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COMPARATIVE TESTS

OF

RUN-OF-MINE AND BRIQUETTED COAL ON LOCOMOTIVES.

INCLUDING TOPEDO-BOAT TESTS AND SOME FOREIGN SPECIFICATIONS FOR BRIQUETTED FUEL

BY

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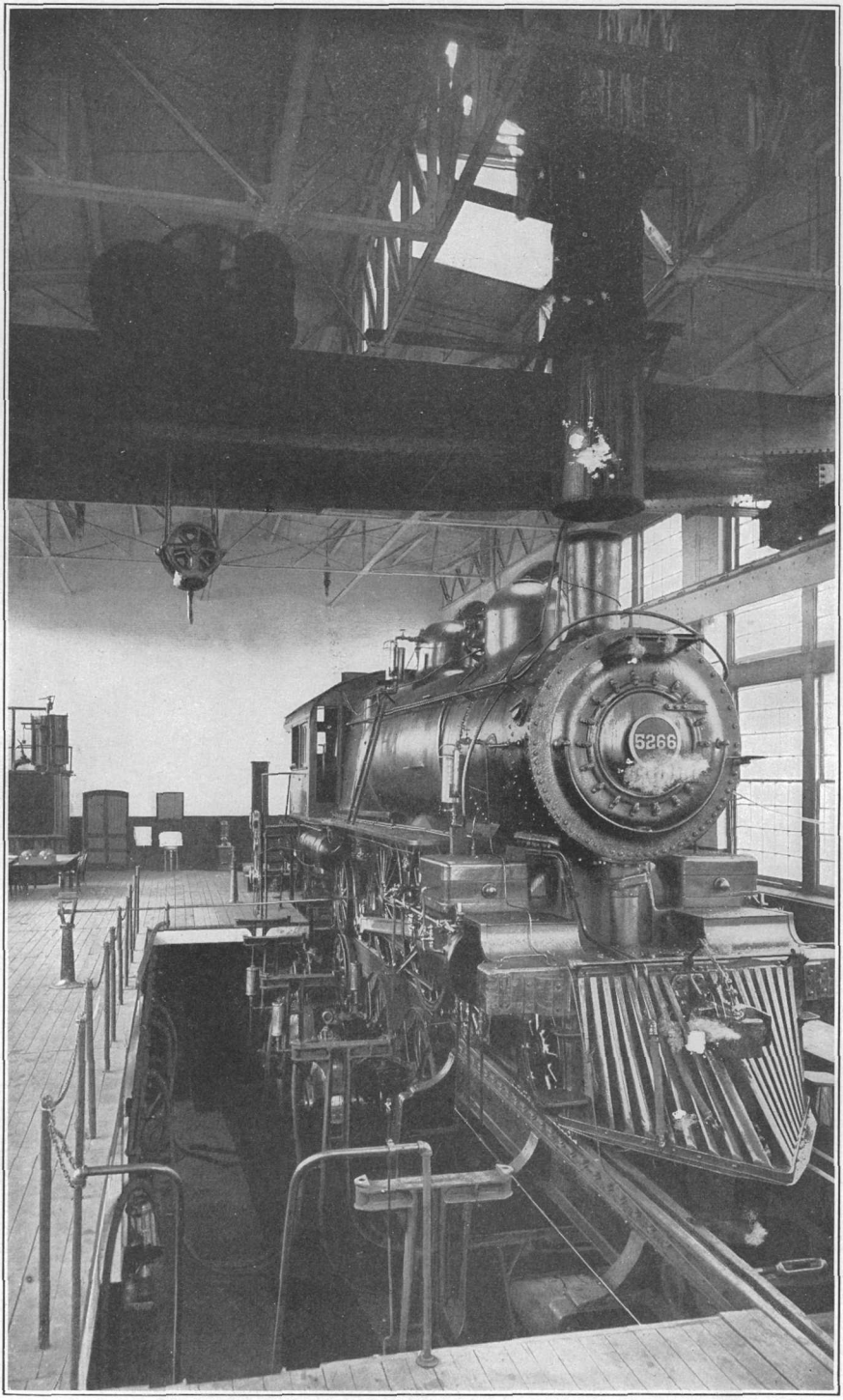


LOCOMOTIVE AND PIT, LOCOMOTIVE TESTING PLANT, ALTOONA, PA.

COMPARATIVE TESTS OF RUN-OF-MINE AND BRIQUETTED COAL ON LOCOMOTIVES.

By W. F. M. Goss.

INTRODUCTION.

THE GEOLOGICAL SURVEY'S EXPERIMENTS IN THE USE OF BITUMINOUS-COAL BRIQUETS.

For the purpose of procuring data that could be used in estimating the value of the briquetting process as applied to American fuels, the United States Geological Survey, in cooperation with other interests, began in 1904, at the Louisiana Purchase Exposition, certain experiments involving the production and use of bituminous-coal briquets. It installed at St. Louis, and later at Norfolk, machines for the manufacture of such briquets, and the output of these machines has been tested in locomotive service on several different railroads in comparison with natural fuels. An elaborate and carefully executed series of tests involving the use of natural coals and of briquets made from the same coal, previously crushed, has been carried out on a locomotive mounted at the testing plant of the Pennsylvania Railroad Company at Altoona, Pa.; and some preliminary experiments involving the use of briquets in marine service have been made in connection with one of the Government's torpedo boats. A description of these tests is presented herewith. The results sustain the following general conclusions:

1. The briquets made on the Government's machines have well withstood exposure to the weather and have suffered but little deterioration from handling.

2. In all classes of service involved by the experiments, the use of briquets in the place of natural coal appears to have increased the evaporative efficiency of the boilers tested.

3. The smoke produced has in no test been more dense with the briquets than with coal; on the contrary, in most tests the smoke density is said to have been less when briquets were used.

4. The use of briquets increases the facility with which an even fire over the whole area of the grate may be maintained.

5. In locomotive service the substitution of briquets for coal has resulted in a marked increase in efficiency, in an increase in boiler capacity, and in a decrease in the production of smoke. It has been especially noted that careful firing of briquets at terminals is effective in diminishing the amount of smoke produced.

6. In torpedo-boat service the substitution of briquets for coal improves the evaporative efficiency of the boiler. It does not appear to have affected favorably or otherwise the amount of smoke produced. The briquets used in this series of tests were of a form requiring considerable bunker capacity for their storage, but as the form of the briquet is a detail entirely within control, this objection need not apply to the use of briquets in actual service.

THE BRIQUET INDUSTRY IN GERMANY.

METHODS AND EXTENT OF PRODUCTION.

In 1905 J. A. Holmes, expert in charge of the technologic branch of the Survey, and in 1907 the writer, who is consulting engineer to this branch on locomotive tests of fuels, visited Europe and carefully studied the briquetting industry and practice there.

The briquet industry as it exists in the German Empire involves two classes of operations—one dealing with the brown coals or lignites of the upper Rhine region and the other with the fine bituminous coals of the Westphalia region.

The brown coals are, in their natural state, of low grade, some of them but little better than peat, and in this condition they are available as fuel only for industrial purposes. The process of briquetting these fuels consists in squeezing out the water. No cementing material is used. The resulting briquet may have any size or form, but is usually from one-half to two-thirds the size of an American building brick and has a rectangular cross section in the middle, with edges that are beveled, rounded, or otherwise curved as they approach the ends. Such briquets bear an impression of their maker's name or brand; they present a surface which is perfectly clean and in some briquets so smooth as to appear to have been glazed. Practically the total output of brown-coal briquets is used in domestic service, for which they present incidental advantages that are not possessed by other forms of solid fuels. For example, (1) owing to their form they can be laid up in regular piles for storage, lost space being reduced to a minimum; (2) they pack nicely for shipment and for transfer from local sellers to purchasers; (3) as they are practically dustless, they neither waste nor produce objectionable litter; and (4) their unformity of size admits of their being sold by number, a feature which, in retail business, is regarded as advantageous. The briquetting process as applied to the brown coals of Germany, there-

fore, serves to convert a low-grade material into a fuel that is peculiarly adapted to the exacting requirements of domestic service. The cost of the process can not be stated with confidence, but it is reported to be about $1.50 a ton.

The fine bituminous coals are extensively briquetted for industrial uses. In the Westphalia region production is practically controlled by the Rheinisch-Westfalisches Kohlen-Syndiket, which produced in 1906 nearly 3,000,000 tons of briquets.[a] In this district the briquetting process is regarded only as a means for disposing of the fine coals. The briquets are not thought to be superior in quality to the coal from which they are made, and large coal is never crushed to supply material for them. There has not been for many years any accumulation of fine coal at the mines; consequently the industry is concerned only with current production. As a preparation for briquetting, the Westphalia fine coals are washed until the ash content does not exceed 7 per cent. The bond used is breeze from the coke ovens. The Syndiket is a large producer of coke, and the use of the breeze with the fine coal in the manufacture of briquets serves in making two by-products marketable. The briquetting process is at best an expensive one, costing in the Westphalia region, under the favorable conditions described, from $1.20 to $1.35 a ton. It is consequently employed only as a last resort. So far as there is a market for the direct use of fine coal, as in automatic stokers, it is disposed of for such use. Coals that will coke are not briquetted, the coking process being regarded as a more economical method of disposing of the fine stuff. The force of these statements as applying to the operations of the 79 companies making up the Syndiket is shown by the returns for the year 1906, which are given herewith. It will be noted that except where several mines are operated by the same company, the companies that produce briquets make no coke and those that produce coke make few briquets or none. The operations of the Syndiket, which embrace more than half the total coal tonnage produced by the Empire, may be taken as typical of the German practice.

[a] For statistical information see Die Steinkohlenzechen, etc., by Heinrich Anplag, published annually by C. L. Kruger-Dortland, price 3 marks. This volume covers the operations of the soft-coal mines in the districts of the lower Rhine and Westphalia, of Aix-la-Chapelle, of the Saar, and of Alsace-Lorraine; also of the operations of the brown-coal mines of the Rhine district. It presents a catalogue of mining companies and of their offices; it gives statistics covering the production of coal, coke, and briquets for each operation; and where briquets are produced, it gives the number of presses and the size, shape, weight, and trade-mark of the briquets. It shows that the fuel production of the whole Empire for the year 1906 was as follows: Soft coal, 136,479,885 tons; brown coal, 56,241,353 tons; coke, 20,265,372 tons; briquets, 14,500,851 tons.

Output of the Rheinisch-Westfalisches Kohlen-Syndiket for 1906, in short tons.

Plant or company.	Coal.	Coke.	Briquets.
Altendorf, Gewerkschaft der Zeche	240,000		72,600
Aplerbecker Aktien-Verein für Bergbau, Zeche Margarethe	300,000		90,450
Arenberg'sche Aktiengesellschaft für Bergbau und Hüttenbetrieb	1,872,702	287,250	
Blankenburg, Gewerkschaft	155,000		100,000
Bochumer Bergwerks-Aktien-Gesellschaft, Zeche Präsident	405,900	136,000	
Bochumer Verein für Bergbau und Gusstahlfabrikation einschl. Gewerkschaft ver. Engelsburg	364,000	4,000	153,000
Borussia, Gewerkschaft der Zeche	194,760	71,000	
Caroline, Gewerkschaft	150,000		36,300
Carolus Magnus, Gewerkschaft	300,000	75,000	
Charlotte, Gewerkschaft	120,000		
Concordia, Bergbau-Aktiengesellschaft	1,526,376	326,800	
Consolidation, Bergwerks-Aktien-Gesellschaft	1,740,000	396,000	
Constantin der Grosse, Gewerkschaft	1,384,500	520,000	
Crone, Gewerkschaft der Zeche	204,000	40,000	
Dahlbusch, Bergwerks-Gesellschaft	1,210,000	183,000	
Deutscher Kaiser, Gewerkschaft	1,500,000	12,000	
Deutsch-Luxemburgische Bergwerks- und Hütten-Aktiengesellschaft	1,785,000	428,000	246,600
Deutschland, Gewerkschaft der Zeche	325,500	100,000	
Dorstfeld, Gewerkschaft	840,000	186,580	
Eintracht Tiefbau, Gewerkschaft der Zeche	582,000	79,000	163,350
Eisen- und Stahlwerk Hoesch, Aktiengesellschaft	550,000	120,000	
Essener Steinkohlenbergwerke, Aktiengesellschaft	1,355,000		460,900
Ewald, Gewerkschaft des Steinkohlen-Bergwerks	1,993,000		54,450
Felicitas, Gewerkschaft	120,000	95,000	
Fried. Krupp, Aktiengesellschaft	700,000		
Friedrich der Grosse, Gewerkschaft	721,500	202,900	
Friedrich Ernestine, Gewerkschaft	360,000	86,560	
Fröhliche Morgensonne, Gewerkschaft	570,000	142,000	180,000
Gelsenkirchener Bergwerks-Aktien-Gesellschaft	7,698,000	1,404,658	72,000
General, Gewerkschaft	100,000	40,000	
Georgs-Marien-Bergwerks- und Hütten-Verein, Aktien-Gesellschaft	158,750		
Gottessegen, Gewerkschaft des Steinkohlen-Bergwerks	180,000		54,450
Graf Beust, Gewerkschaft des Steinkohlen-Bergwerks	434,971	65,660	
Graf Bismarck, Gewerkschaft der Zeche	1,754,700		
Graf Schwerin, Gewerkschaft des Steinkohlen-Bergwerks	468,400	138,000	
Gutehoffnungshütte, Aktien-Verein für Bergbau und Hüttenbetrieb	1,900,000	40,000	
Harpener Bergbau-Aktien-Gesellschaft	7,240,000	1,650,000	47,520
Heinrich, Gewerkschaft der Zeche	169,000		
Helene und Amalie, Gewerkschaft der Zeche	920,000	175,900	
Hibernia, Bergwerks-Gesellschaft	5,416,500	812,800	54,450
Hörder Bergwerks- und Hütten-Verein	150,000		
Johann Deimelsberg, Gewerkschaft	240,000		108,900
Kaiser Friedrich, Gewerkschaft	240,000	90,000	
Kölner Bergwerks-Verein	904,438	238,040	
König Ludwig, Gewerkschaft	1,312,000	340,160	
König Wilhelm, Essener Bergwerks-Verein	1,040,000	313,000	
Königin Elisabeth, Gewerkschaft	780,000	187,000	
Königsborn, Aktien-Gesellschaft für Bergbau, Salinen- und Soolbad-Betrieb	1,124,770	355,600	
Langenbrahm, Gewerkschaft des Steinkohlen-Bergwerks	360,000		
Lothringen, Gewerkschaft des Steinkohlen-Bergwerks	660,000	288,400	
Louis Tiefbau, Dortmunder Steinkohlen-Bergwerk	503,089	192,500	
Magdeburger Bergwerks-Aktien-Gesellschaft, Zeche Königsgrube	550,000		
Mansfeld'sche Kupferschiefer bauende Gewerkschaft	210,000		
Mark, Bergbau-Aktien-Gesellschaft	150,000		54,000
Massen, Bergbau-Aktien-Gesellschaft	600,000	105,000	
Mathias Stinnes, Gewerkschaft der Zeche	968,000	148,195	
Minister Achenbach, Gewerkschaft	400,000	8,100	
Mont Cenis, Gewerkschaft der Steinkohlenzeche	995,000	100,000	
Mülheimer Bergwerks-Verein	1,380,000	95,000	325,200
Neu-Essen, Bergbau-Gesellschaft	770,000		
Neumühl, Gewerkschaft des Steinkohlenbergwerks	1,650,000	363,000	
Neu-Scholerpad und Hobeisen, Gewerkschaften	210,000		
Nordstern, Aktiengesellschaft, Steinkohlenbergwerk	2,740,000	542,640	71,280
Phönix, Aktiengesellschaft für Bergbau und Hüttenbetrieb	300,000		
Rheinische Stahlwerke	630,000	190,000	
Rheinpreussen, Gewerkschaft des Steinkohlen-Bergwerks	3,000,000	590,000	
Siebenplanten, Gewerkschaft	300,000	61,200	132,360
Schalker Gruben und Hütten-Verein, Aktiengesellschaft	1,000,000	222,150	
Schnabel ins Osten, Gewerkschaft	240,000		
Schürbank und Charlottenburg, Gewerkschaft	180,000		72,600
Trappe, Gewerkschaft des Steinkohlen-Bergwerks	150,000		
Tremonia, Gewerkschaft	294,981	43,200	
Union, Aktiengesellschaft für Bergbau, Eisen- und Stahl Industrie	500,000	100,000	
Unser Fritz, Gewerkschaft	820,000		
Victor, Gewerkschaft	770,000	291,940	
Victoria, Gewerkschaft	135,000		54 450
Victoria Mathias, Gewerkschaft des Steinkohlen-Bergwerks	373,300	123,660	

Output of the Rheinisch-Westfalisches Kohlen-Syndiket for 1906, in short tons—Cont'd.

Plant or company.	Coal.	Coke.	Briquets.
Wiendahlsbank, Gewerkschaft	125,463	.....	54,450
Zollverein, Gewerkschaft des Steinkohlen-Bergwerks	1,755,507	240,000	.....
Brikettwerk Dahlhausen	.....	.....	180,000
	76,521,107	13,106,893	2,839,910

GERMAN PROGRESS IN REDUCING THE SMOKE-PRODUCING QUALITIES OF BRIQUETS.

So far as can be learned, little has been accomplished in Germany in the matter of producing smokeless briquets. The fact that the coal entering into the composition of the briquet is fine does not make it less smoky, and the addition of a binding material in the form of pitch, itself a smoky fuel, really makes the briquet, so far as its composition is concerned, more smoky than the original fuel. But the difference in this respect is not great, as the weight of the binder is only 4 or 5 per cent of that of the coal. Moreover, as a practical matter, the disadvantage which may arise from the presence of the pitch may be neutralized by making the briquets of regular and uniform size, a condition which favors satisfactory action in the furnace. On the whole, therefore, as regards its smoke-producing qualities, the German bituminous-coal briquet is no more objectionable than the raw coal.

An attempt to employ a nonsmoking material (quicklime) as a binder has been described by the Deutscher Ingenieur (1903). The fine coal was first dried, and then mixed with milk of lime in such proportions as to make the amount of lime in the mixture from 4 to 6 per cent. This mixture was then pressed into molds under very heavy pressure, after which the briquets were placed in a chamber where they were subjected alternately to the gases of the fire and to a jet of steam, a process which served to change the quicklime in the briquet to carbonate of lime. Briquets thus made became very hard, resisted exposure to air or water, and held together well in the fire; but though several years have passed since the introduction of the process, nothing could be learned concerning the extent of its manufacture or use. Still more recently it has been reported that experiments are now in progress at Stettin involving the use, as a binder, of naphthalene, a by-product resulting from the manufacture of wood alcohol, with a view of keeping down the smoke-producing content of the briquet. Naphthalene costs more than the breeze from the coke ovens, but only one-fourth as much is required, so that the expense per briquet is not increased.

BRIQUETS FROM THE CONSUMER'S POINT OF VIEW.

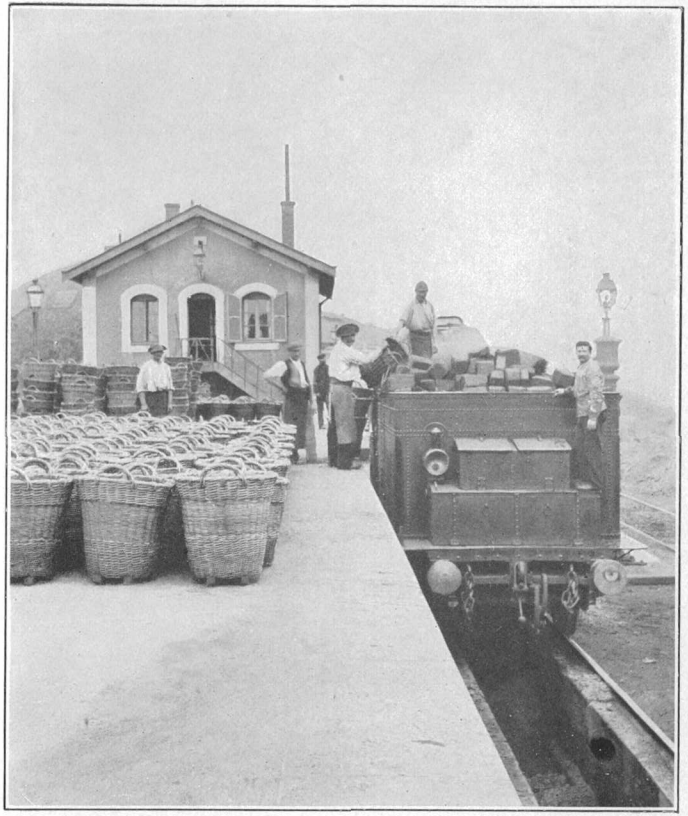
Large consumers of fuel in Germany find it to their advantage to take a certain small percentage of their total supply in the form of bituminous-coal briquets. This is done not because the briquets are

especially preferred, but because there are some uses about manufacturing establishments to which this form of fuel is well adapted, and because by taking them the stock of the seller is evened up. The form and size of the briquets thus taken are within wide limits, subject to choice. By far the largest consumers of briquets in Germany are the railroads. The briquets for use in locomotive service have the form of a rectangular parallelopiped, the corners, perpendicular to the large faces, being rounded. They weigh either 3 or 5 kilograms (6.6 or 11 pounds). Other facts concerning their form and composition will be found concisely stated in the specifications of the Prussian State Railroad presented elsewhere in this paper. Much of the surplus stock of locomotive fuel is carried in this form. The briquets in store are laid up in compact regular courses to form piles from 6 to 8 feet in height along one or both sides of a fuel-storage track. If of good quality, they are but little affected by exposure to the weather, even though they remain untouched for several years. In the piles examined the upper courses, which are most exposed, showed no marked indication of deterioration. In a single locality in southern Germany piles of rather poorly fabricated briquets, which could be easily broken, were found; but it was said that even these briquets would withstand storage exposure for a period of one year.

