A STUDY OF THE EFFECTS OF METHANOL AND WATER
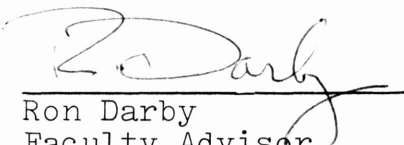
ON THE FRIABILITY OF LIGNITE

by

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ABSTRACT

A Study of the Effects of Methanol and Water
on the Friability of Lignite. (April 1979)
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A study of the effects of methanol and water on the
friability of lignite was made in an effort to quantify
the extent of the effects and compare the utility of the
two liquids. The friability of the lignite will be an
important factor in the design of future coal processing
plants, because the capacity and energy requirements
of size reduction facilities is dependent on this quantity.

Studies of the dry grinding characteristics of
various lignite samples was made by using a modified form
of the Hardgrove Grindability Test. In addition, the wet
grinding and blending of lignite was studied by preparing
methacoal and water slurries in a Waring blender and
measuring the power consumption and the degree of size
reduction. Qualitative observations were made concerning
the reaction between dried lignite and methanol, and also
the qualities of methacoal slurries compared to water
slurries.

The results were inconclusive because the limited

number of measurements required a cautious interpretation of results. The friability of lignite, as measured by dry grinding, was sometimes enhanced by methanol, but some tests indicated a decrease. The blending tests showed that the degree of size reduction was approximately the same whether methanol or water slurries were blended. However, the power requirements for blending methacoal decreased, over a period of time, to a level lower than that required for blending an equivalent water slurry. More extensive study along the lines described herein was recommended to increase the reliability of results.

ACKNOWLEDGEMENTS

I am grateful to many people for their help in this research effort. Dr. Ron Darby served as Faculty Advisor and steered me through the program. Dr. Ralph White provided helpful comments concerning the oral presentation of my results and about the nature of research work generally. Dr. Mel Friedman helped with a short photo-graphic study of the methanol/lignite interaction. Dr. and Mrs. Bill Hoover graciously gave me access to their laboratory, where the Hardgrove grinding tests were conducted. Some laboratory and computer techniques were explained to me by fellow students Nick Stone and John Garza. Finally, another student, Mike Spears, worked with me in the laboratory during the dusty and time-consuming period of data acquisition. Without his help, the project would not have been finished. My sincere appreciation and thanks go out to all of these people.

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INTRODUCTION

Coal is this country's most abundant fossil fuel. It has been estimated that coal reserves constitute about 87% of all the reserves of fuel currently used in the U.S. (1). Besides serving as a fuel, coal can conceivably serve as a feedstock for the petro-chemical industry. Technology is being developed which will allow the liquefaction and gasification of coal, and from thence its utilization as a fuel or a chemical feedstock. However, there are still many obstacles to overcome before utilization of coal can increase signficantly.

Not the least of the problems to be dealt with is transportation. Currently, railroads are the only carriers of coal in bulk quantities. As coal usage increases, a more efficient method of transportation must be found. The use of slurry pipelines (transporting finely pulverized lignite suspended in a liquid) is a method currently being touted (2). Development of a system of underground pipelines for coal delivery is potentially cleaner, safer, and cheaper than a mass expansion of rail facilities. It remains, then, to develop the best slurry pipeline system available.

The most abundant liquid available is, of course, water. The only commercial coal pipeline in the country is the Black Mesa pipeline, which provides a water slurry to the Mojave Power Plant in Arizona. However, there are some disadvantages to the use of water in coal slurry pipelines. The slurry formed is not completely stable; that is, settling of the solids tends to occur unless the mixture is agitated. This means that high pipeline velocities must be maintained to produce a degree of turbulence sufficient to prevent settling. Also, the slurry must be agitated while in storage. The separation of water from the solid is difficult, and water from the slurry is brackish and generally unfit for re-use in other areas; consequently, it must be disposed of. Transportation of coal via water slurry pipeline would be unattractive to the residents of areas with large coal supplies but little spare water--Wyoming, for instance. With these disadvantages in mind, workers have sought for alternative liquids which can be used in coal slurry pipelines.

Another liquid which has been proposed is methanol (methyl alcohol). A patent was obtained in 1977 by Mr. L. J. Keller which described the preparation of a liquid-solid suspension of pulverized, dried coal in methanol (3). This suspension has the trademark name Methacoal, and is claimed to have desirable properties such

as increased stability and superior shear thinning characteristics. It is claimed that a methacoal suspension, by virtue of its increased stability compared to a water slurry, would require less agitation during storage, reducing inventory costs. Also, lower pipeline velocities could be tolerated, and the slurry could be pumped up steeper grades. Reduced viscosity of methacoal should lead to lower pumping costs and better optimization of the pipeline operations.

Dr. Ron Darby, supervisor of the research on which this thesis is based, is conducting studies on methacoal suspensions prepared from Texas lignite. The viscous rheological properties of these suspensions have been compared to water suspensions, and thus far the results confirm the superiority of methacoal (4). Investigation of the rheological properties is continuing; however, there are other aspects of methacoal slurries which differ from water slurries.

Another area of investigation is the effect of methanol on the solid lignite. It has been observed that a reaction occurs when methanol and lignite are mixed (4). The vigor of the reaction increases inversely with moisture content, and is characterized by the evolution of a considerable amount of heat and by the liberation of gas. The heat evolved is thought to be the heat of adsorption of methanol onto lignite. The gas evolved is mostly

carbon dioxide, but the mechanism of its liberation is unknown. The chemical compositions of lignite can vary widely from sample to sample; for this reason, it will be difficult to ascertain the mechanism. It is interesting to note that this reaction has not been observed with coals of higher rank.

Some changes in the structure of lignite have been attributed to its reaction with methanol. The porosity is thought to increase, which could make the solid more combustible or more reactive in a chemical process. Swelling of the coal particles has been reported, and some comminution is said to occur because of the reaction. It has been observed that methanol will absorb into lignite over a period of time, so the effects of the reaction are not limited to the surface of the solid. The friability, or ease of pulverization, is also said to be enhanced. At this time, none of these effects have been quantitatively analyzed.

An increase in the friability of lignite could have significance in the design of a large scale processing facility. The costs for crushing and pulverizing the solid will decrease as the friability increases, because the grinding energy requirements will decrease. Because possible changes in friability could significantly affect an industrial-scale operation, it is important to study the reaction and its effects on lignite.

It is the purpose of this research to investigate the
friability of lignite after treatment with methanol and
quantify any changes when compared with untreated lignite.
Since the acceptance of a methacoal pipeline would probably
be contingent on proving its superiority to a water slurry,
the study will also include a comparison of the effects
of water on the lignite friability. From this investi-
gation, a basis is to be established from which a
comparison of water and methanol can be made, in regards
to their effect on lignite.

