THE PRESENT STATUS OF THE PRODUCER-GAS POWER PLANT IN THE UNITED STATES.

By Robert Heywood Fernald.

INTRODUCTION.

Recent developments indicate very positively that two factors will be of great importance in the economical production of power for manufacturing and transportation purposes. These two factors are the replacing to a marked extent of the steam boiler and steam engine by producer-gas plants, with their accompanying internal-combustion engines, and the centralization of power production and distribution.

RAPID DEVELOPMENT OF THE GAS ENGINE.

It was only during the latter part of the nineteenth century that the gas engine came into common use, and although many types have been devised within the last twenty or thirty years it is only within the past five or six years that large engines have been constructed. This development started eight or ten years ago in Germany, Belgium, and England, but marked progress has been limited to the last six years.

For a long time the natural fuel of these internal-combustion engines was city gas, but this was too expensive except for engines of small capacity. It was seldom found economical to operate units of more than 75 horsepower with this fuel. Cheap gas was essential for the development of the gas engine, but the early attempts to produce cheap gas were somewhat discouraging, and for a time the probability that the gas engine would encroach to any extent on the field occupied by the steam engine seemed very remote. The theoretical possibilities of the internal-combustion engine operating on cheap fuel promised so much however that the practical difficulties were rapidly overcome, with the result that the internal-combustion engine is rapidly becoming a serious rival of the steam engine in many of its applications.

The development of large-sized gas engines within the last few years has been exceedingly rapid. It was only seven years ago that a 600-horsepower engine exhibited at the Paris Exposition was regarded as a wonder, but to-day four-cycle, twin-tandem, double-acting engines run as high as 6,000 horsepower.

DEVELOPMENT OF THE GAS PRODUCER FOR POWER PURPOSES.

The rapid advance of the large gas engine has been made possible by improvements in the production of cheap gas directly from fuel through the aid of the gas producer. An early form of producer introduced in Europe, and now in very general use both abroad and at home, is known as the suction producer, a name suggested by the fact that the engine develops its charge of gas in the producer by means of its own suction stroke. Although many producers of this type are now used, most of them are small, not exceeding 150 horsepower. As far as known the first suction producer operated in the United States was installed in 1903, although producers of other types were tried in this country as early as 1896. A serious limitation to the utility of the suction producer has been the fact that, owing to the manner of generating the gas, no tarry fuels could be used, a restriction that prevented the use of bituminous coals, lignites, peats, and other like fuels. The fuels in most common use for producers of this kind are charcoal, coke, and anthracite coal, although attempts are being made so to construct suction plants that they can be operated on bituminous or tarry coals.

The pressure producer was devised to meet a demand for the concentration of power in large units, to replace a greater number of engines of smaller power. By this producer the gas is generated under slight pressure, due to the introduction of an air and steam blast, and stored in a holder until it is required for the engine. As the gas may thus be stored before passing to the engine, and as it is produced under pressure and its generation does not depend on the suction stroke of the engine, tar and other impurities may be removed from it by devices that permit the use of bituminous coal and lignite. In the progress of invention in this field the pressure producer was closely followed by the down-draft producer, which fixes the tar as a permanent gas and therefore completely uses bituminous coal and lignite.

Pressure and down-draft producers have been in operation for the last few years, but the fuel used in most of them has been anthracite coal. Some plants, however, have used a few well-tried bituminous coals known to be especially free from sulphur, ash, and tarry matter. It remained for the United States Geological Survey, in its testing plant at St. Louis, to attempt the use of any and all bituminous coals, lignites, and peats, without reference to the amount of sulphur or tarry matter they contained. It is gratifying to note that every coal received has been run through the producer and that the results have been more than satisfactory.

TESTS MADE BY THE UNITED STATES GEOLOGICAL SURVEY.

DESCRIPTION OF PLANT.

In view of the possibility that the gas engine, with its gas producer, may displace the steam engine, the problem here considered has become so important that the Government made special provision for producer-gas tests at its fuel-testing plant installed in connection with the Exposition at St. Louis. These tests have furnished valuable data on the relative consumption of coal per horsepower per hour when used by the steam plant and by the gas plant.

The steam plant with which tests were made consists of two 210-horsepower Heine boilers, furnishing steam to a 250-horsepower, simple, noncondensing Corliss engine, which was belted to a Bullock electric generator.

The producer-gas plant is a Taylor pressure gas producer No. 7, of 250-horsepower capacity. Connected with the producer is the usual apparatus for cleansing and storing the gas before it is delivered to the engine—the economizer, scrubber, tar extractor, purifier, and holder.

The gas engine is of the three-cylinder, vertical, Westinghouse type, with cylinders of 19-inch diameter and 22-inch stroke, rated at 235 brake horsepower on producer gas. The engine was belted to a 6-pole 175-kilowatt Westinghouse direct-current generator. The load on the generator was controlled by a water rheostat, especially constructed for the purpose, through which also the energy developed was dissipated.

DETAILS OF TESTS.

By means of this producer-gas plant, which was installed in 1904, 162 tests have been made. The fuels used were bituminous coals, lignites, and peats from 26 different States, as indicated below:

Fuels tested at gas-producer plant of the United States Geological Survey, St. Louis, Mo.

BITUMINOUS COALS.	
Alabama	3
Arkansas	2
Illinois	29
Indiana	15
Indian Territory	2
Iowa	1
Kansas	2
Kentucky	5
Missouri	1
New Mexico	3
Ohio	10
Pennsylvania	13
Tennessee	8
Utah	1
Virginia	5
Washington	1
West Virginia	14
Wyoming	5
	120
SUBBITUMINOUS [a] COALS.	
California	1
Colorado	1
Montana	3
Washington	3
Wyoming	1
	9

[a] The term subbituminous has been adopted by the United States Geological Survey for the class of coal generally called "black lignite."

LIGNITES.

Arkansas	1
North Dakota	4
Texas	4
	9

MISCELLANEOUS FUELS.

Argentine coal	1
Brazil coal	1
California coal and "front end" cinders	2
Florida peat	1
Massachusetts peat	1
Rhode Island anthracite	1
Virginia pea semianthracite	1
Coke breeze	1
Miscellaneous refuse	1
Coke	1
	11

COALS (DUPLICATE TESTS).

Illinois	2
Indiana	4
Kansas	1
Ohio	1
Pennsylvania	2
Tennessee	1
West Virginia	1
	12

LIGNITE (DUPLICATE TEST).

North Dakota	1

The results of these tests, as given in the accompanying table, have been subjected to absolutely no refinements. With the possible exception of two or three coals, only one test has been made on each sample, and the result of each test has, to a great extent, depended on the ability of the producer operator to become familiar with the method of handling a given coal during a period of eight or ten hours preceding the official test.

It should also be borne in mind that all of the tests, whether on bituminous coal, lignite, or peat, have been made in a producer of one size and type—a type designed primarily for use with anthracite coal—and that it has been imperative that the test be made and the required power generated without regard to the proper relations between the gas-producing qualities of the coal and the fuel-bed area. The tests have been conducted under the restrictions of steady load on the engine (235 brake horsepower), and not with a view to determining the maximum power-producing quality of the coal. Despite this restriction the general conclusions are regarded as sufficiently significant for presentation, although they may be modified by later investigations.

Summary of results of producer-gas tests at St. Louis.

Name of sample.	Location of mine.	Size or condition.	Equivalent pounds of coal used per hour.	British thermal units.		Equivalent pounds of coal as fired per horsepower hour.			
				Per pound of coal as fired.	Per cubic foot of standard gas.	Per electrical horsepower. Available for outside purposes.	Per electrical horsepower. Developed at switchboard.	Per brake horsepower. Available for outside purposes.	Per brake horsepower. Developed at engine.
Alabama No. 2	Carbon Hill	Lump	341.4	12,865	149.2	1.77	1.71	1.51	1.45
Alabama No. 4	Belle Ellen	Run of mine	265.2	12,953	152.0	1.45	1.36	1.23	1.16
Alabama No. 6	Dolomite	do	196.6	14,170	143.7	1.02	0.99	0.87	0.84
Arkansas No. 7	Midland	Lump	280.5	12,773	125.5	2.24	2.04	1.90	1.74
Arkansas No. 8	Spadra	4-inch	358.1	12,546	130.0	2.13	2.02	1.81	1.72
Arkansas No. 10	Lester [a]	Lump	523.4	6,356	125.3	4.41	4.07	3.75	3.45
Brazil No. 1	Porto Alegre	Run of mine	369.2	9,058	130.9	2.88	2.60	2.45	2.21
California No. 1	Tesla [b]		597.3	8,530	158.3	3.06	2.88	2.60	2.45
Colorado No. 1	Lafayette [b]	Lump	428.4	9,767	149.0	2.30	2.14	1.95	1.82
Florida No. 1	Orlando [c]	Bricks	620.6	8,127	175.2	3.16	3.03	2.69	2.57
Illinois No. 3	Marion	Run of mine	386.0	12,046	154.8	2.01	1.93	1.70	1.64
Illinois No. 4	Troy	2-inch +	398.2	11,237	151.5	2.11	2.01	1.79	1.71
Illinois No. 6	Coffeen	Lump	418.2	10,141	152.0	2.14	2.02	1.82	1.72
Illinois No. 7	Collinsville	½-inch −	683.8	9,360	109.3	5.25	4.94	4.46	4.20
Do	do	1-inch +	492.1	9,970	138.6	2.52	2.41	2.14	2.05
Do	do	Slack	508.5	9,958	120.2	3.12	2.91	2.65	2.47
Illinois No. 8	Paisley	Nut	411.5	10,680	147.0	2.08	1.98	1.77	1.68
Illinois No. 9	Staunton	Lump	418.1	10,854	143.7	2.11	2.01	1.79	1.71
Illinois No. 10	West Frankfort	Slack	329.5	11,768	140.7	1.69	1.59	1.44	1.35
Illinois No. 11	Carterville	Egg	305.8	12,004	173.4	1.56	1.46	1.33	1.24
Do	do	5 washed	595.1	10,865	109.8	3.66	3.42	3.13	2.91
Do	do	3 washed	277.1	12,361	146.1	1.47	1.38	1.25	1.17
Do	do	do	277.7	12,474	154.9	1.46	1.37	1.24	1.16
Illinois No. 13	Benton	Egg	362.6	11,686	156.8	1.84	1.74	1.56	1.48
Illinois No. 14	Springfield	Lump	356.0	10,679	150.6	1.90	1.79	1.61	1.52
Illinois No. 15	Centralia	do	360.2	10,964	142.9	1.91	1.80	1.63	1.53
Illinois No. 16	Herrin	do	364.1	11,920	149.5	1.91	1.81	1.62	1.54
Illinois No. 18	Lasalle	do	350.3	11,039	147.7	1.85	1.74	1.57	1.48
Illinois No. 19	Zeigler	3-inch +	294.8	11,871	164.1	1.55	1.47	1.32	1.25
Do	do	Run of mine	314.4	11,493	137.8	2.40	2.23	2.04	1.90
Illinois No. 21	Troy	Lump	396.4	10,528	156.1	2.18	2.07	1.85	1.76
Illinois No. 24	New Baden	do	311.8	10,958	160.5	1.63	1.55	1.39	1.32
Illinois No. 23	Donkville	5-inch	379.1	10,667	147.9	2.02	1.91	1.71	1.63
Do	do	Slack	374.9	10,804	145.0	2.17	2.07	1.85	1.76
Illinois No. 22	Maryville	Lump	368.3	10,735	159.6	2.00	1.88	1.70	1.59
Illinois No. 25	Germantown	do	337.7	10,733	168.0	1.78	1.68	1.51	1.43
Illinois No. 26	Lincoln	Run of mine	348.4	10,013	147.2	2.13	2.00	1.81	1.70
Illinois No. 27	Auburn	do	347.4	10,485	122.5	3.06	2.78	2.60	2.36
Illinois No. 29	Livingston	do	370.3	10,719	141.2	2.00	1.91	1.70	1.62
Illinois No. 30	Shiloh	Washed	339.5	12,188	154.4	1.78	1.71	1.51	1.45
Indiana No. 1	Mildred	Run of mine	434.6	11,534	153.7	2.31	2.17	1.96	1.85
Indiana No. 2	Boonville	do	370.1	11,822	139.6	2.36	2.22	2.01	1.89
Indiana No. 3	do	Nut and slack	372.5	11,417	137.2	2.09	1.97	1.78	1.67
Indiana No. 5	Hymera	Run of mine	427.5	11,052	136.7	2.29	2.15	1.95	1.83
Do	do	do	304.4	11,520	145.0	1.62	1.51	1.37	1.28
Indiana No. 6	do	do	387.3	11,158	150.9	2.05	1.94	1.74	1.65
Indiana No. 7	Littles	1¼-inch +	326.5	11,810	158.5	1.74	1.65	1.47	1.40
Indiana No. 8	Terre Haute	Lump	322.7	11,687	151.5	1.70	1.61	1.45	1.37
Indiana No. 9	Macksville	1¼-inch +	360.7	11,246	151.8	1.94	1.84	1.65	1.57
Indiana No. 11	Dugger	Lump	346.8	11,581	147.1	1.83	1.73	1.56	1.47
Indiana No. 12	Hartwell	Run of mine	364.4	11,146	149.4	1.97	1.87	1.67	1.59
Indiana No. 13	Terre Haute	do	333.5	10,924	131.9	2.21	2.09	1.88	1.77
Do	do	do	304.9	11,408	148.0	1.68	1.61	1.43	1.37
Indiana No. 14	Seelyville	do	343.4	11,146	154.1	1.91	1.81	1.62	1.54
Indiana No. 15	Linton	do	314.0	11,651	144.1	1.75	1.66	1.48	1.41
Do	do	do	302.6	11,651	145.7	1.65	1.56	1.40	1.33
Indiana No. 16	do	do	345.8	11,592	136.7	2.06	1.95	1.75	1.66
Indiana No. 18	Winslow	Lump	309.3	12,031	154.7	1.67	1.59	1.42	1.35
Do	do	do	351.1	11,952	152.6	1.88	1.79	1.60	1.52
Indian Territory No. 1.	Henryetta	1¼-inch +	392.7	12,787	159.2	2.00	1.92	1.71	1.64
Indian Territory No. 4.	Lehigh	1-inch +	312.5	10,364	161.1	1.66	1.57	1.41	1.33
Iowa No. 2	Marion County	Run of mine	408.4	8,735	160.2	2.19	2.07	1.86	1.76
Kansas No. 5	West Mineral	⅝-inch +	338.4	12,836	167.2	1.76	1.69	1.50	1.44
Do	do	do	325.3	12,967	128.9	1.65	1.57	1.40	1.33
Kansas No. 6	Jewett	Lump	349.4	11,470	155.2	1.84	1.76	1.56	1.49

[a] Brown lignite. [b] Black lignite. [c] Machined peat.

Summary of results of producer-gas tests at St. Louis—Continued.

Name of sample.	Location of mine.	Size or condition.	Equivalent pounds of coal used per hour.	British thermal units.		Equivalent pounds of coal as fired per horsepower hour.			
				Per pound of coal as fired.	Per cubic foot of standard gas.	Per electrical horsepower: Available for outside purposes.	Per electrical horsepower: Developed at switchboard.	Per brake horsepower: Available for outside purposes.	Per brake horsepower: Developed at engine.
Kentucky No. 1	Straight Creek	Egg	276.7	14,270	166.5	1.49	1.41	1.26	1.19
Kentucky No. 3	Earlington	Run of mine	410.8	12,283	155.9	2.16	2.05	1.86	1.75
Kentucky No. 5	Big Black Mountain.	do	274.4	13,984	163.2	1.47	1.39	1.25	1.18
Kentucky No. 6	Paintsville	do	265.6	13,747	176.0	1.42	1.33	1.20	1.13
Kentucky No. 7	Central City	1½-inch +	322.8	11,986	153.7	1.75	1.65	1.49	1.40
Missouri No. 2	Bevier	Run of mine	384.5	10,505	140.0	2.07	1.94	1.76	1.65
Montana No. 1	Red Lodge	4 washed	506.8	10,575	160.8	2.65	2.54	2.26	2.16
Montana No. 2			424.6	10,478	147.5	2.34	2.25	1.99	1.91
Montana No. 3			347.2	10,685	181.5	1.80	1.74	1.53	1.48
New Mexico No. 3	Van Houten	Run of mine	275.7	11,425	155.1	1.47	1.39	1.25	1.18
New Mexico No. 4	Brilliant	do	287.5	12,501	135.3	1.62	1.52	1.38	1.29
New Mexico No. 5	Blossburg	do	298.1	12,542	159.6	1.60	1.51	1.36	1.29
North Dakota No. 1	Lehigh [a]	Lump	559.5	6,970	160.6	3.04	2.82	2.58	2.40
North Dakota No. 2	Williston [a]	do	510.0	6,802	188.5	4.07	3.80	3.47	2.23
Do	do [a]	do	552.1	7,326	164.1	2.97	2.83	2.53	2.40
Do	do [a]	do	571.6	6,739	145.0	2.97	2.87	2.53	2.44
North Dakota No. 3	Wilton [a]	do	632.8	7,279	158.9	3.42	3.24	2.92	2.75
Ohio No. 3	Shawnee	Washed	303.4	12,200	156.1	1.62	1.51	1.37	1.28
Ohio No. 4	Bradley	Lump	270.4	13,158	148.8	1.41	1.34	1.20	1.14
Ohio No. 5	Rush Run	Nut	254.0	13,414	152.3	1.34	1.26	1.13	1.07
Ohio No. 6	Neff's	Run of mine	254.2	13,035	163.4	1.36	1.30	1.16	1.10
Ohio No. 7	Danford	Lump	331.0	12,841	156.2	1.76	1.67	1.50	1.42
Ohio No. 8	Bixie	Run of mine	309.1	11,302	170.2	1.67	1.56	1.42	1.32
Ohio No. 9	Clarion	Lump	277.7	12,492	154.6	1.51	1.43	1.28	1.21
Ohio No. 10	Mineral City	do	268.7	12,805	165.6	1.40	1.35	1.19	1.15
Ohio No. 11	Flushing	do	296.8	12,287	165.2	1.55	1.49	1.32	1.26
Ohio No. 12	Bellaire	Run of mine	335.5	12,933	164.8	1.77	1.69	1.50	1.43
Do	do	do	309.3	12,739	164.6	1.62	1.56	1.38	1.32
Pennsylvania No. 4	Greensburg	Lump	276.6	13,518	140.6	1.49	1.42	1.27	1.21
Pennsylvania No. 5	Ellsworth	Nut	259.0	13,613	149.3	1.37	1.28	1.16	1.09
Pennsylvania No. 6	East Millsboro	Run of mine	294.8	13,921	126.6	1.63	1.51	1.38	1.28
Do	do	do	238.3	13,025	146.4	1.30	1.23	1.10	1.04
Pennsylvania No. 7	Ligonier	do	284.5	13,223	139.4	1.79	1.68	1.52	1.42
Pennsylvania No. 8	Ehrenfeld	do	240.0	14,353	133.0	1.35	1.28	1.15	1.09
Pennsylvania No. 10.	Bruce	¾-inch	258.6	13,606	159.5	1.38	1.32	1.18	1.12
Pennsylvania No. 11.	Charleroi	Run of mine	265.0	13,775	146.4	1.66	1.55	1.41	1.32
Pennsylvania No. 12.	Atcheson	do	240.2	13,622	147.5	1.28	1.23	1.09	1.05
Pennsylvania No. 13.	Creighton	do	274.5	12,816	153.0	1.49	1.42	1.26	1.21
Do	do	do	255.8	13,181	144.9	1.36	1.30	1.16	1.10
Pennsylvania No. 15.	Wehrum	do	263.3	13,712	144.4	1.43	1.37	1.22	1.17
Pennsylvania No. 16.	Hastings	do	223.0	13,318	149.5	1.17	1.12	0.99	0.95
Pennsylvania No. 17.	White	do	279.9	12,798	141.2	1.55	1.49	1.31	1.26
Pennsylvania No. 22.	Greensburg	do	248.5	13,311	145.6	1.31	1.26	1.11	1.07
Tennessee No. 1	Fork Ridge	do	262.9	12,749	154.5		1.56		1.32
Tennessee No. 2	Gotliffe	do	248.9	13,882	167.9	1.30	1.24	1.11	1.05
Tennessee No. 3	do	do	281.3	13,156	159.7	1.50	1.40	1.27	1.19
Tennessee No. 4	Oliver Springs	do	263.9	13,379	161.7	1.54	1.45	1.31	1.23
Tennessee No. 5	Petros	do	281.2	13,442	142.1	1.61	1.51	1.37	1.28
Tennessee No. 6	Waldencia	do	291.2	11,621	133.3	2.02	1.87	1.72	1.59
Tennessee No. 7	Wilder	do	313.6	12,602	154.6	1.74	1.63	1.48	1.38
Tennessee No. 8	Clifty	do	243.9	13,471	147.4		1.69		1.43
Do	do	do	291.3	13,459	157.5	1.58	1.48	1.34	1.26
Texas No. 1	Crockett [a]	do	660.0	7,267	169.7	3.53	3.34	3.00	2.83
Texas No. 2	Hoyt [a]	do	519.5	7,348	156.2	2.74	2.58	2.33	2.20
Texas No. 3	Olsen [a]	do	549.4	7,603	171.8	2.90	2.75	2.47	2.33
Texas No. 4	Hoyt [a]	do	529.8	7,448	156.1	2.87	2.74	2.43	2.33
Utah No. 1	Price	do	302.0	13,212	171.4	1.55	1.46	1.31	1.24
Virginia No. 1	Crab Orchard	do	300.2	13,324	164.4	1.61	1.53	1.37	1.30

[a] Brown lignite.

Summary of results of producer-gas tests at St. Louis—Continued.

Name of sample.	Location of mine.	Size or condition.	Equivalent pounds of coal used per hour.	British thermal units.		Equivalent pounds of coal as fired per horsepower hour.			
						Per electrical horsepower.		Per brake horsepower.	
				Per pound of coal as fired.	Per cubic foot of standard gas.	Available for outside purposes.	Developed at switchboard.	Available for outside purposes.	Developed at engine.
Virginia No. 2	Crab Orchard	Run of mine	272.7	14,080	169.0	1.47	1.38	1.25	1.17
Virginia No. 3	Toms Creek	Lump	236.7	14,643	156.4	1.29	1.21	1.10	1.03
Virginia No. 4	Darby	do	257.0	14,470	167.2	1.38	1.31	1.17	1.11
Virginia No. 5	Blacksburg	Pea	287.3	12,159	160.7	1.49	1.44	1.27	1.22
Virginia No. 6	Richlands	Run of mine	240.8	13,351	138.1	1.29	1.25	1.09	1.06
Washington No. 1	Renton		496.3	9,787	145.9	3.71	3.44	3.15	2.93
Do	do		440.7	9,680	159.2	3.03	2.82	2.57	2.40
Do	do		506.0	9,634	144.1	2.73	2.59	2.32	2.20
Washington No. 2	Roslyn	Lump	281.8	12,218	168.6	1.52	1.44	1.29	1.22
West Virginia No. 1	Kingmont	Run of mine	320.6	14,166	144.4	1.69	1.60	1.43	1.36
West Virginia No. 4	Kingwood	do	262.8	13,918	143.2	1.39	1.32	1.18	1.12
West Virginia No. 7	Sun	do	299.2	14,283	154.2	1.59	1.50	1.35	1.28
West Virginia No. 8	Ansted	do	364.7	14,168	155.1	1.92	1.82	1.63	1.55
West Virginia No. 9	Powellton	do	328.9	14,195	151.0	1.76	1.64	1.49	1.39
Do	do	do	284.8	14,224	160.5	1.51	1.43	1.28	1.21
West Virginia No. 12.	Big Sandy	do	304.9	14,614	142.5	1.59	1.53	1.35	1.30
West Virginia No. 13.	Page	do	208.0	14,674	139.2	1.10	1.04	0.93	0.88
West Virginia No. 14.	do	do	220.6	14,488	147.0	1.15	1.10	0.98	0.93
West Virginia No. 16.	Monongah	Nut	277.5	13,882	156.1	1.49	1.40	1.26	1.19
West Virginia No. 18.	Glen Alum	Run of mine	238.0	14,152	158.9	1.27	1.20	1.08	1.02
West Virginia No. 20.	Acme	do	257.3	13,948	156.3	1.39	1.31	1.18	1.11
West Virginia No. 25.	Charleston	Lump	273.0	13,288	171.6	1.42	1.37	1.21	1.17
Wyoming No. 2	Cambria	Run of mine	459.8	9,650	151.0	2.49	2.28	2.11	1.94
Do	do	do	440.2	9,853	146.6	2.40	2.28	2.05	1.94
Wyoming No. 3	Aladdin	do	394.5	9,338	160.9	2.19	2.04	1.86	1.74
Wyoming No. 4	Hanna	do	438.2	10,755	151.6	2.38	2.24	2.02	1.91
Wyoming No. 6	Kemmerer	do	474.9	10,460	171.8	2.52	2.38	2.14	2.02

RELATIVE RESULTS OF STEAM AND PRODUCER-GAS TESTS.

In considering the relation between the economic results of plants of the two types under discussion, namely, steam and producer-gas, the fact should be remembered that to-day, in the ordinary manufacturing plant operated by steam power, less than 5 per cent of the total energy in the fuel consumed is available for useful work at the machine.

In that connection it is of interest and value to glance at the possibilities of the best designed and most skillfully operated commercial plant now in use. The data concerning the steam plant selected for this determination are derived from a table prepared by Mr. Stott, superintendent of motive power, Interborough Rapid Transit Company, New York City, which, as Mr. Stott says,[a] shows "the losses found in a year's operation of what is probably one of the most effi-

[a] Stott, H. G., Power Plant Economics; Trans. Am. Inst. Elec. Eng., 1906.

cient plants in existence to-day, and, therefore, typical of the present state of the art."

Average losses in steam plant of the Interborough Company in converting 1 pound of coal, containing 12,500 British thermal units, into electricity.

	British thermal units.	Per cent.
Loss by friction	138	1.1
Loss in exhaust	7,513	60.1
Loss in pipes and auxiliaries	275	2.2
Loss in boiler	1,000	8.0
Loss in stack	1,987	15.9
Loss in ashes	300	2.4
Total losses	11,213	89.7
Energy utilized	1,287	10.3
	12,500	100.0

Mr. Stott further presents a table showing the thermal efficiency of producer-gas plants, concerning which he says:

The following heat balance is believed to represent the best results obtained in Europe and the United States up to date in the formation and utilization of producer-gas.

Average losses in a producer-gas plant in the conversion of 1 pound of coal, containing 12,500 British thermal units, into electricity.

	British thermal units.	Per cent.
Loss in gas producer and auxiliaries	2,500	20.0
Loss in cooling water in jackets	2,375	19.0
Loss in exhaust gases	3,750	30.0
Loss in engine friction	813	6.5
Loss in electric generator	62	0.5
Total losses	9,500	76.0
Converted into electric energy	3,000	24.0
	12,500	100.0

The thermal efficiency of such plants, as given by different writers, runs as high as 33, 36, 38.5 per cent, and for some plants figures as extravagant as "above 40" are boldly published. Although the present aim has been to present figures for a producer-gas plant that may compare favorably with those of the steam plant of the Interborough Company, an effort has been made to keep well within obtainable efficiencies. Attention is also directed to the fact that the producer-gas plant considered should be large enough to compare favorably with the steam plant. This precludes comparisons with suction plants, which are relatively small, but give higher proportional efficiencies than the larger pressure and down-draft plants, for these require more or less auxiliary apparatus.

Mr. Stott seems ready to accept a thermal efficiency of 24 per cent for the best producer-gas plants, for comparison with 10.3 per cent efficiency for his steam plant, but a careful study of the problem has led to a more conservative estimate for the producer-gas plant, namely, 21.5 per cent.

The tables just given show the comparative efficiencies reached in plants of the best type, both steam and producer-gas, but these are seldom realized in common practice. The results obtained in the Government plant at St. Louis are probably more nearly representative of the ordinary type of apparatus. These results are as follows:

Relative economies of steam and gas power plants at St. Louis in the conversion of one pound of coal containing 12,500 British thermal units into electricity.

	Steam power.		Gas power.	
	British thermal units.	Per cent.	British thermal units.	Per cent.
Losses in exhaust, friction, etc	11,892	95.14	10,812	86.5
Converted into electric energy	608	4.86	1,688	13.5
	12,500	100.00	12,500	100.0

The following table shows the comparative results obtained at St. Louis from 75 bituminous coals and 6 lignites used in the gas producer and under the steam boiler.

Table showing equivalent pounds of coal as fired per electrical horsepower per hour developed at the switchboard, for both steam and producer-gas plants.

Fuel used.	Locality.	Steam.	Producer gas.
Alabama No. 2	Carbon Hill	4.29	1.71
Colorado No. 1	Lafayette	6.04	2.14
Florida (peat) No. 1	Orlando	....	3.03
Illinois No. 3	Marion	4.74	1.93
Illinois No. 4	Troy	5.47	2.01
Illinois No. 6	Coffeen	6.28	2.02
Illinois No. 7	Collinsville	5.21	2.41
Illinois No. 8	Paisley	6.26	1.98
Illinois No. 9	Staunton	5.22	2.01
Illinois No. 10	West Frankfort	4.88	1.59
Illinois No. 11	Carterville	4.35	1.37
Illinois No. 13	Burton	4.17	1.74
Illinois No. 14	Springfield	5.27	1.79
Illinois No. 15	Centralia	4.61	1.80
Illinois No. 16	Herrin	4.24	1.81
Illinois No. 18	La Salle	4.53	1.74
Illinois No. 19	Zeigler	4.09	1.47
Indiana No. 1	Mildred	4.95	2.17
Indiana No. 2	Boonville	4.78	1.68
Indiana No. 3	.....do	4.92	1.97
Indiana No. 5	Hymera	4.74	1.51
Indiana No. 6	.....do	4.78	1.94
Indiana No. 7	Littles	4.39	1.65
Indiana No. 8	Terre Haute	4.52	1.61
Indiana No. 9	Macksville	4.63	1.84
Indiana No. 11	Dugger	4.37	1.73
Indian Territory No. 1	Henryetta	4.37	1.92
Indian Territory No. 4	Lehigh	4.95	1.57
Iowa No. 2	Marion County	5.82	2.07
Kansas No. 5	West Mineral	4.11	1.57
Kentucky No. 1	Straight Creek	3.72	1.41
Kentucky No. 3	Earlington	4.58	2.05
Kentucky No. 5	Big Black Mountain	3.54	1.39
Kentucky No. 6	Paintsville	3.68	1.33
Kentucky No. 7	Central City	4.36	1.65
Missouri No. 2	Bevier	5.44	1.94

Table showing equivalent pounds of coal as fired per electrical horsepower per hour developed at the switchboard, for both steam and producer-gas plants—Continued.

Fuel used.	Locality.	Steam.	Producer gas.
Montana No. 1	Red Lodge		2.54
North Dakota No. 1	Lehigh	10.09	2.82
North Dakota No. 2	Williston		3.80
North Dakota No. 2	do		2.83
North Dakota No. 3	Wilton	8.46	3.24
Ohio No. 3	Shawnee	4.27	1.51
Ohio No. 4	Bradley	3.98	1.34
Ohio No. 5	Rush Run	3.96	1.26
Ohio No. 6	Neffs	4.00	1.30
Ohio No. 7	Danford	4.16	1.67
Ohio No. 8	Dixie	4.25	1.56
Ohio No. 9	Clarion	3.91	1.43
Pennsylvania No. 4	Greensburg	3.63	1.42
Pennsylvania No. 5	Ellsworth	3.52	1.28
Pennsylvania No. 6	East Millsboro	3.83	1.23
Pennsylvania No. 7	Ligonier	3.88	1.68
Pennsylvania No. 8	Ehrenfeld	3.43	1.28
Pennsylvania No. 10	Bruce	3.55	1.32
Texas No. 1	Crockett		3.34
Texas No. 2	Hoyt		2.58
Virginia No. 1	Crab Orchard	3.66	1.53
Virginia No. 2	do	3.58	1.38
Virginia No. 3	Toms Creek	3.57	1.21
Virginia No. 4	Darby	3.56	1.31
West Virginia No. 1	Kingmont	3.98	1.60
West Virginia No. 4	Bretz	3.71	1.32
West Virginia No. 7	Sun	3.65	1.50
West Virginia No. 8	Ansted	3.83	1.82
West Virginia No. 9	Powellton	3.58	1.43
West Virginia No. 12	Big Sandy	3.59	1.53
West Virginia No. 13	Page	3.45	1.04
West Virginia No. 14	do	3.41	1.10
West Virginia No. 18	Glen Allen (?)	3.43	1.20
West Virginia No. 20	Acme	3.46	1.31
Wyoming No. 2	Cambria	6.64	2.28
Wyoming No. 2	do	5.64	2.28
Wyoming No. 3	Aladdin	5.35	2.04
Brazil No. 1	Porto Alegre	6.43	2.60

Especial attention is called to the fact that several low-grade coals and lignites that have proved of little value or even worthless under the steam boiler have given excellent results in the gas producer.

The ratios of the total fuel per brake-horsepower hour required by the steam plant and producer-gas plant, under full load, not counting stand-by losses, are presented below as derived from 76 coals, 6 lignites, and 1 peat (Florida).

Ratios of fuel used in steam and gas plants.

Average ratio coal as fired per brake-horsepower hour under boiler to coal as fired per brake-horsepower hour in producer	2.7
Maximum ratio coal as fired per brake-horsepower hour under boiler to coal as fired per brake-horsepower hour in producer	3.7
Minimum ratio coal as fired per brake-horsepower hour under boiler to coal as fired per brake-horsepower hour in producer	1.8
Average ratio lignite and subbituminous coal as fired per brake-horsepower hour under boiler to lignite as fired per brake-horsepower hour in producer	2.7
Maximum ratio lignite and subbituminous coal as fired per brake-horsepower hour under boiler to lignite as fired per brake-horsepower hour in producer	2.9
Minimum ratio lignite and subbituminous coal as fired per brake-horsepower hour under boiler to lignite as fired per brake-horsepower hour in producer	2.2
Average ratio peat as fired per brake-horsepower hour under boiler to peat as fired per brake-horsepower hour in producer	2.3

The figures for the producer-gas tests include not only the coal consumed in the gas producer, but also the coal used in the auxiliary boiler for generating the steam necessary for the pressure blast—that is, the figures given include the *total* coal required by the gas-producer plant.

In the above comparisons between the steam and producer-gas plants no consideration has been made of stand-by losses. The result for each plant has been derived from experiments made during continuous operation for a given period. Data on stand-by losses for plants operated during a portion of each 24-hour day are not at present obtainable at the fuel-testing plant. Very few results of experiments relating to this point have been published, and opinions regarding the amount of fuel required for holding fires over night or during idle periods in both boiler and producer plants seem to differ widely. It is probable that the most reliable figures available to-day concerning this matter are those presented by Messrs. Dowson and Larter in their recent book entitled "Producer Gas." The results obtained by these gentlemen from a number of engineers and experimenters, including such well-known experts as Mr. Bryan Donkin, indicate that for plants of about 250 horsepower the stand-by losses amount to about 67 pounds of coal per standing hour for the steam plant and to about 4 pounds per standing hour for the producer-gas plant.