Concerning the thermal quality of briquets used in German locomotive service, facts are difficult to obtain. The specifications of the Prussian State Railroad contain no requirement with reference to this matter; they are drawn merely to cover ordering, delivery, and payment. In Saxony and Bavaria, so far as could be ascertained, no formal specifications are in use by the Government railways. The briquets are sold under trade names, such as "Sunshine" and "Golden Glow." To speak in very general terms, it is the opinion of German motive-power officials that the best briquets do not equal the best coal, and, aside from all qualifications as to quality, it is not regarded as good practice to supply locomotives entirely with briquetted fuel, except when they are employed in inferior service. A mixture of half briquets and half coal is commonly used and was most heartily commended by a considerable number of motive-power officials as constituting a fuel for locomotives that was entirely satisfactory.

In fast passenger service out of Berlin the use of briquets is avoided as much as possible. In such service the briquets are dumped on top of the load of coal, the quantity being not more than one-fourth of the total fuel supply on the tender. By loading in this way the briquets constitute the first fuel to be used. They serve in starting the fire, and are for the most part gone or at least in the fire box when the engine leaves its terminal. In using this form of fuel the fire box is kept well filled, the fire being a foot or more in thickness. Deep fire boxes are not infrequently filled to the level of the fire door.

A. TENDER OF A COMBINATION LOCOMOTIVE, SHOWING FINE COAL IN FRONT.



B. LOCOMOTIVE ON THE PARIS, LYON AND MEDITERRANEAN RAILWAY; TENDER LOADED WITH BRIQUETS.

The conclusion to be drawn from a rather careful inquiry among German users of briquets, chiefly in locomotive service, is to the effect that the process of briquetting gives a fuel which can be handled and stored with greater facility and with less loss than natural coals, which is of satisfactory thermal value, and the use of which conserves the country's resources.

THE BRIQUET INDUSTRY IN BELGIUM AND FRANCE.

In Belgium, and to a lesser degree in France, the bituminous-fuel briquet is of greater importance than in Germany. All the Belgian coals are fine, nothing approaching the lump coals of Germany, of England, or of the United States being obtainable, except through importation. In Belgium, therefore, the briquet is a more serviceable form of fuel than native coal in its natural state. On the Belgian State railways natural coal is used more or less in freight service, but briquets are used exclusively in passenger service. As they are manufactured by a process which delivers continuously, and as they are not always cut off at the marking, the fragments fired are of all sizes up to one and one-half times the size of the normal briquet. A single normal Belgian briquet weighs 11 pounds. No scoop is necessary in firing these briquets. The fireman picks up the blocks singly, or piles two or three on his hand and wrist, and tosses them into the fire box. The process appears simple and clean, but it is a fact that locomotives thus fired, in spite of the usual precautions taken, are dirty beyond description. The use of a fuel composed of fine coal and pitch is probably responsible for an atmosphere in the cab which, though not visibly objectionable, produces local discoloration upon everything it touches.

The views given in Pls. II and III illustrate some features of the use of briquets by railroads in France. Pl. II shows briquets in baskets, for quick loading, on a station platform, and a locomotive tender with fine coal in front and briquets in the rear. Pl. III shows briquets stored in piles and the tumbling apparatus used for testing the coherency of briquets.

FOREIGN SPECIFICATIONS FOR BRIQUETS.

An idea of the significance of the briquetting industry in several different countries may be had by reviewing the requirements embodied in the specifications governing the purchase of briquets. Four such specifications, which may be accepted as typical, are presented in this report (pp. 48–56). They are those of the Prussian State Railroad, the Belgian State Railroad, the State Railway of France, and the Paris-Orleans Railway, of France. The facts which are set forth by these typical specifications with reference to the composition of briquets and to the mechanical tests employed in determining their value will prove of especial interest to the American reader.

COMPARATIVE TESTS OF LLOYDELL COAL AND BRIQUETS.

PERSONNEL.

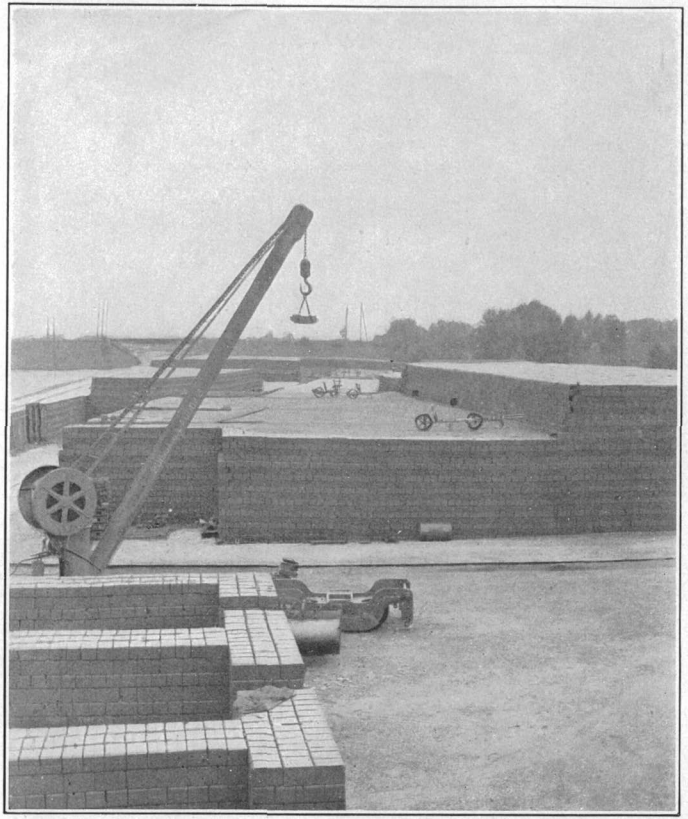
The tests of Lloydell coal and briquets here reported were made under the direction of A. W. Gibbs, general superintendent of motive power of the Pennsylvania Lines, by E. D. Nelson, engineer of tests, at Altoona, Pa. The testing plant was in charge of S. B. Koch, who was assisted by G. E. Roads. G. E. Rider and R. Galt were present and assisted in the tests on behalf of the United States Geological Survey, in cooperation with which these tests were conducted and by which the briquets were manufactured. This report is abridged by the writer from a more elaborate report of results prepared by Mr. Nelson.

PURPOSE OF THE TESTS.

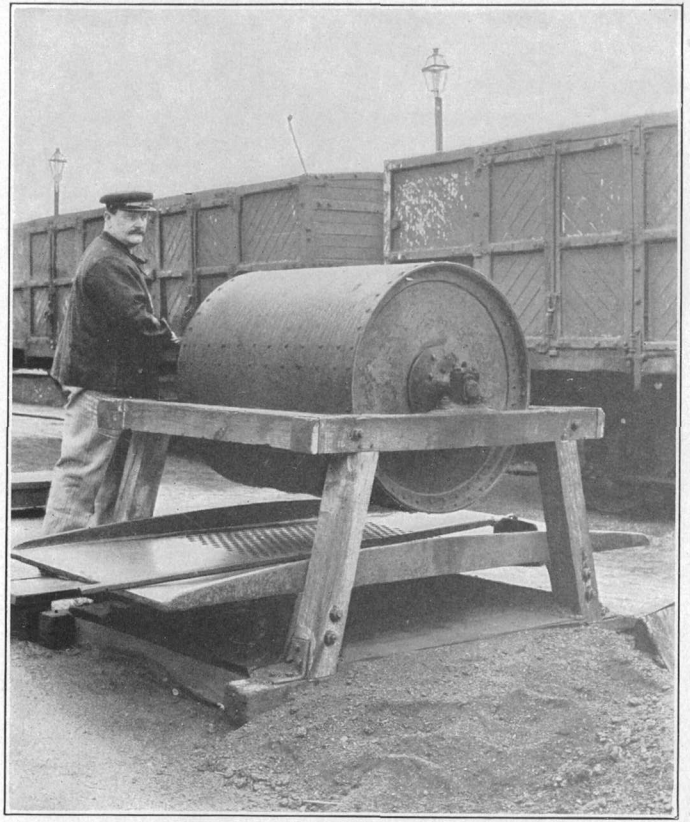
Many low-volatile coals, such as those mined in the vicinity of Johnstown, Cambria County, Pa., are semismokeless and therefore very desirable for use in locomotives at or near terminals; nevertheless, on account of their low evaporative efficiency, they have not been found altogether satisfactory when used as locomotive fuel. Their tendency to disintegrate rapidly on the grate during combustion causes large quantities of cinders and sparks of high calorific value to be discharged. These cinders accumulate in the smoke box of the locomotive, obstruct the draft on the fires, and reduce the capacity of the boiler. The investigation here reported, therefore, was undertaken to determine in what measure, if any, the process of briquetting will serve as a remedy for these defects and to discover the effect of the process on efficiency and capacity.

COAL TESTED.

The coal selected for the tests was taken from a mine working the Lower Kittanning coal bed near Lloydell, Cambria County, Pa., on the South Fork branch of the Pennsylvania Railroad. This coal was practically the same as that mined in the Scalp Level district of Pennsylvania, which was used in all the locomotive tests made by the Pennsylvania Railroad Company at the Louisiana Purchase Exposition in 1904. Its characteristics as a locomotive fuel were therefore well known. The Lloydell coal is a very friable, low-volatile bituminous coal, and the carloads selected for the tests consisted of run of mine. They were loaded and shipped under the supervision of J. S. Burrows, of the Geological Survey. The coal was exposed to the weather for thirty days on the way to the St. Louis testing plant,



A. BRIQUETS STORED FOR LOCOMOTIVE USE IN TIMES OF EMERGENCY, PARIS, LYON AND MEDITERRANEAN RAILWAY.



B. STEEL CYLINDER USED FOR TESTING COHERENCY OF BRIQUETS FOR THE PARIS, LYON AND MEDITERRANEAN RAILWAY.

before being briquetted. It showed but little change due to this exposure except a decided increase in moisture, which, however, was eliminated in the briquetting process.

BRIQUETS TESTED.

The briquets tested were of two sizes, and the amount of binding material in them ranged from 5 to 8 per cent. The larger size, called in the tests "square," was rectangular in form, about 3 by $4\frac{1}{4}$ by $6\frac{3}{4}$ inches, with slightly rounded corners, and weighed about $3\frac{1}{2}$ pounds. The smaller size of briquet, called "round," was cylindrical with convex ends, had a diameter of about 3 inches and a length over the convex ends of 2 inches, and weighed about one-half pound.

The binding material in all the briquets was water-gas pitch. This material was furnished at the briquetting plant of the United States Geological Survey, in St. Louis, at $9 per ton, or 0.45 cent per pound. The least amount of binding material that would make perfect briquets was found to be 5 per cent of the weight of the coal, The cost of the binder in one ton of the 5 per cent briquets was therefore 45 cents.

The cost of briquetting, including all charges, is estimated to be about $1 per ton of briquets; that is, the briquetting added approximately $1 per ton to the cost of the coal. The briquets were made, however, in an experimental plant, and the price is for this reason probably not so low as if they had been made on a much larger scale

The briquets were made by the fuel-testing plant of the United States Geological Survey at St. Louis. The coal was shipped from the mine at Lloydell under the supervision of an inspector of the Survey, who at the same time obtained mine samples. The samples were hermetically sealed and sent to the St. Louis laboratories for analysis. After the coal was made up into briquets it was returned to the locomotive testing plant at Altoona, Pa., for the tests. The method of making the briquets is described in detail in previous reports of the Geological Survey.[a] In this process the binding material is mixed with the crushed coal, the mass is softened by contact with steam as it passes to the briquetting press, and the briquet is finally formed in a compressing machine.

DESCRIPTION OF LOCOMOTIVE.

The locomotive used for all tests was a simple Atlantic (4–4–2) type passenger locomotive of the Pennsylvania Railroad Company's class E 2a. It is shown in the outline elevation in fig. 1, and its

[a] Report on the operation of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St Louis, Mo., 1904: Prof. Paper No. 48. See also Bulletins 290, 332, and 343.

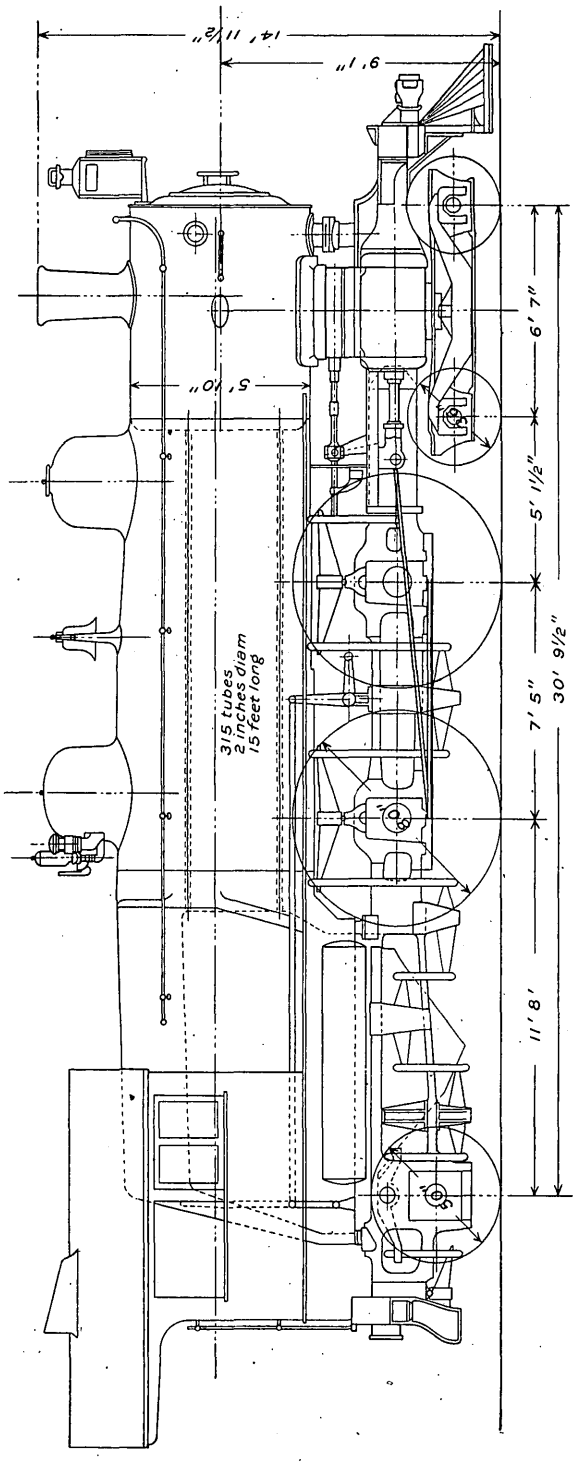


FIG. 1.—Outline elevation of Pennsylvania Railroad Company locomotive, class E 2a.

general appearance in its position at the testing plant is shown in Pl. I. The principal dimensions, etc., are as follows:

Working pressure	pounds	205
Total weight	do	184,167
Weight on drivers	do	110,001
Valves:		
Type		Double-ported balanced slide.
Type of valve motion		Stephenson.
Maximum travel	inches	7
Outside lap	do	1.5
Inside lap	do	.15
Ports:		
Length	do	20
Width of steam port	do	1.5
Width of exhaust port	do	3
Total wheel base	feet	30.75
Rigid wheel base	do	19.08
Cylinders:		
Diameter	inches	20.5
Stroke	do	26
Piston rod diameter	do	3.5
Drivers, diameter	do	80
Boiler:		
Type		Belpaire, wide fire box.
Diameter of front end	inches	70
Number of tubes		315
Length of tubes	inches	179.78
Length of fire box inside	do	114
Width of fire box inside	do	68
Heating surface in fire box	square feet	156.86
Heating surface in tubes, fire side	do	2,162.40
Total heating surface	do	2,319.26
Type of grate		Rocking, Singer.
Grate area	square feet	55.5

LOCOMOTIVE TESTING PLANT.

The Pennsylvania Railroad Company's locomotive testing plant has been fully described elsewhere,[a] so that it is unnecessary to enter into details here. It is sufficient to note that the plant provides for the operation of a locomotive held in position with its wheels resting on supporting wheels, and is so equipped that uniform conditions of running may easily be maintained. The accurate measurements which such a laboratory equipment permits make possible the careful work necessary for satisfactory comparative tests. The plant, originally erected as an exhibit at the Louisiana Purchase Exposition, was later removed to a permanent site at Altoona, Pa., where the tests under consideration were made. Pl. I shows the interior of the

[a] Locomotive tests and exhibits, Louisiana Purchase Exposition, published by the Pennsylvania Railroad System; also Locomotive testing plants, by W. F. M. Goss, Trans. Am. Soc. Mech. Eng., vol. 25, 1904, p. 827.

laboratory and in some detail the locomotive with its supporting machinery and brakes.

TEST CONDITIONS.

In order to obtain results covering all practical rates of evaporation up to the limit of the boiler capacity, tests were made with each style of briquets and with the natural coal under the following conditions of running: First, a low evaporation test at 80 revolutions per minute and 15 per cent cut-off; then a higher evaporation test at 120 revolutions per minute and 20 per cent cut-off; next a still higher evaporation test at 160 revolutions per minute and 25 per cent cut-off; and finally a test made at the maximum possible evaporation. With the briquetted coal this maximum-capacity test was at 200 revolutions per minute and 32 per cent cut-off. Four or at most five tests were thus sufficient to cover the range of boiler capacity.

RESULTS OF TESTS.

A summary of the observed and calculated results is presented in the subjoined table. The data tabulated represent the performance of the boiler and furnace more or less completely; as tests of coal concern primarily the boiler, the record of the engine performance is much abridged, only a few of the more important results being included.

Results of tests of Lloydell coal and briquets at Altoona, Pa., 1907.

1. GENERAL CONDITIONS.

Test No.	Laboratory symbol.	Date of test.	Duration of test (hours).	Position of reverse lever (notches from center forward).	Barometer pressure (pounds per square inch).	Boiler pressure (pounds per square inch).			Temperature of laboratory (°F.).
						Average.	Maximum.	Minimum.	
1	2	3	4	5	6	7	8	9	10
1	80-15-F	May 2	3.0	15.5	14.20	201.4	205	196	63
2	120-20-F	March 17	3.0	15	14.02	203.5	206	198	60
3	160-25-F	March 24	2.0	14	14.06	200.2	204	192	65
	160-25-F	May 1	2.0	14	14.17	201.1	205	192	64
5	160-30-F	May 3	2.0	13	14.16	193.9	205	179	61
6	80-15-F	May 6	3.0	15.5	14.11	204.2	206	202	65
7	120-20-F	May 8	3.0	15	14.12	204.8	206	200	65
8	160-25-F	March 23	2.0	14	13.96	202.5	205	196	60
9	120-20-F	May 9	3.0	15	14.05	205.0	206	203	70
10	160-25-F	March 26	3.0	14	14.07	202.8	205	199	65
11	160-25-F	March 18	2.5	14	14.09	203.8	205	199	58
12	160-30-F	March 19	.5	13	14.01	205.3	206	205	61
13	160-32-F	March 20	2.5	12.5	14.13	202.3	205	190	61
14	200-32-F	March 22	1.0	12.5	14.16	189.1	197	182	52
15	80-15-F	May 7	3.0	15.5	14.03	201.9	204	199	70
16	120-20-F	May 4	3.0	15	14.07	203.9	206	198	64
17	160-25-F	March 25	2.5	14	14.04	201.6	205	196	71
18	160-30-F	March 26	1.83	13	14.08	203.3	206	201	65
19	200-32-F	March 29	1.0	12.5	14.13	187.6	201	166	67
20	200-32-F	March 30	1.0	12.5	14.03	173.6	192	160	72

NOTE.—Throttle opening full in all tests.

Results of tests of Lloydell coal and briquets at Altoona, Pa., 1907—Continued.

