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CRITICAL TECHNOLOGY LIST UPDATE

Final Technical Report

Work Performed Under Contract No. AC05-78OR03054

International Coal Refining Company
Allentown, Pennsylvania

Technical Information Center
Office of Scientific and Technical Information
United States Department of Energy

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**FINAL TECHNICAL REPORT:
CRITICAL TECHNOLOGY LIST UPDATE**

**INTERNATIONAL COAL REFINING COMPANY
P.O. Box 2752, Allentown, Pennsylvania 18001**

**Prepared for the
UNITED STATES DEPARTMENT OF ENERGY
Division of Energy Technology
Under Contract DE-AC05-78-OR03054**

ABSTRACT

ICRC has reviewed and updated its list of Critical Technology. The List comprises all proposed SRC-I Demonstration Plant equipment whose use has been determined to involve some degree of potential safety, performance, or environmental risk. ICRC has subjected equipment on the Critical Technology List to special technical review to ensure the highest possible level of quality and lowest cost commensurate with acceptable overall risks.

SUMMARY

International Coal Refining Company (ICRC) has reviewed and updated its list of Critical Technology. The list comprises all proposed SRC-I Demonstration Plant equipment whose use has been determined to involve potential safety, performance, or environmental risks. These risks are defined and categorized in ICRC's Process Design Criteria, while the priorities and criteria for the selection of items included in Critical Technology are defined in the Master Project Procedure.

Equipment or equipment systems still considered to be high risk are the following:

- Coal Slurry/Hot Oil Heat Exchangers
- Coal Slurry Heaters
- Second-Stage Feed Heaters
- Vacuum Tower Heater
- Vacuum Column
- SRC/Light SRC Stripper - CSD
- Severe Service Valves
- Wastewater Reuse System
- Solid Waste Disposal System

Equipment systems or pieces of equipment that have been downgraded to a lower risk category are the following:

- Coal Weigh-Feed System
- Coal Slurry Dissolvers
- Coal Dissolver Effluent Separator
- LC-Fining Reactors

Finally, ICRC has determined that the following equipment is no longer Critical Technology, and has therefore removed it from the List:

- Slurry Preparation and Mixing System
- Coal Slurry Reciprocating Feed Pumps

- Coal Slurry Circulation Pumps
- Vacuum Column Bottoms Pumps
- Vacuum Column Heater Pumps
- Third-Stage Light Phase Pumps
- High-Pressure Solvent Purge Pumps
- SRC Flush Pumps
- CSD Feed Pumps
- First-Stage Recycle Critical Solvent Pumps
- Medium-Pressure Flash Drums
- High-Pressure Vapor/Recycle Gas Exchanger
- High-Pressure Separator/Recycle Gas Exchanger
- Hot Slurry/Hot Oil Heat Exchangers
- Ash Concentrator System
- Ash Concentrate Conveying System
- SRC Solidifier System
- Feed Oil Charge Pumps
- Reactor Recirculation Pumps
- Feed Oil Heater
- Vacuum Tower Heater
- Coking Heater
- Process Water Treatment System
- Gasifier Refractory Lining
- Coal/KMAC Mix System
- Gasifier Feed System
- Flare Stack
- Wastewater Treatment System
- Coal Grinding and Classification System

INTRODUCTION

The prime contract between the U.S. Department of Energy (DOE) and ICRC provides that ICRC establish a list of "Critical Technology Equipment," which will "undergo special technical review to ensure the highest possible level of quality and lowest cost with commensurate acceptable overall risks." Accordingly, ICRC developed the Critical

Technology List based upon guidelines developed in the Master Project Procedure (MPP) and the Process Design Criteria (PDC). The MPP provides the following definition: Critical Technology is that which imposes technical risk to the success of the SRC-I Demonstration Plant, when such risk could prevent major objectives achievement without process or equipment modifications outside of overall battery budgetary and/or schedule program requirements. Examples of failure to meet major objectives would be unacceptable capacity factor, unacceptable product quality or quantity, unreasonable hazards to Plant personnel, and unacceptable environmental performance.

Table 1 provides excerpts from the MPP pertaining to factors that determine the listing of systems or equipment as Critical Technology, as well as definitions of priorities and criteria used.

Items to be added to or removed from the Critical Technology List are subjected to review by a nominated team or person, with Area Contractor support where necessary. A team leader or responsible person ensures that adequate information is obtained, that a thorough review is undertaken, and that a recommendation for appropriate action is made. All of the above actions are responsive to technical, cost, and schedule requirements. Reviews of the recommendations are performed by other selected individuals and/or teams, and when acceptable, the recommendations are endorsed for approval and/or implementation. Those recommendations having safety or hazards implications are reviewed by the appropriate committee.

The PDC provides an identification of risk. This information is shown in Table 2.

This report is the most up-to-date version of the Critical Technology List, and is useful to all involved in direct coal liquefaction technologies. Information for this effort was gathered from the sources listed in Appendix I. The work is incomplete in that certain areas were not treated as Critical Technology; an example is toxicology, for which an extensive SRC-I testing program is now underway.

This Post-Baseline report is divided into five sections presenting Critical Technology equipment within the battery limits of the Area Subcontractors: Catalytic, Inc., C. E. Lummus Co., The R. M. Parsons Co., and The Rust Engineering Co.

Table 1
Master Project Procedure

FACTORS GOVERNING THE LISTING OF EQUIPMENT AS CRITICAL TECHNOLOGY

- (a) If either a complete system or many items within a system meet a criterion, that system will be listed as Critical Technology. Items of equipment and components within a listed system will not be listed separately as Critical Technology.
- (b) If an item of equipment that is not part of a listed system meets a criterion, that equipment will be viewed as Critical Technology.
- (c) If a component of an unlisted item of equipment meets a criterion, the item of equipment will be listed as Critical Technology. However, in this case, only the critical component will be subject to the special review required by this procedure.

PRIORITIES

- Priority I - Systems and equipment items that are known to meet one or more of the criteria.
- Priority II - Systems and equipment items that are suspected of meeting one or more of the criteria.

CRITERIA

Process Criteria:

- A1 - Gaps or uncertainties are present in the Process Data Base that could affect equipment design, size, or operation.
- A2 - Undemonstrated equipment systems are to be used.
- A3 - Equipment scale-up is beyond the level of previously used scale factors for the same equipment.
- A4 - Use carries possible unexpected environmental risks.

Mechanical Criteria:

- B1 - New or extrapolated design technology is being used.
 - B2 - Equipment is to be a new, untried application of current technology.
 - B3 - Equipment scale-up affects fabrication or normally accepted Q/A procedures, which may increase the risk of failure.
 - B4 - Equipment supplier or contractor has limited experience with equipment design, materials, or manufacture.
 - B5 - Equipment has a history of frequent failure.
-

Table 2
Process Design Criteria

FACTORS DETERMINING TECHNICAL RISK

Since this plant is planned as the first module of a commercial plant, and since it must demonstrate process economic feasibility in the demonstration phase, it shall be designed in accordance with good industrial practice for a commercial plant, with the potential for operating for 20 years at a cost-effective production rate. The plant shall be designed to attain a target of 90% on-stream and utilization factors. The plant shall be designed with the equipment redundancy, installed spares, operating flexibility, and product line flexibility required for a demonstration operation to promote a viable commercial operation utilizing good industrial practice where appropriate. Systems or individual pieces of equipment that do not fit the above definition shall be considered as having high "technical risk."

Where economics of scale suggest that a prototype design be used, and it is decided to proceed with a prototype, such an item will be designated as "critical equipment" because of technical risk. For example, it is recognized that much of the equipment in the SRC Process and Deashing areas is considerably larger than what has been previously built for the service required, but not larger than equipment used in different services. These processes/equipment will require instrumentation in excess of industrial practice to permit diagnostic evaluation and troubleshooting during start-up and operation of the SRC-I Demonstration Plant.

The factors to be considered in technical risk evaluation, in order of importance, are safety, environment, operability, capacity, flexibility, and yields and efficiency. If the results of this subjective evaluation indicate an unacceptably high level of technical risk for the most economic process, this process shall be eliminated in favor of one with an acceptable level of risk.

CATALYTIC AREA

Coal Weigh-Feed System

Equipment: BH-12201 A, B-Coal Feed Calibration Bins

CV-12202 A, B-Coal Feed Screw Conveyor

X-12201 A, B-Coal Feed Flow Meters

AL-12202 A-D-Coal Slurry Drum Air Locks

Priority/Criteria: Old - II/A2, 3; B2, 3, 5

New - II/A2; B5 (Item BH-12201A, B only)

1. Justification for Classification

Handling and accurately measuring large volumes and throughputs of coal present some unique engineering problems that, upon investigation, required certain items to be classified as Critical Technology. Those listed are part of a complex system requiring a continuous capacity of 250 tph. Some components have not been demonstrated at this flow rate.

2. Actions Taken

Trade-off studies and reports were prepared on several aspects of pulverized coal handling. Consultants were contacted to establish the proper design in certain areas. Industries handling similar materials and flow rates were contacted for equipment histories and recommendations.

