THE SEPARABILITY OF PYRITES PARTICLES IN SOME PULVERIZED COALS

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Abstract

The manner of dispersion of pyrites particles in pulverized coal, and their separability from the carbonaceous matter was studied.

The pyrites content was determined in forty-one pulverized coal samples, and in the heavy fractions of these samples obtained in a density separation in a liquid medium. Two of these samples were segregated into sieving fractions. These fractions were also subjected to pyrites determinations and density separations.

More than one half of this group of samples was chosen from among high-sulfur-content coals.

Values for the removal in the heavy fraction of pyrites, ash and combustible matter, are tabulated.

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Introduction

This work was undertaken as a part of a program to study the mineral matter in commercially pulverized coal. Reasons for gathering information about the minerals in coal are questions concerning corrosion in boilers, the formation and manner of deposition of slag in boilers, the combustion properties of coal particles, the composition and properties of fly ash, and related problems.

A commonly occurring coal mineral of considerable interest is pyrites.* This mineral is usually present in lump coal in the form of discreet particles or thin bands, as inspection of polished faces will reveal[1)5)]. Occasionally, the pyrites will be found in forms that exceed millimeter or even centimeter size.

The purpose of this investigation was to gather data from which conclusions could be drawn about the manner of dispersion of pyrites in pulverized coal, and about the limiting values for the physical separability of pyrites from the carbonaceous matter. Literature search did not yield such information.

Two pulverized coals were studied in detail. In sieving fractions, as well as in the whole coal powder, pyrites content was determined. The pulverized coals and their sieving fractions were also subjected to density separations in a liquid medium. Subsequently, a group of coals consisting of thirty-nine samples, including twenty-two high-sulfur-content coals from several states, was studied. Density separations and pyrites determinations were made in order to obtain data for the calculation of the percentage of the pyrites removed from each sample in the heavy fraction. In many cases ash determinations were made as well. This led to the calculation of the percentages of ash and combustible matter that were removed in the heavy fraction during the density separation.

Experimental

Method D 197-30, of the American Society for Testing Materials[2)], was used to obtain sieving fractions from the pulverized coals. Fractions <325 mesh, not mentioned in this procedure, were also prepared.

All density separations were done with a mixture of carbon tetrachloride and xylene, having a density of 1.450 g/ml. This density was chosen after it was found that at lower densities appreciable quantities of light organic particles will fail to be separated from the heavy, partly or wholly inorganic particles that are removed in the sink fraction. Somewhat higher densities did not influence to a great extent the percentage of a powdered coal sample that would sink.

* The word "pyrites" in this work is intended as a term of reference meaning iron disulfide in the form of pyrite or marcasite.

The fluid mixture used was chosen because sharp separations were more readily obtainable in it than in other mixtures that were tried.

The separations were made with samples of 5 grams of pulverized coal, in 500 ml stoppered conical separating funnels. These pyrex funnels had a generating angle of nearly 17°. After introducing the powder into the funnel, 250 ml of density fluid were added, the funnel stoppered and well shaken, and finally clamped in a vertical position. After one hour the contents were carefully shaken in such a manner that the upper part of the vessel would be well wetted, the floating fraction thoroughly disturbed, but the heavy fraction left essentially undisturbed. After one more hour, this procedure was repeated; the funnel was then left untouched until a clear separation had come about. The first 50 ml of fluid and sediment were drawn off at the bottom and filtered; the weight of the sediment was obtained after drying to constant weight at 100°C. The float fractions were similarly reclaimed quantitatively.

Pyrites determinations were made according to a modification[6] of a method described by Mott[4]. Ash was determined by the method of ASTM D 271-48[3]. Pyrites and ash were determined in samples before a density separation had been made, and in the float fraction after such a separation. The pyrites content and ash content of the sink fractions could then be calculated. (Recovery of the sink fractions from the filter paper for direct determination of these quantities, would have been unsatisfactory because of the small amounts involved.)

In the tabulation of data, "sink loss" represents the percentage of the dry powdered coal that sinks in the density fluid. "Pyrites removal", "ash removal" and "combustible loss" express the percentages of the original pyrites, ash and combustible contents respectively, that are found in the heavy fraction of the density separation.

Description of Samples

Samples from a number of different mines were used. They may be arranged in two groups. The first group, tabulated below, consists of bituminous coals from Pennsylvania and West Virginia. If more than one sample from a mine was used, this is indicated by the number following the name of the mine.

