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SURVEY OF BROWN COAL MINING AND PROCESSING IN GERMANY

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[Tables referred to are appended.]

The development of brown coal mining in the past 50 years has been characterized mainly by steady growth. Up to the turn of the century, brown coal mining was a small industry, as opposed to the already greatly developed industry of bituminous mining. At the beginning of the century, the situation changed, as a result of the increased demand for brown coal products and, consequently, in their heightened market value. New regions were opened in increasing numbers, and in various areas, existing works were enlarged and modernized. Especially during the period since the end of World War I, there began, along with the increasing demand for crude brown coal and brown coal briquettes, a unique and irregular development of brown coal technology, not only in respect to the production of brown coal in open-pit mines but also in respect to its use.

I. RESERVES OF BROWN COAL

Because of insufficient drillings, the estimates of brown coal reserves have been incomplete and often have been increased after the opening of new fields. Even today, it is still impossible to secure a clear picture of the reserves in existence.

Estimates of the reserves exist for 1901, 1922, and 1935. In 1901, the reserves of brown coal were estimated at 10 billion tons. The estimate for 1922 gave the total as 22 billion tons, of which 10 billion tons were available from open-pit mines and 12 billion tons from underground mining. Even these

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reserve estimates were well under the actual figures, as indicated by the statistics submitted by the Prussian Geological Institute, which completed an inventory of the German reserves of brown coal in winter 1934 and spring 1935. According to these figures, the known and probable reserves extractable at that time amounted to about 57 billion tons, after deducting for mining losses (10 percent in open-pit mines and 40 percent in underground mining) and quantities lost through local conditions and transport.

Of these, about 18 billion tons were reported as extractable through open-pit mines and about 39 billion tons through underground mining. These reserves were distributed as follows: Approximately 17.7 billion tons, or 31.3 percent, in the Rhineland; 16.4 billion tons, or 28.8 percent, in the Lusatian provinces 9.6 billion tons, or 16.0 percent, in the Magdeburg-Halle-Leipzig region; and 8.4 billion tons, or 14.8 percent, in East Germany. The balance of 4.9 billion tons, or 8.2 percent, was apportioned among the remaining districts of Lower Saxony, Hesse, and Bavaria.

These estimates must also be considered outdated because of the drillings which have since been carried out and the modern open-pit mining techniques which allow reserves now to be worked as open-pit mines which in 1935 still had to be considered underground. This applies especially to the brown coal area in the Rhineland. According to more recent information, the available reserves in this region can be estimated to be at least 25 billion tons, but because of insufficient drillings, a conclusive estimate of the reserves is still not possible.

On the basis of the fact that it is now possible to employ open-pit mining up to an absolute depth of 200 meters (through both rock cover and coal seams), according to the corresponding thickness of the deposits, the estimate of the reserves available through open-pit mining in the Rhineland district in 1935 can be increased from 2.3 billion tons to 4.6 billion tons. By analogy, the estimates of open-pit reserves and, because of lower mining losses in open-pit workings, the estimates of the total reserves in the other brown coal mining districts have increased.

Measured by the production in 1950, the supply from the brown coal mines can be expected to last from 300 to 350 years.

II. DEVELOPMENT OF PRODUCTION

The center of brown coal production has been and still is in the region surrounding the Elbe River and in the Rhineland.

Except for slight variations, brown coal production increased steadily until 1943.

From about 15 million tons in 1885, it rose to about 40 million tons in 1900, 86 million tons in 1913 (see Table 1) and reached, through almost uninterrupted increase, 174 million tons in 1929; by 1932, it sank to about 123 million tons, but later began to rise again, and during the war-- computed in the 1937 boundaries --reached 253.4 million tons in 1943, the highest point ever attained. Of the output in 1943, 80 million tons were produced in the present Federal Republic. In the last year of the war, 1944, production sank to about 230 million tons, and in 1945, it dropped to about 111 million tons, its lowest point since 1920. After the effects of the war were overcome, the output again rose to about 176 million tons in 1948 and about 213 million tons in 1950 (the production figures of the Soviet Zone since 1945 are merely conjecture); this exceeded the production in 1938 by about 18 million tons. For

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1951, an increase in output to about 221 million tons is expected. The share of the Federal Republic in the total 1950 production was 75.8 million tons. In 1951, this share rose to about 83.1 million tons.

