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BULLETIN OF
THE ALABAMA POLYTECHNIC INSTITUTE

Published by the Alabama Polytechnic Institute

Issued Seven Times a Year--January to July

APRIL, 1934

Vol. XXIX.

No. 5

UTILIZATION OF LOW GRADE FUELS,
COKE OVEN AND TAR OIL WASTES

By

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, Bulletin No. 5

ENGINEERING EXPERIMENT STATION

Of the
ALABAMA POLYTECHNIC INSTITUTE

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Entered as Second-Class Matter at the Post Office at Auburn, Ala.

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TABLE OF CONTENTS

	Page
UTILIZATION OF LOW GRADE COALS -----	1
TRENT PROCESS FOR LOW GRADE COALS -----	2
THE UTILIZATION OF LOW GRADE COALS IN GAS PRODUCERS ---	3
BRIQUETTING OF BITUMINOUS COALS -----	3
LOW TEMPERATURE DISTILLATION OF COAL -----	3
HYDROGENATION OF LOW GRADE COALS -----	7
COAL AS THE RAW MATERIAL FOR THE ORGANIC CHEMICAL INDUSTRIES -----	9
MISCELLANEOUS METHODS FOR UTILIZATION OF LOW GRADE COALS -----	10
UTILIZATION OF LIGNITE -----	12
CARBONIZING PROCESSES -----	12
DISTILLATION AT LOW TEMPERATURES -----	12
HIGH TEMPERATURE DISTILLATION -----	14
GAS MAKING PROCESSES -----	15
APPLICATION OF THE TRENT PROCESS -----	15
HYDROGENATION OF LIGNITE -----	16
SPECIAL FUELS FROM LIGNITE-BRIQUETTING -----	16
LIGNITE AS A FUEL -----	17
THE USE OF POWDERED LIGNITE -----	17
MORE RECENT DEVELOPMENTS IN THE UTILIZATION OF LIGNITE IN EUROPE -----	18
MISCELLANEOUS DEVELOPMENTS IN THE UTILIZATION OF LIGNITE -----	21
UTILIZATION OF PEAT -----	23
PEAT AS A FUEL -----	24

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	Page
BRIQUETTING PEAT -----	25
DISTILLATION OF PEAT -----	26b
GASSIFICATION OF PEAT IN GAS PRODUCERS -----	28
MISCELLANEOUS USES OF PEAT -----	29
RECOVERY OF WASTE PRODUCTS IN THE COKING OF COAL-----	30
SULPHUR FROM HYDROGEN SULPHIDE PURIFIERS-----	30
RECOVERY OF CYANOGEN COMPOUNDS -----	30
DRY QUENCHING OF COKE -----	31
RECOVERY OF PYRIDINE -----	32
ETHYL ALCOHOL FROM BY-PRODUCT GAS -----	32
RECOVERY OF PHENOLS FROM AMMONIA STILL WASTE -----	33
UTILIZATION OF ACID SLUDGE -----	34
BENZENE PLANT RESIDUES -----	35
RECOVERY OF WASTE PRODUCTS IN THE REFINING OF TAR OILS -----	33
RECOVERY OF VARIOUS WASTES -----	34
BIBLIOGRAPHY -----	36
COAL -----	36
LIGNITE -----	38
PEAT -----	39
WASTE PRODUCTS IN THE COKING OF COAL -----	40
TAR OIL WASTES -----	40

Utilization of Low Grade and Waste Fuels

Coke Oven and Tar Oil Wastes

In this work the newer methods for concentrating and utilizing low grade and waste coals, lignite and peat are discussed. Many of these methods were reported at the International Conferences on Bituminous Coal held at Pittsburgh. The utilization of wastes relative to the coking of coals and the refining of coal tar oils are also discussed. A complete bibliography containing a large number of references is included.

WASHING OF COAL

The washing of coal to reduce the ash content is so well understood that it will not be discussed here. In this way many high ash coals can be utilized to advantage.

MECHANICAL STOKERS

The use of various types of mechanical stokers such as the Coxe rotating stoker for the burning of coke breeze and various types of low grade and waste coals likewise has been discussed in detail and need not be discussed here.

PULVERIZED COALS

In recent years the use of pulverized coal as a boiler fuel and as a fuel for heating furnaces and retorts employed in the chemical industry, has become very common. Some of the advantages of pulverized fuel firing over combustion as carried out by means of mechanical stokers¹ are as follows:

- (1) Higher boiler efficiencies are said to be possible.
- (2) Banked fires and stand by losses can be eliminated since the fuel can be cut off during no load periods.
- (3) Practically all grades of fuel can be readily burned.
- (4) The control over the furnace is much more flexible.

The employment of pulverized coal as a fuel allows many low grade and waste coals to be utilized to advantage.

A paper² giving much interesting information relative to the nature and use of pulverized coal was presented at the International Conference on Bituminous Coal, in 1926. In this paper an electric vibratory pulverizer is described that will start with 20 mesh and produce 200, 300, 500 or even 1,000 mesh material. This extreme fineness is believed by the author to play an important part in the more efficient burning of anthracite, semi-bituminous, bituminous coal, and lignites. This in turn, it is believed, will lead to many new uses for pulverized fuels. It is mentioned in this article that coal in a mobile state obeys the laws of liquids. Pulverized coal can be made to flow and seek its own level, very much as a liquid. This condition is brought about by heating pulverized bituminous coal to a point at which vapors are generated (either hydrocarbons or chemical water). These vapors form bubbles around the fine particles of coal and reduce friction to such a degree that the coal seeks a horizontal level, that is, it flows. It is believed that the ability to treat coal as a liquid rather than a solid, might bring about a great change in the coal industry and in coal technique.

Great economies are claimed³ for pulverized coal in the firing of annealing furnaces, forge furnaces, puddling, malleable iron melting, copper refining and nickel reverberatory furnaces.

Trent Process for Utilization of Low Grade Coals.

One of the best known processes for removal of ash and increasing the heating value of low grade coals, is the Trent process⁴. This process is said to be based upon three principles: one, when coal is very finely pulverized, the ash and clinkers are readily detached from the combustible matter; two, when pulverized coal is in water suspension, the wet ash particles do not combine with oil; three, particles of wet coal when agitated with a given amount of oil, combine with the oil to form an oil-coal amalgam which is practically free of both water and ash.

Amalgam as the product is known today, is said to be an agglomeration of small spheres of purified coal particles, amounting to eighty per cent, fifteen per cent of oil and five per cent water. For this product many uses are claimed. It is said to be suitable for boiler firing, domestic uses, gas and coke making, and as a raw material for the production of a smokeless clean fuel known as Super fuel. This is made by molding the amalgam and then baking same at a low temperature in the presence of a small amount of oxygen, until the resulting product is hard and clean. Both bituminous and

anthracite coal can be employed for this process.

The process is reported to be essentially as follows:

- (1) The coal is pulverized to about 200 mesh.
- (2) The pulverized coal is mixed with water, the latter being about 200 per cent of the former.
- (3) Add to the mixture a mineral oil to approximately 50 per cent of the coal.
- (4) Agitate the mixture until the oil and coal agglomerate, most of the water being separated.
- (5) Scrub the mixture of coal and oil with water to remove the ash.

The Utilization of Low Grade Coals in Gas Producers

The Bureau of Mines has conducted a number of investigations on the making of producer gas from the poorer grade coals.⁵ The types of gas producers employed include the suction producer, the up draft pressure type, the down draft type and the double zone producer. One type has a revolving grate and automatic feed. A continuous producer also has been developed.

A gas producer for granular fuel containing dust has been developed by Fritz Winkler.⁶ To insure complete gasification, the upper part of the shaft is enlarged and means are provided for admitting super-heated steam.

M. H. Mills⁷ has utilized slack coal in a Mond producer. 62 cubic feet of gas; 80 pounds of ammonium sulphate and 4 gallons of tar are secured per ton of coal.

Briquetting of Bituminous Coals

The reader is referred to Stillman's Briquetting (The Chemical Publishing Co., 1923), and to the various bulletins of the U. S. Bureau of Mines, for details on briquetting of coals. See also the reports of the International Conferences on Bituminous Coal.

Low Temperature Distillation of Coal

In recent years attention has been directed to the low temperature distillation of coal. Millions of dollars have been spent in an attempt to develop a satisfactory process.

Much of the work has been carried out in the hopes of successfully utilizing high volatile bituminous coals, slack from coals of both high and low quality, semi-bituminous coals and lignite.