2. SPEED, WATER, AND STEAM.

Test No.	Laboratory symbol.	Speed.			Water.				Steam.		
		Revolutions per minute.	Miles per hour.	Feet per minute (piston).	Temperature of feed water (°F.).	Water delivered to injectors (pounds).	Water lost from injectors (pounds).	Water delivered to boiler and presumably evaporated (pounds).	Steam delivered by the boiler per hour (pounds).	Quality of steam (per cent).	Dry steam delivered by boiler per hour (pounds).
1	2	11	12	13	14	15	16	17	18	19	20
1	80-15-F	80	18.89	173.1	54.8	43,940	670	43,270	14,423	98.47	14,266
2	120-20-F	120	28.34	259.6	46.7	58,736	399	58,337	19,446	98.60	19,253
3	160-25-F	160	37.78	346.2	47.9	51,510	0	51,510	25,755	98.28	25,441
4	160-25-F	160	37.78	346.2	50.4	51,920	0	51,920	25,960	98.45	25,674
5	160-30-F	160	37.78	346.2	49.9	61,316	0	61,316	30,658	98.40	30,308
6	80-15-F	80	18.89	173.1	53.8	45,201	30	45,171	15,057	98.46	14,891
7	120-20-F	120	28.34	259.6	51.7	60,852	78	60,774	20,258	98.42	20,031
8	160-25-F	160	37.78	346.2	45.9	52,323	0	52,323	26,162	98.42	25,869
9	120-20-F	120	38.34	259.6	53.0	61,098	150	60,948	20,316	98.47	20,095
10	160-25-F	160	37.78	346.2	47.4	78,000	0	78,000	26,000	98.45	25,714
11	160-25-F	160	37.78	346.2	49.9	66,039	42	65,997	26,399	98.48	26,117
12	160-30-F	160	37.78	346.2	46.0	16,173	0	16,173	32,346	98.52	32,006
13	160-32-F	160	37.78	346.2	43.8	87,261	0	87,261	34,904	98.46	34,524
14	200-32-F	200	47.23	432.8	45.0	36,716	0	36,716	36,716	98.31	36,275
15	80-15-F	80	18.89	173.1	54.1	46,088	1,300	44,788	14,929	98.49	14,768
16	120-20-F	120	28.34	259.6	51.8	60,536	0	60,536	20,179	98.49	19,963
17	160-25-F	160	37.78	346.2	47.7	63,953	0	63,953	25,581	98.33	25,279
18	160-30-F	160	37.78	346.2	46.1	58,753	0	58,753	32,105	98.34	31,729
19	200-32-F	200	47.23	432.8	50.4	36,875	0	36,875	36,875	98.54	36,492
20	200-32-F	200	47.23	432.8	49.4	34,473	0	34,473	34,473	98.58	34,121

3. FUEL.

Test No.	Laboratory symbol.	Kind of fuel.	Binder in briquet (per cent).	Fuel as fired (pounds).	Dry fuel fired (pounds).	Dry ash by analysis (pounds).	Combustible by analysis (pounds).	Dry fuel fired per hour (pounds).	Dry fuel per square foot of grate surface per hour (pounds).	Cinders collected in smoke box per hour (pounds).	Sparks discharged from stack per hour (pounds).
1	2	21	22	23	24	25	26	27	28	29	30
1	80-15-F	Coal	.....	5,370	5,303	395	4,908	1,768	31.86	28	39
2	120-20-F	do	.....	8,430	8,325	620	7,705	2,775	50.00	112	37
3	160-25-F	do	.....	8,201	8,099	604	7,496	4,050	72.97	205	140
4	160-25-F	do	.....	8,354	8,250	615	7,636	4,125	74.32	214	347
5	160-30-F	do	.....	11,334	11,193	834	10,359	5,597	100.85	373	385
6	80-15-F	Square briquets.	5	5,291	5,258	437	4,821	1,753	31.59	28	13
7	120-20-F	do	5	7,198	7,153	595	6,558	2,384	42.95	70	29
8	160-25-F	do	5	6,766	6,723	559	6,165	3,362	60.58	199	25
9	120-20-F	do	6	7,016	6,970	591	6,380	2,323	41.86	52	25
10	160-25-F	do	6	10,559	10,490	889	9,610	3,497	63.01	212	26
11	160-25-F	do	7	8,570	8,520	708	7,812	3,408	61.41	126	26
12	160-30-F	do	7	2,345	2,331	194	2,138	4,662	84.00	246	56
13	160-32-F	do	7	13,388	13,310	1,106	12,205	5,324	95.93	419	60
14	200-32-F	do	7	6,257	6,221	517	5,704	6,221	112.09	1,021	118
15	80-15-F	Round briquets.	8	5,290	5,256	473	4,782	1,752	31.57	23	22
16	120-20-F	do	8	7,396	7,348	662	6,686	2,449	44.13	58	95
17	160-25-F	do	8	7,955	7,903	712	7,191	3,161	56.95	61	18
18	160-30-F	do	8	7,653	7,603	685	6,918	4,155	74.86	132	49
19	200-32-F	do	8	7,030	6,984	629	6,355	6,982	125.84	292	149
20	200-32-F	do	8	6,673	6,630	597	6,032	6,630	119.46	776	126

Results of tests of Lloydell coal and briquets at Altoona, Pa., 1907—Continued.

4. FUEL ANALYSIS.

Test No.	Laboratory symbol.	Proximate analysis (per cent).					Calorific value (B. t. u. per pound).			
		Fixed carbon.	Volatile matter.	Moisture.	Ash.	Sulphur (separately determined).	Dry coal.	Combustible.	Cinders.	Sparks.
1	2	31	32	33	34	35	36	37	38	39
1	80-15-F								12,216	8,453
2	120-20-F								11,167	11,167
3	160-25-F	72.03	19.37	1.24	7.36	1.20	14,918	16,119	10,385	12,097
4	160-25-F								12,685	11,618
5	160-30-F								11,019	11,737
6	80-15-F								10,593	9,912
7	120-20-F	69.95	21.16	.63	8.26	1.35	14,745	16,082	10,080	8,524
8	160-25-F								11,618	9,462
9	120-20-F								10,023	9,741
10	160-25-F	69.43	21.50	.65	8.42	1.58	14,612	15,955	11,713	8,091
11	160-25-F								9,157	9,781
12	160-30-F								7,370	9,899
13	160-32-F	69.88	21.28	.58	8.26	1.28	14,777	16,116	11,523	11,048
14	200-32-F								8,434	8,838
15	80-15-F								11,003	9,178
16	120-20-F								10,208	8,574
17	160-25-F								10,022	9,782
18	160-30-F	68.19	22.21	.65	8.95	1.81	14,708	16,164	11,761	8,816
19	200-32-F								11,378	9,941
20	200-32-T								11,378	10,022

5. DRAFT AND SMOKE-BOX GASES.

Test No.	Laboratory symbol.	Draft (inches of water).				Temperature (°F.).		Analysis of smoke-box gases (per cent).			
		In front of diaphragm.	Back of diaphragm.	In fire box.	In ash pan.	In smoke box.	In fire box.	Carbon dioxide (CO_2).	Oxygen (O_2).	Carbon monoxide (CO).	Nitrogen (N_2).
1	2	40	41	42	43	44	45	46	47	48	49
1	80-15-F	2.1	1.9	1.1	0.1	567	1,429	9.6	9.1	0	81.3
2	120-20-F	3.4	3.0	.8	.2	578	1,694	8.7	9.1	0	82.1
3	160-25-F	4.7	4.3	1.4	.2	672	2,226	11.4	7.0	0.2	81.4
4	160-25-F	5.0	4.4	3.0	.2	663	2,044	11.1	6.5	.1	82.3
5	160-30-F	6.3	5.5	2.7	.3	735	1,967	11.7	5.9	.2	82.2
6	80-15-F	2.1	1.9	.5	.1	545	1,585	9.3	9.7	0	81.0
7	120-20-F	3.4	3.1	1.1	.1	609	1,842	9.3	9.5	0	81.2
8	160-25-F	5.2	4.5	1.2	.2	646	1,893	11.0	7.4	Tr.	81.6
9	120-20-F	3.2	2.8	1.1	.1	602	1,862	9.7	9.0	0	81.3
10	160-25-F	5.2	4.5	1 3	.2	678	1,977	11.2	6.8	.07	81.9
11	160-25-F	4.5	4.1	.9	.1	638	1,999	11.0	7.1	0	81.9
12	160-30-F	6.3	5.6	1.4	.1	671	2,199	11.0	7.6	Tr.	81.4
13	160-32-F	8.7	7.9	2.3	.3	746	2,248	12.8	3.5	1.2	82.5
14	200-32-F	10.2	8.6	3.4	.3	779	2,299	13.3	.9	5.1	80.7
15	80-15-F	2.1	1.9	.5	.1	547	1,640	10.0	9.0	0	81.0
16	120-20-F	3.1	2.7	.8	.1	591	1,856	9.9	9.1	0	81.0
17	160-25-F	4.7	4.4	1.3	.3	625	1,802	10.7	7.7	Tr.	81.6
18	160-30-F	6.2	5.5	1.5	.3	695	2,067	10.5	5.4	.2	81.4
19	200-32-F	9.0	7.9	2.2	.4	740	2,316	11.2	2.6	6.6	79.6
20	200-32-F	10.0	9.0	4.5	.3	753	2,298	10.4	.9	7.3	81.5

Results of tests of Lloydell coal and briquets at Altoona, Pa., 1907—Continued.

6. BOILER PERFORMANCE.

Test No.	Laboratory symbol.	Water evaporated (pounds).		Equivalent evaporation (pounds).					Boiler horsepower.	Efficiency of boiler based on dry fuel (per cent).	Heat lost due to cinders and sparks (per cent).
		Per square foot of heating surface per hour.	Per pound of dry fuel.	Per hour.	Per square foot of heating surface per hour.	Per pound of fuel as fired.	Per pound of dry fuel.	Per pound of combustible.			
1	2	50	51	52	53	54	55	56	57	58	59
1	80-15-F	6.15	8.07	17,392	7.50	9.72	9.84	10.63	504.1	63.7	2.55
2	120-20-F	8.30	6.94	23,637	10.19	8.41	8.52	9.20	685.1	55.16	4.02
3	160-25-F	10.97	6.28	31,193	13.45	7.61	7.70	8.32	904.2	49.85	6.32
4	160-25-F	11.07	6.22	31,415	13.55	7.52	7.62	8.23	910.6	49.33	10.97
5	160-30-F	13.07	5.42	37,073	15.98	6.54	6.62	7.16	1,074.6	42.86	10.30
6	80-15-F	6.42	8.49	18,174	7.84	10.30	10.37	11.31	526.8	67.92	1.24
7	120-20-F	8.64	8.40	24,492	10.56	10.21	10.27	11.20	709.9	67.27	2.71
8	160-25-F	11.15	7.69	31,780	13.70	9.39	9.45	10.31	921.2	61.90	5.15
9	120-20-F	8.66	8.65	24,544	10.58	10.49	10.57	11.54	711.4	69.86	2.26
10	160-25-F	11.09	7.35	31,551	13.60	8.96	9.02	9.85	914.7	59.62	5.27
11	160-25-F	11.26	7.66	32,116	13.85	9.37	9.42	10.28	930.9	61.57	3.55
12	160-30-F	13.80	6.87	39,326	16.96	8.39	8.44	9.20	1,140.0	55.16	4.37
13	160-32-F	14.89	6.48	42,485	18.32	7.93	7.98	8.70	1,231.5	52.11	6.97
14	200-32-F	15.64	5.83	44,535	19.20	7.12	7.16	7.76	1,290.9	46.80	10.50
15	80-15-F	6.37	8.43	18,015	7.77	10.22	10.28	11.30	522.2	67.50	1.76
16	120-20-F	8.61	8.15	24,405	10.52	9.90	9.97	10.95	707.4	65.47	3.90
17	160-25-F	10.90	8.00	31,005	13.37	9.74	9.81	10.78	898.7	64.42	2.70
18	160-30-F	13.68	7.64	38,976	16.81	9.32	9.38	10.31	1,129.8	61.59	3.25
19	200-32-F	15.73	5.23	44,590	19.23	6.34	6.34	7.02	1,292.5	41.91	4.67
20	200-32-F	14.71	5.15	41,662	17.96	6.24	6.28	6.91	1,207.6	41.24	10.34

7. LOCOMOTIVE PERFORMANCE.

Test No.	Laboratory symbol.	Drawbar pull (pounds).	Drawbar horsepower.	Steam lost from boiler per hour (pounds).	Fuel lost, due to steam loss, per hour (pounds).	Dry steam per drawbar horsepower per hour (pounds).	Dry coal per drawbar horsepower per hour (pounds).	Thermal efficiency of locomotive based on fuel (per cent).
1	2	60	61	62	63	64	65	66
1	80-15-F	7,464	376.0	290	35.9	37.18	4.70	3.63
2	120-20-F	7,607	574.8	93	13.4	33.34	4.83	3.53
3	160-25-F	8,975	904.2	330	52.6	27.78	4.48	3.81
4	160-25-F	8,854	892.0	212	34.1	28.55	4.62	3.69
5	160-30-F	10,459	1,053.7	193	35.6	28.58	5.31	3.21
6	80-15-F	7,310	368.3	756	89.1	38.40	4.76	3.63
7	120-20-F	8,066	609.5	243	28.9	32.47	3.91	4.41
8	160-25-F	8,955	902.2	200	26.0	28.45	3.73	4.63
9	120-20-F	7,951	600.8	215	24.9	33.09	3.87	4.50
10	160-25-F	8,961	902.8	298	40.6	28.16	3.87	4.50
11	160-25-F	9,012	908.0	319	41.6	28.42	3.75	4.59
12	160-30-F	10,842	1,092.3	273	39.7	29.06	4.27	4.03
13	160-32-F	12,068	1,215.9	226	34.9	28.21	4.38	3.93
14	200-32-F	10,101	1,272.1	188	32.3	28.37	4.89	3.52
15	80-15-F	7,217	363.6	329	39.0	39.72	4.82	3.59
16	120-20-F	7,792	588.8	330	40.5	33.35	4.16	4.16
17	160-25-F	8,590	865.4	199	24.9	28.98	3.65	4.74
18	160-30-F	11,095	1,117.8	254	33.3	28.16	3.72	4.65
19	200-32-F	9,986	1,257.6	186	35.6	28.87	5.55	3.12
20	200-32-F	9,248	1,164.7	173	33.6	29.15	5.69	3.04

Graphic logs for each test are shown in figs. 15 to 34. These are presented to explain some apparent irregularities in the plotted results. For example, in test 1 (fig. 15) the constant slope of the water and coal lines and the absence of abrupt fluctuations in the steam-

pressure line show at once the accuracy of the results. In test 4 (fig. 18) the change of slope in the coal line at the beginning and the end of the test make the reliability of observations during these periods seem more or less doubtful.

ANALYSES OF COAL AND BRIQUETS.

The proximate analyses and calorific values of the fuel are given as columns 31 to 36 in the table. These analyses were made on carefully selected samples from carload lots of the coal, and on briquets of several qualities. They show that the coal contains more fixed carbon and moisture and less volatile matter and ash

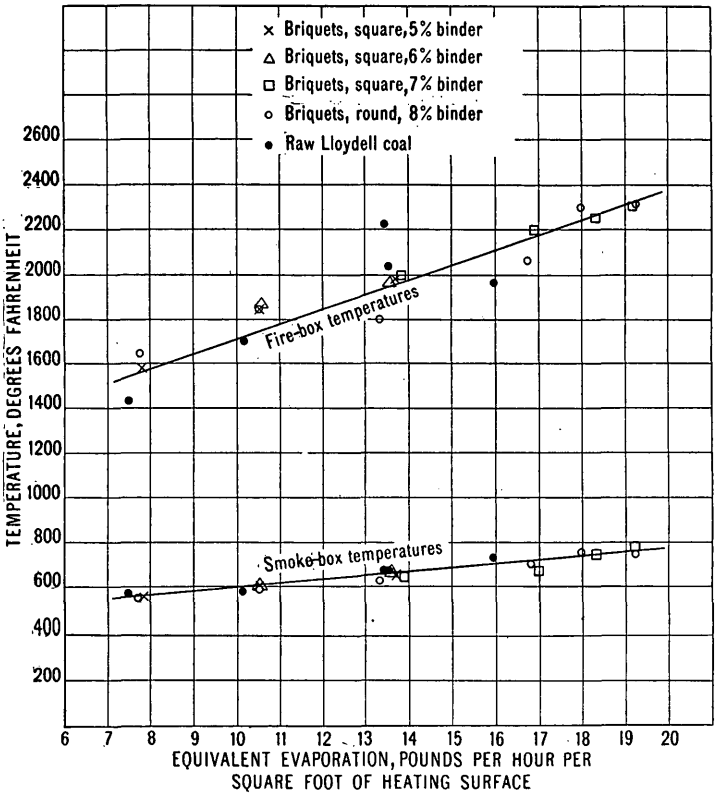


FIG. 2.—Values of smoke-box and fire-box temperatures plotted against rate of combustion.

than the briquets from the same coal. The calorific value per pound of dry fuel seems to be greater for the natural coal than for the briquets, notwithstanding the fact that the binder used in the latter has a higher heating value than the coal itself.

TEMPERATURES.

The smoke-box and fire-box temperatures are given as columns 44 and 45 in the table. These values plotted against rate of combustion are shown in fig. 2. The results indicate that for both coal and briquets, with various percentages of binding material, the tem-

peratures in the fire-box and smokestack increase with increased rate of evaporation.

There is, however, as would be expected, no apparent difference in either the fire-box or the smoke-box temperature due to the use of briquets.

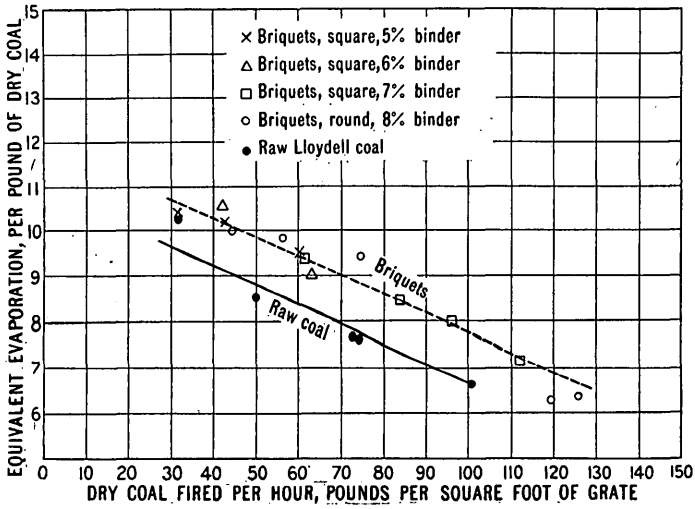


FIG. 3.—Equivalent evaporation per pound of dry coal plotted against rate of combustion.

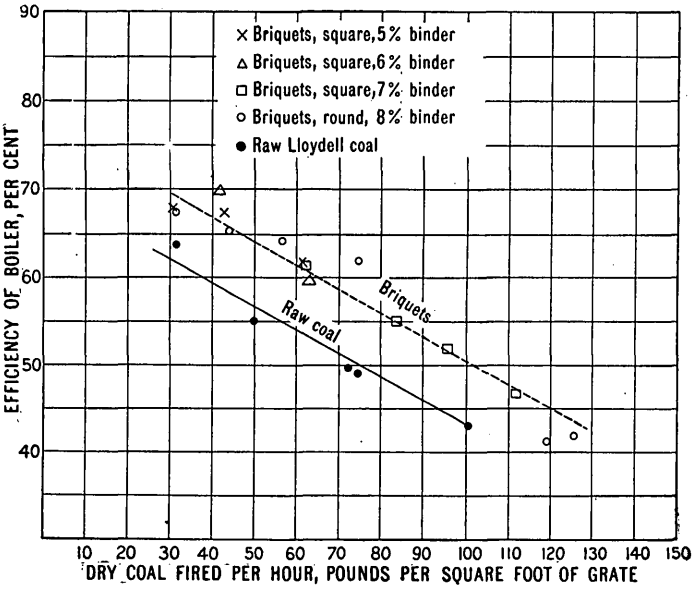


FIG. 4.—Per cent evaporation efficiency of dry coal plotted against rate of combustion.

EVAPORATIVE EFFICIENCY.

Values representing the evaporative efficiency are presented as columns 50 to 59 in the table. In fig. 3 is shown the equivalent evaporation per pound of dry coal plotted against the rate of com-

bustion. The figure represents a comparison under the same test conditions between the natural Lloydell coal and the same coal briquetted. It shows that a well-defined improvement in the evaporation per pound of fuel is obtained by briquetting. Fig. 4 shows the same relation as fig. 3, expressed in per cent.

In fig. 5, where the comparison is made on the basis of evaporation per square foot of heating surface, the better results for briquetting are further emphasized. It will be noted that the maximum evaporation possible with the natural Lloydell coal is 16 pounds per square foot of heating surface per hour, but with the same coal briquetted the evaporation is more than 19 pounds.

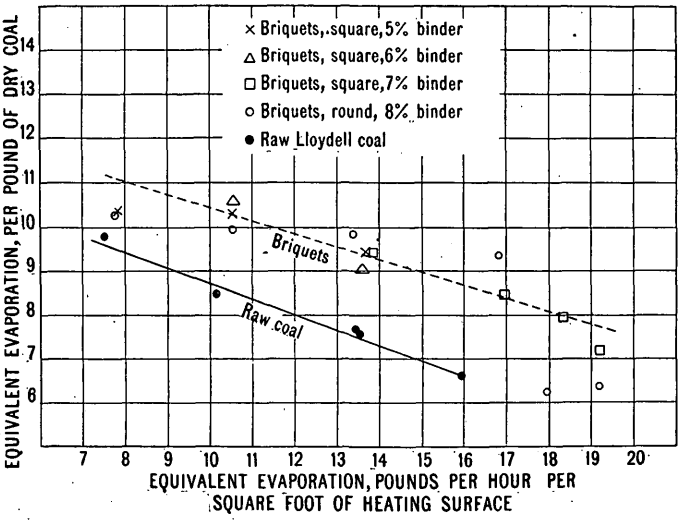


FIG. 5.—Evaporation per square foot of heating surface.

