Effect of Pressure upon the Explosibility of Mixtures of Acetylene with Water Vapor, Air, and Hydrocarbons

Information on the explosibility and ease of ignition of acetylene is important in connection with investigations seeking to determine the cause of acetylene generator explosions. Preliminary tests made by this Bureau showed that certain sizes of carbide may, under certain conditions, attain excessively high temperatures when acetylene-water vapor mixtures are passed through carbides for extended periods.36/ Amendment 3, June 28, 1944, to Federal Specification P-C-101 was effected, which permits a maximum of 7 percent of "1/4 by 1/12" carbide by weight to pass through a 0.0661-inch sieve, and a maximum of 2 percent to pass through a 0.0555-inch sieve. Although this improvement in the size range of the carbides has aided in the prevention of explosions, explosions have occurred when conditions of the latest Federal Specification have been met. Present investigations by the Bureau of Mines indicate that one of the major causes of the explosions is the high reactivity of certain carbides with acetylene-water vapor mixtures. The results of this work will be described in a future Bureau report.

The suggestion has been made that a possible cause of explosions in medium-pressure acetylene generators is air that enters the generator during abnormal operations or remains in the carbide hopper and other parts of the generator following charging or purging. Studies of the effect of small volumes of air upon the ignition temperature of acetylene at varying operating pressures of the generators show37/ that the introduction of up to 10 percent of air into an acetylene generator does not appreciably increase the ease of ignition of the mixtures.

Further investigations have been carried out to provide data on the explosibility of acetylene containing varying percentages of water vapor, air up to 30 percent, and hydrocarbon gases at pressures from atmospheric to 15 pounds per square inch above atmospheric, which is the maximum operating pressure of medium-pressure acetylene generators.38/ The tests were carried out in a special bomb. Observations were also made on the rate of pressure rise and maximum pressure produced in an explosion. Different concentrations of water vapor were obtained by adding water and varying the temperature of the bomb. The following results were found: Acetylene becomes explosive at or above a pressure of 5.9 pounds per square inch. On adding water vapor, the pressure required to explode the mixture increases roughly proportional

36/ Jones, G. W., Scott, G. S., Kennedy, R. E., and Huff, W. J., Explosions in Medium-Pressure Acetylene Generators: Bureau of Mines Rept. of Investigations 3755, 1944, 20 pp.

37/ Jones, G. W., and Kennedy, R. E., Effect of Pressure on Ignition Temperature of Acetylene and Acetylene-Air Mixtures: Bureau of Mines Rept. of Investigations 3809, 1945, 6 pp.

38/ Jones, G. W., Kennedy, R. E., Spolan, I., and Huff, W. J., Effect of Pressure on the Explosibility of Acetylene-Water Vapor, Acetylene-Air, and Acetylene-Hydrocarbon Mixtures: Bureau of Mines Rept. of Investigations 3826, 1945, 17 pp.

to the volume of water vapor present. At 14.5 percent or more of water vapor, it becomes impossible to explode such mixtures below a pressure of 15 pounds gage, the maximum operating pressure of the generators. Tests made with mixtures of acetylene and air to which varying amounts of water vapor have been added show that the presence of up to 10 percent air in acetylene exerts a stabilizing effect upon the acetylene, in that they permit higher pressures to be employed (wet or dry) without danger of explosions than pure acetylene will permit. The presence of 15 or more percent of air in acetylene, however, renders the mixtures more liable to explosions than pure acetylene, the hazard increasing as the percentage of air is increased. For example, dry mixtures containing 25 to 30 percent of air can be exploded at atmospheric pressure. The effect of added water vapor is to decrease the hazard of explosion by increasing the permitted pressure.

The effect of hydrocarbons upon the stability of acetylene was investigated. The hydrocarbons selected were natural gas, propane, and butane, as they are easily procurable, cheap, and in rather wide use at present. All three had a marked stabilizing effect, better than steam and increasing in the order natural gas, propane, butane. The percentages of hydrocarbon required to render the acetylene-hydrocarbon mixture incapable of causing explosions below 15 pounds per square-inch gage are 13.8, 9.2, and 8.4 in the above order. The effectiveness thus seems to increase with molecular weight of the hydrocarbon. This information is valuable and offers a means of preventing explosions in medium-pressure acetylene generators. Propane is particularly suitable for use, as it is readily available, has a higher heating value than equal volumes of acetylene, and is marketed in convenient steel cylinders at relatively low pressures. Tests carried out at the Bureau of Mines with acetylene containing 10 percent propane in a 10-pound experimental acetylene generator, in which exceedingly high temperatures often develop in the test carbide in the hopper, have not resulted in any explosions to date. The use of hydrocarbon gases for the prevention of explosions in acetylene generators will be influenced by the difficulties encountered in introducing the required volumes of hydrocarbons into the generated acetylene and the usefulness of such mixtures in present welding and cutting equipment.

