Heat-absorption studies were completed on two large electric utility boiler furnaces, both pulverized-coal-fired but differing in design and type of firing.58/59/ In both furnaces the heat transfer from the flame was found to be considerably less than that which is theoretically achievable from a perfect radiation source at the temperature of the flame. However, good correlation was noted between the fourth power of the temperature of the gases leaving the furnaces and the heat absorption in the respective furnaces.

Disposal of Radioactive Wastes by Incineration

With increasing use of radioisotopes for research and medical therapy in clinics, hospitals, universities, and other institutions, the care in the disposal of radioactive wastes to prevent contamination of personnel, ground waters, and the atmosphere must be simple and economical. Combustible wastes, such as paper, cloth, wood, animals, etc., comprising the largest part of such wastes, are most conveniently handled by incineration, since a 10- to 15-fold reduction in volume of material is attained. However, ash and other solid incinerator residues and the products of combustion present a special handling problem in densely populated areas, and the Atomic Energy Commission contracted with the Bureau of Mines to develop an incinerator to meet the needs in this respect.

The first phase of this project was completed and consisted of devising a method for collecting dry residues from an incinerator in a manner that would obviate the need for manual handling of the residues, in which the level of radioactivity might be relatively high as compared to the original waste. The method60/ consists of catching and dissolving the residues in molten sodium hydroxide held at a temperature of 1,000° F. during operation of the incinerator. When the flux is saturated with residues, it can be shipped as a solid, compact mass to the final disposal point. It is estimated that a 100-pound charge of sodium hydroxide will handle the residue from approximately 2,000 pounds of waste material. Owing to the low cost of the flux and the use of disposable plain carbon steel pots to retain the flux, the cost of this operation would be a negligible factor in the over-all operating costs. Work is being continued on the design and construction of the incinerator and auxiliary equipment.

CARBONIZATION OF COAL

Survey of Carbonizing Properties of American Coals

Pilot-scale carbonization tests at high temperatures only were continued as during the past 2 years. As this work comprises the third (carbonization) phase of the coking-coal reserve investigation, emphasis was placed on the suitability of the coals tested for making metallurgical coke; however, yields and quality of other carbonization products were also determined. Most coals were carbonized singly and in blends in order to evaluate more completely their coke-making properties.61/

58/ Corey, R. C., and Cohen, P., Furnace Heat Absorption in Paddy's Run Pulverized-Coal-Fired Steam Generator, Using Turbulent Burners, Louisville, Ky.: Trans. Am. Soc. Mech. Eng., vol. 72, No. 7, October 1950, pp. 925-935.

59/ Myers, J. W., and Corey, R. C., Furnace Heat Absorption in Pulverized-Coal-Fired Steam Generator, Willow Island Station: Trans. Am. Soc. Mech. Eng., vol. 73, May 1951, pp. 419-432.

60/ Corey, R. C., Perry, H., and Schwartz, C. H., Off-Site Disposal of Radioactive Incinerator Residues by Solid Fluxes: Am. Ind. Hygiene Assoc. Quarterly, vol. 12, No. 2, June 1951, pp. 52-57.

61/ Davis, J. D., Survey of Carbonizing Properties of American Coals, Bureau of Mines Coal-Carbonization Laboratory, 1949-50: Proc. Am. Gas Assoc., 1950, pp. 402-409.

TABLE 8. - Description and analysis of coals and proportions used in blends

West Virginia

Coal No.	Description	Analysis, percent: Proximate: H_2O	Volatile matter	Fixed carbon	Ash	Sulfur	Dry, mineral matter-free fixed carbon
449........	Beckley bed, Caretta No. 5 mine, [illegible], McDowell County........	3.1	15.8	72.4	8.7	0.7	83.0
449A........	Blend: 20 percent Beckley (449) and 80 percent Pittsburgh (r28).	-	-	-	-	-	-
449B........	Blend: 30 percent Beckley (449) and 70 percent Pittsburgh (r28).	-	-	-	-	-	-
450........	Beckley bed, Glen Rogers No. 2 mine, Glen Rogers, Wyoming County.	1.6	18.5	75.4	4.5	1.1	80.8
450A........	Blend: 40 percent Beckley (450) and 60 percent Pittsburgh (r28).	-	-	-	-	-	-
450B........	Blend: 30 percent Beckley (450) and 70 percent Pittsburgh (r28).	-	-	-	-	-	-
465........	Sewell bed, Imperial No. 3 mine, Quinwood, Greenbrier County.....	2.8	27.1	66.8	3.3	.5	71.4
465A........	Blend: 20 percent Sewell (465) and 80 percent Pittsburgh (r28)..	-	-	-	-	-	-
465B........	Blend: 30 percent Sewell (465) and 70 percent Pittsburgh (r28)..	-	-	-	-	-	-
465C........	Blend: 50 percent Sewell (465) and 50 percent Pittsburgh (r28)..	-	-	-	-	-	-
466........	Pittsburgh bed, Morgan No. 2 mine, Perry County..................	3.0	36.4	54.4	6.2	1.3	60.4
467........	Winifrede bed, Hedley No. 7 mine, Kanawha County.................	2.9	34.1	58.8	4.2	.5	63.6
467A........	Blend: 80 percent Winifrede (467) and 20 percent Pocahontas (475)..	-	-	-	-	-	-
467B........	Blend: 70 percent Winifrede (467) and 30 percent Pocahontas (475)..	-	-	-	-	-	-
467C........	Blend: 90 percent Winifrede (467) and 10 percent Pocahontas (475)..	-	-	-	-	-	-
467D........	Blend: 75 percent Winifrede (467) and 25 percent Pocahontas (475)..	-	-	-	-	-	-
468........	Winifrede bed, Crown Hill No. 4 mine, Kanawha County.............	2.4	35.6	57.8	4.2	.7	62.2
470........	Upper Freeport bed, Sago mine, Sago, Upshur County...............	3.3	38.1	53.5	5.1	2.0	58.7
475........	Pocahontas No. 3 bed..	6.0	17.3	71.3	5.4	.9	81.6

