manufacturers improved equivalent protective devices to replace frame-grounding conductors have been developed and certified by the Bureau of Mines as acceptable. Personnel of the Bureau is making field surveys to determine the effectiveness of these devices in actual service.

Mine Lighting

During 1957 the Bureau announced permissive approval of four generalized mine-lighting systems under Schedule 29, Mine Lighting Equipment for Underground Workings. Encouraging the use of these approved mine-lighting systems and continuing research to improve them should aid in overcoming one of the greatest handicaps to safety and production of underground works, that of poor visibility. Reduction in injuries and increased production are expected to result from the use of approved mine-lighting systems.

Documentary evidence at disasters and at sites of other unusual underground accidents can now be obtained with an explosion-proof, high-power floodlamp and development of a complete system with which these lamps may be safely used. The unit was tried successfully for the first time in September 1957, when scenes were photographed after a coal-mine disaster at Marianna, Pa.

Mine Ventilation

Studies have been continued of major ventilating problems confronting the coal-mining industry. Face ventilation with continuous-type mining machines has been given particular attention. Research is being conducted to develop methods of automatically cutting off power to machines in face areas when the percentage of methane reaches a predetermined minimum and also to develop an audible warning device to alert workers that the concentration of methane is approaching the danger point.

The absolute pressure method of making ventilation surveys in coal mines defines areas of above-average resistance to airflow, and details of the operational procedure were published.[34/] An electric analogue, developed for solution of mine ventilation network problems, has proved valuable in many instances.

As part of the program of coal-mine inspection under the provisions of the Federal Coal Mine Safety Act, approximately 19,000 samples of mine air were analyzed to determine the adequacy of ventilation in coal mines, to detect and aid in eliminating hazards from flammable and toxic gases in mines, and to provide information necessary in controlling and extinguishing fires in coal mines. In the analysis of samples of coal-mine atmosphere conventional gas-volumetric analysis methods were supplemented by the use of infrared absorption spectrometry to determine, both qualitatively and quantitatively, the methane content of certain samples of particular importance.

34/ McElroy, G. E., and Kingery, D. S., Making Ventilation-Pressure Surveys With Altimeters: Bureau of Mines Inf. Circ. 7809, 1957, 20 pp.

Dust Control in Mines

Three drill dust collectors for coal-mine use were approved during 1957, bringing the total of approved collectors to 46. Numerous minor modifications in previously approved equipment were covered by extensions of approval. Dust control in coal mines was discussed at a symposium on coal workers' pneumoconiosis,35/ and information was presented on concentrations of airborne dust resulting from representative mining operations in several bituminous coal mines with different methods of dust control in effect.36/

Safety Education

In the 1957 National First-Aid and Mine Rescue Contest, Louisville, Ky., 57 teams from 7 States participated - 8 teams from 3 States in the mine rescue contest and 49 teams from 7 States in first aid. The contest was held under the auspices of the Federal Bureau of Mines and the Joseph A. Holmes Safety Association and was sponsored by the National Coal Association, United Mine Workers of America, and various State mining departments.

STORAGE AND PREPARATION

Storage of Lignite

Stable, long-term storage of lignite has been demonstrated at Garrison Dam, Riverdale, N. Dak., where over 2 million tons of lignite excavated during construction of the dam, has been stored. Bureau of Mines personnel in cooperation with personnel of the Army Corps of Engineers developed the method of stockpiling. Piles constructed in 1-foot lifts and compacted by sheeps-foot rollers are preserved in their initial condition. Erosion of the protective slack layer by wind and rain continues to be a maintenance problem, and periodically pile surfaces in eroded areas must be dressed and slack accumulations leveled, particularly at snow fences installed for control of slack deposition. As noted in the previous year, scattered and increasing weed growth on side slopes and top surface of the piles is an aid in the control of wind erosion.

Periodic observations are conducted on pile 5. Despite evidence of minor air infiltration at the surface, temperatures have remained at a safe low level, and no difficulty from spontaneous combustion has been encountered. Yearly checks of the heating value of pile depth samples, compared on a moisture- and ash-free basis, have shown a decrease of less than 1-1/4 percent from August 1953 to August 1957. During the year, in addition to the continuing observations, work included a determination of the size consist of a large channel sample removed from one of the piles and determination of the bulk density. Despite the extensive degradation caused by the compaction process, the size consist of the eight individual samples was remarkably uniform, and 23 percent

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35/ Berger, L. B., Some Considerations on Dust Control in Coal Mining: AMA Arch. Ind. Health, vol. 15, No. 6, June 1957, pp. 499-505.

36/ Owings, C. W., and Harmon, J. P., Full-Shift Dust Exposure in Some Bituminous-Coal Mines: Bureau of Mines Rept. of Investigations 5361, 1957, 10 pp.

of the combined sample was plus 2-inch and 72 percent was plus 1/4-inch. The average bulk density of the eight samples was 69.9 lb. per cu. ft.

Freezeproofing Lignite

Producers supply lignite consumers with fuel as required, despite the severity of winter weather. Vaporization of moisture occurs during transport, and recrystallization as frost on coal particles at car walls and the exterior of cars cements particles together, frequently agglomerating the whole mass. Application of 3 to 5 quarts of oil per ton of lignite, as used by industry, is beneficial in reducing th degree of agglomeration, primarily by its influence on the structure of the frost deposited on the particles. In contrast to the dense, strong structure of crystals deposited on untreated particles of lignite those deposited on oil-treated particles are moldlike, delicate, fragile crystal structures and thus produce bonds of weak strength.

A method had been developed to determine the force necessary to rupture the agglomerated mass by measuring the pressure within a balloon imbedded in the center of the sample at the instant of rupture. Improved reproducibility of results has been obtained by equalizing the flow and turbulence throughout the refrigerated test chamber and by obtaining more uniform lignite samples. Testing and comparison of freezeproofing agents have been resumed.

