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POWER SYSTEMS DEVELOPMENT FACILITY

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QUARTERLY TECHNICAL PROGRESS REPORT JULY 1 - SEPTEMBER 30, 1993

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POWER SYSTEMS DEVELOPMENT FACILITY
QUARTERLY TECHNICAL PROGRESS REPORT
JULY 1 - SEPTEMBER 30, 1993

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1.0 INTRODUCTION AND SUMMARY

This quarterly technical progress report summarizes work completed during the Second Quarter of the Second Budget Period, July 1 through September 30, 1993, under the Department of Energy (DOE) Cooperative Agreement No. DE-FC21-90MC25140 entitled "Hot Gas Cleanup Test Facility for Gasification and Pressurized Combustion." The objective of this project is to evaluate hot gas particle control technologies using coal-derived gas streams. This will entail the design, construction, installation, and use of a flexible test facility which can operate under realistic gasification and combustion conditions. The major particulate control device issues to be addressed include the integration of the particulate control devices into coal utilization systems, on-line cleaning techniques, chemical and thermal degradation of components, fatigue or structural failures, blinding, collection efficiency as a function of particle size, and scale-up of particulate control systems to commercial size.

The conceptual design of the facility was extended to include a within scope, phased expansion of the existing Hot Gas Cleanup Test Facility Cooperative Agreement to also address systems integration issues of hot particulate removal in advanced coal-based power generation systems. This expansion included the consideration of the following modules at the test facility in addition to the existing Transport Reactor gas source and Hot Gas Cleanup Units:

1. Carbonizer/Pressurized Circulating Fluidized Bed Gas Source.
2. Hot Gas Cleanup Units to mate to all gas streams.
3. Combustion Gas Turbine.
4. Fuel Cell and associated gas treatment.

This expansion to the Hot Gas Cleanup Test Facility is herein referred to as the Power Systems Development Facility (PSDF).

The major emphasis during this reporting period was continuing the detailed design of the facility, integrating the Carbonizer/Transport and the circulating pressurized fluidized-bed combustor (CPFBC) particulate control devices (PCDs) into structural and process designs, reviewing draft air permit and obtaining the construction stormwater management permit for the facility. Installation of the transport reactor development unit (TRDU) was completed and progress was made in shakedown and preliminary operation

of the unit. Continuation application for Budget Period 3 is being prepared for submittal to DOE early in the next quarter.

The detailed design of the PSDF continued with refinements to P&IDs, preparation of specification bid packages and a move towards freezing the design. Structural, process, electrical, instrumentation and controls, and mechanical information were exchanged between the engineering design team. SRI continued the design of the particulate sampling systems for the PSDF, working with the engineering design team and initiating contacts with sampling train fabricators. Meetings with the selected PCD suppliers and FW, MWK and SCS were held to better define, coordinate and streamline interface points and incorporate the PCD design into the transport and APFBC system designs. The PSDF project was approved under NEPA, and site grading and preparation work commenced on September 21. The protracted contract negotiations between SCS and FW was completed and detailed design of APFBC system is in progress. The development of an Interactive video training/archiving system which incorporates all the PSDF modules was initiated during the quarter. The next major milestone will be reached in the coming quarter with the completion of 50% detailed engineering design and subsequent issue and review of design documents.

It should be noted that this report includes accounts of progress made by Foster Wheeler (FW), M. W. Kellogg (MWK), Combustion Power Company (CPC), Industrial Filter & Pump (IF&P), Westinghouse, Southern Research Institute (SRI), Nolan MultiMedia and University of North Dakota Energy & Environmental Research Center (UNDEERC).

2.0 REVIEW OF TECHNICAL PROGRESS

2.1 PROJECT MANAGEMENT

The negotiations between SCS and Foster Wheeler to amend Foster Wheeler's subcontract for the remainder of the PSDF project was completed and signed by all parties during this time period. The amendments for all the subcontractors for Budget Period 2 were also completed during this time period. A letter agreement was established with Nolan MultiMedia to begin the development of the Interactive Video Training/Archiving system.

Contract negotiations with the PCD vendors continued during this time period. The Industrial Filter & Pump subcontract was completed. However, negotiations continued with Combustion Power Company and Westinghouse. Letter agreements were established with both CPC and Westinghouse to start the engineering work and integration into the PSDF detailed design effort.

A solicitation of interest for providing a gasifier for the PSDF in the event that the transport reactor is not ready for scaleup was released by SCS to a number of commercial and near commercial gasification vendors. Responses were received by interested vendors in late August. SCS prepared a summary of the solicitations of interest for review by DOE and EPRI.

2.2 PHASE 1 - CONCEPTUAL DESIGN ACTIVITIES

2.2.1 Task 1.4 Transport Reactor Development Unit

During this quarter shakedown activities continued at the EERC for the Transport Reactor Development Unit (TRDU). During the shakedown phase several problems were encountered with the air compressor and burner. A data acquisition module was providing the incorrect fuel ratio, resulting in the burner operating at a very rich air/fuel ratio and kept flaming out at pressures above 60 psig. The burner was taken apart and it was discovered that the spark plug was about 1/4 inch above the correct position. The spark plug position was adjusted which corrected the burner problems. The problems with the main air compressor occurred in an oil heat exchanger system which began to

develop leaks. The compressor had to be taken off-line, and an auxiliary compressor had to be used temporarily while the main compressor was repaired and put back in service.

Once these peripheral equipment problems were solved the shakedown of the TRDU proper was started. Initially, circulating fluidized bed (CFB) ash and petroleum coke was used as the starting material. Through attrition and bed drains some CFB bed startup material was lost and not enough ash/coke was available for further startups. The startup bed material was changed to sand due to availability and cost considerations. With sand a cold flow circulation test was successfully conducted at 30 psig and the circulation was maintained for 9 hours at room temperature. Then the reactor was heated up with the burner and pressurized to 110 psig and 800 °F. However, in the bottom of the reactor, near the entry point of the burner air there were some localized hot-spots where the burner outlet temperature was too hot and it melted some of the J-leg refractory material in one of the J-leg spool pieces. The reactor had to be cooled down, depressurized, and that spool piece (Section B) had to be removed and the refractory replaced. Since then the burner operating procedure has been revised such that the burner flame is appropriately quenched with nitrogen prior to entry into the reactor. This ensures that the flame will not be too hot for the refractory, however, it takes a longer time to bring the reactor up to temperature. After the reactor was brought back up in temperature and pressure, sand was circulated for 70 hours (with no coal feed, and no sand withdrawal).

2.3 PHASE 2 - DETAILED DESIGN ACTIVITIES

2.3.1 Task 2.1 Detailed Design

2.3.1.1 MWK: PSDF Transport Train

P&ID development continued during the third quarter of 1993 at the Technical Review Meeting held in Houston in early September; however, material and energy balance measurements were not considered at this meeting. As vendor engineering P&IDs become available, a more complete P&ID picture will emerge for review. Currently, control valve and flow element data sheets are complete and PLC specifications are in preparation. Steam balances and predicted start up temperature profiles of the reactor were issued.

At the Technical Coordination meeting with SCS, the internal/external Primary Gas Cooler bypass issue was resolved by selecting external bypass using orifices due to

higher cost and technical uncertainties with alternatives. Responsibility for the refractory lined pipe was agreed to belong to Kellogg. Also, a plastic model of the transport reactor system will not be built due to development of interactive video training/archiving system which will incorporate 3-D models and CAD drawings.

During the Initial Constructibility meeting with SCS, it was agreed that the time was right for each of the major participants (SCS/MWK/FW) to begin to develop constructibility plans, path of construction scenarios and material field need dates.

The PCD vendor meeting with Combustion Power Company was held during the period and drawings submitted by CPC subsequently have been reviewed. Sufficient information is available for the Granular Bed Filter to begin to incorporate it into the structure and refractory piping system.

During the third quarter, more than half of the equipment item have been committed for vendor engineering only. Inquiry, technical evaluation and commitment to vendor engineering for the quarter is summarized below:

RX0201	Transport Reactor	Inquiry issued
DR0404	Flare Seal Drum	Inquiry issued
DR0501	HTF Surge Drum	Inquiry issued
BR0402	Flare Tip	Inquiry issued
HX0203	Combustion Heat Exchanger	Evaluation Complete
HX0204	Transport Air Cooler	Evaluation Complete
SU0601	Sulfator	Evaluation Complete
ME0540	Heat transfer Fluid System	Evaluation Complete
BR0201	Startup Burner	Vendor Engineering Committed
HX0202	Primary Gas Cooler	Vendor Engineering Committed
HX0402	Secondary Gas Cooler	Vendor Engineering Committed
HX0601	Sulfator Heat Recovery Exch.	Vendor Engineering Committed
CY0201	Reactor Primary Cyclone	Vendor Engineering Committed
CY0207	Disengager	Vendor Engineering Committed
CO0601	Sulfator Air Compressor	Vendor Engineering Committed
CY0601	Sulfator Cyclone	Vendor Engineering Committed

SI0602	Spent Solids Silo	Vendor Engineering Committed
	Spent, fines and sulfator Screw Coolers	Vendor Engineering Committed
	Coal, limestone, and ash Transport System	Vendor Engineering Committed

MWK revised and updated the Startup and Operating philosophy for the transport train. Based on this document, a draft outline for the operations manual was prepared. Both these documents are attached as Appendix A. Work on operations manual will begin after Issue 2 of P&ID's are completed.

2.3.1.2 FW Team Activities

The Phase II detailed engineering/procurement phase is proceeding (without release of any material for purchase). The following events were achieved:

- Meetings were held between FW and SCS to review design change notices and discuss the budget and schedule implications of each. The feasibility of proposed process changes in the topping combustor and gas turbine were discussed along with startup and control strategies. A proposal to delete the booster compressor from the system was discussed. However, it was pointed out that without a booster compressor, the pressure differential between the air compressor outlet and the gas turbine inlet increases, resulting in higher stresses on the thrust bearing located between the turbine and compressor. These higher stresses may exceed the design rating of the bearing, resulting in increased risk of failure and PSDF shutdown while the bearing was overhauled.
- Foster Wheeler reviewed the possibility of containment shell corrosion in refractory lined vessels and piping due to acid dew point, and concluded that the refractory design for the APFBC unit is an acceptable deterrent to gaseous corrosion.
- FW initiated contract negotiations with Westinghouse and Allison by issuing copies of SCS/FW contracts for their review. FW held discussions with Westinghouse on Topping Combustor & overall plant control. FW issued a revised Topping Combustor requisition to Westinghouse incorporating their requirements. The requisition was marked up to reflect the proposed process

changes. FW also issued a marked up Gas Turbine Generator requisition to reflect the proposed process changes. Engineering coordination questions were issued to Allison and Westinghouse.

- FW defined SCS connection locations in the process structure for supply of coal and limestone, and issued revised load data for combustor cyclone & J-valve.
- FW replied to Industrial Filter & Pump Company's technical coordination questions on the Carbonizer PCD. Issued PCD nozzle connection details.
- FW reviewed with vendors the feasibility of igniting the start-up heaters under pressure.
- FW proposed hot char flow from the Carbonizer overflow nozzle to the Combustor, deleting the char screw cooler and the delumper. Also, modification of the Carbonizer bottoms flow for "occasional" rejection of oversized char was proposed. These changes are expected to improve the reliability of the plant.
- Meetings between FW and SCS were held in Birmingham on September 30, 1993 to review the proposed plant construction with particular reference to the sequence of erection of equipment and steel. Procurement and delivery details were reviewed. A number of engineering details were also discussed, including the status of project variance notices. The Wilsonville site was visited to review the progress of site preparation work.

Foster Wheeler's subcontract development for the Turbine/Generator and Topping Combustor is proceeding after the amendment to the contract between FWUSA and SCS were signed off in September 1993. Presently, this delay in FW/SCS contract agreement impacts the fabrication/delivery cycle to the point that a July 1994 equipment delivery date cannot be achieved on these items. Projected delivery date for the Topping Combustor is April 1995, if purchase order is issued to Westinghouse by November 1993.

2.3.1.3 Balance-of-Plant Activities

A milestone was reached during the quarter as a site preparation contractor was selected and site preparation began on September 21. The design team is preparing for the next

phase of construction as an inquiry package was issued and bids were received for the warehouse building. This building will be constructed soon after site preparation is completed, since it will be used as a warehouse during construction. The building will serve as a warehouse, maintenance shop, laboratory and locker room during the operation phase. The designs of the process structure and the inquiry package for the process structure are each nearing completion (90 to 95% complete) in preparation for construction soon after completion of the site preparation.

The conceptual designs for the coal and limestone storage and preparation system has been finalized. A covered concrete pad will be utilized for coal and limestone storage at the site. The existing agglomeration process area will be used in addition to a new storage area. A one week supply of coal and limestone will be available at the site with a much larger supply available from a Southern Company Power Plant or another transloading facility. This approach reduces the cost of the storage area and should lower the shipping cost of the coal to the PSDF site, since the coal can be shipped either by barge or railroad to the intermediate facility and then shipped only a short distance by truck to the PSDF.

The coal and limestone mill system specification originally required two mills of the same size with one alternating between processing coal for the MWK and FW trains and the other mill processing limestone and serving as a backup coal mill for one of the trains. The inquiry was revised to require one coal mill for each train and one limestone mill to serve both trains. The three mill approach was selected. Although there is less redundancy in the mills, reliability should not be a problem, since there is a 36 hour storage bin downstream of the mills and most mill repairs can be completed in less than 24 hours.