The pressures produced by the various acetylene and acetylene-air mixtures were somewhat erratic and appeared to be due to an inherent characteristic of acetylene. In general, the highest pressures resulted when the initial pressure was 12.5 pounds gage or higher. Pressures well over 200 pounds per square inch were developed, and the rate of pressure rise is extremely rapid. Water vapor reduces the maximum pressure developed. Addition of air to acetylene, other conditions being the same, does not markedly affect the maximum pressures. Up to 10 pounds gage, the addition of air appears to increase the maximum pressures, whereas at 12.5 pounds gage and above the addition of air to acetylene has only a minor effect.

Extinction of Flames by the Addition of Helium

Tests were carried out to determine the efficiency of helium as a flame-quenching gas. The results show that this gas has about the same quenching value as nitrogen on alkyl chloride-air mixtures in the lower range of inflammability but has slightly greater quenching value than nitrogen in the upper range.

In tests with heptane-helium-air mixtures it was found that 43.5 percent of helium in heptane-air mixtures is sufficient to prevent propagation of flame under all conditions of use at normal temperatures and pressures.

PREPARATION OF COAL

Metallurgical Coal from High-Sulfur Coal

The rapid depletion of the high-quality metallurgical coal in the Pennsylvania-Pittsburgh seam has necessitated investigation into the large areas of virgin coal in the southwestern portion of the State. The coal in this area is known to be high in sulfur, although information has been lacking for completely appraising these reserves. This study was undertaken to determine the nature of the sulfur present and the possibility of reduction to a point where the clean coal would meet the limitations at present imposed on metallurgical coal by the steel industry.

It was discovered that, even within small areas, both the total sulfur and the forms of sulfur show wide variation. In the high-sulfur samples, a large proportion of the sulfur is in the organic and finely disseminated pyritic forms, which indicate that little improvement could be made by washing - at least, by high-gravity washing. Bench sampling showed that only the lower portion of the seam really responds favorably to washing.

Efficient separation at very low gravities (about 1.30 specific gravity) would produce an acceptable product after thorough blending of the washery feed. The yield, however, would be only about 50 percent, and, owing to the technological difficulties of controlling the gravity, practical operation must await the development of new and improved techniques. Fine-crushing of the coal before separation brings about no substantial reduction of sulfur unless the coal is crushed to 28-mesh top size, which would impose a serious operating problem on the cleaning plant.

Until the development of a washing process that will operate efficiently at a gravity in the 1.35 range, the only practical means of using this coal for metallurgical purposes calls for separate handling of coal from those sections that produce coal of low float-sulfur content at a commercial washing gravity. It appears that relatively large areas of this coal can be marked off and, by means of frequent sampling, a controlled raw product can be fed to the cleaning plant.39/

39/ Fraser, Thomas, and Crentz, William L., Washing Characteristics of the Pittsburgh Coal in a High-Sulfur Area in Green County, Pa.: Bureau of Mines Tech. Paper 689, 1946, 85 pp.

Electrostatic Treatment of Fine Coal

An investigation was made into the separation of ash and fusain from the Pittsburgh-seam and the Illinois No. 6-seam coals. Samples of coal were run through the electrostatic separation of the Ritter Products Co., Rochester, N. Y. The results of this study cannot yet be considered to be indicative of the efficiency of this method of coal cleaning, but the test results of the samples are submitted.

	Ash, percent	Sulfur, percent	Fusain and inert opaque matter, percent
Pittsburgh seam			
Raw 10 x 100-mesh feed	8.57	1.73	5.0
Cleaned coal	4.22	1.43	3.2
Refuse	14.68	1.98	7.6
Illinois No. 6 seam			
Raw 10 x 100-mesh feed	26.69	3.94	5.2
Cleaned coal	22.01	3.94	1.8
Refuse	31.00	3.83	8.6

In the case of the Pittsburgh-seam coal, about 40 percent of the raw 10 x 100-mesh feed was rejected as refuse, whereas approximately 50 percent of the Illinois coal was rejected.

