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POWER SYSTEMS DEVELOPMENT FACILITY**QUARTERLY TECHNICAL
PROGRESS REPORT****JANUARY 1 - MARCH 31, 1994****Prepared by:**

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MASTER

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POWER SYSTEMS DEVELOPMENT FACILITY
QUARTERLY TECHNICAL PROGRESS REPORT
JANUARY 1 - MARCH 31, 1994

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1.0 INTRODUCTION AND SUMMARY

This quarterly technical progress report summarizes work completed during the last quarter of the Second Budget Period, January 1 through March 31, 1994, 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 particulate 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/Circulating Pressurized Fluidized-Bed Combustor 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 Reactor and circulating pressurized fluidized-bed combustor (CPFBC) particulate control devices (PCDs) into structural and process designs, and commencement of construction activities. The Transport Reactor Development Unit (TRDU) program at EERC was discontinued following initial success with operation of the reactor. Responses to DOE questions concerning the Continuation Application for the budget period 3 were submitted. Capital and bulk material costs were updated for submittal to DOE in early April. The project reached a nominal 50% design completion milestone, and a meeting was held on February 16 and 17 to review the status

of the present design and schedule of remaining activities. The PSDF design documents were updated prior to the meeting and distributed to all the participants.

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. The integration of PCDs in the MWK and FW portions of the process structure continued and detailed civil, electrical and mechanical design information was exchanged between PCD suppliers and FW, MWK and SCS.

The PSDF project was approved under NEPA, and site grading and preparation work commenced on September 21. Following site preparation work, tests were conducted to improve the foundation design. Erection of the warehouse/maintenance building is in progress. The contract negotiations between FW and its subcontractors are in progress and are expected to be completed during the next quarter. MWK progressed with the detailed design of the transport train, committing to vendor engineering drawings and procurement and fabrication of all major equipment. "Construction Issue" P&IDs will be issued next quarter for the transport train. The design hazard review of the MWK transport train was completed in January/February, and a report will be issued in April. The development of an Interactive video training/archiving system which incorporates all the PSDF modules was continued and considerable progress was made during the quarter.

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 PSDF steering committee met on January 12 and reviewed the current status of the project. This included the schedule, projected Budget Period 3 expenses, currently available funds and future appropriations and startup dates. The steering committee noted that the PSDF test program should take into account characteristics of particles and process conditions from Clean Coal Technology (CCT) projects. The committee also noted that the process and equipment design uncertainties that may require possible modifications during the first year of operation should be quantified. The next meeting is scheduled for July. Following the recommendation, the CCT projects were reviewed for data on proposed PCD operating conditions. The study was completed and presented at the 50% design review meeting. Potential cost related to equipment design uncertainties was obtained from MWK for the Advanced Gasifier train.

A 60-day no cost extension of Budget period 2 was granted by DOE. The Continuation Application for Budget Period 3 was submitted to DOE in early December. From a technical review of the application, DOE generated a list of questions and comments. SCS submitted responses to DOE in early March. Based on actual vendor quotes, most of the capital and bulk equipment costs were updated. The updated costs will also take into account all the process and equipment design changes that occurred since the last conceptual estimates were submitted in 1992. This information along with a detailed cash flow will be provided to DOE in early April as a revision to the Continuation Application. The cash flow for the entire project reaches a peak during Budget Period 3 which mainly encompasses procurement, fabrication, construction and installation. Currently available funds and future appropriations will have an impact on the construction and startup schedule of both trains.

The 50% design status review meeting was held on February 16 and 17, 1994. Meeting minutes and materials presented at the meeting were distributed. Responses to DOE questions on the 50% design documents are being compiled and will be issued in early April.

Negotiations with CPC on the PCD contract and Nolan Multimedia for the development of the Wilsonville Interactive Learning System were concluded and the contracts were signed. Negotiations between EPRI and SCS on participation agreements for the PSDF were also concluded and the agreements were signed. During the last quarter, negotiations between FWUSA and their subcontractors FWDC, FWEC, Westinghouse, and Allison continued. FWUSA's subcontract drafts were issued for the Turbine/Generator and Topping Combustor.