This study has involved preparation of water and
methacoal slurries from Texas lignite, which was obtained
from the Big Brown mine near Fairfield, Texas. Texas
lignite was used because of its ready availability and
abundance. Tests of friability have been made by con-
ducting both dry grinding tests and wet blending tests.
Since a conventional coal processing facility might
involve either dry or wet pulverization, it is hoped that
the tests will provide useful information relating to
either mode of size reduction.

REVIEW OF METHODS

Designers of dry coal grinding mills have traditionally
used the Hardgrove grindability test to determine grind-
ability and to estimate pulverizer capacity required.
This test was developed by R. M. Hardgrove in the 1930's
and is based on the assumption that the work done in
grinding is proportional to the new surface area produced.
The procedure requires preparation of a fixed quantity
(50 grams) of coal, pulverized to fall between 0.6 and
1.18 mm, and air-dried to equilibrium with the surroundings.
The coal is ground in a ball-and-race mill for a fixed
period, then the mill product is screened on a 75 micron
sieve. The amount of material passing the sieve is
measured, and the grindability is then determined from a
calibration curve. The calibration curve is established
by testing coals with a standard grindability as established
by the Bureau of Mines. For full details of the test,
see ASTM test D-409 (5).

The results from the Hardgrove test have been good
when higher rank Eastern coals are used. However, the
increased interest in use of lower rank bituminous, sub-
bituminous, and lignitic coals has exposed some drawbacks.
It has been reported that the test is strongly influenced
by the moisture level in these coals (6). Since moisture
levels in lignite vary widely, it is misleading to report

a grindability only at the air-dry moisture level as called for in the ASTM procedure. Until revised procedures are approved, though, the Hardgrove test will remain as the most widely used grindability indicator.

The moisture content is also important to the operation of industrial scale grinding equipment. A rod mill is commonly used to grind dry coals by the action of tumbling rods within a rotating cylindrical drum. The efficiency of size reduction is hampered by the buildup of fine material within the drum because this tends to cushion the impact (7). The problem of buildup increases as the required fineness of product increases. It has been found that the chief variable responsible for the buildup is the moisture content of the feed (8). The grinding efficiency decreases as the moisture content increases until such a point that the conditions of wet grinding are achieved. At this point, sufficient water is present to fluidize the solid so that extensive buildup does not occur. The motion and mechanics of the fracturing process are altered considerably during wet grinding also.

These points concerning moisture level and its effects on dry grinding are emphasized because lignites may have natural moisture contents as high as 30%, as is the case for the lignite used in this study. Lignite is quite hygroscopic, and grinding results are therefore affected

by the humidity prevailing during the test, even if the lignite is thoroughly dried beforehand. The time allotted for the research unfortunately did not permit grindability determinations of several mositure levels as has been recommended (6). The moisture level chosen is approximately 8% by weight, which requires drying at $105^{o}C$ for 8 hours. It is felt that this is a moisture level low enough for the methanol/lignite interaction to be sufficiently vigorous; however, it is not so low as to allow adsorption of water from the atmosphere to cloud the results. The humidity during the tests is uncontrollable so complete drying would make adsorption all the more rapid on humid days.

Another variable studied in the Hardgrove tests is the effect of varying the feed size to the mill. The Hardgrove tests call for only one feed size range; however, to observe the effects of particle size on the methanol/lignite interaction, various feed sizes are used. Since lignite is a composite of various organic and in-organic material, the various substances might classify themselves into different size ranges according to hardness after the preliminary grinding step. Harder materials would remain in the larger size range, and softer material would be ground into smaller bits. Hardness is, to some extent, indicative of chemical structure; therefore, if the effects of the chemical reaction between lignite and

methanol vary with particle size, this is an indicator
of differences in chemical composition.

Besides investigating the dry grinding characteristics
of lignite, wet grinding tests were also performed.
Addition of sufficient quantities of liquid serves to
bring and maintain the solid particles in positions
advantageous to receive impact and be broken (9). Prep-
aration of coal slurries would involve a wet grinding step
wherein the solid would be mixed with the liquid and
pulverized to the necessary pipeline consistency. A
Waring blender has been used to blend lignite with water
and methanol in an effort to determine how the two
substances affect the wet grinding procedure. Bench scale
tests of wet grinding machinery are used to design full
scale plants, so the blending test conducted may be
considered similar to such bench scale tests.

PROCEDURE

A proximate analysis of the lignite used in this study is shown in Table 1. Because of the varying composition of lignite, a large sample was originally chosen from which all subsequent experiments could be supplied. This insured the homogeneity of composition for all tests. Approximately 4700 grams of lignite was first crushed in a jaw crusher, and then ground in a disk mill so that all the solid passed a U.S. Number 8 mesh (2.36 mm) sieve. The ground lignite was then placed into shallow pans and dried at approximately $105^{O}C$ for 8 hours. A portion of the dried coal was isolated and capped in a jar to prevent adsorption of moisture from the air. This sample served as the reference--lignite dried but untreated by either water or methanol. The remaining dry lignite was divided into equal portions for mixing with a 2 to 1 volume ratio of either methanol or water. These were the treated samples.

To perform the Hardgrove test, the feed must be dried. Portions of the two soaked samples were removed and dried again at $105^{O}C$. After drying, the samples were screened on a vertical stack of sieves. A Ro-Tap apparatus (Fig. 1) was used to shake and pound the sieves until the lignite was distributed according to particle size. The distribution was recorded, and the solid was then classified

TABLE 1

Proximate Analysis of Lignite

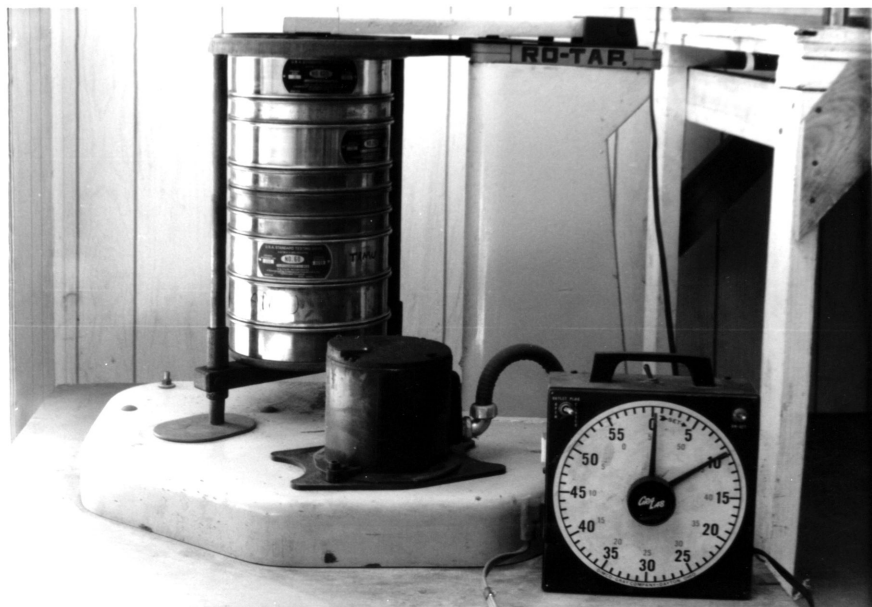|	Normal basis weight percent	Moisture-free basis weight percent
Moisture	30.8	--
Fixed carbon	27.64	42.8
Ash	7.37	10.6
Sulfur	0.57	0.82
Volatile matter	32.18	46.5
Heating value (Btu/lbm)	7846	11300

Fig. 1. Ro-Tap Apparatus

into three size ranges: -8 to +16 mesh; -16 to +30 mesh; and -30 to +60 mesh. Table 2 shows the U.S. mesh designations and the corresponding sieve openings.