Other activities during the quarter included:

- arranged for Plant Gaston to supply demineralized water for the PSDF
- visited UTSI to examine a disassembled Westinghouse topping Combustor
- initiated preliminary P&IDs which will be completed when FW and MWK designs are completed
- assessed the capabilities of distributed control systems from several vendors

2.3.1.4 Process Hazard Review

SCS began the process of defining the requirements of a Process Hazard Analysis. Several safety consultants were contacted to obtain input concerning scope, procedures and documentation requirements. A draft bid package for a process hazard analysis consultant was prepared and is being reviewed internally.

2.3.2 Task 2.2 Facility Design Document

The design document was not updated during this quarter. The 50% design review meeting has been delayed due to prolonged contract negotiations with FW. The date for the 50% design review will be announced in early November. The 50% design mark will feature the freezing of PFDs and near completion of P&IDs for FW and MWK.

2.3.3 Task 2.3 Environmental Permitting and NEPA Support

On July 13, a meeting was held with the Alabama Department of Environmental Management (ADEM) to discuss the Air Permit Application for the Power Systems Development Facility (PSDF). The ADEM officials requested additional information on emission rates and information on expected emissions for Volatile Organic Compounds (VOC's). The information was submitted to ADEM on July 26. The first draft of the Air Permit was received from ADEM on September 2. The draft was reviewed by PSDF staff members, representatives from Southern Company Services Environmental Assessment Department and a representative from Alabama Power Company. A few minor revisions were recommended which led to the issuance of a second draft by ADEM. At the end of the quarter, final arrangements for approving the Air Permit were being made.

The PSDF Storm water construction permit for the site preparation and construction was approved by ADEM and received in August. Prospective bidders for the site preparation contract were made aware of the Storm water construction permit in a pre-bid meeting held in Wilsonville. On September 14, information was received from the Department of Energy that the PSDF project was approved under NEPA. Although the final draft of the air permit had not been received from ADEM, we did discuss with ADEM and received approval to commence site preparation which began on September 21, 1993.

The Air Permit for the PSDF will be finalized in the next quarter. The Storm water construction permit will require periodic inspections. Work will continue on the PSDF ash disposal options. We are expecting to receive representative samples from the TRDU operation at the Energy and Environmental Research Center at Grand Forks and from the Fluidized Bed Combustor operation at the Livingston Pilot plant. Once samples are obtained, they can be characterized for individual properties and for leachate characteristics. This information will be beneficial in determining disposal options.

Information confirming VOC emission rates established by the ADEM in the Air Permit were received by Foster Wheeler USA Corporation and M.W. Kellogg in September. We asked that the FW and MWK confirm these rates since we had estimated them from EPA technical references.

2.3.4 Task 2.4 Particle Characterization and Collection

SRI's work this quarter focused on the detailed design of the particulate sampling system, the revision of SRI's piping and instrumentation diagrams (P&IDs), the preparation of operating procedures for the hazardous operations (hazops) review, the preparation of parts lists for the real-time monitors and for the sampling system instrumentation, and preliminary work on the experimental test plan. SRI started on the final design and detailing of the insertion mechanism of the sampling probe. SRI submitted preliminary drawings of the packing gland assembly and the back portion of the probe casing to their machine shop for cost estimates. SRI revised their P&IDs to incorporate the probe insertion and rotation mechanisms and the programmable logic controller (PLC). SRI continued to work on the parts lists for the real-time particulate monitors and for the instruments associated with the batch particulate sampling system.

SRI has identified a method of correcting the problem with the missing gusset on the plastic model of the cyclone manifold, and a purchase order has been issued to SiCAM Corporation of Somerville, New Jersey to correct this problem. SiCAM will produce a corrected stereolithography (STL) file and a new plastic model of the cyclone manifold with all gussets in place. Comparative quotes will be obtained to cast the manifold out of 310 stainless steel. After casting, SRI will machine the cyclones and lap the tapered sealing surfaces on the cyclones and in the manifold receptacles. The cyclones will be sealed in their receptacles using a ceramic epoxy sealant, and the effectiveness of the sealing will be evaluated by testing the cyclone assembly in the SRI pilot Combustor.

Further details of work performed on batch particulate sampling probes and real time monitors are given in Appendix B.

2.3.5 Task 2.5 Particle Control Technologies

During the quarter a contract was executed with IF&P. Combustion Power Company continued working under a letter agreement. Agreement in principle was reached with Westinghouse and a letter agreement was put in place. A full contract will be executed with Westinghouse and Combustion Power Company within the next quarter. All three PCD vendors are now proceeding with the design of their systems.

An engineering coordination meeting was held between MWK, SCS and CPC in early July at MWK office in Houston, Texas. Since the meeting CPC has issued a number of drawings: general arrangement, PFDs, P&IDs, loading diagrams, filter vessel, de-entrainment vessel and wiring diagrams. New drawings incorporating comments from SCS and MWK will be issued in October. CPC has also issued preliminary quotes for most major vendor items including the regenerative heat exchanger, baghouse, boost blower, pressure vessels and stainless steel vessel internals. Quoted costs have generally been within budgeted amounts. CPC will issue formal inquiries once a contract is in place with SCS early next quarter.

Westinghouse provided design interface information on an as requested basis while contract negotiations continued into September. When agreement in principle was reached in September, a letter agreement was issued to allow Westinghouse to begin design. Interface requirements will now be examined in detail.

IF&P completed preliminary layout drawings, including general specifications such as dimensions, weight, etc., and also completed preliminary P&IDs. Changes from the design included in the proposal are summarized below:

- relocation of the PCD inlet flange from the side of the vessel to the top head to minimize interior pipe strength concerns
- location of jet pulse tank to the top of the PCD vessel to minimize jet pulse losses
- increase in vessel diameter to accommodate the above changes.

2.3.6 Task 2.8 Experimental Test Plan

A meeting to initiate the development an experiment test plan was held between SCS, DOE, EPRI and SRI on August 5 and 6. Based on presentations and discussions at the meeting, the following suggestions emerged: At the end of construction, the various components and units will be subjected to three months of shakedown. This will be followed by three months of characterization tests during which the various PCDs and processes will be subjected to range of process conditions to define and determine problems and operability ranges. The PCDs will be operated in the respective trains (designated earlier in April 1993) for about a year after the characterization tests. The CPC and the Westinghouse filters in the transport train will be operated on a regular basis by periodically interchanging flows between the two filters. During the first year of operation, the Westinghouse filter in the transport train will primarily be tested with one set of internals which will be selected based on tests at Westinghouse. At the end of first year of operation, depending upon operational reliability and performance of the PCDs and the needs of Clean Coal and other projects, a decision will be made on interchanging PCDs and proceeding with further tests.

Project participants are being requested to provide commissioning (shakedown and characterization) plans, overall test plan, test rationale, test matrix and evaluation plans for their portion of equipment and process. This will be incorporated in the facility design documents and reviewed at the 50% design status meeting.

2.4 PHASE 3 - CONSTRUCTION, PROCUREMENT AND INSTALLATION

2.4.1 Task 3.2 Site Preparation

An inquiry package for the site preparation was released and a pre-bid meeting with prospective bidders was held. Bid packages were received and evaluated and the contract for the site preparation work was awarded to Ellard Construction of Birmingham. An estimate is being prepared to lower the site finished grade by an additional four feet in order to reduce the difference in elevations of the coal handling area and the coal storage area. The site layout was revised to provide more room for the coal/limestone handling structure.

A construction manager was hired to oversee all of the construction activities for the PSDF. He has been involved in scheduling activities and constructability meetings

conducted with M. W. Kellogg and Foster Wheeler. These meetings were held to discuss construction and design issues such as equipment delivery schedules, structural deflection limitations, erection of process equipment (sizes and weights), and differential settlements between structures.

Before site preparation could begin, the fence around the decommissioned Agglomeration site was removed except for the part separating the decommissioned liquefaction and agglomeration sites. The removed materials were either used for repairs to the remainder of the fence or stockpiled for future use at the PSDF site.

During the third quarter of 1993, the construction of the PSDF began when Ellard Construction Company was awarded the contract for the site preparation. Ellard mobilized and began the clearing and grubbing activities on September 21, 1993. These activities included flagging the areas to be cleared, clearing the site of trees and brush, and removing stumps and other organic materials.

Site preparation activities were also started. These activities include the removal and stockpiling of topsoil, surveying to establish cut and fill areas, removal of soil in the cut areas, and the placement of fill material in the fill areas. Soil compaction tests were made as the fill material was placed.

2.4.2 Task 3.3.6 Preparations for Operations

The development of an Interactive Video Training/Archiving (IVT/A) system for PSDF was started in August by Nolan MultiMedia. Nolan reviewed the PSDF design documents and began developing an outline of the various modules. The IVT/A system for the PSDF will have a familiarization and introduction module, technology transfer modules, training modules and archiving modules. Nolan tested sample PSDF CAD files with various software configurations to determine the most effective and cost efficient translation method into a format compatible for preparing the IVT/A system. Primary delivery platform is being evaluated, and appropriate authoring platform and scriptwriting database are being selected. Scripts for the familiarization and introduction modules were reviewed by SCS and graphical design and authoring work are in progress. Further details of initial developmental efforts are described in Appendix C.

3.0 PLANS FOR FUTURE WORK

1. Review progress made at UNDEERC with respect to TRDU shakedown activities and preliminary operation with coal feed in the first week of October.
2. Monitor progress and provide any additional information necessary to Alabama Department of Environmental Management (ADEM) in obtaining air permit. Obtain and perform leachate and other tests with ash byproduct from UNDEERC and Livingston facilities and explore possible ways to utilize and dispose ash generated at PSDF.
3. Update the Facility Design Documents for the 50 percent design point and issue the design documents for review prior to the design review meeting with DOE and EPRI.
4. Continue the detailed design of the PSDF:
 - FW will continue to work on the PFDs and P&IDs, stress studies of layout arrangement, the detailed design of the Carbonizer, and requisitions for equipment and instrumentation. Plant sampling requirements including sampling by SRI at the PCDs will be reviewed. Work in this quarter will focus on an independent flare for the APFBC system and integration of the PCDs in the APFBC system design. Also, alternatives to Allison's gas turbine will be reviewed.
 - MWK will issue heat and material balance instrumentation requirements; update P&IDs (1A REV 1) for 50% review meeting; start planning review of the physical design; develop construction plans in greater detail; continue to integrate PCDs into structure provided adequate drawings are received from Westinghouse and CPC; meet with SCS on integrating structural steel refractory piping; issue inquiries for remaining equipment items; technically evaluate RX0201, CO0401, DR0404, and DR0501 and release BR0402, BR0601, CO0401, HX0203, ME0540, RX0201 and SU0601 for vendor engineering.
 - SRI will continue the detailed design of the particulate and alkali sampling system. A prototype of the cyclone assembly and bauxite cartridge will be produced using a laser sintering process and will be used to test various concepts for retaining and sealing the cyclones in the manifold.

- SCS will continue to monitor and complete site preparation and grading work. SCS will also continue to work on the design of the process structures, cooling tower, service water, boiler feed systems and electrical specifications; evaluate revised bids for the coal and limestone grinding systems; evaluate bids for the Warehouse/Maintenance building; and develop and issue specifications packages for foundation, process structure and control system.
5. Continue preparation for a process hazard review of the entire PSDF design at the end of 75% design completion point. SCS will complete the preparation of the scope and bid package for a process hazard analysis consultant, and issue the package for bids.
 6. Develop detailed outline for various Interactive Video Training and Archiving Modules for the PSDF. Continue developing script and authoring of familiarization, introduction and technology transfer modules.
 7. Review solicitations received from gasifier suppliers. Develop a formal Request for Proposal for gasifier suppliers to provide a gasifier for the PSDF, and closely monitor the progress made at UNDEERC with regards to TRDU operation.
 8. Coordinate with project participants and prepare a first draft of an experimental test plan for components and system testing during shakedown, characterization and normal operations
 9. Finalize the subcontract negotiations with Combustion Power Company, Westinghouse and Nolan MultiMedia.

APPENDIX A

TRANSPORT TRAIN: STARTUP AND OPERATION PHILOSOPHY / MANUAL

**START-UP AND OPERATING PHILOSOPHY
FOR THE
HOT GAS CLEANUP FACILITY
OF THE
POWER SYSTEM DEVELOPMENT FACILITY
AT WILSONVILLE, ALABAMA**

THE M.W. KELLOGG COMPANY

**JOB NUMBER: 6704
REV. 03, 02 SEPTEMBER 1993**

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ABSTRACT

This start-up and operating philosophy document for the Hot Gas Cleanup Facility of the Power System Development Facility at Wilsonville, Alabama will form the basis for the development of the Standard Operating Procedure for the plant. The philosophy addresses start-up, operating, shutdown and emergency conditions for each class of equipment in the plant. In addition, it identifies requirements for an orderly start-up and shut down.

1.0 INTRODUCTION

This Start-up and Operating Philosophy is to be used as a basis for preparing the Operating Procedure for the Hot Gas Cleanup Facility of the Power System Development Facility. The content is organized according to equipment classification and addresses the requirements for safe and orderly startup, operation, shutdown and emergency shutdown.

