TABLE 3. - Results of abrasion tests on various coals, sandstone, and coke

State	County	Bed	Mine	Abrasion loss, mg.
Pennsylvania........	Indiana	Upper Kittanning	Cush Creek	12
Washington..........	King	McKay	McKay	18
Do.	Pierce	No. 4	Wilkeson-Wingate	29
Do.	Thurston	Tono	Tono	45
Do.	King	Unnamed	Olson-Cumberland	92
Do.	Whatcom	Bellingham	Bellingham	120
Wyoming.............	Sweetwater	No. 9	D. C. Clark	130
Utah................	Carbon	Hiawatha	King	165
Pennsylvania........	Allegheny	Pittsburgh	Montour No. 10	171
Washington..........	Kittitas	Roslyn	Roslyn No. 3	185
Utah................	Carbon	D	Castle Gate	212
Illinois............	Christian	No. 6	Langley No. 9	242
Pennsylvania........	Schuylkill	-	Coaldale	686
Washington 1/........	-	-	-	1,210
Do. 2/	-	-	-	2,506

1/ Sandstone.
2/ Coke.

Seven of the fourteen coals tested were separated into clean coal and impurity by float-and-sink procedure to permit testing the coal and its associated impurities separately for abrasiveness. In every case the impurities proved far more abrasive than the coal substance. Clean coal ranged in abrasiveness from about 10 to 150 milligrams, while the heavy impurities separated from these samples ranged from about 300 to 2,850 milligrams. Thus, the amount and character of the impurities associated with a coal have a marked influence on its abrasiveness.

COAL MINING

Development of the South American Coal Industry

During the past several years notable improvements have been made in the production of coal in many of the South American countries. Technical contributions to this development made by Bureau of Mines missions and other American technicians have been described.9/ There are large coal reserves in Argentina, Brazil, Chile, Colombia, Peru, and Venezuela, and there is production in Brazil, Chile, Peru, and Colombia. Table 4 shows some data on recent coal production, by countries.

TABLE 4. - Rate of coal production in 1948, by countries

Country	Tons
Argentina..................................	1/62,000
Brazil.....................................	2,013,000
Chile......................................	2,239,000
Colombia...................................	2/1,000,000
Peru.......................................	187,000
Venezuela..................................	21,000

1/ Asphaltites used as fuel.
2/ Estimated.

9/ Fraser, Thomas, Development of the South American Coal Industry: Min. Eng., vol. 190, April 1951, pp. 356-372.

In Argentina recent developments aimed at expanding the national production of coal comprised: (1) Exploration work in the Rio Turbio coal field of Argentine Patagonia, (2) construction of a narrow-gage railway from that coal field to the Atlantic coast port of Rio Gallegos, and (3) the opening of several exploratory and development mining projects. Some test shipments of cargo size have been made to the industrial plants in Buenos Aires.

In the State of Santa Catarina, Brazil, there has been an extensive development that brought about a production of coking coal capable of supplying half of the needs of the new national steel industry. The new Capivari central preparation plant is shown in figure 6. There are smaller developments in the States of Parana and Sao Paulo. The older industry of the State of Rio Grande do Sul has continued at almost an even rate of production, but modern cleaning plants have been installed to improve the product.

In Chile extensive investigations have led to the use of the central Chilean coals for metallurgical purposes in the new steel industry at Huachipato. In Colombia the estimated annual production of coal has doubled the past several years. There are three producing coal fields, each conveniently located near large industrial centers: One is near Bogota, one near Medellin, and one near Cali. The Bureau of Mines is giving technical assistance, and improvements in mining practice, based on American experience, are being introduced.

In Peru new activity has been centered around the anthracite region of the lower Santa River Valley, which is connected to the Pacific coast port of Chimbote by a meter-gage railway. The three active mines in this region are each capable of producing anthracite at the rate of about 200 tons a day. A modern preparation plant embodying the Chance process and the Hydrotator process has been erected near the port of Chimbote, and shipments of well-prepared anthracite are now being made to South American markets, mainly Argentina, where small proportions of this coal are being used in the utility plants of the city of Buenos Aires.

In Venezuela the coal industry has not been very active because of the ready availability of petroleum. A one-time extensive mining operation of the Venezuelan Government in the Naricual Valley has not been producing coal for about 5 years. Recently, production of coal was initiated in the western part of the country near the head of Lake Maracaibo, where one new active company has a record of expanding production, although up to the present the total production has not exceeded 100,000 tons a year.

Estimate of Coking-Coal Reserves

The Bureau's investigation of known recoverable reserves of coking coal is being conducted in three parts as given below and as described in a paper presented at a meeting of the American Gas Association and published in the proceedings.10/

1. Estimate of known (measured plus indicated) recoverable reserves of all coking coals.

2. Study of the preparation characteristics of coking coals to determine which are or can be made suitable for metallurgical use by washing or other beneficiating treatment.

10/ Brown, Ralph L., Bureau of Mines Program of Appraising Minable Reserves of Coking Coal: Proc. Am. Gas Assoc., 1940, pp. 483-486.

