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URBANA

REPORT OF INVESTIGATIONS—NO. 133

CORRELATION OF DOMESTIC STOKER COMBUSTION WITH LABORATORY TESTS AND TYPES OF FUELS

III. EFFECT OF COAL SIZE UPON COMBUSTION CHARACTERISTICS

By

Roy J. Helfinstine

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1948

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Topographic Mapping in Cooperation with the United States Geological Survey.

This report is a contribution of the Coal Division.

May 1, 1948

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TABLES

ILLUSTRATIONS

ILLINOIS STATE GEOLOGICAL SURVEY DIVISION
of the
Department of Registration and Education

CORRECTION

Report of Investigations No. 133

Table 1, p. 11: For the Coal Nos. (col. 1) ending in 3 and 4 (23, 24, 33, 34, etc.), the column headings for "Size of coal burned" should read as follows:

+4 mesh	4 x 6 mesh	6 x 8 mesh	8 x 10 mesh	10 mesh x 0

CORRELATION OF DOMESTIC STOKER COMBUSTION WITH LABORATORY TESTS AND TYPES OF FUELS

III. EFFECT OF COAL SIZE UPON COMBUSTION CHARACTERISTICS

BY

Roy J. Helfinstine

INTRODUCTION

Combustion characteristics of domestic stoker coals have been studied by the Illinois State Geological Survey in order to help meet the specialized demands on our coal resources. This is Part III of the series of investigations. Results of early exploratory tests indicated that the petrographic nature and the free-swelling index of the coals might be important.[1] A more elaborate investigation, in which strictly defined and measurable criteria of performance were set up, furnished strong evidence that the factors of quality which correlate most closely with the combustion characteristics of Illinois coals are the familiar ones of ash, heating value, and carbon content.[2] The scope of this latter investigation was limited to Illinois shaft-mined coal, and in order to avoid possible superimposed effects due to size, all test coals were prepared to the same size range.

The present investigation was undertaken to explore the effects assignable to size. Quality, as defined by ash content and heating value, was held as nearly constant as possible.

Objectives

The objectives of the phase of the investigation described in this report were to determine the effect of the following factors upon the combustion characteristics of domestic stoker coal: (1) top size, (2) removal of minus 10-mesh coal, (3) "loading" the coal with fines, and (4) preparing the stoker coal from crushed nut coal instead of screenings.

Scope

The present series of tests was limited to four reasonably representative Illinois coals from Vermilion, Franklin, Madison, and LaSalle counties. The size ranges explored were 1¼ inch by 0, 1¼ inch by 10 mesh, ¼ inch by 0, ¼ inch by 10 mesh, and 1¼ inch by 0 with heavy loading of fine coal. It was assumed that the largest top size which might be expected to be used in a domestic stoker was 1¼ inch (round hole) and the smallest was ¼ inch (square hole), and that any difference due to size would be evident if these extremes were used. "Dedusting" was established at the common size of 10 mesh. All coals tested were "surface dry" and untreated.

Of the many factors that govern the suitability of coals for domestic stokers, indexes were used that would aid in the evaluation of the following:[3] (1) cost of heat, (2) attention required, (3) ability to maintain desired temperature, (4) smoke emitted, (5) appearance of fuel bed and fire, and (6) ability to maintain fire at low rates of operation. No direct measurements were made that would assist in the evaluation of the quietness of operation, the odors given off by clinkers during their removal, the cleanliness of the coal, or the general appearance of the coal.

The test data which were obtained to enable the calculation of the relative cost of heat were the heat obtained per pound of coal.

The percentage of ash in the coal was considered to be the primary characteristic in determining the attention required.

[1] McCabe, L. C., Konzo, S., and Rees, O. W., Correlation of domestic stoker combustion with laboratory tests and types of fuels. I. Preliminary studies: Illinois Geol. Survey, Rept. Inv. 78, 20 pp., 1942.

[2] Helfinstine, Roy J., and Boley, Charles C., Correlation of domestic stoker combustion with laboratory tests and types of fuels. II. Combustion tests and preparation studies of representative Illinois coals: Illinois Geol. Survey, Rept. Inv. 120, 62 pp., 1946.

[3] No attempt has been made to list in order of importance.

However, other factors, such as the density, friability, and shape of clinker were thought to be important. No objective evaluations of these characteristics were made, but a subjective rating varying from 0 (unsatisfactory) to 5 (ideal) was made at the time of clinker removal.

Five combustion characteristics were considered as indicators of the ability of a coal to maintain the desired temperature in a house. The first was the *uniformity of combustion*, which was expressed as the percentage variation of rate of heat release for a relatively short interval of time, from the mean rate of heat release for the test. The second was the *responsiveness* of the fire to a demand for heat after a prolonged hold-fire period. This was expressed as the ratio of the rate of heat release during the first 30-minutes of stoker operation following the hold-fire period, to the average rate with continuous operation. The third, called *pickup*, was the responsiveness of the fire after a 45-minute off period. This was expressed as the ratio of the average rate of heat release during the first five minutes of stoker operation following the 45-minute off periods, to the average rate with continuous stoker operation. The fourth, called *overrun*, was the tendency of the fire to cause overheating. This was expressed as the ratio of the average rate of heat release during the first five-minutes after the stoker shut off following the 15-minute on periods, to the average rate with continuous stoker operation. The fifth was the *heat output factor*, which was expressed as the ratio of the minimum and average rates of heat release during the test with continuous stoker operation.

The use of ratios for comparing responsiveness, pickup, and overrun in this report, instead of B.t.u. as in Part II of this series, was considered necessary because of the variable rate of coal feed resulting from the change in coal size. Although responsiveness, pickup, and overrun may not be directly proportional to the feeding rate with a given coal, they are certainly influenced by the feeding rate. Hence the ratios were thought to provide more valid comparisons than the actual rate of heat release. A constant rate of coal feed would have been desirable, but the test equipment did not provide for precise control of rate of coal feed.

The opacity of the stack gases was measured by means of a photoelectric cell. Since some of the variables that affect the measurements were not controlled (such as velocity of gas passing through the light beam), the minor variations that occurred were not considered significant, and are not given.

A motion picture camera was used to record the appearance of the fire during a portion of the time with each operation rate.

The ability of a coal to hold-fire was demonstrated by requiring the maintenance of a responsive fire with only three minutes of stoker operation out of each 1¾ hours.

Acknowledgments

The author is particularly indebted to his previous associate, Charles C. Boley, now a member of the Natural Resources Research Institute of the University of Wyoming. All coals were prepared and sampled under Boley's supervision. Grateful acknowledgment of valuable assistance is also extended to Gilbert H. Cady, Head of the Coal Division; O. W. Rees, Head of the Analytical Chemistry Division; Walter E. Cooper, Technical Assistant of the Coal Division; all of the State Geological Survey; and S. Konzo, Research Professor of Mechanical Engineering, University of Illinois.

Most of the coal samples were contributed by the coal companies whose continued cooperation is sincerely appreciated.

EQUIPMENT

The equipment used for the combustion tests was the same as described in Report of Investigations 120. In brief, it consisted of a standard domestic stoker, cast-iron boiler, heat exchanger and auxiliaries, which were operated as a forced circulation hot-water system. The entire unit was mounted on scales.

Instruments for recording the performance of the coal included a hot-water meter to indicate the quantity of water flowing

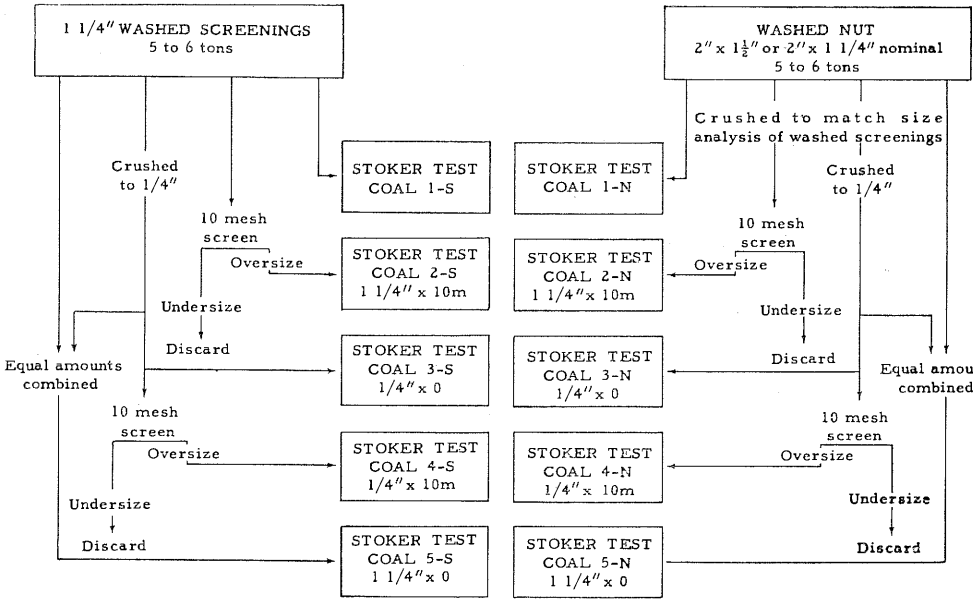

FIG. 1.—Procedure for preparation of test coals.

through the boiler; a two-pen mercury-actuated thermometer to record the temperatures of the water entering and leaving the boiler; a chemical-type meter to record the percentage of CO_2 in the stack gases; a pressure gage to record the static pressure in the stoker air duct; and a multipoint potentiometer to record the temperatures in the stack and room, and the opacity of the stack gases. A 16 mm. motion picture camera was available for taking pictures of either the fuel bed or the scale dial.

PROCEDURE

The general procedure for preparation of the test coals is shown in figure 1. A five to six ton load of 1¼ inch washed screenings was obtained from the selected mine. Approximately 1500 pounds were used as received for test coal 1-S. A sufficient amount was passed over a 10-mesh screen to produce 1500 pounds of 1¼ inch by 10-mesh coal, which was called test coal 2-S. Approximately 4500 pounds were crushed to pass through a ¼ inch screen. About 1500 pounds of this were used as test coal 3-S, and all but 750 pounds were passed over a 10-mesh screen to form test coal 4-S. The remaining 750 pounds of ¼ inch by 0 coal were mixed with an equal part of the original 1¼ inch by 0 screenings to form test coal 5-S. Thus three coals, 1-S, 3-S, and 5-S, were prepared which differed only in size composition.

A load of 2 by 1½ inch, or 2 by 1¼ inch nut coal was obtained from the same mine and all crushed to match the size composition of the washed screenings. This crushed coal was then treated in the same manner as the screenings, and five test coals were prepared.

The sources of the coals tested and their size composition are given in table 1 and figure 2.

Each test coal was burned in the stoker-boiler unit previously described, with a fixed operating schedule[4] representing all rates of stoker operation from hold-fire to continuous.

The stoker air was adjusted to what was considered to be the best for each individual coal. These adjustments were all made prior to the actual test periods. Neither the stoker nor fuel bed received attention during a test which required the combustion of about 300 pounds of coal.

[4] The complete schedule is given as table 36, page 36, Appendix.

FIG. 2.—Location of mines from which samples were obtained.

TABLE 1.—SOURCE AND SIZE OF COALS

Coal No.	Description: Source, County	Description: Size from mine	Size of coal burned: 1¼ inch × ¾ inch *percent*	¾ inch × ⅜ inch *percent*	⅜ inch × 4 mesh *percent*	4 mesh × 10 mesh *percent*	10 mesh × 0 *percent*
21	Vermilion....	1¼ inch by 28 mesh	18.6	32.6	22.5	16.6	9.7
22	Vermilion....	1¼ inch by 28 mesh	20.6	34.7	23.3	18.4	3.0
23	Vermilion....	1¼ inch by 28 mesh	21.1	22.9	15.0	13.3	27.7
24	Vermilion....	1¼ inch by 28 mesh	29.0	29.5	16.2	15.1	10.2
25	Vermilion....	1¼ inch by 28 mesh	6.0	12.4	25.2	36.4	20.0
31	Vermilion....	2 inch by 1¼ inch	16.5	35.7	22.1	13.3	12.4
32	Vermilion....	2 inch by 1¼ inch	19.4	38.1	25.4	14.4	2.7
33	Vermilion....	2 inch by 1¼ inch	24.5	18.5	11.4	12.3	33.3
34	Vermilion....	2 inch by 1¼ inch	32.1	25.1	15.0	15.8	12.0
35	Vermilion....	2 inch by 1¼ inch	6.4	13.4	20.2	31.6	28.4
41	Franklin.....	1¼ inch by 28 mesh	12.5	25.2	20.0	24.5	17.8
42	Franklin.....	1¼ inch by 28 mesh	26.7	30.0	19.8	20.3	3.2
43	Franklin.....	1¼ inch by 28 mesh	21.7	21.0	12.6	13.4	31.3
44	Franklin.....	1¼ inch by 28 mesh	27.3	27.2	17.0	16.4	12.1
45	Franklin.....	1¼ inch by 28 mesh	10.9	14.4	20.8	32.7	21.2
51	Franklin.....	2 inch by 1½ inch	16.6	29.8	14.1	21.6	17.9
52	Franklin.....	2 inch by 1½ inch	16.1	30.3	16.5	28.6	8.5
53	Franklin.....	2 inch by 1½ inch	17.0	22.2	13.4	13.5	33.9
54	Franklin.....	2 inch by 1½ inch	18.4	29.0	19.7	18.7	14.2
55	Franklin.....	2 inch by 1½ inch	5.8	12.3	13.5	37.2	31.2
61	Madison.....	1¼ inch by 0	17.4	36.6	19.4	13.4	13.2
62	Madison.....	1¼ inch by 0	21.8	42.0	19.5	12.8	3.9
63	Madison.....	1¼ inch by 0	22.0	23.9	13.9	12.3	27.9
64	Madison.....	1¼ inch by 0	25.1	27.6	17.2	17.2	12.9
65	Madison.....	1¼ inch by 0	9.9	17.0	19.3	31.4	22.4
71	Madison.....	2 inch by 1¼ inch	21.9	38.0	18.4	11.9	9.8
72	Madison.....	2 inch by 1¼ inch	25.5	39.1	19.5	13.6	2.3
73	Madison.....	2 inch by 1¼ inch	15.3	23.6	14.9	15.0	31.2
74	Madison.....	2 inch by 1¼ inch	15.9	27.1	17.7	19.5	19.8
75	Madison.....	2 inch by 1¼ inch	13.9	18.6	15.9	29.8	21.8
81	LaSalle.......	1¼ inch by 0	10.0	31.1	25.5	20.1	13.3
82	LaSalle.......	1¼ inch by 0	12.7	37.0	25.9	20.2	4.2
83	LaSalle.......	1¼ inch by 0	12.3	19.8	13.3	15.1	39.5
84	LaSalle.......	1¼ inch by 0	15.2	27.9	18.8	20.1	18.0
85	LaSalle.......	1¼ inch by 0	6.9	17.8	19.4	33.1	22.8
91	LaSalle.......	2 inch by 1¼ inch	15.7	27.9	23.7	18.0	14.7
92	LaSalle.......	2 inch by 1¼ inch	15.0	32.7	26.4	20.9	5.0
93	LaSalle.......	2 inch by 1¼ inch	16.1	21.5	12.1	19.4	30.9
94	LaSalle.......	2 inch by 1¼ inch	19.2	27.9	18.6	20.0	14.3
95	LaSalle.......	2 inch by 1¼ inch	10.4	15.1	16.7	31.8	26.0

TABLE 2.—EFFECT OF COAL SIZE UPON HEAT OBTAINED PER POUND
(In B.t.u. per pound)

Coal Series	Size code[a]			Improvement		
	1	3	5	3 over 1	5 over 1	3 over 5
20	7030	7140	7240	110	210	−100
30	6830	7180	7040	350	210	140
40	7670	7750	7690	80	20	60
50	7450	7680	7400	230	−50	280
60	6480	6970	6790	490	310	180
70	6490	6870	6960	380	470	−90
80	6880	7160	6930	280	50	230
90	6940	7290	7040	350	100	250
Average	6971	7255	7136	284	165	119

[a] No. 1 is the 1¼ inch by 0 coal; No. 3 is the ¼ inch by 0 coal; No. 5 has equal parts of No. 1 and No. 3 coals.

