DOE/PC/88881--T6

QUARTERLY REPORT NO. 6

For

ENGINEERING DEVELOPMENT OF ADVANCED PHYSICAL FINE COAL CLEANING TECHNOLOGIES – FROTH FLOTATION

Prepared for
U.S. DEPARTMENT OF ENERGY
PITTSBURGH ENERGY TECHNOLOGY CENTER
Pittsburgh, Pennsylvania

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ICF KAISER ENGINEERS

With

Ohio Coal Development Office

Babcock & Wilcox | **Consolidation Coal Company**

Center for Research on Sulfur in Coal

EIMCO Process Equipment Company | **Illinois State Geologic Survey**

Kentucky Energy Cabinet Laboratory

Virginia Polytechnic Institute & State University

QUARTERLY TECHNICAL PROGRESS REPORT NO. 6

FOR PERIOD

JANUARY 1, 1990, THROUGH MARCH 31, 1990

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1.0 INTRODUCTION

A study conducted by Pittsburgh Energy Technology Center of sulfur emissions from about 1,300 United States coal-fired utility boilers indicated that half of the emissions were the result of burning coals having greater than 1.2 pounds of SO_2 per million BTU. This was mainly attributed to the high pyritic sulfur content of the boiler fuel. A significant reduction in SO_2 emissions could be accomplished by removing the pyrite from the coals by advanced physical fine coal cleaning.

An engineering development project was prepared to build upon the basic research effort conducted under a solicitation for research into Fine Coal Surface Control. The engineering development project is intended to use general plant design knowledge and conceptualize a plant to utilize advanced froth flotation technology to process coal and produce a product having maximum practical pyritic sulfur reduction consistent with maximum practical BTU recovery.

1.1 Scope of this Document

The Department of Energy (DOE) awarded a contract entitled "Engineering Development of Advanced Physical Fine Coal Cleaning Technology - Froth Flotation", to ICF Kaiser Engineers with the following team members, Ohio Coal Development Office, Babcock and Wilcox, Consolidation Coal Company, Eimco Process Equipment Company, Illinois State Geological Survey and Virginia Polytechnic Institute and State University. The organizational chart for this project is presented in Figure 1.1.

This document is the sixth quarterly report prepared in accordance with the project reporting requirements covering the period from January 1, 1990 to March 31, 1990. This report provides a summary of the technical work undertaken during this period, highlighting the major results. A brief description of the work done prior to this quarter is also provided in this report.

1.2 Overall Project Scope

The overall project scope of the engineering development project is to conceptually develop a commercial flowsheet to maximize pyritic sulfur reduction at practical energy recovery values. This is being accomplished by utilizing the basic research data on the surface properties of coal, mineral matter and pyrite obtained from the Coal Surface Control for Advanced Fine Coal Flotation Project, to develop this conceptual flowsheet. The conceptual flowsheet must be examined to identify critical areas that need additional design data. This data will then be developed using batch and semi-continuous bench scale testing. In addition to actual bench scale testing, other unit operations from other industries processing fine material will be reviewed for potential application and incorporated into the design if appropriate.

The conceptual flowsheet will be revised based on the results of the bench scale testing and areas will be identified that need further larger scale design data verification, to prove out the design. The

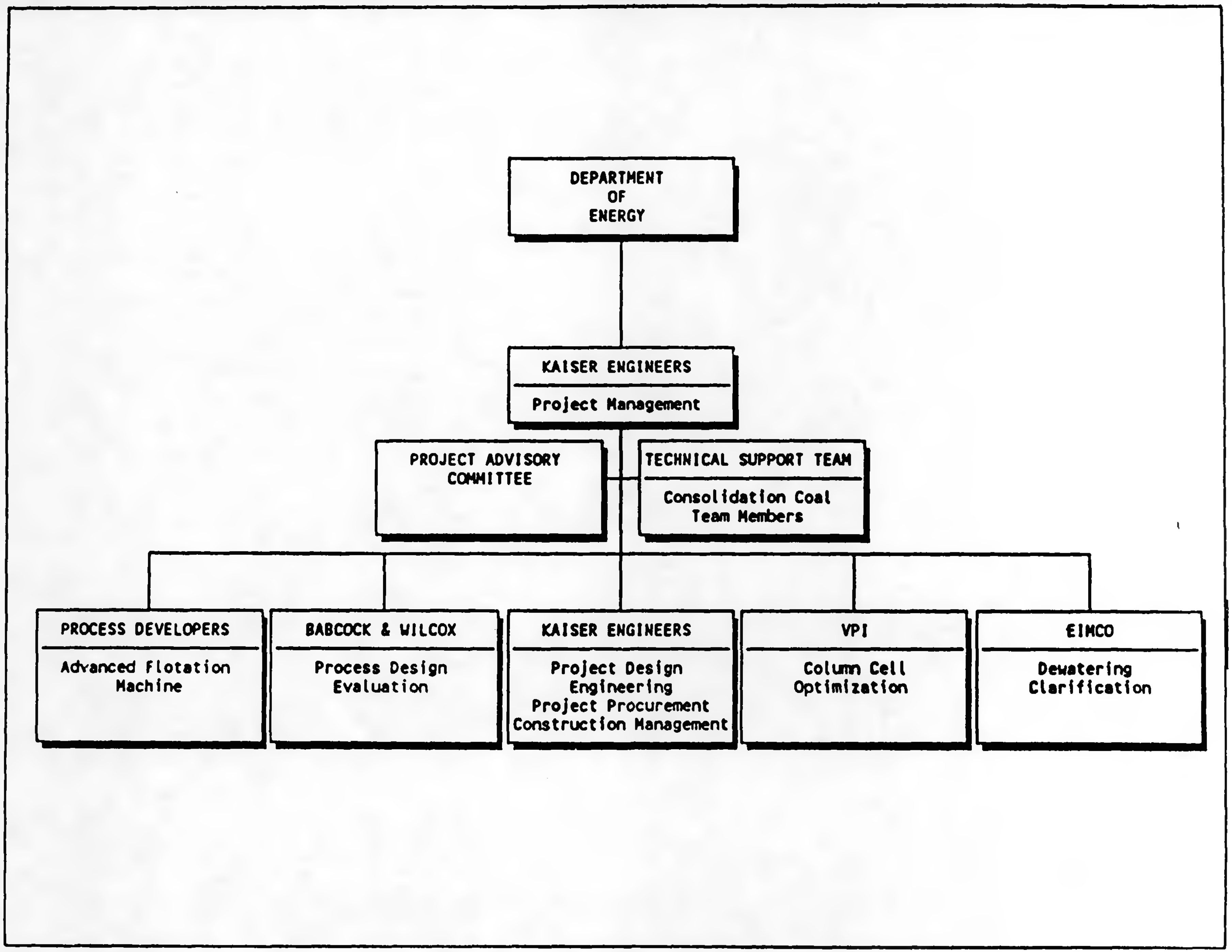


Figure 1-1: Project Organization Chart

proof of concept will be accomplished by designing, constructing, operating and testing a 2-3 ton per hour proof-of-concept plant. This plant will be designed for continuous operation and will include two consecutive 5 days, 24 hour per day runs on each of the three test coals to demonstrate process performance on a commercial basis.

The data from the basic research on coal surfaces, bench scale testing and proof-of-concept scale testing will be utilized to design a final conceptual flowsheet.

The economics of the flowsheet will be determined to enable industry to assess the feasibility of incorporating the advanced fine coal cleaning technology into the production of clean coal for generating electricity. This concept should provide an ability to reduce sulfur oxide emissions more economically than FGD systems when compared on a dollar per ton of sulfur removed basis.

1.3 Work Executed at Different Locations

The project team consists of research and engineering groups at ICF Kaiser Engineers, Babcock and Wilcox, Consolidation Coal Company, Eimco Process Equipment Company, Illinois State Geological Survey and Virginia Polytechnic Institute and State University with ICF Kaiser Engineers as the prime contractor with DOE. The work being conducted by different organizations is based upon their area of expertise and this has been incorporated into the project Work Plan. The work undertaken by the different organizations is identified in Table 1.1. This report is prepared in an integrated manner combining work done by each organization by task. This is considered to be a more effective way of presenting the technical data developed by each organization.

TABLE 1.1
TASKS AND THE RESPONSIBLE TEAM MEMBERS

Task 1	Project Planning	KE
Task 2	Preliminary Conceptual Design	KE, B&W, EIMCO, TSG, TAC
Task 3	Determination of Critical Areas	KE, B&W, EIMCO, TSG, TAC
Task 4	Test Plan Formulation	KE, B&W, EIMCO, TSG
Task 5	Bench Scale Testing	KE, B&W, EIMCO, TSG, TAC
Task 6	Component Development	VPI, TSG
Task 7	Analysis of Test Results	KE, B&W, EIMCO, VPI, TSG
Task 8	Revised Conceptual Design	KE
Task 9	POC Module Design	KE, B&W, EIMCO, TSG, TAC
Task 10	POC Procurement and Fabrication	KE
Task 11	POC Installation and Startup	KE, B&W, EIMCO, TSG
Task 12	POC Test Plan Formulation	KE, B&W, EIMCO, TSG, TAC
Task 13	POC Testing and Operation	KE, B&W, EIMCO, TSG
Task 14	Analysis of POC Test Results	KE, B&W, EIMCO, TSG
Task 15	Final Conceptual Design	KE, B&W, EIMCO, TSG
Task 16	POC Module Removal	KE

The project progress is being maintained based on verbal authorization from DOE. The project is approximately four months behind schedule. All the DOE reporting requirements of technical, cost, and labor reports, except the technical report for Task 2 were generally met on schedule.

1.4 Work Undertaken During the First Six Quarters

Progress was made in the previous six quarters (October 1, 1988 to March 31, 1990). As presented in the previous quarterly reports, the major accomplishments were:

- Contract award on September 27, 1988.
- ICF KE Team Project Kickoff meeting on October 14, 1988.
- Submittal of Draft Work Plan on November 4, 1988.
- DOE Project Kickoff meeting on November 9, 1988.
- Submittal of Final Work Plan and Draft QA/QC Plan on December 23, 1988.
- Subcontracts awarded to B&W, Consol, Eimco, and VPI.
- ICF KE project review meeting held at PETC on January 30.
- ICF KE team review meeting of February 7, 1989 to review conceptual design.
- Completion of Task 2 and Task 3 reports.
- Surface Control Project review meeting on March 30 attended by ICF KE.
- Submittal of Cost and Labor Plans and three monthly Cost and Labor Reports.
- Completion and submittal of revised reports for Task 2 and Task 3.
- Completion submittal and approval of Round Robin plan and Coal Procurement Plan.
- Choice of Peabody Coal as supplier of Illinois #6 coal.
- Receipt of 1600 pounds of Pittsburgh #8 coal at B&W from Praxis, one of the Surface Control Program subcontractors.
- Completion of fabrication and installation of optimized column cell and three circuit configuration cells at VPI.
- Attended project review meeting at PETC for UCB Surface Control Program.
- Completed revised Task 2 report and submitted to DOE and EOS.

- Compared raw coal sample analysis data with UCB data and verified that no further oxidation occurred since original sample was prepared.

- Continued work on column cell simulator.

- Preliminary grinding work at B&W.

- Testing of sample received from Praxis confirmed that it was Pittsburgh #8 coal and that no further oxidation had occurred which impacted the coal's flotation potential.

- Issued five purchase orders for Round Robin participation.

- Prepared and discussed answers to Task 2 questions. Revised Task 2 report.

- Continued preliminary grinding work at B&W and shipped samples to EPRI for washability analysis and to VPI for pyrite particle size analysis.

- Team members reviewed and critiqued the Task 4 report.

- Dr. S.Y. Shiao of B&W visited UBC to observe testing and to discuss significant results of surface modification work.

- Met with TPO to discuss Task 2 and present final approved version of report. Submitted Task 4 draft report and Task 3 revised report for final approval.

- Received EPRI washability analysis and VPI pyrite particle size analysis for two preliminary samples at different grinding times.

- The base coal sample (Pittsburgh #8) was taken September 7 at Ohio Valley Coal. The lab homogenized the sample, made a split for analyses, shipped to B&W in inerted drums.

- B&W completed and shipped coal to the round robin participants. Each shipment contained 120 pounds of coal crushed to 1/4" top size and 40 pounds of coal in a 35% solids concentration slurry. Each participant received the sample preparation details and the inerting procedure used by B&W.

- B&W received approximately 12 tons of Pittsburgh #8 raw coal from Belmont County, Ohio.

- Detailed sample analyses were sent to Round-Robin participants including PSD, washability, pH, ash, total sulfur, pyritic sulfur and Btu.

- ICF KE process engineers visited all round-robin participants except Deister and Allmineral to witness one round-robin test.

- TraDet, Inc. completed the laboratory work on the Head Sample for the Pittsburgh #8 raw coal.

- B&W received the Krebs portable hydrocyclone rig and the Denver 4-cell flotation machine and installation is completed.

- ICF KE presented a paper at the EPRI workshop on September 25, 1989.

- B&W completed preliminary runs and setup of first and second-stage hydrocyclone.

- B&W performed several lab flotation tests and several preliminary runs on the conventional flotation cells to determine reagent dosage levels.

- A technical Support Group meeting was held on January 10 to discuss budgets and schedules for Task 5 work in progress.

- B&W completed preliminary runs and setup of continuous conventional flotation rig.

- B&W completed a continuous test run on the conventional cells and produced seven drums of material that were shipped to VPI for use in Task 6.

- Data from the fourth round robin test was submitted by participants and was analyzed by ICF KE and other team members.

- B&W and VPI worked on budgeting changes to Task 5 in an attempt to reduce costs and improve schedule.

- B&W completed preliminary runs and setup of 2" diameter advanced flotation rig.

- B&W began the bench-scale microgrinding tests.

- Several runs were made to grind to 325M x 0 and the 2" column was set up and operated at various conditions to zero in on a standard set of operating conditions.

- VPI submitted budgeting estimates for Task 5 in an attempt to reduce costs and improve schedule.

- ICF KE halted B&W work on continuous flotation in conventional cells pending an agreement in work scope modifications.

- ICF KE presented a technical paper entitled "Advanced Froth Flotation - An Effective Tool for Reducing An Acid Rain Precursor?" at the annual AIME meeting.

- ICF KE restarted B&W work on continuous flotation in conventional cells on the Pittsburgh #8 coal. B&W completed the preliminary testing on the grab run, split flotation.

- VPI completed, for B&W, a CCSEM analysis of pyrite particle size distribution in a 4" lump of new Pittsburgh #8 coal.

- ICF KE continued preparation of Topical Reports for the pyrite liberation study and for the round robin program.

- B&W continued work on continuous flotation in conventional cells on the Pittsburgh #8 coal.

- B&W conducted the continuous microgrinding tests.

- Analyses of the final bench-scale microgrinding flotation tests were released.

- ICF KE continued preparation of the Topical Report for the pyrite liberation study and completed the Round Robin Technical Report.

- Negotiations began with Process Technology, Inc. in conjunction with Michigan Tech Mineral Research Institute to test Illinois No. 6 and Upper Freeport Coal. This was begun in order to improve the schedule and contain costs.

2.0 TASK 2 PRELIMINARY CONCEPTUAL DESIGN

2.1 Overview and Scope

The completion of this task resulted in the preliminary conceptual design of a 20TPH semi-works advanced froth flotation facility. The non-site-specific plant was designed using the best available information and technology to achieve continuous, steady-state process operation with 90% availability. The process plant is a fully instrumented, integrated, stand-alone facility. A greenfield site was assumed for the plant.

Each sub-task was logically assigned to provide necessary information for the next sub-task, ultimately resulting in completion of the conceptual design. The first sub-task determined the design criteria needed to meet or exceed the advanced froth flotation process specifications. At completion, work under this sub-task provided information to design the flowsheet of the process, complete with energy and material balances of all process streams. A list of all major process equipment was prepared and used as a basis for a factored estimate for the capital, operating and maintenance costs of the semi-works process and plant.

ICF Kaiser Engineers, assisted by the project sub-contractors and Technical Support Group, was responsible for the performance and completion of this task. This conceptual design is the basis for Tasks 3, 4, 5, and 6 and will be revised in Task 8 for use as a basis for the 2-3TPH POC module designs in Task 9.

2.2 Review of Work Completed This Quarter

On August 15, 1989, DOE approved Task 1.2 as submitted. With this as a basis, ICF KE and the team members are now proceeding with the remainder of the project. No additional work was completed during this quarter.

3.0 TASK 3 CRITICAL AREA DETERMINATION

3.1 Overview and Scope

Work performed during the conceptual design of Task 2 has identified areas where uncertainties exist in the design of the unit operations for the advanced froth flotation process. Some of these problem areas cannot be solved based on currently available information or technology. The objective of this task was to determine those critical areas where more information would be necessary and outline the work needed to obtain the design information.

A design deficiency list was generated, and the project team determined the parameters needed for final design of the unit operation - either by further engineering analysis or by experimental data obtained from bench-scale tests. Other solids processing industries, such as phosphate and clay beneficiation, were examined to assess their ability to effectively process ultra fine particles.

Each design deficiency was then ranked according to its relative importance to the successful continuous operation of the advanced froth flotation process. Both a technical and economic analyses of the consequences of not being able to gather the required design information for each deficiency was evaluated.

ICF Kaiser Engineers, Consolidation Coal and the other members of the Technical Support Team (B&W, VPI and EIMCO) have contributed to this task. The process deficiencies identified in this task will be addressed in Tasks 4, 5, and 6 through additional engineering computation and analysis and experimental techniques.

3.2 Review of Work Completed This Quarter

The second draft of this task report has been submitted to DOE for approval. As of the date of this quarterly report ICF KE has not received approval of the task report. No additional work was completed during this quarter.

4.0 TASK 4 TEST PLAN FORMULATION

4.1 Overview and Scope

This task developed the criteria for additional engineering analysis, computation and detailed experimental bench-scale testing for areas of uncertainty identified in Task 3. The engineering analysis, computation, bench-scale testing and component development was formulated to produce necessary design information to define a commercially operating system.

In order to produce the required information by means of bench-scale testing and component development, a uniform coal sample was procured. After agreement with DOE, a selected sample of coal from those previously listed was secured.

The test plan was developed in two parts. The first part listed procedures for engineering and computation analysis of those deficiencies previously identified that are amenable to this type of solution. Likewise, the second part prepared procedures for bench-scale testing and component development for those deficiencies previously identified in Task 3.

The first part, engineering analysis and computation, provided for means of employing presently know theory from other industries to address deficiencies. This included examinations of literature and contacting proven experts and operating personnel in fields related to this deficiency. From the information gathered, engineering calculations will be utilized to resolve the deficiency.

The second part, bench-scale testing and component development, becomes necessary when the part one information is unavailable or the theory has never been commercially applied. Justification for the test work was provided to show that technical data and process needs can only be obtained by test work and that the test work results would produce necessary information to define a commercially operating system.

The test work will be based upon non-continuous and/or semi-continuous bench-scale units of general laboratory design and will be only those unit operations identified as deficiencies in Task 3.

The detailed, quantified tests will address obtaining data necessary for solving problems uncovered in the deficiency review. Each identified deficiency will have a plan developed that will address the reason for the testing, the means for the test matrix to obtain results and the expected results. Each test plan must establish procedures, adhering as much as possible, to known and industry acceptable procedures for sampling and data collection. Raw data collection will be reduced to minimize expenses and to better be able to compare results and obtain meaningful information, especially scale up factors.

The Development Test Plan for both parts one and two contained schedules, manpower requirements, and resources necessary to obtain information to define a commercially available system.

The plan for use of the team members has been developed to comply with the results of the DOE uniform coal sample procurement and storage procedures. The quantity of coal necessary for each testing program was calculated. A sample of all three of the referenced coals will be obtained, preferably from the same source as the Surface Control contractor. This coal will be stored and handled as outlined in the coal procurement and storage plan. These procedures, when properly followed, should minimize physical and chemical changes to the raw coal.

A common database for all data generated throughout the entire program is being developed. The DOE and all team members will be able to access the database via modem at any time to view results of the research completed. Special passwords will allow access to individual team members to write data to the file. No other team member will be permitted to alter that input.

ICF Kaiser Engineers is developing the database and determining the logistics of data entry or data viewing. ICF KE will maintain the system throughout the program and provide technical answers to user questions that arise. The QA/QC plan discusses the precautions KE will take to protect the data and the system.

4.2 Review of Work Completed This Quarter

The Task 4 Report has been submitted to DOE as a draft which at the time of this quarterly report has been verbally approved. Two portions of the test plan have received written approval and have been implemented. The two portions are: "Round Robin Test Plan" and the "Coal Procurement and Storage Plan". Both of these will be discussed further in the Task 5 section.

5.0 TASK 5 BENCH-SCALE PROCESS TESTING

5.1 Overview and Scope

The overall goal of Task 5, "Bench-Scale Process Testing" is to develop the necessary unit operation design and process performance data required to 1) reduce or eliminate the technical and engineering uncertainties of the preliminary 20TPH advanced location semi-works plant and 2) design, build and operate a 2-3 TPH advanced flotation POC module.

The unit operation performance and process design information required to support development of the advanced flotation process will be examined in a multi-tier program at B&W. Laboratory scale studies will be conducted in several key process areas; conventional precleaning of the raw coal, microgrinding of the pre-cleaned coal, advanced froth flotation of the fine coal and dewatering of the product streams. The results of these studies will then be used to guide small, semi-continuous testing of the key unit operations at approximately 100 lb/hr.

The bench-scale and semi-continuous process design evaluation test programs will provide detailed information for developing process material and energy balances. The material balance data will be used to correctly design and size the equipment for the POC module. The energy balance information will allow for estimation of the process operating costs.

The bench-scale test programs will also identify the optimum conditions for microgrinding the coal for maximum pyritic sulfur rejection in advanced flotation and the most promising advanced flotation technique which will be integrated into the overall processing scheme. The 100 lb/hr test program will provide verification of the laboratory tests results and demonstration that these results can be scaled-up for application in the POC module and 20TPH semi-works plant design.

Both the bench-scale and semi-continuous process design evaluation tests will serve as critical reviews of the preliminary process flowsheet. Process deficiencies and limitations discovered in these programs will require modification of the original conceptual flowsheet. This information will aid in identifying solutions to the advanced flotation technology.

The bench-scale and process testing will consist of eleven major subtasks and be performed over a period of 12 months. The Bench-Scale Process Testing "Flowsheet" shown on Figure 5.1, illustrates the relationships between these subtasks. It should be noted that some subtasks are not sequential and there is some overlap in the timing of these activities.

5.2 Review of Work Completed This Quarter

Two portions of Task 5 have received formal approval and progress has been ongoing during this quarter. The two sub-tasks approved by DOE are: 1) Determination of Raw Coal Characterization and 2) Round Robin Column Cell Evaluation.

5.2.1 Raw Coal Characterization - Pittsburgh #8

Topical Report Number 1 was written to present the data for the pyrite liberation study for the Pittsburgh No. 8 coal. This report was completed this quarter and reviewed by the Technical Advisory Committee and will be formally submitted to DOE/PETC early in the seventh quarter.

The purpose of this pyrite liberation study subtask is to measure the pertinent physical and chemical properties of representative samples of the three coals to be used in the program; Pittsburgh No. 8, Upper Freeport, and Illinois No. 6.

Determination of the optimum top size and control of the coal surface properties during coal grinding are essential to achievement of maximum Btu recovery and ash and pyrite rejection in advanced flotation processes. The control of coal size distribution and surfaces depend on coal properties and the particle size distribution of associated minerals, particularly pyrite. Information on the particle size distribution of the pyrite can be obtained from washability data. Standard washability data is also used to predict the expected performance of the proposed raw coal precleaning processes.