The following table, derived from fig. 5, gives a comparison of the different fuels at equal rates of evaporation:

Comparison of coal and briquets at equal rates of evaporation.

Evaporation per square foot of heating surface per hour.	Equivalent evaporation per pound of fuel.	
	Natural Lloydell coal.	Briquetted Lloydell coal.
Pounds.	*Pounds.*	*Pounds.*
8	9.5	10.7
10	8.8	10.2
12	8.0	9.7
14	7.3	9.2
16	6.6	8.7

The ultimate measure of locomotive efficiency is expressed, of course, in terms of coal per dynamometer horsepower hour. This value plotted against dynamometer horsepower is given in fig. 6, which

shows that whatever may be the power developed the briquets give the greater efficiency, but that when the power is extremely low or extremely high the difference is small. At the point of maximum efficiency the difference amounts to nearly 35 per cent. It should be remembered, however, in dealing with dynamometer horsepower that several variable factors, such as machine friction and engine efficiency, are introduced into the equation; and that the only true comparison to disclose the relative values of different fuels is that which is based on boiler performance alone.

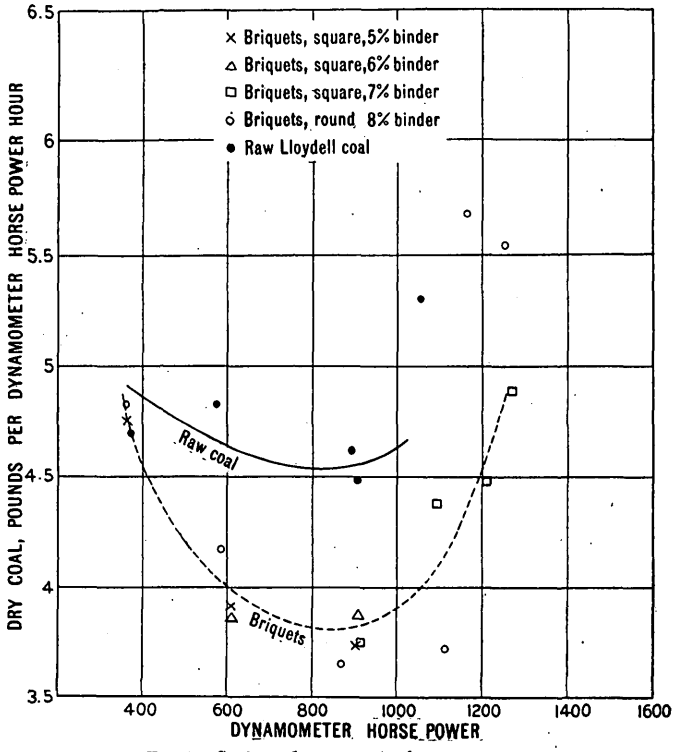


FIG. 6.—Coal per dynamometer horsepower.

CINDERS.

In fig. 7 the weight of cinders collected in the smoke box is shown for different rates of combustion. There appears to be little or no difference in the results obtained from the natural coal and the briquetted coal. The sparks from the stack, when the locomotive was fired with briquets, were in the form of flakes of a size considerably larger than those discharged when coal was fired.

The calorific value of the cinders collected in the smoke box and the sparks discharged from the stack is, in general, higher for the natural coal than for the briquetted coal. That is, the heat loss due

to the sparks and cinders is greater for the natural coal, though the quantities in pounds of cinders may be the same.

The amount of heat lost in the form of cinders and sparks, expressed as a percentage of the total heat supplied, is shown graphically by fig. 8, in which the solid line represents the average cinder and spark loss for raw Lloydell coal at varying rates of combustion, and the broken line the same loss for the briquetted Lloydell coal. The points representing the former lie extremely close to the average line, but those representing the latter do not fall in such close alignment. It is a fact worthy of note, however, that those points which represent tests with briquets having the larger percentage of binder generally fall below the average line, whereas those for the smaller

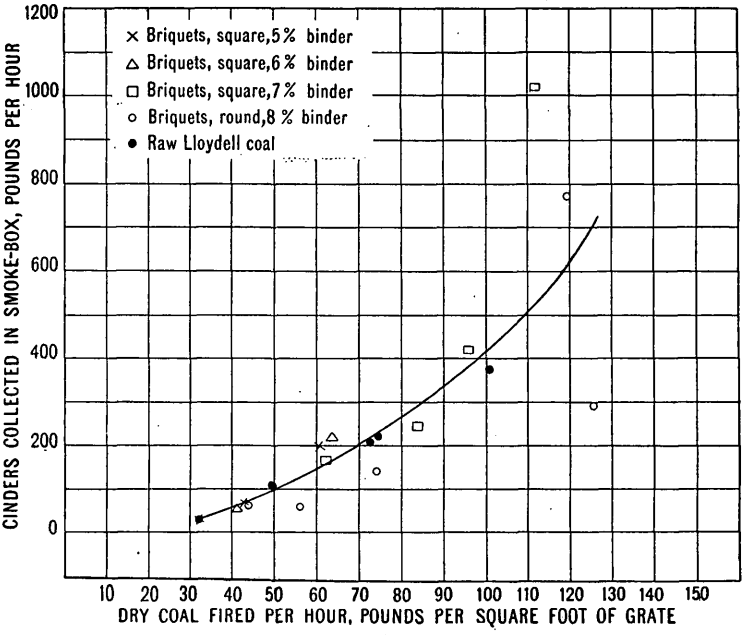


FIG. 7.—Weight of cinders collected in the smoke box.

percentage of binder generally fall above the average line. The curve therefore shows that (*a*) the loss due to cinders and sparks is greater when raw coal is used than when briquets are used, and the difference increases as the rate of evaporation increases; (*b*) the loss due to cinders and sparks decreases slightly as the percentage of binder used in the briquets is increased.

SMOKE.

The density of the smoke from the locomotive was compared with the Ringelmann charts. These charts[a] are usually designated as fol-

[a] A more complete description of Professor Ringelmann's method of smoke comparison may be found in Engineering News, November 11, 1897; or in "The prevention of smoke," by C. Popplewell. See also Bull. Eng. Exper. Sta., Univ. Illinois.

lows: No. 0, no smoke; No. 1, light gray; No. 2, darker gray; No. 3, very dark gray; No. 4, black; No. 5, very black. The gradations in shade corresponding to the above scale of densities are given in Pl. IV.

Smoke records were made at ten-minute intervals, 20 observations, approximately three seconds apart, being made the basis for

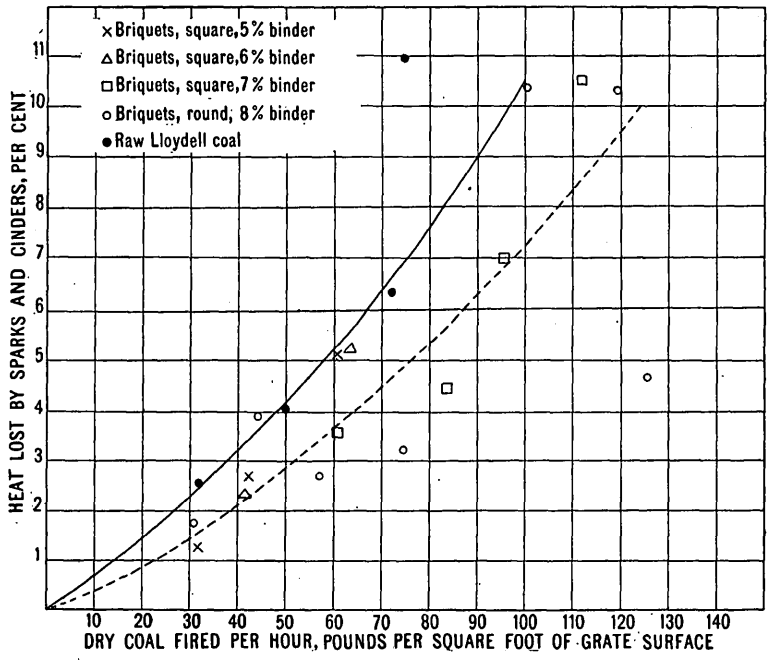


FIG. 8.—Amount of heat lost in the form of cinders and sparks.

each record. It was assumed that observations made for one minute at the beginning of each ten-minute interval would represent the average conditions for the whole interval. To reduce the number of observations to ten for each ten minutes every other reading was taken and the results have been plotted on figs. 9 to 13.

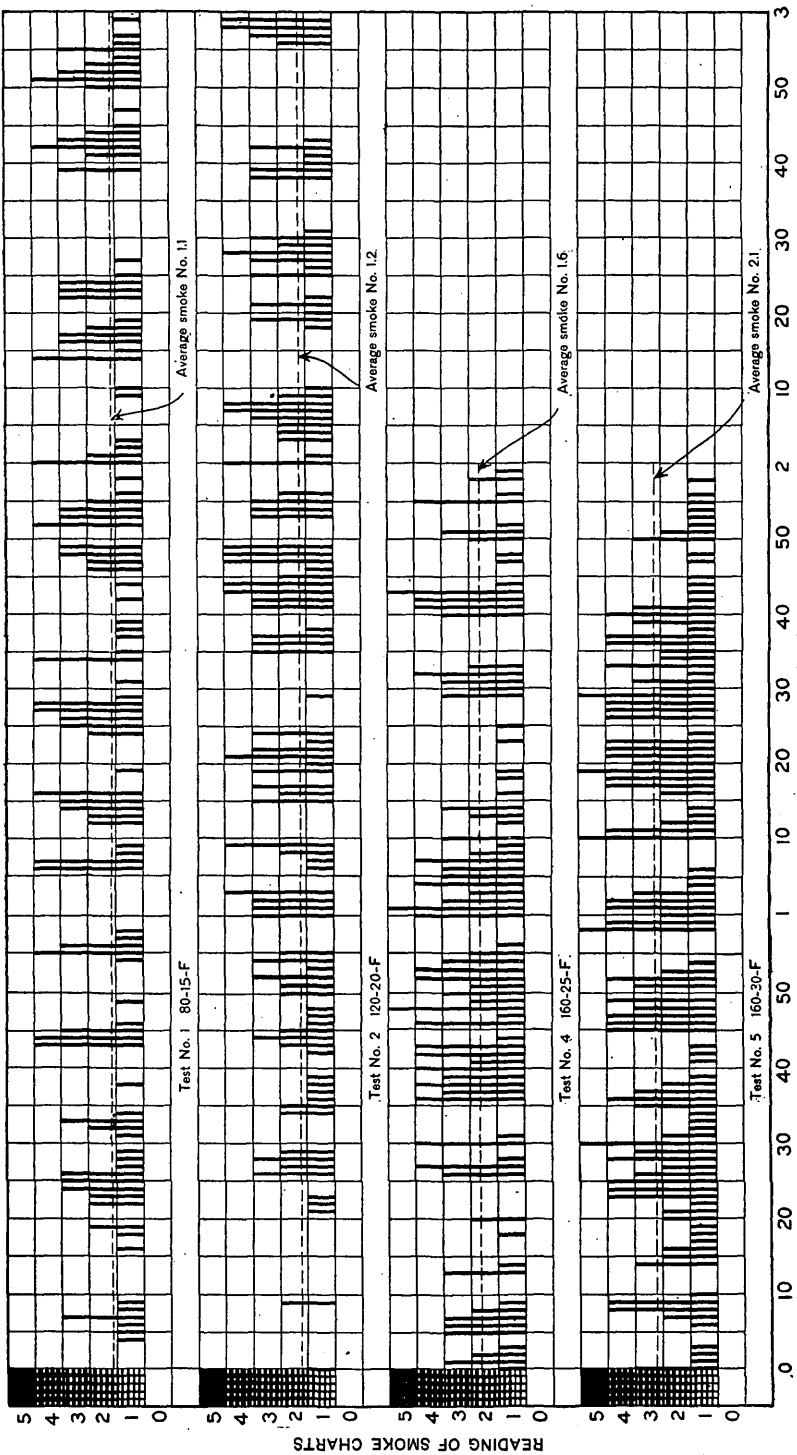
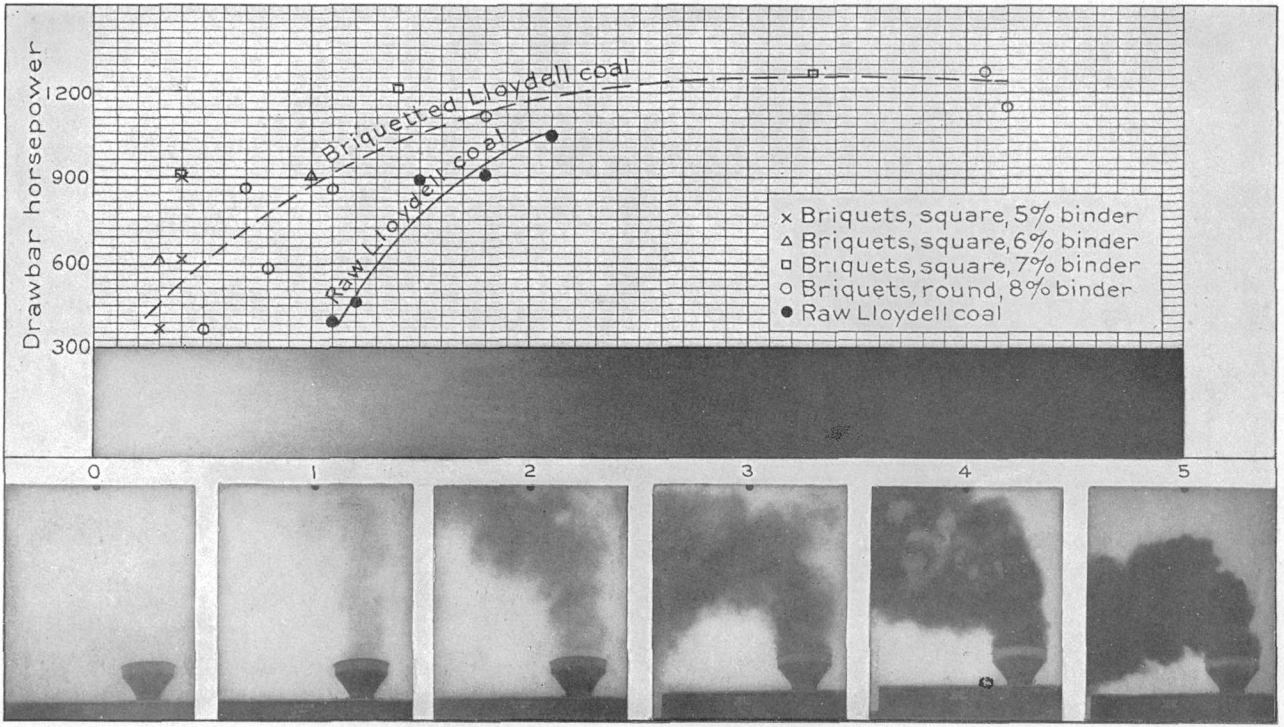


FIG. 9.—Smoke density.



SMOKE CHART AND DIAGRAM OF DRAWBAR PULL.

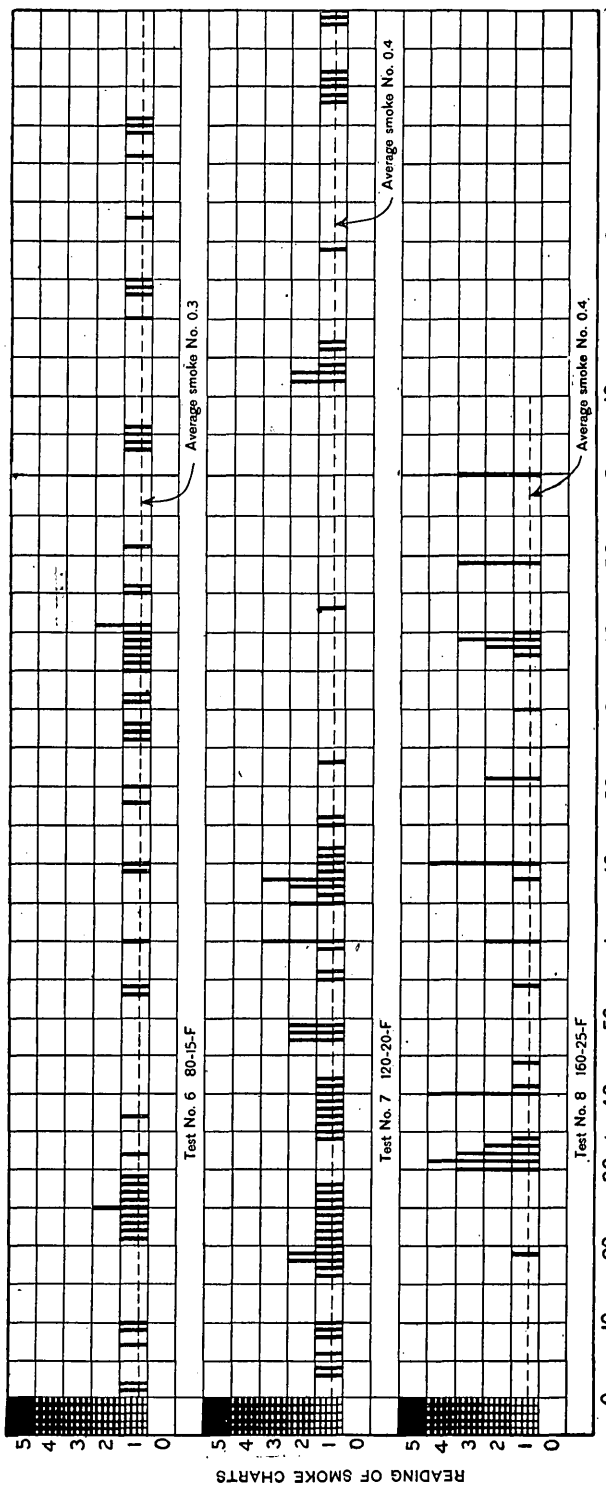


FIG. 10.—Smoke density.

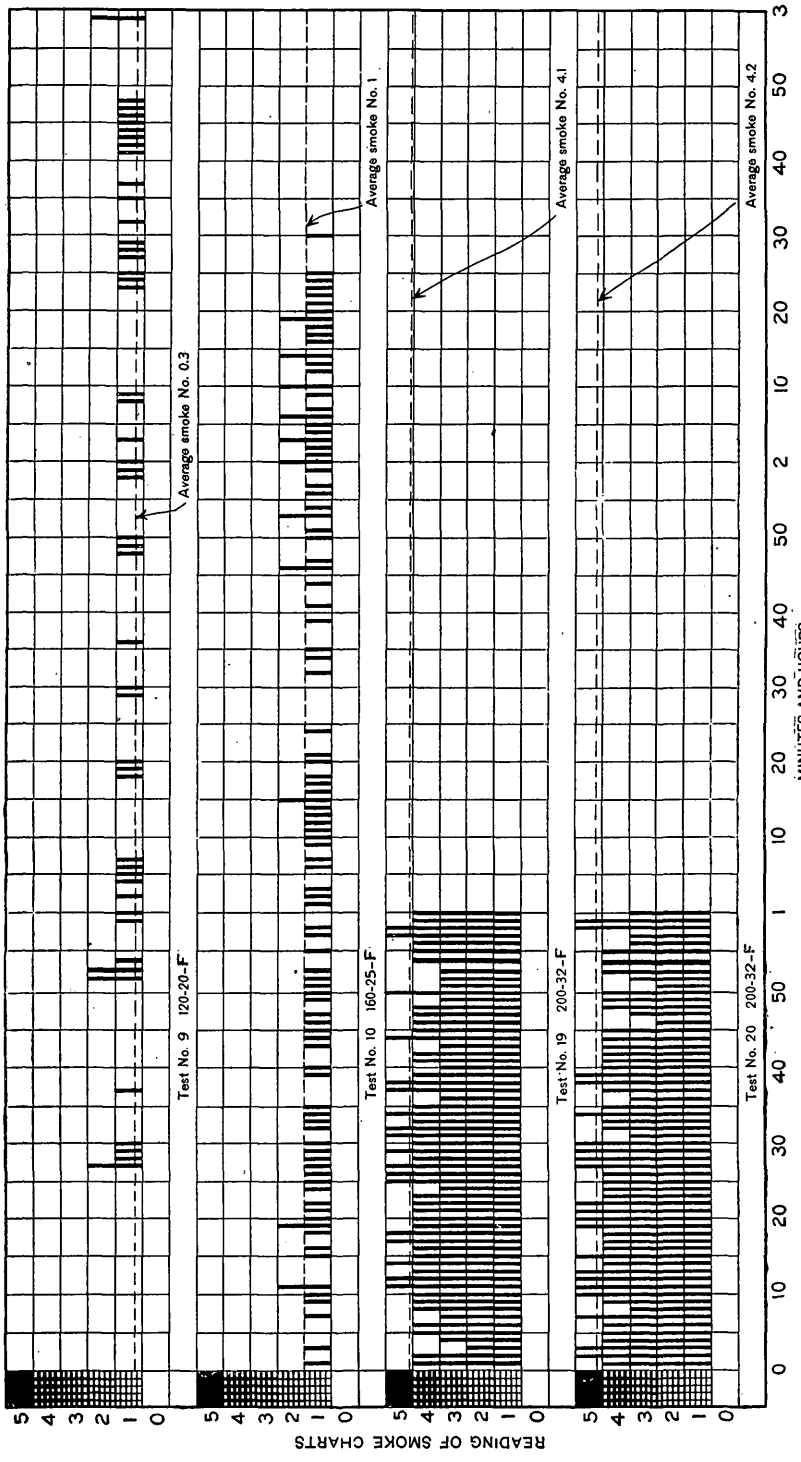


FIG. 11.—Smoke density.