The results of these two tests are not encouraging as far as the reduction in ash and sulfur is concerned, but they do warrant consideration of this process as a means for the reduction of fusain and inert matter, which cannot be removed by conventional specific-gravity separation.

Preparation Characteristics of Maryland Coals

An intensive study of the preparation characteristics of the thinner coal seams of Maryland was undertaken. Although much of the preliminary work has been completed during the fiscal year, test data have not been finally analyzed and interpreted. Indications are that the seams underlying the Pittsburgh seam are all high in ash and sulfur but differ widely in their amenability to washing.

Coal-Preparation Practice in Western Europe

A survey was made of coal-preparation practices and techniques in western Europe, especially enemy countries, primarily to obtain information on any special processes that might be of value to the coal industry in America.

Performance data and operational information were obtained at plants in Germany where especially low-ash coal had been prepared during the war for the manufacture of carbon electrodes and for synthesis of liquid fuels.

A preliminary report of these investigations was presented at the annual meeting, February 1946, of the American Institute of Mining and Metallurgical Engineers by H. F. Yancey and Thomas Fraser entitled "Coal-Preparation Practices in Germany and the Netherlands."

Washability of Coals from the Matanuska Field, Alaska

Research on coal preparation carried out during the war at the two coal mines in Alaska closest to the vital Aleutian Islands chain was published during the fiscal year.[40] The coals dealt with were from the Eska and Evan Jones mines, the two principal operations in the Matanuska field. Located about 70 miles north of Anchorage, both mines are served by a branch line of the Alaska Railroad, and both produced about 6,000 tons of washed coal per month under wartime demand. The data obtained in the washability examinations in the laboratory and by actual washing tests in the washeries at the mines were factors of vital importance to the operators at the time the studies were made and will prove useful to any other operators in this field. Moreover, because the quality of the coal renders the washing operation very difficult, owing to the presence of a high proportion of both heavy impurities and material of intermediate density, the results should prove useful to operators elsewhere who are forced by decreasing reserves to mine coal high in ash or who seek to reclaim coal from washery refuse or waste dumps.

The character of the two coals, from the standpoint of washability, is illustrated in table 6. With coals of ordinary specific-gravity composition, the correlation between washability characteristics and washery performance is sufficiently well-established to permit fairly accurate prediction of the results obtainable in washing. However, the literature contains virtually no information on the results obtainable in washing a material containing such a high proportion of impurity as that present in the Eska coal. Consequently, detailed evaluation was made of the performance of the Eska washery. This correlation between washability characteristics and washing results will be found useful by those concerned with washing unusually dirty coals mined in other localities.

Results Obtained in Washing

Three test runs were made with the jig, the only variable being the specific gravity at which the separation between coal and refuse was made, that is, the proportion of refuse removed. Each test lasted for a full shift of washery operation, and samples of the feed, washed coal, and refuse were collected at uniform intervals during the entire period.

40/ Geer, M. R., and Yancey, H. F., Washability Characteristics and Washing of Coals from the Matanuska Field of Alaska: Bureau of Mines Rept. of Investigations 3840, 1946, 17 pp.

