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# TESTS OF COAL AND BRIQUETS

AS FUEL FOR

# HOUSE-HEATING BOILERS

BY

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# TESTS OF COAL AND BRIQUETS AS FUEL FOR HOUSE-HEATING BOILERS.

By D. T. RANDALL.

## INTRODUCTION.

In carrying out its general plan of determining more efficient and more economical methods of utilizing the fuel resources of the United States, in order to prevent unnecessary waste and thus conserve the available supply, the United States Geological Survey has made a series of experiments on the combustion of fuel in house-heating boilers. As it was realized that steam boilers of the ordinary types used for heating private houses are often installed and operated under conditions unfavorable to fuel economy and smoke prevention, these experiments were made with briquets, raw coal, and washed coal, so as to determine what is to be expected of these fuels in a representative house-heating plant, properly installed and operated.

Briquetted coal had been frequently tested in the hand-fired furnaces under the Heine boilers in the Survey fuel-testing plant at St. Louis. The results were so satisfactory as regards economy and smokelessness that it was decided to conduct a series of tests to determine the value of this fuel for domestic heating purposes. Beginning in October, 1906, a number of evaporation tests were made on the house-heating boiler installed to heat the buildings occupied by the structural-materials laboratory, both briquets and coal being used. After these tests were well under way, it was thought advisable to conduct some additional tests under conditions more constant than could be maintained at this plant. A carload of briquets was shipped to the University of Illinois engineering experiment station at Urbana, Ill., where two house-heating boilers of a size commonly used in residences were available. This equipment permitted more uniform conditions of pressure and capacity, making the results more valuable for comparison. Tests were made with this fuel at Urbana in June and July, 1907. The present paper is an account of both series of tests, and includes also details of tests made at Urbana on three standard fuels in the spring of 1908.

Perhaps the most important result obtained is that showing the relative value of different fuels for domestic purposes. From Table 16. on page 39, it is possible by comparison to arrive at the probable value of any fuel in any part of the country. The figures in the table show that with a sectional boiler the effectiveness of different fuels depends on the number of thermal units they contain. This means that if all fuels cost the same, the cheapest would be the one containing the largest number of thermal units. One basis for ascertaining the relative value of different fuels lies in the cost of evaporating 1,000 pounds of water. If, for example, at a certain place anthracite costs $8 a ton and Pocahontas bituminous coal $4, the cost of evaporating 1,000 pounds of water with anthracite would be 52 cents and with the bituminous coal 23.68 cents. This shows that a saving of about $4 a ton for the same amount of work done would be effected by purchasing the bituminous coal.

The data obtained in the tests show that as the percentage of the rated capacity developed by the furnace increases the percentage of efficiency increases; also that high capacities were not obtained with the good coals, nor were the low capacities the result of burning poor coals.

A comparison of results on coal and on briquets shows no advantage in the briquets over coal of a size larger than screened nut. Briquetting good bituminous coal would be justified only when slack is used for material. The briquets tested gave much smoke, which was due to the pitch used as a binder.

The results indicate that coals containing the higher percentages of fixed carbon give the least smoke and are the most economical.

While these tests were going on a general inquiry was being made into the question of central heating plants. The results obtained in this inquiry, when compared with the results of the tests on house-heating boilers, show that such plants are economical for the householder and that they solve a part of the smoke problem in the cities. A brief summary of the results of this investigation is given on page 41.

All the results here recorded were calculated and checked by H. W. Weeks, who also compiled the tables and assisted in the preparation of this report. The observations on the tests at St. Louis were made by M. E. Baxter. The tests at Urbana were made under the direction of Prof. L. P. Breckenridge, director of the engineering experiment station and consulting engineer on steaming tests of the United States Geological Survey—the briquet tests by C. S. McGovney, assisted by A. B. Cook, Perry Barker, and S. B. Flagg, and the tests on standard fuels by J. M. Snodgrass.

## FUELS TESTED.

At St. Louis 58 tests were made—11 with raw coal and 47 with briquetted coal having a binder of pitch.

At Urbana 24 tests on briquets were made—12 on each of the two boilers. In 18 of these tests round briquets manufactured on the Renfrow machine of the Geological Survey were used; the other

6 tests were conducted with square briquets made on the Survey's English machine. The square briquets were broken in half before firing. The percentage of pitch in the briquets ranged from 7 to 8.5. The briquets were manufactured at the fuel-testing plant. The round briquets were 3⅛ inches in diameter and 2 inches thick, and the square briquets were 4¼ by 6¾ by 2½ inches. Details of the manufacture are given in Table 1.

TABLE 1.—*Coal and binders used in briquets tested at Urbana.*

| Coal. | | | Shape of briquet. | Binder.[a] | | | |
|---|---|---|---|---|---|---|---|
| Field designation. | Locality. | County. | | Percentage used. | Flowing point. | Oils by distillation up to 743° F. | Extraction analysis: Pitch extracted (sample as received) by $CS_2$. |
| | | | | | *° F.* | *Per ct.* | *Per cent.* |
| Arkansas No. 13 | Denning | Franklin | Round | 7 | 140.0 | 34.44 | 95.20 |
| Illinois: | | | | | | | |
| No. 7 E | Near Collinsville | Madison | do | 8 | 143.6 | 25.76 | 96.90 |
| No. 9 C | Near Staunton | Macoupin | do | 9 | 143.6 | 25.76 | 96.90 |
| No. 12 BW | Bush | Williamson | Square | 6.25 | 143.6 | 39.05 | 99.66 |
| No. 29 AW | Livingston | Madison | Round | 7 | 143.6 | 39.05 | 99.66 |
| No. 29 B | do | do | do | 7 | 143.6 | 39.05 | 99.66 |
| No. 30 W | Shiloh | St. Clair | do | 8.5 | 143.6 | 25.76 | 96.90 |
| No. 31 | Warden | do | do | 8 | 143.6 | 25.76 | 96.90 |
| Do | do | do | Square | 7 | 161.6 | 28.98 | 89.31 |
| No. 33 | Trenton | Clinton | Round | 8 | 143.6 | 25.76 | 96.90 |
| Indiana: | | | | | | | |
| No. 1 B | Mildred | Sullivan | do | 8.5 | 161.6 | 28.98 | 89.31 |
| No. 5 B | Hymera | do | do | 9 | 143.6 | 25.76 | 96.90 |
| No. 6 B | do | do | do | 8.5 | 143.6 | 25.76 | 96.90 |
| Do | do | do | Square | 7 | 143.6 | 25.76 | 96.90 |
| Indian Territory: | | | | | | | |
| No. 2 B | Hartshorne | | Round | 8 | 186.8 | 24.70 | 85.57 |
| Do | do | | Square | 8 | 172.4 | 20.00 | 99.60 |
| Kansas: | | | | | | | |
| No. 2 B | Yale | Crawford | Round | 7 | 143.6 | 39.05 | 99.66 |
| Do | do | do | Square | 7 | 143.6 | 39.05 | 99.66 |
| Maryland No. 2 | Frostburg | Allegheny | Round | 8 | 143.6 | 25.76 | 96.90 |
| Missouri No. 10 | Bevier | Macon | do | 8 | 143.6 | 39.05 | 99.66 |
| Pennsylvania: | | | | | | | |
| No. 18 | Lloydell | Cambria | do | 8 | 143.6 | 25.76 | 96.90 |
| Do | do | do | Square | 7 | 143.6 | 25.76 | 96.90 |
| | | | | [b] 8 | 114.8 | 5.76 | 100.00 |
| No. 19 | Herminie | Westmoreland | Round | 8 | 143.6 | 25.76 | 96.90 |
| No. 20 | Near Seward | do | Square | 6 | 161.6 | 28.98 | 89.31 |
| No. 20 W | do | do | Round | 8 | 161.6 | 28.98 | 89.31 |
| No. 22 | Huff | do | do | 7 | 161.6 | 28.98 | 89.31 |
| Do | do | do | Square | 6 | 161.6 | 28.98 | 89.31 |
| Pennsylvania No. 15 (one-fourth). | Wehrum | Indiana | | | | | |
| Rhode Island No. 1 (three-fourths). | Cranston | Providence | Round | 6.25 | 143.6 | 39.05 | 99.66 |
| Pennsylvania No. 18 (one-fourth). | Lloydell | Cambria | | | | | |
| Miscellaneous No. 9 (three-fourths). | | | do | 8 | 143.6 | 25.76 | 96.90 |
| Pennsylvania No. 18 (one-half). | Lloydell | Cambria | | | | | |
| Rhode Island No. 1 (one-half). | Cranston | Providence | do | 8 | 156.2 | 25.47 | 90.56 |
| Pennsylvania No. 18 (three-fourths). | Lloydell | Cambria | | | | | |
| Miscellaneous No. 9 (one-fourth). | | | do | 8 | 143.6 | 25.76 | 96.90 |
| Pennsylvania No. 18 (one-half). | Lloydell | Cambria | | | | | |
| Miscellaneous No. 9 (one-half). | | | do | 8 | 143.6 | 25.76 | 96.90 |
| Virginia No. 5 B | 10 miles west of Blacksburg. | Montgomery | do | 7 | 143.6 | 39.05 | 99.66 |

[a] Water-gas pitch except where otherwise noted.

[b] Wax tailings.

The chemical properties of these fuels are shown in Table 4 (pp. 25–31).

Several months after the briquet tests at Urbana 18 tests were made with the same boilers on three standard fuels—anthracite, coke, and Pocahontas bituminous coal. The results of these tests are also recorded in Table 4.

## EQUIPMENT OF PLANTS.

### ST. LOUIS PLANT.

The boiler on which the tests were made at St. Louis is a sectional steam boiler containing seven separate sections; it is 66 inches long and stands on a foundation 47 by 63 inches. The grate measures 36 by 54⅛ inches. The boiler has three 5-inch steam outlets at the

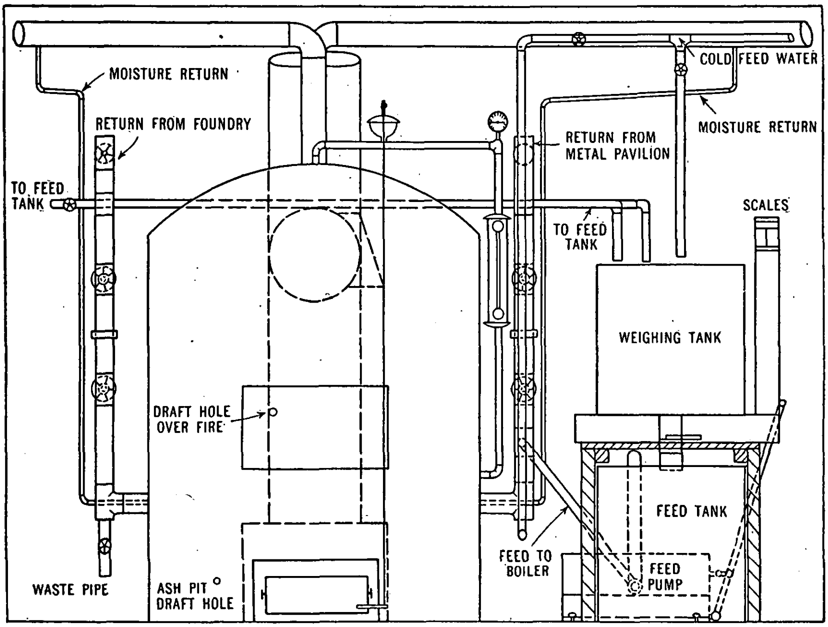



FIG. 1.—Elevation of house-heating boiler plant at St. Louis, Mo.

top of the sections, and is rated to take care of 3,150 square feet of radiating surface. The elevation and plan of the St. Louis plant are shown in figs. 1 and 2.

The boiler furnished steam to two buildings, supplying the necessary amount through two of the three outlets. The front outlet was not in use and was capped over. This boiler is made so that feed water may be supplied to every other section, entering at the base of the section on both sides, just above the grate level. There are six return inlets, but in this installation only the rear two were used. The piping was so arranged that during a test period all of the condensed steam was returned to the weigh tank, then allowed to discharge into a supply tank, from which it was forced into the boiler by a hand pump. The temperature of the water entering the boiler ranged from 100° to 150° F., but usually averaged 140°. During a test all the water entered through one of the rear inlets.

In a sectional boiler as usually installed the steam as it is taken from the sections is first drawn into a collecting drum, so that in case of a sudden demand for steam, water will not be carried into the heating pipes. There was not enough head room for the installation of such a drum at the St. Louis plant, and the steam was drawn

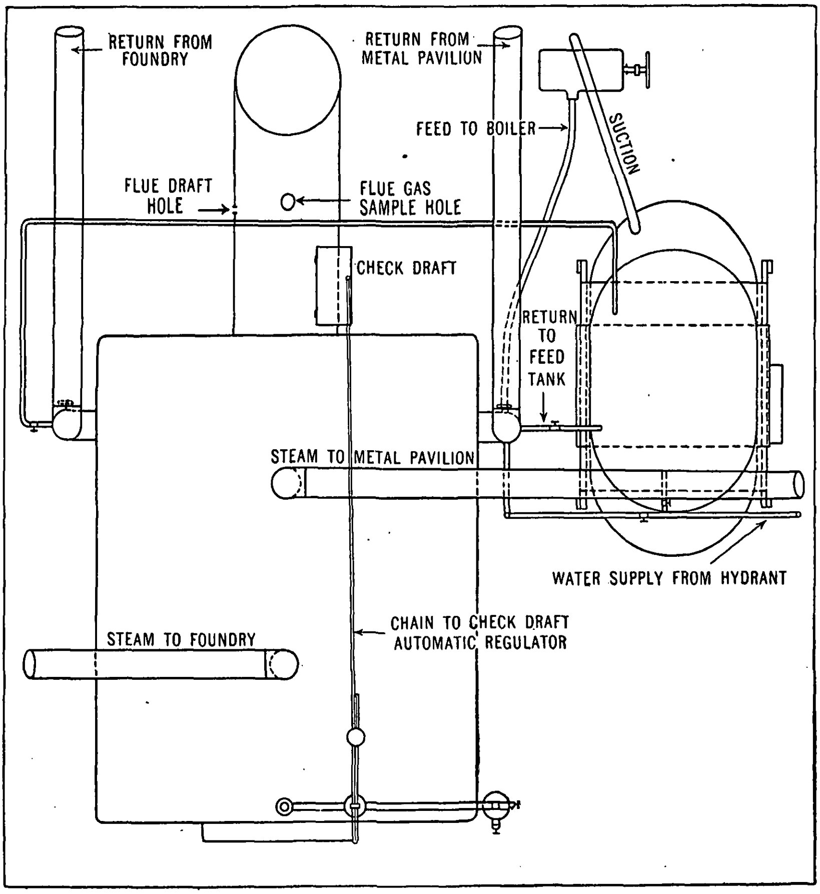



FIG. 2.—Plan of house-heating boiler plant at St. Louis, Mo.

directly from two sections. Drainpipes connected with the bottom of the steam pipes, as shown in fig. 1, carried moisture back to the boiler. No readings of moisture in the steam were taken, and therefore, in calculating water evaporated, the boiler was credited with slightly more work than it performed.

An automatic damper regulator was used to control the draft through the fire, so that a nearly constant steam pressure might be carried. This regulator was connected directly to the lower check and, by an arrangement of pulleys, to the check in the flue. All the exposed surface of the boiler except the front was lagged with about an inch of plastic asbestos covering.

In the first 30 tests the draft was supplied by a stack 32.4 feet high above the grate. In these tests both natural and induced draft were used. In the last 28 tests the stack was raised to a height of 44.8 feet above the grate level. This height always furnished the required draft.

### URBANA PLANT.

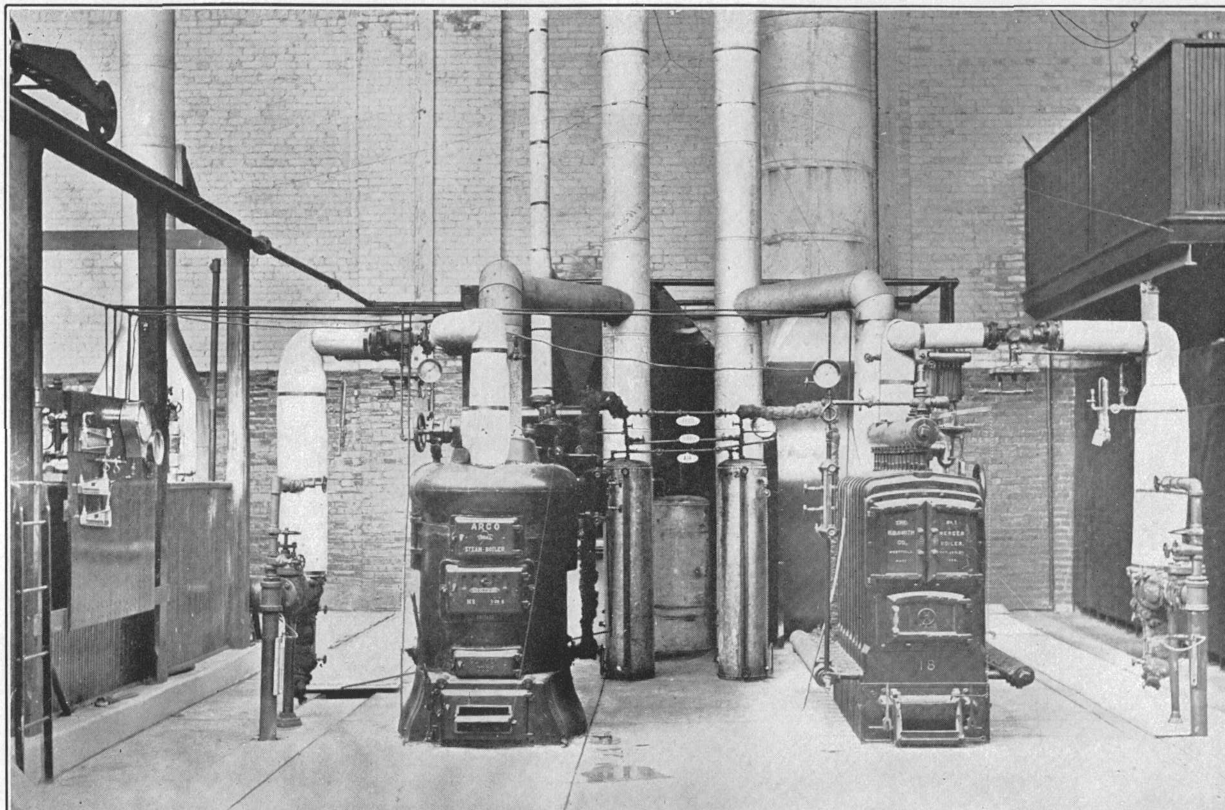
The two house-heating boilers in the experiment station at Urbana will be designated in this report as boiler A and boiler B. Both boilers are standard types supplied for use with either water or steam heating systems, except that in boilers of the type of boiler A a double section is usually substituted for the single intermediate section when used for water heating.

The general arrangement of the plant is shown in Pl. I. The boilers are set independently and each is provided with similar load regulators, return feed systems, and stacks. The flow is so arranged that the steam may be discharged to the atmosphere through an exhaust head above the roof of the building or into heating coils at the rear of the boilers. The coils contain 1,000 square feet of radiating surface, and are arranged in six sections, any number of which may be cut out and the amount of radiation changed in proportion. They constitute, with the overhead discharge pipes, the regular heating system of the experiment-station laboratory.

Boiler A is built up of four cast-iron sections—the base and grate section, the fire pot, the intermediate circulation section, and the dome. The water space surrounds the fire pot, and is continued into the intermediate and dome sections through three nipples. The principal dimensions and proportions of this boiler are given below:

*Details of boiler A.*

| | | |
|---|---|---|
| Rated capacity, radiating surface | square feet | 800 |
| Height over all | feet | 5½ |
| Floor space | square feet | 9 |
| Size of fire door | inches | 8½ by 15 |
| Height of fire door above grate | do | 14 |
| Fuel capacity to center of fire door | pounds | 290 |
| Kind of grate | | Plain rocking. |
| Width of grate | inches | 28 |
| Length of grate | do | 28 |
| Area of grate surface | square feet | 4. 28 |
| Area of air space | do | 2. 15 |
| Ratio of air space to grate surface | per cent | 50 |
| Mean height of furnace | inches | 22. 5 |
| Height of chimney above grate | feet | 39 |
| Sectional area of chimney | square feet | 1. 07 |
| Area of flue connecting to chimney | do | 0. 55 |
| Length of flue connecting to chimney | feet | 14 |
| Least flue area in boiler | square feet | 0. 67 |




HOUSE-HEATING BOILER PLANT AT URBANA, ILL.

| | | |
|---|---|---|
| Ratio of smallest flue area to grate surface | per cent | 15.5 |
| Kind of draft | | Natural. |
| Direct water-heating surface | square feet | 18.8 |
| Indirect water-heating surface | do | 20.7 |
| Superheating surface | do | 4.2 |
| Total heating surface | do | 43.7 |
| Ratio of direct-heating surface to total | per cent | 43 |
| Ratio of total heating surface to grate surface | | 10.2 to 1 |
| Total water and steam space | cubic feet | 7.38 |
| Steam space | do | 3.07 |
| Water space | do | 4.31 |
| Area of external boiler surface in contact with water or steam | square feet | 37.88 |
| Smoke outlet above grate | feet | 4.17 |
| Diameter of flue | inches | 14 |

Boiler B represents a common type of sectional construction in which the base or grate portion and the water-heating portion are built up of interchangeable cast-iron sections, the water legs or sections being connected by means of external circulation drums or headers. The following details apply to this boiler as now installed:

*Details of boiler B.*

| | | |
|---|---|---|
| Rated capacity, radiating surface | square feet | 1,075 |
| Height over all | feet | 5¾ |
| Floor space | square feet | 25 |
| Size of fire door | inches | 9 by 15 |
| Height of fire door (bottom) above grate | do | 10 |
| Fuel capacity to center of fire door | pounds | 370 |
| Kind of grate | | Patent rocker. |
| Width of grate | inches | 18 |
| Length of grate | do | 48 |
| Area of grate surface | square feet | 6 |
| Area of air space | do | 3 |
| Ratio of air space to grate surface | per cent | 50 |
| Mean height of furnace | inches | 22 |
| Height of chimney above grate | feet | 39 |
| Sectional area of chimney | square feet | 1.07 |
| Area of flue connecting to chimney | do | 0.55 |
| Length of flue connecting to chimney | feet | 12½ |
| Least flue area in boiler | square feet | 0.495 |
| Ratio of smallest flue area to grate surface | per cent | 8.23 |
| Kind of draft | | Natural. |
| Direct water-heating surface | square feet | 21.89 |
| Indirect water-heating surface | do | 53.98 |
| Superheating surface | do | None. |
| Total heating surface | do | 75.87 |
| Ratio of direct-heating surface to total | per cent | 28.9 |
| Ratio of total heating surface to grate surface | | 12.6 to 1 |
| Total water and steam space | cubic feet | 11.16 |
| Steam space | do | 3.28 |
| Water space | do | 7.88 |
| Area of external boiler surface in contact with water or steam | square feet | 103.27 |
| Smoke outlet above grate | feet | 3 |
| Diameter of flue | inches | 14 |

The equipment of these small boilers for experiments necessitated an especially devised method of supplying feed water and of controlling the load demand.

