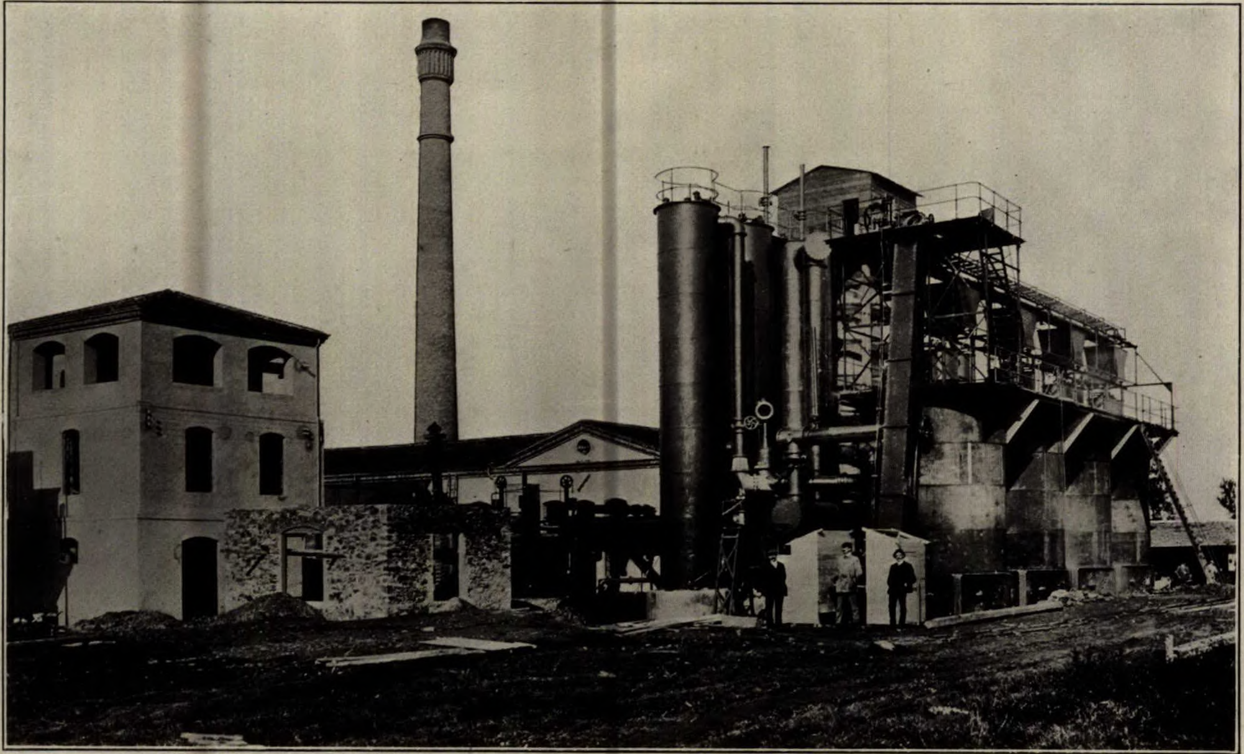


Mond by-product recovery producer.

CANADA
DEPARTMENT OF MINES
HON. LOUIS CODERRE, MINISTER; R. W. BROCK, DEPUTY MINISTER.

MINES BRANCH
EUGENE HAANEL, PH.D., DIRECTOR.

Peat, Lignite, and Coal

Their Value as Fuels for the Production of Gas and Power in the By-Product Recovery Producer.

BY

B. F. Haanel, B.Sc.
Chief of Fuels and Fuel Testing Division

OTTAWA
GOVERNMENT PRINTING BUREAU
1914
No. 299

LETTER OF TRANSMITTAL.

Dr. Eugene Haanel,
Director of Mines Branch,
Department of Mines,
Ottawa.

Sir,—I beg to transmit, herewith, my report on Peat, Lignite, and Coal: their value as fuels for the production of gas and power in the by-product Recovery Producer. The information and data relating to the By-product Recovery Producer industry in Europe were gathered on the spot, by the commission appointed to study the status of the European industry. The commission consisted of myself, and my assistant—Mr. John Blizard, B.Sc. In submitting the report as a whole, I have pleasure in acknowledging my indebtedness to Mr. Blizard for valuable suggestions and criticisms; especially in the preparation of the chapter dealing with the generation of power; and for individual work done in connexion with the notes and curves treating on the drying of peat by air, and, in the making of the tables and curves showing the effect of moisture on the calorific power of peat. Credit is also due to Mr. Edgar Stansfield, M.Sc., for the valuable assistance rendered by him in connexion with the calculations relating to the allowable moisture content in the peat utilized in the Mond producer.

I have the honour to be,

Sir,

Your obedient servant,

(Signed) **B. F. Haanel.**

Ottawa, April 7, 1914.

CONTENTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

PAGE

CHAPTER VIII.

CHAPTER IX.

ILLUSTRATIONS.

Photographs.

Drawings.

Tables.

PEAT, LIGNITE, AND COAL:
THEIR VALUE AS FUELS FOR THE PRODUCTION OF GAS AND POWER IN THE BY-PRODUCT RECOVERY PRODUCER.

PEAT, LIGNITE, AND COAL:

Their Value as Fuels for the Production of Gas and Power in the By-Product Recovery Producer.

INTRODUCTORY.

The trend of present day civilization is in the direction of increasing industrial activity; it is natural, therefore, to look for rapid increase in the production of manufactured commodities of all kinds. In order to maintain this marked increase in the rate of production, fuel in some form is required in ever increasing quantity; and on account of the feverish industrial pace that has been set, the principal sources of the more commonly used fuels are rapidly approaching depletion. Conservative estimates have placed the life of the coal deposits—which at the present time constitute the most valuable fuel—at between one and two hundred years. Hence, it is evident that our present civilization is almost directly dependent on fuel. Consequently, with fuel, more than with any other of the natural resources, is man concerned; for, when the deposits of this natural resource become exhausted, commerce and industry will cease to exist. But while all the natural fuels with which we are acquainted, and which we have learned to use, will, in any case, become extinct in time, there are ways and means of prolonging their life. Reduction of waste, and the employment of more efficient methods for the conversion of the heat energy of the fuel into useful work, will effectively contribute to the desired end. But to these must be added other economies, such as the reservation of the respective fuels for the purpose or purposes to which they may be most economically applied.

It must be apparent to all who have studied the question, that all fuels are not of equal value: for instance, in the production of power, one coal may prove as economical as another; whereas, for metallurgical purposes, where coke is required, only a coking coal will serve the purpose. But all bituminous coals do not possess coking properties; neither do all coking coals produce the same quality of coke. Hence, it may be said, that the various fuels are individually adapted to one or more specific purposes; from which they cannot be diverted without disadvantage. By way of illustration, take the question of generating power, for which purpose the prime requisite is heat: in this case one class of coal, which possesses a certain heating value per unit, is just as suitable as another of like heating value, nothwithstanding the very marked differences which may exist in their composition. A coking coal, in this case, would serve the purpose as well as a non-coking coal; but the non-coking coal could not be substituted for a coking coal when the product required is coke. The same reasoning applies in an equal measure to other fuels, petroleum for example. Petroleum, when utilized in its crude state as a fuel for various purposes, cannot command a much higher market price per 1,000 heat units than any other suitable fuel. In the case of petroleum, the choice lies in the greater convenience with which it can be stored and handled. But petroleum when submitted to a fractional distillation, yields oils of various descriptions, in addition to numerous and valuable by-products; the same does not hold true with the solid fuels, so that it will be seen that petroleum is specially adapted for the manufacture of other fuels, which are indispensable and practically irreplaceable for many and varied purposes both in the arts and industries.

There are, however, certain fuels which are found in great abundance but which are not, at the present time, especially valuable for any one particular purpose. Among these fuels may be classed lignites, and peat, though from both these fuels valuable oils, and other by-products can be obtained by distillation; while coke—which is of special value for some purposes—can be obtained from peat. No economic process, however, is in existence which can effect the distillation of these fuels profitably. Their main value is as generators of heat and they can therefore be best used for the generation of heat for power, or for domestic purposes. By thus classifying the various fuels, according to the purpose for which they are best suited, and for which another fuel cannot be substituted; and ascertaining the most efficient method or process to employ for that particular purpose, conservation will be attained in the most economic manner, and the rapidly decreasing life of the various sources of fuel, considerably prolonged.

The problem which confronts Canada, however, is, not conservation; but the best means of rendering available the various supplies of low grade fuels. The great Coal Measures of Canada are situated in the extreme east and west; but, lying between these points is a vast territory devoid of coal measures, which is, at the present time, dependent on some foreign source for a fuel supply. In one sense conservation is being practised to a very high degree, because, in certain parts of the country, practically all the coal required for industrial and domestic purposes, is being imported from the United States, while valuable fuel deposits are lying practically intact. But this kind of conservation never leads to commercial or industrial prosperity, and cannot, therefore, be recommended. In order to render those portions of Canada which are devoid of Coal Measures independent of foreign supplies of fuel, at least to some extent, it is necessary to convert into some convenient form the great source of potential energy represented by the peat bogs, which are of great extent and well distributed throughout the middle Provinces; and the same necessity applies to the lignite coals which are found distributed throughout the prairie Provinces.

Many of the peat bogs, which are peculiarly adapted for manufacture into fuel for domestic and power purposes, are conveniently situated as regards transportation facilities, and contiguous industrial communities. But notwithstanding this, the manufacture of the raw peat, contained in certain of the bogs, into a marketable fuel has not, up to the present time, met with much success; due, on the one hand, to the long list of failures recorded by those who have impracticably interested themselves in this problem during the past years, and, on the other hand, to unscrupulous speculators, promoters, and so-called inventors. The failures, so far recorded, may be ascribed principally to the methods employed for manufacturing the fuel. It is a fact that a flourishing and permanent peat industry has been established in Europe for almost a century, but no one, in this country, thought of turning to the European peat using countries for advice and enlightenment concerning the best process to employ for the manufacture of peat fuel in Canada. This seems incredible, especially at the present day, when the inventor of processes is still able to hold the attention and sometimes the purse strings of astute business men.

In Europe the annual production of peat is large. In Russia alone, during the last year, over 2,500,000 metric tons were produced; together with a large output in Germany, and other countries. The process employed in all the European countries is the air-dried machine peat process, sometimes called the "wet process": and this is the only economic process for the manufacture of peat fuel known to-day.

Unless the manufacture of peat fuel is conducted on a bog situated reasonably near a community which is able to take over the entire output produced, peat manufactured for domestic or fuel purposes alone would not prove a profitable venture. This is due to the comparatively low heating value of the peat to its moisture content, and to the large volume it occupies, per heat unit, as compared with coal; and when to these disadvantages is added that of high freight rates per ton, the reason of the foregoing statement will be obvious. But while peat may serve as a domestic fuel in only certain cases, it may be well adapted for the production of power, or as a fuel gas. This is especially so in the case of peat which has a high nitrogen content, since this element can be profitably recovered in the ammonia gas formed in the by-product recovery producer. According to the process employed in by-product recovery work, the ammonia gas is fixed with sulphuric acid, and the resulting product "ammonium sulphate" is then sold for agricultural purposes. The demand for this commodity is, to-day, greater than the supply, consequently its price per unit is somewhat high. Whenever, therefore, the nitrogen content of the peat is sufficiently high, the production of a fuel, or power gas, accompanied by by-product recovery, would prove profitable. But in the case of the production of power, the same economies must be introduced into the manufacture of the fuel that apply to a domestic fuel, and even though the content of nitrogen is well above the average, any increase in the cost of fuel rapidly decreases the expected profits. Peat is a low grade fuel which must be manufactured and sold at a comparatively low cost, if it is desired that it should serve as a substitute for coal. It is evident, therefore, for the foregoing reasons, that the manufacture of peat fuel does not hold forth any glowing prospects for getting rich quickly, although reasonable and very good profits should in almost every case be realized when the industry is run on a business-like basis. But the element of speculation, and some of the commonly practised methods of promotion must be eradicated if the peat industry is ever to become an accomplished fact.

In order to encourage the peat industry of Germany, technical societies have been formed, which are under the supervision of the Government; and it is their function not only to educate the people in the uses and manufacture of peat, but to discourage and make impossible the aquisition of peat lands for purposes of speculation.

In one well known instance, the German Government has undertaken the development and cultivation of a large tract of peat land; and its aim is to put this, otherwise waste land, into condition for agricultural purposes. When the project is completed, this particular moor of large extent will be homesteaded by about 3,000 farmers. In order to further promote the interest of agriculturists, and make their lot a happier one, a central power plant is erected on the bog for the purpose of cultivating the entire bog and for operating the agricultural implements of the farmers. Power at this plant is generated entirely from peat, which is manufactured by the government, and sold to the power company for about $1.25 per ton. The quantity of peat required to generate the power at present produced is about 60,000 metric tons annually, but when the plant is operating at maximum load: viz., 10,000 horse power, this quantity will be very greatly increased.

There are certain bogs in Canada, of very large extent, well suited for the manufacture of peat fuel for domestic purposes, and the production of power. and such bogs might be cultivated and colonized in a similar manner. All ploughing, harvesting, etc., could be performed by electric power, and the homes, in addition, lighted by electricity. In this way, a worthless tract of land could be converted into agricultural land of value.

If peat can be manufactured successfully in the northern part of Germany, where the climatic conditions are not so favourable as those obtaining in Canada, it is within reason to assume that the same or a greater degree of success could be realized in this country.

In order to assist the peat industry of Canada, and to place it on a firm foundation, those who had during past years been interested in the actual attempts to manufacture peat, but who had failed, petitioned the Government to send a commission to Europe to investigate and report upon the methods and processes there employed for generating power from peat. Especial attention was paid to the by-product recovery gas producer power plants, and to the methods for preparing the peat for gas producers or steam boilers, as the case might be.

In the following report, the writer has described, in some detail, the methods for manufacturing peat fuel, and has laid considerable stress on the problems encountered in removing by pressure or by means of artificial heat the contained water. It is shown that the artificial drying of peat cannot be accomplished economically, and that to attempt to reduce the water content of the raw peat to below 76 per cent by hydraulic pressure will result in commercial failure. It is further shown that, with peat costing $1.50 per ton delivered at the producer plant, and having a nitrogen content of 1·5 to 2 per cent, power can be produced as cheaply as with some hydro-electric plants; and, that where only gas is generated, the revenue derived from the sale of the ammonium sulphate produced is sufficient to pay a profit on the investment, and to deliver the gas free of charge.

The same cases have been considered for plants utilizing lignite and coal as fuel.

ACKNOWLEDGMENTS.

In concluding this introductory note, the writer wishes to express his thanks to the following companies for the courtesies extended to him during his visit to the various plants: The Power Gas Corporation, London, England; The Siemens and Halske Electrical Company, and the German Mond Gas Company of Germany; and the Mond Gas Company, Italy.

The plans of typical plants, as well as the detailed information concerning plant costs and costs of operation, were furnished by either the Power Gas Corporation or managers of the individual plants. For the illustrations and detailed information relating to the cultivation of the Wiesmoor, together with the description of the power house, the writer is indebted to Prof. Teichmüller, of the Karlsruhe Technische Hochschule.

CHAPTER I.

MANUFACTURE OF PEAT FUEL.

The feasibility of utilizing peat fuel for power purposes is determined by the following factors: (1), cost of fuel to consumer; (2), quantity of fuel available; and (3), quality, as regards heating power, and moisture content. These factors in turn, are directly dependent on the method employed for peat fuel manufacture, on the distance separating the point of consumption from the place of manufacture, and on the quality of the peat in the bog from which the peat fuel is made.

In the case of power plants which are primarily installed for the purpose of recovering the nitrogen content of the peat in the form of sulphate of ammonia, the nitrogen content of the raw peat throughout the entire bog becomes a very important factor.

Inasmuch as the cost of manufacturing peat fuel is the dominant factor, and in most cases the deciding factor in the consideration of its utilization for power purposes, a brief description of the different manufacturing processes will aid clearness of view.

The current processes may be divided into two classes: (1) those depending on the forces of nature—the sun's heat, and the wind—for the removal of the moisture from the raw material; and (2) those depending on mechanical means for the separation of the bulk of the moisture, and on artificial heat for the evaporation of the remainder.

Peat, in its natural state, that is, as it exists in the bog, contains 90 per cent, and sometimes more, of water, and this water content is seldom reduced below 88 per cent, even in the most thoroughly drained bog. In other words, one hundred pounds of raw peat contains 90 pounds of water, and only 10 pounds of dry peat substance: and this dry peat substance represents the total combustible material in the 100 pounds.

In order, therefore, to render this 10 pounds of combustible substance available for fuel purposes the bulk of the 90 pounds of water must first of all be removed. The problem of the economic removal of this water, in a manner which will permit the manufacture of peat fuel to be carried on continuously throughout the year, has not, as yet, been satisfactorily solved. When the drying of the peat is accomplished by means of the direct heat of the sun in the open air, it is evident that its manufacture must cease in rainy weather, or when cold weather sets in; hence this method is not continuous. But though this is the case, it is the only ecomonic method known, at the present time, for the manufacture of peat fuel, depending as it does on atmospheric conditions for the removal of the large amount of moisture. Practically all of the peat fuel produced in Europe, is *air-dried.* An effective method, which has been in successful use for many years, and which depends on the direct sun's heat for the removal of the water from the raw peat, will now be described.

AIR-DRIED MACHINE PEAT.

Air-dried peat, as fuel, has for several centuries been used in many of the countries of Europe, and even today, the peasants of Ireland produce peat fuel, for their domestic purposes, in the same primitive manner that was in use centuries ago.

The peat is simply dug from the bog with ordinary spades, and then laid upon the bog to dry. When sufficiently dry these sods are either stored in a shed or stacked in the open field. In Sweden and Holland a similar method is followed by the peasants, but in these countries the dug peat is placed on hard ground, or on a wooden platform, and kneaded into a pulp by the treading of men or horses. The pulped peat is then moulded by hand into cakes which are laid in the sun to dry.

These primitive hand methods cannot be employed for the manufacture of peat fuel on a large scale and, in countries where the cost of labour is high, this hand method of manufacture can not be considered by the farmers, even on a small scale.

Composition of Peat and effect of Pulping.

Peat consists of the fibres of different Sphagnum and Hypnum mosses, Eriophorum, Carex, and other fibrous and aquatic plants, from which it was derived. These fibres consist of cellulose, hydro-cellulose, and a small amount of albumen.

Hydro-cellulose is a gelatinous substance which possesses the property of absorbing many times its own weight of water, and serves to bind together the particles in the air-dried peat sods. The older and more humified peat bogs contain the highest percentage of this gelatinous substance, hence it will be found to the greatest extent in the deeper layers of a bog, gradually decreasing in amount towards the surface as the newer layers are reached. In almost every peat bog plant fibres and roots are found intermixed with the peat, and not infrequently a bog contains the remains of buried cones, fir needles, trees, trunks, and a considerable amount of roots.

The action of pulping is twofold: (1) it serves to mix thoroughly the different layers of peat; and (2) distributes the hydro-cellulose uniformly throughout the mass. The fact that pulping improved the quality of the finished fuel, was recognized by the peasants, accustomed to make their own supply of domestic fuel, even when this operation was performed in the crude manner above described.

The process of manufacturing air-dried machine peat, as it is carried on to-day on a commercial scale, is simply a refinement and improvement on the primitive method previously described.

The different stages of the process may be enumerated as follows:—

1. Excavation of the raw peat.
2. Pulping or grinding of the excavated peat.
3. Transportation of pulped peat to drying field.
4. Spreading and cutting the pulped peat into suitable blocks.
5. Turning and cubing the practically dry peat.
6. Transportation to cars or shed.

EXCAVATION.

The raw peat, in the case of small manufacturing plants is usually dug by hand, while in large plants, mechanical excavators are employed. Since peat is a low grade fuel, and must therefore sell at a cost considerably below that of coal—if it is to serve as a substitute—every effort should be made to introduce labour-saving appliances in order to reduce the cost of the manufactured product. This economy is particularly applicable to Canada, where the cost of labour is much greater than in foreign countries.

PULPING.

The excavated peat is fed into a specially designed pulping mill, which, in a general way, consists of circular knives revolving against fixed knives, and a conveyer screw which serves to force the peat forward. These parts are enclosed in a strong cast-iron casing. The mill is operated by power, and thoroughly mixes and pulps the peat obtained from the different depths of the bog. Small roots and fibres, in passing through with the peat, are broken or cut up into small pieces, and mixed with the pulp.

Pulping, or, as it is sometimes called, grinding, is one of the most important steps of the process, since the quality of the final product, both as regards appearance and density, is dependent on the thoroughness with which this operation is performed.

Well humified peat which has been thoroughly pulped and repulped, has the appearance, when dry, of a high class lignite. It has a very fine texture, is hard and dense, and offers considerable resistance to breaking; consequently it can stand a large amount of handling without losing much weight resulting from the production of fines.

In practice, however, as the result of years of experience, the raw peat is put through only one pulping operation.

Owing to the many improvements which are being made in the machinery employed in the manufacture of peat, it may be possible to treat it more thoroughly in the ordinary pulp mill or in some form of grinder other than those used at present.

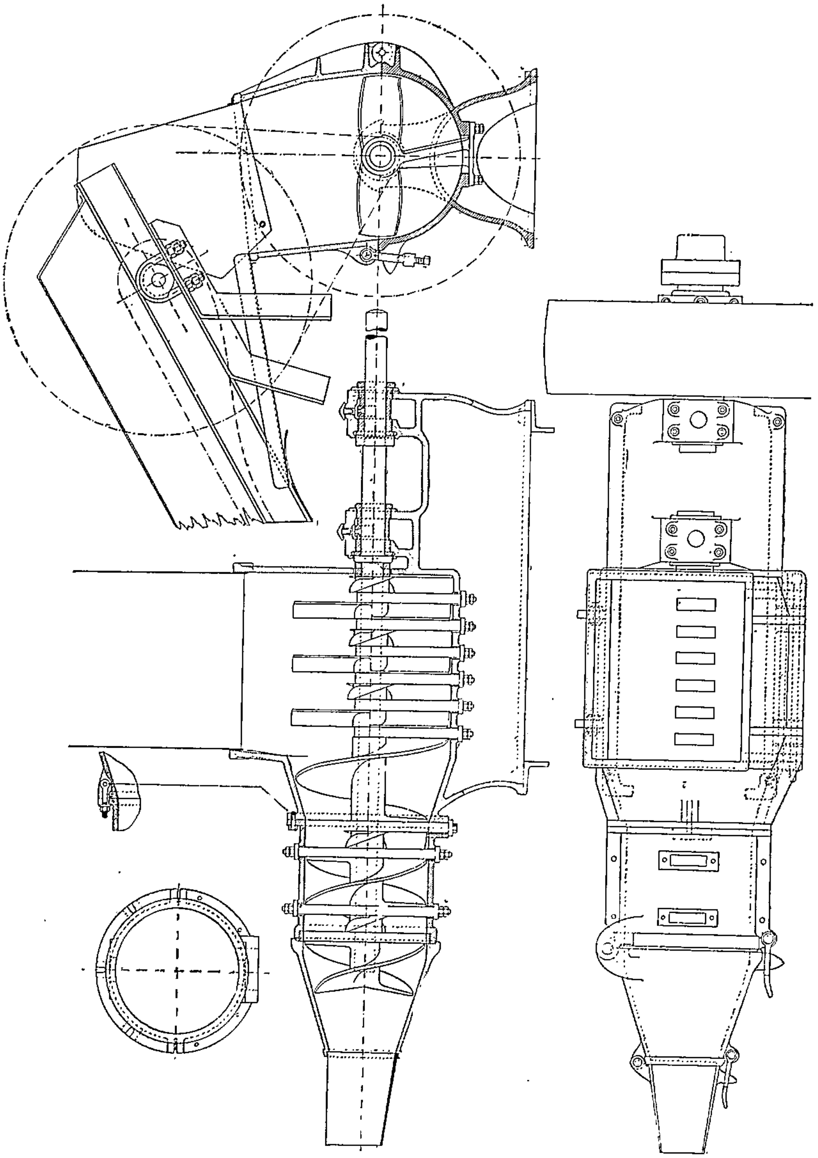


FIG. 1. Anrep pulping mill.

An "Anrep" pulping mill—similar to the one employed by the Mines Branch for demonstrating the process of manufacturing air-dried machine peat—is shown in Fig. 1.

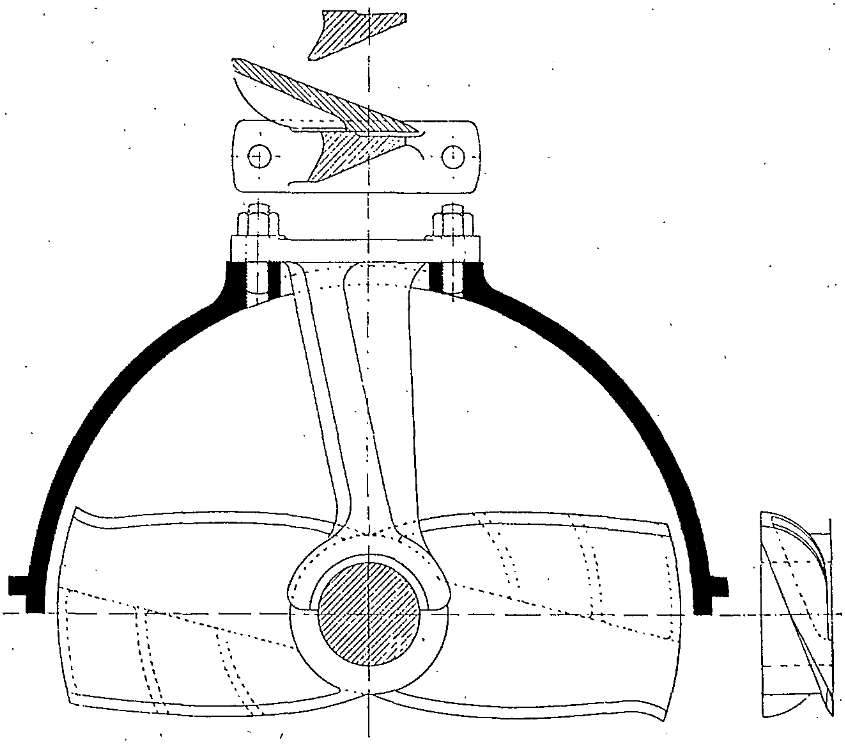


FIG. 2. Rotating and fixed knives of the Anrep pulping mill.

The casing in which the shaft rotates consists of two cylinders of different diameters, connected by a conical piece. In the larger of the two cylinders, just below the feed hopper, the shaft is provided with 2 double knives of the construction shown in Fig. 2. These knives rotate against 6 fixed knives attached to the bottom of the cylinder, and act as half bearings for the shaft. The fixed and rotating knives are of the same pattern, and are made exceptionally strong.

In the conical piece connecting the two cylinders, the shaft is provided with a screw thread, which cuts against the fixed knives provided on either side. The smaller cylinder is provided with 5 fixed knives: two attached at the top, and three at the bottom. These knives form whole bearings for this portion of the shaft. In this part of the pulp mill the shaft is supplied with two knives, and a double screw thread. This double screw thread can be replaced by rotating knives if it is desired to subject the peat to further pulping. The front of the machine is provided with a conical piece which carries the mouth piece of the machine. The shaft in this portion of the mill is provided with a double screw thread, which serves to press the pulped peat towards, and through, the mouth piece.

After the mill has been in operation for a short time, the sharp edges of the knives become dull and worn, leaving a clearance between the two surfaces of contact. The fibres and roots are to a certain extent broken up even when the knives become worn, but the principal action of the machine is plainly not so much one of cutting as it is one of grinding and mixing.

Every effort should be made to perform the operation in the most complete manner possible, since the value of the finished fuel depends, to a large extent, on the thoroughness with which this operation is conducted.

TRANSPORTATION.

The next step in the process, namely, the transportation of the pulped peat from the mill to the drying field, if not accomplished in an economic manner, has a considerable effect on the final cost of the finished product. This operation must be performed without the use of costly machinery and appliances, since the capital charged to manufacturing must be kept as low as possible. The transportation is usually accomplished by a set of small cars running on a portable track. The track may form a square, in which case the filled car ready to leave for the drying field proceeds from the mill along the two outside arms of track to the drying field. When emptied of its contents, the car returns to the mill along the two inside arms of the track. Switches, sidings, and turn tables are arranged to allow for the passing of two cars, or their turning when necessary. The cars are drawn back and forth by a system of cables operated from a drum on the engine which generates the power to drive the pulping mill.

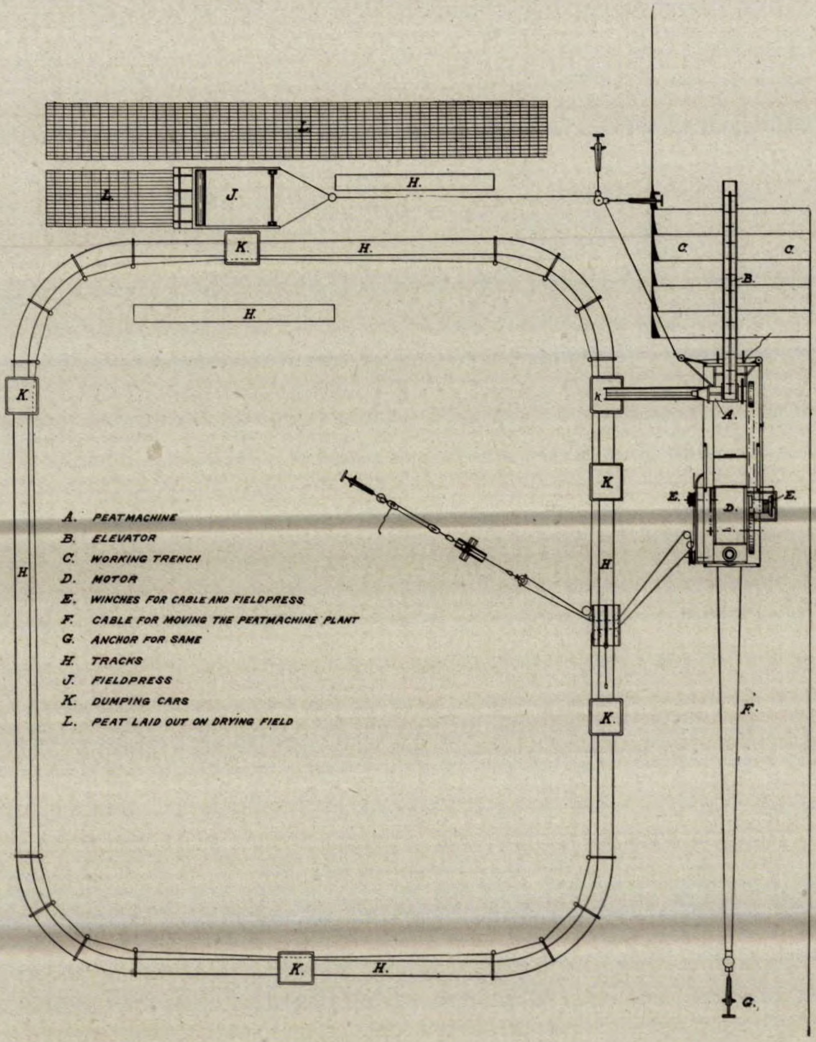
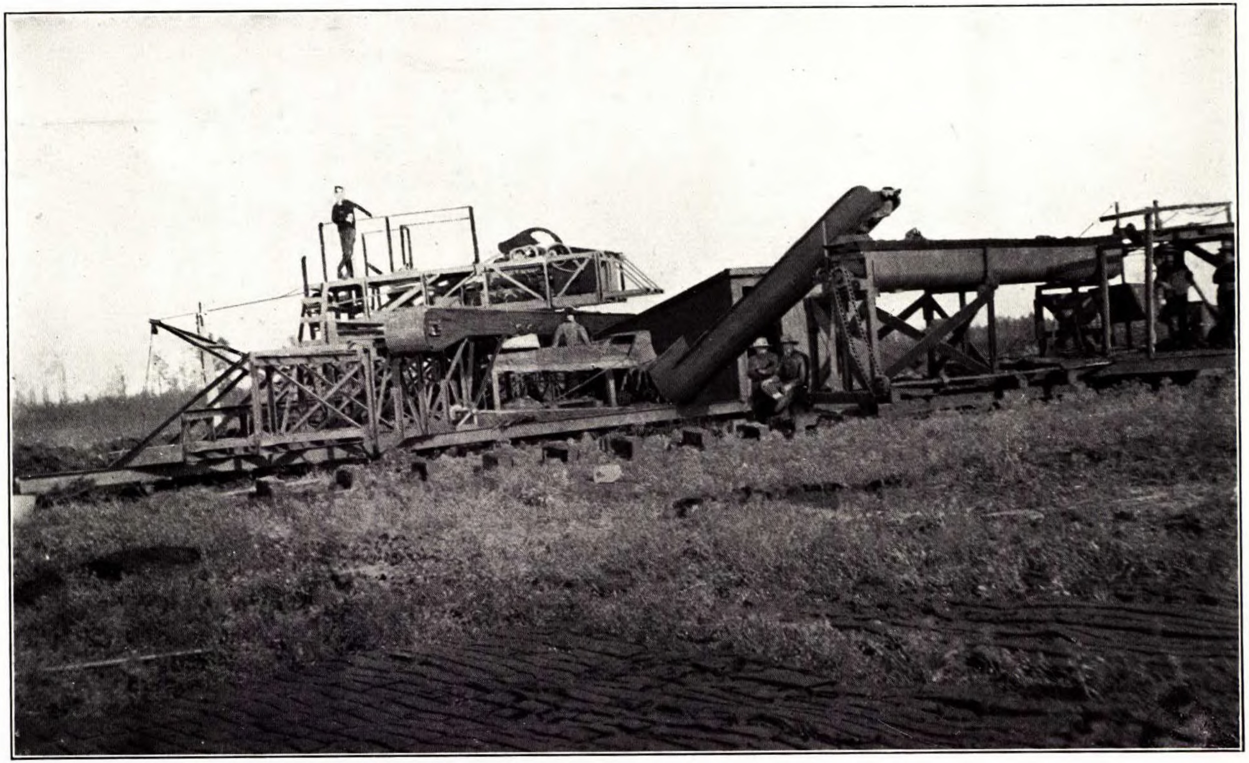


FIG. 3. Layout of track system and drying field and arrangement for operating field press, Anrep system.

The general lay-out of the track system and drying field, and arrangement for operating the field press, are shown in Fig. 3.



Loading hopper and buckets: Anrep automatic peat excavator.

Moore System.

Another system which should be described in some detail, is the one designed by Mr. Ernest V. Moore. This has been adapted to the transportation of peat from the peat machine to the field press and is now in operation at the new plant on the Alfred peat bog, Ontario. Transportation according to this system is accomplished by means of an aerial cable and travelling buckets. The following is a short description of the system.

The cableway consists essentially of two opposed towers, about 900 feet apart, and supported on wheels resting on rails held in place by ties of peculiar construction, so that they can move only in a direction at right angles to a line drawn from one tower to the other, the distance between the towers remaining the same. Two parallel cables, lying in the same horizontal plane, are strung by means of anchorage from the two towers. At each end means are provided for putting any strain desired on the cables, which are attached to two rigid semi-circular tracks connected to the tower. These tracks are attached to the cables in such a manner that a continuous and endless single track is obtained in the form of a horizontal loop about 900 feet long, 9 feet wide, and about 8 feet 6 inches above the surface of the bog.

Light wooden supports are placed at intervals of 75 feet between the two main towers. These are supported on wheels which permit their movement only in a direction parallel to that of the end or main towers. The cableway is attached to these intermediate supports by means of cable saddles, and is in this manner kept parallel, and at the proper distance from the surface of the bog.

Twenty-four steel buckets, each 10 cubic feet capacity, are provided for carrying the machined peat. These buckets are slung in a bail which, by the loosening of a catch, permits them to be dumped. A two wheeled truck, to which the bail is attached by means of a flexible joint, serves to support the buckets. The desired motion is imparted to the buckets through the medium of a clutch fixed to the bail of the buckets, which engages with the haulage cable. The haulage cable is endless, and receives its motion from a series of drums and pulleys situated on the tower nearest the excavator. The 10 H.P. motor which drives the haulage cable is placed on this tower. The haulage cable runs from the drums and pulleys of the inside tower parallel to and under the track cable to the outside tower. At the tower it passes around a large cable sheave, which supports and directs it in such a manner that it keeps directly below the semi-circular track. The cable then returns to the first tower parallel to, and underneath the cable track, on which the emptied buckets are returning to the loading hopper.

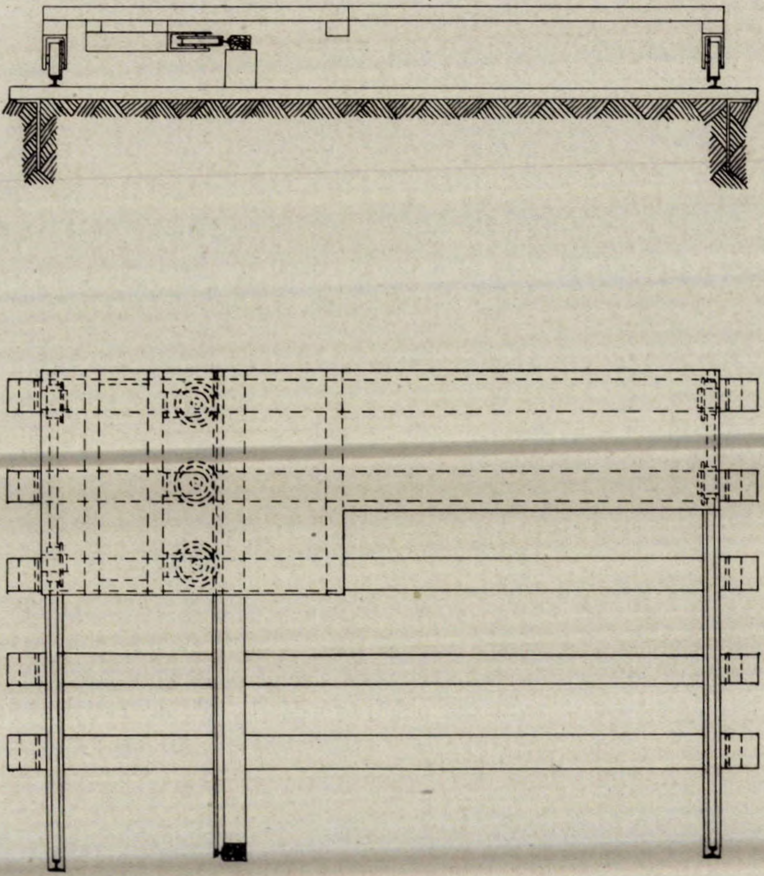
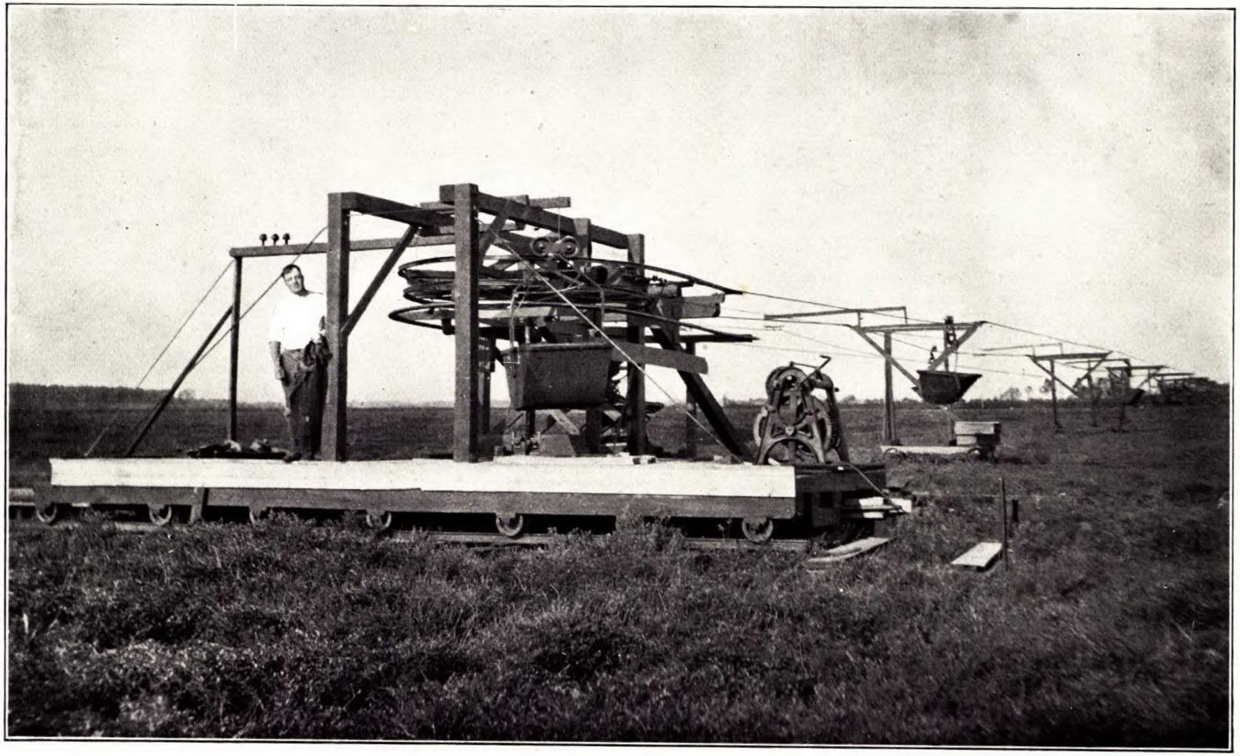
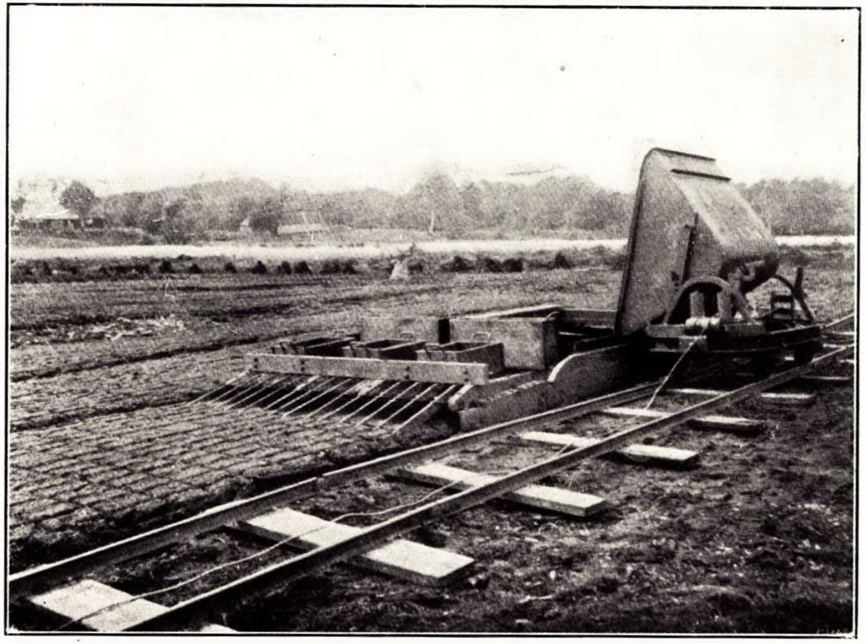


Fig. 4. Detail arrangement for taking up strain on cable,
Moore's transportation system.



Outside tower showing rail in vertical plane for taking up the strain on the cable.



Jakobson's field press and spreader.

The buckets are fixed to the haulage cable at intervals of 75 feet, so that it is impossible for two loaded buckets to get at the same time between any two consecutive cable supports.

The clutches are so designed that they automatically pick up and engage the haulage cable as they are pushed out, when filled from the loading hopper. When it is desired to dump the bucket, the clutch can be made to disengage the haulage cable conveniently, and in such a manner that the cable passes through the clutch without coming out. When the bucket has been dumped, a slight movement of the clutch lever serves to engage the clutch with the haulage cable. When the empty bucket arrives at the loading hopper, it is automatically released from the haulage cable, and passes over a guide pulley to the drum which imparts the motion. The bucket then continues its journey for a short distance until it is in a position convenient to the loading hopper.

Ties supporting the End Towers. When the cableway is in operation, a sufficient stress must be put on the track cables to prevent a deflection greater than twenty-four inches, when the loaded bucket—about 1,000 lbs. in all—is in the centre of a span. This means a stress of many tons tending to pull the two main towers together. The towers, if made sufficiently heavy to resist this pull, would be too cumbersome to move conveniently, hence they are attached to the ties, which in turn, are anchored to the bog. The towers are attached to the ties so that they can be moved when desired without altering the stress on the cables.

SPREADING THE PULPED PEAT.

This stage in the process is usually performed with a Jakobson fieldpress. The fieldpress as shown in Plate III consists of a frame built of wood and provided with two wooden rollers —one at each end. Between the two rollers is fixed a hopper for receiving the pulped peat. The forward roller serves the purpose of levelling the ground, while the roller at the back, which is adjustable in a vertical direction, regulates the thickness of the spread peat. At the extreme back of the machine is placed a number of knives which cut the spread peat into narrow strips. These long narrow strips are afterwards cross-cut with a special tool by a labourer.

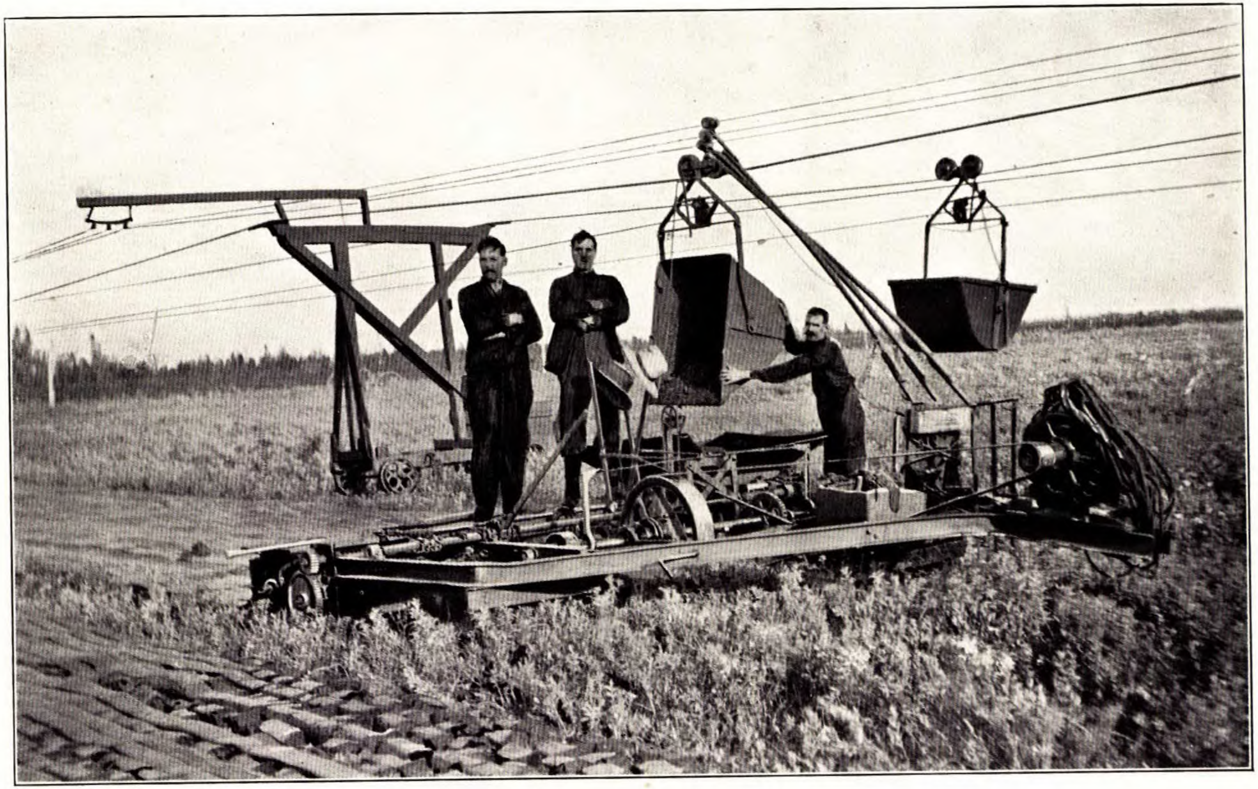
The fieldpress is moved by cables operated from a drum on the engine, shown on plan, Fig. 3.

This fieldpress is generally used in connexion with Anrep peat plants. Other systems employ fieldpresses of somewhat different design, one of which will be described here.

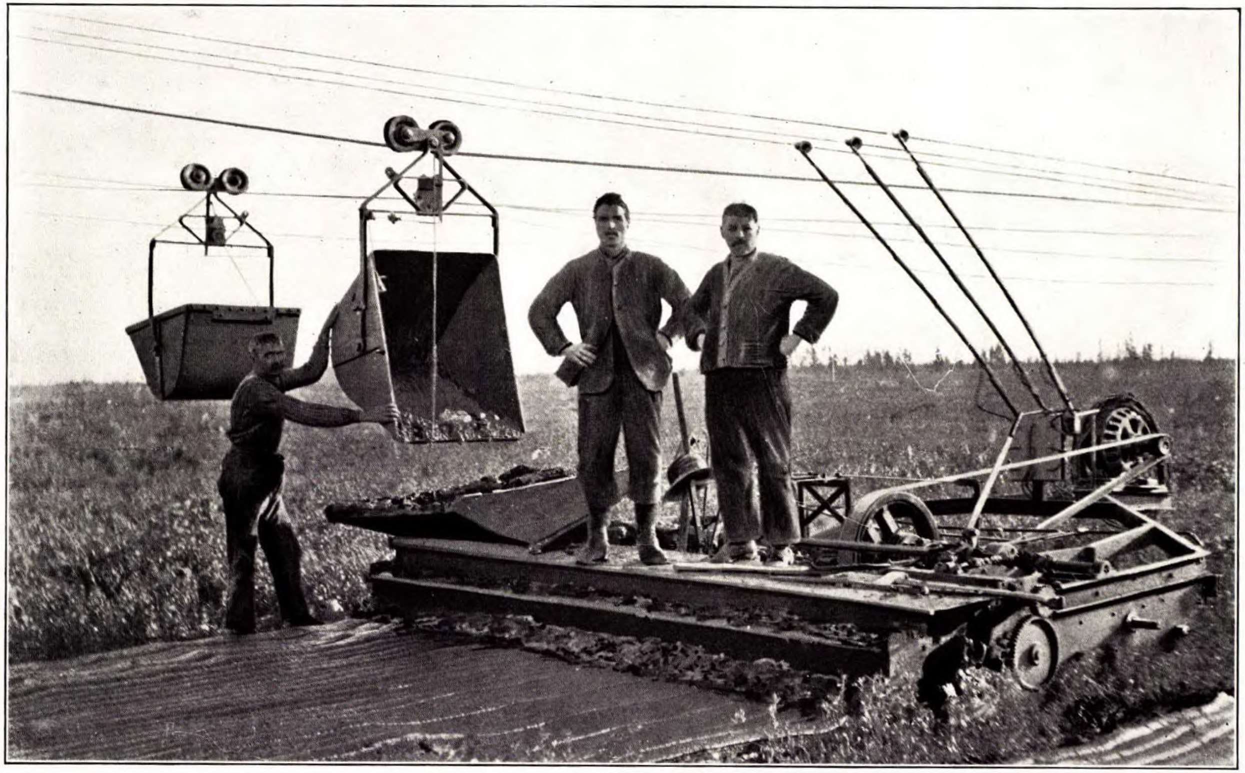
The spreading machine designed by Mr. Ernest V. Moore—for use in connexion with the manufacture of peat fuel at Alfred—possesses some ingenious mechanical features which render it well worthy of special notice.

The spreader is essentially a box into one end of which the peat pulp is dumped. The peat is uniformly distributed n this box by a screw conveyer, and is discharged from the box which travels on the ground, through 34 moulding spouts placed side by side in such a position that the peat is forced out without any drop on to the ground. This is accomplished by the provision of separate screws to feed each spout. The feeding is controlled by a device which regulates these screws in such a manner that the peat may be delivered from the spouts at any desired rate, within a big range. The box is flexibly fastened to a caterpillar tractor, designed especially for this purpose, and which at present draws it along at about eighty-four inches per minute. Electric power is transmitted by trolley wires, strung directly overhead, to a motor placed on the machine. The spreader is steered by a tiller conveniently placed. The peat is automatically crosscut by a special attachment fastened to the rear of the spreader. The spreader is shown on Plates IV and V.

The capacity of the spreader varies directly as the speed of its driving motor. The ascertained data of a run are as follows: thirty-four strips 4″ × 4″ are laid down side by side, making a strip $11\frac{1}{3}$ feet wide. The spreader moves 7 feet in one minute, so that the spread is $11\frac{1}{3} \times 7 \times \frac{1}{3} = 26\frac{1}{2}$ cubic feet per minute. If there were no delays, the capacity of the spreader, at the rate mentioned, would be 8·4 tons per hour of 25 per cent moisture peat fuel.



Moore automatic peat spreader.



Moore' automatic peat spreader: back view.

The spreader with all its moving parts, when loaded, weighs about 3,000 pounds, and, as it is moved over the surface of the drying field, all twigs and bits of moss, in fact all small inequalities in the surface of the bog, are smoothed down, and the peat gently laid on. The adjustment permitting the regulation of the rate at which the peat leaves the moulding box makes it possible for the rate to be kept exactly the same as the linear motion of the spreader, no matter how soft or stiff the pulp may be. As a result, a very uniform section is obtained. The moulding dies are slightly rounded at the corners and so impart rounded edges to the peat bricks.

TURNING, CUBING, AND STACKING.

This part of the process is performed by manual labour, at a specified rate per ton of manufactured peat fuel.

TRANSPORTATION TO CARS OR SHED.

In the case of small plants, the finished peat fuel is transported to a railway siding, or storage shed, in small hand cars, which are pushed over a narrow gauge track. Larger plants may employ small gasolene locomotives to advantage.

Some Types of Peat Machines.

The "Anrep" peat machine, which had a daily capacity of 30 tons of 25 per cent moisture peat fuel, and which was used at the Alfred peat bog, is shown on Plates VII and VIII.

The illustrations show the elevator which carries the dug peat to the pulping mill: the latter being hidden by the housing. The pulped peat is discharged from the mouth piece of the mill upon the belt conveyer, which is seen on the right hand side of the machine. The pulped peat is discharged from the conveyer directly into the small cars shown in the illustration.

The locomobile, mechanical transportation device, and pulping mill, are shown in Plate VIII.

This type of peat plant is used almost exclusively in Russia and Sweden. The systems which appear to be the most popular in Germany are the Dolberg and Strenge. Dolberg's system is also used in Italy.

The principal difference between the Dolberg and the Anrep systems is, the design of the macerator or pulping mill. The Dolberg, unlike the Anrep macerator, is not designed to cut twigs, fibres and roots; hence when the machine is working on a bog containing many roots and fibres, these twist around the shaft, and soon necessitate the stopping of the machine for the purpose of cleaning.

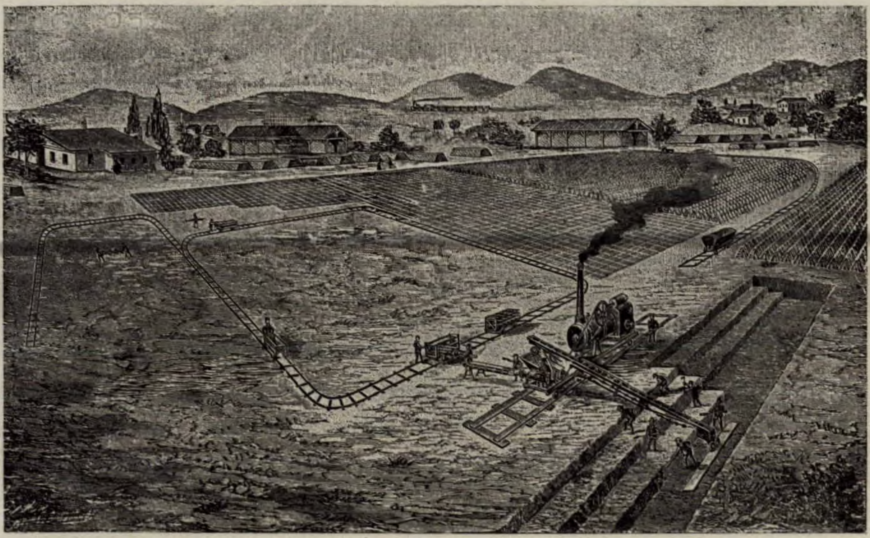
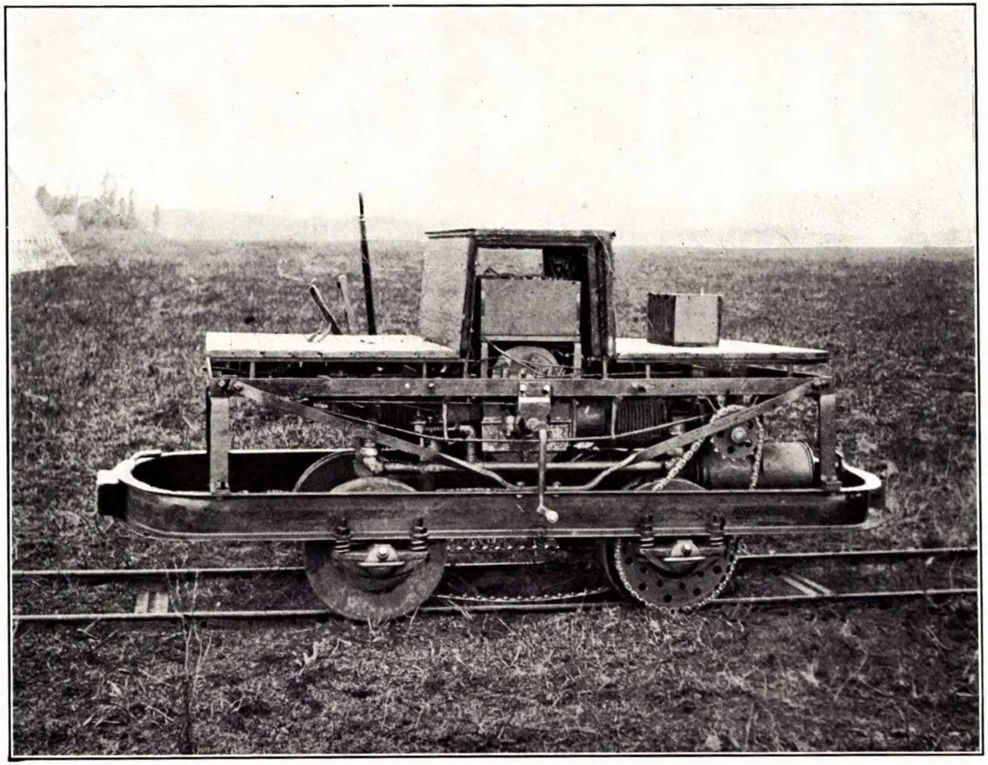


FIG. 5. Arrangement of tracks and general layout of drying field. Dolberg's system.

Later designs of the Dolberg macerator resemble, in many particulars, that of the Anrep, for provision is made for cutting the twigs, roots and fibres, at least to a small extent.

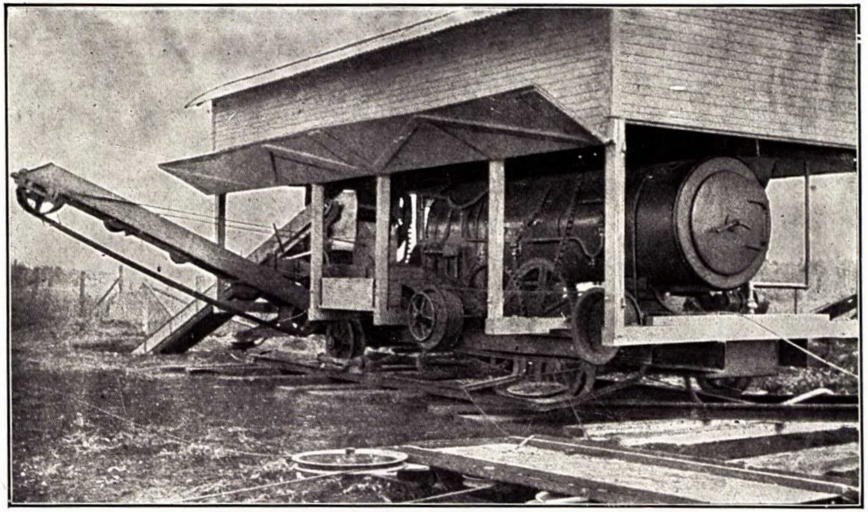
THE DOLBERG MACHINES.

These machines are used on certain bogs in Germany and Italy and are operated by a steam locomobile, as in the case of the Anrep system, but the excavating is done by manual labour.



Improvised gasolene locomotive employed at Alfred, Ont.

30 ton Anrep peat machine: end elevation, showing elevator, trenching operations, and track.



Mechanical transportation device: receiving station for cars.

A bucket elevator is provided for carrying the excavated peat to the pulping mill.

The pulped peat is transported to the drying field in cars, pushed by hand over a narrow gauge track. This method of transportation to and from the drying field, together with the arrangements on the bog,—as employed in Germany and Italy —is shown in Fig. 5.

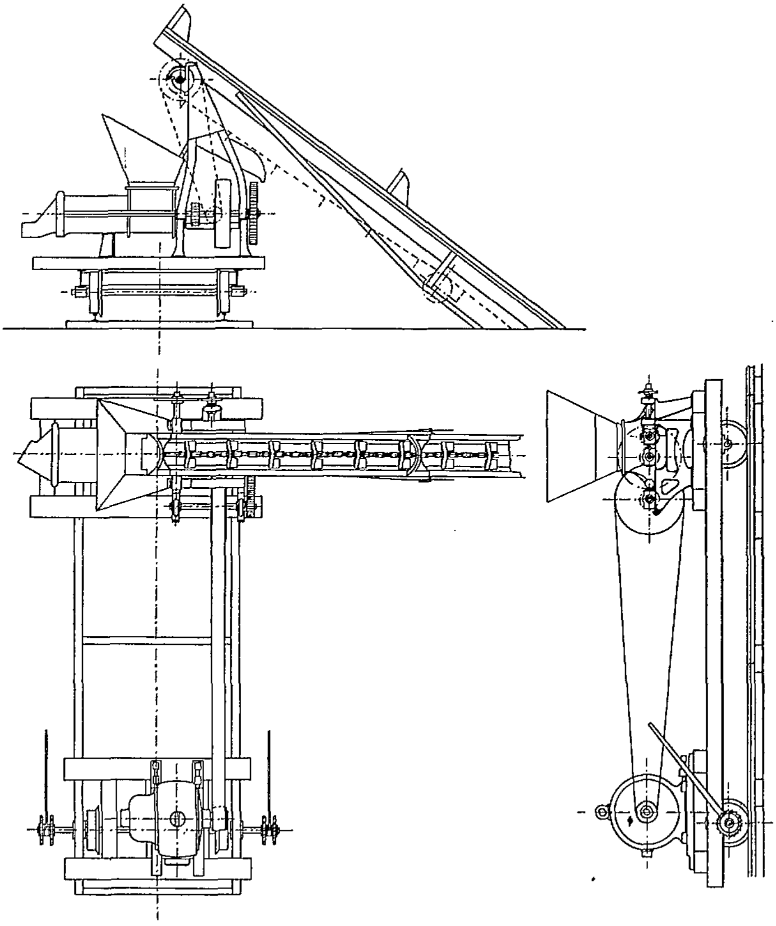


Fig. 6. Details of Dolberg's peat plant, showing peat machine, elevator, and motor.

The above Fig. 6—taken from "Das Kraftwerk im Wiesmoor in Ostfriesland" by J. Teichmüller—shows the details of the Dolberg peat machine as employed at Wiesmoor. It will be seen from the illustration that the machine is provided with a side elevator, the lower part of which must roll on planks laid on the bottom of the excavated trench.

THE STRENGE MECHANICAL EXCAVATOR.

This machine is employed on several bogs in Germany. The peat is mechanically excavated from the bog by an excavator of peculiar design. A mechanical device spreads the pulped peat, and cuts it in longtitudinal and transverse directions. The machine is operated by electric motors, Fig. 7 shows the machine in detail. The machine in operation on the bog at Wiesmoor is illustrated in Plate IX.*

It will be seen from this illustration that the excavator consists of a number of buckets attached to an endless chain, which revolves in a vertical plane, enabling it to move either up or down in a vertical direction, or from right to left horizontally.

The two ends of the arm supporting the buckets are fastened to vertical supports, the outer one resting on the lowest part of the excavated trench, while the inner one rests on a higher portion. The arm carrying the bucket excavator and along which it travels in a horizontal direction is moved up and down on these two vertical supports.

The illustration, Plate IX, clearly indicates the method of excavating. The bog is excavated in steps, hence the different layers of which the bog is made up are not mixed; consequently the finished fuel will vary in quality according to the different constituents of the respective peat layers.

On bogs free from roots, stumps, etc., this machine is said to operate well; but when the bog contains these, to any extent, this system cannot be employed to advantage.

European Practice.

In Sweden and Russia, the "Anrep" system for the manufacture of peat fuel appears to meet with the greatest favour.

---

*Illustration taken from "Das Kraftwerk im Wiesmoor in Ostfriesland," by J. Teichmüller.

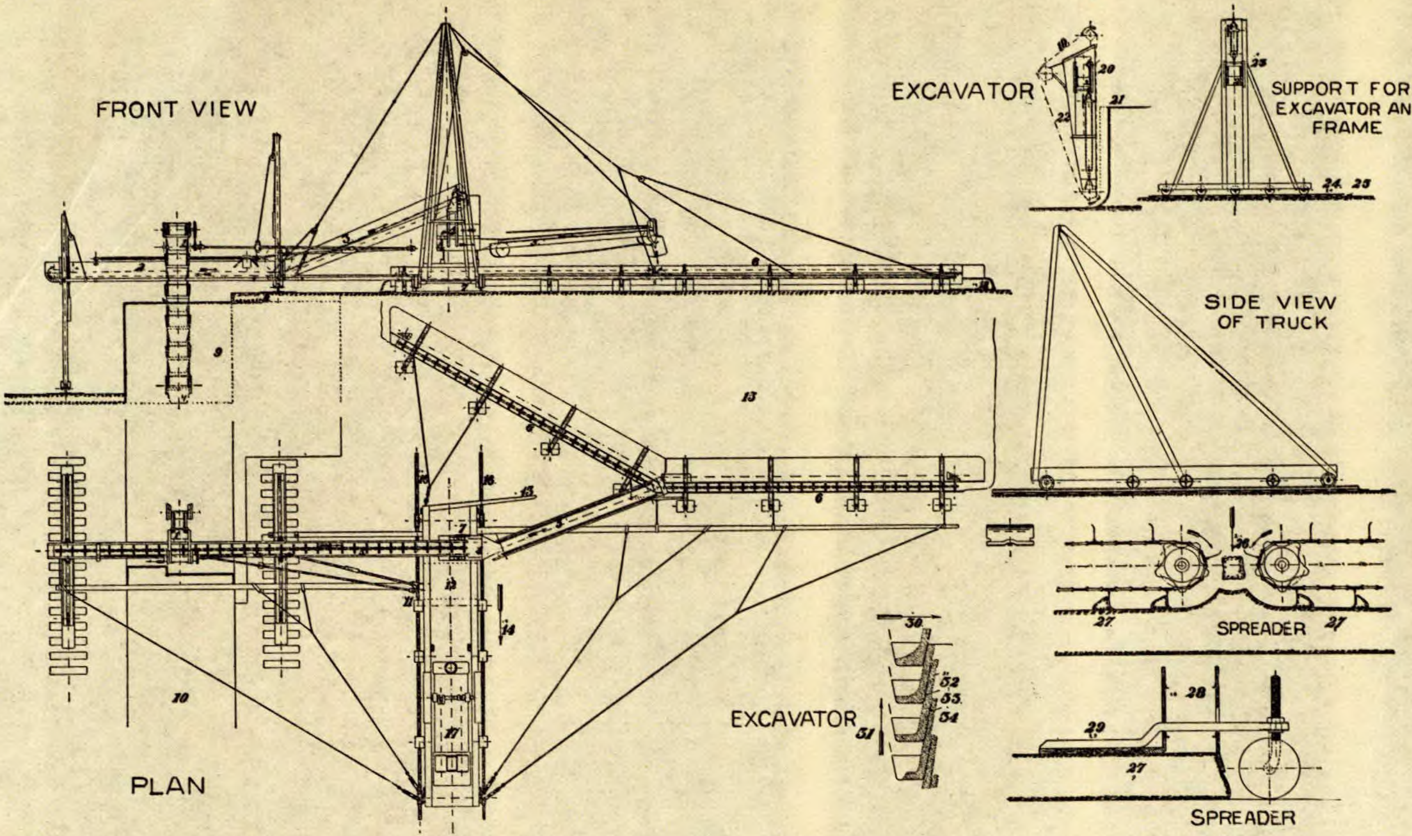
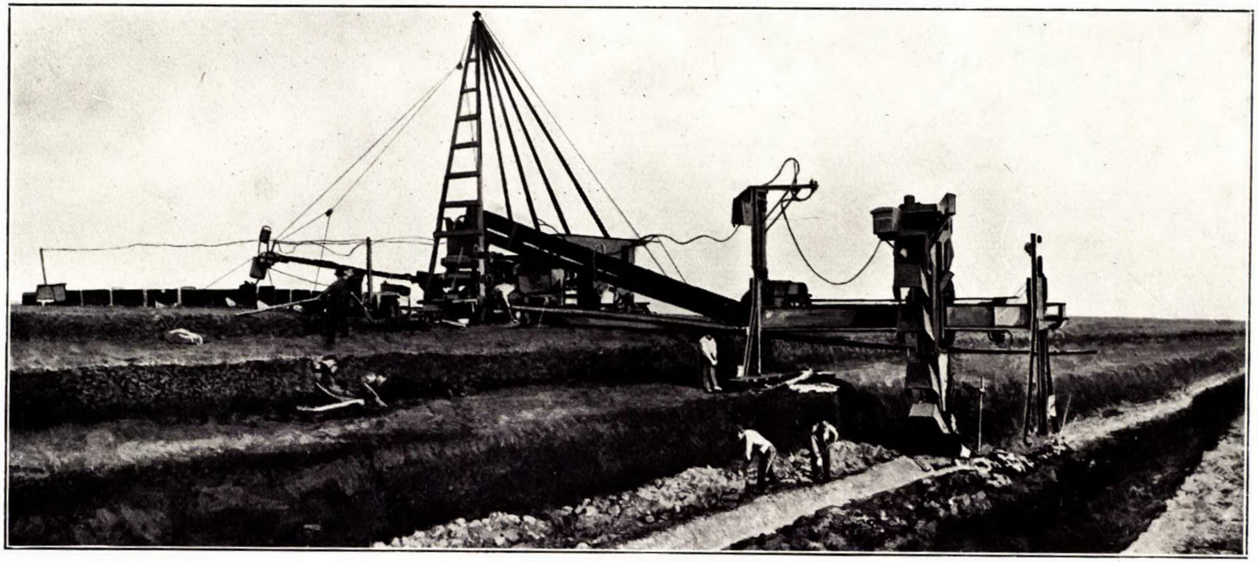


FIG. 7. O. Strenge's Peat Plant, Elisabethfehn, Germany.

