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Fuel Pulverizing Studies

FUEL PULVERIZING STUDIES

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Walter John Risley, Jr.

ENTITLED "FUEL PULVERIZING STUDIES."

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Chemistry.

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Instructor in Charge

APPROVED: W. A. Noyes

HEAD OF DEPARTMENT OF Chemistry

TABLE OF CONTENTS

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Acknowledgment

This investigation was carried on at the University of Illinois and in the laboratory of the McLaughlin Coal Reduction Company, of Decatur, Illinois, during the collegiate year 1919-1920, under the direction of Professor S. W. Parr. The author takes this opportunity to express to Professor Parr his sincere appreciation of the valuable help so freely given during the investigation. The author also wishes to thank Mr. Ollison Craig, the Company's Chief Engineer, and Professor Washburn and Professor Parmelee of the Department of Ceramic Engineering for their suggestions and the use of machinery and equipment.

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FUEL PULVERIZING STUDIES.

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I. Introduction.

1. Purpose of the Investigation.

The purpose of this investigation has been two-fold: (a) to determine the effect of different moisture contents on the cost of pulverizing fuels; and (b) to determine whether or not it was practicable to pulverize low-grade fuels, such as Lignite and Peat, with a high residual moisture content.

A search of technical literature failed to reveal records of any work that had ever been done on either of these points. The literature of fuel pulverizing is practically limited to the last few years, and records of quantitative experimental work are few. It was felt that companies manufacturing machinery and equipment for pulverizing fuel might be able to throw some light on the subject and the author corresponded with the Allis-Chalmers Mfg. Co. of Milwaukee, Wis.; the Raymond Bros. Impact Pulverizer Co. of Chicago; the Fuller-Lehigh Co. of Fullerton, Pa.; and the Fuller Engineering Co. of Allentown, Pa. All these were quite willing to co-operate in giving such information and opinions as was in their power.

They all unite in recommending that the coal be as dry as possible to give the best results in pulverizing and burning; that is, it should in general be dried down to less than 1½ % moisture before pulverizing. This applies to bituminous and higher ranks of fuel. With all these companies this recommendation seemed to be the result of long experience, in which they

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found that better results were obtained with dry coal, rather than the result of any quantitative tests carried out under comparable conditions with a view of determining the effect of moisture content of pulverizing costs. It was therefore deemed advisable to attempt to determine this effect quantitatively. There further seemed to be the opinion that the lower grades of fuel, which normally have a much greater moisture content, should be no exception to the rule that the fuel should be as dry as possible; and the possibility of leaving a considerable fraction of the original moisture in Lignite and Peat was therefore investigated, with a view to cutting down the disproportionate drying capacity considered necessary in a plant handling Lignite or Peat.

2. Outline of Present Investigation.

1. Samples were selected from each of a number of ranks of fuels to be typical in each case of the grade used in the pulverized form.

2. Each sample was divided into a number of portions, according to the original moisture content, each portion being air-dried to a different moisture content.

3. The various samples were pulverized in pebble jars.

II. Experimental.

1. Selection and Preparation of Samples.

In order to make the results of practical application, it was necessary that the samples selected for the work should be

typical in each case of the grade of fuel used for pulverizing. Details of the samples are shown in Table I.

TABLE I.

Showing Details of Samples Selected.

Fuel.	County.	Town.	Grade.	Company.
Pittsburgh Bituminous	Allegheny	Bruceton	Lump	Bureau of Mines, Experimental Mine
Kentucky Bituminous	Bell	Edgewood	Nut	Fort Wayne Rolling Mill Corporation
Illinois Bituminous	Macon	Decatur	Slack	Macon County Coal Co.
No. Dakota Lignite	Burleigh	Wilton	Lump	Washburn Lignite Coal Co.
Minnesota Peat	St.Louis	Hibbing	----	Supt. State Mines.

The moisture and ash contents of these samples are shown in Table II. Other analytical values for the samples are not given as they were not considered pertinent to this investigation.

TABLE II.

Showing some analytical data on samples selected.

Sample	Moisture when received about	Dry Ash
Pittsburgh Bituminous	1.5 %	3.74 %
Kentucky Bituminous	1.5 %	8.96 %
Illinois Bituminous	10.0 %	18.66 %

TABLE II.