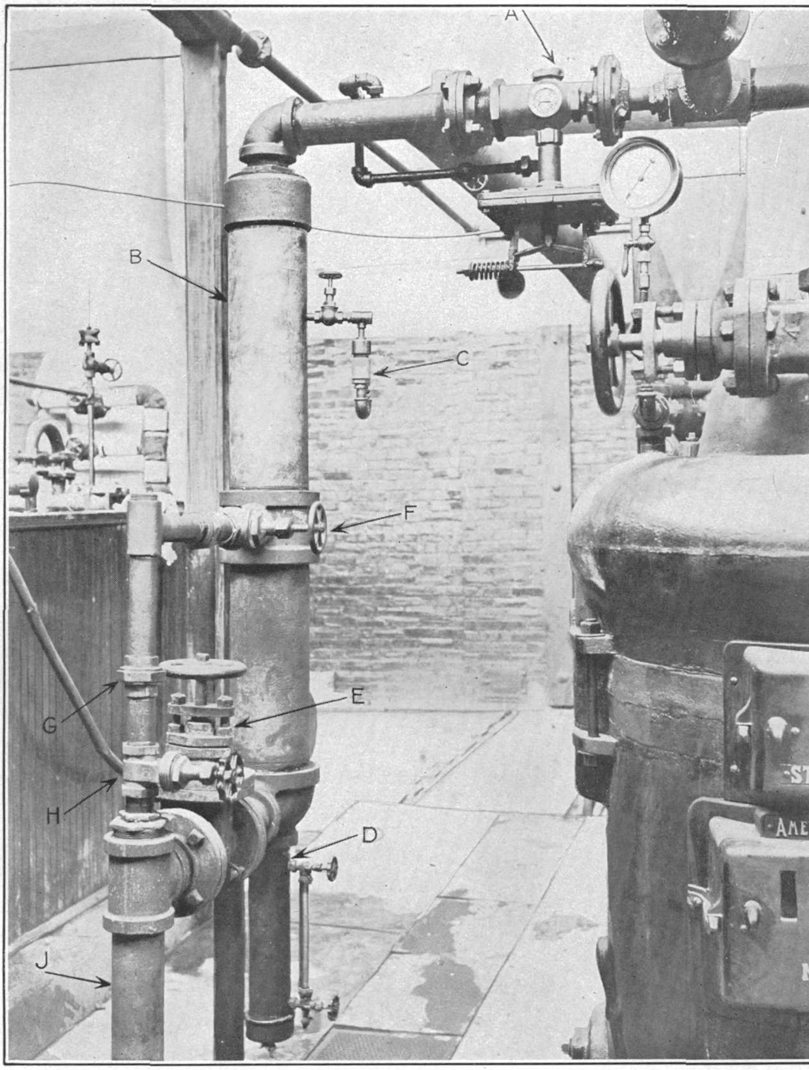
As the condensation return had to be intercepted for the purpose of weighing or measuring the feed water, the usual method of returning the condensed steam by gravity could not be used and other means had to be provided for forcing the water back into the boiler. A number of methods might have been used provided care was taken to insure steady feeding. The decision to adopt the system by which the feed water is forced from the measuring tanks into the boiler with compressed air was influenced to some degree by the temporary necessity of procuring condensation water from the heating coils. As all of the apparatus is located on the same level, this system has proved convenient and satisfactory.

The tanks used are ordinary galvanized-iron range tanks. One supply tank, with a capacity of 54 gallons, is connected directly in the return from the heating coils. The inlet pipe is at the bottom and the outlet at the top, so that the tank is always filled with hot water. The measuring tanks, or feed tanks, one for each boiler, have a capacity of 35 gallons each and are fitted with gage glasses and scales graduated to read pounds direct, correction being made for varying temperatures. An overflow pipe, with valve, placed at the top of the scale, allows filling the tank with a definite charge of water.

These tanks, as stated above, are connected with the compressed-air system and during feeding are under pressure sufficient to force the water into the boilers, a ½-inch needle valve near the boiler allowing close regulation of the feed. The heating system is under 3 to 5 pounds pressure, so that the measuring tanks are rapidly filled by simply opening a valve leading to the supply tank. The air pressure and boiler are cut off and the overflow is opened during charging.

Facility of controlling the rate of combustion is important when comparative studies of fuels are to be made. However, as these small heating boilers are designed to regulate themselves, under control of their automatic damper regulators, the rate of combustion may be kept fairly even by keeping the rate of evaporation constant. This has been accomplished at Urbana by the use of a pressure regulator, by which a steady flow of steam is discharged from a constant-pressure receiver through a suitable orifice into the atmosphere, provision being made for varying the load to suit the specific demand of the test. The receivers perform the duties of separators and are thus used to replace the usual steam calorimeter; for this reason the receivers and pipes are heavily lagged with 1 inch of hair felt laid next to the iron and above this 1 inch of magnesia pipe covering.

Pl. II shows one of the load regulators with its covering removed. The steam from the boiler passes through the pressure regu-




LOAD REGULATOR AT HOUSE-HEATING BOILER PLANT AT URBANA, ILL.

See text for explanation of reference letters.

lator A into a 3-inch pipe which extends through the top of the receiver and nearly to the reducing tee at the bottom. Here the direction of the steam is changed and the entrained moisture separated, the dry steam passing up and out through the valve F to the exhaust main J, through an orifice plate in the 2-inch union G, the pipe J being open to the atmosphere. Pressure in the receiver is indicated by a mercury manometer at C, and another manometer (not shown) gives the back pressure in the pipe J, which is always under a slight pressure due to friction. The latter manometer is used to assist in adjusting the difference of pressure on the orifice. No attempt is made to compute the evaporation in this manner. The moisture separated from the steam collects in the 3-inch trap pipe D, the amount being indicated in pounds and fractions on the gage glass. Some moisture originally in the steam is of course evaporated in passing the reducing valve, consequently corrections of computed results for quality of steam and conversion to equivalent evaporation from and at 212° are made on the basis of the mean pressure maintained in the receiver—usually about 2 pounds.

Variation in load is obtained by the introduction of suitable orifices. The by-pass valve E allows changes to be made during operation, the orifices simply taking the place of a gasket in the union.

## METHOD OF CONDUCTING TESTS.

### TESTS AT ST. LOUIS.

The tests on the structural-materials laboratory boiler at St. Louis were made as nearly as possible under the actual running conditions of the average house-heating boiler plant. Steam was supplied to two buildings for heating, and consequently the load varied with the weather conditions—the temperature of the outside air and the velocity of the wind. On only a few of the tests was the heating load so light that steam was turned into the atmosphere.

Most of the tests covered a period of about eight hours; during this time the operator tried to maintain a steam pressure of about 3 pounds.

The alternate method, as prescribed by the American Society of Mechanical Engineers code for making boiler trials, was used in starting and stopping the tests. The boiler was installed in so small a room that the standard method of starting and stopping was not practicable. Each test was started with a fire about 4 inches thick. This thickness was gradually increased to a maximum of 12 to 18 inches, depending on the kind of coal burned and on the judgment of the operator as to the best thickness for good combustion. To start a test with a 4-inch fuel bed required that the boiler should be fired with the same kind of coal as was used on the test for about four hours before beginning the test. In building up the fire and in burning it down for a close light firing was used. At other times during the tests the charges of coal were considerably greater. Coal was fired whenever the heat requirements demanded it, usually at a time when the fire had burned down and the steam pressure had dropped. The fresh coal was spread over the entire fuel bed. The fire seldom required any attention, and it was never poked unless a coal in burning caked badly. On the tests the fire was cleaned only just before starting and stopping, except in two or three tests when there was an unusually large accumulation of clinker upon the grate.

Readings were taken of draft, temperature, and steam pressure every thirty minutes. Smoke readings were taken as soon after coal was fired as other observations would permit, and at intervals thereafter until the volatile matter had distilled and no smoke was given off from the stack.

Owing to the many duties of the observer there was difficulty in procuring and analyzing representative samples of flue gas, but the results are considered of sufficient accuracy to indicate certain general relations between the air supply and the performance of the boiler. All gas samples analyzed showed some CO. This was to be expected, for the combustion was never complete on any of the tests, as could be seen by watching the top of the stack.

Smoke observations showed black smoke, comparable with the Ringelmann charts, at the times of firing and for several minutes afterwards, gradually turning to gray. This is of interest, owing to the fact that the gases resulting from the combustion of briquets at the Urbana station were as a rule of dirty yellowish color, and not comparable with the usual standards.

All briquets were fired whole. Shortly after they were fired the tar distilled and condensed on the boiler surface, forming a covering over the flue passages. When the fire was allowed to burn freely the coating on the flues ignited. In many tests this happened two or three times during an eight-hour run, and increased the temperature in the flue to a maximum of 1,500° F. On this account a thermocouple was used to take the temperature of the stack gases.

The flue passages were not brushed during the tests with briquets, as the burning of the tar effectually cleaned the boiler surfaces. In some tests the tar coating without doubt greatly lowered the efficiency of the boiler. It will be noted that the coal burned raw gave better results than when briquetted.

The furnace door was opened only at times of firing. On a few special briquet tests an attempt was made to reduce the smoke after firings by opening the slide draft in the furnace door, but either there was not enough air or it was admitted at the wrong point, for no appreciable reduction of smoke resulted. No attempt was made to introduce air over the fire in the regular series of tests.

The analyses of the fuel burned and of the refuse were made at the chemical laboratory of the fuel-testing plant.

## TESTS AT URBANA.

The plan for the tests at Urbana was as follows: (1) The load to be maintained between 60 and 70 per cent of the builders' rated capacity; (2) the load to be uniform throughout the test; (3) a steam pressure of 2 pounds to be carried on the heating system; (4) a definite charge of coal to be supplied at each firing; (5) each test to be of approximately eight hours' duration.

The standard method of starting and stopping the tests, as prescribed by the American Society of Mechanical Engineers, was used. A steam pressure of 5 pounds was maintained in the boiler for thirty to forty minutes before starting. At the start the ashes and the partly burned coal were rapidly removed and a weighed amount of wood was ignited; this operation required about three minutes, during which the steam pressure dropped from 5 pounds to 1 pound. As soon as the wood was lighted a signal was given to start the test and readings of time, water level, and pressures were taken. As soon as the wood was burning well a charge of about 25 pounds of coal was fired. In eight to ten minutes, when the coal was well ignited, the rest of a 75-pound car of coal was fired. The fire was not touched during the remainder of the test, except at times when the steam pressure fell below 5 pounds. When this occurred the fire was poked and raked and another 75-pound firing was made.

The following readings were taken every fifteen minutes: Height of water in boiler, height of water in tank, temperature of feed water, boiler-room temperature, steam pressure, pressure beyond reducing valve, back pressure in separator, height of water in separator, and drafts in ash pit, over the fire, and in the flue.

The air supply was taken entirely through the ash-pit door. On some of the tests it might have been advisable to admit a part of the air used for combustion continuously over the fire through the furnace door, or it might have been possible to increase the over-all efficiency of the boiler by admitting air over the fire for a few minutes after each firing by cracking the furnace door; but as such a procedure is not commercially practicable, no attempt was made to prove its effect.

As the duration of the trials was to be approximately eight hours, just enough coal was put on at the last firing to keep up 5 pounds steam pressure until time to close the test. When the steam pressure dropped below 5 pounds on the last firing, the grate was dumped and the unburned coal was rapidly placed in a can having a tight-fitting cover which prevented further combustion. This unburned fuel removed at the close of the test, known as the residual fuel, was weighed separately from the ash that accumulated during the test. The ash and refuse from the coal were completely removed before the grates were dumped to clean them of the residual fuel. Just as the grates were dumped the final readings of time, water level, and pressures were taken.

The boiler flues were blown after the close of every test, so that the heat developed had an equal chance on the heating surface at the start of each test; however, on some of the trials more soot was formed than on others and the heating surface on these trials was therefore much less effective at the close than at the start.

The chemical analyses were made at the University of Illinois laboratory.

## DATA AND RESULTS.

The principal items of the tables were calculated as indicated in the following formulas:

21.1. $\text{Coal}+0.4\times\text{wood}$

21.2. $\text{Item } 21.1-\dfrac{\text{refuse}\times\text{per cent carbon}\times 14{,}600}{\text{item } 46}$

23. $\text{Item } 21.1\times(100-\text{moisture})$

23.1. $\text{Item } 23-\dfrac{\text{refuse}\times\text{per cent carbon}\times 14{,}600}{\text{item } 45}$

23.2. $\text{Item } 23.1-\dfrac{\text{ash}\times\text{per cent carbon}\times 14{,}600}{\text{item } 45}$

43. $\dfrac{\text{Item } 23.1}{\text{time}}$

44. $\dfrac{\text{Item } 43}{\text{grate}}$

46. $\text{Item } 45\times(100-\text{moisture})$

47. $\dfrac{\text{Separated water}}{\text{item } 49}$

49. Water fed

50. $\text{Item } 49\times\text{item } 48$

51. From Kent's Pocket Book

52. $\text{Item } 50\times\text{item } 51$

53. $\dfrac{\text{Item } 52}{\text{time}}$

54. $\dfrac{\text{Item } 53}{\text{heat surface}}$

55. $\dfrac{\text{Item } 53}{0.3}$

55.1. $\text{Item } 55+\text{surface}$

56. $\dfrac{\text{Item } 55}{\text{rating}}$

57. $\dfrac{\text{Item } 55}{\text{item } 21.2}$

58. $\dfrac{\text{Item } 52}{\text{item } 23.2}$

59. $\dfrac{\text{Item } 21.2\times 100}{\text{time}\times\text{item } 55}$

60. $\dfrac{\text{Item } 43\times 100}{\text{item } 55}$

61. $\dfrac{\text{Item } 58}{\text{item } 45}\times 96{,}580$

62. $\dfrac{\text{Item } 57}{\text{item } 46}\times 96{,}580$

64. $\dfrac{\text{Item } 63\times\text{item } 59}{2{,}000}=\dfrac{\text{item } 59}{20}$

65. $\dfrac{\text{Item } 63\times 100}{2{,}000\times\text{item } 57}=\dfrac{100}{2\times\text{item } 57}$

## RESULTS AT ST. LOUIS.

The results of the tests at St. Louis are given in Table 2.

TABLE 2.—*Tests of fuel in house-heating boiler at St. Louis.*

| Test No. | Designation of fuel. | Description of fuel. | Duration of trial (hours). | Average pressures. | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Steam pressure in boiler (gage). | Barometer (pounds per square inch). | Draft (inch of water). | | |
| | | | | | | Between damper and boiler. | Over fire. | In ash pit. |
| | | | 1 | 10 | 11.1 | 12 | 13 | 13.1 |
| 45 | Arkansas No. 13 | Briquets, round | 8.33 | 2.2 | 14.39 | 0.34 | 0.07 | 0.04 |
| 58 | Illinois No. 1 | Coal, run of mine | 7.92 | 1.9 | 14.36 | .33 | .07 | .03 |
| 59 | do | do | 8.00 | 1.9 | 14.45 | .36 | .05 | .03 |
| 48 | Illinois No. 7 E | Briquets, round | 8.00 | 1.7 | 14.45 | .33 | .06 | .03 |
| 39 | Illinois No. 9 C | do | 8.30 | 1.7 | 14.54 | .36 | .07 | .04 |
| 13 | Illinois No. 12 BW | Briquets, square, slack | 8.25 | 3.8 | 14.39 | .21 | .06 | .05 |
| 52 | Illinois No. 19 E | Coal, egg | 7.80 | 2.4 | 14.56 | .31 | .03 | .03 |
| 53 | do | do | 8.25 | 2.3 | 14.41 | .35 | .05 | .04 |
| 54 | do | do | 8.06 | 2.1 | 14.30 | .32 | .03 | .02 |
| 55 | do | do | 7.83 | 1.3 | 14.35 | .36 | .03 | .02 |
| 9 | Illinois No. 29 AW | Briquets, round | 7.88 | 3.4 | 14.46 | .24 | .10 | .06 |
| 12 | Illinois No. 29 B | Briquets, round, slack | 7.20 | 2.2 | 14.51 | .23 | .08 | .07 |
| 33 | Illinois No. 31 | Briquets, square | 7.83 | 2.7 | 14.37 | .29 | .13 | .10 |
| 34 | do | do | 8.08 | 2.9 | 14.34 | .28 | .10 | .06 |
| 44 | do | Briquets, round | 8.33 | 1.8 | 14.40 | .36 | .07 | .04 |
| 43 | Illinois No. 33 | do | 7.83 | 2.2 | 14.34 | .32 | .08 | .05 |
| 37 | Indiana No. 1 B | do | 8.33 | 2.4 | 14.60 | .35 | .13 | .07 |
| 36 | Indiana No. 5 B | do | 8.41 | 2.7 | 14.26 | .34 | .13 | .08 |
| 38 | Indiana No. 6 B | Briquets, square | 7.88 | 2.8 | 14.64 | .35 | .09 | .06 |
| 10 | Indian Territory No. 2 BW | Briquets, square, slack | 7.92 | 3.3 | 14.59 | .25 | .12 | ...... |
| 11 | Indian Territory No. 2 B | Briquets, round, slack | 7.87 | 4.3 | 14.51 | .22 | .05 | .04 |
| 1 | Kansas No. 2 B | do | 8.00 | 4.1 | 14.46 | .22 | .05 | .03 |
| 40 | do | Briquets, square | 8.25 | 2.5 | 14.36 | .36 | .09 | .06 |
| 21 | Maryland No. 2 | Briquets, round | 8.00 | 2.9 | 14.65 | .28 | .12 | .09 |
| 22 | do | do | 7.50 | 3.2 | 14.55 | .23 | .11 | .10 |
| 23 | do | do | 8.00 | 3.6 | 14.51 | .23 | .11 | .10 |
| 20 | do | Coal, run of mine | 7.88 | 2.2 | 14.52 | .25 | .13 | .09 |
| 2 | Missouri No. 10 | Briquets, round, slack | 7.66 | 3.4 | 14.68 | .24 | .04 | .03 |
| 3 | do | do | 7.83 | 3.1 | 14.46 | .21 | .07 | .05 |
| 4 | do | do | 7.82 | 3.2 | 14.54 | .25 | .08 | .06 |
| 5 | do | do | 8.13 | 2.0 | 14.59 | .26 | .10 | .05 |
| 28 | Pennsylvania No. 18 | Briquets, round | 8.00 | 3.9 | 14.37 | .18 | .09 | .08 |
| 29 | do | do | 8.00 | 4.6 | 14.44 | .18 | .07 | .06 |
| 30 | do | Briquets, square | 7.70 | 3.3 | 14.51 | .22 | .11 | .10 |
| 31 | do | do | 8.00 | 3.4 | 14.60 | .29 | .12 | .10 |
| 46 | do | do | 8.13 | 2.1 | 14.40 | .36 | .03 | .01 |
| 24 | do | Coal, run of mine | 8.00 | 3.0 | 14.55 | .22 | .10 | .09 |
| 25 | do | do | 8.00 | 3.1 | 14.41 | .22 | .13 | ...... |
| 32 | Pennsylvania No. 19 | Briquets, round | 6.58 | 3.6 | 14.33 | .27 | .11 | .07 |
| 15 | do | Coal, run of mine | 7.50 | 3.4 | 14.43 | .23 | .11 | .10 |
| 26 | Pennsylvania No. 20 | Briquets, square | 8.00 | 3.4 | 14.48 | .23 | .12 | ...... |
| 27 | do | do | 8.00 | 3.3 | 14.40 | .22 | .11 | ...... |
| 41 | Pennsylvania No. 20 W | Briquets, round | 7.81 | 3.3 | 14.30 | .32 | .07 | .06 |
| 42 | do | do | 5.20 | 2.9 | 14.32 | .33 | .09 | .08 |
| 16 | Pennsylvania No. 22 | do | 7.83 | 3.7 | 14.46 | .22 | .11 | .08 |
| 17 | do | do | 8.08 | 3.5 | 14.28 | .21 | .09 | .08 |
| 18 | do | Briquets, square | 8.00 | 1.6 | 14.36 | .23 | .09 | .07 |
| 19 | do | do | 8.05 | 2.4 | 14.36 | .23 | .12 | .11 |
| 14 | do | Coal, run of mine | 7.58 | 3.8 | 14.55 | .23 | .10 | .07 |
| 47 | Pennsylvania No. 15 (one-half) and Rhode Island No. 1 (one-half). | Briquets, round | 8.23 | 2.0 | 14.51 | .34 | .07 | .03 |
| 56 | Pennsylvania No. 18 (one-fourth) and Miscellaneous No. 9 (three-fourths). | do | 8.16 | 1.6 | 14.38 | .34 | .04 | .02 |
| 57 | do | do | 7.00 | 2.2 | 14.47 | .36 | .07 | .04 |
| 35 | Pennsylvania No. 18 (one-half) and Rhode Island No. 1 (one-half). | do | 5.66 | 3.2 | 14.31 | .29 | .10 | .07 |
| 49 | Pennsylvania No. 18 (three-fourths) and Miscellaneous No. 9 (one-fourth) | do | 8.23 | 3.0 | 14.45 | .30 | .06 | .04 |
| 50 | Pennsylvania No. 18 (one-half) and Miscellaneous No. 9 (one-half). | do | 7.83 | 2.2 | 14.40 | .34 | .07 | .04 |
| 51 | do | do | 8.00 | 2.5 | 14.46 | .33 | .04 | .02 |
| 7 | Virginia No. 5 B | do | 8.00 | 3.6 | 14.46 | .24 | .12 | .10 |
| 8 | do | do | 7.80 | 4.8 | 14.35 | .19 | .09 | .07 |

TABLE 2.—*Tests of fuel in house-heating boiler at St. Louis*—Continued.