Pennsylvania

Coal No.	Description	H_2O	Volatile matter	Fixed carbon	Ash	Sulfur	Dry, mineral matter-free fixed carbon
442........	Lower Freeport bed, Ross and Hess mine, Dixonville, Indiana County..	2.5	29.3	57.7	10.5	2.9	67.4
442A........	Blend: 70 percent Lower Freeport (442) and 30 percent Lower Kittanning (445)...	-	-	-	-	-	-
442B........	Blend: 80 percent Lower Freeport (442) and 20 percent Lower Kittanning (445)...	-	-	-	-	-	-
442C........	Blend: 80 percent Lower Freeport (442) and 20 percent Pocahontas (475)..	-	-	-	-	-	-
443........	Lower Kittanning bed, McElvin mine, Starford, Indiana County......	3.3	27.3	61.7	7.7	2.1	70.1
444........	Thick Freeport bed, Russellton No. 2 mine, Allegheny County.......	6.0	32.5	52.2	9.3	.9	62.4
445........	Thick Freeport bed, Russellton No. 2 mine, Allegheny County.......	4.3	16.1	16.9	62.7	5.3	65.1
448........	Upper Freeport bed, Decker No. 2 mine, Armstrong County..........	3.2	34.1	56.0	6.7	1.2	62.7
451........	Lower Kittanning bed, Armstrong County............................	1.5	38.6	52.1	7.8	2.5	55.1
452........	Lower Kittanning bed, Cadogan mine, Armstrong County.............	3.5	24.2	28.4	43.9	21.0	61.6
455........	Upper Freeport bed, Ross's mine, Dunbar, Fayette County..........	2.6	31.2	57.6	8.6	2.1	65.7
455A........	Blend: 80 percent Upper Freeport (455) and 20 percent Pocahontas (475)..	-	-	-	-	-	-
455B........	Blend: 70 percent Upper Freeport (455) and 30 percent Pocahontas (475)..	-	-	-	-	-	-
469........	Sewickley bed, Atlas mine, Fayette County.........................	2.9	32.2	53.4	11.5	3.8	61.5
469A........	Blend: 80 percent Sewickley (469) and 20 percent Pocahontas (475)..	-	-	-	-	-	-
469B........	Blend: 70 percent Sewickley (496) and 30 percent Pocahontas (475)..	-	-	-	-	-	-
480........	Upper Freeport bed, [illegible] mines 10 and 10a, [illegible], Westmoreland County...	1.7	32.8	56.2	9.3	3.3	64.1
480A........	Blend: 80 percent Upper Freeport (480) and 20 percent Pocahontas (475)..	-	-	-	-	-	-
480B........	Blend: 70 percent Upper Freeport (480) and 30 percent Pocahontas (475)..	-	-	-	-	-	-

TABLE 8. - Description and analysis of coals and proportions used in blends (Cont.)

Coal No.	Description	Analysis, percent: Proximate: H_2O	Volatile matter	Fixed carbon	Ash	Sulfur	Dry, mineral-matter-free fixed carbon
	Virginia						
476	Tiller bed, Salckler mine, Dickenson County	2.5	25.3	67.9	5.3	0.6	72.0
478	Clintwood bed, from near Gladeville, Wise County	3.3	31.1	58.9	6.7	.6	66.0
	Tennessee						
456	Jellico bed, Blue Hose mine, Morely, Campbell County	2.7	37.3	55.8	4.2	1.0	60.3
456A	Blend: 80 percent Jellico (456) and 20 percent Pocahontas (579)	-	-	-	-	--	-
456B	Blend: 70 percent Jellico (456) and 30 percent Pocahontas (579)	-	-	-	-	--	-
477	Sewanee bed, Needs Cove No. 2 mine, Whitwell, Marion County	2.3	36.5	50.6	8.6	.?	58.7
477A	Blend: 60 percent Sewanee (477) and 40 percent Pocahontas (479)	-	-	-	-	-	-
477B	Blend: 70 percent Sewanee (477) and 30 percent Clintwood (478)	-	-	-	-	-	-
477C	Blend: 70 percent Sewanee (477) and 30 percent Pittsburgh (526)	-	-	-	-	-	-
477D	Blend: 50 percent Sewanee (477) and 50 percent Pittsburgh (528)	-	-	-	-	-	-
477E	Blend: 30 percent Sewanee (477) and 70 percent Pittsburgh (528)	-	-	-	-	--	-
	Alabama						
47[illegible]	Blend: 50 percent Black Creek and 50 percent Mary Lee beds	-	-	-	-	-	-
	Washington						
446	Wilkeson No. 3 bed	3.9	32.1	53.4	10.7	0.4	63.3
447	Wilkeson No. 2 bed	2.0	31.0	55.3	11.7	.4	65.5
	South America						
434	Veta Principal bed, Cundinamarca Dept., Colombia	1.9	33.5	50.0	14.6	3.5	61.2
434A	Blend: 50 percent coal 434 and 50 percent coal 435	-	-	-	-	-	-
435	Veta Secundaria bed, Cundinamarca Dept., Colombia	2.0	20.0	63.4	14.6	1.1	75.5
436	No. 1 bed, Valle del Cauca Dept., Colombia	4.7	27.2	55.5	12.5	2.6	68.4
437	Grande bed, Valle del Cauca Dept., Colombia	4.9	23.0	67.2	3.7	.8	75.9
438	Nos. 5 and 6 beds, Valle del Cauca Dept., Colombia	1.6	40.1	42.6	12.7	3.4	52.5
439	Grarie Nos. 2 and 3 beds, Valle del Cauca Dept., Colombia	4.4	37.5	50.6	7.5	2.7	58.1
440	Nos. 3 and 4 beds, Valle del Cauca Dept., Colombia	1.5	41.9	40.6	15.9	.7	50.3
440A	Blend: 50 percent coal 440 and 50 percent coal 441						
441	Nos. 3 and 4 beds, Valle del Cauca Dept., Colombia	2.8	36.7	33.9	26.6	.9	50.0
459	Large bed, Valle del Cauca Dept., Colombia	3.3	41.1	40.7	14.9	1.1	50.2
460	Grande bed, Valle del Cauca Dept., Colombia	1.5	41.5	45.5	7.5	.7	50.7
461	Mixture of 4 beds, Valle del Cauca Dept., Colombia	3.4	37.9	42.3	16.5	.5	51.4
462	bed, Valle del Cauca Dept., Colombia	5.3	39.5	41.7	13.5	2.5	52.4
463	Nos. 2 and 3 beds, Valle del Cauca Dept., Colombia	4.0	39.6	41.0	15.4	2.5	52.0
464	La Ducha bed, Valle del Cauca Dept., Colombia	5.1	31.5	54.5	6.9	1.7	75.9
	Miscellaneous						
472	Lignite, North Dakota	37.0	25.5	28.5	8.9	0.4	53.6
475	Sandow lignite, Milam County, Tex.	28.1	31.6	29.8	10.0	1.5	49.3
481	Pittsburgh No. 8 bed, Jefferson County, Ohio	5.0	38.0	49.5	7.5	2.7	57.2
482	Pittsburgh No. 8 bed, Belmont County, Ohio	5.2	39.5	47.7	7.6	3.?	55.4
	Blending coals						
526	Pittsburgh bed, Warden mine, Allegheny County, Pa.	3.1	33.0	54.6	9.3	1.9	63.1
528	Pittsburgh bed, Warden mine, Allegheny County, Pa.	1.8	35.4	57.7	5.1	.9	62.4
479	Pocahontas No. 3 bed, McDowell County, W. Va.	2.7	16.9	75.1	5.4	.6	82.2