3. Results of Actions Taken

Two parallel coal feed systems (trains) were established at normal design rates of 125 tph each, with a flow rate of 250 tph under emergency design conditions. This design philosophy covers the calibration bins and the feed screw conveyors. An industrial proven Sanyko flow meter handling cement powder at 240 tph in continuous service was incorporated into the coal feed system. Commercially available parallel 125-tph airlocks with minor modifications for use in pulverized coal service were selected for design purposes.

4. Conclusions

Only the Coal Feed Calibration Bins, BH-12201 A,B, are still considered Critical Technology because a system having such a large capacity has never been demonstrated in continuous service. Therefore, this equipment will have to be designed, constructed, and inspected with the maximum expertise and care.

The other items are no longer considered critical equipment because of improved design by consultants, proven commercial installations, and easily modified standard industrial equipment.

Therefore, this system has been downgraded to a lower risk category within the Critical Technology List.

Slurry Preparation and Mixing System

Equipment: X-12208 A, B-Coal Slurry Premix Unit
A-12201 A, B-Coal Slurry Drum Agitators
V-12201 A, B-Coal Slurry Drums

Priority/Criteria: Old - I/A1, 2, 3; B2, 3, 4
New - Removed from list

1. Justification for Classification

Large-scale mixing of the pulverized coal with solvent to form a homogeneous slurry and to maintain the slurry in suspension for pumping presented unique engineering problems that, because of the concern for reliability, required certain items to be classified as Critical Technology.

2. Actions Taken

Mixing of powdered coal with solvent was conducted at vendor test facilities. The results indicated that a very high energy requirement would be necessary to form and maintain a homogeneous slurry. Tests carried out by other vendors indicated that the desired slurry could be obtained at considerably lower energy consumption by a premix technique rather than normal agitation. Maintaining the slurry in suspension would then require only a minimal amount of energy.

3. Results of Actions Taken

The use of two parallel slurry mixing trains, each sized for normal operation at 50% capacity (125 tph coal feed rate) and at 100% in an emergency, would allow plant operation to continue without interruption, and thus offer greater system reliability. A premix unit followed by an agitated coal slurry drum was adopted as the basis for design. The slurry drum is used for both vapor disengagement and as a hold tank with mild agitation to keep the slurry in suspension for pumping.

4. Conclusions

As a result of the vendor testing and new design of the Slurry Preparation and Mixing System, all of the equipment items listed should be removed from the Critical Technology List.

5. Future Work

Unit testing of both the premix unit and the slurry drum and its agitator is recommended. The tests should be conducted at a rate high enough to facilitate the design of the full-size units.

Coal Slurry/Hot Oil Heat Exchangers

Equipment: E-12202 A-D

Priority/Criteria: Old - I/A1, 2; II/B4
New - I/A1, 2; II/B4

1. Justification for Classification

These exchangers were classified as Critical Technology because units of the size required have not been demonstrated in similar operations. The heat transfer rates used for the design have not been substantiated by pilot plant experience or tests. The rate of tube fouling and/or plugging has not been verified. Because these units represent a high capital expenditure, the design must be investigated and verified as thoroughly as possible.

2. Actions Taken

Investigations were made into various exchanger types and configurations in order to ensure that the most advantageous design would be applied to this service. These investigations included shell and tube exchangers of single-pass, multiple-pass, horizontal, upflow, downflow, and double-pipe types.

The results of these investigations indicated that either an upflow or downflow configuration would achieve the most uniform distribution of slurry solids.

3. Results of Actions Taken

High-pressure shell and tube heat exchangers were selected for design. Multiple exchangers, arranged vertically and in series, are required for each process line. The slurry flow is to be upward through all exchangers. A 25% overdesign was used due to the uncertainty of the heat transfer coefficient.

4. Conclusions

Since many questions remain regarding the design of these exchangers, they should remain on the Critical Technology List.

5. Future Work

To alleviate the technical concerns, it is necessary to obtain better substantiated physical properties (such as thermal conductivity, viscosity, and specific heat of the slurry), the temperature at which gel formation takes place in the slurry, the maximum allowable tube metal temperature in contact with slurry, a single-tube performance test at design velocity, a temperature profile, the maximum tube length (in vertical orientation) in order to permit evaluation of the slurry side heat transfer coefficients and the effects of the upflow vs. downflow on heat transfer, and the limit of slurry velocity for acceptable tube life. Cold-flow tests have been proposed and should be executed. Full-scale hot tests on the installed plant equipment will be required to evaluate performance and long-term operability and maintenance requirements.

Coal Slurry Reciprocating Feed Pumps

Equipment: P-12202 A-F

Priority/Criteria: Old - I/B1, 4, 5; II/A1

New - Removed from List

1. Justification for Classification

Coal slurry mixtures, containing up to 48 wt % coal at temperatures over 400°F, present unique engineering problems. Pumps handling this type of material require special engineering expertise, since the possibility of generating more severe problems than would normally be anticipated exists if they are poorly designed.

Major items of concern for the design details of these pumps for slurry service are: suction and discharge manifolds, type of suction and discharge valves, valve seats, pump plunger design, stuffing box design, special metal and/or coating requirements, and type of plunger flush systems. The concerns for high temperature are: plunger cooling, stuffing box cooling, lubrication systems, and packing material.

The severe process conditions outlined above required that the pumps be classified as Critical Technology.

2. Actions Taken

Input from vendors who are familiar with the state-of-the-art was openly solicited to be certain that as many of the design requirements associated with the severe conditions were evaluated. They were requested to provide data on pump design and available pump sizes and to indicate in what facility, if any, their pumps are presently operational in similar service.

Visits were made to the Exxon Pilot Plant in Baytown, Texas, the H-Coal Plant in Catlettsburg, Kentucky, and to the Wilsonville, Alabama Advanced Coal Liquefaction Facility to observe and review slurry pumping operations and determine the nature of any problems being experienced.

3. Results of Actions Taken

Information received from reciprocating pump vendors and plant operation records from the Exxon Pilot Plant and the H-Coal Plant indi-

cate that slurry pumping at high temperature is the critical factor affecting reciprocating pump performance. Examination of the reports from the Exxon Pilot Plant has supported specified recommendations of the vendors for the design of plungers (flush rate and pressure, lubrication rate and pressure, cooling rates), packing and material, and spring loaded ball valves and for the use of pumps as metering devices.

A specification outlining the design requirements for reciprocating plunger pumps in high-pressure, high-temperature slurry service was developed adopting all known proven parameters as defined by vendor recommendations and operating plant experience.

Based on the information received, each feed pump will be fed by a centrifugal slurry pump. Each slurry train will be furnished with two pumps piped in parallel with one common spare.

4. Conclusions

Based on studies and reports from existing facilities, the vendors' recommendations, and the design redundancy, the reciprocating slurry pumps should be removed from the Critical Technology List.

5. Future Work

Unit testing is recommended. This may not be possible until a demonstration plant pump system is available. The fact that many existing plants are using updated reciprocating high-pressure pumps should alleviate concerns about these items, and should provide historical data for improving the design of the pumps. Tests and consultations with pump vendors should be continued in order to acquire improved data or designs and the latest packing technology, as well as the most recent operating and maintenance procedures.

Coal Slurry Circulation Pumps

Equipment: P-12201 A-F

Priority/Criteria: Old - I/B1, 4, 5; II/A1

New - Removed from List

1. Justification for Classification

Coal slurry mixtures, containing up to 48 wt % coal at temperatures over 400°F, present unique engineering problems. Pumps handling this

type of material require special engineering expertise, since the possibility of generating more severe problems than would normally be anticipated exists if they are poorly designed. Therefore, the pumps were classified as Critical Technology.

2. Actions Taken

Input from vendors who are familiar with the state-of-the-art was openly solicited to be certain that as many of the design requirements associated with the severe conditions were evaluated. They were requested to provide data on pump designs, as well as the locations of any currently operational pumps.

Plant visits were made to the Wilsonville, Alabama Advanced Coal Liquefaction Facility, the Exxon Pilot Plant in Baytown, Texas and the H-Coal Facility in Catlettsburg, Kentucky to observe and review slurry pumping operations and determine any problems being experienced.

3. Results of Actions Taken

The pump vendors provided specific design recommendations such as wear rate factors, impeller tip speed (ft/sec), pump speed (rpm), and materials of construction for impellers and liners. They also furnished test results for mechanical seals and elastomers.

Data received from the plant visits concerned the size and concentration of solids, the nature of solids and liquids, and various operating conditions such as temperatures, pressures, and capacities. Information was also received on slurry pumping as related to pump performance and life expectancy, including data on TDH and efficiency reduction due to erosion and/or wear.

A specification outlining the design requirements for centrifugal slurry pumps was developed for all known proven parameters as defined by vendor recommendations and operating plant experience.

Based on the information received, each slurry train will be furnished with two centrifugal pumps piped in parallel with one common spare.

4. Conclusions

As a result of the vendor investigations and various pilot plant tests performed on centrifugal slurry pumps, it is believed that they should be removed from the Critical Technology List.

