# THE UNIVERSITY OF BRITISH COLUMBIA

"Removal of Inorganic Minerals and Washability of Hat Creek Coal"

Fourth Report

(July 1 to Dec. 31, 1977)

(Supported by B.C. Hydro)

DEPARTMENT OF METALLURGY

VANCOUVER, BRITISH COLUMBIA • CANADA

"REMOVAL OF INORGANIC MINERALS AND WASHABILITY

OF HAT CREEK COAL"

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(Financially supported by the B.C. Hydro and Power Authority)

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December, 1977

## INTRODUCTION

In previous reports on this research project entitled "Mineral Matter Content and Gross Properties of Hat Creek Coal", it has been shown that the extent of the inorganic minerals content in the Hat Creek deposit is found to vary widely from 17% to ∿ 60% by weight. The average value being in the neighbourhood of ∿ 35% by weight. This means that about one-third of the coal deposit is mainly composed of clays, sand and other minerals. To burn this coal, as present in the deposit, entails a significant amount of energy loss to dehydrate (drying), dehydroxylate the clay minerals, decarbonate the carbonates ($CaCO_3$ or ankerite) or other similar high temperature reactions. All these reactions are endothermic i.e. absorbs energy (in the range 40 to 70 Kcal/mole - 5 to 10 BTU/lbs of clays or carbonates) Burning this inorganic minerals along with the coal will also generate a huge quantity of ash. Even a partial success in removing these minerals will increase the efficiency of power generation from this coal in two ways: (i) less energy will be lost to decompose minerals and subsequent fusion to produce ash, and (ii) increasing the heat content per unit mass of coal burnt. Another aspect which should be considered is the large amount of minerals present, if can be removed or separated out of the coal, may find useful markets for ceramic industries. In a nut shell, the prime objective was to obtain the washability data to yield maximum recoverable BTU, with minimum sulphur per pound of coal burnt.

The success of ash removal by washing depends very much on the degree of intergrowth of minerals in organic coal. It is well-known that the size of a coal generally influences its washability characteristics. Therefore, to choose the most suitable top size for washing, knowledge of the dispersion of the minerals and the thickness of the different coal macerals in Hat Creek coal will be extremely useful.

Proposed steps for studying washability characteristics of Hat Creek coal are as follows:

1. Collect all types of coal (in 1 to 5 lbs pieces) as present in the open-pit mining operations.
2. Classify these pieces into different groups according to their ash content and maceral types by visually examining thickness of seam of different coal minerals and the degree of intergrowth of minerals in the organic coal. This should give the starting point in choosing a range of top sizes.

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[Note: Hebley(1), in summarizing comparative burning tests of same coals before and after cleaning, showed that 1% of excess ash in the coal causes a loss in efficiency averaging 0.34%].

3. Major activities are to be confined to performing float and sink tests in different specific gravity fluids on the coal samples from the Bradford Breaker, supplied by B.C. Hydro.
4. Identification and estimation of inorganic minerals in float and sink fractions.
5. Proximate analyses, sulphur and heat content determinations on float and sink fractions.
6. Washability of the coal sample (from the Bradford Breaker) after crushing to different top sizes. The variation of washability with the reduction of coal sizes should also indicate the nature of distribution of inorganic minerals in coal.

## MATERIALS

1. Initially during a field trip with Dr. L. Jory of Dolmage - Compbell Associates Ltd., about 250 lbs of coal pieces were collected by Drs. Chow, Warren and Chaklader. Selection of the coal pieces was made on the basis of their texture, colour, softness and varieties. Efforts were made to collect a few pieces of every type of coal, which could be visually distinguished. This trip was made on June 20 and 21, 1977.

2. Three batches of Bradford Breaker coal samples
   (i) First batch consisted of four bags of coal. Total weight about 160 lbs and delivered in the middle of August, 1977.
   (ii) The second and third batches consisted of one bag of each weighing about 40 lbs (each bag).
3. Washed refuse from Alberta Research Council - one sample ($\sim$ 2 lbs).
4. Inorganic minerals from different depths for identification - eleven samples
5. Bradford Breaker rejects - Hard non-breakable coal-two samples.

## TESTS PERFORMED

#1. Hand-picked specimens (collected during the field trip - visual examination and partial petrographic examination-divided into 6 groups, float and sink tests on one of the groups.

#2.i.Detailed float and sink tests in seven specific gravity fluids, moisture and ash analyses, quantitative X-ray analyses, calorific value and sulphur analyses.

#2.ii. Moisture and ash analyses, calorific value,float and sink tests at 1.45 specific gravity liquids on one of the two samples.

#3. X-ray analyses for minerals present and SEM for elements present in washed rejects.

Two experiments:

(i) sample (bulk)

and (ii) white powdery coating on the sample

#4. X-ray analyses on eleven samples for identification.

#5. Differential thermal (DTA) and thermogravimetric (TGA) analyses on Bradford Breaker rejects (non-breakable rejects)

## EXPERIMENTAL PROCEDURE

### I. Field-Trip Samples

A. During the first two months, attention was focussed mainly on the samples collected during the trip to the Hat Creek coal deposit. The samples collected were divided into six main groups by visual (and occasionally petrographic) examination.

B. Lumps of each of these six samples were placed in water and their behaviour of disintegratibility was observed. They were also stirred occasionally to see whether they would break up in this liquid medium.

C. These six groups of samples were analysed for percentages of moisture, volatile, carbon, ash, calorific value and clay mineral content. Thermogravimetric analysis (TGA) was used for proximate analysis, Parr bomb calorimetry for calorific value determinations and X-ray diffraction for identification and estimation of clay minerals content.

D. One of the six groups (Sample No.3) was crushed and sieved into various sample top sizes for float and sink tests. The various sample top sizes included < 1.5" > 1", < 0.5" > 0.5", - 4 mesh + 7 mesh, - 7 mesh + 10 mesh, - 10 mesh + 14 mesh, -14 mesh + 20 mesh and - 20 mesh. Each top size was placed into 1.3 specific gravity fluid separating the sample into two portions - one float and one sink fractions. The sink fraction was placed into 1.4 specific gravity fluid and again was divided into two portions - float and sink fractions. This procedure was then repeated with 1.5 specific gravity fluid. All the float and sink fractions were weighed and analysed for percentages of moisture, volatile, carbon, ash (i.e. proximate analysis) and heat content. However, only a few fractions were analysed by X-ray for mineral content. A complete study of these groups of samples should include a washability study from 1.3 specific gravity fluid to 1.90 S.G. fluid at six or seven sample top sizes, but was not carried out. Due to lack of time, instead, main effort at this stage was directed to the samples from the Bradford Breaker.

II. <u>Bradford Breaker Samples</u>

A. First Batch (High Ash Content Coal)

About 200 grams of this sample was placed in a bucket, filled with water and stirred at 40 RPM for one hour. The water was then decanted off and the remaining sample was analysed.

The remaining portion of the Bradford Breaker sample was sieved to -1.5" +0.25", -.25" + 4 mesh, -4 mesh +7 mesh, -7 mesh +14 mesh and -14 mesh. Their weight distribution was recorded.

The actual sample top sizes for specific gravity separation were $\lesssim$ 1.5", $\lesssim$1.0", $\lesssim$ 0.5" and $\lesssim$ 0.25". These sample sizes were prepared by crushing the original Bradford Breaker sample to sizes $\lesssim$ 1.5", $\lesssim$ 1.0", $\lesssim$ 0.5" and $\lesssim$ 0.25". Each top size was placed into 1.3 specific gravity fluid separating the sample into two portions - float fraction and sink fraction. The sink fraction was then placed into the next higher specific gravity fluid and again the sink fraction was separated into two portions-float fraction and sink fraction.This procedure was repeated until the last fraction of the sample was floated in 1.7 specific gravity fluid. The range of specific gravities used was 1.3, 1.4, 1.45, 1.50, 1.55, 1.60 and 1.70. The incremental increase of 0.05 rather than 0.10 was chosen between 1.4 and 1.6 specific gravity, because the amount of near-specific gravity material is crucial in selecting the optimum specific gravity for cleaning coal.

Float and sink fractions of all sample sizes (4 sizes used) were weighed, analysed for moisture, ash, heat content, sulphur and mineral contents. All tests are done in duplicates. Sometimes triplicates were made whenever doubt of the accuracy of the result existed. Analyses done in the last part of this study were all quantitative, so that balances of weight, ash calorific value, and mineral content can be calculated reasonably accurately.

B. Second Batch - (High Kaolinite Sample)

Because of shortage of time float - sinks were performed only at 1.45 specific gravity fluid. Analyses for moisture, ash, calorific value and mineral contents were done on both float and sink fractions.

C. Third Batch

No float and sink tests could be performed on this specimen for lack of time. Only proximate analysis for determining moisture, ash, fixed carbon and heat content (BTU) was performed on this sample.

D. Clay Samples (Eleven from Dr. T. McCullough)

Samples were crushed to pass through a 100 mesh sieve. X-ray analyses and SEM were used to identify minerals present. Main emphasis was to determine if significant concentration of kaolinite exists in these samples.

E. Rejects from Bradford Breaker (Hard Coal)

These two samples were first crushed to -100 mesh. Proximate analysis by TGA, calorific value determination and differential thermal analysis were performed. Differential thermal analysis was used to find out the range of combustion temperatures and to study the reactivity of the two low-ash samples during combustion. The results are recorded automatically in the thermograms and interpretation of these readily provided valuable informations about these samples.

## RESULTS

### I. Field Trip Samples

(i) Photographs: The hand-picked samples can be divided into six groups from the point of view of textural, maceral and ash content. Pictures of these samples are shown in Figure 1 (A - F). The ash content varied from as low as 6% to 69.4% (dry basis).

(ii) Proximate Analysis: Proximate analyses were performed to determine moisture, volatile and dehydration of clays, carbon and ash concentrations. The calorific value was determined by the Parr bomb test. X-ray diffraction and SEM (scanning electron microscope) were used only on two samples to identify the inorganic minerals present. The results of the above tests are summarized in Table I. Note that groups #2 and #3 have similar moisture, volatile (including wt. loss by dehydration of clays), carbon and ash contents. It appears that group #2 is the oxidized form of #3 (see pictures).

(iii) Disintegration Test: All six groups were immersed in water to observe their disintegration behaviour in water. They were also stirred occasionally. This test was considered interesting from the point of view of washability characteristics of different groups of coal present in the Hat Creek deposit. It was observed that groups #1 and #4 disintegrated in water especially when stirred. There was no change for groups #2, #3, #5 and #6. Note also the

SORTING* OF COAL SAMPLES FROM HAT CREEK DEPOSIT

#1 High moisture and clay content, complex intergrowth of coal and shale. Coaly shale
Ash: 68% (dry basis)

#2 Complex intergrowth of exinite-vitrinite and clay. Surface highly oxidized and dehydrated
Ash: 11% (dry basis)


#3 Low inherent moisture content, less oxidized hard coal, with complex seam structure of bright and dull bands. Fair amount of imbedded moisture.
Ash: 23% (dry basis)

#4 High ash seaming (yellowish-brown), extremely soft and friable coal pulps. Fair amount of moisture
Ash: 34% (dry basis)


#5 High clay content, brownish (fair amount of moisture) possibly dried up coaly shale, with clay mud visible
Ash: 42% (dry basis)

#6 Low inherent moisture content, non-banded (lustrous) coal. Looks like vitrinite or pitch
Ash: 6% (dry basis)

* by visual examination

## Table I

ANALYSIS OF SIX GROUPS OF HAT CREEK COAL

COLLECTED DURING FIELD TRIP

| GROUP # | PROXIMATE ANALYSIS | | | | CALORIFIC VALUE | | MINERAL CONTENT** |
|---|---|---|---|---|---|---|---|
| | | (db*) | | | | (db*) | |
| | Moisture | Volatile & dehy.of Minerals | Carbon | Ash | BTU/lb | BTU/lb | |
| 1 | 18.7 | 27.3 | 3.3 | 69.4 | 1790 | 2200 | B, K, Q, F |
| 2 | 16.8 | 41.9 | 29.1 | 29. | - | - | - |
| 3 | 15.9 | 39.9 | 35.1 | 25. | 6840 | 8130 | B, K, Q |
| 4 | 17.3 | 45.2 | 21.3 | 33.5 | 5520 | 6680 | - |
| 5 | 30.1 | 42.8 | 15.5 | 41.8 | 3760 | 5380 | - |
| 6 | 20.3 | 42.0 | 52. | 6. | 9500 | 11920 | - |

* dry basis

** in random order

similarity in behaviour of #2 and #3 in this test.

(iv) Float-Sink Test: At the earliest stage of the investigation, it was decided to do some float-sink tests on one of these samples. Samples from group #3 were crushed and sieved into 8 size fractions. Figure 2 shows that as size decreases the yield weight percent decreases with different specific gravity fluid. At smaller sizes more inorganic minerals are released, which in turn, decreases the yield weight percent.

Float and sink tests on all eight size fractions (of Group #3) were conducted at 1.3, 1.4 and 1.5 specific gravity fluids. The results are shown in Table II. The same data are included in Figure 2, where the concentration of the float and sink fractions at three different S.G. fluids and eight size fractions are shown. It is evident from the figure that finer size fractions yields smaller weight percent. Figure 3 shows this more clearly, in which float and sink fractions are shown at the 1.3 S.G. fluid for different size fractions. Table III summarizes the data of the proximate analyses of different size fractions at the 1.3 and 1.4 S.G. fluid separations. The minerals identified by X-ray analyses on the float fractions are also included in the table for completeness. The primary mineral is kaolinite with a small amount of bentonite (and quartz in some cases). The calorific value does not appear to change to any extent with size fractions, indicating that the inorganic minerals are disseminated evenly throughout the coal mass.

Table II

RESULTS OF FLOAT/SINK TEST ON HAT CREEK COAL DEPOSIT SAMPLE*

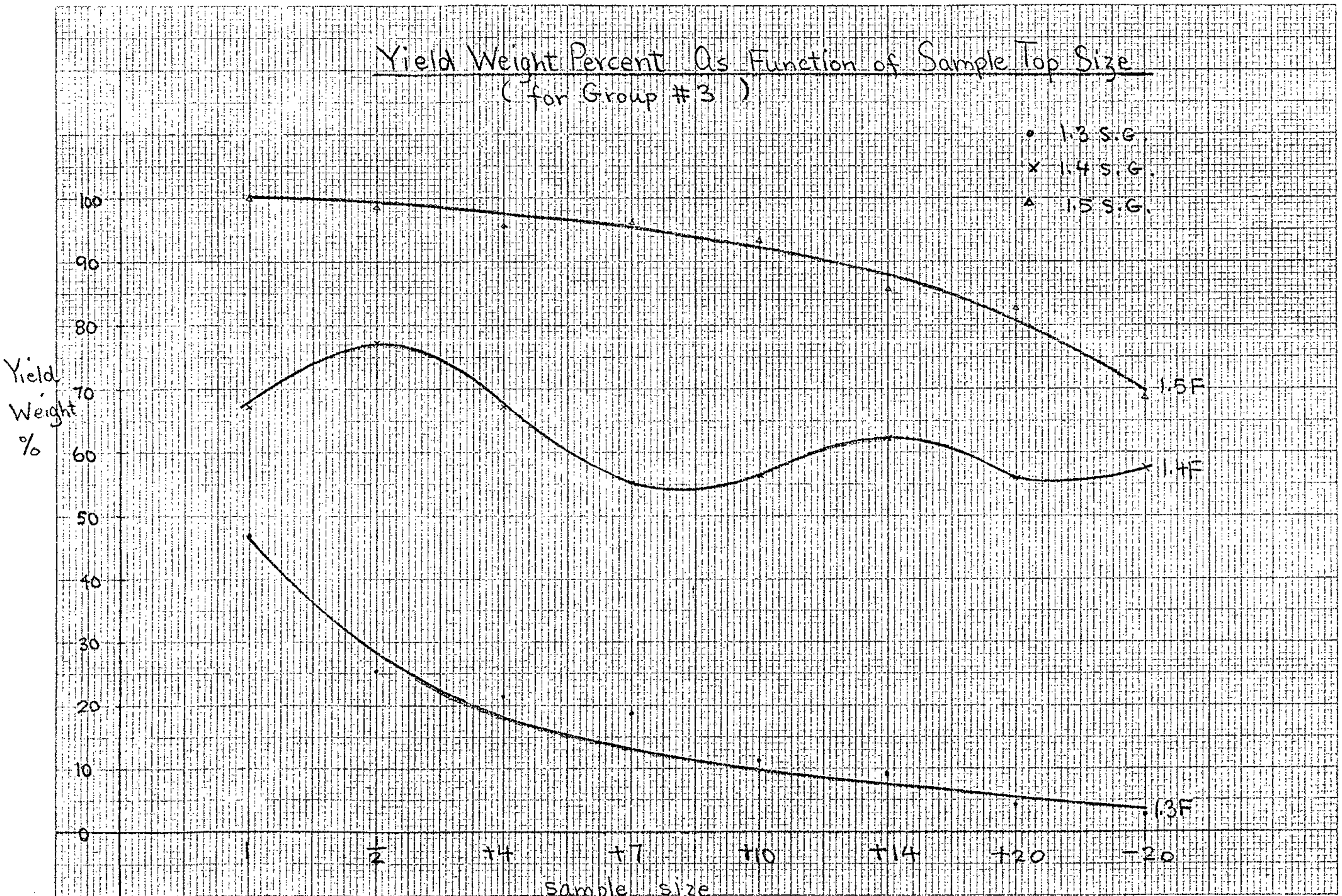
(Group #3)

| Specific Gravity | Sample Size | +1½" | -1½"+1" | -1"+½" | -½"+4m | -4 + 7m | -7 + 10m | -10+14m | -14+20m | -20m |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.3 | Float | - | 47. | 25. | 21.3 | 18.5 | 11.4 | 9.0 | 4.4 | 2.8 |
| | Sink | - | 53. | 74.9 | 78.7 | 81.5 | 88.6 | 91. | 95.6 | 97.2 |
| 1.4 | Float | - | 67.4 | 78.3 | 67.6 | 55.1 | 56.6 | 62.5 | 56.0 | 57.8 |
| | Sink | - | 32.6 | 21.7 | 32.4 | 44.9 | 43.4 | 37.5 | 44. | 42.2 |
| 1.5 | Float | - | 100 | 98.6 | 95.3 | 96.6 | 93.2 | 85.7 | 82.7 | 68.5 |
| | Sink | - | - | 1.4 | 4.7 | 3.4 | 6.8 | 14.3 | 17.3 | 31.5 |

All figures given above are weight percent (%)

* hand-picked: one of the size groups collected at site.

Figure 2


Yield Weight Percent as Function of Sample Top Size
( for Group #3 )
1.3 S.G.
1.4 S.G.
1.5 S.G.
Yield Weight %
100
90
80
70
60
50
40
30
20
10
0
1
½
+4
+7
+10
+14
+20
-20
sample size
1.5F
1.4F
1.3F

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1323

Figure 3

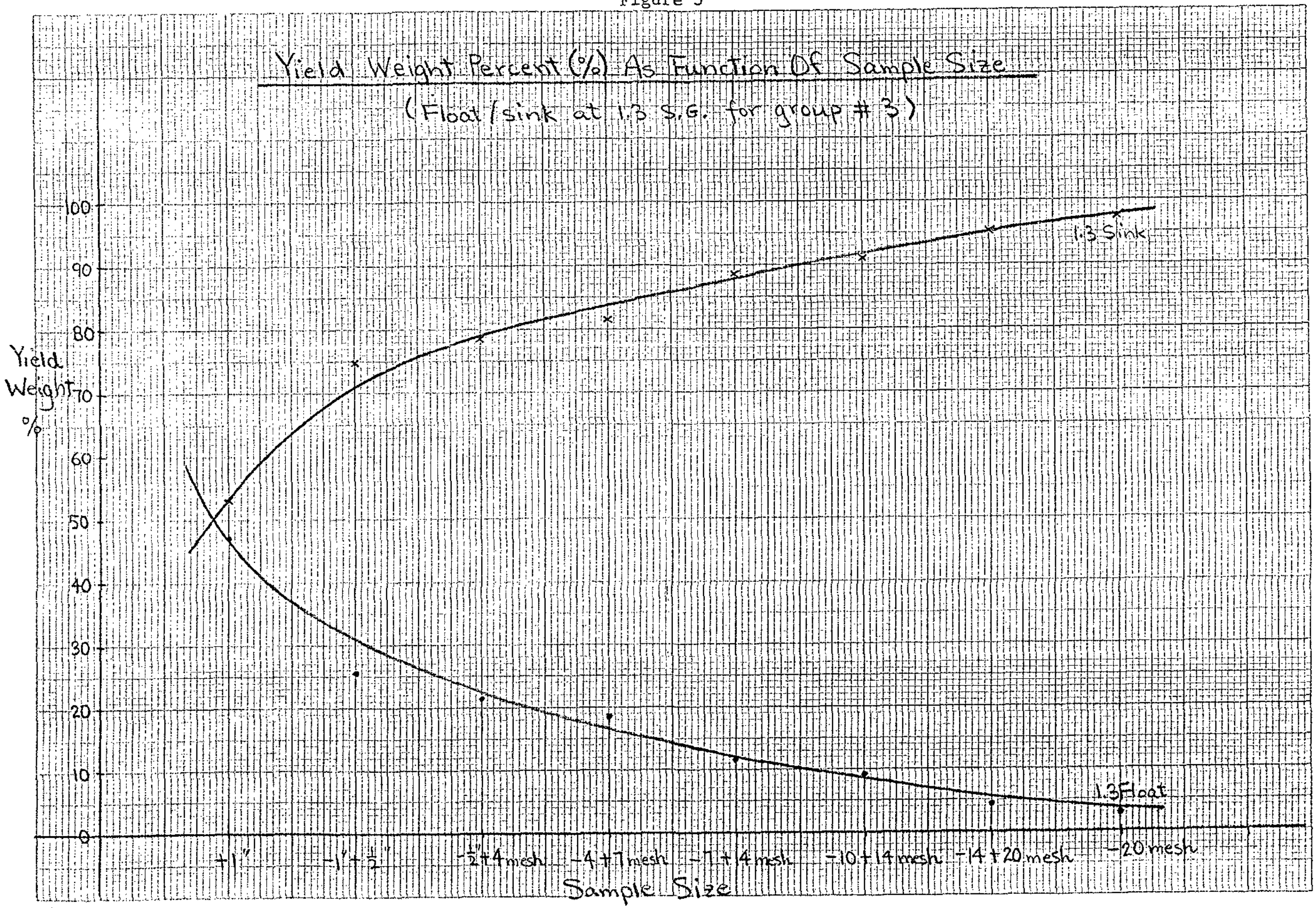


Table III

FLOAT/SINK RESULTS FOR GROUP #3

| Sample Size | Fraction | Moisture | Vol.& Deh* | Carbon | Ash | Vol.& Deh* (Dry Basis) | Carbon (Dry Basis) | Ash (Dry Basis) | Calorific Value BTU/lb(db) | Mineral Identification |
|---|---|---|---|---|---|---|---|---|---|---|
| Specific Gravity: 1.3 | | | | | | | | | | |
| +1" | Float | 14. | 39.1 | 38.4 | 8.5 | 45.4 | 44.7 | 9.9 | 10400 | kaolinite,bentonite |
| -1"+½" | Float | 19.4 | 34.8 | 38.7 | 7.1 | 43.2 | 48.0 | 8.8 | 10840 | patterns not well |
| -½"+4 mesh | Float | 17.5 | 36.3 | 41. | 5.2 | 44. | 49.7 | 6.3 | 11300 | defined |
| -4+7 mesh | Float | 17.2 | 38.8 | 39.7 | 4.4 | 46.9 | 48. | 5.3 | 11350 | " |
| -7+10 mesh | Float | 12.1 | 41.2 | 42.6 | 3.5 | 47.6 | 48.4 | 4.0 | 10170 | " |
| -10+14 mesh | Float | 13.3 | 40.3 | 41.7 | 4.7 | 46.5 | 48.1 | 5.4 | - | " |
| -14+20 mesh | Float | 13.4 | 41. | 43. | 2.6 | 47.3 | 49.7 | 3.0 | 11390 | " |
| -20 mesh | Float | 11.7 | 43.7 | 37.9 | 6.5 | 49.7 | 42.9 | 7.4 | - | " |
| Specific Gravity: 1.4 | | | | | | | | | | |
| +1" | Float | 14.6 | 35.8 | 38. | 11.6 | 41.9 | 44.5 | 13.6 | 10470 | - |
| -1"+½" | Float | 13.4 | 36.5 | 38.3 | 11.8 | 42.2 | 44.2 | 13.6 | 10210 | kaolinite,bentonite |
| -½"+4 mesh | Float | 12.6 | 35.6 | 39.6 | 12.2 | 40.7 | 45.3 | 14. | 10230 | kaolinite,bentonite quartz |
| -4+7 mesh | Float | 14.6 | 38.4 | 37.9 | 9.1 | 45. | 44.4 | 10.6 | 10470 | kaolinite,bentonite |
| -7+10 mesh | Float | 13.5 | 39.5 | 38.9 | 8.1 | 45.6 | 45. | 9.4 | 10220 | patterns not well |
| -10+14 mesh | Float | 14.4 | 36.4 | 41.1 | 8.1 | 42.5 | 48. | 9.5 | 10840 | defined |
| -14+20 mesh | Float | 13.3 | 37.4 | 42. | 7.3 | 43.1 | 48.5 | 8.4 | 10870 | " |
| -20 mesh | Float | 13.4 | 37.9 | 42.9 | 5.8 | 43.8 | 49.5 | 6.7 | 10720 | " |

* Volatile and Dehydration of Clay.

