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Topical Report #2 for DOE Contract No. DE - AC22 - 88PC88881

Controlled Comparison of Advanced Froth Flotation Process Technology and Economic Evaluations for Maximizing BTU Recovery and Pyritic Sulfur Rejection

June 1990

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799/43II/044/901

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

799/43II/044/904

1.0 INTRODUCTION

In October 1988, the Department of Energy (DOE), Pittsburgh Energy Technology Center (PETC) awarded a contract to ICF Kaiser Engineers (ICF KE) entitled "Engineering Development of Advanced Physical Fine Coal Cleaning Technologies - Froth Flotation". The contract is a multiple task contract that includes conceptual design, laboratory scale testing for reducing uncertainties discovered during the conceptual design, building and operating a 2-3 TPH advanced flotation proof of concept (POC) module, and based on POC operating data completing a final conceptual design at 20TPH feed rate.

The overall goal of Task 5 of the Engineering Development Contract is to develop the necessary unit operation design and process performance data to (1) reduce or eliminate the technical and engineering uncertainties of the preliminary 20 TPH advanced flotation semiworks plant and (2) design, build and operate a 2-3 TPH advanced flotation POC module.

There are several alternative advanced flotation techniques currently being developed by others to commercial or near commercial size unit operations. These alternatives differ primarily in the procedure and chemistry used to generate bubbles and/or treat the coal surfaces during flotation, procedures for injecting fine bubbles into the flotation cell, and the physical design of the flotation cell. A round robin program using devices from most of the process developers working in the advanced flotation area has been organized as part of this Task. Two process developers who were contacted declined to participate.

The conceptually designed advanced flotation unit will be initially scaled-down to operate at 100 pounds per hour. The unit will then be scaled up, using the process developers' guidance, and information obtained from Task 6, Component Development, to operate at 20 tons per hour. From this design a proof of concept scale size will be designed, constructed and operated at a feed rate of 2-3 tons per hour. After the testing of the POC size unit, a final 20 tons per hour feed rate machine will be designed.

During subtask 1.5.11, advanced flotation evaluation on a semi-continuous basis, an advanced flotation machine capable of processing 100 pounds per hour is required. This flotation machine will be utilized to verify operating conditions, quality performance, and generating material for filtration, dewatering and clarification equipment testing.

The tests will use the most efficient, cost effective flotation cell available to improve the possibility of attaining the maximum amount of BTU recovery and maximum amount of pyritic sulfur rejection possible for a given coal at a given particle size distribution. Therefore, the objective of this round robin testing is to select the "best available" advanced flotation technology for installation into the semi-continuous process at Babcock and Wilcox (B&W) Alliance Research Center.

2.0 TEST PROGRAM PROCEDURE

Approximately 120 pounds of fine coal slurry and 120 pounds of dry 1/4" x 0 coal were prepared by Babcock & Wilcox at its Alliance Research Center (ARC) for use by each participant in the Round Robin Testing of advanced flotation. Figure 2.1 is a flowsheet outlining the major steps performed in preparing the dry coal sample and the fine slurry. The methodology of grinding, sampling, inerting, and analyzing the samples during preparation is described in detail below.

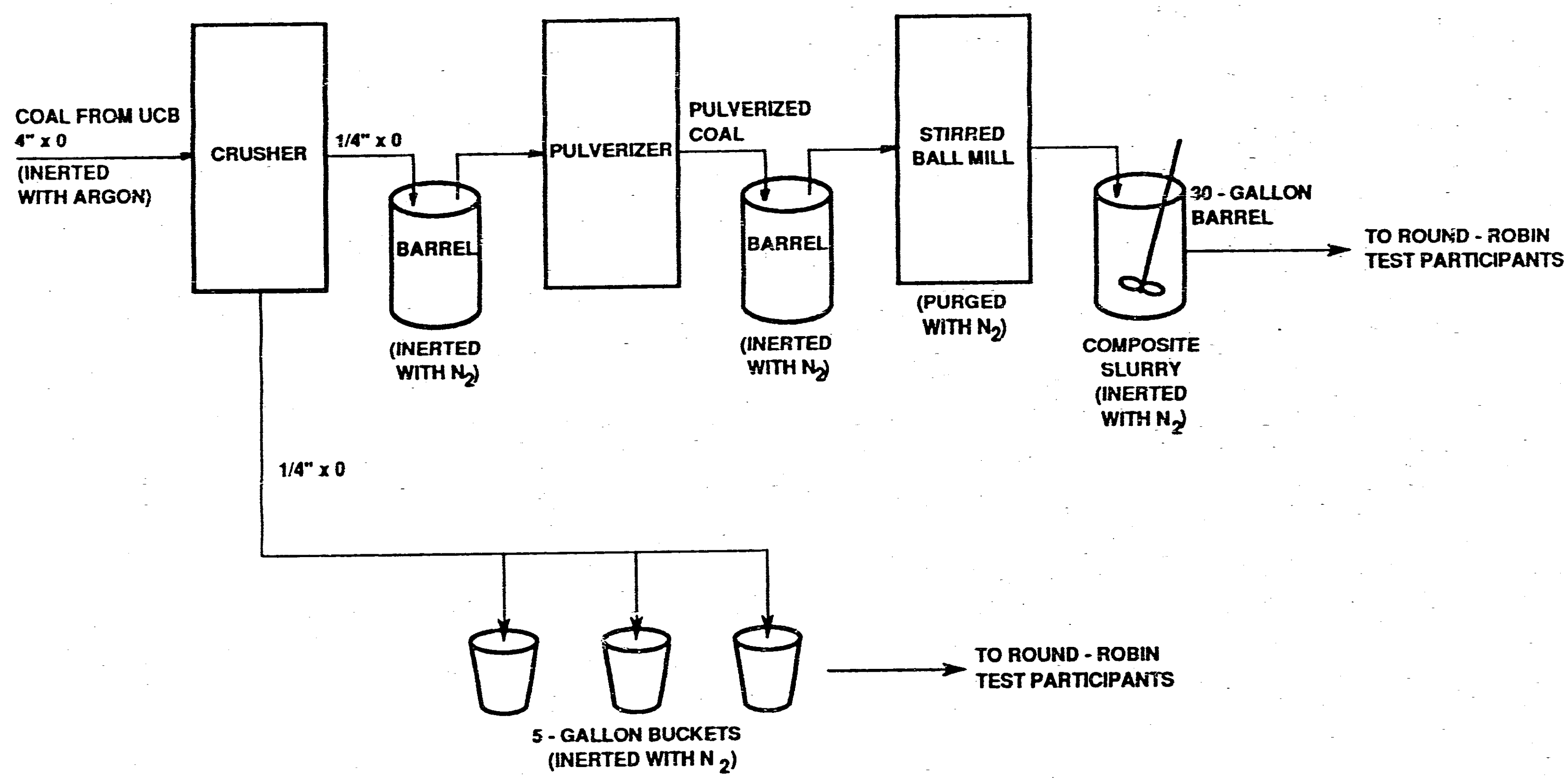


FIGURE 2.1

FLOWSHEET OF COAL AND SLURRY PREPARATION FOR ROUND - ROBIN TEST PARTICIPANTS

2.1 Coal Crushing and Feed Preparation

2.1.1 Coal Crushing

Five Barrels (approximate 1400 lbs) of Pittsburgh No. 8 coal were shipped from Praxis Engineers, Inc. This coal was obtained from Belmont County, Ohio and was supplied by R&F Coal Company. This channel sample of coal was set aside from the DOE/PETC "Coal Surface Control for Advanced Fine Coal Flotation" project. The coal was 4" x 0 and was stored in plastic lined drums, inerted with argon, and taped prior to shipment to the B&W ARC.

Upon arrival, the coal was crushed to 1/4" x 0 using a Hammermill Crusher, Model #3296, from Holmes Bros, Inc. in Danville, Illinois. The size analysis of the 1/4" x 0 fraction is shown in Table 2.1. The crushing was done very quickly and without inerting. The crushed coal was stored in barrels purged with N_2 as it was produced. After all the coal was crushed, the barrels of product coal were dumped on the floor and mixed together before riffling. The sample was riffled down twice. The first time was to produce a sample of approximately 40 lbs. The 40-lb sample was further split into four 10-lb samples and used for coal analysis and flotation analysis to determine signs of oxidation.

The 10 pound samples were stored in separate plastic bags and purged with N_2 for approximately 4 times the volume of the coal. The plastic bags were sealed with a thermal sealer. The samples were then double bagged and again purged with N_2 before the outer bags were sealed. Two of the 10-lb samples were for ASTM coal analysis. The two other 10-lb samples were shipped to Professor D. W. Fuerstenau at the University of California at Berkeley (UCB) for standard flotation tests to verify the coal did not change. Professor Fuerstenau's group at UCB is the lead of the "Coal Surface Control for Advance Coal Flotation Project".

The remaining coal (approximately 1360 pounds) was remixed and riffled again to obtain 40 pound samples for the Round Robin Test participants. Each sample was weighed, bagged, purged with N_2 for approximately 4 times of coal volume, sealed with a thermal sealer, doubled bagged, purged with N_2 again, sealed, and stored in a 5-gallon plastic bucket. Each bucket was purged with N_2 before the lid was tightened. Three 40 pound samples of 1/4" x 0 coal (total of 120 pounds in 9 buckets) were shipped to each participant. The remaining crushed coal (approximately 400 pounds) which was used by B&W to prepare fine coal slurry was stored in a barrel with a plastic liner, purged with N_2, sealed with tape, double bagged, purged with N_2 again, taped, and the barrel was purged with N_2 before the lid was sealed.

2.1.2 Pulverized Feed Preparation

Prior to preparation of slurry, the remaining crushed 1/4" x 0 coal was further reduced in size by pulverizing with a hammermill, a Mikro-Pulverizer, Model 1SH. The pulverized coal has a size distribution of 99.5% less than 300 microns (48 mesh) and 74% less than 75 microns (200 mesh). The size analysis of the pulverized coal is shown in Table 2.2 and Figure 2.2. The pulverized coal fraction was used as feed to a stirred ball mill for fine coal slurry preparation.

TABLE 2.1

Particle Size Distribution of 1/4" x 0 Fraction of Pittsburgh No. 8 Coal

DOE/PETC
ACG-90-4545-08
September 7, 1989

Sample No.	C-20409	
Description	Pittsburgh #8 Coal	
Sizing	Sieve No.	% Thru
	1/2 inch	100.0
	1/4 inch	99.2
	#4	97.6
	8	78.8
	16	49.4
	30	29.7
	50	17.6
	70	12.9
	100	9.6
	140	6.9
	200	5.0
	270	3.0
	325	2.5

TABLE 2.2

Particle Size Distribution of Pulverized Pittsburgh No. 8 Coal

Pittsburgh #8 Coal, Pulverized
For Attritor Round Robin
PBRF0001, 8-29-89

MICRONS	%LESS	DIFF
2400.00		
1697.06		
1200.00		
848.53		
600.00	100.00	0.29
424.26	99.71	0.21
300.00	99.50	2.04
212.13	97.46	5.83
150.00	91.63	6.52
106.07	85.11	11.17
75.00	73.94	13.51
53.03	60.43	11.85
37.50	48.58	10.89
26.52	37.69	9.72
18.75	27.97	6.81
13.26	21.16	6.71
9.38	14.46	5.54
6.63	8.92	3.15
4.69	5.76	2.27
3.31	3.49	1.36
2.34	2.13	0.93
1.66	1.20	0.44
1.17	0.77	0.35
0.83	0.42	0.24
0.69	0.18	0.15
0.41	0.03	0.03
0.29	0.00	0.00
0.21		
0.16		

CSICAL SURF AREA 1=0.40 M==2/CM==3
MMD(D43)=58.82 MICRONS
SMD(D32)=15.12 MICRONS

2.2 Slurry Preparation

2.2.1 Mill Preparation

A laboratory batch stirred ball mill, an attritor mill from Union Process, Model 1S, was used to prepare the fine Pittsburgh No. 8 coal slurry. A photograph of the mill is shown in Figure 2.3. The dimension and the capacity of the mill are shown below:

Mill diameter:	9 inches
Mill depth:	8 inches
Mill volume:	2.5 gallons
Grinding medium:	3/16" 440 stainless steel beads
Medium charge:	60 lbs (approximately 60% of mill volume)

The mill was rinsed with a volume of tap water equivalent to three times the mill volume while the grinding shaft was turning at a slow speed (approximately 70 rpm) to remove any rust in the mill. The mill was then rinsed with distilled water to displace remaining tap water left in the mill. The wash water was drained out while the grinding shaft was rotated at a slow speed.

2.2.2 Fine Grinding

The amount of coal required for grinding was calculated based on the moisture in the coal and water left in the mill. Typical weights of water and coal for fine slurry preparation were as follows:

"Target" solids content in slurry:	35.5%
Moisture in pulverized coal:	3.4%
Water left in the mill:	300 gm
Weight of additional distilled water:	2430 gm
Weight of pulverized coal:	1550 gm

Prior to grinding, the distilled water for making the slurry was poured into the mill. The coal was then slowly fed into the mill while the shaft was rotated at 185 rpm and the timer was started. No dispersants or any other chemicals were used during grinding.

Generally, it took about 15 minutes to load and wet 1550 grams of coal. N_2 purging was not applied during coal feeding because the N_2 flow tended to blow the fine coal out of the mill. After the coal was completely blended into the water, the coal was ground for 5 minutes at 185 rpm while purging with N_2. The temperature of the mill was controlled by circulating cold tap water through the water jacket provided with the mill.

2.2.3 Slurry Handling and Storage

Approximately seventeen, 0.75 gallon batches of slurry were prepared for each Round Robin Test participant. As each batch was ground it was transferred to a 30-gallon plastic container. The container was purged with N_2 after the slurry was transferred and the lid was then sealed. Residual slurry in the mill was cleaned with tap water and rinsed with distilled water, as described above, prior to grinding the next batch.

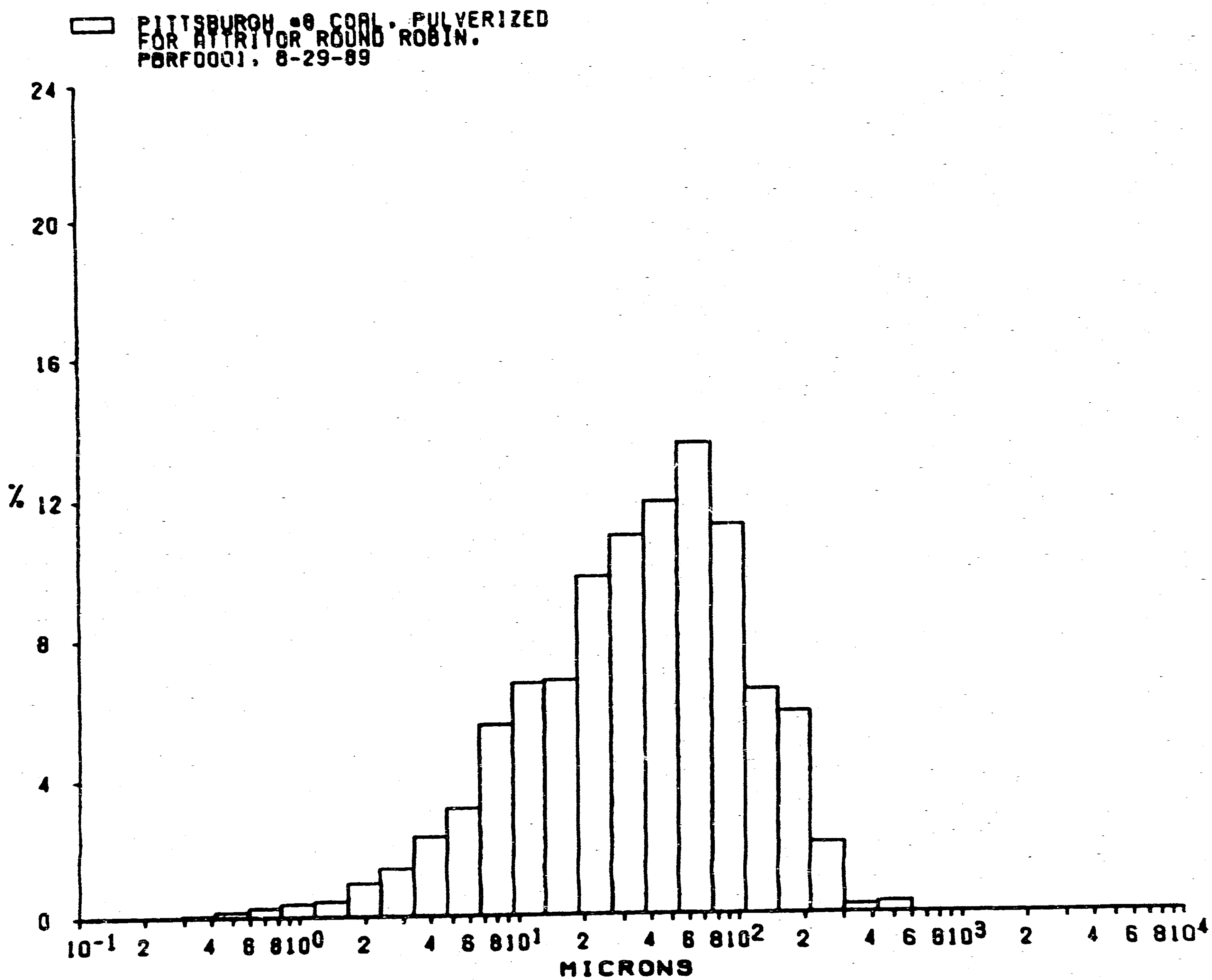
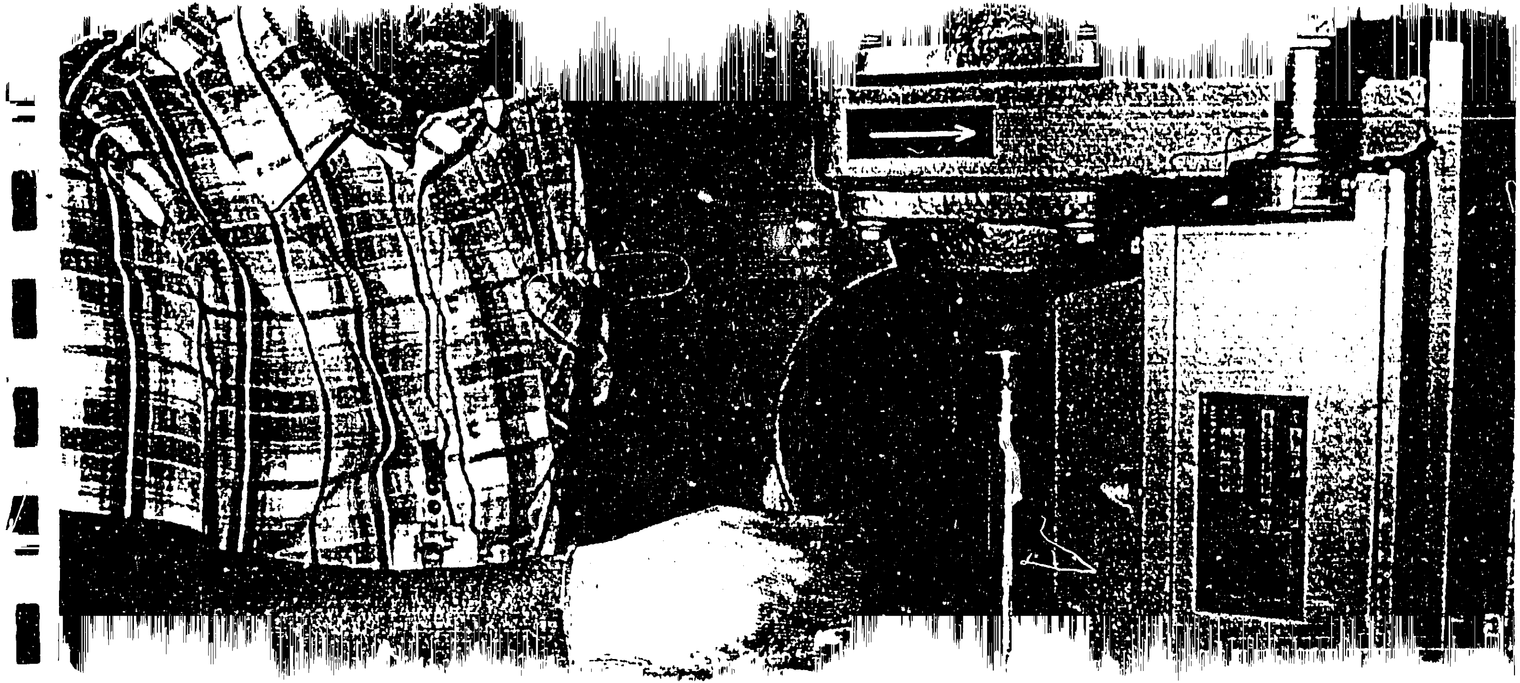


FIGURE 2.2

Histogram of Pulverized Pittsburgh No. 8 Coal



After all 17 batches of slurry were ground, they were mixed at approximately 100 rpm for 10 minutes using an air driven stirrer with an 8-inch diameter impeller. Two, one quart size samples were then taken for solids, particle size distribution (PSD), pH, ash, Btu, total sulfur, and pyritic sulfur determinations. Also, a 2-gallon composite sample of slurry was obtained and shipped for washability analysis. These samples were placed in a plastic bag, purged with N_2, taped, put in a 5-gallon plastic bucket, and purged with N_2 before the bucket was sealed for shipping. The remaining slurry was transferred to another 30-gallon plastic container with double plastic liners. The slurry was purged with N_2 and the inside and the outside plastic liners were sealed with tape. Finally, the container was purged with N_2 and the cover was tightly sealed. The slurry sample (approximately 120 lbs) and 9 buckets of dry coal (approximately 120 lbs) were shipped to each Round Robin Test participants.

2.3 Coal and Slurry Characterization

2.3.1 Coal Analysis

The as-received coal from Praxis Engineers, Inc. was analyzed at B&W for proximate analysis, ultimate analysis, and Btu. Comparison of the B&W coal analysis data from Table 2.3 with previous analysis obtained from UCB Table 2.4 showed that the coal B&W received from Praxis was the same coal used by UCB on "Coal Surface Control for Advanced Fine Coal Flotation" project.

2.3.2 Flotation Tests

UCB has developed standard grinding and froth flotation procedures for testing coals as part of the "Coal Surface Control for Advanced Fine Coal Flotation" project. They performed their standard grinding and flotation tests on the 1/4" x 0 Pittsburgh No. 8 coal samples obtained from B&W. The flotation results were similar to their previous flotation results on Pittsburgh No. 8 coal. This indicated that the batch of Pittsburgh No. 8 coal received by B&W from Praxis Engineers, Inc. did not oxidize during storage.

2.3.3 pH of Dry Coal

The pH of the dry coal was measured by suspending one gram of coal in 100 ml of distilled water. The pH for the dry coal are as follows:

As received coal:	3.1
1/4" x 0 fraction:	3.6
Pulverized coal:	3.8

2.3.4 Particle Size Distribution (PSD)

The PSD of the 1/4" x 0 samples was determined using standard ASTM screening methods. The PSDs of pulverized coal feed and the slurry product were measured using two Leeds and Northrup Microtrac particle size analyzers. Small dry coal and slurry samples were dispersed in dilute surfactant solutions to insure the particles were well dispersed before the PSDs were measured. A standard L&N particle analyzer measured the

TABLE 2.3

Coal Analysis of Pittsburgh No. 8 Coal (From B&W)

DOE/PETC
ACG-90-4545-08
September 7, 1989

Sample No.	C-20369	
Description	Pittsburgh #8 Coal	
Basis	As Received	Dry
Total Moisture, %	5.07	---
Proximate Analysis, %		
Moisture	5.07	---
Volatile Matter	36.28	38.22
Fixed Carbon	46.60	49.09
Ash	12.05	12.69
Gross Heating Value Btu per Lb.	12032	12675
Ultimate Analysis, %		
Moisture	5.07	---
Carbon	66.75	70.32
Hydrogen	4.58	4.82
Nitrogen	1.19	1.25
Sulfur	4.21	4.44
Ash	12.05	12.69
Oxygen (Difference)	6.15	6.48
Total	100.00	100.00

TABLE 2.4

Coal Analysis (From University of California at Berkeley)

Coal	As Recd. Moisture %	Proximate Analysis, Dry Wt %		
		Vol. Matter	Fixed Carbon	Ash
Illinois No. 6	9.5	36.2	46.3	17.5
Pittsburgh No. 8	2.3	35.7	52.5	11.8
Upper Freeport PA	1.0	26.2	61.8	12.0

Coal	As Recd. Moisture %	Ultimate Analysis, Dry Wt %				
		Carbon	Hydrogen	Nitrogen	Sulfur	Oxygen
Illinois No. 6	9.5	63.8	5.7	1.24	5.73	6.10
Pittsburgh No. 8	2.2	71.0	5.1	1.45	4.28	6.40
Upper Freeport PA	1.8	75.6	4.7	1.45	2.38	3.85

particle size range of 4.7 microns to 300 microns. A small L&N particle analyzer measured particles from 0.17 micron to 21.1 microns. The percentages of particles larger than 300 microns were determined using a wet screen method. The PSDs from the two analyzers and the oversized particles (greater than 300 microns) were overlapped using a computer program developed at B&W. THe PSD of the composite slurry is shown in Table 2.5 and the histogram is shown in Figure 2.4.

2.3.5 Solids Content

The solids content of the slurry was measured using a Computrac model Max 50 moisture analyzer. The solids content of the slurry from each grinding and the composite slurry were measured. In general, the solids content ranged between 35.5 to 36.5%. The actual solids content for the composite slurry is given in Table 2.6.

2.3.6 Btu, Ash, Total Sulfur, Pyritic Sulfur, and pH for Composite Slurry

The composite slurry was analyzed for Btu, ash, total sulfur, and pyritic sulfur at B&W using ASTM methods. The pH of the composite slurry was measured by immersing the pH electrode in the slurry. The results are shown in Table 2.6.

2.3.7 Washability and Pyrite Liberation

Washability data on the composite slurry was determined by Tradet Laboratories for the fine grind and by Praxis Engineering for the coarse grind. The results are shown in Tables 2.7 and 2.8 respectively. The pyrite liberation tests on previous slurry samples prepared under similar grinding conditions was measured by Virginia Polytechnic Institute and State University (VPI). The results are shown in Figure 2.5.

2.4 Round Robin Participants

The following participants were contacted and agreed to participate in the advanced flotation Round Robin test program on a cost share basis.

Table 2.9
List of Participants

- Allmineral (Aufberetungstechnik GmbH & Co. KG)
- B. Datta Research
- Center for Applied Energy Research
- Deister Concentrator Company, Inc.
- Illinois State Geological Survey
- Michigan Technological University
- Virginia Polytechnic Institute and State University

Two other organizations were contacted to participate in the Round Robin. They are WEMCO and AFT, Inc. Both of these organizations declined to participate. A third organization was contacted to participate, Advanced Processing Technologies, Inc. A mutual decision between DOE/PETC and ICF KE determined that results from ongoing contracts would be used to compare results of the Air-Spared Hydrocyclone with the advanced flotation devices. Therefore, Advanced Processing Technologies, Inc. was not included in the Round Robin Test.

TABLE 2.5

Particle Size Distribution of Pittsburgh No. 8 Coal-Water Slurry Product

F-4193. ATTRITOR COMBINE SAMPLE.
FOR ILL. ST. GEOL. . 17 BATCHES
OF 5 MIN. GRINDING AT 185 RPM.
96.9% SOLIDS. SPL. NO. PBRP0292. AT 52

MICRONS	% LESS	DIFF
2400.00		
1697.06		
1200.00		
848.53		
600.00	100.00	0.01
424.26	99.99	0.01
300.00	99.99	0.00
212.13		
150.00		
106.07		
75.00		
53.03	99.98	0.83
37.50	99.15	4.52
26.52	94.53	12.72
18.75	81.91	16.03
13.26	65.89	17.42
9.38	48.47	16.96
6.63	31.51	12.20
4.69	19.32	7.58
3.31	11.78	4.62
2.34	7.14	2.81
1.66	4.33	1.53
1.17	2.80	1.20
0.83	1.60	0.83
0.59	0.77	0.56
0.41	0.21	0.21
0.29	0.00	0.00
0.21		
0.15		

CS(CAL SURF AREA)=1.06 M==2/CM=3
MMD(D43)=11.91 MICRONS
SMD(D32)=5.67 MICRONS

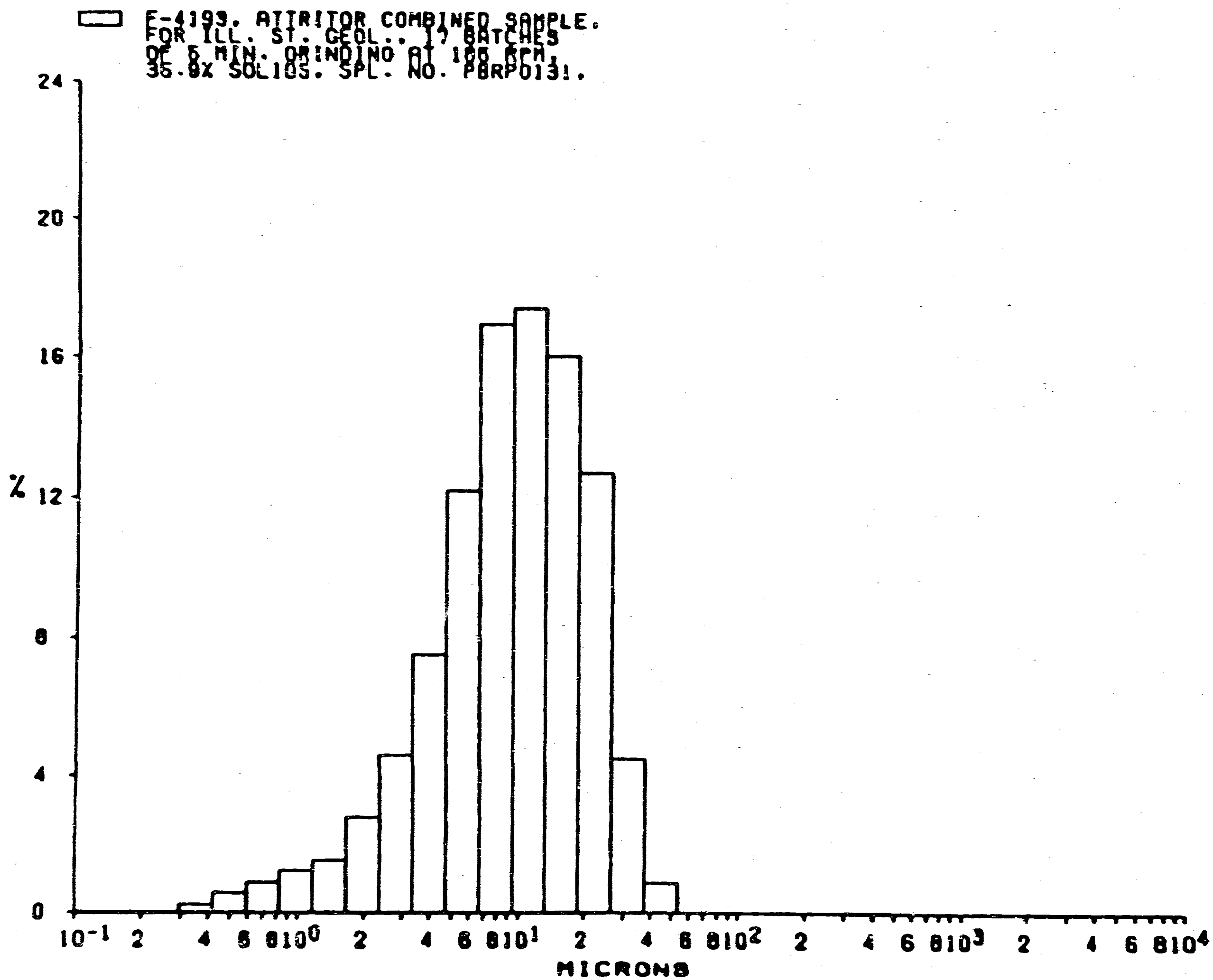


FIGURE 2.4

Histogram of Pittsburgh No. 8 Coal-Water Slurry Product

TABLE 2.6

Characterization of Pittsburgh No. 8 Coal-Water Slurry Product

	Slurry	Dry Basis
Gross Heating Value (Btu/lb)	----	12,389
Ash, %	----	12.05
Total Sulfur, % S	----	3.92
Pyritic Sulfur, % S	----	2.44
pH	5.49	
Solids Content, %	35.9	

TABLE 2.7

WASHABILITY OF FINE GRIND BY TRADET
(MINUS 325 MESH)

SPECIFIC GRAVITY		DRY BASIS								CUMULATIVE PRODUCT (FLOAT)								BTU RECOVERY	PYRSUL REJECT.
Sink	Float	% Wt.	% Ash	% Sulf.	BTU per lb.	MAFBTU per lb.	% Pyr. Sulfur	% Sulf. Sulfur	% Organ. Sulfur	% Wt.	% Ash	% Sulf.	BTU per lb.	MAFBTU per lb.	% Pyr. Sulfur	% Sulf. Sulfur	% Organ. Sulfur	%	%
	1.30	37.83	1.71	1.55	14,462	14,714	0.08	0.11	1.37	37.83	1.71	1.55	14,462	14,714	0.08	0.11	1.37	43.84	98.72
1.30	1.35	17.97	2.45	1.64	14,301	14,660	0.11	0.21	1.33	55.80	1.95	1.58	14,410	14,696	0.09	0.14	1.36	64.43	97.87
1.35	1.40	16.44	3.47	1.65	13,832	14,329	0.17	0.30	1.18	72.24	2.29	1.60	14,279	14,614	0.11	0.18	1.32	82.66	96.63
1.40	1.45	8.00	5.76	1.78	13,434	14,255	0.29	0.44	1.05	80.24	2.64	1.61	14,194	14,579	0.13	0.20	1.29	91.27	95.58
1.45	1.50	3.44	9.70	1.99	12,699	14,063	0.51	0.60	0.88	83.68	2.93	1.63	14,133	14,560	0.14	0.22	1.27	94.77	95.04
1.50	1.60	2.88	14.40	2.27	11,966	13,979	0.76	0.76	0.75	86.56	3.31	1.65	14,061	14,542	0.16	0.24	1.26	97.53	94.13
1.60	1.70	0.85	27.06	3.15	9,818	13,460	1.39	1.19	0.57	87.41	3.54	1.66	14,020	14,534	0.17	0.25	1.25	98.20	93.70
1.70	1.80	0.44	36.92	4.37	8,006	12,692	2.05	1.66	0.66	87.85	3.71	1.68	13,989	14,528	0.18	0.25	1.25	98.48	93.30
1.80		12.15	75.12	20.20	1,556	6,254	18.12	1.31	0.77	100.00	12.39	3.93	12,479	14,243	2.36	0.38	1.19	100.00	0.00

TABLE 2.8

WASHABILITY OF COARSE GRIND BY PRAXIS
(MINUS 200 MESH)

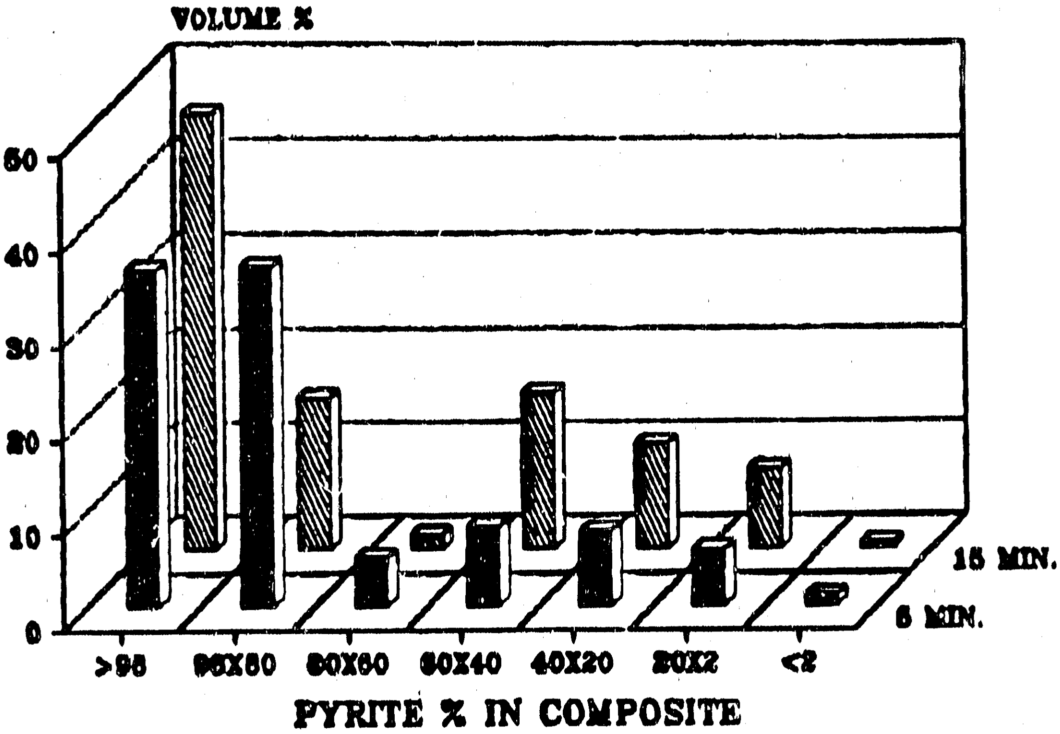
WASHABILITY DATA
SEAM: PITTSBURGH NO. 8
BELMONT COUNTY, OHIO

ORIGINAL SAMPLE, CRUSHED TO 200 M TOPSIZE

SIZE FRACTION: 200 M X 0 - 100.0 %

SPECIFIC GRAVITY		ELEMENTARY DATA						COMPUTED DATA: CUMULATIVE							
SINK	FLOAT	(%) WT%	(%) ASH	(%) TOT SUL	(%) PYR SUL	BTU	# SO2/ M BTU	(%) WT%	(%) ASH	(%) TOT SUL	(%) PYR SUL	BTU	(%) BTU REC	# SO2/ M BTU	%PYR SUL REJECTED
	1.30	53.9	2.08	1.35	0.09	14513	1.86	53.9	2.08	1.35	0.09	14513	61.36	1.86	98.26
1.30	1.35	6.7	4.41	1.50	0.33	14112	2.13	60.6	2.34	1.37	0.12	14469	68.78	1.89	97.46
1.35	1.40	8.6	4.87	1.45	0.37	13580	2.14	69.2	2.65	1.38	0.15	14358	77.94	1.92	96.32
1.40	1.60	17.6	10.57	1.89	0.97	12878	2.94	86.8	4.26	1.48	0.31	14058	95.72	2.11	90.17
1.60	1.80	1.6	26.01	4.80	3.92	10450	9.19	88.4	4.65	1.54	0.38	13993	97.03	2.20	87.92
1.80		11.6	68.34	21.84	21.07	3264	133.82	100.0	12.04	3.90	2.78	12748	100.00	6.11	0.00

FIGURE 2.5



The degree of liberation of Pitts.#8 coal with 5 and 15 minutes grinding.

2.5 Phase I - Tests 1 Through 3

The purpose of Phase I Tests 1-3 was two fold. The first was to determine if oxidation occurred to the B&W prepared sample. The second was to identify if fine grinding to liberate pyrite resulted in better pyrite rejection than coarse grinding.

Test Number 1 was a controlled size distribution test to establish the mean volume size for future tests and to assure that each participant had the "same" coal. Test Number 2 was included to ascertain if oxidation had occurred to the Test 1 sample. Test Number 3 was conducted to indicate if a coarser grind produced the same efficiency as a finer grind thus improving the overall economics of the project.

Tests 1 through 3 were conducted by each participant. Each participant except Deister and Allmineral was observed by a representative of ICF KE during the actual running of one of the first three tests. Each participant performed analytical tests and calculated separation efficiencies. The participant recorded his results and submitted them on Table 2.10, Report Form for Tests 1-3. ICF KE received representative samples of feed, product and tailings for laboratory verification purposes from VPI, Michigan Tech, and ISGS. All other participants did not comply with this request.

TABLE 2.10

REPORT FORM FOR TESTS 1-3

Date ______ Test I.D. ______ Seam Pittsburgh 8

Description: This test is for B&W prepared and participant prepared samples at fixed conditions.

Geometry:

- Height ______ in.
- Diameter ______ in.
- Slurry Feed Point ______ in.
- Wash Water Addition Point ______ in. from top
- Froth Height ______ in. from top
- Pulp Height ______ in.
- Type of Baffles & Spacing ______ in.

Operating Conditions:

- Wash Water Flow Rate ______ GPM.
- Air Flow Rate ______ CFM
- Feed Slurry Flow Rate ______ GPM
- Feed Slurry Percent Solids 10% by weight
- Feed Slurry pH 7.0
- Feed Slurry Particle Size PSD by B&W
- Air Hold-Up ______
- Mean Retention Time 5 minutes

Reagents:

- Collector Name Kerosene
- Collector Addition Rate 3.0 #/Ton
- Frother Name Dowfroth M150
- Frother Addition Rate 1.0 #/Ton
- Modifier Name N/A
- Modifier Addition Rate N/A #/Ton
- Name & Function N/A
- Addition Rate N/A #/Ton

Results:

Stream	Yield Grams	% Solids By Weight	Pyritic Sulfur	Ash	Total Sulfur	
Product	______	______	______	______	______	______
Reject	______	______	______	______	______	______
Feed	______	______	______	______	______	______

BTU Recovery ____________ SO2/MBTU ____________ Pyritic Sulfur Reduction ______

Note: All conditions not specified are to be determined by the participant and for each test recorded on this log sheet. If condition does not apply to participant it must be marked not applicable (N/A).

The data from all tests 1 through 3 of Phase I were forwarded to ICF KE. This data was compiled and the results sent to the Technical Support Team (TST). The TST reviewed the data comparing tests 1 to 2 and test 3 results to the first 2 tests. After the review the TST made recommendations that each participant proceed with Test 4 at the finer grind.

2.6 Phase II - Test 4

The purpose of Phase II Test 4 was two-fold. The first was to permit the participant to alter the reagents to ensure proper operation of their particular devices. The second was to permit the participant the freedom to maximize Btu recovery and maximize pyritic sulfur rejection by whatever means he deemed appropriate. The only restriction placed upon the participant was the size analysis of the feed, which had to match, as closely as possible, the size analysis of Test 1.

Test 4 was conducted by each participant. Each participant, except Deister and Allmineral, was observed by a representative of ICF KE during the actual performance of Test 4. Each participant performed analytical tests and calculated the separation efficiency. The participant recorded his results and submitted them on Table 2.11, Report Form for Test 4. ICF KE received samples from the participants for checking laboratory verification purposes. Feed samples were received from VPI and Center for Applied Energy Research. Michigan Tech, ISGS, B. Datta Research, Allmineral, and Deister did not supply feed samples. Center for Applied Energy Research, B. Datta Research, ISGS, Michigan Tech and VPI supplied samples of Product and Tailings for the Test Number 4. Allmineral and Deister did not supply product and tailings samples.

All received samples were analyzed at Consolidated Coal Company Research Laboratory. The results of this analysis work and the participants reported valves are shown on Table 2.12. All of the participants reported values correlate very closely to Consol verification tests.

The separation efficiency is defined as follows for this report:

$$\text{Separation Efficiency} = \text{BTU Recovery} - (100 - \text{Pyrite Rejection})$$

where

$$\text{Pyrite Rejection} = \frac{(100-\text{Yield}) \times \%\ \text{Pyrite in Refuse}}{100 \times \%\ \text{Pyrite in Feed}}$$

and

$$\text{BTU Recovery} = \frac{\text{WT\% Yield} \times \text{Clean Coal BTU}}{100 \times \text{Raw Coal BTU}}$$

This separation efficiency is based on industry accepted methods as published by Electric Power Research Institute.

TABLE 2.11

REPORT FORM FOR TEST 4

Date ______ Test I.D. ________ Seam Pittsburgh 8

Description: This test is for ICF KE top size specified and participants prepared coal and participants conditions.

Geometry:

- Height ______ in.
- Diameter ______ in.
- Slurry Feed Point ______ in.
- Wash Water Addition Point ______ in. from top
- Froth Height ______ in. from top
- Pulp Height ______ in.
- Type of Baffles & Spacing ______ in.

Operating Conditions:

- Wash Water Flow Rate ______ GPM.
- Air Flow Rate ______ CFM
- Feed Slurry Flow Rate ______ GPM
- Feed Slurry Percent Solids ______ by weight
- Feed Slurry pH ______
- Feed Slurry Particle Size ______
- Air Hold-Up ______
- Mean Retention Time ______ minutes

Reagents:

- Collector Name ______
- Collector Addition Rate ______ #/Ton
- Frother Name ______
- Frother Addition Rate ______ #/Ton
- Modifier Name ______
- Modifier Addition Rate ______ #/Ton
- Name & Function ______
- Addition Rate ______ #/Ton

Results:

Stream	Yield Grams		% Solids By Weight	Pyritic Sulfur	Ash	Total Sulfur
Product	____	____	____	____	____	____
Reject	____	____	____	____	____	____
Feed	____	____	____	____	____	____

BTU Recovery __________ SO_2/MBTU __________ Pyritic Sulfur Reduction ______

Note: All conditions not specified are to be determined by the participant and for each test recorded on this log sheet. If condition does not apply to participant it must be marked not applicable (N/A).

