One of these papers described several methods of examining coal-washing-plant operations and preparing charts and formulas for expressing the efficiency of performance for purposes of comparison.32/ Another paper described the experimental development of the kerosine-flotation process for handling fine coal and the performance of some commercial installations that have been made in the Birmingham field, Ala.33/ The third paper described an improved method of estimating particle size in subsieve size particles.34/ This process was developed by the Heyl and Patterson Co., incidental to a cooperative agreement between that company and the Bureau of Mines.

In the committee meetings at which the Bureau was represented, it was tentatively planned to set up an international committee for standardizing coal-preparation test procedure and formulas for appraising preparation-plant performance.

Evaluating Coal-Washery Performance

The Bureau of Mines has made available to the American coal industry the ideas on the evaluation of coal-washery performance, developed at the International Conference on Coal Preparation, which seem most important from an American viewpoint.35/ The various methods of evaluating washery performance are illustrated with previously published data and with some new data obtained as the result of experimental work undertaken since the conference to provide information on certain controversial points.

Performance can be evaluated in a number of different ways, with the choice of the proper method to use being dictated by the objectives of the investigation and the data available. The performance of any cleaning unit is determined by the character of the raw coal treated, the density of the separation, and the sharpness of the separation effected between the coal and impurity. Thus, three factors enter into performance; one is determined by the coal, one is dictated by market or use considerations, and one is an inherent characteristic of the cleaning unit itself. Efficiency, which is the ratio of the actual to the perfect separation, is influenced by all three factors. It measures directly the loss of saleable coal in the refuse and thus is the performance criterion of greatest practical value to the coal-preparation plant operator.

Sharpness of separation or sharpness of cut between coal and impurity is measured in terms of either error area or probable error, both of which are determined from a distribution curve for the washing operation. These criteria are useful in

32/ Yancey, H. F., and Geer, M. R., [A Critical Examination of Methods Used in Evaluating Coal-Washery Performance] : Rev. ind. minérale, Special Issue No. 1, November 1950, pp. 4-12. Pres. at International Conference on Coal Preparation, Paris, France, June 1950.

33/ Gandrud, B. W., [Kerosine Flotation: A Process for Cleaning and Dewatering Fine Sizes of Coal] : Rev. ind. minérale, Special Issue No. 2, December 1950, pp. 217-243. Pres. at International Conference on Coal Preparation, Paris, France, June 1950.

34/ Notary, Joseph A., Gorman, Henry B., and Fraser, Thomas, [Test Method for Appraising the Performance of Sludge Recovery and Water-Clarifying Equipment] : Rev. ind. minérale, Special Issue No. 2, Dec. 1950, pp. 171-179. Pres. at International Conference on Coal Preparation, Paris, France, June 1950.

35/ Yancey, H. F., Geer, M. R. Efficiency and Sharpness of Separation in Evaluating Coal-Washery Performance: Min. Eng., vol. 3, June 1951, pp. 507-517.

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comparing the operation of washing units making dissimilar separations, because they are substantially independent of either the character of the raw coal or the density of separation. They must not be confused with efficiency, however, because low values of error area or probable error sometimes are accompanied by low efficiency. Table 6 gives a comparison of washery-performance factors for 26 individual washing tests in terms of density of separation, efficiency, percentage of misplaced material, error area, and probable error. These data demonstrate clearly that there is no direct correlation between efficiency and misplaced material on the one hand and error area and probable error on the other. A sharp separation is an efficient one when made on a coal of favorable washability characteristics, but even a very sharp separation may result in a relatively low efficiency if made at a low density or if the coal contains an abnormal amount of material of intermediate density.

TABLE 6. - Comparison of performance criteria for a number of washing operations

Cleaning unit	Size of coal, inches or mesh	Specific gravity of separation[1]	±0.10[2]	Error area	Probable error	Percent: Misplaced material	Percent: Efficiency[3]
Heavy medium	Over 1/4	1.56	7.0	5	0.011	1.4	-
Do[5]	1-1/4 to 3/8	1.50	4.6	24	.037	.7	99.9
Do[4]	2 to 1/4	1.57	22.5	28	.040	5.8	97.1
Do	1-5/8 to 15/16	1.79	20.3	48	.074	3.5	-
Do[4,5]	14 to 35	1.63	1.7	24	.044	.4	99.9
Do[4,5]	8 to 200	1.65	10.4	28	.027	3.0	98.5
Jig, Baum	5 to 0	1.57	7.0	63	.087	4.8	97.5
Do	5 to 0	1.46	14.4	68	.111	21.0	72.2
Do	3 to 0	1.67	10.0	76	.086	8.7	96.1
Do	3 to 0	1.53	5.8	81	.103	3.4	98.0
Jig, pulsator	3 to 1-1/4	1.45	19.8	57	.057	7.9	94.0
Do	1-1/4 to 1/4	1.70	2.3	95	.130	2.2	99.6
Jig, plunger	1-1/4 to 0	1.63	4.3	78	.088	6.0	97.3
Jig, basket	1 to 0	1.72	4.9	93	.130	4.5	97.8
Wet table[4]	3/32 to 0	1.78	6.7	63	.075	4.4	98.0
Do[4]	1/4 to 0	1.70	1.9	79	.103	2.5	99.3
Rheolaveur	4 to 5/16	1.63	10.4	75	.096	8.5	98.8
Do	5/16 to 0	1.70	13.5	130	.294	7.1	94.4
Menzies cone	3 to 2	1.55	8.7	32	.035	2.9	99.3
Do	3/4 to 3/8	1.65	5.8	63	.078	2.5	98.2
Hydrotator	11/16 to 28	1.83	4.2	62	.099	2.6	99.0
Froth flotation	10 to 0	1.57	3.6	73	.127	4.3	98.2
Do	10 to 0	1.69	4.7	125	.234	7.2	96.4
Humphreys spiral[5]	8 to 0	2.04	-	147	.367	-	91.8
Pneumatic table[4]	1/2 to 1/4	1.68	2.0	94	.131	3.2	98.3
Contraflow	2 to 0	1.79	1.8	98	.179	3.0	99.2

1/ The specific gravity at which the distribution curve crosses the 50 percent ordinate, indicating equal distribution of material between washed coal and refuse.
2/ Not adjusted for material heavier than 2.0 specific gravity.
3/ Fraser and Yancey formula: yield of washed coal divided by yield of float coal of same ash content.
4/ Laboratory test, all others plant tests.
5/ Cyclone.

