An
Investigation on the Coking Properties of a Mexican Coal.

By

and

Physics Department

1901
We want to express our thanks to Prof. Hoffman and Prof. Richards, whose valuable aid helped us to get the away to a successful product also to the New England Gas & Coke Co. and the Semet Solom. Process Co. and to the kind ness of their Superintendents and overseers, Messrs. Green, Gowell and Mr. Kelly.
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I. Introduction.

About the middle of the year of 1899, Mr. J. González Treviño and Messrs. Francisco and Ernesto Madero organized a company to develop a coal region located in San Enríquez, on the boundary line between the states of Coahuila and Nuevo León, in the northern part of Mexico.

The coal was discovered there two or three years earlier, not merely by chance but owing to the fact of the similarity of the locality, geological features of the locality to those of the San Thomas coal region on the Texas side of the Rio Bravo, some ten miles below.
The nearest point where railroad facilities could be had, to connect with the principal markets of Mexico, such as Monterrey, Saltillo, etc., is Laredo, where the Mexican National R R starts. Laredo is about 40 miles east of the San Enrique Coal mines, and transportation from these mines is slow and expensive, especially so, if the coal is to be sold as such. If, however, the coal were made into coke, and the gas and by-products, sold separately, the expense of transportation of the coke and by-products, excluding gas, would be smaller in proportion to the price received.

It might then pay to improve the existing means of transportation from the mines to Laredo.

The question, then, is, first to ascertain the quality of the coal, i.e. where it stands as compared with other
coals, whether it is a coking coal, or a good gas coal, or, in short, what is the character of the coal, and what can be done with it.

In choosing a subject for our thesis, we thought that none could be more suitable than making a short investigation on this coal in the line of its coking property.

We have endeavored to make as many tests as we could, in the time allowed, and to make our conclusions as comprehensive as possible.
II. Occurrence of Coal

The mine from which our coal comes is on the south side of the Rio Bravo, some 40 miles west of Laredo, and on the boundary line between the states of Coahuila and Nuevo Leon. It was opened up two or three years ago, but so far, no great effort has been made to get any considerable output, except for private use, on account of the difficulties met with in bringing the coal to market.

The region is similar in every respect to that of the San Thomas Coal mines which are less than ten miles down the river and on the American side of it. The coal of both mines has the same outward appearance, but the quality seems to improve as we go
A brief description of the general geological features and the quality of the coal of the San Thomas mines, as given by Mr. E. T. Humble, will be quoted, so it can very properly be applied to the San Enrique district.

Mr. Humble says, speaking of the Webb county coal: "All of the western half of the Webb county is in the limits of the Nueces coal fields. There are three strata present in a part of the county, but the middle one is the only one of any economical value. This stratum ranges from eighteen to thirty-three inches in thickness, and has a two-inch division of slate in the center. It is a very firm, solid coal, and breaks with a glossy, conchoidal fracture, and is not easily pulverized. It is very clean and free from dust, and has the appearance of hardened asphaltum."

It contains but a few plant impressions, is remarkably free from sulphide of iron, burns with a vigorous bright flame and oily appearance, contains a considerable quantity of ash, but will not make clinkers if separated from the plate in the center of the stratum.

This description of the Webb coal seems to correspond so closely to our coal that further description will be useless. In breaking our coal we found only a few fossil impressions; its strength and fracture corresponded to those of the Webb coal; very few traces of pyrite could be found, and even the chemical composition differed but slightly.

Mr. Shumle (1) continues his description thus:

"The most northern exposure of this coal, observed in Webb county, was about twenty-five miles northwest of San Thomas, where a seam of pitch coal was found, which was black, massive, dense,

(1) Geol. Surv. of Texas. 1872 p. 187.
and so firm that it does not give a greasy streak with finger nail. No trace of wood structure, sub-conchoidal fracture."

"About eight miles west of San Thomas, at Estapada creek, we find three seams of brown coal."

"The upper seam is twelve inches thick, and is a massive pitch coal with conchoidal fracture very similar to the body of the San Thomas coal. It is underlaid by four feet of shale, and this by the San Thomas seam of coal, which is here thirty-four inches thick with a two inch division of plate. This coal is underlaid by thirty feet of shale, below which is a third seam of brown coal, varying in color from light to dark brown, with many traces of woody structure, impressions of leaves, etc."

The locality at Estapada creek referred to in the above quotation, is of particular interest as it lies almost opposite the San Enrique mines from which our coal
Mr. Humble (1) gives the following section at the San Thomas mines:

1. Calcareous sands — 12 feet
2. Triahle sandstone — 12 feet
3. Chocolate, gray, white and brown clays, with sulphur and gypsum crystals in layers, running downward into black clays, with a two inch seam of lignite a few inches above 4. 10 feet.
4. Brown coal of the variety pitch coal, massive, black, and glossy, with conchoidal fracture in places, but having the form of glance coal and structure of bituminous coal in others — 1 foot 3 inches.
5. Hard black clay — 2 inches
6. Brown coal, same as 4. — 1 foot 3 inches
7. Gray clays containing thin seams of lignite in the portion directly underlying 6. 10 feet.

He gives also the dip of the coal seams as 3°.

