PRODUCTION, EXHAUSTION, AND UTILIZATION OF COAL
IN THE UNITED STATES AND WASHINGTON
WITH REFERENCE TO BRIQUETTING

by

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ACKNOWLEDGMENTS

The work for this thesis was begun October 1, 1925 at which date the writer was granted one of five fellowships offered under a cooperative agreement between the United States Bureau of Mines and the College of Mines of the University of Washington. The object of the fellowships is to undertake work which is of especial interest to the state of Washington and of sufficient general importance to warrant the support of the federal government.

The work was done under the supervision of Mr. Byron M. Bird, acting superintendent of the Northwest Experiment Station of the United States Bureau of Mines. Grateful acknowledgment is made to the Professors of the department of Geology and to the Professors of the College of Mines, of the University of Washington, and to the staff of the Northwest Experiment Station, for criticisms and suggestions in the course of the work.

INTRODUCTION

The national aspect of the problem of fuel briquetting was first noted in the year 1904 when the United States Government called the people's attention to the problem of perfecting means for utilizing low-grade fuels. Under the direction of the United States Geological Survey an investigation of the merits of lignite was begun with the object of ascertaining efficient methods for its use. Subsequent investigations carried on by both the United States and individuals have led to a variety of patents for briquet binders.

United States patent number 1,446,322 recently taken out by two Washington men, H.A. Gillen and G.F. Sheehan, introduces the idea of using sulphur as a binder for briquets made from low-rank coal. The method set forth has not yet proved commercially successful, but does merit careful study. The observations thus far made in the investigation will be recorded in this thesis.

A review of the coal production and exhaustion both in the United States and Washington is presented for the purpose of showing the need in perfecting methods of utilization of low-rank coals.

THE PRODUCTION OF COAL IN THE UNITED STATES

In the United States the area underlain by beds of lignite that can probably be mined, is nearly 150,000 square miles. Since millions of acres of this land belong to the United States, the government is immediately concerned with increasing the efficiency of lignite as a fuel. The lignite beds of the Dakota-Montana region occur in the Eocene, the lowest epoch of the Tertiary period, and constitute the greatest quantity of coal originally contained in any single area of continuous coal-bearing rocks. The amount has been estimated at 1,202 billions of tons, or more than one-fourth of the total coal reserves of the United States.

The existence of these beds, called "stone coal" (lignite), in the country of the Mandans was first established by the explorations of the Lewis and Clark expedition, 1804-1806. Under date of Saturday, October 20, 1804, the journal shows that forty miles up the Missouri river from the mouth of the Cannonball, these beds of low-rank coal were observed. (1)

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(1) Lewis and Clark Journals. New Amsterdam Book Co., N.Y., 1814. Pp. 165-170

In 1858 during the days of the territorial surveys, F.V. Hayden (2) of the United States Topographic Engineers, mapped the

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(2) The Cannonball river lignite field. E.R. Lloyd. U.S. Geol. Surv. Bull. 541, 1912. (Reference to Hayden's work.)

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boundaries of the Missouri river as far north as Fort Benton, and thereby obtained the first geological information on the deposits. A later reconnaissance expedition to the Black Hills, under Generals Custer and Ludlow in 1875, with N.H. Winchell as geologist, crossed some of the lignite fields and roughly noted their extent. The lignite beds of this area have since been mapped and included in the estimate of the coal resources of the United States. (3)

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(3) The coal fields of the United States. M.R. Campbell. Prof. Paper 100-A. U.S. Geol. Surv. 1917.

This estimate, on which work was begun by the United States Geological Survey in 1912, considered first the coal contained in strata within 3000 feet of the surface, and secondly that contained below 3000 feet and above 6000 feet. The minimum thickness of vein considered for high grade coal was 15 inches; for subbituminous, 2 feet; for lignite, 3 feet. The maximum ash permissible was arbitrarily taken as 30 per cent. The estimate can be summarized as follows:

Within 3000 feet of the surface,	3,538,554,000,000	short tons.
Between 3000 and 6000 feet,	666,600,000,000	short tons.
Total - - - - - - - - - - - - - -	4,205,154,000,000	short tons.

This is the amount for the United States proper, not including Alaska.

Although the largest area of coal is lignite, the area second in extent is the Green river region of southwestern Wyoming which contains various ranks of coal from subbituminous to anthracite. The third largest is the Appalachian field containing originally 550,898,800,000 short tons. The coal being mined today comes from the areas having the best coal rather than from those having the greatest extent.

Named in order of abundance the classes stand with low-rank bituminous first, lignite second, and subbituminous third. The high-rank coals are relatively scarce, anthracite and semibituminous comprising only 1.2 per cent of the original deposits of the United States. The semibituminous steaming coal is practically limited to the eastern and interior provinces.

It is interesting to note the phenomenal increase in coal production (4) within the last twenty years, and to compare the

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(4) Min. Res. U.S. 1918 chart; 1922 pt. II et seq.

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reserves exhausted with those yet remaining. Figure 1 is a graph in short tons, in ten-year periods, of coal of all kinds produced in the United States from 1815 to 1925 inclusive. For the thirteen years from 1807 to 1820 the coal produced amounted to only 15,000 tons. For the single year 1923 the production had increased to 657,495,000 tons.

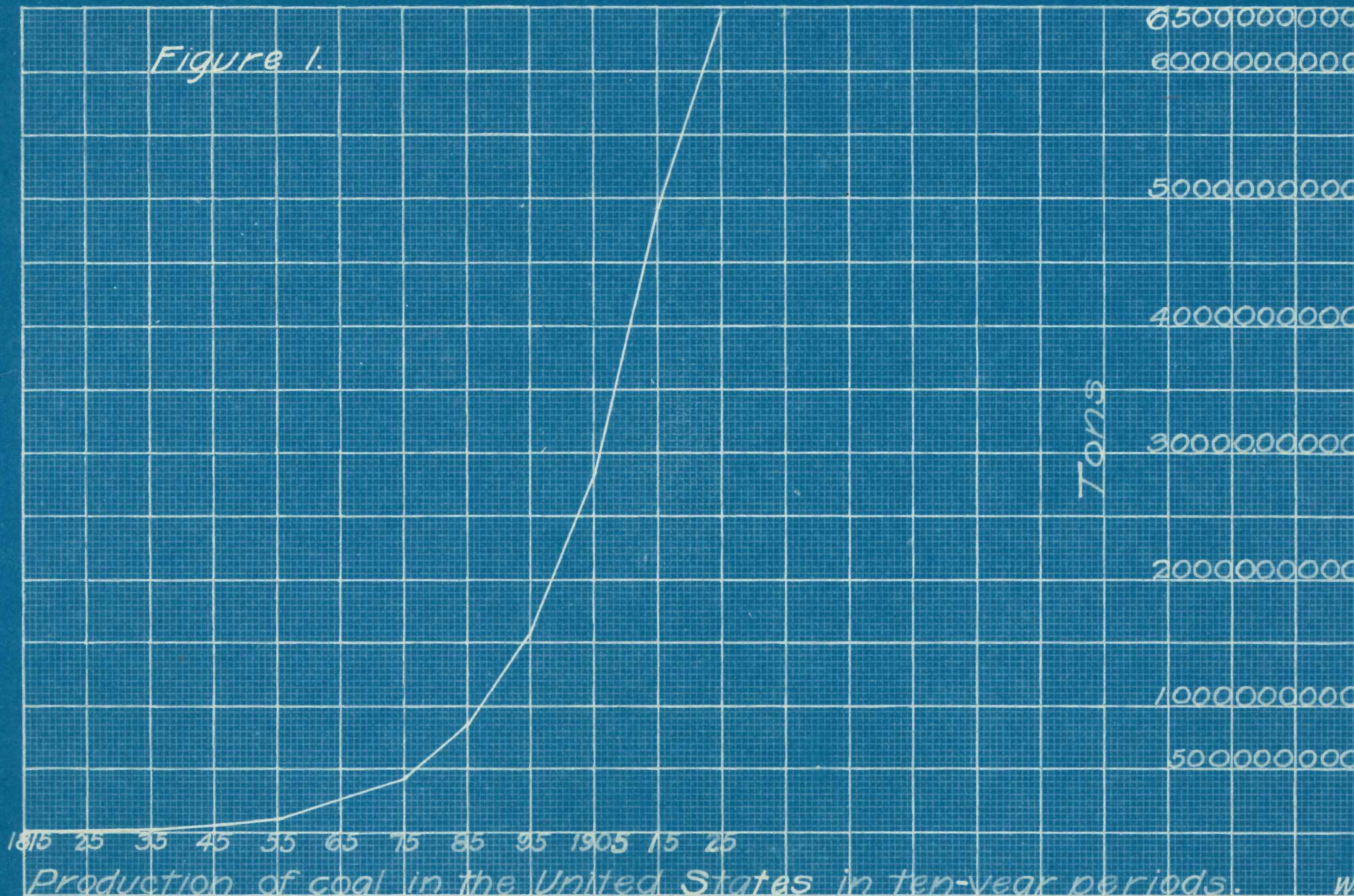
Figure 1.
6500000000
6000000000
5000000000
4000000000
3000000000
2000000000
1000000000
500000000
Tons
1815 25 35 45 55 65 75 85 95 1905 15 25
Production of coal in the United States in ten-year periods.
W.