Bituminous coal production far surpassed brown coal production until 1921; the situation changed after 1922. Except for a period from 1925 to 1927, brown coal production took the lead and has retained it until the present time.

At the turn of the century, only about 30 percent of the brown coal production came from open-pit mines and about 70 percent from underground mining. The portion of the output from open-pit mines had already risen to about 70 percent shortly before World War I, and in 1943, only 5 percent still came from underground mining, while 95 percent came from open-pit mines. Today, the portion from underground mining is probably even smaller.

The increase in the amount of brown coal produced from open-pit mines was made possible by the maximum use of machinery and large-scale production methods, together with a strong concentration of operations, increased productivity, and mining of the deposits with almost no loss.

The number of workers and office employees engaged in brown coal mining rose from 73,300 in 1914 to 109,200 in 1926, fell to 98,400 by 1938, and increased by 1943 to about 129,000 because of war requirements. In 1950, the number of employees was about 158,000. Of this number, about 121,000 were in the Soviet Zone and about 37,000 in the Federal Republic.

III. OPEN-PIT MINING

At the beginning of the century, open-pit mining, as against underground mining was considered economically feasible, if, for a deposit from 10 to 20 meters thick, the ratio of the rock covering to the coal was not more than 1 to 1. Thanks to the development of mining technology, this ratio has constantly improved. Shortly before World War I, and until its end, the economical mining of brown coal in open pits was still limited in deposits of the above-mentioned thickness to a ratio of covering rock to coal of 2 to 1. Today, by excavating and using railroad cars for hauling, it is possible to operate at a ratio from 5 and 6 to 1 and by using conveying bridges when the rock covering and structure of the seams is favorable at a ratio from 7 and 8 to 1 and higher. At the end of the war, an open-pit mine was being opened at Fuerstenberg (Oder), where deposits from 9 to 10 meters thick are covered by 90 meters of rock. It was to be mined by using excavators on tracks. As a matter of fact, at times, open-pit mining operations have been carried out profitably in Lower Lusatia with a ratio of rock covering to coal of 8 to 1 at deposits from 10 to 12 meters.

In open-pit mining of brown coal, the thickness of the deposit naturally plays an important part, as does the actual depth. In other words, a brown coal deposit 20 meters thick can still be worked profitably by open-pit mining with a ratio of rock to coal of 6 to 1, or 120 meters of covering rock to 20 meters of coal. Thereby, the actual depth of the open pit is 140 meters. This is already the case at a few installations in central Germany. If, however, a seam is, for example, 50 meters thick, then the open-pit mine, according to a ratio of rock to coal of 5 to 1, would reach a depth of 300 meters. Despite great progress, open-pit mining technology has not advanced far enough to make coal mining at such depths profitable at the present-day prices of crude coal and briquettes. However, the solution of this problem is of the greatest importance for the mining of deep-lying coal, especially in the Rhineland District. Here, new open-pit projects and mines which are at present being opened are to be mined with deposits from 50 to 80 meters thick and a rock covering of 120 meters and more.

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It is to be hoped and expected that open-pit mining technology will further develop so that the deposits which are still regarded as confined to underground mining with its high mining losses, can be worked by open-pit mining. Where the limits of profitableness between open-pit and underground mining will eventually lie cannot conclusively be stated now, since it will vary as to location and will depend on a variety of factors, especially on the price of the brown coal products.

In accordance with open-pit production and the increased amount of rock covering one ton of coal, the dross rock to be moved has also increased steadily. In 1923 (the figures for previous years are not available), dross removal already totaled 170 million cubic meters; in 1929, it was 244 million cubic meters; in 1938, 325 million cubic meters; and in 1943, the year of the greatest output, the production from open-pit mines of about 242 million tons required dross removal of 512 million cubic meters. Of that, 473 million cubic meters were in the central German region. Thus, with an output from open-pit mines there of at most 172 million tons, an average of 2.8 cubic meters of dross per ton of coal produced required removal. In the Rhineland region, the ratio at that time was considerably more favorable in this respect and has remained so until the present. With an open-pit production of 68.6 million tons in 1943, the dross removal amounted to about 40 million cubic meters, which is equal to about .58 cubic meters per ton of coal produced.