In considering the possible increase in efficiency of the boiler tests with a compound engine, as compared with the simple engine used, the fact should not be overlooked that a corresponding increase in the efficiency of the producer-gas tests may be brought about under corresponding favorable conditions. Not only is the producer passing through a transitional period, but the gas engine must still be regarded in the same light. In the larger sizes the vertical single-acting engine is being replaced by the horizontal double-acting engine. Other changes and improvements are constantly being made, which tend to increase the efficiency of the gas engine as compounding and tripling the expansions have already increased the efficiency of the steam engine.

As has already been stated, the engine used in the tests here reported is of a type that is rapidly becoming obsolete for this size, viz, vertical, three-cylinder, single-acting.

A brief consideration of these points will lead at once to the conclusion that the producer-gas plant and steam plant used in these tests compare very favorably, and that any increase in efficiency in the boiler tests that might result from using a compound engine can be offset by the introduction of a gas engine of more modern type and a producer plant designed to handle the special kinds of fuel used.

It should be noted that many fuels which give poor results under steam boilers have been used with great ease and efficiency in the gas producer, which thus makes it possible to utilize low-grade coals and lignites that have heretofore been regarded as practically useless. Several of the poorest grades of bituminous coals have shown remarkable efficiency in the gas producer, and lignites and peat have been used in it with great readiness, thus opening the way to the introduction of cheap power into large districts that have thus far been commercially unimportant owing to lack of industrial opportunities. Recent experiments with "bone," a refuse product in bituminous coal mining, have given excellent results, showing an efficiency in the product equal to that reached by good steam coal under boilers.

EFFICIENCIES.

It has not been the aim of the testing plant to determine the lowest possible amounts of coal that could produce a given amount of power or to determine the highest possible efficiency of the particular producer plant installed. By an act of Congress, the work of the plant was restricted to the determination of the possibilities of utilizing bituminous coals, lignites, and other fuels for the production of power. In spite of the fact that no series of runs has been made on any one coal for determining the best possible results obtainable, it is nevertheless gratifying to report that official records show that as small an amount of dry coal as 0.95 pound per hour has been burned in the producer per electrical horsepower developed at the switchboard; or 0.80 pound of dry coal per hour has been burned in the producer per brake horsepower per hour, on the basis of an efficiency of 85 per cent for generator and belt.

VIEWS OF MANUFACTURERS OF PRODUCER-GAS PLANTS.

In order to determine as closely as possible the exact status of the producer-gas business, an effort has been made to ascertain the point of view of both the manufacturers and the owners and operators of existing plants. With this object in mind the following question was addressed, about a year ago, to several manufacturers of gas producers:

To what extent is the demand for gas engines and gas producers, and the interest in the same, growing?

The replies were sufficiently significant to warrant their presentation at this time, each reply being separately numbered:

1. We believe there is a waiting and almost unlimited demand for producer power plants, as soon as the manufacturers have something definite to offer and can guarantee quick installation and certain results.

2. The demand for gas engines and gas producers is growing considerably. We have this month closed for an 8,000-horsepower gas-producer plant, and have on our book negotiations pending for over 200,000 horsepower.

3. The demand for gas engines and gas producers is at present apparently only limited by the output, we ourselves having orders way ahead and all the business we

can possibly fill. Were we to go out after business we would immediately swamp the factory. These plants are giving such excellent results in the field that they are bound to replace steam for almost all uses, and in consequence the field may be said to be almost unlimited.

4. The demand for gas producers and the interest manifested in them seems to be growing very rapidly, as indicated by the number of inquiries received at our office and by our agents in different parts of the country.

5. According to inquiries which we are constantly receiving we judge that the interest in the question of gas producers and gas engines is growing considerably, and all indications lead us to believe that the proposition to install gas-power plants will be a very important one in this country before long.

6. Our correspondence indicates a continually growing demand for gas producers for power purposes, especially those adapted for running on soft coals.

7. There has probably never been a mechanical production more widely or thoroughly advertised at such an early period in its history of this country as the suction-producer gas-power equipment. Much of this advertising has aroused curiosity among people, many of whom are not contemplating a purchase. On the other hand, the fuel economy is so remarkable that manufacturers with a reputation for reliable goods and with the fuel guarantees they offer, backed by unquestioned responsibility, are able to sell their product with very little effort.

8. The gas-producer business and the uses to which they have been applied have increased about 50 per cent within the last ten years, and are still growing. We should imagine that the next ten years would show a far greater improvement. We think producer gas is yet in its infancy as to various applications.

9. The demand for gas engines and gas producers is growing in that field where the price of coal is highest, and for that reason any commercial tests in suitable gas producers which will use the fuel of the district will be of value.

10. There is no doubt that the gas engine itself is nowadays in such a state of perfection that its use is bound to become general for power production as soon as the possibility of using bituminous coal to a large extent has been proved.

At the same time the manufacturers were asked:

What are the serious difficulties in the way of more rapid development of gas producers and gas engines as a means of developing power?

A summary of the replies would indicate the difficulties to be about as follows:

1. The fact that the gas engine is not yet so reliable as the steam engine.
2. The lack of engineers who know how to run producer-gas power plants.
3. Inexperienced salesmen—men not familiar with the details of the engines and producers they are handling.
4. The large number of unsuccessful and only partially successful installations made during the experimental period of this development.
5. Lack of proper design and construction of producer-gas engines in the United States.
6. Lack of knowledge and confidence on the part of the public.
7. The fact that the heating of factory buildings must be provided for by a heating plant separate from the power plant.
8. Lack of types of producers which will gasify bituminous coal satisfactorily.
9. Inability to use cheap fuels in the suction gas producer.
10. Lack of complete knowledge as to how successfully the various fuels in different localities can be used in gas systems.
11. Large excess cost of gas-engine–gas-producer power plants over that of steam-power plants.

PRESENT STATUS OF THE GAS ENGINE.

When the manufacturers of producer-gas plants are themselves ready to acknowledge the difficulties outlined above, the situation is most encouraging for the future development of the plants.

Over a year has elapsed since these communications were received, and it is therefore desirable to reexamine the situation briefly but critically to-day, and to consider carefully the 11 difficulties listed above.

1. The fact that the gas engine is not yet so reliable as the steam engine.

There have been good grounds for the feeling that the gas engine was less reliable than the steam engine, but to-day many installations tend to change this impression.

Mr. Paul Windsor, chief engineer of motive power and rolling stock, Boston Elevated Railway Company, says, in an article on the producer-gas power plants installed by his company:

> As a result of my experience with these plants I am absolutely convinced of the economy and reliability of a gas-engine power station.

In order to counteract any lack of confidence in the possibilities of the continuous operation of gas producers and gas engines an endurance test was undertaken at the testing plant at St. Louis, which demonstrated beyond dispute the possibility of operating continuously a producer plant using bituminous coals for power production. The test began March 8 and continued without interruption until April 1, 1905, twenty-four consecutive days.

The average of six analyses of the coal used is as follows:

Analysis of coal used in endurance test.

Moisture	14.68
Volatile matter	30.98
Fixed carbon	42.93
Ash	11.41
	100.00
Sulphur	1.33

12,343 British thermal units per pound of dry coal.

During this entire test calorimetric determinations of the heat value of the gas were made every twenty minutes and volumetric analyses were made every two hours. The average heat value of the gas for the entire run was 156.1 British thermal units per cubic foot, and the average composition of the gas was as follows:

Average composition of gas in endurance test.

Hydrogen disulphide (H_2S)	0.0
Carbon dioxide (CO_2)	9.2
Oxygen (O_2)	0.0
Ethylene (C_2H_4)	0.4
Carbon monoxide (CO)	20.9
Hydrogen (H_2)	15.6
Methane (CH_4)	1.9
Nitrogen (N_2)	52.0
	100.0

During the progress of the test the usual observations were made at intervals of twenty minutes and careful notes were kept of all incidents connected with the operation of the plant. Among the items of interest those relating to the tar extracted during the test are of special significance, as it has often been stated that no plant mechanically separating the tar could run more than five or six days without shutting down. The total tar extracted during this test amounted to 13,455 pounds, or about 143 pounds of tar per ton of coal burned in the producer.

As the plant was laid out for general test purposes the passages which the gas was obliged to traverse were far more tortuous than those it would have traversed in a plant installed for power purposes only. As a result the gas, in passing through a pipe about 3 feet in length, was forced to make three right-angle turns and pass through a water-seal valve, thus traversing a distance of about 20 feet. This construction, necessary only for testing purposes, was unfortunate in connection with this experiment, and, owing to the deposit of tar in the water-seal valve, brought the test to a close at the end of twenty-four days. With this combination of piping removed, even more remarkable endurance records should be made than the surprising twenty-four-day test here recorded.

In order to remove the ashes, which must be taken out at regular intervals, it is usually considered necessary to shut down the entire plant. As such a shut down would be fatal to an endurance test, a special method of taking out the ashes was employed. The ashes were removed about once every forty-eight hours by simply reducing the pressure under which the producer was operated and running the plant on the suction basis during the hour required for removing the ashes. The men worked with entire ease and comfort during this period.

During the entire twenty-four days the engine showed no signs of heating, clogging with tar, or other trouble. It ran steadily at all times and at the end of the test was in perfect condition. The same set of igniters was used throughout the run, and gave absolutely no trouble. An inspection of the engine at the close of the test showed that the cylinders, igniters, and all working parts were in such excellent condition that the engine was not even cleaned nor its mechanism in any way changed before beginning the next test. An inspection of the producer plant at the close of the test also showed that everything about the plant was in excellent condition, and the regular tests went on as usual after the close of the endurance run.

During this test an average of 225.5 brake horsepower was maintained. The coal consumed was 1.40 pounds of dry coal per brake horsepower per hour. Especial attention is called to the fact that during this test, as well as during all other tests conducted at this plant, no attempt was made to remove the sulphur from the gas before it entered the engine. Considerable controversy has arisen in various parts of the country regarding the influence of sulphur on the cylinders of a gas engine, leading to the introduction of this question into some important lawsuits. The engine used at the testing plant since its establishment has received the full charge of sulphur contained in the gas, and shows absolutely no signs of injury from this source, although some of the coals used have contained as much as 8.1 per cent of sulphur.

2. The lack of engineers who know how to run producer-gas power plants.

It can not be denied that many of the difficulties charged to producer-gas power plants are due entirely to incompetent operators. Some plants have been temporarily put out of commission by the prejudices or the lack of ability and training of the operators or engineers in charge. A few of these failures are due to the impossibility of finding men competent to operate the plants, but many of them have undoubtedly been the result of a short-sighted policy on the part of some manufacturers, who are not willing to give proper and necessary information about the design, construction, and operation of the plants made by them. The possibility of a sale at the time is apparently the only interest they keep in mind, and the future is allowed to take care of itself. In the course of a round of visits recently made to a number of plants my attention was called to several such derelictions.

3. Inexperienced salesmen—men not familiar with the details of the engines and producers they are handling.

The ignorance and short-sighted rapacity of unscrupulous salesmen, who have given absurd guaranties and have made unfortunate installations in certain localities, have seriously injured the reputation of some manufacturers and interfered with further business in the same districts. One salesman, representing a house of national reputation, told me that the suction producer made by his firm (which had then completed only one such producer, still in the factory) was guaranteed to operate perfectly on charcoal, anthracite coal, coke, bituminous coal, lignite, and peat. When I informed him that I was ready to buy out the whole producer business of his firm at once if he would put that guaranty in writing, he became decidedly confused.

One agent "worked" an old gentleman in a small town by convincing him that a producer-gas plant was exactly adapted to the intermittent demands of a small gristmill—a mill which may to-day run two hours; to-morrow, seven, and then not again for two or three days. The salesman insisted that his producer plant would do everything exactly as desired—that is, it was just the plant for variable demands. As the old gentleman said, "He offered me a gold brick and I bought it. There it stands." The mill is now run by an electric motor supplied with current from the town-lighting plant.

4. The large number of unsuccessful and only partially successful installations made during the experimental period of this development.

Many failures or only partially successful installations are due in part to the willingness of small companies with little financial backing to allow the public to "be the dog" instead of thoroughly testing their plants before putting them out. The need of money, the anxiety to get ahead of competitors, the lack of knowledge, and the incompetence of designers, operators, and salesmen have combined in the past to produce an unfortunate situation, which, however, is rapidly improving.

5. Lack of proper design and construction of producer-gas engines in the United States.

For lack of proper construction many engines have failed utterly to meet the demands made upon them and have been withdrawn. To-day the majority of manufacturers realize that a special engine must be designed for producer-gas work, and that an engine designed for city gas, or gasoline, and then "patched up" to work on producer gas must be a sorry failure.

6. Lack of knowledge and confidence on the part of the public.

Ignorance of the capabilities of producer-gas plants and lack of confidence in them have been largely due to the five difficulties already mentioned and will be remedied as these are remedied.

7. The fact that the heating of factory buildings must be provided for by a heating plant separate from the power plant.

The necessity of heating factories by means of separate plants may be a serious factor in some places. Several companies, however, claim that they have satisfactorily solved this problem. It is by no means impossible of solution, and simple, practical methods of utilizing the heat from the exhaust, or the producer gas directly, will undoubtedly be devised in the near future.

8. Lack of types of producers which will gasify bituminous coal satisfactorily.

There are to-day at least two types of producers which will gasify bituminous coal reasonably well—the pressure and the down-draft plants. I am informed that producer-gas plants aggregating over 200,000 horsepower are now in operation in America on various kinds of fuel, ranging from wood to the best grades of bituminous coal. The work accomplished by the United States Geological Survey fuel-testing plant certainly establishes beyond doubt the possibilities in this direction.

9. Inability to use cheap fuels in the suction gas producer.

The impossibility of using cheap fuels in the suction plant is a drawback to its proper development. Several companies claim that they have solved this problem, but authorized statements of results are not yet available.

10. Lack of complete knowledge as to how successfully the various fuels in different localities can be used in gas systems.

The special object of investigation[a] made at the Geological Survey's fuel-testing plant for the past three years has been to determine the relative fuel values of coals found in the United States, and it is expected that, as its results become available, this work will supply all necessary information concerning the various kinds of fuel tested.

11. Large excess cost of gas-engine–gas-producer power plants over that of steam-power plants.

Although producer-gas plants have heretofore been more expensive than steam-power plants the cost of gas plants is decreasing, and the statement above is at least open to discussion if not to contradiction, at least as applied to some installments.

Since definite information relating to the cost of producer-gas installations is difficult to obtain, an attempt has been made to procure estimates of cost from all of the leading manufacturers in the United States.

The conclusion reached is that complete producer installation for the larger plants—say from 4,000 to 5,000 horsepower—costs about the same as that of a first-class steam plant of the same size. With smaller installations the balance may be in favor of the steam plant. However, even if the steam plant cost 15 per cent less than the producer-gas plant it should not be forgotten that the increased efficiency in operating the latter will make up the difference in the first cost within a short time—probably in about two years in the average plant. The difference in first cost of plants of over 1,000 horsepower, with coal at $2.75 or more per ton, is usually wiped out within the first year of operation.

In view of the difficulty of determining the exact basis of comparison of the costs of steam and producer-gas plants, I have decided to present the following very complete table, given by Mr. Stott in his paper previously referred to, entitled "Power Plant Economics." Mr. Stott says:

> In this table will be found a tabulation of the relative values of the various items necessary in the maintenance and operation of a power plant. The first column covers a plant with compound condensing reciprocating engines without superheat,

[a] For detailed reports see Bull. U. S. Geol. Survey Nos. 261 and 290, Prof. Paper U. S. Geol. Survey No. 48 (3 parts), and other reports on the subject published by the United States Geological Survey.

and is derived from a year's record of actual costs of a large plant operating with a load factor of approximately 50 per cent, load factor in this case being defined as—

$$\frac{\text{Actual output}}{\text{Maximum hour's load} \times 24.}$$

The values in the other columns have in the main been estimated from the first column, but wherever possible actual data derived from various sources, both domestic and foreign, have been used; but in all cases values have been reduced so as to make them directly comparable with the first column and with one another. The values in maintenance and operation of steam turbines are derived from actual costs.

Distribution of maintenance and operation charges per kilowatt-hour.

[Stated in percentages.]

Item.	Reciprocating engines.	Steam turbines.	Reciprocating engines and steam turbines.	Gas-engine plant.	Gas engines and steam turbines.
Maintenance.					
1. Engine room, mechanical	2.57	0.51	1.54	2.57	1.54
2. Boiler room or producer room	4.61	4.30	3.52	1.15	1.95
3. Coal and ash handling apparatus	0.58	0.54	0.44	0.29	0.29
4. Electrical apparatus	1.12	1.12	1.12	1.12	1.12
Operation.					
5. Coal and ash handling labor	2.26	2.11	1.74	1.13	1.13
6. Removal of ashes	1.06	0.94	0.80	0.53	0.53
7. Dock rental	0.74	0.74	0.74	0.74	0.74
8. Boiler-room labor	7.15	6.68	5.46	1.79	3.03
9. Boiler-room, oil, waste, etc	0.17	0.17	0.17	0.17	0.17
10. Coal	61.30	57.30	46.87	26.31	25.77
11. Water	7.14	0.71	5.46	3.57	2.14
12. Engine room, mechanical labor	6.71	1.35	4.03	6.71	4.03
13. Lubrication	1.77	0.35	1.01	1.77	1.06
14. Waste, etc	0.30	0.30	0.30	0.30	0.30
15. Electrical labor	2.52	2.52	2.52	2.52	2.52
Relative cost of maintenance and operation	100.00	79.64	75.72	50.67	46.32
Relative investment in per cent	100.00	82.50	77.00	100.00	91.20

VIEWS OF OWNERS AND OPERATORS OF PRODUCER-GAS PLANTS.

About twenty companies in the United States are to-day manufacturing gas producers for power purposes. At least twelve of these are fully established on a commercial basis and are in position to give proper guaranties when installing plants.

Over 300 gas-producer power plants, ranging in size from 20 to 6,000 horsepower, are now in operation in the United States. One company alone reports twenty-odd installations, averaging over 2,000 horsepower each, and nearly as many more, averaging about the same size, contracted for or now being erected.

The number of installations and the persistent development has already led the National Board of Fire Underwriters to issue special rules and requirements for the "Construction, installation, and use of coal-gas producers (pressure and suction systems)."

Of the total number of installations in the United States it is interesting to note that about two-thirds are suction plants, operating on anthracite coal, a few using charcoal. Bituminous coal is used in 15 to 20 per cent of the plants installed, but this proportion probably covers 65 to 75 per cent of the aggregate horsepower rating.

During the summer of 1906 it was my privilege to visit several of the producer-gas power plants of the country with the idea of ascertaining from their owners and operators their exact uses, efficiency, and defects. No selection was made of the plants to be visited. The list included producers made by fourteen manufacturers, and the territory visited extended from Maine to central Nebraska.

The deductions made from these visits are:

1. The plants as a whole are giving remarkable satisfaction, considering the very brief period of development that has passed since the introduction of this type of power.

2. The most serious difficulty seems to arise from the lack of competent operators to run the plants rather than from defects or troubles inherent in the plants themselves.

3. Inexperienced salesmen are undoubtedly to blame for serious misrepresentations and misunderstandings.

4. The neglect shown by some manufacturers in respect to their plants after they are installed and paid for has not been far-sighted, and the failure of manufacturers to give the purchasers or operators of plants full information regarding their construction and method of operation has certainly been detrimental to the business.

The situation as a whole at the present time seems to be very favorable for the producer-gas plant, not only as to cost of installation, operation, and maintenance, but also as to reliability. The successful demonstration at the Government fuel-testing plant that bituminous coals, lignites, and peats can be utilized with great economy in these plants should lead to an increase in the use of this form of power within the next few years that may surpass even the most sanguine hopes of the manufacturers.

CENTRALIZATION OF POWER DEVELOPMENT AND DISTRIBUTION.

The rapid increase in the use of electrical power will be greatly accelerated within the next few years by the reduction in cost of power production made possible by the introduction of the gas producer. It would seem ridiculous to predict the immediate doom of the steam locomotive, yet one of the officials of the New York Central Railroad has publicly stated that within ten years, in his opinion, there will be no steam locomotives operating on the New York Central road. Already the New York Central has substituted electric for steam power on its lines from New York City to a point about 40 miles from the Grand Central Station, and it is rumored that before long electric trains will be running on this road from New York to

Buffalo. The Pennsylvania road is to abandon the use of the steam locomotive between Atlantic City and Philadelphia, and the New York, New Haven and Hartford is following the same line of progress by running its trains from Stamford, Conn., to New York City by electric power.

These rapid changes are leading to one end—the centralization of power development and distribution. Now that it is commercially possible to transmit electrical power for distances of 250 or more miles, a central plant could distribute such electric current for a distance of 500 miles—that is, for 250 miles on all sides of the plant—thus covering a circle comprising almost 200,000 square miles—an area nearly four times the size of the State of Illinois. The logical location of such a plant is at or near the mines. With ten or twelve of these great central plants located at the various mining centers, the great railroads of the United States can send their trains speeding from the Atlantic to the Pacific coast; and the passengers, as well as the towns through which the trains pass, will be entirely freed from the usual annoyance of smoke and cinders, and the disastrous fires caused by sparks from locomotives will be a thing of the past.

CONDITION OF THE COAL-BRIQUETTING INDUSTRY IN THE UNITED STATES.

By EDWARD W. PARKER.

GENERAL STATUS OF BRIQUETTING.

Although the briquetting of coals and lignites has been carried on for many years in Europe, and has reached a particularly high state of development in France, Belgium, and Germany, it has made comparatively little progress in the United States. The causes for the backwardness of the United States in this regard are several, and first among them has been the abundant supply of cheap raw fuel with which the manufactured article has to compete. With our millions of acres of coal-producing lands, in which the coal can in most places be cheaply mined, it has appeared in many districts to be more economical to waste the slack or culm, which constitutes a considerable percentage of the product, than to attempt to save it at the additional expense required for briquetting. For this reason large tracts in the anthracite region of Pennsylvania are covered by unsightly culm banks which encumber the ground and mar the view, and in some of the bituminous districts huge piles of unmarketable slack are allowed to burn in order to get rid of them. When the coal is of coking quality, or when the slack can be used for steaming purposes, these losses are not sustained, but many thousands of tons of material that might be converted into usable fuel have been wasted every year simply because of the increased expense involved in its preparation.

The development of the briquetting industry has also been retarded by attempts to exploit patented or secret processes, for which all kinds of extravagant claims have been made, but which have almost invariably proved expensive and unprofitable, and the investment of capital in enterprises of this character has been accordingly discouraged. The Patent Office records teem with patents issued on all sorts of inventions relating to binders, many of which are as fanciful as the idea of perpetual motion.

Another reason for the failure to build up a briquetting industry in the anthracite region of Pennsylvania, where the best opportunity for its development is offered, has been the opposition shown by some of the operators to the introduction of a manufactured domestic fuel which would come in competition with the prepared sizes of anthracite. And such an opposition is natural. The competition of bituminous coal has almost entirely shut out anthracite as a steam fuel. Coke for iron making has almost entirely supplanted anthracite, and the use for domestic purposes of coke and gas made from bituminous coal is growing. Owing to the greater depths to which the mining of anthracite is being carried, the thinner and less favorably located beds which are being worked, and the increasing cost of labor, the mining and preparing of anthracite is becoming more expensive on one hand, while competition is becoming keener on the other. A certain rate of production must be kept up for the protection of the properties themselves, and, when all the conditions are considered, the unfavorable attitude on the part of the operators toward further competition is at least realizable.

Still another reason which has been assigned, rightly or wrongly, for our halting progress in fuel briquetting has been the lack of assurance of a regular supply of coal-tar pitch at reasonably low prices. For out of the many attempts that have marked the incubating period of briquetting development—some of them costly—has grown the knowledge that coal-tar pitch must be relied on to supply, in the Eastern States at least, all or the greater part of the binding material. In California, Arizona, and other parts of the Far West asphaltic pitch, the residual product from the refining of the heavy asphalt-base petroleums of that region, has been and is now successfully used in recently constructed briquetting plants. But in the East coal-tar pitch is the base of the economically successful cementing material—a fact that has been fully demonstrated by the extended investigations carried on at the United States Geological Survey's fuel-testing plant at St. Louis.[a] These investigations included experiments with all kinds of organic and inorganic binders, embracing, besides coal-tar pitch, such materials as rosin, sugar-house refuse, molasses, acid sludge, quicklime, and various mixtures. The results show that either coal-tar or asphaltic pitch are the only really successful binders. Any materials used with them must possess above all others the essential virtue of cheapness.

But while it is claimed on one side that the briquetting industry has been held back by the lack of assurance of a steady supply of coal-tar pitch, it also happens that one of the reasons assigned for the comparatively slow development of the by-product coking ovens in the United States in the last few years is the lack of a profitable demand for coal tar, an important by-product of retort coke ovens. It is well known that the demand for creosoting oils to be used by rail-

[a] Bulls. U. S. Geol. Survey Nos. 261 and 290; Prof. Paper U. S. Geol. Survey No. 48.

road companies for preserving ties, bridge timbers, etc., is far beyond the present domestic production of that coal-tar product, and the statistics compiled by the Bureau of Statistics of the Department of Commerce and Labor show that our imports of the chemical products of coal tar amount to over $10,000,000 in value yearly. To the ordinary observer it would appear that the conditions here presented afford an opportunity for the recognition of a community of interests which may be profitable to the manufacturers and beneficial to the general public. The constantly increasing expense involved in mining and preparing anthracite coal is slowly but surely making that commodity more and more a luxury, and manufactured fuel which will take the place of anthracite for domestic use, particularly among consumers of moderate means, appears to be needed. This is especially true in the northeastern section of the United States.

Two of the briquetting plants, which have been recently constructed, and which are discussed in detail in the following pages, indicate somewhat a "getting together" of the coal-tar producing and the briquetting interests. These are the plants of the United Gas Improvement Company, at Point Breeze, Philadelphia, and of the Semet-Solvay Company, at Del Ray, Mich. Both companies are producers of coal tar, and the plants have been constructed for the purpose of briquetting mixtures of anthracite culm and coke breeze.

It appears now, moreover, that the period of failure and discouragement in the manufacture and use of briquetted fuel has passed and that the industry will be placed on a substantial footing.

BRIQUETTING PLANTS IN THE UNITED STATES.

GENERAL STATEMENT.

The first successful plant in the United States of which the writer has any definite knowledge was built at Stockton, Cal., a few years ago by the San Francisco and San Joaquin Coal Company. This plant, unfortunately, was entirely destroyed by fire in 1905, and the plans for its reconstruction at San Francisco were interrupted by the earthquake and fire which destroyed a large portion of that city in April, 1906.

During the last two years a number of briquetting plants have been built and as complete descriptions of them as it has been possible to obtain are given in the subsequent pages. Some of them have been put in operation since January 1, 1907.

The following list, compiled from newspapers and other sources, shows the name and location of companies which have been organized for the purpose of carrying on the briquetting business, or which have constructed plants to operate in connection with an already established industry:

Arizona Copper Company, Clifton, Ariz. In operation. (See pp. 477–479.)

Ajax Fuel Company, San Francisco, Cal. Operated small plant in 1905; destroyed by earthquake and fire in April, 1906.

Pittsburg Coal Mining Company, San Francisco, Cal. (See pp. 475–477.)

Eureka Briquette Company, Oakland, Cal. Organized, according to press bulletins, with capital of $75,000. Letters addressed to the company were returned unclaimed.

San Francisco and San Joaquin Coal Company, San Francisco, Cal. (See pp. 472–473.)

United States Briquetting Company, San Francisco, Cal. Organized for briquetting mixture of peat and California crude oil. Original plant destroyed by earthquake. Erecting new plant at Stege, Cal. (See p. 477.)

Western Fuel Company, Oakland, Cal. Constructed plant in 1905. (See pp. 473–475.)

American Coal Briquette Company, Washington, D. C. Impossible to locate.

Orlando Water and Light Company, Orlando, Fla. (See p. 481.)

Illinois Coalette Fuel and Mining Company, Alton, Ill. Reported as having organized with capitalization of $1,000,000. No replies received from inquiries.

National Compressed Fuel Company, Chicago, Ill. Organized in 1904 for exploiting the Hoffman patent binder exhibited at the St. Louis exposition. Letters addressed to the company have been returned unclaimed.

Anderson Artificial Coal Company, Anderson, Ind. Incorporated, according to press reports, in 1905; capital stock, $50,000. No replies received to letters.

Globe Coal Manufacturing Company, South Bend, Ind. Incorporated in 1905, but a plant has never been erected.

United States Heyde-Brand Coal Company, Berwick, Me. Letters returned unclaimed.

Eastern Coaleo Manufacturing Company, Baltimore, Md. Organized by L. G. McPherson, T. K. Stewart, and others, but no progress made.

Boston Coal Briquetting Company, Boston, Mass. Letters returned unclaimed.

Semet-Solvay Company, Del Ray, Mich. (See p. 479.)

Gen. Alexander Hughes, Minneapolis, Minn. Carried on some experiments looking toward the briquetting of North Dakota lignite, but has not established any plant.

International Coal Briquette Company, Minneapolis, Minn. Letters returned unclaimed.

Mankato Peat Fuel Company, Mankato, Minn. No replies to letters.

Valentine Coal Binder and Briquette Company, St. Paul, Minn. Letters returned unclaimed.

Coaleo Fuel Manufacturing Company, St. Louis, Mo. No replies to inquiries.

Renfrow Briquette Machine Company, St. Louis, Mo. (See pp. 481–484.)

United States Artificial Coal Company, St. Louis, Mo. Letters returned unclaimed.

Compressed Coal Company, Camden, N. J. Unable to find.

The Briquetting Company, Jersey City, N. J. Letters returned unclaimed.

McGinnis Coal Briquette Company, Jersey City, N. J. Letters returned unclaimed.

Monon Development Company, Jersey City, N. J. Letters returned unclaimed.

New Jersey Briquetting Company, Jersey City, N. J. (See p. 465.)

Sanitation Coal Company, Jersey City, N. J. Letters returned unclaimed.

Peat Fuel Company of New Jersey, Lincoln Park, N. J. No replies to inquiries.

American Fuel Corporation, Newark, N. J. No replies to inquiries.

American Peat Fuel Company, Passaic, N. J. No replies to inquiries.

E. B. Arnold, New York City. (See pp. 468–470.)

The Briquetting Company, New York City. Address given as 52 Broadway. Not found.

Economy Smokeless Coal Company, New York City. Letters returned unclaimed.

D. Grieme Coal Company, New York City. No replies to letters.

International Briquetting Company, New York City. Organized in 1905, but nothing accomplished.

Manhattan Coal Briquette Company, New York City. Letters returned unclaimed.

National Fuel Briquette Company, New York City and Brooklyn, N. Y. (See pp. 477-478.)

New Jersey Briquetting Company, Brooklyn, N. Y. (See pp. 464-467.)

New York Compressed Fuel Company, New York City. Letters returned unclaimed.

North American Coal Briquette Company, New York City. (See p. 478.)

Peat Koal Company, New York City. No replies to inquiries.

Peerless Fuel Company, New York City. Letters returned unclaimed.

Scranton Anthracite Briquette Company, New York City. (See pp. 470-471.)

Standard Briquette Company, New York City. No replies to inquiries.

United States Briquette Company, New York City. Letters returned unclaimed.

Zwoyer Fuel Company, New York City. (See p. 465.)

Briquette Coal Company, Stapleton, N. Y. (See p. 477.)

Koala Fuel Manufacturing Company, Washburn, N. Dak. Letters returned unclaimed.

Hon. W. D. Washburn, Wilton, N. Dak. (See p. 480.)

Composition Fuel Company, Johnstown, Pa. No replies to inquiries.

United Gas Improvement Company, Philadelphia, Pa. (See pp. 471-472.)

R. B. Metcalf, Providence, R. I. Operated a briquetting plant at Portsmouth about ten years ago. Coal found to be unsuitable for briquetting.

International Compress Coal Company, Houston, Tex. (See p. 480.)

North Fort Worth Patent Fuel Company, Fort Worth, Tex. No replies to inquiries.

Eureka Briquette Company, Rockdale, Tex. (See p. 480.)

American Lignite Briquette Company, San Antonio, Tex. (See p. 480.)

International Fuel Company, Rutland, Vt. Organized by the late Henry R. Dorr to manufacture briquettes from anthracite culm. Nothing done since the death of Mr. Dorr in 1906.

Bellingham Briquetting Company, Bellingham, Wash. Organized with a capital of $75,000; nothing done in the way of construction.

Southern Pacific Coal Company, Carbonado, Wash. No replies to inquiries.

Pacific Coke and Coal Briquetting Company, Spokane, Wash. Letters returned unclaimed.

NEW YORK, N. Y.

New Jersey Briquetting Company.—During 1904 and 1905 the New Jersey Briquetting Company, of New York, constructed at the foot of Washington street, Brooklyn, a plant for exploiting the Zwoyer Fuel Company's briquetting process. This plant was intended to be operated in connection with a coal yard on Adams street, but during the construction of the piers and anchorages for the new Manhattan Bridge the company was prohibited from operating the tramway from the coal yard to the plant. This interfered with the operations of the plant, and as extensive storage capacity, either for raw material or for the product, had not been provided for at the site, the work done has been accomplished under much disadvantage. The prohibition put on the tramway and the lack of dock facilities for loading and unloading material has crippled the plant to such an extent that what was supposed to be an excellent location has turned out to be an unfortunate one, and the present methods of receiving and handling the material make the operations so expensive that the briquettes can not successfully compete with raw fuel. As a result of these unfortunate conditions it is proposed to remove the plant to a site better adapted for receiving, storing, and shipping the material. The officials of both the New Jersey Briquetting Company and the Zwoyer Fuel Company are entirely satisfied with the experimental results.

A description of the plant in Brooklyn was published in the Iron Age, from which the following notes have been in part abstracted, additional matter having been furnished by Virgil H. Hewes, treasurer of the Zwoyer Fuel Company.

Prior to the construction of the plant in Brooklyn the Zwoyer Fuel Company had built a small plant in Jersey City, N. J., which was of sufficient capacity for experimental work, but not large enough to be operated as a commercial undertaking, and was abandoned.

It may be stated here that, after a considerable expenditure of time and money in experimenting with different kinds of binders, coal-tar pitch was finally selected as the material best suited to the work, a decision which has been generally reached in the Eastern States, asphaltic pitch having been adopted in the Far West, where that article is cheaply obtained. During the progress of the experimental work about 200 tons of briquettes were made with a binder composed of 6¼ per cent of rosin and oil, 1½ per cent of flour and water, and 6 to 10 per cent of bituminous coal, the body of the briquette being anthracite dust. About 900 tons were made with 5 to 7 per cent of rosin and oil and 10 per cent of bituminous coal, 400 tons were made with 5 to 7 per cent of wood pitch and 10 per cent of bituminous coal, and 1,500 tons were made with 6 to 7 per cent of coal-tar pitch alone. In applying the binder during the last three experiments an atomizer was used.

The plant in Brooklyn has a capacity of 10 tons an hour and was built for the purposes of demonstration. During the winter and spring of 1905-6 about 3,000 tons of anthracite briquettes were made and sold. The price received was $5 per ton of 2,000 pounds at the plant, $5.50 per ton delivered, and $6.60 per ton in bags of 100 pounds each. These prices were 50 cents below the prices of the domestic sizes of anthracite.

