PRODUCER GAS FROM LOW-GRADE FUELS.*

BY

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THE Reports of the U. S. Geological Survey show that, if the rate of increase of fuel consumption in this country that has held for the past fifty years is maintained, the supply of easily available coal will be exhausted before the middle of the next

FIG. 1.

century. As is shown in Fig. 1, the production of coal in the United States increased from less than twenty million tons fifty years ago to nearly five hundred million tons in 1912; if the industries of the country continue to develop at a sufficient pace to maintain this rate of increase, then the limit of our coal supply will be reached in about 200 years. As a matter of fact, the fuel consumption per capita is actually increasing much faster than the population, so that the question of the continuation of this rate of increase is one of considerable importance.

It is interesting to note that the production of coal in the United States has been for some years greater than that in any

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other country. The world's production of coal by countries for 1907—the last year for which figures are available to the writer—is given in Fig. 2.

The disposition of the coal fields in this country, as well as the relative areas of the different grades of coal, is indicated in Fig. 3. The limited supply of good coal makes it necessary to mine large quantities of sub-bituminous coal and lignite to meet future conditions. It will be noted that there is very little overlapping of the bituminous and lignite areas.

Most of the United States lignites do not weather well, but break down and crumble into fine dust when exposed to the atmosphere for any length of time. There are, however, extensive areas

FIG. 2.

of lignites in Alaska which stand up very well under weather conditions.

A great many low-grade bituminous coals and lignites may be utilized for power purposes by briquetting, and the use of this process industrially is gradually increasing. Briquetting, however, raises the price of the fuel by a considerable amount. It costs 90 cents to \$1 per ton to briquette coal, and this large expense is practically prohibitive in competition with cheap fuel. On account of the expense, it appears that briquetted coal will hardly become adopted for large plant work, though this form of fuel undoubtedly serves well under certain conditions for domestic purposes.

Another low-grade fuel is peat. There are large deposits of peat in this country, and in Canada there are some 37,000 square

miles of peat area from six to ten feet in thickness. Peat is prepared in Sweden, Denmark, Germany and Russia, and is also secured extensively in Ireland and some parts of Holland. The distribution of peat in the United States is shown in the map, Fig. 4.

When it comes from the bog, peat contains about 85 per cent. water, but when "commercially dried" by exposing it to the sun, it contains from 25 to 30 per cent. moisture. Commercially dry peat has a heat value of about 8000 B. T. U. per pound, and

FIG. 3.

■ Anthracite & Bituminous, 150,531 sq. m. ■ Sub-bituminous, 97,636 sq. m.
 ▨ Lignite, 148,609 sq. m.

is very suitable for use in gas producers, as very little or no steam need be introduced with it.

In view of the necessity of utilizing, for the production of power, grades and varieties of fuels which have not until recently been considered economical, the U. S. Bureau of Mines has conducted a number of investigations on the making of producer gas from such fuels.

The introduction of the gas producer into this country for power plant work was made about the year 1900. In that year the number of installations was very few—perhaps two or three plants—but since then it has steadily increased. The total number of plants in 1911, of which the writer has record, was 660, and of these a large proportion were double installations, which were

not counted separately. The number of gas producer power plants in the United States at the present time is probably in the neighborhood of 1000. The total horsepower of such plants in the United States in 1900 was 2000; this has increased year by year until in 1911 it was between 160,000 and 170,000, some 80,000 of which was obtained from bituminous coal, some 70,000 from anthracite fuel, and about 10,000 from lignite.

Of the total number of plants operating in 1912, 84.5 per cent. used anthracite coal and 10.7 per cent. bituminous coal, while lignite was used in 4.4 per cent. of the installations. The anthracite plants, however, represented only 47.8 per cent. of the

FIG. 4.

total horsepower developed, the bituminous plants 46.3 per cent., and the lignite plants 5.4 per cent., while wood and oil developed the remaining small percentage.

Summarized data relative to producer gas plants in the United States, March, 1912, are given in Fig. 5.