Showing some analytical data on samples selected.

Sample	Moisture when received about	Dry Ash
North Dakota Lignite	38.0 %	8.70 %
Minnesota Peat	75.0 %	10.89 %

The Pittsburgh Bituminous coal is representative of the class of coal used in the Pittsburgh steel district in the pulverized form, a high-grade, low-ash coal being required for all steel work; and the Kentucky Bituminous coal is typical of the fuel used in the steel mills of the Middle West, this particular sample of coal having come from the mine that supplies the Fort Wayne Rolling Mill Corporation with fuel for this prupose. The Illinois Bituminous coal, on the other hand, is typical of a low-grade, high-ash slack used in the pulverized form for firing boilers, while the Lignite and the Peat are typical of those ranks of fuel.

Considerable difficulty was experienced in drying the different portions of each sample down to different moisture contents, so that the range of moisture contents would be uniform between the dry portion and that with the highest residual moisture. Various methods of determining the moisture content of each portion before and after the drying, were tried. The sampling for this had to be very quickly done, since a short exposure would change the moisture content rapidly, especially when the portion was hot. Riffling was found to take some time, and was accompanied by such a loss of dust that appreciable errors were introduced. The most satisfactory method was found to be to mix the portion thoroughly,

and scoop out a sample of about 100 g. for a moisture determination. All samples had been crushed through jaw-and roll-crushers before drying.

The entire sample was sampled for moisture content, and was then divided into from two to four portions (depending on the original moisture content), each of which was weighed out on a shallow tared galvanized iron pan about twenty inches square. The drying was carried out in a large box-type air-drying oven, which exhausted to a flue. The air-intake at the bottom was heated by a Bunsen burner, and the intake temperature was controlled carefully, so that the coal never attained a temperature above 105° C. There was thus no decomposition of the sample. The moisture content was determined from time to time by the loss of weight in pan and coal, as weighed on a solution scale, and when the desired moisture content had been reached, the portion was sampled to check this value, and the coal put up in ground-glass-stoppered bottles.

2. Results of Efforts to Determine the Effect of Varying Moisture Content on Pulverizing Costs.

For the pulverizing, five one-gallon stoneware pebble jars were obtained from the Maurice A. Knight Co., Akron, Ohio. Pebble charges were made as nearly uniform as possible, 2500 grams being used in each jar, and the pebbles sized as closely as possible. One of the ball-mills in the Glaze Preparation Room of the Ceramics Building was used, the mill being regulated to a speed of approximately 90 r.p.m. A five-figure revolution counter was connected to the shaft of the mill, and each charge was run a certain number of revolutions rather than a certain length of time.

It might be argued that the results of these tests would be of no practical value, simply from the fact that they were being run in a "batch" type of mill, whereas most pulverizing mills have an arrangement for taking off the fine material as fast as it is formed. However, it was not expected that the results could be compared directly to any type of commercial mill. All that was desired was that the results be comparable one with the other, and it was expected that the same ratios between results would be applicable to commercial operating conditions and machinery.

For the dry portion of each sample, the number of revolutions necessary to pulverize the portion to a fineness of about 80-85% through a 200-mesh testing sieve was determined. Then each portion, with the same weight as a charge, was run at the same time for the determined number of revolutions. It was believed that all conditions were constant for each portion, and it was expected, from the generally established opinion previously mentioned, that the fineness of grinding would decrease with an increase in the moisture content, for the same number of revolutions, and consequently for the same amount of work performed. Then, when percent through a 200-mesh sieve was plotted against the moisture content, the resulting curve was expected to give a quantitative relation between moisture content and fineness, for a given amount of work done. In the first trial, different portions of the same sample were run simultaneously in different jars. The results, as shown in Table III, did not bear our the expectations.

TABLE III.

Showing data on the first pulverizing trials.

