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EXPERIMENTAL TESTING OF THE DOUBLE-ROLL CRUSHER
FOR BREAKING SILICON CARBIDE COATINGS ON
UNIRRADIATED FT. ST. VRAIN FUEL PARTICLES

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ABSTRACT

Testing of a 4-inch diameter double-roll crusher for crushing Ft. St. Vrain TRISO particles has been completed. The effect of feed rate, roll speed, roll clearance, and carbon particle interference on crushing efficiency and crushed particle size distribution was determined. Wear rates of the rolls were not determined.

SUMMARY

During reprocessing of Ft. St. Vrain fuel, the silicon carbide coatings must be removed from the fuel particles to expose the thorium and uranium carbides for burning and dissolution. Both jet breakers and double-roll crushers are being considered for the processing.

The crusher tested has two rolls which are 4 inches in diameter and 1.5 inches long. The roll gap and roll speed were adjustable. The feed material was + 35 U. S. Mesh fertile particles from scrap Ft. St. Vrain fuel rods.

The test results showed that: (1) at a roll speed of 40 rpm, the 4-inch diameter roll crusher crushed 2.3 times more material than the required demonstration plant rate, (2) the roll crusher produced a satisfactory secondary burner feed at roll clearances between 0.005 and 0.018 inches, (3) the amount of unbroken particles in the crusher product was insignificant as long as the roll clearance was smaller than any of the particle diameters, (4) the crusher crushed graphite as large as ~ 0.050 inches in diameter, and (5) the feed rate had no appreciable effect on crushed product character.

Insufficient material has been crushed with the pilot-plant crusher to determine reliable wear rates.

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EXPERIMENTAL TESTING OF THE DOUBLE-ROLL CRUSHER
FOR BREAKING SILICON CARBIDE COATINGS ON
UNIRRADIATED FT. ST. VRAIN FUEL PARTICLES

I. INTRODUCTION

During head-end reprocessing of Ft. St. Vrain fuel, silicon carbide coated fissile and fertile particles (Figure 1) are separated from the crushed graphite matrix by burning the graphite in a primary fluidized-bed burner. The fissile particles (initially containing Th and U) and the fertile particles (initially containing only Th) are then classified. Each particle fraction must then be crushed to expose the inner carbon layers and the uranium and/or thorium carbide kernels prior to batchwise secondary burning and leaching.

Two methods have been considered for breaking the silicon carbide coatings: (1) double-roll crushing and (2) fluid-bed jet breaking. Roll crushers have the capacity to crush the coatings at the required throughput rates, but the roll tolerances and gap settings require close monitoring. Wear, misalignment, or changes in the gap setting on the order of three or four thousandths of an inch could result in large quantities of either unbroken or pulverized particles.

Figure 1. Ft. St. Vrain Fertile Particle

Close roll-crusher tolerances could be difficult to monitor and maintain in a "hot" cell. The roll crusher requires a motor, bearings, lubrication, and several moving parts, all of which could create serious problems for remote operation and maintenance.

II. ROLL CRUSHER EQUIPMENT AND PROCEDURES

The roll crusher (Figure 2) used for the experimental testing utilized two cylindrical rolls, 4 inches in diameter and 1.5 inches long. The clearance between the rolls was adjustable from 0.00 to 0.125 inches. The initial gap adjustment was set by a thickness guage which puts no load on the rolls; the clearance was checked under a heavy load by running a small piece of lead solder(0.060 inch diameter) between the rolls and measuring the thickness of the solder. The crusher was driven by an electric motor coupled to a worm gear speed reducer. The roll speed was variable from 0 to 200 rpm. The feed system consisted of a hopper, which flood-fed the crusher by gravity. If a controlled feed rate was desired, the feed rate to the hopper was regulated by a stopcock valve attached to a second hopper.

The run procedure was to set the roll clearance and roll speed and then check the roll clearance with solder. The feed was introduced and the crusher allowed to run until all of the particles were crushed. Any material adhering to the rolls was removed by scrapers and a small air purge was drawn through the crusher by vacuum to prevent dust release. The roll gap was again checked with solder after the run to assure no change had occurred. The time required for the feed to be crushed was recorded to determine the actual crushing rate. The crusher product was screened and weighed to determine its mass mean particle diameter (MMPD). To determine the amount of unbroken particles in the crusher product, the material was leached with thorex solution, dried, and air classified to separate the hulls from the whole particles.