Of the various classifications of

(1) Geol. Surv. of Texas, 1892, p. 190
coals proposed, the one based upon their geological age has, according to Mr. Bumble, come into general use. He states it as follows:

<table>
<thead>
<tr>
<th>NAME</th>
<th>GEOLOGICAL AGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peat</td>
<td>Recent and Quaternary</td>
</tr>
<tr>
<td>Brown coal and lignite</td>
<td>Tertiary to Triassic</td>
</tr>
<tr>
<td>Lignite, coal, and stone coal</td>
<td>Carboniferous and older</td>
</tr>
</tbody>
</table>

Mr. John Fulton states that the Mexican coals are found in the Cretaceous or Tertiary formations, probably the former. They are of the same general character of the Texas coals. Our coal may be classed under the head of brown coal probably of the Cretaceous formation. The greater part of the coal of this age [Bumble, 1892, p. 25] as it is developed in the vicinity of Eagle Pass, Texas, resembles the bituminous coal of the Carboniferous much more closely than it does any variety found in the

Tertiary.

(1) Geol. Surv. of Texas 1892, p. 25.

III. - Physical Properties

We received 155 kilogrammes net of this coal, which was given the Laboratory No. 1325. The coal arrived in bags. It was in lump form, the size of the lumps varying from about 6" to not more than 15" in length, and differing width. The coal withstood transportation well, as when it arrived, it was but little broken and only a small amount of slack was formed.

1) Specific Gravity. - The average Sp. Gr. of our coal was computed from the Sp. Grs. of eight specimens, which represented, as nearly as we could judge, all grades of specimens from the flattest and poorest to the best, strongest, glossy coal we could select.

We determined these specific gravities
by weighing the specimens, first in air, and then again in water, by suspending them from the beam of the balance with a wire of very small diameter. The arrangement of the apparatus is shown in the sketch below.

**SIDE VIEW**

- a = beam of the scale
- b = scale pan
- c = wood bench
- d = coal
- e = beaker containing distilled water
- f = suspending wire
- g = scale-pan support

**FRONT VIEW**
After the specimens in the water, we put the beaker under the bell of an air pump and made as high a vacuum as we could get, allowing in each case the specimen to remain there for 10 minutes. With this precaution any air mechanically enclosed in the coal was removed.

If we call $S$ the weight of the substance in air, $S'$ the weight of the substance in water, and $W$ the weight of the water displaced by the specimen, we have

$$W = S - S'$$

and

$$\text{Sp. Gr.} = \frac{S}{W}$$

The following table gives a complete account of each determination:
<table>
<thead>
<tr>
<th>No</th>
<th>S</th>
<th>S'</th>
<th>W = S - S'</th>
<th>S/S'</th>
<th>Quality of Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.4886</td>
<td>3.0150</td>
<td>7.4736</td>
<td>1.38</td>
<td>poor</td>
</tr>
<tr>
<td>2</td>
<td>9.6342</td>
<td>2.5545</td>
<td>7.0797</td>
<td>1.36</td>
<td>poor</td>
</tr>
<tr>
<td>3</td>
<td>20.4900</td>
<td>4.7975</td>
<td>15.6925</td>
<td>1.30</td>
<td>poor</td>
</tr>
<tr>
<td>4</td>
<td>14.9285</td>
<td>3.3097</td>
<td>11.6188</td>
<td>1.28</td>
<td>medium</td>
</tr>
<tr>
<td>5</td>
<td>19.5356</td>
<td>4.3178</td>
<td>15.2178</td>
<td>1.28</td>
<td>medium</td>
</tr>
<tr>
<td>6</td>
<td>15.5075</td>
<td>3.2725</td>
<td>12.0350</td>
<td>1.24</td>
<td>good (?)</td>
</tr>
<tr>
<td>7</td>
<td>19.1269</td>
<td>4.0510</td>
<td>15.0759</td>
<td>1.26</td>
<td>good</td>
</tr>
<tr>
<td>8</td>
<td>6.3453</td>
<td>1.3241</td>
<td>5.0212</td>
<td>1.26</td>
<td>good</td>
</tr>
</tbody>
</table>

As can be seen, the specific gravities of these specimens range from 1.38 down to 1.26, being smaller and smaller as the quality of the coal is improved.

2) Hardness

The hardness of the coal varies from soft to moderately hard. Few specimens only could be pricked with
finger nail, but most of them were harder and could only be scratched with a knife.

3) Cohesiveness

Most of the specimens were compact and tough, but a good many could easily be broken with a moderately hard blow along the bedding planes.

4) Cleavage

Most of our coal presented a cleavage in one direction only. Some specimens showed no cleavage at all.

5) Fracture

Fracture was usually even. Sometimes conchoidal, or angular, splintery and fibrous.

6) Color

Varying from dark brown to dark

7) Lustre

Varying from dull, waxy to greasy, vitreous and glossy.

8) Streak

Brown.
IV. Coal Analysis

1) Moisture:

Take a weighed platinum crucible (capacity about twenty-five cc.), weigh in it one and a half grams of the powdered coal. Transfer to a drying oven and heat at 103°C for fifteen minutes; cool in a desiccator and weigh. Loss is moisture.
Crucible + cover  22.0477  19.3240
Crucible + cover + coal  22.5495  19.8250
Coal Taken  .5018 .5010
Crucible + cover + coal  before drying  22.5495  19.8250
Crucible + cover + coal  after drying  32.5345  19.8113
Moisture  .0150 .0437

\[
\frac{.0150 \times 100}{.5018} = 2.989\% \text{ Moisture}
\]

\[
\frac{.0137 \times 100}{.5010} = 2.734\% \text{ Moisture}
\]

2) Volatile and Combustible Matter: The crucible containing the dried coal is now heated over a Bunsen burner for three and a half minutes, then over
the blast lamp for three and a half minutes more, taking care that the cover of the crucible fits closely. Cool in a desiccator. Loss in weight equals volatile matter plus one-half of the sulphur.