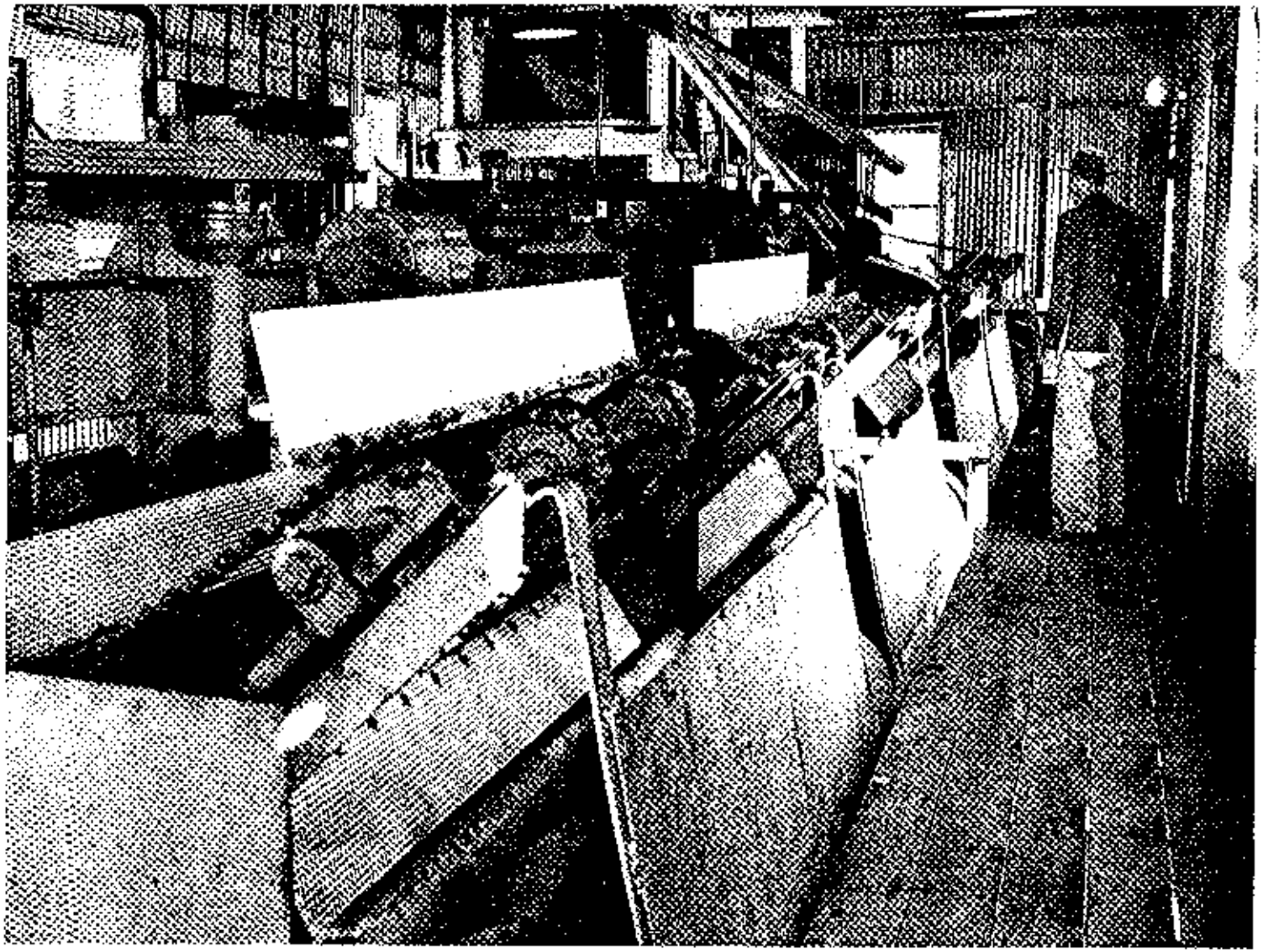

Figure 9. - Kerosine-flotation cells in an Alabama coal-preparation plant.

Cleaning and Recovery of Fine Coal

Another commercial application of the kerosine-flotation process, developed by the Bureau of Mines for cleaning and dewatering fine sizes of coal, makes three such plants now in operation in the Birmingham, Ala., district. (See fig. 9.) One of these plants treats an underflow product from dewatering screens; the other two treat fine coal (approximately 14-mesh to 0) wet-screened out of the run-of-mine coal. The fines that are screened out of the run-of-mine coal are removed, cleaned, and dewatered directly, thus preventing the formation of sludge and slurry and the problems always associated with them. Another advantage of the process is that fine sizes of high-grade coking coal formerly wasted are now recovered. The latest developments in this method of cleaning and dewatering fine-size coal have been published.36/ Subsequent investigations have been directed to improvement in the design of the flotation cells to increase their capacity.

Recently, the Humphreys spiral concentrator has been investigated37/ to provide the coal industry with information to help in the selection of coal-cleaning equipment and to supplement previously published results of detailed performance studies of the wet table, pneumatic table, Dutch cyclone, and jigs of pneumatic, plunger, pulsator, and Baum types. The spiral was used during World War II to treat the chrome-bearing sands of Coos Bay, Oreg., and in the years since its development it has been adopted for treating ores, nonmetallics, and coal. One coal-washing plant using the spiral concentrator went into operation in the Pennsylvania anthracite fields in 1946, and another plant has recently been completed.

