NOTES ON THE USE OF LOW-GRADE FUEL IN EUROPE

BY

R. H. FERNALD
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NOTES ON THE USE OF LOW-GRADE FUEL IN EUROPE.

By R. H. Fernald.

INTRODUCTION.

In its investigations of fuels belonging to or intended for the United States, which form a part of the general work it is doing to increase efficiency in the utilization of the mineral resources of the country, the Bureau of Mines has given attention to the combustion of fuel in furnaces and gas producers and has tested a large number of samples of coal and lignite to determine their value for producing power.

Economic conditions and the realization of the value of scientific research have caused European countries to study their natural resources closely in order to determine how these resources can be utilized most efficiently.

The wide distribution of fuel resources in the United States, the abundant supply of high-grade fuel, the relative freedom from large areas of congested population, with their excessive industrial demands, and a careless indifference to efficient utilization, due in great measure to the abundance of our resources, have led us to neglect far too long the serious consideration of problems upon which hinge many of the possible activities of future generations. The unrestricted use of our better grade fuels and the ruthless waste and neglect of fuels that should be of real commercial value are phases of our national extravagance that are little short of appalling. The Bureau of Mines has repeatedly called attention to the rate at which the supplies of high-grade fuel are being depleted and the need of investigations to ascertain how waste in their mining and utilization can be lessened or prevented.

Through these investigations of the utilization of fuel, the bureau is endeavoring to aid in prolonging the life of the nation's supply of high-grade fuel by lessening present wastes and by bringing about a wider utilization of fuels now neglected. In one of its publications Davis a presents striking comparisons between the conservation and successful use of certain fuels in Europe and the complete indifference to the possibilities from similar fuels in the United States.

In order that the true significance of these important commercial problems might be more fully presented to those responsible for the production, transportation, and utilization of fuel in the United States, an attempt was made during the summer of 1914 to procure in Europe, through personal inspection, definite information relating to (a) the utilization of high-ash coals; (b) the use of wood refuse and other similar material; (c) the recovery from fuel of by-products—ammonium sulphate, tar, pitch, etc.; (d) the recent developments in the preparation and use of peat; (e) the results of low-temperature distillation of fuels; (f) the possibilities of the slagging type of gas producer; and (g) the use of powdered fuel.

INTERRUPTION OF INVESTIGATIONS BY EUROPEAN WAR.

The author spent the greater part of the early summer in the British Isles, Belgium, and Holland. The nature of the problems under consideration and the helpful information received from abroad, indicated that much desirable material was also to be expected from Germany, Norway, Sweden, Russia, Austria, Hungary, Italy, and France. Unfortunately, just as the work was well under way in Germany, the European war broke out. This not only absolutely shut off further researches, but also prevented the procuring of many valuable data and photographs previously promised, thus making impossible the satisfactory completion of the contemplated investigations.

The notes are therefore incomplete, but will serve, perhaps, to indicate the trend in Europe of some of the important fuel problems that are conspicuously before the United States, and should stimulate positive action here in this much-neglected industrial field.

THE UTILIZATION OF HIGH-ASH COALS IN NONBY-PRODUCT PRODUCER-GAS PLANTS.

One of the most serious difficulties encountered in the use of high-ash fuels is excessive clinkering. The interruptions from such clinkering and the failure of the plant to develop rated capacity for continued periods make the satisfactory use of such fuels questionable. The attempt to use these poorer grades of fuel is not new, but their commercial application on a scale large enough to make their use really worth while industrially and on a scale large enough to be a real factor in economic fuel utilization is a recent development.

REVOLVING ECCENTRIC-GRATE GAS PRODUCER.

The demand for a gas producer to handle all grades of fuel, especially those grades usually sent to the dump, has recently brought to the European market the revolving eccentric-grate producer. This producer appears in several forms, the superiority of each form being firmly established in the minds of its advocates.
The essential features of this producer are shown in Plate I and figures 1 and 2, which show three different types of the eccentric-grate application—the Kerpely, the Pintsch, and the Rehmann.

Among the most important advantages claimed for revolving-grate producers as compared with the fixed-grate type is constant and automatic ash removal instead of ash removal by hand. Dependent upon this primary advantage rest the following claims for the revolving grate: (1) Low labor cost for handling ashes; (2) more uniform and more complete combustion; (3) operation for months without interruption; (4) ability to handle much more fuel per square foot of fuel-bed area; (5) less space per 1,000 cubic
feet of gas produced or per horsepower of plant; (6) freedom from dust and the usual excessively hot and dirty conditions during removal of ashes; (7) production of a gas of closely uniform quality; (8) reduction in the cost of upkeep.

If, in addition to rotating the grate, the grate be placed slightly off center, a feature is introduced that is probably of far greater value in handling high-ash clinkering fuels than the mere rotation of the grate. The principle of the eccentric grate is clearly shown by Plate I and figures 1 and 2.

The degree of eccentricity may easily be varied to suit the grade of fuel handled. For fuels that give no trouble from clinkering, or from which the ash is fine, the eccentricity may be reduced to zero, but for fuels that give excessive clinkering troubles or from which the ash is coarse the eccentric grate is found of value as it tends to grind the ash in such a manner as to prevent the clogging of the system.

The construction of these eccentric grates varies in detail with each patent, as is illustrated by Plate II.

The speed at which the grate revolves is determined by the ash content of the fuel and the demand upon the producer. The usual
CROSS SECTION SHOWING ESSENTIAL FEATURES OF REVOLVING ECCENTRIC-GRATE GAS PRODUCER.
A. PINTSCH REVOLVING ECCENTRIC GRATE.

B. REHMANN REVOLVING ECCENTRIC GRATE.
rate is from one-eighth to \(1\frac{1}{4}\) revolutions per hour. The speed of the grate is so slow that little power is required to drive it. The figure given by the manufacturers is about a quarter of a horsepower for a producer of normal size. The usual practice, however, is to install motors of 1 to 2 horsepower for this purpose.

**USE OF WATER JACKET.**

Experience with European fuels has shown that even with the eccentric revolving grate and the usual producer-shell construction clinker troubles are not entirely eliminated when a low-grade fuel with low ash-fusing temperature is used. A further important feature—probably the most important single item—for overcoming clinkering and the tendency of the ash to fuse with the producer lining is water jacketing the part of the producer shell surrounding the hot zone. This construction is shown in figures 1, 2, and 3.

The extent of this jacketing varies from none for coals that give no trouble from clinker formation or tendency to fuse with the producer lining to a maximum for those fuels that give such clinkering and fusing difficulties.

In certain designs an additional variation is made in the height of the grate to correspond to the clinkering tendency of the fuels used. Such a variation is clearly shown by Plate II, \(B\), and Plate III.

Revolving grate producers are made of either the dry or wet bottom type. For extremely fine fuels, such as fine slack and coke breeze, requiring relatively high air pressure for successful gasification, the dry-bottom ash pit is regarded by some manufacturers as being the more desirable on account of the excessive depth of water required by the wet-bottom type.

**ADVANTAGES OF REVOLVING-GRATE PRODUCERS**

The revolving grate producers are reported to gasify two to three times as much fuel per square foot of fuel bed area per hour as can be gasified in corresponding updraft-pressure producers with fixed grates. In the operation of the plants gas leakage is small, as poking of the bed is reduced to a minimum. Work about the producers is thus rendered much more agreeable than is usual with updraft-pressure plants.

Claims of very low percentages of carbon in the ash are also made for this type of producer, the reported record for one installation being 5 per cent carbon, or 0.47 per cent of the fuel gasified.

The claims advanced regarding the steam requirements for clinker-coals used in producers with water jackets around the hot zone are to the effect that not more than one-quarter as much steam is
required as in the jacketless type with fixed grate. The figures given for comparison are 1 pound of steam per pound of fuel for the fixed-grate jacketless producer, and 0.25 pound for the revolving eccentric-grate jacketed producer. Results with United States coals in fixed-grate jacketless producers indicate that 1 pound of steam per pound of coal is rather high for plants of good size. Seven-tenths of a pound is nearer the figure, although there are undoubtedly many plants, indifferently operated, that are not below the 1-pound rate.

The regularity of operation is reported to give a gas of superior quality and of exceptional uniformity. These characteristics, however, depend much on the interest shown in the operation of the plant. Theoretically, one type of plant requires intelligent attention and the other is mechanically automatic, but commercially no plant will run with high efficiency if not given a reasonable amount of interest and attention. The psychological effect of automatic devices often leads to an attitude that results in neglect and a correspondingly low efficiency.