Crucible + cover + coal before heating seven minutes.

22.5345 19.8113

Crucible + cover + coal after heating seven minutes 22.2847 19.5739

0.2498 0.2374

\[ \frac{2498 \times 100}{5018} = 49.981\% \]

\[ \frac{2374 \times 100}{5040} = 47.385\% \]
3) Fixed Carbon

The crucible and contents are now heated over a Bunsen burner (lid of crucible removed) until all carbonaceous matter is consumed. Where the combustion is extremely slow, it can be expedited by introducing into the crucible a slow current of oxygen gas, so regulated that the contents of crucible are not disturbed. Replace cover of crucible when ignition is complete, cool in desiccator and weigh.
Crucible + cover + coal before complete combustion 22.2847 19.5739
Crucible + cover +
cand. after com-
plete combustion 22.0997 19.3756
Dried Carbon
+ ¼ Sulphur 850 1913

\[
\frac{850 \times 100}{5018} = 36.867\% \text{ fixed Carbon + ¼ Sulphur}
\]

\[
\frac{1913 \times 100}{5010} = 39.581\% \text{ fixed Carbon + ¼ Sulphur}
\]

4) Ash:

Crucible + cover + residue after complete combustion (Ash)
22.0997 19.3756
Crucible + cover 22.0477 19.3240
Ash 0.0540 0.0516

\[
\frac{0.052 \times 100}{5018} = 1.0363\% \text{ of ash}
\]
\[
\begin{array}{c}
0.0516 \times 100 = 10.3997 \% \text{ Ash} \\
0.5010
\end{array}
\]

**Resume:**

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount 1</th>
<th>Amount 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>2.989</td>
<td>2.734</td>
</tr>
<tr>
<td>Volatile and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>combustible matter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur</td>
<td>49.781</td>
<td>47.385</td>
</tr>
<tr>
<td>Fixed carbon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur</td>
<td>36.867</td>
<td>39.581</td>
</tr>
<tr>
<td>Ash</td>
<td>10.363</td>
<td>10.399</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100.000</td>
<td>99.999</td>
</tr>
</tbody>
</table>

It is necessary now to determine the percentage of sulfur present in the coal and subtract it from the amounts of volatile and combustible matter and fixed carbon. The method are
used as follows.

Take one gram of finely powdered coal, and mix it upon a piece of blue glazed paper with about ten times its weight of sodium carbonate (dry) and five grains of sodium nitrate.

Place a small portion in a platinum crucible of fifty c.c. capacity, and heat to redness. When combustion is complete, add some more of the coal mixture, repeating the operation until all has been
transferred to the crucible from the glazed surface paper. Heat at a red heat for fifteen minutes, making certain that no particles of carbon remain uncoated.

Allow to cool, transfer crucible and contents to a No. 3 beaker, add 100 c.c. water, and warm carefully until the mass dissolves.

Remove the crucible from the beaker, washing it once with hot water, allowing the washings to run into the beaker.
Dilate the solution, acidify the filtrate with hydrochloric acid, boil and add solution of barium chloride in slight excess. Allow to stand twelve hours (or over night), wash, melt, dry, ignite, weigh as barium sulphate and calculate to sulphur.

Amount of coal taken: 0.5334
Crucible + BaSO₄: 14.7099
Crucible: 14.6765
BaSO₄: 0.0334
S: 0.00175

\[
\frac{0.00175 \times 100}{0.5334} = 70.3 \text{ per cent S.}
\]
By following Prof. Dalbot's advice we made some determinations of the volatile and combustible matter in a little different way. In order to see the effect of heating the crucible slowly at first, without allowing the combustible matter to burn while passing off. When this had been done, the rest of the Bunsen burner was brought to its full capacity, and finally the blast lamp applied for three and a half minutes more, as before.
By the second method the percentage of fixed carbon was greatly increased, while the proportion of volatile and combustible matter was correspondingly lowered. The results obtained were as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>2.998%</td>
</tr>
<tr>
<td>Volatile and Combustible Matter</td>
<td>47.84%</td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>43.18%</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.63%</td>
</tr>
<tr>
<td>Ash</td>
<td>10.465%</td>
</tr>
<tr>
<td>Total</td>
<td>99.998%</td>
</tr>
</tbody>
</table>

The higher average of Fixed Carbon by the second method appears to be more reliable than that by the first.
V. Calorific Power

We made some experiments to determine the calorific power of the coal and used the Mohler Bombé modified by Mr. C. Norton of the Heat Laboratory of the Institute.

The bombé consists of two hollow hemispheres of aluminum brass screwed together, a lead washer making the joint tight. An electric battery is connected with the bombé, the two wires passing through the top. One carries a little platinum tray
which receives one grain of the finely powdered coal, and the other is connected with a fine platinum wire, passing through the coal to the first pole. The resistance of the fine wire to the passing of the electricity is sufficient to generate the heat necessary to burn the coal. Perfect combustion is insured by a pressure of four hundred pounds of oxygen. The heat of the bomb is communicated to a thermometer, and the rise of temperature is observed by means of
a good thermometer with the weight and specific heat of the bombé known, the number of calories set free by the burning coal is readily determined.