Section 3.2, which addresses the PCD operating philosophy, only discusses the impact of the PCD's on the design and operation of the Hot Gas Cleanup Facility. Detailed discussions on the operation of the PCD's proper will have to be developed by the PCD suppliers.

1.1 TRANSPORT REACTOR OPERATING MODES

The Transport Reactor, RX0L01, is designed to operate in either of two modes, gasification or combustion. When operating in the gasification mode, most of the char remaining after fresh coal is devolatilized and reacted with steam to produce fuel gas, and fraction of the circulating char is combusted with air to provide the heat necessary for the endothermic coal devolatilization and steam-char reaction. Sulfur in the coal is released in the reactor as hydrogen sulfide and is captured, in-situ, by converting calcium oxide, from injected limestone, into calcium sulfide which must be oxidized to calcium sulfate in a fluidized bed Sulfator.

In the combustion mode, coal is combusted to extinction, in the reactor, thereby producing heat and flue gas. The sulfur in the coal is liberated as sulfur dioxide and then captured, in-situ, by converting calcium oxide to calcium sulfate.

The Transport Reactor will operate at a pressure of approximately 300 psig in both modes, but the operating temperature will vary depending upon the mode of operation; 1800°F and 1600°F for gasification and combustion respectively. In both modes of operation, the reactor is designed to deliver approximately 1000 acfm of gas, with varying dust loadings, to the PCD.

The Combustor Heat Exchanger, HX0203, is in service only during combustion operation, and the Sulfator system, SU0601 and auxiliaries, is utilized only during gasification operation. The thermal oxidizer, BR0401, must be in service during gasification operation and also during startup of combustion operation. Materials of construction for the equipment common to both modes of operation have been chosen for their ability to function in both an oxidizing and a reducing atmosphere.

1.2 TEST FACILITY OBJECTIVE

The primary objective of this test facility is to test a variety of high temperature, high pressure particulate control devices (PCD) consisting of high efficiency cyclone(s) and absolute filter(s), of various designs, in an atmosphere similar to that which would be found in a commercial, integrated coal gasification combined cycle (IGCC) power plant. The Transport Reactor will produce a hot gas containing a range of particulate loadings for evaluation of the performance of the PCDs. A secondary objective is to demonstrate the operation of the Transport Reactor.

1.3 DEFINITIONS

Inert material: This non-reactive material is free of carbon, and may be used to charge the Transport Reactor at the start of gasification operation. It may be the product from previous combustion operations, or could be limestone.

Char: This material, which is produced by the devolatilization of coal, contains upto 30% carbon. It is produced in the Transport Reactor when operating in the gasification mode.

Cold shot: A stream of cold Boiler Feed Water which is injected into the downcomers feeding a steam generating exchanger to ensure that the water circulation between the steam drum and exchanger is in the proper direction.

Hot shot: A stream of steam which is injected into the risers from a steam generating exchanger to ensure that the water circulation between the steam drum and exchanger is in the proper direction.

DCS: Distributed Control System.

TIC: Temperature Indicating Controller.

PLC: Programmable Logic Controller.

1.4 CONTROL PHILOSOPHY

1.4.1 Introduction

The facility will be controlled by a Distributed Control System (DCS) using electronic field mounted instruments for process measurement and control. The DCS can be linked, by a gateway, to a computer system which will permit the operators to monitor the operation.

The control system will be designed to function with a minimum of operator involvement. Control functions will include normal operation, shutdown and emergency protection. The material conveying systems and other packaged systems will be controlled by dedicated Programmable Logic Controllers (PLC) which can communicate with the DCS system. Likewise, online process analyzers will have the ability to communicate with the DCS system.

1.4.2 Equipment Description

Operator interface with the control systems will be through operating consoles located in a central control room. Recorded historical data will be available for viewing. Process input and output (I/O) equipment needed to communicate with the DCS system will be located in a remote I/O building.

1.4.3 Software

The DCS systems control and monitoring software will be configured by SCS. The software will be reviewed and tested by SCS and Kellogg, prior to plant startup, to verify conformance with the requirements of the process design.

1.4.4 Instrumentation

Electronic field instruments will be wired with individual pair conductors to an I/O building located off the process structure. Communication between the I/O building and the DCS system in the central control room will be carried on data highways.

Packaged equipment containing local control panels and dedicated PLC's will be monitored by the DCS system, but not controlled by it.

2.0 REFRACTORY PHILOSOPHY

The following section outlines a recommended philosophy for installing and maintaining refractory linings in the facility.

2.1 SHOP INSTALLED LININGS

All refractory lining in equipment should be installed and fully dried in the shop, prior to delivery to the plant site. Refractory linings shall not be installed at the site, except for field joints and any unforeseen repairs.

2.2 FIELD JOINTS

Plastic refractory will be applied in the field to seal potential gaps at joints, both flanged and welded. This refractory material does not take a final set until it has been held for at least 3 hours at temperatures exceeding 1000°F. Since the material is hygroscopic, and can be damaged by steam prior to achieving its final set, no steam should be admitted to the unit until the above conditions have been met.

2.3 INITIAL START-UP

On initial start-up, the unit should be brought up to temperature at a rate not to exceed 100°F per hour. When the temperature in all parts of the unit have exceeded 1000°F for 3 hours, steam may be introduced, if desired. This does not require a hold at 1000°F, only a delay in adding steam.

2.4 SUBSEQUENT START-UPS AFTER JOINTS HAVE BEEN OPENED

If any joints have been opened and new plastic refractory has been installed, the same precautions should be taken noted in Section 2.3.

2.5 NORMAL START-UPS

For other than initial start-up, and provided no joints have been opened and no refractory repairs have been made, temperatures may be increased at a rate not to exceed 100°F per hour and decreased at up to 150°F per hour (Temperature decreases are expected to have less of an impact on the refractory than temperature increases). It is understood that at times it may not be possible to control the rates of temperature increases and decreases within the recommended limits, however, every attempt should be made to comply. It is particularly important to observe the 100F°/hr limit on the rate of temperature increases while temperatures are below 1000°F.

2.6 START-UPS AFTER REFRACTORY REPAIRS

Start-ups following repairs to the refractory lining, including any field repairs done during initial construction, must proceed according to the following schedule so that dryout of the new refractory may be successfully accomplished:

- Allow the refractory to cure for 48 hours.
- Circulate air over the refractory for 24 hours at ambient temperatures.
- Increase refractory temperature to 200°F at a rate not to exceed 50F° per hour.
- Increase refractory temperature to 350°F at a rate not to exceed 10F° per hour.
- Increase refractory temperature to 550°F at a rate not to exceed 50F° per hour.
- Increase refractory temperature to 900°F at a rate not to exceed 15F° per hour.
- Increase refractory temperature to normal operating temperature at a rate not to exceed 50F° per hour.

The thermocouple(s) nearest the area of the repair should be used to monitor the rate of temperature increase and the refractory temperature.

2.7 DETECTION OF REFRACTORY FAILURE

2.7.1 Importance of Refractory Linings

The interior of the Transport Reactor operates at high temperature and pressure, which must be contained by the refractory lined steel shell. The steel shell, by itself, cannot withstand the internal operating temperatures, and is, therefore, protected from these temperatures by the refractory lining. A failure of the refractory lining would expose the steel pressure shell to temperatures at which it is not designed to operate, and would likely result in a failure of the shell.

It is important to monitor shell temperatures so that a catastrophic failure can be avoided. Typically, massive refractory failures are preceded by a gradual deterioration of the refractory and accompanying gradual increases in shell temperature. This deterioration of the refractory may be widespread, or highly localized. It should be noted that many refractory failures occur during periods of system temperature change, e.g., start-up, shutdown, etc., because of differential expansion, and consequently, shell temperatures should be monitored very closely during these operations.

2.7.2 Temperature Indicating Paint

Refractory lined equipment will be coated with a temperature sensitive paint so that visual identification of significant shell temperature excursions is possible. The original dark green color of the recommended paint will fade at high temperatures, and any such indication should be responded to by verifying the actual skin temperatures in these areas by more quantitative means such as an infrared optical pyrometer and comparing the measured values to design. Shell temperatures at, or in excess of design should bring about an immediate shutdown and inspection of the refractory lining in the indicated problem area.

There are causes other than high temperature that will cause the paint to fade. These include oxidation with time and the presence of atmospheric contaminants in the immediate vicinity. The paint will gradually oxidize with time, and must be renewed regularly to maintain its effectiveness. The ultimate life of the paint is predicted to be 60 months by the manufacturer, however, the actual serviceable life will be a function of the local atmosphere and the quality of paint application.

Some areas, such as thermal transitions (transitions from lined to unlined pipe) are designed to operate hotter than others, and may operate at temperatures that will cause premature fading of the paint. High temperature indication in these areas, as in any other areas, should be immediately reported to Kellogg for analysis. If it is determined that the area is operating within its design parameters, the area should be noted such that it does not cause future concern; there is no point in renewing temperature indicating paint in such areas.

2.7.3 Optical Thermal Surveys

The temperature sensitive paint is intended to give an immediate visual indication of a possible problem, however, a more quantitative procedure must be in place that will provide more accurate information, and will verify the performance of the paint. Beginning with the initial startup, infrared optical surveys should be taken on a regular basis for the following reasons:

- To provide thermal information during startup.
- To provide a data base for analyzing information and potential problems such as verifying changes indicated by the temperature sensitive paint.
- To provide precise information on skin temperature profiles for various reactor operating conditions.

The data so obtained will allow quantitative analysis of changes and permit comparison of operating conditions with design. In addition, the rate of change with time can be calculated, thereby permitting more accurate scheduling of maintenance, particularly with regard to refractory and temperature sensitive paint.

A complete survey would include all refractory lined surfaces in the unit, and should also include a record of ambient conditions such as temperature and wind velocity and direction. A survey should be taken at least once per shift during each startup and then daily for the first 7 days of continuous operation after startup. Beginning 1 week after startup, the surveys should be repeated weekly until the next shutdown.

2.7.4 Long Term Monitoring

In conjunction with the sustained operation of the unit, a long term plan should be implemented to monitor the skin temperature of the refractory lined equipment. This plan should certainly include the continuation of optical infrared monitoring, as noted above, at intervals determined by experience to provide safe, reliable operation and current information on the status of the refractory system. If long term experience verifies that the performance of the temperature sensitive paint is satisfactory, it can be renewed on a regular basis, if not, other means of skin temperature monitoring, such as continuous thermocouples, may be added.

2.7.5 Actions Required

In the event of any unusual circumstances, e.g., higher than normal skin temperature, rapid increase of skin temperature, etc., one of the following actions needs to be taken, the choice of which is dependent upon the magnitude of the perceived problem:

- Any unusual skin temperature noticed should be reported to Kellogg for analysis and recommendations.
- Whenever there is a sudden increase in skin temperature of 200F° or more, or if steel parts are operating above their design temperature, a full time monitoring program to check for increased refractory deterioration is required and the condition should be reviewed to determine the need for and timing of an orderly shutdown of the unit.

- Emergency shutdown procedures must be initiated without delay if any of the following events occur:
 - If conditions noted above worsen,
 - If there is any glowing or bulging of steel surfaces,
 - If there is any sudden skin temperature increase of 500F° or more, or
 - If the operating temperature of carbon steel parts exceeds 800°F.

3.0 TRANSPORT REACTOR SYSTEM OPERATING PHILOSOPHY

3.1 Transport Reactor Operating Philosophy

Two start-up scenarios are addressed, the choice of which to employ depends upon the starting bed material available, e.g., either inert material such as limestone ash, alumina etc., or char. Regardless of which scenario is chosen, the reactor system, including the PCD, is pressurized to 50 psig using either nitrogen, if char is utilized, or air. The reactor system will also be operated at intermediate pressure of approximately 120 psig during the shakedown period to develop scaleup data.

Depending upon the operating mode, some equipment will be taken out of service. For example, in the gasification mode the Combustor Heat Exchanger, HX0203, must be isolated from the reactor loop by removing spool pieces and inserting blind flanges and the system must be drained of solids. Similarly, the Thermal Oxidizer, BR0401, will not be in service while operating in the combustion mode, however, the Thermal Oxidizer must be in service during startup, regardless of the ultimate operating mode, to oxidize any high, transient levels of carbon monoxide that may be produced.

Prior to loading solids into the reactor loop, purge flows should be established through all nozzles, and maintained at sufficient levels to prevent plugging of the nozzles by solids. Steam nozzles should be purged with nitrogen until steam injection into the reactor is initiated. In the combustion mode, where steam injection is not required, steam nozzles should be purged continuously with nitrogen or air, or temporarily plugged.

Startup bed material must be loaded into the reactor standpipe to seal it from the mixing zone; in the combustion mode, the solids return leg from HX0203 should also be sealed with bed material.

3.1.1 Start-up: Inert Start-up Bed Material

Inert startup bed material should be loaded into the reactor standpipe as described in 3.1, above, and the reactor system, including the PCD, should be pressurized to 50 psig. Process valves should be set such that startup gases will follow the normal process gas flow path through all equipment, including the Thermal Oxidizer, BR0401. In combustion mode operation, the Thermal Oxidizer should be taken out of service when steady state operation has been achieved.