4991

TABLE 9. - Physical properties of coke

A.S.T.M. METHOD

Coal No.	Carbonizing temperature, °C.	True specific gravity	Apparent specific gravity	Cells, percent	Shatter test,1/ cumulative percent upon- 2-inch screen	1-1/2-inch screen	1-inch screen	1/2-inch screen	Tumbler test,1/ cumulative percent upon- 2-inch screen	1-1/2-inch screen	1-inch screen	1/2-inch screen	1/4-inch screen
West Virginia													
449A..........	800	1.88	0.84	55.3	90	95	97	98	19	45	56	59	59
449B..........	800	1.86	.84	54.6	91	96	97	98	21	50	62	64	64
449...........	900	1.90	.92	51.6	64	91	95	99	3	24	56	63	64
449A..........	900	1.92	.85	55.7	69	90	96	97	1	19	51	61	62
449B..........	900	1.89	.88	54.5	68	90	96	98	2	23	50	60	62
450A..........	800	1.86	.87	53.8	88	95	97	98	16	45	59	62	65
450B..........	800	1.85	.85	54.1	91	96	97	98	22	53	62	64	64
450...........	900	1.87	.87	53.5	72	93	97	99	4	30	58	64	65
450A..........	900	1.89	.87	54.0	63	88	96	98	2	22	53	64	66
450B..........	900	1.89	.88	54.5	71	90	97	98	3	24	55	66	67
465B..........	800	1.83	.85	53.6	81	92	96	98	5	32	52	59	60
465C..........	800	1.82	.86	52.3	20	91	96	98	8	30	50	58	59
465...........	900	1.85	.90	56.8	56	65	96	98	2	21	57	63	64
465B..........	900	1.87	.89	52.4	50	63	95	97	0	11	46	61	65
465C..........	900	1.84	.89	52.2	42	54	95	95	0	11	47	63	65
467...........	800	1.83	.85	53.6	[illegible]	88	93	96	3	19	35	51	56
467A..........	800	1.85	.85	54.1	94	94	97	98	14	44	57	60	61
467B..........	800	1.85	.84	54.6	86	95	97	99	14	49	58	61	61
467...........	900	1.87	.87	53.5	46	74	93	97	0	[illegible]	42	59	65
467A..........	900	1.86	.84	53.3	47	84	96	98	0	14	49	55	57
467B..........	900	1.88	.87	53.7	54	82	93	96	0	12	50	66	67
468...........	900	1.87	.86	54.0	45	77	92	97	0	7	39	57	63
470...........	900	1.85	.88	55.7	48	60	92	95	0	1	22	44	47
Pennsylvania													
442...........	900	1.93	0.91	52.8	66	89	95	97	0	3	41	54	57
442A..........	900	1.93	.87	54.9	65	89	95	97	1	24	47	57	59
442B..........	900	1.95	.87	54.9	65	89	95	97	2	22	40	56	59
442C..........	900	1.92	.88	54.2	58	91	97	98	2	26	51	58	60
458...........	900	1.89	.86	54.5	79	93	96	95	5	29	46	56	59
458A..........	800	1.87	.84	55.1	85	95	98	98	12	43	56	58	59
458B..........	800	1.87	.85	54.5	89	95	97	98	21	48	57	58	56
458...........	900	1.91	.88	53.9	57	86	95	97	1	12	47	58	59
458A..........	920	1.90	.85	55.3	53	90	96	98	3	26	54	61	62
458B..........	900	1.90	.85	55.3	60	90	97	95	3	29	54	6[illegible]	61
469...........	500	1.94	.95	50.5	82	91	95	97	4	2[illegible]	38	49	51
469A..........	800	1.91	.96	49.7	87	96	97	98	11	30	53	57	56
469...........	900	1.94	.89	56.2	57	87	95	97	0	9	35	49	55
469A..........	900	1.94	.92	52.5	54	65	96	98	1	11	40	52	54
469B..........	900	1.95	.95	51.3	64	87	96	98	0	16	46	57	59
480...........	800	1.91	.98	48.7	78	90	94	98	5	20	36	50	54
480A..........	800	1.92	.97	49.5	81	93	95	97	7	33	52	57	58
480B..........	800	1.90	.93	51.1	90	99	97	98	16	44	56	59	59
480...........	900	1.95	.91	52.5	58	87	99	97	0	10	40	55	57
480A..........	900	1.94	.96	52.5	60	87	96	97	1	15	46	57	59
480B..........	900	1.93	.91	52.8	64	87	96	95	1	20	49	59	61

TABLE 9. - Physical properties of coke (Cont.)

Coal No.	Carbonizing temperature, °C.	True specific gravity	Apparent specific gravity	Cells, percent	Shatter test,[1] cumulative percent upon: 2-inch screen	1-1/2-inch screen	1-inch screen	1/2-inch screen	Tumbler test,[1] cumulative percent upon: 2-inch screen	1-1/2-inch screen	1-inch screen	1/2-inch screen	1/4-inch screen
Tennessee													
456...........	800	1.82	0.81	55.5	62	77	89	96	0	3	21	47	59
456A..........	800	1.84	.83	54.9	84	92	96	97	8	35	53	59	60
456B..........	800	1.82	.82	54.9	88	95	97	96	12	42	58	61	61
456...........	900	1.86	.81	56.5	49	79	91	96	0	4	28	52	60
456A..........	900	1.86	.86	53.8	47	88	95	98	0	10	47	65	67
456B..........	900	1.86	.84	54.8	51	82	95	97	1	10	48	65	67
477...........	800	1.88	.84	55.3	89	91	97	96	9	47	61	64	64
477D..........	800	1.87	.85	54.5	78	91	96	97	6	29	48	63	64
477E..........	800	1.86	.86	53.8	74	87	95	97	3	21	45	62	64
477...........	900	1.90	.84	55.8	57	85	96	96	1	22	57	66	67
477A..........	900	1.90	.83	56.3	61	89	97	98	4	25	57	66	66
477B..........	900	1.90	.84	55.8	59	87	96	97	2	23	55	60	67
477C..........	900	1.90	.86	54.7	58	85	96	96	1	22	58	68	69
477D..........	900	1.90	.86	54.7	47	85	95	97	[illegible]	18	54	67	68
477E..........	900	1.89	.88	53.4	38	79	95	98	0	10	52	67	68
477...........	1,000	1.93	.85	55.7	26	69	94	96	2	6	46	69	70
Alabama													
475...........	800	1.88	0.92	51.3	88	94	97	96	11	44	57	61	62
475...........	900	1.91	.90	52.8	55	86	95	98	0	15	50	62	64
475...........	1,000	1.93	.90	53.4	24	69	93	98	1	3	36	63	65

BM-AGA METHOD

Coal No.	Carbonizing temperature, °C.	True specific gravity	Apparent specific gravity	Cells, percent	Shatter test,[1] cumulative percent upon: 2-inch screen	1-1/2-inch screen	1-inch screen	1/2-inch screen	Tumbler test,[1] cumulative percent upon: 2-inch screen	1-1/2-inch screen	1-inch screen	1/2-inch screen	1/4-inch screen
Washington													
446...........	900	1.94	0.79	59.3	41	79	95	98	0	19	53	-	63
447...........	900	1.93	.87	54.9	25	76	94	98	0	15	64	-	75
South America													
434...........	900	1.98	0.90	54.5	47	75	93	97	0	20	56	-	67
434A..........	900	1.94	.95	51.0	67	89	96	98	8	39	64	-	71
435...........	900	1.96	.93	52.6	62	88	96	98	11	42	65	-	72
436...........	900	1.99	.78	60.8	38	84	95	98	3	30	60	-	68
437...........	900	1.90	.81	57.4	49	83	95	99	4	30	65	-	78
438...........	900	2.02	.83	58.9	37	65	89	96	0	5	35	-	65
439...........	900	1.94	.74	61.9	28	64	91	97	0	9	46	-	67
440A..........	900	2.06	.89	56.8	68	86	92	96	3	29	35	-	43
459...........	900	2.00	.81	59.5	30	55	75	94	0	1	15	-	60
460...........	900	1.93	.76	60.6	6	42	69	97	0	0	10	-	71
461...........	900	2.01	.80	60.2	42	70	85	95	0	6	34	-	55
462...........	900	1.99	.81	59.3	31	65	89	97	0	2	31	-	63
463...........	900	2.04	.80	60.8	42	78	90	97	1	13	46	-	67
464...........	No tests made; coke was mostly char.												

