molded into large briquettes. These are then set up and joined together on a suitable base to form a continuous resistor between a set of electrodes. They are baked, either before or after being set up, to drive off the volatile matter from the pitch and make them electrical conductors. After a briquet charge is set up, a "retort" is lowered over

the charge on its base, connections are made with a source of electrical power, and current is passed through the charge. The briquets are heated uniformly by the passage of the current and the zinc is distilled off and condensed in a suitable condenser. The briquets retain their shape and strength after the distillation of the zinc; the gangue from the ore is held in the coke matrix and does not fuse. After the zinc has been distilled the hot retort is removed and placed over a new charge, the spent charge is removed from its base and another one set up.

Object of this Investigation.

The object of this investigation was to develop a furnace for the distillation of zinc ores, which would operate on the principle of the Fulton furnace and have its advantages, but which could use small briquets that are more cheaply made than the large ones used in the present form of the Fulton furnace, and which would be of such a nature that, in a furnace of commercial size, briquets could be charged and discharged automatically instead of having to be set up by hand.
Previous Work with a Granular Briquet Furnace.

During the winter and spring of 1925-26 Messrs. William Kahlbaum and E. S. Wheeler, Research Metallurgists of the Missouri School of Mines and Metallurgy, experimented with several forms of a granular briquet furnace. Their best results were obtained in a furnace which consisted of a fixed base; a movable portion which made up the four walls, with a carbon electrode at each end and the full area of the end of the furnace, and with an ordinary retort condenser in one side; and a movable cover. In operating the furnace the four walls were luted to the base and the resulting rectangular chamber between the electrodes filled with small briquets. The cover was then luted on and a current passed through the charge until the zinc was expelled (eight to twelve hours). When the distillation was finished the walls and cover were lifted slightly and moved to one side of the base, thus automatically dumping the charge, and then were set back on the base. The cover was lifted and a new charge introduced and the process repeated. The recoveries they obtained were fair, but not as good as they should have been. This was partly because of absorption of zinc in the walls of the furnace, but also partly because of incomplete condensation of the zinc vapor. By suitable changes in furnace design and condenser capacity it was hoped to improve upon their results in the investigation described in this thesis.
EXPERIMENTAL PROCEDURE.

Materials Used.

Ore:
The ore used in the investigation was roasted Joplin ore containing 69 to 70 per cent zinc and 1.00 to 1.25 per cent fault sulphur. The ore was fine enough to pass a 10-mesh screen, but did not contain much very fine material.

Coke:
The coke used was crushed to pass through a 16-mesh screen.

Pitch:
The selection of the right pitch for a binder in the briquets is essential; the pitch after baking must leave a strong network of coke around the ore and original coke particles. The strength of this network depends upon the amount of fixed carbon in the pitch. Various samples of standard briquetting pitches were used in this investigation, with satisfactory results.

Briquets.
The briquets used in the Fulton electrothermic dry distillation process are made from a mixture of roasted zinc ore and fine coke, with coal tar pitch, or similar carbonaceous material, as a binder. This mixture is formed into briquets under a pressure of
1000 pounds or more per square inch, and finally baked at 400° to 500° C. to drive off volatile hydrocarbons, leaving a coke network uniting the original coke and ore particles.

**Method of Making the Briquets:**

One hundred parts roasted zinc ore and seventy parts coke were mixed in a revolving mixer to give a homogeneous mixture of ore and coke; the excess amount of coke over that required for the reduction of the zinc oxide, was necessary to make the briquet an electrical conductor, and to give it the property of retaining its shape after distillation. This mixture was mixed with 12.8 per cent of its weight of pitch, and heated on electric hot plates to a temperature somewhat above the melting point of the pitch, or to a point at which yellow fumes began to come off.

This heated mixture of ore, coke and pitch was pressed into briquets 5 by 4 by 7 inches at a pressure of 800 to 1000 pounds per square inch in a hand operated press. Later, in the making of the briquets the hand press was replaced by a hydraulic press which operated at 1000 to 1200 pounds per square inch water pressure; this gave a pressure slightly greater than that on the briquet itself.
Baking of Briquets:

The briquets were baked to cokc the pitch and drive off volatile hydrocarbons, thus making them a conductor for the electric current. The raw briquets were baked in a carbon resistance electric baking furnace. They were placed in the furnace and gradually heated for a period of eight hours. The temperature finally attained was 500° to 600° C. This baking was complete when no more volatile hydrocarbons came off. It was necessary to keep the briquets from oxidizing during the baking; this was accomplished by having the baking furnace sealed tightly except for a small exit for the gases that were driven off during the baking. Thus a reducing atmosphere was maintained in the furnace.