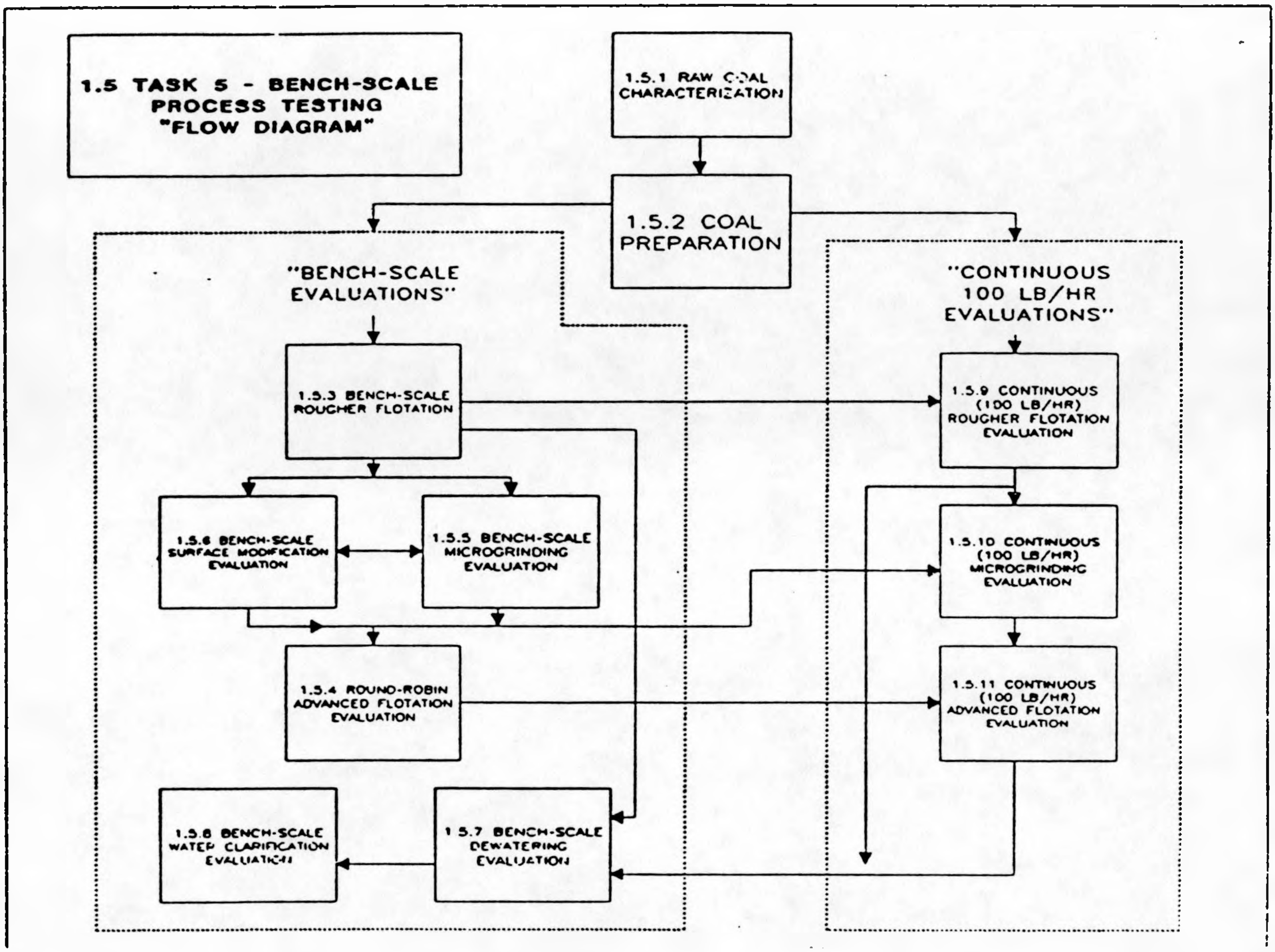


Figure 5.1
Bench Scale Process Testing Flowsheet

The raw Pittsburgh No. 8, seam coal was analyzed to determine their properties relevant to the fine grinding and advanced flotation bench-scale and process tests to be performed. The characterization of the coal began with the size and washability analysis.

The washability test was formulated to simulate the Task 2 advanced flotation flowsheet for Pittsburgh No. 8 . The washability test will aid designers in predicting the theoretical recoveries of precleaning products at various stage crushing sizes, starting at 1/4" x 0. Within the Task 2 flowsheet there was flexibility built into the flowsheet such that it is feasible to recovery a 1/4" x 200m precleaning product (Case A), or a 48 x 200m precleaning product (Case B), or no precleaning product (Case C). However, in all cases the Task 2 flowsheet will reject high gravity low quality material throughout all stage crushing sizes.

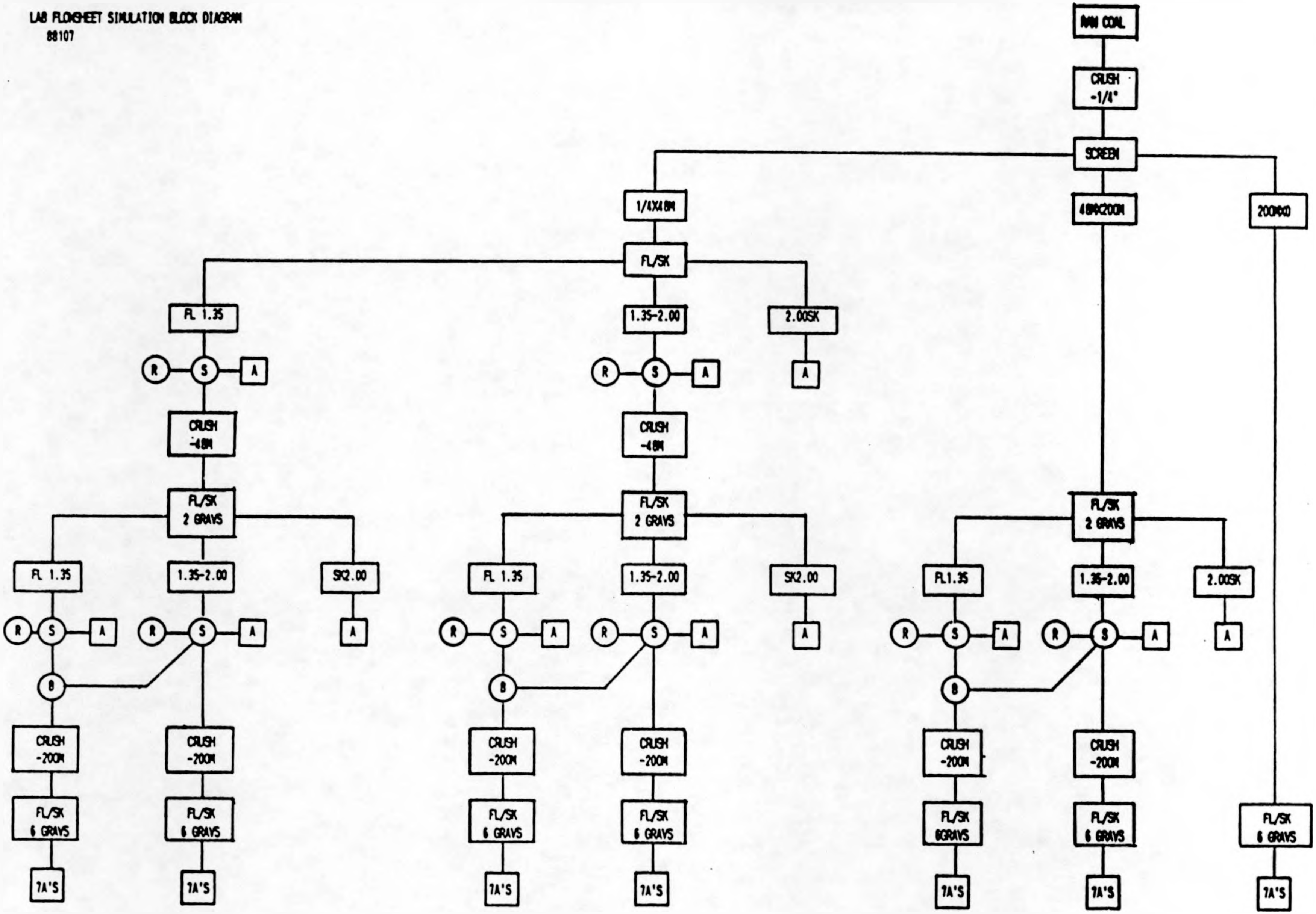
Rather than conduct a conventional washability test on samples crushed to various finer top sizes to evaluate pyrite liberation, it was deemed more appropriate to deviate from the norm and conduct a pyrite liberation washability test to approximate the advanced flotation precleaning circuitry that was developed in the conceptual study of Task 2.

By approximating the advanced flotation conceptual flowsheet design in the pyrite liberation washability study, some of the basic design deficiencies might be resolved. This procedure would also provide a further indication of the possibility of obtaining a product with the desired quality specifications at a coarser size within the gravity separation precleaning circuitry. By extracting an acceptable grade product within the precleaning circuitry one would then avoid directing all the feedstock into the more expensive fine grinding/advanced flotation circuit.

The laboratory process flowsheet used for the pyrite liberation study is presented in - Figure 5.2. The laboratory work in this study was conducted to determine the amount of pyrite liberation occurring at various stage crushing sizes. The philosophy used throughout the flowsheet is to reject high gravity refuse streams containing high quantities of pyritic sulfur and low calorific value (Sink 2.00) while simultaneously collecting a low gravity product stream containing low quantities of pyritic sulfur and high calorific value (Float 1.35). Middling material (1.35 x 2.00 Float Fractions) having neither of the above qualities, would be subjected to further pyrite liberation via stage crushing and additional processing.

The ultimate goal of the study was to determine the weight percentages of high gravity material that could be rejected and of the low gravity material that could be immediately directed to product prior to any of the feedstock reporting

FIGURE 5.2 PYRITE LIBERATION TEST



A ANALYSIS(M,A,S,P,BMMT%,ASH%,TOT. SUL.%,PYR. SUL.%,BTU/#) B BLEND (AS PER WT%'S) S SPLIT 50:50 6 GRAVITIES = 1.30,1.35,1.40,1.60,1.80,2.00 R RESERVE SPLIT PRIOR TO ANY CRUSHING OR BLENDING STEP

NOTE: ALL FLOAT/SINK ANALYSIS ON MINUS 48 MESH SIZE FRACTIONS BY CENTRIFUGE METHOD to fine grinding (approximately minus 200 mesh) and advanced flotation circuitry.

As illustrated in Figure 5.2, the feedstock is first crushed to minus 1/4" to achieve some preliminary liberation. The 1/4" x 0 material is then screened at 48 mesh and 200 mesh to produce three size fractions; 1/4" x 48 mesh, 48 x 200 mesh, and 200 mesh x 0. Both the 1/4" x 48 mesh and 48 x 200 mesh size fractions are precleaned at high and low gravities.

As outlined, the middling (1.35 x 2.00) fractions are stage crushed and subjected to additional float sink analysis. In the conceptual flowsheet, the minus 48 mesh crushed middling would be combined with the raw minus 48 mesh and then processed in secondary precleaning equipment. All material flowstreams progress towards a finer size consist until they all reach the 200 mesh size.

It was assumed that there would be an insignificant amount of 2.00 float material liberated by further stage crushing 2.00 sink material to finer sizes. Therefore, no additional stage crushing was performed on sink 2.00 fractions.

Float/sink analysis was performed on all flowstreams below 200 mesh (even though flotation is a surface, not a gravity phenomena), since the float/sink results could be used to predict the ultimate performance of flotation on this fine sized coal. Float/sink analysis was conducted at six gravities, 1.30, 1.35, 1.40, 1.60, 1.80 and 2.00. All float/sink testing below 48 mesh was done using centrifugal techniques. Each fraction was analyzed for wt%, ash%, total sulfur%, pyritic sulfur%, and Btu content using ASTM standard procedures. Analytical work was conducted by TraDet Laboratories of Wheeling, WV.

The details of the Pittsburgh No. 8 pyrite liberation study were previously given in Quarterly Report No. 5. The size distributions of the samples from each of the sequenced steps are presented in Figure 5.3. The float/sink recoveries are summarized in - Figure 5.4.

Based on the analytical results mass/metallurgical balances were produced. The three different mass/metallurgical balances are as follows: Case A -1/4" x 200m precleaning product, Case B - 48 x 200m precleaning product, and Case C - no precleaning product. A summary of the mass/metallurgical balances nomenclature appears on Table 5.1. A float/sink gravity of 1.60 was used to predict the theoretical performance of the advanced circuitry (flotation).

The size distributions of the samples from each of the sequenced steps, presented in Figure 5.3 - are based upon wet screening. The size reductions to 48 mesh and 200 mesh were done dry with a ball mill. A multi-step milling procedure was utilized to minimize the generation of either minus 200 mesh

Figure 5.3 Size Distribution of Sample Increments

Raw Coal Crushed To Minus 1/4-Inch

1/4" x 48m	82.23 %
48m x 200m	7.84 %
Minus 200m	9.93 %

1/4"x48m → 1.35 Fl Crushed To Minus 48m; 1.35 x 2.00 Crushed To Minus 48m

48x200m

-200m

	1/4"x48m: 1.35 Fl Crushed To Minus 48m	1/4"x48m: 1.35 x 2.00 Crushed To Minus 48m	48x200m
Plus 48m	4.00 %	3.06 %	0.59 %
48x60m	16.42 %	14.41 %	10.56 %
60x100m	35.38 %	32.18 %	41.66 %
100x150m	9.03 %	13.76 %	25.30 %
150x200m	6.66 %	8.80 %	21.05 %
200x325m	11.46 %	7.18 %	0.84 %
325x500m	4.75 %	5.22 %	0.00 %
Minus 500m	12.30 %	15.39 %	0.00 %

	1.35 Fl Crushed To -200m	1.35x2.00 Crushed To -200m	1.35 Fl Crushed To -200m	1.35x2.00 Crushed To -200m	1.35 Fl Crushed To -200m	1.35x2.00 Crushed To -200m	Raw -200m
Plus 200m	0.00 %	0.00 %	0.00	0.00 %	Insuff. Mat'l. for Size Consist	Insuff. Mat'l. for Size Consist	0.85
200 x 270m	8.98 %	7.19 %	3.28	7.71 %			↑
270 x 325m	20.83 %	12.10 %	13.08	12.81 %			10.66
325 x 400m	8.74 %	6.73 %	8.64	8.48 %			↓ ↑
400 x 500m	14.80 %	14.90 %	17.49	15.03 %			10.16 ↓
Minus 500m	46.65 %	59.08 %	57.51	55.97 %			78.33

Figue 5.4 Schematic Flowsheet Summarizing Weight Distributions.

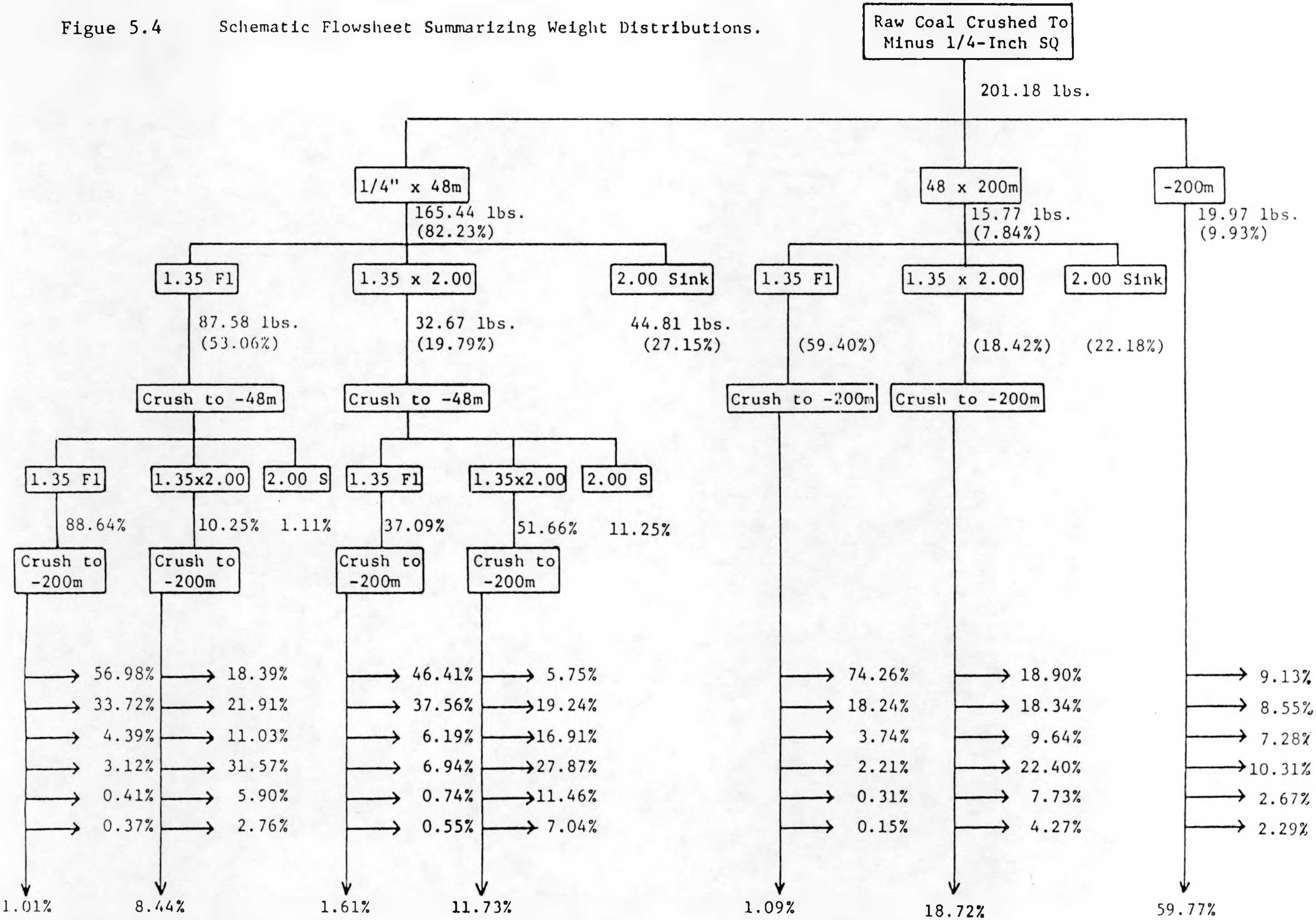


TABLE 5.1
MASS/METALLURGICAL BALANCE NOMENCLATURE

ID	DESCRIPTION
FF	1/4" x 0, Raw Feed
AF	1/4" x 48m, Raw Feed
AC	1/4" x 48m, F 1.35
AM	1/4" x 48m, 1.35 x 2.00
AR	1/4" x 48m, S2.00
BC	1/4" x 48m, F 1.35, C-48m, F 1.35
BM	1/4" x 48m, F 1.35, C-48m, 1.35 x 2.00
BR	1/4" x 48m, F 1.35, C-48m, S2.00
CC	1/4" x 48m, 1.35 x 2.00, C-48m, F 1.35
CM	1/4" x 48m, 1.35 x 2.00, C-48m, 1.35 x 2.00
CR	1/4" x 48m, 1.35 x 2.00, C-48m, S2.00
DF	48 x 200m, Raw Feed
DC	48 x 200m, F 1.35
DM	48 x 200m, 1.35 x 2.00
DR	48 x 200m, S2.00
EF	200m x 0 Raw Feed
GF	200m x 0 Advanced Feed
GC	Advanced Product
GR	Advanced Tails
FC	Final Product
FR	Final Refuse
PC	Preclean Product
PR	Preclean Refuse

material when milling to a 48 mesh topsize or minus 500 mesh material when milling to a 200 mesh topsize.

This approach resulted in somewhat similar size distributions for the prepared minus 48 mesh and minus 200 mesh samples, but very different size distributions as compared to the "naturally" occurring 48 x 200 mesh and minus 200 mesh fractions.

The degree of ash and pyritic sulfur liberation observed in these results is a direct function of the resultant size distribution/degree of milling. The milling procedure utilized in this study minimized the generation of fines which somewhat decreased the degree of liberation.

The sequential float/sink procedure utilized in this study is designed to document the degree of liberation of ash, pyritic sulfur, and coal that occurs while progressing toward finer sizes. As an example, crushing Stream AM, 16.27 wt% of raw feed, to minus 48 mesh and refloating, produced an additional 6.03 wt% float 1.35 (Stream CC). Recrushing Stream CM, 8.41 wt%, to minus 200 mesh, produced an addition 2.10 wt% float 1.35 material.

On the other hand, recrushing and refloating material that was already float 1.35 material did not liberate substantial amounts of 1.35 x 2.00 middlings or sink 2.00 refuse to warrant the expense of introducing that much more material to the grinding and advanced flotation circuitry. In any event, it appears that on this theoretical basis, the 90% Btu recovery and 90% pyrite sulfur reduction guideline can be approached or exceeded without recrushing any Float 1.35 material.

The three cases examined A, B and C are shown on Figures 5.5, 5.6, 5.7 respectively. These mass/metallurgical balances were developed from the washability data from the pyrite liberation study. Comments on the advantages and disadvantages of the three case studies are as follows:

<u>Case A</u> - 1/4" x 200m Precleaning Product.

1. One advantage would be that only 19.78% of the raw feed enters the difficult and expensive to operate advanced circuit.

2. Another advantage would be that a 1/4" x 0 product, assuming that it is dewatered via state-of-the-art dewatering methods, would be handleable in existing conventional materials handling systems.

3. The main disadvantage (even though the predicted results are very close) the desired goal (90% Btu recovery: 90% pyritic sulfur rejection) is not theoretically

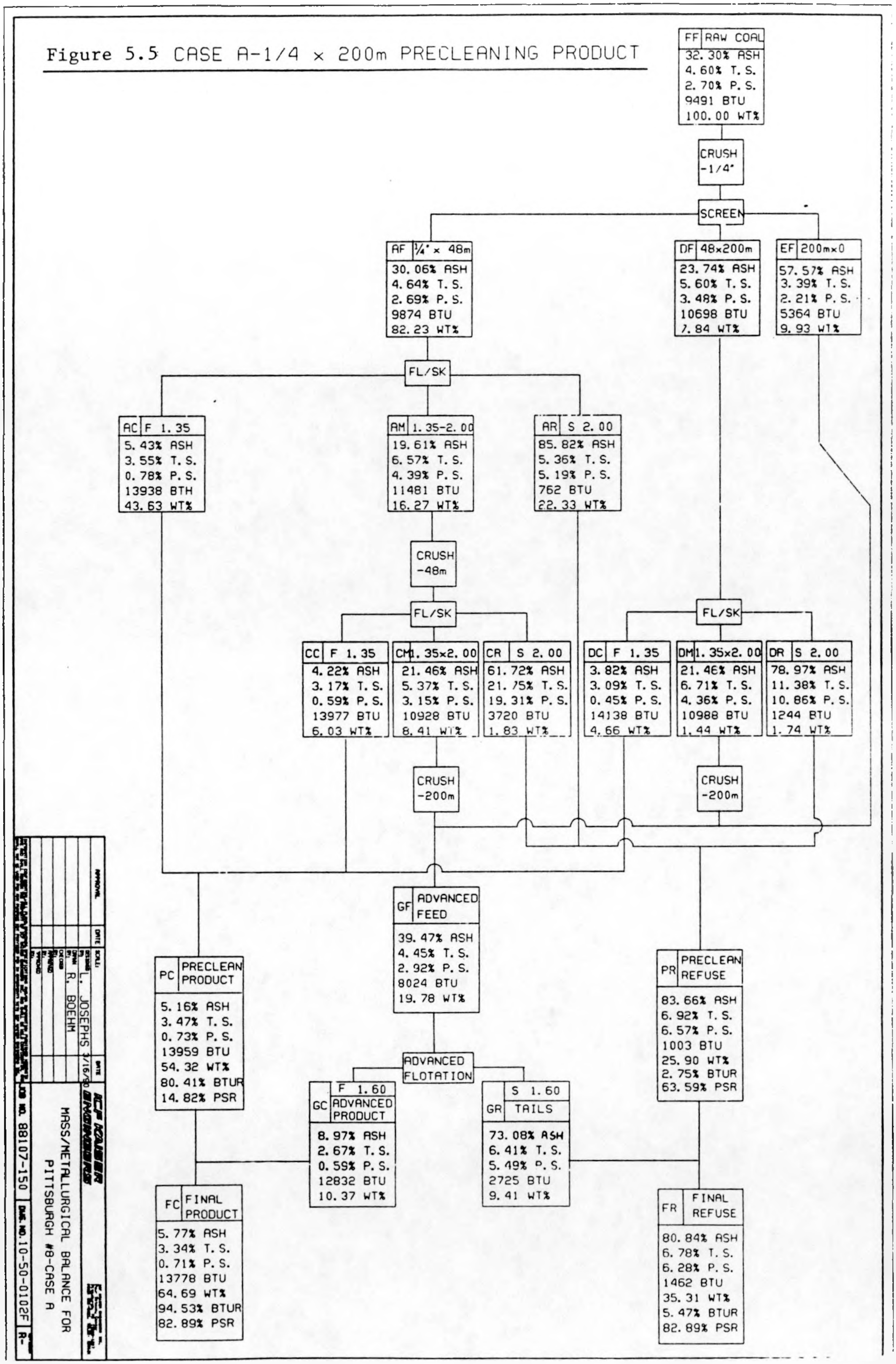
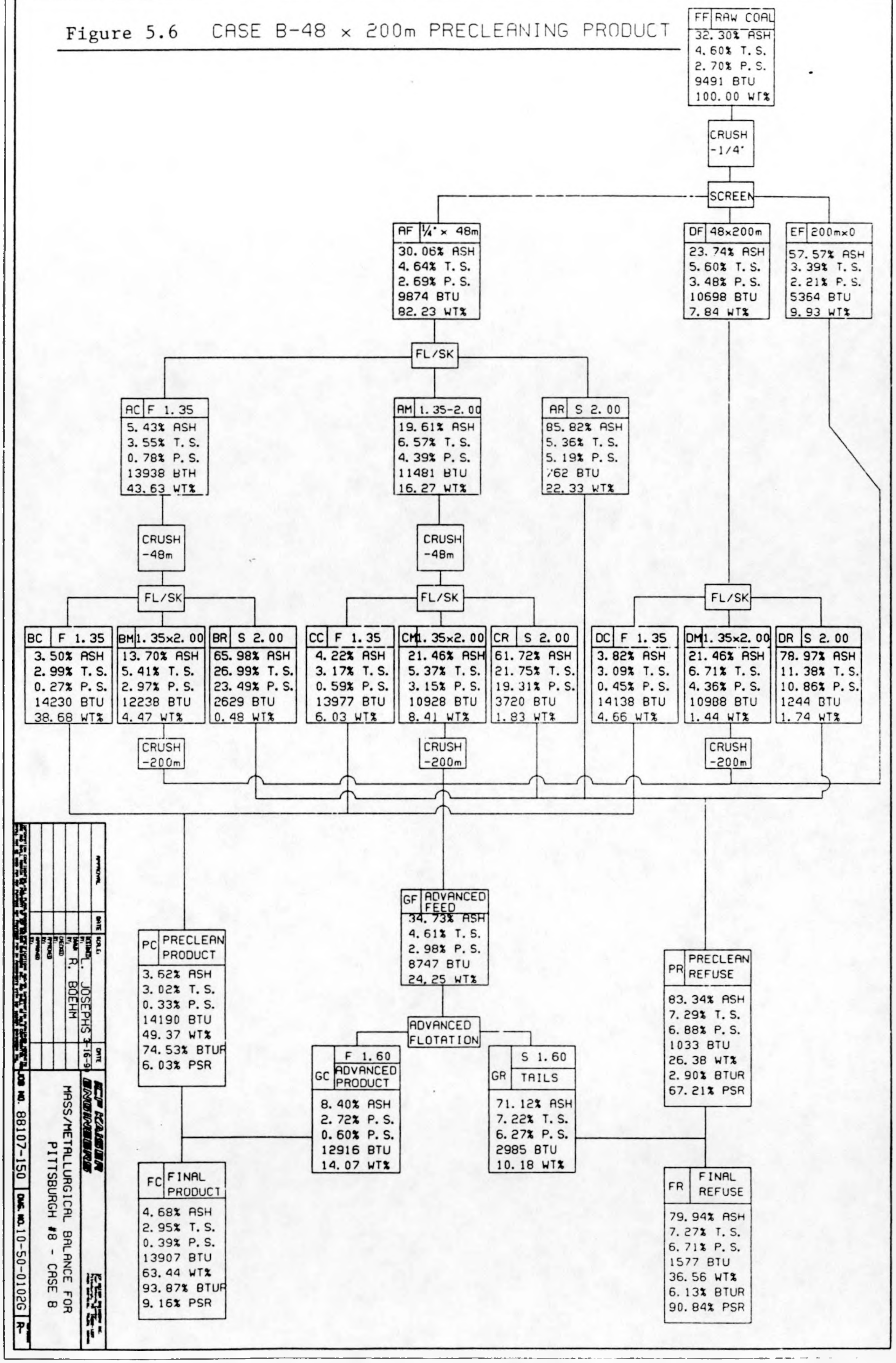