1/ The actual sizes of screens designated at 1, 1/2, and 1/4 inch were 1.06, 0.53, and 0.26 inch, respectively.

Samples from 15 coal beds of the Appalachian region, 2 from Washington, and 14 from Colombia, South America, were tested. The source, proximate analysis, and sulfur content of the coals used and the composition of the blends are given in table 8, which also includes additional samples obtained for plasticity, oxidation, or expansion tests. The Appalachian region coals were tested at 800° and 900° C. in the standard 18-inch retort by the Bureau of Mines-American Gas Association (BM-AGA) methods. Physical properties of the cokes from these tests were determined by standard methods of the American Society for Testing Materials. The Washington and South American coals were tested at 900° C. in the BM-AGA standard 13-inch retort and the cokes by BM-AGA methods, wherein the tumbler test is less severe than the A.S.T.M. method. Expanding properties were measured largely by tests in the Bureau of Mines sole-heated oven. Plastic properties were determined by the Gieseler and Davis methods. Physical properties of the coke, which are primarily important in judging the suitability of a coal or blend for commercial carbonization, are given in table 9, by States, and are summarized below.

West Virginia Coals

Two low-volatile Beckley-bed coals (449 and 450) blended with 80 percent high-volatile Pittsburgh-bed coal gave indexes for the 900° C. cokes that show both coals are suitable for blending with high-volatile coking coals for producing metallurgical coke. Raising the proportion of these Beckley coals to 30 percent did not benefit the coke from the Caretta blend, although some improvement was noted for the Glen Rogers blend. If blended correctly, they could be substituted for Pocahontas No. 3 in coking blends without loss in coke quality.

Sewell-bed coal (465), medium-volatile bituminous in rank, coked strongly when carbonized alone; however, it should be blended with lower-ranking coal for commercial carbonization, because it expands during carbonization. Its blends (465C and 465B) with 50 and 70 percent Pittsburgh-bed coal yielded strong coke at 900° C. The 50:50 blend of this Sewell and of Pittsburgh coal yielded coke of metallurgical grade, and even greater proportions of Sewell coal probably could be used satisfactorily.

Winifrede-bed coals (467 and 468), high-volatile A bituminous in rank, yielded well-fused, moderately fissured coke at 900° C.; the coke from No. 7-mine coal was less abradable. The 80:20 blend of No. 7-mine and Pocahontas No. 3 coals gave strong coke at 900° C. Increasing the proportion of Pocahontas No. 3 to 30 percent did not significantly benefit the coke. Either blend should be suitable for the production of metallurgical coke.

Upper Freeport-bed coal (470), high-volatile A bituminous in rank, yielded rather spongy coke, and, as would be expected, the 1- and 1/4-inch tumbler indexes were low. This coal attains a high fluidity in the plastic state; probably it could be used to produce metallurgical coke if blended with low-sulfur coals of higher rank and lower fluidity.

In addition to the coals listed in table 8, carbonization tests were reported on the Eagle, No. 2 Gas, Pocahontas No. 3, and Pocahontas No. 4 beds from West Virginia.52/ These four coals, the first two of high-volatile A rank and the last two low-volatile, respectively, were found to be suitable for the manufacture of oven coke if blended in proper proportions. The blends should be carbonized at moderate bulk densities, since they may expand enough at high densities to damage oven walls.

52/ Davis, J. D., Reynolds, D. A., Brewer, R. E., Ode, W. H., Naugle, B. W., Wolfson, D. E., Birge, G. W., Carbonizing Properties: West Virginia Coals from the Eagle, No. 2 Gas, Pocahontas No. 3, and Pocahontas No. 4 Beds: Bureau of Mines Bull. 493, 1950, 39 pp.

The carbonizing properties of an additional medium-volatile and five low-volatile coals from West Virginia were reported, with data on three Pennsylvania coals.63/ The low-volatile coals comprised two samples of Pocahontas No. 6-bed coal from Wyoming County and one from Mercer County, Davy Sewell bed-coal from McDowell County, and Fire Creek bed-coal from Greenbrier County. The medium-volatile coal was from the Fire Creek bed, Greenbrier County. Pittsburgh-bed coal from the Warden mine, Allegheny County, Pa., was used in blends with these coals. All samples coked strongly when carbonized singly. The blends containing 80 percent Pittsburgh also coked strongly. The cokes made from these blends compared favorably with those made from the BM-AGA standard blend of coals from Pittsburgh and Pocahontas No. 3 beds. Davy Sewell, Pocahontas No. 6, and Fire Creek low-volatile coals were nearly as suitable for blending with Pittsburgh coal as Pocahontas No. 3. The medium-volatile Fire Creek coal was slightly less suitable, but its blends would probably coke more strongly if it were used in larger proportions.

Pennsylvania Coals

Lower Freeport-bed coal (442), of high-volatile A rank, yielded strong coke when blended with 20 percent medium-volatile Lower Kittanning (443) or 20 percent Pocahontas No. 3 (h75) coals; however, the hardness factors, or 1/4-inch tumbler indexes, of the blend cokes were slightly low at 56 and 60. The coking property of the Lower Freeport-Lower Kittanning blend was not improved by raising the proportion of Lower Kittanning from 20 to 30 percent.

Lower Kittanning-bed coal (443) ranked low in the medium-volatile group. It was carbonized only as blends (442A and 442B) with Lower Freeport coal. Lower Kittanning is a coking coal which should be so blended that the coal rank is changed little.

Upper Freeport-bed coal (458), high-volatile A bituminous in rank, was cleaned by the heavy media process to yield a product containing 8.7 percent ash and 2.1 percent sulfur. The 900° C. coke was well-fused and strong for coal of this rank. Blending with 20 percent Pocahontas No. 3 raised the 1-inch tumbler index from 47 to 54; other indexes were raised less. The tests indicate that 80 percent is about the optimum proportion of this coal to be blended with Pocahontas No. 3.

Another high-volatile A Upper Freeport-bed coal (480) gave 900° C. coke that resisted breakage well in the shatter test but was rather abradable in the tumbler test. Blending with 20 percent Pocahontas No. 3 benefited the coke by raising its 1- and 1/4-inch tumbler indexes from 40 to 46 and from 57 to 59, respectively. The 70:30 blend of these coals yielded slightly stronger coke. Although washed, the high sulfur content of this coal would make it unsuited for metallurgical use.