The chief object of the low temperature distillation of coal is to produce a solid fuel (semi-coke) of a superior quality to high temperature coke. The semi-coke is much easier to ignite than coke and like the latter, is practically smokeless. It is desirable that the semi-coke be of sufficient strength to withstand what handling is necessary for domestic purposes and that it be in a form that can be used for pulverized fuel.

The chief by-products (gas and tar) are quite different from the same products derived from the high temperature distillation of coal. The tar, in at least one case⁷ brings a higher price than high temperature tar. The gas has a much higher heating value than high temperature gas and consequently should bring a better price. At the plant referred to above, which is now nearing completion, it is planned to mix the 300 B.t.u. gas with 300 B.t.u. blue gas, the mixture being sold to a public utility at an advantageous price.

The details of the various methods for the low temperature distillation of coal vary greatly. According to Mueller⁸ the processes which have appeared so far, fall into six groups. These are as follows:

Group A: Processes Employing Indirect Heating

- (1) The coal is carbonized at rest in a batch process.
Example - The Coalite Process.
- (2) The coal is carbonized at rest in a continuous process.
- (3) The coal is carbonized in motion in a continuous process.

Group B: Process Employing Direct Heating.

- (1) The coal is carbonized at rest in a continuous process.
- (2) The coal is carbonized while in slow motion by a continuous process.
- (3) The coal is in rather rapid motion during the carbonization.

A great many processes which have been proposed for low temperature distillation of coal apparently have not proven to be profitable. Three processes that show some indications of commercial success are discussed below. One of these is the plant⁹ recently completed at New Brunswick, New Jersey. This plant employs the same retort used by the "K. S. G." plant now in operation at Karnap, Germany. This is reported to be one of the few projects for carbonization of bituminous coal at low temperature which has been consistently profitable.

The New Brunswick plant has eight of these retorts. They each have a rated capacity of 80 tons of coal per day. The retorts operate on slack bituminous (coking) coal. A single operation is said to produce lumpy semi-coke.

The retorts consist of two externally heated, concentric drums which are slightly inclined from the horizontal. The drums are rotated at a rate of about three-quarters of a revolution per minute. The outer drum is 72 feet long and 10 feet in diameter while the inner one is 85 feet long and 5 1/2 feet in diameter.

The double drum arrangement has proven advantageous in overcoming difficulties which are encountered with a coking coal during its transition through the plastic stage. It was found that with a single drum, carbon deposited on the inner walls. In some cases a tendency developed for the lumps of semi-coke to become excessively large and cause trouble in the discharge mechanism. The double drum greatly reduces these difficulties by reducing to a minimum the time that the fuel is in a plastic state. The coal in its passage through the inner drum is dried and heated to a point somewhat below its softening temperature. It then passes into the upper end of the outer retort where the temperature is the maximum. Each particle of coal is at once hardened with a layer of semi-coke which is not sticky. Consequently, its agglomerating properties are greatly reduced. An additional means taken to prevent carbon from depositing on the walls, consists of the passage of steam through a series of steam chests which are extended along the inner wall of the outer drum for the upper third of its length. The direction of the steam is tangential, a screen of steam being continuously interposed between the coal and the walls of the retort. The adhering carbon is scraped off.

The raw coal is fed from the storage bin into the retort by means of a screw conveyer. It is carried by the helical flanges of the inner drum to the upper end of same where it drops through open ports into the outer drum. The coal slowly passes through the outer drum. On reaching the lower end, it is picked up as semi-

coke, by scoops and carried to the discharge gate. About two hours is required for carbonization.

The retort is heated by producer gas which is from the semi-coke fines. The gas is generated in a central plant. Each retort has an independent heating system. The gas, when burned in a combustion chamber where gas and air are admitted in the exact combining ratio, produces a temperature of about 2500°F. A circulating fan removes part of the flue gas from the base of the stack and mixes it with some of the hot gases from the combustion chamber and forces it into the first pass at the lower end of the retort setting. Here a temperature of about 1200°F is maintained. The mixed gas is forced by means of baffles to take a helical course around the retort.

Another method for low temperature carbonization of coal which is of considerable interest¹⁰ consists of the application of the Hayes process to a high volatile bituminous coal slack. The purpose of the plant employing this process was to produce a domestic fuel from the coal slack. The latter is first carbonized at low temperature and then briquetted.

The coal slack is carbonized in a horizontal externally heated, rotary retort, which is operated continuously and has a definite plan for the transportation of the slack through the retort. Seven retorts are heated by a single furnace. Each retort is heated within individual heating chambers, the operation of each retort being independent of the others.

The retorts are made from a special alloy, and are 20 feet long and 17 inches inside diameter. The speed of rotation of the retorts is one and one-half revolutions per minute. A screw conveyor of a special construction propels the coal through the retorts. This conveyor gives an oscillating motion to the coal. The coal is first given a forward motion towards the discharge end of the retort and then on the reverse oscillation it travels backward a distance slightly less than that of the forward motion.

The furnace built of fire brick consists of seven separate heating chambers. Each chamber is heated by six gas burners situated on the under side and so arranged as to give direct heating to three fourths the total length of the retort. Flexibility in the control of the furnace temperature is secured by providing each burner with an individual combustion chamber connected with the heating chamber.

Coal is fed to the retort continuously by means of a screw conveyor. The slack is fed at a uniform speed so that a depth, not exceeding three inches of coal throughout the retort, is secured. Under these conditions the necessary heat transfer is

rapidly secured.

The carbonaceous residue is discharged from the retorts into a screw conveyer which moves it to the quenching conveyer where it is sprayed with water. The gases generated in the retorts are withdrawn from the coal feed end of the retort and are passed through standard condensing and washing equipment.

The residue is mixed with pitch and briquetted on a Belgium type roll press. It is planned to install a still for the fractionation of the crude tar, the residual pitch being used as the necessary binder for the coal.

The briquettes weigh about 2 1/2 ounces and are pillow shaped. After air drying they withstand handling and shipment with relatively little disintegration. The briquettes burn with little smoke and are said to retain their form until consumed.

A third method of interest consists of the manufacture of a so-called anthracite which has been made recently from bituminous coal¹¹. Briefly the process is as follows; The coal is heated to a temperature of about 850°F. in a retort where it is agitated. The coal first melts to a semi-liquid mass which is plastic. It then passes into solid semi-coke. Because of the stirring motion, the semi-liquid rolls into pellets of various sizes. The pellets are said to be an excellent fuel for pulverized coal furnaces, on chain grates and in gas and water producers.

The pellets are cooled, ground and mixed with pitch. The mixture is then briquetted into pillow shaped briquettes weighing about 1 1/2 ounces. The pitch binder is secured from the tar driven off during the distillation.

The briquettes are then heated in an oven of a special type, at a temperature from 1,000°F to 1,200°F. By this treatment the volatile matter is reduced to 8 to 12 per cent. Consequently, the combustion of the briquettes is nearly smokeless.

For further details on this process as well as on other processes for the low temperature distillation of coal, the reader is referred to the Proceedings of the International Conference on Bituminous Coal Vol. 1 (1926) and Vol. 1 and Vol. 2 (1928) published by the Carnegie Institute of Technology, Pittsburgh, Pa.

HYDROGENATION OF COAL

A method which has been developed by Dr. F. Bergius for the liquification of coals, lignites, sub-bituminous and high

ash bituminous coals, was reported at the International Conference on Bituminous Coals¹² held in Pittsburgh in 1926. The method as worked out by him consists of subjecting coal heated to about 450°C, with a high concentration of hydrogen. The pressure is from 150 to 200 atmospheres. No catalytic agent was used.

The coal liquifaction is said to consist of two different reactions: The first one consists of addition of hydrogen and the second the splitting up of large molecules into smaller ones while additional hydrogen is added. The hydrogen first enters the relatively large and complex molecule. The higher the temperature, the more the larger molecules are broken up into smaller molecules. The addition of hydrogen to these changes the unsaturated molecules into saturated ones.

When larger quantities of coal were employed for the reaction, a coke like substance rather than an oil was secured. The reason for this was found to be that the hydrogenation reaction produced a large amount of heat which increased the reaction temperature to such a degree that the distillation of the coal began. This difficulty was overcome by carrying out the reaction in the presence of a liquid medium, i.e., a coal oil.

