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**Survey and Conceptual Flow Sheets
for Coal Conversion Plant
Handling-Preparation and
Ash/Slag Removal Operations**

F. C. Zapp
O. W. Thomas
M. D. Silverman
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Engineering Technology Division

SURVEY AND CONCEPTUAL FLOW SHEETS FOR COAL
CONVERSION PLANT HANDLING-PREPARATION
AND ASH/SLAG REMOVAL OPERATIONS

F. C. Zapp M. D. Silverman
O. W. Thomas D. A. Dyslin
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Date Published: March 1980

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FOREWORD AND ACKNOWLEDGMENTS

This report focuses on the preparation of conceptual flow sheets, including major equipment lists, and a survey of equipment availability for future coal conversion plant handling and preparation and ash/slag removal operations.

The project was initiated and work performed under the auspices of the Fossil Fuel Processing Division of the Department of Energy and under the guidance of James L. Powell and T. K. Lau.

The authors thank the many equipment industry personnel who gave their time and effort to reply to our equipment survey questionnaires and phone requests and those who met with us to discuss equipment availability and problems. Without their cooperation, this report would not have been possible.

We also express our appreciation to those people of the Coal Technology Department of Bechtel National, Inc., for their cooperation and contributions to this report. Our thanks go also to the many people in the Union Carbide Corporation Nuclear Division who have provided assistance in the typing and editing of this document.

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J. M. Holmes

ABSTRACT

This study was undertaken at the request of the Fossil Fuel Processing Division of the Department of Energy. The report includes a compilation of conceptual flow sheets, including major equipment lists, and the results of an availability survey of potential suppliers of equipment associated with the coal and ash/slag operations that will be required by future large coal conversion plant complexes. Conversion plant flow sheet operations and related equipment requirements were based on two representative bituminous coals — Pittsburgh and Kentucky No. 9 — and on nine coal conversion processes.

It appears that almost all coal handling and preparation and ash/slag removal equipment covered by this survey, with the exception of some coal comminution equipment, either is on hand or can readily be fabricated to meet coal conversion plant capacity requirements of up to 50,000 short tons per day.

Equipment capable of handling even larger capacities can be developed. This approach appears to be unjustified, however, because in many cases a reasonable or optimum number of trains of equipment must be considered when designing a conversion plant complex. The actual number of trains of equipment selected will be influenced by the total required capacity of the complex, the minimum on-line capacity that can be tolerated in case of equipment failure, reliability of specific equipment types, and the number of reactors and related feed injection stations needed for the specific conversion process.

1. INTRODUCTION

The purpose of this project was to conduct a survey to determine the types and availability of industrial coal handling, coal preparation, and ash/slag removal equipment that will be required for coal conversion plants, both near-term demonstration plants and future commercial plants, especially those utilizing coal liquefaction systems. The survey also identifies research and development needs and lead-time requirements for

producing equipment of advanced design for the various unit operations of interest to the Fossil Fuel Processing Division of the Department of Energy (DOE).

The project work was divided into six major tasks:

1. Identify and review coal conversion processes to be used in demonstration plants and future commercial development, and prepare conceptual flow sheets of typical coal handling and preparation systems for future conversion plant complexes.
2. Contact DOE contractors, large-scale coal handlers, and equipment manufacturers to determine the conceptual design requirements of coal handling, preparation, and ash/slag removal systems for demonstration and commercial-scale coal conversion plants, and determine the availability of matched components for all process operations in each system.
3. Analyze the information acquired in Task 2 and prepare equipment specifications for use in industrial survey questionnaires.
4. Prepare survey questionnaires covering various equipment categories, and forward them to industrial firms and equipment vendors.
5. Review and analyze results of the industrial equipment survey, and identify equipment systems and equipment development areas.
6. Prepare and publish a report covering the equipment survey.

The conceptual flow sheet designs and equipment selected were based on nine coal conversion processes and the following set of ground rules:

1. No transportation (train car, truck, or barge) or associated loading and unloading equipment will be included in the survey.
2. The initial starting point for the survey will be a run-of-mine (ROM) coal storage pile; transport to rotary-breaker-type equipment will be assumed as the first operation in coal handling and preparation.
3. Heavy-media washing and separation equipment will not be considered in this survey. (A future follow-up study may include these types of equipment.)
4. Handling and preparation of coal conversion plant complex waste materials also will consider equipment to cool the waste to ambient temperatures and recover heat for other uses within the plant. Transportation

of waste materials will be limited to the plant boundaries and to storage ponds, etc., only within reasonable distances (i.e., a pipeline and pumps for slurry waste disposal).

5. Sampling equipment will be included.

6. Development of flow sheets for coal handling and preparation system designs will be based on (1) two representative ROM coals — bituminous coals of the Pittsburgh and Kentucky types and (2) final coal product size requirements — coarse (all particles greater than 1/4 in.), fine (top size less than 1/4 in. but larger than 20 mesh), and pulverized or ground (40% or greater — 200 mesh) grades — that are to be utilized as feedstock for introduction into the conversion plant feeder system. This coal will be sent to coal-receiving vessels or coal slurry preparation vessels that will be considered to be the final preparation phase of this study. Additional operations and equipment required to prepare the feed material for specific conversion plant feeders are included.

7. A total of 50,000 short tons of coal with 8 wt % moisture per day will be assumed to be the final product used as feed material to the conversion plant and for the generation of steam and electric power for the overall plant complex. Operation will be based on 330 days per year, and the final coal product will be dried when required to a moisture content of 2% or less. Raw coal and ROM requirements for a specific type of coal will be based on the 50,000 short tons per day (stpd) requirement.

This report includes (1) conceptual flow sheets and major equipment lists of coal handling and preparation and ash/slag removal operations for commercial-scale coal conversion plants, and (2) the results of a survey to determine the availability of equipment required for future coal conversion plants. The flow sheets and equipment lists were prepared under a subcontract with Bechtel National, Inc., and are presented in Bechtel Report Job 13022, a basic reference for the present report.¹

Much of the Bechtel material is summarized in this report. For greater detail and additional flow sheet information, the reader is referred to Report Job 13022 and to Bechtel report FE-2370-16 (Vols. 1 and 2).^{1,2}

A number of figures, tables, lists, and flow sheets that appear in the Bechtel report also are included in Appendixes C and D of this report.

The same table, figure, and flow sheet numbers that appear in the Bechtel reports are retained and referred to in this report to facilitate cross reference to the Bechtel documents.

Section 4 presents the bases for conceptual flow sheet development for the two coals and nine conversion processes. Operational descriptions of 2 overall block flow diagrams and 16 flow sheets appear in Sect. 5. The responses to the survey questionnaires appear in Sect. 6, and general conclusions for specific equipment areas are presented in Sect. 7.

References

1. *Conceptual Flow Sheets Development for Coal Conversion Plant Coal Handling — Preparation and Ash/Slag Removal Operations*, Report Job 13022, prepared by Bechtel Corp. for Union Carbide Corp., San Francisco, Calif., July 1979.
2. *Coal Mine-Coal Conversion Plant Interface Evaluation and Conceptual Design*, Vols. 1 and 2, FE-2370-16, prepared by Bechtel Corp. for the Department of Energy, Washington, D.C., November 1977.

2. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

2.1 Summary

This report covers the preparation of conceptual flow sheets, including major equipment lists, and a survey of equipment availability for future coal conversion plant coal handling and preparation and ash/slag removal operations.

Two equipment surveys were conducted — one before the flow sheets were developed and the other after initial flow sheets were completed. The first survey, based on preliminary information, covered pulverizers, thermal dryers, and ash/slag grinders. Questionnaires for all three equipment areas were prepared and sent to all known U.S. manufacturers of this type of equipment. Because of poor response to the initial questionnaires, changes in coal size consist requirements, and additional information gained through flow sheet design studies, a new set of questionnaires was prepared. Equipment areas for this survey were selected from the reference flow sheets developed under subcontract by Bechtel National, Inc. Specifically, the survey included cage mills, rod mills, ball mills, ball tube mills, bowl pulverizers, fluidized-bed driers, screens, and air separators. Because of time restrictions, the survey was conducted by extensive phone conversations and letter follow-up.

The bases and approach used in flow sheet development are presented for coal preparation operations including breaking, coarse-coal cleaning, coarse-coal crushing, fine-coal cleaning, live-storage-blending, dead storage, fine crushing, and grinding. A total of 50,000 stpd having a nominal total moisture content of 8.0 wt % was assumed to be used as feed material to the coal conversion plant complex, including its atmospheric pressure fluidized-bed power/steam plant. Eighty-five percent of the coal is utilized in the reactors for the conversion process, and 15% is fed to the power/steam plant.

Two major bituminous coal seams were specified as possible conversion plant sources: Pittsburgh seam coal as represented by coal from Monongalia County, West Virginia, and Kentucky No. 9 seam coal as represented by coal from Hopkins County, Kentucky.

Selection of the nine coal conversion processes was based on currently funded DOE process development projects. The nine are U-GAS, COGAS, HYGAS, Texaco Partial Oxidation, Exxon Donor Solvent (EDS), Exxon Catalytic Gasification, SRC-I, SRC-II, and H-Coal.

Coal from either seam was postulated to be provided from a coal mine complex adjacent to the conversion plant site or from regional coal mines at appreciable distances from the plant site. For both coal sources, the conceptual flow sheets start at the conversion plant site after coal receiving. The coal operations flow sheets terminate at conversion reactor coal feed systems.

Coal produced from an adjacent coal mine can be cleaned and then conveyed to live- or dead-storage facilities. If it is not cleaned, it is conveyed to live or dead storage after reduction to 2 in. $\times$ 0. Coal transported from regional mines is sized to 2 in. $\times$ 0 and, if the operation is justified, cleaned before transport in rail cars and/or river barges.

In cleaning, the 12 in. $\times$ 0 coal is broken to a 6 in. $\times$ 0 size and wet screened at 3/8 in. Six inch $\times$ 3/8 in. coal is cleaned in coarse-coal jigs, screen dewatered, and crushed to a 2-in. top size before it is conveyed to live or dead storage. Undersize coal and crushed coarse-coal jig middlings can be cleaned by any one of three flow sheet processes: jig, hydrocyclone, or table fine-coal cleaning. After cleaning, fine coal is dewatered with vibrating centrifuges, mixed with crushed coarse coal, and conveyed to live or dead storage. Effluents from both coarse- and fine-coal dewatering are treated to separate -28 mesh solids and recycle water.

Two methods are identified for live-storage-blending following coal cleaning or unloading of coal from regional mines: multiple open, wedge-shaped stockpiles and totally enclosed V-bunkers. Specified design capacity for both methods is 500,000 tons. With this live-storage capacity, normal fluctuations between mining or long-distance transport operations and conversion reactor operations can be accommodated without use of dead-storage facilities. Dead coal storage, for use in emergency situations, is provided by open, sealed coal piles built and reclaimed by mobile equipment.

With the exception of H-Coal, the conversion processes in Table 2.1 require what is defined as fine-coal conversion reactor feed, that is, top size between 20 mesh and 1/4 in. Because of the number of processes requiring this coal size and because of the different size ranges, nine conceptual coal fine-crushing flow sheets and major equipment lists are presented. With two exceptions, these flow sheets use multirow cage mill crushers. The flow sheets provide for

1. single-stage, open-circuit cage mill fine crushing — SRC-I and SRC-II, EDS, Exxon Catalytic Gasification, U-GAS, and COGAS;
2. two-stage, open-circuit cage mill fine crushing — HYGAS and Texaco Partial Oxidation;
3. single-stage, closed-circuit cage mill fine crushing — all fine-coal feed processes except U-GAS and COGAS;
4. single-stage cage mill fine crushing with prescreening — U-GAS;
5. single-stage, open-circuit rod mill grinding — Texaco Partial Oxidation.

Table 2.1 Conversion processes and corresponding coal feed requirements

Process number	Conversion process and type	Conversion reactor feed requirements	
		Coal size consist	Moisture
1	U-GAS — fluidized-bed gasification	100% —1/4 in.	As received
2	COGAS — fluidized-bed gasification	100% —1/8 in.	As received
3	HYGAS — fluidized-bed gasification	100% —14 mesh	As received
4	Texaco Partial Oxidation — entrained flow gasification	100% —20 mesh	As received
5	Exxon Donor Solvent — liquefaction	100% —8 mesh	As received
6	Exxon Catalytic Gasification — fluidized-bed gasification	100% —8 mesh	As received
7, 8	SRC-I and SRC-II — liquefaction	100% —12 mesh	As received
9	H-Coal	70% —200 mesh	2.0 wt %

Some developers of conversion processes that consume fine coal indicate that ultrafines minimization is important for their conversion reactors. However, none has yet defined ultrafines size limitations. In anticipation of possible requirements to remove ultrafines, an ultrafines separation flow sheet is presented. This flow sheet uses centrifugal type air classifiers to remove -100 mesh coal. To ensure efficient separation, hot flue gas can be used in the classifiers for coal drying. One flow sheet is presented for the H-Coal Process. This flow sheet uses single-stage, open-circuit wet ball mills to produce 70% -200 mesh coal. This grinding approach in which the grinding fluid is liquefaction solvent requires further development.

Except for SRC-I, the liquefaction processes involve gasification of liquefaction residual solids. As a result, all conversion processes produce gasification ash or slag. This ash or slag may be discharged as dry solids or as a water slurry, depending on gasifier design. Solid wastes also are produced by the fluidized-bed steam generators specified for the conversion plant power/steam plant and by coal cleaning. Because of limestone injection for control of sulfur oxides, solid wastes from the power/steam plant contain calcium sulfate and calcium oxide in addition to coal ash. Quantities of all three types of solid wastes established for conversion of 50,000 tons of clean coal per day are as follows:

1. granulated slag for conversion processes using slagging gasifiers:
3912 tons per day, or ash for conversion processes using nonslagging gasifiers: 5472 tons per day;
2. power/steam plant solid wastes: 984 tons per day;
3. coal-cleaning refuse: 24,000 tons per day.

Two conceptual flow sheets for ash/slag removal are presented for the handling of the three conversion plant solid waste streams. One is for transport of combined solid wastes as a dry material. Methods considered for transport of dry solid wastes are overland conveyors, rail cars, and trucks. The second ash/slag removal flow sheet is for water slurry transport and recycle of water from the solid wastes disposal site. Nominal distance for transport of ash/slag from conversion plant site to an environmentally acceptable disposal site is 5 miles for both flow sheets.

2.2 Conclusions and Recommendations

Conclusions presented in this section apply to the nine specified coal conversion processes and to typical Pittsburgh and Kentucky No. 9 seam coals. Major conclusions resulting from conceptual flow sheets of coal handling and preparation and ash/slag removal and major equipment lists development are as follows:

1. In general, equipment that meets the projected requirements for coal handling and preparation and ash/slag removal by future commercial coal conversion plants is currently available. Present capacity limits of some commercially used equipment can probably be increased by a scale-up of existing equipment.

2. Improved coal handling and preparation and ash/slag removal equipment is anticipated for future conversion plants because of development of new construction materials, higher equipment reliability requirements, and improved fabrication methods.

3. Because of the large investment that will be required for coal conversion plants, substantial investment in high-reliability coal handling and preparation facilities would be fully justified.

4. Research into the best design approaches for achieving high plant operating reliability in large-capacity coal handling and preparation facilities could result in improved coal conversion economics. In this regard, evaluation of the performance of existing large-capacity materials handling and preparation operations, such as power plant coal operations, could provide useful information.

5. In addition to the best approach(es) to achieving high plant operating reliability, areas where development and demonstration are required include the following:

- a. scale-up of coal pulverizers,
- b. solvent-coal slurry grinding,
- c. scale-up of gravimetric feeders,
- d. coal collection and baghouse explosion prevention system,
- e. pulverized and ultrafine coal transport equipment,
- f. pressurized ash and slag crushers.

6. Based on estimated Pittsburgh and Kentucky No. 9 seam washability data, use of heavy-medium coal cleaning would result in only marginally cleaner coal and/or higher coal recovery than that resulting from the coal-cleaning operations as presented in the conceptual flow sheets.¹ However, both coal seams cover a wide geographic area, and, in some locations, heavy-medium coal cleaning could be more desirable than other coal-cleaning methods. (Consideration of heavy-medium coal cleaning was excluded from the project scope.)

7. For some coal handling and preparation operations, economic trade-off studies are required. These studies determine if certain operations are justifiable for specific coal conversion plants and establish justified performance requirements. Coal handling and preparation operations where trade-offs might be judged beneficial are cleaning, blending, and, for some conversion processes, conversion reactor coal feed size consist requirements.

8. Development of data to improve the predictability of the performance of fine-crushing equipment would be useful in engineering demonstration and commercial coal conversion plants. (Eight of the nine coal conversion processes require fine-coal feed.) Therefore, the need for a coal fine-crushing program should be evaluated. Cage mills appear to be very dependable and versatile machines for a variety of coal comminution operations. It is suggested that a feasibility study be undertaken by DOE to help advance the state of the art, provide statistical data, and eventually establish a sound theoretical basis for design and operation of cage mills. This cooperative research program would be analogous and related to the program now in effect at Kennedy Van Saun Corporation (KVS), which is an investigation of the mass-size balance over time approach to coal comminution. The feasibility of using such equipment for producing large quantities of coal of size consist compatible with Texaco Partial Oxidation and H-Coal conversion processes should be investigated.

9. Development of new or improved large capacity fine-particulate classification equipment could solve the problem of removal of ultrafines (defined in this report as -100 mesh coal) from fine coal before conversion, when such removal is required or economically justified.

10. If coal ultrafines removal is used, development of new or improved methods for ultrafines handling and utilization could be required. Possible uses for the ultrafines include the following:

- a. direct firing in pulverized-coal-fired steam generators,
- b. possible firing in fluidized-bed steam generators by injection of ultrafines into the bottom of the fluidized bed,
- c. agglomeration followed by combustion in a fluidized-bed steam generator or feeding to a conversion reactor.

Except for item a, development work would be required to establish the process.

11. The most economical method for obtaining the large quantities of hot gas required for simultaneous coal drying and pulverizing, or for coal fluidized-bed drying, is from a power plant steam/gas generator. This approach has two advantages over direct coal firing: it is more efficient and, at least in the case of fluidized-bed steam/gas generators, the need for flue gas desulfurization following coal pulverizing or drying is eliminated.

12. Data on the properties of ash/slag from conversion reactors are limited. Additional data would be useful in the engineering of demonstration and commercial coal conversion plants.

13. Apparently, coal feed requirements for coal conversion processes should be based on the largest coal size consistent and highest allowable moisture, ash, and sulfur content compatible with the overall process. This approach will minimize the number of units and types of equipment required and will result in lower overall costs. Fine, dry pulverizing of coal presents one of the most costly alternatives — system capital costs in the two-hundred-million-dollar range.

14. Rod mills can be used as an alternative method for producing a 20 mesh $\times$ 0 feed material for the Texaco Partial Oxidation process. This wet-pulverizing operation would aid in slurring, since the feed would be mixed with water during pulverizing. It is suggested that a feasibility study of this method be undertaken and, if positive, that a program for further study and development be initiated.

15. Ball mills using recycle liquefaction products could be used as an alternative method to produce 70% -200 mesh feed material for the H-coal process. This would eliminate the need for de-entrainment equipment such as cyclones and baghouses. Very little work has been done in the area of solvent pulverizing of coal. We suggest that the R&D work in this area being done at KVS be expanded.

16. Ball tube mills or bowl pulverizers could be used as alternative means to produce 70% -200 mesh feed material for the H-Coal process. This would be a simultaneous drying-pulverizing operation, using flue gas from the steam/power plant as the drying medium. De-entrainment equipment such as cyclones and baghouses must be used if the slurring-feeding facility is not designed to accept the product directly from the pulverizing facility. Dry coal pulverizing is done currently in mills having capacities up to 100 tons/hr. Cement is now pulverized in mills which could pulverize about 300 tons of coal per hour. However, because of differences in grinding characteristics between cement and coal and because of the explosive nature of pulverized coal, scale-up of smaller mills or adaptation of large cement mills may require development work.

17. Thermal dryers that can dry Pittsburgh seam and Kentucky No. 9 coals down to 2% total moisture are available. The fluidized-bed dryers have the largest capacities. Thermal dryers will be required (1) if it is necessary to remove the -100 mesh $\times$ 0 size fraction from the feed material or (2) if it is necessary to remove the moisture from the feed material before solvent slurring, instead of during the first step of the process.

18. Screens can be used to separate the 1/4 in. $\times$ 0 size fraction from the 2 in. $\times$ 0 feed material to the cage mills. The cage mills will produce 1/4 in. $\times$ 0 feed for the U-GAS process. The total moisture content of the 2 in. $\times$ 0 materials must be less than 5%.

19. Air classifiers can be used to remove the 100 mesh $\times$ 0 size fraction from the process feed, if such removal is required.

20. Mass-flow conveyors have been used successfully to transport small quantities of hazardous solids but not large quantities of ultrafine coal. Development work would be required before mass-flow conveyors could be used for large quantities of coal, especially if ultrafine coal requires a large increase in elevation during the transfer.

Other transport alternatives that could be considered for coal ultra-fines include the following:

- a. dilute-phase transport in inert gas,
- b. dense-phase transport in inert gas,
- c. screw conveyors,
- d. water or other fluid slurry transport that is compatible with ultrafines utilization.

21. Ash/slag letdown systems and removal operations require numerous types of equipment, most of which industry either can supply readily or has the capability of supplying within a reasonable time frame. This category includes roll crushers, lockhoppers, dewatering filters, slag conveyors, water pumps, pug mills, and assorted mixing and settling tanks.

22. There is a need for better ash/slurry pumps and pressure letdown valves which can provide long-term service in coal conversion operations (problem areas addressed in the reports cited in the text). Moreover, slag grinding in pressurized systems should be demonstrated under coal conversion process conditions.

23. Close monitoring of the ash composition for most coals will be required for use in slagging gasifiers. Adequate control of the ash composition and ash levels may have to be maintained by adequate coal washing and preparation operations.

24. Fabrication of high-reliability equipment may not be economically feasible. Labor-intensive societies tend to design and build equipment economically, but the amount of maintenance necessary to achieve a certain degree of reliability is high. On the other hand, equipment designed to operate longer under minimum maintenance conditions tends to be more expensive. Such socioeconomic trade-offs must be investigated for specific equipment and operations.

25. If similar equipment surveys are conducted in the future, financial reimbursement should be considered for industry participants as compensation for investing time and supplying data.

26. Considering the time it will take to develop the equipment required for the conversion process itself, ample lead time will be available to fabricate and test equipment required in the coal handling and preparation and ash/slag removal operations investigated in this survey.

27. Coal preparation is still an art and depends, to a great extent, on empirical data and past experience. Overall design of coal preparation systems and of specific operations and equipment requirements must be tailored to the particular coal or coals to be used, the conversion process utilized, total system capacity, and plant mine locations.

Reference

1. *Conceptual Flow Sheets Development for Coal Conversion Plant Coal Handling - Preparation and Ash/Slag Removal Operations*, Report Job 13022, prepared by Bechtel National Corp. for Union Carbide Corp., San Francisco, Calif., July 1979.

3. BACKGROUND

The programs for advanced coal conversion processes outlined by the Department of Energy Fossil Fuel Processing Division will require maximum utilization of reliable and economical commercial-scale facilities and equipment. It is, therefore, necessary to determine the types of equipment required and the capability of manufacturers to supply such equipment.

Equipment systems of matched components for coal handling, coal preparation, or ash/slag removal have not been investigated adequately in support of demonstration of commercial coal conversion plants. Now, as coal conversion projects approach the design phase, information on equipment capacities and performance characteristics is seen to be inadequate. Data on scaling-up procedures for existing components and necessary modifications for their integration into a coal handling and preparation complex — to meet the front-end requirements of large coal conversion plants — have not been reported.

Coal preparation and handling systems for the near term should process coal at rates ranging from 2000 to 8000 tons per day. Ultimately, the feed rates for commercial coal conversion plants using several trains may run as high as 50,000 tons per day — the upper limit of coal-handling requirements for this study. Clearly, the reliability and continuity of plant operations can be no better than the materials-handling components that comprise the front end of the total plant complex. Consideration was also given to the disposal of wastes from the complex — the equipment involved in removal of ash, slag, etc.

The capability to bring commercial-scale coal conversion plants into production depends in part on the availability of equipment and the time required to construct the facilities. Inquiries during FY-1977-1978 revealed that several types and sizes of equipment for proposed coal conversion facilities were not readily available and that, in many of these cases, substantial development is required. The schedule and cost requirements for development of these items of equipment need to be determined and provided for so that such equipment will be available as needed to bring coal conversion facilities on line in a timely manner.

During FY-1977-1978, six industrial surveys were conducted as part of an ongoing DOE program to determine the equipment requirements of several conceptual coal conversion plant processes. The six survey report numbers and equipment areas are

ORNL/TM-6071:	valves,
ORNL/TM-6072:	high-temperature, high-pressure gas purification,
ORNL/TM-6073:	heat recovery and utilization,
ORNL/TM-6074:	rotating components,
ORNL/TM-6585:	letdown valves,
ORNL/TM-6586:	mechanical piping connectors and expansion joints.

An additional report related to the above surveys is ORNL/TM-6587, *Equipment Operating Experience, Prices, and Development Programs*.

3.1 Survey Methodology

Initially, survey methodology was based, in part, on fulfillment of a subcontract by an independent engineering firm to prepare a set of flow sheets and equipment requirements for all coal handling and preparation and ash/slag removal operations for several types of large coal conversion plant complexes. Information derived from the subcontract was to be used as a basis for a literature survey, as were contacts with industrial, research, and consulting engineers.

Because of unavoidable delays, the subcontract was not awarded before the time scheduled for the equipment survey to begin. Based on the best available information, three areas of equipment were identified for investigation in the survey - pulverizers, thermal dryers, and ash/slag grinders. Questionnaires for all three equipment types were prepared and sent to all known U.S. manufacturers of this equipment.

A tentative assumption was made that most of the other types of equipment required for large-scale conversion plant complexes will be readily available or can easily be scaled up and upgraded for use when required. (Such assumptions were not made about equipment such as certain valves, rotating components, etc., which were the subjects of separate surveys.) The questionnaires were to be a preliminary contact to obtain information in these equipment areas. Additional information related to

these equipment types, as well as the bases of assumptions concerning the availability of other equipment, was to be obtained and verified based on information derived from the subcontract* study. These data were to be used to develop conceptual, realistic flow sheets for both coal handling and preparation and ash/slag removal operations that would

1. match the coal feed requirements (size consist and moisture) and ash/slag characteristics of conversion reactors used in the major conversion processes being considered by DOE for development, with emphasis on coal liquefaction processes;
2. identify all equipment performance requirements;
3. demonstrate how individual types of equipment are integrated to form complete, matched, efficient, reliable materials handling and preparation operations;
4. allow identification of areas in which equipment deficiencies exist or in which improved or new equipment would be useful;
5. be used to prepare equipment lists;
6. identify operating conditions;
7. provide power requirements.

Because of poor response to the initial survey, changes in conversion processes coal size consist requirements, and additional information resulting from the subcontract study, a decision was made to prepare a new set of questionnaires, for a second survey, based on equipment areas selected from the reference flow sheets developed by Bechtel National, Inc.

3.2 Coal Conversion Processes

Nine coal conversion processes were selected based on process development projects currently funded by DOE. Table 3.1 lists all processes investigated in this project and their reported conversion reactor coal feed size consist and moisture requirements. All conceptual flow sheets and the equipment selected for various operations were based on the requirements of the nine coal conversion processes.

*Subcontract awarded to Bechtel National, Inc.

Table 3.1 Conversion processes and corresponding coal feed requirements

Process number	Conversion process and type	Conversion reactor feed requirements	
		Coal size consist	Moisture
1	U-GAS — fluidized-bed gasification	100% -1/4 in.	As received
2	COGAS — fluidized-bed gasification	100% -1/8 in.	As received
3	HYGAS fluidized-bed gasification	100% -1/4 mesh	As received
4	Texaco Partial Oxidation — entrained flow gasification	100% -20 mesh	As received
5	Exxon Donor Solvent — liquefaction	100% -8 mesh	As received
6	Exxon Catalytic Gasification — fluidized-bed gasification	100% -8 mesh	As received
7, 8	SRC-I and SRC-II — liquefaction	100% -12 mesh	As received
9	H-Coal	70% -200 mesh	2.0 wt %

4. CONCEPTUAL FLOW SHEET BASES AND DEVELOPMENT

4.1 Introduction

Flow sheets presented in this report represent an extension of a project called the Coal Mine-Coal Conversion Plant Interface Evaluation and Conceptual Design.¹ This project, completed in November 1977, was performed for DOE by Bechtel National. The mine-conversion plant interface that was evaluated consisted of the following:

1. operations required for mining and transport of coal to a coal conversion plant nominally designed to process 50,000 tons of coal per day and hypothetically sited in Appalachia;
2. all coal operations at the conversion plant preceding actual feeding of coal to a conversion reactor, either liquefaction or high- or low-Btu gasification;
3. all operations required to collect, treat, transport, and dispose of solid wastes (including conversion reactor ash/slag) resulting from coal conversion.

Some of the conceptual flow sheets for coal handling and preparation that were developed for the coal mine-coal conversion plant interface project meet some of the flow sheet requirements for this report. These flow sheets have not been reproduced in this report, but are referenced throughout Sect. 5. In addition to flow sheets, the interface project involved development of conceptual plant designs for selected coal operations and estimation of capital costs and annual operating costs.

In developing the flow sheets presented in this report, emphasis was placed on the selected coal liquefaction processes specified in Sect. 3.2. However, because commercial coal liquefaction plants will require gasification operations for hydrogen and/or fuel gas production, coal handling and preparation and ash/slag removal equipment requirements for selected gasification processes also are included in this report.

4.2 Conceptual Flow Sheet Bases

The design bases for conceptual flow sheet development were established by Union Carbide and Bechtel. The bases include properties of

coals, location of mining operations, conversion plant feed coal characteristics, nine coal conversion processes, flow sheet inlet and outlet boundaries, and provision of coal for conversion plant electricity and process steam generation.

Conceptual flow sheets presented in this report consider coal conversion plants that consume 50,000 short tons of coal per day and have a nominal total moisture concentration of 8.0 wt %. For the purpose of calculating coal consumption, an annual conversion plant operation of 330 days per year was specified. Annual conversion plant coal consumption is, therefore, 16.5×10^6 tons. Conversion plant daily operation was specified as 24 hr.

4.2.1 Feed coal characteristics

Two major bituminous coal seams were proposed as possible sources for conversion plants: (1) Pittsburgh seam coal (such as that in Monongalia County, West Virginia) and (2) Kentucky No. 9 seam coal (such as that in Hopkins County, Kentucky). Mining alternatives for coal from either seam were (1) an integrated coal mine complex located adjacent to the coal conversion plant site, (2) a number of separate mines and mine complexes spread over the neighboring counties and located an appreciable distance from the conversion plant site, or (3) both mining alternatives.

The term "integrated coal mine complex" is used to indicate that such a mining operation would be extremely large and probably would consist of several mines connected by a common coal transport system. For the Pittsburgh seam, such a mine complex could consist exclusively of underground mines. For the Kentucky No. 9 seam, a significant portion of the coal, if not all of it, probably could be produced from surface mines.

In the second mining alternative, the distance from a mine to a conversion plant site was postulated to be such that coal would be transported to the conversion plant by rail and/or barge. A remote mine would

1. in general, be smaller than a mine that is part of an integrated mine complex located adjacent to a conversion plant site;

2. in many instances, have a shorter life than the coal conversion plant (spatial distribution of mines relative to the conversion plant site could change with conversion plant life);
3. include both underground and surface mines.

Coal produced by the first mining alternative was specified to have an as-received size consist of 12 in. $\times$ 0 and a nominal total moisture concentration of 7.0 wt %. A coal top size of 12 in. was specified because this size is consistent with design requirements for the types of mine transport systems that would be used in an integrated coal mine complex. It is also the nominal top size of coal typically produced by long-wall shearers and continuous miners.

Coal transported to the conversion plant site in rail cars and/or barges was specified to have an as-delivered size consist of 2 in. $\times$ 0 and a nominal total moisture concentration of 8.0 wt %. The 2 in. $\times$ 0 size is that typically used for rail and barge transport in both West Virginia and Kentucky.

4.2.2 Plant coal and ash/slag boundaries

Two conversion plant site inlet boundaries were established for initiation of coal handling and preparation flow sheets — one for coal from an adjacent integrated coal mine complex and one for coal transported from remote mines to the conversion plant site. The boundary for coarse coal from an integrated mine complex is the discharge point(s) of the mine complex transport receiving facility. The receiving facility provides surge storage between the mine transport system and the conversion plant conveying system. It would include a silo or large bunker. The discharge point(s) of the conveyor(s) used to carry coal from this silo or bunker constitutes the plant's inlet boundary for coarse coal. From this boundary, coal (12 in. $\times$ 0) is fed to a breaking facility.

The coarse-coal conversion plant inlet boundary for coal transported by rail and/or barges to the plant site is the discharge point(s) of rail car and/or barge unloading facilities. (Development of flow sheets for any rail and barge unloading facilities was excluded from the project reported here.) From this boundary, coarse coal (2 in. $\times$ 0) normally

would be conveyed to live or dead storage. In the event, however, that oversize or frozen coal is received, it would be conveyed to a crushing facility and then to storage.

Table 4-1* identifies three basic methods for feeding coal to a pressurized coal conversion reactor or pretreater: lockhopper system, gas injection, and slurry injection. Outlet coal boundaries (the points at which the coal handling and preparation conceptual flow sheets terminate) established for each of these basic methods are as follows:

1. Lockhopper coal feed systems — the coal inlet of the vessel(s) used to provide crushed coal surge storage for the lockhoppers. (Any particulate or other emission control systems associated with the lockhopper receiving vessels are not considered part of coal handling and preparation.)
2. Gas injection coal feed systems (COGAS process only) — the coal inlet of the vessel(s) used to feed the first stage, fluidized-bed pyrolyzer(s).
3. Slurry injection coal feed systems — the coal inlet of the slurry preparation vessel(s) used for slurrying coal in recycle solvent or water. (Off-gas treatment and agitation systems for slurry preparation vessels are not considered part of coal handling and preparation.)

Pretreatment to control agglomeration is believed to be required for HYGAS. As a result, the coal outlet boundary for this process was specified to be the pretreatment coal feed system, not the gasifier coal feed system. When pretreatment is used with HYGAS, the resulting pretreatment char is slurried in a process-derived oil and injected into the gasifier.

Except for the EDS process, ash, char, or slag produced by the gasifiers identified in Table 4-2 is quenched in water at gasifier operating pressure and then periodically removed through a lockhopper or similar mechanical depressurizing system. In these removal systems, steam generated by quenching flows back into the gasifier, where it reacts or exits as part of the gasifier gases. The ash/slag quench-removal systems

*Tables 4-1, 4-2, 4-3, 4-9, 4-10, and 4-11 are from reports by Bechtel National, Inc., and have been reproduced in Appendix C of this report.

identified in Table 4-2 form an integral part of the gasifiers. As a result, the ash/slag removal flow sheets inlet boundary for these processes was specified to be at the point or points where quenched ash/slag is discharged periodically from a lockhopper or similar pressure letdown system.

Most of the ash produced by the EDS fluidized-bed gasifier is entrained in the synthesis gas. This gas flows through a coke heater and then to a waste heat boiler. After heat recovery, ash particulates are removed from the synthesis gas in two stages. First, coarse particles are removed in a dry collection system. The coarse, dry ash then is cooled in an indirect solids cooler and pneumatically conveyed to a transfer point from which it will be transported for disposal. In the second ash removal stage, wet scrubbing is used to remove fine ash particulates. Slurry resulting from synthesis gas scrubbing is dewatered on vacuum filters.

Ash inlet boundaries for the EDS ash removal flow sheets were specified to be at the discharge of the dry ash pneumatic transport system and at the slurry discharge of the wet synthesis gas scrubbing system. The limited number of coke chunks periodically removed from the EDS gasifier were assumed to be combined with dry ash to be transported for disposal.