The feed material for all of the runs was + 35 U. S. Mesh fertile particles obtained from scrap Ft. St. Vrain fuel rods, and the batch feed size was 50 grams.

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Figure 2. Experimental Double-Roll Crusher

III. EXPERIMENTAL RESULTS

The roll crusher performed satisfactorily. All 40 runs were successfully completed except two. Runs 6 and 23 failed because the crusher stalled as a result of the drive unit not having sufficient power at 20 rpm. A summary of test results is given in Table I.

During the first 22 runs, the roll clearance was not measured under a heavy load by passing solder between the rolls nor was the amount of unbroken particles determined. The first five runs tested the effect of roll clearance on product size; the results are shown in Figure 3. Runs 6 through 11 tested various roll speeds and Runs 12 through 22 tested various feed rates. The results of these runs are given in Figures 4 and 5, respectively.

Runs 23 through 27 were made to determine the crusher capacity as a function of roll speed during flood-feeding. These results are shown in Figure 6. The remaining 12 runs were made to more carefully test the effect of roll clearance on product size and to determine the amount of unbroken particles in the product as a function of roll clearance. The effect of roll clearance on product size is shown in Figure 3 with the results of Runs 1 through 5. The line at the far left in Figure 3 is the roll clearance as determined by use of a thickness gauge (no load), and the line at the far right was determined using solder (heavy roll loading). The weight percent of + 35 U. S. Mesh material and whole particles in the crusher product is shown as a function of roll clearance in Figure 7.

In addition to the 40 parametric runs, tests were made to determine the maximum size of graphite the crusher would accept as a function of roll clearance. All of the graphite pieces which were smaller than 14 U. S. Mesh (0.046inch) passed through the crusher. The crusher would accept only part of the graphite in the - 12 + 14 U. S. Mesh (0.046 to 0.055 inch) size range. Changing the roll clearance from 0.002 to 0.024 inch did not cause a significant increase in the size of graphite accepted by the crusher.

TABLE I

SUMMARY OF RESULTS OF ROLL CRUSHER TESTS

Run No.	Roll Clearance, in.		Roll Speed, rpm	Feed Rate, grams/min	Product Size		
	Thickness	Crushed(b)			MMPD,	+ 35 U. S. Mesh,	Unbroken(b),
	Gauge	Solder			inch	wt%	wt%
1	0.002		100	130	0.00639	0.63	
2	0.008		100	130	0.00813	0.74	
3	0.012		100	130	0.01049	0.37	
4	0.018		100	130	0.01530	14.68	
5	0.024		100	130	0.02054	90.61	
6(a)	0.0012		20	130	---	---	
7	0.0012		40	130	0.01027	0.12	
8	0.0012		80	130	0.00958	0.13	
9	0.0012		120	130	0.00899	0.00	
10	0.0012		140	130	0.00873	0.00	
11	0.0012		180	130	0.00837	0.00	
12	0.0012		100	50	0.00959	0.10	
13	0.0012		100	80	0.00943	0.13	
14	0.0012		100	160	0.00886	0.12	
15	0.0012		100	190	0.00908	0.25	
16	0.0012		100	225	0.00912	0.38	
17	0.0012		100	130	0.00821	0.10	
18	0.0012		100	50	0.00923	0.00	
19	0.0012		100	80	0.00853	0.00	
20	0.0012		100	160	0.00866	0.00	
21	0.0012		100	190	0.00845	0.00	
22	0.0012		100	225	0.01053	0.13	

TABLE I (continued)
SUMMARY OF RESULTS OF ROLL CRUSHER TESTS

Run No.	Roll Clearance, in.		Roll Speed, rpm	Feed Rate grams/min	Product Size		
	Thickness Gauge	Crushed(b) Solder			MMPD, inch	+ 35 U. S. Mesh, Unbroken(b) wt%	wt%
23(a)	0.011	0.015	20	---	---	---	---
23(a)	0.011	0.015	20	---	---	---	---
24	0.011	0.015	40	176	0.0114	0.34	0.10
25	0.011	0.015	60	375	0.0116	0.20	0.12
26	0.011	0.015	80	546	0.0108	0.20	0.11
27	0.011	0.015	100	625	0.0108	0.24	0.10
28	0.006	0.010	40	74	0.0072	0.10	0.02
29	0.008	0.012	40	75	0.0080	0.10	0.02
30	0.010	0.014	40	78	0.0083	0.10	0.04
31	0.011	0.015	40	75	0.0092	0.10	0.03
32	0.013	0.016	40	76	0.0106	0.16	0.02
33	0.014	0.017	40	73	0.0124	0.40	0.24
34	0.015	0.018	40	74	0.0134	0.51	0.37
35	0.016	0.019	40	77	0.0142	1.42	0.76
36	0.017	0.020	40	75	0.0152	1.83	0.89
38	0.018	0.021	40	77	0.0175	40.54	7.78
39	0.019	0.022	40	71	0.0178	45.51	10.44
40	0.020	0.023	40	73	0.0187	56.62	36.04