TABLE 2.12
VERIFICATION TESTS

PERFORMANCE PARAMETER	AL MN	BDR	CAER	DCCI	ISGS	MTU	VPI
	#4	#4	[illegible]	#4	#4	#4	#4
FEED							
ASH % REPORTED	N/A	N/A	11.65	N/A	N/A	N/A	11.67
ASH % CHECKED	N/A	N/A	12.72	N/A	N/A	N/A	11.75
TOTAL SULFUR % REPORTED	N/A	N/A	3.92	N/A	N/A	N/A	3.74
TOTAL SULFUR % CHECKED	N/A	N/A	4.49	N/A	N/A	N/A	3.88
PYRITIC SULFUR % REPORTED	N/A	N/A	2.39	N/A	N/A	N/A	2.92
PYRITIC SULFUR % CHECKED	N/A	N/A	2.79	N/A	N/A	N/A	2.22
BTU REPORTED	N/A	N/A	12506	N/A	N/A	N/A	12506
BTU CHECKED	N/A	N/A	12730	N/A	N/A	N/A	12854
PRODUCT							
ASH % REPORTED	N/A	3.73	3.73	N/A	3.60	2.59	2.91
ASH % CHECKED	N/A	3.02	3.94	N/A	5.03	2.68	2.80
TOTAL SULFUR % REPORTED	N/A	1.83	2.13	N/A	1.99	1.65	1.90
TOTAL SULFUR % CHECKED	N/A	1.76	2.08	N/A	2.02	1.77	1.90
PYRITIC SULFUR % REPORTED	N/A	0.80	0.62	N/A	0.77	0.38	0.40
PYRITIC SULFUR % CHECKED	N/A	0.37	0.54	N/A	0.79	0.43	0.51
BTU REPORTED	N/A	14032	14110	N/A	14322	13824	14333
BTU CHECKED	N/A	13922	13900	N/A	13834	14448	14067
REFUSE							
ASH % REPORTED	N/A	79.09	70.27	N/A	61.67	60.15	34.51
ASH % CHECKED	N/A	74.28	71.09	N/A	70.30	60.57	34.00
TOTAL SULFUR % REPORTED	N/A	16.78	17.20	N/A	15.29	15.04	8.52
TOTAL SULFUR % CHECKED	N/A	16.20	17.52	N/A	11.95	14.85	8.76
PYRITIC SULFUR % REPORTED	N/A	15.93	15.50	N/A	14.83	11.10	4.53
PYRITIC SULFUR % CHECKED	N/A	14.64	15.73	N/A	10.24	12.72	6.96
BTU REPORTED	N/A	2562	2440	N/A	3700	4120	9057
BTU CHECKED	N/A	1670	1987	N/A	2430	4248	8991

AL MN = ALL MINERAL, BDR = B. DATTA RESEARCH, CAER = CENTER for APPLIED ENERGY RESEARCH, DCCI = DEISTER CONCENTRATOR COMPANY, INC., ISGS = ILLINOIS STATE GEOLOGICAL SURVEY, MTU = MICHIGAN TECHNOLOGICAL UNIVERSITY, VPI = VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

3.0 TEST RESULTS

In the field of coal preparation, it is common to evaluate and compare coal cleaning devices on the basis of their performance relative to the washability data for the same material being processed. Washability analysis is based on gravitional forces and can demonstrate the theoretical "best" possible results.

The results of the Round Robin testing were evaluated against washability data for two sizes. The first size was 200M x 0 and the second size was 325M x 0. It is important to note that the total size analysis must be evaluated even to compare washability data. In addition to the washability data, ICF KE evaluated the results based upon a technique known as a release analysis.

The following discussions compare the results of the round robin participants based upon three criteria; size analysis, washability by size, and the release analysis.

3.1 Size Analysis

The Round Robin testing was conducted at two different size ranges. The two size ranges were 200M x 0 used for Test Numbers 3 of Phase I and 325M x 0 used for Test Numbers 1 and 2 of Phase I and Test Number 4 of Phase II. Test Number 1 of Phase I was compared to Test Number 3 of Phase I to determine if the reduction in top size improved Btu recovery and pyritic sulfur rejection. The size analysis for Test Number 4 Phase II was to match as closely as possible the 325M x 0 grind used in Test Number 1 of Phase I thus eliminating the particle size variable when comparing results of Test Number 4 of Phase II.

Test Number 1 of Phase I was prepared by B&W. The size analysis for each of the seven participants is shown in Table 3.1 and graphically on Figures 3.1 and 3.2. As can be seen from the data the average d50 size was 9.38 microns with the smallest at 8.50 microns and the largest at 9.96 microns. To better define the curve the d80 and d20 values are also reported on Table 3.1. The d80 average was 17.58 microns varying from 15.96 microns to 17.87 microns. The d20 average was 4.69 microns varying from 4.10 microns to 4.91 microns.

Test number 2 of Phase I was prepared by each participant. The size analysis for each of the participants reporting is shown in Table 3.2 and graphically on Figure 3.3. The data indicates that the average d50 was 8.87 microns varying from 6.71 microns to 11.37 microns. This compares vary closely to the Test 1 Phase I size analysis. Further, comparing the average d80 of 16.15 microns varying from 11.19 microns to 18.74 microns and the average d20 of 4.23 microns varying from 3.26 microns to 6.34 microns with Test Number 1 of Phase I indicates that the participants prepared their samples to acceptable and comparable size ranges.

Test Number 3 of Phase I was prepared by each participant. The size analysis for each participant reporting is shown in Table 3.3 and graphically on Figure 3.4. The data indicates that indeed each participant with the exception of Allmineral produced a grind that was minus 200 mesh at the d80 point. The d50 point average was 33.62 microns varying from 26.92 microns to 41.78 microns. The test was conducted at a coarser size analysis than Test Numbers 1 and 2 of Phase 3. Allmineral produced essentially the same size consist as they did in Test 2.

Test Number 4 of Phase II was prepared by each participant. The size analysis for each of the participants reporting is shown in Table 3.4 and graphically on

TABLE 3.1

TEST #1
SIZE ANALYSIS BY B&W

SIZE MICRONS	AL MN WT.%	BDR WT.%	CAER WT.%	DCCI WT.%	ISGS WT.%	MTU WT.%	VPI WT.%	AVG WT.%
600.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
424.26	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
300.00	99.98	99.98	99.98	99.98	99.98	99.98	99.98	99.98
212.13	99.98	99.98	99.98	99.98	99.98	99.98	99.98	99.98
150.00	99.98	99.98	99.98	99.98	99.98	99.98	99.98	99.98
106.07	99.98	99.98	99.98	99.98	99.98	99.98	99.98	99.98
75.00	99.98	99.98	99.98	99.98	99.98	99.98	99.98	99.98
53.03	99.98	99.98	99.98	99.98	99.98	99.98	99.98	99.98
37.50	99.98	99.98	99.06	98.97	99.16	99.98	99.89	99.57
26.52	96.48	95.42	94.72	96.28	94.63	97.01	96.13	95.81
18.75	86.89	83.33	83.55	82.66	81.91	85.15	86.06	84.22
13.26	75.14	69.02	66.49	66.72	66.89	69.04	68.75	68.86
9.38	56.50	50.51	48.21	48.12	48.47	49.96	49.14	50.13
6.63	37.94	32.47	31.32	31.07	31.51	32.17	32.37	32.69
4.69	24.39	20.01	19.01	18.93	19.32	19.67	20.20	20.22
3.31	15.34	12.61	11.12	11.33	11.76	11.66	12.01	12.26
2.34	9.74	7.73	6.70	6.73	7.14	6.91	7.30	7.46
1.66	6.11	4.63	4.22	4.17	4.33	4.39	4.54	4.63
1.17	4.13	3.06	2.70	2.76	2.80	2.87	2.91	3.03
0.83	2.56	1.83	1.55	1.61	1.60	1.66	1.65	1.78
0.59	1.35	0.92	0.74	0.76	0.77	0.77	0.79	0.87
0.41	0.30	0.21	0.14	0.14	0.21	0.14	0.21	0.19
0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D 50	8.50	9.38	9.96	9.81	9.52	9.38	9.52	9.38
D 80	15.96	17.58	17.87	17.72	17.87	17.28	16.99	17.58
D 20	4.10	4.69	4.91	4.84	4.76	4.69	4.69	4.69

FIGURE 3.1

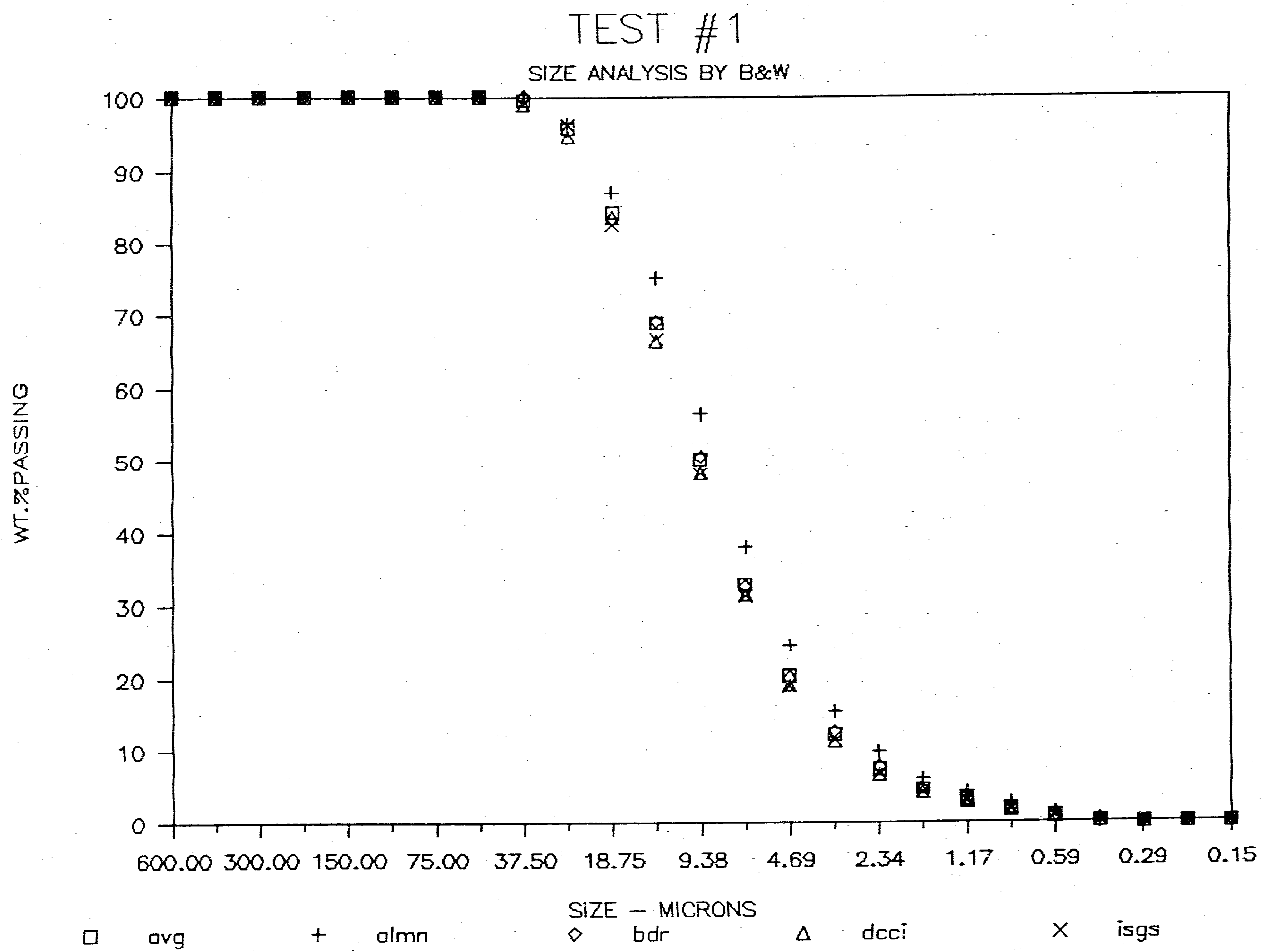

TEST #1
SIZE ANALYSIS BY B&W
WT.%PASSING
100
90
80
70
60
50
40
30
20
10
0
600.00
300.00
150.00
75.00
37.50
18.75
9.38
4.69
2.34
1.17
0.59
0.29
0.15
SIZE — MICRONS
avg
almn
bdr
dcci
isgs

FIGURE 3.2

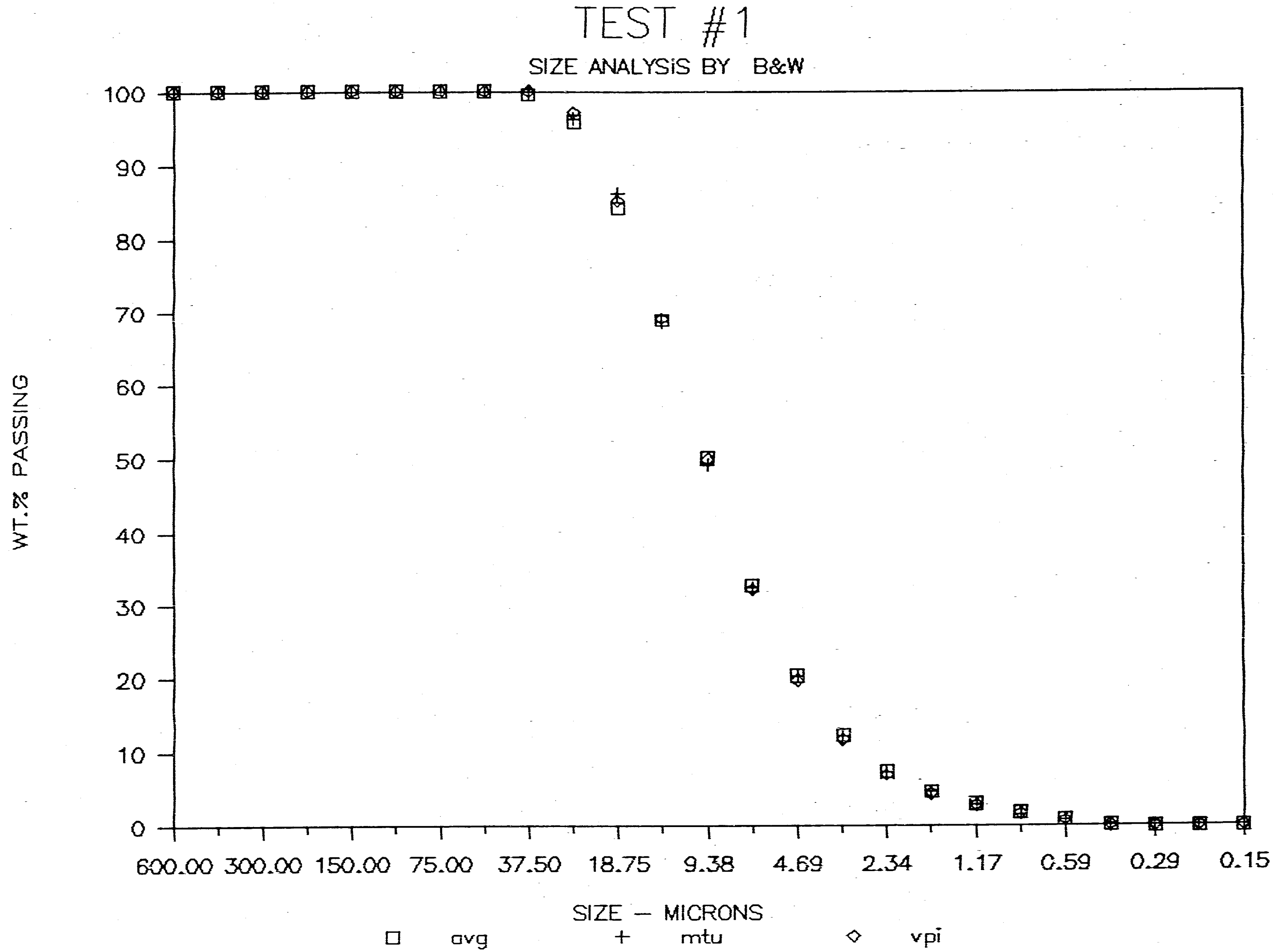

TEST #1
SIZE ANALYSIS BY B&W
WT.% PASSING
100
90
80
70
60
50
40
30
20
10
0
600.00 300.00 150.00 75.00 37.50 18.75 9.38 4.69 2.34 1.17 0.59 0.29 0.15
SIZE — MICRONS
□ avg
+ mtu
◇ vpi

TABLE 3.2

TEST #2
SIZE ANALYSIS BY PARTICIPANT

SIZE MICRON	AL MN WT.%	CAER WT.%	ISGS WT.%	MTU WT.%	VPI WT.%
88.00	100.0	100.0	100.0	100.0	98.70
62.00	100.0	99.90	100.0	100.0	96.30
44.00	100.0	99.70	99.80	99.30	91.90
31.00	99.70	97.00	91.80	95.40	86.70
22.00	98.10	91.00	86.70	87.20	84.20
16.00	93.10	74.00	79.70	74.40	81.30
11.00	79.30	48.00	59.10	59.00	69.20
7.80	59.90	28.00	45.80	44.60	52.50
5.50	42.10	16.00	36.20	32.10	35.30
3.90	27.80	9.30	21.80	22.10	21.20
2.80	15.60	5.50	14.00	14.00	11.60
1.90	7.20	3.00	6.70	6.50	4.80
1.40	0.00	1.90	3.00	2.90	2.00
0.90	0.00	0.00	0.70	0.60	0.40
D 50	6.71	11.37	9.14	9.23	7.88
D 80	11.19	18.46	16.59	18.74	15.75
D 20	3.26	6.34	3.85	3.76	3.94

TABLE 3.3

TEST #3
SIZE ANALYSIS BY PARTICIPANT

SIZE MICRON	AL MN WT.%	CAER WT.%	ISGS WT.%	MTU WT.%	VPI WT.%
250.0	100.0	100.0	100.0	100.0	100.0
176.0	100.0	98.90	100.0	98.80	100.0
125.0	100.0	95.50	100.0	95.50	98.60
88.00	100.0	90.00	89.00	87.30	93.20
62.00	100.0	80.00	74.60	71.40	81.00
44.00	100.0	71.00	60.10	54.10	61.40
31.00	100.0	56.50	43.80	38.90	52.00
22.00	98.30	44.50	34.80	27.70	42.30
16.00	92.80	34.00	27.90	18.90	33.80
11.00	79.30	23.00	18.00	12.20	22.90
7.80	60.10	16.80	12.80	7.90	15.10
5.50	42.10	11.70	9.50	4.90	9.70
3.90	28.00	8.20	4.90	2.90	6.80
2.80	16.10	5.80	2.80	1.40	4.10
1.90	7.60	3.90	0.80	0.10	1.90
1.40	0.00	2.90	0.20	0.00	0.80
0.90	0.00	0.00	0.00	0.00	0.00
D 50	6.70	26.92	36.39	41.78	29.37
D 80	11.90	62.00	73.64	78.43	60.65
D 20	3.20	9.76	12.61	16.98	10.12

TABLE 3.4

TEST #4
SIZE ANALYSIS BY PARTICIPANT

SIZE MICRON	AL MN WT.%	BOR WT.%	CAER WT.%	ISGS WT.%	MTU WT.%
88.00	100.0	100.0	100.0	100.0	100.0
62.00	100.0	98.30	99.5	100.0	99.90
44.00	100.0	98.30	99.20	99.40	97.30
31.00	100.0	89.00	94.00	90.90	90.00
22.00	98.30	76.90	84.00	84.30	78.70
16.00	92.70	64.30	67.00	74.10	63.30
11.00	79.10	46.40	45.00	52.00	47.20
7.80	59.80	34.50	31.00	37.20	34.10
5.50	42.00	12.00	20.50	27.60	23.60
3.90	27.40	7.90	14.00	15.40	16.00
2.80	15.60	0.00	9.50	9.60	9.70
1.90	7.30	0.00	6.00	4.40	3.80
1.40	0.00	0.00	4.10	1.80	1.50
0.90	0.00	0.00	0.00	0.30	0.20
D 50	6.72	12.10	12.22	10.57	11.98
D 80	11.49	24.44	20.66	19.56	22.73
D 20	3.28	6.42	5.32	4.63	4.84

FIGURE 3.3

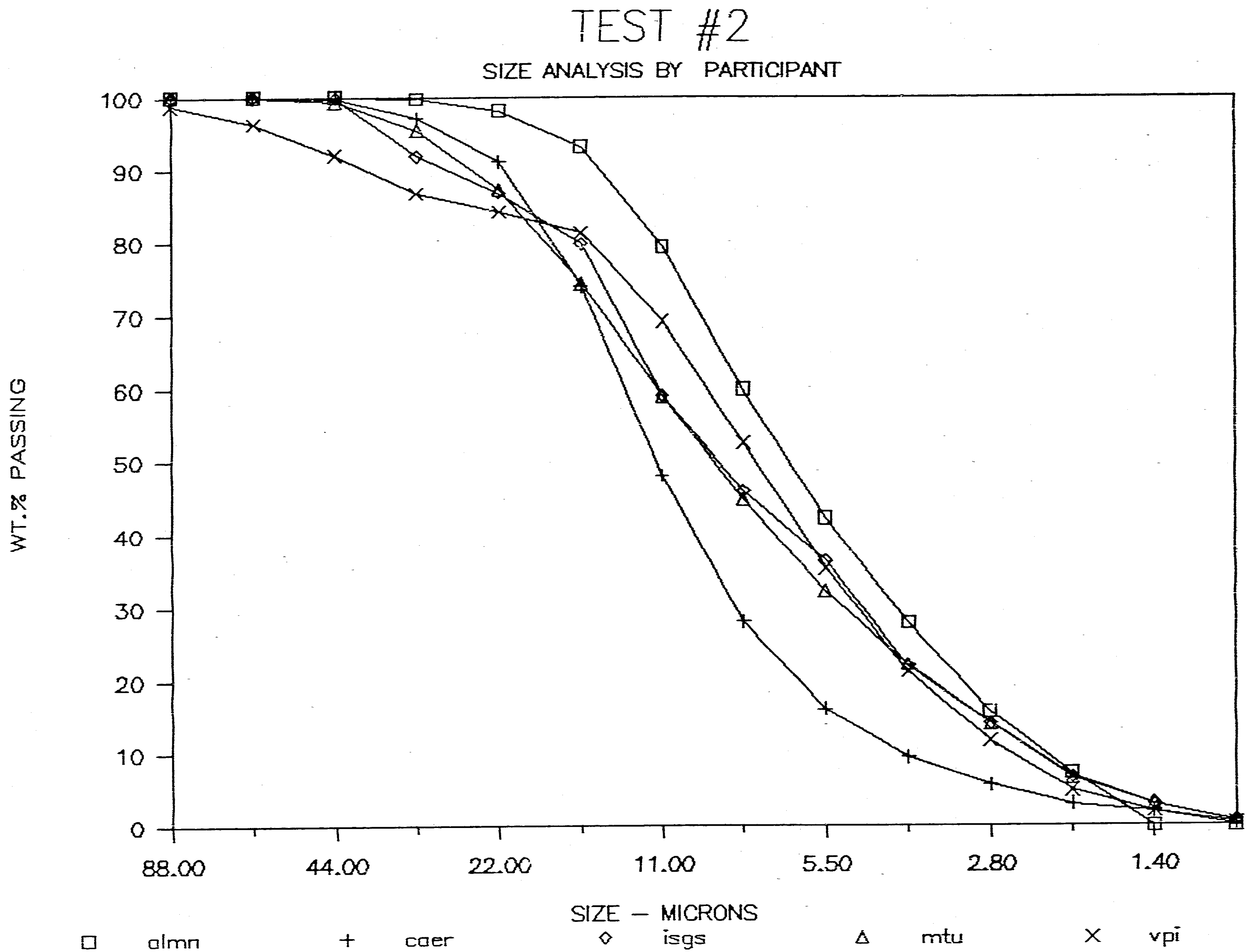

TEST #2
SIZE ANALYSIS BY PARTICIPANT
WT.% PASSING
100
90
80
70
60
50
40
30
20
10
0
88.00
44.00
22.00
11.00
5.50
2.80
1.40
SIZE — MICRONS
almn
caer
isgs
mtu
vpi

FIGURE 3.4

TEST #3

SIZE ANALYSIS BY PARTICIPANT

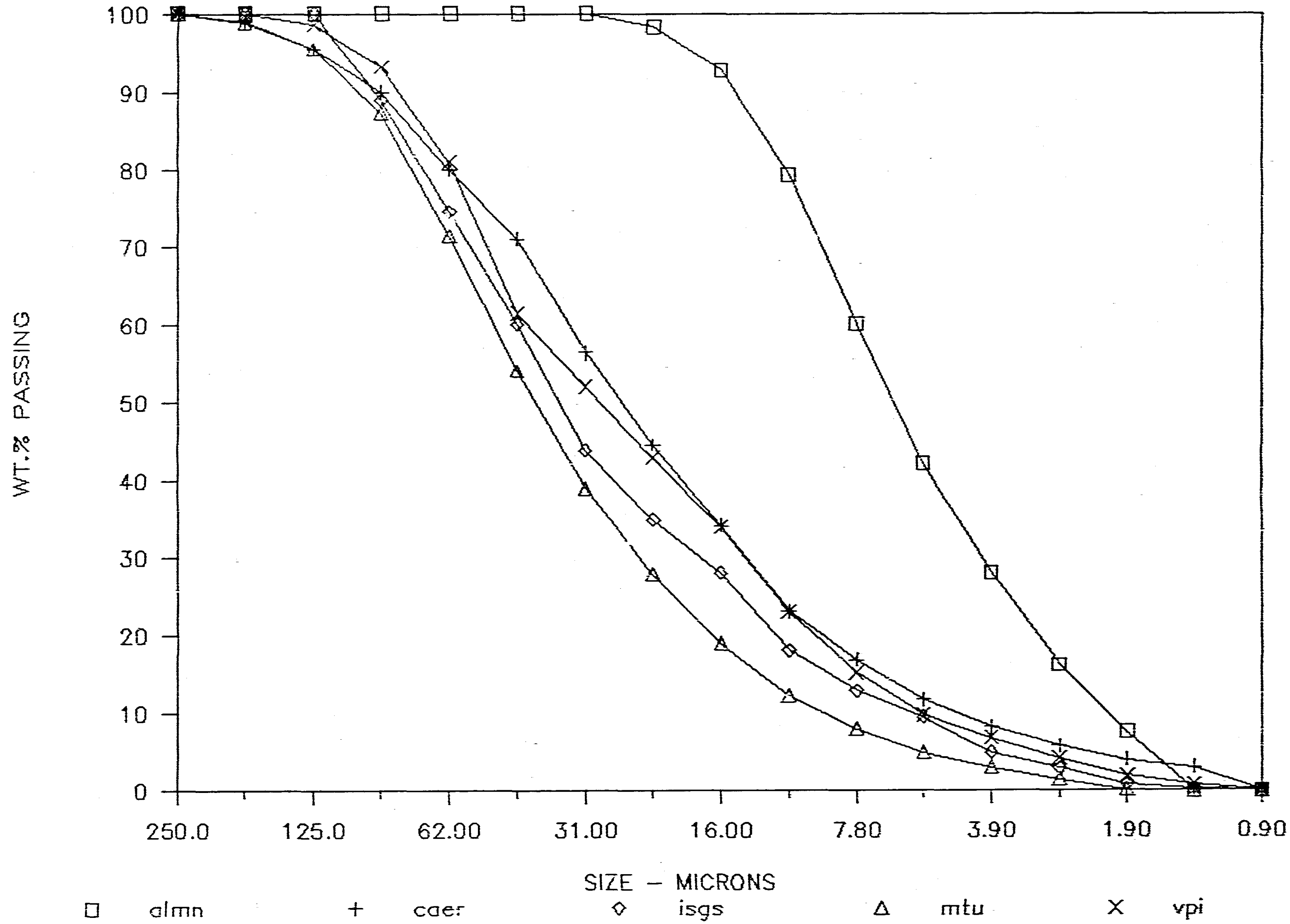


FIGURE 3.5

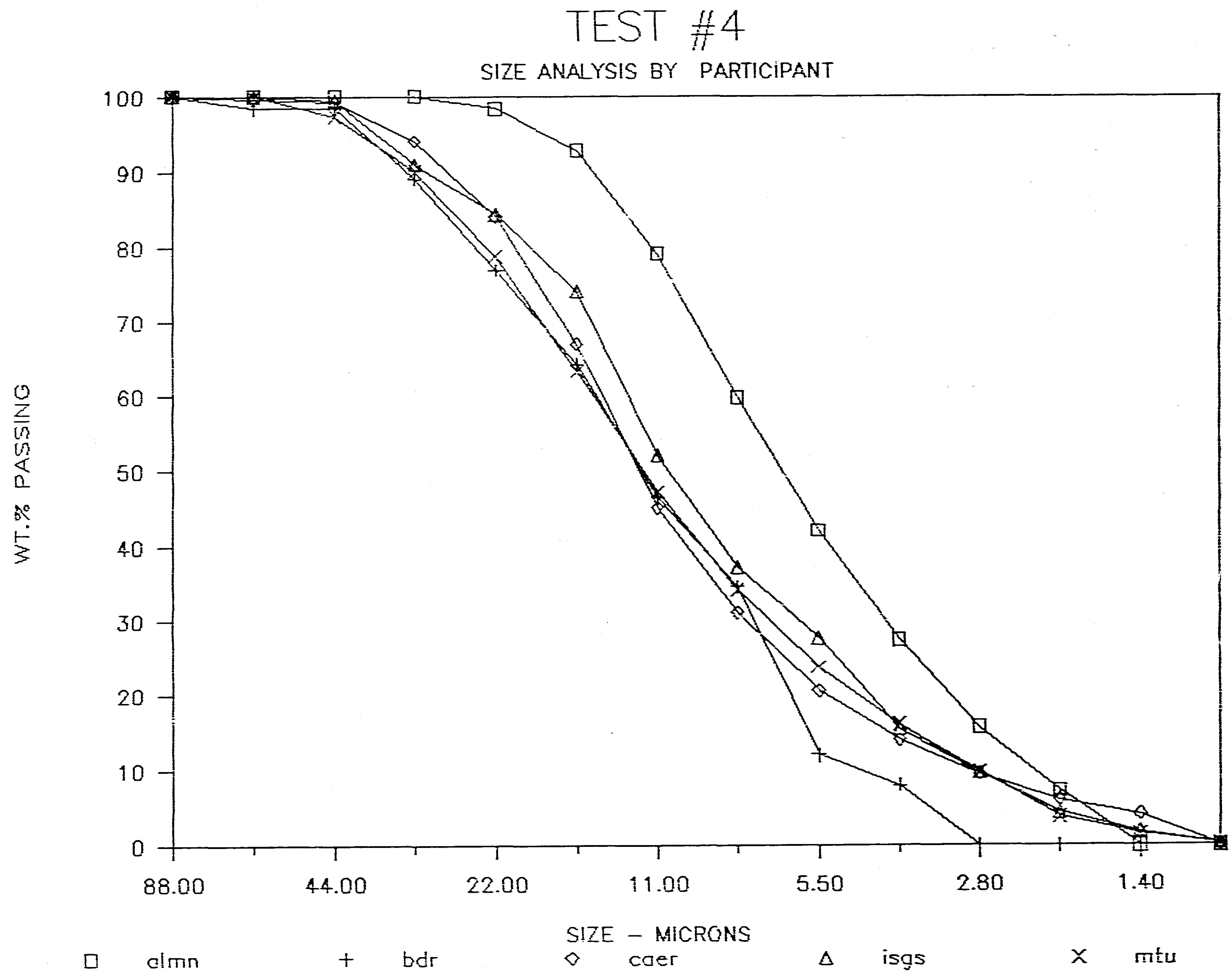

TEST #4
SIZE ANALYSIS BY PARTICIPANT
WT.% PASSING
100
90
80
70
60
50
40
30
20
10
0
88.00
44.00
22.00
11.00
5.50
2.80
1.40
SIZE – MICRONS
□ almn
+ bdr
◇ caer
△ isgs
× mtu

Figure 3.5. The size analysis for this test was specified by the Technical Support Team (TST) based upon comparing the efficiency of Test Numbers 1 and number 3. Allmineral and Center for Applied Energy Research each had better results in Test 3 than Test 1. However, Allmineral's size analysis for Test 3 was finer than Test 1 and Center for Applied Energy Research experienced operating problems with their device attempting to maintain the controlled conditions specified. All of the other participants, except B. Datta Research who had no reported results for Tests 1 thru 3, reported better efficiency of separation at the finer grind. The TST specified that test 4 of Phase II be conducted at the finer size analysis. The average d50 reported was 10.72 microns varying from 6.72 microns to 12.22 microns. The average d80 was 19.78 microns varying from 11.49 microns to 24.44 microns. The average d20 was 4.90 microns varying from 3.28 microns to 6.42 microns. The average values compare quite accurately with Test 1, Phase I size analysis.

3.2 Washability Analysis

The sample of Pittsburgh No. 8 coal was crushed to two different top sizes of 200 mesh and 325 mesh. Both of these samples were subjected to specific gravity washability analysis. The 200 mesh sample was prepared by Praxis Engineering and is shown in Table 3.5. The 325 mesh sample was prepared by Tradet Laboratories and is shown in Table 3.6. The Btu recovery versus Pyritic Sulfur Rejection is plotted for both sizes on Figure 3.6. This graph shows that the finer size grind improves the pyritic sulfur rejection at a given Btu recovery.

The flotation results for Test Number 3 Phase I are plotted along with the 200 mesh washability Btu recovery versus pyritic sulfur rejection on Figure 3.7. Three participants indicated from their results that they recovered more than 100% of Btu and this is indicated as points above the washability curve. These results are clearly erroneous and are most likely the result of poor performance of analytical test work. The three other participants are well below the results predicted by the washability curve.

The flotation results of Test Numbers 1 and 2 of Phase I and Test 4 of Phase II are plotted along with the 325 mesh washability Btu recovery versus pyritic sulfur rejection in Figure 3.8. All of the participants have lower results than the washability plot except for one participant who appears to fall on the washability plot.

All of the Test 4 results, which should be the best possible, fall below the washability curve. This indicates good results, but that the performance could be improved.

3.3 Release Analysis

The previous discussion has compared washability data to the performance of froth flotation. Washability analysis is based on gravitional separation processes. Unfortunately, for a process such as froth flotation, which is based on the differences in the surface properties of the material being treated, washability analysis does not always provide an appropriate basis for comparison. As a result, the release analysis technique was developed by C.C. Dell in the early 1950's as the counterpart in froth flotation to float/sink analysis in gravity separation.

TABLE 3.5

WASHABILITY DATA FOR PITTSBURGH NO. 8 CRUSHED TO MINUS 200M

WASHABILITY DATA
SEAM: PITTSBURGH NO. 8
BELMONT COUNTY, OHIO

ORIGINAL SAMPLE, CRUSHED TO 200 M TOPSIZE

SIZE FRACTION: 200 M X 0 - 100.0 %

SPECIFIC GRAVITY		ELEMENTARY DATA						COMPUTED DATA: CUMULATIVE							
SINK	FLOAT	(%) WT%	(%) ASH	(%) TOT SUL	(%) PYR SUL	BTU	# SO2/ M BTU	(%) WT%	(%) ASH	(%) TOT SUL	(%) PYR SUL	BTU	(%) BTU REC	# SO2/ M BTU	%PYR SUL REJECTED
	1.30	53.9	2.08	1.35	0.09	14513	1.86	53.9	2.08	1.35	0.09	14513	61.36	1.86	98.26
1.30	1.35	6.7	4.41	1.50	0.33	14112	2.13	60.6	2.34	1.37	0.12	14469	68.78	1.89	97.46
1.35	1.40	8.6	4.87	1.45	0.37	13580	2.14	69.2	2.65	1.38	0.15	14358	77.94	1.92	96.32
1.40	1.60	17.6	10.57	1.89	0.97	12878	2.94	86.8	4.26	1.48	0.31	14058	95.72	2.11	90.17
1.60	1.80	1.6	26.01	4.80	3.92	10450	9.19	88.4	4.65	1.54	0.38	13993	97.03	2.20	87.92
1.80		11.6	68.34	21.84	21.07	3264	133.82	100.0	12.04	3.90	2.78	12748	100.00	6.11	0.00

TABLE 3.6

WASHABILITY DATA FOR PITTSBURGH NO. 8 CRUSHED TO MINUS 325M

SPECIFIC GRAVITY		DRY BASIS								CUMULATIVE PRODUCT (FLOAT)								BTU RECOVERY	PYRSUL REJECT.
Sink	Float	% Wt.	% Ash	% Sulf.	BTU per lb.	MAFBTU per lb.	% Pyr. Sulfur	% Sulf. Sulfur	% Organ. Sulfur	% Wt.	% Ash	% Sulf.	BTU per lb.	MAFBTU per lb.	% Pyr. Sulfur	% Sulf. Sulfur	% Organ. Sulfur	%	%
	1.30	37.83	1.71	1.55	14,462	14,714	0.08	0.11	1.37	37.83	1.71	1.55	14,462	14,714	0.08	0.11	1.37	43.84	98.72
1.30	1.35	17.97	2.45	1.64	14,301	14,660	0.11	0.21	1.33	55.80	1.95	1.58	14,410	14,696	0.09	0.14	1.36	64.43	97.87
1.35	1.40	16.44	3.47	1.65	13,832	14,329	0.17	0.30	1.18	72.24	2.29	1.60	14,279	14,614	0.11	0.18	1.32	82.66	96.63
1.40	1.45	8.00	5.76	1.78	13,434	14,255	0.29	0.44	1.05	80.24	2.64	1.61	14,194	14,579	0.13	0.20	1.29	91.27	95.58
1.45	1.50	3.44	9.70	1.99	12,699	14,063	0.51	0.60	0.88	83.68	2.93	1.63	14,133	14,560	0.14	0.22	1.27	94.[illegible]	95.04
1.50	1.60	2.88	14.40	2.27	11,966	13,979	0.76	0.76	0.75	86.56	3.31	1.65	14,061	14,542	0.16	0.24	1.26	97.53	94.13
1.60	1.70	0.85	27.06	3.15	9,818	13,460	1.39	1.19	0.57	87.41	3.54	1.66	14,020	14,534	0.17	0.25	1.25	98.20	93.70
1.70	1.80	0.44	36.92	4.37	8,006	12,692	2.05	1.66	0.66	87.85	3.71	1.68	13,989	14,528	0.18	0.25	1.25	98.48	93.30
1.80		12.15	75.12	20.20	1,556	6,254	18.12	1.31	0.77	100.00	12.39	3.93	12,479	14,243	2.36	0.38	1.19	100.00	0.00

FIGURE 3.6

WASHABILITY - BTU RECOVERY VERSUS PYRITIC SULFUR REJECTION
FOR MINUS 200M AND MINUS 325M

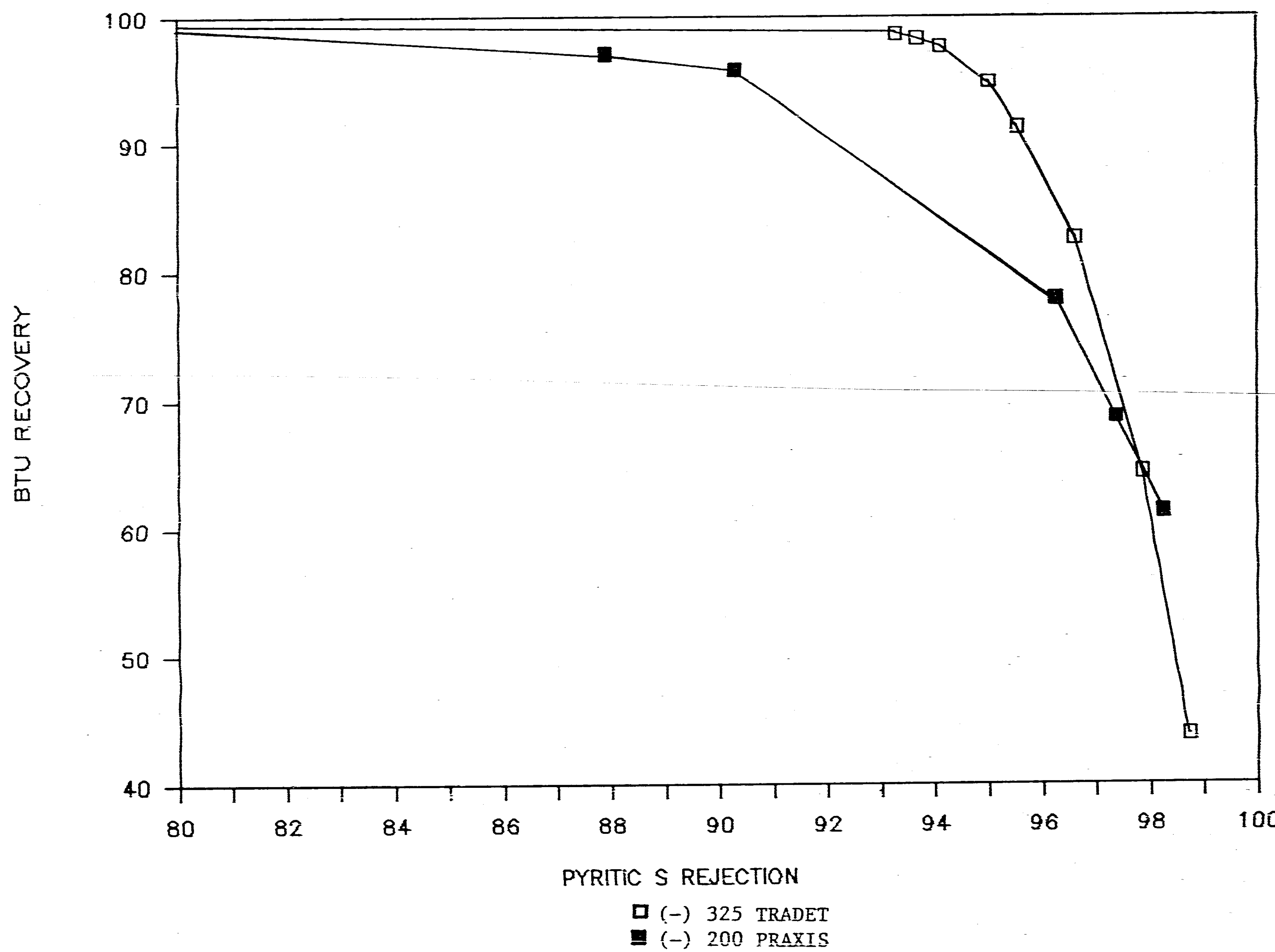


FIGURE 3.7

PARTICIPANTS RESULTS VERSUS WASHABILITY PLOT
OF BTU RECOVERY VERSUS PYRITIC SULFUR REJECTION
FOR TEST #3

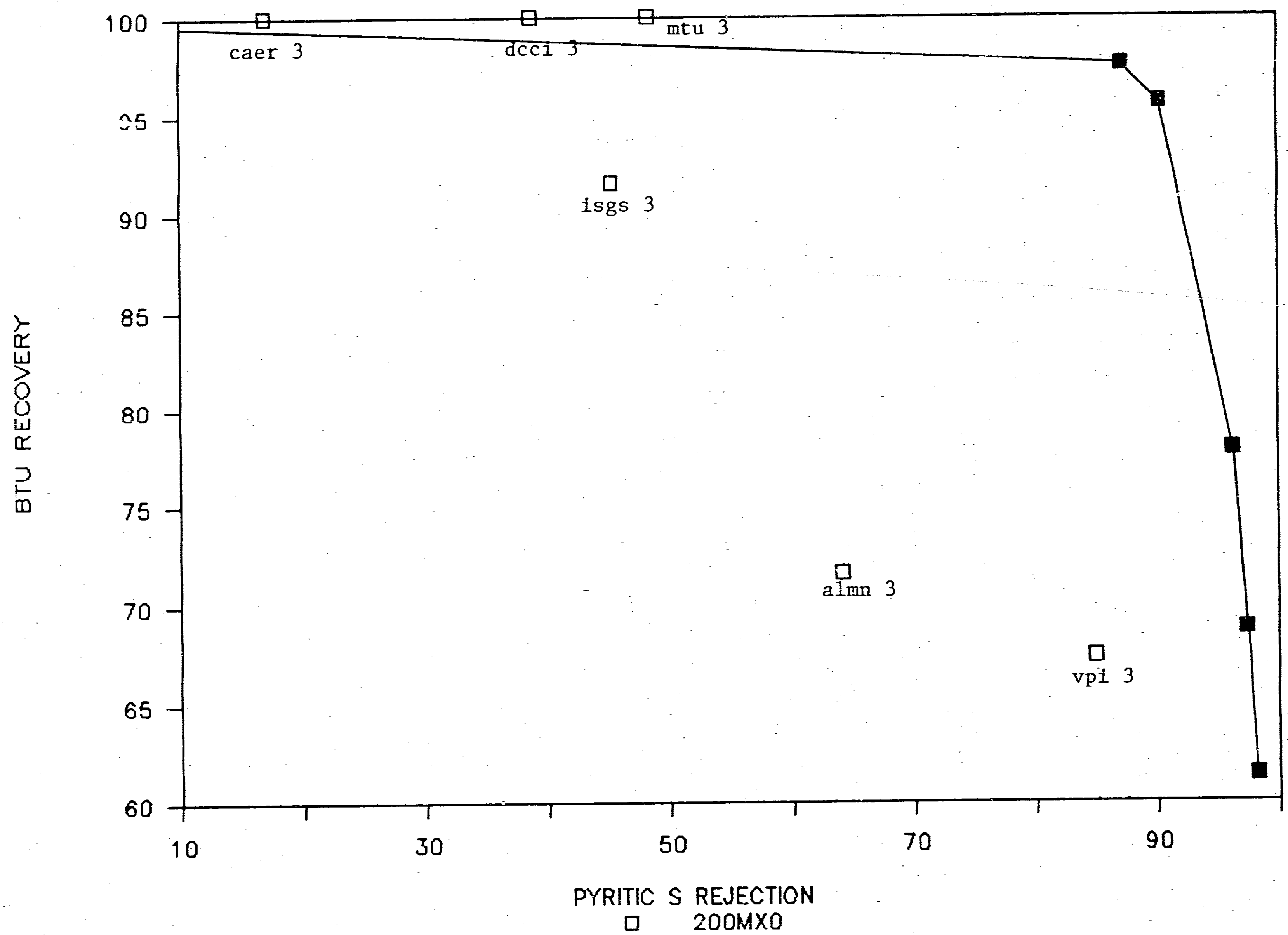
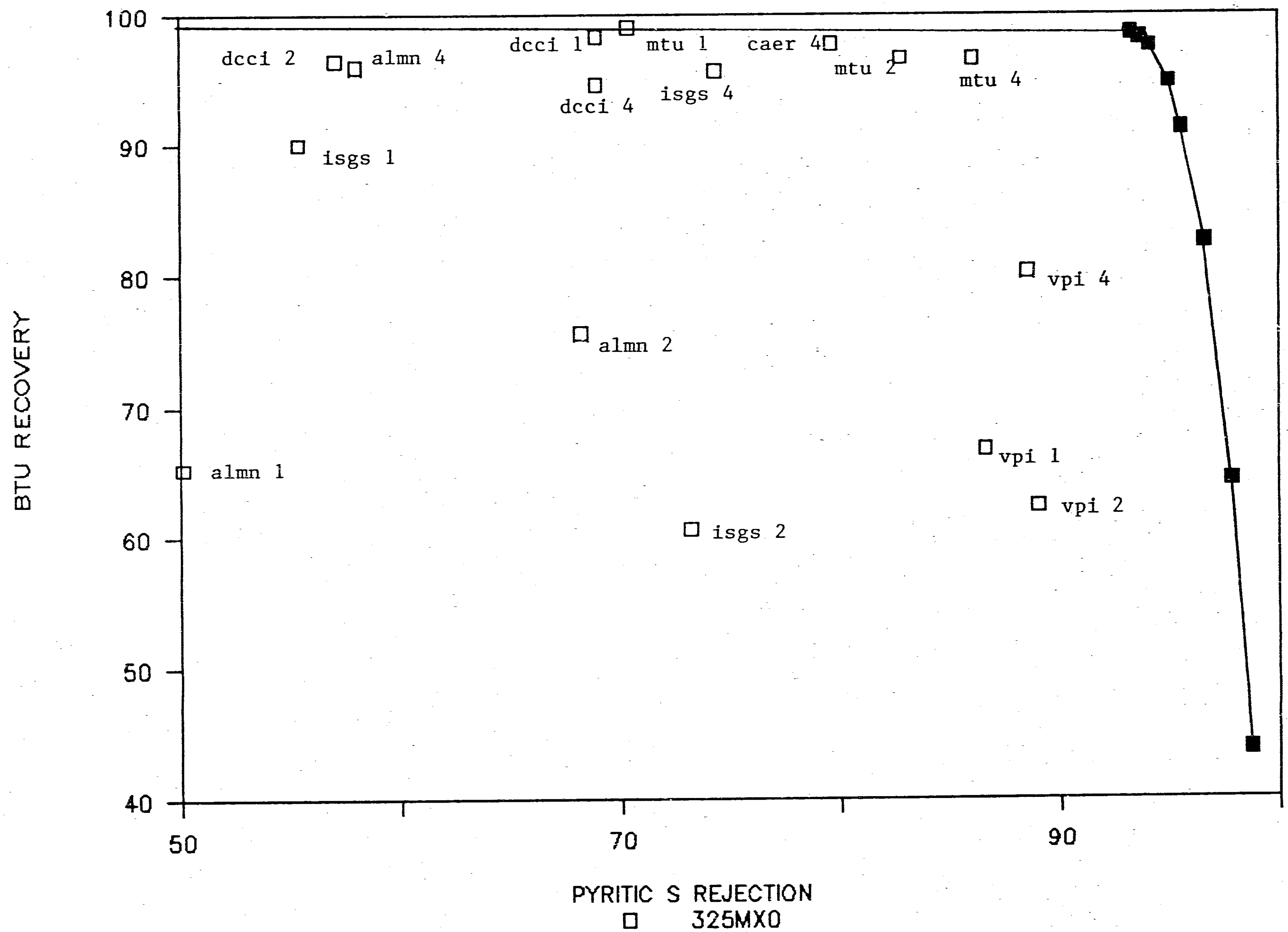


FIGURE 3.8

PARTICIPANTS RESULTS VERSUS WASHABILITY PLOT
OF BTU RECOVERY VERSUS PYRITIC SULFUR REJECTION
FOR TEST #1, #2, AND #4



Several forms of release analysis have been developed over the years including the original technique often referred to as timed release analysis. In 1964, however, Dell [1] showed that a simplified technique which he called "an improved release analysis procedure for determining coal washability" could be used to provide the same results as the more time consuming and complicated original procedure. In this procedure, a sample of coal is floated in a conventional batch flotation cell using every means possible (i.e., high pulp level, high aeration rate, extra frother, etc.) to produce a high recovery. The concentrate from the cell is cleaned an additional three or four times under the same conditions to remove entrained clays and fine mineral matter. This procedure results in a separation of the truly non-floatable material from the floatable material. The floatable material is placed back into the cell and a final separation is made between the highly floatable material and the progressively less floatable material. For this final separation, the air is initially turned off and the impeller speed is reduced to the point where froth formation and flotation ceases. Both are then increased very slowly until flotation is just discernible. This froth is scraped for as long as it keeps appearing. The collection basin is then changed and the aeration rate and impeller speed are increased slightly to collect slightly less floatable material. This procedure is continued until all floatable material has been recovered. Any remaining tailings are combined with the original non-floatable material as part of the overall tailings sample. Each fraction of material is weighed and analyzed to determine cumulative yield, Btu recovery, ash, sulfur, etc. The data are plotted as cumulative Btu recovery versus sulfur rejection. The use of the rejection term normalizes the effect of changes in feed sulfur from one sample to the next so that all samples can be compared on the same basis.