Size of the Briquets:

The briquets used in this investigation were of small size, all passing a 1.5 inch mesh screen but retained on a .25 inch mesh screen. After the large briquets were baked, they were broken to the required size either by hand or by a jaw crusher. The crusher was set so as to produce a minimum amount of fines.
**Apparatus.**

**Hot Plates:**

Figure 1 shows the electrically heated hot plates on which the briquet mixture was prepared for pressing. Heat was supplied by an electric current with a horizontal layer of granular graphite as the resistor. Half inch carbon plates, above the resistor and electrically insulated from it, formed the surface of the hot plates.

**Press:**

Figure 2 shows the hand operated press that was used for making the briquets used in the first runs. The photograph shows the jack-screw and mold in place for making the briquets.

The hydraulic press shown in Figure 3 was used for making the briquets for the last four runs. In this is shown the operating levers which control the movement of the plunger; the movable mold gliding on the four vertical columns; and the sliding head block against which the mixture is pressed.

**Baking Furnace:**

In Figure 4 is shown the carbon resistance electric furnace used for the baking of the raw briquets.

The furnace contained a baking chamber 15.5 inches square by 15.5 inches deep, which had for its cover a fire clay slab. A hole in the center of the slab allowed for the escape of the volatile hydrocarbons. A two-inch layer of granular graphite
Figure 1.

Electrically Heated Hot Plates.
Figure 2.

Hand Operated Briquet Press.
Figure 3.

Hydraulic Briquet Press.
surrounding the refractory tile lining of the furnace and contained
between it and the external walls of the furnace formed the resistor, by means of which the furnace was heated. The electrodes
were 2 by 2 inch-square graphite rods placed vertically at opposite
corners, just outside the lining of the baking chamber, extending
the full depth of the chamber and projecting several inches above
the top; the projecting ends were machined to a cylindrical shape
to receive water-cooled electrode holders. 3

Figure 4.
Carbon Resistance Baking Furnace.
DESCRIPTION OF FURNACES AND RESULTS OBTAINED.

Furnace E:

Furnace E was the first furnace used in the work described in this thesis. The construction of this furnace is shown in detail in Figure 5. This furnace had a smelting chamber with a capacity of 2504 cubic inches. Two carbon electrodes two inches thick and placed sixteen inches apart filled the full area at each end of the smelting chamber. Two carbon rods two inches in diameter were screwed into the center of the faces of the electrodes and extended through the brickwork to the outside of the furnace. On the ends of the rods the electrode holders and coolers were clamped, to which the cables from the current transformers were fastened. The walls and base of the smelting chamber were laid up with a course of fire brick. This inner wall and the carbon electrodes were insulated from the outer wall, of common red brick, by a course of Non-pareil brick. The rods and angle irons shown in the Figure held the masonry from excessive cracking during the expansion and contraction due to the heating and cooling of the inner part of the furnace. A standard retort condenser was built in each side of the furnace, the large end opening into, and two inches below the top of the smelting chamber, and the small end opening to the

Figure 5.
Diagram of Furnace E.
atmosphere. The 6 by 8-inch hole through the wall of the furnace and on the level with the bottom of the smelting chamber allowed for the withdrawal of the spent charge from the bottom of the furnace. When charged this opening was closed with a fire brick and insulated from the atmosphere. Over the top opening of the smelting chamber was luted a fire clay slab and this was insulated with Hom-pareil brick and mineral wool to retain as much heat in the top of the furnace as possible.

Results of Furnace E:

Two runs were made in this furnace using briquets minus 1.5 inch mesh, plus .5 inch mesh; only enough of this charge was added to fill the chamber to the bottom of the condenser. It was observed that the zinc which was distilled condensed and remained on top of the charge. This proved there was not enough heat radiated to this empty portion of the smelting chamber to keep the zinc in the vapor state for a sufficient time for it to pass into the condensors.

No zinc recovery data was taken for these two runs, but they proved that it was necessary to have uniformity of heat in the smelting chamber. This led to a slight modification in the design at the inlet of the condenser.
Modified Form of Furnace E:

A two-inch fire brick was fitted, in a vertical position, into each of the condenser inlets, leaving two narrow slits as openings from the smelting chamber to the condensers, in order that the smelting chamber could be completely filled with the charge without the charge entering the condensers, thereby avoiding condensation of the zinc on the surface of the charge, as in the two previous runs. This change proved beneficial. The results obtained with this furnace are given in Table 1.

It was observed in the runs made with Furnace E that the zinc recovered as metal solidified at the nose of the condenser, so Furnace F was constructed; it was a further modification of Furnace E.