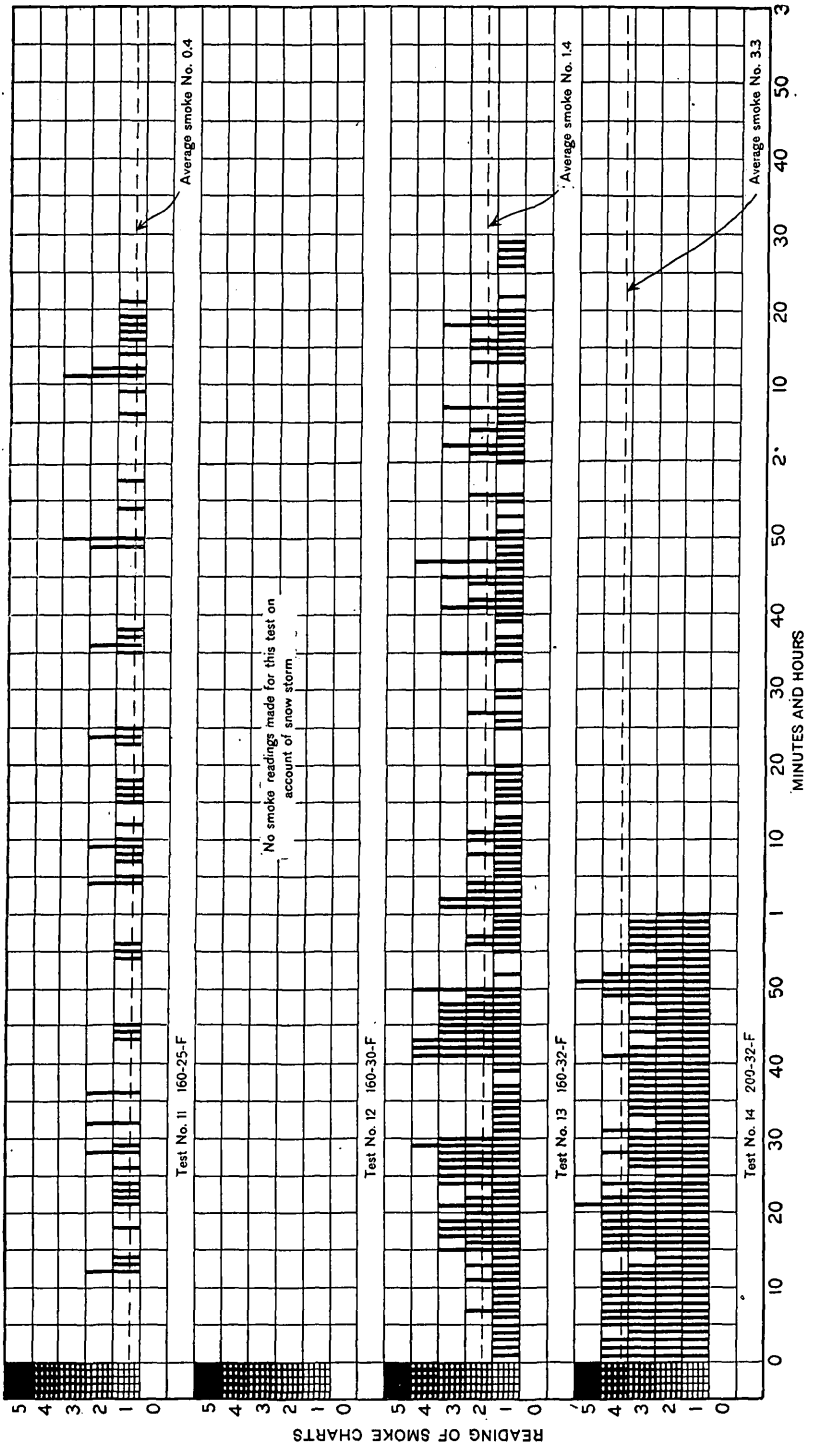


FIG. 12.—Smoke density.

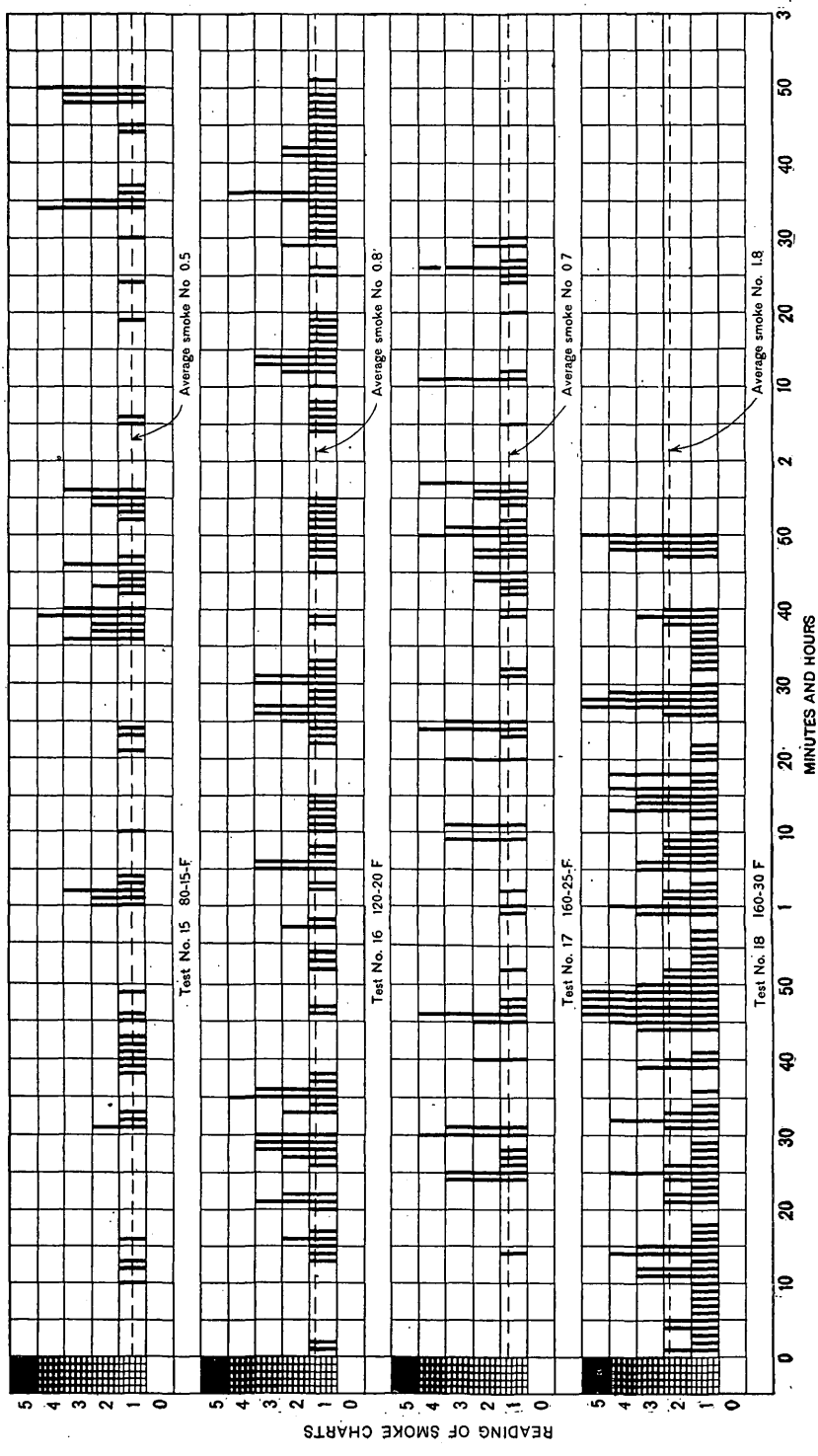


FIG. 13.—Smoke density.

In order to present these smoke indications in better form for comparison, average values have been calculated, and the results are given in the subjoined table.

Results of smoke observations.

Test No.	Laboratory symbol.	Percentage of capacity of boiler. [a]	Density of smoke. [b]	Kind of fuel.
1	80-15-F	43.5	1.1	Coal.
6	80-15-F	45.4	.3	Square briquets, 5 per cent binder.
15	80-15-F	45.0	.5	Round briquets, 8 per cent binder.
2	120-20-F	59.1	1.2	Coal.
7	120-20-F	61.2	.4	Square briquets, 5 per cent binder.
9	120-20-F	61.4	.3	Square briquets, 6 per cent binder.
16	120-20-F	61.0	.8	Round briquets, 8 per cent binder.
3	160-25-F	78.0	1.8	Coal.
4	160-25-F	78.5	1.6	Do.
8	160-25-F	79.5	.4	Square briquets, 5 per cent binder.
10	160-25-F	78.9	1.0	Square briquets, 6 per cent binder.
11	160-25-F	80.3	.4	Square briquets, 7 per cent binder.
17	160-25-F	77.5	.7	Round briquets, 8 per cent binder.
5	160-36-F	92.7	2.1	Coal.
18	160-36-F	97.3	1.8	Round briquets, 8 per cent binder.
13	160-32-F	106.2	1.4	Square briquets, 7 per cent binder.
14	200-32-F	111.3	3.3	Do.
19	200-32-F	111.5	4.1	Round briquets, 8 per cent binder.
20	200-32-F	104.0	4.2	Do.

[a] Based on 40,000 pounds equivalent evaporation per hour.
[b] Average number Ringelmann scale.

A careful examination of this table shows that for a given boiler capacity more smoke is made when raw coal is fired than when briquets are fired. Thus, on comparing tests 3 and 4 with tests 8, 10, 11, and 17, we find the average density of smoke for raw coal to be 1.7, whereas for briquets it is but 0.62.

Test 20 with briquets shows very black smoke, but in this test the boiler was forced to an evaporation far beyond that found possible with natural coal. The smoke-box gases show over 7 per cent of carbon monoxide and less than 1 per cent of oxygen, indicating very incomplete combustion.

In fig. 14 the smoke density is plotted against boiler capacity, and average lines are drawn through points representing tests with raw coal and briquets with 8, 7, and 5 per cent of binder. As there are but two points representing tests with briquets having 7 per cent binder, and as their position seems to be contradicted by the position of the other points, no line has been drawn through them. The curves show that the smoke density is nearly constant for all capacities under 90 per cent of full load, but that for capacities beyond this point the density increases rapidly. It appears that for all tests with briquets the density of the smoke is less than for corresponding tests with raw coal, but more smoke is produced with briquets having 8 per cent binder than with those having 5, 6, or 7 per cent. Whether this fact is to be explained by the varying amounts of binder used or by the difference in size and shape is a question. However, as the binding material employed consists largely of volatile matter, it is reasonable

to suppose that the varying amounts used in the several briquets cause the varying density of the smoke shown in fig. 14.

SMOKE DENSITY IN INTERMITTENT RUNNING.

At the end of test 13, with the locomotive standing, the blower was put on, and after two minutes the smoke cleared. Immediately after the close of test 14, with a very heavy fire, the engine was again started at a slow speed and with partly open throttle. With these conditions of running, the smoke cleared entirely after eighteen minutes. These conditions are not dissimilar to the intermittent operation to which a locomotive is subjected as it enters a terminal,

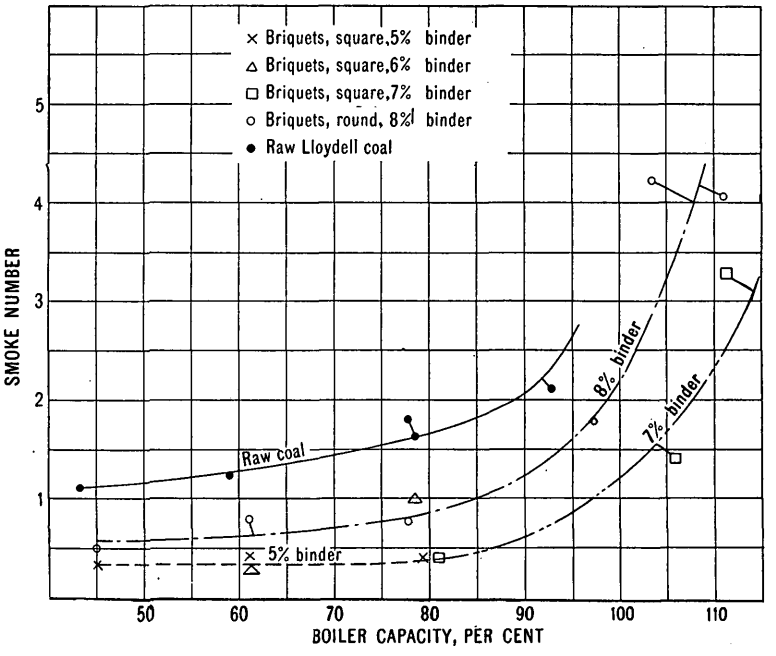


FIG. 14.—Smoke density plotted against boiler capacity.

and the results show the degree of smoke control which the use of briquets makes possible under such adverse conditions.

BEHAVIOR OF COAL AND BRIQUETS DURING COMBUSTION.

Briquets of both small and large size were fired with the ordinary shovel and were handled in much the same manner as coal. In all tests they were fired alone without mixing with coal. It was not necessary to break the briquets in order to handle them readily with the ordinary scoop shovel, and the unbroken briquets burned freely and completely. They disintegrated slowly from the heat of the flame and became more or less porous as they swelled and opened under the action of the heat.

In the process of starting a fire with briquets no difficulty was experienced, the ordinary blower arrangements at the engine house being sufficient. The natural coal was finely divided when fired and did not form so open a mass in the fire box as the briquets. Much of the finer portion was drawn, unburned, through the tubes by the force of the draft.

EFFECT OF HANDLING AND WEATHERING ON BRIQUETS.

To observe the effect on briquets of exposure to the weather, a number of the round and square briquets were placed on the roof of the testing plant. After four months of exposure for the round and three months for the square briquets, no change whatever from their original condition was noticed. They appeared to be entirely impervious to moisture and were still firm and hard.

The briquets were little affected by handling. They were loaded at St. Louis in open gondola cars and shipped to Altoona, where they were unloaded by hand and stacked. They were handled a third time in taking them to the firing platform of the test locomotive. After these three handlings they were still in good condition, very few were broken, and the amount of dust and small particles was practically negligible.

CONCLUSIONS.

The results of the tests justify the following conclusions:

(*a*) The evaporation per pound of fuel is greater for the briquetted Lloydell coal than for the same coal in its natural state. This advantage is maintained at all rates of evaporation.

(*b*) The capacity of the boiler is considerably increased by the use of briquetted coal.

(*c*) Briquetting appears to have little effect in reducing the quantity of cinders and sparks; the calorific value of these, however, is not so high in the briquetted as in the natural fuel.

(*d*) The density of the smoke with the briquetted coal is much less than with the natural coal.

(*e*) The percentage of binder in the briquet has little influence on smoke density.

(*f*) The percentage of binder for the range tested appears to have little or no influence on the evaporative efficiency.

(*g*) The expense of briquetting under the conditions of the experiments adds about $1 per ton to the price of the fuel, an amount which does not seem to be warranted by the resulting increase in evaporative efficiency.

(*h*) With careful firing, briquets can be used at terminals with a considerable decrease in smoke.

(*i*) The briquets appear to withstand well exposure to the weather, and suffer little deterioration from handling.

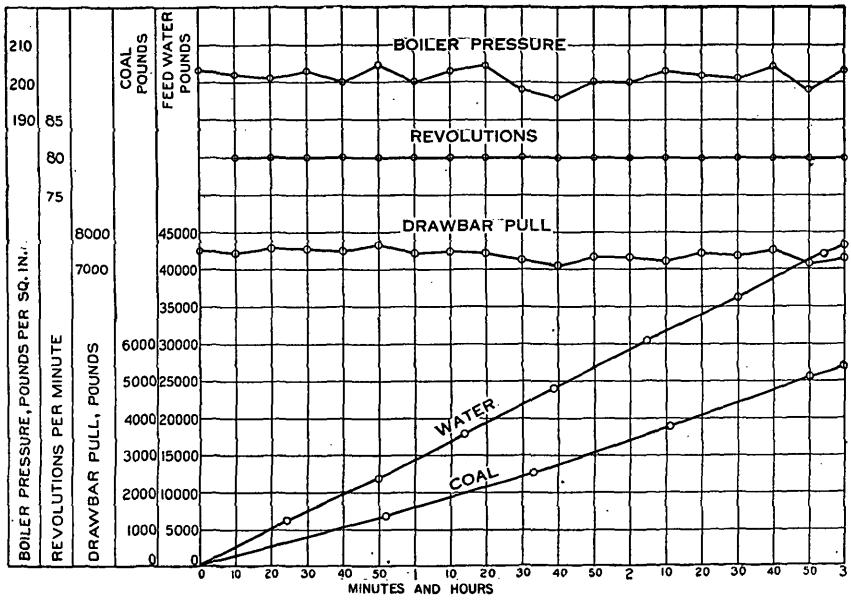


FIG. 15.—Graphic log, test 1.

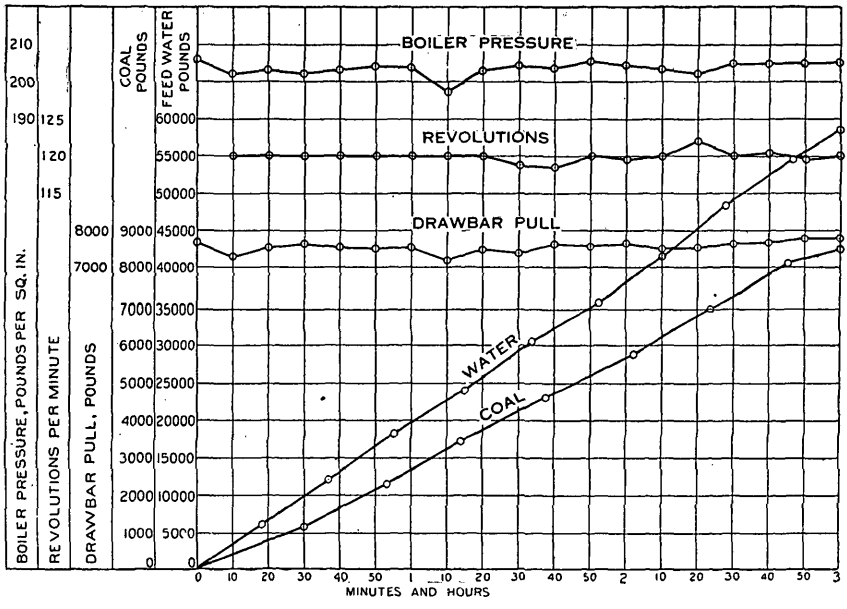


FIG. 16.—Graphic log, test 2.

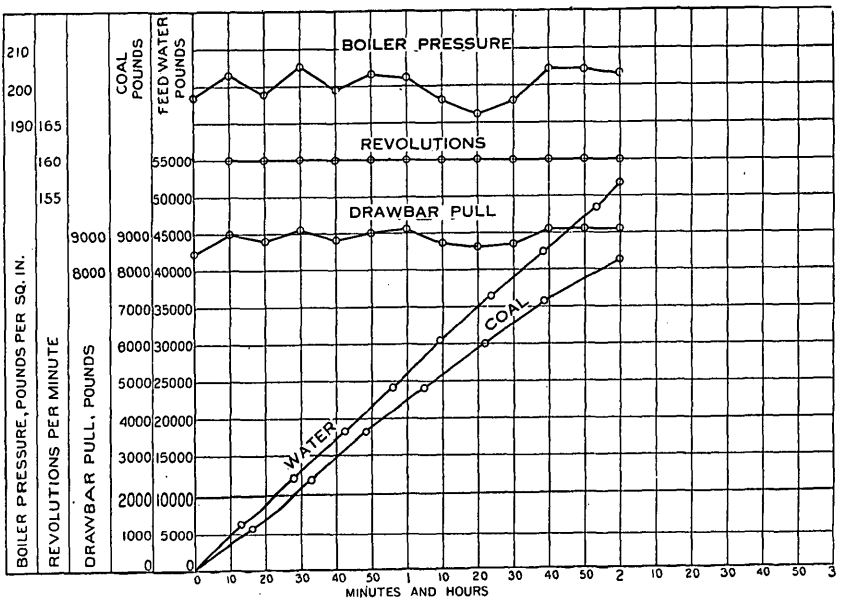


FIG. 17.—Graphic log, test 3.