The products recovered consist of hydrocarbons of the aliphatic, aromatic, and hydro-aromatic series, phenols, cresols, and ammonia. Typical yields from bituminous gas coals are as follows:

1. Motor spirit -----	15%
2. Diesel oil and Creosote oil -----	15%
3. Fuel oil, lubricating oil, pitch -----	20%
4. Ammonia -----	0.5%
5. Water -----	8.0%
6. Gas -----	20%
7. Organic matter, insoluble in benzene --	11.5%
8. Ash -----	10%

Relative to the nature and quality of the coal suitable for hydrogenation, it is stated that coals from all over the world were studied. This included nearly every type of coal

and lignite except anthracite. Lignites are liquified more readily and completely than bituminous coals. It is also stated that inferior coals to those required by the ordinary gas plant can be used. Data is included showing the hydrogenation of coals containing over 30 per cent ash.

The above method is of interest since it demonstrates that motor fuels can be made from coal. The estimated life of the coal deposits greatly exceeds that of the oil deposits. The by-products are also more valuable than those secured by the low temperature or high temperature distillation of coal. A further advantage is the fact that since 15 to 20 per cent of the coal is converted into methane and ethane, the coal liquifaction plant can be operated to advantage as a gas plant. The gas has as high a heating value as gas obtained by coking coal in the ordinary way while the oil by-product is more valuable than the coke.

Coal as the Raw Material for the Organic Chemical Industries

The destructive distillation of coal produces large quantities of carbon monoxide and hydrogen. The direct combination of these gases by catalytic synthesis¹³ produces not only methyl alcohol, as well as other homologous alcohols, but also esters, and ketones, which have various industrial uses.

By varying the nature of the catalyst and its temperature one may secure either methyl alcohol or a mixture of methyl, ethyl, propyl, isobutyl and other alcohols, together with a variable and usually a small proportion of free or combined acids, ketones, and tarry residues.

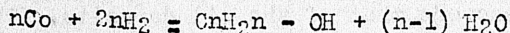
This process for methyl alcohol is already in operation in Germany on a large scale.

The presence of inert gases is considered particularly objectionable in the synthesis of alcohols. The most important of these are methane, and nitrogen. These gases reduce the yield of alcohol.

The necessary carbon monoxide and hydrogen (water gas) can be readily made from coke. A relatively new development permits partially or wholly the substitution of run of mine bituminous coals for coke. A method frequently employed for the complete gassification of bituminous coal consists of the simultaneous distillation and gassification, the resulting gas containing close to 50 per cent hydrogen, 30 per cent carbon monoxide, 3 per cent carbonic acid, 6 to 7 per cent methane, and 8 to 10 per cent nitrogen. The consumption of coal is

from 650 kilograms of crude coal, for 1,000 cubic meters of gas. Allowing for inert gas, leakage, etc., the consumption of coal is about 1.10 kilograms per cubic meter of gas that actually enters into combination and is converted into an organic compound.

The transformation reaction is



On this basis, the theoretically pure gas in cubic meters per kilogram of alcohol can be calculated. This gives 2.20 cubic meters for methyl alcohol. The practical consumption of crude gas in cubic meters, is 3.67 while the practical consumption of coal consumed is 2.42 kilograms.

As already mentioned a series of organic products can be made by this alcoholic synthesis by employing different catalytic agents. The only one that as yet has been secured in the pure state by catalytic action alone is methyl alcohol. An interesting development, however, is that methyl alcohol itself can be made to serve as the raw material for the preparation of the other alcohols. When vapors of methyl alcohol are passed over certain catalytic agents, the product obtained contains essentially the same proportion of higher alcohols as when water gas itself is forced to react with the same catalytic agent. An additional point that is made is that formaldehyde can be readily made from methyl alcohol by simply passing vapors of the latter over reduced copper at 200°C. Free hydrogen is liberated.

It is believed by the writer of the above paper that the cost of synthetic methyl alcohol under present conditions should not exceed 20 cents per gallon.

Relative to the discussion of synthetic organic compounds from water gas derived from coal, it might be mentioned that ordinary by-product gas has some possibilities along this line. This gas contains approximately 50 per cent hydrogen, 25 per cent methane and 2.5 per cent illuminants. By fractional condensation or by other methods these gases might be separated. The hydrogen might be used as a source of ammonia. The methane, by a recently developed process, might be decomposed into carbon and hydrogen in the presence of a catalysist, the carbon converted to carbon monoxide and the carbon monoxide and hydrogen reunited to form methyl alcohol.

Miscellaneous Methods for Utilization of Low Grade Coals

A method¹⁴ for the conversion of slack coal and fines into

lumpy smokeless fuel, by low temperature distillation, is of some interest. To obtain these results the coal is carbonized while tightly packed. The resulting coke lumps appear to have considerable strength.

Coal particles have been successfully recovered¹⁵ from slags by Krupp magnetic separators. It is reported that three to five per cent of the coal or coke fed to the furnaces is recovered in this way.

Coal and coke have been successfully recovered from ashes⁶ by a magnetic separator. The clinkers from coal and coke are magnetic. The separators consist of a fixed system of electro-magnets with one or more semi-cylindrical highly concentrated magnetic fields within which a thin walled drum rotates. The ashes pass to the drum. The coal and coke being non-magnetic drop off by gravity. The magnetic slag is held until the drum reaches the non-magnetic part of the field during its rotation, when it drops off. The separator is said to handle 0.25 to 2 tons per hour. The power consumption is reported as 0.6 to 2.4 per kilowatt hour. Ashes of widely varying composition have been handled.

A similar process for reclaiming coal from combustion residues is described by H. O. Herzog¹⁶. After removal of the iron, the ash is separated into four different sizes by a suitable conical screen drum. The first three sizes are charged on electro-magnetic separators. The clinkers are retained to some extent by the electro-magnetic attraction of the separators (drums) while the coal is thrown off by the centrifugal action produced on rotation of the drums. It is claimed that 30 per cent of the coal from residues derived from station plants and 40 to 45 per cent from locomotives ash may be recovered.

Much ingenuity has been exercised in various devices for the direct burning of low grade and waste coals under boilers. An example of English practice of this type is given by W. S. Coates¹. Induced draught is reported as being sufficient to consume a relatively good grade bituminous or semi-bituminous coal, free from slack, and with a heating value of about 11,000 B.t.u. per pound, when the ash content is not high and the volatile matter is such that ignition is easily obtained.

British practice in the utilization of coal mine wastes, peat, lignite, coke breeze, etc., as a fuel for steam raising and in producer gas and briquette manufacture is discussed in a book by W. F. Goodrich entitled "The Utilization of Low Grade and Waste Fuels", published by Earnest Benn Ltd., London, 425

II - UTILIZATION OF LIGNITE

The developments in the utilization of lignite up to 1925 are summarized in a bulletin by the Bureau of Mines. Several lines of attack for the possible utilization of lignite have been suggested. These are given as follows:

- (1) The production of valuable crude liquids by the distillation of the lignite.
- (2) The preparation of liquid or soluble products by hydrogenation or other processes.
- (3) An inexpensive method for the complete gassification of lignite including an improved method for making producer gas, and a suitable method for the production of water gas.
- (4) A method for making a solid fuel other than by briquetting the carbonized lignite.
- (5) The development of a method for coking the lignite.
- (6) The commercial applicability of the carbonizing and briquetting process and its relation to by-products and methods for plant control.

Only the last of these possibilities offers definite assurance of giving a satisfactory domestic fuel.

CARBONIZING PROCESSES

Both high and low temperature distillation processes have been proposed for lignite¹. It is now recognized that low temperature distillation gives a higher yield of oil (tar) and condensable products. It also gives a larger percentage of phenols and paraffines in the tar, a higher percentage of light oils capable of being refined and used as a motor fuel, a decided decrease in the yield of gas per unit weight of fuel, an increase in the yield of char in some cases, and a decrease in the yield of ammonia in most cases. More difficulty in quenching the residue (char) is encountered and a better grade fuel is secured. The fuel is more readily ignitable, free burning and smokeless. The amount of fuel required for the carbonization is also less than in the case of high temperature carbonization.

Distillation at Low Temperatures

Up to 1924, low temperature distillation had not proved

commercially successful even in the case of bituminous coal from which a salable coke and other by-products can be recovered. The utilization of lignite in this way looks even more unpromising since it often contains as much as 33 per cent water and on distillation gives a gas of lower quality than normally distributed as city gas, while the tar and ammonia at best are no more valuable than the same products obtained from coal. The lignite is also non-coking and gives a powdery residue.

S. W. Parr has developed² a process for low temperature distillation of coals giving a greater heat economy, and a yield of ammonia higher than normal. Parr³ has also successfully carbonized non-coking, high oxygen coals.

It is reported¹ that for the last 60 years brown coals of high bituminous content have been carbonized at low temperatures in Germany. The bitumen varies from 5 to 40 per cent. It is said that these coals are becoming exhausted. Among the products recovered are motor spirits, kerosene, gas oil, lubricating oil, solid paraffin and creosote. Most of the German brown coals contain only from 2 per cent to 3 per cent bitumen, and consequently apparently are not suited for distillation processes.

