Electrical Equipment for Mines

Unless electrical equipment is built, maintained, and used in proper manner in gassy coal mines, that equipment should be regarded as hazardous from the standpoint of initiating mine fires and explosions. As a means of overcoming this hazard, the Bureau of Mines has established certain standards, published as "schedules" to guide manufacturers who produce mine equipment. Equipment that passes the tests and inspections prescribed by these standards is formally approved and becomes known as "permissible" equipment, that is, permissible for use in gassy coal mines. The schedules are amended from time to time as the need arises for changing safety standards. Thus, an amendment[40] to Schedule 2E established tests to bring about the development of trailing cables resistant to propagation of flame. In the past, overloaded or short-circuited cables of portable mine equipment have caught fire and then set the mine on fire. Cables passing the newly established tests will reduce this fire hazard.

Under the eight schedules now in effect, a manufacturer can have nearly every type of equipment used at or near the face of active mine workings investigated for its liability to ignite gas or coal dust or a combination of these. During the fiscal year 1948, 55 approvals were issued. These included 19 loading machines and conveyors, 4 cutting machines, 3 drilling machines, 5 mining machine trucks, 2 air compressors, 3 battery-operated shuttle cars, 1 post puller, 1 timbering machine, 1 fan-drive unit, 1 greasing truck, 1 battery-operated utility truck, 2 pumps, 1 storage-battery locomotive, 5 10-shot blasting units, 3 junction boxes, 1 distribution box, 1 flame safety lamp, and 1 flashlight.

In order to keep safety engineers, mine inspectors, and officials informed as to the number and variety of equipment that has been approved by the Bureau of Mines, classified lists[41, 42] are published periodically.

Electrical Hazards in Coal Mines

Consumption of electric power in bituminous-coal mining has increased continuously since its introduction for haulage purposes about 1887. The use of electric power has been accompanied by numerous hazards and in many respects safe practices have not been adopted as rapidly as applications of electric power have spread. The Bureau has made studies and investigations of practices and equipment connected with use of electric power in coal mines with deep concern for the growing dangers from electric shock, fires and explosions. Safer methods of use and numerous devices for guarding against these hazards have been devised. Engineers of the Health and Safety Branch are engaged in explaining these safety measures and urging their

40/ Bureau of Mines, Amendment to Schedule 2E, Procedure for Testing Junction Boxes and Electric Motor-Driven Mine Equipment for Permissibility: Approved Oct. 21, 1947, 4 pp.; duplicated from Federal Register, vol. 12, No. 219, Nov. 7, 1947, pp. 7285-7287.

41/ Hooker, A. B., Permissible Equipment Approved to Jan. 1, 1947, with Appended List of Available Flame-Lamp Fuels: Bureau of Mines Inf. Circ. 7432, 1947, 44 pp.

42/ Hooker, A. B., Permissible Mine Equipment Approved During the Calendar Year 1947; Supplement to I. C. 7432: Bureau of Mines Inf. Circ. 7465, 1948, 5 pp.

adoption in all coal mines.[43] One of the greatest hazards is the bare trolley wire now an outstanding source of mine fires and electrocutions. Makeshift installations and repairs of machinery and circuits are other serious faults whose danger is commonly overlooked.

Mine-Communication Apparatus

Emergency mine-communication apparatus having a primary objective of locating men trapped in mines after fires and explosions, was developed further and tested under varying conditions in an iron mine and a salt mine as well as in anthracite and bituminous coal mines.[44, 45] In one mine, satisfactory two-way radio communication over the power distribution system was established through a distance of 2-1/2 miles. Satisfactory two-way communication through the ground was achieved through distances up to 1,050 feet in another mine. This distance probably can be increased by improvement in the radio equipment.

Toxic Mine Atmospheres

In connection with requirements of the Federal Coal Mine Inspection Act, approximately 15,000 gas and dust samples were analyzed, which required more than 100,000 individual determinations. These samples were analyzed to determine the presence of dangerous or unhygienic conditions. Where undesirable conditions were found, recommendations were made to eliminate or improve them.