In Table 4-2, design information is presented for establishing ash/slag removal flow sheets (starting or inlet boundaries) and ash/slag characteristics for the nine coal conversion processes. Several types of gasifiers that produce ash/slag wastes have been used in coal conversion pilot plants. At least four of the nine conversion processes under consideration use slagging gasifiers (Fig. 4-8).^{*} These include COGAS, Texaco Partial Oxidation, H-Coal, and SRC-II. Both the H-Coal and SRC-II are liquefaction processes, but current commercial plant conceptual designs for them are based on the use of Texaco Partial Oxidation Gasification for gasification of solids and residual hydrocarbons remaining after liquefaction (e.g., vacuum bottoms from the SRC-II process). The gas produced from these materials by gasification is used for hydrogen and process gas production. In both the Texaco¹ (2500°F, 350 psig) and the COGAS (2000 to 3500°F, 50 psig) gasifiers, molten slag is quenched in water-filled

^{*}All figures referenced in this section are from reports by Bechtel National, Inc., and have been reproduced in Appendix D of this report.

vessels.² These vessels are maintained at the same operating pressure as the gasifier and are connected with it. Steam generated during slag quenching flows back into the gasifier. As a result, much of the energy present in the slag is returned directly to the gasifier or to gas leaving the gasifier.

The U-GAS process uses a nonslagging gasifier (two-stage entrained flow at 1800 to 2000°F, 350 psi) and a heat recovery method similar to that of the COGAS and Texaco gasifiers.³ However, in this process the ash is a hot solid rather than slag.

Several types of gasifiers have been evaluated for use in the EDS liquefaction process. Current commercial plant conceptual designs are based on the use of flexicoker, an Exxon-developed process. In the flexicoker flow scheme, most ash is removed as particulates from a gas stream. Part of the ash is removed by dry separation and part, the finer ash, by water scrubbing. As part of the EDS process, the scrubbed ash is de-watered on drum vacuum filters.

Several different types of waste solids could result from the SRC-I process, depending on the method used to separate liquids and solids (i.e., some type of filter cake or solvent deashing waste product).

Two other slagging gasifiers that may be employed in other conversion processes are the BIGAS gasifier [used in the Parsons Fischer-Tropsch process (3000°F, 470 psig)] and the Fuel Gas Gasifier [Parsons Oil-Gas process (2000 to 2500°F, 30 psig)].^{4,5}

The HYGAS process uses two stages of hydrogasification (in the second stage, reaction occurs at 1750°F, 500 to 1000 psig) to produce a char that is discharged to a steam-oxygen gasifier (a third, nonslagging stage) to produce a synthesis gas for the upper stages.

The design operating temperatures and pressures for the gasifiers given above are approximate values. Actual operating conditions would depend on the feed coal properties, particularly ash fusion-slagging characteristics, and synthesis gas requirements.

Two problem areas that may be present when handling slags from slagging gasifiers used in various coal conversion processes are (1) the effects of variations in ash composition on the viscosity of slags and (2) corrosion of refractories from molten iron in the slags. Pilot plant

studies involving these problems have been reported.^{6,7} Design problems such as taphole size and erosion, slag viscosity, and tuyeres location were investigated, and viscosity-temperature curves were presented for the coals used. Correlations presented in the literature were compared with the viscosity-temperature data obtained on these coals, assuming that the slags behaved as Newtonian fluids.⁸⁻¹⁰ The silica ratio ($100 \text{ SiO}_2 / (\text{SiO}_2 + \text{Fe}_2\text{O}_3 + \text{CaO} + \text{MgO})$) appears to be the most important criterion for estimating the viscosity of any particular slag and undoubtedly will have to be determined for any coal used in slagging gasification. Another important consideration is the transition point corresponding to the nominal liquid temperature of the system, called the temperature of critical viscosity (T_{cv}). Below this temperature many slags develop plastic characteristics. The viscosity of the plastic condition is appreciably higher than that of the liquid and is more sensitive to the temperature change. The T_{cv} varies with specific composition of the slag. Charts have been compiled from experimental data for the separate effects of Ca and Fe^{++} , the principal fluxing constituents, on T_{cv} . Another approach to estimating T_{cv} is to use the Reid and Cohen procedure for calculating the viscosity in the fluid range and assign an estimated value of T_{cv} at a temperature 200°F above the softening temperature determined by the fusing tests.^{9,11}

In practice, tapping of boiler slag in the liquid state is accomplished readily at viscosities of 150 P, or lower, and may be feasible for some compositions up to 250 P at operating temperature. Tapping is more difficult and may become impossible for slags approaching the plastic condition. Therefore, to provide a margin of temperature to maintain fluidity, it is important to know the approximate transition point in relation to specific factors in furnace operation. Thus, the operation of a slagging gasifier will require close monitoring of the ash composition of most coals. Adequate control of ash composition and ash levels can be maintained best by coal washing and preparation operations.

The problem of taphole erosion, along with frequent replacement of the hearth material, was discussed in pilot plant studies.^{6,7} Various design problems involving taphole freezing also were investigated. In a number of tests, iron agglomerates were found during cleanout, and

solidified iron streams were found in the taphole area. Analyses indicated that as much as 25% of the input iron (in oxide form) was reduced to metallic iron. Some pooling of this metallic iron on the hearth resulted in solidification as well as a corroding effect on the silicon carbide hearth lining. Commercial designs will have to consider these erosion and corrosion problems. Slag flow problems should be reduced greatly by the absence of liquid iron. Again, control of ash composition during coal preparation may help alleviate this problem.

Ash compositions and fusion temperatures for Pittsburgh and Kentucky No. 9 coals are presented in Table 4-3. These data, along with the gasifier design operating temperatures presented in Table 4-2 indicate that these coals are compatible with specified gasifiers for the various processes.

4.2.3 Coal conversion processes — requirements

Conceptual flow sheets have been developed that meet the coal handling, preparation, and conversion reactor feed requirements of nine coal conversion processes. These processes and their reported coal feed requirements are presented in Table 4-1. Information presented in this table is believed to be consistent with the latest coal feed specifications of each process developer. However, it should be recognized that all nine conversion processes are developmental. Future process development and demonstration could result in different specifications for coal feed requirements and conversion reactor coal feed systems.

Coal feed requirements presented in Table 4-1 are based on design studies using one of the two coals specified, or similar bituminous coals. With the exception of H-Coal, the processes do not require coal drying, or else coal drying is an integral part of the conversion process. To indicate this condition, the term "as received" has been used to identify conversion reactor coal feed moisture requirement. Processes in which coal drying is part of the conversion reactor system, such as EDS, are identified in the table notes. Actual coal total moisture concentrations considered to be "as-received" total moisture range from 7 to 10 wt %.

The reactor coal feed size consist presented in Table 4-1 for SRC-I and SRC-II is only one of several size consists currently being investigated as part of SRC-II demonstration plant engineering. Others include

1. simultaneous coal drying and fine crushing to 100% -50 mesh through 100% -20 mesh
2. fine crushing without drying to 100% -6 mesh through 100% -12 mesh.

For gasification of Pittsburgh seam, Kentucky No. 9 seam, and similar coals by the HYGAS process, a pretreatment is required. This pretreatment operation produces a nonagglomerating char, which is then fed to the multistage HYGAS gasifier. In the pretreatment operation, coal comes in contact with air in a fluidized bed at 750 to 850°F. This results in coal oxidation that greatly reduces the tendency of the material to agglomerate at the temperatures used for gasification. Gasification of Pittsburgh seam coal by the U-GAS process also may require similar pretreatment.

Conversion reactor pressures presented in Table 4-1 are order-of-magnitude values. They are provided only to indicate the pressurization that must be achieved by conversion reactor coal feed systems. Actual conversion reactor operating pressures depend on the coal being converted, reactor product requirements, and other conditions.

Table 4-2 presents design information used to establish starting (inlet) boundaries for ash/slag removal flow sheets and ash/slag characteristics for the nine coal conversion processes. In the EDS, SRC-II, and H-Coal liquefaction processes, some form of fractionation is used to recover gas and liquid products from the slurry resulting from coal liquefaction. An additional product of liquefied coal fractionation is a high-boiling-point slurry, frequently referred to as "bottoms." This slurry (the solid phase consists of coal mineral matter products and undissolved organics) is gasified to produce synthesis gas, which is used for hydrogen production and in-plant fuel gas. The EDS process, using Exxon Flexicoking technology, also recovers additional gas and liquid products from fractionation bottoms.⁴ In Table 4-2, the gasifier designs identified for the EDS, SRC-II, and H-Coal processes are those believed to be favored currently by the respective process developers for fractionation bottoms gasification. Different gasifiers could be used with these processes, however.

In the SRC-I process, a low-ash solid fuel is produced by removal of solids from liquefied coal. The separated solids may or may not be suitable for gasification. Therefore, for development of ash/slag removal flow sheets, these solids were specified to be discarded without gasification. Hydrogen for SRC-I coal liquefaction was specified as that produced from coal gasification. The Texaco Partial Oxidation gasifier is a probable choice for this purpose.

Gasifier design operating temperatures presented in Table 4-2 are approximate values. Actual operating temperatures would be determined by both feed coal properties (particularly ash fusion-slagging characteristics) and synthesis gas requirements. This is especially true for the liquefaction processes. Much remains to be learned about gasification of fractionation bottoms and other slurries that might result from liquefaction processes.

Two basic types of gasifiers are identified in Table 4-2: slagging (COGAS combustor and Texaco Partial Oxidation) and nonslagging (U-GAS, HYGAS, EDS, and Exxon Catalytic Gasification). Operation of both types is affected by ash fusion or slagging characteristics. Obviously, in the case of liquefied coal fractionation bottoms gasification, other factors will affect gasifier operation, but the mineral composition of the conversion reactor feed coal is probably the most significant. In the notes portion of Table 4-2 an attempt is made to qualify the effects of coal ash fusion characteristics. However, detailed consideration of such effects on gasifier operation is outside the scope of this report.

4.2.4 Coal cleaning

Initial studies established representative coal washability data for both the Pittsburgh and Kentucky No. 9 seam coals. They appear to have similar washability characteristics. Sulfur removal techniques, using conventional coal-cleaning methods, have resulted in a "best" removal of about 30% for both coals. Sulfur removal is limited because large amounts are present as organic sulfur and fine, extensively dispersed pyritic sulfur.

The following conclusions are drawn from the washability data for both coals:

1. Only limited liberation of ash and sulfur can be accomplished by crushing before separation.
2. A cleaning scheme based on crushing, screening of raw coal, cleaning of coarse (+3/8 in.) and fine coal (+28 mesh), and dewatering without thermal drying appears well suited for these coals.
3. The washability data presented elsewhere are sufficient for development of conceptual coal-cleaning facility flow sheets. These include allowances for coal dilution by roof and floor material during mining.¹²
4. The use of more efficient coal-cleaning methods, such as heavy-media cleaning, would not significantly improve clean coal quality or recovery.

The coal-cleaning reference flow sheet FS-1* is based on the above information and the design conditions shown in Table 4-9.

4.2.5 Power/steam plant coal requirements

Many current conceptual designs for commercial-scale coal conversion plants that use the processes identified in Tables 4-1 and 4-2 include large power/steam plants or require purchase of large quantities of electricity. The coal requirements for either onsite power/steam or purchased electricity are frequently of sufficient magnitude that integrated facilities for both power/steam generation and conversion coal handling and preparation appear to be economically attractive. Because of this, several commercial-scale conversion plant conceptual designs were reviewed to estimate roughly the quantity of coal-generated electricity and process steam that might be required to convert 50,000 tons of coal per day.

Results of the brief survey on electricity and steam requirements are presented in Table 4-10. Survey details are given in ref. 12.

* This flow sheet is from a report by Bechtel National, Inc., and has been reproduced in Appendix D of this report.

4.3 Conceptual Flow Sheet Development Approach

Conceptual coal handling and preparation and ash/slag removal flow sheets were developed by a modular approach. The resulting individual flow sheets can be joined in a variety of ways to obtain numerous alternative flow sheets that meet the coal feed and ash/slag removal requirements of all nine specified coal conversion processes. As an aid in assessing and describing alternative flow sheets, a reference flow scheme has been defined. This reference flow scheme is for provision of coal to the SRC-II liquefaction process.

The block flow diagram in Fig. 4-7 identifies the coal handling and preparation operations for which conceptual flow sheets have been developed. The diagram also shows the relationship between individual flow sheet modules or operations. Specific operations are grouped into four general areas: coal cleaning, coal storage and blending, coal fine crushing, and coal pulverizing or grinding. The heavy line running through the first three areas identifies operations that constitute the reference SRC-II flow scheme. All operations in the coal handling and preparation block flow diagram are keyed to specific flow sheets by flow sheet (FS) number.

From consideration of coal feed requirements, the following three general coal size consist classes were defined for the conversion processes and Fig. 4-7 development:

1. coarse coal — coal containing particles greater than 1/4 in.,
2. fine coal — coal with a top size less than 1/4 in. but larger than 20 mesh,
3. pulverized or ground coal — coal that is 40% or greater —200 mesh.

All the conversion processes, except H-Coal liquefaction, require fine coal feed. H-coal requires coal pulverized or ground to a nominal 70% —200 mesh. Coal delivered to the conversion plant from both coal source alternatives is coarse coal, 2 in. or larger top size.

The estimated capital investment for a nominal 50,000-ton-per-day coal conversion plant is several billion dollars. Most of this cost is associated with actual coal conversion, product(s) upgrading, and environmental emission control facilities. Because of the size of this investment and the quantity of product(s) produced, any unplanned interruption

in conversion reactor coal feed would be extremely expensive. In fact, the cost is of such magnitude that substantial investment in highly reliable coal handling and preparation facilities would be fully justified. Therefore, high operating reliability was a prime consideration in the development of the conceptual flow sheets.

High operating reliability can be achieved by provision for (1) appropriate maintenance time or (2) equipment redundancy for proven processes housed in well-engineered, well-constructed, and well-managed plants. Both approaches were used. For all operations before coal live storage, but primarily for coal cleaning, single equipment lines were deemed consistent with high operating reliability when practical. These operations have an annual operating requirement of only 250 days (nominally 5 days per week). This leaves sufficient time for required maintenance. Also, the clean-coal live-storage design capacity specified is sufficient to accommodate most failures that could occur before live storage.

Redundant equipment is specified for coal live storage and all following coal operations. These facilities must operate 365 days per year, 24 hr/day. The redundancy specified is believed to be sufficient to meet this requirement. Spare equipment and excess equipment capacity would be used to compensate for equipment out of service for maintenance or unscheduled repair.

Any commercial coal conversion plant probably will consist of several identical, independent conversion trains because of operating reliability considerations and equipment size limitations. Review of current commercial conversion plant conceptual design studies indicates that four to six trains appear to be a reasonable number for conversion of 50,000 tons of high-rank bituminous coal per day. As a result, a five-train conversion plant was used as a general basis for flow sheet development. This does not mean that all flow sheets for coal operations following live storage have five identical equipment trains. When acceptable reliability was judged possible with a lower number, fewer than five trains were used. Likewise, when current equipment capacity limitations indicate that more than five trains may be required, more than five were used.

Establishment of the best designs for coal handling and preparation facilities for any of the nine specified coal conversion processes will

require major trade-off studies in several important areas. These trade-offs frequently involve whether or not a specific operation is justified for a coal conversion plant and, if so, the degree of justification. Ultimately, such justification becomes a question of economics. The cost of these coal handling and preparation operations, both capital and operating costs, must be offset by cost savings in the actual conversion process or in subsequent conversion plant operations. In addition to cost trade-offs associated with the reliability of coal handling and preparation operations, other major areas requiring trade-off assessment include coal cleaning and blending, and, in some cases, conversion reactor coal feed requirements.

Unfortunately for many conversion processes, the process data required to differentiate between the economic trade-offs of coal handling and preparation operations and actual conversion operations are not yet developed. That is, conversion process data that would allow comparison of the cost savings associated with converting, for example, blended versus unblended coal, simply blended versus fully blended coal, or cleaned versus uncleaned coal generally have not been developed. At some point in the development of coal conversion processes, trade-offs will be made that could significantly affect the design of actual coal conversion plant coal handling and preparation facilities.

One area where trade-off assessments have been attempted on a limited basis is coal cleaning. Both Exxon Research and Engineering Company (for the EDS Process) and Ashland Synthetic Fuels, Inc. (for the H-Coal Process) have made preliminary investigations of potential coal-cleaning benefits. For one version of the EDS process and an Illinois No. 6 coal, Exxon estimates that cleaning to ~9 wt % ash could be justified. This preliminary conclusion is the result of an economic trade-off between coal-cleaning cost and the amount of C_1/C_2^* product required to supplement plant requirements for low-Btu fuel gas produced by gasification of liquefaction solids. For the process conditions currently under consideration and using Illinois No. 6 coal, Ashland has indicated that cleaning to ~8 wt % ash appears justified.

*Ratio of methane/ethane.

4.3.1 Coal cleaning

As shown in the flow diagram, ROM coal received from the adjacent coal mine complex is broken from 12 in. $\times$ 0 to 6 in. $\times$ 0, conveyed to cleaning plant surge storage, and then screened at 3/8 in. Screening at this size results in a coarse-coal size consist that is well suited for a coarse-coal cleaning jig. If screening were not used, -3/8 in. coal would reduce coarse-coal jig separation efficiency. Jigs were the only conventional coarse coal cleaning method considered. The other possibility, heavy-medium cleaning, was not considered.

Three alternatives were considered for fine-coal cleaning: fine-coal jigs, water cyclones, and tabling. Fine coal cleaning flow sheets were developed for each of these alternatives.

Coal transported to the conversion plant site was assumed to be cleaned at the mine sites or in regional cleaning plants serving several neighboring mines, if cleaning was justified. Such cleaning would result in reduced coal transport costs and possibly lower costs for disposal of cleaning plant refuse. Coal-cleaning alternatives identified for the conversion plant site are applicable to mine and/or regional cleaning plants.

4.3.2 Coal storage and blending

Main coal live and dead storage is provided after coal cleaning. Not only does cleaning reduce the storage area needed, because of reduced mass, but the nominal 2-in. top size coal is easier to handle and to pack than is the coarser coal. Coal storage-blending facilities also could be located ahead of coal-cleaning facilities. Advantages associated with this arrangement include reduced surge storage requirement for coal-cleaning facilities, possibly smaller cleaning facilities because of the possibility of longer annual operation, and cleaning of blended coal. In some situations, these advantages may outweigh those associated with live-dead storage after coal cleaning. The flow schemes and major equipment lists for cleaning presented in this report are generally applicable to both cleaning location alternatives.

Blending can improve operation of some types of coal-cleaning plants, but blending would not significantly improve the operation of plants using

cleaning methods identified in Fig. 4-7. In fact, the methods identified accomplish some blending during cleaning. Heavy-medium coal cleaning would benefit most from feeding of blended coal. For coal conversion plants in which heavy-medium cleaning is justified, the beneficial effects of cleaning blended coal may be of sufficient magnitude to justify location of live-storage-blending ahead of coal cleaning.

In the coal-mine coal conversion plant interface evaluation project, a limited investigation was made of the cost trade-offs associated with different live-storage facility design capacities. Conclusions from this investigation were tentative and situation specific. The main conclusion was that coal storage-blending facilities having live-storage capacities sufficient to avoid use of dead-storage facilities, except during emergencies, are less expensive to operate than those that normally require periodic use of dead storage. The main reason for this conclusion is that, when both capital and operating costs are considered, the per-ton cost of moving coal in and out of dead storage is much higher than for a well-designed live-storage facility.

Because of the conclusion about the economics of live and dead storage, a live-storage design capacity of 500,000 tons was established for conceptual flow sheet development. Analysis of probable differences between coal production by a mine complex located adjacent to a conversion plant site and actual daily conversion plant coal consumption indicates that consumption capacity is sufficient to limit any dead-storage facility use to emergency situations only. Emergency situations are defined as coal production shutdown or production slowdown as a result of labor grievances, unforeseen mining conditions, or a mine disaster. The actual analysis was part of the interface project. For the particular conditions assumed — mine complex operation of 250 days per year and conversion plant operation of 365 days per year, allowing 35 days for maintenance for individual conversion plant trains — the analysis showed that at live-storage capacities below ~500,000 tons, coal had to be moved in and out of dead storage periodically to balance mine production with conversion plant consumption. This use of dead storage was not a consequence of any emergency situation. A graph representing possible live-storage coal inventory change with time (a 780-day period) is presented in the final report, on the interface project.¹

In addition to limiting any dead-storage use to emergency situations, the establishment of 500,000 tons as the live-storage-blending design capacity allows identification of equipment limitations that might not be apparent at lower capacities. If adequate equipment is available for handling and blending 500,000 tons, it is available for lesser tonnages.

Dead coal storage is postulated to consist of large piles of coal arranged by mobile equipment, rubber-tired tractors, and scrapers. After construction, these piles of coal weighing ~250,000 tons are covered with an airtight seal of asphalt, road tar, or water-soluble acrylic polymer crusting agent. These piles are used only in emergency situations or when decomposition is imminent.

4.3.3 Coal fine crushing

Eight of the nine specified coal conversion processes require coal crushed to between 1/4 in. $\times$ 0 and 20 mesh $\times$ 0. Further, the developers of processes requiring coal crushed to a top size of 8 mesh or finer indicate in various ways that "fines minimization" is required or is desirable. Just what constitutes fines minimization, however, apparently has yet to be quantified by any of the process developers. It is likely that eventual establishment of specific coal fines or ultrafines limitation requirements will involve both technical and economic considerations. For most processes in which fines are a matter of concern, there appears to be a cost trade-off between removal of fines before coal conversion and removal of fines or fines products from conversion reactor products.

In developing flow sheets for coal fine crushing, reduction in the production of fines was a prime consideration in equipment selection and selection of alternative fine-crushing methods. In addition, a flow sheet for ultrafines separation following fine crushing was developed. This flow sheet could be used with any of the actual fine-crushing flow sheets if ultrafines removal is required or justified. To develop the ultrafines separation flow sheet, ultrafines were defined to be coal particles 100 mesh or finer in size. This range is only an estimate of the size that individual process developers might ultimately define as ultrafines.

Reportedly, coal fines also can be a problem in some types of proposed or existing fluidized-bed steam generators — the type of steam generators postulated for the conversion plant's steam/power plant. Fines or ultrafines can be swept from the fluidized bed after only very short residence time. If this time is too short, the particles may not undergo complete combustion. Also, if particles containing appreciable heat value are not captured and returned to the fluidized bed or a carbon burnup cell, steam generator efficiency will be reduced. Some fluidized-bed steam generators reportedly eliminate or reduce partial fines combustion to acceptable limits by feeding coal below the fluidized bed rather than from the bed top.

4.3.4 Coal pulverizing and grinding

The only process in Table 4-1 requiring pulverized coal is H-coal. There are two ways to meet this feed requirement: dry pulverizing and solvent grinding. Dry coal pulverizing is a well-developed technology, but coal solvent grinding is still an experimental one.

Dry pulverizers (mills) are used exclusively for pulverized coal fired steam generators, utility and industrial, and for many other coal-fired processes. Currently, several different designs of dry coal mills are commercially available. The individual capacities of these mills for bituminous coals range up to 100 tons/hr. Further, when markets for coal conversion equipment exist, dry mill design can probably be scaled up to 200- to 300-ton/hr capacities without sacrificing reliability. Mills of design similar to coal mills with capacities in excess of 300 tons/hr are used currently for pulverizing cement.

Conceptual designs and cost estimates were developed for two coal pulverizing alternatives in the coal mine-coal conversion plant interface project.¹ The flow sheets and major equipment lists that are part of these conceptual designs are believed to be adequate for this report. Therefore, no additional conceptual coal-pulverizing flow sheets were developed.

With one exception (as far as could be determined), coal grinding — in coal liquefaction solvent, water, or other liquids — never has been used in any large-scale commercial operation. There simply has never been

any requirement for large-scale slurry coal grinding. Large-scale wet grinding, however, is used widely in mineral ore beneficiation. Wet ore mills have been built with larger capacities than any dry coal mill. However, on the basis of current design practices, it is expected that very large wet coal mills could be built. Ball mills of 25-ft diameter and having 14,000-hp drive systems currently are being considered for ore grinding. The capability to build very large wet mills could have a direct bearing on the minimum number of grinding lines in projected conversion plants and on their corresponding capital cost.

Wet grinding is used at the Black Mesa, Arizona, coal mine to prepare coal for slurry pipeline transport. The coal size consist produced at Black Mesa, however, is considerably coarser than the 70% -200 mesh size consist required for H-Coal and is purposely skewed (16 to 20% -325 mesh and 30 to 35% +48 mesh). To achieve this special size consist, open-circuit rod mill grinding is used. Slurried, ground coal is piped 273 miles from Black Mesa to the 1580-MW Mohave Power Plant, where it is dewatered and pulverized further in conventional dry coal mills to a nominal size consist of 70% -200 mesh.

Kennedy Van Saun Corporation currently is performing for DOE an extensive investigation of coal pulverizing and grinding. As part of this project, KVS has performed a limited number of grinding tests using Kentucky No. 9 coal and No. 4 and No. 6 fuel oil. Results from this work were used to develop a single conceptual coal-solvent grinding flow sheet that meets H-coal feed requirements (70% -200 mesh coal dried to 2.0 wt % or less total moisture).

4.3.5 Conversion reactor ash/slag removal

All nine coal conversion processes specified produce significant quantities of solid wastes that must be disposed of in an environmentally acceptable manner. The main sources of these wastes are conversion process gasifiers, power/steam plant generators, and coal-cleaning operations. As discussed in Sect. 4.2.2, the liquefaction processes, with the exception of SRC-I, gasify residues resulting from coal liquefaction and recovery of subsequent products. The gasifiers used produce the ash or slag wastes associated with liquefaction. Solid wastes resulting from

SRC-I are the result of a liquefaction reactor liquids-solids separation operation. For flow sheet development, the SRC-I solids were assumed to be disposed of directly; that is, they were not considered to be acceptable gasifier feed.

Figure 4-8 presents possible operations that could be used for ash/slag removal. In reviewing the ash/slag operations required for each of the nine specified conversion processes, the possibility of energy recovery also was evaluated. However, in all cases in which it appeared warranted, energy recovery is already part of the conversion reactor (see Sect. 4.2.2).

To facilitate development of ash/slag removal flow sheets, two types of gasifier solid wastes were defined — granulated slag and ash. The types produced by specific gasifiers are shown in Fig. 4-8. Granulated slag is formed by rapid quenching of molten gasifier slag in water. It is relatively coarse in size, typically contains less than 4 wt % combustibles, and dewateres easily. With the possible exception of U-GAS, ash from the ash-producing gasifiers has a finer size consist than does granulated slag and contains considerably more combustible material (principally carbon).

The daily amounts and composition of granulated slag and ash from ash-producing gasifiers were estimated for a defined coal feed to the conversion plant and to the associated power/steam plant. These are presented in Table 4-11. Handling of the resulting slurries is discussed in detail in Sect. 4.3.5 of the Bechtel report.¹²

References

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5. CONCEPTUAL FLOW SHEET DESCRIPTIONS

5.1 Introduction

This section describes conceptual flow sheets for coal handling and preparation and ash/slag removal operations that will be required by commercial coal conversion plants. Accompanying these flow sheets are major equipment lists.¹ Bases for design and the general approach used in the development of the flow sheets are presented in Sect. 4.

All flow sheets are keyed to the coal handling and preparation operations block flow diagram, Fig. 4-7,* or the ash/slag removal operations block flow diagram, Fig. 4-8, by flow sheet (FS) numbers. These numbers are located on the diagrams in the areas concerned with general coal-cleaning operations and those concerned with specific operations. When more than one single-dash FS number, such as FS-3 and FS-4, is shown for an operation, multiple flow sheets are required to meet the coal feed requirements of coal conversion processes. Flow sheets with double-dash numbers such as FS-4-1 and FS-4-2, are alternative flow sheets for a specific operation (FS-4). Table 5.1[†] gives the locations of all conceptual flow sheets, figures, and drawings referenced in this report.

Most flow sheet operations require multiple units of equipment, which are frequently arranged into independent trains consisting of several operations. In such flow sheets, only a single piece of equipment is shown. Numbers in parentheses after equipment titles are the actual numbers of units of equipment for a specific operation.

To facilitate presentation, this section is divided into subsections corresponding to the four general coal operation areas identified in the Fig. 4-7 block diagram plus a subsection that presents ash/slag removal flow sheets.

*All figures referenced in this section are from reports by Bechtel National, Inc. The location for each figure is given in Table 5.1 of this report.

[†]Table 5.1 is in this section and was compiled by the authors of this report.

Table 5.1. Coal conversion plant conceptual flow sheets, figures, and drawings

	Reference	Location
Coal handling and preparation operations block flow diagram	Fig. 4-7	<i>a</i>
I. Coal cleaning		
Pittsburg seam coal washability characteristics	Fig. 4-3	<i>a</i>
Jig coarse- and fine-coal cleaning and water treatment	FS-1	<i>a</i>
Alternative hydrocyclone fine-coal cleaning	FS-1-1	<i>a</i>
Alternative table fine-coal cleaning	FS-1-2	<i>a</i>
II. Coal storage/blending		
Alternative coarse-coal live-storage V-bunkers	FS-2-1	<i>a</i>
Alternative open coal stockpile (nine options)	Fig. 5-2	<i>a</i>
Alternative enclosed coal storage (five options)	Fig. 5-3	<i>a</i>
Live-storage-blending facility (flow sheet)	PF-1	<i>b</i>
Live-storage-blending facility	D-20	<i>c</i>
Open stockpile live-storage facility	D-22	<i>c</i>
V-bunker live storage and dead storage	D-23	<i>c</i>
III. Coal fine crushing		
Single-stage cage mill coal fine crushing (SRC-I and SRC-II, Exxon Donor Solvent, Exxon Catalytic Gasification)	FS-3	<i>a</i>
Two-stage cage mill coal fine crushing (HYGAS, Texaco Partial Oxidation)	FS-4	<i>d</i>
Alternative two-stage cage mill coal fine crushing stacked arrangement (HYGAS and Texaco Partial Oxidation)	FS-4-1	<i>d</i>
Alternative single-stage cage mill closed-circuit coal fine crushing to minimum ultrafines production	FS-5	<i>d</i>
Single cage mill coal fine crushing (U-GAS and COGAS)	FS-6	<i>d</i>
Coarse-coal thermal drying	FS-7	<i>d</i>
Alternative single-stage cage mill coal fine crushing with prescreening (U-GAS)	FS-8	<i>d</i>
Fine-coal ultrafines separation	FS-9	<i>a</i>
Rod mill coal wet grinding (Texaco Partial Oxidation)	FS-10	<i>d</i>
IV. Coal pulverizing or grinding		
Solvent coal grinding (H-Coal process)	FS-11	<i>a</i>
Coal pulverizing-ball tube mill alternative	PF-5	<i>b</i>
Gas flow schematic ball tube mill system	Fig. 5-9	<i>c</i>
Ball tube mill building	D-26, D-27	<i>c</i>
Coal pulverizing-roller mill alternative	PF-6	<i>b</i>
Gas flow schematic-roller mill system	Fig. 5-10	<i>b</i>
Roller mill building	D-28, D-29	<i>c</i>
V. Ash/slag removal		
Ash/slag removal operations block flow diagram	Fig. 4-8	<i>a</i>
Ash/slag dewatering	FS-12	<i>d</i>
Transport slurry preparation	FS-13	<i>d</i>

^aThis report, Appendix D.^bBechtel National, Inc., FE-2370-16, Vol. I.^cBechtel National, Inc., FE-2370-16, Vol. II.^dBechtel National, Inc., for Union Carbide Corp., Report Job 13022.

All coal flow sheets presented in this report represent the handling and preparation of very large quantities of material. Only one U.S. coal mine, a Western strip mine, currently produces the quantity of coal specified for these conceptual flow sheets (16.5×10^6 tons per year). None of the mines currently operating in either the Pittsburgh or Western Kentucky coal seams have production capacities that even approach this tonnage. A coal-fired power plant capable of consuming 16.5×10^6 tons of coal per year would have a capacity rating on the order of 6200 MW; this is nearly twice the rated design capacity of the largest U.S. coal-fired power plants.

Designing facilities with the capacities specified in this report will require considerable engineering effort. Final selection of equipment and design of facilities will require numerous trade-off studies involving both technical and economic considerations. Flow sheets and equipment specifications for these facilities will reflect the results of these studies and application of engineering expertise.

Major equipment lists present estimated equipment design capacities and, where appropriate, such information as estimated installed equipment power, major overall dimensions, recommended materials of construction, specification requirements, and general comments. In the "Specification Requirements and Comments" part of these lists, reference frequently is made to equipment of "standard design." This term is used to identify equipment that currently is used commercially for coal operations at or above the specified design capacity of the equipment. No further development or demonstration is required for reliable use of this equipment. However, because of capacity requirements, most equipment specified as standard would not be available as off-the-shelf items. Most would have to be custom fabricated from proven design data. As a result, lead times necessary for purchase of standard equipment can be substantial, even though no development or demonstration is required.

Design capacities for coal surge storage silos and bins are presented in the equipment lists. These values are only rough estimates. Extensive equipment layout studies, coal flow design calculations, structural analyses, and cost estimates would be required to arrive at final design dimensions and capacities for coal silos and bins of types and

capacities specified for conversion coal storage. All bins and silos would be designed for mass-flow operation. This flow pattern results in a first-in and first-out flow sequence, which minimizes coal size segregation problems and avoids spontaneous combustion fires that result from formation of dead regions within bins and silos.

In the conceptual flow sheets, extensive use is made of large-capacity belt conveyors. Design of conveyor systems that have sufficient capacities, like the design of storage bins and silos, requires extensive layout studies and design calculations. Conveyor design is affected greatly by storage requirements and is, in fact, a principal cost associated with storage facilities. Bin and silo heights frequently determine the length of conveyors and affect conveyor power requirements. Because of the extensive engineering required to completely specify conveyor systems, conveyor power requirements presented in the equipment lists are only rough estimates. Conveyor belt widths are estimated also, but are not as subject to change as conveyor power estimates.

An important requirement in all coal-handling operations is control of particulates. For this purpose, baghouse dust-collection systems are specified for coal surge storage and for coal breaking. The size of these systems depends on the dimensions of the structure they serve, the amount of coal handled, the specific operation creating the dust, and coal size consists. Because the first two determinants are dependent upon plant layout, baghouse design capacities and power requirements specified in the equipment lists are only rough estimates.

Coal dust explosion is a problem associated with use of baghouses for coal particulate control. Though further development and demonstration are required, explosion of coal particulates theoretically can be controlled through baghouse design, including baghouse ducting design and use of explosion detection-suppression systems. Explosion suppression systems which release a chemical to inhibit combustion reactions are used currently with success in conjunction with baghouses designed to handle dusts similar to pulverized coal, such as wood dust.

In addition to use of baghouses for particulate emissions control, extensive use would be made of spray dust-suppression systems. These systems, though not shown on the conceptual flow sheets or specified in the

equipment lists, would be used at most coal-conveyor and feeder-transfer points and in the coal-breaking area. Each coal dust suppression system would consist of a proportioning-pumping unit, piping, and a series of spray heads. The proportioning-pumping unit provides a solution of water and wetting agent to the spray heads at sufficient pressure to cover coal that is discharged at various transfer points with a fine, mist blanket.

5.2 Coal Cleaning

Three conceptual flow sheets and three major equipment lists were developed for coal-cleaning operations. One set provides for both coarse- and fine-coal cleaning. The other two represent alternative methods for fine-coal cleaning. Material balance estimates for these flow sheets are based on the Pittsburgh seam coal washability data presented in Table 4-6* and Fig. 4-3. This washability data is similar to that developed for Kentucky No. 9 seam coal. As a result, the material balances are also applicable for the Kentucky No. 9 coal.

The coal-cleaning operations, coarse plus fine, are designed to clean 21.8×10^6 tons of ROM coal per year to yield 16.5×10^6 tons of clean coal per year. Clean coal is conveyed to live-storage-blending or to dead storage. Coal-cleaning design conditions are presented in Table 4-9.

5.2.1 Coarse-coal breaking, cleaning, and crushing

FS-1 presents the flow scheme and material balance developed for coarse-coal breaking and cleaning and for clean coarse-coal crushing. It also presents one alternative for fine-coal cleaning. The inlet boundary for this flow sheet is at the discharge point(s) of the discharge conveyor(s) of the integrated coal mine transport coal receiving facility of the complex (Fig. 4-7). This conveyor(s) delivers coal to the breaking operation at a design flow rate of 4353 tons/hr, 20 hr/day.