Coals from Alabama, Kentucky, West Virginia, and Washington were tested in the spiral concentrator, all samples representing natural 8-mesh fines screened from run-of-mine coal except the West Virginia coal, which was prepared by crushing 3-inch slack to pass 8-mesh. The products from the spiral were examined by float-and-sink and screen-sizing tests to determine the mechanics of the separation between coal and impurity. The basic performance characteristics were found to be the same for all of the coals tested. As a result of the modifying influence of particle size, the spiral is unable to make an efficient two-product separation between coal and impurity on these coals without additional treatment. Also, a classified feed can be treated with higher efficiency than is possible on a natural raw coal; consequently, semiclassified feeds, such as silt-bank or classifier-underflow materials, can probably be treated with higher efficiencies than those shown for raw coals. The inherently low efficiency of the unit may be overcompensated under certain conditions by the low operating costs afforded by its extreme simplicity.

In the anthracite region of Pennsylvania, a field study of existing commercial launder-screen installations for preparing fine sizes of anthracite was initiated in September 1950.

To supplement this field study, a full-scale pilot launder screen has been designed and constructed at the Anthracite Research Laboratory, Schuylkill Haven, Pa. This unit is undergoing tests at a regional fine-coal cleaning plant in cooperation

36/ Gandrud, B. W., and Riley, H. L., Recent Developments in Combination Cleaning and Dewatering of Fine Sizes of Coal: Bureau of Mines Rept. of Investigation 4707, 1950, 20 pp.

37/ Geer, M. R., Yancey, H. F., Allyn, C. L., and Eckhouse, E. H., Laboratory Performance Tests of the Humphreys Spiral as a Cleaner of Fine Coal: Am. Inst. Min. and Met. Eng. Tech. Pub. 2944F, Trans. Am. Inst. Min. and Met. Eng., vol. 187, 1950, pp. 1057-1067; Min. Eng., vol. 187, October 1950, pp. 1057-1067; discussion, Trans. Am. Inst. Min. and Met. Eng., vol. 187, 1950, pp. 1160-1162; Min. Eng., vol. 187, November 1950, pp. 1160-1162.

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with the Hudson Coal Co., Scranton, Pa. This pilot unit is 18 feet long by 1 foot wide and is faced with 38-mesh stainless-steel cloth of approximately 60 percent open area. It is being used to determine the maximum quantity of fine coal that can be recovered from material formerly lost in the plant effluent.

Preparation Characteristics of Coking Coal

Cambria County, Pa.

In the preparation phase of the Bureau's investigation of known recoverable coking-coal reserves, the first three reports in a planned series, giving in detail the preparation characteristics, by counties, of the principal coal beds in each county, were published. The first report, covering Cambria County, Pa.,[38] shows that the main washing problem, as in the other two counties studied, concerns the release of sulfur. The important coal reserves are in the Upper Freeport, Lower Freeport, Upper Kittanning, and Lower Kittanning beds. Crushing the Kittanning coals to fine size gave a significant sulfur reduction in the float coal. The Freeport beds, particularly the Upper bed, were not markedly responsive to crushing for release of sulfur. All samples collected in Cambria County, except one Lower Freeport-bed coal sample, indicated that a satisfactory metallurgical-grade washed product could be obtained by mechanical cleaning alone or mechanical cleaning in conjunction with fine crushing. The quality of the Lower Freeport-bed coal tends to improve toward the northern part of the county.

Indiana County, Pa.

According to the second report, which covers Indiana County, Pa.,[39] the principal coal reserves are found in the Upper Freeport, Lower Freeport, and Lower Kittanning beds. Isolated patches of Pittsburgh-bed coal are present, and the Upper Kittanning bed is found in minable thickness at some locations, but production from these sources is not large. The Lower Kittanning bed is moderately responsive to fine crushing for release of sulfur impurities, while the effect of crushing upon the release of sulfur from the Upper and Lower Freeport beds at many places is significant from a practical standpoint. Although the coal from all three important beds at certain selected locations shows a low sulfur content, the upgrading of large areas of coal in Indiana County to metallurgical standards is a difficult technologic undertaking. Upper Freeport-bed coals containing 1.75 percent or less sulfur can be upgraded to metallurgical standards without difficulty but raw coals containing more than 1.75 percent sulfur usually require precise control over the washing operation and economic disposal of a high-ash middling product. The quality of the Lower Kittanning bed tends to improve toward the northern part of the county, while the reverse appears to be true in the case of the Lower Freeport bed.

Armstrong County, Pa.

The important coal deposits in Indiana County extend to the west into Armstrong County.[40] In addition to a small output from the Pittsburgh and Upper Kittanning

38/ Crentz, William L., and Steele, Fern, Preparation Characteristics of Coal Occurring in Cambria County, Pa.: Bureau of Mines Rept. of Investigations 4747, 1950, 40 pp.

39/ Crentz, William L., Steele, Fern, and Bailey, A. L., Preparation Characteristics of Coal Occurring in Indiana County, Pa.: Bureau of Mines Rept. of Investigations 4763, 1951, 33 pp.

40/ Crentz, William L., Steele, Fern, and Bailey, A. L., Preparation Characteristics of Coal Occurring in Armstrong County, Pa.: Bureau of Mines Rept. of Investigations 4788, 1951, 25 pp.