The resulting plot of Btu recovery versus sulfur rejection represents the best result that can possibly be obtained by any flotation process for that particular sample and size distribution. It primarily reflects cleaning down to the liberation limit of the sample. Extensive test work using various frothers and frother dosages shows no effect on release curve. In addition, the dosage of kerosene or fuel oil seems to have little effect on the release curve. The only parameters which are found to change the shape of the release curve are liberation as reflected by the feed size distribution, and reagents which change the relative flotation rates of the various components in the sample. For example, a pyrite depressant which reduces the rate of floatation for pyritic particles more than it does for coal particles will result in an improved release curve.

With the above procedure in mind, release analysis tests were conducted on the sample of Pittsburgh No. 8 coal. The sample had been ground to minus 325 mesh per the instructions provided to all participants. Since some participants had used MIBC and some had used Dowfroth M150 as the frother in their test work, separation release analyses were performed for each frother type. The results verified previous test work that the type of frother and collector do not influence the release curve. Each of the participants are shown on the plots of Btu recovery versus sulfur rejection on Figures 3.9 thru 3.12.

Figure 3.9 shows the results of Round Robin Test Number 1 for all participants. In terms of the Round Robin results, Deister, MTU and CAER appear to fit exactly on the release curve. It should be mentioned, however, that since all recovery versus rejection curves tend to come together at very high and very low recoveries, it is difficult to say whether Deister, MTU and CAER are actually on the release curve. In any case, the most important point is that nobody did

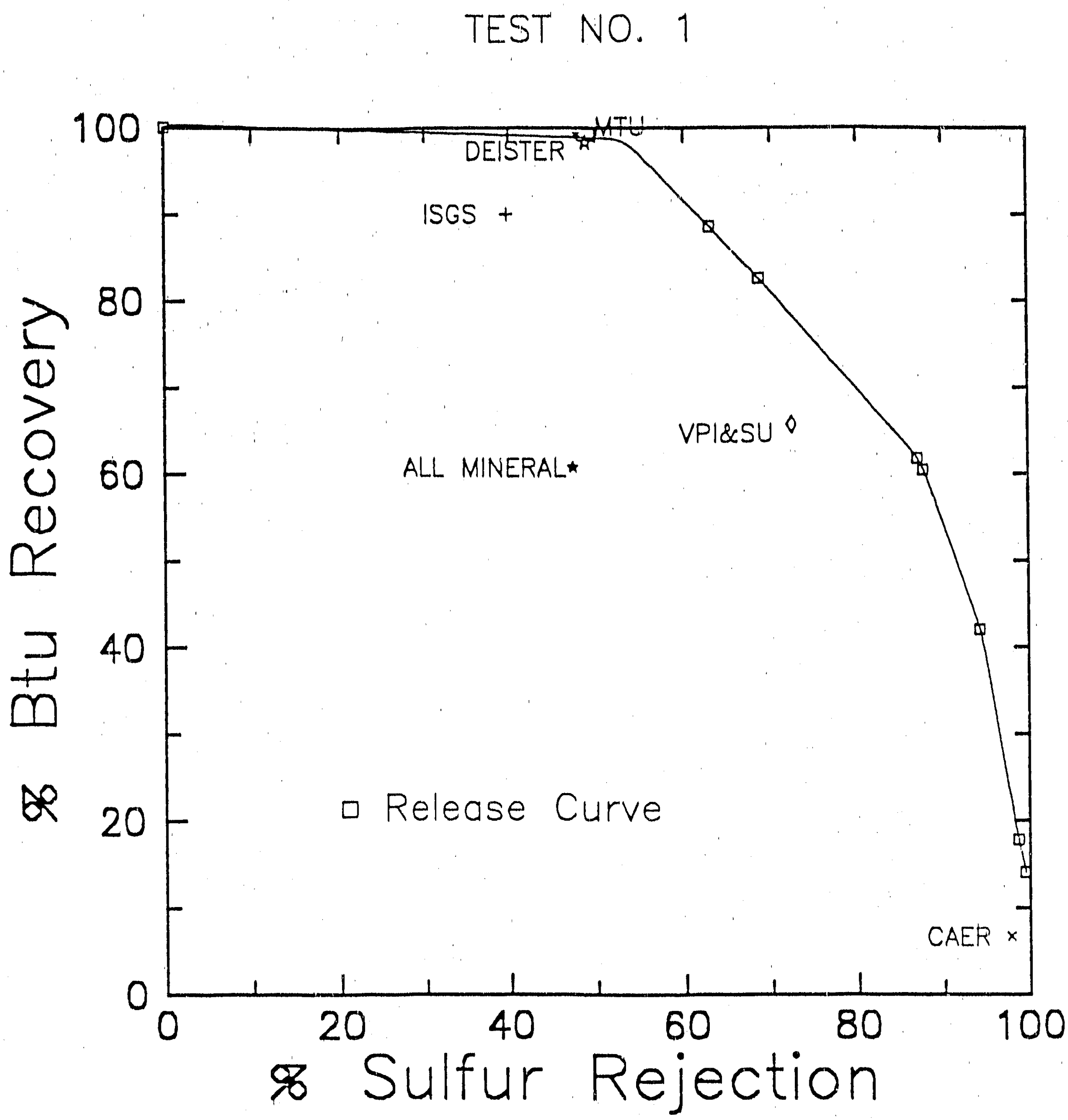


FIGURE 3.9 COMPARISON OF ROUND ROBIN TEST 1 RESULTS WITH THE RELEASE ANALYSIS CURVE FOR SULFUR REJECTION.

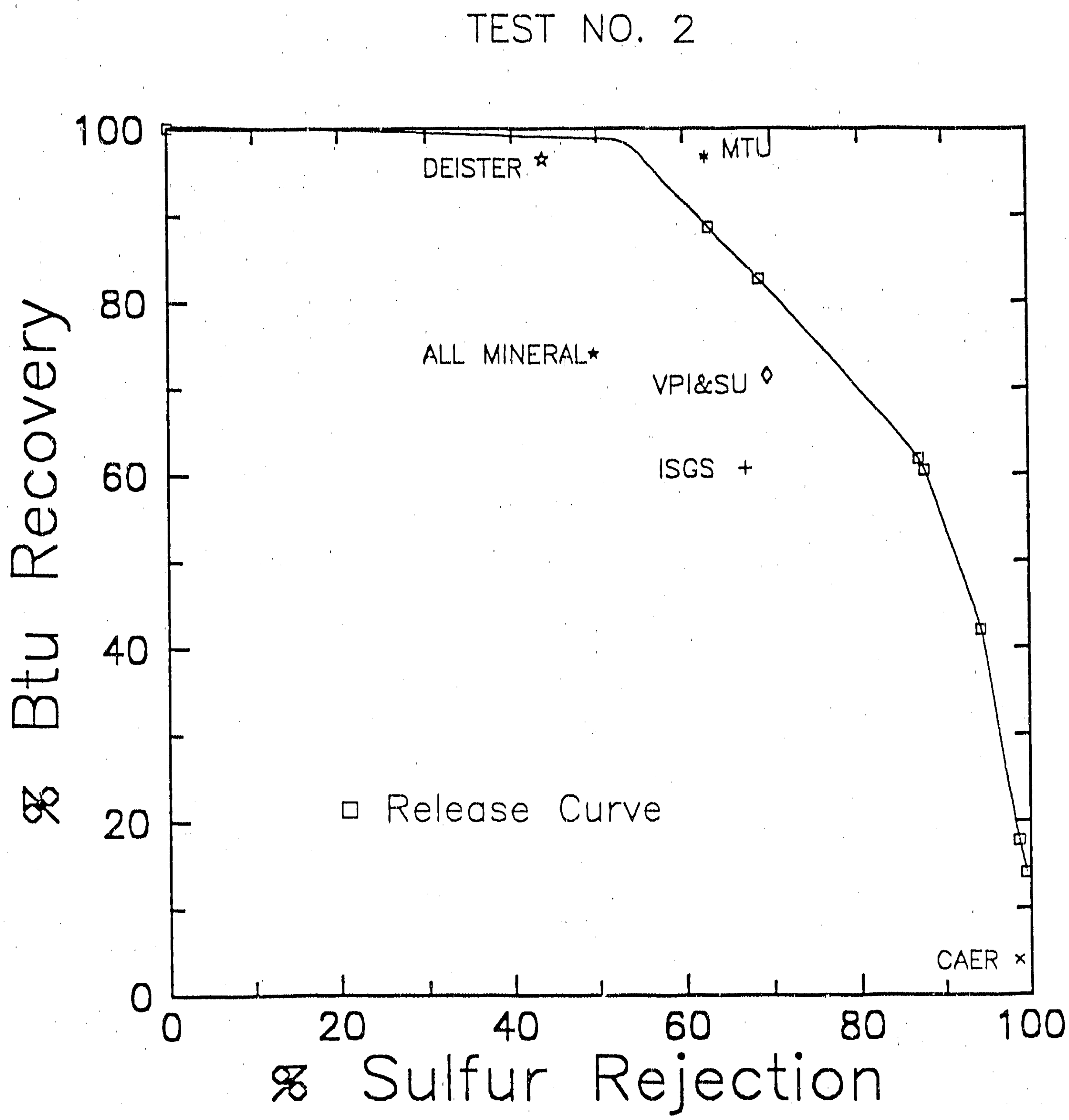


FIGURE 3.10 COMPARISON OF ROUND ROBIN TEST 2 RESULTS WITH THE RELEASE ANALYSIS CURVE FOR SULFUR REJECTION.

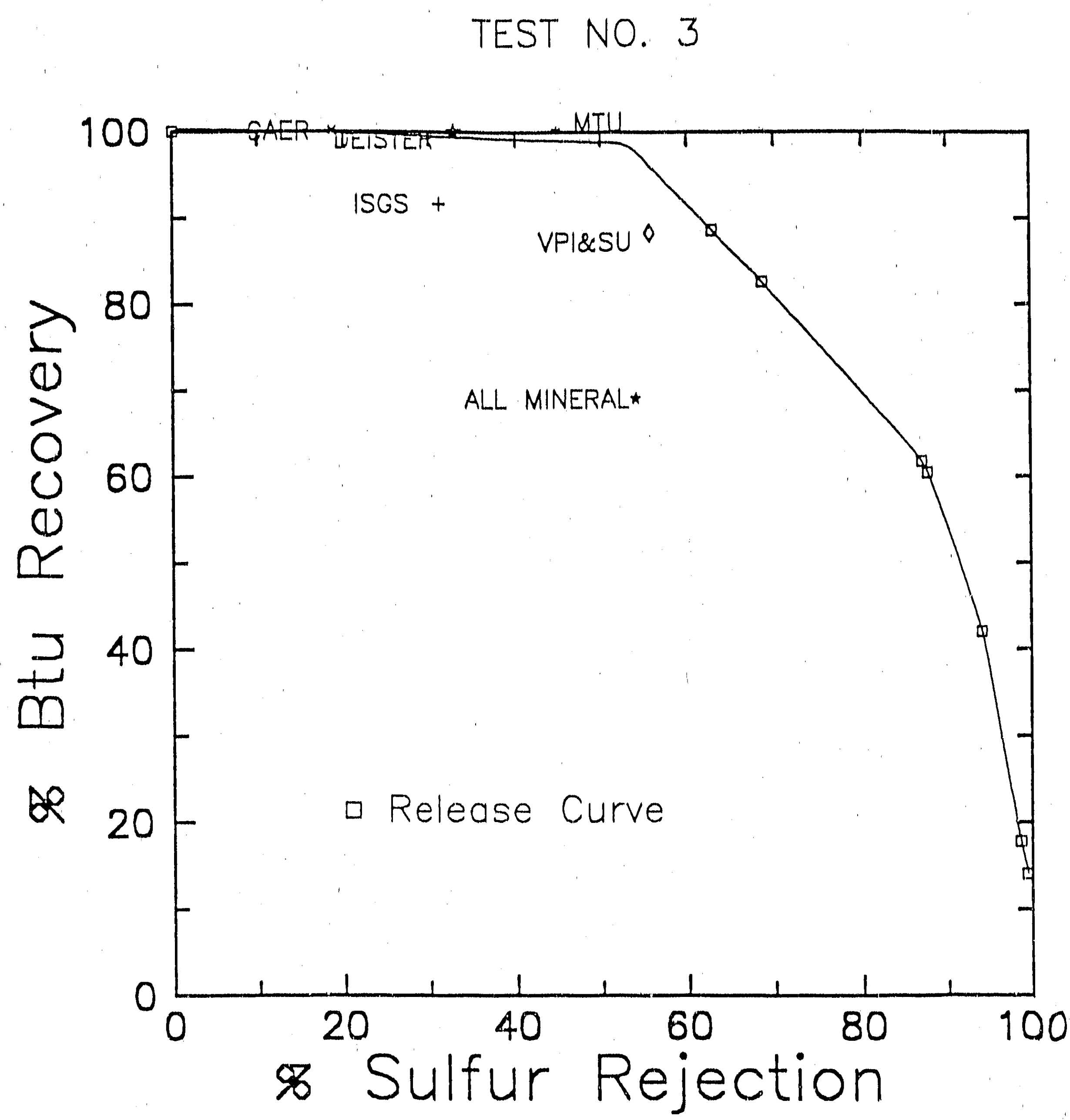


FIGURE 3.11 COMPARISON OF ROUND ROBIN TEST 3 RESULTS WITH THE RELEASE ANALYSIS CURVE FOR SULFUR REJECTION.

TEST NO. 4

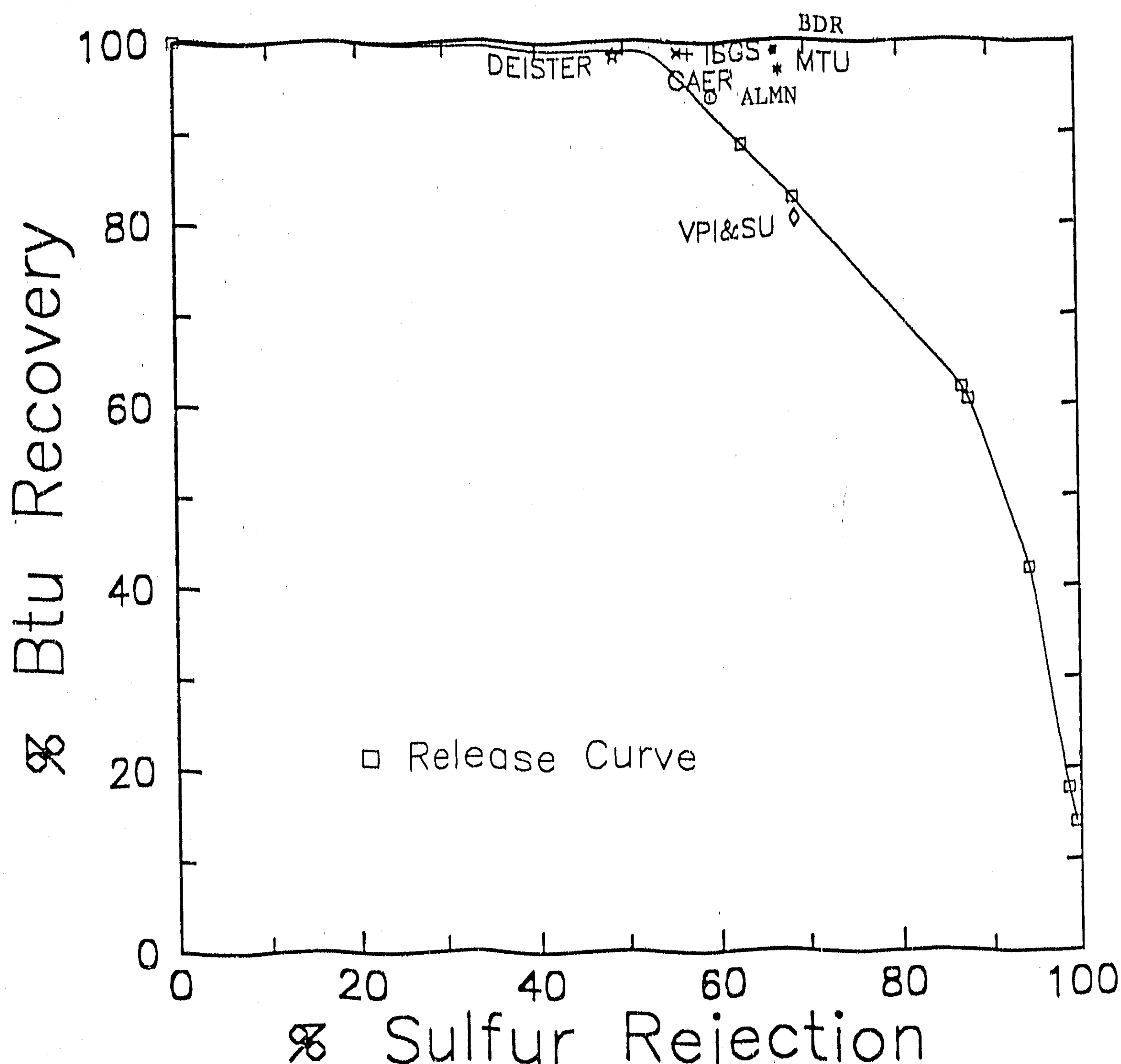


FIGURE 3.12 COMPARISON OF ROUND ROBIN TEST 4 RESULTS WITH THE RELEASE ANALYSIS CURVE FOR SULFUR REJECTION.

better than the release curve. ISGS is below the release curve as one would expect for conventional flotation since mineral matter is entrained in the water which is recovered with the froth. A similar conclusion can be drawn for the result of Allmineral. VPI is below the release curve because of lack of proper retention time.

The results shown in Figures 3.10 for Round Robin Test Number 2 indicate similar conclusions to those seen for Test 1. In this case, Deister, VPI and CAER are slightly below the release curve, Allmineral and ISGS are well below the release curve due to entrainment, and MTU appears to be better than the release curve. Since the result by MTU is clearly impossible, it may be that this data was not collected at steady-state, or sample analysis error exists.

Figure 3.11 shows the results for Test Number 3. It should be pointed out that this test was conducted using a minus 200 mesh sample. Thus, the true release curve for this sample should actually be to the left of the minus 325 mesh release curve since the liberation of pyrite and other mineral matter is not as good. In this case, CAER, Deister and MTU operated at the release curve. VPI may very well be on or near the release curve for the minus 200 mesh sample, while the points for ISGS and Allmineral once again reflect entrainment.

The best results reported by all participants were for Test Number 4. These data are shown in Figure 3.12. As can be seen, Deister, ISGS, CAER and VPI appear to fall on the release curve within normal experimental error. This is as expected since the wash water in any properly operated flotation column should eliminate entrainment and produce essentially the same results as release analysis. Likewise, the multi-stage cleaning process used by ISGS, and Allmineral is essentially a duplication of the release analysis procedure and should also result in a point on the release curve. Deviation from the release curve was exhibited by MTU and B. Datta Research which again may reflect data which was not collected at steady-state or sample analysis error.

In summary, it appears that all columns tested and the multi-stage cleaning technique produce results which are on the same grade versus sulfur rejection curve. Furthermore, these processes produce results which are at the best metallurgical performance that can be obtained as dictated by release analysis.

3.4 Material Balance Analysis

3.4.1 Overview of the Material Balance Problem

In any continuous process, steady-state is defined as the point when the overall mass and the mass of each component (i.e., ash, sulfur, etc.) entering the process is equal to the overall mass and the mass of each component leaving the process. Assuming there is no generation or destruction of mass in the process (i.e., precipitation or leaching), the mass balance can be written in terms of the feed and product streams around a process. For example, the mass balance for a flotation process is given by:

$$F - P - R = 0 \tag{1}$$

where F is the mass flow rate of solids in the feed stream, P is the mass flow rate of solids in the product stream and R is the mass flow rate of solids in the refuse stream. Similarly, the component balance for a flotation process is given by:

$$fF - pP - rR = 0 \quad (2)$$

where f is the fractional assay of a given component (ash, for example) in the feed stream, p is the fractional assay of a given component in the product steam and r is the fractional assay of a given component in the refuse stream.

In an ideal situation, Equations 1 and 2 equal zero and one has what is termed "perfect closure" of the material balance. Unfortunately, the real world is not ideal. It is not always possible to get a perfectly representative sample of every stream. Furthermore, no analysis technique is 100% accurate. Therefore, errors are introduced in sampling and analysis which make it impossible to have "perfect closure" of the material balance. As a result, each set of analysis used in the calculations (i.e., flows, assays, etc.) will give entirely different values for yield, recovery, sulfur rejection, etc.

In the late 1960's and early 1970's, several researchers looked at the material balance problem and developed techniques which used all the data available, but adjusted them so that they would be consistent and meet the material balance criteria established by Equations 1 and 2. The general technique used is known as constrained minimization. The basic idea for this procedure is as follows. It is known that Equations 1 and 2 must be satisfied in order to have a true material balance. Furthermore, Equation 2 must be satisfied for every component (i.e., every essay) in the stream. It is also known that every assay and flow measurement has a certain amount of error associated with it. Thus, adjustments to the values of the assay and flow measurements are required to remove the error and satisfy Equations 1 and 2. However, the amount of adjustments made to each of the flow measurements and assays must be minimized. Therefore, the measured values are adjusted according to how much trust can be placed in each of these values until the mass balance equations are satisfied. In other words, Equations 1 and 2 represent the constraint which must be satisfied, while the difference between the measured value and the adjusted value for each flow and assay must be minimized.

A number of computer programs have been written over the past 20 years which are capable of carrying out the material balance calculations. One such program which has been found to be quite versatile is BILMAT which has been developed and refined by CANMET over the past 20 years [2]. The BILMAT program allows the user to input a description of the process in terms of number of streams and number of nodes, measured values such as pulp, solids and water flow rates, percent solids, size distributions, washability data, and assays in each stream or in each size or gravity fraction, and the relative error associated with each measured value. The program then adjusts the measured values to produce a consistent set of flows and assays. The amount of adjustment for each value is based on the relative error. If the user assigns a large relative error to a value, the program assumes that it is free to adjust this value as it is necessary to provide a mass balance. If the user assigns a small relative error to a value, the program assumes that this value must stay relatively constant and other values must be adjusted to close the balance.

Therefore, the insight of the user in determining the relative error values, known as the error model, is critical to the outcome of the material balance.

3.4.2 Error Model

In order to compare the data from all participants on a fair and equal basis, a consistent error model was developed which was used in all mass balance calculations. The error model was based on the following assumptions.

3.4.2.1 Feed Assays (ash, sulfur, pyritic sulfur and Btu)

It has been determined that feed samples taken during an experimental run can vary greatly depending on the sample location and the feed sump design. For example, pyrite tends to settle out at the bottom or corners of the feed sump. Thus, there is great room for bias in the feed sample collected during an experiment. Therefore, in order to be fair to each participant, it was decided to use the assays reported by B&W as the feed assays for the mass balance calculations. It was assumed that the values were accurate and a small relative error (5%) was entered in the BILMAT program for each of these assays.

3.4.2.2 Ash Assays

At least one assay in each stream had to be trusted in order to complete the mass balance. Since ash is a very routine analysis procedure in most coal labs, it was felt that this value could be trusted with a small relative error (5%). Thus, the relative flow rates of solids reported for each stream were primarily based on the material balance on ash.

3.4.2.3 Total Sulfur Assays

Total sulfur is a very quick and routine analysis which is usually repeated enough times to provide an accurate assay. Unfortunately, the total sulfur values in the refuse stream for nearly all participants were in a range that is usually at the limit of most sulfur analyzers. Thus, it was felt that only the product total sulfur value reported by each participant could be trusted with relative error of 5%. The total sulfur assay for the refuse stream was used in the mass balance calculation, but it was given a relative error of 999.999%. This number is used in BILMAT to indicate an assay which is not very reliable. Thus, BILMAT had total freedom to adjust this value to close the material balance on total sulfur.

3.4.2.4 Pyritic Sulfur Assays

Except for the feed analysis already discussed, none of the pyritic sulfur assays were assumed to be accurate. This results from several problems including the sedimentation of pyrite in sumps and flotation cells, as well as poor analytical procedures. When comparing pyrite results from all the participants, there appears to be considerable variation. In most cases this is the result of analytical procedures. Pyrite determination is a wet chemistry problem that is very operator dependent to produce correct answers. This variation in the pyritic sulfur assay is particularly unfortunate since pyritic sulfur rejection is being used in the Round Robin test program to evaluate the performance of each of the participants' processes. As a result of this finding, a relative error of 999.999% was assumed for the measured pyritic sulfur assays in the product and refuse streams.

3.4.2.5 All Reported Flows (usually feed and wash water) and the Percent Solids in the Feed.

As mentioned previously, the material balance on the components determines the relative solids flow rates in each stream (i.e., yield). The balance on the total pulp and water flows determines the water split, which determines the total pulp flow rate in each stream, which determines the residence time.

The reported feed pulp flow rate, the reported feed percent solids, and an assumed s.g. of 1.4 of the solids was used to calculate the grams per minute of solids in the feed and the ml/min of water in the feed.

In using the BILMAT program to conduct the flow balance, it was assumed that the reported feed pulp flow rate and percent solids were accurate to 5% relative error. It was also assumed that the same accuracy for the reported wash water flowrate could be used. These were the only flows provided by all of the participants. The remaining flows were calculated by the BILMAT program using the percent solids values in the tailings and concentrate streams. Both of these values were given the maximum relative error so that the BILMAT program could adjust them as necessary. The solids flow split was determined from the yield which was determined from the assay balance (based primarily on ash, but partially on total sulfur). Thus, the BILMAT program used the assays to determine the yield. Knowing the yield and the mass flow of feed, the mass flow in all other streams was determined. Knowing the mass flow of feed and percent solids, the water in the feed stream was determined. Knowing the water in the feed stream and the wash water addition rate, the adjustments to the percent solids in the product and refuse streams were minimized in order to complete the balance on water and the balance on pulp.

3.4.2.6 Btu Assays

Btu cannot be balanced by the BILMAT program, because Btu is a function of the ash and moisture ash free (MAF) Btu of a given product. For this reason the results of participants assay were utilized as the assayed Btu for Test Numbers 1 thru 3 of Phase I. The results are subject to calibration errors etc. for each individual participant. This fact is obvious when examining the data which indicates different Btu values for a given ash value. In some cases a higher Btu value is reported for a higher ash value.

Test Number 4 of Phase II is the test used to determine the efficiency of the process and the economics of the test work. For this reason all of the Btu values for the feed and clean coal product were adjusted. The adjustment was determined by the ash content and the moisture ash free Btu value on a linear basis. This made the relationship between Btu and ash hold constant for all participants.

3.5 Results

The results for Test Numbers 1 thru 3 of Phase I are shown in Tables 3.7 and 3.8. Table 3.7 tabulates the technical performance results. The Table includes the values generated by the BILMAT program and directly under these are the results reported by the participant. Table 3.8 contains the process variables used by each participant. In the case of these three tests, feed percent solids, particle size, retention time, pH of feed slurry, and amounts of collector and frother were held constant.

B. Datta Research and Center for Applied Energy Research experienced operating problems with the parameters set as described above. B. Datta Research, during observation of test work by ICF KE, produced no froth under these conditions. In fact for some unexplained reason the coal, which was from the same batch as the other participants, would not respond to flotation under the set conditions even in a lab cell. The Center for Applied Energy Research experienced poor results due to the fact that bubbles were being flushed out tailing stream. The reason they experienced this problem appears to be due to their column geometry. At 1 lb/ton of Dowfroth M150, the actual concentration in their cell was very high. This resulted in the production of very fine bubbles which could not rise against the downward flow of slurry in the column.

There were two purposes for the Phase I Tests. The first purpose was to determine if oxidation occurred during grinding and shipping of the B&W prepared sample. This sample was used for Test 1 of Phase I. The participant prepared the sample for Test 2 of Phase I from 1/4 inch by zero coal ground to the required size distribution by the participant. The second purpose was to determine if grind size influenced the efficiency of separating pyrite from the coal. The participant prepared the sample for Test 3 of Phase I to a particle size of minus 200 mesh.

An indication of oxidation occurring in a sample is the reduction of weight recovery at the same operating conditions. Allmineral showed an increase of recovery from 63.60% to 72.20% with the efficiency index increasing from 15.43 to 43.91. Deister showed virtually no change of recovery (85.6% to 85.50%) with the efficiency index decreasing from 67.17 to 53.56. Illinois State Geological Survey showed a decrease in recovery from 80.70% to 54.10% with accompanying decrease in the efficiency index from 45.5 to 33.80. Michigan Tech showed an increased in recovery from 83.30% to 88.60 with the efficiency index increasing from 69.41 to 79.42. Virginia Polytechnic Institute showed a slight decrease in

TABLE 3.7

FLOTATION PERFORMANCE RESULTS PHASE I

		AL MN #1	AL MN #2	AL MN #3	BDR #1	BDR #2	BDR #3	CAER #1	CAER #2	CAER #3	DCCI #1	DCCI #2	DCCI #3	ISGS #1	ISGS #2	ISGS #3	MTU #1	MTU #2	MTU #3	VPI #1	VPI #2	VPI #3
FEED																						
WEIGHT %	BILMAT	100.0	100.0	100.0	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	REPORTED	100.0	100.0	100.0	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
ASH %	BILMAT	11.75	11.75	11.75	N/A	N/A	N/A	11.95	11.95	11.95	12.14	12.14	12.14	12.05	12.05	12.05	11.99	11.99	11.99	12.40	12.40	12.40
	REPORTED	12.10	12.05	12.10	N/A	N/A	N/A	11.65	11.38	11.65	11.94	11.94	11.87	11.70	13.70	12.40	11.96	11.91	11.84	11.85	11.78	11.99
PYRITIC SULFUR %	BILMAT	2.36	2.36	2.36	N/A	N/A	N/A	2.79	2.79	2.79	2.42	2.42	2.42	2.44	2.44	2.44	2.36	2.36	2.36	2.92	2.92	2.92
	REPORTED	2.08	2.08	2.08	N/A	N/A	N/A	2.20	2.20	2.20	2.81	2.80	2.81	2.75	2.72	2.81	2.12	2.24	2.13	2.52	2.60	2.86
TOTAL SULFUR %	BILMAT	3.98	3.98	3.98	N/A	N/A	N/A	4.20	4.20	4.20	3.93	3.93	3.93	3.92	3.92	3.92	4.07	4.07	4.07	4.26	4.26	4.26
	REPORTED	3.70	4.00	4.10	N/A	N/A	N/A	4.12	4.12	4.12	4.11	3.80	3.88	4.07	3.94	4.18	4.43	4.31	3.93	3.96	3.87	4.01
BTU	REPORTED	12350	12350	12350	N/A	N/A	N/A	12506	12506	12506	12335	12335	12335	12389	12389	12389	12420	12420	12420	12506	12506	12506
CLEAN COAL																						
WEIGHT %	BILMAT	63.80	72.20	65.90				5.90	3.50	93.90	85.60	85.50	90.70	80.70	54.10	83.30	88.60	87.00	89.70	58.40	55.10	60.00
	REPORTED	58.19	69.75	62.93	N/A	N/A	N/A	8.80	9.10	94.60	86.06	85.98	91.17	82.06	40.59	81.86	88.92	87.83	90.69	60.88	58.02	62.15
ASH %	BILMAT	9.20	8.30	7.80	N/A	N/A	N/A	2.47	2.10	8.46	4.72	5.70	6.73	6.60	6.40	7.80	4.44	2.90	5.18	3.35	3.09	4.90
	REPORTED	9.20	8.30	7.80	N/A	N/A	N/A	2.47	2.10	8.48	4.72	5.70	6.73	6.60	6.40	7.80	4.45	2.90	5.19	3.35	3.09	4.90
PYRITIC SULFUR %	BILMAT	1.85	1.04	1.29	N/A	N/A	N/A	0.50	0.39	2.47	0.88	1.21	1.64	1.34	1.20	1.60	0.79	0.46	1.36	0.66	0.58	0.74
	REPORTED	1.69	0.91	1.13	N/A	N/A	N/A	0.50	0.39	2.00	0.95	1.39	1.88	1.53	1.19	1.82	0.69	0.41	1.05	0.65	0.57	0.74
TOTAL SULFUR %	BILMAT	3.70	2.90	3.00	N/A	N/A	N/A	1.68	1.87	3.64	2.35	2.60	2.91	2.93	2.40	3.24	2.40	1.76	2.51	2.06	2.07	2.41
	REPORTED	3.70	2.90	3.00	N/A	N/A	N/A	1.68	1.87	3.64	2.35	2.60	2.91	2.93	2.40	3.24	2.40	1.76	2.51	2.06	2.07	2.41
BTU	REPORTED	12680	12949	13423	N/A	N/A	N/A	14117	13870	13345	14160	13916	13651	13825	13883	13622	13882	13795	13865	14315	14176	14048
REFUSE																						
WEIGHT %	BILMAT	36.40	27.80	34.10				94.10	96.50	6.10	14.40	14.50	9.30	19.30	45.90	16.70	11.40	13.00	10.30	41.60	44.90	40.00
	REPORTED	41.81	30.25	37.07	N/A	N/A	N/A	91.20	90.90	5.40	13.94	14.02	8.83	17.94	59.41	18.14	11.08	12.17	9.31	39.12	41.98	37.85
ASH %	BILMAT	16.20	20.70	19.40	N/A	N/A	N/A	12.54	12.31	66.66	56.42	50.17	64.99	34.80	18.70	33.30	71.23	72.61	72.22	25.09	23.81	23.63
	REPORTED	16.20	20.70	19.40	N/A	N/A	N/A	12.54	12.31	66.74	56.48	50.20	64.97	34.80	18.70	33.30	71.44	72.61	72.49	25.09	23.81	23.63
PYRITIC SULFUR %	BILMAT	3.25	5.79	4.44	N/A	N/A	N/A	2.93	2.88	7.76	11.58	9.53	10.07	7.01	3.89	6.61	14.57	15.03	11.06	6.08	5.79	6.19
	REPORTED	2.97	4.55	3.61	N/A	N/A	N/A	1.90	2.80	7.35	14.25	11.63	10.90	8.33	3.77	7.31	11.15	10.26	8.63	5.43	5.41	6.34
TOTAL SULFUR %	BILMAT	4.47	6.78	5.88	N/A	N/A	N/A	4.36	4.29	12.86	13.33	11.77	13.92	8.05	5.71	7.32	17.08	19.49	17.70	7.34	6.94	7.03
	REPORTED	4.66	6.54	5.98	N/A	N/A	N/A	3.77	4.17	9.13	11.19	12.51	11.54	9.30	5.00	8.44	16.80	18.15	15.14	6.92	6.36	6.64
BTU	REPORTED	11058	10231	10829	N/A	N/A	N/A	11325	12572	3432	5149	6471	3916	8955	11810	9308	2016	1960	2065	10798	10135	8212
BTU RECOVERY		65.30	75.70	71.63	N/A	N/A	N/A	6.66	3.88	100.2	98.26	96.46	100.4	90.05	60.62	91.59	99.03	96.63	100.1	66.85	62.46	67.40
PYRITIC SULFUR REJECTION		50.13	66.20	64.15	N/A	N/A	N/A	98.82	99.61	16.97	68.91	57.10	38.70	55.45	73.18	45.24	70.38	82.79	48.27	86.62	89.03	84.79
EFFICIENCY		15.43	43.91	35.78	N/A	N/A	N/A	5.48	3.49	17.17	67.17	53.56	39.08	45.50	33.80	36.83	69.41	79.42	48.41	53.47	51.49	52.19

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TABLE 3.8

FROTH FLOTATION PROCESS VARIBLES PHASE I

		AL MN			BDR			CAER			DCCI			ISGS			MTU			VPI		
PERFORMANCE PARAMETER		#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3
GEOMETRY	UN																					
HEIGHT	IN	12 3/8	12 3/8	12 3/8	N/A	N/A	N/A	236.0	236.0	236.0	122.0	122.0	122.0	7 7/8	7 7/8	7 7/8	96.00	96.00	96.00	60.00	60.00	60.00
DIAMETER	IN	3.00	3.00	3.00	N/A	N/A	N/A	2.0	2.0	2.0	3.0	3.0	3.0	N/A	N/A	N/A	1.80	1.80	1.80	2.00	2.00	2.00
SLURRY FEED POINT	IN	0.00	0.00	0.00	N/A	N/A	N/A	156.0	156.0	156.0	32.0	32.0	32.0	N/A	N/A	N/A	48.00	48.00	48.00	18.50	18.50	18.50
WASH WATER ADDITION PT	IN	N/A	N/A	N/A	N/A	N/A	N/A	12.0	12.0	12.0	1.0	1.0	1.0	N/A	N/A	N/A	2.00	2.00	2.00	3.50	3.50	3.50
FROTH HEIGHT	IN	1.00	1.00	1.00	N/A	N/A	N/A	48.0	48.0	48.0	18.0	18.0	18.0	0.75	0.75	0.75	N/A	N/A	N/A	18.50	16.50	18.00
PULP HEIGHT	IN	11 3/8	11 3/8	11 3/8	N/A	N/A	N/A	188.0	188.0	188.0	104.0	104.0	104.0	7 1/8	7 1/8	7 1/8	N/A	N/A	N/A	41.50	43.50	42.00
BAFFLES SPACING	IN	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	NOTE 1	NOTE 1	NOTE 1	N/A	N/A	N/A
CONDITIONS																						
WASH WATER RATE	GPM	N/A	N/A	N/A	N/A	N/A	N/A	0.100	0.100	0.100	0.330	0.330	0.330	N/A	N/A	N/A	0.0475	0.0356	0.0475	0.132	0.132	0.132
AIR FLOW RATE	CFM	0.071	0.071	0.071	N/A	N/A	N/A	0.100	0.100	0.100	0.100	0.100	0.100	0.280	0.280	0.280	0.2510	0.3320	0.3320	0.057	0.083	0.053
FEED SLURRY RATE	GPM	0.450	0.450	0.450	N/A	N/A	N/A	0.340	0.340	0.340	0.320	0.320	0.320	N/A	N/A	N/A	0.0167	0.0167	0.0167	0.032	0.032	0.032
FEED % SOLIDS	WT	10.00	10.00	10.00	N/A	N/A	N/A	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
FEED SLURRY pH		7.00	7.00	7.00	N/A	N/A	N/A	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
FEED PARTICLE SIZE	d50	8.50	6.71	6.70	N/A	N/A	N/A	9.96	11.37	26.92	9.81	N/A	N/A	9.52	9.14	36.39	9.38	9.23	41.78	9.52	7.88	29.37
AIR HOLD-UP		N/A	N/A	N/A	N/A	N/A	N/A	9.50	9.50	9.50	N/A	N/A	N/A	N/A	N/A	N/A	30.00	31.00	31.00	8.80	N/A	N/A
RETENTION TIME	MIN	0.33	0.33	0.33	N/A	N/A	N/A	6.00	5.90	11.40	4.90	4.90	4.90	5.00	5.00	5.00	5.00	5.00	5.00	6.80	4.40	3.80
REAGENTS																						
COLLECTOR NAME		NOTE 2	NOTE 2	NOTE 2	N/A	N/A	N/A	NOTE 2	NOTE 2	NOTE 2	NOTE 2	NOTE 2	NOTE 2	NOTE 2	NOTE 2	NOTE 2	NOTE 2	NOTE 2	NOTE 2	NOTE 2	NOTE 2	NOTE 2
COLLECTOR RATE	#/T	3.00	3.00	3.00	N/A	N/A	N/A	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
FROTHER NAME		M150	M150	M150	N/A	N/A	N/A	M150	M150	M150	M150	M150	M150	M150	M150	M150	M150	M150	M150	M150	M150	M150
FROTHER RATE	#/T	1.00	1.00	1.00	N/A	N/A	N/A	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

NOTE 1 STACKED CORRUGATED PLATES ARRANGED IN BLOCK POSITION RIGHT ANGLES TO EACH OTHER
NOTE 2 KEROSENE

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recovery from 58.40% to 55.10% with the efficiency index decreasing from 53.47 to 51.49.