2.2 PHASE 1 - CONCEPTUAL DESIGN ACTIVITIES

2.2.1 Task 1.4 - Transport Reactor Development Unit

Minor maintenance work continued at EERC in January in the tower housing the TRDU. No further runs or data analysis was carried out pending resolution of funding issues. On January 28, EERC submitted a proposal which included cost and schedule for Campaign 1. The EERC proposal assumed pretest activities starting in February, tests taking place between April 1 and April 22, and data reduction/report preparation during April 25 - May 27. This proposal covered EERC's cost only, and did not include any MWK or SCS costs. Since the cost estimate was high, EERC was asked to provide a scaled down proposal with necessary pretest maintenance required for successful operation of Campaign 1. On February 10, EERC submitted a revised cost estimate which had some maintenance items delayed to a later date. While the delayed maintenance items need not be completed prior to the start of Campaign 1, they would have to be accomplished before Campaigns 2 and 3. The revised proposal envisioned Campaign 1 tests taking place between April 18 - 29, followed by data reduction and report preparation.

On February 16, a meeting was held between SCS, DOE, and EPRI to discuss the EERC proposal. After considering a number of aspects of the TRDU program and its projected impact on the PSDF transport reactor design, which was nearly complete, it was decided at that meeting that no further testing will be done with the TRDU. Following the meeting, SCS officially communicated the decision to EERC. Negotiations are ongoing between EERC and SCS to closeout the EERC contract.

2.3 PHASE 2 - DETAILED DESIGN ACTIVITIES

2.3.1 Task 2.1 - Detailed Design

2.3.1.1 MWK: PSDF Transport Train

The physical design of the transport train continues to progress now that equipment vendors have been released for fabrication. MWK has submitted all piping area plant layout studies to SCS and only piping Area "D" remains to be approved. Concurrently, several physical design reviews were conducted with SCS and some of the significant spatial relationships in the structure were noted. Personnel protection will be provided via personnel barriers. MWK will ensure that no low pipes are located on egress routes. MWK will provide sufficient maintenance lugs on spool pieces and will also look at rod out areas for access. Screw coolers will have a lay down area.

Several meetings were held during the quarter which identified and resolved design issues. A joint project technical review/constructability meeting was held between SCS, MWK, and the steel erection contractor, Steel City. Subsequently, a detailed review of the reactor erection plan was conducted. MWK and SCS had a meeting with SRI to resolve all issues relating to their sampling device and the resulting piping modifications have been incorporated into the design. Intergraph's Modelview CAD system is being used extensively to identify and resolve interference problems.

MWK participated in the 50% design review meeting and prepared responses to the questions raised by DOE. The materials of construction and the data sheets for the flow elements, control valves and rotameters were issued. A list of on-line instrumentation for heat and material balance calculations, a list of proprietary measurements and a preliminary nitrogen consumption profile were also issued. Work with the PCD vendors continued with drawing review and physical integration of the Westinghouse PCD into the process structure. The impact of a third cyclone to aid CPC's request for solids load reduction was reviewed by MWK and SCS.

Continuing efforts during the first quarter involved review of a number of vendor drawings, pre-inspection meetings with equipment vendors, preparation of an operating instructions manual (18% complete) for the transport train and obtaining relevant design information for incorporation of the CPC equipment into the structure. A schedule of remaining design activities is given in Appendix A.

2.3.1.2 FW Team Activities

The Phase II detailed engineering and Phase III procurement activities continued. The following activities were achieved in the last quarter:

A detailed engineering coordination meeting was held between FW and SCS. Process/systems engineering design of the plant, as well as detailed engineering, project control, and construction issues were reviewed. A number of items were resolved and action items assigned as needed, some of which are listed below.

- FW will interface with PCD vendors on detail design and process design, but coordination of all comments from FW/SCS to PCD vendors will be by SCS.
- SCS and FW will review the use of coke breeze for startup of the APFBC, to see if it is possible for the FW and MWK trains to utilize the same startup material. Coke feed system can then be finalized for both trains.
- The proposed modularization method of coordinating steel erection was discussed.

A group from SCS and FW visited the AEP Tidd facility on February 22 with a long list of questions and learned from AEP's experiences. A detailed session was held to discuss issues important to the PSDF team, and an extensive tour of the facility was conducted. A summary of the Tidd Trip Report is included in Appendix B.