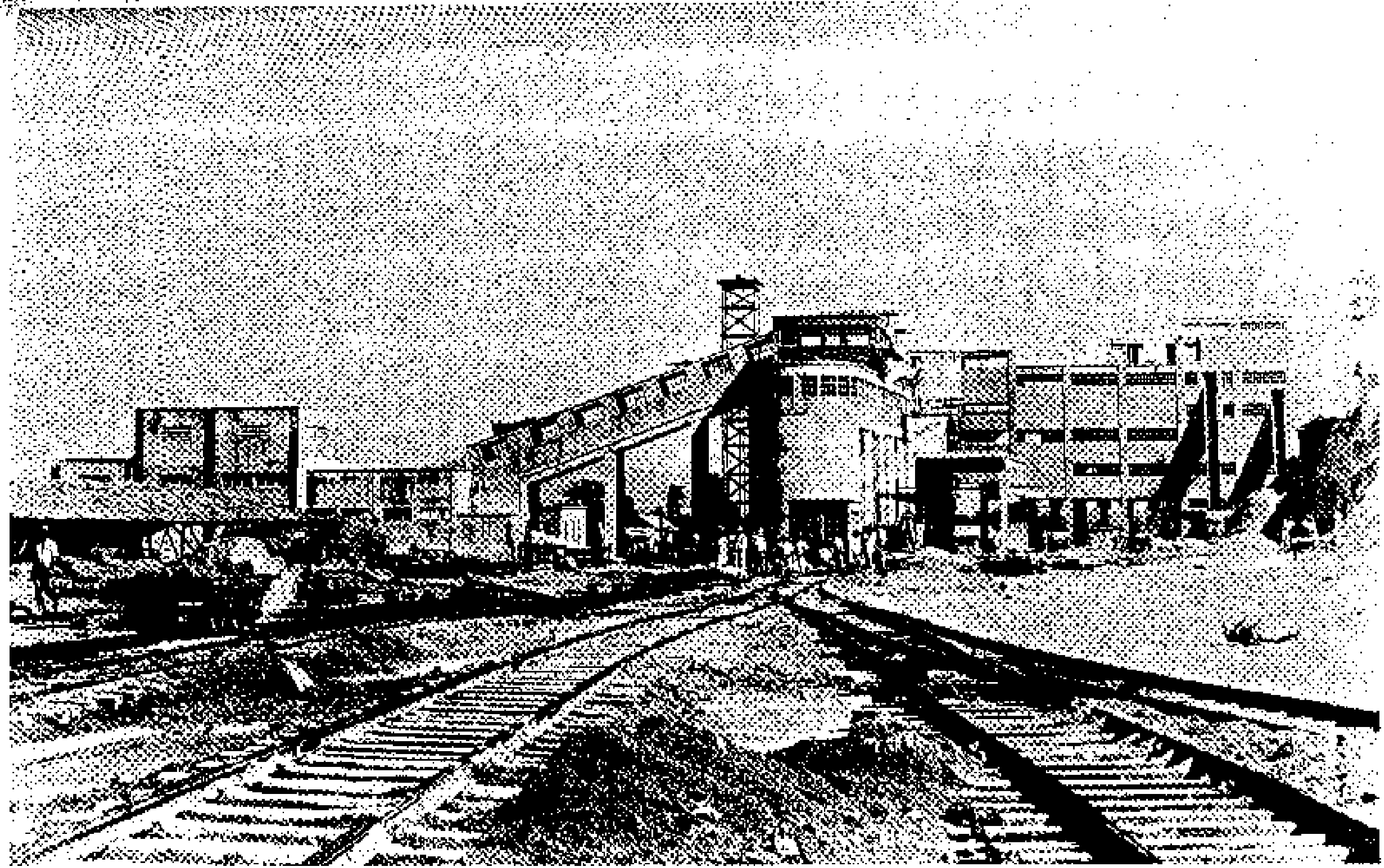

Figure 6. - The Capivarí central preparation plant, Brazil.

3. Study of the carbonizing properties of coals and coal blends to determine metallurgical coke-making properties and most effective blends. The first part of this comprehensive investigation is reported here, the other two parts at appropriate places later in this report.

All bituminous coals in the Appalachian region are potentially coking, and, therefore, until the carbonization tests in part 3 of the study have been completed to determine the coking quality of the coals, all known reserves of coal in the region are included as coking coal. However, not all of the coals included in these reports are suitable for the manufacture of metallurgical coke according to present-day standards. Also, in most beds there are areas where there are too few (or no) bed sections from drill holes, mine workings, or coal outcrops on which to base estimates that would qualify under the definitions of "measured" or "indicated" reserves. These areas may contain additional geologically inferred reserves, but such reserves are not included in the reports.

All coal remaining for any reason within the mined-out area of a mine is considered a loss. No distinction is made between avoidable or unavoidable losses. Included in these losses are: Coal considered too thin to mine; coal that legally is required to be left unmined, such as coal under some highways, railroads, and rivers; coal left to protect gas and oil wells; and coal left in barrier pillars between mines and adjacent to property boundaries.

The recoverable reserves are estimated tons of unmined coal in beds 28 inches and more thick, as of the date of the estimate, multiplied by the percentage of recovery. The percentage of recovery is the weighted average, computed for each bed, and represents the ratio of tons of coal produced from a given area to the estimated total tons originally in place in that area.

Cambria County, Pa.

The investigation shows there are four major coal beds in Cambria County: Upper Freeport (E), Lower Freeport (D), Upper Kittanning, (C'), and Lower Kittanning (B). Three beds of minor importance are the Middle Kittanning (C), Clarion (A'), and Brookville (A).11/

Known (measured plus indicated) reserves in all beds, based on a minimum bed thickness of 14 inches and 1,800 tons per acre-foot of coal in place, are estimated at 2,407 million short tons as of January 1, 1948. Of this total, 1,909 million tons is in beds that measure 28 inches and more thick. All reserves in Cambria County are under less than 2,000 feet of overburden. If future drilling or development should prove reserves in areas omitted from the estimate because of insufficient data, such reserves should be added to the total estimated reserves.

Based on the weighted average percentage of recovery for all beds 28 inches and more thick in Cambria County, the recoverable reserves are estimated at 931 million tons. The weighted average percentage of recovery for all beds in Cambria County, including all mining losses, as determined by this investigation is 48.77.