1. Excavator. 2. Conveyer. 3. Conveyer. 4. Peat Machine. 5. Conveyer. 6. Spreader. 7. Truck. 8. Surface layer of bog. 9. Peat suitable for fuel manufacture. 10. Working trench. 11. Station for driver. 12. Driving arrangement for shafts. 13. Driving device for spreader. 14. Direction in which plant is moved. 15. Drying field with peat mass spread out. 16. Track. 17. Locomobile (or other motor). 18. Peat mass spread out for drying. 19. Excavator chain. 20. Guide for excavator frame. 21. Screw hoist. 22. Support for excavator. 23. Support for conveyer and frame. 24. Iron plates. 25. Ties. 26. Peat mass falling from conveyer to spreader. 27. Peat mass spread out. 28. Guide for chain. 29. Carriage. 30. Direction in which excavator is moved on its frame. 31. Direction in which excavator moves. 32. Peat bed. 33. Buckets. 34. Cutting knife.



Strenge-mechanical peat excavator in operation on the Wiesmoor.

The output of peat fuel in Russia alone for the year 1909, amounted to 2,080,000 metric tons. This output was produced almost entirely by the "Anrep" system with the employment of over 1,300 peat machines. At the present time Russia is the largest producer of this fuel. No mechanical excavators of the "Anrep" type are yet employed in Europe, the one at Alfred, Ontario, being the first of this type constructed.

The statistics of the production of peat fuel in Sweden are not available.

GERMANY.

At Wiesmoor in Ostfriedland, and at Schweger Moor in the government of Osnabruck, the writer visited two large power plants designed for the use of peat fuel. That at Wiesmoor is a steam plant, while that at Schweger Moor is a by-product recovery producer gas power plant.

The total production of peat fuel at these two bogs is in the vicinity of 70,000 metric tons.

At Wiesmoor, 12 Dolberg machines, each with a capacity of 60,000 to 80,000 peat bricks per day of ten hours, and 2 Strenge machines equipped with mechanical excavators and spreaders are employed. The same system is employed at Schweger Moor, Osnabruck.

The cost of peat at Wiesmoor, or rather, the price at which it is sold to the power company, is 5 marks (about $1.25) per metric ton, the average moisture content ranging from 25—30 per cent. Owing to bad drainage, and other difficulties encountered during the first year of operations, the cost of peat fuel at Schweger Moor was about 15 marks ($3.50). This cost will, it is said, be very materially reduced during the ensuing season.

ITALY.

The only peat fuel manufacturing plant visited in Italy was that of the L'Utilizzazione Dei Combustibile Italiani E L'Impianto De Orentano. The total annual output of 30,000 metric tons was produced at this plant, entirely by the Dolberg system—which employs manual labour. The cost of the fuel at this plant is said to be about $1.50 per ton.

Canadian Practice.

At present the manufacture of peat fuel is being prosecuted on a commercial scale at two bogs: Farnham, Que., and Alfred, Ont. These two plants employ machines provided with modern labour saving devices.

The peat plant near Farnham employs at present one mechanical excavator of special design, Plates X and XI, an "Anrep" pulping mill and a modified Jakobson fieldpress. During the summer of 1912 the output of this plant was 2,000 tons of 25 per cent moisture air-dried machine peat.

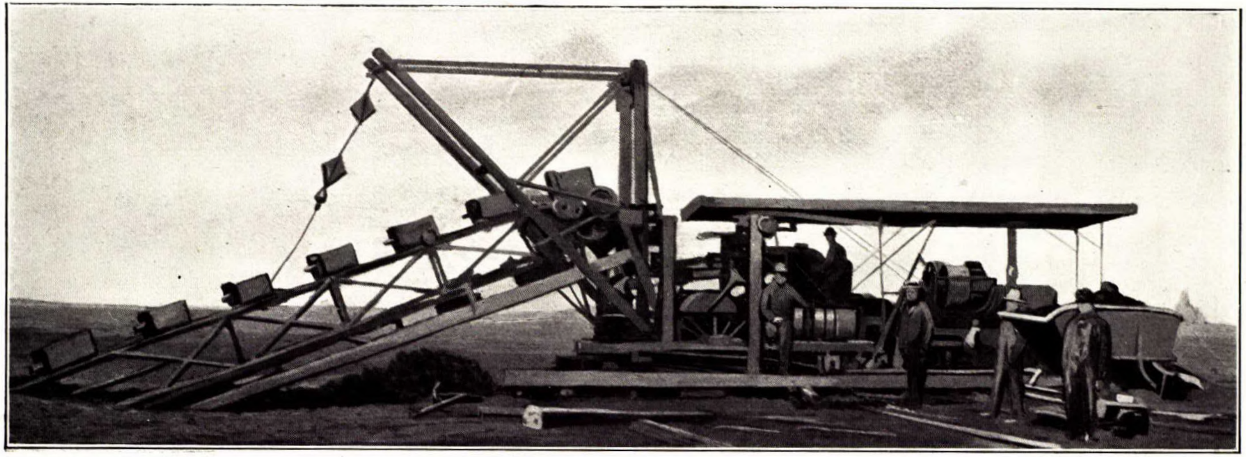
It is expected that a much larger output will be produced this summer. The costs of manufacturing at this plant are not, as yet, available; since the machinery had not during last season passed the experimental stage. A description of the plant can be found in Bulletin No. 9, issued by the Mines Branch.

ALFRED PEAT PLANT.

During two seasons, the Mines Branch manufactured about 3,000 short tons of 25 per cent moisture air-dried machine peat fuel. The method employed was that invented by Anrep, the system which is so extensively used in Russia and Sweden. The plant was not equipped with a mechanical excavator, and its capacity was small—only 30 tons per day,—hence the overhead charges, amortization, interest on investment, etc., were high. The improved "Anrep" system, as employed at this plant, is described elsewhere; it is only necessary, therefore, to add a few remarks regarding the cost of manufacture.

The result of the two seasons' manufacturing operations at Alfred, under unfavourable conditions, indicate that, with efficient management, peat fuel can be manufactured at a cost of $1.75 on the field. This cost includes all expenses; such as, interest on investment, amortization, repairs, etc. It is moreover the opinion of the Swedish peat engineer, who conducted the last season's operations, that a period of 110 working days can be counted on, as a fair period during which manufacturing operations may be conducted. The total production during

PLATE X.



Mechanical excavator employed at Farnham peat bog: side view.

Mechanical excavator employed at Farnham peat bog:
end view showing buckets.

this time would be 3,300 short tons; and this output will be used as a basis for calculating the cost of peat per ton.

In estimating the capital necessary to install an "Anrep" peat plant of 30 tons daily capacity, and to start operations, it is assumed that a bog of 100 acres and 9 feet deep will furnish sufficient peat to supply the plant with peat for 20 years. At the termination of this period, the entire plant, bog, etc., will be amortized. The distribution of the capital expenditure on this basis will be as follows:

100 acres of peat bog at $6 per acre	$ 600
Machinery: Peat machine, locomobile, portable tracks, cars, cables, etc.	7,500
Blacksmith shop and equipment, office, loading platform and railway siding	1,000
Draining bog	1,500
Office, furniture	100
Total	$10,700

In round numbers say $11,000. The amortization on this capital, if the plant is paid for in twenty years, will be 5 per cent; and the interest on the investment will be taken as 5 per cent. The amount which will have to be charged up to these two items is, therefore, $1,100, which will amount to 33⅓ cents per ton, on a total season's production of 3,300 tons.

The labour required is:—

1 engineer	per day	$ 2.50
7 men in trench, excavating peat	at $1.75 each	12.25
3 men on field press	" " "	5.25
1 man filling cars	" " "	1.75
4 boys	" .75 "	3.00
1 extra man		1.75
Total daily wages		$ 26.50
Salary of manager, 5 months at $100 per month		3.85
		$ 30.35

The labour cost, including manager's salary, for five months, is 110 × \$26.50 + 500 = \$3,415, and per ton of peat this will amount to:

\$3,415 ÷ 3,300	\$ 1.04
Cost of turning partially dried peat bricks per ton	0.07
Cost of cubing (piling in small stacks)	0.10
Total cost on field exclusive of amortization and interest	\$ 1.21
Amortization and interest	0.33⅓
Repairs, fuel, oil, waste, etc.	0.15
Total cost on field	\$ 1.69⅓
or	\$ 1.70

The work of cubing, turning, and stacking is done by contract at a fixed sum per ton of peat fuel of 25 per cent moisture. The price paid for this work is as stated in the previous estimation of labour charges.

Before it was decided to discontinue manufacturing operations under government auspices, the manager in charge of the peat plant entered into an agreement with the employees whereby they agreed, for the next season, to work on a unit basis as is the custom in Sweden. It is apparent that this system possesses certain economic advantages over that which operates on a fixed daily wage, and especially is this so when the raw peat is dug by manual labour. In this case, the men excavating in the trench set the pace for the entire number of labourers, and if they are not of an industrious disposition the daily output is bound to be small. When the men are paid a fixed daily wage their desire to produce as large a daily output as possible is not so keen as when they are paid on the unit basis. When employing this latter system the experience has been that the men do better work, and pay closer attention to the details of the work allotted to them, e.g. moving of tracks, cables, etc., and this saves a large amount of time which is very often lost when the men are paid a fixed daily wage. Consequently, the system results in a larger daily output.

The unit prices agreed on by the men employed by the Canadian government were as follows:—

1 engineer at 6c. per ton (2,000 lbs. 25% moisture) ...	$ 0.06
7 men excavating at 6c. per ton....................	0.42
3 men tending field press at 6c. per ton...............	0.18
1 man loading into cars at 6c. per ton.................	0.06
4 boys at 4c. per ton...............................	0.16
1 extra man at 6c. per ton..........................	0.06
Turning at 6c. per ton............................	0.06
Cubing at 12c. per ton............................	0.12
Salary of manager $500 (5 mos. at $100 per mo.)........	0.15
Amortization and interest..........................	0.33
Total cost	$ 1.60

or, in round numbers, $1.65. It is certain that, when working under these conditions, the output would be, at least, 30 tons, per day and quite probably 35 tons.

The foregoing estimates of costs clearly show the necessity for introducing every possible labour saving device, and thus increasing the capacity of the plant unit. In the new plant erected at Alfred by private parties, for purposes of experimentation and demonstration, an improved Anrep mechanical excavator, of novel design, is employed. A graphic description of some of the unique and interesting features of this plant will be found on pp. 19 to 23. This plant has not run continuously for a long enough period to determine, with any accuracy, the cost of the product per ton, but there is every reason to believe that the peat fuel manufactured with this plant will cost considerably under $2 per ton at the Alfred railway siding including all expenses. Its capacity, moreover, is more than double that of the "Anrep" plant previously installed by the government, while the number of men employed is actually less. The cost of equipment, including power house, peat machine, and all other machinery, is considerably greater than that of the pioneer type of plant previously described, but the overhead charges when distributed over a large output is appreciably less than that of the cheaper plant.

One power house, moreover, will be sufficient to supply power for operating several units, and this will decrease the cost of production, by reducing the number of engineers, and, finally, one superintendent or foreman can easily look after at least 4 units, which will result in still further reduction in the cost per ton.

SEPARATION OF WATER BY PRESSURE AND ARTIFICIAL DRYING.

The second method for the manufacture of peat fuel which will be described is that depending on pressure and artificial heat for the separation of the moisture from the raw substance. Since there is no commercial process developed along the lines indicated in existence today, such methods may be regarded as still in the experimental stage. Moreover it is very doubtful whether any such method will ever prove to be economic.

Separation of the Contained Water by Pressing.

For many years past a good deal of experimentation, involving the expenditure of large sums of money, has been conducted for the purpose of devising some means of successfully pressing the water out of raw peat; and even at the present time considerable work is being done in this direction. From time to time reports have been circulated to the effect that the problem has been solved, and, as a result, capital has been invested and lost. The reason why so much time and money has been and is being expended on the solution of this problem, is the desire to render the manufacture of peat fuel independent of weather conditions, and consequently to make it possible to operate continuously throughout the year. A secondary consideration is the higher grade fuel resulting. Air-dried machine peat, as is well known, has a low specific gravity, it is consequently quite bulky when compared with coal, or even with the product manufactured according to the method now under discussion. For power purposes, however, air-dried machine peat is an admirable fuel.

The results of the investigations conducted, so far, on the pressing of water from peat, indicate that the water content of the raw substance cannot be reduced to below 70 per cent by pressure alone. It is true a greater reduction than this has been obtained in laboratory experiments, made on a very small scale, but these results cannot be said to have any practical bearing on the economic possibilities of the process.

Properties of Peat Preventing the Expulsion of Water by Pressure.

After a great deal of experimentation with presses of different designs, capable of developing very high pressure and with peats of various kinds, Ekenberg undertook to investigate the physical properties of peat which make the mechanical separation of the water impossible. He found that the various peats used in his experiments did not all behave alike when submitted to pressure; that some parted with their moisture much more rapidly than did others. For instance, a very fibrous peat, in which the process of humification has not been carried to a great extent, parted with its moisture more readily, and to a far greater extent, then well humified black-fuel peat. The reason for this is the existence in all humified peat, of a complex gelatinous, hydrocarbon compound, termed by Ekenberg, hydrocellulose. The quantity of this hydrocellulose depends on the degree to which humification has progressed. The older and more humified bogs, therefore, contain the largest quantity, while the newer bogs contain the smallest amount. Surface peats, which are as a rule very fibrous, sometimes contain only a trace, or none, of this substance. In well humified black-fuel peat the quantity of hydrocellulose contained, is as much as 1·2 per cent, and more.

Hydrocellulose possesses some rather remarkable properties; it is capable of increasing its volume enormously, through the absorption of water, and in raw, well humified peat, it is found as a swollen mass, having the consistency of soft soap. When this gelatinous substance is separated from the raw peat the bulk of the contained water can be separated by a moderate pressure. For example, raw peat, containing about 90 per cent of water, from which the hydrocellulose has been extracted, will, if placed in a canvas bag and submitted to pressure, part with the bulk of its water. The same peat to which has been added the extracted hydrocellulose, and the same amount of water it originally contained, will not part with the water again when pressed under the like conditions. In the latter case the peat passes through the meshes of the canvas bag with the water.

These are the precise conditions that prevail when raw peat is submitted to pressure in a specially designed hydraulic press or filter press. The peat, after the removal of some of the water, either passes through the openings in the filter plates or screens provided for the escape of water, or else clogs the openings.

A somewhat different explanation is given by Larson of the phenomenon produced by hydrocellulose when raw peat is subjected to pressure. He maintains that when raw peat in a canvas bag is pressed, the hydrocellulose or gelatinous substance —as he prefers to call it—adheres to the surface of the canvas or metallic screen, and prevents the water from passing through. Larson maintains, moreover, that the peat pulp does not consist of cells, since these are destroyed by humification, but of a substance in a gelatinous condition. Hence, according to his theory, the water, which is so difficult to press out, is not contained in the cells as is maintained by Ekenberg. The bulk of the water in peat was supposed by Ekenberg, and others, to be contained in the hydrocellulose. While, however, there is disagreement as to the precise condition in which water exists in the peat direct from the bog, both investigators agree that the raw peat submits much more easily to the separation of its water by pressure when the gelatinous substance is extracted or destroyed.

Since hydrocellulose cannot be economically extracted by mechanical means, another method was sought for, which so altered the nature of the compound that it offered no resistance to the separation of the water from the peat by pressure.

Wet Carbonizing Process.

(*Ekenberg*).

By means of his wet carbonizing process Ekenberg thought that he had technically solved the problem of the economic manufacture of peat fuel. The process is as follows: when raw peat containing approximately 90 per cent of water is heated under pressure in a closed retort, a chemical change is effected. The carbon content is increased, and some of the hydrogen of the peat combines with the free oxygen, forming water, thus increasing the water content. No gases are evolved

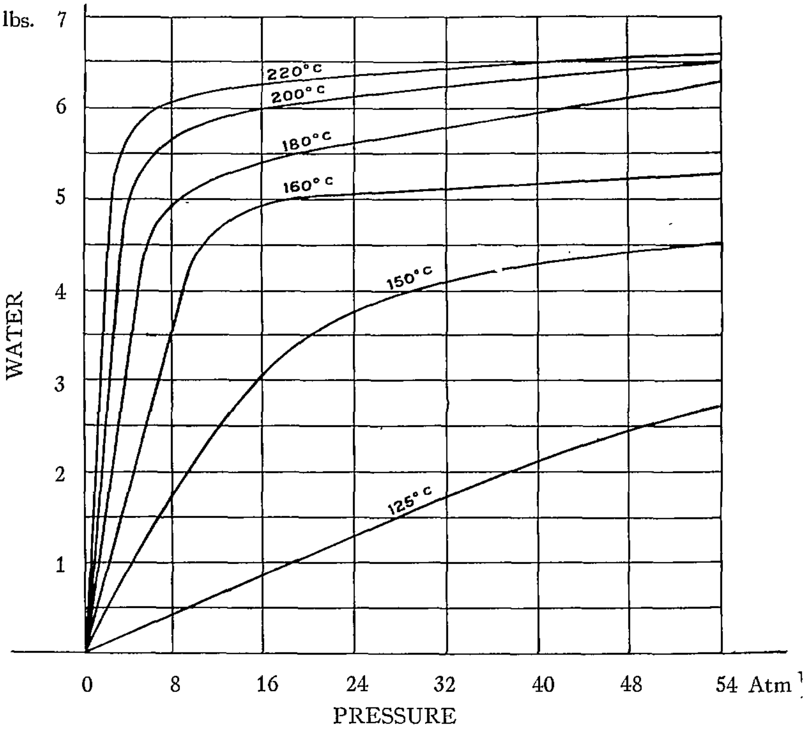


Fig. 8.—Curves illustrating the relation between the pressure employed and quantity of water expelled.

during the heating, as in the case of dry distillation, hence none of the combustible components of the fuel are lost.

When the raw peat is carbonized in this manner, it is subjected to pressure. The illustrative curves[1] (Fig. 8) indicate the relation between the pressure employed and the quantity of water expelled. These curves also indicate the marked influence the temperature at which the process is conducted has on the pressure necessary to employ for separating the water. The peat parts more easily with its water as the temperature rises to 220° C. Nothing is gained by employing higher temperatures. At a temperature of 220° C. the water content of the wet carbonized peat was reduced to about 33 per cent, by means of a pressure of 54 atmospheres (800 lbs. per sq. inch).

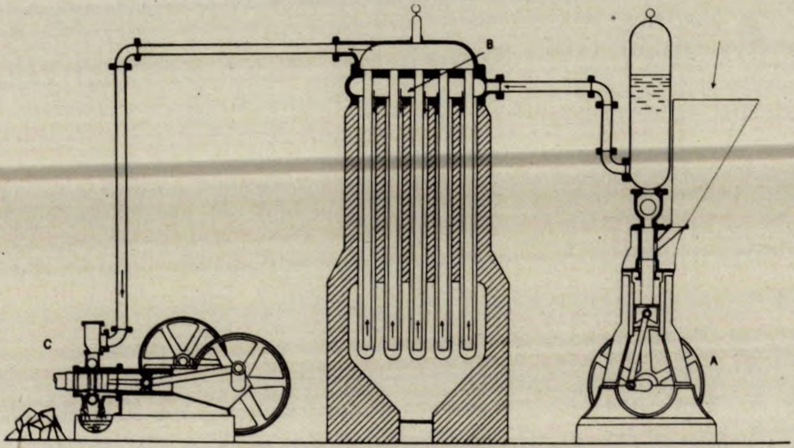


FIG. 9.—Ideal diagrammatic section of apparatus employed for carrying out the Ekenberg wet carbonizing process.

An ideal diagrammatic section of the apparatus employed for carrying out this process is shown in Fig. 9 which is self-explanatory.[2]

An experimental plant was erected some years ago at Dumfries, Scotland, by the Wet Carbonizing Co. of London,

---

[1] Fuel from Peat; Ekenberg, The Journal of the Iron and Steel Institute, No. 1, 1909, page 322.

[2] Journal of the Iron and Steel Institute, No. 1, 1909, page 328, Fuel from Peat, by Ekenberg.

for the purpose of demonstrating the process, and carrying on further investigations. This plant is no longer in existence. A large commercial plant (so the writer was informed) will shortly be in operation, but up to the present time nothing further has been learned concerning this project.

In a paper written by the late Dr. Wolff—technical adviser to the German Peat Society—this process is severely criticized. According to Dr. Wolff, the water content of the wet carbonized peat is not reduced by pressure to below 60 per cent, so that after pressing, the moisture must be further reduced by some system of artificial drying. This was accomplished, it is stated, at the Dumfries plant by burning one-half the pressed carbonized peat in Mond producers, and utilizing the gas thus generated, for heating the driers. The nitrogen content of this portion of the peat was recovered in the form of sulphate of ammonia.

In 1902, the government of Sweden made a grant of 20,000 kronor to Ekenberg and Larson to enable them to carry out further experiments in connexion with this process, and to establish it on a commercial basis. This grant was expended without obtaining any economic results. In 1910, a second grant of 19,000 kronor was made to Dr. DeLaval to enable him to investigate the commercial possibilities of the process, and to make further experiments. In 1911, he received another grant from the Swedish government and, in addition, a considerable sum from the Iron and Steel Society. His report on the results of his work is considered very promising; but those qualified to pronounce an opinion, do not consider the process, as yet, technically solved.

In a recent report on this process, by Larson,* the statement is made that in continuous operation on a large scale, a moisture content below 70 per cent in the pressed cake cannot be counted on. In these experiments a filter press was used to squeeze the water out of the carbonized peat.

Although large funds have been placed at the disposal of various investigators, in order to enable them to demonstrate the economic value of the process, and although a private com-

---

*Peat Bulletin No. 4, Mines Branch, Department of Mines, Canada.

pany has conducted elaborate experiments on a large scale, involving the expenditure of a large amount of money, not one ton of peat fuel has been manufactured on a commercial scale by means of this process.

Brune and Horst Process for Pressing Water out of Peat.

In order to render wet peat amenable to the separation of its moisture by pressure Brune and Horst invented a process, which consists in pressing in a specially constructed hydraulic press, a mixture of dry or partially dry peat, and wet peat in definite proportions. The actual proportion in which the dry and wet peats were mixed was, one part of dry to three parts of wet, by weight. The dry peat should not contain more than 20 per cent moisture. After the wet and dry stuff is thoroughly mixed, it is placed in an hydraulic press, and subjected for a short time to a preliminary pressure of a few atmospheres. Upon the completion of this pressing, the peat cake is removed, broken into small pieces, then returned to the press, where it is subjected for a short time to a greater pressure. As a result of these two pressings, the moisture content is reduced to 53 per cent.

The claim is made that the admixture of dry peat permits the formation of minute channels through which the expelled water can escape.

The further reduction of the water contained in the pressed peat must be accomplished by air-drying or some form of artificial dryer.

The different steps of the process may be enumerated as follows:—

(1). Mixing one part dry with three parts of wet peat.
(2). Pressing the mixture.
(3). Artificial drying of the pressed peat mass.
(4). Briquetting—if desired.

In order to comprehend clearly what is really accomplished by this process, the changes which the raw peat undergoes in passing through the different steps of the process must be clearly kept in view. It must be understood that the dry peat used for mixing does not, theoretically speaking, enter into the final product, but is used over and over again, as an admixture, hence it must be regarded as a fixture of the process. In order to begin the manufacture of peat fuel, according to this process, there must be on hand a certain quantity of dry peat ready for mixing with the raw stuff.

Suppose, by way of illustration, that 100 pounds of peat, containing 20 per cent moisture, is mixed with 300 pounds of raw peat containing 87½ per cent of water; the total dry peat substance contained in the mixture will be $(100\times0\cdot8)+3\,(100\times0\cdot125)=117\cdot5$ pounds, and the total quantity of water contained in this mixture $(100\times0\cdot2)+3\,(100\times0\cdot875)=282\cdot5$ pounds, making the percentage of moisture in the mixture, $282\cdot5\div400=70\cdot6$ per cent.

After pressing, the moisture content of the mixture is reduced to 53 per cent. The amount of water in the pressed cake is $(117\cdot5\times53)\div47=132\cdot5$ pounds.

Quantity of water in mixture before pressing ..	282·5	pounds
Quantity of water in mixture after pressing	132·5	"
Quantity of water removed by pressing	150	"

The total quantity of water in the raw peat is $3\,(100\times0\cdot875)=262\cdot5$ pounds; but if the total quantity of water pressed out of the mixed peat is deducted from this, or $(262\cdot5 - 150=112\cdot5$ pounds), the moisture content will be $112\cdot5\div(112\cdot5+37\cdot5)=75$ per cent. The reduction of the moisture content of the raw peat from 87½ per cent to 75 per cent by pressing is quite possible with ordinary presses. The difficulty arises when attempts are made to reduce the moisture content below 75 per cent.

At Orentano, Italy, for instance, the moisture content of the raw peat is reduced to 77 per cent by means of pressing in an ordinary hydraulic hay press and, in fact, a large portion of the peat produced for consumption in the Mond gas plant at that place, is partially dewatered to this extent in this manner. The further reduction of the moisture content—from 77 to 30 per cent—is then accomplished through the agency of artificial heat.

Whether the raw peat is merely mixed with dry peat, and then pressed until the moisture content is 53 per cent, or simply pressed without the aid of an admixture until its moisture content is reduced to 75 per cent, the quantity of water removed is the same.

In order, therefore, to obtain finished peat with 20 per cent moisture, which is the moisture content of the admixture, the quantity of water which must be removed from the mixed pressed peat is: $400-\frac{400 \times 29\cdot4}{80}=253$ lbs.; of which 150 lbs. has been removed by pressing. Thus, there is left (253—150) or 103 lbs. to be removed by other means.

In the case of the raw peat, the total water to be removed in order to reduce the moisture content from 87½ per cent down to 20 per cent is, $300-\frac{300 \times 12\cdot5}{80}$ or 253 lbs. of which amount 150 lbs., it is assumed, has been removed by pressing in reducing the moisture content from 87½ per cent down to 75 per cent. This leaves—as in the previous case—103 lbs. to be removed by other means. From a technical point of view, therefore, this method is the more rational, inasmuch as there is no unnecessary handling of a quantity of material which is not included in the final product.

The ratio of the dry peat substance contained in the admixture to that contained in the raw peat is 80:37½. This means that more than twice as much dried peat must be added to the raw material as is found in the resultant product; since the dry peat used as an admixture, must, after the pressed substance is dried down to 20 per cent, be separated from the finished product, and used over again. If, for example, the daily output of such a plant is 100 tons of 20 per cent moisture peat, 200 tons must be added and subtracted; this involves the handling and rehandling of about 400 tons of admixture material alone, for the dry peat utilized for mechanically ejecting moisture must be handled twice for every ton of peat made.

Moreover, the presses and drying apparatus must be of sufficient capacity to accommodate enough material to produce 300 tons of 20 per cent moisture peat, when, as a matter of fact, the output is but 100 tons.

Before peat so pressed can be used for fuel purposes its moisture content must be further reduced to, say, 20 per cent moisture. This reduction of moisture involves the evaporation of 103 lbs. of water as previously explained; and the quantity of heat required to evaporate this water is, assuming a dryer efficiency of 70 per cent, $\frac{1120 \times 103}{0{\cdot}70}$ or 164,800 British thermal units. The quantity of heat required to raise one pound of water from 62° F to 212° F, and to evaporate it is, 1120 British thermal units.

If the calorific power of the absolutely dry peat is assumed to be 9,200 British thermal units per pound, its effective heating value, when the moisture is 20 per cent, will be $(9{,}200 \times 0{\cdot}8)$—$(1{,}120 \times 0{\cdot}2)$ or 7,136 British thermal units per pound. The quantity of peat which must be burned in order to produce the required heat is $(164{,}800 \div 7{,}136)$ or about 23 pounds. The total amount of 20 per cent moisture peat obtained with the process, from the 300 pounds of 87½ per cent moisture peat, is 46·9 pounds. The net peat, therefore, available for use or sale is (46·9—23), or 24 pounds, which is about 50 per cent of the total quantity manufactured.

From the foregoing calculations, it will be seen that, in order to produce 20 per cent moisture peat from raw peat containing 87½ per cent water, it is necessary, in addition to pressing, to burn one-half the product manufactured—which is not economic.

Artificial Drying of Peat.

In all forms of artificial driers, devised for evaporating moisture from peat, heat is supplied by the combustion of fuel. Whether the heat thus produced is first used for generating steam, which then transmits heat to the system by means of steam coils or plates—as is done in some forms of drying; or for preheating air—as is sometimes the case, the primary quantity of heat is all that it is necessary to consider here. When heat which would ordinarily be wasted, is available, such as exhaust steam, the products of combustion resulting from the burning of fuel under boilers, or in furnaces, or the exhaust gases of a gas engine, the thermal efficiency of the drying plant is not of much consequence. When, however, fuel in some form must be burned in order to supply the heat, the quantity of heat required to effect the desired result is all important. So important in fact, that a process, otherwise feasible, may technically fail when it comes to the point of artificially drying the wet material through the application of heat.

Many dryers have been devised for evaporating the moisture from peat, for which high efficiencies have been claimed; but none of these have, so far, proved to be economic. The cost of artificial drying is not determined altogether by the fuel which must be burned in order to supply the requisite quantity of heat. Other equally important factors must be taken into consideration, e.g., cost of the drying plant, and the cost of handling the raw and dried peat. Moreover the capacity of the dryers must be large enough to accommodate a large quantity of wet substance, in order to obtain a relatively small quantity of dry peat.

When the peat to be dried contains moisture above a certain percentage the evaporation of the moisture by this means becomes impossible. The illustrative curves (Fig. 10)[1], were constructed to show when the process of drying with heat produced by the combustion of peat containing varying percentages of moisture becomes impossible. These curves show the quantities of dry, 20, 25, 35, and 45 per cent moisture peat it is necessary to burn in order to obtain 100 pounds of peat, dry and of 20, 25, 35, and 45 per cent moisture. The calorific power of absolutely dry peat is assumed, for these calculations, to be 9,500 British thermal units per pound, while the lower calorific power of the peat, when containing 20, 25, 35, and 45 per cent water, is calculated on the assumption that a quantity of heat is required to raise the temperature of the contained water from 62°F

---

[1] Constructed by John Blizard.

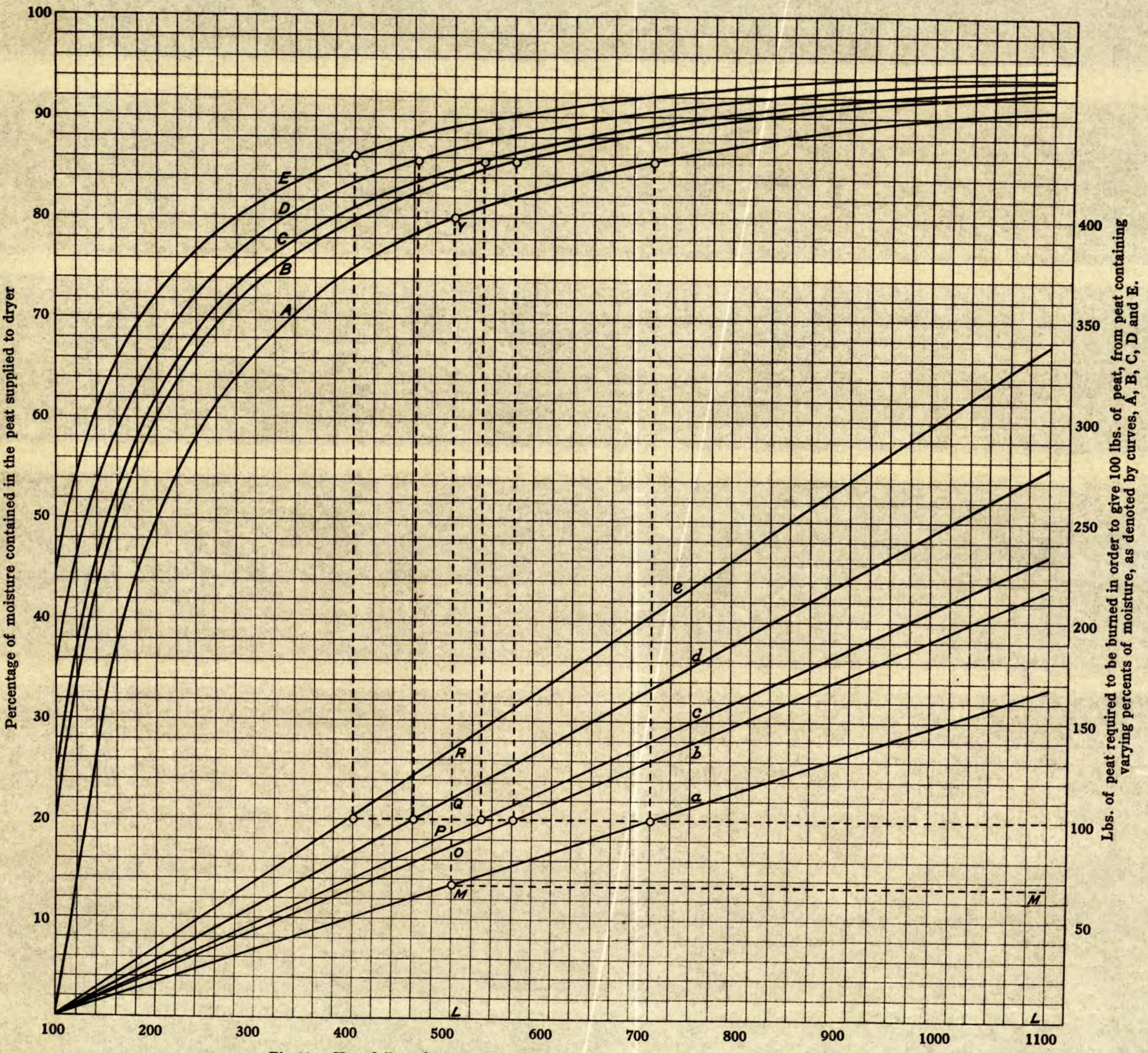


Fig 10. No. of lbs. of peat required to be dried in order to give 100 lbs. of dry and 20, 25, 35 and 45 per cent. moisture peat, as denoted by curves A, B, C, D and E.

to 212°F, and to evaporate it; i.e. the calorific power of peat containing X per cent of moisture is (9,500—106 times moisture per cent), British thermal units. The quantity of heat required to evaporate one pound of contained moisture is taken as 1,120 British thermal units; and the efficiency of the process of evaporation is taken as 70 per cent.

The curves A, B, C, D, and E, show the quantities of raw peat of any moisture content which require to be supplied to the dryer, in order to produce one hundred pounds of dry peat (A): and peat of the following moisture content: 20% (B) 25 per cent (C) 35 per cent (D), and 45 per cent (E). The curves a, b, c, d, and e, show the quantities of peat, dry, and containing 20, 25, 35, and 45 per cent moisture it is necessary to burn in order to evaporate sufficient moisture to produce dry peat, or peat containing 20, 25, 35, and 45 per cent moisture, from peat of any moisture content.

For example, if it is desired to produce 100 pounds of dry peat substance from raw peat containing 80 per cent water, the line (Y-L) dropped from the point (Y), corresponding to 80 per cent moisture, on the curve (A), to the abscissa shows that 500 pounds of peat containing 80 per cent moisture are required to produce 100 pounds of dry peat. The curve (A) shows the number of pounds of raw peat required to produce 100 pounds of dry peat. The intersection of the line (Y-L) with the curve (a) at (M) shows the number of pounds of dry peat—the intersection of (M-M) with the right hand ordinate—it is necessary to burn in order to evaporate the moisture from 500 pounds of raw peat containing 80 per cent moisture, in order to produce 100 pounds of dry peat substance. For this particular case, it will be seen that 67 pounds of dry peat substance must be burned to produce the required heat.

The quantity of peat containing 20, 25, 35, and 45 per cent moisture, it is necessary to burn in order to produce 100 lbs. of dry peat substance from peat containing 80 per cent moisture, can be determined, in like manner, by drawing horizontal lines from the intersections O, P, Q, and R of the line (L-Y) with the curves a, b, c, d, and e, and reading the number of pounds required directly on the right hand ordinate. The number of pounds of peat which must be burned in order to produce 100 lbs. of peat containing 25, 35, etc., per cents of moisture, can be determined in a similar manner from the curves B, C, D, and E.

From these curves it will be seen that in order to produce 100 pounds of dry peat, or 100 pounds of peat containing 20, 25, 35, and 45 per cent of water from peat containing 86 per cent of water, 100 lbs of peat dry, or of 20, 25, 35, and 45 per cent moisture must be burned. Hence the limiting value of the process is 86 per cent—the absurdity, therefore, of attempting to dry peat of this moisture content by means of artificial heat, is apparent.

OTHER FACTORS TO BE CONSIDERED IN THE ARTIFICIAL DRYING OF PEAT.

The artificial drying of peat is not a process which simply involves the evaporation of so many pounds of water. Peat possesses peculiar physical properties that make the solution of the problem difficult: an important one is its poor conductivity of heat. When wet peat is subjected to a comparatively high temperature, as in a drying oven heated directly by the combustion of some fuel, the surface becomes charred before even a small percentage of its moisture has been evaporated. Pieces of peat dried in this manner have on inspection been found to be completely charred on the outside while the moisture content on the inside was in the vicinity of 76 per cent.

In order therefore to completely dry wet peat by such a method a high temperature gradient must be maintained. As a consequence, by the time the drying has been completed, the peat will have lost an appreciable amount of volatile matter. It is quite evident, moreover, that a large quantity of heat is wasted, inasmuch as the wet air and moisture leave at a comparatively high temperature. In the case of the evaporation of water, a thermal efficiency of 70 per cent is quite possible—but when the water to be evaporated is contained in the peat and the heat must be conducted through the peat substance in order to raise the temperature of the moisture to 212° and evaporate it, it is quite apparent that an efficiency of 70 per cent cannot be realized in practice. Unfortunately no reliable data are available concerning this method for drying peat and such data as are available concerning other substances cannot be employed when designing an apparatus for evaporating the moisture from wet peat, since the physical properties of peat differ so much from other substances which require to be dried.

DRYING BY MEANS OF HOT AIR.

This method includes preheated air, the circulation of the hot products resulting from the combustion of fuel under boilers or in furnaces or the hot waste gases from the exhaust of a gas engine. Air, moreover, may be mixed with any of these waste gases and circulated.

When drying peat according to this method, the peat is generally placed on racks supported on trucks which are then rolled on tracks into long rectangular chambers. The ends of these chambers are partially closed when the process begins. The heated air, hot gases, or mixture of both, are admitted through openings in the sides and roof of the chamber, and are forced through and around the trays of peat by means of a power driven fan. A method on the above lines is employed at Orentano for drying a large portion of the peat consumed in the Mond gas plant at that place. The waste heat from the boiler plant, the gas engine exhaust gases and a large amount of heat obtained from a special preheater are mixed with air which is then forced through the drying chambers. At this plant about 20 tons of peat of 30 per cent moisture per day are obtained from the raw peat containing 77 per cent moisture. The heat available for drying is that contained in the hot gases of the gas engines exhaust, the products of combustion of the boiler plant and the heat derived from the combustion of 8 tons of peat, or its equivalent in gas, in a specially constructed furnace for heating air. These hot gases are mixed with a quantity of air which reduces the temperature of the mixture of air and gases to about 150° C. A forty horse power fan, operated by an electric motor, forces this hot gaseous mixture through five drying chambers. The hot gases enter through openings provided on the sides and roof at the middle of the chamber and pass out at both ends. The peat to be dried is loaded on trays which are then placed on trucks, and wheeled into the chambers. Each truck is provided with fourteen trays and has a total capacity of about 4,300 pounds of peat containing 77 per cent moisture (which is the moisture content of the peat after it has been prepared for artificial drying). Each truck is left in the drying chamber for two hours during which time the moisture content of the peat is reduced to about 30 per cent. The maximum quantity of 30 per cent moisture peat obtained by this method is about 1,400 lbs. per car for every two hours—which amounts to 20 metric tons per day of 24 hours.

The following calculation shows the quantity of heat required to produce 20 metric tons of 30 per cent moisture peat.

The quantity of raw peat containing 77 per cent water required to make 20 metric tons of peat containing 30 per cent water is:—

$\frac{20 \times 70}{23} = 61$ tons or 134,000 lbs. Of this quantity 134,000—(20×2,200) or 90,000 lbs. of water must be removed in order to give 20 tons of 30 per cent wet peat. The quantity of heat required to raise this quantity of water from 62° F to 212° F and evaporate it, is:

$90{,}000 \times 1{,}120 = 100{,}000{,}000$ Brit. ther. units (approx.): and the quantity of heat available is:

1st. The heat of exhaust of two gas engines of 300 B.H.P. each or a total of 600 B.H.P. This it might be assumed is 35 per cent of the total heat of combustion of the gas in the cylinders of the engines, which will, therefore, supply per hour, assuming a thermal efficiency of 25 per cent for the gas engine:

$\frac{2545 \times 35}{25} = 3560$ Brit. ther. units per B.H.P. The total heat available for 600 H.P. during 24 hours will be approx.:

$3{,}560 \times 600 \times 24 = 51{,}000{,}000$ Brit. ther. units.

2nd. The gas burned under the boilers: This is equivalent to the heat of combustion of 11 tons of peat fuel of 30 per cent wet peat and of this heat 20 per cent is available as chimney gases. This will be approx.:

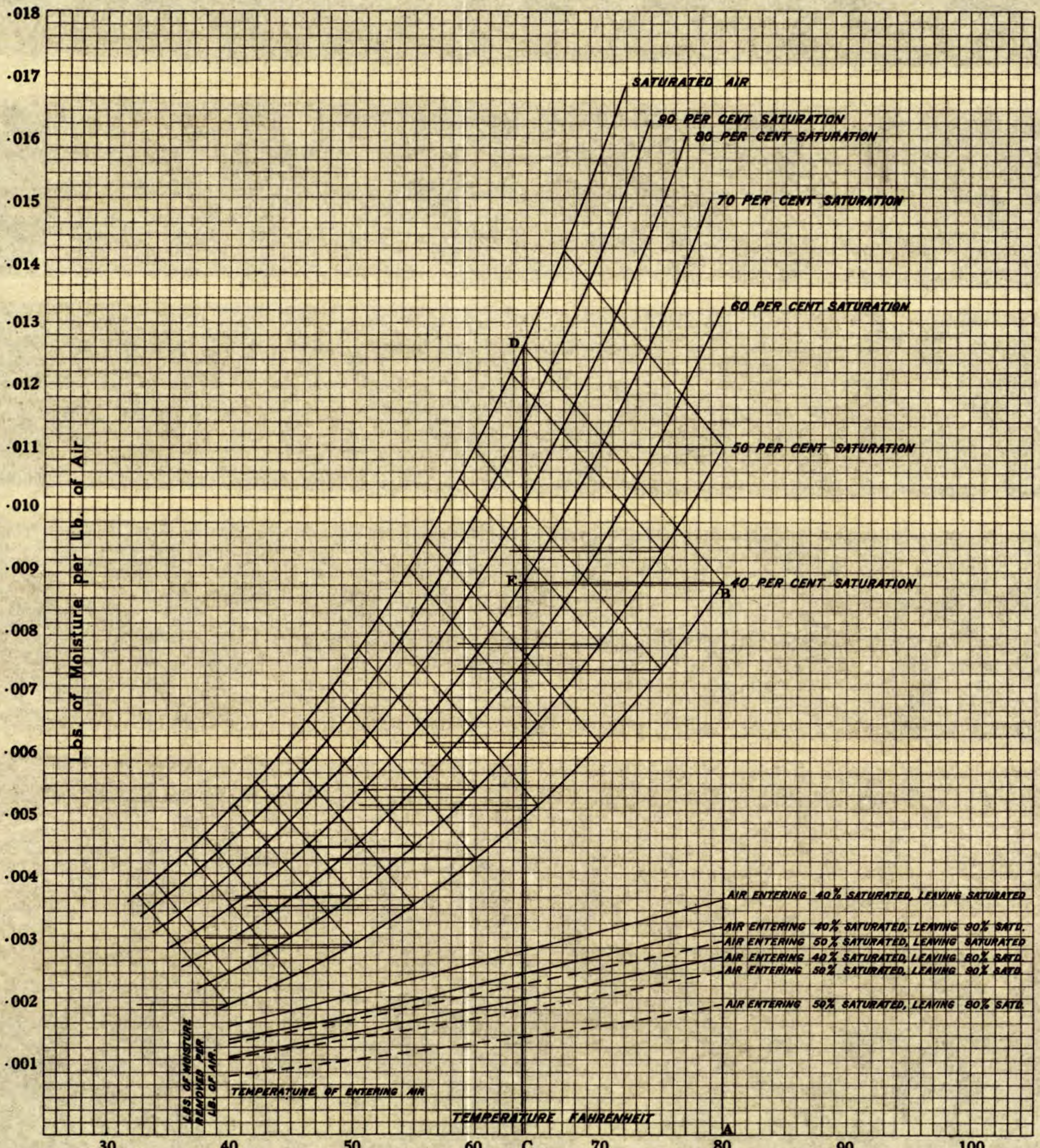


Fig. 11. Curves showing the pounds of moisture present per pound of air for varying degrees of saturation and temperature.

11 × 0.20 × 2,200 × 6,320 = 30,000,000 B.T.U.

3rd. The gas burned under the air preheater: This is equivalent to the heat produced by the combustion of 8 tons of 30 per cent wet peat which is approximately equal to:

6,320 × 2,200 × 8 = 111,000,000 B.T.U.

The total heat available for drying from the above sources is the sum of 1, 2 and 3, or approximately 192,000,000 B.T.U.

The total quantity of heat theoretically required to evaporate the water is 100,000,000 B.T.U. The efficiency of the process is therefore 100,000,000 ÷ 192,000,000 or about 52 per cent. In the above calculation the heat equivalent of the 40 H.P. electric motor required to drive the fan is not taken into account.

ARTIFICIAL DRYING OF PEAT BY AIR.[1]

When unsaturated air is passed over water it becomes more nearly saturated with moisture. In so doing its temperature is reduced. For any degree of saturation of the entering air the fall of temperature in passing over the water will depend upon the degree of saturation of the discharged air. The amount of water removed by the air will depend upon the reduction of temperature of the air as it takes up moisture until it reaches any definite humidity.

A series of curves (see Fig. 11)[2] have been prepared showing the lbs. of moisture present per lb. of air for varying degrees of saturation and temperature. The inclined lines in these curves are drawn to show the increase in the quantity of vapour per lb. of air when the temperature of the air is reduced by passing it over water which is supposed to remain at the constant temperature of 60°F. Thus the ordinate A B represents the lbs. of vapour per lb. of air for 40 per cent saturation and a temperature of 80°F. If this air be passed over water it will become saturated at 63·7°F when the moisture content will be represented by the ordinate C D. The difference between the ordinates C D and A B or E D will then represent the amount of moisture removed per lb. of air. Similarly, from the curves the amount of moisture removed with an increase to 90, 80, 70, 60 or 50 per cent saturation may be found.

---

[1] John Blizard.
[2] Ibid.

The curves have been constructed for air entering at 40 and 50 per cent saturation.

The lower set of curves show the pounds of moisture removed per lb. of air entering with 40 and 50 per cent humidity and varying temperatures and leaving saturated or 90 per cent or 80 per cent saturated.

From these curves the lbs. of air to evaporate one pound of moisture may be calculated. In the case of any proposed installation for the drying of peat by this method of more or less complete saturation of air, it is necessary to estimate the number of heat units in the peat which would be required to drive the air over the moist substance. These figures have been calculated and the results are represented by the curves in Fig. 12. For these calculations the following arbitrary figures are used:

Efficiency of Peat Gas Producer and Gas Engine,	·125
Efficiency of Electric Generator................	·88
" " " Fan Motor.............	·88
" " Fan.............................	·66

giving an overall efficiency of .0639.

The pressure at which the air is delivered to the fan is assumed as $1\frac{1}{2}$ inches of water above the atmosphere.

The heat in the peat necessary to propel one cubic foot of air at a pressure of $1\frac{1}{2}$ inches of water (or 7·8 lbs. per sq. foot), will be

$$\frac{7\cdot8}{778} \times \frac{1}{\cdot0639} = \cdot157 \text{ B.T.U.}$$

It will be observed that the lowest figure shown on the curves is that for air entering with 40 per cent humidity at 80°F and leaving saturated, this figure is as low as 570 B.T.U., but it is extremely unlikely that so low a figure would be reached in practice, the inlet air temperature being higher and the humidity lower than might be expected, moreover, the practicable size of the drying chamber would preclude the complete saturation of the air.

A general examination of the curves will show that with ordinary conditions throughout a season, little, if any, better results might be expected by artificial air drying than by the direct heating method. The limits of such a method as the latter have been previously demonstrated.

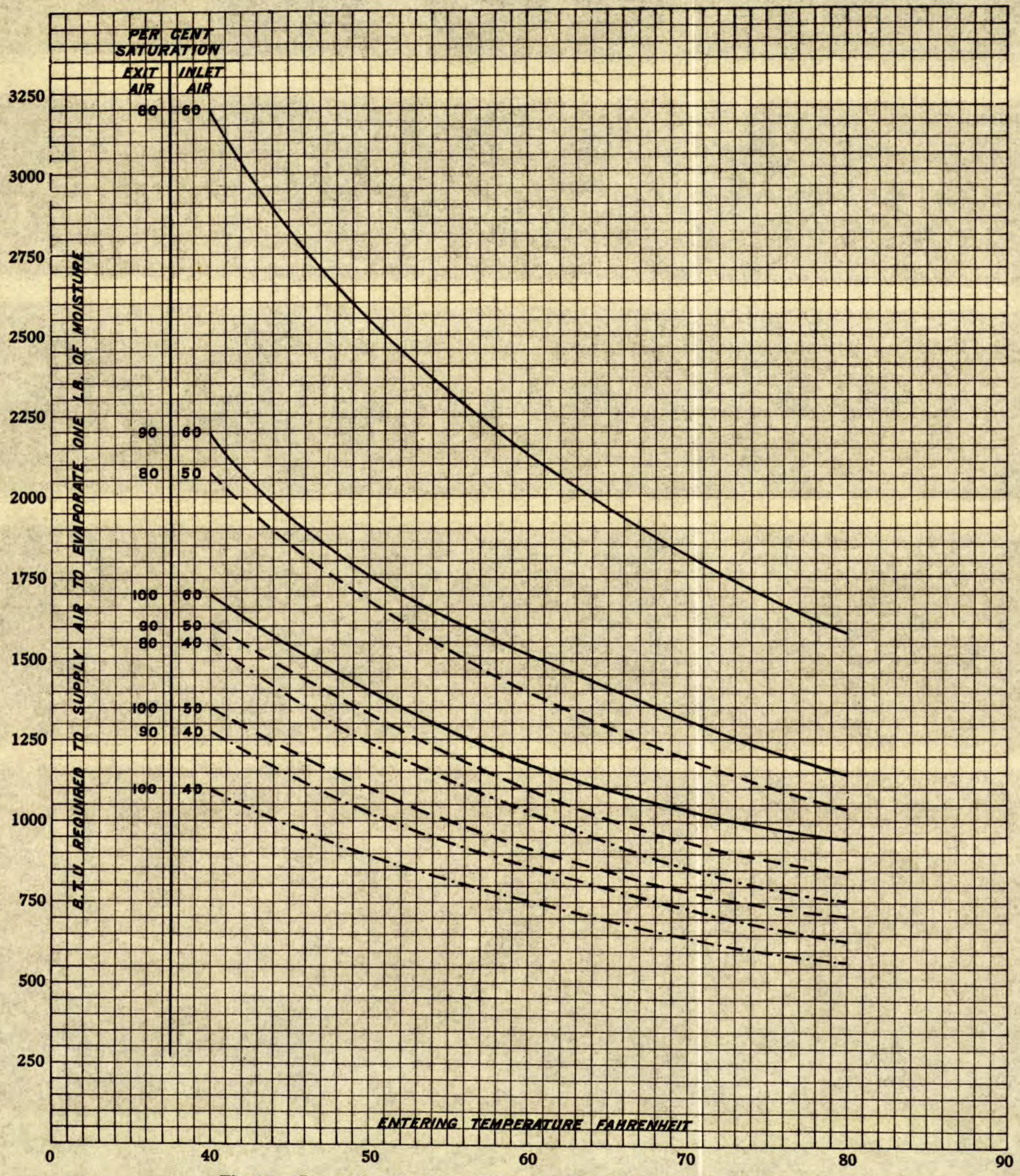


Fig. 12. Curves showing the number of heat units in the peat which would be required to drive the air over the moist substance.

CHAPTER II.

CHEMICAL ANALYSES AND EFFECT OF MOISTURE ON CALORIFIC POWER OF PEAT.

Chemical Analyses. The chemical analyses of the various samples of peat taken from the peat bogs so far examined in the provinces of Ontario, Quebec and Manitoba, are shown in Tables 1, 2, and 3. Only proximate analyses were made of the samples contained in these tables—but these serve to show the slight differences existing between the various samples of peat which are representative of peat bogs separated by considerable distances. The ash content of five of the samples is moderately high, but for the rest it is very low.

For the purpose under discussion in this report, viz., the recovery of the nitrogen contained in the peat, it will be interesting to note that all of the bogs so far examined contain over one per cent of nitrogen, while several of them contain nearly 2 or over 2 per cent. This is a high average, and compares favourably with the best of the European peats, as will be seen by comparing Tables 1, 2, and 3, with Table 4, which gives the analysis of samples of peat taken from many representative European peat bogs.

Sulphur is contained only in slight amounts in all the samples, and requires no further consideration.

Calorific Power.

In considering the feasibility of utilizing peat for power purposes, the calorific power is the most important factor to consider; while the nitrogen content is of equal importance when its recovery is contemplated in conjunction with the generation of power gas in by-product recovery gas producers.

The calorific power of the samples of peat shown in Tables 1 and 2 are determined on the absolutely dry sample. The calo-

TABLE 1.

Analyses of the Different Peat Samples Collected in Ontario.

No. of Samples from each bog.	Peat from	Composition of Peat.	Analyses of Peat (absolutely dry).						
			Volatile matter.	Fixed Carbon.	Ash	Phosphorus	Sulphur	Nitrogen	Calorific value B.T. U. per lb.
1	Mer-Bleu, Ontario	Sphagnum more or less mixed with eriophorum	65·90	24·22	10·88	....	....	....	8821
2	" "		67·57	25·35	7·18	0·026	0·314	1·40	9021
3	" "		68·40	25·00	6·60	....	....	....	
4	" "		63·22	24·86	11·92	....	....	....	8805
5	" "		68·76	25·73	5·51	....	....	....	9126
6	" "		68·73	26·27	5·00	0·024	0·317	1·13	9441
7	" "		69·49	26·04	4·47	....	....	....	9301
1	Alfred, Ontario	Principally formed by sphagnum	68·13	26·56	5·31	0·029	0·292	1·23	8730
2	" "		68·72	24·22	7·06	0·022	0·375	1·92	9058
1	Welland, Ontario	Sphagnum mixed with carex, eriophorum and hypnum......	67·14	26·48	6·38	0·027	0·317	1·13	9118
2	" "		70·90	24·84	4·26	0·024	0·248	1·74	8596
3	" "		70·53	24·28	5·19	....	....	....	8667
1	Newington, Ontario....	Sphagnum slightly mixed with aquatic plants...............	66·75	25·77	7·48	0·028	0·530	1·85	8721
2	" "		67·07	26·27	6·66	0·030	0·494	1·80	8465
3	" "		68·84	26·65	4·51	....	....	....	8877
4	" "		71·32	24·44	4·24	0·032	0·345	1·63	8336
5	" "		69·54	26·75	3·71	....	....	....	9102
6	" "		65·77	27·30	6·93	....	....	....	8210
7	" "		66·97	26·70	6·33	....	....	....	8312
1	Perth, Ontario	Sphagnum mixed with hypnum..	70·34	25·35	4·31	0·030	0·405	1·66	9067
2			71·51	24·60	3·89	0·027	0·334	1·94	9148
1	Victoria Road, Ontario .	Hypnum mixed with sphagnum..	69·52	25·18	5·30	....	....	....	8649
1	Brunner, Ontario	Principally hypnum	64·09	25·16	10·75	0·035	0·303	1·73	8850
1	Komoka, Ontario	Sphagnum mixed with carex.....	60·90	18·52	20·58	0·087	1·34	1·63	7490
1	Brockville, Ontario....	Carex slightly mixed with eriophorum and aquatic plants....	66·70	21·75	11·75	0·038	0·90	2·41	8173
1	Rondeau, Ontario	Carex mixed with remains of grasses and aquatic plants.....	61·00	22·90	16·10	0·049	0·73	2·77	7914
1	Alfred, Ontario: part of bog	Sphagnum slightly mixed with hypnum and eriophorum......	68·23	26·00	5·77	0·033	0·218	1·76	9005

rific power, it will be seen, varies from about 7500 to 9500 B.T.U. per pound. The heating value of all the peat used in the producer trials at the fuel testing plant, which was manufactured at the Alfred peat bog, was above 9400 B.T.U. per pound, and the peat contained in this bog, moreover, contains a fair amount of nitrogen. It is quite probable that as the work of investigating the peat bog progresses, many bogs will be discovered which contain peat of an equally high calorific power, and nitrogen content.

TABLE 2.

Analyses of Samples of Peat taken from the Holland Peat Bog.

Volatile matter...	59·5	63·2	63·4	64·3	59·6	64·6	66·8	63·5	65·0	65·4	53·0
Fixed carbon....	21·2	24·6	23·0	23·5	23·1	20·2	24·2	26·2	24·5	24·1	18·5
Ash......	19·3	12·2	13·6	12·2	17·3	15·2	8·8	10·1	10·5	10·5	28·5
Phosphorus......	....	0·050	....	....	0·69	....	....	0·67	....	....	0·147
Nitrogen....	....	2·7	....	....	2·8.	....	..	2·7	....	....	2·5
Calorific value, B.T.U. per lb...	7610	8350	8080	8390	7790	7950	8380	7980	8250	8510	6720

The heating power, however, of the absolutely dry sample is no index as to the effective heating value of the manufactured peat fuel, since the moisture content of the commercial fuel may be anything from a few per cent up to 60 per cent. It is usual for power purposes to deliver the peat to the power plant with a moisture content of from 25 to 30 per cent and all effective heating values are calculated on this moisture content. In all the calculations and the curves plotted from them the calorific value of the absolutely dry sample of peat has been assumed to be 9500 B.T.U. per pound.

To determine the effective heating value when the moisture content and the calorific power of the absolutely dry peat are known, the following formula may be used:

$$A = \frac{1}{100}[100\,B - X\,(B + 1120)] \qquad (1)$$

TABLE 3.

Peat Bogs Investigated in Ontario.

The names of the peat bogs.	Locality.		Approximate total area.	Volume of workable peat.			Partial analyses of absolutely dry peat.				REMARKS.
	County.	Township.		Tons of fuel with contents 25% moisture.	Tons of litter with contents 20% moisture.	Cubic yards.	Fixed carbon %	Volatile matter %	Ash %	Calorific value	
Mer Bleu..	Russell	Gloucester and Cumberland.	5,004	5,125,665	....	38,442,494	25·00	68·40	6·60	9126	Principally formed of sphagnum.
Alfred.....	Prescott	Alfred and Caledonia,	6,800	9,369,360	....	70,270,200	26·56	68·13	5·31	8730	Principally formed of sphagnum.
Welland.. ..	Welland	Wainfleet and Humberstone.	4,900	4,106,197	....	30,796,480	24·28	70·53	5·19	8667	Formed of hypnum, eriophorum, and sphagnum.
Newington ..	Stormont ..	Osnabruck, Roxborough, and Cornwall.	3,800	6,208,864	....	46,566,478	26·27	67·07	6·66	8465	Principally formed of sphagnum.
Perth.......	Lanark	Drummond.	3,800	5,126,030	....	38,445,222	24·60	71·51	3·89	9148	Formed of sphagnum hypnum, and eriophorum.
Victoria Road	Victoria	Bexley and Carden.	67	53,659	....	402,441	25·18	69·52	5·30	8649	Principally formed of hypnum mixed with sphagnum.
Brunner	Perth	Ellice.	2,288	1,172,130	....	8,790,979	25·16	64·09	10·75	8850	Principally formed of hypnum.
Komoka	Middlesex ..	Caradoc and Lobo..	900	253,831	....	1,903,733	18·52	60·90	20·58	7490	Formed of remains of sphagnum and carex.
Brockville...	Leeds......	Elizabethtown	1,400	1,694,129	....	12,705,969	21·75	66·70	11·75	8173	Formed of remains of sphagnum and carex.
Rondeau ...	Kent	Harwich	1,571	1,047,544	....	7,856,581	22·90	61·00	16·10	7914	Principally formed of carex.
Holland	Simcoe and York	West and East Gwillimbury and King.	14,641	8,218,931	....	61,641,981	26·20	63·50	10·50	8510	Principally formed of carex.
Coney Island	Coney Island.	Lake of the Woods.	25	32,267	....	242,000	....	....	....	......	Principally formed of carex.
Crozier	Rainy River district ...	Crozier	355	....	518,291	6,912,223	....	....	....	......	Principally formed of sphagnum.
Fort Francis.	Rainy River district ...	McIrvine and Crozier.	1,700	891,205	....	6,684,040	28·9	62·4	8·7	8910	Principally formed of sphagnum.
		TOTAL	47,251	43,299,812	518,291	324,748,598					

TABLE 4

Analyses of Peat from Different Countries.*

Description.	Water absorbed.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.	Authority.
Peat dried at 212 F	..	66·55	10·39	18·59	2·76	1·70	Flickenscher, Germany.
" " " "	..	57·03	5·63	29·67	2·09	5·58	Regnault, France.
" " " "	..	58·09	5·93	31·37	..	4·61	" "
" " " "	..	57·79	6·11	30·77	..	5·33	" "
" " " "	..	57·16	5·65	33·39	..	3·80	Mulder, Holland
" " " "	..	59·96	5·52	33·71	..	0·91	" "
" " " "	..	50·85	4·64	30·25	..	14·25	" "
" " " "	..	59·00	5·53	19·50	1·50	14·50	Johnston, Scotland.
Average peat	21·9	42·7	4·0	27·4	1·6	2·4	Tylvad.
Peat dried at 220 F.	..	57·0	5·5	31·0	1·5	5·0	Dr. Machattis.
Surface peat, Phillipstown, dried at 220 F...	..	58·694	6·971	32·883	1·4514	..	Kane and Sullivan.
Dense peat, Phillipstown, dried at 212 F...	..	60·476	6·097	32·546	0·8806	..	" "
Light surface peat, Wood of Allen, dried at 220 F	..	59·920	6·614	32·207	1·2558	..	" "
Dense peat, Wood of Allen, dried at 220 F. .	..	61·022	5·771	32·400	0·8070	..	" "
Surface peat, Twicknevin, dried at 220 F. .	..	60·102	6·723	31·288	1·8866	..	" "
Light surface peat, Shannon, dried at 220 F. ..	..	60·018	5·875	33·152	0·9545	..	" "
Dense peat, Shannon, dried at 220 F.	..	61·247	5·616	31·446	1·6904	..	" "
Kilbeggan, Westmeath..	..	61·040	6·670	30·47	..	..	" "
Kilbuha, Clare.........	..	56·630	6·330	34·48	..	..	Kane.
Cappoge, Kildare	..	51·05	6·850	39·55	..	..	"
Ockta, in Eastern Russia	..	39·084	3·788	51·088	..	..	Waskrescensky.
Peat, 4·5 feet from surface, Tuam, Ireland..	..	57·207	5·655	28·949	3·067	..	Ronalds.
Peat, 3·5 feet from surface, Tuam, Ireland...	..	58·306	5·821	29·669	2·509	..	"
Peat, 2·5 feet from surface, Tuam, Ireland...	..	59·552	5·502	28·414	1·715	..	"
Good air-dried peat, Galway	24·2	45·3	4·6	24·1	..	1·8	Dr. Cameron.
Poor air-dried peat, Galway	29·4	42·1	3·1	21·0	..	4·4	" "
Dense peat, Galway	29·3	42·0	5·1	17·5	1·7	3·8	" "
Air-dried peat, Devon..	25·56	54·02	5·21	28·17	2·30	9·73	Vaux.
Island of Lewes	23·20	60·00	6·90	30·00	1·30	1·90	Paul.
Bresles	2·17	46·80	5·65	41·15	..	6·40	Marsilly.
"	3·14	47·48	7·16	36·03	..	9·00	"
Thesy	3·07	50·67	5·76	36·95	1·92	6·70	"
"	7·20	43·65	5·79	36·66	..	14·00	"
Bourdon	5·55	47·96	6·01	39·30	..	7·00	"
Camon	5·59	46·11	5·99	35·97	2·63	9·40	"
Riemencourt	1·81	12·99	2·22	19·31	..	65·01	"
Vulcaire	..	57·03	5·63	29·67	2·09	5·58	Regnault.
Lory	..	58·09	6·11	30·77	..	4·61	"
Faramont	..	57·79	6·11	30·77	..	5·33	"
Friesland	..	57·16	5·67	33·39	..	3·80	Mulder.
"	..	59·86	5·52	33·71	..	0·91	"
Holland	..	50·85	4·65	30·25	..	14·25	"
Ramstein	16·70	62·15	6·29	27·30	1·66	2·70	Walz.
Steinwenden	16·00	57·50	6·90	31·81	1·75	2·04	"
Neidermoor	17·00	47·90	0·80	42·80	..	3·50	"
Prussian	15·70	50·13	4·20	31·44	..	8·92	Baer.
"	21·70	55·01	5·36	35·24	..	11·17	"
Havel	17·63	56·43	5·32	38·35	..	9·86	Jackel.
"	19·32	53·51	5·90	40·59	..	6·60	"
"	18·89	53·31	5·31	41·38	..	6·80	"
Linum	31·34	59·43	5·26	35·31	..	11·99	"
Hamburg	18·83	57·32	5·32	37·56	..	2·31	"
Bremen	57·84	57·84	5·85	32·76	0·95	2·60	Breuninger.
"	..	57·03	5·56	34·15	1·67	1·57	"
Schopfloch	20·00	53·59	5·60	30·32	2·71	8·10	Nester and Petersen.
Sindefingen	18·00	45·44	5·28	26·21	1·46	21·60	" "
Irish peat, perfectly dry, average..........		59·0	6·0	30·0	1·25	4·0	P. Dawson.
Irish peat, including 25 per cent moisture average	25·0	44·0	4·5	22·5	1·0	3·0	"
Irish peat, including 30 per cent moisture average................	30·0	41·2	4·2	21·0	0·8	2·8	"
Switzerland, air-dried, compressed, average ..	23·17	40·09	4·53	21·50	2·84	7·87	Goppelsroeder.
Peat, air-dried.........	21·9	42·7	4·0	27·4	1·6	2·4	Tyvald.

---

*From "Peat, Its Use and Manufacture," by P. R. Björling and F. T. Gissings.

Where A is the calorific power of the wet peat, in B.T.U. per lb.; B is the calorific power of the absolutely dry peat, in B.T.U. per lb.; X is the percentage of moisture contained in the peat for which it is desired to determine the calorific power.

The total quantity of heat required to raise 1 pound of water from 62°F to 212°F and evaporate it is denoted by 1,120 Brit. ther. units.

If it is desired to calculate the calorific power from the ultimate analysis, the following formula (an adaptation of that of Dulong) may be used:

$$Y = C \times 14600 + (H - \tfrac{1}{8}O)\,62100 - (9\,H + X)\,1120 \qquad (2)$$

C = weight of carbon.
H = " hydrogen.
O = " oxygen.
X = weight of water.

In this formula, the loss due to the water formed by the combination of the hydrogen and oxygen of the fuel is taken into consideration; while in formula (1) such loss is not taken into account.

The following ultimate analysis of a sample of peat taken from the Alfred bog will be used as an illustration.

Carbon	56·0 per cent.
Hydrogen	5·2 "
Ash	6·0 "
Oxygen, nitrogen and sulphur by difference	32·8 "

The nitrogen and sulphur may be taken as 2 per cent, leaving 30·8 per cent as oxygen.

If a moisture content of 25 per cent is assumed, the percentages of carbon, hydrogen, ash and oxygen will be:

Carbon	42·0 per cent.
Hydrogen	3·9 "
Ash	4·5 "
Oxygen	23·1 "

and these values when substituted in formula (2) will give:—

$$Y = 0{\cdot}42 \times 14600 + \left(0{\cdot}039 - \frac{0{\cdot}231}{8}\right)62{,}100 - (9 \times 0{\cdot}039 + 0{\cdot}25) \times 1120;\ \text{or}$$

$Y = 0{\cdot}42 \times 14600 + 621 - 673$, or 6080 Brit. ther. units as the effective calorific value of the wet peat. The calorific value as determined from formula (1) will be:—

$$A = \frac{1}{100}\left[100 \times 9460 - 25\,(9460+1120)\right]$$

$=6815$ Brit. ther. units. Here, 9460 B.T.U. is the actual calorific value of the absolutely dry peat as determined in the bomb calorimeter.

EFFECT OF MOISTURE ON THE CALORIFIC POWER OF PEAT.

The following tables, 5 and 6, have been prepared for the purpose of clearly showing the effect which the quantity of moisture present in the fuel has upon its calorific power.

The column showing the quantity of heat required to evaporate the moisture is calculated; firstly, assuming that the

TABLE 5.*

Lbs. of moisture per lb. of peat (dry)	Per lb. of Wet Peat.					H–a	H–b
	Per cent moisture.	Per cent peat.	Heat content of dry peat. H	Heat to evaporate the moisture. a	Heat to warm, evaporate and superheat. b		
9	90	10	950	870	1170	80	−220
7·3	88	12	1140	850	1140	290	0
6	85·7	14·3	1360	830	1110	530	250
5	83·4	16·6	1580	805	1080	775	500
4	80	20	1900	770	1040	1130	860
3	75	25	2375	720	970	1655	1405
2	66·6	33·3	3166	645	870	2521	2296
1½	60	40	3800	580	780	3220	3020
1	50	50	4750	480	650	4270	4100
2/3 or ·66	40	60	5700	380	520	5320	5180
·54	35	65	6170	340	450	5830	5720
3/7 or ·43	30	70	6650	290	390	6370	6260
1/3 or ·33	25	75	7125	240	330	7885	6795
0	0	100	9500	....	....	9500	9500

---

* Table prepared by John Blizard.