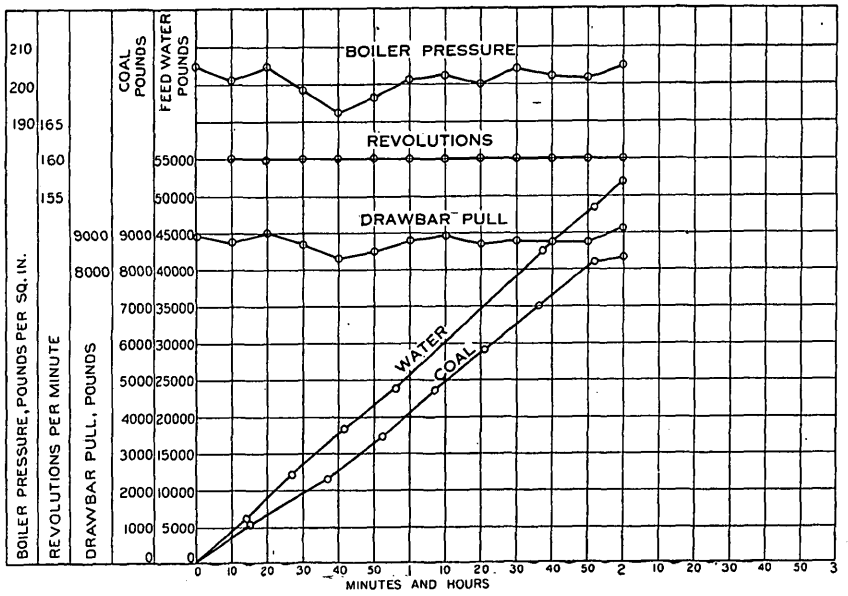


FIG. 18.—Graphic log, test 4.

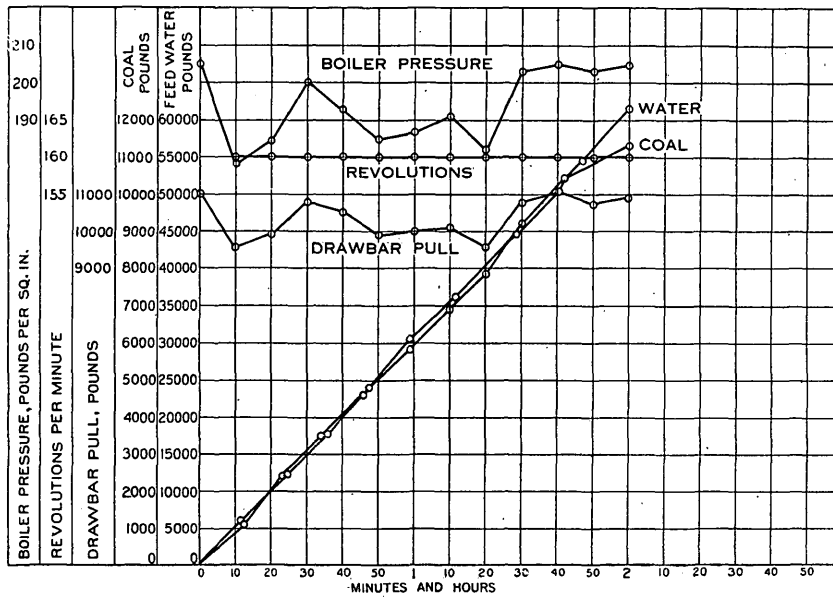


FIG. 19.—Graphic log, test 5.

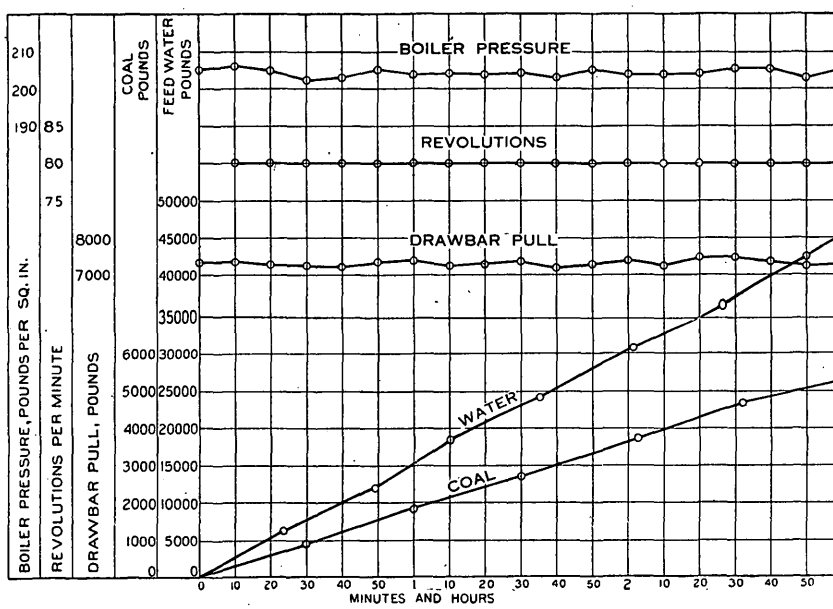


FIG. 20.—Graphic log, test 6.

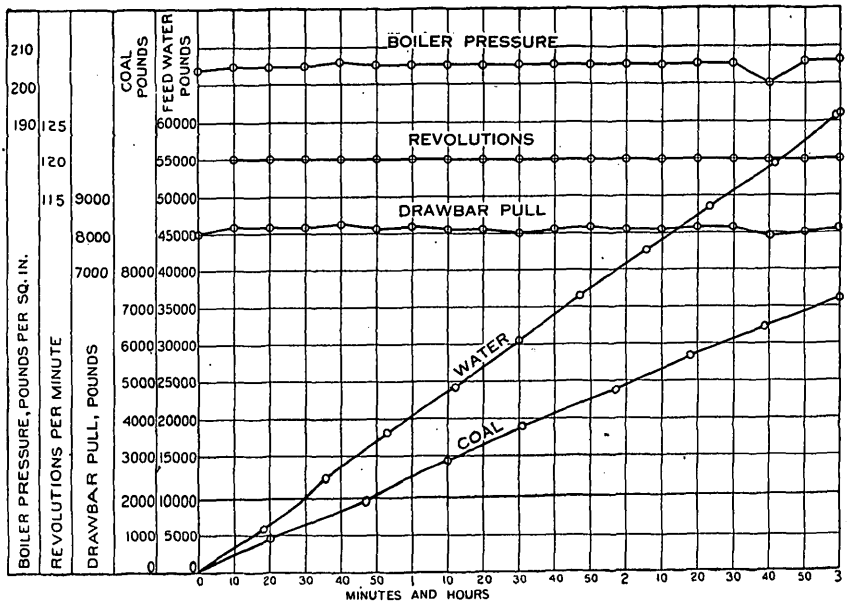


FIG. 21.—Graphic log, test 7.

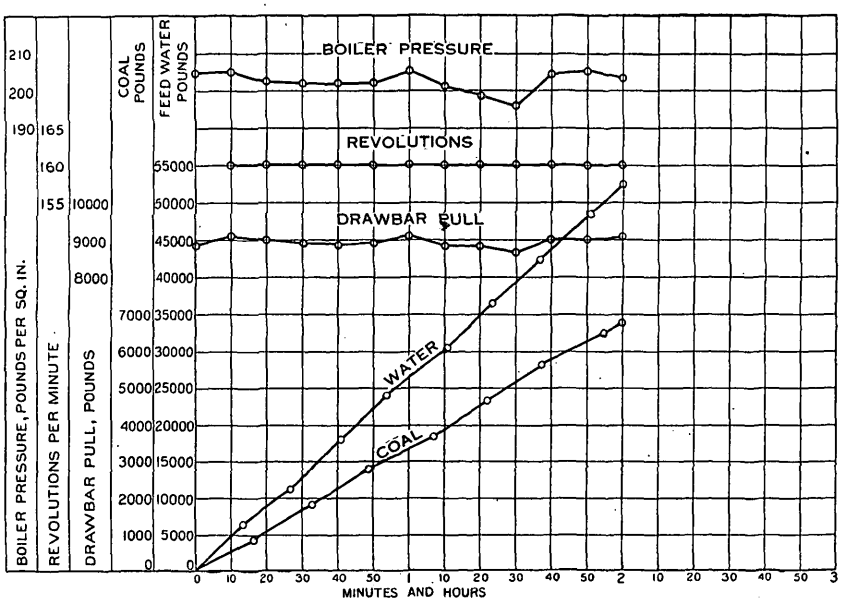


FIG. 22.—Graphic log, test 8.

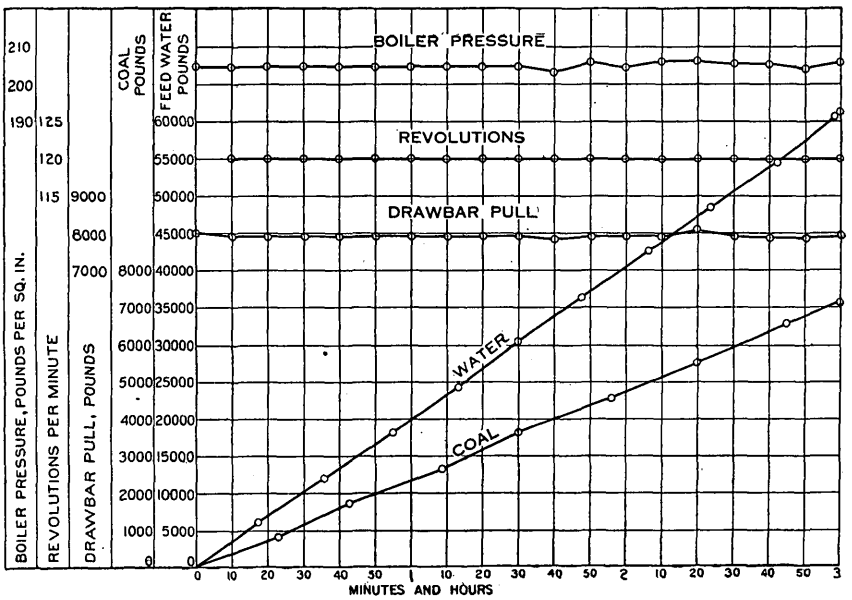


FIG. 23.—Graphic log, test 9.

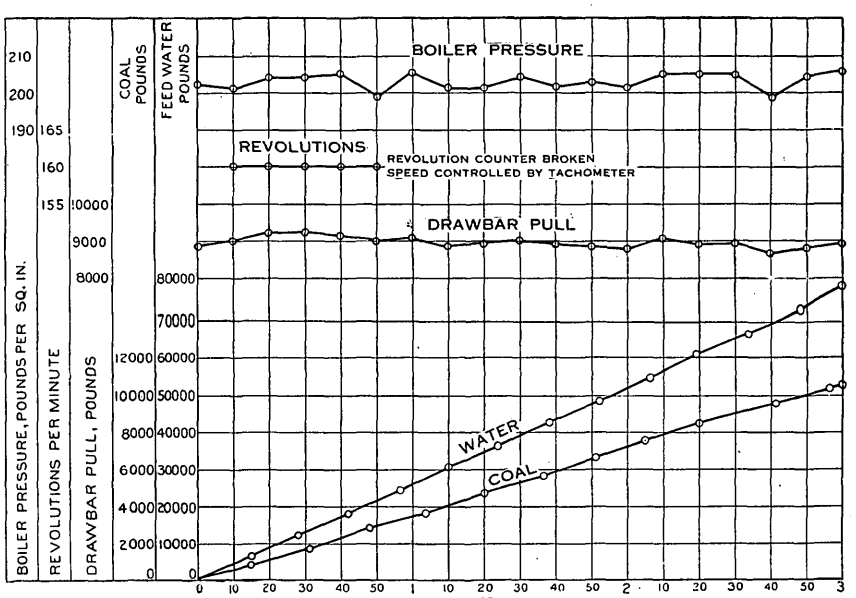


FIG. 24.—Graphic log, test 10.

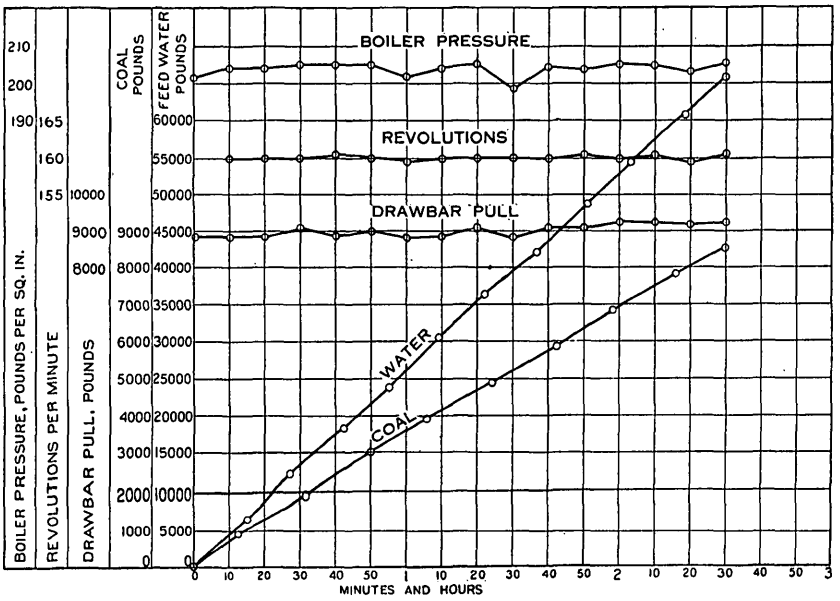


FIG. 25.—Graphic log, test 11.

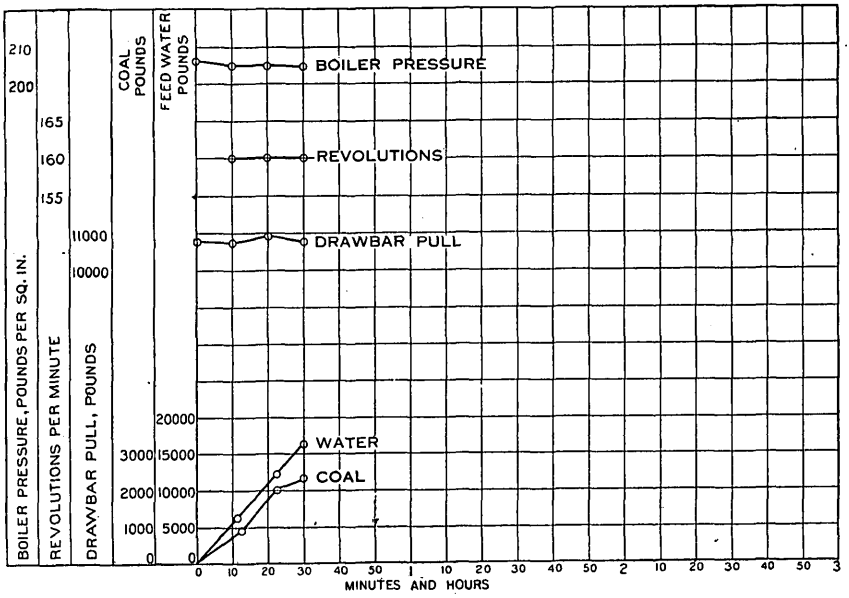


FIG. 26.—Graphic log, test 12.

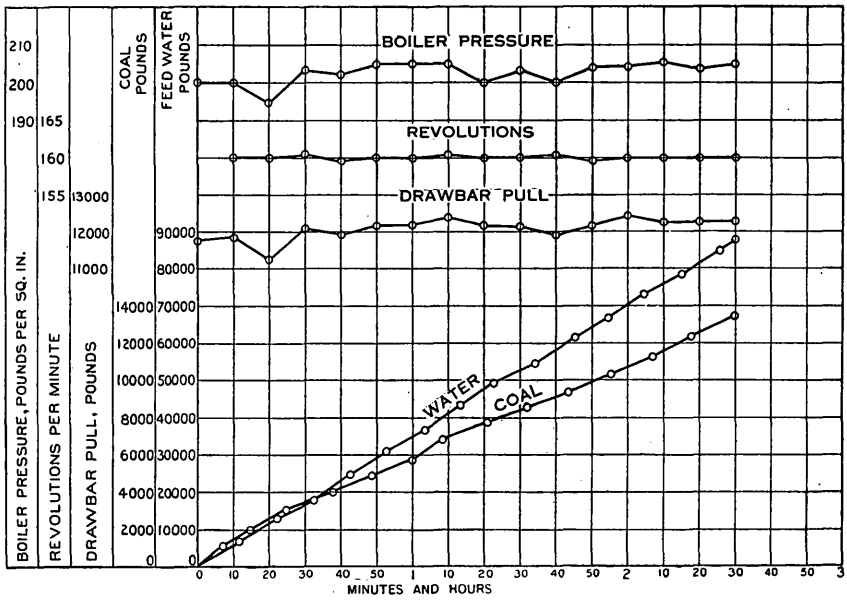


FIG. 27.—Graphic log, test 13.

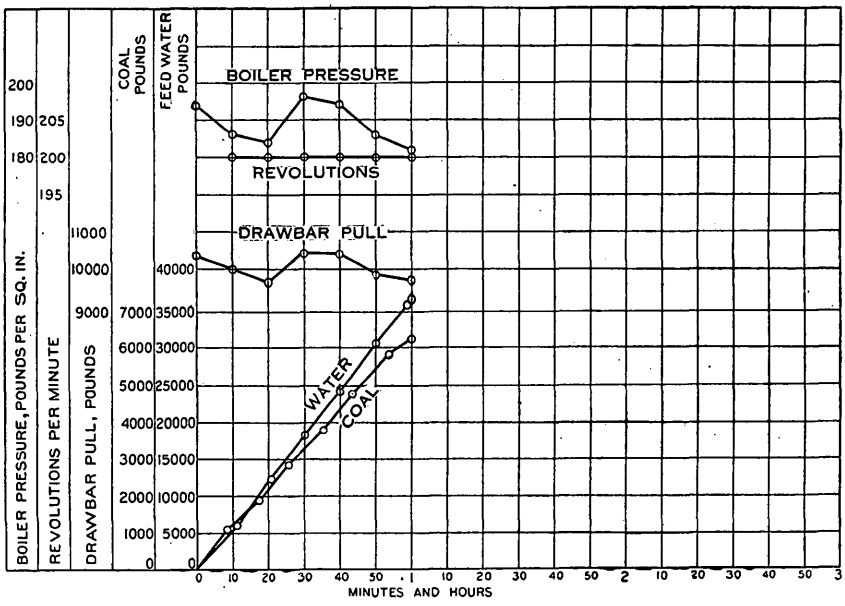


FIG. 28.—Graphic log, test 14.

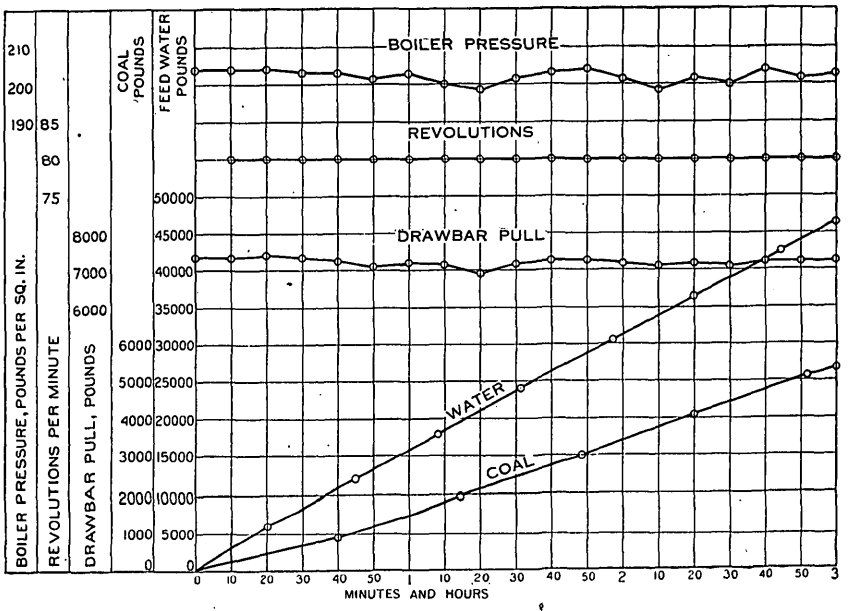


FIG. 29.—Graphic log, test 15.