Figure 5.5 CASE A-1/4 x 200m PRECLEANING PRODUCT

Figure 5.6 CASE B-48 × 200m PRECLEANING PRODUCT



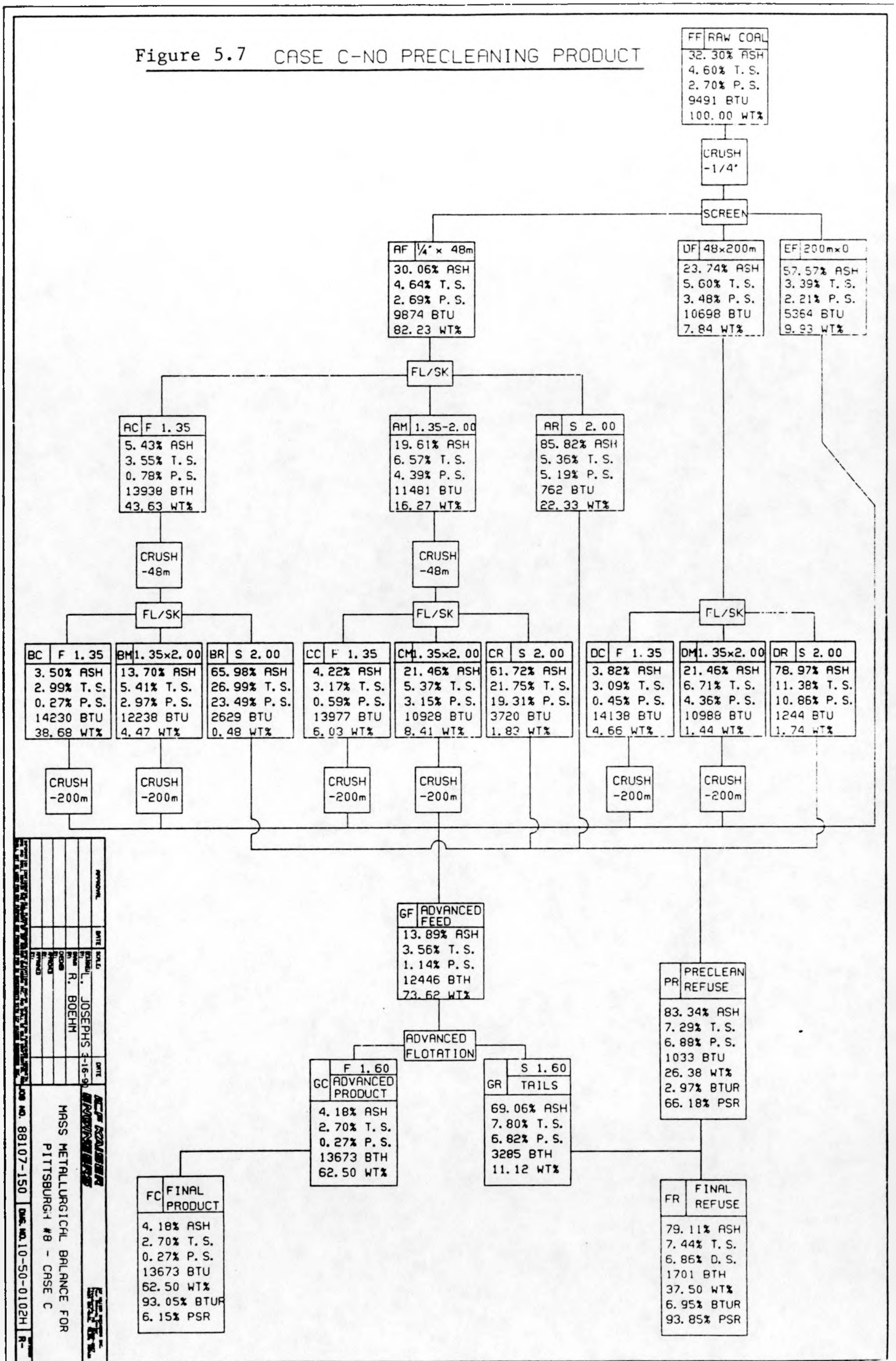


Figure 5.7 CASE C-NO PRECLEANING PRODUCT

attainable. However, the average of the two values is 88.71%, which is very close to the goal.

Case B - 48 x 200m Precleaning Product.

1. The main advantage to this case is that with just an additional 4.47% of the raw feed (24.25% for case B vs. 19.78% for Case A) entering the advanced circuit, the 90:90 goal is theoretically attained. In this case, the average of the two values, Btu recovery and pyritic sulfur rejection is 92.36%.

2. An additional advantage would be gained by producing a 48 x 200m product in addition to the 200m x 0 advanced product; overall dewatering (and reconstitution) cost would be reduced as compared to Case C.

3. The main disadvantage of this case is that the 48M x 0 product is not easily handleable in existing conventional materials handling systems. The 48m x 0 product would require reconstitution (pelletization or briquetting) or the product would have to be ground to a finer size and introduced into the power plant as a coal/water slurry.

4. Considering all of the above comments, this case was the one used for the original Task 2 feasibility study flowsheets and mass/metallurgical balances.

Case C - No Precleaning Product

1. This case study offers no distinct advantage over Case A or B. It affords only a 1.09% increase in the theoretical Btu recovery and pyritic sulfur reduction improvement (93.45% for Case C vs. 92.36% for Case B). Case B had already attained the 90:90 goal. However, this case has still rejected the sink 2.00 material containing low Btu and high pyrite sulfur values.

2. One disadvantage of this case study is that it triples (73.62% vs. 24.25%) the amount of material introduced into the costly advanced circuit.

3. Another disadvantage is that there is no coarser (+200 mesh) material available to blend with the 200 mesh x 0 product to improve dewatering and handleability. Reconstitution would be quite difficult, possibly requiring thermal drying to attain material that could be reconstituted.

In addition to the pyrite liberation study, several pieces of coal 4" coal were sent to VPI for CCSEM analysis to determine the pyrite particle size distribution of the Pittsburgh #8 coal. Previous analyses were done on 100 mesh top size samples. This made determining pyrite liberation difficult since there was no pyrite size distribution done on the uncrushed coal. This analysis, done on the 4" coal, indicates that there is a higher degree of pyrite liberation at 325 mesh top size than at 200 mesh top size. Approximately 40% of the pyrite is liberated at 325 mesh, while only approximately 20% of the pyrite is liberated at 200 mesh.

On Figure 5.8 and Table 5.2 the pyrite size distribution plot and the original raw data are shown. This size distribution represents the true side distribution of the pyrite in the coarse unbroken chunks of Pittsburgh No. 8 coal. Included on the same plot is the size distribution of the -325 mesh coal that was prepared by B&W for the round-robin test program. The comparison of these two distributions provides a useful means of approximating the degree of pyrite liberation one might expect at this grind.

There are several features of interest pertaining to the pyrite size distribution. The first thing to note is that there appears to be two roughly linear regions to the pyrite size distribution which are joined together at approximately the median size (20 microns). This is characteristic of a bimodal distribution containing coarse pyrite greater than 20 microns in size and fine pyrite below 20 microns. By grinding to -325 mesh, it appears that essentially all of the coarse pyrite is liberate and probably some of the finer pyrite, as well. Based on the -325 mesh size distribution, it appears that 100% of the distribution is finer than 30% microns. Referring to the pyrite distribution, it appears that approximately 40% of the pyrite is coarser than 30 microns. Thus, conservatively there must be at least 40% degree of pyrite liberation at -325 mesh. Since image analysis tends to underestimate the size distribution, the actual degree of liberation is probably greater than 40%.

It appears that by grinding to -325 or -400 mesh, an attempt is made to liberate the coarse pyrite. In order to liberate the fine pyrite it would be necessary to grind to -10 or -5 microns, and that would not be practical. Furthermore, grinding to -200 mesh would seem to decrease the amount of liberated pyrite present to a point where the subsequent separation would not be effective. Previous studies of other coals of this type of bimodal distribution of pyrite indicate it may be that grinding to the break point of the distribution is the best compromise between pyrite liberation and grinding costs.

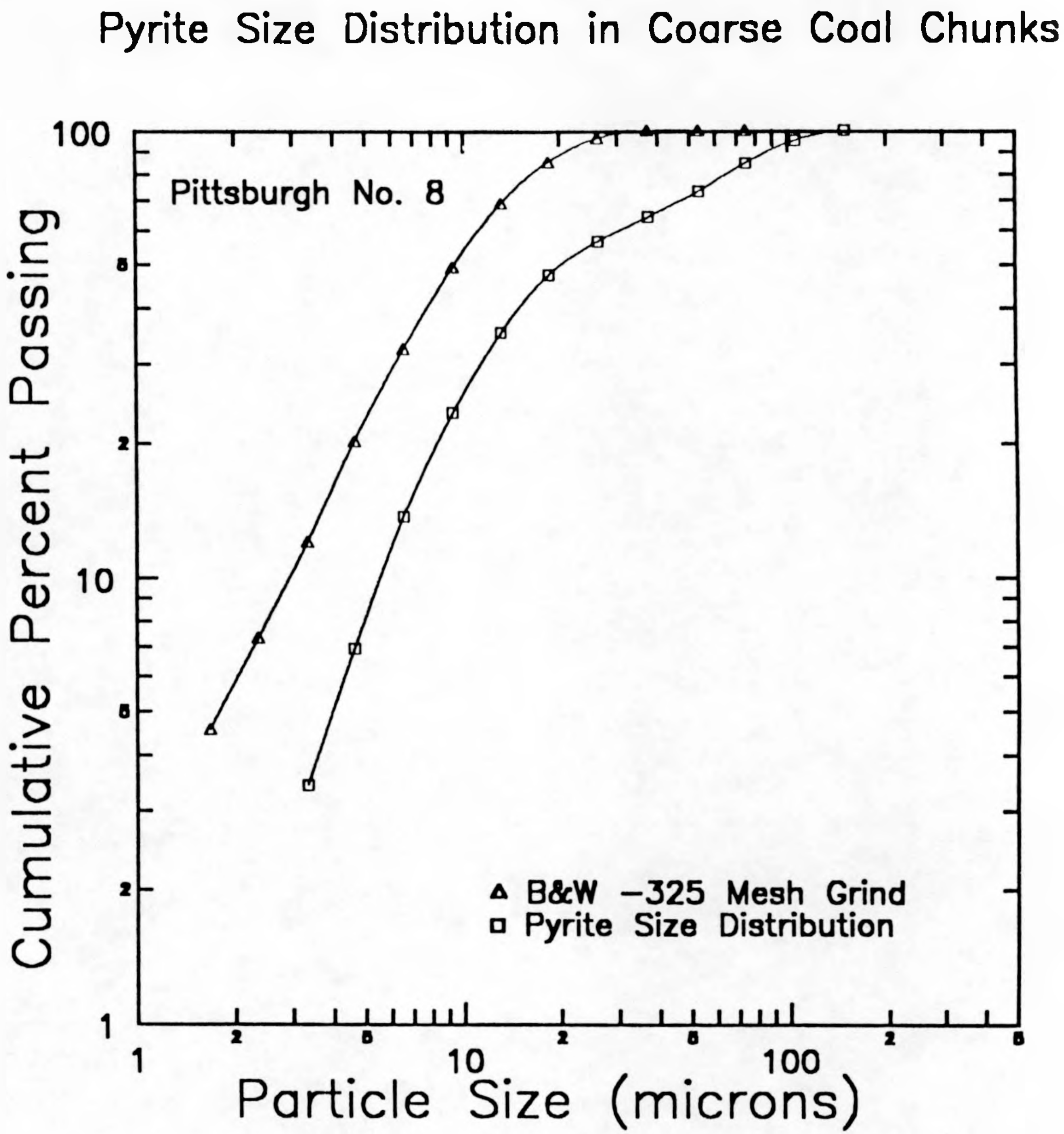


Figure 5.8

Pyrite Size and Coal Size Distribution

TABLE 5.2
PYRITE SIZE AND COAL SIZE DISTRIBUTIONS

Pyritic Size Distributions		-325 Mesh Size Distributions	
Size (microns)	% Passing	Size (microns)	% Passing
150	100.0	150	100.0
106	95.0	106	100.0
75	84.4	75	100.0
53	73.1	53	100.0
37	64.0	37	99.9
26	56.2	26	96.1
19	47.2	19	85.1
13	35.2	13	68.8
9	23.4	9	49.1
7	13.7	7	32.4
5	6.9	5	20.2
3	3.4	3	12.0

5.2.2 Advanced Flotation Round Robin

During this quarter the Round Robin Test program was completed through Phase II. This test program was developed to determine the "best available" advanced flotation device. A topical report was produced during this quarter to cover the final results in detail. This topical report will be reviewed by the Technical Advisory Committee and submitted to DOE/PETC early next quarter.

In the last quarterly report the results from Phase I were reported. During the sixth quarter of the project, Phase II of the Round Robin was completed. A review of the results of Phase II and brief discussion of the results are presented.

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 they 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 of feed, product and tailings for checking laboratory verification purposes from VPI, Michigan Tech, ISGS, B. Datta Research, and Center for Applied Energy Research. All other participants did not comply with the request.

Test Number 4 of Phase II was prepared by each participant. The size analysis for each of the participants reporting is shown graphically on Figure 5.9. The size analysis for this test was specified by the Technical Support Team (TST) based upon comparing the efficiency of Test Numbers 1 and 3. 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.

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 5.10. All of the participants have lower results than the washability plot except for one participant who appears to fall on the washability plot.

Figure 5.9

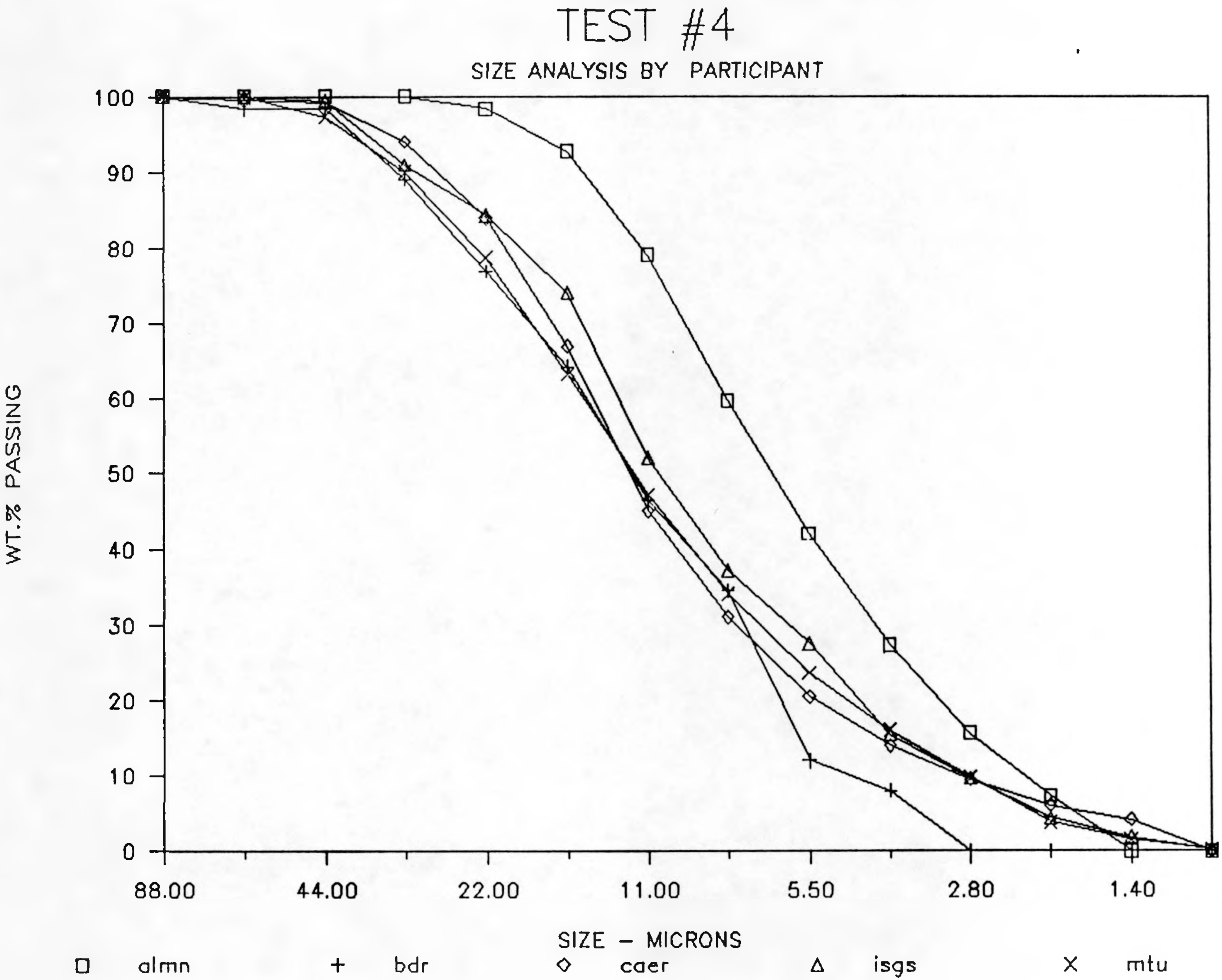
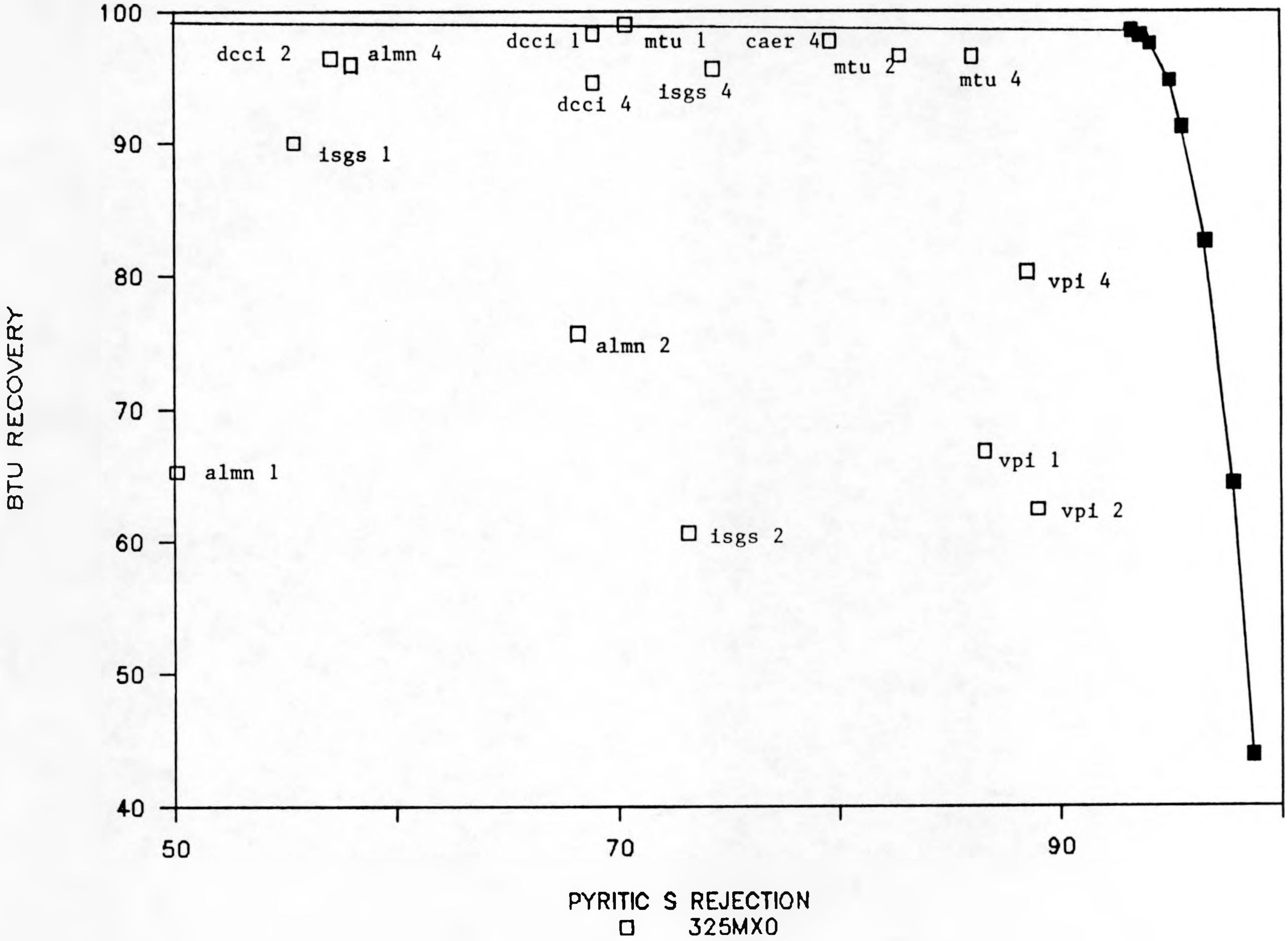

TEST #4
SIZE ANALYSIS BY PARTICIPANT
WT.% PASSING
100
90
80
70
60
50
40
30
20
10
0
88.00
44.00
22.00
11.00
5.50
2.80
1.40
SIZE - MICRONS
almn
bdr
caer
isgs
mtu

Figure 5.10

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



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.

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.

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.

The best results reported by all participants were for Test Number 4. These data are shown in Figure 5.11. 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 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.

