IRRADIATION DOES NOT ALTER THE PARTICLE SIZE OF COAL

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The size reduction of coal is of considerable interest, both fundamentally and commercially, because it makes a larger surface area available for chemical reaction. Also, several potential coal processes are limited, directly or indirectly, by the abrasiveness of coal or coal ash particles moving at high velocities. For example, blades in a coal-burning gas turbine would probably be subject to less wear whenever agglomeration of the ash from micron size coal is avoided during combustion. Many new uses for coal can be envisioned if micron-size coal can be produced economically.

The irradiation of coal with gamma rays has been reported (3) to result in considerable particle size reduction. On the other hand, many coal irradiations have been made without the investigators noticing any significant particle size reduction, although the effect of irradiation on particle size was not closely examined.

Because of the possible economic significance with respect to the size reduction of coal, the Bureau of Mines began work at the Morgantown Coal Research Center to determine the magnitude of this effect.

Since a considerable number of variables could affect the size reduction of coal particles, a qualitative survey was made first on relatively small samples irradiated at low flux. After successive irradiations gave negative results, quantitative tests were later made on larger samples irradiated at higher flux.

Irradiation of Small Samples at Low Flux. Coals irradiated at low flux included lignite, from the Lehigh bed, Stark County, N. D.; subbituminous B coal, from the Adaville No. 1 bed, Elkol Mine, Wyoming; high-volatile C bituminous coal from the No. 2 bed, Wilmington Mine, northern Illinois; strongly coking high-volatile A bituminous coal from the Sewickley bed, Bunker Mine, Monongalia County, W. Va.; anthracite, from the middle bench of the Bottom Ross Seam, Glen Alden Mine, Wilkes-Barre, Pa.; and an unidentified coking-type bituminous coal.

These coals were irradiated at the Radcell Facility, Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tenn. Approximately 6-gram samples of each of the first five coals were sized and irradiated, with and without predrying, for various periods of time. Also, several size-ranges of one coal, the subbituminous B, were irradiated. The sixth coal, the unidentified coking-type bituminous coal, was irradiated in lump form of 1/4-to-1-inch pieces. All samples were placed in stoppered glass vials and irradiated with a Co-60 source at an hourly gamma dose rate of about 2×10^7 ergs per gram (reference to carbon). (One erg per gram equals 0.0114 roentgen.) Untreated samples of each were retained for comparison. Since only qualitative effects were being determined, no particular care was taken in sampling each lot.

The particle sizes of the irradiated and untreated coal samples were determined by the Palo-Travis sedimentation method (4). This method is accurate to 15 microns for comparing the size distributions of similar samples.

Results of the qualitative tests are shown in Table 1. The variables in this table are (a) ranks of coal from lignite to anthracite; (b) sizes from lumps to 200-230 mesh particles; (c) dried and undried coal; and (d) radiation exposure times of 2 hours to 10 days. In no case was there any evidence of a significant reduction in the size of the coal particles. There is some random scatter of data because of the difficulty of handling small samples of powdered coal without segregation of sizes. However, the difference in size of the irradiated and untreated coal fell within the accuracy of the size-determination method. The coal that had been irradiated in lump form was examined under a microscope but there was no visible evidence of any physical change.

Irradiation of Large Samples at High Flux. Since the preliminary investigation failed to reveal any definite indication of particle size reduction, a quantitative investigation was undertaken. In this work, relatively large amounts of coal were irradiated at very high flux levels and the particle-size distributions of the product were determined by several methods.

Sample Preparation and Irradiation. Three pounds each of lignite from the Lehigh bed, Stark County, N. D., and high-volatile C bituminous coal from the Rock Springs bed in Wyoming were irradiated in separate alloy-steel cylinders. The irradiations were performed at the National Reactor Testing Station, Idaho Falls, Idaho, with spent MTR fuel assemblies as sources of high-intensity gamma radiation (1).