Representative analyses of coals from the four major beds show that Cambria County coals are principally low- and medium-volatile bituminous. A summary of the coking and preparation characteristics of these coals indicates that they are coking

11/ Dowd, James J., Turnbull, Louis A., Toenges, Albert L., Cooper, H. M., Abernethy, R. F., Reynolds, D. A., and Fraser, Thomas, Estimate of Known Recoverable Reserves of Coking Coal in Cambria County, Pa.: Bureau of Mines Rept. of Investigations 4734, 1950, 25 pp.

but, in some areas, do not meet present metallurgical standards as to ash and sulfur content. The Upper Freeport, Lower Freeport, Upper Kittanning, and Lower Kittanning coals have been important sources of supply for the manufacture of metallurgical coke for many years, but are usually used in blends with other coals. The Kittanning coals in Cambria County respond well to washing for sulfur reduction, but the Freeport coals are more difficult to wash.

Indiana County, Pa.

The investigation shows there are three major coal beds in Indiana County: Upper Freeport (E), Lower Freeport (D), and Lower Kittanning (B). Five beds of minor importance are the Pittsburgh, Upper Kittanning (C'), Middle Kittanning (C), Clarion (A'), and Brookville (A).12/

Known (measured plus indicated) reserves in all beds, based on a minimum bed thickness of 14 inches and on 1,800 tons per acre-foot of coal in place, are estimated at 2,544 million short tons as of January 1, 1948. Of this total, 1,989 million tons is in beds 28 inches and more thick. All coal beds for which reserves have been estimated in Indiana County are under less than 2,000 feet of overburden. As in Cambria County, areas were omitted where insufficient data were available, and reserves in these areas, if later proved by drilling or development, should be added to the total.

Based on the weighted average percentage of recovery of 48.95 percent for all beds in Indiana County, the recoverable reserves in beds 28 inches and more thick are estimated at 974 million short tons.

Representative analyses of coal from the major producing beds show that the coals of Indiana county are principally medium- and high-volatile A bituminous rank. In summarizing their carbonization and preparation characteristics, the report indicates that these coals generally coke strongly and may be used either singly or as blends to make metallurgical coke, when sufficiently low in ash and sulfur. The Upper and Lower Freeport beds usually contain two or more shale or bone partings, and in many locations in the county the beds are high in sulfur. However, much of the sulfur is present as thin streaks and flakes of iron sulfides that can be removed by mechanical cleaning, and in some cases a high-grade metallurgical-coking coal and a lower-grade steam coal may be produced by a three-product separation in the preparation plant.

Pike County, Ky.

Results of the study of coking-coal reserves in Pike County, Ky.,13/ are given in the third report in this series. There are four coal beds of major importance in Pike County: Upper Elkhorn No. 3, Upper Elkhorn No. 2, Upper Elkhorn No. 1, and Lower Elkhorn. Beds of secondary importance are the Winifrede, Williamson, and Bingham. Ten other beds, in addition to numerous uncorrelated lenses, are of minor importance.

12/ Dowd, James J., Turnbull, Louis A., Toenges, Albert L., Cooper, H. M., Abernethy, R. F., Reynolds, D. A., and Crentz, William L., Estimate of Known Recoverable Reserves of Coking Coal in Indiana County, Pa.: Bureau of Mines Rept. of Investigations 4757, 1950, 22 pp.

13/ Dowd, James J., Turnbull, Louis A., Toenges, Albert L., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Pike County, Ky.: Bureau of Mines Rept. of Investigations 4792, 1951, 34 pp.

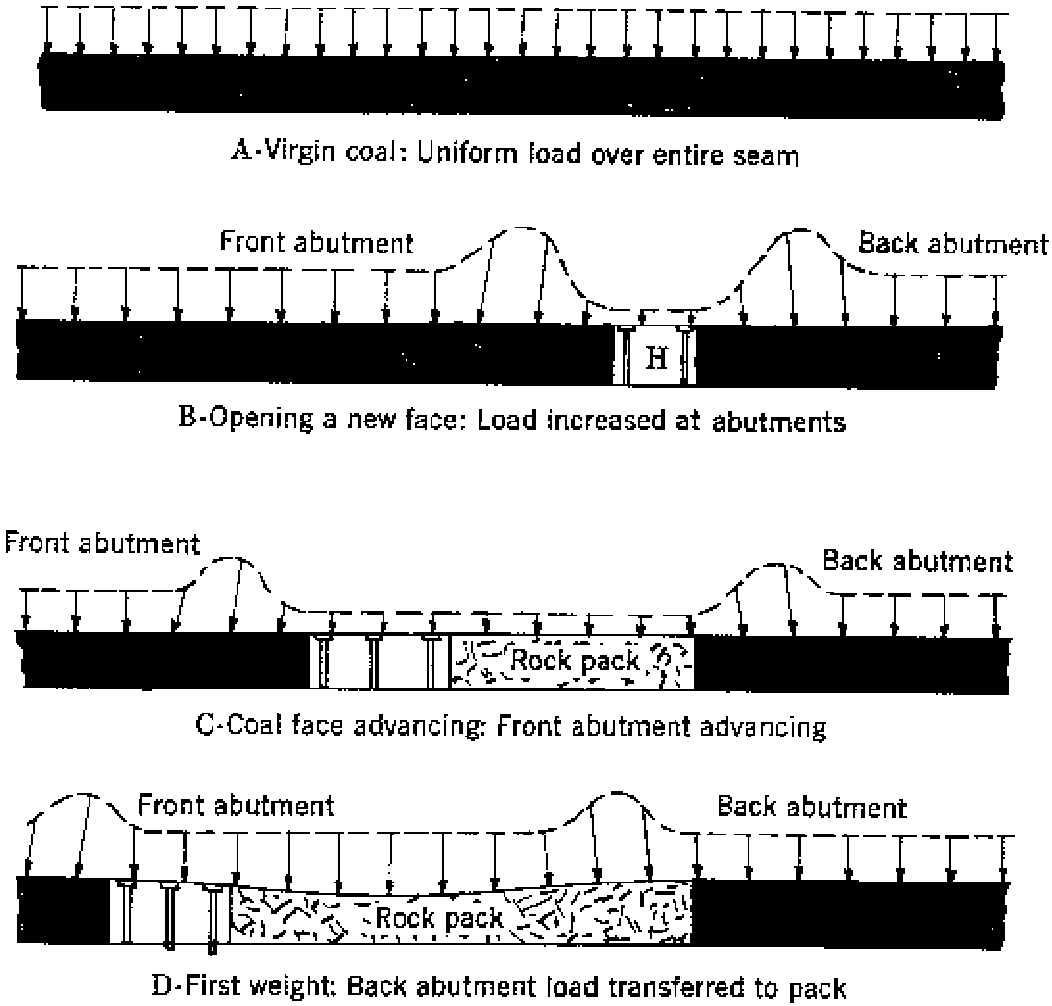

Figure 7. - Distribution of roof load in vicinity of coal face.