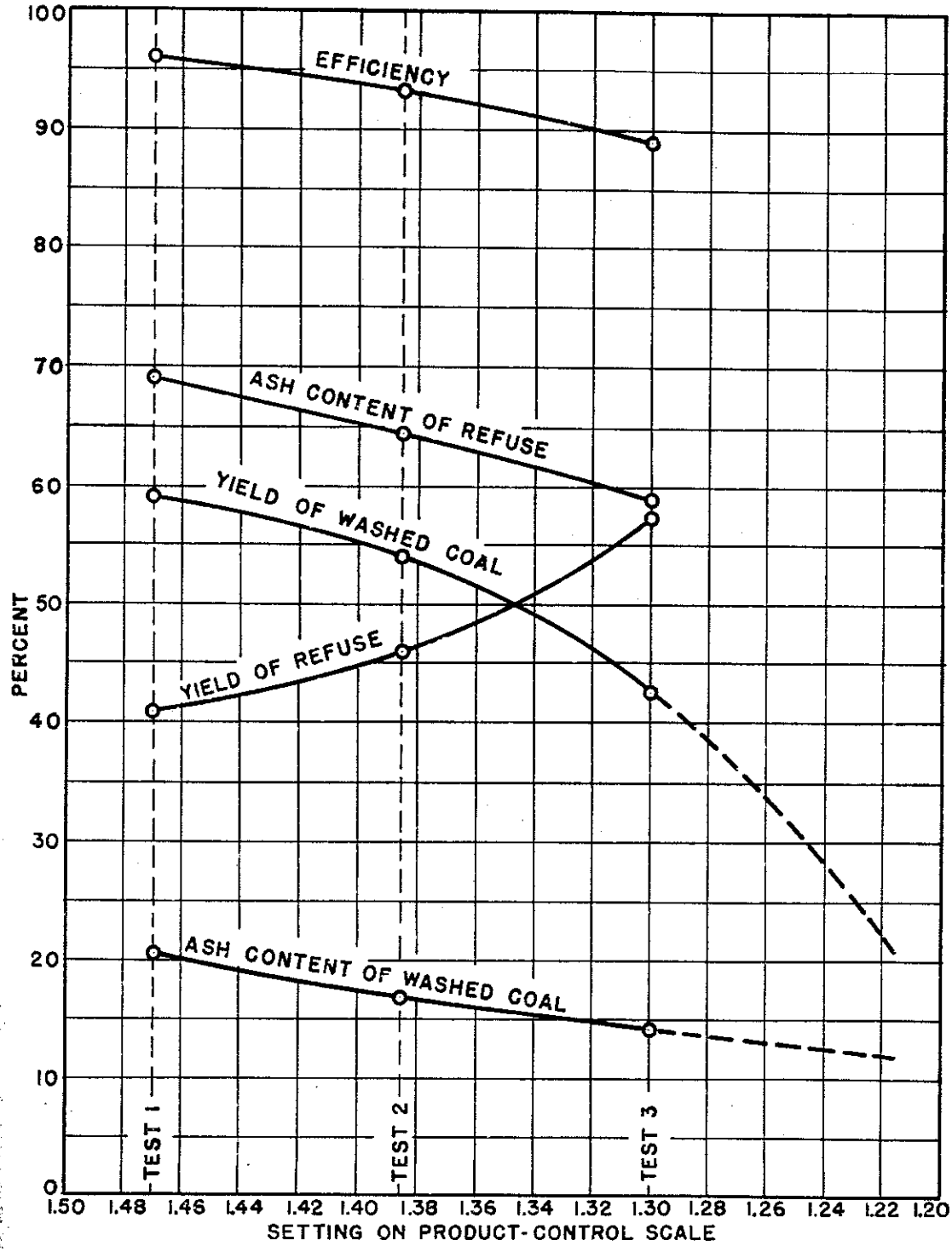

Figure 16. - Yield, ash content, and efficiency in relation to settings on product-control scale of jig.

TABLE 6. - Specific-gravity analyses of 3-inch slack from the Eska and Evan Jones mines, Alaska

Mine	Specific gravity	Weight, percent	Ash, percent[1]	Cumulative Weight, percent	Cumulative Ash, percent[1]
Eska	Under 1.30	20.7	3.8	20.7	3.8
	1.30 to 1.40	13.0	13.1	33.7	7.4
	1.40 to 1.50	11.4	25.9	45.1	12.1
	1.50 to 1.70	14.5	39.3	59.6	18.7
	Over 1.70	40.4	72.1	100.0	40.3
Evan Jones	Under 1.35	35.5	5.6	35.5	5.6
	1.35 to 1.50	25.8	21.0	61.3	12.1
	1.50 to 1.70	17.0	38.5	78.3	17.8
	Over 1.70	21.7	62.6	100.0	27.5

[1] Moisture-free basis.

The principal results of the three washing tests are shown graphically in figure 16. The ash content of the washed coal, its yield, the ash content of the refuse, and the efficiency of the separation made by the jig between washed coal and the refuse are plotted against graduated settings on the product-control scale of the float mechanism that actuates the refuse gate of the jig.

In test 1, the ash content was reduced from 40.3 percent in the feed to 20.4 percent in the washed coal by rejecting a refuse product amounting to 40.9 percent of the feed and containing 69.0 percent ash. The efficiency of the separation was 96.1 percent; that is, the jig recovered 96.1 percent of the coal of 20.4 percent ash present in the feed. The separation was made at a point corresponding to about 1.82 specific gravity. Considerable material heavier than 1.70 specific gravity remained in the washed coal, particularly in the finer sizes. Very little low-density coal was lost in the refuse.

Tests 2 and 3 were made at successively lower specific gravities, 1.66 and 1.55, respectively, by rejecting larger percentages of refuse. The washed coals produced were substantially lower in ash content; and, of course, more coal was lost in the refuse. The efficiencies obtained in this series of tests, namely, from 96 to 89 percent, are lower than those that can be attained in washing ordinary coals.