Each sample of coal was pulverized and screened three times on a Rotap shaker by the A.S.T.M. method to insure that the sample was within the size range specified---minus 200 - 230-mesh U. S. Standard Sieve Series. A small sample of minus 90 - plus 120-mesh lignite was also prepared. After sizing, each coal was carefully mixed and quartered into duplicate samples, separately wrapped and placed in identical cylinders. The duplicate samples were prepared so that the irradiated coal could be compared with untreated coal that had received the same preparation and handling procedure. Each cylinder was evacuated, purged three times with helium and evacuated for 3 days to an absolute pressure of 180 microns of mercury. Helium was then admitted into each cylinder until a gage pressure of 2 inches of mercury was attained. The cylinders were then sealed.

The cylinders were irradiated for 308 hours at a flux rate of about 3×10^8 ergs per gram per hour. The average total dosage of each sample was as follows:

High volatile C	-200 + 230 mesh	7×10^{10} ergs $g^{-1}(C)$
Lignite	-200 + 230 mesh	5 ditto
Lignite	-90 + 120 mesh	6 ditto

Methods of Size Analysis and Results. The irradiated and untreated coals were analyzed for particle-size distribution to determine any changes in size because of irradiation. Since there is no widely accepted method of size analysis of coal, the sizes of the irradiated and untreated coal were determined in several different ways. These included the Palo-Travis sedimentation method, a standard sieve analysis using a Rotap shaker, a microscopic method of direct counting, and the Coulter method of analysis.

Figure 1 shows typical particle-size distribution curves for duplicate tests of irradiated and untreated samples of the high volatile C bituminous coal. These curves were obtained by the Palo-Travis sedimentation method (4). As determined from the integrated area below these curves, the average particle sizes of the irradiated and untreated coals were 70 and 74 microns, respectively. This difference in size is not significant. Even if irradiation reduced the size of a small amount of the particles, the curve would "tail-off" much more in the direction of the smaller particle sizes. As can be seen, however, the size distributions of the irradiated and untreated samples are remarkably similar.

TABLE 1. - Results of Irradiating Small Samples of Pulverized Coal

Type of coal	Original size range, U. S. standard sieve [1]	Exposure time, days	Average size by sedimentation method, microns
Lignite, untreated	-90 + 120	0	169
Lignite	-90 + 120	1	189
Lignite	-90 + 120	3	189
Lignite, dried	-90 + 120	1	182
Subbituminous B, untreated	-40 + 45	0	378
Subbituminous B	-40 + 45	3	390
Subbituminous B, dried	-40 + 45	1	343[2]
Subbituminous B, untreated	-90 + 120	0	176
Subbituminous B	-90 + 120	3	169
Subbituminous B, dried	-90 + 120	1	169
Subbituminous B, untreated	-200 + 230	0	81
Subbituminous B	-200 + 230	2 hrs.	81
Subbituminous B	-200 + 230	10	81
Subbituminous B	-200 + 230	1	81
High volatile A, untreated	-90 + 120	0	158
High volatile A	-90 + 120	1	166
High volatile A	-90 + 120	3	161
High volatile A, dried	-90 + 120	1	160
High volatile C, untreated	-200 + 230	0	88
High volatile C	-200 + 230	1	87
High volatile C	-200 + 230	3	88
High volatile C, dried	-200 + 230	1	90
Anthracite, untreated	-90 + 120	0	126[2]
Anthracite	-90 + 120	1	150
Anthracite	-90 + 120	3	151
Anthracite, dried	-90 + 120	1	138
Coking bituminous	lump	10	unchanged

[1] Various coal types of the same original size-range may differ in average size (shown in column 4) because of different methods of screening.

[2] Probably in error; test could not be repeated owing to insufficient sample.

The same equipment used to size the original coal was used to make sieve analyses of the irradiated and untreated coals. The results are shown in Table 2. No significant particle-size reduction is apparent.

