failure of an asphalt paint coating previously applied to the roof of this mine.[18] The investigation was one part of a study of mine roof being conducted by the Committee on Roof Action of the American Mining Congress. Portions of the sealing material with some of the roof rock, to which it was originally attached, fell in numerous places. It was concluded that the partial failure of the coating to remain on the roof surfaces resulted primarily from the nonuniform composition of the roof rock itself.

Application of Rock Dust in Coal Mines

Successful automatic devices for placing rock dust close to working faces in mechanized coal mines are greatly needed. Tests were made of a recent device which consisted of a wire-mesh basket containing rock dust and provided with a drop bottom. The results showed that the dust was effectively discharged through the drop bottom by the force of pressure waves in advance of the flame of a coal-dust explosion. A review[19] was prepared showing the slow progress in rock dusting during the past 5 years. Examination of reports of 57 dust explosions in mines over the 5-year period ended June 30, 1943, showed that no rock dust had been used in the area traversed by flame in 32 explosions that resulted in 344 deaths and 95 nonfatal injuries. In 9 instances in which rock dusting was unquestionably inadequate, 287 deaths resulted. In the remaining 16 explosions, rock dust played an important part in stopping the explosion. In these 16 explosions, 32 persons died. In 4 others the use of rock dust was apparently the sole cause of stoppage of explosions. Data obtained in some 1,800 explosion tests in the Bureau of Mines Experimental coal mine have provided the fundamentals upon which dust explosions in coal mines could be greatly reduced, if effectively put into practice.

Increase in Charge Limit of Permissible Explosives

To meet the problem created by use of mining machines having cutter bars up to 10 feet in length, the Coal Mining Institute of America requested that the quantity limit for permissible explosives be raised from 1.5 to 3 pounds so that heavier blasting can be practiced. The regular testing gallery for explosives was not equipped for numerous tests with 3-pound charges, nor could equipment suitable for testing such large charges under coal-mine conditions be readily procured. To obtain immediate information, a program of tests in the Experimental Coal Mine was devised and developed. The first 68 tests were limited to determinations of conditions under which a 3-pound charge of a permissible explosive could ignite a gas-air mixture (8 to 9 percent natural gas) placed in front of the face from which the shot is fired. The mixture did not ignite easily, so that closer control of numerous variables had to be made.

18/ Greenwald, H. P., Mine Roof Sealing to Prevent Slate Falls: Min. Cong. Jour., vol. 30, March 1944, pp. 53-55.

19/ Greenwald, H. P., Statistics Show Rock-Dusting Gains Slowly in American Coal Mines: Min. and Met., vol. 25, Feb., 1944, pp. 98-99; also under title, Use of Rock Dust to Prevent Dust Explosions in Coal Mines, 1938-43: Trans. Am. Inst. Min. and Met. Eng., Coal Div., vol. 157, 1944, pp. 116-123.

In the first series of tests all boreholes were 2-1/4 inches in diameter and 6 feet in depth, with a gelatin-type permissible explosive placed at the rear of the hole and a No. 6 detonator at the rear of the charge. The same explosive was used in all tests and represented one of the more dangerous of the permissible types. In each test a minimum volume of about 900 cubic feet of the gas-air mixture surrounded the free face or faces of the coal. The probability of ignition in five tests was determined for each set of conditions. Thus, if there were two ignitions and three nonignitions of the gas, the probability was 0.4. The first determinations were with the explosive unstemmed and packed solidly in the hole, a loading condition called "density 1." Under these conditions 1 pound of explosive gave probability 0.0, 3.5 pounds, 0.4, 8 pounds, 1.0, and 13 pounds, 0.2. Thus, at the point of maximum danger with 8 pounds of explosive, at least 2.5 times the proposed 3-pound charge limit was used. It was next determined that stemming an 8-pound charge of explosive with 1 pound of fire clay reduced the probability of ignition from 1.0 to 0.0. The stemming occupied about 3 inches of the borehole.