Known (measured plus indicated) reserves in all beds based on a minimum bed thickness of 14 inches and 1,800 tons per acre-foot of coal in place are estimated at 3,916 million short tons as of January 1, 1948. Of this total, 3,189 million tons is in beds 28 inches and more thick. All known reserves in Pike County are under less than 2,000 feet of overburden. These totals do not include reserves in areas omitted because of insufficient data. Based on the weighted average percentage of recovery of 55.08 percent for all beds 28 inches and more thick in Pike county, the recoverable reserves are estimated at 1,757 million tons.

Analyses of representative samples show that the coals of Pike county are high-volatile A bituminous, and that the moisture, ash and sulfur contents usually are low. A summary of the carbonizing properties indicates that highly fissured coke generally is obtained from eastern Kentucky coals when carbonized singly; however, when blended with coal of higher rank and carbonized, a strong coke is produced.

Mining Methods and Practices

Anthracite Mechanical Mining Research

The effects of pressures in mining at depth and methods for controlling these pressures in mines of the United Kingdom were studied.[14]

Figure 7 shows distribution of roof load in the vicinity of the coal face, as determined by measuring the loads borne by packs in the United Kingdom. Drawing a lesson from the successful experience of the mining engineers of the United Kingdom, it can be said that the only practical solution of roof-control problems that now prevail in the Pennsylvania anthracite region, which will become increasingly important with future mining at greater depths, lies in a more technical and scientific approach than has been used generally in this country. Instruments must be provided and techniques developed for determining the forces that prevail so that these forces may be controlled intelligently and economically.

To develop instrumentation for measuring loads borne by roadway supports, the Bureau of Mines arranged for the design and construction of a continuous recorder and load cells. As a beginning, a set of 12 cells was installed on collars of conventional 3-piece wood sets in the coal gangway of a steeply pitching bed of the Southern anthracite field for the purpose of recording loads and changes in loads as mining progressed. After several months of use, these instruments were removed for incorporating improvements.

In 1947 a lightweight universal shearing machine of German origin was provided and installed by the Bureau of Mines in a steeply pitching bed of the Southern anthracite field for test purposes. These cutting tests represent the first use of a machine of this kind in steep-pitch mining in the United States.[15]

The machine is driven by compressed-air and weighs 3,000 pounds. It is equipped with a 7-foot bar and a 33-block chain, both of conventional design. The machine is rated at 20 hp. by the manufacturer, and this output was obtained with air at 80 pounds per square inch pressure. At 60 p.s.i. the output was found to be between 16

14/ Buch, John W., and Allan, Andrew, Jr., Some Roof-Control Practices in Coal Mines of the United Kingdom: Bureau of Mines Inf. Circ. 7599, 1951, 7 pp.

15/ Buch, John W., and Allan, Andrew, Jr., Anthracite Mechanical Mining Investigations. Progress Report 3. Preliminary Testing of Korfmann Universal Shearing Machine, Model SK 20: Bureau of Mines Rept. of Investigations 4794, 1951, 11 pp.

and 17 hp. Tests made in anthracite of medium hardness showed that an output of less than 6 hp. is required for cutting with this machine. Cuts 8 feet high and 6 feet deep were made in less than 10 minutes, with air pressure of 50 p.s.i. and air consumption at the rate of less than 400 cubic feet per minute.

The apparent ease with which this machine cuts anthracite may be attributed to its hand feed in contrast to power feed of conventional American machines; to the compressed-air motor, which cannot be overfed without stalling and thus operates with a light-touch ripping effect on brittle coal; and to the "widia" (tungsten-carbide) tipped cutter bits, which remain sharp longer than some other types. Originally designed to meet conditions in mines of the German Ruhr, it is not to be expected that the machine will meet Pennsylvania anthracite conditions fully without some modification. However, the tests showed that the rate of driving gangways in steeply pitching anthracite beds can, by its use, be increased sufficiently to justify further tests and development.

Bituminous-Coal Mining Studies

Studies of the use of mechanical mining equipment for extraction of pillars were continued in two mines in West Virginia and three in eastern Kentucky, and comparative data were obtained from mines not extracting pillars. Arrangements were made for testing an imported German coal planer at a specially developed longwall face in a relatively thin bed of Pocahontas No. 3 coal in Raleigh County, W. Va., and part of the equipment was received from Germany. A 25-year analysis of haulage equipment used in bituminous-coal mines16/ showed that belt-conveyor haulage expanded rapidly in the last 5 years, that there has been a substantial growth of rope haulage in recent years, and that the number of locomotives in use remained substantially constant, with gradual change in types over the years studied.

Studies on the Use of Diesel Engines Underground

Besides the well-known products of combustion in the exhaust gas from Diesel engines, there are many minor constituents that escape detection by ordinary methods of analysis because of their low concentration. Mass spectrometric analysis (table 5) has shown a number of such trace constituents that reveal the extreme complexity of the chemical reactions that occur during combustion.17/ The presence of olefins, for example, is evidence of thermal decomposition, and the appearance of oxygenated hydrocarbons indicates direct oxidation.