TABLE I

First Group of Coal Samples Examined

No.	Name of Mine	State of Origin	General Classification
1	Williams (2)	West Virginia	Fairmont
2	Rich Hill (2)	Pennsylvania	District No. 1
3	Arkwright	West Virginia	Fairmont
4	Purseglove	West Virginia	Fairmont
5	Rosedale	West Virginia	Fairmont
6	Indian Creek (2)	Pennsylvania	District No. 1
7	Kano	West Virginia	Fairmont
8	Badger	West Virginia	Fairmont
9	Compass	West Virginia	Fairmont
10	Lynn	West Virginia	Fairmont
11	Diamond	Pennsylvania	District No. 1
12	Clymer	Pennsylvania	District No. 1
13	Ebensburg	Pennsylvania	District No. 1
14-16	Composite Samples (3)	-	Run of Mill

The samples of this group were all ground in the same commercial mill. It is probably impossible to obtain powders with the same particle size distribution from different coals, even if the factors that influence the operation of the mill, insofar as they do not stem from the coal, could be kept constant. Furthermore, the properties of the various coals differ widely (grindability, hardness).

Of this group, an average of about 90% of a sample passes a 100-mesh sieve, and nearly 60% passes a 200-mesh sieve.

The second group of samples, identified in Table VI by their states of origin, was a selection of high-sulfur-content coal samples supplied by the U. S. Bureau of Mines.* This group of samples was ground in a laboratory type mill. An average of about 88% of a sample passes a 100-mesh sieve, and about 82% passes a 200-mesh sieve.

Data and Discussion

All experimental data presented are averages of at least two replicate determinations; derived data are based on these averages.

TABLE II

Particle Size Distribution, Percent of Whole Coal Powder

Fraction	Williams	Rich Hill
<325 mesh	36.45	44.30
325-200 "	23.65	24.70
200-100 "	27.95	22.90
100-50 "	11.00	7.13
50-30 "	1.50	.86
30-16 "	.12	.03

TABLE III

Pyrites Percentage in Whole Coal, Sieving Fractions and in Float and Sink Fractions of These Sieving Fractions

	Williams Whole Coal: 1.65			Rich Hill Whole Coal: 1.78		
Sieving Fraction	Whole Fraction	Floats	Sinks	Whole Fraction	Floats	Sinks
<325 mesh	.88	.39	25.2	1.59	.52	24.7
200-325 "	1.80	.29	27.0	1.95	.14	15.5
100-200 "	2.26	.31	27.7	2.60	.18	14.6
50-100 "	2.38	.31	46.6	3.37	.22	40.5

Pyrites content of the sink fractions of the sieving fractions varied from 14.6% to 46.6% (Table III). With the exception of the finest fraction, at least 84.8% of the pyrites of each fraction was found in the corresponding sink fraction (Table IV).

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* Through the courtesy of Mr. R. F. Abernathy and Mr. J. J. Barnes, Central Experiment Station, Region V, U. S. Bureau of Mines, Pittsburgh, Pa.

TABLE IV

Heavy Fractions Data

Fraction	Heavy fraction as % of corresponding sieving fraction.		Percentage of pyrites in a sieving fraction removed in sink fraction.	
	Williams	Rich Hill	Williams	Rich Hill
<325 mesh	1.96	4.47	56.5	68.5
200-325 "	5.67	11.30	84.8	93.7
100-200 "	7.00	16.35	87.3	94.2
50-100 "	7.50	20.70	87.9	94.8

This suggests that a large part of the pyrites in these two powdered coals was present in a comparatively unencumbered state, and that a relatively small part of the total weight of the pyrites was located inside of coal particles or attached to relatively large coal particles. This was borne out by a microscopic inspection of the sink fractions. To this purpose samples of these heavy fractions were embedded in blocks of lucite, which were then ground and polished. Few pyrites particles, >325 mesh, were attached to carbonaceous particles. None were found attached to other inorganic materials.

Computation shows that the sum of the amounts of pyrites that settle in the heavy fractions is in excess of 80% of the pyrites content of the original sample. A density separation removes 86.9% of the pyrites from Williams whole powder, and 90.8% of the pyrites from Rich Hill whole powder.

No reason was found to extend this detailed work to other pulverized coals. However, the separability of the pyrites from other whole coal samples was determined by the density separation method mentioned. The data obtained in these separations, as well as the results of pyrites and ash determinations, and derived data, are given in Tables V and VI. The range of the different removal and loss percentages achieved with these forty-one coal samples at a density level of 1.450, is apparent from the data presented in these tables. Pyrites and ash are in part removed in the sink fraction; this heavy fraction varies from 3.85% to 21.68% of the weight of the original sample. Thirty-two samples had a sink loss of less than 10%.

The percentage of the pyrites that is removed, expressed on the basis of the original pyritic sulfur content, varies from 47% to 91%.

Ash removal percentages vary from 27% to 46%.

Combustible losses in the sink fraction range from 2.6% to 17.4%.

Hardgrove grindability numbers have been tabulated when available. These values, and information of geographic nature have only been given for the better identification of the coals.

The various loss and removal data stem from one separation operation. If the sink fraction is subjected to an additional density separation in a fluid of the same density as previously used, a part of the combustible matter can be reclaimed. This was not systematically investigated. In two cases (samples 1 and 2) the combustible loss could thus be decreased by .7%, however. In these two cases, the limit of separability by physical means, had been approached in one density separation.