TABLE 6.*

Per Cent Moisture in Peat.	Lbs. of Moisture per lb. of Dry Peat.	Lbs. of Moisture removed from 1 lb. of Peat containing 90% Moisture.	Per Cent of total Moisture removed from 90% Wet Peat.	Theoretical lbs. of Dry Peat to evaporate and superheat the Moisture content 1 lb. peat for 7·3 lbs. water.	Per Cent of Dry Peat present available for external use.	Net Calorific Power of 1 lb. of Wet Peat B.T.U's.
90	9·0	·0	0	1·23	0	—220
88	7·3	·17	19·0	1·0	0	0
86	6·1	·29	32·2	·835	16·5	220
84	5·25	·37	41·7	·719	28·1	427
82	4·55	·44	49·5	·622	37·8	646
80	4·0	·5	55·5	·548	45·2	858
77	3·35	·56	62·8	·459	54·1	1182
75	3·0	·6	66·7	·410	59·0	1405
70	2·3	·67	74·2	·315	68·5	1950
66	1·9	·71	78·5	·260	74·0	2390
60	1·5	·75	83·4	.205	79·5	3020
55	1·2	·78	86·6	·165	83·5	3570
50	1·0	·80	89·0	·137	86·3	4100
45	·82	·82	91·0	·112	88·8	4630
40	·67	·83	92·5	·096	90·4	5180
35	·54	·846	94·0	·074	92·6	5720
30	·43	·857	95·2	·059	94·1	6260
25	·33	·867	96·3	·045	95·5	6795
20	·25	·875	97·2	·034	96·6	7240
16	·19	·881	97·8	·026	97·4	7780
10	·10	·890	98·9	·013	98·7	8430

heat required is only that which overcomes the latent heat of the water, or 966 B.T.U. per pound; secondly, the calculation assumes conditions which prevail in a gas producer or steam boiler in which it is assumed that the water enters at the temperature of the charged peat—about 60°F—and leaves at the temperature of the hot gases—about 600°F. Under these latter conditions, the total heat required to evaporate the water and then superheat it to 600°F will be per pound, as follows:—

	B.T.U.
To raise the temperature of the water from 60° to 212°F. 212–60	152
Latent heat of water per pound	966

---

* Table prepared by John Blizard.

Heat required to superheat the steam, assuming the specific heat of superheated steam to be 0·48, is 0·48 × (600–212) 186

Total heat per pound of water........... 1304

or, in round numbers, 1300 B.T.U. per pound.

The calorific power of 1 pound of absolutely dry peat is taken as 9500 B.T.U.

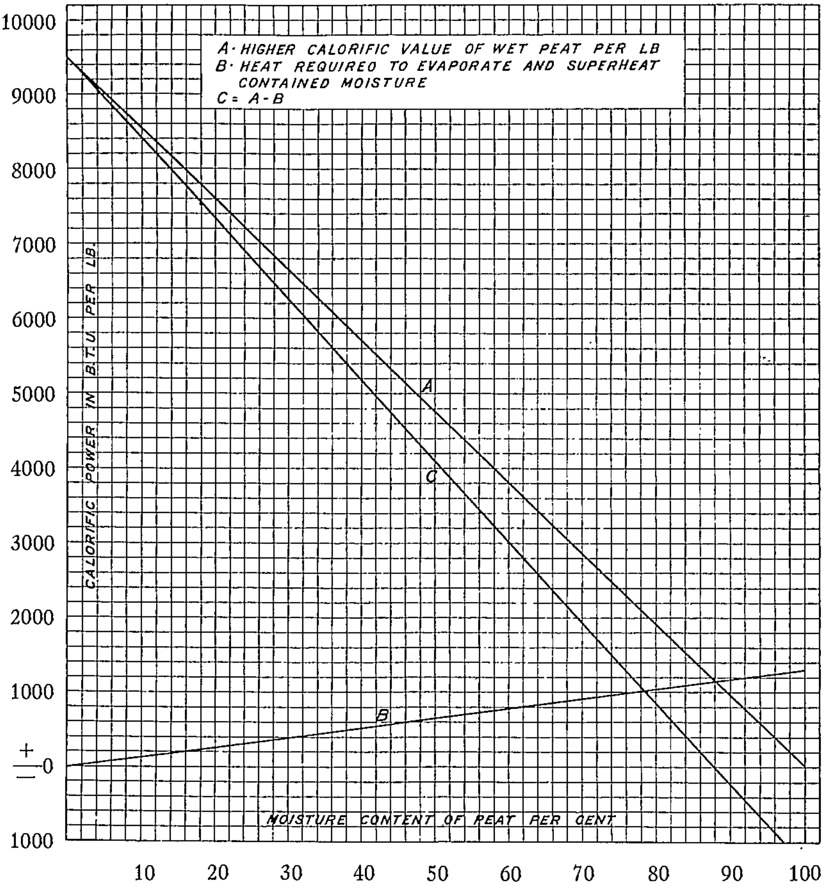


Fig. 13.*—Curves showing the higher and lower calorific power per pound of peat containing different percentages of moisture, and the quantity of heat required to evaporate and superheat the moisture removed.

---

*Curve constructed by J. Blizard.

The curves shown in Fig. 13 show graphically the results set forth in the above tables.

In these curves A is the higher calorific power of wet peat per pound. B is the quantity of heat required to evaporate and superheat the contained moisture. C is the net or effective

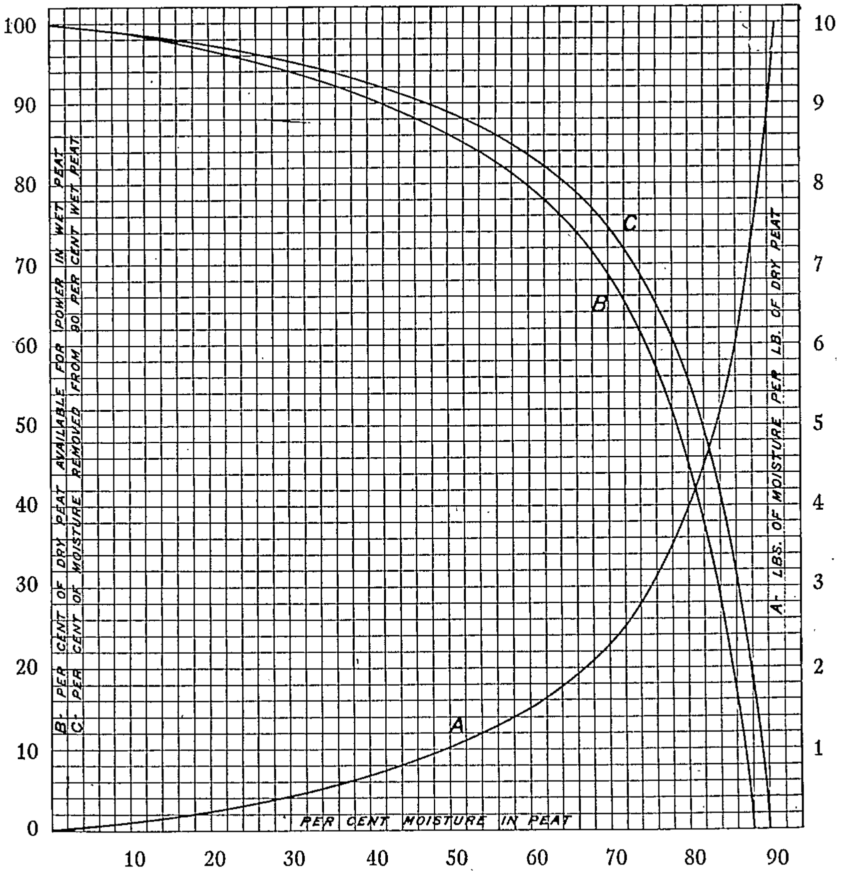


FIG. 14.*—Curves showing pounds of moisture per pound of dry peat, for peat containing different percentages of moisture; percentage of dry peat available for power at different moisture contents; and percentage of total moisture removed from 90 per cent moisture peat in order to obtain peat with different moisture contents.

---

* Curve constructed by John Blizard.

calorific power of the wet peat and is obtained by subtracting the values represented by curve B from those of curve A. The abscissa represents the percentage of moisture in the wet peat and the ordinate the corresponding calorific power in Brit. ther. units. The curves A, B, and C, Fig. 14, show the pounds of moisture contained in the peat substance per pound of dry peat for varying percentages of moisture, the per cent of dry peat available for power purposes in the wet peat, and the percentage of the total moisture contained in the wet peat substance which is removed when the moisture content of the dried peat varies from 0 to 90 per cent.

As an example, suppose it is required to find from curve A how many pounds of moisture per pound of absolutely dry peat are contained in a mass of 50 per cent wet peat. The abscissa shows the quantity of moisture in the peat and the right hand ordinate the weight of water in pounds per pound of dry peat substance. Thus 50 per cent on the abscissa will give one pound on the right hand ordinate as the weight of water contained in the 50 per cent wet peat per pound of dry peat, 80 per cent moisture corresponds to 4 pounds of water to 1 pound of dry peat and 90 per cent moisture to 8 pounds of water per pound of dry peat.

If the peat substance contains 87 per cent water, by referring to curve B, it will be seen that no dry peat is available for power purposes. The percentage of moisture contained in the peat is shown on the abscissa, as in the previous case, and the percentage of dry peat available is shown on the left hand ordinate. If the peat contain 80 per cent moisture the dry peat available for power purposes is about 44 per cent; for 60 per cent moisture about 79½ per cent of the dry peat is available; if it contain 40 per cent, over 90 per cent of the dry peat is available, and so on for any per cent of moisture. Curve C is self-explanatory, the abscissa represents the percentage of moisture contained in the peat and the left hand ordinate the percentage of the total moisture content removed from peat with 90 per cent water content, when the moisture content of the dried peat is between 0 and 90 per cent.

Thus to reduce the moisture content of the peat to 50 per cent, 89 per cent of the total water contained in the 90 per cent wet peat substance must be removed, and so on for other moisture contents.

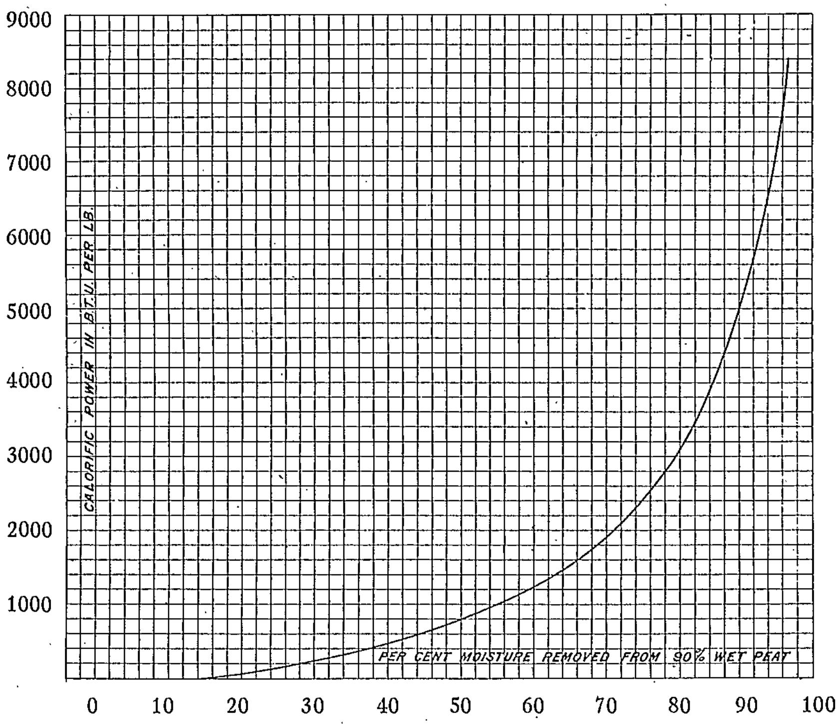


FIG. 15.*—Curve showing the effect on the calorific power of wet peat by removing different percentages of the total moisture content.

The effect produced on the calorific power of wet peat by the removal of different percentages of the total moisture is graphically shown in Fig. 15. The raw peat is assumed to have a moisture content of 90 per cent. If now 50 per cent of the total moisture content be removed the calorific power of the peat will be a little over 600 B.T.U. per lb. If 80 per cent be removed the calorific power will be increased to about 2500 B.T.U., etc.

---

*Curve cosntructed by John Blizard.

CHAPTER III.

AMMONIUM SULPHATE.

Ammonium sulphate is a chemical compound composed of the elements, nitrogen, hydrogen, sulphur, and oxygen. It has the molecular formula $(NH_4)_2SO_4$ and contains 25·75 per cent ammonia (NH_3) when chemically pure. The sulphate obtained in commerce, however, may not contain more than 21–22 per cent.

From the molecular formula $(NH_4)_2SO_4$ the ratio of the pounds of ammonium sulphate to the pounds of nitrogen is found to be:

$$\frac{\text{lbs. of sulphate}}{\text{lbs. of nitrogen}} = \frac{132}{28} = 4 \cdot 7;$$

that is, the quantity of ammonium sulphate formed is 4·7 times the quantity of nitrogen entering into the combination. Thus, if a long ton (2,240 lbs.) of coal contains 1 per cent nitrogen or 22·4 lbs., the quantity of ammonium sulphate which could be theoretically formed would be $22 \cdot 4 \times 4 \cdot 7 = 105 \cdot 6$ lbs.—and for the short ton (2,000) lbs. $20 \times 4 \cdot 7 = 94 \cdot 3$ lbs. The efficiency of the recovery process is seldom greater than 70 to 75 per cent, the ammonium sulphate resulting would, therefore be: $105 \cdot 6 \times 0 \cdot 75 = 79$ lbs. and $94 \cdot 3 \times 0 \cdot 75 = 71$ lbs. respectively. The following curves, Fig. 16, show the quantity of ammonium sulphate which can be theoretically obtained from fuels having a nitrogen content varying from 0·1 to 2·1 per cent nitrogen.

Sources of Ammonia.

The principal commercial sources of ammonia and its compounds with other substances are: the coke ovens, gas works, and by-product recovery gas producer plants. The principal sources of the nitrogen are the coals, lignites, peats, and oil shales, which are found in abundance in almost every country of the world. Ammonia is also formed synthetically from the elements nitrogen and hydrogen on a commercial scale in Germany—but this method for its manufacture does not concern us here. In France considerable quantities of ammonia are obtained from the sewage of Paris and suburbs and from the distillation products of distilleries—but so far as Canada is con-

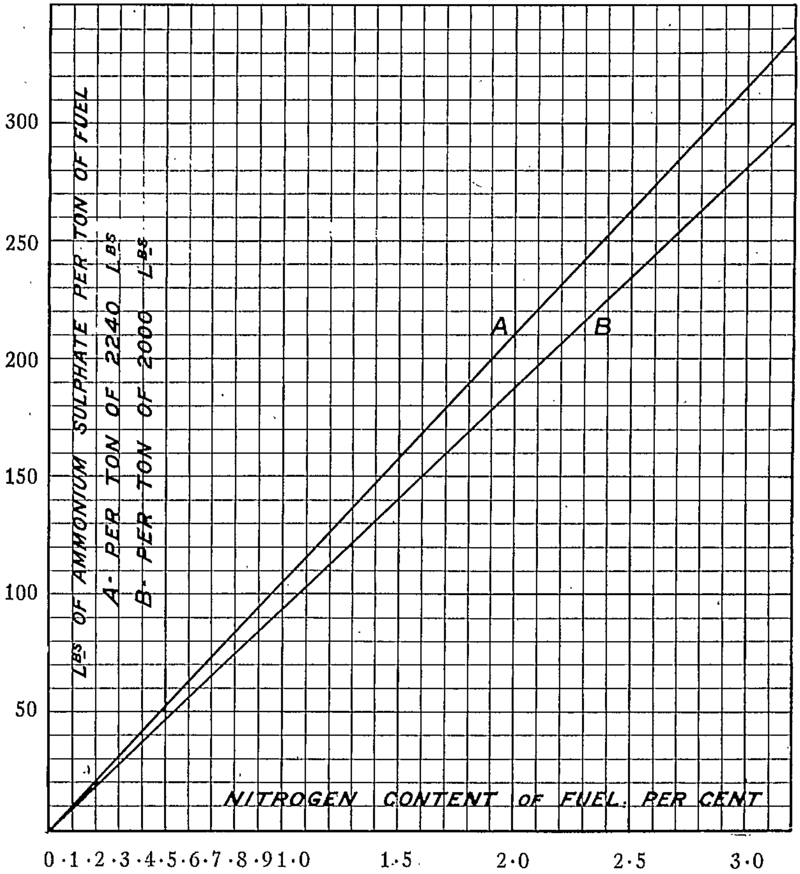


FIG. 16.*—Sulphate of ammonia which can be theoretically obtained from fuels having a nitrogen content, varying from 0·1 to 3·0 per cent.

---

* Curve constructed by J. Blizard.

cerned, at the present time, the principal sources of ammonia are the by-product recovery coke ovens of the steel works.

Such low grade fuels as peat and lignite often contain a high percentage of nitrogen which cannot be profitably recovered by any of the above mentioned processes for the manufacture of an illuminating gas or gas resulting from the coking of coal. These fuels can, however, be utilized in a most efficient manner in the by-product recovery producer. The large quantity of nitrogen contained in these fuels, especially in the enormous areas covered by peat bogs, can by this means be rendered available for the use of man.

In order to show the large quantity of nitrogen which can be recovered from peat bogs in the form of ammonium sulphate, thirteen of the bogs so far examined in the Province of Ontario, which have a total fuel content of 43 million tons of 25 per cent moisture peat and an average nitrogen content of about 1·73 per cent of the dry peat will be taken as an example. The nitrogen content of the wet peat will be 1·3 per cent and this content of nitrogen will correspond to 43,000,000 × 0·013 = 560 thousand tons of nitrogen, which with 70 per cent recovery in the present day practice will give 1,800,000 tons of ammonium sulphate with a gross value, at the present market price, of about 130 million dollars.

In addition to the ammonium sulphate, there would be produced a quantity of power gas sufficient to generate approximately 40,000 H.P. continuously for 100 years.

Applications. According to Lunge,* nearly all of the ammonium sulphate manufactured is employed as a fertilizer. It is especially valuable for the cultivation of beet root and cannot for this purpose be replaced by the cheaper nitrogen of nitrate of soda. This is the principal reason for the very large importation of this salt into Germany. The action of ammonia as a manure is slower than that of nitrate of soda, but for that reason it is all the more lasting. It is absorbed by the soil and retained even after large quantities of rain have come down; whereas under such conditions, nitrate of soda is washed out, and the soda moreover renders the soil in the end too hard for tilling. Am-

---

*Coal-Tar and Ammonia, Lunge, Part II, p. 1105.

monium sulphate is preferable for potatoes, while for wheat, rye, and oats, nitrate of soda is of equal value. The sulphate also serves for preparing the other ammonium salts, and sometimes for liquor ammoniae, and for making ammonia-alum. In the manufacture of ammonia-soda the sulphate is now mostly replaced by the cheaper concentrated gas-liquor.

A 10 per cent solution of ammonium sulphate is employed to render tissues, papers, etc., non-inflammable.

A very important application for ammoniacal nitrogen seems to be in store for the manufacture of nitric acid from ammonia, by the invention of Ostwald and others.

But by far the most important application of this salt, and one which will consume all that is produced for a long time to come, is its use as a manure.

Statistics of Production and Consumption.

ENGLAND.

The sources of production of ammonium sulphate in England are shown in Table 7.[1] An examination of this table will show that the quantity of ammonia recovered from coke ovens and gas producers increased from 17,000 metric tons[2] in 1900 to 129,000 metric tons in 1911, or nearly eight fold, while that recovered from illuminating gas works increased only from 142,000 to 169,000 metric tons. The total production at the end of the ten year period was very nearly 80 per cent greater than in 1900. According to the "Mineral Industry"[3] the coke ovens and producer gas and carbonizing works contributed the following quantities of ammonium sulphate.

	1905	1906	1907	1908	1909	1910	1911	1912
Coke ovens.	30,732	43,677	53,572	64,227	82,886	92,665	105,343	132,000
Producer gas and carbonizing works	15,705	18,736	21,873	24,024	24,705	27,850	29,964	

---

[1] Annuaire Statistique des Engrais et Produits Chimiques destinés à l'Agriculture, by E. & M. Lambert, 1912.

[2] 1 metric ton = 2204 lbs.

[3] Mineral Industry, 1912, Vol. XXI, p. 33.

TABLE 7.

Sulphate of Ammonia.

SOURCES OF PRODUCTION IN ENGLAND.

In Metric Tons.

Sources of Production.	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911
Illuminating Gas.	142,000	143,000	150,000	150,000	150,000	156,000	157,000	165,500	164,000	171,000	168,000	169,500
Blast Furnaces...	17,000	16,500	18,500	19,000	19,500	20,000	21,000	21,000	20,000	19,000	21,000	20,000
Oil Shales	37,000	40,000	37,000	37,500	42,500	46,000	48,500	51,000	51,000	57,000	60,000	60,000
Coke Ovens and Gas Producers .	17,000	18,000	23,500	27,500	33,500	46,500	62,500	75,000	79,000	101,000	120,000	129,000
Total	213,000	217,500	229,000	234,000	245,000	268,500	289,000	312,500	314,000	348,000	369,000	378,500

TABLE 8.

Sulphate of Ammonia.

EXPORTS FROM GERMANY.

In Metric Tons.

Country of Destination.	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911
Belgium	..	..	..	..	..	..	..	16,625	13,380	15,918	20,668	18,944
France	..	..	..	..	..	..	..	11,101	8,813	7,185	11,031	7,558
England	..	..	..	..	..	..	..	..	..	..	203	..
Italy	..	..	..	..	..	..	..	7,162	7,246	6,182	10,065	5,035
Holland	..	..	..	..	..	..	..	1,945	5,619	4,077	6,729	5,338
Switzerland	..	..	..	..	..	..	..	55	210	260	499	507
Antilles and Honolulu	..	..	..	..	..	..	..	1,428	1,631	1,717	1,945	368
Japan	..	..	..	..	..	..	..	10,862	8,353	400	11,262	4,169
Java	..	..	..	..	..	..	..	11,753	25,469	20,596	17,855	27,081
United States	..	..	..	..	..	..	..	..	..	..	4,840	2,215
Portugal	..	..	..	..	..	..	..	..	..	..	624	..
Other countries	..	..	..	..	..	..	..	94	160	285	1,366	1,356
Spain	..	..	..	..	..	..	..	2,160	3,669	3,174	9,154	6,339
Total	2,403	9,841	5,744	5,591	10,696	25,000	38,000	63,185	74,550	59,794	96,241	78,910

TABLE 9.

Sulphate of Ammonia.

IMPORTS INTO GERMANY.

In Metric Tons.

Country.	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911
Belgium	..	..	..	..	..	..	..	860	694	..	..	..
Denmark	..	..	..	..	..	..	..	163	211	..	..	..
England	..	..	..	..	..	..	..	13,500	24,913	34,715	7,105	2,685
Holland	..	..	..	..	..	..	..	809	1,263	..	..	..
Austria-Hungary	..	..	..	..	..	..	..	16,523	17,928	16,925	18,894	18,123
Other countries	..	..	..	..	..	..	..	1,667	4,424	6,492	5,401	3,655
Total	23,104	44,407	42,258	35,168	35,165	48,005	32,454	33,522	49,433	58,132	31,400	24,463

England occupies the second place as a producer of ammonium sulphate—but of the total annual production of 379,000 long tons in 1912[1] her consumption was only 90,000 gross tons for all purposes.

GERMANY.

The production of ammonium sulphate from all sources in this country was in 1911, 400,000 metric tons—see Table 13. The exports and imports were 78,910 and 24,463 metric tons respectively—see Tables 8 and 9.[2] Germany consumes for agricultural purposes a larger quantity of this fertilizer than any other country. The total consumption in 1911 for all purposes was 345,553 metric tons and the rate of increase in both the production and consumption is rapidly increasing. The new by-product recovery plants in connexion with coke ovens and gas producers for utilizing low grade fuels such as peat and lignite which are being erected together with the synthetic process for the manufacture of sulphate of ammonia, will very greatly increase the production of this commodity during the next few years. From Table 9 it will be seen that the total imports in 1900 were 23,104 metric tons, and that these steadily increased up to 1905 when they decreased for the following two years. The next two years, 1908 and 1909, showed a decided increase but from that time on the imports considerably decreased. Germany practically consumes the whole of her ammonium sulphate production, while England exports the major portion of hers.

FRANCE.

The ammonium sulphate produced in France is derived principally from the gas works and coke ovens but a very considerable quantity is obtained from the sewage of the Paris and provincial districts. The production from this source is steadily decreasing (see Table 10), while that from the coke ovens shows

---

[1] Mineral Industry, 1912, Vol. XXI, p. 33.

[2] Annuaire Statistique des Engrais et Produits Chimiques destinés à l'Agriculture, by E. and M. Lambert, 1912.

TABLE 10.

Sulphate of Ammonia.

SOURCES OF PRODUCTION IN FRANCE.

In Metric Tons.

Sources of Production.	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911
Paris Gas Works..	10,000	10,000	10,000	10,500	11,200	11,200	11,200	11,500	11,200	11,500	11,500	12,500
Suburban Gas Works........	..	..	..	..	..	..	..	..	1,300	1,500	1,500	2,800
Province Gas Works........	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,300
Sulphate from the Coke region of the North.....	7,000	7,000	8,000	9,500	13,000	14,500	16,550	17,000	18,000	20,000	24,000	24,300
Sulphate from the Coke Region of the Centre and S.W.	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,800	3,000	4,700
Sulphate from Sewage, Paris District.......	10,000	10,000	10,000	10,000	9,000	9,000	9,000	9,000	9,000	8,500	8,200	8,200
Sulphate from Sewage, Province District.....	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500
Sulphate from Shales.......	500	500	500	500	700	700	800	800	900	900	1,000	1,000
Sulphate from Wine and others	..	..	..	..	..	..	..	..	..	..	800	700
Total.......	37,000	37,000	38,000	40,000	43,400	44,900	47,000	47,800	49,900	52,700	57,500	62,000

TABLE 11.

Ammonia Production of the United States expressed in Sulphate Equivalent.

(Tons of 2000 lbs.)

	1899	1900	1901	1902	1903	1904	1905
By-product coke ovens	6,000	13,800	15,279	18,483	24,098	32,653	41,864
Coal gas and bone carbonizing works	(a) 13,500	(a) 13,800	(a) 14,000	(a) 17,641	17,775	22,011	23,432
Total	19,500	27,600	29,279	36,124	41,873	54,664	65,296
Percentage from coke ovens	31	50	52	51	57	60	64

	1906	1907	1908	1909	1910	1911	1912
By-product coke ovens	.....	62,700	50,073	75,000	86,000	95,000	130,000
Coal gas and bone carbonizing works	.....	36,609	33,327	(a) 31,500	(a) 30,000	(a) 32,000	(a) 35,000
Total	(a) 75,000	99,309	83,400	106,500	116,000	127,000	165,000
Percentage from coke ovens	.....	62	60	70	74	75	79

(a) Estimated.

TABLE 12.

Ammonia Consumption of the United States, Expressed in Sulphate Equivalent. (a)

Tons 2000 lbs.

Year	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
Imports	16,777	16,667	15,288	9,182	32,669	34,274	40,192	63,178	103,743	67,003
Total Consumption	58,650	71,331	80,584	84,182	132,000	121,874	149,192	179,178	230,743	232,003
Average Price....	$62.10	$61.71	$62.92	$62.33	$61.93	$59.90	$56.04	$55.60	$62.21	$65.95

a marked increase. The total annual production has increased from 37,000 metric tons in 1900 to 62,000 metric tons in 1911. France imports about 8000 metric tons a year from Germany. (See Table 8).

UNITED STATES.

Table 11 shows the annual production of ammonia expressed in sulphate equivalent for the years 1899 to 1912 inclusive. The production from the coke ovens shows a remarkable increase of from 6000 tons in 1899 to 130,000 tons in 1912. This indicates that a very large number of coke plants have been equipped with by-product recovery ovens. The remainder of the annual output is obtained from coal gas and carbonizing works and the production from these also shows a very marked increase, viz. from 13,500 tons in 1899 to 35,000 tons in 1912. The total consumption of this fertilizer for the year 1912 was 232,003 tons (see Table 12), while the total production for that year was only 165,000 tons. The deficiency of 65,003 tons was made up of imports from other countries. From this it will be seen that the United States is not only the third largest producer of ammonium sulphate but is also the largest importer. Table 12.

CANADA.

Canada produces a very small amount of ammonium sulphate and this is obtained almost entirely from the coke plants at Sydney, Nova Scotia, and Sault Ste. Marie, Ontario. The total production in 1909, 1910 and 1911 was as follows: 3,351, 3,491 and 7,124 tons respectively. The imports of natural and artificial fertilizers (including ammonium sulphate) for the years 1908 to 1912 inclusive were as follows:

Year	Dutiable	Free	Total
1908	259,132	110,034	369,166
1909	341,102	131,573	474,675
1910	350,907	130,549	481,456
1911	399,597	146,560	546,157
1912	445,385	43,342	488,727

TABLE 13.

Sulphate of Ammonia.

World's Production in Metric Tons.

Country.	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911
England	213,000	217,000	229,000	234,000	245,000	268,000	289,000	313,000	325,500	348,000	369,000	378,500
Germany	108,000	110,000	125,000	140,000	165,000	200,000	255,000	287,000	313,000	330,000	383,000	400,000
France	37,000	37,000	38,000	40,000	43,000	45,000	47,000	48,000	49,000	52,000	57,000	62,000
Belgium	20,000	18,000	18,000	19,000	16,000	18,000	26,000	27,000	30,000	34,000	36,000	40,000
Holland	3,000	3,000	3,000	3,000	3,000	3,500	4,000	5,000	5,000	5,000	5,000	6,000
Austria-Hungary	18,000	18,000	19,000	19,000	20,000	20,000	30,000	35,000	35,000	50,000	70,000	85,000
Spain	8,000	8,000	9,000	9,000	10,000	10,000	10,000	10,000	12,000	12,000	12,000	12,000
Italy	3,000	3,500	3,500	4,000	4,000	4,500	6,000	11,000	11,000	12,000	12,000	12,000
United States	...	...	...	38,000	49,000	59,000	68,000	90,000	80,000	96,000	116,000	127,000
Japan	...	...	...	...	...	500	1,000	1,500	2,500	3,000	4,000	4,000
Other Countries	10,000	20,000	10,000	20,000	20,000	25,000	15,000	10,000	30,000	34,000	36,000	31,000
Total	420,000	434,500	454,500	526,000	575,000	653,500	751,000	837,500	893,000	976,000	1,100,000	1,157,500

TABLE 14.

Sulphate of Ammonia.

WORLD'S CONSUMPTION IN METRIC TONS.

Country.	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911
England.........	68,000	70,000	70,000	72,000	72,000	80,000	80,000	80,000	83,000	87,000	87,000	87,000
Germany.......	126,000	142,000	162,000	169,000	186,000	226,000	250,000	263,000	291,000	330,000	350,000	380,000
France........	52,000	48,000	55,000	56,000	58,000	60,000	67,000	73,000	80,000	80,000	83,000	83,000
Belgium........	19,000	19,500	22,300	19,400	23,700	36,000	37,000	38,100	40,800	49,000	53,000	51,000
Holland.........	6,000	5,800	6,500	7,000	7,000	9,000	9,000	10,000	12,000	12,000	11,000	13,000
Spain and Portugal......	46,000	45,000	50,000	58,000	58,000	55,000	60,000	57,000	60,000	64,000	62,000	68,000
Italy............	8,000	8,000	8,900	9,000	10,800	9,300	14,500	20,000	28,000	30,000	33,000	38,000
United States....	36,000	44,000	54,000	58,000	71,000	80,000	84,000	132,000	122,000	150,000	180,000	193,000
Japan..........	1,000	1,500	3,000	5,000	15,000	35,000	33,000	63,500	43,000	55,000	61,500	81,000
Java...........	15,000	20,000	22,000	25,000	25,000	20,000	30,000	30,000	30,000	45,000	50,000	45,000
Other Countries..	33,000	20,000	15,000	25,000	20,000	19,700	15,000	33,400	31,000	23,000	39,500	11,000
Total.......	410,000	423,800	468,700	498,400	546,500	630,000	679,500	800,000	820,800	925,000	1,010,000	1,050,000

The dutiable fertilizers include the manufactured nitrogenous compounds. The imports of this class of fertilizer increased from 259,132 dollars in 1908 to 445,385 dollars in 1912, while the imports of the free or natural fertilizers dropped from 110,034 dollars to 43,342 dollars during the same period. From this it may be inferred that the demand for such fertilizers as ammonium sulphate is constantly increasing.

THE WORLD'S PRODUCTION AND CONSUMPTION.

Tables 13 and 14 show the world's production and consumption of ammonium sulphate from the years 1900 to 1911.

PRICES.

The average price by years and by the English ton of 2,240 lbs. of ammonium sulphate f.o.b. port of Hull is shown in Table 15. An inspection of this table will show that the price steadily increased from 1901 when it was £10 11s. ($61.24) per ton to £13 15s. ($66.78) in 1911. The average price of this salt in the United States for the years 1903 to 1912 was shown in Table 12. The price in 1912, viz. $65.95, is very nearly the same as the English price for 1911 ($66.78).

The indications are that the prices of ammonium sulphate will remain firm at the present level for some time to come.

The following table* shows the quantities of ammonium sulphate used per acre in Belgium, Germany, England, France, and the United States, and the yield per acre in wheat, barley, oats, and potatoes, obtained from the land fertilized with the salt.—

Country.	Lbs. of ammonium sulphate per acre.	Total crops raised per acre.			
		Wheat.	Barley.	Oats.	Potatoes.
		lbs.	lbs.	lbs.	tons.
Belgium	17·83	2,228	1,908	2,572	6·58
Germany	9·98	2,012	1,400	1,586	5·25
England	5·35	1,756	....	1,591	5·05
France	2·23	1,238	908	1,154	3·18
United States	1·34				

---

*Iron and Coal Trades Review.

TABLE 15.

Sulphate of Ammonia—Average Price[1] by years and by the English ton of 2240 lbs. F.O.B. Port of Hull.

	£	s.	d.
1901	10	11	4
1902	11	16	3
1903	12	9	2
1904	12	3	8
1905	12	10	9
1906	12	0	9
1907	11	15	8
1908	11	12	0
1909	11	5	0
1910	12	3	2
1911	13	15	3

---

[1] Annuaire Statistique des Engrais et Produits Chimiques destinés à l'Agriculture, by E. & M. Lambert.

Recovery of Ammonia as a By-Product in Producer Gas Power Plants.

While the recovery of ammonia as a by-product when peat fuel is utilized in power gas producers is the principal consideration in this report, certain of the power gas plants in England, which burn bituminous coal, will be described in detail.

POWER PLANTS VISITED.

The following by-product recovery power gas plants were visited: The South Staffordshire Mond Gas Co., Dudley Port; The Langwith By-Product Co. Ltd., Langwith; the power plant of the Societa per L'Utilisazzione du Combustibili Italiani, Orentano, Italy, and the ammonia recovery power plant of the German Mond Gas Co., situated in the district of Wittlage and Bersenbrück near the city of Osnabrück. The large steam power plant of the Siemens Electrical Co., situated in Wiesmoor in Ostfriesland, designed for burning peat, was also visited.

All of the above ammonia recovery plants, with the exception of that at Osnabrück, are constructed on the Mond system; that at Osnabrück according to Frank and Caro.

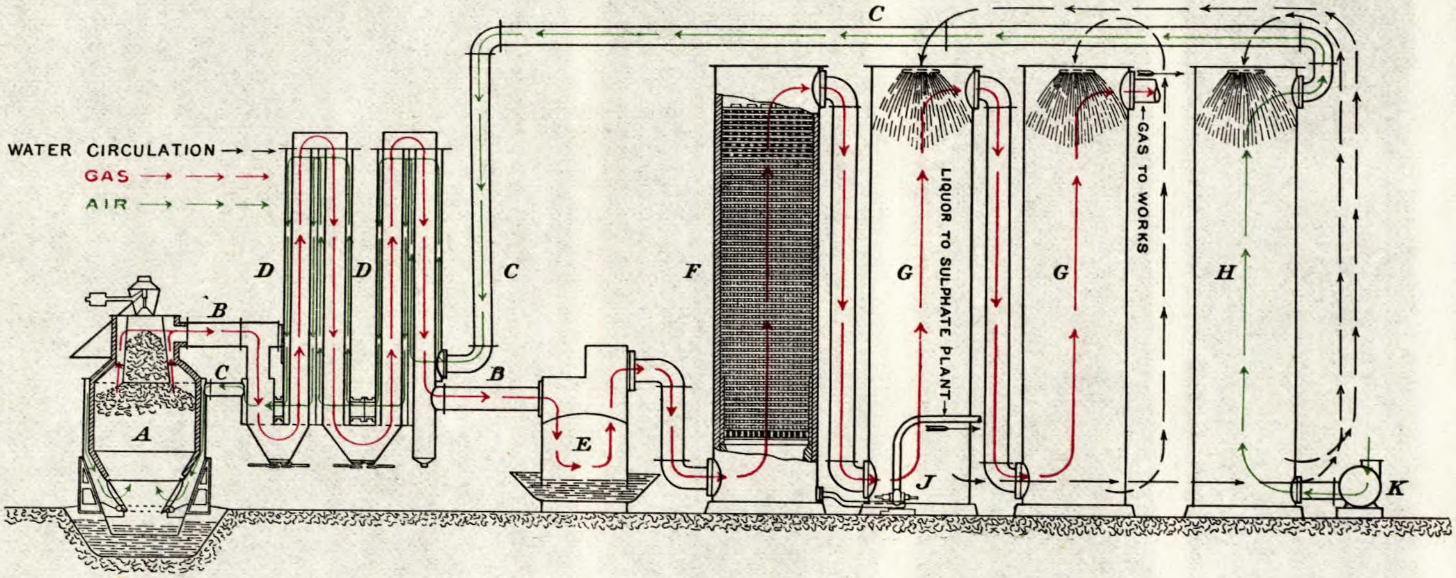


Fig. 17. Diagrammatic section of the Mond by-product recovery producer-gas system.

THE MOND PROCESS.

The Mond process makes use of the fact that a low temperature and the presence of steam in gas-producers are conducive to the formation of ammonia. Hence a limited supply of air charged with a large quantity of steam is introduced into the producer.

The ammonia and tar are collected by cooling and condensing, or the ammonia may be absorbed, without cooling, by a solution of sulphuric acid.

Description of the Mond By-Product Recovery Producer-Gas Power Plant.

A Mond by-product recovery power-gas plant consists, in general, of a producer A, Fig. 17, superheaters D, mechanical washer E, ammonia absorption tower F, gas cooling towers G, air tower H, and the necessary blowers, pumps, etc., for forcing air through the producer, and circulating the water and acid. When the solution of ammonium sulphate is evaporated at the plant suitable evaporators are provided.

The paths of the gas and air are clearly shown by red and green lines respectively in Fig. 17 while the circulation of the hot and cool water is shown by broken black lines.

The gas leaves the producer at the top and passes through one or more superheaters D into a mechanical washer E. From the mechanical washer the gas enters the ammonia absorption tower F at the bottom and leaves at the top, freed of its ammonia gas and some of its tar. From the ammonia absorption tower, the hot gases pass through one or more water cooling towers, from which it is distributed to gas furnaces or is further purified for power purposes. The air which is supplied to the producer is first passed through the air tower H where it absorbs heat and moisture from the hot water leaving the first gas cooling tower. From the air tower the air passes through the superheaters D in which some of the sensible heat of the producer gas is absorbed. From the superheaters the pre-heated air enters the producer near the bottom. Further saturation of the air is accomplished by adding low pressure steam, generated in a boiler plant.

THE MOND PRODUCER.

The producer is of the water bottom type, and consists of an inner shell (the producer proper) constructed of steel plates lined with fire brick encased within a similar outer shell. The air and steam composing the blast passes through the annular space A, Fig. 18, between the inner and outer shells,

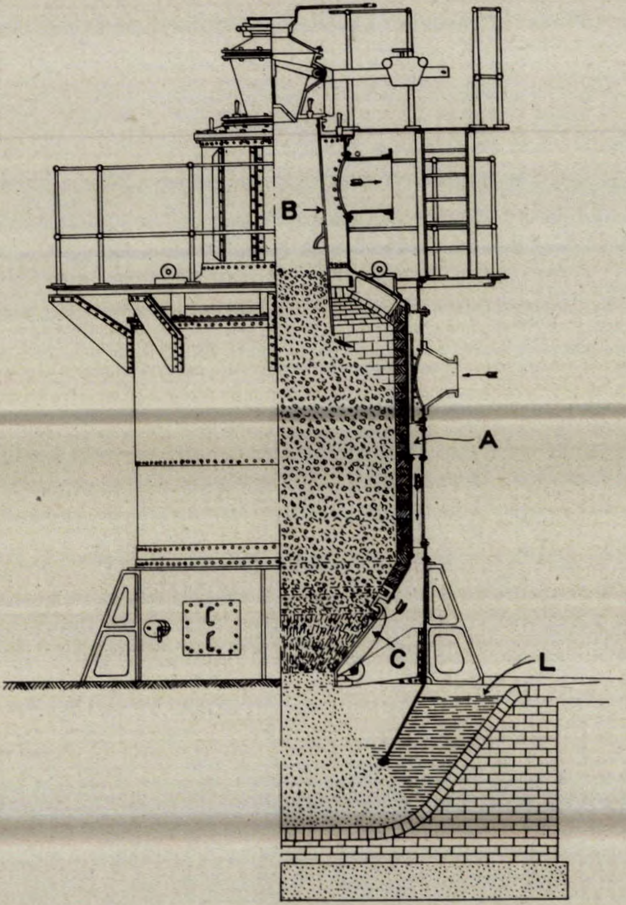
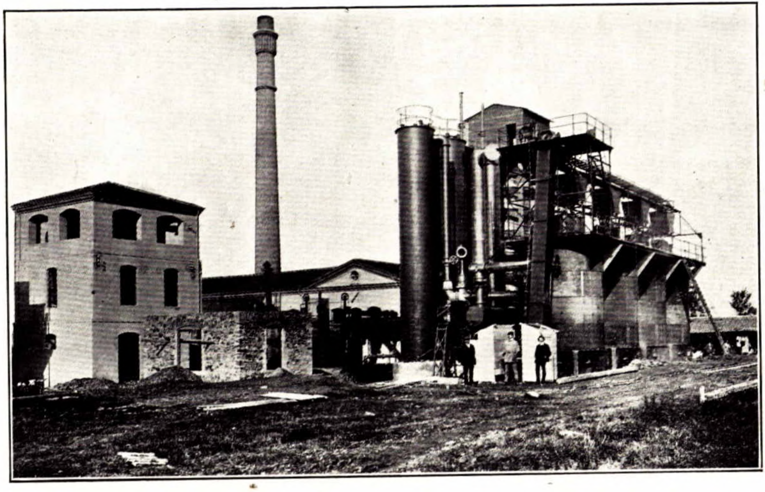


FIG. 18.—Section of Mond gas producer.



Mond, by-product recovery peat producer-gas power plant at Orentano, Italy.

before entering the producer below the fire bars G. The lower part of the producer is conical in shape, and extends downwards into the water lute L.

A constant fuel level is maintained by means of the cast-iron bell B: which is, however, not an essential part of all Mond producers. This bell also assists, to a certain extent, in the preliminary dry distillation of the fuel. The products of this distillation must, moreover, pass out at the bottom of the bell and through the hot fuel in the body of the producer before reaching the gas exit into the superheaters outside. By means of this arrangement, it was generally supposed that the decomposition of a portion of the tarry products of distillation was accomplished, but its value in this respect is somewhat doubtful in the opinion of certain investigators.

The blast, consisting of air and steam, in passing through the annular space A, Fig. 18, abstracts considerable quantities of the heat radiated from the inner shell and, since the blast must, moreover, pass through the hot ashes at the bottom before entering the producer, a considerable heat economy is effected which results in a high thermal efficiency.

The lower part of the producer is poked through holes situated near the fire bars, while the upper portion of the fuel bed is poked through similar holes provided on the top. The ashes are removed from the water seal without in any way interfering with the operation of the producer. Fuel is admitted to the hopper through the hopper slide, and from the hopper into the producer through the hopper bell. This arrangement prevents the escape of gas when fresh fuel is charged. This is clearly shown in Fig. 18.

AIR AND STEAM BLAST SUPERHEATERS.

The superheater consists of two pipes of different diameters, the one of smaller diameter being enclosed within that of the larger diameter, see Fig. 17. The gas leaving the producer passes through the inner or smaller pipe and the air and steam blast pass in the opposite direction through the large or enclosing pipe. In this manner a part of the sensible heat of the gas is abstracted by the entering air and steam. The bases of the superheaters are provided with dust collection boxes, and dust valves, for the easy removal of the dust settling out of the gas.

MECHANICAL WASHER.

The gas, after leaving the superheaters, passes through a mechanical washer. This consists of a steel rectangular chamber, closed on top and sealed at the bottom by means of a lute filled with water. A steel paddle operated by an electric motor is placed within the chamber and impinges on the surface of the water. These paddles turn at about 190 revolutions per minute, and in so doing fill the chamber with a mist through which the hot gas must pass before leaving. This washer removes a large part of the dust, some tarry matter, and at the same time serves to reduce, to a certain degree, the temperature of the gas. The dust and tarry matter separated from the gas float on the surface of the water forming the seal and can be removed from time to time by skimming from the surface of the water in the lute. Since ammonia gas is readily soluble in cold water, the temperature of the water in this washer is kept sufficiently high to prevent such absorption to any appreciable extent.

AMMONIA ABSORPTION TOWER.

This tower consists of a tall cylindrical chamber closed at the top and bottom. The interior is lined with lead and filled with ring tiles. A weak solution of sulphuric acid is introduced at the top in the form of a spray which in falling to the bottom comes into contact with the tiles. The washed gas leaving the producer and charged with its ammonia gas and tarry matter enters this tower at or near the bottom and in passing upward towards the top, where the gas outlet is situated, comes into intimate contact with the sulphuric acid. In this manner chemical reaction is caused to take place between the ammonia gas and the sulphuric acid—the product formed being ammonium sulphate. Considerable tarry matter is separated from the gas in this chamber and in order to prevent its decomposition, which would discolour the ammonia sulphate crystals, the acid solution is kept very weak—in the neighbourhood of 2 per cent sulphuric acid. The liquor consisting of a weak solution of sulphuric acid and ammonium sulphate is circulated over and over until it is sufficiently saturated to send to the sulphate house for evaporation. The strength of the liquor is maintained at 2 per cent by adding sulphuric acid from time to time.

The liquor flows from the bottom of the tower into an open vat from which it is again pumped to the top by means of specially constructed acid pumps.

GAS COOLING TOWER.

The gas cooling tower, or towers, consist of cylindrical steel chambers similar to the ammonia absorption tower just described. They are closed at the top by a steel cap and are sealed at the bottom by means of a water lute. At the top cold water is introduced in the form of a spray which falls to the bottom and into the lute. The hot gas leaving the ammonia tower enters near the bottom and passes upwards through the spray of water to the gas exit situated at or near the top. In its passage towards the exit the gas comes into intimate contact with the cold water to which it gives up most of its sensible heat. Thus the gas leaves the top of the tower comparatively cool while the cold water leaves by the water lute situated at the bottom as hot water. In this tower considerable tar is removed from the gas which can be removed whenever necessary from the water lute. The surplus water resulting from the condensation of the moisture contained in the hot gas overflows at the lute.

If it is desired to further cool the gas, the gas leaving the tower just mentioned is passed through a second, exactly similar to the first. In the second tower traces of tar are separated from the gas and removed in a manner similar to that just described.

AIR-TOWER.

In order to accomplish the two-fold effect of cooling the hot gas in the first gas cooling tower and of warming and saturating the air for the air-blast, a third tower is provided similar to those described above. The air enters at the bottom, which is sealed by means of a water lute, and passes upwards towards the top, where the gas offtake is situated, through a fine spray of hot water, which is pumped from the lute of the first gas cooling tower to the top of the air-tower. In this manner the air, brought into intimate contact with the finely divided particles of hot water, abstracts heat from the water, and at the same time becomes saturated. The hot water, by this means, is sufficiently cooled to return to the first cooling tower to be used over again.

The tar mixed with the hot water leaving the first gas cooling tower is here separated by condensation and is removed from the cleaning lute.

From the second gas cooling tower the gas is led directly to heating furnaces, if it is to be used for heating, without further purification.

When the gas is used for power purposes, by burning in gas engines, it is further purified through centrifugal tar extractors and moisture absorbers.

AUXILIARY APPARATUS REQUIRED.

A Mond gas plant as above described is not complete without a battery of steam boilers. In the above description only the method of carrying out the process is described, the auxiliary machinery and steam generators which are indispensable being left for further consideration.

When the first consideration of the gasification of coal in the Mond gas plant is the recovery of ammonia in the form of ammonium sulphate, the efficiency of the plant as a generator of power gas is to a certain extent sacrificed in order to obtain the maximum ammonia recovery. In order to render the recovery of ammonia from the nitrogen contained in the fuel as high as possible, large quantities of steam must be introduced with the air blast. In ordinary practice, at those plants operated principally for the recovery of ammonia about two lbs. of steam are introduced for every lb. of coal or fuel burned. This necessitates the production of a large quantity of steam in addition to that taken up by the air blast on its travel to the producer. The steam required to make up this deficiency is supplied by a battery of boilers in which coal or producer gas is burned.

AIR, WATER AND ACID CIRCULATING PUMPS.

The air blast is delivered to the producer, by means of a Roots blower which first delivers atmospheric air into the air tower. The air, now charged with moisture, is forced through the superheaters into the bottom of the producer under the pressure generated at the blowers.

Water circulating pumps are provided for pumping the water from the lutes of the cooling towers to the tops of the towers when it is to be used over again for cooling.

The acid pumps are constructed of special metal which is capable of resisting the action of the sulphuric acid. The water and acid circulating pumps are all situated in the same building. In this building is also situated the acid pump which delivers the gas liquor to the sulphate house for evaporation.

SOME CHEMICAL CONSIDERATIONS IN THE MANUFACTURE OF MOND GAS, WITH THE RECOVERY OF SULPHATE OF AMMONIA.

The chemical reactions which take place in an updraft producer of the Mond type in which the air blast is highly saturated with steam, are dependent on the following factors:—

(1) The temperature of the fuel bed.

(2) Depth of fuel bed, and

(3) Rate of flow of gas through the fuel.

In considering the influence which any or all of these factors have on the formation of the final gas as regards its chemical composition and hence its heating value, it is necessary to consider separately the effect of the oxygen of the air on incandescent carbon, and that of the steam entering with the former.

Under ordinary circumstances, i.e., when a shallow depth of fuel is completely burned, the solid carbon of the fuel burns directly to carbon monoxide with the evolution of heat. The reaction may be expressed thus—the quantity of carbon burned being 24 Kilos:—

(a) $2C + O_2 = 2\ CO + 2 \times 29{,}000$ Cals.

The carbon monoxide thus resulting is however almost instantaneously burned to carbon dioxide with a further evolution of heat. The equation expressing this reaction may be written thus:—

(b) $2\ CO + O_2 = 2\ CO_2 + 2 \times 68{,}000$ Cals.

As regards the final result, viz.: the formation of CO_2 and the generation of heat it makes no difference whether the solid carbon is first burned to carbon monoxide which is then burned to carbon dioxide or whether the carbon is at once burned to carbon dioxide,—the evolution of heat in both cases would be the same. These then represent the reactions which take place between the oxygen of the air and the carbon of the fuel when a shallow layer of fuel is burned completely as on grate bars.

In the case of a gas producer, however, when incomplete combustion is aimed at, the carbon dioxide resulting from reaction (b) is again reduced to carbon monoxide in its passage upwards through the bed of fuel, and as was stated before, this is dependent on the temperature and rate of flow of the gas through the fuel bed. The rate of flow of gas through the bed of fuel or the time occupied by a molecule of the gas in traversing the entire depth of the fuel, determines the time of contact between the gas or molecule of gas and the incandescent carbon.

High temperatures favour the formation of carbon monoxide while low temperatures favour the formation of carbon dioxide. Thus it will be seen that the quantity or percentage by volume of either carbon monoxide or carbon dioxide present in a producer gas is dependent on the temperatures prevailing at different heights in the fuel, and that while with a rise of temperature carbon dioxide will be reduced to carbon monoxide, the carbon monoxide is as readily oxidised to carbon dioxide with a fall in temperature. In the first case the reaction takes place with an absorption of heat while in the second case the reaction is accompanied by an evolution of heat.

Thus the reaction between carbon and carbon dioxide is reversible and may be expressed as follows:—

(c) $CO_2 + C \rightleftarrows 2\ CO$.

The arrow replacing the signs of equality in the above equations indicates that the reaction may proceed from right to left or from left to right. The concentrations of the reacting substances, together with the temperatures, govern the direction in which the reaction will proceed, and for every temperature there is a certain constant relation between concentrations of CO and CO_2 in equilibrium with carbon.

According to O. Boudouard, the following mixtures of carbon monoxide and dioxide are in equilibrium with solid carbon under atmospheric pressure, at temperatures of 650, 800 and 925°C respectively.

Temperature	*Percentages of*	
°C	CO	CO_2
650°	39	61
800°	93	7
925°	96	4

From the above it will be seen that the reversible reaction $CO_2 + C = 2\ CO$ tends to increase the percentage of carbon dioxide in the resulting gas when the temperature of the zone of reaction in the producer is lowered.

The percentages of carbon monoxide and dioxide which are in equilibrium with solid carbon at various temperatures, have been more recently investigated by J. K. Clement, L. H. Adams, and C. N. Haskins[1]. In the following table 16 setting forth their results, which includes, also, the value of the equilibrium constant K, it will be seen that the percentages of carbon monoxide in equilibrium with carbon determined for temperatures ranging from 500°—1,600°C do not agree with those determined by Boudouard.

In the manufacture of Mond gas, large quantities of steam are introduced into the producer with the air blast, it is therefore necessary to consider the reactions which take place between steam and incandescent carbon. At comparatively low temperatures (about 500°—600°C) steam reacts with carbon in accordance with the equation

(d) $2\,H_2O + C = 2\,H_2 + CO_2 — 19{,}000$ Cals.

while at temperatures of 1000°C and upwards the main reaction involves the production of carbon monoxide and hydrogen, in accordance with the equation

(e) $H_2O + C = H_2 + CO — 29{,}000$ Cals.

TABLE 16.

Values of K from Experimental Determinations.[2]

Temperature (°C).	K (obs.)	K (cal.)	$X\infty$ (obs.)	$X\infty$ (cal.)	$X\infty$ (obs.) Boudouard
500	......	0·000007	......	0·021	......
600	......	0·00013	....	0·093	......
650	......	0·00046	......	0·185	0·39
700	......	0·00137	......	0·283	......
800	0·0065	0·0090	0·526	0·582	0·93
850	0·022	0·020	0·738	0·722	......
900	0·059	0·042	0·871	0·832	......
925	0·094	0·060	0·912	0·873	0·96
1,000	0·136	0·151	0·939	0·945	......
1,100	0·283	0·448	0·971	0·981	......
1,200	......	1·120	......	0·944	......
1,300	......	2·455	......	0·997	......
1,400	......	4·826	......	0·9985	......
1,500	......	8·671	......	0·9992	......
1,600	......	14·44	......	0·9996	......

---

[1] From "Essential Factors in the Formation of Producer Gas," by J. K. Clement, L. H. Adams, and C. N. Haskins, Department of the Interior, Bureau of Mines, Washington.

[2] Bulletin 7, Bureau of Mines, Washington, D.C., U.S.A., page 33.

This reaction predominates in the manufacture of water gas which requires for its formation two producers if the operation is to be continuous. The first step in the manufacture of water gas is the production of producer gas, which operation is continued until the fuel in the producer is of high temperature (incandescent). When the temperature conditions are right the air supply is cut off and steam is admitted under pressure, which results in the formation of water gas and a cooling of the fuel in the producer. The process of making water gas is discontinued when the temperature of the fuel bed falls below 1,000°C. When this temperature is reached the steam is cut off and the producer again blown with air until the temperature is sufficiently high to again reverse the cycle.

The process of the formation of water gas, it must be understood, is by no means a simple one, the reactions described have simply outlined what occurs.

According to Bone and Wheeler[1], at temperatures between 600° and 1,000°C, the products correspond to a simultaneous occurrence of reaction (d) and (e), the second reaction gradually asserting itself as the temperature rises, until at 1,000°C it entirely supersedes the first. Both reactions are endothermic, i.e., absorb heat, the first named representing the disappearance of 19,000 Cals and the second 29,000 Cals. Both consequently operate in reducing the temperature in the producer and in raising the thermal efficiency of the system.

Bone and Wheeler suggest that the large quantities of steam which are necessarily used in the Mond process, where the chief aim is the recovery of ammonia, may reduce the temperature in the producer sufficiently to allow a considerable occurrence of reaction (d) and that this would probably account for the relatively high percentage of carbon dioxide in Mond gas. The following table 17 shows the percentage composition by volume of gaseous fuels[2]:—

---

[1] Journal of the Iron & Steel Institute, No. 1, 1907, page 129.

[2] Handbook of Chemical Engineering, George E. Davis, Vol. I, page 326.

TABLE 17.

	Natural Gas.	Coal Gas.	Water Gas.	Dowson Gas.	Mond Gas.	Siemens Gas.	Blast Furnace Gas.
Hydrogen	9·2	46·27	48·6	24·36	29·0	8·6	1·96
Marsh Gas	85·1	37·55	0·4	1·31	2·0	2·4	2·23
Carbon Monoxide	1·0	11·19	44·0	17·55	11·0	24·4	26·29
Nitrogen	2·0	1·01	3·7	50·48	42·0	59·4	60·78
Carbonic Acid	0·5	0·80	3·3	6·07	16·0	5·2	8·74
Other Hydro Carbon	2·0	3·17	....	....	...	...	....
Heating Power[1]	952	648	297	144	144	125	118

[1] British thermal units per cu. ft. at 60°F.

In this connexion it is interesting to note that the results of several tests made with the Westinghouse double zone bituminous suction gas producer which was operated with lignite and bituminous coals, shows the same high percentage of carbon dioxide when steam is introduced with the air in the lower zone. The following gas analyses, taken from a portion of a test recently conducted on a lignite taken from Alberta, show the marked increase in carbon monoxide and hydrogen with the introduction of steam into the lower zone.

TABLE 18.[2]

Westinghouse Producer Trial 40, July 16—Lignite.

Sample No.	23	24	25	26
Time	8.0 A.M.	10.0 A.M.	Noon.	2.0 P.M.
Carbon dioxide	9·9	9·5	17·3	14·5
Oxygen	0·8	0·5	0·0	0·8
Ethylene	0·1	0·0	0·0	0·1
Carbon monoxide	17·2	19·2	8·8	11·9
Methane	1·7	1·9	4·4	4·3
Hydrogen	15·3	14·6	23·8	23·1
Nitrogen	55·0	54·3	45·7	45·3
Cal. Val. gross	123	127	149	157
" " net	113	118	132	141

[2] B.T.U. per cu. ft. Mines Branch, Dept. of Mines, Ottawa, Canada.

The carbon dioxide is low in the two samples of gas taken at 8 A.M. and 9 A.M. Up to about 11 A.M. only atmospheric air was introduced into the lower zone of the producer. The considerable amount of hydrogen contained in these two samples of gas is due to the moisture contained in the fuel, viz.: 15 per cent. At about 11 A.M. steam was admitted with the air into the lower zone with the results shown in the analyses of the samples of gas taken at noon and 2 P.M.

It is quite evident from these analyses that the temperature in the lower zone was sufficiently reduced by the introduction of steam to allow the reaction

$$C + 2H_2O = CO_2 + 2\,H_2$$

to proceed to a considerable extent. Continued introduction of steam resulted in the lowering of the temperature of the reaction zone to such an extent that the use of steam, even in small quantities, had to be discontinued.

The products formed by the action of steam and carbon according to the equation.

$$H_2O + C = H_2 + CO$$

and

$$2\,H_2O + C = 2H_2 + CO_2$$

may undergo a readjustment in accordance with the equation

$$H_2O + CO \rightleftarrows H_2 + CO_2$$

This reaction is reversible, i.e., carbon dioxide may react with hydrogen according to the equation

$$CO_2 + H_2 = CO + H_2O$$

or steam may react with carbon monoxide according to the equation

$$H_2O + CO = H_2 + CO_2$$

At all temperatures above 500° or vicinity, steam reacts with carbon monoxide, and hydrogen with carbon dioxide. The direction in which the action proceeds depends on the temperature and the relative concentrations of the reacting substances, so that for every temperature above 500°C there is a condition of equilibrium for which the product of the concentrations on one side divided by the product of the concentrations on the other side of the equation is a constant.

$$\text{Thus: } \frac{H_2O \times CO}{H_2 \times CO_2} = K = \text{a constant.}$$

This constant has been determined by Hahn* for temperatures between 786° and 1,405°C, as follows:—

Temp.	$\frac{H_2O \times Co}{H_2 \times Co_2} = K$
786°	0·81
886°	1·19
986°	1·54
1086°	1·95
1205°	2·10
1405°	2·49

A consideration of these equilibrium constants permits one to predict the direction in which the reaction will take place.

For example: in the case of a mixture which is in equilibrium at a comparatively low temperature, about 800°C, the reaction will take place in the direction

$$CO_2 + H_2 = CO + H_2O$$

as the temperature is raised, and it will proceed in the direction $CO + H_2O = CO_2 + H_2$ when the temperature is lowered. Addition of steam tends to lower the temperature, hence it will cause a change in the latter direction.

When the reaction proceeds in the direction $CO_2 + H_2 = CO + H_2O$ there is an absorption of heat, while a change in the opposite direction involves a corresponding evolution of heat.

The introduction of steam into the reaction zone of a producer not only increases the thermal efficiency of the system but also reduces to a minimum clinker troubles which often arise when high temperatures prevail.

In the case under consideration, however, viz: the gasification of a solid fuel with a view to recovering the maximum amount of ammonia, steam in excessive quantities is introduced for the purpose of carrying out the process, regardless of the thermal efficiency of the system.

As a result of the introduction of an excess of steam the gas produced is inferior in heating value to that obtained when the Mond process is operated for power gas alone, hence its thermal efficiency as a power gas producer is sacrificed, to a certain extent, to the most efficient recovery of ammonia.

---

*Zeitschrift für Physikalische Chemie, 1903, Vol. XLIII, p. 705; Vol. XLIV, p. 513.

The following table 19 containing the results of a series of tests carried out by Bone and Wheeler* with a Mond producer gas power plant at the iron and steel works of Messrs. Monks, Hall and Co., Limited, Warrington, shows the decrease in the

TABLE 19.

Steam saturation temperature.		60°	65°	70°	75°	80°
Coal consumption at producer, cwts. per hour................		16·51	14·26	13·88	14·32	13·21
Coal consumption at boiler, cwts. per hour....................		2·0	1·8	2·38	2·87	3·35
Coal consumption for blast steam		nil.	nil.	0·38	0·87	1·35
Total carbon losses, per cent.....		5·8	7·8	8·1	7·1	8·4
Mean percentage composition of gas obtained.	Carbon dioxide	5·25	6·95	9·15	11·65	13·25
	Carbon monoxide	27·30	25·40	21·70	18·35	16·05
	Hydrogen	16·60	18·30	19·65	21·80	22·65
	Methane	3·35	3·40	3·40	3·35	3·50
	Nitrogen	47·50	45·90	46·10	44·83	44·55
	Total combustibles ..	47·25	47·10	44·75	43·50	42·20
Calorific value of gas....gross....		46·77	46·74	44·74	43·37	42·73
net.....		43·60	43·32	41·14	39·65	38·69
(Kilog. cent. units per cu. ft. at 0° C. and 760 mm.)						
Yield of gas, cu. ft. per ton		138,250	134,400	141,450	145,800	147,500
Lbs. of steam in blast per lb. of coal gasified		0·45	0·55	0·80	1·10	1·55
Percentage of steam decomposed..		87·4	80·0	61·4	52·0	40·0
Cu. ft. of air at 0° C. and 760 mm. in blast per lb. coal gasified....		36·95	34·9	36·8	36·9	37·1
Ratio of $\frac{\text{oxygen from steam.}}{\text{oxygen from air.}}$		0·50	0·62	0·65	0·75	0·80
Ammonia in gas, as lbs. of ammonium sulphate per ton of coal		39·0	44·7	51·4	65·25	71·8
Efficiency ratios in actual trial—						
(1) Including steam for blower engine		0·778	0·750	0·727	0·701	0·665
(2) Including steam for blower engine and washers		0·715	0·687	0·660	0·640	0·604

---

*Journal of the Iron and Steel Institute, No. I, 1907, page 154.

thermal efficiency of the system with the increasing degree of saturation of the air blast.

These tests were made for the purpose of determining the influence of variation in the proportions of air and steam in the blast upon the composition of the gas, its suitability for furnace operations, and upon the general thermal efficiencies of the producers. The plant in question was operated under commercial conditions although no attempt was made at ammonia recovery. Careful determinations were, however, made of the amounts of ammonia present in the gas during the tests.

In the last test the saturation temperature was very nearly that generally maintained when ammonia recovery is one of the chief aims, and will, therefore, serve to indicate what may be expected from such a plant when operating under ordinary commercial conditions for the recovery of ammonia and production of power gas.

The Distillation of the Volatile Matter in the Fuel.

By referring to Fig. 18, which shows in section the Mond gas producer, it will be seen that at the top a large bell is provided into which the fuel is discharged from the hopper above. The level of the fuel in this bell is always maintained above that in the producer proper as is shown in the section. Thus the fuel is maintained at a constant level and the products resulting from the distillation of the fuel in this bell must pass down through a portion of the hotter fuel below the bell before passing out with the gas through the gas offtake.

It has been maintained that this construction favours the decomposition or cracking of some of the volatile matter contained in the fuel and, therefore, certain fixed hydrocarbon gases are formed in this manner; but Bone and Wheeler* are of the opinion that its value in this respect is somewhat doubtful. Practically the total quantity of the tarry products of the distillation resulting here, leaves the producer as tar, which must be separated from the gas by some means, and does not enter in

---

*Journal of the Iron and Steel Institute, No. 1, 1907, page 135 any way into the formation of the final gas. Only that portion of the volatile matter distilled in the hotter zones of the producer will be decomposed into stable hydrocarbon gases. Under the most favourable conditions, however, but a small quantity of the total tarry matter contained in the fuel, is thus decomposed and in the opinion of the writer its value as a factor in the formation of the final gas is quite negligible.

The Formation of Ammonia and Ammonium Sulphate.

The Mond process as here described is designed for the production of power gas and the recovery of the nitrogen content of the fuel in the form of ammonium sulphate.

The first step in the formation of ammonium sulphate is the formation of ammonia gas by the chemical union of hydrogen with nitrogen. Different theories are advanced regarding the manner in which ammonia gas is formed in the producer, but it is not necessary to consider all of them here. A theory has, however, been advanced which seems to fully explain all the phenomena observed. This theory, according to Mr. J. A. Weil, chief chemist to the Power Gas Corporation, is that the ammonia is formed in two stages:

(1) By the low temperature distillation of the fuel; in this stage a considerable amount of nitrogen is lost.
(2) By the action of nascent hydrogen upon nascent nitrogen formed by the reaction of steam upon incandescent, nitrogenous, carbonaceous material.

This view is supported by temperature considerations as theory would demand; with a low concentration of hydrogen less ammonia would be formed and vice-versa. This is found to be a fact. Further, as the temperature is reduced the reversible reaction $CO + H_2O \rightleftharpoons CO_2 + H$, will proceed in the direction $CO + H_2O = CO_2 + H_2$ with evolution of heat. The hydrogen concentration is according to this reaction increased, and this is a condition for high ammonia yield.

The ammonia gas thus formed is passed through a tower when it comes into intimate contact with sulphuric acid with which it reacts according to the equation

$$2NH_3 + H_2SO_4 = (NH_4)_2SO_4.$$

The ammonium sulphate thus resulting is in solution with weak sulphuric acid—about 2 per cent strength—and is recovered in crystalline form by evaporation.

CHAPTER IV.

BY-PRODUCT RECOVERY POWER GAS PLANTS FOR THE UTILIZATION OF PEAT AND COAL, IN OPERATION IN EUROPE.

The object of the writer's visit to Europe was to collect information, by direct observation, concerning the cost—both plant and operating—economy and reliability of producer gas power plants designed for by-product recovery, when operating with coal and peat.

In the case of power plants burning peat fuel, one of the most important factors to be considered is the cost of the fuel at the producers. This phase of the problem was, therefore, fully investigated, and included the methods employed for manufacturing the fuel, and the cost per ton delivered at the producers.

Whenever possible, financial statements were obtained, which set forth the cost of operations covering a period of some months. Such statements were, however, obtained for only two cases—both of which were plants burning coal. The costs and probable profits to be derived from power plants burning peat fuel will be calculated on the basis of the actual plant cost, cost of labour, and the selling prices of the by-products obtained, and the power produced.

The by-product recovery power gas plants designed for burning coal were all confined to Great Britain, and were constructed according to the Mond process—while those designed for burning peat fuel—two in number—were situated in Germany and Italy. The former was designed and constructed on the system devised by Frank and Caro, while the latter was a Mond plant.

The difference between the two systems, viz., the Mond and the Frank-Caro, is so slight, that a description of the one suffices for both, the principle being precisely identical in both.

The plants visited were: the South Staffordshire Mond Gas

Company, Dudley Port; the Langwith By-Product Company, Limited, Langwith; the Deutsche Mond Gas and Nebenproduktion Gesellschaft, in the Schweger Moor, near Osnabrück, Germany, and L'Utilizzazione Dei Combustibili Italiani E. L'Impianto Di Orentano, Italy. At the time of the writer's visit to Europe, a large Mond plant was in course of erection at Codigoro, Italy, for burning peat fuel, while a second large plant designed for burning peat fuel and lignite was nearing completion at the works of the Power Gas Corporation at Stockton-on-Tees. This latter plant will be used for experimental purposes, and for making commercial tests on the two fuels named.

The Mond gas plants of the South Staffordshire Mond Gas Company, and that of the Langwith By-Product Company, were operated with bituminous coal, while the two plants on the continent were designed for burning peat fuel only.

MOND BY-PRODUCT RECOVERY POWER GAS PLANT, AT ORENTANO, ITALY.

This plant (plate XII) is situated on the edge of a bog a few miles distant from Orentano, a village conveniently located as regards railway facilities. The total area of the bog is 600 hectares (1,482 acres), but of this the company operating the recovery power plant owns only about 200 hectares (494 acres). This portion of the bog has an average depth of about 1½ meters (5 feet) of good peat fuel, but this average thickness is, unfortunately, not continuous, but is divided by a parting layer of gravel and clay of about one foot in thickness, into two peat layers, of about equal thickness.

Such physical characteristics militate against the successful winning of peat fuel in all places where labour is dear, but at Orentano the cheapness of labour makes the economic manufacture of the fuel possible. The bog, moreover, lies in the low lands, and must, consequently, be drained by pumping, which is an added expense, likely to reach considerable proportions when a large area is worked.