If the modern requirements outlined by the advocates of the revolving eccentric grate, jacketed type—namely, capacity of dealing with the maximum quantity of fuel; ability to consume even the worst class of combustible, gasifying it in an absolutely perfect manner; uninterrupted and uniform gasification of the coal; uniformity in composition and calorific value of the gas even though only one producer is used; satisfactory working of the producer without the attention of a skilled stoker—are fulfilled, then this type of producer should meet with immediate support in the United States, as the satisfactory use of our high-ash fuels is to-day one of the crying needs of this country.

During the past five or six years many installations of these producers have been made in Germany and other continental countries for gasifying low-grade fuels that have heretofore been neglected. Indifference to the use of high-ash clinkering fuels has been equally marked in England, but within the past few years a notable change in attitude toward this problem is evident, and several installations have been made for the express purpose of utilizing low-grade material.

COST OF REVOLVING-GRATE JACKETED PRODUCERS.

The cost of construction of these revolving-grate jacketed producers is necessarily high, and a direct comparison of their cost with the simpler stationary grate, jacketless type, is of course detrimental to the former. As no definite cost figures are available, the following extract from an article by Smeeton (the representative of a company manufacturing revolving eccentric grate producers) is given here:

---

REHMANN SHALLOW GRATE FOR FUELS SHOWING ONLY SLIGHT CAKING OR CLINKERING TENDENCIES.
The question now arises as to the cost of the modern revolving-grate producer plant, as compared with a fixed-grate installation. Usual practice in works in this country has been to lay down not less than five or six fixed-grate 10-foot producers for two furnaces of, say, 40 tons output each. If we assume gas is required for three 40-ton furnaces, then nine producers would be required. If Rehmann producers of 10 feet diameter were installed, three only would be required, with an additional one for stand-by. The first cost of the producers themselves would be considerably in favor of the former type, owing to the various auxiliaries, such as driving shaft and motor, blower motor, and pipes, required by the mechanical type. The total cost of the complete layout, however, is much in favor of the revolving type, as the cost of building structure, of coal bunkers, and foundations is less than half, and the ground space is economized, as well as the length of gas mains, etc.

The labor costs are also considerably reduced if the fuel tonnage output be taken on an equal basis. One man only is required at the top of each 10-foot producer of 1 ton per hour capacity, and one man below for each four or six producers, for attending to the lubricating of working parts, regulation of the ashes, and removal of same. These economies are very real ones, and should result in the first cost of the plant being paid off in about two years.

Representatives of companies handling eccentric revolving grate producers say that they handle 45 to 55 per cent ash with perfect ease, and are satisfied that such producers can meet the conditions required for American high-ash coals. They would like an opportunity to try our coals and feel confident that these producers can hold their own against any producer now on the United States market.

**TENDENCY TO USE ONLY HIGH-GRADE FUELS IN PRODUCERS.**

An engineer of London, however, who seems vitally interested in the greater economy desired in the use of our fuel resources, believes that for the present the commercial solution is not in the use of low-grade fuels, but in the more efficient use of the better grades. With the eccentric revolving grate producer he believes it quite possible to handle almost any fuel, but the commercial economy is so low with the poorer grades, as the capacity of the plant is so greatly reduced, that he believes it to be a serious financial loss to use anything but good fuel. He does, however, feel that tremendous savings can be made in the processes now in vogue, and is studying several devices that he believes will be of material aid in the solution of the problem. He intimated that the greatest development connected with the economic utilization of fuel is in the United States and that there is little new in this field in England. He believes that powdered fuel is perhaps the most promising solution of our fuel problems.

A large plant in connection with a colliery and iron works equipped with eccentric-grate producers was reported by the producer representative to be using high-ash "batts." On visiting the plant, however, the author found that the producers had not been operating upon "batts" for some time, although the general manager was seriously interested in the use of waste material and in the economies
that are essential to-day in a well-operated plant. He believes that sane and practical efficiency in a large manufacturing plant requires careful consideration of the power-plant economy and the reduction of the fuel cost to a minimum.

**USE OF COLLIERY-REFUSE HEAPS AS FUEL.**

The colliery-refuse heaps in that vicinity have been accumulating and standing unused for years. A few years ago he began using selected "batts" from these dumps; that is, the larger pieces of shale containing a good percentage of coal. He has now put in a crusher at the dump and is crushing the larger material and mixing in the fine, so that the whole dump is being reduced. This material is not used directly in the producers, but is sent first to the washers, and the washed coal is used; 115 tons of the unwashed material give 60 tons of numbers 1, 2, and 3 nuts and 40 tons of slack. This material was reported as containing about 25 per cent ash when used in the producers.

Samples taken at the time of the inspection of the plant and sent to the Washington office of the Bureau of Mines showed the following composition:

**Results of analysis of sample of raw fuel from refuse heap.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.99</td>
<td>18.37</td>
<td>22.52</td>
</tr>
<tr>
<td>2</td>
<td>3.93</td>
<td>19.05</td>
<td>23.35</td>
</tr>
<tr>
<td>3</td>
<td>19.75</td>
<td>24.21</td>
<td>56.04</td>
</tr>
</tbody>
</table>

*a The form of analysis is denoted as follows: 1 = sample as received; 2 = air dried; 3 = moisture free; 4 = moisture and ash free.

**Results of analysis of sample of producer-gas fuel from refuse heap after washing.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.86</td>
<td>28.75</td>
<td>40.79</td>
</tr>
<tr>
<td>2</td>
<td>3.25</td>
<td>29.55</td>
<td>41.92</td>
</tr>
<tr>
<td>3</td>
<td>30.54</td>
<td>43.33</td>
<td>26.13</td>
</tr>
<tr>
<td>4</td>
<td>41.34</td>
<td>55.69</td>
<td>1.62</td>
</tr>
</tbody>
</table>

*a The form of analysis is denoted as follows: 1 = sample as received; 2 = air dried; 3 = moisture free; 4 = moisture and ash free.

NOTE.—Fusing temperature: Lowest fusion point in 50 per cent hydrogen and 50 per cent water vapor, 1,420° C. (2,588° F.).
Utilization of High-Ash Coals.

The manager of the company owning the plant expressed himself as well pleased with these producers. He believes that the company's success in handling this 25 per cent ash fuel continuously is due largely to the water jacket. He stated that the ash from the producers runs about 4 per cent combustible.

Use of Coke Breeze as Fuel.

Additional evidence of the present interest in England in the utilization of refuse material is seen in the use of coke ballast (breeze) in producers for firing brick kilns. The manager of one important plant of this type has made a marked success with this fuel in non-by-product producers with stationary grates. This material was always regarded as refuse until used in gas producers. The manager stated that since 1910 until within the past four months his company has used nothing but coke ballast. Recently considerable coal has been mixed with the ballast, as there has been a demand for a special brick product requiring an especially high-grade gas. This coke ballast is not a low-grade fuel in the sense of being high in ash, as the plant records show the ash to run about 10 per cent. It is regarded as low grade simply because there is no market for it, as it contains such a large percentage of "fines." The plant records as to the sizes of coke used were roughly as follows:

<table>
<thead>
<tr>
<th>Through (\frac{1}{2})-inch mesh</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between (\frac{1}{2}) inch and (\frac{3}{4}) inch</td>
<td>19</td>
</tr>
<tr>
<td>Between (\frac{3}{4}) inch and (\frac{1}{2}) inch</td>
<td>14</td>
</tr>
<tr>
<td>Less than (\frac{1}{2}) inch</td>
<td>27</td>
</tr>
</tbody>
</table>

100

The following analysis by the Bureau of Mines of a sample of coke ballast taken from a lot reported to be identical with that used in the regular operation of the producers shows it to be a fuel of excellent quality, although ordinarily forced to the refuse heap because of its small size:

Results of analysis of sample of coke ballast.a

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>10.77</td>
<td>4.92</td>
<td>72.26</td>
</tr>
<tr>
<td>2.</td>
<td>.73</td>
<td>5.47</td>
<td>80.40</td>
</tr>
<tr>
<td>3.</td>
<td>5.51</td>
<td>80.99</td>
<td>13.50</td>
</tr>
<tr>
<td>4.</td>
<td>6.37</td>
<td>93.63</td>
<td>13.50</td>
</tr>
</tbody>
</table>

a Noncooking.

b The form of analysis is denoted as follows: 1 = sample as received; 2 = air dried; 3 = moisture free 4 = moisture and ash free.

Note.—Fusing temperature: Lowest fusing point in 50 per cent hydrogen and 50 per cent water vapor, 1414° C. (2577° F.).
USE OF LOW-GRADE FUEL IN EUROPE.

USE OF WOOD REFUSE AND SIMILAR MATERIAL.

Within the past five or six years marked progress has been made in Europe in the utilization of various kinds of refuse material not ordinarily given much consideration in the usual discussions of problems pertaining to fuel conservation. Manufacturers of gas producers report the successful use of a large variety of fuels including wood shavings, wood blocks, sawdust, excelsior, coffee husks, rice husks, coconut shells and straw, and spent tan bark.