TABLE 1

PRODUCTION AND EXHAUSTION OF COAL OF ALL KINDS IN THE UNITED STATES

Years	Production for the period	Cumulative production. Net tons	Exhaustion Adding 50%
1807-1820		15,000	22,500
1820-1825	327,181	342,181	513,271
1825-1835	4,168,149	4,510,330	6,765,495
1835-1845	23,177,637	27,687,967	41,531,950
1845-1855	83,417,827	111,105,794	166,658,691
1855-1865	173,795,000	284,900,800	427,351,200
1865-1875	419,425,000	704,326,000	1,056,489,000
1875-1885	847,760,000	1,552,086,000	2,328,129,000
1885-1895	1,586,100,000	3,138,186,000	4,707,276,000
1895-1905	2,832,332,000	5,970,518,000	8,955,777,000
1905-1915	4,918,717,000	10,889,235,000	16,333,852,500
1915-1925	6,446,263,166	17,335,498,000	26,003,247,000

The cumulative production and exhaustion curve in ten-year periods from 1815 to 1925 is shown in figure 2. To date the cumulative production exceeds 17 billions of tons. The exhaustion curve of this figure is based on M.R. Campbell's factor of 50 per cent depletion to be added to the total production. This factor accounts for coal used at the mines and unsold, coal wasted in mining and marketing, coal destroyed by fire in the mines, and non-recoverable coal in mined beds. The United States Fuel Commission puts this factor lower, at 28 per cent for anthracite and 35 per cent for bituminous. The curve shows the exhaustion or depletion of coal of all kinds to be approximately 26 billions of tons at the end of 1925.

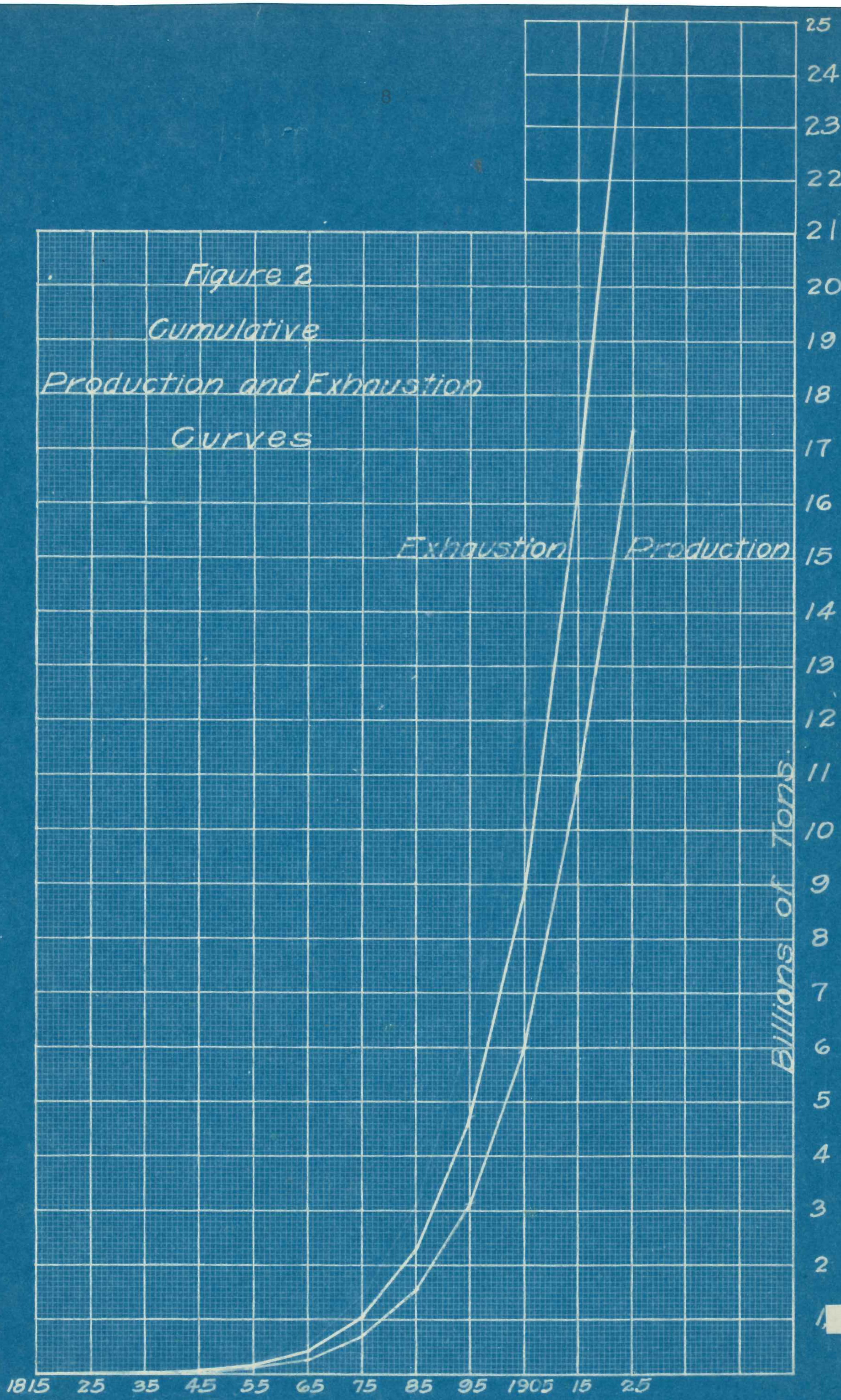

Figure 2
Cumulative
Production and Exhaustion
Curves
Exhaustion
Production
Billions of Tons
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1815
25
35
45
55
65
75
85
95
1905
15
25

TABLE 2

PRODUCTION AND EXHAUSTION FIGURES FOR BITUMINOUS COAL

End of year	Production	Exhaustion (factor of 35%)
1825	258,040	348,040
1835	1,255,177	1,695,177
1845	7,778,308	10,488,308
1855	39,252,798	52,952,798
1865	114,252,800	154,250,000
1875	289,457,400	390,460,400
1885	874,465,000	1,180,465,000
1895	2,337,680,000	3,154,680,000
1905	4,175,365,000	5,635,365,000
1915	8,173,488,000	11,031,488,000
1925	13,891,490,000	18,736,490,000

When this exhaustion of coal reserves to date is considered in terms of the total reserves, that is, 26 billions divided by 4,205 billions, it is found to be but six-tenths of one per cent. That is to say, of the total estimated coal reserves in the United States, only 0.6 per cent has been exhausted. It would appear from these figures, which are approximately correct, that the coal of this country will last for many hundreds of years, even allowing for a continued increase in production. But it must be remembered that this ratio is in terms of total available coal of all kinds, and that more than one-fourth of this supply, lignite, remains as yet unusable.

TABLE 3

ESTIMATED RESERVES OF VARIOUS GRADES OF COAL

WITHIN 3000 FEET OF SURFACE

	Short tons
Anthracite and semianthracite	22,053,000,000
Semibituminous	49,863,500,000
Bituminous	1,442,916,600,000
Subbituminous	989,514,000,000
Lignite	1,051,290,000,000
Total within 3000 feet	3,555,637,100,000
AMOUNT BETWEEN 3000 AND 6000 FEET	666,600,000,000
GRAND TOTAL IN SHORT TONS	4,222,237,100,000

The graph of the yearly production of coal of all kinds for the ten years ending in 1925, appears in figure 3. The anthracite strike reduced the output of that product for 1925, since practically none was produced after September. The 1925 production was 62,064,000 short tons, or about two-thirds of the normal amount. The 1925 bituminous production was 514,827,000 short tons. (5)

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(5) Late figures from Coal Age.

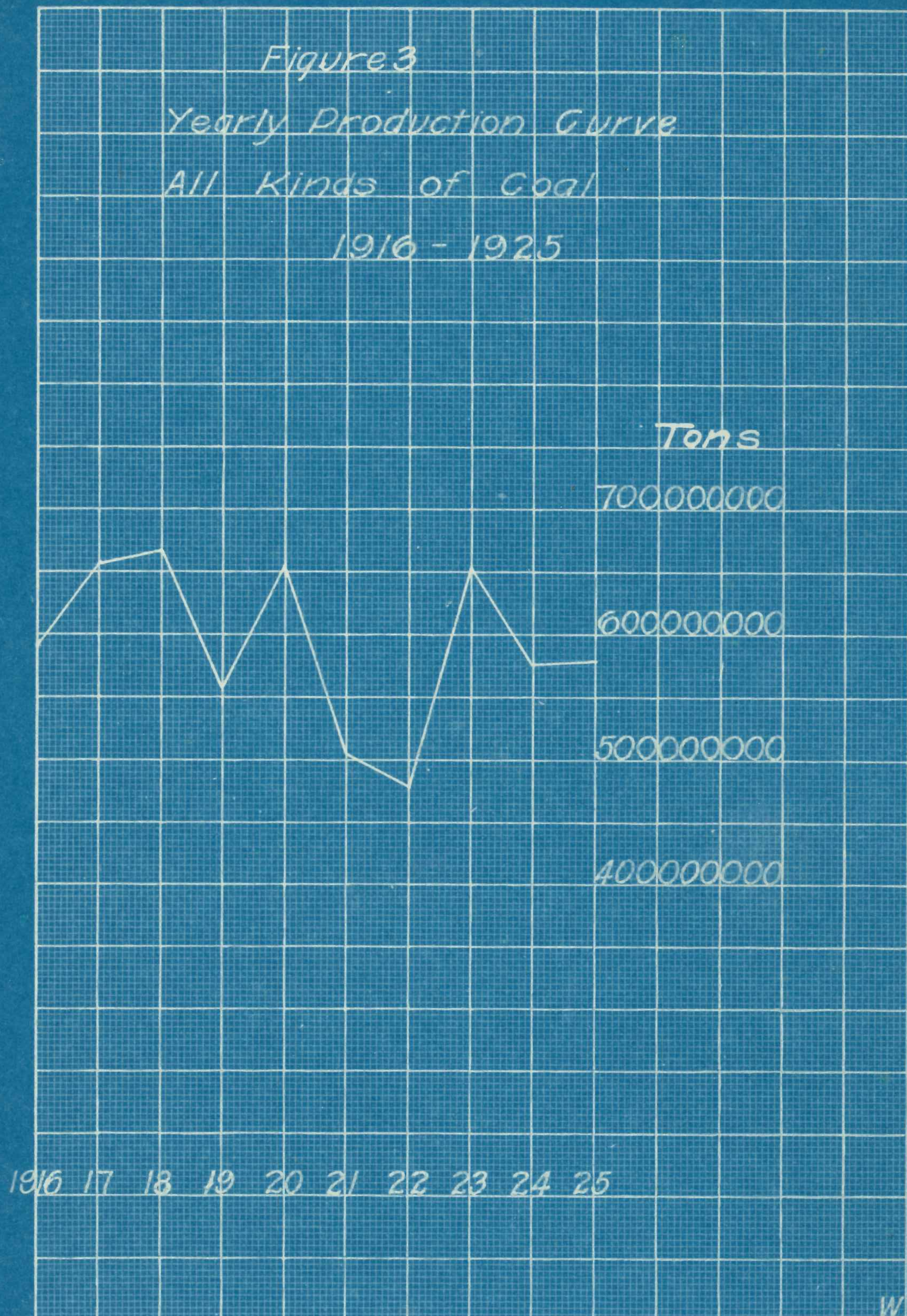


Figure 3
Yearly Production Curve
All Kinds of Coal
1916 - 1925
Tons
700000000
600000000
500000000
400000000
1916 17 18 19 20 21 22 23 24 25
W

