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EXPERIMENTAL WORK

CONDUCTED IN THE

CHEMICAL LABORATORY

OF THE

UNITED STATES FUEL-TESTING PLANT AT ST. LOUIS, MO.

JANUARY 1, 1905, TO JULY 31, 1906

BY

N. W. LORD

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By N. W. LORD.

INTRODUCTION.

The experimental work reported upon herein was performed at the laboratory of the United States fuel-testing plant on the grounds of the Louisiana Purchase Exposition at St. Louis, Mo., between January 1, 1905, and July 31, 1906, and was undertaken for the purpose of checking the results obtained in the routine work of the laboratory, improving the methods of working, and investigating the chemical and physical properties of coal. The laboratory having been designed primarily for the analysis of the coal samples sent to the fuel-testing plant, as well as those taken in connection with the regular testing operations of the boiler, gas-producer, and other divisions of the plant, only a very small proportion of the time of the force was available for experimental work outside of the regular routine.

From the nature of such work it was not possible to separate the results obtained in 1905 from those obtained in 1906, especially as many of the experiments, such as those on the alteration of coal, involved a long time and were started in 1905 and continued to the middle of 1906. This report therefore covers all such work up to its completion in July, 1906.

The complete history of the coals used in these experiments is not given, the samples being usually referred to by their laboratory numbers only, as such information is generally not necessary and does not affect the interpretation of the results obtained in the experiments. Fuller information as to any particular sample may be found in the published reports of the fuel-testing plant for 1905 and 1906.

In the following pages the results of each line of experimental work are given under a special heading indicating the object of the investigation.

While many of the investigations can only be regarded as preliminary, it is believed that the mass of the results will be of value in shedding light on some matters of general interest.

ACCURACY OF METHOD OF TAKING CAR SAMPLES.

The regular method of taking car samples has been fully described under "Sampling" in Professional Paper No. 48, page 175. To check the accuracy of this method, check samples on two cars of coal rather high in moisture, ash, and sulphur were taken at the same time that the regular sample was taken, by opening a gate in the conveyor runway every four or five minutes, and thereby allowing the contents of one or two buckets passing at that time to be emptied into a small bin. In this way a sample of 1,200 to 1,500 pounds was taken during the unloading of the car. This sample was then put through a small crusher, crushed to ½-inch size, and resampled at the conveyor buckets, and a sample was sent to the chemical laboratory for analysis. In the following table the Indiana coal was a run-of-mine coal, and the amount sampled was approximately 20 tons; and the Ohio coal was a run-of-mine coal, and the amount sampled was approximately 26 tons.

Moisture, ash, and sulphur determinations from samples of two cars of run-of-mine coal.

Constituent.	Indiana coal.		Ohio coal.	
	Regular sample.	Check sample.	Regular sample.	Check sample.
Moisture	10.80	10.47	9.01	9.43
Ash	12.62	12.92	11.33	11.59
Sulphur	4.39	4.43	4.02	4.02

For coals containing such high percentages of ash and sulphur the agreement between these independently taken samples is satisfactory. It indicates, so far as the sampling is concerned, that the analytical work may be taken as closely representing the average of the carload.

MOISTURE LOSS IN COARSE SAMPLES FROM STANDING IN COVERED METAL PAILS.

The large samples from the fuel-testing plant were sent to the laboratory in closed metal pails, and some of them were allowed to stand in the pail several hours, or occasionally over night, before sampling. To see if any considerable amount of moisture might be lost in this way, a portion of the wet sample from the washery (Pennsylvania No. 9 coal) was taken as the most favorable case, and allowed to stand for five days in the closed pail in the laboratory before sampling. The average temperature for the five days was 18° C., and the atmospheric humidity 60 per cent. The percentages of moisture determined by

analysis of this sample, and analysis of the portion of the sample reduced at once, are as follows:

	Per cent.
Portion sampled at once	5.07
Portion sampled after standing five days	4.58
Loss by standing	.49

These coals dry down to about 1 per cent moisture, so that the loosely held and surface moisture amounted to about 4 per cent. From this experiment the moisture loss which occurs during the short time that the sample usually is allowed to stand in the laboratory before sampling would appear to be unimportant.

INVESTIGATION OF MOISTURE LOSSES DURING SAMPLING.

In preparing the samples for these tests the coarse sample (40 to 50 pounds in weight), when received at the laboratory, was divided by quartering. One portion of 500 grams was at once ground without air drying in the ball mill. Another portion of about 5 to 10 pounds was air dried in the usual way before the final pulverization. The results (reduced to sample as received) in moisture and ash for the two portions are as follows:

Moisture and ash determinations on air-dried samples and fresh samples of coal.

Designation of sample.	Regular sample (air dried).		Fresh sample (not air dried).	
	Moisture.	Ash.	Moisture.	Ash.
Illinois	13.54	10.74	[a]9.36	11.37
	13.72	10.32	11.92	10.40
Texas No. 4	33.85	7.30	33.00	7.65
Arkansas No. 8	5.19	14.01	3.58	14.16
Indiana No. 12	10.57	11.65	9.95	11.98
Illinois No. 23 B	15.68	15.59	14.78	16.11
Illinois No. 23 A	13.47	11.53	12.43	11.63
Missouri No. 6	13.80	11.74	12.58	11.15
Illinois No. 22 A	11.91	13.01	11.58	12.57

[a] This sample was ground very fine in ball mill, which probably accounts for the loss being so large.

The results obtained for moisture from the original samples that were ground down without preliminary air drying are without exception decidedly lower than the results obtained from the regularly prepared air-dried samples when calculated to the sample as received, the greatest difference being over 4 per cent and the average difference over 1½ per cent. Furthermore, the fine sample, after being ground without previous air drying, as shown by experiments (see pp. 13–17), gives up moisture so readily as to indicate that a large additional loss during the handling and weighing of the sample in the laboratory is almost certain. The consequent errors due to moisture losses are liable to be so large as to affect very seriously the accuracy of the results obtained.

DETERMINATION OF ERRORS DUE TO ABRASION OF PEBBLES USED IN BALL MILL.

During the Louisiana Purchase Exposition the final pulverization of the samples was done on a bucking board. In the work done during 1905 the final grinding of the sample was done in closed jars in the ball mill, quartz pebbles being used.

In order to determine whether there was danger of materially increasing the ash contents of the samples from chipping and abrasion of the pebbles used in grinding, these pebbles were carefully weighed at intervals and the amount of loss determined. The weight of the sample ground each time in the ball mill is approximately 500 grams, and the abrasion of the pebbles (calculated as percentage of the weight of the samples ground) was also carefully determined. The results on three weighed lots of pebbles are as follows:

Losses of weight in three lots of quartz pebbles before and after grinding in the ball mill.

Lot.	Total weight of samples ground.	Weight of pebbles.		Loss by abrasion.	
		Before grinding	After grinding.	Actual.	Ratio to coal ground.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
No. 1 (250 samples ground)	125,000	4,118.6	4,113 1	5.5	0.004
No. 2 (230 samples ground)	115,000	3,502.9	3,499.4	3.5	.003
No. 3 (245 samples ground)	122,500	4,273.2	4,268.3	4.9	.004

These results show that as far as the fine pulverization of the coal is concerned, there is little or no danger of increasing the ash content of the sample appreciably by using quartz pebbles as the grinding medium. The pebbles used show no tendency to chip, as the loss between weighings taken before and after 25 to 50 samples were ground in no case amounted to over 1 gram, the abrasion being in all cases approximately proportional to the weight of samples ground.

COMPARISON OF RESULTS OF AIR DRYING IN THE SPECIAL OVEN AND BY EXPOSURE.

The samples as received at the laboratory were dried to approximately an air-dry condition, before their final pulverization, in an oven especially designed for this purpose. To find out how nearly this method of drying approximates air drying under ordinary conditions, the following tests were made:

The loss in weight of samples of different coals allowed to air dry under observed conditions of temperature and humidity was determined by allowing portions of the coarse samples spread on trays to remain exposed to the air of the laboratory for periods of time ranging from seven to twenty days. The samples were weighed from time

to time and the drying continued until the weight remained almost constant. The air-drying loss of these samples and the loss in weight of the corresponding regular samples dried in the dryer, with the amount of moisture remaining in the dryer samples, are tabulated below. In most of the samples the dryer loss is not widely different from the loss on the air-dry sample. Special exceptions are Nos. 1960 (Indiana No. 9 B) and 1390 (Wyoming No. 6), on which samples the dryer-sample loss is decidedly larger than that on the samples dried by exposure to the air of the laboratory. The samples dried during the summer months were exposed to air of a high average humidity (60 per cent), as the temperature and humidity of the laboratory were approximately that of the outdoor air for that period. The samples dried during the winter months were exposed to air of low average humidity (30 per cent), as the temperature of the laboratory was decidedly higher than that of the outdoor air, with approximately the same absolute amount of moisture present in the laboratory and in the outdoor air. The humidity of the warmer laboratory air is consequently low. The percentage of moisture remaining in the samples dried by exposure to the air of the laboratory was determined by adding or subtracting (according to whether it was plus or minus) the difference between the loss in the dryer and the loss in the exposed sample to the moisture remaining in the "dryer sample," as given in the table below:

Results of tests for moisture in samples of coal.

Sample of coal.		Moisture in sample.					Time of drying by exposure.	Air of laboratory.	
Laboratory number.	Field number.	As received.	Loss on coarse sample, as dried—		After drying—			Temperature.	Humidity.
			By exposure.	In dryer.	By exposure (calculated).	In dryer.			
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Days.*	*° C.*	*Per ct.*
3294	New Mexico No. 5	2.72	1.60	1.40	1.14	1.34	17	25	63
3255	Alabama No. 3	2.72	0.30	1.20	2.44	1.54	13	25	64
3308	New Mexico No. 3	2.75	1.40	1.40	1.37	1.37	19	25	63
3331	New Mexico No. 4 A	2.78	0.40	1.40	2.40	1.40	14	24	62
3406	Indian Territory No. 2 B	2.81	0.60	1.40	2.23	1.43	16	26	64
2626	West Virginia No. 20	2.89	1.98	1.90	0.93	1.01	16	21	26
3315	New Mexico No. 4 B	3.38	1.60	1.70	1.81	1.71	18	25	62
3295	New Mexico No 3 A	3.45	1.50	2.00	1.98	1.48	17	25	63
2332	West Virginia No. 17	3.46	2.07	2.50	1.43	1.00	11	21	47
2572	West Virginia No. 21	3.57	2.24	2.10	1.36	1.50	12	19	28
2420	Virginia No. 1	4.06	2.59	2.40	1.51	1.70	9	25	27
3307	New Mexico No. 3 B	4.36	2.20	3.00	2.20	1.40	19	25	63
2528	Kentucky No. 5	4.36	1.77	2.80	2.63	1.60	10	24	31
2261	West Virginia No. 16 B	5.57	3.89	4.40	1.73	1.22	11	18	57
3286	Utah No. 1	5.83	2.30	2.10	3.61	3.81	17	25	63
3405	Indian Territory No. 2 B	6.27	4.20	4.90	2.14	1.44	16	26	64
1761	Illinois No. 15	9.95	3.62	4.20	6.58	6.00	18	27	64
1876	Indiana No. 6	10.47	6.02	6.30	4.73	4.45	14	27	64
3225	Wyoming No. 5	11.44	4.10	3.70	7.64	8.04	21	25	53
2896	Illinois No. 22 B	13.03	9.74	11.20	3.52	2.06	8	23	35
1960	Indiana No. 9 B	13.53	7.13	10.70	6.74	3.17	18	27	67
2686	Washington No. 1 B	14.30	8.12	9.60	6.68	5.20	9	22	28
2731	Illinois No. 20	14.68	11.80	12.40	3.20	2.60	11	23	34
2803	Illinois No. 23 B	15.68	13.98	13.20	2.08	2.86	10	24	31
3390	Wyoming No. 6	19.00	7.50	11.30	12.48	8.68	16	27	64

These values show that on most of the coals tested drying in the drier brought the sample to approximately an air-dry condition. No effort had been made to do more than this, as the primary object in the air drying is to get the sample into such a condition that the fine sample will not be subject to large moisture changes during subsequent handling in the laboratory. The air drying, therefore, is not to be understood as being a rigidly fixed determination; but it has been found that the values obtained as a rule are within a sufficiently definite range to give this determination some importance as showing the effect of standing and exposure on the percentage of moisture in the coal. This matter is of considerable commercial importance, since, so far as the moisture content is concerned, coals having a large air-drying loss are obviously much more affected than coals having a small air-drying loss. It further has appeared that the amount of residual moisture in the air-dried sample prepared under the described conditions usually lies within a range which is somewhat characteristic of different kinds of coal.

The foregoing table shows this residual moisture to be about 1 per cent in the West Virginia coals, 3 to 6 per cent in the Illinois and Indiana coals, and from 10 to 12 per cent in the Wyoming samples.

COMPARISON OF RESULTS FOR MOISTURE OBTAINED FROM SAMPLES PULVERIZED BY VARIOUS METHODS.

The possibility of moisture loss during grinding on a bucking board has already been referred to. In order to obtain more data upon different coals and under observed conditions of temperature and humidity, duplicate portions of a number of samples were ground down upon the bucking board and the moisture determinations made upon these portions. At the same time portions of the coal which had only passed the 1/10-inch mesh sieve in the process of sampling were reserved as samples for determining moisture in the coal at this size. The moisture was determined in these samples by drying 5 grams for one hour in the air bath, instead of 1 gram as in the regular determination. The moisture results on these samples and the results upon the regular samples ground down in the ball mill, together with the temperature and humidity conditions of the laboratory at the time of sampling, are given in the following table:

Results for moisture from coal samples variously pulverized.