From the above figures, it is obvious that in open-pit mining the primary problem concerns the extraction and haulage of the dross, which, in the central German regions accounted for 70 percent of the total mining costs. However, in the Rhineland region also, the ratio of covering rock to coal in new open-pit mines will increase considerably in the future as compared to the present, so that here, too, dross removal will be the main element of operations.

Therefore, over a period of years, the first objective had to be the increased efficiency of dross removal. The amount of the dross removal per man shift (including workshop personnel and the like) in the central German districts (for the Rhineland District, there are no relative figures) in 1923 was 11.30 cubic meters and increased sharply to a peak of 66.8 cubic meters in 1936. Thereafter, the output of dross per manshift decreased again; in 1939, was down to about 61 cubic meters; in the next 3 years, it remained at about 59 cubic meters; and in 1943, because of the war, it sank to almost 47 cubic meters.

The improvement of operations in the open-pit mining of brown coal after World War I can best be realized by considering the increase in output per man shift. In the open-pit mines of the former Deutsche Braunkohlen-Industrie-Verein e.V., with which all the brown coal companies except those in the Rhineland region were associated, (corresponding figures for the Rhineland have been lost through the effects of the war), this figure increased from 3.63 tons in 1923 to 14.05 tons in 1941, and then, because of the war, declined to 13.73 tons in 1942 and to about 11 tons in 1944. The capacity per capita was thus nearly quadrupled from 1923 to 1943, although the average ratio of the overlying rock to the thickness of the deposit increased from approximately 1.25 to 1, to 2.8 to 1. The aforementioned figures include, in addition to the mine personnel, the haulage personnel, those employed in workshops, and those engaged in associated operations.

IV. UNDERGROUND MINING OF BROWN COAL

In contrast to the great progress in open-pit mining technology, it was impossible to improve the methods of extracting brown coal from underground mines or to increase the production capacity, despite the greatest efforts.

The impossibility of replacing by machinery, to any appreciable extent, the manual labor which has been used almost exclusively in this type of mining from its earliest beginnings until today, with mining losses of up to 40 percent in the pillar caving system, the need for decentralized operations, and other difficulties peculiar to underground mining, have hitherto greatly limited production capacity. Thus, the haulage in underground mines per man shift, which in 1923 was 2.91 tons and which rose to 4.96 tons by 1929, diminished to 3.83 tons in 1939. During the war and in the years following, the per capita production decreased again. In 1950, in underground mining of brown coal in West Germany, the per man-shift capacity averaged 2.37 tons, while in a few installations, peak capacities of up to 4 tons per man-shift were recorded.

Although underground mining output during the past 50 years has declined when measured by total brown coal production, there are today, and there will be in the future, mines which must be restricted to underground mining methods, since they cannot be worked profitably by open-pit methods, despite the expected further development of open-pit brown coal mining techniques.

Since the beginning of the century, and chiefly after World War I, attempts have been made in various localities to replace the pillar caving system with another method which would have lower mining losses and be more productive, but this has not been completely successful. Only in the extraction of coal from fissures has notable improvement been obtained through the installation of conveyers, chutes, and drift conveyers. Through the use of blasting, slitting machines, and conveyers, increased output has been attained. While different types of transporting machines have been developed for brown coal underground mining, they have not satisfactorily solved this problem, but leave room for hope of a solution. In the mining of brown coal in the Rhineland, where two underground mines are being explored and prepared, experiments with transporting machinery are in progress, and new mining processes are being developed which have as their goal complete mechanization of coal mining and conversion to large-scale operations.

V. USE OF BROWN COAL

Because of high moisture content and low heat value of crude brown coal, which does not permit its freighting over great distances because of the competition of bituminous coal the manufacture of briquettes has grown steadily as output has risen. The mining of brown coal has increased, firstly, because of these briquettes, and secondly, because of the increasing use of brown coal for generating electricity and for chemical purposes.

Along with the suitability of brown coal for briquetting, which permits, without addition of binding material, the manufacture of a handy and clean product for home use and a uniform-sized fuel for high-efficiency industrial furnaces and for generators for gas production, the increased use of brown coal is due to its (relatively) high inflammability and rate of combustion and finally, its low heating cost. The low cost of heating with brown coal at the place where it is mined led many large power plants and industries with large heating needs to establish themselves at the site of the brown coal deposits. These included the Goldenbergwerk, with a power output of 530,000 kilowatts and Kraftwerk Zschornewitz, with an output of 515,000 kilowatts, which were the largest power plants in Europe until the beginning of World War II; the Leuna Chemical Works in Bitterfeld near Halle, as well as in Knapsack near Cologne, in addition to the Vereinigte Aluminiumwerke Lauta plants near Senftenberg, and Erftwerk in Grevenbroich.