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:

$$F - P - R = 0 \qquad (1)$$

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:

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

where f is the fractional assay of a given component (ash, for example) in the feed stream, p is the fractional assay of a

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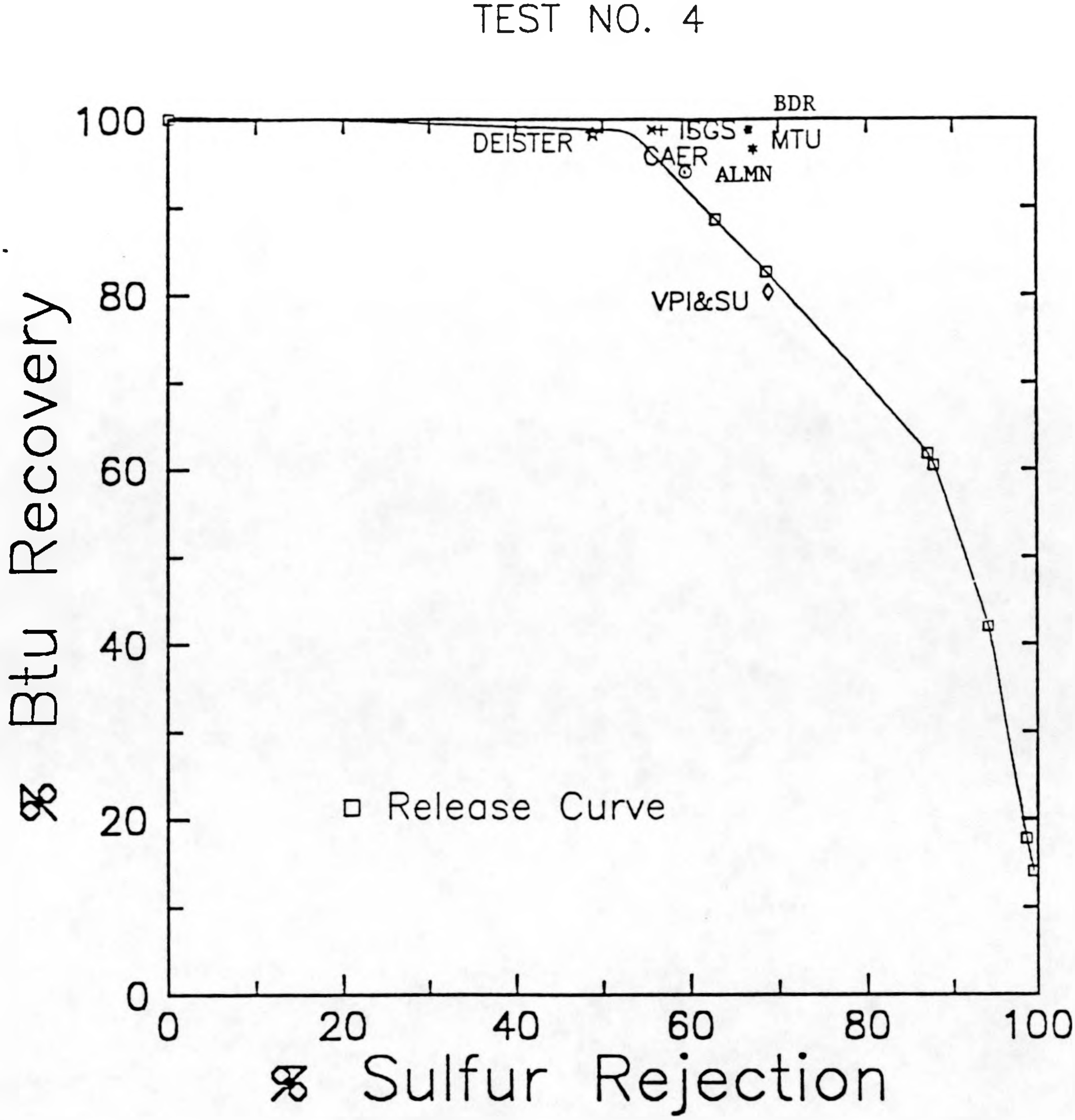

Figure 5.11 COMPARISON OF ROUND ROBIN TEST 4 RESULTS WITH THE RELEASE ANALYSIS CURVE FOR SULFUR REJECTION.

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 valued. 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.

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 performance results for Test 4 of Phase II are shown on Table 5.3. The process variables for this test are shown in Table 5.4. 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 5.3 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 5.4 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 permitted a longer time for the wash water to clean the mineral matter from the froth. 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 5.10. As previously stated a better method to evaluate flotation performance is the release analysis. As can be seen in the 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 a 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.

The economic evaluation and the final conclusion will be presented in the Round Robin Topical Report. The Technical Advisory Committee is to review the data for Round Robin

TABLE 5.3

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

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 5.4

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	UNIT							
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	3.500	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 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

Testing and determine the selection of the round robin participant who will produce the 100#/hour device.

5.2.3 Bench Scale Process Testing

During this quarter B&W continued bench scale process testing on the Pittsburgh No. 8 raw coal. B&W conducted test work on the precleaning circuit. B&W continued the coarse and fine hydrocyclone cleaning of the Pittsburgh No. 8 raw coal. The installation and shakedown of the Denver continuous flotation unit was completed as well as the installation of the VPI two inch diameter column flotation device. The classifying cyclone arrangement shakedown was completed to make acceptable size separations at 200 mesh and 325 mesh. Finally the bench microgrinding at 200 mesh and 325 mesh top size and flotation of these products in the two inch diameter column flotation unit were completed.

Classifying Cyclone (200 mesh)

Shakedown of the classifying cyclone was accomplished. Prior to the shakedown, a particle size analysis was run on the 48M x 0 fine hydrocyclone product to determine the amount of plus and minus 200 mesh material. See Table 5.5. Plus 200 mesh was 29.9%, minus 200 mesh was 70.1%. Krebs was then contacted for recommendations to make this separation. They recommended a 2" diameter vortex finder and 7/8" diameter apex. However, this configuration resulted in an underflow that was 38% -200M. Krebs was contacted again and it was decided to use smaller apex orifices to reduce the percentage of -200M in the underflow. Tests were run with 1/2" and 5/8" apex orifices. Microtrac analyses were run on the overflows and underflows of both tests. The most efficient separation resulted with the 5/8" apex orifices. For a 200M separation with a 5/8" apex, misplaced material in the overflow was 11% (11% of solids in overflow were plus 200M). See Table 5.6. Misplaced material in the underflow was 15% (15% of solids in underflow were minus 200M). See Table 5.7. The results were discussed with Dave Ferris, and the 5/8" apex was chosen to be used. Eighteen drums of fine hydrocyclone clean coal were run through the classifying cyclone. The products were used as the feed for the grab-and-run rougher flotation tests.

An additional 1080 pounds of Pittsburgh #8 coal were washed in the coarse hydrocyclone, fine hydrocyclone, and classified at 200 mesh. Enough feed slurry for the split feed grab-and-run flotation test was produced to run the fine (200M x 0) test for approximately 4 hours (45 drums) and the coarse (48 x 200) test for approximately 1-1/2 hours (13 drums).

TABLE 5.5

FINE HYDROCYCLONE PRODUCT
(FEED TO CLASSIFYING CYCLONE)

Microns	% Less	Diff
2400.00		
1697.06		
1200.00		
848.63		
600.00	100.00	0.63
424.26	99.47	0.37
300.00	99.10	3.81
212.13	95.29	5.53
150.00	89.76	9.69
106.07	80.07	9.97
75.00	70.10	8.25
53.03	61.86	8.60
37.50	53.26	5.71
26.52	47.55	6.16
18.75	41.38	6.62
13.26	34.76	5.98
9.38	28.79	6.71
6.63	22.08	5.78
4.69	16.30	4.66
3.31	11.64	3.61
2.34	8.04	2.67
1.66	5.37	1.72
1.17	3.65	1.34
0.83	2.31	1.00
0.59	1.31	0.92
0.41	0.39	0.39
0.29	0.00	0.00
0.21		
0.15		

CS (CAL SURF AREA) = 0.87 M==2/CM==3
MMD (D43) = 60.63 MICRONS
SMD (D32) = 6.90 MICRONS

TABLE 5.6

CLASSIFYING CYCLONE OVERFLOW
5/8 INCH APEX

Microns	% Less	Diff
300.00		
212.13	100.00	0.62
150.00	99.38	3.29
106.07	96.09	7.55
75.00	88.54	10.40
53.03	78.14	7.02
37.50	71.12	7.64
26.52	63.48	8.80
18.75	54.69	6.31
13.26	48.38	7.91
9.38	40.47	9.86
6.63	30.61	8.00
4.69	22.61	6.13
3.31	16.48	5.17
2.34	11.32	3.75
1.66	7.57	2.35
1.17	5.22	1.96
0.83	3.25	1.54
0.59	1.71	1.25
0.41	0.47	0.47
0.29	0.00	0.00
0.21		
0.15		

CS (CAL SURF AREA) = 1.18 M==2/CM==3
MMD (D43) = 30.13 MICRONS
SMD (D32) = 5.09 MICRONS

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TABLE 5.7

CLASSIFYING CYCLONE UNDERFLOW
5/8 INCH APEX

Microns	% Less	Diff
2400.00	100.00	0.40
1697.06	99.60	0.22
1200.00	99.38	1.59
848.53	97.79	1.18
600.00	96.61	6.40
424.26	90.21	4.52
300.00	85.69	14.91
212.13	70.78	23.91
150.00	46.87	18.17
106.07	28.71	13.54
75.00	15.17	7.54
53.03	7.63	4.11
37.50	3.61	0.51
26.52	3.00	1.11
18.75	1.89	1.89
13.26	0.00	0.00
9.38		
6.63		
4.69		
3.31		
2.34		
1.66		
1.17		
0.83		
0.59		
0.41		
0.29		
0.21		
0.15		

CS (CAL SURF AREA) = 0.05 M==2/CM==3
MMD (D43) = 209.73 MICRONS
SMD (D32) = 110.87 MICRONS

Continuous Rougher Flotation

The shakedown of the conventional froth cell was conducted. Two 160-gallon batch tests were performed to set the conditions of the cell. To increase the run time, the first cell was blocked off and these tests were run with only three of the four cells. Feed solids were 8.0% by weight; retention times were 8 minutes and 4 minutes; kerosene was 2.5 #/T; MIBC was 1 #/T; and the air volume, feed volume, and sand gate were set to maintain steady state. Samples were taken during both runs. Results are shown on Table 5.8. The test with the 4-minute retention time showed the best results. Samples during this test were taken after 15-minute and 20-minute intervals. The clean coal ash in the 20-minute sample was 9.9% and the refuse ash was 83.2%. No flow samples were taken during these tests. By estimating flow rates, BTU recovery was calculated at 95%.

After discussing these results with ICF Kaiser, it was decided to run a continuous test to supply VPI with coal for their 2" column flotation tests and to vary only the kerosene dosage to see how this affected the results. This 3-hour test run was completed on 1/22 with feed, clean coal, and refuse samples taken approximately every one-half hour at kerosene dosages of 2.5 #/T, 3.0 #/T, 3.5 #/T, 4.0 #/T, 4.5 #/T, and 5.0 #/T (results are shown on Table 5.9). Kerosene dosage had little effect on the results, meaning the dosage of 2.5 #/T was sufficient for the collector. Seven drums of the product were shipped to VPI on January 25.

A meeting was held at B&W with Dave Ferris on February 19 to discuss the parameters for the split feed grab-and-run flotation test. The procedure is shown on Table 5.10. Slight modifications were made in the Denver flotation cell to enable B&W to run the test as desired.

Grab-and-run shakedown tests were run on the 200 mesh x 0 and 48 mesh x 200 mesh size fractions. Dave Ferris was present for both tests, and Randy Kosky and Gary Meenan of Consol were present for the 200 mesh x 0 test. The 200 mesh x 0 test ran for three hours, as per the test matrix, and eight sets of samples were taken over the course of the run. Each set of samples consisted of four grab, three scavenger, and one refuse sample. Only one set was submitted for analyses -- the first set that was taken after 15 minutes of run time. The analyses are shown on Table 5.11. A mass balance is shown on Figure 5.12. These results appear to indicate that there is little or no quality improvement in the rougher flotation with the grab-and-run method. However, split feed to the rougher may improve the clean quality coal. For the 48 x 0 rougher test (no-grab-and-run), the clean coal quality was 9% ash and 3.7% total S, while the analyses of this 200 x 0 test show 6% ash and 3.4% total S. However, the BTU recovery for the 200 x 0 test was 75.0% as compared to an estimated 95% for the 48 x 0 standard flotation test. The 48 mesh x 200 mesh test ran

TABLE 5.8
SHAKEDOWN TESTS

SAMPLE NUMBER	F-4322	F-4327	F-4323	F-4325	F-4324	F-4326	F-4328	F-4329	F-4330	F-4331
DESCRIPTION	REFUSE 15 MINUTE 1/12/90	FEED 37 MINUTE 1/12/90	REFUSE 37 MINUTE 1/12/90	PRODUCT 37 MINUTE 1/12/90	REFUSE 45 MINUTE 1/12/90	PRODUCT 45 MINUTE 1/12/90	REFUSE 15 MINUTE 1/16/90	PRODUCT 15 MINUTE 1/16/90	REFUSE 20 MINUTE 1/16/90	PRODUCT 20 MINUTE 1/16/90
ASH %	75.46	28.14	66.02	9.30	68.94	8.76	78.46	10.12	83.21	9.93
TOTAL SULFUR %	3.24	3.71	3.24	3.73	3.22	3.73	3.09	3.64	2.86	3.66
BTU	2415	10308	4036	13267	3496	13223	2061	13078	1215	13103

TABLE 5.9
VPI TEST FLOTATION
48 MESH BY ZERO

SAMPLE NUMBER	F-4336	F-4337	F-4339	F-4340	F-4342	F-4343	F-4345	F-4346	F-4348	F-4349	F-4351	F-4352
DESCRIPTION	PRODUCT 0843 2.5 # COL	REFUSE 0843 2.5 # COL	PRODUCT 0911 3.0 # COL	REFUSE 0911 3.0 # COL	PRODUCT 0939 3.5 # COL	REFUSE 0939 3.5 # COL	PRODUCT 1036 4.0 # COL	REFUSE 1036 4.0 # COL	PRODUCT 1106 4.5 # COL	REFUSE 1106 4.5 # COL	PRODUCT 1136 5.0 # COL	REFUSE 1136 5.0 # COL
ASH %	8.96	77.35	8.96	77.19	9.22	74.90	9.18	75.56	9.54	76.32	9.76	75.94
TOTAL SULFUR %	3.70	2.77	3.74	2.46	3.73	2.47	3.66	2.22	3.60	2.10	3.58	2.10
BTU	13212	2136	13178	2156	13122	2519	13168	2477	13204	22.74	13194	2400

TABLE 5.10

GRAB AND RUN TEST PROCEDURE

All samples collected i.e. the "grab", the scavenger and tailings samples are to be taken simultaneously for a predetermined duration approximately 60 seconds in duration. Each of the samples are to have the following analysis:

Volume Flow Rate
% Solids by Weight
Ash %
Total Sulfur %
BTU
pH of Slurry

On the run that indicates the best "grab" product and best "scavenger" product pyritic sulfur is to be performed.

The reagents for the "grab" are to be added in the first cell. The collector for the scavenger portion is to be added in the second cell. The frother for the scavenger portion is to be added in the second cell.

CONTINUOUS FLOTATION TEST MATRIX

Clock Time Min.	Sample Time Min.	Frother MIBC #/Ton	Collector Kerosene #/Ton	Air Rate SCFM	Frother MIBC #/Ton	Collector Kerosene #/Ton	Air Rate SCFM
0	12	0.05	0.0	33%	1.5	2.50	100%
15	27	0.075	0.0	33%	1.5	2.50	100%
30	42	0.100	0.0	33%	1.5	2.50	100%
45	57	0.125	0.0	33%	1.5	2.50	100%
60	72	0.05	0.0	33%	1.5	2.50	100%
75	87	0.75	0.0	33%	1.5	2.50	100%
90	102	0.100	0.0	33%	1.5	2.50	100%
105	117	0.125	0.0	33%	1.5	2.50	100%

48M x 200M size fraction operated at 8% solids by weight and a retention time of 4 minutes.

200M x 0 size fraction operated at 5% solids by weight and a retention time of 4 minutes.

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TABLE 5.11

200 MESH X 0 GRAB AND RUN FLOTATION

SAMPLE	% ASH	% TOTAL S	BTU/LB
GRAB 1	6.22	3.35	13,523
GRAB 2	6.40	3.44	13,496
GRAB 3	6.40	3.47	13,550
GRAB 4	6.23	3.31	13,525
WEIGHTED AVERAGE	6.32	3.40	13,524
RUN 2	6.86	3.36	13,494
RUN 3	7.05	3.40	13,464
RUN 4	7.19	3.40	13,409
WEIGHTED AVERAGE	7.02	3.39	13,460
REFUSE	70.94	1.75	3,214

(ALL ANALYSES ON DRY BASIS)

FIGURE 5.12

MASS BALANCE FOR 200M X 0 GRAB AND RUN FLOTATION

	STREAM											
VALUE	A	B	C	D	E	F	G	H	I	J	K	L
WEIGHT %	100.0	2.66	3.55	3.69	3.10	13.00	10.64	9.90	8.12	28.66	41.66	58.34
ASH %	44.22	6.22	6.40	6.40	6.23	6.32	6.86	7.05	7.19	7.02	6.80	70.94
TOTAL S %	2.43	3.35	3.44	3.47	3.31	3.40	3.36	3.40	3.40	3.39	3.39	1.75
BTU	7491	13523	13496	13550	13525	13524	13494	13464	13409	13460	13480	3214

BTU RECOVERY 74.93
SULFUR REJECTION 41.84

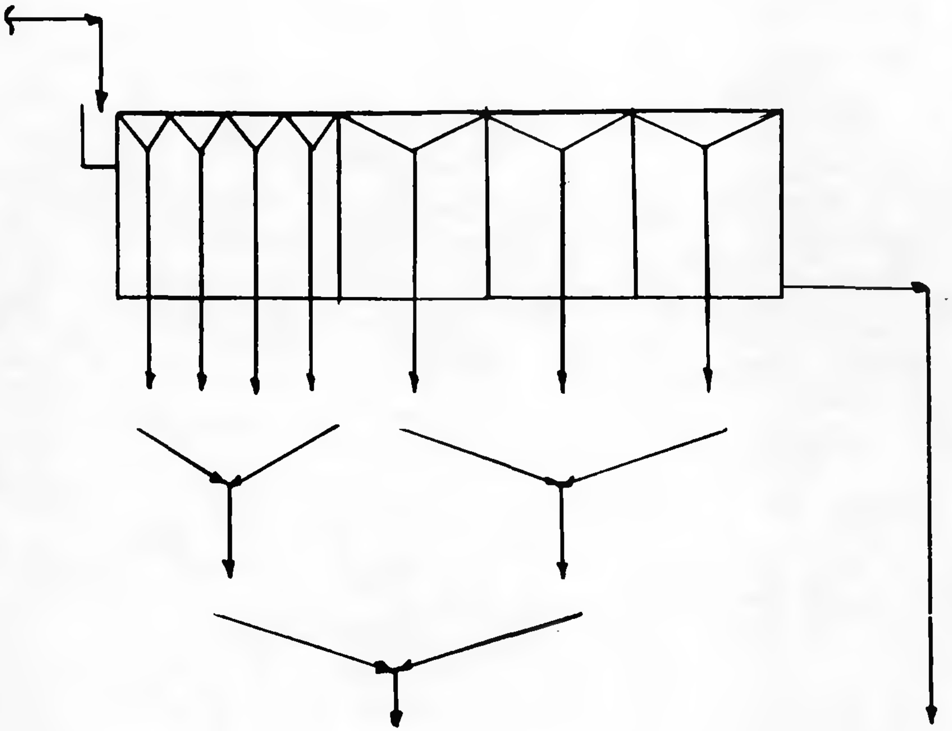
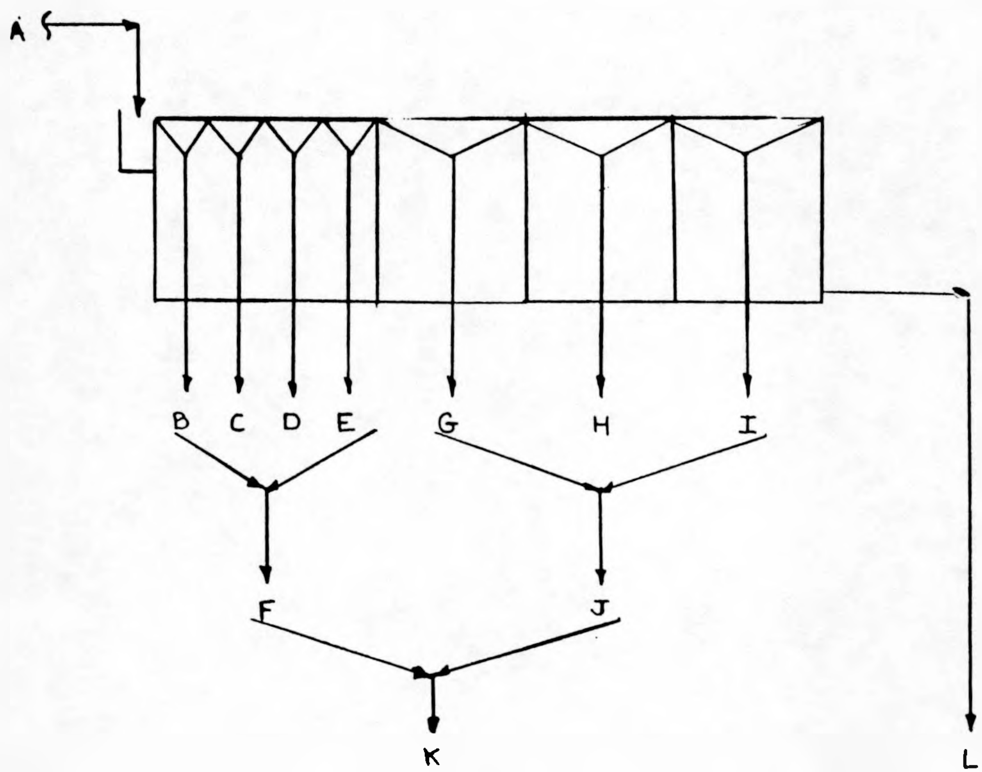


FIGURE 5.12

MASS BALANCE FOR 200M X 0 GRAB AND RUN FLOTATION

VALUE	STREAM											
	A	B	C	D	E	F	G	H	I	J	K	L
WEIGHT %	100.0	2.66	3.55	3.69	3.10	13.00	10.64	9.90	8.12	28.66	41.66	58.34
ASH %	44.22	6.22	6.40	6.40	6.23	6.32	6.86	7.05	7.19	7.02	6.80	70.94
TOTAL S %	2.43	3.35	3.44	3.47	3.31	3.40	3.36	3.40	3.40	3.39	3.39	1.75
BTU	7491	13523	13496	13550	13525	13524	13494	13464	13409	13460	13480	3214

BTU RECOVERY 74.93
SULFUR REJECTION 41.84



for 45 minutes, and the first set taken after 15 minutes of run time. During these tests, it was difficult to maintain a constant feed flow to the cells, so these test results are not reliable. B&W will investigate the use of using Moyno pumps to feed the cell in place of the existing centrifugal pump. The Moyno pumps will pump much less slurry (less than 10 GPM), so the feed rate to the cell should be easier to control.

Bench Scale Microgrinding

Two fine coal slurries, one with a top size of 325 mesh and one with a top size of 200 mesh, were prepared in the laboratory for flotation tests. The 48 x 0 rougher flotation product was used for feed in grinding the slurries. Dewatering normally would have been done by filtration. No filtration facility at ARC with the capacity to handle barrel quantities of rougher flotation product was available. Therefore, the rougher flotation product was air-dried in an oven prior to grinding. The coal and water were premixed with gentle stirring before the coal-water mixture was added to the mill for microgrinding. No dispersant or any other chemicals were used to modify the coal surface during microgrinding.

The slurry products with 325 mesh top size were prepared in a 2-1/2 gallon attritor mill. Limited pretestings were done to determine the final grinding conditions. The coal was ground at two solids levels (35.5% and 36.5%) and at four different retention times (12, 15, 20 and 25 minutes) using 3/16" stainless steel beads. Selection of 3/16" stainless steel beads was based on previous grinding experience obtained from preparing slurries in the Round Robin tests. Small samples of product slurries were tested for particle size distribution using Leeds and Northrup Microtrac analyzers. The conditions under which the slurry product had a top size of 325 mesh were then selected for final slurry preparation. The final slurries with 325 mesh top size were prepared at 36.5% solids and 20 minutes grinding time. Approximately 3 gallons of slurry were prepared. The cumulative PSD of the product 325 mesh slurry are shown on Table 5.12 and Figure 5.13.

The slurry with 200 mesh top size was prepared in a 2-1/2 gallon rod mill. The rod mill was 10" in diameter and 8" high. Stainless steel rods of three different diameters -- 3/4", 5/8", and 1/2" -- were used. The number of rods and diameters are:

Diameter of Rod	Number
3/4"	12
5/8"	14
1/2"	16

The number of rods in the mill was the same as that used in the DOE/PETC's "Coal Surface Control" project by the University of California at Berkeley. Pretesting of the rod mill was done at two coal charges (500 gm and 600 gm), one solids level (40%), at four different grinding times (20, 30, 40, and 50 minutes). The particle sizes of the product slurries were analyzed using Microtrac analyzers. The grinding conditions for final slurry preparation were selected based on the PSD results. The final slurries were prepared at 40% solids with 600 gm of coal in each batch and 40 minutes of grinding time.