Due to the lack of time, a complete study of these 6 groups of samples from the Hat Creek coal deposit including washability study at 1.3 to 1.90 S. G. fluids at six or seven sample top sizes could not be carried out. A complete study of these basic constituents of the deposit should give a set of washability curves applicable to all samples from the deposit and these would be very helpful for future references.

II. <u>Bradford Breaker Samples</u>

A. First Batch (High Ash Content Coal)

Taking advantage of the information that groups #1 and #4 disintegrated in water, Bradford Breaker samples (as received) were placed in water and stirred for one hour at 40 RPM. Some inorganic minerals became loose in water. The ash content of the washed coal was reduced by about 10%. The calorific value of the coal correspondingly increased from 4900 to 6540 BTU/lb on dry basis (or 3800 to 5100 BTU/lb at ∿ 23% moisture). About 8% by weight was lost in this water washing. This weight loss was primarily due to disintegration of the components similar to groups #1 and #4 in water.

The first batch of the Bradford Breaker sample was composed of four sacks. The four bags were thoroughly mixed and the mixed sample was sieved into 6 sizes. The weight percent and cumulative weight percent distribution of different size fraction are given in Table IV and in Figure 4. These sieved samples i.e. all 6 sizes were also gravity separated at 1.3 S.G. fluid for doing some preliminary study.

Table IV

SIZE DISTRIBUTION OF BRADFORD BREAKER SAMPLE

FIRST BATCH (FOUR SACKS)

| Size | Weight % Distribution | Cumulative Weight % |
|---|---|---|
| 2" → 1/2" | 26.8 | 26.8 |
| 1/2 → 1/4" | 32.0 | 58.8 |
| - 1/4" + 4 mesh | 6.8 | 65.6 |
| - 4 + 7 mesh | 10.0 | 75.6 |
| - 7 + 14 mesh | 8.5 | 84.1 |
| - 14 mesh | 15.9 | 100. |

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1323

Figure 4

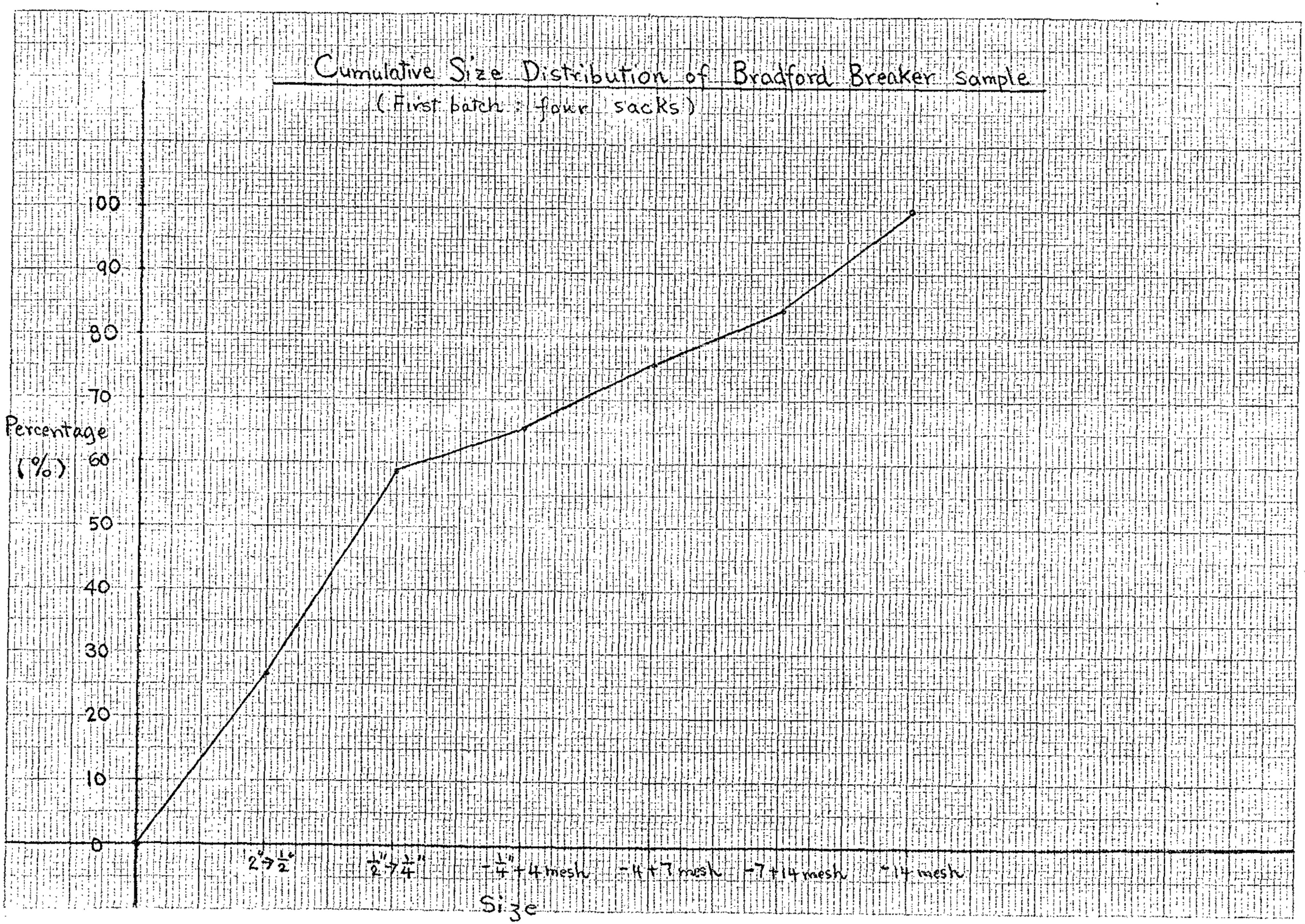


Figure 5 shows the results of this float and sink test for six different size fractions and Table V summarizes the data.

Detailed Float-Sink Tests

Bradford breaker sample of top sizes ≤ 1 1/2", ≤1", ≤1/2" and ≤ 1/4" were floated at specific gravities 1.3 to 1.7. Incremental increase of .10 specific gravity is used except between 1.4 to 1.6 S.G. where the incremental increase is .05 S.G. Samples were not floated at specific gravities higher than 1.7 because the ash contents on dry basis of the float fractions of top sizes ≤ 1 1/2" and ≤ 1" are approximately 66 % and 72 %, respectively. Experiments at higher specific gravity fluid could only result in ash content higher than approximately 70% db (a rough average of 66% and 72%). At 70% ash content, the carbon content is only about 2 to 4% according to TGA results. This means that floating at higher specific gravity will only add to the percentages of recovery and ash, but add very little to the total calorific value.

It should be pointed out that Hat Creek coal is very porous (especially groups #1 and #4-6 groups collected on site) as found by scanning electron microscope. And because alcohol solution (used for F/S tests) has better wettability characteristics than water on coal, comparison of data between F/S tests in alcohol solution and water should be viewed with the following in mind. What happens is that alcohol solution fills up more pores in the coal than water when floated in

Table V

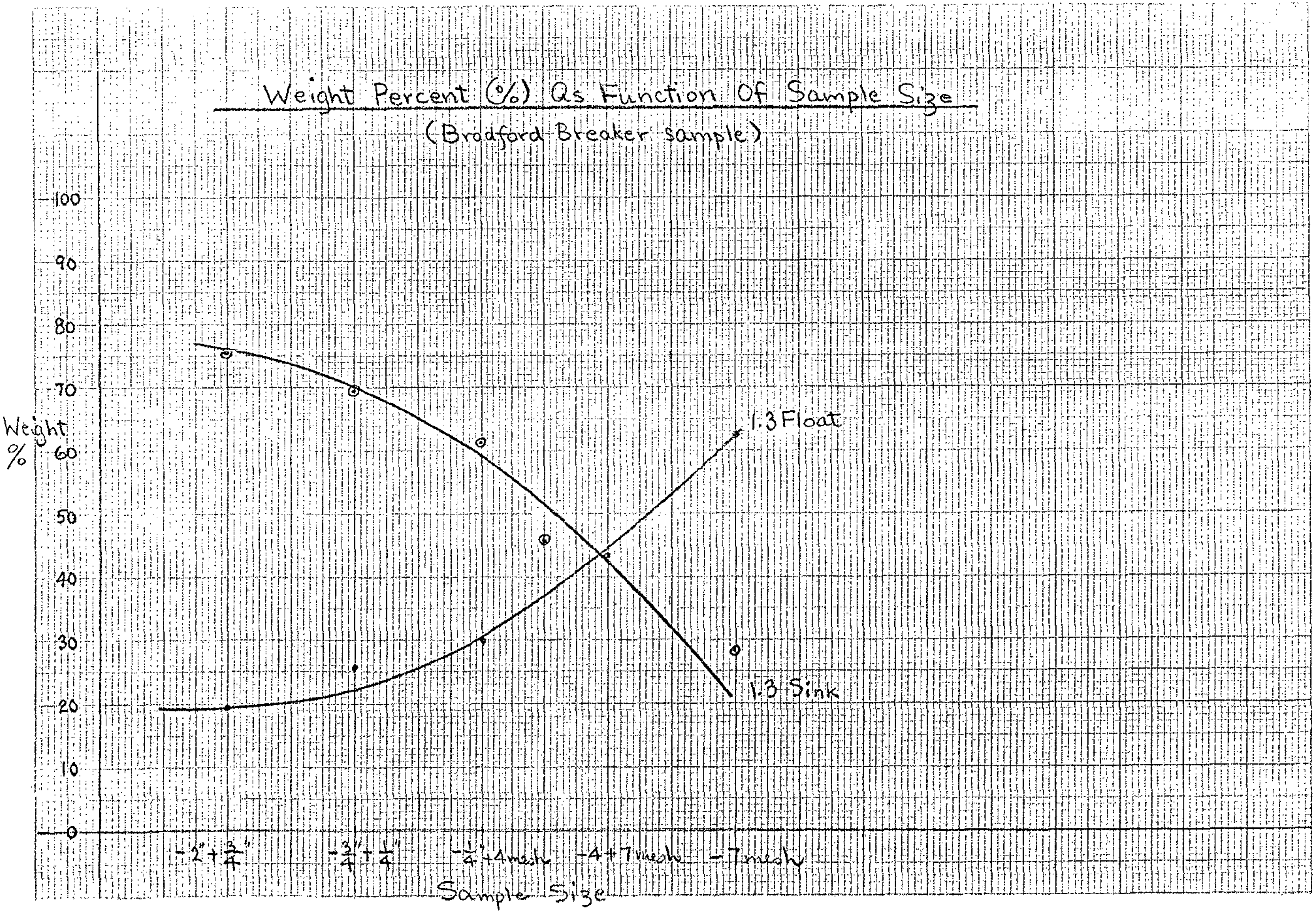
Sample: Bradford Breaker Sample

Float and sink test at 1.3 specific gravity

| Sample Size | wt.% Float | wt.% Sink | Wt.% Loss* |
|---|---|---|---|
| -2" + 3/4 | 19.5 | 75.4 | 5.1 |
| -3/4" + 1/4" | 25.1 | 69.9 | 5.0 |
| -1/4" + 4 mesh | 29.2 | 61.2 | 9.7 |
| -4 + 7 mesh | 43.6 | 45.9 | 10.5 |
| -7 mesh | 62.2 | 28.2 | 9.6 |

* handling losses

Figure 5


Weight Percent (%) as Function Of Sample Size
(Bradford Breaker sample)
Weight %
100
90
80
70
60
50
40
30
20
10
0
1.3 Float
1.3 Sink
-2" + 3/4"
-3/4" + 1/4"
-1/4" +4mesh
-4+7mesh
-7mesh
Sample Size

specific gravity fluids. When the pores are not filled with S.G. fluid, they are filled with air*. This means that the apparent specific gravity of the coal (same type) is lower in water than in alcohol solution. The difference between floating the sample in alcohol and water medium should show up in the washability curves. For example, the washability curve with yield weight percent as a function of specific gravity of sample floated in water medium should shift slightly to the right than that in alcohol medium. The actual amount of specific gravity shifted can only be estimated easily by experimental means.

Experimental results of the float and sink tests are presented in table forms (Table VI to IX). On the left of the tables, listed are the specific gravities at which the samples are floated; the weight percentage of the samples, their moisture contents and the calculated weight percentages of the samples on dry basis. In the next section is information on the float fractions at various specific gravities from weight of float fraction (g) to cumulative calorific value (dry basis). The next section further to the right has information on the sink fractions from the weight of sink fraction (g) to calorific value BTU/lb (dry basis). The last section is on the amount of loss during float/sink tests.

An example on reading these tables should clarify any doubts

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* generally speaking

on the interpretation of the experimental results. Samples with top size $\leq$ 1 1/2" is floated at 1.3 specific gravity (S.G.). The total original weight for floating is 1553 g. at 17.3% moisture yielding 1284 g. on dry basis. This amount of sample, 1284 g. (db) is floated at 1.3 S.G. giving float fraction of 299 g. at 24.3% moisture or 266 g. on dry basis and sink fraction of 1188 g at 16.2% moisture or 996 g. on dry basis. The percentage of moisture is monitored closely for the purpose of balancing the weights throughout the float/sink test.

Float fraction of 266 g. on dry basis constitutes 20.7 weight % of original weight 1284 g. (db). The ash and cumulative ash contents (db) in weight percentages of the float fraction are both 10%. 60% and 40% of the ash content are kaolinite and bentonite respectively. These would mean 1.2% and .8% of the original material (1284 g. db) are kaolinite and bentonite, respectively. The sulfur and cumulative sulfur contents in weight percentages are both .63%, or 256 gram sulfur per million BTU. ( $\frac{1600,000}{11170}$ x 453.5922 x .0063). The heat and cumulative heat contents on dry basis are both 11170 BTU/lb.

Sink fraction of 996 g. on dry basis constitutes 77.5% of the original material for floating (1284 g. db). This 1.3-specific gravity sink fraction is not analysed for ash, heat, and sulfur contents.

Balancing the original weight of material for floating, the weights of the float and sink fractions; the weight percentage of loss (db) is 1.8%.

The sink fraction (996 g.) db of 1.3 S.G. is then used for the float/sink test in 1.4 S.G. fluid. Again, this resulted in a float fraction and a sink fraction.

The weight of the float fraction is 305 g. at 21.2% moisture or 240 g. on dry basis. The weight % is 24.1% ( $\frac{240\text{ g}}{996\text{ g}}$ x 100). Cumulative weight % is 39.4% (20.7 + 18.7%). The weight % of total material is 18.7% ( $\frac{240\text{ g}}{996\text{ g}}$ x 77.5%). The ash content of this fraction is 31.5%. The cumulative ash content is 20.2% (i.e. a sample made up of 1.3 and 1.4 F has ash content of 20.2%). 88% and 12% of the ash content of this fraction are kaolinite and bentonite respectively. The weight % of kaolinite and bentonite of the original material i.e. 1284 g (db) of this fraction are 5.18 and .71% respectively. The cumulative kaolinite and bentonite contents (i.e. a sample made up of 1.3 and 1.4 F has K and B contents of 6.4 and 1.5% respectively) are 6.4 and 1.5% respectively. The weight % of sulfur and cumulative sulfur are .80 and .71% respectively. And the sulfur and comulative sulfur contents in grams of sulfur per million BTU are 429 and 338 respectively.

The heat and cumulative heat contents are 8460 and 988 BTU/lb respectively.

The weight of the sink fraction is 879 g at 14% moisture or 756 g. on dry basis. The weight % of the sink fraction is 75.9% ( $\frac{756 \text{ g}}{996 \text{ g}}$ x 100). The weight % of the total original weight is 58.8% ( $\frac{756}{996}$ x 77.5%). The weight % of ash and cumulative ash contents are actually the same and is equal to 62.5% (db). 49% and 51% of the ash content of this fraction are kaolinite and bentonite respectively. Weight % and cumulative weight % of kaolinite and bentonite are the same and is equal to 18.0 and 18.7% respectively (18. = 58.8% (.625)(.49) and 18.7 = 58.8% (.625)(.51)). The sulfur content of this fraction (i.e. 1.45) in wt.% and grams sulfur per million BTU are 0.45% and 559 respectively. And the calorific value of this fraction is 3650 BTU/lb.

Again 1.4 S.G. sink fraction is used for the float/sink test at 1.45 S.G. to obtain float and sink fractions. Note that only 833 g. of 879 g at 14% moisture of 1.4 sink fraction is floated at 1.45; the difference (879 g. - 833 g. at 14% moisture) is used for analyses.

Insert

LOGS

MO32/4 log 1



Table VI

SAMPLE: BRADFORD BREAKER SAMPLE SIZE: ≤ 1 1/2"

| Specific Gravity Sink | Specific Gravity Float | Weight of Material for F/S(g) | % Moisture | Weight of Material for F/S(g)(db) | Weight of Float Fraction(g) | % Moisture | Weight of Float Fraction (g) (db) | Wt.% of Float Fraction(db*) | Cumulative Weight % of Float Fraction | Wt.% (db) of Original Total Material |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.3 | 1553 | 17.3 | 1284 | 299 | 24.3 | 266 | 20.7 | 20.7 | 20.7 |
| 1.3 | 1.4 | 1188 | 16.2 | 996 | 305 | 21.2 | 240 | 24.1 | 39.4 | 18.7 |
| 1.4 | 1.45 | 833 | 14. | 716 | 247 | 20.1 | 197 | 27.6 | 55.6 | 16.2 |
| 1.45 | 1.50 | 501 | 9.2 | 455 | 35 | 9.8 | 32 | 6.9 | 58.3 | 2.7 |
| 1.50 | 1.55 | 427 | 13.5 | 369 | 13 | 12.5 | 11 | .8 | 58.6 | .3 |
| 1.55 | 1.6 | 429 | 9.0 | 390 | negl. | - | - | - | - | - |
| 1.6 | 1.7 | 429 | 9.0 | 390 | 118 | 9.8 | 107 | 27.4 | 59.2 | .6 |

| Sink | Float | X-ray Analysis Kaol | Bent | Qtz | Sid | Pyp | Ank | Wt.% of Original Total Material(db) Kaol | Bent | Kaol Cumulative | Bent Cumulative | Wt.% Ash (db) | Cumulative Wt.% Ash (db) | Wt.% Sulfur (db) | Cumulative Wt.% Sulfur(db) | Grams Sulfur / Million BTU (db) | Cumulative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.3 | 60 | 40 | t | - | t | - | 1.2 | .8 | 1.2 | .8 | 10. | 10. | .63 | .63 | 256 | 256 |
| 1.3 | 1.4 | 88 | 12 | t | t | t | t | 5.18 | .71 | 6.4 | 1.5 | 31.5 | 20.2 | .80 | .71 | 429 | 338 |
| 1.4 | 1.45 | 74 | 26 | t | t | t | - | 4.81 | 1.69 | 11.2 | 3.2 | 40.1 | 26. | .61 | .68 | 351 | 342 |
| 1.45 | 1.50 | 58 | 42 | t | - | - | t | .89 | .65 | 12.1 | 3.9 | 57. | 27.4 | .57 | .68 | 478 | 348 |
| 1.50 | 1.55 | - | - | - | - | - | - | - | - | - | - | 63. | 27.6 | - | - | - | - |
| 1.55 | 1.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1.6 | 1.7 | 52 | 48 | t | - | t | t | .21 | .19 | 13.3 | 4.1 | 66.2 | 28. | - | - | - | - |

| Sink | Float | Calorific Value BTU/lb | Calorific Value BTU/lb (db) | Cumulative | Weight of Sink Fraction(g) | % Moisture | Weight of Sink Fraction(db) | Wt.% of Sink Fraction(db*) | Wt.% (db) of Original Total Material | X-ray Analysis Kaol | Bent | Qtz | Sid | Pyp | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.3 | 8455 | 11170 | 11170 | 1188 | 16.2 | 996 | 77.7 | 77.5 | - | - | - | - | - | - |
| 1.3 | 1.4 | 6664 | 8460 | 9884 | 879 | 14. | 756 | 75.9 | 58.8 | 49 | 51 | t | t | t | t |
| 1.4 | 1.45 | 6300 | 7880 | 9300 | 522 | 9.2 | 474 | 66.2 | 38.9 | 50 | 50 | t | t | - | t |
| 1.45 | 1.50 | 4878 | 5410** | 9120 | 476 | 13.5 | 412 | 90.5 | 35.2 | 46 | 54 | t | t | - | t |
| 1.50 | 1.55 | - | - | - | 434 | 9.0 | 395 | 99.2 | 34.9 | - | - | - | - | - | - |
| 1.55 | 1.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1.6 | 1.7 | 3164 | 3510 | 9035 | 308 | 9.5 | 279 | 72.8 | 34.3 | 49 | 51 | t | t | - | - |

| Sink | Float | Wt.% of Original Total Material(db) Kaol (of F/S Fractions) | Bent (of F/S Fractions) | Kaol Cumulative | Bent Cumulative | Wt.% Ash(db) | Wt.% Sulfur(db) | gms. S / Mil BTU (db) | Calorific Value BTU/lb (db) | Calorific Value BTU/lb (db) | Wt.% Loss (db) | Cumulative Wt.% Loss (db) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.3 | - | - | | | - | - | - | - | - | 1.8 | 1.8 |
| 1.3 | 1.4 | 18. | 18.7 | 18. | 18.7 | 62.5 | .45 | 559 | 3138 | 3650 | - | 1.8 |
| 1.4 | 1.45 | 13.63 | 13.63 | 13.6 | 13.6 | 70.1 | .42 | 664 | 2610 | 2870 | 6.2 | 5.5 |
| 1.45 | 1.50 | 12.4 | 14.56 | 12.4 | 14.6 | 76.6 | .79 | 498 | 2285 | 2640 | 2.6 | 6.5 |
| 1.50 | 1.55 | - | - | - | - | - | .29 | 498 | - | - | - | 6.5 |
| 1.55 | 1.6 | - | - | - | - | - | .29 | 498 | - | - | - | 6.5 |
| 1.6 | 1.7 | 12.64 | 13.15 | 13.6 | 13.2 | 75.2 | .17 | 426 | 1640 | 1810 | - | 6.5 |