The three Pennsylvania coals, included with the report on West Virginia coals64/ previously mentioned, were medium-volatile coals from the Lower Kittanning bed, Cambria County, and the Upper Kittanning bed, Clearfield County, and high-volatile A coal from the Upper and Lower Freeport beds, Indiana County. All of these coals coked strongly when carbonized alone. The medium-volatile coals, when blended with standard Pittsburgh-bed blending coal, did not make quite as strong coke as blends of low-volatile coal with the Pittsburgh coal, but probably such blends would be stronger if larger proportions of the medium-volatile coals were used.

63/ Davis, J. D., Reynolds, D. A., Brewer, R. E., Wolfson, D. E., Naugle, B. W., and Birge, G. W., Carbonizing Properties: Pocahontas No. 6, Davy Sewell, and Fire Creek Coals from West Virginia and Upper and Lower Kittanning and Upper and Lower Freeport Coals from Pennsylvania: Bureau of Mines Bull. 496, 1950, 42 pp.

64/ See footnote 63.

Virginia Coals

Clintwood-bed coal (478) from an unknown mine near Gladeville, Wise County, Va., ranked high in the high-volatile A classification. As a blend (477B) with 70 percent Sewanee, it coked strongly. The coal was not tested singly.

Tennessee Coals

Jellico-bed coal (456), high-volatile A bituminous in rank, gave rather weak coke, but was improved markedly by blending with 20 and 30 percent Pocahontas No. 3. Either of these blends should yield metallurgical coke in commercial ovens, although the blend containing 30 percent Pocahontas cokes more strongly.

Sewanee-bed coal (477), ranking at the top of the high-volatile A classification, coked strongly when carbonized singly. The 60:40 Sewanee-Pocahontas No. 3 blend (477A), which is carbonized commercially to produce foundry coke, yielded coke that resisted breakage in the shatter test more than the Sewanee coke. The 70:30 Sewanee-Clintwood blend (477B) coked nearly as strongly as Sewanee. Substitution of an equal amount of Pittsburgh-bed coal for Clintwood lowered the shatter indexes and raised the tumbler indexes, although the changes were small.

Washington Coals

Wilkeson No. 2- and No. 3-bed coals (447 and 446), washed at the Bureau station at Seattle, gave cokes that were stronger than the average coke from coals of similar (high-volatile A) rank, except that the No. 3 coke had a hardness factor of 68, whereas the average is 72.

Alabama Coals

A 50:50 blend (475) of Black Creek- and Mary Lee-bed (medium-volatile washed coals from Jefferson County), carbonized at 800°, 900°, and 1,000° C., yielded cokes that were strong at 800° and 900° C. The 1,000° C. coke was unstable in the shatter and tumbler tests because it was more fissured.

Colombia, South America, Coals

The Colombian coals ranged from low in the high-volatile A rank to high in the medium-volatile. High-volatile A Principal-bed coal (434) yielded strong coke that compared favorably with coke made from eastern domestic coals of similar rank. Medium-volatile Secundaria-bed coal (435) yielded the strongest coke; this coke was almost as strong as cokes made from the best coking coals of West Virginia. A 50:50 blend (434A) of these two coals, both from the Department of Cundinamarca, coked almost as strongly as 100 percent Secundaria coal. These coals are suitable for the production of metallurgical coke if blended properly to eliminate the possibility of expansion during carbonization.

Only two coals from the department of Valle del Cauca yielded strong coke. The No. 1 (436) and Grande (437) beds, ranked as high-volatile A bituminous, gave cokes that were satisfactorily strong, considering their rank. Blending with coals of low rank would benefit the coking of these coals.

The following coals from the Department of Valle del Cauca yielded rather weak cokes: No. 5 and No. 6 bed-blend (438), Grande beds Nos. 2 and 3 (439 and 463), No. 3 and No. 4 beds (440), Large bed (459), Grande bed (460), four mixed beds, (461), and an unknown bed (462). Most of these cokes were hard and probably could be strengthened by blending the coals to increase their rank. The coking properties of six samples, containing 13.5 to 26.6 percent ash, probably would be benefited by cleaning the coals to moderate ash content. La Ducha-bed coal (464) did not yield coherent coke, although it ranked high in the medium-volatile group.

Comparison of BM-AGA and Slot-oven Experimental Methods of Carbonization

A comparison was made between carbonizing tests in the BM-AGA cylindrical steel retorts and in a vertical, refractory slot-oven similar to that developed by the Illinois State Geological Survey.65/ Three high-volatile coals and eight blends of coals, differing in rank, were carbonized in BM-AGA retorts at 800° and 900° C. and in the slot oven at 870° to 1,010° C. Average yields from BM-AGA tests at 800° and 900° C. and the slot oven, respectively, were: Coke, percent, 70.5 70.0, and 70.5; gas, cubic feet per ton, 8,900 10,100, and 9,650; tar, gallons per ton, 13.0, 11.4, and 9.0; light oil, gallons per ton, 1.95, 2.39, and 1.75; and ammonium sulfate, pounds per ton, 27.2, 23.6, and 22.3. The slot-oven and 900° C. cokes were of similar chemical composition; the 800° C. cokes contained slightly more volatile matter and less fixed carbon. Generally, other physical properties of the slot-oven cokes were intermediate between those of the 800° and 900° C. BM-AGA cokes. The specific gravity of the gas from the slot-oven generally was intermediate between those of the gases from the 800° and 900° C. BM-AGA tests; heating values were lowest for the slot-oven gas. The tars from the 900° C. BM-AGA and slot-oven tests were similar; they differed significantly only in their content of solids (naphthalene, anthracene, and pitch), which was higher for the slot-oven tar. The light oils from the slot-oven tests contained greater proportions of benzene and lower proportions of paraffins and solvent naphtha.

Small-Scale Laboratory Carbonization Tests

Small-scale laboratory coking tests, made to obtain information on the chemical and physical properties of coals that affect yields and properties of the gas, coke, and coal chemicals, included low-temperature carbonization (Fischer) assays, agglutinating value tests, and free-swelling tests.

Data from these tests on Pocahontas No. 3-, Pocahontas No. 4-, Eagle-, and the No. 2 Gas-bed coals were published66/ to supplement BM-AGA tests at 800° and 900° C. and other tests designed to evaluate plastic and expanding properties of the coals.

Plasticity of Coals

Plastic properties of 39 coals and 34 blends were determined during the fiscal year. Table 8 describes these coals and blends, except blending coal g/5, which is similar to coal h75, and special samples of blends, pretreated coals, and sized fractions. All samples were tested by the Gieseler and/or Davis plastometer methods. A total of 383 tests - 197 by the Gieseler and 185 by the Davis method - was made.

Table 10 lists the numbers of the coals and blends tested, the Gieseler maximum fluidity values in dial divisions per minute, and the Davis maximum resistance values in pound-inches. All coals and blends, except the special samples (not listed), were tested in connection with the BM-AGA survey of their carbonizing and expanding properties. The plastic properties of the coals and blends are summarized under "Remarks" in the table.

65/ Davis, J. D., Reynolds, D. A., Wolfson, D. E., and Birge, G. W., Comparison of BM-AGA and Slot-Oven Experimental Methods of Carbonization, with Results for Eleven Coals: Bureau of Mines Bull. 480, 1950, 37 pp.

66/ See footnote 62.