In a second series of tests 6 inches of coal separated the explosive and gas-air mixture. Thirty tests have been made without a resulting ignition, indicating that the likelihood of igniting gas because of weak or fissured walls of the borehole is small. However, more correlations between results of the two series of tests are needed before the probability of ignition can be known when undisturbed coal lies between the explosive and gas-air mixture.

Explosibility of North Dakota Lignite Dust in Air

To supply information on the explosibility of lignite dust, a study was made of conditions in a North Dakota lignite mine, and samples were collected for analysis and for tests in the Experimental coal mine. Tests of dust of the size found in this mine showed that a self-sustained dust explosion could not be produced when ignited by a blown-out shot of 4 pounds of black blasting powder. When the source of ignition was a strong gas explosion, a self-sustained dust explosion developed at once; this was prevented only when the incombustible content of the dust was raised to 60 percent. When the moisture content of the lignite was reduced to 20 percent, a self-sustained dust explosion developed from a blown-out shot of 4 pounds of black blasting powder. The explosion was prevented by increasing the total incombustible to 40 percent. When the source of ignition was a gas explosion, 60 percent of total incombustible was required to prevent self-sustained explosions. Lignite dust containing 20 percent moisture could be ignited by electric arcs and the flame of detonating dynamite but less readily than low-moisture, high-volatile coals.

Inflammability and Explosibility of Industrial Dusts

As part of a program designed to promote safety in industrial operations, the Bureau of Mines has investigated the explosion hazards of numerous dusts and powdered products. Requests from industries and Government agencies on the explosion hazards of various dusts continued steadily, and 69 samples were received during the year. The samples submitted included dusts of metals, resins, pitch, components of explosives, and agricultural products. A number of requests for information concerned explosion hazards that might be present when airplane-engine pistons are cleaned by a blast of carbonaceous materials, such as cracked wheat or clover seed dust. Other requests were for information on the hazards of dusts that collect in exhaust dusts from vehicular tunnels and of dusts of dried organic materials produced during the complete dehydration of vegetables and other foods.

Explosibility of Powders from the Plastics Industry

A study was made of the inflammability and explosibility of powders used in or produced by the plastics industry.[20] Data from this study were required in formulating a safety code[21] for the prevention of explosions and for safer production and handling of powders from plastics in industry. Fifty-seven powder samples, comprising 31 resins, 15 molding compounds, 4 synthetic resin ingredients, and 7 fillers for molding compounds, were tested in the dust-explosions laboratory. Tests included determinations of the minimum ignition temperature and minimum energy needed for ignition of dust clouds, relative inflammability with two different sources of ignition, minimum concentration required in a dispersion of dust in air to permit ignition and flame propagation, maximum pressure and rate of pressure rise developed in small explosions, and reduction in oxygen content of air necessary to prevent ignition. Test results were obtained on powders of two sizes of fineness, namely, as-received and minus 200-mesh. Comparative data show that the explosibility of fine sizes of many powders from plastics is only slightly lower than that of most inflammable metal powders and that the potential dust-explosion hazard in the manufacture of certain plastics is greater than that of more common carbonaceous dusts.

Precision Measurements of Minimum Static Electric Sparks

A discussion of the importance of fundamental studies on static electric phenomena, a description of precision apparatus for such studies, and a statement of results obtained with various explosive mixtures are contained in a recent publication.[22] In figure 1 are 2 curves for benzene-air mixtures on the left and two curves for natural-gas-air mixtures on the right. The lower benzene-air-mixture curve shows the energy required to ignite mixtures containing 2 to 6 percent benzene with 0.05-inch sparks between 1/8-inch spheres. The upper curve represents data obtained with 1/2-inch spheres also spaced 0.05 inch apart. These curves indicate qualitatively that the smaller the effective cooling area of the electrodes, the lower the minimum ignition energy required to start a self-propagating chemical

20/ Hartmann, O., and Nagy, J., Inflammability and Explosibility of Powders Used in the Plastics Industry: Bureau of Mines Rept. of Investigations 3751, 1944, 38 pp.