The peat so far manufactured into a fuel has been taken, almost entirely, from the upper layer, and before the lower layer can be worked the parting of gravel and clay must be removed, an operation which will prove expensive, even in Italy where labour is cheap.

Method of Manufacture.

The peat, which is excavated entirely by manual labour, is fed into Dolberg peat machines, of which there are five. These machines are provided with belt conveyors, which serve to transport the excavated peat to the macerators.

The peat fuel is transported from the bog to the power plant over a well laid-out narrow gauge railway, by means of box cars hauled by peat-burning locomotives, of which there are two.

A portion of the total quantity of peat supplied to the producers is machined and air-dried on the field, but the larger quantity is simply hand-dug, in the form of sods, stacked on the field, and from time to time transported to the power plant, where it is mechanically treated, and artificially dried. (See Page 96).

For excavating peat during the working season, 70 labourers, at 3 shillings (72 cents), and 30 labourers, at 8 pence (16 cents), per day, are employed. The cost of excavating one metric ton (2,200 lbs.) of peat, on the basis of 30 per cent moisture, is said to be 2 shillings and 6 pence (60 cents).

For mechanically treating that portion of the fuel air-dried on the field, 5 Dolberg machines are employed; 13 men form the necessary complement of labourers for each machine. The capacity of the Dolberg peat machines is 20-22 tons of theoretically dry peat per day of 12 hours.

Notwithstanding the low labour wages prevailing in this section of Italy, great trouble has been experienced in producing the required quantity of peat fuel, viz., 70 tons of theoretically dry peat, per day, to operate the power plant at full capacity. As a consequence, the plant has been operated much under its maximum capacity, the daily consumption being about 30 tons of theoretically dry peat.

The following is from an average analysis of the peat so far manufactured and burned in the producers:

N	1·56%
Total C	56·00%
Total Ash	12·00%

This analysis was made on the absolutely dry sample. The nitrogen content of the peat as fired, with a moisture content varying between 32 and 35%, will, therefore, be about 1·04%. This is comparatively low, in fact too low to permit of its recovery at a profit in places where high labour wages obtain, and, consequently, where the cost of fuel would be high.

Artificial Drying of Peat.

The larger portion of the peat burned in the producers, as is stated elsewhere, is mechanically treated at the power plant and artificially dried with the heat obtained from the exhaust heat of the gas engines, the heat of the boiler chimney gas and the heat resulting from the combustion of a quantity of gas, equivalent to 8 tons of 33½ per cent peat fuel per day, in a special air-preheating furnace. The quantity of peat thus obtained is sufficient to produce about 20 tons of theoretically dry peat per day of 24 hours. If, however, the plant is brought up to full capacity, necessitating the combustion in the producer of 70 tons of theoretically dry peat, or 105 tons of peat containing 33½ per cent moisture, which is the average moisture content of the fuel so far used, other means must be sought for supplying the deficiency, since the heat for drying cannot, with the present efficiency of the drying ovens, be increased sufficiently by the contemplated increase in the production of power to dry the extra 40 tons of peat, without burning an excessive and prohibitive quantity of peat fuel, or its equivalent in gas, in the air-preheating furnace.

Notwithstanding the mild climate which prevails in this section of Italy, the period during which peat can be excavated and dried in the open air is of somewhat short duration; at its best it is not much longer than that which obtains in the eastern and southern portions of the Province of Ontario. In place of snows, heavy rains swamp the bog, which is thus either wholly or partially covered with water for some time.

The management hope, in the near future, to be in a position to supply the plant with the required quantity of peat fuel to enable them to operate at full capacity. In order to make this possible, it will be necessary to produce some 42,000 tons of peat fuel, of 33½ per cent moisture during the manufacturing season.

Nitrogen Content of the Peat Fuel.

If we assume the peat fuel delivered to the producers has an average moisture content of 33½ per cent, then the average nitrogen content of the peat with this moisture content will be 1·04 per cent. The plant at present, as previously stated, is operating under capacity, the daily consumption of peat fuel amounting to only 30 tons of absolutely dry peat, or about 45·11 tons of 33½ per cent moisture peat.

During a year of about 350 working days, the total consumption of fuel on this basis will be 15,790 metric tons (about 17,370 short tons), and the quantity of nitrogen available will be 180 short tons, which, with perfect ammonia recovery, would amount to about 849 short tons of ammonium sulphate.

The recovery of the nitrogen in commercial practice, however, rarely exceeds 70 per cent, and with this efficiency of recovery the available ammonium sulphate would be reduced to 594 short tons.

When the plant is operating at full capacity for a period of 350 days, the quantity of fuel consumed will be 40,530 short tons, and the quantity of nitrogen available for recovery as sulphate of ammonia, assuming 70 per cent as the efficiency of the recovery process, would be 295 short tons. This would represent a quantity of ammonium sulphate equal to about 1,390 short tons.

Quantity and Cost of Sulphuric Acid Used.

The formation of ammonium sulphate—by passing the ammonia containing gas leaving the producer through a spray of sulphuric acid—requires at this plant a quantity of sulphuric acid equal to 1·2 times the weight of the ammonium sulphate produced.

As the plant is now operated, viz., with a capacity of 30 tons of absolutely dry peat per day, the annual production of ammonium sulphate would amount to about 594 short tons. This quantity would require, then, 594 × 1·2, or 713 short tons of sulphuric acid, 50 Baume.

Sulphuric acid delivered at the works costs 42 lire* (about $8.11) per metric ton—2,200 lbs.—or about $7.37 per short ton. The cost of the total quantity of sulphuric acid entering into the process would annually amount to 713 × 7·37, about $5,260, and with a market value of $65 per ton, which is a low valuation at the present time (1913), the gross receipts resulting from the sale of the ammonium sulphate produced would be $594 × 65: = $38,610, and when the plant is operating at full capacity gross receipts which would be realized from this source alone would amount to approximately $90,000.

Description of By-Product Recovery Power Gas Plant.

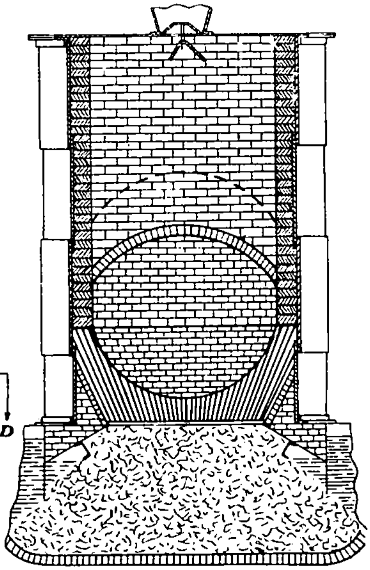
The power gas plant consists of a battery of 4 producers, 3 of which are of the Mond type and one of the Cerasoli type. The 3 Mond producers (see description, page 76) differ from the usual ammonia recovery type in that no space formed by the outer and inner shells is provided. The superheater also generally found on all Mond by-product recovery plants are not installed here.

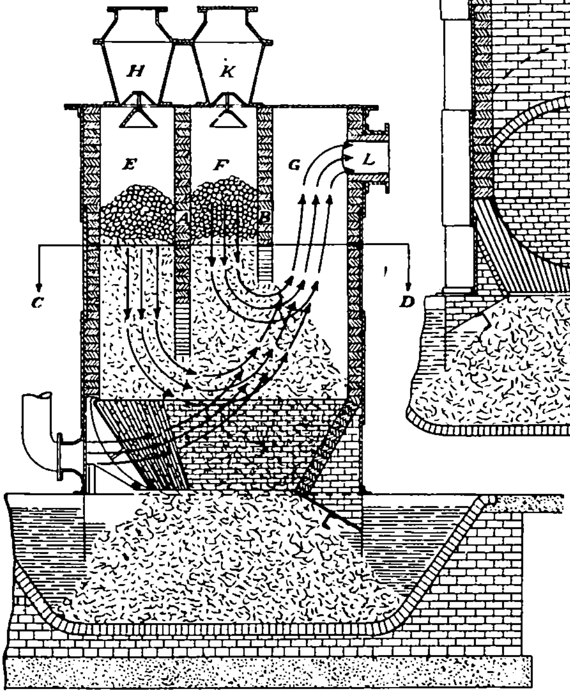
The principal departure from the usual Mond design is found in the Cerasoli producer which constitutes the fourth unit in the battery of producers. This producer is shown in vertical and horizontal section in Figs. 19 and 20.

In designing this producer, an attempt has been made to utilize within the producer itself a portion of the water contained in the peat, in order to reduce the quantity of steam which must be supplied by a battery of boilers. It was also hoped that the ingenious ideas incorporated in the design would permit of the decomposition of a large portion of the tarry matter distilled from the peat, which in the usual type of a Mond producer leaves as tar. The moisture contained in the peat burned in

---

*1 lire=0.193 Can. gold dollar.





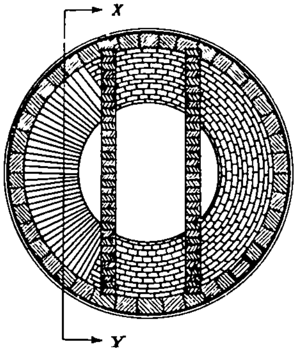


Fig. 19.—Section "CD." Section of Cerasoli producer.
Fig. 20.—Section "XY." Section of Cerasoli producer.

the producer, when no provision is made to utilize it, is evaporated and superheated at the expense of a considerable quantity of heat which lowers the temperature of the producers and is not again recovered. The moisture thus evaporated not only carries away an appreciable quantity of heat but takes no part whatever in the formation of producer gas. If, therefore, a portion of the moisture of the peat can be made to enter into the chemical reactions taking place in the reaction zone of the producer, a conservation of heat would result, (1) by decreasing the quantity of steam otherwise necessarily supplied by a battery of boilers, and (2) by rendering latent a quantity of heat resulting from the decomposition of the steam representing the moisture content of the peat, which can again be recovered when the gas is burned in cylinders of a gas engine or for some other purpose. Theoretically the thermal efficiency of such a producer should be superior to the ordinary Mond type, but no reliable data are at hand to confirm such theoretical considerations.

THE CERASOLI PRODUCER.

From the vertical section, Fig. 19, it will be seen that the producer is internally divided into three compartments by means of two partition walls. The partition A extends from the producer top to within a short distance of the fire bars. Partition B also begins at the producer top, but is considerably shorter than former. The bottom portions of these partitions are arched.

Air is admitted through fire bars for a distance equal to one-third the circumference of the producer—the other two-thirds being solid, as shown in Fig. 19. Thus the combustion of the fuel in chamber E is necessarily more rapid than in chambers F or G. The paths of the gas and air currents are shown by the dotted curves and arrows.

The combustion is so regulated by this manner of admitting the air blast, that about two-thirds of the fuel charged is burned in chamber E, the remaining third being burned in chamber F. By means of this arrangement the volatile matter, consisting largely of tarry matter, is caused to pass down through the fuel bed and through the incandescent carbon, across the bottom, before leaving at the offtake. The moisture evaporated from the peat carbon in chamber E, also passes down and through the incandescent carbon in the lower portion of the producer where it reacts with the hot carbon, forming carbon dioxide or monoxide and hydrogen. The quantity of steam usually required for saturating the air blast is, by this means, reduced.

The volatile matter and moisture distilled in chamber F is but slightly, if at all, decomposed in passing to the gas off-take; but since two-thirds of the moisture and tarry matter of the total fuel charged into the producer is burned in chamber E, and consequently comes into intimate contact with incandescent carbon, only one-third of the moisture and volatile matter, of the total fuel charged leaves the producers without reacting with carbon. Theoretically, therefore, it appears possible, with this arrangement, to effect the decomposition of the larger portion of the volatile matter and moisture, thus reducing the quantity of steam necessary for saturating the air-blast and the quantity of tar usually produced, and it naturally follows that the thermal efficiency of the producer should be increased.

No reliable tests, unfortunately, have been made which would establish any of the above points, and the tests which the writer has seen are too incomplete and of too short duration to enable an opinion to be formed as to the practical advantages offered by this ingenious design.

METHOD OF CHARGING FUEL INTO PRODUCER.

Fuel is delivered by means of a bucket elevator to the charging platform where the fuel is automatically dumped into large hoppers located on the top of each producer. In the case of the Cerasoli producer, two hoppers are provided—one for each compartment. Ashes are removed through a water seal at the bottom of the producer. Poke holes are provided at equal intervals around the producer near the fire bars and on top. The top poke holes are closed by means of iron balls. A producer when burning peat, however, requires but little poking.

STEAM BOILERS FOR SATURATING AIR BLAST.

Three steam boilers arranged for burning gas are supplied for generating the steam necessary for saturating the air blast.

CONSUMPTION OF GAS FOR STEAM RAISING, DRYING PEAT AND POWER PURPOSES.

A quantity of gas equivalent to that generated from 11 tons of peat is daily burned under the boilers for generating steam. This is about one-third of the total peat gasified in the producers.

The heat required to supplement that contained in the exhaust gases of the gas engines and the chimney gases of the boiler plant, which is utilized for drying peat fuel for the producers, necessitates the heating of air in a special pre-heater. The quantity of gas burned in this pre-heater is equivalent to that generated from eight tons of 33½ per cent moisture peat.

The total quantity of peat or its equivalent in gas which is used for raising steam and pre-heating the air, it will be seen amounts to 19 tons. This leaves a quantity of gas equivalent to that generated from eleven tons of 33½ per cent moisture peat, for the production of power.

The general arrangement of a Mond by-product recovery power gas plant designed for burning 100 tons of theoretically dry peat, is shown in Fig. 21. The arrangement of this plant will serve to illustrate the disposition of producer and auxiliary machinery of the plant at Orentano.

ACID TOWER AND GAS COOLING AND AIR PRE-HEATING TOWERS.

The producer gas, charged with ammonia, tar, moisture, etc., is carried by a common main (6) through a mechanical washer (8), where dust and some tar is removed, to the acid tower (9). In this tower the ammonia gas reacts with the sulphuric acid, introduced as a spray, and flows from tower (9), into the lead lined vat (12). From this vat the liquor is circulated over

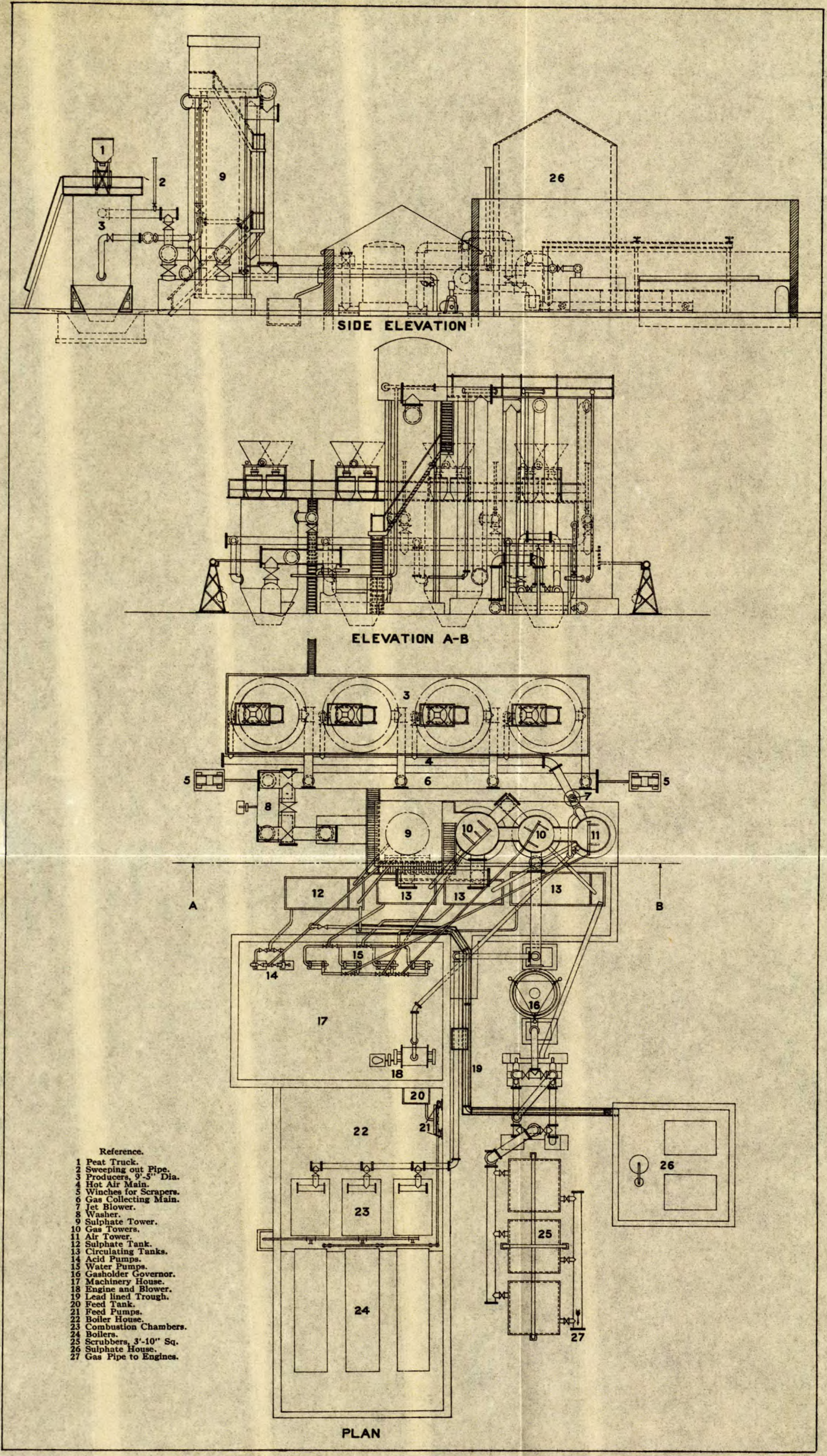


Fig. 21. General arrangement of gas plant to burn 100 tons of dry peat per 24 hours

and over again until it becomes sufficiently saturated to send to the sulphate house for evaporation. The required strength of the liquor is maintained by pouring into this vat small quantities of sulphuric acid.

From the acid tower the gas, now freed from the ammonia gas and some tar, passes through two water cooling towers (10). The gas enters at the bottom and leaves near the top while the path of the cooling water is in the opposite direction. The hot water resulting from the abstraction of the heat from the gas in the first cooling tower is now pumped to the top of tower (11) where in falling to the bottom it comes into intimate contact with the cool air which enters near the bottom of tower (11). In this manner the hot water parts with the greater portion of its heat and thus becomes sufficiently cooled for returning to the first cooling tower, where the cycle of operations is repeated. The air, in addition to performing the function of cooling the water, is itself heated and saturated. The cooling water from the second tower (10) is circulated between the vat (13) and the tower.

CIRCULATING PUMPS.

Specially constructed pumps are provided for circulating the liquor between the vat (12) and the acid tower and, also, for forcing the liquor to the sulphate tower (26). All pipes and troughs through or over which the acid or liquor flows are made of lead or are lead lined.

The hot and cold water which is circulated between vats 13 and towers 10 and 11, is pumped by means of ordinary double acting plunger pumps. Provision is, however, made for introducing steam into the water end of the pumps for the purpose of softening any tar or pitch which collects on the walls of the cylinders and pistons.

A rotary positive blower (18) forces the air required for the producer, through the pre-heating and saturating tower (11) and the air pipe line (4) into the producers. The saturation of the air is completed by introducing live steam at 7 into the air main.

The gas, after leaving the second water cooling tower, passes through a gas holder governor (16) and scrubbers (25) in which moisture and the final traces of tar are removed. From this battery of scrubbers the gas passes through a main (27) into the power house.

ARRANGEMENTS FOR CLEANING PRODUCER PLANT.

The parts of the gas plant which are the most likely to become clogged with dust and tarry matter are, the gas main (6), dust washer (8), and the water circulating system. The gas main (6), through which passes all the gas generated in the producers, collects a considerable quantity of the heavier tarry products and dust. In order to clean this main, without disturbing the operation of the plant, scrapers operated by winches (5) are provided. The tar and dust collecting in the washer (8) are separated through a water lute. The tar separated from the gas in the cooling towers and air pre-heating and saturating tower is in like manner withdrawn from the surface or bottom of the vats provided for circulating the cooling and heating water.

Since the major portion of the tarry matter is separated from the gas before it enters the gasometer governor, and some tar is of course separated out here, the pipes leading from this point in the system to the final scrubbers are fairly free from heavy deposits of tar, but in order to provide against possible shutdowns, due to choking of the main leading from the gas regulator to the scrubbers, this part of the system is duplicated. By means of this arrangement the gas can be by-passed from one leg of the main to the other, thus cutting out from the system the pipe line which it is desired to clean.

SULPHATE HOUSE.

When the ammoniacal liquor has reached the desired degree of saturation in the acid tower, it is pumped to the sulphate house where are situated a vacuum evaporator, air pump, and a centrifugal machine.

The solution of ammonium sulphate is concentrated by evaporation in the vacuum evaporator until saturation is reached, when on cooling, the solid ammonium sulphate crystallizes out. This is further dried in the centrifugal machine and bagged for the market.

POWER EQUIPMENT.

The power equipment consists of two gas engines of 350 metric horse power each, built by Langen and Wolf, at Milan, Italy. These engines drive through belt transmission two alternating current generators, each of which is provided with its own exciter. At 750 revolutions per minute a current is generated at 6,000 volts.

In addition to the above, the power station equipment includes a switch board with the necessary measuring instruments, high tension switches, etc.

The gas engines run continuously from 3 P.M. Sunday to 8 A.M. the following Sunday, and after a shut down of seven hours for purposes of general cleaning they resume their service.

The first of the motors installed was operated, under these conditions, from December 10, 1909, to March 15, 1911, when it had to its credit 9,600 hours service without undergoing any repairs.

No trouble has been experienced in placing the generators in parallel.

Production of Gas.

The total quantity of gas produced per metric ton of peat containing 15 per cent moisture burned in the producer is said to be 1,610 cubic meters. This figure was determined by means of a calculation based on the analysis of the fuel used and of samples of gas collected and examined during a test on the plant*, and is approximately correct.

The quantity of gas per ton of $33\frac{1}{2}$ per cent moisture peat would therefore be

$$\frac{2{,}000 \times 0{\cdot}665 \times 1{,}610 \times 35{\cdot}31}{2{,}220 \times 0{\cdot}85} = 40{,}430$$

---

*Test made by Alberto Cerasoli, consulting engineer for this company and representative of the Power Gas Corporation of London, England.

cubic feet. The apportionment of this quantity, for steam raising, drying peat, and production of power, is as follows:

For steam raising, $\frac{11}{30} \times 40{,}430 = 14{,}824$ cubic feet.

For drying peat, $\frac{8}{30} \times 40{,}430 = 10{,}782$ cubic feet.

For power, $\frac{11}{30} \times 40{,}430 = 14{,}824$ cubic feet.

CALORIFIC POWER OF GAS.

The mean calorific power of the gas was found to be 1,380 calories per cubic meter. This is the higher calorific power, and is equivalent to 155 British thermal units per cubic foot. The lower calorific power is taken as 138 British thermal units per cubic foot.

The following analysis shows the average composition of the gas:—

CO_2	20%
CO	9·5%
CH_4	3·5 %
H	24%
N	43%

GAS AVAILABLE FOR PRODUCTION OF POWER.

The quantity of gas available for the production of power is equal to 14,824 cubic feet for every ton of 33½ per cent moisture peat burned in the producer. The daily consumption of peat fuel is 30 tons absolutely dry peat, or 45·11 tons of 33½ per cent moisture peat.

The total quantity of gas available per day of 24 hours is, therefore, 14,824×45·11, or 736,000 cubic feet. With a mean net calorific power of 138 British thermal units per cubic foot, the quantity of heat available for producing mechanical work is 736,000×138, or over 100 million British thermal units, and the quantity of heat per hour is 736,000×138÷24, or 4,232,000 British thermal units.

The load developed at the electric generator is: 200 K.W. during the day, and 270 K.W. during the night—both periods being of 12 hours' duration. The average daily load is consequently 235 kilowatt days.

The brake horse power developed at the engines is $235 \times 1,000 \div (746 \times 0 \cdot 80) = 394$. The heat consumption per brake horse power hour is, accordingly, $4,232,000 \div 394$, equal to about 10,740. In the above calculation the efficiency of the electric generator is taken to be 80 per cent.

The daily consumption of power at the plant for driving fans, pumps, etc., is approximately 70 K.W., and the electrical energy sold to consumers is on an average 165 K.W. per day—130 kilowatts during the day and 200 kilowatts during the night.

No data concerning the character of the load carried could be obtained, but it is assumed that the usual commercial conditions obtain here, viz., a minimum and a maximum or peak load during certain periods of the day. A load of 394 horse power implies a load factor of over 60 per cent, which is quite usual for power plants of this description.

Plant and Operating Costs.

The cost of the entire plant, including power equipment and transmission line to Pontedera—ten miles distant from Orentano—is said to be 800,000 lira (154,000 dollars). This figure probably does not include the cost of promoting and experimenting which would be considerable and should be charged to the capital expenditure. The above, however, includes the cost of buildings, machinery for manufacturing peat, tracks from bog to producer plant, and two small locomotives for hauling peat cars from the bog to producers.

OPERATING COSTS.

Management, which will include a staff of chemists. It is assumed, in order to arrive at the probable cost of operation, that the salary of the plant manager or superintendent is $1,500 per annum, and that the chemists, one chief and one assistant, receive $800 and $400 per year respectively. The general office expenditures, e.g. salaries of general manager, consulting engineer, etc., cannot be considered here, since information concerning costs of management other than that directly pertaining to the plant, is not in the possession of the writer.

Labour. Operations are carried on continuously in two shifts of 12 hours each. The total number of men employed per shift, including the producer, sulphate plant, and power house, is 21. This number includes two foremen, two engineers, and two electricians.

Six men are employed for attending the producers. Their duties are to feed the fuel, remove ashes and poke the fuel bed at the top and around the bottom. Nine men are employed for performing duties connected with the producer and sulphate plant. Two foremen, one for each shift, superintend the above men.

The power house employs eight men: four men per shift; one engineer, and one oiler, one electrician, and an assistant.

Total Daily Wages. Producer and sulphate plant:—

12 producer men, at 3 lira (60c) per day	$ 7.20
20 men employed for general work, 3 lira each	12.00
2 foremen	1.74
2 engineers, power house, 5 lira each per day,	1·93
2 oilers, “ “ 3 “ “ “	1.16
2 electricians, “ “ 5 “ “ “	1.93
2 assist. “ “ “ 3 “ “ “	1.16
Total	$27.12

The cost of operation for 365 days is:—

17,400 tons of peat for 350 days allowing standby losses for shut down of 7 hours per week or 15 days per year	$17,400.00
Wages on gas plant, including boiler attendants $7,643, say	7,640.00
Wages on power house, $2,255, say	2,260.00
Repairs, stores, maintenance, say	2,000.00

Oil and stores for engine	$ 200.00
Interest, depreciation, and amortization, say 14 per cent on cost of plant	21,610.00
Salary of plant manager, $1,200—$1,500, say	1,500.00
Chemists: 1 chief at $800.00	800.00
1 assistant at $400.00	400.00
713 tons of sulphuric acid at $7.37 per ton	5,260.00
Bags for packing ammonium sulphate at about $0.50 per ton	300.00
	$59,370.00

Credit.

594 tons of ammonium sulphate at $65 per ton	$38,610.00
Net cost of power per annum	$20,760.00
Net cost of power per K.W. hour on the basis of 165 K.W. hrs. for 350 days of 24 hours = 1,386,000 K.W. hours	1·5 cents

In the above estimate of the cost of producing one kilowatt hour, general office expenses, including salaries of general manager, consulting engineer, and the other unforeseen expenses are not as previously stated, included. Such expenses can best be added by those conversant with the methods employed in exploiting and financing such or allied undertakings.

The cost of generating one kilowatt hour, viz. 1·5 cents, is the lowest which can be realized with the conditions obtaining at the plant. Unforeseen expenses might arise which would slightly increase this figure; but it is believed that a lower figure based on the actual cost of the plant, fuel and labour, cannot possibly be obtained. The fact that the plant is being operated much under capacity must be borne in mind when estimating the lowest probable cost per kilowatt hour which can, under the most favourable circumstances, be obtained. On the other hand it must be understood that the plant, even though operating at considerably under half load, is nevertheless favoured with exceedingly cheap fuel—which is assumed to never exceed a moisture content of 33½ per cent—and the recovery of ammonium sulphate is assumed to average 70 per cent of that theoretically possible. In actual practice it is not reasonable to suppose that all the above conditions will be so favourable, e.g. it is highly improbable that a minimum moisture content of 33½ per cent of the peat fuel supplied can be maintained throughout the year for every ton of peat burned in the producers; and it is not likely that the yearly average recovery of the nitrogen in the fuel will reach as high a figure as 70 per cent of that theoretically possible.

The selling price of the power is about 20 centimes per K.W. hour, this is equivalent to 3·86 cents, and as the cost per K.W. is estimated to be 1·5 cents, the margin of profit should be considerable. According, however, to statements made to the writer by the consulting engineer for this company, no dividends have been declared since the inception of the plant—even though the annual cost of operating is greatly reduced by their method of estimating costs, by about 10,000 dollars—the amount charged by the writer to interest and amortization on the capital. In Italy the custom is to charge up against the plant depreciation only.

It is understood that this company will be in a position this year, 1913, to declare a dividend of 6 per cent.

Cost of Power, when Daily Consumption of Fuel is 70 Metric Tons of Absolutely Dry Peat.

In estimating the cost of generating power when the plant is operating at full load, i.e., when the consumption of fuel per 24 hours is 70 metric tons of theoretically dry peat, two conditions will be considered: (1), that the thermal efficiency of the producers is 44·3 per cent as is the case when the fuel consumption is 30 tons of theoretically dry peat per day; and (2), that the thermal efficiency of the producers is 60 per cent. It is quite probable that the thermal efficiency of the producers at maximum load will lie between 44 and 60 per cent. It must be understood, however, that since the plant has not been thoroughly tested under conditions of maximum load, as far as the writer knows, the results that will be obtained are based on theoretical considerations and deductions from data relating to the producers in question when operating at less than half load or that relating to other plants.

In order to gasify 70 tons of theoretically dry peat per day of 24 hours, the only additional requirement is to supply the necessary quantity of peat fuel. The force of labourers, and the office staff will remain the same, since the producer and ammonium recovery plants were originally designed to handle 70 tons of theoretically dry peat per day, and no additional labour is required to handle the increased quantity of fuel burned. It is, therefore, at once evident that a material reduction in the cost of operating the plant per ton of fuel gasified will result, if the cost of the fuel remains the same.

QUANTITY OF FUEL REQUIRED.

The quantity of fuel required at full load will be the same in both cases, i.e., when the thermal efficiency of the producers is 44 per cent and 60 per cent. Seventy metric tons of theoretically dry peat is practically equivalent in heating value to

$\frac{70 \times 2,200}{0.665 \times 2,000}$ = 116 short tons of peat fuel containing 33½ per cent moisture, and it will be assumed that this is the maximum moisture content of the fuel burned in the producers.

The annual consumption of fuel will be, for a working period of 350 days, 116 × 350 + 40 = 40,640 which allows 40 tons for standby losses during 15 days.

Cost of Generating Power when the Thermal Efficiency of the Producers is 44·3 per cent.

With a thermal efficiency of 44·3 per cent, which is that realized when the plant operates at less than half load, the fuel, or its equivalent in producer gas, burned for steam raising, production of power, and for the drying of peat, will bear the ratio 11 : 11 : 8.

According to this apportionment of gas for the various purposes enumerated, the 70 tons of theoretically dry peat would be divided as follows: for power purposes 25·7 tons, steam raising 25·7 tons, and for drying peat 18·6 tons.

POWER.

The average power which it will be possible to develop, assuming the same load factor, viz. 60 per cent, is $235 \times \frac{70}{30} = 548$ K.W. The energy required for driving fans, auxiliary machinery, etc., is assumed to increase in the ratio $\frac{70}{30}$; and since at the lower load factor, 70 K.W. were required for such purposes, with full load factor, the energy required would be $\frac{70 \times 70}{30} = 163$ K.W. The net K.W. which could be sold would therefore be 548 — 163 = 385 K.W.

ADDITIONAL COST OF OPERATING.

The additional cost of operating would be that due to the increased quantity of peat consumed and the larger quantity of sulphuric acid required for the formation of ammonium sulphate—the other cost items will remain the same.

Costs.

40,640 short tons of peat fuel at $1.00 per ton	$40,640.00
Wages on gas plant	7,640.00
Repairs, stores and maintenance	2,000.00
Interest, depreciation and amortization, 14 per cent.	21,610.00
Wages on power house	2,260.00
Oil and stores for engines	200.00
Salary of plant manager $1,200—$1,500	1,500.00
Chemists: 1 chief at $800 per year	800.00
1 assistant at $400 per year	400.00

1,668 tons of sulphuric acid at $7.37 per short ton....	$12,290.00
Bags for packing ammonium sulphate, 50 cents per ton	700.00
Total $90,040.00	

Credit.

1,390 short tons of ammonium sulphate at $65 per ton	$90,350.00
Net profits without sale of gas..........$	310.00

Under these conditions, therefore, the power would be generated free of cost, the sale of which should permit a large profit to be realized.

Cost of Generating Power when the Thermal Efficiency of the Producers is 60 per cent.

The chief effect of an increase in the thermal efficiency of the producers would be the liberation of a larger quantity of gas for power purposes, hence an increase in the amount of power available for sale. This is due to the fact that a smaller proportion of the total peat burned would be required for drying and steam raising, since a greater quantity of heat would be obtained per lb. of peat gasified. The apportionment of the 70 metric tons of dry peat for steam raising, drying wet peat, and for power purposes, will no longer be in the ratio of 11 : 11 : 8, but will be, for power purposes 31 tons, steam raising 23 tons, and for drying peat 16 tons. All other items will remain the same as in the previous case.

HEAT AVAILABLE FOR CONVERSION INTO ELECTRIC ENERGY.

The quantity of heat in the producer gas, available for conversion into electric energy will be $\frac{31 \times 2,200 \times 9,500 \times 60}{24 \times 100}$ $=16,197,000$ British thermal units per hour. Assuming a heat consumption of 18,000 British thermal units per K.W. hour when the load factor is 60 per cent, the amount of electric energy available will be $\frac{16,197,000}{18,000} = 900$ K.W.

POWER REQUIRED FOR DRIVING FANS AND AUXILIARY MACHINERY.

The power required for driving fans for circulating hot air and gases through peat drying chambers will be the same as in the previous case, viz, 163 K.W. The net power available for sale will, therefore, be 900—163 = 737 K.W.

ADDITIONAL POWER UNITS REQUIRED.

In order to develop the increased power, now made possible, three additional power units of 300 horse power each, must be installed. The cost of these, including generators, foundations, etc., fully erected, it is estimated, will be between 30,000 and 40,000 dollars—the exact cost of gas engines and electric generators made in Italy are not known to the writer, but the cost assumed is so much lower than that which could be realized in almost any other country, that it will probably fall on the low side—30,000 dollars will be taken as the additional capital cost to be charged against the power plant.

CAPITAL COST OF ENTIRE PLANT.

With the addition to the power plant, now existing, of three new units, the entire capital cost will be increased by 30,000 dollars. The total capital to be considered is now 154,400 +30,000 = 184,400 dollars.

Costs per year:—

40,640 tons of peat fuel at $1.00 per ton	$40,640.00
Wages on gas plant	7,640.00
Repairs, stores and maintenance	2,000.00
Interest, depreciation and amortization 14 per cent on $184,400, about	25,810.00

Wages on power house	$ 2,260.00
Oil and stores for engines	400.00
Salary of plant manager $1,500 per year	1,500.00
Chemists	1,200.00
1,668 tons of sulphuric acid at $7.37 per ton	12,290.00
Bags for packing sulphate at 50c per ton	700.00
Total	$94,440.00

Credit.

1,390 short tons of sulphate at $65 per ton	$90,350.00
Net cost of power	$ 4,090.00

Power available for sale, 737 K.W. years.

Cost per K.W. hour $\frac{4,090}{737 \times 350 \times 24} = 0{\cdot}00067$ cents.

NET PROFIT RESULTING FROM MANUFACTURE OF SULPHATE.

In order to estimate the possible net profit resulting from a year's operation of the plant for the recovery of ammonium sulphate only, it will be necessary to deduct from the capital cost of the plant the cost of the power equipment and transmission line to Pontedera.

The cost of the power plant will be assumed to be 34,000 and that of the transmission line 20,000 dollars (2,000 dollars per mile) or, a total of 54,000 dollars. On this basis the capital cost of the producer and ammonia recovery plant will be 154,400 —54,000 = about 100,000 dollars.

All charges except those referring to the power plant will remain the same as in the foregoing, and the total costs will be as follows:

Costs per year:—

40,640 tons of peat fuel at $100 per ton	$40,640.00
Wages on gas plant	7,640.00
Repairs, stores and maintenance	2,000.00

Interest, depreciation and amortization 14 per cent on $100,000.00	$14,000.00
Salary of plant manager $1,500 per year	1,500.00
Salary of chemists	1,200.00
1,668 short tons of sulphuric acid at $7.37 per ton	12,290.00
Bags for packing sulphate at 50c per ton	700.00
Total	$79,970.00

Credit.

1,390 short tons of sulphate at $65 per ton	$90,350.00
Net profits	$10,380.00

This profit is equivalent to 10 per cent on a capital investment of 100,000 dollars.

Power is sold to consumers at an average price of 3·86 cents per K.W. hour. At this high price the power is probably sold to many small consumers who require power intermittently. When the total output is sold to many small consumers, the cost of distribution, which has not been taken into consideration, would be considerable and would appreciably increase the cost of producing.

OBSERVATIONS.

In Italy, especially in the interior, the conditions are very favourable for the successful exploitation of a by-product recovery power plant of the type just described.

The cost of coal, which must be imported, is high, and the cost of peat fuel, wages of labour, and even the cost of the plant is much lower than that obtaining in most other countries. On the other hand, the selling price of ammonium sulphate in Italy is governed by the market price of the world, which in turn is governed by the supply and demand. The demand, moreover, is constantly increasing at a more rapid rate than the supply, so in Italy this commodity is sold at the maximum market price and is manufactured at possibly the lowest cost per ton, i.e., with a Mond plant, the conditions for making a large profit on the capital of the plant are consequently most favourable.

The plant has now been operated continuously for more than two years and during this time no trouble has been experienced. The producers require but little attention and the repairs are slight, indeed almost negligible. Owing to the large quantity of steam introduced with the air blast the internal temperatures of the producer are kept very low. As a consequence clinkering of the fuel is avoided, and the life of the producer lining thereby increased.

The power plant is of excellent design and construction—this is of paramount importance in a plant designed for continuous service—and no trouble from any source has been experienced during the long period which they have been in service.

Moisture Content of Peat Fuel burned in the Producer.

The management has made every effort to keep the moisture content of the fuel as low as 33½ per cent, since they maintain that the most efficient results as regards the recovery of ammonium sulphate and production of power gas are obtained with this as a maximum moisture content. The writer concurs in this opinion. To enable them to control the moisture content of the fuel and insure that the peat delivered to the producers shall not contain more than 33½ per cent, an elaborate installation for mechanically treating and drying the fuel has been established at the plant—this portion of the plant has been previously described, and is reiterated here, only for the purpose of emphasizing the importance of keeping the moisture content of the peat fuel as low as possible.

OTHER MOND PLANTS IN COURSE OF ERECTION.

A Mond by-product recovery producer plant of several thousand horse power was at the time of the writer's visit to Europe in course of erection at Codigoro, Italy.

This plant will be capable of burning 100 metric tons of theoretically dry peat per 24 hours, and will be situated close to an extensive peat bog. The quality of the peat in this bog, the writer is informed, is excellent as regards both heating value and nitrogen content. The actual cost of obtaining the peat for the producers will, it is said, be considerably less than is the case at Orentano. This plant is the second one to be erected for the "Society for the Utilization of Italian Combustibles," the plant at Orentano being the first.

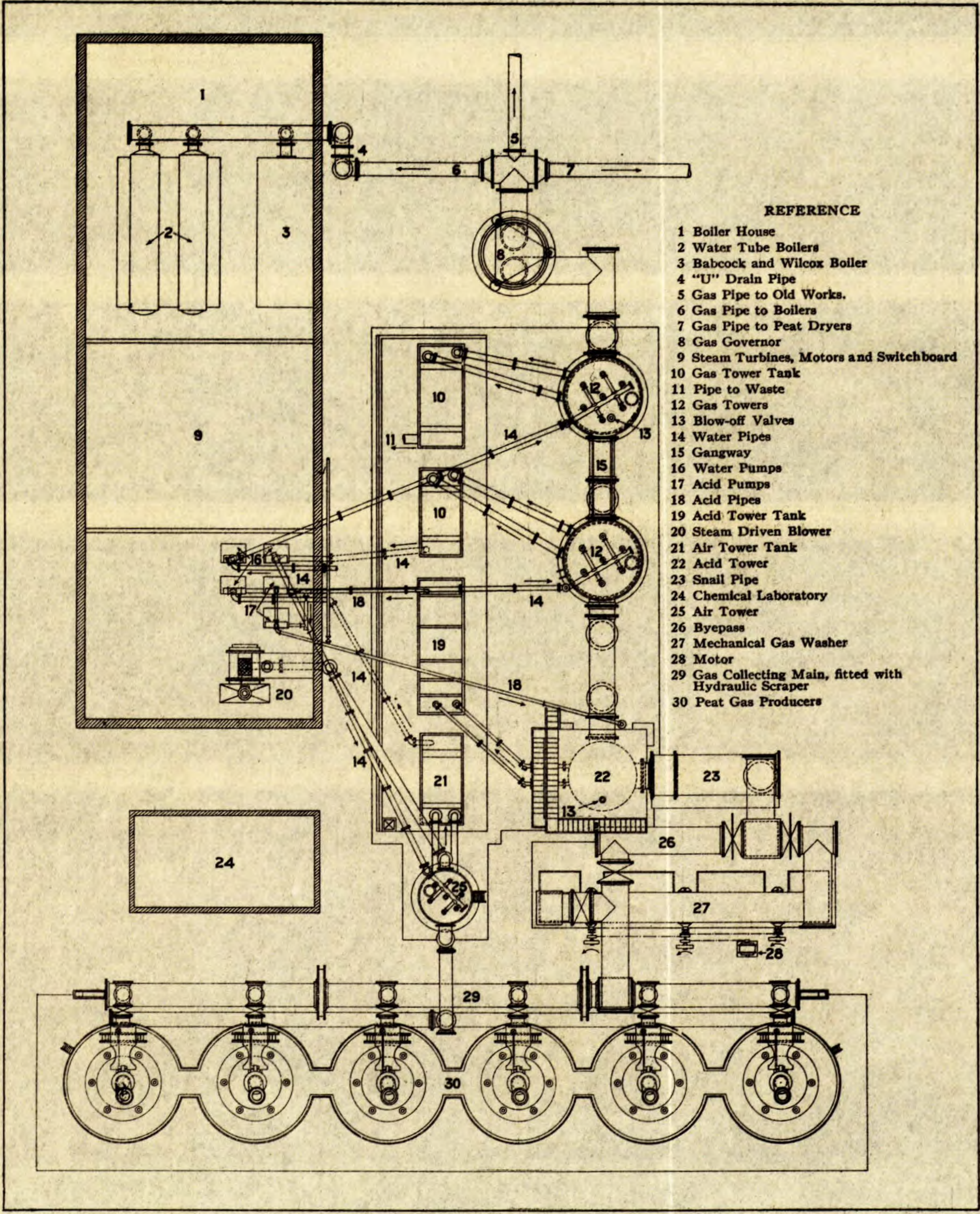
No attempt will be made for some time to utilize the producer gas for power purposes, the sole aim being to recover the ammonia, as ammonium sulphate.

Fig. 22 shows the disposition of producers and machinery of a 100 ton "Mond" plant which will be erected on a large bog in Italy.

BY-PRODUCT RECOVERY PEAT POWER-GAS PLANT NEAR OSNABRÜCK, GERMANY.

The only by-product recovery power-gas plant in Germany designed for burning peat fuel on a large scale, is that erected during 1910-11 by the German Mond Gas and By-Products Company on the Schweger Moor, about 50 kilometers from the city of Osnabrück.

The inventors of this system, which is incorporated in the design of this plant, aimed at the efficient utilization of peat fuel containing upwards of 60 per cent moisture. If peat of such a moisture content could be efficiently burned in the producers, the resulting advantages would at once be apparent. The principal advantage arising would be the lengthening of the season during which peat manufacturing operations could be carried on. Hence a sufficient supply of fuel could in most cases be guaranteed. When it is imperative that the maximum moisture content shall be considerably below 60 per cent, the difficulty of obtaining the requisite quantity of fuel for a year's operations becomes a very serious one during a rainy season. The desire, therefore, to render a plant of large proportions independent—to a small degree at least—of weather conditions, is not to be wondered at. The results of the numerous attempts so far made to utilize peat with a high moisture con-



REFERENCE

1 Boiler House
2 Water Tube Boilers
3 Babcock and Wilcox Boiler
4 "U" Drain Pipe
5 Gas Pipe to Old Works.
6 Gas Pipe to Boilers
7 Gas Pipe to Peat Dryers
8 Gas Governor
9 Steam Turbines, Motors and Switchboard
10 Gas Tower Tank
11 Pipe to Waste
12 Gas Towers
13 Blow-off Valves
14 Water Pipes
15 Gangway
16 Water Pumps
17 Acid Pumps
18 Acid Pipes
19 Acid Tower Tank
20 Steam Driven Blower
21 Air Tower Tank
22 Acid Tower
23 Snail Pipe
24 Chemical Laboratory
25 Air Tower
26 Byepass
27 Mechanical Gas Washer
28 Motor
29 Gas Collecting Main, fitted with Hydraulic Scraper
30 Peat Gas Producers

Fig. 22. General arrangement of Mond gas plant to burn 100 tons of dry peat per 24 hours

tent, do not, unfortunately, give one reason for hoping for an early solution of the problem. The reasons why peat of high moisture content cannot, in the writer's opinion, be successfully utilized for the production of power with by-product recovery, will be considered later in some detail.

Frank-Caro Process.

This process, like that of Mond, aims at the maximum production of a power gas with the maximum recovery of by-products. The two aims are not entirely compatible since the conditions influencing the efficiency with which the two operations are carried out are quite different. For example, the most efficient power gas process is realized when the temperature of the producer is high, while the formation of the maximum quantity of ammonia gas requires that a low working temperature be maintained in the producer. Maximum efficiency in the production of both the power and the ammonia gas cannot therefore be realized—one must be sacrificed to the other, or the efficiencies of both must be reduced.

It is claimed for the Frank-Caro process that the maximum quantity of power gas is obtained with the maximum recovery of ammonia gas from peat containing upwards of *60 per cent moisture.* The only important difference, however, existing between the Mond and Frank-Caro processes is the method of recovering the sensible heat of the gases—both producer and boiler flue gases. In all other respects the two systems are practically identical.

In the Mond system the sensible heat of the gas is abstracted by the cold water introduced in the gas cooling tower. This water becomes heated and is introduced into another tower where its heat and some moisture are imparted to the air blast which is forced through the tower. When burning peat in the producers, according to the usual Mond practice, the temperature of the exit gases is necessarily low. No attempt is therefore made to utilize the sensible heat of the gas leaving the producers by means of superheaters as is the practice when burning coal. The only recovery of heat when employing the

Mond system is, therefore, that of the cooling water of the gas cooling tower. All additional moisture required is obtained by introducing live boiler steam into the air blast main.

Frank and Caro on the other hand do not utilize the sensible heat of the producer gas in the manner explained above, probably on account of the very low temperature of the exit gases due to the excessive moisture content of the peat, but pass the air blast over hot water contained in thermal reservoirs or tanks. The hot water supplied to these tanks is obtained from special economizers situated in the stack of the boiler plant. The waste heat of the boiler furnaces is, therefore, utilized instead of the sensible heat of the producer gas. As a result of this departure from the usual Mond practice 40 per cent more of the gas generated, *it is said*, is available for power purposes.

The operations of the Frank-Caro plant at Osnabrück were unfortunately conducted in great secrecy, hence no information other than that obtained by direct observation could be secured. The above description for this reason merely serves as an outline of the process in general.

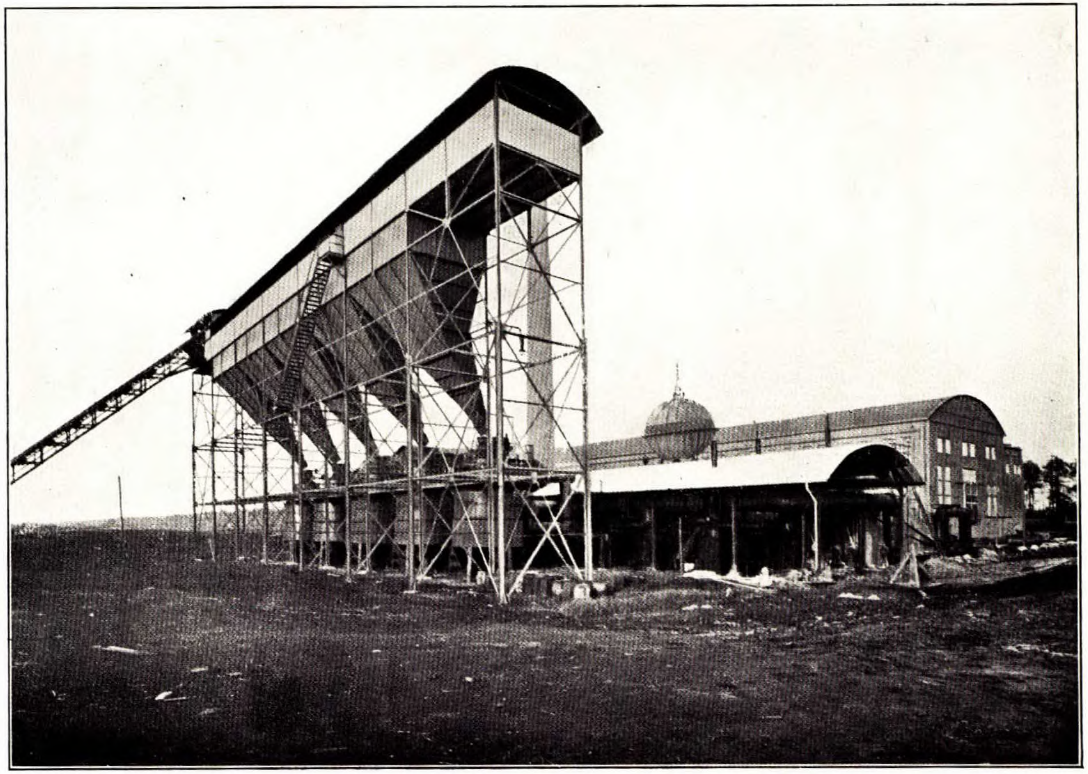
The air blast after passing through the thermal tanks referred to enters the producers at a point about one-third the height of the producer from the ground level. This section of the producer is jacketed and the air blast in passing down to the grates must first fill this annular space, which is situated in the hottest portion of the producer. The temperature of the air blast is consequently raised.

The additional steam required for saturating the air blast is supplied by a battery of boilers which are heated by burning peat and the tar resulting from the process of gasification.

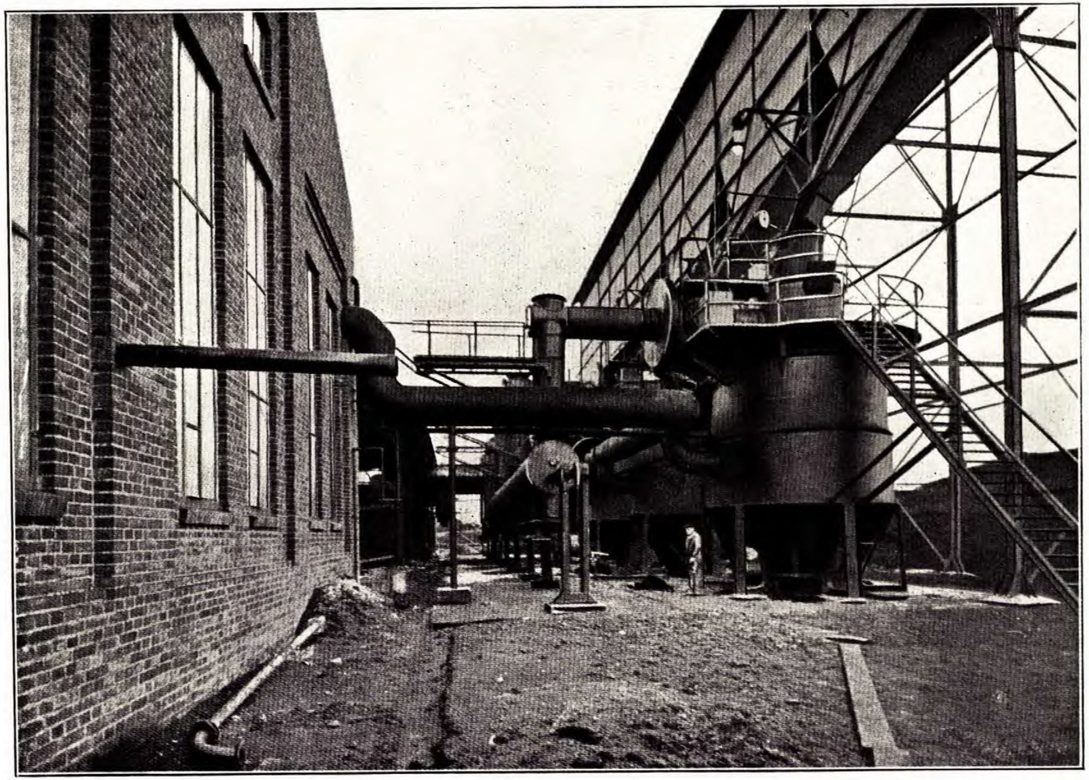
The scrubbing, cooling, and fixing of the ammonia of the gas are effected in a manner similar to that previously described for the Mond process, the only difference existing in the employment of horizontal chambers instead of the towers common to Mond practice.

PRODUCER.

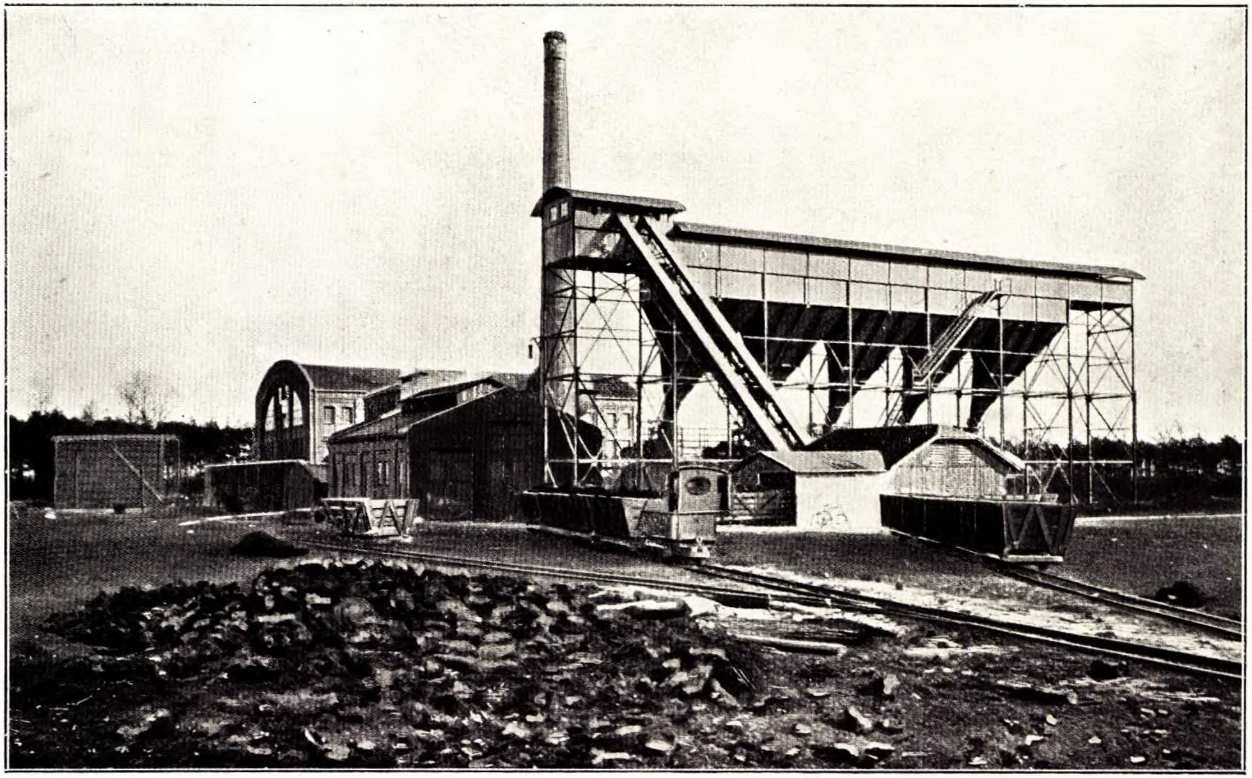
Five producers of the usual Mond design are installed. This battery, it is estimated, will produce a quantity of gas suffi-



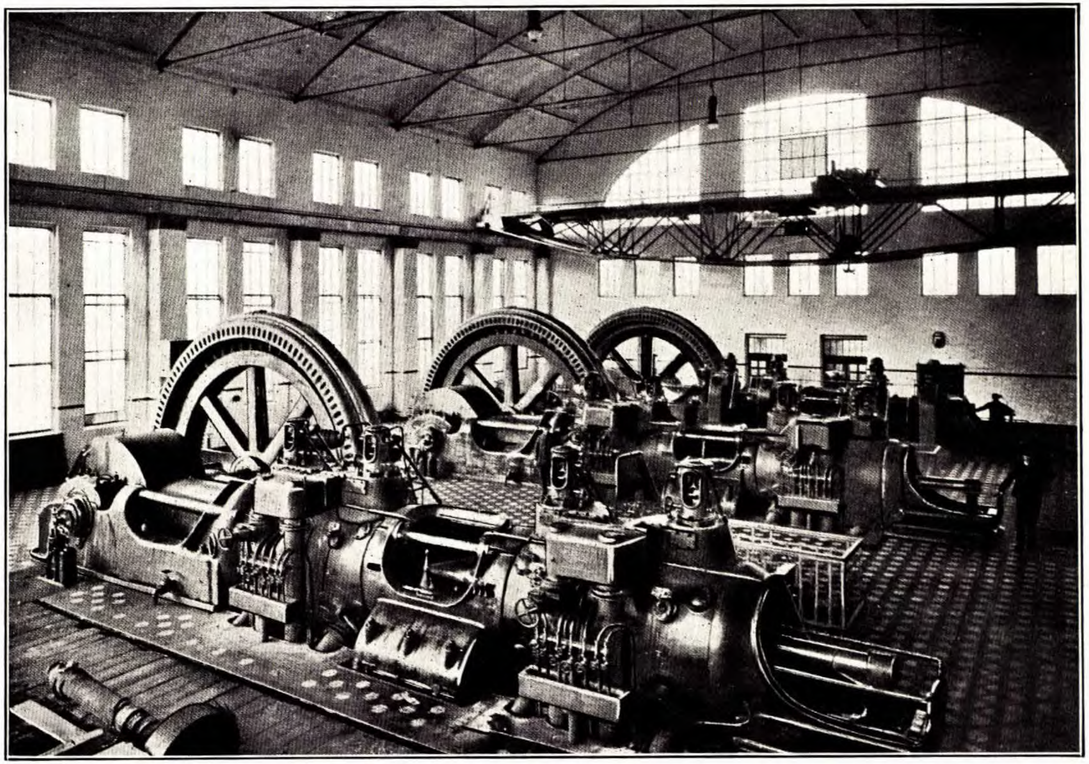
3,000 horse-power by-product recovery peat producer-gas power plant on the Schweger Moor: general view of plant.



3,000 horse-power, by-product recovery peat producer-gas power plant on the Schweger Moor: view showing producers and winch on gas main for operating scrapers.



3,000 horse-power, by-product recovery peat producer-gas power plant on the Schweger Moor: view showing fuel bins, hoppers, and loading device.



3,000 horse-power, by-product recovery peat producer-gas power plant on the Schweger Moor: view showing interior of power house.

cient to generate 3,000 horse power. The fuel bins and charging hoppers are clearly shown in Plate XIII which is a general view of the producers. In Plate XIV a more detailed view of the producers, fuel bins, and charging hoppers is shown. This plate also shows the arrangement which is provided for cleaning the gas main, viz., a winch by means of which a set of scrapers is operated.

The elevator for conveying peat fuel from the cars to the bins above the producers is shown in Plate XV.

POWER PLANT.

The power plant, Plate XVI, was originally designed to generate 2,000 horse power with three one thousand horse power engines—one engine held in reserve. A fourth power unit which was in course of erection during the writer's visit, will raise the total output to 3,000 horse power—with one engine held in reserve. Two of the gas engine units were built by the Augsburg-Nürnberg Engine Company, and the third unit was built by Ehrhardt and Sohmer.

Electric energy is supplied by generators of the fly wheel type, and distributed at a tension of 30,000 volts.

UTILIZATION OF HEAT OF ENGINE EXHAUST.

The heat of the gas engines exhaust is utilized for generating steam in specially designed Nürnberg low pressure boilers. These boilers are placed outside the power house and as near as possible to the engines, thus reducing to the smallest amount the loss of heat and back pressure due to the passage of the exhaust gases from the engines to the boilers. The erection of these steam boilers was under way at the time of the writer's visit to the plant and consequently do not appear in the cuts, which were reproduced from photographs taken some time previously.

The economy which results from the utilization of the heat of the gas engine exhaust will be better understood when it is stated that approximately 30 per cent of the heating value of the gas entering the gas engine cylinder leaves in the gas engine exhaust. If, therefore, the total heat consumption of the gas engine is 10,000 British thermal units per B.H.P. hour—the usually assumed heat consumption in practice—30 per cent or 3,000 British thermal units per B.H.P. hour will pass off in the exhaust. With a higher thermal efficiency than that applied in the above heat consumption a less quantity of heat may be contained in the exhaust. The available heat of the exhaust may be for the average well designed engine assumed to be 2,500 British thermal units per B.H.P. hour. For a power plant generating continuously 3,000 B.H.P. this will mean a total quantity of heat of 3,000 × 2,500 = 7,500,000 British thermal units per hour, which can be utilized for steam raising or other purposes.

This quantity of heat is equivalent to 1,200 pounds of peat containing 30 per cent moisture—assuming the absolutely dry peat to have a calorific power of 9,000 British thermal units per lb.—or 14 short tons per day of 24 hours. If this quantity of peat were burned, under a boiler with a thermal efficiency of 65 per cent, 4 lbs. of water would be evaporated and converted into low pressure steam per lb. of peat burned, or a total quantity of steam generated per hour would be 1,200 × 4 = 4,800 lbs., which would decrease to a considerable extent the quantity of steam necessary to be generated in the main boiler plant.

FUEL BURNED FOR STEAM RAISING.

As was previously mentioned, peat supplemented by the tar resulting from the process of gasification is burned under the boilers. For some time no satisfactory method existed for burning the tar, which was simply mixed with the peat on the ground and burned in the fire box without further treatment. As a result of this imperfect method for burning the tar, a large quantity when sufficiently heated ran through the grate bars and was lost.

At the time of the writer's visit a Körting tar atomizer was employed for burning the tar. The tar by this means is mixed with air in the proper proportions and then introduced into the fire box where it burns with complete combustion.

Prior to the introduction of an efficient tar burning apparatus, coal had to be burned in order to meet the deficiency.

Manufacture and Cost of Peat Fuel: The portion of the 'Schweger Moor owned by the German Mond Gas and By-Products Company comprises about 1,000 hectares—2,470 acres. Before undertaking the erection of the power gas plant, or even before the purchase of a bog, the company entered into a contract with the City of Osnabrück to supply power continuously for various purposes. This necessitated the generation and supply of electrical energy at the earliest possible date. No time could, therefore, be lost in searching for a bog suitable in every way for the manufacture of peat fuel.

The bog obtained was a wet one and sufficient time was not at their disposal for properly draining it. As a consequence when the operations were commenced great difficulty was experienced in manufacturing the necessary quantity of fuel with the desired moisture content. The heavier machines employed in the manufacture of the fuel sank into the bog, which precluded their use, at least on a portion of the bog. The nitrogen content, also, of that portion of the bog from which peat was excavated was too low—1 per cent—to prove satisfactory.

The conditions for manufacturing peat were most unfortunate and the company was forced to supply their plant to a certain extent with peat bought from manufacturers on a small scale. The average cost of the peat fuel per metric ton was said to be in the neighbourhood of $3.50. This coupled with the high moisture content and low nitrogen content cannot in any sense be considered as favourable to the success of the industry.

PEAT MANUFACTURING MACHINERY.

Both the Strenge and Dolberg systems were employed for the manufacture of peat fuel. The Strenge machines are equipped with automatic excavators and spreaders and are said to give satisfaction when employed on bogs free from roots and pieces of wood.

The Dolberg system necessitates the employment of manual labour for the performance of all operations.

MOISTURE CONTENT OF PEAT AS FIRED.

The average moisture content of the peat burned in the producers for a portion of the year 1911 was as follows: October, 45 per cent; November, 53 per cent; December, 60 per cent; January, 58 per cent, and February, 41 per cent.[1]

EFFECTIVE HEATING VALUE OF THE GAS.

The effective heating value of the gas produced during the above mentioned period varied between 1,100-1,300 calories per cubic meter—between 124 and 146 British thermal units per cubic foot.[2]

The following results of the operation of this plant during the months of December, January, and February are obtained from the same source.[3]

December, 1912.

Quantity of wet peat gasified, 1,325 metric tons, 1,457 short tons.
Moisture content of peat as burned, 60 per cent.
Absolutely dry peat, gasified, 530 metric tons, 583 short tons.
Peat burned under boiler, 170 metric tons, 187 short tons.
Absolutely dry peat burned under boiler, 68 metric tons, 75 short tons.
Tar burned under boilers——
Recovery of ammonium sulphate, 18·3 metric tons, 20 short tons.
Recovery of ammonium sulphate per metric ton of absolutely dry peat, 34·5 kilograms, 69 lbs. per short ton.
Nitrogen content of peat, 1 per cent.
Total quantity of absolutely dry peat utilized for production of power gas and recovery of ammonium sulphate, 598 metric tons, 658 short tons.
Total power developed, 427,000 K.W. hours.
Power produced per metric ton of absolutely dry peat, 715 K.W. hours, 650 K.W. hours per short ton.

---

[1] Dr. Hamers: "Report on the results to date of the gas and electric plant in the Schweger Moor and the plans for its further development." See Minutes of the 68th Session of the Prussian Central Moor Commission, 1912, page 36.

[2] Ibid.

[3] Ibid.

January, 1913.

Quantity of peat gasified, 1,454 metric tons, 1,599 short tons.
Moisture content as fired, 58 per cent.
Quantity of absolutely dry peat fired, 611 metric tons, 672 short tons.
Quantity of wet peat burned under boilers, 200 metric tons, 220 short tons.
Quantity of absolutely dry peat burned under boilers, 84 metric tons, 92 short tons.
Quantity of tar burned under boilers——
Total quantity of absolutely dry peat burned in producers and under boilers, 695 metric tons, 764 short tons.
Total production of power, 481,000 K.W. hours.
Total production of power per metric ton of absolutely dry peat, 692 K.W. hours, 629 K.W. hours per short ton.

On account of an alteration to the sulphate plant which was undertaken during this month, a marked reduction in the quantity of sulphate of ammonia resulted, consequently no details are given of the quantity actually produced.

February, 1913.

Result of operations up to and including February 27.

Total wet peat gasified, 930 metric tons, 1,023 short tons.
Moisture content, 41 per cent.
Total quantity of dry peat gasified, 549 metric tons, 604 short tons.
Wet peat burned under boilers, 107 metric tons, 118 short tons.
Absolutely dry peat burned under boilers, 63 metric tons, 69 short tons.
Tar burned under boilers——
Total quantity of dry peat gasified and burned under boilers, 612 metric tons, 673 short tons.
Power produced, 414,000 K.W. hours.
Power produced per metric ton of absolutely dry peat, 676 K.W. hours: 615 K.W. hours per short ton.

Absolutely dry peat gasified for production of ammonium sulphate, 549 metric tons, 604 short tons.
Ammonium sulphate recovered, 19·5 metric tons.
Ammonium sulphate recovered per metric ton of absolutely dry peat, 35·5 kilos. 71 lbs. per short ton.

The quantity of tar recovered and burned under the boilers with the peat fuel is not stated for any of the above tests. The production of tar, however, must have been considerable owing to the low temperature prevailing in the distillation zone of the producer.

The highest average moisture content of the peat burned in the producers at any time was 60 per cent. With this moisture content the production of power is said to have been 650 K.W. hours and of ammonium sulphate, 69 pounds per short ton of absolutely dry peat. During the month of February the average moisture content of the peat was 41 per cent which is the lowest of the three tests cited. With this moisture content the production of power and sulphate of ammonia were 615 K.W. hours and 71 lbs. per short ton respectively. The total quantity of absolutely dry peat gasified and burned under the boilers was approximately 640 metric or 700 short tons for each month. From the monthly reports it would appear that the increase in the moisture content of the fuel burned during December in no sense affected the production of power or ammonia gas. Such a deduction cannot be entertained for a moment, since both the heating value of the power gas and the quantity of ammonia gas formed must vary with the moisture content; an increase in moisture causing a decrease in the quality of the power gas and the quantity of the ammonia gas, a statement which is borne out by the results obtained with other peat producer gas power plants.

Consumption of Fuel per Brake Horse Power Hour.

The production of power per short ton of absolutely dry peat, according to the results previously stated, is for the three months cited; 650 K.W. hours, 629 K.W. hours, and 615 K.W. hours. Consumption of dry peat per K.W. hour is 3·07, 3·18 and 3·25 lbs. respectively, which corresponds to a fuel consumption per B.H.P. hour of 2·29, 2·37, and 2·42 lbs. or 2·06, 2·18, and 2·13 lbs. respectively, when the efficiency of the electrical generator—which is assumed to be 90 per cent—is taken into consideration.

It will be of interest to compare these results with those obtained with the Körting double zone peat producer gas generator designed for the generation of power gas only. This producer is so constructed that all the moisture and volatile matter of the fuel take part in the formation of the final gas. It is apparent then that with ideal conditions all the moisture and volatile matter will interact with incandescent carbon. No losses consequently, will occur, for the tar will be decomposed into stable combustible gases, and the moisture in reacting with carbon will be decomposed thus decreasing the temperature of the producer and consequently the sensible heat of the gas generated, so that the thermal efficiency of the system will be increased. These ideal conditions are partly realized when the moisture content of the peat fuel is 25 per cent. The best result obtained, under these conditions, in the many experimental tests conducted at the Fuel Testing Laboratory of the Mines Branch, was as low as 1·6 pounds of absolutely dry peat per B.H.P. hour—under full load conditions.