| Test No. | Designation of fuel. | Average temperatures (°F.). External air. | Average temperatures (°F.). Boiler room. | Average temperatures (°F.). Feed water in weigh tank. | Average temperatures (°F.). Gases escaping from boiler. | Fuel as fired (pounds). | Dry fuel (pounds). | Total dry fuel fired minus dry fuel equivalent to the carbon in the ash (pounds). | Total ash and refuse from ash pit (pounds). |
|---|---|---|---|---|---|---|---|---|---|
| | | 14 | 15 | 16 | 17 | 21 | 23 | 23.2 | 24 |
| 45 | Arkansas No. 13 | 50 | 81 | 145 | 695 | 777 | 765 | 731 | 137 |
| 58 | Illinois No. 1 | 64 | 88 | 121 | 710 | 854 | 739 | 706 | 151 |
| 59 | ....do | 46 | 73 | 126 | 720 | 874 | 756 | 728 | 128 |
| 48 | Illinois No. 7 E | 45 | 77 | 141 | 650 | 965 | 907 | 874 | 237 |
| 39 | Illinois No. 9 C | 58 | 83 | 137 | 855 | 871 | 824 | 789 | 195 |
| 13 | Illinois No. 12 BW | 69 | 92 | 143 | ........ | 666 | 613 | 587 | 98 |
| 52 | Illinois No. 19 E | 59 | 88 | 138 | 600 | 817 | 757 | 727 | 114 |
| 53 | ....do | 66 | 88 | 128 | 720 | 927 | 859 | 827 | 122 |
| 54 | ....do | 62 | 85 | 135 | 635 | 811 | 752 | 725 | 104 |
| 55 | ....do | 72 | 93 | 123 | 850 | 764 | 708 | 685 | 87 |
| 9 | Illinois No. 29 AW | 31 | 70 | 149 | ........ | 750 | 658 | 648 | 68 |
| 12 | Illinois No. 29 B | 46 | 79 | 147 | ........ | 735 | 688 | 671 | 106 |
| 33 | Illinois No. 31 | 80 | 91 | 106 | 570 | 813 | 738 | 725 | 112 |
| 34 | ....do | 82 | 96 | 101 | 400 | 836 | 759 | 743 | 139 |
| 44 | ....do | 51 | 82 | 138 | 795 | 968 | 901 | 880 | 144 |
| 43 | Illinois No. 33 | 50 | 81 | 146 | 600 | 974 | 882 | 761 | 333 |
| 37 | Indiana No. 1 B | 57 | 91 | 120 | 815 | 1,104 | 1,056 | 1,037 | 120 |
| 36 | Indiana No. 5 B | 63 | 90 | 103 | 730 | 929 | 890 | 868 | 134 |
| 38 | Indiana No. 6 B | 45 | 82 | 140 | 715 | 815 | 768 | 750 | 144 |
| 10 | Indian Territory No. 2 BW | 33 | 71 | 150 | ........ | 736 | 720 | 686 | 100 |
| 11 | Indian Territory No. 2 B | 42 | 76 | 158 | ........ | 737 | 721 | 700 | 126 |
| 1 | Kansas No. 2 B | 40 | 72 | 145 | ........ | 667 | 648 | ........ | 113 |
| 40 | ....do | 48 | 84 | 135 | 665 | 800 | 772 | 743 | 172 |
| 21 | Maryland No. 2 | 31 | 74 | 150 | ........ | 652 | 628 | 612 | 73 |
| 22 | ....do | 30 | 80 | 146 | ........ | 560 | 540 | 534 | 28 |
| 23 | ....do | 41 | 73 | 143 | ........ | 650 | 626 | 611 | 67 |
| 20 | ....do | 32 | 71 | 144 | ........ | 520 | 511 | 502 | 34 |
| 2 | Missouri No. 10 | 32 | 70 | 151 | ........ | 1,159 | 1,031 | 986 | 258 |
| 3 | ....do | 57 | 83 | 149 | ........ | 769 | 684 | 651 | 189 |
| 4 | ....do | 27 | 69 | 139 | ........ | 819 | 729 | 695 | 193 |
| 5 | ....do | 18 | 67 | 154 | ........ | 1,036 | 922 | 898 | 136 |
| 28 | Pennsylvania No. 18 | 46 | 81 | 140 | ........ | 580 | 537 | 531 | 37 |
| 29 | ....do | 54 | 85 | 144 | ........ | 652 | 604 | 598 | 34 |
| 30 | ....do | 42 | 83 | 146 | ........ | 525 | 500 | 496 | 31 |
| 31 | ....do | 58 | 81 | 146 | 550 | 550 | 524 | 516 | 68 |
| 46 | ....do | 44 | 80 | 133 | 685 | 653 | 636 | 610 | 110 |
| 24 | ....do | 43 | 78 | 144 | ........ | 550 | 539 | 527 | 47 |
| 25 | ....do | 42 | 74 | 145 | ........ | 550 | 530 | 518 | 47 |
| 32 | Pennsylvania No. 19 | 86 | 96 | 112 | 675 | 541 | 532 | 527 | 41 |
| 15 | ....do | 55 | 85 | 142 | ........ | 456 | 447 | 438 | 27 |
| 26 | Pennsylvania No. 20 | 44 | 77 | 145 | ........ | 525 | 493 | 484 | 55 |
| 27 | ....do | 52 | 85 | 141 | ........ | 550 | 516 | 508 | 48 |
| 41 | Pennsylvania No. 20 W | 48 | 84 | 146 | 570 | 594 | 587 | 577 | 56 |
| 42 | ....do | 45 | 76 | 134 | 620 | 388 | 383 | 374 | 53 |
| 16 | Pennsylvania No. 22 | 48 | 78 | 141 | ........ | 550 | 538 | 520 | 117 |
| 17 | ....do | 63 | ...... | 138 | ........ | 538 | 526 | 515 | 72 |
| 18 | ....do | 47 | 79 | 140 | ........ | 553 | 533 | 503 | 92 |
| 19 | ....do | 46 | 77 | 140 | ........ | 551 | 531 | 504 | 84 |
| 14 | ....do | 47 | 81 | 144 | ........ | 492 | 483 | 459 | 97 |
| 47 | Pennsylvania No. 15 (one-half) and Rhode Island No. 1 (one-half) | 45 | 77 | 147 | 665 | 652 | 647 | 616 | 112 |
| 56 | Pennsylvania No. 18 (one-fourth) and Miscellaneous No. 9 (three-fourths) | 50 | 80 | 126 | 800 | 644 | 637 | 606 | 112 |
| 57 | ....do | 53 | 83 | 125 | 730 | 652 | 645 | 613 | 117 |
| 35 | Pennsylvania No. 18 (one-half) and Rhode Island No. 1 (one-half) | 84 | 99 | 102 | 705 | 489 | 482 | 475 | 46 |
| 49 | Pennsylvania No. 18 (three-fourths) and Miscellaneous No. 9 (one-fourth) | 47 | 79 | 142 | 550 | 648 | 636 | 609 | 130 |
| 50 | Pennsylvania No. 18 (one-half) and miscellaneous No. 9 (one-half) | 47 | 80 | 140 | 630 | 646 | 638 | 596 | 133 |
| 51 | ....do | 49 | 79 | 139 | 620 | 651 | 643 | 598 | 142 |
| 7 | Virginia No. 5 B | 37 | 72 | 157 | ........ | 712 | 680 | 639 | 154 |
| 8 | ....do | 45 | 77 | 155 | ........ | 613 | 585 | 549 | 134 |

TABLE 2.—*Tests of fuel in house-heating boiler at St. Louis*—Continued.

| Test No. | Designation of fuel. | Proximate analysis of fuel as fired (per cent). | | | | Ultimate analysis of dry fuel (per cent). | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fixed carbon. | Volatile matter. | Moisture. | Ash. | Carbon. | Hydrogen. | Oxygen. | Nitrogen. | Sulphur. | Ash. |
| | | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 |
| 45 | Arkansas No. 13 | 68.30 | 15.11 | 1.49 | 15.10 | 75.05 | 3.84 | 1.81 | 1.35 | 2.62 | 15.33 |
| 58 | Illinois No. 1 | 41.39 | 33.15 | 13.49 | 11.97 | 64.88 | 4.45 | 10.71 | 1.03 | 5.09 | 13.84 |
| 59 | ....do | 41.39 | 33.15 | 13.49 | 11.97 | 64.88 | 4.45 | 10.71 | 1.03 | 5.09 | 13.84 |
| 48 | Illinois No. 7 E | 40.34 | 30.09 | 6.06 | 23.51 | 59.48 | 3.54 | 5.70 | .83 | 5.42 | 25.03 |
| 39 | Illinois No. 9 C | 47.63 | 33.55 | 5.43 | 13.39 | 68.44 | 4.44 | 8.30 | .94 | 3.72 | 14.16 |
| 13 | Illinois No. 12 BW | 49.47 | 31.55 | 7.93 | 11.05 | 71.14 | 4.39 | 8.90 | 1.12 | 2.45 | 12.00 |
| 52 | Illinois No. 19 E | 51.22 | 31.00 | 7.33 | 10.45 | ...... | ...... | ...... | ...... | 2.76 | ...... |
| 53 | ....do | 51.22 | 31.00 | 7.33 | 10.45 | ...... | ...... | ...... | ...... | 2.76 | ...... |
| 54 | ....do | 51.22 | 31.00 | 7.33 | 10.45 | ...... | ...... | ...... | ...... | 2.76 | ...... |
| 55 | ....do | 51.22 | 31.00 | 7.33 | 10.45 | ...... | ...... | ...... | ...... | 2.76 | ...... |
| 9 | Illinois No. 29 AW | 43.99 | 37.16 | 12.29 | 6.56 | 72.22 | 4.92 | 10.25 | 1.07 | 4.06 | 7.48 |
| 12 | Illinois No. 29 B | 44.21 | 37.44 | 6.42 | 11.93 | 67.10 | 4.59 | 10.30 | 1.00 | 4.26 | 12.75 |
| 33 | Illinois No. 31 | 43.90 | 33.03 | 9.17 | 13.90 | 66.14 | 4.33 | 8.93 | 1.01 | 4.29 | 15.30 |
| 34 | ....do | 43.90 | 33.03 | 9.17 | 13.90 | 66.14 | 4.33 | 8.93 | 1.01 | 4.29 | 15.30 |
| 44 | ....do | 42.85 | 35.21 | 6.98 | 14.96 | 66.75 | 4.85 | 7.33 | .93 | 4.06 | 16.08 |
| 43 | Illinois No. 33 | 40.75 | 28.25 | 9.47 | 21.53 | 60.07 | 3.93 | 9.47 | 1.03 | 1.72 | 23.78 |
| 37 | Indiana No. 1 B | 44.78 | 36.21 | 4.34 | 14.67 | 65.26 | 4.58 | 10.84 | 1.20 | 2.78 | 15.34 |
| 36 | Indiana No. 5 B | 48.91 | 35.74 | 4.20 | 11.15 | 70.47 | 4.85 | 7.53 | .94 | 4.57 | 11.64 |
| 38 | Indiana No. 6 B | 43.16 | 37.83 | 5.72 | 13.29 | 66.48 | 4.76 | 8.42 | 1.07 | 5.17 | 14.10 |
| 10 | Indian Territory No. 2 BW | 54.51 | 35.86 | 2.19 | 7.44 | 75.69 | 4.84 | 8.76 | 1.53 | 1.57 | 7.61 |
| 11 | Indian Territory No. 2 B | 51.31 | 34.60 | 2.15 | 11.94 | 71.96 | 4.56 | 8.09 | 1.45 | 1.74 | 12.20 |
| 1 | Kansas No. 2 B | 46.78 | 31.67 | 2.78 | 18.77 | 66.00 | 4.35 | 4.90 | .96 | 4.48 | 19.31 |
| 40 | ....do | 47.58 | 29.09 | 3.47 | 19.86 | 63.78 | 4.01 | 5.92 | 1.03 | 4.69 | 20.57 |
| 21 | Maryland No. 2 | 68.54 | 21.14 | 3.63 | 6.69 | 82.41 | 4.74 | 3.40 | 1.62 | .89 | 6.94 |
| 22 | ....do | 68.54 | 21.14 | 3.63 | 6.69 | 82.41 | 4.74 | 3.40 | 1.62 | .89 | 6.94 |
| 23 | ....do | 68.54 | 21.14 | 3.63 | 6.69 | 82.41 | 4.74 | 3.40 | 1.62 | .89 | 6.94 |
| 20 | ....do | 71.25 | 18.69 | 1.69 | 8.37 | ...... | ...... | ...... | ...... | .92 | ...... |
| 2 | Missouri No. 10 | 38.67 | 32.24 | 11.03 | 18.06 | ...... | ...... | ...... | ...... | 4.18 | ...... |
| 3 | ....do | 38.67 | 32.24 | 11.03 | 18.06 | ...... | ...... | ...... | ...... | 4.18 | ...... |
| 4 | ....do | 38.67 | 32.24 | 11.03 | 18.06 | ...... | ...... | ...... | ...... | 4.18 | ...... |
| 5 | ....do | 38.67 | 32.24 | 11.03 | 18.06 | ...... | ...... | ...... | ...... | 4.18 | ...... |
| 28 | Pennsylvania No. 18 | 64.61 | 19.45 | 7.43 | 8.51 | 80.80 | 4.44 | 2.88 | 1.16 | 1.53 | 9.19 |
| 29 | ....do | 64.61 | 19.45 | 7.43 | 8.51 | 80.80 | 4.44 | 2.88 | 1.16 | 1.53 | 9.19 |
| 30 | ....do | 69.14 | 18.43 | 4.71 | 7.72 | 81.77 | 4.40 | 3.22 | 1.26 | 1.25 | 8.10 |
| 31 | ....do | 69.14 | 18.43 | 4.71 | 7.72 | 81.77 | 4.40 | 3.22 | 1.26 | 1.25 | 8.10 |
| 46 | ....do | 62.80 | 24.23 | 2.55 | 10.42 | 78.65 | 4.36 | 3.38 | .88 | 2.04 | 10.69 |
| 24 | ....do | 71.55 | 16.71 | 1.96 | 9.82 | ...... | ...... | ...... | ...... | 1.91 | ...... |
| 25 | ....do | 71.88 | 16.46 | 3.56 | 8.10 | ...... | ...... | ...... | ...... | 1.76 | ...... |
| 32 | Pennsylvania No. 19 | 55.24 | 33.50 | 1.75 | 9.51 | 75.91 | 4.52 | 7.16 | 1.35 | 1.38 | 9.68 |
| 15 | ....do | 57.20 | 31.71 | 2.03 | 9.06 | ...... | ...... | ...... | ...... | 1.15 | ...... |
| 26 | Pennsylvania No. 20 | 64.38 | 19.23 | 6.16 | 10.23 | 78.13 | 4.20 | 2.83 | 1.09 | 2.85 | 10.90 |
| 27 | ....do | 64.38 | 19.23 | 6.16 | 10.23 | 78.13 | 4.20 | 2.83 | 1.09 | 2.85 | 10.90 |
| 41 | Pennsylvania No. 20 W | 67.74 | 20.58 | 1.23 | 10.45 | 79.20 | 4.56 | 1.52 | 1.12 | 3.02 | 10.58 |
| 42 | ....do | 67.74 | 20.58 | 1.23 | 10.45 | 79.20 | 4.56 | 1.52 | 1.12 | 3.02 | 10.58 |
| 16 | Pennsylvania No. 22 | 55.12 | 32.11 | 2.21 | 10.56 | 75.72 | 4.52 | 6.41 | 1.39 | 1.16 | 10.80 |
| 17 | ....do | 55.12 | 32.11 | 2.21 | 10.56 | 75.72 | 4.52 | 6.41 | 1.39 | 1.16 | 10.80 |
| 18 | ....do | 54.27 | 30.57 | 3.55 | 11.61 | 75.93 | 4.58 | 5.10 | 1.24 | 1.11 | 12.04 |
| 19 | ....do | 54.27 | 30.57 | 3.55 | 11.61 | 75.93 | 4.58 | 5.10 | 1.24 | 1.11 | 12.04 |
| 14 | ....do | 57.96 | 29.45 | 1.77 | 10.82 | ...... | ...... | ...... | ...... | .90 | ...... |
| 47 | Pennsylvania No. 15 (one-half) and Rhode Island No. 1 (one-half) | 69.71 | 15.96 | .74 | 13.59 | 77.47 | 3.05 | 2.66 | .49 | 2.64 | 13.69 |
| 56 | Pennsylvania No. 18 (one-fourth) and Miscellaneous No. 9 (three-fourths) | 69.24 | 15.87 | 1.06 | 13.83 | 76.03 | 2.81 | 4.92 | .81 | 1.45 | 13.98 |
| 57 | ....do | 69.24 | 15.87 | 1.06 | 13.83 | 76.03 | 2.81 | 4.92 | .81 | 1.45 | 13.98 |
| 35 | Pennsylvania No. 18 (one-half) and Rhode Island No. 1 (one-half) | 70.34 | 16.39 | 1.34 | 11.93 | 77.79 | 3.46 | 4.74 | .53 | 1.39 | 12.09 |
| 49 | Pennsylvania No. 18 (three-fourths) and Miscellaneous No. 9 (one-fourth) | 69.52 | 15.05 | 1.83 | 13.60 | 77.21 | 3.12 | 3.48 | .70 | 1.64 | 13.85 |
| 50 | Pennsylvania No. 18 (one-half) and Miscellaneous No. 9 (one-half) | 69.67 | 13.73 | 1.30 | 15.30 | 70.93 | 2.81 | 8.80 | .75 | 1.21 | 15.50 |
| 51 | ....do | 69.67 | 13.73 | 1.30 | 15.30 | 70.93 | 2.81 | 8.80 | .75 | 1.21 | 15.50 |
| 7 | Virginia No. 5 B | 65.93 | 14.28 | 4.52 | 15.27 | 76.18 | 3.67 | 2.52 | .81 | .83 | 15.99 |
| 8 | ....do | 65.93 | 14.28 | 4.52 | 15.27 | 76.18 | 3.67 | 2.52 | .81 | .83 | 15.99 |

TABLE 2.—*Tests of fuel in house-heating boiler at St. Louis*—Continued.

| Test No. | Designation of fuel. | Analysis of ash and refuse (per cent). | | Fuel per hour (pounds). | | | | British thermal units per pound of fuel. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Burned per square foot of grate surface. | | | |
| | | Carbon. | Earthy matter. | As fired. | Dry. | As fired. | Dry. | Dry. | As fired. |
| | | 37 | 38 | 43 | 43.1 | 44.1 | 44 | 45 | 46 |
| 45 | Arkansas No. 13 | 22.06 | 77.94 | 93 | 92 | 6.89 | 6.81 | 13,112 | 12,917 |
| 58 | Illinois No. 1 | 18.40 | 81.60 | 108 | 93 | 8.00 | 6.89 | 12,178 | 10,535 |
| 59 | .....do | 18.40 | 81.60 | 109 | 95 | 8.08 | 7.04 | 12,178 | 10,535 |
| 48 | Illinois No. 7 E | 10.02 | 89.98 | 121 | 113 | 8.96 | 8.37 | 10,667 | 10,021 |
| 39 | Illinois No. 9 C | 15.00 | 85.00 | 105 | 99 | 7.78 | 7.33 | 12,385 | 11,713 |
| 13 | Illinois No. 12 BW | 23.85 | 76.15 | 81 | 74 | 6.00 | 5.48 | 12,958 | 11,930 |
| 52 | Illinois No. 19 E | 22.05 | 77.95 | 105 | 97 | 7.78 | 7.18 | 12,411 | 11,501 |
| 53 | .....do | 22.05 | 77.95 | 112 | 104 | 8.30 | 7.70 | 12,411 | 11,501 |
| 54 | .....do | 22.05 | 77.95 | 101 | 93 | 7.48 | 6.89 | 12,411 | 11,501 |
| 55 | .....do | 22.05 | 77.95 | 98 | 90 | 7.26 | 6.67 | 12,411 | 11,501 |
| 9 | Illinois No. 29 AW | 13.95 | 86.05 | 95 | 84 | 7.04 | 6.22 | 13,306 | 11,671 |
| 12 | Illinois No. 29 B | 13.56 | 86.44 | 102 | 96 | 7.56 | 7.11 | 12,562 | 11,756 |
| 33 | Illinois No. 31 | 9.47 | 90.53 | 104 | 94 | 7.70 | 6.96 | 12,024 | 10,921 |
| 34 | .....do | 9.47 | 90.53 | 103 | 94 | 7.63 | 6.96 | 12,024 | 10,921 |
| 44 | .....do | 11.97 | 88.03 | 116 | 108 | 8.59 | 8.00 | 11,995 | 11,158 |
| 43 | Illinois No. 33 | 26.85 | 73.15 | 124 | 113 | 9.19 | 8.38 | 10,782 | 9,761 |
| 37 | Indiana No. 1 B | 13.13 | 86.87 | 133 | 127 | 9.86 | 9.41 | 11,907 | 11,390 |
| 36 | Indiana No. 5 B | 14.79 | 85.21 | 110 | 106 | 8.15 | 7.85 | 12,970 | 12,425 |
| 38 | Indiana No. 6 B | 10.48 | 89.52 | 103 | 97 | 7.63 | 7.18 | 12,557 | 11,839 |
| 10 | Indian Territory No. 2 BW | 32.11 | 67.89 | 93 | 91 | 6.89 | 6.74 | 13,865 | 13,561 |
| 11 | Indian Territory No. 2 B | 15.05 | 84.95 | 94 | 92 | 6.96 | 6.82 | 13,196 | 12,912 |
| 1 | Kansas No. 2 B | ...... | ...... | 83 | 81 | 6.15 | 6.00 | 12,132 | 11,795 |
| 40 | .....do | 13.53 | 86.47 | 97 | 94 | 7.18 | 6.96 | 11,855 | 11,444 |
| 21 | Maryland No. 2 | 22.64 | 77.36 | 82 | 79 | 6.08 | 5.85 | 14,694 | 14,161 |
| 22 | .....do | 22.64 | 77.36 | 75 | 71 | 5.56 | 5.26 | 14,694 | 14,161 |
| 23 | .....do | 22.64 | 77.36 | 81 | 78 | 6.00 | 5.78 | 14,694 | 14,161 |
| 20 | .....do | 27.30 | 72.70 | 66 | 65 | 4.89 | 4.82 | 14,473 | 14,229 |
| 2 | Missouri No. 10 | 13.89 | 86.11 | 151 | 135 | 11.20 | 10.00 | 11,588 | 10,310 |
| 3 | .....do | 13.89 | 86.11 | 98 | 87 | 7.26 | 6.44 | 11,588 | 10,310 |
| 4 | .....do | 13.89 | 86.11 | 105 | 93 | 7.78 | 6.89 | 11,588 | 10,310 |
| 5 | .....do | 13.89 | 86.11 | 127 | 113 | 9.41 | 8.37 | 11,588 | 10,310 |
| 28 | Pennsylvania No. 18 | 16.64 | 83.36 | 73 | 67 | 5.41 | 4.97 | 14,408 | 13,338 |
| 29 | .....do | 16.64 | 83.36 | 82 | 76 | 6.07 | 5.63 | 14,408 | 13,338 |
| 30 | .....do | 12.02 | 87.98 | 68 | 65 | 5.04 | 4.81 | 14,559 | 13,873 |
| 31 | .....do | 12.02 | 87.98 | 69 | 66 | 5.11 | 4.89 | 14.559 | 13,873 |
| 46 | .....do | 22.54 | 77.46 | 80 | 78 | 5.93 | 5.78 | 14,038 | 13,680 |
| 24 | .....do | 25.38 | 74.62 | 69 | 67 | 5.11 | 4.97 | 14,096 | 13,820 |
| 25 | .....do | 25.38 | 74.62 | 69 | 66 | 5.11 | 4.89 | 14,377 | 13,865 |
| 32 | Pennsylvania No. 19 | 10.44 | 89.56 | 82 | 81 | 6.08 | 6.00 | 13,889 | 13,646 |
| 15 | .....do | 31.05 | 68.95 | 61 | 60 | 4.52 | 4.44 | 13,996 | 13,712 |
| 26 | Pennsylvania No. 20 | 15.53 | 84.47 | 66 | 62 | 4.89 | 4.59 | 14,064 | 13,198 |
| 27 | .....do | 15.53 | 84.47 | 69 | 65 | 5.11 | 4.82 | 14,064 | 13,198 |
| 41 | Pennsylvania No. 20 W | 17.04 | 82.96 | 76 | 75 | 5.63 | 5.56 | 14,069 | 13,896 |
| 42 | .....do | 17.04 | 82.96 | 75 | 74 | 5.56 | 5.48 | 14,069 | 13,896 |
| 16 | Pennsylvania No. 22 | 15.01 | 84.99 | 70 | 69 | 5.18 | 5.11 | 13,867 | 13,561 |
| 17 | .....do | 15.01 | 84.99 | 67 | 65 | 4.96 | 4.82 | 13,867 | 13,561 |
| 18 | .....do | 30.83 | 69.17 | 69 | 67 | 5.11 | 4.96 | 13,764 | 13,275 |
| 19 | .....do | 30.83 | 69.17 | 68 | 66 | 5.04 | 4.89 | 13,764 | 13,275 |
| 14 | .....do | 22.96 | 77.04 | 65 | 64 | 4.82 | 4.74 | 13,812 | 13,568 |
| 47 | Pennsylvania No. 15 (one-half) and Rhode Island No. 1 (one-half) | 24.55 | 75.45 | 79 | 79 | 5.85 | 5.85 | 12,887 | 12,793 |
| 56 | Pennsylvania No. 18 (one-fourth) and Miscellaneous No. 9 (three-fourths) | 24.20 | 75.80 | 79 | 78 | 5.85 | 5.78 | 12,857 | 12,721 |
| 57 | .....do | 24.20 | 75.80 | 93 | 92 | 6.89 | 6.82 | 12,857 | 12,721 |
| 35 | Pennsylvania No. 18 (one-half) and Rhode Island No. 1 (one-half) | 13.89 | 86.11 | 86 | 85 | 6.37 | 6.30 | 13,569 | 13,387 |
| 49 | Pennsylvania No. 18 (three-fourths) and Miscellaneous No. 9 (one-fourth) | 19.30 | 80.70 | 79 | 77 | 5.85 | 5.70 | 13,431 | 13,185 |
| 50 | Pennsylvania No. 18 (one-half) and Miscellaneous No. 9 (one-half) | 28.05 | 71.95 | 83 | 81 | 6.15 | 6.00 | 12,955 | 12,787 |
| 51 | .....do | 28.05 | 71.95 | 81 | 80 | 6.00 | 5.92 | 12,955 | 12,787 |
| 7 | Virginia No. 5 B | 24.07 | 75.93 | 89 | 85 | 6.59 | 6.30 | 13,136 | 12,542 |
| 8 | .....do | 24.07 | 75.93 | 79 | 75 | 5.87 | 5.56 | 13,136 | 12,542 |