FW and SCS reviewed the APFBC process logic description and interlock documents in the 50% Design Document. Also, Rev. B of the FW P&IDs was reviewed and additional instrumentation required for operability, performance evaluation, and heat/material balance closure were identified. Work on updating the FW P&IDs continued throughout the reporting period. The Overall Plant Control Philosophy document for the APFBC system was revised and issued by FW to SCS. In addition, the FW nitrogen flow requirements document was revised and issued to SCS. These documents are included as Appendices C and D. FW also issued updated piping material specifications, plot plans, and the instrument reference schedule, as well as an updated sampling PFD, sampling list, and utility summary tabulation.

FW defined the Topping Combustor injection steam quality requirements. The space requirements for the transport air compressor was determined. Integration of the SRI sampling equipment in the FW detail design continued, including review and discussion of physical locations of sample points, required structural steel support, nozzle details, instrumentation and electrical wiring, P&IDs, and utility interfaces.

A review of FW's electronic PDS model of the APFBC system was jointly conducted by FW, SCS and SRI. A number of comments were noted on the model, such as steel and piping interferences, accessibility for operations and maintenance, space for future additions or modifications, and location of safety showers and eyewash stations.

SCS and FW reviewed a number of process issues. Quenching of bypass gas from the syngas and vitiated air streams to allow use of cold valves and deletion of refractory lined pipe was proposed and are being reviewed. Char transfer system modifications were proposed and are being reviewed, which deletes DR0258 and provides simpler operation. Flow measurement of the carbonizer fuel gas and CPFBC flue gas streams will be incorporated at suitable locations. Westinghouse requested that a nozzle be included for the introduction of tempering air upstream of the CPFBC PCD inlet. A nozzle will be provided. A proposal was received from Westinghouse for development of a special optic fiber thermocouple for direct measurement of the Topping Combustor rich zone temperature. After review, SCS requested that if direct measurement of the rich zone temperature is required, either a conventional method of temperature measurement be used or separate funding be acquired for development of the optical measurement.

A detailed project schedule of remaining design, engineering and procurement activities for the APFBC train is given in Appendix E.

2.3.1.3 Balance-of-Plant Activities

SCS met with SRI and FW to discuss sampling requirements. SCS will provide structural steel at the support locations of the SRI probes. This will consist of a solid surface such as plate steel to accommodate a spring can. SCS will either install a monorail over these probes, or design the floor steel above to allow the probe ball valves to be maintained. SCS provided computer models to MWK and FW to be used in the project review of the process structure. FW and MWK located their equipment into the structure and meetings were held to review the layout of the equipment in the process structure.

The nitrogen system requirements were revised by FW, MWK and the PCD vendors to require a purity of over 99%. This means that the membrane system which was in the conceptual design of the nitrogen plant will now be replaced with a cryogenic system. Initial contacts have been made and budgetary information has been received from nitrogen vendors. Nitrogen consumption requirements are being finalized for all project participants.

The feasibility of several options concerning the compressed air system are under investigation: 1) the use of air to back-pulse the large Westinghouse PCD (preliminary indications are that the capital cost may be too high); and 2) use of enlarged nitrogen plant air compressors to accommodate the plant and instrument air requirements.

The conceptual design of the ash handling system will be modified. In the conceptual design, ash disposal at the Plant Gaston landfill was assumed. Since this landfill is not currently in use, the ash must be shipped further for disposal. Two possibilities exist, one located near Moody, Alabama (~40 miles) and another located in Walker County (~65 miles). To minimize dust, water will be added to the ash prior to shipping. With the increased shipping time, the ash would harden before reaching the disposal site and thus prevent removal from a dump truck. Although tentative, current plans call for the ash to be wetted and stored on a concrete pad until it is hardened, broken up with a front end loader, and then loaded on a dump truck for shipping to the final disposal site (similar in procedure to that followed at AEP Tidd).

The sizing and design of system piping for undergrounds has continued. Blowdown for cooling towers, make-up water to the cooling towers, building drains and utility island drains have been conservatively sized for underground installation at this time, since final flows are not yet available. The underground drawings are scheduled to be completed and issued for construction in April.

The design of the fire protection system continues. The underground drawings were completed and will be issued to construction the first week of April. Work has begun on the new pumphouse layout and the new location of the existing firewater supply tank.