RESULTS

EFFECT OF TOP SIZE OF COAL UPON COMBUSTION CHARACTERISTICS

1. EFFECT UPON HEAT OBTAINED

Crushing the coal from a top size of 1¼ inches to a top size of ¼ inch resulted in a slight increase in heat obtained (table 2 and fig. 3). A maximum improvement of 490 B.t.u. per pound was obtained with the Madison County screenings (60 series). The improvements resulting from crushing the Vermilion and Franklin County screenings (20 and 40 series respectively) were less than could be expected from duplicate tests with the same coal, which were found to be about 200 B.t.u. per pound. The average improvement caused by crushing to ¼ inch top size was 284 B.t.u. per pound, which is considered significant as far as test measurements are concerned. However, this small difference could not be detected by a householder, and should probably be considered insignificant from all practical standpoints.

Table 2 and figure 4 show that with one exception more heat was obtained per pound from the coal that was "loaded with fines" (size code 5) than with the natural 1¼ inch product. The maximum improvement was 470 B.t.u. per pound with the coal prepared from Franklin County nut (70 series). The average improvement of 165 B.t.u. per pound is certainly less than would be of interest from a practical viewpoint. However, it is evidence that the addition of a considerable amount of fine coal does not reduce the efficiency of combustion with the domestic stoker as is often thought.

No great difference in heat obtained per pound was found between the ¼ inch by 0 coal and the 1¼ inch by 0 "loaded" with fines (table 2). The average difference was 119 B.t.u. per pound in favor of the ¼

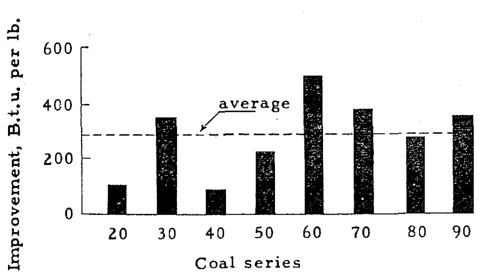

FIG. 3.—Effect of crushing on heat obtained. (1¼ inch coal crushed to ¼ inch top size.)

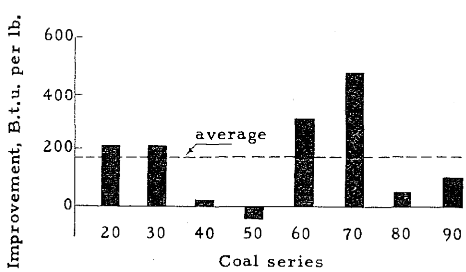

FIG. 4.—Effect of "loading" with fines on heat obtained.

TABLE 3.—HEATING VALUES OF SINGLE SCREENED COALS
(In B.t.u. per pound on the as-fired basis)

Coal Series	Size code[a]			Difference		
	1	3	5	3 minus 1	5 minus 1	3 minus 5
20	11239	11314	11370	75	131	−56
30	11436	11499	11509	63	73	−10
40	12149	12336	12298	187	149	38
50	12246	12206	12195	−40	−51	11
60	11138	11137	11236	−1	98	−99
70	11195	11124	11229	−71	34	−105
80	11353	11283	11260	−70	−93	23
90	11604	11411	11453	−193	−151	−42
Average difference				−6	24	−30

[a] No. 1 is the 1¼ inch by 0 coal; No. 3 is the ¼ inch b y 0 coal; No. 5 has equal parts of No. 1 and No. 3 coals.

TABLE 4.—ASH REPORTED FOR SINGLE SCREENED COALS
(In percent, as-fired basis)

Coal Series	Size code[a]			Difference		
	1	3	5	3 minus 1	5 minus 1	3 minus 5
20	8.7	9.3	9.0	0.6	0.3	0.3
30	10.9	10.6	10.3	−0.3	−0.6	0.3
40	9.5	8.8	9.5	−0.7	0	−0.7
50	9.1	9.7	9.2	0.6	0.1	0.5
60	11.3	10.9	10.6	−0.4	−0.7	0.3
70	9.5	9.5	9.8	0	0.3	−0.3
80	8.9	9.1	9.2	0.2	0.3	−0.1
90	8.8	9.7	9.3	0.9	0.5	0.4
Average difference				0.1	0	0.1

[a] No. 1 is the 1¼ inch by 0 coal; No. 3 is the ¼ inch by 0 coal; No. 5 has equal parts of No. 1 and No. 3 coals.

TABLE 5.—EFFECT OF COAL SIZE UPON CLINKER RATING[a]

Coal Series	Size code[b]			Improvement		
	1	3	5	3 over 1	5 over 1	3 over 5
20	3	3	3	0	0	0
30	3	3	3	0	0	0
40	2	2	2	0	0	0
50	2	3	2	1	0	1
60	3	3	2	0	−1	1
70	2	2	2	0	0	0
80	3	3	3	0	0	0
90	3	3	3	0	0	0
Average	2.6	2.7	2.5	0.1	−0.1	0.2

[a] A subjective rating varying from 0 (unsuitable) to 5 (ideal).
[b] No. 1 is the 1¼ inch by 0 coal; No. 3 is the ¼ inch by 0 coal; No. 5 has equal parts of No. 1 and No. 3 coals.

inch by 0. The two exceptions to this trend were coals from Vermilion and Madison counties (20 and 70 series, respectively). The maximum improvement was 280 B.t.u. per pound.

Briefly stated, the effect of size of the Illinois coals tested upon heat obtained was of no practical importance. However, a slight improvement with the smaller coals was detectable in the laboratory. It should be emphasized that the coals were well mixed before shoveling into the hopper. Thus the results of these tests will not show the effect of feeding a coal of varying size to the hopper with a fixed air setting, such as would be the case if segregation of coal sizes occurred in a bin before feeding to the stoker.

A previous report[5] showed that a close relationship existed between the heat obtained per pound and the heating value of the coal when size was constant. Theoretically, the heating value of each series of three coals should be the same on a moisture-free basis. However, some differences in reported values would be expected because of imperfect mixing, sampling, and analysis. Incidental variations in moisture would cause additional differences on the as-fired basis. The maximum variation reported (table 3) was a loss of 193 B.t.u. per pound with a coal from LaSalle County. This appreciable reduction in heating value with the LaSalle County coal was probably the result of slight heating in the storage bins prior to crushing and sampling.

The average differences in reported heating value on the as-fired basis for the three size ranges tested were 6, 24, and 30 B.t.u. per pound. It is therefore apparent that each series of coals may be considered identical in respect to heating value on the as-fired basis.

[5] Helfinstine and Boley, *op. cit.*

2. EFFECT UPON ATTENTION REQUIRED

The coals used for the size study were from the same original sample, hence the differences in percentage of ash reported would be caused by imperfect sampling, analysis, mixing, and moisture control. Table 4 lists these differences on the as-fired basis. Obviously the differences shown would not affect the attention required.

The size of the coal burned had little apparent effect upon the rating given to the clinker at the time of removal (table 5). Only the clinkers from the coals prepared from Franklin County nut and Madison County screenings received different ratings. No significance should be attached to these differences.

Although no measurements were made to indicate the relative amount of dust caused by handling the three size ranges tested, the finer sizes undoubtedly made the most dust, and would be less desirable from this standpoint.

3. EFFECT UPON ABILITY TO MAINTAIN DESIRED HEAT OUTPUT

a. *Uniformity of heat release.*—Some improvement in uniformity of heat release was caused by crushing to a ¼ inch top size for every coal tested (table 6 and fig. 5). The coals from Madison County (60 and 70 series) showed the greatest improvement. The 1¼ inch by 0 coal prepared from nut coal (No. 71) had an average variation of 20.1 percent, which is very poor in this respect. However, the same coal crushed to ¼ inch top size (No. 73) burned fairly uniformly (7.5 percent variation). The Madison County coal prepared from screenings exhibited the same tendency, but to a lesser degree. The average improvement in uniformity with the ¼ inch over the 1¼ inch coals for all the coals tested was 3.6 percentage figures, which is more than 30 percent.

TABLE 6.—EFFECT OF COAL SIZE UPON UNIFORMITY OF HEAT RELEASE
(Data are given in percent variation from average rate of heat release.)

Coal Series	Size code[a]			Improvement		
	1	3	5	3 over 1	5 over 1	3 over 5
20	5.9	5.2	4.4	0.7	1.5	−0.8
30	6.4	5.4	5.2	1.0	1.2	−0.2
40	10.4	9.5	8.8	0.9	1.6	−0.7
50	11.6	8.2	11.5	3.4	0.1	3.3
60	12.6	6.5	7.8	6.1	4.8	1.3
70	20.1	7.5	9.3	12.6	10.8	1.8
80	6.0	5.1	4.6	0.9	1.4	−0.5
90	7.4	4.3	4.1	3.1	3.3	−0.2
Average	10.1	6.5	7.0	3.6	3.1	0.5

[a] No. 1 is 1¼ inch by 0 coal; No. 3 is the ¼ inch by 0 coal; No. 5 has equal parts of No. 1 and No. 3 coals.

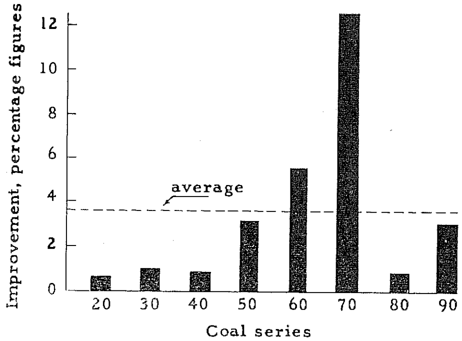

FIG. 5.—Effect of crushing on uniformity. (1¼ inch coal crushed to ¼ inch top size.)

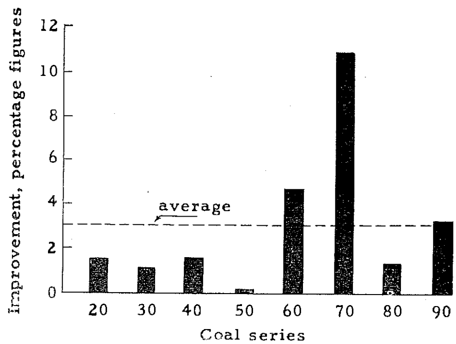

FIG. 6.—Effect of "loading" with fines on uniformity.

The 1¼ inch by 0 coals which were loaded with fines (coals with size code 5) also burned more uniformly than the regular 1¼ inch by 0 coals (table 6 and fig. 6). The greatest improvement was with the Madison County coals. The average improvement for the eight coals tested was 3.1 percentage figures.

Although the average ¼ inch by 0 coal burned more uniformly than the 1¼ inch by 0 coal which was loaded with fines by 0.5 percentage figures (table 6), this difference does not seem to be significant.[6]

b. *Responsiveness.*—Another indicator of the ability of a coal to maintain the desired heat output was the responsiveness of the fire to a demand for heat after a prolonged hold-fire period (see p. 8). The size of the coal had no significant effect upon the responsiveness ratio[7] obtained with most of the coals tested (table 7 and figs.

[6] The minimum variation considered significant depended upon the coal, with a range from one percentage figure with the more uniformly burning coal to five percentage figures for the coals with extreme variability.

[7] The ratio of the rate of heat release during the first 30 minutes of stoker operation, following the hold-fire period, to the average rate with continuous stoker operation.

TABLE 7.—EFFECT OF COAL SIZE UPON RESPONSIVENESS RATIO[a]

Coal Series	Size code[b]			Improvement		
	1	3	5	3 over 1	5 over 1	3 over 5
20	0.33	0.34	0.31	0.01	−0.02	0.03
30	0.33	0.21	0.30	−0.12	−0.03	−0.09
40	0.16	0.16	0.18	0.00	0.02	−0.02
50	0.22	0.17	0.21	−0.05	−0.01	−0.04
60	0.22	0.24	0.23	0.02	0.01	0.01
70	0.20	0.19	0.24	−0.01	0.04	−0.05
80	0.18	0.23	0.33	0.05	0.15	−0.10
90	0.21	0.25	0.24	0.04	0.03	0.01
Average	0.23	0.22	0.25	−0.01	0.02	−0.03

[a] Ratio of rate of heat release during the first 30-minutes of stoker operation following the hold-fire period, to the average rate during the test with continuous stoker operation.
[b] No. 1 is the 1¼ inch by 0 coal; No. 3 is the ¼ inch by 0 coal; No. 5 has equal parts of No. 1 and No. 3 coals.

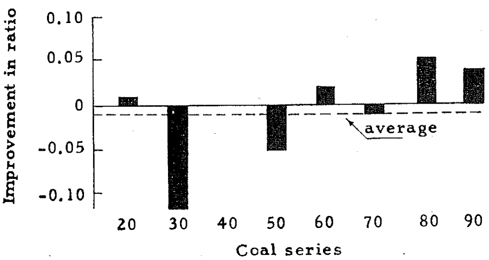

FIG. 7.—Effect of crushing on responsiveness ratio. (1¼ inch coal crushed to ¼ inch top size.)

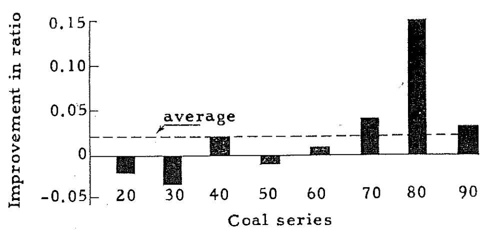

FIG. 8.—Effect of "loading" with fines on responsiveness ratio.

7 and 8). As these data were obtained from only one test with each coal, the variation shown, with the possible exceptions of the 30 and 80 series, does not exceed the variation which might be expected from duplicate tests of the same coal.

c. *Pickup*.—The pickup ratio[8] was lower with the ¼ inch by 0 coal than with the 1¼ inch by 0 coal in five out of eight comparative tests (table 8 and fig. 9). The reduction is considered significant with the coals prepared from Franklin County screenings and Madison County nut (40 and 70 series, respectively). The reduction in average ratio of 0.01 for the 8 comparative tests is not considered significant.

The only significant change in pickup ratio caused by "loading" the 1¼ inch by 0 coal with fines was an increase in ratio of 0.05 with the stoker coal prepared from LaSalle County nut (table 8 and fig. 10). There was no change in average ratio.

d. *Overrun*.—The overrun ratio[9] with the 1¼ inch by 0 coals was superior to that obtained with the ¼ inch by 0 coals with six out of eight comparative tests (table 9 and fig. 11). The maximum superiority was 0.05 (which was obtained with both Franklin county coals) and the average was 0.02.

"Loading" the 1¼ inch by 0 coals with fines did not have a consistent influence on the overrun ratio (table 9 and fig. 12). The maximum spread with comparative tests was the 0.09 greater ratio with the "loaded" 1¼ inch by 0 coal prepared from LaSalle County nut (90 series). The average overrun ratio for the eight comparative tests was 0.01 greater with the 1¼ inch by 0 coals that were loaded with fines.

[8] The ratio of the average rate of heat release during the first five minutes of stoker operation, following the 45-minute "off" periods, to the average rate with continuous stoker operation.

[9] The ratio of the average rate of heat release during the first five minutes after stoker shut off, following the 15-minute "on" periods, to the average rate with continuous stoker operation.

Table 8.—Effect of Coal Size upon Pickup Ratio[a]

Coal Series	Size code[b]			Improvement		
	1	3	5	3 over 1	5 over 1	3 over 5
20	0.25	0.25	0.25	0.00	0.00	0.00
30	0.23	0.21	0.23	−0.02	0.00	−0.02
40	0.26	0.22	0.24	−0.04	−0.02	−0.02
50	0.24	0.23	0.24	−0.01	0.00	−0.01
60	0.25	0.23	0.25	−0.02	0.00	−0.02
70	0.26	0.21	0.23	−0.05	−0.03	−0.02
80	0.24	0.25	0.25	0.01	0.01	0.00
90	0.22	0.24	0.27	0.02	0.05	−0.03
Average	0.24	0.23	0.24	−0.01	0.00	−0.01

[a] Ratio of rate of heat release during first five minutes of stoker operation following a 45-minute "off" period, to the average rate during test with continuous stoker operation.
[b] No. 1 is the 1¼ inch by 0 coal; No. 3 is the ¼ inch by 0 coal; No. 5 has equal parts of No. 1 and No. 3 coals.