Coal (12 in. $\times$ 0) to be conveyed to breaking facilities is discharged into receiving hoppers. From here, it is fed by apron feeders

*Tables 4-1, 4-6, 4-9, 5-1, and 5-2 are from reports by Bechtel National, Inc., and have been reproduced in Appendix C of this report.

onto fixed grizzlies having nominal bar spacings of 4-3/4 in. Grizzly oversize, nominal +6 in. coal size falls into a rotary breaker where it is reduced to a top size of 6 in. A small amount of rock and mine debris at a size of +6 in. is rejected from the breaker. This reject material is discharged to refuse collection and transport. Coal from the rotary breaker discharges onto a conveyor, where it combines with grizzly under-size coal. Coal (6 in. $\times$ 0) is conveyed to a series of four raw coal surge storage silos. These silos are equipped at the feed and discharge points with a baghouse coal dust collection system for particulate emissions control. Agglomerated coal from the baghouse system is fed to at least one of the silos. Vibratory activator feeders located under the raw coal surge storage silos feed coal onto the cleaning plant feed conveyor. The feeder discharge points constitute the outlet boundary for the cleaning plant surge storage operation (Fig. 4-7). The raw-coal sampling station constitutes the boundary between this surge storage operation and the preceding breaking operation. As indicated in Fig. 4-7, an open stockpile is an alternative to silos for raw coal surge storage.

Surge storage coal is conveyed by a cleaning plant feed conveyor onto a series of 16 parallel raw-coal screens. The feed conveyor is equipped with a belt scale to measure the quantity of coal fed to the cleaning plant and to provide a signal for regulating the raw coal screening operation. Wet vibrating screens are used to split cleaning plant feed coal into coarse and fine fractions for separate cleaning. Screening is performed at 3/8 in. using double-deck screens to reduce screen wear and to obtain high screening efficiency. Top screen deck aperture is 1-1/2 in.; the bottom is 3/8 in. Water is applied to the screens at the rate of 78 gal per ton of coal feed. Screening oversize, 6 in. $\times$ 3/8 in., flows by gravity to coarse-coal cleaning. Undersize, at 50 wt % solids and 3/8 in. $\times$ 0, is cleaned in a fine-coal cleaning operation.

Only one method is recommended for coarse-coal cleaning: jigging followed by clean-coal screen dewatering. Consideration of the other general method used commercially for coarse-coal cleaning (i.e., heavy-medium cleaning) was not part of the scope of this project (see Sect. 4.2.4). An automatic, two-stage Baum-type jig is specified for coarse-coal cleaning. This jig produces three products: clean coal, middlings,

and refuse. Middlings and refuse are removed from the jig by bucket elevators and do not require additional physical dewatering. Refuse is discharged onto a refuse conveyor. Middlings are crushed with a hammermill crusher to 3/8 in. top size, slurried in water, and pumped to the fine-coal cleaning operation.

Clean coal from the coarse-coal jigs is physically dewatered on vibrating screens. Screen oversize is crushed to 2-in. top size in roll crushers and discharged onto a clean-coal conveyor. Undersize from the clean-coal dewatering screens, 1/4 in. $\times$ 0, are fines created in the jigs or misplaced in the initial raw-coal screening operation. These fines are pumped to thickening cyclones. Overflow water from these cyclones is clean enough for direct reuse. Cyclone underflows are combined with crushed middlings for separate cleaning in the fine-coal cleaning operation. The clean-coal conveyor collects clean coal, both coarse and fine, and conveys it to live-storage-blending or dead storage.

With one exception, all equipment specified in the FS-1 major equipment list for coal breaking, surge storage, coarse-coal screening, and coarse-coal cleaning is of standard design and is widely used commercially for coal cleaning. The vibratory activator feeders specified for the raw-coal silos are relatively new but do not require further development. These feeders represent an improvement over existing vibrating feeders for feeding large quantities of coarse coal.

5.2.2 Fine-coal cleaning and dewatering

Conceptual flow sheets and major equipment lists were developed for three fine-coal cleaning alternatives. These are jig fine-coal cleaning (FS-1), hydrocyclone fine-coal cleaning, and table fine-coal cleaning (FS-1-1 and FS-1-2). All three flow sheets provide for dewatering of the cleaned fine coal.

The fine-coal cleaning circuit presented in FS-1, like the coarse-cleaning circuit, uses a jig, but of a different design from that used for cleaning coarse coal. Before being cleaned, however, fine coal (3/8 in. $\times$ 0) is deslimed at 28 mesh with sieve bends. Sieve bends are specified for desliming because they permit control of the quantity of water introduced to the fine-cleaning operation.

Jig cleaning of fine coal is accomplished with three parallel Batac-type jigs. Each jig is designed to clean 600 tons of coal per hour. These air-pulsed jigs allow even, regular pulsing of the entire jig bed, which results in improved bed classification compared with a Baum-type jig. Each jig has six air-pulse compartments and two bucket elevators — one for middlings and one for refuse. Clean fine coal overflows at the jig ends. Middlings, which are partially dewatered by the middling elevators, are recycled directly to the jig feed ends. Refuse, also partially dewatered by the refuse elevators, is further dewatered on 28 mesh opening, single-deck, vibrating screens. Oversize refuse discharges to the refuse conveyor. Undersize refuse flows to an effluent treatment operation.

Clean coal overflowing the fine-coal jigs is dewatered to 15 to 20 wt.% total moisture on 28 mesh opening, single-deck vibrating dewatering screens. Oversize from these screens, 3/8 in. × 28 mesh clean coal, is further dewatered to approximately 11 wt % total moisture with vibrating basket centrifuges. Dewatered coal is discharged to the clean-coal conveyor where it combines with crushed, clean coal from the coarse-coal cleaning operation. Water removed by the dewatering screens and centrate are pumped to effluent treatment.

FS-1-1 presents the hydrocycloning fine-coal cleaning alternative. Fine coal from the raw coal screens and crushed middlings and thickened clean-coal dewatering fines from the coarse-coal cleaning operation are initially combined in a sump. Sufficient makeup and hydrocyclone circuit recycle water is added to this sump to produce a coal slurry containing ~14 wt % coal. This slurry is pumped into 25 parallel primary hydrocyclones. Underflow from these hydrocyclones is diluted with water and recleaned in five parallel secondary hydrocyclones. Underflow from these hydrocyclones is refuse. Overflow from the secondary hydrocyclones is recycled to the primary hydrocyclone feed sump.

Fine refuse resulting from hydrocycloning is dewatered on sieve bends in combination with single-deck vibrating screens. Oversize refuse is discharged on the refuse conveyor (FS-1). Undersize refuse, -28 mesh, flows to an effluent treatment operation.

Overflow from the primary hydrocyclones, which contains clean fine coal, is classified at 28 mesh in 20 parallel classifying cyclones. A -28 mesh coal fraction is classified into the cyclone overflows and a 3/8 in. $\times$ 28 mesh fraction is obtained in the underflows. Underflow is dewatered on parallel sieve bends. Sieve bend oversize, 3/8 in. $\times$ 28 mesh, is dewatered further to ~11 wt % total moisture in six parallel vibrating basket centrifuges. Cake from the centrifuges is discharged to the clean-coal conveyor (FS-1) where it combines with crushed, clean coal from the coarse-coal cleaning operation. Centrate flows to the secondary hydrocyclone feed sump for recovery of any misplaced coal. Overflow from the classifying cyclones is combined with dewatering sieve bend underflow in a sump. From here it is pumped to an effluent treatment operation.

FS-1-2 presents the table fine-coal cleaning alternative. As in FS-1-1, fine coal from the raw coal screens plus crushed middlings from the coarse-coal cleaning operation and thickened, clean-coal dewatering fines are combined in a sump. Sufficient water is added to this sump to produce a 50 wt % coal slurry. This slurry is pumped into 20 parallel classifying cyclones for desliming at 28 mesh. The overflow slimes are collected in a sump and then pumped to an effluent treatment operation.

Deslimed fine coal, 3/8 in. $\times$ 28 mesh, is distributed to 60 parallel double-deck shaking tables for cleaning. A large number of tables are required because of table design limitations related to coal feeding. The tables specified are the largest known to be in use for coal cleaning. Clean coal overflows the table sides opposite the feed points into launders that transport it to 6 parallel dewatering sieve bends. Sieve bend oversize, 3/8 in. $\times$ 28 mesh, is further dewatered in 6 parallel vibrating basket centrifuges. Cake from the centrifuges is discharged to the clean-coal conveyor (FS-1), where it combines with crushed clean coal from the coarse-coal cleaning operation. Centrate flows to the cyclone feed sump for recovery of any misplaced coal.

Undersize from the clean coal dewatering sieve bends, -28 mesh coal, flows into the same sump as the cyclone classifier overflow. From here it is pumped to an effluent treatment operation.

Refuse overflows the tables into launders that transport it to spiral classifiers. The heavy fraction from these classifiers is discharged to

the refuse conveyor (FS-1). Spiral classifier overflow flows to an effluent treatment operation.

Like equipment specified for coarse-coal cleaning, that specified for all three fine-coal cleaning alternatives is of standard design and is widely used commercially for coal cleaning. All of the three can produce clean coal of nearly equal quality and at comparable recoveries. Total operating cost, including appropriate capital charges, would be the main factor in selecting a best alternative.

Considering the quantities of equipment required, jig fine-coal cleaning is probably the least expensive of the three alternatives. For an actual coal conversion plant, heavy-medium fine-coal cleaning would be considered, as well as the three alternatives for which flow sheets were developed.

5.2.3 Coal-cleaning effluent treatment

All future coal-cleaning plants will require closed-loop water systems. Effluent emission regulations will not allow release of any polluted water from these plants. As a result, effluent treatment will be an important operation in all future coal-cleaning plants.

FS-1, in addition to presenting flow schemes for coarse-coal cleaning and one fine-coal cleaning alternative, presents a conceptual flow sheet for one cleaning plant effluent treatment scheme. This treatment operation recovers both water for reuse and clean coal. Feed to the effluent treatment operation is produced by all three fine-coal cleaning flow sheets and consists of slimes (-28 mesh coal), fine clean-coal dewatering underflow, and -28 mesh refuse. The slimes and clean-coal dewatering underflow are pumped to froth flotation cells for coal recovery. Minus 28 mesh refuse is sent to a refuse thickener.

Float coal from the flotation cells, clean 28 mesh $\times$ 0 coal, is dewatered on a disc vacuum filter. Filter cake is conveyed to the cleaning plant clean-coal conveyor, where it combines with clean coal from the coarse- and fine-cleaning operations. Filtrate is recycled directly to the flotation cells.

Flotation refuse is pumped to a refuse thickener. Here, it and the other -28 mesh from fine-coal cleaning are thickened with the aid of a

flocculant. Underflow from this thickener is dewatered to ~30 wt % moisture in solid bowl centrifuges. Centrifuge cake discharges onto the refuse conveyor. Centrate and refuse thickener overflow are pumped to the cleaning plant head tank for reuse.

Froth flotation is only one of many methods that could be used to recover coal and produce recyclable water from cleaning plant effluents. However, it is currently the most common approach used when any coal-cleaning plant effluent treatment is provided. Other possible technologies that might be used are indicated in Fig. 4-7. Determination of the best effluent treatment scheme for use in commercial coal conversion plant cleaning operations will depend on economics, applicable plant effluent emission regulations, coal-cleaning plant design, raw-coal characteristics, and refuse disposal considerations.

5.3 Coal Storage and Blending

Two basic types of large-capacity coal storage likely will be required for coal conversion: live storage with or without blending and dead storage. As discussed in Sect. 4.3.2, live-storage design capacity was established at 500,000 tons and dead storage is intended for emergency use only. However, for some storage configurations, differentiation between what constitutes live and dead storage is difficult. As a result, both types are discussed together.

As discussed in Sect. 4, the need for and the degree of blending required has yet to be quantified for any of the nine coal conversion processes considered. Process information required to determine the cost savings, if any, that might be realized for converting blended versus unblended coal has yet to be developed. Once this information is available, these savings can be compared with the cost for different coal-blending levels. Three general blending levels can be considered for coal conversion: simple, intermediate, and full.

Table 5-1 and Figs. 5-2 and 5-3 present major alternatives for large-scale, high-capacity, coarse-coal storage. The three general blending levels and types of equipment required to achieve each are also presented. Two general storage alternatives are identified: open-stockpile storage and enclosed storage.

For a given storage capacity, open stockpiles are inevitably less expensive than enclosed storage. A primary reason for considering enclosed storage for commercial coal conversion plants is fugitive particulates emissions. Current regulations on emission of fugitive particulates from open stockpiles of coal are vague. However, in the future, especially when the time frame for construction of commercial coal conversion plants is considered, regulations may become more precise and stringent. Further, current methods used to control open-stockpile fugitive emissions appear to be expensive.

Also, these methods seem to be limited in their effectiveness in significantly lowering particulate emissions. If allowable fugitive particulate emissions are significantly lowered by future regulations, totally enclosed live-storage facilities and possibly new designs for dead-storage facilities will probably be required. This could be true particularly for storage facilities as large, in terms of the quantities of coal handled and area required, as those required for commercial coal conversion plants. In addition to allowing better fugitive particulates control, use of enclosed storage in locations where long or severe winter conditions exist would reduce problems associated with handling of frozen and wet coal.

As Fig. 5-2 indicates, many open-stockpile configurations are possible. Major factors that influence the configuration best suited for a given situation include the following:

1. required coal flow in and out of storage,
2. live-storage design capacity,
3. dead-storage design capacity,
4. coal-handling criteria (continuous or intermittent),
5. blending requirements,
6. land availability,
7. economics.

For open-stockpile blending, at least two stockpiles are required — one to be reclaimed while the other is being built. There are two approaches for building of blending stockpiles: chevron layering and

windrow layering. Simple blending is achieved by reclaiming a chevron-layered pile in small sections, such as by a bucket wheel reclaimer. When a chevron stockpile is reclaimed in full cross section by such equipment as a drum reclaimer, intermediate blending is achieved. Full blending is achieved when a stockpile built in windrow layers is reclaimed in full cross section. Building windrow piles is more complicated than constructing chevron piles due to the slewing movement required by the traveling stacker booms. Booms on stackers for windrow layering are also usually longer than those used to build chevron piles.

Unless future regulations concerning fugitive particulate emissions prevent the use of open stockpiles or the conversion plant is located in an area having severe winters, live storage most likely would take this form. Also, it is believed that at least intermediate blending would be justified. However, no conceptual flow sheet is presented for this type of live-storage-blending operation. The open-stockpile flow sheet and major equipment list in the final report of the interface evaluation project for coal mine-coal conversion plants are considered to be sufficient for this report. The interface-project open stockpile consists of four long wedge piles built with two traveling stackers and reclaimed in full cross section by two rotary drum reclaimers. Coal design feed rates to and from this live-storage-blending facility are slightly larger than those required for the flow sheets presented in this report.

A conceptual flow sheet (FS-2-1) has been developed for enclosed coarse-coal live-storage-blending. This scheme is considered as an alternative to multiple-wedge open-stockpile storage-blending. It consists of three V-bunkers. These types of enclosed storage structures and wide-span barns are best suited for storage of the large quantities of coal to be required for coal conversion. As shown in Fig. 5-3, a wide-span barn is essentially a covered wedge stockpile. It would use stackers very similar to those used for open wedge stockpiles. These rail-mounted stackers would move along one side of the barn only and, for this reason, would have only a single boom. Bridge-type bucket wheel and drum reclaimers used with wide-span barns are identical to those used for open stockpiles. Conveyor systems required for wide-span barns are similar to

those required for open wedge stockpile facilities. The deciding factor between use of V-bunkers and wide-span barns for large-capacity enclosed live-storage-blending is cost.

V-bunkers could receive coal from a cleaning plant, from a rail and/ or barge receiving facility, or from dead storage. Coarse coal (2 in. $\times$ 0) is fed to the V-bunker facility by a 72-in.-wide live-storage feed conveyor that terminates at a transfer tower (FS-2-1). Here a flop gate diverts coal to either the No. 1 V-bunker or a 72-in.-wide live-storage feed-transfer conveyor. The transfer conveyor transports coal to bunker No. 2 or another transfer conveyor that feeds bunker No. 3. One V-bunker is filled while one of the other two is being reclaimed. Tripper conveyor systems, consisting of a conveyor and a mobile tripper car that moves along it, are used to fill each V-bunker evenly. These tripper conveyor systems are located in the center of the enclosing structure bunker in a conveyor gallery. Coal is discharged into a bunker on both sides of the tripper car through chutes and through continuous slots in the gallery floor. Continuous-seal belts on the floor slots control the escape of dust from the bunker into the conveyor gallery.

Coal is reclaimed from a V-bunker by a rotary plow feeder that travels the entire length of the bunker. Reclaimed coal is discharged from this feeder onto a reclaim conveyor located in a tunnel under the bunker. These conveyors, one per bunker, discharge to one of two transfer conveyors that can divert coal to either the power/steam plant or a two-way switchover bin that feeds coal to the conversion process.

No flow sheets have been developed for dead coal storage. The multiple dead pile arrangement presented in the coal mine-coal conversion plant evaluation final report is judged to be well suited for coal conversion plants.

5.4 Coal Fine Crushing

Nine conceptual flow sheets and major equipment lists have been developed for coal fine crushing. Reasons for developing this number of fine-crushing flow sheets are as follows: the fine coal requirement of eight of the nine coal conversion processes considered, the range of

different required coal feed size consists within the fine-coal classification, possible alternative fine-coal crushing approaches, and a possible need to minimize the formation of ultrafines during coal fine crushing. Coal fine-crushing equipment also is required to prepare coal for the power/steam plant atmospheric pressure fluidized-bed (AFB) steam generators. The feed coal top size desirable for AFB steam generators, however, could be as high as 1/2 in. Though this is a slightly coarser top size than that defined for fine-coal flow sheets, it is well within the capabilities of the type of flow sheets developed to provide 1/4 in. $\times$ 0 and 1/8 in. $\times$ 0 coal for the U-GAS and COGAS processes, respectively. (Fine coal, previously defined in Sect. 4.3, is coal that contains particles not greater than 1/4 in., but with some particles greater than 20 mesh. Note: a less specific definition of fine coal is used in Sect. 5.2.2, to be consistent with coal-cleaning industry terminology.)

Bechtel Table 5-2 summarizes most of the different approaches — different fine-crushing circuits — for which flow sheets and major equipment lists are presented. These circuits are arranged according to the coal conversion processes for which they were developed. The table also identifies crusher designs specified for each circuit.

In Table 5-2, the proposed fine-crushing circuit for each conversion process is that judged, on the basis of current technical information, to provide the best combination of reliability and operating flexibility. For most processes this judgment is subjective and is not based on direct comparison of actual costs for competing crushing circuits. The circuit chosen could change if ultrafines minimization is important. Many factors could result in replacement of a proposed circuit by an alternative or completely new circuit. These factors include more definitive conversion reactor coal feed requirements (particularly for the SRC-I and SRC-II processes), detailed circuit cost estimates, conversion process demonstration plant results, and possible advances in fine-crushing technology.

Evaluation of results of an onsite fine-crushing test program at an actual commercial coal conversion plant represents another principal factor in determining fine-crushing circuit design and equipment specification at that plant. Such a test program would be completely justifiable for crushing facilities of the capacities required for coal conversion.

A possible exception would be when commercial plant feed coal is used in a demonstration plant. In this case a fine-crushing assessment program would be part of the demonstration plant test program. A typical fine-crushing test program would be performed using a large representative coal sample and would involve testing of several crusher designs, a wide range of crusher operating conditions, and, probably, different crushing circuits. For a specific coal, results would quantify the effect of crusher designs and operating conditions on crushed coal size consist. With this information and cost estimates a best crushing circuit design can be formulated.

Unfortunately, as far as could be determined, results of any comprehensive fine crushing test program on either Pittsburgh or Kentucky No. 9 seam coals have not been published or otherwise made available in the public domain. As a result, the flow sheets and crusher selections presented in this report are based on general experience in coal fine crushing and on crusher manufacturer performance estimates.

With one exception (FS-10 in Table 5-2) all fine-crushing flow sheets use multirow cage mills. These mills are well suited to conversion coal fine crushing for the following reasons:

1. They have high capacities — on the order of 50,000 tons of coal per day can be crushed with a reasonable number of mills (eight is the maximum number of mills specified for any of the fine-crushing flow sheets).
2. Compared with other types of fine crushers, ultrafines production is usually lower.
3. They are of relatively simple design.
4. Reliability is high.
5. Maintenance is comparatively easy (cage mills can be designed for rapid cage and lining replacements).
6. They are compact in size.
7. They accept coal with as-received total moisture. (Crushed coal quality and mill capacity, however, decrease as coal moisture concentration increases.)
8. They readily accept 2 in. × 0 and coarser coal.

9. Within limits, mill operating conditions can be changed easily to accommodate changes in coal comminution characteristics. This is particularly true for cage speeds and configuration.
10. Coal conveying-drying gas is not required.
11. They have comparatively low capital cost.

Cage mills crush material primarily by impaction. A typical high-capacity, multirow cage mill consists of two or more concentric cages with adjacent cages rotating in opposite directions. Each cage consists of rows of round bars supported at both ends by rings. Alternate rings are connected through shafts to separate drives for counterrotation of adjacent cages. Coal is gravity fed into the center of the revolving inner cage. Centrifugal force throws it against the inner cage bars and successive cages until it finally hits the breaker plates lining the mill housing. After some rebounding back into the cages, crushed coal exits at the mill base.

The following major cage mill variables affect final product size consist:

1. cage speeds,
2. cage bar spacing,
3. number of cages (rows),
4. whether the mill is in an open or closed crushing circuit (in closed-circuit crushing, mill product is classified and oversize material is returned to the mill for further crushing),
5. number of crushing stages.

With the exception of FS-10 (Table 5-2) in which rod mills are used to produce 100% -20 mesh coal, all fine-crushing flow sheets use belt conveyors for coarse- and fine-coal transport, bins for coal surge storage, gravimetric belt feeders for cage mill feeding, and cage mills. Design capacities established for these components are based on reliability considerations and the need to provide coal to a postulated five-train coal conversion plant. With exception of FS-4, two cage mill capacities were judged to meet these general requirements: 600 and 400 tons/hr. Use of

these two design capacities results in

1. a reasonable number of cage mill trains,
2. no extrapolation of current cage mill designs,
3. sufficient excess mill capacity when required,
4. specification of fine coal conveyors well within existing conveyor capacities,
5. flow sheets that are consistent with the level of current cage mill coal-crushing performance data.

Cage mill requirements specified in the major equipment list are based on use of the largest drives (multirow cage mills require two drivers, one for each cage set) recommended by manufacturers for a given mill size. Actual mill power consumption normally would not reach the specified rates. However, the cost savings to be gained from specifying lower power drives (e.g., 1000 hp instead of 1200 hp) is not significant in comparison to the total capital cost of a fine-crushing facility. Specification of maximum design power for crushers, allowing for a measure of operating flexibility, is normal practice in the minerals beneficiation industry.

The number of cage mills required for a flow sheet determines the number of mill feeders and surge bins required. Each mill is supplied by a single gravimetric belt feeder and a single surge bin. Construction of belt feeders capable of feeding up to 600 tons of coal per hour appears to be technically feasible; however, multiple feeders could be used for a single cage mill.

Coal is conveyed to and from all fine-crushing operations by belt conveyors. For both applications, two full-capacity conveyor systems are provided. Each coal conveyor system has an equipment-to-plant design-capacity ratio of 1.33. The equipment design capacity is that specified for equipment procurement. (Equipment design capacities are presented in major equipment lists.) Plant design capacity for all fine-crushing flow sheets is 1771 tons of coal per hour having a total moisture concentration of 8.0 wt %. This is equivalent to 42,500 tons of conversion reactor feed coal per day or 85% of the entire conversion plant design daily coal consumption of 50,000 tons/day. The other 15% is burned in the power/steam

plant. Plant design capacities at various points in the fine-crushing flow sheets are presented in the material balances provided with each flow sheet.

The conveyor system equipment design to plant design capacities ratio of 1.33 was established because it provides

1. extra conveyor capacity to avoid spillage as a result of inadvertent overloading,
2. faster fine-crushing surge storage filling when required,
3. a safety margin for off-specification crusher performance,
4. for near-plant design surge storage bin filling with a single conveyor system (i.e., when the other bin-filling conveyor system is out of service).

The coal fine-crushing flow sheets provide both high operating reliability and operating flexibility. However, different design approaches could result in flow sheets with comparable operating reliability and flexibility. Actual commercial fine-crushing plant designs are always a compromise among achievement of high reliability, operating flexibility considerations, capital costs, and operating costs.

5.4.1 Coal fine crushing without ultrafines removal

FS-3 is the proposed fine-crushing circuit for preparing 8 mesh $\times$ 0 coal (coal feed for the Exxon Donor Solvent and Exxon Catalytic Gasification Processes) and 12 mesh $\times$ 0 coal (coal feed for the SRC-I and SRC-II Processes). These two crushed coal size distributions could be obtained by use of different cage mill speeds and, possibly, slightly different cage bar spacings. Cage mill design capacities and installed powers would, however, be identical or very similar for both size distributions.

FS-4 is the proposed fine-crushing circuit for preparing 14 mesh $\times$ 0 coal (HYGAS coal feed) and 20 mesh $\times$ 0 coal (Texaco Partial Oxidation Gasification coal feed). First-stage crushing is very similar to FS-3, the main difference being use of larger capacity, two-row-type cage mills.

Coal from first-stage crushing is conveyed by a scissor conveyor system to a second tripper conveyor system that fills eight in-line second-stage crushing surge bins. Feed of coal from these bins is identical to

that for first-stage crushing. Second-stage crushing is accomplished in eight 72-in. four-row cage mills. These mills discharge to one of two fine-coal conveyors.

FS-4-1 presents an alternative two-stage open-circuit fine-crushing arrangement. It makes use of stacked mills that avoid use of conveyors and surge bins between first- and second-stage crushings. Capital cost of this arrangement is usually less than for that presented in FS-4. However, it has less operating flexibility and is less efficient than the FS-4 arrangement.

FS-5 is an alternative flow sheet for both FS-3 and FS-4. Instead of open-circuit crushing, it uses closed-circuit fine crushing. The main advantages of this flow scheme are reduced production of ultrafines and a higher crushing efficiency; that is, the power consumption required for closed-circuit crushing is less than for comparable open-circuit crushing. A disadvantage is its greater complexity and resulting higher cost compared with open-circuit crushing.

In FS-5 coal classification is achieved in an air classifier. Oversize from the classifiers is conveyed by a scissor conveyor system to surge storage for additional size reduction. Coarse-coal feed from live storage is also conveyed by this same scissor conveyor system to surge storage. Coal is fed from surge storage to cage mills in a manner analogous to that described for FS-3 and FS-4.

FS-6 is the proposed fine-crushing circuit for preparing 1/4 in. $\times$ 0 coal (U-GAS coal feed) and 1/8 in. $\times$ 0 coal (COGAS coal feed). Except for the number of parallel trains and the fine crusher specification, this flow sheet is similar to FS-3. The FS-3 general coal flow pattern also applies to this flow sheet.

Two crusher alternatives are specified for production of 1/4 in. $\times$ 0 coal: two-row cage mills and hammermills. Use of hammermills would result in more fines but would save in power consumption. Hammermills, however, are not recommended to produce 1/8 in. coal because of their excessive production of oversize material.

In addition to closed-circuit fine crushing (FS-5), two other flow sheets were developed with minimization of ultrafines in mind. Both of these schemes require relatively dry coal feed. Therefore, a coarse-

coal drying flow sheet was developed. This flow sheet, FS-7, uses a conventional fluidized-bed coal dryer. Drying gas for this dryer, however, is obtained from the power/steam plant. This approach has two main advantages compared with the conventional approach of using dryer product coal as an energy source: first, it is more energy efficient; and, second, since the power/steam plant uses fluidized-bed steam generators with limestone injection, the drying flue gas does not require removal of sulfur oxides.

In FS-7, before drying, coal is handled in equipment similar to that described for FS-3. Gravimetric belt feeders are used to feed coal from three in-line surge bins to three identical, parallel fluidized-bed coal dryers. Fine coal, entrained in dryer flue gas, is removed by cyclones and baghouses in series. Fine coal recovered by the dryer cyclones is discharged through rotary valves and flow switching chutes to one of two parallel fine-coal conveyors. Here it combines with coarse coal discharged directly from the dryers. Ultrafine coal removed by the dryer baghouse systems could be combined with the coarse coal on the fine-coal conveyors without further preparation, if ultrafines are acceptable conversion reactor feed. If ultrafines are detrimental to conversion reactor operation, they could be conveyed by a mass-flow conveyor to an ultrafines treatment operation. This second ultrafines alternative is shown in FS-7.

FS-8 is a flow sheet for minimizing ultrafines in 1/4 in. $\times$ 0 crushed coal (U-GAS coal feed). Dried coarse coal, 2 in. $\times$ 0, is screened in double-deck, vibrating screens to separate -1/4 in. coal. Undersize coal is discharged directly to fine-coal conveyors for transport to the U-GAS reactor lock feed system or pretreater. Screen oversize is conveyed by a scissor conveyor system in series with a tripper conveyor system to surge storage. From here it is crushed to -1/4 in. top size in two-row cage mills. These discharge directly to the fine-coal conveyors where crushed coal and screening undersize are combined.

Dry coal screening at 1/4 in. represents an approximate, practical lower size limit and requires relatively dry coal. Because of this, only FS-8 was considered as a possible ultrafines minimization approach for U-GAS. Also, coal entering FS-8 was specified as coming from FS-7. Screening of coal at sizes finer than 1/4 in. results in rapidly decreased

screen loadings; that is, the screen area required increases rapidly. Also, the amount of coal surface moisture that can be tolerated without deterioration of screen efficiency becomes increasingly smaller. Coal surface moisture content above 2 to 3% is sufficient to "blind" fine dry screens.

The Texaco Partial Oxidation gasification process uses a coal feed system in which a high solids concentration coal-water slurry is injected by positive displacement pumps into an entrained-flow gasifier. Gasifier operating pressure is 500–1500 psig, depending on synthesis gas requirements and coal composition. To produce feed slurry for their gasifier, Texaco has proposed rod mill wet grinding.

FS-10 is a possible wet grinding or fine-crushing flow sheet for Texaco Partial Oxidation. Coarse coal, 2 in. $\times$ 0, after surge storage is ground to 100% –20 mesh in wet rod mills in open circuit. (Water is combined with coal in the mills to produce a slurry containing 60 wt % coal. Thirteen, 14.5-ft-diam $\times$ 20-ft-long rod mills are specified to grind 1771 tons of coarse coal per hour. These rod mills were specified using an estimated power consumption of 10 hp per ton of coal per hour of feed.

The reason for specifying rod mills rather than ball mills in FS-10 is that rod mills produce a narrower size range product. They also produce little oversize and few ultrafines. A disadvantage of rod mills is that they are capacity limited; therefore, multiple units are specified. Rods that will perform properly in large rod mills are not available; the length of rods is limited to approximately 20 ft – longer rods will bend during grinding and break. The largest rod mills currently installed are 15 ft in diameter.

5.4.2 Coal fine crushing with ultrafines removal

As indicated in Sect. 4.3.3, a conceptual fine-coal ultrafines separation flow sheet (FS-9) was developed. It could be used with any of the other fine-crushing flow sheets provided the crushed coal is sufficiently dry. The FS-10 plant design material balance is a continuation of that presented in FS-3 for SRC-I and SRC-II feed coal crushing. Crushed ultrafines separation feed coal total moisture is 8.0 wt %.

In FS-9, fine coal is conveyed to a series of surge bins. From each bin it is fed by a gravimetric belt feeder to an air separator type classifier. These air separators are similar to those described for FS-5, cage mill closed-circuit fine crushing. The main difference is that hot flue gas (450°F) from the power/steam plant is injected into the ultrafines separators to reduce coal moisture. Ultrafine coal is discharged from each separator at two locations: the separator fines cone and the exiting, drying flue gas. Ultrafines collected in the separators are discharged by rotary lock valves to one of two mass-flow conveyors. Ultrafines entrained in separator flue gas are removed by cyclones in series with multicompartment baghouses. Coal collected from both the cyclones and baghouses is discharged to the same mass-flow conveyors as air separator removed ultrafines.

Ultrafines-free coal is discharged from the air separators by rotary lock valves and flow-switching chutes to one of two fine-coal conveyors that carry it to conversion reactor feed systems.

Reliable and efficient operation of air (gas) separator classifiers is dependent on feed coal surface moisture. The amount of moisture acceptable depends upon the type of coal and the separator feed size consist and separation particle size. By hot flue gas injection, both Pittsburgh and Kentucky No. 9 Seam coals can probably be classified successfully at feed sizes down to 100% -20 mesh, the finest of the crushed coal size consists considered. Actual quantities of drying flue gas required and the design of separator internals for specific separation facilities would be determined by testing. The natural balance values presented in FS-9 are only estimated values.

Depending on feed coal size consist, a number of separation trains other than six (shown in FS-9) could be required. The number of separation trains also depends on the ultrafines size. For development of FS-9, ultrafine coal was defined as coal containing particles all of 100 mesh or finer.

In assessing flow sheet FS-9 it should be recognized that dry coal classification at the sizes and capacities that would be required for ultrafines removal has never been commercially practical, as far as could

be determined. Large-scale classification of fine particulates is, however, used for production of other materials, notably cement. This technology may be totally or partially adaptable to large-scale coal classification if it is required.

If fine-coal ultrafines separation is required or justified for a specific conversion process, something must be done with the ultrafines. Consideration of processes for treating ultrafines, however, was not part of the undertaking covered by the project.. Possible uses of ultrafines include firing in pulverized-coal-fired steam generators and agglomeration possibly followed by feeding to the conversion reactor. Agglomeration could be accomplished by either briquetting or pelletizing. As far as is known, however, agglomerated coal ultrafines have never been used in any of the conversion reactors considered in this report.

5.5 Coal Pulverizing and Grinding

As reviewed in Sect. 4.3.4, the two ways of producing the pulverized or ground coal required by H-Coal are dry pulverizing and liquefaction solvent grinding. This section presents a conceptual flow sheet for solvent grinding. Conceptual flow sheets material and enthalpy balances and major equipment lists for two drying-pulverizing alternatives are presented in the coal mine-coal conversion plant interface evaluation and conceptual design project report.²

The two coal-pulverizing alternatives presented in the coal mine-coal conversion interface report are ball tube mill and roller mill coal pulverizing. In both alternatives, large quantities of hot flue gas (450°F) from the power/steam plant are used to transport coal through the mills and simultaneously to dry it from as-received to 2.0 wt % total moisture. After it is pulverized to 70% -200 mesh, coal is de-entrained from the conveying-drying flue gas in cyclones in series with large, multicompart-ment baghouses. Flow sheets and conceptual drawings appear in the interface report (see Table 5.1).

FS-11 presents a conceptual flow sheet for grinding of coal in liquefaction process recycle solvent. To meet the feed coal moisture requirement of the H-Coal process, coal is first dried in FS-7. After drying, coal is conveyed by two parallel full design capacity conveyers to two parallel surge storage tripper conveyor systems that discharge into in-line surge bins. From here coal is discharged by gravimetric belt feeders to fine-crushing cage mills. The surge storage, mill feeding, and fine-crushing operations are very similar to those described in FS-3. Fine crushing is done before grinding to reduce overall comminution power requirement; that is, the power required for the approach shown in FS-11 is considerably less than that required for direct feeding of 2 in. $\times$ 0 coal to a ball mill.

Coal crushed to a nominal 1/8 in. $\times$ 0 size is discharged from the cage mills to screw conveyors that carry it to 18-ft-diam $\times$ 28.5-ft-long ball mills. Estimated installed power requirements for each mill is 6000 hp. Ball mills of the specified size are currently commercially available. Two copper concentrators, located in Bougainville in Papua, New Guinea, and Pinto Valley in Arizona, used 18-ft-diam ball mills for primary grinding. Use of ore grinding ball mills with diameters in excess of 20 ft and lengths of up to 40 ft is anticipated in the near future. The 6000-hp mill power specified is slightly higher than that for currently operating ball mills (5000 hp) but is within the capability of current mill drive systems.

Pulverized coal, as a 45 wt % slurry, is discharged from the ball mills to sumps. From here, it would probably be pumped to high-pressure conversion reactor coal slurry injection pumps.

In FS-11, coal is assumed to be dried before grinding. The material balance feed coal total moisture concentration is 3.0 wt %, one percentage point more than the H-Coal feed moisture requirement presented in Table 4-1. This difference is not considered significant, but, if required, coarse coal probably could be dried to 2.0 wt % moisture as in FS-7 or a similar drying flow sheet. In the EDS, SRC-I, and SRC-II conversion processes coal is dried after solvent slurring by heating and steam flashing. Presumably, this method also could be used with H-Coal. This

would not affect ball mill solvent grinding; 8.0 wt % total moisture coal is acceptable ball mill feed.