TABLE 2.—*Tests of fuel in house-heating boiler at St. Louis*—Continued.

| Test No. | Designation of fuel. | Water (pounds). Fed to boiler. | Water (pounds). Evaporated into dry steam from and at 212° F. | Factor of evaporation. | Equivalent evaporation per hour from and at 212° F. (pounds). | Horsepower developed. | Equivalent evaporation per hour from and at 212° F. per square foot of water heating surface (pounds). | Mean load carried (square feet of radiating surface). | Percentage of builder's rated capacity developed. |
|---|---|---|---|---|---|---|---|---|---|
| | | 49 | 52 | 51 | 53 | 53.1 | 54 | 55 | 56 |
| 45 | Arkansas No. 13 | 4,186 | 4,487 | 1.0720 | 539 | 15.6 | 3.39 | 1,797 | 57.0 |
| 58 | Illinois No. 1 | 3,422 | 3,754 | 1.0970 | 474 | 13.7 | 2.98 | 1,580 | 50.2 |
| 59 | .....do | 3,809 | 4,159 | 1.0919 | 520 | 15.1 | 3.27 | 1,733 | 55.0 |
| 48 | Illinois No. 7 E | 3,708 | 3,989 | 1.0759 | 499 | 14.5 | 3.14 | 1,663 | 52.8 |
| 39 | Illinois No. 9 C | 3,786 | 4,089 | 1.0800 | 493 | 14.3 | 3.10 | 1,643 | 52.2 |
| 13 | Illinois No. 12 BW | 3,188 | 3,430 | 1.0758 | 416 | 12.1 | 2.62 | 1,387 | 44.0 |
| 52 | Illinois No. 19 E | 3,625 | 3,914 | 1.0798 | 502 | 14.6 | 3.16 | 1,673 | 53.1 |
| 53 | .....do | 4,482 | 4,886 | 1.0902 | 592 | 17.2 | 3.73 | 1,973 | 62.6 |
| 54 | .....do | 3,325 | 3,599 | 1.0825 | 447 | 13.0 | 2.81 | 1,490 | 47.3 |
| 55 | .....do | 3,959 | 4,334 | 1.0946 | 554 | 16.1 | 3.49 | 1,847 | 58.7 |
| 9 | Illinois No. 29 AW | 4,900 | 5,239 | 1.0692 | 665 | 19.3 | 4.18 | 2,217 | 70.4 |
| 12 | Illinois No. 29 B | 4,134 | 4,423 | 1.0700 | 615 | 17.8 | 3.87 | 2,050 | 65.1 |
| 33 | Illinois No. 31 | 3,960 | 4,407 | 1.1130 | 563 | 16.3 | 3.54 | 1,877 | 59.6 |
| 34 | .....do | 4,292 | 4,801 | 1.1187 | 594 | 17.2 | 3.74 | 1,980 | 62.9 |
| 44 | .....do | 4,248 | 4,585 | 1.0794 | 550 | 15.9 | 3.46 | 1,833 | 58.2 |
| 43 | Illinois No. 33 | 3,805 | 4,075 | 1.0710 | 521 | 15.1 | 3.28 | 1,737 | 55.2 |
| 37 | Indiana No. 1 B | 4,915 | 5,399 | 1.0985 | 648 | 18.8 | 4.08 | 2,160 | 68.6 |
| 36 | Indiana No. 5 B | 4,523 | 5,048 | 1.1161 | 600 | 17.4 | 3.77 | 2,000 | 63.5 |
| 38 | Indiana No. 6 B | 3,962 | 4,272 | 1.0782 | 542 | 15.7 | 3.41 | 1,807 | 57.4 |
| 10 | Indian Territory No. 2 BW | 4,866 | 5,198 | 1.0682 | 656 | 19.0 | 4.13 | 2,187 | 69.4 |
| 11 | Indian Territory No. 2 B | 5,411 | 5,739 | 1.0606 | 729 | 21.1 | 4.58 | 2,430 | 77.2 |
| 1 | Kansas No. 2 B | 3,433 | 3,686 | 1.0737 | 461 | 13.4 | 2.90 | 1,537 | 48.8 |
| 40 | .....do | 4,023 | 4,357 | 1.0829 | 528 | 15.3 | 3.32 | 1,760 | 55.9 |
| 21 | Maryland No. 2 | 4,895 | 5,224 | 1.0673 | 653 | 18.9 | 4.11 | 2,177 | 69.1 |
| 22 | .....do | 4,188 | 4,489 | 1.0719 | 599 | 17.4 | 3.77 | 1,997 | 63.4 |
| 23 | .....do | 4,260 | 4,581 | 1.0754 | 573 | 16.6 | 3.60 | 1,910 | 60.6 |
| 20 | .....do | 4,079 | 4,377 | 1.0731 | 556 | 16.1 | 3.50 | 1,853 | 58.8 |
| 2 | Missouri No. 10 | 5,152 | 5,498 | 1.0671 | 718 | 20.8 | 4.52 | 2.393 | 76.0 |
| 3 | .....do | 3,824 | 4,087 | 1.0688 | 522 | 15.1 | 3.28 | 1,740 | 55.2 |
| 4 | .....do | 4,036 | 4,356 | 1.0792 | 557 | 16.1 | 3.50 | 1,857 | 59.0 |
| 5 | .....do | 5,415 | 5,755 | 1.0627 | 708 | 20.5 | 4.45 | 2,360 | 74.9 |
| 28 | Pennsylvania No. 18 | 3,720 | 4,014 | 1.0790 | 502 | 14.6 | 3.16 | 1,673 | 53.1 |
| 29 | .....do | 4,879 | 5,246 | 1.0752 | 656 | 19.0 | 4.13 | 2,187 | 69.4 |
| 30 | .....do | 4,404 | 4,722 | 1.0723 | 613 | 17.8 | 3.86 | 2,043 | 64.9 |
| 31 | .....do | 4,095 | 4,393 | 1.0728 | 549 | 15.9 | 3.45 | 1.830 | 58.1 |
| 46 | .....do | 4,343 | 4,710 | 1.0845 | 579 | 16.8 | 3.64 | 1.930 | 61.3 |
| 24 | .....do | 4,209 | 4,520 | 1.0740 | 565 | 16.4 | 3.55 | 1,883 | 59.8 |
| 25 | .....do | 4,113 | 4,413 | 1.0729 | 552 | 16.0 | 3.47 | 1,840 | 58.4 |
| 32 | Pennsylvania No. 19 | 3,142 | 3,480 | 1.1076 | 529 | 15.3 | 3.33 | 1,763 | 56.0 |
| 15 | .....do | 3,239 | 3,487 | 1.0765 | 465 | 13.5 | 2.92 | 1,550 | 49.2 |
| 26 | Pennsylvania No. 20 | 4,069 | 4,367 | 1.0733 | 546 | 15.8 | 3.43 | 1,820 | 57.8 |
| 27 | .....do | 3,829 | 4,126 | 1.0775 | 516 | 15.0 | 3.25 | 1,720 | 54.6 |
| 41 | Pennsylvania No. 20 W | 4,416 | 4,735 | 1.0723 | 606 | 17.6 | 3.81 | 2,020 | 64.2 |
| 42 | .....do | 2,703 | 2,931 | 1.0844 | 564 | 16.3 | 3.55 | 1,880 | 59.7 |
| 16 | Pennsylvania No. 22 | 3,473 | 3,743 | 1.0776 | 478 | 13.9 | 3.01 | 1,593 | 50.6 |
| 17 | .....do | 3,531 | 3,816 | 1.0807 | 472 | 13.7 | 2.97 | 1,573 | 49.9 |
| 18 | .....do | 3,457 | 3,723 | 1.0769 | 465 | 13.5 | 2.92 | 1,550 | 49.2 |
| 19 | .....do | 3,627 | 3,909 | 1.0777 | 486 | 14.1 | 3.06 | 1,620 | 51.4 |
| 14 | .....do | 3,844 | 4,132 | 1.0748 | 545 | 15.8 | 3.43 | 1,817 | 57.7 |
| 47 | Pennsylvania No. 15 (one-half) and Rhode Island No. 1 (one-half) | 3,993 | 4,273 | 1.0700 | 519 | 15.0 | 3.26 | 1,730 | 54.9 |
| 56 | Pennsylvania No. 18 (one-fourth) and miscellaneous No. 9 (three-fourths) | 4,173 | 4,555 | 1.0915 | 558 | 16.2 | 3.51 | 1,860 | 59.1 |
| 57 | .....do | 3,698 | 4,042 | 1.0929 | 577 | 16.7 | 3.63 | 1,923 | 61.0 |
| 35 | Pennsylvania No. 18 (one-half) and Rhode Island No. 1 (one-half) | 3,118 | 3,485 | 1.1177 | 616 | 17.9 | 3.87 | 2,053 | 65.2 |
| 49 | Pennsylvania No. 18 (three-fourths) and miscellaneous No. 9 (one-fourth) | 4,308 | 4,636 | 1.0761 | 563 | 16.3 | 3.54 | 1,877 | 59.6 |
| 50 | Pennsylvania No. 18 (one-half) and miscellaneous No. 9 (one-half) | 3,860 | 4,158 | 1.0773 | 531 | 15.4 | 3.34 | 1,770 | 56.2 |
| 51 | .....do | 3,928 | 4,237 | 1.0787 | 530 | 15.4 | 3.33 | 1,767 | 56.1 |
| 7 | Virginia No. 5 B | 5,353 | 5,678 | 1.0608 | 710 | 20.6 | 4.47 | 2,367 | 75.1 |
| 8 | .....do | 4,270 | 4,544 | 1.0642 | 583 | 16.9 | 3.67 | 1,943 | 61.6 |

TABLE 2.—*Tests of fuel in house-heating boiler at St. Louis*—Continued.

| Test No. | Designation of fuel. | Economic results (pounds). | | | | Efficiency (per cent). | |
|---|---|---|---|---|---|---|---|
| | | Equivalent evaporation from and at 212° F. per pound of fuel. | | Fuel per hour per 100 square feet of radiating surface (mean load carried during test). | | Boiler and furnace (dry fuel basis). | Plant (fuel as fired basis). |
| | | As fired. | Dry. | As fired. | Dry. | | |
| | | 57 | 58 | 59 | 60 | 61 | 62 |
| 45 | Arkansas No. 13 | 5.77 | 6.14 | 5.18 | 5.12 | 45.22 | 43.14 |
| 58 | Illinois No. 1 | 4.40 | 5.32 | 6.84 | 5.89 | 42.19 | 40.33 |
| 59 | .....do | 4.76 | 5.71 | 6.29 | 5.48 | 45.28 | 43.63 |
| 48 | Illinois No. 7 E | 4.13 | 4.56 | 7.28 | 6.80 | 41.28 | 39.80 |
| 39 | Illinois No. 9 C | 4.69 | 5.18 | 6.39 | 6.02 | 40.39 | 38.67 |
| 13 | Illinois No. 12 BW | 5.15 | 5.84 | 5.84 | 5.34 | 43.52 | 41.69 |
| 52 | Illinois No. 19 E | 4.79 | 5.39 | 6.28 | 5.80 | 41.94 | 40.22 |
| 53 | .....do | 5.27 | 5.91 | 5.68 | 5.27 | 45.99 | 44.25 |
| 54 | .....do | 4.44 | 4.97 | 6.78 | 6.24 | 38.67 | 37.28 |
| 55 | .....do | 5.67 | 6.33 | 5.30 | 4.87 | 49.25 | 47.61 |
| 9 | Illinois No. 29 AW | 6.98 | 8.08 | 4.29 | 3.79 | 58.64 | 57.75 |
| 12 | Illinois No. 29 B | 6.02 | 6.59 | 4.98 | 4.68 | 50.66 | 49.45 |
| 33 | Illinois No. 31 | 5.42 | 6.08 | 5.54 | 5.00 | 48.83 | 47.93 |
| 34 | .....do | 5.74 | 6.46 | 5.20 | 4.75 | 51.88 | 50.76 |
| 44 | .....do | 4.74 | 5.21 | 6.33 | 5.89 | 41.94 | 41.02 |
| 43 | Illinois No. 33 | 4.19 | 5.36 | 7.14 | 6.50 | 48.01 | 41.45 |
| 37 | Indiana No. 1 B | 4.89 | 5.21 | 6.16 | 5.88 | 42.25 | 41.46 |
| 36 | Indiana No. 5 B | 5.44 | 5.82 | 5.50 | 5.30 | 43.33 | 42.28 |
| 38 | Indiana No. 6 B | 5.24 | 5.70 | 5.70 | 5.37 | 43.84 | 42.74 |
| 10 | Indian Territory No. 2 BW | 7.06 | 7.58 | 4.25 | 4.16 | 52.79 | 50.28 |
| 11 | Indian Territory No. 2 B | 7.79 | 8.20 | 3.87 | 3.79 | 60.01 | 58.26 |
| 1 | Kansas No. 2 B | 5.53 | 5.69 | 5.40 | 5.27 | 45.29 | 45.28 |
| 40 | .....do | 5.45 | 5.86 | 5.51 | 5.34 | 47.74 | 45.99 |
| 21 | Maryland No. 2 | 8.02 | 8.54 | 3.77 | 3.63 | 56.13 | 54.69 |
| 22 | .....do | 8.02 | 8.41 | 3.76 | 3.55 | 55.27 | 54.69 |
| 23 | .....do | 7.05 | 7.50 | 4.24 | 4.08 | 49.29 | 48.08 |
| 20 | .....do | 8.42 | 8.72 | 3.56 | 3.51 | 58.18 | 57.15 |
| 2 | Missouri No. 10 | 4.75 | 5.58 | 6.31 | 5.64 | 46.50 | 44.49 |
| 3 | .....do | 5.31 | 6.28 | 5.63 | 5.00 | 52.34 | 49.74 |
| 4 | .....do | 5.32 | 6.27 | 5.66 | 5.01 | 52.25 | 49.83 |
| 5 | .....do | 5.55 | 6.41 | 5.38 | 4.79 | 53.42 | 51.98 |
| 28 | Pennsylvania No. 18 | 6.92 | 7.56 | 4.37 | 4.01 | 50.67 | 50.10 |
| 29 | .....do | 8.05 | 8.78 | 3.75 | 3.48 | 58.85 | 58.28 |
| 30 | .....do | 9.00 | 9.52 | 3.33 | 3.18 | 63.15 | 62.65 |
| 31 | .....do | 7.99 | 8.52 | 3.77 | 3.61 | 56.51 | 55.62 |
| 46 | .....do | 7.21 | 7.72 | 4.14 | 4.04 | 52.71 | 50.90 |
| 24 | .....do | 8.22 | 8.58 | 3.67 | 3.56 | 58.78 | 57.44 |
| 25 | .....do | 8.02 | 8.52 | 3.75 | 3.59 | 57.23 | 55.86 |
| 32 | Pennsylvania No. 19 | 6.43 | 6.60 | 4.65 | 4.60 | 45.89 | 45.50 |
| 15 | .....do | 7.64 | 7.96 | 3.94 | 3.87 | 54.92 | 53.81 |
| 26 | Pennsylvania No. 20 | 8.32 | 9.02 | 3.63 | 3.41 | 61.94 | 60.88 |
| 27 | .....do | 7.50 | 8.12 | 4.01 | 3.78 | 55.76 | 54.88 |
| 41 | Pennsylvania No. 20 W | 7.97 | 8.21 | 3.76 | 3.71 | 56.35 | 55.39 |
| 42 | .....do | 7.56 | 7.84 | 3.99 | 3.94 | 53.81 | 52.54 |
| 16 | Pennsylvania No. 22 | 6.81 | 7.20 | 4.40 | 4.33 | 50.14 | 48.50 |
| 17 | .....do | 7.10 | 7.41 | 4.26 | 4.13 | 51.60 | 50.56 |
| 18 | .....do | 6.74 | 7.41 | 4.45 | 4.32 | 51.99 | 49.03 |
| 19 | .....do | 7.09 | 7.76 | 4.20 | 4.07 | 54.45 | 51.58 |
| 14 | .....do | 8.40 | 9.00 | 3.58 | 3.52 | 62.93 | 59.79 |
| 47 | Pennsylvania No. 15 (one-half) and Rhode Island No. 1 (one-half) | 6.55 | 6.94 | 4.57 | 4.57 | 52.01 | 49.44 |
| 56 | Pennsylvania No. 18 (one fourth) and miscellaneous No. 9 (three-fourths) | 7.08 | 7.52 | 4.25 | 4.19 | 56.48 | 53.75 |
| 57 | .....do | 6.20 | 6.60 | 4.84 | 4.79 | 49.57 | 47.07 |
| 35 | Pennsylvania No. 18 (one-half) and Rhode Island No. 1 (one-half) | 7.13 | 7.34 | 4.19 | 4.14 | 52.24 | 51.43 |
| 49 | Pennsylvania No. 18 (three-fourths) and miscellaneous No. 9 (one-fourth) | 7.16 | 7.61 | 4.21 | 4.10 | 54.72 | 52.44 |
| 50 | Pennsylvania No. 18 (one-half) and miscellaneous No. 9 (one-half) | 6.44 | 6.98 | 4.69 | 4.57 | 52.03 | 48.64 |
| 51 | .....do | 6.51 | 7.09 | 4.59 | 4.53 | 52.85 | 49.16 |
| 7 | Virginia No. 5 B | 7.98 | 8.89 | 3.76 | 3.59 | 65.36 | 61.44 |
| 8 | .....do | 7.42 | 8.28 | 4.07 | 3.86 | 60.87 | 57.13 |

TABLE 2.—*Tests of fuel in house-heating boiler at St. Louis*—Continued.

| Test No. | Designation of fuel. | Fuel at $1 per 2,000 pounds. Cost in cents per 100 square feet of radiating surface per hour (mean load carried during test). | Fuel at $1 per 2,000 pounds. Cost (in cents) of evaporating 1,000 pounds of water from and at 212° F. | Thickness of fire (inches). | Average amount of fuel fired at each firing (pounds). | Average interval between firings (hours). | Clinkers in refuse (per cent). | Black smoke (per cent). |
|---|---|---|---|---|---|---|---|---|
| | | 64 | 65 | 69 | 70 | 71 | | 77 |
| 45 | Arkansas No. 13 | 0.2590 | 8.67 | 8–16 | 155 | 1.66 | 15 | 30.3 |
| 58 | Illinois No. 1 | .3420 | 11.36 | 8–14 | 171 | 1.58 | 38 | 25.7 |
| 59 | ....do | .3150 | 10.50 | 8–16 | 175 | 1.60 | 38 | 41.2 |
| 48 | Illinois No. 7 E | .3640 | 12.10 | ........ | 161 | 1.33 | 19 | 40.3 |
| 39 | Illinois No. 9 C | .3200 | 10.65 | ........ | 145 | 1.36 | 28 | 32.6 |
| 13 | Illinois No. 12 B W | .2420 | 9.71 | ........ | 74 | .92 | 0 | 24.1 |
| 52 | Illinois No. 19 E | .3140 | 10.44 | 4–12 | 163 | 1.56 | 0 | 37.1 |
| 53 | ....do | .2840 | 9.49 | 8–16 | 155 | 1.37 | 20 | 30.3 |
| 54 | ....do | .3390 | 11.25 | 8–16 | 162 | 1.61 | 21 | 32.5 |
| 55 | ....do | .2650 | 8.82 | 6–14 | 153 | 1.56 | 0 | 31.5 |
| 9 | Illinois No. 29 A W | .2150 | 7.16 | ........ | 62 | .66 | 0 | 19.2 |
| 12 | Illinois No. 29 B | .2490 | 8.31 | ........ | 67 | .65 | 26 | 34.6 |
| 33 | Illinois No. 31 | .2770 | 9.23 | ........ | 163 | 1.56 | 13 | 22.7 |
| 34 | ....do | .2600 | 8.71 | ........ | 167 | 1.61 | 24 | 23.7 |
| 44 | ....do | .3170 | 10.55 | 8–16 | 161 | 1.39 | 46 | 29.1 |
| 43 | Illinois No. 33 | .3570 | 11.93 | 6–18 | 162 | 1.30 | 14 | 32.8 |
| 37 | Indiana No. 1 B | .3080 | 10.22 | 4–16 | 158 | 1.19 | 48 | 28.5 |
| 36 | Indiana No. 5 B | .2750 | 9.19 | 4–14 | 155 | 1.40 | 34 | 32.2 |
| 38 | Indiana No. 6 B | .2850 | 9.54 | 8–14 | 163 | 1.58 | 47 | 32.3 |
| 10 | Indian Territory No. 2 B W | .2130 | 7.08 | ........ | 74 | .79 | 0 | 30.4 |
| 11 | Indian Territory No. 2 B | .1940 | 6.42 | ........ | 67 | .71 | 0 | 25.2 |
| 1 | Kansas No. 2 B | .2700 | 9.04 | ........ | 56 | .66 | 44 | 22.6 |
| 40 | ....do | .2760 | 9.18 | 6–18 | 160 | 1.65 | 33 | 26.4 |
| 21 | Maryland No. 2 | .1890 | 6.24 | ........ | 93 | 1.14 | 0 | 14.4 |
| 22 | ....do | .1880 | 6.24 | ........ | 140 | 1.32 | 0 | ...... |
| 23 | ....do | .2120 | 7.09 | ........ | 163 | 2.00 | 0 | 10.7 |
| 20 | ....do | .1780 | 5.94 | ........ | 65 | .98 | 0 | 1.4 |
| 2 | Missouri No. 10 | .3160 | 10.52 | ........ | 116 | .77 | 29 | 41.6 |
| 3 | ....do | .2820 | 9.42 | ........ | 55 | .56 | 38 | 51.4 |
| 4 | ....do | .2830 | 9.40 | ........ | 55 | .52 | 29 | 30.6 |
| 5 | ....do | .2690 | 9.01 | ........ | 65 | .51 | 30 | 41.1 |
| 28 | Pennsylvania No. 18 | .2190 | 7.23 | ........ | 145 | 2.00 | 0 | 12.7 |
| 29 | ....do | .1880 | 6.21 | ........ | 163 | 2.00 | 0 | 14.2 |
| 30 | ....do | .1670 | 5.56 | ........ | 131 | 1.92 | 0 | 25.5 |
| 31 | ....do | .1890 | 6.26 | 4–12 | 138 | 2.00 | 0 | 36.8 |
| 46 | ....do | .2070 | 6.94 | ........ | 163 | 2.03 | 20 | 26.7 |
| 24 | ....do | .1840 | 6.08 | ........ | 138 | 2.00 | 0 | 7.2 |
| 25 | ....do | .1880 | 6.24 | ........ | 138 | 2.00 | 0 | 9.2 |
| 32 | Pennsylvania No. 19 | .2330 | 7.78 | ........ | 135 | 1.64 | 0 | 45.7 |
| 15 | ....do | .1970 | 6.54 | ........ | 41 | .68 | 0 | 14.2 |
| 26 | Pennsylvania No. 20 | .1820 | 6.01 | ........ | 131 | 2.00 | 0 | 16.6 |
| 27 | ....do | .2010 | 6.67 | ........ | 138 | 2.00 | 0 | 17.7 |
| 41 | Pennsylvania No. 20 W | .1880 | 6.27 | 4–16 | 148 | 1.96 | 0 | 29.7 |
| 42 | ....do | .2000 | 6.61 | 6–18 | 129 | 1.73 | 0 | ...... |
| 16 | Pennsylvania No. 22 | .2200 | 7.34 | ........ | 61 | .87 | 0 | 25.1 |
| 17 | ....do | .2130 | 7.04 | ........ | 60 | .89 | 0 | 26.7 |
| 18 | ....do | .2230 | 7.42 | ........ | 69 | 1.00 | 0 | 23.3 |
| 19 | ....do | .2100 | 7.05 | ........ | 138 | 2.01 | 0 | 22.9 |
| 14 | ....do | .1790 | 5.96 | ........ | 62 | .95 | 0 | 16.1 |
| 47 | Pennsylvania No. 15 (one-half) and Rhode Island No. 1 (one-half) | .2290 | 7.64 | 4–18 | 163 | 2.06 | 24 | 29.9 |
| 56 | Pennsylvania No. 18 (one-fourth) and Miscellaneous No. 9 (three-fourths) | .2130 | 7.06 | 8–18 | 161 | 2.04 | 24 | 32.2 |
| 57 | ....do | .2420 | 8.06 | 8–16 | 163 | 1.75 | 25 | 31.4 |
| 35 | Pennsylvania No. 18 (one-half) and Rhode Island No. 1 (one-half) | .2100 | 7.01 | 4–12 | 163 | 1.88 | 0 | 19.3 |
| 49 | Pennsylvania No. 18 (three-fourths) and Miscellaneous No. 9 (one-fourth) | .2110 | 6.98 | ........ | 162 | 2.06 | 16 | ...... |
| 50 | Pennsylvania No. 18 (one-half) and Miscellaneous No. 9 (one-half) | .2350 | 7.77 | 8–16 | 162 | 1.96 | 0 | 28.9 |
| 51 | ....do | .2300 | 7.68 | 10–18 | 163 | 2.00 | 0 | 32.6 |
| 7 | Virginia No. 5 B | .1880 | 6.27 | ........ | 65 | .73 | 0 | 16.7 |
| 8 | ....do | .2040 | 6.74 | ........ | 123 | 1.56 | 0 | 39.5 |