* db : dry basis

M032/4 log 2



Table VII

SAMPLE: BRADFORD BREAKER SAMPLE

SIZE: ≤ 1"

| Specific Gravity Sink | Specific Gravity Float | Weight of Material for F/S(g) | % Moisture | Weight of Material for F/S(g)(db) | Weight of Float Fraction(g) | % Moisture | Weight of Float Fraction (g) (db) | Wt.% of Float Fraction(db*) | Cumulative Weight % of Float Fraction | Wt.% (db) of Original Total Material |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.3 | 2576 | 6.5 | 2409 | 437 | 23.9 | 333 | 13.8 | 13.8 | 13.8 |
| 1.3 | 1.4 | 2333 | 20.2 | 1862 | 653 | 16.3 | 547 | 29.0 | 37.1 | 23.3 |
| 1.4 | 1.45 | 1501 | 15.5 | 1268 | 504 | 14.1 | 433 | 33.8 | 56.4 | 19.3 |
| 1.45 | 1.50 | 920 | 16 | 773 | 195 | 9.1 | 177 | 22.6 | 65.8 | 8.6 |
| 1.50 | 1.55 | 547 | 10.4 | 490 | 61 | 11.2 | 54 | 11 | 68.2 | 3.2 |
| 1.55 | 1.6 | 374 | 10.6 | 334 | negl | - | - | - | - | - |
| 1.6 | 1.7 | 374 | 10.6 | 334 | 9 | 10.2 | 8 | 2.3 | 68.3 | .1 |

| Sink | Float | X-ray Analysis Kaol | Bent | Qtz | Sid | Pyp | Ank | Wt.% of Original Total Material(db) Kaol | Bent | Kaol Cumulative | Bent Cumulative | Wt.% Ash (db) | Cumulative Wt.% Ash (db) | Wt.% Sulfur (db) | Cumulative Wt.% Sulfur(db) | Grams Sulfur / Million BTU (db) | Cumulative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.3 | 89 | 11 | - | t | t | - | 1.17 | .14 | 1.2 | .14 | 9.5 | 9.5 | .40 | .40 | 148 | 148 |
| 1.3 | 1.4 | 66 | 34 | - | - | t | - | 4.12 | 2.12 | 5.3 | 2.3 | 26.8 | 20.4 | .73 | .61 | 332 | 264 |
| 1.4 | 1.45 | 62 | 38 | t | t | - | t | 6.83 | 4.19 | 12.1 | 6.5 | 57.1 | 32.9 | .58 | .60 | 480 | 338 |
| 1.45 | 1.50 | 51 | 49 | t | t | - | t | 3.0 | 2.9 | 15.2 | 9.4 | 68.9 | 37.7 | .50 | .59 | 606 | 373 |
| 1.50 | 1.55 | 57 | 43 | t | t | - | t | 1.3 | .98 | 16.4 | 10.3 | 71.3 | 39.2 | - | - | - | - |
| 1.55 | 1.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1.6 | 1.7 | ✓ | ✓ | t | t | t | - | - | - | 16.4 | 10.3 | - | 39.2 | - | - | - | - |

| Sink | Float | Calorific Value BTU/lb | Calorific Value BTU/lb (db) | Cumulative | Weight of Sink Fraction(g) | % Moisture | Weight of Sink Fraction(db) | Wt.% of Sink Fraction(db*) | Wt.% (db) of Original Total Material | X-ray Analysis Kaol | Bent | Qtz | Sid | Pyp | An- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.3 | 9322 | 12250 | 12250 | 2431 | 20.2 | 1940 | 80.5 | 80.5 | 55 | 45 | t | t | - | - |
| 1.3 | 1.4 | 8353 | 9980 | 10820 | 1582 | 15.5 | 1337 | 71.0 | 57.2 | 52 | 48 | t | t | t | - |
| 1.4 | 1.45 | 4707 | 5480 | 8995 | 1008 | 16. | 847 | 66.2 | 37.8 | 56 | 44 | t | - | - | - |
| 1.45 | 1.50 | 3400 | 3740 | 8300 | 677 | 10.4 | 607 | 77.4 | 29.3 | 55 | 45 | t | t | - | - |
| 1.50 | 1.55 | 2762 | 3110 | 8060 | 488 | 10.6 | 436 | 89. | 26.1 | 58 | 42 | t | t | - | - |
| 1.55 | 1.6 | | - | - | 374 | 10.6 | 334 | - | - | - | - | - | - | - | - |
| 1.6 | 1.7 | - | - | 8050 | 375 | 10.8 | 335 | 97.7 | 26. | 60 | 40 | - | - | - | - |

| Sink | Float | Wt.% of Original Total Material(db) Kaol (of F/S Fractions) | Bent (of F/S Fractions) | Kaol Cumulative | Bent Cumulative | Wt.% Ash(db) | Wt.% Sulfur(db) | gms. S / Mil BTU (db) | Calorific Value BTU/lb (db) | Calorific Value BTU/lb (db) | Wt.% Loss (db) | Cumulative Wt.% Loss (db) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.3 | 28.7 | 23.5 | 28.7 | 23.5 | 64.9 | .55 | 514 | 3872 | 4850 | 5.7 | 5.7 |
| 1.3 | 1.4 | 21.24 | 19.6 | 21.2 | 19.6 | 71.4 | .49 | 597 | 3145 | 3720 | - | 5.7 |
| 1.4 | 1.45 | 15.71 | 12.3 | 15.7 | 12.3 | 74.2 | .46 | 705 | 2481 | 2960 | - | 5.7 |
| 1.45 | 1.50 | 11.88 | 9.72 | 11.9 | 9.7 | 73.7 | .39 | 556 | 2847 | 3180 | - | 5.7 |
| 1.50 | 1.55 | 10.8 | 7.8 | 10.8 | 7.8 | 71.5 | .39 | 534 | 2989 | 3310 | - | 5.7 |
| 1.55 | 1.6 | - | - | - | - | - | .39 | - | - | - | - | 5.7 |
| 1.6 | 1.7 | 11.68 | 7.78 | 11.7 | 7.8 | 74.9 | .2] | - | 1633 | 1830 | - | 5.7 |

db : dry basis

SAMPLE: BRADFORD BREAKER SAMPLE (BATH #1)

Table V111

Size: ≤ 1/2"

MO32/4 log 3

| Specific Gravity Sink | Specific Gravity Float | Weight of Material for F/S(g) | % Moisture | Weight of Material for F/S(g)(db) | Weight of Float Fraction(g) | % Moisture | Weight of Float Fraction (g) (db) | Wt.% of Float Fraction(db*) | Cumulative Weight % of Float Fraction | Wt.% (db) of Original Total Material |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.45 | 1457 | 16. | 1224 | 1102 | 20.4 | 877 | 71.6 | 71.6 | 71.6 |
| 1.45 | 1.55 | 317 | 9.4 | 287 | 20 | 15.3 | 17 | 5.8 | 73.1 | 1.5 |
| 1.55 | 1.7 | 274 | 10.2 | 246 | 8.3 | 11. | 7.4 | 3.0 | 73.7 | .6 |

| Sink | Float | X-ray Analysis Kaol | Bent | Qtz | Sid | Pyp | Ank | Wt.% of Original Total Material(db) Kaol | Bent | Kaol Cumulative | Bent Cumulative | Wt.% Ash (db) | Cumulative Wt.% Ash (db) | Wt.% Sulfur (db) | Cumulative Wt.% Sulfur(db) | Grams Sulfur / Million BTU (db) | Grams Sulfur / Million BTU (db) Cumulative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.45 | 59 | 41 | t | t | t | - | 15.67 | 11.78 | 15.67 | 10.89 | 37.1 | 37.1 | .65 | .65 | 360 | 360 |
| 1.45 | 1.55 | 69 | 31 | t | t | t | - | .53 | .24 | 16.2 | 12.02 | 52.6 | 37.4 | - | - | - | - |
| 1.55 | 1.7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

| Sink | Float | Calorific Value BTU/lb | Calorific Value BTU/lb (db) | Calorific Value BTU/lb (db) Cumulative | Weight of Sink Fraction(g) | % Moisture | Weight of Sink Fraction(db) | Wt.% of Sink Fraction(db*) | Wt.% (db) of Original Total Material | X-ray Analysis Kaol | Bent | Qtz | Sid | Pyp | Ar | Wt.% of Original Total Material(db) Kaol (of F/S Fractions) | Bent (of F/S Fractions) | Kaol Cumulative | Bent Cumulative | Wt.% Ash(db) | Wt.% Sulfur(db) | gms. S / Mil BTU (db) | Calorific Value BTU/lb (db) | Calorific Value BTU/lb (db) | Wt.% Loss (db) | Cumulative Wt.% Loss (db) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.45 | 6515 | 8185 | 8185 | 337 | 9.4 | 305 | 25 | 25 | 63 | 37 | t | t | t | - | 12.03 | 7.07 | 12.03 | 7.07 | 74.8 | .38 | 545 | 2866 | 3160 | 3.4 | 3.4 |
| 1.45 | 1.55 | 5167 | 6100 | 8140 | 298 | 10.2 | 268 | 93.4 | 23.4 | 65 | 35 | t | - | - | - | 11.72 | 6.31 | 11.72 | 6.31 | 77.1 | - | - | 2809 | 3130 | .8 | 3.5 |
| 1.55 | 1.7 | - | - | - | 266 | 12.6 | 233 | 94.4 | 22.8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3.5 |

db: dry basis

M032/4 log (4)



Table 1X

SAMPLE: BRADFORD BREAKER SAMPLE
SIZE: ≤1/4"

| Specific Gravity Sink | Specific Gravity Float | Weight of Material for F/S(g) | % Moisture | Weight of Material for F/S(g)(db) | Weight of Float Fraction(g) | % Moisture | Weight of Float Fraction (g) (db) | Wt.% of Float Fraction(db*) | Cumulative Weight % of Float Fraction | Wt.% (db) of Original Total Material |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.45 | 1631 | 22.9 | 1236 | 1229 | 18.5 | 1002 | 81. | 81. | 81. |
| 1.45 | 1.55 | 200 | 7.9 | 184 | 4.4 | 14.4 | 3.8 | 2. | 81.3 | .3 |
| 1.55 | 1.7 | 174 | 4.4 | 166 | negl. | - | - | - | 81.3 | - |

db : dry basis

SAMPLE: BRADFORD BREAKER SAMPLE
SIZE: ≤1/4"

| X-ray Analysis Kaol | Bent | Qtz | Sid | Pyp | Ank | Wt.% of Original Total Material(db) Kaol | Bent | Kaol Cumulative | Bent Cumulative | Wt.% Ash (db) | Cumulative Wt.% Ash (db) | Wt.% Sulfur (db) | Cumulative Wt.% Sulfur(db) | Grams Sulfur / Million BTU (db) | Cumulative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 | 37 | - | - | - | - | 21.8 | 12.8 | 21.8 | 12.8 | 42.7 | 42.7 | .52 | .52 | 313 | 313 |
| 84 | 16 | - | - | - | - | .14 | .03 | 21.9 | 12.8 | 55. | 42.8 | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | 42.8 | - | - | - | - |

SAMPLE: BRADOFRD BREAKER SAMPLE
SIZE: ≤1/4"

| Calorific Value BTU/lb | Calorific Value BTU/lb (db) | Cumulative | Weight of Sink Fraction(g) | % Moisture | Weight of Sink Fraction(db) | Wt.% of Sink Fraction(db*) | Wt.% (db) of Original Total Material | X-ray Analysis Kaol | Bent | Qtz | Sid | Pyp | An |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6145 | 7540 | 7540 | 215 | 7.9 | 198 | 16. | 16. | 72 | 28 | t | t | t | - |
| 5050 | 5900 | 7534 | 189 | 4.4 | 180.7 | 98 | 15.7 | 59 | 34 | - | - | - | t |
| - | 5900 | 7534 | 174 | 4.4 | 166 | 100 | 15.7 | - | - | - | - | - | - |

Table IX

SAMPLE: BRADFORD BREAKER SAMPLE
SIZE: ≤1/4"

| Wt.% of Original Total Material(db) Kaol (of F/S Fractions) | Bent (of F/S Fractions) | Kaol Cumulative | Bent Cumulative | Wt.% Ash(db) | Wt.% Sulfur(db) | gms. S / Mil BTU (db) | Calorific Value BTU/lb (db) | Calorific Value BTU/lb (db) | Wt.% Loss (db) | Cumulative Wt.% Loss (db) |
|---|---|---|---|---|---|---|---|---|---|---|
| 8.99 | 3.49 | 8.99 | 3.49 | 71.8 | 78. | 754 | 2160 | 2345 | 3.0 | 3.0 |
| 7.33 | .87 | 7.33 | .87 | 75.6 | 79.1 | - | 2005 | 2100 | - | 3.0 |
| - | - | - | - | - | - | - | - | 2100 | - | 3.0 |

Washability Curves

From the detailed float-sink data as presented in Tables VI to IX for four top sizes, ≤1.5",≤1.0",≤0.50" and ≤0.25", the washability curves for these samples are drawn and are shown in Figs. 6 to 9. There are six curves in each figure.

Sample Sizes:

≤ 1½, ≤1", ≤½", ≤¼"

| y axis \ x axis | Ash % | Specific Gravity |
|---|---|---|
| Weight % of Float | 1, 2 | 4 |
| Weight % of Sink | 3 | - |
| Calorific Value BTU/lb | - | 5,6 |

● Curve 1: percent ash of cumulative float curve

- traces the variation of cumulative ash percent with the variation in recovery

○ Curve 2: ash curve of sample curve

- traces the variation in ash per cent with variation in recovery

△ Curve 3: percent ash of cumulative sink curve

- traces the variation of the cumulative ash percent with variation in weight per cent sink fraction.

□ Curve 4: recovery curve

- traces the variation of the recovery with the variation in specific gravity.

× Curve 5: cumulative heat content curve

- traces the variation of cumulative heat content with the variation of specific gravity

◇ Curve 6: total recoverable heat content per pound washed coal curve

- traces the variation of total recoverable heat content per pound washed coal with the variation of specific gravity. Calculations are shown in Table X.

Table X

CALCULATION OF TOTAL RECOVERABLE HEAT CONTENT PER POUND
WASHED COAL (WASHABILITY CURVES #6)

| SPECIFIC GRAVITY | TOTAL RECOVERABLE HEAT CONTENT PER POUND WASHED COAL | CUMULATIVE WT.% X HEAT CONTENT |
|---|---|---|
| Sample size $\leq$ 1 1/2" | | |
| 1.3 | 2310 | 20.7 % x 11170 BTU/lb |
| 1.4 | 3890 | 39.4% x 9884 BTU/lb |
| 1.45 | 5170 | 55.6 % x 9300 BTU/lb |
| 1.5 | 5320 | 58.3% x 9120 BTU/lb |
| 1.7 | 5350 | 59.2% x 9035 BTU/lb |
| Sample size $\leq$ 1" | | |
| 1.3 | 1690 | 13.8% x 12250 BTU/lb |
| 1.4 | 4010 | 37.1% x 10820 BTU/lb |
| 1.45 | 5070 | 56.4% x 8995 BTU/lb |
| 1.5 | 5460 | 65.8% x 8300 BTU/lb |
| 1.55 | 5500 | 68.2% x 8060 BTU/lb |
| 1.7 | 5500 | 68.3% x 8050 BTU/lb |
| Sample size $\leq$ 1/2" | | |
| 1.45 | 5860 | 71.6% x 8185 BTU/lb |
| 1.55 | 5950 | 73.1% x 8140 BTU/lb |
| Sample size $\leq$ 1/4" | | |
| 1.45 | 6110 | 81.% x 7540 BTU/lb |
| 1.55 | 6130 | 81.3% x 7534 BTU/lb |

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.



Figure 6

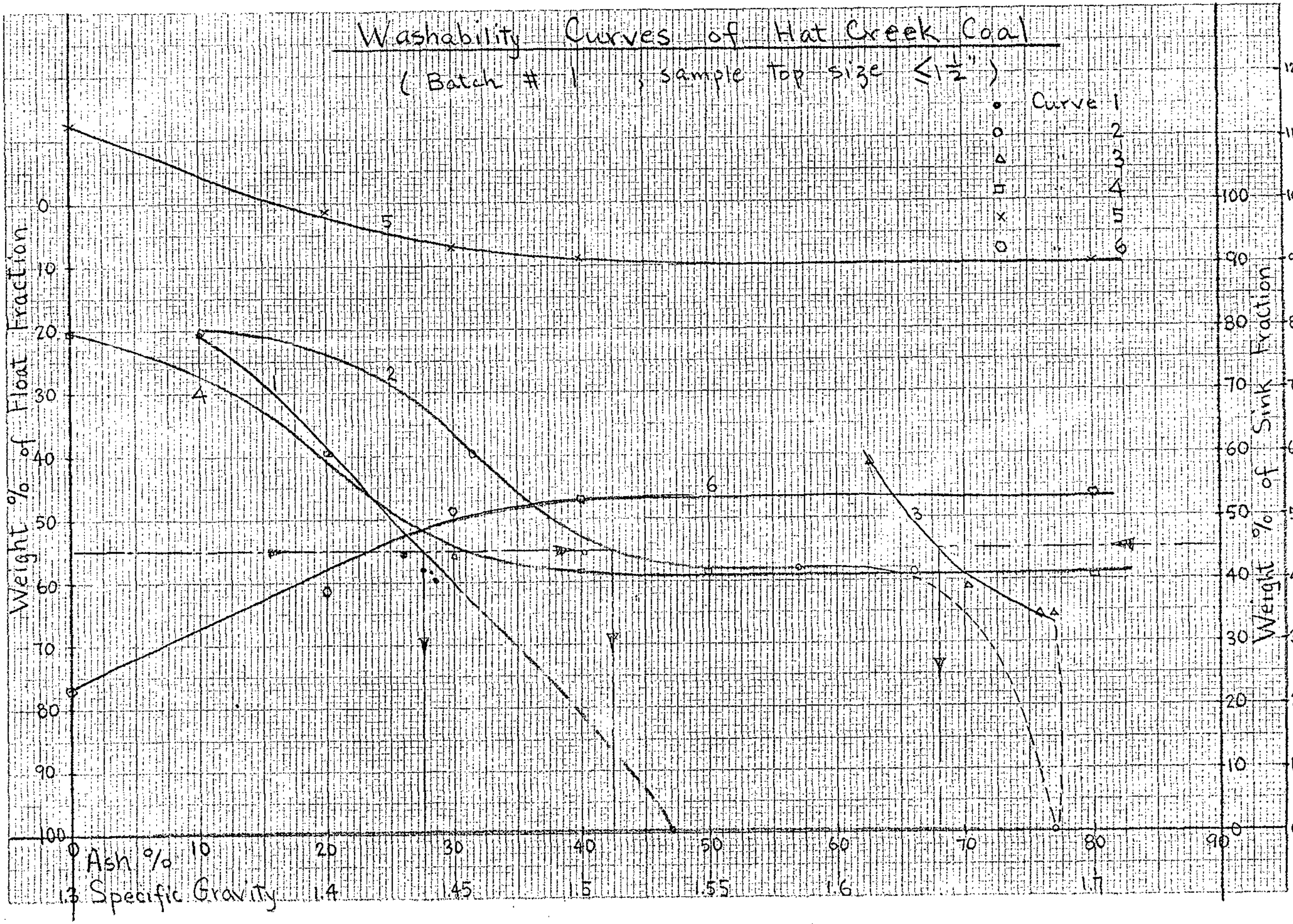


Figure 7

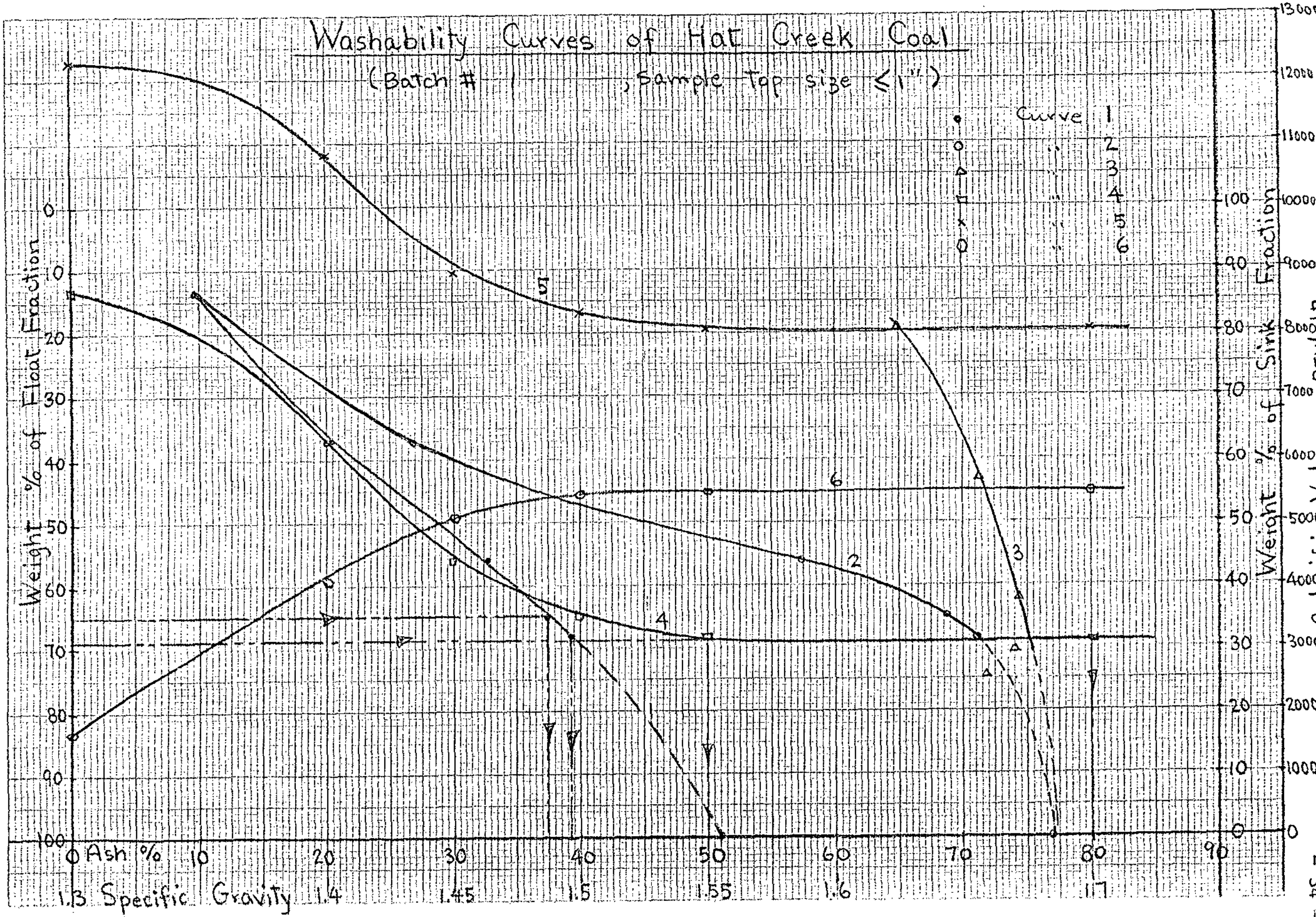
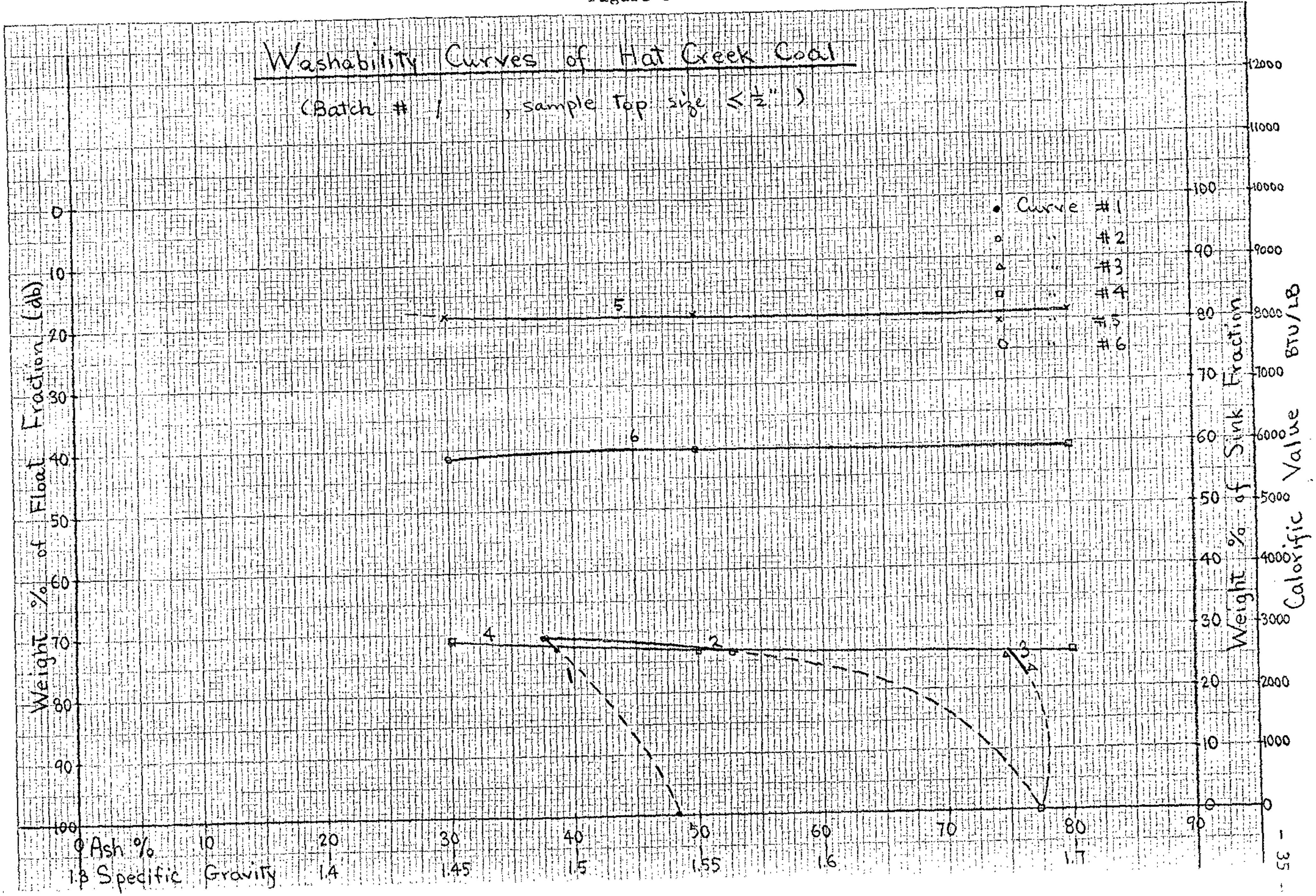
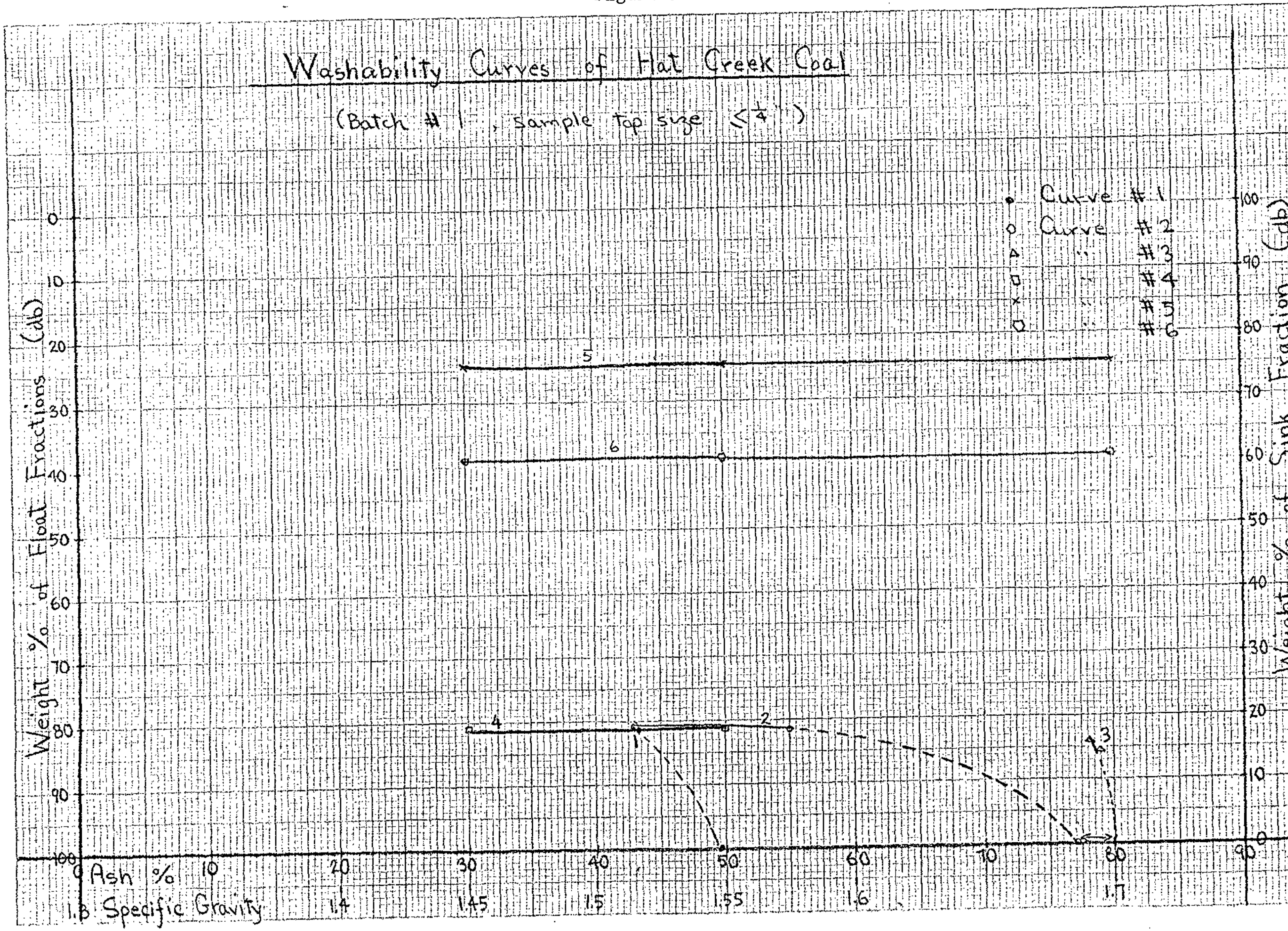