Various low temperature distillation processes have been developed for lignite. An attempt¹ has been made to apply the carbocite process to the low temperature carbonization of lignite and peat. By this process very little tar is produced and it is said that the gas has practically no fuel value since it consists chiefly of carbon dioxide and water vapor. North Dakota lignite was tested by this method. This work was carried out on a laboratory scale, 2,986 grams being dried and slowly heated to 300°C in an electric muffle furnace, this temperature being maintained for 8 hours. The moisture loss was 649.4 grams, while the carbonization loss was 830.7 grams. The residue weighed 1483.5 grams. Consequently, the raw lignite required to make one part carbocite is 1.994 parts. This is exclusive of the fuel required for heat.

The possibilities of Australia lignite have been investigated¹ by that country. Most of this lignite comes from Victoria and is much the same quality as that in the Northwestern part of the United States. Low temperature carbonization tests tally closely with similar tests of North Dakota lignites. The conclusion is reached that as a whole the results are not particularly promising.

The Canadian government has extensively studied¹ the utilization of lignite. Laboratory experiments were so promising that a plant was built by the Lignite Utilization Board of Canada at Bienfait, Sask. with an estimated capacity of 100 tons of residue per day. The plant was designed and equipped to handle lignite, char, and gas and to produce briquettes from the char.

HIGH TEMPERATURE DISTILLATION

Contrary to the impression held by many¹, high temperature distillation of lignite in coke ovens which has been satisfactory for bituminous coal, apparently is not the most economical and satisfactory method for the utilization of lignite under present conditions. This is explained by the many differences between bituminous coal and lignite. Some of these differences are given below. Lignite contains 30 per cent or more of moisture while a good grade coking coal contains less than 5 per cent. This necessitates considerably more heat to expell the additional moisture. The yield of lignite char is about 40 per cent only. This is not a valuable fuel without further processing such as briquetting or the use of special devices. On the other hand good coking coals give as high as 72 per cent coke. The lignite tar is less per ton of fuel carbonized and has a lower commercial value. The gas from lignite has a considerably lower heating value and will not meet existing standards for city gas. Lignite generally costs more at the mine per unit of available heat than higher grade fuels.

The use of standard by-product coke ovens and gas retorts for the carbonization of lignite are not practical because the fixed charges and over head costs are too high. A table showing the comparative costs of distillation of bituminous coal and lignite is as follows:

BITUMINOUS COAL

Coal -----	\$5.35 per ton
Operating Cost ¹ -----	1.50
Fixed charges -----	1.25
Blue gas for heating ovens -----	1.40
Total-----	
LIGNITE (hypothetical)	<u>\$9.50</u>
Lignite at the mines -----	1.50
Operating cost -----	1.50
Fixed charges -----	1.25
Lignite gas used for heating the ovens -----	
Total	<u>\$4.25</u>

The returns are calculated to be \$7.23 in the case of the bituminous coal, and \$1.56 in the case of the lignite which leaves a deficit of \$2.27 in the case of the coal and \$2.69 in the case of the lignite. However, if the 11,000 cu. ft. of gas were sold at 22.6 cents a thousand feet one could come out even on the bituminous coal. Such an opportunity however, does not exist in the case of the lignite.

GAS MAKING PROCESSES

Various gas producing processes¹ (other than by distillation) are making progress. Lignite has been gassified in the gas producer. Both steam and air are passed through the incandescent fuel bed. Lignite producer gas consists of volatile matter from the lignite together with gas resulting from the reactions between the incandescent carbon and the steam and air. It also contains a comparatively large quantity of inert nitrogen. Lignite producer gas is suitable for industrial use and can be used for gas engines when purified.

While lignite can be used successfully in gas producers, in the raw state, it is not an ideal fuel for this purpose since it slacks on heating. A gas producer has been developed recently in Texas to reduce clinker difficulties, and produce simultaneously a gas of higher heating value. A water jacket prevents clinkers from sticking to the side wall, while a revolving grate assists in the proper distribution of air, and prevents the formation of holes in the fuel bed. The higher heating value of the gas is secured by passing the gas and suspended tarry vapors through a chamber in the hot zone of the producer thereby cracking the vapors which are fixed as a gas.

APPLICATION OF THE TRENT PROCESS

This process¹ under proper conditions may prove satisfactory for lignites in districts such as Texas. In this process the lignite is finely ground and mixed with a large quantity of water. A small quantity of cheap oil such as crude heavy oil, tar, tar emulsions, etc., is added and the whole is thoroughly mixed. The oil wets the surface of the fine coal particles which coalesce into granules. The slate and other incombustible matter is not wet by the oil and is partly removed in the water which is removed. The mass of oil-coal contains about 30 per cent oil and resembles a black putty like mass. By the above process, not only is the ash reduced but the resulting product can be coked, provided it is made in part from bituminous coal. It gives a high yield of good quality gas, while the resulting coke is of good quality with a comparatively low ash content. Lignite as mined is not well suited to the Trent process, but probably a means of applying this process can be developed.

EXTRACTION OF LIGNITE WITH VARIOUS SOLVENTS

Probably the most important material recovered in this way is montan wax. The recovery of this product does not look very promising¹ in this country although it has been recovered with some success in Europe. Ordinarily the waxes, resins and bituminous substances are recovered by extraction with benzene or other solvents.

HYDROGENATION OF LIGNITE

Processes¹ to hydrogenate coal or lignite and thereby recover various liquid products from it, generally involve the use of high pressure, temperature control, and in the case of lignite finely divided materials. A definite degree of purity of hydrogen is required and a period of time sufficient for the reaction to take place. The catalytic effect of certain materials present as impurities or otherwise, also must be taken into consideration. It is obvious that a process of this type¹ does not look very promising for the production of a cheap fuel¹.

The process for the hydrogenation of coal has been developed by Bergius. The time required for hydrogenation is given as about fifteen hours, the pressure being from 40 to 200 atmospheres, and the temperature 400°C.

SPECIAL FUELS FROM LIGNITE - BRIQUETTING

Attempts to produce a solid fuel from lignite which does not have the objectionable features¹ of raw lignite include the following: (1) Briquetting of the lignite by pressure alone or by the addition of suitable binders such as tar, lime, cement, water glass, starch or bitumens. (2) The preparation of a colloidal liquid fuel in which the finely ground solid fuel is held in suspension. (3) The preparation of so called amalgams of solid fuel with other substances. (4) The utilization of the dried or partly carbonized lignite, with other coals and binding materials. While these studies have been beneficial the problem has not been solved.

Considerable time and attention has been devoted to briquetting of lignites. The cost of briquetting lignite has been carefully worked out by the Bureau of Mines⁴. The cost of briquetting the lignite without a binder, exclusive of the cost of the lights itself is 83¢ per ton. This calculation was made in 1913. Where a binder is used (6% at \$12.00 per ton) the cost is estimated at \$1.06 per ton.

The lignite briquettes are said⁴ to resist weathering much better than the raw fuel. They also withstand handling better.

As a gas producer fuel the briquettes were 43 per cent more efficient, while as a boiler fuel they were 14.5 per cent more efficient than the raw lignite.

Lignite has been briquetted by the Bureau of Mines both with and without a binder. It does not appear likely that briquetting of western lignites without a binder will be successful. Various binders have been suggested of which pitch appears to be the best. The most economical plan applicable to lignite in the northwest⁴ appears to be to carbonize the lignite, sell part of the char directly as a fuel and to briquette the remainder with a binder made from the pitch recovered from the lignite tar, together with a comparatively small quantity of low-grade flour.

Carbonization followed by briquetting looks promising. In this way, raw lignite can be converted into a satisfactory fuel which has a comparatively high heating value and is well suited to domestic and other use.

The briquetting of lignite is also discussed by Stillman⁵. A complete bibliography is included.

LIGNITE AS A FUEL

Lignite can be burned¹ satisfactorily as domestic and boiler fuel. Stoves are available where lignite can be burned almost as effectively as the higher grade fuels. A larger stove is required however, since about two tons of lignite are equivalent to one ton of high grade fuel in heating value.

Lignite has been utilized as a boiler fuel¹. The employment of special grates, chain grates, step grates, and under-feed stokers are reported to give a fairly high thermal efficiency in the use of this fuel. Proper combustion facilities are all that is required to secure high thermal efficiency from lignite. Lignite is attractive as a boiler fuel. For further details, see Bureau of Mines, Bulletins 21, 40, 80, 89 and 135, and Technical Papers, 137, 205, 217, and 279.