21/ Committee on Dust Explosion Hazards, Division I, Subcommittee for the Prevention of Dust Explosions in the Plastics Industry, National Fire Protective Association. Code for the Prevention of Dust Explosions in the Plastics Industry: Nat. Fire Protec. Assoc. Quarterly, vol. 37, Part 2, April 1944, pp. 4-20.

22/ Guest, P. G., Apparatus for Determining Minimum Energies for Electric-Spark Ignition of Flammable Gases and Vapors: Bureau of Mines Rept. of Investigations 3753, 1944, 16 pp.

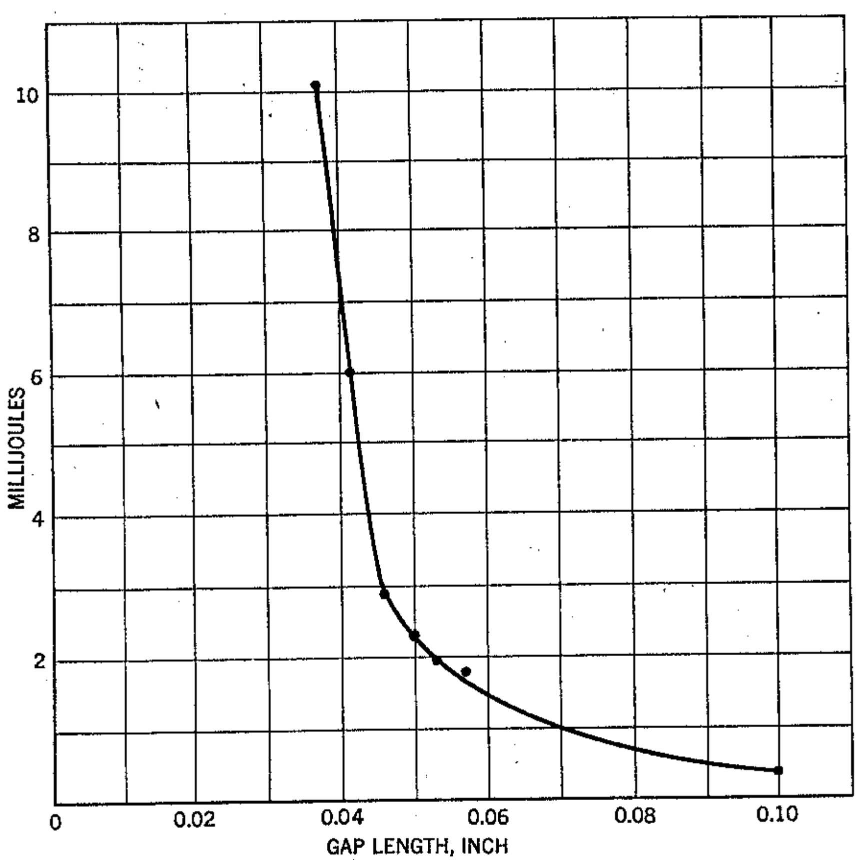

FIGURE 1.- Variation of minimum energies of single static sparks for ignition of mixtures of varying composition, using fixed spark gaps.