Next the Hardgrove procedure was performed on the classified lignite in the three size ranges listed above. For lignite in the -8 to +16 mesh range, 50 grams were weighed out and put into the grinding bowl (Fig. 2). The grinding is done by eight steel bearings which were distributed evenly in the bowl. A grinding ring was put into place, covering the bowl and bearings (Fig. 3). The bowl and ring assembly was bolted into place with a drive shaft being inserted into the ring. The ring is rotated by the shaft which also applied 64 pounds of force vertically onto ring and bearings (Fig. 4). The lignite was ground for 60 revolutions, and the product screened at 100 mesh with the amount of material passing the screen serving as the indicator of grindability. For feed sizes of -16 to +30 and -30 to +60 mesh, the product was screened at 200 and 400 mesh, respectively. Otherwise, the procedure was the same for all samples. The variations in feed and product mesh size were introduced so that a reduction ratio of 10 to 1 would be measured in all cases.

In order to measure the wet grinding characteristics, a Waring blender was used to blend methacoal and water slurries. Lignite was first crushed and dried for 8 hours as described previously. Two samples were prepared by

TABLE 2

U.S. Mesh Designations and Corresponding
Sieve Opening Sizes

Sieve Designation	Opening, microns	Opening, inches
8	2360	.0937
16	1180	.0469
20	850	.0331
30	600	.0234
60	250	.0098
100	150	.0059
140	106	.0041
200	75	.0025
400	38	.0015

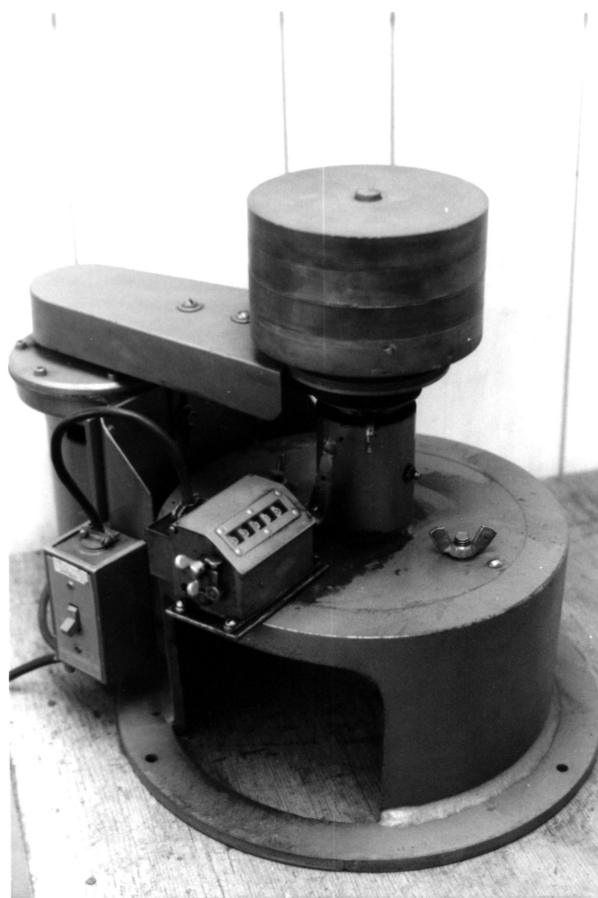Fig. 2.   Grinding Bowl for Hardgrove Tests

Fig. 4. Assembled Hardgrove Mill

mixing the still warm lignite with a 2 to 1 volume ratio
of either methanol or water. The samples were allowed to
stand for approximately 24 hours, so that the methanol/
lignite reaction would have sufficient time to reach
equilibrium. Equal volumes of these samples were blended
at a high speed for 10 minutes. At intervals of 3, 6, and
10 minutes, small portions were removed and stored for
subsequent analysis of the particle size distirbution.
The blender power consumption was measured with a watt
transducer, and the power curve was traced with a strip
chart recorder.

The particle size distributions of the blended samples
were measured so that the degree of size reduction would
be known. A Cahn electrobalance with a sedimentation
attachment was used for this analysis (Fig. 5). A sample
containing about 500 milligrams of solid was uniformly
suspended in a column of liquid (either methanol or water)
and allowed to settle onto a balance pan suspended below
the column. The cumulative weight on the pan was recorded
for a period of approximately 24 hours. A computer program
requiring liquid and solid densities, liquid viscosity,
and cumulative weight with time was then used to generate
a particle size distribution covering a range of approxi-
mately 5 to 150 microns.