THE USE OF POWDERED LIGNITE

Lignite can be successfully burned¹ as powdered fuel. Several factors however, tend to limit its use. In the raw state the moisture content of the lignite is so high that it is not readily pulverized, but tends to "ball up" in the pulverizer. Also, it does not readily ignite. While it is not necessary to remove all the moisture, in order to burn pulverized lignite, it is reported that the moisture should be reduced to possibly 10 to 12 per cent. This is equivalent to the evaporation of 399 pounds

of water for the preparation of 1 ton (2000 lbs.) of lignite with a moisture content of 10 per cent. Consequently, it is uneconomical to ship lignite appreciable distances to be dried.

A potent question then is where and how should lignite be dried and pulverized. It is recommended that the drying of the lignite take place at the mine. Some lignites however, ignite spontaneously after drying, unless they are carefully cooled. Consequently, the shipping of such lignite offers a problem. It is suggested that lignite of this type might be pulverized at the mines and shipped in air tight containers, or it might be partly carbonized at the mine and pulverized after arriving at its destination. The last method is considered the better, for several reasons. It is believed that a definite field exists for lignite handled in this way.

A description of the various methods for preparing and burning powdered fuel and the cost under different conditions, is given in Bureau of Mines Bulletin 217 published in 1923.

Powdered lignite has been shown to be an economical fuel¹ for steam raising, cement making, metallurgical furnaces and for many other purposes. When it is used for steam raising, with properly constructed boiler and furnace, an efficiency of over 80 per cent is claimed. It is considered a satisfactory fuel when the cost does not prohibit its use.

Lignite has been used successfully in the manufacture of decolorizing carbon. One well known commercial carbon is made from this material.

MORE RECENT DEVELOPMENTS IN THE UTILIZATION OF LIGNITE IN EUROPE

The most promising method⁶ for the utilization of Italian lignite is low temperature distillation at 450°C to yield about 25 per cent volatile products and 75 per cent residual semi-coke, the calorific value of which is 6500 calories.

The following developments are taking place in the utilization⁷ of Brown coal in Europe.

- (1) There is increased activity in briquetting, The briquettes are largely used as generator or producer fuel. They must be uniform and dry.
- (2) The extraction of montan wax is reported to be on the decline.
- (3) The Rolle method of carbonization is declining.

- (3) Continued
Newer methods of larger capacity are being developed. The coke is used for power or gas producers. The tar is recovered.
- (4) More improved methods are being developed for refining the tar.
- (5) The Bergius hydrogenation plant at Mersburg is technically successful.
- (6) Complete gassification is being employed as a means for the manufacture of city gas. Approximately 2,300 cu. ft. of gas with a heating value of 450 B.t.u. are secured from one ton of brown coal.

The most recent developments in the utilization of lignite in Europe is given in an article⁶ by Kerschbaum presented at the International Conference on Bituminous Coals, held in Pittsburgh, in 1928. According to this authority, about 3 billion tons of sub-bituminous coal exist of which this country has about 94 per cent. In spite of this fact, the greatest development in the utilization of this material has taken place in Germany.

About half of the German brown coal is burnt as raw coal, the other half being briquetted. Kerschbaum states that this briquetting process would be a satisfactory solution for the utilization of brown coal, were it not for the fact that briquetting requires a certain colloidal structure of the coal, which is found in Germany, and to a certain extent in Australia but nowhere else.

It follows that a more universal solution of the problem of utilizing sub-bituminous coal was needed. Kerschbaum considers that this has been found in carbonization. The conditions being different, carbonization processes had to develop in its own way in Germany independent of processes for coking bituminous coals.

The developments in carbonization processes began with the Rolle furnace. This furnace was used for many years. A more recent furnace based upon the principles employed in the Rolle furnace and designed to give greater efficiency is the Geissen furnace.

In order to utilize and develop the different types of sub-bituminous coal, which are different in both physical and chemical behavior, and which include coals ranging from lignites up to sub-and even to semi bituminous coals, Kerschbaum considers that a more general solution of the problems of carbonization was required. This was found in the development of producer gas practice and briquettes. Tar is obtained as a by-product of the producer gas.

This is obtained by carbonizing the briquettes in the upper part of the producer by the hot gas current itself. A rather high yield of tar, which was much desired, was secured in this way. Some 20 furnaces were erected according to this scheme.

In 1921, another group of German engineers⁸ still further developed the carbonization of brown coal, and succeeded in establishing a rather general system of carbonization known as the Lurgi Process. This process depends upon the following principles:

1. Any kind of fuel can be used provided it is non-coking. No pre-treatment is employed except in the case of coal dust.
2. Coke should be obtained of highest possible heating value, and reactivity. As far as possible the structure of the original fuel should be retained. Tar should be secured with high yield without cracking. There is no gas.
3. Heating up of the fuel should be done directly in order to secure heat economy. This should be done slowly to avoid disintegration. Hot gas currents passing through the coal should be used for this.
4. The hot gas and fuel should be led in counter current system thereby avoiding cracking and condensation of the tar.
5. The zones of drying and carbonization of the coal and the cooling of the coke should be clearly separated.
6. The carbonization temperatures of from 500°C to 1000°C should be applied without exposing materials of iron construction to this temperature.

From an engineering point of view the following are said to be of importance:

- (1) Units of high capacity, i.e., from 100 to 200 tons per day should be developed.
- (2) The entire three step process should be continuous.
- (3) The vertical shaft furnace should be used for the carbonization. The interior walls should be built of firebrick.
- (4) Heating of the gas current should be carried out outside the drying and carbonizing system.

- (5) No movable parts should be used in the furnace except for the motion of the coal (gravity) and the gases (by blowers).
- (6) The simplest possible construction should be used.

Briefly the process is operated as follows: The raw brown coal in pieces up to 4 or 5 inches is charged into the bin which is on top of the pre-dryer, by means of a special charging car. The fuel is fed from the bin into the pre-dryer, where the drying gases are forced through the layers of fuel in two stages. Drying is effected to 0 to 4 per cent moisture. The fuel passes from the pre-dryer through a hose system into the one stage carbonizer, the lower part of which serves as a cooling chamber for the coke. After cooling, the fuel is removed by a sliding table device.

The gases at equilibrium conditions act as follows: The gas passing off from the carbonizer which contains the tar is subjected to the action of the Cottrell electrical tar condenser and afterward is divided into two parts. One part which is the cooling gas current, is led back to the bottom of the carbonizing tower, while the other part passes through a cooler to a washer for recovery of light oil. The gas is then fed into two burners for heating the circulating gas currents exhausted from the carbonizing and drying zone.

Plants of this type are in operation in Greece, Hungary, Germany, England, and plants are under construction in the United States and Canada.

On North Dakota lignite containing 31.6 per cent water, this process is reported to give a coke with a calorific value of 6500 Cal. per kilogram, and a tar yield of 4.2 per cent (90 per cent of the theoretical). No additional fuel is required for the carbonization. Where the coke produced shows too much disintegration, briquetting will be necessary making use of the binder produced from the tar.

MISCELLANEOUS DEVELOPMENTS IN THE UTILIZATION OF LIGNITE

Lignite (American) as a future fuel is discussed by O.P. Hood⁹. Neither the Canadian effort costing over \$1,000,000, nor the American one has established a continuous operating plant on a business basis. Hood thinks that the plant most likely to succeed will be one of the greatest simplicity, of low initial cost, producing only lignite char briquettes which enter into competition with anthracite coal. He believes that the right combination of men, capital and method for a commercially successful industry

has not yet been found

Pulverized lignite fuel has been used¹⁰ in California at an experimental boiler plant. The lignite had a heating value of 12,016 B.t.u. per lb. and contained 54.6 per cent volatile matter, 26.3 per cent fixed carbon and 19.1 per cent ash. The lignite was partly air dried and was then further dried to 6 per cent water, 50 pounds of powdered lignite per ton of fuel being required for this purpose. The dried lignite crushed to 175 mesh, was air separated and stored in concrete bunkers. Evaporation averaged 9 pounds of water per pound of dry fuel. Flue gas temperature was 550°F. 50 per cent of the ash was carried out of the stack. As a result of the above tests, plans were drawn for a large steam electric generating plant, and three industrial power plants.

Tar has been recovered on a laboratory scale from lignite¹¹ by steam distillation. The lignite was steamed for 18 hours with superheated steam. The tar was completely removed with very little decomposition of the original bitumen. Also, 54.8 liters of gas were liberated per kilogram of dry coal as compared with 108 liters by external heating.