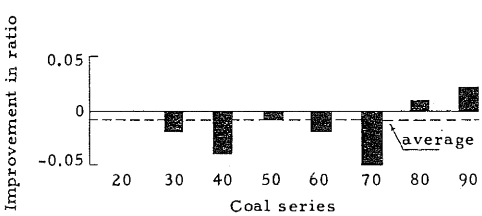

Fig. 9.—Effect of crushing on pickup ratio. (1¼ inch coal crushed to ¼ inch top size.)

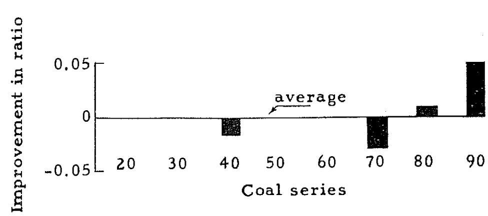

Fig. 10.—Effect of "loading" with fines on pickup ratio.

Table 9.—Effect of Coal Size upon Overrun Ratio[a]

Coal Series	Size code[b]			Improvement		
	1	3	5	3 over 1	5 over 1	3 over 5
20	0.51	0.48	0.49	0.03	0.02	0.01
30	0.46	0.44	0.46	0.02	0.00	0.02
40	0.42	0.47	0.41	−0.05	0.01	−0.06
50	0.42	0.47	0.41	−0.05	0.01	−0.06
60	0.44	0.48	0.48	−0.04	−0.04	0.00
70	0.43	0.47	0.43	−0.04	0.00	−0.04
80	0.46	0.49	0.49	−0.03	−0.03	0.00
90	0.44	0.48	0.53	−0.04	−0.09	0.05
Average	0.45	0.47	0.46	−0.02	−0.01	−0.01

[a] Ratio of rate of heat release during the first five minutes after stoker shut off, following the 15-minute "on" period, to the average rate with continuous stoker operation.
[b] No. 1 is the 1¼ inch by 0 coal; No. 3 is the ¼ inch by 0 coal; No. 5 has equal parts of No. 1 and No. 3 coals.

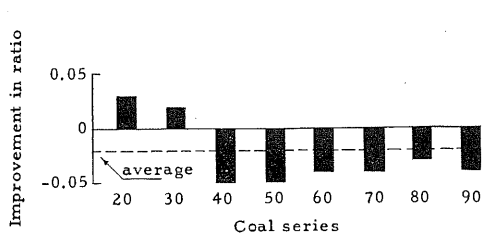

Fig. 11.—Effect of crushing on overrun ratio. (1¼ inch coal crushed to ¼ inch top size.)

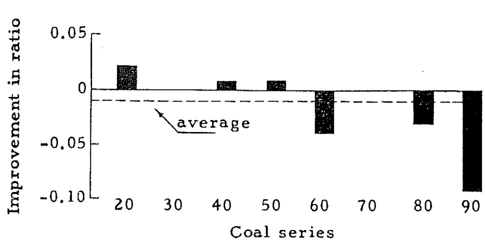

Fig. 12.—Effect of "loading" with fines on overrun ratio.

TABLE 10.—EFFECT OF COAL SIZE UPON FEEDING RATE
(In pounds per hour)

Coal Series	Size code[a]			Change		
	1	3	5	3 minus 1	5 minus 1	3 minus 5
20	24.1	25.9	26.1	1.8	2.0	−0.2
30	23.1	25.0	24.4	1.9	1.3	0.6
40	26.3	26.6	26.0	0.3	−0.3	0.6
50	25.0	26.1	25.7	1.1	0.7	0.4
60	25.0	26.6	26.7	1.6	1.7	−0.1
70	23.5	26.2	25.1	2.7	1.6	1.1
80	24.3	25.9	25.6	1.6	1.3	0.3
90	23.1	24.2	24.3	1.1	1.2	−0.1
Average	24.3	25.8	25.5	1.5	1.2	0.3

[a] No. 1 is the 1¼ inch by 0 coal; No. 3 is the ¼ inch by 0 coal; No. 5 has equal parts of No. 1 and No. 3 coals.

TABLE 11.—EFFECT OF COAL SIZE UPON RATIO OF MINIMUM AND AVERAGE RATES OF HEAT RELEASE WITH CONTINUOUS STOKER OPERATION

Coal Series	Size code[a]			Improvement		
	1	3	5	3 over 1	5 over 1	3 over 5
20	0.92	0.83	0.88	−0.09	−0.04	−0.05
30	0.78	0.92	0.89	0.14	0.11	0.03
40	0.77	0.80	0.71	0.03	−0.06	0.09
50	0.73	0.82	0.84	0.09	0.11	−0.02
60	0.29	0.85	0.71	0.56	0.42	0.14
70	0.39	0.85	0.75	0.46	0.36	0.10
80	0.80	0.88	0.90	0.08	0.10	−0.02
90	0.61	0.91	0.90	0.30	0.29	0.01
Average	0.66	0.86	0.82	0.20	0.16	0.04

[a] No. 1 is the 1¼ inch by 0 coal; No. 3 is the ¼ inch by 0 coal; No. 5 has equal parts of No. 1 and No. 3 coals.

TABLE 12.—EFFECT OF COAL SIZE UPON PRESSURE IN STOKER AIR DUCT
(In inches of water, static pressure)

Coal Series	Size range and code									
	1¼ inch × 0 (1)		1¼ inch × 10 mesh (2)		¼ inch × 0 (3)		¼ inch × 10 mesh (4)		1¼ inch × 0[a] (5)	
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
20	0.85	1.60	0.85	1.22	1.12	1.62	0.72	1.20	1.09	1.55
30	0.81	1.56	0.68	1.20	1.00	1.55	0.82	1.60	1.00	1.59
40	1.26	1.61	1.05	1.50	1.31	1.62	0.92	1.57	1.25	1.61
50	1.20	1.55	0.96	1.66	1.31	1.59	1.01	1.59	1.40	1.68
60	1.00	1.59	0.80	1.37	1.27	1.58	0.39	1.46	1.19	1.58
70	0.76	1.47	0.66	1.48	1.32	1.67	0.39	1.57	1.23	1.59
80	0.90	1.48	0.76	1.12	1.29	1.50	0.87	1.18	1.15	1.67
90	0.96	1.66	0.78	1.22	1.18	1.51	0.83	1.31	1.12	1.52
Average	0.97	1.57	0.82	1.35	1.23	1.58	0.87	1.44	1.18	1.60

[a] Equal parts of original 1¼ inch by 0 and ¼ inch by 0 coals.

e. *Heat output factor.*—The heat output is largely dependent upon the coal feeding rate, which will vary with the size of the coal fed, even though the speed of the feed worm remains constant. Table 10 shows the effect of size upon the feeding rate. The average increase in rate with the 1/4 inch by 0 coal over the 1 1/4 inch by 0 was 1.5 pounds per hour, or 6.2 percent. The 1 1/4 inch by 0 which was loaded with fines fed nearly 5 percent faster than the regular 1 1/4 inch by 0.

However, the capacity of a heating plant is not entirely dependent upon feeding rate. One factor of importance is the relationship between the rate of heat release during a period of poor fire with continuous stoker operation and the average rate. The tests showed that crushing the 1 1/4 inch by 0 coal to 1/4 inch by 0 resulted in an average improvement in ratio of 0.20, which is approximately 30 percent (table 11). The maximum improvement in ratio was 0.56, or 193 percent, with the coal prepared from the Madison County screenings (60 series). The coal prepared from Madison County nut (70 series) was also markedly improved in this respect by crushing. The 1/4 inch by 0 coal prepared from Vermilion County screenings (20 series) was the only exception to the general tendency for improvement over the 1 1/4 inch by 0 coal in respect to the minimum divided by the average rate of heat release. The 1 1/4 inch by 0 coals, which were "loaded" with fines, were usually superior to the regular 1 1/4 inch by 0 in respect to the ratio of the minimum divided by the average. There were two minor exceptions. The average increase in ratio was 0.16 or 24 percent.

4. EFFECT UPON SMOKE, APPEARANCE OF FIRE, AND "HOLD-FIRE" ABILITY

No significant difference in the amount of smoke or appearance of the fire was attributed to size. All the coals tested maintained a responsive fire with stoker operation of 3 minutes out of each 1 3/4 hours, hence they were considered excellent in this respect.

5. EFFECT UPON STATIC PRESSURE IN STOKER AIR DUCT

The air regulator on the stoker used for the tests maintains a substantially constant rate of air delivery with a fixed setting, irrespective of the resistance of the fuel bed, up to the maximum capacity of the fan. Since the coals which include the finer sizes feed at a faster rate than the coarser coals, the air adjustment was set for a higher rate of delivery when burning the finer coals. In addition, the resistance to air passage with the finer coal may be greater than with the coarser coal. These two factors resulted in the maintenance of higher static pressures when burning the fine coal.

There is a definite possibility that under certain conditions some stokers can not supply sufficient air to burn coal as fine as that tested at the maximum rate of coal feed. Although a study of this mechanical characteristic of stokers is not considered to be within the scope of the present investigation, the average and maximum static pressures in the air duct leading from the stoker fan to the retort are given to aid those who desire to study this condition (table 12). It should be emphasized that the static pressures with the fine coal would have been less if the rate of coal feed had been the same as with the larger coal. In fact, it is the author's opinion that much of the increase in static pressure was required because of the increased feeding rate, since the coal did not exist as discrete particles in the fuel bed for any appreciable time. Instead, these particles combined into masses of coke in very much the same manner as with the larger coal. Little or no difference in resistance to air flow was indicated by the appearance of the fuel bed.

This opinion was strengthened further by the observation of the random shifting of the zone of most active combustion over the entire hearth. If the resistance of the fuel bed were materially less with coarse coal, the section of the hearth nearest to the stoker hopper would be the most active zone of combustion, since the largest portion of coarse coal is fed to this section.

TABLE 13.—EFFECT OF COAL SIZE UPON QUANTITY OF FLY ASH
(In percentage of coal burned)

Coal Series	Size range and code									
	1¼ inch × 0 (1)		1¼ inch × 10 mesh (2)		¼ inch × 0 (3)		¼ inch × 10 mesh (4)		1¼ inch × 0[a] (5)	
	Collected	Calculated	Collected	Calculated	Collected	Calculated	Collected	Calculated	Collected	Calculated
20	0.16	0.41	0.12	−0.01	0.22	0.54	0.14	0.19	0.18	0.24
30	0.17	0.75	0.13	0.50	0.21	0.65	0.17	0.78	0.20	0.40
40	0.17	0.35	0.16	0.41	0.22	0.25	0.12	0.96	0.11	1.01
50	0.19	0.12	0.16	0.19	0.28	0.75	0.23	0.38	0.27	0.34
60	0.23	0.88	0.16	0.17	0.25	0.43	0.20	0.79	0.29	−0.12
70	0.16	0.42	0.13	0.46	0.25	0.46	0.18	0.49	0.23	0.59
80	0.35	0.88	0.17	0.89	0.37	1.26	0.16	1.34	0.26	1.04
90	0.25	0.32	0.17	1.16	0.23	1.34	0.18	1.15	0.32	0.32
Average	0.21	0.52	0.15	0.47	0.25	0.71	0.17	0.76	0.23	0.48

[a] Equal parts of original 1¼ inch by 0 and ¼ inch by 0 coals.

6. EFFECT OF SIZE UPON FLY ASH

The fly ash which collected in the boiler passages was removed and weighed after each test. It was found that a reduction in size of coal caused an increase in the amount of fly ash deposited (table 13). The average increase with the ¼ inch by 0 coal over the 1¼ inch by 0 coal was 0.04 percentage figures or 19 percent. The average amount of fly ash deposited with the 1¼ inch by 0 coal which was "loaded" with fines was 0.23 percent of the coal burned, compared with 0.21 and 0.25 percent for the 1¼ inch by 0 and ¼ inch by 0, respectively.

Of course only a portion of the fly ash that leaves the fuel bed remains in the boiler passages. An appreciable quantity passes into the stack. The amount of fly ash leaving the boiler can be determined by subtracting the quantity of ash and clinker removed from the combustion chamber from the amount formed. Unfortunately the amount of ash formed can not be conveniently determined with the precision required. This fact will be readily appreciated by noting in table 41 (Appendix) that the percentages of moisture-free ash reported for coals 91 and 93 were 9.8 and 10.7 respectively, although the coals were presumably identical except in size. If 10.7 is the true average percentage of ash for coal 91, instead of the 9.8 reported, the calculated fly ash would be about three times greater than the 0.32 percent indicated in table 13. Obviously very little reliance should be placed upon the calculated percentages of fly ash.

7. SUMMARY OF EFFECT UPON COMBUSTION CHARACTERISTICS

Table 14 gives the average effect of coal size upon the seven combustion characteristics previously discussed. No appreciable difference is shown for any of these characteristics with the possible exception of the improved uniformity with the smaller coal sizes, as reflected by the lower percent variation from the average rate of heat release and the increase in ratio of minimum to average rates of heat release.

EFFECT OF REMOVING MINUS 10-MESH COAL UPON COMBUSTION CHARACTERISTICS

Most of the commercially prepared coals for domestic stokers have the finer coal particles removed, which is commonly called "dedusting." Because it was considered desirable to test three coals (from each mine) that differed only in size composition, the fine coal caused by crushing was not removed from these coals. To gain informa-

TABLE 14.—SUMMARY OF EFFECT OF COAL SIZE UPON PERFORMANCE CHARACTERISTICS

Performance characteristic	Size code[a]			Average improvement		
	1	3	5	3 over 1	5 over 1	3 over 5
Heat obtained, B.t.u. per pound	6971	7255	7136	284	165	119
Uniformity, percent variation from average	10.1	6.5	7.0	3.6	3.1	0.5
Responsiveness[b]	0.13	0.22	0.25	−0.01	0.02	−0.03
Pickup[c]	0.24	0.23	0.24	−0.01	0.00	−0.01
Overrun[d]	0.45	0.47	0.46	−0.02	−0.01	−0.01
Clinker rating	2.6	2.7	2.5	0.1	−0.1	0.2
Minimum ÷ average rate of heat release[e]	0.66	0.86	0.82	0.20	0.16	0.04

[a] No. 1 is the 1¼ inch by 0 coal; No. 3 is the ¼ inch by 0 coal; No. 5 has equal parts of No. 1 and No. 3 coals.
[b] Ratio of rate of heat release during the first 30 minutes of stoker operation following the hold-fire period to the average rate during test with continuous stoker operation.
[c] Ratio of rate of heat release during the first five minutes of stoker operation following a 45-minute off period to the average rate during test with continuous stoker operation.
[d] Ratio of rate of heat release during the first five minutes after stoker shut off, following the 15-minute on period to the average rate during test with continuous stoker operation.
[e] With continuous stoker operation.

TABLE 15.—EFFECT OF REMOVING MINUS 10-MESH COAL UPON HEAT OBTAINED
(In B.t.u. per lb.)

Coal Series	Size range and code		Improvement, 2 over 1	Size range and code		Improvement, 4 over 3
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)		¼ inch × 0 (3)	¼ inch × 10 mesh (4)	
20	7030	6970	− 60	7140	7460	320
30	6830	7240	410	7180	7320	140
40	7670	7500	−170	7750	7940	190
50	7450	7410	− 40	7680	7720	40
60	6480	6800	320	6970	7030	60
70	6490	6690	200	6870	7080	210
80	6880	6970	90	7160	7370	210
90	6940	6780	−160	7290	7290	0
Average	6971	7045	74	7255	7401	146

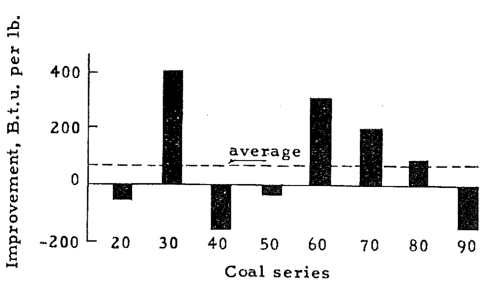

FIG. 13.—Effect of dedusting on heat obtained. (Removal of minus 10-mesh from 1¼ inch by 0 coal.)