Fig. 5.   Sedimentation Attachment for a Cahn
Electrobalance

RESULTS

Particle Size Distributions from Sieve Analyses

Particle size distributions were determined for four
lignite samples: before drying; after drying; after water
soaking and drying; and after methanol soaking and drying.
The results are presented in Fig. 6 and Fig. 7, which are
plots of the cumulative weight percent collected on the
sieves versus the size of the opening. The curve for
lignite at its natural moisture content represents the
size distribution after grinding in the disk mill, but
before any drying or soaking. Approximately 94 percent
of the material is larger than 100 microns, indicating
that the disk mill produced little fine material. After
drying for 8 hours at $105^{O}C$, the curve is shifted to the
right, representing an overall decrease in the particle
size distribution. The drying caused a decrease in
moisture content from approximately 30 to 8.5 weight per-
cent. Fig. 7 shows the particle size distributions for
the treated samples. Methanol-soaked lignite shows a
slightly larger mean size distribution than does the water-
soaked sample. Both of these curves, though, lie within
the bounds of the curves of Fig. 6. The effect of drying
is to reduce the particle size, but soaking in a liquid
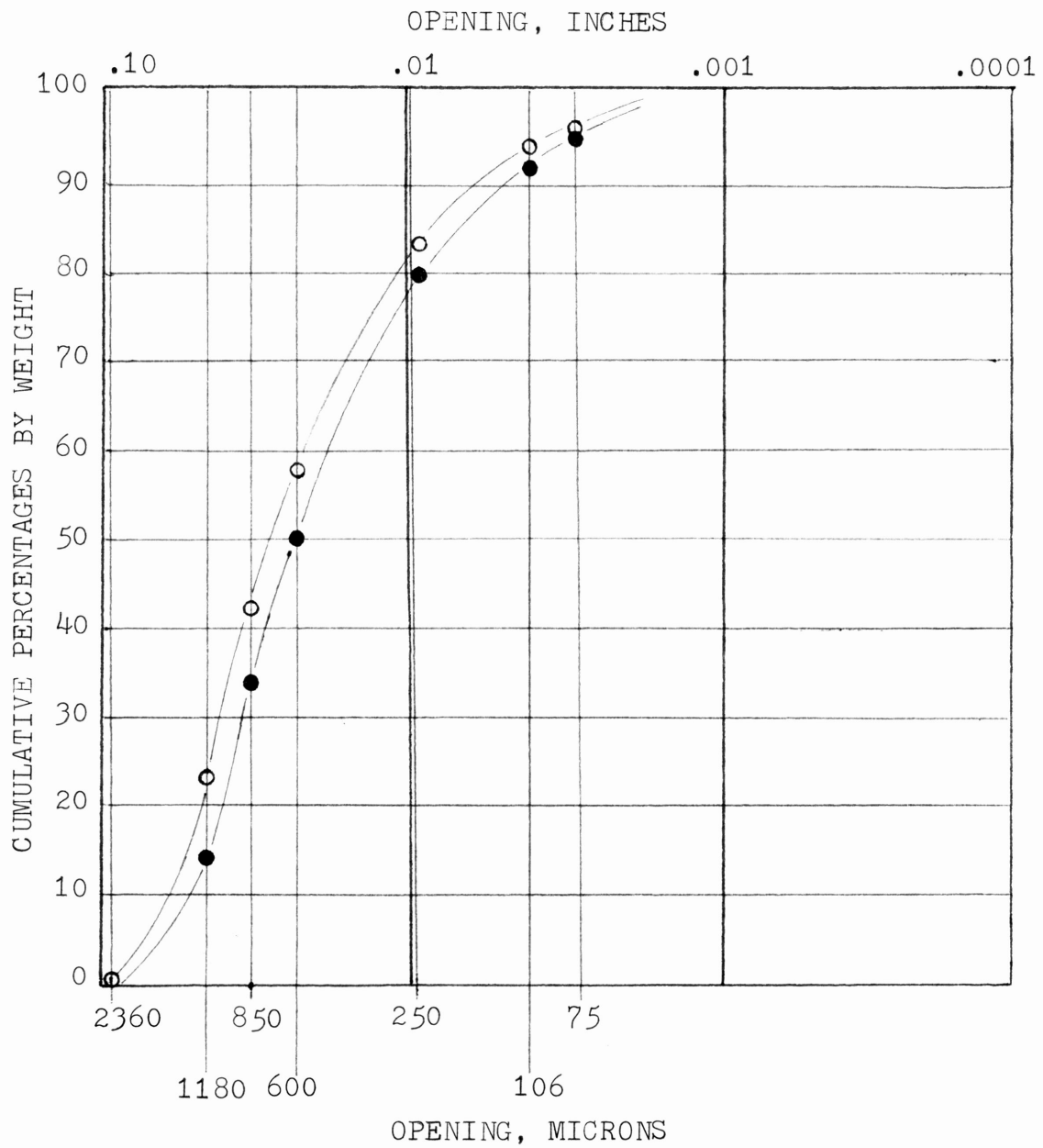increases the size distribution again, however, not to the

OPENING, INCHES

Fig. 6. Particle Size Distributions from Screening of
Untreated Lignite

o -Natural moisture content
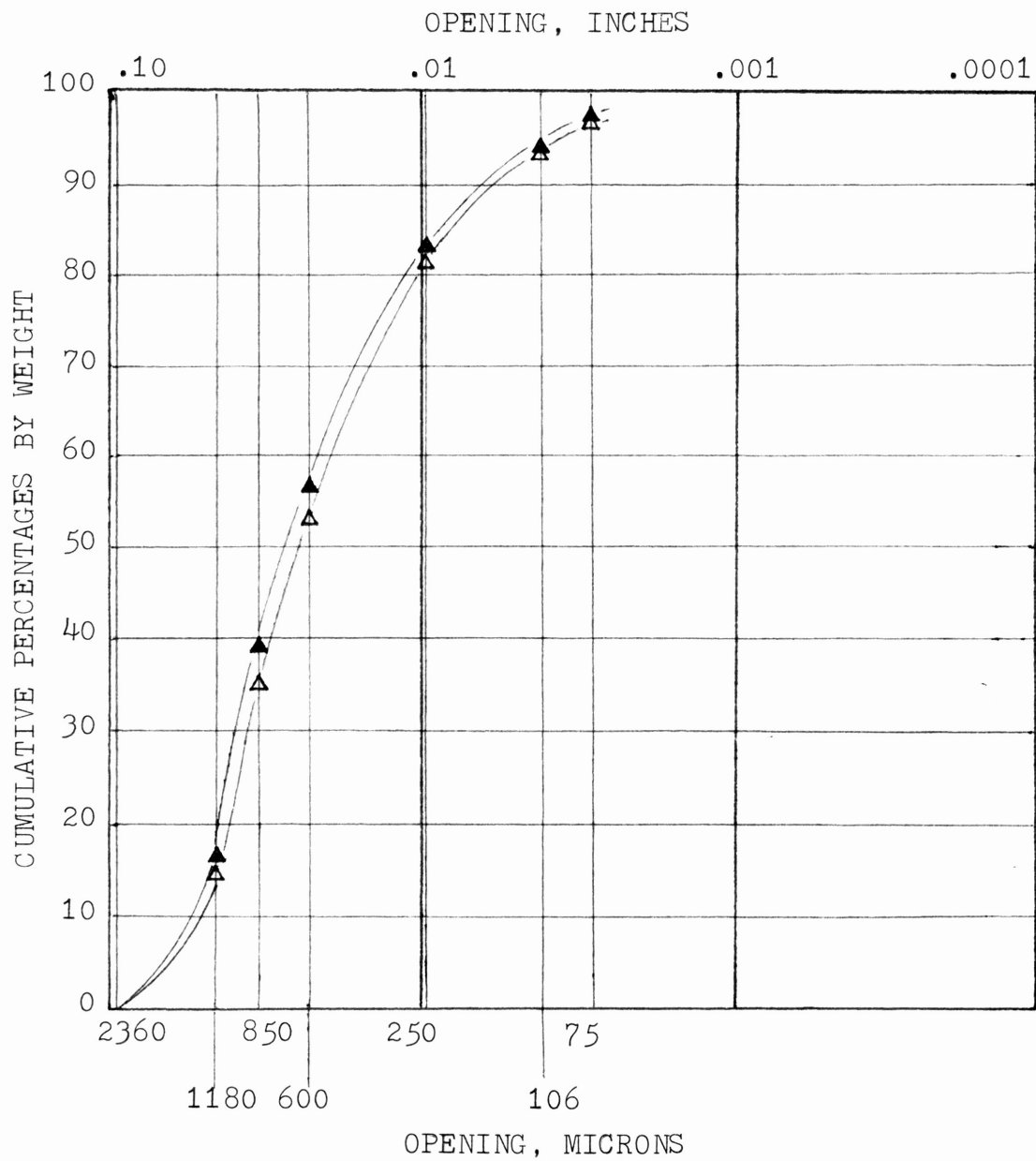● -Dried 8 hours

