

we can meet these conditions. We work on about 35-lb. samples of coal.

Just one other word in regard to the inquiry about whether the material is any good for metallurgical purposes. With Mr. Sperr in the room, I would hardly attempt to pass judgment on it in that particular. I asked a blast-furnace man not long ago to describe what a good blast-furnace coke was. He said, "After changing our minds so radically within the last few years, we are not absolutely sure as we once were." Some will say that it is entirely unsuited for blast furnace use. It does violence, I think, to nearly everything that would ordinarily be described by a blast-furnace man as being necessary. I do not know, however, but that if we could make enough at the rate of 35 lbs. per run to supply a blast furnace for a week, we could find out for a certainty.

I want to say in that connection that the initial incentive for all this work comes out of the great anthracite strike of 1902. We thought it would be desirable to make smokeless fuel for domestic purposes out of Illinois coal, and that has been the main idea all along. We do not know much about metallurgical coke, although I will say this, that so far as strength, and carrying the burden, and a lot of those physical conditions are concerned, it certainly looks very encouraging, but there are other conditions, like high ash, etc., which would enter into the problem.

### CARBONIZATION OF CANADIAN LIGNITE<sup>1</sup>

By Edgar Stansfield

LIGNITE UTILIZATION BOARD, OTTAWA, CANADA

The researches on lignite outlined in this paper were commenced early in 1917 by the chemical staff of the Fuel Testing Division of the Mines Branch, Department of Mines, Ottawa, and the work is still in progress. The primary object of the investigation was to obtain accurate data essential for the scientific design and control of a plant for the carbonization of lignite on a commercial scale, rather than to design such a plant.

In the summer of 1918 the Lignite Utilization Board of Canada was created by an Order-in-Council of the Dominion of Canada, supplemented by an agreement as to finances with the provincial governments of Manitoba and Saskatchewan. The Board was created to establish an industry for the conversion of the low-grade lignites of southern Saskatchewan, and elsewhere, into a high-grade domestic fuel by means of carbonization and briquetting. The laboratory investigations of the Lignite Board have been carried out at the Fuel Testing Station of the Mines Branch by members of the staff of the Board working in coöperation with the members of the Mines Branch Staff. This latter work has carried to a logical conclusion the earlier work of the Mines Branch. The points essential for the successful carbonization of lignite, under the economic conditions prevailing in southern Saskatchewan, were first decided upon, and then a carbonizer design was evolved which embodied these features. A semicommercial-scale carbonizer was erected in Ottawa, and, after many trials and modifications, successfully operated.

It is worthy of note that the experience and information gained in the operation of the carbonizer at Ottawa have been embodied by the engineer of the

board, Mr. R. De L. French, in the design of six carbonizers for a plant now being erected by the Board near Bienfait, Sask. This plant is expected to treat about 200 tons of raw lignite per day.

This paper attempts to trace in outline the progress of the investigation up to the operation of the carbonizer in Ottawa, and to show why this particular design of carbonizer was adopted. No full report of any stage of the work has yet been made, but the methods employed and results obtained in the earlier stages have been published in some detail.<sup>1</sup>

The work falls naturally into several stages, but these are not chronologically distinct. The investigation was commenced with lignite from the Shand Mine in the Souris, or Estevan area, Sask. Later other Souris lignites were studied. Now Alberta lignites, and also peat, are being tested in a similar manner.

Souris lignite when mined contains from 30 to 35 per cent of inherent moisture, and has a calorific value of about 4000 cal. per gram. It loses moisture rapidly when exposed, and the lumps then disintegrate. This lignite is employed in the raw state, but it is a low-grade fuel, unsatisfactory for transportation or storage. By drying and carbonizing it, a product is obtained which may have a calorific value as much as 75 per cent higher than that of the original coal.

### SMALL-SCALE LABORATORY TESTS

In these experiments samples of from 3 to 10 g. were employed. This allowed very exact control of the conditions of the experiment, and also allowed a large number of experiments to be carried out, under widely varying conditions, within a reasonable time. It was not possible, however, to study the by-products. The results were used to cut down unnecessary work in the larger tests, and were also valuable as checks on the accuracy of control in all subsequent experiments, and for the comparison of different lignites. The factors determined included the yield, analysis, and calorific value of the carbonized residue. The conditions under which the lignite was carbonized were varied in order to show the influence on the results of the final temperature to which the charge was heated, the rate of heating, the pressure in the retort, and the atmosphere in the retort.

COAL USED—The particular coal chosen for most of these experiments was from the Shand mine of the Saskatchewan Coal, Brick, and Power Co., Ltd. The sample, which consisted of a single lump of coal shipped by express from the mine in a wooden box, was crushed and ground to a fine powder in a ball mill. For convenience of manipulation, and as a preventative of the rapid change which a powdered coal undergoes owing to moisture loss and oxidation, this powder was briquetted in a small hand press. The briquets were cylindrical, 0.25 in. in diameter, about 0.25 in. long, and ran about 5 or 6 to the gram. They were stored in stoppered bottles until required, and from

<sup>1</sup> Published by permission of Dr. Eugene Haanel, Director, Mines Branch, Department of Mines, Ottawa, Canada.