Sample of coal.		Moisture in sample from—			Air of laboratory.	
Laboratory number.	Field number.	Bucking board.	Ball mill.	⅛-inch mesh sieve.	Temperature.	Humidity.
		Per cent.	*Per cent.*	*Per cent.*	*° C.*	*Per cent.*
3255	Alabama No. 3	1.43	1.54	1.43	29	66
2689	Arkansas No. 1 B	0.89	0.85	0.69	23	30
2688	Arkansas No. 7 A, 7 B	0.62	0.60	0.50	23	30
2722	Arkansas No. 7 B	0.94	1.05	0.87	23	30
2744	Arkansas No. 8	0.75	0.83	0.81	28	37
2690	Arkansas No. 9	1.22	1.11	1.03	23	30
1835	Brazil	5.40	4.95	4.80	30	67
1680	California No. 1	.....	9.05	[a] 7.28	29	60
1699	.....do	.....	8.89	7.42	22	61
1702	Illinois No. 6 B	.....	4.17	4.22	27	52
1780	Illinois No. 7 D	6.82	7.60	7.48	24	70
1635	Illinois No. 9 A	4.92	4.99	5.36	20	59
1639	Illinois No. 9 B	.....	4.03	3.73	25	39
1638	.....do	10.58	12.34	12.35	21	60
1648	Illinois No. 10	.....	2.79	2.94	28	37
1653	Illinois No. 11 A	.....	2.98	2.59	24	55
1654	.....do	.....	3.11	2.82	24	55
1717	Illinois No. 11 C	2.97	2.42	2.39	27	64
1802	Illinois No. 11 D	6.06	6.30	6.01	26	64
1786	Illinois No. 13	4.22	3.89	3.68	25	63
1740	Illinois No. 14	5.24	5.19	5.29	35	53
1761	Illinois No. 15	6.10	6.00	5.84	25	77
1820	Illinois No. 16	4.74	4.61	4.46	28	72
1926	Illinois No. 19 A	6.46	6.39	6.20	31	56
3447	Illinois No. 19 C	5.43	6.01	5.57	33	49
3448	Illinois No. 19 D	3.98	3.87	3.95	33	49
3451	.....do	4.83	5.27	4.96	33	49
2731	Illinois No. 20	2.89	2.60	2.57	25	39
2852	Illinois No. 21	4.42	5.74	5.61	23	30
2905	Illinois No. 22 A	4.45	6.39	6.39	24	20
2896	Illinois No. 22 B	2.14	2.06	1.86	24	20
2803	Illinois No. 23	2.47	2.86	2.65	24	31
2819	Illinois No. 23 A	2.05	2.23	1.93	22	28
1941	Indiana No. 3	5.19	5.12	4.93	29	60
1844	Indiana No. 4	4.04	3.58	3.42	28	72
1859	Indiana No. 5	5.62	5.21	5.60	21	68
1875	Indiana No. 6	5.76	5.91	5.71	21	60
1881	Indiana No. 7 A	5.60	5.50	5.46	27	71
2037	Indiana No. 8	3.99	5.19	5.16	23	69
1960	Indiana No. 9 B	3.30	3.17	3.04	28	72
1979	Indiana No. 10	2.98	2.85	2.62	31	63
2087	Indiana No. 11	7.92	8.49	8.52	22	75
2759	Indiana No. 12	3.45	4.45	4.29	19	35
3405	Indian Territory No. 2 B	1.70	1.44	1.34	31	63
3406	.....do	1.65	1.43	1.38	31	63
2843	Kansas No. 6	1.71	2.09	1.83	24	25
2528	Kentucky No. 5	1.66	1.60	1.34	23	37
2592	Kentucky No. 6	2.66	2.99	2.80	22	28
2274	Maryland No. 1	1.12	0.94	0.99	24	70
2865	Missouri No. 5	1.59	1.71	1.55	24	25
2904	Missouri No. 6	1.63	2.49	2.62	24	31
2937	Missouri No. 7	5.25	7.41	7.45	21	33
2942	.....do	2.54	2.48	2.28	20	37
3295	New Mexico No. 3	1.03	1.48	1.34	30	57
3307	New Mexico No. 3 B	1.43	1.40	1.38	28	65
3308	.....do	1.33	1.37	1.33	25	65
3315	New Mexico No. 4	1.56	1.71	1.64	28	43
3331	New Mexico No. 4 A	1.54	1.40	1.14	31	47
3294	New Mexico No. 5	1.36	1.34	1.24	30	67
2071	Ohio No. 1	3.40	2.96	2.65	21	75
2109	Ohio No. 2	5.60	5.60	5.57	27	72
2144	Ohio No. 3	5.43	6.24	6.15	18	73
2083	Ohio No. 4	2.56	2.16	1.94	24	85
2062	Ohio No. 5	2.25	1.99	1.84	18	73
2310	Ohio No. 9 A	2.55	2.47	2.56	19	66
2311	Ohio No. 9 B	2.78	2.65	2.37	19	66
2115	Pennsylvania No. 5 A	1.82	1.77	1.77	24	76
2068	Pennsylvania No. 5 B	1.57	1.47	1.38	21	75
2152	Pennsylvania No. 8	0.77	0.64	0.87	31	53
3102	Tennessee No. 6	1.27	1.02	1.02	24	31
3127	Tennessee No. 8 A	1.01	1.05	0.98	29	38
3128	Tennessee No. 8 B	0.92	1.14	1.02	25	33
2734	Texas No. 3	9.06	9.88	8.48	23	24
2717	Texas No. 4	8.63	9.76	8.67	21	26
3199	Utah No. 1	2.23	2.34	2.32	24	31
2420	Virginia No. 1 A	1.60	1.70	1.60	24	25

[a] Heated two hours, moisture = 7.86; heated three hours, moisture = 8.03.

Results for moisture from coal samples variously pulverized—Continued.

Sample of coal.		Moisture in sample from—			Air of laboratory.	
Laboratory number.	Field number.	Bucking board.	Ball mill.	$\frac{1}{16}$-inch mesh sieve.	Temperature.	Humidity.
		Per cent.	*Per cent.*	*Per cent.*	° *C.*	*Per cent.*
2358	Virginia No. 4	2.35	2.40	2.28	28	26
2687	Washington No. 1 A	5.38	5.98	5.85	20	24
2686	Washington No. 1 B	4.55	5.20	4.65	20	24
2250	West Virginia No. 4 B	1.45	1.35	1.19	23	69
2028	West Virginia No. 13	1.10	1.17	1.15	23	69
2004	West Virginia No. 14	2.00	2.05	2.05	34	50
2332	West Virginia No. 17	1.15	1.00	1.00	20	59
2527	West Virginia No. 18	1.29	1.28	1.13	23	37
2549	West Virginia No. 19	0.65	0.68	0.65	22	22
2572	West Virginia No. 21	1.43	1.50	1.44	20	24
2131	Wyoming No. 2 B	4.57	4.65	4.48	23	85
3213	Wyoming No. 5	5.61	6.00	6.04	31	46
3390	Wyoming No. 6	8.90	8.68	8.24	32	55

The results for moisture obtained on the 5-gram portion of the coarse sample, as a rule, run from 0.1 to 0.2 per cent lower than the moisture value as determined upon the sample ground in the ball mill. In a few cases the moisture result on the coarse sample is somewhat higher than the result on the ball-mill sample, while in a few other cases, noticeably the lignite samples from California and Texas, the moisture result on the coarse sample is decidedly lower. This result, as shown by tests on sample 1680, California No. 1, may be ascribed to the fact that the moisture in a coarse sample of lignite is very incompletely expelled by one hour's heating. An additional two hours of heating upon this sample resulted in an increased moisture value of over 0.7 per cent. As a method applied to any and all coals, the determination of the moisture in the fine sample appears to be preferable to the determination in the coarse sample. The results obtained for moisture upon the samples ground down on the bucking board, as compared with the results obtained on the samples ground down in the ball mill, show that the bucking-board samples may either gain or lose moisture, depending on the thoroughness of the preliminary drying of the coarse samples and the humidity of the air in the laboratory at the time of sampling. For Illinois coals previously dried down to a moisture content of about 5 or 6 per cent, the bucking-board sample took up moisture during grinding when the humidity was high (70 per cent or more). On the other hand, with low humidity (20 to 30 per cent), the moisture loss during grinding was considerable, and a careful study of the results obtained upon the bucking-board sample, as compared with the results on the ball-mill sample, taken in connection with the humidity changes, shows that any success in attempting to work the sample down on the bucking board without danger of moisture changes is practically impossible of realization, and that the sample ground down on the bucking board can not be in any case regarded as entirely satisfactory on account of the danger of moisture changes during the sampling. The experiments reported under the

following heading, showing the rapid changes in moisture in coal samples when spread on the watch glass, indicate that there is probably a slight gain or loss of moisture in the ball-mill sample even during the short time that this sample is exposed to air during sampling, and that this change may be considerable if the coarse sample be very far from an air-dried condition before being ground down. The grinding down of samples in the ball mill can not, therefore, be considered as perfectly satisfactory in so far as moisture changes are concerned; but this method of grinding, in connection with the preliminary drying of the coarse sample, is much more satisfactory and reliable than any other practical method that has been devised of which the writer has any knowledge. Therefore it appears that the handling of samples in this manner, as compared with the practice in most general use, is an important step in the direction of securing a sample for analysis with a minimum amount of unaccounted-for changes in moisture.

CHANGES IN MOISTURE CONTENT OF FINE SAMPLES OF COAL UNDER MODIFIED CONDITIONS.

That coal in a fine condition changes rapidly in moisture content is well known. In order to obtain definite information as to the rate of this change a number of tests were made on coals under different conditions. The first selection for testing was a fine sample (No. 1638 C) of undried Illinois coal, containing 12.4 per cent moisture. One gram of this sample was spread out on a 4-inch watch glass and weighed at intervals, a record of the temperature and humidity being taken at the time of the different weighings. A second series of tests was also made on a 10-gram portion of this sample spread upon a 4-inch watch glass. A third series of tests was made upon another portion of this sample (17.2 grams) by allowing it to stand in an open, wide-mouthed 2-ounce bottle and weighing at intervals. The results for these three series of tests are as follows:

Changes in moisture content of sample (No. 1638 C) of undried Illinois coal.

FIRST SERIES—1 GRAM ON 4-INCH WATCH GLASS.

Time interval between weighings.	Loss or gain in weight.		Air of laboratory.	
			Temperature.	Humidity.
	Grams.	*Per cent.*	° *C.*	*Per cent.*
5 minutes	−0.0202	− 2.02	22	21
5 minutes	− .0075	− .75	.....	.....
15 minutes	− .0090	− .90	.....	.....
1½ hours	− .0110	− 1.10	25	50
24 hours	− .0350	− 3.50	24	36
24 hours	− .0120	− 1.20	28	36
25 hours	+ .0140	+ 1.40	25	63
42 hours	+ .0060	+ .60	18	64
104 hours	− .0127	− 1.27	27	35
15 days	+ .0007	+ .07	32	41
48 days	− .0175	− 1.75	32	55
Total loss in 72 days	.....	10.42	.....	.....

Changes in moisture content of sample (No. 1638 C) of undried Illinois coal—Continued.

SECOND SERIES—10 GRAMS ON 4-INCH WATCH GLASS.

Time interval between weighings.	Loss or gain in weight.		Air of laboratory.	
			Temperature.	Humidity.
	Grams.	*Per cent.*	° *C.*	*Per cent.*
5 minutes	−0.0280	−0.28	25	50
5 minutes	− .0380	− .38		
15 minutes	− .0605	− .61		
1½ hours	− .1965	−1.96	25	43
21 hours	− .2535	−2.54	24	36
24 hours	− .2140	−2.14	28	35
25 hours	+ .0575	+ .58	25	63
42 hours	+ .0130	+ .13	18	64
104 hours	− .0518	− .52	27	35
15 days	− .0622	− .62	32	41
48 days	− .0725	− .72	32	55
Total loss in 72 days		9.06		

THIRD SERIES—17.2 GRAMS IN OPEN, WIDE-MOUTHED 2-OUNCE BOTTLE.

10 minutes	−0.0025	−0.014	22	61
1½ hours	− .0115	− .067		
3½ hours	− .0260	− .15		
21 hours	− .0800	− .47	24	36
Stirred and reweighed	− .0020	− .01		
24 hours	− .0855	− .50	28	36
Stirred with spoon	− .0020	− .01		
26 hours	− .0885	− .51	25	63
Stirred with spoon	− .0015	− .01		
42 hours	− .0625	− .36	18	64
Stirred with spoon	− .0010	− .005		
4 days	− .1190	− .70	27	35
Stirred with spoon	− .0005	− .003		
15 days	− .3625	−2.11	32	41
Stirred with spoon	− .0000	− .000		
48 days	− .0200	− .116	32	55
Total loss in 72 days		5.035		

A second sample (No. 1638 E) of undried Illinois coal contained 11.89 per cent moisture, and being a duplicate of No. 1638 C, except that it was perhaps more finely pulverized, was also tested in a similar way, by spreading 1 gram on a 3-inch watch glass and 10 grams on a 3-inch watch glass, and by placing 14.5 grams in an open, wide-mouthed 2-ounce bottle. The changes occurring in these three samples are given in the following table:

Changes in moisture content of sample (No. 1638 E) of undried Illinois coal.