To assist operators in providing better working conditions, information was presented on laboratory equipment for the analysis of mine atmospheres[46] and on determination of carbon monoxide[47] and sulfur dioxide.[48] Information was presented[49] on the interpretation of analytical results in relation to the maximum allowable concentration of toxic substances permitted in the air of working places. A report was published describing a mine-air-conditioning chart to provide for the rapid determination of psychometric data and for the rapid solution of air-conditioning problems of major interest to the mining industry.[50]

43/ Bureau of Mines, Electrical Accidents at Bituminous-Coal Mines, Coal-Mine Accident Prevention Course - Section 6: Miners' Circ. 59, 1947, 70 pp.

44/ Coggeshall, E. J., Felegy, E. W., and Harrison, L. H., Some Studies of Emergency Mine Communications: Bureau of Mines Rept. of Investigations 4135, 1948, 44 pp.

45/ Felegy, E. W., and Coggeshall, E. J., Applicability of Radio to Emergency Mine Communications: Bureau of Mines Rept. of Investigations 4294, 1948, 56 pp.

46/ Berger, L. B., and Schrenk, H. H., Laboratory Equipment for the Analysis of Mine Atmospheres: Bureau of Mines Inf. Circ. 7441, 1948, 18 pp.

47/ Berger, L. B., Determination of Carbon Monoxide by Absorption in the Haldane-Type Gas-Analysis Apparatus: Bureau of Mines Rept. of Investigations 4187, 1947, 6 pp.

48/ Pearce, S. J., and Schrenk, H. H., Determination of Sulfur Dioxide in Air by Means of the Midget Impinger: Bureau of Mines Rept. of Investigations 4282, 1948, 6 pp.

49/ Schrenk, H. H., Interpretation of Permissible Limits in the Breathing of Toxic Substances in Air: Bureau of Mines Inf. Circ. 7457, 1948, 7 pp.

50/ McElroy, G. E., A Mine Air-Conditioning Chart: Bureau of Mines Rept. of Investigations 4165, 1947, 23 pp.

To aid in the selection of respiratory protective devices, a list of such equipment approved by the Bureau of Mines was published.51/

The introduction of new products often is accompanied by new hazards. The introduction of the many new synthetic resins raises the question as to possible toxic gases that might be produced when such materials are burned or thermally decomposed. A report describing the various toxic gases produced under laboratory conditions was published.52/

New types of breathing apparatus were tested under the Bureau schedule of permissibility to insure that the use of such equipment in dangerous atmospheres would not endanger the lives of the wearers and to determine the limitations of the new equipment.53/

Safety and Efficiency in Coal Mining

The high rate of accidents from falls of roof is accompanied by loss of production due to interruptions at the working faces. Experiments on suspension supports are being conducted at several mines to determine if they can be used as effectively in the coal mines as in the lead-zinc mines of the Tri-State District.54, 55/

In cooperation with the State mine officials, a study is being made in Washington coal mines of methods for extinguishing mine fires by using dry ice.

A bibliography of Bureau of Mines publications dealing with health and safety was prepared for the conveniences of the mineral industry.56/

Barricading as a Life-Saving Measure

The value of barricading methods has long been recognized after mine explosions and during mine fires where deadly gases spread through the workings and imperil the men who survive. In 1923 Miners' Circular 23 was issued to give information on instances of actual barricading by trapped men, so that others would be familiar with effective methods in an emergency. This circular was revised and brought up to date in 1941 and again in 1946.57/ This study of experiences to the present shows that a

51/ Schrenk, H. H., List of Respiratory Protective Devices Approved by Bureau of Mines: Bureau of Mines Inf. Circ. 7444, 1948, 14 pp.

52/ Berger, Lawrence B., Schrenk, H. H., Gale, James A., Stewart, Ralph W., and Sieffert, Lorenz E., Toxicity and Flame Resistance of Thermosetting Plastics: Bureau of Mines Rept. of Investigations 4134, 1947, 11 pp.