RESULTS WITH VARIOUS FUELS.

One company regards rice husks as an ideal fuel.

The figures on fuel consumption reported by the manufacturers run as follows:

With reasonably dry wood (say mixed oak, ash, and elm) the consumption has been as low as 2 pounds per brake horsepower-hour. With sawdust, the consumption averaged 3½ pounds per brake horsepower-hour, and with spent tan bark containing 50 per cent moisture, 4½ pounds.

One company reports the following results of full-load tests:

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Quantity per horse-power-hour (Pounds)</th>
<th>Fuel</th>
<th>Quantity per horse-power-hour (Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmon gum</td>
<td>2.3</td>
<td>Collie coal</td>
<td>1.2</td>
</tr>
<tr>
<td>Mulga scrub</td>
<td>2.2</td>
<td>Brown coal (46 per cent moisture)</td>
<td>1.8</td>
</tr>
<tr>
<td>Box blocks</td>
<td>2.15</td>
<td>Spent tan bark</td>
<td>3.13</td>
</tr>
<tr>
<td>Jarrah sawdust and shavings</td>
<td>2.40</td>
<td>Pine shavings and blocks</td>
<td>2.31</td>
</tr>
<tr>
<td>Bituminous coal</td>
<td>.92</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CHARACTER OF PLANTS.

Plants for such fuels are made in sizes ranging from 25 to 500 horsepower. Figure 3 shows the section of a down-draft suction gas producer designed for a range of fuels from bituminous coal to spent tan bark. Because of the down-draft principle no mechanical tar extractor is used. This point is particularly featured in the printed material supplied by this company. At the works several producers were seen that were reported to operate successfully with wood refuse, shavings, etc., but unfortunately at the time of the inspection the only producers in use were using anthracite. The company had, however, only recently taken over this business for English territory.

As distinct from the type shown in figure 3 a section and the plan of another wood-refuse gas producer of the up-draft type using a mechanical tar extractor are presented in Plate IV.
SECTION AND PLAN OF WOOD-REFUSE GAS PRODUCER OF UP-DRAFT TYPE USING A MECHANICAL TAR EXTRACTOR.
The customary claims regarding uniform gas quality, freedom from dust and tar, simplicity of operation, and continuity of service are put forward by each of the several companies handling these plants and the published testimonials from users indicate the usual general satisfaction.

**UTILIZATION OF WOOD REFUSE IN UNITED STATES.**

In view of the manifest interest in the United States in the utilization of wood refuse a somewhat detailed report of a few typical installations examined during the summer of 1914 may not be amiss. The author first visited a small suction up-draft plant of 30 or 40 horsepower working with perfect ease on wood refuse, chippings and sawdust.

The fuel is delivered directly to the operating floor from the cyclones, and consists largely of maple chips and sawdust from the planers, jointers, and saws. No vapor is used for this material in the gas making. This is a normal up-draft plant and produces some tar, which is passed through a centrifugal tar extractor. By the arrangement of water seals the suction of the plant is reduced to a minimum, which the designer believes imperative for the prevention of dust clogging. The tar is of a brownish color and is used in this plant for painting the ends of sawed timber for regulating its drying. The mill company seems well pleased with the plant.

Another make of suction up-draft producer examined was a plant of 220 horsepower rated capacity. In this producer wood chippings, shavings, and sawdust from the planers and saw are used. The
plant furnishes the power for woodworking factories. The principal woods used are maple, pine, spruce, and pitch pine. At the time of the inspection the plant was running smoothly. The tar was removed by a centrifugal extractor and was fairly heavy and black. The operator says the tar output, including probably 10 per cent water, amounts to about 60 gallons per 10 hours with the plant developing 180 horsepower on 3½ pounds of wood refuse per horsepower-hour. No vapor was being used. Once in awhile, if the refuse is particularly dry and the fire channels, water is thrown into the ash pit.

There is a distinct feeling that the proper depth of the fuel bed is the key to the successful running of these plants, as the depth varies with the load demand. There seems to be no clinker trouble save when dirt is shoveled up with the shavings or when bark is used, as considerable sand is often present in the bark.

The next plant inspected was an excellent installation of 350 horsepower using bark, chippings, sawdust, match splints, and veneer. The wood is mostly Russian pine. It comes in large logs from which the bark is stripped and the outside film removed in lathes. This bark and outside material makes splendid fuel. The mixture is put into a hay cutter and reduced to small strips and pieces before firing. It is fairly wet and the plant seemingly had required no water for a long time. This particular type of producer has an open grate upon which water may be trickled when needed, but seemingly this is seldom if ever done in this plant, as the catch-water basins were full of dust and completely clogged. This plant is in splendid surroundings and every care is taken of the equipment. At the time of the author’s visit a repeat order for 400 horsepower additional was going through and the foundations were already in. This company has available about 11 tons of material per week. The present producer is using about 6 tons. Three barrels of tar is recovered per week. This is sold for about 50 cents per barrel. The plant has been erected three to four years. It is reported that the first wood plant was put out about six years ago in Ireland. Similar plants in Africa are said to be running on nut shells, and the manufacturers regard corn cobs, husks, and bagass as ideal fuels.

The next installation visited was a 30-horsepower plant using by volume one-half shavings and sawdust and one-half wood blocks up to 6 by 6 by 6 inches. This is the refuse from furniture stock, mostly birch. The quantity of tar is small. No care is taken of the plant, but, in spite of this fact, it runs the factory, and the owner, a shrewd American type, is keeping it because it is much cheaper than any other power.

**VIEWS AS TO SUCCESS OF WOOD-REFUSE PLANTS.**

The representative of one of the large gas-engine companies says that the waste-wood plants of nearly all makes are giving excellent results.
Somewhat opposed to this statement is the view of the representative of another producer company, who states that the success of plants operating on wood and other similar material is problematical. One succeeds and the next fails. One on tan bark works perfectly and the next will do nothing. Success depends, he believes, on the condition of the fuel. Each plant has to be built for its special material. He claims that no company can make a plant for such fuels and be sure it will work unless it has been built for the conditions to be met in the particular installation in question. He says that there is more or less fake about the method of working these plants to prevent pulling over fine dust and clogging up the entire system. For example, a plant may have a 7-inch gas main leading to the engine, but near the engine the pipe will have inside a baffle with a 1-inch hole for wire-drawing the gas and for catching the dust.

The large pipe acts as a reservoir. This arrangement he says will work for single-cylinder engines, but for multicylinder engines it will not, as the pull on the gas main becomes too constant.

The success of these wood-refuse producers is peculiarly interesting in the view of the limited success of wood-refuse producers in the United States.

DESCRIPTION OF SUCCESSFUL WOOD-REFUSE PLANT.

Although there seems to be considerable demand for such producers, and inquiries regarding them are frequent, yet in 1913 only one plant operating successfully on wood refuse could be found in this country. Others were reported to be operating in Mexico, but no authentic information was available. The one successful plant referred to is that of the Southern Cotton Oil Co. at Gretna, La. This was inspected in December, 1913, and the following statements by Snypp \(^a\) clearly present the operating conditions at the plant:

Our producer plant was installed for the purpose of burning Pittsburgh bituminous coal, guaranteed to furnish gas of about 125 B. t. u. to the engines. As a matter of fact, we operated the plant continuously for about four years on various kinds of coal.

The producer we used was a pressure type Wood producer. The capacity of the producer plant was 840 horsepower, consisting of a combination of three units, each having a producer shell 8 feet in diameter by 12 feet high with steam-jacketed top, one wet scrubber 5 feet by 18 feet high, one dry scrubber 8 feet in diameter by 3 feet high, one pressure fan, one gas holder, and one motor-driven mechanical tar extractor.

The refuse that we use is known as "cypress hog." It consists of about 50 per cent of sawdust and 50 per cent of chips, such as are discharged from the "hog," which is a machine used by sawmills to destroy their refuse. This material runs from 30 to 55 per cent moisture, and this moisture seems to be necessary for best working conditions.


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I will state that we have to guard against the sawdust blowing over into the pipes which conduct the gases to the wet scrubber. This is probably a local trouble, due no doubt to the strength of the blast that we use in order to get capacity. We have been able to realize full capacity using sawmill refuse, and our engines deliver a brake horsepower on about 4½ pounds of this fuel.

The changes necessary to fire sawmill refuse are merely the removing of the coal-dump hoppers and substituting a hollow cylinder about 10 feet high, slightly tapered and made larger at the bottom and fitted with a slide gate at both top and bottom; these slides are worked with levers and the sawmill refuse is locked into the producers through these tubes.