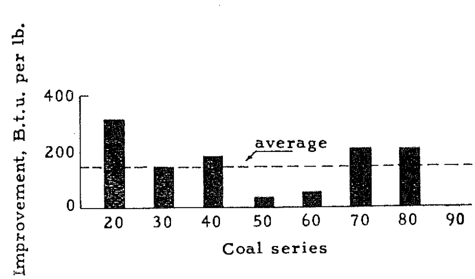

FIG. 14.—Effect of dedusting on heat obtained. (Removal of minus 10-mesh from ¼ inch by 0 coal.)

TABLE 16.—EFFECT OF REMOVING MINUS 10-MESH COAL UPON HEATING VALUE
(In B.t.u. per lb., as-fired basis)

Coal Series	Size range and code		Improvement, 2 over 1	Size range and code		Improvement, 4 over 3
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)		¼ inch × 0 (3)	¼ inch × 10 mesh (4)	
20	11,239	11,349	110	11,314	11,410	96
30	11,436	11,415	−21	11,499	11,460	−39
40	12,149	12,241	92	12,336	12,281	−55
50	12,246	12,136	−110	12,206	12,246	40
60	11,138	11,187	49	11,137	11,309	172
70	11,195	11,290	95	11,124	11,286	162
80	11,353	11,411	58	11,283	11,457	174
90	11,604	11,295	−309	11,411	11,391	−20
Average	11,545	11,540	−5	11,539	11,605	66

TABLE 17.—EFFECT OF REMOVING MINUS 10-MESH COAL UPON QUANTITY OF ASH
(In percent, as-fired basis)

Coal Series	Size range and code		Improvement, 2 over 1	Size range and code		Improvement, 4 over 3
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)		¼ inch × 0 (3)	¼ inch × 10 mesh (4)	
20	8.7	8.6	0.1	9.3	8.6	0.7
30	10.9	10.5	0.4	10.6	10.5	0.1
40	9.5	8.7	0.8	8.8	9.1	−0.3
50	9.1	9.2	−0.1	9.7	9.3	0.4
60	11.3	9.8	1.5	10.9	10.2	0.7
70	9.5	9.4	0.1	9.5	9.5	0.0
80	8.9	8.3	0.6	9.1	8.4	0.7
90	8.8	9.6	−0.8	9.7	9.7	0.0
Average	9.6	9.3	0.3	9.7	9.4	0.3

tion regarding the effect of dedusting, the minus 10-mesh coal was removed from both the 1¼ inch by 0 and the ¼ inch by 0 coals, and comparative tests were made.

1. EFFECT UPON HEAT OBTAINED

In four out of the eight comparative tests, the 1¼ inch by 10-mesh coal furnished more heat per pound than the 1¼ inch by 0 coal (table 15 and fig. 13). The exception of the greatest magnitude was the 170 B.t.u. per pound with the Franklin County coal prepared from screenings (40 series), which should not be considered significant. The improvement of 410 and 320 B.t.u. per pound caused by dedusting the coals prepared from Vermilion County nut and Madison County screenings (30 and 60 series respectively) is considered significant. This improvement does not appear to be caused by a corresponding increase in heating value (table 16). In fact the reported heating value of the Vermilion County 1¼ inch by 10-mesh coal was 21 B.t.u. per pound less than the corresponding 1¼ inch by 0 coal.

None of the ¼ inch by 0 coals furnished more heat per pound than the same coals after dedusting (table 15 and fig. 14). Although only the coal prepared from Ver-

TABLE 18.—EFFECT OF REMOVING MINUS 10-MESH COAL UPON CLINKER RATING[a]

Coal Series	Size range and code		Improvement, 2 over 1	Size range and code		Improvement, 4 over 3
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)		¼ inch × 0 (3)	¼ inch × 10 mesh (4)	
20	3	3	0	3	3	0
30	3	3	0	3	3	0
40	2	2	0	2	3	1
50	2	2	0	3	2	−1
60	3	3	0	3	3	0
70	2	3	1	2	3	1
80	3	3	0	3	3	0
90	3	3	0	3	4	1
Average	2.6	2.7	0.1	2.7	3.0	0.3

[a] A subjective rating varying from 0 (unsatisfactory) to 5 (ideal).

milion County screenings (20 series) furnished an appreciable improvement, the rather consistent trend appears to be one of very slight superiority for the dedusted coals. The average improvement caused by removing the minus 10-mesh from the ¼ inch by 0 coal was 146 B.t.u. per pound. The average increase in heating value caused by dedusting was 66 B.t.u. per pound (table 16), which partially accounts for the increase in heat obtained.

2. EFFECT UPON ATTENTION REQUIRED

The only significant change in the percentage of ash which resulted from the removal of the minus 10-mesh coal was a reduction of 1.5 percentage points (13 percent) with the Madison County screenings (table 17). All other differences in ash between comparable coals could be caused by moisture variations and imperfect sampling and analysis. More precise information about the relative amount of ash in the various size fractions is given in table 37 (Appendix). The minus 10-mesh coal had a higher percentage of ash than the plus 10-mesh coal, although the difference was not great except with the Madison and LaSalle County screenings (60 and 80 series).

Table 18 shows the effect of removing the fines upon the subjective clinker rating. The clinkers from both the 1¼ inch by 10-mesh and ¼ inch by 10-mesh coals prepared from Madison County nut (70 series) appeared more suitable than the corresponding coals that were not dedusted. The ¼ inch by 10-mesh coals appeared to be more suitable from the clinkering standpoint for two other coals (70 and 90 series), but less suitable for another (50 series). In all other tests no change in clinker desirability resulted from dedusting.

The present investigation was concerned only with effect of coal size upon its combustion properties, so no study of the relative dustiness of the coals was made. It is obvious that the fine coal would tend to make more dust, and would be more difficult to render dustless.

3. EFFECT UPON THE ABILITY TO MAINTAIN DESIRED HEAT OUTPUT

a. *Uniformity of heat release.*—The removal of the minus 10-mesh coal did not have a consistent effect upon the uniformity of heat release. In nine out of 16 comparative tests, the dedusted coals burned more uniformly (table 19 and figs. 15 and 16). Of the seven comparative tests in which the dedusted coals burned less uniformly, the difference in uniformity was significant only with the Franklin County 1¼ inch coals (40 and 50 series). With these coals, the 1¼ inch by 0 coals burned with about 25 percent less variation in rate of heat release (4.0 and 3.9 percentage figures) than the 1¼ inch by 10-mesh coals. The greatest percentage point improvement caused by

TABLE 19.—EFFECT OF REMOVING MINUS 10-MESH COAL UPON UNIFORMITY OF HEAT RELEASE
(In percent variation from average rate of heat release)

Coal Series	Size range and code		Improvement, 2 over 1	Size range and code		Improvement, 4 over 3
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)		¼ inch × 0 (3)	¼ inch × 10 mesh (4)	
20	5.9	5.7	0.2	5.2	5.8	−0.6
30	6.4	3.8	2.6	5.4	5.5	−0.1
40	10.4	14.4	−4.0	9.5	8.0	1.5
50	11.6	15.5	−3.9	8.2	8.3	−0.1
60	12.6	8.6	4.0	6.5	7.3	−0.8
70	20.1	14.1	6.0	7.5	6.2	1.3
80	6.0	6.2	−0.2	5.1	4.1	1.0
90	7.4	6.0	1.4	4.3	4.2	0.1
Average	10.1	9.3	0.8	6.5	6.2	0.3

dedusting was 6.0 with the coal prepared from Madison County nut (70 series). However, the greatest percentage improvement was 41 with the coal prepared from Vermilion County nut (30 series). The 4.0 percentage figure improvement with the coal prepared from Madison County screenings (60 series) might be expected because of the reduction in ash caused by dedusting. However, no logical explanation can be given to account for the other changes in uniformity of combustion that are greater than might be obtained from duplicate tests on the same coal.

b. *Responsiveness.*—The fire was usually more responsive after a prolonged holdfire period with the dedusted coals (table 20 and figs. 17 and 18). There were three exceptions, of minor magnitude, out of 16 comparative tests. In one case, no change in responsiveness ratio[10] was caused by dedusting, and in several others the increase in responsiveness was not significant.

c. *Pickup.*—Removing the minus 10-mesh coal from the 1¼ inch by 0 coal did not appreciably affect the rate of pickup of the fire after a 45-minute off period (table 21 and fig. 19). The maximum change in pickup ratio[11] was 0.03. Removing the minus 10-mesh coal from the ¼ inch by 0 coal increased the pickup ratio for all the coals tested (table 21 and fig. 20). The maximum increase in ratio of 0.05 (20 to 24 percent) was obtained with three coals. The average increase in ratio was 0.04 (17 percent).

[10] Defined in footnote 7, page 15.
[11] Defined in footnote 8, page 16.

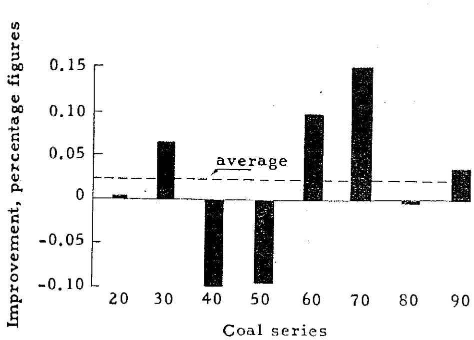

FIG. 15.—Effect of dedusting on uniformity. (Removal of minus 10-mesh from 1¼ inch by 0 coal.)

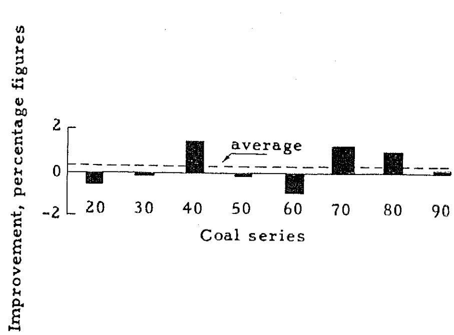

FIG. 16.—Effect of dedusting on uniformity. (Removal of minus 10-mesh from ¼ inch by 0 coal.)

TABLE 20.—EFFECT OF REMOVING MINUS 10-MESH COAL UPON RESPONSIVENESS RATIO[a]

Coal Series	Size range and code: 1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)	Improvement, 2 over 1	Size range and code: ¼ inch × 0 (3)	¼ inch × 10 mesh (4)	Improvement, 4 over 3
20	0.33	0.28	−0.05	0.34	0.37	0.03
30	0.33	0.31	−0.02	0.21	0.33	0.12
40	0.16	0.17	0.01	0.16	0.23	0.07
50	0.22	0.22	0.00	0.17	0.25	0.08
60	0.22	0.25	0.03	0.24	0.40	0.16
70	0.20	0.21	0.01	0.19	0.40	0.21
80	0.18	0.27	0.09	0.23	0.20	−0.03
90	0.21	0.23	0.02	0.25	0.26	0.01
Average	0.23	0.24	0.01	0.22	0.30	0.08

[a] The ratio of the rate of heat release during the first 30 minutes of stoker operation following the hold-fire period, to the average rate with continuous stoker operation.

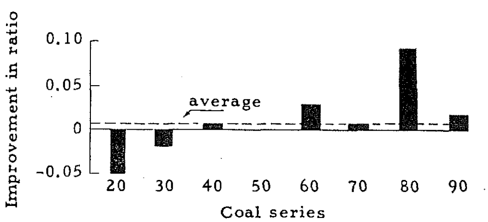

FIG. 17.—Effect of dedusting on responsiveness ratio. (Removal of minus 10-mesh from 1¼ inch by 0 coal.)

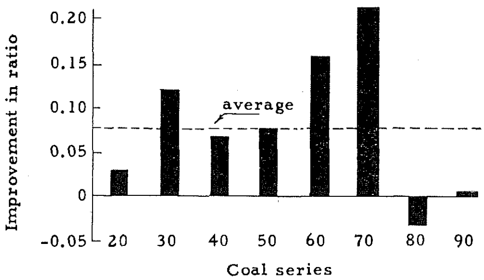

FIG. 18.—Effect of dedusting on responsiveness ratio. (Removal of minus 10-mesh from ¼ inch by 0 coal.)

TABLE 21.—EFFECT OF REMOVING MINUS 10-MESH COAL UPON PICKUP RATIO[a]

Coal Series	Size range and code: 1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)	Improvement, 2 over 1	Size range and code: ¼ inch × 0 (3)	¼ inch × 10 mesh (4)	Improvement, 4 over 3
20	0.25	0.23	−0.02	0.25	0.29	0.04
30	0.23	0.24	0.01	0.21	0.26	0.05
40	0.26	0.23	−0.03	0.22	0.24	0.02
50	0.24	0.26	0.02	0.23	0.25	0.02
60	0.25	0.26	0.01	0.23	0.26	0.03
70	0.26	0.24	−0.02	0.21	0.26	0.05
80	0.24	0.24	0.00	0.25	0.27	0.02
90	0.22	0.24	0.02	0.24	0.29	0.05
Average	0.24	0.24	0.00	0.23	0.27	0.04

[a] The ratio of the average rate of heat release during the first five minutes of stoker operation following the 45-minute off period, to the average rate with continuous stoker operation.

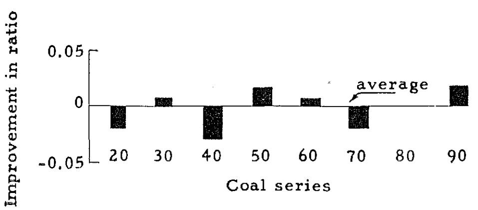

FIG. 19.—Effect of dedusting on pickup ratio. (Removal of minus 10-mesh from 1¼ inch by 0 coal.)

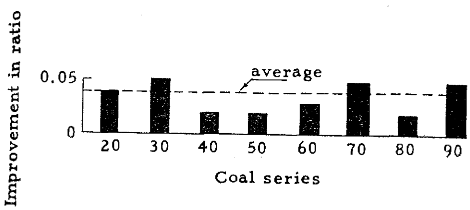

FIG. 20.—Effect of dedusting on pickup ratio. (Removal of minus 10-mesh from ¼ inch by 0 coal.)

TABLE 22.—EFFECT OF REMOVING MINUS 10-MESH COAL UPON OVERRUN RATIO[a]

Coal Series	Size range and code		Improvement, 2 over 1	Size range and code		Improvement, 4 over 3
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)		¼ inch × 0 (3)	¼ inch × 10 mesh (4)	
20	0.51	0.48	0.03	0.48	0.49	−0.01
30	0.46	0.48	−0.02	0.44	0.51	−0.07
40	0.42	0.42	0.00	0.47	0.47	0.00
50	0.42	0.45	−0.03	0.47	0.45	0.02
60	0.44	0.51	−0.07	0.48	0.50	−0.02
70	0.43	0.43	0.00	0.47	0.50	−0.03
80	0.46	0.48	−0.02	0.49	0.49	0.00
90	0.44	0.44	0.00	0.48	0.51	−0.03
Average	0.45	0.46	−0.01	0.47	0.49	−0.02

[a] The ratio of the average rate of heat release during the first five minutes after stoker shut-off following the 15-minute on periods, to the average rate with continuous stoker operation. A decrease in ratio is an improvement.

d. *Overrun.*—Removing the minus 10-mesh coal increased the overrun ratio[12] in nine out of the 16 comparative tests (table 22, and figs. 21 and 22). In only two tests (30 and 60 series) was the increase more than might be expected from duplicate tests with the same coal. No change in overrun ratio was obtained with dedusted coals in five comparative tests, and a slight decrease was obtained with the other two tests.

e. *Heat output factor.*—Removing the minus 10-mesh coal increased the ratio of the minimum to the average rate of heat release with continuous stoker operation in seven out of the 16 comparative tests (table 23). The increase was considered to be significant in only two cases. One of these was the 0.46 increase in ratio with the coal prepared from Madison County screenings (60 series). The ash in this coal was decreased 1.5 percentage figures (13 percent), so an improvement in ratio of minimum to average rate of heat release might be expected. The other improvement considered significant was the increase of 0.22 in ratio for the LaSalle County coal (90 series). The reason for this improvement is not known. There is no significant difference in percentage of ash. However, this is the coal that heated slightly in the bins (reached a temperature of about 130°F.), and possibly this "preoxidation" had some effect. No explanation can be given for the decrease in ratio with the dedusted Vermilion and Franklin County coals (30 and 40 series). Possibly variations of this magnitude could be expected from duplicate tests of the same coal and should be considered insignificant.