Sample Wt. Charge No. Rev.	Moisture Content of Various Portions; Fineness through 200-mesh, Various Portions.					
Pittsburgh Bituminous, 500 grams, 11,000 rev.	Moisture	0.4 %	1.4 %			
	Fineness	86.3 %	84.0 %			
Kentucky Bituminous, 500 grams, 11,000 rev.	Moisture	0.3 %	1.3 %			
	Fineness	73.1 %	75.0 %			
Illinois Bituminous, 500 grams, 11,000 rev.	Moisture	0.8 %	1.7 %	3.2 %	3.5 %	5.6 %
	Fineness	80.2 %	96.6 %	88.1 %	95.5 %	92.9 %
No. Dakota Lignite, 500 grams, 8,700 rev.	Moisture	8.4 %	12.1 %	14.8 %	21.8 %	
	Fineness	70.5 %	78.2 %	80.9 %	58.6 %	
Minnesota Peat, 300 grams 7,000 rev.	Moisture	9.3 %	12.5 %	17.3 %	25.3 %	
	Fineness	68.4 %	56.7 %	47.3 %	43.9 %	

From this table, it will be seen that the results are not at all concordant, except in the cases of the Pittsburgh Bituminous and the Peat. A careful examination of the insides of the five pebble jars showed that no two of them had exactly the same inside diameter or length. It had previously been noticed that Jar #2 was considerably larger inside, and this jar was not used after the first run, except for trial purposes on other samples.

It was concluded that the discrepancies in the results must have been due to variation in the inside measurements of the jars, and it was decided to repeat the trials, running the different

portions of each sample in the same jar, successively. The results obtained on the different portions of a given sample should then be comparable, since there would be no variation in jar measurements, no variation in sizes of pebbles, etc. The results of this trial are shown in Table IV.

TABLE IV.

Showing the results obtained on the second pulverizing trial.

Sample Wt. Charge, No. Rev.	Moisture Content of Various Portions; Fineness through 200-mesh, Various Portions.				
Pittsburgh Bituminous, 500 grams, 12,000 rev.	Moisture	0.4 %	1.4 %		
	Fineness	90.5 %	90.1 %		
Kentucky Bituminous, 500 grams, 12,000 rev.	Moisture	0.3 %	1.4 %		
	Fineness	89.6 %	90.4 %		
Illinois Bituminous, 500 grams, 12,000 rev.	Moisture	0.8 %	1.9 %	3.7 %	5.7 %
	Fineness	87.7 %	90.4 %	88.9 %	83.0 %
No. Dakota Lignite 500 grams, 10,000 rev.	Moisture	9.0 %	15.2 %	17.8 %	
	Fineness	78.7 %	73.2 %	55.3 %	
Minnesota Peat, 350 grams, 6,575 rev.	Moisture	9.2 %	12.8 %	15.3 %	24.1 %
	Fineness	76.8 %	63.7 %	46.8 %	38.0 %