Analyses of flue gas for $CO_2$, $O_2$, and CO were made with the following results:

TABLE 3.—*Average percentage of $CO_2$, $O_2$, and CO from 53 tests made on fuel in house-heating boiler at St. Louis.*

| Test No. | $CO_2$. | $O_2$. | CO. | Test No. | $CO_2$. | $O_2$. | CO. |
|---|---|---|---|---|---|---|---|
| 7 | 10.1 | 6.35 | 0.40 | 34 | 7.2 | 10.9 | 0.1 |
| 8 | 10.9 | 5.4 | 1.02 | 35 | 7.8 | 9.80 | .10 |
| 9 | 10.22 | 7.56 | 1.7 | 36 | 7.9 | 8.3 | .96 |
| 10 | 9.74 | 8.44 | .34 | 37 | 12.1 | 4.3 | .75 |
| 11 | 7.57 | 10.0 | .68 | 38 | 9.3 | 6.8 | .55 |
| 12 | 9.26 | 8.30 | .44 | 39 | 8.75 | 5.45 | 1.0 |
| 13 | 6.96 | 11.35 | .20 | 40 | 8.2 | 8.86 | .53 |
| 14 | 7.0 | 10.68 | .52 | 41 | 6.7 | 10.8 | .20 |
| 15 | 5.8 | 11.30 | .18 | 42 | 7.1 | 9.8 | .25 |
| 16 | 6.8 | 11.3 | .56 | 43 | 6.8 | 11.4 | .4 |
| 17 | 6.8 | 10.26 | .43 | 44 | 7.6 | 9.4 | .4 |
| 18 | 7.2 | 9.85 | .65 | 45 | 13.3 | 4.3 | .6 |
| 19 | 8.0 | 8.77 | .84 | 46 | 10.3 | 6.75 | .65 |
| 20 | 7.13 | 9.83 | .53 | 47 | 9.2 | 9.25 | .15 |
| 21 | 8.6 | 7.25 | .51 | 48 | 8.3 | 9.8 | .6 |
| 22 | 8.0 | 6.58 | 1.62 | 49 | 8.1 | 9.80 | .60 |
| 23 | 7.5 | 7.40 | 1.28 | 50 | 8.6 | 9.3 | .15 |
| 24 | 6.8 | 11.84 | .24 | 51 | 9.4 | 9.0 | .60 |
| 25 | 7.0 | 11.60 | .11 | 52 | 8.75 | 7.65 | 1.50 |
| 26 | 7.6 | 10.35 | .28 | 53 | 9.8 | 6.65 | 1.0 |
| 27 | 5.8 | 12.81 | .05 | 54 | 9.7 | 6.5 | .6 |
| 28 | 7.5 | 10.75 | .46 | 55 | 12.5 | 4.0 | .75 |
| 29 | 7.4 | 10.76 | .34 | 56 | 9.8 | 7.10 | .40 |
| 30 | 7.4 | 10.63 | .13 | 57 | 9.9 | 7.90 | .25 |
| 31 | 6.5 | 10.40 | .30 | 58 | 9.3 | 8.1 | .45 |
| 32 | 7.0 | 10.35 | .15 | 59 | 9.7 | 7.4 | 1.2 |

## RESULTS AT URBANA.

The results of tests made at Urbana are given in the following table:

TABLE 4.—*Tests of fuel in house-heating boilers at Urbana.*

TESTS ON BRIQUETS.

| Test No. | Boiler. | Designation of fuel. | Shape of briquets. | Date. | Duration of test (hours). | Average pressure. Steam (gage). Boiler. | Average pressure. Steam (gage). Receiver. | Average pressure. Draft (inch of water). Flue. | Average pressure. Draft (inch of water). Over fire. | Average temperature (°F). External air. | Average temperature (°F). Boiler room. | Average temperature (°F). Feed water in weigh tank. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 136 | A | Illinois No. 7 E...... | Round.. | June 19.... | 8.62 | 4.25 | 1.87 | 0.15 | 0.10 | .... | .... | 148.9 |
| 137 | B | .....do............... | ...do.... | ...do...... | 7.38 | 4.98 | 1.58 | .16 | .06 | .... | .... | 158.0 |
| 152 | A | Illinois No. 9 C....... | ...do.... | June 28.... | 7.78 | 6.39 | 2.02 | .15 | .12 | 74 | 79 | 164.5 |
| 153 | B | .....do............... | ...do.... | ...do...... | 8.02 | 5.04 | 1.71 | .15 | .06 | 74 | 79 | 168.3 |
| 154 | A | Illinois No. 30 W..... | ...do.... | June 29.... | 7.97 | 7.04 | 2.06 | .15 | .12 | 82 | 83 | 159.9 |
| 155 | B | .....do............... | ...do.... | ...do...... | 7.50 | 3.60 | 1.32 | .13 | .03 | 82 | 83 | 161.6 |
| 142 | A | Illinois No. 31......... | ...do.... | June 22... | 7.35 | 6.69 | 2.05 | .15 | .11 | .... | .... | 151.3 |
| 143 | B | .....do............... | ...do.... | ...do...... | 6.85 | 5.22 | 1.67 | .15 | .05 | .... | .... | 153.7 |
| 144 | A | .....do............... | Square.. | June 24.... | 7.93 | 5.61 | 1.94 | .17 | .10 | .... | .... | 150.8 |
| 145 | B | .....do............... | ...do.... | ...do...... | 7.52 | 6.02 | 1.70 | .22 | .04 | .... | .... | 144.5 |
| 158 | A | Illinois No. 33....... | Round.. | July 2..... | 7.97 | 6.78 | 2.05 | .15 | .12 | 75 | 81 | 165.1 |
| 159 | B | .....do............... | ...do.... | ...do...... | 8.15 | 5.34 | 1.71 | .18 | .05 | 75 | 81 | 166.0 |
| 140 | A | Indiana No. 1 B....... | ...do.... | June 21... | 7.97 | 6.12 | 2.08 | .15 | .12 | .... | .... | 152.3 |
| 141 | B | .....do............... | ...do.... | ...do...... | 7.47 | 5.30 | 1.68 | .18 | .04 | .... | .... | 157.0 |
| 146 | A | Indiana No. 6 B....... | ...do.... | June 25.... | 8.05 | 6.32 | 1.97 | .15 | .11 | 78 | 82 | 169.1 |
| 147 | B | .....do............... | ...do.... | ...do...... | 8.00 | 3.76 | 1.46 | .19 | .02 | 78 | 82 | 173.4 |
| 148 | A | .....do............... | Square.. | June 26.... | 8.08 | 6.59 | 2.07 | .17 | .13 | 77 | 83 | 155.8 |
| 149 | B | .....do............... | ...do.... | ...do...... | 8.25 | 5.44 | 1.74 | .17 | .05 | 77 | 83 | 156.6 |
| 138 | A | Missouri No. 10...... | Round.. | June 20.... | 7.95 | 5.68 | 1.97 | .14 | .10 | .... | .... | 163.1 |
| 139 | B | .....do............... | ...do.... | ...do...... | 7.67 | 4.44 | 1.86 | .20 | .05 | .... | .... | 162.7 |
| 156 | A | Pennsylvania No. 20 W. | ...do.... | July 1..... | 9.17 | 6.11 | 2.00 | .14 | .12 | 83 | 88 | 167.2 |
| 157 | B | .....do............... | ...do.... | ...do...... | 8.02 | 5.40 | 1.60 | .14 | .07 | 83 | 88 | 169.7 |
| 150 | A | Pennsylvania No. 22. | Square.. | June 27.... | 8.13 | 5.72 | 2.02 | .18 | .14 | 74 | 79 | 157.5 |
| 151 | B | .....do............... | ...do.... | ...do...... | 8.45 | 6.09 | 1.86 | .15 | .06 | 74 | 79 | 165.4 |

TESTS ON STANDARD FUELS.

| Test No. | Boiler. | Designation of fuel. | Shape of briquets. | Date. | 1 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 162 | A | Anthracite.......... | .......... | Feb. 24.... | 8.77 | 6.0 | 2.0 | 0.13 | 0.10 | .... | 83 | 173 |
| 163 | B | .....do............... | .......... | ...do...... | 8.00 | 4.5 | 2.0 | .12 | .05 | .... | 82 | 175 |
| 166 | A | .....do............... | .......... | Mar. 2, 3.. | 16.55 | 6.0 | 2.0 | .15 | .11 | .... | 85 | 174 |
| 167 | B | .....do............... | .......... | ...do...... | 17.52 | 5.5 | 2.0 | .08 | .05 | .... | 85 | 174 |
| 170 | A | .....do............... | .......... | Mar. 9, 10. | 24.05 | 6.5 | 2.0 | .14 | .11 | .... | 79 | 175 |
| 186 | A | .....do............... | .......... | May 4, 5... | 23.15 | 7.0 | 2.0 | .21 | .12 | .... | 76 | 180 |
| 187 | B | .....do............... | .......... | ...do...... | 26.00 | 5.0 | 2.0 | .12 | .07 | .... | 76 | 179 |
| 178 | A | Coke.................. | .......... | Apr. 11.... | 8.43 | 7.0 | 2.0 | .13 | .08 | .... | 69 | 168 |
| 180 | A | .....do............... | .......... | Apr. 7.... | 15.83 | 5.5 | 2.0 | .12 | .10 | .... | 80 | 177 |
| 185 | B | .....do............... | .......... | May 2..... | 15.55 | 5.5 | 2.0 | .10 | .06 | .... | 72 | 147 |
| 181 | B | .....do............... | .......... | Apr. 7.... | 14.92 | 5.5 | 2.0 | .12 | .07 | .... | 80 | 174 |
| 182 | A | .....do............... | .......... | Apr. 17, 18. | 26.23 | 5.5 | 2.0 | .10 | .09 | .... | 79 | 177 |
| 172 | A | Pocahontas.......... | .......... | Mar. 17.... | 10.07 | 6.0 | 2.0 | .17 | .12 | .... | 84 | 165 |
| 173 | B | .....do............... | .......... | ...do...... | 12.65 | 5.0 | 2.0 | .12 | .09 | .... | 83 | 157 |
| 174 | A | .....do............... | .......... | Mar. 21, 22 | 17.03 | 4.5 | 1.5 | .16 | .12 | .... | 83 | 172 |
| 175 | B | .....do............... | .......... | ...do...... | 16.05 | 5.5 | 2.0 | .13 | .07 | .... | 83 | 172 |
| 176 | A | .....do............... | .......... | Mar. 23, 24 | 25.13 | 5.5 | 2.0 | .18 | .13 | .... | 80 | 177 |
| 177 | B | .....do............... | .......... | ...do...... | 25.93 | 5.5 | 2.0 | .13 | .08 | .... | 80 | 174 |

TABLE 4.—*Tests of fuel in house-heating boilers at Urbana*—Continued.

TESTS ON BRIQUETS.

| Test No. | Boiler. | Designation of fuel. | Fuel as fired (pounds). Wood. | Fuel as fired (pounds). Briquets. | Fuel as fired (pounds). Briquets plus wood. | Fuel as fired (pounds). Corrected for residual fuel. | Dry fuel (pounds). Total fired. | Dry fuel (pounds). Corrected for residual fuel. | Dry fuel (pounds). Actually consumed (corrected for carbon in ash). | Total ash and refuse from ash pit (pounds). | Residual fuel removed (pounds). |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 20 | 21 | 21.1 | 21.2 | 23 | 23.1 | 23.2 | 24 | 25 |
| 136 | A | Illinois No. 7 E | 6.0 | 372 | 374.4 | 340.5 | 347.9 | 316.4 | 307.4 | 34.0 | 82.5 |
| 137 | B | .....do | 6.2 | 335 | 337.5 | 318.9 | 313.6 | 296.3 | 272.8 | 76.0 | 34.0 |
| 152 | A | Illinois No. 9 C | 10.0 | 275 | 279.0 | 266.2 | 259.8 | 247.8 | 245.2 | 26.0 | 27.0 |
| 153 | B | .....do | 10.0 | 375 | 379.0 | 363.0 | 352.9 | 338.0 | 325.8 | 51.0 | 23.5 |
| 154 | A | Illinois No. 30 W | 10.0 | 255 | 259.0 | 251.1 | 242.6 | 235.2 | 233.9 | 13.0 | 14.2 |
| 155 | B | .....do | 10.0 | 300 | 304.0 | 280.5 | 284.7 | 262.7 | 256.9 | 23.0 | 27.7 |
| 142 | A | Illinois No. 31 | 6.0 | 265 | 267.4 | 253.9 | 241.9 | 229.7 | 224.0 | 27.0 | 24.0 |
| 143 | B | .....do | 10.0 | 275 | 279.0 | 269.3 | 252.4 | 243.6 | 232.6 | 45.0 | 14.0 |
| 144 | A | .....do | 7.5 | 275 | 278.0 | 267.8 | 254.5 | 245.2 | 236.1 | 35.5 | 16.0 |
| 145 | B | .....do | 7.2 | 300 | 302.9 | 288.9 | 277.3 | 264.4 | 249.7 | 42.5 | 20.5 |
| 158 | A | Illinois No. 33 | 10.0 | 260 | 264.0 | 254.6 | 247.5 | 238.6 | 235.8 | 24.0 | 19.0 |
| 159 | B | .....do | 10.5 | 340 | 344.2 | 326.8 | 322.7 | 306.3 | 301.4 | 34.5 | 26.5 |
| 140 | A | Indiana No. 1 B | 10.0 | 275 | 279.0 | 268.7 | 260.0 | 250.4 | 240.6 | 32.5 | 16.0 |
| 141 | B | .....do | 10.0 | 300 | 304.0 | 291.8 | 283.3 | 271.9 | 261.4 | 43.0 | 15.5 |
| 146 | A | Indiana No. 6 B | 10.0 | 265 | 269.0 | 261.4 | 255.3 | 248.1 | 244.2 | 23.0 | 17.5 |
| 147 | B | .....do | 10.0 | 340 | 344.0 | 318.6 | 326.5 | 302.4 | 297.2 | 33.5 | 33.0 |
| 148 | A | .....do | 10.0 | 265 | 269.0 | 253.2 | 255.8 | 240.8 | 238.8 | 21.0 | 31.5 |
| 149 | B | .....do | 10.0 | 340 | 344.0 | 326.3 | 327.1 | 310.3 | 303.5 | 38.5 | 26.5 |
| 138 | A | Missouri No. 10 | 6.0 | 300 | 302.4 | 282.5 | 282.6 | 264.0 | 247.5 | 57.0 | 27.0 |
| 139 | B | .....do | 6.0 | 375 | 377.4 | 360.2 | 352.6 | 336.5 | 322.7 | 62.5 | 32.0 |
| 156 | A | Pennsylvania No. 20 W | 10.0 | 225 | 229.0 | 214.6 | 221.8 | 207.8 | 202.7 | 17.2 | 16.0 |
| 157 | B | .....do | 11.0 | 225 | 229.4 | 217.4 | 225.2 | 210.6 | 201.9 | 22.0 | 14.7 |
| 150 | A | Pennsylvania No. 22 | 10.0 | 225 | 229.0 | 209.2 | 220.7 | 201.6 | 196.7 | 20.0 | 24.0 |
| 151 | B | .....do | 10.0 | 276 | 280.0 | 252.5 | 269.9 | 243.4 | 236.0 | 25.0 | 38.0 |

TESTS ON STANDARD FUELS.

| Test No. | Boiler. | Designation of fuel. | Wood. | Briquets. | Briquets plus wood. | Corrected for residual fuel. | Total fired. | Corrected for residual fuel. | Actually consumed (corrected for carbon in ash). | Total ash and refuse from ash pit (pounds). | Residual fuel removed (pounds). |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 162 | A | Anthracite | 25 | 275 | 285 | 221 | 274 | 212 | 206 | 11 | 79 |
| 163 | B | .....do | 30 | 315 | 327 | 226 | 314 | 217 | 207 | 15 | 115 |
| 166 | A | .....do | 25 | 450 | 460 | 390 | 443 | 376 | 365 | 25 | 91 |
| 167 | B | .....do | 30 | 525 | 537 | 452 | 517 | 435 | 414 | 39 | 106 |
| 170 | A | .....do | 25 | 600 | 610 | 543 | 584 | 520 | 506 | 38 | 91 |
| 186 | A | .....do | 25 | 600 | 610 | 533 | 585 | 511 | 495 | 40 | 103 |
| 187 | B | .....do | 30 | 735 | 747 | 636 | 716 | 610 | 587 | 47 | 147 |
| 178 | A | Coke | 20 | 225 | 233 | 217 | 219 | 204 | 201 | 7 | 28 |
| 180 | A | .....do | 20 | 375 | 383 | 366 | 365 | 348 | 346 | 10 | 38 |
| 185 | B | .....do | 25 | 420 | 430 | 401 | 414 | 386 | 382 | 10 | 53 |
| 181 | B | .....do | 25 | 420 | 430 | 396 | 410 | 378 | 373 | 16 | 52 |
| 182 | A | .....do | 20 | 600 | 608 | 580 | 567 | 540 | 537 | 27 | 43 |
| 172 | A | Pocahontas | 15 | 225 | 231 | 217 | 226 | 213 | 204 | 14 | 21 |
| 173 | B | .....do | 20 | 315 | 323 | 303 | 317 | 297 | 278 | 28 | 32 |
| 174 | A | .....do | 15 | 375 | 381 | 369 | 373 | 361 | 352 | 18 | 24 |
| 175 | B | .....do | 20 | 420 | 428 | 406 | 419 | 398 | 377 | 32 | 33 |
| 176 | A | .....do | 15 | 600 | 606 | 595 | 594 | 584 | 564 | 36 | 29 |
| 177 | B | .....do | 20 | 630 | 638 | 621 | 625 | 608 | 581 | 45 | 27 |

TABLE 4.—*Tests of fuel in house-heating boilers at Urbana*—Continued.