FIRST SERIES—1 GRAM ON 3-INCH WATCH GLASS.

Time interval between weighings.	Loss or gain in weight.		Air of laboratory.	
			Temperature.	Humidity.
	Grams.	*Per cent.*	° *C.*	*Per cent.*
5 minutes	−0.0215	−2.15	25	50
5 minutes	− .0160	−1.60		
20 minutes	− .0110	−1.10		
1½ hours	− .0290	−2.90	25	43
20½ hours	− .0055	−0.55	24	36
24½ hours	− .0063	−0.63	28	36
25 hours	+ .0143	+1.43	25	63
42 hours	+ .0060	+ .60	18	64
104 hours	− .0142	−1.42	27	35
15 days	+ .0025	+ .25	32	41
48 days	− .0173	−1.73	32	55
Total loss in 72 days		9.80		

Changes in moisture content of sample (No. 1638 E) of undried Illinois coal—Continued.

SECOND SERIES—10 GRAMS ON 3-INCH WATCH GLASS.

Time interval between weighings.	Loss or gain in weight.		Air of laboratory.	
			Temperature.	Humidity.
	Grams.	*Per cent.*	° *C.*	*Per cent.*
5 minutes	−0.0518	−0.52	25	50
5 minutes	− .0270	− .27	.....	.....
15 minutes	− .0530	− .53	.....	.....
1½ hours	− .2180	−2.18	25	43
21½ hours	− .2000	−2.00	24	36
24½ hours	− .1937	−1.94	28	36
25 hours	+ .0692	+ .69	25	63
42 hours	+ .0095	+ .095	18	64
104 hours	− .0550	− .55	27	35
15 days	− .0590	− .59	32	41
48 days	− .0870	− .87	32	55
Total loss in 72 days	.....	8.67	.....	.....

THIRD SERIES—14.5 GRAMS IN OPEN, WIDE-MOUTHED 2-OUNCE BOTTLE.

10 minutes	−0.003	−0.02	22	61
1½ hours	− .0135	− .09	.....	.....
3½ hours	− .0340	− .23	.....	.....
21 hours	− .0890	− .60	24	36
Stirred with spoon	− .0020	− .01	.....	.....
24 hours	− .0995	− .68	28	36
Stirred with spoon	− .0025	− .02	.....	.....
26 hours	− .0850	− .56	25	63
Stirred with spoon	− .0015	− .01	.....	.....
42 hours	− .0625	− .42	18	64
Stirred with spoon	− .0010	− .01	.....	.....
104 hours	− .0875	− .60	27	35
Stirred with spoon	− .0015	− .01	.....	.....
15 days	− .2538	−1.71	32	41
Stirred with spoon	− .0010	− .01	.....	.....
48 days	− .0500	− .35	32	55
Total loss in 72 days	.....	5.33	.....	.....

Other experiments were likewise performed on a similar sample (No. 1639 C) of Illinois coal, which contained 4.12 per cent moisture, although the coarse sample had been well air-dried before the preparation of the fine sample. The changes in weight in the 1-gram sample spread on a watch glass, in the 10-gram sample spread on a watch glass, and in a portion (8.3 grams) allowed to stand exposed in an open, wide-mouthed 2-ounce bottle were as follows:

Changes in moisture content of sample (No. 1639 C) of well-dried Illinois coal.

FIRST SERIES—1 GRAM ON 4-INCH WATCH GLASS.

Time interval between weighings.	Loss or gain in weight.		Air of laboratory.	
			Temperature.	Humidity.
	Grams.	*Per cent.*	° *C.*	*Per cent.*
5 minutes	−0.0093	−0.93	28	36
5 minutes	− .0025	− .25	.....	.....
15 minutes	− .0015	− .15	.....	.....
2½ hours	+ .0045	+ .45	.....	.....
23 hours	+ .0135	+1.35	25	63
2 days	+ .0070	+ .70	18	64
4 days	− .0170	−1.70	27	35
14 days	+ .0050	+ .40	32	41
Total loss in 21 days	.....	0.13	.....	.....

Changes in moisture content of sample (No. 1639 C) of well-dried Illinois coal—Continued.

SECOND SERIES—10 GRAMS ON 4-INCH WATCH GLASS.

Time interval between weighings.	Loss or gain in weight.		Air of laboratory.	
			Temperature.	Humidity.
	Grams.	*Per cent.*	° *C.*	*Per cent.*
5 minutes	−0.0190	−0.19	28	36
5 minutes	− .0120	− .12		
15 minutes	− .0175	− .175		
1 hour	− .0280	− .28		
23 hours	+ .1235	+1.24	25	63
2 days	+ .0195	+ .20	18	64
4 days	− .0580	− .58	27	35
14 days	− .0280	− .28	32	41
Total loss in 21 days		0.18		

THIRD SERIES—8.3 GRAMS IN OPEN, WIDE-MOUTHED 2-OUNCE BOTTLE.

10 minutes	+0.0015	+0.02	23	69
20 minutes	+ .0010	+ .01		
20 minutes	− .0000			
5½ hours	+ .0080	+ .08	25	63
2 days	+ .0230	+ .29	18	64
Stirred	− .0000			
4 days	+ .0240	+ .29	27	35
14 days	− .0175	− .21	32	41
Stirred	− .0000	− .00		
Total gain in 20 days		0.48		

An inspection of these results shows that in samples of fine coal prepared from coal not previously air dried the loss may be rapid, being in a 1-gram portion of undried sample over 2 per cent in five minutes and over 8 per cent in twenty-four hours. That samples kept in bottles may lose a considerable amount of moisture unless tightly stoppered is also shown by the results obtained from weighing the samples in an open bottle, the loss in twenty-four hours being nearly 0.7 per cent and in seventy-two hours almost 2 per cent. This loss continued until the total loss in twenty-four days was about 5 per cent. That the danger from losses in handling a fine sample which has been well air dried is not nearly so great is shown by the tests upon No. 1639 C. Upon the 1-gram portion of this sample the loss in five minutes was 0.93 per cent, but the additional loss afterwards was small, showing that the sample was not far from air dry under the existing conditions. In fact, under the conditions existing on the next afternoon the sample as ground was drier than air dry, as is shown by an increase of over 1 per cent in weight. That this sample was about air dry, under the average conditions existing, is furthermore shown by the results obtained on the sample exposed in an open bottle, where the sample at different times shows small losses and small gains in weight. The rapidity with which the 1-gram portion of this dried sample gave up the little moisture it possessed over and above the existing air-dry conditions shows the extreme sensitiveness of finely ground coal samples to changes in the moisture content of the air.

As might be expected, the rapidity of gain or loss is greatest in the 1-gram sample and least in the sample kept in an open bottle. A comparison of these losses after seventy-two days on the undried samples shows, however, that even in that time the loss on the 1-gram sample is decidedly in excess of that on the 10-gram sample, and about twice that on the sample in the open bottle. This result would lead to the inference that the change in weight is not due entirely to moisture losses, but is influenced more or less by oxidation changes. That such is the case is shown by the results of tests of the gain or loss in weight, from time to time, of fine samples kept in tightly stoppered bottles, moisture determinations being made at the same time to find out whether the amount of moisture present in the sample varies with the change in weight. These tests are described under "Alteration of weight of samples of coal when kept in a finely powdered state," pages 19–22.

COMPARISON OF EFFECTS OF DIFFERENT DRYING REAGENTS USED IN THE DESICCATORS EMPLOYED IN MOISTURE DETERMINATIONS.

In the determinations of moisture made during the Louisiana Purchase Exposition and during the earlier part of 1905 duplicate results often were not as close as was desirable. This lack of agreement was found to be due, in part at least, to the use of calcium chloride as a drying reagent in the desiccators in which the fine samples of coal were allowed to cool after drying at 105° C., as may be seen from inspection of the following table giving the values obtained over concentrated sulphuric acid, fused calcium chloride, and granular calcium chloride.

Certain values from samples allowed to stand overnight, which are marked with a star (*), were on different gram portions of the sample. The values given for the other determinations, weighed as soon as cooled and weighed after standing in the desiccator overnight, are on the same weighed-out portions of the sample, which, as soon as weighed the first time, were put back in the desiccator and allowed to stand until the next day and then again weighed. The values over sulphuric acid are, as a rule, about one-tenth of 1 per cent lower on the sample after standing overnight, but this result can probably be accounted for by the small amount of moisture which might be taken up by the sample during the time required for making the first weighing.

Moisture determinations obtained by the use of different drying reagents.

Laboratory number.	Sample of coal. Field number.	Concentrated H_2SO_4. 1.[a]	Concentrated H_2SO_4. 2.[b]	$CaCl_2$, fused. 1.[a]	$CaCl_2$, fused. 2.[b]	$CaCl_2$, granular. 1.[a]	$CaCl_2$, granular. 2.[b]
1660	Illinois No. 11 B	3.46	.....	3.42 3.38	.....	3.38 3.40	.....
1786	Illinois No. 13	3.92	.....	.....	.....	3.86	.....
1802	Illinois No. 11 D	6.34	.....	6.26	.....	.....	.....
1801	Illinois No. 7 D	2.74	.....	.....	.....	2.74	.....
1803	Illinois No. 13	7.62	.....	7.46	.....	.....	.....
1804	.....do	4.74	.....	4.80	.....	.....	.....
1794	Alabama	1.38	.....	1.18	.....	.....	.....
1798	Illinois No. 13	4.96	.....	.....	.....	4.80	.....
1812	.....do	3.56	.....	3.46	.....	.....	.....
1817	Indian Territory	1.42	.....	.....	.....	1.30	.....
1828	Indiana No. 8	3.62	.....	3.46	.....	.....	.....
1835	Brazil	4.99	4.92	.....	.....	4.91	4.58
1837	Illinois No. 7 D	3.60	3.60	3.55	3.23	.....	.....
1807	Indiana No. 4	4.94	.....	.....	.....	4.88	.....
1808	Illinois No. 12	5.90	.....	.....	.....	5.82	.....
1836	Illinois No. 13	2.76	.....	.....	.....	2.70	.....
1838	Illinois No. 18	.....	.....	.....	.....	5.08	.....
1842	Illinois No. 7 D	1.06	.....	1.02	.....	.....	.....
1843	Colorado	.....	.....	.....	.....	7.98	7.40
1845	Illinois No. 11 D	.....	.....	4.12	3.46	.....	.....
1846	Illinois No. 7 D	6.98	6.88	6.90	6.36	.....	.....
1855	Illinois No. 11 D	1.24	1.14	.....	.....	1.14	.94
1844	Indiana No. 4	3.60	.....	.....	.....	3.56	.....
1741	Illinois No. 18	.....	.....	3.32	2.58*	.....	.....
1743	Indian Territory	.....	.....	2.36	1.38*	.....	.....
1745	.....do	.....	.....	3.38	2.76*	.....	.....
1753	Illinois No. 14	.....	.....	12.09	11.58*	.....	.....

[a] Weighed as soon as cooled.
[b] Weighed after standing in desiccator overnight.

The values obtained over both granular and fused calcium chloride, where the sample was weighed as soon as cooled, are but little lower than the values obtained over sulphuric acid; but the values from the samples over calcium chloride when allowed to stand overnight are so decidedly lower as to show beyond a doubt the superiority of concentrated sulphuric acid over calcium chloride as a desiccating reagent for coal.

EFFECTS OF VARYING AMOUNTS OF SAMPLE AND OF DIFFERENCES IN DURATION OF HEATING ON RESULTS OBTAINED FOR MOISTURE.[a]

The following results were obtained on (1) a very finely ground sample of Illinois coal, and (2) a fine sample of Indiana coal. They show the loss in weight which occurred when the samples were dried for different times, in different amounts, and under different conditions. This change in weight represents not merely the loss of moisture, but includes any changes due to oxidation and other causes. These changes undoubtedly vary with the kind of coal and the condition of the sample.

[a] The official method for the determination of moisture is to heat 1 gram of the fine sample for one hour at 105° C. in a drying oven.

Moisture determinations on Illinois coal (percentages).

Details of treatment.	½-gram sample.	1-gram sample.	2-gram sample.
Loss after 15 minutes' heating at 100° to 107°	8.42	6.65	5.24
Additional loss after another 15 minutes' heating at 100° to 107°	.84	2.62	3.70
Total loss after 30 minutes' heating	9.26	9.27	8.94
Additional loss after heating another 30 minutes at 100° to 107°	.06	.16	.43
Total loss after 1 hour's heating	9.32	9.43	9.37
Gain in weight by standing uncovered 41 hours	3.68	3.68	3.55
Total loss after heating another 30 minutes	8.86	9.20	9.27
Gain in weight after standing 41 hours and reheating as compared with the value at the end of 1 hour's heating	.46	.23	.10

Moisture determinations on Indiana coal (percentages).