The building is nearly triangular in outline. The anthracite dust is received on Washington street at the end of a screw conveyor, which carries it to the foot of an elevator, where it is lifted to the top of the plant and spouted to a screen located over the dust bin. The coarser material is spouted either to the boiler room or to an oversize bin in the rear of the dust bin and then fed into a crusher, crushed and passed to the foot of the dust elevator, where it is again carried to the screen. The dust is drawn from the dust bin by a conveyor, driven from a variable-speed countershaft, and is fed to the 16 by 36 inch roll crusher. It then passes to an elevator and is carried to the mixers. After passing through six mixers it is carried to the second floor, where it falls into the press hopper.

From the press the briquettes are carried by a belt conveyor to the baking oven (when smokeless briquettes are wanted) and are then elevated to and distributed upon the cooling table, which is located on the second floor. After cooling, the briquettes are run into chutes and loaded into wagons for delivering, or are stored. In New York the briquettes sell readily when not baked.

On one side of the dust bin there is a bin from which soft coal is fed into a 19 by 4 inch roll crusher and passed to the same elevator that carries the dust to the mixers. Development has shown that it is not necessary to use soft coal with anthracite dust. However, this bin is used when experimental runs are made requiring the mixing of different materials with the dust.

The binder used is coal-tar pitch, which is received in barrels on the Plymouth street side of the building. It is hoisted to the second floor by means of a barrel hoist; the staves are then removed and the pitch is thrown into the binder melting tank (a tank holding about 15 tons of pitch) and pumped by means of a rotary pump into the storage or hot binder tank, where it is kept heated.

The number of units necessary in a mixer depends on the material to be briquetted and the condition in which it is received. At this plant six mixers are used, which have proved well adapted to the handling of coal (hard and soft, wet or dry), coke breeze, and even iron concentrates.

The dust enters mixer No. 1, and is carried through mixers Nos. 1 to 6, and then by conveyor to the press. In passing through mixers Nos. 1 and 2 the dust is heated by furnaces to drive off all the moisture. The coal-tar pitch, which has been previously heated, is pumped from the storage tank by a small rotary pump driven from a variable-speed countershaft, which regulates the percentage of pitch used. The pitch is atomized by means of a steam jet and delivered to mixer No. 3.

The above apparatus and process are patented.

A press of the roll type is used, the rolls being built up of disks which are milled to form the pockets and then assembled and bolted together on the shaft. This method of constructing the rolls, as well as the design of the briquettes, is patented. Briquettes are made in two sizes—$1\frac{7}{8}$ by $1\frac{7}{8}$ by $1\frac{1}{4}$ inches and $2\frac{1}{8}$ by $2\frac{1}{8}$ by $1\frac{3}{8}$ inches. The briquettes are square "pillow" or "pin-cushion" shape. The smaller ones weigh 2 ounces and the larger 3.3 ounces.

The cooling table consists of three endless belts composed of steel plates carried at their ends by sprocket chains. The belts are placed one over the other and carry the briquettes back and forth six times over a distance of 84 feet, making a total travel of 504 feet. The briquettes are then run into bins or loaded into wagons.

Staten Island plant.—The Briquette Coal Company, J. P. Egbert, manager, No. 2 Stone street, New York City, has just completed the construction of a briquetting plant at Stapleton, on Staten Island. This plant is constructed for the purpose of using anthracite dust as delivered at the plant, with coal-tar pitch as the basis of the binding material. The plant does not possess any novelties in its design except that there are two presses of radically different types. One of these is of German manufacture, having been built at the works of Schuchtermann & Kremer, of Dortmund. This press is of the plunger type and in the manner of feed, compression, and ejection is similar to the Johnson (English) machine used at the Geological Survey testing plant at St. Louis, except that the disk containing the compressing molds is set and revolves horizontally instead of vertically. The briquette is a parallelopiped in shape, with the end edges rounded. The dimensions are $4\frac{3}{4}$ by $2\frac{1}{4}$ by $2\frac{1}{2}$ inches and the briquettes weigh about 1.5 pounds. They have a specific gravity of about 1.24.

The second press is of what is generally classed as the Belgian type, similar to the one described as the "American" machine used at the Geological Survey testing plant. This particular machine was made at the works of H. Stevens, at Charleroi, Belgium. The product is of the eggette pattern, which is more desirable for domestic use than the larger briquette. The eggettes weigh about 5 ounces and have a specific gravity of 1.37. The manager of the company, Mr. Egbert, extended to the writer every courtesy possible. The total capacity of this plant, with both presses in operation, is 120 tons of briquettes per day of ten hours. The German machine will turn out $4\frac{1}{2}$ tons and the French machine $7\frac{1}{2}$ tons per hour.

South Brooklyn plant.—Another plant, which has just been completed as this report is written, is that of the National Fuel Briquette Machinery Company of New York City. This plant is located at the foot of Court and Smith streets, Brooklyn, close to the Gowanus Canal, by which the materials to be used can be brought in barges and discharged at a minimum of expense. While intended to be operated on a commercial basis, it may be considered rather as a demonstrating plant. It is planned to use anthracite dust, with coal-tar pitch as a binder. The press is of the Belgian type, producing eggettes or "boulets" somewhat smaller than an ordinary hen's egg, and made exclusively for domestic use. The machinery used in this plant was patented in this country (United States patent No. 799149, September 12, 1905) by Robert Devillers, with whom the writer visited the plant and to whom acknowledgments are made for courtesies extended. The eggettes here produced are much smaller than those ordinarily made, weighing only about 1.5 ounces each. They have a specific gravity of 1.3.

North American Coal Briquette Company.—This company, whose office is at 177 Broadway, New York City, has been incorporated for the purpose of exploiting the Forst briquetting process. The main feature of this process consists in the material to be used as a binder, part of which is kept secret, but which consists principally of coal-tar pitch. The merit claimed for the secret ingredients of the binder is that they permit a great economy in the quantity of binder used for the manufacture of superior briquettes. The company has negotiated for the purchase of a Duprey (French) machine, and has sent 10 tons of anthracite coal and 1 ton of binder to Paris for the purpose of demonstrating the claims made for this process.

The Mashek briquetting process.—The briquetting press designed by G. J. Mashek (now with the Traylor Engineering Company, New York City) was described in detail by him in the Iron Age of April 19, 1906. It was designed for the purpose of overcoming the objections to the use of briquetting machinery which had developed principally through the failure of certain foreign-made machines to meet the requirements of the American trade. When Mr. Mashek started on the development of his plans, in 1903, the general type of machine in use in Europe was that which made large, rectangular-sided briquettes weighing from 7 to 20 pounds each, and these proved unsuitable to American use. In designing his press Mr Mashek adopted the Belgian idea of molds contained in the peripheries of two tangential wheels, but, instead of the eggette pattern, developed one which minimizes the blank spaces between the molds and produces a briquette of pillow or pincushion shape.

The Traylor Engineering Company has recently built for E. B. Arnold a Mashek press, which has been installed at the foot of West Forty-seventh street, New York City. The building was designed and erected for, and originally equipped with, a different type of machinery, but the briquettes made proved to be of a shape and character unsuited to the trade, and the cost of manufacture was also too high to enable the briquettes to compete with natural coal. When it was decided to substitute a Mashek press for the old one, it was also deemed advisable to use the same building, which is a substantial one, and also as far as possible the old machinery (such as elevators, shafting, power plant, etc.), which was practically new and in good order, but which did not permit the most desirable arrangement.

The new press installed has a capacity of about 14 tons of 2-ounce briquettes per hour, but on account of the inconvenience resulting from the use of so much of the old equipment it is impossible to handle sufficient material to keep the machinery running at its full capacity and it is now operated at the rate of about 10 tons per hour. The cost of labor, fixed charges, and other expense being the same, the cost of production is slightly higher per ton of briquettes than it would be if the plant were operated up to its maximum capacity. The size of the briquettes has been determined by putting them on the market and selling them for domestic purposes, starting with 1-ounce briquettes and running up to 3 ounces. It was found that the majority of users preferred a 2-ounce size, which corresponds with the "stove" size of anthracite. The weight, of course, will vary with the nature of the dust from which the briquette is made, and it has been found that in using coke breeze a 2½-ounce briquette is most desirable, and about a 3-ounce if made of soft coal and lignite. The press is so designed that a change of the mold shells can be made in about two hours.

The anthracite dust is elevated to the dust bin, from which it is drawn by a feed conveyor so arranged that the feed is constant and can be regulated as desired. This conveyor discharges into a chain elevator, which in turn discharges into a battery of five 18-inch rotary driers and heaters. These are superimposed one above another and all bricked in. The material is conveyed through these driers by means of screw mixers until it passes into the elevator.

On the side of these driers is constructed a furnace, the products of combustion from which are distributed into the driers through openings into the different units, so that no unit gets heat sufficient to either char the dust or burn out the ironwork of the paddle conveyor. An exhaust fan draws off the products of combustion and the moisture. The temperature of the discharge gases and moisture from the drier rarely exceeds 212° F. After the material passes out of the drier into the elevator it is raised and dropped into a 36-inch Williams pulverizer, which crushes the larger pieces so that everything passes through about a 12-mesh screen. From the pulverizer the material is again elevated to another series of mixers and coolers similar in construction to the driers. At this point the anthracite dust has a temperature of about 300° F. The coal-tar pitch is here introduced by means of a pitch pump so arranged that it will deliver a definite quantity of pitch, as desired. Alongside of the last battery of mixers is a small furnace which heats the two upper mixers, maintaining an even temperature in the mixture and not allowing it to stiffen or set. From the last mixer the material drops to an elevator that takes it up to the second floor and discharges it onto an 18-inch belt conveyor, which delivers the material into the hopper of the press. The press is run continually, discharging the briquettes into a perforated pan conveyor, which conveys them to the briquette bin.

While in this conveyor the briquettes are subjected to a heavy spray of water in order to cool and clean them.

The coal-tar pitch used in this plant is of the ordinary roofing hardness. It is delivered by lighter on the adjacent dock and carted to the pitch-melting house, where it is melted in a tank, 6 feet wide, 12 feet long, and 8 feet deep. This tank will hold about 22 tons of pitch, which requires approximately twenty hours to melt. After the pitch is melted and brought up to the proper temperature for use, it is drawn off by means of a large pitch pump into the "prepared-pitch tank," from which it is pumped into the mixers.

This plant requires about 125 horsepower to turn out 10 tons per hour. It has been in operation about two months and is said to be giving excellent results. The product is used almost entirely for domestic purposes and commands the same price as the best grade of prepared anthracite coal in the New York market. A large portion of the output is put up in paper bags and handled by grocers and small coal dealers the same as charcoal or crushed coke. The bag trade caters to the poor people who do not buy in large quantities and is a considerably cleaner method of distributing the product than that formerly used.

The briquettes are handled in the same way as ordinary coal, and experience in this and other plants has shown that abrasion or breakage averages about 3 per cent, which is slightly less than that with ordinary prepared coal.

PENNSYLVANIA.

It might be supposed that the briquetting industry would have its greatest development in or near the anthracite region of Pennsylvania, where a plentiful supply of raw material is available in the great culm banks created through many years of mining and in the still large amount of fine coal produced at the breakers for which no profitable market has yet been found. Up to the present time, however, there are but two briquetting plants in operation in the State, and one of these is located at Point Breeze, in the city of Philadelphia. The other is located at Dickson, a few miles from Scranton. Both were put into operation in 1906. The plant at Dickson is in the immediate vicinity of the mine of that name operated by the Delaware, Lackawanna and Western Railroad, and uses the fine coal or screenings, below marketable sizes, that come from the washery operated in connection with the mine. The owner of this plant, the Scranton Anthracite Briquette Company, withholds information relative to the details of its operations. The writer has been told, however, by one of the officials of the company, that the base of the binding material used is coal-tar pitch, and that the plant is producing at present (April, 1907) from 300 to 325 long tons of briquettes per day. It is the intention to double this output by running the plant night and day. The briquettes are of the oval or eggette shape, the press being of the Belgian type and similar to the American machine used at the testing plant of the United States Geological Survey at St. Louis during the exposition period.[a] The entire product is taken by the Delaware, Lackawanna and Western Railroad, for use principally on its locomotives.

The plant at Point Breeze is owned and operated by the United Gas Improvement Company, and was constructed for the purpose of utilizing the coke breeze produced at the gas houses of the company. As at the Dickson plant, the product is not placed on the market, but is used by the company in its retorts for the manufacture of water gas. The writer is indebted to W. H. Gartley, engineer of works, of the United Gas Improvement Company, for the following detailed description of the plant.

It has been found advantageous to use a mixture of anthracite culm and coke breeze, with 5 to 7 per cent of coal-tar pitch as a binder. The proportions of culm and coke used are variable, according to the quantity of material on hand. At the time the writer visited the plant (November, 1906) three parts of culm to two parts of coke were being used. The press is of the Belgian type, producing eggettes about the size of a goose egg. The rated capacity of the plant is 10 tons of eggettes per hour. It has been in operation regularly, producing 90 tons per nine-hour day, except when it has been shut down for repairs and changes.

The breeze or screenings from the coke screen fall into a pocket or hopper, into which is also dumped the culm. The contents are raised by an elevator into a storage tank, discharging through the funnel-shaped bottom onto an automatic feed table, by which a measured stream of the material is continuously poured, part into the crusher and part directly into the hopper below the crusher. The material is then elevated and discharged into the drier. The dried material, together with the dust from the dust chamber of the drier, is elevated and discharged through a shaking screen into a storage tank located above the mixer. All material not fine enough to pass through the screen is returned to the crusher. The dried material is discharged through the funnel-shaped bottom onto an automatic feed table, by which a measured stream is continuously poured into the mixer. Into the feed end of the mixer is also poured a continuous stream of liquid pitch through a positive measuring faucet driven from the driving mechanism of the mixer through a variable speed device. The pitch is brought into the building as broken from the pitch bays of the tar distillery, fed into a pitch cracker, elevated and

[a] Bull. U. S. Geol. Survey No. 261, and Prof. Paper No. 48, 1906.

discharged into large steam-heated pitch storage tanks, where it is melted. From these tanks the melted pitch is drawn, as required, into a smaller steam-heated tank, to which the faucet previously mentioned is attached.

The warm, dry, and continuously measured crushed breeze and culm, together with the melted and continuously measured pitch, are thoroughly mixed and kneaded in the steam-jacketed mixer. The mixed mass is discharged from the mixer, divided into two streams, and carried by two mixing conveyors, allowing time for cooling and setting, into the feed pans of the two presses, purchased in France. The presses form the eggettes and discharge them onto the shaking screens below, which screen out the waste and fines. They are then discharged onto a woven-wire belt conveyor, on which they have time to cool and set, and conveyed either to the cars or to the hoppers from which the buggies for the generator house are filled.

The waste and fines from the shaking screens under the presses are conveyed by conveyors to a hopper at the discharge of the drier.

Screenings from the eggettes taken from the storage piles are returned by an elevator to the discharge of the mixer and assist in the cooling of the heated mixture.

CALIFORNIA.

The manufacture of briquettes has shown more actual progress in California than in any other State of the Union. This has been brought about through efforts to improve the fuel quality of the rather low-grade California subbituminous coals, and has been encouraged by the high prices of the better grades of bituminous coal or anthracite brought into the State from Washington, the Rocky Mountains, and the Eastern States, or imported from British Columbia, England, Australia, and Japan. It has also been encouraged by the abundance of cheap asphaltic pitch, which can be obtained from California petroleum and which not only serves excellently as a binder, but adds to the calorific value of the briquetted fuel.

The first plant to be put into successful operation in California was one built at Stockton by the San Francisco and San Joaquin Coal Company. The plant was completed in 1901, and when running at full capacity could produce 125 tons of briquettes per day. The fuel used was subbituminous coal from the Tesla mine, in Alameda County. The plant was, unfortunately, destroyed by fire in 1905 and has not been rebuilt. It is stated that the plans of the company were to rebuild the plant at San Francisco, but these were upset by the earthquake and fire which destroyed a large part of that city in April, 1906. A complete description of the Stockton plant, by the designer of the presses, Robert Schorr, of San Francisco, was published in the Engineering and Mining Journal August 18, 1904. The briquettes produced at this plant were round, convex lenses or "boulets," which weighed from 6 to 8 ounces.

The Western Fuel Company, of Oakland, completed early in 1905 a briquetting plant, also designed by Mr. Schorr.[a] In mechanical construction this plant differs materially from the one destroyed by fire at Stockton. The shape of the briquettes is cubical instead of "boulet." The advantage claimed for the cubical shape is that the briquettes ignite more readily, though it is admitted that there is more waste in handling.

The capacity of this plant is 480 briquettes per minute, or 8½ tons per hour. The fuel used is coal-yard screenings from lignites, anthracite, and subbituminous coals, with about 7½ per cent of asphaltic pitch. This pitch is obtained by the distillation of California crude petroleum. The temperature of the still for the production of pitch of the proper grade is about 600° F. Some difficulty has been experienced in obtaining suitable pitch on account of the tendency of the refineries to "rush the stills," their aim being the production of refined oils rather than pitch. An excellent asphaltic pitch is obtained by keeping the stills at a temperature of 500° F. and using a vacuum to force the distillation. Grade "D," the quality best adapted for the purpose, is fairly hard up to 60° F., but begins to soften above that temperature. It becomes liquid at 250° F., and has a specific gravity of 1.05 to 1.1.

Before the earthquake the Western Fuel Company paid $10.50 per ton for the ordinary pitch "D" delivered at its plant, and a properly and carefully prepared pitch was worth from $12 to $13. Owing to the enormous building activity in San Francisco since the earthquake the demand for asphaltum for roofing materials has increased by leaps and bounds. Consequently there is a great scarcity and the price per ton ranges now from $14 to $20. This scarcity necessitated many shut downs of the plant at Oakland, and for that reason the company is negotiating for the importation of coal-tar pitch from the East and from Europe. As three new refineries are contemplated, conditions may gradually return to their normal state.

All of the coal purchased and used by the Western Fuel Company is brought in ships and is unloaded by electric hoists into receiving bins. When drawn from the storage bins it is screened, all material that passes through the perforations dropping into auxiliary bins from which it is fed into a Williams crusher. The disintegrated coal from the crusher is elevated into the iron hopper of an automatic feeder that feeds into the coal heater. The heated coal enters the mixer, where it meets the binder. The mixer, the binder distribution, and the tempering of the mixture embody some novel features.

---

[a] See Eng. and Min. Jour., September 2, 1905.

The prepared material is conveyed into the feed hopper of a Schorr press, style "A," which is belted for 6 revolutions per minute. At that speed 480 briquettes of 9½ ounces in weight are discharged per minute, or more than 17,000 pounds per hour. The briquettes are rectangular in shape, with rounded corners, and uniform in size, 2¾ by 2½ by 1⅞ inches, and are branded with a "W." They have a specific gravity of 1.22.

All wearing parts of the press are lined with phosphor bronze, and are thoroughly lubricated under an air pressure of 40 pounds to the square inch. Oil is also atomized and sprayed into the molds and upon the plungers.

The briquettes drop upon a short conveyer that delivers them to another one located outside the building. At this point they are sacked for the local market or taken to the top of the storage bunkers, where they are discharged into cars or distributed into the bunker compartments. The average output is 64 long tons per shift of eight hours. Four men are employed, one of them getting $4, one $2, one $3, and one $2.75 per day, which makes about 20 cents per ton of briquettes. By running twenty-four hours a day over 200 tons could be made, which would reduce the labor item to about 14½ cents per ton. This can be further cut down by speeding the press up to 7 revolutions per minute. This would produce 560 briquettes per minute, or 20,000 pounds of 9½-ounce briquettes per hour. With a forced feed attachment a further increase in speed may be possible.

Since the foregoing was written wages have been increased considerably, most of the men getting $3.50 per shift, working through the lunch hour.

The present pressure arrangement was tested up to 48,000 pounds, exerted on two 2½ by 2¾ inch surfaces, making over 3,700 pounds per square inch. The adjustment is placed to give about 2,900 pounds, which is ample and makes a better burning briquette than when a greater pressure is used. The press is figured for a maximum pressure of 6,000 pounds.

The following description of the briquetting press is taken in the main from an article by Mr. Schorr: [a]

Two soleplates with heavy bearings are arranged to carry a stationary steel shaft, on which a large spur wheel is revolving, driven by means of gearing, countershaft, and friction-clutch pulley. The spur-wheel rim is made integral with a mold ring, which has a series of holes and sliding plungers (pistons) therein. The pistons are under the continuous control of cams, which are supported by heavy shields. The pistons are released from the cam way only when the final pressure is applied, and this is done by a large wheel with steel tire, pivoted in two levers. This wheel is pressed against the piston heads by

[a] See Eng. and Min. Jour., October 7, 1905.

means of an adjustable spring which permits a perfect regulation of pressure up to 4,000 pounds per square inch. After leaving the pressure wheel—that is, after the briquette is made—the plungers are gradually forced forward to eject the briquettes, which drop upon a vibrating discharge chute. The pistons are then gradually withdrawn and in passing the feed box the cavities become filled with the mixture of coal and pitch. At the end of this feed box all surplus material is scraped off by a steel plate. After passing the scraper plate the pistons are gradually forced in, pressing the material against the resistance block, which is supported by the main shaft. This pressure is effected by a cast-iron stand with phosphor-bronze liner. When the pistons are about half an inch from their terminal they strike against the rocking pressure wheel and are forced home. In this way the briquettes are made and the play repeats itself with every revolution.

The machine is entirely self-contained, and it is claimed that there is no possibility of its getting wrecked by overfeed or obstruction. It is also claimed that as the pressure is applied slowly and gradually this type of press permits briquetting mixtures containing 13 to 14 per cent of moisture, and that this is an advantage not possessed by intermittently acting presses. Up to the present time two styles have been made—one with two rows of 2-inch cylindrical molds and the other with two rows of $2\frac{1}{2}$ by $2\frac{3}{4}$ inch rectangular shapes with rounded corners. There is no difficulty in making other shapes and heavier briquettes. A simple arrangement permits working with half the capacity whenever desired. No complications are presented if it is desired to have more than two rows of molds, and the press can be built for a much larger capacity. On the other hand, should the market for briquettes be lessened for some months in the year, the capacity can be cut down without requiring any change in speed or other alterations.

From 80 to 120 briquettes are made for each revolution, the number depending on the size and shape of the briquettes. These factors govern also the capacity, which ranges from 6 to $24\frac{1}{2}$ tons per hour.

Mr. Schorr states that all wearing parts of the machine can be quickly and cheaply replaced. The lubricating is done by an air compressor and oil atomizer.

The press is especially adapted for the manufacture of small briquettes, and the advantages of such in preference to large blocks are obvious. Small briquettes can be readily shoveled into furnaces, whereas the large ones have first to be broken up, thus causing labor, waste, and dust.

A briquetting plant of an entirely different type, designed by Charles R. Allen, was built and put into operation by him during 1905 at Pittsburg, at the junction of San Joaquin and Sacramento rivers, about 50 miles from San Francisco. This plant as originally projected was intended to utilize the subbituminous coal produced by the Pittsburg Coal Mining Company at Somersville, but the enormous increase in the production of oil in California has had so demoralizing an effect on the coal trade generally that there has been little or no market for the coal during the last two years and the mines have been shut down. The material used has been screenings obtained from the coal yards of San Francisco, the binder here, as at other plants in the State, being asphaltic pitch. The screenings are sold at less than the cost of mining coal, and as long as the supply of this material is available at such prices it will continue to be used.

The methods of preparing the briquetting mixture differ somewhat from those used at other plants, in that the binder, together with the fuel, is passed through the retorts under a high degree of heat. This it is claimed insures an intimate and thorough mixture, each particle of fuel being impregnated with the binder. This treatment it is asserted prevents the binder from being consumed before the coal is ignited, which is apt to be the case, particularly with subbituminous coal, if the mixing is merely superficial. Mr. Allen claims that in his process the nature of the fuel is changed so that the subbituminous coal partakes of the character of bituminous coal, the briquettes remaining firm and hard until entirely consumed. He claims also that the process possesses as much of novelty and value as the press.

The compressing machine consists of two nonconcentric rings horizontally placed one within the other, the periphery of the smaller one being corrugated, or scalloped, and engaging with similar corrugations in the inside of the larger ring. The briquetting mixture is fed into a hopper one-fourth of a revolution of the smaller ring from the point of compression, and the amount of pressure is regulated by the distance of the feed from the point of compression; that is to say, the hopper may be placed farther away if a greater pressure is desired, or nearer if the pressure is to be reduced. Relief from an excess of pressure is provided for by two heavy spiral springs on the outer bearings and two over the upper pressure plate, the lower pressure plate being fixed. The machine has been operated without using any of the springs, with the result that when there was a surplus of feed the operating belt was thrown off through the choking of the machine.

Mr. Allen's invention is United States patent No. 851007. The briquettes as now made are approximately cylindrical in shape, with flat ends. They weigh from 8 to 10 ounces each and have a specific gravity of 1.14. It is Mr. Allen's intention to reduce the size of the briquette and change its shape by having the smaller ring of the press made without corrugations. This will be done in order to meet the demand for a briquette better adapted for domestic use.

The plant is at present turning out about 5 tons of briquettes per hour, at a moderate running speed. With a smaller briquette the production per hour would be decreased with the same speed, but by increasing the speed the same production could be maintained.

The Standard Coal Briquetting Company, of Oakland, constructed in 1905 a plant designed by a Mr. Crawford. An accident to the press shortly after being put in operation practically wrecked it and the enterprise was unsuccessful.

Another plant, beginning operations in 1905, used a small press of the plunger type, designed by A. Demetrak and built by the American Briquetting Company (afterwards reorganized as the Ajax Briquetting Company), of San Francisco. It was destroyed by the earthquake and fire of April, 1906, and has not been rebuilt. The plant had a capacity of about 15 tons a day, using subbituminous coal from Coos Bay, Oregon, sometimes mixed with coal-yard screenings and asphaltic pitch.

The United States Briquette Company, of Stege, Contra Costa County, has undertaken the manufacture of briquettes from a mixture of peat and California crude petroleum. This plant had not been completed at the time of writing this report, but some briquettes made of the mixture in an experimental way are interesting productions. They give promise of a method of using California oil as a domestic fuel, the peat on account of its spongy character acting as a carrying vehicle for the oil and at the same time performing duty as fuel. The briquettes are cubical in shape and of attractive appearance. They weigh about 10 ounces and have a specific gravity of 1.3. It is claimed that they are as well adapted for steam raising as for domestic purposes, giving an intense heat under forced draft and burning freely under ordinary draft; that they can be handled without waste from breakage, and that they leave a minimum amount of ash and do not clinker.

ARIZONA.

The Arizona Copper Company (Limited), of Clifton, Ariz., installed during 1905 a briquetting plant purchased from Yeadon, Son & Co., of Leeds, England. The plant was put into operation in September, 1905, and produced during the first six months of 1906, 690 short tons of briquettes having a total value of $4,830, or an average of $7 per ton. About 300 tons were produced in experimental runs in 1905. The plant was installed for the threefold purpose of utilizing coke breeze, which is without value and nonusable as such, of procuring better efficiency from the slack coal (Gallup, N. Mex.) which is used as fuel, and of obtaining a fuel that could be stored without material deterioration and without danger of spontaneous ignition. James Colquhoun, president of the company, states that the economic advantages realized are from the first and third operations. By briquetting the coke fines or breeze a profit of about $4 per ton is made in the conversion of a material formerly wasted into a usable fuel. In using the Gallup slack, which is subbituminous coal ("black lignite"), the expense of briquetting brings the total cost up to approximately $6.80 per ton, or about the same as that of the lump coal obtained from the same source, although the price for the slack at the mines is very low compared with that of lump coal. The briquettes have been found to burn freely and satisfactorily under locomotive and stationary boilers, and appear to be equal to the best of Gallup lump coal, but no laboratory tests as to their calorific power have been made. The real profit in the briquetting of this coal lies in the superiority of the briquettes over lump coal for stacking purposes. They stand weathering perfectly, while the lump coal disintegrates on exposure, loses a portion of its combustible gases, and becomes in time a very inferior fuel. It is also liable to spontaneous combustion, which the briquettes are not.

In making the briquettes 92 per cent of the coal is mixed with 8 per cent of California asphaltic pitch. The capacity of the plant is 2½ tons of briquettes per hour.

The following description of the plant at Clifton has been furnished by the company. In design the press is similar to the one used by the Geological Survey fuel-testing plant at St. Louis. This was designated the "English" machine, and has been described in the reports of those tests.[a]

The coal or coke fines are fed from the bins into the boot of a bucket elevator, which discharges them into the hopper at one end of a mixer, where it is mixed with pitch that has previously been broken in a pitch breaker into pieces of one-half inch maximum size. The quantity of pitch found to give the best results is about 8 per cent. From the mixer the material is sent into a disintegrator, which thoroughly pulverizes the coal and pitch into grains of 2 mm. size or less. It is then elevated and passed into a heater, where it is subjected to the action of live steam, which gives the pitch sufficient fluidity to bind the other ingredients. From the heater the material drops into a pug mill, which, while stirring the mass, sweeps it into a false bottom. This false bottom is behind the disk of the briquetting machine, and at each revolution of the main shaft the material is rammed into a pair of compartments in the disk. The disk contains eight pairs of such compartments, and at the same time that a pair of briquettes is being rammed into the disk on one side another pair is being compressed on the opposite side, while a third pair is being pushed out from the top of the disk onto an endless-belt conveyor, which delivers

[a] Bull. U. S. Geol. Survey No. 261, and Prof. Paper No. 48, 1906.

the briquettes to the side of a railroad car in front of the building. The briquette disk is made to revolve intermittently in eight periods to each complete revolution. During the pause in each period the three operations referred to take place simultaneously.

The capacity of the plant is 25 tons per ten hours. It is arranged to mix three ingredients into material for briquettes, but at present only coal or coke fines and pitch are used. The briquettes are rectangular in shape and weigh approximately 4 pounds each.

MICHIGAN.

The Semet-Solvay Company, of Syracuse, N. Y., has recently completed the construction of a briquetting plant at Del Ray, Mich., to be operated in connection with the by-product coking ovens and chemical works installed there several years ago by the same company. The installation of the briquetting plant was begun about two and a half years ago. As originally constructed the briquetting machine was a reciprocating press of English make, but after carefully working out the process the company came to the conclusion that a press of the reciprocating type is adapted only to large briquettes, whereas the domestic trade of the city of Detroit, for which this product was intended, demands a small briquette. As the result of the experience gained with the English machine, the company has developed a process for the manufacture of small briquettes, and, although this plant is just beginning operations, it gives excellent promise.

The process consists, essentially, of the intimate mixing of finely powdered pitch of proper quality and consistency with pulverized coal, so that theoretically each particle of coal is coated with the fine pitch. The mixture is then brought up to the proper temperature with steam, or steam and hot water, and is fed to a rotary Mashek press built by the Traylor Engineering Company, of New York. The output of the plant is from 10 to 15 tons of briquettes per hour. They are from 2½ to 3 ounces in weight, and about 1⅞ inches square, shaped somewhat like a miniature sofa pillow. This shape is satisfactory for shoveling and for handling in household stoves and furnaces. The company is using a portion of coke breeze with the coal and pitch with a view of utilizing the breeze from its coke plant, and it is also experimenting on the best mixtures and the best grades of coal. The briquettes made so far are said to burn well and to give no smoke, except a slight puff when they are first thrown on the fire. As the plant is not yet in full operation, some minor adjustments are still being made to perfect the product, but the operators are much encouraged by results so far obtained, and expect within a short time to be making a thoroughly satisfactory commercial product.

NORTH DAKOTA.

During 1905 ex-United States Senator W. D. Washburn, president of the Washburn Lignite Coal Company, erected a small plant at Minneapolis, Minn., for experimental work in briquetting North Dakota lignite. The plant was too small to be operated successfully from a commercial standpoint. Several hundred tons of briquettes were made without the use of a binder. They proved a satisfactory fuel for domestic purposes and for stationary boilers, but were not adapted to locomotive use, as the heavy exhaust draft in the locomotive has the effect of disintegrating the briquette before combustion and causes the throwing off of large sparks.

Robert L. Stewart, also of Minneapolis, who is interested in lignite properties near Kenmare, Ward County, N. Dak., reports that he has been conducting a series of experiments with a view to briquetting this fuel, and as a result of his investigations the American Briquetting and Manufacturing Company has been organized. This company contemplates constructing, during the present year, a briquetting plant in North Dakota convenient to the lignite deposits and having a capacity of 1,000 tons of briquettes per day. Mr. Stewart states that the briquettes can be manufactured at a cost not to exceed $2 per ton f. o. b., this cost including the expense of mining the lignite and delivering it to the briquetting plant.

TEXAS.

Three companies have been organized recently in Texas for the purpose of briquetting lignite, which occurs in great abundance through the eastern part of that State. These are the International Compress Coal Company, of Houston; the American Lignite Briquette Company, of San Antonio; and the Eureka Briquette Company, of Rockdale. The plant of the Eureka Company has been erected and is ready for operation at the time of writing this report, except for the fact that the drying apparatus has been found too small and the plant has been shut down pending the erection of a larger drier. The details of the plant have not been obtained.

The American Lignite Briquette Company, while incorporated at San Antonio, will locate its plant at Rockdale, to be operated in connection with the lignite mines of J. J. Olsen & Son. The company has purchased a press made by the Klein Briquette Company, of St. Louis, Mo., and the plant will probably be in operation by the time this report is ready for distribution.

The International Compress Coal Company has been negotiating for the construction of a plant, but no actual building had been begun at the time of writing this report. All these plants expect to use asphaltic pitch made from heavy Texas oil.

FLORIDA.

In September, 1905, the Orlando Water and Light Company, of Orlando, Fla., completed the installation of a plant for the treatment and briquetting of peat, which occurs abundantly in the low-lying lands of Florida. The plant is located about 3 miles from Orlando, on the border of a peat bog from which its supply is drawn. As originally installed, this plant consisted of a macerating machine or pug mill, in which the fiber of the peat is entirely destroyed, and a brick press. The briquettes as they came from the press were about the size of an ordinary building brick, but when dried in the sun shrunk to about one-fourth their former bulk and lost from 75 to 85 per cent in weight. The briquetting feature of the plant was abandoned in the summer of 1906, as it was found that this part of the work represented 75 per cent of the total cost, and that a satisfactory fuel could be made without briquetting. The method of treatment at the present consists simply of "machining" the peat in the pug mill and dumping it in masses of several hundred tons. As the peat dries it shrinks and cracks into large, irregularly rectangular blocks, which are broken off from the heap and stored. When thoroughly dried, these blocks make a good hard fuel, which it is stated may be used for both locomotive and stationary boilers, for household purposes, and for the manufacture of gas. Tests of the machined peat for producer gas at the Geological Survey fuel-testing plant gave excellent results.[a]

The machine used at the Orlando plant was built by the Moore and Wyman Elevator and Machine Works, South Boston, Mass., under patents issued to the late T. H. Leavitt, of Boston.

MISSOURI.