The diesel drivers on the firewater pumps were started and serviced and found to be in excellent running order. The firewater pumps were checked and also found in excellent running order.

A major milestone was accomplished for Instrumentation & Controls in the issue of a purchase order for the DCS for PSDF. The Foxboro Company was the selected vendor. The purchase request is presently for engineering only with a planned release for manufacturing within 60 days.

2.3.1.4 Process Hazard Review

A Design Hazard Review (DHR) of the Advanced Gasifier Train was conducted in January. The hazard review team members included MWK and SCS engineers. The DHR was continued in February with the feed and char transport portions of the process. A Simon Air Systems representative participated during the latter review. The review methodology was based on the "What-If" technique augmented by a guideword checklist and was performed in accordance with the guidelines published by the Center for Chemical Plant Safety (CCPS) of the American Institute of Chemical Engineers (AIChE). The objective of the review was to identify and assess the risks of potential hazards, and make recommendations based on the results of the review. A secondary objective was to identify potential equipment hazards from operability events and deviations and recommend resolutions for the identified operation problem. The DHR work plan for the transport train, submitted with the previous quarterly report, was followed during the review. A draft report on the DHR findings is to be issued in April.

SCS began the process of defining the requirements of a process hazard analysis for the FW process, PCDs and the balance-of-plant. Several safety consultants were contacted to obtain input concerning scope, procedures and documentation requirements. A bid package for a process hazard analysis consultant is being prepared and will be issued in the middle of the next quarter. Based on the current status and anticipated design progress in both the FW train and balance-of-plant areas, the DHR is scheduled for the beginning of the third quarter.

2.3.2 Task 2.2 - Facility Design Document

The PSDF design documents were updated with material received from all participants and submitted to DOE and EPRI for review. After review, DOE submitted a list of questions, and responses are being prepared. A 50% design status review meeting was held on February 16 and 17. All project participants participated in the meeting and made presentation as to the status of their current design and schedule of remaining activities. Presentation material and meeting notes were distributed.

SCS reviewed the process logic description and interlock documents in the 50% Design document, and provided comments to FW. Also, Revision B of the FW P&IDs in the design documents were reviewed and additional instrumentation required for operability, performance evaluation, and heat/material balances were identified.

2.3.3 Task 2.3 - Environmental Permitting and NEPA Support

Regular PSDF site visits and inspections were performed during this quarter. On February 10, stormwater runoff samples were collected from the construction site in accordance with requirements of the NPDES Stormwater Construction Permit. The samples were submitted to a local laboratory for analysis and the results were forwarded to the Alabama Department of Environmental Management (ADEM) on March 18 in the Discharge Monitoring Report. No significant erosion or pollution runoff problems have resulted from the site preparation. Slopes and conveyance passages have been hydroseeded and the grass has become well established and minimizes erosion problems.

Visits were made to two local subtitle "D" landfills that serve the Shelby county area. Each will be evaluated as a possible site for disposal of the PFBC ash. These facilities meet the new EPA requirements for landfills and are permitted to accept non-hazardous waste. One facility is 40 miles from the plant and the other is 65 miles away.

Two PFBC ash samples were received from Foster Wheeler's Livingston Facility. One is from bituminous coal operation and the other is from subbituminous operations. SCS was informed that the subbituminous sample was not representative and that a replacement sample would be sent. These samples will be submitted for laboratory analysis and the results should be helpful in ash disposal considerations.

On March 24, SCS attended a meeting on in-situ calcium-based sorbents at DOE/METC. The emphasis was on chemistry, disposal, and regulatory issues pertaining to fluidized bed combustion ash. The sulfide to sulfate conversion reaction was discussed extensively and is a significant concern in view of the stringent EPA reactivity test for sulfide. Another concern brought out was the potential inadequacy of the reactivity test as it is applied to usually highly caustic coal ash waste. The coal ash caustic compounds can neutralize the acid thus interfering with release of sulfide that may be present. The testing and disposal issues need further discussions.

Work has begun on gathering necessary information for the NPDES permit application. A six month review period by ADEM is customary before approval. SCS holds the NPDES permit for the Clean Coal Research Center in Wilsonville. A permit modification to include the PSDF discharge requirements will be submitted to ADEM for approval.