Weight of coal 1 gram

water in calorimeter 1500 "
Specific heat of bombé, stirrer and fai 0.95

Weight of bombé 3586 grams

" " stirrer 150 "

" " fai 33.5

Initial temperature of water 17.3 °C

Final " " 22.03 °C

\[3586 + 150 + 33.5 \times 0.95 = 386.745 \text{ water equivalent}\]

\[386.745 + 1500 = 1886.745\]

\[1886.745 \times 4.73 = 8924.304 \text{ calories}\]
VI Coking properties

We next determined the coking properties of the coal, following Hook as one of the leading authorities on the subject. We know that in general the smallest the size of the coal, the better the cake, because the particles fuse more readily and adhere better to one another.

As we could not obtain any references upon the size to which the coal ought to be crushed, "Chemie der Steinkohle" page 6-15 and page 36 and Mr. Leipzig January 1871.
me began our work by making a series of ex-
periments using different
sizes of coal, and at
the same time em-
ploying different tempe-
ratures in cooking by
varying the distance bet-
ween crucible and mouth
of burner.
A weight of one grain
coal was used throughout
all the operation, and the
sizes of coal tested were
numbers 10, 14, 20, 30, 40
meshes.
Two kinds of tests were
made to determine, first,
the emalling powers of the
coil, as this has a rela-
tion to the coking proper-

and, second, the cuttingower.

In the experiments we used a standard flame of eighteen centimeters length, we placed our crucibles, three, six and nine centimeters from the mouth of the burner, and we also determined the effect of using a distance of three centimeters and afterwards applying the blast lamp.

It would be almost impossible to describe the appearance of the coke and the different effects. The accompanying photographs and tables, may perhaps prove more satisfactory than a written description.
<table>
<thead>
<tr>
<th>10 MESH</th>
<th>14 MESH</th>
<th>20 MESH</th>
<th>30 MESH</th>
<th>40 MESH</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="10M.png" alt="Image" /></td>
<td><img src="14M.png" alt="Image" /></td>
<td><img src="20M.png" alt="Image" /></td>
<td><img src="30M.png" alt="Image" /></td>
<td><img src="40M.png" alt="Image" /></td>
</tr>
<tr>
<td><img src="3cm.png" alt="Image" /></td>
<td><img src="4cm.png" alt="Image" /></td>
<td><img src="6cm.png" alt="Image" /></td>
<td><img src="9cm.png" alt="Image" /></td>
<td><img src="3cm+BLAST.png" alt="Image" /></td>
</tr>
</tbody>
</table>

Note: The images are not clearly visible in the text representation.
<table>
<thead>
<tr>
<th>Mesh</th>
<th>3 cm from Burner</th>
<th>6 cm from Burner</th>
<th>9 cm from Burner</th>
<th>3 cm + Blast Lamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 MESH</td>
<td>coal 1.00 g, coke 0.57 g</td>
<td>coal 1.00 g, coke 0.57 g</td>
<td>coal 1.00 g, coke 0.57 g</td>
<td>coal 1.00 g, coke 0.57 g</td>
</tr>
<tr>
<td>30 MESH</td>
<td>coal 1.00 g, coke 0.51 g</td>
<td>coal 1.00 g, coke 0.51 g</td>
<td>coal 1.00 g, coke 0.51 g</td>
<td>coal 1.00 g, coke 0.51 g</td>
</tr>
<tr>
<td>20 MESH</td>
<td>coal 1.00 g, coke 0.48 g</td>
<td>coal 1.00 g, coke 0.48 g</td>
<td>coal 1.00 g, coke 0.48 g</td>
<td>coal 1.00 g, coke 0.48 g</td>
</tr>
<tr>
<td>14 MESH</td>
<td>coal 1.00 g, coke 0.50 g</td>
<td>coal 1.00 g, coke 0.50 g</td>
<td>coal 1.00 g, coke 0.50 g</td>
<td>coal 1.00 g, coke 0.50 g</td>
</tr>
<tr>
<td>10 MESH</td>
<td>coal 1.00 g, coke 0.52 g</td>
<td>coal 1.00 g, coke 0.52 g</td>
<td>coal 1.00 g, coke 0.52 g</td>
<td>coal 1.00 g, coke 0.52 g</td>
</tr>
</tbody>
</table>

**Coal and Coke Percentages**

- 30 MESH: 70% coal, 30% coke
- 20 MESH: 70% coal, 30% coke
- 14 MESH: 70% coal, 30% coke
- 10 MESH: 70% coal, 30% coke

**Note:**
- Meshes refer to particle size distribution.
- The values provided are approximate and may vary depending on the specific conditions and tests conducted.
We might perhaps say that the number 14 and 20-mesh sieves gave a little better results than the other sizes, but the differences were so slight as to be almost unnoticeable, especially in a photograph. It can be easily seen in the photograph that the samples from working with a distance of three centimeters plus half again are slightly different from the others, the center being black. The coke, also, weighed less than that of the other treated portion of the heavy volatile hydrocarbons which had remained in the other
Specimen when using a Bunsen burner was further decomposed here, the carbon being precipitated in the coolest central spark.

In the three pots of tests using the Bunsen burner alone, the crucibles were heated for five minutes and the gases were allowed to be burnt off as recommended by Muck on pages 6 to 15.