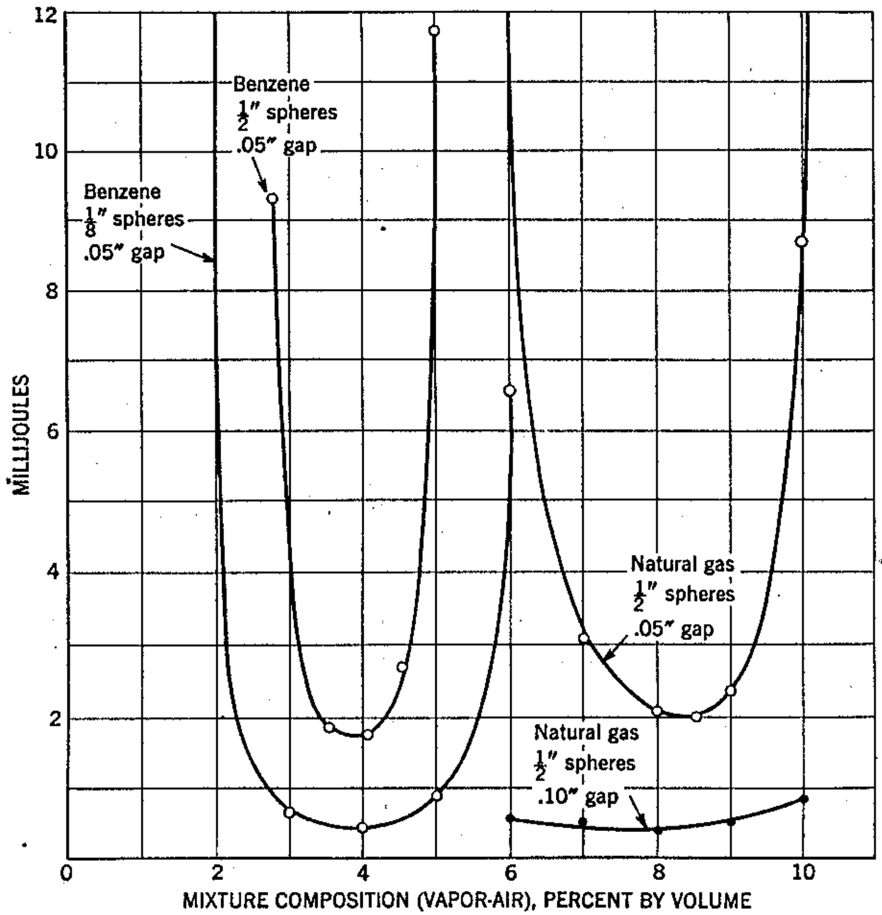

FIGURE 2.- Variation of minimum energies of single static sparks for ignition of mixtures of 8 percent natural gas, using $\frac{1}{2}$-inch spheres and varying spark gaps.

reaction. The upper and lower curves for natural-gas-air mixtures were obtained by using 1/2-inch spherical electrodes, spaced 0.05 inch and 0.10 inch, respectively. The electrode cooling effect is seen here also, since, as the gap and hence the zone of initial activation is increased, the energy required for ignition is reduced.

The relationship between ignition energy and length of spark is represented better in figure 2, which shows the data obtained with 1/2-inch sphere electrodes in mixtures of identical composition. It seems likely that the rather abrupt change in slope, as the spark gap is made shorter than 0.05 inch, is due to a shift in the locus of flame inception from the path of the discharge to an annular region surrounding it. Both the benzene and the natural-gas curves show the well-known variation of ease of ignition with mixture composition. The benzene-air mixture most susceptible to spark ignition is somewhat richer than the most perfectly combustible mixture which contains 2.71 percent C_6H_6, while the most sensitive natural-gas-air mixture is on the lean side. It can be seen that ignition of mixtures near the upper and lower limits for flame propagation (1.41 to 6.75 percent for benzene and 4.75 to 13.8 percent average for Pittsburgh natural gas) requires comparatively high energy when sparks shorter than 0.05-inch occur between electrodes 1/2 inch or larger in diameter.

A critical review of the literature dealing with the electrical conductivity of solid dielectrics was made.[23] Methods of removing static charges are described, methods and conditions for the measurement of resistivity are discussed, and equations for the calculation of resistivity are given. In addition to fundamental laboratory research on static electric phenomena, such as the resistivity of various dielectrics at different humidities, data were obtained on the energy of static sparks that may be drawn by the human body in contact with charged surfaces, such as blankets and sheets in hospital operating rooms and from handling materials in munitions plants.