2.3.4 Task 2.4 - Particle Characterization and Collection

SRI's work this quarter focussed on the revision of their P&IDs, the design of the cyclone manifold and cascade impactor, the preparation of fabrication and assembly drawings for the sampling system components, and coordination with MWK and with FW on a variety of interface issues. SRI's P&IDs were revised to include references to appropriate MWK and FW drawings for supplies of nitrogen, air, and water and for discharges to the thermal oxidizer, flare header, and vent header. Other P&ID changes included the addition of NEMA enclosures for instruments in the MWK part of the process structure; the addition of cutoff valves in cooling water supply lines; the addition of check valves in discharge lines to the thermal oxidizer, flare, and vent; and the replacement of nitrogen with air in all pneumatic actuators.

Design drawings for the cyclone manifold were submitted to SiCAM Corporation of Somerville, New Jersey and to Dolphin, Inc. of Phoenix, Arizona. Based on the SRI drawings, SiCAM and Dolphin created solid models of the cyclone manifold in their CAD systems. SRI met with Dolphin to inspect their CAD model and to discuss the casting process. Dolphin is now in the process of casting a prototype manifold. On March 16, SRI and SCS met with SiCAM to inspect SiCAM's CAD model. After approval of the CAD model, SiCAM produced a plastic model of the manifold, which is now being inspected at SRI. The fabrication and assembly drawings for the sampling system components were completed and submitted for bids.

SRI participated in engineering coordination meetings with MWK in Houston on February 24 and 25 and with FW in Livingston from March 14 to 16. The purpose of these meetings was to define and coordinate all interfaces between SRI and MWK and between SRI and FW. The meetings focused on SRI's requirements for utilities (air, water, and nitrogen); nozzles (size, number, and location); platforms and working space; electrical and signal wiring; and supports for the batch sampling system. At the meetings, SRI gave MWK and FW tables of utility requirements for all sampling and monitoring locations. SRI recommended that two of the sampling systems on the MWK train be relocated to improve access to the samplers and packing glands. As suggested in the meetings, SRI supplied to MWK and to FW recommended internal diameters (I.D.s) and projections for all SRI nozzles and electrical wiring details for all SRI sampling and monitoring systems. MWK and FW agreed to specify supports (spring hangers or spring cans) for the SRI batch sampling systems based on loads to be supplied by SRI.

2.3.5 Task 2.5 - Particle Control Technologies

Design issues associated with PCD interchangeability between the two trains at the PSDF are being addressed with PCD vendors, FW, MWK and SCS. SCS issued a scope of work to MWK and FW for estimation of engineering costs to accomodate, at present, any design changes that may be necessary to interchange the IF&P PCD with the Westinghouse Transport Reactor PCD at a later date.

Combustion Power Company PCD for Transport Gasifier

CPC submitted a heatup schedule of the granular bed filter (GBF). At an operating pressure of 50 psig, the filter is below the dewpoint for the first 2-4 hours of heatup, and the baghouse is below the dewpoint during the first 6-8 hours of startup. It is possible that even with the baghouse above dewpoint, condensation could occur in other parts of the filter system. CPC would prefer that the GBF not receive particulate laden gas if there is moisture in the filter system, even though this has been successfully done in other filter installations. CPC would like MWK to consider delaying the injection of solids into the transport reactor until at least the tenth hour of startup to allow the granular bed filter to reach temperatures above the condensation temperature. MWK is considering alternative means of providing startup heat to the CPC unit.

Formal specifications were issued for major vendor items, and by the end of March, nearly complete responses to formal specifications were received. CPC is close to choosing suppliers for the packaged recuperative heat exchanger, gas/air heat exchanger, the baghouse, and the boost blower. A few references still need to be checked on the baghouse, and some details need to be settled on the other equipment. A summary discussion of boost blower and recuperative heat exchanger designs that took place during the quarter follows:

Boost Blower: A study was essentially completed that considered a change to a boost blower that operates at 400-500°F instead of a blower that operates at 250°F. Basically, the cost for the higher temperature boost blower was much higher than that originally estimated by the vendors, making this option less attractive. On reconsidering the lower temperature boost blowers CPC found that the temperature range could be extended up to 275°F at the inlet; well above the condensation point. While CPC has not officially made a decision, pending review of formal quotes for the lower temperature blowers, it is likely that the choice will be between one of the suppliers of the lower temperature, lobe-type blowers. Comparisons were made between positive displacement, lobe-type units that operate at about 250°F and a centrifugal unit that operates at 400-500°F.