Based on the above results it is concluded that there may have been oxidation of the B&W prepared sample. This oxidation may have occurred on the pyrite particle which shows up in the efficiency index. In all cases, except for ISGS, there is increased weight recovery of the freshly ground coal. Therefore, it is concluded that advanced flotation should occur immediately after grinding to minimize oxidation problems. It should be noted that as long as two weeks could have elapsed between the time B&W prepared the sample for Test 1 and the time the participant actually performed the test.

The information for Test Numbers 1 thru 3 of Phase I were forwarded to the Technical Support Team (TST) composed of representative of Consolidation Coal, Virginia Polytechnic Institute, Babcock and Wilcox and ICF Kaiser Engineers. The TST was to compare the results of Test 2 with Test 3. Test 2 involved grinding the coal to minus 325 mesh and Test 3 involved grinding the coal to minus 200 mesh. The TST concluded that Test Number 2 had improved the pyritic sulfur rejection and therefore the fine grind should be utilized in Test Number 4 of Phase II.

The results of Tests 1 thru 3 shown on Table 3.7 for all of the participants shows that the pyritic sulfur of the product for Test 2 is always lower than in Test 3. This is a result of a finer grind liberating free pyritic sulfur that is then rejected in the advanced flotation device being tested.

The performance results for Test 4 of Phase II are shown on Table 3.9. The process variables for this test are shown in Table 3.10. As previously stated this test was open for the participant to utilize any means at his discretion to maximize Btu recovery and maximize pyritic sulfur rejection. By examining the data on Table 3.9 all of the participants except VPI opted to maximize Btu recovery and accept the pyritic sulfur rejection that occurred at that Btu recovery. VPI decided to maximize pyritic sulfur rejection resulting in the lowest Btu recovery.

The major difference that can be concluded by examining the data found in Table 3.10 is the difference in retention time when compared to the first three tests. The participants who improved their performance in Test 4 did so by mostly increasing the retention time required to float the coal. This increased retention time allowed for additional recovery which moved the participants higher up the grade-recovery curve. ISGS and Allmineral improved their results by cleaning and recleaning the rougher flotation product. The reagents used for Test 4 were similar to the first three tests. The only sulfur depressants used were by Allmineral who used a German chemical named Vanis pers and VPI who raised the pH of the feed slurry to 9.20.

Test 4 of Phase II is the base condition for the performance evaluation utilized in the economic evaluation. All of the participants fall short of the washability analysis as shown in Figure 3.8. As previously stated a better method to evaluate flotation performance is the release analysis. As can be seen in Figure 3.12, Deister, ISGS, CAER, and VPI appear to fall on the release curve within normal experimental error. This is to be expected with column flotation devices utilizing wash water. Likewise ISGS and Allmineral by using multi-stage cleaning process should result in a point on the release curve. Two participants Michigan Tech and B. Datta Research plot to the upper right of the release curve.

This is not possible. The conclusions is that the samples were not collected at steady state conditions or sample analysis error. This would result in an error of results.

TABLE 3.9

FLOTATION PERFORMANCE RESULTS PHASE II

PERFORMANCE PARAMETER		AL MN #4	BDR #4	CAER #4	DCCI #4	ISGS #4	MTU #4	VPI #4
FEED								
WEIGHT %	BILMAT	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	REPORTED	100.0	100.0	100.0	100.0	100.0	100.0	100.0
ASH %	BILMAT	11.75	12.00	11.95	12.14	12.05	11.99	12.40
	REPORTED	11.80	12.77	11.65	11.94	11.45	11.67	11.67
PYRITIC SULFUR %	BILMAT	2.36	2.19	2.79	2.42	2.44	2.36	2.92
	REPORTED	2.08	2.62	2.39	3.58	2.67	1.99	1.54
TOTAL SULFUR %	BILMAT	3.98	3.93	4.20	3.93	3.92	4.07	4.26
	REPORTED	4.11	3.62	3.92	2.80	3.79	3.66	3.74
BTU	CALCULATED	12378	12339	12347	12317	12331	12340	12277
	REPORTED	12350	12412	12506	12335	12389	12420	12506
CLEAN COAL								
WEIGHT %	BILMAT	89.50	89.00	87.50	85.60	85.40	83.70	70.00
	REPORTED	89.49	88.00	88.10	86.06	86.48	84.97	72.28
ASH %	BILMAT	6.64	3.73	3.72	4.72	3.60	2.59	2.91
	REPORTED	6.65	3.73	3.73	4.72	3.60	2.59	2.91
PYRITIC SULFUR %	BILMAT	0.92	0.76	0.65	0.88	0.73	0.39	0.47
	REPORTED	0.84	0.80	0.62	0.95	0.77	0.38	0.40
TOTAL SULFUR %	BILMAT	2.92	1.83	2.13	2.35	1.99	1.65	1.90
	REPORTED	2.92	1.83	2.13	2.35	1.99	1.65	1.90
BTU	CALCULATED	13268	13786	13788	13614	13809	14236	14088
	REPORTED	13424	14082	14110	14160	14322	13824	14333
REFUSE								
WEIGHT %	BILMAT	10.50	11.00	12.50	14.40	14.60	16.30	30.00
	REPORTED	10.51	12.00	11.90	13.94	13.52	15.03	27.72
ASH %	BILMAT	55.64	78.99	69.97	56.42	61.58	60.15	34.51
	REPORTED	55.70	79.09	70.27	56.48	61.67	60.15	34.51
PYRITIC SULFUR %	BILMAT	13.04	13.77	17.78	11.58	12.42	12.46	8.62
	REPORTED	12.67	15.93	15.50	14.25	14.83	11.10	4.53
TOTAL SULFUR %	BILMAT	14.70	20.89	18.66	13.33	15.19	16.47	9.76
	REPORTED	14.20	16.78	17.20	11.19	15.29	15.04	8.52
BTU	REPORTED	6895	2562	2440	5149	3700	4120	9057
BTU RECOVERY		95.94	99.44	97.71	94.61	95.64	96.56	80.33
PYRITIC SULFUR REJECTION		58.02	69.16	79.66	68.91	74.32	86.06	88.56
EFFICIENCY		53.95	68.60	77.37	63.52	69.95	82.62	68.89

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TABLE 3.10

FROTH FLOTATION PROCESS VARIBLES PHASE II

PERFORMANCE PARAMETER	UNIT	AL MN #4	BDR #4	CAER #4	DCCI #4	ISGS #4	MTU #4	VPI #4
GEOMETRY								
HEIGHT	IN	23.00	182.0	236.0	122.0	8.00	96.00	60.0
DIAMETER	IN	3.00	3.00	2.0	3.0	N/A	1.80	2.0
SLURRY FEED POINT	IN	0.00	60.00	156.0	32.0	N/A	46.00	18.5
WASH WATER ADDITION PT	IN	N/A	21.00	12.0	1.0	N/A	2.00	3.5
FROTH HEIGHT	IN	1.00	48.00	48.0	18.0	1.00	N/A	20.0
PULP HEIGHT	IN	22.00	120.0	188.0	104.0	7.00	N/A	48.0
BAFFLES SPACING	IN	N/A	N/A	N/A	N/A	N/A	NOTE 1	N/A
CONDITIONS								
WASH WATER RATE	GPM	N/A	0.159	0.10	0.330	N/A	0.0356	0.132
AIR FLOW RATE	CFM	0.071	0.120	0.070	0.100	0.280	0.2120	0.044
FEED SLURRY RATE	GPM	0.450	3.509	0.130	0.320	N/A	0.0180	0.017
FEED % SOLIDS	WT	5.00	10.00	10.00	10.00	9.80	10.00	8.89
FEED SLURRY pH		7.00	7.00	7.00	7.00	7.00	7.00	9.20
FEED PARTICLE SIZE	d50	6.72	12.10	12.22	N/A	10.57	11.98	N/A
AIR HOLD-UP		N/A	10.80	9.50	N/A	N/A	30.00	26.12
RETENTION TIME	MIN	0.99	5.00	13.50	4.90	18.00	28.30	5.20
REAGENTS								
COLLECTOR NAME		NOTE 2	NOTE 4	NOTE 4	NOTE 4	NOTE 4	NOTE 5	NOTE 4
COLLECTOR RATE	#/T	1.10	3.00	2.00	3.00	6.40	2.56	1.00
FROTHER NAME		N/A	MIBC	MIBC	M150	M150	NOTE 6	M150
FROTHER RATE	#/T	N/A	2.00	1.00	1.00	2.99	1.43	3.94
MODIFIER NAME		NOTE 3	N/A	N/A	N/A	N/A	N/A	N/A
MODIFIER RATE	#/T	0.22	N/A	N/A	N/A	N/A	N/A	N/A

NOTE 1 STACKED CORRUGATED PLATES ARRANGED IN BLOCK POSITION AT RIGHT ANGLES TO EACH OTHER
NOTE 2 MONTANOL 551 F2 THIS IS FROTHER AND COLLECTOR COMBINATION
NOTE 3 Vanis pers
NOTE 4 KEROSENE
NOTE 5 NO. 2 FUEL OIL
NOTE 6 PINE OIL

4.0 ECONOMICS

The economic study of the results from Phase II involved contacting each participant and requesting, based on Test 4 parameters, their best estimate of the capital cost of a nominal 20 tph advanced froth flotation circuit using the circuit configuration of that test. This estimate was to assume that the feed material would be prepared to 10% solids by weight and be ground to minus 325 mesh top size. No downstream dewatering was to be included in the circuit. The participant was to supply all of the utilities and the rates required for their flotation device.

The economic evaluation is to be based upon annual $/ton of SO_2 removed and $/ton of clean coal. In order for this comparison to be fair to all participants a series of calculations were made so that each participant produced the same annual Btu to match the demands of a 25 MW electrical power generation station.

The electrical power generation station was assumed to have a net heat rate of 9493 Btu/KWhr. Net heat rate is plant boundary fuel input to busbar electricity. It was further assumed that the plant availability factor would be 75%. The availability factor is the fraction of the year the power generation station is "available" to produce power at some useful output level excluding planned or unplanned shutdowns. Based upon these assumptions the power plant requires 1.5592×10^{12} Btu per year.

The advanced froth flotation coal preparation plant must produce the equivalent amount of Btu as required by the power generation station. The coal preparation plant operates for 16 hours per day, 230 days per year and has a 90% availability factor or operates 3312 hours per year. The coal preparation plant must produce 1.5592×10^{12} Btu in 3312 hours or 4.7078×10^{8} Btu per hour.

Based upon each of the participants calculated Btu values from Test #4 and the weight recovery from Test #4, each participant's hourly clean coal and raw coal feed was calculated. ICF KE acknowledges that the "as received" Btu will be lower than the "moisture free" Btu, however, if all participants are assumed to have the same final moisture then the relative differences will be in the same ratio as the "moisture free" Btu. Therefore "moisture free" Btu was used to calculate the clean coal and raw coal tons per hour.

The calculated values of clean coal and raw coal tons per hour for each participant to produce 4.7078×10^{8} Btu per hour are shown on Table 4.1.

Table 4.1

Required Clean Coal and Raw Coal
for Economical Evaluation

Participant	Test #4 Btu/#	Test #4 Yield	Clean Coal TPH	Raw Coal TPH
ALMN	13268	89.5	17.74	19.82
CAER	13788	87.5	17.07	19.51
DCCI	13614	85.6	17.29	20.20
ISGS	13809	85.4	17.05	19.96
MTU	14236	83.7	16.53	19.75
VPI	14088	70.0	16.71	23.87

ICF KE, in the interest of fairness to all of the participants, contacted known suppliers of froth flotation reagents, and known suppliers for equipment utilized in common by all of the participants, such as reagent feeders, air compressors, and feed pumps. The above information was utilized in all of the participants' calculated capital cost. See Table 4.2 Common Equipment and Reagent Costs.

The participant's capital cost for the flotation device was incorporated with the cost of the other equipment and multiplied by 3 to determine the total installed cost of the flotation plant.[3]

The operating and maintenance cost estimates were based upon the participant's flowsheet, the equipment list, the capital cost estimate and calculated values based upon known and/or estimated costs for expendables, power, and manpower. The assumed criteria was that the plant operates at 90% availability. Based upon two shifts per day, eight hours per shift and 230 operating days per year, the total annual operating hours, total annual raw coal and clean coal tonnages were calculated.

Values from literature, estimates, or material suppliers were established as costs per unit for all operating expendables. The hourly and supervisory manpower for operation was established on an annual basis. The expendables for power, flotation reagents, water, and manpower costs were then estimated. Reagent dosages were based on participant's Test #4 results.

The maintenance material costs were estimated as 10% of the equipment costs. The maintenance manpower was established on an annual basis. From the above values, maintenance materials and manpower costs were estimated.

The total operating and maintenance costs are expressed as total annual cost, dollars per ton of raw coal and dollars per ton of clean coal.

The total capital cost and the operating costs per ton of raw coal were used as input to an economic model. This model takes into consideration the plant life, three months of working capital, 100% debt financing, 11% annual debt interest rate, debt loan period, an income tax rate and tax depreciation period.

Coal cleaning results in some loss of BTU that were retained in the raw coal. For this reason ICF KE penalized each participant for the extra raw coal needed to provide the BTU required to fire the 25 MW power plant. This was accomplished by first calculating the raw coal tons required to fire the boiler based upon Test #4 feed BTU. Second the raw coal that was required to fire the boiler based upon Test #4 clean coal weight yield and clean coal BTU values was calculated. The difference of these two numbers was multiplied by $20.00 per ton and added as an additional cost of cleaning the coal.

Table 4.2

Common Equipment and Reagent Costs

Reagent Costs

Reagent Name	$/Pound*	Source
MIBC	0.61	PB&S Chemical
Pine Oil	0.63	Hercules Chemical
M150	0.85	Betz Chemical
No. 2 Fuel Oil	0.088	Orris Fuel Company
Kerosene	0.106	Orris Fuel Company

* Based on 3,000 gallon bulk shipments.

Equipment

Name	Cost - $/HP	Source
Feed Pump	13,200/40	Gould (Goyne)+
Air Compressor	-	Airtech, Inc.++
150-300 cfm @ 40 psi	48,530/40	
500 cfm @ 50 psi	69,890/50	
1,000 cfm @ 50 psi	89,730/150	
Reagent Pumps	-	Pulsa Feeder+++
Collector	2,476/0.17	
Frother	2,462/0.17	

+ Hi chrome construction all wetted parts, variable speed drive, motor, guards and OH mount.

++ Joy reciprocating, oil free with motor, drive and regenerative drying.

+++ 316 SS construction with 4-20 ma controls, back pressure valves, motor and drive.

The output of this model is a first year estimate of dollars per clean coal ton, dollars per million BTU, annual dollars per year and annual dollars per ton of sulfur dioxide removed.

The economic analysis maintains all of the common equipment prices and manpower prices constant for each participant, therefore any variation in capital and operating and maintenance is based upon the participant's capital estimate and utilities for the scaled up version of their laboratory device.

The test work for Test #4 was performed on coal ground to pass 44 micron. Furthermore, all participants are operating column type flotation devices, except ISGS who used conventional flotation. Several papers have been recently published that state the scale up and performance of a column flotation device is limited by the rate of concentrate removal. There is a maximum rate at which solids can be removed related to individual bubble loading and the bubble surface area rate. Another name for this is "carrying capacity" and is expressed as mass of solids to overflow per unit time per unit of column cross sectional area [4]. This value calculates to be 0.092 tph/ft^2 for Test #4 conditions.

The carrying capacity is the product of the D80 particle size in microns and the specific gravity of the particle. A graph shown in Figure 4.1 indicates the tons per hour per square foot carrying capacity required to size the column flotation. In order for all participants to meet the carrying capacity criteria it is necessary for Allmineral, Center for Applied Energy Research, Deister and VPI to provide four of their respective column flotation cells. Michigan Tech requires two of their column flotation cells. ISGS, because it is conventional flotation exceeds the carrying capacity criteria as proposed.

The Technical Support Team examined the reagent dosages used by the participants in Test #4. The TST determined that the collector could be scaled up based upon pounds per ton of solids in the feed. However, the frother should be scaled up based upon concentration in the cell. In order to scale up the frother addition, the concentration of the frother was calculated for each participant's Test #4 results. The same concentration was used to calculate the pounds per ton of frother at the required feed rate corrected for the required number of columns to meet the carrying capacity criteria discussed previously. The results of the frother concentration calculations are shown in Table 4.3. The calculated frother concentration was used to back-calculate the required pounds per ton of frother used in the economic model. The concentration was not calculated for Allmineral due to insufficient Test #4 data and ISGS due to the system being conventional flotation. The frother rate used for both of these participants are was same as reported by each for the required tph scale up.

B. Datta Research was not included in the economic evaluation because the machine has not yet been patented and any disclosure of the equipment may have an adverse impact on the patent application. Because of this, the participant did not provide economic information for his device thus preventing developing the economic model.

The detailed operating and maintenance costs and economic model are contained in Appendix "I". Table 4.4 Economic Parameters shows the major numbers generatnd in the economic evaluation, with and without additional raw coal added to the final costs. The results are based upon Test #4 results with the proper material balances by the BILMAT program. The costs per ton of clean coal on a first year basis for the required tph circuit range from $16.71 to $21.29 without additional raw coal added. This dollar figure is a result of all costs divided by the annual clean coal produced.

The annual dollars per ton of sulfur dioxide removed range from $237.00 to $677.00 without additional raw coal added.

The costs per ton of clean coal on a first year basis for the required tph circuit including additional raw coal required range from $17.23 to $25.50. Likewise, the annual dollars per ton of sulfur dioxide removed including additional raw coal required range from $305.00 to $707.00.

Figure 4.1

CARRYING CAPACITY CURVE

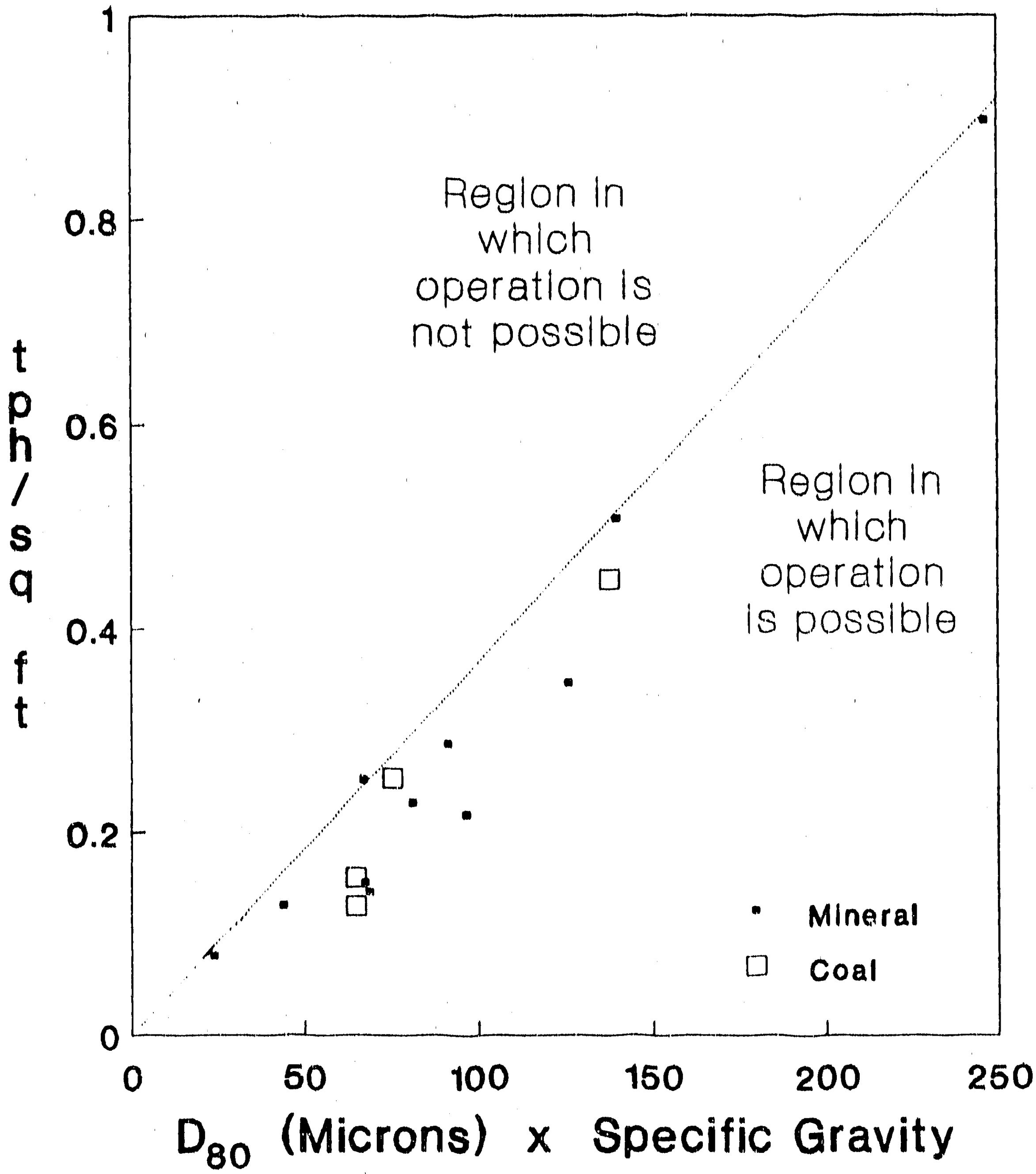

TABLE 4.3
FROTHER CONCENTRATION

	FACTOR	VPI TEST 4	VPI 20 TPH	MTU TEST 4	MTU 20 TPH	DCCI TEST 4	DCCI 20 TPH	CAER TEST 4	CAER 20 TPH
SOLID SPECIFIC GRAVITY	-	1.400	1.400	1.400	1.400	1.400	1.400	1.400	1.400
LIQUID SPECIFIC GRAVITY	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
COLUMN DIAMETER	CM	5.080	243.840	4.570	344.000	7.620	243.840	5.080	243.840
COLUMN LENGTH	CM	152.400	670.560	243.840	1219.200	309.880	731.520	599.440	701.040
NUMBER of COLUMNS	-	1	4	1	2	1	4	1	4
FEED PER CENT SOLIDS	PER CENT	8.900	10.000	10.000	10.000	10.000	10.000	5.000	19.000
FEED FLOWRATE	ML/MIN	69	880893	68	1457698	1211	745456	492	719982
WASH WATER FLOWRATE	ML/MIN	500	934895	135	596138	1249	1249050	379	908400
BUBBLE GENERATION WATER	ML/MIN	0	0	0	0	946	189250	0	0
TAILINGS FLOWRATE	ML/MIN	475	1640027	141	1780208	2464	1241972	717	1259582
BIAS FACTOR	-	0.812	0.812	0.541	0.541	0.246	0.246	0.594	0.594
FEED SOLIDS MASS RATE	GM/MIN	6.301	90880.111	7.000	150057.157	222.065	76738.082	24.959	74116.840
FROTHER DOSAGE	LBS/TON	3.900	0.907	1.430	0.821	1.000	1.253	1.000	0.581
LIQUID FLOWRATE	ML/MIN	470	1575256	136	1673025	2306	997909	699	1206641
FROTHER CONCENTRATION	MG/L	26.116	26.116	36.801	36.801	48.162	48.162	17.8[illegible]	17.849
FROTHER MASS RATE	GM/MIN	0.012	41.139	0.005	61.569	0.111	48.061	0.012	21.537
RETENTION TIME	MIN	6.50	19.08	28.35	63.62	5.73	32.43	16.94	25.98

NOTES
1. BILMAT VALUES USED FOR VOLUME AND MASS FLOW RATES FOR TEST #4
2. 20 TPH TAILINGS FLOWRATE SCALED-UP BASED ON CONSTANT BIAS FACTOR FROM TEST #4
3. FROTHER CONCENTRATION CONSTANT FROM TEST #4 TO 20 TPH SCALE-UP
4. FEED FLOERATE BASED ON FEED RATE REQUIRED FOR CONSTANT BTU PRODUCTION
5. BIAS FACTOR EQUALS (TAILINGS FLOWRATE - FEED FLOWRATE) / WASH WATER FLOWRATE

TABLE 4.4

ECONOMIC PARAMETERS

DESCRIPTION OF PARAMETER	UNIT	AL MN	BDR	CAER	DCCI	ISGS	MTU	VPI
PLANT FEED RATE	TPH	19.82	N/A	19.51	20.20	19.98	19.75	23.87
PLANT RECOVERY RATE	PER CENT	89.50%	N/A	87.50%	85.60%	84.50%	83.70%	70.00%
CLEAN COAL	TONS/YEAR	58751	N/A	56540	57268	55861	54750	55340
OPERATING HOURS	PER YEAR	3312	N/A	3312	3312	3312	3312	3312
FLOTATION REAGENT COSTS	$/YEAR	$248,341	N/A	$34,274	$95,529	$204,695	$48,569	$69,329
OPERATING COSTS PER YEAR	PER CC TON	13.535	N/A	9.953	11.050	13.595	11.216	11.939
MAINTENANCE COSTS PER YEAR	PER CC TON	3.703	N/A	3.748	3.736	3.647	4.434	4.009
TOTAL O&M COSTS PER YEAR	PER CC TON	17.238	N/A	13.701	14.785	17.242	15.650	15.948
PLANT ESTIMATE CAPITAL COST	DOLLARS	$1,153,812	N/A	$985,362	$1,045,362	$738,333	$1,909,308	$1,238,882
ADDITIONAL RAW COAL REQUIRED	TONS	2660	N/A	1470	3606	2885	2236	15556
COSTS PER YEAR WO/PENALTY	PER CC TON	$20.69	N/A	$16.71	$17.95	$19.75	$21.29	$19.88
$/TON OF SO2 REMOVED WO/PENALTY	DOLLARS	$677	N/A	$313	$401	$373	$331	$237
COSTS PER YEAR W/PENALTY	PER CC TON	$21.80	N/A	$17.23	$19.21	$20.78	$22.10	$25.50
$/TON OF SO2 REMOVED W/PENALTY	DOLLARS	$707	N/A	$323	$429	$392	$344	$305

ALMN - ALLMINERAL, BDR - B. DATTA RESEARCH, CAER - CENTER for APPLIED ENERGY RESEARCH, DCCI - DEISTER CONCENTRATING COMPANY INC., ISGS - ILLINOIS GEOLOGICAL SURVEY, MTU - MICHIGAN TECHNOLOGY UNIVERSITY, VPI - VIRGINIA POLYTECHNIC INSTITUTE

5.0 CONCLUSIONS

The overall objective of the round robin was to select the most efficient, as determined by the efficiency index, cost effective, as determined by the annual cost per ton of SO_2 removed, advanced flotation device available. This machine was to process ultra fine coal, maximize Btu recovery and maximize pyritic sulfur rejection.

The device will first be installed as a one hundred pound per hour capacity unit and, subject to the outcome of Task 6 of the Engineering Development Contract, increased to a 3 ton per hour capacity unit for installation into a proof-of-concept preparation plant.

It is very difficult to select one winner from all the participants. Any advanced technology being tested can and will at a given time produce values better and worse than have been reported in this text. Therefore, a means was determined to select a device based upon the results of this round robin report.

All of the technical and economic results were submitted to the TST for consideration. The TST members evaluated the data and determined to rank each of the participants 50% on technical merit and 50% on economic merit. The technical merit was to be the efficiency index. The economical merit was to be the annual dollars per ton of clean coal corrected for carrying capacity and frother concentration and the results of Test #4. This factor does not penalize a particular technology for not meeting a 90% pyritic sulfur rejection and therefore leaves something to be desired as <u>the</u> only economic basis for decision.

For the above reason ICF KE determined a second economic evaluation criteria was required that considered the $/ton of sulfur dioxide removed. This value was calculated and also presented.

The technical and economic factors were calculated and added together for the final evaluation ranking. The technical factor was calculated by multiplying the efficiency index for each participant by 0.5. The two economic factors were calculated by dividing 1,000 by the $/ton of clean coal and multiplying by 0.5 and by dividing 10,000 by the $/ton of sulfur dioxide removed and multiply by 0.5. The 1,000 and 10,000 are numbers selected such that when divided by their economic factors, respective numbers resulted in a two digit number. The results of these calculations are shown in Table 5.1

ICF KE recommends that both economic factors be utilized to select an advanced flotation device to be tested at the 100#/hr feed rate. Therefore, ICF KE recommends testing Michigan Tech and Center for Applied Energy Research.

The reasons for testing both of these units are based on the Round Robin Test Results. Michigan Tech reported values that were better than the release analysis curve. The opinion is that results better than the release curve are not possible. Therefore larger scale testing is recommended to verify this technology. Additionally, a problem was discovered with the Center for Applied Energy Research scale-up results involving the amount of air volume required. In order to determine whether or not this is incorrect, larger scale testing is recommended.

ICF KE gave an opportunity for each of the participants to review a draft copy of this topical report. Included in the draft copy was a ranking system that was not acceptable to the replying participants. Therefore, the TST reevaluated the ranking system and replaced the draft system with the ranking system included in this report.

TABLE 5.1

FINAL EVALUATION RANKING

PARTICIPANT	TECHNICAL PARAMETER		ECONOMIC PARAMETER				FINAL RANKING	
	EFFICIENCY INDEX	TECHNICAL FACTOR	$/TON OF SO2 REMOVED	ECONOMIC FACTOR 1	$/TON OF CLEAN COAL	ECONOMIC FACTOR 2	COMBINED RANKING 1	COMBINED RANKING 2
ALLMINERAL	53.95	26.975	707.00	7.072	21.60	23.148	34.047	50.123
CENTER FOR APPLIED ENGERY RES.	77.37	38.685	323.00	15.480	17.23	29.019	54.165	67.704
DEISTER CONCENTRATING CO. INC	63.52	31.760	429.00	11.655	19.21	26.026	43.415	57.786
ILLINOIS ST. GEOLOGICAL SURVEY	69.95	34.975	392.00	12.755	20.78	24.062	47.730	59.037
MICHIGAN TECH UNIVERSITY	82.62	41.310	344.00	14.535	22.10	22.624	55.845	63.934
VIRGINIA POLYTECHIC INSTITUTE	68.89	34.445	305.00	16.393	25.50	19.608	50.838	54.053

A copy of the letter mailed to each of the participants requesting their comments and the comments of the three participants who replied are included in Appendix II. These comments were taken into consideration for this report. Those comments acceptable to the TST were included - such as the ranking system. These comments not acceptable to the TST were not included - such as comments concerning carrying capacity.

6.0 DISCLAIMER

Reference in this paper to any specific commercial product, process, or service is to facilitate understanding and does not necessarily imply its endorsement or favoring by the United States Department of Energy, ICF Kaiser Engineers, Inc., Consolidation Coal Company, Babcock and Wilcox, and Virginia Polytechnic Institute and State University.

7.0 ACKNOWLEDGEMENTS

We wish to acknowledge the excellent cooperation of each of the process developers, whose data truly constitute this paper. Through the courtesy of each process developer, time and equipment were utilized in obtaining the performance data for the evaluation of the state-of-the-art in advanced froth flotation devices.

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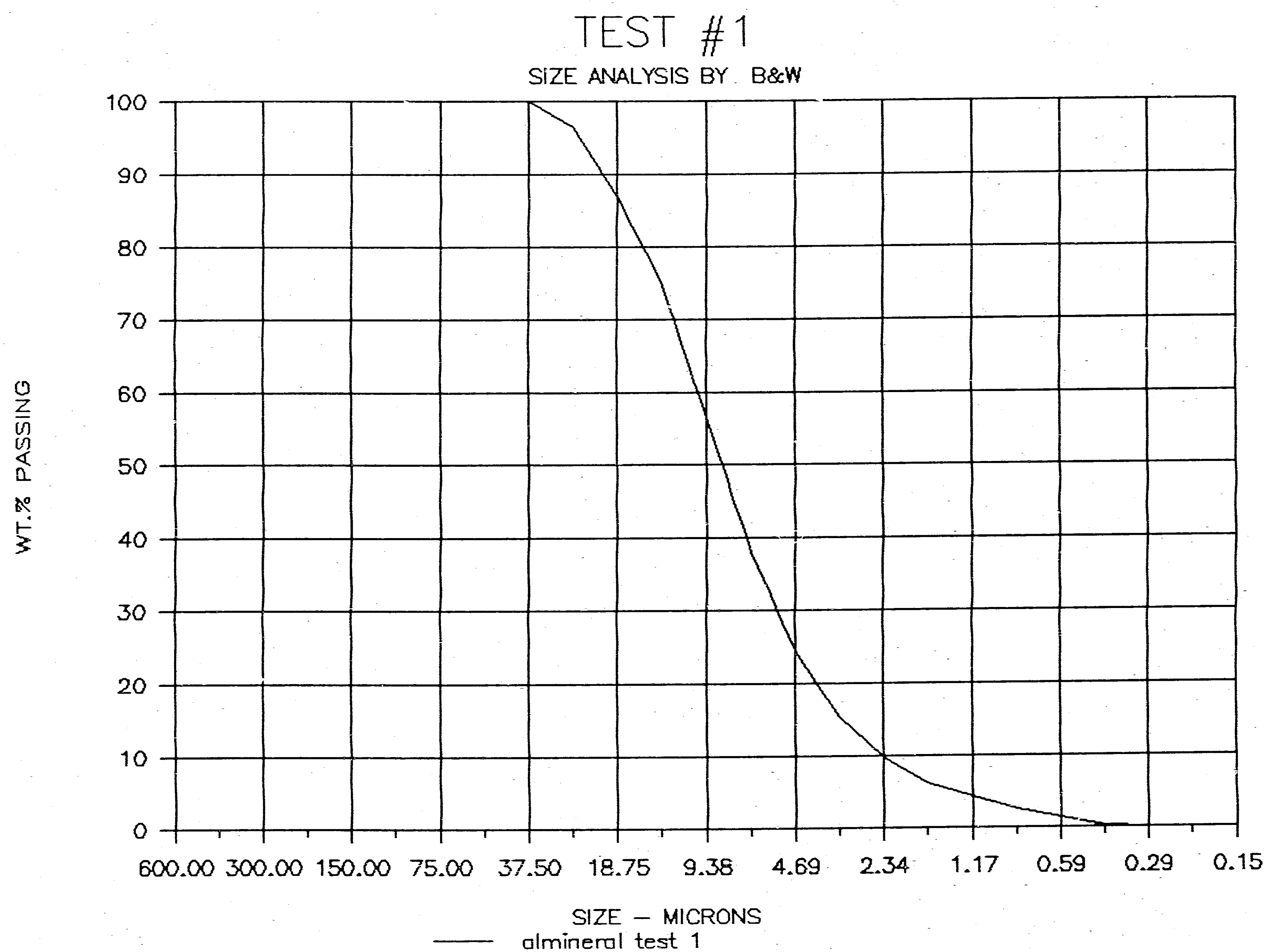
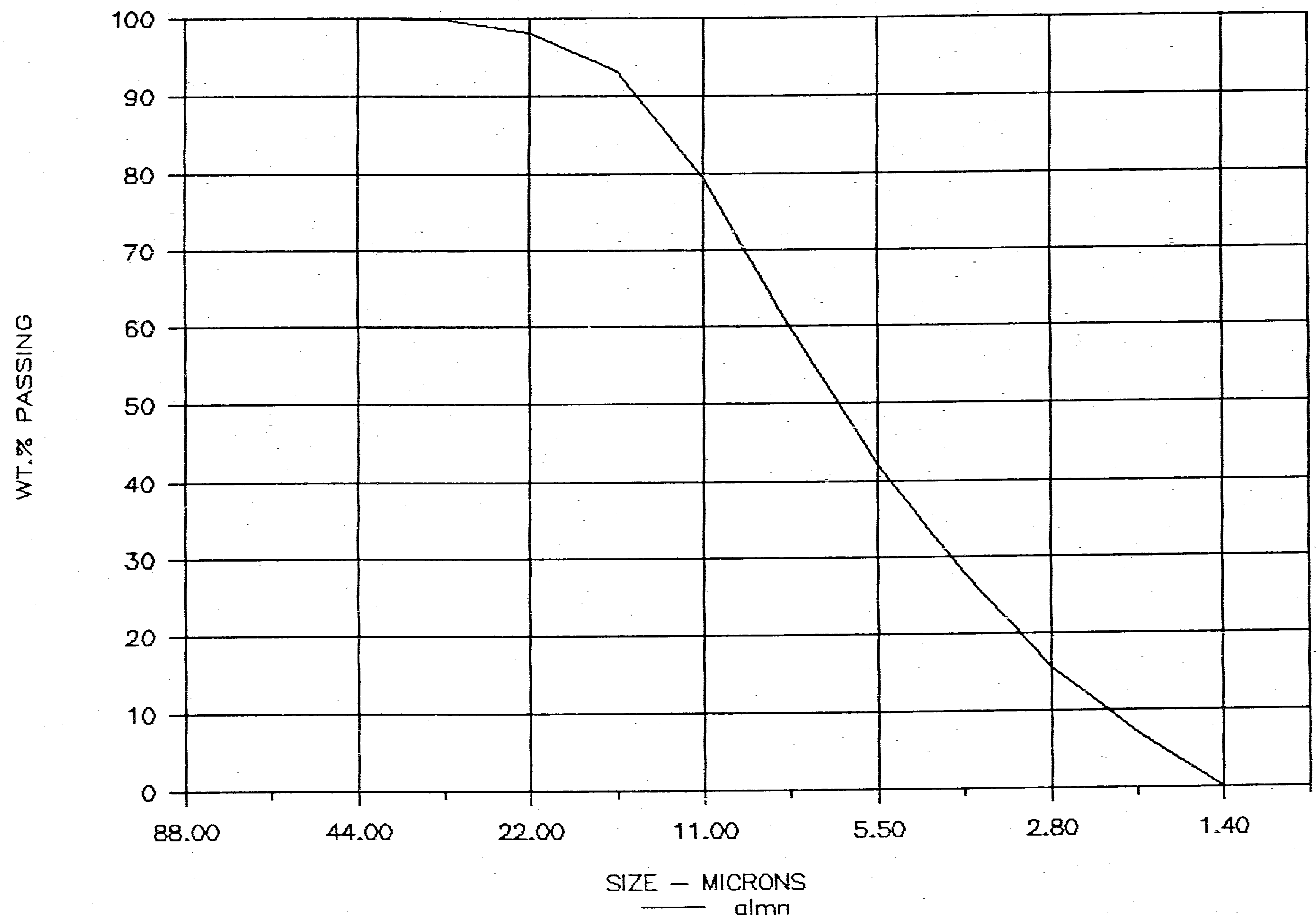
APPENDIX I

ALL MINERAL


TEST #1
SIZE ANALYSIS BY B&W
WT.% PASSING
100
90
80
70
60
50
40
30
20
10
0
600.00 300.00 150.00 75.00 37.50 18.75 9.38 4.69 2.34 1.17 0.59 0.29 0.15
SIZE – MICRONS
almineral test 1

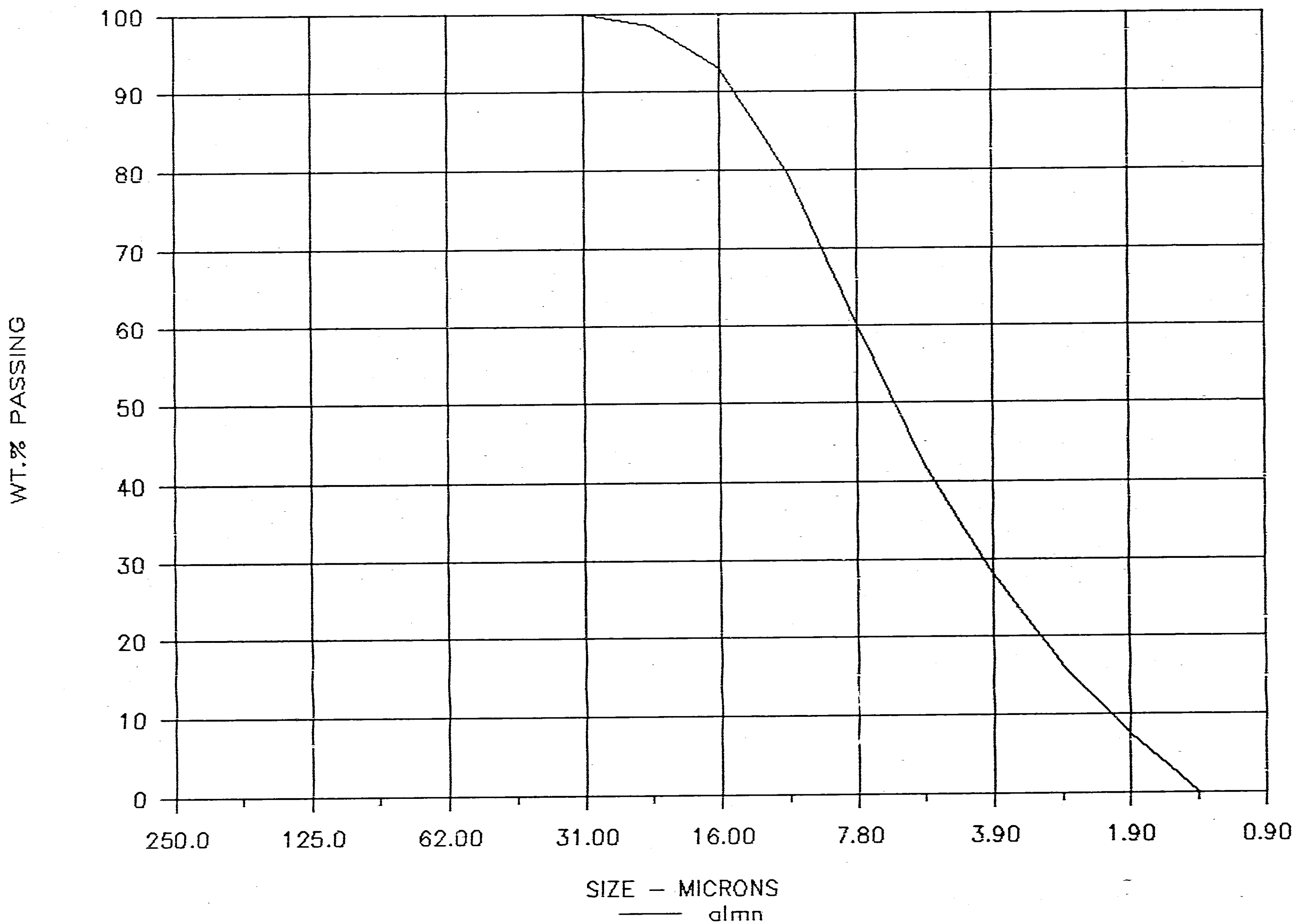
TEST #2

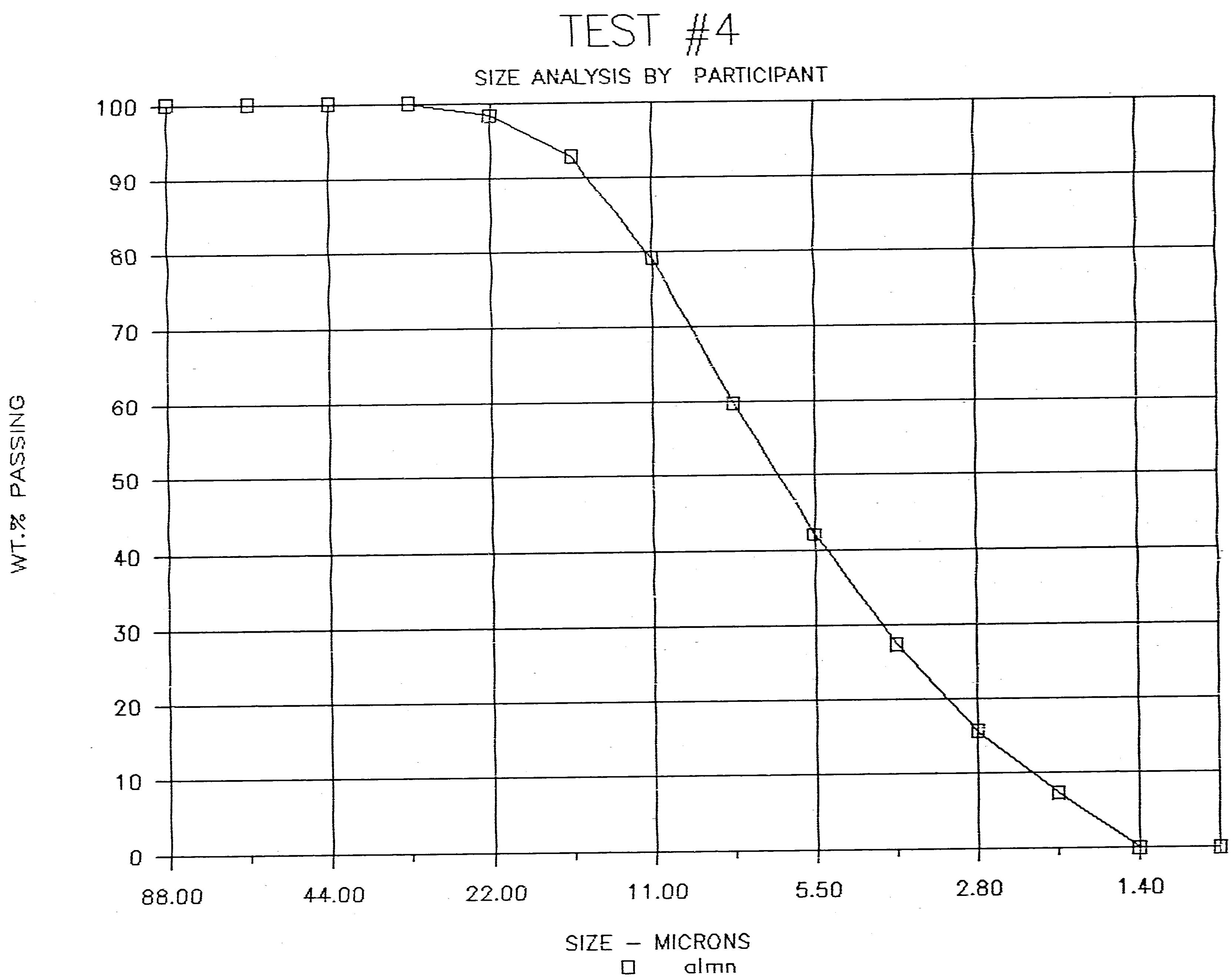
SIZE ANALYSIS BY PARTICIPANT



TEST #3

SIZE ANALYSIS BY PARTICIPANT




TEST #4
SIZE ANALYSIS BY PARTICIPANT
WT.% PASSING
100
90
80
70
60
50
40
30
20
10
0
88.00
44.00
22.00
11.00
5.50
2.80
1.40
SIZE – MICRONS
almn

ALL MINERAL ADVANCED FLOTATION PREPARATION PLANT
COAL CLEANING ECONOMICS MODEL

CLEANING PLANT		
Raw Coal Total Sulfur		3.98%
Clean Coal Total Sulfur		2.92%
Raw Coal Feed Rate		19.82 (tons/hour)
Scheduled Operating Days		230 (days/year)
Operating Shifts/Day		2 (shifts/day)
Shift Length		8.00 (hours)
Annual Scheduled Operation		3,312 (hours/year)
Mean Plant Availability		90.00%(%)
Yield		89.50%(% of raw coal)
Raw Coal Heating Value		12,378 (dry Btu/lb)
Clean Coal Heating Value		13,268 (dry Btu/lb)
Energy Recovery		95.94%(%)
Annual Raw Coal Feed		65,644 (tons/year)
Annual Clean Coal Product		58,751 (tons/year)
ECONOMIC PARAMETERS		
Design Capital Cost	(Input)	$58,215 (per raw ton/hour)
Plant Capital Cost	PCOST	$1,153,812
Plant Life	PL (Input)	20 (years, 30 years maximum)
Working Capital Allotme	(Input)	3.0 (months)
Working Capital	WORKCAP	$253,187
Proportion Debt	D (Input)	100.0%(decimal)
Borrowed Capital	DCOST	$1,406,999
Investor's Capital	CAPITAL	($0)
Debt Interest Rate	DC (Input)	11.00%(decimal)
Debt Loan Period	DPER (Input)	20 (years)
Discounted Return	(Input)	15.0%(decimal)
Income Tax Rate (all)	(Input)	38.0%(decimal)
Tax Dep. Period	TL (Input)	20 (years)

		Raw Coal Based ($/t)	Clean Coal Based (Salable Coal) ($/t)	Clean Coal Based (Salable Coal) ($/MBtu)	Annual ($/yr)
Prep Plant Raw Coal TPY Required	65644	-	-	-	
Raw Coal TPY Required	62984	-	-	-	-
Additional Raw Coal TPY Required	2660	$20.00	-	-	$53,197
Coal Cost		$0.00	$0.00	$0.000	$53,197
Plant O&M Cost		$15.43	$17.24	$0.650	$1,012,748
Refuse Disposal O&M Cost	$0.00 /ton	$0.00	$0.00	$0.000	$0
O&M Subtotal		$15.43	$17.24	$0.650	$1,012,748
Coal and O&M Cost		$15.43	$17.24	$0.650	$1,065,945
Cost of Capital		$3.90	$4.36	$0.164	$202,793
Producer's Revenue Req.		$19.33	$21.60	$0.814	$1,268,738
Transportation			$0.00	$0.000	$0
Delivered Cost			$21.60	$0.814	$1,268,738

$707 ANNUAL $/TON OF SULFUR DIOXIDE REMOVED

EQUIPMENT NO.	DESCRIPTION	QUANTITY	OPERATING QUANTITY	PRICE	HP	MOTOR SUPPLIED	COMMENTS
100	CONDITIONING/FEED SUMP	1	-	-	-		2500 GALLON CAPACITY -
101.1	CONDITIONING/FEED SUMP MIXER	1	1	10550	30.00	YES	PHIADELPHIA MODEL 3805-S-PTO
105	ROUGHER FEED PUMP	1	1	13200	40.00	YES	GOYNE MODEL 500C, 65' TDH / 900 GPM
110	COLLECTOR/FROTHER REAGENT PUMP	1	1	2476	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
115	ROUGHER DEPRESSANT REAGENT PUMP	1	1	2462	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
120	ROUGHER FLOTATION MACHINES	2	2	118000	15.00	YES	ALLFLOT MODEL 3.250
125	CONDITIONING/FEED SUMP	1	-		-		1100 GALLON CAPACITY
125.1	CONDITIONING/FEED SUMP MIXER	1	1	6875	15.00	YES	PHIADELPHIA MODEL 3803-S-PTO
130	CLEANER FEED PUMP	1	1	13200	40.00	YES	GOYNE MODEL 5000, 65' TDH / 900 GPM
135	CLEANER FLOTATION MACHINES	1	1	59000	15.00	YES	ALLFLOT MODEL 3.250
140	COLLECTOR/FROTHER REAGENT PUMP	1	1	2476	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
145	CLEANER DEPRESSANT REAGENT PUMP	1	1	2462	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
150	CONDITIONING/FEED SUMP	1	-	-	-	-	1100 GALLON CAPACITY
150.1	CONDITIONING/FEED SUMP MIXER	1	1	6875	15.00	YES	PHIADELPHIA MODEL 3803-S-PTO
155	RECLEANER FEED PUMP	1	1	13200	40.00	YES	GOYNE MODEL 5000, 65' TDH / 900 GPM
160	RECLEANER FLOTATION MACHINES	1	1	59000	15.00	YES	ALLFLOT MODEL 3.250
165	COLLECTOR/FROTHER REAGENT PUMP	1	1	2476	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
170	RECLEANER DEPRESSANT REAGENT PUMP	1	1	2462	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
	AIR COMPRESSOR	1	1	69890	50.00	YES	AIRTEC - 500 CFM @ 12 PSIG
	TOTAL			384604	261.20		

TOTAL ESTIMATED CAPITAL COST IS BASED ON HOFFMAN-MUNTNER REPORT NO. EPA-600/7-78-124, "AN ENGINEERING/ECONOMIC ANALYSIS OF COAL PREPARATION PLANT OPERATION AND COST"

THIS REPORT STATES THAT THE CAPITAL COST OF A PREPARATION PLANT CAN BE ESTIMATED BY MULTIPLING THE EQUIPMENT COST BY 3.