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Of the crude brown coal production of 83.7 million tons in 1914, the briquette factories and allied boiler plants consumed 64.3 million tons, or 76.8 percent; about 12 million, or 1.4 percent, was carbonized, and 18.2 million tons, or 21.7 percent, was sold directly on the market. In 1943, the output of about 253 million tons was distributed as follows: 144 million tons, or 56.9 percent for briquettes; 24 million tons, or 9.5 percent, used by the mines themselves for supplying electric and steam power and for payment in kind; 2 million tons, or 0.8 percent, for carbonization (the crude brown coal which is carbonized in the form of briquettes is not included); 83 million tons, or 32.8 percent, for consumer coal.

Of the 83 million tons of consumer coal, about 44 million tons went to public power plants, about 36 million tons to industry, about 2 million tons for household fuel, and about 1 million tons to transportation.

There are no figures for the distribution of crude brown coal production for all of Germany in the postwar years.

In the Federal Republic, the distribution of the 1950 output, amounting to 75.8 million tons, was as follows: 32.2 million tons, or 42.5 percent, coal for briquettes; 14.4 million tons, or 19.0 percent, for use of the coal mines and payment in kind; 2.1 million tons, or 2.8 percent, converted to energy; 2.0 million tons, or 2.6 percent, for carbonization; 2.0 million tons, or 2.6 percent, for a power plant and briquette factory in the Soviet Zone; 18.0 million tons, or 23.8 percent, for large power plants; and 5.1 million tons, or 6.7 percent, for other consumers.

Manufacture of Briquettes

After an introductory period of more than 10 years, the manufacture of briquettes became well established by the beginning of the 1880's. From about 0.75 million tons in 1885, it increased steadily over a period of years; in 1900, production was about 6.5 million tons; in 1914, it was already 21 million tons; and, after slight losses from 1930 to 1935, it reached its highest peak of 61.3 million tons in 1943 (see Table 1). After the war, it fell to 25 million tons in 1945; there was a slow recovery to over 43 million tons in 1948, up to about 53 million tons in 1950, and it was expected to reach about 55 million tons in 1951. In this connection, it should be borne in mind that in the Soviet Zone, briquette factories with capacities amounting to 12 - 13 million tons per year have been dismantled; this is almost the total capacity of the briquette factories in the entire Federal Republic. The increase in the Soviet Zone, despite the dismantling, is due to the fact that the briquette factories are in continuous operation, 350 days a year.

The largest portion of the briquettes manufactured has always been used for domestic heating and by small businesses, which accounts for the fact that the briquette market, even during the periods of depression, has been relatively free from crisis. Since about 1935, the rest has been used in increasing quantities for carbonization, for gasification, and, in smaller quantities, for industrial furnaces.

The 1943 briquette output of 61.2 million tons was divided somewhat as follows: 32.9 million tons, or 53.7 percent, domestic fuel (without small business); 13.2 million tons, or 21.5 percent, industry and small business: 11.9 million tons, or 19.5 percent, carbonization; 1.2 million tons, or 2.1 percent, for use of the plants themselves and for payment in kind; 1.0 million tons, or 1.6 percent, supply (generation of electricity); and 1.0 million tons, or 1.6 percent, transportation.

Figures on the distribution of briquette production since the war are likewise available only for the Federal Republic. The 1950 output of 14.98 million tons was distributed as follows: 7.7 million tons, or 51.5 percent, for domestic fuel and small consumers; 4.5 million tons, or 30.1 percent, for industry and generation of electricity; 1.6 million tons, or 10.8 percent, for export; 0.5 million tons, or 3.3 percent, for use of the plants themselves and for payment in kind; and 0.3 million tons, or 2.0 percent, for transportation and occupation troops.

Use of Brown Coal as Fuel

Despite its high moisture content of from 50 to 62 percent, crude brown coal possesses high specific furnace efficiency and great elasticity. These are due to the wealth of volatile constituents, besides the colloidal nature of brown coal, to which its briquetting quality and ready reactivity are also due. These qualities are even more pronounced in brown coal dust and briquettes.