Recuperative Heat Exchanger: The design of the recuperative heat exchanger evolved during this quarter. Early quotes were for designs using small diameter tubes and low gas velocities. Review of parameters needed for a successful design indicates the need to limit the tube size to 2" or larger and limit velocities to 50-65 ft/sec. The chosen configuration is a pipe-within-a-pipe type heat exchanger 300' in length in three 100' sections. Dirty gas is cooled inside a single 3" pipe and clean gas is reheated inside a 6" pipe surrounding the 3" pipe. The gas/air heat exchanger is 70' long. Revised bids were received in late March and early April. This configuration is shown on CPC's general arrangement drawing. CPC's approach to a commercial granular bed filter includes a recuperative heat exchanger of similar configuration, with the exception of tubesheets to support multiple tubes.

Filter inlet design sketches were revised in response to discussions with MWK in which the configuration of the inlet ducting was clarified. MWK ducting at the inlet is 30" with an 8" refractory ID. The filter inlet is designed to allow for thermal expansion between the filter internals and the pressure vessel enclosure. A similar configuration has been reviewed by CPC's welding consultant and a potential refractory contractor. GBF detailed design drawings have been started.

Design drawings were issued for the major pressure vessels. These drawings were transmitted to SCS and MWK, including:

- The general arrangement drawing, showing how the filter system is situated in the structure. This drawing has been updated to show the larger filter vessel and the recuperative heat exchanger.
- The granular bed filter assembly, showing the updated filter vessel with the refractory and internals. The pressure vessel drawing was also issued to define the exterior configuration of the filter and the weights. Drawings for the metal internals and the refractory configuration were also completed.
- The de-entrainment vessel assembly, showing the fully developed configuration of this item. Included was the pressure vessel configuration drawing giving the external dimensions and weights. Drawings for the metal internals and the refractory configuration were also completed.
- The media make-up hopper, showing the configuration of this hopper that is used to collect excess filter material and to receive additional filter material as needed.

Of significance, the changes that were made to the P&IDs include the following:

- The gas/air heat exchanger was shown in series with the recuperative heat exchanger. This allows flexibility to operate within the wide envelope defined by the proposed test conditions. It also helps to protect the baghouse from over-temperature in case of unexpectedly high heat exchanger fouling. A cooling air fan was added to provide cooling air.
- A cooling water bypass was added across the water-cooled heat exchanger. On turndown, the water outlet temperature will increase above the 120°F limit; although, the water flow will be very slow. The bypass will mix inlet water at 95°F with hot water to insure water returning to the cooling water system is not above 120°F.

Detailed mechanical design of the refractory lined equipment (which includes the filter, de-entrainment vessel, media add hopper and refractory lined pipe) are being addressed. Enough vender information is now available for a meaningful update of the loading diagram. The electrical drawing package is being updated. Target date to release these drawings and the loading diagram is April 15, 1994.

Industrial Filter & Pump PCD for the Carbonizer

Industrial Filter & Pump has recently subcontracted the participation of Stanton Energy Industry Consultants, Inc. (SEIC) of New Stanton, PA to assist in the detailed design aspects of the IF&P PCD. Specifically, the SEIC group will focus on finite element analysis (FEA) of the ceramic tubesheet, ceramic hold down plate, and other critical internal ceramic components of the PCD, as well as sealing, gasketing, and overall high temperature design considerations.

Because of the unique design of the IF&P PCD, which incorporates an inlet pipe passing downward through the tubesheet into the filter candle section of the vessel, two separate flow modeling approaches have been undertaken. With the assistance of DOE/METC, a mathematical model has been developed defining the PCD operation, using all process parameters (such as gas flow rate, particulate loadings, temperature, pressure, etc.). By utilizing a FLUENT software package, the flow characteristics of the gas, as well as the particle trajectories within the PCD unit, are currently being evaluated at METC. The model is capable of alterations to permit changes in PCD design, so as to optimize the flow characteristics within the filter.