53/ Grove, G. W., and Quenon, E. E., Approval of Newly Developed Self-contained Breathing Apparatus, Instructions in its Care and Use: Bureau of Mines Inf. Circ. 7413, 1947, 18 pp.

54/ Thomas, E., Suspension Roof Support for Coal-Mine Roadways: Coal Age, vol. 53, No. 7, 1948, pp. 86-88.

55/ Thomas, E., Seeling, C. H., Perz, F., and Hansen, M. V., Suggested Roof Supports for Use at Faces in Conjunction with Mechanical Loading: Bureau of Mines Inf. Circ. 7471, 1948, 9 pp.

56/ Davenport, S. J., Bibliography of Bureau of Mines Publications Dealing with Health and Safety in the Mineral and Allied Industries, 1910-46: Bureau of Mines Tech. Paper 705, 1948, 154 pp.

57/ Harrington, D., and Fene, W. J., Barricading as a Life-Saving Measure in Mine Fires and Explosions: Bureau of Mines Miners' Circ. 42 (revised Dec. 1946) 1948, 80 pp.

tight stopping usually can be erected in a suitable place in 30 minutes to a few hours. Air circulation in the area outside the barricade should be short-circuited, and a large enough area should be enclosed to provide at least 1,000 cubic feet of air per man and as much more as can be readily enclosed.

Coal-Mine Disasters

After rescue and recovery work at coal-mine disasters during the year engineers and inspectors of the Health and Safety Branch made investigations and prepared reports on the causes of these disasters with recommendations for protection from the hazards shown.58/ In the fiscal year 1947, 17 mine explosions, causing 154 deaths, were reported; of these, 4 were major disasters (loss of 5 or more lives at a time), causing a total of 144 deaths. One explosion in Illinois killed 111 persons; the cause was unsafe blasting practices, coupled with utterly inadequate rock dusting. An explosion in Indiana, resulting in 8 deaths, also was found to have been caused by unsafe blasting and failure to apply rock dust to the active workings. Two gas explosions in Pennsylvania anthracite mines caused the loss of 25 lives; the primary cause in both instances was laxity in testing for methane.

Miscellaneous Causes of Coal-Mine Injuries

A study of various supposedly minor causes of coal-mine accidents shows that the total of injuries from machinery, flying particles, steam, compressed air, stumbling, falls of persons, hand tools, and other causes amount to about 45 percent of all coal-mine injuries. A detailed discussion of such hazards with recommended protective measures has been compiled and published for use in teaching classes of accident prevention for mine officials.59/ Numerous safe practices are discussed in addition to the over-all problems of supervision, inspection, formulation of safety rules, and the education and training of workers.

Gaseous Explosions and Use of Explosives

Permissibility Tests

The conditions and requirements governing the chemical and physical testing of explosives to determine their characteristics so that they can be used safely in gassy and dusty coal mines are set forth in Schedule 1F.60/

Four samples of explosives were submitted to determine their safety for use in gassy and dusty coal mines. Two of these passed the required tests for permissibility, and two were withdrawn from use.

Twenty-three samples of explosives containing TNT and ammonium nitrate were tested for possible use as permissible explosives. All samples failed to pass the gallery tests.

58/ Harrington, D., Fene, W. J., and Humphrey, H. B., Coal-Mine Explosions and Coal- and Metal-Mine Fires in the United States during the Fiscal Year Ended June 30, 1947: Bureau of Mines Inf. Circ. 7456, 1948, 21 pp.

59/ Bureau of Mines, Miscellaneous Accidents in Bituminous-Coal Mines, Section 7, Coal-Mine Accident Prevention Course: Miners' Circ. 60, 1947, 85 pp.

60/ Bureau of Mines, Procedure for Testing Explosives (Including Sheathed Explosives) and Blasting Devices for Permissibility and Suitability: Sched. 1F, approved Jan. 20, 1945, 11 pp., with amendments approved Mar. 14 and Aug. 7, 1945, June 24, 1946, and Feb. 27, 1948.