It is not reasonable to suppose, therefore, that a better result, or even one as good, can be expected to be obtained with a system which utilizes neither the moisture nor tarry content of the fuel but introduces large quantities of steam externally generated in order to carry out the process.

Production of Ammonium Sulphate.

The production of ammonium sulphate during the two months cited was 69 and 71 lbs. respectively per short ton of absolutely dry peat. Theoretically a nitrogen content of 1 per cent would yield 94 lbs. of ammonium sulphate, the efficiencies of the recovery process are therefore 73 and 76 per cent respectively —which are high, to say the least.

Notwithstanding the results alleged to have been obtained with peat containing as high a moisture content as 60 per cent the company was in 1912 considering the establishment of a steam power plant to be connected with the Schweger high voltage transmission lines in order to carry the load contracted for. This auxiliary or main power plant, will, if erected, be built at a coal pit,* about 43 kilometers distant from the plant under discussion.

On account of the adverse conditions obtaining at the plant, especially as regards the supply and cost of peat fuel, the officials were not desirous of giving out information concerning the cost of operation, power developed and sold, and the financial conditions of the undertaking of the company.

The writer was informed by an official at the plant that the peat contained too high a percentage of moisture to enable them to obtain the best results. This unsatisfactory condition, coupled with the high cost of the fuel and its low nitrogen content, militated against the realization of any profits since the inception of the plant. A report has recently come to the writer's attention to the effect that the plant has been indefinitely closed down.

Permissible Moisture Content of the Peat Fuel.

So much has been said and written by men of recognized authority concerning the high moisture content allowable in peat utilized in this process, that a few explanatory remarks concerning this subject should be made.

The current technical literature on the gasification of peat fuel for power purposes either with or without by-product recovery, contains statements to the effect that peat containing up to 70 per cent water can be economically burned in the gas producers.

Such a statement of the case is, in the writer's opinion, not borne out by facts and consequently is so misleading that much harm has resulted to this particular and most important branch of the peat industry. Several eminent writers have simply taken the statements of the various inventors concerned

---

*Electrotechnik und Moor Kultur. (Das Kraftwerk im Wiesmoor in Ostfriesland). von J. Teichmüller in Karlsuuhe.

without in any way attempting to verify their accuracy, and in this manner many persons, including engineers of repute, have been led to believe the proposition to be entirely feasible.

In order to enable one to form an opinion as to the possibility of burning peat containing as high as 60-70 per cent moisture in producers designed for by-product recovery, the principal factors governing the process must be stated and discussed.

It has been previously stated that the principal novelty of the Mond process consists in the method of saturating the air blast. For the formation of ammonia gas in the producer large quantities of steam must be introduced into the reaction zone for the purpose of supplying, by interaction with hot carbon, the necessary hydrogen to combine with the nitrogen of the fuel, and secondly, to reduce the temperature of the reaction zone sufficiently to permit the combination of the hydrogen and nitrogen to proceed.

In order to effect all of the above reactions a large quantity of heat is required: and it is this quantity of heat and that required to maintain the working temperature of the producer and provide for radiation and other losses which must be taken into consideration.

When the fuel gasified is coal of high calorific power the conditions cited above are easily met; but when the fuel is of low calorific power, as is the case with peat, the quantity of heat available is much less, and the reactions under certain conditions might not be effected.

When absolutely dry peat, of average Canadian quality, is completely burned, a quantity of heat equivalent to 9,000 British thermal units per lb. is evolved, and this is the maximum quantity of heat the peat is capable of producing. If the peat now contains water its useful calorific power is decreased by an amount equal to the weight of the water and the quantity of heat required to raise the water contained up to 212°F. and evaporate it, i.e., the latent heat of vaporization which is entirely lost, as far as the process is concerned.

In addition to the heat required to evaporate the moisture a certain quantity is required to distil the volatile matter, a part of which is lost in this type of producer. The tarry matter which is distilled leaves the producer without taking any part in the formation of the producer gas, and since it possesses a high calorific value and is of considerable quantity, the heat lost to the process in this manner is considerable, and must be taken into account.

The steam introduced with the air blast must be raised to the temperature of the reaction zone, a portion of it is decomposed liberating hydrogen and giving rise to the formation of either carbon monoxide or carbon dioxide, depending on the temperature, but the larger portion escapes without parting with much of its heat. Finally, the heat of the ashes passing into the water lute and the heat lost by radiation are not inconsiderable.

It is doubtful whether peat of 60-70 per cent moisture would burn at all under these conditions where if a producer gas is desired the combustion must be incomplete, but it is quite certain, even if we assume that combustion can take place, that the temperature of the combustion zone will in time fall to such a degree that only carbon dioxide will be formed and perhaps also a certain quantity of hydrogen. When this condition arises the steam in the air blast must be reduced.

The most conclusive proof, however, that peat of 60-70 per cent moisture cannot be efficiently burned in the producer is found in the results of operations of the Mond gas plant at Orentano, Italy. At this plant great care is taken to furnish the producer with peat containing not more than 33½ per cent moisture, and in order to insure this low moisture content artificial heat is employed for drying the peat. If it were possible to utilize peat of a higher moisture content, say, e.g. 60 per cent, the company operating this plant would be only too glad to do so, since the producers, and consequently the entire plant are operating at less than half load owing to the difficulty of obtaining the necessary quantity of peat, and, as has been previously stated, sufficient peat to run the plant at full load might easily be manufactured with a moisture content of 60 per cent. The difficulty is to produce the desired quantity of peat fuel with the much lower moisture content.

The results of three months operations of the gas plant of the German Mond Gas Company, at Osnabrück, cited elsewhere, show that the quantity and heating value of the gas were high, viz. 36·1 cubic feet per lb., and 140 British thermal units per cubic foot respectively, and that the production of power was 1,000 horse power hours per ton of absolutely dry peat. This result is said to have been obtained with peat containing 60 per cent moisture. It will be interesting to compare the above results with those cited by Lunge,[1] from an article by A. Frank, in Z. Angew, Chem. 1908, p. 1597, on the results obtained with the Mond-Caro process in working up raw peat, with 40 or 50 per cent water, at Sodingen, in Westphalia. It will be noted that the moisture content was 40 or 50 per cent, it could not have been both, the lower moisture content, viz., 40 per cent, will, therefore, be taken as the one most likely to give the following results; Nitrogen content of peat 1·05 per cent, ashes 3 per cent, quantity of gas per 1,000 kg. (2,200 lbs.) dry peat 2,800 cu. m., about 45 cu. ft. per lb.; analysis of gas, CO_2, 17·4 to 18·8 per cent; CO, 9·4 to 11 per cent; H_2, 22·4 to 25·6 per cent; CH_4, 2·4 to 3·6 per cent, and N, 42·6 to 46·6 per cent; calorific power, 1,400 calories per cubic meter (157 British thermal units per cubic foot) equal to a production of 1,000 actual horse power hours. The yield of ammonia was up to 40 k.g. of sulphate per metric ton equivalent to 80 lbs. per short ton. Under most favourable conditions such results as these might be obtained with peat containing not more than 40 per cent water, but the calorific power of the peat must be high.

The following calculations,[2] based on theoretical considerations, has been made to show that the results cited in the report on the Osnabrück gas power plant cannot possibly be obtained by burning peat containing 60 per cent water. The calorific value of the gas obtained at the Osnabrück plant is said to be 140 British thermal units gross or 134 net. In this calculation a gas composition is assumed which will give a net heating value of 131 British thermal units per cubic foot.

THE FOLLOWING ASSUMPTIONS ARE MADE.

That all the peat substance is completely gasified.

---

[1] Coal Tar and Ammonia, Lunge, Part II, page 869.

[2] The calculations were made by Mr. Edgar Stansfield, M.Sc.

That all the water in the peat is distilled off with the gas undecomposed.
" air enters the producer saturated at 60° C.
" steam introduced with the air is decomposed.

HEAT BALANCE.

Entering the Producer:—

1. Potential heat units of wet peat fired = gross calorific power of wet peat.
2. Sensible heat (above 0° C.) viz. air + water at 60° C.
3. Latent heat of steam at 60° C.

Leaving the Producer:—

4. Potential heat units in gas generated = gross calorific value of gas.
5. Sensible heat of gases, including the steam, at 200°C., reckoned from 0°C.
6. Latent heat of steam in gases, at 0° C.
7. Radiation losses.

VALUES USED IN CALCULATION.

$H = 1, \quad C = 12, \quad N = 14, \quad O = 16.$

1 gram mol. occupies 22·4 litres at 0° C. and 760 mm.

Latent heat of steam at t° C, = 606·5 — 0·695t calories (Regnault).

Mean specific heats, at constant pressure

of air, 0° – 60°C = 0·237 Regnault.
N_2 0° – 200°C = 0·244 "
CH_4 0° – 200°C = 0·593 "
H_2 0° – 200°C = 3·409 "
CO_2 0° – 200°C = 0·217 "
CO 0° – 200°C = 0·245 "
steam 0° – 200°C = 0·453 Pier.

Gross Calorific Powers, in Calories per Gram Molecule.

CO = 68,200
CH_4 = 213,500
H_2 = 69,000

Analysis of Peat Burned:—

	dry	60% H_2O
Carbon	56·0%	22·40%
Hydrogen	5·2%	2·08%
Nitrogen	1·9%	0·76%
Oxygen	30·9%	12·36%
Ash	6·0%	2·40%
Water	0·0%	60·00%

Calorific Power:—

Calories per gram	2102·2	
Brit. Therm. Units per lb.	9,460	3784·0

100 grams of peat containing 60% H_2O, 86·0 grams of air, and 13·4 grams of H_2O, *can* give in the producer, 2·40 grams of ash, 60 grams of steam together with 66·82 grams N_2+2·72 grams CH_4+2·89 grams H_2+46·93 grams CO_2+17·64 CO.

The permanent gases are:—

2·386 gram mols. N_2+0·170 gram mols. CH_4+1·445 gram mols. H_2+1·067 gram mols. CO_2 + O·630 gram mols. CO;
Total 5·698 gram mols. i.e. 127·6 litres.

This gas has the percentage composition:—

N_2	41·88%
CH_4	2·98%
H_2	25·36%
CO_2	18·72%
CO	11·06%

Calorific power in B.T.U. per cubic foot moist at 60° F and 30″ Hg.

gross	147
net	131

The air in order to carry with it the above proportion of steam must have been saturated at a temperature of about 60°C.

HEAT BALANCE.

(1) = 210,220	calories,	(4) = 178,950	calories,
(2) = 2,027	“	(5) = 13,890	“
(3) = 7,570	“	(6) = 36,390	“
		(7) = 9,410	“
Total 219,820	“	Total 219,820	“

It will readily be seen from the above calculation that under the most ideal conditions—which do not and cannot obtain in actual practice—the quantity of heat generated by the burning of peat containing 60 per cent moisture in a producer, is not sufficient to effect the various reactions and provide for losses. It is, therefore, impossible to produce from peat containing so high a moisture content, a power gas of the heating value claimed. It is more within the realm of probability that complete combustion would have to take place in order to permit the production of the necessary quantity of heat—in which case the gas resulting would contain no combustible components whatever, except perhaps a small percentage of hydrogen.

With the introduction, moreover, of the large quantity of steam with the air blast, which must be in excess of that theoretically required, it is quite probable that the temperature, as stated previously, would fall too low, even for the formation of ammonia gas.

In order to obtain the best results, the writer believes that the moisture content of the peat fuel must be kept as low as 30 to 35 per cent. This opinion is based on the results obtained from other by-product recovery plants operating with peat and on the results of the investigation of the utilization of peat for power purposes conducted in the laboratories of the Mines Branch. In conclusion it might be stated, as a final and conclusive argument against the feasibility of burning peat high in moisture in the producer, that the only plant of this description at present in satisfactory operation is the Mond gas plant at Orentano, in which peat with a moisture content not exceeding 33½ per cent is burned.

COAL BURNING BY-PRODUCT RECOVERY POWER GAS PLANTS.

In the previous chapters of this report a full description has been given of the Mond process and its application to a low grade fuel such as peat, but so far nothing has been said concerning its application to coal and lignite. Indeed the Mond process was devised solely for the utilization of coal, and its application to other fuels followed some time after it had been proven a complete success with coal. Several large power gas plants employing the Mond system are to day, and have been for several years, in successful operation. The gas generated is employed for a wide variety of purposes, and the demand for such a gas, instead of decreasing, is on the increase. Two of the most interesting of the Mond power gas plants in operation in the British Isles are the plants of the Staffordshire Mond Gas Company, and the Langwith By-Product Company, Limited. Neither of these plants produces power other than for purposes of the plant, hence the position they occupy is a unique and interesting one. For this reason and the possibility of introducing such a method into Canada for utilizing the low grade coals, such as mine waste, lignite, etc., they will be fully described.

THE SOUTH STAFFORDSHIRE MOND GAS COMPANY.

The data for the following description was obtained largely from a paper by Herbert Alfred Humphrey, on "The generation and distribution of Producer Gas in South Staffordshire;" supplemented with personal observations by the present writer.

The South Staffordshire Mond Gas Company is a pioneer undertaking inasmuch as it was the first example of a company furnishing a supply of producer gas for public purposes. The gas generated at this plant is not converted into electric energy or other form of power at the plant itself, but is transmitted under pressure through specially designed and constructed mains to works and manufactories situated in the region surrounding the plant. For this reason, as is stated above, the plant occupies an unique and interesting position.

FIG. 23.—Map showing district supplied with gas by the South Staffordshire Mond Gas Company.

According to the charter granted by Parliament, this company has the right to supply gas over an area of 123 sq. miles. Within this area are included six corporations, sixteen urban district councils, and three rural district councils, and gas for heating and power purposes is used by 100 miles of railway, 106 miles of canals, and more than 2000 works of various description.

Fig. 23 shows this area.* The design of the central station and of the distributing system was carried out by Herbert Alfred Humphrey, who acted as consulting engineer to the Company. The entire plant was erected by the Power Gas Corporation, Limited, of London and Stockton-on-Tees.

Producer Gas and By-Product Recovery Plant.

The producer plant consists of eight Mond producers (one held in reserve), together with the necessary plant for cooling, cleaning, and compressing the gas; plant for the recovery of ammonium sulphate and tar; and auxiliary machinery consisting of steam boilers, circulating pumps, electric generating plant, motors, fans and blowers. The capacity of the plant is 140 tons of coal per day. At the time of the writer's visit, additions were being made which will increase the present capacity by about 80 per cent.

In order to minimize the risk of a stoppage of the gas supply the first unit installed contained a duplicate set of cooling towers, and a larger proportion of spare machinery than would usually have been provided. Other provisions were made to insure against stoppage due to a breakdown of some portions of the plant, e.g., the producer portion was divided into two independent sections each having its own coal elevator, gas collecting mains, and mechanical washers. Cross connexions were made at numerous points and by-passes fitted in such a manner that practically any portion could be cut out for cleaning purposes without in any way affecting the production of gas.

STEAM BOILERS.

The steam boiler plant originally consisted of 4 "climax" water tube boilers; but these had been supplanted by Lancashire boilers sometime previous to the writer's visit owing to the trouble experienced in feeding the former with hot water. The boilers are arranged for coal and gas firing. Gas firing is resorted to when the demand for gas has considerably decreased, as it does during a portion of the day.

---

*This and other plates and illustrations have been furnished through the courtesy of the Power Gas Corporation, London.

In order to gas fire the boilers without interfering with the coal firing, Mr. Humphrey devised a special method. This consists of a belt, surrounding the boiler above the grate bars, into which the gas is conducted through four pipes. On the inner side of this belt there are a large number of 4$\frac{5}{8}$ inch holes through which the gas is fired. The air necessary for combustion is supplied through a short 3 inch pipe which protrudes into the belt in such a manner that the air is in the centre and the gas surrounds it. Each hole is provided with a jet of this description. Each boiler is capable of evaporating 15,000 lbs. of water per hour at a pressure of 120 lbs. per square inch. Two of these were, however, sufficient for supplying all the required steam.

Since a very large quantity of steam is introduced with the air into the combustion zone of the producer, viz.,2 lbs. of steam per lb. of coal, the auxiliary machines are steam operated and their exhaust steam used for saturating the blast, in addition to the live steam which may be required. The large quantity of steam required for the process may be better appreciated when it is stated that if the producers are burning 140 tons of coal per day, 240 tons of steam are required for saturating the air blast. This is equivalent to 10 tons, or 20,000 lbs of steam per hour. More than half the entire quantity of steam required for saturating the air blast is obtained from the system of recuperation by circulating water which is employed in the Mond system described earlier in the report.

BLOWERS.

The air forced through the producers is supplied by three blowers of the Root type driven by steam engines. Two of these blowers are sufficient to meet all the demands; the third unit is consequently held in reserve. Since a continuous supply of gas to the consumers is absolutely imperative, and this depends on the quantity of air forced through the producers at all times, special care has been taken to render this portion of the plant as reliable as possible.

Other gas plants are provided with gas holders of large capacity so that the supply of gas will continue undisturbed during a considerable period of shut down. In this and other Mond gas plants, however, the gas is delivered direct from the

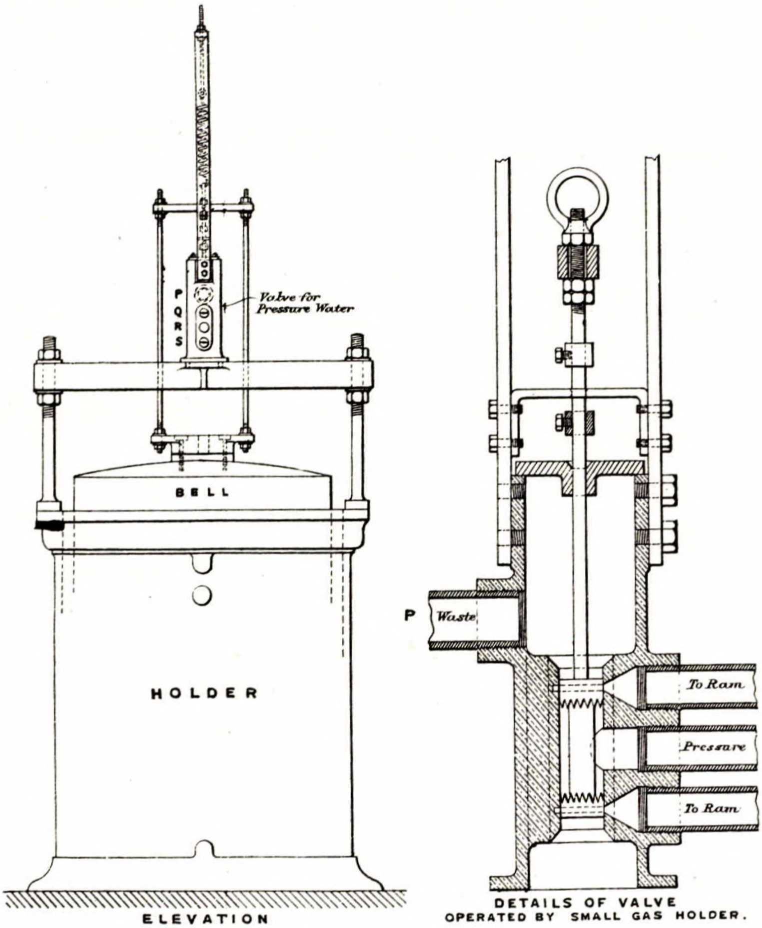


FIG. 24.—Apparatus for controlling blowers to give constant gas pressure.

gas cleaning system to the compressors and thence to the distributing mains. Steam is considered more reliable than other sources of energy, hence the blowers are recommended to be steam driven. Each blower has a capacity of 6,000 cubic feet of free air per minute at a pressure of 28 inches of water when running at a speed of 100 revolutions per minute. The guaranteed steam consumption of the engines is stated to be 32·5 lbs. of steam per indicated horse power hour when exhausting against a back pressure of 5 lbs per sq. inch. Although these blowers can run under a wide variation of speed there is a limit below which it is not safe to run, for fear of stopping. When, therefore, the demand for gas is reduced below a certain quantity, further regulation is obtained by allowing a portion of the air to escape into the atmosphere, Fig. 24. The blowers maintain the pressure throughout the gas-generating plant up to the point where the purification fans again increase the pressure.

PRODUCERS.

Gas is generated in two batteries of four producers, each having a capacity of 2,000 H.P., or a total of 16,000 H.P. These producers are of the usual Mond design which is described elsewhere. Each producer is rated at 20 tons (2,240 lbs.) of coal per 24 hours; but the actual capacity depends to a certain extent on the quality of the fuel. At the time of the writer's visit to the plant the producers were working at a capacity of 24 tons (of 2,240 lbs.) each per day. Ashes are withdrawn from the bottom of the producers through a water lute, and it is the practice to draw ashes once on each shift or three times during the day of 24 hours. A storage hopper with a capacity of 50 tons of fuel is placed over each producer. This is done as a matter of precaution in case of breakdown of the coal handling apparatus. These hoppers hold a sufficient quantity of fuel to feed the producers for about three days. Fig. 25 shows the device employed for distributing the fuel.

SUPERHEATER.

The gas leaving the producer passes through a superheater —one supplied for each producer—which serves as a heat exchanger between the entering cool air blast and the leaving hot producer gas. The temperature of the entering air blast is in this manner considerably increased. After leavingth e superheater the gas passes into the gas collecting mains and thence to mechanical washers, ammonia recovery tower, gas cooling tower, and then to tar extractor and purifying system to compressors and distributing mains. The mechanical washer, acid tower, gas cooling, and air saturating and preheating towers and all other apparatus connected with a Mond gas system have been fully described elsewhere.

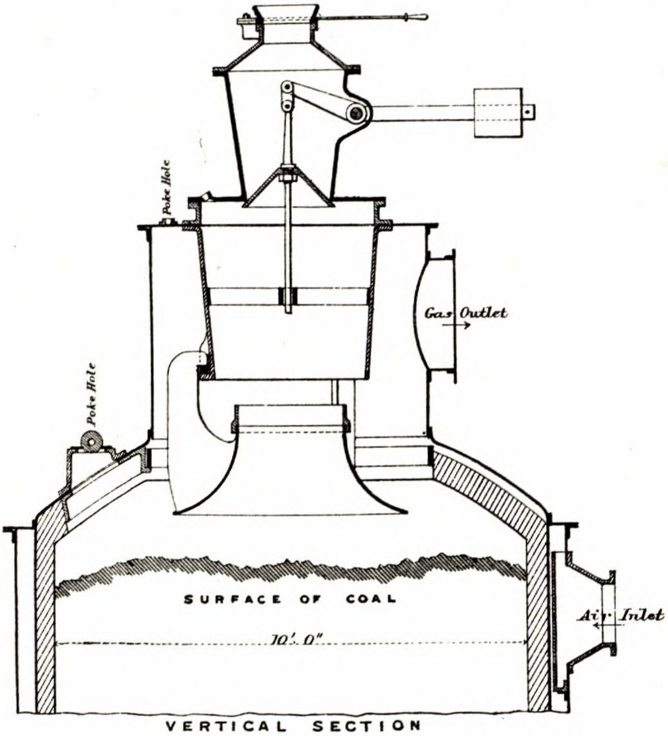


FIG. 25.—Fuel distributor applied to Mond Gas producer.

ROTARY METERS.

The cleaned gas passes through rotary meters on its way to the suction side of the gas compressors; two meters are installed, which can be used separately or in parallel.

GAS COMPRESSORS.

The gas compressing plant consists of three steam driven compressors, two of which are normally in operation. The steam cylinders are provided with Corliss gear and the gas cylinder with Riedler valves which are operated automatically. Each compressor has a capacity of 9,400 cubic feet of free gas per minute and when running at a speed of 80 revolutions per minute will compress this quantity of gas to a gauge pressure of 10 lbs. per square inch. The indicated H.P. of each compressor when operating at full load, is 430. Hence 860 indicated H.P., as a general rule, are sufficient to compress the entire quantity of gas produced during a normal day. Fig. 26 shows the arrangement of automatic control of by-pass between suction and delivery of gas compressor.

PUMPS.

Eight direct acting steam pumps are provided for the circulation of water in cooling and air preheating and saturating towers. Two additional pumps are installed for supplying the works with water from the adjacent canal. The capacity of each pump is 200 tons of water per hour.

For circulating the acid liquor four pumps are provided, two of which are held in reserve. The acid pumps are fitted with gun-metal rams and valves to resist the action of the sulphuric acid. The capacity of these pumps is about 7,000 gallons per hour on a lift of 90 feet.

ELECTRIC POWER.

Electricity is generated by two three cylinder 250 H.P. Westinghouse gas engines direct coupled to dynamos, one unit being held in reserve. The exhaust from these engines passes through tubular boilers which abstract some of its heat and also serve to silence it. The electric power thus generated is used for operating the various motors and for lighting the plant.

CLEANING OF THE PLANT.

The blowers, cleaning fans, and gas compressors are run for six weeks continuously day and night and are then changed over for examination or overhauling.

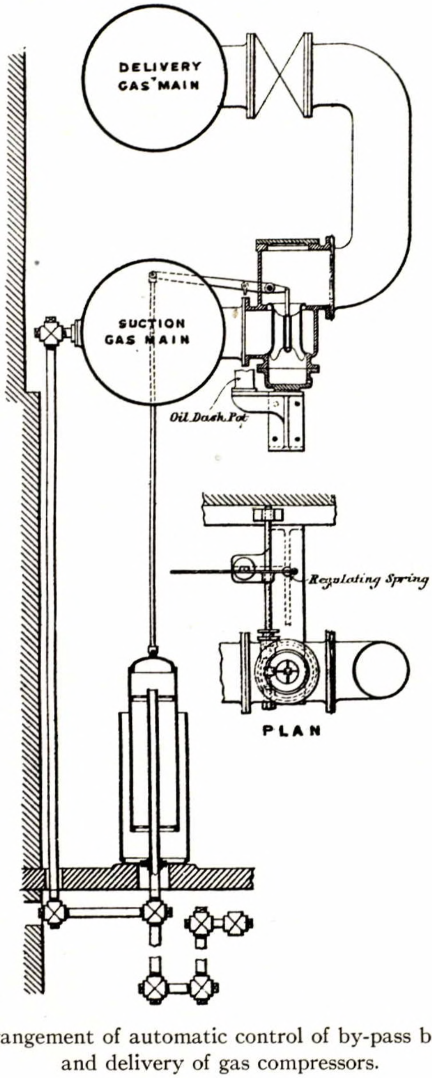


FIG. 26.—Arrangement of automatic control of by-pass between suction and delivery of gas compressors.

The gas engines are run continuously for a similar period, with the exception of a shut down for one hour once a week when the ignition plugs are cleaned.

As a general rule the circulating pumps are run continuously for a period of three weeks, when they are shut down for the purpose of cleaning the valves of any tar which has collected.

The gas producers run continuously for two years, and then each producer is in rotation put out for examination and, if necessary, repaired. Only slight repairs, however, have been found necessary. The superheaters run for a similar period before being cleaned. The mechanical washers run for three years before being closed down for repairs, and one of the two gas-collecting mains is cleaned every six months.

The acid towers run continuously for two years, they are then changed over for examination, and for repairs to the lead-work, if necessary.

It has not been found necessary to change over the gas-cooling and air-heating towers during the time the plant has been in operation—about eight years—up to the time the plant was visited by the writer.

The steam boilers are cleaned every three months, and the ammonium sulphate evaporators are run about one year before any repairs require to be made to the lead steam coils. The evaporators require re-lining with lead once in three years.

Tar Plant.

The tar produced is collected from various portions of the plant, especially from the settling tanks which receive the outflow from the various cooling towers, and then run into tar-eggs from which it is later blown to a tar collecting plant. Since the tar as it comes from the producer plant contains from 30 to 40 per cent water, it must be dehydrated in order to render it suitable for the market. This is accomplished by running it into large vertical vessels supplied with steam coils; the temperature is by this means raised to 80°C. and the water is slowly evaporated from the tar.

Analysis and Calorific Value of Coal Used and Gas Produced.

The average analysis of the coal burned in the producers for a considerable period was:

Ash	12%
Volatile matter	36%
Nitrogen	1·2% on dry coal.
Moisture	12%

and its calorific value was 11,600 British thermal units per lb.

A nitrogen content of 1·2 per cent in the absolutely dry coal would be equivalent to 1·06 per cent for coal containing 12 per cent moisture. If seven of the eight producers are in continuous operation, and each burns 24 tons of coal during 24 hours, the nitrogen available per day will be 24×7×0·0·0106 1·78 long tons or about 4,000 lbs. The total quantity of ammonum sulphate which can be theoretically obtained from this quantity of nitrogen is $\frac{1\cdot78}{21\cdot21}\times100=8\cdot4$ long tons.

Analysis and Heating Value of Gas.

CO_2	17·40	per cent	by volume.
CO	10·31	"	"
H_2	25·55	"	"
CH_4	3·25	"	"
N_2	43·49	"	"
	100·00	"	"

Higher calorific value, average for 18 months = 155 B.T.U. per cubic foot.

Ammonia Recovery.

From 70-80 per cent of the total nitrogen contained in the fuel is recovered in the ammonium sulphate produced. This

For testing and analyses of gas—2 men at night and 3 men by day.

In addition to the employees cited there are a large number employed on the district distribution system. The total number of men employed at the gas plant and on the distributing system is 120. Superintendent, clerks, and foreman are not included in this number.

Quantity of Fuel Used and By-Products Obtained.

During the latter part of the first six months of 1912, the quantity of coal gasified per month reached 3,300 long tons, and the quantities of sulphate of ammonia and tar produced during this same period were 120 tons and 280 tons per month respectively. These figures have been considerably increased since then. In fact, although the producers were designed to gasify only 140 tons of coal per day, the daily rate of gasification has been as high as 200 tons.

Gas Produced and Sold.

The maximum quantity of gas sold to consumers during the week ending August 24, 1912, was 868,700 cubic feet per hour and the minimum taken by consumers was 195,000 cubic feet per hour, for the same period. The peak load has reached 1,000,000 cubic feet per hour. When the peak load occurs the gas used in the works is reduced and the steam boilers are fired with coal.

The first period of the operations of this plant resulted in a loss, owing to the difficulty of persuading consumers to use producer gas for various industrial purposes, and the present satisfactory financial condition was only obtained by strenuous efforts and the expenditure of considerable money in training an efficient staff to undertake investigations into the most efficient method of using producer gas for the different industrial purposes then existing in the district covered by the company's main. This staff was even trained and educated in the design of heating and other furnaces and were thus placed in a position

Cost per 1000 Cubic Feet of Gas Manufactured.*

As estimated for the Bill in 1901 (based on 225,000 tons gasified per annum).		Results actually obtained in 1912 (based on 40,000 tons gasified per annum).
	cents	cents
Slack for producers and boilers	1·2856	1·5826
Cost of manufacturing, compressing, and distributing, including wages, materials, acid, stores, etc., and all repairs and maintenance	1·3100	1·4086
	2·5956	2·9912
By sale of by-products	1·2696	2·1912
Net cost (excluding general charges)	1·3260	0·8000
General charges (excluding interest)	0·2914	1·7740 (Includes debenture interest)
Per 1000 cubic of gas made	1·6174	2·5740

A low grade slack coal is used and its cost per long ton at the producers is in the neighbourhood of $1.80—this cost is based on the cost of coal per 1,000 cubic feet of gas shown in the above table and on the assumption that one long ton of coal represents 140,000 cubic feet of producer gas.

If the lower calorific value of the producer gas is taken as 144 British thermal units per cubic foot, or 144,000 British thermal units per 1,000 cubic feet and one long ton of coal represents a quantity of heat equivalent to $11{,}600 \times 2{,}240 = 25{,}984{,}000$ B.T.U., then $\frac{25{,}984{,}000}{144} = 180{,}440$ cubic feet of gas will contain a quantity of heat equivalent to one long ton of coal of an average calorific value of 11,600 B.T.U. per lb.

The cost of manufacturing 180 thousand cubic feet of producer gas, according to the foregoing table, is $180 \times 2{\cdot}574 = \$4.63$.

---

*"The Generation and Distribution of Producer Gas in South Staffordshire," by Herbert Alfred Humphrey, M. Inst., C.E., Minutes of Proceedings of the Institution of Civil Engineers, Vol. CXCII, page 42.

Selling Cost of the Gas.

SCHEDULE OF CHARGES FOR MOND PRODUCER GAS:[1] TO CONSUMERS.

For gas used for power, japanning, or tubular heaters.

Cubic feet per quarter.	Price per 1,000 cubic feet.
Up to 1,250,000	5½c
From 1,250,000 to 2,500,000	5 c
" 2,500,000 to 5,000,000	4½c
" 5,000,000 to 10,000,000	4¼c
" 10,000,000 to 20,000,000	4 c
" 20,000,000 to 30,000,000	3¾c
" 30,000,000 to 50,000,000	3½c
Over 50,000,000	3 c

FOR GAS USED IN ANNEALING OVENS AND GALVANIZING BATHS OR FURNACES.

Cubic feet per quarter.	Price per 1,000 cubic feet.
Up to 4,000,000	4 c
From 4,000,000 to 8,000,000	3¾c
" 8,000,000 to 16,000,000	3½c
" 16,000,000 to 32,000,000	3¼c
Over 32,000,000	3 c

The average price at which the gas was sold in 1912 was 3·5 cents per 1,000 cubic feet.[2] This is equivalent to coal of 11,600 B.T.U. costing $180\times3{\cdot}5=\$6.30$ per long ton.

Such a comparison of the costs of the two forms of fuel based on their heating values, however, neither presents in a fair light the real relation existing between them, nor the advantages possessed by the one over the other. If a quantity of producer gas equivalent in heating value to one ton of slack coal cost the

---

[1] "The Generation and Distribution of Producer Gas in South Staffordshire," by Herbert Alfred Humphrey, M. Inst., C.E., Proceedings of the Institution of Civil Engineers, Vol. CXCII, page 42.

[2] Ibid, p. 29.

Selling Cost of the Gas.

SCHEDULE OF CHARGES FOR MOND PRODUCER GAS:[1] TO CONSUMERS.

For gas used for power, japanning, or tubular heaters.

Cubic feet per quarter.	Price per 1,000 cubic feet.
Up to 1,250,000	$5\frac{1}{2}$c
From 1,250,000 to 2,500,000	5 c
" 2,500,000 to 5,000,000	$4\frac{1}{2}$c
" 5,000,000 to 10,000,000	$4\frac{1}{4}$c
" 10,000,000 to 20,000,000	4 c
" 20,000,000 to 30,000,000	$3\frac{3}{4}$c
" 30,000,000 to 50,000,000	$3\frac{1}{2}$c
Over 50,000,000	3 c

FOR GAS USED IN ANNEALING OVENS AND GALVANIZING BATHS OR FURNACES.

Cubic feet per quarter.	Price per 1,000 cubic feet.
Up to 4,000,000	4 c
From 4,000,000 to 8,000,000	$3\frac{3}{4}$c
" 8,000,000 to 16,000,000	$3\frac{1}{2}$c
" 16,000,000 to 32,000,000	$3\frac{1}{4}$c
Over 32,000,000	3 c

The average price at which the gas was sold in 1912 was 3·5 cents per 1,000 cubic feet.[2] This is equivalent to coal of 11,600 B.T.U. costing $180 \times 3 \cdot 5 = \$6.30$ per long ton.

Such a comparison of the costs of the two forms of fuel based on their heating values, however, neither presents in a fair light the real relation existing between them, nor the advantages possessed by the one over the other. If a quantity of producer gas equivalent in heating value to one ton of slack coal cost the

---

[1] "The Generation and Distribution of Producer Gas in South Staffordshire," by Herbert Alfred Humphrey, M. Inst., C.E., Proceedings of the Institution of Civil Engineers, Vol. CXCII, page 42.

[2] Ibid, p. 29.

consumer $6.30, and one ton of the above coal also costs $6.30, it might be inferred that the one is just as suitable as the other —at least for some purposes—but this is not exactly the case; producer gas of a heating value of 144 B.T.U. per cubic foot is considerably cheaper at $6.30 per 180 thousand cubic feet than slack coal at $6.30 per long ton, for the reason that less waste results in the burning of the gas than with coal. There are many other reasons why a gas distributed in the manner described above, is more economical for various purposes than coal and which need not be mentioned here, but it is quite evident to any one accustomed to the use of coal for domestic or power purposes, that for consumers using heat or power intermittently the prodducer gas at a much higher price than that used as an illustration will prove far more economical than coal.

Purposes for which Mond Producer Gas is Used.

Mond producer gas is at present being used for thirty-three different purposes. The most important of these and the number of applications in each case are as follows.*

Gas engines	157
Iron melting	1
Malleable annealing	49
Sheet annealing	2
Stamping annealing	10
Hardening furnaces	25
Bar heating	4
Tube welding	1
Barffing and Coslett processes	5
Enamelling	23
Enamel-drying	22
Core-drying	14
Japanning	87
Soldering	74
Plating vats	12
Water vats	19
Radiators	114

---

*"The Generation and Distribution of Producer Gas in South Staffordshire," by Herbert Alfred Humphrey, M. Inst., C.E., Proceedings of The Institution of Civil Engineers, Vol. CXCII, page 40.

Other purposes for which Mond producer gas is employed are, melting, welding, and annealing furnaces of various kinds, vulcanizing, and brazing. The highest temperatures used are required for iron-melting and tube-welding furnaces.

USE OF MOND GAS FOR GAS ENGINES.

From the foregoing table it will be seen that the number of gas engines running on Mond gas is very considerable. The capacity of the various engine installations varies from a few B.H.P. to 650 B.H.P. The total B.H.P. developed with Mond gas up to the end of 1912, in this manner from gas generated at this plant, was approximately 9,500 H.P. A large number of small gas engines are employed for a large variety of purposes where the demand for power is not continuous for any length of time—in fact a great many cases can be cited in industrial localities where such an engine would not be required for more than a few hours each week. In such cases the economy resulting from the use of gas distributed from a central plant, would be very marked. This also applies to small power plants operating more or less continuously but of too small capacity to enable power to be generated economically in a self contained plant, i.e., a producer and gas engine. When, however, the power required is considerable, e.g. over one or two hundred horse power and the demand is continuous for at least ten or twelve hours during the day, it might prove more economical to install a self contained power unit. Such cases are, however, not so common as those of much smaller capacity. The economy realized in using Mond gas over other kinds of gas for the production of power on a small scale is best illustrated by the following table.*

The gas used in the different power plants cited which are compared with those using Mond gas are; town gas (retort gas) and suction or pressure producer gas.

---

*"The Generation and Distribution of Producer Gas in South Staffordshire," by Herbert Alfred Humphrey, M. Inst., C.E., Proceedings of the Institution of Civil Engineers.

(1) Suction plant, engine 23 H.P. working 54 hours, cost$7.32.
Mond “ “ “ “ “ “ 5.06
(2) Suction “ 20 B.H.P. “ “ “ 6.12
Mond “ “ “ “ “ “ 5.14
(3) Town gas plant, 25 B.H.P., 36c. per 1,000 cu. ft. cost, 25c. per hour.
Mond gas plant, 25 B.H.P., 5c. per 1,000 cu. ft. cost, 12c. per hour.
(4) Town gas plant, 30 B.H.P., 42c. per 1,000 cu. ft. cost, 27c. per hour.
Mond gas plant, 30 B.H.P., 5c. per 1,000 cu. ft. cost 15c. per hour.
(5) Town gas plant, 90 B.H.P., 36c. per 1,000 cu. ft. cost, 77½c. per hour.

Replaced by Mond gas driven engine developing 140 B.H.P. costing 32 cents per hour total.

The cost of Mond gas and suction or pressure producer gas in the case of the 90 and 140 B.H.P. plants are unfortunately not compared.

PRODUCER GAS FOR STEAM RAISING.

The great improvements made in the generation of steam in gas fired boilers based upon the investigations of W. A. Bone, opens up a new field for the application of producer gas generated in and distributed from a large central station. In the steam generator devised by Professor Bone, advantage is taken of the phenomenon of "surface combustion." Surface combustion obtains only when a combustible gaseous mixture is employed as the source of heat. With his boiler Professor Bone has obtained remarkable thermal efficiencies, and wherever steam is required, whether for power, heating or other purposes, producer gas might well be employed in such a generator.

Producer gas when manufactured on a large scale, with the greatest possible efficiency in the recovery of by-products, has been demonstrated beyond all doubt to be an ideal fuel for a great and varied number of purposes in the industrial world.

Not only is it especially well adapted for the generation of power in both large and small gas engine units but serves as an excellent fuel for steam raising in specially designed boilers.

THE LANGWITH BY-PRODUCT RECOVERY COMPANY LIMITED.

The Mond gas plant operated by the Langwith By-Product Recovery Company is situated at Langwith near a large colliery from which it obtains its coal. This plant was erected for the recovery of by-products only. All the gas generated is used either at the plant for its own purposes or is piped to the colliery which generates steam in gas fired boilers. The gas, therefore, in the strictest sense, is not a source of revenue, notwithstanding the fact that the colliery reduces the cost of the coal sold to the Mond plant in return for the gas supplied to it.

This plant is, in its general design and method of operation, identical with all other Mond gas plants, hence a description of one will suffice for the other. In respect to details such e.g. as the type of circulating pumps employed, this plant differs somewhat from the usual Mond practice. This will be discussed later.

Producer Plant.

This portion of the plant consists of six Mond producers capable of gasifying 25 tons of coal each, per day of 24 hours. The entire battery is operated continuously hence no spare unit is provided. The total capacity of plant per day is 150 tons of coal.

The cleaning, cooling, air-preheating system, acid tower, blowers, etc., are similar to those already described.

Circulating Pumps.

Centrifugal pumps are employed at this plant for circulating the hot and cold water and also the acid liquor. These pumps were made by Mather and Platt and have proven entirely satisfactory. It is quite well known that considerable tar adheres to the pistons and rams of the ordinary plunger pump used for circulating the cooling water, and when such accumulation becomes excessive considerable trouble is generally experienced. This annoyance is successfully prevented by the employment of centrifugal pumps. When these pumps stick, owing to tar, on starting up the use of live steam for a few moments will sufficiently soften the tar to permit the pump to properly operate. Four centrifugal pumps are provided for circulating water, two of these being held in reserve. The acid liquor is circulated with one centrifugal pump, but one reserve unit is provided.

The remaining plant machinery consists of a Mirrlees Watson pump for air cooling the water cooling tower; one centrifugal dryer for the sulphate plant; an Ernest Scott evaporator for evaporating the sulphate liquor, and an air pump for use in connexion with it.

The Ernest Scott vacuum evaporator is capable of evaporating 9 tons of ammonium sulphate in 24 hours, using steam at 2 lbs. per sq. inch and a vacuum of 20″.

Boilers.

The boiler battery comprises five gas fired steam generators, four of which have a steaming capacity of 7,500 lbs. per hour, or a total of 30,000 lbs. for the four boilers. The remaining boiler is of less capacity.

Tar and Pitch Recovery.

The liquid tar resulting from the process of gasification is collected and placed in a tar still in which it is boiled at a temperature of about 200° C until all the water and lighter oils are distilled off. The hot liquid pitch resulting is poured into open converter tanks in which it is left until sufficiently hard to be broken up and removed.

Analyses of Fuel Used and of Gas Produced.

The following average analysis of the fuel used, covering a considerable period, is:—

Ash	13%
Volatile matter	22%
Nitrogen	1·2%

Unfortunately, neither was a complete analysis made, nor was its heating value determined. The nitrogen content as determined by this analysis, viz., 1·2 per cent, is not in accord with that obtained in the following analysis, which the writer obtained through the courtesy of the Power Gas Corporation, but it will be used in subsequent calculations.

COAL SUPPLIED DURING THE FIRST TWO WEEKS IN NOVEMBER, 1912.

Sheepbridge Company.			*Power Gas Corporation.*		
Grading.	Nitrogen content.	Ash.	Grading.	Nitrogen content.	Ash.
Over ¼″ – 69·87%	1·45%	6·90%	Over ¼″ – 63·00%	1·51%	10%
Through ¼″ – 17·80%	1·28%	8·86%	Through ¼″ – 18·00%	1·49%	..
Through 1-8″ – 12·33%	1·04%	13·74%	Through 1-8″ – 19·00%	1·29%	..
Average	1·37%	8·09%	Average	1·47%	10%

COAL SUPPLIED DURING LAST TWO WEEKS IN NOVEMBER, 1912.

Sheepbridge Company.			*Power Gas Corporation.*		
Grading.	Nitrogen content.	Ash.	Grading.	Nitrogen content.	Ash
Over ¼″ – 70·77%	1·45%	5·60%	Over ¼″ – 68·01%	1·52%	8·66%
Through ¼″ – 15·38%	1·45%	7·92%	Through ¼″ – 14·41%	1·48%	..
Through 1-8″ – 13·84%	1·08%	11·36%	Through 1-8″ – 17·58%	1·29%	..
Average	1·40%	6·75%	Average	1·48%	8·66%

The coal supplied to the plant in October was:

Received at plant...............3,570 tons
Dust eliminated at colliery ......2,922 tons

Total paid for ....6,492 tons

"Fine" in coal received....22·6% = 807 tons
"Fine" in whole quantity paid for .... 807 + 2,922 tons.
= 3,729 tons = 57·44%

The average grading of the samples of coal at the Company's works, at the Sheepbridge colliery, and at the works of the Power Gas Corporation were respectively, 22·6 per cent, 30 per cent, and 34½ per cent.

From the above it will be seen that a large quantity of "fines" was included in the coal sent to the gas plant, but by a special agreement, as the writer was informed, a rebate was allowed on all dust separated out at the gas plant. The gross cost of coal supplied at gas plant was 5 shillings per ton, and this by virtue of the rebates received and the gas delivered to the colliery was reduced to 3 shillings.

The average analysis of the gas produced was:

CO_2	16·8%
O_2	
CO	8·4%
H_2	22·8%
CH_4	3·6%
N_2	48·4%
	100·0%

The net calorific value per cubic foot was from 135 to 140 B.T. Units. The quantity of gas per ton of coal, calculated from the analysis of the gas is 135,000 cubic feet, or 60 cubic feet per lb. (nearly) and its total heating value = 60 × 140 = 8,400 British thermal units.

Quantity of Ammonium Sulphate Produced.

In order to estimate the total quantity of ammonium sulphate annually produced, the average nitrogen content of the fuel used for a period of 12 months will be taken as 1·2 per cent. This will represent a quantity of nitrogen per ton equal to $2{,}240 \times \cdot 012 = 26 \cdot 88$ pounds which will form, theoretically,

$$\frac{26 \cdot 88}{21 \cdot 21} \times 100 = 126 \cdot 7$$

pounds of ammonium sulphate. The ammonium sulphate made at this plant is 96 per cent pure, that is, contains

96 per cent of $(NH_4)_2SO_4$ and contains 24·5 per cent ammonia, 2·7 per cent water, and 0·8 per cent sulphuric acid. The quantity of sulphate actually recovered per ton of coal is 85 to 90 pounds, or for two months operation an average of 87·86 pounds, 96 per cent pure. The total recovery of absolutely pure sulphate would be $87 \cdot 86 \times 0 \cdot 96 = 84 \cdot 35$ pounds. Since theoretically 126·7 pounds could be obtained the efficiency of the recovery process is $\frac{84 \cdot 35}{126 \cdot 7}$ or, 66·6 per cent. The quantities of coal gasified during the months of October and November, 1912, were 3,531 and 3,792 tons respectively, or an average of 3,660 tons per month and if this represents the average monthly rate of gasification for a period of one year, the total tons of coal gasified for that period will be $3{,}660 \times 12 = 43{,}920$ tons. The total ammonium sulphate produced per year would consequently be $\frac{43920 \times 87 \cdot 86}{2240} = 1{,}722$ long tons 96 per cent pure, which would require $1{,}722 \times 0 \cdot 95 = 1{,}636$ long tons of sulphuric acid (140 Twaddel) for its formation.

Production of Pitch.

The total quantities of pitch actually recovered during the months of October and November, 1912, were 70 tons, 1 cwt., and 83 tons, 2 cwt., respectively, or an average recovery per month of 76·56 long tons. During this period the average monthly rate of gasification was 3,600 tons of coal. The total annual recovery of pitch on this basis would, therefore, be $76 \cdot 56 \times 12 = 918$ long tons. This is equivalent to $\frac{76 \cdot 56 \times 2240}{3600} = 47$ pounds (about). 47 pounds of tar is equal to about 4·06 gallons.

Statement of Operations for the Months of October and November, 1912.

	Coal gasified.	Sulphate made.	Lbs. of Sulphate per ton of coal.		Tar (dry) made.	Gals. of tar per ton of coal.
		Tons, cwt.	make.	Washer Liquor.	Tons, cwt.	
Nov.	3792 tons	149:10	88·31	5·92	83:2	4·27
Oct.	3531 "	137:17	87·45	4·87	70:1	3·86

COSTS AND SELLING PRICES.

	November			*October*		
	Amount	Per ton of sulphate	Per ton of coal	Amount.	Per ton of sulphate	Per ton of coal
	£	s	d	£	s	d
Wages	345·770	46·25	21·89	352·293	51·08	23·95
Coal to producers..........	679·717	90·92	43·02	611·747	88·75	41·58
Coal to boilers	76·300	10·25	4·83	95·025	13·75	6·46
Exhaust steam............	16·666	2·25	1·06	16·667	2·42	1·13
Feed-water heater	4·000	·50	·25	4·000	·58	·27
Water	13·900	1·83	·88	12·979	1·92	·88
Acid	237·701	31·83	15·04	212·439	30·84	14·44
Stores and laboratory	59·887	8·00	3·79	24·875	3·58	1·69
Repairs	6·520	·83	·41	13·088	1·92	·89
Sulphate committee	4·363	·58	·28	4·021	·58	·27
Shunting and carting.......	5·250	·67	·33	10·375	1·50	·71
Estbt. charges	108·500	14·58	6·87	108·500	15·75	7·37
Renewal fund	59·800	8·00	3·78	41·354	6·00	2·81
	1618·374	216·49	102·43	1507·363	218·67	102·45

November			*October*		
Credit for tar 83:2 at 36/- =	149·579		Credit for tar 70:1 at 36/2 = .	126·675	
Credit for washer liquor 100:19 at 9/3.......	46·687	26·25	Credit for washer liquor 101:8 at 9/1.........	46·054	25·00
	1422·108	190·24		1334,634	193·67
Average selling price		258·33	Average selling price		259·08
Profit per ton		68·09	Profit per ton		65·41
Tons, cwt. on 149:10 = £508/18/6			Tons, cwt. on 137:17 = £450/17/8.		

From the foregoing statement of costs and selling prices for a period of two months operations, it will be seen that the net profits per ton of sulphate for the months of October and November were 65·41 and 68·09 shillings respectively, and that the average selling prices for the same period were 259·08 and 258·83 shillings respectively or very nearly £13.

If the average rate of production of ammonium sulphate for the two months cited can be taken as the average monthly rate for 12 months, the production of sulphate would annually amount to 1,722 long tons. The net profits on this quantity would be $1{,}722 \times \frac{65{\cdot}41+68{\cdot}09}{2} = 114{,}943{\cdot}5$ shillings or over 28,000 dollars.

The net profits resulting from the sale of the pitch produced would be 918×36=33,048 shillings or $8,060. Total net profits derived from operations of plant for one year, 28,000 +8,060=36,060 dollars.

CAPITALIZATION.

The net capital of the company is £66,000 (about $320,000) and a net profit of $36,000 on this amount would be equivalent to over ten per cent.

The results of the operations covering a period of several years shows that with coal containing 1·2 per cent nitrogen and costing 3 shillings (about 72c.) per ton, a profit of approximately ten per cent on the capital invested can be made under the labour conditions obtaining in England. The method of estimating the net profits is considerably different from that employed in Canada or the United States. For example, if interest on the capital invested, amortization, and depreciation were, in this particular case, charged against the costs of operations, the net profit would be considerably less than that shown above.

REMARKS.

For the purpose of estimating the quantity of ammonium sulphate which can be obtained from a fuel with any nitrogen content the efficiency of the recovery process has been taken as 75 per cent, i.e. 75 per cent of the quantity theoretically possible.

At the plants of the South Staffordshire Mond Gas Company and the Langwith By-Product Company the efficiency of the recovery process was considerably less than 75 per cent. Both of these plants were, however, operated at a capacity considerably below their normal rating, and in the case of the South Staffordshire Mond Gas Company the load was not uniform but varied from a fraction of the normal capacity to overload during a portion of the day. Such conditions of operations may militate against the most efficient recovery of the ammonia. The efficiency of the ammonia recovery process at the South Staffordshire Mond Gas Company for the period covering the first six months of 1912 was 64·2 per cent which is obtained as follows:—

Monthly rate of gasification towards the end of the period...	3,300 tons.
Nitrogen content of fuel burned.	1·2%
Ammonium sulphate per month actually produced	120 tons.
Ammonium sulphate per ton actually produced	$\frac{120}{3300}=0\cdot0363$ tons.
Ammonium sulphate theoretically possible to obtain per month.	3,300×0·012×4·71=186·5 tons.
Efficiency of recovery........	$\frac{120}{186\cdot5}=64\cdot2$ per cent.

The average production of ammonium sulphate per ton of coal gasified during the year 1913, was, according to the statement of the Works' manager, 85 to 90 lbs. The nitrogen content of the coal gasified during this period averaged 1·2 per cent, or about 27 pounds per long ton, and this will theoretically enter into the formation of 27×4·71=127 pounds of ammonium sulphate. On this basis the efficiency of the recovery process is:—

$$\frac{85+90}{2\times127}=68\cdot8 \text{ per cent.}$$

The production of tar during the latter part of the period covering the first six months of 1912 was about 280 tons per month. The coal gasified per month during the same period was 3,300 tons, the production of tar per ton of coal was consequently $\frac{280}{3300} = \cdot085$ tons or 190 lbs. (about 10 gallons). At the time of the writer's visit this tar was not being distilled. This quantity of tar, it must be understood, includes a considerable portion of water.

Langwith By-Product Company.

The average production of ammonium sulphate at this plant was 85-90 pounds per ton of coal gasified, and with a nitrogen content of 1·2 per cent in the coal gasified, the efficiency of the recovery process is 68·8 per cent.

CHAPTER V.

PEAT BURNING STEAM POWER PLANT ON THE WIESMOOR IN OSTFRIESLAND, GERMANY.

The data embodied in this chapter was largely abstracted from a pamphlet entitled "Das Kraftwerk im Weismoor in Ostfriesland," by T. Teichmüller, Karlsruhe, Germany.

This central power plant, which is situated in the centre of an enormous peat bog some little distance from any town or village of any size, owes its existence to the intense interest manifested by the Prussian Government in the cultivation of waste land for agricultural purposes.

The chief credit for the establishment of this plant is due to Dr. Ramm, Privy Councillor in the State Ministry of Agriculture, who urged the great undertaking to completion in the face of many and serious obstacles.

The original installation consisted of a steam plant of 200 horse power which was used for generating electric power for cultivating the bog, ditching, stripping, ploughing, etc. The utilization of the bog for the production of power was not, therefore, the original idea, although at the present time the plant has grown to such large proportions that the utilization of peat for such purposes may be considered of equal importance to the cultivation of the moor. This small power plant was, for a short time, capable of supplying the energy necessary for the cultivation work then contemplated—but at a later date it was decided to increase the capacity of the plant. In the spring of 1908, The Siemens-Schuckert Company commenced negotiations on behalf of the Prussian Estate office (Domanenfiskus), with a number of surrounding towns or villages, such as Wilhelmshafen, Baut, Heppens, Nevende, and the cities of Leer and Emden, with regard to their connexion with the Fiscal Power installation. As a result of their negotiations the Domanenfiskus decided to turn over the management and operation of the installation and the distribution of the power to a private company. A contract was accordingly made with the Siemens Electrical Company, through the Siemens-Schuckert Company, whereby they were to erect a power plant, but no other buildings, and transmission lines for an overland central at their own expense, which they were to control and operate. According to the terms of this contract the Prussian Estate office agreed to sell to the company the peat required for running the plant, and the company in turn agreed to sell to the Prussian Estate office the electric energy required for cultivating the moor.

The erection of the new and much enlarged power plant was begun in January, 1909. In order to be in a position to deliver electric energy within the time limit stated in the contract the work was energetically prosecuted. The reconstruction of the old installation capable of producing only 200 H.P. to provide for an output of 5,400 H.P. was made more difficult on account of the necessity of maintaining the old installation intact until the installation of the new power plant was capable of delivering power.

Great difficulties were encountered in transporting the new and heavy machinery across the bog, and of unloading and placing it in the power house. The housing and feeding of the large and increasing number of mechanics, erectors, and labourers in the midst of the wild moor, required unusual measures. In spite, however, of all the difficulties encountered, among which was a strike of the bricklayers and carpenters which lasted several weeks, the work progressed with such rapidity that the power plant was in operation by the beginning of December, 1909, just a year, lacking one month, after the work was begun—an unusual record. In August, 1910, the plant was complete.

DESCRIPTION OF POWER HOUSE.

The power house is situated (see Fig. 27) on the main road between Bagband and Wiesederfehn, at the crossing of the main road with the canal, which is to be built, to connect the Ems-Jade Canal with the Nord-Geogsfehn canal. When this canal is constructed the power plant will have water connexion with

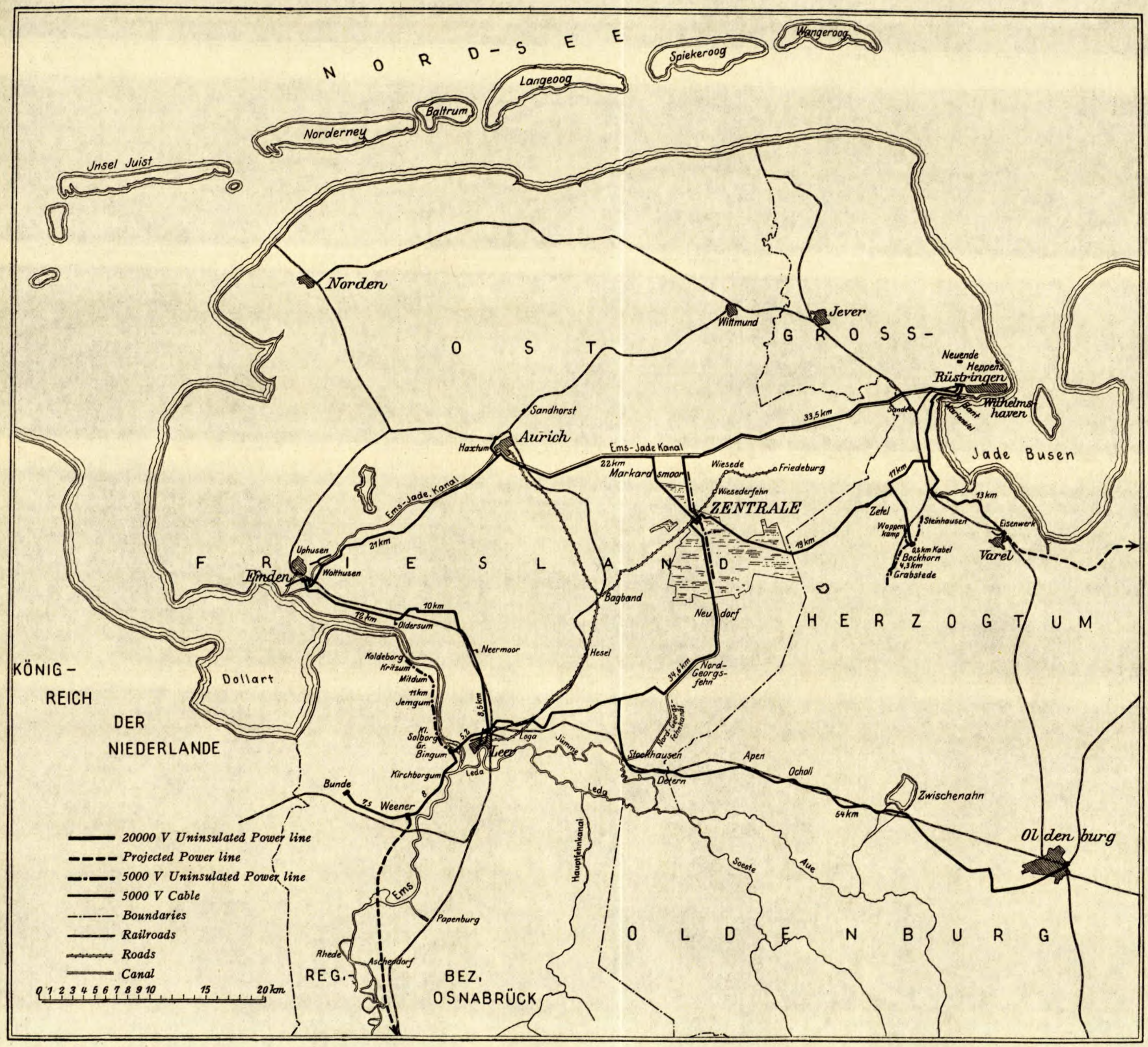
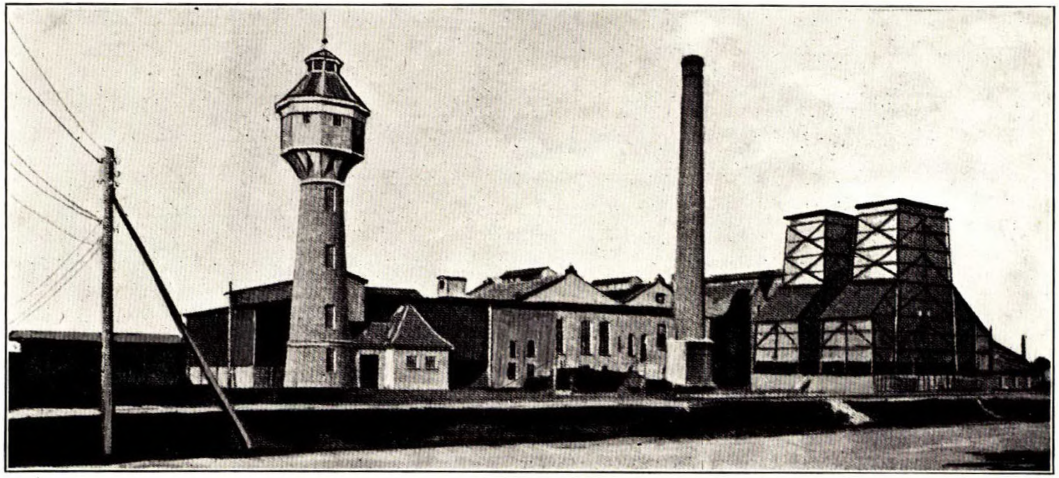


Fig. 27. Map of Ostfresland showing peat bogs to be cultivated and the district to be served with electrical energy



Power house as seen from southeast.

Ems in two directions—on the south line over the Jümme and the Leda. The situation as regards transportation facilities is, therefore, very favourable.

Fig. 28 shows the ground plan of the power house and Plate XVII a view of it as seen from the southeast. The general arrangement of the power house, as regards its rooms and fittings, does not differ from other electrical installations of the Siemens-Schuckert works, and the fact that the new building has been produced by rebuilding another is scarcely noticeable. The only real difference exists in the relative positions of the switch and engine room. In this case the administrative offices are placed between the switch and engine rooms, which would not be the case in an entirely new construction.

BOILER HOUSE.

The boiler installation comprises four water-tube boilers with a water heating surface of 300 sq. meters (3,228 sq. ft.), superheating surface of 100 sq. meters (1,076 sq. ft.), and a grate area of 8 sq. meters (86 sq. ft.) each. The boilers were designed and built by the Augsburg-Nürnberg engine works for a working pressure of 12 atmospheres (176½ lbs. per sq. in.).

The distribution of fuel from the bunkers to the boiler furnaces and the method of firing the boilers presented many difficulties which had to be overcome. This will be considered later in detail. Three steam pumps supply the boiler with feed water. The water is first purified by means of a water purifier and then mixed with the condensed steam from the turbines. This water is delivered to a feed water reservoir from which it is pumped to the boilers.

Method of Purifying the Feed Water.

For the purpose of purifying the bog water which contains humic acid, lime, and iron, an ordinary water purifier was used. The Suco-filter installed in the water tower for this purpose did not prove satisfactory. An air filter was therefore added (see Fig. 28 and Plate XVII at the extreme left), in which the

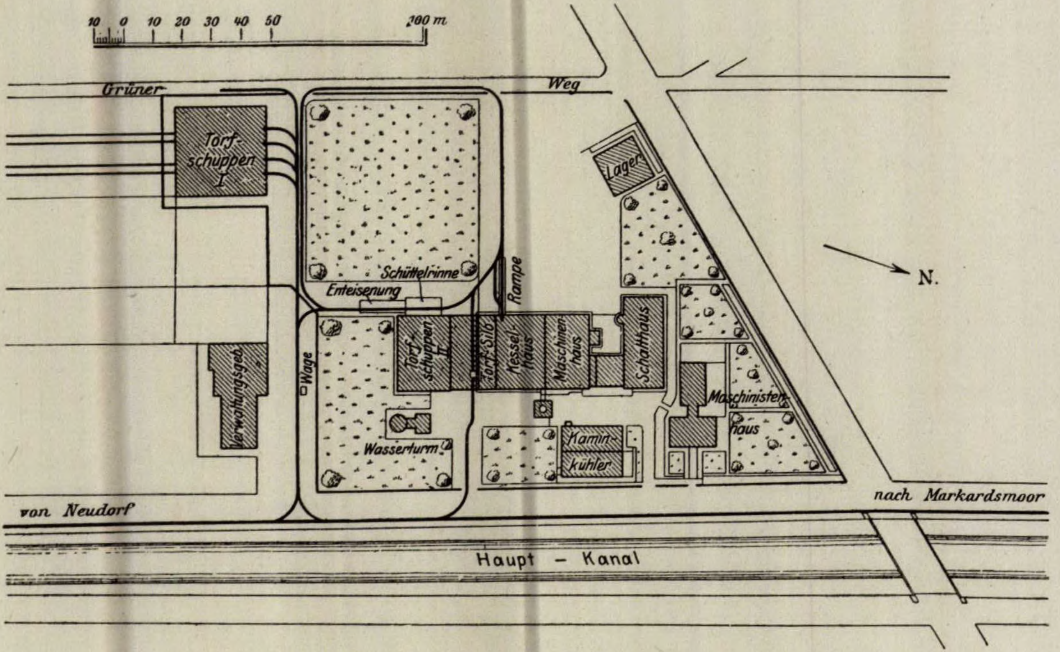
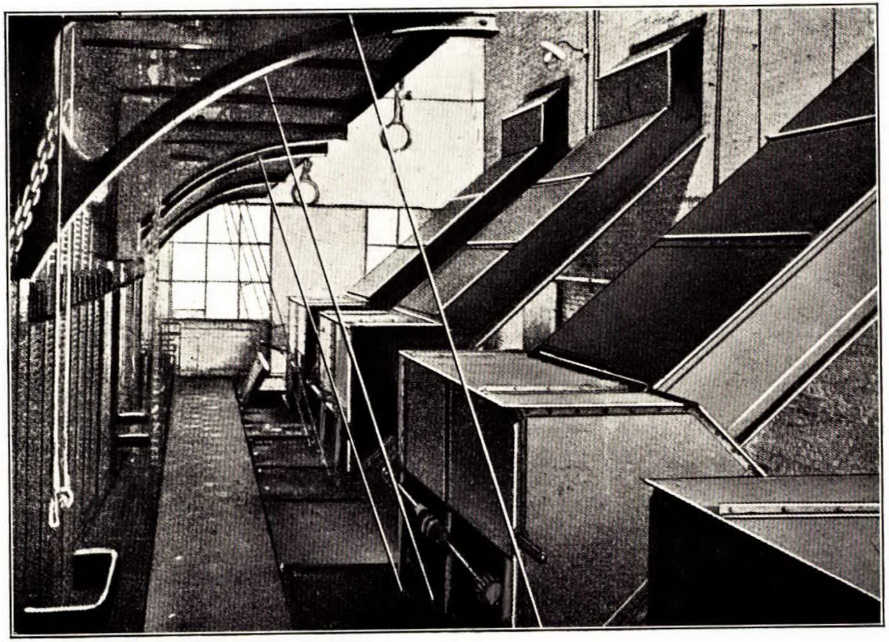
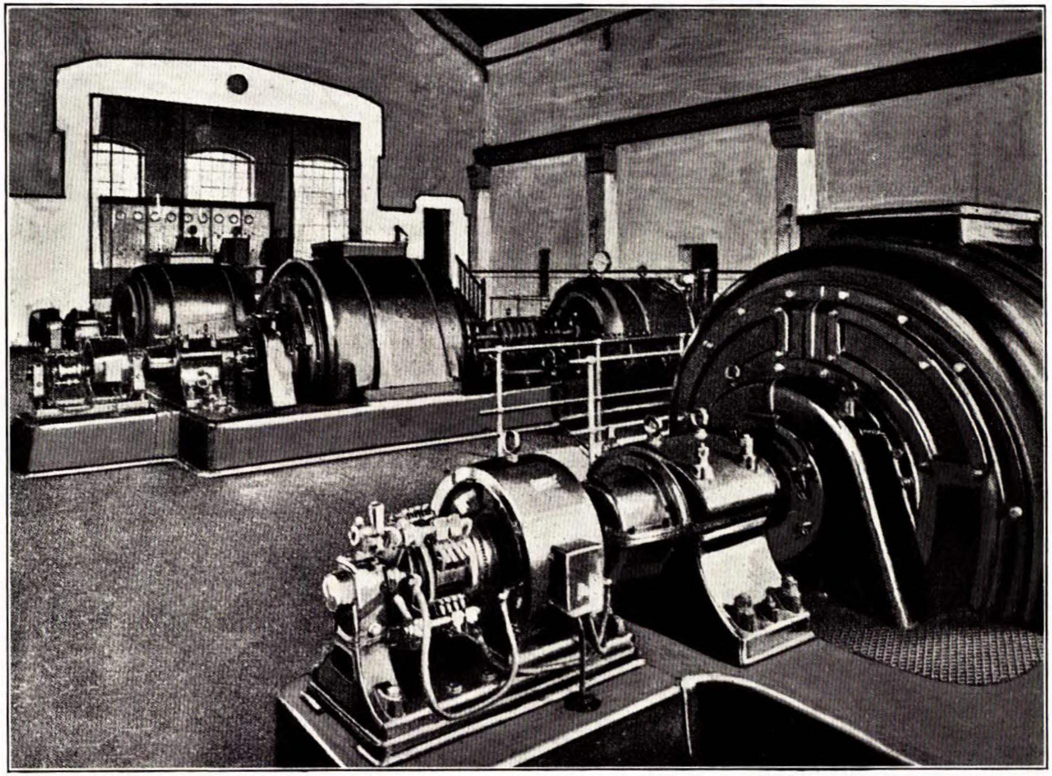


FIG. 28.—Ground plan of power house.



Boiler house, showing feeding hoppers.



Power house, showing steam turbines.

iron is precipitated. The Suco-filter is now only used to separate from the water the iron which has been precipitated by the air filter.

POWER PLANT.