Washability Curves of Hat Creek Coal
(Batch # 1 , Sample Top size ≤1")
Curve 1
2
3
4
5
6
Weight % of Float Fraction
Weight % of Sink Fraction
Calorific Value BTU/LB
Ash %
Specific Gravity
1.3
1.4
1.45
1.5
1.55
1.6
1.7

Figure 8



Washability Curves of Hat Creek Coal
(Batch # 1 , sample Top size ≤ ½" )
• Curve #1
○ " #2
△ " #3
□ " #4
× " #5
○ " #6
Weight % of Float Fraction (db)
Weight % of Sink Fraction
Calorific Value BTU/LB
Ash %
Specific Gravity

Figure 9


Washability Curves of Hat Creek Coal
(Batch # 1 , sample top size ≤ ¼" )
Curve # 1
Curve # 2
" # 3
" # 4
" # 5
" # 6
Weight % of Float Fractions (db)
Weight % of Sink Fraction (db)
Calorific Value BTU/LB
Ash %
Specific Gravity
0 10 20 30 40 50 60 70 80 90
1.3 1.4 1.45 1.5 1.55 1.6 1.7

The dotted portions of curves number 1, 2, and 3 are projections of the existing curves based on experimental data. For example, at 100% recovery, the cumulative ash % of the float fractions of sample top sizes $\leq 1$ 1/2, $\leq 1$" are 47% and 51% respectively as shown by curve #1. These cumulative ash % are obtained by ash balances* of the float and sink fractions and they represent the ash content of the original (before washing) coal. Also at 100% recovery, the ash content of the float fractions are around 77% ash**. This means that as the samples are continued to be floated off as the specific gravity is increased; the ash % of the floated portion will be increased up to around 77% at 100% recovery. As the % of recovery and % of sink fraction approach 100 and 0 respectively, the ash contents (%) of the float and sink fraction should be the same. Therefore Curve #2 and #3 should converge to about 77% ash because both fractions should contain almost entirely of inorganic minerals when the percentage of recovery approaches 100.

---

** TGA analysis showed that sample containing only about 2% carbon has about 77% ash (from 76 → 80% ash). This sample contains almost entirely of inorganic minerals.

* See calculation of ash content of coal before washing by ash balance of float and sink fractions for sample top sizes $\leq$ 1 1/2", $\leq$ 1".

Interpretation of Washability Curves

Curves #1, 2 and 3 give information on the qualities of the clean coal and refuse at a chosen recovery. For example**, at 55% recovery considering top size $\lesssim$ 1 1/2, the ash % of the float-sink fraction is 42.5% (Curve #2), the cumulative ash % of the float fraction is 27% (Curve #1) and the ash % of the sink fraction is 68% (Curve #3). (Note that line is projected from (100% - 55% =) 45% of the sink fraction).

Curves #1 and #2 which are cumulative ash content and ash content of the float fraction curves, should indicate the variation of ash content with recovery which in turn indicate the specific gravity for separation. The ash content of the coal of sample top size $\lesssim$ 1" before cleaning is about 51% by ash balance*. Reduction of ash content by 12% (51% - 39%) corresponds to approximately 69%++* recovery at 1.55 to 1.7 specific gravity separation. Again from curve #1, reduction of ash content by 13.5% (51 - 37.5%) corresponds to approximately 65% *+* recovery at 1.5 specific gravity separation.

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*+* See lines on washability curves for sample size $\lesssim$1"

** See washability curves of sample top size $\lesssim$ 1 1/2", see lines with direction arrows.

* See calculation of ash content of coal before washing in Appendix.

++* See lines on washability curves (#1 and 4) for sample top size < 1".

Curve #4 traces the variation of recovery with the variation of specific gravity. This furnishes information on the amount of near gravity*+ material present. The significance*** of the amount of near gravity material on the operation of coal-preparation plant is shown on Table XI.

As seen in washability curves #4 of sample top sizes ≤ 1 1/2" and ≤ 1", the curves start to flatten out at around 1.5 S.G. The curves are completely flat from specific gravities (S.G.) 1.5 to 1.7. This means that the near gravity material at 1.6 → 1.65 S.G. is almost zero and floating the coal at this specific gravity will separate the coal easily. Curves #4 will drop very little as the specific gravities are increased. This prediction is based on experimental results - that the yield weight % of the float fractions remain fairly constant, the ash % of the sink fraction can increase very little, and the specific gravity of coal is around 1.3 to 1.4 S.G.*+++ Curves #4 will abruptly drop when the specific gravity is increased to that of one of the inorganic minerals

*** Chemistry of Coal Utilization, Supplementary Volume, p.326.

*+ Near-gravity material defined as the percentage of coal that will float in a range within plus and minus 0.10 specific of the cleaning value.

*+++ Around 1.3 to 1.4 at sample top sizes used here. But if sample top sizes are very small, e.g. -400 mesh, the true specific gravity can be as high as 1.7 → 1.8 due to decrease of porosity as the sample is grinded to smaller sizes.

Table XI

SIGNIFICANCE*OF AMOUNT OF NEAR-GRAVITY MATERIAL**

| Amount of Near Gravity Material | | Estimate of Coal-Preparation Plant Cleaning Problem |
|---|---|---|
| Greater than | Less than | |
| 0% | 7% | Simple |
| 7% | 10% | Moderately difficult |
| 10% | 15% | Difficult |
| 15% | 20% | Very difficult |
| 20% | 25% | Exceedingly difficult |
| 25% | | Formidable |

* Ref.#2 Chemistry of Coal Utilization, Supplementary Volume, H.H. Lowry, Editor, NAS-NRC Comittee on Chemistry of Coal, Wiley

** The near gravity material is defined as the percentage of the coal sample that will float in a range within plus and minus .10 specific gravity of the cleaning value.

in the coal. In view of the inorganic minerals present, this should happen at around 2.0 S.G.

Additional float and sink tests have been performed at 1.6 S.G., 1.7 S.G., 1.8 S.G. and 1.9 S.G. for sample top sizes ≤ 1/2" and ≤ 1/4". Negligible increases of recovery of the float fraction are observed. This confirms the above speculation.

## Summary of Interpretation of Washability Curves

From washability curves #1 to #4, it was found that the amount of recovery increases with decreasing sample top sizes at any specific gravity. The recoveries for sample top sizes ≤ 1-1/2", ≤1", ≤1/2" and ≤1/4" at 1.55 S.G. (for example) are 58.3%, 68.2%, 73.1% and 81.3% respectively. For all sample top sizes, the amounts of recovery remain constant from 1.5 S.G. to 1.7 S.G. Since additional float/sink tests were performed with sample top sizes ≤1/2" and ≤1/4", the amounts of recovery remain constant from 1.5 S.G. to 1.9 S.G. It can be speculated that the same finding is applicable for other top size samples. The near-gravity material is almost zero at 1.6 → 1.8 S.G. for all sample sizes.

## Total Recoverable Heat

Of all six curves, the most important curve to consider is

Curve #6. It traces the variation of total recoverable heat content per pound washed coal with variation of specific gravity. From balance* of all float and sink fractions, the heat content of Bradford Breaker sample ≤ 1" before washing is about 6050+ BTU/lb. But the total heat content of the coal varies from about 5200+ to 5450+ BTU/lb at specific gravities 1.45 to 1.7, respectively. This definitely shows that floating the coal beyond 1.7 S.G. will only increase the total heat content slightly. Therefore, the optimum specific gravity for floating the coal should be within this range i.e. 1.45 to 1.7 for maximum total recoverable heat content.

The effect of sample top size on the total recoverable heat content per pound washed coal is shown in Figure 10. The total recoverable heat content per pound washed coal is calculated with the cumulative calorific value as well as the cumulative weight percent recovery of the float fractions taking into consideration.

This figure shows the trend that as the sample top size is decreased, the total recoverable heat content per pound washed coal is increased at any specific gravities between 1.4 and 1.7. The actual heat content increase in BTU/lb between sample top sizes should not be taken from this graph because all four top size samples have slightly different calorific values before washing. From heat content balances,

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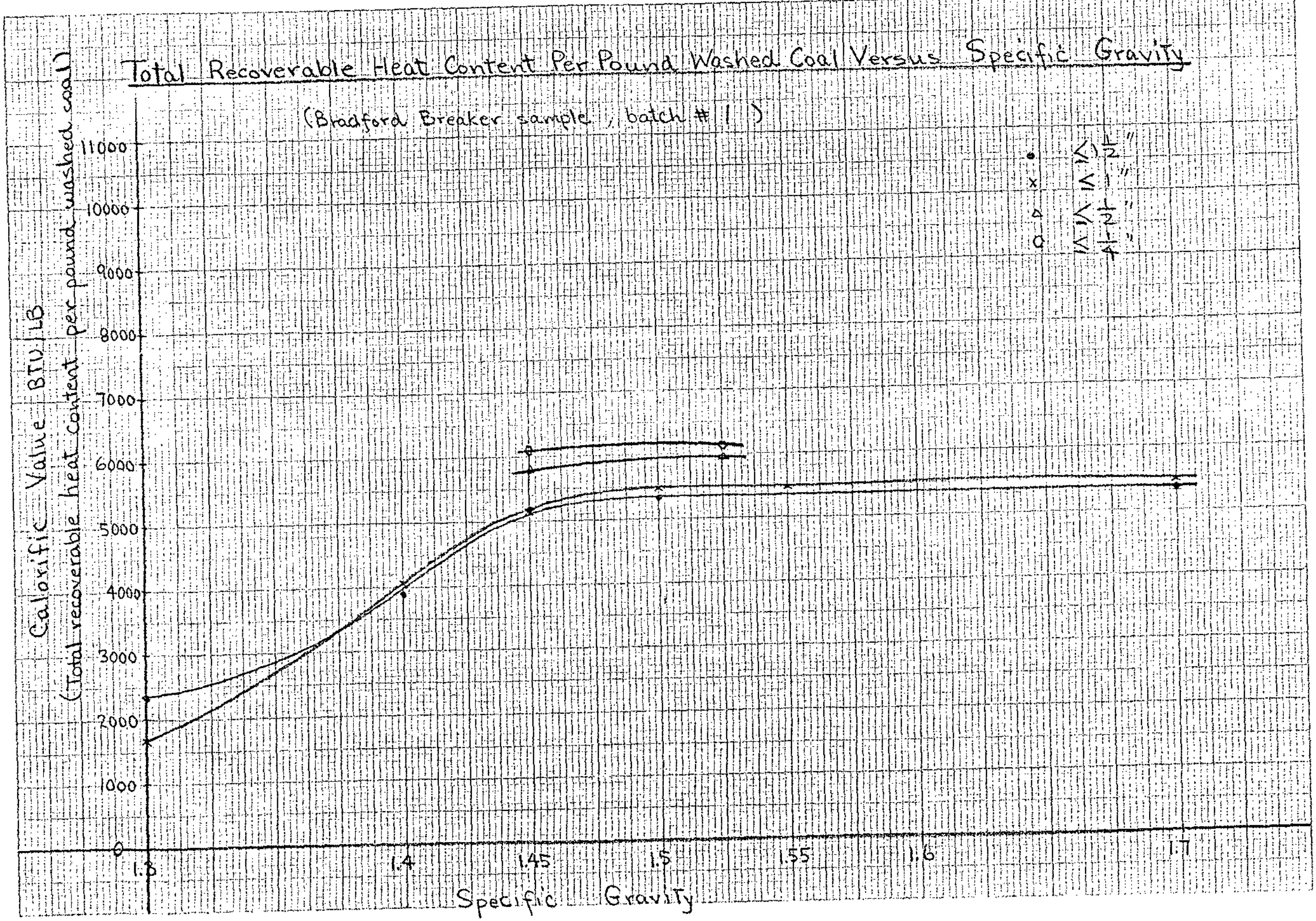
* See Appendix

\+ dry basis

Figure 10


Total Recoverable Heat Content Per Pound Washed Coal Versus Specific Gravity
(Bradford Breaker sample, batch # 1)
Calorific Value BTU/LB
(Total recoverable heat content per pound washed coal)
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1.3
1.4
1.45
1.5
1.55
1.6
1.7
Specific Gravity

the calorific values of sample top sizes ≤1 1/2", ≤1", ≤1/2" and ≤1/4" are 6050, 6050, 6730 and 6440 BTU/lb+ respectively. Comparison of the increase of total recoverable heat contents of the four top size samples in percentages should be more meaningful. This is shown in Table XII.

Table XII

| Sample Top Size | Cumulative total recoverable heat content per/lb washed coal(BTU/lb (db)) | Heat content of sample before washing (BTU/lb (db)) | % of heat content of sample before washing | % loss of total heat content |
|---|---|---|---|---|
| ≤1½" | 5330* | 6050 | 88.1 | 11.9 |
| ≤1" | 5500 | 6050 | 90.9 | 9.1 |
| ≤½ | 5950 | 6730 | 88.4 | 11.9 |
| ≤¼ | 6130 | 6440 | 95.2 | 4.8 |

The percentage increase of heat content seems to be very small as sample top size decrease from ≤1 1/2" to ≤ 1", and from ≤ 1" to ≤ 1/2" Significant increase is noted though as sample top size decreases from ≤ 1/2" to ≤ 1/4". At sample top size ≤ 1/4", the percentage of loss of heat content is only around 5%. Therefore, as far as total recoverable heat content per pound washed coal is concerned, smaller sample top size coal is definitely more advantageous for using as the feed material to coal preparation plant than larger sizes.

* Assume 10 BTU/lb increase at 1.55F from 1.5 F since at 1.5F heat content is 5320 BTU/lb and at 1.7F, it is 5350 BTU/lb.

\+ dry basis

Summary of Total Recoverable Heat Content

The percentages of recoverable heat content are approximately 90% for sample top sizes ≲1 1/2", ≲1" and ≲1" and ≲1/2" at 1.55 S.G.. But for sample top size ≲1/4", the percentage of recoverable heat content is about 95% at 1.55 S.G. with only about 5% loss of total heat content in the coal. The recoverable heat contents** of all sample top sizes remain fairly constant from 1.5 S.G. to 1.9 S.G.***

Distribution of Inorganic Minerals

Another area of investigation in this project is on the distribution of inorganic minerals in the float and sink fractions at various specific gravity separations. Cumulative weight % of float fraction as a function of cumulative ash % curves for sample top sizes ≲1 1/2", ≲1", ≲1/2" and ≲1/4" are shown in Figure 11. This figure shows that the ash content of the various top size samples before washing is about the same i.e. ≈ 49% ash. The mineral contents of the samples should then be a little higher than 49%.

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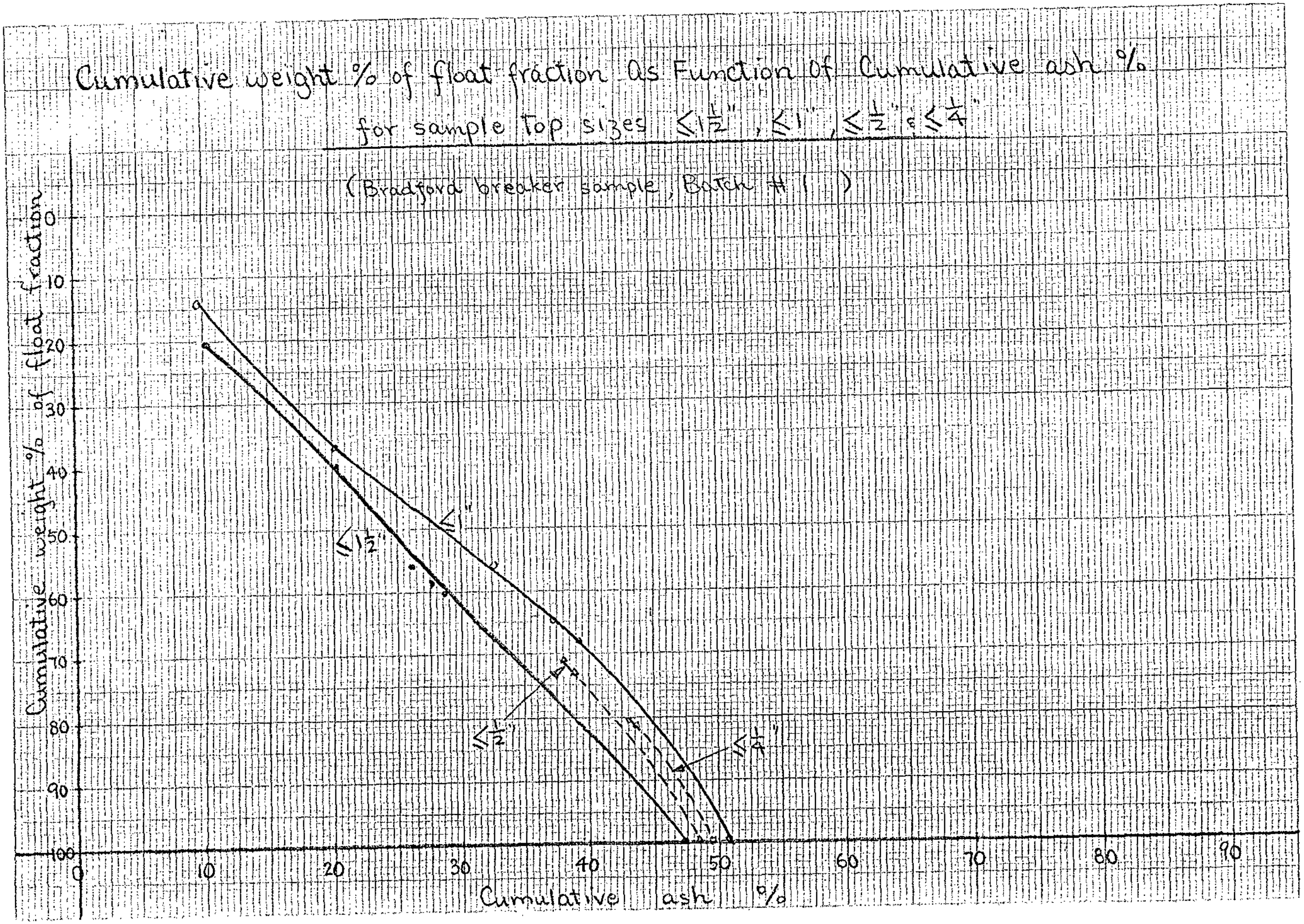
** of float fractions

*** 1.9 S.G. because of additional F/S tests at 1.8 S.G. and 1.9 S.G. for sample top sizes ≲1/2" and ≲1/4".

Figure 11


Cumulative weight % of float fraction As Function of Cumulative ash %
for sample Top sizes ≤1½", ≤1", ≤½" & ≤¼"
(Bradford breaker sample, Batch # 1 )
Cumulative weight % of float fraction
0
10
20
30
40
50
60
70
80
90
100
Cumulative ash %
0
10
20
30
40
50
60
70
80
90
≤1½"
≤1"
≤½"
≤¼"

The two major inorganic minerals present in the coal (Bradford Breaker sample, Batch #1) are bentonite and kaolinite. Minor minerals occur in traces only are quartz, siderite, pyrite and ankerite.

Because the inorganic part of the sample is almost entirely of bentonite and kaolinite, mass balance* and cumulative* mass balance are carried out only for these two minerals. Kaolinite/bentonite mass balance should show that the sum of these two minerals in the float and sink fraction at one specific gravity should equal to the sum of these minerals in the sink fractions of the previous lower specific gravity. Cumulative kaolinite/bentonite mass balance should show that at any specific gravity, the sum of these minerals in the float and sink fractions should equal to that at any other specific gravity (See Appendix for more explanation).

Figure 12 A and B summarize the distributions of minerals in the float and sink fractions by specific gravity separation. The two main minerals in the Bradford breaker sample (Batch #1) are kaolinite and bentonite. The distributions of minerals in both float and sink fractions are of interest because the float fraction will eventually end up in the furnace for power generation and the sink fraction will be used for brick-making if the scheme is proven feasible.