TESTS ON BRIQUETS.

| Test No. | Boiler. | Designation of fuel. | Proximate analysis of fuel as fired (per cent).[a] Fixed carbon. 26 | Volatile matter. 27 | Moisture. 28 | Ash. 29 | Ash in ultimate analysis of dry fuel (per cent). 35 | Analysis of residual fuel (per cent). Carbon. 37 | Earthy matter. 38 |
|---|---|---|---|---|---|---|---|---|---|
| 136 | A | Illinois No. 7 E | ........ | ........ | 7.07 | ........ | 27.43 | 26.50 | 73.50 |
| 137 | B | .....do | ........ | ........ | 7.07 | ........ | 27.43 | 35.34 | 64.66 |
| 152 | A | Illinois No. 9 C | ........ | ........ | 6.89 | ........ | 14.69 | 35.87 | 64.13 |
| 153 | B | .....do | ........ | ........ | 6.89 | ........ | 14.69 | 51.44 | 48.56 |
| 154 | A | Illinois No. 30 W | ........ | ........ | 6.34 | ........ | 8.35 | 46.47 | 53.53 |
| 155 | B | .....do | ........ | ........ | 6.34 | ........ | 8.35 | 71.34 | 28.66 |
| 142 | A | Illinois No. 31 | ........ | ........ | 9.53 | ........ | 16.81 | 40.71 | 59.29 |
| 143 | B | .....do | ........ | ........ | 9.53 | ........ | 16.81 | 50.39 | 49.61 |
| 144 | A | .....do | ........ | ........ | 8.46 | ........ | 16.76 | 46.16 | 53.84 |
| 145 | B | .....do | ........ | ........ | 8.46 | ........ | 16.76 | 49.72 | 50.28 |
| 158 | A | Illinois No. 33 | ........ | ........ | 6.26 | ........ | 13.67 | 40.06 | 59.94 |
| 159 | B | .....do | ........ | ........ | 6.26 | ........ | 13.67 | 53.09 | 46.91 |
| 140 | A | Indiana No. 1 B | ........ | ........ | 6.80 | ........ | 14.11 | 50.81 | 49.19 |
| 141 | B | .....do | ........ | ........ | 6.80 | ........ | 14.11 | 62.24 | 37.76 |
| 146 | A | Indiana No. 6 B | ........ | ........ | 5.08 | ........ | 12.27 | 35.80 | 64.20 |
| 147 | B | .....do | ........ | ........ | 5.08 | ........ | 12.27 | 63.04 | 36.96 |
| 148 | A | .....do | ........ | ........ | 4.91 | ........ | 13.51 | 40.29 | 59.71 |
| 149 | B | .....do | ........ | ........ | 4.91 | ........ | 13.51 | 53.58 | 46.42 |
| 138 | A | Missouri No. 10 | ........ | ........ | 6.56 | ........ | 21.57 | 51.85 | 48.15 |
| 139 | B | .....do | ........ | ........ | 6.56 | ........ | 21.57 | 37.98 | 62.02 |
| 156 | A | Pennsylvania No. 20 W | ........ | ........ | 3.16 | ........ | 7.98 | 85.21 | 14.79 |
| 157 | B | .....do | ........ | ........ | 3.16 | ........ | 7.98 | 76.78 | 23.22 |
| 150 | A | Pennsylvania No. 22 | ........ | ........ | 3.61 | ........ | 9.68 | 74.34 | 25.66 |
| 151 | B | .....do | ........ | ........ | 3.61 | ........ | 9.68 | 65.23 | 34.77 |

TESTS ON STANDARD FUELS.

| Test No. | Boiler. | Designation of fuel. | Fixed carbon. 26 | Volatile matter. 27 | Moisture. 28 | Ash. 29 | Ash in ultimate analysis of dry fuel (per cent). 35 | Carbon. 37 | Earthy matter. 38 |
|---|---|---|---|---|---|---|---|---|---|
| 162 | A | Anthracite | 77.30 | 7.04 | 3.94 | 11.72 | ........ | 70.50 | 29.50 |
| 163 | B | .....do | 77.30 | 7.04 | 3.94 | 11.72 | ........ | 76.65 | 23.35 |
| 166 | A | .....do | 77.54 | 7.06 | 3.64 | 11.76 | ........ | 66.82 | 33.18 |
| 167 | B | .....do | 77.54 | 7.06 | 3.64 | 11.76 | ........ | 70.18 | 29.82 |
| 170 | A | .....do | 76.99 | 7.00 | 4.33 | 11.68 | ........ | 64.11 | 35.89 |
| 186 | A | .....do | 79.85 | 4.27 | 4.13 | 11.75 | ........ | 65.01 | 34.99 |
| 187 | B | .....do | 79.85 | 4.27 | 4.13 | 11.75 | ........ | 65.13 | 34.87 |
| 178 | A | Coke | 81.35 | 2.78 | 6.12 | 9.75 | ........ | 46.71 | 53.29 |
| 180 | A | .....do | 82.61 | 2.82 | 4.67 | 9.90 | ........ | 38.11 | 61.89 |
| 185 | B | .....do | 85.20 | 1.73 | 3.71 | 9.36 | ........ | 47.17 | 52.83 |
| 181 | B | .....do | 82.61 | 2.82 | 4.67 | 9.90 | ........ | 54.55 | 45.45 |
| 182 | A | .....do | 80.79 | 2.76 | 6.76 | 9.69 | ........ | 54.06 | 45.94 |
| 172 | A | Pocahontas | 73.36 | 19.50 | 1.97 | 5.17 | ........ | 65.71 | 34.29 |
| 173 | B | .....do | 73.36 | 19.50 | 1.97 | 5.17 | ........ | 63.06 | 36.94 |
| 174 | A | .....do | 73.32 | 19.49 | 2.02 | 5.17 | ........ | 50.36 | 49.64 |
| 175 | B | .....do | 73.32 | 19.49 | 2.02 | 5.17 | ........ | 66.18 | 33.82 |
| 176 | A | .....do | 73.32 | 19.49 | 2.02 | 5.17 | ........ | 37.15 | 62.85 |
| 177 | B | .....do | 73.32 | 19.49 | 2.02 | 5.17 | ........ | 63.69 | 36.31 |

[a] Moisture only determined except in standard tests.

TABLE 4.—*Tests of fuel in house-heating boilers at Urbana*—Continued.

TESTS ON BRIQUETS.

| Test No. | Boiler. | Designation of fuel. | Ash (per cent). | | Dry fuel per hour (pounds). | | British thermal units per pound of fuel. | | Moisture in steam (per cent). |
|---|---|---|---|---|---|---|---|---|---|
| | | | Carbon. | Earthy matter. | Total. | Per square foot of grate surface. | Dry. | As fired. | |
| | | | 40 | 41 | 43 | 44 | 45 | 46 | 47 |
| 136 | A | Illinois No. 7 E | 18.30 | 81.70 | 36.72 | 8.58 | 10,142 | 9,425 | 1.02 |
| 137 | B | .....do | 21.47 | 78.53 | 40.13 | 6.69 | 10,142 | 9,425 | .61 |
| 152 | A | Illinois No. 9 C | 8.23 | 91.77 | 31.84 | 7.43 | 11,845 | 11,029 | .99 |
| 153 | B | .....do | 19.44 | 80.56 | 42.16 | 7.03 | 11,845 | 11,029 | .90 |
| 154 | A | Illinois No. 30 W | 9.32 | 90.68 | 29.52 | 6.90 | 13,134 | 12,301 | .82 |
| 155 | B | .....do | 22.77 | 77.23 | 35.03 | 5.84 | 13,134 | 12,301 | 1.11 |
| 142 | A | Illinois No. 31 | 17.01 | 82.99 | 31.25 | 7.30 | 11,685 | 10,571 | .83 |
| 143 | B | .....do | 19.50 | 80.50 | 35.56 | 5.93 | 11,685 | 10,571 | .66 |
| 144 | A | .....do | 20.30 | 79.70 | 30.90 | 7.22 | 11,574 | 10,595 | 1.09 |
| 145 | B | .....do | 27.41 | 72.59 | 35.17 | 5.86 | 11,574 | 10,595 | .72 |
| 158 | A | Illinois No. 33 | 10.26 | 89.74 | 29.95 | 7.00 | 12,573 | 11,786 | .95 |
| 159 | B | .....do | 12.38 | 87.62 | 37.58 | 6.26 | 12,573 | 11,786 | .89 |
| 140 | A | Indiana No. 1 B | 25.57 | 74.43 | 31.43 | 7.34 | 12,379 | 11,537 | .85 |
| 141 | B | .....do | 20.85 | 79.15 | 36.42 | 6.07 | 12,379 | 11,537 | .69 |
| 146 | A | Indiana No. 6 B | 14.58 | 85.42 | 30.82 | 7.20 | 12,617 | 11,976 | .90 |
| 147 | B | .....do | 13.47 | 86.53 | 37.81 | 6.30 | 12,617 | 11,976 | .93 |
| 148 | A | .....do | 7.87 | 12.13 | 29.78 | 6.96 | 12,319 | 11,714 | .76 |
| 149 | B | .....do | 14.94 | 85.06 | 37.61 | 6.27 | 12,319 | 11,714 | .81 |
| 138 | A | Missouri No. 10 | 21.87 | 78.13 | 33.21 | 7.76 | 11,012 | 10,290 | .93 |
| 139 | B | .....do | 16.64 | 83.36 | 43.89 | 7.32 | 11,012 | 10,290 | .65 |
| 156 | A | Pennsylvania No. 20 W | 28.87 | 71.13 | 22.67 | 5.30 | 14,262 | 13,811 | .98 |
| 157 | B | .....do | 38.61 | 61.39 | 26.26 | 4.38 | 14,262 | 13,811 | .78 |
| 150 | A | Pennsylvania No. 22 | 23.17 | 76.83 | 24.79 | 5.79 | 13,646 | 13,153 | 1.08 |
| 151 | B | .....do | 27.70 | 72.30 | 28.80 | 4.80 | 13,646 | 13,153 | .80 |

TESTS ON STANDARD FUELS.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 162 | A | Anthracite | 46.07 | 53.93 | 24.2 | 5.65 | 13,216 | 12,698 | 0.96 |
| 163 | B | .....do | 62.98 | 37.02 | 27.1 | 4.52 | 13,218 | 12,698 | .68 |
| 166 | A | .....do | 38.45 | 61.55 | 22.7 | 5.31 | 13,218 | 12,737 | .93 |
| 167 | B | .....do | 49.26 | 50.74 | 24.8 | 4.14 | 13,218 | 12,737 | .61 |
| 170 | A | .....do | 34.52 | 65.48 | 21.6 | 5.05 | 13,217 | 12,645 | .94 |
| 186 | A | .....do | 36.76 | 63.24 | 22.1 | 5.16 | 13,179 | 12,635 | 1.10 |
| 187 | B | .....do | 44.78 | 55.22 | 23.5 | 3.92 | 13,179 | 12,635 | .88 |
| 178 | A | Coke | 34.66 | 65.34 | 24.0 | 5.60 | 12,805 | 12,021 | 1.05 |
| 180 | A | .....do | 18.89 | 81.11 | 22.0 | 5.10 | 12,804 | 12,206 | 1.04 |
| 185 | B | .....do | 38.66 | 61.34 | 24.8 | 4.13 | 13,028 | 12,545 | .82 |
| 181 | B | .....do | 29.45 | 70.55 | 25.0 | 4.20 | 12,804 | 12,206 | .78 |
| 182 | A | .....do | 9.61 | 90.39 | 21.0 | 4.90 | 12,805 | 11,939 | 1.08 |
| 172 | A | Pocahontas | 67.91 | 32.09 | 21.1 | 4.93 | 15,055 | 14,758 | 1.00 |
| 173 | B | .....do | 70.31 | 29.69 | 23.5 | 3.91 | 15,055 | 14,758 | .69 |
| 174 | A | .....do | 50.10 | 49.90 | 21.2 | 4.96 | 15,055 | 14,751 | 1.07 |
| 175 | B | .....do | 66.53 | 33.47 | 24.8 | 4.13 | 15,055 | 14,751 | .95 |
| 176 | A | .....do | 57.11 | 42.89 | 23.2 | 5.42 | 15,055 | 14,751 | 1.03 |
| 177 | B | .....do | 62.78 | 37.22 | 23.4 | 3.90 | 15,055 | 14,751 | .77 |

TABLE 4.—*Tests of fuel in house-heating boilers at Urbana*—Continued.

TESTS ON BRIQUETS.

| Test No. | Boiler. | Designation of fuel. | Factor for correction, quality of steam. | Water (pounds). Fed to boiler. | Water (pounds). Corrected for quality of steam. | Water (pounds). Evaporated into dry steam from and at 212° F. | Factor of evaporation. | Water per hour (pounds). Equivalent evaporation from and at 212° F. | Water per hour (pounds). Equivalent evaporation from and at 212° F. per square foot of water-heating surface. | Horsepower developed. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 48 | 49 | 50 | 52 | 51 | 53 | 54 | |
| 136 | A | Illinois No. 7 E | 0.9905 | 1,292 | 1,280 | 1,366 | 1.0677 | 158.5 | 3.63 | 4.59 |
| 137 | B | .....do | .9943 | 1,386 | 1,377 | 1,457 | 1.0580 | 197.3 | 2.69 | 5.72 |
| 152 | A | Illinois No. 9 C | .9907 | 1,215 | 1,204 | 1,266 | 1.0517 | 162.7 | 3.72 | 4.72 |
| 153 | B | .....do | .9914 | 1,589 | 1,575 | 1,650 | 1.0477 | 205.8 | 2.80 | 5.97 |
| 154 | A | Illinois No. 30 W | .9923 | 1,302 | 1,292 | 1,365 | 1.0566 | 171.3 | 3.92 | 4.97 |
| 155 | B | .....do | .9895 | 1,234 | 1,221 | 1,287 | 1.0542 | 171.6 | 2.34 | 4.97 |
| 142 | A | Illinois No. 31 | .9923 | 1,147 | 1,138 | 1,212 | 1.0655 | 165.0 | 3.78 | 4.78 |
| 143 | B | .....do | .9938 | 1,346 | 1,337 | 1,421 | 1.0626 | 207.5 | 2.83 | 6.01 |
| 144 | A | .....do | .9900 | 1,228 | 1,216 | 1,296 | 1.0660 | 163.5 | 3.74 | 4.74 |
| 145 | B | .....do | .9933 | 1,457 | 1,447 | 1,552 | 1.0722 | 206.7 | 2.82 | 5.99 |
| 158 | A | Illinois No. 33 | .9910 | 1,270 | 1,259 | 1,323 | 1.0512 | 166.0 | 3.80 | 4.81 |
| 159 | B | .....do | .9916 | 1,515 | 1,502 | 1,577 | 1.0497 | 193.5 | 2.64 | 5.61 |
| 140 | A | Indiana No. 1 B | .9920 | 1,216 | 1,206 | 1,285 | 1.0650 | 161.3 | 3.69 | 4.68 |
| 141 | B | .....do | .9935 | 1,281 | 1,273 | 1,350 | 1.0592 | 180.7 | 2.47 | 5.24 |
| 146 | A | Indiana No. 6 B | .9914 | 1,270 | 1,259 | 1,320 | 1.0469 | 164.0 | 3.75 | 4.76 |
| 147 | B | .....do | .9911 | 1,420 | 1,407 | 1,466 | 1.0420 | 183.3 | 2.50 | 5.31 |
| 148 | A | .....do | .9929 | 1,299 | 1,289 | 1,368 | 1.0609 | 169.2 | 3.87 | 4.91 |
| 149 | B | .....do | .9923 | 1,669 | 1,655 | 1,754 | 1.0598 | 212.5 | 2.90 | 6.16 |
| 138 | A | Missouri No. 10 | .9912 | 1,243 | 1,232 | 1,297 | 1.0532 | 163.2 | 3.74 | 4.73 |
| 139 | B | .....do | .9939 | 1,557 | 1,546 | 1,630 | 1.0534 | 212.5 | 2.90 | 6.16 |
| 156 | A | Pennsylvania No. 20 W | .9907 | 1,377 | 1,364 | 1,431 | 1.0489 | 156.1 | 3.57 | 4.53 |
| 157 | B | .....do | .9926 | 1,555 | 1,543 | 1,614 | 1.0460 | 201.3 | 2.74 | 5.84 |
| 150 | A | Pennsylvania No. 22 | .9899 | 1,264 | 1,251 | 1,325 | 1.0590 | 163.0 | 3.73 | 4.73 |
| 151 | B | .....do | .9924 | 1,689 | 1,676 | 1,761 | 1.0506 | 208.4 | 2.84 | 6.04 |

TESTS ON STANDARD FUELS.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 162 | A | Anthracite | 0.9911 | 1,348 | 1,336 | 1,393 | 1.0428 | 159 | 3.64 | ...... |
| 163 | B | .....do | .9937 | 1,577 | 1,567 | 1,631 | 1.0407 | 204 | 2.69 | ...... |
| 166 | A | .....do | .9914 | 2,518 | 2,496 | 2,601 | 1.0419 | 157 | 3.59 | ...... |
| 167 | B | .....do | .9944 | 3,432 | 3,413 | 3,556 | 1.0418 | 203 | 2.67 | ...... |
| 170 | A | .....do | .9913 | 3,700 | 3,668 | 3,817 | 1.0407 | 159 | 3.64 | ...... |
| 186 | A | .....do | .9898 | 3,568 | 3,532 | 3,658 | 1.0356 | 158 | 3.62 | ...... |
| 187 | B | .....do | .9918 | 4,960 | 4,919 | 5,099 | 1.0366 | 196 | 2.58 | ...... |
| 178 | A | Coke | .9904 | 1,387 | 1,374 | 1,440 | 1.0481 | 171 | 3.91 | ...... |
| 180 | A | .....do | .9904 | 2,393 | 2,370 | 2,462 | 1.0387 | 156 | 3.57 | ...... |
| 185 | B | .....do | .9926 | 3,012 | 2,990 | 3,199 | 1.0700 | 206 | 2.72 | ...... |
| 181 | B | .....do | .9928 | 2,954 | 2,934 | 3,057 | 1.0418 | 205 | 2.70 | ...... |
| 182 | A | .....do | .9900 | 4,047 | 4,007 | 4,162 | 1.0387 | 159 | 3.63 | ...... |
| 172 | A | Pocahontas | .9908 | 1,423 | 1,410 | 1,481 | 1.0501 | 147 | 3.36 | ...... |
| 173 | B | .....do | .9937 | 2,372 | 2,357 | 2,497 | 1.0595 | 197 | 2.60 | ...... |
| 174 | A | .....do | .9901 | 2,460 | 2,436 | 2,542 | 1.0435 | 149 | 3.41 | ...... |
| 175 | B | .....do | .9912 | 3,286 | 3,257 | 3,400 | 1.0439 | 212 | 2.79 | ...... |
| 176 | A | .....do | .9905 | 3,963 | 3,925 | 4,077 | 1.0387 | 162 | 3.71 | ...... |
| 177 | B | .....do | .9929 | 5,261 | 5,224 | 5,442 | 1.0418 | 210 | 2.77 | ...... |

TABLE 4.—*Tests of fuel in house-heating boilers at Urbana*—Continued.

TESTS ON BRIQUETS.

| Test No. | Boiler. | Designation of fuel. | Mean load carried. | | Percentage of builder's rated capacity developed (per cent). | Economic results (pounds). | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Square feet of radiating surface. | Square feet of radiating surface plus radiating surface of boiler. | | Equivalent evaporation from and at 212° F. per pound of fuel. | | Fuel per hour per 100 square feet of radiating surface (mean load carried during test). | |
| | | | | | | Fuel as fired. | Dry fuel consumed. | As fired. | Dry. |
| | | | 55 | 55.1 | 56 | 57 | 58 | 59 | 60 |
| 136 | A | Illinois No. 7 E | 528 | 566 | 66.0 | 4.01 | 4.44 | 7.48 | 6.95 |
| 137 | B | .....do | 658 | 761 | 61.2 | 4.57 | 5.34 | 6.57 | 6.10 |
| 152 | A | Illinois No. 9 C | 542 | 580 | 67.8 | 4.76 | 5.16 | 6.31 | 5.87 |
| 153 | B | .....do | 686 | 789 | 63.8 | 4.55 | 5.06 | 6.60 | 6.15 |
| 154 | A | Illinois No. 30 W | 571 | 609 | 71.4 | 5.44 | 5.84 | 5.52 | 5.17 |
| 155 | B | .....do | 572 | 675 | 53.2 | 4.59 | 5.01 | 6.54 | 6.12 |
| 142 | A | Illinois No. 31 | 550 | 588 | 68.8 | 4.77 | 5.41 | 6.28 | 5.68 |
| 143 | B | .....do | 692 | 795 | 64.3 | 5.28 | 6.11 | 5.68 | 5.14 |
| 144 | A | .....do | 545 | 583 | 68.2 | 4.84 | 5.49 | 6.19 | 5.67 |
| 145 | B | .....do | 689 | 792 | 64.1 | 5.37 | 6.22 | 5.58 | 5.10 |
| 158 | A | Illinois No. 33 | 553 | 591 | 69.2 | 5.20 | 5.61 | 5.77 | 5.41 |
| 159 | B | .....do | 645 | 748 | 60.0 | 4.83 | 5.23 | 6.22 | 5.83 |
| 140 | A | Indiana No. 1 B | 538 | 576 | 67.2 | 4.78 | 5.34 | 6.27 | 5.85 |
| 141 | B | .....do | 602 | 706 | 56.0 | 4.63 | 5.16 | 6.49 | 6.05 |
| 146 | A | Indiana No. 6 B | 547 | 585 | 68.3 | 5.05 | 5.41 | 5.94 | 5.64 |
| 147 | B | .....do | 611 | 714 | 56.8 | 4.60 | 4.93 | 6.52 | 6.19 |
| 148 | A | .....do | 564 | 602 | 70.5 | 5.40 | 5.73 | 5.55 | 5.28 |
| 149 | B | .....do | 708 | 812 | 65.8 | 5.38 | 5.78 | 5.58 | 5.31 |
| 138 | A | Missouri No. 10 | 544 | 582 | 68.0 | 4.59 | 5.24 | 6.53 | 6.10 |
| 139 | B | .....do | 708 | 812 | 65.9 | 4.53 | 5.05 | 6.63 | 6.20 |
| 156 | A | Pennsylvania No. 20 W | 520 | 558 | 65.0 | 6.67 | 7.06 | 4.50 | 4.36 |
| 157 | B | .....do | 671 | 774 | 62.4 | 7.42 | 7.99 | 4.04 | 3.91 |
| 150 | A | Pennsylvania No. 22 | 543 | 581 | 67.9 | 6.33 | 6.74 | 4.73 | 4.56 |
| 151 | B | .....do | 695 | 798 | 64.6 | 6.97 | 7.46 | 4.30 | 4.15 |

TESTS ON STANDARD FUELS.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 162 | A | Anthracite | 530 | ........ | 66.3 | 6.30 | 6.76 | 4.75 | 4.56 |
| 163 | B | .....do | 680 | ........ | 63.2 | 7.22 | 7.88 | 4.15 | 3.99 |
| 166 | A | .....do | 523 | ........ | 65.4 | 6.67 | 7.13 | 4.51 | 4.34 |
| 167 | B | .....do | 677 | ........ | 63.0 | 7.86 | 8.59 | 3.81 | 3.66 |
| 170 | A | .....do | 530 | ........ | 66.3 | 7.03 | 7.54 | 4.26 | 4.08 |
| 186 | A | .....do | 527 | ........ | 65.9 | 6.86 | 7.39 | 4.37 | 4.19 |
| 187 | B | .....do | 653 | ........ | 60.7 | 8.02 | 8.69 | 3.75 | 3.60 |
| 178 | A | Coke | 570 | ........ | 71.3 | 6.64 | 7.16 | 4.52 | 4.21 |
| 180 | A | .....do | 520 | ........ | 65.0 | 6.73 | 7.12 | 4.45 | 4.23 |
| 185 | B | .....do | 687 | ........ | 63.9 | 7.98 | 8.37 | 3.75 | 3.61 |
| 181 | B | .....do | 683 | ........ | 63.5 | 7.72 | 8.19 | 3.89 | 3.66 |
| 182 | A | .....do | 530 | ........ | 66.3 | 7.18 | 7.75 | 4.17 | 3.96 |
| 172 | A | Pocahontas | 490 | ........ | 61.3 | 6.82 | 7.26 | 4.40 | 4.31 |
| 173 | B | .....do | 657 | ........ | 61.1 | 8.24 | 8.98 | 3.65 | 3.58 |
| 174 | A | .....do | 497 | ........ | 62.1 | 6.89 | 7.22 | 4.36 | 4.27 |
| 175 | B | .....do | 707 | ........ | 65.8 | 8.37 | 9.02 | 3.58 | 3.51 |
| 176 | A | .....do | 540 | ........ | 67.5 | 6.85 | 7.23 | 4.38 | 4.30 |
| 177 | B | .....do | 700 | ........ | 65.1 | 8.76 | 9.37 | 3.42 | 3.34 |

TABLE 4.—*Tests of fuel in house-heating boilers at Urbana*—Continued.