[12] Defined in footnote 9, page 16.

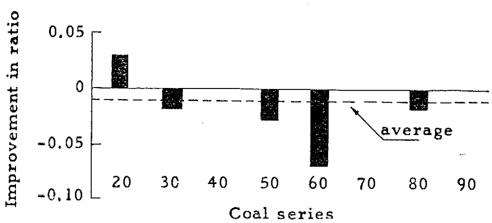

FIG. 21.—Effect of dedusting on overrun ratio. (Removal of minus 10-mesh from 1¼ inch by 0 coal.)

4. EFFECT UPON FLY ASH, SMOKE, APPEARANCE OF THE FIRE, AND "HOLD-FIRE" ABILITY

Although only a slight improvement in combustion characteristics was usually

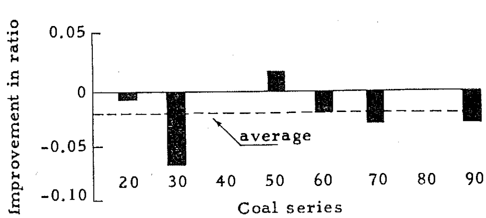

FIG. 22.—Effect of dedusting on overrun ratio. (Removal of minus 10-mesh from ¼ inch by 0 coal.)

TABLE 23.—EFFECT OF REMOVING MINUS 10-MESH COAL UPON RATIO OF MINIMUM TO AVERAGE RATES OF HEAT RELEASE WITH CONTINUOUS STOKER OPERATION

Coal Series	Size range and code: 1¼ inch × 0 (1)	Size range and code: 1¼ inch × 10 mesh (2)	Improvement, 2 over 1	Size range and code: ¼ inch × 0 (3)	Size range and code: ¼ inch × 10 mesh (4)	Improvement, 4 over 3
20	0.92	0.79	−0.13	0.83	0.91	0.08
30	0.78	0.86	0.08	0.92	0.72	−0.20
40	0.77	0.52	−0.25	0.80	0.78	−0.02
50	0.73	0.70	−0.03	0.82	0.81	−0.01
60	0.29	0.75	0.46	0.85	0.78	−0.07
70	0.39	0.42	0.03	0.85	0.82	−0.03
80	0.80	0.85	0.05	0.88	0.90	0.02
90	0.61	0.83	0.22	0.91	0.98	−0.04
Average	0.66	0.71	0.05	0.86	0.83	−0.03

caused by removing the minus 10-mesh coal, other important reasons will probably require the continuance of this practice. One of the primary reasons appears to be the difficulty of rendering domestic stoker coal dustless without first removing the fines. Another reason for removing the fine coal is to reduce the amount of fly ash formed. Considerably less fly ash was deposited in the boiler passages when burning the dedusted coals than when burning the corresponding single screened coal (table 13). The "calculated" fly ash did not show this trend, but the accuracy of these data are questionable for the reasons discussed on page 20.

The removal of the minus 10-mesh coal did not appreciably affect the amount of smoke formed, the appearance of the fire, or the "hold-fire" ability.

5. SUMMARY OF EFFECT UPON COMBUSTION CHARACTERISTICS

Table 24 shows the average effect of removing the minus 10-mesh coal upon seven of the combustion characteristics measured.

TABLE 24.—SUMMARY OF EFFECT OF REMOVING MINUS 10-MESH COAL UPON COMBUSTION CHARACTERISTICS

Combustion Characteristic	Size range and code: 1¼ inch × 0 (1)	Size range and code: 1¼ inch × 10 mesh (2)	Improvement, 2 over 1	Size range and code: ¼ inch × 0 (3)	Size range and code: ¼ inch × 10 mesh (4)	Improvement, 4 over 3	Average Improvement
Heat obtained, B.t.u. per pound	6971	7045	74	7255	7401	146	110
Uniformity, percent variation from average	10.1	9.3	0.8	6.5	6.2	0.3	0.5
Responsiveness[a]	0.23	0.24	0.01	0.22	0.30	0.08	0.04
Pickup[b]	0.24	0.24	0.00	0.23	0.27	0.04	0.02
Overrun[c]	0.45	0.46	−0.01	0.47	0.49	−0.02	−0.01
Clinker rating	2.6	2.7	0.1	2.7	3.0	0.3	0.2
Minimum ÷ average rate of heat release[d]	0.66	0.71	0.05	0.86	0.83	−0.03	0.01

[a] Ratio of rate of heat release during the first 30 minutes of stoker operation following the hold-fire periods, to the average rate with continuous stoker operation.
[b] Ratio of average rate of heat release during the first five minutes of stoker operation following the 45-minute off period to the average rate with continuous stoker operation.
[c] Ratio of average rate of heat release during the first five minutes after stoker shut-off following the 15-minute on period, to the average rate with continuous stoker operation.
[d] With continuous stoker operation.

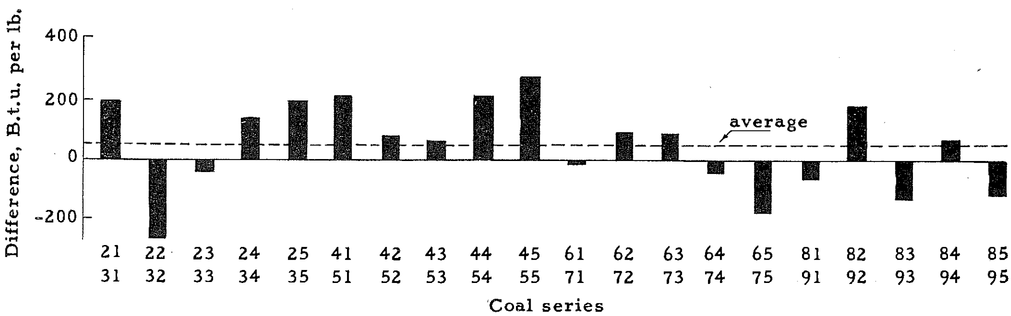

FIG. 23.—Difference in heat obtained from stoker coals prepared from screenings and from nut coal.
(Plus values—screenings superior; minus values—nut coal superior.)

A slight improvement is indicated for all these combustion characteristics except overrun, but the improvement is usually less than might be expected from normal fluctuations when burning the same coal, and would be undetectable in a household installation.

COMPARISON OF COMBUSTION CHARACTERISTICS OF STOKER COALS PREPARED FROM SCREENINGS AND NUT COAL

1. HEAT OBTAINED

There was very little difference in the amount of heat obtained from the comparative tests on coals prepared from screenings and nut coal (table 25 and fig. 23). Most of the variations found might be expected from duplicate tests on the same coal. In 12 comparative tests out of 20, the coals prepared from screenings furnished more heat per pound than those prepared from nut coal. The average difference was only 54 B.t.u. per pound, which is certainly insignificant. The maximum difference was 290 B.t.u. per pound with the Franklin County 1¼ inch by 0 coals which were loaded with fines (coals 45 and 55).

The coals prepared from screenings had an average heating value of 43 B.t.u. per pound less than that prepared from nut coal

TABLE 25.—HEAT OBTAINED FROM STOKER COALS PREPARED FROM SCREENINGS AND NUT COALS
(In B.t.u. per pound)

Coal Series[a]	Size range and code					Average
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)	¼ inch × 0 (3)	¼ inch × 10 mesh (4)	1¼ inch × 0[b] (5)	
20	7030	6970	7140	7460	7240	
30	6830	7240	7180	7320	7040	
difference	200	−270	−40	140	200	46
40	7670	7500	7750	7940	7690	
50	7450	7410	7680	7720	7400	
difference	220	90	70	220	290	178
60	6480	6800	6970	7030	6790	
70	6490	6690	6870	7080	6960	
difference	−10	110	100	−50	−170	4
80	6880	6970	7160	7370	6930	
90	6940	6780	7290	7290	7040	
difference	−60	190	−130	80	−110	−6
Average difference	88	30	0	97	53	54

[a] The 20, 40, 60, and 80 series were prepared from screenings and the others from nut coals.
[b] Equal parts of No. 1 and No. 3 coals.

TABLE 26.—HEATING VALUES OF STOKER COALS PREPARED FROM SCREENINGS AND NUT COALS
(In B.t.u. per pound, as-fired basis)

Coal Series[a]	Size range and code					Average
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)	¼ inch × 0 (3)	¼ inch × 10 mesh (4)	1¼ inch × 0[b] (5)	
20	11,239	11,349	11,314	11,410	11,370	
30	11,436	11,415	11,499	11,460	11,509	
difference	−197	−66	−185	−50	−139	−127
40	12,149	12,241	12,336	12,281	12,298	
50	12,246	12,136	12,206	12,246	12,195	
difference	−97	105	130	35	103	55
60	11,138	11,187	11,137	11,309	11,236	
70	11,195	11,290	11,124	11,286	11,289	
difference	−57	−103	13	23	7	−23
80	11,353	11,411	11,283	11,457	11,260	
90	11,604	11,295	11,411	11,391	11,453	
difference	−251	116	−128	66	−193	−78
Average difference	−151	13	−43	19	−56	−43

[a] The 20, 40, 60, and 80 series were prepared from screenings, and the others from nut coals.
[b] Equal parts of No. 1 and No. 3 coals.

(table 26), although the reverse trend was shown for heat obtained. This means that the average efficiency of combustion was higher with the coal prepared from screenings than with that prepared from nut coal. However, the increase indicated was only 0.7 percentage point, which is too small to be of practical significance.

2. ATTENTION REQUIRED

In as far as the percentage of ash governs the attention required, the stoker coals prepared from screenings were superior in 12 out of the 20 comparative tests (table 27 and fig. 24). The average difference in ash was only 0.4 percentage point which is certainly insignificant. Only the stoker coals prepared from Madison County nut coal (70 series) were consistently lower in ash than the corresponding stoker coal prepared from screenings (60 series).

There is no significant difference between the clinker ratings assigned to coals prepared from screenings and those prepared from nut coal (table 28).

3. ABILITY TO MAINTAIN DESIRED HEAT OUTPUT

a. *Uniformity of heat release.*—The stoker coals prepared from screenings burned more uniformly than the corresponding coal prepared from nut coal for 13 out of the 20 comparative tests (table 29 and fig. 25). The average improvement was 0.9 percentage point, which is not considered significant. The greatest improvement was 7.5 percentage points (37 percent) with the Madison County 1¼ inch by 0 coals (coals 61 and 71). However, the 1¼ inch by 10-mesh coals from the same county had a greater percentage improvement (39 percent). This improved uniformity of burning with the Madison County coals prepared from screenings is contrary to that expected, since the percentage of ash was lower in the coals prepared from the nut coal. One possible explanation is the difference in the amounts of vitrain (table 30). Although the coal prepared from screenings (61) has only 4.6 percentage figures more vitrain than the coal prepared from nut

TABLE 27.—QUANTITY OF ASH IN STOKER COALS PREPARED FROM SCREENINGS AND NUT COALS
(Data are given in percent, as-fired basis)

Coal Series[a]	Size range and code					Average
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)	¼ inch × 0 (3)	¼ inch × 10 mesh (4)	1¼ inch × 0[b] (5)	
20	8.7	8.6	9.3	8.6	9.0	
30	10.9	10.5	10.6	10.5	10.3	
difference	−2.2	−1.9	−1.3	−1.9	−1.3	−1.7
40	9.5	8.7	8.8	9.1	9.5	
50	9.1	9.2	9.7	9.3	9.2	
difference	0.4	−0.5	−0.9	−0.2	0.3	−0.2
60	11.3	9.8	10.9	10.2	10.6	
70	9.5	9.4	9.5	9.5	9.8	
difference	1.8	0.4	1.4	0.7	0.8	1.0
80	8.9	8.3	9.1	8.4	9.2	
90	8.8	9.6	9.7	9.7	9.3	
difference	0.1	−1.3	−0.6	−1.3	−0.1	−0.6
Average difference	0	−0.8	−0.4	−0.7	−0.1	−0.4

[a] The 20, 40, 60, and 80 series were prepared from screenings, and the others from nut coals.
[b] Equal parts of No. 1 and No. 3 coals.

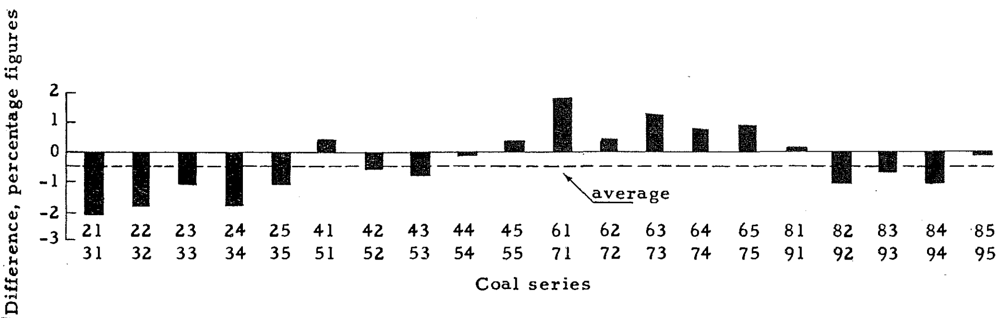

FIG. 24.—Difference in percentage of ash in stoker coals prepared from screenings and from nut coal.
(Plus values—nut superior; minus values—screenings superior.)

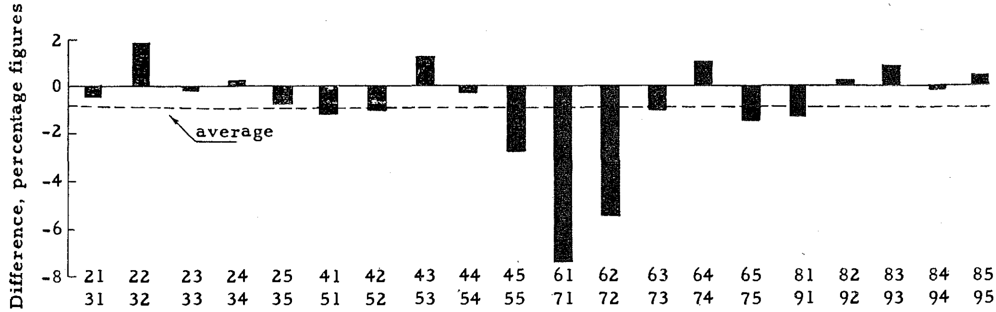

FIG. 25.—Difference in uniformity of heat release with stoker coals prepared from screenings and from nut coal.
(Plus values—nut superior; minus values—screenings superior.)

TABLE 28.—CLINKER RATING[a] OF STOKER COALS PREPARED FROM SCREENINGS AND NUT COALS

Coal Series[b]	Size range and code					Average
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)	¼ inch × 0 (3)	¼ inch × 10 mesh (4)	1¼ inch × 0[c] (5)	
20	3	3	3	3	3	
30	3	3	3	3	3	
difference	0	0	0	0	0	0
40	2	2	2	3	2	
50	2	2	3	2	2	
difference	0	0	−1	1	0	0
60	3	3	3	3	2	
70	2	3	2	3	2	
difference	1	0	1	0	0	0.4
80	3	3	3	3	3	
90	3	3	3	4	3	
difference	0	0	0	−1	0	−0.2

[a] A subjective rating varying from 0 (unsatisfactory) to 5 (ideal).
[b] The 20, 40, 60, 80 series were prepared from screenings, and the others from nut coals.
[c] Equal parts of No. 1 and No. 3 coals.