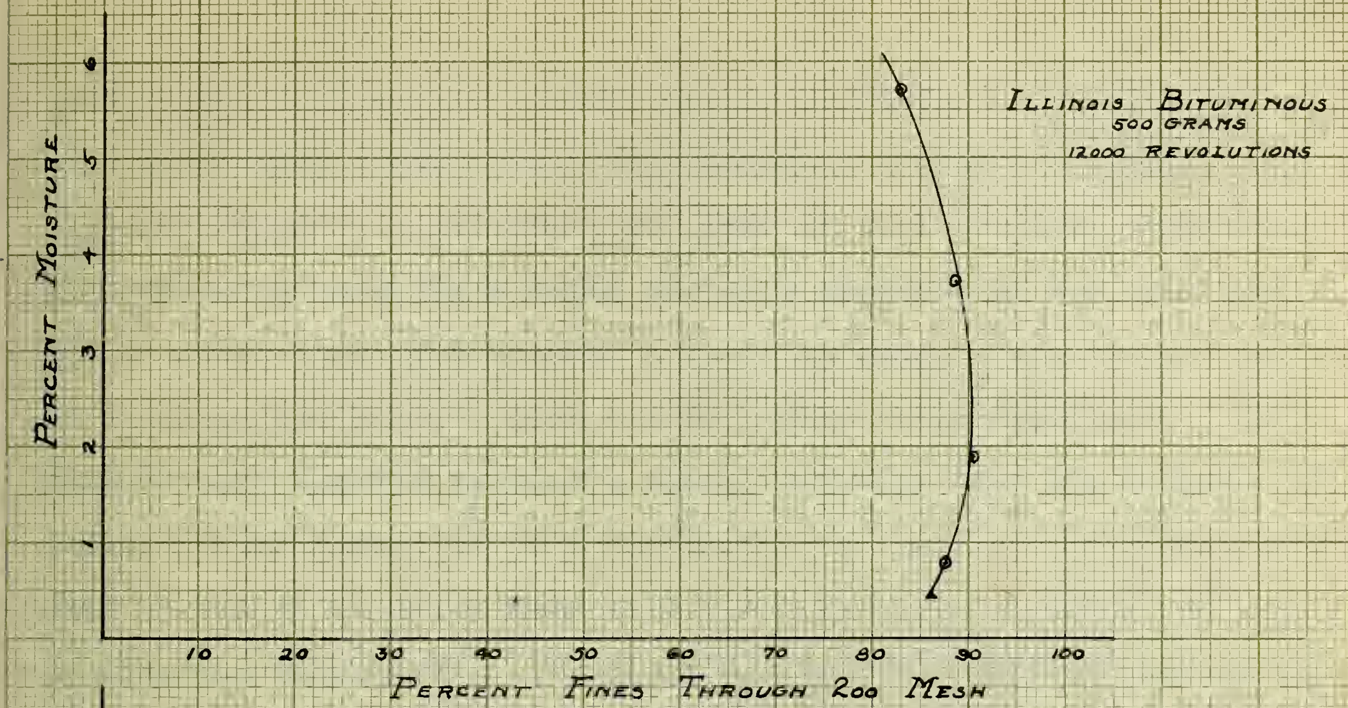
It will be seen from the table, that even with added precautions taken to insure uniform conditions, the results are not in general comparable. It was concluded that the difference in pulverizing cost of the portions of Bituminous coals with varying

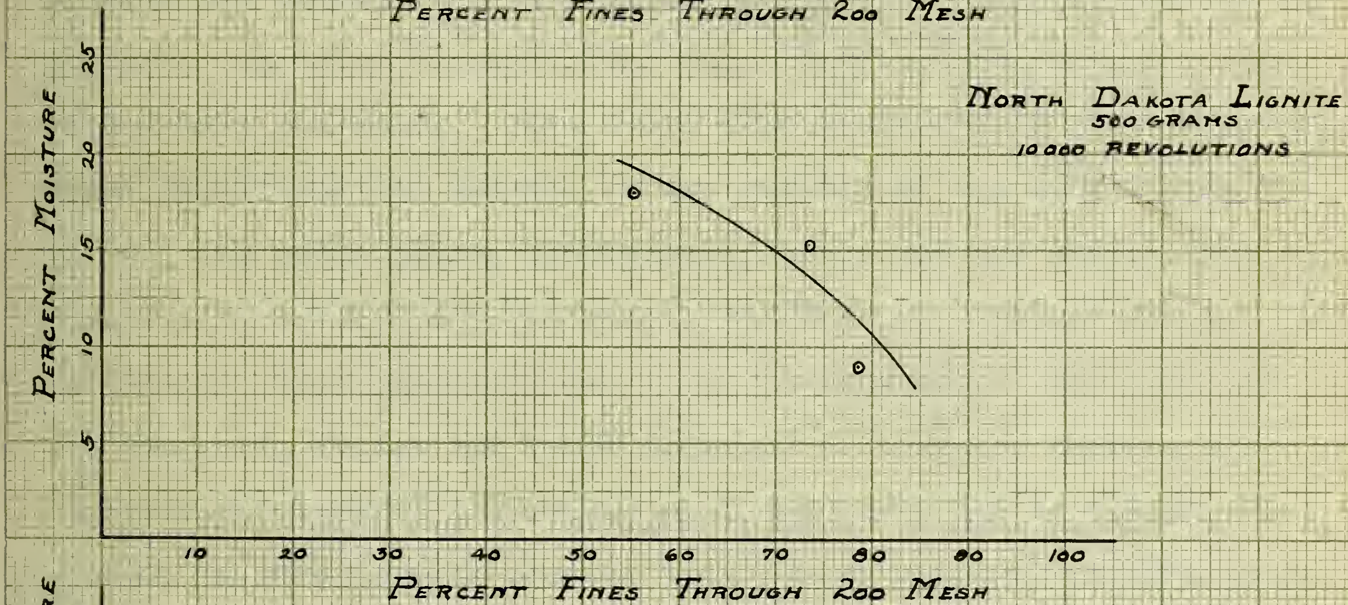
moisture content was not sufficient to show up through the cover of the small variables which evidently enter the work. Under these variables might be included abrasion of the jar, variation in sampling, etc. It is seen that in the two cases where there was a wide range in the moisture contents - Lignite, with a range of 8 %, and Peat, with a range of 15 %, the differences do show up over the variables, although evidently variables have had the effect of making the decrease in fineness with increased moisture decidedly irregular.