Judging by smelling tests our coke seems to lie between what Muck calls “Sinterkohle” and “Magere kohle” or between “Flammenkohle” and “Gaskohle”, both of which closed short
similar smelling properties. The former contains 65-90 % of fixed carbon, the latter 60 to 68 per cent. Hence our coal resembles rather the "Flammen" or gas Kohle", but our average of fixed carbon is still lower, viz. 43 per cent. The table of weights of these coking experiments show that the weight remains nearly constant at 51 grams, diminishing slightly when the blast lamps were used. Most of the coke pans were seen to be broken at the center, which is due perhaps to shrinkage.
<table>
<thead>
<tr>
<th>Mesh number</th>
<th>Coal grams</th>
<th>Sand grams</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>7.5</td>
<td>Caked</td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>1</td>
<td>Caked poorly</td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>2</td>
<td>Very poorly caked</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
<td>1</td>
<td>Poorly caked</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>1</td>
<td>4</td>
<td>Very</td>
</tr>
<tr>
<td>60</td>
<td>1</td>
<td>1</td>
<td>Poorly caked</td>
</tr>
<tr>
<td>60</td>
<td>1</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>1</td>
<td>4</td>
<td>Very</td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>5</td>
<td>Could possibly stay together.</td>
</tr>
</tbody>
</table>
VII Binding Power

He made a number of experiments to determine the binding power of our coal, and compared it with other coking coals given in the "Journal of the Iron and Steel Institute", 1896, Volume 1, page 349.

L. Compridon * mixes the powdered sample of coal with a sufficient weight of an inert body, such as sand, and it will not produce in coking anymore a coherent mass. In practice, he uses 1 grain of coal, powdered.

To pass through a piece of 400 meshes to the square centimeter (about 2600 meshes per sq. inch, or a little finer than number 50), and mixes it with sand which passes through a 14-mesh screen but remains on a 70-mesh. The mixture is poked in a porcelain crucible at a red heat, and after a few trials the maximum weight of sand that the coal can bear is readily determined. The binding power for the best coking coal reaches seven-
Laboratory of the Vignac Works

Below are given a few results by Campredon on
sulfur sands dried at 100°C

<table>
<thead>
<tr>
<th>No.</th>
<th>Volatile Matter</th>
<th>Ash</th>
<th>Fixed Carbon</th>
<th>Result of Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.90</td>
<td>6.70</td>
<td>82.90</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>34.35</td>
<td>10.80</td>
<td>54.93</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>34.70</td>
<td>8.35</td>
<td>56.93</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>19.80</td>
<td>7.70</td>
<td>72.50</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>27.20</td>
<td>8.70</td>
<td>64.10</td>
<td>13</td>
</tr>
<tr>
<td>5b</td>
<td>No 5 oxidized by heating at 100°C during one year. 28.17</td>
<td>63.53</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>37.83</td>
<td>8.75</td>
<td>63.42</td>
<td>14</td>
</tr>
<tr>
<td>7</td>
<td>29.50</td>
<td>8.50</td>
<td>62.00</td>
<td>17</td>
</tr>
<tr>
<td>8</td>
<td>44.82</td>
<td>8.60</td>
<td>34.58</td>
<td>20</td>
</tr>
</tbody>
</table>
Campden recommends to cred
the coal through a number
50 or 60 mesh pieces.

We tried both sizes, but
found the No. 40 sufficiently
fine. He further advised the
use of porcelain crucibles
for fusing, but we obtained
better results with one of
platinum.

In heating, the crucibles
were placed 6 centimeters
above the mouth of the Burn-
ner burner; in some tests
they were placed at first
3 centimeters above the burner, and afterwards tested
with a flat lump lamp,
but no better results were
obtained.

A uniform time of five
minutes, was allowed for the heating of each sample. We used different sizes of our coal, but always one grain, taking different proportions of coal and sand, from 1 grain of coal and 0.1 grains of sand to 1 grain of coal and 5 grains of sand. The cakes of coke were good and strong up to the proportion of 7.5 grains of sand to 1 grain of coal, afterwards they became weak, but were still good when a proportion of 1 grain of coal to 1.5 grains of sand was used. With 2 grains of sand and 1 of coal, a readily crumbling cake of coke was
The Table on page 36 gives the results obtained in our work.

We can say that the binding power of our coal is 1 1/2, if we, according to Compton, take as unit of binding power, the proportion of one part of coal to one part of sand.

As can be seen referring back to page 39, our coal resembles that of New Castle in composition, as well as in binding power.
VIII. Washing Tests.

Although the coal in lump form was very clean showing scarcely any slate and only occasionally a grain of pyrite, the high percentage of ash found by chemical analysis suggested that probably a portion of it could be successfully washed out in a concentrating machine.

A set of preliminary washing tests was made in the Spitzlutte.

8.7 kilos. of coal were crushed through a 10-mesh sieve (square holes of 2.5 mm linear measurement) and received on a 12-mesh sieve (square holes of 1.9 mm linear measurement) to insure a uniform size. This product was treated in a Spitzlutte having a sorting column of 2" diameter with three different rising currents: (a) a slow current of 50 m,m
a second; (b) a strong current of 69 mm a second, and (c) a medium current of 55 mm a second.

a) Slow Current

The dial of the clear water cock was set at 35°. The weight of the overflow water discharged in 1 minute is 6.5 kilos; as the true inside diameter of the pipe is 2.067 inches, or 52.505 mm; the sectional area is \( \left( \frac{\pi d^2}{4} \right) = 2165.5 \text{ sq mm} = 21.66 \text{ sq cm} \).