<sup>1</sup> Stansfield and Gilmore, "The Carbonization of Lignite," *Trans. Roy. Soc. Can.*, [3] 11 (1917), 85; [3] 12 (1918), 121. See also Mines Branch Summary Reports for 1918 and 1919.

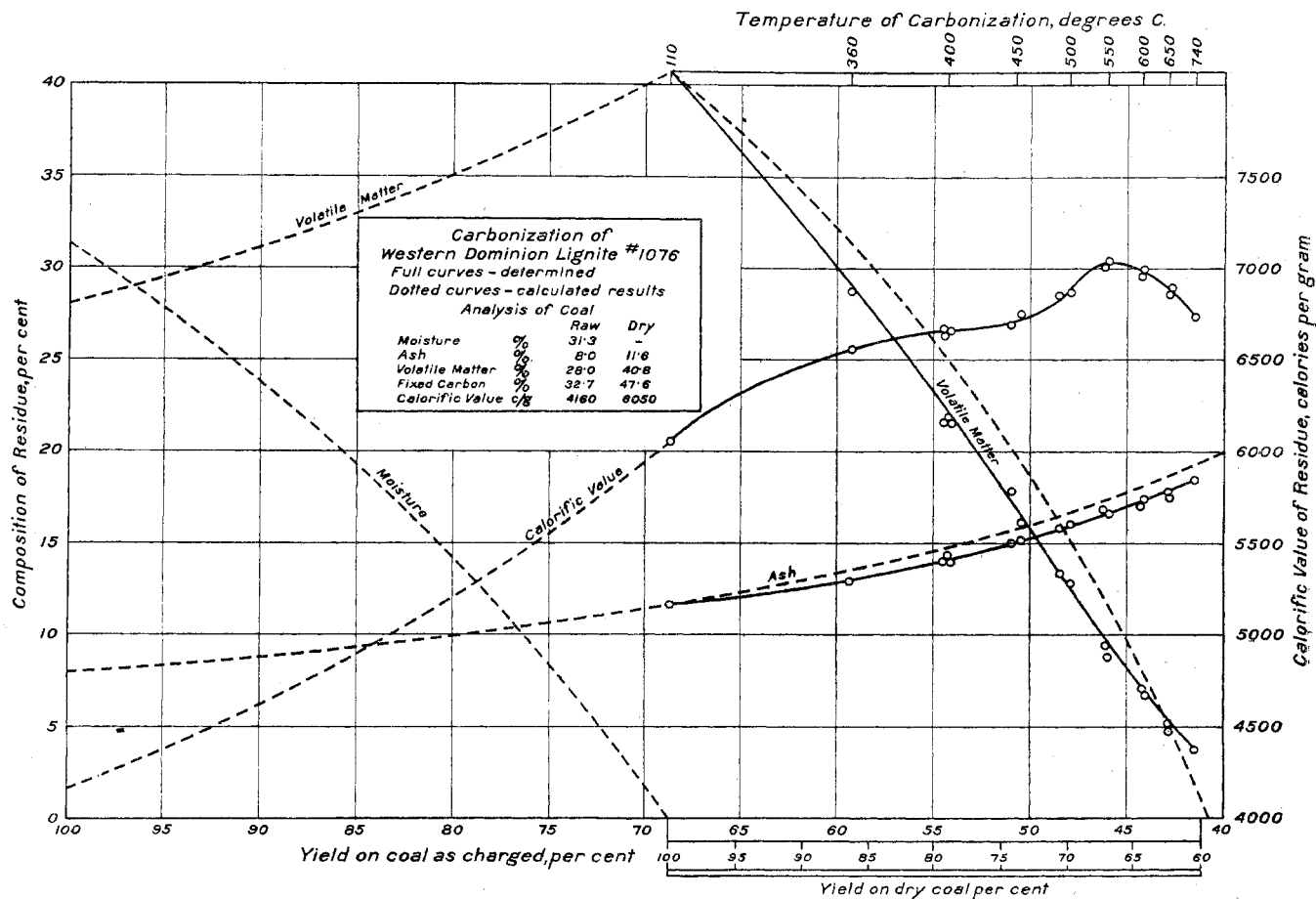


FIG. 1

time to time moisture control determinations were made upon them. It may be noted that during a period of 2 mo. the moisture contents fell only 1 per cent from an original of over 30 per cent.

The gross calorific value of this coal was 4260 cal. per gram. Its average analysis was as follows:

	Per cent
Moisture.....	31.8
Ash.....	5.2
Volatile matter.....	28.9
Fixed carbon.....	34.1

**APPARATUS**—The apparatus used for most of the experiments consisted of a cylindrical iron retort 1.5 in. high and 1.5 in. diameter, inside measurement, having a lid which was held on by a small clamp, the joint being rendered airtight by means of an asbestos gasket. A small inlet tube was screwed into the bottom of the crucible, and an outlet tube into the lid, the inlet and outlet tubes being so arranged that the retort could be completely immersed in an oil or lead bath. For the experiments under pressure a slightly larger and heavier retort was employed, with a hexagonal screw cap rendered gastight with an asbestos-copper gasket. The inlet tube was dispensed with, and a pressure gage and relief valve connected with the outlet tube.