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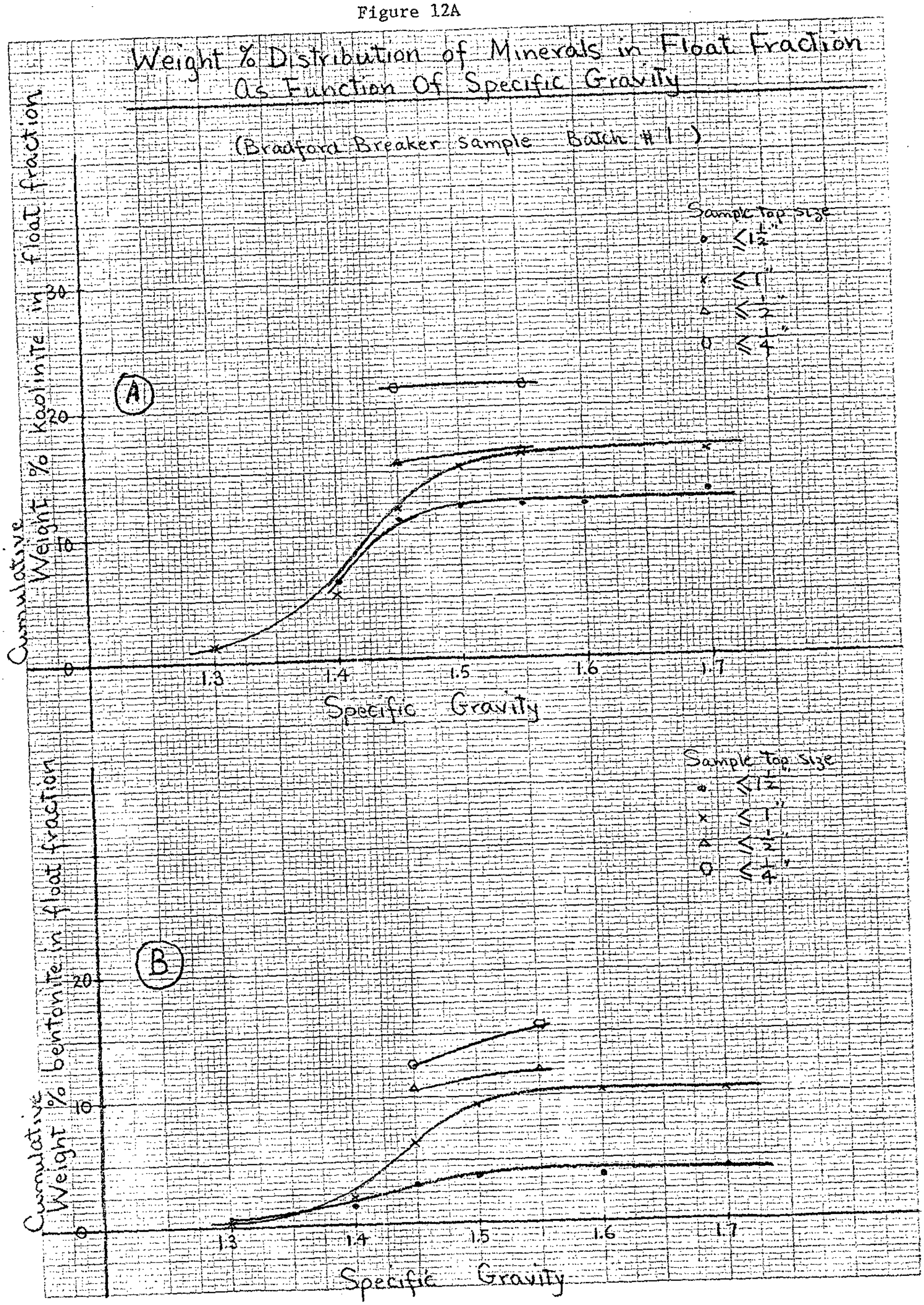
* See Appendix

Figure 12A

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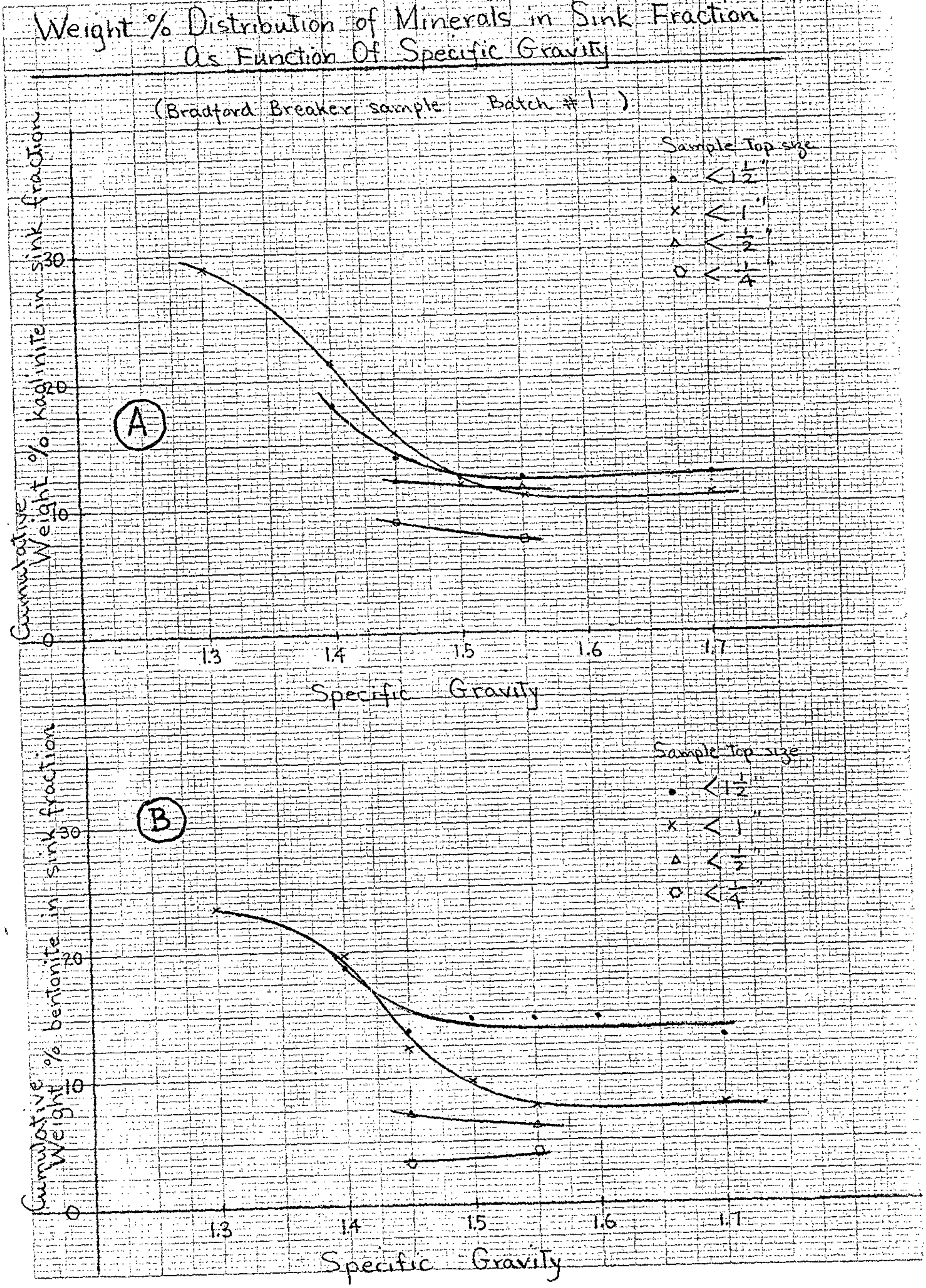
The fusion temperature of the feed to the furnace is dependent somewhat on the amount of kaolinite and bentonite in the coal. Generally speaking, bentonite decreases and kaolinite increases the fusion temperature. As shown in Figure 12 A and B, the cumulative weight % of both kaolinite and bentonite increases as the sample top size decreases. The increase in weight percent of the minerals is due primarily to the increase in recovery of the float fraction as the sample top size decreases. For example, the recoveries of sample top sizes ≤ 1 1/2", ≤ 1", ≤ 1/2" and ≤1/4" are 58.6%, 68.2%, 73.1% and 81.3% respectively at <u>1.55</u> specific gravity. As a whole, the increase of fusion temperature by kaolinite is offset by the decrease of fusion temperature by bentonite; the fusion temperature of the feed should therefore remain relatively the same for all sample top sizes.

The mineral distribution curves (Figure 13 A to B) of the sink fraction shows that as the sample top size decreases, the cumulative weight percent of the minerals decreases also. The decrease of the minerals can be explained by the decrease of the weight percent of sink fraction. For example, the weight percent of sink fraction of sample top sizes ≤ 1 1/2", ≤1", ≤1/2" and ≤1/4" are 34.9%, 26.1% 23.4% and 15.7% respectively at 1.55 specific gravity. But, the decrease of bentonite with decrease of sample top sizes is at a faster rate than that of kaolinite. This means that the sink fraction contains smaller percentage of bentonite at smaller top size than at

Figure 13

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K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

larger top sizes. For brick-making purposes, the decrease in bentonite is definitely a plus as bentonite is not desirable. Therefore smaller top size sample should be fed into preparation plant.

X-Ray identification of minerals and proximate analysis have been performed to trace losses of mineral during the cleaning process. TGA results show that"handling-loss Sample" is consisted of approximately (on dry basis) 20.5% volatile and dehydration of clay, 2.5% carbon and 77% ash. An X-ray analysis has shown that the sample is composed primarily of bentonite and only a small amount of kaolinite.

Summary of Distribution of Inorganic Minerals

Between 1.4 S.G. and 1.9 S.G.*, the cumulative weight % of both kaolinite and bentonite in the float fraction increases as the sample top size decreases. The increase in weight percentage of the minerals is due primarily to the increase in recovery of the float fraction as the sample top size decreases. Both the weight % of kaolinite and bentonite in the sink fraction decrease with decrease in sample top size. But the concentration of bentonite with decrease of sample top size decreases at a faster rate than that of kaolinite. This means that the sink fractions of smaller top sizes contain higher

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* Weight distribution curves show 1.4 S.G. to 1.7 S.G. But this is extended to 1.9 S.G. because no increase in recovery is observed in additional tests done at 1.8 S.G. and 1.9 S.G. for sample top sizes ≤1/2" and ≤1/4".

percentages of kaolinite than that of larger top sizes.

## Sulphur Removal by Washing

Sulfur distribution in the float and sink fractions is studied in search of suitable specific gravities for separation at which the sulfur content of the coal is reduced to the minimum. Reduction of the sulfur content in the float fraction would in turn reduces the amount of sulfur dioxide produced during combustion of the coal.

Hat Creek coal is a low sulfur coal having a mean sulfur content of approximately .41% as reported by Dolmage-Campbell and Associates Ltd.** Examination of the sulfur contents of drillholes 76-135 and 76-136 shows that large concentration of sulfur is present in the coal as organic sulfur, small percentage as pyritic sulfur, and almost none as sulfate sulfur. The distribution of sulfur in the proportions obtained is typical of low-sulfur coal***.

Generally speaking***, sulfur occurring in inorganic combination as pyrite and sulfate can be removed by specific gravity separation. However, the finer the pyrite particles in a coal grain and the lower its concentration, the more difficult it is to remove. Sulfur in organic combination or organic sulfur cannot be removed by mechanical cleaning or preparation processes because it is present

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** CIM Bulletin June 1977, p.107

*** Chemistry of Coal Utilization, p.425, p.426.

* Petrology, p.338

in the organic matter making up the coal. This imposes limitation on the extent sulfur can be removed by mechanical means.

Sulfur analyses were performed on 1.3, 1.4, 1.45, 1.5 specific gravity float and sink fractions of top sizes ≤1 1/2" and ≤1" samples. But for top sizes ≤1/2" and ≤1/4" samples, sulfur analyses were done only for the 1.45 S.G. float and sink fractions. Therefore, comparison of reduction of sulfur for the four top size samples will be made only at this specific gravity.

From Table XIII, the weight % reduction of sulfur (i.e. the weight % of total S in washed coal (db) column for the sink fraction) for top sizes ≤1 1/2", ≤1", ≤1/2" and ≤1/4" at 1.45 specific gravity are 30.1%, 34.0%, 20.8% and 14.6% respectively. At the same time, the weight % of the sink fractions of the four top sizes are decreasing. The weight % of the sink fractions of top sizes ≤1 1/2", ≤1", ≤1/2" and ≤1/4" are 38.9%, 37.8%, 37.1% and 16.%. The weight % recovery of the float fraction of top sizes ≤ 1 1/2", ≤ 1", ≤ 1/2" and ≤1/4" are 55.6%, 56.4%, 71.6% and 81.0%.The weight % reduction of sulfur is decreased with decreasing sample top size at the expense of increase in the recovery of the float fraction.

Reduction of sulfur on Table XIV is presented in terms of grams sulfur per million BTU. The percentages of reduction in grams

Table XIII

PERCENT REDUCTION WEIGHT % OF SULFUR IN WASHED COAL

(Bradford Breaker sample, Batch #1)

| Specific Gravity Sink | Specific Gravity Float | FLOAT FRACTION Cumulative wt. % (db) of Fraction | FLOAT FRACTION Cumulative wt. % S (db) | FLOAT FRACTION Cumulative wt.% Fraction x Cumulative wt. % S | FLOAT FRACTION Wt. % of Total S in Washed Coal (db) | SINK FRACTION Cumulative wt. % (db) of Fraction | SINK FRACTION Cumulative wt. % S (db) | SINK FRACTION Cumulative wt.% Fraction x Cumulative wt. % S | SINK FRACTION Wt. % of Total S in Washed Coal (db) | Total S in Washed Coal (db) |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample Top Size ≤ 1 1/2 | | | | | | | | | | |
| | 1.3 | 20.7 | .63 | .13 | - | 77.5 | - | - | - | - |
| 1.3 | 1.4 | 39.4 | .71 | $.28^{o}$* | 51.4 | 58.8 | .45 | $.26_5$ | 48.6 | $.54_5$ |
| 1.4 | 1.45 | 55.6 | .68 | $.37^{o}_{8}$ | 69.9 | 38.9 | .42 | $.16_3$ | 30.1 | $.54_1$ |
| 1.45 | 1.5 | 58.3 | .68 | $.39_6$ | 79.5 | 35.2 | .29 | $.10_2$ | 20.5 | $.49_8$ |
| Sample Top Size ≤ 1" | | | | | | | | | | |
| | 1.3 | 13.8 | .40 | $.05_5$ | 11.0 | 80.5 | .55 | $.44_3$ | 89.0 | $.49_8$ |
| 1.3 | 1.4 | 37.1 | .61 | $.22_6$ | 44.7 | 57.2 | .49 | $.28_o$ | 55.3 | $.50_6$ |
| 1.4 | 1.45 | 56.4 | .60 | $.33_8$ | 66.0 | 37.8 | .46 | $.17_4$ | 34.0 | $.51_2$ |
| 1.45 | 1.5 | 65.8 | .59 | $.38_8$ | 77.3 | 29.3 | .39 | $.11_4$ | 22.7 | $.50_2$ |
| Sample Top Size ≤ 1/2" | | | | | | | | | | |
| | 1.45 | 71.6 | .65 | $.46_5$ | 79.2 | 37.1 | .33 | $.12_2$ | 20.8 | $.58_7$ |
| Sample Top Size ≤ 1/4" | | | | | | | | | | |
| | 1.45 | 81.0 | .52 | $.42_1$ | 85.4 | 16. | .45 | $.07_2$ | 14.6 | $.49_3$ |

* Sample calculation $.28_o$ = (cumulative wt.% of fraction)(cumulative wt.% S) = (.394)(.71)

Table XIV

PERCENT REDUCTION OF GRAMS SULFUR PER MILLION BTU

IN WASHED COAL

(Bradford Breaker sample, Batch #1)

| Specific Gravity Sink | Specific Gravity Float | FLOAT FRACTION: Cumulative wt.% (db) of Fraction | FLOAT FRACTION: Cumulative S $\frac{g\ S}{Mil\ BTU}$ | FLOAT FRACTION: % of Total wt.% Fraction x cumulative S $\frac{g\ S}{Mil\ BTU}$ | FLOAT FRACTION: % of Total Cumulative S $\frac{g\ S}{Mil\ BTU}$ | SINK FRACTION: Cumulative wt. % (db) of Fraction | SINK FRACTION: Cumulative S $\frac{g\ S}{Mil\ BTU}$(t) | SINK FRACTION: Cumulative wt.% Fraction x Cumulative S $\frac{g\ S}{Mil\ BTU}$ | SINK FRACTION: % of Total Cumulative S $\frac{g\ S}{Mil\ BTU}$ | Total Cumulative $\frac{g\ S}{Mil\ BTU}$(db) |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample Top Size < 1 1/2" | | | | | | | | | | |
| | 1.3 | 20.7 | 256 | - | - | 77.5 | - | - | | |
| 1.3 | 1.4 | 39.4 | 338 | 133 | 28.8 | 58.8 | 559 | 329 | 71.2 | 462 |
| 1.4 | 1.45 | 55.6 | 342 | 190 | 42.4 | 38.9 | 664 | 258 | 57.6 | 448 |
| 1.45 | 1.5 | 58.3 | 348 | 203 | 53.7 | 35.2 | 498 | 175 | 46.3 | 378 |
| Sample Top Size < 1" | | | | | | | | | | |
| | 1.3 | 13.8 | 148 | 20 | 4.6 | 80.5 | 514 | 414 | 95.4 | 434 |
| 1.3 | 1.4 | 37.1 | 264 | 98 | 22.3 | 57.2 | 597 | 341 | 77.7 | 439 |
| 1.4 | 1.45 | 56.4 | 338 | 191 | 41.8 | 37.8 | 705 | 266 | 58.2 | 457 |
| 1.45 | 1.5 | 65.8 | 373 | 245 | 60. | 29.3 | 556 | 163 | 40. | 408 |
| Sample Top Size < 1/2" | | | | | | | | | | |
| | 1.45 | 71.6 | 360 | 258 | 56.1 | 37.1 | 545 | 202 | 43.9 | 460 |
| Sample Top Size < 1/4" | | | | | | | | | | |
| | 1.45 | 81.0 | 313 | 254 | 67.7 | 16. | 754 | 121 | 32.3 | 375 |

sulfur per million BTU at 1.45 specific gravity for sample top sizes ≤1 1/2", ≤1", ≤1/2" and ≤1/4" are 57.6%, 58.2%, 43.9% and 32.3%. Again the percentage of reduction of sulfur is decreased with decreasing sample top size at the expense of increase in the recovery of the float fraction. But the percentage reduction of sulfur in terms of grams sulfur per million BTU is twice the percent reduction of sulfur in terms of weight %. For example, the percentage of reduction of sulfur is 32.3 grams sulfur/million BTU or 14.6 weight % sulfur for sample top size ≤ 1/4" at 1.45 specific gravity separation.

Even though sulfur analyses were not available for 1.50 float and sink fractions for top size samples ≤1/2" and ≤1/4", there will definitely be slight decreases of weight percent reduction of sulfur at 1.50 S.G. for these two sample sizes. This is because the weight % of sink fractions at 1.50 S.G. are less than that at 1.45 S.G. The decrease is 1.6% from 25.% at 1.45 S.G. to 23.4% at 1.5 S.G. for top size sample ≤1/2". And the decrease is only 0.3% from 16.0% at 1.45 S.G. to 15.7% at 1.5 S.G. for top size sample ≤1/4". In view of the weight % decrease of sink fractions of sample top sizes ≤ 1 1/2" and ≤1" are about 3% to 9% respectively, the decrease of weight % reduction of sulfur at 1.50 S.G. for sample top sizes ≤1/2" and ≤1/4" are estimated to be around 3 to 4% and 0 to 1% respectively. An assumption is made here that the quality of the coal floated at 1.50 S.G. is about the same for all four sample top sizes.

Applying the same reasoning of the decreases of sink fractions from 1.45 S.G. to 1.50 S.G., estimations of decrease of % reduction of sulfur in terms of grams sulfur per million BTU are around 5 to 6% for sample top size ≲1/2" and 2 to 3% for sample top size ≲1/4".

A table (Table XV) of percentage reduction of sulfur in terms of grams sulfur per million BTU and weight % at 1.45 and 1.50 S.G. for four sample top sizes is presented below. Note that % reduction at 1.50 S.G. for sample top sizes ≲1/2" and ≲1/4" are estimations and for sample top sizes ≲1 1/2" and ≲1" are experimental results.

Table XV

PERCENTAGE REDUCTION OF SULFUR

| Sample Top Size | % Recovery of Float Fraction | | grams Sulfur / Million BTU | | Weight % Sulfur | |
|---|---|---|---|---|---|---|
| | 1.45 S.G. | 1.5 S.G. | 1.45 S.G. | 1.5 S.G. | 1.45 S.G. | 1.5 S.G. |
| ≲1½" | 55.6 | 58.3 | 57.6 | 46.3 | 30.1 | 20.5 |
| ≲1" | 65.8 | 65.8 | 58.2 | 40.0 | 34. | 22.7 |
| ≲½" | 71.6 | 73.1 | 43.9 | 38 to 39 | 20.8 | 17 to 18 |
| ≲¼" | 81. | 81.3 | 32.3 | 29 to 30 | 14.6 | 13 to 14 |

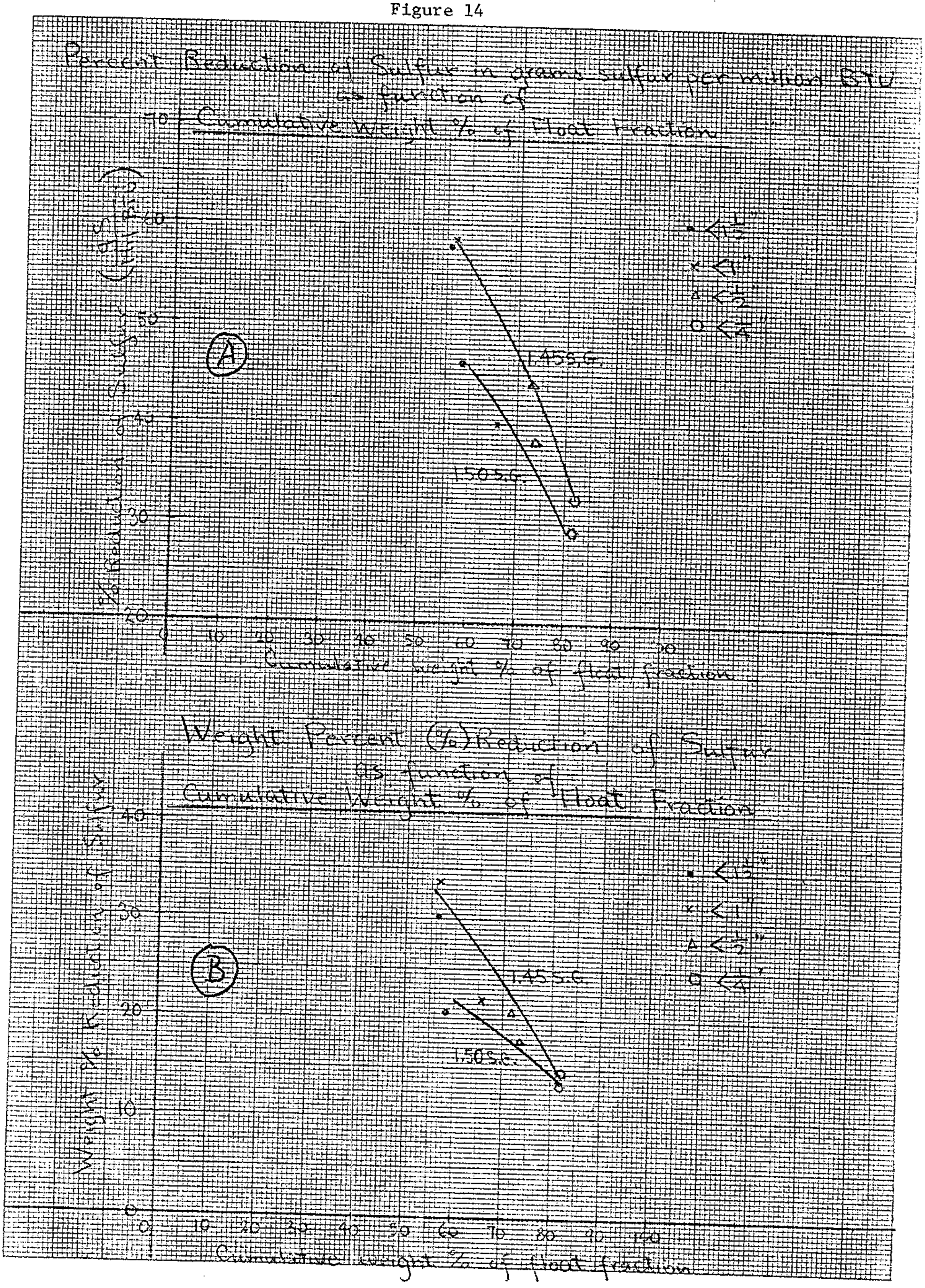
Percent reduction of sulfur in weight % and grams sulfur per million BTU as function of weight % of recovery of float fraction at 1.45 and 1.50 S.G. are plotted in Figure 14 A and B. These figures show the observations made earlier that the % reduction of sulfur is decreased with decreasing sample top size at the expense of increase in the recovery of the float fraction. An additional and crucial information can be obtained from these plots, the % reductions of sulfur in weight % or in grams sulfur per million BTU decreased slightly about 2 to 3% as the specific gravity for separation is increased from 1.45 S.G. to 1.50 S.G. at sample top size $\lesssim$1/4" only. This is not true with other sample sizes.

At higher specific gravities 1.55 to 1.7, the percentage reduction of sulfur will remain fairly constant to that at 1.5 S.G. for all sample top sizes. This is so because the weight % of recovery of the float fractions (see washability curves #4) and conversely, the weight % of the sink fractions remain constant at 1.50 to 1.7 S.G.

<u>Summary on Sulfur Removal</u>

From sulfur analyses, it seems that the percent reduction of sulfur is decreased with decreasing sample top size at the expense of increase in the recovery of the float fraction. At 1.5 specific gravity, the recovery of the float fraction of top size $\lesssim$1/4" sample

Figure 14


Percent Reduction of Sulfur in grams sulfur per million BTU
as function of
Cumulative Weight % of Float Fraction
% Reduction of Sulfur
A
1.45 S.G.
1.50 S.G.
Cumulative weight % of float fraction
Weight Percent (%) Reduction of Sulfur
as function of
Cumulative Weight % of Float Fraction
Weight % Reduction of Sulfur
B
1.45 S.G.
1.50 S.G.
Cumulative weight % of float fraction

is 81.3%, the percent reduction of sulfur achieved in terms of weight % is 13 to 14% and in terms of grams sulfur per million BTU is 29 to 30%. The percent reduction of sulfur should remain fairly constant from 1.5 to 1.8 S.G. because the weight % increase in the float fractions is negligible.