The recovery of oil and wax¹² from brown coal is discussed by R. Tedmayne. The occurrence, working and treating of brown coals according to German practice is discussed.

It has been found that lignite breaks down¹³ on pressure heating. Rhineland lignite was placed in 0.1 N.KOH and subjected to heating under pressure. Oxidation and saponification reactions take place. Possibly hydrogenation takes place also. About 25 per cent of the lignite is unattacked. Various acids, volatile fatty acids, non-volatile acids, humic acid, catechol and pyro-catechuic acid were found in the alkaline solution. The total yield of products was 68 per cent.

Relative to low temperature carbonization, Davis and Gallo-way give laboratory results from the distillation of 23 sub-bituminous coals and lignites by three different methods. Berthelet¹⁴ gives small scale results of the carbonization of lignites and bituminous shales. He concludes that the Salerni retort is one of the best adapted for this. The same writer reports¹⁶ that there is a revival of interest in France in connection with low temperature carbonization. This process should not only produce metallurgical coke and lead to the development of electrical power, but it should also aid in supplying liquid fuel. The horizontal Salerni retort is said to be best for this work. The various systems for the distillation of coal are divided into 3 groups depending upon the method of applying the heat to the coal. Several systems for the distillation of coals¹⁷, especially for

brown coals and lignites are described with comparative costs of the different systems, with diagrams and illustrations. Work done by the Canadian Department of Mines¹⁸ shows that a Saskatchewan lignite with a water content of 35 per cent and calorific value of 7200 B.t.u. can be transformed to a fuel of 75 per cent greater value by drying and carbonizing processes.

Some of the advances in the utilization of lignite in gas producers are given below. The best conditions¹⁹ for the gassification of lignite in a producer are (1) a slowly downward moving fuel column. (2) A uniform blast distribution over the cross section of the producer and thus a horizontal zone of combustion. A producer utilizing these principles is described. Modern requirements in German producer design for gassification of lignite is discussed by Curt-Bube-Halle²⁰. The removal of all the tar formed is complicated by the filtering action of the moist fuel in the drying zone. However, this is desirable since it removes coke breeze from the gas. Slag formation and ash handling, regulation of water vapor, and air distribution are still partly unsolved problems.

Low temperature carbonization coke from sub-bituminous coal is an ideal fuel²⁰ for pulverized coal firing. This coke also must be regarded as a new and valuable raw material for chemical purposes. Examples are the use of this coke for adsorption carbon, and in gas producers. Its use here is advantageous in that the reaction $C + 2H_2O = CO_2 + 2H_2$ is approached whereby 2 molecules of hydrogen are secured per atom of carbon instead of one as is usually the case.

UTILIZATION OF PEAT

The utilization of peat has been extensively investigated in many parts of the world. Some of the countries investigating this problem have been Ireland, Canada and United States.

Peat is widely distributed in United States nearly half of the states of the Union containing this material. The northern states containing most¹ of this material are: Minnesota, Wisconsin, Michigan, New York and Maine. It is also reported in large quantities in Virginia, North Carolina, Florida, Oregon and Washington.

It might be mentioned here that attempts to utilize peat have attained considerable success. The various methods that have been employed for peat might be classified as follows:

- (a) Peat as a Fuel.
- (b) The Use of Peat in Gas Producers.

- (c) Destructive distillation of Peat.
- (d) Briquetting of Peat.
- (e) Miscellaneous uses of Peat.

The various uses for peat are discussed below in some detail.

PEAT OR A FUEL

Peat often contains 80-90 per cent water. When relatively dry¹ it is often a satisfactory fuel. The removal of the excess water is one of the chief difficulties in the use of peat as a

The removal of the water by pressing is not generally satisfactory. Only a relatively small amount of the water is removed in this way. The removal of the excess water by solar or artificial heat is more promising. At the present time the use of artificial heat has been discarded as not being practical.

Practically all of the methods which have been successful depend upon the utilization of solar heat for the drying of the peat. In order to reduce the cost of manufacture, the peat is usually excavated, macerated, dried and harvested by the aid of machinery especially designed for this purpose. The peat is usually removed from the bog by a floating dredge which travels along the bog, or by a steam shovel. In some cases specially devised excavators seem to be best suited for this purpose.

Peat has been recovered in Europe on a considerable scale in some years with fair success. Of course conditions are quite different in this country, and results secured in Europe are not dependable, necessarily, in this country.

The most extensive investigation of the production of peat fuel, on this continent, has been carried out by the Canadian Government¹ with the expenditure of nearly a half million dollars. This work was later transferred to a private company. Since conditions of production are much the same as those in the northern part of the United States, this work is of particular interest.

The peat is dug by a specially designed chain and bucket excavator. This excavator cuts a section thirty feet wide. The machine has a capacity of over 150 cubic yards of material per hour. The peat is automatically delivered to a grinder which thoroughly macerates it and deposits it on a belt conveyor which extends several hundred yards into the drying field which is at right angles to the working face. The peat is discharged automatically into a spreading device which spreads it on the bog.

a layer 12 feet wide, 5 inches thick and nearly 800 feet long. The machine cuts the peat into blocks 10 inches long and 5 inches wide. When one row of peat blocks have been put down, the spreading equipment moves forward the width of another row and the operation repeated. It is said that about 100 tons of peat blocks can be laid every 10-hour day.

The peat is exposed to the weather until the moisture content is reduced to about 30 per cent. Contrary to what might be expected after the peat has been exposed to the air for a time it does not readily take up water. Consequently, it is not necessary to protect it from weather during the drying period.

The peat fuel is cut into blocks about 8 inches long, 2 1/2 inches wide and 2 1/2 inches thick for the market. It is reported as having a heating value of about 7,000 B.t.u. per pound, one ton having a volume of about 60 cubic feet. It is readily ignited and with a free draft gives a long fat flame. Peat fuel is recommended for use in open fire places, cook stoves and for similar purposes. It has been used also for the generation of power. No clinkers are formed during the combustion of the peat, nor does it give the dark colored smoke which one secures from bituminous coal.

The various methods that have been developed for the mining of the peat are very numerous. A recent development² applies hydraulic mining to this material. It is reported that this process has been in operation in Russia for several years. The peat is disintegrated with a stream of water at 300 pounds pressure. The water containing the peat is pumped through pipes and spread on drying fields to form a layer 20 cm. thick. Furrows are cut in the bed of peat by a special tractor-driven roller so that efficient drying can be secured. A single unit of the plant will recover 20,000 to 30,000 tons of air dried peat per year. The process effects a saving of 40 per cent of the cost of production of air-dried peat.

The profitable utilization of peat as a fuel depends in large measure upon the cost of coal and other fuels. According to the 1922 report of the peat committee², the cost of peat for a 10-hour day is \$4.48 per ton, while for a 20-hour day it is \$3.50 per ton. It is estimated¹ that Illinois coal at \$5.00 to \$5.25 per ton is equivalent to peat fuel at \$2.53 per ton, without including the extra handling charge which must be paid for peat.

BRIQUETTING PEAT

The briquetting of peat has been investigated by many experimenters. It is reported¹ that as far back as 1856 there was

attempts in Europe to produce briquettes from peat. The air dried peat was screened and the finely divided material dried in an oven to a moisture content of 12 to 15 per cent, and pressed into briquettes in a high-pressure briquetting press. Plants for producing these briquettes were unsuccessful, the peat entering into competition with a higher grade fuel that was even cheaper than the peat.

The so called "Ekenberg wet carbonizing process" is said⁴ to have interesting possibilities. The peat as obtained from the bog is charged into retorts where it is heated to 150°C at a pressure up to eight atmospheres. The water distributed throughout the peat serves as a heating medium causing charring to take place.

The peat heated as described loses its colloidal nature which promotes the removal of water later. A slight charring is reported, the material turning black. Hydrocarbons that would be lost ordinarily are retained by the peat. Water can be pressed easily from the charred residue which is briquetted.

Plants employing the above process were established in both Sweden and Scotland, but were not very successful. Eventually, both plants ceased operations. A company known as the Wet Carbonizing Limited had established the plant in Scotland with the support of the British Government. The plant commenced operations again at the beginning of the world war. The modified process is reported as follows: Peat with 93 per cent moisture is pulped and then forced by hydraulic pressure into steam jacketed pipes two inches in diameter. In these pipes the wet carbonization takes place. The peat is then forced by a pressure of 120 pounds per square inch into filter presses. Here the water is reduced to 25 per cent. The pulverized filter cake is then blown through boiler flues where the moisture is reduced to a very low figure. The material is then briquetted upon an open-mold press.