The concentration of carbon monoxide and of aldehydes in the exhaust gas of a 2-stroke-cycle, 3-cylinder Diesel engine were studied as a function of fuel-to-air ratio and of engine speed. A minimum of 0.03 to 0.06 volume-percent of carbon monoxide was found at a fuel-to-air ratio of about 0.015 to 0.020. The concentration of carbon monoxide did not vary with engine speed over the range of fuel-to-air ratios studied. The minimum concentration of aldehydes, on the other hand, was about fifty times as high (5 p.p.m.) at 1,300 and 2,000 r.p.m. as it was at 600 r.p.m. (0.1 p.p.m.).

16/ Young, W. H., and Anderson, R. L., Underground-Haulage Trends at Bituminous Mines: Coal Age, vol. 56, No. 6, June 1951, pp. 96-97.

17/ Elliott, M. A., Davis, R. F., and Friedel, R. A., Products of Combustion from Diesel Fuel: Proc. Third World Petrol. Conf., sec. VII, Preprint 25, June 1951, 27 pp.

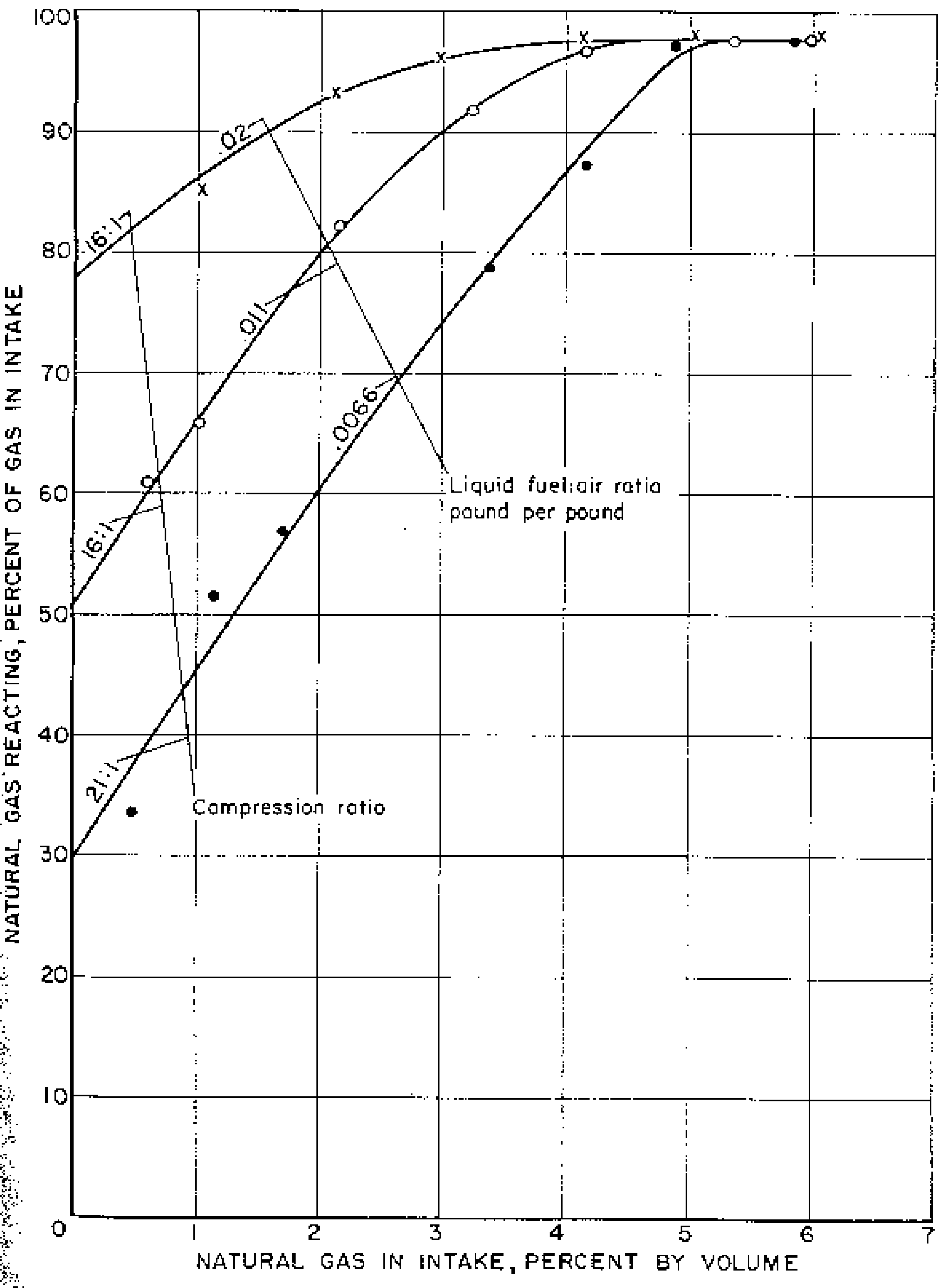

Figure 8. - Relation between proportion of natural gas reacting, concentration of gas in intake, and liquid fuel-air ratio in tests of a CFR Diesel engine.

TABLE 5. - Mass spectrometer analysis of exhaust gas from a 6-cylinder, 4-stroke-cycle Diesel engine[1]

Haldane gas analysis		Mass spectrometer analysis		Mass spectrometer analysis	
Product of combustion usually determined	Percent by volume	Hydrocarbons	P.p.m. by volume	Oxygenated compounds	P.p.m. by volume
CO_2	1.68	Methane	1.5	Formaldehyde	98.8
CO	.10	Ethylene	16.2	Acetaldehyde	31.5
O_2	18.50	Propylene	5.3	Methanol	5.7
C_nH_{2n+2}	.00	Butylene	6.6	Acetic acid	49.3
N_2	79.72	Pentylene	10.4	Propionic acid	7.4
		Hexylene	10.5	Acetone	17.6
		Acetylene	1.0 (?)	NO	29.0
		Butadiene	.5 (?)	NO_2	.004
		Benzene	Trace		
		Toluene	Trace		
		Other hydrocarbons[2]	50		

1/ Engine operating conditions: Speed, 675 r.p.m.; load, none; fuel consumption, 2.52 lb. per hr.; fuel-air ratio, 0.0085 lb. per lb.