The direct fired Start-up Burner, BR0201, is used to preheat the reactor system from its idle temperature (75°F) to 1400°F, while circulating inert solids. The rate of heating is controlled by ramping the exhaust temperature from 200°F to 1800°F; the ramping is accomplished by means of quenching with secondary air or nitrogen. The maximum heating rate is established by refractory and differential expansion considerations. It is estimated that upto 40 hours will be required to heat the reactor system from cold start to 1400°F, provided no refractory repairs have been made.

A start-up with inert bed material could follow a prior operation in the gasification mode. If this is the case, the system must be purged with nitrogen, and nitrogen purge should be maintained in all nozzles that are not in use during the start-up sequence. Extreme caution must be taken to limit the oxygen concentration in the burner exhaust gas to less than 2%, so as to limit localized combustion of any carbon fines in downstream equipment and piping.

When the reactor exit temperature reaches 1400°F, flows of coal and limestone into the reactor are initiated, and combustion begins utilizing the excess air in the Start-up Burner exhaust gas. After establishing coal ignition, the Start-up Burner firing rate is reduced and combustion air flow is diverted to the air nozzles located on the reactor. When heat input from the Start-up Burner is no longer required to maintain temperature, the burner may be taken out of service. When operating in the combustion mode, the Combustor Heat Exchanger, HX0203, will be brought on line when the reactor exit temperature reaches 1500°F (See Section 3.3.3).

If the gasification mode of operation is desired, the startup procedure is modified to convert from an oxidizing atmosphere to a reducing one. With the start-up burner in operation, quench air should be replaced with nitrogen when the reactor temperature reaches 1400°F. Coal and limestone feeds into the reactor are initiated, and most of the combustion air should be diverted to the air feed nozzles. Steam feed should be initiated after the reaction temperature reaches 1600°F. Start-up burner firing should be reduced, and ultimately stopped when reactor conditions stabilize at a temperature of approximately 1750°F for Illinois #6 coal, or 1700°F for Eagle Butte coal. Steam and air flows may then be adjusted to achieve optimum reactor conditions. Nitrogen being used for fluidization and aeration of the reactor standpipe and cyclone dipleg should be replaced with recycled process gas when it becomes available.

After steady state is attained, the system pressure may be increased at approximately 100 psi/hr (rate to be verified with PCD vendors) to the desired set pressure. While increasing operating pressure, the oxidant and coal and limestone feed rates must be increased to maintain a constant riser velocity.

As system pressure increases, the quantity of steam produced in the Combustor Heat Exchanger, HX0203, will increase if in the combustion mode, and if in the gasification mode, the gas quality (heating value) will improve since heat leak will represent a smaller percentage of the total heat released.

3.1.2 Start-up: Active Char (Gasification Mode Only)

This scenario may occur when re-starting after operating in the gasification mode, and may begin with the bed cold or hot; carbon in the bed material may represent up to 30 wt%. If the previous shutdown was planned and orderly, the carbon content of the bed material may have been reduced, however, it will still represent at least 10 wt%.

The Thermal Oxidizer must be on-line prior to start-up and the Start-up Burner will be used to provide heat, as in 3.1.1 above, but nitrogen must be used to quench the burner exhaust gas in order to limit the oxidation of the circulating char inventory. The oxygen content in the burner exhaust gas should be maintained at 1 to 2%, such that it will be consumed by combustion of carbon in the char. The two primary control criteria during this type of startup are:

- Limit the oxygen content of the Start-up Burner exhaust gas to that which can be consumed without causing localized hot spot, and
- Ensure that all of the oxygen introduced to the reactor is consumed so that there is no oxygen downstream of the reactor.

All of the heat necessary to raise the reactor exit temperature to 1400°F is supplied by the Start-up Burner. When the reactor exit temperature reaches approximately 1400°F, flows of coal, limestone and steam into the reactor are initiated. The Start-up Burner firing rate is gradually reduced and eventually shut down when conditions are stabilized at a reactor temperature of approximately 1750°F for Illinois #6 coal and 1700°F for Eagle Butte coal. The reactor temperature will be stabilized at the desired level by adjusting the oxidant and steam feed rates to their set points at 50 psig. The carbon inventory in the circulating solids should be increased to the level required for the targeted conversion.

As in 3.1.1 above, when steady state conditions have been established, the system pressure may be increased to the desired operating pressure at a rate of 100 psi/hr (to be verified with PCD vendors) while adjusting the oxidant, coal and limestone feed rates to maintain a constant riser exit velocity.

3.1.3 Start-up: Auxiliary Systems

A. Solids Handling

Provisions have been made for adding startup bed material to seal the reactor standpipe and Combustor Heat Exchanger, HX0203, J-leg and to ensure adequate solids circulation. When the unit is in operation, additional material may be required, and may be added into the mixing zone via the Limestone Feeder System, FD0220.

Excess inventory may be drained from the standpipe through the Spent Solids Transporter System, FD0510. Planned and emergency shutdown may make it necessary to drain all solids from the reactor system through the screw cooler.

3.1.4 Shutdown

A. Planned Shutdown

A planned shutdown of the transport reactor is one for which there has been adequate notice to permit the shutdown to proceed in an orderly fashion. This type of shutdown may occur at the end of a test campaign or upon the discovery of potentially severe refractory deterioration as described in 2.7.5, above. The shutdown philosophy to be applied depends upon the mode of operation.

In the combustion mode, the following sequence is suggested:

- Stop coal and limestone feeds and continue to purge the feed nozzles.
- Depressurize the system through the control valve at a rate of 60 psi/hr and reduce the flow of air while continuing to transport the solids from the mixing zone and the riser into the standpipe. At the same time, reduce the aeration flow to the reactor and Combustor Heat Exchanger standpipes and J-legs to a standby level in order to stop solids circulation.
- When the system pressure has fallen to 50 psig, and all solids have been conveyed from the mixing zone into the standpipe, the solids may be drained from the reactor if it is so desired.
- Continue to depressurize the system to atmospheric pressure. Stop all feed flows to the reactor but maintain purge flows through all instrument and aeration taps.

In the gasification mode, the following sequence is suggested:

- Stop coal and limestone feeds and purge the feed lines with nitrogen.
- Replace the combustion air with nitrogen, and, if needed, increase the flow of steam through the reactor. Steam flow may be stopped when the reactor temperature falls to 1200°F.
- Continue the shutdown by following the above procedure for the combustion case beginning with the system depressurization, except that the reactor system should be purged with nitrogen and a nitrogen blanket must be maintained after the combustion air supply has been stopped.

B. Emergency Shutdown

When an emergency shutdown is necessary, stop feeding coal, limestone and oxidant (route combustion air to vent), and maintain all purge flows. Trip the Recycle Gas Booster Compressor, CO0401. If system depressurization is required, depressurize the system as rapidly as possible. Specific actions for proceeding from this point depend upon the mode of operation, and are discussed below. Refer to the section on shutdown for additional procedural suggestions.

- If the emergency is caused by pluggage at the exit of the Disengager, CY0207, first, drain all bed material through the Spent Solids Screw Cooler, FD0206, and then close the main pressure let down valve upstream of the Thermal Oxidizer, BR0401, and open the pressure letdown valve upstream of the PCD. Equalize the pressure across the emergency vent valve downstream of the Disengager by injecting nitrogen either upstream or downstream of the vent valve, as required, and then open the emergency vent valve and use the main pressure let down valve to manually depressurize the system at a controlled rate.

When operating in the gasification mode, stop all air supply to the reactor and replace it with nitrogen. If required, drain the bed solids through the Spent Solids Screw Cooler. If the emergency is caused by hot spots in the mixing zone, it is necessary to maintain coal and limestone feed after the combustion air is stopped, until the temperature in the mixing zone begins to fall. Steam flow to the reactor should be stopped when the temperature reaches 1200°F.

In the combustion mode of operation there is no danger of ash ignition, and the system can be depressurized as rapidly as can be tolerated by system components, after coal and limestone feeds are stopped. The standpipe can be drained, if necessary, through the Spent Solids Screw Cooler.

3.1.5 Safety Issues

A. Change-over Operation

The Transport Reactor, when operating as a gasifier, circulates solids containing 30 wt%, or more, carbon at approximately 1800°F and 300 psig. During operation, a portion of the circulating carbon is oxidized to CO using sub-stoichiometric air, thus, producing a gas which contains no oxygen.

Although a major portion of the char is kept in the reactor, and withdrawn from the standpipe as spent solids, some high carbon fines escape the cyclone system and continue downstream to the PCD. The presence of char fines downstream of the reactor presents a potential hazard when changing operating modes. Combustion operation cannot follow gasification operation unless the system has been purged of char fines because the excess oxygen in the flue gas produced during combustion operation may cause the fine char particles to ignite and produce localized hot spots along with other attendant problems. However, so long as the reactor continues to be operated in the gasification mode, this safety hazard does not exist.

Gasification operation can safely follow combustion operation, and gasification operation can also follow another gasification operation so long as adequate precautions are taken to prevent oxygen leakage through the reactor during start-up. It would, therefore, be most preferable to conduct all combustion tests in series followed by all gasification tests in series.

B. Aeration/Fluidization Gas Requirements

During start-up, recycle gas will not be available. Nitrogen or air may be used for aeration and fluidization of the standpipe and dipleg when starting with an inert starting bed material, and nitrogen only must be used when starting with an active char bed. In both cases, the change to recycle gas should be accomplished as soon as possible.

During normal operation, flue gas or air can be used for aeration and fluidization in the combustion mode and process gas or nitrogen can be used in the gasification mode.

3.2 PCD OPERATING PHILOSOPHY

The details of this section will have to be written by the selected Particulate Control Device (PCD) vendors.

The test program involves a performance evaluation of various types of PCDs in terms of their ability to capture particulate at high temperature and pressure, and, to a lesser extent, to capture alkali. Two PCDs are included in the current configuration, but only one PCD will be on-line at any one time. The PCDs will be tested over a range of temperatures from 1000°F to reactor outlet temperature. As this temperature is decreased from the maximum, pressure must also be decreased to maintain a constant volumetric flow of 1000 acfm at the PCD inlet. With the present configuration, these changes cannot be made on-line, and will require a shutdown between successive runs. During this shutdown, the temperature and pressure for the next run must be established and the appropriately sized orifice plate installed.

PCD performance testing will involve:

- Operating the transport reactor in combustion and gasification modes.
- Testing over a range of PCD inlet temperatures from 1000°F to Transport Reactor exit gas temperature. The operating pressure upstream of the PCD will be adjusted to deliver approximately 1000 acfm of gas at the inlet to the PCD at each selected operating temperature.
- Test pressures will be up to approximately 300 psig.
- Solids (fines) loading to the PCD will be varied.

The nominal operating pressure for the Transport Reactor is 300 psig when in the air blown mode. Initial operation will begin at 50 psig, and will be gradually increased to the desired pressure of 300 psig.

The Primary Gas Cooler, HX0202, will be on line if PCD operation is at temperatures less than the transport reactor outlet.

3.3 OPERATING PHILOSOPHY FOR HEAT EXCHANGERS

3.3.1 Common Operating Philosophy

A. Start-up

The steam system should be brought to operating temperature and pressure with boiler feed water (BFW) circulating through each exchanger prior starting the flow of process gas (See Section 3.10 for details of the steam system start-up). Process gas temperature and flow should be increased gradually; gradual temperature rise being the most critical. During the period in which the process gas flow is cooler than the BFW in the system, BFW circulation through the exchanger must be maintained to prevent cooling of the BFW in the exchanger. Note: The BFW side of the Combustor Heat Exchanger, HX0203, should be blinded off and maintained under clean conditions (nitrogen blanketing if required) while the steam system is being flushed prior to start-up. Only after the steam system has been cleaned should the Combustor Heat Exchanger be connected to the steam system.

B. Operation

The steam system should be operated with intermittent blowdown at an interval to be established for the plant. The BFW supply to each exchanger is by natural circulation from the Steam Drum and shall remain uninterrupted during all operating cases. The exchanger outlet temperature shall not to be controlled by adjusting the flow of BFW.

C. Shut-down

The hot gas flow, temperature and pressure are to be gradually reduced until a no flow condition is reached, at which time the gas side of the exchanger shall be purged with nitrogen while BFW circulation to the exchangers is maintained as in start-up.

3.3.2 Primary Gas Cooler, HX0202

Details of the startup, operation and shutdown of this exchanger are to be provided by the selected vendor. A hot gas bypass around this exchanger shall be used to control the inlet temperature to the PCD. When the PCD is operated at reactor exit pressure and temperature, the heat exchanger will be fully bypassed, but for operation below reactor exit temperature and pressure, flow through the heat exchanger and bypass will be balanced to yield the desired temperature.

3.3.3 Combustor Heat Exchanger, HX0203

During steady state operation in the combustion mode, the reactor temperature is controlled by removing excess reaction heat. In addition to reactor heat loss, a portion of the heat leaves as sensible heat in the flue gas exiting the reactor, and the remainder is removed by generating steam in the Combustor Heat Exchanger, an external, bayonet boiler.