5. Future Work

Unit testing is recommended. This may not be possible until a demonstration plant pump system is available. The installation of centrifugal slurry pumps with removable liners in many existing plants will add to the historical data for updating wear rates and other critical factors. Tests and consultations with pump vendors should be continued in order to acquire further data that may improve service life of such items as pump liners and impellers. Further tests are recommended for double mechanical seals and flush systems in order to determine true life expectations for various designs and arrangements in slurry pumping service.

Miscellaneous Area 12000 Centrifugal Pumps

Equipment: P-12601 A,B - Vacuum Column Bottoms Pumps

P-12602 A,B - Vacuum Column Heater Pumps

Priority/Criteria: Old - I/B1, 4, 5; II/A1

New - Removed from List

Equipment: P-12724 A,B - Third-Stage Light-Phase Pumps

Priority/Criteria: Old - I/A1; B2, 4

New - Removed from List

1. Justification for Classification

Coal/ash slurry mixtures, containing up to 21 wt % coal at temperatures of 600°F and a solvent stream also over 600°F present unique engineering problems. Pumps handling these types of materials require special engineering expertise since the possibility of generating more severe problems than would normally be anticipated exists if they are poorly designed.

Therefore, the pumps were classified as Critical Technology.

2. Actions Taken

Input from vendors who are familiar with the state-of-the-art was openly solicited to be certain as many of the design requirements associated with the severe conditions were evaluated. The vendors were also requested to provide data on pump designs, as well as the locations of any currently operational pumps.

Plant visits were made to the Wilsonville, Alabama Advanced Coal Liquefaction Facility, the Exxon Pilot Plant in Baytown, Texas and the H-Coal Facility in Catlettsburg, Kentucky to observe and review both slurry and solvent pumping operations and to determine any problems being experienced.

3. Results of Actions Taken

The pump vendors provided specific design recommendations such as wear rate factors, impeller tip speed (ft/sec), pump speed (rpm), and materials of construction for impellers and liners. They also furnished test results for mechanical seals and elastomers.

Data received from the plant visits concerned the size and concentration of solids, the nature of solids and liquids, and various operating conditions such as temperatures, pressures, and capacities. Information was also received on slurry pumping as related to pump performance and life expectancy, including data on TDH and efficiency reduction due to erosion and/or wear.

A specification outlining the design requirements for centrifugal slurry pumps was developed for all known proven parameters as defined by vendor recommendations and operating plant experience.

Based on the information received, each slurry centrifugal pump will be furnished with a spare pump.

High-temperature pumping of solvents is currently being practiced in industry. The appropriate sealing mechanism for P-12724 A, B should be carefully selected to handle the solvent as its characteristics change during continuous operation.

4. Conclusions

As a result of the vendor investigations and various pilot plant tests performed on centrifugal slurry pumps, as well as the availability

of commercial high-temperature pumps in solvent service, it is believed that these items should be removed from the Critical Technology List.

5. Future Work

Unit testing is recommended for the slurry pumps only. This may not be possible until a demonstration plant pump system is available. The installation of centrifugal slurry pumps with removable liners in many existing plants will add to the historical data for updating wear rates and other critical factors. Tests and consultations with pump vendors should be continued in order to acquire further data that may improve service life of such items as pump liners and impellers. Further tests are recommended for double mechanical seals and flush systems in order to determine true life expectations for various designs and arrangements in slurry pumping service.

It is also recommended that the nature of non-Newtonian fluid behavior in centrifugal pumps be investigated, since both the Vacuum Column Bottoms Pumps (P-12601 A,B) and the Vacuum Column Heater Pumps (P-12602 A,B) will be pumping a non-Newtonian fluid.

Miscellaneous Area 12000 Reciprocating Pumps

Equipment: P-12105 A,B - High-Pressure Solvent Purge Pumps

Priority/Criteria: Old - II/B4

New - Removed from List

Equipment: P-12126 A,B - SRC Flush Pumps

Priority/Criteria: Old - I/B2, 4, 5

New - Removed from List

Equipment: P-12608 A, B - CSD Feed Pumps

Old - I/A1; B2, 4, 5

Priority/Criteria: New - Removed from List

Equipment: P-12706 A,B - First-Stage Recycle Critical Solvent
Pumps

Priority/Criteria: Old - I/B4, 5

New - Removed from List

1. Justification for Classification

Coal/ash slurry mixtures containing up to 21 wt % coal at temperatures up to 600°F and solvent streams containing up to 3% ash with temperatures up to 400°F present unique engineering problems. Pumps handling these types of material require special engineering expertise, since the possibility of generating more severe problems than would normally be anticipated exists if they are poorly designed.

Major items of concern for the design details of these pumps for both the solvent and slurry service are: suction and discharge manifolds, type of suction and discharge valves, valve seats, pump plunger design, stuffing box design, special metal and/or coating requirements, and type of plunger flush systems. The concerns for high temperature are: plunger cooling, stuffing box cooling, lubrication systems, and packing material.

The severe process conditions outlined above required that these pumps be classified as Critical Technology.

2. Actions Taken

Input from vendors familiar with the state-of-the-art was openly solicited to be certain as many of the design requirements associated with the severe conditions were evaluated. They were requested to provide data on pump design and available pump sizes, and to indicate in what facility, if any, their pumps are currently operational in similar service.

Visits were made to the Exxon Pilot Plant in Baytown, Texas, the H-Coal Plant in Catlettsburg, Kentucky, and to the Wilsonville, Alabama Advanced Coal Liquefaction Facility to observe and review both slurry and solvent pumping operations and to determine the nature of any problems being experienced.

3. Results of Actions Taken

Information received from reciprocating pump vendors and plant operation records from the Exxon Pilot Plant and the H-Coal Plant indicate that slurry pumping at high temperature is the critical factor affecting reciprocating pump performance. Examination of the reports

from the Exxon Pilot Plant have supported specified recommendations of the vendors for the design of: plungers (flush rate and pressure, lubrication rate and pressure, cooling rates), packing design and materials, spring loaded ball valve design, and the use of pumps as metering devices.

A specification outlining the design requirements for reciprocating plunger pumps in high-pressure, high-temperature slurry service was developed, adopting all known proven parameters as defined by vendor recommendations and operating plant experience.

Based on the information received, the design basis will utilize a spare pump for all services.

4. Conclusions

Based on studies and reports from existing facilities, the vendors recommendations, and the design redundancy, these reciprocating slurry and solvent pumps should be removed from the Critical Technology List.

5. Future Work

Unit testing is recommended for the CSD Feed Pumps (P-12608 A,B) only. This may not be possible until a demonstration plant pump system is available. The fact that many existing plants are using updated reciprocating high-pressure pumps should alleviate concerns about these items and should provide historical data for improving the design of the pumps. Tests and consultations with pump vendors should be continued in order to acquire improved data or designs and the latest packing technology, as well as the most recent operating and maintenance procedures.

Coal Slurry Heaters

Equipment: H-12301 A-D

Priority/Criteria: Old - I/A1, 2; B2, 3, 4

New - I/A1, 2; B2, 3, 4

1. Justification for Classification

It was determined at the outset that heaters of the size required for this project have not been demonstrated in a similar service.

The flow regime in the tubes and the heat transfer rate used for design have been based on theory. They have not been verified by tests or in services similar to those necessary for this facility. The rate of coking and the ability to decoke have not been demonstrated, and the problem of maintaining the coal in suspension at the turndown velocities, and the long range erosion and corrosion effects on tube metallurgy had to be addressed. To develop an economical unit based on existing heaters in similar services, large scale-up factors were utilized. This scale-up contributed to uncertainties regarding such information as heat transfer data, three-phase flow characteristics, viscosity, and transients. These design problems are the reason that the Coal Slurry Heater was classified as Critical Technology.

2. Actions Taken

Historical data from fired heater operations in existing coal liquefaction facilities and literature sources were researched extensively. Studies were prepared evaluating radiant design, convective design, radiant and convective design, and electric heaters. Various burner arrangements were also studied. The methods of controlling heat flux at various segments of the heat transfer surfaces were also investigated. Tests on simulated slurry flows to determine physical properties were initiated with Creare, Inc. Inquiries were made to heater vendors for design and cost information.

3. Results of Actions Taken

The various studies and investigations indicated that a radiant/convective type heater would be best for the service required. The design adopted is a radiant type having a small independent convection section.

The initial design of the fired heater is based on extensive data from the operation of the fired heater at the Ft. Lewis Pilot Plant. The design of the fired heater (H-12301 A-D) meant an extrapolation from 2-in. I.D. pipe at Ft. Lewis to 6.8-in. I.D. pipe in the SRC-I Demonstration Plant. The design assumptions regarding the three-phase fluid flow behavior have been verified in a 2-year cold flow modeling study.

The presence of slug flow has been confirmed and ICRC has also developed limited heat transfer data.

Tests are being conducted by Creare, Inc. in a 6.75-in. I.D. pipe using a sodium carboxy methyl cellulose/water mixture and Freon gas to simulate coal/solvent slurry and hydrogen flows. The heat transfer data are being developed in a 5-ft-long test section of the pipe. The gas and liquid phase superficial velocities, gas density, and liquid viscosity are varied from the design conditions to as low as one-third load to confirm flow behaviors. The liquid phase velocity is further lowered to identify the flow regime boundary from slug to stratified flow.