Peat briquettes have been made successfully on a roll press⁵. The Peat Products Corporation employing a Universal press, is turning out a good grade peat briquette which is said to bring a good price in the neighborhood of Grand Rapids, Michigan. The process consists simply of passing the air-dried peat containing about 35 per cent water directly into the press. The peat goes through a secondary drying after it has attained the briquette form. This is accompanied by both setting and hardening and the development of weather proofing qualities.

The finished briquette is hard, can be shoveled and has about 67 per cent of the heating value of coal. It is reported that these briquettes due to their excellent heat radiating

value and to the fertilizer value of the ash might bring a price not far below that of the best coal.

Peat briquettes are claimed⁷ to be an excellent house fuel. They have been used also for the production of peat charcoal. Peat bricks⁷ have been produced which are successful for paving purposes.

DISTILLATION OF PEAT

In 1920 and 1921 extensive investigation¹ of the carbonization of machined peat was made by the British Research Board. The peat used is said to be very similar to much American peat. The dried peat was in blocks about 10 inches long and a cross section of about 2 inches. A Glover West vertical retort was employed, with a capacity of 3 tons of peat per 24 hours. Steam was introduced at the base of the retorts to quench the char. The char is said to be an ideal fuel for suction gas producers.

The yields are as follows:

Ziegler process. In this process air dried machine peat briquettes containing about 25 per cent water are carbonized in vertical retorts. The peat is charged at the top of the ovens and the coke withdrawn at the bottom. The by-products are worked up yielding paraffin, creosote, gas, oil, acetates, wood alcohol and ammonium sulphate. The better grade peat is used to produce a charcoal to be used for smelting purposes. The lower grade peats are used for a semi-coke, which still contains part of the oil matter.

The vertical retorts used in the Ziegler process are about 40 feet high with an elliptical cross section. They rest on a cast iron foundation. Above this is a hopper for discharging the charcoal. Cast iron covers at the top carry the feed boxes. The maximum temperature attained in the retorts is approximately 600°C.

The Willmarth process¹⁰ employs an interesting principle. The raw peat is thoroughly disintegrated and the moisture reduced to 25 per cent. It is then carbonized and the by-product recovered. The peat charcoal, while still warm, is mixed with 50 per cent air dried peat, the mixture thoroughly mixed and the mixture briquetted in an open-mold Exter press.

Peat is sometimes carbonized in much the same way as wood. The disintegrated peat is carried slowly through a series of heated horizontal retorts by means of a screw conveyer. In at least one instance the peat is only partly carbonized (250°C) the semi coke being briquetted at high pressure in a hydraulic press.

GASSIFICATION OF PEAT IN GAS PRODUCERS

The greatest difficulties in the utilization of peat are due to its great bulk and to the high water content. In a gas producer these difficulties are overcome in large measure. The bulk of the peat is not an unsurmountable difficulty, while water if not already present is added in the form of steam.

Power plants employing peat in gas producers as a source of power are in operation in Europe¹. Relatively little progress has been made along this line in this country. The reasons for this are said to be more economic than technical. The peat enters into direct competition with coal and other high grade fuels which are little if any more expensive than the peat at the present time.

Both producer and water gas may be made from peat. The by-products may or may not be recovered, as desired. At one producer gas plant¹¹, operating on peat, one ton of theoretically dry peat, gave from 88,000 to 92,000 cu. ft. of gas. If 39,000 cu. ft. is used in the preheater, from 49,000 to 53,000 feet remain, which will give 700-750 h.p. hrs. From 70 to 85 per cent of

the nitrogen is recovered as ammonia.. The tar yield is from 3 to 6 per cent. The by-products are said to pay the whole working expense.

Using peat containing 50 per cent water, a producer employing peat produces 1,000 h.p. per hour while the same producer on coal produces 3,000 h.p. per hour.

Figures given by the Bureau of Mines¹ show that producer gas made from peat is much more expensive than that made from coal. For example, the cost of the gas without regeneration or scrubbing, made from bituminous coal and peat each at \$3.00 per ton is \$3.42 per 1000 feet (145 B.t.u. per cu. ft.) for coal gas and \$7.32 per 1,000 feet (145 B.t.u. per cu. ft.) for the peat gas. The coal had a calorific value of 14,000 B.t.u. per pound, while the peat had a calorific value of 6,750 B.t.u. per pound and contained 25 per cent moisture.

The production of water gas from peat has been suggested by the Bureau of Mines (Bull. 253, "Possibilities for Commercial Utilization of Peat". p. 119). Under certain assumed conditions it is approximately as cheap to make gas from peat as from coke. This comparison does not take into account the extra handling of the larger volume of peat required and the removal of the increased quantity of ash. For further details see the bulletin mentioned above.

MISCELLANEOUS USES OF PEAT

Peat has been suggested as a source of liquid fuel¹². It is reported that liquid fuel can be economically recovered from peat, where the peat gives a high yield of primary oils, or where the yield of liquid fuel is increased by catalytic action or by cracking.

The yield of oil by the semi-commercial low temperature carbonization of peat was 7 per cent. Some of the products recovered from this oil are as follows:

Refined gasoline -----	13.88 per cent
(P.P. 110-225)	
Gas, oil -----	12.07
(B.P. 105-330)	
Lubricating oil -----	9.28
Phenols and cresols -----	15.55
Acid resins. -----	4.14
Pitch -----	4.90
Paraffin (M.P. 40°G) -----	3.82
Pyridine and other bases -----	6.43
Residual cokes -----	5.73
Total losses -----	27.06

The miscellaneous uses of peat are summarized below¹³.

(1) Ethyl Alcohol from Peat.

It is well known that various cellulose containing materials can be hydrolyzed into glucose by enzymes or dilute mineral acid. The glucose is then fermented by yeast, giving grain alcohol which is recovered by distillation. This method has been applied to peat. The method is not considered very promising due to the relatively low cellulose content of the peat, the high dilution of the alcohol, and to the fact that the refuse from the peat has very little value. It is reported that the production of alcohol from wood waste sawdust, etc., has not been a pronounced success, although the yield of alcohol is nearly twice as great as from peat. (Yields calculated on the dry basis)

(2) Peat as a Fertilizer.

The adsorptive properties of peat and its ability to retain water are said to be of value in the preparation of composts and in utilizing them in fertilizers. Peat itself is not considered a concentrated plant food although certain types of soil are appreciably benefited by the addition of peat, the peat acting as a "soil conditioner". The peat is also considered in some cases to have some fertilizer value. The partly decayed peat or "humus" is considered to be much superior to ordinary peat as a conditioner.

Other possible uses for peat¹³ include its use as a filler in fertilizers, the use of fibrous peat as bedding for stock, as an insulating material (heat), for absorbent or decolorizing carbons, for porous brick, in sweeping compounds, and as a substitute for sawdust and wood flour.

IV. RECOVERY OF WASTE PRODUCTS IN THE COKING OF COAL

SULPHUR FROM THE HYDROGEN SULPHIDE PURIFIERS

When the coke oven gas containing hydrogen sulphide is passed through the iron oxide in the purifiers, the two react forming iron sulphide. One of the products of the reaction is free sulphur. This collects in considerable quantities in the purifiers. The sulphur can be recovered by extracting with carbon disulphide or by other solvents. This product is probably of declining importance on account of the growth of "wet" methods for the removal of the hydrogen sulphide. For more recent methods for removal of sulphur from gas, see an article by F. W. Sperr, "Gas Purification in Relation to Coal Sulphur, I C.B. (1928) Vol. II. p. 37.

RECOVERY OF CYANOGEN COMPOUNDS

Cyanogen compounds are present in various liquors and gases derived from by-product coke oven plants. They are found chiefly

in the gas, quenching liquor, still waste and liquor from the secondary cooler. Attempts to recover these products were quite numerous some years ago. The belief held today, with few exceptions, is that their recovery is hardly worthwhile, except in a few isolated cases.

A method¹ which has been employed for the recovery of cyanogen from the gas consists of scrubbing the gas with a solution of ferrous sulphate. The ammonia and hydrogen sulphide contained in the gas, reacts with the ferrous sulphate to form ferrous sulphide. This reacts with more ammonia and cyanogen to form the insoluble iron-ammonium cyanide. This substance present as a black mud, is filter pressed and decomposed with lime to form calcium ferrocyanide, which is drawn off from the residue and decomposed with potassium carbonate yielding potassium ferrocyanide. The ammonia can be recovered by distillation.

In case the ammonia has been previously removed from the gas, it is necessary to add sodium carbonate to the ferrous sulphate solution.