The anthracite plants are scattered all over the country, though several are congregated around New York and Philadelphia. The lignite plants are chiefly in Texas and Washington; there was a marked increase in 1912 in lignite plants in the former of these States. The largest total horsepower is produced in New York, and the next in Missouri.

Factors which influence the installation of any particular type of plant are cost of installation and of maintenance, and economy. The average cost of producer gas installations is about equal to that of reciprocating steam engines; the cost of maintenance is, however, only about one-half, while the economy has been shown in several cases to be from two to three times as great. These statements are illustrated in Fig. 6.

At the Interboro Rapid Transit Company's Fifty-ninth Street Station, New York City, is one of the most efficient steam plants of which the writer has knowledge. At this plant 970 B. T. U. have to be put into the furnace to realize 100 B. T. U. at the

FIG. 6.

busbars. A theoretical gas plant devised on the same scale by Mr. Stott, Superintendent of Motive Power of the Interboro Rapid Transit Company, is shown in comparison in Fig. 7. In the gas plant 100 B. T. U. are obtained at the busbars when only 465 B. T. U. are charged into the producer.

Representing the figures in the above example in percentages, out of 100 per cent. of energy thrown into the furnace of the Interboro Rapid Transit Company's boilers, 10.3 per cent. is realized as useful work at the busbars. The theoretical gas plant assumed for comparison would deliver 21.5 per cent. to the busbars; this comparison is shown in Fig. 8.

At the Bureau of Mines Testing Station a 250 H. P. Corliss Engine, with 26.6 pounds water rate, with Heine Boilers, re-

quired 2060 B. T. U. charged into the furnace to secure 100 B. T. U. at the busbars, while a gas producer and gas engine, using the same fuel, required only 740 B. T. U. to deliver 100 B. T. U. at the busbars. In other words, 4.85 per cent. of the energy in the fuel charged into the furnace of the steam plant was delivered to the busbars, while 13.5 per cent. of that charged into the producer was delivered in the same way. These figures are shown graphically in Figs. 7 and 8 under "B. of M."

FIG. 7.

B.T.U.'s

FIG. 8.

PER CENT

From a series of tests on a number of different Illinois coals, a comparison of the quantity of fuel per horsepower hour required in the steam plant and in the producer gas plant at the Bureau of Mines showed that, on the average, the former required 2.6 times as much as the latter. With fuel ranging in heat value from 14,000 to 15,000 B. T. U. per pound, the gas plant consumed approximately one pound, and the steam plant approximately three pounds per horsepower hour. Similarly, with fuels ranging between 7000 and 8000 B. T. U. per pound, the

gas plant consumed $2\frac{3}{4}$ pounds per horsepower hour while the steam plant required 7 pounds. These figures represent the average of a large series of tests of coals and lignites from different sections of the country. The following results were secured under similar conditions at each of these plants.

2.9 pounds of West Virginia run of mine coal containing 2.4 per cent. moisture per brake horsepower per hour were required

FIG. 9.

in the steam plant, while the gas plant required but 0.85 pound of the same coal.

With New Mexican run of mine coal, containing 19.6 per cent. ash, the gas plant required 1.1 pounds per brake horsepower hour, or just a little more than of the highest grade West Virginia coal, and very much less than the steam plant with West Virginia coal.

With West Virginia bone coal containing 44 per cent. ash which came in such form that a great deal of it resembled rock and, when struck with a hammer, threw out sparks, only 1.66 pounds per horsepower hour were required.

Many such fuels as the above can be utilized in producer gas plants, which require, as indicated, much less coal per horsepower hour than the corresponding steam plant.

Lignites usually run high in moisture, but make a gas of excellent quality. Less lignite was required per horsepower hour in the gas plant than of West Virginia coal in the steam plant.

Fig. 9 shows the distribution of heat in typical steam and gas plants. The heat losses in the two plants are as follows:

STEAM PLANT.

	Per cent.
Heat lost in ashes	2.00
Heat lost in radiation and cooling	4.60
Heat lost in smoke	24.60
Total losses in boiler	31.20
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Heat lost in radiation and friction	3.30
Heat lost in exhaust	53.50
Heat lost in jacket water	
Heat lost in auxiliaries	7.30
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Total heat losses in entire plant	95.30
Net efficiency of plant	4.70

GAS PLANT.