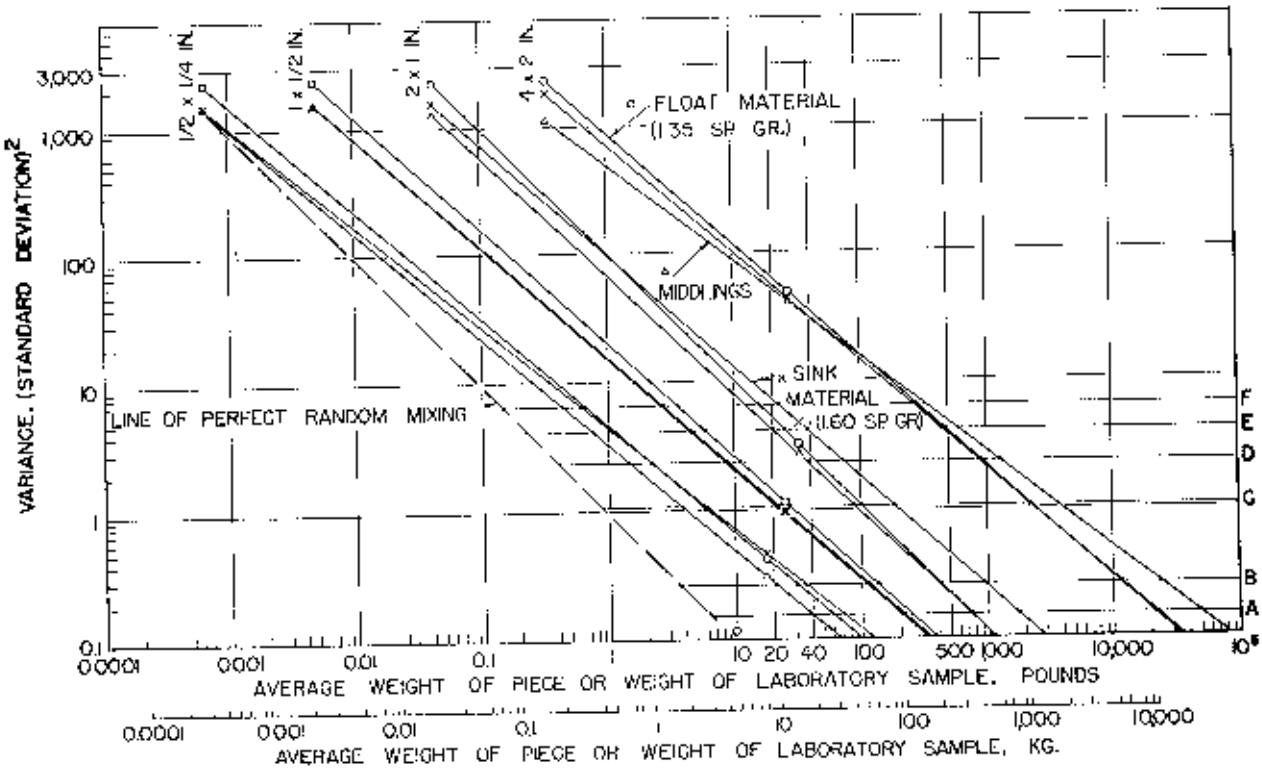

Figure 10. - Float-and-sink sampling characteristics of four sizes of a western Pennsylvania bituminous coal.

beds, the Middle Kittanning bed is mined to a small degree in Armstrong County. The Lower Freeport bed is opened at some places, but it is usually too thin and spotty in occurrences to support large-scale operations. A study of the washing characteristics of the Armstrong County coals shows that the Upper Freeport and Lower Freeport beds are responsive to fine crushing for release of sulfur impurities, whereas the Lower Kittanning bed is unaffected. The Upper Freeport bed is the major source of production and offers interesting possibilities as a source of coking coal. The sulfur in the coal ranges from less than 1 percent to more than 3 percent without forming a perceptible geographic pattern. Precise preparatory methods would upgrade the Upper Freeport bed to metallurgical standards over a wide area. Conclusive examination of the washing characteristics of the Lower Freeport bed in Armstrong County is hampered by the small number of mining operations. The meager data obtained indicates a possibility of preparing a satisfactory metallurgical fuel from the coal in the northwest section of the county. The Lower Kittanning bed, which is secondary in importance to the Upper Freeport bed, is a high-ash and high-sulfur deposit. The high sulfur content, much of which occurs in those forms of sulfur that cannot be removed by specific-gravity separation, removes this bed from consideration as a source of metallurgical coal.

Float-and-Sink Control Tests

An intensive study[1/] of coal sampling and float-and-sink testing was made to provide statistical data for estimating the size of samples needed for precise work in float-and-sink testing. The basic data obtained in these tests covered the size range of 4 inches to 1/4 inch, divided for testing into four size increments (that is, 4- by 2-inch, 2- by 1-inch, 1- by 1/2-inch, 1/2- by 1/4-inch). By statistical analysis of the data obtained in these experiments, the fundamental curves of figure 10 were projected to show the relation between particle size or sample weight and standard deviation in test results. Based on these curves the estimates of table 7 were set up to show the sample required in relation to size of particles in the coal sample.

TABLE 7. - Weights of laboratory sample required to fulfill accuracy of lines A to f, figure 10, for degree of mixing obtained and for perfect random mixing, in pounds

Line	Float		Middlings		Sink	
	As found	Perfect mixing	As found	Perfect mixing	As found	Perfect mixing
Size: 1/2 by 1/4 in.						
A	59.0	11.0	40.0	7.0	72.0	7.0
B	32.0	6.0	21.0	4.0	36.0	4.0
C	5.8	1.5	3.8	.9	5.9	1.0
D	2.5	.7	1.5	.5	2.3	.5
E	1.2	.4	.8	.3	1.1	.3
F	.7	.3	.5	.2	.6	.2
Size: 4 by 2 in.						
A	21,500	5,600	49,500	2,700	22,000	4,400
B	11,500	3,200	24,000	1,550	11,500	2,500
C	2,260	780	3,650	375	2,200	600
D	910	350	1,250	170	860	270
E	480	196	580	96	440	154
F	285	125	320	61	255	97

1/ Landry, Bertrand and Bailey, Arthur L., Coal Sampling for Float-and-Sink Control Tests: Rev. ind. minérale, Special Issue No. 2, December 1950, pp. 123-133. Pres. at International Conference on Coal Preparation, Paris, France, June 1950.