Fig. 7. Particle Size Distributions from Screening of Treated Lignite

△ -Water-soaked and dried
▲ -Methanol-soaked and dried

original limits. The cause of this upward shift is most likely a combination of swelling from methanol absorption and agglomeration. The amount of fines present in the methanol-soaked sample is slightly reduced indicating that any comminution affects are negligible or else beyond the measurement of a screen analysis. Since the size distribution for the methanol-soaked samples is higher than for the water-soaked samples, this supports the belief that some swelling accompanies the lignite/methanol interaction.

Hardgrove Grindability Tests

Grindability tests were performed on untreated, water-soaked, and methanol-soaked lignite. The results were averaged for presentation in Table 3 which gives the number of repetitions for each sample along with the grams passing the product sieve. The change in grindability of water- or methanol-soaked samples is expressed as the percent change in grams passed, compared to the sample which was only dried. The disk mill ground most of the lignite into the -16 to +60 mesh range; therefore, less solid was available and fewer repetitions were made in the -8 to +16 mesh feed range.

For the largest size feed (8 x 16 mesh), it is evident that the grindability was enhanced 9.5% by water and almost 26% by methanol. However, for the 16 x 30 material, the grindability was evidently reduced somewhat

TABLE 3

Summary of Grindability Tests

I.   Feed: 8 x 16 mesh   **Product:** Passing 100 mesh

Sample Treatment	Number of Repetitions	Grams of Product	Avg. Percent Increase
D	2	9.45	--
W	2	10.35	9.5
M	2	11.90	25.9

II.   Feed: 16 x 30 mesh   **Product:** Passing 200 mesh

Sample Treatment	Number of Repetitions	Grams of Product	Avg. Percent Increase
D	4	5.13	--
W	5	4.56	-11.1
M	5	5.02	-2.1

III.   Feed: 30 x 60 mesh   **Product:** Passing 400 mesh

Sample Treatment	Number of Repetitions	Grams of Product	Avg. Percent Increase
D	3	2.77	--
W	4	2.92	5.4
M	3	2.90	4.7

D-Dried 8 hours

W-Water-soaked, then dried

M-Methanol-soaked, then dried

for both soaked samples. Again for the 30 x 60 mesh feed, the grindability was enhanced but only slightly. For only two of the three size ranges, then, was grindability enhanced. Also, the grindability of methanol-soaked lignite was higher than water-soaked lignite for only two cases (8 x 16 and 16 x 30 mesh feed). The inconsistency of results calls for an examination of the procedures and variables involved in the test.

The first variable is time. For all samples, the grindability tests were performed at least 6 days after the sample was prepared and stored in a tightly capped container. This period was sufficient for any slow adsorption of atmospheric moisture to occur. Therefore, the waiting period would have affected all samples equally and should not have been the cause of the discrepancy.

The next variable is the moisture content of the sample during the grinding test. As the lignite was ground, new surface area was produced on which adsorption of atmospheric moisture could have occurred. As discussed in the review of methods and purposes, moisture content will affect the efficiency of dry grinding mills. The tests were conducted over several days during which the humidity varied significantly. However, the significant scatter of individual data points was confined to the 16 x 30 mesh tests, where the discrepancy of decreased grindability showed up. Individual results from the tests

on the other two feed size ranges showed insignificant scatter. Since any effects due to humidity should have caused scatter in all three size ranges, it was concluded that the moisture content of the samples did contribute greatly to the inconsistency.

There was one difference in experimental technique for the 16 x 30 mesh tests which may have caused the inconsistency. Several different 200 mesh sieves were used to screen the product. For the other size ranges, only one 100 mesh and one 400 mesh screen were available for use. It is possible that variations in the conditions of the several 200 mesh screens caused the scatter in the data. This is felt to be the most likely cause of the inconsistency, although a close re-examination of the individual results reveals no screen consistently passing an atypical amount of mill product.

The final variable in the dry grinding tests was the particle size. Presumably, the original grinding would classify the lignite components according to hardness and chemical structure with the hardest materials in the largest size ranges. The effects of methanol were greatest on the 8 x 16 mesh particles and least (reducing the grindability) on the 16 x 30 mesh particles. The fact that the relative increase in grindability was not the same in all cases lends some support to the assumption that different-sized particles may have different chemical

structures. The evidence is by no means conclusive, however.

Blending Tests

The power required to blend the water and methanol suspensions was measured as a function of time. The samples were prepared with a 2 to 1 volume ratio of liquids to solids originally; however, because of the absorption of methanol into the lignite, this rate decreased slightly for the methanol sample. Water does not have an affinity for lignite and no absorption for these samples was noticed.

A sketch representing the observed power consumption curves for the blended samples is shown in Fig. 8. During the first few seconds of blending, a peak was observed. This peak was caused because the solids settled in a mass around the blade and more power was required to agitate the mass. After the agitation period, the sample was uniformly mixed and the power consumption was noticeably higher for the methanol/lignite sample. This was attributed to the observation that the lignite particles formed a more cohesive mass in methanol than in water. The high affinity of methanol for lignite apparently caused the cohesion. Lignite particles in water demonstrated a certain buoyancy and were less cohesive.