The technical feasibility of grinding coal in liquefaction process solvent has yet to be demonstrated. Major potential problems associated with solvent-coal grinding include the following:

1. control of coal solvent temperature. Most liquefaction processes use recycle slurring solvent that would have to be heated to reduce its viscosity to values suitable for grinding.
2. mill system sealing. The entire mill system would have to be sealed to prevent solvent vapor losses.
3. mill coal feeding. A system for feeding large quantities of crushed coal to a sealed mill system would have to be demonstrated.

5.6 Ash/Slag Removal Operations

The three general types of ash handling systems are hydraulic, pneumatic, and mechanical; but only the first two have been in general use in this country. Both the pneumatic and hydraulic systems are readily available from a number of manufacturers. The choice between the two systems usually is dictated by plant location. There are very few installations having fill areas in the vicinity of the plant, where hydraulic handling is applicable. In most cases plant locations are such that ashes have to be trucked away. Pneumatic handling systems are used in these instances.

Hydraulic systems can handle high capacities, ~20 to 30 tons of fly ash and 30 to 50 tons of bottom ash per hour. In a typical system, bottom ash is transferred from a primary storage hopper to the fill area by means of a hydraulic jet pump or centrifugal materials-handling pump. Fly ash is collected through a vacuum system serving the dust hoppers and conveyed to a hydraulic vacuum producer. Ash then is mixed with water and discharged into a deaerating tank and from there discharged by gravity to the fill. Valves in the discharge line provide the means of directing either fly ash or bottom ash to fill, one at a time.

Stream jet systems (pneumatic) have been designed for almost any capacity, depending on pipeline sizes and stream jet capacity. A single storage point can be used for both fly ash and bottom ash. Bottom ash

capacities of up to 50 tons/hr and fly ash capacities up to 25 tons/hr have been employed.

A typical ash discharge system is described below. Its operation is similar to that used in conventional boilers with the additional requirement of having to operate at superatmospheric pressure (up to 1000 psig). Suppliers would have to modify system designs to meet coal conversion plant requirements.

A slag-disintegrating vessel, designed according to American Society of Mechanical Engineers codes, is connected to the lower portion of the gasifier. The vessel is equipped with a water-cooled slag sweeper, wiper, and slag spray header. The hot molten slag is discharged through the slag monkey and falls into a chilled water bath (disintegrator vessel maximum temperature is 140°F). The slag is quenched into frits, which are easily discharged from the system. A continuous recirculating water system is required to remove the heat of quenching and maintain the water temperature below 140°F.

A slag wiper may be provided to prevent the buildup of beards around the slag monkey. This type of equipment typically includes a double-roll slag grinder which ensures that the frits are of adequate size to be handled satisfactorily in the slag transfer system outside of the gasifier. A recirculation pump provides water at sufficient pressure to serve as seal water for the grinder and, after passing through a heat exchanger, as quenching water and cooling water for the slag sweeper.

The slag discharge from the grinder falls into a lockhopper system, which is depressurized when filled to capacity. A slag pump is used to pump out the depressurized chamber; the effluent is sent to a series of hydrobins for water recovery.

The slag settles during the water recovery phase in the hydrobin, and the water is decanted into a slag water clarifier. The dewatered slag at the end of a hydrobin cycle is discharged into railroad hopper cars and transported to the disposal area. This material can be used for road building or other fill purposes; it could also be returned to the coal mine for disposal.

The water recovered from the hydrobins, after clarification, is returned to the transport water storage tank and reused. Sludge slurry

pumps are provided to empty the settled material from the clarifier and return same to the hydrobins. These pumps are operated as necessary.

Alternative methods for ash and slag disposal are presented in FS-12 and FS-13. These flow sheets do not cover the letdown system itself (see inlet boundary in Sect. 4.2.2) but begin with a wet ash or slag. FS-12 shows the steps involved in dewatering the ash/slag slurry and subsequent solids removal by rail or cross country conveyor to a solid waste disposal site. In FS-13 the wet ash or slag is transported by slurry pipeline to an impoundment where decantation, fixation, and stabilization take place before landfill disposal. All of the equipment described in FS-12 and FS-13 is readily available commercially; sizing will depend on the quantities of material to be handled in each process.

References

1. *Conceptual Flow Sheets Development for Coal Conversion Plant Coal Handling - Preparation and Ash/Slag Removal Operations*, Report Job 13022, prepared by Bechtel Corp. for Union Carbide Corp., San Francisco, Calif., July 1979.
2. *Coal Mine-Coal Conversion Plant Interface Evaluation and Conceptual Design*, Vols. 1 and 2, FE-2370-16, prepared by Bechtel Corp. for the Department of Energy, Washington, D.C., November 1977.

6. RESPONSE TO SURVEY QUESTIONNAIRES

6.1 Introduction

Initially, questionnaires were prepared to survey vendors about three types of equipment — pulverizers, thermal dryers, and ash/slag grinders.

The initial pulverizer questionnaire covered two types of coal; five different product size consists, and three pulverizing processes — dry, wet, and simultaneous drying and pulverizing. A response matrix consisting of 27 items was included. The questionnaire, which was sent to 19 vendors, was evidently too complex. Nine of the 19 vendors did not reply, and 7 replied negatively giving such reasons as "too much time involved to answer," "fine grinding requirements too stringent," or "this is proprietary information." Three vendors did return partially completed questionnaires. The equipment recommended by 2 of the 3 vendors would require an inordinate number of units to meet the system feed rate (in one case, 120 units and in the other, from 45 to 82 units, depending on product size requirements).

The initial thermal dryer questionnaire was based on two types of coal, seven different feed size consists, and a reduction of total moisture from 10 to 2%. The response matrix had 29 items. Of the 20 vendors receiving the questionnaire, 7 replied negatively, 5 did not reply, and 8 replied positively. Most vendors did not complete the questionnaire because of the time required to do so (estimated in excess of 100 man-hours in one case). The majority of replies did not answer the questions in many instances.

The ash/slag grinder questionnaire covered two types of coal and operating conditions for six conversion processes. The response matrix had 25 items. Of the vendors receiving the questionnaire, only two supplied meaningful information.

Coal feed size consist requirements for the nine coal conversion processes selected for this survey were found to differ greatly from those found in recent studies of these processes. Based on this new information on size consists, along with the lack of response to the original questionnaires and the availability of a coal handling and preparation block

flow diagram developed by Bechtel National, Inc., a second survey (based on Bechtel's recommendations) covering eight types of coal conversion equipment was conducted. The equipment types surveyed were cage mills, rod mills, ball mills, ball tube mills, bowl pulverizers, fluidized-bed dryers, screens, and separators. (The second survey did not include ash/slag grinders or any thermal dryers besides fluidized-bed dryers.) The second survey was conducted by telephone because of time limitations. Table 6.1 lists the types of equipment selected for the second survey and specifies coal feed and product sizes and moisture conditions for each type. Results of the second survey are presented in Sects. 6.2, 6.3, and 6.4. Each table presenting survey responses is preceded by a short

Table 6.1. Types of equipment included in the second survey

Equipment	Feed size	Product size	Moisture
Cage mills	2 in. $\times$ 0	8 mesh $\times$ 0 ^a 14 mesh $\times$ 0 ^a 20 mesh $\times$ 0 ^a	10 and 5% 10 and 5% 10 and 5%
Rod mills	2 in. $\times$ 0	100% -20 mesh	Wet grind (water)
Ball mills	1/8 in. $\times$ 0	70% -200 mesh	Wet grind (solvent)
Ball tube mills	2 in. $\times$ 0	70% -200 mesh	2%
Bowl pulverizers	2 in. $\times$ 0	70% -200 mesh	2%
Fluidized-bed dryers	2 in. $\times$ 0	2 in. $\times$ 0	From 10 to 5%
Screens	2 in. $\times$ 0	2 in. $\times$ 1/4 in. and 1/4 in. $\times$ 0	5% 5%
Air separators	8 mesh $\times$ 0 14 mesh $\times$ 0 20 mesh $\times$ 0	8 $\times$ 100 mesh ^a 14 $\times$ 100 mesh ^a 20 $\times$ 100 mesh ^a	5% 5% 5%

^aMinimum amount of -100 mesh material.

discussion of the particular type of equipment and a table listing operating conditions.

Copies of the completed questionnaires were mailed subsequently to each of the vendors surveyed by telephone. Vendors were asked to verify their responses and to reply by mail in the cases of incorrect responses or further comment. Copies of the questionnaires from the first and second surveys are presented in Appendixes B and A, respectively.

6.2 Comminution Equipment

6.2.1 Cage mills

Results of our study indicate that cage mills will be utilized in almost all coal preparation operations related to coal conversion plant processes. The operating conditions that were the basis for the survey are presented in Table 6.2. Note that there are two different moisture conditions and three different product sizes. Table 6.3 presents the results of the survey.

Both vendors contacted recommended open-circuit grinding for all product size and moisture combinations. The requirement for a maximum of nine mills to process 1800 short tons per hour (stph) of coal should be quite workable. Predicted maintenance downtime for cage mills is very low. All of the cage mills recommended were 4-row machines because the product size consists on the questionnaire were 8 mesh $\times$ 0, 14 mesh $\times$ 0, and 20 mesh $\times$ 0.

Cage mills appear to be very dependable and versatile machines for a variety of coal comminution operations. The results of this survey suggest the need for a DOE feasibility study to help advance the state of the art, provide statistical data, and eventually establish a sound theoretical basis for design and operation of cage mills. Such a cooperative research program would be analogous and related to the program now being carried out at KVS to investigate the mass-size balance over time approach to coal comminution.

Table 6.2 Operating conditions — cage mills

OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia, and Kentucky No. 9 in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

PERCENT MOISTURE IN FEED: CASE 1 10% TOTAL 8% SURFACE

CASE 2 5% TOTAL 3% SURFACE

FEED SIZE: 2 in. x 0

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	+2 in.	+1-1/2 in.	+1 in.	+3/4 in.	+1/2 in.	+1/4 in.	+8 mesh
% RETAINED	12.66	22.79	32.83	48.63	67.08	83.76	

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SOLIDS MEAN SPECIFIC GRAVITY: 1.4

DESIRED PRODUCT SIZES: 8 mesh x 0

14 mesh x 0

20 mesh x 0

PRODUCT REQUIREMENT: Minimum amount of -100 mesh material

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER CAGE MILL (OR LINE): 800 hr/year

The vendors surveyed contributed the following recommendations and miscellaneous information on cage mills:

1. Recommended circuit and arrangement. A single-stage, one-mill-per-stage, open-circuit arrangement should be used.
2. Types of motors recommended. Totally enclosed, fan-cooled motors should be used for the lower-horsepower motors. However, because such motors are difficult to obtain in the higher-horsepower range, any type of motor meeting code requirements for this application could be used.

Table 6.3 Results of cage mill survey

ID No.	Vendor	Feed material moisture (% total/% surface)	Product size	Recommended mill size [diam (in.)]	Number of mills recommended (operating/standby)	Cage mill capacity (stph)	Predicted amount of the following in product:	
							-100 mesh (%)	-200 mesh (%)
1	A	10/8	8 mesh × 0	72	5	360	18-20	6-7
2	B	10/8	8 mesh × 0	75	3/1	600	41	24
3	A	5/3	8 mesh × 0	72	5	360	18-20	6-7
4	B	5/3	8 mesh × 0	75	3/1	600	41	24
5	A	10/8	14 mesh × 0	72	7	258	25-30	8-10
6	B	10/8	14 mesh × 0	75	3/1	600	46	27
7	A	5/3	14 mesh × 0	72	7	258	27	8-10
8	B	5/3	14 mesh × 0	75	3/1	600	46	27
9	A	10/8	20 mesh × 0	72	9	200	40	12-13
10	B	10/8	20 mesh × 0	75	3/1	600	56	35
11	A	5/3	20 mesh × 0	72	9	200	40	12-13
12	B	5/3	20 mesh × 0	75	3/1	600	56	35

ID No.	Vendor	Power required per unit (hp)	Motor (rpm)	Type drive	Reduction ratio	Maintenance downtime per unit (hr/year)	Cost of each unit f.o.b. factory (\$)	Shipping weight per unit (lb)
1	A	1400 ^a	1200	V-belt	2:1 ^b	50	100,000	52,000
2	B	3500 ^a	1800	c	3:1 ^b	70	300,000	50,000
3	A	1200 ^d	1200	V-belt	2:1	50	100,000	52,000
4	B	3500	1800	c	3:1	70	300,000	50,000
5	A	1400 ^a	1200	V-belt	2:1	50	100,000	52,000
6	B	4600	1800	c	2.7:1	70	300,000	50,000
7	A	1200 ^d	1200	V-belt	2:1	50	100,000	52,000
8	B	4600	1800	c	2.7:1	70	300,000	50,000
9	A	1400 ^a	1200	V-belt	2:1	50	100,000	52,000
10	B	6000 ^d	1800	c	2.47:1	70	300,000	50,000
11	A	1200 ^d	1200	V-belt	2:1	50	100,000	52,000
12	B	6000	1800	c	2.47:1	70	300,000	50,000

^a Driven by dual motors - 800 hp driving the large cage, and 600 hp driving the small cage.

^b Not more than 3:1.

^c Gearbox, single input, double output with a direct-coupled motor.

^d Driven by dual motors - 700 hp driving the large cage, and 500 hp driving the small cage.

3. Lubrication system. The lubrication of cage mills is done mainly by static oil bath and grease.
4. Setting adjustments. The setting of space between impact bars is constant (preset), not variable.
5. Air volume control. If air volume control is required, a pipe is installed between the outlet and inlet of the mill. This also helps reduce mill noise.
6. Recommended method of feed and feed control. Any method of feeding and feed control that provides relatively constant feed is acceptable. The chute to the mill inlet should be enclosed to eliminate dusting.

6.2.2 Rod mills

Rod mills are proposed for the final grinding operation to produce 100% -20 mesh coal and water slurry product for the Texaco Partial Oxidation process. The operating conditions that were the basis for the survey are given in Table 6.4, and the results of the survey are given in Table 6.5.

Vendor C stated that the initial feed size of 2 in. $\times$ 0 would have to be precrushed to $-3/8$ in. before being fed to their rod mill. The use of ten operating mills, along with one standby mill, appears to be a practical approach. Maximum practical length of rod mills is about 20 ft; longer rods tend to tangle and break up when tumbled.

6.2.3 Ball mills

Ball mills are proposed (solvent grinding) for the H-Coal process, which requires a 70% -200 mesh size consist coal-solvent slurry. Number 6 fuel oil is assumed to be the solvent; the feed size produced by the cage mills is $1/8$ in. $\times$ 0. The operating conditions that were the basis for the survey are presented in Table 6.6; the results of the survey are presented in Table 6.7.

The difference in capacity of the two mills (A and B) shown in Table 6.7 is a result of uncertainty of the vendors about the grinding characteristics of coal in recycle oil. Both vendors stated that the oil properties, and thus the grinding action, varied greatly. However, using the

Table 6.4. Operating conditions — rod mills

OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia, and Kentucky No. 9 seam in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

PERCENT MOISTURE IN FEED: .10% TOTAL 8% SURFACE

TYPE OF CIRCUIT: Wet, open circuit (water)

FEED SIZE: 2 in. x 0

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	+2 in.	+1-1/2 in.	+1 in.	+3/4 in.	+1/2 in.	+1/4 in.	+8 mesh
% RETAINED		12.66	22.79	32.83	48.63	67.08	87.76

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SOLIDS MEAN SPECIFIC GRAVITY: 1.4

DENSITY OF MILL DISCHARGE: 60 to 64 wt % SOLIDS

DESIRED PRODUCT SIZE: 100% -20 mesh

PRODUCT REQUIREMENT: Minimum amount of -325 mesh material

ESTIMATED MILL POWER AT MILL PINION SHAFT: 10 hp/stph

TOTAL PLANT FEED CAPACITY: 45,000 otpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER ROD MILL: 800 hr/year

more conservative 180-stph-capacity machines, ten mills in operation and one standby mill seems quite practical. One advantage of solvent grinding is that the coal does not need to be dried. Another advantage is that the slurring of coal and recycle oil is done in the mill, thus eliminating the need for additional equipment.

6.2.4 Ball tube mills

Ball tube mills can be used for dry pulverizing coal to 70% -200 mesh for the H-Coal process. The operating conditions that were the basis for

Table 6.5. Results of survey of rod mills (wet grinding)

	Vendor		
	A	B	C ^a
Mill size, diameter × length, ft	14.5 × 20	13.5 × 19.5	13 × 18.7
Capacity of each mill, stph	180	150	245
Number of mills (operating/standby)	10/1	12/2	8/1
Predicted amount of -325 mesh coal in product, %	25	29	20
Calculated power of each mill, hp	1800	1425	1500
Recommended motor for each mill, hp/rpm	1800/720	1500/?	1500/225
Mill speed, rpm	13.1	13.6	14.5
Rod diameter, in.	1.5 and 2.5	3 and 4	1.5-4
Rod charge, tons/% mill volume	200/35		147/35
Predicted maintenance downtime, hr/year	800	722	400
Recommended feeder	<i>b</i>	<i>b</i>	
Recommended feeder control	<i>c</i>	<i>d</i>	
Mill cost per unit (no motor or charge), \$	660,000	652,000	525,000
Shipping weight each mill (without motor and rod charge), tons	400	235	203

^a Feed to be precrushed to -3/8 in.

^b Continuous weigh feeder.

^c Percent by weight proportional control.

^d Nuclear density meter regulates water flow.

Table 6.6. Operating conditions — ball mills

OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia, and Kentucky No. 9 seam in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

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PERCENT MOISTURE IN FEED: 10% TOTAL 8% SURFACE

TYPE OF CIRCUIT: Grinding in solvent, open circuit

FEED SIZE: 1/8 in. × 0 (cage mill product)

ESTIMATED FEED SCREEN ANALYSIS:

SIZE (mesh)	6	20	100	200
% PASSING	100	50	12-15	4-8

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SOLIDS MEAN SPECIFIC GRAVITY: 1.4

DENSITY OF MILL DISCHARGE: 47 to 50 wt % SOLIDS

DESIRED PRODUCT SIZE: 70% 200 mesh

SOLVENT TYPE: No. 6 fuel oil

OIL/COAL RATIO: 1.14 (BY WEIGHT)

OIL TEMPERATURE 172°F

OIL FLASH POINT: 230°F

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER BALL MILL: 800 hr/year

Table 6.7. Results of survey of ball mills
(solvent grinding)

	Vendor A	Vendor B
Mill size, diameter × length, ft	16 1/2 × 30	16 × 44
Capacity of each mill, stph	500	180
Number of mills (operating/standby)	4/?	10/1
Predicted amount of -325 mesh coal in product, %	50	48
Calculated power at design capacity, hp	5000	5634
Recommended motor, hp/rpm	5000/720	6000/900
Mill speed, rpm	13	14.4
Ball diameter, in.	2-1/2 to 1/2	1-1/2 to 3/4
Ball charge, tons/% mill volume	370/40	812/?
Predicted maintenance downtime, hr/year	400	250
Recommended feeder	<i>a</i>	<i>b</i>
Recommended feeder control	<i>c</i>	<i>d</i>
Mill cost per unit (no motor or charge), \$	1,450,000	827,000
Ball charge cost, \$		293,000
Shipping weight (no motors), lb	1,200,000	2,790,000

a Continuous spout feeder.*b* Weigh belt feeder.*c* Percent by weight proportional control.*d* Nuclear density meter controls solvent flow.

the survey are given in Table 6.8. Flue gas flowing through the ball tube mills would be used for drying the coal. Table 6.9 gives the results of the survey.

Vendors A and B quoted data from their largest mills; an excessive number of units would be needed to process such large system capacities. Vendor C indicated that a larger mill could be designed and built if required. A crushing and drying operation is required to reduce the moisture and size of the 2 in. × 0 initial feed size before it enters the ball tube mill. Each of the large mill systems requires a total of 6600 hp. Although vendor C specified a mill capacity of 250 stph — seven units plus one standby unit — the others specified up to ten units — more backup

Table 6.8. Operating conditions — ball tube mill coal pulverizers

 OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia, and Kentucky No. 9 seam in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

PERCENT MOISTURE IN FEED: 10% TOTAL 8% SURFACE

TYPE OF CIRCUIT: Dry, closed circuit

FEED SIZE: 2 in. x 0

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	+2 in.	+1-1/2 in.	+1 in.	+3/4 in.	+1/2 in.	+1/4 in.	+8 mesh
% RETAINED		12.66	22.79	32.83	48.63	67.08	83.76

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SPECIFIC GRAVITY: 1.4

DESIRED PRODUCT SIZE: 70% -200 mesh

DESIRED MOISTURE IN PULVERIZED COAL: 2.0% TOTAL

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER MILL: 800 hr/year

FLUE GAS AVAILABLE FOR OPERATION OF MILLS: Yes

because of the unproven design. All vendors stated that their mills are highly reliable, having 100 hr/year or less of downtime for maintenance.

An alternative would be to use large bowl pulverizers which have been operated at large capacities. Dry pulverizing, either with ball tube mills or bowl pulverizers, involves very high drying costs. Wet pulverizing does not involve high drying costs.

Table 6.9. Results of ball tube mills survey

	Vendor		
	A	B	C
Mill size, diameter × length, ft	14 × 19.5	13 × 19	20 × 24
Capacity of each mill, stph	106	90	250
Number of mills (operating/standby)	17/1	20/1	7/1
Predicted amount of -325 mesh in product, %	48	46	
Power required, excluding fan, hp	1927	1500	5100
Recommended motor, hp/rpm	2000/1200	1500/1200	6000/1200
Mill speed, rpm	16.5	16	10
Ball diameter, in.		1.25-1.5	<i>a</i>
Ball material		Forged steel	Forged steel
Ball charge, tons/% mill volume	113/?	90/27	225/28
Maintenance downtime, hr/year	40	100	500
Flue gas required, acfm	150,000	115,000	350,000
Flue gas, inlet/outlet temperature, °F	450/160	650/160	450/187
Mill feed crusher		<i>b</i>	<i>c</i>
Recommended feeder		Volumetric	<i>d</i>
Recommended feeder control	Audio control	Variable speed	<i>e</i>
Mill cost per unit (without motor and ball charge), \$	596,000	950,000	3,750,000
Ball charge cost, \$	67,000		
Shipping weight (no motor or charge), lb	418,000	602,000	1,600,000

a 25% 2-in. diameter, 75% 1.25-in. diameter.

b Swing-hammer crusher required at each end of mill to reduce feed to -1.5 in. (70 hp each).

c Swing-hammer crusher required at each end of mill (300 hp each).

d Continuous weigh feeder.

e Audio; measures mill power and sound level in mill.

6.2.5 Bowl coal pulverizers

Bowl pulverizers can be used to dry pulverize coal to 70% -200 mesh for the H-Coal process. The operating conditions that were the basis for the survey are given in Table 6.10. Flue gas flowing through the pulverizers would be used for drying the coal. Table 6.11 gives the results of the survey.

Vendors B and D manufacture very large roller mills for pulverizing limestone. Both stated that their mills would be adapted for coal pulverization with reduced ratings. Although vendor B recommended 7 units plus

Table 6.10. Operating conditions — bowl coal pulverizers

OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia, and Kentucky No. 9 in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

PERCENT MOISTURE IN FEED: 10% TOTAL 8% SURFACE

FEED SIZE: 2 in. x 0

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	+2 in.	+1-1/2 in.	+1 in.	+3/4 in.	+1/2 in.	+1/4 in.	+8 mesh
% RETAINED		12.66	22.79	32.83	48.63	67.08	83.76

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SPECIFIC GRAVITY: 1.4

DESIRED PRODUCT SIZE: 70% -200 mesh

DESIRED MOISTURE IN PULVERIZED COAL: 2.0% TOTAL

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER MILL: 800 hr/year

FLUE GAS AVAILABLE FOR OPERATION OF MILLS: Yes

1 standby unit, the others estimated that as many as 14 units would be needed, based on the unproven design and maintenance problems with equipment of this type. Vendor D proposed a unit that had been built for limestone, having a capacity in excess of 400 stph, be adjusted to 360 stph for coal application. If this type of mill could be adapted successfully, substantial savings in the number of units required could result.

Vendors B and D both stated that larger mills probably would be impractical because their mills are approximately five stories high and cost over \$3,000,000 each. Besides these factors, six to ten small mills would

Table 6.11. Results of bowl pulverizer survey

	Vendor			
	A	B	C	D
Mill size, diameter, in.	118	168		169
Capacity of each mill, stph	120	260	90	360
Number of mills (operating/standby)	15/2	7/1	20/2	5/1
Predicted amount of -325 mesh coal in product, %	48	50	55	23
Calculated power of each mill, excluding fans, hp	990	3000	785	3010
Recommended motor for each mill, hp/rpm	1250/900	3000/900	800/900	3000/1200
Total power of each mill, including fans, hp	2200	4000	1630	6800
Mill speed, rpm	21.5			28
Maintenance downtime for each mill, hr/year	200	200	400	100
Flue gas required for each mill, acfm	170,000	300,000		405,000
Flue gas, inlet/outlet temperature, °F	590/170	600/150	500/170	760/190
ΔP , inlet to outlet, in. H ₂ O	25	25	25	43
Seal air fan for each mill, acfm/hp	2400/40	400/?	1000/?	10,000/150
Recommended feeding method	<i>a</i>	Weigh	Volumetric	Screw
Recommended feeder control	<i>b</i>			<i>b</i>
Mill cost per unit (without motor), \$	825,000	3,250,000	830,000	3,300,000
Shipping weight of each mill, tons	280	750	258	750

^a Gravimetric belt coal feeder.

^b Feed rate is a function of the primary air flow to the pulverizer.

be more practical than two or three large ones because of the dramatic effect that the failure of a large mill would have on total plant capacity.

6.3 Thermal Drying Equipment

For more efficient operation of certain coal conversion processes, vendors suggested that the 100 mesh $\times$ 0 size fraction should be removed from the feed coal. This can be accomplished by use of screens or air separators (classifiers). However, both screens and air separators function most efficiently when the surface moisture of the feed coal is less than 5%. An anticipated 33% of the feed coal will be 1/4 mesh $\times$ 0 and will contain ~12% surface moisture. It is very difficult to reduce the surface moisture of this size fraction to less than 8 to 10% by mechanical dewatering. Thermal dryers, however, could reduce the surface moisture to less than 5%.

Another possible application for thermal dryers is to remove moisture from the feed material before it enters the system. By using this method, the moisture can be released into the atmosphere and/or routed to a water treatment facility, thereby avoiding the problem of disposal within the system.

The telephone survey on thermal dryers covered fluidized-bed dryers only, and the initial survey covered thermal dryers in general. The operating conditions specified for fluidized-bed dryers are presented in Table 6.12, and those for thermal dryers in general are presented in Table 6.14. Table 6.13 presents the results of the fluidized-bed dryer survey. Table 6.15 presents the results of the initial thermal dryer survey.

The results of the fluidized-bed dryer survey show that fluidized-bed dryers are available for drying both types of coal at a size of 2 in. $\times$ 0. These dryers can be built with a single-unit capacity near the total hourly plant capacity. However, all vendors agreed that the practicality of such a large unit was questionable. The vendors also stated a preference for a maximum feed size of 1-1/2 in. $\times$ 0 rather than 2 in. $\times$ 0; with the smaller top size, the fluidizing of the bed and the loss of fines are more easily controlled. The maximum size of feed for which current fluidized-bed dryers have been designed seems to be 1-1/2 in. $\times$ 0.

Table 6.12. Operating conditions — fluidized-bed dryers

 OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia, and Kentucky No. 9 seam in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

HEAT VALUE: 11,300 Btu/lb

PERCENT MOISTURE IN FEED: 10% TOTAL 8% SURFACE

FEED SIZE: 2 in. x 0

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	+2 in.	+1-1/2 in.	+1 in.	+3/4 in.	+1/2 in.	+1/4 in.	+8 mesh
% RETAINED		12.66	22.79	32.83	48.63	67.08	83.76

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SOLIDS MEAN SPECIFIC GRAVITY: 1.4

COAL SPECIFIC HEAT: 0.3 Btu/lb·°F ANGLE OF REPOSE: 35 to 40

COAL TEMPERATURE (FEED): 60°F

DESIRED MOISTURE IN PRODUCT: 5% TOTAL 3% SURFACE

WATER TO BE EVAPORATED: 110 stph/system

FUEL TYPE: Dried Product Coal

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER UNIT: 800 hr/year

Vendors surveyed contributed the following recommendations and miscellaneous information on fluidized-bed dryers:

1. Type of fluidizing gas. All vendors surveyed specified air as the fluidizing gas. However, flue gas from the power-generating facility is acceptable.
2. Dust-collecting equipment. The fines from the dryers are collected in cyclones followed by wet venturi scrubbers.

Table 6.13. Results of fluidized-bed dryer survey

Vendor	Size of dryer	Number of dryers	Dryer capacity		Dryer operating temperature		
			Dried product (stph)	Water removed (stph)	Gas inlet (°F)	Gas exit ^a (°F)	Product (°F)
A	16-ft diam	2	947	55	1400	150	160
B	9 × 12 ft	4/1 ^b	474	27.5	1100	150	140
C	10 × 14 ft	3	632	36.7	1200	150	140
D	No. 170	2	947	55	1000-1200	150	135-140
E	16-ft diam	2	947	55	1000	180	180

Vendor	Fluidizing gas per unit (acfm) ^c	Power req'd per unit (kW)	Type dryer furnace	Dryer furnace fuel	Dryer fuel requirements		Maintenance downtime (hr/year)
					10 ⁶ Btu/hr	stph	
A	198,000	2051	<i>d</i>	<i>e</i>	165	7.3	800
B	172,500	2300	<i>d</i>	<i>e</i>	130	5.75	1600
C	135,100	1707	<i>f</i>	<i>e</i>	158.5	7	400
D	210,000	1976	<i>f</i>	<i>e</i>	160	7	400
E	335,000	3150	<i>f</i>	<i>e</i>	265	11	400

Vendor	Induced draft fan (hp)	Fluidizing fan (hp)	Overfired fan (hp)	Underfired fan (hp)	Pulverizer fan (hp)	Dryer cost per unit f.o.b. factory ^g (\$)	Shipping weight per unit (lb)
A	1900	750			40	1,250,000	600,000
B	2300	50-60			150	1,665,000	600,000
C	2200		40	50		1,260,000	650,000
D	2500		30	50		1,000,000	600,000
E	3000		200	300		1,700,000	600,000

^a At ID fan inlet.^b Operating/standby.^c At cyclone exit and ID fan inlet.^d Pulverized coal fired using pulverized coal burners.^e Dried product.^f Stoker fired.^g Motors and structural steel not included.

Table 6.14. Operating conditions — thermal dryers

 OPERATING CONDITIONS

TYPE OF COAL TO BE DRIED: Pittsburgh seam in Monongalia County, West Virginia, and Kentucky No. 9 seam in Hopkins County, Kentucky

FEED COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15%

GRINDABILITY: 55 HARDGROVE

MOISTURE: 10% TOTAL

TOTAL FEED RATE: 1800 stph

DRIED PRODUCT CHARACTERISTICS

MOISTURE: 2% TOTAL

TOTAL PRODUCT FLOW RATE: 1653 stph

3. Type feeders. One vendor is undecided at this time as to the type feeder to use. All other vendors use roll feeders for feeding from the feed bin to the dryers.
4. Recommended equipment for collection and transport of product. All vendors recommended that covered belt conveyors be used to collect and transport the dried product at the dryer and cyclone discharge.
5. Dust loading in dryer exhaust gas. All vendors design the dryer dust-collection systems so that the exhaust gases discharged into the atmosphere will not contain particulate matter in excess of 0.031 grain/dscf.

Responses from the thermal dryer survey show that thermal dryers that can dry the two types of coal down to 2% total moisture for size consists from 70% -200 mesh to 3/8 in. x 0 are available. Thermal dryers that dry by indirect heat produce a minimum of particulate matter and no SO_x. The rotating, indirect-heat dryers have lower capacities than the nonrotating,

Table 6.15. Results of thermal dryer survey

Vendor	Product size	Type of dryer ^a	Number of dryers	Dryer capacity ^b		Heating capacity of each dryer		Operating temperature (°F)	Product discharge temperature (°F)
				Dried product (stph)	Water removed (stph)	10 ⁶ Btu/hr	Water removed (Btu/lb)		
A	70% -200 mesh	G ₁	15	110	10	28	1372	365	220
	10 × 100 mesh	G ₁	15	110	10	28	1372	365	220
	1/8 in. × 0	G ₁	15	110	10	28	1372	365	220
	3/8 in. × 0	G ₁	15	110	10	28	1372	365	220
B	70% -200 mesh	B	5	331	29	166	1800	1600	200
	10 × 100 mesh	B	5	331	29	166	1800	1600	200
	1/8 in. × 0	B	5	331	29	166	1800	1600	200
	3/8 in. × 0	B	5	331	29	166	1800	1600	200
C	10 × 100 mesh	A	4	413	37	127	1562	165	165
	1/8 in. × 0	A	4	413	37	127	1562	165	165
	3/8 in. × 0	A	4	413	37	127	1562	165	165
D	10 × 100 mesh	A	5	331	29	145	1975	1200	150
	1/8 in. × 0	A	5	331	29	145	1975	1200	150
	3/8 in. × 0	A	5	331	29	145	1975	1200	150
E	70% -200 mesh	G ₁	20	83	7	24	1300	500	212
	10 × 100 mesh	G ₁	20	83	7	24	1300	500	212
F ^c	1/8 in. × 0	A/E	4/14	413/118	37/11	138.7/56.4	1888/2685	1100/850	165/250
	3/8 in. × 0	A/E	3/8	55./207	49/18	184.9/98.5	1888/2685	1100/850	165/250
G	70% -200 mesh	G ₂	6	276	26	80	1500		180
	10 × 100 mesh	G ₂	6	276	26	80	1500		180
F	70% -200 mesh	G ₃	20	83	7	42	2787	750	160-180
	10 × 100 mesh	G ₃	20	83	7	42	2787	750	160-180
	1/8 in. × 0	G ₃	20	83	7	42	2787	750	160-180
	3/8 in. × 0	G ₃	20	83	7	42	2787	750	160-180

^aA = fluidized-bed dryer; B = flash dryer; F = drum, direct heating; G₁ = hollow, rotating multiple disc; G₂ = indirect heating, product fluidized over heating coils; G₃ = drum, indirect heating, heat applied to outside surface of drum.

^bDryer capacity refers to the capacity required per dryer to produce a total product of 1800 stph at 2% total moisture.

^cThis vendor differentiated between coals by giving data related to each coal thusly: Pittsburgh seam/Kentucky No. 5.