Size Reduction of Lignite

In its natural state lignite is tough and resilient and resists fracture. Emphasis in the study of size reduction continues on a study of pulverization characteristics and power requirements.

Pulverization of lignite was continued in an experimental impact pulverizer loaned by the chemical engineering department of the University of North Dakota. Stable, controlled operation without using preheated air was achieved by removing an internal fan, designed to return larger particles to the grinding zone. External classification and return of larger particles to the grinding zone resulted in a product with high degree of fineness.

Mechanism of Flotation

A study is being made of the theory and practice of flotation of very fine sizes of coal that cannot be cleaned by gravity separation. The results of this study should lead to more efficient preparation methods, which in turn should contribute materially to extending our coal reserves.

During the year, continued emphasis has been placed on elucidating the mechanism of froth and kerosine flotation and determining the influence of operating variables on cell capacity. A comprehensive investigation of flotation rates and their relation to feed characteristics and operating variables has been undertaken, using flotation cells ranging in capacity from a few pounds to several tons per hour. Analysis of the flotation data indicates that the relation of the rate of flotation to the operating variables is

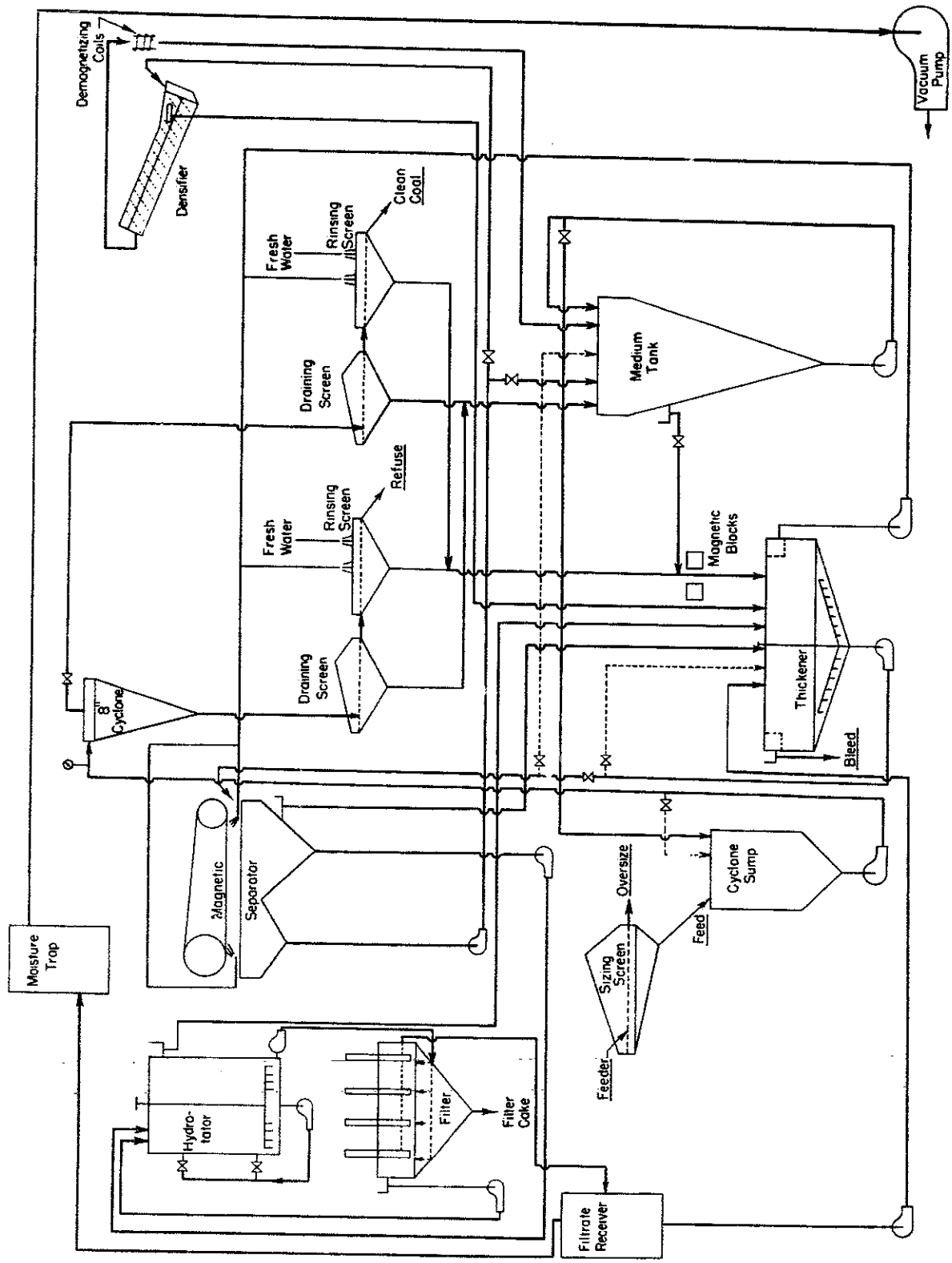

FIGURE 4. - Schematic Diagram of Coal-Preparation Plant With Dense-Medium Cyclone.

improve the vacuum filtration of some slurries.[39/] A slurry that was virtually nonfilterable in natural form because it contained much fine material and clay was tested with 15 different flocculants in a test-leaf apparatus to determine the influence of flocculation on filtration. The flocculants varied widely in effectiveness, both as to the amount of increased filter capacity and as to the strength (and therefore ease of handling) of the flocs. With the better flocculants, cake rates that exceeded 200 pounds per square foot per hour were obtained, even on finely woven filter cloth.