TABLE 2. - Size analysis of irradiated and untreated coals by sedimentation and sieve methods

Type of coal	Average size by sedimentation method, microns	Sieve analysis 1/		
		+200	-200 + 230	-230
High volatile C				
Irradiated	70	7.5	82.1	10.4
Untreated	74	11.6	82.0	6.4
Lignite				
Irradiated	99	8.2	80.3	11.5
Untreated	99	7.4	78.4	14.2
		+ 90	- 90 + 120	-120
Lignite				
Irradiated	167	0.8	87.4	11.8
Untreated	166	.5	85.5	14.0

1/ Weight-percent shown with each indicated mesh-size.

A microscope method of size analysis also was used. In this method, the actual number of particles in each size range is counted (2). Table 3 shows a typical size analysis of the high volatile C bituminous coal. The results showed there was no alteration in particle size due to irradiation.

TABLE 3. - Size analysis by microscope count method of irradiated and untreated high volatile C bituminous coal

Particle size, microns	Percentage by count		Percent by volume	
	Irradiated	Untreated	Irradiated	Untreated
0-2	73.90	59.82	0.01	0.01
2-5	21.84	36.42	.15	.31
5-10	.70	.82	.05	.07
10-20	.11	.14	.06	.10
20-40	.40	.42	1.72	2.22
40-60	2.10	1.63	41.46	40.04
60-80	.81	.60	43.79	40.51
>80	.14	.15	12.76	16.74

The Coulter method of analysis was also used to determine the particle-size distributions of the irradiated and untreated Rock Springs coal. The size distributions are shown in figure 2. Again there is no indication of any difference in particle sizes of irradiated and untreated coal. It is interesting to note the similarities of the size distributions determined by the sedimentation method (figure 1) and those determined by the Coulter method (figure 2).

Irradiation of Bituminous Coals of the Same Rank. Although irradiation of coals of different rank did not reveal any indication of significant size reduction, the possibility remained that some other coal within the same rank might be affected by irradiation. The coal previously reported to have been reduced in size by means of irradiation was a high-volatile C bituminous coal from the Kenilworth seam in Utah. Accordingly, samples of the Kenilworth coal and two other bituminous coals of the same class---a low-volatile bituminous coal from the Pocahontas No. 3 bed, W. Va., and a high-volatile A bituminous coal from the Pittsburgh seam, Bruceton, Pa., ---were prepared and irradiated at the National Reactor Testing Station as described previously.

The average total gamma dose given each coal was 5×10^{10} ergs per gram (reference to carbon). Following irradiation the size of each irradiated coal was determined by each of the four methods previously used. In no case was there any indication of size reduction.

A fifth method of size comparison was made with the Kenilworth coal. Part of the irradiated and untreated Kenilworth coal was returned to the supplying organization, the Denver and Rio Grande Western Railroad Company. This company compared the two samples by photographing the coals with an electron microscope at a magnification of 50. Figure 3 shows the electron photomicrographs of the irradiated and untreated Kenilworth coal. The photomicrographs do not reveal any difference in particle size.

DISCUSSION

The tests conducted by the Bureau of Mines show that irradiating coal with gamma rays does not change the size of the particles. Errors due to segregation and sampling of pulverized coal may cause apparent effects that might easily be attributed to irradiation effects. Casual inspection of the data in Table 1, for instance, might lead to a conclusion that irradiation slightly altered the size of anthracite. Subsequent irradiations with careful sampling, however, showed there was actually no significant change in particle size.

Several coals irradiated with neutrons were visually inspected and revealed no apparent change in size, but the induced radioactivity of the ash in the coal precluded more detailed examination.

An attempt was made to measure the increase in hardness of irradiated coals by determining the difference in grindability. Small samples of irradiated and untreated coal were ground in a ball mill for equal periods of time and the size distribution of each coal compared. The accuracy of this method was quite poor, reproducibility of the method being about 10 percent. Within these wide limits, there was no significant difference between grindability of gamma irradiated and untreated coal. The results suggest that if irradiation increases the hardness of coal, the increase in grindability must be less than 10 percent.