TABLE 5.12

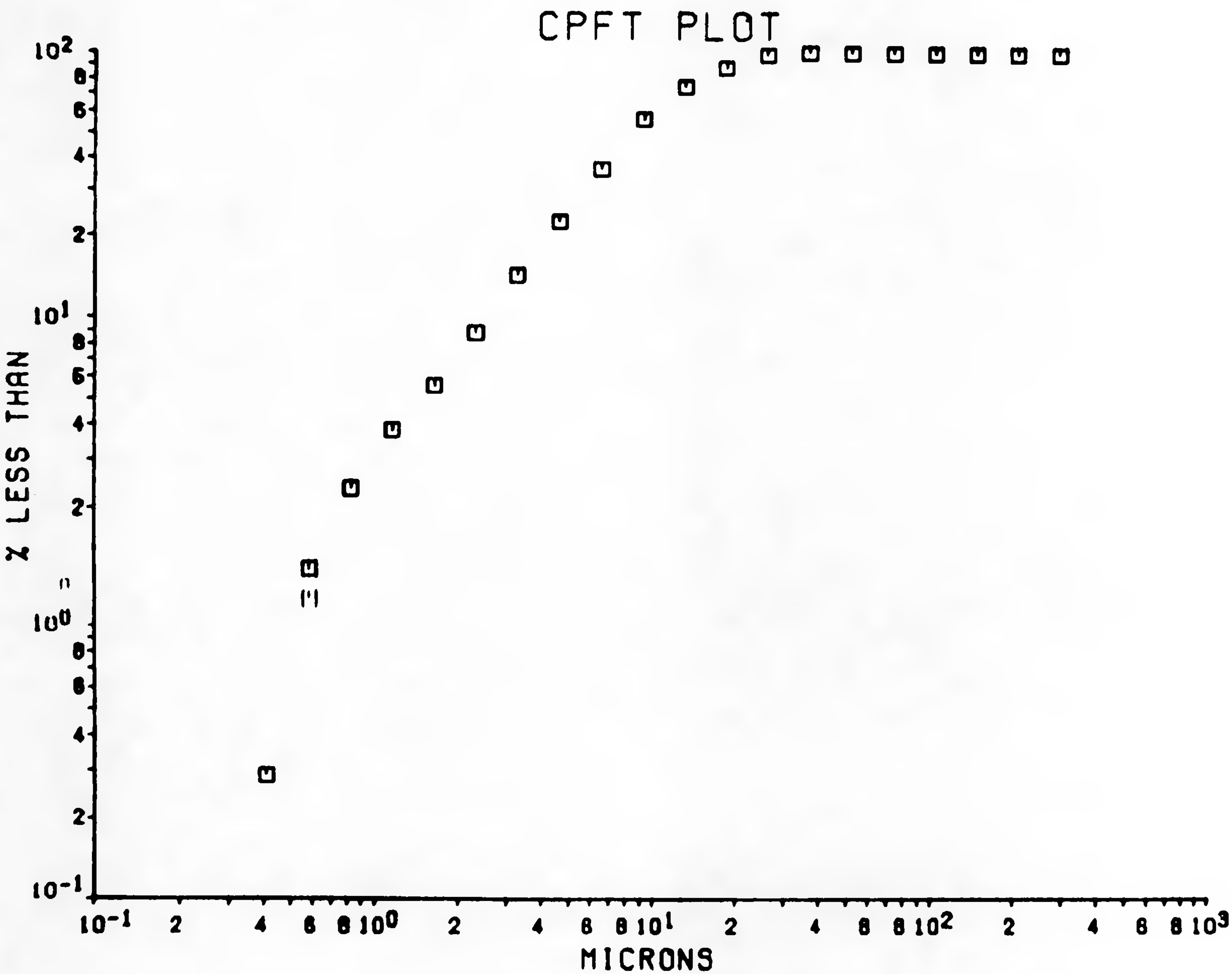
325 MESH FEED SAMPLE SIZE DISTRIBUTION

Microns	% Less	Diff
300.00	-	
212.13		
150.00		
106.07		
75.00		
53.03		
37.50	100.00	2.04
28.52	97.96	11.02
18.75	86.95	13.24
13.26	73.71	18.42
9.38	55.29	19.36
6.63	35.94	13.47
4.69	22.47	8.34
3.31	14.13	5.37
2.34	8.78	3.23
1.66	5.54	1.73
1.17	3.81	1.44
0.63	2.37	1.14
0.59	1.23	0.94
0.41	0.29	0.29
0.29	0.00	0.00
0.21		
0.15		

CS (CAL SURF AREA) = 1.22 M==2/CM==3
MMD (D43) = 10.26 MICRONS
SMD (D32) = 4.91 MICRONS

Figure 5.13

325 Mesh Feed Sample Size Distribution Plot



Approximately 3 gallons of slurry were prepared. The cumulative PSD Of the 200 mesh product slurry are shown in Table 5.13 and Figure 5.14.

A 2-inch diameter microbubble column purchased from Virginia Polytechnic Institute and State University was installed for advanced flotation tests. A water spray system was installed at the top of the column to wash down the overflow froth product for collection. Mr. Mike Forest from VPI visited B&W and assisted in the shakedown of the column.

Flotation tests were run based on approximately 4 minutes retention time. Conditions were changed during the flotation tests in order to improve the column performance. Initial conditions were similar to VPI's Round Robin test parameters. Conditions changed were frother dosage, wash water rate, aeration rate, and slurry feed rate as per the suggestions of Mr. Forest. However, no attempt was made to optimize the column performance on these tests for the two sizes.

The tests were started with an empty column. The retention time was checked by feeding the empty column with water at preset conditions for wash water, frother dosage, and aeration rate. However, no coal was fed to the column at this time. The time it took to fill the column gave a rough indication of the retention time of the test. Then the coal slurry was fed to the column. Tests were run for 15 to 20 minutes before froth product and reject samples were first taken. Another 20 minutes were allowed for sample collection before the flotation conditions were changed.

The flotation conditions for 200 mesh and 325 mesh top size fractions are listed in Table 5.14. The feed, froth products, and reject samples were filtered and dry weights were obtained. The BTU, ash, and pyritic sulfur of the samples were analyzed using ASTM standard methods. Results are shown in Table 5.15. Even though the tests were not optimized, it is clear that grinding to 325 mesh top size results in higher reduction of pyritic sulfur, ash, and a higher efficiency at the same Btu recovery as the 200 mesh top size. Pyritic sulfur reduction was higher - 39.6% versus 25.7%, ash reduction was higher - 59.3% versus 48.5%, and efficiency was higher - 33.6% versus 21.6%. Consequently, it was decided to grind to 325 mesh top size in the continuous microgrinding tests.

TABLE 5.13

200 MESH FEED SAMPLE
SIZE DISTRIBUTION

Microns	% Less	Diff
300.00		
212.13		
150.00		
106.07		
75.00	100.00	4.44
59.03	95.56	9.26
37.50	88.30	13.13
28.52	73.17	18.70
18.75	54.47	12.75
13.26	41.72	10.96
9.38	30.76	10.96
6.63	19.80	6.96
4.69	12.84	4.75
3.31	8.09	2.87
2.34	5.22	1.82
1.86	3.41	1.11
1.17	2.29	0.90
0.83	1.39	0.67
0.59	0.72	0.52
0.41	0.20	0.20
0.29	0.00	0.00
0.21		
0.15		

CS (CAL SURF AREA) = 0.79 M==2/CM==3
MMD (D43) = 20.36 MICRONS
SMD (D43) = 7.56 MICRONS

Figure 5.14

200 Mesh Feed Sample Size Distribution Plot

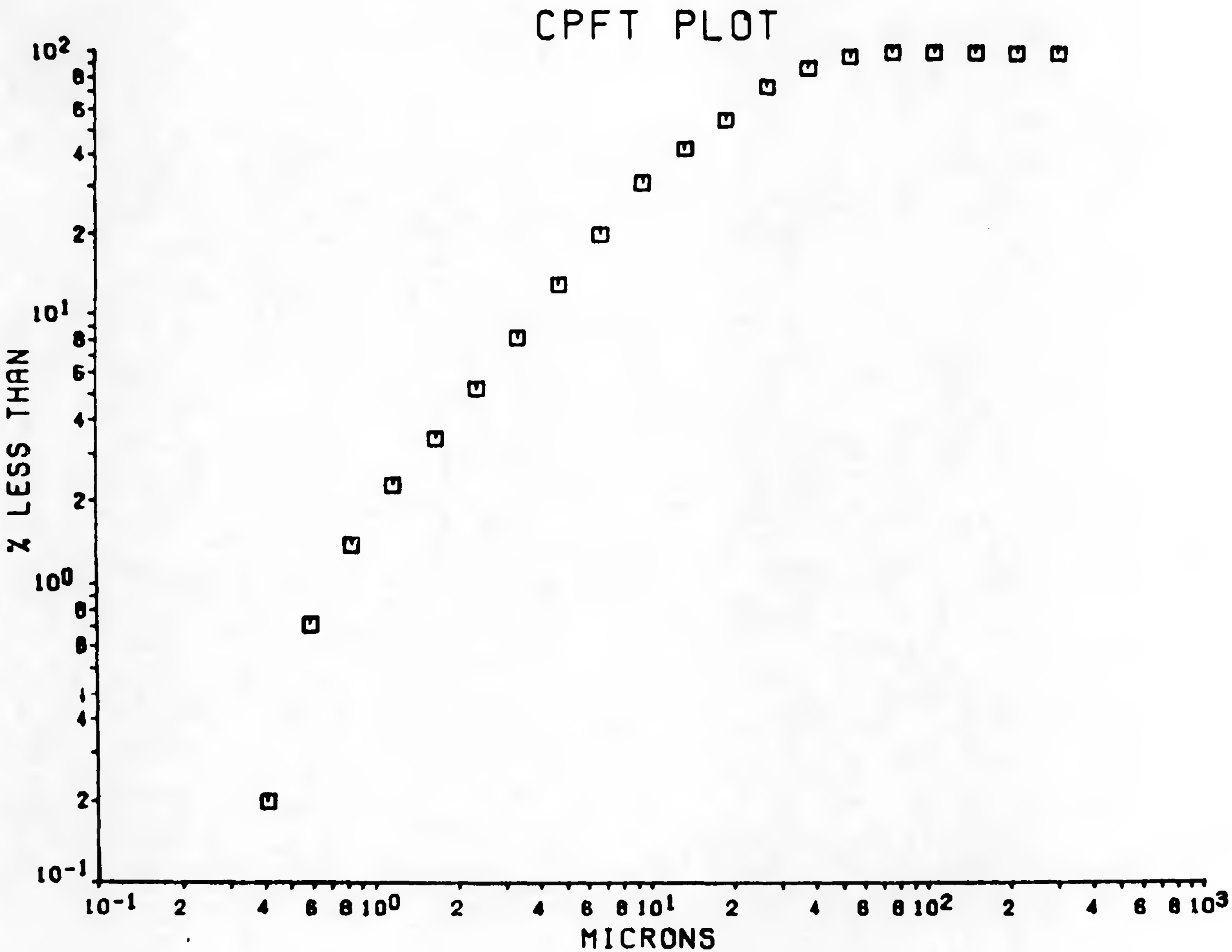


TABLE 5.14

FROTH FLOTATION PROCESS VARIBLES

		200 M	200 M	325 M	325 M
		#1	#2	#1	#2
GEOMETRY	**UNIT**				
HEIGHT	IN	84	84	84	84
DIAMETER	IN	2	2	2	2
SLURRY FEED POINT	IN	16	16	16	16
WASH WATER ADDITION PT	IN	10	10	10	10
FROTH HEIGHT	IN	16.00	16.00	16.00	16.00
PULP HEIGHT	IN	68.00	68.00	68.00	68.00
CONDITIONS	**UNIT**				
WASH WATER RATE	GPM	0.2250	0.2110	0.1850	0.1850
AIR FLOW RATE	CFM	0.0616	0.0238	0.0616	0.0616
FEED SLURRY RATE	GPM	0.0238	0.0238	0.0238	0.0238
FEED % SOLIDS	WT	8.6	8.6	8.9	8.9
FEED SLURRY pH		7.75	7.75	7.63	7.63
FEED PARTICLE SIZE		200m	200m	325m	325m
RETENTION TIME	MIN	3.70	3.90	4.40	4.40
REAGENTS					
COLLECTOR NAME		NOTE 1	NOTE 1	NOTE 1	NOTE 1
COLLECTOR RATE	#/T	1	1	1	1
FROTHER NAME		NOTE 2	NOTE 2	NOTE 2	NOTE 2
FROTHER RATE	#/T	2.78	2.78	3.05	4.04

NOTE 1 KEROSENE
NOTE 2 BETZ M150

TABLE 5.15

FLOTATION PERFORMANCE RESULTS

	200 M	200 M	325 M	325 M
PERFORMANCE PARAMETER	#1	#2	#1	#2
FEED				
WEIGHT %	100.0	100.0	100.0	100.0
ASH %	9.62	9.62	9.2	9.2
PYRITIC SULFUR %	1.07	1.07	1.13	1.13
TOTAL SULFUR %	3.36	3.36	3.33	3.33
BTU	13115	13115	13073	13073
CLEAN COAL				
WEIGHT %	91.52	91.34	87.36	90.66
ASH %	5.12	4.99	3.83	4.05
PYRITIC SULFUR %	0.91	0.91	0.71	0.74
TOTAL SULFUR %	3.36	3.3	3.18	3.19
BTU	13740	13587	13794	13567
REFUSE				
WEIGHT %	8.48	8.66	12.64	9.34
ASH %	49.81	52	42.74	51.95
PYRITIC SULFUR %	3.33	3.4	3.66	4.11
TOTAL SULFUR %	4.25	4.47	5.03	5.26
BTU	6489	6075	7652	6190
BTU RECOVERY	95.88	94.62	92.17	94.08
PYRITIC SULFUR REJECTION	26.39	27.51	40.94	33.97
EFFICIENCY	22.27	22.14	33.11	28.05

Continuous Microgrinding

The first step in this subtask was to prepare the feed for the pilot stirred ball mill. The feed to the mill was prepared in a 6" thickening cyclone as follows: The scavenger products from the split feed grab and run rougher flotation tests were collected separately (48M x 200M and 200M x 0) in drums. The frother products were weighed, and the weight of solids in each size fraction was determined. The frother products were then recombined in the ratio of 2.7:1, fine:coarse, based on the weights of solids. This concentrated slurry was then diluted to 5% solids to be used as feed for shakedown of the 6" thickening cyclone. Prior to the shakedown, Microtrac particle size analyses were run on the feed (see Table 5.16 and Figure 5.15) to aid in determining the shakedown parameters. Krebs was contacted for recommendations. They recommended beginning with a 1-1/2" diameter vortex finder, 1/2" diameter apex insert, 5% feed solids, and 25-30 psig feed pressure. Tests were run with 1/2", 5/8" and 7/8" apex orifices at a feed pressure of 27 psig. Microtrac analyses were run on the overflows and underflows of the 1/2" and 5/8" tests. The underflow with the 7/8" apex was approximately 15% solids, which is too dilute to use as a feed to the stirred ball mill. Consequently, no analyses were run on these samples. The most efficient separation resulted with the 5/8" apex. For a 325M separation with a 5/8" apex, misplaced material in the overflow was 22.6% (22.6% of solids in the overflow were +325 mesh), and misplaced material in the underflow was 7.5% (7.5% of solids in the underflow were -325M) (see Table 5.17 and Figure 5.16 for overflow size analysis and Table 5.18 and Figure 5.17 for underflow size analysis). Overall, 79.4% of the +325 mesh solids in the feed reported to underflow and 91.6% of the -325 mesh solids in the feed reported to overflow. Underflow feed concentration was 48.2% solids, which is satisfactory to feed the stirred ball mill. The results were discussed with ICF Kaiser, and approval was given to use the 5/8" apex. The combined froth products have been run through the cyclone to prepare the feed for the continuous stirred ball mill. The 325 mesh x 0 overflow will be stored in drums and recombined with the stirred ball mill product prior to cleaning in the advanced column flotation cell.

Surface Modification

B&W continues to review the progress reports of the "Coal Surface Control for Advanced Fine Coal Flotation" program performed by the UCB and the team members. So far, no coal surface modifiers have been identified that show substantial improvements in BTU recovery and pyrite rejection. Some recommendations by B&W on coal surface modifies may be provided to UCB to be considered in Task 7 of the "Coal Surface Control Program."

TABLE 5.16

325 MESH THICKENING CYCLONE FEED SIZE DISTRIBUTION

Microns	% Less	Diff
2400.00		
1697.06		
1200.00		
848.53		
600.00	100.00	0.70
424.26	99.30	0.50
300.00	98.80	1.71
212.19	97.09	7.90
150.00	89.19	8.28
106.07	80.91	11.71
75.00	69.20	13.23
53.03	55.97	11.04
37.50	44.93	8.94
26.52	35.99	9.05
18.75	26.94	6.37
13.26	20.57	3.80
9.38	16.77	5.62
6.63	11.14	4.21
4.69	6.94	2.39
3.31	4.54	1.50
2.34	3.04	0.98
1.66	2.06	0.63
1.17	1.43	0.52
0.83	0.91	0.41
0.59	0.49	0.36
0.41	0.14	0.14
0.29	0.00	0.00
0.21		
0.15		

CS (CAL SURF AREA) = 0.47 M==2/CM==3
MMD (D43) = 65.96 MICRONS
SMD (D32) = 12.76 MICRONS

Figure 5.15

325 Mesh Thickening Cyclone Feed Size Distribution Plot

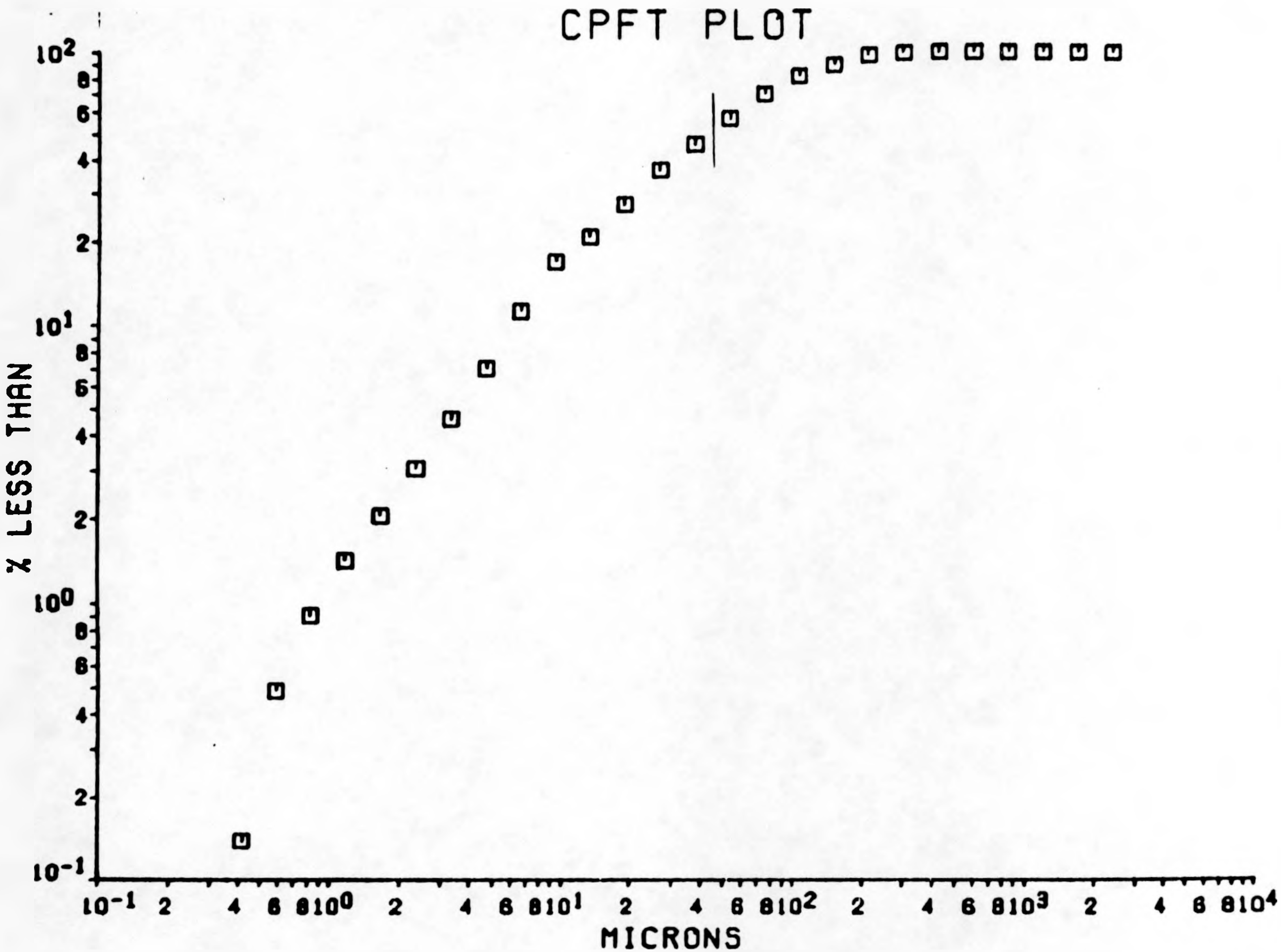


Figure 5.10

325 Mesh Thickening Cyclone Overflow
5/8 inch Apex Size Distribution Plot

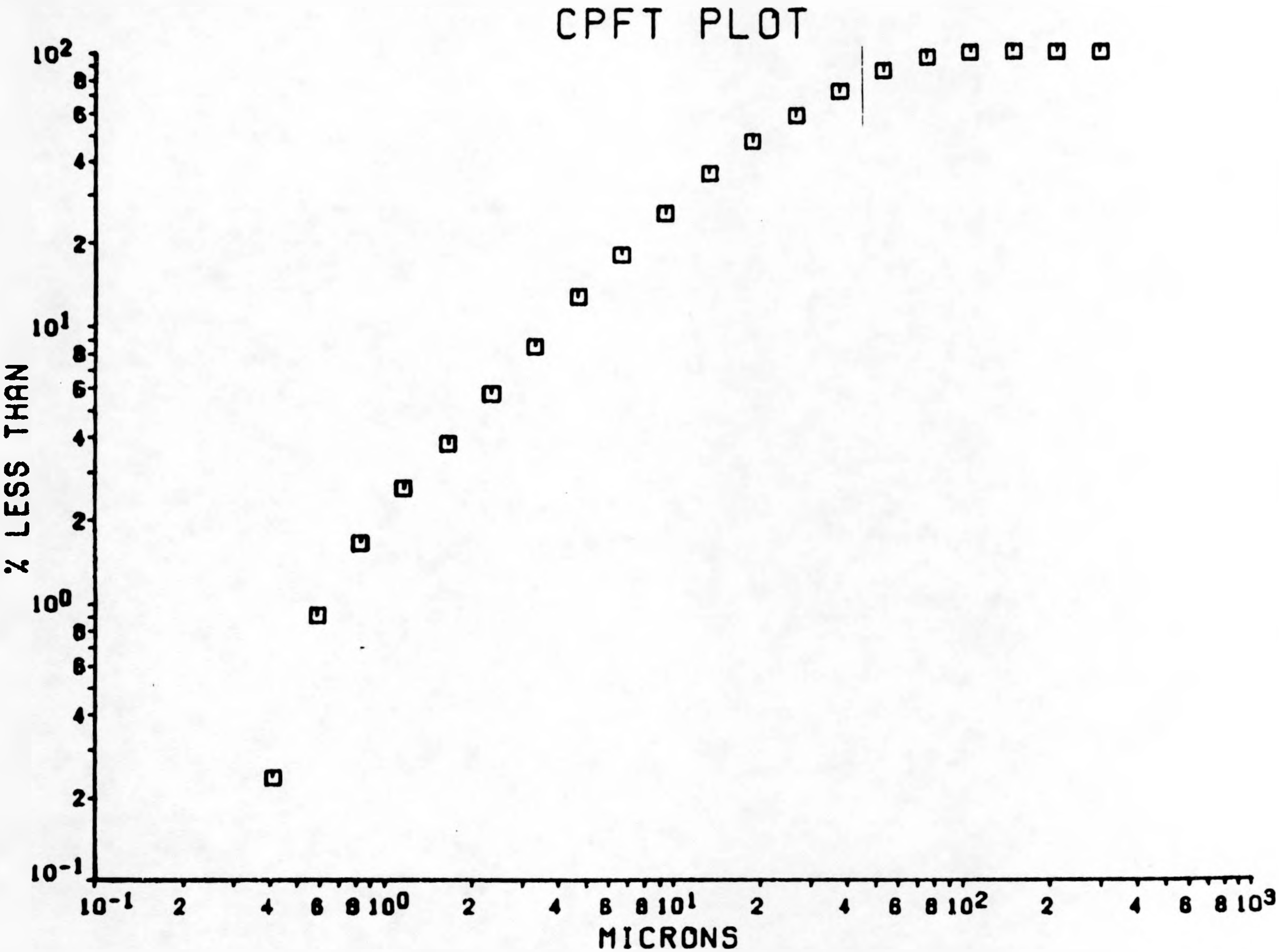


TABLE 5.17

325 MESH THICKENING CYCLONE OVERFLOW
5/8 INCH APEX SIZE DISTRIBUTION

Microns	% Less	Diff
300.00		
212.13		
150.00	100.00	0.84
106.07	99.16	4.86
75.00	94.29	10.29
53.03	84.00	13.38
37.50	70.62	13.38
26.52	57.25	11.32
18.75	45.93	10.85
13.26	35.07	10.01
9.38	25.06	7.30
6.63	17.77	5.19
4.63	12.58	4.18
3.31	8.39	2.70
2.34	5.69	1.92
1.66	3.77	1.15
1.17	2.62	0.94
0.83	1.68	0.76
0.59	0.92	0.68
0.41	0.24	0.24
0.29	0.00	0.00
0.21		
0.15		