TABLE 10. - Plastic properties of coals and blends

Coal No.	Gieseler[1/]	Davis[2/]	Remarks
West Virginia Coals and Blends			
449	(3/)	29	Increased Gieseler fluidity and decreased Davis resistance values (blends 449A, 449B, 450A, and 450B) result by blending low-volatile Pocahontas No. 3 coals (449 and 450) with 80 and 70 percent high-volatile A Pittsburgh coal (r28). Reverse trends (blends 465A, 465B, and 465C) are shown by blending medium-volatile Sewell coal (465) with 80, 70, and 50 percent Pittsburgh coal. Top of bed of Pittsburgh coal (466) was excluded, and data are not representative of bed. Blending high-volatile A Winifrede coal (467) with 20 and 30 percent low-volatile Pocahontas No. 3 coal (475) decreases fluidity and increases resistance values. High-volatile A Winifrede coal (468) shows higher fluidity and higher resistance than Winifrede coal (467). High-volatile A Upper Freeport coal (470) gives extremely high fluidity and average resistance. Pocahontas No. 3 coal (479) shows plastic characteristics typical of its low-volatile rank.
449A	600	18.5	
449B	620	29	
450	55	58	
450A	450	35	
450B	325	27	
465	1,950	70	
465A	735	12.8	
465B	1,095	39	
465C	1,250	34	
466	(4/)	9.8	
467	1,640	11.8	
467A	460	35	
467B	150	35	
468	5,640	15	
470	60,000	18.5	
479	29	72	
Pennsylvania Coals and Blends			
442	30,000	12.3	Gieseler fluidity values cover a wide range. Davis resistance values are normal and indicate good coke-making properties. Except for medium-volatile Lower Kittanning coal (443) and washed Upper Freeport coal, (448) which cannot be classified, all others are high-volatile A in rank. Upper Freeport coal (448) is much less fluid than the Upper Freeport coal (458). Excepting blends 442A and 442B containing coal 443, all others contain 20 and 30 percent low-volatile Pocahontas No. 3 coal (h75). Gieseler values for blends 442B, 458A, and 469A are unexpectedly high. All other blends show expected changes in both fluidity and resistance on blending.
443	(4/)	12	
442A	3,765	9	
442B	60,000	10.5	
442C	(4/)	12	
448	13	9	
458	5,725	12.5	
458A	6,330	19	
458B	3,300	11.3	
469	6,330	12.3	
469A	23,500	31	
480	60,000	9	
480A	50,000	11.8	
480B	15,670	37	
Virginia Coals			
476	2,000	-	Medium-volatile Tiller coal (476) and high-volatile A Clintwood coal (478) show values consistent with the rank of the coals and indicate good coke-making properties.
478	8,570	21	
Tennessee Coals and Blends			
456	215	7.5	Decreased fluidity and increased resistance (blends 456A and 456B) show effect of blending 20 and 30 percent low-volatile coal (s75) with high-volatile A coal (456), also shown by 477A with 40 percent low-volatile coal (479) and high-volatile A coal (477). Thirty percent high-volatile A Clintwood coal (478) is more effective than Pittsburgh coal (s28) in increasing fluidity; 50 and 70 percent of latter decrease maximum resistance, indicating weak coke.
456A	125	60	
456B	150	41	
477	500	30	
477A	100	27	
477B	1,290	35	
477C	780	37	
477D	3,430	12.8	
477E	5,470	15	
Alabama Blend			
472	3,160	23	50:50 blend gives expected values.
Washington Coals			
445	(4/)	22.5	Data indicate fair coke-making properties.
447	(4/)	11.5	Do.
Colombia, South America, Coals and Blends			
434	30,000	12.8	The plastic properties of the 14 coals and 2 blends vary widely. Eight coals (435, 437, 438, 439, 461, 462, 463, and 464) do not fuse at the normal rate of heating of 3° C. per minute in the Davis tests and develop only low fluidity in the Gieseler tests. Two coals (434) and (440) give high fusion; two blends (434A and 440A), containing equal parts of coals 434 and 435 and of 440 and 441, respectively, and four coals (436, 441, 459, and 460) show lower fusion. These six coals and two blends indicate fair coke-making properties which could be improved by judicious blending.
435	1.5	(5/)	
434A	3.1	63.5	
436	5.1	13	
437	0.6	(5/)	
438	8.4	(5/)	
439	1.5	(5/)	
440	1,450	8	
441	(6/)	12	
440A	295	7.3	
459	280	6	
460	380	7.5	
461	340	(5/)	
462	195	(5/)	
463	295	(5/)	
464	(4/)		
Blending Coals			
r28	2,070	-	The high-volatile A blending samples (r28 and s28) show good fusion, typical of this coal rank. The low-volatile blending samples (s75 and h75) show characteristic values. Coals 28 and 75, when used in proper proportions, are excellent blending coals.
s28	2,730	11	
s75	1.9	(5/)	
h75	5.5	8.6	

1/ Gieseler plastometer, maximum fluidity in dial divisions per minute.
2/ Davis plastometer, maximum resistance in pound-inches.
3/ No dial movement greater than 0.1 dial divisions per minute.
4/ Coal caked and shrank away from retort wall; test discontinued.
5/ No resistance developed at normal rate of heating of 3° C. per minute.
6/ Coal swelled and stirring shaft froze at 430° C.; test discontinued.

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Expanding Properties of Coals During Carbonization

Another sole-heated expansion oven was constructed, and 62 tests have been made in it. A total of 169 tests was made in both ovens. Except for the method of applying pressure, the new oven was built to duplicate the older one as closely as possible so that a coal tested in either oven would give the same expansion within the limits of experimental error. The test results from the two ovens duplicate each other well.

A load of 2.2 pounds per square inch is applied on the coal charge during carbonization. In the older oven this pressure is maintained by manual adjustment of pressure in an oil gland controlling the pressure plate that rests on the coal charge. In the new oven a method maintaining automatically a constant pressure on the charge consists essentially of two hydraulic cylinders with pistons, one of small bore connected to another of larger bore so as to oppose each other. The piston of the small bore cylinder is appropriately weighted, and the liquid medium applies the same unit pressure to the large cylinder. The piston in this cylinder then continuously exerts the required pressure on the pressure plate contacting the coal. Figure 11 is a photograph of the new oven, showing the larger cylinder controlling the pressure plate.

The pressure plate of the new sole-heated oven was equipped with a cast iron base instead of transite, which was in use on the older oven. Comparison of results of tests using this plate and the older plate in the same oven indicated that the cast iron plate resting directly on the coal did not change the results significantly and gave more trouble-free operation, particularly with coals that became quite fluid; therefore, the transite part of the pressure plate of the older oven was replaced with cast iron.

The expanding properties of the coals and blends tested during the year are given in table 11. The State and bed for each coal is given to facilitate finding the complete description and chemical analyses given in table 8, wherein the coals are listed by States.

The Upper Freeport coals tested (470 from West Virginia, and 448, 458, and b480 from Pennsylvania) became very fluid during carbonization, and all but 448 were highly contracting. Blends of up to 30 percent Pocahontas No. 3 with coals 480 and b480 were still contracting enough to indicate they would be safe for use in commercial ovens, and coal 470 was so highly contracting that it would be expected to behave similarly. Blends of coal 458 with Pocahontas No. 3 were borderline coals that could be dangerous for most coke ovens. Coal 448 appears safe for industrial carbonization when used alone, but it was not tested in blends.