(a) The crusher drive did not have sufficient power at 20 rpm and the crusher stalled.

(b) This data not taken for Runs 1-22.

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Figure 3. Effect of Roll Clearance on Crusher Product Size

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Figure 4. Effect of Roll Speed on Crusher Product Size

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Figure 5. Effect of Feed Rate on Crusher Product Size

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Figure 6. Effect of Roll Speed on Roll Crusher Capacity

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Figure 7. Effect of Roll Clearance on Percent of + 35 U.S. Mesh and Unbroken Particles in Roll Crusher Product

IV. DISCUSSION OF RESULTS

As expected, the product MMPD is a strong (almost linear) function of roll clearance as shown in Figure 3. The average product size for most of the settings is 1 to 3 thousandths of an inch smaller than the thickness gauge roll clearance. The two lines representing data points for Runs 28 to 40 show that there is a change in roll clearance of about 0.003 inch when a heavy load is put on the rolls. The actual roll clearance during crushing was not determined, but the load on the rolls was definitely less than when the solder was being crushed and more than with the thickness gauge. For the purposes of this report, it will be assumed that the actual roll clearance was midway between the two lines shown on Figure 3. Experimental secondary burner tests at General Atomic have shown that an average burner feed size of less than 60μ (0.0024 inch) results in particle sintering in the bed. The results in Figure 3 indicate that all of the roll clearances tested would produce burner feed which is satisfactory.

The product MMPD decreased slightly with increasing roll speed as shown by Figure 4. As the roll speed increased, the particles were apparently subjected to a more sudden and violent force which caused a more complete breaking of the particles.

The feed rate did not affect the product MMPD, as Figure 5 shows. The solid line through the data is a linear, least-squares curve. Statistical evaluation of the data indicates there is no significant effect of feed rate on product MMPD at the 95% confidence level.

The HTGR Hot Demonstration Plant processing rate of 12 blocks of Ft. St. Vrain fuel per day corresponds to a fertile particle processing rate of 76 grams per minute. The results presented in Figure 6 show that even at 40 rpm (the minimum roll speed at which the drive unit has enough power to run the crusher) the crushing rate was 176 grams per minute. Extrapolation of the results indicate that a roll speed as low as 20 rpm would probably have the necessary 76 grams per minute capacity for the demonstration plant.

The roll crusher is very effective in crushing the particles as long as the roll clearance remains smaller than the particle diameter as shown in Figure 7. However, as the roll clearance exceeds the particle size, the number of unbroken particles in the product rises exponentially. The figure also shows that although the + 35 mesh fraction of the product is not an absolute measure of the amount of unbroken particles, it is a good relative measure since all of the feed particles were larger than 35 mesh. The tests also showed that the maximum graphite particle size (approximately 0.050 inch) which 4-inch diameter rolls will crush is nearly independent of roll clearance in the range tested (0.002 to 0.024 inches).

Since only 16 kilograms of fertile particles have been crushed in the pilot-plant double-roll crusher, reliable wear data were not determined.

V. CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

- (1) At a roll speed of 40 rpm, the 4-inch diameter roll crusher will crush 2.3 times more material than the required demonstration plant rate of 76 grams per minute.
- (2) The roll crusher will produce a satisfactory secondary burner feed with roll clearances between 0.005 and 0.018 inches.
- (3) As long as the roll clearance is less than any of the particle diameters, the amount of whole particles in the product is insignificant.
- (4) The 4-inch diameter roll crusher will accept particles as large as 0.050 inches in diameter.
- (5) The roll speed has only a slight effect on product size. To minimize wear, the roll speed should be kept as slow as required plant throughput will allow.
- (6) The feed rate does not appreciably affect the crushed product size.

Recommendation:

- (1) Reliable wear rate data for the double-roll crusher should be obtained as soon as possible.

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