The main consumers for crude brown coal and coal dust are, as aforementioned, power plants and industry, especially the chemical industry. The largest share of briquette production goes for domestic fuel and small industry. Consequently, the big steam generators and the small home fireplaces and kitchen stoves represent the mainstay of the use of brown coal as fuel; their technical development reflects the course of brown coal consumption.

Between 1914 and 1915, a development began which brought to unexpected levels the effectiveness of the brown coal heating plants. This was the establishment of the public electric power supply and the creation of a large chemical industry, with its great demand for large quantities of brown coal for steam; it can almost be said that the story of crude brown coal as a fuel is a part of the story of the establishment of the German power industry. The first two large power plants using brown coal, Goldenberg and Zschornewitz, which were erected in 1913 and 1915 respectively, were followed by the Trattendorf, Lauta, Harbke, Finkenheerd, Fortuna, Frimmersdorf, Zukunft, Hirschfelde, Boehlen, Elbe, and Espenhain power plants in rapid succession. By the end of the war, public power works using brown coal had a total capacity of about 3.2 million kilowatts. Of the brown coal power plants in the Soviet Zone, which had a total capacity of about 2.2 million kilowatts, power plants amounting to a total of about 1.2 million kilowatts were dismantled.

While brown coal was used in only 23 percent of the public electric companies in Germany in 1913, this proportion rose to 49.3 percent in 1923 and stayed at about this level because of constantly increasing power production until the end of World War II (see Table 2). In the private electric power industry, the share using brown coal in 1934 was 30.6 percent and rose to 35.6 percent in 1939. Figures for the sources of electric power since 1940 are not available to the author.

After the effects of World War II on the public power plants using brown coal were overcome, their expansion by about 1,000 megawatts was begun in 1949 in the Federal Republic. In addition, construction of two new power plants with a capacity of 300 megawatts each is planned, so that after the completion of expansion and new construction, the public power plants in the Federal Republic using brown coal will have a total capacity of about 2.5 million kilowatts, which will increase the production capacity of about 6.5 billion kilowatt-hours in 1950 to 17 or 18 billion kilowatt-hours per year. The mine power plants connected with the briquette factories, which furnish the largest part of the electricity generated for public use, will be expanded from 220 megawatts to about 360 megawatts.

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Chemical Uses for Brown Coal

In addition to its importance as a fuel, brown coal has earned an important place as a raw material for innumerable chemical processes; since World War I it has developed amazingly.

The chemical use of brown coal has developed along various lines, particularly: (1) through carbonization for the production of coal tar and its by-products, motor fuel, petroleum, and paraffin; (2) through high-pressure hydrogenation for the production of motor fuel and lubricating oils; (3) through gasification for the production of heating gas, marsh gas, water gas, and synthetic gas, the last two for the synthesis of ammonia and alcohol, as well as the Fischer-Tropsch synthesis method of producing motor fuel, paraffin, and lubricating oils; and (4) through extraction, for the production of crude and refined montan wax.

1. Carbonization

The first attempts at carbonizing brown coal date back to the middle of the last century, in connection with the conversion of carbonized tar into illuminating oils and paraffin. These led, in 1858, to the construction of the first low-temperature carbonizing plant in the confines of central Germany. The Rolle furnace, which was developed for this purpose and operates on the retort principle, except for a few improvements, by and large kept much the same form as it had at that time. The throughput of freshly mined, crude, brown coal per furnace has, it is true, increased in the course of the years, but it has never exceeded 5 - 6 tons per day. By using dry brown coal or briquettes, as has been done since World War I, the daily capacity has been increased to from 10 to 12 tons with dry coal, or to 23 tons with briquettes; since 1922, new Rolle furnaces are no longer being made.

A new period of development began in 1923 with the entrance on the market of the Kosag-Geissen furnace, also operating on the retort principle; it was able to process dry brown coal at a rate of 65 - 70 tons per day. An improvement over the Kosag-Geissen furnace in respect to carbonization techniques was brought about by the Borsig-Geissen furnace, whose capacity of dry brown coal of about 30 - 35 tons, however, was only about 50 percent of the above-mentioned furnace's capacity. Three installations are operating with the Kosag process and one with the Borsig process.