Table 6.15 (continued)

Vendor	Product size	Dryer fuel required	Drying medium	Power required per dryer (hp)	Dryer operating availability (%)	Cost of dryer delivered (\$ × 10 ³)	Largest dryer available (stph)	Power required by largest dryer (hp)	Cost of largest dryer delivered (\$ × 10 ³)
A	70% -200 mesh	d	e	160	95	850	10	160	850
	10 × 100 mesh	d	e	160	95	850	10	160	850
	1/4 in. × 0	d	e	160	95	850	10	160	850
	3/8 in. × 0	d	e	160	95	850	10	160	850
B	70% -200 mesh	f	g	1065	80	1600	900	2200	
	10 × 100 mesh	f	g	1065	80	1600	900	2200	
	1/4 in. × 0	f	g	1065	80	1600	900	2200	
	3/8 in. × 0	f	g	1065	80	1600	900	2200	
C	10 × 100 mesh	h	i	2100	95	1000	700	3200	1225
	1/8 in. × 0	h	i	2100	95	1000	700	3200	1225
	3/8 in. × 0	h	i	2100	95	1000	700	3200	1225
D	10 × 100 mesh	j	i	2800	80	2120	600	3500	
	1/8 in. × 0	j	i	2800	80	2120	600	3500	
	3/8 in. × 0	j	i	2800	80	1923	600	3500	
E	70% -200 mesh	k	l	120	95	289 ⁿ	90	120	289 ^m
	10 × 100 mesh	k	l	120	95	289 ^m	90	120	289 ^m
F ^c	1/8 in. × 0	10,079/4,369 ⁿ	Heated air	2410/1000	80	2100	630/130	3,625/1,000	3,000/2,100
	3/8 in. × 0	13,628/7,646 ⁿ	Heated air	3130/1360	80	2100	850/225	4,330/1,360	3,000/2,100
G	70% -200 mesh	d	o	350	98	500 ^p	300	350	500 ^p
	10 × 100 mesh	d	o	350	98	500 ^p	300	350	500 ^p
H	70% -200 mesh	q	r	250	95	325	90-100	250	325
	10 × 100 mesh	q	r	250	95	325	90-100	250	325
	1/4 in. × 0	q	r	250	95	325	90-100	250	325
	3/8 in. × 0	q	r	250	95	325	90-100	250	325

d Coal or oil.

e 31,000 lb of steam per hour at 250 psig.

f 9,800 lb of coal fines per hour.

g Product of combustion gases.

h 10,625 lb of coal per hour at 12,000 Btu/lb.

i Heated air or flue gas.

j 12,600 lb of coal per hour.

k 52.6 gpm of fuel oil for 20 dryers.

l Indirect heat transfer fluid.

m f.o.b. factory.

n Pounds of coal per hour.

o 100,000 lb of steam per hour at 250 psig in internal heating coils.

p Boiler not included.

q 315 gal of No. 2 fuel oil per minute.

r Air or flue gas.

indirect-heat dryers or any of the direct-heat dryers. Direct-heat dryers (flash, fluidized-bed, or drum) produce more particulates and SO_x in the exhaust gases, but have a greater capacity per unit. Nonrotating, indirect-heat dryers, not yet used for coal, dry by means of a fluidized bed over internal heating coils. This method produces a minimum of particulate matter and capacities would approach those of direct-heat dryers. The rotating, indirect-heat dryers employ hollow, rotating multiple discs through which a heated fluid flows. Another rotating type of dryer is a drum type in which heat is applied to the outside of the drum.

The vendors surveyed contributed the following recommendations and miscellaneous recommendations on thermal dryers:

1. Dryer availability and limiting factors. Although dryers of the type recommended by the vendors of this survey have been built, none are off-the-shelf items. Because of the variability of coal, it is difficult to have one design and size of equipment perform satisfactorily for all conditions. Therefore, equipment is available only by special order through the particular company. Representatives of two companies stated that fluidized-bed and flash dryers for drying fine (pulverized) sizes are not now available through their companies, but that with the technology already present "in house," the dryers will probably be produced if market forces become more attractive.

2. Recommended drive and transmission. All respondents recommended the use of electric motors and either direct or gear-reduction drive (depending on load and rpm).

3. Type of lubrication. Various means of lubrication were recommended, such as splash, intermittent, and manual lubrication; permanently lubricated bearings also were recommended.

4. Recommended type feeder to dryer. Fluidized-bed dryers are fed by a roll feeder at the outlet of the dryer surge (supply) bin. However, belt feeders were recommended for feeding to the surge bin, and screw feeders were recommended for feeding to drum and multiple-disc dryers.

5. Recommended dryer discharge equipment. In general, vendors recommended that air-lock-type equipment be used for discharging the product from the bed and cyclones of the fluidized-bed dryer. Some drum and

multiple-disc dryers use rotary-type discharge. All respondents recommended hooded belt conveyors for transporting the product from the dryer discharge.

6. Emissions from dryers. The design of drum and multiple-disc dryers recommended is such that the product is dried by indirect heat only; therefore, no particulate matter or SO_x compounds are formed. Because flash dryer and fluidized-bed dryers use the hot products of coal combustion, these dryers do emit particulates and SO_x compounds. Cyclones and wet venturi scrubbers are used with these systems to remove these contaminants. Each system is designed to meet the 0.031 grain/dscf requirement.

The thermal dryers would be located just upstream of the final sizing equipment. However, the 70% -200 mesh coal would be dried during pulverizing.

6.4 Classifying Equipment

6.4.1 Screens

Based on the coal preparation operations block flow diagram, screens can be used to prescreen cage mill feed primarily for the U-GAS and COGAS processes. The operating conditions that were the basis for the screen survey are given in Table 6.16, and the results of the survey are given in Table 6.17.

Replies from four vendors indicate that screen capacity can vary from 0.75 to 3.75 tons/ft². Vendor C recommended 15 screens. This number of screens may present problems in plant layout. The most practical screen width (which determines capacity) seems to be 8 to 10 ft; wider screens would be more difficult to feed evenly. Screening efficiency is directly proportional to the screen length. Additional screen decks might increase capacity, but none of the four vendors surveyed recommended more than two decks. Power requirements for screens are relatively insignificant when compared with those for comminution equipment.

Table 6.16. Operating conditions — screens

OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia, and Kentucky No. 9 seam in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

PERCENT MOISTURE IN FEED: 5% TOTAL 3% SURFACE

FEED SIZE: 2 in. × 0

ESTIMATED FEED SCREEN ANALYSIS

SIZE	+2 in.	+1-1/2 in.	+1 in.	+3/4 in.	+1/2 in.	+1/4 in.	+8 mesh
% RETAINED	12.66	22.79	32.83	48.63	67.08	83.76	

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SOLIDS MEAN SPECIFIC GRAVITY: 1.4

SCREEN SERVICE: Prescreening of cage mill feed

DESIRED PRODUCT SIZES: 2 in. × 1/4 in. (cage mill feed) and
1/4 in. × 0

TYPE OF CIRCUIT: Open, dry

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER UNIT: 800 hr/year

SCREEN FEED METHOD: Belt feeder between surge bin and screen feed box

6.4.2 Air separators

Air separators probably would be used just downstream of the cage mills to effect a separation at 100 mesh of the -8 mesh or -20 mesh coal. These product size consists (8 × 100 mesh and 20 × 100 mesh) would be used in the HYGAS, Texaco Partial Oxidation, and EDS processes. The operating conditions that were the basis for the survey are given in Table 6.18 and the results of the survey are given in Table 6.19.

Table 6.17 Results of screen survey

Vendor	Screen size (ft)	No. decks	Screen capacity (stph)	No. screens (operating/standby)	Screen efficiency (%)	Particle size distribution			
						Top deck		Second deck	
						Size (in.)	Percent passing	Size (in.)	Percent passing
A	10 × 24	2	300	6/1	95	5/8		1/4	
B	8 × 20	2	600	3/1	90-95	3/4	62	5/16	30
C	8 × 20	2	120	15/0	90-95	1/2	49	1/4	31
D	8 × 16	2	200	9/2	95	2	99	1/4	31

Vendor	Top deck					Second deck				
	Type screen	Opening size (in.)	Open area (%)	Opening shape	Wire size or plate thickness (in.)	Type screen	Opening size (in.)	Open area (%)	Opening shape	Wire size (in.)
A	Woven wire	3/4	72	Square	0.135 diam	Woven wire	5/16	66	Square	0.072 diam
B	Woven wire	3/4	65	Square	0.177 diam	Woven wire	5/16	70	Square	0.080 diam
C	Woven wire	1/2		Square		Woven wire	1/4		Square	
D	Woven wire	2	79	Square	0.250 diam	Tyrod	1/4 × 2	55-60	Rectangular	0.120 diam

Vendor	Motor		Maximum moisture screen will handle at these conditions (%)	Maintenance downtime per unit (hr/year)	Price per unit, f.o.b. factory (\$)	Shipping weight per unit (lb)
	hp	rpm				
A	25 (2 each)	1800	5	800	53,805 ^a	34,000
B	30	1800		50	32,226 ^b	19,700
C	40	1800	3	40	35,000 ^c	25,000
D	25	1800	8	1600	26,854 ^d	14,300

^aWith screen, feed box, pivoted motor base, dual V-belt drives and guards, timing belts and drives, and motors.

^bWith screens, motor base, feed box, but no motor.

^cWith motor, screens, and V-belts.

^dWith motors, screen, feed box and liner, cover, motor base, V-belt drive, panel lip liners, and guards.

Table 6.18. Operating conditions — air separators

OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia, and Kentucky No. 9 in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

PERCENT MOISTURE IN FEED: 5% TOTAL 3% SURFACE

FEED SIZE: 8 mesh × 0 (Cage Mill Product)

ESTIMATED FEED SCREEN ANALYSIS

SIZE	8 mesh	20 mesh	100 mesh	200 mesh
% PASSING	100	78	20	7

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SOLIDS MEAN SPECIFIC GRAVITY: 1.4

DESIRED PRODUCT SIZE: 8 × 100 mesh

PRODUCT REQUIREMENT: Minimum amount of -100 mesh material

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER UNIT: 800 hr/year

FLUE GAS AVAILABLE FOR OPERATION (IF REQUIRED): Yes

ADDITIONAL FEED AND PRODUCT SIZE CONDITIONS:

(ALL OTHER CONDITIONS REMAIN THE SAME)

FEED SIZE: 14 mesh × 0 (Cage Mill Product)

ESTIMATED FEED SCREEN ANALYSIS

SIZE	14 mesh	20 mesh	100 mesh	200 mesh
% PASSING	100	92	30	20

DESIRED PRODUCT SIZE: 14 × 100 mesh

FEED SIZE: 20 mesh × 0 (Cage Mill Product)

ESTIMATED FEED SCREEN ANALYSIS

SIZE	20 mesh	100 mesh	200 mesh
% PASSING	100	40	20

DESIRED PRODUCT SIZE: 20 × 100 mesh

Table 6.19. Results of air separator survey

	Vendor		
	A	B	C
Size of units recommended, diameter, ft	20 ^a	22	16
Design capacity of each unit, stph	225	450	125
Number of units — operating/standby	8/?	4/1	15/?
Predicted amount of -100 mesh coal in product, %, for			
8 x 100 mesh	5	5	5
14 x 100 mesh		5-10	8.6
20 x 100 mesh		15-20	13.3
Maintenance downtime, hr/year	330	10	48
Maximum moisture tolerated, wt %	5	5	
Motor, hp/rpm	250/1800 ^b	400/1200	100/1800
Type of drive	V-belt ^c	Speed red.	V-belt + gear reducer
Reduction ratio		2.25	9.1
Feeding method		Gravity belt feed	Belt feed
Feeding controls	Pneumatic gate control	Conventional	Conventional
Estimated price per unit, \$			
f.o.b. factory	350,000	124,945 ^f	43,346 ^d
Total price	500,000 ^e	142,790 ^f	43,346
Shipping weight, lb	130,000 ^e	92,000	35,000

^aNo moving parts in separator.

^bThis motor is required for fan.

^cDrive between motor and fan.

^dMotor not included.

^eIncludes separator, cyclone, fan, fan motor, ductwork, support steel.

^fIncludes liners, couplings, guards, speed reducer; motor not included.

All three vendors stated that use of their equipment would not yield sharp size cuts (separation); that is, some fines would be found in the coarse product stream and visa versa. Maintenance downtime is low for air separators, and four machines operating with one spare can process 1800 stph for any of the three size cuts specified. Power requirements are low, as are equipment costs, when compared with the comminution equipment.

6.5 Ash/Slag Removal Equipment

6.5.1 Crushers (grinders)

Vendors of crushing equipment for handling ash/slag residues were surveyed for this study. Ten vendors listed as roll-crusher suppliers in

the *Thomas Register* and *Coal Age* were contacted, and questionnaires were mailed to them. Of these ten, three stated that they did not handle clinker grinders or ash-crushing equipment. Information obtained from the remaining seven can be summarized as follows:

1. One vendor refused to supply information, claiming it would involve too much effort.
2. Two promised to complete the questionnaire or supply brochures, but repeated contacts produced no information.
3. Two stated that they were only licensees for European suppliers and possessed no meaningful data and, therefore, were unable to complete the questionnaire. However, one of these companies stated that its European supplier was licensed originally to handle equipment for an American firm, so that any information supplied by the American firm also would apply to its own equipment.
4. Two vendors submitted information for our survey: the first firm completed the questionnaire fully and supplied appropriate brochures describing their equipment; the second vendor supplied a brochure and equipment specifications along with information by telephone, from which most of their questionnaire could be completed.

Vendor A produces a complete line of ash and slag handling equipment, including crushers, lockhoppers, pneumatic and hydraulic transfer systems, etc. They manufacture double-roll crushers that have capacities of the size needed for handling ash and slag from any of the coal conversion processes. These crushers have been used in pressurized systems of up to several atmospheres. The vendor reported, however, that work on designs for 500-psi systems is in progress. A 15-in. double-roll crusher capable of handling up to 125 stph will cost approximately \$20,500, installed (1978 dollars). Operating costs are \$5400/year; however, major maintenance costs of \$46,500 yearly (WP-4 case involving 95 stph of ash) are based on a roll life of 100,000 tons. The rolls, made of cast manganese steel, are rewelded for replacement. Problem areas for this equipment are erosion and seal failure. The largest grinder available from this firm is a double-roll crusher powered by a 50-hp unit, capable of

handling up to 300 stph. This piece of equipment can be delivered in less than 12 months, based on a 12-month development time.

The other vendor that supplied information manufactures only one type of ash grinder, a 50-stph capacity, single-roll spiral crusher, powered by a 5-hp unit. The grinder costs \$15,000 (1978 dollars) and can be delivered in 8 or 9 months. It is designed for a nonpressurized system. According to the vendor, its in-service availability is "very high, with yearly maintenance," (e.g., up to 12 hr/day, 350 days per year). Maintenance costs are estimated to be approximately 25% of initial costs per year.

Table 6.20 gives the results of the ash/slag grinder survey.

Table 6.20. Results of ash/slag grinder survey

	Vendor	
	A and C ^a	B
Type of grinder	Double roll	Single roll spiral
Capacity, stph	125 (15 in.)	50
Horsepower/unit	25	5
Recommended drive	Fluid coupling plus chain and sprocket	Electrofluid motor roller chain
Cost/unit, 1978 dollars	\$18,000	\$15,000
Total cost (unit installation)	\$20,500	
Operating cost/year	\$5,400	
Estimated maintenance cost/year	\$46,400 ^b	25%/year
In-service availability	<60% (roll life)	12 hr/day ^c 350 days/year
Delivery time, months	<12	8-9
Problem areas	Erosion, seal failure	
Largest grinder available, stph	300	
Development time, months	12	
Remarks	Used in pressurized system up to several atmospheres; also designed for 500 psi	Designed for non-pressurized system

^a Vendor C is licensed to use the same equipment as vendor A.

^b Based on a roll life of 100,000 tons.

^c "Very high with yearly maintenance."

6.5.2 Combustion systems

Combustion systems (e.g., boilers) used by industry usually involve the handling of ash/slag at high temperatures, but not under high pressures. Almost all coal conversion processes, however, operate at high pressures, so that either efficient and serviceable pressure letdown valves will be required, or mechanical depressurization will be employed for ash/slag letdown systems.

Except for the EDS process, the ash, char, or slag produced by the various gasifiers discussed previously (Sect. 4.2.2) is quenched in water at gasifier operating pressure and then removed periodically through a lockhopper or similar mechanical depressurizing system. In this type of removal system, steam generated by quenching flows back into the gasifier. The ash or slag quenching section forms an integral part of the gasifier. Pilot plant testing of the various coal conversion processes has revealed equipment problems in certain areas. The availability of pressure letdown valves and slurry pumps for commercial demonstration plants has been questioned. These types of equipment have been investigated for commercial availability, and the data have been summarized in two reports: *Survey of Industrial Coal Conversion Equipment Capabilities: Letdown Valves*, ORNL/TM-6585, and *Rotating Components*, ORNL/TM-6704.^{1,2}

6.5.3 Pressure letdown valves

Although the valve industry has the capability to supply letdown valves in the sizes required by coal conversion plants, it currently is not capable of supplying standard valves for such service.¹ Currently, modifications and/or special trims are required to extend valve life. Most types of letdown valves are used as control valves and, under the high-temperature and high-pressure operating conditions such as are encountered in existing coal conversion pilot plants, have already presented problems. The most severe letdown conditions have occurred with char slurry letdown from the coal conversion reactor; similar problems would be encountered with highly erosive ash materials. Modified oil-field choke valves and angle valves have worked best in pilot plant applications. However, early experience with these valves (Willis choke valve and DBAQ

Fisher high-pressure angle valve) was unsatisfactory; the original trim would last only from several hours to several days. New trim of 94% tungsten carbide and modifications to valve discharge have extended valve life by an order of magnitude, but further improvements are necessary for long-term service.

Specifications for valves are needed so that the valve industry can begin to manufacture and supply acceptable letdown valves for the coal conversion industry. A "systems approach" to the preparation of specifications requires an understanding of the entire letdown system, which involves the following factors:

1. understanding the fluid stream and its peculiarities (proneness to flashing; cavitation; gas, liquid, and particulate contents, etc.);
2. reducing the amount of pressure letdown across a single valve (e.g., incorporating a flow nozzle downstream of the valve to absorb a major part of the pressure drop);
3. using nozzle cascades for high-temperature and high-pressure gas letdown not requiring control valves;
4. simplifying the piping systems upstream and downstream of the valve, including replacement of sharp bends with long-radius bends and straight pipe and the enlargement of piping diameters to reduce turbulence;
5. incorporating noise and vibration monitoring systems to provide an early warning of cavitation in valves and piping;
6. investigating valve designs other than existing pressure-reducing valves and control valves that may be used for erosive letdown, and possibly simplifying valve and trim configuration;
7. disseminating test results and data from previous valve experience in coal conversion plants to avoid further misapplication of valve designs.

A strong effort to test and develop satisfactory pressure letdown valves (using lockhopper systems) has been undertaken by DOE during the past two years. The Lock Hopper Valve and Testing Program, centered at the Morgantown Energy Technology Center, is aimed toward the development

and production of long-life valves for handling both the feeding and removal of solids in coal conversion reactions.³ Numerous state-of-the-art valves have undergone various degrees of testing during the past 2 years to evaluate their capability for current lockhopper applications in pilot plant use. In addition, prototype valve designs formulated by two contractors will be evaluated under simulated service conditions to compare their design performance with those of the state-of-the-art valves.

6.5.4 Hydraulic jet pumps

Hydraulic jet pumps or centrifugal materials-handling pumps have been used for moving ash in hydraulic systems. Erosion is the principal problem with slurry pumps, and the use of better construction materials is the best way to increase their life expectancy. Single-stage, low-pressure, low-head centrifugal pumps are available from several manufacturers who supply equipment for the mineral beneficiation industry, although short pump life and frequent maintenance is to be expected.

A vendor of ash systems employs the Warman materials-handling pump, which has a Ni-Hard impeller (very tough alloy) that can last for 6 months. By way of contrast, a commercial installation⁴ that has handled large quantities of ash from a gasification system emphasizes, "under no circumstances must ash slurries be pumped." They began pumping such slurries and discovered that the lifetime of pump impellers was only a few days. The problem was reduced by sluicing ash slurries from a high to a lower elevation to obviate the need for pumps. Also, this installation has assigned its highest priority for equipment development to ash lockhopper and ash grate systems, the lifetimes of which can be extended longer than the present 3-month period. High-temperature erosion of the surfaces of the various moving parts is the major problem encountered.

6.5.5 Seal development

Slurry pumps were surveyed in *Rotating Components*.² Answers to the pump questionnaires indicated that seals were one of the problem areas associated with slurry pumps, but that corrosion and erosion problems far

outweighed seal problems. Very little discussion or attention was given to seal problems in this report.

In a letdown system proposed by a leading manufacturer of ash-handling equipment (Sect. 5.6), the water provided by a recirculation pump at 2048 gpm and a differential pressure of 125 psi serves as the seal water for the heavy-duty clinker grinder and, after it passes through a heat exchanger to lower its temperature, as quenching and cooling water for the slag sweeper.

References

1. D. W. Hatcher, T. M. Andress, and W. A. Bush, *Survey of Industrial Coal Conversion Equipment Capabilities: Letdown Valves*, ORNL/TM-6585, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 1979.
2. W. R. Williams et al., *Survey of Industrial Coal Conversion Equipment Capabilities: Rotating Components*, ORNL/TM-6074, Oak Ridge National Laboratory, Oak Ridge, Tenn., April 1978.
3. J. F. Gardner and F. D. Freeburn, "Update on Lockhopper Valve Developments," paper presented at AIChE Symposium on Critical Components for Coal Conversion Plants, Houston, Texas, April 1979.
4. R. C. Forrester, *Summary Report of Visit to the South African Coal, Oil, and Gas Corp. Ltd., Sasolburg, South Africa*, Oak Ridge National Laboratory, Oak Ridge, Tenn., Working Paper 24, March 1978.

7. CONCLUSIONS AND RECOMMENDATIONS ON EQUIPMENT

7.1 Coal Equipment

7.1.1 Comminution equipment

Cage mills. Cage mills appear to be very dependable and versatile machines for a variety of coal comminution operations. We suggest that a feasibility study be undertaken by DOE to help advance the state of the art, provide statistical data, and eventually establish a sound theoretical basis for design and operation of cage mills. This cooperative research program would be analogous and related to the program now in effect at KVS, which is an investigation of the mass size balance over time approach to coal comminution.

Rod mills. Rod mills can be used as an alternative method for producing a 20 mesh $\times$ 0 feed material for the Texaco Partial Oxidation process. This wet-pulverizing operation would aid in slurring, since the feed would be mixed with water during pulverizing. We suggest that a feasibility study of this method be undertaken and, if positive, that a program for further study and development be initiated.

Ball mills (solvent pulverizing). Ball mills using a liquefaction solvent could be used as an alternative method to produce 70% -200 mesh feed material for the H-Coal process. This would eliminate the need for de-entrainment equipment such as cyclones and baghouses. Very little work has been done in the area of solvent pulverizing of coal. We suggest that the R&D work in this area being done at KVS be expanded.

Ball tube mills. Ball tube mills could be used as an alternative means to produce 70% -200 mesh feed material for the H-Coal process. This would be a simultaneous drying-pulverizing operation, using flue gas from the steam/power plant as the drying medium. De-entrainment equipment such as cyclones and baghouses must be used if the slurring-feeding facility is not designed to accept the product directly from the ball tube mill facility.

Bowl pulverizers. Bowl pulverizers can be used to produce 70% -200 mesh feed material for the H-Coal process. This would be a simultaneous drying-pulverizing operation utilizing the flue gas from the combination

steam/power facility. If de-entrainment cannot be accomplished in the slurring-feeding facility, de-entrainment such as cyclones and baghouses must be used.

7.1.2 Thermal drying equipment

Thermal dryers that can dry Pittsburgh seam and Kentucky No. 9 coals down to 2% total moisture are available. The fluidized-bed dryers have the largest capacities. Thermal dryers will be required (1) if it is necessary to remove the 100 mesh $\times$ 0 size fraction from the feed material* or (2) if it is necessary to remove the moisture from the feed material before solvent slurring, instead of during the first step of the process.

7.1.3 Classifying equipment

Screens. Screens can be used to separate the 1/4 in. $\times$ 0 size fraction from the 2 in. $\times$ 0 feed material to the cage mills. The cage mills will produce 1/4 in. $\times$ 0 feed for the U-GAS process.* The total moisture content of the 2 in. $\times$ 0 material must be less than 5%.

Air classifiers. Air classifiers can be used to remove the 100 mesh $\times$ 0 size fraction from the process feed, if such removal is required.

7.1.4 Ash/slag removal equipment

Ash/slag letdown systems and removal operations require numerous types of equipment, most of which industry can supply either readily or within a reasonable length of time. Included in this category are roll crushers, lockhoppers, dewatering filters, slag conveyors, water pumps, pug mills, and assorted mixing and settling tanks.

Two components that have presented problems in coal conversion systems are slurry pumps and pressure letdown valves. The properties of the ash being handled determine whether ash slurry pumps can be used. For highly erosive ash slurries, water sluicing by gravity may have to be employed to prevent rapid wear of pump impellers.

*See Fig. 4-7 in Appendix C.

The severe operating conditions associated with the various coal conversion processes in pilot plants have shown pressure letdown valves to be a serious problem. Modified oil-field choke valves have been used, but even the modified design and the use of tungsten carbide trim have not extended valve life beyond several months. As a result, current designs for pressurized letdown systems employ a series of valves and adjustment to the letdown piping to avoid severe corrosion and erosion problems.

7.2 Recommended Equipment Development

7.2.1 Scale-up of pulverizers

Dry coal pulverizing currently is done in mills having capacities up to 100 tons/hr. Cement is now pulverized in mills which could pulverize about 300 tons of coal per hour. However, because of differences in grinding characteristics between cement and coal and because of the explosive nature of pulverized coal, scale-up of smaller mills or adaptation of large cement mills may require development work.

7.2.2 Transport of ultrafines

Mass-flow conveyors have been used successfully to transport small quantities of hazardous solids but not large quantities of ultrafine coal. Development work would be required before mass-flow conveyors could be used for large quantities of coal, especially if ultrafine coal requires a large increase in elevation during the transfer.

Other transport alternatives that could be considered for coal ultrafines include the following:

1. dilute-phase transport in inert gas,
2. dense-phase transport in inert gas,
3. screw conveyors,
4. water or other fluid slurry transport that is compatible with ultrafines utilization.

7.2.3 Removal of ultrafines

If removal of coal ultrafines is required or justified for a specific conversion process, some use must be made of the ultrafines. Possible uses for the ultrafines include the following:

1. direct firing in pulverized-coal-fired steam generators,
2. possible firing in fluidized-bed steam generators by injection of ultrafines into the bottom of the fluidized bed,
3. agglomeration followed by combustion in a fluidized-bed steam generator or feeding to a conversion reactor.

Except for item 1, development work would be required to establish the process.

7.2.4 Wet grinding with recycle solvent

To the extent of our knowledge, coal grinding in coal liquefaction solvent, water, or other liquids has been done in only one large-scale commercial operation — the Black Mesa, Arizona, coal slurry preparation plant, where coal is ground in water. Development work would be required to demonstrate the grinding of coal in a recycle slurry.

7.2.5 Ash/slag equipment

The need for better ash/slurry pumps and pressure-letdown valves that can provide long-term service in coal conversion operations — problem areas that have been addressed in the reports we have cited — is further emphasized here. Slag grinding in pressurized systems should be demonstrated under coal conversion process conditions.

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Appendix A

QUESTIONNAIRES USED IN SECOND SURVEY

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QUESTIONNAIRE FOR CAGE MILLS

I. OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia,
and Kentucky No. 9 in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

PERCENT MOISTURE IN FEED: CASE 1 10% TOTAL 8% SURFACE

CASE 2 5% TOTAL 3% SURFACE

FEED SIZE: 2 in. x 0

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	+2 in.	+1-1/2 in.	+1 in.	+3/4 in.	+1/2 in.	+1/4 in.	+8 mesh
% RETAINED		12.66	22.79	32.83	48.63	67.08	83.76

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SOLIDS MEAN SPECIFIC GRAVITY: 1.4

DESIRED PRODUCT SIZES: 8 mesh x 0

14 mesh x 0

20 mesh x 0

PRODUCT REQUIREMENT: Minimum amount of -100 mesh material

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER CAGE MILL (OR LINE): 800 hr/year

QUESTIONNAIRE FOR CAGE MILLS (continued)

II. GENERAL INFORMATION ON EQUIPMENT AVAILABILITY

1. AVAILABLE EQUIPMENT	<u>YES</u>	<u>NO</u>
- IS EQUIPMENT AVAILABLE OFF THE SHELF?	—	—
- IS EQUIPMENT AVAILABLE BY SPECIAL ORDER?	—	—

AVAILABLE TECHNOLOGY

- COULD EQUIPMENT BE DEVELOPED TO MEET
OPERATING CONDITIONS AS SPECIFIED IN
SECTION I IF MARKET FORCES ARE ATTRACTIVE?	—	—
- IS EQUIPMENT NOT FEASIBLE AS SPECIFIED IN
SECTION I?	—	—

ADDITIONAL COMMENTS: _____

Note: This sheet was used for each type of equipment, but in this report it is not repeated each time.

QUESTIONNAIRE FOR CAGE MILLS (continued)

III. INFORMATION ON AVAILABLE EQUIPMENT

EQUIPMENT REQUIRED TO MEET OPERATING CONDITIONS AS SPECIFIED IN

SECTION I: FEASIBLE _____ AVAILABLE _____

TYPE OF EQUIPMENT: _____

MODEL: _____ SIZE: _____

DESIGN CAPACITY, EACH UNIT: _____ DRY stph

_____ stph @ _____ TOTAL MOISTURE

_____ stph @ _____ TOTAL MOISTURE

RECOMMENDED NO. OF UNITS: _____

RECOMMENDED CIRCUIT AND ARRANGEMENT (DESCRIBE CIRCUIT, IF SINGLE OR DOUBLE
STAGE, CLOSED OR OPEN CIRCUIT, NUMBER OF MACHINES FOR EACH STAGE, ETC.):_____

PREDICTED PRODUCT SIZE: _____

PREDICTED AMOUNT OF -100 MESH MATERIAL IN PRODUCT _____ %

-200 MESH _____ %

PREDICTED SCHEDULE MAINTENANCE DOWNTIME REQUIRED PER UNIT (OR LINE)

IF DIFFERENT FROM THAT SPECIFIED IN SECTION I: _____ hr/yr

CALCULATED POWER @ DESIGN CAPACITY: _____ hp

RECOMMENDED MOTOR(S) (hp & rpm): _____

DRIVE: TYPE _____ REDUCTION RATIO _____

DESCRIBE LUBRICATION SYSTEM: _____

QUESTIONNAIRE FOR CAGE MILLS (continued)

SETTING ADJUSTMENTS: _____

METHOD TO CONTROL AIR VOLUME PRODUCED BY EQUIPMENT: _____

RECOMMENDED FEEDING METHOD: _____

RECOMMENDED FEED CONTROLS: _____

ESTIMATED PRICE, FOB FACTORY, EACH MACHINE: \$ _____

AUXILIARY EQUIPMENT (IF ANY):

TOTAL COST, FOB FACTORY:

SHIPPING WEIGHT, EACH UNIT:

_____ 1b

QUESTIONNAIRE FOR ROD MILLS

I. OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia,
and Kentucky No. 9 in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

PERCENT MOISTURE IN FEED: 10% TOTAL 8% SURFACE

TYPE OF CIRCUIT: Wet, open circuit (water)

FEED SIZE: 2 in. x 0

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	+2 in.	+1-1/2 in.	+1 in.	+3/4 in.	+1/2 in.	+1/4 in.	+8 mesh
% RETAINED		12.66	22.79	32.83	48.63	67.08	83.76

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SOLIDS MEAN SPECIFIC GRAVITY: 1.4

DENSITY OF MILL DISCHARGE: 60 to 64 wt % solids

DESIRED PRODUCT SIZE: 100% -20 mesh

PRODUCT REQUIREMENT: Minimum amount of -325 mesh material

ESTIMATED MILL POWER AT MILL PINION SHAFT: 10 hp/stph

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER ROD MILL: 800 hr/year

QUESTIONNAIRE FOR ROD MILLS (continued)

III. INFORMATION ON AVAILABLE EQUIPMENT

EQUIPMENT REQUIRED TO MEET OPERATING CONDITIONS AS SPECIFIED IN

SECTION I: FEASIBLE _____ AVAILABLE _____

TYPE OF EQUIPMENT: _____

MODEL: _____ SIZE (INSIDE SHELL): _____

DESIGN CAPACITY, EACH UNIT: _____ stph (DRY BASIS)

PREDICTED PRODUCT SIZE: _____

PREDICTED AMOUNT OF -325 MESH MATERIAL IN PRODUCT: _____ %

CALCULATED POWER AT DESIGN CAPACITY: _____ hp

RECOMMENDED MOTOR (hp & rpm): _____

ROD CHARGE, VOLUMETRIC LOADING: _____ %

MILL SPEED: _____ rpm _____ % of critical speed

ROD SIZES: _____ ROD MATERIAL: _____

ROD CHARGE: _____ TONS AT _____ % MILL VOLUME

MILL LINERS: TYPE _____ LINER MATERIAL _____

PREDICTED SCHEDULE MAINTENANCE DOWNTIME REQUIRED PER UNIT IF

DIFFERENT FROM THAT SPECIFIED IN SECTION I: _____ hr/year

DRIVE TYPE: _____ REDUCTION RATIO: _____

DESCRIBE LUBRICATION SYSTEM: _____

RECOMMENDED FEEDING METHOD: _____

QUESTIONNAIRE FOR ROD MILLS (continued)

RECOMMENDED FEED CONTROLS: _____

ESTIMATED PRICE, FOB FACTORY, EACH MILL: \$ _____

1 SET OF LINERS: _____

AUXILIARY EQUIPMENT: _____

TOTAL COST, FOB FACTORY:

\$ _____

SHIPPING WEIGHT, EACH UNIT:

_____ 1b

(1) SET LINERS:

_____ 1b

TOTAL:

_____ 1b

QUESTIONNAIRE FOR BALL MILLS

I. OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia,
and Kentucky No. 9 seam in Hopkins County, Kentucky

COAL CHARACTERISTICS

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE 16.2 WORK INDEX

PERCENT MOISTURE IN FEED: 10% TOTAL 8% SURFACE

TYPE OF CIRCUIT: Grinding in solvent, open circuit

FEED SIZE: 1/8 in. x 0 (cage mill product)

ESTIMATED FEED SCREEN ANALYSIS

SIZE	6	20	100	200 mesh
% PASSING	100	50	12-15	4-8

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SOLIDS MEAN SPECIFIC GRAVITY: 1.4

DENSITY OF MILL DISCHARGE: 47 to 50 wt % solids

DESIRED PRODUCT SIZES: 70% -200 mesh

SOLVENT TYPE: No. 6 fuel oil

OIL/COAL RATIO: 1.14 (by weight)

OIL TEMPERATURE: 172°F

OIL FLASH POINT: 230°F

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER BALL MILL (OR LINE): 800 hr/year

QUESTIONNAIRE FOR BALL MILLS (continued)

III. INFORMATION ON AVAILABLE EQUIPMENT

EQUIPMENT REQUIRED TO MEET OPERATING CONDITIONS AS SPECIFIED IN

SECTION I: FEASIBLE _____ AVAILABLE _____

RECOMMENDED:

TYPE OF EQUIPMENT: _____

MODEL: _____ SIZE (INSIDE SHELL): _____

DESIGN CAPACITY, EACH UNIT: _____ stph (DRY BASIS)

PREDICTED PRODUCT SIZE: _____

CALCULATED POWER AT DESIGN CAPACITY: _____ hp

RECOMMENDED MOTOR (hp & rpm): _____

BALL CHARGE, VOLUMETRIC LOADING: _____ %

MILL SPEED: _____ rpm _____ % of critical speed

BALL SIZES: _____ BALL MATERIAL: _____

BALL CHARGE: _____ TONS AT _____ % MILL VOLUME

MILL LINERS: TYPE _____ LINER MATERIAL _____

PREDICTED SCHEDULE MAINTENANCE DOWNTIME REQUIRED PER UNIT IF

DIFFERENT FROM THAT SPECIFIED IN SECTION I: _____ hr/year

DRIVE TYPE: _____ REDUCTION RATIO: _____

DESCRIBE LUBRICATION SYSTEM: _____

QUESTIONNAIRE FOR BALL MILLS (continued)

RECOMMENDED FEEDING METHOD: _____

RECOMMENDED FEED CONTROLS: _____

ESTIMATED PRICE, FOB FACTORY, EACH MILL: \$ _____

1 SET OF LINERS: _____

AUXILIARY EQUIPMENT: _____

TOTAL COST, FOB FACTORY:

\$ _____

SHIPPING WEIGHT, EACH UNIT:

_____ 1b

(1) SET LINERS:

_____ 1b

TOTAL:

_____ 1b

QUESTIONNAIRE FOR BALL TUBE MILL COAL PULVERIZERS

I. OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia,
and Kentucky No. 9 seam in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

PERCENT MOISTURE IN FEED: 10% TOTAL 8% SURFACE

TYPE OF CIRCUIT: Dry, closed circuit

FEED SIZE: 2 in. x 0

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	+2 in.	+1-1/2 in.	+1 in.	+3/4 in.	+1/2 in.	+1/4 in.	+8 mesh
% RETAINED		12.66	22.79	32.83	48.63	67.08	83.76

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SPECIFIC GRAVITY: 1.4

DESIRED PRODUCT SIZE: 70% -200 mesh

DESIRED MOISTURE IN PULVERIZED COAL: 2.0% TOTAL

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER MILL: 800 hr/year

FLUE GAS AVAILABLE FOR OPERATION OF MILLS: Yes

QUESTIONNAIRE FOR BALL TUBE MILL COAL PULVERIZERS (continued)