TABLE 4

YEARLY PRODUCTION OF COAL OF ALL KINDS IN THE UNITED STATES 1916-1925

Year	Production short tons	Increase per cent	Decrease per cent
1916	590,098,175		
1917	651,402,374	10.3	
1918	678,211,904	4.3	
1919	553,952,259		18.3
1920	658,264,932	17.0	
1921	506,395,401		23.1
1922	476,951,121		5.8
1923	657,495,000	37.7	
1924	573,494,000		12.8
1925	576,891,000	0.6	

Figure 4 shows the production of anthracite in the United States for the period from 1825 to 1925 in ten-year units. The yearly production of anthracite during the past twenty years has changed but slightly in comparison with the increase in the bituminous ranks.

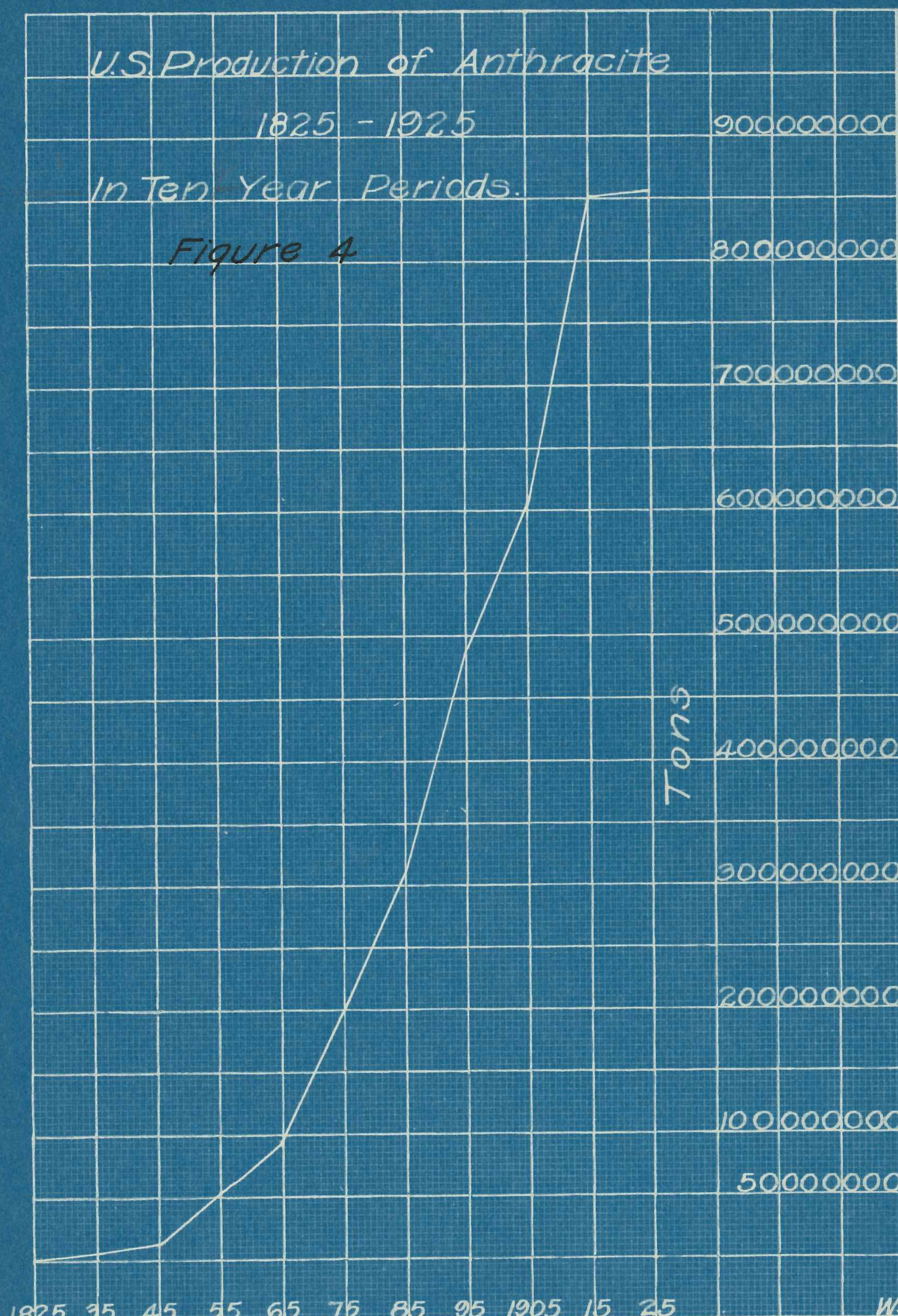

U.S. Production of Anthracite
1825 - 1925
In Ten Year Periods.
Figure 4
900000000
800000000
700000000
600000000
500000000
400000000
300000000
200000000
100000000
50000000
Tons
1825 35 45 55 65 75 85 95 1905 15 25
W.

TABLE 5

UNITED STATES PRODUCTION AND EXHAUSTION OF ANTHRACITE 1815-1925

End of year	Cumulative Production in short tons	Exhaustion (factor of 28%)	Amount Exhausted per cent
1825	163,641	209,441	.01
1835	3,171,012	4,057,012	.03
1845	16,564,496	21,204,496	.10
1855	68,512,833	87,692,833	.40
1865	167,105,873	213,905,873	.97
1875	365,542,595	467,542,595	2.10
1885	675,534,383	865,034,383	3.91
1895	1,162,319,137	1,488,319,137	6.75
1905	1,774,634,000	2,270,634,000	10.30
1915	2,626,512,578	3,360,512,000	15.30
1925	3,478,511,938	4,423,512,000	20.00

Figure 5 is a percentage curve showing the relative amounts of anthracite, all grades of bituminous, and lignite exhausted by mining. It will be noted that at the end of the year 1925, twenty per cent of the available supply of anthracite had been exhausted, while only six-tenths of one per cent of the bituminous ranks, and practically no lignite, has been exhausted.

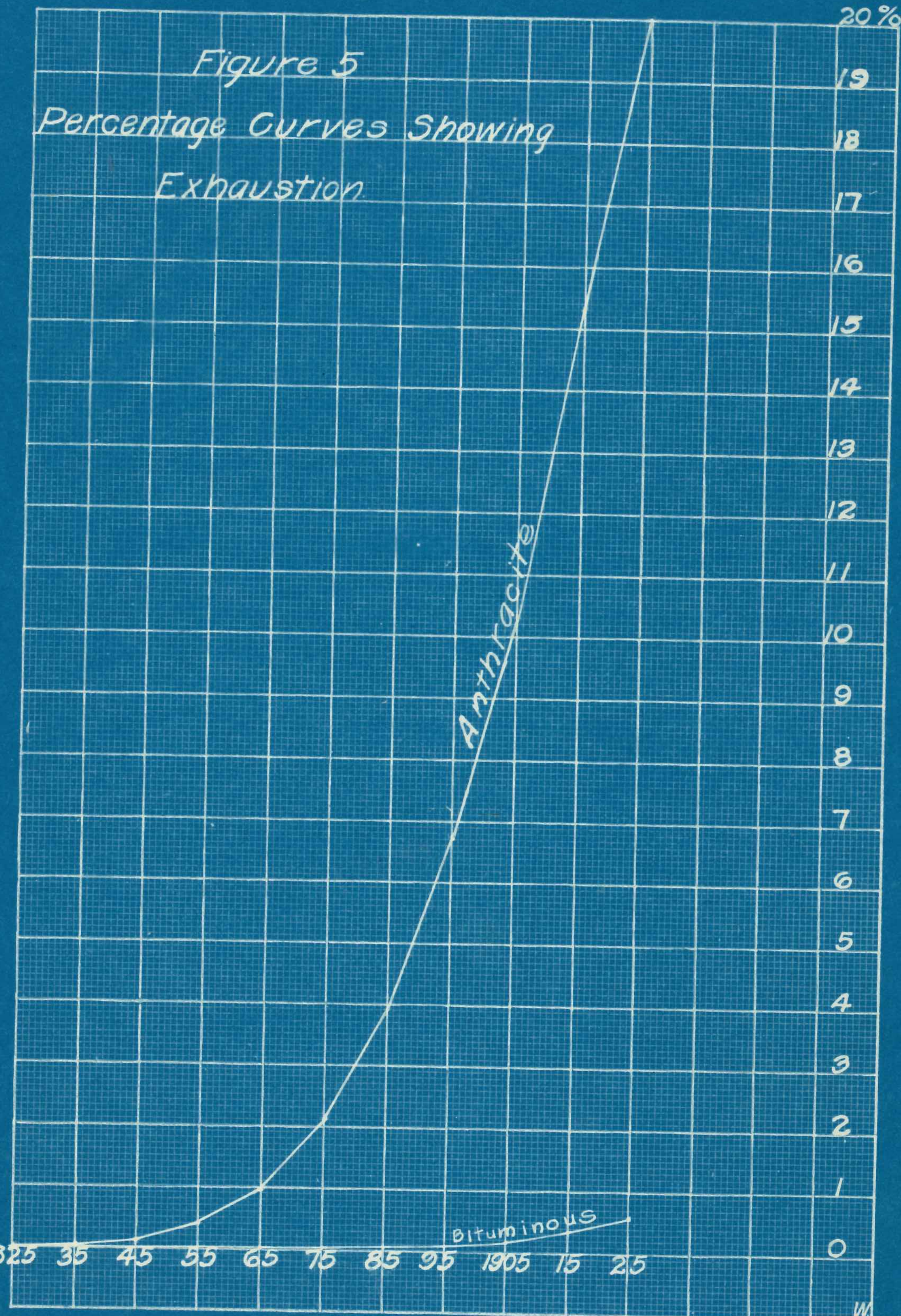


Figure 5
Percentage Curves Showing
Exhaustion
Anthracite
Bituminous
20%
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1825 35 45 55 65 75 85 95 1905 15 25
W