CS (CAL SURF AREA) = 0.76 M==2/CM==3
MMD (D43) = 29.04 MICRONS
SMD (D32) = 7.90 MICRONS

TABLE 5.18

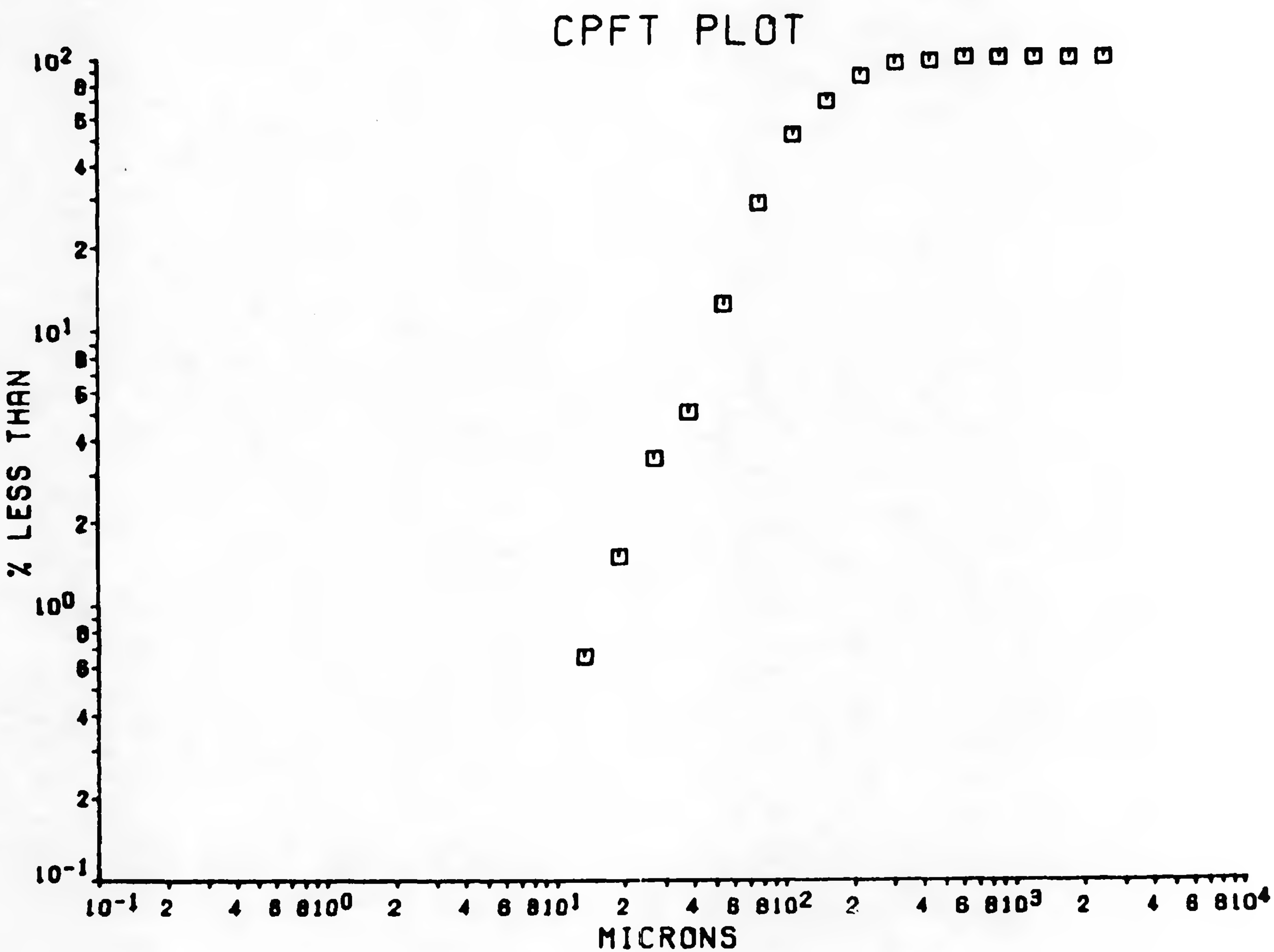
325 MESH THICKENING CYCLONE UNDERFLOW
5/8 INCH APEX SIZE DISTRIBUTION

Microns	% Less	Diff
2400.00	100.00	0.01
1697.06	99.99	0.00
1200.00	99.98	0.19
848.63	99.80	0.14
600.00	99.66	3.03
424.26	96.63	2.15
300.00	94.48	9.83
212.13	84.65	16.72
150.00	67.93	17.57
106.07	50.36	22.20
75.00	28.16	15.97
53.03	12.19	7.18
37.50	5.01	1.61
26.52	3.40	1.89
18.75	1.51	0.85
13.26	0.66	0.66
9.38	0.00	0.00
6.63		
4.69		
3.31		
2.34		
1.66		
1.17		
0.63		
0.59		
0.41		
0.29		
0.21		
0.15		

CS (CAL SURF AREA) = 0.07 M==2/CM==3
MMD (D43) = 139.11 MICRONS
SMD (D32) = 84.84 MICRONS

Figure 17

325 Mesh Thickening Cyclone Underflow
5/8 Inch Apex Size Distribution Plot



6.0 TASK 6 COMPONENT AND UNIT OPERATIONS DEVELOPMENT

6.1 Overview and Scope

The Task 6 effort involves three main elements including column cell development (Subtask 1.6.1), flotation circuit testing (Subtask 1.6.2) and flotation cell modeling (Subtask 1.6.3). The work outlined in Subtask 1.6.1 is to research column designs and operation parameters in developing an optimized column flotation cell (OCFC) to meet the overall program objectives. The test results obtained through this effort will be evaluated against the results obtained from the round-robin test program in Task 5. Any design parameters of operating conditions that are unique with the round-robin test winner that were not evaluated as part of the optimized column development work will be reviewed and tested so as to incorporate all possible scenarios in presenting DOE with the best available flotation process for use in the 2 to 3 ton per hour POC.

Following development of the OCFC, various flotation circuit configurations will be evaluated (Subtask 1.6.2) to determine the "best" circuit design for the 2 to 3 ton per hour POC. Single and multiple stage flotation, grab and run, rougher/scavenger/cleaner, etc., test circuits will be tested as part of this effort. Upon completion of this test work, the "best" possible flotation cell will have been tested in a number of possible flotation circuit designs to possibly provide the "best" flotation approach in meeting the design criteria.

In conjunction with the flotation test effort, model development work will be conducted to provide a tool in evaluating the various flotation circuit configurations and in predicting flotation performance (Subtask 1.6.3). The model will be useful in selecting operating conditions in the POC and in evaluating the performance of the POC.

6.2 Review of Work Completed This Quarter

Several functions have been completed as described in the next paragraphs.

6.2.1 Optimum Column Cell Development Test Work

The objective of this subtask has been to utilize parametric testing to determine the effects of various operating parameters on the performance of a column flotation cell. To date, two different samples of the Pittsburgh No. 8 am coal have been examined. Initial test work was conducted using an in-house sample of run-of-mine coal. These tests were conducted while a precleaned coal sample was being prepared by B & W.

During the past quarter, testing was begun to complete the proposed test program which was submitted to ICF Kaiser Engineers on July 28, 1989. The precleaned coal sample was received in slurry form and arrived at Virginia Tech in several received in slurry form and arrived at Virginia Tech in several 55-gallon drums. The solids content of the froth product in each drum was approximately 15-30%. Grab samples indicated that the quality of the material in each drum was highly variable and that blending would be required before the samples could be used in the test work.

Homogenization of the samples was accomplished in several steps. First, the contents of each barrel was thoroughly agitated using a low-speed drum mixer. This procedure was necessary to redisperse coarse particles which had settled to the bottom of the drums during shipment. The contents of each drum were then transferred to a 500-gallon sump which was agitated by means of a mixer and a pumping circuit which continuously recirculated the slurry. After emptying all the drums, representative samples of the well-mixed slurry were pumped from the sump into individual 5-gallon containers. Each container was flooded with nitrogen and sealed prior to storage. Randomly selected samples from these containers were very consistent in terms of quality.

Minus-325-mesh samples were prepared for flotation by grinding in a stirred ball mill for 4 minutes. Prior to flotation, the samples were diluted to an appropriate solids content using tap water. The flotation behavior of each of the coal samples was determined from timed release analysis tests conducted using a Model D-12 Denver flotation machine. The frother and collector dosages for the release analysis tests were 3.85 and 0.99 lbs/ton, respectively. The release test required approximately 26 minutes for the recovery of all floatable material.

The results of the release analysis tests are shown in Figure 6.1 for both the in-house and precleaned samples of Pittsburgh No. 8 seam coal. Both samples displayed essentially the same cleaning characteristics in terms of ash rejection. This result was surprising in light of the fact that the feed ash content of in-house sample was considerably higher than that of the precleaned sample, i.e., 11.7% versus 9.6%. These results indicate that the data collected from the in-house test work, which was not originally proposed, may also be useful for assessing the effects of the various test parameters on flotation column performance.

The standard conditions used during the parametric testing of the in-house sample of the Pittsburgh No. 8 seam coal are provided in Table 6.1. The following parameters were examined in the parametric testing of the in-house sample: collector dosage, aeration rate, air fraction, retention time, wash water rate and feed rate. The results of the test work are summarized in Figure 6.2. As expected, all of the data points fall near or just below the release curve. Since the parametric testing was conducted over a wide range of operating conditions, the data shown in Figure 6.2 support the conclusion that the release curve represents the ultimate

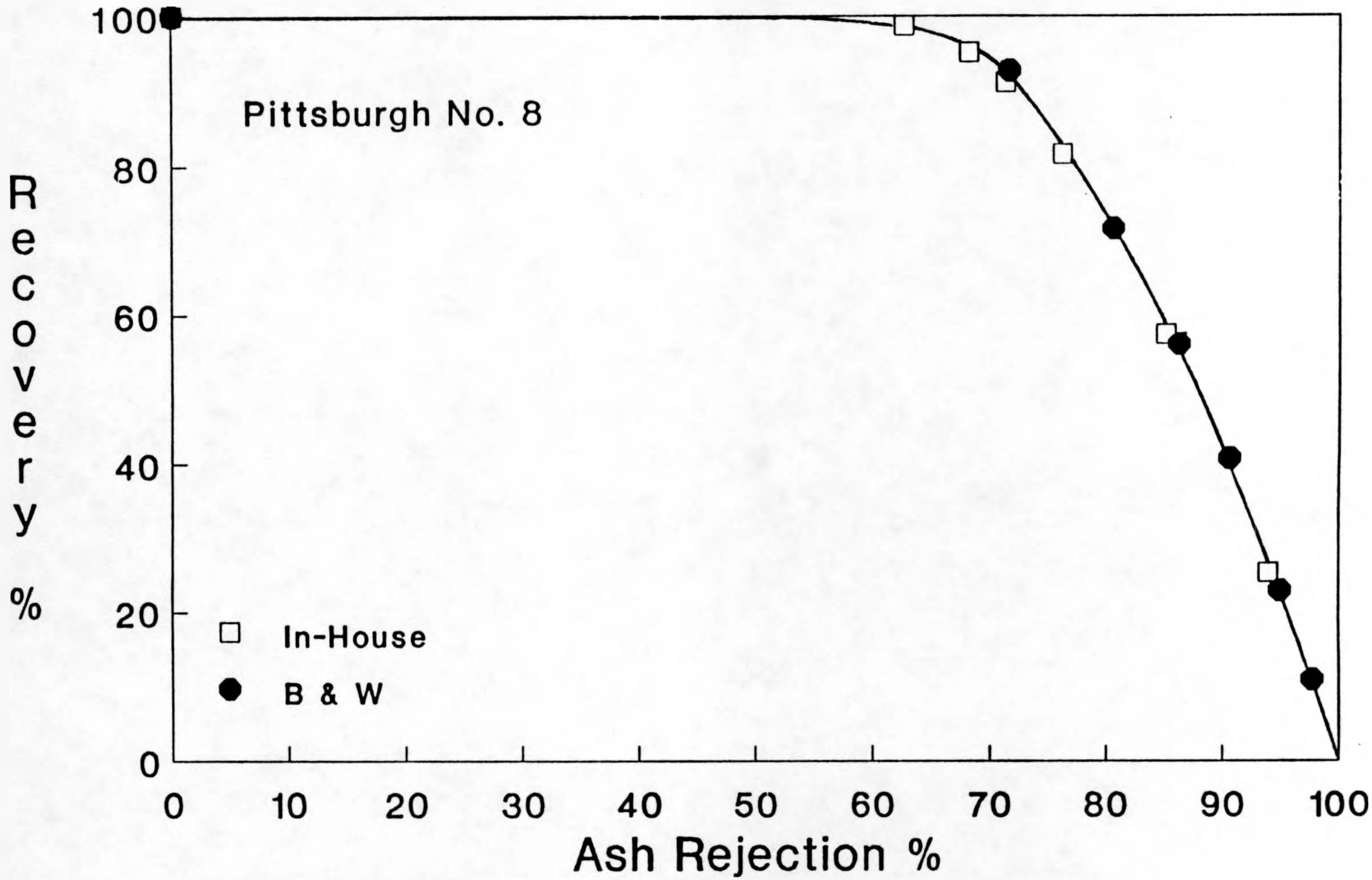


Figure 6.1 Comparison of the release analysis curves for samples of the Pittsburgh No. 8 seam coal examined in the present work.

Table 6.1 Standard Conditions Used for Parametric Testing of the In-House Sample of Pittsburgh No. 8 Seam Coal

Column Diameter	2 inches
Column Length	60 inches
Grind Time	4 minutes
Grind Size	-325 mesh
Wash Water Addition Point	15 cm above pulp
Sparger Length	30 cm
Sparger Diameter	1.3 cm
Feed Percent Solids	10%
Frother Type	Dowfroth M-1012
Frother Dosage	0.5 kg/ton
Collector Type	Kerosene
Collector Dosage	1.0 kg/ton
Aeration Rate	750 cm3/min
Wash Water Rate	250 ml/min
Feed Rate	600 ml/min
Baffles	None

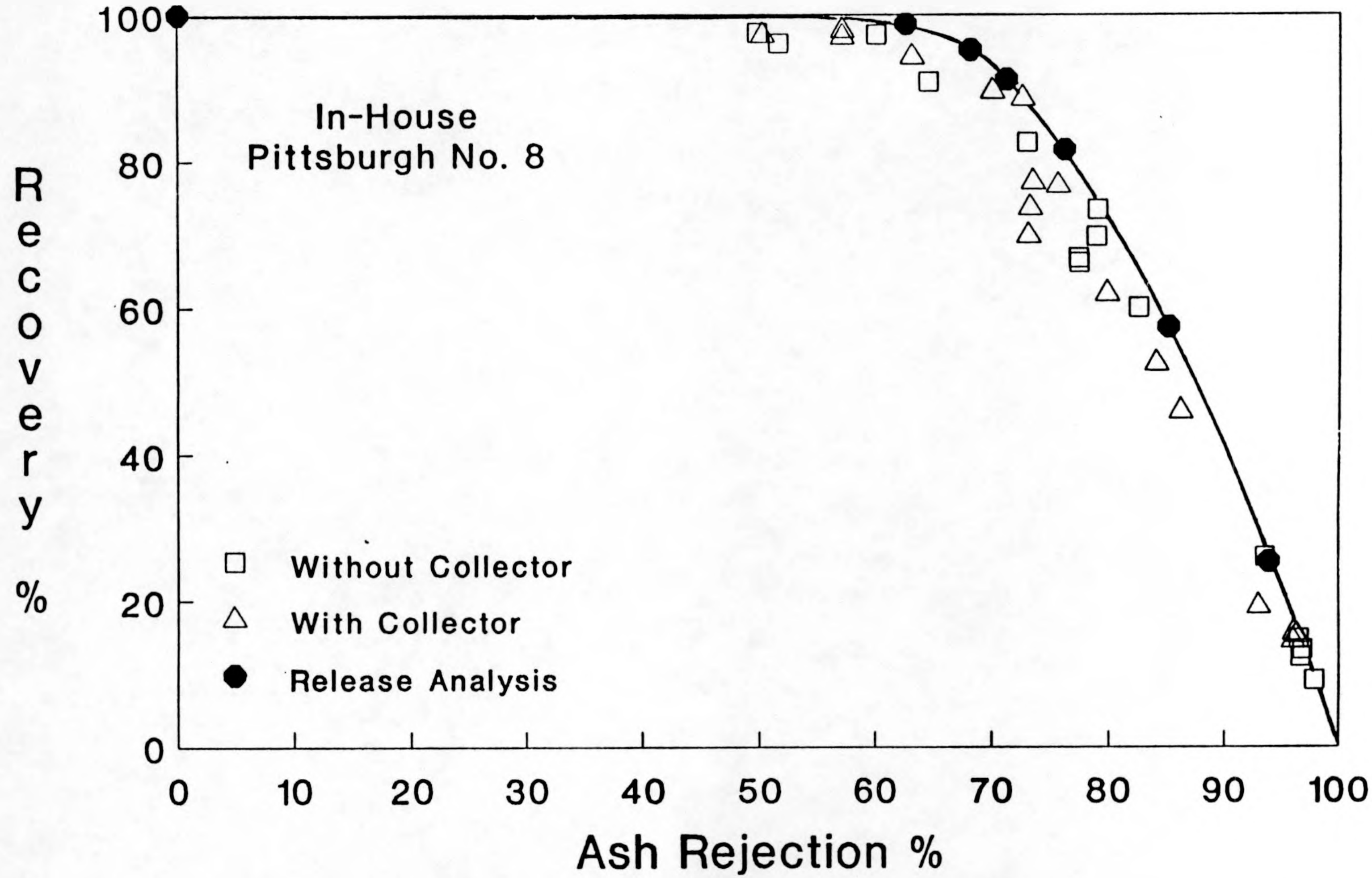


Figure 6.2 **Recovery versus ash rejection for the in-house Pittsburgh No. 8 seam coal.**

indicate that the ash rejection is somewhat less effective at higher dosages of collector (i.e., 3 lb/ton). An explanation for this result is that an excessive dosage of collector may lead to formation of large agglomerates of coal which may entrap mineral matter and increase the product ash content. Thus, excessively high dosages of hydrocarbon collectors should be avoided. The test data obtained using the in-house sample are currently being analyzed using the DESIGN-EXPERT statistical software. The results of this analysis will be detailed in a forthcoming progress report.

At the suggestion of the Consolidation Coal Company, modifications were made to the original parametric test program used to examine the in-house sample of Pittsburgh No. 8 seam coal. The new test program, which was submitted to ICF Kaiser Engineers on July 28, 1989, consists of a Box-Behnken design having 54 individual tests. The specific experiments to be conducted are outlined in Table 6.2. The parameters to be examined include feed solids content, frother dosage, collector dosage, feed rate, aeration rate and wash water rate. The levels to be examined for each parameter are as follows:

TABLE 6.3
PARAMETER LEVELS

	Level		
Parameter	Low	Normal	High
Feed Solids (%)	5	10	15
Frother Dosage (lb/ton)	0.25	0.5	0.75
Collector Dosage (lb/ton)	0.5	1.0	1.5
Feed Rate (ml/mini	300	600	900
Aeration Rate (cm /min)	500	750	1000
Wash Water Rate (ml/min)	100	250	400

All tests have been performed in random order in an attempt to minimize operator bias. Throughout the test program, a number of experiments are being conducted under "normal" test conditions to monitor any changes in coal

Table 6.2 Box-Behnken Experimental Design for the Advanced Flotation Cell Optimization Studies.

Test No.	Collector Dosage	Frother Dosage	Aeration Rate	Feed Solids	Feed Rate	Wash Water Rate
1	1	1	0	1	0	0
2	-1	1	0	1	0	0
3	1	-1	0	1	0	0
4	1	1	0	-1	0	0
5	-1	-1	0	1	0	0
6	1	-1	0	-1	0	0
7	-1	1	0	-1	0	0
8	-1	-1	0	-1	0	0
9	0	1	1	0	1	0
10	0	-1	1	0	1	0
11	0	1	-1	0	-1	0
12	0	1	1	0	-1	0
13	0	-1	-1	0	1	0
14	0	1	-1	0	-1	0
15	0	-1	1	0	-1	0
16	0	-1	-1	0	-1	0
17	0	0	1	1	0	1
18	0	0	-1	1	0	1
19	0	0	1	-1	0	1
20	0	0	1	1	0	-1
21	0	0	-1	-1	0	1
22	0	0	1	-1	0	-1
23	0	0	-1	1	0	-1
24	0	0	-1	-1	0	-1
25	1	0	0	1	1	0
26	-1	0	0	1	1	0
27	1	0	0	-1	1	0
28	1	0	0	1	-1	0
29	-1	0	0	-1	1	0
30	1	0	0	-1	-1	0
31	-1	0	0	1	-1	0
32	-1	0	0	-1	-1	0
33	0	1	0	0	1	1
34	0	-1	0	0	1	1
35	0	1	0	0	-1	1
36	0	1	0	0	1	-1
37	0	-1	0	0	-1	1
38	0	1	0	0	-1	-1
39	0	-1	0	0	1	-1
40	0	-1	0	0	-1	-1

Table 6.2 (continued). Box-Behnken Experimental Design for the Advanced Flotation Cell Optimization Studies.

Test No.	Collector Dosage	Frother Dosage	Aeration Rate	Feed Solids	Feed Rate	Wash Water Rate
41	1	0	1	0	0	1
42	-1	0	1	0	0	1
43	1	0	-1	0	0	1
44	1	0	1	0	0	-1
45	-1	0	-1	0	0	1
46	1	0	-1	0	0	-1
47	-1	0	1	0	0	-1
48	-1	0	-1	0	0	-1
49	0	0	0	0	0	0
50	0	0	0	0	0	0
51	0	0	0	0	0	0
52	0	0	0	0	0	0
53	0	0	0	0	0	0
54	0	0	0	0	0	0

quality which may affect the floatability of the coal in later stages of the test program. The precleaned Pittsburgh No. 8 coal sample prepared by B & W is being used for completing the parametric test program.

The results of the initial parametric tests using the B & W prepared sample are shown in Figure 6.3. After completing about 50% of the required tests, two problems were observed with the data. The first problem was that the overall recovery for each test was too low. This suggests that the choice of values for each level for parametric testing, which were based on the test results obtained for the in-house sample, were not appropriate for the sample prepared by B & W. The B & W sample displayed a somewhat lower flotation rate and, as a result, produced lower recoveries. In order to resolve this problem, tests were conducted with the sample prepared by B & W to the determine the most appropriate levels for each test variable. The following levels were found to produce the desired range of recoveries for the parametric testing:

TABLE 6.4
REVISED PARAMETER LEVELS

	Level		
Parameter	Low	Normal	High
Feed Solids (%)	5	10	15
Frother Dosage (lb/ton)	0.5	1.5	2.5
Collector Dosage (lb/ton)	0.5	1.0	1.5
Feed Rate (ml/mini	50	150	250
Aeration Rate (cm /min)	500	1000	1500
Wash Water Rate (ml/min)	200	400	600

All further parametric test work was conducted using these values.

A second problem with this series of tests was that the ash rejection obtained with the column appeared to be considerably lower than that attainable according to release analysis. Previous test work has shown that this type of problem is usually associated with the improper addition of countercurrent wash water (e.g., plugging of the water distributor, column not vertical, improper flow meter calibration, etc.). As a result, the column was disassembled, thoroughly inspected and properly reassembled. In addition, all flow meters and feed pumps were recalibrated.