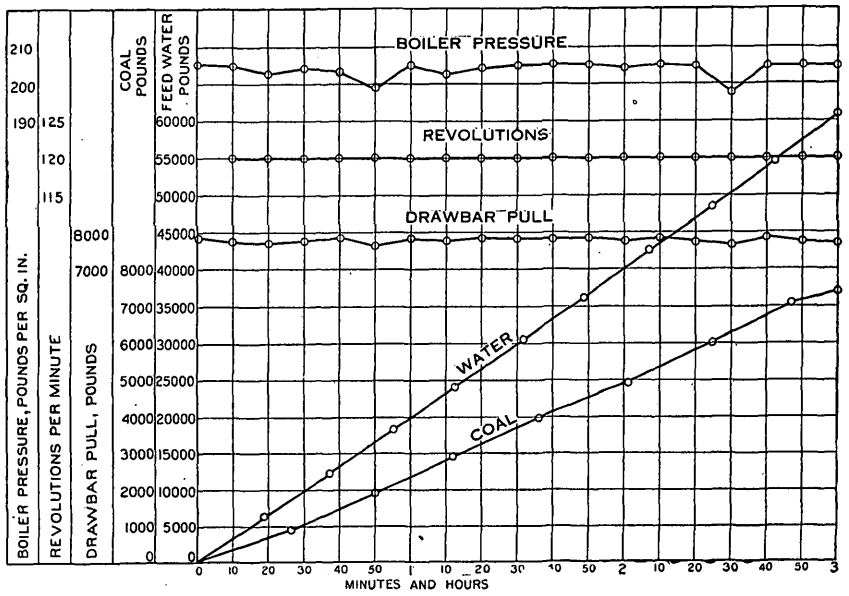


FIG. 30.—Graphic log, test 16.

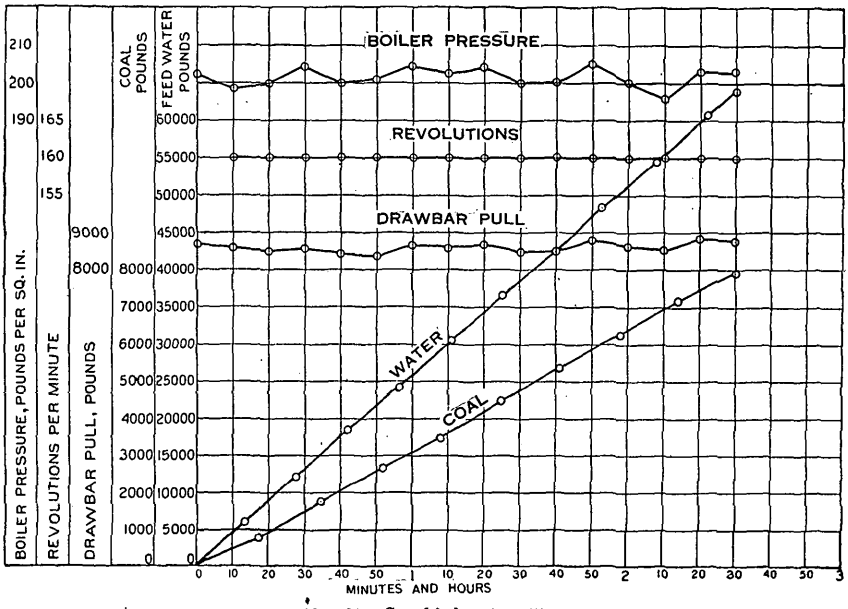


FIG. 31.—Graphic log, test 17.

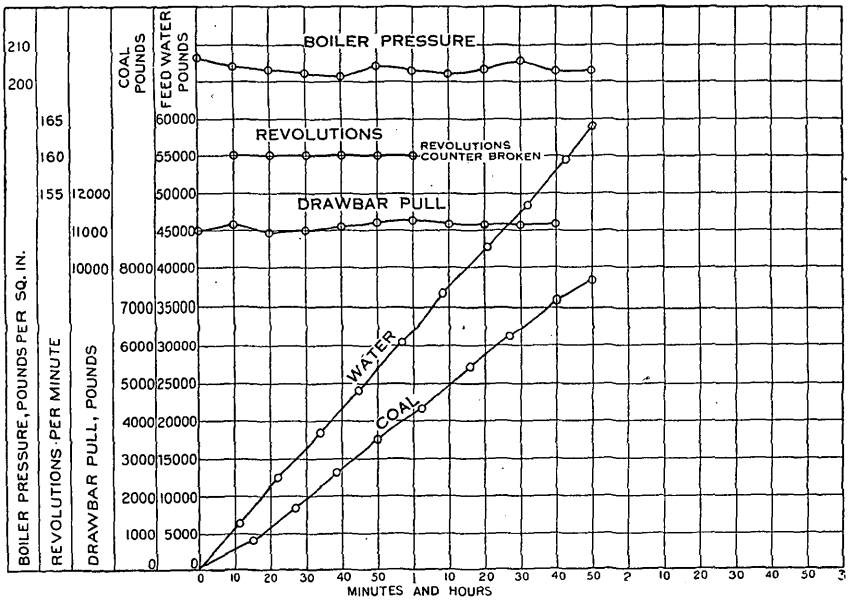


FIG. 32.—Graphic log, test 18.

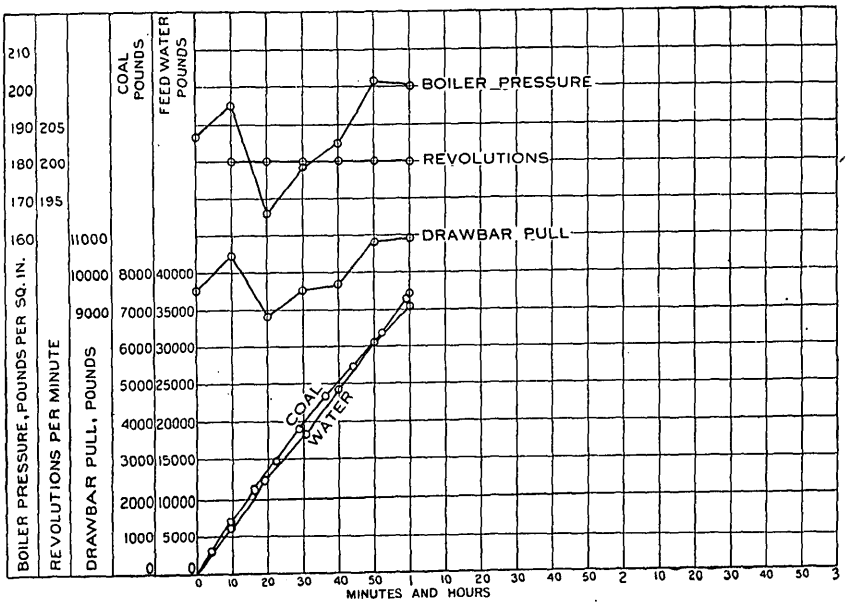


FIG. 33.—Graphic log, test 19.

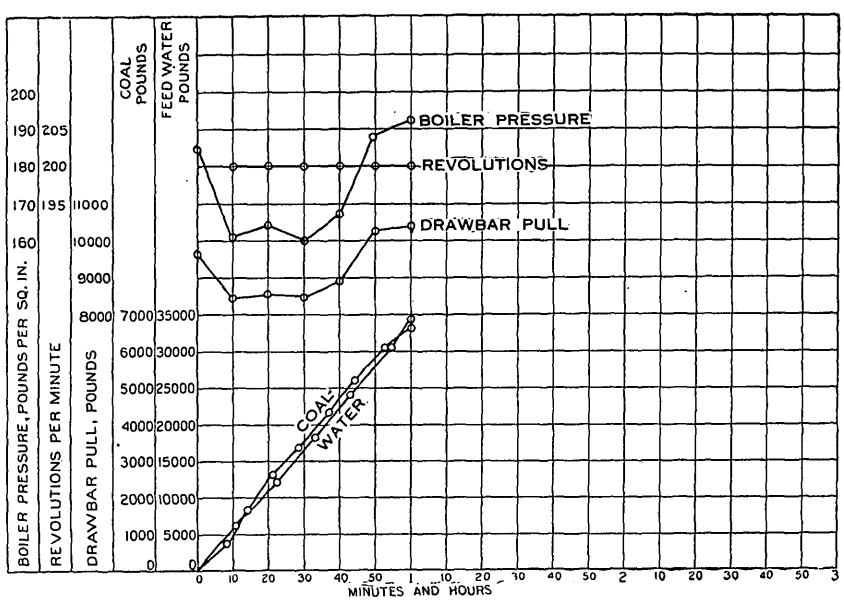


FIG. 34.—Graphic log, test 20.

LOCOMOTIVE ROAD TESTS OF BRIQUETS.

In cooperation with the Missouri Pacific, the Lake Shore and Michigan Central, the Chicago, Rock Island and Pacific, the Chicago, Burlington and Quincy, and the Chicago and Eastern Illinois railroads, 100 locomotive tests have been made by the United States Geological Survey to determine the value, as a locomotive fuel, of briquets made from a large number of western coals. All tests were made on locomotives in actual service on the road. In some tests there was small opportunity for procuring elaborate data, but in others, where dynamometer cars were employed, it was possible to obtain more detailed results. The purpose which these tests were intended to serve was not so much to determine the evaporative efficiency of briquets as to investigate their behavior in practical use.

Briquets made from Arkansas semianthracite, two qualities of Indian Territory slack, Indian Territory screenings, Missouri slack, Indiana Brazil block slack, coke breeze, and a mixture of coke breeze and washed Illinois coal were tested, and comparisons were drawn either with the same coal that was used in the briquet or with coal similar to it. In nearly every test the results reported show that the coal when burned in the form of briquets gives a higher evaporative efficiency than when burned in the natural state. For example, Indian Territory screenings give a boiler efficiency of 59 per cent, whereas briquets made from the same coal give an efficiency of 65 to 67 per cent. Decrease in smoke density, the elimination of objectionable clinkers, and an apparent decrease in the quantity of cinders and sparks are named as the chief reasons for this increased efficiency.

COMPARATIVE ROAD TESTS OF COAL AND BRIQUETS.

ATLANTIC COAST LINE RAILROAD.

In the following table are presented the results of comparative tests of run-of-mine New River coal and of briquets of the same fuel, made in December, 1907, on a locomotive in the regular passenger service of the Atlantic Coast Line Railroad. These tests were conducted under the supervision of R. E. Smith, general superintendent of motive power of the railroad, in cooperation with the United States Geological Survey. Sixteen complete test trips were run between Rocky Mount and Wilmington, N. C., with the same engine, crew, and trains. An equal number of tests were made with run-of-mine coal furnished by the railroad company and with round and rectangular briquets made at the Geological Survey fuel-testing plant at Norfolk, Va., from the same coal, with 6 per cent of water-gas pitch binder.

Tests of run-of-mine New River coal and briquets.

	Coal.	Briquets.
Number of test trips	16	16
Total pounds consumed	172,700	161,980
Average pounds consumed per trip	10 794	10,124
Average tons consumed per trip	5.397	5.062
Total engine miles	1,984	1,984
Total car miles	10,912	12,896
Pounds consumed per car mile	15.8	12.5
Average cars per train	5.5	6.5

It is reported that from a practical standpoint the briquets thus tested were very satisfactory. Their use was found to eliminate all black smoke. No objectionable clinker was formed and the fuel seemed to burn completely.

CHESAPEAKE AND OHIO RAILWAY.

In December, 1907, the United States Geological Survey cooperated with the Chesapeake and Ohio Railway in making a series of comparative road tests of the performance of run-of-mine coal and briquets of the same coal on locomotives in regular service. These tests were conducted under the supervision of J. F. Walsh, superintendent of motive power of the railway. One car of fuel was used in tests run on a passenger locomotive between Old Point and Richmond, Va., and four cars on through express locomotives between Washington, D. C., and Charlottesville, Va. The briquets were made at the fuel-testing plant of the Geological Survey at Norfolk, Va., from run-of-mine coal furnished by the railroad company, with 6 per cent of water-gas pitch used as a binder.

The coal for these tests came from a mine working the Fire Creek coal bed at Minden, in the New River district of West Virginia. This coal was shipped without being inspected. The sample consisted of run-of-mine coal and reached the testing plant after a maximum exposure to the weather of sixteen days, the first car of coal to arrive being exposed for only eight days. This was a typical example of the low-volatile or semibituminous friable coals of the New River district.

No attempt was made in these tests to make careful measurements of fuel and water; however, during the tests the following facts were developed. The briquets ignited freely, made an intensely hot fire, and when the engine was working emitted very little smoke. It was found that a comparatively heavy fire could be carried without danger of clinkering. Few ashes were left in the fire box or ash pan, and the cinder deposit in the front end was small. The results do not show that any apparent improvement in evaporative efficiency was obtained by the use of briquets, as compared with that obtainable from the natural fuel.

COMPARATIVE TESTS OF COAL AND BRIQUETS ON U. S. TORPEDO BOAT BIDDLE.

In the accompanying table are given the results of 20 comparative tests, made on board the U. S. torpedo boat *Biddle*, of run-of-mine New River coal and briquets, both round and rectangular, of the same coal. These tests were made in cooperation between the United States Geological Survey and the Bureau of Steam Engineering and the Bureau of Navigation of the Navy Department. The conduct of the tests was under the immediate supervision, on behalf of the Navy, of Lieut. Commander Kenneth McAlpin, assisted by Lieutenant Richardson, in command of the *Biddle*. The Geological Survey was represented by Walter T. Ray and Henry W. Kreisinger, of the steam-engineering section. The coal was briquetted with 6 per cent of water-gas pitch binder at the fuel-testing plant of the Survey at Norfolk, Va., one-half on the English or Johnson machine and one-half on the Renfrow or American machine.

The coals used in the tests on the *Biddle* were taken from two mines in the New River district of West Virginia—one working the Sewell bed at Red Star, on the Chesapeake and Ohio Railway, and the other working the Beckley bed at West Raleigh, on the same railway. Both of these samples consisted of run-of-mine coal and were loaded and shipped to the Jamestown Exposition testing plant under the supervision of Inspector K. M. Way, of the Survey. These coals are low-volatile bituminous or semibituminous in character and are very friable. The Sewell coal was exposed to the weather for forty days on the way to Norfolk, and the Beckley coal reached the testing plant after an exposure of twenty-three days.

Evaporative efficiency from tests on U. S. torpedo boat Biddle.

Coal.	Tests on run-of-mine coal.		Tests on briquets.		Remarks.
	Rate of combustion per square foot of grate per hour.	Actual water evaporated per pound of coal.	Rate of combustion per square foot of grate per hour.	Actual water evaporated per pound of briquets.	
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	
Sewell coal	20.0	7.83	21.7	7.61	Large square briquets made on Johnson machine.
	29.9	7.58	29.34	6.63	
	41.9	7.3	46.15	6.36	
Do	20.9	7.98	20.75	8.22	Small round briquets made on Renfrow machine.
	30.7	7.06	32.1	7.54	
	46.6	6.93	46.0	7.2	
			66.0	6.36	
Beckley coal	21.7	7.61	24.3	7.35	Do.
	30.7	7.13	37.9	7.09	
	53.7	6.60	53.0	6.97	
			69.4	6.19	

The results are also shown graphically in fig. 35. In all except the first tests the evaporative efficiency seems to have been improved

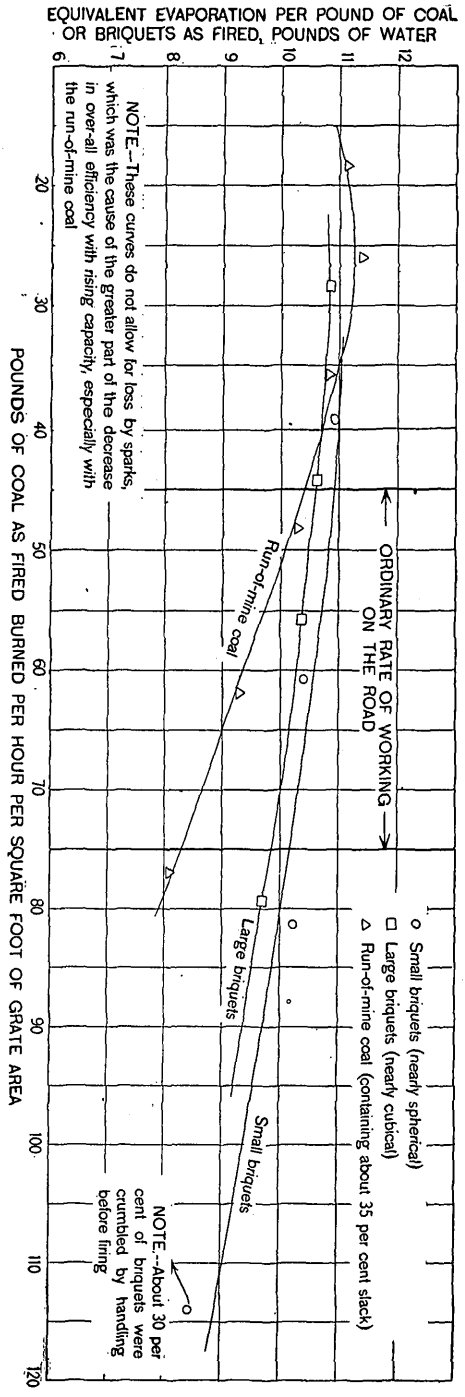


FIG. 35.—Graphic chart showing relative evaporative efficiency of briquets and coal.

by briquetting. Observations during the tests revealed little difference in the density of smoke resulting from the coal and the briquets.

It is reported that on account of their uniformity of size the briquets required more than 20 per cent more storage space than that required by an equal weight of lump or run-of-mine coal.

FOREIGN SPECIFICATIONS GOVERNING THE PRODUCTION OF BRIQUETTED FUEL.

The specifications employed by some foreign railroads that have long been heavy consumers of briquets describe the essential facts with reference to the composition and the physical and chemical qualities of such fuel. As examples of such specifications those used by the Prussian State Railroad, the Belgian State Railroad, and the State Railway of France are presented herewith. A fourth specification, that of the Paris-Orleans Railway, is added as an example of a French specification which is more flexible in its requirements than that of the State railroads.

SPECIFICATIONS OF THE PRUSSIAN STATE RAILROAD.

1. *Quality.*—Coal briquets must be made from selected washed coal of small size and as free as possible from impurities. They must have high mechanical strength. The slag deposit must be easily removable.

2. *Weight and measure.*—The German system of weights and measures is to be used. In this connection attention is called to the fact that all briquets delivered are to be measured and paid for exclusively by weight.

3. *Orders and delivery.*—Delivery of briquets is made according to the demands of the service, on the basis of unfilled orders the fifth day before the month of delivery. Orders are made through the business office of the division making the contract. The monthly order is proportioned according to the number of working days in the month. In this way delivery is so distributed as to make the daily delivery, exclusive of Sundays and holidays, as nearly uniform as possible. If the contractor is delinquent, the management may procure the amount of the delinquency on the open market, at any price, at the expense of the contractor. In case of mobilization of the army and during the progress of war, the railroad may cause the suspension of delivery of briquets ordered, entirely or in part, until further notice. In such a case the contractor is not entitled to damages, nor can he withdraw from his contract. The division office will inform the contractor of the suspension or limitation of delivery in case of mobilization of the army and during a war, as well as of the resumption of the deliveries concerned, and the amount needed.

4. *Acceptance.*—Acceptance tests for quality and weight will be made at the place of consumption. Briquets which do not satisfy the specifications are placed at the disposal of the contractor. He must remove them within five days after receiving notice, otherwise charges will be made for demurrage or storage subject to the regulations of the railroad management. The management reserves the right to exercise its judgment in unloading briquets which have been rejected, the expense incurred to be borne by the contractor. Whenever such briquets are carried at the expense of the railroad, or as material for use in its service, the contractor must refund the full scheduled freight charges.

5. *Interruption of mine operations and delayed deliveries.*—Interruptions of operations at the mines or the briquet factory will not affect the obligations of the contractor

unless they are sufficient to limit the production of briquets to at least one-fourth the amount concerned. In such a case the contractor must immediately inform the division management of the interruption, give the reason for it, and state its possible extent. In default of such a notice the delinquency will not be excused. If an interruption coming under these rules lasts longer than four weeks, the contractor will be relieved of the responsibility of delivery in proportion to the magnitude and extent of the interruption. If the interruption lasts longer than the limit of delivery stated in the contract, due allowance for the entire period will be made. If the interruption lasts four weeks or less, the contractor must deliver the amount specified in the contract. He is relieved, however, of his obligation in regard to time of delivery during the interruption, and in proportion to its extent. In such a case after notifying the division management the contractor may make up the deficiency with briquets from any other factory whose product is of equal quality. Delayed deliveries must be made within the time specified in the contract. Strikes are treated as any other interruptions of operations.

6. *Payments.*—Payment on account is made on the basis of the contractor's statement giving a list of the cars delivered and the weight of the briquets during the month. Any amounts to be deducted are retained. The rules of paragraph 15 of the general specifications will apply in the case of all final payments.

7. *Arbitrations.*—The referee (paragraph 20, section 6, of the general specification) is named by the president of the Royal Railway management who is located nearest to the management concerned and who is not concerned in the controversy.

8. *Form.*—Briquets made from hard coal (briquets of the first and second classes) must be delivered in the form of prisms with rectangular bases. The following forms are allowed: Form *a*, length 280 mm., width 150 mm., height 110 mm., weight 5 kg.; form *b*, length 220 mm., width 110 mm., height 105 mm., weight 3 kg.