To start firing a producer with sawmill refuse it is not necessary to have an underlying bed of cinders or ash to cover the blast pipe. The fuel can be dumped in on the water seal and fire can be started either on top or through the side poke holes. Aside from these conditions, the beds seem to be subject to all conditions prevalent in the firing of coal. A clinker is formed of a brittle nature and can be easily removed with the fine ash. The percentage of ash is so small that a producer can be operated about three weeks before removing the ash.

Cavities and chimney's will burn in the bed, and eternal vigilance and poking are necessary to produce a uniform quality of gas. In order to lessen the labor of poking, it is good practice to feed occasionally, say once a day or when the quality of the gas fluctuates, one or two charges of blocks ranging in size from stove lengths to 15 inches in diameter. These blocks will find their way into the cavities and stop the chimneys, and the producer will respond instantly. I have had cavities form low down in the beds and cause trouble, but we have always succeeded in poking down overlying fuel and closing the cavity.

We also experimented with "pine hog," and we find that it is more efficient fuel for producer gas than "cypress hog." An average of 10 analyses made on gas produced from "pine hog" showed 161.4 effective B. t. u. against 130 to 135 for cypress. The reason for this is probably due to the greater heat value of pine itself as compared with cypress. The analyses of heating value of these two fuels showed that the cypress was 5,540 B. t. u., while pine was 7,605 B. t. u. These are on fuel as received and therefore include moisture. The only reason that we do not use pine is that cypress is more available as far as our plant is concerned, which means that it is cheaper, comparatively speaking, although pine is, pound for pound, a much richer fuel.

I have added below a number of analyses of gas produced from various kinds of fuel that it has been my lot to experiment with in solving our problem.

**Analyses of gas from gas producer using different kinds of fuel.**

<table>
<thead>
<tr>
<th>Kind of fuel.</th>
<th>Number of analyses</th>
<th>Effective B. t. u.</th>
<th>COB.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pittsburgh bituminous.</td>
<td>15</td>
<td>125.3</td>
<td>9.6</td>
</tr>
<tr>
<td>Do.</td>
<td>6</td>
<td>119.9</td>
<td>9.6</td>
</tr>
<tr>
<td>Do.</td>
<td>8</td>
<td>122.5</td>
<td>9.7</td>
</tr>
<tr>
<td>Alabama and Pittsburgh bituminous.</td>
<td>3</td>
<td>112.7</td>
<td>11.3</td>
</tr>
<tr>
<td>Alabama bituminous.</td>
<td>9</td>
<td>140.9</td>
<td>9.3</td>
</tr>
<tr>
<td>Do.</td>
<td>12</td>
<td>112.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Alabama bituminous (Rock Castle).</td>
<td>15</td>
<td>134.4</td>
<td>11.4</td>
</tr>
<tr>
<td>Pecanflax coke.</td>
<td>10</td>
<td>13.1</td>
<td></td>
</tr>
<tr>
<td>Do.</td>
<td>8</td>
<td>57.8</td>
<td>7.2</td>
</tr>
<tr>
<td>Nut coal.</td>
<td>3</td>
<td>103.4</td>
<td>10.5</td>
</tr>
<tr>
<td>Coke breeze.</td>
<td>4</td>
<td>110.5</td>
<td>10.1</td>
</tr>
<tr>
<td>Do.</td>
<td>4</td>
<td>113.8</td>
<td></td>
</tr>
<tr>
<td>Anthracite coal.</td>
<td>11</td>
<td>110.2</td>
<td>12.4</td>
</tr>
<tr>
<td>Do.</td>
<td>4</td>
<td>111.3</td>
<td>12.2</td>
</tr>
<tr>
<td>Cypress hog.</td>
<td>12</td>
<td>134.2</td>
<td>10.3</td>
</tr>
<tr>
<td>Cypress hog and petroleum.</td>
<td>7</td>
<td>133.2</td>
<td></td>
</tr>
<tr>
<td>Do.</td>
<td>5</td>
<td>135.0</td>
<td></td>
</tr>
<tr>
<td>Pine hog.</td>
<td>11</td>
<td>161.4</td>
<td>9.9</td>
</tr>
</tbody>
</table>
USE OF WOOD REFUSE AND SIMILAR MATERIAL.

To summarize, the advantages to be derived from burning sawmill refuse where it is available are as follows:

(1) Little ash; therefore little cleaning to be done.
(2) High-grade gas; that is, gas of higher heat value as compared with other fuels in our type producer.
(3) A lesser quantity of tar and much more limpid in character.
(4) Gas of constant quality with less labor.
(5) No deadly gases to overcome the workmen.
(6) Finally, the all-important factor of lower cost per horsepower-hour must not be forgotten.

Relative costs of fuels used.

Cost of cypress waste fuel (basis 44 pounds per horsepower-hour at 50 cents per ton) per horsepower-hour..........................cents... 0.1125
Cost of firing 44 pounds...............................................do.... 0.1125

Total cost per horsepower-hour for cypress waste..........................do.... 0.2250
Cost of Pittsburgh bituminous coal (basis 1.5 pounds per horsepower-hour at $4.10 per ton) per horsepower-hour..........................cents... 3.075
Cost of firing 1.5 pounds of Pittsburgh bituminous coal......................do.... 0.0750

Total cost per horsepower-hour for Pittsburgh bituminous coal...do.... 3.825
Cost of Alabama bituminous coal (basis 1.5 pounds per horsepower-hour at $2.75 per ton) per horsepower-hour..........................cents... 2.062
Cost of firing 1.5 pounds of Alabama bituminous coal......................do.... 0.0750

Total cost per horsepower-hour for Alabama bituminous coal...do.... 2.812

USE OF "MESQUITE."

A recent series of tests of Texas "mesquite" indicated exceptional possibilities with this material. Trump\(^a\) reports as follows:

The first Humphrey pump to be installed in the United States of a size comparable with those in operation at Chingford, England, will be used for irrigation work on the G. Bedell Moore estate near Del Rio, Tex. In design it differs from the English type in several important details, the requirements of American pumping-engine practice, as well as experience with the Humphrey pump abroad, having made it advisable to simplify the construction.

A 300 horsepower Akerlund down-draft producer will furnish gas for the pump and be capable of gasifying either soft coal or mesquite wood. The latter is obtainable by the necessary clearing of the land to be irrigated and will be used alone or in combination with semibituminous coal until the supply is exhausted, after which soft coal will be used entirely.

In a recent test of this producer with mesquite the following results were obtained:

- Gas generated per pound of wood, cubic feet.......................... 54.7
- Heat value of gas per cubic foot, British thermal units............. 114.5
- Wood per square foot of fire area, pounds............................. 20.8
- Wood per horsepower-hour, pounds................................. 1.76

BY-PRODUCT PLANTS.

As has been pointed out in the preceding pages, there has been a great increase in European interest in the use of low-grade fuels since the same field was reviewed six years ago. In many quarters,

in which little or no interest was apparent then, real enthusiasm is now seen.

In connection with by-product gas installations serious consideration has been given to the utilization of low-grade materials, and several installations have been made with the avowed purpose of using the refuse material at the collieries. It seems, however, that after a brief period of operation the possibilities of larger immediate financial returns overshadow interest in true economy and maximum utilization of fuel resources, with the result that in the majority of cases the poorer grades of fuel have been consigned to the dump and commercially marketable high-grade material has been used in these by-product plants even when erected at the mine.

It was a somewhat common experience to be told that such and such a plant was using only coals containing 30 or 40 per cent ash or more; that the plant was designed for the use of waste material; and that great economies were resulting; but the almost unfailing result of a visit to the plant was to find it actually operating on the highest grade material obtainable; that is, on the material giving the largest by-product return—sulphate of ammonia, pitch, etc.—although at the time the plant was installed the undoubted intention of the management was to use only refuse material and to sell all the high-grade fuel from the mines.

As a result few, if any, by-product plants of any size in England are using low-grade material at this time.

SIZE OF EUROPEAN PLANTS.