DRY QUENCHING OF COKE

By the ordinary or wet quenching method, the coke is pushed from the oven into a steel car which passes under a tower where it is sprayed with water. This method is wasteful since the sensible heat of the coke is not recovered.

It has been suggested that this heat of the coke be recovered. This has been successfully accomplished about three-fourths of the heat being recovered as steam. Various other advantages are claimed, some of which are a cleaner coke, a coke which has less tendency to shatter on cooling, more uniformity in size, and somewhat better efficiency on combustion. The procedure consists essentially of the discharge of the coke into a closed container, the heat of the former being utilized by radiation to boilers or by heating circulating gases.

A method for the dry quenching of coke which has been successfully operated for several years on a large scale is described by F. J. Pfluke². The coke is delivered to a brick lined, closed container. Air, from which practically all the oxygen has been removed, is passed through the hot coke, and is then delivered to boilers where it serves for the generation of steam.

By making certain adjustments in the process, 506 pounds of steam were produced per 1000 pounds of coke. The coke possessed a smaller average size than that produced by wet quenching, is more resistant to handling, is cleaner, and is more efficiently burned.

Various intangible benefits were also secured.

From an economic standpoint this process is claimed to be very promising. When the value of steam is taken as 50¢ per 1000 pounds, the dry quencher showed a return of over 20 per cent on the investment. It is estimated that the process will become even more attractive as the coke production increases.

RECOVERY OF PYRIDINE

Pyridine is found in relatively small quantities in coal tar, crude light oil and in the ammonium sulphate.

When various fractions of oil distilled from coal tar are washed by sulphuric acid the pyridine is removed in the acid sludge as pyridine sulphuric acid. Pyridine is sometimes recovered from the sulphuric acid washings of the light oils (from coal tar or from coke oven gas). Ammonia gas is passed into the solution and the latter is partly saturated. The liquid separates into two layers, the bottom one being a solution of pyridine ammonium sulphate. This layer is removed and completely saturated with ammonia. The pyridine which collects as an oil is drawn off and fractionated.

Much of the pyridine can be removed from solid ammonium sulphate by heating. A method for the removal of pyridine from ammonium sulphate solution³ consists of the steam distillation of the solution.

The heat which is liberated when pyridine sulphate is decomposed by ammonia is said to be⁴ enough to evaporate and distill the free pyridine.

Ethyl Alcohol From By-Product Gas

After purification of the coke oven gas the illuminants still present in the gas amount to approximately 2.5 per cent. This is nearly all ethylene. Various attempts have been made to convert this into ethyl alcohol. The usual procedure consists of bubbling the gas slowly through hot concentrated sulphuric acid. Some provision is made to secure good contact between the acid and the gas. The acid is then removed, diluted and the ethyl hydrogen sulphate hydrolyzed to alcohol by water or steam. The alcohol is recovered by distillation of the diluted acid solution.

Many attempts have been made to develop the above process on a practical basis. The chief difficulties lie in the impure alcohol ordinarily recovered, and in the expense of reconcentrating the acid. Because of these difficulties the process is not

considered very promising at the present time.

RECOVERY OF PHENOLS FROM ALMONIA STILL WASTE

The purpose of the earlier work carried out along this line was to remove the toxic substances from this material, so that its disposal would not be a problem. Coke oven plants employing the direct system of by-product recovery secure from 20 to 25 gallons of still waste per ton of coal. The liquor contains phenols, sulpho and ferro cyanides in quantities often amounting to one or two tenths of a per cent. These materials are present in sufficient amount to kill fish life and to give a decided taste to river water miles from the point where the still waste is discharged into the river.

Earlier attempts to purify the waste consisted of its use for quenching coke, which was fairly satisfactory and adsorption of the phenols by lignite peat, or animal charcoal. Bacteriological processes were also developed. The bacteria found in ordinary sewage possess the ability of destroying the toxic properties of the largely diluted waste.

Recent methods make an attempt to recover the phenols. The usual method employed consists of extracting the crude phenols from the liquor by benzene. The phenols are then removed from the benzene by sodium hydroxide solution which on acidification, liberates the phenols. According to H. E. Jones⁵, phenols can be extracted continuously from the crude liquor by motor benzene, with an efficiency of 96 per cent. The phenols are then removed from the benzene by 23 per cent sodium hydroxide solution. The sodium phenolate on acidification with 60°Be sulphuric acid gives a crude phenol of the following volumetric composition: Phenol 54 per cent, Cresol 23 per cent, Water 16 per cent, and tarry matter 7.0 per cent.

The German cost of recovering the phenol by a similar process is given as 5 cents per pound.

V. RECOVERY OF WASTE PRODUCTS IN THE REFINING OF TAR OILS

Tar, once a waste product, is now distilled and the distillates separated into several fractions. The usual fractions are approximately as follows: (1) Up to 170°C. Benzene fraction. (2) From 170°C, to 270°C. Creosote Oil fraction. (3) 270°C. to 350°C. or 400°C. Anthracene oil fraction. (4) Residue - Pitch.

It should be noted that the temperature ranges for the above fractions are varied according to the market for the various products. For example, if a soft pitch is desired for some special purpose the temperature may be carried only to 350°C. or even to 300°C.

The Benzene fraction contains Benzene and its homologues Toluene and Xylene, ammonia liquor, small amounts of phenols, pyridine and other impurities. The ammonia liquor is separated and the oil redistilled, and then washed with about 5 per cent of concentrated sulphuric acid, whereby, phenols, sulphur compounds and unsaturated hydrocarbons are dissolved or resinified. The impure acid settles to the bottom and is drawn off. The oil is washed with water, and then with dilute caustic soda which dissolves pyridine and other organic bases, the alkali liquor drawn off, the oil collected and fractionally distilled. The fractions may be collected, i.e., (1) First Runnings, up to 70°C. (2) Crude Benzol, 70°C. to 170°C. (3) Residue above 170°C.

The first runnings contain carbon disulphide, pentane and hexane. The crude benzol secured above may be rectified and separated into pure benzol, toluol, and Xylol. If desired, the benzol, toluol and Xylol may not be separated, the whole fraction being sold as a motor fuel.

The creosote oil is allowed to stand, when large quantities of naphthalene crystallize out, and are separated by filtration. The mother liquor contains considerable phenol which may be recovered by extracting with a 10 to 20 percent caustic soda solution. The alkaline liquid is drawn off from the oil and acidified, whereby, the phenol collects as an oil on top. Much of the crude liquor, after removal of the naphthalene, is sold for the creosoting of timber.

The anthracene oil is highly complex. The chief valuable constituent is anthracene, which is present in relatively small amounts.

The pitch is the residue remaining in the still and consists of 50 to 60 per cent of the tar.

The products collected from the various fractions are used for a great variety of purposes which include insecticides, ammonia fertilizers, disinfectants, motor fuels, solvents, explosives, dyes, synthetic perfumes and drugs and the creosoting of timber.

For further details on the distillation and refining of coal tar, the reader is referred to a larger work.

RECOVERY OF VARIOUS WASTES

Almost pure motor benzene, sulphuric acid of a reasonable strength, and a carbonaceous fuel¹ has been recovered from the acid sludge drawn off in the washing of crude benzene with conc. sulphuric acid. The sludge is steam distilled, whereby, the benzene

is distilled off, the acid liquor remaining is filtered from the residue, which is soft and sponge like. The crude benzene can be purified by washing and redistillation, if desired. The acid liquor contains 35 to 55 per cent sulphuric acid. The residue could be used as a fuel. It contains 74 per cent volatile matter, 25 per cent fixed carbon and 1 per cent ash.

Resinous products² have been recovered from the waste sulphuric acid from benzene purification by extracting with a solvent.

Resins have been recovered from benzene plant residue³ by dissolving in solvent naphtha, separating the insoluble matter from solution, and distilling the solution to 150-300°C. air or steam being blown in to remove naphthalene or other volatile substances.

The acid can be recovered from the solid sludge by steaming. On standing the empyreumatic resin separates out at the surface. The solution is then filtered through coke or other inert material. The collected acid which is dark colored is approximately 40-50°Be and is used for various purposes. The resin can be collected and distilled if desired.

The caustic soda solution from the washed benzene is sometimes worked up for the recovery of phenol. The excess alkali may be neutralized with sulphuric acid recovered from the acid wash, or by carbonic acid made by burning coal. The phenol collects on top. It is separated from the liquor and may be refined by distillation or used for creosoting.

Caustic soda solution from the washed benzene is used to some extent⁴ directly as soda creosote for impregnating mine timbers.

COAL

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