On June 30, 1948, the permissible list[61] contained the names of 191 explosives and 9 blasting devices compared with 186 explosives and 9 blasting devices on the list as of June 30, 1947.

Field Samples of Permissible Explosives

A permissible explosive or blasting device, after approval for use in gassy and dusty coal mines, must be so manufactured that it will have all the chemical and physical characteristics of the basic sample. To check on their quality, 28 samples of permissible explosives were collected from the manufacturers' magazines. Two samples failed to pass the gallery tests and several others did not meet the established tolerances for some of their physical characteristics. The items in which these explosives failed and the number of failures, respectively, were as follows: Physical examination, 7; chemical analysis, 10; rate of detonation, 7.

Consumption of Permissible Explosives

During the fiscal year 1948 the consumption of permissible explosives in coal mines totaled approximately 116 million pounds. In addition to this, approximately 33 million pounds of black blasting powder and approximately 136 million pounds of high explosives were used, the last chiefly in strip-mining operations. Thus, three and one-half times as much permissible explosives as black blasting powder were used. During the past few years, the quantity of permissible explosives used has increased, whereas the quantity of black blasting powder used has remained almost the same.

Vibrator-Type Multiple-Shot Blasting Unit

To meet the need for a satisfactory permissible multiple-shot blasting unit, which would be capable of firing 10 detonators in series and be safe for use in underground mining where a gas ignition hazard may exist, the Bureau developed a capacitor-battery type.[62] It is based upon utilization of the discharge energy from a capacitor charged to a given voltage and having capacitance adequate to store enough energy to initiate 10 detonators in series. The primary source of energy is a 4-volt cap-lamp battery and the voltage is built up to the required value by means of a vibrator.

To operate safely in gassy atmospheres, the voltage on the capacitor in the unit must be reduced to such a value that dangerous sparking resulting from breakage of the firing circuit does not occur after movement of the coal face has possible released gas. The present unit has been found to be safe in this respect. The experimental model has been operated hundreds of times during test work and has performed satisfactorily.

Extinction of Isobutane Flames by Carbon Dioxide and Nitrogen

Recently, isobutane has become a commercially important raw material in the production of aviation gasoline by the alkylation process, in which isoparaffins are

61/ Tiffany, J. E., and Gaugler, Z. C., Active List of Permissible Explosives and Blasting Devices Approved Previous to December 31, 1945: Bureau of Mines Rept. of Investigations 3910, 1946, 20 pp.

62/ Gibson, F. C., and Brown, F. W., Vibrator-Type Multiple-Shot Blasting Unit: Bureau of Mines Rept. of Investigations 4136, 1947, 5 pp.

combined with olefins to give higher molecular weight compounds of branched-chain structure. Therefore, the general explosion hazards of this substance have been determined.[63]

The lower and upper limits of inflammability of isobutane in air were found to be 1.83 and 8.43 percent by volume, respectively.

Tests were carried out with isobutane-air mixtures to which increasing proportions of nitrogen or carbon dioxide were added both in the lower- and upper-limit ranges. The concentrations of these gases were increased eventually to the point where the mixtures became noninflammable when mixed with air in any proportions. Figure 19 shows the total areas of inflammability of isobutane-air-nitrogen and isobutane-air-carbon dioxide mixtures. It is seen that the addition of nitrogen to isobutane-air mixtures in the lower-limit range has virtually no effect upon the limit of inflammability. On the other hand, the addition of nitrogen in the upper-limit range decreases the limit progressively almost in direct proportion to the amount of nitrogen. When the mixture contains 39.8 percent of added nitrogen, the lower and upper limits of inflammability merge, and further additions of nitrogen produce mixtures that are entirely noninflammable. This point is reached when 26 percent of carbon dioxide is present in the mixture.