The power plant consists of three turbo-dynamos, two of which generate a three phase alternating current of 1,250 K.V.A. at a tension of 5,000 V. These alternators run at 3,000 r.p.m. The third turbo-dynamo generates a three phase current of 1,550 K.V.A. at the same tension and speed.

The turbines are all constructed on the Zoelly system. The Germania Works in Kiel, the Augsburg-Nurnberg Engine Works and the firm of Escher-Wysz and Company each supplied one turbo-dynamo set complete.

Steam is delivered to the turbines at a pressure of 11½ atmospheres (about 170 lbs. per sq. inch) and a mean superheat temperature of 300°C. The boiler house is shown in Plate XVIII and the engine house in Plate XIX. The surface condensers are installed under the engine room floor according to customary practice. Electrically operated centrifugal pumps deliver the condensed steam to the feed water reservoir mentioned above.

The condenser cooling water is supplied by two Balckeschen coolers (Rückkühlern). The supplementary water for the cooling apparatus is obtained from the bog. Since the bog water contains humic acid, all parts of the cooling apparatus which come into contact with it are made of cast iron or bronze, and the brass tubes in the surface condenser are made of an alloy containing a very high proportion of copper, which is tinned.

These protective measures have proven to be very satisfactory. An arrangement is also made for supplying, if necessary, the feed water reservoir from the tower visible in Figure 28. This tower is supplied with water by electrically operated pumps from a well about 50 meters deep. This tower is chiefly used, however, to supply the dwelling houses of the officials and workmen with water, and, holds a sufficient supply of water at a considerable pressure for use in case of fire.

The electric energy is conducted from the generator through circuit breakers, which serve as a protection to the dynamos, and cables to the switch house.

Two transmission lines, for the purposes of the Royal Moor Administration, are led into the open air from a special bus bar system which may be connected with both lower voltage bus bars through automatic switches. From here the transmission line is carried by specially constructed towers to the moors to be cultivated, in the north and the south. In addition to the above there are two transformers, each of 125 K.V.A., with a transformation ratio of 5,000/208,120. From the lower voltage side of these transformers, the power house and immediate vicinity, including the hotel and dwellings of the manager, foreman and workmen, receive current for light and power. One of the transformers is held in reserve.

From the higher voltage bars four long distance transmission lines branch off.

PEAT AS FUEL.

In the foregoing description of the power house, but little has been said concerning the boiler plant and its accessories. This part of the power development is indeed the most important of the entire plant and merits a separate and detailed description.

It is needless to mention the fact, that at the time the construction of this power plant was undertaken, the knowledge concerning the design and methods of operating steam boilers fired with peat was no further advanced than the steam boiler fired with coal many decades ago. For this reason a large amount of experimental work had to be conducted along this line while the plant was in actual operation, and it redounds very greatly to the credit of the designing engineers and builders that the plant was brought to its present state of perfection after only three years' work.

So many difficulties were encountered in the handling and firing of the peat fuel, on account of the meagre knowledge concerning this method of utilization of this fuel, that a fuller description will be justified than would be the case with other fuels.

Not only were technical difficulties encountered in the burning of peat under a steam boiler, but much trouble was experienced in its transportation from the field to the boilers. This of course had to be done in the cheapest manner possible, if any advantages were to be gained over the use of coal.

The principal difficulties encountered were: (1), getting and storing matured peat for burning, (2), transporting the dry peat from the storage places to the boiler grates and finally economically burning it in the fire box.

MANUFACTURE OF THE PEAT FUEL.

For obtaining the raw peat and working it up into a suitable fuel, both the Strenge and Dolberg systems are employed. Since, however, the cheapness of the fuel is of prime importance mechanical excavators are used whenever possible.

The Strenge system employs both mechanical excavators and spreaders and operates well in uniform portions of the bog which are free from trunks and roots of trees. Two of such excavators are employed. Before starting operations with the Strenge machine, the white or surface moss must be first removed, since this has no value as a fuel for boilers.

The bucket apparatus or excavator is driven by an electric motor through a worm and wheel. A second motor moves the bucket apparatus as a whole in a to and fro direction, over a breadth of four meters (12 feet), by means of a shaft, (illustrations of this machine in operation are shown in Plate IX. in the chapter on the manufacture of peat fuel). The movements produced by the two motors are automatically controlled. The wet peat (this bog contains about 90 per cent water), is thrown by the buckets on to a conveyer trough on which it is raised by means of a conveyer chain and carried into a pulping mill driven by a separate motor. The peat issues from the pulping mill as a uniform pulp, and is in this condition spread upon the levelled surface of the drained bog by means of spreaders.

The entire machine is automatically moved forward on heavy broad board planks by means of an electric motor.

Great care must be exercised in operating this machine to prevent the excavator from excavating sand or clay with the peat. This is likely to occur where the subsoil is undulating. Unlike other mechanical excavators, this one cannot be adjusted as far as the depth to which it excavates is concerned, while it is in motion.

During the first period of the peat manufacturing operations, this fault had not yet been learned, consequently so much sand was mixed with the peat which was burned under the boiler that the resulting clinkers melted the grate bars and interfered in other ways with the proper operation of the boilers.

When the spread peat is dry enough to support men walking on broad boards, it is first cut superficially with a hand cutter and then with an electrically operated cutter. The disc shaped knives of this cutter are guided by the superficial cuts. The pieces thus obtained—called sods—are 10×12×33 centimeters (4″× 5″× 13″) in size.

When the peat thus exposed to the air has dried to about 25-30 per cent moisture it is gathered up and hauled by small petrol locomotives on rails to the power house, where it is immediately burned, or to storage houses. During the hot summer of 1911 the average moisture content of the peat was only 18 to 22 per cent. In order to keep a large supply of peat on hand, a large quantity of the fuel is stored on the field in stacks about ten meters (33 ft.) in height and fifty meters or more (160 ft.) in length. The abundant harvest of 1911 made it possible to build a great many such stacks and so store up a large supply of fuel.

In addition to the two automatic excavators just described twelve Dolberg peat machines are employed. This machine has been described in the chapter on the manufacture of peat fuel. (See pp. 22 to 24). According to the guarantee of the firm, a Dolberg machine can produce from 60,000 to 80,000 sods in a day of 10 hours.

According to another somewhat different process also used in the Wiesmoor, the peat is pressed from the forming machine upon a conveyer belt, and without being cut into sods is piled up into heaps by the belt. The peat is cut from these heaps after wintering.

The total output of all the machines, during a season of average length, i.e., from April to August, is about 30,000 metric tons (33,000 short tons) of 25-30 per cent moisture peat. In the summer of 1911, 35,000 metric tons (38,500 short tons) were harvested.

From the foregoing it will be seen that, even with the employment of mechanical excavators, a great deal of hand labour is still necessary for operating the machine, turning, stacking, and transporting the peat from the drying field. The necessity for introducing the utmost economy into every branch of the manufacture of peat fuel is apparent to all engaged in this particular industry. In past years, owing to the extremely low wages prevailing, the necessity for substituting mechanical appliances for hand labour was not so apparent, but to-day this condition of affairs no longer exists, the wages of the ordinary labourer are not only rapidly increasing, but labour itself is in some localities hard to obtain. This latter statement applies mainly to American conditions.

The first machine especially constructed for decreasing the labour force on the peat field at Wiesmoor was an elevator, Fig. 29, invented and constructed by Dolberg. This elevator, which is employed for piling the air-dried peat in stacks, must not be confused with the elevators or belt conveyers with which all Dolberg peat machines are equipped. It is an individual machine, of special design, and is used for only one purpose, viz., for stacking peat. This machine consists of a carrier trough about 16 meters (52 ft.) long, in which the peat is conveyed by a carrier chain and carriers. This trough can be raised or lowered, with one of its ends held fast in the carrying frame, so that the dumping height, beginning with a small elevation, can be increased to 10 meters (33 ft.)

The carrying frame is secured to a platform resting on two trucks. These trucks rest on tracks of 0·6 meters (about 2 feet) gauge and at least 100 meters (328 feet) in length. The elevator can, therefore, be moved over a distance of 328 feet. The train of loaded peat cars is drawn up an inclined track which is laid parallel to the elevator tracks. At the top of the inclined track a platform, into which a large hopper is placed, is constructed

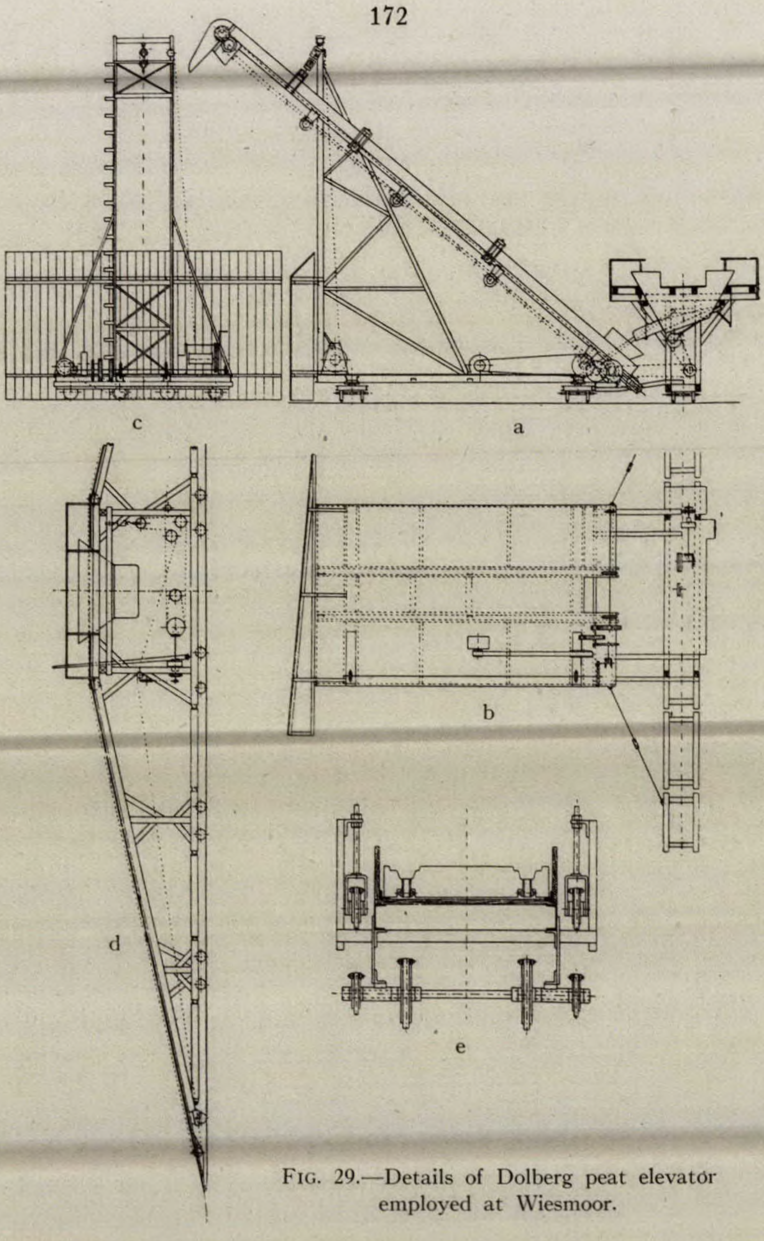
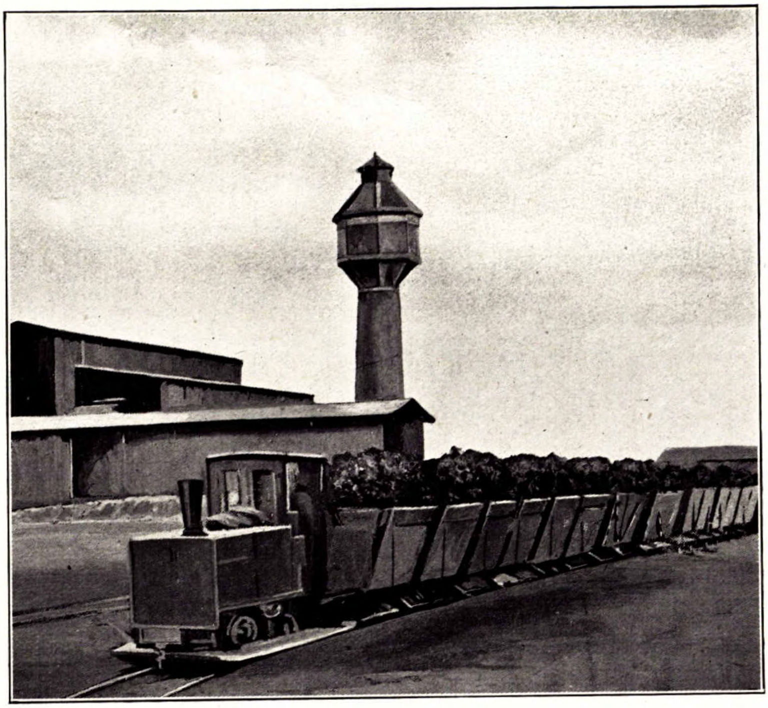


FIG. 29.—Details of Dolberg peat elevator employed at Wiesmoor.

(a) Dolberg's moveable peat elevator resting on two small cars provided with rails. (To the right) mounting platform for peat cars, with hopper and shaking apparatus.
(b) Plan of elevator frame and mounting platform.
(c) View of elevator frame seen from mounting platform; to the right is placed a windlass for lifting and sinking the elevator trough.
(d) Mounting platform for peat cars with arrangement for hoisting cars.
(e) Enlarged section through the middle of elevator trough; the two pulleys placed above each other on the outside are for the driving chain; the pulleys placed on the inside are for the elevator chain on which can be seen the scoop.

Peat elevator in operation.



Gasolene locomotive drawing peat cars.

for unloading the cars. The peat blocks are dumped from the peat cars into the hopper. From here they are sent by means of a rocking apparatus into a hopper placed at the lower end of the elevator. The carriers or buckets seize the peat from this hopper and transport it to the upper or highest end where it is thrown off onto the pile or stack.

An electric motor of 15 H.P. supplies the power necessary for operating the machine. This motor also furnishes power for moving the entire apparatus along the rails, which may be detached in sections and reattached at the other end, as the length of the stack increases or when it is desired to move the elevator to some other part of the drying field. The capacity of the elevator is 20 metric tons (22 short tons) per hour. The method of operation is illustrated in Plate XX, which shows an older type of elevator.

From the time the peat is dug to the completion of the peat stacks, rain is a source of much trouble, since peat not sufficiently air-dry eagerly absorbs moisture up to the original amount contained in the raw peat, and when this occurs the drying of the peat has to start again from the beginning. Air-dry peat on the other hand does not absorb moisture. Care must be taken, nevertheless, to protect the uncompleted stacks or piles from rain, even though the peat be air-dry. If this precaution is taken, the peat will keep dry in the stacks for years.

Air-dry peat is also immune from cold weather; it does not freeze. This is a most important property, since frozen peat is quite unsuitable for burning under boilers.

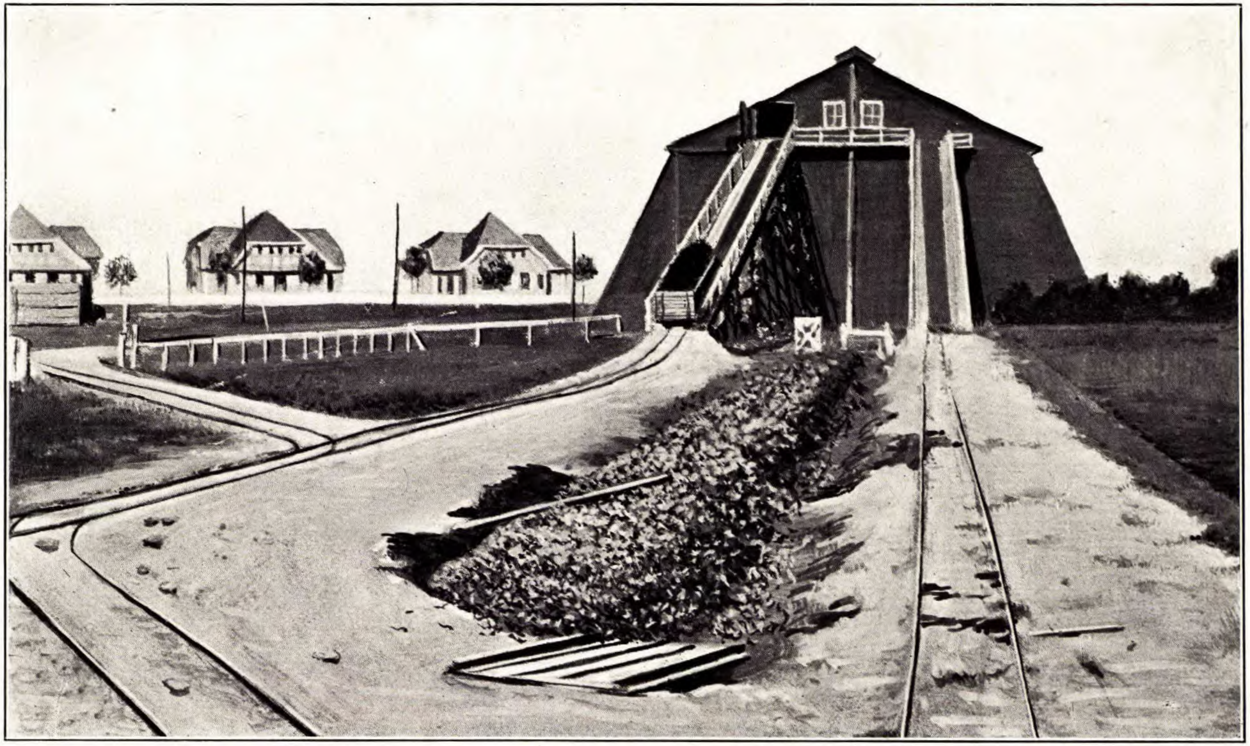
In transporting the peat from the field to the stack sheds, or power house, small locomotives run over narrow gauge tracks, are employed. Plate XXI. Horse drawn vehicles would prove much too expensive, since the distances are great and increase from year to year. The original intention was to employ electric traction, but this idea has been abandoned for the time being owing to the still comparatively small total load of the installation. So heavy a load, as this would prove to be, is, therefore, objectionable on a single phase.

The peat cars, six of which usually form a train, are specially constructed with regard to lightness and ease of unloading the peat without manual labour into hoppers or on to heaps. The rails have a gauge of about 60 centimeters (about 2 feet) and rest upon a layer of sand 20 to 25 centimeters (8 to 10 inches) thick. The rail bed as well as the roads about the moor are ballasted with the cinders drawn from the boiler furnaces, of which there was a large quantity before peat free from sand was obtained.

The methods of manufacturing a sufficient quantity of peat to serve the purposes of the power plant for a year have been fully explained. The most difficult problem, however, has as yet not been mentioned. The manufacturing season, is, as a rule, from April to August, and during this time the total quantity for a year's operation must be obtained. Peat fuel is consequently not manufactured continuously, and in this respect offers many difficult and unique problems to the large power producer which are not met with in the case of coal.

No trouble, whatever, is experienced in producing the desired quantity of peat during the average season, but to keep a large supply of sufficiently dry peat on hand ready for use, is the real problem which had to be solved. Of the total quantity of peat fuel obtained during the working season, the peat manufactured towards the end of the season is not sufficiently dry for burning. It is imperative that the greatest care be exercised in storing this peat in stacks in such a manner that it cannot freeze.

During the early months of 1910 the management had occasion to realize that manufacturing the peat and keeping it on hand ready for use were entirely different things. In January of that year only 6,000 tons of air-dry peat were available for immediate use. Another supply of 6,000 tons of still wet peat could not be used until the following May. In consequence, however, of the unexpectedly great requirements for power for the construction of the locks in Emden harbour, a daily consumption of 75 tons of peat had to be provided for. If the 6,000 tons of dry peat on hand had been used for this purpose it would have lasted for only eighty days or to the end of March. It was necessary, therefore, to resort to coal as a supplementary fuel. This was mixed with the peat, since the grates, especially designed for burning peat, proved unsatisfactory for firing



Peat storage bin, capacity 2,000 metric tons; workmen's dwellings in background.

with coal alone. In this manner the operation of the plant was maintained at full load without in any way interfering with the terms of the existing contracts for supplying current.

Brown coal (lignite) briquettes were found to be the most suitable for mixing with peat and the necessary supply of this fuel had to be hauled in wagons to the power house from the nearest railway station, eleven kilometers (about 7 miles) distant. Later the 6,000 tons of peat, which it was confidently expected would be in proper condition for use in May, was found to be almost completely ruined by frost, and almost useless, therefore, for boiler firing.

As a result of this unfortunate experience, several peat depots were erected. A sufficient supply of peat can of course be stored in stacks, but in rainy weather, and particularly in the winter when the snow is deep, it becomes very difficult to transport the desired quantity of dry peat or peat free from rain or snow. In order to avoid these difficulties a large peat shed with a capacity of 2,000 tons was erected close to the power house. Plate XXII. This shed is capable of supplying fuel for a month at an average consumption of 65 tons per day.

The shed is filled from peat trains, which are hauled up a steeply inclined railway by means of an electrically driven windlass to the top. Here provision is made for dumping the peat into the shed.

Peat is withdrawn from the opposite side and loaded on cars by hand, which are then hauled to the power house whenever desired. A second storage room or peat shed marked No. 2 on the ground floor plan of the power house shown in Fig. 28, is capable of holding from 300 to 500 tons, depending on the method of filling, i.e., if it is stowed by hand, 500 tons can, in this manner, be stored, while if the peat is simply allowed to fall from the conveyer belt its capacity is only about 300 tons. A third provision is made in the erection of small bunkers or silos. These are situated immediately in front of the boiler room and hold from 100 to 120 tons of peat. They are accessible from the boiler room through iron doors which are placed directly opposite to the furnace doors. The boilers can be easily hand fired from these bins if necessary.

Transportation of Peat from Storage Bins to Boiler Grates.

The transportation from the bins to the grates of the boilers presented many difficulties on account of the physical properties of the peat. The knowledge gained in the handling of coal as the result of many generations could not therefore be applied to this form of fuel. The approved apparatus now employed in large power plants for feeding coal into the boilers did not even serve as a suitable model. Entirely new contrivances had to be constructed and tried before the proper method was disclosed, and the results thus obtained and which will serve as a guide for further exploitations along the same line cost considerable money and time.

Peat in the form of sods or even when broken into comparatively small pieces, does not easily fall by its own weight down a chute or trough. It is especially inclined to jam when in the form of sods or blocks, or as it is usually fed to the furnaces. The attempts made to break or cut the peat by machinery all resulted in failure, principally on account of the large amount of fines which resulted. The refuse or fines thus produced were of practically no value for firing purposes and consequently were looked upon as a total loss. When the peat was handled in the form of blocks, the tendency to jam, as mentioned before, was a source of much trouble, e.g., when emptying the bunkers sometimes no peat at all would fall out of the opening in the containers, which were hopper shaped at the bottom, but if the material were loosened it would rush down in greater volume and with greater violence than was desired. By altering certain of the minor details the problem of transporting the peat was successfully solved.

Normally the peat is transported in the most expeditious manner from the stacks to the boiler grates and the supplies of peat stored in the sheds and silos are not drawn upon except in cases of emergency.

The transportation of the peat from the stacks or sheds to the bunkers is accomplished in the following manner. The cars of the peat train pass in front of peat shed No. 2 in such a manner that they are stopped in turn over a hopper situated at its westend.

Their sides are then opened, and the peat slides down the sloping bottom of the car into the hoppers. This arrangement is not unlike that of the well known Talbot car used for the transportation of coal. From the hopper the peat falls on a rocking trough which carries it through an ashlar wall to an elevator. This raises the peat to the top storey on to a conveyer belt, which moves over the middle of the two bunkers, and passing by a dumping car, carries the peat to the other end of the building. Here it falls upon a second conveyer belt, at right angles to the first mentioned. At this point of the transportation system a Schenk automatic weigher is inserted. After the peat passes this weighing machine it falls upon a third conveyer belt which runs in a direction parallel to the first, i.e., parallel to the boiler house. This conveyor, by means of a dumping arrangement, discharges the peat directly through chutes into the charging hoppers of the boilers. The entire transportation of the peat, so far considered, is accomplished mechanically and is consequently practically automatic. The machinery is operated by electric motors and but very little manual labour is required to oversee and occasionally render assistance.

The maximum quantity of peat that can be transported by this method is 18 metric tons (20 short tons) per hour, which is considerably in excess of the maximum quantity of fuel burned in that time.

Disposition of Peat in Boiler House.

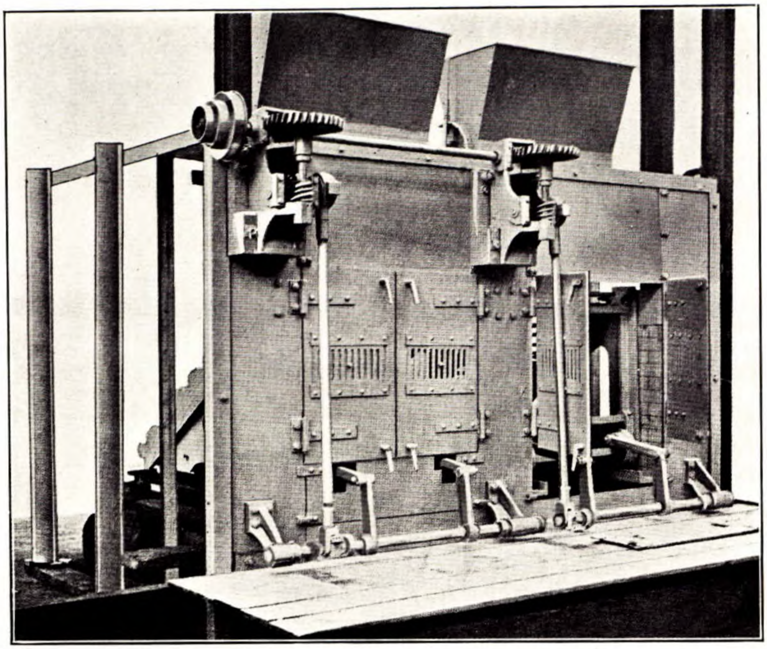
The peat discharged from the last belt conveyer, as mentioned above, falls into large hoppers which fill by gravity the inclined chutes leading to the enclosed hoppers directly over the step grates of the boiler furnaces. See Plate XVIII. Every quarter of an hour or more, depending on the rate of steaming and the quality of the peat, the stoker feeds the peat on to the step grates, by operating two levers, one of which closes the hopper vertically and the other horizontally. By means of this arrangement a definite quantity of peat, equal to the capacity of the hopper which is situated directly over the grate, is fed into the furnaces every time the stoker operates the levers. The arrangement of the step grates is similar to that applied to the Babcock and Wilcox boilers shown in Plate XXIII.

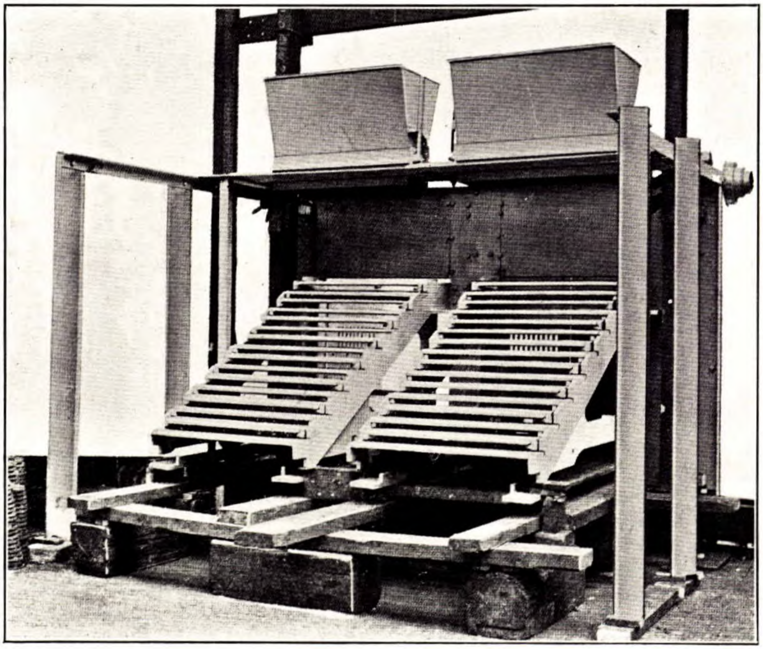
The peat reaches the grates in whole blocks, the formation of fines or dust from the stacks to the boiler is as a result not more than 10 per cent. This quantity of fines includes, however, a certain amount which already existed in the stacks and so cannot be ascribed to the transportation arrangements.

When no extraordinary demands are made on the power plant, the above described system of supplying the required peat is strictly adhered to. A deviation from this method may, however, at times be advisable. If for instance the load on the plant is considerably increased or the peat that falls upon the grates happens to be of rather poor quality, then the supply of about two tons in the hopper and the chute (including a small pile at the upper opening of the latter) may not be sufficient to repeat the charge of from three-tenths to one-half of a ton rapidly enough, or without an appreciable pause. In such a case peat is drawn from the silos in front of the boilers. These, as was previously mentioned, are accessible through iron doors placed directly in front of the boiler furnaces. These silos are filled by dumping the peat, by means of the dumping arrangement, into the silos directly beneath, instead of into the chutes and hoppers just described. Since the original difficulties were overcome, it has not been found necessary to encroach upon the supply of peat stored in these small silos.

Second Large Peat Fuel Reserve.

The second large reserve of peat which is stored in large bunkers in peat shed No. 2, is drawn upon only when the supply by means of the field railway ceases. These bunkers, which are filled during the periods of moderate operation by means of the first mentioned dumping car, or from the peat cars raised on an ordinary elevator, are now emptied by means of trap door openings situated at the botton. From these trap doors the peat drops onto a belt conveyer which carries it to the end of the rocking trough in front of the elevator. From here it passes to the boilers in the manner described above. It has not been found





Peat burning furnace, with moveable bars, as applied to Babcock and Wilcox boilers.

necessary to resort to this auxiliary fuel supply for some time, and if its bunkers are periodically emptied in the manner above described, at intervals of about six weeks, it is simply due to considerations of convenience in operation which appear desirable to the manager of the power house. These bunkers can be emptied in about five or six days.

The reserve of peat fuel stored in peat shed No. 1 is only used in cases of the most extreme necessity. Its construction was due to the impressions received during the first difficulties encountered in obtaining the required quantity of peat to operate the power house for one year. At the present time its construction might not be considered necessary. The peat is taken from this shed in small cars to the hoppers of the rocking trough in exactly the same manner as it is taken from the stacks.

Provision has been made for supplying peat to the boiler in case the mechanical transporting devices are put out of commission for a period exceeding two days. Adjacent to the main track of the field railway an incline leads directly into the boiler house. The peat cars are drawn up this incline by means of an electric winch from the track into the boiler house. The track shown beside the incline in Fig. 28 leads into the room below the boilers and serves to carry away the ashes.

It is evident from the foregoing detailed description of the methods employed for transporting the peat fuel from the field to the boilers, that every possible measure has been taken to provide against a repetition of the troubles encountered during the early days of the plant. The transporting of the peat is now independent of contingencies. Probably more precautions were taken than are absolutely necessary, but in the case of a large power plant situated like this in the midst of a barren moor many miles distant from towns, cities, or villages, and far from a supply of coal, the precautions taken can never be too great.

When one considers the magnitude of the undertaking, the unforeseen difficulties encountered in utilizing in this manner a fuel about which but little or nothing was known as regards its suitability for steam raising on a large scale, and the problems which had to be technically solved, one cannot help but regard this achievement as marvellous.

DESIGN OF BOILER FURNACES.

In the design of the boiler furnaces, and it may be added of the boilers themselves, many problems arose which required considerable time and the expenditure of large amounts of money, before a satisfactory solution was obtained. Peat when burned under a boiler behaves entirely differently to coal, or in fact any other form of solid fuel. The existing boiler practice brought to its high degree of perfection through years of experience cannot, therefore, be applied to the use of peat. The problem confronting the designer was a unique one, which had to be studied in every detail from beginning to end. As stated above, this involved much time and expense before the present efficient boiler installation was constructed, but the evolution of the peat fired boiler from its crude state to its present high state of perfection was accomplished in less than three years, and this accomplishment must be a source of great satisfaction to both the originators and the builders and designers of the plant.

The departure from the usual boiler construction which merits description and which is of especial interest, is the fire box and grates. Many types of grates and combustion chambers were tried before the engineers were satisfied that they had secured the best. Step grates inclined at 36° to the horizontal (see Plate XXIII) are now employed with great success. The grate is in two parts each four sq. meters (43 sq. ft.) in area. The two halves are charged alternately from the hopper placed in front of the entire grate. In the latter arrangement an excessive access of air during the charging is avoided by the peat itself, and its rapid passage from the hopper to the grates. This fact is of great importance since the air-dry peat has a very low heat value—only 2,500 to 3,500 calories per kg. (4,500—6,300 British thermal units per lb.) and must consequently be charged frequently, not only on account of the low heating value, but also on account of the relatively large volume occupied by the fuel. The volume occupied by 100 kilograms of air-dry peat bricks or sods is at least 0·4 cu. meters (about 14 cu. ft.) The heating value of a cubic meter is, therefore, about 620,000 calories.

Before good results were obtained in burning a fuel of so low a heating value per cubic meter, very careful observations concerning the operation under different conditions had to be made. The varying character of the peat, also, caused much trouble. The moisture content, e.g., was not uniform, nor can this ever be expected in practice, and the peat blocks of different moisture contents rushed down the chutes into the combustion chambers with varying speeds due to their varying dimensions. For this reason, as can be easily understood, the rate of combustion per unit time was never constant but varied to a considerable degree. At times, moreover, the peat contained too little moisture and this could not be remedied by wetting since air-dry peat does not absorb water, in fact cannot be even moistened to any extent.

The results of the combustion and charging of the peat were consequently quite unsatisfactory.

The heating value also of the individual peat blocks varied considerably for other reasons than that ascribed to the varying moisture content, e.g. during the first operation of peat manufacturing the surface moss which was not suitable for fuel purposes was mixed with the peat and sand or clay taken from the undulating floor of the bog entered into the finished peat fuel, and this not only reduced its heating value but seriously interfered with its combustion on the grates. Finally, before the present methods of transporting and storing the peat were inaugurated, frozen peat was fired which proved to be almost worthless. It burned too quickly like the surface moss, forming only 5 to 6 per cent carbonic acid gas, the largest quantity of the heat of the fuel was as a consequence produced somewhere in the boiler stack instead of in the boiler.

All of these difficulties have been conquered and the plant to-day is a complete success.

At the time of the writer's visit a large boiler of new design was in course of erection with which they confidently expect to obtain a greater efficiency in the utilization of peat. The grate area of this boiler, it is said, will be about 25 per cent smaller than those now in use.

The following are the results of a boiler test made in 1910, before the boilers were accepted.

The Average Results of Several Tests.

Average steam boiler pressure	12·1 atmospheres (177·9 lbs. sq. inch).
" temperature of steam	247·5°C (478°F)
" CO_2 content of flue gases	12·8%
" (CO_2+O) content of flue gases	19·6%
" temperature of flue gases	330°C (626°F)
" temperature of air draft	28°C (82·4°F)
" draft above grates	5·6 mm. (0·22 in.)
" draft in flue above damper	8·3 mm. (0·33 in.)
" draft in main flue	17·6 mm (0·69 in.)
" temperature of feed water	47·7°C (117°F)
" heat in steam per kg	653·6 cal. (1,176 B.T.U. per lb.)

The quantity of peat burned during the tests was between 15,266 and 14,027 kilograms and from 44,982 to 43,092 kilograms of water were evaporated, from which the rate of evaporation per kilogram is:

$$\frac{44{,}982 + 43{,}092}{15{,}266 + 14{,}027} = 3{\cdot}01$$ kilograms per kilogram of peat burned, this is equivalent to an evaportaion of 5·4 lbs. of water per lb. of peat.

The quantity of heat utilized is:

653·6 × 3·01 = 1967 cal. per kg. = 3,541 B.T.U's, per lb. which gives as the boiler efficiency where the average heating value of the peat burned is 2,680 calories (4,824 B.T.U. per lb.)

$$\frac{1{,}967}{2{,}680} = 73{\cdot}5$$ per cent which is far in excess of the efficiency guaranteed, viz., 65 per cent.

This excellent result cannot possibly be realized in every day operation. Up to the present time it has only been possible to attain a consumption of 2·7 kilograms (5·94 lbs.) per kilowatt hour in rare and isolated cases. A consumption of 2·4 kilograms (5·28 lbs.) per kilowatt hour has even been obtained.

In wet weather, however, the fuel consumption is 3 kilograms (6·6 lbs.) and upwards per kilowatt hour.

In order to compare these figures with that of the evaporation given above, the relation $\tau.\mathrm{d.} = \delta' = 1{\cdot}1\ \delta$ must be considered where

$\delta, \dfrac{\text{Kg.}}{\text{K.W. hour}}$ = specific steam consumption of the turbo-generator.

$\delta', \dfrac{\text{Kg.}}{\text{K.W. hour}}$ = steam which must be generated for the auxiliary machinery, feed water pumps, condensers, etc., in addition to that used by the turbo generator.

$\mathrm{d}, \dfrac{\text{Kg.}}{\text{Kg. peat}}$ = the weight of steam generated per Kg. of peat burned, in other words the evaporation figure.

$\tau, \dfrac{\text{Kg.}}{\text{K.W. hour.}}$ = consumption of peat per kilowatt hour.

If the steam consumption of the partially loaded turbo-generator is taken at $\delta = 7{\cdot}3$, then $\tau\mathrm{d} = 8$. The evaporation figure $\mathrm{d} = 3{\cdot}01$ would, therefore, represent the specific consumption of peat, $\tau = 2{\cdot}66$ Kg./K.W. hour, and inversely the estimate last made of 3 kilograms of peat per K.W. hour would represent an evaporation figure, $\mathrm{d} = 2{\cdot}67$Kg./Kg peat which would give a boiler efficiency of $\dfrac{654 \times 2{\cdot}67}{2{,}680} = 65$ per cent, i.e. the efficiency guaranteed by the builders.

If the cost of peat per ton is taken as 5 marks ($1.20) which is the price at which the Government sells the fuel to this company—a fuel consumption of 2·4 to 2·8 Kg. (5·28—6·16 lbs.) per K.W. hour would cost 1·2 to 1·6 pfennig (0·3 to 0·35 cents) per K.W. hour, i.e., about the same price as when coal (Steinkohle) is burned.

In the light of the experience so far gained a specific consumption of 2·5 Kg. per K.W. hour can hardly be expected in ordinary operation. But the results obtained are truly wonderful and have demonstrated the fact that air-dry peat fuel can be utilized for generating power by means of steam boilers.

THE CULTIVATION OF THE WIESMOOR.

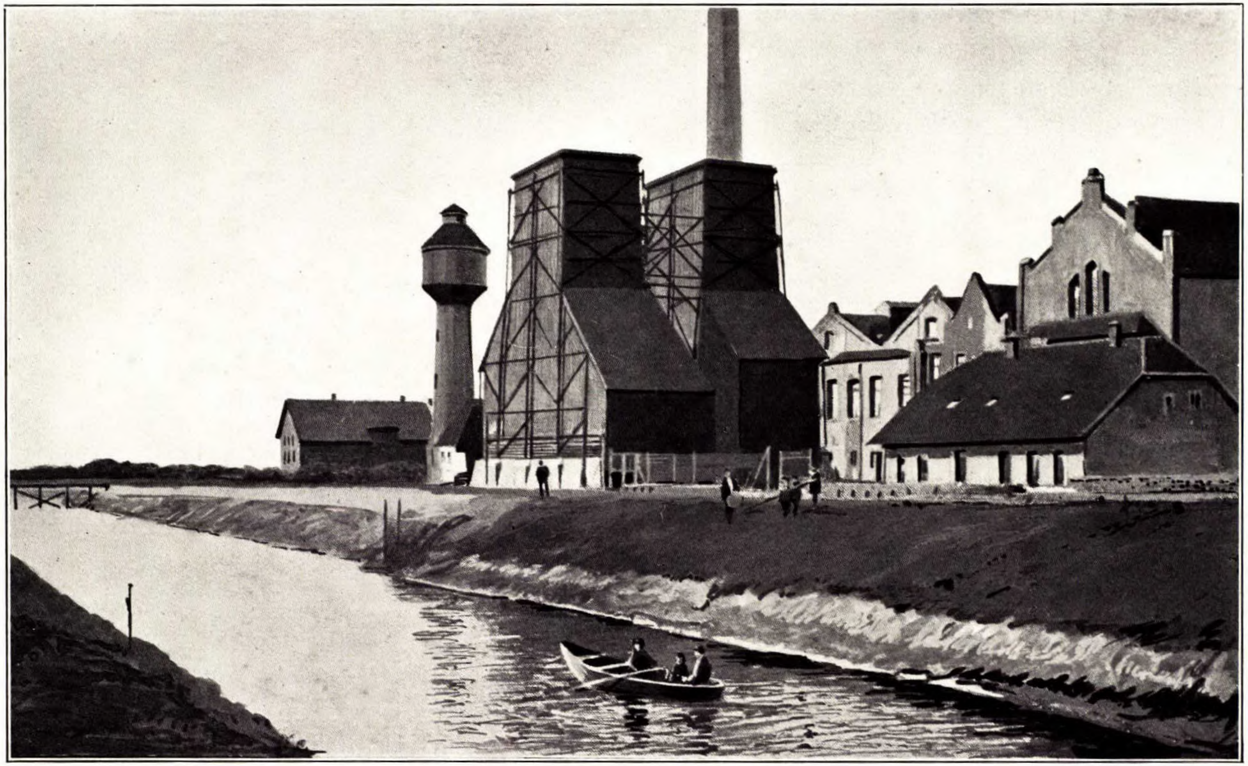
A description of the Wiesmoor steam power plant would be incomplete without some reference to the methods employed for putting the large area covered by the Wiesmoor under cultivation. The cultivation of this large bog is in fact the main objective and the power plant originally occupied a secondary position, its principal function being to generate and supply power for the purposes of cultivation.

This is true to a large extent, even at the present time, but rapid increase in the capacity of the power plant has placed it in a more prominent position than it previously occupied, and it may now rank with the cultivation proper of the bog in importance.

In order to prepare any peat bog for cultivation it must first be drained, and this is accomplished by constructing a system of main and subsidiary ditches or trenches. In this respect the preliminary preparations necessary for the manufacture of peat fuel only are very similar, the only difference consisting in the extent and dimensions of the ditches. But a bog which has been thoroughly prepared for cultivation is likewise well prepared for the manufacture of peat fuel and at the Wiesmoor these two different pursuits are being carefully and successfully prosecuted.

Before the establishment of the Wiesmoor central power plant, steam ploughs, excavators, etc., were tried, but their excessive weight militated against their use and they were finally abandoned. The successful work now being carried out along this line is due entirely to the introduction of electrically operated machinery which can be constructed much lighter than the old steam machinery.

The description of the preliminary work of surveying and levelling the bog need not be entered into in detail here, it is sufficient to state that two sets of levels must be taken—both the surface and the subsoil—and this, of course, is a tedious and expensive piece of work.



Completed portion of canal in front of power house.

Canals.

Two principal sets of canals are constructed, viz., the main canal and the side canals. In addition to these there are secondary canals which will be referred to later. The total length of the canals is about 58 kilometers (36 miles). A profile of a canal is shown in Fig. 30. As will be seen from this profile, the canals are bordered on both sides by roads of generous width. A narrow tow path is also provided for the use of canal boats, on this a light railway can be constructed should it become necessary. The homesteads into which the moor is divided by this system of canals and roads have an average area of from 7 to 10 hectares (17-25 acres).

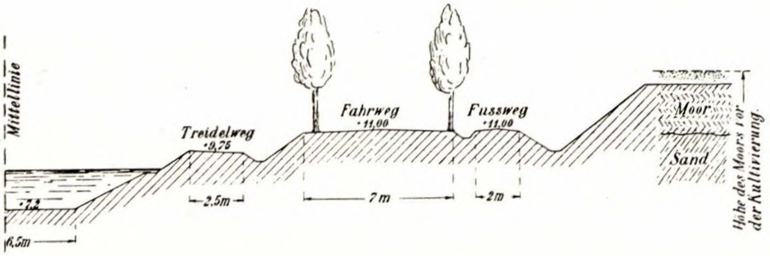


FIG. 30.—Profile of Canal.

The construction of the canal system was begun by excavating the north and south canal 15 kilometers (9 miles) long. Up to April, 1912, a portion of the canal, about 1 kilometer (·62 mile) in length and stretching in a southerly direction, had been completed. The narrow canal or trench, which must always be excavated by manual labour first, extends considerably farther to both the north and south. This preliminary canal or trench must be dug by manual labour since the wet moor cannot support the power dredge. This completed portion of the canal in front of the power house is shown in Plate XXIV.

The excavation of the peat is followed by that of the subsoil, which in this case is sand. The sand taken from the bottom of the canal is utilized for building roads and field railways, and is consequently a very valuable material. A power shovel of 50 cubic meters (1,765 cu. ft.) capacity per hour, driven by a 25 horse power motor, is employed for removing the sandy bottom.

From the data given in the plan of cultivation and the profile of the canal, the total quantities of peat contained in the bog as a whole and in the canals can be calculated. It must be understood, of course, that the result obtained will be only approximate, since the data supplied are only approximate. If the average depth of the fuel peat is 2½ meters (8·2 feet) the content of the bog will be 6,200 × 2·5 × 10,000 = 155,000,000 cubic meters, and if the weight of a cubic meter of peat containing 90 per cent water is taken as one metric ton, the content of the bog will represent 155,000,000 metric tons of 90 per cent moisture peat, or 22,000,000 metric tons of peat with a moisture content of 30 per cent. If now the consumption of peat, containing 30 per cent moisture per kilowatt hour, is taken as 2·5 kilos, and the yearly output of power at 20,000,000 kilowatt hours, i.e., about two and a half times the output of the first year of operation, the peat of the district now to be cultivated will last for about 450 years. As a matter of fact, the canals alone, which have a width of 50 meters through the entire depth of the fuel peat, can supply the plant, operating under present load conditions, with sufficient fuel to last 20 years or more, probably 30, since the production of power is far from reaching that used as a basis in the calculation. It will be seen from these figures that the power plant is assured of a supply of fuel; but it will, also, be recognized that the immense quantity of peat excavated from the canals alone could not be disposed of if the power plant were only of sufficient capacity to satisfy the requirements of the Moor Commission. If such were the case and the power developed were limited to only a few hundred thousand kilowatt hours per year, the quantity of fuel contained in the canals alone would be sufficient to supply the fuel requirements for 1,000 to 2,000 years—and an equal length of time would have to be devoted to their construction.

It is plain, therefore, that the necessity for establishing a

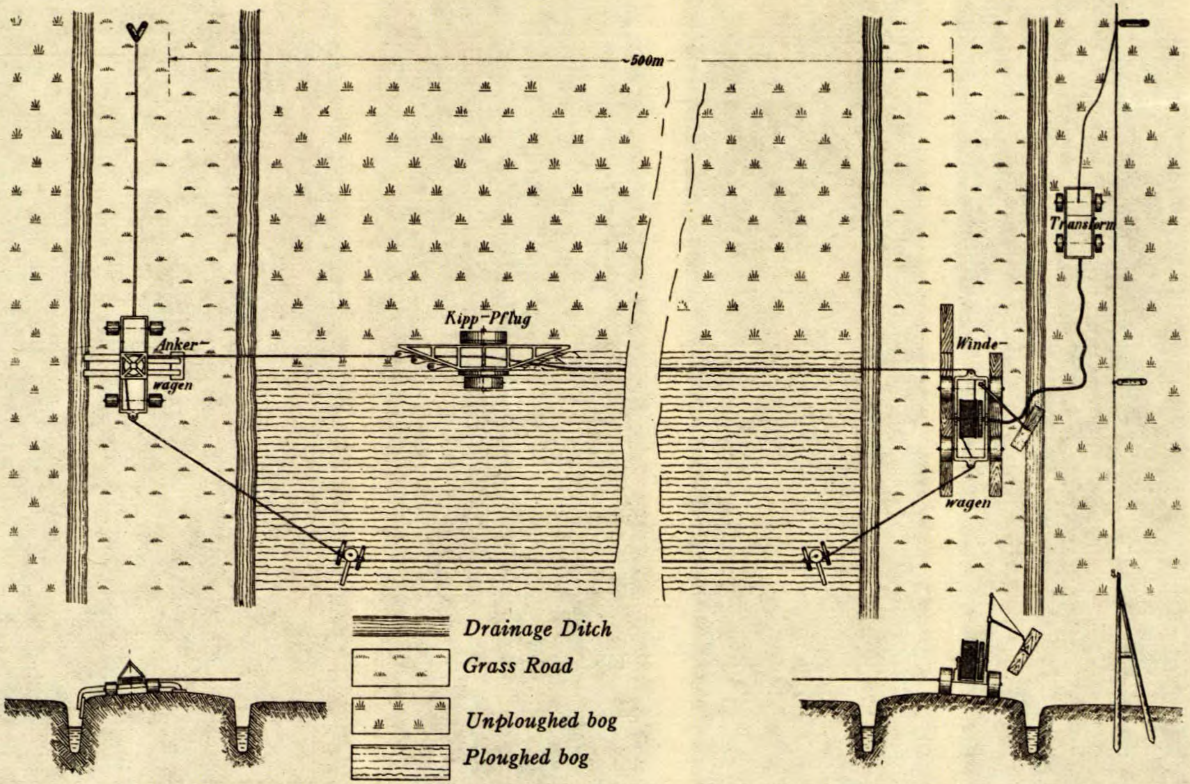


Fig. 31. Method of ploughing according to the one machine system.

fairly large power plant was a real one, if the desire to economically utilize all the peat fuel made available by this system of cultivation is to be realized. For this reason the power plant occupied a far more prominent position in the scheme of cultivation than it would have otherwise done.

The power to be disposed of when the plant is operating at full capacity is, as explained above, far in excess of that required for moor cultivation, other markets for the larger portion of the power production had consequently to be found. This question will be referred to again later.

After the construction of the canal has proceeded to a certain depth, the bog in the vicinity will have dried sufficiently to permit the peat to be spread out on the banks to dry and to allow the construction of roads to proceed. These roads, in accordance with the plans being carried out, are seven meters (22 feet) wide and are laid out in straight lines running at right angles to the main canal. The distance separating them is such that they will eventually lie between two homesteads and at the same time far enough apart to assist in the cultivation of the moor. At such a place, the homesteads are each 100 meters (320 feet) in width, so the clear distance between the roads is made 400 or 500 meters (1,280—1,600 feet) corresponding to the width of four or five homesteads.

Construction of Roads.

On the right and left of the proposed road very narrow ditches about one meter (3·2 ft.) deep are dug. These ditches drain the water from the immediate neighbourhood, but particularly that in the bog between them which is intended for the road bed. This portion of the bog is raised by the material excavated from the ditches, and is cultivated to make it firmer and is then sown with grass seed. The newly sown ground and later the turf is heavily rolled several times, this results in so good a grass road that even a heavy windlass supported on broad planks can pass over it.

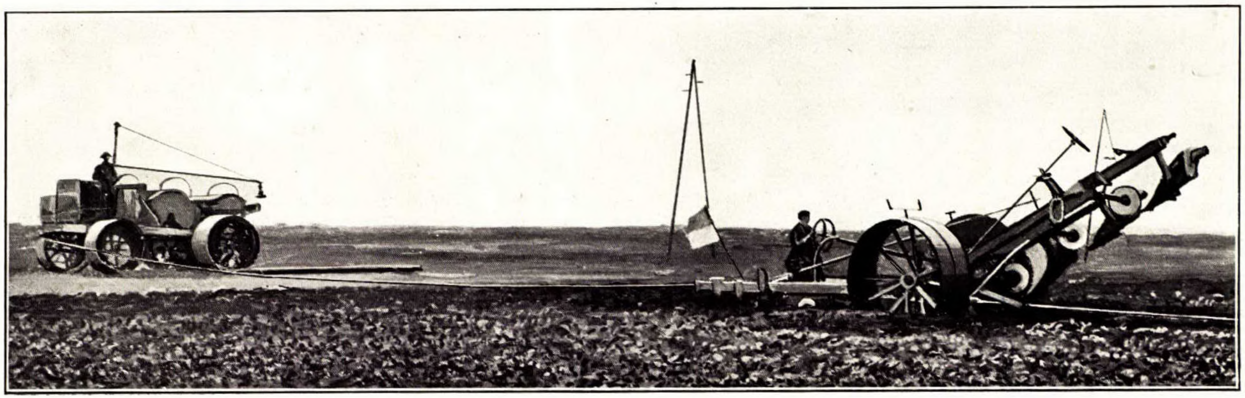
After this preliminary work has been accomplished the drainage ditches are dug to a depth of from one to one meter and a half (3·2 to 4·8 feet). No further work is done for six or eight months. During this period the water of the moor drains rapidly into these and other ditches into the main canal. As a result of this drainage the moor dries considerably and consequently sinks sufficient to decrease the depth of the drainage ditches from 1 to 1½ meters to 80 centimeters (2·6 ft.) At the termination of the six or eight months above mentioned the ditches are excavated to their original depth and then drain pipes or tiles are laid in them. These pipes are embedded in heather and are provided with valves at predetermined intervals which permit the flow of water to be checked in dry periods. When the peat in this section of the bog is manufactured into peat fuel, at some time later, these pipes can be recovered. As soon as the drain tiles have been laid the ditches are completely filled, and when the area thus prepared is sufficiently large, cultivation by machinery is at once begun.

Cultivation.

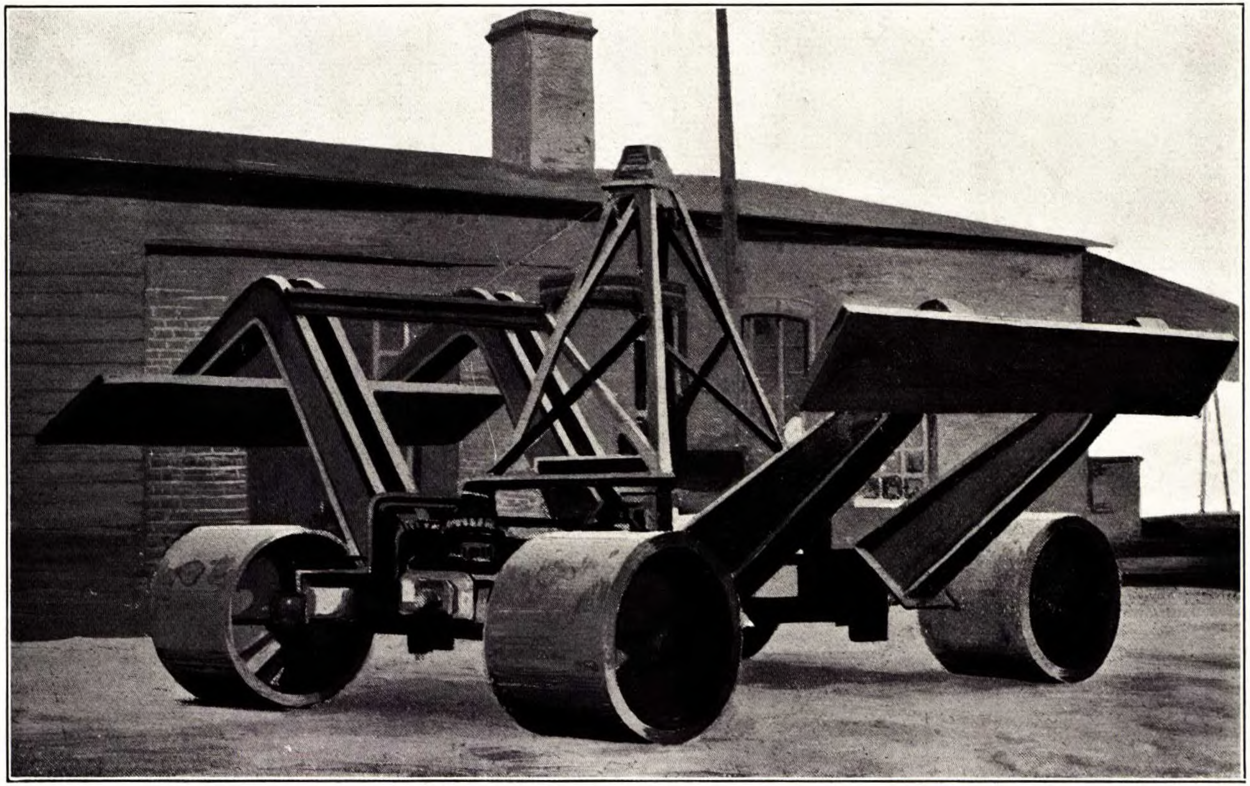
When the preliminary work just described is completed the cultivating machinery is brought to that portion of the bog to be put under cultivation. The necessary field equipment comprises a transformer of 60 K.V.A. capacity and transforming ratio 5,000 V. to 500 V, a windlass wagon equipped with a 50 horse power motor and an anchor wagon. A power line is now connected with the main high voltage line which runs along the main canal. The power plough can now be set to work. This is a tilting plough with three shares made by the firm of Fowler and Co. It is provided with a special wheel which runs in the furrow last made and serves the purpose of supporting the plough and preventing it from sinking into the bog. Fig. 31 shows the method of working, Plate XXV shows the plough in operation, and Plate XXVI is an illustration of the new anchor wagon, invented by Mr. Schweizer, the administrator of the moor.

Fig. 31 shows how the two extensions at the right and left of the wagon are turned down, and bolted to the frame of the wagon, when in use, in such a manner that one taking hold in the ditch on the far side of the road resists the pull of the steel

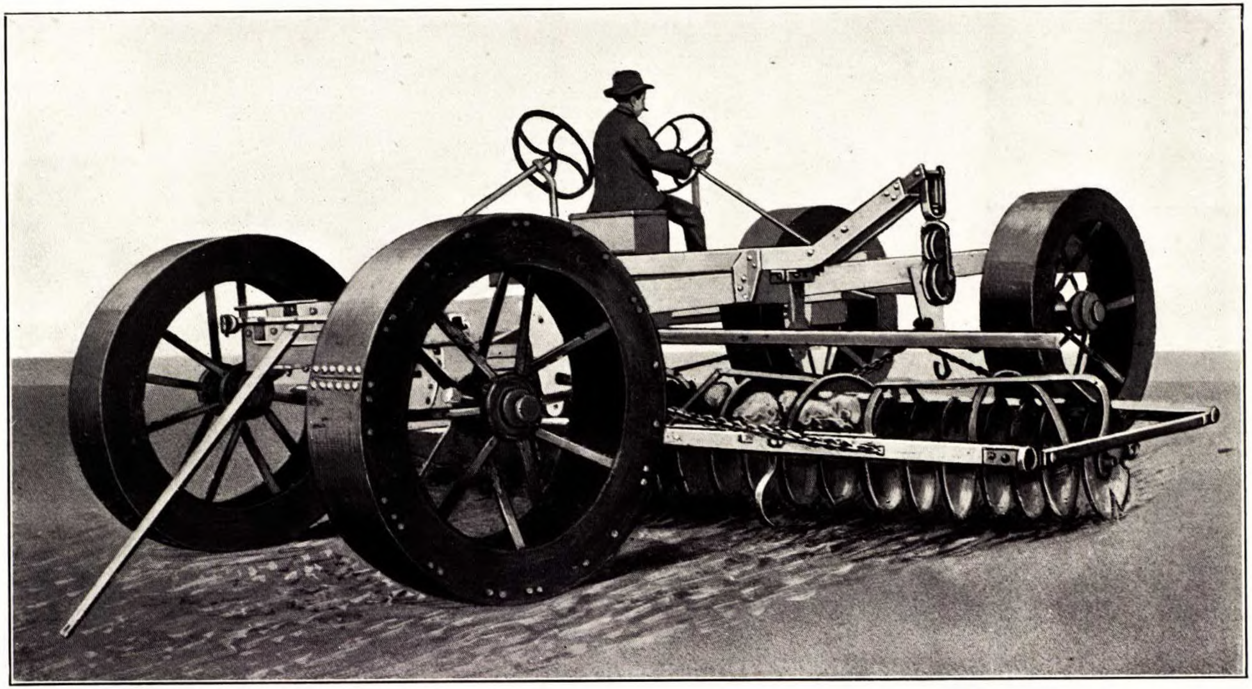
PLATE XXV.



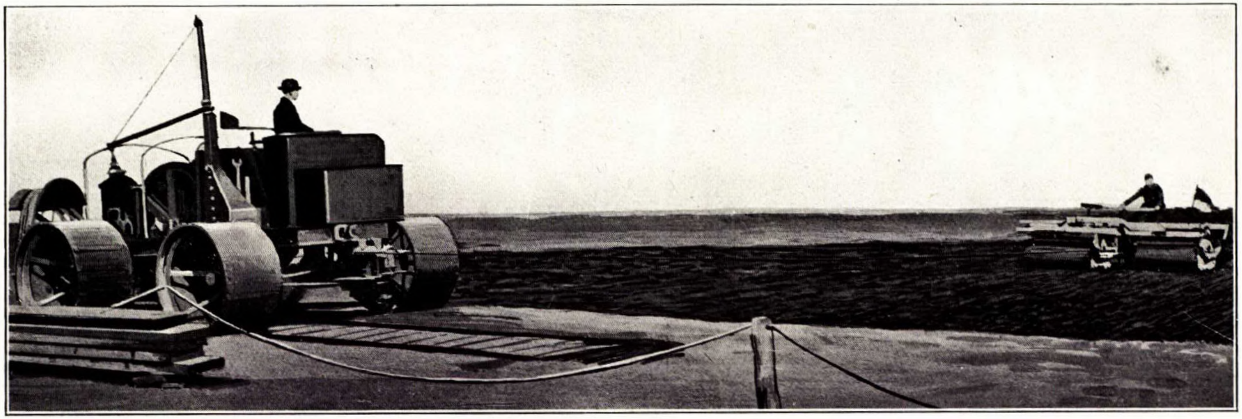
Plough in operation.



Anchor wagon.



Harrow employed on the Wiesmoor.



Roller used on the Wiesmoor after the operation of harrowing has been completed.

cable stretched between the windlass and the anchor wagon, while the other lying flat on the grassy surface resists the torsional force exercised by the cable.

The same figure shows how the anchor wagon winds itself along as the work progresses.

After the ploughing has been completed, the harrow, Plate XXVII, is used, but before the harrowing is commenced it is usual to allow the newly ploughed field to remain for a winter. This permits the harrow to perform its function of breaking up and comminuting the peat and levelling the surface of the soil to better advantage.

When the harrowing is accomplished the roller is used. This is drawn to and fro, in the same manner, between the windlass and the anchor wagon, see Plate XXVIII. Lime and artificial manure are now scattered on the rolled surface and thoroughly harrowed in. The field is now in condition for sowing.

It may be assumed that the reader is, in a general way, acquainted with the literature concerning the cultivation of agricultural land with the aid of electrical power and the implements, particularly the electric plough, which are employed.

It is also taken for granted that the relation of the electric plough to the steam plough is thoroughly understood. For a more extended knowledge of this subject the reader is referred to the able and valuable work of Wallem*. What he says concerning the weights of the various machines and their importance to their practical application, applies even in a higher degree to the case under discussion. The soil of the moor which is always loose and spongy even after being drained for a considerable period, is not able to carry weights like the steam plough even if its wheels are made twice the usual width. In fact heavy planks must be laid under the wheels of the electric windlass wagon which weighs twelve tons, or only about one-half as much as the steam plough. These planks are laid by an electrically operated crane and winch shown in Figure 31 and Plate XXVIII. The electrically operated machinery, though too heavy to rest on the bog without first laying broad planks under the wheels fulfils all the requirements of moor culture. The wheels of the

---

*H. Wallem: Electricity in Agriculture and its relation to Overland Centrals. Electro Technische Zeitung, 1910, page 671.

disc harrow which normally have a width of 35 cm. are increased for use on the moor to 60 cm. (23 in.) This machine weighs only three metric tons. The wheels of the windlass wagon are 70 cm. (27 in.) and those of the anchor wagon 75 cm. (29 in.) wide. The latter machine is considerably lighter, weighing only about 3½ metric tons, and can travel, in virtue of its wide wheels, on roads which are not prepared. The weights of all the other machines employed in cultivating the moor are small in comparison with that of the windlass wagon. The plough, transformer wagon, and the roller weigh about three tons each. The roller can, however, be weighted to five tons.

The capacity of the different machines employed on the moor are:

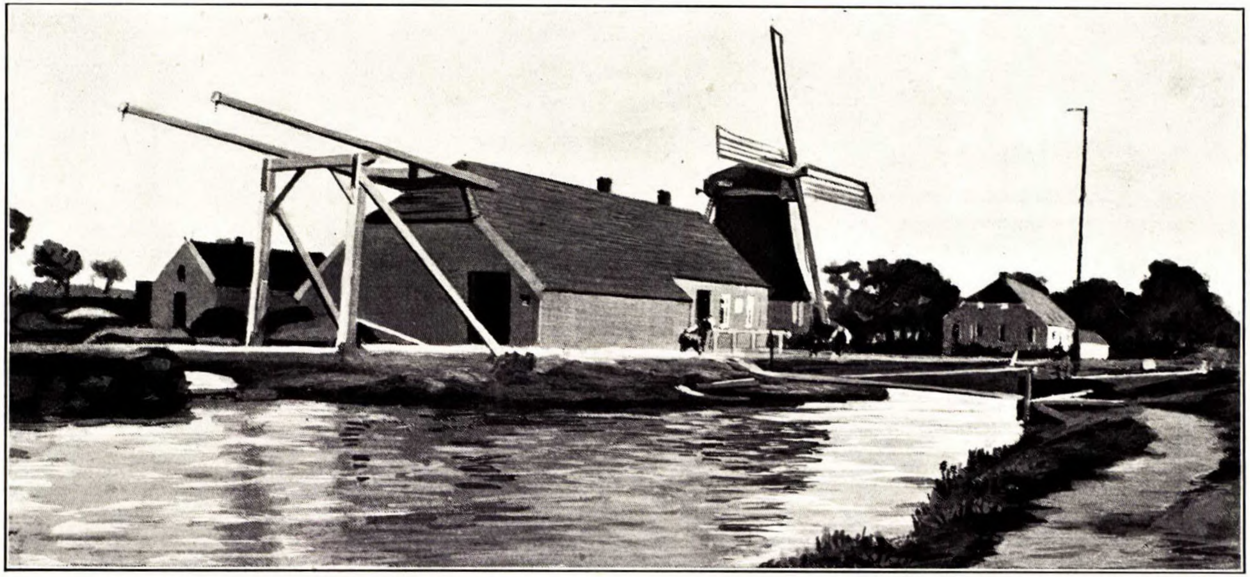
Electric plough,	5 hectares (12 acres) per day.
" harrow (2 harrowings)	10 hectares (24 acres) per day.
" roller,	15 hectares (37 acres) per day.

It has been proved impossible to realize the original estimated capacity of the roller and harrow, viz., 40 and 20 hectares, respectively. The frequent relaying of the planks reduces the capacities to a marked degree. The one set of machines, at present employed, is capable of cultivating 750 hectares (1,852 acres) per year of 200 working days.

According to recent calculations, the cost of cultivating the Wiesmoor amounts to 600 marks (about 150 dollars) per hectare, that is about $60 per acre.

The homesteads are handed over to the settlers when they have been thoroughly cultivated, and when a site for the dwelling has been stripped of peat. The houses in this case, unlike that of older reclamations, are not temporary structures, but are built of stone and on a foundation of sand. The further and final excavation of the peat for fuel purposes is left for the settler to do. This fuel is always easy to dispose of, since the power plant depends upon it.

Plate XXIX is intended to show how the bog will appear in the future when settled by homesteaders. The Weismoor up to the end of the year 1912 was not so far advanced; only a few fields, meadows, and pastures were completed. But these



Appearance of bog when completely cultivated and settled by homesteaders.

have demonstrated that the hopes based upon the cultivation of the moor is justified—in fact these hopes have been very considerably surpassed by the abundant harvests of grain, potatoes, and other crops, and by the excellence of the pastures. A single harvest—that of the first rye harvest—sold standing for from 300 to 400 marks per hectare (about $29 to $38 per acre).

A practical agriculturist Frh. von Wangenheim, president of the association for furtherance of moor culture in the German Empire, pronounced the following judgment upon the success so far attained: "The quality of the work which is being done among us is the best that can be imagined, and we can very proudly say that we in Prussia have now surpassed our former models, the Hollanders. The old Dutch cultivations are excellent, what Oldenburg is accomplishing is splendid, but what we have seen in our midst of late years in the Provincial Moor, in the Markardsmoor, and especially by the electric central station in the Wiesmoor, on the areas which have been worked under the direction of Privy Councillor Ramm, is the finest specimen of the work of cultivation that we have ever seen."

The intention of the Government is to divide the entire tract of land into small homesteads of 7 to 10 hectares apiece, so that small peasant holdings will be created which will be farmed by one family alone without outside help. The yield from such a homestead will support an entire family. In this manner it is hoped to build up a reliable population, attached to the soil. Every peasant will live upon his own homestead, upon his own soil and ground, and in the course of a few decades there will arise a colony of over 3,000 people spread with an even density over an area of 6,500 hectares (1,600 acres).

CHAPTER VI.

FEASIBILITY OF ERECTING BY-PRODUCT RECOVERY PEAT PRODUCER GAS POWER PLANTS IN CANADA.

The successful introduction of a peat burning, by-product, recovery power gas plant into Canada, is dependent on the following factors:—

(1) Cost of peat supplied to producer and its nitrogen content.
(2) Cost of labour and labour conditions.
(3) Plant costs.
(4) Cost of sulphuric acid laid down at the plant.
(5) Market for power produced.

The first factor. The cost of peat fuel laid down at the producers and the quantity of peat fuel available is the most important, since if this condition cannot be satisfactorily fulfilled, the feasibility of erecting such a plant requires no further discussion.

From the foregoing description and analysis of operation of the European plants utilizing peat fuel, the serious difficulties encountered in obtaining the requisite quantity of peat fuel to operate the plant, are fully realized. Not only has it proved a most obstinate problem to manufacture the desired quantities of peat fuel, but, in some instances, almost impossible to deliver the fuel with the proper moisture content to the producers. For this very reason efforts have been made to utilize peat with a high moisture content, but such attempts as have so far been made, have not proven successful, so this phase of the question will not be considered. Finally, after the requisite quantity of peat fuel has been manufactured during the working season of about 3 or 4 months, the question of storing the dry, partially dry, and still wet peat thus manufactured, in such a manner that it will not be ruined by rain. frost, or snow, is one which requires very serious consideration. All of the above problems have arisen in the manufacture of peat fuel in Europe and it can be safely said that all have been satisfactorily solved. In considering, therefore, the establishment of a new industry of this kind in Canada full use should be made of the results obtained with similar plants in Europe.