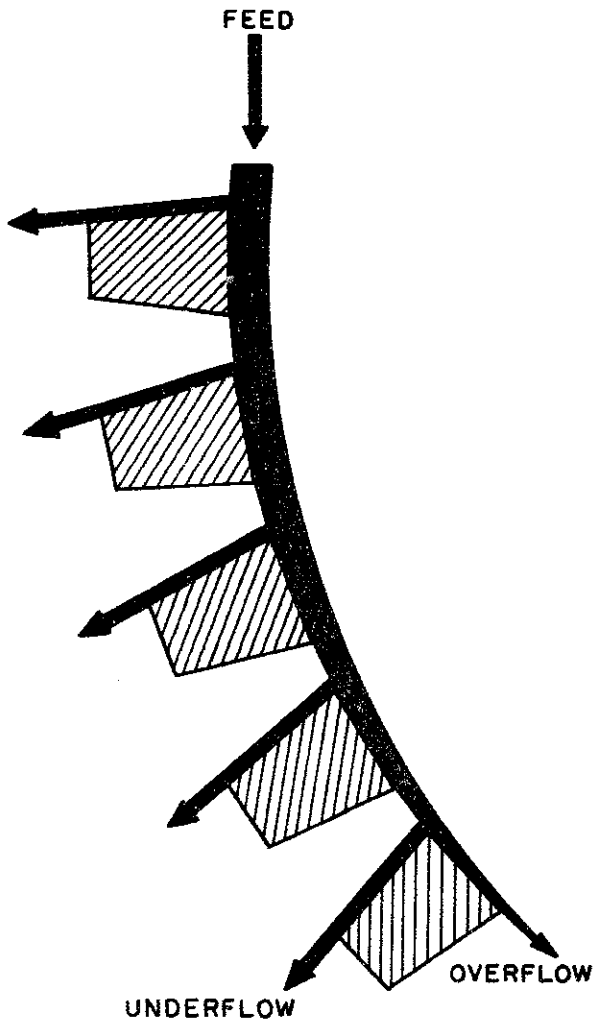

FIGURE 5. - Diagram of Sieve Bend for Cleaning Coal (After Fontein).

Closely related to the problem of dewatering slurry and equally difficult is the task of screening out fine sizes before further treatment. A radically new type of screen for this service is being tested. Developed in The Netherlands several years ago and known as the DSM (Dutch State Mines) screen or sieve bend, it is essentially a stationary section of wedge-wire screen bent to a 60° arc (fig. 5). As slurry flows down the screen, each successive wedge bar slices a layer off the bottom of the stream, carrying with it particles up to half the size of the net bar spacing. Thus a 1/2-mm. screen sizes at 1/4 mm. The laboratory tests have demonstrated that the screen has very high capacity and is capable of effective sizing in the difficult 1/4-mm. range.

Preparation Characteristics of Coking Coal

Coals are being tested for preparation characteristics on a county basis, initially in the Appalachian area. During 1957 reports for one West Virginia, one Kentucky, and one Virginia county were published. Figure 6 shows the 21 counties for which reports have been published and the status of the uncompleted counties. In addition, a New Mexico coal was examined for its washability characteristics.[40/]

39/ Jacobsen, P. S., and Mauser, J. E., Flocculation Improves Vacuum Filtration: Coal Age, vol. 62, No. 12, December 1957, pp. 74-75.

40/ Crentz, W. L., Washability Characteristics of Coal From San Juan County, N. Mex.: Bureau of Mines Rept. of Investigations 5335, 1957, 20 pp.