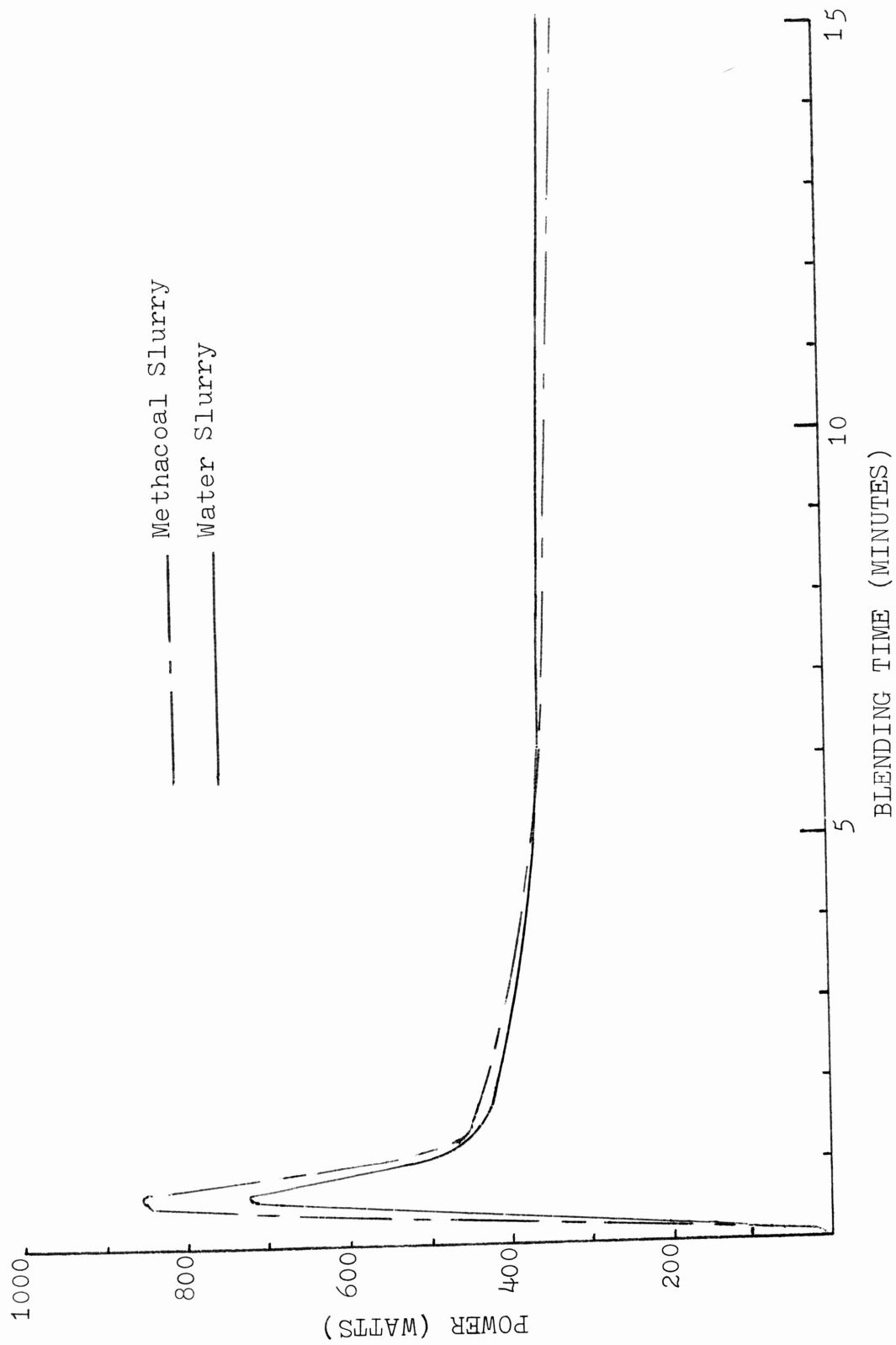During the first 3 to 4 minutes of the blending

Fig. 8. Power Requirements for Blending

period, the power consumption was roughly 2 to 3% higher for the methanol sample. However, after longer blending times the power requirements leveled off for the water sample while the power consumption continued to fall for the methanol sample. The result was that, after 4 or 5 minutes, the power consumption was less for blending the methanol sample than for the water sample. Over an extended period of time, then, these trends indicate that the total power required to blend equivalent samples would be less for methacoal than for water slurries.