Briquets made from bituminous coal (briquets of the third class) must be delivered in the form of prisms with square bases and of the following dimensions: Form *c*, length 160 mm., width 160 mm., height 105 mm., weight 3 kg.

Briquets intended for the city and belt railroad of Berlin (anthracite briquets) must be delivered in the form of prisms of rectangular bases and of the following dimensions: Form *d*, length 150 mm., width 75 mm., height 95 mm., weight 1.5 kg.

Dimensions other than those mentioned as forms *a*, *b* *c*, and *d* are not allowable. Dimensions exceeding the normal length and width not more than 10 mm. and the normal height not more than 3 mm. will be accepted.

SPECIFICATIONS OF THE BELGIAN STATE RAILROAD.

The specifications issued by the Belgian State Railroad relate to the "special conditions for the furnishing and reception of combustibles." General conditions dealing with contracts, right of inspection, method of shipment, delay in furnishing, acceptance, necessary tests, manner of payment, etc., are first specified. Under the heading "Special conditions" various kinds of coals are discussed. Briquets are treated as follows:

CONDITIONS COMMON TO THE TWO TYPES OF BRIQUETS.

1. *Nature of the pitch and quantity to be used.*—The pitch should be dry or "half-fat" and be the product of tar from pit coal exclusively. The amount of water should not be greater than 1 per cent, and distillation in a closed vessel, in a reductive atmosphere, should give as residue an inflated coke the weight of which should not be less

than 30 per cent of the total quantity tested. The proportion of pitch entering into the briquets shall not exceed 10 per cent.

2. *Physical properties of the briquets.*—The briquets shall be well agglomerated, sonorous, entire, and sharp-edged, and shall be of about equal weight. They should be hard and should retain all their hardness at 50° C. Their degree of cohesion should be at least 55 per cent. The fracture shall be clean cut, brilliant, and homogeneous.

3. *Behavior in the furnace.*—The briquets should light easily without disintegrating or causing dense black smoke; they should burn with a quick, bright flame without emitting sulphurous fumes. Briquets giving slag or fused ashes which adhere to the grates will not be accepted.

CONDITIONS PECULIAR TO BRIQUETS, TYPE I.

4. *Quality of the coal.*—The coal used in making briquets of Type I should be semianthracite having for a minimum 12 per cent of volatile matter. It should be of recent extraction.

5. *Composition of briquets.*—The amount of water in the briquets shall not exceed 4 per cent. The amount of ash shall not exceed 8 per cent. Nevertheless briquets manufactured from semianthracite coal shall admit of an allowance for each 1 per cent volatile matter above 12 per cent, so that, for example, briquets made from coal containing 14 per cent of volatile matter may contain 10 per cent of ash. In any case coal containing more than 11 per cent ash shall not be accepted.

6. *Uses of briquets and tests.*—The briquets should be suitable for firing in the deep or moderately deep fire box of the State Railroad's locomotives other than types 17 and 18. In the trip from Termonde to Anvers, G. C., and return, including stops, by an ordinary train of the type of 415 and 418, making the trip in an hour and 15 minutes and an hour and 51 minutes respectively, the evaporation in a deep fire box of one locomotive, type 15, drawing a minimum load of 40 units and a maximum of 45 units, shall not be less than 8 kilograms of water per kilogram of briquets.

CONDITIONS PECULIAR TO BRIQUETS, TYPE II.

7. *Quality of the coal.*—The coal used in the manufacture of briquets Type II should embody the same properties as semianthracite coal, Type IV, of the State.[a] It should be of recent extraction.

8. *Composition of the briquets.*—The amount of water in the briquets shall not exceed 4 per cent, that of ash shall not exceed 8 per cent, and the volatile matter shall not be less than 15.5 nor greater than 18 per cent.

9. *Uses of briquets and tests.*—The briquets should be suitable for firing State Railroad locomotives of types 17 and 18. In making the trip from Bruxelles-Nord to Veriers by a locomotive, type 17, drawing a maximum load of 55 units and a minimum load of 45 units, or by a locomotive of type 18, drawing a maximum load of 65 units and a minimum load of 55 units, with a train of type 624 making the run, including stops, in 2 hours and 50 minutes, the evaporation shall not be less than 9 kilograms of water per kilogram of briquets.

SPECIFICATIONS OF THE STATE RAILWAY OF FRANCE.

1. *Object of the specifications.*—The present specification has for its object the furnishing to the State Railway briquets of agglomerated coal for firing locomotives.

2. *Tonnage to be furnished.*—The tonnage to be furnished is indicated in the contract. Through derogation of the provisions of article 20 of the clauses and general conditions relating to shipment of supplies of the State Railway, dated February 1, 1904, the State Railway can neither increase nor diminish the amount furnished.

[a] Type IV should evaporate a minimum of 7.5 liters of water per kilogram of coal.

3. *Description of the briquets.*—The briquets shall be composed of small agglomerated coal and dry pitch. They shall have the form of a rectangular parallelopiped and shall bear a trade-mark showing their origin. They shall be reasonably uniform in weight and have a constant mean weight; this mean weight shall be indicated by the contractor in his contract.

4. *Quality of the first material.*—The small coal entering into the composition of briquets shall be of the quality called "demi-gras" (semianthracite) giving at its calcination, in a closed vessel, a hard cake partially blended. It shall be of recent extraction, free from sulphur, pyrites, and all foreign matter.

5. *Quality of the briquets.*—(1) General conditions: The briquets shall be hard, sonorous, homogeneous, and almost without odor. (2) Cohesion: The briquets shall have normally a degree of cohesion of 0.55 at the minimum. (3) Ash: The briquets should not leave, normally, after complete incineration, a proportion of ash greater than 10 per cent. (4) Volatile matter: Briquets should not lose through distillation in a closed vessel a proportion of volatile material less than 16 per cent nor greater than 22 per cent. (5) Humidity: They shall be, as far as possible, free from moisture, and shall not be weighed or delivered until five days after their manufacture. (6) Conditions of combustion of briquets in the furnaces of locomotives: The briquets should light easily, burn with a bright, clear flame, and produce only a light-gray smoke; they should neither agglomerate in masses, nor disintegrate before combustion is complete; they should not produce slag which adheres to the grates; the ash should pass easily between the bars without adhering to them.

6. *Inspection of the manufacture.*—Conforming to article 24 of the clauses and general conditions, the State Railways can inspect, in the establishments of the contractor, all the operations which make up the manufacture of briquets, through one or several agents authorized by them. These agents shall have free access to the mines, depots and storehouses, ships, etc., containing the materials which enter into the composition of briquets furnished to the State Railways in the establishments where the briquets are made. They shall have the right to take out all the samples which they judge necessary to assure themselves of the good quality of the materials entering into the manufacture of briquets, before they are used. To this effect the contractor is obliged, at all the demands of the agent of the State Railway, to show the material in the warehouse intended for the manufacture of briquets. A "procès-verbal" of the transaction is always drawn up. This "procès-verbal" is submitted as evidence of the facts recorded therein and bears the signature of the contractor.

7. *Examination of briquets at the factory, taking of samples, and authorization for shipment.*—The contractor shall be obliged to deliver the briquets loaded on cars. He should consult, at least forty-eight hours in advance, with the agent of the State Railway in order to fix the day and the hour at which each car can undergo examination before its departure from the factory to the weighing machine. On the day and hour fixed by common consent, the agent of the State Railway shall examine the loaded briquets and assure himself, to the extent of the means at his disposal, that they conform to the conditions fixed by paragraph 1 of article 5, above. He shall proceed immediately to collect samples from various parts of the several cars, the number of briquets taken being at least equal to the number of cars. After accomplishing this, the agent of the State Railway shall give the contractor authority to send the shipment immediately to the place indicated in his order, with the understanding that this authorization does not constitute an acceptance [of the briquets]; this can be given only after the formalities described in paragraph 9 have been accomplished. The cars whose shipment has been authorized, shall be limed and weighed in the presence of the State Railway's agent, who shall notice the weight of each of them. He shall make note of the delay caused during manufacture. If, at the time of weighing, the briquets have been manufactured less than five days, the receiving agent shall deduct 2 per cent of the weight delivered, to take account of the humidity.

8. *Number of tests and preparation of specimens.*—Complete tests shall be made for each 400 tons of briquets. To this end, whenever the total reaches 400 tons, the briquets taken out on various shipments shall be collected at the time of the last shipment and shall be prepared for the various tests as if they had been taken from one shipment. From the briquets thus collected enough shall be sawed up into small parts weighing about 500 grams each, to make a total weight of 60 kilograms. There should be at least 1,000 fragments. These shall be used for the cohesion test under the conditions explained in paragraph 9. The fragments and residue from the cohesion test, together with the remaining part of the briquet sample, shall be gaged for laboratory test by means of the so-called cone and cylinder method, to obtain 500 or 600 grams of powdered briquets, fine enough to pass entirely through a No. 60 screen. From this sample three receivers each of about 50 grams capacity shall be filled. They shall be numbered and closed with the seal of the State Railway and that of the contractor. One shall be addressed to the central laboratory of the State Railway at Paris, another shall be retained by the contractor, and the third shall be kept by the State Railway's agent to serve in case of damage to the first sample. The State Railway may also, after mixing the fragments, proceed to pulverize the entire amount by means of a mechanical grinder. The powder thus obtained should be fine enough to pass through a No. 60 screen. A detailed "procès-verbal" of all the operations described in this paragraph shall be drawn up as evidence of the facts stated and of the weights delivered, with the signature of the contractor, who shall receive a shipment of it on demand. The contractor shall furnish free of charge the material and the labor required to carry on the operations discussed in this paragraph. The work shall be done under the direction of the agent of the State Railway. The receivers for holding the samples will be furnished by the State Railway.

9. *Tests of briquets.*—The samples taken from each shipment shall be submitted to the following tests:

(1) Cohesion test: The fragments to be tested for cohesion will be tested in a grinding apparatus (navy type) described as follows: The apparatus consists of a cylinder 100 centimeters long and 90 centimeters in diameter and is made of sheet iron 10 millimeters thick. Its ends are closed by disks of the same thickness. An axle fastened in the interior follows the axis of the cylinder. This rests horizontally on two supports. In the interior of the cylinder are placed three floating boards, or vanes, of sheet iron fastened along planes inclined 120° to each other. These vanes are of the same length as the cylinder and are 20 centimeters high. An opening by means of a sliding panel provides for the introduction of the sample to be tested. In preparation for a test 50 kilograms of briquets sawed up into pieces of about 500 grams weight and prepared as described in the preceding paragraph are placed in the cylinder. The cylinder is caused to revolve for two minutes at the rate of 25 revolutions per minute. The contents are then emptied on a bar screen made of round bars (not square) so spaced as to leave 40 millimeters between them. The degree of cohesion is determined by the ratio of the weight remaining on the screen to the total weight tested. This value will be applied to all shipments from which the fragments tested were taken.[a]

(2) Laboratory tests: The sample directed to the central laboratory at Paris shall be tested by the usual method; after drying the sample at a temperature of 100° C., the percentages of volatile matter and of ash shall be determined. The values obtained shall apply to all shipments from which the samples were taken. The contractor may not contest the results of this analysis. He may be represented and may assist in the test, but neither his absence nor the absence of his representative shall be permitted to delay operations.

[a] Pl. III, *B*, is reproduced from a photograph of the machine used in making this test.

10. *Acceptance of briquets.*—If for each lot of 400 tons all the conditions previously noted have been met, the lot will be accepted. If the amount of ash established by a test is less than 9 per cent and the volatile matter equal to 16 per cent at least, the price per ton of the corresponding shipment shall be increased 4 millimes for each hundredth of 1 per cent of ash less than 9 per cent. If the degree of cohesion determined by test is less than 0.55, the price per ton of the corresponding lot shall be reduced 15 centimes for each hundredth less than 0.55 up to 0.45 inclusive; for each hundredth less than 0.45 the rate of reduction will be from 15 to 25 centimes. If the amount of ash established by test is greater than 10 per cent, the price per ton of the corresponding shipment shall be diminished by 5 millimes for each hundredth of 1 per cent in excess of 10 per cent. If the degree of cohesion of a lot is less than 0.40, or if the ash exceeds 12 per cent, or if the volatile matter exceeds 22 per cent or is less than 16 per cent, the lot can be refused; if it is accepted, it will be only with a reduction and according to the conditions set forth in paragraph 27 of the clauses and general conditions.

11. *Loading, shipment, and transportation of supplies.*—The briquets shall be loaded on cars in such a manner as to prevent displacement during shipment. The shipments which the agent of the State Railway shall order sent out shall be delivered to the railway station designated by the contractor in his contract. The contractor shall assure himself that the shipment conforms to the orders of the State Railway. Contrary to article 16 of the clauses and general conditions, the State Railway assumes the expense of transportation between the station where shipment is loaded and its destination.

12. *Importance of penalties for delay.*—The penalty stated by article 21 of clauses and general conditions is fixed, for each week of delay, at 0.2 per cent of the price of the delayed shipment after having, if there is cause, reduced this price as stated in paragraph 10 above.

13. *Conditions for furnishing.*—The total quantity furnished is to be distributed among the different depots of the State Railway in the proportion indicated by the table attached to the back of the contract. Each competitor shall indicate in his contract (1) the station at which he intends to deliver the briquets (this station can be any station on the French system); (2) the price offered per ton of briquets delivered free of charge to the designated station; (3) the total tonnage offered by the contractor.

The order of preference accorded to the different contracts, for the supply of the several depots, shall be established according to the following rules. For each depot there shall be added to the price demanded (1) the expense incurred by the State Railway for transporting the briquets on systems other than that belonging to the State Railway; (2) the price of transportation from the station of entry on the State system to the depot of destination, determined at the rate of 1 centime per ton and per kilometer. A table, giving for each depot the net cost resulting from the offers of each contractor, shall be drawn up. By means of this table the supply for the different depots shall be distributed to the various contractors according to the order of the lowest price and to the extent of the quantities offered.

14. *Payment of installments.*—Through derogation of the provisions of article 30 of clauses and general conditions, the payment of installments is effective to the extent of four-fifths of the price of the whole amount of briquets received during the month accountable to the depots of destination indicated by the orders. The notices of payment of these installments are delivered during the fortnight following the end of the month. They can be retained if they come during an interval of delay in the delivery by the contractor or the refusal of the briquets by the State Railway. The payment of an installment does not alter the right of the State Railway to refuse or to accept with reduction briquets which have not fulfilled the conditions of quality specified by these specifications. The amount is paid, after the cost of lading (article 30 of clauses and general conditions) is deducted, all under the conditions of article 34 of the same clauses and general conditions drawn up and proposed.

SPECIFICATIONS OF THE PARIS-ORLEANS RAILWAY COMPANY OF FRANCE.

1. *Object of the specifications.*—The present specifications have for their object the determining of the conditions for furnishing the briquets used by the Paris-Orleans Railway Company.

2. *Quantity.*—The contract shall determine the quantity to be delivered yearly or monthly. The company reserves the right to increase or diminish this according to its needs, by one-sixth the quantity fixed in the contract. In case of increasing or diminishing the amount, the company should notify the contractor at least a month in advance.

3. *Manner and places of delivery.*—The briquets shall be delivered in cars at a point fixed in the contract. They shall be loaded, as far as possible, in cars belonging to the company, under the direction and at the expense of the contractor. The cars shall be weighed before and after loading, on the weighing machine of the station if the factory is on the company's system. The top layer of briquets in each car should be whitewashed under the direction of the contractor.

4. *Inspection of the manufacture.*—The company reserves the right to inspect the manufacture of briquets and the production of coal and pitch used. The contractor should give the company entire freedom in his establishments, ships, and boats. The provisional acceptance made at the factory by an agent of the company shall by no means restrict the right of the company to refuse briquets which, when they arrive at the destination, shall be found not to conform to the conditions of the specifications nor the contract. The final acceptance shall take place only at the designated stations, and after tests have been made in the laboratory of the company in Paris.

5. *Tests.*—Tests will be made, when the company thinks fit, to determine the quality of the briquets and their evaporative efficiency. The samples for tests of all kinds shall be collected by the agents of the company, either at the departure or at the arrival of the consignment at its destination, at the discretion of the company. The tests shall be made at Paris, in the laboratory of the company. The contractor shall have the right to assist or to be represented, but his absence or that of his representative can not delay operations. The results obtained by these tests shall be accepted by the contractor without recourse to other tests. The results shall be communicated to the contractor.

6. *Delay in delivery.*—In case of a delay arising, either from insufficient deliveries or from the refusal of delivered briquets through the fact that the time fixed by contract has expired through letters of order, and without which there would be need of entering a suit, the contractor shall incur, for each month of delay, a penalty of 2 per cent of the value of the delivery not effected. When the delayed quantity is equal to or greater than the supply for a month, the company shall have the right—eight days after entering a suit by registered letter, this remaining without effect—unless a case of superior force be duly established—of suing for the amount due. If the company sees fit to refuse the deliveries when they are not produced within the fixed period of delay, it may annul the contract, and this through full right, without recourse to law.

7. *Quality of the materials.*—The small coal to be used for the manufacture of briquets shall be provided exclusively from the mines of ..... It shall be of recent extraction and free, so far as possible, from sulphur, pyrites, and all foreign matter. It should not produce slag of a nature to impair the gratings or affect the production of steam. Coal coming from parts of the mine affected by fire shall be excluded. The agglomerated material shall be dry pitch—that is to say, the residue from the tar mineral from which 40 per cent of the volatile matter has been removed, and which in this state should be altogether solid and almost without odor. The pitch, submitted for test in a closed vessel, should leave in the

crucible an inflated cake, the weight of which should be less than 42 per cent of the quantity of pitch tested. There shall be at least 8 per cent of pitch in the briquets.

8. *Form of briquets.*—The briquets shall have the form of a rectangular parallelopiped and should have practically the same weight, which shall be —— kilograms. They must be of recent manufacture. The briquets shall be hard, sonorous, homogeneous, a little hygrometrical, and almost without odor. They should light easily and burn with a light, clear flame without disintegrating. After being placed in an oven for six hours at a temperature of 60° C. they should show neither softening nor sensible loss of weight. Their density shall be between 1.13 and 1.21.

9. *Humidity of briquets.*—If the briquets have been manufactured less than five days, 2 per cent of the weight delivered shall be deducted in order to take into account the moisture of manufacture. The company can, moreover, refuse to receive briquets which have been manufactured less than three days.

10. *Tests of cohesion.*—The briquets shall be made under pressure sufficient to give them perfect cohesion. This cohesion, tested by means of a grinding apparatus adopted by the navy and the State roads, should not be less than 50 per cent. This apparatus consists of a sheet-iron cylinder, closed at both ends and provided with a horizontal axis which can turn freely on two supports. On the inside there are three equidistant plates of sheet iron, 20 centimeters in height and of a length equal to that of the cylinder. The dimensions of the cylinder are: Length, 100 centimeters; diameter, 90 centimeters. A door closing by means of a sliding panel provides for the introduction of the material to be tested. The test shall be made of 50 kilograms of agglomerated material and the fragments put into the cylinder should each weigh about 500 grams. The door being well closed, the apparatus is caused to rotate fifty times in two minutes with a uniform speed. Then the débris of the agglomerated matter is removed, and all the fragments which will not pass through a sheet of metal perforated with square holes, 3 centimeters on a side, are weighed. These fragments should weigh at least 50 per cent of the weight tested, or 25 kilograms. When the briquets have a cohesion less than 0.50, a reduction of 15 centimes for each hundredth less than 0.50 shall be made on the price per ton. The briquets which have less than 0.40 cohesion can be refused. In case the company does not exercise its right of refusal, a reserve of 30 centimes will be applied for each hundredth less than 0.50.

11. *Amount of ash.*—The proportion of ash should not exceed .... per cent. If the average during the month exceeds this proportion, the price per ton of briquets will be diminished by ..... for each unit in advance of the figure fixed. If the mean figure given for the ash is greater than .... per cent of the figure fixed, or .... per cent, the reduction in price shall be doubled, and it shall be applied per unit for the least amount of ash—that is to say, ... per cent. The reserve shall be, for order, applied according to the following schedule:

[Schedule follows.]

If it is greater than ..... units, the company can, at will, apply the reduction in price or refuse the supply.

12. *Manner of shipment.*—The briquets shall be loaded on cars, unbroken and without any small pieces or dust. They shall be placed flat and pressed one against the other in a way to avoid displacement on the road. In case they arrive at their destination broken or damaged, a settlement will not be made with the contractor except for the weight of those known to be acceptable. The remainder will be held at the disposal of the contractor, who should have them removed at his expense within fifteen days after notice has been given to him.

13. The contractor will be, unless by contrary stipulations, responsible for the shipment of the briquets, conforming to information given him by the company. The quantity furnished for each depot shall be so far as possible delivered in equal amounts each day. The contractor shall send each day to the chief engineer of mate-

rial and traction, at Paris, a statement indicating the number of cars included in each shipment, the weight and nature of their contents, the names of the depots for which they are destined, and the date of the shipment. During the three days following the 24th of each month, he shall send to the chief engineer an invoice, agreed upon in the clauses and general conditions, of the deliveries which he has made during the month.

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