TABLE 29.—UNIFORMITY OF HEAT RELEASE WITH STOKER COALS PREPARED FROM SCREENINGS AND NUT COALS

(In percent variation from average rate of heat release; thus lower values are superior)

Coal Series[a]	Size range and code					Average
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)	¼ inch × 0 (3)	¼ inch × 10 mesh (4)	1¼ inch × 0[b] (5)	
20	5.9	5.7	5.2	5.8	4.4	5.4
30	6.4	3.8	5.4	5.5	5.2	5.3
difference	−0.5	1.9	−0.2	0.3	−0.8	0.1
40	10.4	14.4	9.5	8.0	8.8	10.2
50	11.6	15.5	8.2	8.3	11.5	11.0
difference	−1.2	−1.1	1.3	−0.3	−2.7	−0.8
60	12.6	8.6	6.5	7.3	7.8	8.5
70	20.1	14.1	7.5	6.2	9.3	11.4
difference	−7.5	−5.5	−1.0	1.1	−1.5	−2.9
80	6.0	6.2	5.1	4.1	4.6	5.2
90	7.4	6.0	4.3	4.2	4.1	5.2
difference	−1.4	0.2	0.8	−0.1	0.5	0
Average difference	−2.7	−1.1	−0.2	0.3	−1.1	−0.9

[a] The 20, 40, 60, and 80 series were prepared from screenings, the others from nut coals.
[b] Equal parts of No. 1 and No. 3 coals.

TABLE 30.—PETROGRAPHIC ANALYSES OF MADISON COUNTY COALS

	1¼ inch × 0 screenings *percent*	2 inch × 1¼ inch nut *percent*
Vitrain	19.3	14.7
Clarain	76.1	73.6
Durain	2.3	9.9
Fusain	1.7	1.6
Refuse	0.6	0.2

(71), the increase is 31 percent, which may account for the more uniform combustion.

Another possible explanation is the difference in composition of the ash (table 44, Appendix). Stoker coal 61 prepared from screenings had 2.48 percentage figures (14 percent) less Fe_2O_3 in the ash than stoker coal 71 prepared from nut. This explanation is not too reasonable, since no previous correlation was found between the Fe_2O_3 and the uniformity of combustion. Neither do the tests in this investigation indicate

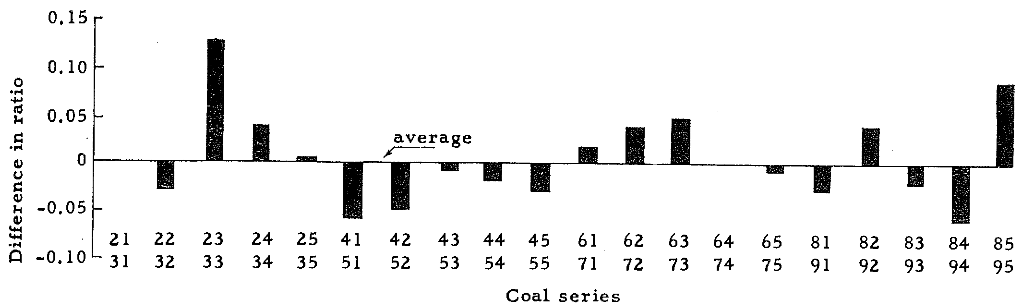

FIG. 26.—Difference in responsiveness ratio with stoker coals prepared from screenings and from nut coal.
(Plus values—screenings superior; minus values—nut coal superior.)

TABLE 31.—RESPONSIVENESS RATIO[a] WITH STOKER COALS PREPARED FROM SCREENINGS AND NUT COALS

Coal Series[b]	Size range and code					Average
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)	¼ inch × 0 (3)	¼ inch × 10 mesh (4)	1¼ inch × 0[c] (5)	
20	0.33	0.28	0.34	0.37	0.31	0.33
30	0.33	0.31	0.21	0.33	0.30	0.30
difference	0.00	−0.03	0.13	0.04	0.01	0.03
40	0.16	0.17	0.16	0.23	0.18	0.18
50	0.22	0.22	0.17	0.25	0.21	0.21
difference	−0.06	−0.05	−0.01	−0.02	−0.03	−0.03
60	0.22	0.25	0.24	0.40	0.23	0.27
70	0.20	0.21	0.19	0.40	0.24	0.25
difference	0.02	0.04	0.05	0.00	−0.01	0.02
80	0.18	0.27	0.23	0.20	0.33	0.24
90	0.21	0.23	0.25	0.26	0.24	0.24
difference	−0.03	0.04	−0.02	−0.06	0.09	0.00
Average difference	−0.02	0.00	0.04	−0.01	0.01	0.00

[a] Ratio of the rate of heat release during the first 30 minutes of stoker operation following the hold-fire period, to the average rate with continuous stoker operation.
[b] The 20, 40, 60, and 80 series were prepared from screenings, the others from nut coals.
[c] Equal parts of No. 1 and No. 3 coals.

TABLE 32.—PICKUP RATIO[a] WITH STOKER COALS PREPARED FROM SCREENINGS AND NUT COALS

Coal Series[b]	Size range and code					Average
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)	¼ inch × 0 (3)	¼ inch × 10 mesh (4)	1¼ inch × 0[c] (5)	
20	0.25	0.23	0.25	0.29	0.25	0.25
30	0.23	0.24	0.21	0.26	0.23	0.23
difference	0.02	−0.01	0.04	0.03	0.02	0.02
40	0.26	0.23	0.22	0.24	0.24	0.24
50	0.24	0.26	0.23	0.25	0.24	0.24
difference	0.02	−0.03	−0.01	−0.01	0.00	0.00
60	0.25	0.26	0.23	0.26	0.25	0.25
70	0.26	0.24	0.21	0.26	0.23	0.24
difference	−0.01	0.02	0.02	0.00	0.02	0.01
80	0.24	0.24	0.25	0.27	0.25	0.25
90	0.22	0.24	0.24	0.29	0.27	0.25
difference	0.02	0.00	0.01	−0.02	−0.02	0.00
Average difference	0.01	−0.01	0.02	0.00	0.01	0.01

[a] The ratio of average rate of heat release during the first five minutes of stoker operation following the 45-minute off periods, to the average rate with continuous stoker operation.
[b] The 20, 40, 60, and 80 series were prepared from screenings, the others from nut coals.
[c] Equal parts of No. 1 and No. 3 coals.

such a trend. For example, little or no difference in uniformity of combustion was obtained with the LaSalle County coals, although the ash from coal 81 had 6.93 percentage figures (17 percent) less Fe_2O_3 than the ash from coal 91.

b. *Responsiveness.*—The responsiveness of the fire to a demand for heat after a prolonged hold-fire period was about the same for the stoker coal prepared from screenings and as that prepared from the corresponding nut coal (table 31 and fig. 26). The maximum difference in responsiveness ratio[13] was 0.13 with the ¼ inch by 0 coals from Vermilion County (series 23 and 33). The average difference with the Vermilion County coals was only 0.03 which is not considered to be significant.

c. *Pickup.*—There was no significant difference between the average pickup ratios[14] with the stoker coals prepared from screenings and from nut coal (table 32 and fig. 27). The maximum difference of 0.04 was with the ¼ inch by 0 coals from Vermilion County (coals 23 and 33). This difference is greater than would be expected from duplicate tests on the same coal, and is particularly significant because the same relative tendency was exhibited with "responsiveness." The cause of this significant difference in pickup and responsiveness with this particular size of coal is not known.

[13] Defined in footnote 7, page 15.

[14] Defined in footnote 8, papge 16.

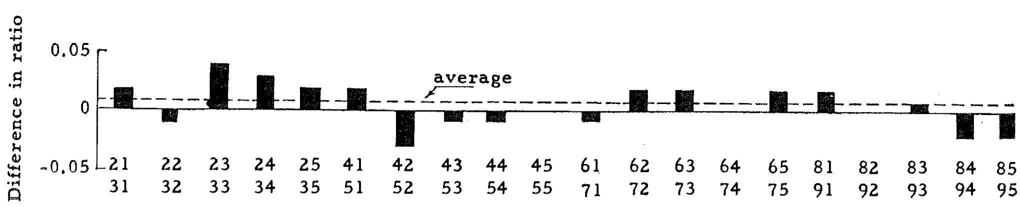

FIG. 27.—Difference in pickup ratio with stoker coals prepared from screenings and from nut coal.
(Plus values—screenings superior; minus values—nut coal superior.)

TABLE 33.—OVERRUN RATIO[a] WITH STOKER COALS PREPARED FROM SCREENINGS AND NUT COALS

Coal Series[b]	Size range and code					Average
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)	¼ inch × 0 (3)	¼ inch × 10 mesh (4)	1¼ inch × 0[c] (5)	
20	0.51	0.48	0.48	0.49	0.49	0.49
30	0.46	0.48	0.44	0.51	0.46	0.47
difference	0.05	0.00	0.04	−0.02	0.03	0.02
40	0.42	0.42	0.47	0.47	0.41	0.44
50	0.42	0.45	0.47	0.45	0.41	0.44
difference	0.00	−0.03	0.00	0.02	0.00	0.00
60	0.44	0.51	0.48	0.50	0.48	0.48
70	0.43	0.43	0.47	0.50	0.43	0.45
difference	0.01	0.08	0.01	0.00	0.05	0.03
80	0.46	0.48	0.49	0.49	0.49	0.48
90	0.44	0.44	0.48	0.51	0.53	0.48
difference	0.02	0.04	0.01	−0.02	−0.04	0.00
Average difference	0.02	0.02	0.02	−0.01	0.01	0.01

[a] The ratio of average rate of heat release during the first five minutes after stoker shut off following the 15-minute on periods, to the average rate with continuous stoker operation.
[b] The 20, 40, 60, 80 series were prepared from screenings, the others from nut coals.
[c] Equal parts of No. 1 and No. 3 coals.

d. *Overrun.*—There were only a few comparable tests in which an appreciable difference in overrun was found between the stoker coals prepared from screenings and those prepared from nut coal (table 33 and fig. 28). The maximum difference in overrun ratio[15] was 0.08, with the 1¼ inch by 10-mesh Madison County coals (Nos. 62 and 72). The average difference for the 20 comparative tests was only 0.01 which is not significant.

e. *Heat output factor.*—No consistent superiority was exhibited by stoker coals prepared from screenings or nut coal in respect to the capacity of the heating plant during periods of poor fire. The greatest difference in ratio of minimum to maximum rates of heat release was 0.33 (table 34). The average difference for the 20 comparative tests was only 0.01, which is not significant.

[15] Defined in footnote 9, page 16.

4. SMOKE, APPEARANCE OF FIRE, AND "HOLD-FIRE" ABILITY

No difference was observed between the stoker coals prepared from screenings and nut coal in the amount of smoke produced,

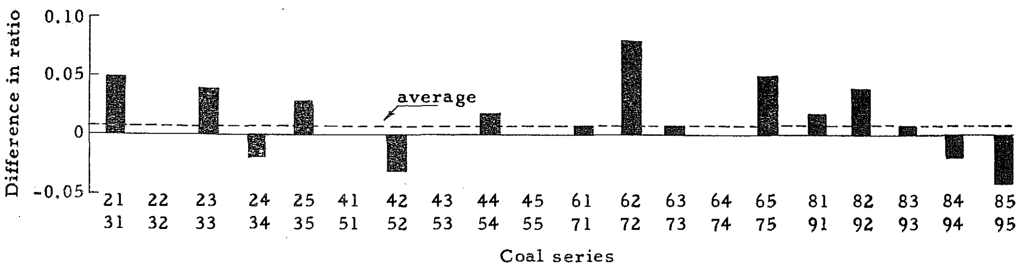

FIG. 28.—Difference in overrun ratio with stoker coals prepared from screenings and from nut coal.
(Plus values—nut superior; minus values—screenings superior.)

TABLE 34.—RATIO OF MINIMUM TO AVERAGE RATES OF HEAT RELEASE WITH STOKER COALS PREPARED FROM SCREENINGS AND NUT COALS[a]

Coal Series[b]	Size range and code					Average
	1¼ inch × 0 (1)	1¼ inch × 10 mesh (2)	¼ inch × 0 (3)	¼ inch × 10 mesh (4)	1¼ inch × 0[c] (5)	
20	0.92	0.79	0.83	0.91	0.89	0.87
30	0.78	0.86	0.92	0.72	0.89	0.84
difference	0.14	−0.07	−0.09	0.19	0.00	0.03
40	0.77	0.52	0.80	0.78	0.71	0.72
50	0.73	0.70	0.82	0.81	0.84	0.78
difference	0.04	−0.18	−0.02	−0.03	−0.13	−0.06
60	0.29	0.75	0.85	0.78	0.71	0.68
70	0.39	0.42	0.85	0.82	0.75	0.65
difference	−0.10	0.33	0.00	−0.04	−0.04	0.03
80	0.80	0.85	0.88	0.90	0.90	0.86
90	0.61	0.83	0.91	0.87	0.90	0.82
difference	0.19	0.02	−0.03	0.03	0.00	0.04
Average difference	0.07	0.03	−0.04	0.04	−0.04	0.01

[a] Data are from tests with continuous stoker operation.
[b] The 20, 40, 60, and 80 series were prepared from screenings, the others from nut coal.
[c] Equal parts of No. 1 and No. 3 coals.

the appearance of the fire, or the ability to maintain a fire at low rates of operation.

5. SUMMARY OF RELATIVE COMBUSTION CHARACTERISTICS

Table 35 summarizes the differences in seven combustion characteristics which were found from the comparative tests of stoker coals prepared from screenings and those prepared from nut coal. The only significant difference shown is the more uniform rate of heat release (2.9 percentage points) with the stoker coals prepared from Madison County screenings than with those prepared from nut coal from the same mine.

TABLE 35.—SUMMARY OF COMBUSTION CHARACTERISTICS OF STOKER COALS PREPARED FROM NUT COALS AND SCREENINGS

	Improvement of screenings over nut coal				
	Vermilion County	Franklin County	Madison County	LaSalle County	Average
Heat obtained, B.t.u. per pound	50	180	0	−10	55
Uniformity, percent variation from average	−0.1	0.8	2.9	0.0	0.9
Responsiveness[a]	0.02	−0.03	0.02	0.00	0.00
Pickup[b]	0.02	−0.01	0.01	0.00	0.01
Overrun[c]	−0.02	0.00	−0.03	0.00	−0.01
Clinker rating	0.0	0.0	0.4	−0.2	0.1
Minimum ÷ average rate of heat release[d]	0.03	−0.06	0.03	0.04	0.01

[a] Ratio of rate of heat release during the first 30 minutes of stoker operation following the hold-fire period, to the average rate with continuous stoker operation.
[b] Ratio of rate of heat release during the first five minutes of stoker operation following a 45-minute off period to the average rate with continuous stoker operation.
[c] Ratio of rate of heat release during the first five minutes after stoker shut off following the 15-minute on periods, to the average rate with continuous stoker operation.
[d] With continuous stoker operation.

CONCLUSIONS

The performance characteristics of the stoker coals tested were not materially affected by the size range. The changes which occurred in responsiveness, pickup, overrun, and heat output were no more than might be expected from duplicate tests with the same coal. The average ¼ inch by 0 coal did furnish slightly more heat per pound than the corresponding 1¼ inch by 0 coal, although the difference would probably be undetectable with a normal installation in a house. The most significant difference in performance was in the more uniform rate of heat release with the smaller sized coal.

The performance characteristics of the 1¼ inch by 0 coals which were "loaded" with fines were equal or slightly superior to those of the corresponding natural 1¼ inch by 0 coals. The public rejection of coals with a large proportion of fines is evidently based upon prejudice, difference in quality of coal, or improper dust treatment. The latter two reasons are the most probable, since the fine sizes as hoisted from a mine frequently have higher ash, and they are much more difficult to render dustless.

The removal of the minus 10-mesh coal resulted in a slight improvement in nearly all combustion characteristics, but the improvement was usually less than might be expected from normal fluctuations with the same coal, and would probably be undetectable in a household installation.