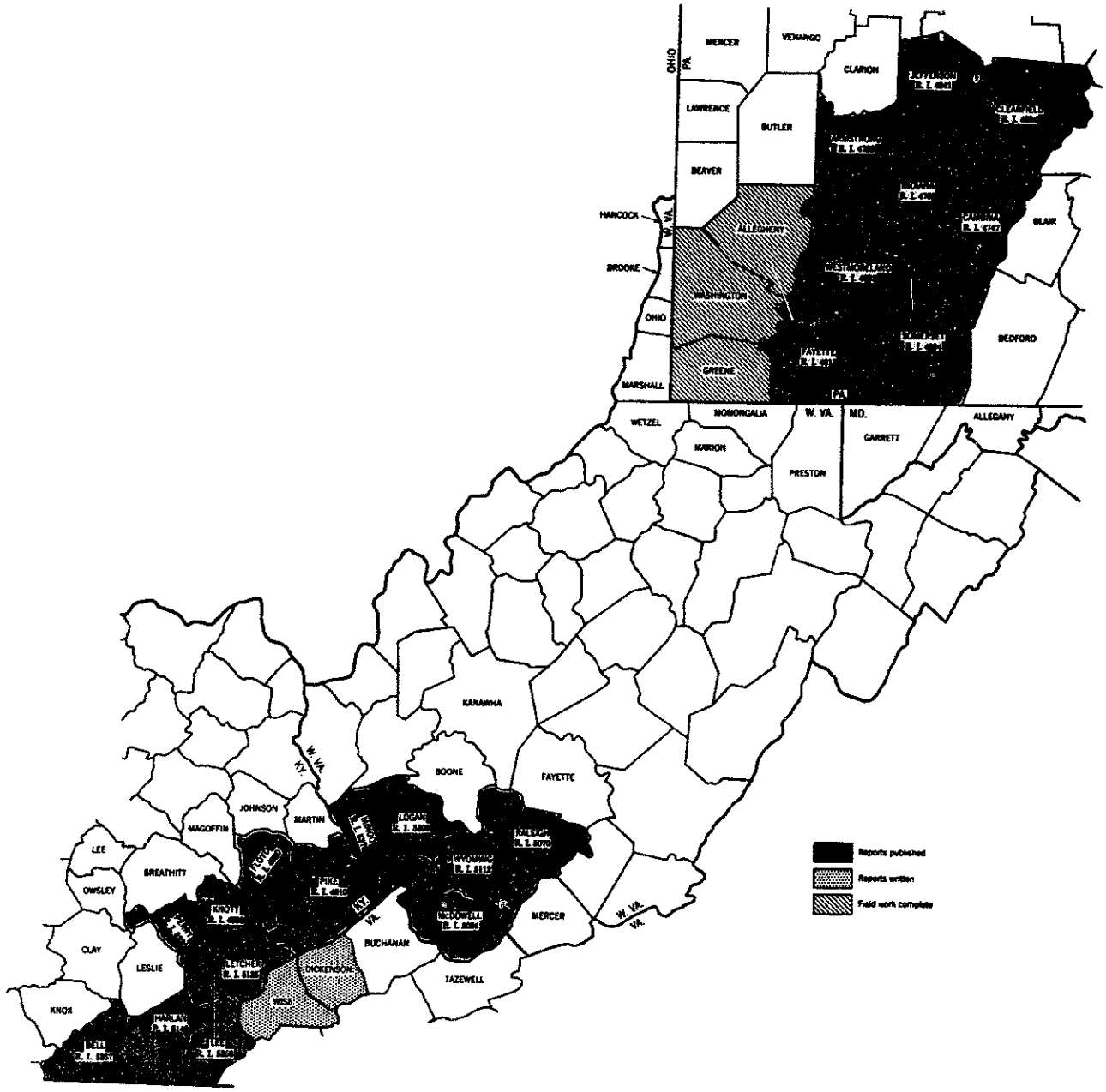

FIGURE 6. - Map Showing 1957 Status of Reports on Washability of Coking Coal.

Logan County, W. Va.

The Cedar Grove group and the No. 2 Gas coalbeds are important from both the reserve and production standpoints and can be prepared by mechanical cleaning to yield coal suitable for metallurgical use.41/ The Cedar Grove group of

41/ Miller, J. W., and Jolley, T. R., Preparation Characteristics of Coal From Logan County, W. Va.: Bureau of Mines Rept. of Investigations 5306, 1957, 48 pp.

coalbeds consists of four mining horizons; each horizon is treated as a separate bed to report the preparation characteristics effectively, except that the Upper Cedar Grove bed could not be sampled and studied. However, all coal produced from the Cedar Grove group was combined in the table of production. The Chilton bed also is important from a production standpoint, and its coal can be prepared to produce a chemically suitable metallurgical fuel. The Alma bed has important reserves in the county but is unimportant in production. In some areas this coal can be upgraded to metallurgical fuel and in others it cannot because of a variable sulfur content. The No. 5 Block, Stockton, and Buffalo Creek coalbeds have minor importance from both production and reserve standpoints, but the coal from these beds may be prepared to produce a low-ash product chemically suited for metallurgical use.

Logan County coals generally are not responsive to fine crushing as a means of product improvement. The total production of coal in Logan County in 1953 was 17,190,007 tons, of which approximately 68 percent was cleaned in 24 mechanical cleaning plants. The Cedar Grove group, the Chilton, and the No. 2 Gas coalbeds were the sources of most of the cleaned coal.

Bell County, Ky.

The Dean, Mingo, and Harlan beds are the major sources of production for the county, and the Mingo, Poplar Lick, and Jellico coalbeds have the largest reserves.42/ Two faults divide the county into three coal-bearing areas - Log Mountain, Puckett Creek and Hance, and the area north of Pine Mountain, in which the correlation of beds is difficult. The preparation characteristics of coal in each of these areas were determined.

In the Log Mountain area coal from the Red Spring, Hignite, Stray, and Mingo beds can be prepared to produce fuel for metallurgical use. The Sterling coalbed cannot be considered a source of metallurgical fuel under present standards because of high sulfur content. Coal from the Sandstone Parting bed can be washed mechanically to yield a metallurgical fuel.

In the Puckett Creek and Hance area coals from the Creech and Harlan beds can be prepared to yield a chemically suitable product of Metallurgical grade. The Imboden coal in the western part of the area can be prepared to produce a low-ash, medium low-sulfur product suitable for making metallurgical coke; in the eastern part of the area the sulfur content of this coal is too high under present standards for coking coals. The Dean coalbed varies in sulfur content, and for this reason Metallurgical-grade coal may be prepared from some areas but not from others.

In the area north of Pine Mountain the Moss bed cannot be considered a source of metallurgical fuel because of the difficulty of reducing the sulfur content by present cleaning methods. Coal from the Jellico bed can be prepared by an easy washing operation to produce a low-ash, low-sulfur product chemically suited for metallurgical use.

42/ Jolley, T. R., and Miller, J. W., Preparation Characteristics of Coal From Bell County, Ky.: Bureau of Mines Rept. of Investigations 5357, 1957, 30 pp.

In 1954 the total production of coal in Bell County was 1,247,160 tons, of which 30.7 percent was cleaned in five mechanical cleaning plants. Most of the coal cleaned came from the Mingo and Dean beds. Little benefit would be gained by finer crushing for beneficiation, because of the difficulty in handling the excess fines in a commercial cleaning plant.

Lee County, Va.

Only a small area in the north central part of the county supports mining.43/ Beds in this area are difficult to correlate because of geologic movement. The Taggart coal bed is the major source of production, and the Kirk, Harlan, Imboden, and Pardee coalbeds have minor importance. Total production was 660,395 tons in 1955, of which 38,756 tons from the Taggart bed was cleaned on air tables.

Coal from the Taggart and Imboden beds is suited for metallurgical use as mined. Coal from the Kirk and Harlan beds cannot be upgraded to metallurgical use under present standards because of excessive sulfur content. Lee County coals do not generally respond to finer crushing for product improvement.

Pierce County, Wash.

In addition to the regular coking-coal survey, which is confined to the Appalachian region, washability examinations were made of samples from a deposit in Pierce County, Wash., which contains the only known reserves of coking coal on the Pacific coast. This work was undertaken in cooperation with a company that is exploring the deposit. The coals examined have high free-swelling indexes and low sulfur contents but are difficult to clean and cannot be reduced readily to less than 10 to 11 percent ash.