**METHOD**—The coal briquets were weighed out into a quartz crucible which fitted inside the iron retort. The heating was done by immersing the retort in a bath, which for tests up to 300° C. was of oil, and for

those above that temperature of lead. The lead was contained in a 4-in. length of 4-in. iron pipe with a capped end, and was heated in a gas-fired furnace which gave a very uniform temperature throughout the bath, and which permitted rapid heating and easy control. The temperature was followed by two pyrometers immersed in the lead.

For the regular tests, the retort was plunged into the bath, previously heated to the desired temperature. The temperature was kept constant until the evolution of gas ceased, and the retort was then removed, cooled, and opened, and the contents weighed and examined. In other tests, the retort was slowly heated to about 250° C. in an oil bath, then transferred to a just molten lead bath, and the temperature slowly raised to the desired point. In the vacuum tests, the pressure in the retort was kept below 25 mm. of mercury by means of a good water pump. In the steam tests, a slow current of steam was passed through the retort. In the pressure tests, the relief valve was closed at the beginning of the test, but was opened as required to maintain the pressure in the retort, due to the escaping gases, at about 120 lbs. per sq. in. Dry coal was employed for the pressure series.

A striking phenomenon, first observed in connection with the vacuum series, was later found to take place with every sample of dried or carbonized lignite. In every case the residue rapidly gained in weight after removal from the retort, even when stored in a

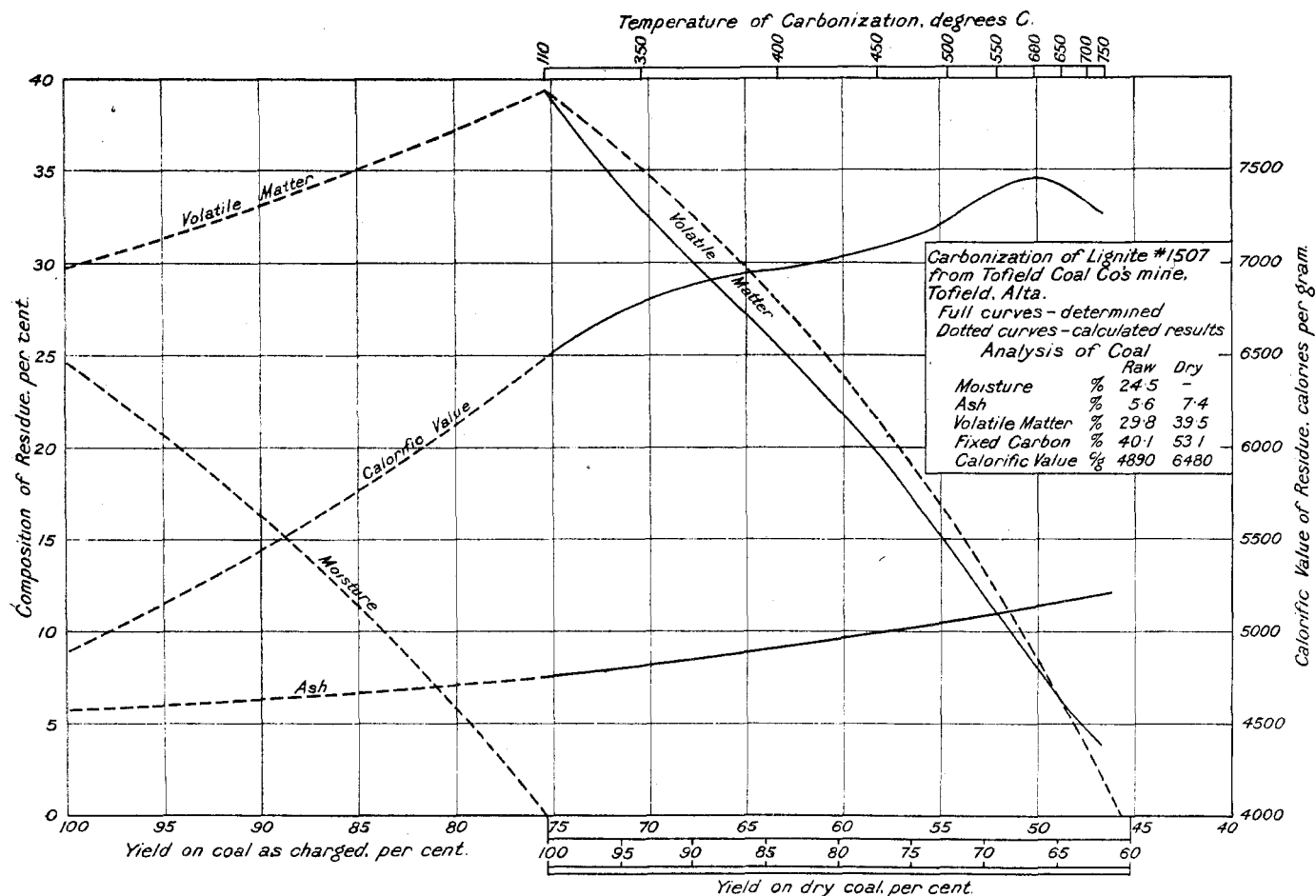


Fig. 2

desiccator over sulfuric acid, its calorific value at the same time decreasing. This was later shown to be mainly due to an occlusion of air. All published results are, with a few stated exceptions, for weights and calorific values determined immediately after the experiment.