TESTS ON BRIQUETS.

| Test No. | Boiler. | Designation of fuel. | Efficiency (per cent). Boiler and furnace (dry fuel basis). | Efficiency (per cent). Plant (fuel as fired basis). | Cost, in cents, per 100 square feet of radiating surface per hour (mean load carried during test).[a] | Cost, in cents, of evaporating 1,000 pounds of water from and at 212° F.[a] | Average amount of fuel fired at each firing (pounds). | Average interval (hours)— Between firings. | Average interval (hours)— Between times of shaking and raking. | Maximum interval of maintaining 2 pounds or more steam pressure without attention (hours). |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 61 | 62 | 64 | 65 | 70 | 71 | 72 | 73 |
| 136 | A | Illinois No. 7 E | 42.28 | 41.09 | 0.374 | 12.47 | 75 | 1.53 | 1.02 | 2.00 |
| 137 | B | ....do | 50.85 | 46.83 | .328 | 10.94 | 45 | 1.04 | .76 | 1.77 |
| 152 | A | Illinois No. 9 C | 42.07 | 41.69 | .316 | 10.50 | 75 | 2.13 | 2.13 | 2.22 |
| 153 | B | ....do | 41.26 | 39.84 | .330 | 10.99 | 75 | 1.76 | 1.77 | 2.22 |
| 154 | A | Illinois No. 30 W | 42.94 | 42.71 | .276 | 9.19 | 75 | 2.40 | 2.40 | 2.55 |
| 155 | B | ....do | 36.84 | 36.04 | .327 | 10.89 | 75 | 1.74 | 1.74 | 2.37 |
| 142 | A | Illinois No. 31 | 44.72 | 43.58 | .314 | 10.48 | 75 | 2.31 | 2.31 | 2.38 |
| 143 | B | ....do | 50.50 | 48.24 | .284 | 9.47 | 75 | 2.13 | 2.13 | 2.73 |
| 144 | A | ....do | 45.81 | 44.12 | .310 | 10.33 | 75 | 2.52 | 2.52 | 2.60 |
| 145 | B | ....do | 51.90 | 48.95 | .279 | 9.31 | 75 | 2.01 | 2.01 | 2.25 |
| 158 | A | Illinois No. 33 | 43.09 | 42.61 | .289 | 9.62 | 75 | 2.61 | 2.61 | 2.83 |
| 159 | B | ....do | 40.17 | 39.58 | .311 | 10.35 | 75 | 1.91 | 1.91 | 2.62 |
| 140 | A | Indiana No. 1 B | 41.66 | 40.02 | .314 | 10.46 | 75 | 2.21 | 2.21 | 2.22 |
| 141 | B | ....do | 40.26 | 38.76 | .325 | 10.80 | 75 | 1.94 | 1.94 | 2.05 |
| 146 | A | Indiana No. 6 B | 41.41 | 40.73 | .297 | 9.90 | 75 | 2.54 | 2.54 | 3.03 |
| 147 | B | ....do | 37.74 | 37.10 | .326 | 10.87 | 75 | 1.89 | 1.89 | 2.48 |
| 148 | A | ....do | 44.92 | 44.52 | .278 | 9.26 | 75 | 2.73 | 2.81 | 3.62 |
| 149 | B | ....do | 45.31 | 44.36 | .279 | 9.29 | 75 | 2.14 | 2.14 | 1.83 |
| 138 | A | Missouri No. 10 | 45.96 | 43.08 | .327 | 10.89 | 75 | 1.91 | 1.91 | 2.00 |
| 139 | B | ....do | 44.29 | 42.52 | .332 | 11.04 | 75 | 1.42 | 1.46 | 1.67 |
| 156 | A | Pennsylvania No. 20 W | 47.81 | 46.64 | .225 | 7.50 | 75 | 3.25 | 3.25 | 3.60 |
| 157 | B | ....do | 54.11 | 51.89 | .202 | 6.74 | 75 | 3.12 | 3.13 | 3.35 |
| 150 | A | Pennsylvania No. 22 | 47.70 | 46.48 | .237 | 7.90 | 75 | 3.44 | 3.44 | 3.68 |
| 151 | B | ....do | 52.80 | 51.18 | .215 | 7.17 | 75 | 2.51 | 2.52 | 2.17 |

TESTS ON STANDARD FUELS.

| Test No. | Boiler. | Designation of fuel. | 61 | 62 | 64 | 65 | 70 | 71 | 72 | 73 |
|---|---|---|---|---|---|---|---|---|---|---|
| 162 | A | Anthracite | 49.40 | 47.91 | 0.238 | 7.94 | 75 | 2.24 | 4.39 | 3.17 |
| 163 | B | ....do | 57.58 | 54.91 | .208 | 6.92 | 105 | 1.73 | 4.00 | 4.55 |
| 166 | A | ....do | 52.10 | 50.58 | .226 | 7.50 | 75 | 2.62 | 5.52 | 3.43 |
| 167 | B | ....do | 62.76 | 59.60 | .191 | 6.36 | 105 | 3.27 | 4.38 | 3.67 |
| 170 | A | ....do | 55.09 | 53.69 | .213 | 7.11 | 75 | 2.98 | 3.00 | 3.45 |
| 186 | A | ....do | 54.16 | 52.43 | .219 | 7.29 | 75 | 2.82 | 11.6 | 3.00 |
| 187 | B | ....do | 63.68 | 61.30 | .188 | 6.23 | 105 | 3.55 | 8.67 | 4.67 |
| 178 | A | Coke | 54.00 | 53.34 | .226 | 7.53 | 75 | 2.53 | 0 | 1.70 |
| 180 | A | ....do | 53.71 | 53.25 | .223 | 7.43 | 75 | 3.12 | 0 | 3.00 |
| 185 | B | ....do | 62.50 | 61.44 | .188 | 6.27 | 105 | 3.81 | 3.11 | 3.33 |
| 181 | B | ....do | 61.77 | 61.08 | .195 | 6.48 | 105 | 3.71 | 3.73 | 3.33 |
| 182 | A | ....do | 58.45 | 58.08 | .209 | 6.96 | 75 | 3.26 | 0 | 3.00 |
| 172 | A | Pocahontas | 46.57 | 44.63 | .220 | 7.33 | 75 | 2.95 | 1.26 | 1.87 |
| 173 | B | ....do | 57.60 | 53.92 | .183 | 6.07 | 105 | 3.53 | 1.05 | 2.63 |
| 174 | A | ....do | 46.31 | 45.11 | .218 | 7.26 | 75 | 3.08 | .85 | 2.00 |
| 175 | B | ....do | 57.86 | 54.80 | .179 | 5.97 | 105 | 3.83 | 1.23 | 3.60 |
| 176 | A | ....do | 46.38 | 44.84 | .219 | 7.30 | 75 | 3.12 | .74 | 1.20 |
| 177 | B | ....do | 60.11 | 57.35 | .171 | 5.71 | 105 | 4.24 | 1.13 | 2.82 |

[a] Based on fuel at $1 per 2,000 pounds.

Table 5 shows the amount and character of soot formed on flues of boilers A and B as determined and recorded at end of test.

TABLE 5.—*Amount and character of soot formed on flues of boilers A and B in briquet tests at Urbana.*

| Test No. | Boiler. | Soot measurements. | Test No. | Boiler. | Soot measurements. |
|---|---|---|---|---|---|
| 136 | A | | 140 | A | Heavy; $\frac{1}{8}$ inch thick. |
| 137 | B | | 141 | B | Heavy; $\frac{1}{8}$ to $\frac{1}{4}$ inch thick. |
| 152 | A | Heavy; $\frac{1}{16}$ to $\frac{1}{8}$ inch thick. | 146 | A | Heavy; large amount. |
| 153 | B | Do. | 147 | B | Large amount; choked draft entirely off. |
| 154 | A | Light and fluffy; $\frac{1}{8}$ inch thick. | 148 | A | $\frac{1}{16}$ to $\frac{1}{8}$ inch thick. |
| 155 | B | Light and fluffy; $\frac{3}{4}$ inch thick; choked draft entirely off. | 149 | B | Heavy; large amount. |
| 142 | A | Heavy. | 138 | A | Very little. |
| 143 | B | Do. | 139 | B | Do. |
| 144 | A | Do. | 156 | A | Fine and heavy; small amount. |
| 145 | B | Do. | 157 | B | Very little. |
| 158 | A | Very little. | 150 | A | $\frac{1}{16}$ inch thick or less. |
| 159 | B | Flaky; $\frac{1}{4}$ inch thick. | 151 | B | Do. |

Owing to the fact that the character of the soot was so variable, it is difficult to draw any conclusion on comparative thickness deposited. Table 5 shows that there was a great variation in the amount formed. It is noticeable that in several of the tests a great deal of soot lodged in the flues, and that in two the flues were filled, choking the draft entirely. More difficulty was experienced with soot on boiler B than on boiler A.

The smoke observations for the tests made at Urbana are not reported in this table owing to the uncertainty as to their comparative accuracy. The readings were extremely difficult to make, owing largely to the peculiar color of the smoke. Smoke of about a shade between Ringelmann Nos. 1 and 2 (20 to 40 per cent black) from briquets made with pitch binder is of a dirty yellowish color, and though it is far more offensive than No. 4 smoke (80 per cent black) from raw or washed coal, it would probably be of about the same gravimetric density. In all the briquet tests the stack smoked badly for three-quarters of an hour after firing. About one hour after firing the stack became almost clean, remaining so until another charge was fired.

## DEDUCTIONS FROM TEST DATA.

Table 6 is a compilation of nine different items from the St. Louis tests (exclusive of tests on mixed coals and one on Arkansas No. 13) averaged on the percentage of volatile matter in the combustible as a base. These results emphasize the difficulty of burning high-volatile coal in the fire pot of the average house-heating boiler, which has either inefficient or insufficient combustion space. The volatile matter varied over a wide range. The proximate analyses of fuel as fired showed that the lowest percentage of volatile matter was 14, in a Virginia coal, and the highest 38, in an Indiana coal. The efficiency decreased regularly and decidedly as the volatile matter increased. The drop in efficiency was undoubtedly hastened by clinker formation, the percentage of clinker increasing with increase in sulphur values. Both the color and the analyses of the gases of combustion indicated lessening completeness of combustion as the percentage of volatile matter increased. The table shows that the volatile matter was neither an index of the $CO_2$ in the flue gas nor of the rated capacity developed, but this was to be expected, for each coal was made to carry the load required by weather conditions and was not burned at its highest possible rate of combustion.

TABLE 6.—*Average of results from 50 tests, based on percentage of volatile matter in the combustible.*

| Number of tests averaged. | Volatile matter in the combustible. | Sulphur in dry coal. | Ash in dry coal. | Efficiency. | Clinker. | Black smoke. | Percentage of rated capacity developed. | $CO_2$ in dry flue gases. | CO in dry flue gases. |
|---|---|---|---|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per ct.* | | *Per cent.* | *Per cent.* |
| 4 | 18.30 | 1.33 | 8.00 | 60.56 | 0 | 18.2 | 63.7 | 8.7 | 0.44 |
| 12 | 22.71 | 1.74 | 8.94 | 56.33 | 0 | 18.0 | 61.1 | 7.3 | .50 |
| 7 | 34.70 | 1.23 | 11.27 | 54.11 | 2.9 | 22.1 | 52.8 | 7.4 | .55 |
| 11 | 38.79 | 2.64 | 15.02 | 47.19 | 12.0 | 30.8 | 57.1 | 8.7 | .62 |
| 16 | 44.46 | 4.35 | 14.57 | 47.19 | 30.4 | 32.9 | 61.3 | 9.1 | .74 |

Table 7 was derived by averaging the efficiency obtained in 52 of the St. Louis tests on the percentage of rated capacity developed as a base, the manner in which coals were grouped in getting the average points being shown in Table 8. A study of Table 7 shows that as the capacity increased the percentage of efficiency increased. The high capacities were not obtained with the good coals nor were the low capacities a result of burning poor coal. This relation of efficiency and capacity might be expected when it is remembered that to burn sufficient coal to develop high capacity the available draft must be used, giving more air for the combustion of the coal.

TABLE 7.—*Relation between percentage of rated capacity developed and efficiency.*

| | Number of tests averaged for each point. | Percentage of rated capacity developed. | Efficiency. |
|---|---|---|---|
| | | | *Per cent.* |
| Group I | 1 | 44 | 43.5 |
| Group II | 3 | 48 | 48.5 |
| Group III | 12 | 53 | 47.8 |
| Group IV | 20 | 58 | 52.5 |
| Group V | 9 | 64 | 53.3 |
| Group VI | 5 | 69 | 53.7 |
| Group VII | 2 | 76 | 62.7 |

TABLE 8.—*Grouping of coals in forming Table 7.*

| | Test No. | Designation of fuel. |
|---|---|---|
| Group I | 13 | Illinois No. 12 BW. |
| Group II | 54 | Illinois No. 19 E. |
| | 15 | Pennsylvania No. 19. |
| | 18 | Pennsylvania No. 22. |
| Group III | 58 | Illinois No. 1. |
| | 59 | Do. |
| | 48 | Illinois No. 7 E. |
| | 39 | Illinois No. 9 C. |
| | 52 | Illinois No. 19 E. |
| | 43 | Illinois No. 33. |
| | 28 | Pennsylvania No. 18. |
| | 27 | Pennsylvania No. 20. |
| | 16 | Pennsylvania No. 22. |
| | 50 | Pennsylvania No. 19 and Miscellaneous No. 9. |
| | 19 | Pennsylvania No. 22. |
| | 47 | Pennsylvania No. 15 and Rhode Island No. 1. |
| GROUP IV | 45 | Arkansas No. 13. |
| | 55 | Illinois No. 19 E. |
| | 24 | Pennsylvania No. 18. |
| | 25 | Do. |
| | 44 | Illinois No. 31. |
| | 38 | Indiana No. 6 B. |
| | 40 | Kansas No. 2 B. |
| | 23 | Maryland No. 2. |
| | 20 | Do. |
| | 31 | Pennsylvania No. 18. |
| | 46 | Do. |
| Group IV—Con. | 32 | Pennsylvania No. 19. |
| | 26 | Pennsylvania No. 20. |
| | 42 | Pennsylvania No. 20 W. |
| | 49 | Pennsylvania No. 18 and Miscellaneous No. 9. |
| | 14 | Pennsylvania No. 22. |
| | 56 | Pennsylvania No. 18 and Miscellaneous No. 9. |
| | 57 | Do. |
| | 17 | Pennsylvania No. 22. |
| | 51 | Pennsylvania No. 19 and Miscellaneous No. 9. |
| Group V | 53 | Illinois No. 19 E. |
| | 12 | Illinois No. 29 B. |
| | 34 | Illinois No. 31. |
| | 36 | Indiana No. 5 B. |
| | 22 | Maryland No. 2. |
| | 30 | Pennsylvania. |
| | 41 | Pennsylvania No. 20 W. |
| | 35 | Pennsylvania No. 18 and Rhode Island No. 1. |
| | 8 | Virginia No. 5 B. |
| Group VI | 9 | Illinois No. 29 AW. |
| | 10 | Indian Territory No. 2 B. |
| | 21 | Maryland No. 2. |
| | 29 | Pennsylvania No. 18. |
| | 37 | Indiana No. 1 B. |
| Group VII | 11 | Indian Territory No. 2 BW. |
| | 7 | Virginia No. 5 B. |

When the boiler is run at low capacities the lower check draft is closed a large part of the time and, although this is effective in reducing the rate of combustion, the coal that burns is consumed with a very small air supply, resulting in a loss of combustible gases and making both the boiler and the furnace inefficient. Table 9, based on 52 of the St. Louis tests, shows the loss in efficiency when running with a diminished air supply. This table was obtained by averaging the percentage of CO in the flue gas and the efficiencies on the percentage of $CO_2$ in the flue gas as a base, the manner in which the coals were grouped to determine the average points being shown in Table 10. Table 9 shows that as the $CO_2$ increased the CO values became higher, but not with regularity, probably owing to differences in the character of the fuels. However, the low CO averages appear with the low $CO_2$ averages, and vice versa. This is sufficient proof that the combustion becomes less complete with a reduction of the air supply, resulting in higher values of $CO_2$. It is noticeable that at all times there was a harmful amount of CO present. The table demonstrates that with only one exception the boiler efficiency decreased with increase of $CO_2$, so that when the value of 13.3 per cent $CO_2$ had been reached the efficiency had dropped to 45.0, its lowest point. That high $CO_2$ in the flue gas is not necessarily an indication of high economy was pointed out in Bulletin 325.[a]

[a] A study of four hundred steaming tests: Bull. U. S. Geol. Survey No. 325, 1907, p. 27.

It is important to note that in the tests showing the lowest $CO_2$ the most air entered the furnace, the coal was more nearly burned, and the highest boiler efficiency was obtained. The table shows that the efficiency was higher with low CO values and accompanying excess of air than with reverse conditions. In all the tests there was not sufficient air used.

TABLE 9.—*Relation between $CO_2$ and CO in flue gas and efficiency.*

| | Number of tests averaged. | $CO_2$ in flue gas. | CO in flue gas. | Boiler efficiency. |
|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* |
| Group I | 2 | 5.8 | 0.12 | 55.3 |
| Group II | 6 | 6.7 | .36 | 53.6 |
| Group III | 17 | 7.4 | .42 | 53.4 |
| Group IV | 9 | 8.4 | .82 | 49.3 |
| Group V | 11 | 9.6 | .54 | 48.2 |
| Group VI | 4 | 10.4 | .94 | 59.4 |
| Group VII | 2 | 12.3 | .75 | 45.8 |
| Group VIII | 1 | 13.3 | .60 | 45.2 |

TABLE 10.—*Grouping of coals in forming Table 9.*

| | Test No. | Designation of fuel. |
|---|---|---|
| Group I | 15 | Pennsylvania No. 19. |
| | 27 | Pennsylvania No. 20. |
| Group II | 41 | Pennsylvania No. 20 W. |
| | 16 | Pennsylvania No. 22. |
| | 17 | Do. |
| | 43 | Illinois No. 33. |
| | 31 | Pennsylvania No. 18. |
| | 24 | Do. |
| Group III | 42 | Pennsylvania No. 20 W. |
| | 18 | Pennsylvania No. 22. |
| | 14 | Do. |
| | 35 | Pennsylvania No. 18 and Rhode Island No. 1. |
| | 13 | Illinois No. 12 BW. |
| | 34 | Illinois No. 31. |
| | 44 | Do. |
| | 36 | Indiana No. 5 B. |
| | 11 | Indian Territory No. 2 BW. |
| | 23 | Maryland No. 2. |
| | 20 | Do. |
| | 28 | Pennsylvania No. 18. |
| | 29 | Do. |
| | 30 | Do. |
| | 25 | Do. |
| | 32 | Pennsylvania No. 19. |
| | 26 | Pennsylvania No. 20. |
| Group IV | 19 | Pennsylvania No. 22. |
| | 49 | Pennsylvania No. 18 and Miscellaneous No. 9. |
| | 50 | Pennsylvania No. 19 and Miscellaneous No. 9. |
| | 48 | Illinois No. 7 E. |
| | 39 | Illinois No. 9 C. |
| | 52 | Illinois No. 19 E. |
| | 40 | Kansas No. 2 B. |
| | 21 | Maryland No. 2. |
| | 22 | Do. |
| Group V | 47 | Pennsylvania No. 15 and Rhode Island No. 1. |
| | 56 | Pennsylvania No. 18 and Miscellaneous No. 9. |
| | 57 | Do. |
| | 51 | Pennsylvania No. 19 and Miscellaneous No. 9. |
| | 58 | Illinois No. 1. |
| | 59 | Do. |
| | 53 | Illinois No. 19 E. |
| | 54 | Do. |
| | 12 | Illinois No. 29 B. |
| | 38 | Indiana No. 6 B. |
| | 10 | Indian Territory No. 2 B. |
| Group VI | 7 | Virginia No. 5 B. |
| | 8 | Do. |
| | 9 | Illinois No. 29 AW. |
| | 46 | Pennsylvania No. 18. |
| Group VII | 55 | Illinois No. 19 E. |
| | 37 | Indiana No. 1 B. |
| Group VIII | 45 | Arkansas No. 13. |

Table 11 gives the average results of the tests at Urbana on three different kinds of standard fuel. Boiler B, a sectional boiler, shows a decided gain in efficiency when burning the same fuel over boiler A, a vertical boiler of the usual type. As the percentage of volatile matter in the combustible increases from 3.30 to 20.99, the efficiency of boiler A drops about 9 per cent, but that of boiler B drops only about 3.5 per cent. This shows not only that boiler A is much less efficient than boiler B, but also that it is entirely unfitted for high-volatile coals.

TABLE 11.—*Average results of tests on standard fuels at Urbana.*

| Kind of fuel. | Length of test (hours). | British thermal units per pound of dry fuel. | Efficiency (dry-fuel basis). | Cost of evaporating 1,000 pounds water from and at 212° F. (cents).[a] | $CO_2$ in dry flue gases (per cent). | CO in dry flue gases (per cent). | Flue temperature (° F.). | Per cent of volatile matter in the combustible. |
|---|---|---|---|---|---|---|---|---|
| BOILER A. | | | | | | | | |
| Coke | 16.83 | 12,805 | 55.39 | 7.31 | 4.9 | 0.38 | 651 | 3.30 |
| Anthracite | 16.46 | 13,208 | 52.20 | 7.52 | 4.1 | 1.70 | 589 | 8.35 |
| Pocahontas | 17.41 | 15,055 | 46.42 | 7.30 | 5.1 | .47 | 607 | 20.99 |
| BOILER B. | | | | | | | | |
| Coke | 15.24 | 12,916 | 62.14 | 6.38 | 13.2 | 0.25 | 480 | 2.65 |
| Anthracite | 17.17 | 13,205 | 61.34 | 6.50 | 9.2 | .66 | 519 | 7.26 |
| Pocahontas | 18.21 | 15,055 | 58.52 | 5.92 | 8.2 | .35 | 520 | 20.99 |

[a] Based on fuel at $1 per 2,000 pounds.

Table 12, compiled from four tests made on an Illinois coal raw, three tests on an Illinois coal briquetted, and three tests on a Maryland coal briquetted, shows the relation between capacity and efficiency of the three fuels.

TABLE 12.—*Relation between rated capacity developed and efficiency with three different fuels.*

| Designation of fuel. | Test No. | Percentage of rated capacity developed. | Efficiency. |
|---|---|---|---|
| | | | *Per cent.* |
| Illinois No. 19 E (raw coal) | 53 | 62.6 | 45.99 |
| | 55 | 58.7 | 49.25 |
| | 52 | 53.1 | 41.94 |
| | 54 | 47.3 | 38.67 |
| Illinois No. 31 (briquets) | 34 | 62.9 | 51.88 |
| | 33 | 59.6 | 48.83 |
| | 44 | 58.2 | 41.94 |
| Maryland No. 2 (briquets) | 21 | 69.1 | 56.13 |
| | 22 | 63.4 | 55.27 |
| | 23 | 60.6 | 49.29 |

Table 13 gives three heat balances on the house-heating boiler and one on a 210-horsepower hand-fired Heine boiler, determined at the fuel-testing plant at St. Louis. Test 39 was taken because it was a low-efficiency test with a high average flue-gas temperature; test 31 was a high-efficiency test with a low flue-gas temperature; and test 56 was a high-efficiency test with a high flue-gas temperature. The test on the high-pressure boiler was added for comparison of the results obtained when burning coal in a small boiler and a reasonably large one. This test gave a higher efficiency than may be expected of the average commercial plant; it shows, however, what may be accomplished in the large plant as compared with the small one. The three loss items which differ the most are the loss up the stack, loss due to incomplete combustion of carbon, and radiation and unaccounted-for loss. These items must be higher on the house-heating boiler owing to the higher flue-gas temperature and poorer combustion. The high flue-gas temperature is due to inefficient heating surface, either poorly arranged or made inefficient by the soot and other products of incomplete combustion. Bulletins describing the work of the fuel-testing plant have called attention to the fact that the CO loss was indicative only of the true loss due to incomplete combustion and might not be nearly so large as the unknown loss. In the tests of Table 13, as the CO loss increases both the unaccounted-for loss and the loss up the stack increase; this corroborates former work of the Survey on high-pressure boilers and emphasizes the importance of constructing furnaces so that the fuel may be burned with a sufficient amount of air, properly distributed.