2/ In addition to those listed, includes paraffin hydrocarbons.

The operation of dual-fuel Diesel engines is of increasing economic importance, especially in areas where there is low-cost natural gas. Dual-fuel combustion means the simultaneous burning of liquid and gaseous fuel. The gaseous fuel is generally mixed uniformly with the intake air. The liquid fuel is injected into the compressed gas-air mixture and furnishes a source of ignition for the mixture.[18] Figure 8 shows the relation between the proportion of natural gas reacting, concentration of gas in intake, and the liquid fuel-to-air ratio in a test of a 4-stroke cycle CFR Diesel engine. Substantially all of the gas reacts, regardless of liquid fuel:air ratio, when the concentration of gas reaches the lower limit of flammability. Under the test conditons this is about 5 volume percent. If the concentration of combustible gas is greater than the lower limit of flammability, the flame will propagate throughout the gas-air mixture when the liquid fuel ignites. The attendant rapid rate of heat release may result in engine-operating difficulties and "knock." If the concentration of gas is below the lower limit of flammability, the gas is not burned completely. The presence of unreacted gas in the exhaust indicates that high temperature regions do not permeate the entire combustion space. The fraction of gas reacting increases with an increase in liquid fuel-air ratio, with concentration of combustible gas in the gas-air mixture, and is affected by type of engine and by engine speed. The lower limit of flammability of natural gas was 5 percent; propane, 1.9 percent; butane, 0.9 percent; and hydrogen, 10 percent.

Three commercial Diesel mine locomotives were tested to determine if they met the requirements of Schedule 22.[19] Two of these were designed and built in the United States, and one in England. Tests disclosed design features in each that required modification, and these modifications, which were worked out with the manufacturers on the basis of the permissibility tests, have been or are being made.

18/ Elliott, M. A., and Davis, R. F., Dual-Fuel Combustion in Diesel Engines: Ind. Eng. Chem., vol. 43, 1951, (in press); Am. Chem. Soc., Div. Petrol. Chem. and Div. Gas and Fuel Chem., Joint Symposium on Combustion Chemistry, April 1951, pp. 267-290.

19/ Procedure for Testing Diesel Mine Locomotives for Permissibility and Recommendations on the Use of Diesel Locomotives Underground: Bureau of Mines Schedule 22, 1944, 31 pp.

Control of Coal-Mine Fires

At a cost of less than 1 cent a ton, more than 120,000,000 tons of bituminous and anthracite coal have been saved from fire and destruction as the result of the Bureau of Mines program of controlling fires in inactive coal deposits throughout the United States during the past 3 years. At current market prices, it is estimated that this coal would be worth over $500,000,000 when mined. Since Congress authorized the fire-control work in the 1949 fiscal year, 21 projects have been undertaken by the Bureau of Mines, and 15 of them are now completed. In addition to saving the coal, health hazards from noxious gases released by these fires have been eliminated, and many millions of dollars worth of private and public property have been saved from possible damage or destruction.

In widely scattered areas of the country, some of the fires in inactive coal deposits had been burning for a generation or more. Fires on public domain were put out or controlled entirely at the expense of the Federal Government. The Government provided two-thirds of the funds for controlling fires on private, State, and county lands, with the landowners supplying one-third of the cost. Various methods have been used in fighting mine fires, including sealing, flooding, use of carbon dioxide, and combinations of these methods. Sealing was used to control an outcrop fire in a steeply pitching bed near Rifle, Colo.20/ Although the 21 fires in inactive coal deposits, which have been or are being controlled by the Bureau of Mines, include some of the worst ones known to exist, Bureau officials have investigated more than 80 uncontrolled fires of this type in different parts of the country.

Coal-Mine Explosions and Fires

Improvement is evident in the reduction of explosion and fire hazards in coal mines, as shown by the records for 1949.21/ The safeguards and attention accorded to these hazards since 1946 apparently have reduced the loss of life and damage to property, although the number of fires and ignitions has not been decreased. Deaths from explosions and fires in 1949 totaled 17, compared with 48 in 1948 and an average of 106 for the years 1944-47.

Loss of life in coal-mine explosions in 1949 was 8, compared with 46 in 1948 and an average of 78 in the 5 years from 1944 to 1948. The total of 8 deaths was the smallest since 1870, the first year for which records were kept. A total of 14 coal-mine explosions was studied in 1949, of which 6 were in anthracite mines. This compares with an average of about 25 explosions for the preceding 5 years and with 29 explosions reported in 1948.

In 1949, 30 coal-mine fires were reported, with 4 deaths, compared with 16 fires and 7 fatalities in 1948 and an average of 18 underground coal-mine fires annually for the 5-year period 1944-48.

Causes of Fatalities in Mines

The investigation of major and minor coal-mine disasters has been a regular function of the Bureau of Mines since its creation in 1910, and the facts obtained

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20/ East, J. E., Jr., Russell, E. W., and Bolmer, R. L., How a Coal-Outcrop Fire was Controlled: Min. Cong. Jour., vol. 36, No. 1, January 1950, pp. 24-25.

21/ Forbes, J. J., Fene, W. J., and Humphrey, H. B., Coal-Mine Explosions and Coal- and Metal-Mine Fires in the United States in 1949: Bureau of Mines Inf. Circ. 7572, 1950, 17 pp.

during such investigations have been used as a basis for recommendations made to forestall similar occurrences. A comprehensive study of individual fatal coal-mine accidents was not attempted until February 10, 1950, when the policy of investigating all coal-mine fatalities in the United States was approved. These investigations are now being conducted by Federal coal-mine inspectors functioning under the provisions of the Coal-Mine Inspection and Investigation Act of May 1941, Public Law 49. Reports covering the investigations are distributed to management, the State mine-inspection agency, and representatives of the mine workers' organization having jurisdiction at the mine.