The estimated supply of anthracite and semianthracite is 22,053,000,000 short tons. The annual rate of consumption is about 90,000,000 short tons. Add to this amount the factor of 28 per cent for waste, unmined coal, and coal used at the mines, and the yearly exhaustion is practically 115,000,000 short tons. At this rate of depletion it will be seen that the anthracite will last for more than 150 years, provided it can all be mined. The yearly average production for the last ten years has been roughly 90,000,000 short tons, and for the ten years preceding that, about 85,000,000 short tons. In view of this situation for these twenty years, one might hazard a guess that the anthracite production has nearly reached its saturation point. The chief reasons for this stable condition are the increased use of the various bituminous ranks of coal, the substitution of coke for domestic fuel, and the use of oil, natural gas, and manufactured gas, for domestic fuel.

The data presented above show that the best ranks of coal are being depleted at a rate which indicates that some thought should now be given to the efficient utilization of wasted fines of all these ranks. The future problem will be the utilization of lignite in briquetted forms, which is one of the most important means of effecting an efficient use of such fuels. Briquetting has been making gradual progress for the past twenty years in the eastern, central, and Pacific coast states.

COAL PRODUCTION IN THE STATE OF WASHINGTON

The estimate of the original quantity of coal in the state of Washington, published by the United States Geological Survey in 1917 (3), shows the following items:

Bituminous coal	11,412,000,000 short tons.
Subbituminous coal	52,442,900,000 short tons.
Total of all ranks	63,854,900,000 short tons.

The production of coal in Washington for the last twenty years has not kept pace with the production of the United States as a whole. In fact, during the years 1905-1914 the annual production exceeded any year from 1921-1925, while in the United States as a whole there was an almost continual increase in production.

Figure 6 graphically shows the production of coal in Washington in five-year periods from 1885 to 1925, the figures for which are given in table 6. Even tho the period is taken for as long a time as five years, still the curve is erratic, while a similar time for the United States as a whole produces a remarkably steady curve. Altho the production figures were obtained from the Territorial Survey Reports as far back as the year 1860, the production previous to 1885 was so small as to be out of place on figure 6, which is designed to show the production of later years.

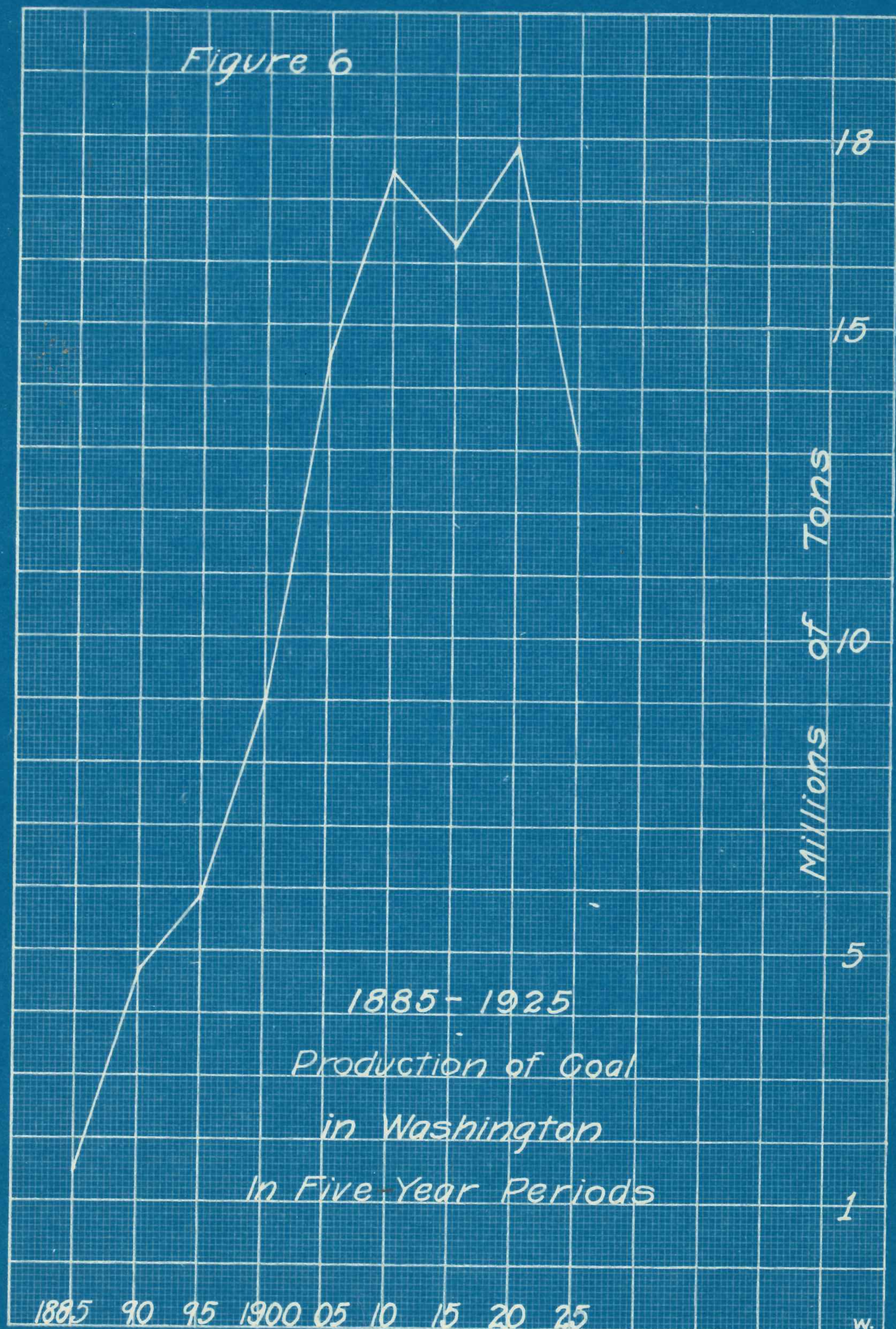


Figure 6
18
15
10
5
1
Millions of Tons
1885 - 1925
Production of Coal
in Washington
In Five-Year Periods
1885 90 95 1900 05 10 15 20 25
W.

TABLE 6

PRODUCTION OF ALL RANKS OF COAL IN WASHINGTON IN FIVE-YEAR PERIODS

1885-1925

Period ending	Production for period
1885	1,500,010
1890	4,706,154
1895	5,832,433
1900	9,018,161
1905	14,455,311
1910	17,495,821
1915	16,305,553
1920	17,878,242
1925	13,114,116

Figure 7 is a graph of the yearly production of coal in Washington for the twenty years previous to 1925. The figures for the years 1924 and 1925 are taken from the advance sheet of the State Mine Inspector since the figures given by the United States Geological Survey summaries are not yet available. There is frequently a slight difference between the two sets of figures. The yearly production in Washington since 1860 is shown on table 7. It will be seen that at no time, over a period of several years, has the production of coal steadily increased in Washington after 1880. A decided increase is usually followed by a noticeable decrease.