It has been satisfactorily demonstrated that peat fuel with a moisture content of from 25 to 30 per cent can be manufactured in Canada during the usual summer season, and in comparatively large quantities. For example, a small Anrep unit of about 25 tons capacity per day of ten hours, has produced as high as 2,200 tons of 25 per cent moisture peat during the working season of about 90 days. Several such units operating over a large area could consequently produce the required quantity of fuel, and according to the methods followed in Germany at Ostfriesland, this quantity of peat could be safely stored during the winter and rainy seasons.

In Canada, however, the existing conditions are not favourable to the manufacture of any commodity of such low value with a process wholly dependent on manual labour. Processes or methods must therefore, be applied which will render to a certain extent at least, the manufacture of peat fuel independent of manual labour. The process above mentioned, which depends entirely on manual labour, for the performance of all its operations, cannot, therefore, be considered in an undertaking of large proportions, when a large quantity of fuel must be produced at the lowest possible cost.

As a result of the last two seasons' operations on two Canadian bogs—Alfred and Farnham—there is every reason to believe that the manufacture of peat fuel on a large scale with automatic machinery, is an established fact. No trouble should, therefore, be experienced in obtaining the required quantity of fuel for a season's operations.

The nitrogen content of the peat fuel, when the peat is burned in a by-product recovery producer, is of no less importance than the winning of the fuel itself, since on this element depends the profitable utilization of the peat. When selecting a bog, therefore, for the manufacture of fuel in connexion with such a plant, great importance must be given to the average nitrogen content of the peat fuel contained in the entire bog. Peat containing less than 1½ per cent nitrogen in the absolutely dry sample would prove entirely unsuitable for by-product recovery. When considering, therefore, the suitability of Canadian bogs for the manufacture of fuel for the by-product recovery producers, only such bogs will be considered as have a nitrogen content of over one and a half per cent.

Second, cost of labour and labour conditions. Canada is a new and growing country, and the many large undertakings always under way demand an ever increasing number of labourers, and naturally when the demand exceeds the supply the wages increase. Other factors, also, are responsible for the high labour wage in North America, but these will not be discussed here. Labour wages in Canada, especially in certain sections, are much higher than obtain in any European country, and for this reason alone, an industry which has proven feasible where cheap labour is plentiful may absolutely fail in a country where the wages are much higher. It is apparent then that economy as regards the number of labourers employed, must be strictly practised in every branch of the industry under discussion. It is the usual custom in Canada to divide a working day of 24 hours into three shifts of 8 hours each, while in Europe two shifts of 12 hours each is often the case.

The number of labourers it is necessary to employ to operate a by-product recovery producer plant continuously may, therefore, exceed that necessary in European practice. In certain localities it might be possible to introduce the 12 hour shift, but in the majority of cases, and in time this custom will become general—an eight hour shift will have to be reckoned with. The daily wages for ordinary labourers differ considerably in the extreme eastern and western portions of Canada. About $1.75 to $2 per day of 8 hours may be taken as the standard wage for ordinary labour in Eastern Canada, while $3 per day obtains, for the same class of labour, in British Columbia and sections of the Prairie Provinces.

Skilled labour demands a much higher wage in Canada than in European countries, but since the number of such men employed in a producer plant will be inconsiderable, the total daily wage account will not be affected to any appreciable extent by this increased wage. In this class of labour is included machinists, engineers, electricians, and foremen.

So in considering the probable profits which are to be derived from the operation of a by-product recovery power gas plant, the fact that labour in Canada is far more expensive than in Europe where such plants are in successful operation, must be given prominent attention.

Third, plant costs. The cost of manufacturing machinery in Canada and also the United States is considerably greater than it is in Europe, and its importation from European countries implies a duty of about 30 per cent of its sale price where made. In some cases it might be found cheaper to import certain portions of the plant and to manufacture others. But when everything is taken into consideration, the plant costs will be very considerably in excess of that obtaining for similar plants in European countries.

The plant costs include buildings, producers and fuel handling appliances, gas scrubbers, ammonia recovery plant, all accessory machinery, such as circulating pumps for acid and water, blowers, machine shop, etc. In addition to these must be added the power house and equipment if it is desired to utilize the gas generated for power purposes. The cost of the peat bog and peat manufacturing machinery will not be included in the total capital charges against a by-product recovery plant nor will any accessory peat drying apparatus be considered.

The fourth factor which must be considered is the cost of the sulphuric acid used for fixing the ammonia gas. Since approximately 1·1 tons of sulphuric acid of a strength of 60° Baume is required for every ton of ammonium sulphate made, the necessity for keeping its cost as low as possible will be appreciated. At those places where sulphuric acid cannot be obtained at a reasonable cost, some arrangement must be made for manufacturing it at the plant. This in itself might prove, in many cases, an expensive undertaking owing to the comparatively small output required in proportion to the cost of the sulphuric acid plant, but if the acid can be manufactured at the plant for a lower cost than it can be obtained from an acid manufacturer such a plant should be installed.

It must not be forgotten that ammonium sulphate sells the world over for between $65-$70, at the present market price (1913), and that plants established in Canada for its recovery must compete with foreign companies whose manufacturing costs are considerably lower than they will be here. It is, therefore, evident that little or no benefit will accrue, in a financial way, from recovering the nitrogen in the fuel if the costs of the components entering into its composition and those necessary for its recovery are out of all proportion to the gross profits realized from its sale. In certain sections of Canada this may be found to be the case and then such a by-product recovery process cannot be profitably employed in working up a low grade fuel.

The fifth and last factor to be considered, viz., the market for the power produced, is of great importance. It is not probable that many by-product recovery producer gas plants could be established in Canada for the recovery of ammonium sulphate alone. In the majority of cases, therefore, the sale of ammonium sulphate would only serve to reduce the cost of generating gas and power, and if it failed to accomplish this no advantage, other than from a conservation standpoint, would accrue from its recovery. The main object, then, of establishing such a plant would be the production of a gas to be used for power and other purposes, and this phase of the problem will have to be thoroughly investigated before any such industry is considered.

Canada, especially in its Eastern sections, is well supplied with water powers, and the development of these has of late years been vigorously prosecuted. When a water development is a large and comparatively inexpensive one, electrical power can be developed at a very low figure, and if this power development is capable of supplying all the energy required in the region surrounding, any other power development depending on the combustion of some form of fuel cannot compete. But if the energy developed at a hydro-electric plant must be transmitted long distances before being disposed of, its cost to the user will be greater than it is to those nearer the power plant. In such cases the hydro-electric plant may fail and the fuel power plant assert its position. Electric energy cannot be transmitted for long distances even at high voltage without considerable expense, and this added to the expense of constructing the power transmission line and substations and transformers may deprive the otherwise cheap power of all its advantages.

A market must, therefore, be established for the power it is proposed to generate before the actual building of a by-product recovery power gas plant is undertaken. If such precautions are taken failure will be prevented, at least in the majority of cases.

CAPITAL, AND OPERATING COSTS.

The following approximate costs of erecting complete a by-product recovery producer gas plant are based on estimates made by the Power Gas Corporation for a similar peat burning plant in the United States. This latter plant, however, is unfortunately intended for the gasification of the peat for the recovery of the ammonia only and will not, therefore, serve as an example of a by-product recovery power gas plant. The operating costs will be worked out to suit Canadian conditions.

The plant under consideration will be capable of gasifying 120 tons of theoretically dry peat per day of 24 hours, and the nitrogen content of the fuel will be assumed to vary from 0·2 to 2·6 per cent. Fig. 32 shows the disposition of the producers, auxiliary machinery, etc., of a plant of similar capacity designed for utilizing peat in the United States.

Plant Costs.

Item	i—Gas plant delivered on site, about......	$98,000.00
	ii—Spares and sundries..................	8,000.00
	iii—Estimated extra for parts manufactured in Canada	9,000.00
	iv—Freight, duty, and insurance on parts made in England, about............	4,800.00
	v—Foundations, buildings, etc............	19,000.00
	vi—Erection, about......................	15,000.00
	vii—Workmen's houses, say................	8,000.00

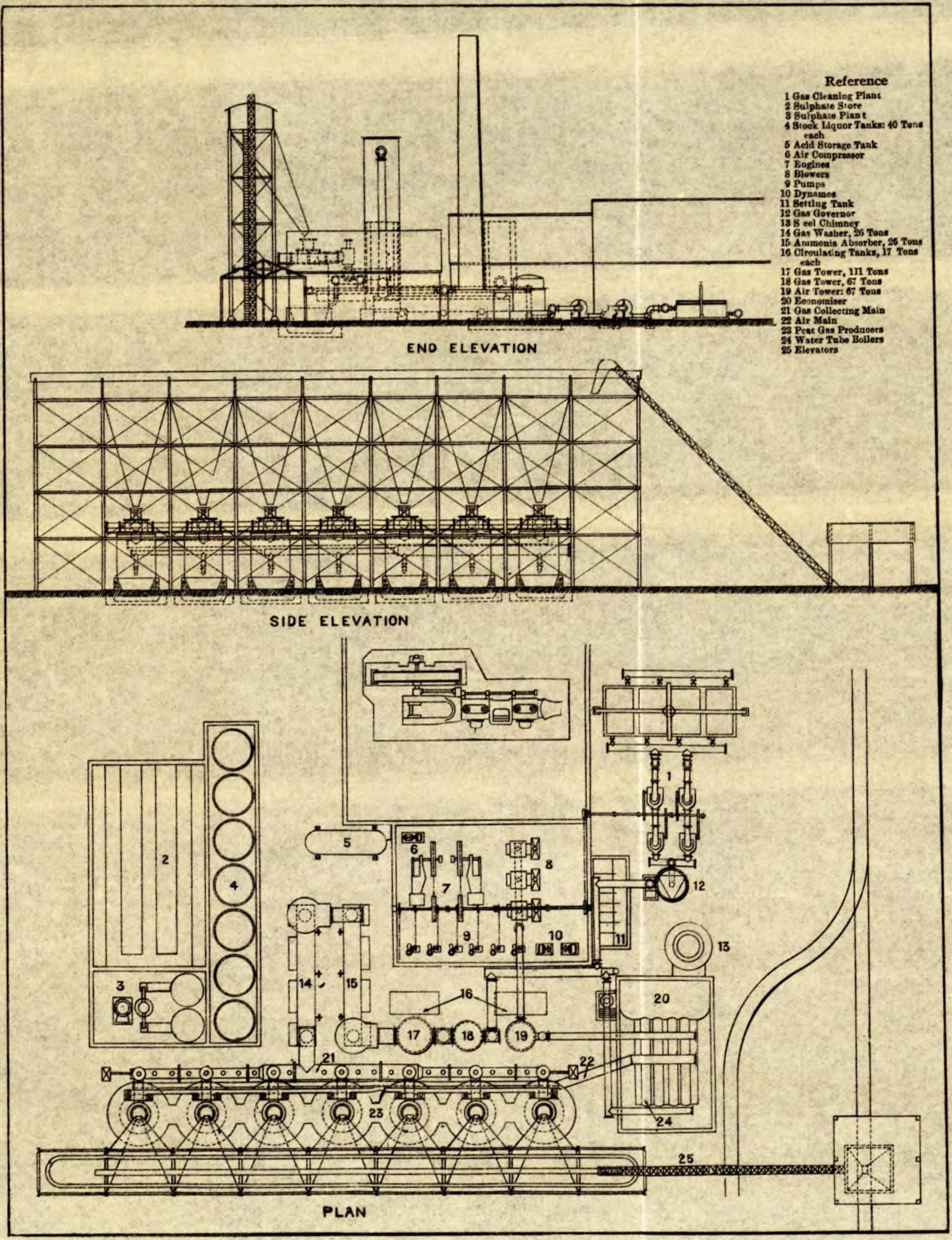


Fig. 32. General arrangement of 150 ton peat plant

Plant Costs, continued.

viii—Well, about	$ 600.00
ix—Sulphuric acid plant, approximate	36,000.00
x—Working capital	36,000.00
xi—Gas engine installation, including building, electrical generators, switch boadrs, all complete and 5 engines of 1,000 H.P. each, 1 held in reserve	300,000.00
	$534,000.00

Labour Costs.

PRODUCER AND SULPHATE PLANT.

1 foreman	per shift	$3.00 per day, per 3 shifts	$ 9.00
6 labourers	per shift	$2.00 each per day, per 3 shifts	36.00
1 superintendent		$4.00 per day	4.00
1 extra labourer		$2.00 per day	2.00
1 master mechanic		$3.50 per day	3.50

Total daily wage....................$ 54.50

Total wages per year of 365 days............. =$19,892.50

POWER PLANT.

1 engineer	per shift	$3.50 per 3 shifts	$ 10·50
1 assistant	per shift	2.00 "	6.00
1 electrician	per shift	3.50 "	10.50
1 assistant	per shift	2.00 "	6.00

Total daily wages....................$ 33.00

Total wages per year of 365 days..........12,045.00

Interest and Amortization

It will be assumed that the plant will be amortized in 20 years.

Interest at 6% on items (i, ii, iii, iv, v, vi, vii, viii, x) = $11,904.00 (e).

Interest and amortization on item ix is included in the cost of manufacturing sulphuric acid.

Amortization at 5% on items (i, iii, v, vi, vii, viii) = $7,480.00 (f) = e + f = 11,904 + 7,480 = $19,384.00.

(a)	Interest and amortization	$ 19,384.00
(b)	Labour, gas and sulphate plant (in round numbers)	19,900.00
(c)	Manager and clerks	4,000.00
	Chemists—1 chief and 1 assistant	1,800.00
	Lubricants, etc.	1,700.00
	Sundry stores	2,400.00
	Repairs	3,000.00
	General expenses	5,000.00
(F)	Fuel, 60,000 tons of 30% moisture peat at $1.50 per ton	90,000.00

ASSUMPTIONS.

SUMMARY OF COSTS.

1.	Calorific value of 1 lb. of absolutely dry peat	9,000 B.T. units.
2.	Efficiency of producer	70 per cent.
3.	Heating value of gas per cu. ft.	140 B.T. units.
4.	Steam required per lb. of absolutely dry fuel gasified	2 lbs.
5.	Steam supplied by recuperation per lb. of dry peat	1 lb. at 5 lbs. gauge pressure.
6.	Efficiency of steam generator	70 per cent.
7.	Efficiency of ammonia recovery process	70 per cent.

QUANTITIES OBTAINED.

1. Heat entering into gas per lb. of fuel gasified, $9{,}000 \times 0 \cdot 7 =$ 6,300 British thermal units.
2. Quantity of gas per lb. of dry peat gasified $= \frac{6{,}300}{140} = 45$ cu. ft.
3. Quantity of gas required to raise 1 lb. of steam at 5 lbs. gauge pressure $= \frac{1{,}130}{140 \times 0 \cdot 7} = 11 \cdot 5$ cu. ft.
4. Quantity of gas per lb. of dry peat available for power or other purposes $= 45 - 11 \cdot 5 = 33 \cdot 5$ cu. ft.
5. Total quantity of gas per ton of absolutely dry peat $= 45 \times 2{,}000 = 90{,}000$ cu. ft.
6. Total quantity of gas per ton of absolutely dry peat available for power or other purposes, $33 \cdot 5 \times 2{,}000 = 67{,}000$ cu. ft.
7. Heating value of total quantity of gas generated per ton of absolutely dry peat, $90{,}000 \times 140 = 12{,}600{,}000$ B.T. units.
8. Heating value of available gas per ton of absolutely dry peat gasified, $67{,}000 \times 140 = 9{,}380{,}000$ B.T. units.
9. $(NH_4)_2SO_4$ per ton of absolutely dry peat with (X) per cent nitrogen $= 2{,}000 \times 0 \cdot 7 \times 4 \cdot 71 \times \frac{X}{100} = \underline{65 \cdot 94X}$
10. H_2SO_4 required per ton of sulphate, $1 \cdot 1 \times 65 \cdot 94X = \underline{72 \cdot 53X}$
11. Gross receipts from sale of sulphate per ton of dry peat gasified $= \frac{65 \times 65 \cdot 94X}{2{,}000} = \underline{\$2.143X}$

    (65 = market price of ammonium sulphate in dollars.)
12. Cost of H_2SO_4 required $= \frac{8 \times 72 \cdot 53X}{2{,}000} = \underline{\$0 \cdot 29X}$

    (8 = cost of H_2SO_4 per ton in dollars.)

13. Cost of packing and bagging per ton of sulphate at $1\frac{1}{2}$ dollars per ton $= \dfrac{1.5 \times 65{\cdot}94\,X}{2{,}000} = \underline{\$0{\cdot}0495X}$

14. Net return from sulphate exclusive of fuel and operating costs $= 2{\cdot}143 - (0{\cdot}29 + 0{\cdot}0495)\,X = 1{\cdot}8X$

15. Total cost per ton of absolutely dry peat gasified,

$$\frac{(a + b + c) + BF}{42{,}000} = \left\{\frac{A + BF}{F}\right\} = \$3{\cdot}50 \quad (1)$$

A = items a + b + c.
F = quantity of dry peat in tons.
B = cost of fuel per ton.

16. Net costs per ton of absolutely dry peat gasified,

$$\left\{\frac{A + BF}{F}\right\} - 1{\cdot}8X \qquad (2)$$

$$= 1{\cdot}8\left\{\frac{A + BF}{1{\cdot}8F} - X\right\} = 3{\cdot}50 - 1{\cdot}8\,X = \$1{\cdot}8\ (1{\cdot}94 - X)$$

17. Net Cost of Available Gas per 1000 cu. ft.

$$1{\cdot}8\left\{\frac{\dfrac{A + BF}{1{\cdot}8F} - X}{67}\right\} = 0{\cdot}0268\left\{\frac{A + BF}{1{\cdot}8F} - X\right\} \qquad (3)$$

$$= \$0{\cdot}0268\ (1{\cdot}94 - X)$$

18. Net Cost of Gas Required to Produce One B.H.P. Year with a Gas Engine.

1. Total quantity of heat available for power per ton of fuel, = 9,380,000 B.T.U.

2. Heat consumption of gas engine per B.H.P. hour, = 10,000 B.T.U.

3. Capacity of plant 5 tons of dry peat per hour.

4. Total quantity of heat available for power per hour 9,380,000 × 5 B.T.Units.
Power available:—

$$\frac{9,380,000 \times 5}{10,000} = 4690 \text{ B.H.P. hours.}$$

Capacity of plant will be assumed to be 4,000 B.H.P. Cu. ft. gas per B.H.P. year on this basis will be:—

$$\frac{10,000 \times 350 \times 24}{140 \times 1,000} \times \frac{4,690}{4,000} = 704 \text{ thousand cu. ft.}$$

Cost of gas per B.H.P. year.

$$(4) \quad 704 \times 0{\cdot}0268 \left\{\frac{A + BF}{1{\cdot}8F} - X\right\} = 18{\cdot}9 \left\{\frac{A + BF}{1{\cdot}8F} - X\right\} = \$18{\cdot}9\,(1{\cdot}94 - X)$$

19. Net Cost of Producing One B.H.P. Year:—

Normal capacity of plant........	4,000 B.H.P.
Capital cost of power plant.................	$300,000.00
Interest and amortization 11%..............	$ 33,000.00
Labour and attendants per year of 365 days..	12,040.00
Lubricants, etc............................	1,500.00
Repairs	4,000.00
Total	$ 50,540.00

Costs per B.H.P. year exclusive of cost of gas:

$$\frac{50,540}{4,000} = \$12.63$$

Net cost per B.H.P. year for any load factor expressed by the equation:

$$\frac{1}{C}\left[1263 + 1890 \left\{\frac{A + BF}{1{\cdot}8F} - X\right\}\right] \qquad (5)$$

When C = load factor[1] in per cent,
and X = nitrogen content of absolutely dry peat in per cent.

When the load factor is 100 per cent and the operating costs and fixed charges (A) and the cost of fuel (B) and quantity (F) are as stated for the case described this equation becomes:

$$18\cdot9 \quad (2\cdot61 - X) \qquad (6)$$

If all the factors are varied, viz., the cost of plant, hence operating and fixed costs of both the producer and power plants and the cost and quantity of fuel; the cost of generating one B.H.P. year may be expressed by the following equation:

$$\frac{100}{C}\left[A' + 18\cdot9 \quad \left\{\frac{A + BF}{1\cdot8F} - X\right\}\right] \qquad (7)$$

In this equation A′ = the fixed and operating costs on the power plant.
C = load factor in per cent.
A = fixed and operating costs on producer and sulphate plant.
[2]F = quantity of absolutely dry peat in short tons per year.
B = cost in dollars per ton.
X = nitrogen content of absolutely dry peat in per cent.

Price of sulphate assumed to be 65 dollars per ton.

The second member of equation (7), viz., $18\cdot9\left\{\frac{A + BF}{1\cdot8F} - X\right\}$ represents the cost of the required quantity of gas to produce one B.H.P. year when the plant is operating at full load. And when this is divided by the number of thousand feet of gas required for this purpose the expression becomes the cost of 1,000 cubic feet of gas. If this now be multiplied by the number of thousand feet of available gas produced by gasifying one ton of theoretically dry peat, viz., 67, the expression becomes

---

[1] Load factor is here taken as the average yearly load divided by the number of hours the plant is in operation (350 days per year).

[2] F in all cases is 42,000 tons of absolutely dry fuel per year. That is, the plant is assumed to operate at full capacity, viz., 120 tons of dry fuel per day for the year.

1·8 (1·94 — X), which is the cost per ton of absolutely dry peat gasified and the net cost of recovering the ammonium sulphate obtained from one short ton of absolutely dry peat.

From equations (5) and (6) it will be seen that when X is equal to 1·94 the cost of 1,000 cubic feet of gas, and the cost of recovering or manufacturing sulphate of ammonia is zero, and that when X = 2·62, equation (6), the cost of productng one B.H.P. year at full load is zero.

The effect produced on the cost of power by an increase in the nitrogen content of the fuel is clearly shown in Fig. 33. Fig. 34 shows the effect on the cost of power produced by burning peat costing from 50c to $3.50 per ton and with nitrogen contents varying from 0·2 per cent to 2·6 per cent. The variation in the cost of sulphate and one thousand cubic feet of gas caused by a variation in the cost of peat per ton is clearly shown in Fig. 35.

In the foregoing estimate of cost of plant, the land on which the power plant is erected is not taken into consideration, since in any case it will have to be built on or near a bog, very probably located some distance from thickly settled districts, consequently the cost of such land will be inconsiderable. The general results as outlined will, therefore, not be affected to any appreciable extent by leaving out of the calculation this comparatively small item. As a matter of fact the plant would, of necessity, be situated on or near the bog purchased for the supply of peat fuel, and it would make but little difference whether the manufacture of peat fuel is considered as a part of the general plant or a subsidiary industry run as a separate company.

MANUFACTURE OF PEAT FUEL.

In order to supply 42,000 tons of absolutely dry peat, or 60,000 tons of 30 per cent moisture peat per year, would require a peat manufacturing plant of large capacity operating on a bog of considerable area. For the purpose under consideration, the bog, it will be assumed, has an area of 1,000 acres, and the length of the season during which manufacturing operations can be conducted will be taken as 100 days.

The quantity of 30 per cent moisture peat that must be

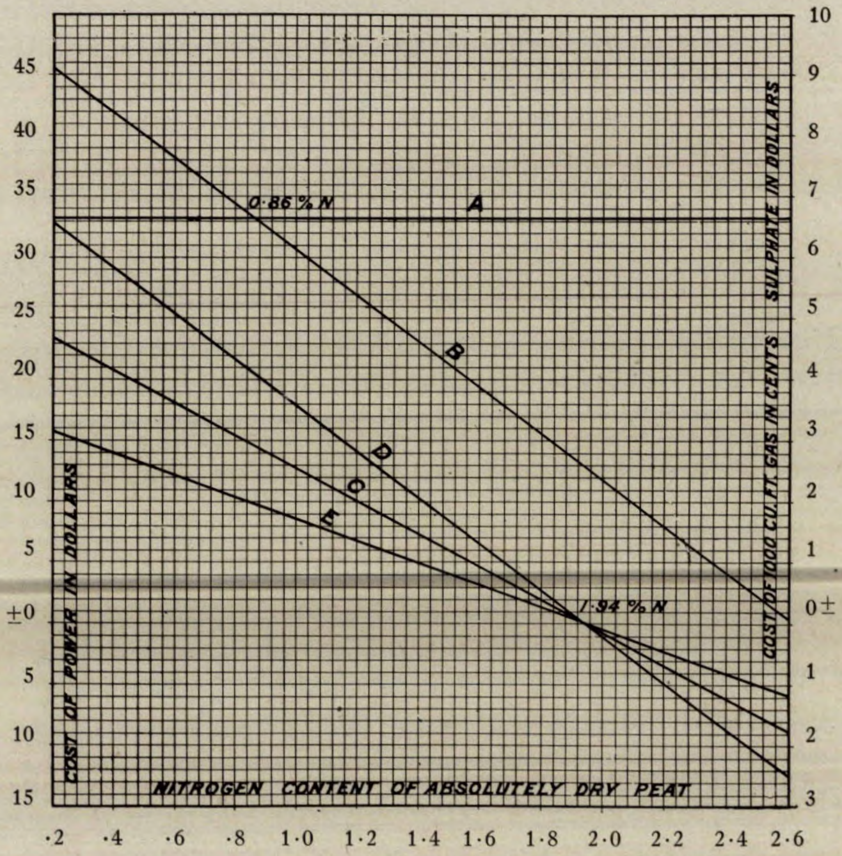


FIG. 33.—Curves illustrating effect of increase of nitrogen content on cost of generating power from peat.

A Cost of producing One B.H.P. Year With Non-By-Product Recovery Peat Producer Gas Plant.

B Cost of producing One B.H.P. Year With By-Product Recovery Peat Producer Gas Plant.

C Cost of producing 1000 Cu. Ft. of gas With By-Product Recovery Peat Producer Gas Plant.

D Cost of producing Gas for one B.H.P. year With By-Product Recovery Peat Producer Gas Plant.

E Net cost of recovering Ammonium Sulphate per ton of Absolutely Dry Peat gasified.

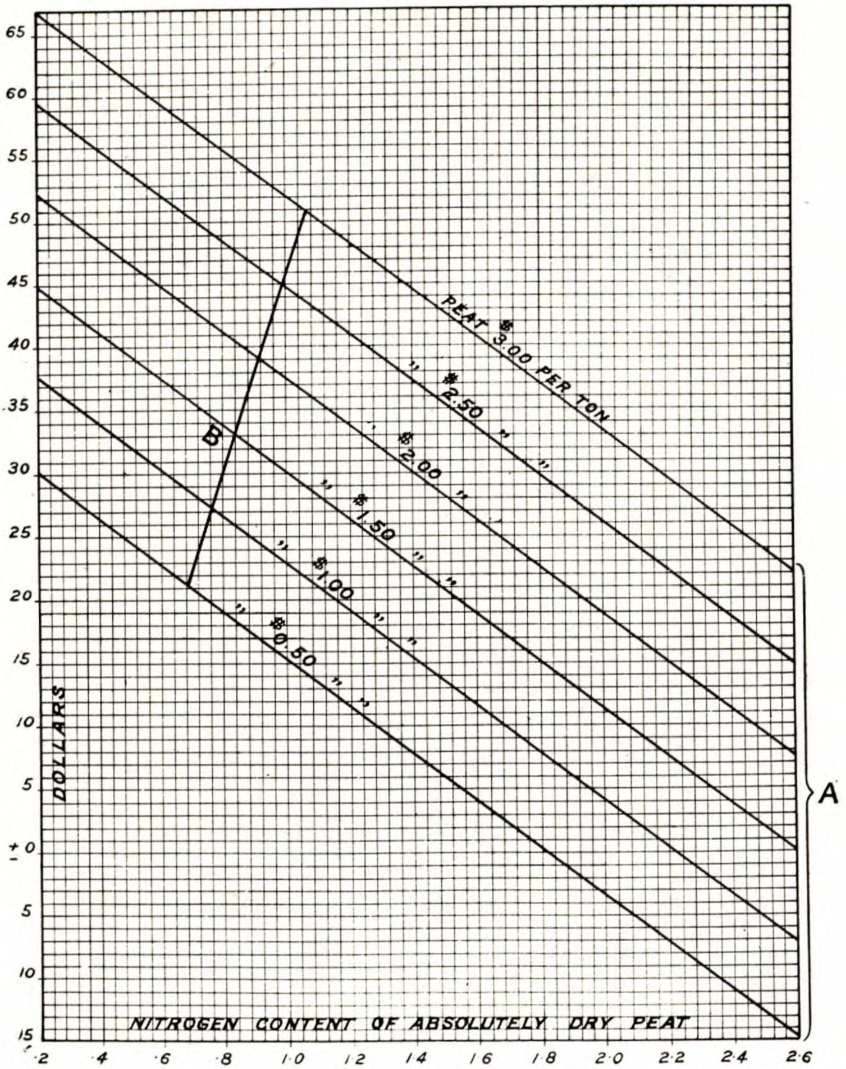


FIG. 34.—Curves A show the effect of increase of fuel costs on cost of power. Curve B shows the nitrogen the fuel must contain in order to permit by-product recovery plant to compete with non-by-product recovery producer gas power plant.

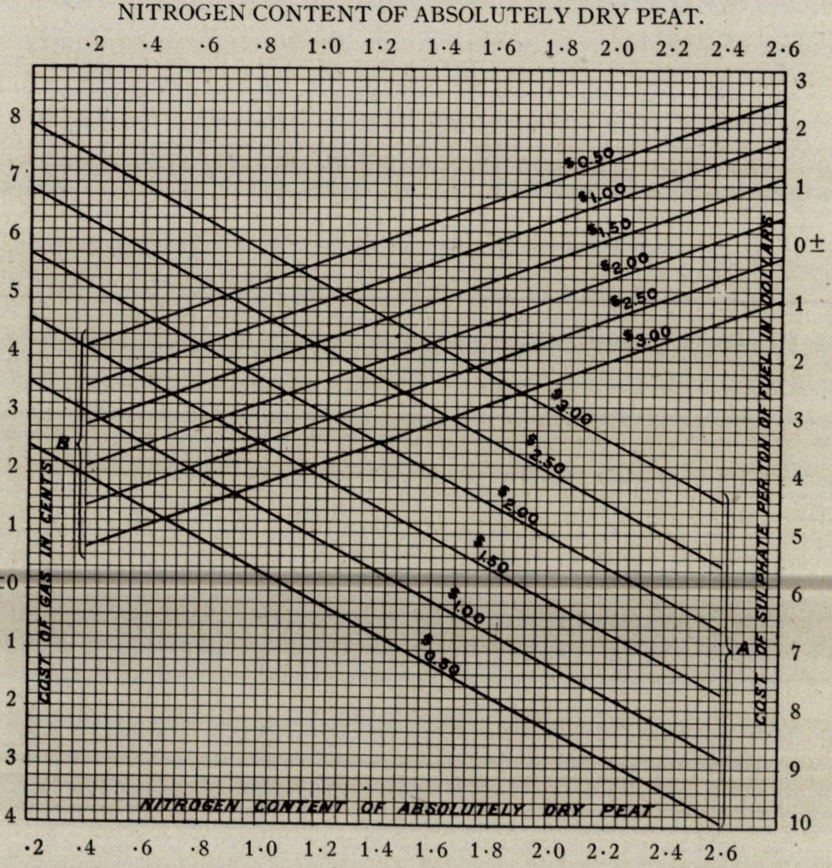


FIG. 35.—Curves A showing cost of 1000 cu. ft. gas when peat costs $0.50 to $3.00 per ton.
Curves B showing cost of sulphate when peat costs $0.50 to $3.00 per ton.

manufactured per day of ten hours is 600 short tons. If one peat manufacturing unit, equipped with mechanical excavator and other labour saving devices, is assumed to have a daily capacity of 60 tons of finished peat fuel, then ten such units will be required to manufacture the requisite quantity of fuel, viz., 600 tons per day. If on the other hand the units are operated for two ten hour shifts, then five units will be sufficient to produce the required daily tonnage. If the five unit system is employed the cost of the peat fuel will be decreased by an amount proportional to the interest, amortization, and depreciation on the capital cost of the extra five units. To be on the conservative side, however, the larger number of units will be considered.

Capital Cost of Peat Manufacturing Plant.

Peat bog, 1,000 acres at $10 per acre	$ 10,000.00
10 peat manufacturing units complete with conveyer system, automatic spreaders, etc.	120,000.00
2 peat sheds of 2,000 tons capacity each	10,000.00
Locomotives, tracks, etc	10,000.00
Portable transmission line to cover entire field of operation	10,000.00
Draining and preparing bog for manufacturing peat	10,000.00
Ten houses for boarding and lodging 140 labourers	20,000.00
Total	$190,000.00

Labour, Management, and Other Costs.

140 men at $2 per day for 100 days	$28,000.00
1 manager at $1,800 per year	1,800.00
2 superintendents at $5 per day	1,000.00
Power, 500,000 H.P. hours at ·005 cents a H.P. hour	2,500.00
Lubricants, etc.	3,000.00
Repairs	6,000.00
Interest, amortization, and depreciation on capital	26,600.00
Total	$68,900.00

Quantity of fuel manufactured 60,000 net, of run 30 per cent moisture peat.

Cost per ton $\frac{68,900}{60,000}=\$1.15$. Cost of peat per ton, \$1.15.

The above cost of \$1.50 per ton delivered at the producers is considered a very conservative figure when operations are conducted on a scale as large as that outlined above. Actual operations might demonstrate that this cost can be materially reduced.

The cost of the entire equipment, including gas producer, power and peat getting plant, the writer believes is on the high side, and that the probable results are, therefore, conservative.

In light of the results obtained in Germany on the Wiesmoor, no serious trouble should be encountered in the storing of even this large quantity of peat fuel.

No mention was made concerning the utilization of the heat of the engine's exhaust for steam raising, that this would be done was taken for granted. Too much stress cannot be laid on the importance, and even necessity, of introducing every possible economy into the operation of a plant of this description. The fuel must be handled mechanically, if possible, from the field to the producer bunkers, and all unnecessary labour dispensed with.

Since 60,000 tons is the net quantity of fuel required to operate the plant 350 days at full capacity, a larger quantity of fuel must be manufactured to provide a margin for unforeseen contingencies. The peat manufacturing units, it is assumed, are capable of meeting this extra requirement.

A sulphuric acid plant would have to be built in almost any case, since this commodity if bought in quantities from some independent manufacturer and transported to the power plant at the bog would prove too expensive when the operations are conducted on so narrow a margin. The writer believes that sulphuric acid can be manufactured for the price stated above, viz., \$8 or less in almost any place in Eastern Canada favourably situated with respect to railway or water transportation.

The costs of plant, operation, management, etc., which the writer believes are quite liberal, cannot be taken as being exact. They are approximate and are only intended to serve the purpose of pointing out the probable use to which some of the Canadian peat bogs might be put. Every locality, where the erection of such a plant is contemplated, must be studied separately, since no definite costs and probable profits can be stated to cover all cases, moreover, the costs of such a plant manufactured either in England or Canada must be obtained from the builder.

The minimum capacity of the plant should not be under 100 tons of absolutely dry peat per twenty-four hours. Owing to the high plant and operating costs in this country a plant of smaller capacity would not prove profitable except in cases where the content of nitrogen is very high. An increase in the nitrogen content of the fuel will, of course, permit a further reduction in the cost of generating power and thereby make a plant of smaller daily capacity a profitable venture, in fact there are cases where a satisfactory profit could be made on the manufacture of ammonium sulphate alone. The minimum nitrogen content with which satisfactory results can be obtained may be put at 1·5 to 1·75 on the absolutely dry sample. There are several bogs suitable for the manufacture of fuel which contain 2 per cent nitrogen and over, but the larger number of such bogs contain a considerably less amount.

UTILIZATION FACTOR.

In the above estimate of the cost of producing one kilowatt and one horse power year the ratio of the average yearly load to the installed capacity of the plant, i.e., its ulilization factor, was not taken into consideration. The maximum efficiency of a gas engine installation is realized when the engines are operating at full load, and for this reason, it was assumed for purposes of arriving at a probable cost of generating power, that the power plant would operate continuously at full load. This will never be the case in practice unless the load is so arranged that the gas engine units will carry the constant portion and the variable or peak portion is carried by an auxiliary steam unit or extra gas engine units, or else the entire output is sold en bloc and retailed by the purchaser.

Certain kinds of work require a uniform load during several hours of the day while others will take a uniform load during 24 hours. But there are other demands for power, and these are in the majority, which are fluctuating.

In order, therefore, to meet the various demands made on the plant and at the same time operate the gas engine units at their full rating, an auxiliary steam plant seems advisable. This auxiliary plant should preferably be a steam turbine. On account of the great flexibility of steam engines in general, but especially of steam turbines, the momentary load carried may be far in excess of the rated capacity of the machine. One such unit might, in all probability, be sufficient to meet the peak demands on the plant.

A steam boiler will also have to be provided and this should be, preferably, gas fired.

The gas for this purpose might be generated in a spare producer unit, which can lie over during the greater part of the day. The consumption of fuel in such a case would not be considerable during the stand-by. The advantage of this method of firing the boiler is the recovery of the nitrogen of the peat burned when the steam plant is in operation, which would be lost if the peat were burned directly under the boilers. A sufficient quantity of gas for keeping the boiler in steam during idle periods might be obtained from the general gas plant.

A load factor less than unity will considerably increase the cost of power. Thus a load factor of 50 per cent will increase the cost of generating a horse power year from $12.63 at full load, and when the nitrogen content is 1·95 per cent to $25.20. (See equation 5 page 203).

GENERATION OF STEAM FOR PRODUCERS.

This quantity of steam is very considerable, about 2 lbs. per lb. of dry fuel burned, so that a gasification of 5 tons of absolutely dry peat per hour would necessitate a quantity of steam for the producers alone of about 10 tons. Unless all of the waste heat of the plant is utilized for steam raising, the larger portion of this quantity will have to be raised at the expense of the power gas, which would necessitate a reduction in the power devoloped.

The sources of heat which must be utilized for saturating the air blast and generating live steam are: the sensible heat of the producer gas; heat of boiler flue gases; and heat of the gas engine's exhaust, steam from blower pumps, etc., in addition, the tar resulting from the process must be recovered and burned under the boilers. The introduction of such economies as those enumerated will appreciably increase the over-all efficiency of the plant and render available a larger quantity of gas for power purposes.

Producer Gas for Heating Purposes.

In certain cases it might be advisable to distribute the power gas generated, in mains to nearby manufacturing towns, or cities, for heating and other purposes. Such a disposition of the gas generated is made at the large Mond by-product recovery power gas plant at Dudleyport, Staffs, England. The costs of producing 1,000 cu. ft. of gas are shown on the curves Figs. 34 and 35, for nitrogen contents of the fuel burned varying from 0·2 per cent to 2·6 per cent. This subject will be referred to in detail later.

CANADIAN PEAT BOGS AS A SOURCE OF FUEL FOR THE PRODUCTION OF GAS IN THE BY-PRODUCT RECOVERY POWER GAS PRODUCER.

The results of previous investigations have conclusively demonstrated that peat fuel can successfully compete with coal for the production of power in the non-by-product recovery gas producer, when the cost of coal at the producer is in the neighbourhood of $4 per ton and peat containing 25 per cent moisture costs not more than $2 per ton. This, of course, applies to the utilization of the two fuels in the same manner. When power produced from peat in a power gas plant is compared with that generated from coal in a steam power plant the advantage lies very much in favor of the former. When, therefore, a power plant is required to serve a district where cheap hydro-electric power is not available, such a peat producer gas power plant will economically answer the requirements, provided of course a suitable peat bog is situated within the district in question.

Unfortunately many localities do not exist in Canada where such conditions obtain. In the first place the various Provinces are more or less sparsely settled and in those districts which are thickly populated, and where industries of various kinds abound, water power is available in more or less large quantities. In still other thickly populated districts peat bogs of suitable proportions and quality are not situated within a reasonable distance. The opportunities, therefore, for developing on a large scale such a power plant designed exclusively for the use of peat fuel are not many, since such a power plant, to prove a feasible undertaking, must be able to compete with existing sources of power, and at a profit.

This phase of the utilization of peat can therefore be dispensed with in the consideration of those cases requiring the production of energy on a large scale, even though its successful application might be found in a few isolated cases where small powers are required.

If the cost of generating power with a producer gas power plant can be decreased by any means to such an extent that it is capable of competing successfully with other forms of cheap energy, its field of application will be greatly increased. The hopes of investigators and of those desirous of converting into some useful commodity the immense quantities of peat now lying dormant, were materially raised when the Mond process for the gasification of low grade fuels with by-product recovery was devised. But while this process, when applied to peat fuel, possesses many inherent advantages and does in many cases materially decrease the cost of generating power, its field of application is also limited. The main difficulties encountered in the generation of power in a producer gas power plant may be enumerated as follows: (1) the maximum economy is realized only when the producers and gas engines are operating at their maximum load, and (2) the inability of the gas engine to carry over load. For these reasons a producer gas power plant would not prove suitable for a service subject to extreme variations in the daily loads or where the utilization factor is very low. In the former case the gas engine plant would have to be supplemented by a steam plant which would carry the over load or else the gas engine units would have to be increased out of all proportion to the capacity for which the plant is designed. In the latter case the economy resulting from the use of gas engines would be entirely lost if the load or utilization factor is very much less than unity, since the maximum economy is only realized when the engines are running at their normal rating, and if a large percentage of the power units are lying idle a considerable part of the time, the fixed charges will be too large to permit of the economic production of power. The most desirable and ideal conditions are met with when the load is of such a character that the gas engine installation can operate at full or nearly full load during the greater portion of the day, all excess demands being taken up by either an extra gas engine unit or else an independent steam turbine unit. Another possible but not quite practicable solution to the problem is the installation of a storage battery plant of sufficient capacity to absorb the load when the demand for power is light and of supplementing with this stored energy the power units when the extra or peak demands arise. Such a solution, though it would in almost every way meet the requirements necessary for the most economical operation of a gas engine power plant, would prove impracticable on account of the high initial cost and subsequent upkeep of the storage battery system. This case cannot therefore be considered at this moment.

The advantages, moreover, resulting from the recovery of by-products such as ammonia and tar, are more apparent than real, since the economies resulting from their recovery are dependent on their cost at the plant and their disposal at a reasonable market price. It is quite probable that ammonium sulphate prices will continue firm at existing or higher levels for some time to come, but its cost of manufacture is somewhat uncertain, due to the uncertainty of supplying the raw materials required for its manufacture at a sufficiently low price, and this alone in many localities might militate against its recovery with a reasonable profit. The market for the tar produced is also very uncertain, if it is reduced to pitch by subsequent distillation its market price will be considerably enhanced, but even under these conditions a material of so low a grade cannot stand long haulage. But it is hardly necessary to consider the tar produced as a by-product since in most by-product recovery producer gas plants the tar is burned under the boilers of the plant, and this particularly is the case in the peat burning plants. This then leaves ammonium sulphate as the only by-product recovered which can serve to materially decrease the cost of generating power.

Although plants of this description have been erected for the sole purpose of generating power from peat, only one, to the writer's knowledge, is in successful operation at the present time. The reasons advanced for the failure of the others are not satisfactory, for example, the difficulty of supplying the required quantity of peat with a sufficiently low moisture content and a satisfactory nitrogen content are cited as the cause of failure in one case. The principal cause for the unsuccessful termination of these ventures, is in the writer's opinion, due to the fact that insufficient consideration was given to all the details on which the success or failure of the project depends. Before deciding upon the erection of any power plant for the utilization of peat fuel, full particulars of the bog both physical and chemical should be obtained and fully considered. If this course is followed, a plant will not be erected on a bog unsuitable for the manufacture of fuel and where the average nitrogen content is too low to permit of the profitable recovery of ammonia. It is not difficult to determine whether a bog is suitable or unsuitable for the manufacture of peat fuel and how large a quantity with the desired moisture content can be manufactured during the usual summer season. If the bog be a wet one and difficult to properly drain or its drainage would prove too expensive, then it should be abandoned and a new one searched for. Great care, moreover, should be taken to obtain the most accurate results concerning the average nitrogen content of the entire bog, since any variation will materially affect the financial results it is expected to obtain. After a bog suitable in every respect for the manufacture of peat fuel with the desired nitrogen content has been selected, the conditions governing the sale of electric energy within the region surrounding the bog should be most carefully investigated. If the results of such investigation prove promising the erection of the plant may be safely undertaken. To-day, most of the factors which determine the ultimate success or failure of any enterprise of this description are well understood. The difficulties, e.g., encountered in the manufacture of peat fuel on a large scale are well known as are also the methods of overcoming them, and no mistake should be made concerning the maximum moisture content of the fuel permissible. This phase has been thoroughly investigated and requires no further experimenting. If it be decided, in any case, that the required quantity of fuel with a maximum moisture content of forty per cent cannot be manufactured at a cost of under two dollars per ton delivered at the producers, then the project should be abandoned. See curves Figs. 34 and 35.

As previously stated, there are many bogs suitable in every detail to the manufacture of peat fuel for gasification in by-product recovery producers which are situated in districts already supplied with cheap electrical energy, the utilization of the peat content of such bogs for power purposes is, therefore, manifestly not feasible except in a few isolated cases. The employment of such bogs for the manufacture of an industrial and domestic fuel gas will therefore be discussed. All of the gas manufactured for industrial and domestic purposes in Canada, with the possible exception of coke oven gas, is largely "retort" or "town gas," and this is dependent in the larger number of instances on coking coal imported from the United States. In the manufacture of "town" or "retort" gas only the volatile matter in the coal is gasified, the fixed carbon remaining in the retort as coke. Coke is, therefore, a by-product which meets with a ready market in most large cities and towns, and contributes towards a reduction of the manufacturing costs of the gas. In addition to coke a small amount of ammonia and tar is formed. The maximum quantity of ammonia resulting in any case is only a small percentage of that theoretically possible. The recovery of ammonia does not therefore contribute very considerably towards the economy of the process. The average quantity of retort gas produced per ton of coal (2,240 lbs.) is 11,000 cubic feet or 10,000 cubic feet per short ton (2,000 lbs.), and its average heating value is about 560 British thermal units per cubic foot. In the case of gas generated from peat in a Mond by-product recovery producer the quantity of gas available for power or other purposes produced per ton of absolutely dry peat as shown on page 201 is about 67,000 cubic feet and the heating value may be put at 140 British thermal units per cubic foot. One thousand cubic feet would in this case represent a heating value of 140,000 British thermal units or 25 per cent of the "retort" gas.

The quantities of "retort" gas made from coal and of producer gas generated from peat which are equivalent in heating value to one short ton of coal with a heating value of 12,500 British thermal units per lb. are 45 thousand and 179 thousand cubic feet respectively. 2·67 tons of absolutely dry peat of a heating value of 9,000 British thermal units per lb. would be required to produce 179 thousand cubic feet of gas, and if the cost of peat containing 30 per cent moisture laid down at the producer is $1.50 per ton or $2.13 dollars per ton of absolutely dry peat, the cost of the fuel alone, required to produce 179,000 cubic feet of gas would be $2{\cdot}13\times2{\cdot}67=5{\cdot}70$ dollars; while in the case of "retort" gas 4½ short tons of coal of a heating value of 12,500, or over, British thermal units per lb. would be required to produce 45 thousand cubic feet of gas with a heating value of 560 British thermal units per cubic foot. If the cost of gas-making coal laid down at the gas retorts is assumed to be $2.50 per short ton, the fuel cost alone would be $2{\cdot}50\times4{\cdot}5=11.25$ dollars, about twice as much as with peat. The by-products obtained in the "retort" gas process are coke—principally—ammonia and tar; while in the case of the producer gas plant, ammonia and tar constitute the by-products. The following calculations show the costs of the fuel required in the "retort" process using coal and the "Mond" process using peat to produce a quantity of gas equivalent in heating value to one short ton of coal with a heating value of 12,500 British thermal units per lb. The cost of recovering the ammonia produced with the Mond process is taken from the estimated costs of operating a 120 ton Mond plant burning peat fuel. See page 200.

RETORT GAS.

Products Resulting from the Gasification of one short ton of Coal.

Illuminating gas, 10,000 cu. ft.—heating value 560 B.T.U. per cu. ft. . . . .
Coke 1,100 lbs. about.
Sulphate of ammonia—20 lbs. (nitrogen content of coal 1½%)
Tar.

Fuel Costs.

4½ tons of coal at $2.50 per ton.	$11.25
By credit, gross profit from sale of 4,950 pounds of coke at $5 per ton = $12.37 about and 90 lbs. sulphate of ammonia at $65 per ton = $2.92	$15.30
Net cost of coal, exclusive of manufacturing and other costs.	−$4.05

MOND PRODUCER GAS.

Products resulting from the gasification of one short ton of absolutely dry peat with a heating value of 9000 B.T.U. per lb.

Gas 67,000 cu. ft. heating value 140 B.T.U. per cu. ft.

Sulphate of ammonia—128 lbs. nitrogen content of peat, 1·94 per cent.

Tar.

Fuel Costs.

2·67 tons of absolutely dry peat at $2.13 per ton	$5.70
By credit 2·67 × 128 lbs. of sulphate of ammonia, gross profit from sale of	$11.00
Net cost of fuel, exclusive of manufacturing and other costs.	–$5.30

When operating under the conditions cited on p. 205, viz., peat costing not more than $2.15 per absolutely dry ton, and gasifying at the rate of 120 tons of peat containing 1·94 per cent nitrogen, per day of 24 hours, it is possible to produce the gas free of cost, while the cost of the "retort" gas would include in addition to the net fuel costs, operating and fixed charges, which are very considerable.

Four thousand cubic feet of producer gas would have to be supplied for every 1,000 cubic feet of "retort" gas in order to supply the equivalent heating value.

A producer plant capable of gasifying 120 tons of absolutely dry peat per day would generate 335,000 cubic feet per hour when running at normal capacity. This, however, could be considerably increased for short periods. A plant of this capacity could meet all the requirements, both industrial and domestic, of several towns and villages. The gas could be profitably used for heating houses as well as for supplying the other domestic demands for heat.

In estimating the costs of one or the other plants only the actual cost of the gas plant need be considered, for purposes of comparison, since the gas mains in the one case will serve for the other. If the gas mains are already laid and are designed to transmit town or retort gas, then, since four times the quantity of producer gas must be forced through the mains, the pressure will have to be increased. The Canadian peat bogs, which might be profitably utilized in this manner, are those which have a high nitrogen content in addition to a satisfactory heating value. They must also be situated reasonably near towns or cities of sufficient size to consume all the gas generated. The following bogs will be cited as examples, on account of their satisfactory nitrogen content, to merely point out the possibilities in this direction:—Brockville, Holland, Large Tea Field and Small Tea Field. There are many other bogs suitable for the manufacture of peat fuel but which do not contain a sufficient quantity of nitrogen to render its recovery profitable.

BROCKVILLE PEAT BOGS.

This bog is situated in Elizabethtown township, Leeds county, Province of Ontario, about three miles distant from the town of Brockville. It has a total area of 1,400 acres, but the depth of the peat varies in different portions. If that portion of the bog containing peat with a depth of over 5 feet is taken into consideration, the total workable area is 1,044 acres with an average depth of over 8 feet, and if the peat contained were all manufactured into a fuel with a moisture content of 25 per cent, over 1,500,000 short tons would be rendered available.

The average nitrogen content is 2·41 per cent on the absolutely dry peat or 1·81 per cent on 25 per cent moisture peat. This is a very high nitrogen content and the heating value, 8,170 British thermal units per lb., is quite satisfactory.

The peat fuel which could be obtained from this bog, if it were completely exhausted of its contents, is, as previously stated, over 1,500,000 short tons, or a sufficient quantity to keep a plant of an annual capacity of 47,000 tons of 25 per cent moisture peat fuel, or 50,000 tons of 30 per cent moisture peat fuel, supplied for $\frac{1,500,000}{47,000} = 32$ years. In this particular case the nitrogen content is sufficiently high to permit of a reduction in the capacity of the plant, but for purposes of illustration this will be taken as 100 tons of theoretically dry peat per 24 hours or 50,000 tons of 30 per cent moisture peat per year. The total nitrogen available in the entire bog is $1,500,000 \times \cdot 01807 =$ about 27,000 tons, which theoretically would make about 127,000 tons of ammonium sulphate. The actual quantity it is possible to obtain is $127,000 \times 0 \cdot 7$ or 88,900 tons assuming the ammonium recovery process to have an efficiency of 70 per cent.

The bog will be assumed to be depleted in 20 years, i.e., only $\frac{20}{32}$ of the total available tonnage will be manufactured into peat fuel and at the termination of this period the capitalization charges against the plant will be written off. The ammonium sulphate available on this basis will be $88,900 \times \frac{20}{32} =$ about 55,600 tons, which at a market price of $65 per ton would show a credit of 3,614,000 dollars or $\frac{3,614\ 000}{20} = 180,700$ dollars per year, if the operating and plant costs are assumed to be the same as for the case worked out on page 198.

The probable profits on the recovery of the ammonium sulphate alone would be:

Cost of operation including amortization, depreciation, and interest on entire plant, sulphuric acid, bagging, packing, etc., about	$ 85,870.00
Fuel 50,000 tons with 30 per cent moisture, $1.50 per ton	75,000.00
Total	$160,870.00
By credit ammonium sulphate as per above	180,700.00
Net profit,	$19,830.00
or about	$20,000.00

In this case, also, the gas would cost nothing to produce, the only expense being that incurred in its distribution to consumers, or its conversion into electric energy. A plant capable of gasifying 100 tons of dry peat per day could generate over 3,000 horse power continuously per day of 26 hours. See Figs. 34 and 35 for approximate costs of generating power.

The accompanying map, Fig. 36, shows the situation of the peat bog, with respect to the towns or villages within a radius of 30 miles. The principal towns are: Brockville, Prescott, Smiths Falls, Newboro, Westport, Gananoque, and the two cities on the United States shore of the St. Lawrence river, Morristown and Ogdensburg. Brockville and Prescott are the only two towns which might be supplied with producer gas for domestic, industrial and power purposes.

Brockville	10,000	population.
Prescott	2,800	"

and they are situated within a short distance of the bog. The field, however, for the transmission of electric energy is quite considerable and includes the following cities, towns and villages:

	Population.
Brockville	10,000
Gananoque	3,764
Prescott	2,800
Smiths Falls	6,361
Westport	803
Newboro	469
Kemptville	1,192
Morristown	On the United States side of the St. Lawrence river
Ogdensburg	

in addition to numerous smaller villages and hamlets.

Although the Brockville peat bog cannot supply a plant burning 100 tons of absolutely dry peat per day for a period much exceeding twenty years, such a period should prove sufficient, unless unforeseen difficulties were encountered, to pay off the capital charges in addition to a substantial profit. The land, more-

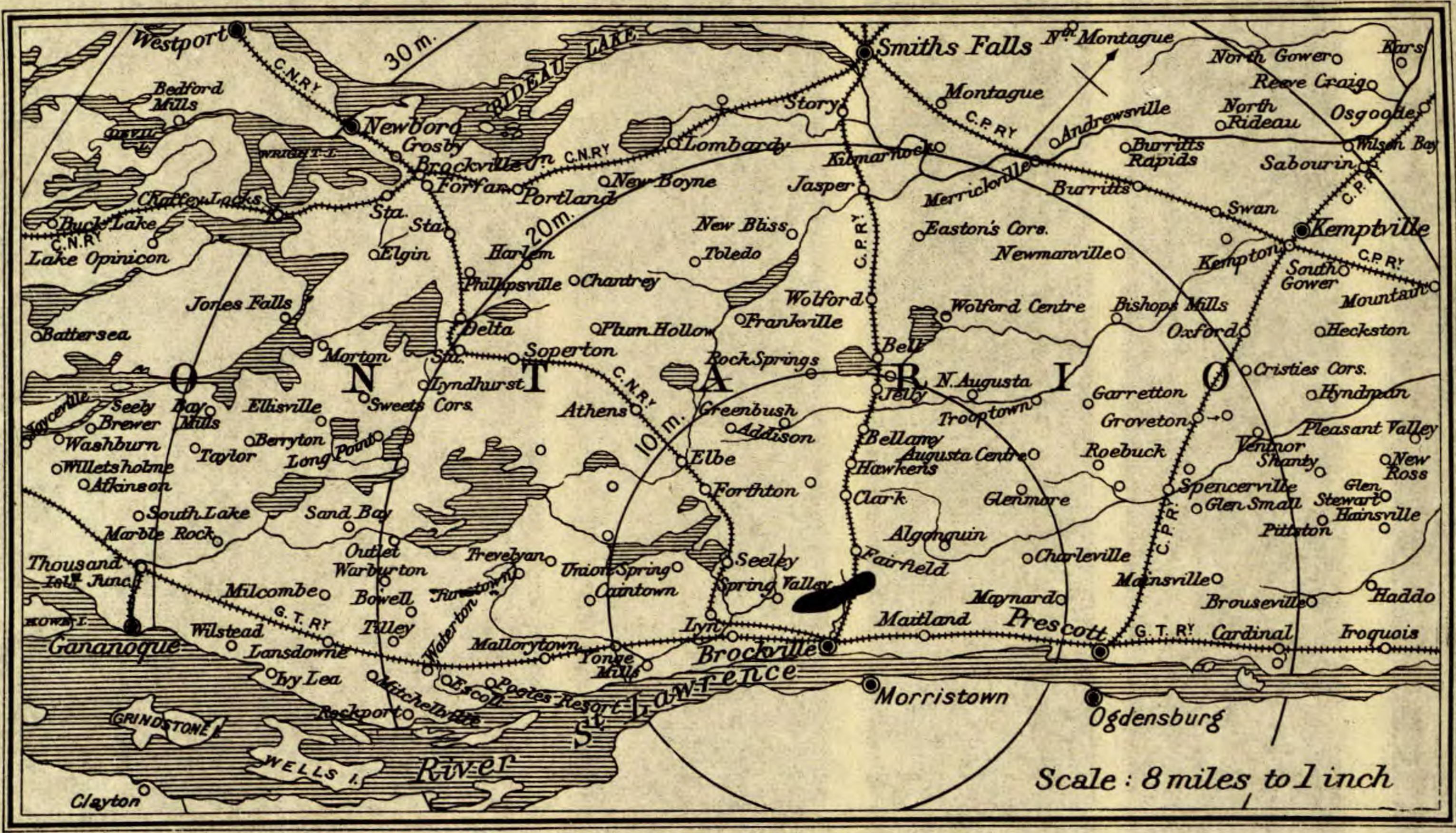


Fig 36. Brockville peat bog, showing towns and villages within a radius of 30 miles

over, left after the removal of the peat, would be available for agricultural purposes, and would sell for a considerably higher price than that originally paid for it.

For the production of power only, plants of much smaller capacity not equipped for the recovery of ammonia, might prove entirely feasible.

LARGE TEA FIELD AND SMALL TEA FIELD PEAT BOGS.

These two bogs are situated in the Province of Quebec, in the county of Huntingdon, township of Godmanchester. The accompanying map shows their position with respect to the cities, towns and villages situated within a radius of 30 miles. The Alfred peat bog, distant about 30 miles, in a northwesterly direction, is also shown on the map. The Large Tea Field bog comprises a total area of 5,268 acres of which the larger portion is suitable for the manufacture of peat fuel. The total quantity of 25 per cent moisture peat which can be obtained from the workable portion is over 4,800,000 tons and the average nitrogen content and heating value are 1·8 per cent and 9,300 B.T.U. per lb. respectively. This quantity of fuel would supply a plant burning 120 tons of theoretically dry peat per day of 24 hours for a period of $\frac{4,800,000}{120 \times 350} \times \frac{75}{100} = 86$ years. The total quantity of ammonium sulphate which could be recovered during this period would be:

$$4,800,000 \times 0{\cdot}75 \times 0{\cdot}018 \times 4{\cdot}71 \times 0{\cdot}7 = 213,600 \text{ tons or } \frac{213,600}{86} = 2,480 \text{ tons per year.}$$

The power gas available would be sufficient to produce 4,000 horse power continuously for the above period of 86 years or a total of 4,000 × 86 = 344,000 horse power years. The net cost of the gas, under the conditions cited on p. 202 would be as follows:

Operating costs, including fixed charges, sulphuric acid, bagging, sulphate, etc.	$82,800.00

60,000 tons of 30 per cent moisture peat fuel at $1.50 per ton	$ 90,000.00
Total costs	$172,800.00
By credit 2,480 tons of ammonium sulphate at $65 per ton	$161,200.00
Net cost of gas produced per year	$11,600.00

The effect which a decrease in the nitrogen content of the fuel has upon the profit or loss for a year's operation is readily seen by comparing the net cost of the gas in this case with that obtained for the Brockville bog. In the latter case the year's operations resulted in a profit in addition to the gas produced which cost absolutely nothing. In the former case owing to a reduction in the nitrogen content of the fuel of only 0·6 per cent, the year's operations, under precisely similar conditions as regards cost of fuel, plant, labour, etc., results in a net cost of the gas produced of about $11,600.

Since the production of available gas from one ton of theoretically dry peat when burned in a Mond producer, is about 67,000 cubic feet with a heating value of 140 B.T.U. per lb., the cost to manufacture 1,000 cubic feet will be $\frac{11{,}600}{67 \times 42{,}000} = 0{\cdot}00412$ dollars or 0·40 cents, which however is low.

SMALL TEA FIELD PEAT BOG.

This bog is situated only a short distance from the Large Tea Field just described and comprises a total area of 4,190 acres. From that portion suitable for the manufacture of peat fuel about 3,300,000 tons, containing 25 per cent moisture, can be manufactured. The average nitrogen content is about 1·85 per cent and the heating value 9,200 B.T.U. per lb.

The Big Tea Field and Little Tea Field peat bogs should be taken as one if the erection of a Mond by-product recovery producer gas plant for the utilization of peat is considered at this place.

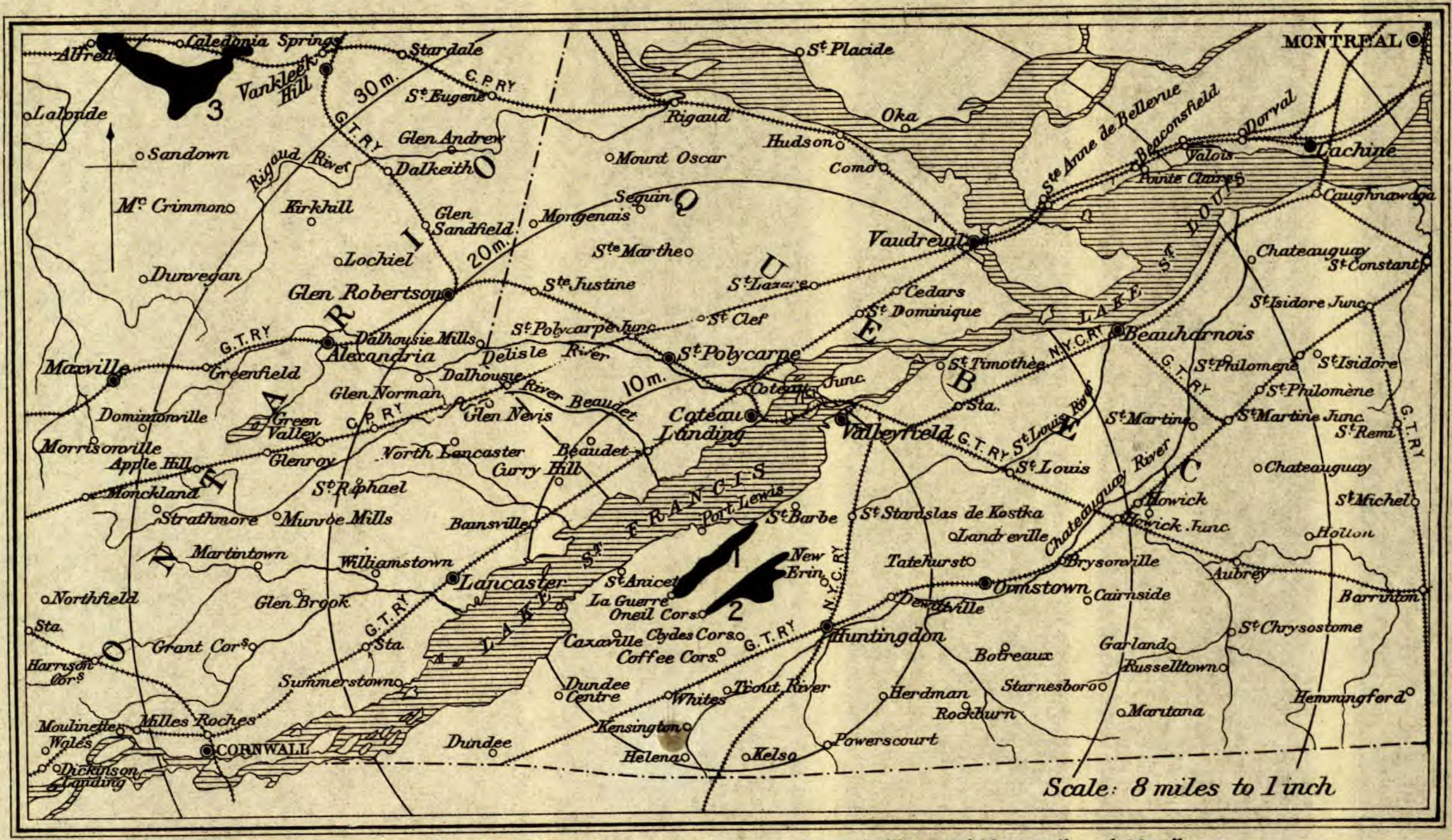


Fig. 37. Large and Small Tea Field peat bogs, showing towns and villages within a radius of 30 miles.

No. 1 Small Tea Field peat bog : No. 2 Large Tea Field peat bog : No. 3 Alfred peat bog

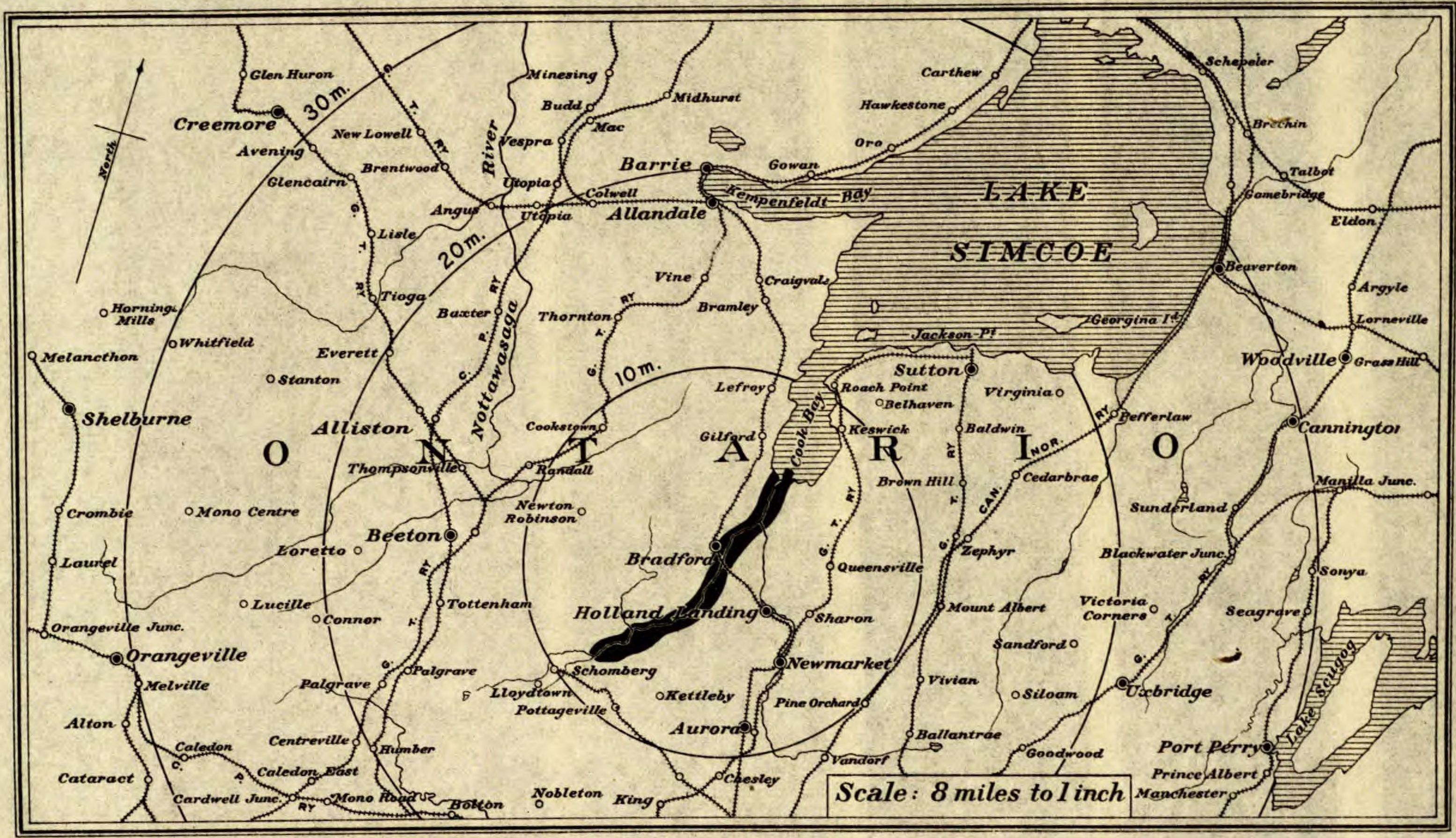


Fig. 38. Holland peat bog, showing towns and villages within a radius of 30 miles

By referring to the map, Fig. 37, of the district including these bogs it will be seen that several large towns are situated within a comparatively short distance of the bogs. The larger cities and towns are: Valleyfield, Huntingdon, Ormstown, and Beauharnois, in addition to numerous villages and hamlets. Montreal and Vaudreuil are about 30 miles distant.

HOLLAND PEAT BOG.

This bog is situated in West and East Gwillimbury and King townships, Simcoe and York counties, Ontario, and runs in a north and south direction. The total area comprises about 14,600 acres but of this 9,000 acres has an average depth of about 3 feet and is consequently too shallow to permit of the economical manufacture of fuel. The remaining portion of about 5,000 acres has an average depth of over 12 feet and is suitable in every way for the manufacture of fuel. Mechanical excavators can be employed to good advantage owing to the freedom from roots and burned stumps and logs. A thorough drainage of the bog would involve a large expenditure of money on account of its low situation and owing to the fact that it is flooded in the spring time. However, a thorough drainage would eventually prove to be a profitable proposition since the value of the land, which in its present condition is very low, would be considerably increased, and, moreover, the entire farming country surrounding the bog would be greatly improved.

The total quantity of peat containing 25 per cent moisture which could be manufactured is 8,218,000 tons. The nitrogen content is also very high, averaging about 2·5 per cent. The heating value per lb. of absolutely dry peat is rather low, ranging from 6,700 to 8,300 British thermal units per lb. But in that portion of the bog which has a considerable depth the heating value averages over 8,000 British thermal units per lb. which is quite satisfactory.