Figs. 1 and 2 show in graphical form the principal results obtained in the regular tests on one Saskatchewan and one Alberta lignite.

In every lignite tested the calorific value of the carbonized residue increases up to a maximum and then decreases. The temperature for maximum calorific value lies between 550° and 650° C., varying with the lignite. But the yield of carbonized residue for maximum calorific value has been found to be remarkably constant when expressed on the basis of the dry coal taken. Five out of six samples taken from different areas in Saskatchewan and Alberta gave a maximum value with about 67 per cent recovery, the sixth with about 71 per cent.

#### LARGE-SCALE LABORATORY TEST

In these experiments the results determined include the yield and calorific value of the carbonized residue; the yield, composition, and calorific value of the gas generated; the yield, calorific value, and economic value of the tar produced; and the ammonium sulfate yield available. The conditions under which the lignite was carbonized were, in the experiments here

described, varied only to show the influence on the results of the final temperature to which the charge was heated, the rate of heating, and the moisture conditions of the coal treated. Further experiments have been commenced which show the effect of the pressure in the retort and the atmosphere in the retort.

APPARATUS—The apparatus (Fig. 3) employed in most of these tests embodies three important features:

- (1) Accurate temperature control.
- (2) Reduction, as far as possible, of the temperature lag from the walls to the center of the charge.
- (3) Complete removal and easy collection of the tar vapors.

The temperature control is effected by the use of an electrically heated lead bath, B, with suitable thermal insulation. The bath rests on a movable platform which can be raised by the screw C. The temperature is observed by means of a pyrometer and regulated by switches and rheostat.

The reduction of lag is effected by the use of a tubular retort, A. This consists of seven 12-in. lengths of 2-in. boiler tubing, mounted in a cast-iron head. No part of the charge is thus more than 1 in. from the walls of the retort, which has a capacity, to the top of the tubes, of 2300 g. of pea-size lignite with about 35 per cent moisture content. In later work, a cast-iron retort of cruciform cross-section was employed. This has a capacity of 3500 g.

COLLECTION OF TAR—A satisfactory method for collecting the tar was evolved only after many weeks

of work and many failures. Not only was it hard to remove the last traces of tar fog, but the condensate was usually in the form of a watery emulsion, very difficult to handle.

The method employed was as follows: The hot gases leaving the retort passed down through the center tube of a small scrubber, D, made of iron pipe and containing three interlacing coils of wire, and passed up again through a surrounding annular space; the whole scrubber being jacketed with superheated steam. The heavy tar oils were here condensed in a practically water-free condition, and dropped into a weighed glass beaker. The lighter oils, steam, and gases passed on and down through the simple tubular condenser E, where the two former condensed and collected in a receiver, the oils floating on the water and showing only a slight tendency to emulsify. The cool gases leaving the condenser still contained some tar fog; they were therefore passed down through a tube scrubber, F, filled with glass beads and a thin layer of glass wool (shown shaded), through which a jet of steam from a weighed boiler was also passed.

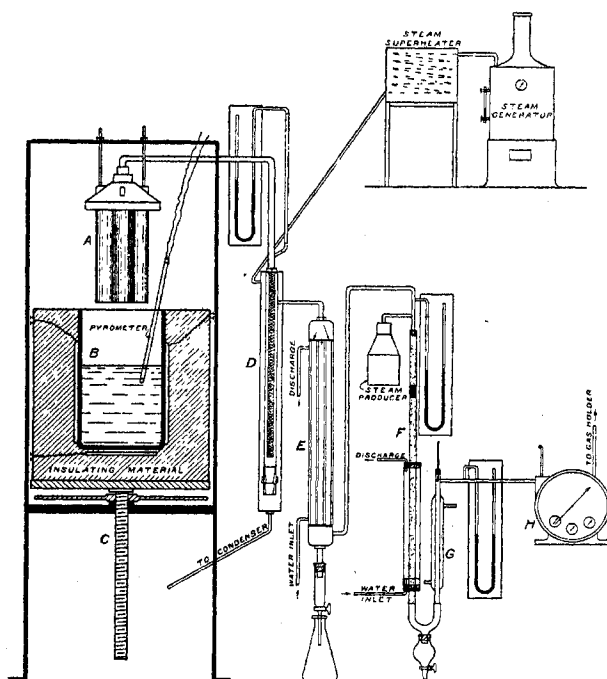


FIG. 3—APPARATUS FOR LIGNITE CARBONIZATION

The bottom half of this scrubber was water cooled. This scrubber completely removed the tar fog from the gas. The oil first condensed on the beads acted as an oil scrubber collecting more of the tar, the steam prevented the clogging of the scrubber by keeping the tar hot and fluid, and also, when condensing at the bottom, carried down with it any vapors still remaining. The gases were thus completely cleaned, and all the liquid products, as well as the ammonia, from the lignite were collected in the vessels and could readily be weighed and examined. The tar thus collected was reasonably free from water and could be redistilled without excessive bumping or frothing. The gases leaving the scrubber F passed through a final cooling tube, G, through a gas meter,

H, and into a gas holder which is not shown in the figure.