TOTAL EQUIPMENT COST	384604
TOTAL PROJECT ESTIMATE	1153812

OPERATING AND MAINTENANCE COSTS

OPERATING CRITERIA			
CONNECTED HORSEPOWER	261	HP	
WATER REQUIREMENTS	0.00	GPM	
PLANT FEED RATE	19.82	TPH	
PLANT RECOVERY	89.50%		
PRODUCTION RATE	17.74	TPH	
PLANT AVAILABILTY	90.00%		
UNIT SUPPLY COSTS			
ELECTRIC POWER	0.060	$/KW HR	
FROTHER - MIBC	0.610	$/#	
FROTHER - M150	0.850	$/#	
FROTHER - PINE OIL	0.630	$/#	
FROTHER/COLLECTOR - MONTANOL 551 F2	3.530	$/#	
COLLECTOR - FUEL OIL	0.088	$/#	
COLLECTOR - KERSOSENE	0.106	$/#	
DEPRESSANT - Vanis pers	8.820	$/#	
MAKE UP WATER	0.02	$/1000 GAL	
LUBRICANTS	0.02	PER TON RAW COAL	
SUPERINTENDENT	50000	PER YEAR	
BENEFITS	22500		0.45 TIMES SALARY
FOREMAN	35000	PER YEAR	
BENEFITS	15750		0.45 TIMES SALARY
LABOR			
CLASS A	15.00	PER HOUR	
BENEFITS	8.25		0.55 TIMES RATE
CLASS B	12.00		
BENEFITS	6.60		0.55 TIMES RATE
YEARLY OPERATING HOURS			
HOURS/SHIFT	8		
SHIFTS/DAY	2		
DAYS/YEAR	230		
HOURS/YEAR	3312		
RAW COAL/YEAR	65644		
CLEAN COAL/YEAR	58751		

FLOTATION REAGENT COSTS PER YEAR

ROUGHER		
FEED RATE	19.820	TPH
FROTHER/COLLECTOR RATE	0.660	$/TON
DEPRESSANT RATE	0.044	$/TON
SCAVENGER NO. 1		
FEED RATE	9.080	TPH
FROTHER/COLLECTOR RATE	0.165	$/TON
DEPRESSANT RATE	0.066	$/TON
SCAVENGER NO. 2		
FEED RATE	5.430	TPH
FROTHER/COLLECTOR RATE	0.275	$/TON
DEPRESSANT RATE	0.110	$/TON
TOTAL FROTHER	187911	$/YEAR
TOTAL DEPRESSANT	60429	$/YEAR
TOTAL FLOTATION COST	248341	$/YEAR

I. ESTIMATED OPERATING COSTS

A. OPERATING SUPPLIES

1. POWER		
DIVERSITY	0.80	FACTOR
CONNECTED HP	261.20	KWH
HEAT AND LIGHT	350.00	KWH
POWER COST	97166	$/YEAR
ASSUME 1HP=1KVA=1KWH		
2. FLOTATION REAGENT COST	248341	$/YEAR
3. WATER COST	0	$/YEAR
4. LUBRICANTS	1313	$/YEAR
TOTAL OPERATING SUPPLIES	346820	$/YEAR
B. OPERATING MANPOWER		
1. SUPERVISION		
SUPERINTENDENT	1	PER YEAR
SALARY	50000	$/YEAR
BENEFITS	22500	$/YEAR
FOREMAN	1	PER YEAR
SALARY	35000	$/YEAR
BENEFITS	15750	$/YEAR
2. LABOR		PER SHIFT
CLASS A		
PLANT OPERATER	1	PER SHIFT
EQUIPMENT OPERATOR	1	PER SHIFT
MECHANIC-ELECTRIAN	1	PER SHIFT
TOTAL CLASS A	165630	$/YEAR
BENEFITS	91080	$/YEAR
CLASS B		
UTILITY	1	PER SHIFT
TOTAL CLASS B	44160	$/YEAR
BENEFITS	24288	$/YEAR
TOTAL OPERATING MANPOWER	448378	$/YEAR
TOTAL OPERATING COST	795198	$/YEAR

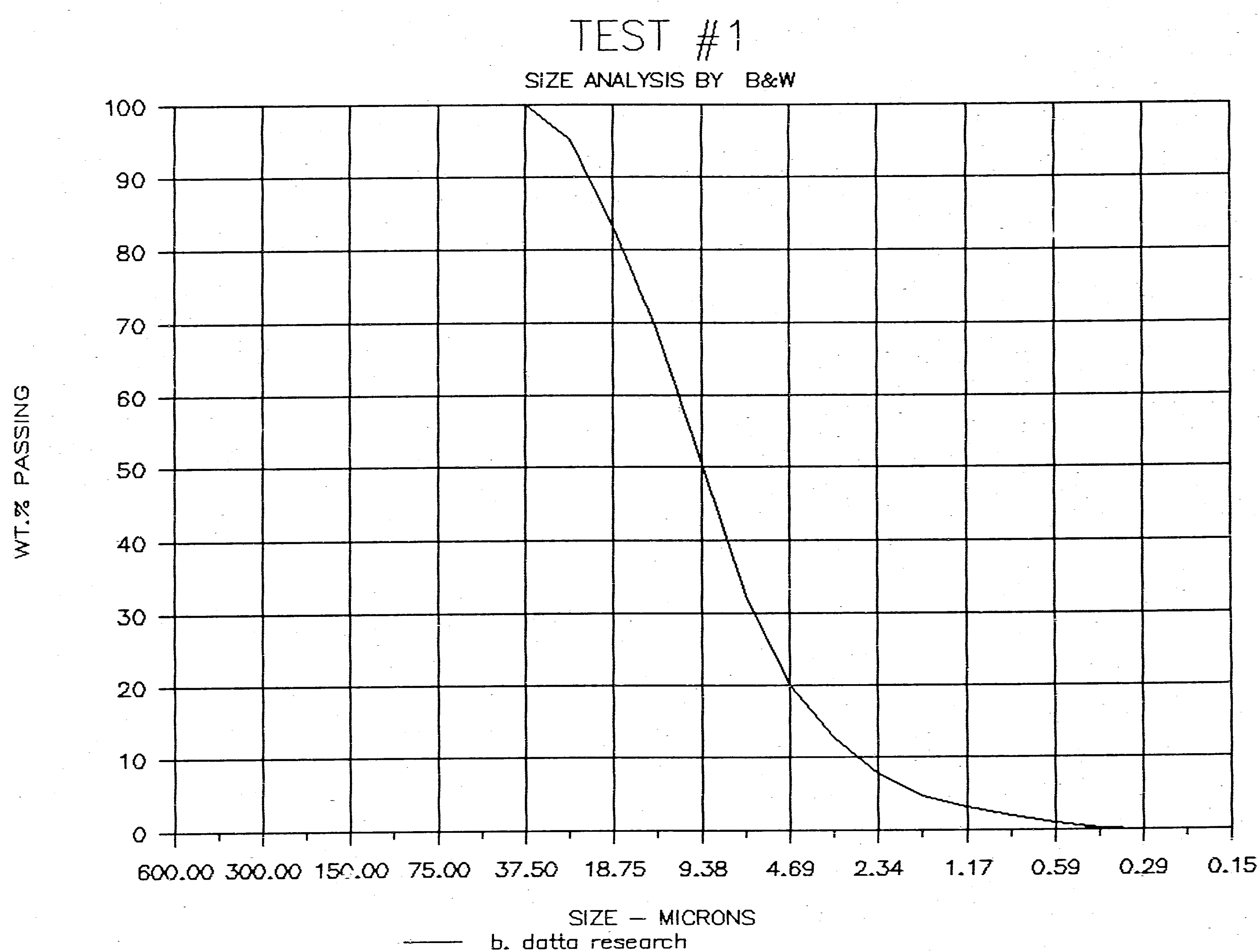
II. ESTIMATED MAINTENANCE COST

A. MAINTENANCE SUPPLIES		
EQUIPMENT	384604	
PER CENT MULTIPLIER	10.00%	
TOTAL EQUIPMENT	38460	
		TOTAL DOLLAR
TOTAL MAINTENANCE SUPPLIES	38460	
		$/YEAR
		$/YEAR
B. MAINTENANCE SUPERVISION AND LABOR		
1. SUPERVISION		
FOREMAN	1	PER YEAR
SALARY	35000	$/YEAR
BENEFITS	15750	$/YEAR
2. LABOR	1	SHIFT
CLASS A		
MECHANICS	1	PER SHIFT
WELDERS	1	PER SHIFT
ELECTRICIAN	1	PER SHIFT
TOTAL CLASS A	82800	$/YEAR
BENEFITS	45540	$/YEAR
TOTAL MAINTENANCE MANPOWER	179090	$/YEAR
TOTAL MAINTENANCE COST	217550	$/YEAR

ESTIMATED OPERATING AND MAINTENANCE COSTS

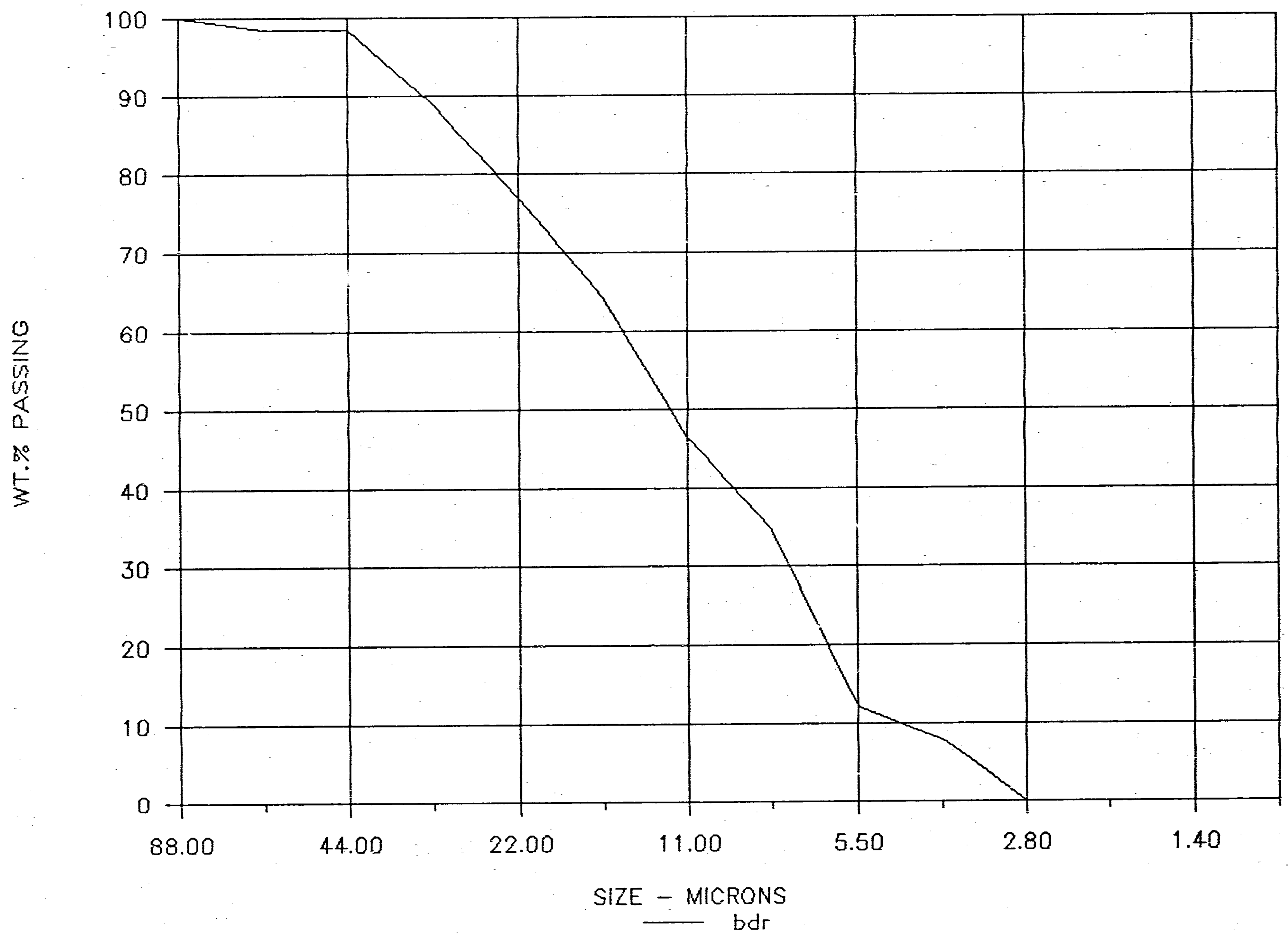
	PER YEAR	PER RAW TON	PER CLEAN TON
I. OPERATING SUPPLIES			
POWER	97166	1.480	1.654
FLOTATION REAGENTS	248341	3.783	4.227
WATER	0	0.000	0.000
LUBRICANTS	1313	0.020	0.022
TOTAL OPERATING SUPPLIES	346820	5.283	5.903
II. OPERATING SUPERVISION AND LABOR			
SUPERVISION	85000	1.295	1.447
BENEFITS	38250	0.583	0.651
LABOR	209760	3.195	3.570
BENEFITS	115368	1.757	1.964
TOTAL OPERATING MANPOWER	448378	6.830	7.632
TOTAL OPERATING COSTS	795198	12.114	13.535
III. MAINTENANCE SUPPLIES			
EQUIPMENT	38460	0.586	0.655
TOTAL MAINTENANCE SUPPLIES	38460	0.586	0.655
IV. MAINTENANCE SUPERVISION AND LABOR			
SUPERVISION	35000	0.533	0.596
BENEFITS	15750	0.240	0.268
LABOR	82800	1.261	1.409
BENEFITS	45540	0.694	0.775
TOTAL MAINTENANCE MANPOWER	179090	2.728	3.048
TOTAL MAINTENANCE COST	217550	3.314	3.703
TOTAL OPERATING & MAINTENANCE COST	1012748	15.428	17.238

B. DATTA RESEARCH


TEST #1
SIZE ANALYSIS BY B&W
WT.% PASSING
100
90
80
70
60
50
40
30
20
10
0
600.00
300.00
150.00
75.00
37.50
18.75
9.38
4.69
2.34
1.17
0.59
0.29
0.15
SIZE — MICRONS
b. datta research

TEST #4

SIZE ANALYSIS BY PARTICIPANT

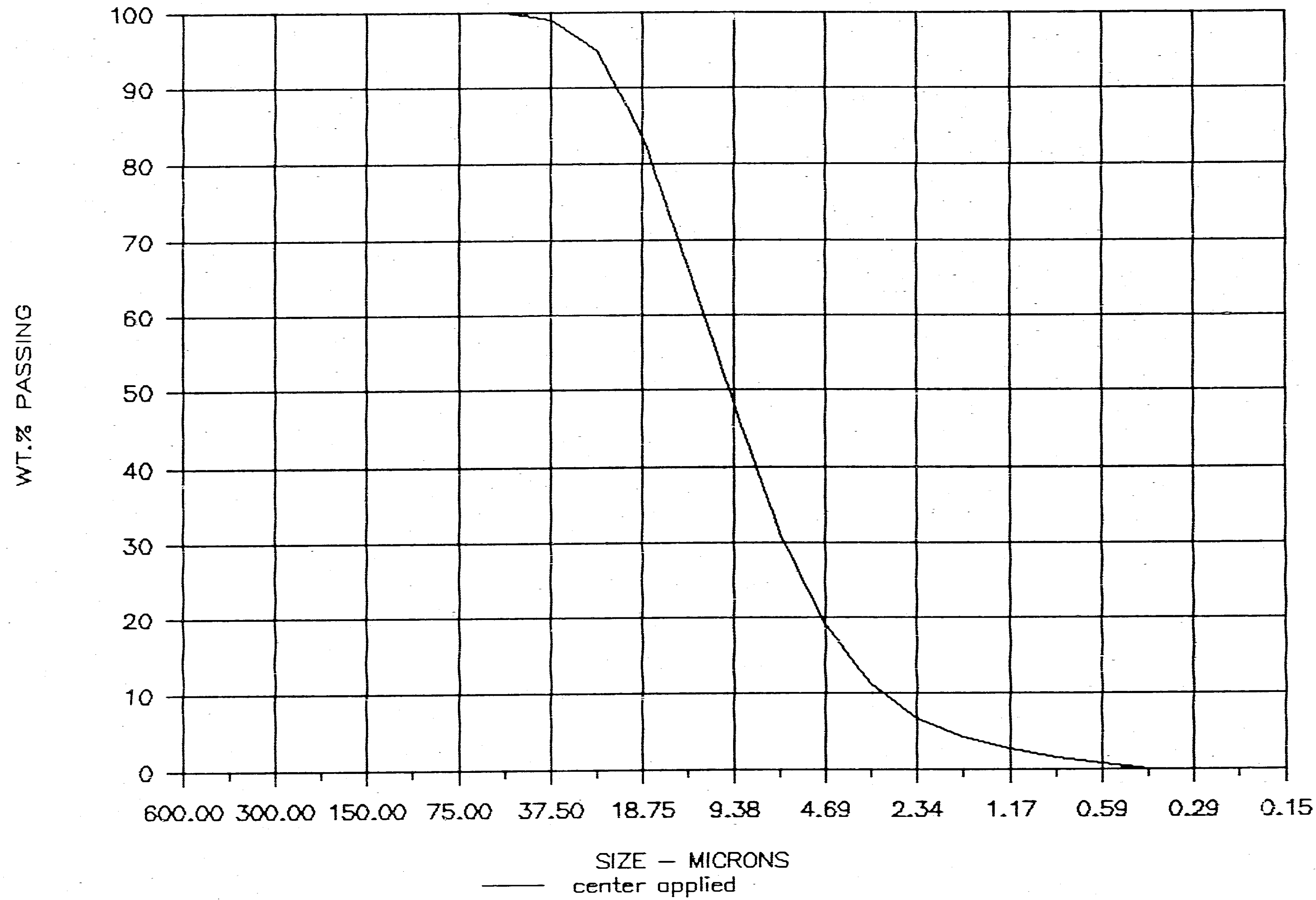


CENTER FOR APPLIED ENERGY RESEARCH

799/43JJ/051/9046

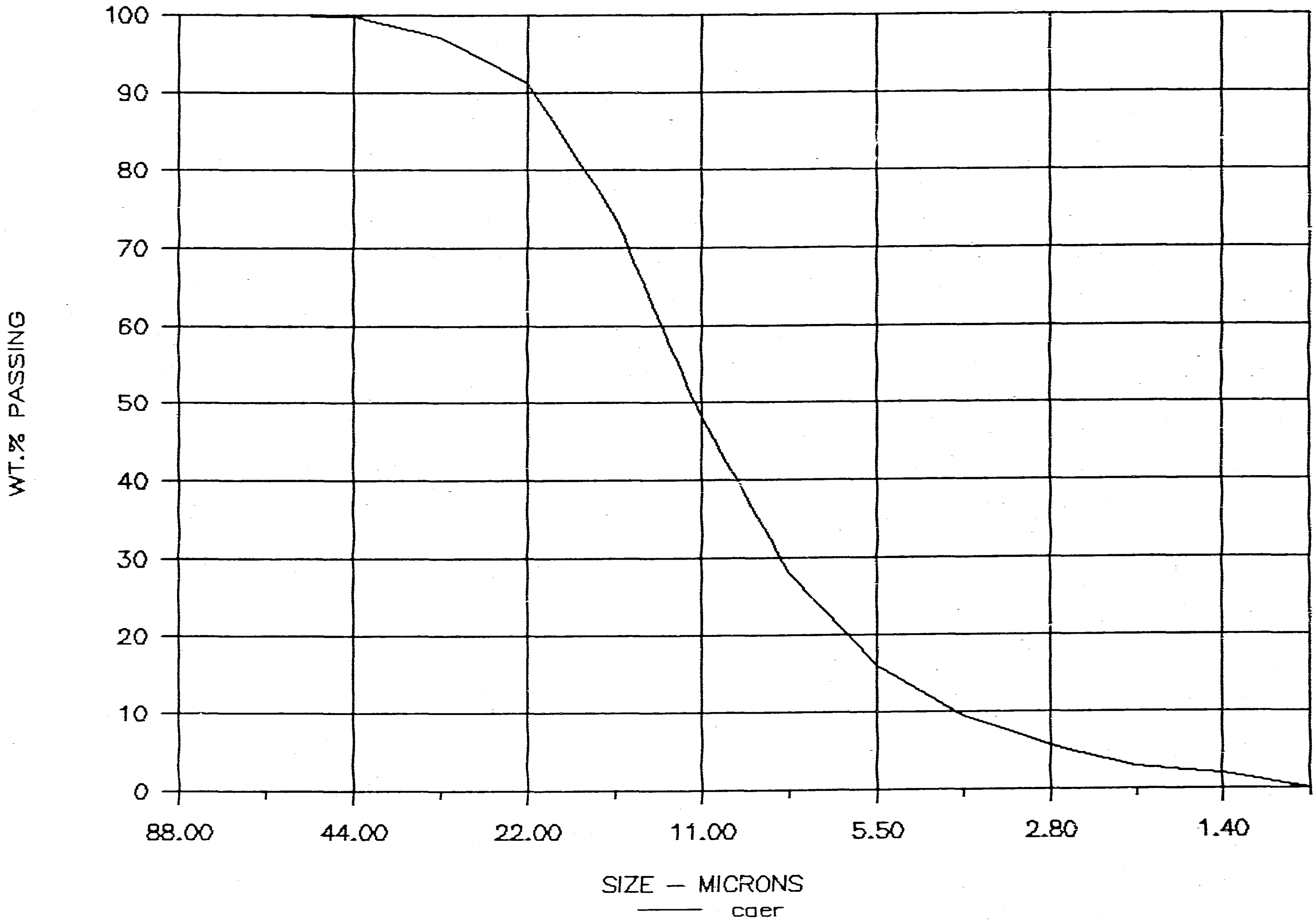
TEST #1

SIZE ANALYSIS BY B&W



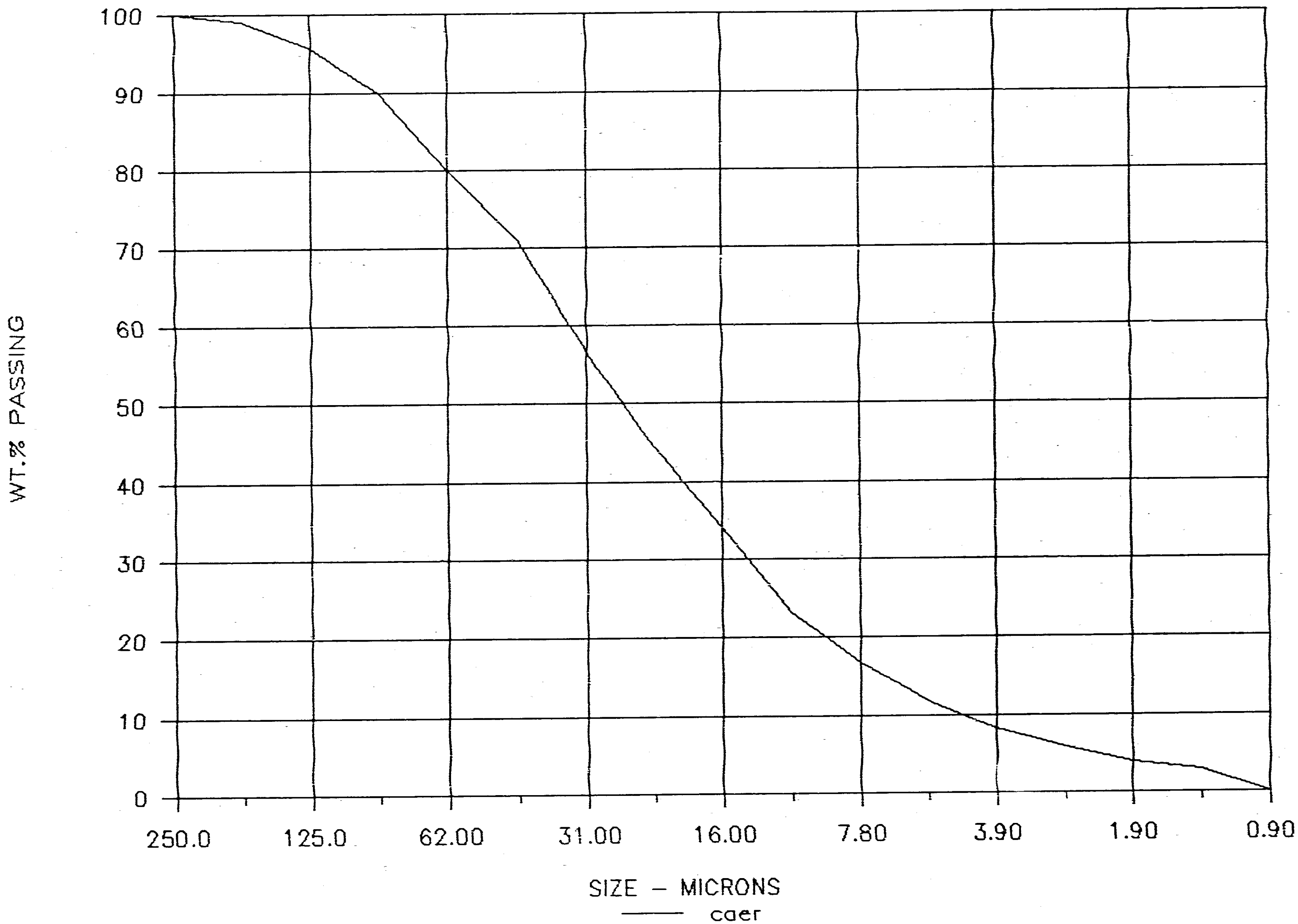
TEST #2

SIZE ANALYSIS BY PARTICIPANT



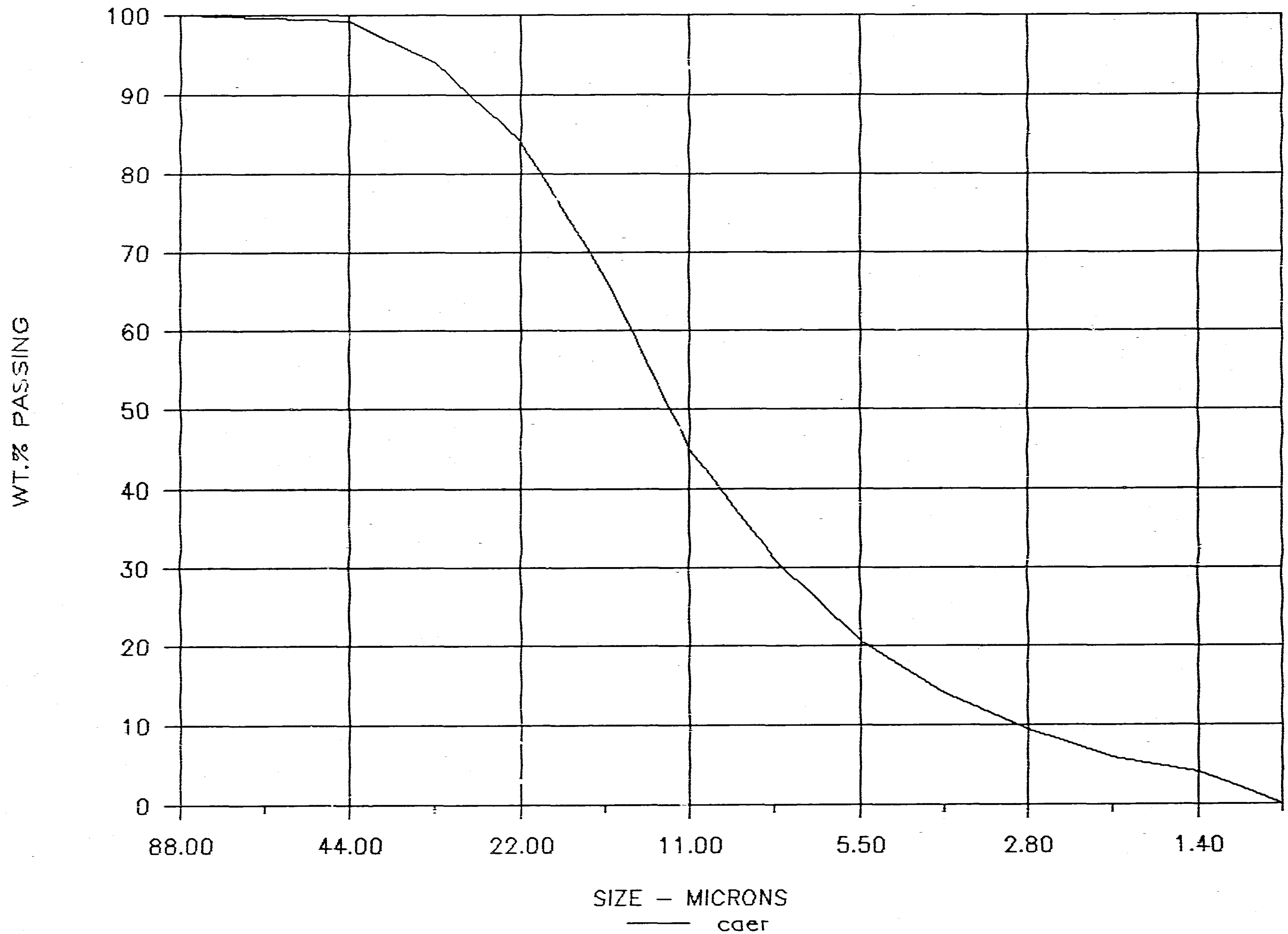
TEST #3

SIZE ANALYSIS BY PARTICIPANT



TEST #4

SIZE ANALYSIS BY PARTICIPANT



CAER ADVANCED FLOTATION PREPARATION PLANT
COAL CLEANING ECONOMICS MODEL

CLEANING PLANT	
Raw Coal Total Sulfur	4.20%
Clean Coal Total Sulfur	2.13%
Raw Coal Feed Rate	19.51 (tons/hour)
Scheduled Operating Days	230 (days/year)
Operating Shifts/Day	2 (shifts/day)
Shift Length	8.00 (hours)
Annual Scheduled Operation	3,312 (hours/year)
Mean Plant Availability	90.00%(%)
Yield	87.50%(% of raw coal)
Raw Coal Heating Value	12,347 (dry Btu/lb)
Clean Coal Heating Value	13,788 (dry Btu/lb)
Energy Recovery	97.71%(%)
Annual Raw Coal Feed	64,617 (tons/year)
Annual Clean Coal Product	56,540 (tons/year)
ECONOMIC PARAMETERS	
Design Capital Cost (Input)	$50,505 (per raw-ton/hour)
Plant Capital Cost FCOST	$985,362
Plant Life PL (Input)	20 (years, 30 years maximum)
Working Capital Allotme (Input)	3.0 (months)
Working Capital WORKCAP	$193,667
Proportion Debt D (Input)	100.0%(decimal)
Borrowed Capital DCOST	$1,179,029
Investor's Capital CAPITAL	($0)
Debt Interest Rate DC (Input)	11.00%(decimal)
Debt Loan Period DPER (Input)	20 (years)
Discounted Return (Input)	15.0%(decimal)
Income Tax Rate (all) (Input)	38.0%(decimal)
Tax Dep. Period TL (Input)	20 (years)

		Raw Coal Based	Clean Coal Based (Salable Coal)		Annual
		($/t)	($/t	($/MBtu)	($/yr)
Prep Plant Raw Coal TPY Required	64617	-	-	-	-
Raw Coal TPY Required	63147	-	-	-	-
Additional Raw Coal TPY Required	1470	$20.00	-	-	$29,400
Coal Cost		$0.00	$0.00	$0.000	$29,400
Plant O&M Cost		$11.99	$13.70	$0.497	$774,668
Refuse Disposal O&M Cost	$0.00 /ton	$0.00	$0.00	$0.000	$0
O&M Subtotal		$11.99	$13.70	$0.497	$774,668
Coal and O&M Cost		$11.99	$13.70	$0.497	$804,068
Cost of Capital		$3.09	$3.53	$0.128	$170,207
Producer's Revenue Req.		$15.08	$17.23	$0.625	$974,275
Transportation			$0.00	$0.000	$0
Delivered Cost			$17.23	$0.625	$974,275

$323 ANNUAL $/TON OF SULFUR DIOXIDE REMOVED

EQUIPMENT NO.	DESCRIPTION	QUANTITY	OPERATING QUANTITY	PRICE	HP	MOTOR SUPPLIED	COMMENTS
100	CONDITIONING/FEED SUMP	1	-	-	-	-	2500 GALLON CAPACITY
101.1	CONDITIONING/FEED SUMP MIXER	1	1	10550	30.00	YES	PHIADELPHIA MODEL 3805-S-PTO
105	FEED PUMP	1	1	13200	40.00	YES	GUYNE MODEL 5000, 80' TDH / 800 GPM
110	ROUGHER COLLECTOR REAGENT PUMP	4	4	7428	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
115	ROUGHER FROTHER REAGENT PUMP	4	4	7386	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
120	ROUGHER FLOTATION MACHINES	4	4	220000	0.00	YES	KEN-FLOTE' COLUMN FLOTATION CELL 8' DIA X 23' HIGH
120.1	ROUGHER FLOTATION BLOWER	1	1	69890	50.00	YES	AIRTEC - 500 CFM @ 50 PSIG
	TOTAL			328454	121.60		

TOTAL ESTIMATED CAPITAL COST IS BASED ON HOFFMAN-MUNTNER REPORT NO. EPA-600/7-78-124, "AN ENGINEERING/ECNOMIC ANALYSIS OF COAL PREPARATION PLANT OPERATION AND COST"

THIS REPORT STATES THAT THE CAPITAL COST OF A PREPARATION PLANT CAN BE ESTIMATED BY MULTIPLING THE EQUIPMENT COST BY 3.

TOTAL EQUIPMENT COST 328454

TOTAL PROJECT ESTIMATE 985362

OPERATING AND MAINTENANCE COSTS

OPERATING CRITERIA			
CONNECTED HORSEPOWER	122	HP	
WATER REQUIREMENTS	960.00	GPM	
PLANT FEED RATE	19.51	TPH	
PLANT RECOVERY	87.50%		
PRODUCTION RATE	17.07	TPH	
PLANT AVAILABILTY	90.00%		
UNIT SUPPLY COSTS			
ELECTRIC POWER	0.06	$/KW HR	
FROTHER - MIBC	0.61	$/#	
FROTHER - M150	0.85	$/#	
FROTHER - PINE OIL	0.63	$/#	
COLLECTOR - FUEL OIL	0.09	$/#	
COLLECTOR - KERSOSENE	0.11	$/#	
DEPRESSANT	0.00	$/#	
MAKE UP WATER	0.02	$/1000 GAL	
LUBRICANTS	0.02	PER TON RAW COAL	
SUPERINTENDENT	50000	PER YEAR	
BENEFITS	22500		0.45 TIMES SALARY
FOREMAN	35000	PER YEAR	
BENEFITS	15750		0.45 TIMES SALARY
LABOR			
CLASS A	15.00	PER HOUR	
BENEFITS	8.25		0.55 TIMES RATE
CLASS B	12.00		
BENEFITS	6.60		0.55 TIMES RATE
YEARLY OPERATING HOURS			
HOURS/SHIFT	8		
SHIFTS/DAY	2		
DAYS/YEAR	230		
HOURS/YEAR	3312		
RAW COAL/YEAR	64617		
CLEAN COAL/YEAR	56540		

FLOTATION REAGENT COSTS PER YEAR

ROUGHER			
FEED RATE	19.510	TPH	
FROTHER RATE	0.581	#/TON	MIBC
COLLECTOR RATE	2.000	#/TON	NO. 2 FUEL OIL
DEPRESSANT RATE	0.000	#/TON	
CLEANER			
FEED RATE	N/A	TPH	
FROTHER RATE	N/A	#/TON	
COLLECTOR RATE	N/A	#/TON	
DEPRESSANT RATE	N/A	#/TON	
RECLEANER			
FEED RATE	N/A	TPH	
FROTHER RATE	N/A	#/TON	
COLLECTOR RATE	N/A	#/TON	
DEPRESSANT RATE	N/A	#/TON	
TOTAL FROTHER	22901	$/YEAR	
TOTAL COLLECTOR	11373	$/YEAR	
TOTAL DEPRESSANT	0	$/YEAR	
TOTAL FLOTATION COST	34274	$/YEAR	

I. ESTIMATED OPERATING COSTS

A. OPERATING SUPPLIES

1. POWER		
DIVERSITY	0.80	FACTOR
CONNECTED HP	121.60	KWH
HEAT AND LIGHT	350.00	KWH
POWER COST	74973	$/YEAR
ASSUME 1HP-1KVA=1KWH		
2. FLOTATION REAGENT COST	34274	$/YEAR
3. WATER COST	3815	$/YEAR
4. LUBRICANTS	1292	$/YEAR
TOTAL OPERATING SUPPLIES	114354	$/YEAR
B. OPERATING MANPOWER		
1. SUPERVISION		
SUPERINTENDENT	1	PER YEAR
SALARY	50000	$/YEAR
BENEFITS	22500	$/YEAR
FOREMAN	1	PER YEAR
SALARY	35000	$/YEAR
BENEFITS	15750	$/YEAR
2. LABOR		PER SHIFT
CLASS A		
PLANT OPERATER	1	PER SHIFT
EQUIPMENT OPERATOR	1	PER SHIFT
MECHANIC-ELECTRIAN	1	PER SHIFT
TOTAL CLASS A	165600	$/YEAR
BENEFITS	91080	$/YEAR
CLASS B		
UTILITY	1	PER SHIFT
TOTAL CLASS B	44160	$/YEAR
BENEFITS	24288	$/YEAR
TOTAL OPERATING MANPOWER	448378	$/YEAR
TOTAL OPERATING COST	562732	$/YEAR

11. ESTIMATED MAINTENANCE COST

A. MAINTENANCE SUPPLIES		
EQUIPMENT	328454	
PER CENT MULTIPLIER	10.00%	
TOTAL EQUIPMENT	32845	
		TOTAL DOLLAR
TOTAL MAINTENANCE SUPPLIES	32845	
		$/YEAR
		$/YEAR
B. MAINTENANCE SUPERVISION AND LABOR		
1. SUPERVISION		
FOREMAN	1	PER YEAR
SALARY	35000	$/YEAR
BENEFITS	15750	$/YEAR
2. LABOR	1	SHIFT
CLASS A		
MECHANICS	1	PER SHIFT
WELDERS	1	PER SHIFT
ELECTRICIAN	1	PER SHIFT
TOTAL CLASS A	82800	$/YEAR
BENEFITS	45540	$/YEAR
TOTAL MAINTENANCE MANPOWER	179090	$/YEAR
TOTAL MAINTENANCE COST	211935	$/YEAR

ESTIMATED OPERATING AND MAINTENANCE COSTS

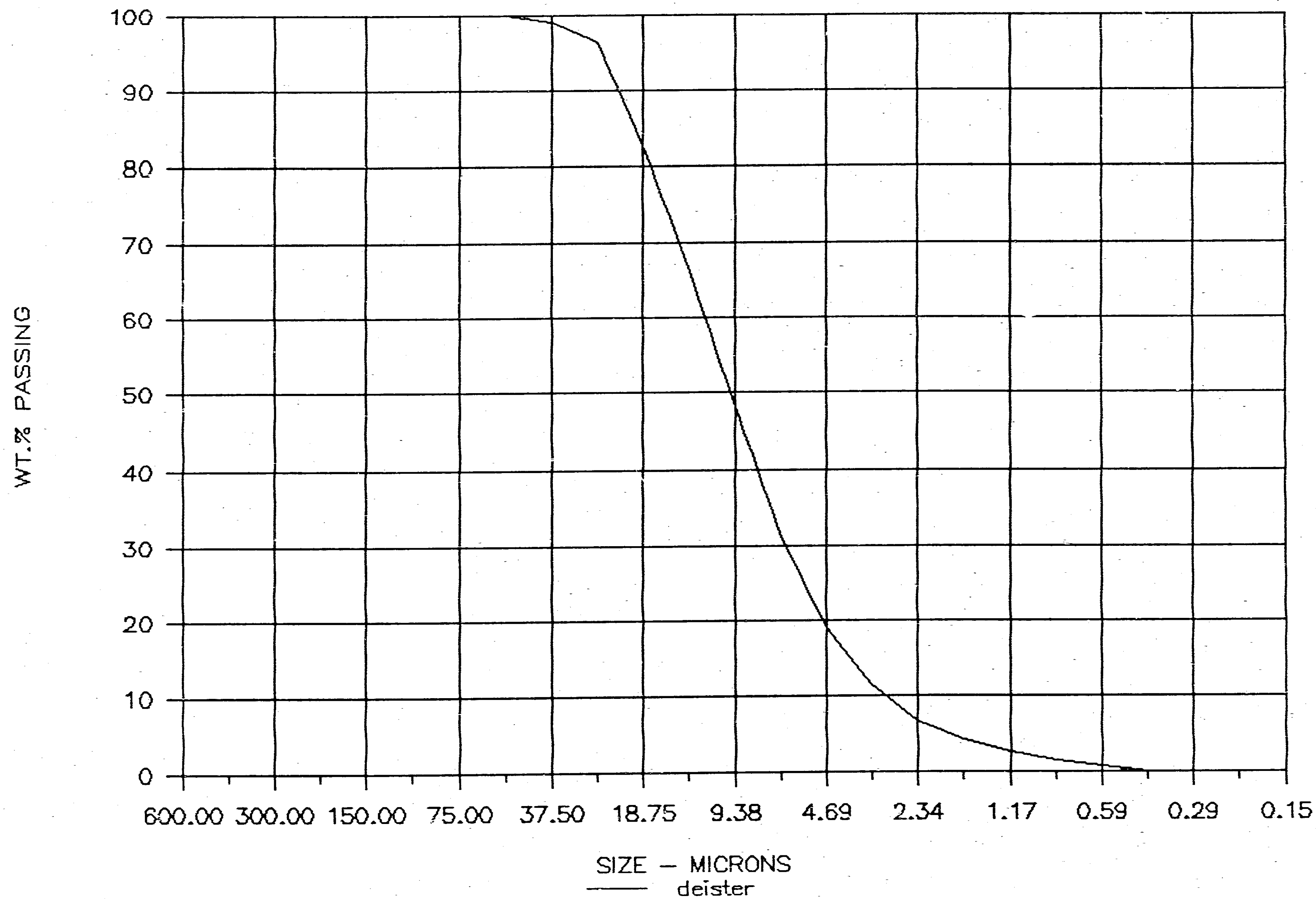
	PER YEAR	PER RAW TON	PER CLEAN TON
I. OPERATING SUPPLIES			
POWER	74973	1.160	1.326
FLOTATION REAGENTS	34274	0.530	0.606
WATER	3815	0.059	0.067
LUBRICANTS	1292	0.020	0.023
TOTAL OPERATING SUPPLIES	114354	1.770	2.023
II. OPERATING SUPERVISION AND LABOR			
SUPERVISION	85000	1.315	1.503
BENEFITS	38250	0.592	0.677
LABOR	209760	3.246	3.710
BENEFITS	115368	1.785	2.040
TOTAL OPERATING MANPOWER	448378	6.939	7.930
TOTAL OPERATING COSTS	562732	8.709	9.953
III. MAINTENANCE SUPPLIES			
EQUIPMENT	32845	0.508	0.581
TOTAL MAINTENANCE SUPPLIES	32845	0.508	0.581
IV. MAINTENANCE SUPERVISION AND LABOR			
SUPERVISION	35000	0.542	0.619
BENEFITS	15750	0.244	0.279
LABOR	82800	1.281	1.464
BENEFITS	45540	0.705	0.805
TOTAL MAINTENANCE MANPOWER	179090	2.772	3.167
TOTAL MAINTENANCE COST	211935	3.280	3.748
TOTAL OPERATING & MAINTENANCE COST	774668	11.989	13.701

DEISTER CONCENTRATOR COMPANY, INC.