Details of treatment.	½-gram sample.	1-gram sample.	2-gram sample.	4-gram sample.
Loss after 30 minutes' heating at 105°	5.50	5.60 to 5.58	5.62 to 5.61	5.49
Loss after heating another 30 minutes at 105°	.04	.08 to .04	.07 to .02	.15
Total loss after 1 hour's heating	5.54	5.68 to 5.62	5.69 to 5.63	5.64
Gain in weight by standing uncovered 20 hours	3.44	3.43 to 3.35	3.41 to 3.35	3.34
Total loss after heating another hour at 105°	5.20	5.45 to 5.37	5.53 to 5.48	5.55
Gain in weight after 20 hours' standing and 1 hour's reheating compared with weight after first hour's heating	.34	.23 to .25	.16 to .15	.09
Gain in weight by standing uncovered 120 hours	3.06	3.12 to 2.95	3.15 to 3.11	3.12
Total loss after heating another hour at 105°	4.90	5.14 to 5.10	5.19 to 5.17	5.21
Gain in weight compared with weight after the first hour's heating	.64	.54 to .52	.50 to .46	.43
Gain in weight by standing uncovered 24 days	3.70	3.62 to 3.58	3.52 to 3.51	3.45
Total loss after another hour's heating at 105°	4.20	4.60 to 4.62	4.72 to 4.70	4.77
Gain in weight compared with weight after first hour's heating	1.34	1.08 to 1.00	.97 to .93	.87

These results show that practically all of the moisture is expelled from coals of these kinds during the first thirty minutes, and, furthermore, that there was an appreciable amount of oxidation in the sample during standing or from reheating. For short periods this oxidation value in these experiments was apparently a surface reaction, dependent on the surface exposure of the sample and not on the amount. The samples were all weighed out in porcelain crucibles of the same size, and the amount of sample directly exposed was practically the same in all. In this case the percentage effect of equal oxidation on the Illinois samples would be in the ratio of 4, 2, and 1. The gains actually determined at the end of 41 hours were 0.46, 0.23, and 0.10 per cent, respectively, which are very close to this ratio.

On the Indiana sample the gains for oxidation at the end of twenty hours were 0.34, 0.24, 0.15, and 0.09 per cent, respectively. At the end of twenty-four days the percentages of gain on the different amounts are more nearly the same, but the gain is still greatest on the ½-gram sample and least on the 4-gram sample, the gains on the four amounts taken being 1.34, 1.04, 0.95, and 0.87 per cent, respectively.

ALTERATION OF WEIGHT OF SAMPLES OF COAL WHEN KEPT IN A FINELY POWDERED STATE.

In order to investigate the question of the extent of alteration of the samples when kept in a finely powdered condition as prepared for analysis, portions of a number of such samples were put in weighed

bottles, which were securely closed with rubber stoppers. These bottles were kept in the laboratory and weighed from time to time. Moisture determinations were made on portions of the sample at the times of the weighings, allowance being made for the portions removed for this purpose. The following table gives the percentage of moisture originally present in the sample, the percentage of gain or loss in weight at the several weighings, and the time interval between the weighings; also the total time covered by the experiment:

Alteration of weight of finely powdered coal.

[Minus sign denotes loss.]

Sample of coal.		Days between weighings.	Change in weight.	Moisture determination.
Laboratory number.	Field number.			
			Per cent.	*Per cent.*
1635	Illinois No. 9 A			5.10
		4	0.17	5.13
		20	.47	5.31
		42	.46	5.36
		25	.19	5.29
		172	.00	4.99
		124	−.33	4.38
		387	.96	−.72
1638 C	Illinois No. 9 B			12.34
		4	.16	12.58
		19	.45	12.12
		27	.22	12.03
		41	.23	11.79
		172	.00	11.62
		263	1.06	−.72
1638 E	do			11.89
		4	.17	11.97
		46	1.07	11.80
		41	.40	11.64
		191	.00	11.06
		282	1.64	−.83
1639	do			4.03
		23	.61	4.03
		42	.47	4.38
		34	.31	4.53
		163	.27	4.37
		127	−.12	4.23
		389	1.54	.20
1660	Illinois No. 11 B			3.25
		15	.40	3.26
		27	.42	3.47
		50	.43	3.89
		183	.10	3.60
		107	.00	3.57
		382	1.35	.32
1844	Indiana No. 4			3.58
		7	.22	3.79
		34	.48	3.90
		183	.53	3.87
		107	.14	3.63
		331	1.37	.05
1867	West Virginia No. 13			1.03
		24	.24	1.16
		191	.15	1.21
		108	.07	1.09
		323	.46	.06

Alteration of weight of finely powdered coal—Continued.

[Minus sign denotes loss.]

Sample of coal.		Days between weighings.	Change in weight.	Moisture determination.
Laboratory number.	Field number.			
			Per cent.	*Per cent.*
2062	Ohio No. 5			1.99
		9	.22	
		18	.22	
		149	.40	2.49
		108	.13	2.43
		284	.97	.44
2131	Wyoming No. 2			4.65
		2	.04	
		3	.06	
		24	.18	
		7	.10	
		43	.09	
		28	.00	
		55	.06	4.55
		107	.02	4.46
		269	.55	−.19
2243	North Dakota No. 3			26.64
		4	.05	
		3	.03	
		7	.08	
		43	.23	
		28	.07	
		55	.16	25.91
		107	−.05	25.64
		247	.57	−1.00
2275	Wyoming No. 2 B			6.37
		2	.05	
		7	.05	
		43	.13	
		28	.02	
		55	.06	6.15
		135	.31	−.22
2278	Wyoming No. 3			12.59
		2	.09	
		7	.22	
		43	.68	
		28	.15	
		55	.38	11.97
		107	.26	11.81
		242	1.78	−.78
2255	North Dakota No. 3			12.62
		2	.02	
		5	.17	
		43	.34	
		28	.15	
		56	.16	12.86
		134	.84	.24
2718	Texas No. 4			33.00
		6	.29	
		42	.24	
		3	.03	32.87
		51	.56	−.13
2828	Massachusetts peat			13.60
		8	.07	
		13	.09	
		3	.00	13.72
		103	−.72	13.16
		127	−.56	−.44

Without exception these samples all increased in weight upon standing. At the same time the moisture values usually decreased. The gain in weight is to be ascribed to oxidation, and the decrease in moisture either to actual loss or to fixation of a portion of the moisture present by the oxidation changes. If the moisture loss be considered as an actual escape of moisture from the sample, the total gain due to oxidation is equal to the observed gain plus an amount equal to this moisture loss. The table below gives the total oxidation changes considered on this basis, together with the original and final calorimeter determinations on some of the samples, also the loss in calorific value in excess of that due merely to changes in weight of the sample. For purposes of comparison the amounts of moisture, ash, and sulphur present in the sample are also given.

Determinations of oxidation, calorific value, moisture, ash, and sulphur.

[Minus sign denotes loss.]

Sample of coal.			Calorific value.					
Laboratory number.	Field number.	Increase in weight due to oxidation.	Original.	Final.	Gain or loss above that accounted for by oxidation.	Moisture.	Ash.	Sulphur.
		Per cent.	*Calories.*	*Calories.*	*Calories.*	*Per cent.*	*Per cent.*	*Per cent.*
1635	Illinois No. 9 A	1.68	.....	.....	.....	4.99	11.80	4.43
1638C	Illinois No. 9 B	1.78	.....	.....	.....	12.34	.....	.....
1638E	.....do	2.47	.....	.....	.....	11.89	.....	.....
1639	.....do	1.34	.....	.....	.....	4.03	11.48	4.40
1660	Illinois No. 11 B	1.03	.....	.....	.....	3.25	12.38	2.62
1844	Indiana No. 4	1.32	6,426	6,265	−77	3.58	16.05	2.59
2828	Massachusetts peat	1.00	4.055	4,049	35	13.60	20.74	.58
2243	North Dakota No. 3	1.57	4,498	4,431	3	26.64	8.88	1.32
2255	.....do	.60	.....	.....	.....	12.62	8.77	1.22
2062	Ohio No. 5	.53	7,501	7,375	−86	1.99	7.48	1.76
2718	Texas No. 4	.69	.....	.....	.....	33.00	7.66	.....
1867	West Virginia No. 13	.40	8,408	8,359	−17	1.03	2.40	.83
2131	Wyoming No. 2	.74	5,815	5,747	−26	4.64	21.77	4.22
2275	Wyoming No. 2 B	.53	.....	.....	.....	6.37	19.69	4.09
2278	Wyoming No. 3	2.56	5,108	4,903	−75	12.59	17.20	6.86

The oxidation changes in every case are sufficiently large to be of practical importance, the smallest change—that in the Ohio No. 5 sample—being 0.53 per cent, while the Illinois No. 9 B sample showed a change of 2.47 per cent. The Wyoming No. 3 sample showed an increase of 2.56 per cent in weight and a decrease of 205 calories in heating value. The changes in weight correspond to a decrease in heating value of 144 calories, the final calorific value obtained being 75 calories lower than is accounted for by the changes in weight. Further results along these lines are desirable, but the values already obtained show very clearly that old samples of coal can not be regarded as representative of the original coal in composition or in calorific value.

DETERMINATIONS OF SPECIFIC GRAVITIES OF THE COALS.

Two determinations of specific gravity were made on a number of lumps about 1 inch in diameter. The first determination was made upon a number of specially selected lumps representing as clean coal as could be picked out, carefully avoiding portions contaminated with slate or pyrites; the second was made upon a number of lumps selected to represent the average quality of the coal as nearly as could be expected in pieces of this size. The determinations of each kind were made (in duplicate and sometimes in triplicate) with a large Nicholson's hydrometer designed for use with the coke samples and capable of handling 1,000 grams of coal. The following table gives the results on the two kinds of lumps. For ease of reference and for comparison the determinations of ash and sulphur on the car samples of each coal are also tabulated.

Determinations of ash, sulphur, and specific gravity.

Designation of coal sampled.	Car sample.		Specific gravity.	
	Ash.	Sulphur.	Selected lumps.	Average lumps.
Alabama No. 2 B	14.59	1.12	1.32	1.37
Alabama No. 3	14.36	.55	1.30	1.38
Alabama No. 4	12.92	1.08	1.28	1.32
Arkansas No. 7 A	11.69	2.02	1.32	1.44
Brazil	21.93	2.72	1.37	1.40
Illinois No. 19 B	9.36	.91	1.31	1.33
Illinois No. 23 A	11.53	4.41	1.22	1.26
Illinois No. 25	13.40	4.76	1.26	1.30
Illinois No. 26	12.09	3.51	1.22	1.31
Illinois No. 27	13.77	4.05	1.24	1.28
Indiana No. 5	10.88	4.27	1.28	1.42
Indiana No. 6	12.62	4.39	1.25	1.39
Indiana No. 7 A	9.21	3.74	1.27	1.40
Indiana No. 8	10.61	3.72	1.29	1.30
Indiana No. 9 A	10.30	3.27	1.25	1.36
Indiana No. 9 B	10.76	3.15	1.25	1.33
Indiana No. 10	8.57	3.83	1.24	1.29
Indiana No. 11	8.14	1.41	1.26	1.30
Indiana No. 12	11.65	3.87	1.26	1.32
Kansas No. 6	15.72	3.72	1.23	1.34
Kentucky No. 1 B	3.37	.88	1.27	1.40
Kentucky No. 5	3.70	.67	1.29	1.30
Kentucky No. 6	2.76	.57	1.27	1.28
Kentucky No. 7	9.48	3.60	1.31	1.44
Maryland No. 1	13.13	1.49	1.36	1.41
Missouri No. 6	11.74	5.60	1.21	1.36
New Mexico No. 3	16.67	.73	1.29	1.37
New Mexico No. 4 A	14.57	.61	1.30	1.39
New Mexico No. 5	14.57	.69	1.31	1.35
North Dakota No. 1 B	11.42	3.54	1.25	1.44
North Dakota No. 3	7.75	1.15	[a]1.22	
Ohio No. 1	11.95	4.61	1.29	1.35
Ohio No. 2	11.33	4.02	1.31	1.36
Ohio No. 3	11.58	1.81	1.30	1.33
Ohio No. 4	9.12	3.47	1.30	1.39
Ohio No. 5	7.30	1.72	1.29	1.33
Ohio Nos. 6 A, 6 B	8.52	3.33	1.29	1.35
Ohio No. 7	6.37	2.16	1.30	1.34
Ohio No. 8 A	8.37	2.84	1.30	1.42
Ohio No. 9 A	8.29	3.15	1.29	1.31
Ohio No. 9 B	11.93	3.35	1.30	1.36
Pennsylvania No. 4	10.41	1.26	1.30	1.35
Pennsylvania No. 5 A	6.02	1.20	1.30	1.31
Pennsylvania No. 5 B	6.05	.88	1.28	1.33
Pennsylvania No. 6	13.00	1.95	1.30	1.33
Do	12.52	1.94	1.30	1.38
Pennsylvania No. 7 A, 7 B	12.47	2.08	1.33	1.41
Pennsylvania No. 8	6.63	.94	1.31	1.36
Pennsylvania No. 9	11.33	2.04	1.35	1.39

[a] No distinction made between clean or selected lumps and average lumps.

Determinations of ash, sulphur, and specific gravity—Continued.