While the production of carbonized tar increased from 79,000 tons in 1913 to only about 198,000 tons in 1929, a new ear in brown coal carbonization began about 1935, with the introduction of the Lurgi furnace, leading to an increase in the production of carbonized tar to about 1.6 million tons in 1943 - 1944 (see Table 3).

In the Lurgi furnace, which operates on the gas recirculation carbonization method, the consumption of brown coal briquettes was increased from 250 - 300 tons a day and the capacity per furnace, up to 420 tons through improvements made during the war. From Lurgi furnace installations, of which there were eight in Germany at the end of the war (one of which was in the Federal Republic; some, which were in the Soviet Zone, have since been dismantled), 11.9 million tons of brown coal briquettes were processed during 1943 - 1944, producing about 1.45 million tons of carbonized tar. The Kosag and Borsig-Geissen furnaces used about one million tons of dry brown coal and produced about 120,000 tons, and the Rolle furnace installations produced about 60,000 tons of tar. Expressed in terms of crude brown coal in 1943 - 1944, about 27 million tons were used for carbonization as compared to 1.45 million tons in 1913.

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The production of coke through carbonization increased during this period from 0.43 million tons per year to about 6.6 million tons per year (see Table 3).

While the largest part of the coke produced in the Rolle, Kosag, and Borsig furnaces was used in domestic Grude stoves, the situation changed when lump coke came on the market as a result of the Lurgi gas process. This coke was used predominantly in industrial furnaces, especially boiler furnaces, and was also used in increasing quantities for gasification and metallurgical purposes. Of the 6.6 million tons produced in 1943 - 1944, about 1.60 million tons were used as domestic fuel; the balance was used for the production of electricity, as well as for gasification and metal production.

The gas, obtained as a by-product besides tar and coke, was already being used during World War I, together with the light oil it contains, as heating gas for Rolle furnaces. It was first released from the slowly simmering components in 1922 in the same manner as in the production of benzol. After this time, this method of producing light oil was used in all low-temperature carbonization plants; the washing processes for this operation have been constantly improved. The light oil, which in carbonization amounts to about 12 - 18 percent of the liquid products, or 1.5 - 2 percent of the briquettes, is a highly knockproof fuel after distillation and refining. During the last war, the sulfur contained in the gas produced in carbonization was utilized in two installations; the yield was 40,000 tons per year.

Shortly before and during World War II, some installations began to extract the phenol contained in the carbonization water. This product, in a concentration of from 5 to 6 grams per liter, cannot be drained. Of the various processes developed for this, some have since been discarded; the process of dissolving the phenol has proved best, and one low-temperature carbonization plant in the Federal Republic has been using this method since 1950.

2. Processing of Tar

The processing of tar, up to about 1925, was done exclusively by distillation or cracking (under heat and pressure). According to processes which were improved through the years, a change occurred through the introduction of benzine production by the I.G. Farben method of high-pressure hydrogenation. This process was made ready for use in a large experimental plant of the Leunawerke; according to this process, by far the largest portion of the tar produced in carbonizing brown coal was processed into fuel for engines. Of the tar produced by carbonization in 1943 - 1944, amounting to 1.6 million tons, about 1.2 million tons were processed by high-pressure hydrogenation, and only about 0.4 million tons were processed by the distillation and cracking method. In the latter process, which can be varied according to the amount of the individual products, the main product by quantity is heating oil, with by-products of diesel fuel, paraffin, and benzine. By heat and pressure, the aim is to get a higher proportion of diesel fuel and benzine, through pitch is unavoidable.

In the motor-fuel factories of the Braunkohlen-Benzin-A.G. (Brabag) in Boehlen near Leipzig, Magdeburg, and Zeitz, brown coal tar is used exclusively according to I. G. high-pressure hydrogenation process; in the Leunawerke, part of the tar is processed in this way. According to this process, either only benzine or diesel fuel, lubricating oils, and paraffin are produced besides butane and propane, depending on the pressure and temperature. The plant at Magdeburg, as well as part of the Leunawerke, fell victim to dismantling.

As a new method of processing the tar produced from carbonizing brown coal, and in addition to the processes which had been used up to that time, the Edeleanu process was developed during the last war. It uses SO_2 as a selective solvent and was taken from the petroleum industry; it first had to be further developed to be used in processing tar from carbonized brown coal. In 1944, a plant associated with the large Espenhain carbonizing plant near Leipzig was completed. It was capable of processing 200,000 tons and operated on the Edeleanu method. This plant is said to have been dismantled. Its products were diesel fuel, 30 - 35 percent; heating oil, 40 percent; and paraffin, 14 percent.