Variation in the extent of heat removal necessary to maintain heat balance is achieved by varying the hot ash circulation rate through the exchanger. If, during operation, there is a need to turn down the boiler further than can be achieved by control of solids flow, the entire facility will be shut down and, after the boiler has cooled down, a spool piece will be inserted to decrease the submergence of bayonet tubes in the fluid bed, thereby reducing the heat transfer surface area. Hot solids from the upper portion of the standpipe flow down an aerated "sloping" pipe into the shell side of the vertical bayonet boiler where they exchange heat with boiler feed water in the tubes. Cooled ash exits the bottom of the exchanger through a vertical standpipe and returns to the reactor mixing zone through an aerated J-leg. The rate of ash circulation through the boiler will be controlled by J-leg aeration. Heat release in the reactor can be controlled by adjusting the coal feed rate or the riser velocity, therefore, it may not be necessary to turn down the boiler during operation.

Recycled flue gas, which is introduced through a pipe distributor located in the lower portion of the Combustor Heat Exchanger, is used to fluidize the solids as they pass through the exchanger. The rate of gas flow to the distributor can be adjusted to optimize the solids flow. In the event of fluidization gas failure, nitrogen will automatically replace it.

BFW flows through the tubes of the Combustor Heat Exchanger by natural circulation from the Steam Drum. This type of circulation system requires little attention during normal operation, except to monitor the Steam Drum operating parameters of pressure, water level, etc. During start-up, however, the direction of BFW circulation can reverse in the circuit. If not corrected, the reverse flow can result in operating problems and possible mechanical damage to the exchanger tube bundle. This situation can be avoided by using "cold shot" BFW to initiate flow in the proper direction (for more discussion on this refer to Section 3.10). After heat has been applied to the tubes of the exchanger, and normal circulation through the downcomers and risers is established, the "cold shot" can be discontinued. Steam injection, "hot shot", into the risers can also be used to establish correct water circulation during start-up, and concurrently preheat the boiler feed water in the system.

3.3.4 Transport Air Cooler, HX0204

The discharge air temperature from the Transport Air Cooler should be maintained at, or below 95°F at all times. Therefore, should the cooling water supply temperature increase to the point where this is not possible, well water should be used as an alternate cooling water source. The flow of cooling water to this cooler should not be throttled to control the gas outlet temperature.

3.3.5 Secondary Gas Cooler, HX0402

See comments common to all shell and tube exchangers in the steam system, Section 3.3.1 above and Section 3.10, below. There have been no provisions made to control the outlet temperature of the process gas, and, hence, it will vary from case to case.

3.3.6 Compressor Feed Cooler, HX0405

The outlet gas temperature from this cooler is not to be controlled by throttling cooling water. Instead, the temperature of the gas at the inlet to the Recycle Gas Booster Compressor, CO0401, will be controlled by a hot gas bypass around the cooler.

3.3.7 Sulfator Heat Recovery Exchanger, HX0601

See comments common to all shell and tube exchangers in the steam system and Section 3.10, below. No provisions have been made to control the outlet gas temperature from this exchanger.

3.4 OPERATING PHILOSOPHY FOR COMPRESSORS

3.4.1 Main Air Compressor, CO0201

This compressor will operate at a constant discharge pressure which will be controlled by throttling the compressor suction. The actual flow required by the

process will be controlled by flow control valves. At the lower limit of suction throttling, the compressor surge point, excess capacity will be vented to atmosphere to keep the compressor in a stable operating condition.

3.4.2 Recycle Gas Compressor, CO0401

This service will be provided by a single stage reciprocating compressor operating at a constant volumetric throughput. Process capacity control will be accomplished by venting excess gas to the Thermal Oxidizer, BR0401.

3.4.3 Sulfator Air Compressor, CO0601

This compressor will be a standard rotary lobe blower, which is a positive displacement type machine. Startup unloading and operating capacity control will be provided by venting the discharge to atmosphere through a pressure control valve. The compressor will be belt driven, and will be provided with inlet and discharge silencers and an acoustic enclosure to control noise inherent to rotary lobe type machines.

3.5 OPERATING PHILOSOPHY FOR HEAT TRANSFER FLUID SYSTEM, ME0540

The heat transfer fluid system will be a package consisting of a storage reservoir, two 100% capacity, motor driven centrifugal pumps, an air cooled heat exchanger with temperature controls provided to bypass heat transfer fluid around the cooler and return the fluid to the reservoir/storage tank. The pumps will pump the silicon based heat transfer fluid, UCON 500, through the elements of three screw coolers to cool them. In the event of upset, or loss of heat transfer fluid flow, a head tank will provide a continued supply of cooling fluid to the the screw coolers to protect them through the ensuing shutdown. Both of the Heat Transfer Pumps will be equipped with an auto-start which will be activated on loss of pressure in the pump discharge. To avoid the possibility of process side condensation, a startup heater will be provided in the storage reservoir to preheat the UCON 500 to normal operating temperature prior to system startup.

3.6 OPERATING PHILOSOPHY FOR COMBUSTION EQUIPMENT

3.6.1 Start-up Burner, BR0201

The Start-up Burner, BR0201, is a direct fired, in-line air preheater. It contains a single raw gas burner with a pre-mix pilot burner and fires into a refractory lined combustion chamber. Flue gases are directed to the Transport Reactor as discussed under Transport Reactor Start-up, Section 3.1, above.

A. Precommissioning

The refractory lining shall be dried out in the vendor's shop, however, when the unit is first placed in service, it shall be heated slowly to working temperature. The first heatup should be at a maximum rate of 50 F°/hour for at least the first 300 degrees and then 100 F°/hour to working temperature.

Prior to supplying fuel gas to the unit, all fuel lines should be blown out with nitrogen, air or steam with the burner disconnected. Fuel lines shall then be purged with nitrogen, and charged with fuel gas up to the automatic, double block isolation valves.

B. Start-Up

The startup burner is furnished with a relay logic based burner management system designed in accordance with NFPA requirements for single burner installations. Burner ignition will follow a sequenced purge and ignition cycle which is initiated by push buttons on the local control panel.

C. Operation

Control of the Start-up Burner firing rate shall be by means of fuel gas flow control. The start-up burner outlet temperature shall be controlled by quenching the burner effluent with secondary air or nitrogen. The choice of quench material depends upon the operating mode of the Transport Reactor as discussed under Transport Reactor Start-up, Section 3.1, above.

D. Shutdown

The Start-up Burner may be shut down by any of the process defined interlocks, or by any interlock in the burner management system. The burner management system supplied with the Start-up Burner shall be capable of accepting external shutdown signals, and reporting the burner status to the DCS.

On shutdown, after completion of reactor preheat, the Start-up Burner shall be automatically pressurized to a level above that in the reactor mixing zone. When operating in the gasification mode, nitrogen will be used for pressurization; air will be used when operating in the combustion mode. The differential pressure so established, will be maintained to prevent the backflow of solids and gases from the Transport Reactor into the burner. This feature shall be incorporated into the burner management system logic.

3.6.2 Thermal Oxidizer, BR0401

The Thermal Oxidizer, BR0401, is a supplemental gas fired combustor which will be used to oxidize the low Btu process gas produced in the Transport Reactor during gasification mode operation. A waste heat recovery section is included to reduce the temperature of the flue gas prior to discharge to the SCS supplied baghouse.

In addition to the above described function, the Thermal Oxidizer will be used to provide heat to the steam system during plant startup.

A. Precommissioning

All fuel lines shall be disconnected, thoroughly blown out and then purged with nitrogen. The burner management system shall have been functionally tested at the Thermal Oxidizer supplier's factory, and the steam system shall have been chemically cleaned in conjunction with the cleaning of the plant steam system. Refractory shall have been dried out at vendor's shop.

B. Start-Up

The Thermal Oxidizer will be furnished with a PLC based burner management system which is in accordance with NFPA requirements for single burner installations. Burner ignition will be achieved by means of a sequenced purge and ignition cycle which is initiated by push buttons located on the local control panel. Instructions for the ignition cycle will be provided in the vendor's Installation and Operating Instructions.

C. Operation

Supplementary fuel gas firing shall be utilized to sustain combustion. The fuel gas firing rate shall be automatically controlled by a TIC on the combustion chamber.

Quench air will be used to reduce the temperature of the gases leaving the combustor because excessive flue gas temperatures may cause ash particles in the gas to soften and deposit on refractory and downstream heat transfer surfaces. The quench air rate shall be automatically controlled.

D. Shutdown

The Thermal Oxidizer burner may be shutdown by any process defined interlock, or by any interlock in the burner management system. The burner management system supplied with the Thermal Oxidizer shall be capable of accepting external shutdown signals, and reporting the burner status to the DCS.

When the Thermal Oxidizer is shut down, for any reason, process gas must be automatically isolated from the unit and re-routed to the flare. A shutdown signal from the burner management system to the DCS will be provided for this purpose.

3.6.3 Sulfator Start-up Heater, BR0602

The function of the Sulfator Start-up Heater is to pre-heat the sulfator fluidizing/combustion air in order to:

- Bring the unit to the threshold temperature for carbon ignition.
- Supply additional heat to maintain the proper bed temperature in the event that there is insufficient carbon in the ash coming from the Transport Reactor to do so by combustion.

Fluidizing/combustion air is supplied by the Sulfator Air Compressor, CO0601, and flows through a coil in the startup heater where it is heated to a temperature of approximately 1200°F. Heat is provided by a gas fired natural draft burner mounted in the floor of the cylindrical shell and firing vertically upward. The shell is internally lined with a castable refractory or ceramic fiber.

A. Precommissioning

The various steps required for precommissioning are the same as those given in Section 3.6.2 A.

B. Start-Up

The startup sequence will follow the same steps outlined in Section 3.6.2 B. The Sulfator Start-up Heater will be furnished with an NFPA based burner management system and safety shutdown system.

C. Operation.

The firing rate shall be controlled based on the temperature of the outlet combustion air, and the air flow rate will be manually adjusted to ensure minimum fuel use. Pilot burners will be maintained in service to allow for instant re-ignition of the main burner, should it be required.

D. Shutdown

The Sulfator Start-up Heater may be shut down by any process defined interlock, or by any interlock in the burner management system. The Sulfator Start-up Heater burner management system shall be capable of accepting external shutdown signals, and reporting the burner status to the DCS.

3.6.4 Flare, BR0402

The flare is provided to combust the offgases from the Transport Reactor, in the event that:

- The Thermal Oxidizer, BR0401, suffers an unplanned outage.
- A pressure excursion in the process gas system occurs which causes the release of process gas through a pressure relief valve.

The flare is designed to combust the low BTU gases produced by the gasification of various coals. To ensure that complete combustion occurs, the gases being released to the flare will be enriched with propane so that the mixture has a minimum heating value of 200 Btu/scf.

The flare is comprised of an inlet water seal, remote pilot ignition system and elevated flare burner assembly. The latter is supplied with dual continuous pilots, pilot flame monitoring thermocouples and velocity seal. A continuous purge with either fuel gas (propane) or nitrogen shall be maintained at all times to ensure against air ingress. The purge rate shall be based on a velocity of 0.5 ft/sec through the flare tip.

Pilots shall be of the self air inspired type, capable of maintaining a stable flame under full inert gas vent flow (gasification or combustion mode). The pilot ignition system will consist of a flame front generator with manual electronic ignition.

A. Precommissioning.

All lines connected to the flare via the Flare Seal Drum, DR0404, shall be blown through into the drum, and all scale and debris shall be removed from the base of the drum prior to filling it with water and starting operation. Fuel lines to the flare pilots and ignition system shall be blown clean with the pilots and flame front panel disconnected.

The main flare header, vent lines, pilot ignition, and pilot fuel lines shall be purged and blanketed with nitrogen and the Flare Seal Drum shall be filled with water to the normal level. The pilot ignition circuits shall be fully checked out, including the observation that a spark is fully developed in the flame front generator ignition chamber prior to bringing fuel into the system.

B. Startup

Startup consists of bringing fuel gas into the pilot ignition system to displace the nitrogen, in accordance with the manufacturers instructions. When the pilots are in service, the flare is considered commissioned.

C. Shutdown

The flare shall not be shut down (pilots out), for any reason, while the plant is under pressure. Shutdown of the flare system requires that the system be inerted with nitrogen, and the pilots be shut down. The pilot fuel system, including the igniter line shall also be inerted.

3.7 OPERATING PHILOSOPHY FOR SULFATOR, SU0601

The solids withdrawn from the reactor standpipe when the reactor is operating in the gasification mode cannot be disposed off in an environmentally acceptable manner without being further processed to inert them. The spent solids contain carbon, CaS, CaO and coal ash. The carbon and the CaS are oxidized to CO₂ and CaSO₄ respectively in a fluidized bed sulfator at near atmospheric pressure.

Spent solids are pneumatically fed into the sulfator, and, additional limestone may be added, if necessary, to capture any SO₂ which may be evolved. If the exothermic heat of reaction exceeds the system requirements, the excess heat will be removed and the sulfator temperature will be controlled between 1600° and 1650°F by superheating steam in submerged heat transfer tubes. Alternatively, if there is insufficient carbon in the spent solids to sustain the required system temperature, the Sulfator Start-up Heater will be fired to provide the additional heat necessary by preheating the Sulfator combustion air.

Air from the Sulfator Air Compressor, CO0601, is used to fluidize the solids in the sulfator and to support the required oxidation reactions. The bed height in the Sulfator is fixed by an overflow discharge pipe. Inerted solids from the Sulfator pass through the Sulfator Solids Screw Cooler, FD0602, where they are cooled to 300°F for disposal.

The Sulfator is equipped with a Sulfator Start-up Heater, BR0602, which heats the bed to 1200°F to initiate combustion. Operation of this heater is described in Section 3.6.3, above.