Designation of coal sampled.	Car sample.		Specific gravity.	
	Ash.	Sulphur	Selected lumps.	Average lumps.
Pennsylvania No. 10	6.17	1.26	1.30	1.36
Tennessee No. 2	6.81	.98	1.28	1.33
Tennessee No. 3	7.05	.99	1.29	1.32
Tennessee No. 4	9.53	.98	1.29	1.37
Tennessee No. 6	14.43	.78	1.29	1.31
Tennessee No. 7 A	12.85	3.26	1.34	1.39
Tennessee No. 8 A	13.42	4.38	1.34	1.37
Tennessee No. 10	59.14	.21	1.35	.....
Texas No. 3	7.88	.99	.....	1.25
Texas No. 4	7.30	.51	.....	1.26
Virginia No. 1 A	4.73	1.20	1.27	1.30
Virginia No. 1 B	5.01	1.11	1.27	1.34
Virginia No. 2 B	5.58	.92	1.28	1.37
Virginia No. 3	4.48	.67	1.27	1.28
Virginia No. 4	4.33	.79	1.28	1.28
Washington No. 1 B	11.37	.72	1.28	1.33
Washington No. 2	12.26	.38	1.32	1.39
West Virginia No. 4 B	7.76	.81	1.31	1.35
West Virginia No. 13	3.91	.89	1.27	1.30
West Virginia No. 14	3.27	1.03	1.27	1.28
West Virginia No. 15	8.55	2.54	1.28	1.31
West Virginia No. 16 A	5.57	1.06	1.30	1.37
West Virginia No. 16 B	8.37	1.20	1.28	1.34
West Virginia No. 17	8.12	1.45	1.28	1.41
West Virginia No. 18	5.83	.67	1.30	1.34
West Virginia No. 19	5.01	.89	1.26	1.38
West Virginia No. 20	8.03	1.38	1.27	1.34
West Virginia No. 21	4.85	1.32	1.28	1.34
Wyoming No. 2 B	20.79	4.03	1.31	1.37
Wyoming No. 3	16.70	6.66	1.28	1.40
Wyoming No. 4	6.77	.26	1.33	1.35
Wyoming No. 5	3.41	.81	1.26	1.30
Wyoming No. 6	3.12	.49	1.28	.....

It is obvious from the foregoing table that the specific gravity of the lumps of coal is considerably affected by the amount of impurities contained. Even the selected lumps were not free from ash and sulphur, so that it is not possible to obtain the true specific gravity of the pure coal itself.

In order to further investigate the relation of impurities to specific gravity, five of the coals in the foregoing table were selected as representing the great diversity of character. These coals were separated first into sizes and then each size, except the dust, was further separated by "float-and-sink" tests upon heavy solutions, of 1.35 specific gravity calcium chloride and 1.45 and 1.65 specific gravity zinc chloride. The procedure in detail was as follows:

The coal, after crushing till it all passed a ½-inch screen, was sifted over a series of sieves—80 mesh, 40 mesh, 10 mesh, and 4 mesh. That passing the first two screens was designated "dust;" that passing the 10 mesh and retained on the 40 mesh was designated "fine;" that passing the 4 mesh and retained on the 10 mesh "medium," and that retained on the 4 mesh "coarse." The dust was not separated on the solution, but each of the remaining classes was then stirred in a solution of 1.35 specific gravity, and the floating coal was removed, washed, and air dried. That sinking in this solution was then washed, dried, weighed, and stirred in a solution of 1.45 specific gravity, and the floating coal treated as before; and the process was again repeated in a solution of

1.65 specific gravity with the coal that sank. Each product was washed, air dried, and analyzed.

The results are given in the following table. Column 1 gives the percentage that the amount of coal in each grade of fineness forms of the entire sample treated; column 2, the percentage that the amount of coal in each class separated by gravity forms of the amount in its grade of fineness, and column 3, the percentage that the amount of coal in each class forms of the entire sample. Column 4 gives the determination of the ash in each class, expressed as a percentage of the amount of coal in the class; column 5, this determination of the ash expressed as a percentage of the entire sample of coal, and columns 6 and 7 give the same percentages for the sulphur. The totals of the results for ash and sulphur, in columns 5 and 7, should obviously equal the ash and sulphur determinations, respectively, in the original coal, which are printed below them for purposes of comparison. The differences are due to unavoidable errors in the work and, in some cases, probably in part to the presence of sulphates extracted in washing.

Impurities in coal as related to different grades of fineness and classes of specific gravity.

NO. 2023, BRAZIL NO. 1.[a]

Grade and class of coal.	Mechanical distribution of coal.			Amount of ash in each class.		Amount of sulphur in each class.	
	Per cent of entire sample in each grade.	Amount in each class.		As per cent of coal in the class.	As per cent of entire sample of coal.	As per cent of coal in the class.	As per cent of entire sample of coal.
		Per cent of its own grade.	Per cent of entire sample.				
	1.	2.	3.	4.	5.	6.	7.
Dust { 80	3.95	56.43		28.64	1.131	1.90	0.075
Dust { 80 to 40	3.05	43.57		26.35	.804	1.60	.049
Sum	7.00	100.00	7.00				
Fine, 40 to 10	18.10						
Specific gravity—							
Under 1.35		62.11	11.15	11.64	1.298	.61	.068
1.35 to 1.45		2.23	.40	15.33	.061	.84	.003
1.45 to 1.65		17.83	3.20	30.22	.967	.615	.020
Above 1.65		17.83	3.20	54.49	1.744	5.41	.173
Sum		100.00	17.95				
Medium, 10 to 4	30.45						
Specific gravity—							
Under 1.35		55.53	17.55	13.90	2.439	.60	.105
1.35 to 1.45		3.64	1.15	23.38	.269	.59	.007
1.45 to 1.65		28.01	8.85	33.38	2.954	.55	.049
Above 1.65		12.82	4.05	55.08	2.231	8.92	.361
Sum		100.00	31.60				
Coarse, 4 to 2	44.60						
Specific gravity—							
Under 1.35		45.10	21.20	17.33	3.674	.64	.136
1.35 to 1.45		3.19	1.50	26.52	.398	.50	.007
1.45 to 1.65		31.92	15.00	32.74	4.911	.66	.099
Above 1.65		19.79	9.30	59.08	5.494	21.24	1.975
Sum		100.00	47.00				
Total	100.15		103.55		28.375		3.127
Original sample					28.18		4.28

[a] Sp. gr. of average lumps, 1.40; of selected lumps, 1.37.

Impurities in coal as related to different grades of fineness, etc.—Continued.

NO. 2346, MARYLAND NO. 1.[a]

Grade and class of coal.	Mechanical distribution of coal.			Amount of ash in each class.		Amount of sulphur in each class.	
	Per cent of entire sample in each grade.	Amount in each class.		As per cent of coal in the class.	As per cent of entire sample of coal.	As per cent of coal in the class.	As per cent of entire sample of coal.
		Per cent of its own grade.	Per cent of entire sample.				
	1.	2.	3.	4.	5.	6.	7.
Dust {80	5.05	52.06	.....	15.47	0.781	2.00	0.101
Dust {80 to 40	4.65	47.94	.....	12.99	.604	1.55	.072
Sum	9.70	100.00	9.70				
Fine, 40 to 10	33.45	.....	.....	.....	.....	.....	.....
Specific gravity—							
Under 1.35	.....	81.40	27.10	6.25	1.694	.92	.249
1.35 to 1.45	.....	10.07	3.35	13.62	.456	1.25	.042
1.45 to 1.65	.....	3.75	1.25	25.02	.313	2.21	.028
Above 1.65	.....	4.78	1.60	61.48	.984	9.04	.145
Sum	.....	100.00	33.30				
Medium, 10 to 4	41.95	.....	.....	.....	.....	.....	.....
Specific gravity—							
Under 1.35	.....	63.60	26.65	5.57	1.484	.84	.224
1.35 to 1.45	.....	25.54	10.70	13.77	1.473	1.21	.129
1.45 to 1.65	.....	5.85	2.45	25.63	.628	2.36	.058
Above 1.65	.....	5.01	2.10	57.63	1.210	8.14	.171
Sum	.....	100.00	41.90				
Coarse, 4 to 2	14.70	.....	.....	.....	.....	.....	.....
Specific gravity—							
Under 1.35	.....	39.15	5.75	6.45	.371	.84	.048
1.35 to 1.45	.....	38.10	5.60	14.16	.793	1.07	.060
1.45 to 1.65	.....	10.84	1.60	25.68	.411	2.48	.040
Above 1.65	.....	11.91	1.75	55.90	.978	7.28	.127
Sum	.....	100.00	14.70				
Total	99.80	.....	99.60	.....	12.180	.....	1.49
Original sample	.....	.....	.....	.....	12.53	.....	1.51

NO. 2308, PENNSYLVANIA NO. 6.[b]

Dust {80	5.50	55.85	.....	14.74	0.811	2.36	0.130
Dust {80 to 40	4.35	44.15	.....	12.35	.537	2.19	.095
Sum	9.85	100.00	9.85				
Fine, 40 to 10	20.40	.....	.....	.....	.....	.....	.....
Specific gravity—							
Under 1.35	.....	88.36	17.85	6.44	1.149	1.10	.196
1.35 to 1.45	.....	2.97	.60	17.55	.105	2.75	.016
1.45 to 1.65	.....	1.98	.40	28.26	.113	4.04	.016
Above 1.65	.....	6.69	1.35	67.45	.911	10.20	.138
Sum	.....	100.00	20.20				
Medium, 10 to 4	29.75	.....	.....	.....	.....	.....	.....
Specific gravity—							
Under 1.35	.....	81.38	24.25	6.15	1.491	1.10	.267
1.35 to 1.45	.....	9.06	2.70	16.97	.458	2.39	.065
1.45 to 1.65	.....	2.68	.80	29.70	.238	3.42	.027
Above 1.65	.....	6.88	2.05	63.95	1.311	11.39	.233
Sum	.....	100.00	29.80				
Coarse, 4 to 2	39.70	.....	.....	.....	.....	.....	.....
Specific gravity—							
Under 1.35	.....	70.42	27.95	6.21	1.736	1.07	.299
1.35 to 1.45	.....	13.86	5.50	16.37	.900	2.33	.128
1.45 to 1.65	.....	4.78	1.90	29.57	.562	2.47	.047
Above 1.65	.....	10.94	4.35	66.20	2.880	7.06	.307
Sum	.....	100.00	39.70				
Total	99.70	.....	99.55	.....	13.202	.....	1.964
Original sample	.....	.....	.....	.....	12.61	.....	1.76

[a] Sp. gr. of average lumps, 1.41; of selected lumps, 1.36.
[b] Sp. gr. of average lumps, 1.33; of selected lumps, 1.30.

Impurities in coal as related to different grades of fineness, etc.—Continued.

NO. 2298, WEST VIRGINIA NO. 15.[a]

Grade and class of coal.	Mechanical distribution of coal.			Amount of ash in each class.		Amount of sulphur in each class.	
	Per cent of entire sample in each grade.	Amount in each class.		As per cent of coal in the class.	As per cent of entire sample of coal.	As per cent of coal in the class.	As per cent of entire sample of coal.
		Per cent of its own grade.	Per cent of entire sample.				
	1.	2.	3.	4.	5.	6.	7.
Dust {80	5.35	55.15	5.35	10.35	0.554	3.42	0.183
Dust {80 to 40	4.35	44.85	4.35	8.27	.360	3.10	.115
Sum	9.70	100.00	9.70				
Fine, 40 to 10	22.65						
Specific gravity—							
Under 1.35		92.68	20.90	4.39	.917	1.62	.338
1.35 to 1.45		1.33	.30	13.63	.041	6.37	.019
1.45 to 1.65		.89	.20	22.75	.046	10.10	.020
Above 1.65		5.10	1.15	57.78	.671	26.95	.310
Sum		100.00	22.55				
Medium, 10 to 4	33.20						
Specific gravity—							
Under 1.35		90.65	30.05	4.56	1.370	1.59	.478
1.35 to 1.45		3.77	1.25	13.40	.167	6.48	.081
1.45 to 1.65		1.81	.60	22.89	.137	10.25	.061
Above 1.65		3.77	1.25	53.03	.663	26.26	.328
Sum		100.00	33.15				
Coarse, 4 to 2	34.30						
Specific gravity—							
Under 1.35		86.30	29.60	5.40	1.597	1.73	.512
1.35 to 1.45		6.42	2.20	13.10	.288	6.40	.141
1.45 to 1.65		3.49	1.20	24.88	.298	7.40	.089
Above 1.65		3.79	1.30	66.15	.860	13.05	.171
Sum		100.00	34.30				
Total	99.85		99.70		7.969		2.846
Original sample					7.34		2.82

NO. 2278, WYOMING NO. 3.[b]

Dust {80	2.05	54.62		23.45	0.481	8.89	0.182
Dust {80 to 40	1.70	45.38		19.43	.330	8.21	.139
Sum	3.75	100.00	3.75				
Fine, 40 to 10	11.50						
Specific gravity—							
Under 1.35		74.12	8.30	5.46	.453	4.91	.407
Above 1.35		25.88	2.90	47.51	1.378	14.43	.418
Sum		100.00	11.20				
Medium, 10 to 4	29.85						
Specific gravity—							
Under 1.35		77.03	22.65	5.54	1.255	4.72	1.069
Above 1.35		22.97	6.75	47.98	3.239	15.54	1.049
Sum		100.00	29.40				
Coarse, 4 to 2	54.85						
Specific gravity—							
Under 1.35		69.65	38.20	6.53	2.494	4.66	1.780
Above 1.35		30.35	16.65	50.03	8.330	18.04	3.004
Sum		100.00	54.85				
Total	99.95		99.20		17.960		8.048
Original sample					17.96		8.36

[a] Sp. gr. of average lumps, 1.31; of selected lumps, 1.28.
[b] Sp. gr. of average lumps, 1.40; of selected lumps, 1.28.