Although only a slight change in combustion characteristics was caused by removing the fine coal, other important reasons will probably require the continuance of this practice. One of the primary reasons appears to be the difficulty of rendering domestic stoker coal dustless without first removing the fines.

Coal was obtained from too few mines to furnish any conclusive data concerning the relative combustion characteristics of stoker coals prepared from screenings and nut coal. Little or no difference was found with the coals tested.

APPENDIX

TABLE 36.—OPERATING SCHEDULE FOR COMBUSTION TESTS

TUESDAY	
7:00 a.m.	Start fire on clean hearth. Cause stoker to operate continuously.
10:00 a.m.	Beginning of test period for continuous stoker operation.
3:45 p.m.	Start taking motion pictures of fuel bed.
4:25 p.m.	Stop taking motion pictures of fuel bed.
8:00 p.m.	End of test period with continuous stoker operation. Remove clinker, fill hopper, and change stoker operating rate to 45 minutes on and 15 minutes off.
10:15 p.m.	Beginning of test period with stoker operating 45 minutes out of each hour.
WEDNESDAY	
10:50 a.m.	Start taking motion pictures of fuel bed.
11:05 a.m.	Stop taking motion pictures of fuel bed.
11:13 a.m.	Start taking motion pictures of fuel bed.
11:40 a.m.	Stop taking motion pictures of fuel bed.
1:15 p.m.	End of test period with stoker operating 45 minutes out of each hour. Remove clinker, fill hopper, and change stoker operating rate to 30 minutes on and 30 minutes off.
4:30 p.m.	Beginning of test period with stoker operating 30 minutes out of each hour.
THURSDAY	
10:45 a.m.	Start taking motion pictures of fuel bed.
11:05 a.m.	Stop taking motion pictures of fuel bed.
11:28 a.m.	Start taking motion pictures of fuel bed.
11:45 a.m.	Stop taking motion pictures of fuel bed.
2:30 p.m.	End of test period with stoker operating 30 minutes out of each hour. Remove clinker, fill hopper, and change stoker operating rate to 15 minutes on and 45 minutes off.
6:30 p.m.	Beginning of test period with stoker operating 15 minutes out of each hour.
FRIDAY	
8:43 a.m.	Start taking motion pictures of fuel bed.
9:05 a.m.	Stop taking motion pictures of fuel bed.
9:43 a.m.	Start taking motion pictures of fuel bed.
9:55 a.m.	Stop taking motion pictures of fuel bed.
SATURDAY	
10:30 a.m.	End of test period with stoker operating 15 minutes out of each hour. Remove clinker and change stoker operating rate to hold-fire (3 minutes out of each 1¾ hours).
MONDAY	
11:45 a.m.	Start stoker operating continuously.
1:45 p.m.	Stop stoker. Quench fire, remove clinker and ash from hearth, and fly ash from boiler passages. Remove coal from hopper, worm, and retort.

TABLE 37.—CHEMICAL COMPOSITION OF VARIOUS SIZE FRACTIONS OF TEST COALS

Coal Series	1¼ inch by 0 coal: Size fraction[a]	Ash, %	Heating value, B.t.u./lb	Sulfur, %	¼ inch by 0 coal: Size fraction	Ash, %	Heating value, B.t.u./lb	Sulfur, %
20	+ ¾ inch	9.5	12927	1.69	+ 4 mesh	10.9	12764	1.68
	¾ inch × ⅜ inch	9.8	12944	1.84	4 mesh × 6 mesh	10.5	12854	1.82
	⅜ inch × 4 mesh	10.1	12912	1.78	6 mesh × 8 mesh	9.9	12967	1.74
	4 mesh × 10 mesh	9.8	12943	1.86	8 mesh × 10 mesh	9.5	12949	1.73
	10 mesh × 0	13.3	12442	2.13	10 mesh × 20 mesh	10.0	12805	1.79
					20 mesh × 0	12.2	12401	2.16
30	+ ¾ inch	14.2	12316	1.56	+ 4 mesh	12.1	12620	1.56
	⅜ inch × ⅜ inch	11.1	12788	1.63	4 mesh × 6 mesh	11.3	12797	1.58
	⅜ inch × 4 mesh	9.9	13025	1.63	6 mesh × 8 mesh	11.4	12744	1.69
	4 mesh × 10 mesh	9.9	12982	1.68	8 mesh × 10 mesh	11.2	12756	1.61
	10 mesh × 0	13.3	12427	2.13	10 mesh × 20 mesh	13.2	12498	1.95
					20 mesh × 0	11.1	12805	1.64
40	+ ¾ inch	9.7	13028	3.05	+ 4 mesh	10.0	13039	2.76
	¾ inch × ⅜ inch	9.0	13098	2.73	4 mesh × 6 mesh	8.9	13206	2.63
	⅜ inch × 4 mesh	8.5	13172	2.76	6 mesh × 8 mesh	8.8	13231	2.66
	4 mesh × 10 mesh	8.9	13221	2.74	8 mesh × 10 mesh	19.0	13138	2.65
	10 mesh × 0	13.0	12543	2.89	10 mesh × 20 mesh	9.1	13115	2.64
					20 mesh × 0	11.6	12760	2.85
50	+ ¾ inch	11.0	12715	2.11	+ 4 mesh	11.3	12856	2.64
	¾ inch × ⅜ inch	9.9	12942	2.24	4 mesh × 6 mesh	10.3	13001	2.56
	⅜ inch × 4 mesh	9.6	12971	2.26	6 mesh × 8 mesh	9.4	13087	2.36
	4 mesh × 10 mesh	9.3	13053	2.41	8 mesh × 10 mesh	9.4	13129	2.34
	10 mesh × 0	10.4	12838	2.58	10 mesh × 20 mesh	9.4	13150	2.35
					20 mesh × 0	10.8	12902	2.49
60	+ ¾ inch	10.9	12443	3.82	+ 4 mesh	11.0	12453	3.90
	¾ inch × ⅜ inch	10.4	12551	3.80	4 mesh × 6 mesh	10.8	12449	3.90
	⅜ inch × 4 mesh	11.1	12537	3.79	6 mesh × 8 mesh	10.2	12514	3.87
	4 mesh × 10 mesh	10.8	12513	3.58	8 mesh × 10 mesh	10.2	12504	3.91
	10 mesh × 0	19.8	11103	3.83	10 mesh × 20 mesh	11.1	12389	3.90
					20 mesh × 0	16.1	11631	4.03
70	+ ¾ inch	13.6	12201	3.66	+ 4 mesh	10.7	12529	4.17
	¾ inch × ⅜ inch	9.8	12669	4.02	4 mesh × 6 mesh	10.6	12627	4.06
	⅜ inch × 4 mesh	10.0	12718	3.81	6 mesh × 8 mesh	10.5	12593	3.92
	4 mesh × 10 mesh	10.2	12643	3.91	8 mesh × 10 mesh	10.3	12647	3.87
	10 mesh × 0	12.0	12329	3.91	10 mesh × 20 mesh	10.3	12613	3.93
					20 mesh × 0	10.8	12526	3.94
80	+ ¾ inch	8.9	13008	3.92	+ 4 mesh	9.2	12946	4.13
	¾ inch × ⅜ inch	9.6	12780	4.32	4 mesh × 6 mesh	8.9	12938	3.92
	⅜ inch × 4 mesh	9.3	12802	4.31	6 mesh × 8 mesh	8.9	13001	3.97
	4 mesh × 10 mesh	9.2	12804	3.91	8 mesh × 10 mesh	9.2	13008	3.95
	10 mesh × 0	15.0	11917	4.58	10 mesh × 20 mesh	9.3	12891	3.94
					20 mesh × 0	13.2	12284	4.48
90	+ ¾ inch	7.1	13255	3.65	+ 4 mesh	10.5	12545	5.16
	¾ inch × ⅜ inch	8.2	13064	4.10	4 mesh × 6 mesh	9.6	12756	4.47
	⅜ inch × 4 mesh	9.9	12867	4.52	6 mesh × 8 mesh	9.2	12873	4.56
	4 mesh × 10 mesh	9.5	12805	4.56	8 mesh × 10 mesh	9.3	12838	4.44
	10 mesh × 0	12.8	12208	4.79	10 mesh × 20 mesh	9.4	12737	4.28
					20 mesh × 0	12.0	12316	4.92

[a] Determined with standard Tyler square-opening sieves.

TABLE 38.—HEAT OBTAINED AND COAL BURNED FOR EACH OPERATION RATE

Coal No.	Heat obtained, M B.t.u./lb.					Average efficiency, %	Coal burned, lb./hr.			
	60[a]	45[a]	30[a]	15[a]	Average		60[a]	45[a]	30[a]	15[a]
21	6.86	6.89	7.05	7.32	7.03	62.6	23.76	17.74	11.82	5.85
22	6.97	6.90	6.86	7.17	6.97	61.4	22.97	17.14	11.66	5.73
23	7.08	7.05	6.93	7.52	7.14	63.1	26.68	18.78	12.58	6.26
24	7.23	7.29	7.48	7.86	7.46	65.4	24.29	17.87	11.79	5.84
25	7.24	7.16	7.06	7.52	7.24	63.7	25.44	18.90	13.21	6.33
31	6.75	6.81	6.65	7.12	6.83	59.7	22.46	16.46	11.60	5.38
32	7.07	6.86	7.34	7.70	7.24	63.4	21.46	16.12	10.54	5.17
33	7.42	7.39	6.96	6.97	7.18	62.4	24.54	18.40	12.09	6.04
34	7.12	7.26	7.24	7.67	7.32	63.9	22.55	16.62	11.03	5.54
35	7.07	7.01	6.86	7.23	7.04	61.2	24.03	17.54	12.18	5.90
41	7.65	7.56	7.68	7.78	7.67	63.1	25.09	18.11	12.62	6.53
42	7.40	7.38	7.53	7.63	7.50	61.3	22.46	16.39	11.10	5.55
43	7.67	7.87	7.60	7.86	7.75	62.8	26.46	18.70	11.78	6.68
44	7.92	7.88	7.97	7.99	7.94	64.7	23.45	17.38	11.68	5.92
45	7.83	7.93	7.36	7.66	7.69	62.4	24.97	18.18	12.29	6.15
51	7.25	7.29	7.60	7.64	7.45	60.8	24.44	17.87	11.76	5.85
52	7.34	7.37	7.46	7.49	7.41	61.1	22.80	16.63	10.94	5.58
53	7.57	7.74	7.45	7.96	7.68	62.9	25.76	17.72	12.48	6.36
54	7.52	7.51	7.79	8.05	7.72	63.0	23.00	16.91	11.28	5.49
55	7.32	7.40	7.46	7.41	7.40	60.7	24.74	18.07	12.40	5.94
61	6.33	6.40	6.47	6.74	6.48	58.2	24.32	18.11	12.00	6.07
62	6.71	6.66	6.69	7.15	6.80	60.8	22.63	17.00	11.42	5.75
63	6.92	7.02	6.95	7.00	6.97	62.6	26.47	18.99	12.89	6.34
64	6.97	6.89	6.98	7.30	7.03	62.2	24.62	17.44	11.67	5.89
65	6.69	6.71	6.82	6.93	6.79	60.4	25.71	18.85	12.70	6.50
71	6.55	6.52	6.45	6.45	6.49	53.0	21.92	17.11	11.64	5.78
72	6.74	6.68	6.51	6.82	6.69	59.3	22.08	16.56	11.08	5.53
73	6.96	6.98	6.81	6.72	6.87	61.8	25.56	18.17	12.32	6.32
74	7.05	6.97	7.11	7.21	7.08	62.7	23.68	17.29	11.51	5.88
75	7.00	7.17	6.94	6.74	6.96	62.0	24.18	17.99	12.47	5.99
81	6.89	6.86	6.78	7.01	6.88	60.6	23.86	17.86	11.76	5.91
82	6.98	6.89	6.83	7.19	6.97	61.1	22.68	16.74	11.00	5.52
83	7.09	7.14	7.15	7.25	7.16	63.5	25.56	18.88	12.68	6.32
84	7.48	7.35	7.19	7.47	7.37	64.3	23.24	17.14	11.54	5.62
85	6.96	6.89	6.72	7.15	6.93	61.5	24.88	18.69	12.62	6.10
91	7.08	6.84	6.85	6.98	6.94	59.8	22.84	16.54	11.15	5.56
92	6.99	6.74	6.71	6.67	6.78	60.0	21.30	15.87	10.57	5.26
93	7.34	7.27	7.19	7.35	7.29	63.9	23.84	17.93	11.95	5.81
94	7.19	7.16	7.16	7.67	7.29	64.0	22.04	15.97	10.66	5.32
95	7.04	6.88	6.93	7.30	7.04	61.5	23.07	17.58	12.11	5.86

[a] Minutes of stoker operation per hour.

TABLE 39.—MISCELLANEOUS DATA ON COMBUSTION CHARACTERISTICS

Coal No.	Boiler output with continuous stoker operation			Uniformity		Responsiveness		Pickup		Overrun	
	Average M B.t.u./hr.	Minimum M B.t.u./hr.	Minimum ÷average	Average variation %	Ratio of minimum to average heat output[a]	M B.t.u. first 30-min.	M B.t.u. first 60-min.	Average cycle M B.t.u. per hr.	Minimum cycle M B.t.u. per hr.	Average cycle M B.t.u per hr.	Maximum M B.t.u. per hr.
21	163	149	0.92	5.9	0.89	27	97	41	31	83	104
22	160	126	0.79	5.7	0.85	23	90	37	27	77	92
23	189	156	0.83	5.2	0.85	32	108	47	35	91	118
24	176	160	0.91	5.8	0.87	32	115	51	37	86	109
25	184	162	0.88	4.4	0.87	29	99	45	34	89	104
31	152	118	0.78	6.4	0.84	25	93	36	30	70	84
32	152	130	0.86	3.8	0.90	24	75	36	29	73	83
33	182	168	0.92	5.4	0.83	19	88	38	31	80	103
34	161	115	0.72	5.5	0.83	26	94	41	30	82	102
35	170	152	0.89	5.2	0.88	25	84	39	31	78	97
41	192	149	0.77	10.4	0.78	15	64	49	34	80	110
42	166	86	0.52	14.4	0.67	14	42	39	28	69	95
43	203	163	0.80	9.5	0.78	16	82	44	27	94	131
44	186	145	0.78	8.0	0.81	21	96	44	31	86	112
45	196	138	0.71	8.8	0.79	18	59	46	34	80	106
51	177	130	0.73	11.6	0.70	19	58	42	32	74	95
52	167	118	0.70	15.5	0.69	18	66	43	34	74	104
53	195	160	0.82	8.2	0.79	17	73	45	33	92	117
54	173	141	0.81	8.3	0.77	22	103	43	34	77	108
55	181	152	0.84	11.5	0.76	19	63	43	32	75	113
61	154	45	0.29	12.6	0.65	17	60	38	29	68	98
62	152	114	0.75	8.6	0.83	19	66	38	27	77	97
63	183	156	0.85	6.5	0.77	22	93	41	28	87	103
64	172	134	0.78	7.3	0.82	34	106	44	33	85	111
65	172	122	0.71	7.8	0.78	20	79	43	31	83	110
71	144	56	0.39	20.1	0.63	15	63	37	30	62	79
72	149	63	0.42	14.1	0.64	16	70	35	28	64	90
73	178	151	0.85	7.5	0.82	17	95	38	27	84	106
74	167	137	0.82	6.2	0.84	33	119	43	35	84	112
75	169	127	0.75	9.3	0.80	20	82	39	32	73	92
81	165	132	0.80	6.0	0.86	15	53	40	33	76	90
82	158	135	0.85	6.2	0.88	21	78	38	29	76	91
83	181	159	0.88	5.1	0.87	21	89	44	34	90	114
84	174	157	0.90	4.1	0.90	18	83	47	39	85	98
85	173	156	0.90	4.6	0.87	28	95	43	32	85	99
91	162	98	0.61	7.4	0.79	17	63	36	30	72	89
92	149	123	0.83	6.0	0.83	17	53	35	26	66	78
93	175	159	0.91	4.3	0.89	22	75	42	34	83	100
94	158	138	0.87	4.2	0.91	21	77	46	38	81	90
95	162	146	0.90	4.1	0.92	20	74	44	33	86	102

[a] Average of all operation rates except hold-fire.