When the Sulfator is to be shut down for maintenance access, the bed must first be cooled to about 300°F with fluidization air. The cooled bed material can then be discharged into a closed container for removal and disposal as a hazardous waste due to the likely presence of unconverted calcium sulfide. Facilities and equipment are required for vacuum removal of the bed material.

If the Sulfator is to be shut down, and access to the Sulfator is not required, bed material need not be discharged. Instead, if the unit is to be taken out of service for more than a few hours, it should be cooled to 300°F with air, and then placed under a nitrogen blanket at 2 to 3 psig until restart.

Under any circumstances, facilities and equipment must be provided to recycle solids from the Spent Solids Silo, SI0602, back into the Sulfator.

3.7.1 Precommissioning

All feed, and steam lines shall be thoroughly cleaned by air and steam blowing, as applicable. The refractory lining shall have been dried out in the vendor's shop, however when the unit is first placed into service, it shall be heated slowly to working temperature. The first heatup should be conducted at a maximum rate of 50 F°/hour for at least the first 300 F° and then at a maximum rate of 100 F°/hour to working temperature.

3.7.2 Start-Up

Prior to start-up, all nozzles must be purged with air to prevent plugging, and the solids feed nozzle should be purged with nitrogen. The Sulfator shall be charged with approximately one-half the operating bed weight of inert solids such as limestone or ash prior to start-up. Fluidizing (combustion) air shall be introduced to fluidize the inert solids and the Sulfator Start-up Heater, BR0602, shall be put into service as described in Section 3.6.3. The fluidized bed temperature shall be increased at a rate not to exceed that specified by the refractory manufacturer for refractory heat up. When the fluidized bed temperature reaches 800°F, spent solids feed (LASH, char, inerts) may be initiated, but not before steam flow is established through the superheater coils. The Sulfator Start-up Burner is kept on-line until stable combustion is achieved and the Sulfator temperature can be sustained without it.

The superheater coils shall be adequately vented and drained prior to, and during the initial heat-up of the Sulfator. Steam should not be introduced into the superheater coils until the bed temperature is 50°F above the steam drum saturation temperature.

3.7.3 Operation

The fluidized bed temperature shall be maintained either by controlling the flow of steam to the superheater coils, or, if necessary, adding additional heat to the bed by fluidizing (combustion) air preheat. The incremental air preheat, if necessary, will be supplied by the Sulfator Start-Up Heater under temperature control.

The fluidizing (combustion) air flowrate is on automatic control and the height of the fluidized bed is fixed by an overflow solids outlet connected to the Sulfator Solids Screw Cooler, FD0602. The rotational speed of the screw cooler will be controlled to maintain a fixed level of solids in the overflow standpipe.

Processed solids drained from the sulfator must be analyzed for CaS. If the CaS level does not meet specification, the material must be recycled from the Spent Solids Silo, SI0602, to the Sulfator for reprocessing.

Should SO₂ emissions from the Sulfator exceed acceptable levels, limestone may be fed, batchwise, from the Sulfator Limestone Feeder System, FD0610, for in-situ sulfur removal in the fluidized bed.

3.7.4 Shutdown

If it is necessary to shut down the Sulfator, solids feed shall be stopped and the feed line continuously purged with nitrogen. If the Sulfator Start-up Heater is in operation, it must come off-line. Fluidizing air flow must be maintained to prevent collapse of the bed and to provide cooling for protection of the Sulfator internals. If the shutdown is to be for an extended period, the flow of fluidizing air should be maintained until the bed temperature decreases to about 300°F.

Alarms for high temperature, low steam flowrate and low air flowrate forewarn of impending shutdown and offer the opportunity to correct the problem and avoid the shutdown.

3.8 OPERATING PHILOSOPHY FOR SOLIDS TRANSPORT AND COOLING SCREW SYSTEMS.

3.8.1 Introduction

A common, PLC based system with a main control panel shall be provided for the following:

<u>Item No.</u>	<u>Description</u>
FD0210	Coal Feeder System
FD0220	Limestone Feeder System
FD0510	Spent Solids Transporter System
FD0520	Fines Transporter System
FD0530	Spent Solids Feeder System
FD0610	Sulfator Limestone Feeder System

Control functions for each system will include status indication, alarms, manual override controls, and shutdown.

3.8.2 Solids Transport Systems

A. Coal Feeder System, FD0210

The feed rate to the Transport Reactor is controlled by adjusting the speed of the feeder to a level corresponding to the desired feed rate. A load cell system on the Coal Feeder System Surge Bin, FD0210-BN01, is used to calculate the actual average feed rate based on a loss in weight. Feeder speed can be adjusted at any time.

When activated, the shutdown sequence will stop the flow from the bin and allow the system to continue to operate until it is empty and depressurized. This will permit inspection or maintenance functions to be performed safely, and minimize time for restart. The feed line should be purged with nitrogen when not feeding solids.

During an emergency shutdown, the system should be allowed to drain as much as possible. The worst case scenario would be for the entire system to shutdown instantaneously, and this will impose no unsafe conditions so long as the equipment need not be accessed. The unit should be capable of restarting in the normal fashion, with the transfer line first purging itself. The most probable cause for system malfunction during a restart with material in the system would be due to the line not being cleared of solids.

During longer periods of inactivity after an emergency shut down, or if the equipment must be accessed, it should be emptied and depressurized. A diverter valve has been provided at the bin discharge to direct material either to the pneumatic feeder or to atmosphere for system clean out.

The dust collector is self contained and includes controls for activating the pulse-jet cleaning system. The controls permit adjustment of the pulse duration and frequency. The cleaning cycle is initiated by high differential pressure across the bags, and should be adjusted to maintain a maximum pressure drop of 4 to 5 inches of water. When higher pressures drops are noted, it is an indication that the bags are not being properly cleaned. This could be indicative of the cleaning system not functioning properly or the bags needing replacement. The bags in the dust collector and the equipment must be adequately grounded.

B. Limestone Feeder System, FD0220

This system is similar to the Coal Feeder System, FD0210, and functions in a similar manner. The only differences are in the size of the equipment and no need to ground the dust collector bags in this system.

C. Spent Solids Transporter System, FD0510

The system shall be interlocked with the high level indicator on the Spent Solids Feeder System Receiver, FD0530-HO01, so that it may only operate when the receiver is not full. The system, when activated, will function automatically to receive material from the Spent Solids Screw Cooler, FD0206, under high pressure, depressurize the material and pneumatically convey it to the Spent Solids Feeder System Receiver.

Under normal shutdown conditions, the system should run until empty. Start-up after an emergency shutdown with material remaining in the system should begin by first purging the conveying lines free of solids, after which the system can start in the normal fashion. The equipment should be depressurized prior to access for clean out and repair.

D. Fines Transporter System, FD0520

This system is similar to the Spent Solids Transporter System, FD0510, and will function in a similar manner.

E. Spent Solids Feeder System, FD0530

The Spent Solids Feeder System Receiver, FD0530-HO01, is equipped with high level indicators which are interlocked with the two systems feeding the bin (FD0510 and FD0520) to prevent their operation when the bin is full. The dust collector venting the bin operates in a similar manner as that described for the dust collector in the Coal Feeder System.

The lower portion of the bin has a series of level indicators which permit maintenance of an adequate reserve of material in the bin by varying the solids discharge rate through the pneumatic transfer equipment.

To transfer material, the flow of transfer gas is initiated, and, after setting the speed, the feeder is started. The system will then function automatically to transfer material at a continuous rate. The rate can be adjusted at any time to meet operating requirements. The system functions in a similar manner to the coal feeder pneumatic system for all shut down conditions.

The dust collector bags and the equipment must be adequately grounded.

F. Sulfator Limestone Feeder System, FD0610

The feed bin in this system has high and low level indicators which provide signals calling for additional limestone from the SCS limestone feed system or stopping the flow. On low level, the SCS dense phase system will transfer one charge of limestone to the Sulfator Limestone Feeder System Bin, FD0610-HO01. The high level will indicate overfilling and will stop the flow of material to the bin immediately.

To charge limestone to the sulfator, the length of run and the time interval between batches are set and the system activated. When the feeder stops running, the limestone charge into the pressure vessel is completed and it is automatically blown into the Sulfator. The initial charge of start-up limestone is introduced into the Sulfator through a 'Y' on the feed connection.

When the system is not transporting material, an air purge is continuously passed through the conveying line to prevent any solids blowback and plugging.

Under a normal shutdown, the screw feeder should be stopped and the pressure vessel discharged to clear it and the conveying line. An emergency shut down with material left in the conveying line and equipment will not result in any dangerous condition, but the conveying line should be purged of solids before restarting the system.

A two way valve at the discharge of the screw feeder is provided to collect material for calibration of the screw.

3.8.3 Cooling Screws

Hot solids discharged from the Transport Reactor, PCD and Sulfator are cooled to 300°F in Screw Coolers FD0206, FD0502 and FD0602 respectively. Heat transfer fluid is used as cooling medium.

A. Spent Solids Screw Cooler FD0206

The unit will be equipped with a variable speed drive and automatic speed control to maintain a desired height of material in the standpipe of the Transport Reactor. A level indicator in the reactor standpipe will signal the drive to change speed, in increments, so as to maintain the desired solids level. A manual override shall also be provided.

A temperature sensor in the screw cooler discharge will control the solids discharge temperature by throttling the flow of heat transfer fluid. A manual override shall also be provided.

The unit shall be interlocked with the Heat Transfer Fluid System, ME0540, and the Spent Solids Transporter System, FD0510, so that it will not run unless both of these systems are operating. After verifying that both systems are operating, and setting both a starting speed for the screw and a valve setting for the heat transfer fluid control valve, the Spent Solids Screw Cooler is commissioned. When the operation has stabilized, the system can be put on automatic control.

Ideally, the unit should be kept operating until feed has stopped and the unit has cleaned itself out before it is shut down. The screw can then be stopped and the heat transfer fluid control valve should automatically close to the minimum stop position. Normally it will be shut down full of solids.

In a shutdown resulting from a stoppage of the screw, the heat transfer fluid should be allowed to flow for a period of time to cool the material in the screw prior to closing the control valve. The system can be restarted in the normal manner.

In a shutdown resulting from loss of heat transfer fluid, the screw should automatically stop to prevent any more hot material from entering. The system can be restarted in the normal fashion, but should be closely observed to insure that the screw is operating properly and has not been noticeably damaged by excessive heat.

Prior to accessing the equipment for repair or maintenance, it should be depressurized and cleared of solids.

B. Fines Screw Cooler FD0502

This unit is similar in design and function to the Spent Solids Screw Cooler, FD0206, except that material is received from the PCD rather than the Transport Reactor standpipe. The screw's rotational speed is manually controlled to prevent material build up in the PCD hopper, and also to provide an adequate material level in the screw for efficient cooling. The coolant flow will be controlled manually.

C. Sulfator Solids Screw Cooler, FD0602

This unit is also similar in design and function to the Spent Solids Screw Cooler, FD0206, except that the rotational speed is automatically controlled to maintain the desired solid level in the standpipe. A signal from the level indicator in the Spent Solid Silo, SI0602, will prevent this screw from operating if the silo is full.

3.9 SPENT SOLIDS SILO, SI0602

The Spent Solids Silo will be furnished with three level indicators which will function as follows:

- **High Level** - To send a signal that the bin is nearly full and that material should be withdrawn from the bin using the SCS provided pneumatic conveying system.
- **High High Level** - To send a signal to stop the cooling screw, FD0602, and prevent the silo from being overfilled.
- **Low Level** - To send a signal that the bin has been emptied and that the SCS provided conveying system should be stopped.

The dust collector on the silo is provided with controls to activate the pulse jet cleaning system. The controls permit adjustment of both the length and frequency of the cleaning pulse, and the cleaning cycle will be activated by high differential pressure across the bags. The controls will be adjusted to maintain a maximum pressure drop of 4 to 5 inches of water across the bags; higher pressure drops are a signal to check that the cleaning system is working properly or to replace the bags.

The flow aid system should be interlocked with the SCS provided pneumatic system so that it will start automatically when material is being withdrawn from the silo.

3.10 OPERATING PHILOSOPHY FOR THE STEAM SYSTEM

3.10.1 Assumptions

- The feedwater system and steam generating equipment were flushed and boiled out with a hot alkaline solution and chemically cleaned (if required) prior to initial startup. The BFW side of the Combustor Heat Exchanger should be blinded off and maintained in a clean condition (nitrogen blanketing if required) while the steam system is being flushed prior to start-up. Only after the steam system is cleaned should the exchanger be piped into the steam system.
- The system was layed up wet with deaerated boiler feed water and blanketed with nitrogen.
- Deaerated, demineralized water (boiler feed quality) at approximately 250°F is available from SCS.
- Steam headers are pressurized and in service, riding on the SCS steam system headers.

3.10.2 Start-up

The Steam Drum, DR0402, is charged with BFW to a low operating level and the start-up vent to atmosphere is open. The steam generating equipment is aligned for the correct mode of operation, i.e., the Sulfator Heat Recovery Exchanger, HX0601, and Sulfator, SU0601 are isolated and not in use when operating the reactor in the the combustion mode.