Attention is called to the fact that these by-products plants are in many cases of large proportions; they are not plants of only 2,000 or 3,000 horsepower, the majority range from 5,000 to 30,000 horsepower. One company alone reports the installation of by-product recovery producer-gas plants using 3,000 tons of fuel a day and aggregating approximately 300,000 horsepower. The capacity and purpose of a few of the larger installations are as follows:

*Capacity and purpose of large producer-gas plants.*

<table>
<thead>
<tr>
<th>Installation No.</th>
<th>Tons.</th>
<th>Fuel capacity per day</th>
<th>Purpose for which plant was installed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>320</td>
<td></td>
<td>Special plant for the recovery of by-products from waste fuels. Gas used for firing boilers and for power.</td>
</tr>
<tr>
<td>2.</td>
<td>270</td>
<td></td>
<td>Central distributing station.</td>
</tr>
<tr>
<td>3.</td>
<td>250</td>
<td></td>
<td>Power and chemical purposes, calcining ore, etc.</td>
</tr>
<tr>
<td>4.</td>
<td>130</td>
<td></td>
<td>Special plant for the recovery of by-products. Gas used for firing colliery boilers. Power, forge, and plate furnaces, fire-clay kilns, etc.</td>
</tr>
<tr>
<td>5.</td>
<td>133</td>
<td></td>
<td>Power and for firing caustic pots.</td>
</tr>
<tr>
<td>6.</td>
<td>123</td>
<td></td>
<td>Evaporating brine.</td>
</tr>
<tr>
<td>7.</td>
<td>120</td>
<td></td>
<td>Power and chemical furnaces.</td>
</tr>
<tr>
<td>8.</td>
<td>100</td>
<td></td>
<td>Firing chrome furnaces.</td>
</tr>
<tr>
<td>9.</td>
<td></td>
<td></td>
<td>Chemical furnaces.</td>
</tr>
<tr>
<td>10.</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
BY-PRODUCT PLANTS.

CHARACTER OF PLANTS.

The majority of these plants are used for power development and gas heating, and the by-products, such as sulphate of ammonia and tar, are secondary objects in the operation of the plant. On the other hand, there are several installations in which power is the secondary object, the plant being run primarily for the valuable by-product, sulphate of ammonia, which brings a commercial return of $50 to $60 a ton. When it is realized that from a good grade of bituminous coal containing about 1.3 per cent nitrogen, some 80 or 90 pounds of sulphate of ammonia can be recovered as a by-product from each ton of coal charged into the producer the temptation to use high-grade fuels is a natural one.

A few plants are operated for the by-products alone. In certain districts in which the manufacturing and industrial interests do not offer a market for the gas, the so-called "by-products" become the main products, and the true by-products—producer gas—goes to waste. This condition of affairs is peculiarly true in regions in which the local fuel runs high in nitrogen. It is reported that an extensive plant of this character is soon to be erected in Africa.

Peat seems to be peculiarly adapted to the requirements for the production of sulphate of ammonia, and several commercial by-product plants using this fuel are now in operation in Europe. Among these are two plants in Italy, using 140 tons and 90 tons of peat daily.

The possibilities of a large installation in connection with extensive peat deposits in the United States are now under consideration, considerable preliminary investigation having already been carried forward.

COMBINATION BY-PRODUCT COKE PLANT.

One of the most interesting of the plants visited last summer is a combination by-product coke plant, in which the coke-oven gas is the main product and the coke the by-product. The coke-oven gas is turned into the city mains for general use. In order to procure all this gas for sale to the city, a distinct central producer-gas plant has been installed, as this poorer grade gas, which is not available for general city uses, is entirely satisfactory for heating the coke ovens. The originator of this combined method says:

The great advantage of this system is the fact that coke breeze and low-grade fuel generally can be used in the producers without lowering the efficiency of the plant.

The producer plant consists of five units, each having a fuel capacity of 20 tons a day. The coke from the ovens, which is regarded as a by-product, finds a ready market for blast-furnace work, and it is estimated that the by-products from the producer-gas plant, sulphate of ammonia and pitch, practically pay the cost of operation of the
producer-gas installation. The coal used in the producers is double-screened nut and contains no dust. It is a fine-looking coal and is reported to be high in oils. The analysis of one sample showed 10 per cent moisture, 19 per cent ash, 1.6 per cent nitrogen, and 36 per cent volatile matter. The average analysis is reported to be in the neighborhood of 15 per cent ash, 1.3 per cent nitrogen, and 25 to 28 per cent volatile matter. From this coal the company obtains 19 gallons of water-free tar per ton of coal used in the producers.

The tar is removed by centrifugal tar extractors. It is converted into pitch on the premises and sold for road-construction work. This company is a firm believer in the utilization of low-grade fuels, but commercially this procedure is regarded as far from a financial success. The company feels that the size of the plant required for high-ash fuels is prohibitive, the wear and tear excessive, and the labor out of all proportion to the results, so that the net result is a financial loss instead of gain.

OTHER BY-PRODUCT PLANTS.

Another by-product plant that has been in operation for several years has recently undergone renovation and extension, so that the plant now consists of eight 20-ton producers and four 30-ton units. The secretary of the company has the same opinion as many others regarding the use of low-grade fuel, namely, that it ought to be used but that such use would practically mean commercial suicide. The coal used in this plant, at the present time, runs from 10 to 27 per cent ash, but this high percentage of refuse is not coal ash, but dirt shoveled up with the coal. The plant is really using a good grade of fuel.

At one of the large collieries in England is a splendid producer-gas installation consisting of 13 large producers, 11 or 11$\frac{1}{2}$ feet in diameter, with a complete up-to-date by-product recovery plant. The capacity of the producer plant is approximately 320 tons of coal per day, or roughly the equivalent of 30,000 to 35,000 horsepower. The plant was put up with the understanding that it was to use mine refuse containing 40 per cent ash, but it was soon found that it was not feasible to use this high-ash material, as the usual desire for quick financial returns proved too strong. Here is a plant set down at the colliery—an ideal position for making good on high-ash refuse—but the amount of ammonium sulphate produced from the low-grade material proved too small to be attractive. The usual procedure in such cases followed, and the plant is actually using a good grade of material in order to get larger financial return. The whole colliery is laid out on a large scale and the equipment is of very high grade. Samples of the fuel actually running to the producers at the time of inspection by the
author were forwarded to the Bureau of Mines. Reports of the analyses are as follows:

Results of analyses of two samples of coal used in by-product producer-gas plant.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Proximate</th>
<th>Ultimate</th>
<th>Calorific value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moisture</td>
<td>Volatile</td>
<td>Ash</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>6.63</td>
<td>24.46</td>
<td>55.67</td>
</tr>
<tr>
<td>2</td>
<td>6.65</td>
<td>25.00</td>
<td>58.05</td>
</tr>
<tr>
<td>3</td>
<td>7.60</td>
<td>26.20</td>
<td>59.62</td>
</tr>
<tr>
<td>4</td>
<td>8.00</td>
<td>28.53</td>
<td>69.47</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>6.56</td>
<td>25.77</td>
<td>55.40</td>
</tr>
<tr>
<td>2</td>
<td>6.65</td>
<td>26.46</td>
<td>56.90</td>
</tr>
<tr>
<td>3</td>
<td>6.74</td>
<td>28.74</td>
<td>68.29</td>
</tr>
</tbody>
</table>

a The form of analysis is denoted as follows: 1-sample as received; 2-air dried; 3-moisture free; 4-moisture and ash free.

b Fusing temperature: Lowest fusion point in 50 per cent hydrogen and 50 per cent water vapor, 1178° C. (2145° F.). Crucible coke dense—medium grade.
c Fusing temperature: Lowest fusion point in 50 per cent hydrogen and 50 per cent water vapor, 1161° C. (2122° F.). Crucible coke dense—low grade.

In this plant 70 to 80 pounds of ammonium sulphate is realized per ton of fuel fired. The tar from the plant is converted into pitch, 14.5 pounds of pitch being recovered per ton of coal gasified, and 8 tons of oil with every 123 tons of pitch. The tar return is small per ton of coal, but the pitch sells for approximately $10 per ton. This company also sells the wash water which contains about 3 per cent ammonia. The sulphate of ammonia, the principal by-product from the plant, runs about 25.3 per cent ammonia. This plant has been largely remodeled by the owners. Steel washers were originally installed with the plant but they failed, and lead washers have been substituted at a heavy expense.

**IMPORTANCE OF STEAM INTRODUCTION.**

One of the important factors in by-product gas plants is the introduction of the proper amount of steam. Even after the air has been superheated and advantage has been taken of all available means for reducing the steam demand, the usual by-product plant seems to require about a ton of steam per ton of fuel gasified, or a pound of water to a pound of coal. This heavy steam consumption becomes an item of considerable expense in this process of gas making.

One of the more recent companies to enter the by-product producer-gas field makes a special claim for the small amount of steam required by its plants, namely, 0.5 to 0.6 of a pound per pound of fuel. This
amount, the company states, is so far below that required in some plants as to give the company an exceptional hold on the market. It further states that it is able to guarantee both the steam consumption and the amount of ammonium sulphate. More sulphate may be had by increasing the steam consumption, but an excess demand for steam tends to make the proposition financially prohibitive. The company has had many calls from the collieries for tests of low-grade fuel; that is, high-ash material containing much dust. It recognizes fully the need of such plants. It has made many tests and reports little difficulty in handling these materials, as tests that it has conducted have proved successful with coals containing 23 to 52 per cent ash and running 25 to 30 per cent dust—that is, passing a $\frac{1}{4}$-inch screen—but it has no commercial plants installed for operation on fuels of this grade. The difficulty as the company sees it is, that to meet commercial needs with high-ash coals, excessively large plants are required. With high ash content and high percentages of dust the rate of gasification is so reduced as to necessitate a plant so large as to make both initial and operating costs excessive.