Effects of Hydrocarbons and Other Gases Upon the Explosibility of Acetylene

There is considerable interest at present in the safe handling of acetylene under pressure. The maximum permissible pressure in portable acetylene generators is 15 pounds per square inch gage. Tests by the Bureau of Mines have shown that this pressure is too high to prevent explosions of gaseous acetylene in the absence of air. In fact, dry acetylene gas can be exploded at pressures greater than 5.9 pounds per square inch gage. It was found that the addition of hydrocarbons such as natural gas, propane, or butane to acetylene rendered the latter less explosive. The effectiveness was found to increase with the molecular weight of the hydrocarbon. For example, at 15 pounds gage pressure, the percentage of hydrocarbon required to be present in the acetylene to prevent explosion is as follows: Natural gas, 13.8 percent; propane, 9.2 percent; butane, 8.4 percent by volume.

It seemed desirable to determine the inhibiting effects of these hydrocarbons at pressures up to 100 pounds gage.[64] The amounts required to prevent explosions of acetylene at different pressures are shown in table 4. The efficiency of the added hydrocarbons is thus seen to increase with increasing molecular weight.

For comparison, additional experiments were carried out with carbon dioxide, nitrogen, helium and hydrogen with results shown in table 5. It is seen that the inhibiting effects of these gases, except carbon dioxide, are low compared with the hydrocarbons and that there is little difference in the effects of nitrogen, helium, and hydrogen. Carbon dioxide is comparable to natural gas.

These results are shown graphically in figure 20.

63/ Jones, G. W., and Scott, G. S., Extinction of Isobutane Flames by Carbon Dioxide and Nitrogen: Bureau of Mines Rept. of Investigations 4095, 1947, 9 pp.

64/ Jones, G. W., Kennedy, R. E., and Spolan, I., Effect of Hydrocarbons and Other Gases Upon the Explosibility of Acetylene: Bureau of Mines Rept. of Investigations 4196, 1948, 8 pp.