During the summer of 1903 Gov. W. C. Renfrow, of Oklahoma, became financially interested in a briquetting company in St. Louis. In the fall of the same year E. D. Mizner, of Hamilton, Ontario, visited St. Louis to make a report for some Canadian interests relative to the purchase of the Canadian rights for the patents of this company. The results of these investigations, and the efforts of Governor Renfrow to force the briquette company to deliver a machine, ended in the bankruptcy of the company. In October, 1903, an agreement was made between Governor Renfrow and Mr. Mizner by which Mr. Mizner was to build a briquette machine which would overcome the difficulties encountered with the other press. No company was organized at that time, but contracts were drawn satisfactory to the people interested.

[a] Campbell, M. R., Peat: Mineral Resources U. S. for 1905, U. S. Geol. Survey, 1906, p. 1320.

The following spring Mr. Mizner built the first Renfrow press, which made briquettes 2 inches in diameter, weighing about 4 ounces. This press had some of the essential features of the original Renfrow press, but made briquettes only at one end of the stroke—that is, 12 briquettes per revolution. After this machine was built it was discovered that the briquettes were too small and that the construction of the machine was too light. Mr. Mizner also developed the idea of making briquettes at both ends of the stroke, thus doubling the capacity of the machine. It was decided to build a much heavier machine, making a briquette 3 inches in diameter. Changes were also made in the method of mixing and heating the material. The cast-iron vertical heaters of the original press were supplanted with horizontal jacketed heaters, using ordinary spiral conveyor flights for mixing and handling the fuel. To this was added a short vertical heater, acting as a reservoir into which live steam was admitted just before the mixture was delivered to the molds.

This machine was completed in the fall of 1905. C. T. Malcolmson, of the Geological Survey testing plant,[a] inspected this press at the shops of the Ramming Machine Company, at St. Louis, and burned some of the briquettes under a boiler at that plant. Difficulties were developed from the fact that the fuel remained too long in the vertical heaters, and some trouble was also experienced in getting the material from the die filler to the die proper. Occasionally briquettes would stick in the dies, resulting in a double charge, which finally crippled the machine. Provision was then made to overcome these difficulties and the machine was rebuilt. The new machine was first tested in March, 1906. The heating capacity was increased so that the charge remained in the conveyors about fifteen minutes before reaching the dies, thus allowing the material to become thoroughly heated and the melted pitch to mix with the coal. Brushes were added to insure the charge being carried to its proper position in front of the die, and an ejector, operated by a magnet, effected the delivery of the briquettes from the ends of the plungers. Many of the parts of the machine were strengthened and steel and bronze were substituted for cast iron in the wearing parts. The results of the tests on this machine made under the supervision of Mr. Malcolmson for J. A. Holmes, expert in charge of the Geological Survey fuel-testing plant, at the company's testing plant, resulted in a contract for the rental of this machine by the Government. In May, 1906, the first success-

[a] The briquetting portion of the Geological Survey coal-testing plant at St. Louis during the exposition has already been described in Bulls. Nos. 261 and 290, and Prof. Paper No. 48. After the close of the exposition the American machine, installed by the National Compressed Fuel Company, of Chicago, was removed, and early in 1906 the remaining portion of the briquetting plant was destroyed by fire. In rebuilding the plant provision was made for the installation of a Renfrow briquette machine.

fully operating Renfrow machine was installed at the fuel-testing plant.

The results of the tests made on the Renfrow machine from May, 1906, to March, 1907, indicated that the design of this press was, in the main, satisfactory, and that the difficulties experienced were due almost entirely to bad or weak construction of the machine. This machine was the result of many changes, and it was impossible to strengthen some of the weak parts owing to the limited space, or to the fact that the size of the part was fixed by the original design.

The difficulties encountered in operating this machine at the fuel-testing plant soon indicated its weaknesses, and as a result the Renfrow Company designed and built two new presses, one of which was installed and is now being operated by the Western Coalette Fuel Company at Kansas City. The other is now ready for delivery to the Government fuel-testing plant at the Jamestown exposition. The new press makes a briquette 3¼ inches in diameter, weighing about a pound. The machine which was operated at the St. Louis fuel-testing plant could not be depended on to deliver more than 1,000 pounds pressure per square inch on the briquettes without seriously straining the frame of the press. The new machine will deliver a maximum pressure of about 2,500 pounds per square inch without straining. All the wearing parts not under pressure are made of bronze, so as to prevent corrosion; the dies are made of case-hardened steel and, owing to the abrasive action of the fuel, are kept clean and bright. The cams and rollers, which were originally made of chilled cast iron, are in the new machine made of case-hardened tool steel, and the design of the housing has been so changed that any of the parts can be removed without dismantling the machine. Provision has also been made to so feed the heaters that they will always run clean and at the same time keep a full load in the chamber above the die filler. This chamber, closed in the old machine, is open in the new, thus allowing the operator to regulate the supply of fuel to the press at all times. The plungers are arranged so as to make it practically impossible for a double charge to enter the press, and the length of the spring behind the plungers has been increased so that a double charge would not affect the press in any way.

Early in 1906 the Renfrow Briquette Machine Company was incorporated under the laws of the State of Missouri, with a capital of $1,000,000. W. C. Renfrow is president, J. M. Smith, secretary and treasurer, and E. D. Mizner superintendent, and it is a close corporation. The company will not offer for sale any machines until after the Kansas City plant has proved successful. So far as can be learned, the construction of the Kansas City plant was brought about by the willingness of J. H. Durkee, president of the Western Coalette Fuel

Company, to accept a Renfrow machine without a guaranty, simply on the strength of the work done at the fuel-testing plant. There are still, of course, some difficulties to be overcome, as is the case in the operation of any new plant, but in the main the mechanical operations of this plant are satisfactory, and the Renfrow Company has been able to deliver what it contracted to deliver. Financial difficulties have threatened the life of the plant under the present organization, but Governor Renfrow has stated that he will not allow this plant to fail for this reason. A contract has been signed to deliver one of the machines to a company at Detroit, but under the terms of the contract no date is fixed for the delivery of this machine, and no guaranty from the Renfrow Company has been required. Governor Renfrow is also authority for the statement that the Detroit machine will not be delivered until after the Kansas City plant has been successfully operated and put on a commercial basis.

The Renfrow Briquette Machine Company has no plant of its own, but has under serious consideration the establishment of a factory at St. Louis. All the machines above mentioned were built by machine shops under contract. The Kansas City machine was built by the Excelsior Tool and Machine Company at East St. Louis, and the other machines by the Ramming Machine Company, of St. Louis.

COST OF MANUFACTURE.

The cost of manufacture of briquettes at one of the plants in the State of New York is as follows:

Cost of manufacturing briquettes.

Pitch:		
6 per cent of pitch, at $10 per ton	$0.60	
Deducting for increased weight of product due to pitch, calculating product at $5 per ton	.30	
Net cost of pitch		$0.30
Fuel:		
For boiler, broken coal and screenings, broken briquettes, 4 tons per day of 10 hours, at $2.50 per ton=$10; per ton of briquettes		.10
For heaters, driers, and pitch melting, 3 tons, at $2.50 per ton=$7.50; per ton of briquettes		.075
Labor:		
1 foreman ... per day	$5.00	
2 pitch melters ... do	3.50	
1 dust-bin man ... do	1.75	
1 engineer ... do	3.50	
1 man on second floor ... do	1.75	
1 man on ground floor ... do	1.75	
1 night watchman ... do	1.75	
1 oiler ... do	1.75	
	20.75	
Per ton of briquettes		.21

Miscellaneous:	
Wear and tear per ton of briquettes	$0.10
Lubricating oil per ton of briquettes	.01
Insurance per ton of briquettes	.005
Interest on capital invested—$40,000 at 6 per cent	.10
Office expense, telephone, stenographer, and stationery—$2,000 per annum	.09
	.99
Anthracite dust at $1.40 per long ton, per net ton of briquettes	1.25
Total cost of briquetting	2.24
Rebriquetting 3 per cent of breakage and abrasion, charging it back to plant as dust, per ton of briquettes	.06
Net cost per ton of briquettes	2.30
Wholesale selling price in bin	4.80
Net profit per short ton	2.50

THE IMPORTANCE OF UNIFORM AND SYSTEMATIC COAL-MINE SAMPLING.

By John Shober Burrows.

INTRODUCTION.

In determining the value of a coal deposit it is essential to know two things—(1) the amount of workable coal available and (2) the quality of that which is marketable. The first of these has been ascertained by well-established methods of surveying and prospecting, but the second is not so easily determined, although at first sight it might seem much more easy to pronounce on the quality of the coal when once it is taken from the mine than to determine its amount where it lies. The usual means of determining the quality has been to make a chemical analysis of a small sample of the coal, taken either from the bed itself or from a pile or car of coal that has been freshly mined; and although this seems to be an exceedingly simple matter, and great reliance has been placed on it, previous to 1904 little or no effort had been made to test its accuracy, and consequently its value was entirely unknown. Since that year, however, the United States Geological Survey, in connection with the fuel tests which it has made at St. Louis, has collected a large number of most valuable data on this important subject. These data have shown that sampling as ordinarily done is not reliable and that in most cases the chemical analysis of such a sample shows a much cleaner coal than is actually obtained in mining. Discrepancies of this nature are due largely to the human tendency to select the best coal for the sample, regardless of the amount of extraneous matter that will be likely to get into the commercial product through careless mining and handling.

Attention was first called to this matter by M. R. Campbell,[a] who, at the close of the St. Louis exposition, summed up the results of mine sampling as compared with car sampling in the first year's work of the fuel-testing plant. These results showed conclusively that a sample obtained by the usual method of mine sampling can not be relied on to represent the average commercial product of the mine. From the data obtained during the first year certain coefficients were determined for correcting mine samples, so that when sampling is done in a uniform and systematic manner the result can be relied upon to approx-

[a] Prof. Paper U. S. Geol. Survey No. 48, 1906, p. 142.

imate the quality of the commercial product. Later[b] Campbell verified his original conclusions by the data obtained in the more refined method of mine sampling adopted for the work of the fuel-testing plant in 1905.

The writer has been in active charge of mine sampling for the fuel-testing plant since the exposition tests were completed, and the present paper sums up the general results of all mine and car sampling that has been done in connection with the fuel-testing work since its establishment at St. Louis in September, 1904, to its completion in March, 1907. During this period the inspectors of the fuel-testing plant visited, personally inspected, and sampled the coal in 159 mines located in 23 different States. From each of these mines at least two mine samples were obtained and one or more cars of coal were shipped to St. Louis, where they were carefully sampled and tested. Inasmuch as all of the work of sampling from its inception up to the present time has been done on practically the same general plan, with only slight modifications in the matter of minor details, the results are entirely comparable, forming the greatest mass of such material that has ever been accumulated. Not only is the material valuable on account of the great number of samples involved, but also on account of the variations in quality, the samples ranging from the lowest grade of brown, woody lignite to anthracite coal. The sampling has also been done under a great variety of climatic conditions, ranging from midwinter temperature to the heat of summer and from the semiarid conditions of the plateau country of New Mexico and Wyoming to the more humid conditions of the Mississippi Valley and the excessive rainfall of the western front of the Cascade Mountains.

SAMPLING FOR GEOLOGICAL SURVEY FUEL-TESTING PLANT.

One of the important features of the work of the fuel-testing plant has been the method adopted for collecting the material to be tested. In organizing the work, in 1904, it was decided that coal in carloads for practical tests should be shipped under the personal supervision of an inspector and that the inspector should also secure small mine samples for chemical analysis; that when the cars of coal arrived at the testing plant a representative sample should be taken from each car in the manner provided, and that complete analyses of the mine and car samples should be made for the purpose of comparison.

CAR SAMPLING.

The cars of coal were unloaded into a roll crusher, with the rolls set 1½ inches apart, the coal falling into the boot of a bucket elevator. As the buckets of the elevator moved upward to the storage bin, a sample was taken by a man with a small shovel from about every

[b] Economic Geology, vol. 2, No. 1, January-February, 1907, p. 48.

eighth or tenth bucket, and the sampling was continued until the entire car was emptied. The sample, which was kept in a tightly covered iron bucket of 80 to 100 pounds capacity, was sent to the laboratory without further preparation and was pulverized and quartered down to the requisite size. Several trials of different methods of car sampling proved this to be the best for obtaining uniform results.

MINE SAMPLING.

The method of mine sampling has been practically uniform throughout, but from time to time minor changes have been made as experience demonstrated the possibility of improvement. In the work done in 1905 the principal change consisted in crushing the sample in the mine immediately after taking it, instead of carrying it outside, as had been done in 1904. The old method permitted the sample to lose some of its moisture, but this was largely obviated by crushing in the mine, where the atmospheric conditions are generally constant. Another important change consisted in taking larger samples and in weighing them to be sure that a sufficient amount of coal was obtained. More detailed records were kept by the samplers, showing for each sample a complete section of the coal bed, the parts included in the sample, the parts excluded as contrasted with the partings thrown out by the miner, the gross weight of the sample, and the length of time it was exposed to the atmosphere of the mine while being crushed and quartered and sealed in the can.

In detail the method of taking the mine samples used from the close of the St. Louis exposition to the completion of the series of tests in March, 1907, is as follows:

For mine sampling two or more places were selected at widely separated points in the mine where the coal bed had an average development and from which most of the coal was being mined for shipment. At one of these places the face was cleared of burned powder, loose coal, and dirt for about 5 feet, and insecure pieces of the roof were taken down to prevent their falling into the sample. The sampler then spread a waterproof blanket on the floor of the mine close up to the face of the coal and made a perpendicular cut from floor to roof, including in the sample everything but the parts of the bed discarded by the miner. Sufficient coal was cut to make not less than 5 pounds to the foot in height—that is, a sample weighing not less than 20 pounds would be cut from a 4-foot bed of coal and a sample weighing at least 30 pounds from a 6-foot bed. When shale or other partings were to be included in the sample, great care was exercised to cut them the full width and depth of the groove, in order to preserve the proper proportion of coal and extraneous matter. When the required amount of coal was obtained, a detailed measurement was made of the section of the bed from top to bottom, every perceptible parting and variation in the section being noted. The parts of the bed not included in the sample were clearly shown in the record, and from these notes the value of the sample could be judged. The cuttings were at once weighed and then sifted through a screen with a half-inch mesh. The remaining lumps were broken on a portable bucking board, and this process of screening and breaking was continued until the entire sample would pass through the screen. The sample was then mixed by two men grasping the opposite corners of the blanket. They rolled the sample diagonally by raising one corner of the blanket at a time, thereby mixing the sample thoroughly. When the larger pieces of coal were evenly distributed throughout the mass, the sample was quartered down, and two opposite quarters were discarded. The remainder was then mixed as before, and if the sample was still too bulky to be conveniently handled it was again quartered down. The material finally remaining was spread into a circular mass about 2 inches deep on the blanket, and a small trowel was used to fill a sample can with portions from the circumference to the center of the mass around the entire circle. The can was then closed and hermetically sealed with insulating tape ready for mailing to the chemical laboratory. The weight of this can showed accurately what proportion of the original sample was preserved.

The entire process of sampling was carried on as rapidly as possible at the place in the mine where the sample was cut, the maximum time for cutting and preparing a large sample being about one hour. It was assumed that as the sampling was quickly done in the native atmosphere of the coal there would be little or no loss in moisture.

PROPOSED METHOD OF MINE SAMPLING.

In discussing the results of mine and car sampling for the testing plant for 1904 Campbell concluded that the efforts to make the mine samples correspond to commercial coal were unsuccessful, and he recommended an arbitrary method of determining what should and what should not be included in the sample, as follows:

All material encountered in a cut across the face of the coal should be included in the sample, except partings or binders more than three-eighths of an inch in thickness, and lenses or concretions of sulphur or other impurities greater than 2 inches in maximum diameter and one-half inch in thickness.

If the sample is wet it should be taken out of the mine and dried until all sensible moisture has been driven off.

The main difference between the method proposed by Campbell and the method used by the inspectors of the fuel-testing plant lies in the manner of excluding impurities. In the Campbell method, as stated above, partings or binders of a certain size are arbitrarily discarded, whereas in the inspectors' method only the partings which are actually discarded by the miner are excluded from the sample. The method of imitating the miner would seem to be the best, but it requires very careful judgment, as no two miners can be relied on to discard the same partings consistently, even at mines where the most rigid regulations are in force for cleaning the coal. The results of sampling done in this way show a decided improvement as experience is gained, but the method depends too much on personal judgment, and therefore it is not recommended for general use. Campbell's proposed method seems to fulfill all the present requirements when used in conjunction with the coefficients given on page 512 of this paper, and should be followed where samples are taken for purposes of comparison.

ANALYTICAL RESULTS OF SAMPLING FOR GEOLOGICAL SURVEY FUEL-TESTING PLANT, 1905-1907.

TABULAR SUMMARY.

During the first year mainly run-of-mine coal was shipped to the testing plant, but since then other sizes have been accepted for various sorts of tests. This has afforded excellent opportunities to compare the mine samples with screened coal as well as with run-of-mine coal. Three tables have been prepared showing the impurities in the mine and car samples, and comparing the average of the mine samples with the average of the car samples. Table 1 includes only the results on samples of run-of-mine coal. Table 2 is composed entirely of results on screened-coal samples, including all samples that were shipped as lump, egg, nut, etc., as well as many other special sizes which were obviously neither run-of-mine nor slack coal. Table 3 is made up from the results on samples of coal that were shipped as slack or screenings.

TABLE 1.—*Classification of impurities in mine and car samples of run-of-mine coal.*

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Alabama No. 2 B, Carbon Hill:										
Mine sample	3011	4.71	10.17	1.33	4.61	9.54	1.40	0.66	......	0.28
Do	3012	4.51	8.92	1.48						
Car sample	3211	3.95	14.59	1.12	3.95	14.59	1.12	......	5.05	......
Alabama No. 3, Garnsey:										
Mine sample	3018	3.03	10.72	.49	3.14	11.44	.51	.42	......	......
Do	3019	3.25	12.16	.53						
Car sample	3255	2.72	14.36	.55	2.72	14.36	.55	......	2.92	.04
Alabama No. 4, Belle Ellen:										
Mine sample	3034	3.67	3.14	1.22	3.63	2.80	1.36	......	......	.28
Do	3035	3.60	2.46	1.50						
Car sample	3103	6.43	12.92	1.08	6.43	12.92	1.08	2.80	10.12	......
Alabama No. 5, Lehigh:										
Mine sample	4090	4.72	4.14	.83	3.82	3.43	.74	......	......	......
Do	4091	2.93	2.73	.65						
Car sample	4252	5.59	16.08	1.40	5.59	16.08	1.40	1.77	12.65	.66

TABLE 1.—*Classification of impurities in mine and car samples of run-of-mine coal*—Continued.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Alabama No. 6, Dolomite:										
Mine sample	4292	3.23	3.83	.57	3.02	3.67	0.58	......	......	......
Do	4293	2.81	3.51	.59						
Car sample	4338	3.23	6.71	.61	3.39	6.83	.59	0.37	3.16	0.01
Do	4353	3.56	6.95	.58						
Arkansas No. 10, Lester:										
Mine sample	2647	39.50	12.58	.53	40.37	10.19	.51	.94	.48	.02
Do	2648	41.25	7.81	.50						
Car sample	2726	39.43	9.71	.49	39.43	9.71	.49	......	......	......
California No. 1, Tesla:										
Mine sample	1606	17.59	18.03	2.89	17.80	17.20	2.98	......	1.71	......
Do	1607	18.02	16.37	3.07						
Car sample	1680	18.51	15.49	3.05	18.51	15.49	3.05	.71	......	.07
Illinois No. 6 B, Coffeen:										
Mine sample	1661	12.90	11.08	3.78	12.90	11.08	3.78	.97	......	......
Car sample	1702	11.93	14.18	4.29	11.93	14.18	4.29	......	3.10	.51
Illinois No. 7 D, Collinsville:										
Mine sample	1608	12.27	11.35	4.66	12.07	11.46	4.70	1.21	......	.17
Do	1609	11.87	11.58	4.75						
Car sample	1780	10.86	13.18	4.53	10.86	13.18	4.53	......	1.72	......
Illinois No. 9 A, Staunton:										
Mine sample	1625	13.29	8.90	4.12	14.28	9.05	3.91	.74	......	......
Do	1626	15.27	9.20	3.70						
Car sample	1635	13.54	10.74	4.03	13.54	10.74	4.03	......	1.69	.12
Illinois No. 11 B:										
Mine sample	1634	8.30	9.26	2.82	8.30	9.26	2.82	......	......	.36
Car sample	1660	8.86	11.66	2.46	8.86	11.66	2.46	.56	2.40	......
Illinois No. 12, Bush:										
Mine sample	1683	8.29	10.83	2.81	8.35	11.35	3.22	.15	......	......
Do	1688	8.41	11.88	3.63						
Car sample	1762	8.20	12.95	3.48	8.20	12.95	3.48	......	1.60	.26
Illinois No. 19 C, Zeigler:										
Mine sample	1871	9.90	7.74	.48	10.03	7.13	.47	.45	......	......
Do	1872	10.53	7.40	.47						
Do	3408	9.65	6.25	.45						
Car sample	3447	9.58	11.00	.52	9.58	11.00	.52	......	3.87	.05
Illinois No. 25 A, Germantown:										
Mine sample	2856	11.64	8.66	3.41	11.89	8.97	3.71	.54	......	......
Do	2857	12.15	9.28	4.01						
Car sample	2991	11.35	13.40	4.76	11.35	13.40	4.76	......	4.43	1.05
Illinois No. 26, Lincoln:										
Mine sample	2881	14.77	12.58	3.95	15.14	12.41	3.80	......	.32	.29
Do	2882	15.52	12.35	3.65						
Car sample	3003	15.68	12.09	3.51	15.68	12.09	3.51	.54	......	......
Illinois No. 27, Auburn:										
Mine sample	2897	14.29	8.18	4.41	14.23	9.02	4.38	......	......	.33
Do	2898	14.18	9.86	4.36						
Car sample	3052	16.00	13.77	4.05	16.00	13.77	4.05	1.77	4.75	......
Illinois No. 29 B, Livingston:										
Mine sample	3911	14.25	9.44	3.72	13.47	9.10	3.67	1.00	......	......
Do	3913	12.69	8.76	3.62						
Car sample	3958	12.47	12.56	4.37	12.47	12.56	4.37	......	3.46	.70
Illinois No. 34 B, Harrisburg:										
Mine sample	4413	7.55	7.15	1.56	7.53	7.31	1.57	......	......	......
Do	4414	7.51	7.48	1.58						
Car sample	4622	7.81	8.38	2.36	7.81	8.38	2.36	.28	1.07	.79
Indiana No. 5, Hymera:										
Mine sample	1773	12.14	8.96	3.54	12.15	9.06	4.10	.12	......	......
Do	1774	12.17	9.16	4.66						
Car sample	1859	12.03	10.88	4.27	12.03	10.88	4.27	......	1.82	.17
Indiana No. 6, Hymera:										
Mine sample	1772	10.45	9.58	4.04	9.83	10.37	3.99	......	......	......
Do	1776	9.22	11.17	3.94						
Car sample	1875	10.80	12.62	4.39	10.80	12.62	4.39	.97	2.25	.40
Indiana No. 9 B, Macksville:										
Mine sample	1848	13.73	8.65	3.00	14.03	8.56	2.85	.50	......	......
Do	1849	14.33	8.47	2.70						
Car sample	1960	13.53	10.76	3.15	13.53	10.76	3.15	......	2.20	.30
Indiana No. 12, Hartwell:										
Mine sample	2701	11.29	6.87	3.09	11.19	7.69	3.47	.62	......	......
Do	2702	11.10	8.52	3.86						
Car sample	2759	10.57	11.65	3.87	10.57	11.65	3.87	......	3.96	.40
Indiana No. 13, Terre Haute:										
Mine sample	3467	13.43	7.34	2.16	13.65	8.01	2.71	.86	......	......
Do	3468	13.88	8.69	3.26						
Car sample	3748	12.79	12.09	3.18	12.79	12.09	3.18	......	4.08	.47

TABLE 1.—*Classification of impurities in mine and car samples of run-of-mine coal*—Continued.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Indiana No. 14, Seelyville:										
Mine sample	3491	13.62	7.11	3.28	12.54	8.90	4.36	4.66		
Do	3492	11.46	10.70	5.45						
Car sample	3775	7.88	14.20	5.14	7.88	14.20	5.14		5.30	0.78
Indiana No. 15, Linton:										
Mine sample	3473	13.53	7.55	.95	13.75	7.32	.95	.17		.04
Do	3474	13.98	7.10	.96						
Car sample	3567	13.58	8.15	.91	13.58	8.15	.91		.83	
Indiana No. 16, Linton:										
Mine sample	3475	10.19	9.21	3.16	10.85	10.21	3.66	.55		
Do	3476	11.51	11.22	4.17						
Car sample	3564	10.30	11.75	4.23	10.30	11.75	4.23		1.54	.57
Indiana No. 17, Bicknell:										
Mine sample	3516	10.60	8.30	3.69	11.23	8.18	3.87			.22
Do	3517	11.87	8.06	4.05						
Car sample	3981	12.08	11.02	3.65	12.08	11.02	3.65	.85	2.84	
Kentucky No. 5, Head of Big Looney Creek:										
Mine sample	2271	4.45	3.23	.54	4.49	2.66	.52	.13		
Do	2272	4.72	2.48	.54						
Do	2270	4.32	2.28	.48						
Car sample	2528	4.36	3.70	.67	4.36	3.70	.67		1.04	.15
Kentucky No. 6, Paintsville:										
Mine sample	2405	6.95	2.03	.48	6.73	2.14	.46	1.61		
Do	2406	6.52	2.26	.45						
Car sample	2592	5.12	2.76	.57	5.12	2.76	.57		.62	.11
Kentucky No. 8, Sturgis:										
Mine sample	3678	7.46	4.60	.97	7.77	4.88	1.02	2.31		
Do	3679	8.09	5.16	1.07						
Car sample	3860	5.46	7.92	1.18	5.46	7.92	1.18		3.04	.16
Kentucky No. 9 B, McHenry:										
Mine sample	3722	10.03	7.67	2.56	9.96	8.18	2.50	1.92		
Do	3723	9.89	8.69	2.45						
Car sample	4211	8.04	10.05	2.97	8.04	10.05	2.97		1.87	.47
Maryland No. 1, Piedmont, W. Va.:										
Mine sample	2018	2.47	9.55	1.23	2.96	10.20	1.41	.63		
Do	2019	3.45	10.85	1.60						
Car sample	2274	2.33	13.13	1.49	2.33	13.13	1.49		2.93	.08
Maryland No. 2, Frostburg:										
Mine sample	4334	2.54	6.14	.87	2.50	6.22	.83			
Do	4335	2.47	6.30	.79						
Car sample	4386	3.42	7.09	.84	3.42	7.09	.84	.92	.87	.01
Missouri No. 5, Higbee:										
Mine sample	2795	13.38	10.02	4.48	13.63	10.72	4.33	.71		
Do	2796	13.89	11.52	4.19						
Car sample	2865	12.92	13.62	5.03	12.92	13.62	5.03		2.90	.70
New Mexico No. 3 A, Van Houten:										
Mine sample	3221	2.50	9.13	.72	2.98	10.02	.68			
Do	3222	3.48	12.92	.64						
Car sample	3295	3.45	16.67	.73	3.45	16.67	.73	.47	6.65	.05
New Mexico No. 4 A, Brilliant:										
Mine sample	3228	2.19	11.11	.57	2.43	10.46	.57			
Do	3229	2.67	9.82	.58						
Car sample	3331	2.78	14.57	.61	2.78	14.57	.61	.35	4.11	.04
New Mexico No. 5, Blossburg:										
Mine sample	3226	2.25	12.37	.75	2.28	12.73	.70			.01
Do	3227	2.31	13.10	.66						
Car sample	3294	2.72	14.57	.69	2.72	14.57	.69	.44	1.84	
North Dakota No. 3, Wilton:										
Mine sample	1935	40.53	5.05	.76	41.20	5.16	.86	5.24		
Do	1938	41.88	5.28	.96						
Car sample	2243	35.96	7.75	1.15	35.96	7.75	1.15		2.59	.29
Ohio No. 1, Wellston:										
Mine sample	1896	8.45	6.73	3.10	7.97	8.62	4.27	.26		
Do	1897	7.50	10.51	5.44						
Car sample	2071	7.71	11.95	4.61	7.71	11.95	4.61		3.33	.34
Ohio No. 2, Wellston:										
Mine sample	1898	9.38	7.62	4.08	9.16	8.48	4.24	.15		.22
Do	1899	8.95	9.34	4.41						
Car sample	2109	9.01	11.34	4.02	9.01	11.34	4.02		2.86	
Ohio No. 3, Shawnee:										
Mine sample	1900	10.78	6.13	1.11	10.27	6.07	1.27	.37		
Do	1901	9.79	6.01	1.43						
Car sample	2144	9.90	11.58	1.81	9.90	11.58	1.81		5.51	.54
Ohio No. 6, Neff's:										
Mine sample	2095	3.99	8.07	3.49	4.02	7.25	3.42			.09
Do	2096	4.06	6.44	3.35						
Car sample	2392	5.31	8.52	3.33	5.31	8.52	3.33	1.29	1.27	

TABLE 1.—*Classification of impurities in mine and car samples of run-of-mine coal*—Continued.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Ohio No. 8, Dixie:										
Mine sample	2119	8.92	5.85	3.00	8.89	4.92	2.37	1.34		
Do	2120	8.87	4.00	1.74						
Car sample	2559	7.55	8.37	2.84	7.55	8.37	2.84		3.45	0.47
Ohio No. 12, Bellaire:										
Mine sample	3987	3.32	6.77	3.55	3.21	6.40	3.48			
Do	3988	3.10	6.03	3.42						
Car sample	4151	4.14	9.38	3.96	3.55	9.67	3.80	.34	3.27	.32
Do	4178	2.97	9.97	3.65						
Pennsylvania No. 6, East Millsboro:										
Mine sample	1968	4.08	9.50	1.64	3.44	9.06	1.82	.09		
Do	1970	2.81	8.63	2.00						
Car sample	2161	3.24	12.52	1.94	3.35	12.76	1.94		3.70	.12
Do	2176	3.46	13.00	1.95						
Pennsylvania No, 7. Ligonier:										
Mine sample	1994	3.30	11.18	1.79	3.04	11.95	1.83			
Do	1995	2.78	12.73	1.88						
Car sample	2154	4.09	12.47	2.08	4.09	12.47	2.08	1.05	.52	.25
Pennsylvania No. 8, Ehrenfeld:										
Mine sample	2014	3.49	5.71	.95	3.29	5.58	1.06			.12
Do	2015	3.09	5.46	1.18						
Car sample	2152	3.51	6.63	.94	3.51	6.63	.94	.22	1.05	
Pennsylvania No. 9, Kimmelton:										
Mine sample	2016	2.63	10.21	2.05	3.26	9.27	1.90	.17		
Do	2017	3.90	8.33	1.76						
Car sample	2199	3.09	11.33	2.04	3.09	11.33	2.04		2.06	.14
Pennsylvania No. 11, Charleroi:										
Mine sample	3421	2.50	5.34	1.14	2.53	6.14	1.70	.58		.52
Do	3422	2.56	6.95	2.27						
Car sample	3532	1.95	7.29	1.18	1.95	7.29	1.18		1.15	
Pennsylvania No. 12, Atcheson:										
Mine sample	3441	2.60	5.63	1.19	2.90	5.75	1.20	.94		
Do	3442	3.21	5.88	1.22						
Car sample	4038	1.96	9.25	2.19	1.96	9.25	2.19		3.50	.99
Pennsylvania No. 13, Creighton:										
Mine sample	3437	2.53	8.98	2.21	2.73	8.25	2.04	.08		
Do	3438	2.93	7.53	1.87						
Car sample	3879	2.65	13.16	2.16	2.65	13.16	2.16		4.91	.12
Pennsylvania No. 15, Wehrum:										
Mine sample	4026	3.83	9.25	4.57	3.33	8.76	3.84	.48		
Do	4027	2.84	8.27	3.11						
Car sample	4082	3.13	9.81	3.77	2.85	10.07	3.87		1.31	.03
Do	4104	2.57	10.33	3.97						
Pennsylvania No. 16, Hastings:										
Mine sample	4028	2.86	6.79	1.42	2.80	7.01	1.46			
Do	4029	2.74	7.23	1.51						
Car sample	4169	4.25	7.87	1.59	4.25	7.87	1.59	1.45	.86	.13
Pennsylvania No. 17, White:										
Mine sample	4336	2.22	7.20	1.39	2.22	7.81	1.46			
Do	4337	2.22	8.42	1.54						
Car sample	4421	4.35	11.90	1.51	4.35	11.90	1.51	2.13	4.09	.05
Pennsylvania No. 18, Lloydell:										
Mine sample	4347	2.43	6.61	1.34	2.54	7.58	2.15			.66
Do	4348	2.66	8.56	2.97						
Car sample	4509	4.46	8.47	1.49	4.46	8.47	1.49	1.92	.89	
Pennsylvania No. 19, Herminie:										
Mine sample	4351	2.81	6.27	.99	2.41	6.29	1.19			.14
Do	4352	2.01	6.32	1.39						
Car sample	4489	3.39	8.36	1.05	3.39	8.36	1.05	.98	2.07	
Pennsylvania No. 20, Seward:										
Mine sample	4349	2.80	7.96	2.29	2.64	8.60	2.66			
Do	4350	2.48	9.24	3.03						
Car sample	4517	4.00	10.54	2.85	4.00	10.54	2.85	1.36	1.94	.19
Pennsylvania No. 21, Connellsville:										
Mine sample	4412	2.82	7.37	1.22	2.61	7.29	1.09			.23
Do	4411	2.40	7.22	.97						
Car sample	4609	5.13	8.71	.86	5.13	8.71	.86	2.52	1.42	
Tennessee No. 1, Fork Ridge:										
Mine sample	2907	3.71	4.74	1.28	3.68	5.78	1.13			
Do	2908	3.66	6.83	.99						
Car sample	3016	4.81	11.15	1.58	4.81	11.15	1.58	1.13	5.37	.45
Tennessee No. 2, Gatliff:										
Mine sample	2931	3.61	3.41	.83	3.40	2.89	.85			
Do	2932	3.19	2.38	.88						
Car sample	3129	5.09	6.81	.98	5.09	6.81	.98	1.69	3.92	.13