For temperatures above 700° C. a smaller apparatus was employed, with no lead bath. The retort consisted of a simple piece of 3-in. boiler tube, 16 in. long. It was heated by placing it inside a tube of 3-in. bore wound around the outside with a coil of nichrome wire. A charge of 1000 g. was taken for all experiments with this retort. The temperature of the lignite was observed by means of two pyrometers, one in the center and one near the wall of the retort.

**METHOD**—In the regular series of tests, with rapid heating, the retort was charged, usually with pea-size lignite containing about 34 per cent moisture, but in a few experiments with dried lignite, and connected to the purifying train which was then swept out with gas from a previous run. The lead bath, heated to a temperature higher than that desired for the test, in order to allow for the cooling effect of the retort, was then raised to surround the retort. The temperatures and pressures at the different parts of the system and also the meter readings were recorded at frequent intervals, and the experiments continued until the evolution of gas had practically ceased. The gas volumes were corrected for temperature, pressure, and moisture content, being reduced to moist gas at 60° F. and 30 in. of mercury. All other products were weighed, and all the products were carefully analyzed. In a number of the experiments the gas was collected in two separate holders, and the two portions were analyzed separately. The gas from the second half of the run is much richer than that collected in the first holder.

In some tests slow heating was tried, and in others the retort was evacuated, or was kept under pressure, or a slow current of steam was passed through.

The results cannot be summarized. The following are a few of the most important results obtained by the rapid carbonization of Shand lignite at 555° C.

**WEIGHT BALANCE SHEET (Dry Coal Basis)**

	Per cent
Water of decomposition.....	11.7
Gas.....	17.0
Crude tar.....	4.1
Carbonized residue.....	66.7
Loss.....	0.5

**THERMAL BALANCE SHEET (Heat Content of Products as Percentage of Heat in Original Charge)**

Gas.....	8.3
Tar.....	6.0
Carbonized residue.....	78.1
Loss.....	7.6

**COMMERCIAL PRODUCTS (Yields per 2000 Lbs. of Moist Coal Charged)**

Gas, cu. ft.....	3130
Ammonium sulfate, lbs.....	10.2
Tar, imp. gal.....	5.3
Carbonized residue, lbs.....	910

The coal charged contained 31.8 per cent moisture. The gas had a gross calorific value of 385 B. t. u. per cu. ft. and a density of 0.94. The crude tar had a density of 1.00.

**LOW-TEMPERATURE CARBONIZATION BY SHORT EXPOSURE TO HIGH TEMPERATURES**

Figs. 1 and 2 show that the maximum calorific value of the residue is obtained by carbonization at a temperature of about 600° C. It is clear from the shape