Of the other coals tested, the Pocahontas No. 3 is well-known to be a dangerously expanding coal when used alone. The tests indicated that the Lower Kittanning (443), the Sewell (465), the Sewanee (477), and the Beckley coals (449 and 450), when used alone, and a few of the blends would be potentially dangerous, particularly if coked at high speed in narrow ovens. A blend of two expanding coals, the Sewanee (477) and Pocahontas No. 3 (479), is commercially coked, with a carbonizing time of 30 hours, but oven damage is probably avoided because of the slow rate of carbonization in ovens that are wider than in many of the newer ovens.

A carbonizing-time study was made in the large vertical expansion oven with Pittsburgh-bed coal, Morgan mine No. 2, Perry County, W. Va., (446), under conditions simulating fast coking in very narrow slot ovens (8 inches wide). Wall temperatures used were higher than for those equivalent to flue temperatures 2,300° to 2,500° F. in commercial ovens. It was found that the carbonizing time in 8-inch ovens should be at least 6 hours to produce satisfactory furnace coke.

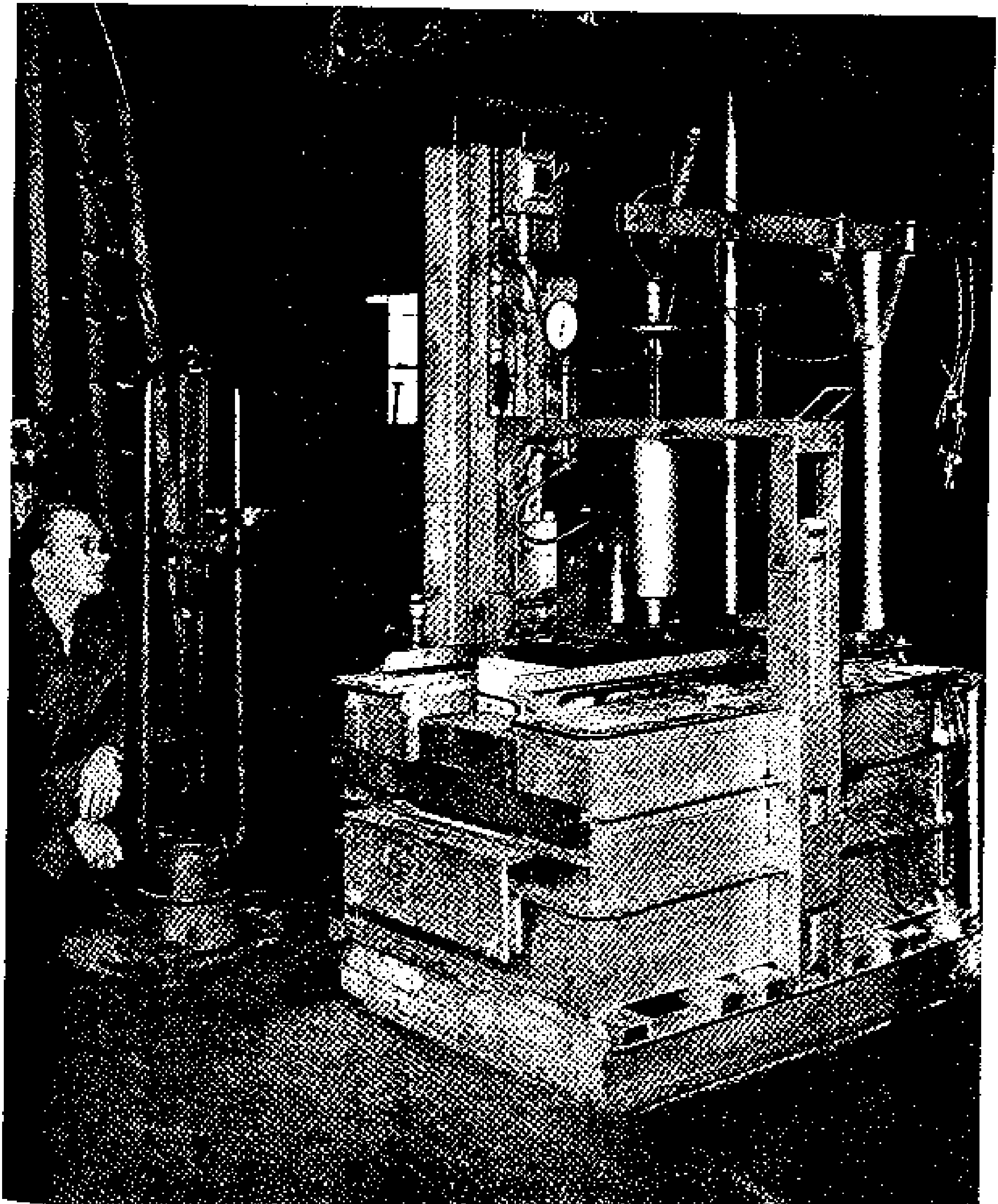

Figure 11. - New sole-heated expansion oven.

TABLE 11. - Expanding properties of coal in the sole-heated oven

Coal No.	State	Bed	Test moisture, percent	Expansion, percent: At 55.5 pounds per cubic foot[1]	Expansion, percent: Dry, solid coal
428	Pennsylvania	Pittsburgh	1.8	-17.3	24.0
475	West Virginia	Pocahontas No. 3	2.7	+30.7	103.6
469[2,3]	Pennsylvania	Sewickley	2.9	-	-
469B[2]		Blend	2.6	-16.1	30.5
470[2]	West Virginia	Upper Freeport	3.3	-29.0	8.0
480[2]	Pennsylvania	do.	1.7	-21.3	21.4
b480[2]	do.	do.	1.9	-30.2	10.3
480A		Blend	1.7	-17.5	27.3
480B		do.	2.0	- 9.9	39.4
458	Pennsylvania	Upper Freeport	2.6	-14.8	30.6
458A		Blend	2.7	- .6	53.8
458B		do.	2.5	+ 4.5	61.2
448[2]	Pennsylvania	Upper Freeport	3.2	- 5.5	44.7
442	do.	Lower Freeport	2.5	-19.8	25.7
443	do.	Lower Kittanning	3.3	+14.4	74.8
442A		Blend	2.5	- 2.7	51.8
442B		do.	2.2	- 6.4	46.2
442C		do.	1.9	- 1.9	51.6
467	West Virginia	Winifrede	2.9	- 5.3	43.4
467A		Blend	2.4	+ 1.6	54.3
467B		do.	2.5	+ 3.1	56.8
467C		do.	2.9	- 1.5	49.2
467D		do.	2.9	+ 1.6	55.0
468	West Virginia	Winifrede	2.4	- 8.8	39.6
456	Tennessee	Jellico	2.7	- 7.2	42.3
456A		Blend	2.5	- 1.0	51.7
456B		do.	2.7	+ 1.0	53.9
476	Virginia	Tiller	2.5	- 1.1	47.0
465	West Virginia	Sewell	2.8	+ 6.5	58.0
465A		Blend	2.9	-11.3	37.5
465B		do.	3.1	- 8.8	41.7
465C		Blend	2.8	- 5.3	45.6
477	Tennessee	Sewanee	2.3	+ 5.8	63.3
478	Virginia	Clintwood	3.3	-17.7	27.1
479	West Virginia	Pocahontas No. 3	6.0	+17.7	86.7
477A		Blend	3.8	+ 8.2	70.2
477B		do.	2.6	- .4	56.2
477C		do.	2.3	+ 5.2	60.0
477D		do.	2.1	+ 1.2	55.5
449	West Virginia	Beckley	3.1	+ 7.5	70.5
449A		Blend	3.1	- 7.5	44.7
449B		do.	3.2	- 4.8	50.3
450	West Virginia	Beckley	1.6	+12.8	68.1
450A		Blend	2.9	- 3.9	49.0
450B		do.	2.7	- 1.4	53.7
475	Alabama	do.	2.5	- 8.9	39.6