The several companies manufacturing by-product gas plants believe that there is a large field for such plants in the United States if the fuels used are carefully selected. They regard our coals as bad for this type of plant.

**USES OF TAR.**

Although in the United States there is little or no demand for producer-gas tar, in Europe the situation is different, as a market for tar seems to be readily found.

This difference is probably due, in part at least, to the much larger size of the European plants as well as to the difference in economic conditions. The disposition made of the tar from a few plants in England will indicate the return that may be expected from this commodity.

Plant A is getting 19 gallons of water-free tar per ton of coal used in the producers. The tar is converted into pitch and sold for road-construction work.

At plant B tar sells for $1.25 to $2.50 per ton according to demand. Sometimes, however, it can hardly be given away. On the whole the market is good.

The tar from plant C, using wood refuse, is of a brownish color and is used in this plant for painting the ends of sawed timber for regulating the drying.

In another wood-burning plant the tar is collected in a tub and allowed to stand a few hours until the water collects on top; then
the tar is drawn off from the bottom into oil barrels. The tar is sold to a distillery company for 50 cents a barrel, the distillery company furnishing the barrels and hauling the tar.

In another wood-burning plant about three barrels of tar is collected per week from 6 tons of bark, chippings, sawdust, match splints, and veneer. This tar also sells for 50 cents a barrel.

The owners of plant F find the tar from the by-product plant valuable, as their distillation plant soon converts it into pitch. The extensive proportions of the tar-reducing plant and the amount of money expended upon it indicate that the return from tar is exceedingly good.

From plant G the owners recover about 14.5 pounds of pitch per ton of coal, the tar being converted into pitch. About 8 tons of oil is obtained from 123 tons of pitch. This pitch sells for $10 per ton.

LOW-TEMPERATURE DISTILLATION.

One of the recent processes that is attracting considerable attention in England is that of low-temperature distillation of fuel. Two installations were inspected, but each was being run by the developing company, so that little disinterested information was available.

The principal purpose of this process is to obtain a clean, smokeless fuel for the great number of fireplaces in England and at the same time to recover from the original fuel large percentages of oils, "motor spirits," and ammonia.

The rather elaborate prospectus of one company contains this introduction:

The company has been formed for the purpose of producing oil and motor spirit by the distillation of cannel coal and oil shale within the British Isles. The importance of a supply of home-produced oil is becoming increasingly urgent, especially from the point of view of national defense. At present this country is dependent for most of its supplies of liquid fuel for admiralty, motor transport, and other uses on imports from distant foreign oil fields.

This company expects to use the coke residue for gas making in producers, particularly in by-product plants, as the company claims that the nitrogen content remains in the coke after the distillation process.

Attempts are being made to utilize low-grade fuels in one of these plants but with what success could not be ascertained. Cannel coal, shale, high-ash coals, peat, and even briquetted sewage sludge have been tried. The residue from this last material is stated to be an excellent fertilizer, selling at a good price for direct spreading on the soil.
USE OF LOW-GRADE FUEL IN EUROPE.

Samples of both the raw fuel and the residue coke from this plant were analyzed by the Bureau of Mines with the following results:

Results of analyses of two samples of fuel.

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a The form of analysis is denoted as follows: 1—sample as received; 2—air-dried; 3—moisture free; 4—moisture and ash free.

b Raw fuel used for low-temperature distillation.

c Coke resulting from low-temperature distillation of fuel represented by A.

CHARACTER OF PROCESS.

So little authentic information is available from disinterested sources relating to these processes that probably the clearest presentation that can be offered at this date is a part of a lecture delivered before an English gas association about a year ago:

Low-temperature distillation, per se, can not, in my opinion, even be completely successful if carried out under pressure, as with a temperature of only 900° to 1,000° F. the time of distillation would be too long, and the valuable oil constituent and the coke would be ruined. But, as we have proved, low temperature, plus a complete, or nearly complete, vacuum in the retorts, enables us to carbonize in three to four hours, and so save the light oils we are in search of, and at the same time produce a hard, dense, easily ignitable coke or fuel containing 5 to 10 per cent of volatile matter (probably methane) and over 80 per cent of carbon free from all tarry and condensable matter.

The fact that low-temperature distillation to be successful must be carried out under a vacuum seems to be borne out by the extraordinarily interesting experiments conducted by Prof. S. W. Parr and Mr. H. L. Ollin, of the University of Illinois, which go to prove that in low-temperature carbonization a good coke texture can be obtained, and the other products be more or less modified in their characteristics, by the exclusion of oxygen from the retort.

DETAILS OF THE PROCESS.

Refferring to the details of the process, the lecturer says:

An absolutely thin layer of coal, not exceeding 2½ to 3 inches, is necessary.

The coke drops out in two long slabs. No quenching is required, as the coke is black; and to this fact we owe the freedom from breeze.

a Marshall, F. D., Low-temperature carbonization in vacuo in its relation to the production of smokeless fuel, oils, and motor spirit; a university lecture to the Manchester and District Junior Gas Association: Jour. Gas Lighting, vol. 124, 1913, pp. 50-54.
LOW-TEMPERATURE DISTILLATION.

The density of the coke is due to the compression of the coal between the annular spaces—a density which would effectually prevent the quick evolution of the gases were it not for the extreme vacuum employed.

By the time the gases have passed the vacuum pump, everything condensable under atmospheric and impact conditions has been removed; but tailing onto the vacuum pump is a compressor, in which the entire gas is compressed under a pressure of 50 to 60 pounds on the square inch. By a mechanical arrangement the pressure is suddenly released, the result being that the gas parts with a vapor which, on speedily condensing, proves to be a spirit of high value. The yield from this portion of the plant is approximately 1 gallon of spirit (specific gravity 0.818) per ton of bituminous slack. We do not tap this off, and it runs into the reservoirs receiving the other spirits which we obtain subsequently. The compression and expansion is quite automatic, and the apparatus needs no special attention.

Passing from the compressing plant, the gas at this stage, of approximately 750 B. t. u., passes through a stripping plant, which reduces it to about 300 B. t. u. It has then just a trace of luminosity; but it is, on the other hand, a perfect gas for engine purposes, or for splitting up into hydrogen and carbon. The choice of the crude oil for stripping purposes is important. This we have determined, and a proper oil can be saturated up to 15 or 16 per cent without becoming "fatigued," and on distillation yields the absorbed spirits readily. These spirits must not be confused with benzols, as they are practically paraffins, or paraffinoids, and their homologues. These spirits, when mixed with those from the compressing plant, amount, on the average, to:

- Cannel.................................gallons per ton... 6.74
- Slack............................................do... 3.3
- Specific gravity________________________ 0.796 and 0.818
- Boiling point, ° C........................................... 170

After washing these spirits with alkalies to remove the acids, a motor cycle was run 200 miles on 2 gallons of the spirit.

The above figures represent the quantity of the spirits obtained (a) by compressing, and (b) by "stripping" the gas.

YIELD OF GAS, COKE, AND CONDENSATES.

We have now to deal with the other products, namely, the gas, coke, and condensates.

Gas.—The yield of gas per ton of coal is approximately 5,000 cubic feet from slack and 7,000 cubic feet from cannel, and is partially consumed under the retorts and for running the works plant after it has been stripped of its valuable products. The balance is disposed of according to circumstances.

Coke.—Over 150 different tests of samples of coals, slacks, and cannels have been made, extending over several years; and it is found that the process will deal with almost any range of coal or cannel, including peat; and an excellent smokeless fuel is produced. We have found that if a coal is too poor in bituminous matter, the simple mixing with a percentage of another more bituminous coal insures good results. We are assured as to the output, and we appear to have no difficulty in obtaining over 30s. per ton for the article.

Condensates.—Although the process was based originally on the production of a smokeless fuel, yet later results appear to prove that coal can be made to yield a most valuable condensate in the form of oils, which, when fractioned or split up, yield products of exceptional value, as set forth in the accompanying statements, which are simply typical of many others. These tar oils differ absolutely from ordinary gasworks tars. They contain no benzenoid hydrocarbons nor the volatile solids, naphthalene or anthracene, but yield, on ordinary fractionation, paraffins and paraffinoid
hydrocarbons and unsaturated derivatives. The average yield of water-free crude condensates is—

Cannel (poor) ........................................ gallons per ton 52 to 60
Cannel (good) ........................................... do 60 to 80
Slack ..................................................... do 20 to 25

The specific gravity is 1.060, or lower than that of gas tar.

RESULTS OF TEST RUNS.