Research Pilot Plant

A coal-preparation research pilot plant with facilities for experimental treatment of coal on a pilot-plant scale has been erected on the Experimental mine property of the Bureau of Mines at Bruceton, Pa.[42] This research plant is in the same building with the boiler plant serving the Synthetic Liquid Fuels Research and Development laboratories, and the equipment is arranged so that a common coal-handling and refuse-disposal facility serves both plants. The pilot plant consists of a permanent installation of coal-handling equipment to unload coal from railway cars or trucks, convey it into the building, and distribute it to a series of overhead bins adapted to feed any desired preparation facilities that may be installed in the pilot-plant area. The pilot-plant area now has a 5-foot heavy-medium separating cone, with the necessary accessory equipment to make a complete heavy-medium washing unit; a complete ball mill pulverizing plant, with provisions for drying coal in the mill; and an installation of froth-flotation cells adapted for treatment of test lots of fine coal by the froth-flotation process, or for the reconditioning of nonmagnetic-flotation media for the heavy-medium washing system.

Coal Preparation for Synthetic Fuels

The Bureau has investigated the bituminous-coal fields of the United States containing large reserves of bituminous or subbituminous coals that may be economically used for synthesis of liquid fuels.[43] Samples were taken in coal fields of Pennsylvania, Ohio, West Virginia, Indiana, Illinois, Kentucky, Utah, Wyoming, Montana, and North Dakota. These were tested to show how the coal would be expected to respond to washing treatment for preparing a fuel adapted to synthetic fuels manufacture. The coals examined varied greatly in their responsiveness to preparatory treatment. While major emphasis was placed on ash reduction in these tests, other characteristics, such as petrographic constituents and sulfur content, were affected by preparatory treatment in a measure usually somewhat comparable to the ash reduction. These factors, as well as preparation losses and operating costs, must all be considered in appraising the value of washing these coals.

Drying Low-Rank Coals

Fluidized Drying

As part of the general investigation of processing and upgrading low-rank coals, experimental work conducted to date in the fluidized drying pilot plant has given further proof that the fluidized drying process is amenable to advance calculation as to rates and yield, and that any noncoking fuel can be dried by this technique. On the basis of previously reported work and a report summarizing 14 tests made on subbituminous coal from Colorado, Wyoming, and Alaska, and lignites from Texas and Greece,[44] the following conclusions were made:

42/ Fraser, Thomas, and Barrett, O. T., Federal Bureau Operates Coal-Preparation Research Plant: Mechanization, September 1950, pp. 111-119.

43/ Fraser, Thomas, Crentz, William L., and Barrett, Orrin T., Preparation Characteristics of Some Coals Available for the Synthetic Liquid Fuels Industry: Bureau of Mines Bull. 495, 1950, 132 pp.

44/ Parry, V. F., and Wagner, E. O., Drying Fine Coal in the Entrained and Fluidized State: Min. Eng., vol. 187, September 1950, pp. 974-982. Trans. Am. Inst. Min. and Met. Eng., vol. 187, 1950, pp. 974-982.

1. The capacity of a drying unit is about 500 pounds of water liberated by the fuel per hour and square foot of cross-sectional area.

2. It is practical to remove 90 to 93 percent of the total moisture in the coal by drying in the fluidized column without apparent devolatilization or modification of the chemical structure of the coal.

3. The rapid evolution of moisture and shrinkage of the coal cause considerable degradation of the coal particles during drying. In general, the decrease in average sizes of the coal particles is approximately equal to the bed moisture of the coal treated.

4. The drying of a given coal to any given degree is a straightforward heat balance problem.

5. The dried coal dusts are free flowing and flow through orifices by gravity at rates similar to the flow of fluids. Tests show that the flow of dust in pounds per minute equals $14.5 \times D^{2.65}$, where D is the diameter of the orifice in inches.

6. It is estimated that the investment costs of fluidized drying units should be in the range of $150 to $200 per ton of daily capacity, depending on the moisture content of the coal, and the costs of removing water from coal in the fluidized dryer should range from $0.85 to $1.00 per ton of water removed, based on cost data for 1948.

Modified Fleissner Process

In a study of the mechanism of drying lignite in a modified Fleissner[45/] process using steam at 400 p.s.i.g., it was indicated that the degree of drying and disintegration is determined by: (1) Size of lignite; (2) time of contact between lignite and drying agent; (3) temperature of drying agent; (4) humidity of drying agent; and (5) porosity of lignite bed in drier. The steam consumption for drying was calculated as 0.8 pound per pound of water removed; final moisture content of dried lignite was approximately 14 percent; and the lump size of lignite was preserved much better than in other methods of drying.

Storage of Lignite

Lignite recovered during the construction of the Garrison dam across the Missouri River, north of Bismarck, N. Dak., is being placed in storage in large million-ton piles. During the last year, 380,000 tons of lignite was stored, bringing the total in storage to 880,000 tons. When the Garrison Dam is completed, approximately 3 million tons of lignite will have been recovered and stored. The Bureau's method of stockpiling, worked out successfully on several piles of Colorado subbituminous coals, has to date been successful with this North Dakota lignite, when proper methods of piling were used. Under the conditions prevailing at the Garrison Dam site, the investigations indicate that this lignite can be stored for indefinite periods in large uncapped piles without firing spontaneously, if the Bureau's methods of piling are rigorously followed.

As part of an informal service to lignite consumers on the storage of lignite, many industrial stockpiles have been visited, and advice has been given on methods

45/ Oppelt, W. H., The Mechanism of Drying Lignite: Proc. North Dakota Acad. Sci., vol. 4, 1950, November, 1950, pp. 33-39.

of safely storing lignite. Also, experimental work on storage of steam-dried lignite has been continued in a simulated silo-type storage of dried minus-3/8-inch lignite. During a 15-month period of observation, no signs of hot spots or spontaneous ignition were noted, indicating that this type of storage is suitable for smaller sizes of steam-dried lignite.

UTILIZATION OF COAL AND OTHER FUELS FOR COMBUSTION

Fuel-Engineering Service

Fuel-engineering service to Government establishments in the selection, testing, and use of fuel and fuel-burning equipment and in the economical use of steam was continued. Services on 195 special problems were given 40 different Federal agencies, in addition to those described in the following paragraphs.