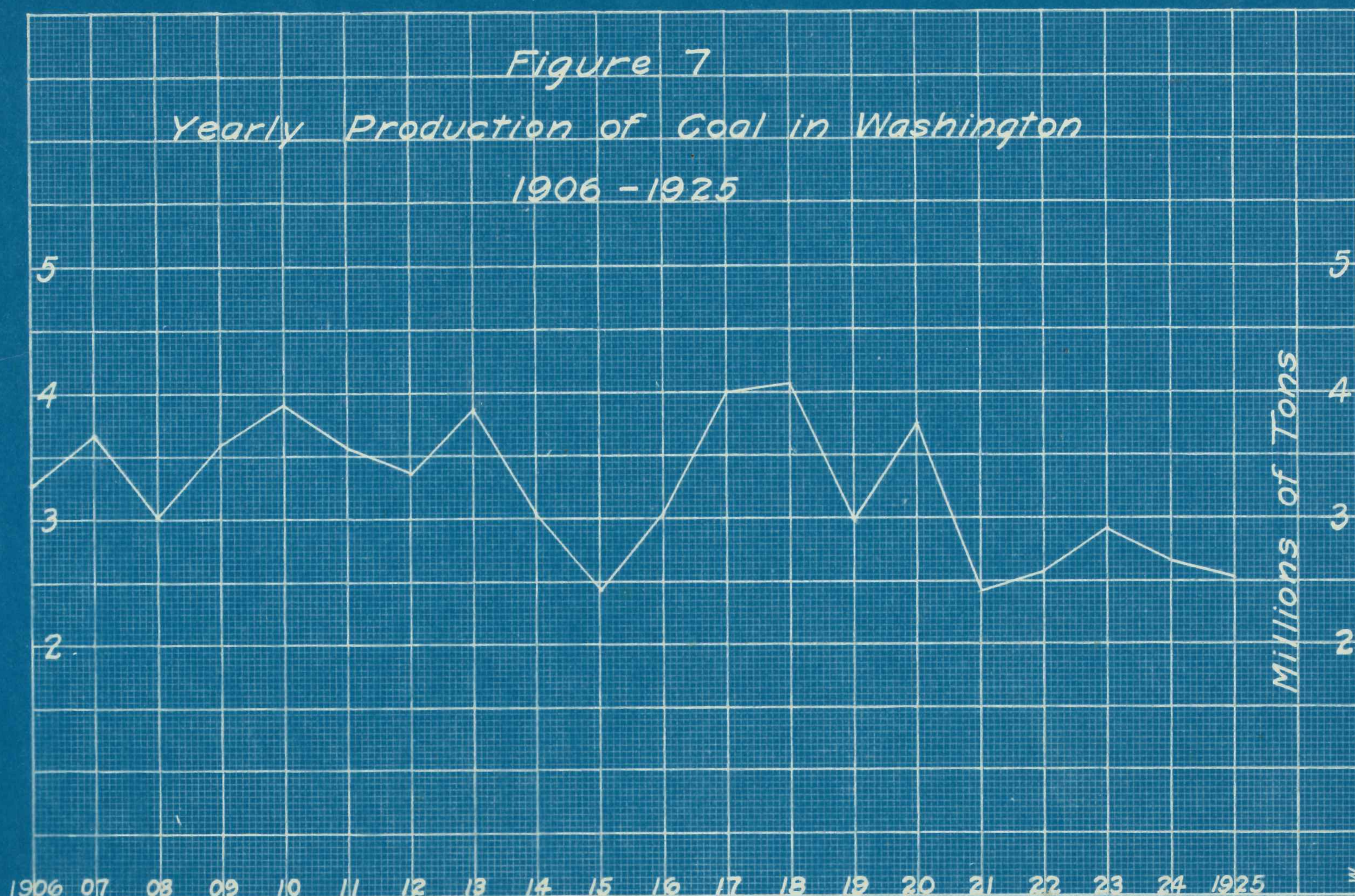


Figure 7
Yearly Production of Coal in Washington
1906 - 1925
5
4
3
2
Millions of Tons
1906 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 1925

TABLE 7

YEARLY PRODUCTION OF COAL OF ALL RANKS IN WASHINGTON 1860-1925

Year	Production	Year	Production	Year	Production
1860	5,374	1882	177,340	1904	3,137,681
1861	6,000	1883	244,990	1905	2,864,926
1862	7,000	1884	166,936	1906	3,276,184
1863	8,000	1885	380,250	1907	3,680,532
1864	10,000	1886	423,525	1908	3,024,943
1865	12,000	1887	772,612	1909	3,602,263
1866	13,000	1888	1,215,750	1910	3,911,899
1867	14,500	1889	1,030,578	1911	3,572,815
1868	15,000	1890	1,263,689	1912	3,360,932
1869	16,200	1891	1,056,249	1913	3,877,891
1870	17,844	1892	1,213,427	1914	3,064,820
1871	20,000	1893	1,264,877	1915	2,429,095
1872	23,000	1894	1,106,470	1916	3,038,588
1873	26,000	1895	1,191,410	1917	4,009,902
1874	30,352	1896	1,195,504	1918	4,082,212
1875	99,568	1897	1,434,112	1919	2,990,447
1876	110,342	1898	1,884,571	1920	3,757,093
1877	120,896	1899	2,029,881	1921	2,428,722
1878	131,660	1900	2,474,093	1922	2,581,165
1879	142,666	1901	2,578,217	1923	2,926,392
1880	145,015	1902	2,681,214	1924	2,654,915
1881	196,000	1903	3,193,273	1925	2,522,992

Total short tons produced 100,945,794

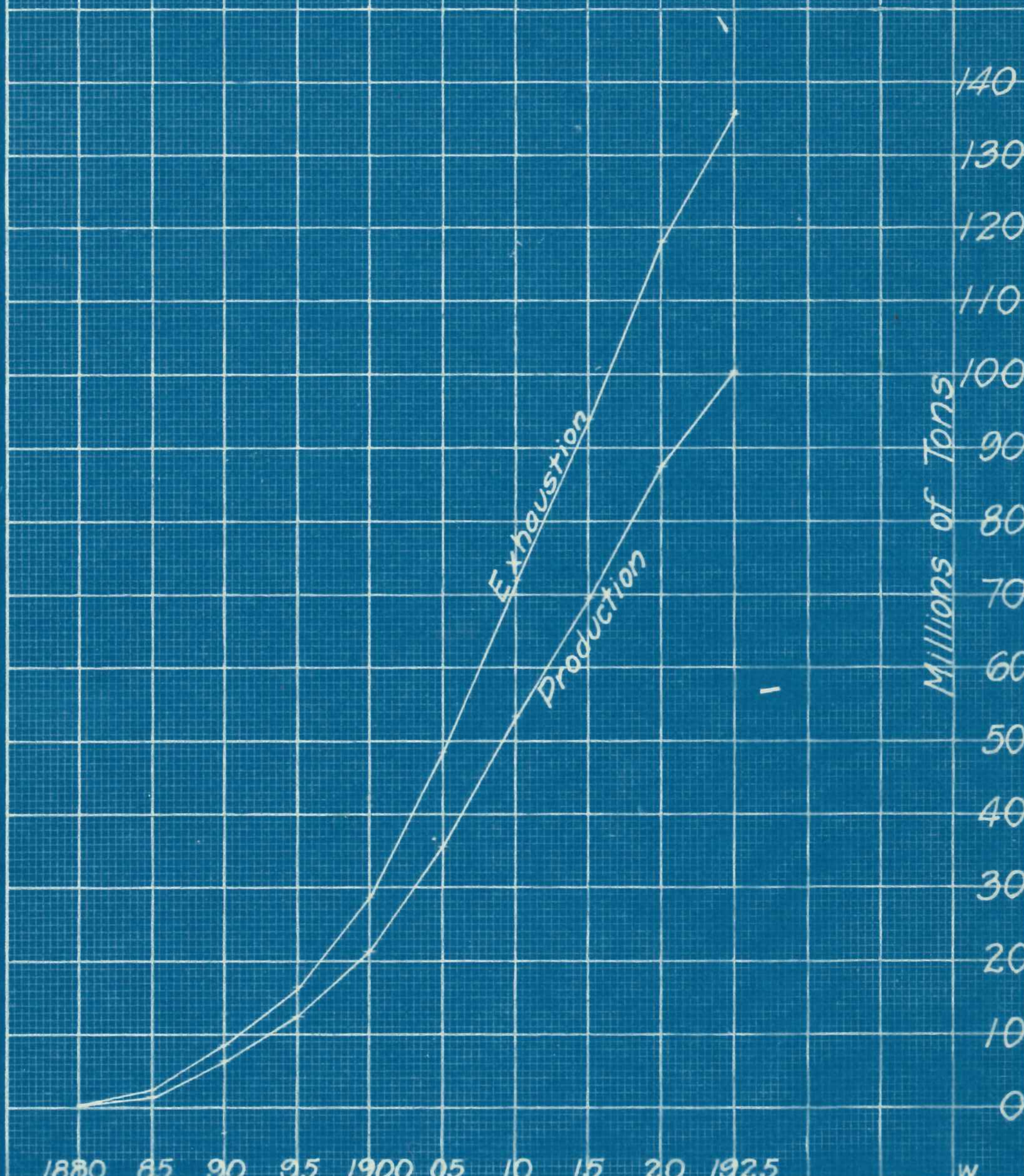
TABLE 8

CUMULATIVE PRODUCTION AND EXHAUSTION FIGURES FOR WASHINGTON IN FIVE-YEAR PERIODS, 1885-1925

Period ending	Production for period	Cumulative production	Cumulative exhaustion (factor 35%)
Total to 1880 inclusive		974,391	1,314,000
1885	1,165,516	2,139,907	2,889,000
1890	4,706,154	6,846,061	9,250,000
1895	5,832,433	12,678,494	17,118,000
1900	9,018,161	21,696,655	29,266,000
1905	14,455,311	36,151,966	48,772,000
1910	17,495,821	53,647,787	72,448,000
1915	16,305,553	69,953,340	94,453,000
1920	17,878,242	87,831,582	118,582,000
1925	13,114,116	100,945,698	136,246,000

The total exhaustion of the coal resources of the state is shown to be practically 136,000,000 short tons. The figures given for exhaustion are accurate within 1000 tons. Figure 8 on the following page graphically represents the data given above in table 8.

Figure 8
Production and Exhaustion Curves
of Washington
1880 – 1925



DISCOVERIES AND DESCRIPTION OF WASHINGTON COAL

Henry Landes in the Annual report of the Washington Geological Survey for 1901 says, "The first authentic record we have of coal being found in Washington was in 1851, when some pieces of coal were picked up on the Stilaguamish river." (6) Other important

(6) Landes, H. The coal deposits of Washington. Wash. Geol. Surv., Annual Report, 1901. Vol. I, pp. 257-281.

discoveries are noted in the same article. In the fall of 1852 coal was discovered on Bellingham bay; about a year later coal was discovered at Sehome, and a mine was operated there for a number of years. From that time forward until about 1875 discoveries were made in various parts of the state and operations carried on in a small way.

The coal-bearing rocks, according to Bailey Willis, are Eocene in age and are for the most part sandstones of variable composition, texture, and color, in the Puget Sound area. In other areas of the state the containing rocks are sandstones and shales. The sandstones are thinly bedded and frequently cross stratified. (7). They have

(7) Willis, B. Some coal fields of Puget Sound. Eighteenth Annual Report, U.S. Geol. Surv. Pt. III 1897. Pp. 400-436.

been in some places sharply folded and shattered, while in other places the strata are nearly horizontal. The coals range in rank from low-grade subbituminous to anthracite, the bituminous ranks constituting about one-fifth and subbituminous four-fifths of the total amount. The base of the coal measures was rarely found at first, but the later work has determined that the combined thickness of the coal-bearing strata is as much as 10,000 feet in some localities. The seams vary in number, thickness, and quality. As a general rule the principal coal seams lie well toward the bottom of the coal series. (8)

(8) Landes, H. Coal deposits of Washington. Wash. Geol. Surv. Ann. Report, Vol. II. 1902. Pp. 167-257.