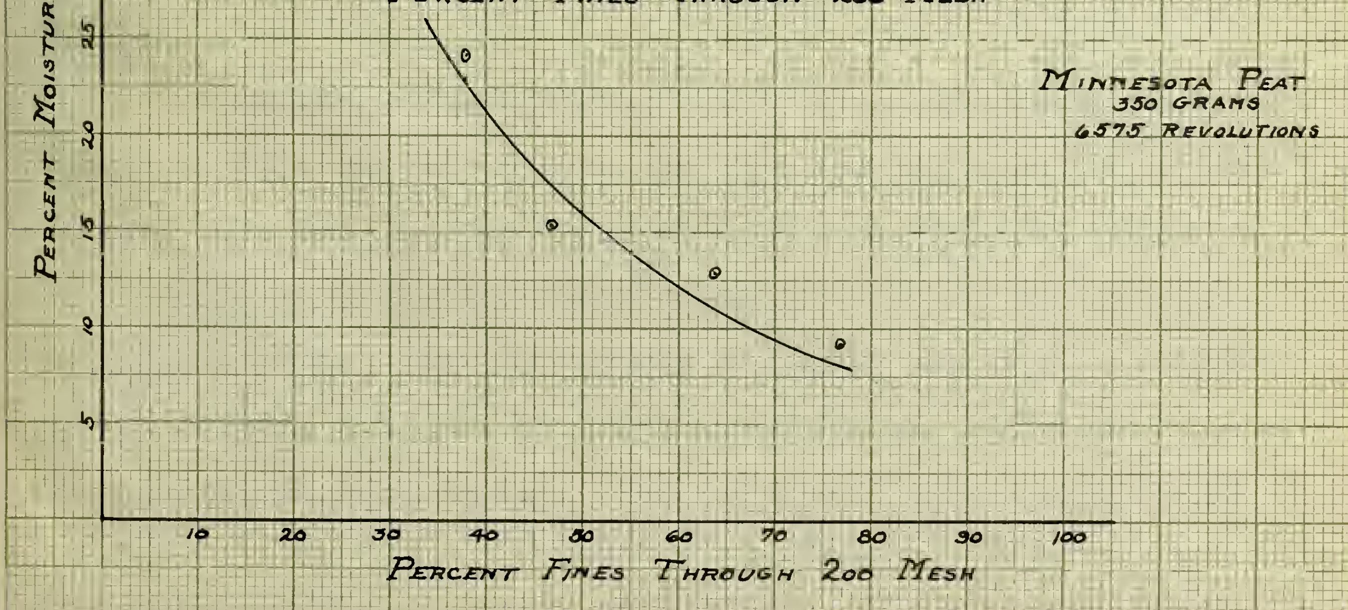
The accompanying graph shows moisture content plotted against fineness for the Illinois Bituminous, the North Dakota Lignite, and the Minnesota Peat, the values being those obtained in the second pulverizing trials as shown in Table IV. The irregularity is easily seen, but a critical study of the points as plotted shows that there is probably a moisture content zone of maximum efficiency. It will be noticed that, although the general trend of the curves is downward, there is a rise with the Illinois Bituminous curve and then a drop, and an indication of a similar tendency with the other two curves. This would seem to indicate that there is nothing gained by drying the Bituminous coal below 2 % moisture, and that the best point for the other two fuels lies considerably above that. Further investigation along this line would be very desirable.