III. INFORMATION ON AVAILABLE EQUIPMENT

EQUIPMENT REQUIRED TO MEET OPERATING CONDITIONS AS SPECIFIED IN

SECTION I: FEASIBLE _____ AVAILABLE _____

RECOMMENDED:

TYPE OF EQUIPMENT: _____

MODEL: _____ SIZE (INSIDE SHELL): _____

DESIGN CAPACITY, EACH UNIT: _____ stph (DRY BASIS)

MOISTURE IN FINAL PRODUCT: TOTAL _____% SURFACE _____%

PREDICTED PRODUCT SIZE: _____

PREDICTED AMOUNT OF -325 MESH MATERIAL IN PRODUCT: _____%

CALCULATED POWER AT DESIGN CAPACITY: _____ hp (EXCLUDING FAN)

RECOMMENDED MOTOR (hp & rpm): _____

BALL CHARGE, VOLUMETRIC LOADING: _____%

MILL SPEED: _____ rpm _____% of critical speed

BALL SIZES: _____ BALL MATERIAL: _____

BALL CHARGE: _____ TONS AT _____% MILL VOLUME

MILL LINERS: TYPE _____ LINER MATERIAL _____

PREDICTED SCHEDULE MAINTENANCE DOWNTIME REQUIRED PER UNIT IF

DIFFERENT FROM THAT SPECIFIED IN SECTION I: _____ hr/year

FLUE GAS REQUIREMENTS: _____ acfm/UNIT AT _____°F

MILL EXIT GAS TEMPERATURE: _____°F

AUXILIARY EQUIPMENT:

NO. OF CYCLONES & SIZE: _____ PRESSURE DROP: _____ in. H₂O

MILL FEED CRUSHER: TYPE _____ hp _____

PULVERIZER SEAL AIR FAN: SIZE _____ acfm _____ hp

QUESTIONNAIRE FOR BALL TUBE MILL COAL PULVERIZERS (continued)

DRIVE TYPE FOR PULVERIZER: _____ REDUCTION RATIO: _____

DESCRIBE LUBRICATION SYSTEM: _____
_____RECOMMENDED FEEDING METHOD: _____

_____RECOMMENDED FEED CONTROLS: _____

ATTACH PROPOSED FLOWSHEET, IF POSSIBLE: _____

ESTIMATED PRICE, FOB FACTORY, EACH MILL: \$ _____

1 SET OF LINERS: _____

AUXILIARY EQUIPMENT: _____

TOTAL COST, FOB FACTORY: \$ _____

SHIPPING WEIGHT, EACH UNIT: _____ lb

(1) SET LINERS: _____ lb

TOTAL: _____ lb

QUESTIONNAIRE FOR BOWL COAL PULVERIZERS

I. OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia,
and Kentucky No. 9 in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

PERCENT MOISTURE IN FEED: 10% TOTAL 8% SURFACE

FEED SIZE: 2 in. x 0

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	+2 in.	+1-1/2 in.	+1 in.	+3/4 in.	+1/2 in.	+1/4 in.	+8 mesh
% RETAINED	12.66	22.79	32.83	48.63	67.08	83.76	

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SOLIDS MEAN SPECIFIC GRAVITY: 1.4

DESIRED PRODUCT SIZE: 70% -200 mesh

DESIRED PULVERIZED COAL MOISTURE: 2.0%

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER PULVERIZER: 800 hr/year

FLUE GAS AVAILABLE FOR OPERATION OF MILLS: Yes

QUESTIONNAIRE FOR BOWL COAL PULVERIZERS (continued)

III. INFORMATION ON AVAILABLE EQUIPMENT

EQUIPMENT REQUIRED TO MEET OPERATING CONDITIONS AS SPECIFIED IN

SECTION I: FEASIBLE _____ AVAILABLE _____

RECOMMENDED:

TYPE OF EQUIPMENT: _____

MODEL: _____ SIZE: _____

DESIGN CAPACITY, EACH UNIT: _____ stph (DRY BASIS)

MOISTURE IN FINAL PRODUCT: TOTAL _____ % SURFACE _____ %

PREDICTED PRODUCT SIZE: _____

PREDICTED AMOUNT OF -325 MESH MATERIAL IN PRODUCT: _____ %

TYPE OF CLASSIFICATION: _____

CALCULATED POWER (EXCLUDING FAN) AT DESIGN CAPACITY: _____ hp

RECOMMENDED MOTOR (hp & rpm): _____

TOTAL POWER INPUT, INCLUDING FANS: _____ kWhr

PULVERIZER SPEED: _____

PREDICTED SCHEDULE MAINTENANCE DOWNTIME REQUIRED PER UNIT IF

DIFFERENT FROM THAT SPECIFIED IN SECTION I: _____ hr/year

FLUE GAS REQUIREMENTS: _____ acfm/UNIT AT _____ °F, PRESSURE _____ psi

MILL EXIT GAS TEMPERATURE: _____ °F

PULVERIZER SEAL AIR FAN: SIZE _____ acfm _____ hp

QUESTIONNAIRE FOR BOWL COAL PULVERIZERS (continued)

DRIVE TYPE FOR PULVERIZER: _____ REDUCTION RATIO: _____

DESCRIBE LUBRICATION SYSTEM: _____
_____RECOMMENDED FEEDING METHOD: _____

_____RECOMMENDED FEED CONTROLS: _____

ATTACH PROPOSED FLOW SHEET, IF POSSIBLE: _____

ESTIMATED PRICE, FOB FACTORY, EACH UNIT: \$ _____

AUXILIARY EQUIPMENT: _____

TOTAL COST, FOB FACTORY: \$ _____

SHIPPING WEIGHT, EACH UNIT: _____ lb

QUESTIONNAIRE FOR FLUIDIZED BED-DRYERS

I. OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia,
and Kentucky No. 9 in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE HEAT VALUE: 11,300 Btu/lb

PERCENT MOISTURE IN FEED: 10% TOTAL 8% SURFACE

FEED SIZE: 2 in. x 0

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	+2 in.	+1-1/2 in.	+1 in.	+3/4 in.	+1/2 in.	+1/4 in.	+8 mesh
% RETAINED		12.66	22.79	32.83	48.63	67.08	83.76

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SOLIDS MEAN SPECIFIC GRAVITY: 1.4

COAL SPECIFIC HEAT: 0.3 Btu/lb·°F ANGLE OF REPOSE: 35 to 40

COAL TEMPERATURE (FEED): 60°F

DESIRED MOISTURE IN PRODUCT: 5% TOTAL 3% SURFACE

WATER TO BE EVAPORATED: 110 stph per year system

FUEL TYPE: Dried Product Coal

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER UNIT: 800 hr/year

QUESTIONNAIRE FOR FLUIDIZED-BED DRYERS (continued)

III. INFORMATION ON AVAILABLE EQUIPMENT

EQUIPMENT REQUIRED TO MEET OPERATING CONDITIONS AS SPECIFIED IN

SECTION I: FEASIBLE _____ AVAILABLE _____

RECOMMENDED:

TYPE OF EQUIPMENT: _____

MODEL: _____ SIZE: _____

BUILDING SPACE (W × L × H): _____ ft

DESIGN CAPACITY: _____ stph (DRIED SOLIDS)

_____ stph WATER EVAPORATED

FUEL REQUIREMENTS: _____ Btu/hr _____ stph

POWER REQUIREMENTS: _____ kWhr

OPERATING TEMPERATURES: INCOMING GAS _____ °F EXIT GAS _____ °F

PRODUCT DISCHARGE _____ °F

FLUIDIZING GAS: _____ acfm AT EXIT TEMPERATURE

ESTIMATED DUST LOADING IN DRYER EXIT GAS: _____ GRAINS/scf

AUXILIARY EQUIPMENT/UNIT:

TYPE OF FURNACE: _____

DUST COLLECTION EQUIPMENT (DESCRIBE): _____

NUMBER OF FANS, TYPE (ID, FD), ARRANGEMENT AND LOCATION, hp: _____

PREDICTED SCHEDULED MAINTENANCE DOWNTIME REQUIRED PER UNIT IF

DIFFERENT THAN THAT SHOWN IN SECTION I: _____

QUESTIONNAIRE FOR FLUIDIZED-BED DRYERS (continued)

RECOMMENDED FEEDING METHOD AND TYPE OF DRIED COAL COLLECTING

EQUIPMENT: _____

_____RECOMMENDED CONTROLS: _____

ESTIMATED PRICE, FOB FACTORY, EACH UNIT: \$ _____

AUXILIARY EQUIPMENT: - _____

\$ _____

TOTAL COST, FOB FACTORY: \$ _____

SHIPPING WEIGHT, EACH UNIT: _____ 1b

QUESTIONNAIRE FOR SCREENS

I. OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia,
and Kentucky No. 9 in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

PERCENT MOISTURE IN FEED: 5% TOTAL 3% SURFACE

FEED SIZE: 2 in. x 0

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	+2 in.	+1-1/2 in.	+1 in.	+3/4 in.	+1/2 in.	+1/4 in.	+8 mesh
% RETAINED	12.66	22.79	32.83	48.63	67.08	83.76	

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SOLIDS MEAN SPECIFIC GRAVITY: 1.4

SCREEN SERVICE: Prescreening of cage mill feed

DESIRED PRODUCT SIZES: 2 in. x 1/4 in. (cage mill feed)

1/4 in. x 0

TYPE OF CIRCUIT: Open, dry

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER UNIT: 800 hr/year

SCREEN FEED METHOD: Belt feeder between surge bin and screen feed box

QUESTIONNAIRE FOR SCREENS (continued)

III. INFORMATION ON AVAILABLE EQUIPMENT

EQUIPMENT REQUIRED TO MEET OPERATING CONDITIONS AS SPECIFIED IN

SECTION I: FEASIBLE _____ AVAILABLE _____

RECOMMENDED:

TYPE OF EQUIPMENT: _____

MODEL: _____ SIZE: _____

DESIGN CAPACITY, EACH UNIT: _____ stph (DRY BASIS)

NUMBER OF DECKS: _____

PARTICLE SIZE DISTRIBUTION:

PRODUCT, TOP DECK		PRODUCT, 2ND DECK		PRODUCT, BOTTOM DECK	
SIZE	% PASSING	SIZE	% PASSING	SIZE	% PASSING
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

PREDICTED SCHEDULE MAINTENANCE DOWNTIME REQUIRED PER UNIT IF

DIFFERENT FROM THAT SPECIFIED IN SECTION I: _____ hr/year

SCREEN EFFICIENCY: (OVERALL) _____ %

TYPE OF VIBRATING MECHANISM: _____

MOTOR REQUIRED: _____ hp _____ rpm

TYPE OF MOUNTING: _____

MAXIMUM MOISTURE IN FEED THAT SCREEN WILL HANDLE AT DESIGN FEED

RATE AND SIZE DISTRIBUTION: _____ % SURFACE MOISTURE

QUESTIONNAIRE FOR SCREENS (continued)

SCREENING SURFACE:

	TOP DECK	2ND DECK	BOTTOM DECK
TYPE	_____	_____	_____
OPENING	_____	_____	_____
OPEN AREA, %	_____	_____	_____
OPENING SHAPE	_____	_____	_____
WIRE SIZE OR PLATE THICK	_____	_____	_____

TYPE OF BRACKET MOUNTS OF FLOOR STANDS (DESCRIBE): _____

NUMBER OF MOUNTS OR STANDS: _____

LUBRICATION (DESCRIBE): _____

SEALS (DESCRIBE): _____

SPECIAL REQUIREMENTS: _____

ESTIMATED PRICE, FOB FACTORY, EACH UNIT: \$ _____

AUXILIARY EQUIPMENT:

TOTAL COST, FOB FACTORY: \$ _____

SHIPPING WEIGHT, EACH UNIT: _____ lb

QUESTIONNAIRE FOR AIR SEPARATORS

I. OPERATING CONDITIONS

TYPE OF COAL TO BE GROUND: Pittsburgh seam in Monongalia County, West Virginia,
and Kentucky No. 9 in Hopkins County, Kentucky

COAL CHARACTERISTICS:

ASH CONTENT: 12 to 15% GRINDABILITY: 60 HARDGROVE

PERCENT MOISTURE IN FEED: 5% TOTAL 3% SURFACE

FEED SIZE: 8 mesh x 0 (Cage Mill Product)

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	8 mesh	20 mesh	100 mesh	200 mesh
% PASSING	100	78	20	7

BULK DENSITY OF FEED: 45 lb/ft³ (DRY)

SOLIDS MEAN SPECIFIC GRAVITY: 1.4

DESIRED PRODUCT SIZE: 8 x 100 mesh

PRODUCT REQUIREMENT: Minimum amount of -100 mesh material

TOTAL PLANT FEED CAPACITY: 45,000 stpd (DRY BASIS)

PLANT OPERATING SCHEDULE: 24 hr/day 365 days/year

DESIRED CAPACITY PER SYSTEM: 1800 stph (DRY BASIS)

SCHEDULED MAINTENANCE DOWNTIME PER UNIT: 800 hr/year

FLUE GAS AVAILABLE FOR OPERATION (IF REQUIRED): Yes

QUESTIONNAIRE FOR AIR SEPARATORS (continued)

ADDITIONAL FEED AND PRODUCT SIZE CONDITIONS:

(ALL OTHER CONDITIONS REMAIN THE SAME)

FEED SIZE: 14 mesh × 0 (Cage Mill Product)

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	14 mesh	20 mesh	100 mesh	200 mesh
% PASSING	100	92	30	20

DESIRED PRODUCT SIZE: 14 × 100 meshFEED SIZE: 20 mesh × 0 (Cage Mill Product)

ESTIMATED FEED SCREEN ANALYSIS:

SIZE	20 mesh	100 mesh	200 mesh
% PASSING	100	40	20

DESIRED PRODUCT SIZE: 20 × 100 mesh

QUESTIONNAIRE FOR AIR SEPARATORS (continued)

III. INFORMATION ON AVAILABLE EQUIPMENT

EQUIPMENT REQUIRED TO MEET OPERATING CONDITIONS AS SPECIFIED IN

SECTION I: FEASIBLE _____ AVAILABLE _____

RECOMMENDED:

TYPE OF EQUIPMENT: _____

MODEL: _____ SIZE: _____

DESIGN CAPACITY, EACH UNIT: _____ stph (DRY BASIS)

PREDICTED PRODUCT SIZE: _____

AMOUNT OF -100 MESH IN PRODUCT: _____ %

OVERALL SEPARATION EFFICIENCY: _____

PREDICTED SCHEDULE MAINTENANCE DOWNTIME REQUIRED PER UNIT IF

DIFFERENT FROM THAT SPECIFIED IN SECTION I: _____ hr/year

FLUE GAS REQUIREMENTS (IF REQUIRED), EACH UNIT: _____

FLOW RATE: _____ acfm

TEMPERATURE: IN _____ °F OUT _____ °F

PRODUCT FINAL TEMPERATURE: _____ °F

DESCRIBE CIRCUIT ARRANGEMENT (GAS BLEED-OFF, CYCLONE, BACHOUSE
REQUIREMENTS, OR ATTACH RECOMMENDED FLOW SHEET): _____

MAXIMUM SURFACE MOISTURE TOLERATED IN AIR SEPARATOR FEED: _____ %

RECOMMENDED MOTOR (hp & rpm): _____

DRIVE: TYPE _____ REDUCTION RATIO _____

RECOMMENDED FEEDING METHOD: _____

QUESTIONNAIRE FOR AIR SEPARATORS (continued)

RECOMMENDED CONTROLS: _____

ESTIMATED PRICE, FOB FACTORY, EACH UNIT: \$ _____

AUXILIARY EQUIPMENT, IF ANY:

TOTAL PRICE, FOB FACTORY:

\$ _____

SHIPPING WEIGHT, EACH UNIT:

_____ lb

Appendix B

QUESTIONNAIRES USED IN INITIAL SURVEY

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ATTACHMENT

Investigation of Coal Handling, Preparation, and Ash/Slag Letdown
and Removal Equipment CapabilitiesPulverizers

This attachment contains a list of typical applications for pulverizers in proposed coal preparation systems of future coal conversion plants. Also included is a questionnaire for determining the availability of pulverizers for these applications.

Pages 1 through 5 of this attachment list general instructions for completing the questionnaire.

Page 6 lists the availability code to use in completing item 18 of the instructions.

Page 7 is an address and reference form which should be completed to properly reference your firm and point of contact. One individual should be named on this form for further contact by telephone during this study if necessary.

Pages 8, 9, 10 and 11 list the typical applications for pulverizers in coal conversion plants and provide blank columns for inserting the information requested by this questionnaire.

You may feel that some of the questions are too difficult or time consuming to answer. We will appreciate your effort in answering these questions to the extent practicable.

PULVERIZERS

GENERAL INSTRUCTIONS

The following alphabetic & numerical instructions refer to the respective column letters and numbers on p. 8 through 11. Columns A, B, C, D & E list specific process conditions. Columns 1 through 27 provide space for answers to the information requested. Please use footnotes when appropriate.

PROCESS CONDITIONS

Please note that there are three general types of pulverizing processes to be considered. Dry (DP), wet (WP) (with water or solvents), & (D + P) simultaneous drying & pulverizing.

A. Identifier

Each alphanumeric designation in column A identifies a specific set of process conditions based on columns B, C, D, & E.

B. Type of CoalCODE

- A West Virginia - Monongalia Co. - Pittsburgh Seam
- B Kentucky No. 9 - Hopkins County

Assume ASH of 12-15 wt % and Hardgrove No. 55

C. Coal Feed Size Consist

Feed coal to all processes is 3/4" x 0". Assume 10% by weight moisture max. or appropriate moisture based on coal type & previous experience. Please indicate if other than 10%.

D. System Total Feed Rate

This is the total feed rate to all trains in short tons per hour.

E. Product Size

Five different size consists conditions are listed as the product leaving the pulverizers. Final moisture content for the drying + pulverizing process shall be 2% by wt.

RESPONSE MATRIX

1. Coal Drying Medium (if used)

The code letter in column 1 shall indicate the type of drying medium proposed in accordance with the code listed below:

<u>CODE</u>	<u>MEDIUM</u>
A	Dry Air - Assume Air Source at Required Temp.
B	Other Gas - State Type Utilized
C	Coal-Water Slurry
D	Coal-Solvent Slurry

2. Drying Medium Inlet Temperature

Indicate inlet temperature - °F

3. Drying Medium Outlet Temperature

Indicate outlet temperature - °F

4. Drying Medium - Flow Rate

Indicate flow rate in actual cubic feet per minute or gallons per minute.

5. Type of Pulverizer Recommended

Indicate type of pulverizer chosen for specific process. Choose the appropriate code letters from the list below:

<u>CODE</u>	<u>TYPE</u>
A	Vertical Roll Mill
B	Hammer Mill
C	Ball Mill
D	Rod Mill
E	Sowl Mill
F	Cage Mill
G	Other - (Specify)

6. Size & No. of Pulverizers Recommended

Indicate single unit size (STPH) & total number of units (& TRAINS) for total feed rate.

7. Power Required (each unit)

Indicate horse power required for each unit.

8. Recommended Type of Drive

Indicate drive type. Preferred unit shall be explosion proof, direct drive, or state alternative. Also indicate recommended method of control.

9. Recommended Type of Lubrication

Indicate the recommended type of lubrication for rotating parts by choosing the appropriate code from the following list and inserting in column 9.

<u>Code</u>	<u>Type Lubrication</u>
A	Continuous-automatic forced pumping
B	Splash
C	Intermittent-manual
D	Permanent lubricated bearings
E	Other - Please indicate with footnote

10. Cost of Recommended Pulverizer Delivered

Indicate cost of single unit delivered in 1978 dollars.
(Indicate with or without motor)

11. Estimated Installation Cost

Indicate estimated installation cost for each unit in 1978 dollars.

12. Estimated Total Installed Cost

Indicate the total installed cost for all units in 1978 dollars.
(Columns 10 & 11)

13. Cost of Recommended Spare Parts

Indicate total cost of recommended spare parts for single unit in 1978 dollars.

14. Auxiliary equipment Required and Cost

Indicate auxiliary equipment (associated with process) cost in 1978 dollars. A separate list of the items involved will be helpful.

15. Estimated Operating Cost/Yr

Indicate estimated operating cost per year for each unit in 1978 dollars.

16. Estimated Maintenance Cost

Please consider the average annual repair and maintenance cost during the first ten years of the life of the pulverizer when used in the service indicated. Please insert in column 16 the number which best represents your estimate of the average annual maintenance cost as a percentage of the initial cost of the pulverizer: <5%, <10%, <25%, <50%, <100%, or >100%.

17. In-Service Availability

Please provide in column 17 your projection of available in-service time: 98%+, 95%+, 80%+, 60%+, <60%.

18. Pulverizer Availability

Select the applicable availability code from page 6 & insert in column 18.

19. Limiting Factors

If your availability code in column 18 is not A1 or A2, please indicate the particular characteristics which are the limiting factors. Expand on this with additional sheets, if necessary, and reference footnotes in column 19.

20. Delivery Time

For equipment which you make or anticipate making, please insert in column 20 the number below which best represents the anticipated lead time in months required from order placement through installation and check out: <6, <12, <18, <24, <36, or >36. (Delivery time does not include development time which should be included in column 21.)

21. Development Time

For equipment not yet available but specified for applications listed, please state the total anticipated time for research, development, and testing required to provide the first unit of reliable equipment. Please state in years in column 21.

22. Problem Areas

For the equipment specified for this application, please identify the most severe problems anticipated by inserting the most appropriate code(s) in column 22 from the following list.

A. Corrosion	G. Seals
B. Erosion	H. Couplings
C. Pitting	I. Vibration
D. Deposits	J. Drivers
E. Plugging	K. Intermediate Transmissions
F. Bearings	L. Other

23. Largest Pulverizer Available

Indicate in column 23 the largest capacity single unit pulverizer which you do make for the process conditions listed. (Based on several units for the overall total system feed rate)

24. Power Required for Largest Unit

Indicate the horse power required for the largest single unit.

25. Cost of Largest Unit

Indicate cost of unit in 1978 dollars.

26. Catalogs

Please provide two copies of catalogs on your equipment for the following:

- a. equipment for the more difficult applications;
- b. the most advanced line of equipment presently manufactured by your company.

Catalog numbers and/or other identifying information may be added in column 26.

27. Additional Comments

Additional comments on specific applications are welcomed. These may be stated or footnoted in column 27. Attach additional sheets, if necessary.

Industry Capabilities and Quantities

Please provide your general comments and your assessment of industry's capability to supply pulverizers of advanced design in sufficient quantities for demonstration and commercial coal conversion plants. This is assuming that coal conversion will become a major industry within the next ten to fifteen years.

AVAILABILITY CODES FOR USE IN COMPLETING ITEM 18

<u>Code</u>	<u>Description</u>
<u>Available Equipment</u>	
A1	Available off-the-shelf equipment produced by <u>our company</u> .
A2	Equipment available by special order through <u>our company</u> .
A3	Equipment not presently available through out company but believed to be available within the <u>industry</u> .
<u>Technology Available for Scale-up</u>	
B1	Equipment is not presently available through our company but technology is available <u>in-house</u> which will likely be used if market forces are attractive.
B2	Equipment is not presently available through our company but technology is available within the <u>industry</u> which will likely be used by one or more companies if market forces are attractive.
<u>Anticipated Technology by 1982</u>	
C1	Anticipated technology requiring R&D which will likely be funded by <u>our company</u> if market forces are attractive.
C2	Anticipated technology requiring R&D which can be funded by <u>industry</u> if market forces are attractive.
C3	Anticipated technology requiring R&D which can be handled through <u>our company</u> provided governmental assistance is available.
C4	Anticipated technology requiring R&D which can be handled <u>within the industry</u> provided <u>governmental assistance</u> is available.
<u>Anticipated Technology: 1982 to 1987</u>	
D1	Very advanced future technology requiring extensive R&D which is likely to be handled by industry by 1987 <u>without governmental assistance</u> .
D2	Very advanced future technology requiring extensive R&D which requires governmental assistance for development by 1987.
<u>Questionable Technology</u>	
E1	Technology not believed possible before 1987.
E2	Technology not believed possible for these conditions.
<u>Inapplicable</u>	
F1	None of the above codes are applicable or appropriate for our firm to use. Insert a footnote in column 27 for additional comments, if so desired.

Pulverizers

Page 7

To: Coal Equipment Survey
 Union Carbide Corporation-
 Nuclear Division
 Building 1000 - MS-223C
 Post Office Box X
 Oak Ridge, TN 37830

Investigation of Industrial Coal Conversion
Equipment Capability

Address and Reference Form for Manufacturers
of
Pulverizers

1. Please indicate below the name and address of your company as you would like to have it listed in the final report.

COMPANY _____
 AND _____
 DIVISION _____
 STREET _____
 CITY _____ STATE _____ ZIP _____

2. Please indicate below an individual's name and address available for additional communication, if necessary, during the period of this study.

NAME _____
 COMPANY _____
 AND _____
 DIVISION _____
 STREET _____
 CITY _____ STATE _____ ZIP _____

3. Please indicate below the name and address of a person (or position) you would like to have the final report mailed to.

NAME _____
 COMPANY _____
 AND _____
 DIVISION _____
 STREET _____
 CITY _____ STATE _____ ZIP _____

Respectfully submitted,

 Date _____

Please return this sheet together with sheets 8, 9, 10, and 11 of this attachment for pulverizers.

PULVERIZERS

A	PROCESS CONDITIONS				RESPONSE MATRIX				Page 8
	B	C	D	E	1	2	3	4	
	Type of Coal	Coal Feed Size Consist	System Total Feed Rate	Product Size	Coal Drying Medium	Drying Medium Inlet Tem.	Drying Medium Outlet tem.	Drying Medium Flow Rate	
		Inches	STPH			°F	°F	ACFM/GPM	
D P-1	A	3/4 x 0	1800	70%-200M					
D P-2	A	3/4 x 0	1800	5%+20M25%-200M					
D P-3	A	3/4 x 0	1800	40%-200M					
D P-4	A	3/4 x 0	1800	-10M+100M					
D P-5	A	3/4 x 0	1800	100%-40M					
D P-6	B	3/4 x 0	1800	70%-200M					
D P-7	B	3/4 x 0	1800	5%+20M25%-200M					
D P-8	B	3/4 x 0	1800	40%-200M					
D P-9	B	3/4 x 0	1800	-10M+100M					
D P-10	B	3/4 x 0	1800	100%-40M					
W P-1	A	3/4 x 0	1800	70%-200M					
W P-2	A	3/4 x 0	1800	5%+20M25%-200M					
W P-3	A	3/4 x 0	1800	40%-200M					
W P-4	A	3/4 x 0	1800	-10M+100M					
W P-5	A	3/4 x 0	1800	100%-40M					
W P-6	B	3/4 x 0	1800	70%-200M					
W P-7	B	3/4 x 0	1800	5%+20M25%-200M					
W P-8	B	3/4 x 0	1800	40%-200M					
W P-9	B	3/4 x 0	1800	-10M+100M					
W P-10	B	3/4 x 0	1800	100%-40M					
D+P-1	A	3/4 x 0	1800	70%-200M					
D+P-2	A	3/4 x 0	1800	5%+20M25%-200M					
D+P-3	A	3/4 x 0	1800	40%-200M					
D+P-4	A	3/4 x 0	1800	-10M+100M					
D+P-5	A	3/4 x 0	1800	100%-40M					
D+P-6	B	3/4 x 0	1800	70%-200M					
D+P-7	B	3/4 x 0	1800	5%+20M25%-200M					
D+P-8	B	3/4 x 0	1800	40%-200M					
D+P-9	B	3/4 x 0	1800	-10M+100M					
D+P-10	B	3/4 x 0	1800	100%-40M					

RESPONSE MATRIX								
Page 9								
A	5	6	7	8	9	10	11	12
Identifier	Type of Pulverizer Recom.	Size & No. of Pulverizers Recom.	Power Required Each Unit H.P.	Recom. Type of Drive	Recom. Type of Lub.	Cost of Recom. Pulverizer Delivered \$	Estimated Install. Cost \$	Estimated Total Install. Cost \$
D P-1								
D P-2								
D P-3								
D P-4								
D P-5								
D P-6								
D P-7								
D P-8								
D P-9								
D P-10								
W P-1								
W P-2								
W P-3								
W P-4								
W P-5								
W P-6								
W P-7								
W P-8								
W P-9								
W P-10								
D+P-1								
D+P-2								
D+P-3								
D+P-4								
D+P-5								
D+P-6								
D+P-7								
D+P-8								
D+P-9								
D+P-10								

RESPONSE MATRIX								Page 11
A	21	22	23	24	25	26	27	
Identifier	Develop. Time	Problem Areas	Largest Pulverizer Avail.	Power Req. for Largest Unit	Cost of Largest Unit	Catalogs	Additional Comments	
	Years		STPH	H.P.	\$			
D P-1								
D P-2								
D P-3								
D P-4								
D P-5								
D P-6								
D P-7								
D P-8								
D P-9								
D P-10								
W P-1								
W P-2								
W P-3								
W P-4								
W P-5								
W P-6								
W P-7								
W P-8								
W P-9								
W P-10								
D+P-1								
D+P-2								
D+P-3								
D+P-4								
D+P-5								
D+P-6								
D+P-7								
D+P-8								
D+P-9								
D+P-10								

ATTACHMENT

Investigation of Coal Handling, Preparation, and Ash/Slag Letdown
and Removal Equipment CapabilitiesThermal Dryers

This attachment contains a list of typical applications for thermal dryers in proposed coal preparation systems of future coal conversion plants. Also included is a questionnaire for determining the availability of thermal dryers for these applications.

Pages 1 through 5 of this attachment list general instructions for completing the questionnaire.

Page 6 lists the availability code to use in completing item 3 of the instructions.

Page 7 is an address and reference form which should be completed to properly reference your firm and point of contact. One individual should be named on this form for further contact by telephone during this study if necessary.

Pages 8 through 12 list the typical applications for thermal dryers in coal conversion plants and provide blank columns for inserting the information requested by this questionnaire.

You may feel that some of the questions are too difficult or time consuming to answer. We will appreciate your effort in answering these questions to the extent practicable.

THERMAL DRYERS

GENERAL INSTRUCTIONS

The following alphabetic & numerical instructions refer to the respective column letters and numbers on page 8 through 12. Columns A, B, C & D list specific process conditions. Columns 1 through 31 provide space for answers to the respective information. Please use footnotes when appropriate.

PROCESS CONDITIONS

A. Identifier

Each alphanumeric designation in column A identifies a specific set of process conditions based on columns B, C, & D.

B. Type of CoalCode

A	West Virginia - Monongalia Co. - Pittsburgh Seam
B	Kentucky No. 9 - Hopkins Co.

Assume ASH of 12-15 wt % and Hardgrove No. 55

C. System Total Feed Rate

This is the total feed rate to all trains in short tons per hour. Assume the feed materials to have a maximum moisture of 10% by wt.

D. Product Size

Seven different size consist conditions are listed in column D to be dried. Assume that the dried coal to have a final maximum moisture content of 2% by wt.

RESPONSE MATRIX

1. Type of Thermal Dryer Recommended

Indicate the type of thermal dryer recommended by choosing the appropriate code from the list below and inserting in column 1.

<u>Code</u>	<u>Type</u>
A	Fluidized Bed
B	Suspension or Flash
C	Multi-Louvre
D	Vertical Tray and Cascade
E	Continuous Carrier
F	Drum (Roto-Louvre)
G	Other - Please indicate with footnote

2. Number of Thermal Dryers Recommended

Indicate in column 2, the number of thermal dryers recommended. Consider an adequate number of parallel operations to enable maintenance to be performed and to minimize the occurrence of unscheduled shutdowns of an entire process line.

3. Thermal Dryer Availability

Please choose the appropriate availability code from the list on page 6 and insert it in column 3.

4. Limiting Factors

If your availability code in column 3 is not A1 or A2, please indicate the particular characteristics which are the limiting factors. Expand on this with additional sheets, if necessary, and reference footnotes in column 4.

5. Power Required for Each Thermal Dryer

Indicate in column 5 the power, horsepower (Hp), required by each thermal dryer.

6. Heating Capacity of Each Dryer

Please indicate the heating capacity of the recommended dryer by inserting the BTU/hour and BTU/lb of H₂O in Col. 6.

7. Operating Temperature of Each Dryer

Indicate in column 7, the maximum recommended operating temperature of the dryer - °F.

8. Product Temperature at Discharge

Indicate in column 8, the maximum recommended temperature of the coal leaving the dryer - °F.

9. Dryer Fuel Requirements

Indicate in column 9 the type and quantity (in pounds per hour or GPM) of fuel required for the dryer.

10. Drying Medium

Specify in column 10 the drying medium required by the dryer and if drying medium is to be provided by the seller or buyer.

11. Recommended Drive and Transmission

Indicate drive type. Preferred unit shall be explosion proof, direct drive, or state alternative. Also indicate recommended method of control.

12. Recommended Type of Lubrication

Indicate the recommended type of lubrication for rotating parts by choosing the appropriate code from the following list and inserting in column 12.

<u>Code</u>	<u>Type Lubrication</u>
A	Continuous-automatic forced pumping
B	Splash
C	Intermittent-manual
D	Permanent lubricated bearings
E	Other - Please indicate with footnote.

13. Recommended Type of Feeder to Dryer

Indicate in column 13 the type feeder recommended for use with the dryer by choosing the appropriate code from following list.

<u>Code</u>	<u>Feeder</u>
A	Screw
B	Vibrating
C	Roll
D	Star (rotary gate)
E	Other - Please indicate with footnote

14. Dryer Product Discharge Equipment

Indicate in column 14 the type of dried coal collecting and discharge equipment recommended for use with the dryer.

15. Estimated In-Service Availability

Indicate in column 15 your estimation of available in-service time: 90%+, 75%+, 60%+, 40%+, and <40%.

16. Problem Areas

For the equipment specified, identify the most severe problems anticipated by inserting in column 16 the most appropriate code(s) from the following list.

A. Corrosion	H. Couplings
B. Erosion	I. Vibration
C. Pitting	J. Drivers
D. Deposits	K. Intermediate transmissions
E. Plugging	L. Control of temperature
F. Bearings	M. Control of drying medium
G. Seals	N. Fires & Explosions
	O. Other

17. Delivery Time

For equipment which you make or anticipate making, please insert in column 17 the number below which best represents the anticipated lead time in months required from order placement through installation and check out: <6, <12, <18, <24, <36, or >36. (Delivery time does not include development time which should be included in item 18.)

18. Development Lead Time

For equipment not yet available but specified for applications listed, please state the total anticipated time for research, development, and testing required to provide the first unit of reliable equipment. Please state in years in column 18.

19. Cost of Dryer Delivered

Insert in column 19 the cost, in 1978 U.S. dollars, of the recommended dryer unit delivered.

20. Estimated Installation Cost

Insert in column 18 the estimated cost of installing each recommended dryer.

21. Installed Cost

This is the total, estimated, installed cost and is the sum of columns 19 and 20. Please insert the total cost, in 1978 dollars, in column 21.

22. Spare Parts

Furnish a list of recommended spare parts and insert in column 23 their cost in 1978 dollars.

23. Auxiliary Equipment

Furnish a list of required auxiliary equipment and insert the cost of this auxiliary equipment in 1978 dollars in column 23.

24. Anticipated Maintenance Cost

Please consider the average annual repair and maintenance cost during the first ten years of the life of the thermal dryers when used in the service indicated. Please insert in column 24 the number which best represents your estimate of the average annual maintenance cost as a percentage of the initial cost of the thermal dryers: <5%, <10%, <25%, <50%, <100%, or >100%.

25. Estimated Operating Cost

Please insert in column 25 your estimate of the annual operating cost in 1978 dollars. Do not include maintenance costs.

26. Largest Capacity Thermal Dryer Available

Please indicate in column 26, the largest capacity, STPH, thermal dryer that you do make for the process conditions listed.

27. Power Required By Largest Dryer

Indicate in column 27 the horsepower of the largest dryer.

28. Cost of Largest Dryer, Delivered

Indicate in column 28 the cost, delivered, of the largest dryer.

29. Catalogs

Please provide two copies of catalogs on your equipment for the following:

- a. thermal dryers for the more difficult applications;
- b. the most advanced line of thermal dryers presently manufactured by your company.

Catalog numbers and/or other identifying information may be added in column 29.

30. Additional Comments

Additional comments on specific applications are welcomed. These may be stated or footnoted in column 30. Attach additional sheets, if necessary.