## SUMMARY AND CONCLUSIONS

### Washability of Bradford Breaker Samples

It appears that the Hat Creek coal deposit can be classified into several groups of coal as shown in Figure 1. So far six different groups (A-F) of coal with ash content as low as 6% (db) to as high as 69.4% (db) have been encountered. It is surmized that the whole deposit, which consists of four zones A, B, C and D, is mainly composed of admixtures of these coal groups in different proportions. For example, the seams (or zones) C and D, which have high fixed carbon (consequently high calorific values) should have higher proportion of coal groups D,E, and F as shown in Figure 1. Conversely, Zones A and B may contain more of the coal groups A, B and C as shown in Figure 1. However, the exact proportion of each of these coal groups in any particular zone has not been determined.

The above observation is made only to indicate the complex nature of the coal present in this deposit. The success of benefici- ation i.e. ash removal by washing depends very much on the degree of intergrowth of minerals in organic coal. The disintegration characteristic of coal in water (with moderate stirring) indicates, whether the coal in general can be broken down in water and beneficiated without much difficulty. But as shown previously, only two of the six coal groups disintegrated in water, implying that breaking this coal by mechanical means will be necessary before higher degree of ash removal can be accomplished.

It is well-known[1] that the size of coal generally influence its washability characteristics, as breaking down the coal into smaller sizes makes the inorganic minerals more accessible for removal by washing. Therefore to determine the most suitable top size for washing, knowledge of the dispersion of the minerals and the thickness of the different coal macerals in coal is extremely useful.

The washability characteristics of a coal is perhaps the most important tool available to determine the extent to which a coal may be cleaned. Examination of washability data for a particular coal or for particular size of coal will reveal the quality of coal which may be obtained by mechanical cleaning as well as the quantity of coal of a particular quality. The data may also indicate the ease or difficulty with which the coal may be cleaned.

The washability curves shown in Figures 6 to 9 indicate the quantity and quality of coal to be obtained by cleaning at certain specific gravities. Before selecting the optimum specific gravity for separation of Hat Creek coal (Batch #1), a review of the results obtained in the various areas of study should be helpful.

First of all, water washing (along with stirring) alone of Hat Creek coal will reduce the ash content by $\sim$ 10% (by weight). For better cleaning, washing in specific gravity fluids (or equivalent) will be necessary.

From the washability curves (#1 to #4 in Figures 6 to 9), it can be seen that the amount of recovery increases with decreasing sample top sizes at any specific gravity. For all sample top sizes, the amounts of recovery remain constant from 1.5 S.G. to 1.9 S.G. The near-gravity material is almost zero between 1.6 and 1.8 S.G. for all samples. This indicates that the coal can be easily cleaned by washing (compare Table XI).

The important aspect of washability is the recoverable heat content. It is found* that the total recoverable heat content per pound of washed coal is highest within 1.45 to 1.9 specific gravity range with only $\sim$ 5% loss of the heat content at sample size

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* from washability curves #6 (Figure 6 to 9)

$\leq$ 1/4".

In terms of mineral differentiation in washing it was found that the percentage of bentonite in the sink fraction decreased with decreasing sample size. This means that sink fractions of sample top size $\lesssim$ 1/4" is more desirable to recover kaolinite by washing. The weight % distribution of the two major inorganic minerals i.e. kaolinite and bentonite remains constant at 1.45 to 1.7 specific gravity fluid separation.

The last area of study on sulphur distribution shows that the % reductions of sulphur decrease only 2 to 3% within the range of specific gravity 1.45 to 1.7 for sample top size $\lesssim$ 1/4". The % reductions of sulphur decrease anywhere from 5 to 11% within the same specific gravity range for sample top sizes < 1 1/2", < 1" and < 1/2".

In view of the results obtained for Bradford Breaker sample having approximately 50% ash, 6000 BTU/lb on the dry basis; the optimum specific gravity for separation is within 1.6 → 1.8 S.G. and the optimum sample size $\lesssim$ 1/4". The cumulative heat content of the float fraction within 1.6 → 1.8 S.G. is 7530 BTU/lb (db), and the total recoverable heat content per pound washed coal is 6130 BTU/lb which is about 95% of the heat content of coal before washing. The ash reduction is about 12% db.* The percent reduction of sulfur in

* This may appear to be low as compared to ordinary water washing (~10%). It should be noted that this result is only applicable to this coal containing a very high concentration of ash, which disintegrated in water. For other types of coal this may not be applicable.

weight % is about 14% and in grams sulfur per million BTU is 30%. The near-gravity is almost zero at 1.6 to 1.8 S.G. and specific gravity separation within this range should create <u>no</u> problem!

It should be pointed out that the presence of a large concentration of bentonite in some of the coal sections may introduce problems into the cleaning circuit during specific gravity separation. Attempts should be made to mix these coal sections with other sections of coal containing primarily kaolinite (or other minerals) for dilution. This particular aspect needs further study. If washability of Hat Creek coal is found not to be feasible, another alternative method - dry specific gravity separation (i.e. without water medium) should be tried. This will circumvent the problem of water jellying up with high bentonitic clay concentration in some coal sections.

II. <u>Bradford Breaker Sample</u>

B. Batch #2 Low Ash Content Sample

One single sack of this sample was supplied, containing about 40 lbs of sample. One quarter of the batch was crushed to minus 0.5" size. Proximate analysis on this material could not be carried out as the TGA equipment was broken down. From static analyses, it is found that sample consists approximately 25.9% moisture, 24.7% ash (or 33.3% ash on the dry basis). From Parr bomb tests, the heat content is found to be 5860 BTU/lb or 7900 BTU/lb db. The inorganic minerals present are identified by X-ray diffraction. The major minerals present are kaolinite, bentonite, quartz and siderite, with kaolinite making up of approximately 60 to 70% of the total inorganic minerals. The results are shown in Table XVI.

The sample at top size $\leq$ 0.5" is subjected to 1.45 specific gravity separation yielding a float fraction of 86.4% and a sink fraction of 7.6% on the dry basis*. The weight percent ash of the float fraction is 27% and the sink fraction is only 63.8%. The recovery can definitely be increased past 90% (by weight) as the ash weight % of the sink fraction can be increased up to around 73 to 75% if 1.5 to 1.7 specific gravity fluid for separation is used.

Even at 1.45 specific gravity separation, a few minerals are very well separated. The minerals present in the sample before float-sink separation are kaolinite, bentonite, quartz and siderite. But after float-sink separation at 1.45 S.G., bentonite is concentrated only in the float fraction and siderite is concentrated only in the sink fraction. Siderite, being a high specific gravity mineral should concentrate in the sink fraction. Kaolinite and quartz are

---

* The balance is lost during handling.

present in both float and sink fractions.

The data of the float-sink test for ≤ 1/2" top size sample at 1.45 S.G. are shown in Table XVII. For ≤ 1/2" top size sample the calorific value for the float fraction is 7663 BTU/lb ( or 9410 BTU/lb db) and 4650 BTU/lb (or 5030 BTU/lb db) in the sink fraction.

Because of lack of time no exhaustive study could be made on this sample.

II. Bradford Breaker Sample

C. Batch #3

No float-sink test is performed on this sample. Only moisture, ash content are determined by the static tests and the calorific value is determined by the Parr bomb test. By qualitative X-ray analysis, the inorganic minerals are determined. All these results are shown in Table XVIII.

III. Refuse Sample from Alberta Research

Two parts - bulk and surface

1. refuse from float/sink tests
2. white coating on this refuse

Identification of minerals is done by X-ray diffractometry

Table XVI

Bradford Breaker sample: Batch #2

| | Average * |
|---|---|
| Moisture | 25.9% |
| Ash | 24.7% |
| Ash (dry basis) | 33.3% |
| Calorific value BTU/LB | 5860 BTU/LB |
| Calorific value (dry basis) | 7900 BTU/LB |
| Clay mineral content ** | Kaolinite (≃ 60→70%)<br>quartz (≃ 40→30%) |

Table XVIII

Bradford Breaker sample: Batch #3

| | Average * |
|---|---|
| Moisture | 28.3% |
| Ash | 42.0% |
| Ash (dry basis) | 58.6% |
| Calorific value BTU/LB | 2110 BTU/LB |
| Calorific value (dry basis) | 2940 BTU/LB |
| Clay mineral content ** | bentonite≃kaolinite<br>quartz, pyrite (t) |

* All tests are done in duplicates.
** Given in descending order.

M032/4 log (5)



Table XV11

Sample Top Size ≤ 1/2" (Bradford Breaker Sample Batch #2)

| Specific Gravity Sink | Specific Gravity Float | Weight of Material for F/S(g) | % Moisture | Weight of Material for F/S(g)(db) | Weight of Float Fraction(g) | % Moisture | Weight of Float Fraction (g) (db) | Wt.% of Float Fraction(db*) | Cumulative Weight % of Float Fraction | Wt.% (db) of Original Total Material |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.45 | 1895 | 27.2 | 1379 | 1561 | 23.6 | 1192 | 86.4 | 86.4 | 86.4 |

| X-ray Analysis Kaol | Bent | Qtz | Sid | Pyp | Ank | Wt.% of Original Total Material(db) Kaol | Bent | Qtz | Wt.% Ash (db) | Cumulative Wt.% Ash (db) | Wt.% Sulfur (db) | Cumulative Wt.% Sulfur(db) | Grams Sulfur / Million BTU (db) Cumulative | Calorific Value BTU/lb | Calorific Value BTU/lb (db) Cumulative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57 | 20 | 23 | | | | 13.30 | 4.67 | 5.37 | 22. | 27. | - | - | - | 7663* | 9410 |

| Weight of Sink Fraction(g) | % Moisture | Weight of Sink Fraction(db) | Wt.% of Sink Fraction(db*) | Wt.% (db) of Original Total Material | X-ray Analysis Kaol | Bent | Qtz | Sid | Pyp | Ank | Wt.% of Original Total Material(db) Kaol (of F/S Fractions) | Bent (of F/S Fractions) | Quartz | Sid | Wt.% Ash(db) | Wt.% Sulfur(db) | gms. S / Mil BTU (db) | Calorific Value BTU/lb (db) | Calorific Value BTU/lb (db) | Wt.% Loss (db) | Cumulative Wt.% Loss (db) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 121 | 7.6 | 105 | 7.6 | 7.6 | 56 | - | 25 | 19 | | | 2.72 | - | 1.21 | .93 | 63.9 | | | 4650 | 5030 | 6.0 | 6.0 |

db - dry basis
* At time of Parr bomb test, moisture = 18.6% (from duplicate).

and scanning electron microscopy (SEM) techniques. Kaolinite, quartz, bentonite and trace of gypsum were found in the refuse sample from float/sink tests. The white coating of this refuse was found to contain large percentage of gypsum as well as kaolinite, bentonite, and quartz. (see Table XIX)

Gypsum has not been found in the previous samples sent for X-ray analyses. However, there are reasons to believe that some of the previous samples contain traces of gypsum because of the presence of sulfur detected by scanning electron microscopy (SEM) which cannot be accounted for by other minerals such as pyrite, marcasite, etc., or by organic sulfur (sulfur in organic part of coal). The identification of gypsum was not possible because X-ray diffraction technique is not capable of producing clear identifiable diffraction peaks of minerals of 5 wt.% or less.

The concentration of gypsum on the coating of the refuse suggests liberation of this mineral during the crushing and specific gravity separation stages and eventual concentration on the coating of the refuse.

## IV. Clay Samples

Results of X-ray analyses on these samples are shown in

Table XlX

Mineral Analyses of refuse (from Alberta Research Council)

: X-ray analysis

: SEM

SEM results*

#1: Si, Al, Fe, Ca, S, K, Ti

#2: Si, Al, Ca, S, Fe, K, Ti

X-ray analysis*

#1: Kaolinite, quartz, bentonite, gypsum (small quantity only)

#2: Kaolinite, bentonite, gypsum, quartz

Si - silicon
Al - aluminum
Fe - iron
Ca - calcium
S - sulfur
K - potassium
Ti - titanium

* listed in decreasing quantities

Table XX. The sample numbers given in the table are supplied by Dr. T. McCullough. The mineral content in the table are listed in decreasing quantities but no quantitative estimation of these minerals are carried out by the internal standard method. It can be seen that the major mineral in all these specimens (except one) is bentonite.

V. Bradford Breaker Reject Samples

Two samples which are rejects of the Bradford Breaker was supplied by Mr. Max French. These specimens are very hard to break. Proximate analyses are performed on these specimens and calorific values are determined. These results are shown in Table XXI. These samples are referred to as "Low Ash Samples", as they contain very small concentration of ash in the range 3 to 6% (wet basis).

Table XX

Mineral Identification by X-ray Diffractometry and Scanning Electron Microscopy (SEM)

| | Minerals(listed in descreasing quantities) |
|---|---|
| HC 74-29 625' | bentonite, feldspar, kaolinite, quartz |
| HC 74-34 448' | bentonite, feldspar, siderite |
| HC 74-34 479' | bentonite, siderite, feldspar |
| HC 74-34 491' → 561' | bentonite, siderite, quartz, feldspar |
| HC 74-34 618' → 620' | bentonite, feldspar, siderite, quartz |
| HC 74-44 2167' | bentonite, quartz, feldspar, kaolinite |
| HC 74-48 1342 | bentonite, feldspar, quartz, siderite, kaolinite, ankerite |
| HC 74-144 212' (2115 → 2130') | bentonite, quartz, feldspar |
| HC 76-123 410' | bentonite, kaolinite |
| HC 76-123 590' | bentonite, quartz, siderite, pyrite (t) |
| HC 76-135 1975' | quartz, calcite, bentonite, kaolinite |

## Table XXI

### Analyses of Low Ash Samples*

| Sample No | | Proximate Analysis (by TGA) Moisture | Volatile and Dehydration** | Carbon | Ash | Calorific Value BTU/LB (by Paar bomb) | Minerals present (by x-ray diffraction) | heating rate °C/min | Temperature range (°C) at which carbon burned (by DTA) ++ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 13 | 110 → 560 |
| 1 | as is | 12.8 | 33.8 | 50.8 | 2.6 | 11,000 | not detectable | 30 | 170 → 900 |
| | dry basis | - | 38.8 | 58.2 | 3.0 | 12,600 | - | | |
| 2 | as is | 27.8*+ | 32.7 | 33 | 6.5 | 8,000 | kaolinite, quartz | 30 | 150 → 750 |
| | dry basis | - | 45.3 | 45.7 | 9.0 | 11,100 | - | | |

++ see appendix

* two low ash samples brought by Max French of B.C. Hydro (rejects from Bradford Breaker)

** Dehydration of Clay

*+ sample was collected on rainy day at Hat Creek deposit

# APPENDIX

EXOTHERMIC AND ENDOTHERMIC REACTIONS OF MINERALS

| | Endothermic, peaks (maximum) | | Exothermic, peaks (maximum) | |
|---|---|---|---|---|
| | Temp.°C | Magnitude | Temp.°C | Magnitude |
| 1. kaolinite | 105 | small | 985 | v. large |
| | 585 | large | | |
| 2. bentonite | 140→150 | medium | 900→920* | small |
| | 490→540* | medium | | |
| | 700* | medium | | |
| | 875* | medium | | |
| 3. feldspar: orthoclas | 850 | small(broad) | – | |
| albite | 820 | medium | – | |
| 4. quartz | 573 | v. small | – | |
| 5. siderite | 545 | medium | 620 | large |
| 6. Calcite | 880 | v. large | – | |
| 7. ankerite | ** | | ** | |
| 8. pyrite | – | | 440 | large |

* See p.891 of Benn. bentonite consists of mont. etc.

* information not available in Benn reference

## SPECIFIC GRAVITIES* OF VARIOUS MINERALS

| | | Specific Gravity |
|---|---|---|
| Kaolinite | $Al_2(Si_2O_5)(OH)_2$ | 2.61 |
| Bentonite | various | 2.64 → 2.66 |
| Feldspar | various | 2.55 → 3.2 |
| Chlorites | various | 2.57 → 3.0 |
| Quartz | $SiO_2$ | 2.65 |
| Pyrite | $FeS_2$ | 5.02 |
| Calcite | $CaCO_3$ | 2.71 |
| Siderite | $FeCO_3$ | 3.85 |
| Dolomite | $(CaMg)CO_3$ | 2.86 |
| Ankerite | $(CaMgFe)CO_3$ | 3.5 → 3.8 |
| Iron disulphides | (pyrite, marcasite, melnikovite pyrite) | 5 |

* References: The Chemistry and Physics of Clays, A.B. Searle and R.W. Grinshaw

BENN p.890 → 901

Petrology p.281

Coal Utilization New, p.314.

Differential Thermal Analysis (DTA) of two low ash samples (rejects from Bradford Breaker):

Differential thermal analysis (DTA) is the technique used to find the range of combustion temperatures and to study the reactivity of the two low ash samples during combustion. The results are recorded automatically in the thermograms and interpretation of these readily gives valuable informations about these samples.

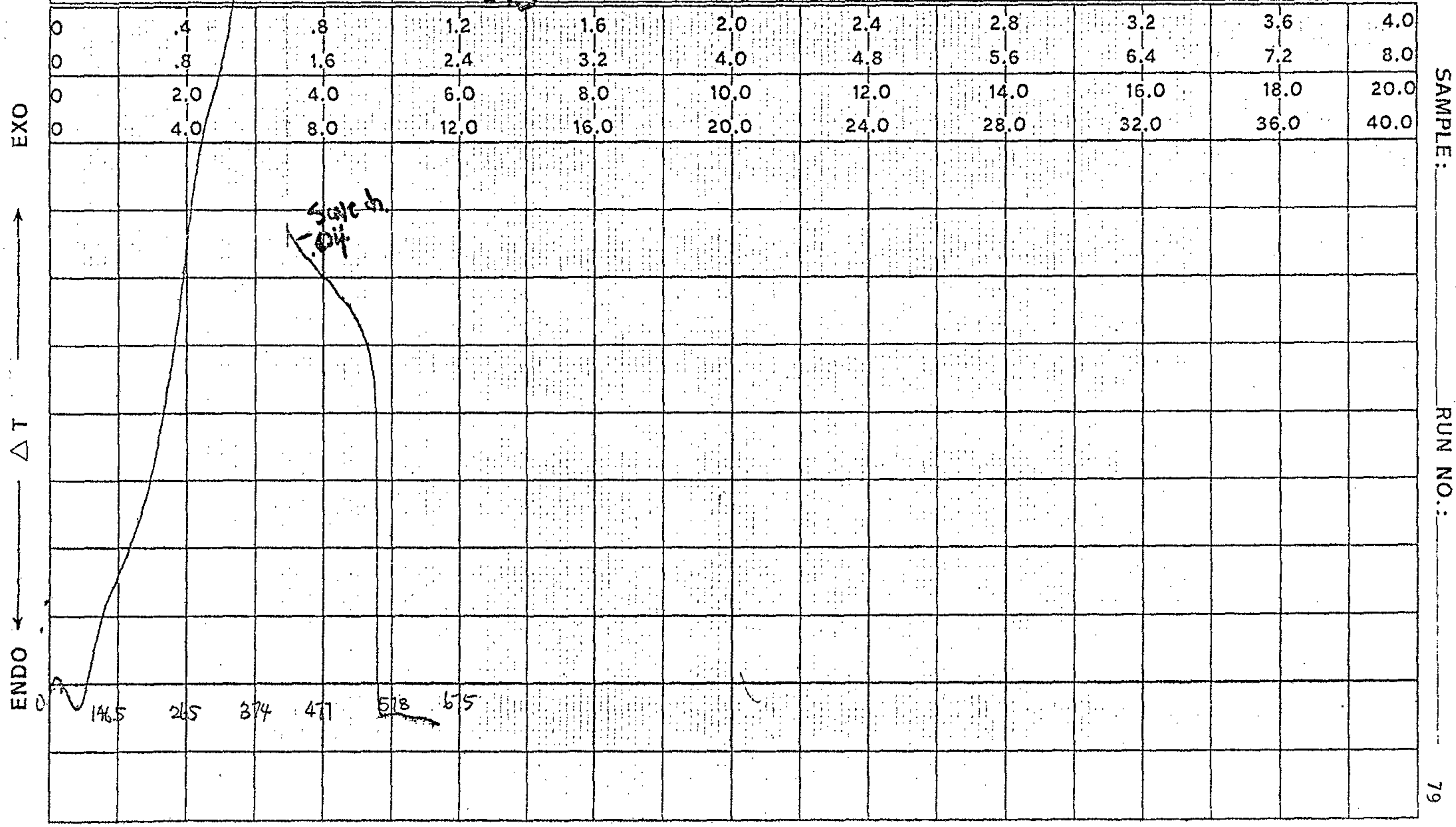
The thermograms are plotted with differential temperature ($\Delta T$) as a function of furance temperature (T). Air (not preheated) is fed continuously (at constant rate for all three tests)into the furnace during heating. The differential temperature ($\Delta T$) measures the increase of the difference of temperatures between the sample and the reference material ( in this case $Al_2O_3$ is used). And the faster increase of the sample temperature compared to the reference material temperature is produced by the exothermic heat of the sample during burning.

As seen in Table XXI, the range of combustion temperatures is dependent on the heating rate. For example, the range of the combustion temperature of sample number one is decreased as the heating rate is decreased. Decrease of heating rate means there are more time for combustion of the sample. This therefore explained why combustion is completed at about 540°C at heating rate of 13°C/min as compared to about 900°C at heating rate of 30°C/min. Similarly, when sample number two is heated at a rate of about 10 → 15°C/min., the thermogram is shifted to the left indicating faster completion of combustion at a lower temperature. The completion temperature of combustion will also be increased or decreased by a hundred or so degree centigrade depending on the type and amount of coal maceral, and mineral content present.

The reactivity of the coal sample can be readily obtained from the thermograms also. For example, looking at thermogram of sample number one heated at 30°C/min., the more-reactive part of the sample reacts first and the less-reactive part last as the furnace temperature is increased. The combustions of the more-reactive part and the less-reactive part of the sample are represented by the first and second peaks respectively on the thermograms. Given samples heated at the same heating rate, broad exothermic peaks suggest the presence of greater amount of low reactive materials. This is shown by sample number one and two heated at about 30°C/min. The first exothermic peaks of the more-reactive part of the both samples occur at about 450°C, whereas the second peak of sample number one occur at 890°C of compared to 740°C of sample number two indicating the presence of greater amount of less-reactive material in sample number one.