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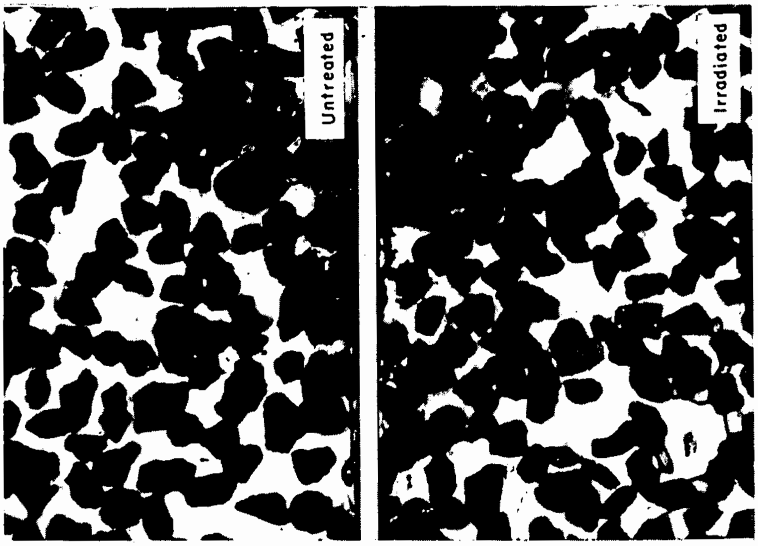
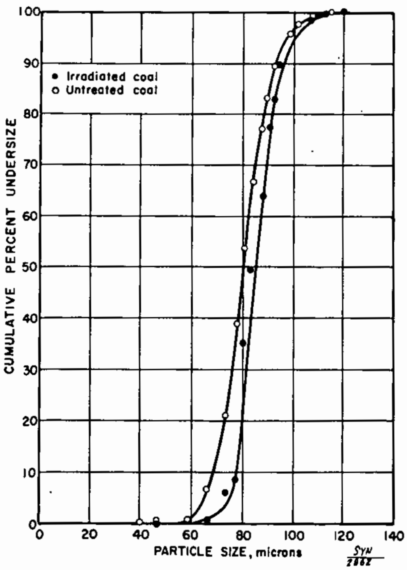


Electron Photomicrographs of Untreated and Irradiated Kenilworth Coal

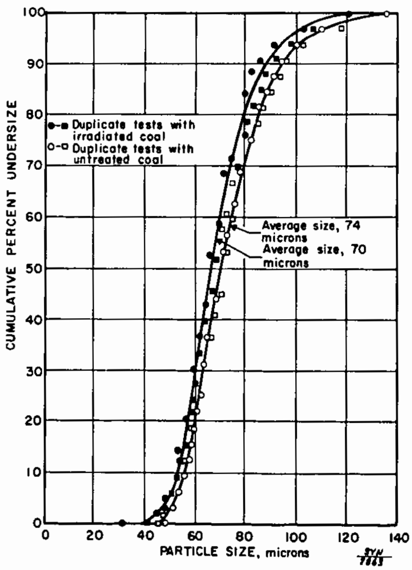
Composite Photograph Courtesy of the Denver and Rio Grande Western Railroad Co.

FIGURE 3



SIZE DISTRIBUTION CURVES OF IRRADIATED AND UNTREATED HIGH VOLATILE C BITUMINOUS COAL, AS DETERMINED BY THE COULTER METHOD

FIGURE 2



TYPICAL SIZE DISTRIBUTION CURVES OF IRRADIATED AND UNTREATED HIGH VOLATILE C BITUMINOUS COAL, AS DETERMINED BY THE PALO TRAVIS SEDIMENTATION METHOD

FIGURE 1