The following results were obtained on test runs of 2 to 5 tons of coal, and were conducted under the supervision of Dr. Young and Dr. Dunstan, of the East Ham Technical College, and may be accepted as reliable:

CANNEL COAL NO. 1.

Tarless fuel, 14 hundredweight.
Surplus gas, stripped to 300 B. t. u., 5,000 cubic feet.
Sulphate of ammonia, 25.33 pounds.
Water-free oil, as per analysis A, 44 gallons.
Spirits recovered by compression and gas stripping, as per analysis B, 8.75 gallons.

ANALYSIS A.

Water-free oil (specific gravity 0.940), 44 gallons.

Water in oil (which has been deducted), 7 per cent.
Light oil, distilled at 170° C., 2.9 gallons.
Middle oil, 170° to 270° C., 7.9 gallons.
Oil distilling above 270° C. (crude lubricating oil), 11.9 gallons.
Tar acids (creosyl acid and homologues), 3 gallons.
Pitch, 191 pounds.

ANALYSIS B.

2.6 gallons oil recovered by compression and expansion, specific gravity, 0.858, 75 per cent of which distilled up to 200° C.—1.95 gallons. (The oil distilling between 85° and 150° C. had a specific gravity of 0.812.)
The stripping oil carried 7 per cent of light oil boiling below 150° C., with a specific gravity of 0.820—6.8 gallons.

CANNEL COAL NO. 2.

Tarless fuel, 14 hundredweight.
Surplus stripped gas, 5,000 cubic feet.
Sulphate of ammonia, 6.5 pounds.
Oil, as per analysis C, 53.5 gallons.
Spirit, as per analysis D, 4.93 gallons.

ANALYSIS C.

Water-free oil, specific gravity, 0.9165, 53.5 gallons.

Light oil, distilled at 170° C., 3.8 gallons.
Middle oil (specific gravity, 0.832), 170° to 270° C., 14 gallons.
Oil above 270° C. (specific gravity, 0.880), crude lubricating oil, 20 gallons.
Tar acids, 4 gallons.
Pitch, 150 pounds.

ANALYSIS D.

Compression and expansion oil (specific gravity, 0.796), 0.43 gallons.
Light oil, specific gravity, 0.796, from stripping oil, 4.5 gallons.
BITUMINOUS COAL.

Tarless fuel, 14 hundredweight.
Surplus stripped gas, 5,000 cubic feet.
Sulphate of ammonia, 23.8 pounds.
Oil, as per analysis E, 22 gallons.
Spirit, as per analysis F, 2.2 gallons.

Analysis E.

Water-free oil, specific gravity, 1.060 (water 9 to 9.5 per cent, which has been deducted), 22 gallons.

Light oil, distilled at 170°, 1.3 gallons.
Middle oil, 170° to 270° C., specific gravity, 0.970, containing 10 per cent of tar acids (cresylic and homologues), 5.7 gallons.
Oils above 270°. A large proportion can be obtained, though with some decomposition. If the distillation is stopped when 40 per cent of bituminous pitch is left there is obtained heavy oil, specific gravity, 1.04, flash point 125° C., 4 gallons.
Pitch (bituminous), 90 pounds.

Analysis F.

The light oils from the compression and expansion plant and from the stripping oil yielded:
Oil distilling up to 150° C., specific gravity, 0.818, 1.2 gallons.
Oil distilling 150° to 200° C., specific gravity, 0.845, 1 gallon.
The coal was found to contain 5.4 per cent and the tarless fuel 7.4 per cent ash.

MISCELLANEOUS FEATURES.

A few additional points from Dr. Young's report are worthy of emphasis.

He says—

The process is one of destructive distillation of coal at low temperature (900° to 1,000° F.) under a high vacuum (20 to 25 inches of mercury), and results in the formation of products very different to those obtained by the usual gas-works practice of distillation at high temperatures. While the general nature of those products is the same whatever coal may be used the amounts in which they are obtained vary with the class of coal, consisting generally of 70 per cent of coke or residue and about 50 gallons of oil from a cannel coal, or 24 gallons of oil per ton from a bituminous coal. With some cannel coals the yield of oil has run to over 80 gallons per ton of coal. In the case of the three coals, actual working details of which are appended, the first cannel gave a total of 52.7 gallons, the second cannel 58.4 gallons, and the bituminous coal 24.2 gallons of oil per ton of coal. The process results also in the formation of ammonium in generally good amounts but varying markedly with the coal employed; the three coals mentioned yielded ammonium equivalent to 25.33 pounds, 6.5 pounds, and 23.8 pounds of ammonia sulphate per ton of coal, respectively.

The coke, or residue, consists of a dense but porous fuel, which is not readily friable. It is easily ignited and can be burned in any ordinary open grate, when it forms a clear, hot fire, burning with a good flame, but not giving any smoke or soot. The fuel can also be used in the manufacture of suction gas, with the great advantage of yielding a gas entirely free from tarry matters.

In regard to their specific gravities, the "tarless fuels" oils lie between shale oil and gas-works tar, to the former of which they are much more closely related in their chemical nature, consisting, as they do, of paraffinoid compounds and unsaturated derivatives. The benzenoid hydrocarbons, including the volatile solids, such as
naphthalene and anthracene, which form such a large proportion of gas tar, are entirely absent. Hence the light oils on a fractionation yield solvent naphtha and a motor spirit which resembles petrol rather than benzol. The total light oils, obtained partly by fractionation of the condensates and partly by stripping the gas from the three coals mentioned, amounted to 11.6 gallons, and 3.5 gallons per ton of coal.

Marshall adds—

A gas generator or producer requires nothing but carbon, and the less it is contaminated with bituminous matter in the shape of volatile products the better. These add great expense for their removal far beyond their mercantile values, except the ammonia, which is recovered in gas generators in greater quantity than by any other known process. I would suggest, instead of charging generators with the crude coal direct from the collieries, first to treat it by a low-temperature plant, recovering the oils, gas, and what ammonia is produced by such a process, and then to feed the generators with the resultant clean and pure carbon coke.

Samples of the raw coal and the coke residue from the plant described by Marshall were also forwarded to the Bureau of Mines and analyzed; the results are as follows:

Results of analyses of two samples of fuel.

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<td>4</td>
<td>10.79</td>
<td>80.21</td>
<td>8.06</td>
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a The form of analysis is denoted as follows: 1 = sample as received; 2 = air dried; 3 = moisture free; 4 = moisture and ash free.
b Raw fuel used for low-temperature distillation.
c Coke resulting from low-temperature distillation of fuel represented by sample A.

This coke residue sells for domestic use at an average price of $7.50 per ton at the plant. The dealers give this smokeless fuel a fancy name and in some instances receive as much as $9 and $10 per ton. For this class of service a high-grade fuel is used to insure a high-grade coke, as the financial return is enough to warrant such use.

SUMMARY OF CERTAIN INVESTIGATIONS.

In connection with the above statements the following summary of the investigations of low-temperature distillation by Parr and Francis a is of especial interest:

The results thus far obtained are by no means complete, but they are of sufficient interest to warrant publication in this preliminary form. Aside from the gases evolved, the by-products have received but little attention.

In the residual liquors there seem to be no tarry compounds present but oils, phenols, ammonia, etc. Some quantitative results on the latter show as the highest result obtained from the wash liquors about 11 per cent of the total nitrogen present in the coal. In most instances the yield was less than 1 per cent. This matter is receiving further attention.

Concerning the coal residue, enough has already been developed to indicate that it would have a special value for domestic use and such industrial operations as require a smokeless fuel. While much of the volatile constituent remains, it has undergone a change which makes it not difficult to carry on combustion without the production of smoke. This fact is, perhaps, suggested by the rather close resemblance in composition to the so-called smokeless coals. Because of the very great ease with which this material may be broken down, it would require, in all probability, to be subjected to the briquetting process.

As a rule, finely pulverized coals in contact with oxygen, either diluted as in the case of air or in the pure state, begin oxidation at a temperature between 120° and 155°. In some instances, however, this temperature of oxidation is higher, though in none of the tests did it exceed 155°.

The ignition temperature varies with the type of coal and to a certain extent also with the fineness of division. Finely divided bituminous coals ignite in oxygen at a temperature not far from 160°. Buckwheat sizes ignite at about 260° to 300°. Semi-bituminous coals ignite at about 200° and anthracites at about 300°.

**SLAGGING GAS PRODUCER.**

By many the blast-furnace type of gas producer is regarded as presenting problems in upkeep that make the cost of the plant prohibitive. As one man puts it, "After a few hours' run the plant is out of commission for several days for relining."

Others with whom this subject was discussed see nothing in the blast-furnace type of plant. They feel that the varying character of the ash makes the fusing indefinite and unreliable; one day it fuses; the next day it does not; no practical success has been had from such plants.