Anthracite Preparation

Activities in the preparation field have been confined largely to the establishment of a laboratory suitably equipped for the study of special preparational procedures; the objective is to provide quality anthracite products for new demands of the changing market.

Heyl-Patterson cyclones have been installed to study desliming, sizing, and deashing of fine sizes of anthracite and to supplement equipment used for studying reduction of the ash content of fine-size, heavy-medium feed. A drum-type, heavy-medium pilot plant has been installed, and enough tests were completed to determine the operating characteristics of the unit. A unitized, air-swept, ball-mill system has also been installed to study size reduction of anthracites along with the effect of size on various cleaning processes. A 10-compartment, washability-assay tank has been installed in the preparation laboratory, and separations are possible at 1.40 to 2.00 specific gravity at 0.05 increments. Tests conducted on preparation of minimum ash fractions from conventional domestic coal sizes have indicated that for a low-volatile, hard-structure coal increments containing as little as 1.25 percent ash are possible.

43/ Miller, J. W., Preparation Characteristics of Coal from Lee County, Va.: Bureau of Mines Rept. of Investigations 5358, 1957, 14 pp.

For a high-volatile anthracite studied, increments containing as little as 0.75 percent ash have been prepared. A sample of mine-run anthracite has been obtained for study in the heavy-medium plant, and samples from conventional breaker operations have been received for study in the cyclone system.

A study of the preparation required for anthracite feed to a Lurgi-type gas-producer plant has been initiated in conjunction with the gasification investigation. This study covers two possible preparation procedures that yield products suitable either for operation of a gas plant in conjunction with a large, modern, conventional mining and preparation operation or for a new mining operation wherein the entire output from the mine would be used in a large, commercial gas plant. The first type of operation entails collecting all plus-3/16-inch refuse, crushing to 9/16- by 3/16-inch, and separating to produce a gas-plant feed with 20- to 25-percent ash content. This type of operation, however, limits the size of the gas plant but makes possible a low-cost fuel. The second type of operation places no restriction on the size of the plant but does require anthracite production at a price lower than is possible with mining procedures as now developed. If the cost of mining should be reduced appreciably, this type of operation will offer a far more versatile type of gasification operation.

COMBUSTION, BOILER-WATER TREATMENT, AND POLLUTION

Heat Transfer in Furnaces

Efficient use of fuels for producing heat and power is of major importance in our industrial economy.[44/] A continuing program in this field has included studies of heat transfer in steam-boiler furnaces and of ash and slag deposits that form on the external surfaces of boiler tubes, where they reduce heat flow and hinder gas flow through the furnace.

Field tests and analyses of data have been completed in the sixth of a series of tests on large steam-boiler furnaces, carried out in cooperation with the American Society of Mechanical Engineers. Theoretical flame temperatures, based on methods of computation previously described, have proved useful in correlating the performance of the different furnaces. These correlations have been based upon the theoretical flame temperature as a measure of the initial heat-transfer potential and the residence time of a given volume of gas in the furnace.

Deposits on the external surfaces of boiler tubes of ash and slag that bear little resemblance in composition or physical form to the mineral content of the coal fired have been a subject of continued study. The mineral content is released from the coal as particles of varying size, composition, and fusion temperature. Depending upon local conditions of temperature, gas composition, and agglomeration or lack of agglomeration, ash may leave the combustion zone as molten slag, fly ash, or volatilized matter. The type of deposit that forms on a given surface depends upon the particular ash components conveyed to that

44/ Corey, R. C., Discussion of An Effort to Use a Laboratory Test as an Index of Combustion Performance, by F. J. Ceely and R. I. Wheater: Trans. ASME, vol. 79, No. 5, July 1957, pp. 1177-1184.

surface and upon the conditions of temperature and gas composition. Experiments are being continued in synthetic furnace atmospheres on changes in composition and physical state of fly ash subjected to high temperatures and high-temperature gradients. Chemical and X-ray analyses show migration of ash components within the deposits. The release of ash components from coal will be considered in relation to the study of pulverized coal flames.

Results were published of a study of burning solid fuels in thin beds.45/

Combustion of Coal in Suspension

An increasingly large fraction of coal used in large steam-boiler furnaces is burned as pulverized coal in suspension. Equipment is being developed for studying pulverized-coal flames burning 1 to 5 pounds of coal per hour. Flame velocities and other conditions needed for producing well-defined flames are known for small flames from a few milligrams per minute to a few grams of coal per hour. One purpose of the investigation is to extend such measurement to higher burning rates, and another is to determine the effect of local intensity of combustion upon the release of ash and subsequent formation of ash deposits.

Fluid Mechanics

Fluid flow patterns, turbulence, and momentum interchange often control and always significantly influence combustion reactions. A survey will be made of developments in this field that are applicable to the study of combustion equipment. Also, a background of experience in fluid mechanics will be obtained for application to other projects.

Activity during 1957 included reviews of a new book46/ and of work in this field published the preceding year.47/ Also included were field studies of hydraulic transport of coal from mine to washing plant. Transport with a centrifugal pump through a 6-inch line was feasible, but size degradation was excessive, probably due in large part to the pump. Further work will be needed to determine the effect of different pump designs.

Combustion of Anthracite in Small Industrial Stokers

Because virtually no information is available on the characteristics of industrial stokers in the 100- to 400-pound-per-hour class, technologists have conducted tests on four stokers, classified as small, industrial anthracite burners. Preliminary runs were made on a Coxe traveling-grate stoker and on a Skelly underfeed, side-retort, moving-grate bar stoker (fig. 7). The maximum heat efficiencies obtained in these trial runs were 63 percent with the Coxe

45/ Carman, E. P., Graf, E. G., and Corey, R. C., Combustion of Solid Fuels in Thin Beds: Bureau of Mines Bull. 563, 1957, 92 pp.