At the request of the Veterans' Administration total boiler-plant operating-cost comparisons were made of the use of oil, gas, and coal, and the proper type of fuel-burning equipment was recommended for four projects. A study was made of a hospital boiler plant at Dwight, Ill., and recommendations were made for new boilers, new fuel-burning equipment, and fuel; recommendations were made on the proper choice of fuel-burning equipment for a large boiler plant at Perry Point, Md., for new fuel-burning equipment at Augusta, Ga., and for a new project at Manila, Philippines.

A series of tests was also made for the Veterans' Administration on chain grate-type fuel-burning equipment, normally burning rice, to determine the relative performance of rice and barley anthracites of various size consists and volatile contents.46/ Efficiency and capacity were limited by the grate-link design, as well as the design of the furnace, when barley was substituted for rice. Careful maintenance and operation were particularly necessary with barley. In general, the efficiency and capacity decreased with decreased fuel size and volatile content, the ranges on the 250-hp. boiler tested being from 63 to 74 percent in efficiency and from 130 to 170 percent in boiler rating. With barley, the size consist affected both efficiency and capacity to a greater extent than the volatile content, but with a normal amount of undersize the efficiency decrease from the substitution of barley for rice was about 3 percent.

Fuel-cost comparisons were made for three projects for the Federal Power Commission and for one project for the Department of Agriculture. Acceptance tests as to efficiency and capacity of new boiler equipment at the Bryant Street pumping station were made at the request of the Department of Engineering of the District of Columbia. A survey and recommendations were made for hot water and heating equipment for two buildings at the Bureau of Mines Mount Weather Station, Bluemont, W. Va. A new domestic type of automatic stoker for burning anthracite was tested at the request of several Federal agencies. Cooperative work with the Air Preheater Corp. of Wellsville, N. Y., on the prevention of deposits and corrosion on air preheaters was continued.

At the request of the General Services Administration, many operating tests were made on experimental auxiliary air-jet equipment installed to prevent smoke emission from large, underfeed stoker-fired boilers, when using cheaper high-volatile coal, and to improve efficiency at the higher loads. These tests were part of a comprehensive program to determine the best equipment for several plants of this type being operated in the Washington area. General Services administration was also supplied

46/ Burdick, L. R., and Morgan, R. E., Burning Anthracite Barley on a Chain-Grate Stoker in a Two-Arch Furnace: Bureau of Mines Rept. of Investigations 4720, 1950, 7 pp.

with information and recommendations on the decentralization of coal purchasing and the development of methods of purchasing coal in various regions.

Performance tests of specially twisted metal strips inserted in the tubes of fire-tube boilers to improve heat transfer were made at the request of the Department of the Navy. They operate a great number of boilers of this type, and it was found that an average fuel saving of about $130 per year per boiler could be expected from such equipment.

At the request of the Public Buildings Administration and the Federal Supply Service, plans were developed for a new coal-storage supply of about 100,000 tons for the Washington area, the general type of coal decided upon, the specification analytical limits determined, and recommendations as to award made. Federal coal-purchasing agents were supplied needed information on mines for use in making awards of contracts, the bids for supplying coal to a number of agencies were studied, and recommendations made for award.

An investigation was made of the possible increased use of wood fuel in case of the need for greater defense efforts. A paper[47/] on the burning of wood waste for commercial heat and power was published covering the composition and burning characteristics of wood, the types of wood-waste fuels, their heating values and analyses, the transportation and storage of wood, furnace designs for wood burning, and a tabulation of general information on present-day wood-burning installations.

A handbook[48/] was prepared from basic information on the use of propane and butane fuels, previously published as Bureau of Mines Information Circular 7519. The handbook covers the properties of these fuels, the safety precautions to be observed in their use, the methods of transportation, the various purposes for which the fuels are used, the equipment needed, and the amounts used in the United States.

Boiler Feed-Water Conditioning

Analyses and resulting recommendations were made on 9,714 samples of boiler water during the fiscal year as follows: 3,582 from the Department of the Army; 1,908 from the Department of the Air Force; 1,701 from the Veterans' Administration; 663 from the Department of the Navy; 547 from the Post Office Department; 446 from the District of Columbia Government; 293 from the Public Housing Administration; 225 from the Department of Justice; 184 from the Bureau of Indian Affairs; 64 from the Federal Security Agency; 32 from the General Services Administration; 21 from the Public Health Service; 16 from the Department of Commerce; 13 from the Department of Agriculture; 11 from the Bureau of Mines; 4 from the Smithsonian Institution; 3 from the Bureau of Reclamation; and 1 from Howard University. This is about a 4-percent increase over the previous year.

Reports and recommendations covering 27 analyses of various scales, sludges, and deposits, 22 miscellaneous special analyses, and 5 analyses of boiler compounds were made.

A total of 1,148 special Bureau of Mines field water-test kits, 12,764 bottles of chemical reagents, and 14,781 test-kit replacement items was distributed to

47/ Barkley, J. F., and Morgan, R. E., Burning Wood Waste for Commercial Heat and Power: Bureau of Mines Inf. Circ. 7580, 1950, 12 pp.

48/ Barkley, J. F., Questions and Answers on Propane and Butane Fuels, Question and Answer Handbook 4, 1950, 28 pp.

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various Government activities. These amounts are increases over the previous year of about 98 percent, 24 percent, and 23 percent, respectively. Distributing these kits and reagents from a central source saved Government agencies about $20,000 this year as compared to open market purchase.