Furnace F:

Furnace F is shown in Figure 6, with electrical and cooling water connections in place and the charge in the smelting chamber ready for the cover to be luted on. The construction of the furnace is shown in detail in Figure 7.

The two standard retort condensers were built in one wall of the furnace. The insulating brick were removed from around and below the condensers and laid up seven inches from the furnace wall in order to allow more heat to radiate to the condensers. The portion of the condenser that was exposed to the air was covered with
Table I.

Results Obtained with Modified Form of Furnace E.

<table>
<thead>
<tr>
<th>Description</th>
<th>Run 3</th>
<th>Run 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run Number</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Weight of Charge, pounds</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>Per cent Zine in Charge</td>
<td>37.12</td>
<td>56.72</td>
</tr>
<tr>
<td>Zine in Charge, ounces</td>
<td>464</td>
<td>459</td>
</tr>
<tr>
<td>Weight of Residue, pounds</td>
<td>38.5</td>
<td>37</td>
</tr>
<tr>
<td>Analysis of Residue in Zine, per cent</td>
<td>11.84</td>
<td>4.33</td>
</tr>
<tr>
<td>Zine in Residue, ounces</td>
<td>73</td>
<td>26</td>
</tr>
<tr>
<td>Zine Recovered as Metal, ounces</td>
<td>183</td>
<td>159</td>
</tr>
<tr>
<td>Zine Recovered as Blue Powder, ounces</td>
<td>114</td>
<td>194</td>
</tr>
<tr>
<td>Total Zine Recovered, ounces</td>
<td>297</td>
<td>558</td>
</tr>
<tr>
<td>Total Zine Accounted for, ounces</td>
<td>370</td>
<td>379</td>
</tr>
<tr>
<td>Per cent of Total Zine Recovered</td>
<td>63.99</td>
<td>78.20</td>
</tr>
<tr>
<td>Per cent of Total Zine in Residue</td>
<td>15.75</td>
<td>5.44</td>
</tr>
<tr>
<td>Per cent Zine Accounted for</td>
<td>79.72</td>
<td>82.56</td>
</tr>
<tr>
<td>Duration of Run in Hours</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>
Figure 6.
Furnace I.
Figure 7.

Diagram of Furnace I.
sheet asbestos. The size of the furnace and discharge hole remained the same as in Furnace \( F \).

The briquets were of the same size as were used in the first runs. A mistake was made in the proportion of coke and ore in making up the briquets for Run No. 9. They were made up of 100 parts coke, 70 parts ore, and 25 parts pitch. Run No. 12 was made with briquets made up of 100 parts ore, 50 parts coke and 25 parts pitch.

**Results of Furnace \( F \):**

The results obtained with this furnace are given in Table II. The average power input was 14 kilowatts at an average of 55 volts. A typical data sheet for a run with Furnace \( F \), showing the form used for keeping the records of the various runs, is given in Table III.
### Table II.

Results Obtained with Furnace F.