4. Conclusions

As a result of the assumptions made for the design and the questions remaining concerning the larger scale slurry fired heaters, the Coal Slurry Heaters should remain on the Critical Technology List.

5. Future Work

Further tests and simulations should be made to determine more accurately the physical properties of the slurry, such as thermal conductivity, viscosity, and erosion rates (at various viscosities).

Additional efforts should be directed toward the determination of the correlation between heat duty and residence time, as well as the development of temperature vs. enthalpy profiles. These heat transfer data in the demonstration plant size pipe are badly needed, and more comprehensive heat transfer testing using longer test sections is recommended.

Second-Stage Feed Heaters

Equipment: H-12701 A, B

Priority/Criteria: Old - I/A1; B2, 3, 4

New - I/A1; B2, 3, 4

1. Justification for Classification

This equipment has many of the same problems associated with the Coal Slurry Heaters (H-12301 A-D). Therefore, the Second-Stage Feed Heaters were also classified as Critical Technology.

2. Actions Taken

The same steps were initiated for these heaters as for the Coal Slurry Heaters.

3. Results of Actions Taken

This equipment has many of the complexities associated with the Coal Slurry Heaters (H-12301 A-D). The flow regime for the combination heavy SRC and light-phase mixture is probably slug flow. The unsteady nature of the flow mean variable heat transfer rates depend upon liquid or vapor phase in contact with the pipe wall. Even though the heaters are not identical by design or application, the flow and heat transfer behaviors in these heaters would be similar. Therefore, the cold flow modeling tests conducted for the Coal Slurry Heaters should be able to define and then help eliminate problems in the design of the Second-Stage Feed Heaters. The operation of the CSD unit at Wilsonville has provided a significant amount of physical property data that could be used to reasonably establish the heater duties.

4. Conclusions

As a result of the assumptions made for the design and the questions remaining concerning the larger scale units, the Second-Stage Feed Heaters should remain on the Critical Technology List.

5. Future Work

Further tests and simulations should be made to determine more accurately the physical properties of the slurry, such as thermal conductivity, viscosity, and erosion rates (at various viscosities). Additional efforts should be directed toward the determination of the correlation between heat duty and residence time, as well as the development of temperature vs. enthalpy profiles. These heat-transfer

data in the demonstration plant size pipe are badly needed, and more comprehensive heat transfer testing using longer test sections is recommended. The use of carbon steel in this heater should be further investigated. If metal temperatures reach 1,200-1,300°F because of hot spots, tube ruptures could occur and cause serious fires in the heaters.

Coal Slurry Dissolvers

Equipment: R-12401 and R-12402

Priority/Criteria: Old - I/A1, 2, 3; B2, 3, 4; II/B1

New - I/A1, 2, 3; B2, 3, 4; II/A2; B1

1. Justification for Classification

The Coal Slurry Dissolvers were classified as Critical Technology because of the following reasons:

- ° Limited availability of fabricators having the capability and/or experience to fabricate such large-diameter, thick-walled vessels
- ° Unavailability of materials capable of withstanding the stresses of design requirements
- ° Local occurrences of temperature extremes during operating and transient conditions, and the resulting thermal stresses (fatigue and creep) on the vessel wall
- ° Limited understanding of the flow characteristics of a mixed phase flow consisting of coal slurry and hydrogen gas
- ° Lack of data on hydrogen consumption

2. Actions Taken

Fabricators knowledgeable in the design and fabrication of large heavy-walled vessels were surveyed to determine their capabilities and experience.

3. Results of Actions Taken

Specifications were prepared for the design and fabrication of these vessels based on the vendor survey. These documents established

the operating conditions, emergency operating conditions, service life expectancy, materials of construction, corrosion allowance requirements, fabrication requirements, testing, and controls. Proposals for these vessels were then solicited from selected bidders.

4. Conclusions

Although many of the questions regarding the design and fabrication of the Dissolvers have been addressed, sufficient concern remains about the fabrication of such heavy-walled vessels, the extreme variations in temperature realized during operating and transient conditions and the resultant stresses, as well as the question of the rate of hydrogen consumption. Therefore, the Coal Slurry Dissolvers should remain on the Critical Technology List, although downgraded to a lower risk category.

5. Future Work

To alleviate the technical concerns, more information should be gathered regarding creep and fatigue data for the 2- $\frac{1}{4}$ Cr-1 Mo steel selected as the material of construction. Unit testing is recommended on scaled vessels operated under design conditions and in slurry service to resolve the questions of gas holdup and coke formation in the dissolvers.

Coal Dissolver Effluent Separator

Equipment: V-12401

Priority/Criteria: Old - I/A1, 2, 3; B2, 3, 4; II/B1

New - I/A1, 2, 3; B2, 3, 4; B1

1. Justification for Classification

The Coal Slurry Effluent Separator was classified as Critical Technology primarily because of the following reasons:

- ° Limited availability of fabricators having the capability and/or experience to fabricate such a large-diameter, thick-walled vessel

- Unavailability of materials capable of withstanding the stresses of design requirements
- Local mixing of temperature extremes during operating and transient conditions causing thermal stresses (fatigue and creep) on the vessel wall
- Level detection difficulty

2. Actions Taken

Fabricators knowledgeable in the design and fabrication of large heavy-walled vessels were surveyed to determine their capabilities and experience. Various level detection systems were investigated for use in this service.

3. Results of Actions Taken

Specifications were prepared for the design and fabrication of these vessels based on the vendor survey. These documents established the operating conditions, emergency operating conditions, service life expectancy, materials of construction, corrosion allowance requirements, fabrication requirements, testing, and controls. Proposals for these vessels were then solicited from selected bidders. Nuclear level gauging was ruled out due to the wall thickness. Differential head meters purged with hydrogen were selected as the primary level detection devices.

4. Conclusions

Although many of the questions regarding the design and fabrication of the Separator have been addressed, sufficient concern remains about the fabrication of such a heavy-walled vessel, the extreme variations in temperature realized during operating and transient conditions, and the resultant stresses. Therefore, the Separator should remain on the Critical Technology List, although downgraded to a lower risk category.

5. Future Work

To alleviate the technical concerns, more information should be gathered regarding creep and fatigue data for the 2- $\frac{1}{4}$ Cr-1 Mo steel

selected as the material of construction. Unit testing on a scaled vessel operated under design conditions and in slurry service is recommended to resolve the questions of internal equipment design and coke formation.

Medium-Pressure Flash Drums

Equipment: V-12402 A, B

Priority/Criteria: Old - I/B4

New - Removed from List

1. Justification for Classification

Level detection is envisioned as the major operating problem for this vessel. Internal wear due to abrasion and erosion by the letdown slurry is also a concern. For this reason, the Medium-Pressure Flash Drums were classified as Critical Technology.

2. Actions Taken

Methods of level detection were evaluated for use in this service. Consideration of the letdown slurry entry point (side radial vs. vertical top-head) were undertaken by the Area Subcontractor.

3. Results of Actions Taken

A hydrogen purged differential head meter was selected as the primary level detection device with backup provided by a two radiation source nuclear level gauge. The radial side entry point for the letdown slurry was selected for Baseline design purposes.

4. Conclusions

As a result of the features incorporated into the design, it is believed that the Medium-Pressure Flash Drums should be removed from the Critical Technology List.

5. Future Work

The entry point for the letdown slurry should be reconsidered during the final design phase in conjunction with a review of slurry letdown valves.

High-Pressure Vapor/Recycle Gas Exchanger

Equipment: E-12403

Priority/Criteria: Old - II/B4

New - Removed from List

1. Justification for Classification

Concern over plugging and/or fouling of this exchanger classified it as Critical Technology.

2. Actions Taken

Plugging of this exchanger was determined to occur only with overflow of the Coal Dissolver Effluent Separator, V-12401.

3. Results of Actions Taken

A redundant level detection system will be installed on V-12401 to prevent overflow into the exchanger. Sufficient vapor disengaging space has been provided in the vessel to eliminate particulate carry-over.

4. Conclusions

As a result of the features incorporated into the design, the High-Pressure Vapor/Recycle Gas Exchanger should be removed from the Critical Technology List.

High-Pressure Separator/Recycle Gas Exchanger

Equipment: E-12406

Priority/Criteria: Old - II/B4

New - Removed from List - Deleted from design

Hot Slurry/Hot Oil Heat Exchangers

Equipment: E-12416-18

Priority/Criteria: Old - I/A1; II/B4

New - Removed from List - Deleted from design

Vacuum Column Heater

Equipment: H-12601

Priority/Criteria: Old - II/A1

New - II/A1

1. Justification for Classification

Although this heater is to be used during start-up of T-12601 and during upset conditions requiring heat input to the T-12601 feed slurry, it has many of the same problems associated with the Coal Slurry Heaters (H-12301 A-D) and the Second-Stage Feed Heaters (H-12701 A, B).

2. Actions Taken

The actions taken for the other slurry fired heaters were initiated for this equipment.

3. Results of Actions Taken

In addition to the comments for the other slurry-fired heaters, this equipment has an outlet bulk slurry temperature requirement of 650°F, and thus the heater wall temperatures may be high enough to cause coking.