An examination of the figures in the foregoing table shows the very rapid increase in impurity of the coal with increase in specific gravity. The finer the coal is crushed the more complete would be the mechanical separation of the heavy impurities from the coal, but the behavior in this respect evidently varies greatly with different coals. In the Brazil coal the sulphur is nearly the same in all the coal under ½-inch size and below 1.65 specific gravity, while the ash increases both with size and with the specific gravity. In the Maryland coal both sulphur and ash increase with specific gravity, and apparently without very much reference to size of product. Practically the same is true of the Pennsylvania No. 6 coal and of the West Virginia coal. The record of the Wyoming coal is not sufficiently complete for comparison. In all but the Brazil coal there is a marked tendency to increase of ash and sulphur in the fine dust, suggesting that the impurities are liberated in crushing and are more brittle than the mass of the coal. Noticeably different compositions in ash and sulphur of the portions of the various coals below 1.35 specific gravity, may indicate either actual variations in the specific gravity of the coal proper or variations in the nature of the combination of the sulphur and mineral matter.

Further experiments along these lines seem very desirable.

LABORATORY METHODS OF DETERMINING ADAPTABILITY OF COALS TO IMPROVEMENT BY WASHING.

The laboratory method of testing consists in floating the sample upon solutions of different density and thereby separating the coal into portions of different specific gravity, the amounts of these portions being determined and each portion analyzed separately for ash and sulphur, as noted under the last heading. The samples used were crushed to one-half inch and finer before testing, and for convenience in handling were divided by sifting into two portions, one one-half inch to one-fortieth inch, the other one-fortieth inch and finer. On some of the earlier samples the division was made at one-twentieth inch. The solutions used for washing the samples were a calcium-chloride solution of 1.35 specific gravity and a zinc-chloride solution of 1.65 specific gravity. Solutions of 1.45 and 1.90 specific gravity were also used occasionally. The clean coal, low in ash, floats upon a solution of 1.35 specific gravity. Moderately high-ash coal sinks in a solution of this gravity, but floats upon a solution of 1.45 specific gravity. Coal very high in ash is heavier than 1.45, but floats upon a solution of about 1.65 specific gravity, while the slate and pyrites sink in solution of this gravity. The results obtained by washing the samples upon these different solutions and the analysis of the resultant products, together with the analysis of the original sample and the analysis of samples obtained from actual washing tests made at the washery connected with the fuel-testing plant upon 5- to 6-ton lots of

certain of the coals, are given in the tables of results below. As these laboratory samples were all crushed to one-half inch and finer before testing, these results do not necessarily show what might be done with the coal crushed to other sizes. They do, however, give an indication of the possible improvements which may be expected from washing.

The "one-fortieth inch and finer" portion of the sample was tested as follows: The sample was stirred up with water, and after settling for one minute the liquid was decanted off very closely and the remaining portion was dried, weighed, and analyzed. The loss on decantation indicates in a very general way the extent to which the coal breaks down into a fine powder upon handling or crushing, and is an indication of the amount of fine coal lost during washing. The particular crushing machinery used would, however, greatly affect the amount of fines produced in crushing. The analytical results on the portion remaining after decantation are in a general way an index to the way the impurities separate from the coal in crushing.

The interpretation of these results may perhaps be understood best by a consideration of the results derived from some particular sample, as Indiana No. 7 A. In this sample the ash and sulphur contents in the unwashed coal are, respectively, 9.03 and 3.75. The sample crushed to "$\frac{1}{2}$ inch to $\frac{1}{40}$ inch" was separated by sifting into 91.1 per cent coarse and 8.6 per cent fine. Considering the coarse portion: The part lighter than 1.35 specific gravity amounted to 86.7 per cent of the entire sample, and contained 6.69 per cent ash and 3.05 per cent sulphur. It is quite probable that in actual washing practice a large part of the "$\frac{1}{40}$ inch and finer" would be reduced in ash and sulphur contents to about the same percentage, which would indicate the possibility of improving this coal 2 per cent in ash and 0.7 per cent in sulphur, accompanied by a washing loss of about 10 per cent. The distribution of the ash and sulphur on the heavier portion is shown by the percentage results on the "1.35 to 1.65" portion and on the portion "Heavier than 1.65." The washery tests do not show so great an improvement in ash and sulphur as might be expected from the analysis of the portion "Lighter than 1.35," and a portion of the "1.35 to 1.65" specific gravity material evidently remained with the washed coal. However, washery tests upon such small lots of coal can not be expected to give the best results; also the possible improvement at $\frac{1}{2}$-inch size is apt to be greater than can be obtained at $1\frac{1}{4}$-inch size, at which the sample was worked at the washery. The results of the laboratory tests indicate that the high sulphur and the comparatively high ash in the washed coal from the washery is not the fault of the washing, but is due to the combination in which the ash and sulphur occur, showing that a very low ash and sulphur product can not be obtained from this coal by washing. The laboratory tests do, how-

ever, indicate that under the best conditions of washing there would be some improvement, but not much, over the results obtained at the washery of the fuel-testing plant.

Determinations of ash and sulphur in coal samples variously treated.

ILLINOIS NO. 9 A.

[Unwashed coal—ash, 11.21; sulphur, 4.53.]

	Portion.	Ash.	Sulphur.	Compared with original sample.	
				Ash.	Sulphur.
First series:					
½ inch to $\frac{1}{20}$ inch	91.9				
Lighter than 1.35	75.2	6.08	3.16	4.57	2.38
1.35 to 1.65	12.1	21.04	4.80	2.55	.58
Heavier than 1.65	4.2	58.34	16.93	2.45	.71
$\frac{1}{20}$ inch and finer	9.0				
Very fine, decanted [a]	2.3			.26	.10
Remainder	5.6	13.88	4.20	.78	.24
				10.61	4.01
Second series:					
½ inch to $\frac{1}{20}$ inch	91.9				
Lighter than 1.45	84.9	8.22	3.32	6.98	2.82
Heavier than 1.45	7.7	44.02	14.12	3.39	1.09
$\frac{1}{20}$ inch and finer	7.7				
Very fine, decanted [a]	2.4			.27	.11
Remainder	5.6	13.88	4.20	.78	.24
				11.42	4.26
Washed at 1½-inch size:					
Sample No. 1		8.14	3.63		
No. 2		8.26	3.71		

ILLINOIS NO. 11 B.

[Unwashed coal—ash, 12.54; sulphur, 2.86.]

½ inch to $\frac{1}{20}$ inch	80.1				
Lighter than 1.35	56.5	5.71	1.72	3.22	0.97
1.35 to 1.65	16.1	17.49	2.48	2.82	.40
Heavier than 1.65	5.7	58.42	11.91	3.33	.68
$\frac{1}{20}$ inch and finer	19.5				
Very fine, decanted [a]	5.8			.73	.17
Remainder	13.7	17.42	3.15	2.39	.43
				12.49	2.65

ILLINOIS NO. 19 B.

[Unwashed coal (boiler-test sample, No. 2044)—ash, 10.57; sulphur, 0.49.]

½ inch to $\frac{1}{40}$ inch	92.8				
Lighter than 1.35	80.9	4.79	0.63	3.88	0.51
1.35 to 1.65	5.6	27.03	.52	1.51	.03
Heavier than 1.65	6.5	65.75	.29	4.28	.02
$\frac{1}{40}$ inch and finer	6.9				
Very fine, decanted [a]	3.5			.37	.02
Remainder	3.4	16.05	.60	.55	.02
				10.59	.60

[a] Estimated from results on unwashed coal.

Determinations of ash and sulphur in coal samples variously treated—Continued.

INDIANA NO. 4.

[Unwashed coal (boiler-test sample, NO. 1892)—ash, 15.63; sulphur, 2.74.]

	Portion.	Ash.	Sulphur.	Compared with original sample.	
				Ash.	Sulphur.
⅛ inch to $\frac{1}{20}$ inch	81.9				
Lighter than 1.35	61.8	5.89	1.82	3.66	1.12
1.35 to 1.65	11.9	17.50	3.54	2.10	.42
Heavier than 1.65	8.9	69.29	7.01	6.17	.62
$\frac{1}{20}$ inch and finer	17.5				
Very fine, decanted [a]	5.3			.83	.15
Remainder	12.2	23.83	2.84	2.88	.35
				15.64	2.66
Washed at 1½-inch size:					
Sample No. 1		8.26	2.26		
No. 2		7.69	2.26		

INDIANA NO. 6.

[Unwashed coal (boiler-test sample, No. 1928)—ash, 13.54; sulphur, 4.83.]

⅛ inch to $\frac{1}{20}$ inch	76.1				
Lighter than 1.35	56.2	6.63	2.92	3.73	1.64
1.35 to 1.65	13.6	19.58	5.54	2.66	.75
Heavier than 1.65	6.7	54.89	13.75	3.68	.91
$\frac{1}{20}$ inch and finer	23.2				
Very fine, decanted [a]	6.9			.93	.33
Remainder	16.3	17.10	5.19	2.79	.85
				13.79	4.48
Washed at 1½-inch size:					
Sample No. 1		10.34	3.67		
No. 2		10.98	3.94		
No. 3		10.06	3.73		

INDIANA NO. 7 A.

[Unwashed coal (boiler-test sample, No. 1939)—ash, 9.03; sulphur, 3.75.]

⅛ inch to $\frac{1}{40}$ inch	91.1				
Lighter than 1.35	86.7	6.69	3.05	5.80	2.64
1.35 to 1.65	3.6	26.23	4.39	.94	.16
Heavier than 1.65	3.4	55.84	23.48	1.90	.80
$\frac{1}{40}$ inch and finer	8.6				
Very fine, decanted [a]	5.4			.49	.20
Remainder	3.2	17.13	4.48	.55	.14
				9.68	3.94
Washed at 1½-inch size:					
Sample No. 1		8.94	3.33		
No. 2		8.18	3.36		

INDIANA NO. 9 B.

[Unwashed coal (boiler-test sample, No. 2035)—ash, 10.98; sulphur, 3.02.]

⅛ inch to $\frac{1}{20}$ inch	78.4				
Lighter than 1.35	64.2	8.04	2.30	5.16	1.48
1.35 to 1.65	7.3	25.90	4.60	1.89	.33
Heavier than 1.65	3.2	60.75	16.70	1.94	.52
$\frac{1}{20}$ inch and finer	21.3				
Very fine, decanted [a]	8.8			.97	.26
Remainder	12.5	19.87	4.24	2.48	.53
				12.44	3.12
Washed at 1½-inch size:					
Sample No. 1		9.22	2.91		
No. 2		8.54	2.69		

[a] Estimated from results on unwashed coal.

Determinations of ash and sulphur in coal samples variously treated—Continued.

INDIANA NO. 11.

[Unwashed coal (boiler-test sample, No. 2421)—ash, 8.60; sulphur, 1.61.]

	Portion.	Ash.	Sulphur.	Compared with original sample.	
				Ash.	Sulphur.
¼ inch to $\frac{1}{20}$ inch	80.9				
Lighter than 1.35	72.4	6.10	1.22	4.42	0.88
1.35 to 1.65	4.9	25.90	2.78	1.27	.14
Heavier than 1.65	3.4	54.34	10.14	1.85	.34
$\frac{1}{20}$ inch and finer	18.7				
Very fine, decanted [a]	9.7			.83	.16
Remainder	9.0	13.69	2.30	1.25	.21
				9.62	1.73

KENTUCKY NO. 6.

[Unwashed coal (boiler-test sample, No. 2662)—ash, 3.15; sulphur, 0.44.]

¼ inch to $\frac{1}{20}$ inch	89.8				
Lighter than 1.35	88.4	2.27	0.56	2.01	0.50
1.35 to 1.65	.6	27.30	.71	.15	.00
Heavier than 1.65	.6	71.61	.85	.43	.01
$\frac{1}{20}$ inch and finer	9.8				
Very fine, decanted [a]	6.0			.19	.03
Remainder	3.9	6.85	.70	.27	.03
				3.05	.57

MISSOURI NO. 5.

[Unwashed (boiler-test sample, No. 2892)—ash, 16.94; sulphur, 5.60.]

¼ inch to $\frac{1}{20}$ inch	91.5				
Lighter than 1.35	74.7	6.86	3.17	5.12	2.37
1.35 to 1.65	8.4	23.13	6.97	1.94	.59
Heavier than 1.65	9.4	55.85	16.28	5.25	1.53
$\frac{1}{20}$ inch and finer	8.2				
Very fine, decanted [a]	3.3			.57	.19
Remainder	4.9	25.30	6.73	1.24	.33
				14.12	5.01
Washed at 1½-inch size:					
Sample No. 1		10.28	4.10		
No. 2		10.12	3.94		

MISSOURI NO. 6.

[Unwashed coal (boiler-test sample, No. 2927)—ash, 11.67; sulphur, 5.52.]

¼ inch to $\frac{1}{20}$ inch	89.2				
Lighter than 1.35	79.6	6.96	3.69	5.54	2.94
1.35 to 1.65	7.0	21.08	8.33	1.48	.58
Heavier than 1.65	6.1	46.89	20.81	2.86	1.27
$\frac{1}{20}$ inch and finer	10.4				
Very fine, decanted [a]	2.0			.23	.11
Remainder	8.4	16.55	6.66	1.39	.56
				11.50	5.46

[a] Estimated from results on unwashed coal.

Determinations of ash and sulphur in coal samples variously treated—Continued.

OHIO NO. 1.