31. Industry Capabilities and Quantities

Please provide your general comments and your assessment of industry's capability to supply thermal dryers of advanced design in sufficient quantities for demonstration and commercial coal conversion plants. This is assuming that coal conversion will become a major industry within the next ten to fifteen years.

32. & 33. Emission Standards

Indicate the amount of particulate matter and sulfur dioxide in micrograms per cubic meter in the discharge from the thermal dryer during operation.

AVAILABILITY CODES FOR USE IN COMPLETING ITEM 3

<u>Code</u>	<u>Description</u>
<u>Available Equipment</u>	
A1	Available off-the-shelf equipment produced by <u>our company</u> .
A2	Equipment available by special order through <u>our company</u> .
A3	Equipment not presently available through our company but believed to be available within the <u>industry</u> .
<u>Technology Available for Scale-up</u>	
B1	Equipment is not presently available through our company but technology is available <u>in-house</u> which will likely be used if market forces are attractive.
B2	Equipment is not presently available through our company but technology is available within the <u>industry</u> which will likely be used by one or more companies if market forces are attractive.
<u>Anticipated Technology by 1982</u>	
C1	Anticipated technology requiring R&D which will likely be funded by <u>our company</u> if market forces are attractive.
C2	Anticipated technology requiring R&D which can be funded by <u>industry</u> if market forces are attractive.
C3	Anticipated technology requiring R&D which can be handled through <u>our company</u> provided governmental assistance is available.
C4	Anticipated technology requiring R&D which can be handled <u>within the industry</u> provided <u>governmental assistance</u> is available.
<u>Anticipated Technology: 1982 to 1987</u>	
D1	Very advanced future technology requiring extensive R&D which is likely to be handled by industry by 1987 <u>without governmental assistance</u> .
D2	Very advanced future technology requiring extensive R&D which requires governmental assistance for development by 1987.
<u>Questionable Technology</u>	
E1	Technology not believed possible before 1987.
E2	Technology not believed possible for these conditions.
<u>Inapplicable</u>	
F1	None of the above codes are applicable or appropriate for our firm to use. Insert a footnote in column 3 for additional comments, if so desired.

Thermal Dryers

Page 7

To: Coal Equipment Survey
 Union Carbide Corporation-
 Nuclear Division
 Building 1000 - MS-223C
 Post Office Box X
 Oak Ridge, TN 37830

Investigation of Industrial Coal Conversion
Equipment Capability

Address and Reference Form for Manufacturers
of
Thermal Dryers

1. Please indicate below the name and address of your company as you would like to have it listed in the final report.

COMPANY _____
 AND _____
 DIVISION _____
 STREET _____
 CITY _____ STATE _____ ZIP _____

2. Please indicate below an individual's name and address available for additional communication, if necessary, during the period of this study.

NAME _____
 COMPANY _____
 AND _____
 DIVISION _____
 STREET _____
 CITY _____ STATE _____ ZIP _____

3. Please indicate below the name and address of a person (or position) you would like to have the final report mailed to.

NAME _____
 COMPANY _____
 AND _____
 DIVISION _____
 STREET _____
 CITY _____ STATE _____ ZIP _____

Respectfully submitted,

 Date _____

Please return this sheet together with sheets 8, 9, 10, 11, and 12 of this attachment for thermal dryers.

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[illegible]

[illegible]

ATTACHMENT

Investigation of Coal Handling, Preparation, and Ash/Slag
Letdown and Removal Equipment Capabilities

This attachment contains a list of typical applications for clinker grinders in proposed coal preparation systems of future coal conversion plants. Also included is a questionnaire for determining the availability of grinders for these applications.

Pages 1 through 5 of this attachment list general instructions for completing the questionnaire.

Page 6 lists the availability code to use in completing item 16 of the instructions

Page 7 is an address and reference form which should be completed to properly reference your firm and point of contact. One individual should be named on this form for further contact by telephone during this study if necessary.

Pages 8 through 12 list the typical applications for clinker grinders in coal conversion plants and provide blank columns for inserting the information requested by this questionnaire.

You may feel that some of the questions are too difficult or time consuming to answer. We will appreciate your effort in answering these questions to the extent practicable.

CLINKER GRINDERS, DELUMPERS, AND OTHER SLAG CRUSHERS

GENERAL INSTRUCTIONS

The following alphabetic and numerical instructions refer to the respective column letters and numbers on page 8 through 12. Columns A through J list specific process conditions. Columns 1 through 24 provide space for answers to the information requested. Please use footnotes when appropriate.

PROCESS CONDITIONS

Note that a wet process involving injected water (WP) is the usual method for cooling and breaking up slag.

A. Identifier

Each alphanumeric designation in column A identifies a specific set of process conditions based on columns B thru J.

B. Type of CoalCode

A West Virginia, Monongalia County, Pittsburg seam

B Kentucky No. 9, Hopkins County

Assume Ash of 12-15 wt % and Hardgrove No. 55

- C. System total feed rate, standard tons per day (STPD).
- D. Ash/slag produced, STPD.
- E. Ash/slag temperature at bottom of gasifier.
- F. Ash/slag pressure at bottom of gasifier.
- G. Grinder discharge rate, STPD.
- H. Ash/slag size = product leaving the grinder.
- I. Solids content of slurry (leaving the ash/slag section) going to waste disposal.
- J. pH of slurry.

RESPONSE MATRIX

1. Coolant flow rate (GPS) to reduce slag to $\sim 160^{\circ}\text{F}$ and ~ 1 psig.

2. Type of Grinder Recommended

Indicate type of grinder chosen for specific process. Choose the appropriate code letters from the list below:

<u>Code</u>	<u>Type</u>
A	Clinker grinder-double roll
B	Clinker grinder-single roll plus breaker
C	Delumper
D	Other (specify)

3. Size and No. of Grinders Recommended

Indicate single unit size (STPD) and total number of units for total ash/slag rate.

4. Power Required (per unit)

Indicate HP.

5. Recommended Type of Drive

Indicate drive type. Preferred unit shall be explosion proof, direct drive, or state alternative. Also indicate recommended method of control.

6. Recommended Type of Lubrication

Indicate the recommended type of lubrication for rotating parts by choosing the appropriate code from the following list and inserting in column 6.

<u>Code</u>	<u>Type of Lubrication</u>
A	Continuous-automatic forced pumping
B	Splash
C	Intermittent-manual
D	Permanent lubricated bearings
E	Other- Please indicate with footnote

8. Cost of Recommended Grinder Delivered

Indicate cost of single unit delivered in 1978 dollars. (Indicate with or without motor.)

9. Estimated Installation Cost

Indicate estimated installation cost for each unit in 1978 dollars.

10. Estimated Total Installed Cost

Indicate the total installed cost for all units in 1978 dollars. (Columns 8 and 9.)

11. Cost of Recommended Spare Parts

Indicate total cost of recommended spare parts for single unit in 1978 dollars.

12. Auxiliary Equipment Required and Cost

Indicate auxiliary equipment (associated with process) cost in 1978 dollars. A separate list of the items involved will be helpful.

13. Estimated Operating Cost/Year

Indicate estimated operating cost per year for each unit in 1978 dollars.

14. Estimated Maintenance Cost

Please consider the average annual repair and maintenance cost during the first 10 years of the life of the grinder when used in the service indicated. Please insert in column 14 the number which best represents your estimate of the average annual maintenance cost as a percentage of the initial cost of the grinder: <5%, <10%, <25%, <50%, <100%, or >100%.

15. In-service Availability

Please provide in column 15 your projection of available in-service time: 98%+, 95%+, 80%+, 60%+, <60%.

16. Grinder Availability

Select the applicable availability code from page 6 and insert in column 16.

17. Limiting Factors

If your availability code in column 16 is not A1 or A2, please indicate the particular characteristics which are the limiting factors. Expand on this with additional sheets, if necessary, and reference footnotes in column 17.

18. Delivery Time

For equipment which you make or anticipate making, please insert in column 18 the number below which best represents the anticipated lead time in months required from order placement through installation and check out: <6, <12, <18, <24, <36, or >36. (Delivery time does not include development time which should be included in column 19.)

19. Development Time

For equipment not yet available but specified for applications listed, please state the total anticipated time for research, development, and testing required to provide the first unit of reliable equipment. Please state in years in column 19.

20. Problem Areas

For the equipment specified for this application, please identify the most severe problems anticipated by inserting the most appropriate code(s) in column 20 from the following list.

A. Corrosion	G. Seals
B. Erosion	H. Couplings
C. Pitting	I. Vibration
D. Deposits	J. Drivers
E. Plugging	K. Intermediate transmissions
F. Bearings	L. Other

21. Largest Grinder Available

Indicate in column 21 the largest capacity single unit grinder which you do make for the process conditions listed. (Based on several units for the overall total system feed rate.)

22. Power Required for Largest Unit

Indicate the horsepower required for the largest single unit.

23. Cost of Largest Unit

Indicate cost of unit in 1978 dollars.

24. Catalogs

Please provide two copies of catalogs on your equipment for the following:

- a. Equipment for the more difficult applications;
- b. The most advanced line of equipment presently manufactured by your Company.

Catalog numbers and/or other identifying information may be added in column 24.

25. Additional Comments

Additional comments on specific applications and problem areas are welcomed. These may be stated or footnoted in column 25. Attach additional sheets, if necessary.

Industry Capabilities and Quantities

Please provide your general comments and assessment of industry's capability to supply grinders of advanced design in sufficient quantities for demonstration and commercial coal conversion plants. This is assuming that coal conversion will become a major industry within the next 10 to 15 years.

Grinders

6

AVAILABILITY CODES FOR USE IN COMPLETING ITEM 16

<u>Code</u>	<u>Description</u>
<u>Available Equipment</u>	
A1	Available off-the-shelf equipment produced by <u>our company</u> .
A2	Equipment available by special order through <u>our company</u> .
A3	Equipment not presently available through out company but believed to be available within the <u>industry</u> .
<u>Technology Available for Scale-up</u>	
B1	Equipment is not presently available through our company but technology is available <u>in-house</u> which will likely be used if market forces are attractive.
B2	Equipment is not presently available through our company but technology is available within the <u>industry</u> which will likely be used by one or more companies if market forces are attractive.
<u>Anticipated Technology by 1982</u>	
C1	Anticipated technology requiring R&D which will likely be funded by <u>our company</u> if market forces are attractive.
C2	Anticipated technology requiring R&D which can be funded by <u>industry</u> if market forces are attractive.
C3	Anticipated technology requiring R&D which can be handled through <u>our company</u> provided governmental assistance is available.
C4	Anticipated technology requiring R&D which can be handled <u>within the industry</u> provided <u>governmental assistance</u> is available.
<u>Anticipated Technology: 1982 to 1987</u>	
D1	Very advanced future technology requiring extensive R&D which is likely to be handled by industry by 1987 <u>without governmental assistance</u> .
D2	Very advanced future technology requiring extensive R&D which requires governmental assistance for development by 1987.
<u>Questionable Technology</u>	
E1	Technology not believed possible before 1987.
E2	Technology not believed possible for these conditions.
<u>Inapplicable</u>	
F1	None of the above codes are applicable or appropriate for our firm to use. Insert a footnote in column 24 for additional comments, if so desired.

Grinders

7

To: Coal Equipment Survey
 Union Carbide Corporation-
 Nuclear Division
 Building 9201-3; MS-5
 Post Office Box Y
 Oak Ridge, TN 37830

Investigation of Industrial Coal Conversion
Equipment Capability

Address and Reference Form for Manufacturers
of
Grinders

1. Please indicate below the name and address of your company as you would like to have it listed in the final report.

COMPANY _____
 AND _____
 DIVISION _____
 STREET _____
 CITY _____ STATE _____ ZIP _____

2. Please indicate below an individual's name and address available for additional communication, if necessary, during the period of this study.

NAME _____
 COMPANY _____
 AND _____
 DIVISION _____
 STREET _____
 CITY _____ STATE _____ ZIP _____

3. Please indicate below the name and address of a person (or position) you would like to have the final report mailed to.

NAME _____
 COMPANY _____
 AND _____
 DIVISION _____
 STREET _____
 CITY _____ STATE _____ ZIP _____

Respectfully submitted,

 Date _____

Please return this sheet together with sheets 8, 9, 10, 11, and 12 of this attachment for serial.

CLINKER GRINDERS

		PROCESS CONDITIONS						Page 8
A	B	C	D	E	F	G	H	I
Identifier	Type of Coal	System Total Feed Rate (STPD)	Waste Product Ash/Slag Rate (STPD)	Bottom of Ash/Slag Temp. (°F)	Gasifier Ash/Slag Pressure (psig)	Grinder Discharge Rate (STPD)	Ash Size Leaving Grinder	% Solids in Slurry to Waste Disposal
WP-1	A	10,000	1200	1800	1000			25
WP-2	A	5670	1513	3000	200			46
WP-3	A							
WP-4	A	9,573	2280	800-900	1600-3000			
WP-5	A	13,000	1080	1850	1200			25
WP-6	A		224	2000-3500	50			
WP-7	A			1900	300			
WP-1	B	10,000	1200	1800	1000			
WP-2	B	5,670	1513	3000	200			
WP-3	B							
WP-4	B							
WP-5	B	13,000	1080	1850	1200			
WP-6	B		224	2000-3500	50			
WP-7	B			1900	300			

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RESPONSE MATRIX								
Page 10								
A	7	8	9	10	11	12	13	14
Identifier	Type of Seal	Cost of Unit Recommended	Estimated Install. Cost per Unit	Total Install. Cost	Total Cost of Recommended Spare Parts per Unit	Auxiliary Equip. Required and Cost	Estimated Operating Cost per Unit/Year	Estimated Maint. Cost
		\$1978	\$1978	\$1978	\$1978	\$1978	\$1978	\$
WP-1								
WP-2								
WP-3								
WP-4								
WP-5								
WP-6								
WP-7								
WP-1								
WP-2								
WP-3								
WP-4								
WP-5								
WP-6								
WP-7								

RESPONSE MATRIX								
								Page 11
A	B	15	16	17	18	19	20	21
Identifier	Type of Coal	In-service Availability %	Grinder Avail (Code)	Limiting Factors	Delivery Time Months	Development Time Years	Problem Areas	Largest Grinder Available STPD
WP-1	A							
WP-2	A							
WP-3	A							
WP-4	A							
WP-5	A							
WP-6	A							
WP-7	A							
WP-1	B							
WP-2	B							
WP-3	B							
WP-4	B							
WP-5	B							
WP-6	B							
WP-7	B							

A	B	22	23	24	25			
Identifier	Type of Coal	HP for Largest Unit	Cost of Largest Unit	Catalogs	Additional Comments			
		H.P.	\$1978					
WP-1	A							
WP-2	A							
WP-3	A							
WP-4	A							
WP-5	A							
WP-6	A							
WP-7	A							
WP-1	B							
WP-2	B							
WP-3	B							
WP-4	B							
WP-5	B							
WB-6	B							

Appendix C

TABLES FROM BECHTEL REPORT

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Table 4-1
COAL CONVERSION PROCESSES COAL
FEED REQUIREMENTS

Process No.	Conversion Process and Type	Conversion Reactor Coal Feed Size Requirements	Conversion Reactor Coal Feed Total Moisture Requirements Wt Percent	Conversion Reactor Coal Feed System	Conversion Reactor Design Operating Pressure psig	Notes	References ⁽¹⁾
1	U-Gas Fluidized-Bed Gasification	100 percent minus 1/4 inch May contain up to 10 percent minus 200 mesh coal	As received	Lock Hopper	50-350	(1) Cleaned and uncleaned Kentucky No. 9 Seam coal has been successfully gasified in a pilot gasifier (3 ft diameter) without pretreatment to control agglomeration during gasification. (2) Pittsburgh Seam coal may require pretreatment to control agglomeration during gasification.	1,2 1,3
2	COGAS Fluidized-Bed Gasification	100 percent minus 1/3 inch.	As received	Hot Flue Gas Injection	50	(1) The COGAS Process uses multiple-stage fluidized-bed pyrolysis. Coal is dried in the first-stage fluidized-bed reactor(s).	
3	HYGAS Fluidized-Bed Gasification	100 percent minus 14 mesh with minimum minus 100 mesh	As received	Low-Pressure Lock Hopper (Feeds Coal to a Pretreatment Vessel)	1,155-1,165	(1) Both Pittsburgh Seam and Kentucky No. 9 Seam coal were assumed to require pretreatment to control agglomeration during gasification. (2) Coal is dried during pretreatment.	1,4,5
4	Texaco Partial Oxidation Entrained Flow Gasification	100 percent minus 20 mesh with minimum ultrafines	As received	Water Slurry Injection from a Slurrying and Surge Storage Vessel	500-1,500	(1) Operating temperature and pressure for the Texaco Partial Oxidation gasifier depends on synthesis gas requirements and feed coal composition.	1,6
5	Exxon Donor Solvent Liquefaction	100 percent minus 8 mesh	As received	Donor Solvent Slurry Injection from Slurrying and Drying Vessel	1,485	(1) Coal is dried to less than 4 wt percent total moisture after fine crushing during slurrying in hot (275°F) recycle donor solvent.	7
6	Exxon Catalytic Gasification Fluidized-Bed Gasification	100 percent minus 8 mesh	As received	Lock Hopper	500	(1) Coal is dried after fine crushing and catalyst addition. Catalyst is added as an aqueous solution.	8

⁽¹⁾ Presented in Report References section

Table 4-1 (Continued)

Process No.	Conversion Process and Type	Conversion Reactor Coal Feed Size Requirements	Conversion Reactor Coal Feed Total Moisture Requirements Wt Percent	Conversion Reactor Coal Feed System	Conversion Reactor Design Operating Pressure psig	Notes	References ⁽¹⁾
7 and 8	SRC-I and SRC-II Liquefaction	100 percent minus 12 mesh	As received	Solvent Slurry Injection from a Slurrying and Drying Vessel	2,400	(1) Gulf Mineral Resource Co. is currently evaluating a range of conversion reactor coal feed size consists for SRC-I and II demonstration plants. These range from 100 percent minus 6 mesh to 100 percent minus 50 mesh. (2) In some commercial-scale conceptual conversion plant designs, pulverized coal (nominally 70 percent minus 200 mesh) has been specified for the SRC-II process. (3) Coal is dried after fine crushing during slurrying in hot recycle solvent.	9,10
9	H-Coal Liquefaction	100 percent minus 40 mesh 70 percent minus 200 mesh	2 wt percent	Solvent Slurry Injection from a Slurrying Vessel	2,700	(1) Coal is dried during pulverizing.	10

(1) Presented in Report References section

Table 4-2

COAL CONVERSION PROCESSES ASH/SLAG
REMOVAL SYSTEMS DESIGN INFORMATION

Process No.	Conversion Process	Gasifier Design ⁽¹⁾	Gasifier Design Operating Temperature of	Gasifier Ash or Slag Removal Method	Ash or Slag Characteristics	Notes	References ⁽²⁾
1	U-Gas	Nonslagging Fluidized Bed	1,800-2,000	The U-Gas gasifier is designed to agglomerate fine ash particles in a specially designed spout or spouts located at the bottom of the gasifier fluidized bed. When ash particles grow to sufficient mass they deentrain from the fluidized bed and fall into a water-filled lock hopper located at the gasifier bottom. Agglomerated ash-water slurry is periodically discharged from the ash lock hopper.	Reported mean particle sizes for agglomerated ash range from 6 to 14 mesh Ash agglomerates contain 5-10 wt percent carbon	(1) Gasifier operating temperature is dependent on coal ash fusion temperature characteristics. Steam and oxygen fed to the gasifier ash agglomerating spout(s) located at the bottom of the fluidized bed are controlled to maintain ash particles near their softening temperature. (2) Agglomerated ash size consists depends on feed coal size, gasifier temperature, and agglomerating spout configuration.	1,2,11
2	COGAS	Fluidized Bed and a Cyclone Char Combustor	1,600-1,700	Char from multiple-stage coal pyrolysis is gasified with steam in a fluidized bed. Heat for char gasification is obtained by burning char fines in a vertical, cyclone, slagging combustor operating at moderate pressure. Molten slag from the combustor flows to a water-filled vessel located below the combustor where it is quenched and granulated. Granulated slag-water slurry is periodically discharged from the quench vessel by means of a valve system.	Granulated slag contains less than 0.5 wt percent carbon.	(1) Operation of cyclone combustors is dependent upon slag viscosity which is dependent on coal ash composition. Fluxing compounds could be required to control slag viscosity of char produced by pyrolysis of some coals.	1,3,12

Table 4-2 (Continued)

Process No.	Conversion Process	Gasifier Design ⁽¹⁾	Gasifier Design Operating Temperature or	Gasifier Ash or Slag Removal Method	Ash or Slag Characteristics	Notes	References ⁽²⁾
3	HYGAS	Vertical Multi-stage Fluidized Bed	1,500-1,800 (Steam-Oxygen Gasification Stage)	The HYGAS gasifier produces a high ash char which can be burned for steam generation and/or disposed of as solid waste. Char removed from the steam-oxygen gasification stage is water-quenched in the gasifier bottom. Char-water slurry is periodically discharged from the gasifier by means of a water-filled lock hopper system.	Reported char ash concentration is on the order of 65 wt percent. Reported char higher heat value is on the order of 5,400 Btu/lb, dry basis.	(1) The HYGAS gasifier is non-slugging. As a result coal and char ash fusion temperatures must be sufficiently high to prevent slugging or sintering during hydrogasification and steam-oxygen gasification.	1,4,5,13
4	Texaco Partial Oxidation	Slagging Entrained Downflow	2,000-2,800	At the temperatures used in this oxygen-blown gasifier most coal ash is converted to slag. Most of this slag is captured, quenched, and granulated in the water-filled bottom of the gasifier. Granulated slag passes to a water-filled lock hopper system located below the gasifier. Granulated slag-water slurry is periodically discharged from the lock hopper system.	Granulated slag size consists of coal dependent. Slag carbon concentration is 2 wt percent or less.	(1) The Texaco Partial Oxidation gasifier operates at a temperature approximately 50°F above coal feed ash fusion temperature. Coals with high ash fusion temperatures require more oxygen than coals having lower ash fusion temperatures.	1,6

Table 4-2 (Continued)

Process No.	Conversion Process	Gasifier Design ⁽¹⁾	Gasifier Design Operating Temperature of	Gasifier Ash or Slag Removal Method	Ash or Slag Characteristics	Notes	References ⁽²⁾
5	Exxon Dor.or Solvent	Fluidized Bed	N.A.	Three types of coke result from the EDS Flexicoking approach to treatment of liquefaction process fractionation bottoms: dry coke fines, coke slurry, coke chunks-agglomerates. Dry coke fines are removed by cyclones from the low-Btu fuel gas resulting from coke gasification. Coke slurry results from water scrubbing of the low-Btu gas resulting from coke gasification. Coke chunks and agglomerates are periodically removed from the gasifier bed.	Estimated total coke ash is 66 wt percent. Dry Coke Fines: Bulk Density, 25 lbs/ft ³ Size Consist, 100 percent minus 20 microns Coke Slurry: 60 wt percent moisture after vacuum filtration Chunk Coke: Bulk Density, 65 lbs/ft ³ Size Consist, 1/4-1 inch mean size	(1) Several approaches for treatment of fractionation bottoms are being evaluated for the EDS Process. Other coke gasification processes include Texaco Partial Oxidation-Gasification.	7
6	Exxon Catalytic Gasification	Fluidized Bed	1,300	Char resulting from gasification is water quenched at gasification pressure and fed to a digester using a lock hopper system. Char is digested at approximately 300°F with Ca(OH) ₂ . After digestion, the char slurry is washed countercurrently with water in multiple vessels. Vacuum filtration would likely be used for final char dewatering.	Not Available	(1) This is a relatively new gasification process and has not been developed to the same extent as the other gasification processes considered in this table.	8,14
7 and 3	SRC-I and SRC-II	Slagging Entrained Down Flow	2,000-2,800	For development of conceptual ash/slag removal flow sheets SRC-II fractionation bottoms are assumed gasified using the Texaco Partial Oxidation (Process No. 4). SRC-I solids are removed from liquified coal by filtration.	See Process No. 4	(1) For SRC-I Texaco Partial Oxidation gasification of coal was assumed to be used for hydrogen production.	-

Table 4-2 (Continued)

Process No.	Conversion Process	Gasifier Design ⁽¹⁾	Gasifier Design Operating Temperature of	Gasifier Ash or Slag Removal Method	Ash or Slag Characteristics	Notes	References ⁽²⁾
9	H-Coal	Slagging Entrained Down Flow	2,000-2,800	For development of conceptual ash/slag removal flow sheets fractionation bottoms from the H-Coal Process are assumed gasified using the Texaco Partial Oxidation Process (see Process No. 4).	See Process No. 4	-	-

(1) All liquefaction conversion processes except SRC-I considered in this table gasify solids resulting from coal liquefaction and subsequent liquefied coal fractionation. For these processes, this column identifies the type of gasifier currently being considered for such gasification.

(2) Presented in Report References section

Table 4-3

SELECTED COAL ASH ANALYSIS AND
FUSION TEMPERATURES⁽²⁾

Coal Ash	Kentucky No. 9 Seam Coal	Illinois No. 5 Seam Coal ⁽¹⁾	Pittsburgh Seam Coal
Coal Ash, wt. percent	7.9	10.3	9.0
Coal S, wt. percent	3.3	3.6	2.9
Ash Component	Ash Analysis - Wt. Percent		
SiO ₂	43.7	48.0	41.1
Al ₂ O ₃	22.1	14.7	25.0
Fe ₂ O ₃	29.0	18.7	27.5
TiO ₂	1.0	0.6	1.1
P ₂ O ₅	0.23	0.44	0.18
CaO	0.9	10.4	1.7
MgO	0.9	0.6	0.8
Na ₂ O	0.2	0.2	0.8
K ₂ O	2.3	1.8	1.6
SO ₃	0.8	2.1	1.6
	Ash Fusion Temperatures		
Initial Deformation Temperature, °F	2,050	1,940	2,000
Softening Temperature, °F	2,140	2,000	2,120
Fluid Temperature, °F	2,430	2,230	2,400

Notes:

(1) Illinois No. 5 and Kentucky No. 9 are the same coal seam.

(2) Data taken from Reference (5).

Table 4-6

PITTSBURGH SEAM COAL
WASHABILITY CHARACTERISTICS WITH ROOF AND FLOOR DILUTION

Specific Gravity	Elementary Data					Cumulative Data				
	Weight Percent	Ash Percent	Sulfur		HHV Btu/lb	Weight Percent	Ash Percent	Sulfur		HHV Btu/lb
			Pyritic Percent	Total Percent				Pyritic Percent	Total Percent	
			1.5 inch (38 mm) x 200 mesh							
-1.30	46.28	4.85	0.40	1.77	14,413	46.28	4.85	0.40	1.77	14,413
1.30-1.40	25.66	10.02	1.18	2.47	13,630	71.94	6.69	0.68	2.02	14,133
1.40-1.60	4.86	19.65	2.72	4.00	11,682	76.80	7.51	0.81	2.15	13,978
1.60-1.80	3.20	50.75	9.82	10.62	8,510	80.00	9.24	1.17	2.49	13,759
+1.80	20.00	73.50	10.77	12.09	3,179	100.00	22.09	3.09	4.41	11,643
Total	100.00	22.09	3.09	4.41	11,643					
			3/8 inch (9.5 mm) x 200 mesh							
-1.30	49.70	4.70	0.35	1.77	14,432	49.70	4.70	0.35	1.77	14,432
1.30-1.40	21.20	9.98	1.04	2.47	13,639	70.90	6.27	0.56	1.98	14,194
1.40-1.60	5.08	18.99	2.82	3.91	11,592	75.98	7.13	0.71	2.11	14,020
1.60-1.80	4.02	54.93	9.92	10.62	8,358	80.00	9.53	1.17	2.54	13,316
+1.80	20.00	73.50	11.07	12.24	4,759	100.00	22.32	3.15	4.48	11,603
Total	100.00	22.32	3.15	4.48	11,603					
			14 mesh (1.4 mm) x 200 mesh							
-1.30	47.68	3.90	0.23	1.62	14,553	47.68	3.90	0.23	1.62	14,553
1.30-1.40	22.00	10.16	0.72	2.02	13,611	70.56	5.93	0.39	1.75	14,247
1.40-1.60	5.12	21.45	2.90	4.12	11,557	75.68	6.98	0.56	1.91	14,065
1.60-1.80	4.32	50.35	9.60	10.40	8,480	80.00	9.32	1.05	2.37	13,763
+1.80	20.00	73.50	11.10	12.72	3,118	100.00	22.15	3.06	4.44	11,634
Total	100.00	22.15	3.06	4.44						

Table 4-9

COAL CLEANING FLOW SHEETS DESIGN CONDITIONS

Design Clean Coal Capacity	16.5 million short tons/year
Design Operating Schedule	
Daily:	20 hours/day
Weekly:	5 days/week
Annual Capacity Determination:	250 days/year
Design Separation Specific Gravity	1.8
Design Coal Weight Recovery	
Theoretical:	80 percent
Actual:	75.6 percent
Design Clean Coal Composition	
Ash:	9.0 wt percent
Total Moisture:	8.0 wt percent
Design Coal Feed Size Consist (Also see Figure 4-6)	
6 inch x 1/2 inch:	65 percent
1/2 inch x 28 mesh:	25 percent
28 mesh x 0:	10 percent

Table 4-10

SELECTED COAL CONVERSION PROCESSES ESTIMATED
ELECTRICITY AND STEAM REQUIREMENTS⁽¹⁾

Process No.	Conversion Process and Type	Estimated Conversion Process Requirement			Reported Conversion Process Steam Conditions		Estimated Conversion Process Requirement	References ⁽⁵⁾
		Electricity ⁽²⁾	Process Steam				Total Steam ⁽³⁾	
		MW	Million lb/hr	Billion Btu/hr	Temperature °F	Pressure psia	Billion Btu/hr	
2	COGAS Fluidized-Bed Gasification	In the current COGAS commercial plant conceptual design all steam required for electricity generation and process use is obtained from process heat recovery and not from any coal-fired power/steam plant.						15
3	HTGAS Fluidized-Bed Gasification	150	5.7	5.4	1,500	925	6.6	16
4	Texaco Partial Oxidation Entrained Flow Gasification	210	3.0	2.9	1,500	925	4.5	16
5	Exxon Donor Solvent Liquefaction	350	0	0	—	—	2.7	7
8	SRC-II Liquefaction	550	1.3	1.0	615	468	—	17
			0.4	0.3	75	308	—	
				1.3			5.6	
9	H-Coal Liquefaction	790	1.1	0.8	615	468	—	17
			0.5	0.3	75	308	—	
				1.1			7.2	
	Mean Value ⁽⁴⁾	410		2.1			5.3	

- Notes: (1) All estimates are for a coal conversion plant converting 50,000 tons/day of coal having a higher heating value of 11,520 Btu/lb-dry.
(2) This excludes any electricity required for coal handling, preparation, and mining.
(3) A value of 7,769.5 Btu/kW-hr was used to estimate steam required for generation of estimated conversion process electricity requirement. This value was developed from information presented in the *General Electric Energy Conversion Alternatives Study* for a power plant using an atmospheric pressure fluidized-bed steam generator.
(4) Excludes COGAS Process.
(5) Presented in Report References section.

Table 4-11

ESTIMATED GASIFICATION ASH AND GRANULATED
SLAG CHARACTERISTICS

Characteristic	Ash Producing Gasifiers	Slagging Gasifiers
Gasifier Slurry Solids Concentration	40 wt percent	40 wt percent
Ash or Slag Combustible Concentration	30 wt percent	2 wt percent
Dewatered Ash or Slag Moisture Concentration	30 wt percent	10 wt percent

Table 5-1
LIVE COAL STORAGE
ALTERNATIVES SUMMARY⁽¹⁾

Live Storage Type	Stacking Methods	Reclaim Methods	Comments
OPEN STOCKPILE STORAGE ALTERNATIVES			
1. Simple Storage	Stationary Stacker with Telescopic Chute Conveyor with Telescopic Lowering Well Stationary Stacker with Luffing Boom(s) Tripper Conveyor with Telescopic Chute Mobile Equipment	Bucket Wheel Reclaimer Belt or Vibrating Feeders Mobile Equipment	<ul style="list-style-type: none"> No Blending Achieved Dead Portion Reclaim Requires Mobile Equipment Stockpile Arrangements: Ramped Pile, Conical, Kidney-Circular, or Single Wedge
2. Simple Blending - Chevron Layers	Traveling Stacker with Luffing Boom(s) Stacker-Reclaimer with Luffing Boom(s) Tripper Conveyor with Telescopic Chute	Bucket Wheel Reclaimer Stacker-Reclaimer Rotary Plow	<ul style="list-style-type: none"> Possible Coal Segregation Stockpile Arrangements: Single Wedge, Multiple Wedge, Wedge-Flat Top, Flat Top with Active Section, or Semi-Active For Wedge-Flat Top, Flat Top with Active Section, and Semi-active Stockpiles Mobile Equipment is Required for Reclaim of Semi-Active and Dead Portions
3. Intermediate Blending - Chevron Layers with Full Cross Section Reclaim	Traveling Stacker with Luffing Boom(s)	Bridge Type Bucket Wheel Reclaimer Scraper Reclaimer Drum Reclaimer	<ul style="list-style-type: none"> Stacking and Reclaiming Can Be Highly Automated Stockpile Arrangements: Single Wedge, Multiple Wedge, or Wedge-Flat Top For Wedge-Flat Top Stockpile Mobile Equipment is Required for Reclaim of Semi-Active Coal
4. Full Blending - Windrow Layers with Full Cross Section Reclaim	Traveling Stacker with Luffing and Slewing Boom(s)	Drum Reclaimer	<ul style="list-style-type: none"> Best Bed Blending Entire Blending Operation can be Automated Stockpile Arrangements: Multiple Wedge
ENCLOSED STORAGE ALTERNATIVES			
1. Silo(s)	Belt Conveyor	Belt or Vibrating Feeders Rotary Plow	<ul style="list-style-type: none"> Low Capacity Storage Simultaneous Discharge from Multiple Silos Provides Full Blending
2. Circular Barn	Belt Conveyor	Belt to Vibrating Feeders Rotary Plow	<ul style="list-style-type: none"> Low Capacity No Blending Achieved
3. Geodesic Dome	Rotating Belt Conveyor	Bridge Type Bucket Wheel Reclaimer	<ul style="list-style-type: none"> Simple Blending Low Capacity
4. Wide Span Barn	Tripper Conveyor Traveling Stacker	Bridge Type Bucket Wheel Reclaimer Drum Reclaimer	<ul style="list-style-type: none"> Large Capacity Storage Intermediate Blending Stockpile Arrangement: Circular
5. "V" Bunker	Tripper Conveyor	Rotary Plow	<ul style="list-style-type: none"> Large Capacity Storage Simple Arrangement Intermediate Blending

(1) Stockpile arrangements are presented in Figure 5-2 and enclosed storage structures are presented in Figure 5-3.