In order to estimate the efficiency of blending, the particle size distributions of the blended samples were measured, and the results plotted in Fig. 9, 10, and 11. The plots show the size distributions for each sample after blending times of 3, 6, and 10 minutes, expressed as the weight percent less than a given diameter. For the three minute run, the water sample showed approximately 30% solids less than 100 microns, while the methacoal sample contained only 22% less than 100 microns. This indicates a greater degree of size reduction for the water sample. However, the size distributions after 6 and 10 minutes blending are almost identical for water and methanol. Apparently the efficiency of wet blending becomes essentially the same as time progresses. For long blending times, then, the degree of size reduction is approximately equal, but the power required is less
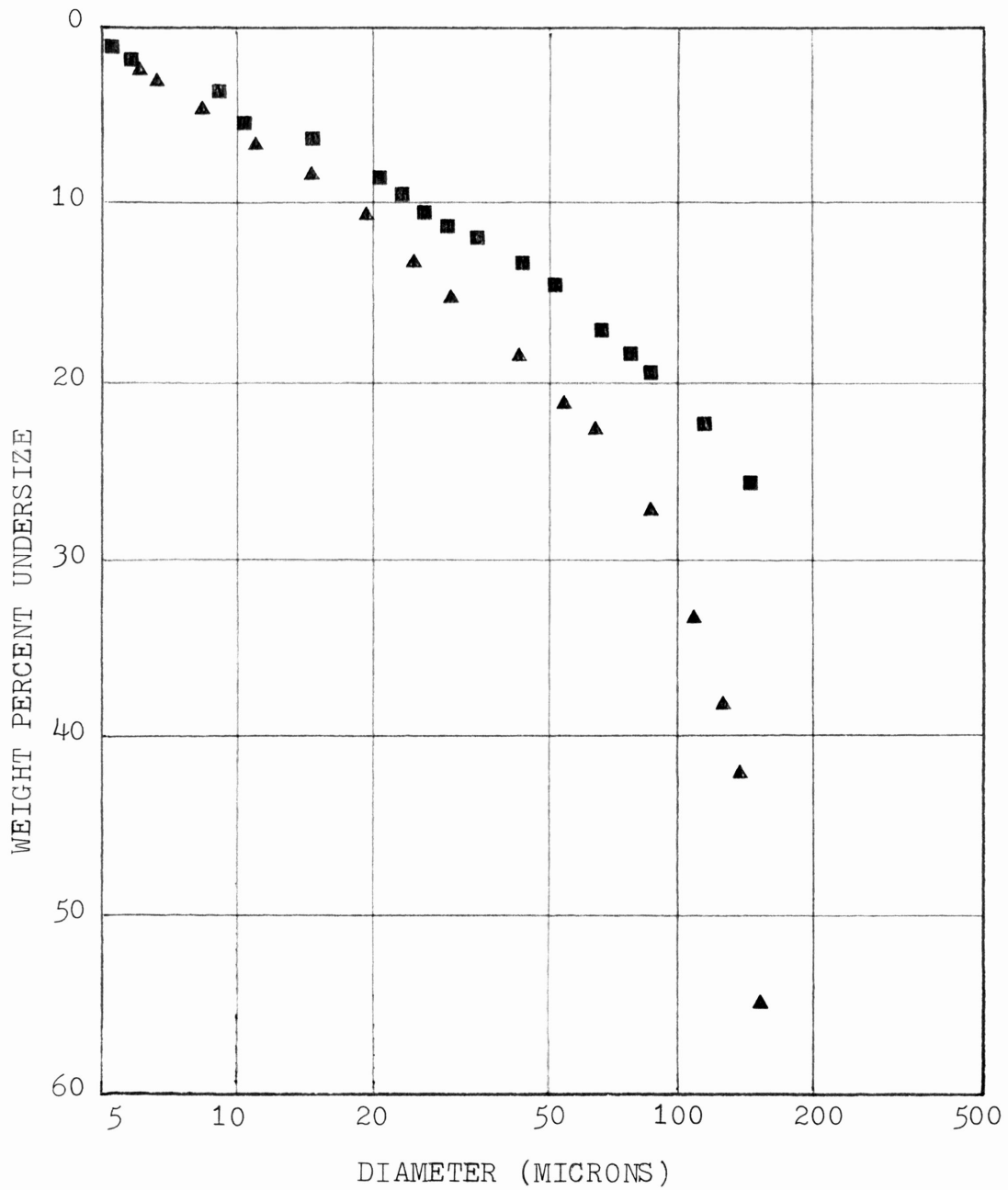
Fig. 9. Particle Size Distributions after Blending 3
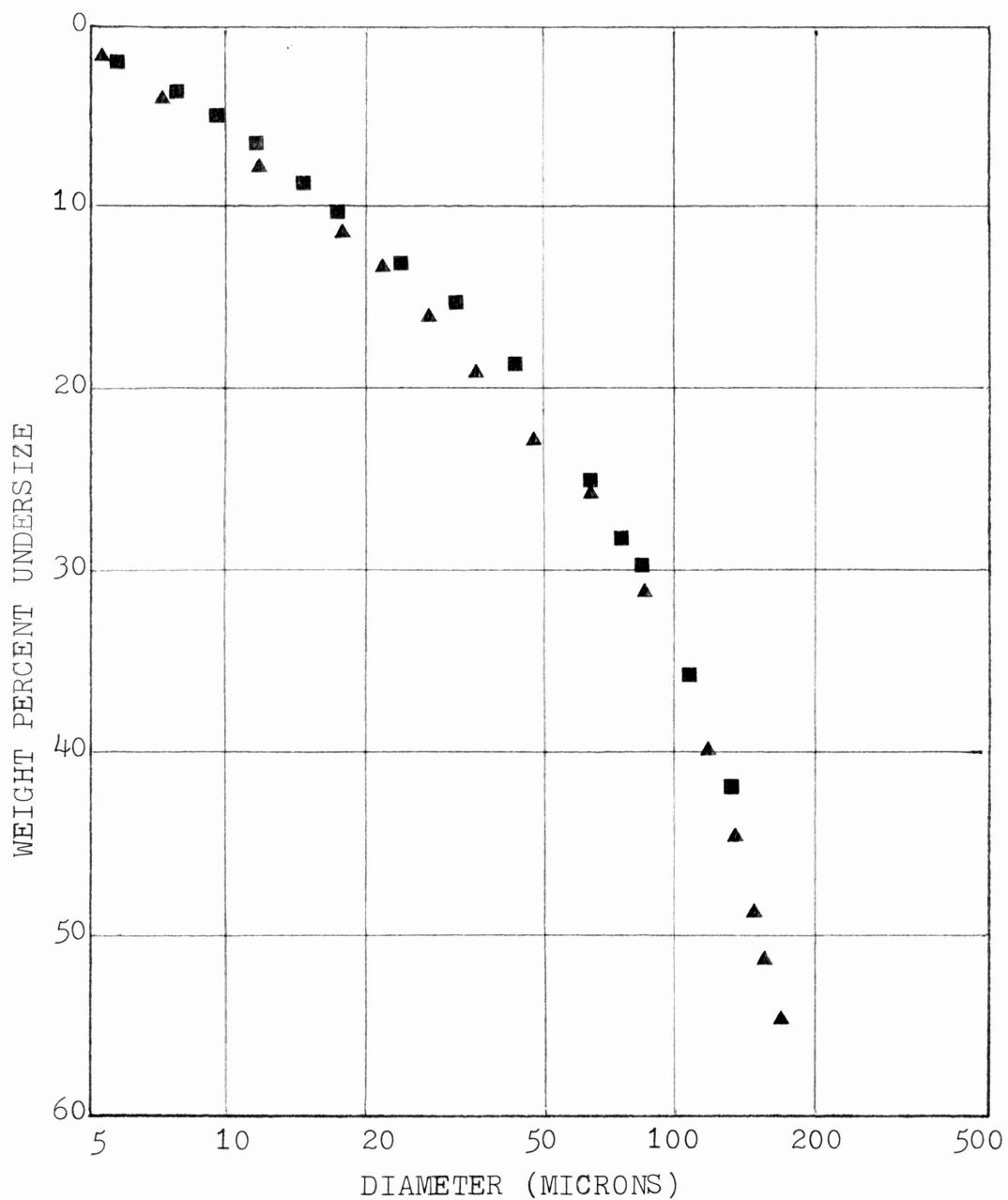Minutes
■ Methacoal
▲ Water Slurry