The swamps in which the coal-making material was deposited were evidently subject to intermittent floods which washed sand and silt from the surrounding lands, causing interstratification with the vegetal matter. An even more difficult cleaning problem is presented by the intimate admixture of silt and carbonaceous material which composes the bone of the coal beds. To free the coal from the bony material accompanying it, much of it must be crushed to fine sizes. Because of the folding and movement of the containing rocks, since the period of formation of the coal, an additional large percentage has been broken to fine sizes, the result being that in certain fields of the state the proportion of fine coal produced in mining is large compared with the amount of lump. (9)

(9) Williams, C.E. and Bird, B.M. Coal situation in the state of Washington. 1924. Unpublished.

The nearest competing field is in British Columbia and the strongest competitor, Utah, is about 1000 miles away, yet one-third of the coal used in the state comes from these districts. In Washington the relatively low production in tons per man per day, the high percentage of waste, and the difficulty and expense of cleaning the coal, and the low percentage of lump, make the cost of the local coal so high, that coal from outside sources can successfully compete with the coal mined near at hand.

TABLE 9

WASHINGTON COAL PRODUCTION COMPARED WITH TONNAGE BROUGHT FROM OUTSIDE SOURCES

Year	Washington production (a)	Total coal from Canada (b)	Coal from Utah: Wyo. (c)
1915	2,429,095	94,258	
1916	3,038,588	157,609	
1917	4,009,902	212,786	
1918	4,082,212	276,193	
1919	2,990,447	329,333	
1920	3,757,093	271,634	
1921	2,428,722	315,179	
1922	2,581,165	416,197	
1923	2,926,392	311,000	
1924	2,654,913	219,884	526,177
1925	2,522,992	411,812	516,073

(a) Min. Res. of U.S.
(b) Daniels, J. Trans. Can. Inst. Min. Met. Vol. XXVI, 1924.
Figures 1915-1923 are in long tons; 1924 and 1925 in short tons.
(c) Maltby, W.E. Mgr. Wash. Coal Prod. Assn.
Washington production for 1924 and 1925 from State Mine Inspector.

These figures show that the amount of coal from outside sources used in Washington during the year 1925 was 927,885 short tons, or 27 per cent of the total. It is true also that some of the Washington coal produced is sent to other coast states, and about 25,000 tons yearly to Alaska, but these are small amounts and only serve to make the outside coal an even larger factor in consumption than the 27 per cent. The figure probably is not less than 30 per cent, which is also the domestic trade consumption of coal for the state. That the figures correspond is significant. The conclusion reached is that the lump coal produced in the state is not sufficient for the domestic trade. There are other competitors for the local coals beside outside coal. Wood, hogged fuel, and fuel oil are all to be considered, although they influence the steam and industrial market more than the domestic. It is desirable therefore, to consider means of preparing the small sizes of local coal for the domestic market.

Possible methods for preparing the local coal so that it may be used more extensively, include small stokers for pea coal, powdered fuel for firing purposes, and briquetting coal for use especially in the domestic trade. The use of powdered fuel for firing purposes requires skilled firing, and presents certain storage and transportation difficulties. The small stokers will doubtless develop with the increase in industrial growth but are too high priced at this time for general use by the average householder. In briquetting, however, is found a method readily adaptable to small unit manufacture, which can furnish a product that will supply the domestic demand, and which is practicable for the fine size coals that constitute such a large part of Washington production. For instance, in Whatcom county 55 per cent of the coal is pea size or smaller and in King county 70 per cent is pea size or smaller.

The Washington fuel market presents additional reasons for inviting attention to briquetting at this time. Thirty per cent of the fuel is used by the domestic trade as compared with 16.6 per cent for the entire United States. The railroads account for 45 per cent of the fuel consumed, and large users including industries, power plants, heating plants for large buildings, and gas manufacture require 15.1 per cent. The remainder is divided between bunker trade, losses in shipping and marketing, and fuel consumed for power at the mines. In the fall of 1925 there was a considerable demand for briquets for use in smudging orchards in Oregon and California during the frosty season. Another demand for this product is in its increased use in donkey engines. Briquetting offers a means of meeting these demands and supplying the domestic market, while at the same time utilizing the fine sizes of coal much of which is a total loss today. The requirements for a briquet for domestic purposes are that it can be burned easily with an ordinary draft, without odor and without excessive soot, that it will hold together in the fire until completely consumed, that it will furnish heat commensurate with its cost, and that the ash will not exceed an arbitrary limit of about 15 per cent.

HISTORY OF BRIQUETTING

Some processes for making briquets from coal have been known for at least three hundred years. Mr. G.J. Mashek, President of the Mashek Engineering Company, stated (10) that briquetting originated

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(10) Bacon, R.F. and Hamor, W.A. American fuels. 1922. P.224.

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in China, and that hand-made balls of coal were used there as a fuel in the sixteenth century.

Shortly before the beginning of the seventeenth century (1594), continental nations made reference to "cole balls" as a form of fuel. Sir High Pratt (10) published a pamphlet at this time suggesting the briquetting of coal. The beginning of the industry has frequently been credited to England. There is some evidence that it was known and carried on in the time of Queen Elizabeth. The first published specification relating to fuels of this character in the English patent office records is dated April, 1773. All of these were no doubt incidental uses of coal and were not of sufficient proportions to be called manufacturing.

Tables 10 and 11 are chronological records of the briquetting industry in the United States. It should be mentioned that the names of towns, of men, and of dates are frequently conflicting in the literature from which this table has been compiled. The sources for the table are the Mineral Resources of the United States, publications of the United States Geological Survey, publications of the United States Bureau of Mines, and the book on briquetting written by A.L. Stillman.

TABLE 10

CHRONOLOGICAL TABLE OF BRIQUETTING PLANTS IN THE UNITED STATES

Date	Place	Designer or promoter	Coal used	Binder	History
1872	Philadelphia, Pa.	Loiseau, E.F.	Anthracite culm	Clay and shellac	Failed
1876	Philadelphia, Pa.	Loiseau, E.F.	Anthracite culm	Gashouse tar	Exhibition
1876	Roundout, N.Y.	Delaware and Hudson Canal company	Anthracite culm	Gas tar	Two years' operation
1878	Roundout, N.Y.	American Fuel Co.	Anthracite culm	Pitch	Failed
1878	Nesquehoning, Pa.	Loiseau, E.F.	Anthracite culm	Pitch	Abandoned
1885	Camden, Ark.		Lignite	Carbonized	Temp. operations.
1885	Poplar Bluffs Mo.		Lignite	Retorting	Experimental
1890	Mahanoy, Pa.	Anthracite Pressed Fuel Company	Anthracite culm	Coal tar pitch	Failed
1892	Richmond, Va.	Gay, W.B.	Semianthracite	Pitch	Failed
1895	Huntington, Ark.	National Eggette Coal Company	Semianthracite and bituminous	Pitch	Failed
1896	Rockdale Texas	Dumble, E.T.	Lignite	Pitch	Burned
1897	Port Morien Nova Scotia		Dust from coal screenings	Pitch	Abandoned
1904	Perth Amboy, N.J.	Zwoyer Brothers	Anthracite	Resin, oil, pitch	Burned

TABLE 10 (CONTINUED)

CHRONOLOGICAL TABLE OF BRIQUETTING PLANTS IN THE UNITED STATES

Date	Place	Designer or promoter	Coal used	Binder	History
1905	Del Ray, Mich.	Semet-Solvay Co.	Coal and coke	Pitch	Four years' operation
1905	Minnesota	Washburn, W.D.	Lignite (N.D)	None	Abandoned
1905	Arkansas	Darling, S.M.	Lignite	Carbonized	Experiment
1906		Amer. Briq. Co. Stewart, R.L.	Lignite	Flax syrup Resin	Experiment
1906	Philadelphia, Pa.	United Gas Imp. Co.	Coke braize	Coal tar	Abandoned
1906		Parker, Thos.	Coal	Coalite patent	Experiment
1906	Dickson City, Pa.	Lovejoy, J.F.	Anthracite culm	Coal tar pitch	Operation?
1906	Clifton, Ariz.	Ariz. Copper Co.	Lignite and coke breeze	Pitch	Failed
1907	Rockdale Tex.	Eureka Briq. Co.	Lignite	Pitch	Failed
1907	San Antonio, Tex.	Amer. Lig. Briq. Co.	Lignite	Pitch	Failed
1907	Philadelphia, Pa.	United States Coal Mfg. Co.			Failed
1907	Stapleton, Staten Island, N.Y.	Briq. Coal Co.	Slack coal	Pitch	Burned

TABLE 10 (CONTINUED)

CHRONOLOGICAL TABLE OF BRIQUETTING PLANTS IN THE UNITED STATES

Date	Place	Designer or promoter	Coal used	Binder	History
1907	New York City	Mashek, G.J.	Anthracite dust	Pitch	Ceased 1912
1907	Brooklyn N.Y.	Nat. Fuel Briq. Mach. Co.	Anthracite culm	Pitch	Ceased 1913
1907	Kansas City, Mo.	Renfrow Mach. Co.	Semi-anthracite	Coal tar pitch	Ceased 1911
1907	Hartshorne, Okla.	Renfrow Mach. Co.	Bituminous	Water-gas pitch	Ceased 1911
1907	Bankhead, Alta.	C.P. Ry. Co. Zwoyer press		Pitch	Operating
1908	Lansford, Pa.	Lehigh Coal Co.	Culm	Pitch	Burned 1909
1908	Indianapolis, Ind.	Ind. Press. Fuel Co.	Slack	Pitch	Burned 1911
1909	Philadelphia, Pa.	Coal Compress Co.	Screenings	Flour	Ceased 1909
1909	Detroit, Mich.	Detroit Coalette Co.	Pocohantas coal	Pitch	Ceased 1915
1909	Livingston, Ill.	Rutledge & Taylor		Pitch	Successful
1909	Kansas City, Mo.	Standard Briq. Fuel Co.	Semianthracite	Pitch	Successful
1909	Oshkosh, Wis.	Coal Briq. Mach.Co.	Anthracite	Pitch	Ceased 1910
1909	Deerlodge, Mont.	U.S. Fuel Briq. Co.	Lignite		Failed

TABLE 10 (CONTINUED)

CHRONOLOGICAL TABLE OF BRIQUETTING PLANTS IN THE UNITED STATES.