TABLE 40.—HEAT BALANCE, STACK TEMPERATURE, AND CO_2 IN STACK GAS

Coal No.	Results obtained with continuous stoker operation											
	Stack temperature °F	CO_2 %	Heat balance									
			Heat absorbed		Stack loss		Moisture loss		Hydrogen loss		Radiation and unaccounted	
			B.t.u.	%	B.t.u.	%	B.t.u.	%	B.t.u.	%	B.t.u.	%
21	900	11.4	6860	61.0	2830	25.2	187	1.7	433	3.8	929	8.3
22	875	10.6	6970	61.4	2970	26.1	172	1.5	430	3.8	807	7.2
23	935	12.3	7080	62.6	2710	23.9	171	1.5	437	3.9	916	8.1
24	910	11.5	7230	63.4	2810	24.6	160	1.4	433	3.8	777	6.8
25	925	10.5	7240	63.7	3160	27.8	165	1.5	437	3.8	368	3.2
31	900	10.6	6750	59.0	3070	26.8	145	1.3	467	4.1	1004	8.8
32	880	11.5	7070	61.9	2770	24.2	139	1.2	463	4.1	973	8.5
33	930	13.7	7420	64.5	2490	21.7	138	1.2	472	4.1	979	8.5
34	915	10.2	7120	62.1	3230	28.2	139	1.2	470	4.1	501	4.4
35	—	11.2	7070	61.4	—	—	—	—	—	—	—	—
41	985	12.0	7650	63.0	3180	26.2	97	0.8	480	3.9	742	6.1
42	945	10.4	7400	60.4	3720	30.4	94	0.8	473	3.9	554	4.5
43	1025	12.8	7670	62.2	3310	26.8	90	0.7	485	3.9	781	6.4
44	985	—	7920	64.5	—	—	91	0.7	477	3.9	—	—
45	995	—	7830	63.7	—	—	87	0.7	480	3.9	—	—
51	930	—	7250	59.2	—	—	99	0.8	520	4.2	—	—
52	870	10.4	7340	60.5	3180	26.2	104	0.9	508	4.2	1004	8.2
53	1030	11.9	7570	62.0	3370	27.6	97	0.8	535	4.4	634	5.2
54	950	11.3	7520	61.4	3240	26.5	91	0.7	525	4.3	870	7.1
55	975	—	7320	60.0	—	—	93	0.8	527	4.3	—	—
61	870	9.8	6330	56.8	3030	27.2	154	1.4	427	3.8	1197	10.8
62	880	9.8	6710	60.0	3070	27.5	148	1.3	429	3.8	830	7.4
63	980	11.5	6920	62.1	2960	26.6	137	1.2	443	4.0	677	6.1
64	920	10.8	6970	61.6	2940	26.0	135	1.2	435	3.9	829	7.3
65	955	10.2	6690	59.5	3220	28.7	134	1.2	440	3.9	752	6.7

71	860	9.2	6550	58.5	3290	29.4	159	1.4	530	4.7	666	6.0
72	845	9.7	6740	59.7	3070	27.2	152	1.3	528	4.7	800	7.1
73	950	10.8	6960	62.6	3170	28.5	166	1.5	547	4.9	281	2.5
74	930	11.4	7050	62.5	2930	25.9	142	1.3	543	4.8	621	5.5
75	905	10.9	7000	62.3	2940	26.2	150	1.3	538	4.9	601	5.3
81	865	10.3	6890	60.7	2970	26.2	166	1.4	440	3.9	887	7.8
82	830	9.8	6980	61.2	3000	26.3	164	1.4	438	3.8	829	7.3
83	910	11.2	7090	62.8	2920	25.9	174	1.5	450	4.0	649	5.8
84	890	—	7480	65.3	—	—	157	1.4	447	3.9	—	—
85	900	10.8	6960	61.8	3000	26.7	162	1.3	448	4.0	690	6.2
91	880	10.8	7080	61.0	2980	25.7	150	1.3	492	4.2	902	7.8
92	840	9.0	6990	61.9	3350	29.7	142	1.2	485	4.3	328	2.9
93	900	10.8	7340	64.3	3050	26.8	127	1.1	493	4.3	401	3.5
94	890	10.2	7190	63.1	3170	27.9	129	1.1	492	4.3	410	3.6
95	885	10.2	7040	61.5	3150	27.5	135	1.2	491	4.3	638	5.5

Table 41.—Heating Value, Ash, and Sulfur on Various Bases

Coal No.	Analysis No.	County	Seam	Moisture as-fired, %	Heating value, B.t.u./lb.					Ash, percent		Sulfur, percent		
					As-fired	Moisture free	Moisture and ash free	Unit coal, dry	Unit coal, moist	As-fired	Moisture free	As-fired	Moisture free	Moisture and ash free
21	C4129	Vermilion	6	13.1	11239	12931	14362	14556	12436	8.7	10.0	1.53	1.76	1.96
22	C4189	Vermilion	6	12.2	11349	12926	14334	14515	12545	8.6	9.8	1.58	1.80	2.00
23	C4206	Vermilion	6	11.9	11314	12840	14346	14544	12610	9.3	10.5	1.59	1.81	2.02
24	C4207	Vermilion	6	11.2	11410	12853	14237	14414	12611	8.6	9.7	1.51	1.70	1.88
25	C4235	Vermilion	6	11.5	11370	12854	14318	14506	12627	9.0	10.2	1.55	1.76	1.96
31	C4294	Vermilion	6	10.2	11436	12730	14482	14704	12998	10.9	12.1	1.51	1.69	1.92
32	C4306	Vermilion	6	9.8	11415	12648	14322	14533	12909	10.5	11.7	1.46	1.62	1.84
33	C4360	Vermilion	6	9.6	11499	12719	14417	14636	13024	10.6	11.8	1.54	1.70	1.93
34	C4336	Vermilion	6	9.7	11460	12685	14355	14556	12960	10.5	11.6	1.44	1.59	1.80
35	C4350	Vermilion	6	9.7	11509	12740	14374	14587	12987	10.3	11.4	1.53	1.69	1.91
41	C4375	Franklin	6	6.6	12149	13006	14479	14718	13609	9.5	10.2	2.65	2.84	3.16
42	C4380	Franklin	6	6.5	12241	13091	14428	14638	13580	8.7	9.3	2.55	2.73	3.01
43	C4400	Franklin	6	6.1	12336	13138	14493	14713	13701	8.8	9.4	2.48	2.64	2.91
44	C4411	Franklin	6	6.2	12281	13093	14496	14724	13695	9.1	9.7	2.69	2.86	3.17
45	C4424	Franklin	6	5.9	12298	13070	14543	14768	13780	9.5	10.1	2.61	2.78	3.09
51	C4439	Franklin	6	6.9	12246	13150	14566	14775	13644	9.1	9.7	2.31	2.48	2.75
52	C4452	Franklin	6	7.4	12136	13101	14538	14757	13539	9.2	9.9	2.33	2.51	2.79
53	C4468	Franklin	6	6.5	12206	13053	14564	14793	13701	9.7	10.4	2.35	2.51	2.80
54	C4495	Franklin	6	6.3	12246	13069	14508	14718	13678	9.3	9.9	2.28	2.44	2.71
55	C4496	Franklin	6	6.4	12195	13028	14452	14673	13604	9.2	9.9	2.30	2.46	2.73
61	C4512	Madison	6	10.8	11138	12486	14289	14588	12765	11.3	12.6	3.46	3.88	4.44
62	C4531	Madison	6	10.5	11187	12506	14052	14321	12587	9.8	11.0	3.52	3.94	4.42
63	C4538	Madison	6	9.4	11137	12289	13969	14249	12704	10.9	12.0	3.62	4.00	4.54
64	C4556	Madison	6	9.4	11309	12479	14054	14326	12790	10.2	11.2	3.55	3.92	4.42
65	C4554	Madison	6	9.3	11236	12387	14029	14306	12769	10.6	11.7	3.49	3.85	4.36
71	C4578	Madison	6	11.3	11195	12620	14125	14391	12550	9.5	10.7	3.57	4.02	4.50
72	C4600	Madison	6	10.9	11290	12669	14161	14420	12642	9.4	10.5	3.51	3.94	4.40
73	C4602	Madison	6	11.5	11124	12571	14074	14344	12469	9.5	10.7	3.53	3.98	4.46
74	C4615	Madison	6	9.9	11286	12532	14016	14283	12656	9.5	10.6	3.64	4.05	4.53
75	C4616	Madison	6	10.5	11229	12550	14090	14354	12635	9.8	10.9	3.57	3.99	4.47

81	C4652	LaSalle...........	2	11.8	11353	12874	14326	14584	12636	8.9	10.1	3.50	3.97	4.42
82	C4653	LaSalle...........	2	11.8	11411	12944	14294	14542	12609	8.3	9.4	3.57	4.05	4.47
83	C4668	LaSalle...........	2	12.2	11283	12845	14328	14595	12592	9.1	10.3	3.67	4.18	4.66
84	C4703	LaSalle...........	2	11.1	11457	12892	14232	14482	12678	8.4	9.4	3.60	4.05	4.49
85	C4721	LaSalle...........	2	11.4	11260	12705	14179	14451	12582	9.2	10.4	3.69	4.16	4.64
91	C4709	LaSalle...........	2	10.6	11604	12978	14396	14672	12919	8.8	9.8	4.12	4.61	5.11
92	C4725	LaSalle...........	2	10.2	11295	12573	14071	14365	12703	9.6	10.6	4.54	5.05	5.65
93	C4788	LaSalle...........	2	8.9	11411	12525	14026	14318	12848	9.7	10.7	4.38	4.81	5.38
94	C4745	LaSalle...........	2	9.1	11391	12530	14020	14318	12832	9.7	10.6	4.67	5.14	5.75
95	C4746	LaSalle...........	2	9.5	11453	12651	14094	14375	12832	9.3	10.2	4.4	4.8	5.4

Table 42.—Proximate Analyses of Main Samples

Coal No.	Proximate Analysis: As-fired				Moisture-free			Moisture and ash-free		Dry mineral matter-free		Moist mineral matter-free		
	Moisture, %	Ash, %	Volatile matter, %	Fixed carbon, %	Ash, %	Volatile matter, %	Fixed carbon, %	Volatile matter, %	Fixed carbon, %	Volatile matter, %	Fixed carbon, %	Moisture, %	Volatile matter, %	Fixed carbon, %
21	13.1	8.7	32.0	46.2	10.0	36.8	53.2	40.9	59.1	40.0	60.0	14.5	34.2	51.3
31	10.2	10.9	32.1	46.8	12.1	35.7	52.2	40.6	59.4	39.6	60.4	11.7	35.0	53.3
41	6.6	9.5	33.8	50.1	10.2	36.2	53.6	40.3	59.7	39.2	60.8	7.5	36.2	56.3
51	6.9	9.1	32.8	51.2	9.7	35.3	55.0	39.1	60.9	38.0	62.0	7.8	35.0	57.2
61	10.8	11.3	33.4	44.5	12.6	37.4	50.0	42.8	57.2	41.3	58.7	12.6	36.2	51.2
71	11.3	9.5	34.1	45.1	10.7	38.5	50.8	43.0	57.0	41.8	58.2	12.9	36.4	50.7
81	11.8	8.9	34.3	45.0	10.1	38.9	51.0	43.3	56.7	42.0	58.0	13.3	36.4	50.3
91	10.6	8.8	34.3	46.3	9.8	38.4	51.8	42.5	57.5	41.2	58.8	12.0	36.2	51.8

TABLE 43.—ULTIMATE ANALYSES OF MAIN SAMPLES

Coal No.	Ultimate Analysis																
	As-fired						Moisture-free						Moisture and ash-free				
	Hydrogen, %	Carbon, %	Nitrogen, %	Oxygen, %	Sulfur, %	Ash, %	Hydrogen, %	Carbon, %	Nitrogen, %	Oxygen, %	Sulfur, %	Ash, %	Hydrogen, %	Carbon, %	Nitrogen, %	Oxygen, %	Sulfur, %
21	5.90	62.43	1.30	20.15	1.53	8.69	5.11	71.83	1.49	9.81	1.76	10.00	5.68	79.78	1.66	10.92	1.96
31	5.83	63.05	1.33	17.46	1.51	10.82	5.22	70.18	1.48	9.38	1.69	12.05	5.94	79.85	1.68	10.61	1.92
41	5.37	67.08	1.49	13.88	2.65	9.53	4.97	71.81	1.59	8.58	2.84	10.21	5.54	79.94	1.77	9.59	3.16
51	5.82	66.73	1.58	14.47	2.31	9.09	5.43	71.65	1.70	8.98	2.48	9.76	6.01	79.37	1.88	9.99	2.75
61	5.69	59.97	1.11	18.51	3.46	11.26	5.04	67.22	1.24	10.00	3.88	12.62	5.77	76.93	1.42	11.44	4.44
71	6.35	62.27	1.21	17.17	3.57	9.43	5.75	70.19	1.37	8.04	4.02	10.63	6.43	78.56	1.53	8.98	4.50
81	5.77	62.59	1.08	18.17	3.50	8.89	5.05	70.97	1.22	8.71	3.97	10.08	5.62	78.98	1.36	9.62	4.42
91	5.91	63.68	1.07	16.41	4.12	8.81	5.29	71.22	1.20	7.82	4.61	9.86	5.86	79.00	1.33	8.70	5.11

TABLE 44.—ASH FUSION TEMPERATURES, ASH ANALYSES, GIESELER PLASTICITY, AND FREE-SWELLING INDEXES

Coal No.	Ash Fusion Characteristics			Ash Analysis							Gieseler Plasticity				Free swelling index
	Initial deform., °F	Softening, °F	Fluid, °F	SiO_2, %	Al_2O_3, %	Fe_2O_3, %	MgO, %	CaO, %	SO_3, %	Ignition loss, %	Fusion, °C	Maximum fluidity, °C	Solidification, °C	Maximum fluidity, divisions per min.	
21	2172	2212	2245	43.99	24.04	14.87	0.70	6.05	5.48	0.98	—	—	—	—	4
31	2230	2286	2325	43.42	23.35	12.23	0.98	8.31	7.85	0.60	—	—	—	—	3
41	2004	2053	2124	43.42	19.40	17.63	0.89	7.95	8.42	0.08	400	418	445	31	5
51	2019	2092	2225	47.67	21.95	16.68	0.40	4.46	4.93	3.24	401	419	448	40	4
61	2008	2071	2377	51.34	21.25	14.96	0.81	3.85	3.38	3.30	345	—	438	5	3.5
71	1913	2093	2363	50.86	22.05	17.44	0.88	2.26	1.37	1.47	392	407	439	35	3.5
81	2068	2172	2443	27.01	13.69	33.40	0.25	10.27	12.70	7.64	—	418	442	4.6	4.5
91	2103	2193	2589	26.72	13.41	40.33	0.15	7.79	8.98	4.83	401	416	449	34	4

TABLE 45.—VARIETIES OF SULFUR

Coal No.	Varieties of Sulfur											
	As-fired				Moisture-free				Moisture and ash-free			
	Sulfate, %	Pyritic, %	Organic, %	Total, %	Sulfate, %	Pyritic, %	Organic, %	Total, %	Sulfate, %	Pyritic, %	Organic, %	Total, %
21	0.04	0.88	0.61	1.53	0.04	1.02	0.70	1.76	0.05	1.13	0.78	1.96
41	0.03	1.32	1.30	2.65	0.03	1.42	1.39	2.84	0.03	1.58	1.55	3.16
61	0.02	1.40	2.04	3.46	0.02	1.57	2.29	3.88	0.02	1.79	2.63	4.44
81	0.16	2.11	1.23	3.50	0.19	2.39	1.39	3.97	0.21	2.66	1.55	4.42