3. Results of Special Work on Lignite and Peat.

It will be noticed in Tables III and IV, that Peat and Lignite portions with moisture as high as 25.3 % and 21.8 % respectively, were pulverized. The second purpose of this investi-


Illinois Bituminous
500 Grams
12000 Revolutions
Percent Moisture
1
2
3
4
5
6
10
20
30
40
50
60
70
80
90
100
Percent Fines Through 200 Mesh


North Dakota Lignite
500 Grams
10000 Revolutions
Percent Moisture
5
10
15
20
25
10
20
30
40
50
60
70
80
90
100
Percent Fines Through 200 Mesh


Minnesota Peat
350 Grams
6575 Revolutions
Percent Moisture
5
10
15
20
25
10
20
30
40
50
60
70
80
90
100
Percent Fines Through 200 Mesh

gation was to determine whether or not it would be practicable to pulverize these fuels with a high residual moisture content. In a plant designed to pulverize 200 tons of fuel per day, provision is ordinarily made for a drier having a capacity of ten tons per hour, drying from 10 % down to 1 %, or an evaporation of 0.9 ton of moisture per hour. Such a drier costs about $8,000.00. If Lignite were handled in such a plant, assuming that the Lignite contained an average of 30 % moisture as it came to the plant, and that it was to be dried down to 5 % (it is quite difficult to dry Lignite any below this, as a disproportionate amount of heat is required), the driers in the plant would have to evaporate 2.5 tons of moisture per hour. This would make necessary an investment of about $16,000.00 for driers, to say nothing of the extra space required, the extra labor, maintenance, etc.; and any practicable proposition which would materially reduce this, without unduly increasing other expenditures, would be welcomed. The shops of the Missouri, Kansas and Texas Railroad at Parsons, Kansas, were equipped for burning pulverized coal, and they had to abandon an attempt to burn Lignite because their drier capacity was not great enough.

In this investigation, the Lignite samples as shown in Table IV, were run in the same jar that the Illinois Bituminous samples were run, so that at least some idea might be gotten as to the comparison in cost between wet and dry Lignite and dry Bituminous coal. The same weight of charge was used, although the Bituminous coal was run 12,000 revolutions, while the Lignite was run 10,000 revolutions. The Bituminous sample with 0.8 %

moisture was pulverized to 87.7% through 200-mesh; the Lignite with 9.0 % to 78.7 %; and the Lignite with 17.8 % to 55.3 % through 200-mesh. The fineness to which a fuel should be pulverized for maximum efficiency for any given type depends on the specific gravity of the material, and since the specific gravity of Lignite is considerably lower than that of Bituminous coal, and that of Peat considerably lower than Lignite, a range of comparison representing equivalent efficiencies for these three types would seem to be for Bituminous coal 80-85% through 200-mesh, for Lignite 70-75 %, and for Peat 55-70 %. This, it is assumed, would represent a condition sufficiently fine to insure particles light enough to be carried in the air current with the same ease in each case. It can, therefore, be seen from the curves on Page 9-A that whereas the range of moisture content giving maximum efficiency for Bituminous coal is below 6 %, the range for Lignite is below 16 %, and that of Peat below 15 %. The range of such tests should be extended, and the ranges here indicated should be repeated a sufficient number of times to establish a certainty for these values. The author expects to be able to contribute to these ends in a short time, having available a carload of Lignite.

III. Summary and Conclusions.

1. It was found as a result of the experiments undertaken that a differentiation as to the factor for percentage of fineness over small ranges of moisture values was obscured by reason of other variables inherent in the conditions formulated.

2. For a fair interpretation of the values obtained, it is

proper to recognize different percentages of fineness for variations in specific gravity. That is, a recognition of lower percentages in the case of those types having lower specific gravities.

3. So far as an interpretation of the results here obtained is concerned, the work indicates that the highest moisture content for efficient pulverizing with Bituminous coals is about 6 %; that with Lignite about 16 %; and that with Peat about 15 %. With these values as the maximum for each type, the desired fineness may be obtained with unit grinding. Further work in confirmation of the trend of the curves as generally indicated by this investigation would be desirable.