The total quantity of nitrogen available is: $8{,}218{,}000 \times \cdot 025 \times 0\cdot 75 = 154{,}000$ tons, which would theoretically make $154{,}000 \times 4\cdot 71 = 725{,}000$ tons of ammonium sulphate or $725{,}000 \times 0\cdot 7 = 507{,}500$ tons when the efficiency of the recovery process is taken into consideration. Practically the whole of the 8,218,000 tons of peat could be manufactured into a fuel and the above quantity of nitrogen recovered, but this would mean the utilization of the entire quantity in a by-product recovery producer. A plant buring 120 tons of theoretically dry peat per day of 24 hours or 42,000 tons per year of 350 days could be supplied with fuel for a period of $\frac{8,218,000 \times 0\cdot 75}{42,000}$ = about 147 years. The annual production of ammonium sulphate would amount to approximately $\frac{507,500}{147}$ = 3,460 tons, which at a market price of $65 per ton would represent gross receipts of 3,460×65 = 225,000 dollars.

If the plant and operating costs are assumed to be the same as for the two preceding cases the net annual profit would be:

Operating costs, including fixed charges, sulphuric acid, etc., about	$100,000.00
60,000 tons of peat containing 30 per cent moisture at $1.50 per ton	90,000.00
Total costs	$190,000.00
By credit 3,460 tons of ammonium sulphate at $65 per ton	225,000.00
Net profits	$35,000.00

This would amount to considerably more than 10 per cent net on the capital invested in the by-product recovery producer gas plant. Cases of so high a nitrogen content are rare and this bog should prove a most excellent one for the exploitation of such a process for the development of an industrial and domestic fuel gas or a power gas.

The area covered by the Holland bog is greater than that being put under cultivation at the Wiesmoor in Ostfriesland, Germany, and a scheme similar to that employed in Germany for putting the waste lands under cultivation should prove feasible here. The power developed at a central station could be utilized for putting the bog in a condition fit for agricultural purposes and afterwards for farming. In the case of a power plant of the capacity outlined a large amount of energy would still be unused after all the demands for farming and preparing the bog were satisfied. This surplus energy could be transmitted to the surrounding towns and villages, and even to Toronto, some 42 miles distant, where it would be in demand for industrial purposes. The accompanying map, Fig. 38, shows the location of this bog with respect to the towns and villages situated within a radius of 30 miles. Toronto is not shown on the map.

The Holland bog is excellently situated with respect to railway facilities, the Grand Trunk, and Canadian Pacific railways passing within short distances.

CHAPTER VII.

LIGNITE.

Notwithstanding the existence of enormous deposits of coal in the extreme eastern and western portions of Canada, certain of the Provinces are dependent on foreign sources for their supply of coal for industrial and other purposes. This is especially true of portions of the western Provinces, where large deposits of lignite coal are found close to cities, towns, or villages. For certain purposes the lignite coals of the Provinces of Manitoba, Saskatchewan, and Alberta cannot be used at all. For example, its use for firing locomotives has been strictly forbidden by the Railway Commission of Canada, owing to its property of emitting dangerous sparks. For domestic purposes it has been used with more or less success, but for even this purpose it proves but a poor substitute for the anthracite coal, to which all are accustomed, and, for the use of which, almost every domestic stove has been specially designed. In order to render this fuel in some form suitable for locomotive and domestic purposes, it must be modified in some manner by previous treatment, and then briquetted. It is along this line that the attention of certain investigators has been directed, but up to the present time the results of their labours cannot be said to be entirely satisfactory. Other methods must, therefore, be found for utilizing lignite coal, which will render, at least to some extent, these Provinces independent of foreign sources of fuel. Every community of any size is to-day dependent on electricity for lighting and power purposes, and almost every city and many towns possess a gas plant for the manufacture of an illuminating and domestic fuel gas. The use of city (retort gas) for cooking is increasing at a rapid rate, even though all the coal required for its manufacture is imported from some foreign source. If, therefore, lignite could be successfully substituted for these two purposes, viz., the production of power and a fuel gas, those portions of Canada which are well supplied with this fuel would be rendered independent to a very large extent of foreign supplies of coal.

It has been shown in the previous chapters of this report that peat can be successfully utilized not only for generating steam, but also power and fuel gas, and an instance has been cited where such gas generated from low grade coal is used for various industrial purposes, and there is no reason why lignite should not prove equally satisfactory for such purposes. In order to determine the value of some of the western lignites as a fuel for the production of a power gas in a non-by-product recovery gas producer, tests were made with commercial samples taken from five producing mines, and the results obtained demonstrated that lignite coal could be efficiently utilized for such purposes. Where cheap hydro-electric energy is not available—and this is the case in Edmonton and vicinity—power can be profitably generated from lignite in the manner above stated. But certain of the lignites, so far examined, contain comparatively large amounts of nitrogen, and this is too valuable to lose. The recovery of the nitrogen content of the lignites as ammonium sulphate, wherever possible, would prove of great value to those sections of the Provinces depending almost entirely on the productiveness of agricultural land for their wealth. This reason for the necessity of recovering the nitrogen content of fuels may not be apparent at the present time, but the productiveness of the virgin soil, which is now very satisfactory will, in time, decrease, and then some sort of artificial manure will have to be employed. If, however, the immediate need for artificial fertilizers is not yet apparent, such nitrogenous compounds as are recovered from the gasification of lignites can easily be disposed of, either in the western Provinces or in the United States or Japan. The profits resulting from its sale would, in any case, tend towards a reduction in the manufacturing cost of the gas, and consequently the power generated—and since the generation of power and an industrial fuel gas are the main objectives to be considered, everything which will contribute towards a reduction of their cost should be taken advantage of.

The municipal power plant at Edmonton, which consists of several steam power units and one producer gas power unit, uses almost exclusively the lignite coal from the mines in the near vicinity. In this case the most satisfactory results are obtained with the producer gas power plant, notwithstanding the exceedingly high capital charge against it. The type of producer installed is, however, not entirely suitable for burning lignite, and much better results might be looked for with a properly designed power gas plant.

Of the five samples of lignite received at the Fuel Testing Station and which were submitted to a thorough investigation, one is especially satisfactory as regards its nitrogen content. The Gainford lignite contains 1·6 per cent of nitrogen in the moist sample, that is, in the coal as it was received at the plant. The analyses, both proximate and ultimate, are contained in the following table.

TABLE 20.

Chemical Analyses of Lignites from Alberta and Saskatchewan.

	Tofield.	Gain-ford.	Rose-dale.	Cardiff colliery.	Twin City.	Souris, Sask.
Moisture	25%	17·0	16·5	20·0	18·1	29·7
Fixed carbon	36·7	43·8	43·4	40·4	41·3	49·6
Volatile matter	29·8	30·8	33·6	31·6	33·3	44·5
Nitrogen	0·9	1·6	1·3	1·2	1·1	1·3
Sulphur	0·3	0·6	0·4	0·2	..	0·6
Ash	8·5	8·4	6·5	8·0	7·3	12·4
Calorific power	7990 B.T.U.	9040	9650	8767	9685	10170 dry coal

When considering the possibility of developing power in the manner outlined above, the fact that the cost of labour and plant, together with the cost of manufacturing sulphuric acid, are considerably higher than in the eastern sections of Canada must be given prominent attention. The cost of plant delivered on site at Edmonton or vicinity should not be much in excess of a similar plant laid down in the Eastern Provinces since the shipment of the main parts manufactured in England could be made by water to within about 400 miles of Edmonton.

The increased costs would be those affected by the higher labour wage and would consist of the erection of machinery, the building of foundations, and the various buildings required.

The probable cost of manufacturing sulphuric acid at Edmonton or vicinity, has been estimated as 12.50 dollars* net per ton, and is based on Japanese sulphur laid down at Edmonton, at a cost of $20 per ton, and a cost of plant and buildings for a capacity of 3,000 tons of acid per year, not exceeding $60,000. The above figure, $12.50 is, however, estimated for an annual output of 2,000 tons.

Since the writer has no reliable data concerning the costs of by-product recovery producer gas plants exceeding a capacity of 120 tons of fuel per day, a plant of such a capacity will be used as an illustration to show the possibilities of utilizing lignites for the production of power or fuel gas accompanied with the recovery of by-products in this particular locality.

There is no particular reason for choosing Edmonton for the illustration to be worked out, other than the fact that several representative samples of lignite, taken from producing mines in the vicinity of that city, have been thoroughly investigated by the Mines Branch. Other portions of Alberta and of the Provinces of Saskatchewan and Manitoba, contain deposits of lignite coal which might be utilized with advantage in a similar manner. In fact a power plant designed for burning lignite, either with or without by-product recovery, and erected at some mine favourably situated with respect to farming communities would, in the writer's opinion, do much towards improving the conditions of such communities, both from an agricultural and sociological stand point. The extensive peat bogs of Germany are, in certain portions of the Empire, being put to such use, but in this case the farms allotted to each person or family are not large, so that when completely homesteaded, the central power plant will be able to supply a comparatively large number of farms and homes with electricity for agricultural purposes and for lighting dwellings.

In the case of the Western Provinces, different conditions prevail, e.g., the farms are of large extent, and consequently, in

---

*Estimate made by A. W. G. Wilson, Chief of the Metal Mines Division, Mines Branch, Department of Mines.

the majority of instances, the dwellings are far apart. For this reason a central power plant could not be erected to serve profitably such farms alone. In order to develop such a scheme successfully, the plant would have to be situated within reasonable distances of cities or towns of some size, so that the power or gas could all be disposed of.

PLANT AND OPERATING COSTS.

In estimating costs of plant and erection the extra cost of transporting the parts of which the plant is composed as well as the increased cost of erection has been taken into consideration.

Item	1.	Gas plant delivered on site, about	$100,000.00
	2.	Spares and sundries	9,000.00
	3.	Estimated extra for parts manufactured in Canada	10,000.00
	4.	Freight, duty, and insurance on parts made in England, about	5,000.00
	5.	Foundation, buildings, etc.	25,000.00
	6.	Erection	20,000.00
	7.	Workmen's houses	15,000.00
	8.	Sulphuric acid plant	60,000.00
	9.	Working capital	40,000.00
	10.	Gas engine installation, including buildings, electrical generators, switchboards, all complete, and 5 engines of 1,000 B.H.P. each, 1 held in reserve	340,000.00
		Total	$624,000.00

Operating Costs.

PRODUCER AND SULPHATE PLANT.

24 men as follows:—

1 foreman, per shift,	$4.00	per shift,	3 shifts...	$12.00
6 labourers, " "	3.00	"	"	54.00
1 superintendent,	5.00	"	....	5.00
1 extra labourer	3.00	"	....	3.00
1 master mechanic,	4.00	"	....	4.00
				$78.00
	Total wages per year of 365 days,....			$28,470.00

POWER PLANT.

1 engineer, per shift,	$4.50	for	3 shifts, ...	$13.50
1 assistant, " "	3.00	" "	"	9.00
1 electrician, " "	4.50	" "	"	13.50
1 assistant, " "	3.00	" "	"	9.00
	Total daily wage..............			$45.00
	Total wages per year of 365 days, ...			$16,425.00

Interest and Amortization.

It will be assumed that the plant will be amortized in 20 years.

Interest at 6% on Items (1, 2, 3, 4, 5, 6, 7, and 9), $13,440.00 (e).
Amortization at 5% on Items (1, 3, 5, 6, and 7), $9,000.00 (f).
(a) = e + f = $22,440.00.

Interest and amortization on Item (8) is included in the cost of manufacturing sulphuric acid.

Summary of Costs.

(a)—Interest and amortization	$22,440.00
(b)—Labour, gas and sulphate plant (in round numbers)	28,400.00

(c)	Managers and clerks	$4,000.00
	Chemists	2,000.00
	Lubricants	2,000.00
	Sundry stores	3,000.00
	Repairs	3,000.00
	General expenses	5,000.00
(f)	—50,000 tons of lignite containing 17 per cent moisture at $1 per ton—equivalent to 42,000 tons absolutely dry	50,000.00
		$119,840.00
	Say	$119,800.00

Assumptions.

1.	Calorific value of 1 lb. of lignite containing 17 per cent moisture	9,000 B.T.U.
2.	Efficiency of producer	70 per cent.
3.	Heating value of gas per cubic foot	140 B.T.U.
4.	Steam required per lb. of absolutely dry fuel gasified	2 lbs.*
5.	Steam supplied by steam boilers	1 lb. at 5 lbs. gauge pressure.
6.	Efficiency of steam boilers	70 per cent.
7.	" " ammonia recovery process	70 per cent.

Quantities Obtained.

1. Heat entering into gas per lb. of fuel gasified.

$$9{,}000 \times 0\cdot 7 = 6{,}300 \text{ B.T.U.}$$

2. Quantity of gas per lb. of lignite gasified,

$$\frac{6300}{140} = 45 \text{ cu. feet.}$$

3. Quantity of gas required to raise 1 lb. of steam at 5 lbs. gauge pressure.

---

*One half of this quantity is supplied by recuperation.

$$\frac{1,130}{140 \times 0{\cdot}7} = 11{\cdot}5 \text{ cu. feet.}$$

4. Quantity of gas per lb. of lignite containing 17 per cent moisture available for power or other purposes.

$$(45 - 11{\cdot}5) = 33{\cdot}5 \text{ cu. ft.}$$

5. Total quantity of gas per ton of lignite as fired.

$$45 \times 2,000 = 90,000 \text{ cu. ft.}$$

6. Total quantity of gas per ton of lignite as fired available or power or other purposes.

$$33{\cdot}5 \times 2,000 = 67,000 \text{ cu. ft.}$$

7. Heating value of total quantity of gas generated per ton of lignite as fired.

$$90,000 \times 140 = 12,600,000 \text{ B.T.U.}$$

8. Heating value of available gas per ton of lignite as fired,

$$67,000 \times 140 = 9,380,000 \text{ B.T.U.}$$

9. Ammonium sulphate $(NH_4)_2SO_4$ per ton of lignite, with (X) per cent nitrogen (N) =

$$2,000 \times 0{\cdot}7 \times 4{\cdot}71 \times \frac{X}{100} = 65{\cdot}94 \text{ X lbs.}$$

10. Sulphuric acid, H_2SO_4 required per ton of sulphate,

$$1{\cdot}1 \times 65{\cdot}94 X = 72{\cdot}53X.$$

11. Gross receipts from sale of sulphate per ton of lignite as fired,

$$\frac{65 \times 65{\cdot}94X}{2,000} = 2{\cdot}143X \text{ dollars.}$$

(65 = market price of ammonium sulphate in dollars).

12. Cost of sulphuric acid (H_2SO_4) required,

$$\frac{12{\cdot}50 \times 72{\cdot}53X}{2,000} = 0{\cdot}453X \text{ dollars}$$

\$12.50 is cost of sulphuric acid per ton of 2,000 lbs. in dollars).

13. Cost of packing and bagging per ton of sulphate at 1½ dollars per ton =

$$\frac{1{\cdot}5 \times 65{\cdot}94X}{2,000} = 0{\cdot}0495X \text{ dollars.}$$

14. Net return from sulphate, exclusive of fuel and operating costs =

$$\left\{2\cdot143 - (0\cdot453 + 0\cdot0495)\right\} X = 1\cdot64X \text{ dollars}$$

15. Total cost per ton of absolutely dry lignite,

$$\frac{(a + b + c) + BF}{42{,}000} = \left\{\frac{A + BF}{F}\right\} = \$2.85 \quad (1)$$

or per ton of lignite as fired.............. = $2·395

A = items (a + b + c),

F = quantity of lignite in tons, per year.

B = cost of fuel per ton.

16. Net costs per ton of absolutely dry lignite gasified.

$$\left\{\frac{A + BF}{F}\right\} - 1\cdot64X = \qquad (2)$$

$$1\cdot64\left\{\frac{A + BF}{1\cdot64F} - X\right\} = 1\cdot64\ (1\cdot74 - X)$$

17. Net cost of available gas per 1,000 cu. ft.

$$1\cdot64\left\{\frac{\dfrac{A + BF}{1\cdot64F} - X}{67}\right\} = 0\cdot0245\left\{\frac{A + BF}{1\cdot64F} - X\right\} \quad (3)$$

$$= \$0\cdot0245\ (1\cdot74 - X)$$

18. Net cost of gas required to produce one B.H.P. year with a gas engine, assuming that plant uses full amount of lignite 42,000 tons per year.

1. Total quantity of heat available for power per ton lignite gasified, = 9,380,000 B.T.U.
2. Heat consumption of gas engine per B.H.P. hour = 10,000 B.T.U.
3. Capacity of plant per hour, = 5 tons of absolutely dry lignite.
4. Total quantity of heat available for power per hour, = (9,380,000 × 5) B.T.U.

Power available:—

$$\frac{9,380,000 \times 5}{10,000} = 4,690 \text{ B.H.P.}$$

Capacity of plant assumed to be 4,000 B.H.P. cost of gas per B.H.P. year on this basis will be:—

$$(4) \qquad \frac{600\text{[1]} \times 1\cdot64}{67} \times \frac{4,690}{4,000}(1\cdot74 - x) = 17\cdot22\ (1\cdot74 - X)$$

19. Net cost of producing one B.H.P. year:—

Normal capacity of plant	4,000 B.H.P.
Capital cost	$340,000.00
Interest and amortization, 11%	37,400.00
Labour	16,425.00
Lubricants	1,500.00
Repairs	4,000.00
Total costs per year	$59,325.00

Costs per B.H.P. year, exclusive of cost of gas:—

$$\frac{59,325}{4,000} = 14\cdot83$$

Net cost per B.H.P. year for any load factor is expressed by the equation:—

$$\frac{1}{C}\left[1483 + 1722\left\{\frac{A + BF^2}{1\cdot64F} = X\right\}\right] \qquad (5)$$

when C = load factor in per cent.

X = nitrogen content of lignite as gasified in per cent.

When the load factor is 100 per cent, and the operating costs and fixed charges (A) and the cost of fuel (B) and quantity (F)[2] are as stated for the case described, this equation becomes

$$17\cdot22\ (2\cdot6 - X) \qquad (6)$$

If all the factors are varied, the following equation will represent the cost of generating one B.H.P. year:—

---

[1] 600 is the number of thousand cubic feet of gas required to produce one horse power year of 350 days of 24 hours each.

[2] F is the quantity of absolutely dry fuel used per year when the plant is operating at full capacity, viz., 42,000 tons per year.

$$\frac{100}{C}\left[A' + 7\cdot 122\left\{\frac{A + BF^*}{1\cdot 64F} - X\right\}\right]$$

See equation 7 page 204.

In the case of lignite the quantity of fuel and the nitrogen content may be reduced to the absolutely dry state, but since the nitrogen content of the samples of lignite are usually determined for the sample as received, i.e., in its moist condition, it will be simpler to substitute in the above formula the quantities of the nitrogen content of the moist fuel it is intended to gasify.

It will be seen from equation 6 that when the nitrogen content of the lignite is 2·6 per cent, the cost of power is zero.

Fig. 39 shows the effect of an increase in the nitrogen content on the cost of gas, power, etc.

SULPHURIC ACID.

The cost of manufacturing sulphuric acid depends to a very large extent on the cost of transporting the raw materials necessary for its manufacture to the plant. Consequently the cost of sulphuric acid must be obtained for every individual case.

Acid Imported by Rail from Works in Eastern Canada.

The following estimates of costs have been supplied by Dr. A. W. G. Wilson of the Mines Branch. Sulphide, Ontario or Hamilton, Ontario: Costs include freight at present quoted rates; in the event of considerable business developing it is probable that the freight would be materially reduced. At present rates the freight charges constitute from 60 to 66 per cent of the total cost. It is assumed that acid of 66° Baumé scale would be imported, and diluted to meet the requirements of the work. The costs are given on the basis of 60° Baumé acid, and are approximately as follows—

Edmonton, Alta....................	$30.00
Tofield	30.00

---

[*] F is the quantity of absolutely dry fuel used per year when the plant is operating at full capacity, viz. 42,000 tons per year.

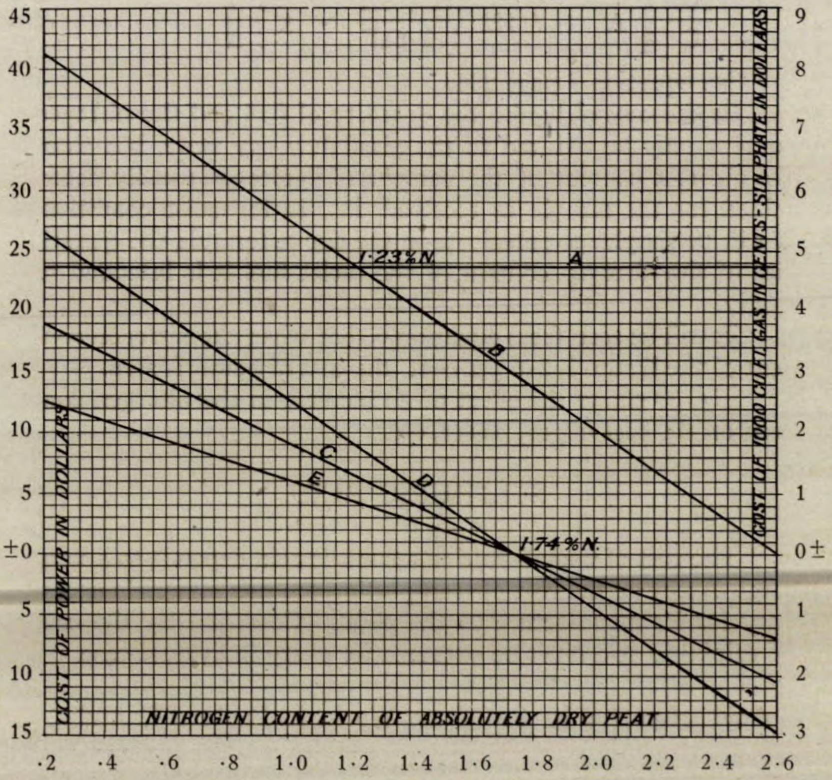


FIG. 39—Curves illustrating effect of increase of nitrogen content on cost of generating power from lignite.

A- Cost of producing One B.H.P. Year with Non-By-Product Recovery Lignite Producer Gas Plant.

B- Cost of producing One B.H.P. Year with By-Product Recovery Lignite Producer Gas Plant.

C- Cost of producing 1000 Cu. Ft. of Gas with By-Product Recovery Lignite Producer Gas Plant.

D- Cost of producing Gas for One B.H.P. Year with By-Product Recovery Lignite Producer Gas Plant.

E- Net Cost of Recovering Ammonium Sulphate per Ton Lignite with 17% moisture.

Gainford	$31.00
Moose Jaw, Sask.	26.00
Estevan, Sask.	25.25

Sulphuric acid at the above costs cannot be profitably used in the manufacture of ammonium sulphate. In almost every case, therefore, the acid required must be manufactured at the plant where the fuel is gasified.

Estimated Cost of Manufacturing Sulphuric Acid in Western Canada.*

It is probable that Japanese sulphur can be laid down at Edmonton at a net cost of $20 per ton. Louisiana sulphur will cost about $30 per ton at Estevan. The buildings and equipment to produce about 3,000 tons of acid per year are placed at $60,000. On this basis 60° Baumé at Edmonton would cost about 12.50 dollars per ton, and at Estevan about $14.50, with an annual output of 2,000 tons, being less than the capacity of the plant.

The estimated cost of a sulphuric acid plant of from 3,000 to 4,000 tons of acid per year, which was given in connexion with the discussion of by-product recovery producer gas plants for Eastern Canada, was the same as that estimated for a similar plant in the United States, viz., $36,000. If the estimate of cost, $60,000 for a plant of similar capacity to be situated at Edmonton is correct, then it is quite probable that the former estimate of $36,000 is considerably too low for Eastern Canada. The cost, however, of the manufactured acid, viz., $8, which was used throughout the calculations in connexion with the discussion of the establishment of such plants in Eastern Canada, is about correct, and will not vary much in either direction.

---

*Estimate by Dr. A. W. G. Wilson, Chief of Metal Mines Division, Mines Branch Department of Mines, Ottawa, Canada.

CHAPTER VIII.

COAL.

The feasibility of generating a power or fuel gas with bituminous coals in the by-product recovery producer has been fully discussed in previous chapters, and requires but few additional remarks. A large number of such plants are, and have been for several years, successfully producing gas for power and other purposes at many of the representative industrial works in the British Isles and Europe. A Mond by-product recovery power gas plant of 1,000 horse power has been installed in the municipal central station at Accrington, England, and has proven successful from every standpoint.

The analyses of many samples of coal taken from the representative coal mines of Canada show that as regards the nitrogen content they are entirely suitable for the by-product recovery producer process. The nitrogen contents of some of the samples of the principal mines are as follows:—

SYDNEY COAL FIELD, CAPE BRETON COUNTY, N.S.

North Atlantic Collieries, Gowrie Seam, Port Morien.

Regular sample over ¾″ screen and picking belt: Nitrogen 1·0 per cent, calorific value, 12,620 B.T.U. per pound.

Dominion Coal Co., Glace Bay, Hub Seam, Dominion No. 7.

Regular sample over 2½″ screen and picking belt: Nitrogen 1·6 per cent, calorific value of dry coal, 13,860 B.T.U.'s per lb. Washed coal: Nitrogen 1·7 per cent, calorific value of dry coal, 14,310 B.T.U.'s per lb.

Harbour Seam, Dominion No. 9.

Regular sample over 2½″ screen and picking belt: Nitrogen, 1·5 per cent, calorific value, 14,000 B.T.U.'s per lb.

Phalen Seam, Dominion No. 5, or Reserve Colliery.

Regular sample over $1\frac{1}{2}''$ screen and picking belt: Nitrogen 1·4 per cent, calorific value, 14,040 B.T.U.'s per lb.

Emery Seam, Dominion No. 10 Colliery.

Regular sample run of mine over picking belt: Nitrogen 1·2 per cent, calorific value, 13,120 B.T.U.'s per lb. Washed coal: Nitrogen 1·3 per cent, calorific value, 13,880 B.T.U.'s per lb.

Lingan Seam, Dominion No. 12 Colliery.

Regular sample run of mine coal: Nitrogen 1·6 per cent, calorific value, 13,790 B.T.U.'s per lb.

NOVA SCOTIA STEEL AND COAL CO., SYDNEY MINES.

No. 1 Colliery.

Regular sample over $\frac{7}{8}''$ screen and picking belt: Nitrogen 1·3 per cent, calorific value, 13,770 B.T.U.s per lb. Washed coal: Nitrogen 0·9 per cent, calorific value, 14,490 B.T.U.'s per lb.

No. 3 Colliery.

Regular sample over $\frac{1}{2}''$ screen and picking belt: Nitrogen, 1·4 per cent, calorific value, 13,680 B.T.U.'s per lb.

INVERNESS COAL FIELD, INVERNESS COUNTY, N.S.

Inverness Coal and Railway Co., Inverness Colliery.

Regular sample over $\frac{5}{8}''$ screen and picking belt: Nitrogen 0·9 per cent, calorific value, 12,150 B.T.U.'s per lb.: Washed coal: Nitrogen 0·6 per cent, calorific value, 12,800 B.T.U.'s per lb.

Richmond Railway Co., Port Hood Colliery.

Regular sample over ¾″ screen and picking belt: Nitrogen 0·8 per cent, calorific value, 11,770 B.T.U.'s per lb. Washed coal: Nitrogen 0·6 per cent, calorific value, 12,550 B.T.U.'s per lb.

PICTOU COAL FIELD, PICTOU COUNTY, N.S.

Acadia Coal Co., Vale Colliery, Thorburn, Six Foot Seam.

Regular sample over ¾″ screen and picking belt: Nitrogen 1·8 per cent, calorific value, 12,020 B.T.U.'s per lb. Washed coal: Nitrogen 1·7 per cent, calorific value, 12,760 B.T.U's. per lb.

Acadia Coal Co., Allan Shaft Colliery, Stellarton, Foord Seam.

Regular sample run of mine coal over picking belt: Nitrogen 1·9 per cent, calorific value, 13,230 B.T.U.'s per lb. Fresh sample for coking test: Nitrogen 2·2 per cent, calorific value, 14,000 B.T.U.'s per lb.

Acadia Coal Co., Albion Colliery, Stellarton, Third Seam.

Regular sample run of mine coal: Nitrogen 1·7 per cent, calorific value, 12,580 B.T.U.'s per lb. Washed coal: Nitrogen 1·5 per cent, calorific value, 13,050 B.T.U.'s per lb. Original coal resampled 12 months later: Nitrogen 1·6 per cent, calorific value, 12,460 B.T.U.'s per lb.

Acadia Coal Co., Albion Colliery, Cage Pit Seam.

Regular sample of run of mine coal: Nitrogen 2·1 per cent, calorific value, 13,180 B.T.U.'s per lb.

Acadia Coal Co., Acadia Colliery, Westville, Main Seam.

Regular sample over 1″ screen and picking belt: Nitrogen 1·6 per cent, calorific value, 13,860 B.T.U.'s per lb. Fresh sample for coking test: Nitrogen 2·2 per cent.

Intercolonial Coal Co., Drummond Colliery, Westville, Main Seam.

Regular sample over 1″screen and picking belt: Nitrogen 2·1 per cent, calorific value, 12,960 B.T.U.'s per lb. Washed coal: Nitrogen 2·0 per cent, calorific value, 13,550 B.T.U.'s per lb. Fresh sample for coking test: Nitrogen 1·9 per cent.

SPRINGHILL COAL FIELD, CUMBERLAND COUNTY, N.S.

Cumberland Railway and Coal Co., No. 1 Colliery, Springhill.

Special sample for coking tests: Nitrogen 1·9 per cent, calorific value, 14,190 B.T.U.'s per lb.

Cumberland Railway and Coal Co., No. 2 Colliery, Springhill.

Regular sample over ¾″ screen and picking belt: Nitrogen 1·2 per cent, calorific value, 13,370 B.T.U.'s per lb. Washed coal: Nitrogen 1·0 per cent, calorific value, 13,860 B.T.U.'s per lb. Fresh sample for coking tests: Nitrogen 2·0 per cent, calorific value, 13,880 B.T.U.'s per lb.

Cumberland Railway and Coal Co., No. 3 Colliery, Springhill.

Regular sample over ¾″ screen and picking belt: Nitrogen 1·8 per cent, calorific value, 13,000 B.T.U.'s per lb. Washed coal: Nitrogen 1·4 per cent, calorific value, 13,570 B.T.U.'s per lb. Fresh sample for coking test: Nitrogen 1·8 per cent.

FRANK-BLAIRMORE COAL FIELD, ALBERTA.

Nitrogen content of samples analyzed, averages about 1·0 per cent.

CROWSNEST COAL FIELD, B.C.

Nitrogen content of samples analyzed, varies from 1·2 to 1·3 per cent.

CASCADE COAL FIELD, ALBERTA.

Nitrogen content 1·0 to 1·7 per cent.

NICOLA VALLEY COAL FIELD, B.C.

Nitrogen content 1·3 to 2·0 per cent.

NANAIMO-COMOX COAL FIELD, VANCOUVER ISLAND, B.C.

Nitrogen content 1·0 to 1·2 per cent.

The nitrogen content of almost every coal tested is sufficiently high to permit of its profitable recovery in the by-product recovery producer when the plant and operating costs are not excessivley high, but it would not prove practicable in many cases to install such plants for the recovery of the nitrogen alone. In sparsely settled districts, or where by-product coke ovens are in operation for the manufacture of coke, the field for the utilization of producer gas would be very limited. In the latter instance sufficient gas would be produced to answer all requirements for power and other purposes, and the interests of conservation would be served to a certain extent, although the efficiency of the recovery process in connexion with coke ovens is not so high as that of the by-product recovery producer. At coal mines conveniently situated with regard to shipping facilities, the nitrogen content, if sufficiently high, might be profitably recovered in a by-product recovery producer gas plant, irrespective of what disposal is made of the gas generated.

Such mines exist in the Eastern part of Canada in Nova Scotia. At some of these mines it might be found practicable to burn the low grade coal in gas producers for the recovery of the nitrogen alone. It is not necessary, in the case of coal, to enter into a detailed discussion of costs of generating power, etc., since its gasification in producers of any type is not problematical. The quantity of gas greatly exceeds that possible with the lower grade fuels and, consequently, the cost per 1,000 cu. ft. will be considerably less, i.e., if the plant and operating costs are the same. When bituminous coal is gasified in a by-product recovery producer, considerable profit might be derived from the recovery of the tar. Where coal is briquetted, as at some of the mines in Eastern Canada, pitch derived from coal in this manner would prove of considerable value, since large quantities would be required as a binder when the briquetting operations are conducted on an extensive scale.

CHAPTER IX.

SUMMARY.

It has been shown in preceding chapters that under favourable conditions peat can be utilized for the production of a power and domestic fuel gas in by-product recovery producers. The maximum moisture content in order to effect the most efficient utilization of the peat must be not more than 40 per cent—preferably 30 per cent—and the cost per ton containing 30 per cent moisture should not exceed $1.50. When the nitrogen content falls below 1½ per cent on the absolutely dry fuel, its utilization in a by-product recovery producer should not be attempted, since there are certain factors in the winning and utilization of peat which are more or less uncertain. Ample margin must, therefore, be provided to cover losses which are liable to occur, either through an insufficiency of supply of fuel or an excessive moisture content due to an extremely wet season. Certain peat bogs have been cited where the production of a power and fuel gas might prove profitable. In these cases the nitrogen content is above the average and the process under the conditions cited could be carried on for the recovery of ammonium sulphate alone. The problem of manufacturing and storing the requisite quantities of fuel for a year's operations are fully discussed, and it has been shown how, in the case of a European plant, these difficulties have been overcome. The steam power plant on the Wiesmoor in Germany, designed for the exclusive use of peat fuel, has been described in detail. This plant has proven a greater success than was anticipated by its designers and promoters, and with peat costing one and a quarter dollars per ton, at the plant, power can be produced at a lower figure than from coal costing about three dollars and a half per ton. In the case of the Mond by-product recovery power gas plant at Osnabrück the operation was not an entire success, owing in part to the selection of an unsuitable bog for the manufacture of peat. Time was not available for thoroughly draining before beginning manufacturing operations, and the average nitrogen content was too low—in the vicinity of 1 per cent. Contracts were made to deliver power at a definite date before the erection of the plant was begun, it was consequently impossible to devote the required time to the preparation of the bog. The result was high cost of fuel with an excessive moisture content and, according to information, obtained by the writer, failure to live up to the contract. On the other hand marked success was achieved in the case of the Mond gas plant situated near Orentano, Italy.

It has been shown that under favourable conditions power can be produced on certain of the Canadian peat bogs at a cost equal to or below that possible with a hydro-electric plant.

The feasibility of utilizing coal and lignite for the production of a power or fuel gas in the by-product recovery producer is discussed in some detail. The Mond gas plant in South Staffordshire, England, which manufactures and distributes a power and fuel gas over a large industrial district is fully described. At this plant it has been demonstrated that a gas suitable for industrial purpose, can be sold at a cost per 1,000 cubic feet far below that of a quantity of town gas of equal heating value. The field for serving towns and cities with such gas for domestic purposes is a very large one, but its distribution among householders is at present prohibited by an existing parliamentary act. In those portions of Canada where a domestic fuel gas is in demand and where a suitable domestic fuel cannot be obtained at reasonable prices, the distribution of producer gas, manufactured according to the process described, should prove of great economic advantage to the entire country as well as the individual community directly benefited. In this connexion it has been pointed out how the lignites of the Western Provinces might be efficiently utilized, especially those lignite deposits situated with respect to Edmonton and other smaller communities.

For the representative coals of Canada, the average nitrogen contents of general samples have been cited to show which coals are particularly suited for the by-product recovery process.

When the establishment of a by-product recovery producer gas plant is considered either for the production of a power or fuel gas, or for the recovery of the ammonium sulphate alone, the exact estimates of costs of plant delivered on site and the cost of erection and operation must be obtained in every case from the manufacturers; and since sulphuric acid is an important factor in the recovery process, the cheapest means for obtaining it must be fully considered. On the Atlantic coast or a short distance inboard the cost of sulphuric acid manufactured at the plant has been placed at $8 per ton. This cost, it must be understood, is merely an estimate, although it will not vary much in either direction.

In conclusion it may be stated as the writer's opinion that by-product recovery producer gas plants can be profitably operated for the production of a power or fuel gas—and in certain cases for the manufacture of ammonium sulphate alone—at certain of the Canadian peat bogs, and in the Western Provinces at certain of the lignite deposits. When a disposition can be made of the gas generated this process can be profitably applied to the Canadian bituminous coals; but since coking plants are already established at the principal coal mines where coking coal is found and the gas generated by this means is very probably sufficient to answer all requirements for some time to come, it would be better from a financial standpoint to establish by-product recovery plants in connexion with the coke ovens. This in fact is being done both in Nova Scotia and Sault Ste. Marie, Ont.

INDEX

CANADA
DEPARTMENT OF MINES
HON. LOUIS CODERRE, MINISTER; R. W. BROCK, DEPUTY MINISTER.

MINES BRANCH
EUGÈNE HAANEL, PH. D., DIRECTOR.

REPORTS AND MAPS

PUBLISHED BY THE

MINES BRANCH

REPORTS.

1. Mining Conditions in the Klondike, Yukon. Report on—by Eugène Haanel, Ph. D., 1902.

†2. Great Landslide at Frank, Alta. Report on—by R. G. McConnell, B.A., and R. W. Brock, M.A., 1903.

†3. Investigation of the different electro-thermic processes for the smelting of iron ores, and the making of steel, in operation in Europe. Report of Special Commission—by Eugene Haanel, Ph.D., 1904.

†4. Rapport de la Commission nommée pour étudier les divers procédés électro-thermiques pour la réduction des minerais de fer et la fabrication de l'acier employés en Europe—by Eugene Haanel, Ph.D. (French Edition), 1905.

5. On the location and examination of magnetic ore deposits by magnetometric measurements—by Eugene Haanel, Ph.D., 1904.

†7. Limestones and the Lime Industry of Manitoba. Preliminary Report on—by J. W. Wells, M.A., 1905.

†8. Clays and Shales of Manitoba: Their Industrial Value. Preliminary Report on—by J. W. Wells, M.A., 1905.

†9. Hydraulic Cements (Raw Materials) in Manitoba: Manufacture and Uses of. Preliminary Report on—by J. W. Wells, M.A., 1905.

---

†Publications marked thus † are out of print.

†10. Mica: Its Occurrence, Exploitation, and Uses—by Fritz Cirkel, M.E., 1905. (See No. 118.)

†11. Asbestos: Its Occurrence, Exploitation, and Uses—by Fritz Cirkel, M.E., 1905. (See No. 69.)

†12. Zinc Resources of British Columbia, and the Conditions affecting their Exploitation. Report of the Commission appointed to investigate—by W. R. Ingalls, M.E., 1905.

†16. *Experiments made at Sault Ste. Marie, under Government auspices, in the smelting of Canadian iron ores by the electro-thermic process. Final Report on—by Eugene Haanel, Ph.D., 1907.

†17. Mines of the Silver-Cobalt Ores of the Cobalt district: Their Present and Prospective Output. Report on—by Eugene Haanel, Ph.D., 1907.

†18. Graphite: Its Properties, Occurrence, Refining, and Uses—by Fritz Cirkel, M.E., 1907.

†19. Peat and Lignite: Their Manufacture and Uses in Europe—by Erik Nystrom, M.E., 1908.

†20. Iron Ore Deposits of Nova Scotia. Report on (Part 1)—by J. E. Woodman, D.Sc.

†21. Summary Report of Mines Branch, 1907-8.

22. Iron Ore Deposits of Thunder Bay and Rainy River districts. Report on—by F. Hille, M.E.

†23. Iron Ore Deposits along the Ottawa (Quebec side), and Gatineau rivers. Report on—by Fritz Cirkel, M.E.

24. General Report on the Mining and Metallurgical Industries of Canada, 1907-8.

25. The Tungsten Ores of Canada. Report on—by T. L. Walker, Ph.D.

26. The Mineral Production of Canada, 1906. Annual Report on—by John McLeish, B.A.

26a. French Translation: The Mineral Production of Canada, 1906. Annual Report on—by John McLeish, B.A.

---

*A few copies of the Preliminary Report 1906, are still available.
†Publications marked thus † are out of print.

27. The Mineral Production of Canada, 1907. Preliminary Report on—by John McLeish, B.A.

†27a. The Mineral Production of Canada, 1908. Preliminary Report on—by John McLeish, B.A.

†28. Summary Report of Mines Branch, 1908.

†28a. French translation: Summary Report of Mines Branch, 1908.

29. Chrome Iron Ore Deposits of the Eastern Townships. Monograph on—by Fritz Cirkel, M.E. (Supplementary Section: Experiments with Chromite at McGill University—by J. B. Porter, E.M., D.Sc.

30. Investigation of the Peat Bogs and Peat Fuel Industry of Canada, 1908. Bulletin No. 1—by Erik Nystrom, M.E., and A. Anrep, Peat Expert.

32. Investigation of Electric Shaft Furnace, Sweden. Report on—by Eugene Haanel, Ph.D.

47. Iron Ore Deposits of Vancouver and Texada Islands. Report on—by Einar Lindeman, M.E.

†55. Report on the Bituminous, or Oil-shales of New Brunswick and Nova Scotia; also on the Oil-shale industry of Scotland—by R. W. Ells, LL.D.

56. French translation: Bituminous or Oil-shales of New Brunswick and Nova Scotia: also on the Oil-shale Industry of Scotland. Report on—by R. W. Ells, LL.D.

58. The Mineral Production of Canada, 1907 and 1908. Annual Report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1907-8:—*

†31. Production of Cement in Canada, 1908.
42. Production of Iron and Steel in Canada during the Calendar Years 1907 and 1908.
43. Production of Chromite in Canada during the Calendar Years 1907 and 1908.

---

†Publications marked thus † are out of print.

44. Production of Asbestos in Canada during the Calendar Years 1907 and 1908.

†45. Production of Coal, Coke, and Peat in Canada during the Calendar Years 1907 and 1908.

46. Production of Natural Gas and Petroleum in Canada during the Calendar Years 1907 and 1908.

59. Chemical Analyses of Special Economic Importance made in the Laboratories of the Department of Mines, 1906-7-8. Report on—by F. G. Wait, M.A., F.C.S. (With Appendix on the Commercial Methods and Apparatus for the Analyses of Oil Shales—by H. A. Leverin, Ch. E.)

Schedule of Charges for Chemical Analyses and Assays.

†62. Mineral Production of Canada, 1909. Preliminary Report on—by John McLeish, B.A.

63. Summary Report of Mines Branch, 1909.

67. Iron Ore Deposits of the Bristol Mine, Pontiac county, Quebec. Bulletin No. 2—by Einar Lindeman, M.E., and Geo. C. Mackenzie, B.Sc.

†68. Recent Advance in the Construction of Electric Furnaces for the Production of Pig Iron, Steel, and Zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

69. Chrysotile-Asbestos: Its Occurrence, Exploitation, Milling, and Uses. Reports on—by Fritz Cirkel, M.E. (Second Edition, enlarged.)

†71. Investigation of the Peat Bogs and Peat Industry of Canada, 1909-10; to which is appended Mr. Alf. Larson's Paper on Dr. M. Ekenberg's Wet-Carbonizing Process; from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. v. Anrep, Jr.; also a translation of Lieut. Ekelund's Pamphlet entitled 'A Solution of the Peat Problem', 1909, describing the Ekelund Process for the Manufacture of Peat Powder, by Harold A. Leverin, Ch. E. Bulletin No. 4—by A. v. Anrep (Second Edition, enlarged.)

81. French Translation: Chrysotile-Asbestos: Its Occurrence, Exploitation, Milling, and Uses. Report on—by Fritz Cirkel, M.E.

82. Magnetic Concentration Experiments. Bulletin No. 5—by Geo. C. Mackenzie, B.Sc.

---

†Publications marked thus † are out of print.

83. An investigation of the Coals of Canada with reference to their Economic Qualities as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E. M., D.Sc., R. J. Durley, Ma.E., and others—
    - Vol. I—Coal Washing and Coking Tests.
    - Vol. II—Boiler and Gas Producer Tests.
    - Vol. III—
        - Appendix I
            - Coal Washing Tests and Diagrams.
    - Vol. IV—
        - Appendix II
            - Boiler Tests and Diagrams.
    - Vol. V—
        - Appendix III
            - Producer Tests and Diagrams.
    - Vol. VI—
        - Appendix IV
            - Coking Tests.
        - Appendix V
            - Chemical Tests.

†84. Gypsum Deposits of the Maritime Provinces of Canada—including the Magdalen Islands. Report on—by W. F. Jennison, M.E. (See No. 245.)

88. The Mineral Production of Canada, 1909. Annual Report on—by John McLeish, B.A.

> NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1909.*

- †79. Production of Iron and Steel in Canada during the Calendar Year, 1909.
- †80. Production of Coal and Coke in Canada during the Calendar Year, 1909.
- 85. Production of Cement, Lime, Clay Products, Stone, and other Structural Materials during the Calendar Year, 1909.

89. Reprint of Presidential address delivered before the American Peat Society at Ottawa, July 25, 1910. By Eugene Haanel, Ph.D.

90. Proceedings of Conference on Explosives.

92. Investigation of the Explosives Industry in the Dominion of Canada, 1910. Report on—by Capt. Arthur Desborough. (Second Edition.)

---

†Publications marked thus † are out of print.

93. Molybdenum Ores of Canada. Report on—by Professor T. L. Walker, Ph. D.

100. The Building and Ornamental Stones of Canada. Report on—by Professor W. A. Parks, Ph. D.

100a. French Translation: The Building and Ornamental Stones of Canada. Report on—by W. A. Parks.

102. Mineral Production of Canada, 1910. Preliminary Report on—by John McLeish, B.A.

†103. Summary Report of Mines Branch, 1910.

104. Catalogue of Publications of Mines Branch, from 1902 to 1911; containing Tables of Contents and list of Maps, etc.

105. Austin Brook Iron-bearing district, Report on—by E. Lindeman, M.E.

110. Western Portion of Torbrook Iron Ore Deposits, Annapolis county, N.S. Bulletin No. 7—by Howells Fréchette, M.Sc.

111. Diamond Drilling at Point Mamainse, Ont. Bulletin No. 6—by A. C. Lane, Ph.D., with Introductory by A. W. G. Wilson. Ph.D.

118. Mica: Its Occurrence, Exploitation, and Uses. Report on—by Hugh S. de Schmid, M.E.

142. Summary Report of Mines Branch, 1911.

143. The Mineral Production of Canada, 1910. Annual Report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1910.*

†114. Production of Cement, Lime, Clay Products, Stone and other Structural Materials in Canada, 1910.
†115. Production of Iron and Steel in Canada during the Calendar Year 1910.
†116. Production of Coal and Coke in Canada during the Calendar Year 1910.

---

†Publications marked thus † are out of print.

†117. General Summary of the Mineral Production of Canada during the Calendar Year 1910.

145. Magnetic Iron Sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

149. French translation: Magnetic Iron Sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

†150. The Mineral Production of Canada, 1911. Preliminary Report on—by John McLeish, B.A.

151. Investigation of the Peat Bogs and Peat Industry of Canada, 1910-1911. Bulletin No. 8—by A. v. Anrep, Peat Expert.

154. The Utilization of Peat Fuel for the Production of Power, being a record of experiments conducted at the Fuel Testing Station, Ottawa, 1910-11. Report on—by B. F. Haanel, B.Sc.

155. French translation: The Utilization of Peat Fuel for the Production of Power, being a record of experiments conducted at the Fuel Testing Station, Ottawa, 1910-11. Report on—by B. F. Haanel, B.Sc.

156. French translation: The Tungsten Ores of Canada. Report on—T. L. Walker, Ph.D.

167. Pyrites in Canada: Its Occurrence, Exploitation, Dressing, and Uses. Report on—by A. W. G. Wilson, Ph.D.

169. French translation: Pyrites in Canada: Its Occurrence, Exploitation, Dressing, and Uses. Report on—by A. W. G. Wilson, Ph.D.

170. The Nickel Industry: with Special Reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

180. French translation: Investigation of the Peat Bogs, and Peat Industry of Canada, 1910-11. Bulletin No. 8—by A. v. Anrep, Peat Expert.

184. Magnetite Occurrences along the Central Ontario Railway. Report on—by E. Lindeman.

195. French translation: Magnetite Occurrences along the Central Ontario Railway. Report on—by E. Lindeman, M.E.

---

†Publications marked thus † are out of print.

196. French translation: Investigation of the Peat Bogs and Peat Industry of Canada, 1909-10; to which is appended Mr. Alf. Larson's paper on Dr. Ekenburg's Wet Carbonizing Process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. v. Anrep; also translation of Lieut. Ekelund's Pamphlet entitled "A solution of the Peat Problem," 1909, describing the Ekelund Process for the Manufacture of Peat Powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. v. Anrep, Peat Expert. (Second Edition, enlarged.)

197. French translation: Molybdenum Ores of Canada. Report on—by Professor T. L. Walker, Ph.D.

198. French translation: Peat and Lignite: Their Manufacture and Uses in Europe—by Erik Nystrom, M.E., 1908.

201. The Mineral Production of Canada during the Calendar Year 1911. Annual Report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1911.*

181. Production of Cement, Lime, Clay Products, Stone, and other Structural Materials in Canada during the Calendar Year 1911. Bulletin on—by John McLeish, B.A.

†182. Production of Iron and Steel in Canada during the Calendar Year 1911. Bulletin on—by John McLeish, B.A.

183. General Summary of the Mineral Production in Canada during the Calendar Year 1911. Bulletin on—by John McLeish, B.A.

†199. Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and other Metals of Canada, during the Calendar Year 1911. Bulletin on—by C. T. Cartwright, B.Sc.

†200. The Production of Coal and Coke in Canada during the Calendar Year 1911. Bulletin on—by John McLeish, B.A.

202. French translation: Graphite: Its Properties, Occurrence, Refining, and Uses—by Fritz Cirkel, M.E., 1907.

203. Building Stones of Canada—Vol. II: Building and Ornamental Stones of the Maritime Provinces. Report on—by Professor W. A. Parks, Ph.D.

209. The Copper Smelting Industry of Canada. Report on—by A. W. G. Wilson, Ph.D.

---

†Publications marked thus † are out of print.

216. Mineral Production of Canada, 1912. Preliminary Report on—by John McLeish, B.A.

219. French translation: Austin Brook Iron-bearing district. Report on—by E. Lindeman, M.E.

222. Lode Mining in Yukon: An investigation of the Quartz Deposits of the Klondike Division. Report on—by T. A. MacLean, B.Sc.

224. Summary Report of the Mines Branch, 1912.

226. French translation: Chrome Iron Ore Deposits of the Eastern Townships. Monograph on—by Fritz Cirkel, M.E. (Supplementary Section: Experiments with Chromite at McGill University—by Professor J. B. Porter, E.M., D.Sc.)

227. Sections of the Sydney Coal Field—by J. G. S. Hudson.

†229. Summary Report of the Petroleum and Natural Gas Resources of Canada, 1912—by F. G. Clapp, A.M. See. No. 224.)

230. Economic Minerals and the Mining Industries of Canada.

231. French translation: Economic Minerals and the Mining Industries of Canada.

233. French translation: Gypsum Deposits of the Maritime Provinces of Canada—including the Magdalen Islands. Report on—by W. F. Jennison, M.E.

245. Gypsum in Canada: Its Occurrence, Exploitation, and Technology Report on—by L. H. Cole, B.Sc.

254. Calabogie Iron-Bearing District. Report on—by E. Lindeman, M.E.

259. Preparation of Metallic Cobalt by Reduction of the Oxide. Report on—by Professor H. T. Kalmus, B.Sc., Ph.D.

262. The Mineral Production of Canada during the Calendar Year 1912. Annual Report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1912.*

238. General Summary of the Mineral Production of Canada, during the Calendar Year 1912. Bulletin on—by John McLeish, B.A.

†247. Production of Iron and Steel in Canada during the Calendar Year 1912. Bulletin on—by John McLeish, B.A.

---

†Publications marked thus † are out of print.

†256. Production of Copper, Gold, Lead Nickel, Silver, Zinc, and other Metals of Canada, during the Calendar Year 1912—by C. T. Cartwright, B.Sc.

257. Production of Cement, Clay Products, stone, and other Structural Materials during the Calendar Year 1912. Report on—by John McLeish, B.A.

†258. Production of Coal and Coke in Canada, during the Calendar Year 1912. Bulletin on—by John McLeish, B.A.

264. French translation: Mica: Its Occurrence, Exploitation, and Uses. Report on—by Hugh S. de Schmid, M.E.

265. French translation: Annual Mineral Production of Canada, 1911. Report on—by John McLeish, B.A.

266. Investigation of the Peat Bogs and Peat Industry of Canada, 1911 and 1912. Bulletin No. 9—by A. v. Anrep, Peat Expert.

279. Building and Ornamental Stones of Canada—Vol. III. Report on—by Professor W. A. Parks, Ph.D.

281. The Bituminous Sands of Northern Alberta. Report on—by S. C. Ells, M.E.

283. Mineral Production of Canada, 1913. Preliminary report on—by J. McLeish, B.A.

288. French translation: Production of Coal and Coke in Canada during the Calendar Year 1912. Bulletin on—by John McLeish, B.A.

290. French translation: Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and Other Metals of Canada, during the Calendar Year 1912. Bulletin on—by C. T. Cartwright, B.Sc.

299. Peat, Lignite, and Coal: Their Value as Fuels for the Production of Gas and Power in the By-product Recovery Producer. Report on—by B. F. Haanel, B.Sc.

303. Moose Mountain Iron-Bearing District. Report on—by E. Lindeman, M.E.

309. The Physical Properties of the Metal Cobalt, Part II. Report on—by H. T. Kalmus, B.Sc., Ph.D.

315. The Production of Iron and Steel during the Calendar Year 1913. Bulletin on—by John McLeish, B.A.

---

†Publications marked thus † are out of print.

316. The Production of Coal and Coke during the Calendar Year 1913. Bulletin on—by John McLeish, B.A.

318. The Production of Cement, Lime, Clay Products, Stone, and other Structural Materials in Canada, during the Calendar Year, 1913. By J. McLeish, B.A.

319. A General Summary of the Mineral Production in Canada during the Calendar Year 1913. Bulletin on—by J. McLeish, B.A.

NOTE.—*The Division of Mineral Resources and Statistics has prepared the following lists of mine, smelter, and quarry operators: Metal mines and smelters, Coal mines, Stone quarry operators, Manufacturers of clay products and Manufacturers of lime; copies of the lists may be obtained on application.*

IN THE PRESS.

179. French translation: The Nickel Industry: with Special Reference to the Sudbury region. Report on—by Prof. A. P. Coleman, Ph.D.

204. French translation: Building Stones of Canada—Vol. II: Building and Ornamental Stones of the Maritime Provinces. Report on—by W. A. Parks, Ph.D.

263. French translation: Recent Advances in the Construction of Electric Furnaces for the Production of Pig Iron, Steel, and Zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

285. Summary Report of Mines Branch, 1913.

287. French translation: Production of Iron and Steel in Canada during the Calendar Year 1912. Bulletin on—by John McLeish, B.A.

289. French translation: Production of Cement, Lime, Clay Products, Stone, and Other Structural Materials during the Calendar Year 1912. Bulletin on—by John McLeish, B.A.

291. Petroleum and Natural Gas Resources of Canada. Report on—by F. G. Clapp, A.M., and others.

305. Non-metallic minerals used in the Canadian Manufacturing Industries. Report on—by H. Frechette, M.Sc.

308. French translation: An investigation of the Coals of Canada with reference to their Economic Qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others:

Vol. I—Coal Washing and Coking Tests.
Vol. II—Boiler and Gas Producer Tests.
Vol. III—
  Appendix I
    Coal Washing Tests and Diagrams.
Vol. IV—
  Appendix II
    Boiler Tests and Diagrams.

314. French translation: Iron Ore Deposits, Bristol Mine, Pontiac county, Quebec. Report on—by E. Lindeman, M.E.

317. The Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and other Metals, during the Calendar Year 1913. Bulletin on—by C. T. Cartwright, B.Sc.

320. The Mineral Production of Canada, 1913. Annual Report on—by John McLeish, B.A.

322. Economic Minerals and Mining Industries of Canada. (Revised Edition, for Panama-Pacific Exposition.)

MAPS.

†6. Magnetometric Survey, Vertical Intensity: Calabogie Mine, Bagot township, Renfrew county, Ontario—by E. Nystrom, 1904. Scale 60 feet to 1 inch. Summary report, 1905. (See Map No. 249.)

†13. Magnetometric Survey of the Belmont Iron Mines, Belmont township, Peterborough county, Ontario—by B. F. Haanel, 1905. Scale 60 feet to 1 inch. Summary report, 1905. (See Map. No. 186).

†14. Magnetometric Survey of the Wilbur Mine, Lavant township, Lanark county, Ontario—by B. F. Haanel, 1905. Scale 60 feet to 1 inch. Summary report, 1905.

†33. Magnetometric Survey, Vertical Intensity: Lot 1, Concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch.

†34. Magnetometric Survey, Vertical Intensity: Lots 2 and 3, Concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch.

NOTE.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†35. Magnetometric Survey, Vertical Intensity: Lots 10, 11, and 12, Concession IX, and Lots 11 and 12, Concession VIII, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch.

*36. Survey of Mer Bleue Peat Bog, Gloucester township, Carleton county, and Cumberland township, Russell county, Ontario—by Erik Nystrom, and A. v. Anrep. (Accompanying report No. 30.)

*37. Survey of Alfred Peat Bog, Alfred and Caledonia townships, Prescott county, Ontario—by Erik Nystrom, and A. v. Anrep. (Accompanying report No. 30.)

*38. Survey of Welland Peat Bog, Wainfleet and Humberstone townships, Welland county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*39. Survey of Newington Peat Bog, Osnabruck, Roxborough, and Cornwall townships, Stormont county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*40. Survey of Perth Peat Bog, Drummond township, Lanark county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*41. Survey of Victoria Road Peat Bog, Bexley and Carden townships, Victoria county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*48. Magnetometric Survey of Iron Crown claim at Nimpkish (Klaanch) river, Vancouver island, B.C.—by E. Lindeman. Scale 60 feet to 1 inch. (Accompanying report No. 47.)

*49. Magnetometric Survey of Western Steel Iron claim, at Sechart, Vancouver Island, B.C.—by E. Lindeman. Scale 60 feet to 1 inch. (Accompanying report No. 47.)

*53. Iron Ore Occurrences, Ottawa and Pontiac counties, Quebec, 1908—by J. White and Fritz Cirkel. (Accompanying report No. 23.)

*54. Iron Ore Occurrences, Argenteuil county, Quebec, 1908—by Fritz Cirkel. (Accompanying report No. 23.) Out of print.

*57. The Productive Chrome Iron Ore District of Quebec—by Fritz Cirkel. (Accompanying report No. 29.)

NOTE.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†60. Magnetometric Survey of the Bristol Mine, Pontiac county, Quebec—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 67.)

†61. Topographical Map of Bristol Mine, Pontiac county, Quebec—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 67.)

†64. Index Map of Nova Scotia: Gypsum—by W. F. Jennison.

†65. Index Map of New Brunswick: Gypsum—by W. F. Jennison

†66. Map of Magdalen Islands: Gypsum—by W. F. Jennison.

(Accompanying report No. 84)

†70. Magnetometric Survey of Northeast Arm Iron Range, Lake Timagami, Nipissing district, Ontario—by E. Lindeman. Scale 200 feet = 1 inch. (Accompanying report No. 63.)

†72. Brunner Peat Bog, Ontario—by A. v. Anrep.

†73. Komoka Peat Bog, Ontario—by A. v. Anrep.

74. Brockville Peat Bog, Ontario—by A. v. Anrep.

75. Rondeau Peat Bog, Ontario—by A. v. Anrep.

†76. Alfred Peat Bog, Ontario—by A. v. Anrep.

†77. Alfred Peat Bog, Ontario: Main Ditch profile—by A. v. Anrep.

(Accompanying report No 71)

Out of print.

†78. Map of Asbestos Region, Province of Quebec, 1910—by Fritz Cirkel. Scale 1 mile to 1 inch. (Accompanying report No. 69.)

†94. Map showing Cobalt, Gowganda, Shiningtree, and Porcupine districts—by L. H. Cole. (Accompanying Summary report, 1910.)

†95. General Map of Canada, showing Coal Fields. (Accompanying report No. 83—by Dr. J. B. Porter.)

†96. General Map of Coal Fields of Nova Scotia and New Brunswick. (Accompanying report No. 83—by Dr. J. B. Porter.)

†97. General Map showing Coal Fields in Alberta, Saskatchewan, and Manitoba. (Accompanying report No. 83—by Dr. J. B. Porter.)

NOTE.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†98. General Map of Coal Fields in British Columbia. (Accompanying report No. 83—by Dr. J. B. Porter.)

†99. General Map of Coal Field in Yukon Territory. (Accompanying report No. 83—by Dr. J. B. Porter.)

†106. Geological Map of Austin Brook Iron Bearing district, Bathurst township, Gloucester county, N.B.—by E. Lindeman. Scale 400 feet to 1 inch. (Accompanying report No. 105.)

†107. Magnetometric Survey, Vertical Intensity: Austin Brook Iron Bearing District—by E. Lindeman. Scale 400 feet to 1 inch. (Accompanying report No. 105.)

†108. Index Map showing Iron Bearing Area at Austin Brook—by E. Lindeman. (Accompanying report No. 105.)

*112. Sketch plan showing Geology of Point Mamainse, Ont.—by Professor A. C. Lane. Scale, 4,000 feet to 1 inch. (Accompanying report No. 111.)

†113. Holland Peat Bog, Ontario—by A. v. Anrep. (Accompanying report No. 151.)

*119–137. Mica: Township maps, Ontario and Quebec—by Hugh S. de Schmid. (Accompanying report No. 118.)

†138. Mica: Showing Location of Principal Mines and Occurrences in the Quebec Mica Area—by Hugh S. de Schmid. Scale 3.95 miles to 1 inch. (Accompanying report No. 118.)

†139. Mica: Showing Location of Principal Mines and Occurrences in the Ontario Mica Area—by Hugh S. de Schmid. Scale 3.95 miles to 1 inch. (Accompanying report No. 118.)

†140. Mica: Showing Distribution of the Principal Mica Occurrences in the Dominion of Canada—by Hugh S. de Schmid. Scale 3.95 miles to 1 inch. (Accompanying report No. 118.)

†141. Torbrook Iron Bearing District, Annapolis county, N.S.—by Howells Fréchette. Scale 400 feet to 1 inch. (Accompanying report No. 110.)

†146. Distribution of Iron Ore Sands of the Iron Ore Deposits on the North Shore of the River and Gulf of St. Lawrence, Canada—by Geo. C. Mackenzie. Scale 100 miles to 1 inch. (Accompanying report No. 145.)

NOTE.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†147. Magnetic Iron Sand Deposits in relation to Natashkwan harbour and Great Natashkwan river, Que. (Index Map)—by Geo. C. Mackenzie. Scale 40 chains to 1 inch. (Accompanying report No. 145.)

†148. Natashkwan Magnetic Iron Sand Deposits, Saguenay county, Que.—by Geo. C. Mackenzie. Scale 1,000 feet to 1 inch. (Accompanying report No. 145.)

†152. Map showing the Location of Peat Bogs investigated in Ontario—by A. v. Anrep.

†153. Map Showing the Location of Peat Bogs investigated in Manitoba—by A. v. Anrep.

†157. Lac du Bonnet Peat Bog, Manitoba—by A. v. Anrep.

†158. Transmission Peat Bog, Manitoba—by A. v. Anrep.

†159. Corduroy Peat Bog, Manitoba—by A. v. Anrep.

†160. Boggy Creek Peat Bog, Manitoba—by A. v. Anrep.

†161. Rice Lake Peat Bog, Manitoba—by A. v. Anrep.

†162. Mud Lake Peat Bog, Manitoba—by A. v. Anrep.

†163. Litter Peat Bog, Manitoba—by A. v. Anrep.

(Accompanying report No. 151)

†164. Julius Peat Litter Bog, Manitoba—by A. v. Anrep.

†165. Fort Francis Peat Bog, Ontario—by A. v. Anrep.

(Accompanying report No. 151.)

*166. Magnetometric Map of Mine No. 3, Lot 7, Concessions V and VI McKim township, Sudbury district, Ont.—by E. Lindeman. (Accompanying Summary Report, 1911.)

†168. Map showing Pyrites Mines and Prospects in Eastern Canada, and their relation to the United States Market—by A. W. G. Wilson. Scale 125 miles to 1 inch. (Accompanying report No. 167.)

†171. Geological Map of Sudbury Nickel region, Ont.—by Prof. A. P. Coleman. Scale 1 mile to 1 inch. (Accompanying report No. 170.)

NOTE.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†172. Geological Map of Victoria mine—by Prof. A. P. Coleman.

†173. Geological Map of Crean Hill mine—by Prof. A. P. Coleman.

†174. Geological Map of Creighton mine—by Prof. A. P. Coleman.

(Accompanying report No. 170.)

†175. Geological Map showing contact of Norite and Laurentian in vicinity of Creighton mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†176. " " of Copper Cliff offset—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†177. " " No. 3 Mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†178. " " showing vicinity of Stobie and No. 3 mines—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†185. Magnetometric Survey, Vertical Intensity: Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†185a. Geological Map, Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186. Magnetometric Survey, Belmont iron mine, Belmont township, Peterborough county, Ont.—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186a. Geological Map, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187. Magnetometric Survey, Vertical Intensity: St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187a. Geological Map, St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

NOTE.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†188. Magnetometric Survey, Vertical Intensity: Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†188a. Geological Map, Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†189. Magnetometric Survey, Vertical Intensity: Ridge iron ore deposits, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†190. Magnetometric Survey, Vertical Intensity: Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†190a. Geological Map, Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184).

†191. Magnetometric Survey, Vertical Intensity: Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†191a. Geological Map, Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†192. Magnetometric Survey, Vertical Intensity: Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†192a. Geological Map, Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193. Magnetometric Survey, Vertical Intensity: Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193a. Geological Map, Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

NOTE.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†194. Magnetometric Survey, Vertical Intensity: Bow Lake iron ore occurrences, Faraday township. Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†204. Index Map, Magnetic occurrences along the Central Ontario Railway —by E. Lindeman, 1911. (Accompanying report No. 184.)

†205. Magnetometric Map, Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman, 1911. (Accompanying report No. 303.)

†205a. Geological Map, Moose Mountain iron-bearing district, Sudbury district, Ontario. Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman. (Accompanying report No. 303.)

†206. Magnetometric Survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Northern part of Deposit No. 2—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†207. Magnetometric Survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 8, 9, and 9A—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208. Magnetometric Survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposit No. 10—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208a. Magnetometric Survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: Eastern portion of Deposit No. 11—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208b. Magnetometric Survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: Western portion of Deposit No. 11—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208c. General Geological Map, Moose Mountain iron-bearing district, Sudbury district, Ontario—by E. Lindeman, 1912. Scale, 800 feet to 1 inch. (Accompanying report No. 303.)

†210. Location of Copper Smelters in Canada—by A. W. G. Wilson. Scale 197·3 miles to 1 inch. (Accompanying report No. 209.)

NOTE.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†215. Province of Alberta: Showing properties from which samples of coal were taken for gas producer tests, Fuel Testing Division, Ottawa. (Accompanying Summary Report 1912.)

†220. Mining Districts, Yukon. Scale 35 miles to 1 inch—by T. A. MacLean. (Accompanying report No. 222.)

†221. Dawson Mining District, Yukon. Scale 2 miles to 1 inch—by T. A. MacLean. (Accompanying report No. 222.)

*228. Index Map of the Sydney Coal Field, Cape Breton, N.S. (Accompanying report No. 227.)

†232. Mineral Map of Canada. Scale 100 miles to 1 inch. (Accompanying report No. 230.)

†239. Index Map of Canada, showing gypsum occurrences. (Accompanying report No. 245.)

†240. Map showing Lower Carboniferous formation in which gypsum occurs. Scale 100 miles to 1 inch. (Accompanying report No. 245.)

†241. Map showing relation of gypsum deposits in Northern Ontario to railway lines. Scale 100 miles to 1 inch. (Accompanying report No. 245.)

†242. Map, Grand River gypsum deposits, Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 245.)

†243. Plan of Manitoba Gypsum Co.'s properties. (Accompanying report No. 245.)

†244. Map showing relation of gypsum deposits in British Columbia to railway lines and market. Scales 35 miles to 1 inch. (Accompanying report No. 245.

†249. Magnetometric Survey, Caldwell and Campbell mines, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†250. Magnetometric Survey, Black Bay or Williams mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

NOTE.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†251. Magnetometric Survey, Bluff Point iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†252. Magnetometric Survey, Culhane mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†253. Magnetometric Survey, Martel or Wilson iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254).

†261. Magnetometric Survey, Northeast Arm iron range, Lot 339 E. T. W. Lake Timagami, Nipissing district, Ontario—by E. Nystrom, 1903. Scale 200 feet to 1 inch.

†268. Map of Peat Bogs Investigated in Quebec—by A. v. Anrep, 1912.

†269. Large Tea Field Peat Bog, Quebec " "

†270. Small Tea Field Peat Bog, Quebec " "

†271. Lanorie Peat Bog, Quebec " "

†272. St. Hyacinthe Peat Bog, Quebec " "

†273 Rivière du Loup Peat Bog " "

†274. Cacouna Peat Bog " "

†275. Le Parc Peat Bog, Quebec " "

†276. St. Denis Peat Bog, Quebec " "

†277. Rivière Ouelle Peat Bog, Quebec " "

†278. Moose Mountain Peat Bog, Quebec " "

†284. Map of northern portion of Alberta, showing position of outcrops of bituminous sand. Scale 12½ miles to 1 inch. (Accompanying report No. 281.)

†293. Map of Dominion of Canada, showing the occurrences of oil, gas, and tar sands. Scale 197 miles to 1 inch. (Accompanying report No. 291.)

NOTE.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†294. Reconnaissance Map of part of Albert and Westmorland counties, New Brunswick. Scale 1 mile to 1 inch. (Accompanying report No. 291.)

†295. Sketch plan of Gaspe oil fields, Quebec, showing location of wells. Scale 2 miles to 1 inch. (Accompanying report No. 291.)

†296. Map showing gas and oil fields and pipe-lines in Southwestern Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 291.)

†297. Geological Map of Alberta, Saskatchewan and Manitoba. Scale 35 miles to 1 inch. (Accompanying report No. 291.)

†298. Map, Geology of the forty-ninth parallel, 0.9864 miles to 1 inch. (Accompanying report No. 291.)

†302. Map showing location of main gas line, Bow Island-Calgary. Scale 12½ miles to 1 inch. (Accompanying report No. 291.)

†311. Magnetometric Map, McPherson mine, Barachois, Cape Breton county, Nova Scotia. Scale 200 feet to 1 inch.

†312. Magnetometric Map, iron ore deposits at Upper Glencoe, Inverness county, Nova Scotia. Scale 200 feet to 1 inch.

†313. Magnetometric Map, iron ore deposits at Grand Mira, Cape Breton county, Nova Scotia. Scale 200 feet to 1 inch.

Address all communications to—
DIRECTOR MINES BRANCH,
DEPARTMENT OF MINES,
SUSSEX STREET, OTTAWA.

NOTE.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.