A. Combustion Mode

"Hot shot" and "cold shot" flows are started to the risers and downcomers respectively of the on-line exchangers. As these flows are adding extra water to the steam system, a heavy blowdown is required to maintain the proper level in the Steam Drum, DR0402. Because of the heavy blowdown it may be necessary to increase the rate of chemical addition.

Process streams are introduced to the Primary Gas Cooler, HX0202, the Combustor Heat Exchanger, HX0203 and the Secondary Gas Cooler, HX0402, and steam production will begin as process heat is removed. Steam produced initially will flow to atmosphere from the Steam Drum via the startup vent. As steam production increases, the vent valve is slowly closed, thus increasing drum pressure to a level that will permit the produced steam to flow into the system header. The valve to the header

must be opened as the vent valve is closed. "Hot shot" and "cold shot" should be discontinued and blowdown and chemical injection flows should be reduced to normal values. During this period, the density of the fluid in the downcomer and the differential pressure between the risers and downcomers of the Combustor Heat Exchanger, HX0203, must be monitored to ensure that circulation has been established and maintained in the correct direction. If it appears that circulation is reversed, "cold shot" and "hot shot" flows are restarted in an attempt to correct the direction of circulation. If the correct direction of flow cannot be established within a reasonable length of time, the process stream flowing through the exchanger must be decreased, or stopped, and then a restart should be attempted.

B. Gasification Mode

When operating in the gasification mode, the Combustor Heat Exchanger, HX0203, is not in service and must be isolated from the system. The steam generation and steam superheating coils in the Thermal Oxidizer, BR0401, the Sulfator Heat Recovery Exchanger, HX0601 and the steam superheating coils in the Sulfator, SU0601, are placed in service.

The Thermal Oxidizer is a direct fired unit, therefore, at start-up, a flow of import steam must be started through the superheater coil and vented to atmosphere to cool the coil until ample steam is being generated. At that time, the import steam is replaced with saturated steam from the Steam Drum, DR0402, and the superheated steam is vented to atmosphere until an acceptable superheat temperature is achieved. Superheated steam as well as saturated steam will then flow into their respective headers.

The Sulfator, SU0601, is heated with hot air from the Sulfator Start-up Heater, BR0602. When the bed temperature reaches 50°F above the saturation temperature in the Steam Drum, DR0402, a flow of saturated steam from the Steam Drum is started through the Sulfator superheater coil and vented to atmosphere. When an acceptable superheat temperature is achieved, venting is stopped and the steam is directed into the header.

3.10.3 Changing Operating Modes

Start-up will be the same as described in Section 3.10.2, above, except that when the Steam Drum is hot and the BFW in the heat exchangers is much colder, the "hot shot" and "cold shot" are used to heat the contained BFW. Process fluid should not be introduced to the heat exchangers until the differential temperatures between the tube metal and contents of Steam Drum are within 50F°.

3.10.4 Shutdown

Individual heat exchangers in the steam system are taken out of service by closing only the isolation valves in the risers so as to ensure that the heat exchanger remains full of water and pressurized while it is cooling.

For a long term shutdown, such as a turnaround, the system should be layed up wet with a nitrogen blanket.

3.11 MAINTENANCE PHILOSOPHY

Hot and potentially combustible particulates are being handled in the Transport Reactor, RX0201, and downstream equipment. These particulates look and behave like dust, with sizes ranging from sub-micron to greater than 200 microns. When operating in the gasification mode, the particles contain carbon and are combustible, while in the combustion mode they are inert. Thus, to ensure safe conditions for maintenance of equipment requires that the equipment be cooled, depressurized and relatively dust free, the dust having been removed by discharging to an inerted environment. Cooling may be accomplished by recycling cooled gas and/or nitrogen to the equipment in question, and the contained dust may be cooled using the cooling screws, or by direct gas quenching. Safety procedures developed for the facility must be followed when entry into a vessel is required.

4.0 PROCESS FLOW DIAGRAMS.

P-7521-D

P-7522-D

P-7524-D

P-7525-D

P-7526-D

NOTE:
 1. CLOSE COUPLED TO H0201.
 2. FOURTH CLOSE COUPLED TO H0201.
 3. HTF, HEAT TRANSFER FLUID.

REVISION		DATE		BY		CHKD		APP'D		REASON	
1	FROM H0201	01-10-77	01	01	01	01	01	01	01	01	01
2	FROM H0201	01-10-77	01	01	01	01	01	01	01	01	01
3	FROM H0201	01-10-77	01	01	01	01	01	01	01	01	01
4	FROM H0201	01-10-77	01	01	01	01	01	01	01	01	01
5	FROM H0201	01-10-77	01	01	01	01	01	01	01	01	01
6	FROM H0201	01-10-77	01	01	01	01	01	01	01	01	01
7	FROM H0201	01-10-77	01	01	01	01	01	01	01	01	01
8	FROM H0201	01-10-77	01	01	01	01	01	01	01	01	01
9	FROM H0201	01-10-77	01	01	01	01	01	01	01	01	01
10	FROM H0201	01-10-77	01	01	01	01	01	01	01	01	01

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THE M. B. FELLOWS COMPANY
 ONE SOUTHERN COMPANY SERVICES
 ATLANTA, GEORGIA
 PROCESS FLOW DIAGRAM
 TRANSPORT REACTOR AREA 2001
 6704 P-7522-D
 CLASS AREA JOB NUMBER DRAWING NUMBER

TRANSPORT TRAIN:

OPERATIONS MANUAL - TABLE OF CONTENTS DRAFT

7 SEP. 1993

(DRAFT-STANDARD)

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NOTE: The Table of Contents at this stage of development is not all inclusive. Vendor documents/drawings and any other summaries, sketches, drawings, etc., prepared for this project, that may be helpful to understand the operations of the unit, will be added.

APPENDIX B

PARTICLE CHARACTERIZATION AND COLLECTION

Appendix B

Particle Characterization and Collection

B.1 Detailed Design Interface (Task 2.4.1)

Under this task, SRI is working with SCS, MWK, and FW on sampling and monitoring requirements that affect the facility design. These requirements include the sizes and locations of ports and platforms, piping arrangements, and provisions for access to sampling equipment and instrumentation. SRI plans to have a meeting with MWK in November to finalize the sampling port design so that they can proceed with the detailed design of the sampling probe and insertion mechanism. SRI will coordinate with FW to determine whether the same port design can be used in their piping.

Some of the requirements for sampling and monitoring ports were discussed at the test plan meeting at SCS on August 5 and 6. At that meeting, SCS asked SRI to provide a list of the characterization tests that will be used on the ash samples from the PSDF and to determine what could be done to reduce the time required for the batch particulate sampling runs. SCS also asked SRI to provide information required for specifying the distributed control system (DCS) and for performing the hazardous operations (hazops) review. These items are discussed in the following sections.

Ash Characterization Tests. The tests that will be used to characterize ash samples from the PSDF are described below.

- Chemical composition. Standard techniques are used to determine the mineral constituents of an ash sample that has been ignited overnight at 750°C. Loss on ignition is determined gravimetrically. Soluble sulfate and equilibrium pH values are measured using aqueous suspensions of the as-received samples.
- Particle size distribution. The particle size distribution and Stokes' mean particle diameter are determined by centrifugally-augmented sedimentation. The results indicate whether an ash is typically sized in comparison to other ashes, or abnormally fine or coarse. An abnormal size distribution can have significant effects on filtration behavior. In general, filter cakes composed of extremely fine ash particles exhibit abnormally high filtering drags.
- Specific surface area. The total (internal and external) surface area of an ash sample of known mass is determined by the Brunauer-Emmett-Teller (BET)

technique. Ashes that have abnormally high specific surface areas are usually highly cohesive and can form filter cakes with relatively high porosity's.

- True density. The true (skeletal) density of the ash is measured by helium pycnometry. The true density is a factor in calculating porosity, Stokes' diameter, and drag-equivalent diameter.
- Uncompacted bulk porosity. A container of known volume is filled with a known weight of ash, and the bulk porosity is determined from the sample weight, volume, and true density. The uncompacted bulk porosity is often used as an estimate of the porosity of the filter cake that would be formed in a conventional fabric filter.
- Drag-equivalent diameter. The drag-equivalent diameter is a fitted parameter used to rank the characteristic gas flow resistances of ashes at equal porosities. Increasing values of the drag-equivalent diameter indicate a lower resistance to gas flow at a given porosity. Changes in drag-equivalent diameter are generally correlated with changes in the physical size of the ash particles, but the drag-equivalent diameter best expresses the fineness of an ash as it relates to its effect on gas flow resistance. Ashes with smaller values of drag-equivalent diameter are generally more cohesive.
- Relative gas flow resistance. The resistance to air flow through a simulated filter cake is measured in a laboratory test device. The relative gas flow resistance is the resistance measured when the porosity of the simulated filter cake is equal to the estimated characteristic filter cake porosity for the ash being tested. The relative gas flow resistance is the pressure drop across the filter cake normalized to an areal ash loading of 1 lb/ft² and to a face velocity of 1 ft/min.
- Tensile strength. The effective tensile strength of an ash layer is determined from the electrostatic field required to overcome the attractive forces between ash particles. The tensile strength is a direct measure of ash cohesivity.
- Morphology The ash sample is examined in a scanning electron microscope, and representative photographs are taken at magnifications of 100, 500, 1000, and 5000. The appearance of the particles often provides valuable insight into the thermal history of the ash and the bulk sample characteristics. The photographs also allow quick comparison of different samples and qualitative verification of particle sizing data.

Time Required for Particulate Sampling Runs. In the test plan meeting, SRI suggested that the sampling run time would be about four hours and that it should be possible to complete a set of inlet and outlet runs within a normal, eight-hour operating shift. A run time of four hours is required to collect sufficient ash in the five-stage cyclone assembly for the complete battery of ash characterization tests. The time required for the cyclone runs could be reduced when the ash characterization tests are not needed. The time required for the impactor runs depends directly on the outlet particulate loading. If the outlet loading is 10 ppm, the required run time is about four hours. With an outlet loading of 20 ppm, the required run time is reduced to about two hours.

With either the cyclone assembly or the impactor, SRI expects that about four hours out of the total turnaround time will be associated with connecting the sampler to the probe, bolting up the outer casing and packing gland, allowing the sampler to preheat prior to sampling, allowing the sampler to cool after sampling, disconnecting the outer casing, and disconnecting the sampler. There is not much that can be done to speed up these steps, but the turnaround time could be reduced from eight hours to six hours, if the outlet loading is at least 20 ppm and if no ash characterization is required. Four sets of runs can be completed within three operating shifts with faster turnaround. An even faster turnaround might be possible with higher outlet loadings or if the probe heats up faster than projected. A breakdown of the turnaround time is given below.

Step	Time required
Connect sampler to probe	15 minutes
Bolt up outer casing and packing gland	15 minutes
Insert probe and hold for heat up	2 hours
Sample with cyclone train or impactor	2 to 4 hours
Retract and hold for cooling	1 hour
Remove packing gland and outer casing	15 minutes
Remove sampler from probe	15 minutes
TOTAL TURNAROUND TIME	6 to 8 hours

The run time could also be reduced somewhat by sampling at a higher flowrate. (Our previous estimates have been based on a sampling rate of 1 acfm.) Increased sampling rates can result in particle bounce and reentrainment in the cascade impactor, leading to erroneous particle size measurements. SRI have designed the impactor stages for the lowest reasonable jet velocities to minimize bounce and reentrainment, and SRI does not recommend increasing the sampling rate.

Information Required to Specify DCS. DCS requirements for sampling probes and other monitors are summarized below.

DCS input, output, or component	Number
4 to 20 mA inputs (self-powered)	None
4 to 20 mA inputs (powered from DCS)	86
4 to 20 mA outputs	None
Type-K thermocouple inputs	None
Contact (digital) inputs	64
Contact (digital) outputs	22 (5 V & 0.1 A)
PID loops	None
Sequence-of-events inputs	None
Programmable logic controllers (PLCs)	6

The PLCs will be Parker Compumotor Model No. SX106-250. Each PLC will have an RS232C, serial, three-wire control interface to the DCS and an RP240 remote panel interface. The normal communications protocol between the PLC and DCS will be 8 data bits, 1 stop bit, no parity, and 9600 baud.

Information Needed for Hazops Review. For the hazops review, SCS asked SRI to provide updated P&IDs and operating procedures for the batch particulate sampling system. In response to this request, SRI revised the P&IDs for the batch sampling system to incorporate the probe insertion and rotation mechanisms. SRI also prepared two new P&IDs for the sniffers to be located upstream and downstream of the PCDs. The procedures for probe insertion and retraction are given in Exhibit B-1.

B.2 Particulate Sampling Equipment (Task 2.4.2)

During this quarter, SRI continued to work on the design of the particulate sampling systems and the evaluation of particulate monitors. Specific items that were addressed this quarter included: preparation of parts lists for the sampling and monitoring instrumentation, preparation of AutoCAD files for the cyclone manifold and cascade impactor, preparation of assembly and fabrication drawings, and revision of P&IDs. The work performed on each of these items is discussed below.

Parts List. SRI continued to work on the parts lists for the batch sampling system and for the real-time monitors. A preliminary version of the parts list for the batch sampling system has been completed. This parts list will be finalized, and the parts list for the real-

time monitors will be completed in October. The parts lists will include complete specifications and costs for all real-time monitors and all instruments in the batch sampling system. While gathering the required information on the real-time monitors, SRI is negotiating with the monitor vendors for the free use of the monitors during a trial period so that the usefulness of the monitors can be determined prior to purchase.