Preliminary test results obtained using the properly assembled column and modified test levels are shown in Figure 6.4 and 6.5. The clean coal recoveries obtained in

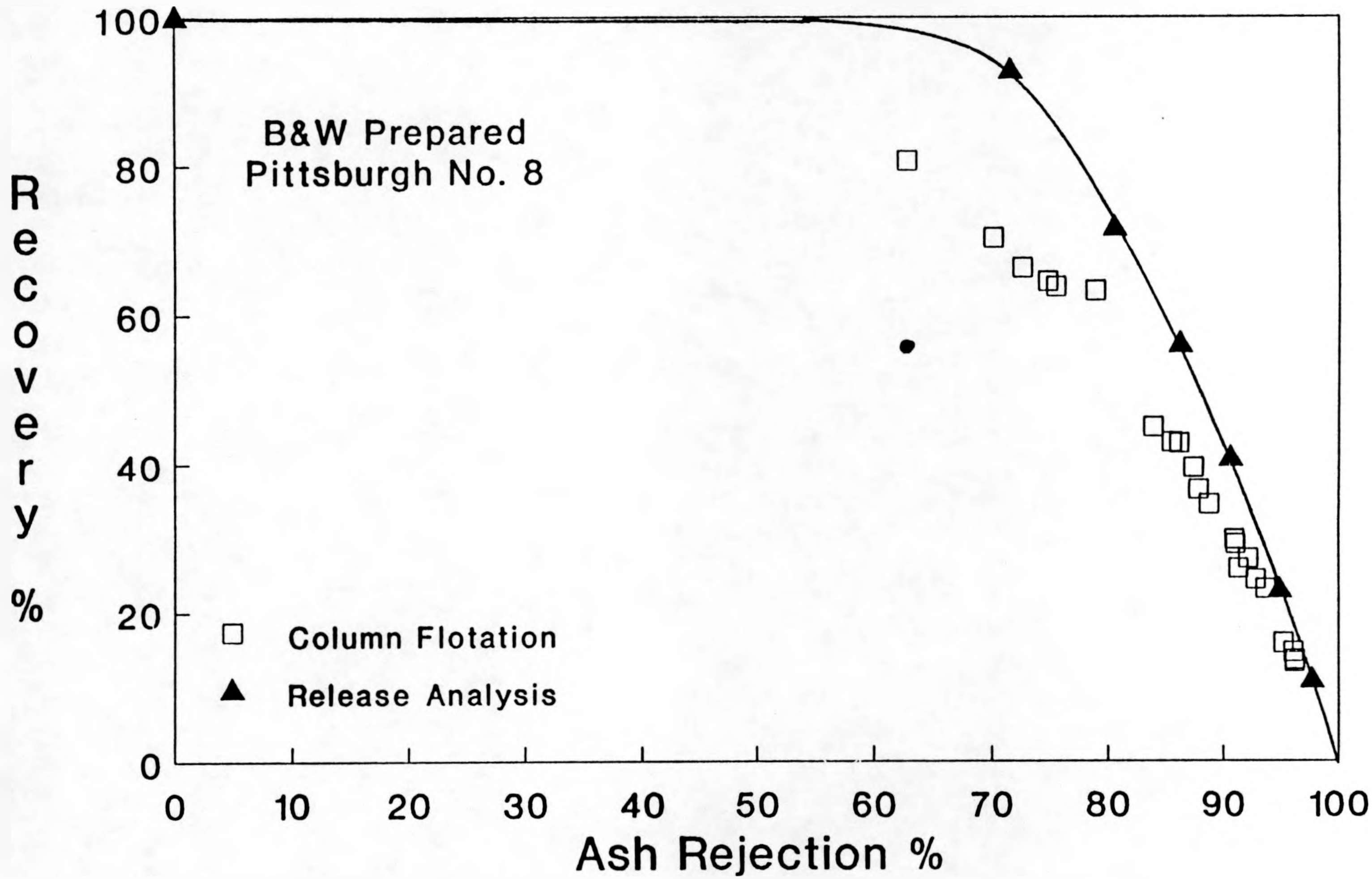


Figure 6.3 **Recovery versus ash rejection for the B & W prepared Pittsburgh No. 8 seam coal using the original parametric test plan.**

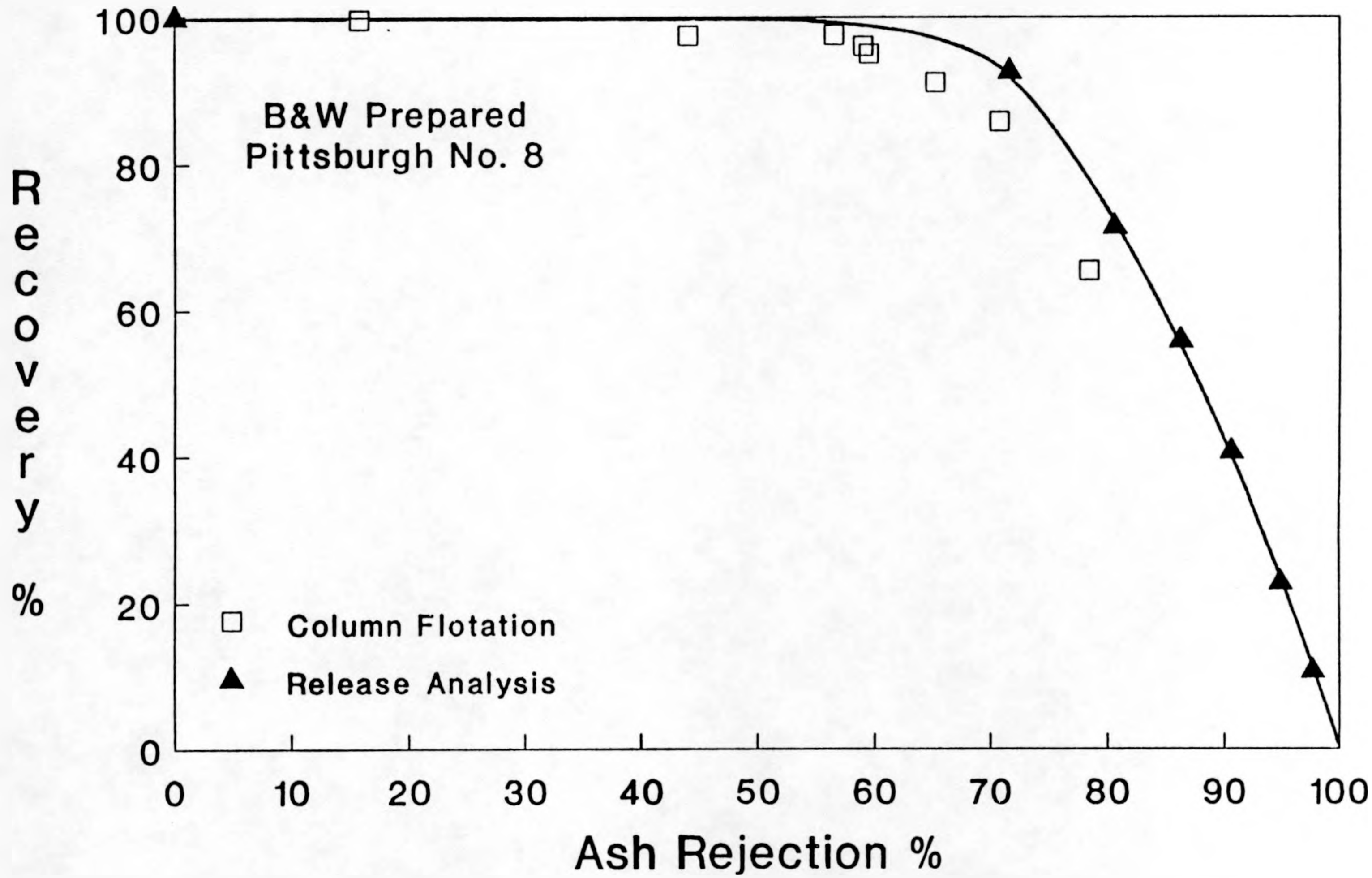


Figure 6.4 Recovery versus ash rejection for the B & W prepared Pittsburgh No. 8 seam coal using the modified parametric test plan.

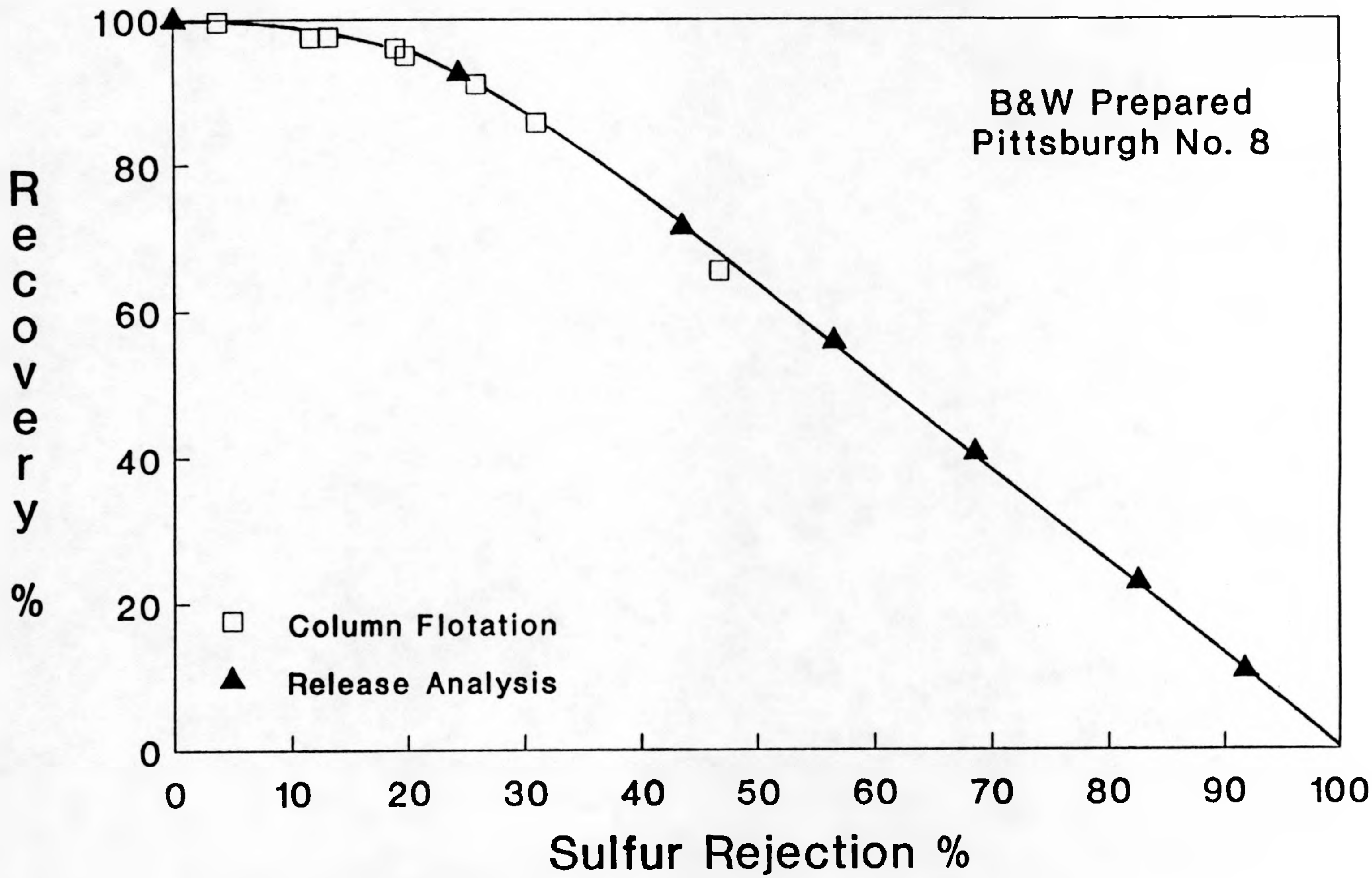


Figure 6.5 Recovery versus sulfur rejection for the B & W prepared Pittsburgh No. 8 seam coal using the modified parametric test plan.

these tests were generally higher than those obtained using the old test levels. This range of recovery values is more representative of that which is expected to be attained in the POC flotation circuit. The data shown in Figure 6.4 also appear to be much closer to the release analysis curve than do the data obtained in the previous test work. This is true despite that fact that most of the tests were conducted at a low level of wash water addition. This indicates that problems associated with the proper addition and distribution of the wash water appear to have been corrected. When completed, the parametric expressions derived from these test data should prove to be very useful for the development of the final engineering design.

The appropriate levels for each parameter have now been selected and the parametric test work is proceeding at a faster rate. Complete characterization of the various test samples is also underway. Btu and pyritic sulfur analyses are being conducted on each test sample and should be completed shortly. These results, along with the completed experimental design test work and data analysis using the STAT-EASE software, is expected to be completed in time for inclusion in the next quarterly report.

6.2.2 Optimum Column Cell Circuit Configuration

The complete 3-cell flotation column circuit which was constructed for this project has been tested using the Pittsburgh No. 8 seam coal sample prepared by B & W. Three different circuit arrangements have been examined to date, including rougher-scavenger-cleaner (RSC) Figure 6.6, rougher-cleaner-recleaner (RCRC) Figure 6.7 and rougher-scavenger-scavenger cleaner (RSSC) Figure 6.8. In addition, several single-stage tests have been conducted. All tests have been performed as a function of the volumetric feed rate of slurry.

The results obtained from the single-stage tests conducted using the Pittsburgh No. 8 seam coal prepared by B & W are summarized in Table 6.5. Material balances, using the BILMAT program, are being performed for each circuit; however, these material balances were not completed in time for inclusion in this report. The material balances, along with full laboratory characterization of each of the test samples (i.e., Btu, pyritic sulfur, etc.), will be reported in the next technical progress report.

Each of the three circuits were tested at feed flow rates of 50, 100, 200 and 300 ml/min. Frother dosages for these tests varied from 1-3 lb/ton, depending on the given feed slurry flow rate and circuit arrangement. Kerosene collector was added directly to the coal in the primary feed sump and was held constant at a value of approximately 0.5 lb/ton in all tests. Other test conditions which were held constant for each of the column circuits include:

Figure 6.6

Rougher - Scavenger - Cleaner Circuit Arrangment

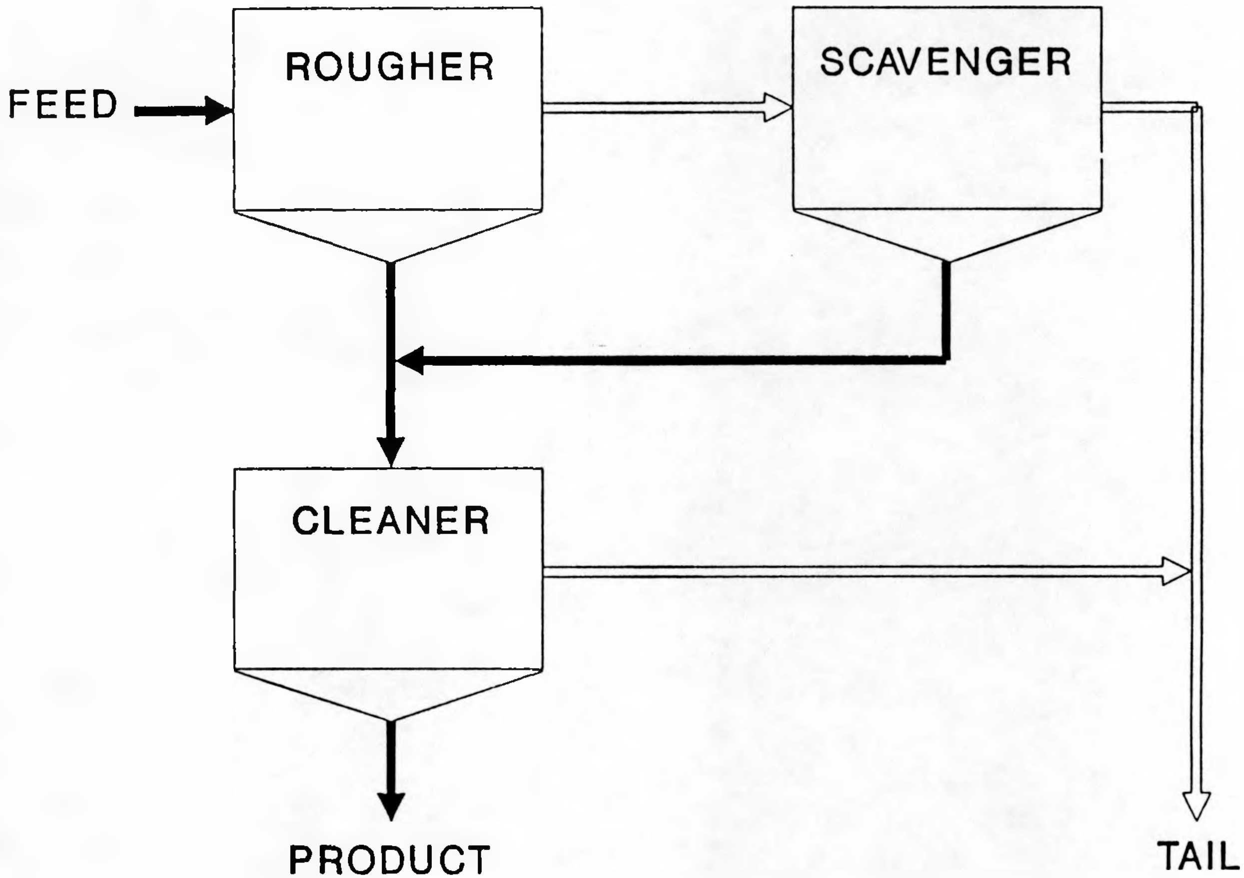


Figure 6.7

Rougher - Cleaner - Recleaner Circuit Arrangement

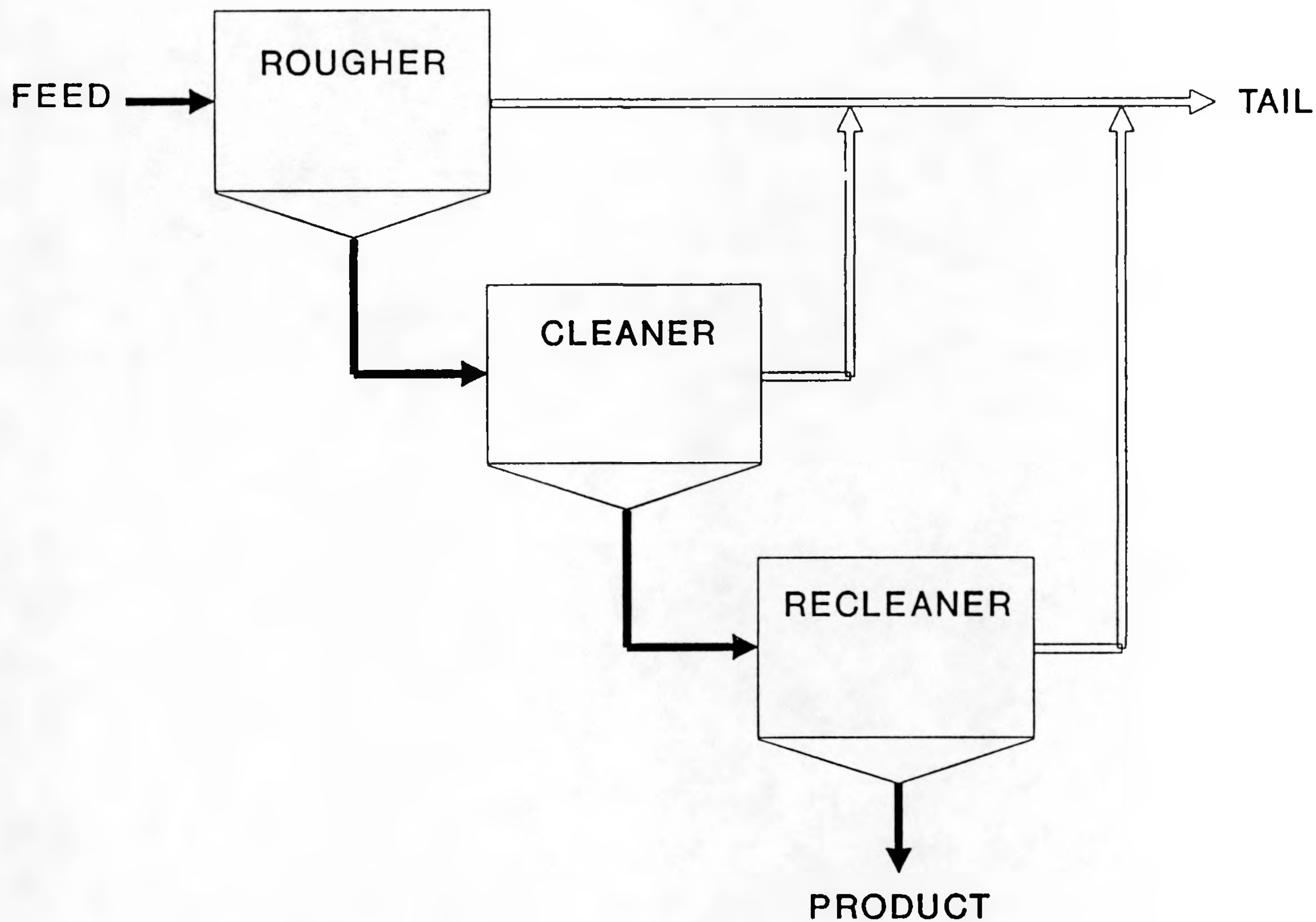


Figure 6.8

Rougher - Scavenge - Scavenger - Recleaner Circuit Arrangement

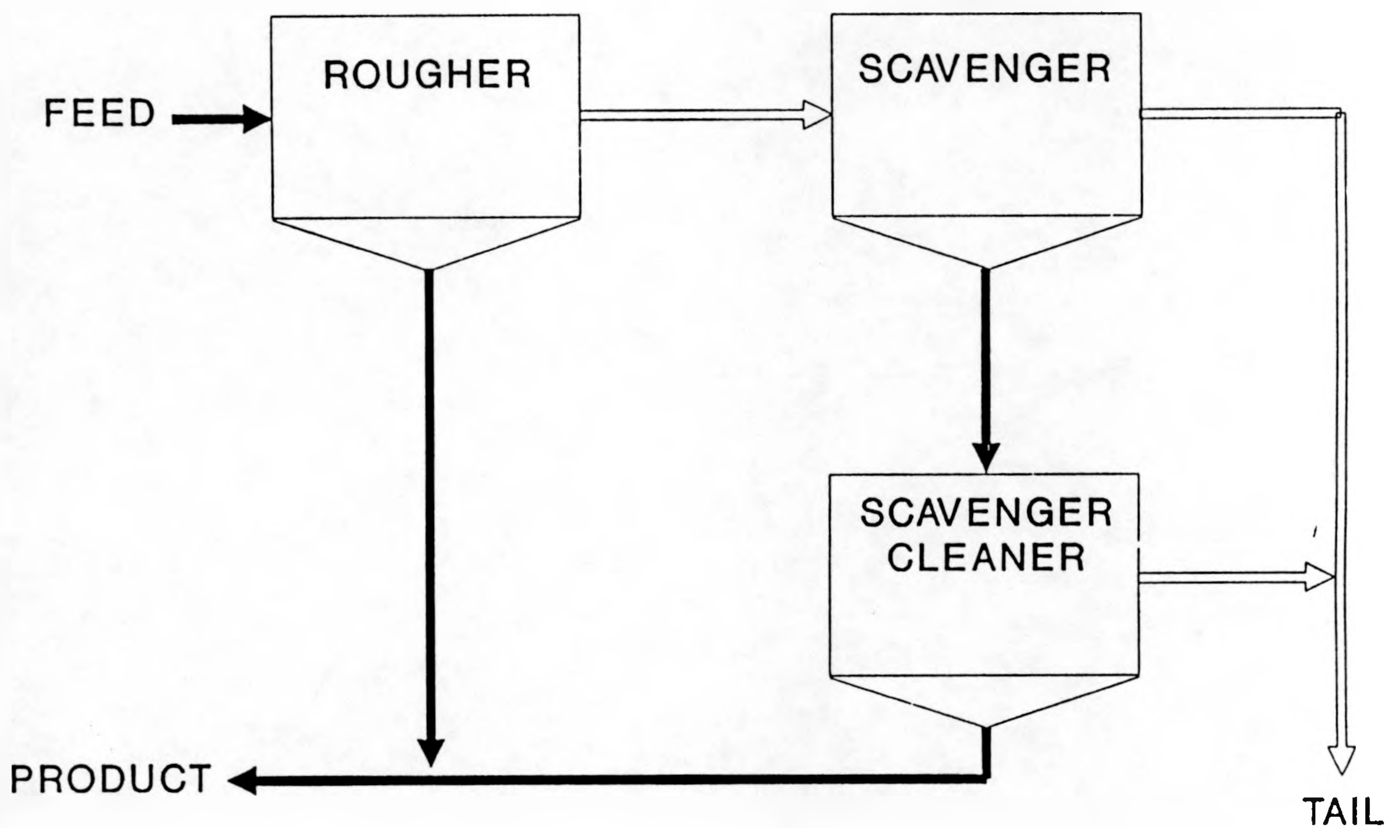


TABLE 6.6
TEST CONDITIONS

Feed Solids:	5%
Conditioning Time:	15 minutes
Particle Size:	-325 mesh
Aeration Rate:	1500 cm^3/min.
Froth Height:	15 inches below overflow lip
Wash Water Point:	6 inches below overflow lip
Feed Point:	16 inches below overflow lip

The effects of feed slurry flow rate on combustible recovery for each of the circuits is shown in Figure 6.9. For a given feed rate, the rougher-scavenger-scavenger cleaner circuit produced the highest overall recoveries, while the rougher-cleaner-recleaner circuit produced the lowest. The single-stage and rougher-scavenger-cleaner circuits behaved in a very similar fashion and produced recovery values intermediate to the other two circuits. With the exception of the rougher-scavenger-scavenger cleaner circuit, all circuits yielded a reduction in clean coal recovery with increasing feed flow rate.

The effects of feed rate on ash and sulfur rejection for each of the circuits is shown in Figures 6.10 and 6.11, respectively. In varying this parameter, the rougher-scavenger-scavenger cleaner circuit produced the poorest rejection of both ash and sulfur regardless of feed rate. The rougher-cleaner-recleaner circuit, which gave the lowest overall recoveries, produced the highest ash and sulfur rejections.