TABLE 1.—*Classification of impurities in mine and car samples of run-of-mine coal*—Continued.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Tennessee No. 3, Gatliff:										
Mine sample	2929	4.25	4.13	.93	4.33	3.41	0.86			
Do	2930	4.42	2.70	.80						
Car sample	3040	5.38	7.05	.99	5.38	7.05	.99	1.05	3.64	0.13
Tennessee No. 4, Oliver Springs:										
Mine sample	2956	3.25	6.61	.85	3.18	6.41	.85			
Do	2957	3.12	6.21	.86						
Car sample	3058	6.39	9.53	.98	6.39	9.53	.98	3.21	3.12	.13
Tennessee No. 5, Petros:										
Mine sample	2958	2.25	6.91	2.96	2.22	7.55	3.40			.17
Do	2959	2.20	8.20	3.84						
Car sample	3050	5.59	9.76	3.23	5.59	9.76	3.23	3.37	2.21	
Tennessee No. 6, Waldencia:										
Mine sample	2977	3.80	4.50	.78	3.40	5.33	.93			.15
Do	2978	3.00	6.16	1.08						
Car sample	3102	3.89	14.43	.78	3.89	14.43	.78	.49	9.10	
Tennessee No. 7 A, Wilder:										
Mine sample	2979	3.46	9.08	2.42	3.25	9.60	3.13	.22		
Do	2980	3.04	10.13	3.84						
Car sample	3133	3.03	12.85	3.26	3.03	12.85	3.26		3.25	.13
Tennessee No. 8, Clifty:										
Mine sample	3005	3.01	10.76	3.42	3.12	10.96	3.50	.25		
Do	3006	3.23	11.16	3.58						
Car sample	3127	2.63	13.42	4.38	2.87	13.77	4.56		2.81	1.06
Do	3128	3.12	14.12	4.74						
Texas No. 4, Hoyt Station:										
Mine sample	2635	36.80	6.25	.53	35.83	6.94	.52	1.98		.01
Do	2636	34.87	7.64	.50						
Car sample	2717	33.85	7.30	.51	33.85	7.30	.51		.36	
Virginia No. 1, Crab Orchard:										
Mine sample	2246	4.72	4.63	2.55						
Do	2268	5.69	8.11	2.31	5.65	5.71	1.89	1.30	.84	.74
Do	2269	6.55	4.40	.80						
Car sample	2504	4.64	5.01	1.11	4.35	4.87	1.15			
Do	2420	4.06	4.73	1.20						
Virginia No. 2, Crab Orchard:										
Mine sample	2248	3.90	5.06	.90	5.35	3.49	.79	2.00		
Do	2249	6.80	1.93	.68						
Car sample	2476	3.35	5.58	.92	3.35	5.58	.92		2.09	.13
Virginia No. 6, Richlands:										
Mine sample	4304	3.03	4.62	1.70	2.81	4.55	1.52			.31
Do	4305	2.60	4.48	1.35						
Car sample	4573	5.62	9.79	1.21	5.62	9.79	1.21	2.81	5.24	
Washington No. 1, Renton:										
Mine sample	2455	16.18	8.86	.46	17.07	8.32	.44	2.77		
Do	2456	17.97	7.78	.43						
Car sample	2686	14.30	11.37	.72	14.30	11.37	.72		3.05	.28
West Virginia No. 4 B, Bretz:										
Mine sample	2054	3.57	6.21	.85	3.52	5.69	.82			
Do	2055	3.47	5.18	.80						
Car sample	2250	3.91	10.11	1.07	3.91	10.11	1.07	.39	4.42	.25
West Virginia No. 13, Page:										
Mine sample	1867	5.48	2.29	.79						
Do	1868	2.93	4.95	1.22	3.74	3.88	1.14			.25
Do	2177	2.82	4.41	1.40						
Car sample	2028	3.74	3.91	.89	3.74	3.91	.89		.03	
West Virginia No. 14, Page:										
Mine sample	1869	3.53	2.34	.92						
Do	1870	2.96	7.44	1.04	3.53	5.74	.92		2.47	
Do	2178	4.11	7.45	.80						
Car sample	2004	5.09	3.27	1.03	5.09	3.27	1.03	1.56		.11
West Virginia No. 15, Clarksburg:										
Mine sample	2039	2.80	5.55	2.40	3.03	5.64	2.40	1.02		
Do	2040	3.27	5.74	2.41						
Car sample	2195	2.01	8.55	2.54	2.01	8.55	2.54		2.91	.14
West Virginia No. 17, Bretz:										
Mine sample	2056	3.22	7.33	1.73	3.63	6.46	1.44	.17		
Do	2057	4.05	5.60	1.16						
Car sample	2332	3.46	8.12	1.45	3.46	8.12	1.45		1.66	.01
West Virginia No. 18, Glen Alum:										
Mine sample	2348	2.81	6.50	.66	3.42	5.83	.65	.56		
Do	2349	4.04	5.16	.64						
Car sample	2527	2.86	5.83	.67	2.86	5.83	.67			.02
West Virginia No. 19, Macdonald:										
Mine sample	2359	3.26	2.46	.78	3.38	2.50	.65	.42		
Do	2360	3.51	2.55	.53						
Car sample	2549	2.96	5.01	.89	2.96	5.01	.89		2.51	.24

TABLE 1.—*Classification of impurities in mine and car samples of run-of-mine coal*—Continued.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
West Virginia No. 20, Acme:										
Mine sample	2375	2.66	4.44	1.14	2.75	4.83	1.24	.....	.....	.....
Do	2376	2.84	5.23	1.35						
Car sample	2556	2.82	8.03	1.38	2.85	7.83	1.44	0.10	3.00	0.20
Do	2626	2.89	7.63	1.50						
West Virginia No. 21, Winifrede:										
Mine sample	2377	3.57	3.62	1.14	3.64	3.87	1.15	.07	.....	.....
Do	2378	3.72	4.12	1.16						
Car sample	2572	3.57	4.85	1.32	3.57	4.85	1.32	.....	.98	.17
West Virginia, No. 22 B, Hernshaw:										
Mine sample	3456	2.75	5.49	.63	3.12	5.96	.63	.....	.....	.....
Do	3457	3.49	6.44	.63						
Car sample	3905	3.42	7.82	.83	3.42	7.82	.83	.30	1.86	.20
West Virginia No. 23 A, Monarch:										
Mine sample	3458	3.13	3.54	.59	3.65	4.92	.91	1.60	.....	.....
Do	3459	4.17	6.30	1.24						
Car sample	3965	2.05	8.10	1.35	2.05	8.10	1.35	.....	3.18	.44
Wyoming No. 2 B, Cambria:										
Mine sample	1376	8.60	21.90	4.94	8.91	21.43	4.63	.....	.64	.60
Do	1377	9.23	20.97	4.33						
Car sample	2131	8.93	20.79	4.03	8.93	20.79	4.03	.02	.....	.....
Wyoming No. 3, Aladdin:										
Mine sample	1976	17.74	11.55	7.03	18.08	10.82	6.88	2.96	.....	.22
Do	1977	18.42	10.10	6.73						
Car sample	2278	15.12	16.70	6.66	15.12	16.70	6.66	.....	5.88	.....
Wyoming No. 4, Hanna:										
Mine sample	3160	12.32	5.19	.23	12.05	5.13	.29	.75	.....	.01
Do	3161	12.66	3.88	.21						
Do	3162	11.49	5.89	.44						
Do	3163	11.73	5.57	.29						
Car sample	3363	11.30	7.31	.28	11.30	7.31	.28	.....	2.18	.....
Wyoming No. 5, Rock Springs:										
Mine sample	3165	13.10	3.34	1.04	12.75	2.93	.92	1.11	.....	.11
Do	3164	12.41	2.52	.80						
Car sample	3213	11.64	3.41	.81	11.64	3.41	.81	.....	.48	.....
Wyoming No. 6, Kemmerer:										
Mine sample	3202	20.57	2.63	.51	20.72	2.59	.52	1.72	.....	.03
Do	3203	20.88	2.56	.54						
Car sample	3390	19.00	3.12	.49	19.00	3.12	.49	.....	.53	.....
Average, mine samples	.....	.....	.....	.....	8.01	7.54	2.04	1.01	1.08	.24
Average, car samples	.....	.....	.....	.....	7.92	10.21	2.16	1.17	2.98	.28
Number of mine samples	.....	.....	.....	.....	87	87	87	50	6	28
Number of car samples	.....	.....	.....	.....	87	87	87	36	80	59

TABLE 2.—*Classification of impurities in mine and car samples of screened coal.*

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Arkansas No. 7 A, Midland (lump):										
Mine sample	2593	3.97	5.91	1.53	4.67	7.37	2.36	.....	.....	0.34
Do	2594	5.38	8.84	3.20						
Car sample	2688	5.47	11.69	2.02	5.47	11.69	2.02	0.80	4.32	.....
Arkansas No. 8, Spadra (No. 4):										
Mine sample	2587	3.12	8.46	1.84	2.92	8.41	2.31	.....	.....	.26
Do	2588	2.72	8.37	2.78						
Car sample	2744	5.19	14.01	2.05	5.19	14.01	2.05	2.27	5.60	.....
Georgia No. 1, Menlo (lump):										
Mine sample	4155	2.40	9.34	1.12	2.62	8.59	.89	.....	.....	.....
Do	4156	2.85	7.84	.67						
Car sample	4320	3.80	14.49	1.27	3.80	14.49	1.27	1.18	5.90	.38
Illinois No. 7 B, Collinsville (nut):										
Mine sample	1608	12.27	11.35	4.66	12.07	11.46	4.70	.61	.....	.30
Do	1609	11.87	11.58	4.75						
Car sample	1611	11.46	17.31	4.40	11.46	17.31	4.40	.....	5.85	.....
Illinois No. 9 B, Staunton (lump):										
Mine sample	1625	13.29	8.90	4.12	14.28	9.05	3.91	.56	.....	.....
Do	1626	15.27	9.20	3.70						
Car sample	1639	13.72	10.32	3.96	13.72	10.32	3.96	.....	1.27	.05

TABLE 2.—*Classification of impurities in mine and car samples of screened coal*—Con.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Illinois No. 11 A, Carterville (egg):										
Mine sample	1634	8.30	9.26	2.82	8.30	9.26	2.82	0.54	......	0.85
Car sample	1654	7.76	10.61	1.97	7.76	10.61	1.97	......	1.35	......
Illinois No. 13, Benton (egg):										
Mine sample	1695	10.28	7.94	1.06	9.87	8.03	1.34	1.56	......	......
Do	1694	9.46	8.12	1.63						
Car sample	1786	8.31	10.48	1.55	8.31	10.48	1.55	......	2.45	.21
Illinois No. 14, Springfield (lump):										
Mine sample	1704	13.89	11.26	3.83	14.17	10.96	3.64	1.40	......	......
Do	1705	14.45	10.66	3.46						
Car sample	1740	12.77	11.78	4.16	12.77	11.78	4.16	......	.82	.52
Illinois No. 15, Centralia (lump):										
Mine sample	1725	10.25	12.53	3.70	11.06	10.68	3.47	1.11	......	......
Do	1726	11.88	8.83	3.25						
Car sample	1761	9.95	13.23	3.87	9.95	13.23	3.87	......	2.55	.40
Illinois No. 16, Herrin (lump and egg):										
Mine sample	1731	9.37	7.37	1.25	8.98	7.17	1.51	.55	......	.37
Do	1732	8.59	6.97	1.78						
Car sample	1820	8.43	9.60	1.14	8.43	9.60	1.14	......	2.43	......
Illinois No. 18, La Salle (lump):										
Mine sample	1741	13.87	10.31	3.44	14.71	8.94	3.22	2.32	.02	......
Do	1742	15.55	7.58	3.01						
Car sample	1779	12.39	8.92	3.92	12.39	8.92	3.92	......	......	.70
Illinois No. 19 A, Zeigler (lump):										
Mine sample	1871	9.90	7.74	.48	10.21	7.57	.47	......	......	......
Do	1872	10.53	7.40	.47						
Car sample	1926	14.91	8.93	.52	14.91	8.93	.52	4.70	1.36	.05
Illinois No. 19 B, Zeigler (lump):										
Mine sample	1871	9.90	7.74	.48	10.21	7.57	.47	......	......	......
Do	1872	10.53	7.40	.47						
Car sample	2020	10.72	9.36	.91	10.72	9.36	.91	.51	1.79	.44
Illinois No. 19 D, Zeigler (lump):										
Mine sample	1871	9.90	7.74	.48	10.21	7.57	.47	1.34	......	......
Do	1872	10.53	7.40	.47						
Car sample	3448	9.45	9.07	.60	8.87	9.82	.56	......	2.25	.09
Do	3451	8.30	10.57	.52						
Illinois No. 21, Troy (lump):										
Mine sample	2770	15.23	9.03	1.59	16.51	10.06	1.49	1.28	......	.26
Do	2771	17.79	11.09	1.40						
Car sample	2852	15.54	10.93	1.38	15.23	11.21	1.23	......	1.15	......
Do	3015	14.92	11.49	1.09						
Illinois No. 22 A, Maryville (lump):										
Mine sample	2772	13.51	10.15	4.01	13.67	9.96	4.05	1.76	......	......
Do	2773	13.83	9.77	4.10						
Car sample	2905	11.91	13.01	5.34	11.91	13.01	5.34	......	3.05	1.29
Illinois No. 22 B, Maryville (nut, pea, and slack):										
Mine sample	2772	13.51	10.15	4.01	13.67	9.96	4.06	.64	......	......
Do	2773	13.83	9.77	4.10						
Car sample	2896	13.03	14.53	4.35	13.03	14.53	4.35	......	4.57	.29
Illinois No. 23 A, Donkville (lump):										
Mine sample	2774	13.07	10.06	3.59	12.92	10.67	3.76	......	......	......
Do	2775	12.79	11.29	3.94						
Car sample	2819	13.47	11.53	4.41	13.47	11.53	4.41	.55	.86	.65
Illinois No. 23 B, Donkville (screenings):										
Mine sample	2774	13.07	10.06	3.59	12.93	10.67	3.76	......	......	......
Do	2775	12.79	11.29	3.94						
Car sample	2803	15.68	15.59	3.98	15.68	15.59	3.98	2.75	4.92	.22
Illinois No. 24 B, New Baden (lump):										
Mine sample	2854	13.43	9.18	3.35	13.08	9.39	3.47	1.64	......	......
Do	2855	12.73	9.60	3.60						
Car sample	2972	11.44	10.71	4.94	11.44	10.71	4.94	......	1.32	1.47
Illinois No. 28 B, Herrin (screenings):										
Mine sample	3629	8.72	7.62	1.00	8.80	7.82	.99	2.99	......	......
Do	3632	8.88	8.03	.99						
Car sample	2141	5.81	10.92	2.03	5.81	10.92	2.03	......	3.10	1.04
Illinois No. 28 C, Herrin (lump):										
Mine sample	3629	8.72	7.62	1.00	8.80	7.82	.99	1.02	......	......
Do	3632	8.88	8.03	.99						
Car sample	3789	7.78	9.98	1.32	7.78	9.98	1.32	......	2.16	.33
Illinois No. 29 A, Livingston (screenings):										
Mine sample	3911	14.25	9.44	3.72	13.47	9.20	3.67	.37	......	......
Do	3913	12.69	8.76	3.62						
Car sample	3963	13.10	16.00	4.17	13.10	16.00	4.17	......	6.80	.50

TABLE 2.—*Classification of impurities in mine and car samples of screened coal*—Con.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Illinois No. 30, Shiloh Station (nut):										
Mine sample	3910	10.73	9.26	4.12	10.30	10.03	3.97	......	......	......
Do	3912	9.88	10.81	3.83						
Car sample	4364	11.69	13.19	4.38	11.69	13.19	4.38	1.39	3.16	0.41
Illinois No. 31, Worden (screenings):										
Mine sample	4251	14.38	8.75	3.13	13.77	9.52	3.17	.67	......	......
Do	4250	13.17	10.29	3.22						
Car sample	4376	13.10	13.25	3.66	13.10	13.25	3.66	......	3.73	.49
Illinois No. 34 A, Harrisburg (screenings):										
Mine sample	4413	7.55	7.15	1.56	7.53	7.31	1.57	......	......	......
Do	4414	7.51	7.48	1.58						
Car sample	4636	9.33	11.89	2.76	9.33	11.89	2.76	1.80	4.58	1.19
Indiana No. 3, Boonville (nut):										
Mine sample	1759	11.28	7.63	3.58	11.19	8.65	3.95	......	......	......
Do	1760	11.10	9.68	4.33						
Car sample	1941	13.18	15.63	4.79	13.18	15.63	4.79	1.99	6.98	.84
Indiana No. 4, Star City (screenings):										
Mine sample	1775	14.86	7.35	2.26	14.11	7.38	2.18	.12	......	......
Do	1807	13.37	7.42	2.10						
Car sample	1844	13.99	14.32	2.31	13.99	14.32	2.31	......	6.94	.13
Indiana No. 7 A, Littles (lump, egg, and nut):										
Mine sample	1824	10.18	8.12	3.96	10.08	8.05	3.60	1.18	......	......
Do	1825	9.99	7.97	3.25						
Car sample	1881	8.90	9.21	3.74	8.90	9.21	3.74	......	1.16	.14
Indiana No. 7 B, Littles (screenings):										
Mine sample	1824	10.18	8.12	3.96	10.08	8.05	3.60	......	......	......
Do	1825	9.99	7.97	3.25						
Car sample	1882	11.12	9.35	3.78	11.12	9.35	3.78	1.04	1.30	.18
Indiana No. 8, West Terre Haute (lump):										
Mine sample	1828	10.68	12.24	4.38	10.90	11.22	4.07	1.35	.61	.35
Do	1829	11.13	10.21	3.76						
Car sample	2037	9.55	10.61	3.72	9.55	10.61	3.72	......	......	......
Indiana No. 9 A, Mocksville (lump):										
Mine sample	1848	13.73	8.65	3.00	14.03	8.56	2.85	1.21	......	......
Do	1849	14.33	8.47	2.70						
Car sample	1973	12.82	10.30	3.27	12.82	10.30	3.27	......	1.74	.42
Indiana No. 10, Rosedale (lump):										
Mine sample	1853	11.54	9.62	4.41	11.90	8.97	4.56	1.18	.40	.73
Do	1854	12.26	8.32	4.71						
Car sample	1979	10.72	8.57	3.83	10.72	8.57	3.83	......	......	......
Indiana No. 11, Dugger (lump):										
Mine sample	1883	14.23	5.72	.89	13.42	6.35	1.62	1.27	......	.21
Do	1884	12.62	6.98	2.35						
Car sample	2087	12.15	8.14	1.41	12.15	8.14	1.41	......	1.79	......
Indiana No. 18 B, Winslow (lump):										
Mine sample	3525	12.88	6.14	1.70	13.35	6.08	1.55	2.22	......	......
Do	3526	13.83	6.02	1.41						
Car sample	3801	11.13	6.98	1.64	11.13	6.98	1.64	......	.90	.09
Indiana No. 19 Diamond (screenings):										
Mine sample	3534	13.70	5.91	2.66	13.82	5.49	2.29	4.73	......	......
Do	3535	13.93	5.07	1.93						
Car sample	4230	9.09	15.60	3.04	9.09	15.60	3.04	......	10.11	.75
Indiana No. 20, Perth (screenings):										
Mine sample	3536	15.38	5.88	1.95	15.64	5.36	1.58	......	......	......
Do	3537	15.91	4.85	1.22						
Car sample	3979	16.91	17.37	1.89	16.91	17.37	1.89	1.27	12.01	.31
Indian Territory No. 2 C, Hartshorne (lump):										
Mine sample	1071	1.46	6.40	1.38	1.38	7.03	1.48	......	......	......
Do	1073	1.30	7.65	1.58						
Car sample	3406	2.81	8.75	1.82	2.81	8.75	1.82	1.43	1.72	.34
Kansas No. 6, Jewett (lump):										
Mine sample	2790	11.13	12.60	2.41	10.62	12.70	2.53	1.58	......	......
Do	2791	10.12	12.81	2.66						
Car sample	2843	9.04	15.72	3.72	9.04	15.72	3.72	......	3.02	1.19
Kentucky No. 1 B, Straight Creek (lump):										
Mine sample	2350	3.42	3.18	1.53	3.34	3.06	1.22	.73	......	.34
Do	2351	3.25	2.93	.91						
Car sample	2517	2.61	3.37	.88	2.61	3.37	.88	......	.31	......

TABLE 2.—*Classification of impurities in mine and car samples of screened coal*—Con.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Kentucky No. 1 C, Straight Creek (nut):										
Mine sample	2350	3.42	3.18	1.53	3.34	3.05	1.22	......	......	.10
Do	2351	3.25	2.93	.91						
Car sample	2445	5.21	8.22	1.12	5.21	8.22	1.12	1.87	5.17	......
Kentucky No. 7, Central City (lump and egg):										
Mine sample	2453	8.76	9.42	4.07	8.75	10.09	3.88	.28	.61	.28
Do	2454	8.75	10.77	3.69						
Car sample	2595	8.47	9.48	3.60	8.47	9.48	3.60	......	......	......
Kentucky No. 9 A, McHenry (nut):										
Mine sample	3722	10.03	7.67	2.56	9.96	8.18	2.50	1.26	......	......
Do	3723	9.89	8.69	2.45						
Car sample	3865	8.70	8.96	3.14	8.70	8.96	3.14	......	.78	.64
Missouri No. 6, Huntsville (lump):										
Mine sample	2817	14.01	10.29	5.23	12.69	9.37	4.40	......	......	......
Do	2818	11.38	8.45	3.57						
Car sample	2904	13.80	11.74	5.60	13.80	11.74	5.60	1.11	2.37	1.20
Missouri No. 7 A, Nouinger (nut):										
Mine sample	2823	17.19	9.28	2.76	16.69	10.98	2.89	.33	......	......
Do	2824	16.19	12.69	3.03						
Car sample	2936	16.36	19.51	3.53	16.36	19.51	3.53	......	8.53	.64
Missouri No. 7 B, Nouinger (nut):										
Mine sample	2823	17.19	9.28	2.76	16.69	10.98	2.89	.30	......	......
Do	2824	16.19	12.69	3.03						
Car sample	2937	16.39	20.18	3.12	16.39	20.18	3.12	......	9.20	.23
Missouri No. 7 C, Nouinger (screenings):										
Mine sample	2823	17.19	9.28	2.76	16.69	10.98	2.89	......	......	......
Do	2824	16.19	12.69	3.03						
Car sample	2942	17.30	23.38	2.94	17.30	23.38	2.94	.61	12.40	.05
New Mexico No. 3 C, Van Houten (lump):										
Mine sample	3221	2.50	9.13	.72	2.99	11.02	.68	.24	......	.04
Do	3222	3.48	12.92	.64						
Car sample	3308	2.75	15.52	.64	2.75	15.52	.64	......	4.50	......
New Mexico No. 4 B, Brilliant (screenings):										
Mine sample	3228	2.19	11.11	.57	2.43	10.46	.57	......	......	......
Do	3229	2.67	9.82	.58						
Car sample	3315	3.38	13.54	.61	3.38	13.54	.61	.95	3.08	.04
Ohio No. 4, Bradley (lump):										
Mine sample	1910	4.06	7.75	3.67	4.13	7.63	3.44	.60	......	......
Do	1911	4.20	7.51	3.22						
Car sample	2083	3.53	9.12	3.47	3.53	9.12	3.47	......	1.49	.03
Ohio No. 5, Rush Run (lump):										
Mine sample	1944	4.69	6.01	1.54	4.84	5.85	1.24	.50	......	......
Do	1945	4.99	5.70	.95						
Car sample	2062	4.34	7.30	1.72	4.34	7.30	1.72	......	1.45	.48
Ohio No. 7, Danford (lump):										
Mine sample	2090	6.28	7.30	3.55	6.04	6.94	3.08	......	......	......
Do	2091	5.80	6.58	2.62						
Car sample	2656	6.65	10.55	3.13	6.65	10.55	3.13	.61	3.61	.05
Ohio No. 9 A, Clarion (lump):										
Mine sample	2208	6.79	7.66	3.34	7.08	6.91	3.05	1.49	......	......
Do	2209	7.38	6.16	2.77						
Car sample	2310	5.59	8.29	3.15	5.59	8.29	3.15	......	1.38	.10
Ohio No. 9 B, Clarion (screenings):										
Mine sample	2208	6.79	7.66	3.34	7.08	6.91	3.05	......	......	......
Do	2209	7.38	6.16	2.77						
Car sample	2311	8.10	11.93	3.35	8.10	11.93	3.35	1.02	5.02	.30
Ohio No. 10, Mineral City (lump):										
Mine sample	3968	5.61	8.72	2.89	5.03	8.63	3.31	.54	1.10	.38
Do	3969	4.46	8.54	3.73						
Car sample	4059	4.49	7.53	2.93	4.49	7.53	2.93	......	......	......
Ohio No. 11, Flushing (lump):										
Mine sample	3985	3.96	9.04	4.25	4.05	8.50	4.18	.61	......	......
Do	3986	4.13	7.96	4.12						
Car sample	4157	3.44	12.94	4.32	3.44	12.94	4.32	......	4.44	.14
Pennsylvania No. 4, Greensburg (lump):										
Mine sample	1942	2.73	9.13	1.33	2.76	8.60	1.08	......	......	......
Do	1943	2.80	8.07	.83						
Car sample	2187	3.15	10.41	1.26	3.15	10.41	1.26	.39	1.81	.18
Pennsylvania No. 5, Ellsworth (lump):										
Mine sample	1966	3.01	4.83	.73	2.96	5.11	.90	.50	......	.02
Do	1967	2.91	5.40	1.08						
Car sample	2068	2.46	6.05	.88	2.46	6.05	.88	......	.94	......

TABLE 2.—*Classification of impurities in mine and car samples of screened coal*—Con.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Pennsylvania No. 10, Bruce (lump):										
Mine sample	2080	3.67	5.46	1.37	3.87	5.39	1.34	1.26	......	.08
Do	2081	4.08	5.32	1.31						
Car sample	2229	2.61	6.17	1.26	2.61	6.17	1.26	......	.78	......
Tennessee No. 9 A, Coalmont (lump):										
Mine sample	2995	3.44	9.21	.73	3.60	8.69	.71	......	......	......
Do	2996	3.77	8.17	.68						
Car sample	3113	3.92	14.09	.94	3.92	14.09	.94	.32	5.40	.23
Texas No. 3, Olsen (lump):										
Mine sample	2562	36.01	7.38	.77	35.78	7.71	.76	4.72	......	......
Do	2563	35.56	8.04	.75						
Car sample	2734	31.06	7.88	.99	31.06	7.88	.99	......	.17	.23
Virginia No. 3, Toms Creek (lump):										
Mine sample	2281	2.70	4.49	.52	2.80	4.31	.53	......	......	......
Do	2282	2.91	4.13	.55						
Car sample	2382	3.05	4.48	.67	3.05	4.48	.67	.25	.17	.14
Virginia No. 4, Darby (lump):										
Mine sample	2323	3.89	3.06	.34	3.72	2.78	.42	......	......	......
Do	2324	3.55	2.51	.50						
Car sample	2358	4.35	4.33	.79	4.35	4.33	.79	.63	1.55	.37
West Virginia No. 16 A, Monongah (lump):										
Mine sample	2041	2.89	5.71	.69	2.78	5.64	.87	......	......	......
Do	2042	2.68	5.57	1.06						
Car sample	2808	4.12	8.00	1.17	4.12	8.00	1.17	1.34	2.36	.30
West Virginia No. 22 A, Hernshaw (nut):										
Mine sample	3456	2.75	5.49	.63	3.12	5.96	.63	......	......	......
Do	3457	3.49	6.44	.63						
Car sample	3711	4.59	9.80	1.01	4.59	9.80	1.01	1.47	3.84	.38
West Virginia No. 23 B, Monarch (nut):										
Mine sample	3458	3.13	3.54	.59	3.65	4.92	.91	.40	......	......
Do	3459	4.17	6.30	1.24						
Car sample	3625	3.25	7.58	1.22	3.25	7.58	1.22	......	2.66	.31
West Virginia No. 25, Charleston (lump):										
Mine sample	4290	3.46	8.20	.58	3.68	7.49	.61	......	.27	......
Do	4291	3.91	6.78	.64						
Car sample	4360	4.21	7.22	.64	4.21	7.22	.64	.53	......	.03
Average, mine samples	......	......	......	......	9.41	8.14	2.32	1.19	.50	.31
Average, car samples	......	......	......	......	9.17	11.20	2.57	1.26	3.42	.42
Number of mine samples	......	......	......	......	67	67	67	41	6	16
Number of car samples	......	......	......	......	67	67	67	26	61	51

TABLE 3.—*Classification of impurities in mine and car samples of slack coal.*

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Arkansas No. 1 B, Huntington:										
Mine sample	2585	3.53	7.77	1.29	3.76	7.45	1.30	......	......	0.24
Do	2586	4.00	7.14	1.32						
Car sample	2689	7.49	17.97	1.06	7.49	17.97	1.06	3.73	10.52	......
Arkansas No. 9, Bonanza:										
Mine sample	2599	1.99	7.06	1.05	2.05	6.88	1.41	......	......	.41
Do	2600	2.12	6.70	1.78						
Car sample	2690	5.26	24.81	1.00	5.26	24.81	1.00	3.21	17.93	......
Illinois No. 7 C, Collinsville:										
Mine sample	1608	12.27	11.35	4.66	12.07	11.46	4.70	1.53	......	.52
Do	1609	11.87	11.58	4.75						
Car sample	......	10.54	25.30	4.18	10.54	25.30	4.18	......	13.84	......
Illinois No. 9 C, Staunton:										
Mine sample	1625	13.29	8.90	4.12	14.28	9.05	3.91	......	......	.10
Do	1626	15.27	9.20	3.70						
Car sample	4247	15.25	15.35	3.81	15.25	15.35	3.81	.97	6.30	......
Indiana No. 18 A, Winslow:										
Mine sample	3525	12.88	6.14	1.70	13.35	6.08	1.55	......	......	.07
Do	3526	13.83	6.02	1.41						
Car sample	3747	15.09	7.43	1.48	15.09	7.43	1.48	1.74	1.35	......

TABLE 3.—*Classification of impurities in mine and car samples of slack coal*—Con.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Indian Territory No. 2 B, Hartshorne:										
Mine sample	1071	1.46	6.40	1.38	1.38	7.02	1.48	......	......	......
Do	1073	1.30	7.65	1.58						
Car sample	3405	6.27	14.29	1.79	6.27	14.29	1.79	4.89	7.27	.31
Kansas No. 2 B, Yale:										
Mine sample	1017	2.44	10.60	5.63	2.40	11.19	5.75	......	......	1.05
Do	1019	2.36	11.79	5.88						
Car sample	4361	8.01	20.38	4.70	8.01	20.38	4.70	5.61	9.19	......
Missouri No. 10, Bevier:										
Mine sample	4196	15.26	8.70	4.37	15.33	10.15	4.07	.10	......	.38
Do	4197	15.41	11.61	3.78						
Car sample	4257	15.23	20.50	3.69	15.23	20.50	3.69	......	10.35	......
New Mexico No. 3 B, Van Houten:										
Mine sample	3221	2.50	9.13	.72	2.99	11.02	.68	......	......	......
Do	3222	3.48	12.92	.64						
Car sample	3307	4.36	15.92	.83	4.36	15.92	.83	1.37	4.90	.15
Tennessee No. 7 B, Wilder:										
Mine sample	2979	3.46	9.08	2.42	3.25	9.60	3.13	......	......	1.04
Do	2980	3.04	10.13	3.84						
Car sample	3425	3.37	10.06	2.09	3.37	10.06	2.09	.12	.46	......
Tennessee No. 9 B, Coalmont:										
Mine sample	2995	3.44	9.21	.73	3.60	8.69	.70	......	......	......
Do	2996	3.77	8.17	.68						
Car sample	3114	5.68	18.55	.74	5.68	8.55	.74	......	......	......
Do	......	......	......	......	......	......	......	2.08	9.86	.04
Utah No. 2, Coalville:										
Mine sample	3200	14.07	6.26	1.28	13.96	5.76	1.30	1.30	......	......
Do	3201	13.86	5.26	1.32						
Car sample	3259	12.66	5.85	1.39	12.66	5.85	1.39	......	.09	.09
Virginia No. 5 A, Blacksburg:										
Mine sample	4092	3.51	17.64	.84	3.24	19.79	.76	......	1.76	.13
Do	4093	2.98	21.94	.68						
Car sample	4287	4.80	18.03	.63	4.80	18.03	.63	1.56	......	......
Virginia No. 5 B, Blacksburg:										
Mine sample	4092	3.51	17.64	.84	3.24	19.79	.76	......	3.56	.11
Do	4093	2.98	21.94	.68						
Car sample	4294	7.52	16.23	.65	7.52	16.23	.65	4.28	......	......
West Virginia No. 16 B, Monongah:										
Mine sample	2041	2.89	5.71	.69	2.78	5.64	.87	......	......	......
Do	2042	2.68	5 57	1.06						
Car sample	2264	5.57	8.37	1.20	5.57	8.37	1.20	2.79	2 73	.33
Average, mine samples	......	......	......	......	6.51	9.97	2.16	.98	2.66	.41
Average, car samples	......	......	......	......	8.47	15.94	1.95	2.70	7.29	.18
Number of mine samples	......	......	......	......	15	15	15	3	2	10
Number of car samples	......	......	......	......	15	15	15	12	13	5

MOISTURE.

MOISTURE IN RUN-OF-MINE COAL.

An examination of Table 1 shows a slight excess of moisture in the general average of the mine samples over that of the car samples, these averages being 8.01 and 7.92, respectively. In the entire lot of 87 coals sampled, 36, or 41.4 per cent, show an excess of moisture in the car samples, and 50, or 57.5 per cent, show an excess in the mine samples. One coal, equal to 1.1 per cent of the whole, showed an equal amount of moisture in the average mine and car samples. This coal is West Virginia No. 13, one of the low-moisture coals of the Kanawha River district. The equality in moisture content of both kinds of samples is of course purely accidental. Of the 50 samples collected during the exposition, 26, or 52 per cent, showed an excess of moisture in the car samples, and 24, or 48 per cent, showed an excess in the mine samples. On comparing the results of both periods, it is seen that in the exposition work the results very nearly balance, a slight majority of the car samples containing a greater amount of moisture than the mine samples. In the sampling work which followed, when the mine samples were being pulverized in the mine, this condition was reversed, more moisture being found in the mine samples than in the car samples.

A further examination of the table of run-of-mine samples shows that the greatest excess of moisture found in the car samples was 3.37 per cent, in Tennessee No. 5; that 0.02 per cent, in Wyoming No. 2 B, represented the smallest excess; and that the average excess for the whole was 1.17 per cent. The average for the work done in 1904 was 1.35 per cent, showing that there has been some improvement in reducing the excess of moisture in the car sample over that in the mine sample.

The greatest excess of moisture in the mine samples is in North Dakota No. 3, which shows 5.24 per cent more in the average mine sample than in the car sample. The smallest difference, 0.07 per cent, is in West Virginia No. 21. The average, 1.01 per cent for the entire lot of mine samples containing more moisture than the car samples, is practically the same as the average of 1.11 per cent obtained in 1904.

In order to compare these results further and arrive at a definite coefficient for correcting the moisture of the mine samples, the results have been arranged in two tables according to the actual amount of moisture contained in the average mine samples. Table 4 is made up of samples having a moisture content of less than 5 per cent; Table 5 comprises those having a moisture content of more than 5 per cent.

Of the 87 coals sampled as run-of-mine coal five (Arkansas No. 10, California No. 1, North Dakota No. 3, Texas No. 4, and Wyoming No. 6) are lignites and on account of the high moisture content, affecting the whole analysis, have been omitted from the tables.