3. Hydrogenation of Coal and Fischer-Tropsch Synthesis

Besides the process of obtaining tar from carbonized brown coal, brown coal was hydrogenated in two plants according to the I. G. high-pressure hydrogenation method, in the Leunawerke (partly) and in a plant in Wesseling near Cologne. While that part of the Leuna plant which was not dismantled is still operating, coal hydrogenation in Wesseling had to be discontinued after 1945.

The Fischer-Tropsch synthesis, originally developed for brown coal at the Brabaganlage Schwarzheide in Lower Lusatia, shortly before the outbreak of World War II, had been applied in a section of the motor-fuel factory of the Wintershall AG, in its Luetzkendorf plant near Merseburg; petroleum had also been hydrogenated there. This plant was destroyed in the war. The same is true of the big Rositz brown coal tar refinery of the Deutsche Erdoel AG, which has been partially rebuilt.

In conclusion, it can be said that the production of motor fuel from brown coal, from the beginning of the 1930's to the end of World War II, has become a sustaining pillar of the German motor-fuel economy. In 1943, it reached, as Table 4 shows, about 2.3 million tons (including about 0.3 million tons from the Treibstoffwerk Brux in the Sudetenland) and was about 39 percent of the total production of about 5.9 million tons. The raw materials were: black coal, about 1.7 million tons or 29 percent; petroleum (former Reich), about 0.6 million tons or 10 percent; and other raw materials (including alcohol), about 1.3 million tons or 22 percent.

4. Gasification

For the gasification of brown coal, which first became significant after the beginning of the century, various processes have been developed, depending on whether the gas is to be used as weak gas, power gas, water gas, synthetic gas, or coal gas. The gasification of briquettes at the same time as the production of tar was particularly brought to a high degree of efficiency. In contrast, the small-scale gasification of freshly mined, crude brown coal in normal generators has remained limited to sifted lump coal.

In addition to its significance in the production of weak gas for metallurgical purposes (smelters, annealing furnaces, heating ovens, tempering-ovens, and block ovens) and other purposes, brown coal has assumed increasing importance in the last 25 years chiefly as a raw material for the production of water gas and synthetic gas. The inexpensive manufacture of water gas from brown coal briquettes, dry brown coal, and coke is important for gasworks, especially, however, for the synthesis of fuel.

When the Ruhr coal industry presented its plans for supplying gas to all of Germany some 25 years ago, the possibilities of manufacturing coal gas of like value from brown coal began to be investigated. For this purpose, various processes were developed at experimental plants. However, the only outstanding success has been the Lurgi pressure-gasification process. According to this method, operating with the addition of oxygen under a pressure of 20 atmospheres, a suitable coal gas of from 4,200 to 4,300 kilocalories per cubic meter was produced simultaneously with the production of tar from sifted, dry brown coal, and, more recently, from brown coal briquettes.

At the conclusion of these experiments, a rather small plant with a capacity of 6 million cubic meters per year was erected in Hirschfelde in 1934; it was followed a few years later by a large plant in Boehlen near Leipzig for the production of 160 million cubic meters per year.

According to the most recent experiments by Professor Dr Draw of Berlin, if a Fischer-Tropsch synthesis unit is installed behind a Lurgi pressure gas generator, a rich gas of 8,000 kilocalories per cubic meter can be manufactured simultaneously with the production of primary products. It is expected that this new process will soon be applied to brown coal.

5. Production of Montan Wax

Among the chemical uses of brown coal, there is finally to be mentioned the production of montan wax, which was begun as early as the beginning of this century and which is limited to central Germany. While, in the carbonization of brown coal, all the bitumen, consisting of resins and waxes, is converted into tar, in the production of montan wax, only the waxy content is extracted from dried coal through a mixture of benzol and alcohol. The montan wax thus obtained can lose its dark color through a refining process and has many uses, such as for the manufacture of floor wax, cable wax, shoe polish, transmission-belt grease, sealing wax, bottled wax, and other products.