Table 6.5 Results of Single-Stage Column Testing Using the Pittsburgh No. 8 Seam Coal Prepared by B&W

Feed Rate (ml/min)	Process Stream	Yield (%)	Ash (%)	Sulfur (%)	Recovery (%)
50	Product	86.5	3.30	3.28	91.88
	Reject	13.5	35.26	6.24	8.12
100	Product	81.7	3.05	3.23	87.08
	Reject	18.3	35.78	5.40	12.92
200	Product	79.1	3.17	3.19	84.74
	Reject	20.9	33.09	5.14	15.26
300	Product	67.5	2.94	3.24	72.18
	Reject	32.5	21.82	4.45	27.82

Yield% = Weight Recovery

Recovery% =

$$\text{Combustible Recovery} = 100 \times \frac{\text{Product Rate 16/hr} \times (100 - \text{Product Ash\%})}{\text{Feed Rate 16/hr } (100 - \text{Feed Ash\%})}$$

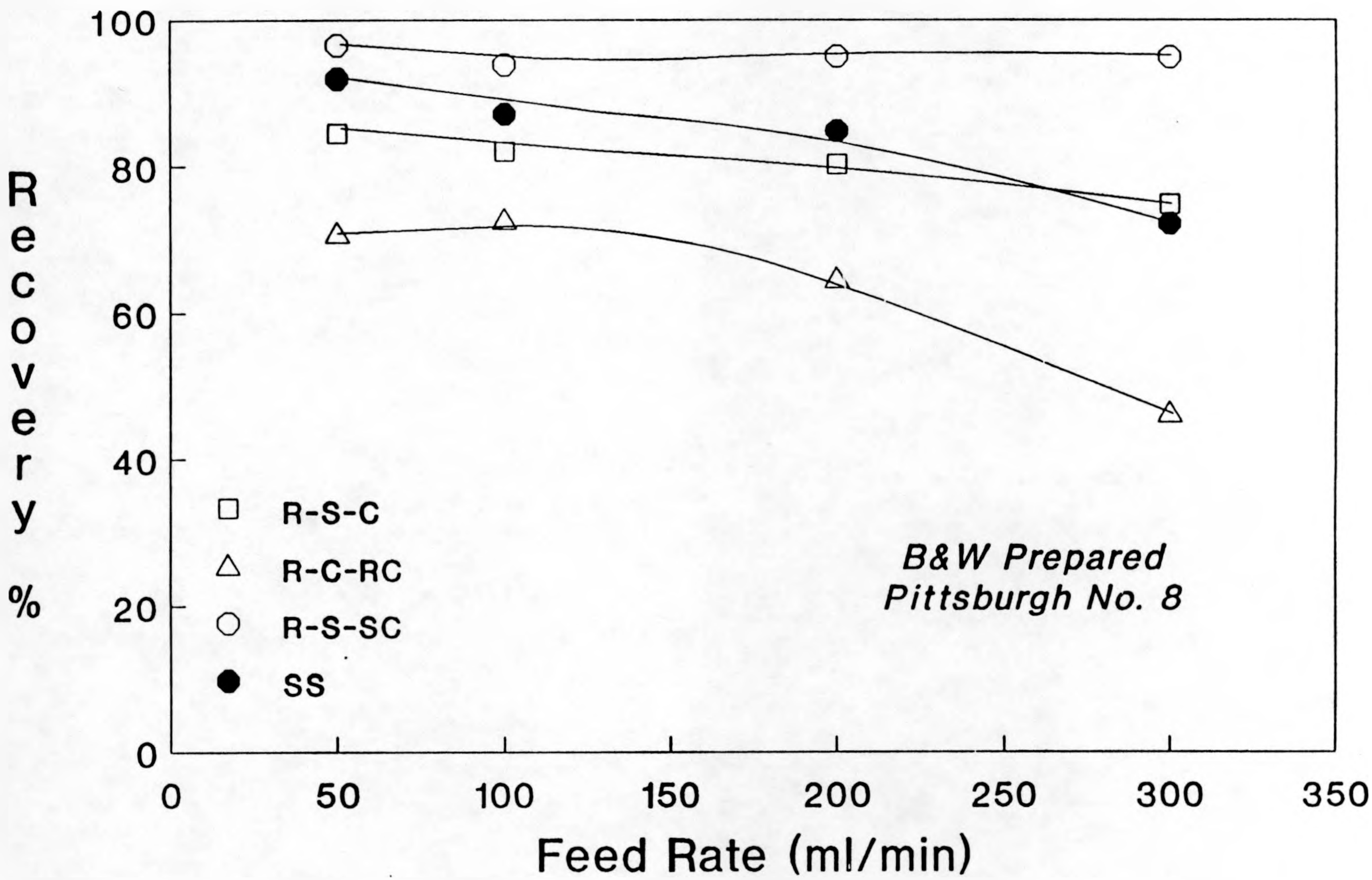


Figure 6.9 The effect of slurry feed rate on the clean coal recovery for various column flotation circuit configurations.

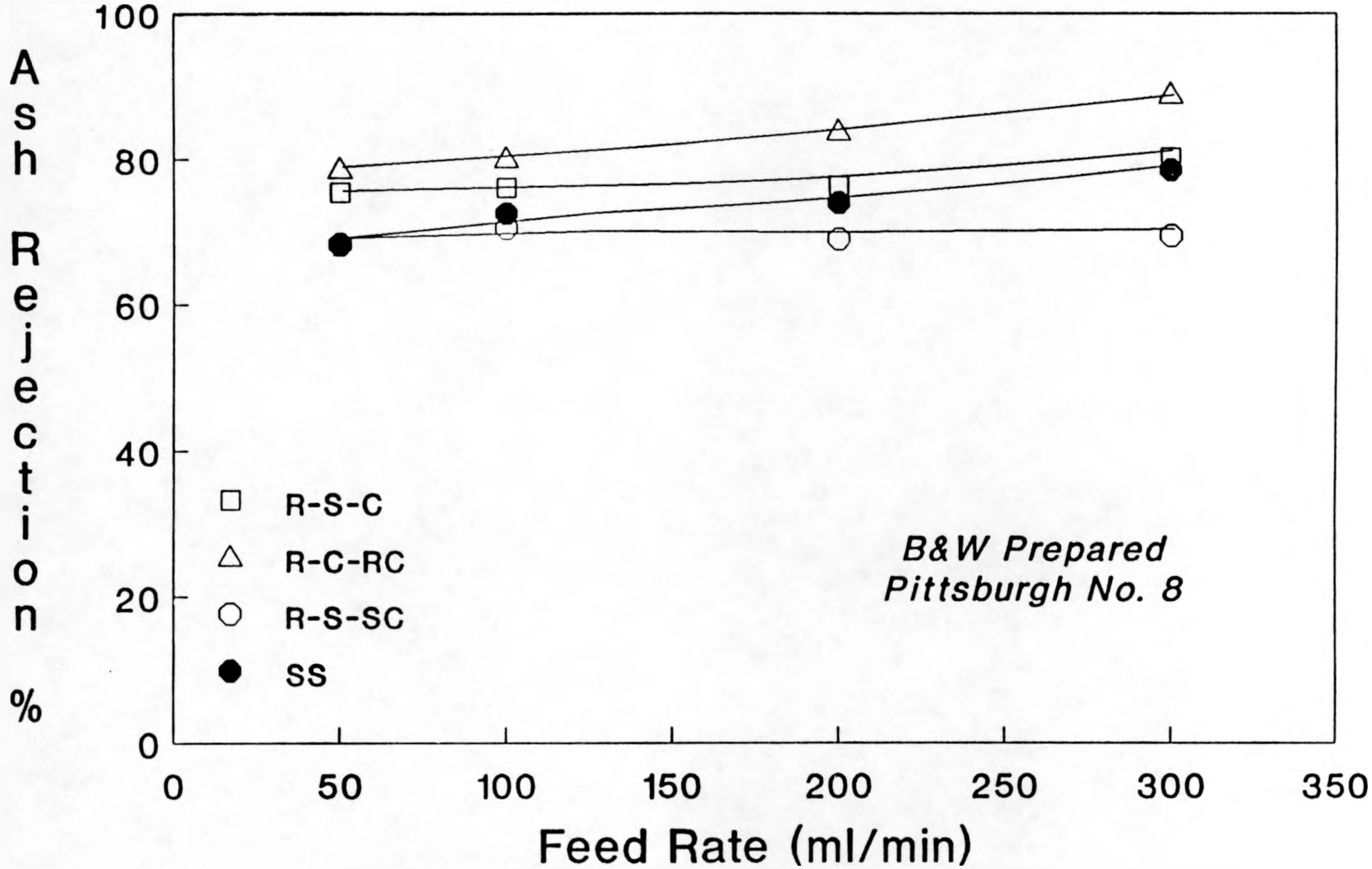


Figure 6.10 The effect of slurry feed rate on the rejection of ash for various column flotation circuit configurations.

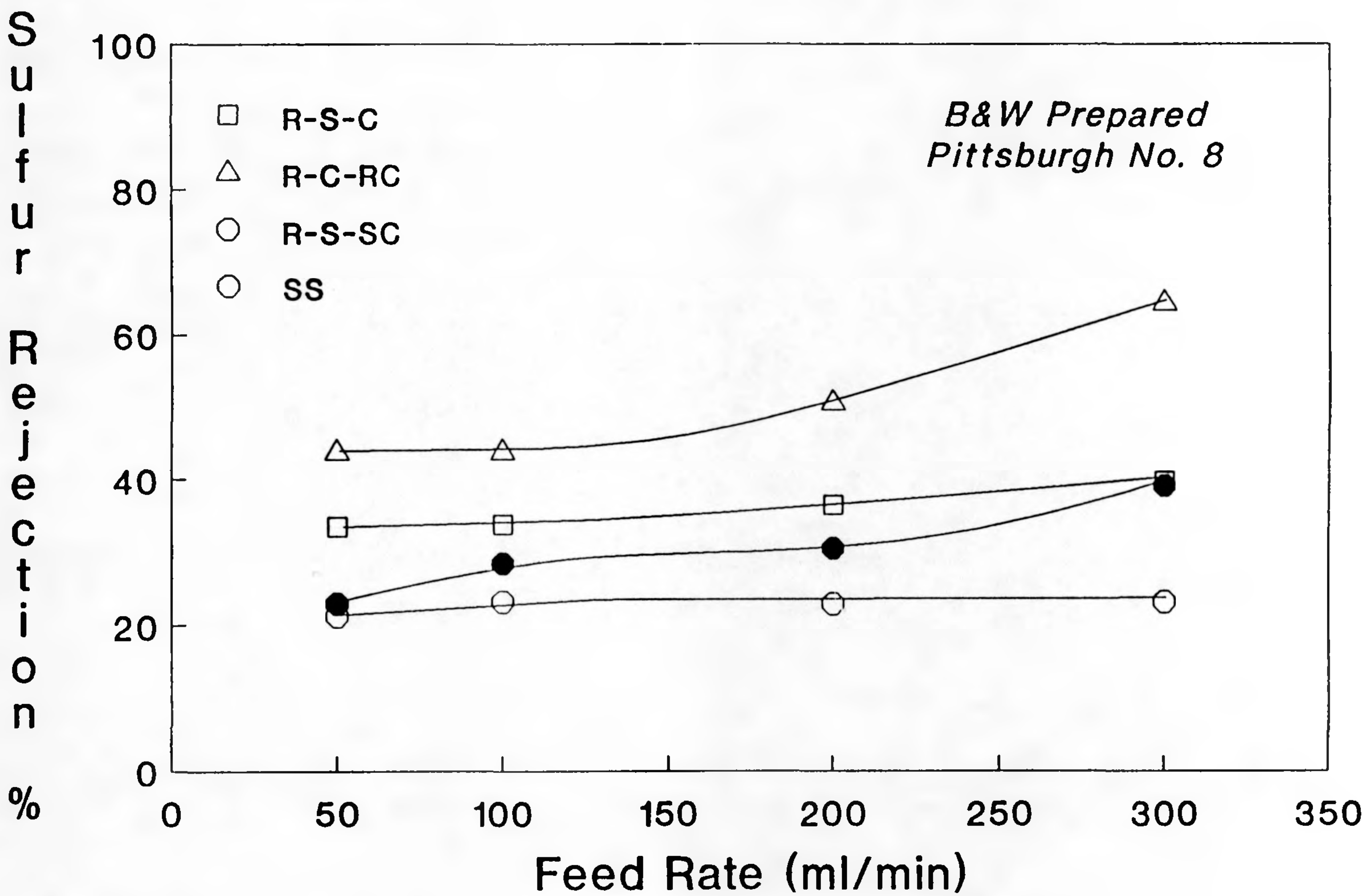


Figure 6.11 The effect of slurry feed rate on the rejection of sulfur for various column flotation circuit configurations.

The recovery-grade relationship was plotted for each of the circuits in order to better compare their performance. As shown in Figure 6.12, essentially the same recovery versus ash rejection results were obtained with each of the circuits. The same trends were observed in the recovery versus sulfur rejection data shown in Figure 6.13. In both cases, the results obtained for the various circuits appear to be in very good agreement with those obtained using the release analysis technique. In general, a clean coal recovery of 90% will produce corresponding rejections of ash and sulfur of approximately 73% and 28%, respectively. The ash and sulfur rejections will increase to 77% and 37%, respectively, if the clean coal recovery is reduced to 80%. The extent of rejection of pyritic sulfur will be made available as soon as the laboratory analyses are completed. The single-stage test results, which are also shown in Figure 6.12, are only slightly inferior to those obtained using the other circuits. This difference in performance is most likely due to a small amount of particle entrapment (or possibly entrainment) which may have taken place in the single-stage tests.

The test results shown in Figure 6.12 and 6.13 demonstrate that differences in the level of performance for the individual column circuits are due to shifts along a single recovery-grade curve. No changes in metallurgical performance, i.e., shifts in the recovery-grade curve itself, were observed for any of the circuits tested to date. This conclusion is further supported by the data shown in Figure 6.14, which demonstrate that ash and sulfur rejection are directly related by a single curve. In conventional flotation circuits, differences in performance are usually due to the nonselective entrainment of fine particles of mineral matter into the froth product. Multiple cleaning stages are generally capable of reducing entrainment and improving the final separation. However, since most flotation columns utilize a countercurrent flow of wash water to prevent entrainment of fines, multiple column circuits may have little advantage for improving performance.

Since any of the column circuits are capable of achieving the same metallurgical performance, other factors should be considered in the selection of an appropriate circuit for coal cleaning. For example, considerations should be given to maximizing throughput capacity and minimizing the overall reagent dosage requirements. Also, the use of multiple column-circuits may be desirable from the point of view that additional columns provide safeguards in the event that one of the columns is not operating properly. For example, if one of the columns in a rougher-cleaner-recleaner circuit has a plugged wash water distributor, the performance of that column will be diminished; however, the other columns in the circuit will continue to guarantee that product quality is met for the overall circuit. Establishing which

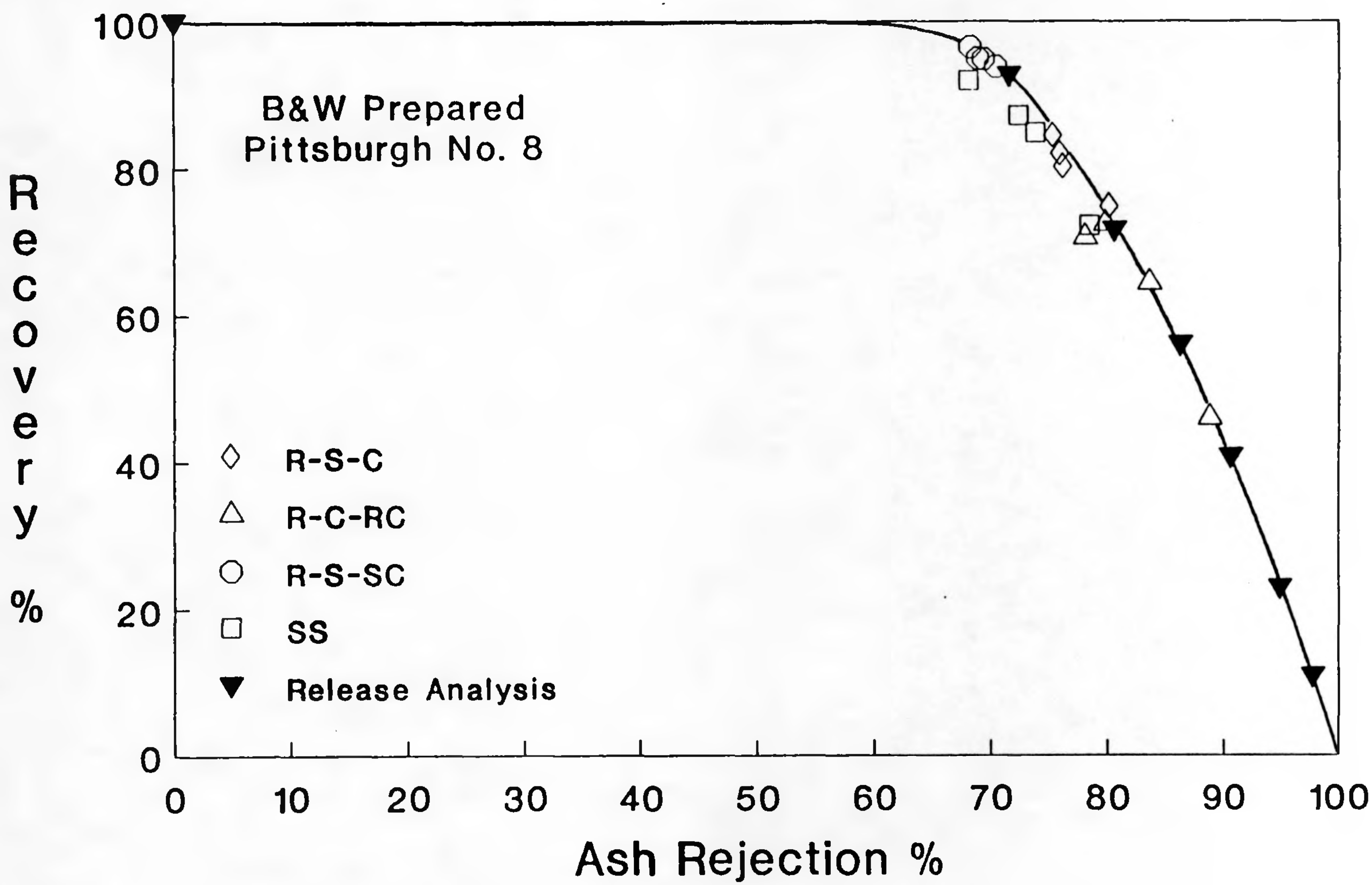


Figure 6.12 Recovery versus ash rejection for the B & W prepared Pittsburgh No. 8 seam for various column flotation circuit configurations.

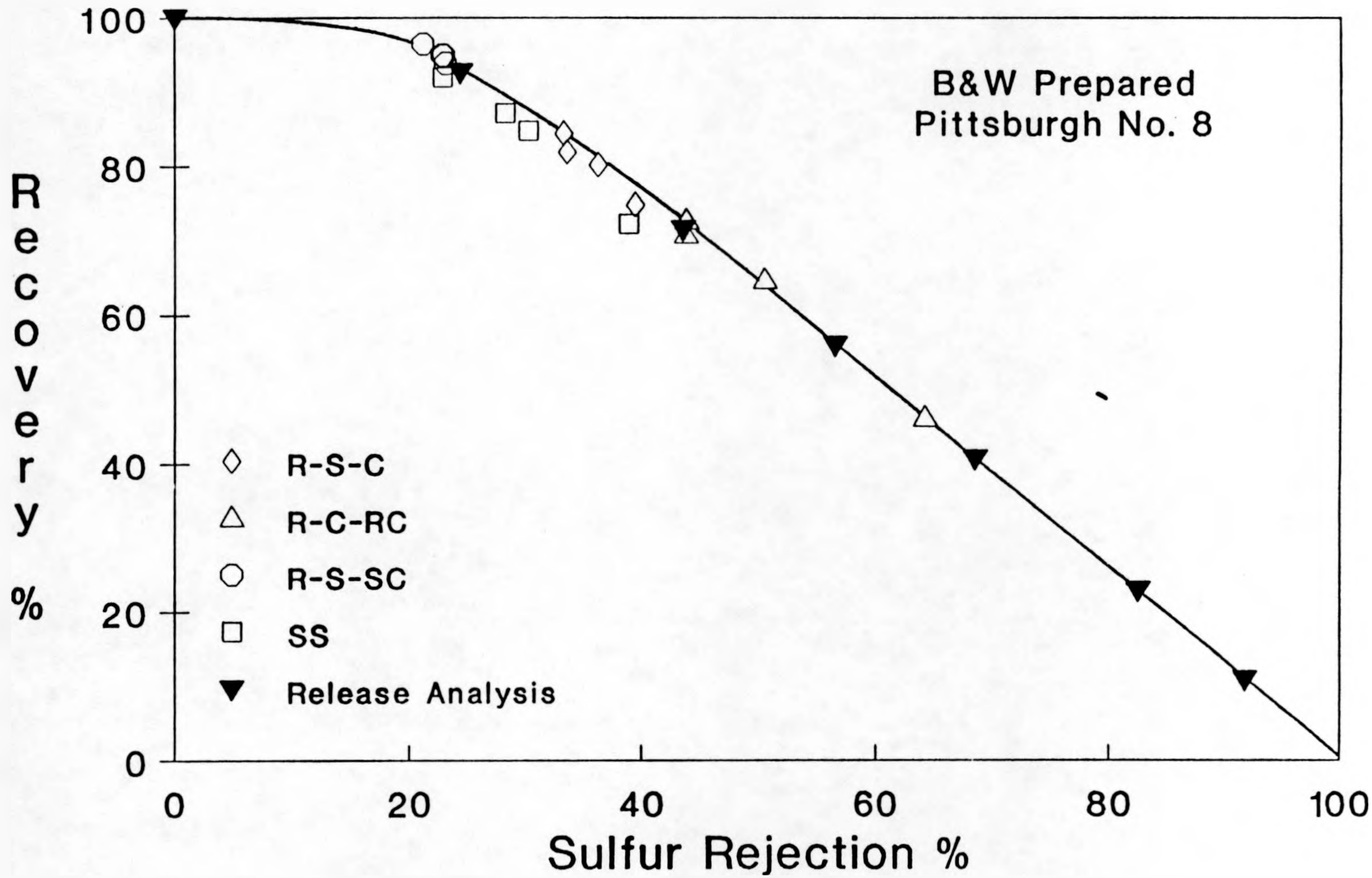


Figure 6.13 Recovery versus sulfur rejection for the B & W prepared Pittsburgh No. 8 seam for various column flotation circuit configurations.

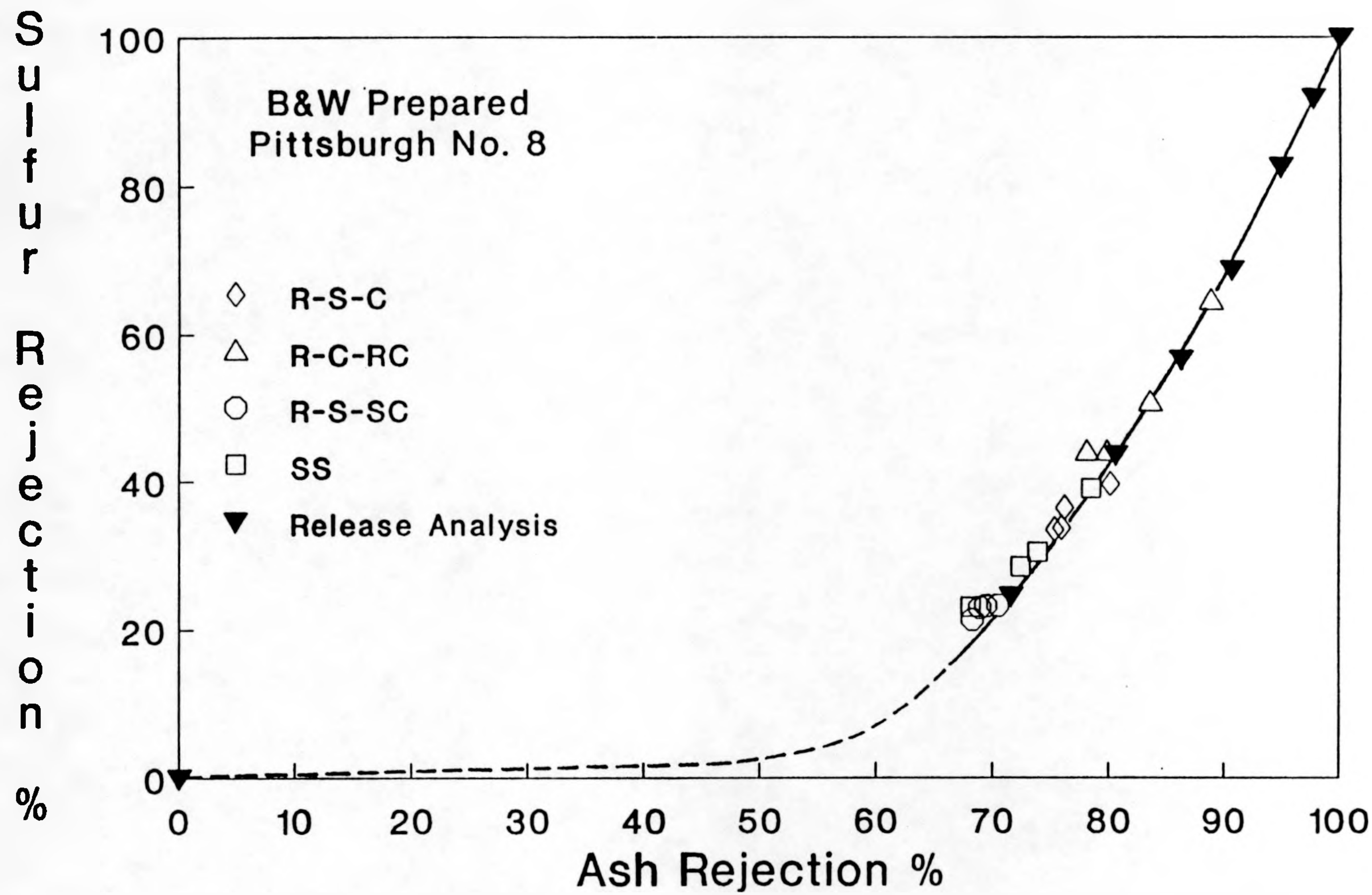


Figure 6.14 Relationship between total ash rejection and total sulfur rejection of the various column flotation circuit configurations.

column arrangements are most capable of producing consistent results with a high throughput capacity and low consumption of reagents will be one of the primary objectives of work conducted throughout the remainder of this subtask.

6.2.3 Column Cell Flotation Model Development

Rate constant data generated from the various circuit tests are being analyzed. These data are being used to conduct circuit simulations which are being compared to the actual test results obtained with the various circuits.

A key parameter that appears to impact the performance of the columns is the gas carrying capacity. Experiments are presently being conducted in an attempt to better quantify this parameter for use in the simulation program. Additional programming has also taken place during the past quarter to make the simulator more user-friendly. A number of circuit simulations have been conducted for the Pittsburgh No. 8 seam coal prepared by B & W. The results of these simulations are presently being analyzed and the results should be available in time for the next quarterly report.

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