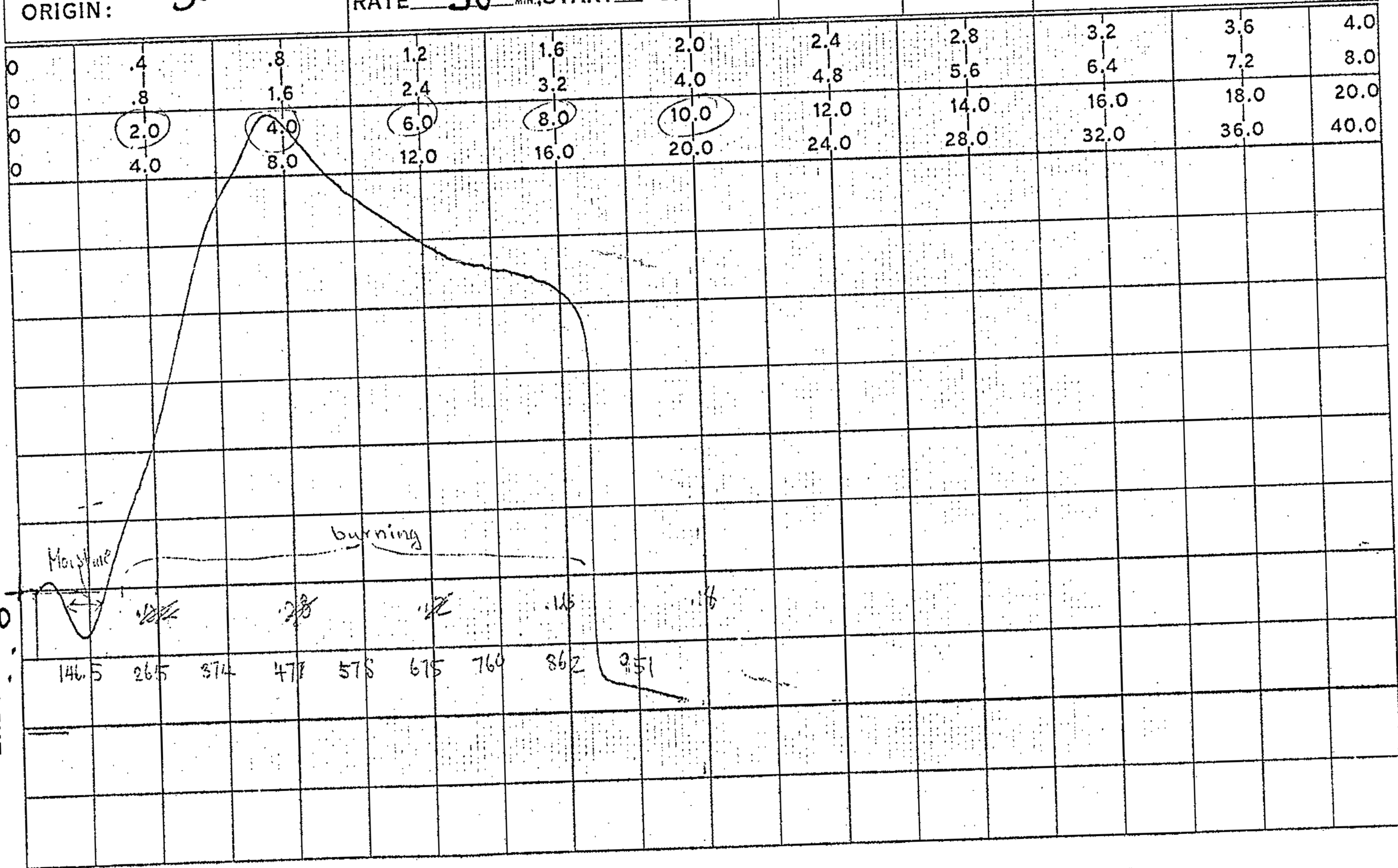
DU PONT INSTRUMENTS

| SAMPLE: B.C. Hydro #1 | SIZE | ATM. 180 ml/min. Air MM | RUN NO. 2 |
|---|---|---|---|
| | REF. $Al_2O_3$ | T / ΔT | DATE June 16/'97 |
| | PROG. MODE heat | SCALE 2 MV/IN. / .02 MV/IN. | OPERATOR LAu |
| ORIGIN: | RATE 26x5 °C/MIN. ≈13° START 0 °C. | SHIFT ___ IN. ___ IN. | BASE LINE SLOPE 0 |

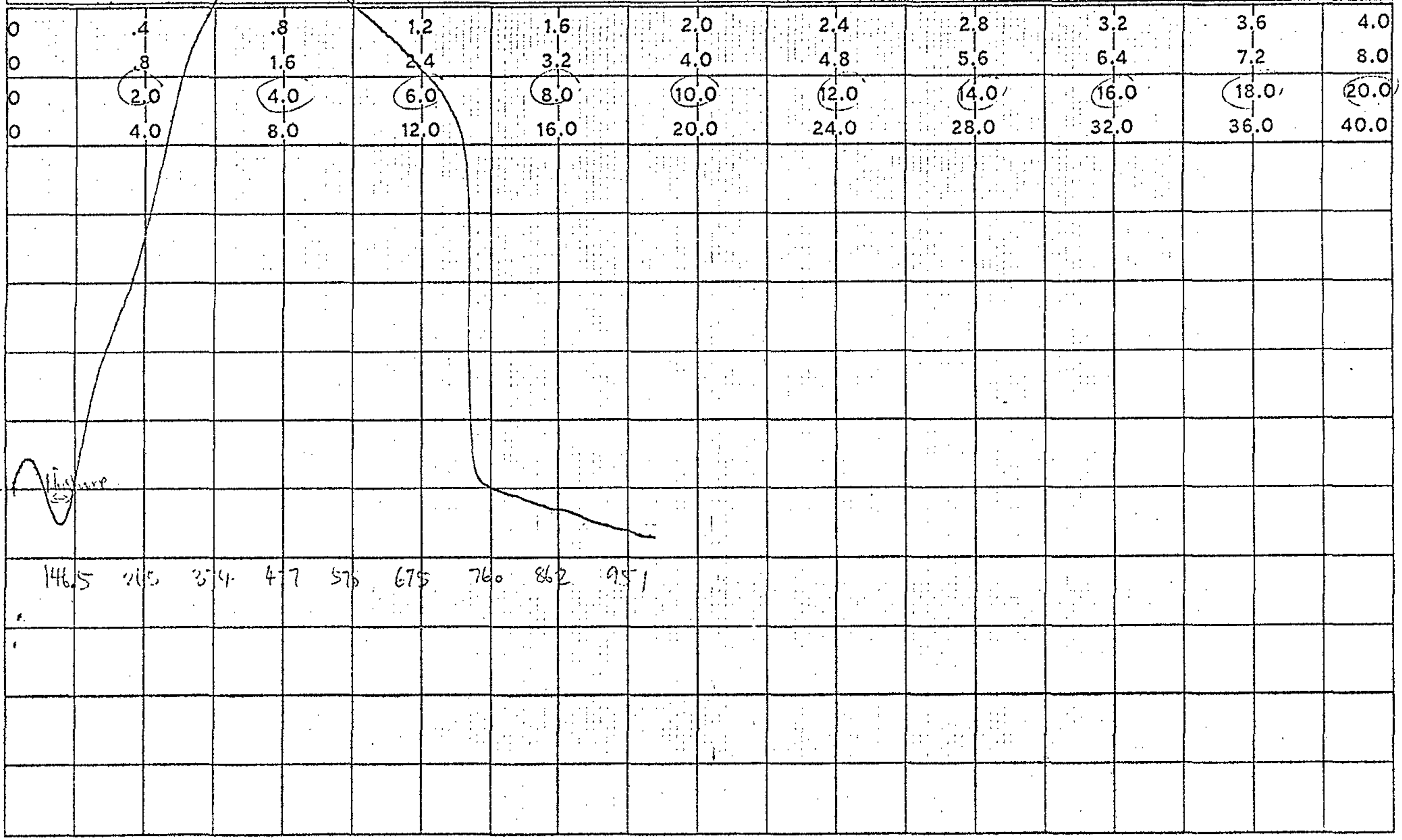



79

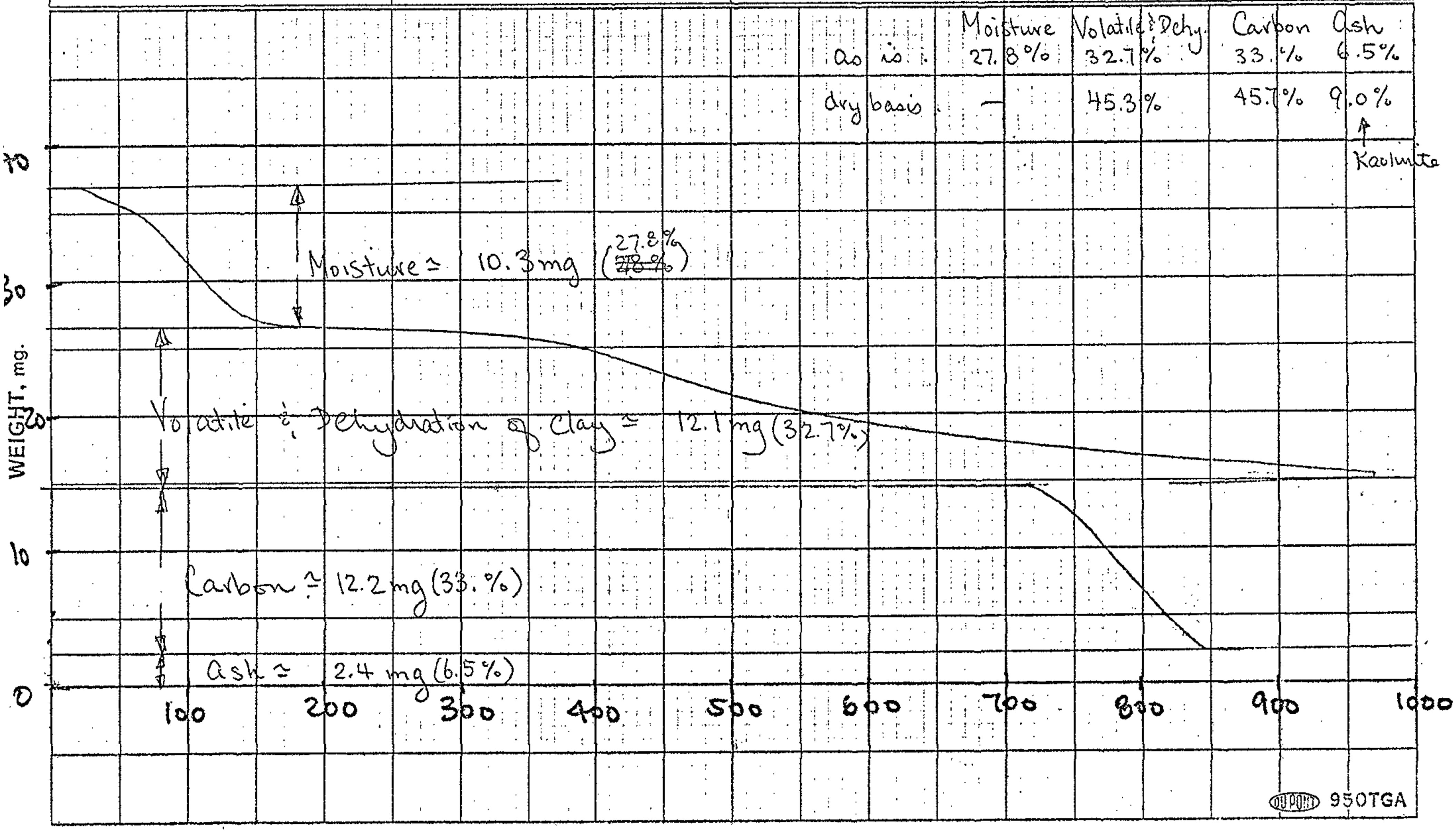
| | | | |
|---|---|---|---|
| SAMPLE: B.C. Hydro Sample #1 | SIZE | ATM. Air 700 ml/MIN | RUN NO. 1 |
| | REF. $Al_2O_3$ | T: — ; △T: — | DATE June 15/'77 |
| | PROG. MODE heat | SCALE T: 2 MV/IN. ; △T: .04 MV/IN. | OPERATOR LAU |
| ORIGIN: | RATE 30 °C/MIN. START 0 °C. | SHIFT T: ____ IN. ; △T: ____ IN. | BASE LINE SLOPE 0 |



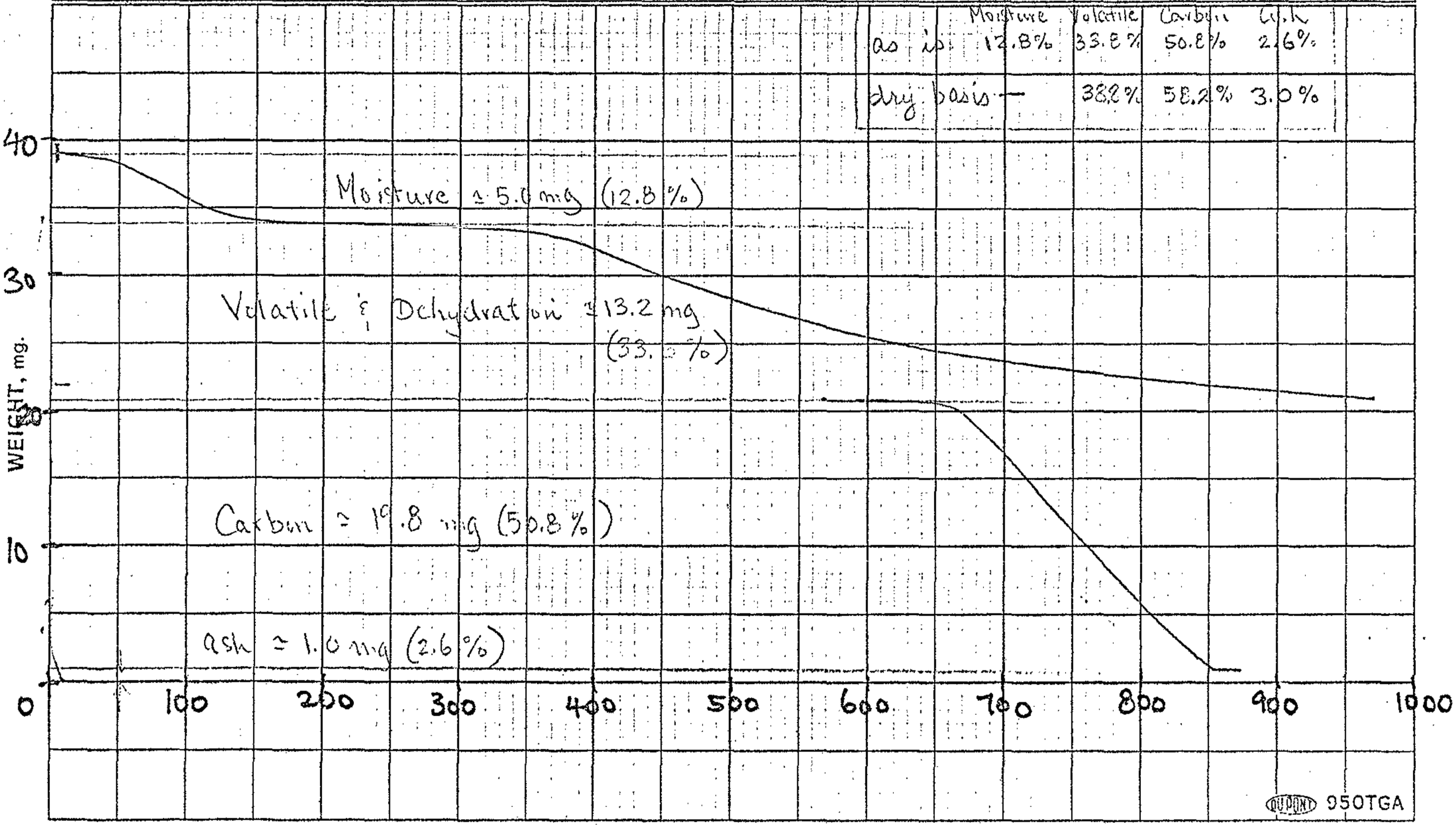
| | | | |
|---|---|---|---|
| SAMPLE: B.C. Hydro #2 | SIZE — | ATM. 100 ml/min Air MM | RUN NO. 1 |
| | REF. $Al_2O_3$ | T / ΔT | DATE June 16/'77 |
| | PROG. MODE heat | SCALE 2 MV/IN. / .04 MV/IN. | OPERATOR LAU |
| ORIGIN: | RATE .66x5 °C/MIN. START 0 °C. | SHIFT ___ IN. / ___ IN. | BASE LINE SLOPE 1 |



| SAMPLE: B.C. Hydro Sample #2 (clay) | X-AXIS | Y-AXIS | RUN NO. 1 DATE June 15/77 |
|---|---|---|---|
| | TEMP. SCALE 100 °C/inch | SCALE 10 mg./inch (SCALE SETTING X 2) | OPERATOR LAU, MAY |
| | SHIFT 0 inch | | HEATING RATE 15 °C/min. |
| | | | ATM. 100 ml/min N2 / Air |
| SIZE 37. mg. | TIME SCALE (ALT.) 0 | SUPPRESSION 0 mg. | TIME CONSTANT 1 sec. |



| SAMPLE: B.C. Hydro. #1 | X-AXIS | Y-AXIS | RUN NO. 2 DATE June 13/97 |
|---|---|---|---|
| | TEMP. SCALE 100 °C/inch | SCALE 10 mg./inch (SCALE SETTING X 2) | OPERATOR LAU, MAY |
| | SHIFT 0 inch | | HEATING RATE 15 °C/min. |
| | | | ATM. 100ml/min N2/Air |
| SIZE 39.0 mg. | TIME SCALE (ALT.) 0 | SUPPRESSION 0 mg. | TIME CONSTANT 1 sec. |




| | Moisture | Volatile | Carbon | Ash |
|---|---|---|---|---|
| as is | 12.8% | 33.8% | 50.8% | 2.6% |
| dry basis | — | 38.8% | 58.2% | 3.0% |

TEMPERATURE*, °C

SAMPLE SIZE $\lesssim$1 1/2"

Calculation of cumulative heat content in float fractions

| Specific Gravity | Weight % | Calorific Value (Exper.)BTU/lb | Calorific Value (Cumulative) BTU/lb | CALCULATIONS |
|---|---|---|---|---|
| 1.3F | 20.7 | 11170 | 11170 | 20. |
| 1.4F | 18.7 | 8460 | 9884 | $\frac{20.7}{39.4}(11170)+\frac{18.7}{39.4}(8460)=5869+4015.3=9884$ |
| 1.45F | 16.2 | 7880 | 9300 | $\frac{20.7}{55.6}(11170)+\frac{18.7}{55.6}(8460)+\frac{16.2}{55.6}(7880)$ $=4158.6+2845.4+2296=9300$ |
| 1.5F | 2.7 | 5410 | 9120 | $\frac{20.7}{58.3}(11170)+\frac{18.7}{58.3}(8460)+\frac{16.2}{58.3}(7880)+\frac{2.7}{58.3}(5410)$ $=3966.0+2713.6+2189.6+250.5=9120$ |
| 1.7F | .9(.3+.6) | 3510 | 9035 | $\frac{20.7}{59.2}(11170)+\frac{18.7}{59.2}(8460)+\frac{16.2}{59.2}(7880)+\frac{2.7}{59.2}(5410)$ $+\frac{.9}{59.2}(3510)=3956.7+2672.3+2156.4+246.7+53.4$ $=9034.5$ |
| 1.7S | 34.3 | 1810 | 1810 | |

Calculation of heat content of coal before washing by heat balance of float and sink fractions

| | | | |
|---|---|---|---|
| 1.3F: | 20.7 wt.% at 11170 BTU/LB | 2312.2 | |
| 1.4F: | 18.7 wt.% at 8460 BTU/LB | 1582.0 | |
| 1.45F: | 16.2 wt.% at 7880 BTU/LB | 1276.6 | |
| 1.5F: | 2.7 wt.% at 5410 BTU/LB | 146.1 | |
| 1.55/1.7F: | .9* wt.% at 3510 BTU/LB | 31.6 | |
| 1.7S: | 34.3 wt.% at 1810 BTU/LB | 620.8 | |
| Loss: | 6.5 wt.% at 1300 BTU/LB | 84.5 | |
| | | 6053.8 | 6050 BTU/LB |

* .9 = .6 + .3 from 1.7F & 1.55F respectively, assumption is made that heat content 1.55F ≈ 1.7F

SAMPLE SIZE ≤1 1/2"

Calculation of Cumulative Ash in float fractions

| Specific Gravity | Weight % | Wt.% Ash (Exper.) | Wt.% Ash (Cumulative) | CALCULATIONS |
|---|---|---|---|---|
| 1.3F | 20.7 | 10. | 10. | |
| 1.4F | 18.7 | 31.5 | 20.2 | $\frac{20.7}{39.4}(10.) + \frac{18.7}{39.4}(31.5) = 5.253 + 14.951 = 20.204$ |
| 1.45F | 16.2 | 40.1 | 26. | $\frac{20.7}{55.6}(10.) + \frac{18.7}{55.6}(31.5) + \frac{16.2}{55.6}(40.1) = 3.723 + 10.594 + 11.684$ $= 26.001$ |
| 1.5F | 2.7 | 57. | 27.4 | $\frac{20.7}{58.3}(10.) + \frac{18.7}{58.3}(31.5) + \frac{16.2}{58.3}(40.1) + \frac{2.7}{58.3}(57.)$ $= 3.551 + 10.104 + 11.143 + 2.640 = 27.438$ |
| 1.55F | .3 | 63. | 27.6 | $\frac{20.7}{58.6}(10.) + \frac{18.7}{58.6}(31.5) + \frac{16.2}{58.6}(40.1) + \frac{2.7}{58.6}(57.) + \frac{.3}{58.6}(63.)$ $= 3.532 + 10.052 + 11.086 + 2.626 + .323 = 27.6$ |
| 1.7F | .6 | 66.2 | 28. | $\frac{20.7}{59.2}(10.) + \frac{18.7}{59.2}(31.5) + \frac{16.2}{59.2}(40.1) + \frac{2.7}{59.2}(57.) + \frac{.3}{59.2}(63.)$ $+ \frac{.6}{59.2}(66.2) = 3.497 + 9.950 + 10.973 + 2.60 + .319 + .671$ $= 28.01$ |

Calculation of ash content of unwashed coal by ash balance of float and sink fractions

| | | |
|---|---|---|
| 1.3F: | 20.7 wt.% at 10% ash | 2.07 |
| 1.4F: | 18.7 wt.% at 31.5% ash | 5.891 |
| 1.45F | 16.2 wt.% at 40.1% ash | 6.496 |
| 1.5F | 2.7 wt.% at 57.% ash | 1.539 |
| 1.55F | .3 wt.% at 63.% ash | .189 |
| 1.7F | .6 wt.% at 66.2% ash | .397 |
| 1.7S | 34.3 wt.% at 75.2% ash | 25.794 |
| Loss | 6.5 wt.% at 77.%* ash | 5.005 |
| | | 47.381 → 47.4% ash (db) |

* obtained by TGA

Kaolinite/Bentonite Mass Balance

SAMPLE SIZE: ≤1 1/2"

| Specific Gravity | | Kaolinite | | | Percent | Bentonite | | | Percent |
|---|---|---|---|---|---|---|---|---|---|
| Sink | Float | Float | Sink | Total | Deviation | Float | Sink | Total | Deviation |
| | 1.3 | 1.24 | – | – | – | .83 | – | – | – |
| 1.3 | 1.4 | 5.18* | 18. | 23.2 | – | .71 | 18.1 | 19.4 | – |
| 1.4 | 1.45 | 4.81 | 13.63 | 18.4 | +2.3% | 1.69 | 13.63 | 15.3 | -18.2% |
| 1.45 | 1.5 | .89 | 12.4 | 13.3 | -2.4% | .65 | 14.56 | 15.2 | +11.5% |
| 1.5 | 1.55 | – | – | – | – | – | – | – | – |
| 1.55 | 1.6 | – | – | – | – | – | – | – | – |
| 1.6 | 1.7 | .21 | 12.64 | 12.8 | +3.2% | .19 | 13.15 | 13.3 | -8.7% |

All figures given are % of total weight (dry basis) before washing. These are quantitively analyses of the specific gravity fractions. At any specific gravity, the total percentages of kaolinite and bentonite will not be equal as these are not cumulative percentages. But, the percentage of kaolinite or betonite at any specific gravity should equal to the percentage of kaolinite or be bentonite in the sink fraction of the lower specific gravity. For example, the total percentages of kaolinite in the float and sink fractions at 1.45 S.G. is 18.42% and this is ≈ equal to the percentage of kaolinite in 1.4S which is 18.%.