Therefore, for 1 kilo per min. we have

\[
\text{speed in cm per min} \times 21.66 = 1000
\]

or \[
\text{speed in cm per min} = \frac{1000}{21.66} = 46.17 \text{ cm}
\]

and

\[
\frac{461.7}{60} = 7.7 \text{ mm a second for 1 kilo of water per minute. For 6.5 kilos, we have}
\]

\[7.7 \times 6.5 = 50.05 \text{ mm a second}\]

We fed 250 gms of the 10-mesh coal. At the end of 20 minutes, as no more coal appeared at the overflow, the water was
shut off and the suspended particles which were too heavy to rise and too light to sink in this current, were allowed to fall into the spigot.

During the run we observed that only a very small amount of material was light enough to be carried up by such a small current, the rest sinking to the bottom in a heavy stream.

Both, the spigot and the overflow, were placed in small drying pans, dried on the steam table and weighed. We obtained 217 grams spigot coal and 33 grams overflow.

We determined the specific gravities and the percentages of ash, the result being shown in the following table.
<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>Wt. in Grams</th>
<th>% of the Wt. Fed.</th>
<th>Sp. Gr.</th>
<th>% of Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overflow</td>
<td>33</td>
<td>13.2</td>
<td>1.267</td>
<td>8.02</td>
</tr>
<tr>
<td>Spigot</td>
<td>217</td>
<td>86.8</td>
<td>1.268</td>
<td>8.83</td>
</tr>
</tbody>
</table>

The detailed description of the determinations of the specific gravities and percentages of ash of each product, will be omitted here, as they are given as a summary at the end of the chapter, in a table containing full details of the operations.

6) Strong current.

Test (a) having given a small overflow and a large spigot carrying apparently, much good coal which should have gone into the overflow, we made a second test using the same amount of coal (250 g).
with a stronger current.

The dial set at 41° gave a discharge of 9.0 kilos of water a minute which corresponds to a velocity of \((9.0 \times 7.7) = 69.3\) mm a second in the sorting column.

The time required to bring up the last particles of the overflow was 20 minutes, but we let the water run several minutes longer, to allow any doubtful grains to go one way or the other. We then, shut off the water and let the last grains again fall into the spigot.

With the 50 mm current, we had a large spigot and a small overflow; here, with the 69 mm current, the reverse took place. An exceedingly large overflow and a very small spigot was the result.

The subjoined table gives the figures
<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>WT. IN Grams</th>
<th>% OF THE WT. FED.</th>
<th>SP. GR.</th>
<th>% OF ASH.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overflow</td>
<td>24.5</td>
<td>97.2</td>
<td>1.287</td>
<td>8.29</td>
</tr>
<tr>
<td>Spigot</td>
<td>7</td>
<td>2.8</td>
<td>1.455</td>
<td>17.13</td>
</tr>
</tbody>
</table>

The spigot was poor coal; grains of slate and a few grains of pure pyrite could be seen. These two heavy, waste materials accounted for the high specific gravity and high percentage of ash obtained later.

The overflow was large, but its percentage of ash was only a trifle smaller than that of the unwashed coal, showing that in a strong current like this, a large percentage of the waste material is carried along with the overflow coal, and, therefore, unsatisfactory.
c) Medium Current.

The dial set at 38° gave 7.2 kilos of water or a current of \((7.2 \times 7.7 =)\) 55.44 mm per second.

These conditions gave a fairly good ratio between the spigot and overflow in regard to size and appearance of the products, the overflow coal being a little cleaner than the spigot coal.

The specific gravities and the percentages of ash in these products were, as would be expected, intermediary between those of similar products obtained with the 50 and the 69 mm currents. The weights of the 55 mm products were also between those formerly obtained with the high and low currents.

The following table gives the results of the run.
<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>WT. IN GRAMS</th>
<th>% OF THE WT. FED</th>
<th>SP. GR.</th>
<th>% OF ASH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overflow</td>
<td>200</td>
<td>80</td>
<td>1.268</td>
<td>5.10</td>
</tr>
<tr>
<td>Spigot</td>
<td>50</td>
<td>20</td>
<td>1.295</td>
<td>10.91</td>
</tr>
</tbody>
</table>

These three experiments showed that no practical means of washing can be applied to our coal. With the slow current (a), the spigot was so large that most of the coal would be lost by the washing; the spigot of the 69 mm. current (b) was so small that it reduced the percentage of ash in the overflow only a trifle to warrant the coal washing; with the medium current of 56 mm. (c) the spigot and the overflow coals were so nearly alike as to make the washing useless.

The following gives the details of the determinations of specific gravities, and percentages of ash of these products.
1) Specific gravity determinations.

The specific gravities were determined by weighing the coal in air, and the weighing it immersed in a small flask full of water, the flask full of water having previously been weighed. Then if

\[ W = \text{weight of the flask + water} \]
\[ W_1 = \text{weight of the flask + water + solid} \]
\[ S = \text{wt of the solid in air} \]

the weight of the water displaced is

\[ W + S - W_1 \]

and the specific gravity is

\[ \frac{S}{W + S - W_1} \]

Again, before weighing \( W_1 \), we placed the flask containing the solid under the bell of an air pump for 10 minutes to extract all air bubbles.