A study covering the Federal investigations of 76 of the 92 fatalities that were charged to the anthracite industry of Pennsylvania during the calendar year 1950[22] revealed that 64 percent of these fatalities were charged to falls of roof, face, or rib; 15 percent were charged to haulage, almost half of them occurred on the surface; and the remainder was from miscellaneous causes. It was determined that approximately 71 percent of these fatalities were the result of human failure.

A study was made of 263 of the 315 fatalities from falls of roof, face, or rib charged to the bituminous-coal industry during the calendar year 1950.[23] In 1950, 67 percent of all fatalities that occurred underground at bituminous-coal mines resulted from falls of roof, face, or rib. Three of every four of these accidents occurred within 25 feet of the working face. Again, three out of four fatalities in this zone occurred in the area from the last permanent roof support and the face. Only one of the fatalities resulted from a fall of roof that was bolted. The data show that roof bolting is an effective means of reducing roof-fall accidents. The chief factors responsible for the roof-fall fatalities were found to be: Failure by the face boss or foreman to give adequate supervision, negligence by the employee, reliance on roof testing as a substitute for roof supports, and acceptance of the hazard as not meriting stronger protective measures.

A study of 131 fatal haulage accidents from 14 coal-mining States and Alaska was another part of the program to reduce the hazards mainly responsible for mine fatalities.[24] Records of the past year show that haulage accidents caused 27 percent of the coal-mine fatalities, while haulage personnel represented only 12 to 15 percent of the mine employees. Of the 121 fatal injuries investigated, 102 occurred underground, 14 on the surface, and 5 at strip operations. The most frequent types of accidents were: Falling or stumbling into the path of moving equipment, caught between equipment and roof or timber, derailments, and collisions. Physical hazards were: Scant clearance, inadequate retarding devices, and defective equipment. Unsafe practices were: Excessive speed, disregard of rules or instructions, riding in unsafe position, pushed trips, getting on and off moving equipment, and negligent operation.

Toxic Mine Atmospheres

The Bureau of Mines has developed an approval system for respiratory protective devices[25] as part of its continuing work in setting forth the minimum requirements

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22/ Forbes, J. J., and Weaver, H. F., Why Men Were Killed at Pennsylvania Anthracite Mines in 1950: Bureau of Mines Inf. Circ. 7609, 1951, 13 pp.

23/ Forbes, J. J., Back, T. L., and Weaver, H. F., Falls of Roof: The No. 1 Killer in Bituminous-Coal Mines: Bureau of Mines Inf. Circ. 7605, 1951, 11 pp.

24/ Ankeny, M. J., and Kingery, D. S., Analysis of Haulage Fatalities in Bituminous-Coal Mines in 1950: Bureau of Mines Inf. Circ. 7604, 1951, 28 pp.

25/ Pearce, S. J., Bureau of Mines Approval System for Respiratory Protective Devices: Bureau of Mines Inf. Circ. 7600, 1951, 6 pp.

that various types of equipment should meet to be considered safe and satisfactory for use in certain hazardous or unhealthful conditions. Provisions have been made for testing and approving the following types of respiratory protective devices: Self-contained breathing apparatus, supplied-air respirators, gas masks, dispersoid respirators, and chemical cartridge respirators. These devices are tested at the Central Experiment Station of the Bureau of Mines in Pittsburgh, Pa., self-contained breathing apparatus by the Safety Branch and the other types of respirators by the Health Branch.

Bureau of Mines approval of respiratory protective devices is based upon performances tests rather than upon specifications as to how the devices must be built. The submission of respiratory protective devices to the Bureau of Mines for approval is entirely voluntary on the part of the manufacturer, the Bureau having no regulatory power requiring that all respirators be submitted for approval testing. The Bureau acts merely as an impartial testing agency that makes available to the public a list of respiratory protective devices that have met definite performance requirements, but wide acceptance of Bureau of Mines approval of these devices encourages the manufacturers to submit them for approval. The Bureau of Mines checks the approved respirators that are on the market from time to time to ascertain if they conform to the device originally approved in physical make-up and in performance.

In 1950, 9 new approvals and 34 extensions of approval were granted on respiratory protective equipment, including industrial gas masks, supplied-air respirators, and respirators for protection against particulate matter. Numerous check tests were made on approved protective equipment purchased in the open market, and any deficiencies disclosed were brought to the attention of the manufacturers.

In connection with the work carried out under the provisions of the Federal Coal-Mine Inspection Act, approximately 14,000 samples of mine air were analyzed to determine the adequacy of ventilation in coal mines, to detect and aid in the elimination of hazards from flammable and toxic gases in mines, and to aid in the control and extinguishment of mine fires.

Surveys conducted in coal mines to determine the concentrations of air-borne dust produced by mining operations, such as drilling rock strata above and below the coal measures, were directed toward providing information for the formulation of recommendations for control measures to reduce exposure of coal-mine workers to dusts that are potentially harmful, because they tend to cause silicosis, a lung disease. As a result of cooperative tests of dust-collecting devices, which were being developed commercially, several collectors were developed that are capable of reducing to acceptable limits the dust disseminated into the air of working places during roof drilling for roof bolting.

More than 1,600 examinations were conducted to determine the concentration and particle size of air-borne dusts, and the composition of such dusts and dust-source materials, with particular reference to free silica content, to evaluate their hygienic significance in the working environment of coal and other types of mines. These examinations were conducted by microscopic, petrographic, X-ray diffraction, and spectrographic methods. Examinations were made also of various materials to determine their suitability for use in rock-dusting coal mines to reduce the hazard of coal-dust explosions.