Date	Place	Designer or promoter	Coal used	Binder	History
1909	Superior, Wis.	Stott Briq. Co. Mashek, G. J.	Anthracite and bituminous	Hydrolene	Successful
1909	Dallas, Tex.	Diamond Briq. Co.	Semianthracite		Burned
1910	New York City	Coal Boulet Co.		Hydrolene	Ceased 1914
1910	St. Louis, Mo.	Renfrow Fuel Co.	Anthracite	Pitch	Ceased 1911
1910	Rhode Island	R.I. Coal. Co.	Anthracite	Pitch	Failed
1911	Hebron, N.D.	U.S. Bu. Mines	Lignite	Various	Experiment
1911	Phoenix, Me.	Nat. Fuel Briq. Mach. Co.	Georges Creek coal	Asphaltic pitch	Sold 1915
1912	Superior, Wis.	Berwind Fuel Co.	Screenings	Pitch	Operating
1912	Trenton, N.J.	Eggette Coal Co.	Anthracite	Gilsonite	Sold 1915
1912	Richmond, Va.	Va. Coal Briq. Co.	Semianthracite	Hite	Ceased 1915
1913	Philadelphia, Pa.	Amer. Coalette Co.	Secret Anthracite ?	Hydrolene	4 years' operation
1913	Denver, Colo.	McKinley Coal Co. Hill-West Briq. Co.	Slack	Pitch	Abandoned
1914	Minot, N.D.	North. Briq. Co. Babcock, E. J.	Lignite	Asphalt	Closed

TABLE 10 (CONTINUED)

CHRONOLOGICAL TABLE OF BRIQUETTING PLANTS IN THE UNITED STATES

Date	Place	Designer or promoter	Coal used	Binder	History
1914	San Antonio, Tex.	New Fuel Co.	Coal dust	Creosote and pitch	Experiment
1915	Parrott, Va.	Delparen Anthracite Briq. Co. Mashek	Semianthracite	Vegetable Hydrolene	Success
1915	Irvington, N.J. Clinchfield, Va.	Inter. Fuel. Prod. Co.	Bituminous	Distillation	Success
1916	Scranton, N.D.	Johnson Fuel Co.	Lignite		
1916	Denver, Colo.	Amer. Coal By-Prod. Company	Lignite	Distillation	Two years' operation.
1916	Harrisburg, Pa.	Gamble Fuel Briq. Co.	Slack	Sulphite liquor	Ceased 1919
1916	Richmond, Va.	So. Briq. Coal Co.		Sulphite liquor Asphalt	Success
1916	Norfolk, Va.	Grace and Company	Slack	Pitch	Intermittent
1917	Piedmont, W. Va.	Althouse & Co.	Fines	Pitch	Failed
1917	Philadelphia, Pa.	Amer. Briq. Co.	Anthracite	Hite	
1918	Lykens, Pa.	Amer. Briq. Co.	Culm	Starch and asphalt	Success
1918	Lansford, Pa.	Lehigh Coal & Nav. Co.	Dust from screenings	Asphalt	Success
1920	Newark, N.J.	Burnrite Coal Co.	Anthracite	Secret	Ceased 1923

TABLE 11

CHRONOLOGICAL TABLE OF BRIQUETTING PLANTS ON THE PACIFIC COAST

Date	Place	Designer or promoter	Coal used	Binder	History
1901	Stockton, Cal.	San Francisco and San Joaquin Coal Co.	Lignite		Burned
1905	Los Angeles, Cal.	Los Angeles Gas and Elect. Co.	Carbon	Hydrocarbon	Operated
1905	Pittsburg, Cal.	Allen Briq. Co.	Lignite	Asphalt	Burned
1905	San Francisco, Cal.	Amer. Ajax Briq. Co.	Lignite	Asphalt	Burned
1905	Oakland, Cal.	West. Fuel Co.	Lignite	Pitch	Burned
1907	Pittsburg, Cal.	Pittsburg Coal Mining Co.	Screenings	Pitch	Burned
1908	Tacoma, Wash.	Northwest Imp. Co.		Retorted	Abandoned
1909	Marshfield, Ore.	Pac. Coal. Briq. Co.	Lignite	None	Failed
1911	Seattle, Wash.	United Collieries Co.	Bituminous	Pitch and gluten	Ceased 1915
1913	Linnton, Ore.	Portland, G. &. E. Co.	Crude oil for carbon	Oil tar	Operating
1914	Briquettville, Renton, Wash.	Pacific Coast Coal Co. Malcolmson Briq. Co.	Newcastle, Black Diamond, So. Prairie	Asphalt	Operating
1915	Oakland, Cal.	Pacific G.&.E. Co.	Oil carbon		Success
1915	May, Cal.	Lignite Fuel Co. Ione Coal Co.	Lignite	Very little	Operated one year.

BRIQUET PRODUCTION IN THE UNITED STATES AND WASHINGTON

The production of briquets in the United States is given in the United States Mineral Resources in three groups, eastern states, central states, and Pacific coast states. The figures for an individual state are not obtainable from this source. In table 12 are presented the figures for the total United States production for each year since 1907.

TABLE 12

TOTAL YEARLY PRODUCTION OF FUEL BRIQUETS IN THE UNITED STATES

Year	Production	Year	Production
1907	66,524	1916	295,155
1908	90,358	1917	406,856
1909	139,661	1918	477,235
1910	180,000	1919	295,734
1911	218,443	1920	567,192
1912	220,064	1921	398,949
1913	181,859	1922	619,425
1914	250,635	1923	696,810
1915	221,537	1924	580,470

A graphical representation of the total production and a composite curve of production of the eastern, central, and Pacific coast states is given on the following page. It will be seen that the production is erratic and that decreases and increases are sudden and pronounced. On the whole the industry is growing and the production is rapidly increasing.

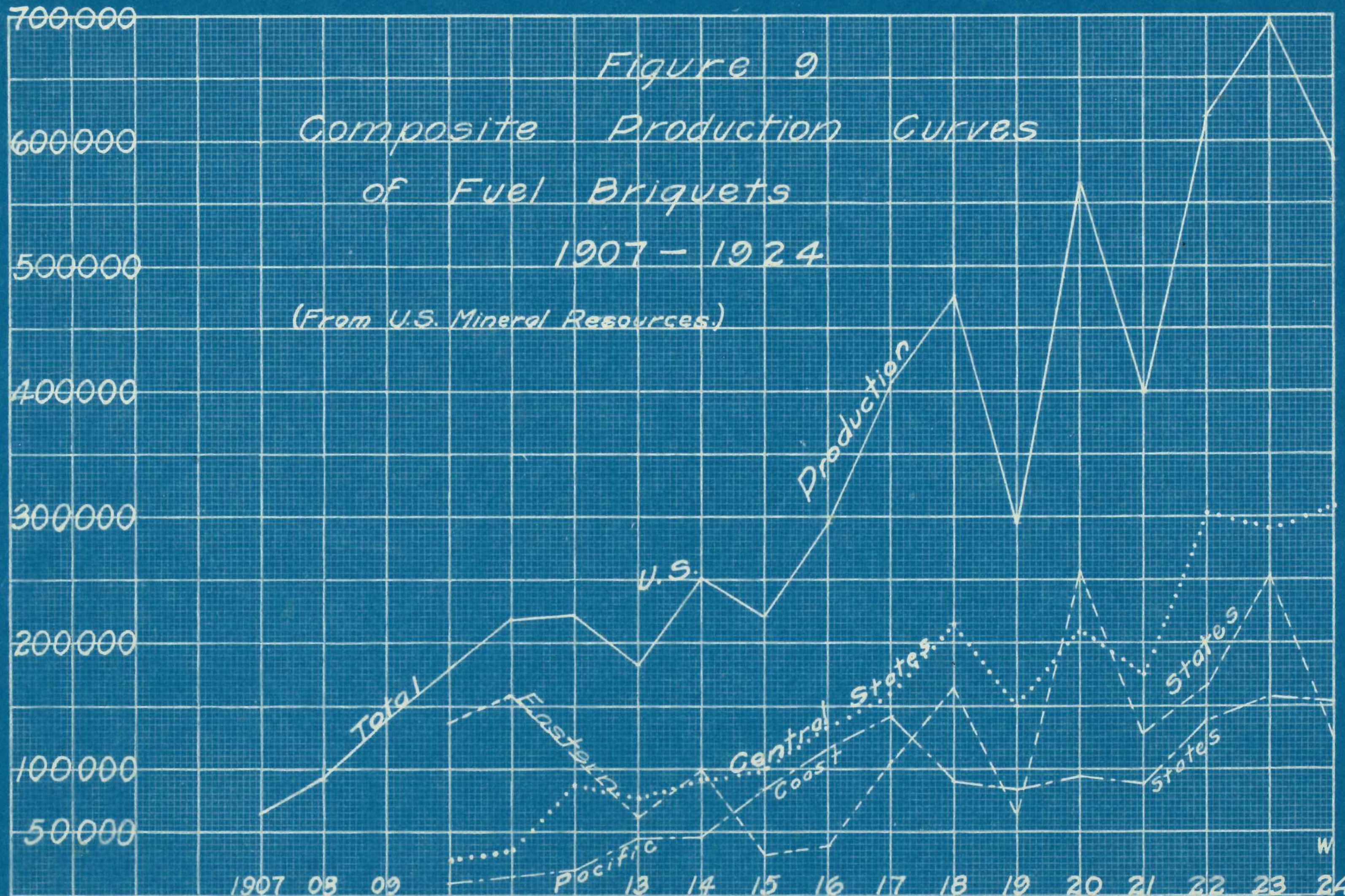
Figure 9
Composite Production Curves
of Fuel Briquets
1907 - 1924
(From U.S. Mineral Resources.)
700000
600000
500000
400000
300000
200000
100000
50000
1907
08
09
13
14
15
16
17
18
19
20
21
22
23
24
Total U.S. Production
Eastern States
Central States
Pacific Coast States
W

The largest fuel briquet producer in Washington is the Pacific Coast Coal Company. Its plant at Renton is probably the largest producer on the Pacific coast. In 1917 for example, this plant produced over 80 per cent of the total Pacific coast production. But in 1920 it produced less than 30 per cent of the production of the west coast. The average lies between these two figures, and for the past four years has been about 60 per cent of the Pacific coast production. The figures for the last ten years are given in table 13.