[Unwashed coal (boiler-test sample, No. 2136)—ash, 16.91; sulphur, 5.34.]

	Portion.	Ash.	Sulphur.	Compared with original sample.	
				Ash.	Sulphur.
½ inch to $\frac{1}{20}$ inch	87.0				
Lighter than 1.35	57.5	5.97	2.91	3.43	1.67
1.35 to 1.65	16.8	18.91	5.87	3.18	.98
Heavier than 1.65	7.3	54.35	15.01	3.97	1.10
$\frac{1}{20}$ inch and finer	12.9				
Very fine, decanted[a]	7.3			1.23	.39
Remainder	5.7	29.56	7.04	1.69	.40
				13.50	4.54
Washed at 1½-inch size:					
Sample No. 1		9.20	3.98		

OHIO NO. 5.

[Unwashed coal (boiler-test sample, No. 2101)—ash, 8.02; sulphur, 1.65.]

½ inch and $\frac{1}{20}$ inch	90.8				
Lighter than 1.35	78.1	4.77	1.39	3.73	1.09
1.35 to 1.65	7.5	17.33	2.53	1.30	.19
Heavier than 1.65	3.4	69.67	3.72	2.37	.13
$\frac{1}{20}$ inch and finer	8.9				
Very fine, decanted[a]	6.4			.51	.10
Remainder	2.6	12.70	2.74	.33	.07
				8.24	1.58

PENNSYLVANIA NO. 8.

[Unwashed coal (boiler-test sample, No. 2446)—ash, 6.33; sulphur, 0.89.]

½ inch to $\frac{1}{20}$ inch	78.5				
Lighter than 1.35	71.0	5.02	0.58	3.56	0.41
1.35 to 1.65	4.8	21.19	1.49	1.02	.07
Heavier than 1.65	1.6	51.98	8.36	.83	.13
$\frac{1}{20}$ inch and finer	21.2				
Very fine, decanted[a]	12.6			.80	.11
Remainder	8.6	7.51	1.10	.65	.09
				6.86	.81

PENNSYLVANIA NOS. 7 A AND 7 B.

[Unwashed coal (boiler-test sample, No. 2182)—ash, 11.36; sulphur, 1.68.]

½ inch to $\frac{1}{20}$ inch	90.6				
Lighter than 1.35	73.5	8.81	1.40	6.48	1.03
1.35 to 1.65	14.6	23.12	2.03	3.38	.30
Heavier than 1.65	1.1	43.65	9.71	.48	.11
$\frac{1}{20}$ inch and finer	9.0				
Very fine, decanted[a]	7.4			.84	.13
Remainder	1.7	12.53	3.59	.21	.06
				11.39	1.63
Washed at 1½-inch size:					
Sample No. 1		10.62	1.63		
No. 2		11.36	1.68		

[a] Estimated from results on unwashed coal.

Determinations of ash and sulphur in coal samples variously treated—Continued.

PENNSYLVANIA NO. 10.

[Unwashed coal (boiler-test sample, No. 2373)—ash, 6.37; sulphur, 1.35.]

	Portion.	Ash.	Sulphur.	Compared with original sample.	
				Ash.	Sulphur.
¼ inch to $\frac{1}{40}$ inch	87.0				
Lighter than 1.35	78.5	4.50	1.07	3.53	0.85
1.35 to 1.65	5.6	13.15	1.84	.75	.10
Heavier than 1.65	1.9	62.70	8.70	1.19	.17
$\frac{1}{40}$ inch and finer	12.7				
Very fine, decanted *a*	7.6			.48	.11
Remainder	5.0	9.49	2.27	.48	.11
				6.43	1.34

TENNESSEE NO. 6.

[Unwashed coal (boiler-test sample, No. 3102)—ash, 14.86; sulphur, 0.80.]

¼ inch to $\frac{1}{40}$ inch	93.8				
Lighter than 1.35	71.5	3.42	0.67	2.45	0.-7
1.35 to 1.65	7.7	20.64	1.18	1.59	.09
Heavier than 1.65	14.0	70.99	2.74	9.94	.38
$\frac{1}{40}$ inch and finer	5.9				
Very fine, decanted *a*	2.7			.40	.02
Remainder	3.3	22.75	1.08	.75	.04
				15.13	1.00

VIRGINIA NO. 4.

[Unwashed coal (boiler-test sample, No. 2533)—ash, 4.02; sulphur, 0.45.]

¼ inch to $\frac{1}{40}$ inch	92.8				
Lighter than 1.35	88.3	1.93	0.48	1.70	0.41
1.35 to 1.65	1.3	15.91	.95	.20	.01
Heavier than 1.65	2.6	72.22	.92	1.877	.02
$\frac{1}{40}$ inch and finer	6.8				
Very fine, decanted *a*	4.6			.18	.02
Remainder	2.3	10.24	.77	.24	.02
				4.19	.48

VIRGINIA NO. 2.

[Unwashed coal (boiler-test sample, No. 2557)—ash, 6.58; sulphur, 0.83.]

¼ inch to $\frac{1}{20}$ inch	82.6				
Lighter than 1.35	71.2	2.74	0.69	1.95	0.49
1.35 to 1.65	9.0	16.57	1.35	1.49	.12
Heavier than 1.65	1.3	60.02	9.65	.78	.13
$\frac{1}{20}$ inch and finer	17.1				
Very fine, decanted *a*	12.6			.82	.10
Remainder	4.6	12.33	1.23	.57	.06
				5.61	.90
Washed at 1¼-inch size:					
Sample No. 1		4.15	.92		
No. 2		4.02	.95		
No. 3		4.55	.86		

a Estimated from results on unwashed coal.

Determinations of ash and sulphur in coal samples variously treated—Continued.

WEST VIRGINIA NO. 13.

[Unwashed coal (boiler-test sample, No. 2058)—ash, 3.93; sulphur, 0.96.]

	Portion.	Ash.	Sulphur.	Compared with original sample.	
				Ash.	Sulphur.
½ inch to ¼₀ inch	93.6				
Lighter than 1.35	89.1	2.41	0.83	2.15	0.74
1.35 to 1.65	2.2	20.72	1.27	.46	.03
Heavier than 1.65	1.7	70.16	2.59	1.19	.04
¼₀ inch and finer	6.1				
Very fine, decanted [a]	3.6			.14	.04
Remainder	2.5	9.64	1.08	.24	.03
				4.18	.88

WEST VIRGINIA NO. 14.

[Unwashed coal (boiler-test sample, No. 2052)—ash, 2.27; sulphur, 1.07.]

½ inch to ¼₀ inch	88.6				
Lighter than 1.35	84.4	1.52	0.88	1.28	0.74
1.35 to 1.65	1.0	14.52	2.11	.15	.02
Heavier than 1.65	1.0	58.60	13.45	.59	.13
¼₀ inch and finer	11.1				
Very fine, decanted [a]	7.7			.17	.08
Remainder	3.4	7.10	1.89	.24	.07
				2.43	1.04

WEST VIRGINIA NO. 18.

[Unwashed coal (boiler-test sample, No. 2607)—ash, 6.21; sulphur, 0.67.]

½ inch to ¼₀ inch	91.0				
Lighter than 1.35	86.0	4.88	0.68	4.20	0.59
1.35 to 1.65	3.0	22.81	.50	.68	.02
Heavier than 1.65	1.0	62.55	.57	.63	.01
¼₀ inch and finer	8.6				
Very fine, decanted [a]	6.1			.38	.04
Remainder	2.5	7.97	.83	.20	.02
				6.09	.68

WYOMING NO. 2 B.

[Unwashed coal (boiler-test sample, No. 2164)—ash, 21.38; sulphur, 4.41.]

½ inch to ¼₀ inch	94.0				
Lighter than 1.35	62.1	10.85	4.34	6.77	2.70
1.35 to 1.65	21.4	31.84	3.27	6.81	.70
Heavier than 1.65	12.1	64.30	6.48	7.78	.78
¼₀ inch and finer	5.9				
Very fine, decanted [a]	3.3			.71	.15
Remainder	2.6	31.45	4.41	.82	.11
				22.89	4.44

[a] Estimated from results on unwashed coal.

Determinations of ash and sulphur in coal samples variously treated—Continued.

SPECIAL TEST ON REFUSE FROM A WASHING.

[Original refuse—ash, 47.50; sulphur, 1.71.]

	Portion.	Ash.	Sulphur.	Compared with original sample.	
				Ash.	Sulphur.
½ inch to $\frac{1}{40}$ inch	85.2				
Lighter than 1.35	15.0	12.23	0.88	1.83	0.13
1.35 to 1.65	17.7	28.13	.76	4.98	.13
Heavier than 1.65	51.4	64.88	1.79	33.35	.92
$\frac{1}{40}$ inch and finer	14.5				
Very fine, decanted[a]	3.0			1.43	.05
Remainder	11.6	33.27	1.48	3.83	.17
				45.42	1.40

[a] Estimated from results on original refuse.

VOLATILE MATTER IN COALS AND LIGNITES.[a]

The official method of determining volatile matter, recommended by the committee on coal analysis appointed by the American Chemical Society, is as follows:

Place 1 gram of fresh, undried, powdered coal in a platinum crucible weighing 20 or 30 grams and having a tightly fitting cover. Heat over the full flame of a Bunsen burner for seven minutes. The crucible should be supported on a platinum triangle, with the bottom 6 to 8 centimeters above the top of the burner. The flame should be fully 20 centimeters high when burning free, and the determination should be made in a place free from draughts. The upper surface of the cover should burn clear, but the under surface should remain covered with carbon. To find "volatile combustible matter," substract the per cent of moisture from the loss found here.

This method has been used regularly in the volatile determinations made in the laboratory, the only modification being that the flame is protected from air currents by inclosing the apparatus in a cylindrical asbestos shield 15 centimeters long and 7 centimeters in diameter, the platinum triangle being located 3 centimeters below the top of the shield. The use of the shield gives more uniformity in the heat treatment, with a corresponding greater uniformity of results.

In most coals the routine results obtained in the laboratory have checked to within less than 0.3 or 0.4 per cent; occasionally a sample has given trouble, and the variation between duplicates, without any apparent reason, was as great as 1 per cent. On some lignites it has been found impossible to obtain close duplicates, and on a few samples the official method gives very inaccurate determinations—as may be shown by the following results obtained in the laboratory upon two different samples, Nos. 2734 and 2764, of Texas No. 3 lignite, which differed only in the amount of moisture remaining in the air-dried sample, and perhaps in the fineness of grinding:

[a] By permission of Dr. J. A. Holmes, in charge, and the director of the laboratory, the results of this investigation of the volatile matter was published by Prof. E. E. Somermeier as a paper in the Journal of the American Chemical Society, August, 1906.

Laboratory analyses on samples 2734 and 2764 of Texas No. 3 lignite.

Constituent.	Samples.		
	2734.	2764.	
	1.	2.	3.
Moisture	9.88	20.24	20.24
Volatile matter	36.17	58.48	35.42
Fixed carbon	43.65	10.85	33.91
Ash	10.30	10.43	10.43
Sulphur	1.30	1.03	1.03

This great difference in the fixed-carbon results shown in columns 1 and 2 could not be accidental, as all of the determinations on both samples were duplicated. A series of determinations was begun, to learn, if possible, the cause of this great variation. The two following causes were suspected, both of which were found to be partly responsible for the difference: (1) Mechanical loss due to the throwing out of solid particles by the too rapid expulsion of the volatile matter. The possibility of loss from this source is mentioned in the report of the committee of the American Chemical Society, but the results of their experiments are negative. (2) A different breaking down of the hydrocarbon compounds when expelled under different conditions and in the presence of variable amounts of moisture.

The results of Mr. N. M. Austin's preliminary treatment of the sample with a low heat and then with the application of the full flame of the Bunsen burner gives higher results in fixed carbon than where the full flame of the Bunsen burner is applied from the beginning. The proximate analysis of sample 2764, giving the unusual results, which was finally reported by the laboratory, is shown in column 3.

A series of seven results by the official method gave for volatile matter on this sample an average of 62.5 per cent, with a variation between high and low results of over 12 per cent. Three results of volatile matter on this sample made after previous expulsion of the moisture at 105° C. gave average volatile matter 39.6 per cent, with a variation between high and low results of 5.9 per cent. Preliminary treatment by driving off the moisture and most of the volatile matter at a low heat was then tried, the flame of the Bunsen burner being turned down to 10 centimeters and the crucible gradually heated. The application of the heat was regulated by holding the burner in the hand and heating in such a way as to expel the moisture slowly and gradually smoke off most of the volatile matter, the volatile matter escaping freely enough during the last minute of this preliminary heating to burn with a small flame around the edge of the crucible cover. Two results with five minutes of preliminary heating and then seven minutes over the full flame of the Bunsen burner gave an average in volatile matter of 35.08 per cent, the variation between the two results being 0.23 per cent. Two results with three minutes' pre-

liminary heating and seven minutes over the full flame of the Bunsen burner gave an average of 35.6 per cent, with a variation of 0.75 per cent between results. A result obtained by four minutes of preliminary heating and then seven minutes over the full flame gave 35.42 per cent. The difference in results obtained by the three-, four-, and five-minute preliminary treatment is small, and in all subsequent experimental tests the time of the preliminary heating was four minutes. To determine the mechanical losses and difference in volatile compounds given off, a number of ash determinations were made after the driving off of the volatile matter by the official method and after driving off the volatile matter in connection with the preliminary heating. The results of volatile matter and ash on three determinations by the official method and on two determinations by the modified method of four minutes of preliminary heating and then seven minutes over the full flame are as follows:

Determinations of volatile matter by two methods.