**INSTALLATION IN DEUTSCH-LUXEMBURG.**

At a colliery in Deutsch-Luxemburg, however, is an interesting installation consisting of four slagging producers and two rotating grate producers. The slagging producers are approximately 10 feet in internal diameter, and at the time of the author's visit in 1914 gasified 60 tons of fuel each per 24-hour day. The first had been installed one and one-half years previously and had required much study and many changes. It was working splendidly at the time of this inspection and the slag was easily drawn. Its performance was excellent. The producer had required three linings for the lower third of the generator during the one and one-half years of operation, but for the upper two-thirds the original lining was still in use.
No water jacket was used, although at first the producer was heavily jacketed. This water jacket had been gradually eliminated until the only water used was for cooling the blast pipes, and they required only a small quantity. The producer linings had called for special study and, peculiarly, it had been demonstrated that the cheapest lining was the best. The lining used at the time of inspection was a cement brick that was about 50 per cent clay. The lower third of the second producer was being relined after six months' operation. Upon examination, however, the lining was found to be in excellent condition and could undoubtedly have run at least three months longer, but as additional preheaters were being installed it was deemed best to put in the new lining at this time. The upper part of the lining seemed to be in excellent shape. In contrast, the expensive high-grade silica lining of producer 3 had given out after one month's operation. The fourth producer, a new one, had been running only two or three days but was working splendidly. This producer was tapped during the inspection and the slag flowed remarkably well.

The following details are of interest:

Charge.—Thirty kilos of blast-furnace slag to 1 cubic meter of coke breeze.
Blast.—Preheated. Preheated blast has proved much more efficient than cold blast, so additional preheaters are being installed.
Slag.—The slag from the producers is used for brickmaking.
Iron.—Four hundred kilos of iron is recovered as a daily by-product from 60 tons of fuel.

This company has American patents and expects to begin commercial operations in the United States at an early date.

At present these producers are working on fuel containing 10 per cent ash, but as soon as commercial conditions will permit setting aside one of the producers for experimental work, the company desires to try fuel containing 20 to 30 per cent ash. The gas runs 31 to 33 per cent carbon monoxide and 1 to 2 per cent carbon dioxide.

German companies are reported to be using slagging producers, and two or three French types are understood to have reappeared on the market after an absence of several years, but the advent of the war has prevented further investigations in this important field. That this type of producer has a real commercial position is shown by the catalogue of one of the large producer manufacturers of Germany, which, among several other classifications, lists its producers as (1) producers with rotating grate; (2) slagging producers; (3) flat-grate producers; (4) step-grate producers.
USE OF POWDERED FUEL.

Several prominent engineers both in Europe and America seem to think that one of the most promising fields of fuel conservation lies in the use of powdered or pulverized fuel. The recent interest shown in this subject by such organizations as the American Institute of Mining Engineers and the American Society of Mechanical Engineers is indicative of its importance.

All opportunity of studying this subject on the Continent was cut short, so that the meager amount of information gathered relates only to conditions in the British Isles. There it seemed to be the opinion that America can show the most important developments in this field. Even if this be the case, sufficient interest attaches to the Bettington boiler to warrant a brief consideration of its application. Figure 4 shows a sectional elevation of this boiler.

The fuel passes from the coal bunker to the pulverizer. It is then picked up by the blower and carried into the furnace through the air and fuel pipe by a jet of preheated air. On its way to the furnace the fuel is passed through a separator, which removes particles of fuel that are not sufficiently pulverized to meet the successful operating requirements of the plant. The fuel is injected vertically upward, the blast pressure being regulated to prevent the impinging of the flame on the surface of the upper drums.

The vertical inner tubes are surrounded by brickwork with the exception of the lower ends, so that the gases of excessively high temperature and the impinging flame are practically confined in a brick-lined combustion chamber.

The molten ash and slag collect in the ash receiver below the boiler.

DIFFICULTIES IN APPLYING POWDERED FUEL.

A summary of the difficulties encountered in applying powdered fuel to steam-boiler practice is presented as follows in the catalogue published in the interest of this boiler:

Although the benefits to be derived from pulverized fuel are taken advantage of at places for burning cement in special kilns, no commercial success, in the past, has been established in its use for firing boilers; and this will be readily understood from the following statement of the difficulties involved in the form of apparatus hitherto employed:

1. The difficulty of maintaining continuous and steady ignition, a difficulty only met by maintaining a uniform and very high temperature in the furnace.

2. The failure to find an economical material to stand the destructive temperature necessary in the furnace as hitherto arranged for boiler firing.

3. The difficulty of producing a continuously homogeneous mixture with varying grades of coal, sometimes very wet, and high in ash.

4. The difficulty of maintaining a homogeneous mixture of fuel dust and air during the full period required for complete combustion; the tendency of the larger solid
particles being to concentrate in certain lines of direction, a difficulty met in part by extremely fine pulverization of the fuel.

5. Difficulty of handling the molten ash, which, from the required type of furnace and temperature, must usually form solid deposits of slag.
An examination of the installation at the works of the English agents of this boiler gave an excellent impression of the operation of the pulverizing equipment with its freedom from floating dust. Unfortunately, no examination of the effect of fusing of the ash could be made as the boiler was under test and access to its interior was out of the question. The company claimed that after years of experimental work with special fire bricks it has developed that the method of inclosing the water tubes of the boiler practically amounts to water-cooling the brick. It is, therefore, possible to dispense with special, expensive, high-grade brick for this purpose and to use common fire brick.

DETAILS OF ENGLISH PLANTS.

This installation consists of a boiler of slightly over 2,600 square feet of heating surface which has an evaporative capacity of 14,000 to 22,000 pounds of water per hour. The power required for pulverizing and feeding the fuel is stated to be about 3 per cent of the boiler capacity.

No definite information regarding depreciation and maintenance was available, but by some these items are regarded as excessive.

The manager of a steel plant in Wales reported that he was using two of these boilers. He had installed two “twenty thousands,” that is, two boilers rated to evaporate 20,000 pounds of water each per hour. He stated that he was using refuse coal containing 25 to 27 per cent ash—a mixture of colliery dust and coke dust. The boilers had been installed only about two weeks and had consequently not been thoroughly tried out. Tests of the boilers showed them to be working with an efficiency of 75 per cent, and the indications were that the boilers would prove entirely successful.
PUBLICATIONS ON THE UTILIZATION OF COAL.

A limited supply of the following publications of the Bureau of Mines is temporarily available for free distribution. Requests for all publications can not be granted, and applicants should limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines, Washington, D. C.


BULLETIN 14. Briquetting tests of lignite at Pittsburgh, Pa., 1908-9; with a chapter on sulphite-pitch binder, by C. L. Wright. 1911. 64 pp., 11 pls., 4 figs.


BULLETIN 54. Foundry cupola gases and temperatures, by A. W. Belden. 1913. 29 pp., 3 pls., 16 figs.

BULLETIN 55. The commercial trend of the producer-gas power plant in the United States, by R. H. Fernald. 1913. 93 pp., 1 pl., 4 figs.


BULLETIN 76. United States coals available for export trade, by Van H. Manning. 1914. 15 pp., 1 pl.

TECHNICAL PAPER 1. The sampling of coal in the mine, by J. A. Holmes. 1911. 18 pp., 1 fig.

TECHNICAL PAPER 2. The escape of gas from coal, by H. C. Porter and F. K. Ovitz. 1911. 14 pp., 1 fig.

TECHNICAL PAPER 8. Methods of analyzing coal and coke, by F. M. Stanton and A. C. Fieldner. 1913. 42 pp., 12 figs.


TECHNICAL PAPER 20. The slagging type of gas producer, with a brief report of preliminary tests, by C. D. Smith. 1912. 14 pp., 1 pl.

TECHNICAL PAPER 31. Apparatus for the exact analysis of flue gas, by G. A. Burrell and F. M. Seibert. 1913. 12 pp., 1 fig.

TECHNICAL PAPER 35. Weathering of the Pittsburgh coal bed at the experimental mine near Braceton, Pa., by H. C. Porter and A. C. Fieldner. 1914. 35 pp., 14 figs.

TECHNICAL PAPER 50. Metallurgical coke, by A. W. Belden. 1913. 48 pp., 1 pl., 23 figs.

TECHNICAL PAPER 55. The production and use of brown coal in the vicinity of Cologne, Germany, by G. A. Davis. 1913. 15 pp.


TECHNICAL PAPER 76. Notes on the sampling and analysis of coal, by A. C. Fieldner. 1914. 59 pp., 6 figs.


TECHNICAL PAPER 89. Coal-tar products and the possibility of their manufacture in the United States, by H. C. Porter, with a chapter on coal-tar products used in explosives, by C. G. Storm. 1915. 21 pp.