Consulting service was given to the Red Lake Indian Mills, Redby, Minn., on the use of chemicals bought on specification to replace a more costly proprietary boiler compound; the Bureau of Yards and Docks, Department of the Navy, on the use of boiler water antifoams and on an operating manual for treatment of boiler water in the Marianas area; the St. Elizabeth's Hospital, Washington, D. C., on the control of brine corrosion in refrigeration plant; the Forest Products Laboratory, Department of Agriculture, Madison, Wis., on the control of sludge formation; the Office of the Chief of Engineers, Department of the Army, on chemical analyses procedures for use in Europe; the District of Columbia Government on the use of external feed-water treating equipment and on the chemical treatment of hot-water heating systems; the District of Columbia filtration plant on boiler-water treatment for low-pressure boilers; the Public Housing Administration on boiler corrosion at Cambridge, Mass.; the Department of the Air Force on condensate-line corrosion in stations in Alaska; the Veterans' Administration on control of deposits in nozzles in spray equipment and on return-line corrosion; and the Housing Authority of Baltimore on setting up a central boiler-water control and research laboratory.

At the request of the Potomac River Naval Command, Washington, D. C., visits were made to their local laboratory to instruct in boiler-water testing; to the Marine Barracks, Washington, D. C., where recommendations were made on control of steam losses due to leaking traps and on control of boiler-scale formation; to the Marine Barracks, Quantico, Va., on return-line corrosion problems; to the Naval Communications Station, Washington, D. C , and the Naval Air Station, Anacostia, D. C., on boiler-water difficulties; and to the Naval Research Laboratory, Anacostia, D. C., on making boiler-water tests, on design of chemical and feeding equipment, and on the control of chemical dosages.

Various agencies requested that studies be made at their installations as follows: Boiler plant of the Public Housing Administration, Beltsville, Md., where recommendations were made on boiler-water treatment, resulting in appreciable savings from the elimination of a proprietary boiler-water compound; Naval Hospital, Bethesda, Md., where a comprehensive study of return-line corrosion was made and the causes determined; Naval Powder Factory, Department of the Navy, Indian Head, Md., where the cause of excessive boiler-water carry-over and methods for its prevention were determined and methods were recommended for the elimination of excessive return-line corrosion costing about $20,000 annually; Naval Hospital, Bureau of Yards and Docks, Department of the Navy, St. Albans, Long Island, N. Y., where tests and studies were made to verify the need for a hydrogen-zeolite softener about to be purchased for control of return-line corrosion, but it was found that satisfactory water conditions could be maintained without the need for this equipment, resulting in a saving of an expenditure of about $10,000; Navy Photographic Center Laboratory of the Naval Air Station, Anacostia, D. C., where recommendations were made for cleaning sediment from the water filters and for cleaning slime in the film-rinsing tanks and cheaper chemicals bought on specifications were substituted for a proprietary compound for treating refrigeration water; Detention Headquarters, United States Department of Justice, New York, N. Y., where the boiler plant was to be surveyed, recommendations were to be made on boiler-water treatment, and the engineer was to be instructed in boiler-water testing and control of chemical treatment.

A Bureau of Mines handbook on boiler-water treatment[49] covers essential information needed by operators, particularly in Government power plants, for applying and controlling chemical treatment of boiler water. The handbook includes chapters on boiler-water causticity and how it is maintained in control; a description of different types of chemical feeders and methods of adjusting dosages; a discussion of the use of soda ash, caustic soda, and phosphate chemicals for control of boiler-scale formation; instructions on the use of tannin in boiler-water treatment; a discussion of control of corrosion in boilers during operating and idle periods and on the use of volatile amines for control of corrosion in return lines; instructions on boiler-water blow-down and its control; and an explanation of boiler-water analyses and how to apply such information to the control of chemical residuals in boiler water.

Boiler-Water Research

Research on the fundamental causes of corrosion in steam condensate-return lines included studies of preventative chemicals, such as amines and ammonia, particularly from the standpoint of lowering the costs of necessary chemical treatment. Contrary to some impressions in industry that the use of amines for this purpose is quite expensive, a written discussion of a paper[50] emphasizing the idea of high costs of amine treatment pointed out that field tests have shown a cost of less than $300 for an entire year for three large housing developments of 4,227 dwelling units, or about 75 cents per million pounds of steam. In other examples cited, the average yearly costs ranged from $57 to $150. In these cases, it was found that the amine morpholine proved to be the most economical amine to use.

At the request of the Department of Justice, an investigation was made of supposed difficulties in dyeing from the use of an amine, where steam was used in direct contact with wool material. It was found that the difficulties resulted from the presence of iron rust previously accumulated in the pipelines.

A laboratory study of a method of removing corrosion products that plugged condensate-return piping in a Government-operated heating plant showed there was some merit in using polyphosphates for this purpose, but a saving of about $1,000 per year resulted when equally active material available on the open market was substituted for a proprietary compound previously used.

A summary on the results of about 2,000 tests obtained with 600 embrittlement detectors in 500 stationary boiler plants and of approximately 500 tests on 20 locomotive boilers was presented at the 1950 Annual Meeting of the American Society of Mechanical Engineers.[51] The results showed the effectiveness of sodium nitrate, Quebracho tannin, and zero-caustic treatments to prevent embrittlement cracking. Nitrate and quebracho are inhibitors against intercrystalline corrosion in hot, concentrated caustic solutions. The zero-caustic treatment prevents the formation of concentrated solutions of caustic that cause corrosion. The survey also showed that the frequency of test-specimen failure was not affected by the A.S.M.E.-recommended sulfate-to-carbonate ratios, since it was approximately the same as when no

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49/ Goldman, Louis, Boiler-Water-Treatment Manual for Federal Plant Operators: Bureau of Mines Handbook 5, 1951, 94 pp.

50/ Berk, A. A., Discussion of "New Polar Film Treatment for the Control of Return-Line Corrosion." by E. L. Kohler and J. R. Brown: Proc. Tenth Annual Water Conf., Eng. Soc. of Western Pennsylvania, 1949, pp. 121-122.