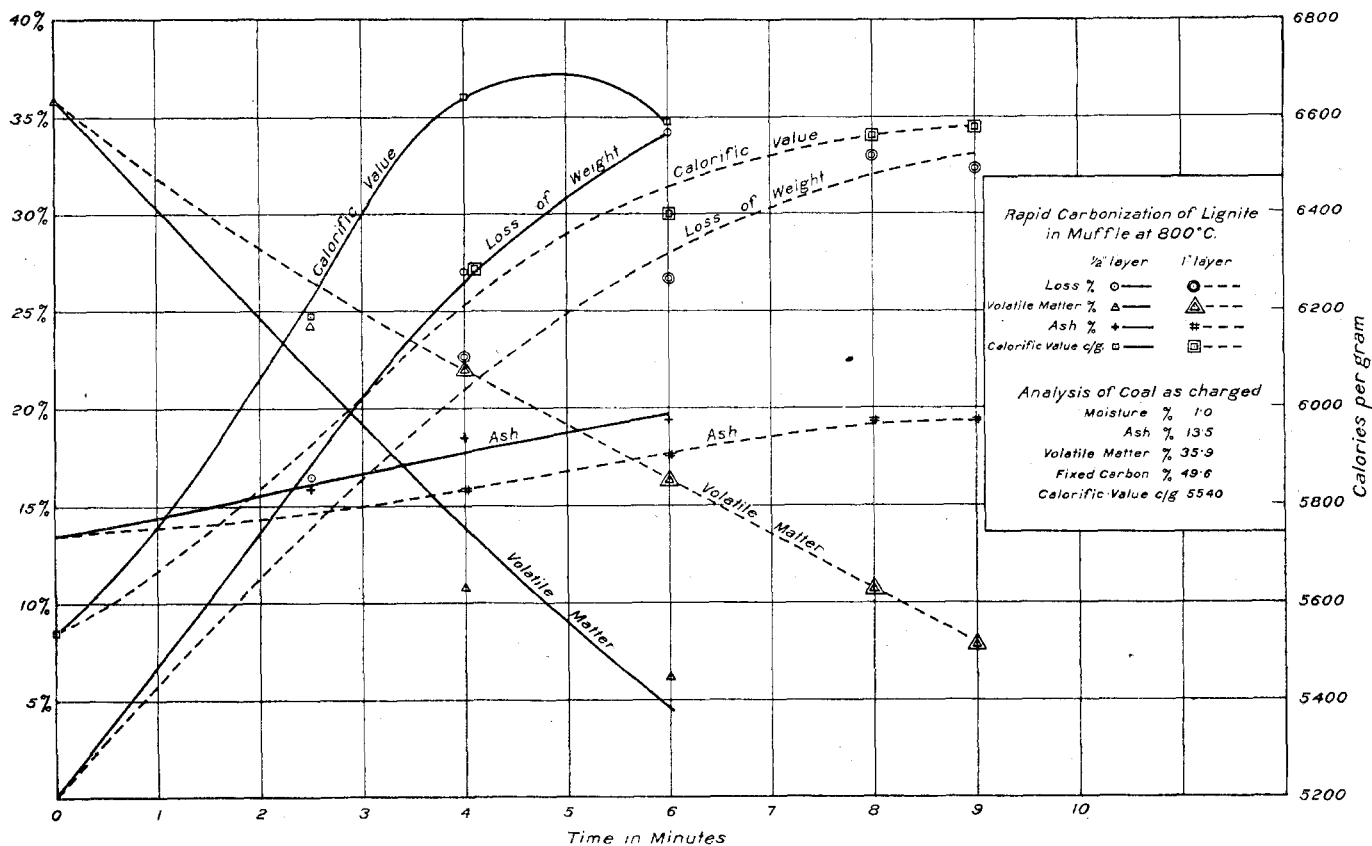


FIG. 4

of these curves that if lignite is heated in a retort under the conditions usually met in commercial operations, with the layers near the wall very distinctly hotter than those in the center of the charge, no regulation of the average temperature of the mass will give a residue with the maximum obtainable calorific value. The amount which the calorific value of the residue falls below the optimum will increase with the thickness of the charge and with the temperature gradient from the walls to the center.

**METHOD**—Some preliminary experiments were carried out to test the possibility of obtaining the equivalent of carbonization at, say, 600° C., by short exposure in a thin layer to a distinctly higher temperature. Samples of dried Shand lignite, crushed to pass a 10-mesh screen, were carbonized for a definite number of minutes in a metal box in a muffle furnace electrically heated to temperatures of 750° to 800° C. The boxes were 6 in. × 3 in. × 1 in., inside dimensions, of No. 18 gage sheet iron, with loosely fitting lids of the same metal. When making a test the muffle was brought up to heat, and the lid of the box was also heated. A charge either to half or quite fill the box was weighed out and placed in the cold box. The heated cover was put on, the box immediately placed on the floor of the muffle, and the muffle door closed. At the expiration of the desired time, the box with its contents was removed from the muffle, cooled as rapidly as possible, and the residue weighed and analyzed.

No great accuracy is claimed for the results, which are shown graphically in Fig. 4. It is obvious that the number of experiments should have been con-

siderably increased to render the curves reliable. They do, however, show that the results of such rapid carbonization follow the lines which theory indicates, and the advantage to be gained by further experiments was not thought to be commensurate with the work involved.

Comparison of the optimum results obtained with a 0.5-in. and 1-in. layer with those obtained by complete carbonization of the same sample at 590° C. and at 600° C., show, as might be expected, that the yield and composition of the residue is approximately the same in all cases, but that the calorific values of 6760 and 6750 cal. per gram obtained with temperature control, fall to 6690 and 6590, respectively, with the 0.5-in. and 1-in. layers.

#### BEARING OF RESULTS ON DESIGN OF COMMERCIAL CARBONIZER

The primary object of the Lignite Utilization Board is to produce a domestic fuel from Souris lignite. It is therefore desirable, unless other reasons are found to outweigh this, to carbonize the lignite in such a way as to give the residue with the maximum calorific value. It has been shown that this is accomplished by complete carbonization at a temperature of about 575° C., and that the same result can be approximated by short exposure in a very thin layer to a distinctly higher temperature. As the object to be attained is to bring all parts of the mass to the same optimum temperature, a somewhat thicker layer continually stirred should give the same result as a thinner layer at rest. The economic advantage, in the way of reduction of capital cost of equipment, to

be gained by the acceleration of the process by the use of high temperatures is too obvious to need amplification.

No increase in the yield of by-products can be attained without a corresponding decrease in the yield and calorific value of the residue. The gas obtained at the above temperature is barely sufficient to provide the heat necessary for the operations of drying and carbonizing the lignite. The tar yield is also low. The plant of the Board is situated in southern Saskatchewan, remote from any large center of industry. Under these conditions it does not appear probable that, in the beginning of the industry, at least, the possible profits to be made from the full recovery of by-products will justify either the capital expenditure necessary for a by-product recovery plant, or the depreciation of the carbonized residue by any attempt to increase the by-products. It is fully recognized, however, that at a later date with a larger and well-established industry this policy may require revision.

None of the results obtained give any indication that the use of vacuum, pressure, steam, or other modified method of carbonization would have any economic advantage.

Finally, it has been found that Souris lignite does not soften or become sticky at any stage of its carbonization. This is in marked distinction to the behavior of bituminous coal, and permits a design of carbonizer which is simpler and cheaper than can be employed for the latter material.