799/43JJ/051/9041

TEST #1

SIZE ANALYSIS BY B&W



DCCI ADVANCED FLOTATION PREPARATION PLANT
COAL CLEANING ECONOMICS MODEL

CLEANING PLANT		
Raw Coal Total Sulfur	3.93%	
Clean Coal Total Sulfur	2.35%	
Raw Coal Feed Rate	20.20	(tons/hour)
Scheduled Operating Days	230	(days/year)
Operating Shifts/Day	2	(shifts/day)
Shift Length	8.00	(hours)
Annual Scheduled Operation	3,312	(hours/year)
Mean Plant Availability	90.00%	(%)
Yield	85.60%	(% of raw coal)
Raw Coal Heating Value	12,317	(dry Btu/lb)
Clean Coal Heating Value	13,614	(dry Btu/lb)
Energy Recovery	94.61%	(%)
Annual Raw Coal Feed	66,902	(tons/year)
Annual Clean Coal Product	57,268	(tons/year)
ECONOMIC PARAMETERS		
Design Capital Cost (Input)	$51,751	(per raw-ton/hour)
Plant Capital Cost PCOST	$1,045,362	
Plant Life PL (Input)	20	(years, 30 years maximum)
Working Capital Allotme (Input)	3.0	(months)
Working Capital WORKCAP	$211,683	
Proportion Debt D (Input)	100.0%	(decimal)
Borrowed Capital DCOST	$1,257,045	
Investor's Capital CAPITAL	$0	
Debt Interest Rate DC (Input)	11.00%	(decimal)
Debt Loan Period DPER (Input)	20	(years)
Discounted Return (Input)	15.0%	(decimal)
Income Tax Rate (all) (Input)	38.0%	(decimal)
Tax Dep. Period TL (Input)	20	(years)

		Raw Coal Based	Clean Coal Based (Salable Coal)		Annual
		($/t)	($/t	($/MBtu)	($/yr)
Prep Plant Raw Coal TPY Required	66902	-	-	-	-
Raw Coal TPY Required	63296	-	-	-	-
Additional Raw Coal TPY Required	3606	$20.00	-	-	$72,128
Coal Cost		$0.00	$0.00	$0.000	$72,128
Plant O&M Cost		$12.66	$14.79	$0.543	$846,734
Refuse Disposal O&M Cost	$0.00 /ton	$0.00	$0.00	$0.000	$0
O&M Subtotal		$12.66	$14.79	$0.543	$846,734
Coal and O&M Cost		$12.66	$14.79	$0.543	$918,862
Cost of Capital		$3.79	$4.43	$0.163	$181,393
Producer's Revenue Req.		$16.45	$19.21	$0.706	$1,100,255
Transportation			$0.00	$0.000	$0
Delivered Cost			$19.21	$0.706	$1,100,255

$429 ANNUAL $/TON OF SULFUR DIOXIDE REMOVED

EQUIPMENT NO.	DESCRIPTION	QUANTITY	OPERATING QUANTITY	PRICE	HP	MOTOR SUPPLIED	COMMENTS
100	CONDITIONING/FEED SUMP	1	-	-	-	-	2500 GALLON CAPACITY
101.1	CONDITIONING/FEED SUMP MIXER	1	1	10550	30.00	YES	PHIADELPHIA MODEL 3805-S-PTO
105	FEED PUMP	1	1	13200	40.00	YES	GUYNE MODEL 5000, 80' TDH / 800 GPM
110	ROUGHER COLLECTOR REAGENT PUMP	4	4	7428	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
115	ROUGHER FROTHER REAGENT PUMP	4	4	7386	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
120	ROUGHER FLOTATION MACHINES	4	4	240000	15.00	YES	FLOTAIRE MODEL FL8024 8' DIA X 24' HIGH
120.1	ROUGHER FLOTATION BLOWER	1	1	69890	50.00	YES	AIRTEC - 500 CFM @ 50 PSIG
	TOTAL			348454	181.60		

TOTAL ESTIMATED CAPITAL COST IS BASED ON HOFFMAN-MUNTNER REPORT NO. EPA-600/7-78-124, "AN ENGINEERING/ECONOMIC ANALYSIS OF COAL PREPARATION PLANT OPERATION AND COST"

THIS REPORT STATES THAT THE CAPITAL COST OF A PREPARATION PLANT CAN BE ESTIMATED BY MULTIPLING THE EQUIPMENT COST BY 3.

TOTAL EQUIPMENT COST 348454

TOTAL PROJECT ESTIMATE 1045362

OPERATING AND MAINTENANCE COSTS

OPERATING CRITERIA			
CONNECTED HORSEPOWER	182	HP	
WATER REQUIREMENTS	1520.00	GPM	
PLANT FEED RATE	20.20	TPH	
PLANT RECOVERY	85.60%		
PRODUCTION RATE	17.29	TPH	
PLANT AVAILABILTY	90.00%		
UNIT SUPPLY COSTS			
ELECTRIC POWER	0.06	$/KW HR	
FROTHER - MIBC	0.61	$/#	
FROTHER - M150	0.85	$/#	
FROTHER - PINE OIL	0.63	$/#	
COLLECTOR - FUEL OIL	0.09	$/#	
COLLECTOR - KERSOSENE	0.11	$/#	
DEPRESSANT	0.00	$/#	
MAKE UP WATER	0.02	$/1000 GAL	
LUBRICANTS	0.02	PER TON RAW COAL	
SUPERINTENDENT	50000	PER YEAR	
BENEFITS	22500		0.45 TIMES SALARY
FOREMAN	35000	PER YEAR	
BENEFITS	15750		0.45 TIMES SALARY
LABOR			
CLASS A	15.00	PER HOUR	
BENEFITS	8.25		0.55 TIMES RATE
CLASS B	12.00		
BENEFITS	6.60		0.55 TIMES RATE
YEARLY OPERATING HOURS			
HOURS/SHIFT	8		
SHIFTS/DAY	2		
DAYS/YEAR	230		
HOURS/YEAR	3312		
RAW COAL/YEAR	66902		
CLEAN COAL/YEAR	57268		

FLOTATION REAGENT COSTS PER YEAR

ROUGHER			
FEED RATE	20.20	TPH	
FROTHER RATE	1.253	#/TON	M150
COLLECTOR RATE	3.00	#/TON	KEROSENE
DEPRESSANT RATE	0.00	#/TON	
CLEANER			
FEED RATE	N/A	TPH	
FROTHER RATE	N/A	#/TON	
COLLECTOR RATE	N/A	#/TON	
DEPRESSANT RATE	N/A	#/TON	
RECLEANER			
FEED RATE	N/A	TPH	
FROTHER RATE	N/A	#/TON	
COLLECTOR RATE	N/A	#/TON	
DEPRESSANT RATE	N/A	#/TON	
TOTAL FROTHER	71254	$/YEAR	
TOTAL COLLECTOR	21275	$/YEAR	
TOTAL DEPRESSANT	0	$/YEAR	
TOTAL FLOTATION COST	92529	$/YEAR	

I. ESTIMATED OPERATING COSTS

A. OPERATING SUPPLIES

1. POWER		
DIVERSITY	0.80	FACTOR
CONNECTED HP	181.60	KWH
HEAT AND LIGHT	350.00	KWH
POWER COST	84512	$/YEAR
ASSUME 1HP=1KVA=1KWH		
2. FLOTATION REAGENT COST	92529	$/YEAR
3. WATER COST	6041	$/YEAR
4. LUBRICANTS	1338	$/YEAR
TOTAL OPERATING SUPPLIES	184420	$/YEAR

B. OPERATING MANPOWER

1. SUPERVISION		
SUPERINTENDENT	1	PER YEAR
SALARY	50000	$/YEAR
BENEFITS	22500	$/YEAR
FOREMAN	1	PER YEAR
SALARY	35000	$/YEAR
BENEFITS	15750	$/YEAR
2. LABOR		PER SHIFT
CLASS A		
PLANT OPERATER	1	PER SHIFT
EQUIPMENT OPERATOR	1	PER SHIFT
MECHANIC-ELECTRIAN	1	PER SHIFT
TOTAL CLASS A	165600	$/YEAR
BENEFITS	91080	$/YEAR
CLASS B		
UTILITY	1	PER SHIFT
TOTAL CLASS B	44160	$/YEAR
BENEFITS	24288	$/YEAR
TOTAL OPERATING MANPOWER	448378	$/YEAR
TOTAL OPERATING COST	632798	$/YEAR

II. ESTIMATED MAINTENANCE COST

A. MAINTENANCE SUPPLIES		
EQUIPMENT	348454	
PER CENT MULTIPLIER	10.00%	
TOTAL EQUIPMENT	34845	
		TOTAL DOLLAR
TOTAL MAINTENANCE SUPPLIES	34845	
		$/YEAR
		$/YEAR
B. MAINTENANCE SUPERVISION AND LABOR		
1. SUPERVISION		
FOREMAN	1	PER YEAR
SALARY	35000	$/YEAR
BENEFITS	15750	$/YEAR
2. LABOR	1	SHIFT
CLASS A		
MECHANICS	1	PER SHIFT
WELDERS	1	PER SHIFT
ELECTRICIAN	1	PER SHIFT
TOTAL CLASS A	82800	$/YEAR
BENEFITS	45540	$/YEAR
TOTAL MAINTENANCE MANPOWER	179090	$/YEAR
TOTAL MAINTENANCE COST	213935	$/YEAR

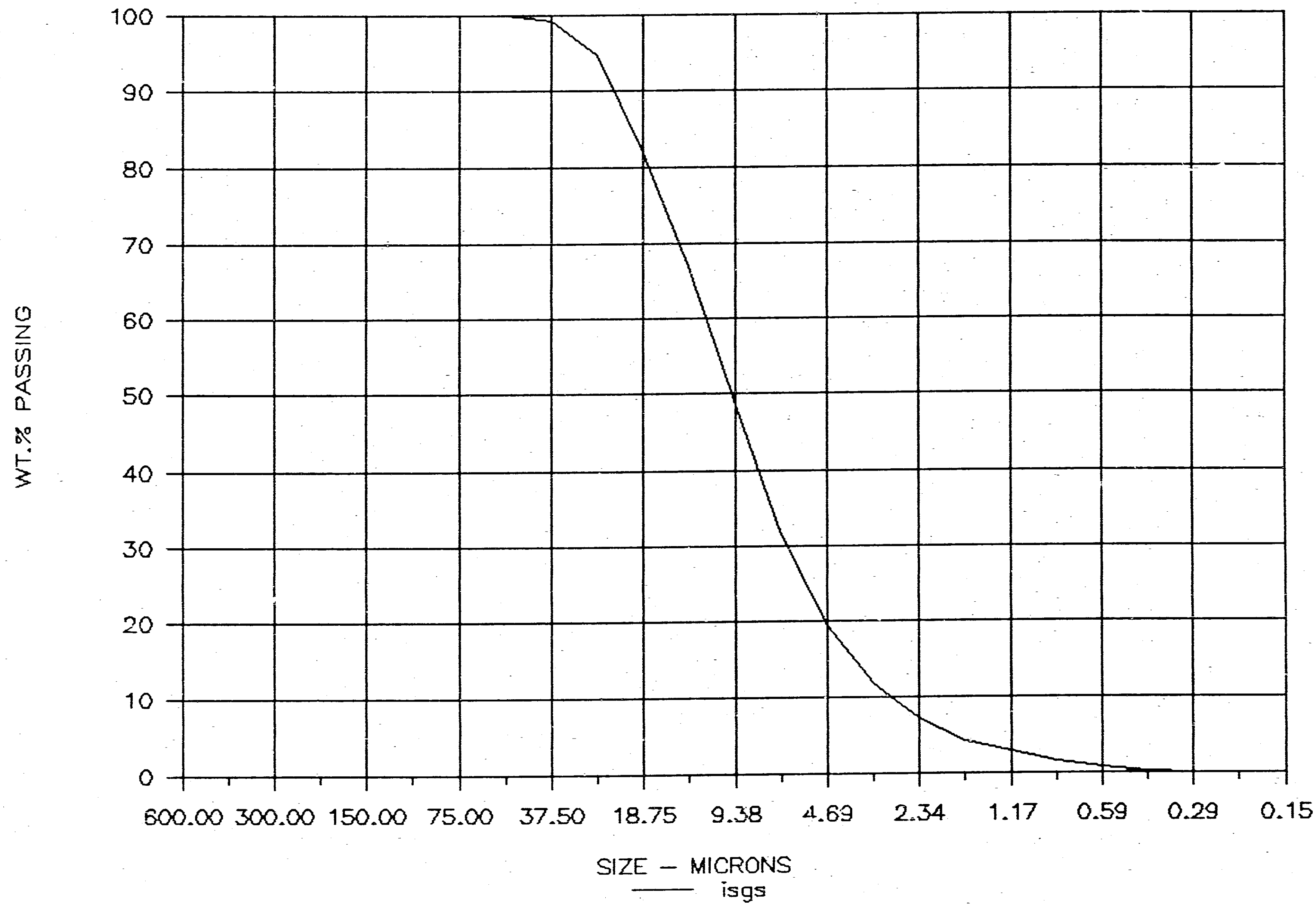
ESTIMATED OPERATING AND MAINTENANCE COSTS

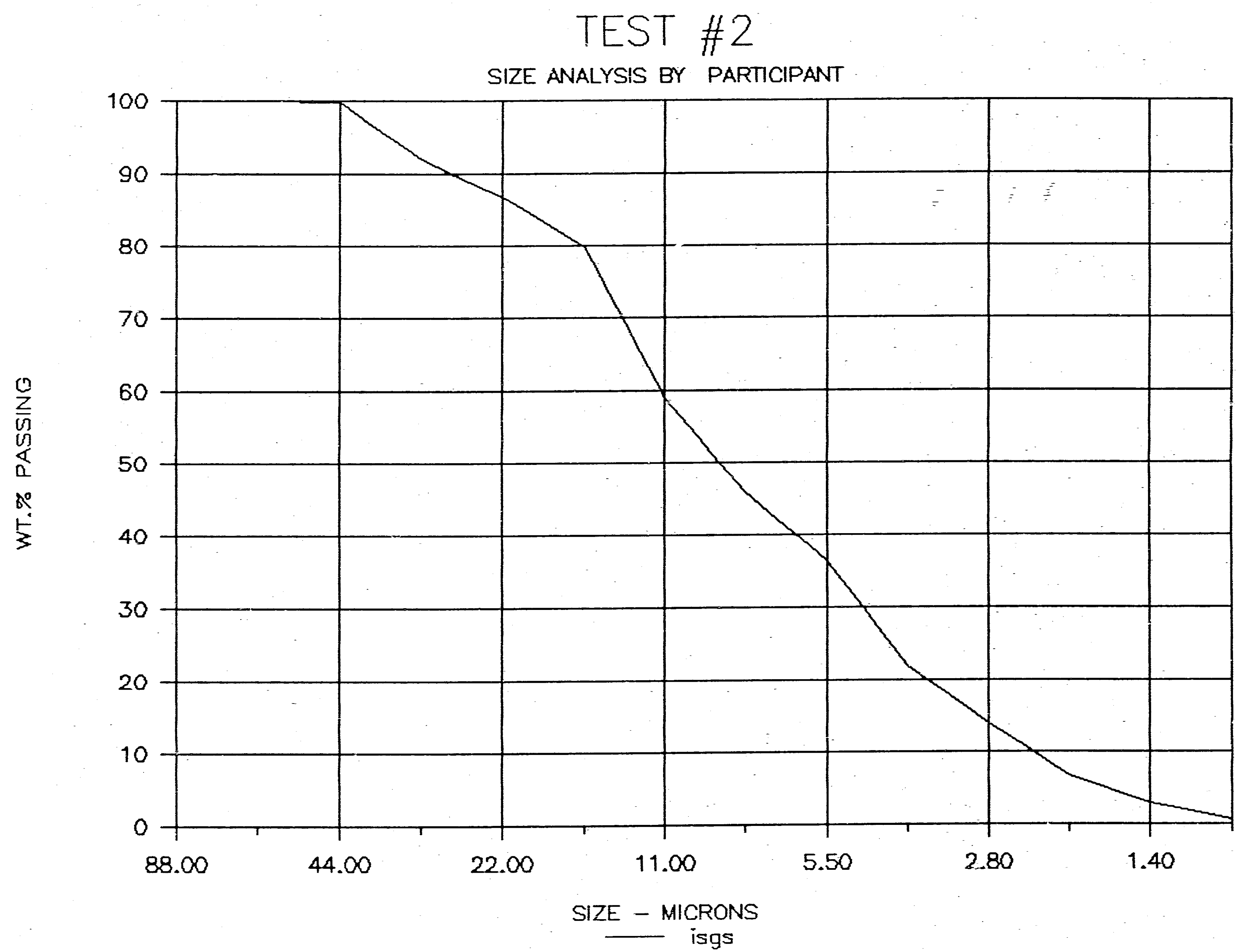
	PER YEAR	PER RAW TON	PER CLEAN TON
I. OPERATING SUPPLIES			
POWER	84512	1.263	1.476
FLOTATION REAGENTS	92529	1.383	1.616
WATER	6041	0.090	0.105
LUBRICANTS	1338	0.020	0.023
TOTAL OPERATING SUPPLIES	184420	2.757	3.220
II. OPERATING SUPERVISION AND LABOR			
SUPERVISION	85000	1.271	1.484
BENEFITS	38250	0.572	0.668
LABOR	209760	3.135	3.663
BENEFITS	115368	1.724	2.015
TOTAL OPERATING MANPOWER	448378	6.702	7.829
TOTAL OPERATING COSTS	632798	9.459	11.050
III. MAINTENANCE SUPPLIES			
EQUIPMENT	34845	0.521	0.608
TOTAL MAINTENANCE SUPPLIES	34845	0.521	0.608
IV. MAINTENANCE SUPERVISION AND LABOR			
SUPERVISION	35000	0.523	0.611
BENEFITS	15750	0.235	0.275
LABOR	82800	1.238	1.446
BENEFITS	45540	0.681	0.795
TOTAL MAINTENANCE MANPOWER	179090	2.677	3.127
TOTAL MAINTENANCE COST	213935	3.198	3.736
TOTAL OPERATING & MAINTENANCE COST	846734	12.656	14.785

ILLINOIS STATE GEOLOGICAL SURVEY

TEST #1

SIZE ANALYSIS BY B&W

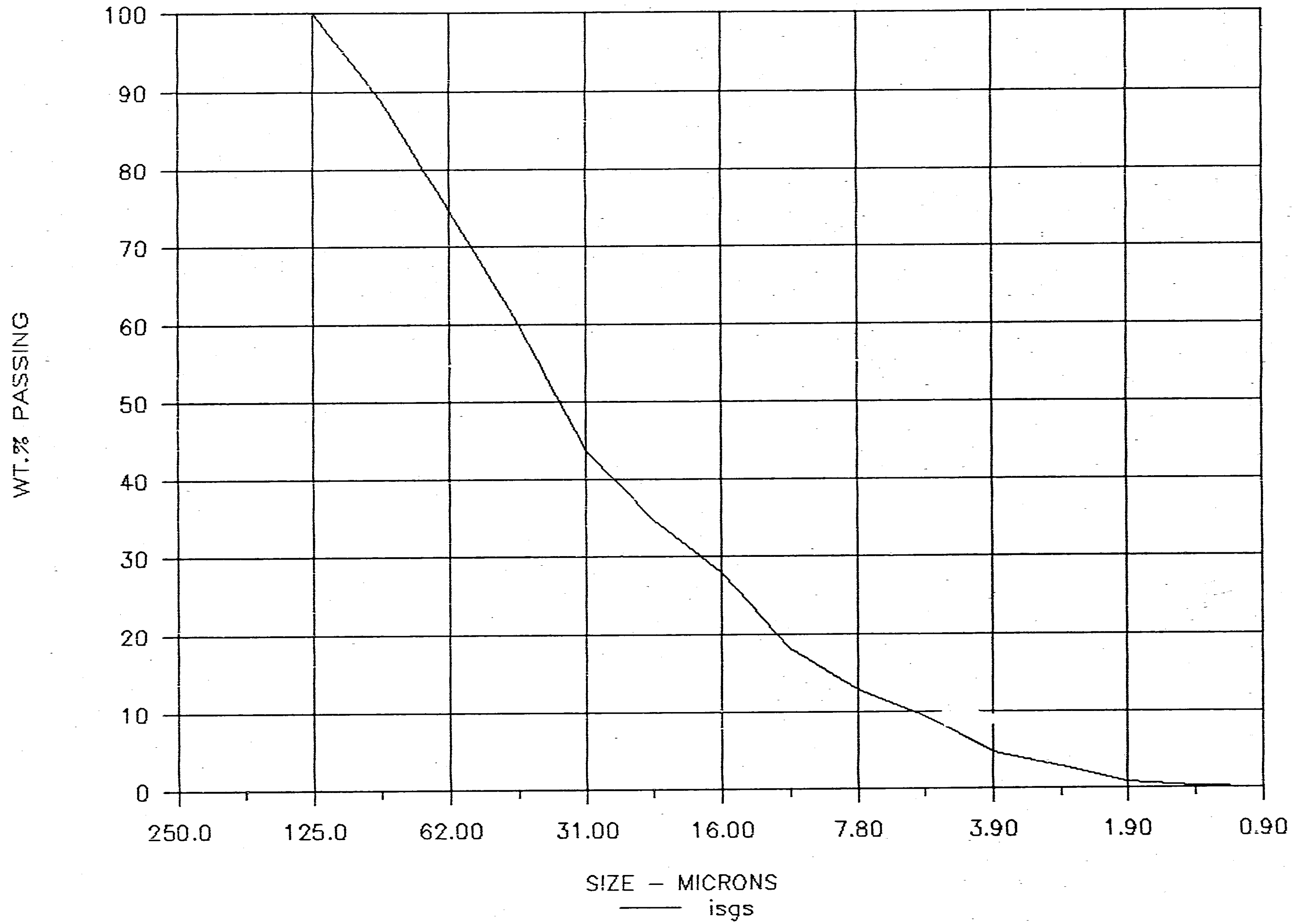




TEST #2
SIZE ANALYSIS BY PARTICIPANT
100
90
80
70
60
50
40
30
20
10
0
WT.% PASSING
88.00
44.00
22.00
11.00
5.50
2.80
1.40
SIZE – MICRONS
isgs

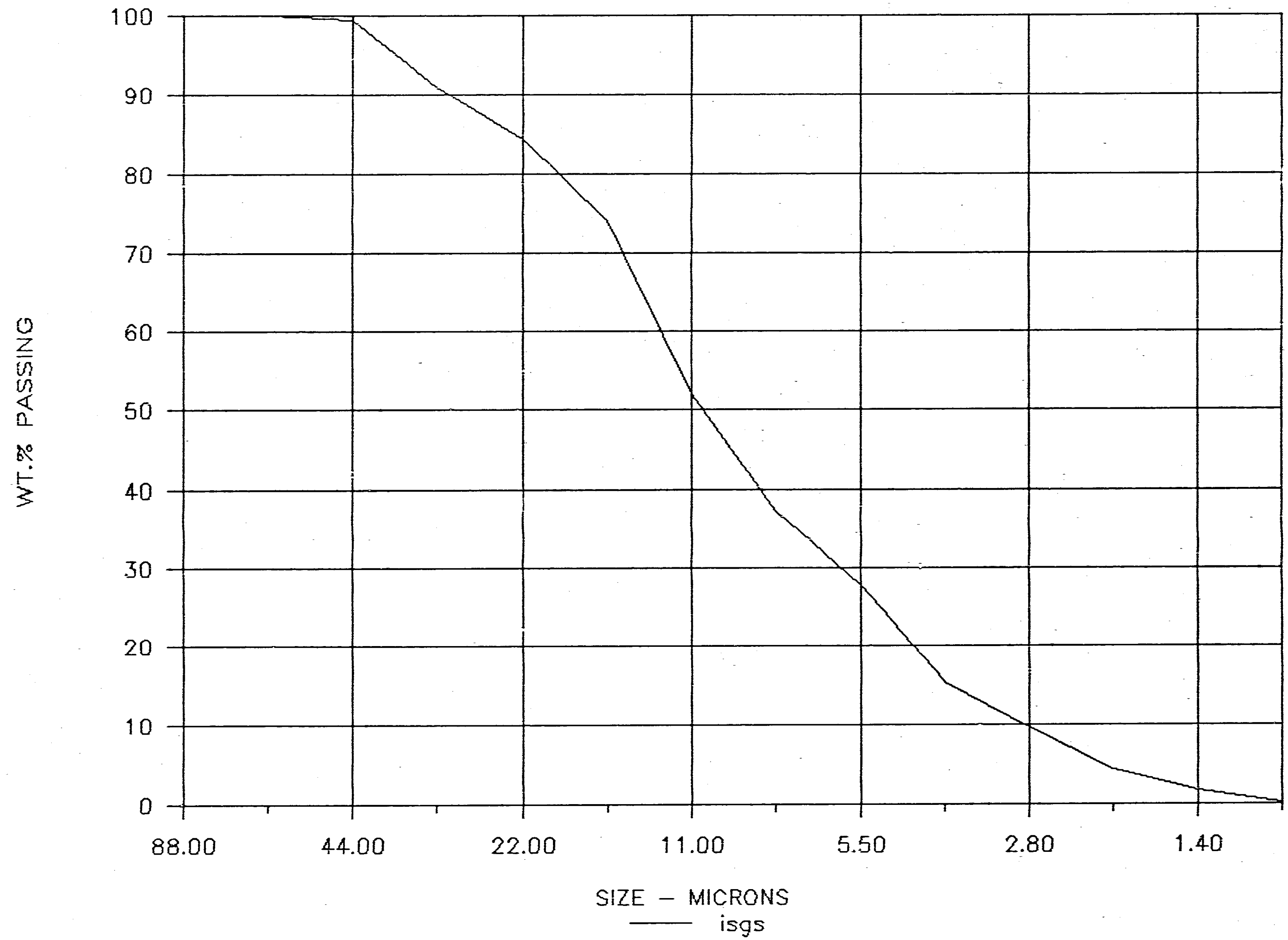
TEST #3

SIZE ANALYSIS BY PARTICIPANT



TEST #4

SIZE ANALYSIS BY PARTICIPANT



UC@B

ISGS ADVANCED FLOTATION PREPARATION PLANT
COAL CLEANING ECONOMICS MODEL

CLEANING PLANT		
Raw Coal Total Sulfur		3.92%
Clean Coal Total Sulfur		1.99%
Raw Coal Feed Rate		19.96 (tons/hour)
Scheduled Operating Days		230 (days/year)
Operating Shifts/Day		2 (shifts/day)
Shift Length		8.00 (hours)
Annual Scheduled Operation		3,312 (hours/year)
Mean Plant Availability		90.00%(%)
Yield		84.50%(% of raw coal)
Raw Coal Heating Value		12,331 (dry Btu/lb)
Clean Coal Heating Value		13,809 (dry Btu/lb)
Energy Recovery		94.63%(%)
Annual Raw Coal Feed		66,108 (tons/year)
Annual Clean Coal Product		55,861 (tons/year)
ECONOMIC PARAMETERS		
Design Capital Cost	(Input)	$36,991 (per raw-ton/hour)
Plant Capital Cost	PCOST	$738,333
Plant Life	PL (Input)	20 (years, 30 years maximum)
Working Capital Allotme	(Input)	3.0 (months)
Working Capital	WORKCAP	$240,787
Proportion Debt	D (Input)	100.0%(decimal)
Borrowed Capital	DCOST	$979,120
Investor's Capital	CAPITAL	($0)
Debt Interest Rate	DC (Input)	11.00%(decimal)
Debt Loan Period	DPER (Input)	20 (years)
Discounted Return	(Input)	15.0%(decimal)
Income Tax Rate (all)	(Input)	38.0%(decimal)
Tax Dep. Period	TL (Input)	20 (years)

		Raw Coal Based ($/t)	Clean Coal Based (Salable Coal) ($/t	($/MBtu)	Annual ($/yr)
Prep Plant Raw Coal TPY Required	66108	-	-	-	
Raw Coal TPY Required	63223	-	-	-	
Additional Raw coal TPY Required	2885	$20.00	-	-	$57,690
Coal Cost		$0.00	$0.00	$0.000	$57,690
Plant O&M Cost		$14.57	$17.24	$0.624	$963,147
Refuse Disposal O&M Cost	$0.00 /ton	$0.00	$0.00	$0.000	$0
O&M Subtotal		$14.57	$17.24	$0.624	$963,147
Coal and O&M Cost		$14.57	$17.24	$0.624	$1,020,838
Cost of Capital		$2.99	$2.54	$0.128	$140,175
Producer's Revenue Req.		$17.56	$20.78	$0.753	$1,161,012
Transportation			$0.00	$0.000	$0
Delivered Cost			$20.78	$0.753	$1,161,012

$392 ANNUAL $/TON OF SULFUR DIOXIDE REMOVED

0088

EQUIPMENT NO.	DESCRIPTION	QUANTITY	OPERATING QUANTITY	PRICE	HP	MOTOR SUPPLIED	COMMENTS
100	CONDITIONING/FEED SUMP	1	-				2500 GALLON CAPACITY
101.1	CONDITIONING/FEED SUMP MIXER	1	1	10550	30.00	YES	PHILADELPHIA MODEL 3805-S-PTO
105	FEED PUMP	1	1	13200	40.00	YES	GOYNE MODEL 5000, 80' TDH / 800 GPM
110	ROUGHER COLLECTOR REAGENT PUMP	1	1	2476	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
115	ROUGHER FROTHER REAGENT PUMP	1	1	2462	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
120	ROUGHER FLOTATION MACHINES	1	4	70833	15.00	YES	DENVER 180 CU. FT. - 4 CELLS BANK
120.1	ROUGHER FLOTATION BLOWER	1	1	-	20.00	YES	INCLUDED WITH FROTH CELLS
125	CLEANER FLOTATION MACHINES	1	4	70833	15.00	YES	DENVER 180 CU. FT. - 4 CELLS BANK
125.1	CLEANER FLOTATION BLOWER	1	1	-	20.00	YES	INCLUDED WITH FROTH CELLS
130	CLEANER FROTHER REAGENT PUMP	1	1	2462	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
135	RECLEANER FLOTATION MACHINES	1	4	70833	15.00	YES	DENVER 180 CU. FT. - 4 CELLS BANK
135.1	RECLEANER FLOTATION BLOWER	1	1	-	20.00	YES	INCLUDED WITH FROTH CELLS
140	RECLEANER FROTHER REAGENT PUMP	1	1	2462	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
	TOTAL			246111	310.80		

TOTAL ESTIMATED CAPITAL COST IS BASED ON HOFFMAN-MUNTNER REPORT NO. EPA-600/7-78-124, "AN ENGINEERING/ECNOMIC ANALYSIS OF COAL PREPARATION PLANT OPERATION AND COST"

THIS REPORT STATES THAT THE CAPITAL COST OF A PREPARATION PLANT CAN BE ESTIMATED BY MULTIPLING THE EQUIPMENT COST BY 3.

TOTAL EQUIPMENT COST	246111
TOTAL PROJECT ESTIMATE	738333

OPERATING AND MAINTENANCE COSTS

OPERATING CRITERIA		
CONNECTED HORSEPOWER	311	HP
WATER REQUIREMENTS	0.00	GPM
PLANT FEED RATE	19.96	TPH
PLANT RECOVERY	84.50%	
PRODUCTION RATE	16.87	TPH
PLANT AVAILABILTY	90.00%	
UNIT SUPPLY COSTS		
ELECTRIC POWER	0.06	$/KW HR
FROTHER - MIBC	0.61	$/#
FROTHER - M150	0.85	$/#
FROTHER - PINE OIL	0.63	$/#
COLLECTOR - FUEL OIL	0.09	$/#
COLLECTOR - KEROSENE	0.11	$/#
DEPRESSANT	0.00	$/#
MAKE UP WATER	0.02	$/1000 GAL
LUBRICANTS	0.02	PER TON RAW COAL
SUPERINTENDENT	50000	PER YEAR
BENEFITS	22500	0.45 TIMES SALARY
FOREMAN	35000	PER YEAR
BENEFITS	15750	0.45 TIMES SALARY
LABOR		
CLASS A	15.00	PER HOUR
BENEFITS	8.25	0.55 TIMES RATE
CLASS B	12.00	
BENEFITS	6.60	0.55 TIMES RATE
YEARLY OPERATING HOURS		
HOURS/SHIFT	8	
SHIFTS/DAY	2	
DAYS/YEAR	230	
HOURS/YEAR	3312	
RAW COAL/YEAR	66108	
CLEAN COAL/YEAR	55861	

FLOTATION REAGENT COSTS PER YEAR

ROUGHER			
FEED RATE	19.96	TPH	
FROTHER RATE	1.49	#/TON	M150
COLLECTOR RATE	6.40	#/TON	KEROSENE
DEPRESSANT RATE	0.00	#/TON	
CLEANER			
FEED RATE	18.349	TPH	
FROTHER RATE	0.86	#/TON	M150
COLLECTOR RATE	0.00	#/TON	
DEPRESSANT RATE	0.00	#/TON	
RECLEANER			
FEED RATE	17.593	TPH	
FROTHER RATE	0.64	#/TON	M150
COLLECTOR RATE	0.00	#/TON	
DEPRESSANT RATE	0.00	#/TON	
TOTAL FROTHER	159847	$/YEAR	
TOTAL COLLECTOR	44847	$/YEAR	
TOTAL DEPRESSANT	0	$/YEAR	
TOTAL FLOTATION COST	204695	$/YEAR	

I. ESTIMATED OPERATING COSTS

A. OPERATING SUPPLIES

1. POWER		
DIVERSITY	0.80	FACTOR
CONNECTED HP	310.80	KWH
HEAT AND LIGHT	350.00	KWH
POWER COST	105051	$/YEAR
ASSUME 1HP=1KVA=1KWH		
2. FLOTATION REAGENT COST	204695	$/YEAR
3. WATER COST	0	$/YEAR
4. LUBRICANTS	1322	$/YEAR
TOTAL OPERATING SUPPLIES	311068	$/YEAR
B. OPERATING MANPOWER		
1. SUPERVISION		
SUPERINTENDENT	1	PER YEAR
SALARY	50000	$/YEAR
BENEFITS	22500	$/YEAR
FOREMAN	1	PER YEAR
SALARY	35000	$/YEAR
BENEFITS	15750	$/YEAR
2. LABOR		PER SHIFT
CLASS A		
PLANT OPERATER	1	PER SHIFT
EQUIPMENT OPERATOR	1	PER SHIFT
MECHANIC-ELECTRIAN	1	PER SHIFT
TOTAL CLASS A	165600	$/YEAR
BENEFITS	91080	$/YEAR
CLASS B		
UTILITY	1	PER SHIFT
TOTAL CLASS B	44160	$/YEAR
BENEFITS	24288	$/YEAR
TOTAL OPERATING MANPOWER	448378	$/YEAR
TOTAL OPERATING COST	759446	$/YEAR

II. ESTIMATED MAINTENANCE COST

A. MAINTENANCE SUPPLIES		
EQUIPMENT	246111	
PER CENT MULTIPLIER	10.00%	
TOTAL EQUIPMENT	24611	
		TOTAL DOLLAR
TOTAL MAINTENANCE SUPPLIES	24611	
		$/YEAR
		$/YEAR
B. MAINTENANCE SUPERVISION AND LABOR		
1. SUPERVISION		
FOREMAN	1	PER YEAR
SALARY	35000	$/YEAR
BENEFITS	15750	$/YEAR
2. LABOR	1	SHIFT
CLASS A		
MECHANICS	1	PER SHIFT
WELDERS	1	PER SHIFT
ELECTRICIAN	1	PER SHIFT
TOTAL CLASS A	82800	$/YEAR
BENEFITS	45540	$/YEAR
TOTAL MAINTENANCE MANPOWER	179090	$/YEAR
TOTAL MAINTENANCE COST	203701	$/YEAR

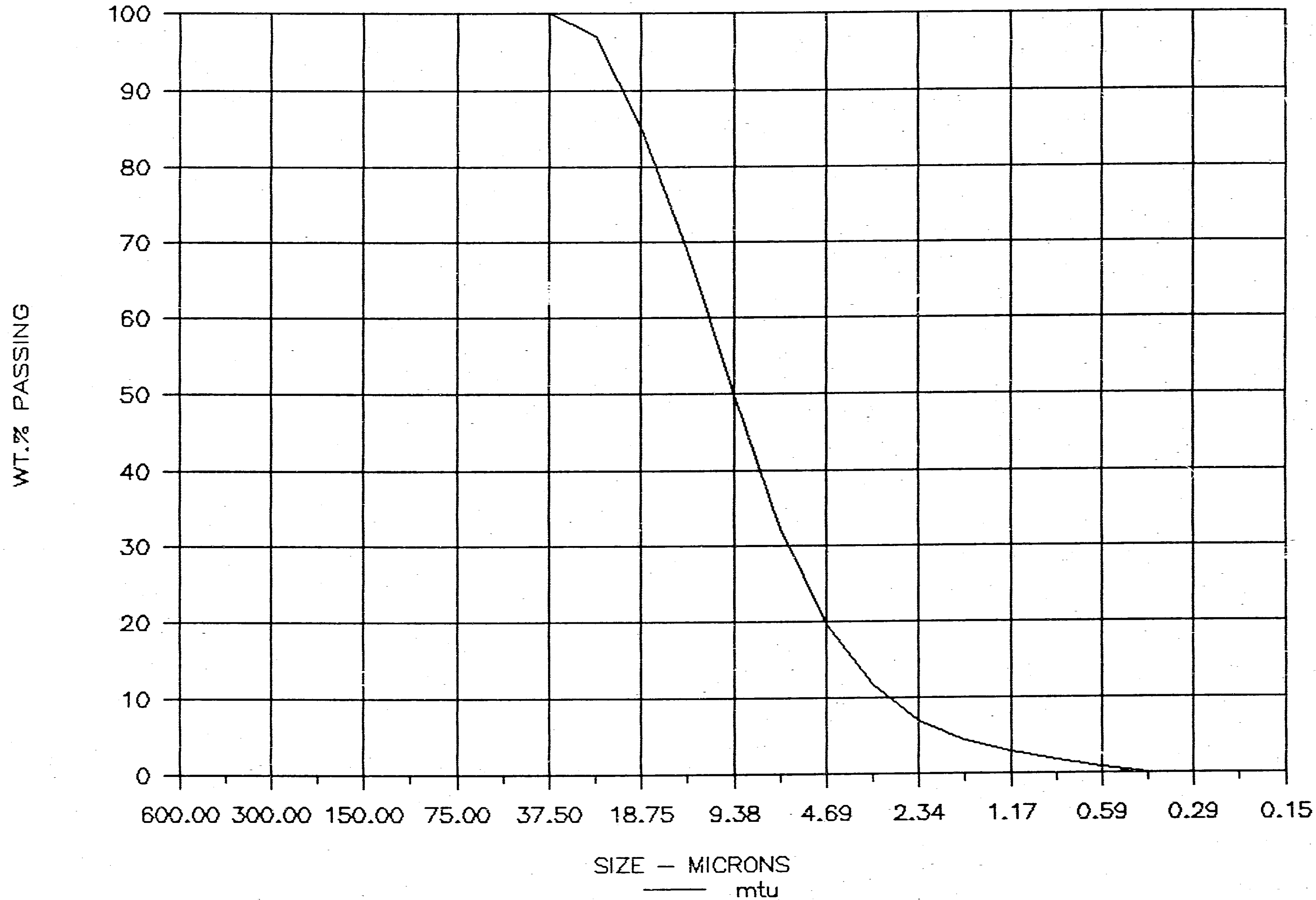
ESTIMATED OPERATING AND MAINTENANCE COSTS

	PER YEAR	PER RAW TON	PER CLEAN TON
I. OPERATING SUPPLIES			
POWER	105051	1.589	1.881
FLOTATION REAGENTS	204695	3.096	3.664
WATER	0	0.000	0.000
LUBRICANTS	1322	0.020	0.024
TOTAL OPERATING SUPPLIES	311068	4.705	5.569
II. OPERATING SUPERVISION AND LABOR			
SUPERVISION	85000	1.286	1.522
BENEFITS	38250	0.579	0.685
LABOR	209760	3.173	3.755
BENEFITS	115368	1.745	2.065
TOTAL OPERATING MANPOWER	448378	6.783	8.027
TOTAL OPERATING COSTS	759446	11.488	13.595
III. MAINTENANCE SUPPLIES			
EQUIPMENT	24611	0.372	0.441
TOTAL MAINTENANCE SUPPLIES	24611	0.372	0.441
IV. MAINTENANCE SUPERVISION AND LABOR			
SUPERVISION	35000	0.529	0.627
BENEFITS	15750	0.238	0.282
LABOR	82800	1.253	1.482
BENEFITS	45540	0.689	0.815
TOTAL MAINTENANCE MANPOWER	179090	2.709	3.206
TOTAL MAINTENANCE COST	203701	3.081	3.647
TOTAL OPERATING & MAINTENANCE COST	963147	14.569	17.242