* Sample calculation

| 5.8% = | .187 | x | 31.5% | x | .88 |
|---|---|---|---|---|---|
| | ↑ | | ↑ | | ↑ |
| | wt.% 1.4F of total material | | % ash in 1.4F | | % kaolinite in 1.4F |

Cumulative Kaolinite/Bentonite Mass Balance

Sample Size: ⩽ 1 1/2"

| Specific Gravity Sink | Specific Gravity Float | Float Fraction: Kaol. % of Float Fraction | Float Fraction: Bent. % of Float Fraction | Float Fraction: Kaol. % of Total Material | Float Fraction: Bent. % of Total Material | Sink Fraction: Kaol. % of Sink Fraction | Sink Fraction: Bent. % of Sink Fraction | |
|---|---|---|---|---|---|---|---|---|
| | 1.3 | 6.0 | 4.0 | 1.2 | .8 | – | – | wt.% 1.3F, % Ash, % Kaol., wt.% 1.4F, % Ash, % Kaol. |
| 1.3 | 1.4 | 16.3 | 3.9 | 6.4 | 1.5 | 18. | 18.7 | K $\frac{20.7}{39.4}(10.)(.60)+\frac{18.7}{39.4}(31.5)(.88)$<br>B $\frac{20.7}{39.4}(10.)(.40)+\frac{18.7}{39.4}(31.5)(.12)$ |
| 1.4 | 1.45 | 20.3 | 5.8 | 11.2 | 3.2 | 13.6 | 13.6 | K $\frac{20.7}{55.6}(10.)(.60)+\frac{18.7}{55.6}(31.5)(.88)+\frac{16.2}{55.6}(4$<br>B $\frac{20.7}{55.6}(10.)(.40)+\frac{18.7}{55.6}(31.5)(.12)+\frac{16.2}{55.6}(40.1)($ |
| 1.45 | 1.5 | 20.8 | 6.6 | 12.1 | 3.9 | 12.4 | 14.6 | K $\frac{20.7}{58.3}(10)(.6)+\frac{18.7}{58.3}(31.5)(.88)+\frac{16.2}{58.3}(40.1)($ $+\frac{2.7}{58.3}(57.)(.58)$<br>B $\frac{20.7}{58.3}(10.)(.4)+\frac{18.7}{58.3}(31.5)(.12)+\frac{16.2}{58.3}(40$ $+\frac{2.7}{58.3}(57.)(.42)$ |
| 1.5 | 1.55/ 1.6 | 20.8 | 6.6 | 12.1 | 3.9 | 12.4 | 14.6 | only .3% of total weight* is floated at 1.55F and 1.6F. Assume no change in % kaolinite and bentonite |
| 1.55/ 1.6 | 1.7 | 20.8 | 6.9 | 13.3 | 4.1 | 12.6 | 13.2 | K $\frac{20.7}{59.2}(10.)(.60)+\frac{18.7}{59.2}(31.5)(.88)+\frac{16.2}{59.2}(40.1)(.74)+\frac{2.7}{59.2}(57.)(.58)+\frac{.6}{59.2}(66.2)(.52)$<br>B $\frac{20.7}{59.2}(10.)(.40)+\frac{18.7}{59.2}(31.5)(.12)+\frac{16.2}{59.2}(40$ $+\frac{2.7}{59.2}(57.)(.42)+\frac{.6}{59.2}(66.2)(.48)$ |

* weight of sample for washing

At any one specific gravity, the cumulative percentages of kaolinite and bentonite in the float and sink fractions (% of total material in the float fraction and % of sink fraction) should equal to that at another specific gravity. Listed below is a table of the total kaolinite and bentonite contents for comparison.

| Specific Gravity Sink | Float | Cumulative % Loss (% of total wt.) db, at 77% ash | % Loss + Total % K & B | Total kaolinite and bentonite contents (% of total material for washing) db | |
|---|---|---|---|---|---|
| | 1.3 | 1.39 | | | |
| 1.3 | 1.4 | 1.39 | 46. | 44.6 | 6.4 + 1.5 + 18. + 18.7 |
| 1.4 | 1.45 | 4.23 | 45.8 | 41.6 | 11.2 + 3.2 + 13.6 + 13.6 |
| 1.45 | 1.5 | 5.01 | 48. | 43. | 12.1 + 3.9 + 12.4 + 14.6 |
| 1.5 | 1.55/ 1.6 | 5.01 | 48. | 43. | " |
| 1.55/ 1.6 | 1.7 | 5.01 | 48.2 | 43.2 | 13.3 + 4.1 + 12.6 + 13.2 |

Average: 47.2 - total ash content (db) of sample $\leq$ 1 1/2"

SAMPLE SIZE = $\leq 1\ 1/2''$

Calculation of cumulative sulphur in float fractions

| Specific Gravity Sink | Float | Weight % of total | Wt.% S (exp.data)db | g S/Mil.BUT (db) | Cumul. Wt.% S | Cumul. $\frac{g\ S}{Mil\ BTU}$(db) | |
|---|---|---|---|---|---|---|---|
| | 1.3 | 20.7 | .63 | 255.8 | .63 | 256 | |
| 1.3 | 1.4 | 18.7 | .80 | 428.9 | .71 | 338 | $\frac{20.7}{39.4}(.63)+\frac{18.7}{39.4}(.8) = .33+.38 = .71$<br>$\frac{20.7}{39.4}(255.8)+\frac{18.7}{39.4}(428.9) = 337.9$ |
| 1.4 | 1.45 | 16.2 | .61 | 351.1 | .68 | 342 | $\frac{20.7}{55.6}(.63)+\frac{18.7}{55.6}(.8)+\frac{16.2}{55.6}$ $= .68$<br>$\frac{20.7}{55.6}(255.8)+\frac{18.7}{55.6}(428.9)+\frac{16.2}{55.6}(351.1) = 341.8$ |
| 1.45 | 1.5 | 2.7 | .57 | 477.9 | .68 | 348 | $\frac{20.7}{58.3}(.63)+\frac{18.7}{58.3}(.8)+\frac{16.2}{58.3}$ $= .68$<br>$\frac{20.7}{58.3}(255.8)+\frac{18.7}{58.3}(428.9)+\frac{16.2}{58.3}(351.1)+\frac{2.7}{58.3}(477.$ $= 348.1$ |

SAMPLE SIZE: ≲1"

Calculation of cumulative heat content in float fractions

| Specific Gravity | Weight % | Calorific Value(actual) BTU/lb | Calorific Value(cummul.) BTU/lb | CALCULATIONS |
|---|---|---|---|---|
| 1.3F | 13.8 | 12250 | 12250 | |
| 1.4 | 23.3 | 9980 | 10820 | $\frac{13.8}{37.1}(12250) + \frac{23.3}{37.1}(9980) = 4556.6 + 6267.$[illegible]<br>$= 10824$ |
| 1.45F | 19.3 | 5480 | 8995 | $\frac{13.8}{56.4}(12250) + \frac{23.3}{56.4}(9980) + \frac{19.3}{56.4}(5480)$<br>$= 2997.3 + 4122.9 + 1875.2 = 8995.4$ |
| 1.5F | 8.6 | 3740 | 8300 | $\frac{13.8}{65.}(12250) + \frac{23.3}{65.}(9980) + \frac{19.3}{65.}(5480)$<br>$+ \frac{8.6}{65.}(3740) = 2600.8 + 3577.4 + 1627. + 4$[illegible]<br>$= 8300.0$ |
| 1.55F | 3.2 | 3110 | 8060 | $\frac{13.8}{68.2}(12250) + \frac{23.3}{68.2}(9980) + \frac{19.3}{68.2}(5480)$<br>$+ \frac{8.6}{68.2}(3740) + \frac{3.2}{68.2}(3110) = 2478.7 + 3409.$[illegible]<br>$+ 1550.8 + 471.6 + 145.9 = 8056.6$ |
| 1.7F | .1 | 3110* | 8050 | $\frac{13.8}{68.3}(12250) + \frac{23.3}{68.3}(9980) + \frac{19.3}{68.3}(5480)$<br>$+ \frac{8.6}{68.3}(3740) + \frac{3.3}{68.3}(3110) = 2475.1 + 340$[illegible]<br>$+ 1548.5 + 470.9 + 150.3 = 8049.4$ |

Calculation of heat content of unwashed coal by heat balance of float and sink fractions (db)

| | | |
|---|---|---|
| 1.3F: | 13.8 wt.% at 12250 BTU/lb | 1690.5 |
| 1.4F: | 23.3 wt.% at 9980 BTU/lb | 2325.3 |
| 1.45F: | 19.3 wt.% at 5480 BTU/lb | 1057.6 |
| 1.5F: | 8.6 wt.% at 3740 BTU/lb | 321.6 |
| 1.55F & 1.7F | 3.3(3.2 + .1)wt.% at 3110 BTU/lb | 102.6 |
| 1.7S: | 26. wt.% at 1830 BTU/lb | 475.8 |
| Loss: | 5.7 wt.% at 1300 BTU/lb | 74.1 |
| | 100 | 6047.5 → 6050 BTU/lb |

*Assume 1.7F has ≈ 3110 BTU/LB - based on 1.55F/1.55S heat contents.

SAMPLE SIZE: $\leq$ 1"

Calculation of Cumulative Ash in Float Fractions

| Specific Gravity | Weight % | Wt.% Ash (Actual) | Wt.% Ash (Cumulative) | CALCULATIONS |
|---|---|---|---|---|
| 1.3F | 13.8 | 9.5 | 9.5 | |
| 1.4F | 23.3 | 26.8 | 20.4 | $\frac{13.8}{37.1}(9.5)+\frac{23.3}{37.1}(26.8) \doteq 3.534+16.831=20.365$ |
| 1.45F | 19.3 | 57.1 | 32.9 | $\frac{13.8}{56.4}(9.5)+\frac{23.3}{56.4}(26.8)+\frac{19.3}{56.4}(57.1)$ $\doteq 2.324+11.072+19.540$ $\doteq 32.936$ |
| 1.5F | 8.6 | 68.9 | 37.7 | $\frac{13.8}{65.}(9.5)+\frac{23.3}{65.}(26.8)+\frac{19.3}{65.}(57.1)+\frac{8.6}{65.}(68.9)$ $= 2.017+9.607+16.954+9.116$ $= 37.694$ |
| 1.55F | 3.2 | 71.2 | 39.2 | $\frac{13.8}{68.2}(9.5)+\frac{23.3}{68.2}(26.8)+\frac{19.3}{68.2}(57.1)+\frac{8.6}{68.2}(68.9)$ $+\frac{3.2}{68.2}(71.2)=1.922+9.156+16.159+8.688+3.34$ $\doteq 39.266$ |
| 1.7F | .1 | - | ~39.2 | only .1 % of total material is floated at 1.7 S.G. ∴ wt.% cumulative ash $\doteq$ 39.2 also |

Calculation of ash content of unwashed coal by ash balance of float and sink fractions.

| | | |
|---|---|---|
| 1.3F: | 13.8 wt.% at 9.5% ash | 1.311 |
| 1.4F: | 23.3 wt.% at 26.8% ash | 6.244 |
| 1.45F: | 19.3 wt.% at 57.1% ash | 11.020 |
| 1.5F: | 8.6 wt.% at 68.9% ash | 5.925 |
| 1.55F: | 3.2 wt.% at 71.2% ash | 2.278 |
| 1.7F: | .1 wt.% at 71.2% ash | .071 |
| 1.7S: | 26.wt.% at 74.9% ash | 19.474 |
| Loss: | 5.7 wt.% at 77.%* ash | 4.389 |
| | 100. | 50.712 → 50.7% ash (db) |

* obtained by TGA

Kaolinite/Bentonite Mass Balance

SAMPLE SIZE: $\leq$1"

| Specific Gravity Sink | Float | Kaolinite Float | Sink | Total | Percent Derivation | Bentonite Float | Sink | Total | Percent Derivation |
|---|---|---|---|---|---|---|---|---|---|
| | 1.3 | 1.17 | 28.7 | 29.9 | - | .14 | 23.5 | 23.6 | - |
| 1.3 | 1.4 | 4.12 | 21.24 | 25.3 | -11.5% | 2.12 | 19.60 | 21.7 | -7.7% |
| 1.4 | 1.45 | 6.83* | 15.71 | 22.5 | +5.9% | 4.19 | 12.3 | 16.5 | -15.8% |
| 1.45 | 1.5 | 3.0 | 11.88 | 14.9 | -6.0% | 2.90 | 9.72 | 12.6 | +2.1% |
| 1.5 | 1.55 | 1.3 | 10.82 | 12.1 | +1.8% | .98 | 7.8 | 8.8 | -9.5% |
| 1.55 | 1.6 | - | - | - | - | - | - | - | - |
| 1.6 | 1.7 | - | 11.68 | - | - | - | 7.78 | - | - |

All figures given are % of total weight (dry basis) before washing. At any specific gravity, the total percentages of kaolinite and bentonite will <u>not</u> be equal. Explanation is given in Kaolinite/Bentonite Mass Balance for sample $\leq$1 1/2".

* sample calculation

6.83% = .193 x 57.1% x .62

.193: wt.% of 1.45F of total material.

57.1%: % ash in 1.45F

.62: % kaolinite in 1.45F

Cumulative kaolinite/bentonite balance

SAMPLE SIZE: $\lesssim$1"

| Specific Gravity | | Float Fraction | | | | Sink Fraction | | |
|---|---|---|---|---|---|---|---|---|
| Sink | Float | Kaol. % of Float Fraction | Bent. | Kaol. % of total material (Cumul.) | Bent. | Kaol. % of sink Fraction (Cumul.) | Bent. | CALCULATIONS |
| | 1.3 | 8.46 + | 1.05 | 1.17 | .14 | 28.7 | 23.5 | |
| 1.3 | 1.4 | 14.25 | 6.11 | 5.29* | 2.26 | 21.24 | 19.6 | wt.% 1.3F, % ash 1.3F, % Kaolinite 1.3F, wt.% 1.4F, % ash 1.4F, % Kaolinite 1.4F<br>K $\frac{13.8}{37.1}(9.5)(.89) + \frac{23.3}{37.1}(26.8)(.66)$<br>$= 3.14 + 11.11$<br>B $\frac{13.8}{37.1}(9.5)(.11) + \frac{23.3}{37.1}(26.8)(.34)$<br>$= .39 + 5.72 = 6.11$ |
| 1.4 | 1.45 | 21.49 | 11.45 | 12.12 | 6.46 | 15.71 | 12.3 | K $\frac{13.8}{56.4}(9.5)(.89) + \frac{23.3}{56.4}(26.8)(.66) + \frac{19.3}{56.4}(57.1)(.6$<br>$= 2.07 + 7.31 + 12.11$<br>B $\frac{13.8}{56.4}(9.5)(.11) + \frac{23.3}{56.4}(26.8)(.34)$<br>$+ \frac{19.3}{56.4}(57.1)(.38) = .26 + 3.76 + 7.43$ |
| 1.45 | 1.5 | 23.3 | 14.40 | 15.15 | 9.36 | 11.88 | 9.72 | K $\frac{13.8}{65.}(9.5)(.89) + \frac{23.3}{65.}(26.8)(.66) + \frac{19.3}{65.}(57.1)(.62$<br>$+ \frac{8.6}{65.}(68.9)(.51)$<br>B $\frac{13.8}{65.}(9.5)(.11) + \frac{23.3}{65.}(26.8)(.34)$<br>$+ \frac{19.3}{65.}(57.1)(.38) + \frac{8.6}{65.}(68.9)(.49)$ |
| 1.5 | 1.55 | 24.1 | 15.16 | 16.44 | 10.3 | 10.8 | 7.8 | K $\frac{13.8}{68.2}(9.5)(.89) + \frac{23.3}{68.2}(26.8)(.66) + \frac{19.3}{68.2}(57.1)(.62)$<br>$+ \frac{8.6}{68.2}(68.9)(.51) + \frac{3.2}{68.2}(71.2)(.57)$<br>B $\frac{13.8}{68.2}(9.5)(.11) + \frac{23.3}{68.2}(26.8)(.34) + \frac{19.3}{68.2}(57.1)(.38)$<br>$+ \frac{8.6}{68.2}(68.9)(.49) + \frac{3.2}{68.2}(71.2)(.43)$ |
| 1.55 | 1.6/ 1.7 | 24.1 | 15.2 | 16.4 | 10.3 | 10.8 | 7.8 | Only .1% of total weight** is floated at 1.6&1.7S.G.+++ |

** total weight - weight of Bradford Breaker sampling for Float/sink tests.

sample calculation:

* 5.29% = % kaolinite in 1.3F + % K in 1.4F from table of Kaolinite/ Bentonite mass balance.

+++ Assume no change in % of kaolinite and bentonite.

+ K 8.46 = 9.5 (.89) = (% ash)(% Kaolinite)

At any one specific gravity, the cumulative percentages of kaolinite and bentonite in the float and sink fractions (% of total material in the float fraction and % of sink fraction) should equal to that at another specific gravity. Listed below is a table of the total kaolinite and bentonite contents for comparison.

| Specific Gravity Sink | Float | Cumulative % Loss (at 77% ash) (% of total db) | Total Kaolinite and bentonite contents (% of total material for washing )db | |
|---|---|---|---|---|
| | 1.3 | 4.39 | 53.52 | 1.17 + .14 + 28.7 + 23.5 |
| 1.3 | 1.4 | 4.39 | 48.39 | 5.29 + 2.26 + 21.24 + 19.6 |
| 1.4 | 1.45 | 4.39 | 46.59 | 12.12 + 6.46 + 15.71 + 12.3 |
| 1.45 | 1.5 | 4.39 | 46.11 | 15.15 + 9.36 + 11.88 + 9.72 |
| 1.5 | 1.55 | 4.39 | 45.34 | 16.44 + 10.3 + 10.8 + 7.8 |
| 1.55 | 1.6/ 1.7 | 4.39 | 45.34 | 16.44 + 10.3 + 10.8 + 7.8 |

Average: 47.55
+ 4.39

Average: 51.9 - total ash content (db) of sample $\leq$ 1"

SAMPLE SIZE: $\leq$1"

Calculation of cumulative sulfur in float fractions

| Specific Gravity Sink | Specific Gravity Float | Weight % of total | Wt.% S (Exp.Data)db | g S/Mil.BTU (db) | Cumulative $\frac{g\ S}{Mil\ BTU}$(db) | Cumulative $\frac{g\ S}{Mil\ BTU}$(db) | CALCULATIONS |
|---|---|---|---|---|---|---|---|
| | 1.3 | 13.8 | .40 | 148.1 | .40 | 148 | |
| 1.3 | 1.4 | 23.3 | .73 | 331.8 | .61 | 264 | $\frac{13.8}{37.1}(.40) + \frac{23.3}{37.1}($<br>$= .149 + .458 =$<br>$\frac{13.8}{37.1}(148.11) + \frac{23.3}{37.1}($<br>$= 263.5$ |
| 1.4 | 1.45 | 19.3 | .58 | 480.1 | .60 | 338 | $\frac{13.8}{56.4}(.40) + \frac{23.3}{56.4}(.7$<br>$+ \frac{19.3}{56.4}(.58) = .60$<br>$\frac{13.8}{56.4}(148.11) + \frac{23.3}{56.4}(33$<br>$+ \frac{19.3}{56.4}(480.08) = 33$ |
| 1.45 | 1.5 | 8.6 | .50 | 606.4 | .59 | 373 | $\frac{13.8}{65.}(.40) + \frac{23.3}{65.}(.7$<br>$+ \frac{19.3}{65.}(.58) + \frac{8.6}{65.}($<br>$= .59$<br>$\frac{13.8}{65.}(148.11) + \frac{23.3}{65.}($<br>$+ \frac{19.3}{65.}(480.08)$<br>$+ \frac{8.6}{65.}(606.41)$ |

SAMPLE: $\leq$1/2"

Calculation of cumulative heat content in float fractions:

| Specific Gravity Sink | Specific Gravity Float | Weight % | Calorific Value (Exp.BTU/lb) | Cumulative Calorific Value(BTU/lb) | CALCULATIONS |
|---|---|---|---|---|---|
| | 1.45 | 71.6 | 8185 | 8185 | |
| 1.45 | 1.55 | 1.5 | 6100 | 8140 | $\frac{71.6}{73.1}(8185) + \frac{1.5}{73.1}(6100)$<br>$= 8017. + 125.2$<br>$= 8142$ |

Calculation of heat content of coal before washing by heat balance of float and sink fractions.

| | | |
|---|---|---|
| 1.45F: | 71.6 wt.% at 8185 BTU/lb | 5860.45 |
| 1.55F | 1.5 wt.% at 6100 BTU/lb | 91.5 |
| 1.55S: | 23.4 wt.% at 3130 BTU/lb | 732.4 |
| Loss: | 3.5 wt.% at 1300 BTU/lb | 45.5 |
| | | 6729.85 → 6730 BTU/lb |

SAMPLE SIZE: $\leq$1/2"

Calculation of cumulative ash in float fractions;

| Specific Gravity Sink | Specific Gravity Float | Weight % (db) | Wt.% Ash (exp.) | Wt. % Ash (Cumul.) | CALCULATIONS |
|---|---|---|---|---|---|
| | 1.45 | 71.6 | 37.1 | 37.1 | |
| 1.45 | 1.55 | 1.5 | 52.6 | 37.4 | $\frac{71.6}{73.1}(37.1) + \frac{1.5}{73.1}(52.6)$ $= 36.3 + 1.08 = 37.4$ |
| 1.55 | 1.65 | - | - | - | wt% of 1.7→1.9 S.G. floats are negligible. |

Calculation of ash content of unwashed coal by ash balance of float and sink fractions.

| | | |
|---|---|---|
| 1.45F | 71.6 wt.% at 37.1 % Ash | 26.56 |
| 1.55F | 1.5 wt.% at 52.6% ash | .79 |
| 1.55S | 23.4 wt.% at 77.1% ash | 18.04 |
| Loss | 3.5 wt.% at 77.%* ash | 2.70 |
| | | 48.09 → 48.1% ash (db) |

* obtained by TGA

SAMPLE: $\leq$1/4"

Calculation of cumulative heat content in float fractions:

| Specific Gravity Sink | Float | Weight % | Calorific Value (Experimental)* | Cumulative Calorific Value* | Calculations |
|---|---|---|---|---|---|
| | 1.45 | 81. | 7540 | 7540 | |
| 1.45 | 1.55 | .3 | 5900 | 7534 | $\frac{81.}{81.3}(7540) + \frac{.3}{81.3}(5900)$ $= 7512.2 + 21.77$ |

* BTU/1b

Calculation of heat content of coal before washing by heat balance of float and sink fractions.

| | | |
|---|---|---|
| 1.45F | 81.wt% at 7540 BTU/1b | 6107.4 |
| 1.55F | .3wt.% at 5900 BTU/1b | 17.7 |
| 1.55S | 15.7wt.% at 2005 BTU/1b | 314.79 |
| Loss | 3.0 wt.% at 1300 BTU/1b | 3.9 |
| | | 6443.79 → 6440 BTU/1b |

SAMPLE SIZE: $\leq$1/4"

Calculation of cumulative ash in float fractions:

| Specific Gravity Sink | Specific Gravity Float | Weight % (db) | Wt. % Ash (Experi.) | Wt. % Ash (Cumul.) | CALCULATIONS |
|---|---|---|---|---|---|
| | 1.45 | 81. | 42.7 | 42.7 | |
| 1.45 | 1.55 | .3 | 55. | 42.8 | $\frac{81.}{81.3}(42.7) + \frac{.3}{81.3}(55.)$<br>$= 42.542 + .203$<br>$= 42.745$ |

Calculation of ash content of coal before washing by ash balance of float and sink fractions.

| | | |
|---|---|---|
| 1.45F | 81.wt.% at 42.7% ash | 34.587 |
| 1.55F | .3 wt.% at 55.% ash | .165 |
| 1.55S | 15.7 wt.% at 79.1% ash | 12.419 |
| Loss | 3. wt.% at 77.%* ash | 2.31 |
| | 100. | 49.481 → 49.5% ash (db) |

* obtained by TGA

Kaolinite/Bentonite Mass Balance:

SAMPLE SIZES: $\leq$1/2", $\leq$1/4"

| Specific Gravity Sink | Specific Gravity Float | Kaolinite Float | Kaolinite Sink | Kaolinite Total | Percent Derivation | Bentonite Float | Bentonite Sink | Bentonite Total | Percent Derivation |
|---|---|---|---|---|---|---|---|---|---|
| Sample Size $\leq$ 1/2" | | | | | | | | | |
| | 1.45 | 15.67* | 10.89 | 26.6 | - | 11.78 | 6.92 | 18.7 | - |
| 1.45 | 1.55 | .53 | 11.72 | 12.3 | -7.6 | .24 | 6.31 | 6.6 | 4.6 |
| Sample Size $\leq$ 1/4" | | | | | | | | | |
| | 1.45 | 21.8** | 8.99 | 30.8 | - | 12.8 | 3.49 | 16.3 | - |
| 1.45 | 1.55 | .14 | 7.33 | 7.47 | 16.9 | .03 | 4.22 | 4.25 | 21.8 |

All figures given are % of total weight (dry basis) before washing. At any specific gravity, the total percentages of kaolinite and bentonite will <u>not</u> be equal. Explanation is given in Kaolinite/Bentonite Mass Balance for sample $\leq$ 1 1/2".

* 15.67 = (wt.% of 1.45F)(wt.% ash)(wt.% kaolinite) = (.716)(37.1)(.59)
** 21.8 = (wt.% of 1.45F)(wt.% ash)(wt.% kaolinite) = ( .81)(42.7)(.63)

Cumulative kaolinite/bentonite balance

SAMPLE SIZE: ≲1/2",≲1/4"

| Specific Gravity | | Float Fraction | | | | Sink Fraction | | |
|---|---|---|---|---|---|---|---|---|
| Sink | Float | Kaol. % of float Fraction | Bent. | Kaol. % of total Material | Bent. | Kaol. % of Sink Fraction | Bent. | CALCULATIONS |
| Sample Size ≤ 1/2" | | | | | | | | |
| | 1.45 | 21.89 | 15.21 | 15.67 | 11.78 | 12.03 | 7.07 | |
| 1.45 | 1.55 | 22.18 | 15.23 | 16.2 | 12.02 | 11.72 | 6.31 | K $\frac{71.6}{73.1}(37.1)(.59) + \frac{1.5}{73.1}(52.6)(.69)$ <br> $= 21.43 + .75$ <br> B $\frac{71.6}{73.1}(37.1)(.41) + \frac{1.5}{73.1}(52.6)(.31)$ <br> $= 14.9 + .33$ |
| Sample Size ≤ 1/4" | | | | | | | | |
| | 1.45 | 26.9 | 15.8 | 21.8 | 12.8 | 8.99 | 3.49 | |
| 1.45 | 1.55 | 27. | 15.77 | 21.9 | 12.8 | 7.33 | 4.22 | K $\frac{81.}{81.3}(42.7)(.63) + \frac{.3}{81.3}(55.)(.84)$ <br> $= 26.8 + .17$ <br> B $\frac{81.}{81.3}(42.7)(.37) + \frac{.3}{81.3}(55.)(.16)$ <br> $= 15.74 + .03$ |

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