TABLE 13

PRODUCTION OF BRIQUETS AT THE PACIFIC COAST COAL COMPANY PLANT

Year	Production	Year	Production
1914 (6 months)	13,722	1920	26,222
1915	40,800	1921	18,112
1916	64,018	1922	58,576
1917	109,177	1923	96,299
1918	46,222	1924	93,509
1919	31,640	1925	102,651
		1926 (4 months)	25,871
		Total	726,819

The plant produces about 3000 tons of briquets each week when it is running full time. The demand for the product is seasonal, and during the light season the plant operates part time only. It has been closed for practically all the month of May. While the undertaking is successful, the supply exceeds the market demand. Furthermore the mixture used at the plant is limited to 50 per cent coking coal with an equal amount of free-burning coal. The present necessity of using this large proportion of coking coal in order to make briquets accentuates the need for discovering a good cheap binder suitable for use with the low-grade coals of the state. With this in mind experiments were begun in making briquets with varying amounts of binder of different kinds. The first experiments dealt with the use of sulphur and asphalt as a binder for both coking and low-grade (Tono) coal.

DESCRIPTION OF BUREAU OF MINES BRIQUETTING EXPERIMENTS CARRIED ON AT THE NORTHWEST EXPERIMENT STATION

APPARATUS

The Bureau of Mines had not conducted previous research on briquetting at the Northwest Experiment station. The apparatus which was needed for the processes was, therefore, lacking. Two principal pieces of machinery were needed, first a mixer for the coal and the binder, and second a press. The first attempts at mixing were made with kettles of various kinds and stirring rods, none of which were satisfactory. They served to show that the mixer needed was one in which the distribution of heat would be uniform and the temperature control regulated to a reasonable degree. After the failure of several types, the mixer which was designed consisted of a drum twenty inches long and twelve inches in diameter, set on motor-driven rollers. The speed of rotation was regulated by changing the size of pulleys. The mixer was mounted on an iron frame beneath which was placed a gas plate consisting of four double burners. The temperature could be regulated to a sufficient degree by increasing or diminishing the gas flow. The accompanying photograph shows the mixing apparatus.

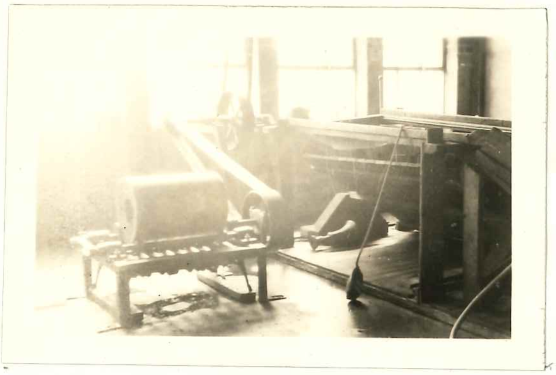

PLATE 1 PHOTOGRAPH OF MACHINE FOR MIXING BINDER WITH COAL.

The other machine required was a press. The first attempts at pressing were made with an iron casing as a mold and a sledge as a press. The mix would eventually take the form of a briquet, but having done so, could not be driven from the mold without shattering. The second attempt was with a crude press rigged from a jack placed against the end of an upright timber, and held in position while the mold and plunger were placed beneath. The jack was then turned by an iron bar until sufficient pressure had been exerted to compact the mix to briquet form. One of the worst features of this plan was, that the timber would not keep its alignment although it was braced from four directions. Consequently it was taken down and placed on the floor between two uprights. The results here were very much better, but some difficulties yet remained. The time required to The time required to get the mix into the mold allowed the mix to cool, and the briquet resulting after pressing would not hold together. The mold was then fitted with a steam jacket which kept it warm at the time of pressing, but even so much difficulty was encountered from other directions. There was still the trouble of getting the briquets out of the mold without shattering. They were removed by a second plunger and sledge, but after the first few briquets were removed, the small amount of mix adhering to the inside of the mold, would cause the later ones to shatter in being driven out. The whole operation was too laborious and slow to yield good results from the mix, and accordingly a hydraulic press was borrowed from the chemistry department and installed in Mines Laboratory beside the mixer. This press allowed a pressure of about 1000 pounds per square inch on a two-inch mold, without the use of the hand pump. By using the hand pump the pressure could be increased to about 3000 pounds per square inch. The press, which was very satisfactory, is shown in the accompanying photograph.

PLATE 2 PHOTOGRAPH OF HYDRAULIC PRESS USED IN COMPRESSING BRIQUETS.

Two kinds of coal were used in the experiments, the first series of briquets being made from Wilkeson, float 1.38, a coking coal, and the later series from Tono, a low-grade subbituminous coal.

The binder used was asphalt, either alone or mixed with varying percentages of sulphur. It had been stated by H.S. Gillen and G.F. Sheehan, who patented a process for briquetting coal by the use of asphalt and sulphur (see page 2), that the effect of the sulphur is to cause a coking action on the coal at the time of combustion. This statement was confirmed by the work of Dr. H.K. Benson. (11).

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(11) Benson, H.K. Effect of sulphur in the briquetting of subbituminous coal. Indust. and Eng. Chem., vol. 18, no. 2, 1926. P. 116.

At the present time in this experimental work, good briquets are being made from Tono coal using 8 per cent or more asphalt with or without sulphur. In burning the briquets in a forge, no difference appears to exist, caused by the presence or absence of sulphur, in the manner in which they hold together after firing. A more thorough study, however, will have to be made of this point. To do this, a special stove has been purchased for burning the briquets, in which conditions will closely approximate those met in actual domestic use.

A sample of each set of briquets has been analyzed for moisture, ash, volatile matter, fixed carbon, and sulphur. These analyses are given in table 14.

TABLE 14

KINDS OF BINDER USED AND ANALYSES OF BRIQUETS

WILKESON COAL

No.	Binder	Moist.	Ash	Vol. M.	Fix. C.	S.	Temp.	Result	Pressure
1	6% Asph. 3% S.	1.09	7.34	31.74	59.83	1.92		Fair	
2	6% Asph. 6% S	0.96	7.07	32.42	59.55	4.62		Fair	
3	8% Asph. 5% S	1.12	6.57	33.42	58.89	4.33		Good	
4	10% Asph 5% S	0.85	7.13	33.23	58.79	3.88	140	Good	
5	10% Asph 5% S	1.02	6.63	33.92	58.43	4.15	150	Good	
6	6% Asph 1% S	0.96	7.17	33.03	58.84	1.47	150	Fair	
6a	6% Asph 1% S	1.00	6.96	32.91	59.13	1.46	150	Fair	
6b	6% Asph 1% S	0.75	6.43	32.75	60.07	1.11	150	Fair	
6c	6% Asph 1% S	1.01	6.35	33.53	59.11	1.09	150	Fair	
7	8% Asph	0.95	6.17	35.35	57.53	0.82	145	Fair	
8	8% Asph	1.04	6.73	33.55	58.68	0.78	145	Good	
9	Unsuccessful								
10	10% Asph	1.04	5.98	35.49	57.49	0.68	140	Good	
11	10% Asph	1.01	6.40	35.55	57.04	0.74	140	Good	
12	10% Asph	1.00	6.67	35.67	56.66	0.72	140	Good	

TABLE 14 (CONTINUED)

KINDS OF BINDER USED AND ANALYSES OF BRIQUETS

TONO COAL

No.	Binder	Moist.	Ash	Vol. M.	Fix. C.	S	Temp.	Results	Pressure
Tono coal		9.64	22.54	44.22	23.60	0.76	(Grab sample)		
T1	10% Asph 6% S	3.66	11.22	40.71	44.41	4.80	140	Good	2200
T2	10% Asph 4% S	4.03	10.99	43.40	41.58	5.13	140	Good	2400

As far as can be seen from these determinations, sulphur has no effect on the briquet prior to its burning. That is its physical action on the binder and coal is not noticeable. The chemical effect of the sulphur will have to be determined by further experiments in burning.

In appearance and hardness the best briquets were those made after the installation of the hydraulic press, although the coal used was of poorer quality than that used previously in the hand press. This illustrates the importance of the mechanical element in the manufacture of fuel briquets. The appearance and size of the briquets are shown by the accompanying photographs.

PLATE 3 BRIQUETS FROM HAND PRESS PLATE 4 BRIQUETS FROM HYDRAULIC PRESS

CONCLUSIONS

1. Because of the character of much of the coal mined in the state of Washington there is need of a method of increasing the utilization of fine sizes of coal.

2. The art of briquetting affords a method which can make use of fine coal and at the same time supply the large domestic demand.

3. The requirements for a briquet for domestic purposes are that it can be burned easily with an ordinary draft, without odor or soot, that it will hold together in the fire until completely consumed, that it will furnish heat commensurate with its cost, and that the ash will not be excessive.

4. The binder is the most important single element in the process of meeting the above requirements. It is essential, therefore, to continue investigation of various binders which can be used with low-grade coal.

5. Judging from burning the briquets in a forge, the addition of sulphur has no effect on the coking properties of Wilkeson coal. The experiments are not numerous enough to be conclusive.

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