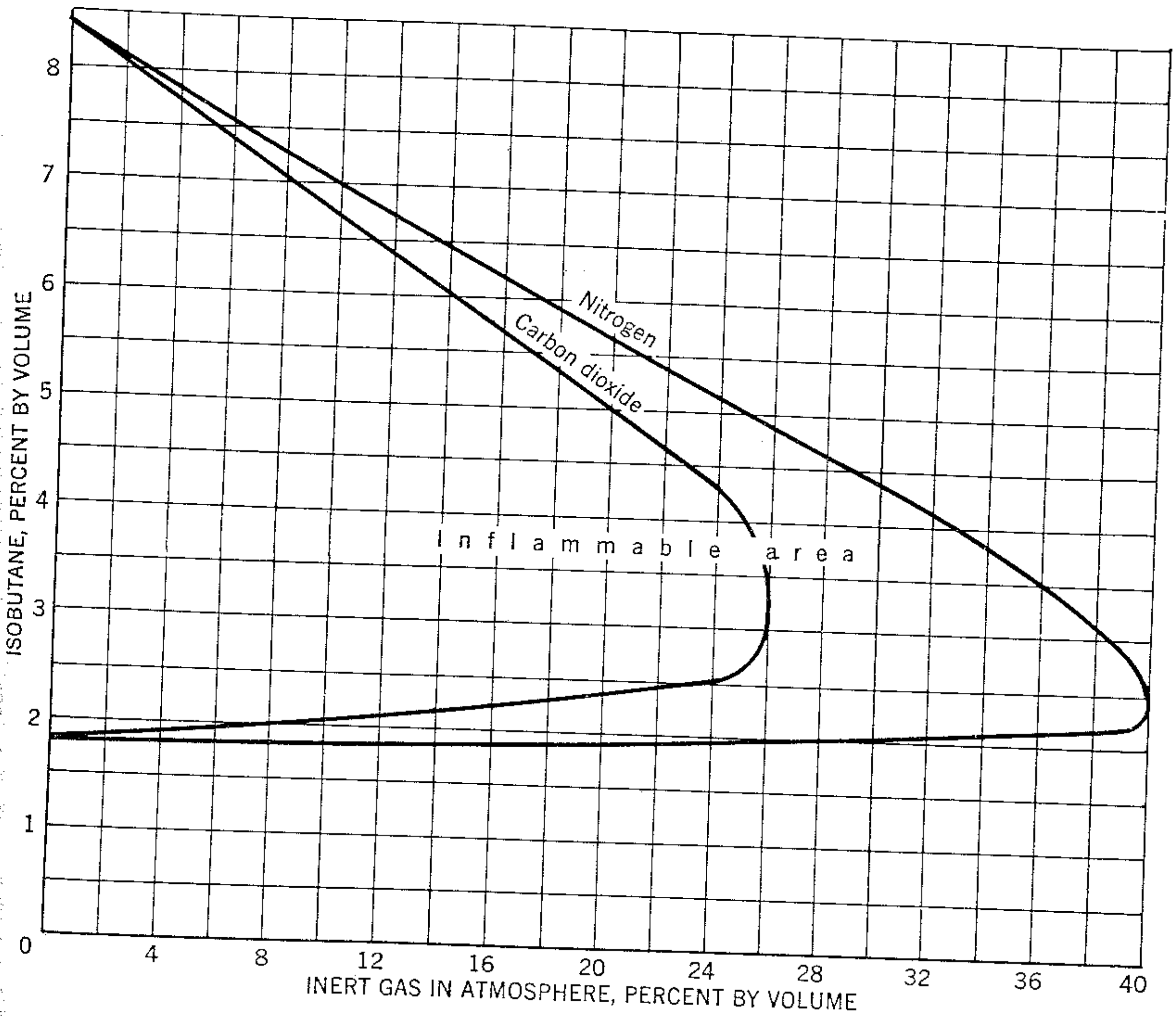

Figure 19. - Limits of inflammability of isobutane in air, nitrogen, and carbon dioxide atmospheres.