The production of montan wax, for which only a small amount of the brown coal in the Oberroeblinger and Nachterstedter districts near Halle is still suitable, and the production of which has been improved during the course of the years, amounted to from 15,000 to 18,000 tons per year. Of this, before World War II, by far the largest part was exported. Of the two plants that existed in the Oberroeblinger District at the end of the war, the more modern one has been dismantled.

Table 1. Development of Brown Coal Output and Briquette Production (million tons)

Year	Brown Coal Output	Briquette Production
1885	15.32	0.75
1900	40.28	6.50
1913	87.23	21.98
1920	111.89	24.28
1925	139.72	33.63
1929	174.46	42.08
1932	122.65	29.70
1938	194.90	44.10
1943	253.40	61.30
1944	229.80	55.70

Table 1. (Contd)

Year	Federal Republic	Soviet Zone*	Total	Federal Republic	Soviet Zone*	Total
1946	51.59	108.60	160.19	10.77	29.20	39.97
1947	58.73	101.70	160.43	11.84	26.60	38.44
1948	64.86	111.00	175.86	12.90	30.00	42.90
1949	72.26	124.00	196.26	14.25	34.50	48.75
1950	75.84	137.00	212.84	14.91	38.00	52.91
1951	80.50	141.00	221.50	15.70	39.50	55.20

*From 1946 on, no accurate production figures are available for the Soviet Zone. Absolute accuracy, therefore, is not claimed for those figures

Table 2. Distribution of Sources of Power for Generation of Electricity, Based on 1937 Borders (percent)

	1913	1922	1925	1934	1935	1936*	1937	1939
Public Electric Power Plants								
Bituminous	63.0	39.8	32.6	31.0	30.5	30.5	32.2	31.5
Brown coal	23.0	49.3	55.0	49.5	47.2	47.2	48.4	47.1
Mixture	--	--	--	0.1	--	--	--	--
Total solid fuels	86.0	89.1	87.6	80.6	78.6	77.7	80.6	78.6
Water	2.0	1.4	2.4	18.7	20.7	21.6	18.3	20.2
Gas and others	12.0	9.5	10.0	0.7	0.7	0.7	1.1	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0 [sic]
Private Power Plants								
Bituminous	--	--	--	40.4	40.1	42.0	41.4	43.1
Brown coal	--	--	--	30.8	30.3	29.8	31.5	35.6
Mixture	--	--	--	1.0	0.6	--	--	--
Total solid fuels	--	--	--	72.2	71.0	71.8	72.9	78.7
Water	--	--	--	10.2	9.6	9.2	[8.8]	[4.9]
Gas and others	--	--	--	17.6	19.4	19.0	18.3	16.4
Total	--	--	--	100.0	100.0	100.0	100.0	100.0

*Including the Saarland

Table 3. Development of the Production of Tar and Coke From Brown Coal Carbonization (1,000 tons)

Year	Tar Production*	Coke Production*
1913	79	435
1920	63	378
1926	78	445
1929	198	760
1935	251	994
1938	696	3278
1941 - 1942	1115	5300
1942 - 1943	1250	6000
1943 - 1944	1590	6600

*Until 1938, small quantities of slate and peat are included

Table 4. Production of Motor Fuel From Brown Coal in 1943 (1,000 tons)

Installation	Processing Methods	Production*	End Product
Brabag-Boehlen	High-pressure hydrogenation	268	Tar
Brabag-Magdeburg	High-pressure hydrogenation	225	Tar
Brabag-Zeitz	Low-temperature hydrogenation	253	Tar
Brabag-Schwarzheide	Fischer-Tropsch synthesis	160	Brown coal briquettes
Leuna	High-pressure hydrogenation	630	Tar and brown coal
Wesseling	High-pressure hydrogenation	200	Brown coal
Luetzkendorf	High-pressure hydrogenation and Fischer-Tropsch synthesis	75	Tar and brown coal
Bruex	High-pressure hydrogenation	300	Tar
Rositz	Cracking and distillation	160	Tar
Webau-Gerstewitz	Distillation	28	Tar
Goelzau	Cracking and distillation	26	Tar
Koepsen	Distillation	25	Tar
Boesdorf	Distillation	7	Tar
Total		2357	

*The production figures include only benzine, diesel fuel, "kogasin" [a type of Fischer-Tropsch distillation], and motor fuel. Paraffin, paraffin products, lubricating oils, and heating oils are not included.

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