<table>
<thead>
<tr>
<th>Run Number</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of Charge, pounds</td>
<td>78</td>
<td>77.5</td>
<td>77.5</td>
<td>77</td>
<td>69</td>
<td>76.5</td>
<td>80</td>
<td>85</td>
</tr>
<tr>
<td>Per cent Zinc in Charge</td>
<td>36.49</td>
<td>36.91</td>
<td>37.64</td>
<td>37.01</td>
<td>26.27</td>
<td>34.13</td>
<td>38.66</td>
<td>42.50</td>
</tr>
<tr>
<td>Zinc in Charge, ounces</td>
<td>465</td>
<td>457</td>
<td>467</td>
<td>457</td>
<td>290</td>
<td>355</td>
<td>493</td>
<td>578</td>
</tr>
<tr>
<td>Weight of Residue, pounds</td>
<td>38</td>
<td>39.5</td>
<td>38</td>
<td>36</td>
<td>42</td>
<td>43</td>
<td>36</td>
<td>34</td>
</tr>
<tr>
<td>Analysis of Residue, percent Zinc</td>
<td>10.36</td>
<td>13.96</td>
<td>10.57</td>
<td>3.55</td>
<td>6.03</td>
<td>15.30</td>
<td>10.22</td>
<td>15.05</td>
</tr>
<tr>
<td>Zinc in Residue, ounces</td>
<td>65</td>
<td>88</td>
<td>64</td>
<td>20</td>
<td>41</td>
<td>91</td>
<td>59</td>
<td>72</td>
</tr>
<tr>
<td>Zinc Recovered as Metal, ounces</td>
<td>154</td>
<td>144</td>
<td>226</td>
<td>286</td>
<td>148</td>
<td>184</td>
<td>510</td>
<td>519</td>
</tr>
<tr>
<td>Zinc Recovered as Blue Powder, ounces</td>
<td>106</td>
<td>104</td>
<td>107</td>
<td>84</td>
<td>38</td>
<td>35</td>
<td>60</td>
<td>88</td>
</tr>
<tr>
<td>Total Zinc Recovered, ounces</td>
<td>260</td>
<td>248</td>
<td>335</td>
<td>372</td>
<td>186</td>
<td>219</td>
<td>370</td>
<td>407</td>
</tr>
<tr>
<td>Total Zinc Accounted for, ounces</td>
<td>325</td>
<td>336</td>
<td>397</td>
<td>392</td>
<td>227</td>
<td>310</td>
<td>429</td>
<td>479</td>
</tr>
<tr>
<td>Per cent of Total Zinc Recovered</td>
<td>57.15</td>
<td>54.25</td>
<td>71.81</td>
<td>81.56</td>
<td>66.13</td>
<td>60.32</td>
<td>75.05</td>
<td>70.58</td>
</tr>
<tr>
<td>Per cent of Total Zinc in Residue</td>
<td>15.85</td>
<td>19.25</td>
<td>15.70</td>
<td>4.39</td>
<td>14.14</td>
<td>25.06</td>
<td>11.95</td>
<td>12.45</td>
</tr>
<tr>
<td>Per cent Zinc Accounted for</td>
<td>70.98</td>
<td>73.50</td>
<td>85.01</td>
<td>85.95</td>
<td>78.27</td>
<td>85.38</td>
<td>87.01</td>
<td>85.08</td>
</tr>
<tr>
<td>Duration of Run in Hours</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>16</td>
<td>14</td>
<td>14</td>
<td>16</td>
<td>15</td>
</tr>
</tbody>
</table>

*Runs Nos. 9 and 12 were made with briquettes of different proportions of coke and ore. Run No. 9: 100 parts coke, 70 parts ore and 25 parts pitch; Run No. 12: 100 parts ore, 50 parts coke and 25 parts pitch.*
### Table III.

**Example of Typical Data Sheet for Run.**

**Run Number 10**  
**December 31, 1924**  

**Furnace started at 6:15 A.M.**  
**Weight of charge - 77.5 pounds.**

**Analysis of charge - 34.15 per cent zinc.**

**Metal zinc in charge - 22 pounds and 11 ounces; 363 ounces.**

**Brickets used in this run were made in the hydraulic press using low melting point pitch.**

#### Running Log.

<table>
<thead>
<tr>
<th>Time</th>
<th>Volts</th>
<th>K. W.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:15 A M</td>
<td>280</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6:45</td>
<td>240</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6:55</td>
<td>210</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:30</td>
<td>146</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>8:00</td>
<td>124</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>8:30</td>
<td>110</td>
<td>15</td>
<td>Good flame</td>
</tr>
<tr>
<td>9:00</td>
<td>100</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>9:30</td>
<td>98</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>10:00</td>
<td>93</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>10:30</td>
<td>93</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>11:00</td>
<td>92</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>11:30</td>
<td>85</td>
<td>14</td>
<td>Zinc in flame; Prolongs put on</td>
</tr>
<tr>
<td>12:00</td>
<td>83</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>12:30 P M</td>
<td>82</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>1:00</td>
<td>76</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>1:30</td>
<td>68</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>2:00</td>
<td>66</td>
<td>14.5</td>
<td>Good flame</td>
</tr>
<tr>
<td>2:30</td>
<td>62</td>
<td>13.5</td>
<td>Good flame</td>
</tr>
<tr>
<td>3:00</td>
<td>60</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>3:30</td>
<td>55</td>
<td>14</td>
<td>Zinc in flame</td>
</tr>
<tr>
<td>4:00</td>
<td>50</td>
<td>14.5</td>
<td>Zinc in flame</td>
</tr>
<tr>
<td>4:30</td>
<td>49</td>
<td>14</td>
<td>Zinc in flame</td>
</tr>
<tr>
<td>5:00</td>
<td>45</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>5:30</td>
<td>45</td>
<td>14</td>
<td>Good flame</td>
</tr>
<tr>
<td>6:00</td>
<td>45</td>
<td>14.5</td>
<td>Zinc in flame</td>
</tr>
<tr>
<td>6:30</td>
<td>44</td>
<td>14</td>
<td>Metal zinc run from condenser</td>
</tr>
<tr>
<td>7:00</td>
<td>44</td>
<td>15</td>
<td>Zinc in flame</td>
</tr>
<tr>
<td>7:30</td>
<td>42</td>
<td>14.5</td>
<td>Zinc in flame</td>
</tr>
<tr>
<td>8:00</td>
<td>42</td>
<td>14.5</td>
<td>Zinc in flame</td>
</tr>
<tr>
<td>8:15</td>
<td>41</td>
<td>15</td>
<td>Power off</td>
</tr>
</tbody>
</table>
Table III. Continued.