MICHIGAN TECHNOLOGICAL UNIVERSITY

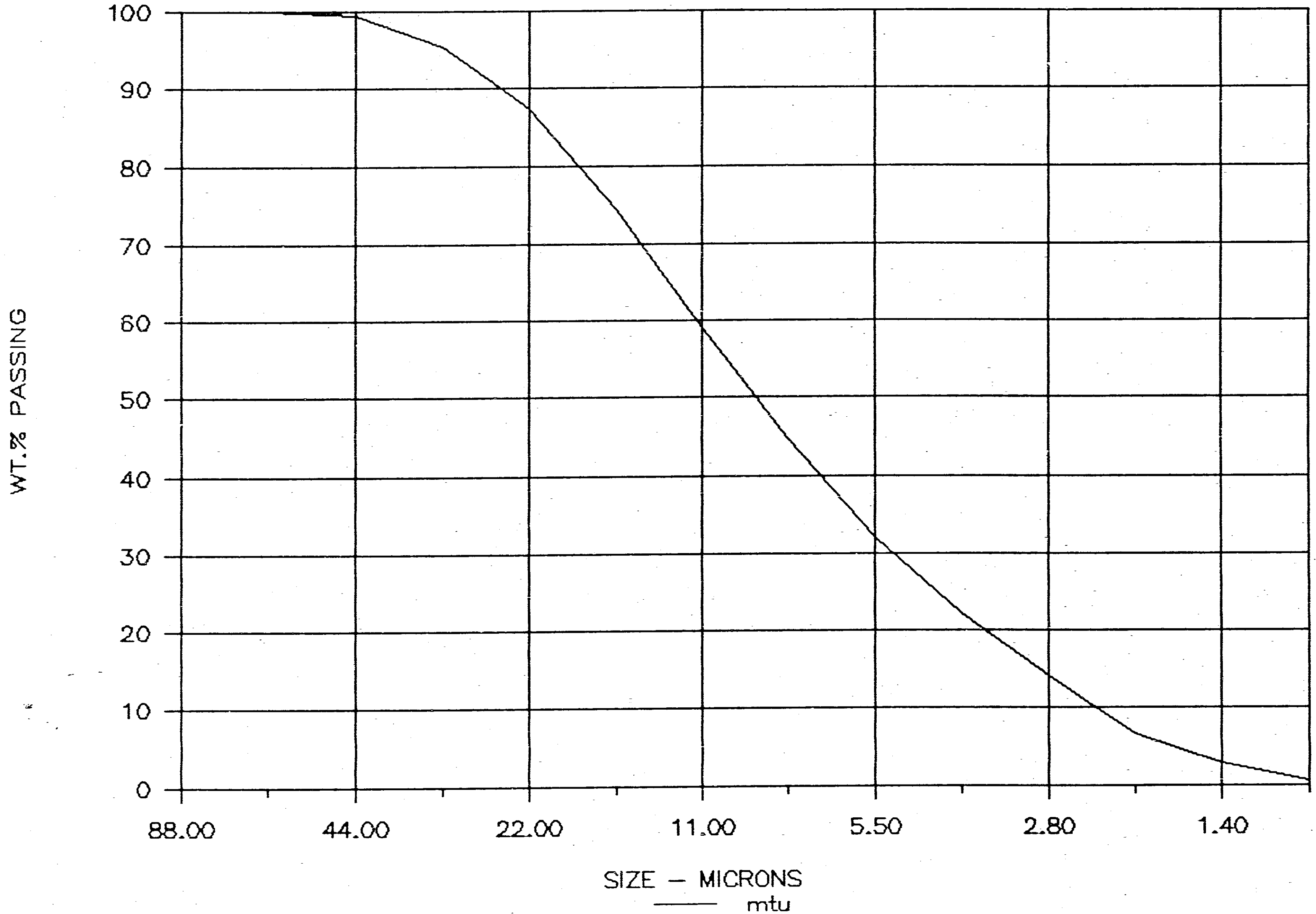
TEST #1

SIZE ANALYSIS BY B&W



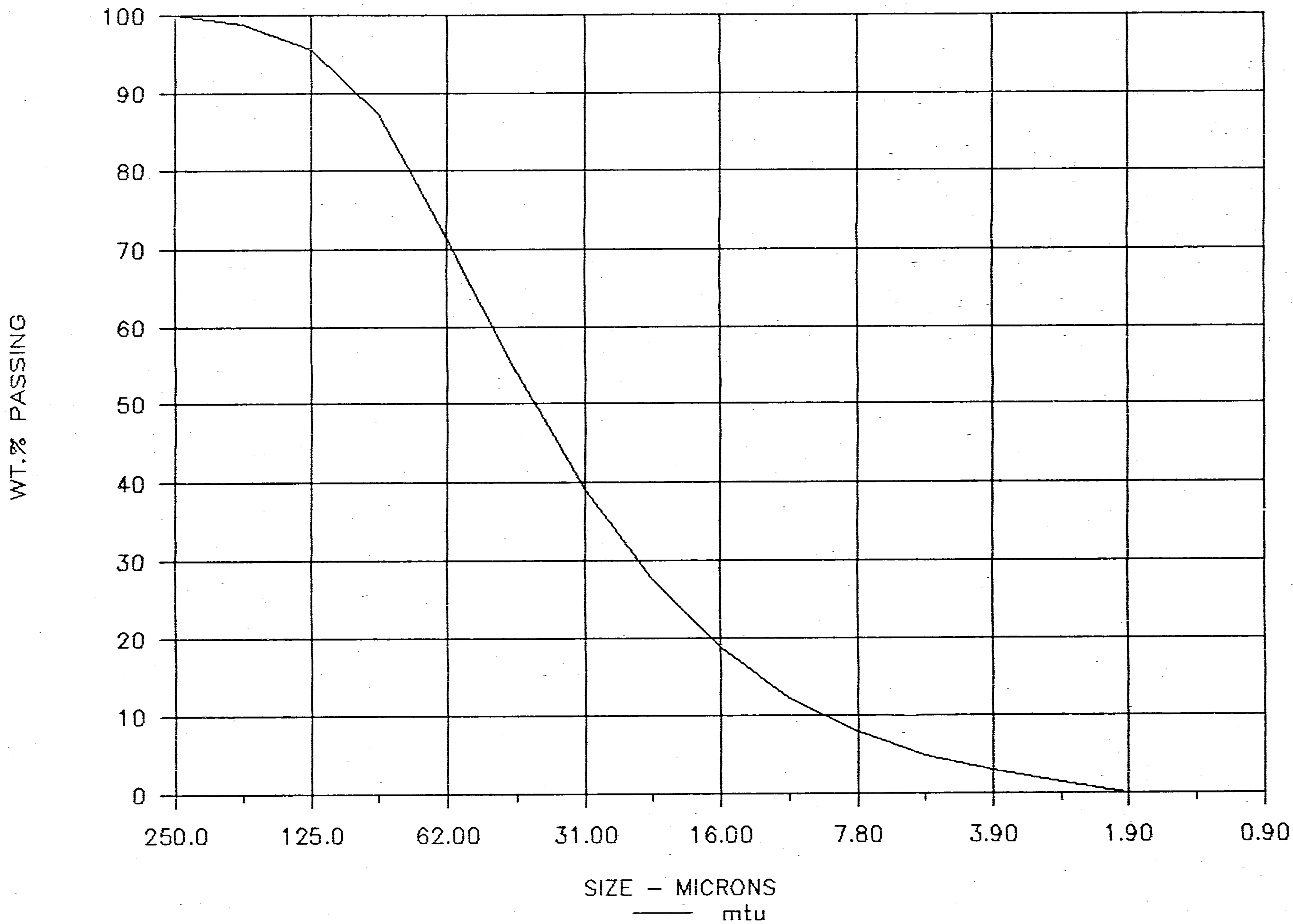
TEST #2

SIZE ANALYSIS BY PARTICIPANT



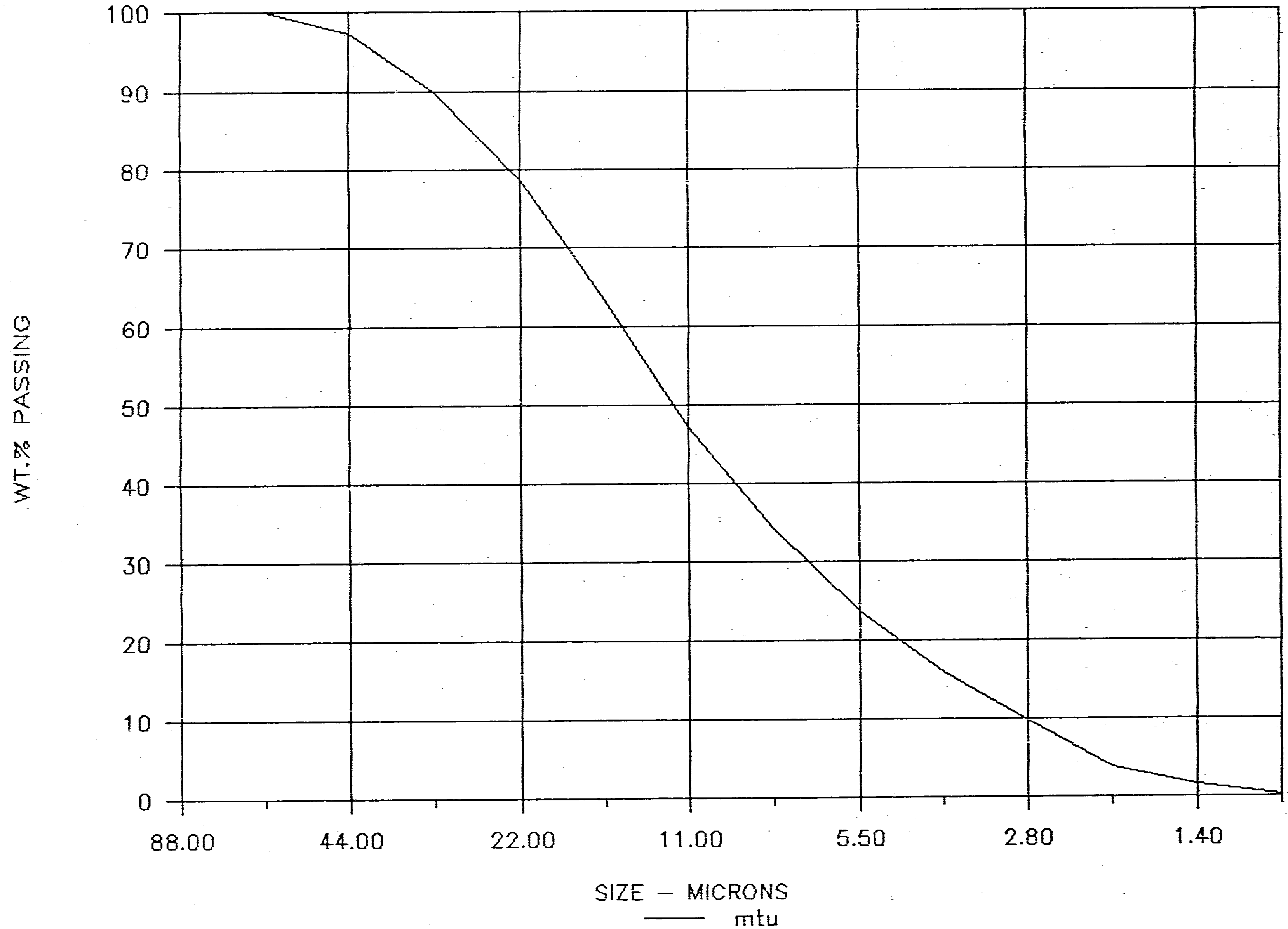
TEST #3

SIZE ANALYSIS BY PARTICIPANT



TEST #4

SIZE ANALYSIS BY PARTICIPANT



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MTU ADVANCED FLOTATION PREPARATION PLANT
COAL CLEANING ECONOMICS MODEL

CLEANING PLANT		
Raw Coal Total Sulfur		4.07%
Clean Coal Total Sulfur		1.65%
Raw Coal Feed Rate		19.75 (tons/hour)
Scheduled Operating Days		230 (days/year)
Operating Shifts/Day		2 (shifts/day)
Shift Length		8.00 (hours)
Annual Scheduled Operation		3,312 (hours/year)
Mean Plant Availability		90.00%(%)
Yield		83.70%(% of raw coal)
Raw Coal Heating Value		12,340 (dry Btu/lb)
Clean Coal Heating Value		14,236 (dry Btu/lb)
Energy Recovery		96.56%(%)
Annual Raw Coal Feed		65,412 (tons/year)
Annual Clean Coal Product		54,750 (tons/year)
ECONOMIC PARAMETERS		
Design Capital Cost	(Input)	$96,674 (per raw-ton/hour)
Plant Capital Cost	PCOST	$1,909,308
Plant Life	PL (Input)	20 (years, 30 years maximum)
Working Capital Allotme	(Input)	3.0 (months)
Working Capital	WORKCAP	$214,208
Proportion Debt	D (Input)	100.0%(decimal)
Borrowed Capital	DCOST	$2,123,516
Investor's Capital	CAPITAL	$0
Debt Interest Rate	DC (Input)	11.90%(decimal)
Debt Loan Period	DPER (Input)	20 (years)
Discounted Return	(Input)	15.0%(decimal)
Income Tax Rate (all)	(Input)	38.0%(decimal)
Tax Dep. Period	TL (Input)	20 (years)

		Raw Coal Based ($/t)	Clean Coal Based (Salable Coal) ($/t)	($/MBtu)	Annual ($/yr)
Prep Plant Raw Coal TPY Required	65412	-	-	-	-
Raw Coal tpy Required	63176	-	-	-	-
Additional Raw Coal TPY Required	2236	$20.00	-	-	$44,720
Coal Cost		$0.00	$0.00	$0.000	$44,720
Plant O&M Cost		$13.10	$15.65	$0.550	$856,831
Refuse Disposal O&M Cost	$0.00 /ton	$0.00	$0.00	$0.000	$0
O&M Subtotal		$13.10	$15.65	$0.550	$856,831
Coal and O&M Cost		$13.10	$15.65	$0.550	$901,551
Cost of Capital		$5.40	$6.45	$0.227	$308,529
Producer's Revenue Req.		$18.50	$22.10	$0.776	$1,210,080
Transportation			$0.00	$0.000	$0
Delivered Cost			$22.10	$0.776	$1,210,080

$344 ANNUAL $/TON OF SULFUR DIOXIDE

OC&B

EQUIPMENT NO.	DESCRIPTION	QUANTITY	OPERATING QUANTITY	PRICE	HP	MOTOR SUPPLIED	COMMENTS
100	CONDITIONING/FEED SUMP	1	-	-	-	-	2500 GALLON CAPACITY
101.1	CONDITIONING/FEED SUMP MIXER	1	1	10550	30.00	YES	PHILADELPHIA MODEL 3805-S-PTO
105	FEED PUMP	1	1	13200	40.00	YES	GOYNE MODEL 5000, 80' TDH / 800 GPM
110	ROUGHER COLLECTOR REAGENT PUMP	2	2	4952	0.20	YES	PULSAFEEDER MODEL 68GC-S-AE
115	ROUGHER FROTHER REAGENT PUMP	2	2	4924	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
120	ROUGHER FLOTATION MACHINES	2	2	423350	0.00	YES	MICH TECH PACKED COLUMN 10' ID X 40' HIGH
120.1	ROUGHER FLOTATION BLOWER	2	2	179460	150.00	YES	AIRTEK - 1000 CFM @ 50 PSIG
	TOTAL			636436	370.80		

TOTAL ESTIMATED CAPITAL COST IS BASED ON HOFFMAN-MUNTNER REPORT NO. EPA-600/7-78-124, "AN ENGINEERING/ECNOMIC ANALYSIS OF COAL PREPARATION PLANT OPERATION AND COST"

THIS REPORT STATES THAT THE CAPITAL COST OF A PREPARATION PLANT CAN BE ESTIMATED BY MULTIPLING THE EQUIPMENT COST BY 3.

TOTAL EQUIPMENT COST	636436
TOTAL PROJECT ESTIMATE	1909308

OPERATING AND MAINTENANCE COSTS

OPERATING CRITERIA		
CONNECTED HORSEPOWER	371	HP
WATER REQUIREMENTS	315.60	GPM
PLANT FEED RATE	19.75	TPH
PLANT RECOVERY	83.70%	
PRODUCTION RATE	16.53	TPH
PLANT AVAILABILTY	90.00%	
UNIT SUPPLY COSTS		
ELECTRIC POWER	0.060	$/KW HR
FROTHER - MIBC	0.610	$/#
FROTHER - M150	0.850	$/#
FROTHER - PINE OIL	0.630	$/#
COLLECTOR - FUEL OIL	0.088	$/#
COLLECTOR - KERSOSENE	0.106	$/#
DEPRESSANT	0.000	$/#
MAKE UP WATER	0.020	$/1000 GAL
LUBRICANTS	0.020	PER TON RAW COAL
SUPERINTENDENT	50000	PER YEAR
BENEFITS	22500	0.45 TIMES SALARY
FOREMAN	35000	PER YEAR
BENEFITS	15750	0.45 TIMES SALARY
LABOR		
CLASS A	15.00	PER HOUR
BENEFITS	8.25	0.55 TIMES RATE
CLASS B	12.00	
BENEFITS	6.60	0.55 TIMES RATE
YEARLY OPERATING HOURS		
HOURS/SHIFT	8	
SHIFTS/DAY	2	
DAYS/YEAR	230	
HOURS/YEAR	3312	
RAW COAL/YEAR	65412	
CLEAN COAL/YEAR	54750	

FLOTATION REAGENT COSTS PER YEAR

ROUGHER			
FEED RATE	19.750	TPH	
FROTHER RATE	0.821	$/TON	PINE OIL
COLLECTOR RATE	2.560	$/TON	FUEL OIL
DEPRESSANT RATE	0.000	$/TON	
CLEANER			
FEED RATE	N/A	TPH	
FROTHER RATE	N/A	$/TON	
COLLECTOR RATE	N/A	$/TON	
DEPRESSANT RATE	N/A	$/TON	
RECLEANER			
FEED RATE	N/A	TPH	
FROTHER RATE	N/A	$/TON	
COLLECTOR RATE	N/A	$/TON	
DEPRESSANT RATE	N/A	$/TON	
TOTAL FROTHER	33833	$/YEAR	
TOTAL COLLECTOR	14736	$/YEAR	
TOTAL DEPRESSANT	0	$/YEAR	
TOTAL FLOTATION COST	48569	$/YEAR	

I. ESTIMATED OPERATING COSTS

A. OPERATING SUPPLIES

1. POWER		
DIVERSITY	0.80	FACTOR
CONNECTED HP	370.80	KWH
HEAT AND LIGHT	350.00	KWH
POWER COST	114590	$/YEAR
ASSUME 1HP=1KVA=1KWH		
2. FLOTATION REAGENT COST	48569	$/YEAR
3. WATER COST	1252	$/YEAR
4. LUBRICANTS	1308	$/YEAR
TOTAL OPERATING SUPPLIES	165719	$/YEAR
B. OPERATING MANPOWER		
1. SUPERVISION		
SUPERINTENDENT	1	PER YEAR
SALARY	50000	$/YEAR
BENEFITS	22500	$/YEAR
FOREMAN	1	PER YEAR
SALARY	35000	$/YEAR
BENEFITS	15750	$/YEAR
2. LABOR		PER SHIFT
CLASS A		
PLANT OPERATER	1	PER SHIFT
EQUIPMENT OPERATOR	1	PER SHIFT
MECHANIC-ELECTRIAN	1	PER SHIFT
TOTAL CLASS A	165600	$/YEAR
BENEFITS	91080	$/YEAR
CLASS B		
UTILITY	1	PER SHIFT
TOTAL CLASS B	44160	$/YEAR
BENEFITS	24288	$/YEAR
TOTAL OPERATING MANPOWER	448378	$/YEAR
TOTAL OPERATING COST	614097	$/YEAR

II. ESTIMATED MAINTENANCE COST

A. MAINTENANCE SUPPLIES		
EQUIPMENT	636436	
PER CENT MULTIPLIER	10.00%	
TOTAL EQUIPMENT	63644	
		TOTAL DOLLAR
TOTAL MAINTENANCE SUPPLIES	63644	
		$/YEAR
		$/YEAR
B. MAINTENANCE SUPERVISION AND LABOR		
1. SUPERVISION		
FOREMAN	1	PER YEAR
SALARY	35000	$/YEAR
BENEFITS	15750	$/YEAR
2. LABOR	1	SHIFT
CLASS A		
MECHANICS	1	PER SHIFT
WELDERS	1	PER SHIFT
ELECTRICIAN	1	PER SHIFT
TOTAL CLASS A	82800	$/YEAR
BENEFITS	45540	$/YEAR
TOTAL MAINTENANCE MANPOWER	179090	$/YEAR
TOTAL MAINTENANCE COST	242734	$/YEAR

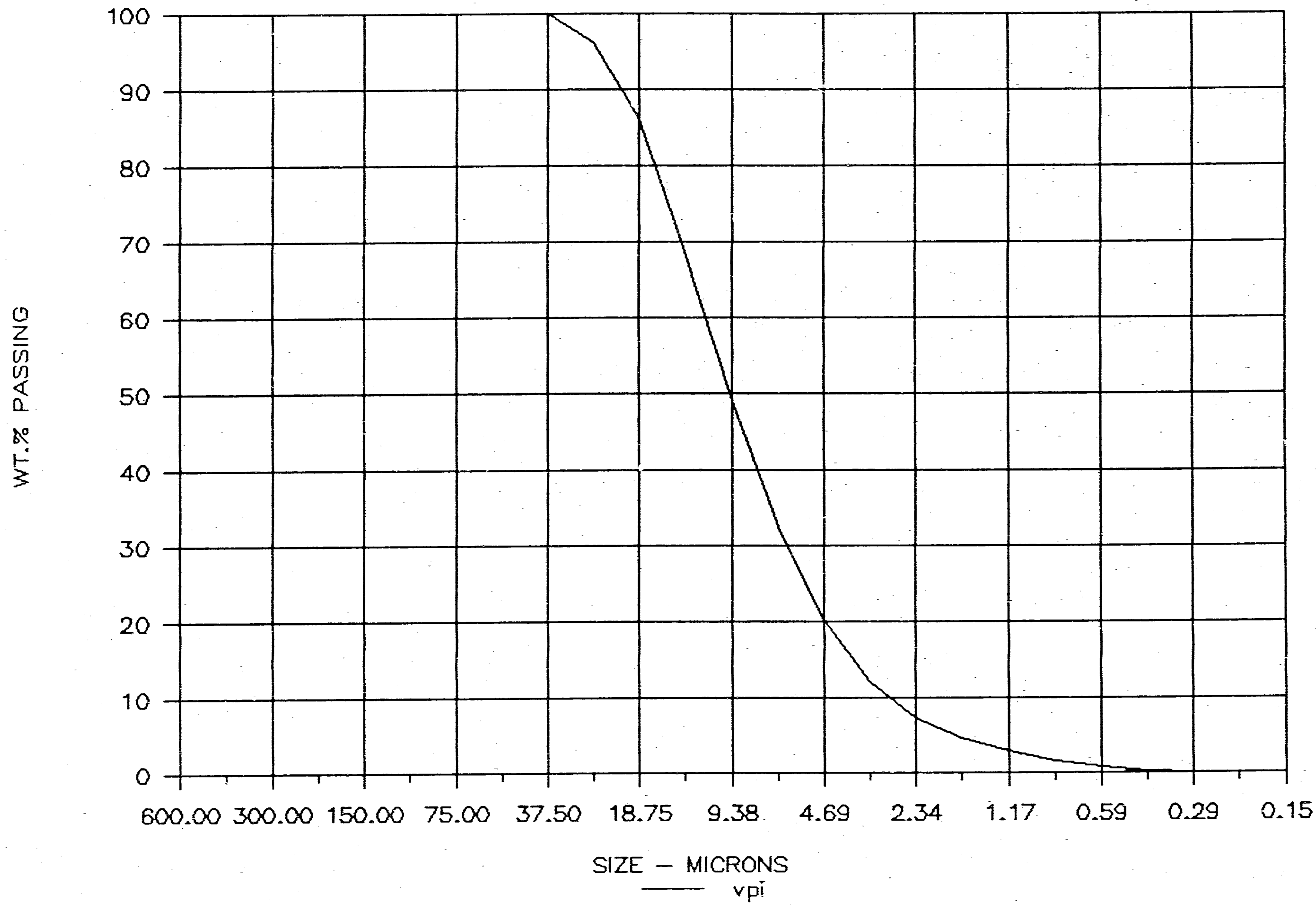
ESTIMATED OPERATING AND MAINTENANCE COSTS

	PER YEAR	PER RAW TON	PER CLEAN TON
I. OPERATING SUPPLIES			
POWER	114590	1.752	2.093
FLOTATION REAGENTS	48569	0.743	0.887
WATER	1252	0.019	0.023
LUBRICANTS	1308	0.020	0.024
TOTAL OPERATING SUPPLIES	165719	2.533	3.027
II. OPERATING SUPERVISION AND LABOR			
SUPERVISION	85000	1.299	1.553
BENEFITS	38250	0.585	0.699
LABOR	209760	3.207	3.831
BENEFITS	115368	1.764	2.107
TOTAL OPERATING MANPOWER	448378	6.855	8.190
TOTAL OPERATING COSTS	614097	9.388	11.216
III. MAINTENANCE SUPPLIES			
EQUIPMENT	63644	0.973	1.162
TOTAL MAINTENANCE SUPPLIES	63644	0.973	1.162
IV. MAINTENANCE SUPERVISION AND LABOR			
SUPERVISION	35000	0.535	0.639
BENEFITS	15750	0.241	0.288
LABOR	82800	1.266	1.512
BENEFITS	45540	0.696	0.832
TOTAL MAINTENANCE MANPOWER	179090	2.738	3.271
TOTAL MAINTENANCE COST	242734	3.711	4.434
TOTAL OPERATING & MAINTENANCE COST	856831	13.099	15.650

VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY

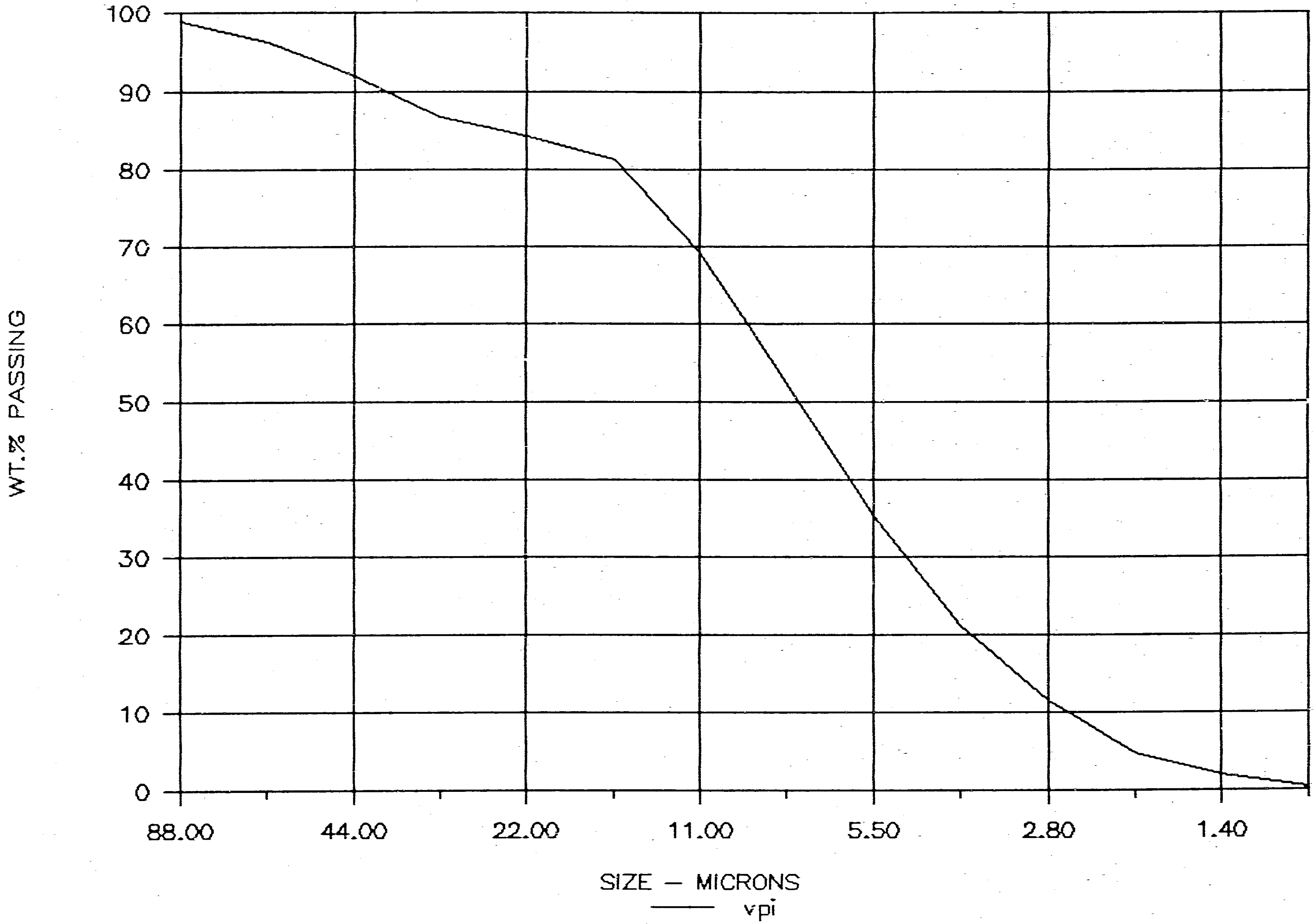
TEST #1

SIZE ANALYSIS BY B&W



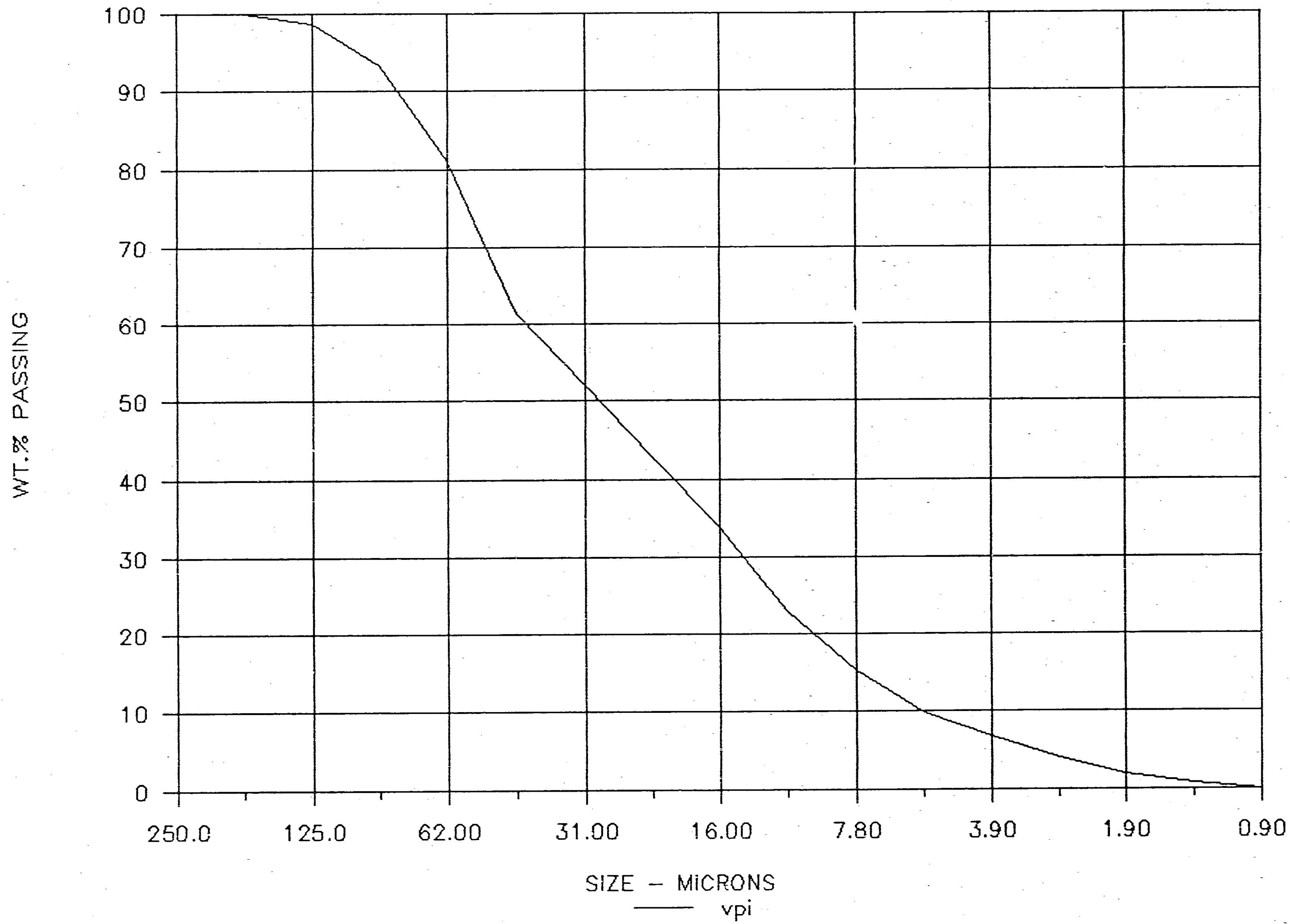
TEST #2

SIZE ANALYSIS BY PARTICIPANT



TEST #3

SIZE ANALYSIS BY PARTICIPANT



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VPI ADVANCED FLOTATION PREPARATION PLANT
COAL CLEANING ECONOMICS MODEL

CLEANING PLANT		
Raw Coal Total Sulfur	4.26%	
Clean Coal Total Sulfur	1.90%	
Raw Coal Feed Rate	23.87	(tons/hour)
Scheduled Operating Days	230	(days/year)
Operating Shifts/Day	2	(shifts/day)
Shift Length	8.00	(hours)
Annual Scheduled Operation	3,312	(hours/year)
Mean Plant Availability	90.00%	(%)
Yield	70.00%	(% of raw coal)
Raw Coal Heating Value	12,277	(dry Btu/lb)
Clean Coal Heating Value	14,088	(dry Btu/lb)
Energy Recovery	80.33%	(%)
Annual Raw Coal Feed	79,057	(tons/year)
Annual Clean Coal Product	55,340	(tons/year)
ECONOMIC PARAMETERS		
Design Capital Cost (Input)	$53,787	(per raw-ton/hour)
Plant Capital Cost PCOST	$1,283,892	
Plant Life PL (Input)	20	(years, 30 years maximum)
Working Capital Allotme (Input)	3.0	(months)
Working Capital WORKCAP	$220,647	
Proportion Debt D (Input)	100.0%	(decimal)
Borrowed Capital DCOST	$1,504,539	
Investor's Capital CAPITAL	$0	
Debt Interest Rate DC (Input)	11.00%	(decimal)
Debt Loan Period DPER (Input)	20	(years)
Discounted Return (Input)	15.0%	(decimal)
Income Tax Rate (all) (Input)	38.0%	(decimal)
Tax Dep. Period TL (Input)	20	(years)

		Raw Coal Based	Clean Coal Based (Salable Coal)		Annual
		($/t)	($/t	($/MBtu)	($/yr)
Prep Plant Raw Coal TPY Required	79057	-	-	-	-
Raw Coal TPY Required	63501	-	-	-	-
Additional Raw Coal TPY Required	15556	$20.00	-	-	$311,129
Coal Cost		$0.00	$0.00	$0.000	$311,129
Plant O&M Cost		$11.16	$15.95	$0.566	$882,588
Refuse Disposal O&M Cost	$0.00 /ton	$0.00	$0.00	$0.000	$0
O&M Subtotal		$11.16	$15.95	$0.566	$882,588
Coal and O&M Cost		$11.16	$15.95	$0.566	$1,193,717
Cost of Capital		$6.69	$9.55	$0.339	$217,587
Producer's Revenue Req.		$17.85	$25.50	$0.905	$1,411,304
Transportation			$0.00	$0.000	$0
Delivered Cost			$25.50	$0.905	$1,411,304

$305 ANNUAL $/TON OF SULFUR DIOXIDE REMOVED

0023

EQUIPMENT NO.	DESCRIPTION	QUANTITY	OPERATING QUANTITY	PRICE	HP	MOTOR SUPPLIED	COMMENTS
100	CONDITIONING/FEED SUMP	1	-	-	-		2500 GALLON CAPACITY
101.1	CONDITIONING/FEED SUMP MIXER	1	1	10550	30.00	YES	PHIADELPHIA MODEL 3805-S-PTO
105	FEED PUMP	1	1	13200	40.00	YES	GOYNE MODEL 5000, 80' TDH / 800 GPM
110	ROUGHER COLLECTOR REAGENT PUMP	1	1	2476	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
115	ROUGHER FROTHER REAGENT PUMP	4	4	9848	0.20	YES	PULSAFEEDER MODEL 680C-S-AE
120	ROUGHER FLOTATION MACHINES	4	4	322000		YES	VPI COLUMN FLOTATION CELL 8' DIA X 22' HIG
120.1	RECIRCULATION PUMP	4	4	-	100.00	YES	GOYNE MODEL 5000, 80' TDH / 1800 GPM
120.2	ROUGHER FLOTATION BLOWER	1	1	69890	50.00	YES	AIRTEC 500 CFM @ 60 PSIG
	TOTAL			427964	521.00		

TOTAL ESTIMATED CAPITAL COST IS BASED ON HOFFMAN-MUNTNER REPORT NO. EPA-600/7-78-124, "AN ENGINEERING/ECONOMIC ANALYSIS OF COAL PREPARATION PLANT OPERATION AND COST"

THIS REPORT STATES THAT THE CAPITAL COST OF A PREPARATION PLANT CAN BE ESTIMATED BY MULTIPLING THE EQUIPMENT COST BY 3.

TOTAL EQUIPMENT COST	427964
TOTAL PROJECT ESTIMATE	1283892

OPERATING AND MAINTENANCE COSTS

OPERATING CRITERIA

CONNECTED LORSEPOWER	521	HP
WATER REQUIREMENTS	741.00	GPM
PLANT FEED RATE	23.87	TPH
PLANT RECOVERY	70.00%	
PRODUCTION RATE	16.71	TPH
PLANT AVAILABILTY	90.00%	

UNIT SUPPLY COSTS

ELECTRIC POWER	0.06	$/KW HR
FROTHER - MIBC	0.61	$/#
FROTHER - M150	0.85	$/#
FROTHER - PINE OIL	0.63	$/#
COLLECTOR - FUEL OIL	0.09	$/#
COLLECTOR - KERSOSENE	0.11	$/#
DEPRESSANT	0.00	$/#
MAKE UP WATER	0.02	$/1000 GAL
LUBRICANTS	0.02	PER TON RAW COAL

SUPERINTENDENT		50000	PER YEAR
	BENEFITS	22500	0.45 TIMES SALARY
FOREMAN		35000	PER YEAR
	BENEFITS	15750	0.45 TIMES SALARY
LABOR			
	CLASS A	15.00	PER HOUR
	BENEFITS	8.25	0.55 TIMES RATE
	CLASS B	12.00	
	BENEFITS	6.60	0.55 TIMES RATE

YEARLY OPERATING HOURS

HOURS/SHIFT	8
SHIFTS/DAY	2
DAYS/YEAR	230
HOURS/YEAR	3312

RAW COAL/YEAR	79057
CLEAN COAL/YEAR	55340

FLOTATION REAGENT COSTS PER YEAR

ROUGHER			
FEED RATE	23.87	TPH	
FROTHER RATE	0.907	#/TON	M150
COLLECTOR RATE	1.00	#/TON	KEROSENE
DEPRESSANT RATE	0.00	#/TON	
CLEANER			
FEED RATE	0.00	TPH	
FROTHER RATE	0.00	#/TON	
COLLECTOR RATE	0.00	#/TON	
DEPRESSANT RATE	0.00	#/TON	
RECLEANER			
FEED RATE	0.00	TPH	
FROTHER RATE	0.00	#/TON	
COLLECTOR RATE	0.00	#/TON	
DEPRESSANT RATE	0.00	#/TON	
TOTAL FROTHER	60949	$/YEAR	
TOTAL COLLECTOR	8380	$/YEAR	
TOTAL DEPRESSANT	0	$/YEAR	
TOTAL FLOTATION COST	69329	$/YEAR	

1. ESTIMATED OPERATING COSTS

A. OPERATING SUPPLIES

1. POWER		
DIVERSITY	0.80	FACTOR
CONNECTED HP	521.00	KWH
HEAT AND LIGHT	350.00	KWH
POWER COST	138468	$/YEAR
ASSUME 1HP=1KVA=1KWH		
2. FLOTATION REAGENT COST	69329	$/YEAR
3. WATER COST	2945	$/YEAR
4. LUBRICANTS	1581	$/YEAR
TOTAL OPERATING SUPPLIES	212324	$/YEAR
B. OPERATING MANPOWER		
1. SUPERVISION		
SUPERINTENDENT	1	PER YEAR
SALARY	50000	$/YEAR
BENEFITS	22500	$/YEAR
FOREMAN	1	PER YEAR
SALARY	35000	$/YEAR
BENEFITS	15750	$/YEAR
2. LABOR		PER SHIFT
CLASS A		
PLANT OPERATER	1	PER SHIFT
EQUIPMENT OPERATOR	1	PER SHIFT
MECHANIC-ELECTRIAN	1	PER SHIFT
TOTAL CLASS A	165600	$/YEAR
BENEFITS	91080	$/YEAR
CLASS B		
UTILITY	1	PER SHIFT
TOTAL CLASS B	44160	$/YEAR
BENEFITS	24288	$/YEAR
TOTAL OPERATING MANPOWER	448378	$/YEAR
TOTAL OPERATING COST	660702	$/YEAR

II. ESTIMATED MAINTENANCE COST

A. MAINTENANCE SUPPLIES		
EQUIPMENT	427964	
PER CENT MULTIPLIER	10.00%	
TOTAL EQUIPMENT	42796	
		TOTAL DOLLAR
TOTAL MAINTENANCE SUPPLIES	42796	
		$/YEAR
		$/YEAR
B. MAINTENANCE SUPERVISION AND LABOR		
1. SUPERVISION		
FOREMAN	1	PER YEAR
SALARY	35000	$/YEAR
BENEFITS	15750	$/YEAR
2. LABOR	1	SHIFT
CLASS A		
MECHANICS	1	PER SHIFT
WELDERS	1	PER SHIFT
ELECTRICIAN	1	PER SHIFT
TOTAL CLASS A	82800	$/YEAR
BENEFITS	45540	$/YEAR
TOTAL MAINTENANCE MANPOWER	179090	$/YEAR
TOTAL MAINTENANCE COST	221886	$/YEAR

ESTIMATED OPERATING AND MAINTENANCE COSTS

	PER YEAR	PER RAW TON	PER CLEAN TON
I. OPERATING SUPPLIES			
POWER	138468	1.751	2.502
FLOTATION REAGENTS	69329	0.877	1.253
WATER	2945	0.037	0.053
LUBRICANTS	1581	0.020	0.029
TOTAL OPERATING SUPPLIES	212324	2.686	3.837
II. OPERATING SUPERVISION AND LABOR			
SUPERVISION	85000	1.075	1.536
BENEFITS	38250	0.484	0.691
LABOR	209760	2.653	3.790
BENEFITS	115368	1.459	2.085
TOTAL OPERATING MANPOWER	448378	5.672	8.102
TOTAL OPERATING COSTS	660702	8.357	11.939
III. MAINTENANCE SUPPLIES			
EQUIPMENT	42796	0.541	0.773
TOTAL MAINTENANCE SUPPLIES	42796	0.541	0.773
IV. MAINTENANCE SUPERVISION AND LABOR			
SUPERVISION	35000	0.443	0.632
BENEFITS	15750	0.199	0.285
LABOR	82800	1.047	1.496
BENEFITS	45540	0.576	0.823
TOTAL MAINTENANCE MANPOWER	179090	2.265	3.236
TOTAL MAINTENANCE COST	221886	2.807	4.009
TOTAL OPERATING & MAINTENANCE COST	882588	11.164	15.948

APPENDIX II

ICF KAISER ENGINEERS

ICF KAISER ENGINEERS, INC.
FOUR GATEWAY CENTER 12TH FLOOR
PITTSBURGH, PENNSYLVANIA 15222
412/281-8121

January 17, 1990

Reference: ICF Kaiser Engineers' Number 88107-150
Round Robin Test #4
Capital and Operating Cost Evaluation

Dear Sir:

The Technical Advisory Committee (TAC) has requested ICF Kaiser Engineers (ICF KE) to prepare capital costs and operating costs for each participants flotation scheme.

In order to prepare an accurate estimate of capital costs and address some concerns of the participants, ICF KE requests that each participant prepare a flowsheet for their particular Test #4 scheme. The flowsheet is to be based on processing 20 tons per hour of precleaned coal. The precleaned coal will be ground to minus 325 mesh and diluted to 10 percent solids by weight.

Your flowsheet is to be based on the above and your parameters for your Test #4. The flowsheet should indicate mass and water balance for the flotation process only, i.e. no dewatering equipment is to be included. The flowsheet is to further indicate all outside utilities required for your process i.e. compressed air cfm, wash water gpm, reagent dosages etc.

Your capital cost for flowsheet is to include all major equipment i.e. flotation machine(s), air compressor, slurry pumps, etc.

ICF KE requires that you supply the capital cost of your flotation device and an itemized list and cost of all additional equipment required to operate your flotation circuit. If you require instrumentation to properly operate your flotation device, include a listing of this instrumentation and the costs. (Do not include control panels, computers, PLC, etc.)

The operating costs for your flowscheme will be prepared based on, but not limited to, power consumption, reagent costs and water costs.