It is not likely that many of the samples studied are truly representative

for a coal seam or a mine. The varying conditions under which coal has been formed have caused an infinite number of different results. This makes it difficult wholly to represent the coal of even one bed by a group of samples as limited in number as the group that was studied. In view of the great variety in origin and type of coal in this group of samples, a discussion of averages of results and of correlation data is therefore omitted.

Conclusions

1) Pyrites particles in commercially pulverized coal are largely present as free particles, or as particles that are relatively unencumbered by carbonaceous or other inorganic matter. This is also true for coal pulverized to a somewhat greater degree in a laboratory type mill.

2) Part of the pyrites can be segregated from the pulverized coal by a density fluid. Forty-one samples were studied. At a density level of 1.450, the percentage of pyrites removed varied from 47% to 91%. At the same time, the ash content of the powder was decreased by an amount varying from 27% to 46%. This was accompanied by a loss of combustible matter, ranging from 2.6% to 17.4%.

TABLE V

Results of Density Separations, Ash and Pyrites Determinations; Removal Values and Grindability Data
(First Group of Coals)

Sample Number	Sinks, % of Coal	Pyrites in Whole Coal, %	Pyrites in Floats, %	Pyrites Removal, %	Ash in Whole Coal, %	Ash in Floats, %	Ash Removal, %	Combustible loss, %	Hardgrove Grindability
1	5.74	1.65	.22	87	-	-	-	-	61
1a	5.99	3.20	.52	85	8.54	4.97	42	2.6	65
2	9.98	1.78	.17	91	-	-	-	-	98
2a	10.18	1.98	.22	87	10.33	6.85	34	7.5	98
3	7.24	1.59	.45	72	-	-	-	-	67
4	7.07	1.50	.60	61	-	-	-	-	70
5	7.49	1.95	.47	76	-	-	-	-	75
6	11.88	2.56	.21	93	-	-	-	-	97
6a	10.54	2.08	.24	87	9.43	5.71	40	7.5	100
7	4.23	1.03	.30	70	-	-	-	-	67
8	5.45	1.20	.39	70	-	-	-	-	-
9	4.98	2.55	.51	80	6.68	4.38	34	2.9	63
10	5.81	2.51	.49	80	7.07	4.85	31	3.9	77
11	8.45	3.73	.84	77	8.66	5.10	41	5.4	115
12	9.72	2.32	.64	73	11.08	6.69	40	6.0	104
13	6.35	1.70	.43	75	6.05	4.66	23	5.3	112
14	6.10	2.58	.43	85	7.30	4.99	32	4.1	-
15	5.84	2.40	.47	80	7.48	5.03	33	3.7	-
16	6.93	3.01	.49	84	8.20	4.90	41	4.0	-
Column Averages	7.36	2.20	.43	80	8.26	5.28	35	4.8	

TABLE VI

Results of Density Separations, Ash and Pyrites Determinations; Removal Values
(High-sulfur-content Coals)

Sample Number	State of Origin	Sinks, % of Coal	Pyrites in Whole Coal, %	Pyrites in Floats, %	Pyrites Removal, %	Ash in Whole Coal, %	Ash in Floats, %	Ash Removal, %	Combustible loss, %
20	Illinois	8.45	2.32	1.10	52	7.98	4.89	39	5.8
21	"	8.05	2.04	.67	67	7.57	5.47	28	6.4
22	"	9.98	3.26	1.05	68	8.83	5.88	31	7.7
23	"	9.91	2.63	.97	64	9.86	6.23	37	7.0
24	"	8.90	2.51	.97	61	9.32	6.23	33	6.4
25	"	9.24	2.51	.90	64	9.74	6.73	31	6.9
26	Kentucky	5.45	2.02	.92	55	6.53	4.48	31	2.6
27	"	7.44	2.23	.92	59	8.00	4.49	46	4.3
28	"	3.85	2.04	.99	51	5.26	3.83	27	2.6
29	"	7.73	2.36	1.05	56	7.87	5.07	36	5.4
30	Ohio	6.82	2.56	1.35	47	7.82	5.27	32	4.6
31	"	7.80	3.03	1.01	67	7.88	5.63	29	4.9
32	"	21.68	9.62	3.24	66	12.07	5.69	53	17.4
33	"	17.27	7.82	3.00	61	9.71	5.91	39	14.5
34	"	12.35	5.20	2.15	59	7.56	4.58	39	10.3
35	"	11.53	6.40	2.36	63	9.09	5.00	45	10.4
36	W. Virginia	7.88	3.41	.67	80	9.08	5.91	35	5.2
37	"	6.94	3.18	.62	81	8.51	5.44	36	4.3
38	"	12.40	4.83	.79	72	12.28	6.79	45	7.9
39	"	10.36	2.36	.60	75	10.73	7.49	30	8.0
40	Kansas	8.24	3.28	1.46	55	10.49	6.08	42	4.2
41	"	7.59	3.07	1.39	55	9.56	5.66	41	4.1
Column Averages		9.53	3.58	.96	63	8.90	5.58	37	6.9

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