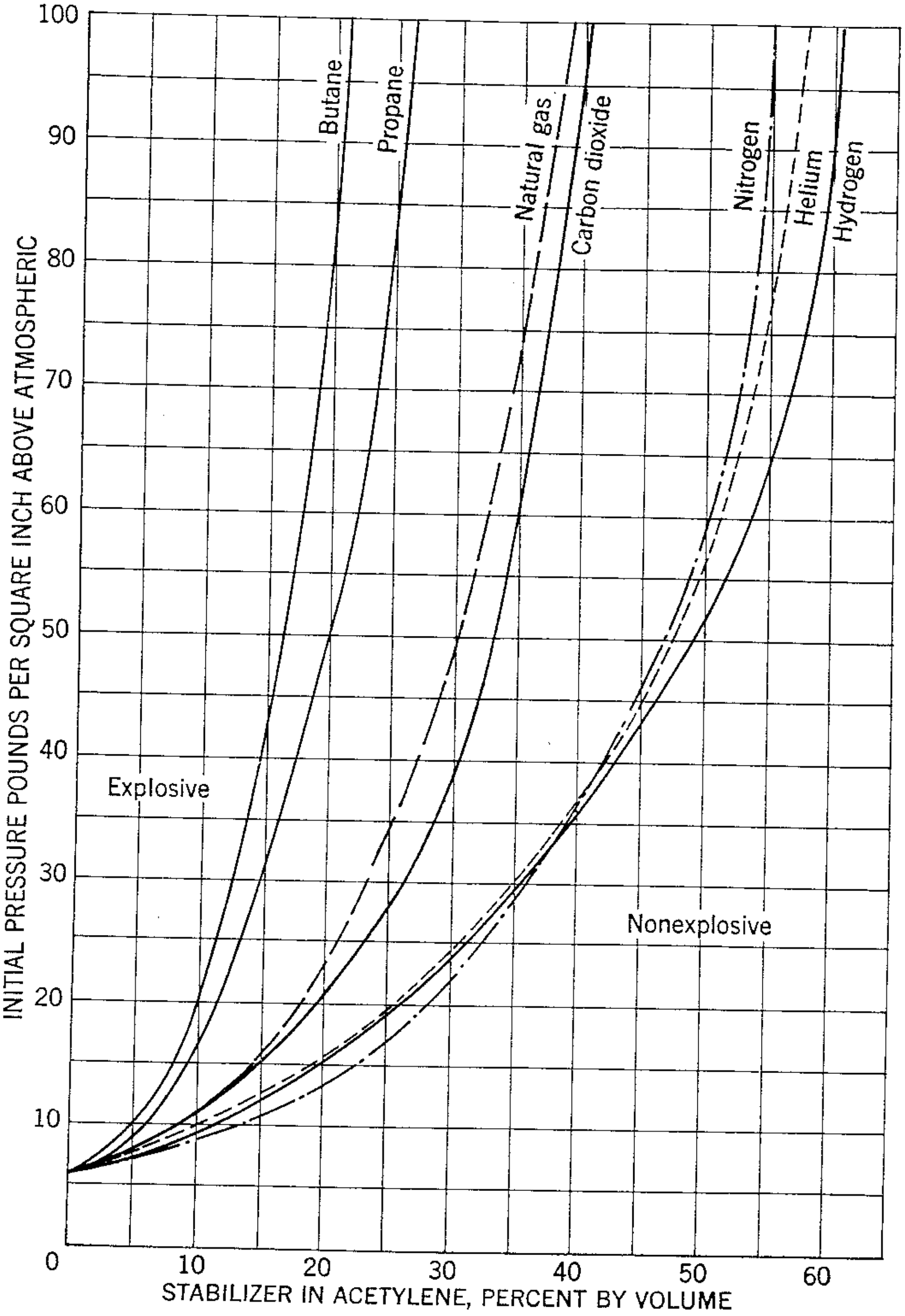

Figure 20. - Effect of pressure on the explosibility of acetylene-hydrocarbon and acetylene-gas mixture.

TABLE 4. - Amount of hydrocarbon required to prevent explosions in acetylene at different pressures

Initial pressure, lb./sq. in. gage	Hydrocarbon required to prevent explosion in acetylene, percent by volume		
	Butane	Propane	Natural gas
15	8	10	15
25	11	13	21
50	17	20	31
75	19	24	36
100	21	26	39

TABLE 5. - Amount of gas required to prevent explosions in acetylene at different pressures

Initial pressure, lb./sq. in. gage	Gas required to prevent explosions in acetylene, percent by volume			
	Carbon dioxide	Nitrogen	Helium	Hydrogen
15	15	23	19	19
25	23	32	31	31
50	33	47	48	49
75	38	53	55	58
100	41	55	58	61

Flammability of Gasoline Vapor - Air Mixtures at Low Pressures

The operation of jet combustion engines at high altitudes and the general aspects of combustion processes in rarefied atmospheres have created considerable interest in the problem of ignition and flame propagation at low pressures.

Experiments carried out with natural gas-air mixtures at reduced pressures showed[65] that the flammable limits are affected but little at reduced pressures down to 75 mm. mercury. As the pressure is reduced below atmospheric, the mixtures become more difficult to ignite. However, if a suitable source of ignition is employed, the limits are as wide at 175 mm. as they are at atmospheric pressure. In view of these results, mixtures of gasoline and air were investigated similarly.[66]

PREPARATION OF COAL

Coal Washing

New Cleaning and Dewatering Process for Fine-Size Coal

Development of a new "kerosine-flotation" process for the cleaning and dewatering of fine-size coal in the 10-mesh to 0 range was carried to the commercial

65/ Jones, G. W., and Kennedy, R. E., Inflammability of Natural Gas: Effect of Pressure upon the Limits: Bureau of Mines Rept. of Investigations 3798, 1945, 13 pp.

66/ Jones, G. W., and Spolan, I., Inflammability of Gasoline Vapor-Air Mixtures at Low Pressures: Bureau of Mines Rept. of Investigations 3966, 1946, 5 pp.