Cyclone Manifold. SRI worked with AutoCAD to resolve a problem with the meshing of the wire-frame drawing for the cyclone manifold. In late August, SRI was notified by AutoCAD that the problem was caused by a flaw in the SOLMESH algorithm. This flaw was known to cause incomplete meshing of complex geometries. In SRI's case, the flaw caused one of the manifold support gussets to be lost from the stereolithography (STL) file, resulting in a plastic model that was missing one gusset. AutoCAD representative informed SRI that AutoCAD would not be able to correct the problem. In September, SRI talked to several companies that make models and prototypes from STL files, and SRI identified a company that could correct our STL file and produce a complete model of the manifold. SRI issued a purchase order to SiCAM Corporation of Somerville, New Jersey to deliver a corrected STL file and a complete plastic model. SiCAM also agreed to send the model to Howmet, Inc., a foundry in the Chicago area, to get a quote on casting a prototype of the manifold. SRI will also obtain a quote for a single casting from Dolphin, Inc., a foundry in Phoenix, Arizona. The two quotes will be evaluated in terms of costs and technical considerations to select the foundry that will make the prototype.

After the prototype manifold is received, SRI will machine cyclones to fit into the manifold receptacles and lap the tapered sealing surfaces on the cyclones and in the receptacles. The cyclones will be sealed in the receptacles with the aid of a ceramic epoxy and an anti seize compound. The effectiveness of the sealing will be evaluated by testing the cyclone assembly in the SRI pilot combustor. SRI will also develop a wiring harness to retain the cyclones in the receptacles in the event that the seal is broken.

Cascade Impactor. SRI began to prepare AutoCAD drawings of the cascade impactor. The impactor unit will be designed with an integral bauxite cartridge in a manner similar to the design of the cyclone assembly. Most of the impactor stages will be similar to those used in Andersen Mark 3 cascade impactors manufactured by Graesby-Andersen. SRI plans to incorporate a precutter that was designed specifically for high-temperature sampling by SRI for the California Air Resources Board (McCain, 1993). Details of the impactor design will be finalized in the coming quarter.

Assembly and Fabrication Drawings. In August, SRI began work on the assembly and fabrication drawings for the back end of the sampling system. Work on the front-end components will be postponed until the design of the sampling port has been finalized.

There are about 91 components to be detailed. Some vendors have been selected, and SRI is negotiating with other vendors on modification of their standard products to suit PSDF needs. Preliminary drawings of the packing gland assembly and the back portion of the probe casing were submitted to SRI's machine shop for cost estimates. SRI expects to have all of the components detailed and all assembly and fabrication drawings done by first quarter of 1994.

Piping and Instrumentation Diagrams (P&IDs). In August, SRI began revising P&IDs to incorporate the probe insertion and rotation mechanisms and the PLC. SRI also created two new P&IDs for the inlet and outlet sniffers (surrogate filter and leak detector). The last round of internal reviews of the P&IDs was completed in late September. The P&IDs will be released in the next quarter. Preliminary copies of the revised P&IDs are shown in Figures 1 to 6.

B.4 References

McCain, J. D. Development of Particle Size Test Methods for Sampling High-Temperature and High-Moisture Effluents. Southern Research Institute. Final Report on California Air Resources Board (CARB). CARB Contract No. A132-084. April 30, 1993.

Figure 5. Piping and Instrumentation Diagram for Inlet Sniffer/Surrogate Filter
(SRI Drawing No. P7252-012.R0)

EXHIBIT B-1: Procedures for Probe Insertion and Retraction

Procedures for *Inserting* Particulate Sampling Probe

Note: P1, P2, P3, P4 refer to positions of sampler at various stages of insertion

N1, N2, N3 refer to solenoid valves in nitrogen purge lines

F1, F2 refer to solenoid valves in bleed lines to flare

See accompanying Figures 1, 2, and 3 for locations of valves and positions

1. Prior to insertion, both ball valves are closed, and Valve N1 is opened to purge the sampling port with nitrogen. Valves N2, N3, and F2 are closed. Valve V1 is open to prevent buildup of combustible gases in casing.
2. After checking to make sure there is no pressure in outer cavity, the packing gland flange is disconnected from the outer casing flange, and the probe is fully retracted as shown in Figure 1.
3. The sampler is bolted onto the end of the probe as shown in Figure 1.
4. The probe is advanced until the sampler reaches Position P1, and the packing gland flange is bolted to the outer casing flange, as shown in Figure 2. If necessary, the flange gasket and the packing gland are replaced before bolting up the flange.
5. Valve F1 is closed. Valves N2, and N3 are opened to pressurize the casing with nitrogen and check for leaks.
6. After verifying that there are no leaks, the first ball valve is opened, and the probe is advanced until the sampler reached Position P2.
7. Valve N2 is closed, the second ball valve is opened, and the probe is advanced until the sampler reaches Position P3.
8. Valve N1 is closed, and the sampler is allowed to remain at Position P3 to preheat.
9. After preheating the sampler, the probe is advanced until the sampler enters the process gas stream and reaches Position P4, as shown in Figure 3.
10. The flowrate of purge nitrogen through Valve N3 is reduced to 1 acfm, and the sampler is allowed to reach thermal equilibrium with the process gas.
11. After the sampler is equilibrated, the probe is rotated 180 degrees so that the sampling nozzle points into the gas flow, and sampling is started.

Procedures for *Retracting* Particulate Sampling Probe

1. Prior to retraction, both ball valves are opened, and Valve N3 is opened. Valves N1, N2, F1, and F2 are closed.
2. The probe is retracted until the sampler reached Position P3.

3. The sampler is allowed to remain at Position P3 until it cools to 600 F.
4. After verifying that the sampler has cooled sufficiently, the probe is retracted until the sampler reaches Position P2.
5. The second (innermost) ball valve is closed.
6. Valve N1 is opened to purge port, nitrogen flow through Valve N1 is increased, and nitrogen is allowed to flow through probe to purge probe.
7. Valve N2 is closed, and Valve F1 is opened to purge the space between the ball valves.
8. The probe is retracted until the sampler reaches Position P1.
9. The first (outermost) ball valve is closed.
10. Valve N3 is closed, and Valve F2 is opened to purge the outer cavity.
11. After verifying that there is no pressure in the outer cavity, the packing gland flange is disconnected, and the probe is fully retracted so that the sampler can be removed from the probe. Another sampler or a plug is placed on the probe and reinserted as described previously.

Figure 1 Particulate Sampling Probe and Insertion Mechanism (Shown with Flange Disconnected)

P1, P2, P3, P4 refer to positions of sampler at various stages of insertion

N1, N2, N3 refer to solenoid valves in nitrogen purge lines

F1, F2 refer to solenoid valves in bleed lines to flare

Figure 2. Particulate Sampling Probe and Insertion Mechanism (Shown with Flange Connected)

P1, P2, P3, P4 refer to positions of sampler at various stages of insertion

N1, N2, N3 refer to solenoid valves in nitrogen purge lines

F1, F2 refer to solenoid valves in bleed lines to flare

Figure 3. Particulate Sampling Probe and Insertion Mechanism (Shown with Probe Fully Inserted)
P4 refers to position of sampler in gas stream when fully inserted
N1, N2, N3 refer to solenoid valves in nitrogen purge lines
F1, F2 refer to solenoid valves in bleed lines to flare

APPENDIX C

DEVELOPMENT OF AN INTERACTIVE VIDEO TRAINING / ARCHIVING SYSTEM

APPENDIX C

Development of Interactive Video Training / Archiving System The Wilsonville Interactive Learning System (WILS Project)

C.1 Overview

August marked the official beginning of development of an Interactive Video Training/- Archiving system, the Wilsonville Interactive Learning System (WILS) project for the Power Systems Development Facility.

During August and September, planning, scriptwriting and interface designing began for Phase 1 deliverables (see summary below). Selection of the development platform was made and a Macintosh Quadra 840AV was purchased for use on the project. Because of its speed, the new unit will be used to produce graphics and animation; when not needed for that purpose, it will be used for interface development. Also, research and testing was performed on PSDF CAD file examples (Intergraph) to determine the most effective and cost efficient translation method for preparing animation and graphics in an Apple/Macintosh compatible format.

In June '93, a demonstration was held at Alabama Power Company on the use of interactive compact disc (CD ROM) systems for delivery of interactive video-based programs. The possibility and advantages of incorporating this new technology as a delivery system for the PSDF project was discussed. Since then, the decision has been made to proceed with a CD ROM-based delivery system (see "Proprietary versus Non-Proprietary Versions", and the discussion on cross-platform authoring software later in this report).

C.2 Summary Of Phase 1 Deliverables & Progress

A broad outline of Interactive Video Training/Archiving system is given in Exhibits C-1 to C-6. The attached "Phase 1 Flowchart" describes the planning and development to date on the Familiarization section. The Familiarization section presents only non-proprietary information.

As shown in Exhibit C-1, the front end of the program begins with an "Attract Loop" (#101 on the flowchart), which will continuously play a short montage of visuals from this section until the user clicks to advance to the Main Menu (#201).

"About WILS" (#301 on the flowchart) provides program users with information on WILS itself: the program's objectives, instructions on how to use the program and what the icons mean. A separate flowchart for "About WILS" has been included. A detailed script was submitted and reviewed by SCS. Many of the icons have been created, and development of the interface has begun.

The "Introduction" (#401 on the Phase 1 flowchart) provides the "what, where, why, and who" on PSDF. Using 3D solid modeling techniques and animation, program users will "fly-around" the facility for a bird's eye view. Through a series of interactive videotaped interviews, users can begin to learn about the facility, i.e., its importance, and what technologies will be tested there.

Thus far on the Introduction, a script was submitted and reviewed, and several of the graphics have been produced. A flowchart for the Introduction outlines the program flow and indicates branch-points for interactivity. One day of production either in Birmingham or at DOE/METC is needed for the interviews. This can be scheduled to coincide with the 50% design review and steering committee meetings in which all the project participants will be attending. To produce the fly-around, CAD files of PSDF are desirable; although not entirely necessary, these files would make the process more efficient and the end-product more accurate.

The "Technology Transfer Modules" (#501 on the Phase 1 flowchart) provide illustrated process descriptions for the APFBC train, the Transport Reactor train, and 3 PCDs in the HGCU area (see Exhibit C-5, the list of Tech Transfer Categories for a detailed breakdown). Within these 5 modules are numerous branch-points to deeper levels of information that the user can access as an option. These options are represented by a series of icons that appear on the interface when they are active.

As listed on the Phase 1 flowchart, the options include:

"Glossary"	shows narration in text form; allows the user to look up terms used in the program and their definitions.
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"You Are Here"	contains 2 views of PSDF for orientation purposes: an aerial view and a fly-around of the facility using 3D animation; the user can toggle between either view; each particular plant location will be highlighted
"Additional Views"	drawings or diagrams to be replaced with still photographs of equipment or areas when available.
"Chemical Reactions"	identifies and explains internal reaction/s using animation; also provides the formulas.
"P&IDs"	engineering drawings or diagrams.
"Process Performance"	text-based data or tables which will consist of projections initially and be replaced with actual data later; periodically updated.

Two scripts for the Technology Transfer Modules (APFBC and Transport Reactor) have been prepared and are being reviewed.

C.3 Authoring Software And CD ROM Development

A multimedia database is the preferred type of software to use for authoring the WILS program. A database at the heart of an interactive multimedia training application should increase efficiency and decrease the number and volume of paper documents. This will become important when changes in procedures (i.e., training content) are required.

The Macintosh system will be used primarily for development, program testing and verification; the primary distribution platform would be on interactive CD. Although the primary focus of the multimedia industry is on commercial applications, industrial and scientific applications such as the WILS project stand to benefit as engineers and technical administrators become familiar with what multimedia has to offer. The advantages of interactive CD-based systems are substantial: the new CD systems are much smaller, more portable, and cost far less than conventional multimedia systems. They are fully self-contained and do not require the use of an external computer: the software needed to run the program, along with the animation, video and other multimedia assets, is contained on the CD itself. The advantages of using a highly

portable, low-cost system for delivery of the WILS project are significant, especially when plant personnel will receive training.

C.4 Graphics Translation

CAD files (Intergraph) from SCS were received and tests were performed. Two file formats were sent: the native Intergraph format, DGN, and files converted by SCS into an alternative format, DXF. Although conversion to DXF from DGN adds to the size of a file, DXF is the only format that can be translated into a suitable Macintosh format that can be manipulated for animation and other purposes. As for the solid modeling (3D views), currently being done on PSDF by project participants, further testing is required to see if the 3D "attributes" can be translated without significant loss.

EXHIBIT C-1

WILS - PROPRIETARY VERSION

WILS - NON-PROPRIETARY VERSION

EXHIBIT C-3

**WILS Project - Technology Transfer Modules
5 Categories (non-proprietary)**

9/9/93

- APFBC (Foster Wheeler)

- HGCU
 - Westinghouse PCDs
 - F/W process
 - Kellogg process
 - IF&P PCD
 - CPC PCD

- Transport Reactor (Kellog)

access categories from simplified process flow
diagram (similar to PSDF Introduction, figure 1.1)

WILS - Tech Transfer Modules flowchart (Note - 3 PCD modules not shown)
9/21/93

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