4. Conclusions

As a result of the assumptions made for the design and the questions remaining concerning the larger scale units, the Vacuum Column Heater should remain on the Critical Technology List.

5. Future Work

The same recommendations outlined for the other slurry-fired heaters apply to this equipment.

Vacuum Column

Equipment: T-12601

Priority/Criteria: Old - I/A1, 2

New - I/A1, 2

1. Justification for Classification

The feed for the Vacuum Column contains high concentrations of solids particles composed of unconverted coal and ash. The presence of these particles in the feed creates special problems. As the feed flashes across the pressure control valve located on the feed line, the resulting high velocity of the mixture of gas and SRC slurry will cause erosion of the inlet pipe(s) and/or column walls on impact. The letdown valve (pressure control valve) is also subject to a very erosive environment and a properly designed valve is critical. Since the column operates under high vacuum, any holes created by the erosion will permit air to be sucked in, thereby creating a very hazardous condition.

The Vacuum Column bottoms section is sized to provide an adequate holdup volume to minimize surges in the CSD unit feed. Excessive surge volume is not desirable, since the preasphaltene/asphaltene ratio in the feed increases with longer storage, and will affect the SRC recovery in the CSD unit. Design of the Vacuum Column bottom section is also considered critical since settling and/or accumulation of solids in this section may also cause interruption of the feed flow to the CSD unit by plugging of the bottoms pump suction line. Proper functioning of the level controller, located on the bottom section of the column is also considered important, since it controls the feed flow to the CSD unit.

Finally, selection of the proper material of construction for corrosion control as well as erosion resistance poses a problem.

Therefore, due to the erosive nature of the feed to the Vacuum Column, the sensitivity of the bottoms product to holdup time, and the need for proper design of the control instruments, this unit should remain on the Critical Technology List.

2. Actions Taken

Various arrangements for the column feed system were evaluated, such as tangential entry, single-entry feed nozzle, and double-entry feed nozzles (opposing each other). Modes of dissipating kinetic energy of feed and the effect of migration of sonic waves on column operation were also investigated.

Designs were reviewed in order to prevent solids carryover into the liquid draw-off tray located above the feed zone.

Studies of different column bottom configurations to prevent accumulation of solids and to ensure a steady flow of material to the CSD unit were made.

A study report on the letdown valve system for the reactor was prepared. Most of the considerations of that study are applicable to the pressure control valve on the feed line, as well as to other pressure control valves in slurry service.

3. Results of Actions Taken

Tangential entry is quite common for feed to a Vacuum Column in the petroleum industry because it helps separate vapors from liquids by the centrifugal action it creates. However, because of the presence of the solids particles in the feed for this Vacuum Column, such a design would cause rapid erosion of the column walls. Therefore, this design was ruled out.

The calculations for a single-entry radial feed nozzle indicate that when using an 84-in.-diam size, the velocity of the feed entering the column is in excess of 200 ft/sec. This is considered unacceptably high. In the petroleum industry, the normal practice is to design for the entrance velocity of approximately 100 ft/sec. Therefore, in order to limit the entrance velocity to an acceptable level, the column is provided with two 84-in.-diam entrance nozzles, 180° apart.

To stabilize the flow of feed downstream of the pressure control valve on the feed line, a section of straight pipe 50 ft in length is recommended on each of the entrance nozzles. These feed pipes are designed to have annular flow with a core of vapor flowing at a lower speed through the center of the pipe. The slurry flows through the annular space between the vapor flow and the pipe walls. A transition piece was designed to have a gradual increase in size downstream of the control valve, so that no eddy currents would be formed in this pipe section.

To dissipate the kinetic energy of the feed so that the solids in the slurry do not hit the column walls directly with great force, target

plates, designed for easy replacement in case of erosion, are provided at the center of the column. The target plates have shrouds located at the top to prevent direct solids carry-over to the draw-off tray above. Additionally, approximately 7 ft of free height is provided between the feed nozzles and the draw-off tray to permit proper disengagement of solid particles. The bottom sections of the target plates are inclined inwardly to prevent direct splashing of the slurry into the bottom liquid level. Minimizing the disturbance to this liquid level is considered vital to permit the proper functioning of the level controller which controls the steady flow of feed to the CSD unit.

The column bottom configuration is designed using a 60° cone in order to avoid dead zones for solids buildup and to provide a free flowing slurry to the suction of the bottoms pump. A need to have a reliable level control, in order to feed the CSD unit at a steady rate, makes it imperative that a cylindrical section (where the volume of liquid slurry is linear to the height of the level) is included in the design. A single cone design does not provide the linear relationship. Hence, a straight vertical cylindrical section between two cone sections was provided to meet this requirement for level control. This addition increases the overall height of the column. The level control system chosen utilized a solvent-purged differential head meter as the primary control, with backup provided by a single radiation source nuclear level gauge.

Although not part of the Vacuum Column, the pressure control valve(s) in the slurry line(s) are also critical. Limited experience regarding the life of letdown valves in this type of service has been obtained from Wilsonville and Fort Lewis pilot plants only. Further experience has been gained in larger (approximately 100-250 tpd) pilot plants such as EDS and H-Coal units. A Letdown System Study was prepared to evaluate letdown valves in general. Control valves have been used for similar service in other areas of this facility. The study concludes that by proper selection of materials (for valve seat and trim) and using the proper geometry for valve positioning, the life of such valves can be prolonged.

Selection of 316L SS clad material (CS base) was deemed to solve the corrosion control problem.

4. Conclusions

The inlet piping design, the section of the vacuum column at the inlet(s), and the pressure control valve(s) should remain on the Critical Technology List because of the uncertainty of the behavior of slurry under the process conditions. However, the bottom section design of the Vacuum Column should be removed from the List.

5. Future Work

An expert in this field should review the proposed configuration and recommend modifications as required.

Ash Concentrator System

Equipment: BH-12701 A, B - Concentrator Receiving Bins
CV-12701 A, B - Concentrator Screw Conveyor
DC-12701 A, B - Ash Concentrator Primary Cyclone
AL-12705 A, B - Ash Classifier Rotary Valve.

Priority/Criteria: Old - I/A1, 2, 3; B2, 4
New - Removed from List

1. Justification for Classification

The Ash Concentrator System was originally classified as Critical Technology because industrial and equipment manufacturers have little experience with the Kerr-McGee ash concentrate (KMAC) solids.

The feed to this system is a slurry containing SRC, unconverted carbon, ash, and process solvent. This deashing unit separates the slurry into product SRC, light SRC, and by-product ash concentrate. The ash concentrate is a fine-particle material having complex characteristics. It is a very pyrophoric material, and under process upset conditions the increased percentages of solvent in this ash will make it virtually untransportable. This condition will also result if the normal operating temperature has been violated.

Since the KMAC has a very narrow operating temperature "window," the equipment used to concentrate this material will be prone to severe problems of agglomeration at high temperatures and compaction at low temperatures.

All of the equipment items required for concentrating KMAC are of special design. These items are similar to units in operation at other facilities. However, the modifications necessary due to the severe process conditions and the operating problems to which they may be subjected, require that the Ash Concentrator System be placed on the Critical Technology List.

2. Actions Taken

A test program conducted by an outside consultant (Jenike and Johanson) was initiated to obtain design data for the KMAC material. Their study was to test and define the material sufficiently so that design parameters for the bins and related equipment could be established. Further tests at the Wilsonville Pilot Plant also added information. A separate program was initiated to determine the explosion sensitivity range of KMAC.

3. Results of Actions Taken

For reliability, the design incorporates two separate full-size Ash Concentrator System trains consisting of the individual items of equipment listed above. Should problems develop in one train, the second train has the capacity to handle the entire flow. It is felt that if process upset conditions do occur, the KMAC will not be conveyable, and plugging will be limited to the Ash Concentrator System. Indications are that KMAC flow during a process upset will not go beyond the screw conveyor due to the severe cohesiveness of the material, thereby, protecting the equipment downstream of the rotary valve.

The Jenike and Johanson tests determined that mass flow bins must be used in order to provide reliable and continuous flow, and recommendations for design parameters were outlined for the bins, the gas permeation system, and the screw conveyor. A nitrogen purge system to maintain an inert atmosphere was recommended to offset the explosive sensitivity of KMAC.

4. Conclusions

Although no industrial installations for continually conveying material similar to KMAC under parallel conditions exist, the mechanical

equipment used in the Ash Concentrator System will be standard industrial units modified for the severe characteristics of the KMAC material. The bins and cyclones are to be designed and fabricated specifically for KMAC service following the consultant's design parameters.

Therefore, it is felt that the Ash Concentrator System should be removed from the Critical Technology List.