The subjoined table shows the results.
<table>
<thead>
<tr>
<th>Date</th>
<th>17.13</th>
<th>6.34</th>
<th>16.01</th>
<th>8.10</th>
<th>8.13</th>
<th>8.2</th>
<th>8.02</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.11</td>
<td>17.16</td>
<td>6.42</td>
<td>10.15</td>
<td>10.1</td>
<td>8.07</td>
<td>8.08</td>
<td>8.18</td>
</tr>
<tr>
<td>0.3</td>
<td>0.008</td>
<td>0.004</td>
<td>0.0432</td>
<td>1.140</td>
<td>0.0434</td>
<td>0.0434</td>
<td>0.0434</td>
</tr>
<tr>
<td>0.3276</td>
<td>0.4384</td>
<td>0.3852</td>
<td>0.5362</td>
<td>0.5362</td>
<td>0.3852</td>
<td>0.4384</td>
<td>0.3276</td>
</tr>
<tr>
<td>II</td>
<td>I</td>
<td>II</td>
<td>II</td>
<td>I</td>
<td>II</td>
<td>I</td>
<td>II</td>
</tr>
</tbody>
</table>

Product

Check: 0
IX

Coking in Retort Ovens.

Through the kindness of the "New England Gas and Coke Company" at Everett, Mass, and Mr. O. A. Greim, Superintendent and Mr. Kellisky, former of the oven, we were enabled to make some experiments in the old Hopkinson furnaces of the Company.

Through the kindness of Mr. W.B. Bogardus, Superintendent of the Slosson Process Company, Syracuse, N.Y., we were permitted to have similar experiments carried on, in the Smet...
Sulphur ores of the Company
Oven tests.

**Sampling**

The coal was first broken with a hammer to
the size of a foot, taking care to reduce the amount
of pieces to a minimum.

It was then passed through
the Blake jaw crushe,
the Gates gyratory crushe,
and the rolls until no
more coal remained on
an eight mesh piece. The
then mixed the coal thorou-
ghly, and quartered it down
twice. One half of the
coal was used for filling
the boxes going to Everett
and the other half, being
reserves for stone going to Syracuse.

**Boxes.** -

We used two kinds of boxes, some made of wrought iron, and some made of iron wire.

The wrought iron boxes were of number 20 (1/2") wrought iron and had holes punched into them from the outside, leaving two holes on the inside. The holes were punched every 1/4" with a punched of 1/6", giving small inside hole which prevented fine coal from falling out.

Each box had a tightly fitting lid, and diagram (a) and figure (b) show construction.
and general appearance

(a)

(b)
There were 13 flat iron boxes made in all; 6 were 10" cube, and the remaining 6 were 6" cube.

The weight of a large box was 3.6 kilos when empty, increasing to 14.5 kilos when filled with coal. Thus, making the charge of coal to be coked 10.9 kilos.

The small boxes weighed 2.4 kilos, and their weight when filled was 4.6 kilos, giving for the charge of coal 1.2 kilos.

Our idea, in having 12 boxes was to make it at Everett, of which four were to be put in furnace, making flat furnace
coke, that is furnaces run for 30 or 34 hours; the other four boxes were to be put in the hour furnaces, or furnaces making steam coke. It happened that at the Works, they were making only one kind of coke, a mean varying between blast furnace and steam coke. Seventy-five per cent of the coke made might be classified as blast furnace coke, but it was not kept separate from the rest, as there is not a ready market for the hard coke, while the demand for the mixture for Blast Furnace Revers, is
exceeding the present production.

The boxes were distributed in different ovens of two batteries of furnaces. The other kind of box, that was used later, was made of No. 15 wire woven to a 10-meck piece. The unfolded box had the shape of a cross, as shown in the figure, so that in folding, it would make a box of 6" cube with lid. Enough extra wire mesh was left all around so that the ends overlapped and allowed tying the corners with strong wire several times.
The inside of the box was covered with thin paper so that it might keep the coal from being sifted out, and thus prevent any loss in the weight of coal and subsequent reduction of the percentage of coke.

The furnaces.

The mill omit a detailed description of the furnaces at Everett and at Lynn, though a few words of comparison may not be out of place.

The furnaces used by the "New England Gas and Coke Company", belong to the old Hoffmann type, with vertical flues, com-
Furnaces having thick walls and regenerative chambers.

The Sermat Soloya ovens of the “Soloya Process Company” Syracuse, N.Y., have horizontal flat floors and thin walls. Both are by-product ovens, and their qualities of coke are about the same, though the works at Everett on account of the regenerative chambers heating the air have more purfusus gas than the ovens at Syracuse.

An Oth-Koffmann furnace has a capacity of 6 tons and is charged at 3 different places by a feeding machine of eight tons capacity, the coking lasting 50 hours. There is coming off
the first fifteen hours are kept separate from those coming off the last fifteen hours and go to the gas holders as illuminating gas; the gas coming off the last fifteen hours proves to heat the ovens.

The temperature of the ovens is in the vicinity of 1100°, and the furnaces are emptied and refilled every twenty to thirty four hours.

The proof in the Everett ovens on our first 8 iron boxes lasted about 39 hours, and they were put in six different furnaces. They persisted the
action of the heat very well. Although they were wrapped around with raw hay, we lost two of them as the covers came off and some of the gaseous lost in discharging the over.

Time of cooking

The Time of cooking varied from 27 to 39 hours in the sheet iron boxes. The poke of the two large boxes treated for 27 hours was the same in quality as that of the two large boxes treated for 39 hours; the poke in the smaller boxes was a little better than that of the large boxes.
boxes, in which the time of cooking was from 1 1/2 to 5 1/2 hours, was the heat.

D�ty two hours in an 8th Holfmann oven, would be more than sufficient to have driven off most of the volatile matter of the coal, as can be seen in the table on page 66.