Mining Methods and Practices

Improvements in coal-mining practices in the interest of safety, efficiency, and conservation have resulted in increased production of coal this year. Mining practices were studied, particularly in the steeply dipping mines of the Roslyn and Pierce County fields of Washington, in the Monarch mine at Sheridan, Wyo., and in coal-stripping operations in Ohio, Pennsylvania, and West Virginia.

Pillar Extraction

A plan of pillar extraction in the Monarch mine in Wyoming was developed that would result in an increased recovery of 36 percent of coal at an additional cost of $0.07 per ton. This increased cost probably can be offset by the decrease in capital charges per ton resulting from increased production from a section of the mine.

[23] Cohn, E. M., and Guest, P. G., Influence of Humidity Upon the Resistivity of Solid Dielectrics and Upon the Dissipation of Static Electricity: Bureau of Mines Inf. Circ. 7286, 1944, 41 pp.

Coal Strip Mining

Reduction in highway, airport, and drainage construction, as a result of the war, has made more earth-moving equipment available, and many contractors have entered the coal-stripping fields. Carry-alls and other light equipment are easily transported and appear to be successful in hillside-stripping operations in mountainous country. Increase in the use of such equipment has resulted in increased production of badly needed coal.

Control of Sulfur and Ash in Mine-Run Metallurgical Coal

As a requisite for suitable coke, emphasis has always been placed on low sulfur and ash content in the coal, so that the resulting coke would also be low in these impurities. However, uniformity of the sulfur and ash content of coke for blast-furnace use is also very important, both for efficient operation of the furnace and for increased production of pig iron for war. Bureau of Mines engineers studied the mining methods and practices of sampling, selective mining, grading, underground and surface blending, and surface preparation as followed at five representative mines. The results obtained at these mines have been summarized.[24] This study showed that, at certain mines, part of the minable coal area or part of the coal bed produced unsatisfactory metallurgical coal, but when this coal is graded and blended with coal having a smaller percentage of impurities from other parts of the same mine, a satisfactory metallurgical coal is obtained. It is hoped that by the introduction at other mines of some of the practices at the mines studied, additional coal may be made available for metallurgical purposes that otherwise could not be used because of wide variation of sulfur and ash content. The plan has been recommended by the Coke Production Committee, which has been functioning at the suggestion of the Solid Fuels Administration for War. Interest of coal industrialists in this subject as a means of contributing to their own war activities in producing more uniform metallurgical coal was evidenced by invitations to present the results of this study before semiannual meetings of the Eastern States Coke Oven and Blast Furnace Association and the Coal Division of the American Institute of Mining and Metallurgical Engineers.

Roof Control

Any system that is effective in reducing roof falls in all parts of a mine is of definite benefit to the coal-mining industry. Continual interchange of moisture between mine air and roof rock of shaly composition is known to weaken the roof and increase roof falls. A study[25] was made at the Beech Bottom mine of the Windsor Power House Co. near Wheeling, W. Va.,

24/ DeKay, H. E., Jr., Turnbull, L. A., Scudder, J. N., and Toenges, A. L., Control of Sulfur and Ash in Mine-Run Metallurgical Coal. Report 1: Bureau of Mines Rept. of Investigations 3742, 1943, 28 pp.