	Per cent.
Heat lost in ashes	1.10
Heat lost in radiation and cooling	18.60
Heat lost in smoke	
Total losses in producer	19.70
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Heat lost in radiation and friction	4.30
Heat lost in exhaust	23.70
Heat lost in jacket water	33.50
Heat lost in auxiliaries	
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Total heat losses in entire plant	81.30
Net efficiency of plant	18.80
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Original heat in the coal in both plants = 13,500 units per pound.	

There are several types of gas producers now in use, among which are the suction type, the up-draft pressure type, the down-draft type and the double-zone type.

The suction producer is the simplest in form. A typical suction producer is shown in Fig. 10. The operation is as follows: The producer *B* is fed with fuel from the hopper *A*, which is provided with some feeding device so that the fuel may be dropped into the container below without admitting air. *C* is the vaporizer for vaporizing the water and mixing it with the air. The steam-saturated air passes down through the pipe *P* to the bottom of the producer. *D* is the starting fan. The hot gas leaving the producer enters a vertical pipe *E*, the upper part of which can be opened to the air to allow the poorer gas to escape when starting.

FIG. 10.

The gas passes down the vertical pipe through a water seal to the coke scrubber *G*. Tar collects at the bottom of *E* and runs into the tank shown. From the scrubber, the gas passes into the expansion box *H*, from which it is drawn by the piston of the engine into the cylinder.

The gas produced by the use of air and carbon only has certain excellent qualities for power purposes, but is rather low in heat value, and further than that, in making such gas there is a tendency for the temperature to rise to such a point that excessive clinkering is produced and fuel troubles are caused. The introduction of water or steam maintains the temperature at a sufficiently low point to prevent clinker formations.

When producer gas is made from coal, its constituents are carbon monoxide, a limited percentage of hydrogen and a small amount of marsh gas. Carbon monoxide is the main constituent.

Some gas producers embodying special features are shown in Figs. 11 and 12. The producer illustrated in Fig. 11 has a re-

FIG. 11.

volving grate and an automatic feed. That shown in Fig. 12 is a mechanically-poked continuous gas producer.

A number of gas plants are provided with centrifugal tar extractors, for removing tar. Getting rid of this tar after it is removed is a very serious problem, and many attempts are being made to effect an increased utilization of this product commercially. Fig. 13 shows a system in which arrangement is made for converting the tar into gas available for use in the engine.

The method is to run two generators on a certain grade of fuel. The bed is a layer of coke; the fire is built on top of this and green coal is charged in over the fire. By this means an incandescent bed is formed. The draft produced by the exhauster draws the gas downward from the green coal through the incandescent bed, and the tarry compounds are supposedly converted

FIG. 12.

into gas. The products are then drawn through the wet and dry scrubbers to the holder. As shown in the figure, the exhauster is situated between the wet and dry scrubbers.

With the above system, after a certain period of operation, the tarry compounds, dust, soot, etc., tend to clog the fuel bed and the pull on the exhauster increases. Under normal conditions, the average pull is from 5 to 6 inches of water, increasing steadily.

FIG. 13.

When the pull has risen to about 20 inches, the process of "shooting the bed" is gone through. The charging doors and the gas valve are closed, and steam under 60 to 80 pounds pressure is turned on under the grate. This jet of steam shakes up the whole fuel bed and sends the dirt, dust, soot, etc., through the by-pass into the other gas generator. After the process is completed the

FIG. 14.

gas has a heat value of about 200 B. T. U. instead of 105 B. T. U.

A double purpose is served with this type of plant, as two kinds of gas are produced—the first being commonly called air gas and the second water gas.

The system is used by a company in Boston which, however, requires no water gas, but simply gas for the engines. As a re-

sult, the bed is shot just as seldom as possible, sometimes not oftener than every six hours.

Another company uses a 4000-horsepower plant of this type. This company requires about 2000 horsepower for engine purposes, and the remainder of the gas for heating, tempering, an-

FIG. 15.

nealing, etc. In consequence, they shoot the bed just as often as possible, heating it up as rapidly as they can and then shooting it.