TABLE 4.—*Coals containing less than 5 per cent of moisture in the average mine samples, exclusive of lignites.*

Coal.	Average per cent of moisture in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples.
Alabama No. 2 B	4.61	3.95	0.66	....
Alabama No. 3	3.14	2.72	.42	....
Alabama No. 4	3.63	6.43	....	2.80
Alabama No. 5	3.82	5.59	....	1.77
Alabama No. 6	3.02	3.39	....	.37
Kentucky No. 5	4.49	4.36	.13	....
Maryland No. 1	2.96	2.33	.63	....
Maryland No. 2	2.50	3.42	....	.92
New Mexico No. 3 A	2.98	3.45	....	.47
New Mexico No. 4 A	2.43	2.78	....	.35
New Mexico No. 5	2.28	2.72	....	.44
Ohio No. 6	4.02	5.31	....	1.29
Ohio No. 12	3.21	3.55	....	.34
Pennsylvania No. 6	3.44	3.35	.09	....

TABLE 4.—*Coals containing less than 5 per cent of moisture in the average mine samples, exclusive of lignites*—Continued.

Coal.	Average per cent of moisture in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples.
Pennsylvania No. 7	3.04	4.09	....	1.05
Pennsylvania No. 8	3.29	3.51	....	.22
Pennsylvania No. 9	3.26	3.09	.17	....
Pennsylvania No. 11	2.53	1.95	.58	....
Pennsylvania No. 12	2.90	1.96	.94	....
Pennsylvania No. 13	2.73	2.65	.08	....
Pennsylvania No. 15	3.33	2.85	.48	....
Pennsylvania No. 16	2.80	4.25	....	1.45
Pennsylvania No. 17	2.22	4.35	....	2.13
Pennsylvania No. 18	2.54	4.46	....	1.92
Pennsylvania No. 19	2.41	3.39	....	.98
Pennsylvania No. 20	2.64	4.00	....	1.36
Pennsylvania No. 21	2.61	5.13	....	2.52
Tennessee No. 1	3.68	4.81	....	1.13
Tennessee No. 2	3.40	5.09	....	1.69
Tennessee No. 3	4.33	5.38	....	1.05
Tennessee No. 4	3.18	6.39	....	3.21
Tennessee No. 5	2.22	5.59	....	3.37
Tennessee No. 6	3.40	3.89	....	.49
Tennessee No. 7A	3.25	3.03	.22	....
Tennessee No. 8	3.12	2.87	.25	....
Virginia No. 6	2.81	5.62	....	2.81
West Virginia No. 4 B	3.52	3.91	....	.39
West Virginia No. 13	3.74	3.74	....	....
West Virginia No. 14	3.53	5.09	....	1.56
West Virginia No. 15	3.03	2.01	1.02	....
West Virginia No. 17	3.63	3.46	.17	....
West Virginia No. 18	3.42	2.86	.56	....
West Virginia No. 19	3.38	2.96	.42	....
West Virginia No. 20	2.75	2.85	....	.10
West Virginia No. 21	3.64	3.57	.07	....
West Virginia No. 22 B	3.12	3.42	....	.30
West Virginia No. 23 A	3.65	2.05	1.60	....
Average	3.18	3.78	.47	1.30
Number of samples	47	47	18	28

Table 4 comprises 47 coals having a moisture content of less than 5 per cent in the average mine samples. Of these 47 coals, 18, or 38 per cent, show an excess in the mine samples, and 28, or 60 per cent, show an excess in the car samples. In one sample the moisture is equal in both car and mine samples. Comparing this table with the general table of run-of-mine samples (Table 1), we see that conditions are reversed, and that the conclusions drawn from the general table do not apply to these selected samples. In the general table the average excess in the mine samples is 1.01 per cent, as compared to 0.47 per cent in the coals having less than 5 per cent of moisture in the mine samples. In the general table the average excess in the car samples is 1.17 per cent, as compared to 1.30 per cent in Table 4. The average moisture in the mine samples containing less than 5 per cent is 3.18 per cent, and the average in the corresponding car samples is 3.78 per cent. If we divide the average in the car samples by the average in the mine samples we get a coefficient for correcting the moisture in mine samples containing less than 5 per cent to approximately the moisture that might be expected in commercial run-of-mine coal. This result is $3.78 \div 3.18 = 1.19$. It will, however, be safe to use this coefficient only when the coal is dry, and when it is certain that no great amount of moisture has been added from outside sources, such as wet places in the mine, rain, etc.

The coals which do not appear in Table 4—that is, those containing more than 5 per cent of moisture in the average mine sample—have been arranged in Table 5.

TABLE 5.—*Coals containing more than 5 per cent of moisture in the average mine samples, exclusive of lignites.*

Coal.	Average per cent of moisture in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples
Illinois No. 6 B	12.90	11.93	0.97	
Illinois No. 7 D	12.07	10.86	1.21	
Illinois No. 9 A	14.28	13.54	.74	
Illinois No. 11 B	8.30	8.86		0.56
Illinois No. 12	8.35	8.20	.15	
Illinois No. 19 C	10.03	9.58	.45	
Illinois No. 25 A	11.89	11.35	.54	
Illinois No. 26	15.14	15.68		.54
Illinois No. 27	14.23	16.00		1.77
Illinois No. 29 B	13.47	12.47	1.00	
Illinois No. 34 B	7.53	7.81		.28
Indiana No. 5	12.15	12.03	.12	
Indiana No. 6	9.83	10.80		.97
Indiana No. 9 B	14.03	13.53	.50	
Indiana No. 12	11.19	10.57	.62	
Indiana No. 13	13.65	12.79	.86	
Indiana No. 14	12.54	7.88	4.66	
Indiana No. 15	13.75	13.58	.17	
Indiana No. 16	10.85	10.30	.55	
Indiana No. 17	11.23	12.08		.85
Kentucky No. 6	6.73	5.12	1.61	
Kentucky No. 8	7.77	5.46	2.31	
Kentucky No. 9 B	9.96	8.04	1.92	
Missouri No. 5	13.63	12.92	.71	
Ohio No. 1	7.97	7.71	.26	
Ohio No. 2	9.16	9.01	.15	
Ohio No. 3	10.27	9.90	.37	
Ohio No. 8	8.89	7.55	1.34	
Virginia No. 1	5.65	4.35	1.30	
Virginia No. 2	5.35	3.35	2.00	
Washington No. 1	17.07	14.30	2.77	
Wyoming No. 2 B	8.91	8.93		.02
Wyoming No. 3	18.08	15.12	2.96	
Wyoming No. 4	12.05	11.30	.75	
Wyoming No. 5	12.75	11.64	1.11	
Average	11.19	10.42	1.15	.71
Number of samples	35	35	28	7

The 35 coals listed in Table 5 contain from 5.35 per cent moisture in Virginia No. 2 to 18.08 per cent in Wyoming No. 3. Of these, 28, or 80 per cent, contain more moisture in the mine samples than in the car samples, and 7, or 20 per cent, contain more moisture in the car samples than in the mine samples. The average excess in the mine samples is 1.15 and the average excess in the car samples is 0.71. The average moisture in the mine samples is 11.19 per cent and in the car samples 10.42 per cent. The coefficient for correcting the moisture in mine samples containing more than 5 per cent so that they will represent commercial run-of-mine coal is $10.42 \div 11.19 = 0.93$. In other words, when coals containing more than 5 per cent of moisture are sampled in the mine by the prescribed method, the moisture to be expected in commercial run-of-mine coal can be found by multiplying the moisture content of the sample as determined by analysis by 0.93.

MOISTURE IN SCREENED COAL.

Table 2 gives a complete list of samples of screened coal received at the fuel-testing plant. By screened coal is meant all coal that has been sized at the mine, and is neither run-of-mine nor slack nor fine coal. This includes lump, nut, egg, and various special sizes, as Nos. 1, 2, 3, etc. There are 67 of these coals on which to base conclusions; 41 show an excess of moisture in the mine samples, and 26 an excess in the car samples. Expressing these figures in percentages, we find 38.8 per cent of the coals with an excess in the car samples, and 61.2 per cent with an excess in the mine samples. The moisture in the mine sample ranges from 35.78 per cent in a Texas lignite down to 1.38 per cent in Indian Territory No. 2; the moisture in the car samples ranges from 31.06 per cent in the same Texas lignite down to 2.46 per cent in Pennsylvania No. 5. The average moisture in all the mine samples in the table is 9.41 per cent, and the average in the car samples is 9.17 per cent. The average excess in the mine samples is 1.19 per cent, and the average excess in the car samples is 1.26 per cent. These figures very nearly balance, so that from the evidence at hand the moisture in mine samples can be considered to represent that in commercial screened coal. For the reason that a more compact mass is found in a carload of the smaller sized coal, it is not safe to predict the moisture from the mine sample for sizes below nut coal. The actual coefficient for determining the moisture in screened coal from the moisture found in mine samples is $9.17 \div 9.41 = 0.97$.

MOISTURE IN SLACK COAL.

The results on slack coal from 15 mines are shown in Table 3. The data are not sufficient to draw final conclusions, but the comparisons are made here as a matter of interest. Of these 15 coals, 12 show an excess of moisture in the car samples and 3 show an excess in the mine samples. The average moisture for all the mine samples is 6.51 per cent, and the average for the car samples is 8.47 per cent. From these figures we get the following coefficient: $8.47 \div 6.51 = 1.30$.

CONCLUSIONS.

Summing up the data on moisture, we find that when the run-of-mine coals as shown in Table 1 are subdivided into two classes (Tables 4 and 5), consisting of coals containing less than 5 per cent of moisture and coals containing more than 5 per cent, the following results are obtained:

Run-of-mine coal containing less than 5 per cent of moisture will under normal conditions gain some moisture when exposed to the weather, and if the moisture in any mine sample taken by the method described above and containing less than 5 per cent be multiplied by the coefficient 1.19 the probable amount of moisture in commercial run-of-mine coal will be found. The coefficient for this same class of coal based on the previous sampling was 1.47; this figure is less specific than the new one, however, as it was based on other grades of coal as well as run-of-mine, and should therefore be discarded.

The coals containing more than 5 per cent of moisture in the average mine sample show a decided loss of moisture in the car samples. The coefficient for this class of coal is 0.93. Therefore to determine the amount of moisture in run-of-mine coal containing more than 5 per cent of moisture in the mine sample, multiply the percentage of moisture in the mine sample by 0.93. The coefficient for such coal based on the previous work was 0.72, which should be discarded for the new figure, as it was based on various grades of coal and not entirely on run-of-mine. A prominent feature noted in comparing these two classes of coals is that there seems to be a tendency on the part of the high-moisture coals and the low-moisture coals to approach a common limit very near 5 per cent. This is shown by the fact that the average loss in the car samples of coal with an original moisture content of more than 5 per cent was 1.15 per cent, and the average gain in moisture in the coals with an original moisture content of less than 5 per cent was 1.30 per cent, the gains and losses very nearly balancing.

On reviewing the figures obtained for screened coal it is seen that, as would be expected, the screened coal will tend to lose moisture when exposed under normal conditions. The coefficient for determining the amount of moisture that may be expected in the commercial product is 0.97, and therefore multiplying the moisture in the mine sample by 0.97 will give the moisture in commercial coal.

The figures obtained in reference to slack coal are probably not based on sufficient evidence to draw final conclusions, but slack is generally rather wet, as it receives any water that drains from the other sizes of coal while being screened. It is certain that under normal conditions slack coal contains a larger amount of moisture than mine samples, but from the evidence brought out in the results on high-moisture run-of-mine coal the slack is likely to lose some of the moisture added in screening, and consequently will vary greatly under varying conditions. The coefficient obtained is 1.30, but, as stated, it is based on too meager data to be reliable.

Finally, it appears from all the evidence that moisture is an extremely irregular constituent of coal. For this reason, in taking mine samples great care should be exercised to select a dry place in the mine for cutting the sample and to prevent an excessive amount of moisture from getting into the coal in the form of water by the drip from the roof of the mine or by contact with the sample on the floor. It is of the utmost importance to crush the sample in the atmosphere of the mine, or where it has been impossible to procure a dry sample, to dry the coal before crushing until all signs of visible moisture have been removed. More important than anything else in this connection is the manner in which the sample is packed for the laboratory. The sample should be sealed in an air-tight glass jar, bottle, or can. To illustrate the importance of this precaution, duplicate samples containing 9 per cent of moisture were sent to the chemical laboratory, one in the regulation can provided by the fuel-testing plant, and the other in a canvas sack such as is ordinarily used for this purpose. The samples were analyzed at the same time, and the moisture in the sample that had been kept in the sack for less than a week was approximately 3 per cent less than in the sample from the can. Another sample was weighed in a can and then sent by mail from St. Louis to Washington and back. It was again weighed and the result showed that samples sealed in an air-tight receptacle do not undergo any loss in weight.

SULPHUR.

Sulphur plays an important part in sampling only when it occurs in bands or other consolidated masses, generally in the form of pyrites. In most coals the percentage is comparatively small. The following results show what may be expected when samples are taken by the method recommended in this paper:

SULPHUR IN RUN-OF-MINE COAL.

Of the 87 coals included in Table 1, 28 show an excess in the mine samples and 59 an excess in the car samples. The average sulphur content of the mine samples is 2.04 per cent, and the average for the car samples is 2.16 per cent. From these figures we get $2.16 \div 2.04 = 1.06$, the coefficient of increase. For the work of 1904 this coefficient was 1.04, and Mr. Campbell, in studying the results of sampling for 1904 and 1905, combined the two and found the sulphur coefficient to be the same as the one just determined—1.06. In order to obtain a more definite coefficient, however, the sulphur items for 82 coals in Table 1 have been divided into two classes, as shown in Table 6, comprising the coals containing less than 3 per cent of sulphur in the average mine sample, and Table 7, comprising the coals containing more than 3 per cent.

TABLE 6.—*Coals containing less than 3 per cent of sulphur in the average mine samples.*

Coal.	Average per cent of sulphur in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples.
Alabama No. 2 B	1.40	1.12	0.28	
Alabama No. 3	.51	.55		0.04
Alabama No. 4	1.36	1.08	.28	
Alabama No. 5	.74	1.40		.66
Alabama No. 6	.58	.59		.01
Illinois No. 11 B	2.82	2.46	.36	
Illinois No. 19 C	.47	.52		.05
Illinois No. 34 B	1.57	2.36		.79
Indiana No. 9 B	2.85	3.15		.30
Indiana No. 13	2.71	3.18		.47
Indiana No. 15	.95	.91	.04	
Kentucky No. 5	.52	.67		.15
Kentucky No. 6	.46	.57		.11
Kentucky No. 8	1.02	1.18		.16
Kentucky No. 9 B	2.50	2.97		.47
Maryland No. 1	1.41	1.49		.08
Maryland No. 2	.83	.84		.01
New Mexico No. 3 A	.68	.73		.05
New Mexico No. 4 A	.57	.61		.04
New Mexico No. 5	.70	.69	.01	
Ohio No. 3	1.27	1.81		.54
Ohio No. 8	2.37	2.84		.47
Pennsylvania No. 6	1.82	1.94		.12
Pennsylvania No. 7	1.83	2.08		.25
Pennsylvania No. 8	1.06	.94	.12	
Pennsylvania No. 9	1.90	2.04		.14
Pennsylvania No. 11	1.70	1.18	.52	
Pennsylvania No. 12	1.20	2.19		.99
Pennsylvania No. 13	2.04	2.16		.12
Pennsylvania No. 16	1.46	1.59		.13
Pennsylvania No. 17	1.46	1.51		.05
Pennsylvania No. 18	2.15	1.49	.66	
Pennsylvania No. 19	1.19	1.05	.14	
Pennsylvania No. 20	2.66	2.85		.19
Pennsylvania No. 21	1.09	.86	.23	
Tennessee No. 1	1.13	1.58		.45
Tennessee No. 2	.85	.98		.13
Tennessee No. 3	.86	.99		.13
Tennessee No. 4	.85	.98		.13
Tennessee No. 6	.93	.78	.15	
Virginia No. 1	1.89	1.15	.74	
Virginia No. 2	.79	.92		.13
Virginia No. 6	1.52	1.21	.31	
Washington No. 1	.44	.72		.28
West Virginia No. 4 B	.82	1.07		.25
West Virginia No. 13	1.14	.89	.25	
West Virginia No. 14	.92	1.03		.11
West Virginia No. 15	2.40	2.54		.14
West Virginia No. 17	1.44	1.45		.01
West Virginia No. 18	.65	.67		.02
West Virginia No. 19	.65	.89		.24
West Virginia No. 20	1.24	1.44		.20
West Virginia No. 21	1.15	1.32		.17
West Virginia No. 22 B	.63	.83		.20
West Virginia No. 23 A	.91	1.35		.44
Wyoming No. 4	.29	.28	.01	
Wyoming No. 5	.92	.81	.11	
Average	1.27	1.36	.26	.23
Number of samples	57	57	16	41

Of the coals containing less than 3 per cent of sulphur in the average mine samples, 41 show an excess in the car sample and 16 show an excess in the mine sample, the average excess being 0.23 per cent and 0.26 per cent, respectively. The average amount of sulphur contained in the mine samples is 1.27 per cent, and the corresponding average in the car samples is 1.36 per cent. These figures show that no great difference exists between the mine samples and the car samples as regards their sulphur content. The coefficient for this class of coals is $1.36 \div 1.27 = 1.07$.

TABLE 7.—*Coals containing more than 3 per cent of sulphur in the average mine samples.*

Coal.	Average per cent of sulphur in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples.
Illinois No. 6 B	3.78	4.29		0.51
Illinois No. 7 D	4.70	4.53	0.17	
Illinois No. 9 A	3.91	4.03		.12
Illinois No. 12	3.22	3.48		.26
Illinois No. 25 A	3.71	4.76		1.05
Illinois No. 26	3.80	3.51	.29	
Illinois No. 27	4.38	4.05	.33	
Illinois No. 29 B	3.67	4.37		.70
Indiana No. 5	4.10	4.27		.17
Indiana No. 6	3.99	4.39		.40
Indiana No. 12	3.47	3.87		.40
Indiana No. 14	4.36	5.14		.78
Indiana No. 16	3.66	4.23		.57
Indiana No. 17	3.87	3.65	.22	
Missouri No. 5	4.33	5.03		.70
Ohio No. 1	4.27	4.61		.34
Ohio No. 2	4.24	4.02	.22	
Ohio No. 6	3.42	3.33	.09	
Ohio No. 12	3.48	3.80		.32
Pennsylvania No. 15	3.84	3.87		.03
Tennessee No. 5	3.40	3.23	.17	
Tennessee No. 7 A	3.13	3.26		.13
Tennessee No. 8	3.50	4.56		1.06
Wyoming No. 2 B	4.63	4.03	.60	
Wyoming No. 3	6.88	6.66	.22	
Average	3.99	4.20	.26	.47
Number of samples	25	25	9	16

Table 7 comprises 25 coals containing more than 3 per cent of sulphur in the average mine sample. Nine of these show an excess in the mine sample and 16, nearly twice as many, show an excess in the car sample. The average sulphur contained in the mine samples is 3.99 per cent, and the average for the car samples is 4.20. The average excess in the mine samples is 0.26, and the average excess in the car samples 0.47 per cent. This would indicate that in dealing with coals having a high sulphur content the chances are in favor of the mine sample being taken with too great an amount of care in discarding sulphur partings. The coefficient for correcting the sulphur shown by the mine sample is $4.20 \div 3.99 = 1.05$.

SULPHUR IN SCREENED COAL.

Screened coal for sampling was obtained from 67 mines. Of these coals, 16, or 24 per cent, show an excess of sulphur in the mine samples, and 51, or 76 per cent, an excess in the car samples, the average excess being 0.31 and 0.42 per cent for the mine samples and car samples, respectively. This indicates that in screened coal the sulphur can be expected generally to show an increase in commercial coal over that in the mine sample. The increase is slight, however, the average sulphur in the car samples being 2.57 per cent, and the average sulphur in the mine samples being 2.32 per cent. From these averages we get the coefficient of increase, $2.57 \div 2.32 = 1.10$. Therefore, to determine the amount of sulphur that may be expected in commercial screened coal (lump, nut, etc.), multiply the amount shown in the mine sample by 1.10.

SULPHUR IN SLACK COAL.

As already noted, at only 15 mines were samples of slack coal obtained on which to base conclusions, and this number is manifestly insufficient. Of the 15 coals, however, 10, or approximately 67 per cent, show more sulphur in the mine samples than in the car samples; the balance, or about 33 per cent, show more sulphur in the car samples than in the mine samples. Most of the coals in this list are comparatively low in sulphur, the smallest amount noted in the car samples being 0.63 per cent, and the maximum in the car samples 4.70 per cent. The average for the car samples is 1.95 per cent, and for the mine samples 2.16 per cent. The average excess in the car samples is 0.18 per cent, and in the mine samples 0.41 per cent. The correction coefficient obtained from the averages is $1.95 \div 2.16 = 0.90$.

CONCLUSIONS.

The differences in sulphur between mine samples and commercial coal will in most cases be slight, provided too much care is not used in excluding sulphur in partings and concretions from the sample. In the above results the sulphur in the run-of-mine samples very nearly balances, the correction coefficient being 1.07 for the coals showing less than 3 per cent of sulphur in the mine samples and 1.06 for those containing more than 3 per cent. With the screened coal, the actual results show more sulphur than in the run-of-mine coal, but the differences between mine samples and car samples remain slight, the coefficient determined being 1.10. Of course, the sulphur content in coal of this class will vary slightly, depending on the grade of coal and the size of the screen through which it is passed, as well as the form in which the sulphur occurs. If the sulphur comes from the mine in large pieces of a uniform size, it will pass into the coal of corresponding size and the other grades will show less sulphur. On this account it will be difficult to predict the amount of sulphur that is likely to be found in any particular size.

Contrary to expectation, the slack-coal results show more sulphur in the mine samples than in the cars. This is to be accounted for by the fact that comparatively few samples were examined and by the low average sulphur content of the coals forming this group of samples. As with screened coal, the form in which the sulphur occurs will have a great deal to do with the amount to be found in slack coal, and the coefficient 0.90 is of value only in studying the results on this particular set of samples of slack coal.

ASH.

ASH IN RUN-OF-MINE COAL.

By far the most important impurity in coal affecting any method of sampling is the ash due to extraneous matter associated with the coal. The results of the systematic sampling of the inspectors of the fuel-testing plant show that the variation in ash, while the greatest in amount, is the most constant. According to Table 1, 80 coals show an excess of ash in the car samples and 6 show an excess in the mine samples; in one coal the ash is equal in the average of the mine samples and the car sample. The maximum amount of ash noted in the car samples is 20.79 per cent and the minimum 2.76 per cent; the maximum for the mine samples is 21.43 per cent and the minimum 2.14 per cent. The average for the mine samples is 7.54 per cent and the average for the car samples 10.21 per cent. These figures indicate that the coal samples have a considerable range in their ash content, and on this account the run-of-mine samples, exclusive of lignites, have been divided into two classes, those containing less than 7 per cent of ash (Table 8) and those containing more than 7 per cent (Table 9).

TABLE 8.—*Coals containing less than 7 per cent of ash in the average mine samples.*

Coal.	Average per cent of ash in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples.
Alabama No. 4	2.80	12.92		10.12
Alabama No. 5	3.43	16.08		12.65
Alabama No. 6	3.67	6.83		3.16
Kentucky No. 5	2.66	3.70		1.04
Kentucky No. 6	2.14	2.76		.62
Kentucky No. 8	4.88	7.92		3.04
Maryland No. 2	6.22	7.09		.87
Ohio No. 3	6.07	11.58		5.51
Ohio No. 8	4.92	8.37		3.45
Ohio No. 12	6.40	9.67		3.27
Pennsylvania No. 8	5.58	6.63		1.05
Pennsylvania No. 11	6.14	7.29		1.15
Pennsylvania No. 12	5.75	9.25		3.50
Pennsylvania No. 19	6.29	8.36		2.07
Tennessee No. 1	5.78	11.15		5.37
Tennessee No. 2	2.89	6.81		3.92
Tennessee No. 3	3.41	7.05		3.64
Tennessee No. 4	6.41	9.53		3.12
Tennessee No. 6	5.33	14.43		9.10
Virginia No. 1	5.71	4.87	0.84	
Virginia No. 2	3.49	5.58		2.09
Virginia No. 6	4.55	9.79		5.24
West Virginia No. 4 B	5.69	10.11		4.42
West Virginia No. 13	3.88	3.91		.03
West Virginia No. 14	5.74	3.27	2.47	
West Virginia No. 15	5.64	8.55		2.91
West Virginia No. 17	6.46	8.12		1.66
West Virginia No. 18	5.83	5.83		
West Virginia No. 19	2.50	5.01		2.51
West Virginia No. 20	4.83	7.83		3.00
West Virginia No. 21	3.87	4.85		.98
West Virginia No. 22 B	5.96	7.82		1.86
West Virginia No. 23 A	4.92	8.10		3.18
Wyoming No. 4	5.13	7.31		2.18
Wyoming No. 5	2.93	3.41		.48
Average	4.80	7.77	1.65	3.35
Number of samples	35	35	2	32

Of the 82 coals considered, 35 contain less than 7 per cent of ash. Of these, 32 show an excess in the car sample and only 2 show an excess in the mine sample. In one of the coals showing an excess in the mine sample (Virginia No. 1) the excess was only 0.84 per cent and is unimportant so far as it affects the general results. This slight excess is probably due to the fact that the mine from which the sample was taken was only a prospect and the place in the mine from which the sample was taken was too near the outcrop, the car sample being taken from cleaner coal farther in the mine. The other coal showing an excess of ash in the mine sample is West Virginia No. 14, the mine sample of which contained 2.47 per cent more ash than the car sample. In this mine the coal was taken out with the greatest care and this, coupled with the fact that the sampler secured too much ash in all of his sampling, probably accounts for the discrepancy.

The average ash in the mine samples included in Table 8 is 4.80 per cent and the average in the car samples is 7.77 per cent. Dividing 7.77 by 4.80 gives 1.618, the coefficient for multiplying the ash shown by a mine sample containing less than 7 per cent to determine the amount of ash that may be expected in the commercial run-of-mine coal.

TABLE 9.—*Coals containing more than 7 per cent of ash in the average mine samples.*

Coal.	Average per cent of ash in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples.
Alabama No. 2 B	9.54	14.59		5.05
Alabama No. 3	11.44	14.36		2.92
Illinois No. 6 B	11.08	14.18		3.10
Illinois No. 7 D	11.46	13.18		1.72
Illinois No. 9 A	9.05	10.74		1.69
Illinois No. 11 B	9.26	11.66		2.40
Illinois No. 12	11.35	12.95		1.60
Illinois No. 19 C	7.13	11.00		3.87
Illinois No. 25 A	8.97	13.40		4.43
Illinois No. 26	12.41	12.09	0.32	
Illinois No. 27	9.02	13.77		4.75
Illinois No. 29 B	9.10	12.56		3.46
Illinois No. 34 B	7.31	8.38		1.07
Indiana No. 5	9.06	10.88		1.82
Indiana No. 6	10.37	12.62		2.25
Indiana No. 9 B	8.56	10.76		2.20
Indiana No. 12	7.69	11.65		3.96
Indiana No. 13	8.01	12.09		4.08
Indiana No. 14	8.90	14.20		5.30
Indiana No. 15	7.32	8.15		.83
Indiana No. 16	10.21	11.75		1.54
Indiana No. 17	8.18	11.02		2.84
Kentucky No. 9 B	8.18	10.05		1.87
Maryland No. 1	10.20	13.13		2.93
Missouri No. 5	10.72	13.62		2.90
New Mexico No. 3 A	10.02	16.67		6.65
New Mexico No. 4 A	10.46	14.57		4.11
New Mexico No. 5	12.73	14.57		1.84
Ohio No. 1	8.62	11.95		3.33
Ohio No. 2	8.48	11.34		2.86
Ohio No. 6	7.25	8.52		1.27
Pennsylvania No. 6	9.06	12.76		3.70
Pennsylvania No. 7	11.95	12.47		.52
Pennsylvania No. 9	9.27	11.33		2.06
Pennsylvania No. 13	8.25	13.16		4.91
Pennsylvania No. 15	8.76	10.07		1.31
Pennsylvania No. 16	7.01	7.87		.86
Pennsylvania No. 17	7.81	11.90		4.09
Pennsylvania No. 18	7.58	8.47		.89
Pennsylvania No. 20	8.60	10.54		1.94
Pennsylvania No. 21	7.29	8.71		1.42
Tennessee No. 5	7.55	9.76		2.21
Tennessee No. 7 A	9.60	12.85		3.25
Tennessee No. 8	10.96	13.77		2.81
Washington No. 1	8.32	11.37		3.05
Wyoming No. 2 B	21.43	20.79	.64	
Wyoming No. 3	10.82	16.70		5.88
Average	9.50	12.19	.48	2.83
Number of samples	47	47	2	45

Of 82 coals sampled as run-of-mine (see p. 489) 47 contain more than 7 per cent of ash in the average mine sample, 2 of which show an excess in the mine sample and 45 an excess in the car sample. The excess in the two mine samples referred to is insignificant (less than 1 per cent), so that on the whole these results confirm the statement that in this grade of coal mine samples contain less ash than commercial coal.

The average ash contained in the mine samples listed in Table 9 is 9.50 per cent and the average for the corresponding car samples is 12.19 per cent. From these averages we get 12.19÷9.50=1.283, the coefficient for coals containing more than 7 per cent of ash.

ASH IN SCREENED COAL.

An examination of Table 2 reveals the fact that of the 67 samples of screened coal 6 show an excess of ash in the mine sample and 61 an excess in the car sample. The excess in the mine samples is probably due to the character of the slate and other ash-forming impurities and to the kind and size of the screens employed in each case. The greatest amount of ash recorded for the car samples of screened coal is 23.38 per cent and the minimum for the car samples is 2.37 per cent. The greatest amount of ash noted in the mine samples is 12.70 per cent and the minimum 2.78 per cent. The average for the car samples is 11.20 per cent and the average for the mine samples 8.14 per cent. These averages give 11.20÷8.14=1.376 as the coefficient for this grade of coal.

ASH IN SLACK COAL.

Table 3 includes only 15 coals sampled as slack coal, of which 13 show a decided increase in ash in the car samples and 2 an excess in the mine samples. These two mine samples were taken from the same mine, which is working a bed of anthracite(?) coal near Blacksburg, Va. They were compared with prepared sizes of the coal, so the comparison can hardly be considered a fair one. The greatest amount of ash noted in the car samples is 25.30 per cent and the car sample showing the smallest amount of ash contains 5.85 per cent, the average being 15.94 per cent. Compared with the car samples are mine samples ranging from 5.64 per cent up to 19.79 per cent, the average being 9.97 per cent. Exclusive of the Virginia anthracite referred to above the averages are for the car samples 15.75 per cent and for the mine samples 8.46 per cent. Dividing 15.75 by 8.46 gives 1.861, the coefficient for slack coal.

CONCLUSIONS.

The results of the comparison of the ash in the mine samples with the ash in the car samples show the greatest and most constant variation of all the impurities in the coals examined. The best comparisons are, of course, on the run-of-mine coal, and indicate that the ash will run higher in this grade of coal as marketed than in the mine sample. The coefficients determined, however, are sufficiently accurate for correcting the mine samples, provided they are taken by the method already recommended.

With regard to screened coal, the results are considered uncertain, and although the coefficient determined for this class of coal may be applied to mine samples for screened coal in general as compared to run-of-mine coal, it is not recommended that it be used for a specific grade of coal, such as lump or nut.

The coefficient determined for ash in slack coal, nearly 2, is considered good for determining the amount of ash in this grade of coal when it contains a large amount of fine dust, but it will probably be found that the coefficient will not give accurate results for special grades of slack or for coals free from fine shale partings and with good roofs and floors.

COEFFICIENTS.

The subjoined table contains all the coefficients determined from the results published in this paper. In this table the coefficients having a (?) after them are considered unreliable.

Coefficients for correcting mine samples approximately to commercial coal.

Moisture:	
For run-of-mine coal with less than 5 per cent in mine sample	1.19
For run-of-mine coal with more than 5 per cent in mine sample	.93
For screened coal (lump, egg, nut, etc.)	.97
For slack coal	1.30 (?)
Sulphur:	
For run-of-mine coal with less than 3 per cent in mine sample	1.07
For run-of-mine coal with more than 3 per cent in mine sample	1.06
For screened coal (lump, egg, nut, etc.)	1.10
For slack coal	.90 (?)
Ash:	
For run-of-mine coal with less than 7 per cent in mine sample	1.62
For run-of-mine coal with more than 7 per cent in mine sample	1.28
For screened coal	1.37
For slack coal	1.86

EXPERIMENTAL SAMPLING.

In order to demonstrate the variation in samples of coal, and the variation due to the different methods of treatment in sampling, the inspectors of the fuel-testing plant have carried on the experiments described in the following paragraphs at a mine in Williamson County, Ill. The coal in this mine is very hard, has a "blue band" of shale or clay near the bottom, and carries several small partings of bone. The ash content runs from 6 to 10 per cent, the sulphur ranges from 0.5 to nearly 2 per cent, and the moisture is about 9 per cent. Fig. 6 shows the sections of the coal bed at the places where the samples were cut, as well as a map of that portion of the mine in which the samples were taken. On the map the letters A, B, C, etc., indicate

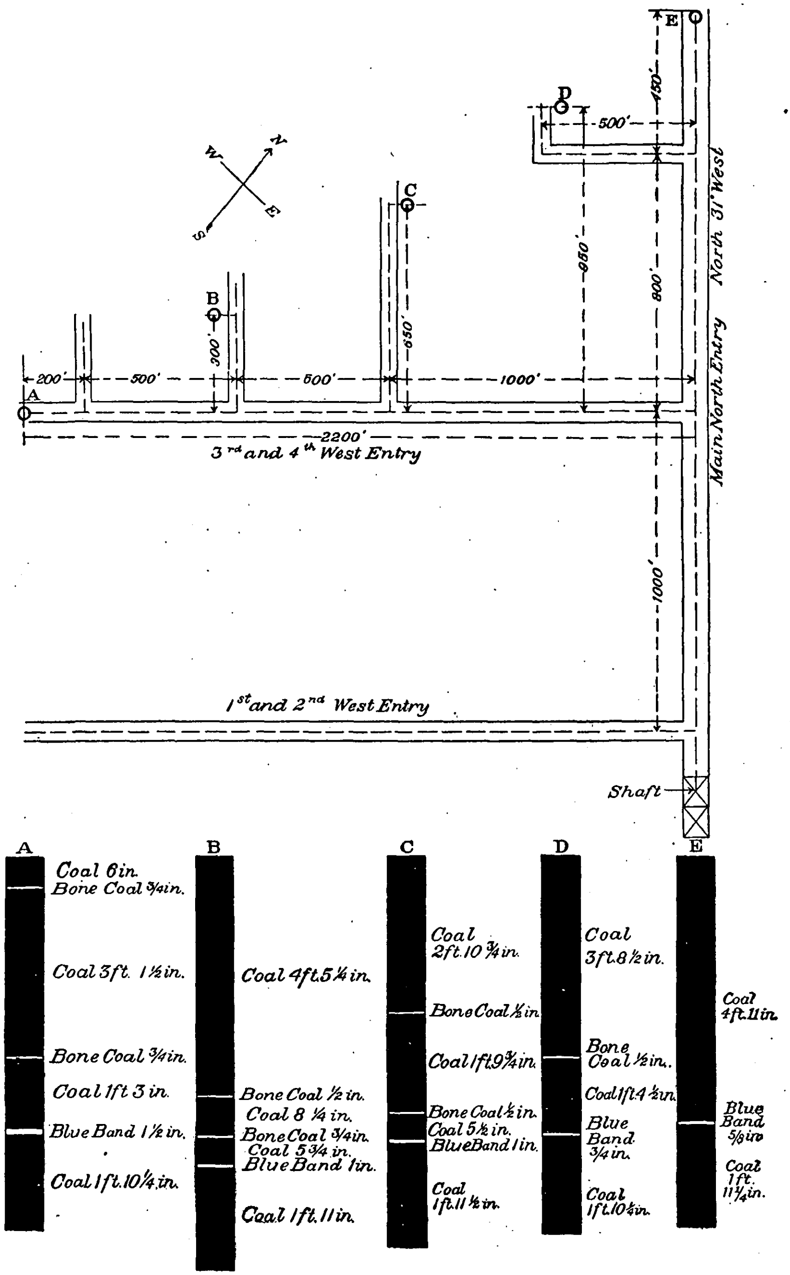

FIG. 6.—Map of mine and sections of coal used in sampling experiments.

the location of the corresponding sections, also lettered in the same manner.