The participant is further requested to supply the overall dimensions of the 20TPH flotation device on a drawing of the device suitable for including into the final report of the round robin results.

If you have any questions and/or comments, please contact the writer at your convenience. ICF KE requests that you return this information no later than January 31, 1990. Thank you for your cooperation in this matter.

Very truly yours,

ICF KAISER ENGINEERS, INC.

Dave D Ferris

Dave D. Ferris
Project Technical Director

DDF/bam

ICF KAISER ENGINEERS

ICF KAISER ENGINEERS, INC.
FOUR GATEWAY CENTER, 12TH FLOOR
PITTSBURGH, PENNSYLVANIA 15222
412/281-8121

88107-150

April 6, 1990

Reference: Topical Report #2 - Round Robin Test Results for DOE Contract Number DE-AC22-88PC88881 ICF Kaiser Engineers Number 88107-150

Dear

Please find enclosed a draft copy of the Round Robin Test Results for Advanced Flotation for your information. This report will be presented and discussed at a meeting of the Technical Advisory Committee on April 17, 1990.

After the meeting, the conclusions will be incorporated into the final report to be submitted to the Department of Energy. This will fulfill a subtask for the above referenced contract.

Please review the enclosed report and comment on the report no later than April 16, 1990. Your comments are to be limited to your device only. Any comments related to other participants will be edited out of your comments. You may comment on methods of evaluation and state any improvements to your particular advanced flotation device. Your comments, less any edited material, will be incorporated as an appendix to the report submitted to DOE.

Very truly yours,

Dave D. Ferris

Dave D. Ferris
Project Technical Director

DDF/mah

Enclosure

168/1B09.DDF

Michigan Technological University

Houghton, Michigan 49931

Institute of Materials Processing
906/487-2600
FAX: 906/487-2921

April 16, 1990

Dave D. Ferris
Project Technical Director
ICF Kaiser Engineers, Inc.
Four Gateway Center, 12th Floor
Pittsburgh, PA 15222

Reference: Topical Report #2 - Round Robin Test Results for
DOE Contract Number DE-AC22-88PC88881
ICF Kaiser Engineers Number 88107-150

Dear Dave:

Thank you for the draft copy of the Round Robin Test Results for Advanced Flotation. We have carefully reviewed the report and have a few comments on methods of evaluation. Please find our comments in the attachment.

If you have any questions, please do not hesitate to call me or David Yang. We are very glad to have the opportunity to work with your company.

Sincerely,

J. Y. Hwang
Program Manager, Minerals
and Solid Waste Processing Group

JYH/tea

Enclosure

MAY 03 1990

MTU COMMENTS
(04/16/90)

Reference: Topical Report #2 - Round Robin Test Results for DOE Contract Number DE-AC22-88PC88881 ICF Kaiser Engineers Number 88107-150

1. **Technical Evaluations**

a. The objective of this study is to determine the most efficient, cost effective flotation cell for obtaining maximum amount of BTU recovery and maximum amount of pyritic sulfur rejection for a given coal at a given particle size distribution. The separation efficiency (= BTU recovery - (100 - Pyrite Rejection)) is the parameter designed to evaluate the technical efficiency. We believe that this parameter should be utilized as the sole basis for the technical evaluation.

b. BTU recovery and pyrite rejection have been counted in the separation efficiency. They should not be evaluated as independent parameter. If for any reason they need to be considered, the weight ratio of these parameters should not be equal to the separation efficiency.

c. The weight % recovery of coal becomes a parameter to penalize good coal cleaning processes in the technical evaluation. The same is true for the BTU recovery parameter if it stands alone. A process without cleaning the coal will obtain the best score because it gets 100% weight recovery and 100% BTU recovery.

d. If the technical evaluation needs to include any parameter other than the separation efficiency, we suggest to select from the parameters such as the ash separation efficiency, pyrite content, ash content, and BTU value of the clean coal.

e. We suggest that all tests should be considered in the evaluation to obtain balanced comparison. A good flotation device should be able to function consistently well under various conditions as the coal industry requires. The use of Test #4, but excluding Test #1 thru #3, as the basis for comparison may not provide a complete evaluation. We believe that the results of Tests #1 thru #3 (or #4) may be combined to provide an independent technical evaluation parameter.

2. **Economic Evaluations**

a. All of the four economic evaluation parameters are calculated or utilized to punish good coal cleaning processes. Without any coal cleaning treatment, one can obtain the best score for each parameter because the cost is zero. We certainly believe that this is not the intention of this evaluation and suggest to design a more appropriate economic evaluation system.

b. Cleaned coal will observe the benefits on transportation, power plant ash collection and disposal, and flue gas desulfurization treatment, etc. These benefits are the most important economic driving force for coal cleaning. However, they are not recognized in any of the economic evaluation parameters. According to the calculations shown in the Appendix I, these benefits are all assumed to be of no economic value.

c. We suggest to use the balance between the total costs and total benefits to evaluate the economics of various processes.

d. The flotation plant installation cost is assumed to be about 3 times of the capital cost of the flotation device (see p. 53, 3rd paragraph). High capital cost device usually has considered all the variables already and requires much less efforts in installation, testing, and operation. We suggest to use a more reasonable factor for high capital cost device. In addition, we suggest to exclude the capital cost factor from the operation and maintenance cost parameter and the other parameters if the capital cost stands by itself as a parameter. We believe that high capital device should not be punished in every economic evaluation parameter.

3. Overall Considerations

As we discussed earlier, the separation efficiency should be the sole basis for technical evaluation. The MTU process should be ranked first with this approach. When the benefits of cleaning are considered in the economic evaluations, the MTU process shall also become the first ranked. Thus, the MTU process should be ranked first overall.

COLLEGE OF ENGINEERING

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
VIRGINIA CENTER FOR COAL AND MINERALS PROCESSING (703) 231-4508 TELEX: (910) 333-1861 fax: (703) 231-4070
Blacksburg, Virginia 24061-0239

April 16, 1990

Mr. David Ferris
ICF Kaiser Engineers, Inc.
4 Gateway Center
12th Floor
Pittsburgh, Pennsylvania 15222

Dear Mr. Ferris:

Per your letter dated April 6, 1990, please find below our comments to be included in the appendix of the final report on the round-robin test program. The comments are broken up into two areas; changes in the technical and economic information pertaining to the VPI&SU column flotation process, and comments on the evaluation procedure used in ranking the various advanced flotation technologies. Per your instructions, we have avoided comments on advanced flotation technologies other than our own. We have also included copies of the final release analysis curves which have been revised to reflect the linearized Btu values which were included in your final report. In this way, all of the reported Btu recoveries and the release curves are based on a consistent set of data. These release curves also include the error bar for the pyritic sulfur and total sulfur measurements.

Technical and Economic Changes

After analyzing the technical and economic data which you provided, we would like to point out a few discrepancies in the information related to VPI&SU which we would like to correct. Based on an area scale-up of aeration rate from the test number 4 data reported by VPI&SU, it appears that we suggested an oversized compressor. If we scale-up exactly from our laboratory data, we require 304 CFM which means our economics should be based on one 300 CFM compressor rather than a 500 CFM compressor.

In terms of the equipment costs, it appears that our column cost can be reduced based on our most recent information. As you know, at the time that we provided our equipment specifications, we were still conducting our first major in-plant test on a large-scale column. Based on the data we have now collected, it seems that we were overly conservative on our estimate of the pump size. After conducting considerable test work with 3-4 inch in-line bubble generators, it now appears that a 30 HP pump will be more than sufficient for an eight-foot diameter column. Thus, the overall cost for three VPI&SU columns, including pumps and instrumentation, should be reduced to $180,000.

Finally, in evaluating the operating costs for each process, we noticed how far out of line the high frother consumption was for the VPI&SU column. Realizing that the round-robin test program is now complete, we decided to run an additional set of tests for our own benefit using the same sample and the same grind as in Test No. 4 to see if we could operate at a lower frother dosage and a higher kerosene dosage. It appears that we may have been using excess frother as an expensive collector in our previous test. The data from these tests are included for your information. We realize that you may not be able to include these results in the economic evaluation; however, it does show that we can obtain an 86% Btu recovery with an 81% pyritic sulfur rejection using 1.6 lb/ton of Dowfroth M150 and 3 lb/ton of kerosene.

Evaluation Procedure

We were a bit dismayed to see our names on the draft version of the final report on the round-robin test program which was sent to all participants. This was particularly unsettling since we did not have a chance to see or comment on the final version of the evaluation procedure selected. Furthermore, the appearance of our names on the cover sheet of this report would tend to indicate that we agree with all the conclusions and statements made in this report, which is definitely not true.

First of all, the evaluation procedure is seriously flawed. Out of the eight criteria used to evaluate each process, four are weighted toward yield. These four are weight recovery, Btu recovery, efficiency index, and $/CC ton. Furthermore, three out of the four criteria for the technical evaluation are based on yield. Only two out of eight criteria are weighted toward sulfur rejection. These are pyritic sulfur rejection and $/Ton SO_2 removed. As a result of the heavy weighting toward yield, any process which produces a high yield, regardless of the amount of sulfur rejection, does very well. For example, if a pipe was connected to the feed stream so that the entire stream was placed into the final product without separation, it would finish second as shown below.

Evaluation Including Pipe

PARTICIPANT	BTU REC	SUL REJ	EI	YIELD	SUB	O&M	CAPITAL	$/T CC	$/T SO_2	SUB	TOT	RANK
ALLMINERAL	4	6	6	2	2.25	5	4	4	6	2.37	4.62	6
CAER	2	4	2	3	1.38	2	3	2	1	1.00	2.38	1
DCCI	6	5	5	4	2.50	3	5	3	5	2.00	4.50	5
ISGS	5	3	3	5	2.00	6	2	5	4	2.12	4.12	4
MTU	3	2	1	6	1.50	4	7	6	3	2.50	4.00	3
VPI&SU	7	1	4	7	2.37	7	6	7	2	2.75	5.12	7
PIPE	1	7	7	1	2.00	1	1	1	7	1.25	3.25	2

If we included a process which can meet the DOE objective of 90 % Btu recovery and 90 % pyritic sulfur rejection, it would have finished only third in terms of technical performance.

Evaluation Including 90-90

PARTICIPANT	BTU REC	SUL REJ	EI	YIELD	SUB	O&M	CAPITAL	$/T CC	$/T SO_2	SUB	TOT	RANK
ALLMINERAL	3	7	7	1	2.25							5
CAER	1	5	3	2	1.38							1
DCCI	5	6	6	3	2.50							6
ISGS	4	4	4	4	2.00							4
MTU	2	3	1	5	1.38							1
VPI&SU	7	2	5	7	2.62							7
90-90	6	1	2	6	1.88							3

In order to evaluate all processes fairly, one should begin by looking at technical performance. Assuming that all test data are collected at steady-state, then all of the processes fall on the same grade-recovery curve (i.e., the release analysis curve) as discussed in our reports dated 2-8-90, 2-19-90, 3-5-90 and 3-26-90, and it is immaterial to carry out a technical evaluation based on grade and recovery. In other words, all of the processes are capable of achieving the same result. Therefore, the economic evaluation should be based on the same yield for all participants. In conducting this economic evaluation, however, it is important to consider several other factors. For instance, are the economic numbers based on steady-state data, how accurately have the parties involved been able to predict scale-up from laboratory data, how will each system operate over the long-term (i.e., can control be maintained, will the bubble generation system be susceptible to plugging, etc.). These are all very important factors since economic values based on non-steady-state data or improperly scaled equipment are meaningless.

I hope you find this information and analysis useful. Please feel free to contact us if you have any questions concerning our comments or the data enclosed.

Sincerely,

Roe-Hoan Yoon

Greg T. Adel

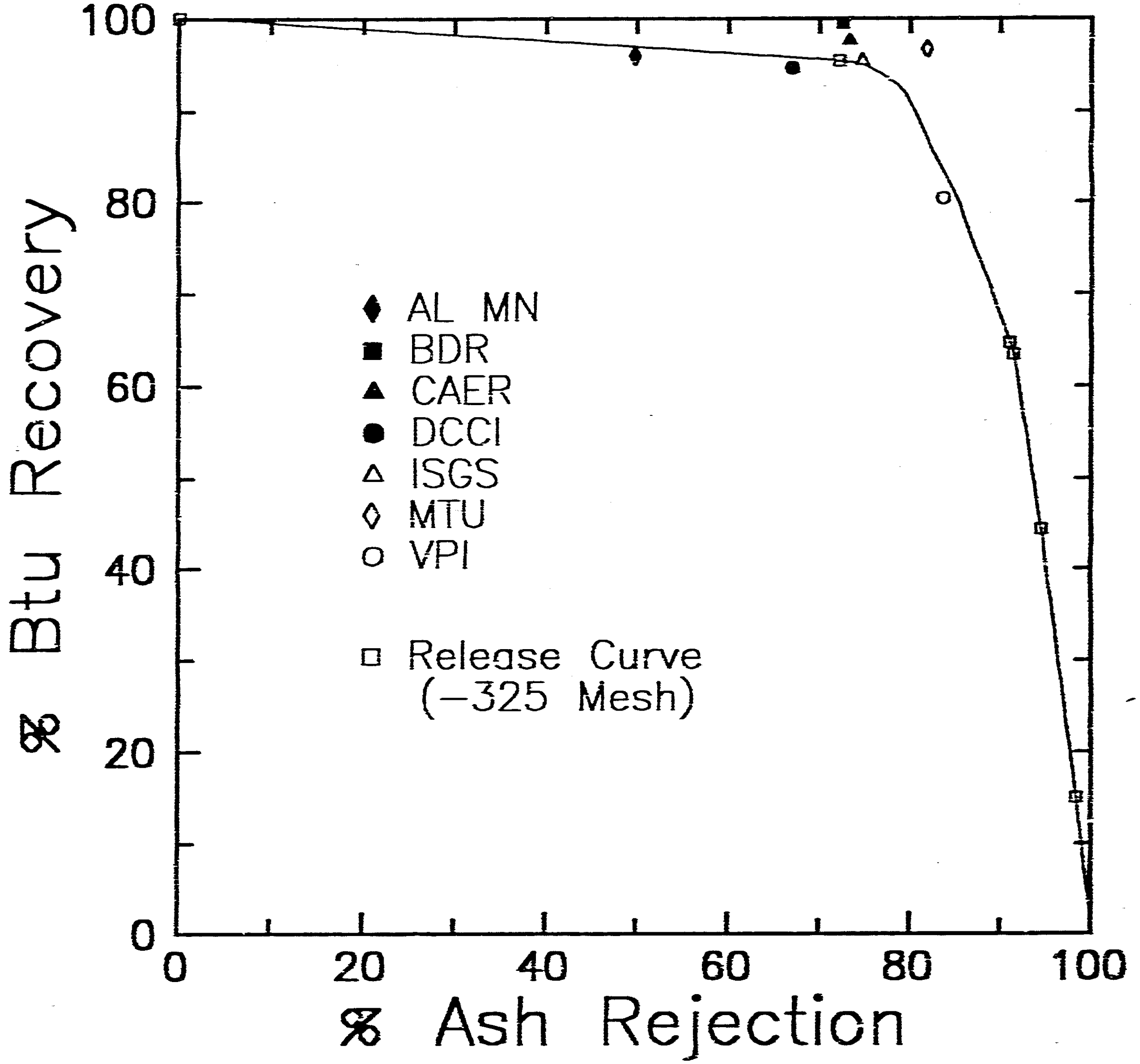
Gerald H. Luttrell

	VPI&SU Test 5.1	Test 5.2	Test 5.3	Test 5.4
FEED				
Ash (%)	12.40 (12.53)	12.40 (12.53)	12.40 (12.53)	12.40 (12.53)
Total Sulfur (%)	4.26 (4.15)	4.26 (4.15)	4.26 (4.15)	4.26 (4.15)
Pyritic Sulfur (%)	2.92 (****)	2.92 (****)	2.92 (****)	2.92 (****)
PRODUCT				
Ash (%)	3.50 (3.50)	3.79 (3.79)	4.05 (4.05)	3.58 (3.58)
Total Sulfur (%)	2.10 (2.10)	2.19 (2.19)	2.20 (2.20)	2.07 (2.07)
Pyritic Sulfur (%)	0.61 (****)	0.71 (****)	0.73 (****)	0.58 (****)
REFUSE				
Ash (%)	32.02 (32.02)	32.94 (32.94)	40.04 (40.04)	41.88 (41.88)
Total Sulfur (%)	9.02 (7.69)	9.20 (7.82)	11.08 (9.28)	11.58 (9.72)
Pyritic Sulfur (%)	8.01 (****)	8.20 (****)	10.17 (****)	10.74 (****)
OVERALL				
Retention Time (min)	5.8 (6.1)	5.7 (5.1)	5.4 (3.9)	5.8 (7.1)
Yield (%)	68.8 (68.8)	70.5 (70.5)	76.8 (76.8)	77.0 (77.0)
Btu Recovery (%)	77.6 (77.6)	79.1 (79.1)	85.9 (85.9)	86.7 (86.7)
Ash Rejection (%)	80.6 (80.6)	78.5 (78.5)	74.9 (74.9)	77.8 (77.8)
Sulfur Rejection (%)	66.1 (56.3)	63.8 (54.2)	60.3 (50.5)	62.6 (52.5)
Pyritic S. Rejection (%)	85.6 (****)	82.8 (****)	80.8 (****)	84.6 (****)
Separation Efficiency (%)	63.2 (****)	61.9 (****)	66.7 (****)	71.3 (****)

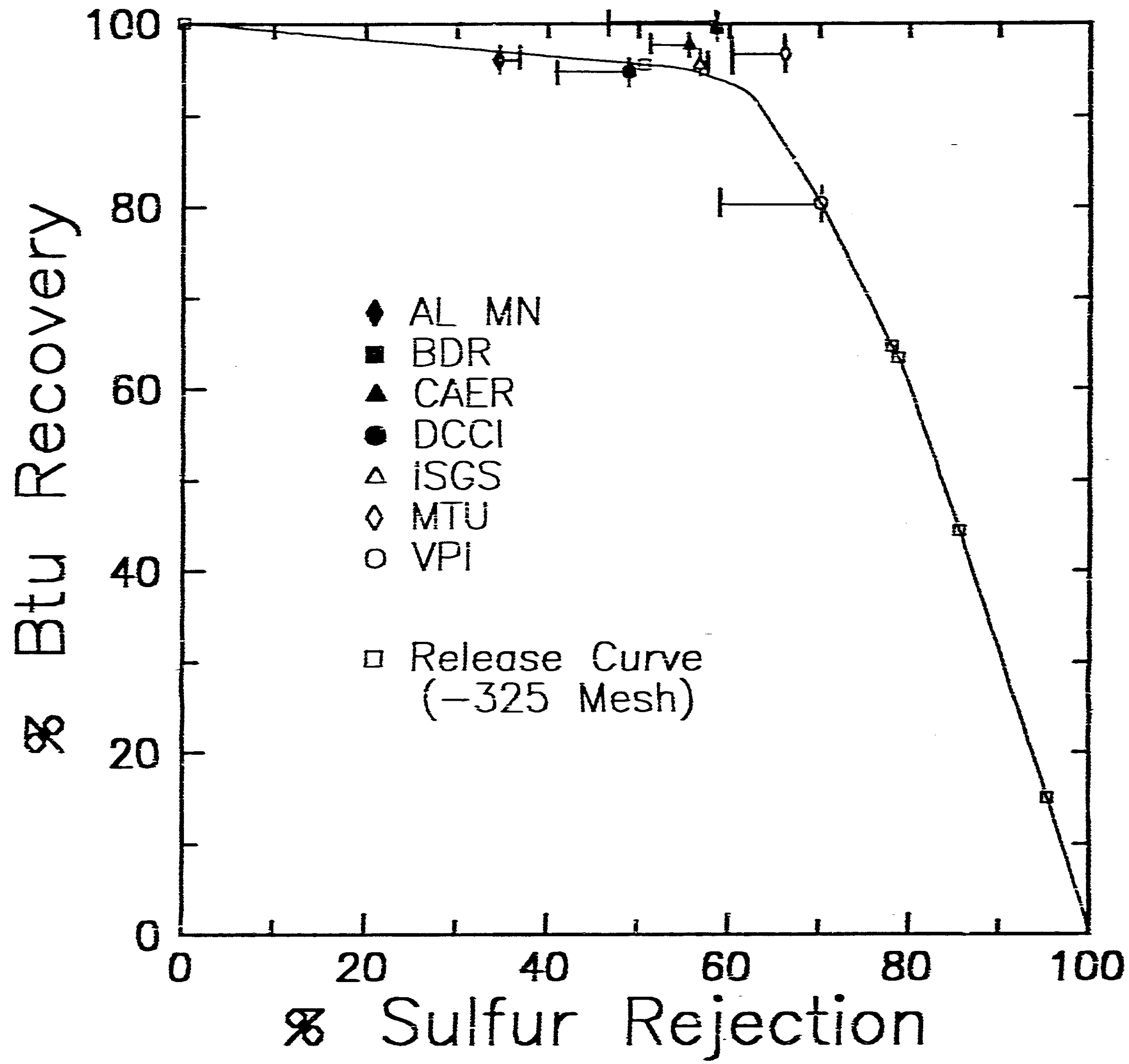
	VPI&SU Test 1	Test 2	Test 3	Test 4
FEED				
Pulp Flow (ml/min)	74 (***)	77 (***)	102 (***)	64 (**)
Water Flow (ml/min)	66 (***)	69 (***)	92 (***)	57 (**)
Solids Flow (g/min)	7.3 (****)	7.6 (****)	10.1 (****)	6.3 (***)
% Solids	9.9 (9.9)	9.9 (9.9)	9.9 (9.9)	9.9 (9.9)
PRODUCT				
Pulp Flow (ml/min)	62 (66)	89 (91)	48 (50)	45 (48)
Water Flow (ml/min)	56 (60)	83 (86)	40 (42)	41 (42)
Solids Flow (g/min)	5.0 (6.0)	5.3 (5.5)	7.7 (8.4)	4.8 (5.9)
% Solids	8.2 (9.1)	6.0 (6.0)	16.1 (16.7)	10.6 (12.1)
REFUSE				
Pulp Flow (ml/min)	512 (486)	488 (542)	554 (757)	518 (419)
Water Flow (ml/min)	510 (484)	486 (540)	552 (755)	517 (418)
Solids Flow (g/min)	2.3 (1.9)	2.2 (2.2)	2.3 (2.3)	1.4 (1.1)
% Solids	0.4 (0.4)	0.5 (0.4)	0.4 (0.3)	0.3 (0.3)
WASH WATER				
Water Flow (ml/min)	500 (500)	500 (500)	500 (500)	500 (500)
OVERALL				
Pulp Volume (ml)	2984	2779	2984	2984
Retention Time (min)	5.8 (6.1)	5.7 (5.1)	5.4 (3.9)	5.8 (7.1)

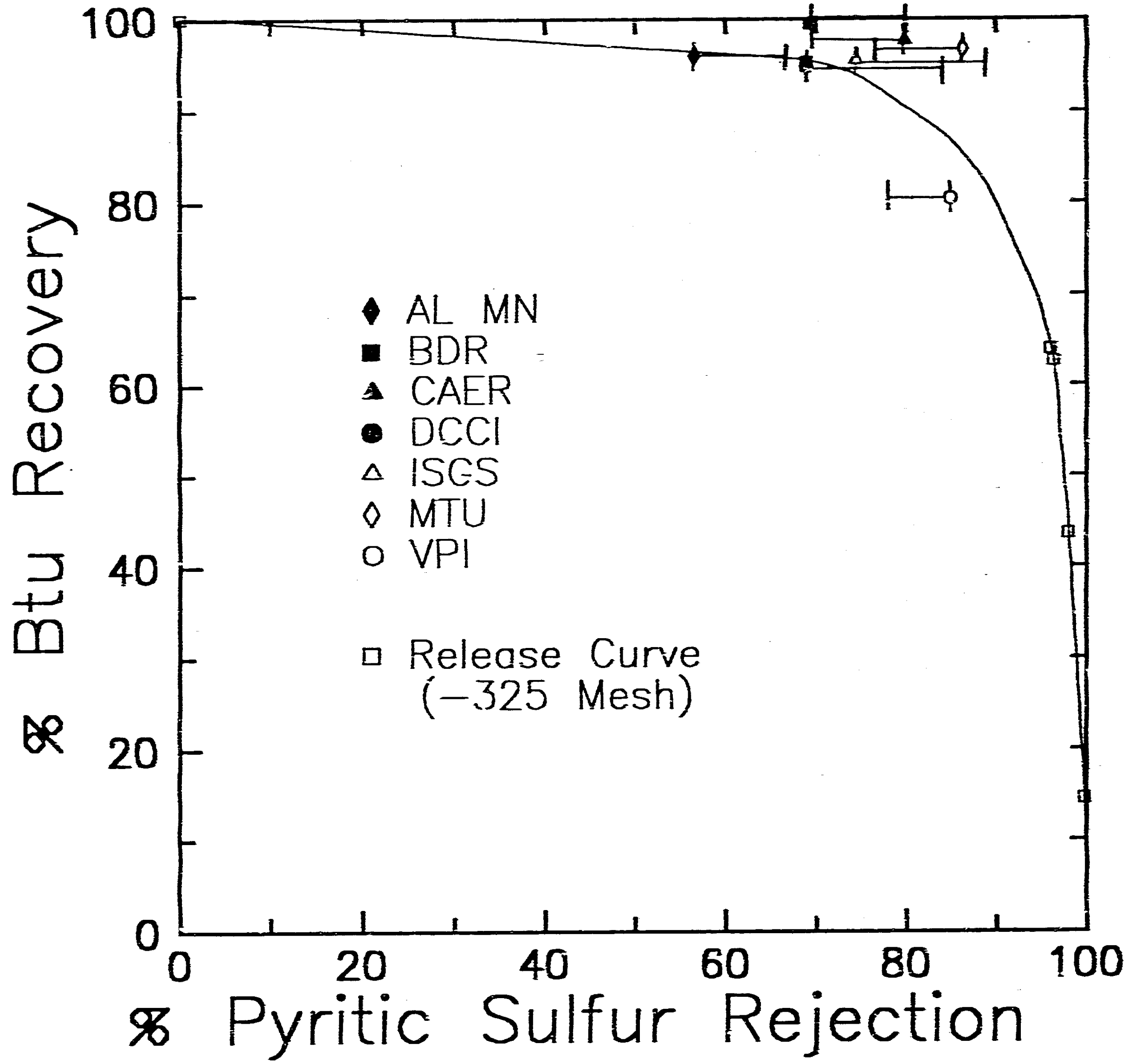
Test Number	5.1	5.2	5.3	5.4
GEOMETRY				
Height (in)	78	78	78	78
Diameter (in)	2	2	2	2
Slurry Feed Point (in)	?	?	?	?
Wash Water Addition Point (in)	?	?	?	?
Froth Height (in)	20	24	20	20
Pulp Height (in)	58	54	58	58
Baffles Spacing (in)	N/A	N/A	N/A	N/A
CONDITIONS				
Wash Water Rate (GPM)	0.132	0.132	0.132	0.132
Air Flow Rate (CFM)	0.036	0.036	0.049	0.036
Feed Slurry Rate (GPM)	0.020	0.020	0.027	0.017
Feed % Solids (Wt)	9.9	9.9	9.9	9.9
Feed Slurry pH	7.8	7.8	7.8	7.8
Feed Particle Size (d50)	Same as in Round-Robin Test No. 4			
Air Hold-Up	?	?	?	?
Retention Time (min)	5.8	5.7	5.4	5.8
REAGENTS				
Collector Name	Kerosene	Kerosene	Kerosene	Kerosene
Collector Rate (lb/ton)	3	3	3	3
Frother Name	M150	M150*	M150	M150
Frother Rate (lb/ton)	2.2	2.1	1.6	3.2
Modifier Name	N/A	N/A	N/A	N/A
Modifier Rate	N/A	N/A	N/A	N/A

* Frother added in with feed rather than in bubble generation circuit.



% Btu Recovery
% Ash Rejection
0
20
40
60
80
100
AL MN
BDR
CAER
DCCI
ISGS
MTU
VPI
Release Curve
(−325 Mesh)


% Btu Recovery
100
80
60
40
20
0
0
20
40
60
80
100
% Sulfur Rejection
AL_MN
BDR
CAER
DCCI
iSGS
MTU
VPI
Release Curve
(−325 Mesh)


100
80
60
40
20
0
% Btu Recovery
0
20
40
60
80
100
% Pyritic Sulfur Rejection
AL MN
BDR
CAER
DCCI
ISGS
MTU
VPI
Release Curve
(−325 Mesh)

The Deister Concentrator Company, Inc.
P.O. Box 1 · 901 Glasgow Avenue Fort Wayne, Indiana 46801
(219) 424-5128 · Telex 23-2428 · Facsimile No. (219) 420-3252 · Cable RETSIED

April 27,1990

Mr. Dave D. Ferris
ICF KAISER ENGINEERS,INC.
Four Gateway Center,12th Floor
Pittsburgh,Pennsylvania 15222

Reference: Comments For:Topical Report #2-Round Robin Test Results
DOE Contract Number DE-AC22-88PC88881
ICF Kaiser Engineers Number 88107-150

Dear Mr. Ferris:

Please let Deister know if we must submit these comments separately to DOE at this late date. I did not receive the preliminary draft till after the deadline date.

Comments For DOE

Capital equipment costs for The Deister Concentrator Co.,Inc. column plant were increased by 3 times by the evaluation committee. When multiplying equipment costs by 3 times to obtain preparation plant capital costs, a 9 times factor is imposed on the Deister installation. The number of Deister columns required to process 20 TPH raw coal was increased by the evaluation committee from 1 to 3 claiming that froth loading of 0.344 TPH/ft^2 must be reduced to 0.115 TPH/ft^2. Two(2) patented features of Deister Columns, center froth crowders and radial revolving froth removal blades, allows Deister columns to operate efficiently at froth loadings of up to 0.5 TPH/ft^2. Indeed, this increased froth loading over other advanced flotation process technology is an essential part of the Deister column improved ash and sulfur removal as well as increased froth % Solids to minimize downstream dewatering costs. Deister has commercial columns operating successfully at 0.425 TPH/ft^2. Correction of this erroneous equipment addition changes Deister's rating for economic parameters from 4th place to 1st place.

Technical parameter performance, The Deister Concentrator Co.,Inc. used result for standard grind and standard chemical conditions from Test #1 to be the same for Test #4 without changing grind and chemical conditions. Yet, Table 3.7,pg.48 lists Deister BTU recovery at 98.6% for Test 1 while a typographic error relists Deister BTU Recovery at 94.61% for Test 4,Table3.9, pg.51. Correction of this typographic error changes Deister's rating for BTU recovery from 5th place to 1st place.

Total Performance - Correction of the capital cost error and correction of the typographic performance error gives Deister a 1.750 technical performance index and a 0.500 economical performance index for an overall performance index of 2.250- the best of all.

Second place contender would have an overall index of 2.375.

Very truly yours,
THE DEISTER CONCENTRATOR CO,INC

Donald E. Zipperian,Chief
Mineral Processing Engineer.

Equipment Manufacturers for Separating and Sizing of Material Since 1906

APR 30 1990

TABLE 3.7

FLOTATION PERFORMANCE RESULTS PHASE 1

		AL MN			BDR			CAER			DCCI			ISGS			MTU			VPI		
		#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3
FEED																						
WEIGHT %	BILMAT	100.0	100.0	100.0	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	REPORTED	100.0	100.0	100.0	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
ASH %	BILMAT	11.75	11.75	11.75	N/A	N/A	N/A	11.95	11.95	11.95	12.14	12.14	12.14	12.05	12.05	12.05	11.99	11.99	11.99	12.40	12.40	12.40
	REPORTED	12.10	12.05	12.10	N/A	N/A	N/A	11.65	11.38	11.65	11.94	11.94	11.87	11.70	13.70	12.40	11.96	11.91	11.84	11.85	11.78	11.99
PYRITIC SULFUR %	BILMAT	2.36	2.36	2.36	N/A	N/A	N/A	2.79	2.79	2.79	2.42	2.42	2.42	2.44	2.44	2.44	2.36	2.36	2.36	2.92	2.92	2.92
	REPORTED	2.08	2.08	2.08	N/A	N/A	N/A	2.20	2.20	2.20	2.81	2.80	2.81	2.75	2.72	2.81	2.12	2.24	2.13	2.52	2.60	2.86
TOTAL SULFUR %	BILMAT	3.98	3.96	3.98	N/A	N/A	N/A	4.20	4.20	4.20	3.93	3.93	3.93	3.92	3.92	3.92	4.07	4.07	4.07	4.26	4.26	4.26
	REPORTED	3.70	4.00	4.10	N/A	N/A	N/A	4.12	4.12	4.12	4.11	3.80	3.88	4.07	3.94	4.18	4.43	4.31	3.93	3.96	3.87	4.01
BTU	REPORTED	12350	12350	12350	N/A	N/A	N/A	12506	12506	12506	12335	12335	12335	12389	12389	12389	12420	12420	12420	12506	12506	12506
CLEAN COAL																						
WEIGHT %	BILMAT	63.60	72.20	65.90				5.90	3.50	93.90	85.60	85.50	90.70	80.70	54.10	83.30	88.60	87.00	89.70	58.40	55.10	60.00
	REPORTED	58.19	69.75	62.93	N/A	N/A	N/A	8.80	9.10	94.60	86.06	85.98	91.17	82.06	40.59	81.86	88.92	87.83	90.69	60.88	58.02	62.15
ASH %	BILMAT	9.20	8.30	7.80	N/A	N/A	N/A	2.47	2.10	8.46	4.72	5.70	6.73	6.60	6.40	7.80	4.44	2.90	5.18	3.35	3.09	4.90
	REPORTED	9.20	8.30	7.80	N/A	N/A	N/A	2.47	2.10	8.48	4.72	5.70	6.73	6.60	6.40	7.80	4.45	2.90	5.19	3.35	3.09	4.90
PYRITIC SULFUR %	BILMAT	1.85	1.04	1.29	N/A	N/A	N/A	0.50	0.39	2.47	0.88	1.21	1.64	1.34	1.20	1.60	0.79	0.46	1.36	0.66	0.58	0.74
	REPORTED	1.69	0.91	1.13	N/A	N/A	N/A	0.50	0.39	2.00	0.95	1.39	1.88	1.53	1.19	1.82	0.69	0.41	1.05	0.65	0.57	0.74
TOTAL SULFUR %	BILMAT	3.70	2.90	3.00	N/A	N/A	N/A	1.68	1.87	3.64	2.35	2.60	2.91	2.93	2.40	3.24	2.40	1.76	2.51	2.06	2.07	2.41
	REPORTED	3.70	2.90	3.00	N/A	N/A	N/A	1.68	1.87	3.64	2.35	2.60	2.91	2.93	2.40	3.24	2.40	1.76	2.51	2.06	2.07	2.41
BTU	REPORTED	12680	12949	13423	N/A	N/A	N/A	14117	13870	13345	14160	13916	13651	13825	13883	13622	13882	13795	13865	14315	14178	14048
REFUSE																						
WEIGHT %	BILMAT	36.40	27.80	34.10				94.10	96.50	6.10	14.40	14.50	9.30	19.30	45.90	16.70	11.40	13.00	10.30	41.60	44.90	40.00
	REPORTED	41.81	30.25	37.07	N/A	N/A	N/A	91.20	90.90	5.40	13.94	14.02	8.83	17.94	59.41	18.14	11.08	12.17	9.31	39.12	41.98	37.85
ASH %	BILMAT	16.20	20.70	19.40	N/A	N/A	N/A	12.54	12.31	66.66	56.42	50.17	64.99	34.80	18.70	33.30	71.23	72.61	72.22	25.09	23.81	23.63
	REPORTED	16.20	20.70	19.40	N/A	N/A	N/A	12.54	12.31	66.74	56.48	50.20	64.97	34.80	18.70	33.30	71.44	72.61	72.49	25.09	23.81	23.63
PYRITIC SULFUR %	BILMAT	3.25	5.79	4.44	N/A	N/A	N/A	2.93	2.88	7.76	11.58	9.53	10.07	7.01	3.89	6.61	14.57	15.03	11.06	6.08	5.79	8.19
	REPORTED	2.97	4.55	3.61	N/A	N/A	N/A	1.90	2.80	7.35	14.25	11.63	10.90	8.33	3.77	7.31	11.15	10.26	8.63	5.43	5.41	6.34
TOTAL SULFUR %	BILMAT	4.47	6.78	5.88	N/A	N/A	N/A	4.36	4.29	12.86	13.33	11.77	13.92	8.05	5.71	7.32	17.08	19.49	17.70	7.34	6.94	7.03
	REPORTED	4.66	6.54	5.98	N/A	N/A	N/A	3.77	4.17	9.13	11.19	12.51	11.54	9.30	5.00	8.44	16.80	18.15	15.14	6.92	6.36	6.64
BTU	REPORTED	11058	10231	10829	N/A	N/A	N/A	11325	12572	3432	5149	6471	3916	8955	11810	9308	2016	1980	2085	10798	10135	8212
BTU RECOVERY		65.30	75.70	71.63	N/A	N/A	N/A	6.66	3.88	100.2	98.26	98.46	100.4	90.05	60.62	91.59	99.03	98.63	100.1	86.85	62.46	67.40
PYRITIC SULFUR REJECTION		50.13	68.20	64.15	N/A	N/A	N/A	98.82	99.61	16.97	68.91	57.10	38.70	55.45	73.18	45.24	70.38	82.79	48.27	86.62	89.03	84.79
EFFICIENCY		15.43	43.91	35.78	N/A	N/A	N/A	5.48	3.49	17.17	67.17	53.56	39.08	45.50	33.80	36.83	69.41	79.42	48.41	53.47	51.49	52.19

AL MN = ALL MINERAL, BDR = B. DATTA RESEARCH, CAER = CENTER for APPLIED ENERGY RESEARCH, DCCI = DEISTER CONCENTRATOR COMPANY, INC., ISGS = ILLINOIS STATE GEOLOGICAL SURVEY
MTU = MICHIGAN TECHNOLOGICAL UNIVERSITY, VPI = VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

TABLE 3.9

FLOTATION PERFORMANCE RESULTS PHASE 2

PERFORMANCE PARAMETER		AL MN #4	BDR #4	CAER #4	DCCI #4	ISGS #4	MTU #4	VPI #4
FEED								
WEIGHT %	BILMAT	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	REPORTED	100.0	100.0	100.0	100.0	100.0	100.0	100.0
ASH %	BILMAT	11.75	12.00	11.95	12.14	12.05	11.99	12.40
	REPORTED	11.80	12.77	11.65	11.94	11.45	11.67	11.67
PYRITIC SULFUR %	BILMAT	2.36	2.19	2.79	2.42	2.44	2.36	2.92
	REPORTED	2.08	2.62	2.39	3.58	2.67	1.99	1.54
TOTAL SULFUR %	BILMAT	3.98	3.93	4.20	3.93	3.92	4.07	4.26
	REPORTED	4.11	3.62	3.92	2.80	3.79	3.66	3.74
BTU	CALCULATED	12378	12339	12347	12317	12331	12340	12277
	REPORTED	12350	12412	12506	12335	12389	12420	12506
CLEAN COAL								
WEIGHT %	BILMAT	89.50	89.00	87.50	85.60	85.40	83.70	70.00
	REPORTED	89.49	88.00	88.10	86.06	86.48	84.97	72.28
ASH %	BILMAT	6.64	3.73	3.72	4.72	3.60	2.59	2.91
	REPORTED	6.65	3.73	3.73	4.72	3.60	2.59	2.91
PYRITIC SULFUR %	BILMAT	0.92	0.76	0.65	0.88	0.73	0.39	0.47
	REPORTED	0.84	0.80	0.62	0.95	0.77	0.38	0.40
TOTAL SULFUR %	BILMAT	2.92	1.83	2.13	2.35	1.99	1.65	1.90
	REPORTED	2.92	1.83	2.13	2.35	1.99	1.65	1.90
BTU	CALCULATED	13268	13786	13788	13614	13809	14236	14088
	REPORTED	13424	14082	14110	14160	14322	13824	14333
REFUSE								
WEIGHT %	BILMAT	10.50	11.00	12.50	14.40	14.60	16.30	30.00
	REPORTED	10.51	12.00	11.90	13.94	13.52	15.93	27.72
ASH %	BILMAT	55.64	78.99	69.97	56.42	61.58	60.15	34.51
	REPORTED	55.70	79.09	70.27	56.48	61.67	60.15	34.51
PYRITIC SULFUR %	BILMAT	13.04	13.77	17.78	11.58	12.42	12.46	8.62
	REPORTED	12.67	15.93	15.50	14.25	14.83	11.10	4.53
TOTAL SULFUR %	BILMAT	14.70	20.89	18.66	13.33	15.19	16.47	9.76
	REPORTED	14.20	16.78	17.20	11.19	15.29	15.04	8.52
BTU	REPORTED	6895	2562	2440	5149	3700	4120	9057
BTU RECOVERY		95.94	99.44	97.71	94.61	95.64	96.56	80.33
PYRITIC SULFUR REJECTION		58.02	69.16	79.66	68.91	74.32	86.06	88.56
EFFICIENCY		53.95	68.60	77.37	63.52	69.95	82.62	68.89

TABLE 3.10

FROTH FLOTATION PROCESS VARIBLES PHASE 2

PERFORMANCE PARAMETER	UNIT	AL MN #4	BDR #4	CAER #4	DCCI #4	ISGS #4	MTU #4	VPI #4
GEOMETRY								
HEIGHT	IN	23.00	182.0	236.0	122.0	8.00	96.00	60.0
DIAMETER	IN	3.00	3.00	2.0	3.0	N/A	1.80	2.0
SLURRY FEED POINT	IN	0.00	60.00	156.0	32.0	N/A	46.00	18.5
WASH WATER ADDITION PT	IN	N/A	21.00	12.0	1.0	N/A	2.00	3.5
FROTH HEIGHT	IN	1.00	48.00	48.0	18.0	1.00	N/A	20.0
PULP HEIGHT	IN	22.00	120.0	186.0	104.0	7.00	N/A	48.0
BAFFLES SPACING	IN	N/A	N/A	N/A	N/A	N/A	NOTE 1	N/A
CONDITIONS								
WASH WATER RATE	GPM	N/A	0.159	0.10	0.330	N/A	0.0366	0.132
AIR FLOW RATE	CFM	0.071	0.120	0.070	0.100	0.280	0.2120	0.044
FEED SLURRY RATE	GPM	0.450	3.500	0.130	0.320	N/A	0.0180	0.017
FEED % SOLIDS	WT	5.00	10.00	10.00	10.00	9.80	10.00	8.89
FEED SLURRY pH		7.00	7.00	7.00	7.00	7.00	7.00	9.20
FEED PARTICLE SIZE	d50	6.72	12.10	12.22	N/A	10.57	11.98	N/A
AIR HOLD-UP		N/A	10.80	9.50	N/A	N/A	30.00	26.12
RETENTION TIME	MIN	0.99	5.00	13.50	4.90	18.00	28.30	5.20
REAGENTS								
COLLECTOR NAME		NOTE 2	NOTE 4	NOTE 4	NOTE 4	NOTE 4	NOTE 5	NOTE 4
COLLECTOR RATE	#/T	1.10	3.00	2.00	3.00	6.40	2.56	1.00
FROTHER NAME		N/A	MIBC	MIBC	M150	M150	NOTE 6	M150
FROTHER RATE	#/T	N/A	2.00	1.00	1.00	2.99	1.43	3.94
MODIFIER NAME		NOTE 3	N/A	N/A	N/A	N/A	N/A	N/A
MODIFIER RATE	#/T	0.22	N/A	N/A	N/A	N/A	N/A	N/A

NOTE 1 STACKED CORRUGATED PLATES ARRANGED IN BLOCK POSITION AT RIGHT ANGLES TO EACH OTH
NOTE 2 MONTANOL 551 F2 THIS IS FROTHER AND COLLECTOR COMBINATION
NOTE 3 Vanis pers
NOTE 4 KEROSENE
NOTE 5 NO. 2 FUEL OIL
NOTE 6 PINE OIL

100	CONDITIONING/FEED SUMP	1	-	-	-	-	2500 GALLON CAPACITY	10,550
101.1	CONDITIONING/FEED SUMP MIXER	1	1	10550	30.00	YES	PHIADELPHIA MODEL 3805-S-PTO	13,200
105	FEED PUMP	1	1	13200	40.00	YES	GOYNE MODEL 5000, 80' TDH / 800 GPM	
110	ROUGHER COLLECTOR REAGENT PUMP	3	3	7428	0.20	YES	PULSAFEEDER MODEL 680C-S-AE	7428
115	ROUGHER FROTHER REAGENT PUMP	3	3	7386	0.20	YES	PULSAFEEDER MODEL 680C-S-AE	7386
120	ROUGHER FLOTATION MACHINES	3	3	240000	15.00	YES	FLOTAIRE MODEL FL8024 8' DIA X 24' HIGH	77,000 use 80,000
120.1	ROUGHER FLOTATION BLOWER	1	1	48530	40.00	YES	AIRTEC - 300 CFM @ 40 PSIG	48530

167,094
x 3
501,282

TOTAL		327094	156.20

TOTAL ESTIMATED CAPITAL COST IS BASED ON HOFFMAN-MUNTNER REPORT NO. EPA-600/7-78-124, "AN ENGINEERING/ECNOMIC ANALYSIS OF COAL PREPARATION PLANT OPERATION AND COST"

THIS REPORT STATES THAT THE CAPITAL COST OF A PREPARATION PLANT CAN BE ESTIMATED BY MULTIPLING THE EQUIPMENT COST BY 3.

TOTAL EQUIPMENT COST 327094

TOTAL PROJECT ESTIMATE 981282

END

DATE FILMED

11 / 08 / 90