51/ Berk, A. A., The Prevention of Embrittlement Cracking: Combustion, vol. 22, No. 6, December 1950, pp. 52-53.

treatment was used. The report also discussed the 26 cases of cracking of stationary boilers studied during the period 1942-49. Of these, 24 were definitely due to embrittlement cracking, and cracks were found in butt straps, drum metals, tube seats, and tube ligaments. The boiler drums were welded in six of the plants and were riveted in the others. Embrittlement-detector tests did not show enough nitrate or a tannin-type inhibitor to be present in concentrations to prevent cracking, although five of the plants were maintaining the prescribed sulfate to carbonate ratios at the time of failure. However, the effectiveness of the ratios could not be accurately proved or disproved, inasmuch as none of the plants had complete data to show that the ratios had always been maintained.

Results of tests on embrittlement cracking in Great Britain frequently vary with those obtained by the Bureau. A discussion[52/] of a report on such an investigation showed that the author's findings were not inconsistent with the previously published American work. The same effects of concentrated stress and highly concentrated solutions of pure sodium hydroxide were obtained. The author's results on the inhibiting effects of tannin were also in agreement, insofar, as they went, with our tests.

Laboratory study disclosed that a projected use of a proprietary compound to acid-clean a boiler at a naval installation in Maryland would result in serious deterioration of the boiler; stopping the proposed acid-cleaning operation undoubtedly saved a boiler valued at many thousands of dollars.

Smoke Abatement

Smoke-abatement work throughout the United States continued to be very active. Cities requesting Bureau of Mines publications and consulting service included the following: Victoria, British Columbia; Windsor, Conn.; Elgin, Ill.; Louisville, Ky.; Rumford, Maine; Detroit, Mich.; Weehawken, N. J.; Amsterdam, N. Y.; Dayton, Ohio; Erie, Pa.; Austin, Tex.; and Tacoma, Wash. Consulting and field services were given various Federal agencies on problems of abating smoke and dust, including acceptance tests of new dust-precipitating equipment for the West Central Heating Station in Washington, D. C. The National Smoke Abatement Society of England exhibited American publications and charts on smoke abatement at Manchester, England. Work on smoke-abatement problems for the International Joint Commission was continued by its Technical Advisory Board on Air Pollution, which includes a Bureau of Mines engineer. Studies were made regarding the education of personnel and changes in fuel-burning equipment on vessels of the Great Lakes using the Detroit River.

A historical paper on air-pollution prevention in the United States[53/] gave a history of adoption of ordinances, the emissions prohibited and standards of measurements, the developments in continuing the work, related activities, a discussion of the general nature of the problem, and a list of references. Another paper[54/] presented quantitative data from a number of metallurgical operations on air pollution by industrial fumes, gases, and dusts and discussed allowable stack discharge

52/ Berk, A. A., Discussion of "Caustic Cracking: Stress Corrosion Tests at Elevated Temperatures," by C. C. Weir: Inst. Mech. Eng. (London), War Emerg. Proc., No. 55, 1949, p. 24.

53/ Barkley, J. F., Air-Pollution Prevention in the United States: Mech. Eng., April 1951, vol. 73, No. 4, pp. 284-288.

54/ McCabe, Louis C., Air Pollution by Industrial Fumes, Gases, and Dusts: Am. Inst. Min. and Met. Eng. Tech. Pub. 2915F, Trans. Am. Inst. Min. and Met. Eng., vol. 187, 1950, pp. 971-973; Min. Eng. vol. 187, No. 9, September 1950, pp. 971-973.

in terms of effluent-weight ratio. Types of equipment used for recovery of stack effluents were cited. A Bureau of Mines information circular covering general aspects of smoke abatement[25] was published. Several model ordinances were included and discussed, with a discussion on smoke abatement at plants.

Coal and Energy in the Western States

A review was made of pertinent technical and economic facts relating to the western coal industry.[26] The demand for energy on the west coast was analyzed, and it was estimated that if the oil produced and imported does not exceed 1,000,000 barrels per day and the natural gas produced and imported does not exceed 2 billion cubic feet per day, the demand for coal will increase to 6 to 8 million tons per year. Since 1920, coal has lost 30 percent of its markets in the Western States due to competition with oil and gas. In 1920 coal supplied 7.1 percent of the energy produced, but at the present time it supplies only about 4 percent. The paper lists the various coal-mining fields and gives the history of coal production of the Western States and averages analyses of the coal from each field. The classification of coal is discussed, and charts are given to correlate the analysis of coal with heating value and classification.

Combustion Characteristics of Packaged Fuels

An investigation was conducted as an extension of previous Bureau studies of packaged fuels containing anthracite fines to determine the combustion characteristics of packaged fuels made of high-volatile and low-volatile bituminous coals.[27] Particular attention was given to the smoke-producing properties of the packaged fuels, because of the demands for the reduction of smoke from hand-fired domestic-heating furnaces.

It was found that packaged fuel of sufficient cold strength for handling can be made if sufficient binder is used. The combustion tests indicated that most of the packaged fuels made from the more strongly caking coals and 4 percent asphalt binder had satisfactory burning properties. The quantity of smoke produced increased with the volatile content of the fuel. Only two of the six different lots of packaged fuels tested would satisfy the smoke ordinances if burned without secondary air, but all except one lot were acceptable if burned with sufficient secondary air.

Factors Affecting Heat Absorption in Furnaces

To provide a basis for rational and economical design of furnaces and to permit the most economic use of available coals, the Special Research Committee on Furnace Performance Factors of the American Society of Mechanical Engineers continued its cooperation with the Bureau of Mines in investigations to determine the effect of method of firing, load, excess air, and cleanliness of furnace walls on heat absorption in boiler furnaces.

25/ Barkley, J. F., Fundamentals of Smoke Abatement: Bureau of Mines Inf. Circ. 7588, 1950, 34 pp.

26/ Perry, V. F., Production, Classification, and Utilization of Western United States Coals: Econ. Geol., vol. 45, No. 6, September-October 1950, pp. 515-532.

27/ Myers, James W., and Corey, Richard C., Combustion Characteristics and Physical Properties of Packaged Fuels Containing Bituminous Coal: Bureau of Mines Rept. of Investigations 4797, 1951, 30 pp.