Ash Concentrator Conveying System

Equipment: CL-12701 A, B - Ash Concentrate Classifiers
BH-12702 A, B - Classified Ash Concentrate Bins
CV-12702 A, B - Classified Ash Concentrate Screw Conveyors
X-12702 A, B - Ash Conveying Diverter Valves
V-12718 A-D - Ash Conveying Blow Drums
X-12704 A-D - Ash Blowdrum Outlet Slide Valves
X-12715 A, B - Ash Conveying Isolating Slide Valves
X-12707 - Ash Conveying Dust Separator Diverter Valve
X-12706 A-D - Ash Conveying Dust Separator Slide Valves
DC-12703 A, B - Ash Conveying Dust Separators
AL-12703 A, B - Ash Conveying Dust Separator Rotary Valves
X-12716 A, B - Classifier Ash Concentrate Slide Valves
Alternate Designs and Approaches

Priority/Criteria: Old - I/A1; B2, 4

New - Removed from List

1. Justification for Classification

The Ash Concentrate Conveying System was originally classified a Critical Technology Package because industrial and equipment manufacturers have little experience with the Kerr-McGee concentrate (KMAC) solids.

The feed to this system is the fine particles ash portion of the slurry being fed to the Ash Concentrator System. This ash has many very complex characteristics. It is pyrophoric, and, with an increase in solvent, will become virtually untransportable.

Having a very narrow operating temperature "window," the equipment used to transfer the KMAC 1,200 ft. will be prone to severe problems of agglomeration (at high temperatures) and compaction (at low temperatures).

All of the equipment required for transferring KMAC is similar to units in operation in other facilities. However, the modifications dictated by the severe process conditions and possible operating problems require that the Ash Concentrate Conveying System be placed on the Critical Technology List.

2. Actions Taken

Studies were made of potential methods of transferring KMAC material to storage over a distance of 1,200 ft. The alternate methods investigated were vibratory conveyors, screw conveyors, dense phase pneumatic conveyors, air slides, and the Fuller-Kinyon pumping system. These studies were based on using material having the handling characteristics of fly ash. When the results of the Jenike and Johanson test program were incorporated into the study, only the dense phase pneumatic system was recommended.

The Fuller Company conducted a test program to fully demonstrate that KMAC may be pneumatically conveyed and to run the tests over a wide range of temperatures, conveying rates, various gas-to-solids ratios, and with a blow-pot pressure system to compare its capability with the Fuller-Kinyon pumping system. Process design data and mechanical equipment recommendations were to be included in their report based on the test results.

3. Results of Actions Taken

Test results indicated that KMAC may be pneumatically conveyed as well as any other powdered material as long as it is dry and not sticky (i.e., at temperatures of 550 to 580°F). As a result of the reviews, studies, and tests, it was determined that the blow-pot pressure system should be used for design. This system was chosen since it uses the minimum number of rotating machinery items that would be susceptible to the adverse effects of erosion. Two separate trains will be used for

design, and the system is designed in accordance with the Fuller Company report. All equipment is designed to operate in an inert (nitrogen) atmosphere to offset the explosive nature of KMAC.

4. Conclusions

Although no industrial installations conveying material similar to KMAC under parallel conditions exist, the mechanical equipment used in the Ash Concentrate Conveying System will be standard industrial units modified for the severe characteristics of the KMAC material. All components will be designed in conformance with the report by the Fuller Company. Separate trains of equipment in the critical areas will be provided to assure continuous conveying of the material.

Therefore, it is felt that the Ash Concentrate Conveying System should be removed from the Critical Technology List.

SRC/Light SRC (LSRC) Stripping System - CSD

Equipment: T-12701 - SRC Stripper

T-12702 - LSRC Stripper

Priority/Criteria: Old - Not on List

New - I/A1, 2

1. Justification for Classification

Steam stripping to reduce deashing solvent levels in the SRC/LSRC Stripping System to the 0.1 wt % design specification has been a problem at the Wilsonville Pilot Plant. In addition, emulsion formation in the stripper overheads has caused serious difficulty. This problem will have to be eliminated before final system design. For these reasons, the SRC/Light SRC Stripping System has been added to the Critical Technology List.

2. Actions Taken

Kerr-McGee will replace the undersized stripping equipment at the Wilsonville Pilot Plant with larger strippers and preflash separators. In addition, Kerr-McGee plans further testing in their own process development unit to expand the data base for SRC/LSRC stripping.

3. Results of Actions Taken

No new information is available to either confirm or revise the 0.1 wt % design criteria at this time. As this criteria was based on early laboratory work by Kerr-McGee, the present value should remain until such time that data are presented to justify a change.

4. Conclusions

Since the design criteria of 0.1 wt % critical solvent in the SRC Stripper bottoms stream has been difficult to achieve in practice and no solutions to overcome this and the emulsion formation problem have been presented, it is felt that the SRC/LSRC Stripping System should be added to the Critical Technology List.

SRC Solidifier System

Equipment: Solidifiers S0-12801, S0-12802

Priority/Criteria: Old - I/A1, 2; B2, 4

New - Removed from List

1. Justification for Classification

Units of the size proposed for the demonstration plant have never been operated or proven in this service. Solidification tests at the Wilsonville Pilot Plant performed on the Rexnord unit indicated that a lower solidification rate than that used in the design may be anticipated. For these reasons, the SRC Solidifier System was placed on the Critical Technology List.

2. Actions Taken

Studies were made of various methods of solidifying molten SRC product, and plant sites were visited to review the operation of these methods. The Wilsonville Pilot Plant conducted solidification tests, and Rütgers in Germany was asked to run a test on solidifying molten SRC using their water bath technology. Mitsui Company of Japan also utilizes the latter technology and was contacted.

3. Results of Actions Taken

Based on the early tests, the vibratory multiple water-cooled deck solidification system by Rexnord was chosen for the design. Although Rütgers successfully demonstrated that their water bath technology could solidify molten SRC, the process was not tested at Wilsonville and negotiations with them were terminated for economic reasons.

A contract was then established with the Koppers Company to provide a design Baseline package for an SRC solidification system based on their water bath technology.

4. Conclusions

The design package prepared by Koppers utilizes the same equipment presently in use in several pitch solidification plants owned and operated by Koppers. The scale-up factor between these operating plants and the demonstration plant requirements is very nominal. All equipment is proven in continuous service under conditions very similar to those required when processing molten SRC. Since the design is based on proven industrial practice, it is felt that the SRC Solidifier System should be removed from the Critical Technology List.

Valves: Severe Service

Equipment: SRC Liquefaction HP Slurry Letdown
SRC Liquefaction HP Slurry Block
SRC MP Slurry Letdown
First-Stage, Heavy-Phase Critical Solvent Letdown
Vacuum Column (T-12601) Letdown

Priority/Criteria: Old - I/B1, 3, 4, 5
New - I/R1, 3, 4, 5

1. Justification for Classification

The SRC-I coal liquefaction process requires a letdown of several process slurries from a high pressure to a much lower processing pressure. The potential for erosion due to the solids content of the slurry presents a formidable design problem. Although solutions to similar problems have been found and applied to this and other processes, none

can be considered wholly satisfactory. This slurry letdown system and the others listed above were the subject of concern from the inception of the project, and therefore, the general group of Valves in Severe Service was classified as Critical Technology.

2. Actions Taken

The successes and failures of letdown systems in existing plants were thoroughly reviewed. The original design criterion of double block valves upstream and downstream of each letdown valve was also reviewed. Input from valve manufacturers, operators of existing pilot plants, and an outside engineering consultant was solicited and studied. Control valve sizing was given a thorough review. Piping layouts and arrangements were studied in order to minimize the potential for wear and plugging. Materials of construction for block and control valves were reviewed.

3. Results of Actions Taken

The results of the above actions are contained in the report "SRC-I Letdown System Study," issued in the July-September 1982 SRC-I Quarterly Technical Report.

Control valve sizing is no longer considered to be of concern due to the empirical sizing information gained from the H-Coal and Exxon plants. This information includes valve design features such as geometry to minimize impingement angles, and shape of valve trim, which has been found to have a major impact on valve performance. These data were used in the design. Modifying the start-up methods included in the proposed operating procedure is expected to reduce the failure rate of the fragile valve trim. It was determined that control excursions and plant turndowns should be minimized. SRC-I liquefaction slurry letdown valves have been greatly improved since the 1980 tests at the H-Coal Pilot Plant. The best design approaches have been identified with successful testing of Kieley and Mueller (K/M) sweep angle flow, flow-to-close valves, and the Cameron Iron Works modified oil field flow-to-close choke valves. The Masoneilan flow-to-open Sasol-type valves are also promising. Valve life successes at the Exxon, Baytown, Texas

Pilot Plant have been most encouraging with use of a modified K/M valve, which may be purchased from the manufacturer with modifications. Material wear has been greatly reduced with low-cobalt binder tungsten carbides. Now it appears that an average trim life of 2 to 3 months can be expected, instead of 2 to 3 hours with the original designs.

SRC-I liquefaction high-pressure slurry block valves have also greatly improved. The Mogas Company has demonstrated very good valve performance at the H-Coal Pilot Plant using a relatively simple design. Cameron Iron Works, Inc. is developing a valve similar to the Mogas valve (i.e., the basic Cameron C-1 design), which has a trunion-mounted ball. Valve flushing is an important requirement for all slurry block valves.

Acceptable block valve life is now possible, but quality control of valve components will have to be stringent for their use on a demonstration or commercial scale, since these valves have never been manufactured in the required size and pressure rating.

For the design, a single-stage pressure control valve is used for the letdown of high-pressure slurry to the lower processing pressure. The downstream block valves were eliminated. The letdown valves discharge radially directly into the ensuing piece of process equipment.