The instructions for carrying on the experiments, the results of which appear in Table 10, were as follows:

Experiment No. 1: Take five samples in the usual manner (see mine-sampling, p. 487) about 500 feet apart in a straight line in that portion of the mine nearest the largest unworked body of coal. The rejected quarters of these samples are to be thoroughly mixed into one sample for analysis, the rejected quarters of the composite sample to be placed in a sack and sent to the chemical laboratory for analysis.

Experiment No. 2: At the place from which one of the above samples were taken [see map, fig. 6, D] secure another sample, crushing it in the usual manner to ½-inch mesh, and quarter down to two samples; place each half in a separate can, and the rejected quarters in sacks, quartering down if necessary to secure the necessary amount.

Experiment No. 3: From the same place in the mine secure as small a sample as possible to represent the total height of the bed and treat it in the usual manner, carefully noting the weight of the sample.

Experiment No. 4: From the same point [D] cut a sample from that part of the bed above the blue band, and one from that part of the bed below the blue band, and place them in separate cans, sending the rejected quarters to the laboratory in sacks.[a]

Experiment No. 5: From the same point [D] cut one sample the entire height of the bed, including the blue band. Break down to ½-inch mesh and then halve the sample by quartering. Prepare one half in the usual manner and place in can. Then crush the remaining half to ¼-inch size, and quarter down to can size. Place the rejected quarters of both these samples in separate sacks and send to the laboratory for analysis.

Experiment No. 6: From the same point in the mine [D] cut another sample and break up the largest lumps to not less than 1½-inch cubes and place the entire sample in a sack without crushing in the usual manner.

The results of these experiments are shown in Table 10. The "kind of sample" refers to the way in which the sample was packed for the laboratory. The regular metal cylinder with screw top sealed with adhesive tape was used for those samples marked "Can" and a light-weight canvas sack, such as is ordinarily used for this purpose, was used for the samples marked "Sack."

TABLE 10.—*Results of experimental sampling.*

	Experiment No. 1. (See map, fig. 6.)							Experiment No. 2.	
	Individual samples.					Composite sample.		First half of sample.	Second half of sample.
Kind of sample	Can	Can	Can	Can	Can	Can	Sack	Can	Can
Location in mine	A	B	C	D	E	A, B, C, D, and E	A, B, C, D, and E	D	D
Laboratory No	3629	3628	3630	3631	3632	3633	3677	3634	3635
Weight of gross sample (pounds)	37	36	37	39	39	....	....	44	44
Moisture	8.72	8.80	9.02	8.63	8.88	9.00	6.97	8.85	9.29
Volatile matter	30.38	29.98	29.76	30.02	29.49	28.83	....	29.28	29.16
Fixed carbon	53.28	52.77	52.79	52.95	53.60	54.12	....	52.66	52.95
Ash	7.62	8.45	8.43	8.40	8.03	8.05	8.43	9.21	8.60
Sulphur	1.00	1.58	1.15	.99	.99	1.17	1.18	1.00	1.04

[a] Unfortunately one of these samples was lost in the mail, so that it was not possible to make the comparison.

TABLE 10.—*Results of experimental sampling*—Continued.

	Experiment No. 2.		Experiment No. 3, sample weighing 10 pounds.	Experiment No. 5.				Experiment No. 6, sample of 1½-inch cubes.	Car sample, lump coal.
	From first half of sample.	From second half of sample.		Through ¼-inch screen.		Through ½-inch screen.			
Kind of sample	Sack	Sack	Can	Can	Sack	Can	Sack	Sack	....
Location in mine	D	D	D	D	D	D	D	D	....
Laboratory No	3675	3676	3636	3638	3670	3637	3671	3672	3789
Weight of gross sample (pounds)	44	44	10	41	41	41	41	....	....
Moisture	7.08	7.13	8.80	9.00	6.99	8.90	6.79	6.73	7.78
Volatile matter	....	....	29.85	29.11	....	29.29	....	....	29.85
Fixed carbon	....	....	53.83	52.19	....	52.13	....	....	52.39
Ash	8.87	8.92	7.52	9.70	9.34	9.68	9.48	9.07	9.98
Sulphur	1.12	1.07	1.13	1.40	1.50	1.37	1.44	1.52	1.32

Experiment No. 1 was made to see to what extent samples from the same coal bed varied over a small area of the mine and also to see how the average of a number of samples compared with a composite sample made up of parts of the individual samples. A glance at Table 10 shows that the moisture in the five samples collected from the mine showed but slight variation, ranging from 8.63 per cent in sample D to 9.02 per cent in sample C. In these same samples the ash varied less than 1 per cent and the sulphur a little over 0.5 per cent. These results indicate that when the coal is fairly regular, one or two samples taken by the method already recommended will suffice in judging the quality of the coal. The composite sample, composed of the discarded portions of the five individual samples, compares very well with the average of those samples. The moisture in the composite sample shows 9 per cent, as compared with 8.81 per cent, the average for the five samples; the ash in the composite sample is 8.05 per cent, as compared with the average of 8.18 per cent for the five samples; and there is 1.17 per cent of sulphur in the composite sample, as compared with 1.14 per cent for the average sulphur in the five samples taken separately.

A striking and important result in experiment No. 1 is the comparison of the moisture in the composite sample sealed in a metal can with that in the discarded portions of this sample that were sent to the chemical laboratory in an ordinary canvas sack. The moisture in the can sample is 9 per cent; in the sack sample 6.97 per cent. This is a considerable loss in moisture, due to the method of packing, and the result not only misrepresents this important constituent, but affects the whole analysis.

Experiment No. 2 was made with the object of showing the importance of thoroughly mixing mine samples. In collecting the sample, one cut was made from the face of the coal, and the sample crushed and halved by quartering. As shown by the analysis in Table 10, the results are not equal within the error of the chemical determinations involved, there being a difference of 0.44 per cent in moisture, 0.61 per cent in ash, and 0.04 per cent in sulphur. The sack samples obtained in this experiment show about the same loss in moisture as the sack sample obtained in experiment No. 1. The ash shows a smaller difference than the can samples and the sulphur is greater. This would seem to indicate that the difference between the two can samples in experiment No. 2 is due to some extent to the amount of moisture they contained.

Experiment No. 3 was made for the purpose of determining to what extent the quantity of coal taken for a sample affects the analysis. Ten pounds of coal was taken in this experiment, about 40 pounds being cut for the other samples. The analysis shows much less ash in this sample than in the others—7.52 per cent, as compared with 9.98 per cent in the car sample of lump coal. The other constituents, however, compare favorably with those in the heavier samples. The results of this experiment only emphasize the necessity of taking large samples.

Experiment No. 5 was made to learn to what extent the fineness of crushing affects the results. Half of the sample was crushed finer than one-half inch, and the other half finer than one-fourth inch. The analytical results show that the difference due to different fineness of crushing is insignificant below one-half inch. The sack samples taken in this experiment both lost about the same amount of moisture, showing also that there is very little difference in the drying out of one-half inch and one-fourth inch coal.

In experiment No. 6 a sample of 1½-inch cubes was sent to the laboratory in a sack, to see if forwarding the sample without crushing would assist it to retain moisture. The results of this experiment show a greater loss of moisture than in any of the others, the amount contained in this sample being 6.73 per cent. The ash content is 9.07 per cent and the sulphur 1.52 per cent.

CLASSIFIED LIST OF PAPERS DEALING WITH COAL, COKE, LIGNITE, AND PEAT CONTAINED IN PUBLICATIONS OF U. S. GEOLOGICAL SURVEY.

Compiled by WILLIS T. LEE and JOHN M. NICKLES.

Papers general in scope are given first, then those dealing with restricted areas, listed in chronologic order under the States arranged alphabetically.

The citation of a folio of the Geologic Atlas of the United States indicates that coal is found in the area and is more or less fully treated according to its economic importance.

STATISTICAL.

The reports on coal in the volumes of Mineral Resources of the United States contain, in addition to statistical matter, various other information. The statistics are given for the United States as a whole and for the States severally in alphabetic arrangement.

Mineral Resources of the United States. Albert Williams, jr. [For 1882–3], 1883: coal, pp. 1–107. Calendar years 1883 and 1884, 1885: coal, pp. 11–143; the manufacture of coke, by J. D. Weeks, pp. 144–213. Calendar year 1885, 1886: coal, pp. 10–73; the manufacture of coke, by J. D. Weeks, pp. 74–129.

Mineral Resources of the United States. David T. Day. Calendar year 1886, 1887: coal, by C. A. Ashburner, pp. 224–377; the manufacture of coke, by J. D. Weeks, pp. 378–438. Calendar year 1887, 1888: coal, by C. A. Ashburner, pp. 168–382; the manufacture of coke, by J. D. Weeks, pp. 383–435. Calendar year 1888, 1890: coal, by C. A. Ashburner, pp. 168–394; the manufacture of coke, by J. D. Weeks, pp. 395–441. Calendar years 1889 and 1890, 1892: coal, by E. W. Parker, pp. 145–286. Calendar year 1891, 1893: coal, by E. W. Parker, pp. 177–356; the manufacture of coke, by J. D. Weeks, pp. 357–402. Calendar year 1892, 1893: coal, by E. W. Parker, pp. 263–550; the manufacture of coke, by J. D. Weeks, pp. 551–602. Calendar year 1893, 1894: coal, by E. W. Parker, pp. 187–414; manufacture of coke, by J. D. Weeks, pp. 415–460.

Mineral Resources of the United States, 1894, nonmetallic products. Sixteenth Ann. Rept., pt. 4, 1895: coal, by E. W. Parker, pp. 1–217; manufacture of coke, by J. D. Weeks, pp. 218–304; origin, distribution, and commercial value of peat deposits, by N. S. Shaler, pp. 305–314.

Mineral Resources of the United States, 1895. Seventeenth Ann. Rept., pt. 3, 1896: coal, by E. W. Parker, pp. 285–542; coke, by J. D. Weeks, pp. 543–620.

Mineral Resources of the United States, 1896. Eighteenth Ann. Rept., pt. 5, 1897: coal, by E. W. Parker, pp. 351–632; coke, by E. W. Parker, pp. 659–746.

Mineral Resources of the United States, 1897. Nineteenth Ann. Rept., pt. 6, 1898: coal, by E. W. Parker, pp. 273–543; coke, by E. W. Parker, pp. 545–642.

Mineral Resources of the United States, 1898. Twentieth Ann. Rept., pt. 6, 1899: coal, by E. W. Parker, pp. 295–507; coke, by E. W. Parker, pp. 509–608.

Mineral Resources of the United States, 1899. Twenty-first Ann. Rept., pt. 6, 1901: coal, by E. W. Parker, pp. 321–519; coke, by E. W. Parker, pp. 521–633.

Mineral Resources of the United States. David T. Day. Calendar year 1900, 1901: coal, by E. W. Parker, pp. 273–457; coke, by E. W. Parker, pp. 459–536. Calendar year 1901, 1902: coal, by E. W. Parker, pp. 279–449; coke, by E. W. Parker, pp. 451–523. Calendar year 1902, 1904: coal, by E. W. Parker, pp. 289–447; coke, by E. W. Parker, pp. 449–515. Calendar year 1903, 1904: coal, by E. W. Parker, pp. 351–538; coke, by E. W. Parker, pp. 539–608. Calendar year 1904, 1905: coal, by E. W. Parker, pp. 381–577; coke, by E. W. Parker, pp. 579–648; peat, by H. H. Hindshaw, pp. 1229–1234. Calendar year 1905, 1906: coal, by E. W. Parker, pp. 453–714; coke, by E. W. Parker, pp. 715–766; peat, by M. R. Campbell, pp. 1319–1322.

TECHNOLOGICAL.

Preliminary report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1894, E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. Bull. No. 261, 1905. 172 pp.

Survey work on coal during 1905, by M. R. Campbell. Bull. No. 285, 1906, pp. 203–210.

Gives a short account of geologic work on coal areas in 1905, of the work of the fuel-testing division, and of the classification of coals.

Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905. J. A. Holmes, in charge. Bull. No. 290, 1906. 240 pp.

Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. Prof. Paper No. 48, 1906. (In three parts.) 1492 pp.

AREAL.

GENERAL.

General account of the fresh-water morasses of the United States, with a description of the Dismal Swamp district of Virginia and North Carolina, by N. S. Shaler. Tenth Ann. Rept., 1890, pp. 303–304.

Discusses briefly the utilization of peat.

The coal fields of the United States, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 7–24.

Distribution and geologic relations of the various coal fields in the United States, classification of coals, production, and marketing.

The northern Appalachian coal field, by David White, M. R. Campbell, and R. M. Haseltine. Twenty-second Ann. Rept., pt. 3, 1902, pp. 119–226.

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 227–263.

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga, and Birmingham districts, embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

The eastern interior coal field, by G. H. Ashley. Twenty-second Ann. Rept., pt. 3, 1902, pp. 265–305.

An account of the coal field embracing parts of Indiana, Illinois, and Kentucky.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333–366.

An account of the coal field occupying parts of Missouri, Kansas, Nebraska, and Iowa.

The southwestern coal field, by Joseph A. Taff. Twenty-second Ann. Rept., pt. 3, 1902, pp. 367–413.

An account of the coals of Arkansas, Indian Territory, and northern Texas.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

The coal fields of the Pacific coast, by George Otis Smith. Twenty-second Ann. Rept., pt. 3, 1902, pp. 473–513.

An account of the coals occurring in Washington, California, and Oregon.

Coal fields of the United States, by C. W. Hayes. Bull. No. 213, 1903, pp. 257–269.

A general account of the distribution and geologic relations of the coal fields, and the classification and marketing of coals.

ALABAMA.

The coal measures of Alabama, by E. A. Smith. Mineral Resources U. S. for 1892, 1893, pp. 293–300.

Stevenson folio, Alabama-Georgia-Tennessee, description, by C. W. Hayes. Geologic Atlas U. S., folio 19, 1895.

Gadsden folio, Alabama, description, by C. W. Hayes. Geologic Atlas U. S., folio 35, 1896.

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 227–263.

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga, and Birmingham districts embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

The Warrior coal basin in the Brookwood quadrangle, Alabama, by Charles Butts. Bull. No. 260, 1905, pp. 357–381.

The Warrior coal basin in the Birmingham quadrangle, Alabama, by Charles Butts. Bull. No. 285, 1906, pp. 211–222.

ARIZONA.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1884–85. Bull. No. 27, 1886, p. 74.

Gives analyses of coal from Deer Creek Valley, Ariz.

The Deer Creek coal field, Arizona, by M. R. Campbell. Bull. No. 225, 1904, pp. 240–258.

ARKANSAS.

The coal fields of Arkansas, by J. C. Branner. Mineral Resources U. S. for 1892, 1893, pp. 303–306.

Preliminary report on the Camden coal field of southwestern Arkansas, by J. A. Taff. Twenty-first Ann. Rept., pt. 2, 1900, pp. 313–329.

The southwestern coal field, by J. A. Taff. Twenty-second Ann. Rept., pt. 3, 1902, pp. 367–413.

An account of the coals of Arkansas, Indian Territory, and northern Texas.

Fayetteville folio, Arkansas-Missouri, description, by G. I. Adams and E. O. Ulrich. Geologic Atlas U. S., folio 119, 1905, p. 6.

CALIFORNIA.

The coal deposits of California, by H. W. Turner. Mineral Resources U. S. for 1892, 1893, pp. 308–310.

Sacramento folio, California, description, by Waldemar Lindgren. Geologic Atlas U. S., folio 5, 1894.

Jackson folio, California, description, by H. W. Turner. Geologic Atlas U. S., folio 11, 1894.

Lassen Peak folio, California, description, by J. S. Diller. Geologic Atlas U. S., folio 15, 1895.

Marysville folio, California, description, by Waldemar Lindgren and H. W. Turner. Geologic Atlas U. S., folio 17, 1895.

The coal fields of the Pacific coast, by G. O. Smith. Twenty-second Ann. Rept., pt. 3, 1902, pp. 473–513.

An account of the coals occurring in Washington, California, and Oregon.

Coal in the Mount Diablo Range, Monterey County, Cal., by Ralph Arnold. Bull. No. 285, 1906, pp. 223–225.

COLORADO.

A report of work done in the division of chemistry and physics mainly during the fiscal year 1888–'89, by F. W. Clarke. Bull. No. 64, 1890, p. 55.

Gives analyses of coals from Gunnison County, Colo.

Coal fields of Colorado, by R. C. Hills. Mineral Resources U. S. for 1892, 1893, pp. 319–365.

Anthracite-Crested Butte folio, Colorado, description of the sedimentary formations, by G. H. Eldridge. Geologic Atlas U. S., folio 9, 1894.

Geology of the Denver basin in Colorado: Economic geology, by G. H. Eldridge. Monograph XXVII, 1896, pp. 317–387.

Includes an account of the coal resources and their development.

Elmoro folio, Colorado, description, by R. C. Hills. Geologic Atlas U. S., folio 58, 1899.

La Plata folio, Colorado, description: Economic geology, by C. W. Purington, Geologic Atlas U. S., folio 60, 1899, p. 14.

Walsenburg folio, Colorado, description, by R. C. Hills. Geologic Atlas U. S., folio 68, 1900, pp. 4–5.

Spanish Peaks folio, Colorado, description, by R. C. Hills. Geologic Atlas U. S., folio 71, 1901, pp. 4–6.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton. Prof. Paper No. 32, 1905, pp. 372–379.

Gives a general account of the occurrence of coal in Colorado, Wyoming, South Dakota, and Nebraska.

The Yampa coal field, Routt County, Colo., by N. M. Fenneman and H. S. Gale. Bull. No. 285, 1906, pp. 226–239.

The Durango-Gallup coal field of Colorado and New Mexico, by F. C. Schrader. Bull. No. 285, 1906, pp. 241–258.

The Yampa coal field, Routt County, Colorado, by N. M. Fenneman and H. S. Gale. With a chapter on the character and use of the Yampa coals by M. R. Campbell. Bull. No. 297, 1906. 96 pp.

GEORGIA.

Ringgold folio, Georgia-Tennessee, descriptive text, by C. W. Hayes. Geologic Atlas U. S., folio 2, 1894.

Stevenson folio, Alabama-Georgia-Tennessee, description, by C. W. Hayes. Geologic Atlas U. S., folio 19, 1895.

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 227–263.

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga and Birmingham districts, embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

IDAHO.

Boise folio, Idaho, description, by Waldemar Lindgren. Geologic Atlas U. S., folio 45, 1898.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

ILLINOIS.

Danville folio, Illinois-Indiana, description, by M. R. Campbell. Geologic Atlas U. S., folio 67, 1900, pp. 6–7.

The eastern interior coal field, by G. H. Ashley. Twenty-second Ann. Rept., pt. 3, 1902, pp. 265–305.

An account of the coal field embracing parts of Indiana, Illinois, and Kentucky.

Recent work in the coal field of Indiana and Illinois, by M. L. Fuller and G. H. Ashley. Bull. No. 213, 1903, pp. 284–293.

Patoka folio, Indiana-Illinois, description, by M. L. Fuller and F. G. Clapp. Geologic Atlas U. S., folio 105, 1904, pp. 7–9.

INDIANA.

The eastern interior coal field, by G. H. Ashley. Twenty-second Ann. Rept., pt. 3, 1902, pp. 265–305.

An account of the coal field embracing parts of Indiana, Illinois, and Kentucky.

Ditney folio, Indiana, economic geology, by G. H. Ashley. Geologic Atlas U. S., folio 84, 1902, p. 7.

Recent work in the coal field of Indiana and Illinois, by M. L. Fuller and G. H. Ashley. Bull. No. 213, 1903, pp. 284–293.

Patoka folio, Indiana-Illinois, description, by M. L. Fuller and F. G. Clapp. Geologic Atlas U. S., folio 105, 1904, pp. 7–9.

INDIAN TERRITORY (OKLAHOMA).

Geology of the McAlester-Lehigh coal field, Indian Territory, by J. A. Taff. Nineteenth Ann. Rept., pt. 3, 1899, pp. 423–456.

An account of the stratigraphy of the field and the distribution and character of the coals.

Geology of the eastern Choctaw coal field, Indian Territory, by J. A. Taff and G. I, Adams. Twenty-first Ann. Rept., pt. 2, 1900, pp. 257–311.

An account of the stratigraphy and structure of the field, the distribution and character of the coal, and the mining developments.

Coalgate folio, Indian Territory, description, by J. A. Taff. Geologic Atlas U. S. folio 74, 1901, p. 6.

The southwestern coal field, by J. A. Taff. Twenty-second Ann. Rept., pt. 3, 1902. pp. 367–413.

An account of the coals of Arkansas, Indian Territory, and northern Texas.

Atoka folio, Indian Territory, description, by J. A. Taff. Geologic Atlas U. S., folio 79, 1902, p. 7.

Progress of coal work in Indian Territory, by J. A. Taff. Bull. No. 260, 1905, pp, 382–401.

Muscogee folio, Indian Territory, description, by J. A. Taff. Geologic Atlas U. S., folio 132, 1906, p. 6.

IOWA.

Sketch of the coal deposits of Iowa, by C. R. Keyes. Mineral Resources U. S. for 1892, 1893, pp. 398–404.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333–366.

An account of the coal field occupying portions of Missouri, Kansas, Nebraska, and Iowa.

KANSAS.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333–366.

An account of the coal field occupying portions of Missouri, Kansas, Nebraska, and Iowa.

Stratigraphy and paleontology of the upper Carboniferous rocks of the Kansas section, by G. I. Adams, G. H. Girty, and David White. Bull. No. 211, 1903, 123 pp.

Includes notes on the occurrence of coal beds.

Economic geology of the Iola quadrangle, Kansas, by G. I. Adams, E. Haworth, and W. R. Crane. Bull. No. 238, 1904, pp. 74–75.

Notes the occurrence of coal of no economic value.

Economic geology of the Independence quadrangle, Kansas, by F. C. Schrader and E. Haworth. Bull. No. 296, 1906. Coal, pp. 48–52.

Joplin district folio, Missouri-Kansas, description, by W. S. T. Smith and C. E. Siebenthal. Geologic Atlas U. S., folio 148, 1907, pp. 19–20.

KENTUCKY.

The coal fields of Kentucky, by J. R. Proctor. Mineral Resources U. S. for 1892, 1893, pp. 415–417.

Geology of the Big Stone Gap coal field of Virginia and Kentucky, by M. R. Campbell. Bull. No. 111, 1893, 106 pp.

Estillville folio, Kentucky-Virginia-Tennessee, description, by M. R. Campbell. Geologic Atlas U. S., folio 12, 1894.

Richmond folio, Kentucky, description, by M. R. Campbell. Geologic Atlas U. S., folio 46, 1898.

London folio, Kentucky, description by M. R. Campbell. Geologic Atlas U. S., folio 47, 1898.

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 227–263.

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga, and Birmingham districts, embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

The eastern interior coal field, by G. H. Ashley. Twenty-second Ann. Rept., pt. 3, 1902, pp. 265–305.

An account of the coal field embracing parts of Indiana, Illinois, and Kentucky.

The Cumberland Gap coal field of Kentucky and Tennessee, by G. H. Ashley. Bull. No. 225, 1904, pp. 259–275.

Coal resources of the Kenova quadrangle, by W. C. Phalen. Bull. No. 285, 1906, pp. 259–268.

Geology and mineral resources of part of the Cumberland Gap coal field, Kentucky, by G. H. Ashley and L. C. Glenn. Prof. Paper No. 49, 1906, 239 pp.

MARYLAND.

Piedmont folio, West Virginia-Maryland, description, by N. H. Darton and J. A. Taff. Geologic Atlas U. S., folio 28, 1896.

The bituminous coal field of Maryland, by David White. Twenty-second Ann. Rept., pt. 3, 1902, pp. 201–214.

MICHIGAN.

The northern interior coal field, by A. C. Lane. Twenty-second Ann. Rept., pt. 3, 1902, pp. 307–331.

MISSOURI.

The coal measures of Missouri, by Arthur Winslow. Mineral Resources U. S. for 1892, 1893, pp. 429–436.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333–366.

An account of the coal field occupying portions of Missouri, Kansas, Nebraska, and Iowa.

Joplin district folio, Missouri-Kansas, description, by W. S. T. Smith and C. E. Siebenthal. Geologic Atlas U. S., folio 148, 1907, pp. 19–20.

MONTANA.

The Laramie and the overlying Livingston formation in Montana, by W. H. Weed. Bull. No. 105, 1893, p. 105.

A brief statement regarding the occurrence and character of the coal beds.

Livingston folio, Montana, description, by J. P. Iddings and W. H. Weed. Geologic Atlas U. S., folio 1, 1894.

Three Forks folio, Montana, description, by A. C. Peale. Geologic Atlas U. S., folio 24, 1896.

Geology and mineral resources of the Judith Mountains of Montana, by W. H. Weed and L. V. Pirsson. Eighteenth Ann. Rept., pt. 3, 1898, pp. 614–616.

Gives an account of the coals mined in the area.

Fort Benton folio, Montana, description, by W. H. Weed. Geologic Atlas U. S., folio 55, 1899.

Little Belt Mountains folio, Montana, description, by W. H. Weed. Geologic Atlas U. S., folio 56, 1899.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Development of the Bear Creek coal fields, Montana, by C. A. Fisher. Bull. No. 285, 1906, pp. 269–270.

The North Dakota-Montana lignite area, by A. G. Leonard. Bull. No. 285, 1906, pp. 316–330.

NEBRASKA.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333–366.

An account of the coal field occupying portions of Missouri, Kansas, Nebraska, and Iowa.

Lignites of the middle and upper Missouri Valley, by E. F. Burchard. Bull. No. 225, 1904, pp. 276–288.

Describes the occurrence and character of lignite deposits in Dakota County, Nebraska, and in North Dakota.

Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton. Prof. Paper No. 32, 1905, pp. 372–379.

Gives a general account of the occurrence of coal in Colorado, Wyoming, South Dakota, and Nebraska.

NEVADA.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Coal deposits between Silver Peak and Candelaria, Esmeralda County, Nev., by J. E. Spurr. Bull. No. 225, 1904, pp. 289–292.

Ore deposits of the Silver Peak quadrangle, Nevada, by J. E. Spurr. Prof. Paper No. 55, 1906, pp. 165–168.

Includes an account of the coal occurring in the area.

NEW MEXICO.

Report of work done in the division of chemistry and physics, mainly during the fiscal year 1885–86, by F. W. Clarke. Bull. No. 42, 1887, p. 147.

Gives an analysis of "natural coke" from Purgatory Cañyon, N. Mex.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Coal fields of the White Mountain region, New Mexico, by C. A. Fisher. Bull. No. 225, 1904, pp. 293–294.

The Engle coal field, New Mexico, by W. T. Lee. Bull. No. 285, 1906, p. 240.

The Durango-Gallup coal field of Colorado and New Mexico, by F. C. Schrader. Bull. No. 285, 1906, pp. 241–258.

NORTH CAROLINA.

Report of work done in the division of chemistry and physics, mainly during the fiscal year 1885–86, by F. W. Clarke. Bull. No. 42, 1887, p. 146.

Gives analyses of coals from Gulf and from Stokes County, N. C.

Correlation Papers—the Newark system, by I. C. Russell. Bull. No. 85, 1892, coal, pp. 36–43.

The Atlantic coast Triassic coal field, by J. B. Woodworth. Twenty-second Ann. Rept., pt. 3, 1902, pp. 25–53.

NORTH DAKOTA.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Lignites of the middle and upper Missouri Valley, by E. F. Burchard. Bull. No. 225, 1904, pp. 276–288.

Describes the occurrence and character of the lignite deposits in Dakota County, Nebraska, and in North Dakota.

The lignite of North Dakota and its relation to irrigation, by F. A. Wilder. Water-Sup. and Irr. Paper No. 117, 1905. 59 pp.

The North Dakota-Montana lignite area, by A. G. Leonard. Bull. No. 285, 1906, pp. 316–330.

OHIO.

Stratigraphy of the bituminous coal field in Pennsylvania, Ohio, and West Virginia, by I. C. White. Bull. No. 65, 1891, 212 pp.

Huntington folio, West Virginia-Ohio, description, by M. R. Campbell. Geologic Atlas U. S., folio 69, 1900, pp. 5–6.

The bituminous coal field of Ohio, by R. M. Haseltine. Twenty-second Ann. Rept., pt. 3, 1902, pp. 215–226.

Coal resources of the Kenova quadrangle, by W. C. Phalen. Bull. No. 285, 1906, pp. 259–268.

OKLAHOMA. *See* Indian Territory.

OREGON.

Report of work done in the division of chemistry and physics, mainly during the fiscal year 1887–88, by F. W. Clarke. Bull. No. 60, 1890, p. 170.

Gives an analysis of coal from Pend d'Oreille, Oreg.

A geological reconnaissance in northwestern Oregon, by J. S. Diller. Seventeenth Ann. Rept., pt. 1, 1896, pp. 491–508.

Includes an account of the coal fields of northwestern Oregon.

Roseburg folio, Oregon, description, by J. S. Diller. Geologic Atlas U. S., folio 49, 1898.

The Coos Bay coal field, Oregon, by J. S. Diller. Nineteenth Ann. Rept., pt. 3, 1899, pp. 309–376.

The coal and pitch coal of the Newport mine, by W. C. Day. Nineteenth Ann. Rept., pt. 3, 1899, pp. 370–376.
Discusses the origin of the pitch coal.

Coos Bay folio, Oregon, description, by J. S. Diller. Geologic Atlas U. S., folio 73, 1901, pp. 4–5.

The coal fields of the Pacific coast, by G. O. Smith. Twenty-second Ann. Rept., pt. 3, 1902, pp. 473–513.
An account of the coals occurring in Washington, California, and Oregon.

Port Orford folio, Oregon, description, by J. S. Diller. Geologic Atlas U. S., folio 89, 1903, pp. 4–5.

PENNSYLVANIA.

Anthracite coal mining, by H. M. Chance. Mineral Resources U. S. for 1883 and 1884, 1885, pp. 104–131.

Stratigraphy of the bituminous coal field in Pennsylvania, Ohio, and West Virginia, by I. C. White. Bull. No. 65, 1891, pp. 212.

The stratigraphic succession of the fossil floras of the Pottsville formation in the southern anthracite coal field, Pennsylvania, by David White. Twentieth Ann. Rept., pt. 2, 1900, pp. 854–857.
An account of the occurrence of the Lykens coals in Stony Mountain and in the Dauphin basin.

The Pennsylvania anthracite coal field, by H. H. Stoek. Twenty-second Ann. Rept., pt. 3, 1902, pp. 55–117.

The bituminous coal field of Pennsylvania, by David White and M. R. Campbell. Twenty-second Ann. Rept., pt. 3, 1902, pp. 127–200.

Masontown-Uniontown folio, Pennsylvania, description, by M. R. Campbell. Geologic Atlas U. S., folio 82, 1902, pp. 10–18.

Gaines folio, Pennsylvania, New York, description, by M. L. Fuller. Geologic Altas U. S.., folio 92, 1903, p. 9.

Brownsville-Connellsville folio, Pennsylvania, description, by M. R. Campbell. Geologic Altas U. S., folio 94, 1903, pp. 11–17.

Recent work in the bituminous coal field of Pennsvlvania, by M. R. Campbell. Bull. No. 213, 1903, pp. 270–275.

The Barnesboro-Patton coal field of central Pennsylvania, by J. S. Burrows. Bull. No. 225, 1904, pp. 295–310.

The Elders Ridge coal field, Pennsylvania, by R. W. Stone. Bull. No. 225, 1904, pp. 311–324.

Coal mining along the southeastern margin of the Wilmore basin, Cambria County, Pa., by Charles Butts. Bull. No. 225, 1904, pp. 325–329.

Indiana folio, Pennsylvania, description, by G. B. Richardson. Geologic Atlas U. S., folio 102, 1904, pp. 4–6.

Latrobe folio, Pennsylvania, description, by M. R. Campbell. Geologic Atlas U. S., folio 110, 1904, pp. 12–15.

Kittanning folio, Pennsylvania, description, by Charles Butts. Geologic Atlas U. S., folio 115, 1904, pp. 12–13.

Mineral resources of the Elders Ridge quadrangle, Pennsylvania, by R. W. Stone. Bull. No. 256, 1905. Coal, pp. 31–54. Coke, p. 55.

Pittsburg coal in the Burgettstown quadrangle, Pennsylvania, by W. T. Griswold. Bull. No. 260, 1905, pp. 402–410.

Waynesburg folio, Pennsylvania, description, by R. W. Stone. Geologic Atlas U. S., folio 121, 1905, pp. 9–10.

Elders Ridge folio, Pennsylvania, description, by R. W. Stone. Geologic Atlas U. S., folio 123, 1905, pp. 7–9.

Rural Valley folio, Pennsylvania, by Charles Butts. Geologic Atlas U. S., folio 125, 1905, pp. 7–10.

Ebensburg folio, Pennsylvania, description, by Charles Butts. Geologic Atlas U. S., folio 133, 1905, pp. 7–9.

Beaver folio, Pennsylvania, description, by L. H. Woolsey. Geologic Atlas U. S., folio 134, 1905, pp. 11–12.

Economic geology of the Kittanning and Rural Valley quadrangles, Pennsylvania, by Charles Butts. Bull. No. 279, 1906. Coal, pp. 44–102.

Clearfield coal field, Pennsylvania, by G. H. Ashley. Bull. No. 285, 1906, pp. 271–275.

The Punxsutawney and Glen Campbell coal fields of Indiana and Jefferson counties, Pa., by F. B. Peck and G. H. Ashley. Bull. No. 285, 1906, pp. 276–279.

Economic geology of the Beaver quadrangle, Pennsylvania (southern Beaver and northwestern Allegheny counties), by L. H. Woolsey. Bull. No. 286, 1906. Coal, pp. 26–55.

Economic geology of the Amity quadrangle, eastern Washington County, Pennsylvania, by F. G. Clapp. Bull. No. 300, 1907. 145 pp.

Oil and gas fields of Greene County, Pa., by R. W. Stone and F. G. Clapp. Bull. No. 304, 1907. Map showing coal outcrops, in pocket.