Constituent.	Official method.			Modified method.	
	1.	2.	3.	4.	5.
Volatile matter	66.72	67.47	54.82	36.06	36.65
Ash	4.30	4.38	[a]7.25	11.16	11.15

[a] This result is possibly explained by the fact that this sample stood for two hours in the crucible after weighing out, and a considerable amount of the moisture content may have escaped before the sample was treated for the determination of the volatile matter.

That mechanical losses occurred during the rapid evolution of the volatile matter by the official method was also indicated by the shower of solid carbon particles driven off as sparks during the first few minutes, while with the preliminary heating these sparks were nearly or entirely absent. The average volatile matter on the first two determinations was 67.1 per cent, the average ash 4.34 per cent. The average volatile matter on the two results by the modified method was 36.35 per cent, ash 11.15 per cent. The moisture in the sample determined at this time was 19.78, giving fixed carbon 32.72 per cent. The difference in the ash results on the two pairs is 6.81 per cent, or the part of the ash driven off mechanically by the regular method is 6.81 ÷ 11.15, or 61 per cent. Taking this portion of the fixed-carbon result by the modified method gives 20 per cent as the amount of fixed carbon expelled mechanically in the first determinations. The results by the official method after making this correction, and also after taking the correct ash value, are shown in column 1 of the table below.

After making this correction for mechanical losses the difference in the fixed carbon by the two processes is still 10.75 per cent, which difference must be due to the difference in the breaking down of the hydrocarbon compounds by the different heat treatment. The ash

from the third result by the official method was 7.25 per cent, or the loss of ash 3.9 per cent. Correction for fixed carbon mechanically carried off is accordingly 3.9÷11.15, or 35 per cent. This portion of the fixed carbon as shown by the modified method gives 11.4 per cent as the amount of fixed carbon expelled mechanically. The result, after making the fixed-carbon and ash corrections, is shown in column 2 of the following table:

Corrected determinations by the official method.

Constituent.	Corrected results.	
	1.	2.
Moisture	19.78	19.78
Volatile matter	47.10	43.42
Fixed carbon	21 97	25.65
Ash	11.15	11.15
	100.00	100.00

The difference in this case in fixed carbon, due to the different heat treatment, is 7.07 per cent.

This particular sample was very finely ground. To find out how much the difference in result was due to the fineness of grinding a duplicate portion of the same sample was ground down till it passed a 40-mesh sieve. The results of duplicates by the official method and by the modified method are shown in the next table. The proximate analysis of the first sample by the modified method is shown in column 2. The correction for fixed carbon to be applied to the result of the official method is 0.95÷11.20, or 8.5 per cent of the fixed-carbon result of the modified method, which is 2.9 per cent. The results by the official method, after correcting for mechanical loss of fixed carbon and ash, are shown in column 1. The difference in fixed carbon between the two methods, due to different heat treatment, is 3.45 per cent. These results show, at least for lignites, that the fineness of the sample has an important effect. Upon a second sample of lignite, similar to the first except that it contained more moisture (30.45 per cent), the average results by the modified process are as tabulated in column 4. A comparison of the results in volatile matter and ash by the official method shows that the correction to be applied to the fixed carbon and ash for mechanical loss is 2.71÷10.83. These corrections, as applied to the results obtained by the official method, are shown in column 3.

Determinations on sample ground to pass a 40-mesh sieve.

Constituent.	First sample.		Second sample.	
	Official method.	Modified method.	Official method.	Modified method.
	1.	2.	3.	4.
Volatile matter	42.07	35.72	44.40	30.97
Ash	10.25	11.20	8.12	10.83
Loss in ash	.95	.....	2.71	.....
Proximate analysis;				
Moisture	a19.35	19.35	a30.45	30.45
Volatile matter	a39.17	35.72	a37.43	30.97
Fixed carbon	a30.28	33.73	a21.29	27.75
Ash	a11.20	11.20	a10.83	10.83
	100.00	100.00	100.00	100.00

a After correcting for mechanical loss of fixed carbon and ash, the difference in the fixed-carbon results between the two samples, due to different heat treatment, is 6.46 per cent.

To test the effect of the fineness of grinding upon the determination of the volatile matter in ordinary bituminous coal, a sample of coal, Kentucky No. 1 C, containing 2 per cent moisture, 5.7 per cent ash, and 0.9 per cent sulphur, was still further reduced in ash content by floating on a calcium-chloride solution of 1.32 specific gravity. The lighter portion was then thoroughly air dried and separated by sifting into five sizes, and proximate analyses of the parts were made by the official method, with the following results:

Determinations for volatile matter on Kentucky No. 1 C coal.

Constituent.	Sizes of separation by sifting.				
	$\frac{1}{4}$ to $\frac{1}{10}$	$\frac{1}{10}$ to $\frac{1}{20}$	$\frac{1}{20}$ to $\frac{1}{40}$	$\frac{1}{40}$ to $\frac{1}{80}$	$\frac{1}{80}$ and finer.
Moisture	1.15	1.45	1.70	1.90	2.05
Volatile matter	39.05	38.80	38.55	38.05	35.54
Fixed carbon	58.20	58.55	58.35	58.40	59.66
Ash	1.60	1.20	1.40	1.65	2.75

By the modified process with four minutes of preliminary heating the result in volatile matter on the "$\frac{1}{2}\frac{1}{0}$ to $\frac{1}{4}\frac{1}{0}$" size was 33.75 per cent and on the "$\frac{1}{8}\frac{1}{0}$ and finer," 32.85 per cent.

The results in volatile matter on these different sizes are somewhat higher on the coarse samples. However, the different ash contents of the different sizes indicate that the sizing had to a degree separated the coal into somewhat different varieties, as the higher ash content of the finer sample would not in itself be sufficient to account for the lower volatile results. In order to see whether the difference was due to the fineness of grinding or difference in the coals, a portion of the "$\frac{1}{2}\frac{1}{0}$ to $\frac{1}{4}\frac{1}{0}$" sample was ground down in an agate mortar and the volatile matter determined on this fine portion. The average of several results was 37.6 per cent, as against 38.55 per cent on the coarse sample.

From this series of results it appears, at least in low-moisture bituminous coals, that the finer ground samples give somewhat lower

volatile matter than the coarser samples, probably due to the more complete sintering together of the fine samples upon heating, with the consequent effect upon the giving off of the volatile matter.

In order to find out how much effect different heat treatment has on different fuels, a series of samples was selected ranging from anthracite to peat, most of the samples used in the tests having been previously more or less completely air dried so as to permit of better handling in the laboratory. Determinations for volatile matter were made in duplicate by the regular official method and by the modified method with four minutes' preliminary heating. The proximate analyses of the samples with the volatile matter determined by the official method are shown in columns 1 to 5 of the next table; the results for volatile matter by the preliminary heating are given in column 6; and the differences in volatile matter by the two methods are given in column 7. The determinations for moisture were all made in accordance with the official method, by weighing out a separate sample. The same is true of the determinations for ash, with the exception that upon two or three of the lignite samples and one of the Pennsylvania samples the results for ash are those obtained after the determination of the volatile matter by the modified process. These particular samples and results are all specifically mentioned elsewhere (p. 42).

Effect of different heat treatment on determination of volatile matter.

Fuel treated.	Proximate analysis (official method).					Volatile matter (modified method.)	Difference.
	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		
	1.	2.	3.	4.	5.	6.	7.
Colorado anthracite	2.80	5.05	77.55	14.60	0.60	4.90	0.15
Arkansas	.83	12.47	72.05	14.65	2.14	12.37	.10
Pennsylvania	.90	17.35	74.92	6.83	.97	16.07	1.28
Do	1.05	33.10	53.30	12.55	1.76	30.35	2.75
Kentucky	2.99	37.51	56.68	2.82	.58	34.78	2.73
Indiana	4.20	37.70	45.65	12.45	4.13	34.67	3.03
Washington	6.65	35.87	44.57	12.91	.68	34.25	1.62
Indiana	8.40	34.40	48.72	8.48	1.47	32.00	2.40
North Dakota lignite	11.65	45.58	32.97	9.80	1.04	40.17	5.41
Illinois	12.40	32.18	42.82	12.60	1.30	30.12	2.06
Texas lignite (fine)	19.78	62.50	6.57	11.15	1.03	[a]35.42	27.08
Texas lignite (40-mesh duplicate)	19.35	42.07	27.38	11.20	.....	35.72	6.35
Texas lignite (not air dried)	30.45	44.40	15.42	9.73	.....	30.97	13.43
Massachusetts peat	13.25	49.80	16.21	20.74	.58	47.92	1.88

[a] Two determinations upon the fine sample of Texas lignite made by heating for four minutes over a flame 5 centimeters high and then seven minutes over the full flame (25 cm.) gave 35.47 per cent volatile matter—almost an exact check upon the result obtained by the four-minute preliminary heating with a 10-centimeter flame regulated by holding burner in the hand.

With the exception of the anthracite and semianthracite samples, the results by the preliminary heating, as compared with those by the official method, all show a considerably less amount of volatile matter and a correspondingly greater amount of fixed carbon. In the case of the lignites, the greater volatile matter by the official method, as has been shown, is partly due to mechanical losses.

In order to see if mechanical losses might account for the differences on the bituminous coals, determinations for the ash after the determination of the volatile matter were made on one of the Pennsylvania samples. The average results for ash on the samples by the two methods are: Official method, 12.56; preliminary heating, 12.53. These results indicate no mechanical loss whatever, and in none of the samples except the lignites were visible solid carbon particles driven off in the form of sparks, and the differences must be ascribed to the different breaking down of the hydrocarbon compounds by the difference in heat treatment.

Comparisons of the results of volatile matter on a great number of samples differing from one another in moisture content indicate that the presence of loosely held moisture in the sample causes a higher volatile result. In order to obtain more definite data on this question, three samples low in moisture and representing widely different kinds of coal were selected for a series of determinations. The effect of loosely held moisture upon the determinations for volatile matter in each of these samples was determined by adding definite amounts of water to the sample after weighing out. The water was thoroughly mixed with the sample by means of a fine platinum wire and the volatile determination then made in the usual manner according to the official method. The first sample selected was a sample of Pennsylvania coal. The proximate analysis of the air-dried sample and the results for volatile matter determined in the presence of additional moisture are shown in the next table. Air-dried samples of Illinois coal and Arkansas lignite were treated in the same way, with the results also shown in the table.

Determinations of volatile matter (percentages) showing effect of loosely held moisture.

Fuel treated.	Proximate analysis (official method).					Volatile-matter determinations in the presence of stated amounts of added moisture.					
	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	0.03 gram.	0.05 gram.	0.1 gram.	0.15 gram.	0.2 gram.	0.3 gram.
Pennsylvania coal	1.05	33.00	53.30	12.55	1.75	.....	33.60	33.70	33.80	34.10	33.90
Illinois coal	2.35	39.35	44.65	13.65	.....	39.60	39.30	40.00	40.05	39.75	.....
Arkansas lignite	10.85	38.50	31.40	19.25	.83	.....	40.35	41.20	40.90	44.90	.....

Without exception these results show that the presence of loosely held moisture in the sample increases the value obtained for the volatile combustible matter. The average increase for the Pennsylvania sample is about 0.7 per cent. On the Illinois sample the increase for volatile matter is 0.4 per cent. On the Arkansas lignite the increase is 3.3 per cent.

To see what effect this loosely held moisture might have on the volatile determinations where the sample was first subjected to four

minutes' preliminary heating over a low flame, determinations were made upon these samples with and without additional moisture, with the following results:

Determinations of volatile matter (percentages) after four minutes' preliminary heating, showing effect of loosely held moisture.

Fuel treated.	Volatile-matter determinations (by modified method) in the presence of stated amounts of added moisture.			
	No moisture added.	0.15 gram.	0.2 gram.	0.3 gram.
Pennsylvania coal	30.35	.....	.....	31.65
Illinois coal	34.85	36.10	.....	.....
Arkansas lignite	36.90	.....	37.40	.....

These results show that even with a gradual preliminary heating the presence of loosely held moisture increases the value of the volatile determinations, the difference in some of the samples being as great as the difference by the official method; from which it appears that the rapid application of heat sufficient to drive off this moisture results in a reaction between the water vapor and the carbon or hydrocarbons in the coal.

The results of the foregoing experiments and tests show that the value obtained for volatile matter in coal is affected to an important degree: (1) By the method of heating the sample, (2) by the fineness of pulverization, and (3) by the amount of loosely held moisture present. In bituminous coals these differences do not exceed 3 or 4 per cent, and appear to be entirely due to a different breaking up of the hydrocarbon compounds under the different conditions of heat treatment, fineness of sample, and amount of moisture present. In the case of lignites, where the difference may be as high as 25 per cent, this difference is largely due to the mechanical loss in the sample during the rapid expulsion of the volatile matter.

In the routine work of the laboratory in making the determinations of volatile matter the official method is at present used for ordinary bituminous coals, while lignites or other coals with more than 10 per cent moisture are heated for four minutes at a low temperature and then for seven minutes over the full flame of the Bunsen burner.

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CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Bulletin No. 323.]

The publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists can be had on application.

Most of the above publications can be obtained or consulted in the following ways:

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2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost.

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Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

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