46/ Weintraub, Murray, Book Review of Momentum Transfer in Fluids by Corcoran, Opfell, and Sage: Ind. Eng. Chem., vol. 49, No. 5, May 1957, pp. 83A-84A.

47/ Weintraub, Murray, Flow of Fluids: Ind. Eng. Chem., vol. 49, No. 3, March 1957, part II, pp. 497-502.

and 70 percent with the Skelly stoker. The chief difficulties experienced in these operations were: (1) The average CO_2 content of the flue gases for any run did not exceed 9 percent, probably the result of excessive air flow; and (2) the varying combustible content remaining in the ash-pit refuse was high - 20 percent in the two best runs on the Skelly stoker, 37 and 43 percent in the Coxe stoker. The Skelly stoker was thoroughly reconditioned before another series of tests was made. In these tests the maximum hearth efficiency was 78 percent; CO_2 in the flue gases ranged from 9 to 12.5 percent; and combustibles in the ashes ranged from 23 to 75 percent.

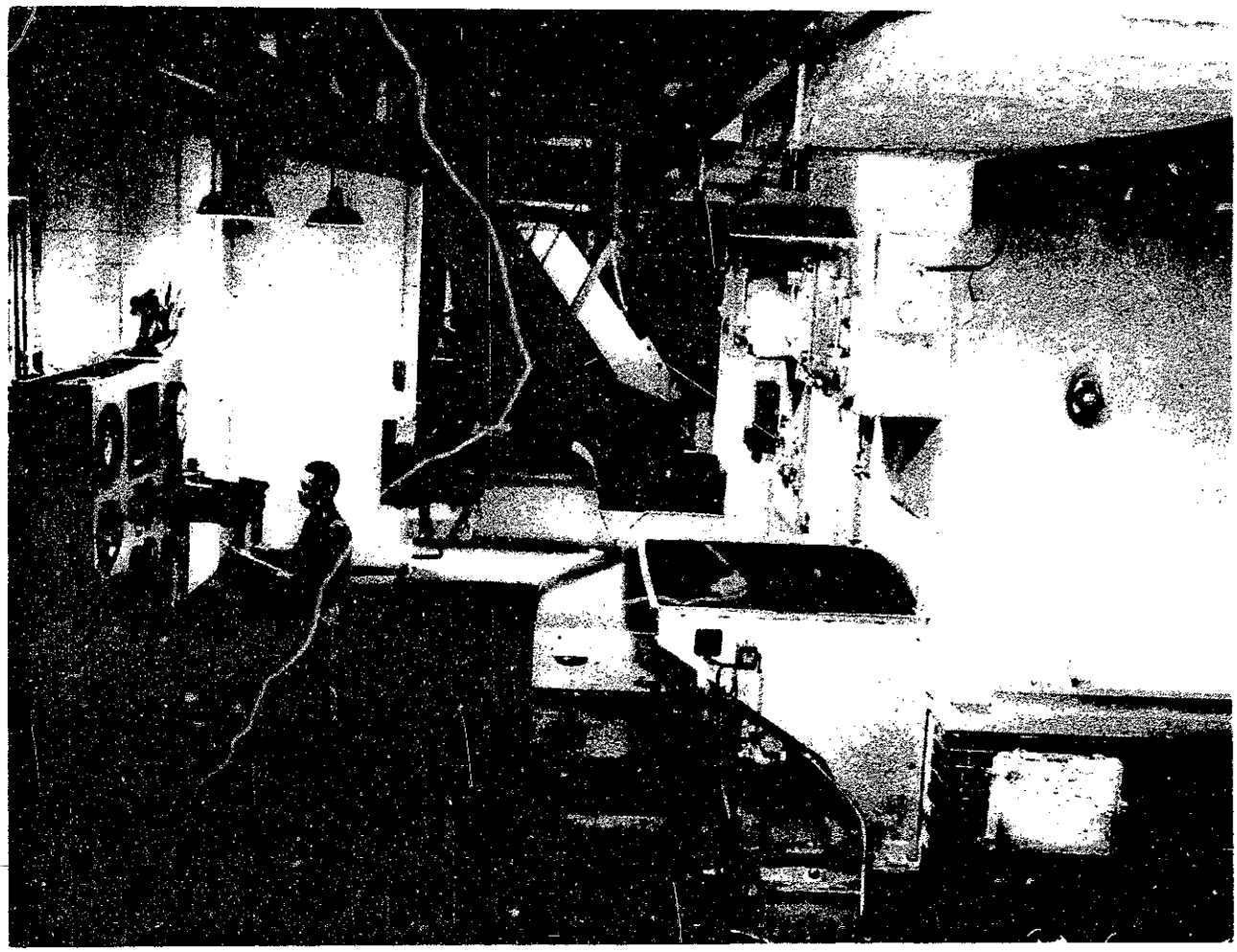

FIGURE 7. - General View of Boilerroom Showing, Two Stoker-Boiler Combinations, Instrument Panel, Coal Hopper, and Larry Car.

The stoker study included tests of two water-cooled, reciprocating-pan, crossfeed stokers installed successively in place on the Skelly stoker. On these new units (which were essentially the same size, construction, and operation, although manufactured under different trade names) 31 runs were made at fuel rates ranging from 63 to 287 pounds of wet coal per hour. The CO_2 contents averaged 10.8 to 11.5 percent in the two tests, and heat efficiencies ranged from 69 to 84 percent; there was very little difference between the two

units. Peak efficiencies of 83 and 82 percent were obtained at about 80 percent of the boiler manufacturer's rated output (100 percent equals 2.5 million B.t.u. per hour). The carbon content of the ashpit refuse ranged from 12 to 43 percent. The average carbon content of the ashes for the two tests was 22 and 25 percent.