4. Conclusions

Although improvements in block and control valves have been made from the standpoint of materials of construction, trim life, and overall performance, the anticipated limited service life for the general area of Valves in Severe Service requires that they remain on the Critical Technology List.

5. Future Work

Valve testing programs should be monitored so as to incorporate the latest findings in the design of the block and control valves for the demonstration plant.

LUMMUS AREA: HYDROCRACKER SECTION

Feed Oil Charge Pumps

Equipment: P-13202 A, B

Priority/Criteria: Old - I/B1, 4, 5

New - Removed from List

Reactor Recirculation Pumps

Equipment: P-13201 A, B

Priority/Criteria: Old - I/B4, 5

New - Removed from List

1. Justification for Classification

Centrifugal pumps handling SRC-I/oil blends at high temperatures and pressures present unique engineering problems. Therefore, these pumps were classified as Critical Technology.

2. Actions Taken

The course of action taken was in conjunction with that taken for the Miscellaneous Area 12000 Centrifugal Pumps. Input from vendors familiar with the state-of-the-art was openly solicited to ensure that as many of the design requirements associated with the severe conditions were evaluated. They were also requested to provide data on pump designs and to indicate plants at which any of their pumps are currently operational.

Plant visits were made to the Wilsonville Pilot Plant, Exxon Pilot Plant in Baytown, Texas, and the H-Coal Facility in Catlettsburg, Kentucky to observe and review solvent pumping operations and determine any problems being experienced.

3. Results of Actions Taken

The pump vendors provided specific design recommendations such as wear rate factors, impeller tip speed (ft/sec), pump speed (rpm), and materials of construction for impellers and liners. They also furnished test results for mechanical seals and elastomers. Data suggest that the fluid (36% SRC blended with oil) will probably be Newtonian at the shear rates of the Feed Oil Charge Pumps (P-13202 A, B).

Originally, some concern resulted from reported unsatisfactory experience with the Reactor Recirculation Pumps (P-13201 A, B) on similar units installed at the H-Coal Pilot Plant. The key problem was associated with material wear and resultant vibration of impeller vanes and vane bolts. Since then, it has been determined that the design of this Byron-Jackson pump is sound, and that the wear problems were exaggerated. ICRC has no reason to expect unusual problems (i.e., different from those of similar installed units) with the reactor recycle pumps on the SRC-I Plant hydrocracker.

4. Conclusions

As a result of the vendor investigations and the pilot plant operating experience, as well as the availability of commercial high-temperature pumps in solvent service, it is believed that the Feed Oil Charge Pumps and the Reactor Recirculation Pumps should be removed from the Critical Technology List.

LC-Fining Reactors

Equipment: R-13201 A, B

<u>Priority/Criteria:</u>	Old - I/A1; B3	II/B4
	New - I/A1; B3	II/B4

1. Justification for Classification

The LC-Fining Reactors were classified as Critical Technology because of the limited availability of fabricators having the capability and/or the experience to fabricate such large-diameter, thick-walled vessels; the availability of materials capable of withstanding the design requirements; the local occurrences of temperature extremes during operating and transient conditions; and the resulting thermal stresses (fatigue and creep) on the vessel wall. In addition, other critical areas of concern were reaction yields and catalyst consumption, coking, flow distribution, and reactor temperature measurement and control.

2. Actions Taken

Fabricators knowledgeable in the design and fabrication of large heavy-walled vessels were surveyed to determine their capabilities and experience.

3. Results of Actions Taken

Specifications were prepared for the design and fabrication of these vessels based on the vendor survey. These documents established the operating conditions, emergency operating conditions, service life expectancy, materials of construction, corrosion allowance requirements, fabrication requirements, testing, and controls.

4. Conclusions

Although many of the questions regarding the design and fabrication of the LC-Fining Reactors have been addressed, sufficient concern remains about the fabrication of such heavy-walled vessels, the extreme variations in temperature realized during operating and transient conditions, the resultant stresses, and the rate of hydrogen consumption. Therefore, the LC-Fining Reactors should remain on the Critical Technology List, although downgraded to a lower risk category.

5. Future Work

To alleviate the technical concerns, more information should be gathered regarding creep and fatigue data for the 2- $\frac{1}{4}$ Cr - 1 Mo steel selected as the material of construction.

Coking, flow distribution, and reactor temperature measurement are still matters of concern. No better alternative to the present Lummus grid plate design has been offered, and probably will not be forthcoming. Existing options for reactor wall temperature and level measurements and subsequent control should also receive serious consideration. Finally, an information base sufficient to determine reliable reaction yields and catalyst consumption should be developed.

Feed Oil Heater

Equipment: H-13201

Priority/Criteria: Old - II/A1

New - Removed from List

1. Justification for Classification

Concern over the uncertain heat transfer rate on the SRC-I/oil blend side caused the Feed Oil Heater to be classified as Critical Technology.

2. Actions Taken

Physical properties of the tube-side material were determined for use in the design.

3. Results of Actions Taken

A conservative design approach was used for this heater. The maximum bulk fluid temperature was specified at 650°F. While the possibility of fouling exists, the problem is considered manageable.

4. Conclusions

Because of the conservative design approach and similarity to existing fired heaters in the petroleum refining industry, the Feed Oil Heater should be removed from the Critical Technology List.

Vacuum Tower Oil Heater

Equipment: H-13261

Priority/Criteria: Old - II/A1

New - Removed from List

1. Justification for Classification

Concern over the uncertain heat transfer rate on the feed oil side caused the Vacuum Tower Heater to be classified as Critical Technology.

2. Actions Taken

Physical properties of the tube-side material were determined for use in the design.

3. Results of Actions Taken

A conservative design approach was used for this heater. Both the bulk fluid and the inside film temperature were limited to alleviate the coking problem. Good operation of this unit to maintain the oil wall temperatures at safe levels is mandatory since the bulk fluid outlet temperature is lower than the inlet temperature.

4. Conclusions

Because of the conservative design approach and the similarity to existing fired heaters in the petroleum refining industry, the Vacuum Tower Heater should be removed from the Critical Technology List.

LUMMUS AREA: COKER SECTION

Coking Heater

Equipment: H-13101

Priority/Criteria: Old - I/A1

New - Removed from List

1. Justification for Classification

Concern over the coking and fouling potential of the heat transfer surfaces caused the Coking Heater to be classified as Critical Technology.

2. Actions taken

Physical properties of the tube-side material were determined for use in the design.

3. Results of Actions Taken

A conservative design approach based on similar units in petroleum coking installations was adopted. The problem of coking exists, but with the proper controls and good maintenance procedures for decoking, this operation becomes similar to that of coking heaters in the petroleum refining industry.

4. Conclusions

Because of the conservative design approach and similarity to existing units in industry, the Coking Heater should be removed from the Critical Technology List.

PARSONS AREA

Process Water Treatment System

Equipment: General process equipment used for water treatment

Priority/Criteria: Old - II/A1; B4

New - Removed from List

1. Justification for Classification

Concern over the effects of process water quality on the process water treatment equipment's material life caused the Process Water Treatment System to be classified as Critical Technology.

2. Actions Taken

The advice of equipment vendors with respect to corrosion allowances, equipment lining techniques, and proper operating procedures can be sought to answer any design problems.

3. Results of Actions Taken

Conventional water treatment equipment design plus conservative corrosion allowances and/or acceptable linings should eliminate any questions concerning equipment material life.

4. Conclusions

This unit is very conventional in design and in operation. Therefore, the Process Water Treatment System should be removed from the Critical Technology List.

Gasifier Refractory Lining

Equipment: - R-15051 A-C Gasifiers

Priority/Criteria: Old - II/A1; B4

New - Removed from List

1. Justification for Classification

Concern over the performance and life of refractory lining materials caused this item to be classified as Critical Technology.

2. Actions Taken

Refractory performance in similar installations was reviewed.

3. Results of Actions Taken

Commercial experience with similar gasifiers and comparable equipment in the petroleum/petrochemical and chemical industries indicates that refractory materials are available to provide good performance in this service. Vendor's advice as to material selection, installation, curing, and operation should be sought and followed to achieve optimum results.

4. Conclusions

Commercial use of refractory materials in this service in many installations is well-documented. Therefore, it is believed that the Gasifier Refractory Lining should be removed from the Critical Technology List.

Coal/KMAC Mix System

Equipment: All mixers

Priority/Criteria: Old - I/A1 II/A2; B2

New - Removed from List

1. Justification for Classification

Concern for an untested humidification technique that might produce lumpy feed material caused the Coal/KMAC Mix System to be classified as Critical Technology.

2. Actions Taken

GKT determined that humidification of the coal/KMAC mixtures was required to assure proper performance of the downstream screw feeders.

3. Results of Actions Taken

GKT has designed an conventional humidification system with sufficient controls to assure that only the design rate of humidification occurs. All equipment has been insulated and/or steam-traced to maintain elevated temperatures to prevent water condensation.

4. Conclusions

The recent Jenike and Johanson report confirmed that KMAC can be handled provided certain criteria with respect to equipment design are followed. The conservative design (two parallel trains) that GKT has used for this unit should allow continual mixing of the coal and KMAC in specified quantities and at the proper moisture content. Therefore, it is believed that the Coal/KMAC Mix System should be removed from the Critical Technology List.