Tar can be satisfactorily converted into gas under the proper operating conditions. If, however, the temperature is not quite right, lamp black usually results.

In the type of plant described above, as the ash accumulates between the coke bed and the green fuel bed, the plant is intermittent and must be shut down in order to recharge. The charg-

FIG. 16.

FIG. 17.

ing door may be opened and the coal charged directly into the producer, the whole operation being in full view of the operator.

Fig. 14 shows a type of producer with a double zone, in which are run two fuel beds, the object being to get rid of the tar. The coke which comes down through the upper zone becomes the main fuel for the lower zone.

A plant which was installed in the summer of 1913 and which illustrates the latest type of producer is shown in Fig. 15.

FIG. 18.

This producer is installed in Illinois, and is the largest single generator producer in the world. The producer proper is of simple construction and is made out of sheet steel and channels. It has semi-cylindrical ends and flat sides, as shown in Fig. 16. The capacity of the plant is forty tons of Illinois bituminous coal per twenty-four hours. The producer is equipped with what is known as the "Smith Type F Tar Extractor," having a capacity of 250,000 cubic feet per hour. This is not a centrifugal extractor, but consists of a double-tee arrangement; it has no moving parts and requires no water. The tar extractor in posi-

tion on the charging floor is shown in Fig. 17. In this figure may also be seen the gas exhauster. Fig. 18 is another view of the charging floor, showing the charging hoppers and the engine-driven gas pump.

FIG. 19.

FIG. 20.

Centralization will undoubtedly become one of the essential factors in producer gas work, and even now railroads are considering the question of installing large central plants at the coal mines and utilizing the fuel there. Many important advantages are to be secured by the installation of such large plants, not the

least of which is the practical elimination of the smoke nuisance. A striking contrast between the old coal-burning methods and modern producer practice is illustrated in Figs. 19 and 20. Fig. 19 shows a typical view of coal plants in Staffordshire, England, and Fig. 20 shows a 16,000-horsepower producer gas station at Dudley Port, Staffordshire (recently enlarged to about 30,000 H. P.). This gas plant is one of the largest in the world. It is run as a by-product plant, and produces about 90 pounds of sulphate of ammonia per ton of coal. The gas is sold at a price which would correspond to 14 cents per 1000 cubic foot for city gas.

High-frequency Spectra of the Elements. H. G. J. MOSELY. (*Phil. Mag.*, xxvi, 1024.)—In the absence of any available method of spectrum analysis, the characteristic types of Röntgen radiation, which an atom emits when suitably excited, have hitherto been described in terms of their absorption in aluminum. This paper contains a description of a method of photographing the high-frequency spectra, which makes the analysis of the Röntgen rays as simple as any other branch of spectroscopy. It is intended first to make a general survey of the principal types of high-frequency radiation and then to examine the spectra of a few elements in greater detail and with great accuracy. The results already obtained show that such data have an important bearing on the question of the internal structure of the atom, and strongly support the views of Rutherford and of Bohr. Kaye has shown that an element excited by a stream of sufficiently rapid kathode rays emits its characteristic Röntgen reaction. He used as targets a number of substances mounted on a truck inside an exhausted tube, a magnetic device enabling each target to be brought in turn into the line of fire. This apparatus was modified to suit the present work. The kathode stream was concentrated on to a small area of the target, and a platinum plate with a fine vertical slit was placed immediately in front of the part bombarded. The tube was exhausted by a Gaede pump, charcoal in liquid air was also used sometimes to remove water vapor. The Röntgen rays after passing through the slit, emerged through an aluminum window 0.02 mm. thick. The rest of the radiation was shut off by a lead box which surrounded the tube. The rays fell on a cleavage face of a crystal of potassium ferrocyanide which was mounted on the prism table of a spectrometer. A photographic plate was mounted on the spectrometer arm, and both the plate and slit, S , were 17 cm. from the axis. If P is the part of the crystal where the radiation strikes the surface, and L the line on the photographic plate corresponding to radiation of definite frequency with glancing angle of incidence θ , then