TABLE 13.—*Heat balances, or distribution of the heating values of the combustibles from boiler tests.*

| Kind of boiler | House-heating. | | | Power plant. |
|---|---|---|---|---|
| Test No. | 39. | 31. | 56. | 56. |
| Designation of sample | Ill. No. 9 C. | Pa. No. 18. | Pa. No. 18 and Misc. No. 9. | W. Va. No. 11. |
| Total heat value of 1 pound of combustible, British thermal unit | 14.428. | 15,842. | 14,947. | 15,934. |
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Heat absorbed by boiler | 40.39 | 56.51 | 56.48 | 71.21 |
| Loss due to— | | | | |
| Moisture in coal | .65 | .43 | .11 | .46 |
| Moisture formed by burning of hydrogen | 4.53 | 3.43 | 2.72 | 3.24 |
| Heat carried away in dry chimney gases | 25.91 | 22.82 | 24.93 | 19.37 |
| Incomplete combustion of carbon | 5.75 | 2.51 | 2.35 | .33 |
| Radiation unaccounted for | 22.77 | 14.30 | 13.41 | 5.39 |
| | 100.00 | 100.00 | 100.00 | 100.00 |

Table 14 was derived by averaging the percentage of clinker in refuse and of black smoke on the percentage of $CO_2$ in flue gas as a base. Although it shows, with but one exception, that the $CO_2$ increases as the clinker in the refuse increases, the reader must not infer that the reduced air supply was entirely the result of clinker formation. It is true that when clinker forms on the grate there is more difficulty in drawing air through the fuel bed than when coal burns to a free ash; however, on these tests the lower check draft was open only from a quarter to half the time, so that during the major portion of each test the coal was burned with reduced air supply. It is interesting to note from this table and from Table 6 that the smoke increased in density as the percentage of clinker in the refuse increased.

TABLE 14.—*Relation between $CO_2$ in flue gas, clinker in refuse, and smoke.*

| Number of tests averaged for each point. | $CO_2$ in flue gas. | Clinker in refuse. | Black smoke. |
|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* |
| 2 | 5.8 | 0.0 | 16.0 |
| 6 | 6.7 | 2.3 | 26.4 |
| 16 | 7.4 | 6.5 | 20.6 |
| 8 | 8.4 | 12.0 | 25.3 |
| 11 | 9.6 | 24.0 | 32.1 |
| 4 | 10.4 | 5.0 | 25.5 |
| 2 | 12.3 | 24.0 | 30.0 |

Table 15, determined by averaging results on percentage of clinker in the refuse as a base, shows that the percentage of sulphur in dry coal followed closely the percentage of clinker in the refuse—that is, most of the low sulphur values were found in Group I and the high sulphur values in Groups V and VI.

TABLE 15.—*Relation between clinker in refuse, efficiency, and sulphur.*

| | Number of tests averaged for each group. | Clinker in refuse. | Efficiency. | Sulphur in dry coal. |
|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* |
| Group I | 32 | 0 | 54.8 | 1.67 |
| Group II | 2 | 14 | 48.4 | 2.96 |
| Group III | 4 | 19 | 48.7 | 2.97 |
| Group IV | 9 | 26 | 48.7 | 3.21 |
| Group V | 6 | 35 | 47.4 | 4.63 |
| Group VI | 4 | 46 | 43.3 | 4.12 |

Table 16 gives the relative values of several fuels for heating purposes. The results were obtained by evaporative tests on house-heating boilers of the two different types—sectional and vertical. These tests were made at Urbana on boilers A and B. The chemical analysis, British thermal unit determination, and efficiency of the boiler are given for each fuel. The figures under relative fuel values show that with a sectional boiler the effectiveness of different fuels is in proportion to the number of thermal units they contain; thus, if all fuels were sold at the same price the cheapest would be the one containing the largest number of thermal units.

TABLE 16.—*Relative values of fuels for use in house-heating boilers.*

| Kind of fuel. | No. of tests made. | Coal as fired. | | | | | Efficiency of boiler and grate. |
|---|---|---|---|---|---|---|---|
| | | Moisture. | Volatile matter. | Fixed carbon. | Ash. | British thermal units. | |
| SECTIONAL BOILER. | | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | | *Per ct.* |
| Pocahontas | 3 | 2.00 | 19.49 | 73.33 | 5.17 | 14,753 | 55 |
| Maryland | 1 | 1.69 | 18.69 | 71.25 | 8.37 | 14,229 | 57 |
| Pennsylvania | 2 | 2.75 | 16.58 | 71.71 | 8.96 | 13,842 | 57 |
| Do | 2 | 1.90 | 30.58 | 57.58 | 9.94 | 13,640 | 57 |
| Coke | 2 | 4.19 | 2.28 | 83.91 | 9.63 | 12,376 | 61 |
| Anthracite | 3 | 3.90 | 6.12 | 78.23 | 11.74 | 12,690 | 59 |
| Illinois | 4 | 7.33 | 31.00 | 51.22 | 10.45 | 11,501 | 42 |
| Do | 2 | 13.49 | 33.15 | 41.39 | 11.97 | 10,535 | 42 |
| VERTICAL BOILER. | | | | | | | |
| Coke | 3 | 5.85 | 2.79 | 81.58 | 9.78 | 12,055 | 55 |
| Pocahontas | 3 | 2.00 | 19.49 | 73.33 | 5.17 | 14,753 | 45 |
| Anthracite | 3 | 4.01 | 6.33 | 77.92 | 11.73 | 12,679 | 51 |

| Kind of fuel. | Cost (in cents) of evaporating 1,000 pounds of water from and at 212° F. with price of fuel ranging from $1 to $10 per ton of 2,000 pounds. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $1. | $2. | $3. | $4. | $5. | $6. | $7. | $8. | $9. | $10. |
| SECTIONAL BOILER. | | | | | | | | | | |
| Pocahontas | 5.92 | 11.84 | 17.76 | 23.68 | 29.60 | 35.52 | 41.44 | 47.36 | 53.28 | 59.20 |
| Maryland | 5.94 | 11.88 | 17.82 | 23.76 | 29.70 | 35.65 | 41.58 | 47.52 | 53.46 | 59.40 |
| Pennsylvania | 6.16 | 12.32 | 18.48 | 24.64 | 30.80 | 36.96 | 43.12 | 49.28 | 55.44 | 61.60 |
| Do | 6.25 | 12.50 | 18.75 | 25.00 | 31.25 | 37.50 | 43.75 | 50.00 | 56.25 | 62.50 |
| Coke | 6.38 | 12.76 | 19.14 | 25.52 | 31.90 | 38.28 | 44.56 | 51.04 | 57.42 | 63.80 |
| Anthracite | 6.50 | 13.00 | 19.50 | 26.00 | 32.50 | 39.00 | 45.50 | 52.00 | 58.50 | 65.00 |
| Illinois | 10.00 | 20.00 | 30.00 | 40.00 | 50.00 | 60.00 | 70.00 | 80.00 | 90.00 | 100.00 |
| Do | 10.93 | 21.86 | 32.79 | 43.72 | 54.65 | 65.58 | 76.51 | 87.44 | 98.37 | 109.30 |
| VERTICAL BOILER. | | | | | | | | | | |
| Coke | 7.19 | 14.38 | 21.57 | 28.76 | 35.95 | 43.14 | 50.33 | 57.52 | 64.71 | 71.90 |
| Pocahontas | 7.30 | 14.60 | 21.90 | 28.20 | 36.50 | 43.80 | 51.10 | 58.40 | 65.70 | 73.00 |
| Anthracite | 7.46 | 14.92 | 22.38 | 29.84 | 37.30 | 44.76 | 52.22 | 59.68 | 67.14 | 74.60 |

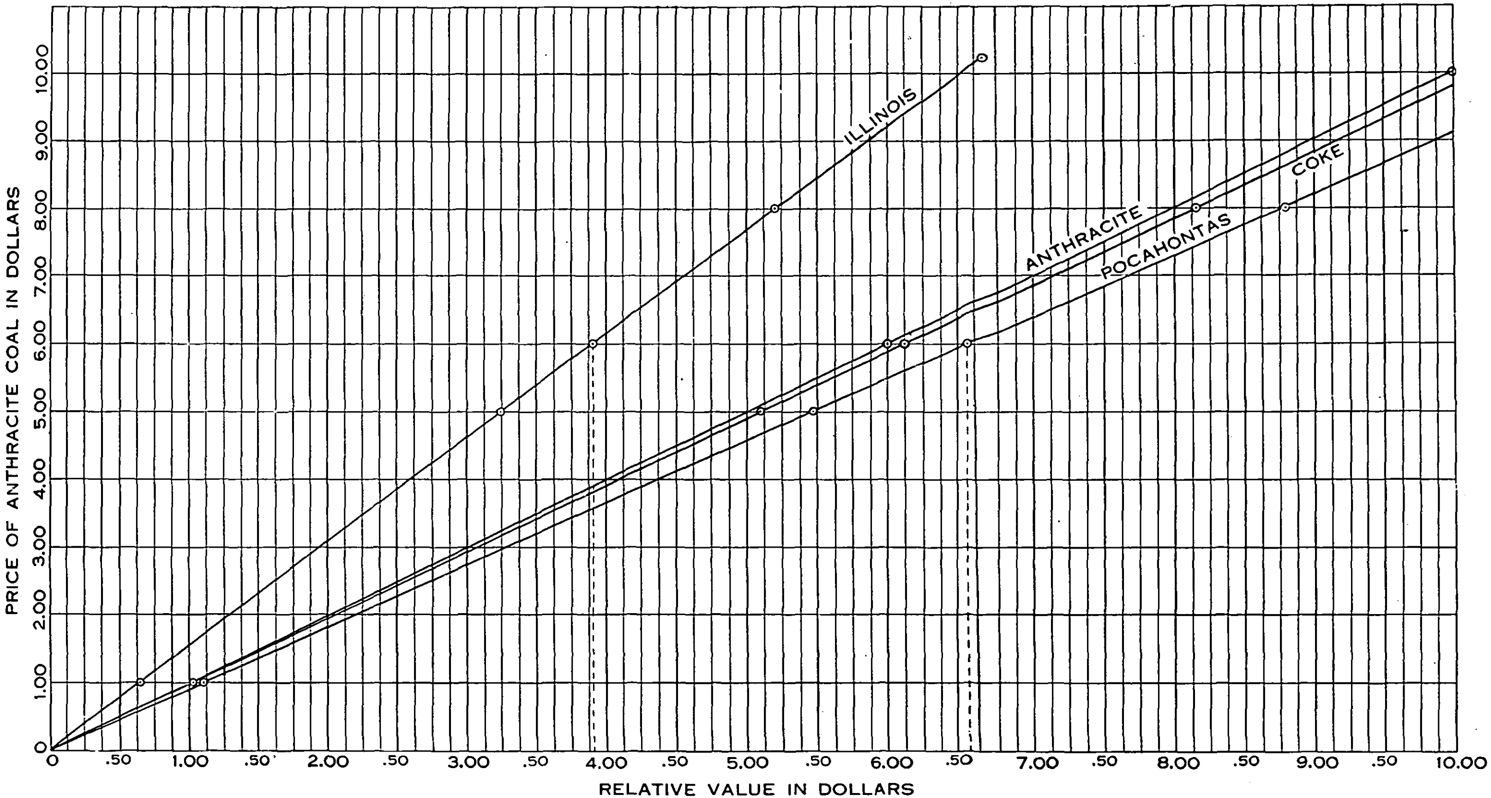
| Kind of fuel. | Relative values of fuels (determined by evaporative tests) with price varying from $1 to $10 per ton of 2,000 pounds for Pocahontas coal. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $1. | $2. | $3. | $4. | $5. | $6. | $7. | $8. | $9. | $10. |
| SECTIONAL BOILER. | | | | | | | | | | |
| Pocahontas | $1.00 | $2.00 | $3.00 | $4.00 | $5.00 | $6.00 | $7.00 | $8.00 | $9.00 | $10.00 |
| Maryland | .997 | 1.994 | 2.991 | 3.988 | 4.985 | 5.982 | 6.979 | 7.976 | 8.973 | 9.970 |
| Pennsylvania | .961 | 1.922 | 2.883 | 3.844 | 4.805 | 5.766 | 6.727 | 7.688 | 8.649 | 9.610 |
| Do | .947 | 1.894 | 2.841 | 3.788 | 4.735 | 5.682 | 6.629 | 7.576 | 8.523 | 9.470 |
| Coke | .928 | 1.856 | 2.784 | 3.712 | 4.640 | 5.568 | 6.496 | 7.424 | 8.352 | 9.280 |
| Anthracite | .911 | 1.822 | 2.733 | 3.644 | 4.555 | 5.466 | 6.377 | 7.288 | 8.199 | 9.110 |
| Illinois | .592 | 1.184 | 1.776 | 2.368 | 2.960 | 3.552 | 4.144 | 4.736 | 5.328 | 5.920 |
| Do | .542 | 1.084 | 1.626 | 2.168 | 2.710 | 3.252 | 3.794 | 4.336 | 4.878 | 5.420 |
| VERTICAL BOILER. | | | | | | | | | | |
| Coke | .985 | 1.970 | 2.955 | 3.940 | 4.925 | 5.910 | 6.895 | 7.880 | 8.865 | 9.850 |
| Pocahontas | 1.00 | 2.00 | 3.00 | 4.00 | 5.00 | 6.00 | 7.00 | 8.00 | 9.00 | 10.00 |
| Anthracite | 1.022 | 2.044 | 3.066 | 4.088 | 5.110 | 6.132 | 7.154 | 8.176 | 9.198 | 10.220 |

A part of this table is figured on the cost of evaporating 1,000 pounds of water. Different fuels may be compared on this basis; for example, at a locality where anthracite costs $8 a ton and coke $6, the cost of evaporating 1,000 pounds of water with anthracite in a sectional boiler would be 52 cents and with coke 38.28 cents. This means that at such a locality the same amount of work could be accomplished at a saving of about $2 a ton by using coke instead of anthracite. Similar comparisons of other fuels may be made from this table.

The last part of this table offers another method for determining the comparative values of fuel at any given locality. For instance, if at a certain place Pocahontas coal costs $5 a ton, anthracite is actually worth $4.56, coke $4.64, good Illinois coal $2.96, and Pennsylvania coal $4.80. If anthracite sells at this same place for $8, it is a luxury by $3.44 a ton over Pocahontas, which, on the other hand, may not be the cheapest available fuel in that market. If good Pennsylvania coal can be purchased for $3.50 a ton, or good Illinois coal for $2.50, they offer a saving of $1.30 and $0.46, respectively, over the cost of Pocahontas at this particular locality. The relatively higher price of anthracite may be offset in public opinion by the fact that the coal is cleaner and burns without smoke.

At another place, should anthracite cost $8.20 a ton, Pocahontas coal would be worth $9 a ton, good Pennsylvania coal $8.65, coke $8.35, and good Illinois coal $5.33. If any of the four last-named fuels cost less than the amounts stated, they would be just that much cheaper than anthracite coal.

A more convenient way of determining the comparative cheapness of different fuels is by means of a diagram like that forming Pl. III, in which the cost of anthracite coal is taken as a standard and the values of three other fuels based on the results of tests are referred to it. Suppose a man wishes to know the relative values of Illinois and Pocahontas coals in a locality where anthracite can be had for $5 per ton. Placing a straightedge on the $5 horizontal line, he notes the point of intersection with the line showing the value of Illinois coal and the point at which a perpendicular from this point of intersection strikes the base and finds that with anthracite at $5 a good Illinois coal is worth $3.25. In the same way he finds that Pocahontas coal is worth $5.47. At another locality, where anthracite can be had for $6, Illinois coal, as shown by the diagram, is worth $3.90, Pocahontas coal $6.58, and coke $6.12.




RELATIVE VALUE OF FUELS FOR HOUSE-HEATING BOILERS.

## SUMMARY OF RESULTS.

The briquets and coal burned in the tests at St. Louis came from eleven States and Territories. There were 58 tests—11 on raw coals, 34 on round briquets, and 13 on square briquets. Most of the tests were run for about eight hours at an average steam pressure of 2 to 3 pounds. The charge of fuel at each firing ranged from 55 to 175 pounds. The interval between firings varied considerably; in some tests coal was fired every half hour and in others every two hours. The average efficiency in all the tests was 51.48 per cent; it ranged from 38.67 per cent on an Illinois coal to 65.36 per cent on a Virginia coal. The average percentage of builder's rated capacity developed was 59.2; it ranged from 44 per cent on an Illinois coal to 77.2 per cent on an Indian Territory coal. The lowest boiler horsepower developed was 12.1 and the highest 20.6. With the cost of fuel assumed at $1 per 2,000 pounds, the cost of evaporating 1,000 pounds of water from and at 212° F. ranged from 5.56 cents for a briquetted Pennsylvania coal to 11.93 cents for a briquetted Illinois coal. Most of the briquets, whether made from eastern or western coal, smoked badly for several minutes after firing. Of the coals tested raw, six were western and five eastern. The high-volatile western coals smoked badly, but the eastern coals made comparatively little smoke.

An average capacity of 65 per cent was carried on all the 24 briquet tests at Urbana, the range being from 53.2 to 71.4 per cent. To carry only 65 per cent of the rated radiating surface, the draft through the fire was wholly or very nearly cut off for half to three-quarters of the time. The boiler horsepower developed on boiler A ranged from 4.52 to 4.96 and on boiler B from 4.97 to 6.16. The average efficiency of the boiler and furnace, figured on a dry-coal basis, was 44.85 per cent for the 24 tests. A comparison of eight tests on briquets, of which four were made on large briquets and four on small briquets, shows that the large briquets invariably gave an appreciably higher efficiency, indicating that the size of the coal burned is an important factor. With the cost of fuel assumed at $1 per 2,000 pounds, the cost of evaporating 1,000 pounds of water from and at 212° F. ranged from 6.74 cents on a Pennsylvania briquet test to 12.47 cents on an Illinois test. The briquets started readily from a wood fire and burned well, but owing to the difficulty of obtaining complete combustion, the average efficiency from an eight-hour test was low. The formation of soot in the flues of boiler B was more troublesome and affected the economy more than in boiler A. So much soot was formed from partial combustion of the briquets in both boilers that the flues were blown after every test. In two tests the flues of boiler B were completely stopped up at the end of the eight-hour run.

## CONCLUSIONS.

On comparing the results of tests on the coal and briquets there seems to be no advantage in the briquets over coal of a suitable size for house-heating boilers. Briquetting a good bituminous coal would be justified only when slack is used for material and the gain from briquetting would lie almost entirely in the more favorable size of the fuel. This gain would be less for coals that coke readily than for noncoking coals or for coking coals that are not suitable for domestic purposes in the form of slack. Briquets made from such coal burn fairly well, as they allow the air to pass up through the fuel bed.

The experiments showed that the pitch binders used are not suitable for a furnace working at the low temperatures common in a house-heating boiler, as they volatilized and in most cases escaped unburned or were deposited on the surface of the boiler. In the St. Louis tests this coating burned off once or twice a day, causing a high temperature in the flue and, as a consequence, danger from fire. There was a similar deposit of tarry matter on the boilers at Urbana, but it did not ignite, probably because owing to the more perfect control of the conditions the fire did not get hot enough. This deposit reduced the efficiency of the boiler. Briquets with binders that do not volatilize so readily would probably show superior results.

The briquets tested gave off much smoke, owing to the nature of the material used as a binder, and for this reason also such briquets are unsuited for domestic use.

The results of these tests indicate that coals containing the higher percentages of fixed carbon give the least smoke and the best results for economy.

## COST OF HEAT FROM CENTRAL PLANTS.

In the course of an investigation into the causes that contribute to the smoke nuisance of cities, outlined in Bulletin 334, inquiries were sent to all the known commercial steam or hot-water heating plants of the United States. This was done because the substitution of large units equipped for burning coal in the most economical manner in the place of small units of less efficient design offers one way of reducing the total quantity of smoke given off in burning a certain amount of coal and in addition is a possible factor in conserving the nation's fuel supplies. Inquiries were sent to 150 plants and replies were received from 57. The information gathered from these replies is to be published in detail in a bulletin now in preparation. Of the plants that answered 41 gave figures showing the price of heat to the consumer either per square foot of radiating surface or per 1,000 pounds of condensed steam. The figures are presented in the following table:

TABLE 17.—*Price of heat from central heating plants.*

| State. | Steam. Per square foot. | Steam. Per 1,000 pounds. | Hot water. Per square foot. | State. | Steam. Per square foot. | Steam. Per 1,000 pounds. | Hot water. Per square foot. |
|---|---|---|---|---|---|---|---|
| | *Cents.* | *Cents.* | *Cents.* | | *Cents.* | *Cents.* | *Cents.* |
| Colorado | 65 | | | Missouri | | | 25 |
| Illinois | 24 | | | Montana | 60 | | |
| Do | | 45 | | New York | | 50 | |
| Do | 25 | | | Do | | 50 | |
| Do | 28 | | | Do | | 42.5 | |
| Do | 25 | | 15 | Do | | 48 | |
| Do | 22.5 | | 17.5 | North Dakota | | 60 | |
| Do | | | 15 | Do | | 40 | |
| Do | | | 20 | Ohio | | | 15 |
| Indiana | | | 20 | Do | | | 15 |
| Do | | | 18 | Do | | | 20 |
| Do | | | 15.5 | Do | | | 17.5 |
| Do | | | 12.5 | Do | | 50 | |
| Do | | | 15 | Pennsylvania | 25 | | |
| Do | | | 17 | Do | | 40 | |
| Iowa | | | 18 | Do | 34 | | |
| Do | | | 20 | Do | 33.3 | | |
| Do | | | 15 | Rhode Island | | 66 | |
| Do | | 50 | | Wisconsin | | | 25 |
| Minnesota | | 60 | | Do | | | 25 |
| Missouri | | 56 | | | | | |

On a comparison of the figures showing the rate per 1,000 pounds of condensed steam with those of cost for evaporating 1,000 pounds of water given in Table 16 (p. 39), it becomes evident that considering all the factors concerned in the production of heat on the premises, such as cost of plant, depreciation, repairs, cost of fuel and labor, and the elimination of all discomfort from dust, ashes, or smoke, the householder is fortunate who can purchase heat from a central station at a reasonable price.

## SURVEY PUBLICATIONS ON FUEL TESTING.

The following publications, except those to which a price is affixed, can be obtained free by applying to the Director, Geological Survey, Washington, D. C. The priced publications can be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

BULLETIN 261. Preliminary report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, in St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1905. 172 pp. 10 cents.

PROFESSIONAL PAPER 48. Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1906. In three parts. 1492 pp., 13 pls. $1.50.

BULLETIN 290. Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905, by J. A. Holmes. 1906. 240 pp. 20 cents.

BULLETIN 323. Experimental work conducted in the chemical laboratory of the United States fuel-testing plant at St. Louis, Mo., January 1, 1905, to July 31, 1906, by N. W. Lord. 1907. 49 pp.

BULLETIN 325. A study of four hundred steaming tests, made at the fuel-testing plant, St. Louis, Mo., 1904, 1905, and 1906, by L. P. Breckenridge. 1907. 196 pp.

BULLETIN 332. Report of the United States fuel-testing plant at St. Louis, Mo., January 1, 1906, to June 30, 1907; J. A. Holmes, in charge. 1908. 299 pp.

BULLETIN 334. The burning of coal without smoke in boiler plants; a preliminary report, by D. T. Randall. 1908. 26 pp.

BULLETIN 336. Washing and coking tests of coal and cupola tests of coke, by Richard Moldenke, A. W. Belden, and G. R. Delamater, 1908. 76 pp.

BULLETIN 339. The purchase of coal under Government and commercial specifications on the basis of its heating value, with analyses of coal delivered under Government contracts, by D. T. Randall. 1908. 27 pp.

BULLETIN 343. Binders for coal briquets, by J. E. Mills. 1908. 56 pp.

BULLETIN 363. Comparative tests of run-of-mine and briquetted coal on locomotives, by W. F. M. Goss. 1908. 57 pp.

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