25/ Fish, E. L., Turnbull, L. A., and Toenges, A. L., A Study of Summer Air Conditioning With Water Sprays to Prevent Roof Falls at the Beech Bottom Coal Mine, West Virginia. Appendix by I. Hartmann: Bureau of Mines Rept. of Investigations 3775, 1944, 20 pp.

of the operation of its water-spray, air-conditioning plant and its effect on minimizing roof falls in all parts of the mine. Laboratory tests showed that shales deteriorate when moist and are strongest when dry. After alternate wetting and drying, shales never returned to their original dry strength but became weaker after each change. Studies at the Beech Bottom mine showed that desorption and absorption of moisture by the shale were minimized by maintaining uniform temperature and moisture content of the mine air. Roof falls were diminished at this mine by installing an air-conditioning plant. Physical tests of the roof rock indicated that factors other than moisture changes, such as the modulus of elasticity and bending strength of the rocks and perhaps oxidation of the abundant pyrite in the roof, also contributed to roof failures. The study also indicated that moisture is absorbed from the roof rock during the winter and is deposited on the rock during the summer. This change from drying to wetting weakens the rocks and causes them to fall. Conditioning of incoming winter air will reduce absorption of moisture from the roof rocks. Air conditioning is desirable in winter as well as in summer.

Use of Diesel Engines Underground

Among the hazards that may attend the use of Diesel engines in mines, tunnels, and other underground operations, the presence of harmful constituents of the exhaust gas in such places must receive due consideration to prevent the formation of unsafe or unhealthful working environments. The latest report in a series of laboratory studies made to evaluate conditions that may exist when Diesel engines are used underground presents the results of tests conducted with a high-sulfur fuel (2.4 percent sulfur) to determine the effect on exhaust-gas composition when operating with a fuel of this type.[26] Essentially all of the sulfur in the fuel appeared in the exhaust gas as sulfur dioxide and sulfur trioxide; with increased temperatures the proportion of sulfur dioxide increased. It was concluded that the sulfur content of fuel for Diesel engines operating underground should be limited to 0.3 to 0.4 percent; otherwise, ventilation requirements would have to be increased to dilute the sulfur gases in the exhaust to concentrations permissible in working environments.

Grounding Electrical Equipment in Coal Mines

Although mine safety rules, codes, or standards state that electrical equipment in and about mining operations should be effectively grounded, the question arises concerning the effectiveness of grounding methods now in use. To be effective in minimizing shock and fire hazards, grounding must be capable of preventing dangerous potentials from building up on metal frames, casings, and other parts of equipment that might become electrically charged through accident or insulation failure.[27] A further objective is to

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26/ Berger, L. B., Elliott, M. A., Holtz, J. C., and Schrenk, H. H., Diesel Engines Underground. V - Effect of Sulfur Content of Fuel on Composition of Exhaust Gas: Bureau of Mines Rept. of Investigations 3713, 1943, 13 pp.

27/ Griffith, F. E., and Gleim, E. J., Grounding Electrical Equipment in and about Coal Mines: Bureau of Mines Rept. of Investigations 3734, 1943, 15 pp.

minimize stray currents that may cause premature firing of electric squibs, detonators, and devices fired electrically. Conclusions indicate that metal parts of machines used for loading and shortwall mining are not effectively grounded with the earth when they are at rest or are being moved over the mine floor. A single peg or rod driven into the mine floor also gives no assurance of making a connection of sufficiently low resistance to be satisfactory as a grounding electrode. Although, fish-plated, unbonded track ordinarily forms a satisfactory grounding electrode, the only dependable method to be employed in determining the effectiveness of a protective ground, either on the surface or underground, is from frequent measurements of the resistance of the grounding connection. Visual examination alone does not give any real measure of the effectiveness of protective grounds.

Ground-Resistance Measurements of Drill-Hole Casings

Questions have been raised concerning the necessity or advisability of providing protective grounding for drill-hole casings. It has been suggested that drill-hole casings be grounded effectively and permanently when electric conductors are installed in drill holes.[28] Test data appear to indicate, however, that drill-hole casings themselves are far superior to a rod as a grounding electrode. If effective grounding protection is to be achieved, resistance measurements must be made, because the true worth of the grounding circuit can be determined in no other manner.