Fig. 10. Particle Size Distributions after Blending 6 Minutes
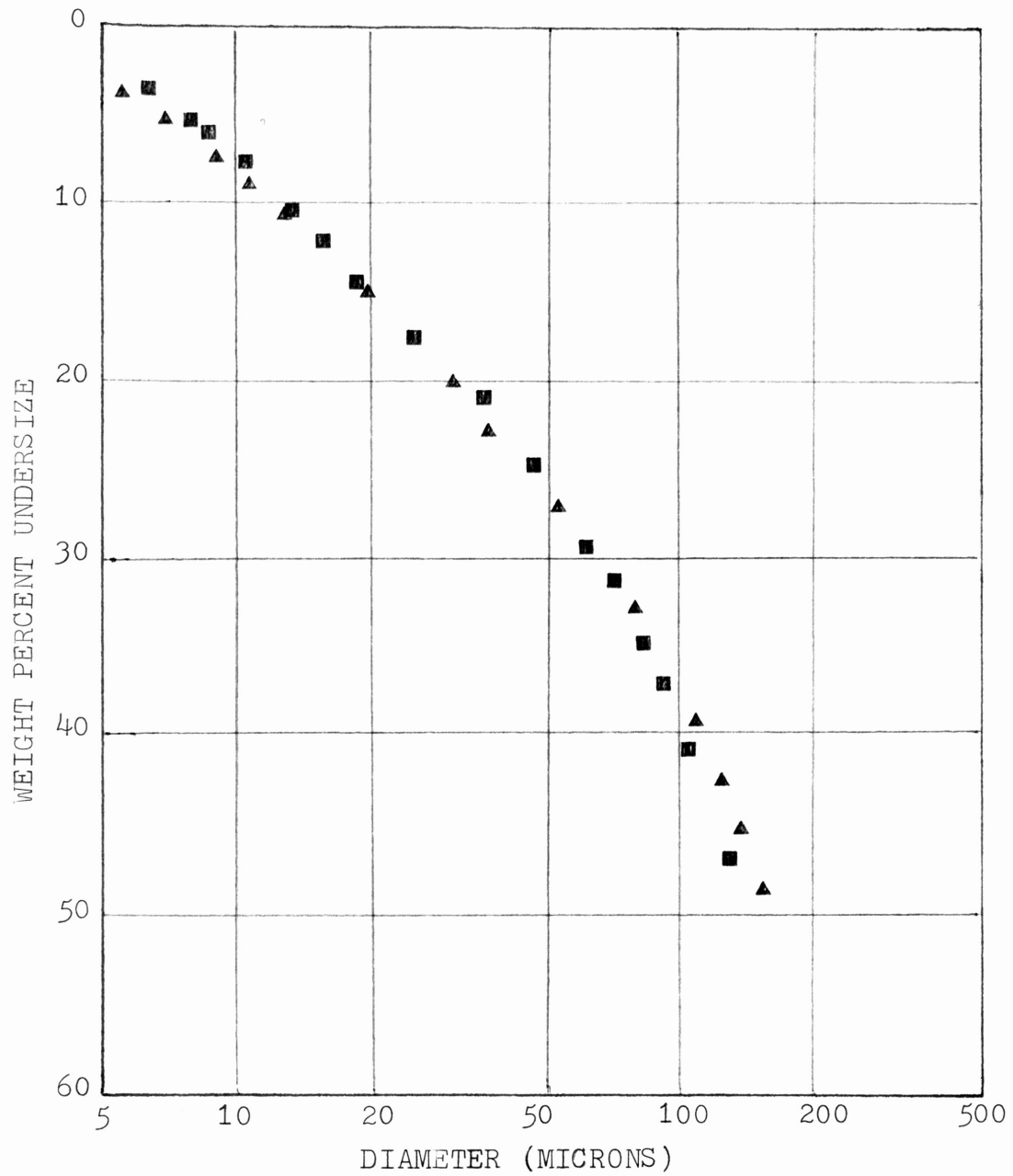
■ Methacoal
▲ Water Slurry

Fig. 11. Particle Size Distribution after Blending 10
Minutes

■ Methacoal
▲ Water Slurry

for methacoal than for water slurries.

Some quantitative observations were made about the blended samples. Generally, the solids settled to a lower equilibrium level in the water samples than in the methacoal samples. Most (but not all) of the methacoal samples were more fluid after settling than the water samples, and it required less agitation to stir them up again. As noted earlier, methanol was absorbed into the lignite, reducing the original 2 to 1 ratio of liquids to solids somewhat so that during blending there was less free liquid to fluidize the lignite particles. This influenced the blending performance of the methacoal samples, but its effect was not evaluated quantitatively.

CONCLUSIONS

Quantitative measurements of the effect of methanol on the friability of lignite have shown an increase in some cases and a slight decrease or no change in others. There is some evidence that size reduction by dry grinding would be enhanced by using methacoal rather than water slurries. The evidence for this is the increased grindability of lignite in the 8 x 16 mesh size range. Also, the gradual decrease in power consumption for blending methacoal slurries is significant when compared with the power required to blend water slurries. The indications are that, for long blending times, it would be cheaper to blend methacoal slurries.

Some of the evidence from the Hardgrove tests indicate that the grindability of lignite is reduced slightly by the reaction with methanol. The tests where this result was indicated did show a significant amount of scatter, however, and these tests should be repeated in an effort to get more consistent results.

The results of the screen analysis did not reveal a significant comminution effect from the methanol/lignite interaction. The analyses did show an increase in particle size distribution after methanol treatment which was attributed to a combination of swelling and agglomeration of the particles. The same effect, to a lesser

extent, was observed for the water-soaked samples.

It was observed that lignite will absorb methanol noticeably after a period of several hours. No such observation was made concerning water. This suggests that the methanol/lignite interaction will affect the lignite particles internally as well as externally. Qualitative observations of the fluidity of blended water and methacoal slurries indicates that methacoal is generally more fluid than a water slurry.

Based on the study described herein, no conclusion claims can be made concerning the superiority of methanol-treated lignite over water-treated lignite. In some cases, the results indicated a superiority, but in others no change or a slight inferiority was observed. The limited number of repetitions necessarily calls for a guarded interpretation which prohibits any claims to be quantified. It is felt, however, that a more extensive testing program similar to this one would provide sufficient data for making conslusions with confidence. We may conclude that the claimed superiority of methacoal to water slurries is not so obvious that it can be taken for granted. Any such claims will have to be supported by thorough research.

SUGGESTIONS FOR FURTHER STUDY

By taking advantage of the experience gained in this study, it is possible to note improvements which could be made in the described procedure, and to suggest some other interesting areas of study. First, as suggested in the review of methods, it would be well to conduct Hardgrove tests at several different moisture levels. Also, control of humidity during storage and testing could only improve the reliability of results. Extension of the standard Hardgrove grinding procedure to several particle sizes is probably not helpful when the product is screened at less than 75 microns. The selection and breakage character-istics of the Hardgrove mill are rather poor at such a small size. Larger screen sizes are more in keeping with the mill capability. Also for future tests, only one screen should be used to screen the product from the mill. Using several screens to analyze several samples at a time reduced the time required, but seemed to reduce the reproducibility of results. An attempt was made to procure standard coals from the Bureau of Mines with which to compare the lignite samples. These coals are assigned a Hardgrove Grindability Index, a relative measure of grindability and comparison of these with lignite would help in the interpretation of the Hardgrove test results. Unfortunately, the standards were not

shipped in time for the comparisons to be made.

The study of the wet grinding of lignite would be most realistic when conducted in a lab-sized rod or ball mill adapted to wet grinding because these are similar to industrial type mills. In the event that these are not available, however, the blender tests should be extended to 20 or 30 minutes. A study should also be made of the rate and extent of absorption of methanol into lignite. Possible variables affecting the absorption would include the size of the lignite particles and the moisture content. After determining the extent of absorption, the blender tests should be repeated with methanol being added to the samples to compensate for the absorption. This would provide a true 2 to 1 volume ratio of free liquid to solid during blending.

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