Amity folio, Pennsylvania, description, by F. G. Clapp. Geologic Atlas U. S., folio 144, 1907, pp. 12–13.

Rogersville folio, Pennsylvania, description, by F. G. Clapp. Geologic Atlas U. S., folio 146, 1907, pp. 12–14.

RHODE ISLAND.

A report of work done in the Washington laboratory during the fiscal year 1883–84, by F. W. Clarke and T. M. Chatard. Bull. No. 9, 1884, p. 18.

Gives an analysis of coal from Cranston, R. I.

General geology of the Narragansett basin, by N. S. Shaler. Monograph XXXIII, 1899, pp. 79–88.

Describes the stratigraphy, occurrence, and character of the coal deposits in the Narragansett basin in Rhode Island.

SOUTH DAKOTA.

The lignites of the Great Sioux Reservation: A report on the region between the Grand and Moreau rivers, Dakota, by Bailey Willis. Bull. No. 21, 1885. 16 pp.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Edgemont folio, South Dakota-Nebraska, description, by N. H. Darton and W. S. T. Smith. Geologic Atlas U. S., folio 108, 1904, pp. 9–10.

Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton. Prof. Paper No. 32, 1905, pp. 372–379.

Gives a general account of the occurrence of coal in Colorado, Wyoming, South Dakota, and Nebraska.

TENNESSEE.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1887–88, by F. W. Clarke. Bull. No. 60, 1890, p. 170.

Gives analyses of coal from Claiborne County, Tenn.

A report of work done in the division of chemistry and physics mainly during the fiscal year 1888–89, by F. W. Clarke. Bull. No. 64, 1890, pp. 54, 55.

Gives analyses of coals and cokes from Campbell County, Tenn.

The Tennessee coal measures, by J. M. Safford. Mineral Resources U. S. for 1892, 1893, pp. 497–506.

Ringgold folio, Georgia-Tennessee, description, by C. W. Hayes. Geologic Atlas U. S., folio 2, 1894.

Kingston folio, Tennessee, description, by C. W. Hayes. Geologic Atlas U. S., folio 4, 1894.

Chattanooga folio, Tennessee, description, by C. W. Hayes. Geologic Atlas U. S., folio 6, 1894.

Sewanee folio, Tennessee, description, by C. W. Hayes. Geologic Atlas U. S., folio 8, 1894.

Stevenson folio, Alabama-Georgia-Tennessee, description, by C. W. Hayes. Geologic Atlas U. S., folio 19, 1895.

Pikeville folio, Tennessee, description, by C. W. Hayes. Geologic Atlas U. S., folio 21, 1895.

McMinnville folio, Tennessee, description, by C. W. Hayes. Geologic Atlas U. S., folio 22.

Loudon folio, Tennessee, description, by Arthur Keith. Geologic Atlas U. S., folio 25, 1896.

Briceville folio, Tennessee, description, by Arthur Keith. Geologic Atlas U. S., folio 33, 1896.

Wartburg folio, Tennessee, description, by Arthur Keith. Geologic Atlas U. S., folio 40, 1897.

Standingstone folio, Tennessee, description, by M. R. Campbell. Geologic Atlas U. S., folio 53, 1899.

Maynardville folio, Tennessee, description, by Arthur Keith. Geologic Atlas U. S., folio 75, 1901, p. 5.

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 227–263.

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga, and Birmingham districts, embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

The Cumberland Gap coal field of Kentucky and Tennessee, by G. H. Ashley. Bull. No. 225, 1904, pp. 259–275.

TEXAS.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1886–87, by F. W. Clarke. Bull. No. 55, 1889, p. 87.

Gives an analysis of coal from Burnet County, Texas.

The coal fields of Texas, by R. T. Hill. Mineral Resources U. S. for 1892, 1893, pp. 507–510.

Reconnaissance in the Rio Grande coal fields of Texas, by T. W. Vaughan. Bull. No. 164, 1900, 100 pp.

Uvalde folio, Texas, description, by T.W. Vaughan. Geologic Atlas U. S., folio 64, 1900, p. 5.

The southwestern coal field, by J. A. Taff. Twenty-second Ann. Rept., pt. 3, 1902, pp. 367–413.

An account of the coals of Arkansas, Indian Territory, and northern Texas.

UTAH.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1890–91, by F. W. Clarke. Bull. No. 90, 1892, p. 75.

Gives analyses of coals from Little Cottonwood gulch and from the Wasatch Mountains.

Coal fields of Utah, by Robert Forrester. Mineral Resources U. S. for 1892, 1893, pp. 511–520.

The Colorado formation and its invertebrate fauna, by T. W. Stanton. Bull. No. 106, 1893, pp. 35, 36.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Coal in Sanpete County, Utah, by G. B. Richardson. Bull. No. 285, 1906, pp. 280–284.

Notes on the Weber River coal field, Utah, by J. A. Taff. Bull. No. 285, 1906, pp. 285–288.

Book Cliffs coal field, Utah, west of Green River, by J. A. Taff. Bull. No. 285, 1906, pp. 289–302.

VIRGINIA.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1885–86, by F. W. Clarke. Bull. No. 42, 1887, p. 146.

Gives an analysis of "natural coke" from Midlothian, Va.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1886–87, by F. W. Clarke. Bull. No. 55, 1889, p. 87.

Gives analyses of coal and coke from Scott County, Va.

Correlation papers—the Newark system, by I. C. Russell. Bull. No. 85, 1892, coal, pp. 36–43.

The Clinch Valley coal fields, by A. S. McCreath and E. V. D'Invilliers. Mineral Resources U. S. for 1892, 1893, pp. 521–528.

Geology of the Big Stone Gap coal field of Virginia and Kentucky, by M. R. Campbell. Bull. No. 111, 1893, 106 pp.

Estillville folio, Kentucky-Virginia-Tennessee, description, by M. R. Campbell. Geologic Atlas U. S., folio 12, 1894.

Staunton folio, Virginia-West Virginia, description, by N. H. Darton. Geologic Atlas U. S., folio 14, 1894.

Pocahontas folio, Virginia-West Virginia, description, by M. R. Campbell. Geologic Atlas U. S., folio 26, 1896.

Tazewell folio, Virginia-West Virginia, description, by M. R. Campbell. Geologic Atlas U. S., folio 44, 1897.

Geology of the Richmond basin, Virginia, by N. S. Shaler and J. B. Woodworth. Nineteenth Ann. Rept., pt. 2, 1899, pp. 511–515.

Gives an account of the natural coke and bituminous coal of this area.

Bristol folio, Virginia-Tennessee, description, by M. R. Campbell. Geologic Atlas U. S., folio 59, 1899.

The Atlantic coast Triassic coal field, by J. B. Woodworth. Twenty-second Ann. Rept., pt. 3, 1902, pp. 25–53.

WASHINGTON.

A geological reconnaissance in central Washington, by I. C. Russell. Bull. No. 108, 1893, p. 76.

A brief note on the occurrence of coal of little economic value near Wenatchee.

Some coal fields of Puget Sound, by Bailey Willis. Eighteenth Ann. Rept., pt. 3, 1898, pp. 393–436.

Tacoma folio, Washington, description, by Bailey Willis and G. O. Smith. Geologic Atlas U. S., folio 54, 1899.

A preliminary paper on the geology of the Cascade Mountains in northern Washington, by I. C. Russell. Twentieth Ann. Rept., pt. 2, 1900, coal, pp. 205–206.

The coal fields of the Pacific coast, by G. O. Smith. Twenty-second Ann. Rept., pt. 3, 1902, pp. 473–513.

An account of the coals occurring in Washington, California, and Oregon.

A geological reconnaissance across the Cascade Range near the forty-ninth parallel, by G. O. Smith and F. C. Calkins. Bull. No. 235, 1904, p. 97.

Notes the occurrence of coal and coal mines in northwestern Washington.

Mount Stuart folio, Washington, description, by G. O. Smith. Geologic Atlas U. S., folio 106, 1904, pp. 9–10.

Coal in Washington, near Portland, Oreg., by J. S. Diller. Bull. No. 260, 1905, pp. 411–412.

Coal in Clallam County, Wash., by Ralph Arnold. Bull. No. 260, 1905, pp. 413–421.

Snoqualmie folio, Washington, description, by G. O. Smith and F. C. Calkins. Geologic Atlas U. S., folio 139, 1906, p. 13.

WEST VIRGINIA.

Coal mining in the Kanawha Valley of West Virginia, by S. M. Buck. Mineral Resources U. S. for 1883 and 1884, 1885, pp. 131–143.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1884–85. Bull No. 27, 1886, pp. 73, 74.

Gives analyses of coals from Randolph County, W. Va.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1887–88, by F. W. Clarke. Bull. No. 60, 1890, p. 169.

Gives analyses of coals and cokes from Piedmont, W. Va.

A report of work done in the division of chemistry and physics mainly during the fiscal year 1888–89, by F. W. Clarke. Bull. No. 64, 1890, p. 54.

Gives analyses of coals from Kanawha County, and of coal and coke from Tucker County, W. Va.

Stratigraphy of the bituminous coal field in Pennsylvania, Ohio, and West Virginia, by I. C. White. Bull. No. 65, 1891, 212 pp.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1889–90, by F. W. Clarke. Bull. No. 78, 1891, p. 128.

Gives analyses of coals from Barbour County, W. Va.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1890–91, by F. W. Clarke. Bull. No. 90, 1892, p. 75.

Gives analyses of coal and coke from Tucker County, W. Va.

The Potomac and Roaring Creek coal fields in West Virginia, by J. D. Weeks. Fourteenth Ann. Rept., pt. 2, 1894, pp. 567–590.

Geologic section along the New and Kanawha rivers in West Virginia, by M. R. Campbell and W. C. Mendenhall. Seventeenth Ann. Rept., pt. 2, 1896, pp. 473–511.
Describes the stratigraphy of the Coal Measures in this section. Includes analyses of the coals.

Pocahontas folio, Virginia-West Virginia, description, by M. R. Campbell. Geologic Atlas U. S., folio 26, 1896.

Piedmont folio, West Virginia-Maryland, description, by N. H. Darton and J. A. Taff. Geologic Atlas U. S., folio 28, 1896.

Franklin folio, West Virginia-Virginia, description, by N. H. Darton. Geologic Atlas U. S., folio 32, 1896.

Buckhannon folio, West Virginia, description, by J. A. Taff and A. H. Brooks. Geologic Atlas U. S., folio 34, 1896.

Tazewell folio, Virginia-West Virginia, description, by M. R. Campbell. Geologic Atlas U. S., folio 44, 1897.

Huntington folio, West Virginia-Ohio, description, by M. R. Campbell. Geologic Atlas U. S., folio 69, 1900, pp. 5–6.

Charleston folio, West Virginia, description, by M. R. Campbell. Geologic Atlas U. S., folio 72, 1901, pp. 6–9.

Raleigh folio, West Virginia, description, by M. R. Campbell. Geologic Atlas U. S., folio 77, 1902, pp. 4–8.

The Meadow Branch coal field of West Virginia, by M. R. Campbell. Bull. No. 225, 1904, pp. 330–344.

Coal in the Nicholas quadrangle, West Virginia, by G. H. Ashley. Bull. No. 260, 1905, pp. 422–428.

Coal resources of the Kenova quadrangle, by W. C. Phalen. Bull. No. 285, 1906, pp. 259–268.

WYOMING.

The coal fields of Wyoming, by G. C. Hewitt. Mineral Resources U. S. for 1893, 1894, pp. 412–414.

A geological reconnaissance in northwest Wyoming, by G. H. Eldridge. Bull. No. 119, 1894. Coal, pp. 49–62.

Coals and Coal Measures of Wyoming, by W. C. Knight. Sixteenth Ann. Rept., pt. 4, 1895, pp. 208–215.

Field observations in the Hay Creek coal field, by W. P. Jenney. Nineteenth Ann. Rept., pt. 2, 1899, pp. 568–587.
Includes some account of the coals of the area.

Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming, by N. H. Darton. Twenty-first Ann. Rept., pt. 4, 1901, pp. 582–584.
Gives an account of the distribution of coal in the Lakota formation in northeastern Wyoming.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Coal of the Bighorn basin, in northwest Wyoming, by C. A. Fisher. Bull. No. 225, 1904, pp. 345–362.

Newcastle folio, Wyoming-South Dakota, description, by N. H. Darton. Geologic Atlas U. S., folio 107, 1904, pp. 8–9.

The coal of the Black Hills, Wyoming, by N. H. Darton. Bull. No. 260, 1905, pp. 429–433.

Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton. Prof. Paper No. 32, 1905, pp. 372–379.

Gives a general account of the occurrence of coal in Colorado, Wyoming, South Dakota, and Nebraska.

Sundance folio, Wyoming-South Dakota, description, by N. H. Darton. Geologic Atlas U. S., folio 127, 1905, p. 12.

Aladdin folio, Wyoming-South Dakota-Montana, description, by N. H. Darton and C. C. O'Harra. Geologic Atlas U. S., folio 128, 1905.

Mineral resources of the Bighorn Mountain region, by N. H. Darton. Bull. No. 285, 1906, pp. 303–310.

Includes an account of coal deposits in northeastern Wyoming.

Mineral resources of the Bighorn basin, by C. A. Fisher. Bull. No. 285, 1906, pp. 311–315.

Includes an account of the coal of the area.

Coal and oil in southern Uinta County, Wyo., by A. C. Veatch. Bull. No. 285, 1906, pp. 331–353.

Geology of the Bighorn Mountains, by N. H. Darton. Prof. Paper No. 51, 1906, pp. 62–67, 111–112.

Gives an account of the stratigraphy, character, and mining of coal in the Bighorn Mountains of Wyoming.

Geology and water resources of the Bighorn basin, Wyoming, by C. A. Fisher. Prof. Paper No. 53, 1906, pp. 46–56.

Describes the character, occurrence, and development of the coal deposits of the area.

Bald Mountain-Dayton folio, Wyoming, description, by N. H. Darton. Geologic Atlas U. S., folio 141, 1906, p. 14.

Cloud Peak-Fort McKinney folio, Wyoming, description, by N. H. Darton. Geologic Atlas U. S., folio 142, 1906, p. 15.

Devils Tower folio, Wyoming, description, by N. H. Darton and C. C. O'Harra. Geologic Atlas U. S., folio 150, 1907, p. 8.

INDEX.

CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Bulletin No. 316.]

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:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained, free of charge (except classes 2, 7, and 8), on application.

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.

4. Copies of all Government publications are furnished to the principal public libraries in the large cities throughout the United States, where they can be consulted by those interested.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports; Q, Fuels; R, Structural materials. This paper is the ninety-eighth in Series A, and the fifty-first in Series E, the complete lists of which follow (PP=Professional Paper; B=Bulletin; WS=Water-Supply Paper.):

SERIES A, ECONOMIC GEOLOGY.

B 21. Lignites of Great Sioux Reservation: Report on region between Grand and Moreau rivers, Dakota, by Bailey Willis. 1885. 16 pp., 5 pls. (Out of stock.)

B 46. Nature and origin of deposits of phosphate of lime, by R. A. F. Penrose, jr., with introduction by N. S. Shaler. 1888. 143 pp. (Out of stock.)

B 65. Stratigraphy of the bituminous coal field of Pennsylvania, Ohio, and West Virginia, by I. C. White. 1891. 212 pp., 11 pls. (Out of stock.)

B 111. Geology of Big Stone Gap coal field of Virginia and Kentucky, by M. R. Campbell. 1893. 106 pp., 6 pls. (Out of stock.)

B 132. The disseminated lead ores of southeastern Missouri, by Arthur Winslow. 1896. 31 pp. (Out of stock.)

B 138. Artesian-well prospects in Atlantic Coastal Plain region, by N. H. Darton. 1896. 228 pp., 19 pls.

B 139. Geology of Castle Mountain mining district, Montana, by W. H. Weed and L. V. Pirsson. 1896. 164 pp., 17 pls.

B 143. Bibliography of clays and the ceramic arts, by J. C. Branner. 1896. 114 pp.

B 164. Reconnaissance on the Rio Grande coal fields of Texas, by T. W. Vaughan, including a report on igneous rocks from the San Carlos coal field, by E. C. E. Lord. 1900. 100 pp., 11 pls. (Out of stock.)

B 178. El Paso tin deposits, by W. H. Weed. 1901. 15 pp., 1 pl.
B 180. Occurrence and distribution of corundum in United States, by J. H. Pratt. 1901. 98 pp., 14 pls. (Out of stock; see No. 269.)
B 182. A report on the economic geology of the Silverton quadrangle, Colorado, by F. L. Ransome. 1901. 266 pp., 16 pls. (Out of stock.)
B 184. Oil and gas fields of the western interior and northern Texas Coal Measures and of the Upper Cretaceous and Tertiary of the western Gulf coast, by G. I. Adams. 1901. 64 pp., 10 pls. (Out of stock.)
B 193. The geological relations and distribution of platinum and associated metals, by J. F. Kemp. 1902. 95 pp., 6 pls.
B 198. The Berea grit oil sand in the Cadiz quadrangle, Ohio, by W. T. Griswold. 1902. 43 pp., 1 pl. (Out of stock.)
PP 1. Preliminary report on the Ketchikan mining district, Alaska, with an introductory sketch of the geology of southeastern Alaska, by A. H. Brooks. 1902. 120 pp., 2 pls.
B 200. Reconnaissance of the borax deposits of Death Valley and Mohave Desert, by M. R. Campbell. 1902. 23 pp., 1 pl. (Out of stock.)
B 202. Tests for gold and silver in shales from western Kansas. by Waldemar Lindgren. 1902. 21 pp. (Out of stock.)
PP 2. Reconnaissance of the northwestern portion of Seward Peninsula, Alaska, by A. J. Collier. 1902. 70 pp., 11 pls.
PP 10. Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers, by W. C. Mendenhall. 1902. 68 pp., 10 pls.
PP 11. Clays of the United States east of the Mississippi River, by Heinrich Ries. 1903. 298 pp., 9 pls. (Out of stock.)
PP 12. Geology of the Globe copper district, Arizona, by F. L. Ransome. 1903. 168 pp., 27 pls.
B 212. Oil fields of the Texas-Louisiana Gulf Coastal Plain, by C. W. Hayes and William Kennedy. 1903. 174 pp., 11 pls. (Out of stock.)
B 213. Contributions to economic geology, 1902; S. F. Emmons and C. W. Hayes, geologists in charge. 1903. 449 pp. (Out of stock.)
PP 15. The mineral resources of the Mount Wrangell district, Alaska, by W. C. Mendenhall and F. C. Schrader. 1903. 71 pp., 10 pls.
B 218. Coal resources of the Yukon, Alaska, by A. J. Collier. 1903. 71 pp., 6 pls.
B 219. The ore deposits of Tonopah, Nevada (preliminary report), by J. E. Spurr. 1903. 31 pp., 1 pl. (Out of stock.)
PP 20. A reconnaissance in northern Alaska in 1901, by F. C. Schrader. 1904. 139 pp., 16 pls.
PP 21. Geology and ore deposits of the Bisbee quadrangle, Arizona, by F. L. Ransome. 1904. 168 pp., 29 pls.
B 223. Gypsum deposits in the United States, by G. I. Adams and others. 1904. 129 pp., 21 pls. (Out of stock.)
PP 24. Zinc and lead deposits of northern Arkansas, by G. I. Adams. 1904. 118 pp., 27 pls.
PP 25. Copper deposits of the Encampment district, Wyoming, by A. C. Spencer. 1904. 107 pp., 2 pls. (Out of stock.)
B 225. Contributions to economic geology, 1903, by S. F. Emmons and C. W. Hayes, geologists in charge. 1904. 527 pp., 1 pl. (Out of stock.)
PP 26. Economic resources of the northern Black Hills, by J. D. Irving, with contributions by S. F. Emmons and T. A. Jaggar, jr. 1904. 222 pp., 20 pls.
PP 27. A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho, by Waldemar Lindgren. 1904. 123 pp., 15 pls.
B 229. Tin deposits of the York region, Alaska, by A. J. Collier. 1904. 61 pp., 7 pls.
B 236. The Porcupine placer district, Alaska, by C. W. Wright. 1904. 35 pp., 10 pls.
B 238. Economic geology of the Iola quadrangle, Kansas, by G. I. Adams, Erasmus Haworth, and W. R. Crane. 1904. 83 pp., 11 pls.
B 243. Cement materials and industry of the United States, by E. C. Eckel. 1905. 395 pp., 15 pls.
B 246. Zinc and lead deposits of northwestern Illinois, by H. Foster Bain. 1904. 56 pp., 5 pls.
B 247. The Fairhaven gold placers of Seward Peninsula, Alaska, by F. H. Moffit. 1905. 85 pp., 14 pls.
B 249. Limestones of southeastern Pennsylvania, by F. G. Clapp. 1905. 52 pp., 7 pls.
B 250. The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. 1905. 65 pp., 7 pls.
B 251. The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska, by L. M. Prindle. 1905. 89 pp., 16 pls.
WS 117. The lignite of North Dakota and its relation to irrigation, by F. A. Wilder. 1905. 59 pp., 8 pls.
PP 36. The lead, zinc, and fluorspar deposits of western Kentucky, by E. O. Ulrich and W. S. T. Smith. 1905. 218 pp., 15 pls.
PP 38. Economic geology of the Bingham mining district, Utah, by J. M. Boutwell, with a chapter on areal geology, by Arthur Keith, and an introduction on general geology, by S. F. Emmons. 1905. 413 pp., 49 pls.

PP 41. Geology of the central Copper River region, Alaska, by W. C. Mendenhall. 1905. 133 pp., 20 pls.
B 254. Report of progress in the geological resurvey of the Cripple Creek district, Colorado, by Waldemar Lindgren and F. L. Ransome. 1904. 36 pp.
B 255. The fluorspar deposits of southern Illinois, by H. Foster Bain. 1905. 75 pp., 6 pls. (Out of stock.)
B 256. Mineral resources of the Elders Ridge quadrangle, Pennsylvania, by R. W. Stone. 1905. 86 pp., 12 pls.
B 259. Report on progress of investigations of mineral resources of Alaska in 1904, by A. H. Brooks and others. 1905. 196 pp., 3 pls.
B 260. Contributions to economic geology, 1904; S. F. Emmons and C. W. Hayes, geologists in charge. 1905. 620 pp., 4 pls.
B 261. Preliminary report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes and M. R. Campbell, committee in charge. 1905. 172 pp. (Out of stock.)
B 263. Methods and cost of gravel and placer mining in Alaska, by C. W. Purington. 1905. 273 pp., 42 pls. (Out of stock.)
PP 42. Geology of the Tonopah mining district, Nevada, by J. E. Spurr. 1905. 295 pp., 24 pls.
PP 43. The copper deposits of the Clifton-Morenci district, Arizona, by Waldemar Lindgren. 1905. 375 pp., 25 pls.
B 264. Record of deep-well drilling for 1904, by M. L. Fuller, E. F. Lines, and A. C. Veatch. 1905. 106 pp.
B 265. Geology of the Boulder district, Colorado, by N. M. Fenneman. 1905. 101 pp., 5 pls.
B 267. The copper deposits of Missouri, by H. Foster Bain and E. O. Ulrich. 1905. 52 pp., 1 pl.
B 269. Corundum and its occurrence and distribution in the United States (a revised and enlarged edition of Bulletin No. 180), by J. H. Pratt. 1906 175 pp., 18 pls.
PP 48. Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1906. (In 3 parts.) 1,492 pp., 13 pls.
B 275. Slate deposits and slate industry of the United States, by T. N. Dale, with sections by E. C. Eckel, W. F. Hillebrand, and A. T. Coons. 1906. 154 pp., 25 pls.
PP 49. Geology and mineral resources of part of the Cumberland Gap coal field, Kentucky, by G. H. Ashley and L. C. Glenn in cooperation with the State Geological Department of Kentucky, C. J. Norwood, curator, 1906. 239 pp., 40 pls.
B 277. Mineral resources of Kenai Peninsula, Alaska; Gold fields of the Turnagain Arm region, by F. H. Moffit; Coal fields of the Kachemak Bay region, by R. W. Stone. 1906. 80 pp., 18 pls.
B 278. Geology and coal resources of the Cape Lisburne region, Alaska, by A. J. Collier. 1906. 54 pp., 9 pls. (Out of stock.)
B 279. Mineral resources of the Kittanning and Rural Valley quadrangles, Pennsylvania, by Charles Butts. 1906. 198 pp., 11 pls.
B 280. The Rampart gold placer region, Alaska, by L. M. Prindle and F. L. Hess. 1906. 54 pp., 7 pls. (Out of stock.)
B 282. Oil fields of the Texas-Louisiana Gulf Coastal Plain, by N. M. Fenneman. 1906. 146 pp., 11 pls.
PP 51. Geology of the Bighorn Mountains, by N. H. Darton. 1906. 129 pp., 47 pls.
B 283. Geology and mineral resources of Mississippi, by A. F. Crider. 1906. 99 pp., 4 pls.
B 284. Report on progress of investigations of the mineral resources of Alaska in 1905, by A. H. Brooks and others. 1906. 169 pp., 14 pls.
B 285. Contributions to Economic Geology, 1905; S. F. Emmons and E. C. Eckel, geologists in charge. 1906. 506 pp., 13 pls. (Out of stock.)
B 286. Economic geology of the Beaver quadrangle, Pennsylvania, by L. H. Woolsey. 1906. 132 pp., 8 pls.
B 287. Juneau gold belt, Alaska, by A. C. Spencer, and A reconnaissance of Admiralty Island, Alaska, by C. W. Wright. 1906. 161 pp., 27 pls.
PP 54. The geology and gold deposits of the Cripple Creek district, Colorado, by W. Lindgren and F. L. Ransome. 1906. 516 pp., 29 pls.
PP 55. Ore deposits of the Silver Peak quadrangle, Nevada, by J. E. Spurr. 1906. 174 pp., 24 pls.
B 289. A reconnaissance of the Matanuska coal field, Alaska, in 1905, by G. C. Martin. 1906. 34 pp., 5 pls.
B 290. Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905, by J. A. Holmes. 1906. 240 pp.
B 293. Reconnaissance of some gold and tin deposits of the southern Appalachians, by L. C. Graton, with notes on the Dahlonega mines, by W. Lindgren. 1906. 134 pp., 9 pls.
B 294. Zinc and lead deposits of the upper Mississippi Valley, by H. Foster Bain. 1906. 155 pp., 16 pls.
B 295. The Yukon-Tanana region, Alaska, description of Circle quadrangle, by L. M. Prindle. 1906. 27 pp., 1 pl.
B 296. Economic geology of the Independence quadrangle, Kansas, by Frank C. Schrader and Erasmus Haworth. 1906. 74 pp., 6 pls.

B 297. The Yampa coal field, Routt County, Colo., by N. M. Fenneman, Hoyt S. Gale, and M. R. Campbell. 1906. 96 pp., 9 pls.

B 298. Record of deep-well drilling for 1905, by Myron L. Fuller and Samuel Sanford. 1906. 299 pp.

B 300. Economic geology of the Amity quadrangle in eastern Washington County, Pa., by Frederick G. Clapp. 1907. 145 pp., 8 pls.

B 303. Preliminary account of Goldfield, Bullfrog, and other mining districts in southern Nevada, by F. L. Ransome; with notes on Manhattan district, by G. H. Garrey and W. H. Emmons. 1906. 98 pp., 5 pls.

B 304. Oil and gas fields of Greene County, Pa., by R. W. Stone and Frederick G. Clapp. 1906. 110 pp., 3 pls.

PP 56. Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil, by A. C. Veatch. 1907. 178 pp., 26 pls.

B. 308. A geologic reconnaissance in southwestern Nevada and eastern California, by S. H. Ball. 1907. 218 pp., 3 pls.

B 309. The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California, by G. H. Eldridge and Ralph Arnold. 1907. 266 pp., 41 pls.

B 312. The interaction between minerals and water solutions, with special reference to geologic phenomena, by E. C. Sullivan. 1907. 69 pp.

B 313. The granites of Maine, by T. Nelson Dale, with an introduction by G. O. Smith. 1907. 202 pp., 14 pls.

B 314. Report of progress of investigations of mineral resources of Alaska in 1906, by A. H. Brooks and others. 1907. 235 pp., 4 pls.

B 315. Contributions to economic geology, 1906, Part I: Metals and nonmetals, except fuels; S. F. Emmons and E. C. Eckel, geologists in charge. 1907. 504 pp., 4 pls.

WS 215. Geology and water resources of a portion of the Missouri River Valley in northeastern Nebraska, by G. E. Condra. 1908. — pp., 11 pls.

WS 216. Geology and water resources of the Republican River Valley in Nebraska and adjacent areas by G. E. Condra. 1907. 71 pp., 13 pls.

B 316. Contributions to economic geology, 1906, Part II: Coal, lignite, and peat; M. R. Campbell, geologist in charge. 1907. 543 pp., 23 pls.

SERIES E, CHEMISTRY AND PHYSICS.

B 9. Report of work done in the Washington laboratory during the fiscal year 1883-84, by F. W. Clarke and T. M. Chatard. 1884. 40 pp. (Out of stock.)

B 14. Electrical and magnetic properties of the iron carburets, by Carl Barus and Vincent Strouhal. 1885. 238 pp. (Out of stock.)

B 27. Report of work done in the Division of Chemistry and Physics, mainly during the year 1884-85. 1886. 80 pp.

B 32. Lists and analyses of the mineral springs of the United States (a preliminary study), by Albert C. Peale. 1886. 235 pp. (Out of stock.)

B 35. Physical properties of the iron carburets, by Carl Barus and Vencent Strouhal. 1886. 62 pp.

B 36. Subsidence of fine solid particles in liquids, by Carl Barus. 1886. 58 pp. (Out of stock.)

B 42. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1885-86, by F. W. Clarke. 1887. 152 pp., 1 pl. (Out of stock.)

B 47. Analyses of waters of the Yellowstone National Park, with an account of the methods of analyses employed, by F. A. Gooch and J. E. Whitfield. 1888. 84 pp. (Out of stock.)

B 52. Subaerial decay of rocks and origin of the red color of certain formations, by I. C. Russell. 1889. 65 pp., 5 pls. (Out of stock.)

B 54. On the thermoelectric measurement of high temperatures, by Carl Barus. 1889. 313 pp., 11 pls. (Out of stock.)

B 55. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1886-87, by F. W. Clarke. 1889. 96 pp. (Out of stock.)

B 60. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1887-88. 1890. 174 pp. (Out of stock.)

B 64. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1888-89, by F. W. Clarke. 1890. 60 pp.

B 68. Earthquakes in California in 1889, by J. E. Keeler. 1890. 25 pp.

B 73. The viscosity of solids, by Carl Barus. 1891. xii, 139 pp., 6 pls.

B 78. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1889-90, by F. W. Clarke. 1891. 131 pp. (Out of stock.)

B 90. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1890-91, by F. W. Clarke. 1892. 77 pp.

B 92. The compressibility of liquids, by Carl Barus. 1892. 96 pp., 29 pls.

B 94. The mechanism of solid viscosity, by Carl Barus. 1892. 138 pp.

B 95. Earthquakes in California in 1890 and 1891, by E. S. Holden. 1892. 31 pp.

B 96. The volume thermodynamics of liquids, by Carl Barus. 1892. 100 pp.

B 103. High temperature work in igneous fusion and ebullition, chiefly in relation to pressure, by Carl Barus. 1893. 57 pp., 9 pls.
B 112. Earthquakes in California in 1892, by C. D. Perrine. 1893. 57 pp.
B 113. Report of work done in the Division of Chemistry and Physics during the fiscal years 1891-92 and 1892-93, by F. W. Clarke. 1893. 115 pp.
B 114. Earthquakes in California in 1893, by C. D. Perrine. 1894. 23 pp.
B 125. The constitution of the silicates, by F. W. Clarke. 1895. 100 pp. (Out of stock.)
B 129. Earthquakes in California in 1894, by C. D. Perrine. 1895. 25 pp.
B 147. Earthquakes in California in 1895, by C. D. Perrine. 1896. 23 pp.
B 148. Analyses of rocks, with a chapter on analytical methods, laboratory of the United States Geological Survey, 1880 to 1896, by F. W. Clarke and W. F. Hillebrand. 1897. 306 pp. (Out of stock.)
B 155. Earthquakes in California in 1896 and 1897, by C. D. Perrine. 1898. 47 pp.
B 161. Earthquakes in California in 1898, by C. D. Perrine. 1899. 31 pp., 1 pl.
B 167. Contributions to chemistry and mineralogy from the laboratory of the United States Geological Survey; F. W. Clarke, Chief Chemist. 1900. 166 pp.
B 168. Analyses of rocks, laboratory of the United States Geological Survey, 1880 to 1899, tabulated by F. W. Clarke. 1900. 308 pp. (Out of stock.)
B 176. Some principles and methods of rock analysis, by W. F. Hillebrand. 1900. 114 pp. (Out of stock.)
B 186. On pyrite and marcasite, by H. N. Stokes. 1900. 50 pp.
B 207. The action of ammonium chloride upon silicates, by F. W. Clarke and George Steiger. 1902. 57 pp. (Out of stock.)
PP 14. Chemical analyses of igneous rocks published from 1884 to 1900, with a critical discussion of the character and use of analyses, by H. S. Washington. 1903. 495 pp.
PP 18. Chemical composition of igneous rocks expressed by means of diagrams, with reference to rock classification on a quantitative chemico-mineralogical basis, by J. P. Iddings. 1903. 98 pp., 8 pls.
B 220. Mineral analyses from the laboratories of the United States Geological Survey, 1880 to 1903, tabulated by F. W. Clarke, Chief Chemist. 1903. 119 pp.
B 228. Analyses of rocks from the laboratory of the United States Geological Survey, 1880 to 1903, tabulated by F. W. Clarke, Chief Chemist. 1904. 375 pp.
PP 28. The superior analyses of igneous rocks from Roth's tabellen, 1869 to 1884, arranged according to the quantitative system of classification, by H. S. Washington. 1904. 68 pp.
B 239. Rock cleavage, by C. K. Leith. 1904. 216 pp., 27 pls.
B 241. Experiments on schistosity and slaty cleavage, by G. F. Becker. 1904. 34 pp., 7 pls.
B 253. Comparison of a wet and crucible-fire method for the assay of gold telluride ores, with notes on the errors occurring in the operations of fire assay and parting, by W. F. Hillebrand and E. T. Allen. 1905. 33 pp.
B 261. Preliminary report of the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1905. 172 pp.
B 262. Contributions to mineralogy from the United States Geological Survey, by F. W. Clarke, W. F. Hillebrand, F. G. Ransome, S. L. Penfield, Waldemar Lindgren, George Steiger, and W. T. Schaller. 1905. 147 pp.
PP 48. Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1906. 3 parts. 1,492 pp., 13 pls.
B 290. Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905, by J. A. Holmes. 1906. 240 pp.
B 305. The analysis of silicate and carbonate rocks, by W. F. Hillebrand. 1906. 200 pp.
B 312. The interaction between minerals and water solutions, with special reference to geologic phenomena, by E. C. Sullivan. 1907. 69 pp.
B 316. Contributions to economic geology, 1906, Part II: Coal, lignite, and peat; M. R. Campbell, geologist in charge. 1907. 543 pp., 23 pls.

Correspondence should be addressed to

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

NOVEMBER, 1907.

O