Table 5-2. Summary of coal fines crushing alternatives

Coal conversion process	U-GAS	COGAS	HYGAS	Texaco Partial Oxidation	Exxon Donor Solvent and Catalytic Gasification	SRC-I and SRC-II
1. Conversion reactor coal feed requirements						
1.1 Size consist	100% -1/4 in.	100% -1/8 in.	100% -14 mesh	100% -20 mesh	100% -8 mesh	100% -12 mesh ^a
1.2 Fines limitations	Up to 10% -200 mesh	None reported	Minimum -100 mesh	Minimum ultrafines	None reported	None reported
1.3 Total moisture	As received (Pittsburgh seam coal may require pretreatment to control agglomeration)	Drying is part of conversion process	Coal is dried during pretreatment	As received	Drying is part of both conversion processes	Drying is part of both conversion processes
2. Fine-crushing circuits						
2.1 Proposed flow sheet and circuit	FS-6 As received ^b - single-stage open-circuit	FS-6 As received ^b - single-stage open-circuit crushing	FS-4 As received ^b - two-stage open-circuit crushing	FS-4 As received ^b - two-stage open-circuit crushing	FS-3 As received ^b - single-stage open-circuit crushing	FS-3 As received ^b - single-stage open-circuit crushing
2.2 Alternative flow sheet and circuit	FS-8 Dry to 3% total moisture, ^c screen, and crush oversize coal in single-stage open-circuit to minimize fines		FS-4-1 As received ^b - two-stage open-circuit crushing, stacked mills	FS-4-1 As received ^b - two-stage open-circuit crushing, stacked mills	FS-5 As received ^b - single-stage closed-circuit crushing	FS-5 As received ^b - single-stage closed-circuit crushing
2.3 Alternative flow sheet and circuit			FS-5 As received ^b - single-stage closed-circuit crushing	FS-5 As received ^b - single-stage closed-circuit crushing		
2.4 Alternative flow sheet and circuit				FS-10 As received ^b - single-stage open-circuit grinding		

Table 5-2 (continued)

Coal conversion process	U-GAS	COGAS	HYGAS	Texaco Partial Oxidation	Exxon Donor Solvent and Catalytic Gasification	SRC-I and SRC-II
3. Type of fine-crushing equipment						
3.1 Proposed circuit	Four 72-in., 2-row cage mills, 600 tph each mill	Four 72-in., 2-row cage mills, 600 tph each mill	First-stage crushing: four 72-in., 2-row cage mills, 600 tph each mill. Second-stage crushing: eight 72-in., 4-row cage mills, 300 tph each mill	First-stage crushing: four 72-in., 2-row cage mills, 500 tph each mill. Second-stage crushing: eight 72-in., 4-row cage mills, 300 tph each mill	Six 72-in., 4-row cage mills, 400 tph each mill	Six 72-in., 4-row cage mills, 400 tph each mill
3.2 Alternative circuit	Four 60" x 1.0-in.-wide center feed, reversible hammer-mills, 600 tph each mill ^d		First-stage crushing: six 72-in., 2-row cage mills, 400 tph each mill. Second-stage crushing: six 72-in., 4-row cage mills, 400 tph each mill	First-stage crushing: six 72-in., 2-row cage mills, 400 tph each mill. Second-stage crushing: six 72-in., 4-row cage mills, 400 tph each mill	Six 72-in., 2-row cage mills, 400 tph each mill	Six 72-in., 2-row cage mills, 400 tph each mill
3.3 Alternative circuit	Four 72-in., 2-row cage mills, 600 tph each mill ^e		Six 72-in., 2-row cage mills, 400 tph each mill	Six 72-in., 2-row cage mills, 400 tph each mill		
3.4 Alternative circuit				Thirteen 14-1/2-ft-diam x 20-ft-long rod mills, 180 tph each mill		

^aGulf Mineral Resources Co. is currently evaluating a range of conversion reactor coal feed size consists for the SRC-I and SRC-II demonstration plants. These range from 100% -6 mesh (approximately 1/8 in.) to 100% -50 mesh.

^bAs received coal has a nominal size consist of 2 in. x 0 and can have up to 10 wt % total moisture.

^cFlow sheet FS-7 is for coarse coal thermal drying.

^dThis alternative crushing equipment is for flow sheet FS-6.

^eThis alternative crushing equipment is for flow sheet FS-8.

Reference

1. *Conceptual Flow Sheets Development for Coal Conversion Plant Coal Handling-Preparation and Ash/Slag Removal Operations*, Report Job 13022, prepared by Bechtel Corp. for Union Carbide Corp., San Francisco, Calif., July 1979.

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Appendix D

FIGURES AND FLOW SHEETS FROM BECHTEL REPORT

Figure 4-3 PITTSBURGH SEAM COAL WASHABILITY CHARACTERISTICS
WITH ROOF AND FLOOR DILUTION

ORNL-OWG 80-4214 ETD

NOTES:

- (1) COAL TRANSPORTED TO CONVERSION PLANT SITE - THIS COAL IS TRANSPORTED IN RAIL CARS AND/OR BARGES FROM DISTANT MINES TO THE COAL CONVERSION PLANT SITE. THE COAL IS SIZED TO 2 IN. X 0 BEFORE TRANSPORT. IF COAL CLEANING IS JUSTIFIED, IT IS PERFORMED PRIOR TO LONG-DISTANCE TRANSPORT.
- (2) RUN-OF-MINE COAL - THIS COAL IS PRODUCED BY A GRATED COAL MINE COMPLEX LOCATED ADJACENT TO THE COAL CONVERSION PLANT SITE. AFTER RUN-OF-MINE COAL BREAKING, CLEANING, AND CRUSHING TO 2 IN. X 0, THE COAL HANDLING AND PREPARATION OPERATIONS REQUIRED FOR BOTH RUN-OF-MINE COAL AND COAL TRANSPORTED TO THE CONVERSION PLANT SITE ARE IDENTICAL.
- (3) NO COAL CLEANING OR PARTIAL COAL CLEANING - IF RUN-OF-MINE COAL CLEANING IS NOT ECONOMICALLY JUSTIFIED OR CLEANING OF ONLY PART OF THE RUN-OF-MINE COAL IS JUSTIFIED, BROKEN RUN-OF-MINE COAL WOULD BE CONVEYED DIRECTLY TO CRUSHING AND THEN TO COARSE COAL STORAGE.
- (4) COARSE AND FINE COAL CLEANING ALTERNATIVES - CONSIDERATION OF HEAVY-MEDIUM COARSE AND FINE COAL CLEANING HAS EXCLUDED FROM THE PROJECT SCOPE.
- (5) FLUE GAS SOURCE - FLUE GAS REQUIRED FOR FINE AND PULVERIZED COAL DRYING AND TRANSPORT IS PROVIDED FROM THE POWER/STEAM PLANT.
- (6) ULTRAFINES SEPARATION ALTERNATIVES - THE ALTERNATE CONVERSION REACTOR COAL FEED SIZE CONSISTS OF ESTIMATES OF SIZE CONSISTS THAT MIGHT BE SPECIFIED IF COAL ULTRAFINES SEPARATION IS REQUIRED OR ECONOMICALLY JUSTIFIED FOR CONVERSION PROCESSES REQUIRING FINE COAL FEED.
- (7) BALL TUBE MILL COAL PULVERIZING - BALL TUBE MILL COAL PULVERIZING SYSTEMS INCLUDE IMPACT CRUSHER-DRYERS WHICH ARE AN INTEGRAL PART OF THE MILL SYSTEM. THE IMPACT CRUSHER-DRYERS REDUCE COARSE COAL TO NOMINALLY 14 MESH X 0 AND PARTIALLY DRY IT BEFORE IT IS SWEEP INTO THE BALL TUBE MILL.
- (8) HYGAS COAL FEEDING - FOR THE HYGAS GASIFICATION PROCESS, COAL IS ASSUMED TO BE FED TO A PRETREATMENT VESSEL RATHER THAN TO THE HYGAS CONVERSION REACTOR. PRE-TREATMENT IS REQUIRED TO REDUCE COAL AGGLOMERATION DURING GASIFICATION.
- (9) A CYCLONE-BAGHOUSE SYSTEM IS PROVIDED FOR PARTICULATE COLLECTION. THE DUST FROM THE CYCLONES IS FED TO ULTRAFINES SEPARATION AND COAL PARTICULATE FROM THE BAGHOUSE IS TRANSPORTED TO ULTRAFINES AGGLOMERATION.

Figure 4-7 COAL HANDLING AND PREPARATION OPERATIONS BLOCK FLOW DIAGRAM

Figure 4-8
ASH/SLAG REMOVAL OPERATIONS
BLOCK FLOW DIAGRAM (4)

OPEN STOCKPILE ARRANGEMENTS →

RAMPED PILE

STOCKPILE CONSTRUCTION METHOD → MOBILE EQUIPMENT DRAG LINE

STOCKPILE RECLAIM METHOD → MOBILE EQUIPMENT

CONICAL

 BELT CONVEYOR
LIVE PORTION: BELT OR VIBRATING FEEDERS
DEAD PORTION: MOBILE EQUIPMENT TO LIVE PORTION

KIDNEY OR CIRCULAR

 RADIAL STACKER
LIVE PORTION: BELT OR VIBRATING FEEDERS
DEAD PORTION: MOBILE EQUIPMENT TO LIVE PORTION

SINGLE WEDGE

 TRAVELING STACKER
STACKER-RECLAIMER
TRIPPER CONVEYOR
STACKER-RECLAIMER
BUCKET WHEEL RECLAIMER
BRIDGE TYPE BUCKET WHEEL RECLAIMER
BRIDGE TYPE DRUM RECLAIMER
SCRAPER RECLAIMER

MULTIPLE WEDGE

 TRAVELING STACKER
STACKER-RECLAIMER
TRIPPER CONVEYOR
STACKER-RECLAIMER
BUCKET WHEEL RECLAIMER
BRIDGE TYPE BUCKET WHEEL RECLAIMER
BRIDGE TYPE DRUM RECLAIMER
SCRAPER RECLAIMER

WEDGE-FLAT TOP COMBINATION

 STOCKPILE CONSTRUCTION METHOD → TRAVELING STACKER
STACKER-RECLAIMER
MOBILE EQUIPMENT REQUIRED FOR SEMI-ACTIVE PORTION

 STOCKPILE RECLAIM METHOD → STACKER-RECLAIMER
BUCKET WHEEL RECLAIMER
BRIDGE TYPE BUCKET WHEEL RECLAIMER
BRIDGE TYPE DRUM RECLAIMER
SCRAPER RECLAIMER
(MOBILE EQUIPMENT REQUIRED FOR RECLAIM OF SEMI-ACTIVE PORTION)

FLAT TOP WITH ACTIVE SECTION

TRIPPER CONVEYOR AND MOBILE EQUIPMENT

 ROTARY PLOW
MOBILE EQUIPMENT REQUIRED FOR RECLAIM
OF DEAD PORTIONS

FLAT TOP DEAD PILE

TRAVELING STACKER AND MOBILE EQUIPMENT

MOBILE BUCKET WHEEL RECLAIMER

SEMI-ACTIVE PILE

TRAVELING STACKER AND MOBILE EQUIPMENT

TRACK MOUNTED BUCKET WHEEL RECLAIMER

Figure 5-2 OPEN COAL STOCKPILE ALTERNATIVES

ENCLOSED STORAGE ARRANGEMENTS →

SILLO
(MASS FLOW BOTTOM)

CIRCULAR BARN

GEODESIC DOME

WIDE SPAN BARN

ORNL-DWG 80-4212 ETO

"V" BUNKER

ENCLOSED STORAGE FEED METHOD →

BELT CONVEYOR

BELT CONVEYOR

ROTATING BELT CONVEYOR

TRAVELING STACKER

TRIPPER CONVEYOR

ENCLOSED STORAGE RECLAIM METHOD →

BELT OR VIBRATING FEEDERS
ROTARY PLOW

BELT OR VIBRATING FEEDERS
ROTARY PLOW

BRIDGE TYPE BUCKET WHEEL RECLAIMER

BRIDGE TYPE BUCKET WHEEL RECLAIMER
DRUM RECLAIMER

ROTARY PLOW

Figure 5-3 ENCLOSURE COAL STORAGE ALTERNATIVES

STREAM NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
DRY SOLIDS, TONS/HOUR	4,048	2	1,429	2,612	-	526	254	1,841	1,815	26	24	2	-	278	1,707	1,529	128	-	1,649	347	120	1,182	311	36	1,036	146	1,036	-	-	324	185	139	185	-	175	-	175	175	-	3,036	1,012	2	-
WET TOTALS, TONS/HOUR	4,953	1,411	2,498	2,912	5,318	584	282	7,364	1,893	5,481	80	5,401	564	926	3,784	2,184	1,600	2,363	4,697	495	150	4,052	366	129	1,295	2,757	1,164	131	-	4,975	740	4,235	252	487	4,697	4,114	585	250	333	3,300	1,200	9,515	14,000
WATER, GPM	1,220	5,660	5,716	1,164	21,272	232	112	22,092	272	21,820	274	21,990	2,206	70	8,594	7,620	5,988	9,452	12,192	592	120	11,480	220	372	1,036	10,444	512	524	-	18,604	2,220	16,344	272	1,948	16,384	16,456	1,632	300	1,332	1,056	752	39,052	58,000
WATER, WT PERCENT	7	-	50	10	21	10	10	75	3.6	-	70	-	-	70	55	30	89	-	05	30	20	71	15	72	20	95	11	-	-	93	75	97	27	-	96	-	70	30	-	8.0	15.7	-	-

UNION CARBIDE CORPORATION -- NUCLEAR DIVISION OAK RIDGE NATIONAL LABORATORY		
CONCEPTUAL FLOW SHEETS DEVELOPMENT FOR COAL CONVERSION PLANT COAL HANDLING-PREPARATION AND ASH/SLAG REMOVAL OPERATIONS CONTRACT NO. 62X - 45724V		
JIG COARSE AND FINE COAL CLEANING		
BECHTEL NATIONAL, INC. SAN FRANCISCO 94119		
BECHTEL JOB 13022	DATE JULY 1979	FLOW SHEET NUMBER FS-1

MAJOR EQUIPMENT LIST
J1G COARSE AND FINE COAL CLEANING
REFERENCE FLOW SHEET FS-1

Number Required	Equipment Title	HP Each	Design Rating and Description	Specification Requirements and Comments
			COAL BREAKING EQUIPMENT	
2	ROM Coal Receiving Hopper	-	Design Capacity: 150 tons	Mass flow bin with lined bottom for even flow promotion.
2	ROM Coal Feeder	20	Design Capacity: 2,600 tph	Standard design apron type feeder.
2	ROM Coal Grizzly	7½	Design Capacity: 2,600 tph Nominal Opening: 4-¾ in. Size: 60 in. x 12 ft	Grizzlies of this capacity are standard equipment. Manganese steel abrasion resistant deck.
2	Rotary Breaker	150	Design Capacity: 600 tph Diameter: 14 ft Length: 30 ft Openings: 6 in.	Breakers of this capacity are standard equipment. Screen material is abrasion resistant steel.
1	Raw Coal Conveyor No. 1	200	Design Capacity: 5,400 tph Width: 60 in. Estimated Length: 600 ft	See General Conveyor Specification.
1	Coal Breaking Area Baghouse Dust Collection System	150	Design Capacity: 50,000 acfm	Standard Baghouse System.
			CLEANING PLANT SURGE COAL STORAGE EQUIPMENT	
1	Raw Coal Conveyor No. 2	500	Design Capacity: 5,400 tph Width: 60 in. Estimated Length: 800 ft	See General Conveyor Specification.
4	Raw Coal Silo	-	Design Capacity: 5,000 tons	Mass flow bin with lined bottom for even flow promotion.
16	Raw Coal Feeder	10	Design Capacity: 300 tph Width: 48 in. Length: 10 ft	Vibratory-Activator Feeders. This is a new type of feeder.
1	Raw Coal Silo Area Baghouse Dust Collection System	60	Design Capacity: 20,000 acfm	Standard Baghouse System.

MAJOR EQUIPMENT LIST
JIG COARSE AND FINE COAL CLEANING
REFERENCE FLOW SHEET FS-1

Number Required	Equipment Title	HP Each	Design Rating and Description	Specification Requirements and Comments
1	Cleaning Plant Feed Conveyor	500	COARSE COAL SCREENING EQUIPMENT Design Capacity: 5,400 tph Width: 60 in. Estimated Length: 500 ft	See General Conveyor Specification.
16	Raw Coal Screen Feeder	20	Design Capacity: 300 tph Width: 36 in.	Standard Design Vibrating Feeder.
16	Raw Coal Screen	30	Design Capacity: 300 tph Type: Double Deck Vibrating Size: 8 ft x 20 ft Openings: 1½ in. and 3/8 in.	Standard Design Double Deck Vibrating Screen. Rubber Deck construction.
3	Coarse Coal Jig	350	COARSE COAL CLEANING EQUIPMENT Design Capacity: 1,000 tph Type: Baum Size: 180 sq ft	Baum jigs of this capacity are standard equipment, but are custom designed for each coal. Actual design is based primarily on coal washability data and clean coal requirements. The specified jig is a three product unit with two elevators and five compartments.
1	Middlings Crusher	250	Design Capacity: 280 tph Type: Hammermill	Standard Design Hammermill.
9	Clean Coal Dewatering Screen	20	Design Capacity: 250 tph Type: Single Deck Vibrating Size: 6 ft x 10 ft	Standard Design Single Deck Vibrating Screen Stainless Steel Wedge Wire Deck.
2	Clean Coal Crusher	600	Design Capacity: 900 tph Type: Four Roll Crusher Size: 36 in. x 60 in.	Standard Design Four Roll Crusher.
10	Thickening Cyclone	-	Diameter: 24 in.	Several standard designs of coal classifying cyclones are currently available. Cast Ni-Hard construction with cast refractory apex nozzles.
1	Clean Coal Conveyor	200	Design Capacity: 5,400 tph Width: 60 in.	See General Conveyor Specification.
1	Refuse Conveyor	50	Design Capacity: 1,600 tph Width: 48 in.	See General Conveyor Specification.

MAJOR EQUIPMENT LIST
JIG COARSE AND FINE COAL CLEANING
REFERENCE FLOW SHEET FS-1

Number Required	Equipment Title	HP Each	Design Rating and Description	Specification Requirements and Comments
FINE COAL COAL CLEANING AND DEWATERING EQUIPMENT				
9	Desliming Sieve Bend	-	Design Capacity: 180 tph Opening: 28 mesh	Standard Design Fixed Sieve Bend.
3	Fine Coal Jig	350	Design Capacity: 600 tph Size: 180 sq ft Type: Batac	A three product, Batac, air-pulsed jig is specified for fine coal cleaning due to the even bed air distribution achievable with this jig design. The specified jig has six compartments and two elevators. 600 tph Batac jigs are currently used for fine coal cleaning.
3	Fine Refuse Dewatering Screen	10	Design Capacity: 120 tph Type: Single Deck Vibrating Size: 4 ft x 8 ft	Standard Design Horizontal Vibrating Screen. Stainless Steel Wedge Wire Deck.
6	Fine Clean Coal Dewatering Screen	15	Design Capacity: 165 tph Type: Single Deck Vibrating Size: 8 ft x 20 ft	Standard Design Single Deck Vibrating Screen. Stainless Steel Wedge Wire Deck.
6	Clean Coal Vibrating Centrifuge	75	Design Capacity: 165 tph	Standard Basket Type Coal Centrifuge. Stainless Steel Wedge Wire Basket.
COAL CLEANING EFFLUENT TREATMENT EQUIPMENT				
12	Flotation Cells	15	Design Capacity: 320 tph Size: 2 banks of six cells	Standard Design Coal Cleaning Flotation Cells.
1	Clean Coal Vacuum Filter	200	Design Capacity: 200 tph Type: Disc Filter Size: 12½ ft diameter x 13 discs	Standard Design Coal Disc Vacuum Filter.
1	Refuse Thickener	15	Design Capacity: 150 tph Size: 200 ft diameter	Standard Design Rake Mechanism.
2	Refuse Solid Bowl Centrifuge	300	Design Capacity: 100 tph Size: 36 in. x 96 in.	Standard Design Solid Bowl Centrifuge.

MAJOR EQUIPMENT LIST
HYDROCYCLONE FINE COAL CLEANING
ALTERNATIVE FLOW SHEET FS-1-1

Number Required	Equipment Title	HP Each	Design Rating and Description	Specification Requirements and Comments
25	Primary Hydrocyclone	-	Design Capacity: 2,000 gpm slurry Diameter: 24 in.	Several standard designs of water only coal cleaning cyclones are currently available. Cast Ni-Hard construction with cast refractory apex nozzles.
5	Secondary Hydrocyclone	-	Design Capacity: 2,000 gpm slurry Diameter: 26 in.	Several standard designs of water only coal cleaning cyclones are currently available. Cast Ni-Hard construction with cast refractory apex nozzles.
3	Fine Refuse Dewatering Sieve Bend	-	Design Capacity: 120 tph Opening: 28 mesh	Standard Design Fixed Sieve Bend.
3	Fine Refuse Dewatering Screen	10	Design Capacity: 120 tph Type: Single Deck Vibrating Size: 4 ft x 8 ft	Standard Design Horizontal Vibrating Screen. Stainless Steel Wedge Wire Deck.
20	Classifying Cyclone	-	Design Capacity: 2,000 gpm slurry Diameter: 26 in.	Several standard designs of coal classifying cyclones are currently available. Cast Ni-Hard construction with cast refractory apex nozzles.
6	Fine Clean Coal Dewatering Sieve Bend	-	Design Capacity: 200 tph Opening: 28 mesh	Standard Design Fixed Sieve Bend.
6	Clean Coal Vibrating Centrifuge	75	Design Capacity: 165 tph	Standard Design Basket Type Coal Centrifuge. Stainless Steel Wedge Wire Basket

UNION CARBIDE CORPORATION - NUCLEAR DIVISION
OAK RIDGE NATIONAL LABORATORY

CONCEPTUAL FLOW SHEETS DEVELOPMENT FOR COAL
CONVERSION PLANT COAL HANDLING PREPARATION
AND ASH/SLAG REMOVAL OPERATIONS
CONTRACT NO. 82X - 45724V

ALTERNATIVE: TABLE FINE COAL CLEANING

BECHTEL NATIONAL, INC., SAN FRANCISCO 94119

BECHTEL JOB 13027	DATE JULY 1979	FLOW SHEET NUMBER FS-1-2
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MAJOR EQUIPMENT LIST
TABLE FINE COAL CLEANING
ALTERNATIVE FLOW SHEET FS-1-2

Number Required	Equipment Title	HP Each	Design Rating and Description	Specification Requirements and Comments
20	Cyclone Classifier	-	Design Capacity: 2,000 gpm slurry Diameter: 26 in.	Several standard designs of coal classifying cyclones are currently available. Cast Ni-Hard construction with cast refractory apex nozzles.
60	Shaking Table	3	Design Capacity: 25 tph Type: Suspended Double Deck	This table is the largest capacity table that can presently be built due to feeding limitations. Rubber Deck Construction.
2	Refuse Spiral Classifier	15	Design Capacity: 160 tph Type: Spiral Spiral Diameter: 84 in.	Standard Design Spiral Classifier.
6	Fine Clean Coal Dewatering Sieve Bend	-	Design Capacity: 160 tph Opening: 28 mesh	Standard Design Fixed Sieve Bend.
6	Clean Coal Vibrating Centrifuge	75	Design Capacity: 165 tph	Standard Design Basket Type Coal Centrifuge. Stainless Steel Wedge Wire Basket.

STREAM NUMBER	1	2	3	4
COAL - TONS/HOURS - DRY	3,036	1,916	1,629	287
PERCENT MOISTURE	8.0	8.0	8.0	8.0
TONS/HOURS - WET	3,300	2,083	1,771	312

UNION CARBIDE CORPORATION - NUCLEAR DIVISION OAK RIDGE NATIONAL LABORATORY		
CONCEPTUAL FLOW SHEETS DEVELOPMENT FOR COAL CONVERSION PLANT COAL HANDLING- PREPARATION AND ASH/SLAG REMOVAL OPERATIONS CONTRACT NO. 82X - 45724V		
ALTERNATIVE: COARSE COAL LIVE STORAGE - V-BUNKERS		
BECHTEL NATIONAL INC., SAN FRANCISCO 94119		
BECHTEL JOB 13022	DATE JULY 1979	FLOW SHEET NUMBER FS-2-1

MAJOR EQUIPMENT LIST
COARSE COAL LIVE STORAGE-V-BUNKERS
ALTERNATIVE FLOW SHEET FS-2-1

Number Required	Equipment Title	HP Each	Design Rating and Description	Specification Requirements and Comments
1	Live Coal Storage Feed Conveyor	750	Design Capacity: 4,400 tph Belt Width: 72 in.	See General Conveyor Specification.
2	Live Coal Storage Feed Transfer Conveyor	250	Design Capacity: 4,400 tph Belt Width: 72 in.	See General Conveyor Specification.
3	Live Coal Storage Tripper Conveyor	500	Design Capacity: 4,400 tph Belt Width: 72 in.	See General Conveyor Specification.
3	Coal Reclaim Rotary Flow Feeder	30	Design Capacity: 2,400 tph	Rotary flow feeders of this capacity are available as standard equipment.
3	Live Storage Reclaim Conveyor	150	Design Capacity: 2,400 tph Belt Width: 60 in.	See General Conveyor Specification.
2	Live Coal Storage Transfer Conveyor	200	Design Capacity: 2,400 tph Belt Width: 60 in.	See General Conveyor Specification.
2	Power/Steam Plant Feed Transfer Conveyor	75	Design Capacity: 400 tph Belt Width: 36 in.	See General Conveyor Specification.
1	Two-Way Switchover Bin	-	Dimensions: 30 ft x 15 ft x 25 ft	Mass flow surge bin.
2	Switchover Bin Reclaim Belt Feeder	50	Design Capacity: 2,400 tph Belt Width: 72 in.	See General Belt Feeder Specification.
2	Power/Steam Plant Feed Conveyor	75	Design Capacity: 400 tph Belt Width: 36 in.	See General Conveyor Specification.
2	Conversion Coal Feed Conveyor	300	Design Capacity: 2,400 tph Belt Width: 60 in.	See General Conveyor Specification.

STREAM NUMBER	5	6	9
COAL - TONS/HOUR - DRY	1,629	271	1,625
PERCENT MOISTURE	8.0	8.0	8.0
TONS/HOUR - WET	1,771	295	1,778

UNION CARBIDE CORPORATION - NUCLEAR DIVISION OAK RIDGE NATIONAL LABORATORY		
CONCEPTUAL FLOW SHEETS DEVELOPMENT FOR COAL CONVERSION PLANT COAL HANDLING PREPARATION AND ASH/LAG REMOVAL OPERATIONS CONTRACT NO 62X - 45724V		
SINGLE STAGE CAGE MILL COAL FINE CRUSHING SRC I AND II, EXXON DONOR SOLVENT, AND EXXON CATALYTIC GASIFICATION		
BECHTEL NATIONAL, INC., SAN FRANCISCO 94119		
BECHTEL JOB ~13022	DATE JULY 1979	FLOW SHEET NUMBER FS-3

MAJOR EQUIPMENT LIST
SINGLE-STAGE CAGE MILL COAL FINE CRUSHING
FLOW SHEET FS-3

Number Required	Equipment Title	HP Each	Design Rating and Description	Specification Requirements and Comments
2	Fine Crushing Surge Storage Tripper Conveyor System	150	Design Capacity: 2,400 tph Belt Width: 60 in.	See General Conveyor Specification.
6	Fine Crushing Surge Bin	-	Design Capacity: 300 tons (1,800 tons, total combined capacity)	Mass flow bin with lined bottom for even flow promotion.
1	Fine Crushing Surge Bins Baghouse Dust Collection System	60	Design Capacity: 20,000 acfm	Standard Baghouse System.
6	Fine Crushing Gravimetric Belt Feeder	25	Design Capacity: 400 tph Belt Width: 72 in.	See General Gravimetric Belt Feeder Specification.
6	Coal Fine Crusher	1,400	Design Capacity: 400 tph Type: Four Row Cage Mill Size: 72 in. diameter	See General Cage Mill Specification.
2	Fine Coal Conveyor	300	Design Capacity: 2,400 tph Belt Width: 60 in.	See General Conveyor Specification.

UNION CARBIDE CORPORATION - NUCLEAR DIVISION OAK RIDGE NATIONAL LABORATORY		
CONCEPTUAL FLOW SHEETS DEVELOPMENT FOR COAL CONVERSION PLANT COAL HANDLING PREPARATION AND ASH/SLAG REMOVAL OPERATIONS CONTRACT NO. 67X - 43724V		
FINE COAL ULTRAFINESSE SEPARATION		
BECHTEL NATIONALS, INC., SAN FRANCISCO 94119		
BECHTEL JOB 12027	DATE JULY 1979	FLOW SHEET NUMBER FS-9

MAJOR EQUIPMENT LIST
FINE COAL ULTRAFINES SEPARATION
FLOW SHEET FS-9

Number Required	Equipment Title	HP Each	Design Rating and Description	Specification Requirements and Comments
2	Ultrafines Separation Surge Storage Tripper Conveyor System	150	Design Capacity: 2,400 tph Belt Width: 60 in.	See General Conveyor Specification.
6	Ultrafines Separation Surge Bin	—	Design Capacity: 300 tons (1,800 tons, total combined capacity)	Mass flow bin with lined bottom for even flow promotion.
6	Air Classifier Gravimetric Belt Feeder	30	Design Capacity: 400 tph Belt Width: 72 in.	See General Gravimetric Belt Feeder Specification.
6	Crushed Coal Air Classifier	500	Design Capacity: 400 tph Type: Mechanical Centrifugal Air Classifier with Drying Gas Injection Size: 22 ft diameter	Air Classifiers of up to 24 ft in diameter are currently used for closed-circuit cement grinding. Hot flue gas is added to control coal surface moisture for efficient classification. Abrasion resistant steel lined.
24	Air Classifier Exhaust Gas Cyclone	—	Design Capacity: 20,000 acfm Type: Centrifugal Gas Cyclone Number of Cyclone Clusters: 6 Size: 6 ft diameter	Cyclones of this size are of standard design and are widely used for gas particulate separation. Cyclones are manifolded together in clusters of four cyclones which have a common underflow bin. Abrasion resistant steel lined
3	Particulate Coal Collection System Multi-Compartment Baghouse	60	Design Capacity: 200,000 acfm Number of Compartments: 6 Design Pressure Drop: 8 in. H ₂ O Area: 120,000 ft ² Bag Material: Fiberglass	Baghouse collectors of this capacity are custom designed and fabricated. The baghouse is equipped with an explosion detec- tion and suppression system. The baghouse systems include coal collection bins and interconnecting mass flow conveyors.
3	Baghouse Induced Draft Fan	1,000	Design Capacity: 200,000 acfm Design Head: 30 in. H ₂ O Design Temperature: 180°F	Standard Design Flue Gas Fan.
2	Ultrafines Mass Flow Conveyor	300	Design Capacity: 600 tph Type: Chainflight mass flow Width: 40 in.	This type of totally enclosed conveyor has not been demonstrated on ultrafine coal. Equipment development may be required.
2	Fine Coal Conveyor	300	Design Capacity: 1,800 tph Width: 60 in.	See General Conveyor Specification.
1	Ultrafines Surge Bins Baghouse Dust Collection System	150	Design Capacity: 50,000 acfm	Standard Baghouse System.

MAJOR EQUIPMENT LIST
SOLVENT COAL GRINDING
FLOW SHEET FS-11

Number Required	Equipment Title	HP Each	Design Rating and Description	Specification Requirements and Comments
2	Coal Grinding Surge Storage Tripper Conveyor System	200	Design Capacity: 2,400 tph Belt Width: 60 in.	See General Conveyor Specification.
5	Coal Grinding Surge Bin	-	Design Capacity: 200 tons (1,800 tons, total combined capacity)	Mass flow bin with lined bottom for even flow promotion.
9	Coal Grinding Gravimetric Belt Feeder	30	Design Capacity: 300 tph Belt Width: 72 in.	See General Gravimetric Belt Feeder Specification.
9	Coarse Coal Crusher	800	Design Capacity: 300 tph Type: 2 Row Cage Mill Size: 72 in. diameter	See General Cage Mill Specification.
9	Crushed Coal Screw Conveyor	40	Design Capacity: 300 tph Type: Double Helicoid Flights Flight Diameter: 10 in.	Screw Conveyors of this capacity are standard equipment.
9	Coal Ball Mill	6,000	Design Capacity: 300 tph Type: Overflow Discharge Size: 18 ft diameter by 28½ ft long Volume Loading: 40 percent Operating Speed: 13 rpm (68.7 percent critical speed) Ball Charge: 393 tons	Wet ball mills of this size are currently used for ore grinding, but not coal. Solvent coal grinding has yet to be demonstrated. Mill system vapor scaling is an area where development is required.
9	Ball Mill Discharge Sump	-	Design Capacity: 300 ft ³ Construction: Concrete	This sump would require a vapor control system.
9	Ball Mill Discharge Pump	75	Design Capacity: 1,800 gpm Type: Horizontal Centrifugal Construction: Ni-Hard Impeller and Casing	Pumps for handling of pulverized coal-solvent slurry are being developed as part of coal conversion process development and demonstration projects.
1	Coal Grinding Surge Bins Dust Collection System	50	Design Capacity: 20,000 acfm	Standard Baghouse System.

Reference

1. *Conceptual Flow Sheets Development for Coal Conversion Plant Coal Handling-Preparation and Ash/Slag Removal Operations*, Report Job 13022, prepared by Bechtel Corp. for Union Carbide Corp., San Francisco, Calif., July 1979.

Appendix E
PARTICIPATING VENDORS

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First Survey

Vendors Participating In First SurveyPulverizers

1. BEPEX Corporation
K-G Division
10225 W. Higgins Road
Rosemont, IL 60018
2. Steadman Foundry & Machine Co.
Division of Wean United
500-600 Indiana Ave.
Aurora, IN 47001
3. Williams Patent Crusher and Pulverizer Co.
2701-2723 North Broadway
St. Louis, MO 63102

Thermal Dryers

1. BEPEX Corporation
K-G Division
10225 W. Higgins Road
Rosemont, IL 47001
2. Cameron Engineers, Inc.
Division of The Pac Company Consultants
and Engineers, Inc.
1315 South Clarkson Street
Denver, CO 80210
3. Dorr-Oliver, Inc.
Industrial Thermal Processing
77 Havemeyer Lane
Stamford, CT 06904
4. ENI Engineering Company
Division of Lively Manufacturing
and Equipment Co.
339 Haymaker Road
Monroeville, PA 15146
5. Envirotech Corporation
BSP Division
One Davis Drive
Belmont, CA 94002
6. FMC Corporation
Materials Handling Systems Division
3400 Walnut Street
Colmar, PA 18915

7. Fuller Company
Division GATX Co.
P.O. Box 29
Catasauqua, PA 18032
8. Indiana Steel & Fabricating Co.
Airport Road
Indiana, PA 15701

Ash/Slag Removal Equipment

1. Allen-Sherman-Hoff
Great Valley Center
Malvern, PA 19355
2. Detroit Stoker
1510 East First Street
Monroe, MI 48161

Second Survey

Vendors Participating in Second SurveyFluidized-Bed Dryers

1. Dorr-Oliver, Inc.
77 Havemeyer Lane
Stamford, CT 06904
2. ENT Engineering
Division Lively Manufacturing
and Equipment Co.
339 Haymaker Road
Monroeville, PA 15146
3. FMC Corporation
Materials Handling Systems Division
3400 Walnut St.
Colmar, PA 18915
4. Heyl & Patterson, Inc.
7 Parkway Center
Pittsburgh, PA 15220
5. Fuller Company
Division of GATX Co.
P.O. Box 29
Catasauqua, PA 18032

Grinding & PulverizingBall Mills (Solvent Grinding)

1. Allis-Chalmers
Mining Systems Division
P.O. Box 512
Milwaukee, WI 53201
2. Kennedy Van Saun Corporation
P.O. Box 102
Danville, PA 17821

Ball Tube Mill

1. Kennedy Van Saun Corporation
P.O. Box 102
Danville, PA 17821

2. Riley Stoker Corporation
P.O. Box 547
Worcester, MO 01613

Bowl Pulverizer

1. Babcock & Wilcox
Industrial & Marine Division
4282 Strausser St., N.W.
North Canton, OH 44720
2. Combustion Engineering, Inc.
CE Raymond/Bartlett-Snow Division
200 W. Monroe St.
Chicago, IL 60606
3. Foster-Wheeler Energy Corporation
110 South Orange Ave.
Livingston, NJ 07039
4. Fuller Company
Division of GATX Company
P.O. Box 29
Catasauqua, PA 18032

Cage Mills

1. Rexnord-T.J. Gundlack Division
No. 1 Freedom Drive
P.O. Box 385
Belleville, IL 62223
2. Stedman Foundry & Machine Co.
Division of Wean United
500-600 Indiana Ave.
Aurora, IN 47001

Rod Mills

1. Allis Chalmers
Mining Systems Division
P.O. Box 512
Milwaukee, WI 53201

2. Kennedy Van Saun Corporation
P.O. Box 102
Danville, PA 17821
3. Rexnord, Inc.
Nordberg Division
P.O. Box 383
Milwaukee, WI 53201

Classifying

Air Separators

1. Envirotech Corporation
Buell-Emission Control Division
200 N. 7th Street
Lebanon, PA 17042
2. Sturtevant Mill Company
103 Clayton Street
Boston, ME 02121
3. Universal Road Machinery Company
27 Emerick Street
Kingston, NY 12401

Screens

1. Allis-Chalmers
Crushing and Screening Division
P.O. Box 2219
Appleton, WI
2. Hewitt-Robbins Division
Litton Systems, Inc.
P.O. Box 1481
Columbia, SC 29202
3. Rexnord, Inc.
Vibrating Equipment Division
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Louisville, KY 40213
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Mentor, OH 44060

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