Gasifier Feed System

Equipment: All feed system equipment

Priority/Criteria: Old - I/A1, 2

New - Removed from List

1. Justification for Classification

Concern over acceptable feed system performance when using coal/KMAC feed with regard to stickiness of material, oversize feed, and the need to remove critical solvent caused the Gasifier Feed System to be classified as Critical Technology.

2. Actions Taken

GKT undertook the task of evaluating the effect of a coal/KMAC mixture on the performance of the screw feeders. It also evaluated the use of a pneumatic feed system.

3. Results of Actions Taken

GKT has determined that humidification of coal/KMAC mixtures would assure proper performance of the screw feeders and has incorporated this system into the design. Adequate controls were used to limit the amount

of water added and to assure complete mixing of the water and KMAC and then coal to achieve a homogeneous mixture suitable for use in the gasifier feed system.

GKT is currently offering a pneumatic feed system for selected feedstocks as a replacement for the screw feed system. This option would eliminate all concerns regarding the mechanical handling of the coal/KMAC feed to the gasifiers.

The residual critical solvent in the KMAC as received by the gasifier mix and feed systems will be stripped from the solids by the carrier nitrogen gas during transfer operation. It will be recovered during the nitrogen cleanup before recycle of the carrier gas.

4. Conclusions

As a result of the GKT work done for the design, the paralleling of equipment in the feed system, and the possibility of using an all-pneumatic feed system to eliminate mechanical feeding, it is felt that the Gasifier Feed System should be removed from the Critical Technology List.

5. Future Work

Follow-up on the use of a pneumatic feed system for coal/KMAC mixtures is recommended. A demonstration run should be conducted before this option is incorporated into the design.

RUST AREA

Flare Stack

Equipment: X-16810

Priority/Criteria: Old - I/A1, 2; B2, 4 II/A4

New - Removed from List

1. Justification for Classification

Initially, the gas loads, compositions, and temperatures associated with this equipment were unknown. In addition, the quantities and compositions of liquids to be sent through headers to the stack were not

determined. Hence, stack and header system sizing was not possible. For these reasons, the Flare Stack was classified as Critical Technology.

2. Actions Taken

Accurate assessments were made for the temperature flows and compositions of all streams entering the flare system.

3. Results of Actions Taken

Reasonable and conservative flow quantities were established. Quenches were added to reduce the liquid quantities sent into the flare stack system. Headers and auxiliary equipment were sized based on the design loads.

4. Conclusions

A conservative design was adopted for the flare system following standard industrial practices. The Flare Stack should be removed from the Critical Technology List.

Wastewater Treatment System

Priority/Criteria: Old - I/A1; B2

New = Removed from List

1. Justification for Classification

Information derived from the Wastewater Characterization and Treatability Study (ICRC, 1983) conducted at Air Products R&D indicates that there are sufficient differences between the wastewaters generated by the various coal liquefaction processes (e.g., H-Coal, EDS) to warrant specific wastewater treatment system evaluations. Therefore, the Wastewater Treatment System was classified as Critical Technology.

2. Actions Taken

Screening tests indicated that the SRC-I process water has a high phenolics and tar acid content. Laboratory tests were initiated to dephenolize the wastewater by solvent extraction techniques. Catalytic,

Inc. began an evaluation of the effect of dephenolized wastewater on the downstream treatment system.

3. Results of Actions Taken

The phenol removal system was designed based on the laboratory work, and, in turn, a new wastewater treatment system was designed based on a dephenolized feed. Significant savings in equipment sizing and operating costs were achieved.

4. Conclusions

As a result of the laboratory work, the phenol recovery unit design, and the new wastewater treatment system design, it is felt that the Wastewater Treatment System should be removed from the Critical Technology List.

Wastewater Reuse System

Priority/Criteria: Old - I/A1, 2; B1, 2, 4, 5

New - I/A1, 2; B1, 2, 4, 5

1. Justification for Classification

Preliminary testing of the wastewater reuse system during the Wastewater Characterization and Treatability Study (ICRC, 1983) showed that additional work is required to consistently remove the suspended solids to a point at which the wastewater is an acceptable feed to the reverse osmosis (RO) unit. Oak Ridge National Laboratory encountered RO membrane fouling after short operating times using H-Coal Pilot Plant wastewater. For this reason, the Wastewater Reuse System was classified as Critical Technology.

2. Actions Taken

Laboratory tests were initiated to overcome the RO membrane fouling problem.

3. Results of Actions Taken

RO membrane fouling continues to be a problem. Screening work conducted by ICRC on chemical stabilization of evaporator soluble salt

cake indicates that vacuum filtering or drying the sluiced fly ash for moisture control may be needed if it is to be used for stabilization. Dewatering or drying fly ash was not addressed in the Baseline design.

4. Conclusions

This area remains under investigation. For this reason, the Wastewater Reuse System should remain on the Critical Technology List.

Solid Waste Disposal

Priority/Criteria: Old - I/A1, 2; B1, 2, 4

New - I/A1; B1, 2, 4

1. Justification for Classification

Stabilization feasibility tests run on a 50/50 sodium chloride/sodium sulfate mixture indicated that chemical stabilization could produce a monolithic mass in which soluble salt leaching due to rainfall could be mitigated to an acceptable level. Leaching was controlled by increasing the proportion of fly ash and binders in the monolith. However, increased binder content significantly increases the solid waste volume.

Sodium sulfate poses a problem in that it undergoes a crystal change from the anhydrous to the decahydrate form. If it is introduced into the monolith as anhydrite, the crystal change occurring upon its contact with moisture will rupture the monolith. Ways of limiting the amount of sodium sulfate entering the wastewater treatment system must be found.

2. Actions Taken

Review of the entire solid waste disposal system was undertaken and culminated in the redesign of the Wastewater Treatment System by Catalytic, Inc.

3. Results of Actions Taken

Catalytic's revised design of the Wastewater Treatment System will be used to redesign the Solid Waste Disposal System.

4. Conclusions

Although a conservative design has been developed for this area, concern for the fate of the sodium compounds and their effect on the system causes the Solid Waste Disposal System to remain on the Critical Technology List.

Coal Grinding and Classification System

Equipment: Coal Pulverizers

Priority/Criteria: Old - II/B3, 4, 5

New - Removed from List

1. Justification for Classification

Originally, pulverizers of 124 tph capacity were selected for use. These large units were expected to experience frequent problems. Therefore, this system was classified as Critical Technology.

2. Actions Taken

Investigations were made to determine the availability of smaller commercial units that exhibit good performance.

3. Results of Actions Taken

The number and capacity of the pulverizers were changed to four 85-tph units. Standard auxiliary equipment for the pulverizers was also specified.

4. Conclusions

Available data indicate that equipment of this size poses no significant risk. Therefore, the Coal Grinding and Classification System should be removed from the Critical Technology List.

LITERATURE CITED

Catalytic, Inc. 1982. SRC-I high-pressure slurry letdown system study. Pages 73-225 in SRC-I quarterly technical report, July-September. DOE/OR/03054-9. International Coal Refining Co., Allentown, PA.

Fuller Company. 1982a. Conveying Kerr-McGee ash concentrate in Fuller-Kinyon pumps. ICRC subcontract no. 01-13072.

_____. 1982b. Conveying of Kerr-McGee ash concentrate in a blow tank. ICRC subcontract no. 01-13082.

ICRC. 1983. Final technical report: wastewater characterization and treatability studies. DOE/OR/03054-10. International Coal Refining Co., Allentown, PA.

Appendix I

Sources of Information

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- Prime contract and statement of work
 - SRC-I Project Baseline technical volumes
 - ICRC Central Files for all correspondence, particularly Section 7.33
 - Equipment vendor meetings and telephone conversations
 - Reports on vendor equipment tests
 - Published literature on coal liquefaction and gasification equipment and processes
 - Trips to the Wilsonville Advanced Coal Liquefaction Facility and to the H-Coal, EDS, and Ft. Lewis pilot plants
 - Telephone conversations and meetings with pilot plant technical personnel
 - Pilot plant operations reports
 - ORNL reports, and discussions with ORNL personnel
 - DOE critical components meetings and reports
 - Conference proceedings on critical technology equipment issues (valves, pumps, heat exchangers, fired heaters, materials, pressure vessels)
 - Reports from ICRC consultants
 - Area Contractor files and reports on critical technology equipment items (i.e., from Catalytic, Inc., C. E. Lummus Co., The Rust Engineering Co., The Ralph M. Parsons Co., Air Products and Chemicals, Inc. and Gesellschaft für Kohle-Technologie mbH of Essen, Germany)
 - Meetings of the Technology Advisory Board of Air Products and Chemicals, Inc. on critical technology issues
 - Independent testing laboratories' statements of work and reports
 - ICRC Mechanical Technology Group technical evaluations and assessments
 - ICRC notes on meetings between Mechanical Technology, Process Engineering, Project Engineering, and Manufacturing Engineering groups, the ICRC Configuration Control Board, and research and technology development groups
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