#### DESIGN OF CARBONIZER

The design of carbonizer retort adapted to fulfil the above conditions is briefly described below. The actual details of construction are unimportant for the purpose of this paper. It consists essentially of a strongly heated surface, or retort floor, inclined at an angle slightly steeper than the angle of repose of the crushed lignite. The material to be treated flows down the heated surface from a hopper at the top, passing under a succession of baffle plates, which control the thickness of the layer. The rate of flow of the material is controlled entirely by the rate of withdrawal from the bottom of the retort. This can be accomplished by any suitable mechanism. The retort is suitably enclosed at the sides and top, and gas offtakes are provided in the cover. The thickness of the layer is controlled by the difference between the slope of the retort and the angle of repose of the lignite, by the distance between successive baffles, and by the clearance between the baffle and the retort floor. The material is repeatedly stirred by its passage under the baffles.

The heated surface may be heated from below with gas. It should be hottest at the bottom of the retort and progressively cooler towards the top. The temperature of the lower part of the heated surface may be as high as the materials of construction will permit. The regulation of the degree of carbonization of the lignite is entirely controlled by the time of its passage through the retort, that is, by the rate of withdrawal from the bottom.

#### SEMICOMMERCIAL CARBONIZER

Some experiments have been carried out with a very small model of the above design. In this model the working surface varies from 2 in. to 4 in. in width, is 4 ft. long, inclined at an angle of  $45^\circ$ , and is electrically heated. The bulk of the experiments, however, were carried out in a retort approximately 10.5 in. wide and 10 ft. long. The angle of inclination could be varied at will, but  $45^\circ$  was found to be satisfactory. Different materials were tried for the floor of the retort, but ultimately carborundum slabs were adopted. Twelve baffles were used in the final arrangement; these were made of cast-iron and supported from the floor by means of end plates. The clearance under the baffles varied from 0.5 to 1 in. The lignite was crushed to pass 0.25-in. mesh. It was found advisable to dry it before treatment to a moisture content of 15 per cent or less.

The capacity of the retort varied widely with the degree of carbonization produced, with the temperature attained in the gas flue below the retort floor, and with the moisture in the lignite charge. It may be rated roughly as equivalent to 200 lbs. of raw lignite per hour.

The results obtained, with regard to output, ease of control, and smoothness of operation, were regarded as sufficient to warrant proceeding with the design and construction of commercial carbonizers on the same principle, for a plant capable of treating 200 tons of raw lignite per day.

#### DISCUSSION

MR. R. DE L. FRENCH: That I think is briefly what we have accomplished so far. While we do not believe that the work is at an end, yet it was successful enough in our minds to warrant us in going ahead with the construction of a plant on a commercial scale. This plant is now under construction. We hope to have it in operation sometime, and when we do, we hope to be able to say just what this process will cost in dollars and cents, and whether or not it is a commercially feasible thing to carbonize Canadian lignite and to briquet the residue and sell it as a passing fair substitute for anthracite coal, which a week ago was selling for \$22.60 a ton in the most easterly of the western cities, and at a higher price further west; I think at about \$27 in Regina last week. Our raw coal will cost us about \$1.80 at the mine. As we are in the middle of the field we should have no difficulty in getting plenty of coal at a low price.

I might say that the lignite with which we are dealing is probably about as low grade a lignite as we have on this continent. It has the following analysis:

RAW LIGNITE	
	Per cent
Moisture.....	31.8
Ash.....	5.2
Volatile matter.....	28.9
Fixed carbon.....	34.1
Calories, per gram.....	4260

You can see it is a very wet lignite and hasn't a particularly high calorific value. Practically all our work has been carried out on this lignite because we started with it and because we wished to compare our results we have endeavored to stick to it all the way through.

PROF. E. P. SCHOCH (of the University of Texas, Austin, Texas, who presented the following resumé of "A Process for the Economic Manufacture of Fuel from Texas Lignite"):

Lignites are characterized by a high water content, the property of "slacking" on exposure to air, and a high content of

carbon dioxide (7 to 8 per cent in Texas lignites). It is this 32 to 40 per cent incombustible volatile matter which causes briquets made from raw lignite to explode in the fire. Hence lignite must be retorted to render it fit for briquetting. The question arises: What is the most economic extent of retorting? For our experimental study of this question, the lignite used was obtained in the open market in Austin, but all of it was from the same mine. The lignite thus obtained was of rather mediocre quality. To our knowledge better lignite can be obtained even at this mine and certainly in other localities, but what we used is representative of much of the lignite now sold in Texas; hence, the figures presented below may be considered to be safe for all commercial lignites in Texas, but low for specially good lignites.

In our first set of experiments we retorted lots of 10 lbs. each in powdered form with constant stirring and fractionated the gas evolved as the temperature was raised. These experiments revealed:

- (1) The fact that the evolution of carbon dioxide ceases abruptly at about 525° C.
- (2) That the per cent by volume of carbon dioxide in the gas collected up to this temperature is from 23 to 33 per cent.
- (3) That the other constituents of the gas evolved up to 525° C. have high calorific powers, so that the mixture has a calorific power of 410 B. t. u.
- (4) That all the tar is evolved with this gas.