These results show that with Matanuska coals a product of comparatively low ash content can be obtained only at a great sacrifice in yield. Thus, the value of lower-ash coal must be sufficiently great to justify the waste of natural resource involved.

Removing of Extraneous Material from Industrial and Domestic Coals

Further progress has been made towards perfecting the new Bureau of Mines process for cleaning and dewatering the fine sizes of coal, which in the past have been mainly responsible for the slurry and sludge problems in coal-preparation plants. The cooperating company has purchased and installed two more cells, which, with the two original cells, can now be operated in series as a 4-cell machine - a combination that gives approximately three times the capacity of the original 2-cell machine.

In order to device means of improving hydraulic classification as a method of preparing the feed in the wet-table process of coal cleaning, the conditions prevailing in teeter columns of various depths have been studied. In a report on the results of this study,41/ the conditions of teeter during continuous hydraulic classification of bituminous coal, anthracite coal, and an iron-ore tailing are depicted in panorama. Data are given regarding size distribution of float-and-sink products, settling ratios, specific gravity of solids, pulp densities, and pulp consistencies of various strata within the teeter column.

The washability characteristics of Rhode Island graphitic anthracite have been studied. A chapter giving the results of this study has been written and is to be included as a part of a later Bureau of Mines report on the results of a wartime survey of the economic possibilities of Rhode Island anthracite. The washability study showed that the Rhode Island material of the type under investigation cannot be improved materially by washing unless it is first crushed to a very fine size. Liberation of ash-forming impurities is not appreciable in sizes coarser than 14 or 20 mesh.

Hand Preparation of Coal

Manual cleaning and sizing of coal at the mine have been common practice the world over, and even with the great gains that have been made in mechanical preparation practice, hand picking is still a very important operation. Yet very little has been done to systematize the application of this old-time operation or even to ascertain its effectiveness.

In the course of cooperative work with the Department of Mineral Production in Brazil to increase wartime production in that country, an exceptional opportunity was afforded to study the performance and cost of extensive hand-preparation operations.

In the State of Santa Catarina it has been the standard practice to prepare coal for railroad locomotive and industrial use by hand sorting and breaking. With the development of the national steel industry dependent upon

41/ Coe, G. Dale, Fold, I. L., Williams, M. F., Jr., and Coghill, W. H., Continuous Hydraulic Classification: Constitution of the Teeter Column Throughout its Depth: Bureau of Mines Rept. of Investigations 3851, 1946, 8 pp.

that field for metallurgical fuel, an entirely new and different preparation problem developed, and a modern Baum jig-Rheolaveur plant has been installed to take care of it. However, the hand-picking operations have been tentatively incorporated into the general plan to remove the more obvious impurities at the mines, which are rather widely scattered and have varying rail hauls to the preparation plant.

To examine the rather clear-cut problem of economy of operation in this situation, an extensive series of tests of hand-picking performance and cost was undertaken at individual mines in the Cresciuma Urusanga area.42/

Typical data on performance and operating costs at two of the plants examined in this investigation are presented in tables 7 and 8. The picking operation is on a piecework basis at $3.50 cruzeiros per ton of picked coal in both cases (at present rate of exchange, the cruzeiro is equivalent to approximately 5 cents).

TABLE 7. - Results obtained in two typical check studies of cleaning

Product	Weight		Impurities, percent	Ash, percent
	Tons	Percent		
Bainha plant:				
R.O.M. (raw)	751	100.0	44.6	36.7
Picked coal	408	54.3	35.9	32.3
Refuse	143	19.1	80.1	54.6
Slack (raw)	200	26.6	45.0	36.5
Mina do Mato:				
R.O.M. (raw)	1,508	100.0	46.3	37.0
Picked coal	912	60.8	35.8	32.7
Refuse	326	21.6	72.3	47.8
Slack	270	17.9		43.9

TABLE 8. - Comparative operating-cost data unit costs in cruzeiros per metric ton of picked coal

Operation step	Bainha	Mato
Picking operation only	3.50	3.50
Screening		2.00
Transporting coal, slack, refuse to stock		2.00
Inspections	.19	.93
Supervision	.38	.20
Total cost	4.07	8.63
Metric tons picked coal per picker per hour	.34	.13

42/ Fraser, Thomas, Abreu, A. P., Hand Preparation of Coal in Southern Brazil: A.I.M.E. Tech. Pub. No. 1884, Feb. 1946, 12 pp.