Fuel-Engineering Service

Engineering assistance and technical advice were provided to Federal agencies in selecting, testing, and using fuel and fuel-burning equipment. At the request of the agencies listed, the following services were rendered:

Early in the year tests were run on the new 150,000-lb.-per-hr. power and heating boiler at the Naval Gun Factory, Washington, D. C. A low-volatile and a high-volatile coal were used to determine whether this equipment could burn these coals at low, medium, and high rating without exceeding limitations on smoke and dust emission. With both coals these limitations were not exceeded at the low and medium rates of operation but were exceeded by a wide margin at full rating. After the equipment had been modified by the manufacturer, complete continuous-rating, overload, and efficiency tests were run. The boiler and accessories met specifications, except for high superheat temperatures and rate of dust loading in the fly-ash collection hoppers; smoke emission from the stack at full rating barely met specifications.

The coal was inspected and operation was observed of the heating boilers at the Patuxent Naval Air Station, Lexington Corners, Md. Recommendations were made as to coal specifications for future coal purchases.

An air-pollution problem in the Philadelphia Naval Shipyard was investigated, and recommendations were made concerning operation of the offending equipment in the yard under the weather conditions prevailing when most trouble was experienced.

Problems regarding corrosion of the gas side of air preheaters for boilers at the Naval Shipyard, Bremerton, Wash., were discussed with the staff there, and recommendations were made for alleviating the difficulties.

Operating conditions, damaged grates, and coals being used at the New York Naval Shipyard, Brooklyn, N. Y., were examined and discussed with the staff there, and recommendations were made to segregate coals when shipments from more than one contractor were received and to burn the coals separately. Later, the performances of different coals in the boilers were observed, and recommendations were made to improve fuel-bed conditions.

Boiler-Water Treatment

Condensate Corrosion

Federal agencies spend millions of dollars annually for maintenance work involving the replacing of valves and piping in the large condensate-return systems that save water, fuel, and chemicals by returning the condensed steam

for boiler feedwater. This waste stems from the impurities that are brought into the boiler with the raw makeup water. It is cumulative because larger condensate losses from leaky return lines increase the raw-water makeup requirements and corrosion therefore occurs more rapidly. Boiler corrosion from dissolved oxygen in the feedwater also is promoted when condensate-return lines fail, because feedwater heaters are not often sized to deaerate unusually large quantities of cold makeup.

A consendate-corrosion tester was developed to survey corrosion problems. The tester is essentially a nipple in which the average rate of pipe-wall thinning is obtainable from weight loss and the factors responsible for the corrosion are disclosed by the corrosion pattern. The tester therefore provides information both on the overall corrosivity of the steam condensate and on the extent to which corrosion tends to be localized in the form of channeling or pitting. A total of 465 such testers were evaluated during the year, and 328 new tests were begun.

When a survey discloses a corrosion problem, operating practices at the plant are reviewed as the first step toward control. Problems have been solved by decreasing the carbonate content of the feedwater, better deaeration, use of cation-exchange resins, distillation, or chemical treatment.

The principal current use of the Bureau of Mines tester is to determine the effectiveness of preventive chemical treatment or the suggested improvements in operating practices. A considerable number of the testers have shown that decreasing the carbonate content of the feedwater decreases the severity of the corrosion problem. Neutralizing amines were found to be very effective when the dosage was sufficient to neutralize the acidity of the condensate. However, the tester results have also shown that the filming amines have not been consistently satisfactory because the nipples were wormed and pitted at nearly half of the plants where filming treatment was used.

The boiler tests showed that an apparent loss of amine during steam distillation of amine recovery in the condensate is a reasonable criterion. Because no amine was found in the blowdown, the only logical conclusion is that part of the amine was degraded to something that did not react like octadecylamine with bromphenol blue or the other analytical agents. This disappearance was traced to the probable coalescence of octadecylamine to dioctadecylamine, a secondary amine.

Indications are that dimerization to dioctadecylamine occurs both in hot water and in steam. However, most of the secondary amine formation was shown to occur during condensation of steam containing octadecylamine. Therefore, it should make little difference with respect to degradation whether the amine is fed to the boiler for steam distillation or pumped into the export steam.

Octadecylamine alone, when pumped continuously into the condensate, developed a good corrosion-inhibiting film on the tester metal. However, contamination with sodium sulfate resulted in a decrease in film continuity, so that the tester surfaces were pitted. Condensate containing sulfate and octadecylamine caused deeper corrosion than condensate to which neither had been added.

To test laboratory findings in an operating plant, provision was made for sampling at various points in a Department of the Army heating system that is given octadecylamine treatment. Approximately 50 pounds of amine was pumped into the steam over a period of several months. At no time has octadecylamine or dioctadecylamine been found in the condensate returned to the boiler. However, an unusual increase to more than 2 p.p.m. was noted in the ammonia content of the condensate. This ammonia could not possibly be attributed to the makeup water monitored. Much of the amine appears to collect in steam traps and a large percentage of it is in the form of the secondary amine.

Engineering Service

Engineering assistance was given to Federal agencies on water problems. In some instances considerable laboratory work was involved. Special assistance to the General Services Administration included the assay of samples submitted with bids on Federal stock items for boiler-feedwater treatment. Also, the final draft of an interagency-approved Federal specification for sodium polyphosphate was reviewed for the accuracy of its technical content. Assistance of a similar nature was given to the Cataloguing Division on its listing for quebracho tannin. The Department of the Army was assisted with a variety of water problems, including overall policy on water supply. Special assistance was given in several instances on problems of corrosion in potable-water piping. Other problems involved corrosion and deposition in cooling systems and corrosion in hot-water piping. The Department of Agriculture was assisted with a cooling-water problem, and the Capitol architect was helped with the specifications and operation of the new Capitol air-conditioning system. The Veterans Administration was given special assistance with several contamination problems which had led to deep pitting of hot-water piping. Assistance to the Department of the Air Force included evaluation of the test specimens from two embrittlement-detector surveys. There were also the usual problems of corrosion in hot-water piping and in refrigeration systems. Special assistance to the Department of the Navy included the solution of silica-contamination problems at two plants that generate electricity. A third generating plant had trouble from deposited iron oxide. Special advice was given on a formal program of corrosion testing at the Naval Boiler and Turbine Laboratory at Philadelphia. Examination was made of ion-exchange resins, the exchange capacities of which had deteriorated. The Navy also had some peculiar scale and sludge problems as well as the usual problems of corrosion and deposition of corrosion products.