Electrical Equipment for Mines

Tests of equipment for approval as "permissible" for use in gassy mines were conducted during the year.26/ Types of equipment submitted for testing approved in 1950 included air compressors, drills, loading and conveying machines, mining machines, trucks for moving machines, pumps, locomotives, power trucks, distribution boxes, timbering machines, cleaners, sprayers, flashlights, and multiple-shot blasting units.

There is need for better methods and improved protective devices in coal mines, because electrical hazards from fires and explosions resulting from electrical failures are greater in the coal-mining industry than in any other industry. Studies and tests designed to determine the possible value of the short-circuited contactor as an electrical protective device for coal-mine service were investigated.27/ Preliminary tests were made to determine the operating characteristics of the device that is intended primarily for protection against damage from accidental short circuit, after which tests were made under actual service in three coal mines.

The mine operator who uses electrical equipment has, in general, the choice of installing fuses or circuit breakers to protect his equipment from the effects of electrical failures. In many instances both devices are used in the same mine. Although fuses and circuit breakers have been used widely for many years, they have objectionable characteristics that are inherent in their designs, which have not been overcome after many years of service experience in coal mines. It is common knowledge that a rubber-insulated cable, such as used with mobile equipment in mining service, can be badly damaged or completely ruined by a short circuit in the cable when a fuse of proper size to permit starting current is provided at the cable nip. This is due to the fact that a fuse has considerable time lag before "blowing" and the resistance of the arc produced by the short circuit in the cable has a limiting effect upon the current. As a result, the arc may be maintained with a current value below that required to melt the fuse element, and the cable may be badly damaged before the circuit is deenergized and the arc extinguished.

The tests of this investigation and information from other sources indicate that the short-circuiting contactor offers possibilities for the development of a simple, rugged, inexpensive protective device for mine electrical circuits. Such a contactor, in combination with an ordinary fuse, can be made to provide high-speed, short-circuit protection for electrical circuits approaching that of the best air circuit breakers.

Roof Control

Although the principles of supporting mine roofs remain the same, changes in mining roof-support methods make it necessary to relate new practices to the fundamental principles and to revise earlier handbooks issued on these subjects. As a part of the program to reduce the fatalities and injuries from roof falls, a concise explanation in question and answer form has been compiled for use as a text in educational courses, which are conducted by the Bureau for miners.28/ The text covers the stresses leading to roof failure, the methods of putting in timbers, roof bolts, or other forms of support, and safe practices that should be followed. Sketches and photographs illustrate most of the points discussed. The education accomplished with the aid of this text is essential to the reduction of roof-fall accidents.

26/ Brunot, H. B., Permissible Mine Equipment Approved During the Calendar Year 1950: Bureau of Mines Inf. Circ. 7606, 1951, 8 pp.

27/ Harrison, L. H., The Short-Circuiting Contactor as an Electrical Protective Device for Coal-Mine Service: Bureau of Mines Rept. of Investigations, 4759, 1951, 11 pp.

28/ Forbes, J. J., Thomas, Edward, and Barry, A. J., Questions and Answers on Roof Support in Bituminous-Coal Mines: Bureau of Mines Handbook, 1951, 90 pp.

Original installations of roof bolts in American mines have been found in widely separated mining districts. A few of the known installations have been in place as long as 40 years. A study of the history[29] of the practice in the United States shows that some early attempts were not continued, because the expense was above that of conventional timbering and was not compensated for by the added efficiency of mechanical mining.

Although considerable theoretical information has been published on the subject of roof control, little knowledge is available that can be applied practically by the mining engineer. The Bureau of Mines has equipped a roof-control laboratory at College Park, Md., and a crew at work in the field with "stratascope" will provide basic engineering data to supply this need. Preliminary experiments show considerable promise.

Anthracite Flood Prevention

In continuing the Bureau of Mines work on the underground mine-water problem in the anthracite region of Pennsylvania, data from a study on the design, installation, and operation of centrifugal pumps used in the region were published[30] as possible assistance for mines in which pumping problems are met.

A clay, sand, and gravel deposit known as the "Buried Valley" of the Susquehanna River in the Northern Field of the anthracite region makes great care necessary in mining operations to avoid breaking the strata between the mine workings and these valley-fill deposits to avoid inundation that would result from such break-through. Operators of mines in this area must be familiar with the water-bearing deposits and surrounding strata to conduct their operations safely. A study was completed of the mine-water problem concerned with the "Buried Valley."[31] Engineers of the Bureau of Mines have ascertained the accuracy of mine plans and maps, the size and thickness of barrier pillars necessary to hold water safely in different circumstances, the effects of faults, the porosity of barriers and of strata, the method of approach to abandoned or flooded mine workings, the use of bore holes, the precautions to be observed in and after tapping water, and the building of dams in the mines.

PREPARATION OF COAL

Coal Washing

International Conference on Coal Preparation

The First International Conference on Coal Preparation was held in Paris in June 1950. The coal-preparation staff of the Bureau of Mines collaborated with the appropriate divisions of the National Coal Board of France and the British National Coal Board in organizing this Conference, and the Director of the Bureau of Mines served on the committee for selecting papers to be presented. Cerchar, the research organization of the French Coal Board, was host to the meeting. Twelve papers were prepared and presented by American authors, three of them by members of the Bureau staff.

29/ Thomas, Edward, Roof Bolting in the United States: Bureau of Mines Inf. Circ. 7583, 1950, 8 pp.
30/ Lesser, William H., Centrifugal Pump Installations in Anthracite Mines of Pennsylvania: Bureau of Mines Rept. of Investigations 4749, 1950, 22 pp.
31/ Ash, S. H., Buried Valley of the Susquehanna River: Anthracite Region of Pennsylvania: Bureau of Mines Bull. 494, 1950, 27 pp.