Example of Typical Data Sheet for Run.

Weight of Residue - 45 pounds

Analysis of Residue - 13.50 per cent zinc

Metal in residue - 5 pounds and 11 ounces; 91 ounces.

Analysis of Residue at Bottom of Furnace - 0.95 per cent zinc.
Table III. Continued.

Example of Typical Data Sheet for Run.

Metal Account No. 10.

Metal Recovered:

**North Condenser:**
- Zinc Metal .............. 6 pounds, 7 ounces.
- Blue Powder in Condenser 14 ounces.
- Blue Powder in Prolong 4 ounces.

**South Condenser:**
- Zinc Metal ............. 5 pounds, 1 ounce.
- Blue Powder in Condenser 1 pound, 1 ounce.
- Blue Powder in Prolong 3 ounces.

**Total**
- Zinc Metal .............. 11 pounds, 8 ounces.
- Blue Powder .............. 2 pounds, 3 ounces.

**Summary.**

<table>
<thead>
<tr>
<th>Zinc Recovered</th>
<th>Weight</th>
<th>Per cent</th>
<th>Accumulative per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc Metal .............</td>
<td>11 lb. 6 oz.</td>
<td>50.68</td>
<td>50.68</td>
</tr>
<tr>
<td>Blue Powder in Condenser</td>
<td>1 lb. 12 oz.</td>
<td>7.68</td>
<td>58.36</td>
</tr>
<tr>
<td>Blue Powder in Prolong</td>
<td>6 oz.</td>
<td>1.65</td>
<td>60.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zinc Accounted for</th>
<th>Weight</th>
<th>Per cent</th>
<th>Accumulative per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc Metal Recovered ...</td>
<td>13 lb. 11 oz.</td>
<td>60.01</td>
<td>60.01</td>
</tr>
<tr>
<td>Zinc in Residue .......</td>
<td>5 lb. 11 oz.</td>
<td>25.06</td>
<td>85.07</td>
</tr>
</tbody>
</table>

Condensation – 84 per cent as metal.
SUMMARY AND CONCLUSIONS.

Although the work described in this thesis cannot be considered complete until larger furnaces of the same type have been tried, and operated continuously over considerable periods of time under semi-commercial conditions, the results of the experiments indicate that the granular briquet resistance furnace has considerable promise as a furnace for the distillation of zinc ores.

The recoveries obtained in the experiments that have been described may be criticised. It must be remembered, however, that the furnaces were changed and worked under a variety of conditions. In many cases only one or two charges were distilled in a given furnace; if these runs indicated that changes in the furnace design were desirable, the changes were made at once and the new furnace tried. Under these conditions there was little opportunity to standardise operating conditions or to ascertain the time necessary to distill the charge completely. Enough charges were distilled to completion to prove that with proper operating conditions all but three to five per cent of the zinc can be distilled. For the same reasons not all the zinc distilled was condensed, in many of the runs; this fact, together with the fact that none of the furnaces were operated for a sufficiently long time for the walls to become saturated with zinc, explains the considerable amounts of
sino unaccounted for in all the runs. The proportion of sino
condensed to metal, rather than blue powder, was very satisfac-
tory, especially in the last type of furnace (Furnace F).

No attempt was made to obtain data for the power con-
sumption, because of the large radiating surface of the furnaces
compared to their volume, which was larger than it would be in a
commercial-sized furnace. A considerable amount of the total
energy was consumed in heating the cold furnace to the tempera-
ture at which distillation began. Reasoning by analogy, it seems
that the power consumption in the granular briquet furnace should
be about the same as in the Fulton furnace.

The laboratory furnace that has been developed would
necessarily be changed in many respects in enlarging it to commer-
cial size. Various possible forms for a commercial furnace sug-
gest themselves, but as they have not been worked out in detail
they will not be discussed here. It seems that there should be no
difficulty in designing a large furnace so that it could be charged
from a hopper or by a crane, and discharged with a minimum of labor.
The condenser for a furnace of large capacity would, of course, be
entirely different; the same type of condenser that is used for
the Fulton furnace should be satisfactory.
BIBLIOGRAPHY.


Figure 6.

Switch Board for Controlling Current to Furnaces.