Work continued on the analysis of boiler water and miscellaneous raw and return samples from Government agencies, and the analysis resulted in recommendations on boiler water treatment. During the year a total of 14,054 samples of water were analyzed for these agencies and recommendations were made. Reports and recommendations were also made covering analyses of 6 boiler-plant scales and deposits, 292 miscellaneous special water samples, and 3 boiler-water-treatment compounds. More than 3,000 orders from Government agencies were distributed for use by engineers for testing boiler water.

Consulting service was provided many agencies on boiler-water treatment, prevention of corrosion, scale, and sludge deposits, prevention of contamination by oil, and related problems. The number of plants being serviced

increased about 2 percent during the year, bringing the total number of boilers serviced to an estimated 9800. Through operation of the program substantial savings are being realized by Government agencies in increased boiler efficiency and lower plant maintenance and repair costs. Some representative plants report savings of $3,400 per boiler per year in fuel, maintenance, and replacement costs.

Air Pollution

Combustion Characteristics of Refuse

Investigation of combustion characteristics of refuse has continued. The objective of this work is to obtain information for designing and operating incinerators capable of producing completely innocuous discharges.

Conditions necessary for ignition, rates of burning, and rates of penetration of thermal and combustion waves into the refuse bed have been determined in a cylindrical furnace with 100 percent overfire air fed from tangential ports. The refuse, used as fuel, was a blended mixture of wood chips, shredded cardboard, paper, and enough shredded lettuce to give a moisture content of either 25 or 50 percent. The burning rate increased with air-flow rate, decreased with increased moisture content, and was not affected by the hood temperature provided it was adequate for ignition, at least 1,600° F. The rates of penetration of the evaporation and combustion waves depended upon moisture content, air rate, and level in the bed, with a possible effect of the hood refractory temperature on spacing of the separate waves.

Disposal of Radioactive Wastes

Cooperative work with AEC continued on incineration of radioactive wastes during 1957. A paper reporting results of this study has appeared in the Fuel Society Journal of the University of Sheffield; other publications are planned.48/

Air Pollution by Sulfur Dioxide

In cooperation with the Public Health Service, the Bureau is investigating methods for decreasing air pollution resulting from sulfur dioxide in flue gases and unburned hydrocarbons in automotive exhaust. Most of this sulfur dioxide is evolved in the air of the larger cities. Sulfur dioxide is highly irritating to man's respiratory system, deleterious to plant life, and injurious to metals, fabrics, and building materials.

48/ Corey, R. C., and Schwartz, D. H., Combustion of Low-Ash, High-Volatile Solids With Tangential Overfire Air: Fuel Society Jour., University of Sheffield, vol. 8, 1957, pp. 5-13.

In previously developed processes for absorption of sulfur dioxide, absorption in aqueous solutions has been used almost exclusively. Cost estimates have been prepared for three of these processes.49 50/

The experimental program has been directed toward developing cyclic absorption processes for removing sulfur dioxide. Bench-scale investigations include: (1) Absorption by solid oxides of copper, manganese, lead, calcium, iron, and aluminum; (2) adsorption with impregnated charcoals; and (3) regeneration of absorbents.

Temperatures available for absorption are either in the range 250° to 300° F. (at which the flue gas leaves the air preheater before entering the stack) or 600° to 650° F. (the temperature of the flue gas before it enters the preheater). Absorption in the higher range now under investigation offers certain advantages: (1) The rates of reaction are considerably higher, greatly extending the field of potential absorbents; and (2) removel of sulfur dioxide would eliminate the corrosion problem now encountered in the air preheater of powerplants. Methods of regenerating spent absorbent and recovering sulfur products under study are: (1) Thermal decomposition of the sulfide or sulfate; (2) reduction of spent absorbent with a reducing gas such as hydrogen or methane; and (3) electrolysis of the metal sulfate to produce sulfuric acid.

Air Pollution by Automobile Exhausts

Air pollution from the exhaust gases of an automobile engine might be avoided by catalytic oxidation. A complicating factor is poisoning of the catalyst by lead deposits from leaded gasoline. Thus, in the initial program, development of effective catalysts in the absence of lead compounds and tolerance of lead are being studied. One-component catalysts - oxides of chromium, iron, nickel, copper, and aluminum - have been investigated between 200° and 600° C. with several hydrocarbons. Tests to determine the amount and nature of lead deposits have just begun.

Stream Pollution

Little work was done on this subject during 1957, owing to lack of personnel. At the invitation of the American Institute of Engineers a paper was written on the utilization and disposal of waterborne industrial wastes.51/

49/ Field, J. H., Brunn, L. W., Haynes, W. P., and Benson, H. E., Cost Estimates of Liquid-Scrubbing Processes for Removing of Sulfur Dioxide From Flue Gases: Jour. APCA, vol. 7, No. 2, August 1957, pp. 109-115.

50/ Field, J. H., Brunn, L. M., Haynes, W. P., and Benson, H. E., The Costs of Scrubbing Out SO_2 From Flue Gases: Combustion, vol. 29, No. 5, November 1957, pp. 61-66.

51/ Berk, A. A., Utilizing and Disposing of Waterborne Industrial Wastes: Min. Eng., vol. 9, No. 7, July 1957, pp. 780-783.