These results were obtained also with a different kind of a lignite from a totally different field. The gas fractions obtained at temperatures higher than 525° C. have heating powers of 410 B. t. u. per cu. ft. or less, and the total amount of gas obtainable by retorting a ton of this lignite is not more than 6500 cu. ft. (the lignite from another region gave 6900 cu. ft.), with an average heating power of the whole gas of 410 B. t. u. This result is in marked contrast with the 10,000 cu. ft. of 400 B. t. u. reported heretofore.

The coke left after complete retorting has an ash content of 25 to 28 or even 30 per cent and a heating power of 10,000 B. t. u. or below. The relatively poor quality of this coke and the fact that the gas obtained with it would have to be enriched to make it fit for "city use" led us to consider the feasibility of retorting the lignite with a maximum temperature of 525° C. It was evident that by removing as much as possible of the large per cent (about 30 per cent) of carbon dioxide from the gas obtained up to 525° C., its heating power could be raised substantially, and a simple trial showed that this could be done readily to such an extent as to make the gas directly fit for "city use."

To try out this whole procedure on a sufficiently large scale, we constructed an apparatus which retorted 1100 lbs. of lignite per 24 hrs. and purified all the gas. The retort was a 6-in. cast-iron pipe placed vertically and surrounded by a brick furnace 7 ft. high, with gas burners at the bottom. The low temperature required made it easy to operate in such a manner as not to injure the iron retort; its life is likely to be great. The amount of gas obtained was 2250 to 2500 cu. ft. per ton of raw lignite with a heating power of 525 to 540 B. t. u.; the yield of coke was 900 lbs. of 11,000 B. t. u. (or more!), and the yield of dry tar was 2 per cent. The carbon dioxide was removed down to 2 per cent by means of potassium and sodium carbonate solution.

Calculation shows that the amount of lignite needed as fuel for retorting is about 7.5 per cent of the lignite retorted. The coke comes out of the retort at a temperature just high enough for briquetting, and not so high as to take fire on exposure to air.

The advantages of this procedure are:

- (1) A coke of the highest heating power obtainable.
- (2) A gas immediately usable in city mains.
- (3) The maximum amount of tar obtainable.
- (4) A cheap retort with large capacity, operating under mild conditions, and yielding the coke at a temperature at which it can be easily and immediately handled for briquetting.

PROF. PARR: I would like to ask Mr. French if he expects sufficient binder for his briquet to come from the tars. One of his numerical factors especially interests us. He says 7 per cent of heat is lost in the final accounting for the heat. If he finds it possible to locate, with sufficient accuracy, those percentages of heat in the various constituents, and then say pretty accurately here is 7 per cent of heat unaccounted for, we would like to know about it. It is one method of getting at the exothermic quantity of heat. Seven per cent of 4000 cal. would be somewhere within the range where we think the measurement of quantity of exothermic heat resides. That factor, 7.6, is exceedingly interesting to our work.

MR. FRENCH: A remark of Prof. Schoch's reminds me I should mention some things myself. We found exactly the same things in the beginning of our work that he did. We never got 10,000 cu. ft. of gas or anything like it. I suggest that some of those high figures may be due to the method of carbonization, because I know of one case where a man was actually operating a carbonizer so designed that they fed moist coal to it. The moisture that was driven off passed through the hot charge and what you got was a gas producer on a small scale. This person may have got 12,000 or 20,000 cu. ft. of gas, but he was getting it at the expense of his residue. I judge from Prof. Schoch's remarks that he was primarily after gas. We were after residue, and it appears that with our own carbonizers we had just about enough to operate the carbonizers, and not much more.

Mr. Stansfield ran a series of experiments in the small retorts under pressure, vacuum, and with a steam atmosphere, but none of these seemed to show any advantage, and he went back to practically atmospheric pressure.

In answer to Prof. Parr's question on tars, we took the tar and distilled it at 325° C. On that basis, we got what we called "available binder," a quantity of pitch representing 2.5 to 3 per cent of the carbonized residue, and that is not sufficient. It is probably not a quarter of what is required. It takes a large quantity of binder to make residue briquets, because physically the residue more nearly resembles charcoal than it does coke. I imagine it will be similar to some coke which Prof. Parr has here.

Answering Dr. Porter, the water is the water of constitution. It is dry coal. It is dried at 105° C., and that is the water left after drying.

Returning to Prof. Parr, so far as loss of heat is concerned, I would prefer that Mr. Stansfield should answer that question himself, because I do not know very much about his calculations, except that I have a number of them, and I know the loss of heat always runs around the figures given.

## THE COMMERCIAL REALIZATION OF THE LOW-TEMPERATURE CARBONIZATION OF COAL

By Harry A. Curtis

INTERNATIONAL COAL PRODUCTS CORPORATION, IRVINGTON, NEW JERSEY

The process herein described was developed for converting bituminous coal into a uniform, smokeless fuel resembling anthracite in properties. It was recognized at the outset that the problem was one in which small-scale tests alone would not yield the necessary data for plant design, and while much valuable information has been secured in small apparatus, the development of the process has been very largely through use of commercial-size units. For the past four and a half years large-scale experimental work has been carried on in parallel with laboratory tests. The experimental plant, as finally developed, has a capacity of about 100 tons of raw coal per day, but