The central portion of the cake was not, however, well fixed.

This proves that in order to obtain good coke, the coal a higher temperature than that most used at Everett must be employed.
Experiments made at Everett Mills.

<table>
<thead>
<tr>
<th>TIME OF COMING THROUGH</th>
<th>SHEET IRON BOXES</th>
<th>FIXED CARBON</th>
<th>VOLATILE MATTER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SIZE No.</td>
<td>GOOD COKE</td>
<td>MEDIUM COKE</td>
</tr>
<tr>
<td>27 to 29</td>
<td>10&quot; cube</td>
<td>4</td>
<td>89.47%</td>
</tr>
<tr>
<td>27 to 29</td>
<td>6&quot; cube</td>
<td>4</td>
<td>81.12%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TIME OF COMING THROUGH</th>
<th>SCREEN BOXES</th>
<th>FIXED CARBON</th>
<th>VOLATILE MATTER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SIZE No.</td>
<td>GOOD COKE</td>
<td>MEDIUM COKE</td>
</tr>
<tr>
<td>42</td>
<td>6&quot; cube</td>
<td>1</td>
<td>84.16%</td>
</tr>
<tr>
<td>52</td>
<td>6&quot; cube</td>
<td>1</td>
<td>84.70%</td>
</tr>
</tbody>
</table>
The Coke:

1) At Everett:

The coke in the sheet iron boxes varied from "good" for that being against the walls to "poor" for that in the center. This was due to the fact that the temperature of the oven did not penetrate well into the central part of the box, and that the heat there was not high enough to melt the coal and transform it into a strongly coherent mass. That the coke would poke was shown by the fact that the coke next to the walls of the box...
gave a good solid, well
sliced cake, diminishing
in its good quality as
we examined it toward
the center.

Our experiments gave us
almost negative results.
The trouble perhaps the
wrought
iron boxes contained too
much iron and kindness
in a certain extent, the
passage of the heat to
the center of the box
We also observed that
the smaller iron boxes had
a better kind of cake than
the large ones, due just
Jarvis the heat had pene-
trated more deeply.

The took the opostric-
mity offered to us through the kindness of the Company to have a furnace run for 32 hours for our special benefit, and we decided to intro-duce some more bo-"des of a small piece (6" cube) hoping to ob-tain better results by diminishing the quantity of iron as much as possible and by making the box smaller, so as to ensure a better passage of the heat.

The made some analyses of the resulting caked taking samples from the outside, the
middle and the central parts, calling them "good," "medium," and "bad" cakes. The table on page 66 can give us a fair resume of the results of cooking in Everett.
At Syracuse.

The results at Syracuse, in the Semet-Holley oven, gave less satisfactory results than in the Otto Hoffmann oven.

The following table shows us the analysis of the coke from the large and small boxes.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size</td>
<td></td>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4 hr 16&quot; inside 2</td>
<td>1100</td>
<td></td>
<td>Good</td>
<td>2.37</td>
<td>87.31</td>
<td>15.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medium</td>
<td>1.31</td>
<td>82.54</td>
<td>15.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bad</td>
<td>3.64</td>
<td>81.50</td>
<td>14.85</td>
</tr>
<tr>
<td>2.4 hr 6&quot; inside 2</td>
<td>1100</td>
<td></td>
<td>Good</td>
<td>2.09</td>
<td>82.84</td>
<td>15.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medium</td>
<td>1.86</td>
<td>83.46</td>
<td>14.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bad</td>
<td>2.78</td>
<td>80.76</td>
<td>16.30</td>
</tr>
</tbody>
</table>
**Analysis of coal**

in which the sample was placed to be cooled and also the analysis of coke

<table>
<thead>
<tr>
<th></th>
<th><em>Everett</em></th>
<th><em>Syracuse</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coal</td>
<td>Coke</td>
</tr>
<tr>
<td>H₂O</td>
<td>7.7</td>
<td>1.08</td>
</tr>
<tr>
<td>Vol. Matter</td>
<td>37.53</td>
<td>1.92</td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>57.34</td>
<td>85.94</td>
</tr>
<tr>
<td>Sulfur</td>
<td>1.33</td>
<td>1.86</td>
</tr>
<tr>
<td>Ash</td>
<td>5.13</td>
<td>9.20</td>
</tr>
</tbody>
</table>

* Analysis made by the Chemist of the New England Coke Co. East, Mass.
Conclusions.

The characteristics of the coke in the Semet Dhoog oven were quick coking, but the coke obtained with a lower heated oven as the Otto Hoffmann gave better results. So in order to obtain a more uniform coherent coke, one must have a slow coking process, that is, the coking operation taking a longer time (perhaps 60 hours) with a high finishing temperature.

In preparing the coal, it might be advantageous to have the coal crushed as fine as possible (say 1/16”), so as to have it lie closer together and thus facilitate the burning of...
the coke.

Though the coal is of an inferior coking quality, it may be possible to make good coke with it, by working in a large scale on an old Hauffmann, or rather an old oven.

It is probable that still better results can be obtained by mixing the coal with a small percentage of a more fusible coking coal, as that of Sabinas or Sampago's, or if possible, with crushed alumina coal.

In any case better final conclusions could be drawn if the coking of the mixture were done in a large scale and a whole oven used instead.
of a box, thus securing a more uniform and perfect heating of the coal.
Analysis of coal

Emmett Syracuse

Coal Coke Coal Coke

H. or
V. M.
F.
S.
Ash