Air Flow at Fan-Pipe Lines Discharge

As the ventilation of working places in mines is vital to the miners' health and safety, studies were made of the air flow at the discharge of fan-pipe lines in mines.[29] Data showed that, although the air-distribution conditions of free expansion into quiet air occur close to the pipe discharge, the mine walls themselves exert preponderant effects on flow conditions farther away for the range of relative sizes of drift and discharge openings involved in the tests. The change of velocity along the axis of the jet beyond a certain distance becomes an exponential function of distance in the instance of an enclosed jet rather than continuing as a power function, as for a free jet. In the same range of distances it was found that the distribution of velocities at right angles to the axis could be expressed approximately by a simple power function rather than by the complex series expressions developed theoretically for free jets. Converging pipe ends give about the same flow conditions as uniform-area ends, while diverging end pieces cause velocities to fall at much higher rates. The conditions of flow are practically independent of the velocity of discharge. Velocity ratios increase with size but are not affected appreciably by minor changes in shape.

28/ Griffith, F. E., and Gleim, E. J., Ground-Resistance Measurements of Drill-Hole Casings: Bureau of Mines Rept. of Investigations 3756, 1944, 7 pp.

29/ McElroy, G. E., Air Flow at Discharge of Fan-Pipe Lines in Mines. II - Effect of Size and Shape of Pipe and of Adjacent Walls on Velocity and Entrainment Ratios: Bureau of Mines Rept. of Investigations 3730, 1943, 30 pp.

Mine-Fan Signal Alarms and Power Releases

Any condition that interrupts the ventilating current or changes its normal course through mine workings is a distinct hazard and should receive serious consideration.[30] If the ventilating fan should stop, it would be impossible to ignite a resultant accumulation of explosive gas by electrical arcs or sparks if the electrical power were cut off at the surface. Hand operation of the cut-off has proved disastrous in several instances. Devices can and should be installed that automatically open the underground circuits if the fan ceases to function properly. Several types of power release and signal alarms now in use described in detail.

Construction of Mine Ventilating Doors

Adequate volumes of pure air must be supplied at the working faces, along the haulageways, and wherever men work in mines, to dilute and carry away methane liberated from the coal and adjoining strata, noxious gases evolved by explosives, carbon dioxide exhaled by men and formed by oxidation of carbonaceous material, and any other gases and dusts that may be present in mine workings. Careful construction and maintenance of mine doors will minimize leakage of air and conserve an adequate supply to working places. Mine-door and doorframe construction merit careful consideration, based upon efficiency rather than initial cost.[31] Mine-door construction and installation are discussed.

Precautions for Old Mine Workings

The attention of the Bureau has been called to the lack of consideration or utter disregard of an old and presumably widely known mine safety rule, namely, the necessity for precaution when approaching old or abandoned workings of a mine.[32] Representative examples are given of scores of accidents that have occurred in relatively recent years and that continue to occur far too frequently. Recommendations are made for safe-operating practices.

Permissible Mine Equipment

The Bureau continued to investigate electrical equipment used in mines in connection with the prevention of mine explosions and fires. A list of permissible mine equipment, which was tested and approved during the calendar year 1943, was published.[33]

Gas Explosions and Use of Explosives

To insure continued safety when permissible explosives are used, the Bureau made physical, chemical, and control tests on a number of explosives

30/ Fene, W. J., and Weaver, H. F., Mine-Fan Signal Alarms and Power Releases: Bureau of Mines Inf. Circ. 7262, 1943, 8 pp.
31/ Hartley, J. C., and Moschetti, A. C., Standardized Construction of Mine Ventilating Doors: Bureau of Mines Inf. Circ. 7280, 1944, 4 pp.
32/ Harrington, D., and Warncke, R. G., Precautions to Be Taken When Approaching Old Mine Workings: Bureau of Mines Inf. Circ. 7288, 1944, 20 pp.
33/ Gleim, E. J., Permissible Mine Equipment Approved During 1943: Bureau of Mines Inf. Circ. 7283, 1944, 5 pp.