1/ End-of-test contraction for contracting coals; maximum expansion for expanding coals.

2/ Single tests.

3/ Had contracted 18.2 percent when removed from oven in 3-1/2-hour test time; this is a highly contracting coal.

Spontaneous Heating Tendencies of Coals and Refuse

The self-heating or spontaneous heating tendencies of five cleaned bituminous coals, five coal-refuse samples, and two lignites were determined under controlled oxidation in the adiabatic calorimeter. Table 12 shows the moisture condition of the samples as received, their analyses, and the self-heating rates at selected temperatures. Origin of the samples is given in table 8. The two Thick Freeport coals (444 and 445) that were very wet when received were air-dried before testing. The other coals, refuse, and lignites received in coarse sizes were crushed to 0-to 1/4-inch size, and all samples were dried in a rotary drum with nitrogen gas at 100° C. before testing in the calorimeter. The use of dry, sized coal under closely controlled conditions of oxygen supply and thermal equilibrium in the adiabatic calorimeter minimizes the effects of purely physical factors on the self-heating rate of the coal.

The Thick Freeport cleaned coal (444), with a high carbon content, self-heats at much faster rates at comparable temperatures than the Thick Freeport refuse coal (445), with a very high ash content, and the Lower Kittanning cleaned and refuse coals (451 and 452) behave in a similar manner. After 2 months of outdoor storage, the self-heating rates of the refuse coal (452-s2) increase and at comparable temperatures exceed those of the cleaned coal (451). These self-heating rates increase progressively as the time of outdoor storage of the refuse coal increase to 8 months. The surfaces of the particles of these two samples showed appreciable ferrous sulfate, some of which was lost before charging the dry samples in the adiabatic calorimeter. The increase in ferrous sulfate during 8 months of outdoor storage was from 0.46 to 1.56 percent (dry basis) for the refuse coals (452 and 452-s8). The accompanying decrease in pyritic sulfur in these two samples from 20.0 and 17.3 percent (dry basis) indicates that oxidation of pyrites was responsible in part for the high self-heating rates of the refuse coal (452-s8), which had been stored outdoors for 8 months.

The two cleaned Pittsburgh No. 8 coals (481 and 482) were relatively similar in chemical composition, but not in oxidizing properties. The higher rates found for coal 481 are in accord with the observed fact that this coal has heated and even ignited during shipment and storage, whereas coal 482 shows excellent storage properties. The cleaned Pittsburgh coal (s25), which was tested as a check with two other samples from the same mine previously tested, gave results that checked well for the three coals, showing that this coal is uniform in composition and has excellent storage properties. The high self-heating rates of the lignites indicate that spontaneous heating and ignition may be expected, unless proper precautions are taken in transporting and storing these coals.

Physical Properties of Coke: Size and Its Measurement

The adequacy of physical tests of coke for the purposes for which they are made has been a subject for discussion for many years. In 1944 the Bureau decided that data obtained from the testing procedures on samples of coke produced in commercial ovens would give information on (1) the degree of precision of tests commonly used in the industry, (2) the causes of the known poor reproducibility in several of the physical tests, and (3) possible improvements or modifications of existing physical testing procedures. Enough data have been collected on several aspects of coke testing to make presentation of data on the size of coke and its measurement worth while.[67]

67/ Agvil, E. Stuart, and Gayle, John B., Physical Properties of Coke: Size and Its Measurements: Bureau of Mines Rept. of Investigations 4735, 1950, 27 pp.

TABLE 12. - Analysis and self-heating rates of coals, coal refuses, and lignites

Coal No.	Condition of sample[1]	Moisture as received, percent	Analysis, dry basis, percent					Self-heating rate in oxygen, °F./hour at given temperatures, °F.					
			Ash	H	C	Total S	Pyritic S	122	150	176	212	248	284
444.........	Cleaned, not dried, 0- to 1/4-in.	17.8	9.9	5.1	76.6	0.9	0.5	-	-	1.53	3.92	11.1	25.4
445.........	Refuse, not dried, 0- to 1/4-in.	16.3	65.6	1.7	22.0	8.7	8.2	-	-	.13	0.74	2.75	11.6
451.........	Cleaned, 3/8- to 1-1/4-in.	1.5	7.9	5.3	77.0	2.5	1.4	-	0.81	1.44	5.16	11.4	26.5
452.........	Refuse, 0- to 4-in.	1.5	43.9	2.5	34.0	21.0	20.0	-	.20	1.34	2.92	5.97	9.9
452-s2......	Refuse, 0- to 1/4-in., stored outdoors 2 mo.	3.5	45.5	2.4	32.4	21.8	20.1	-	1.57	1.39	7.78	18.6	52.3
452-s4......	Refuse, 0- to 1/4-in., stored outdoors 4 mo.	4.6	45.5	2.4	33.0	21.9	20.4	-	2.07	4.66	8.87	21.7	84.4
452-s8......	Refuse, 0- to 1/4-in., stored outdoors 8 mo.	1.4	42.7	2.5	34.6	29.5	17.3	-	13.7	35.7	178.5	315.8	315.8
481.........	Cleaned and dried, 0- to 1/4-in.	5.0	7.9	5.1	75.1	2.9	1.7	-	-	5.22	10.5	29.5	44.2
482.........	Cleaned and dried, 0- to 1/4-in.	5.2	8.1	5.2	74.5	3.9	1.7	-	2.70	3.94	9.5	20.2	46.3
s28.........	Cleaned, 2- to 4-in. lump	1.3	5.3	-	-	-	-	-	-	2.30	2.90	4.85	Couple failed.
471.........	Raw lump lignite.........	37.0	34.1	4.2	61.3	0.7	-	12.8	23.0	28.9	76.5	109.0	79.1
473.........	Raw lump lignite.........	28.4	14.0	4.4	62.7	1.8	0.6	8.7	19.2	34.3	88.3	206.4	277.8

1/ After removing special moisture samples, coals 444 and 445 were air-dried before sampling; samples s28, 471, and 473 were crushed to nominal minus-1/4-in. size. All samples were dried in nitrogen at 100° C. in closed rotary-drum unit before charging to adiabatic calorimeter.