A second flow modeling approach is underway at IF&P's R&D facility. Through the use of an existing flow visualization test rig, several filter candles will be tested using a tubesheet and inlet pipe arrangement similar to the full size PCD. Testing will be accomplished at ambient temperature, and slightly elevated pressure, using dust having characteristics similar to the carbonizer dust envisioned at the PSDF facility. Pressure differentials and dust cake formation will be evaluated during this flow modeling test series.

In addition, a separate test series involving a complete cluster of 13 filter candles is underway at IF&P. This testing uses one of the Valtek Mark One jet pulse control valves to be used on the full-scale PCD, in an effort to optimize the jet pulse plenum design, as well as other jet pulse operational parameters, at conditions involving actual valve response times. In this test series, pressure differentials on the dirty side, clean side, and in other areas of the PCD will be monitored, as well as pressure transients within the bore of several of the filter candles. The data generated will be used to assess the proportion of jet pulse cleaning gas actually reversed through the candle to effect candle cleaning, under various conditions of operation.

IF&P is in the process of evaluating various approaches to the ceramic tubesheet fabrication process. Samples are being tested, using non-destructive and destructive (i.e., modulus of rupture) test methods, to determine which approach yields the optimum strength characteristics. The tests are being performed on samples before and after temperature exposure cycles to determine any changes in geometry and strength which

might result. Similarly, filter candle development is on-going as a function of this project, as a result of in-house and SBIR research efforts.

The inlet piping and jet pulse plenum for the PCD are two of the more critical components in terms of high temperature durability, strength, and corrosion resistance. In both instances, the components must exhibit high strength, low weight, low thermal expansion, and excellent thermal and corrosion resistance. In the case of the jet pulse plenums, a high degree of thermal shock resistance is required; in the inlet pipe application, erosion resistance is essential. After researching many different ceramic materials, it was concluded that a continuous fiber ceramic composite material (CFCC) would be most desirous in both instances. Amercom, Inc. of Chatsworth, CA, has been contacted to assist in the design, engineering and fabrication of these various critical components, which is underway.

The use of ceramic fiber blanket insulating material in the PCD is currently being investigated, in the clean gas area (discharge) of the vessel, as well as the area surrounding the filter candles. The ceramic filter blanket insulation is light weight, highly efficient, less expensive, easy to install and repair, and will not crack, spall, etc. as may happen with traditional refractory linings. Because of the low velocities in the area surrounding the filter candles, ceramic fiber blanket material may be well suited for this application. In the upper (clean) section of the PCD, where gas velocities are low and little particulate matter will be present, ceramic blanket material is ideal and will allow easy access to tubesheet supports, etc., during scheduled maintenance. Because the blanket material can be made rigid or toughened to add strength and prevent any scaling or erosive damage, the rigidized approach is being evaluated and will most likely be used in the area where the blanket is in contact with dust. The cone bottom section of the PCD, however, will incorporate a gunnited layer of hard ceramic refractory material in order to support the ash prior to discharge from the PCD.

IF&P has interfaced with SCS as well as FW in an effort to finalize the nitrogen consumption requirements for the PCD. A revised utility specification will be forthcoming shortly. FW has advised that the carbonizer ash has excellent flow characteristics, hence ash removal from the 70 degree included angle cone bottom of the PCD vessel is to be accomplished by gravity. The cone bottom will have a 30" flanged opening (13.5" clear bore opening), instead of the original 24" flange (7.5" clear bore opening), to permit better ash flow characteristics out of the PCD. The hard refractory lining in the cone bottom of the vessel will be coated with either an oxidation resistant grade of boron nitride, or a similar but more chemically stable coating (such as "Slip-Cote™"), to prevent dust adhering to the lining.

Provision for the possible future addition of high pressure, high temperature air cannons, manufactured by Martin Engineering Corp., has been made in the PCD design. The air

cannons consist of a pressurized chamber which quickly releases a finite volume of compressed nitrogen through a "fan-jet" distributor, to dislodge any accumulated ash in the cone bottom section of the PCD. A "Y-connection" is used between the device and the PCD to prevent excessive heat transfer back to the cannon. Three vertically staggered flanged connections, positioned at 0, 120 and 240 degrees around the cone bottom of the PCD, will be provided for future mounting of the air cannons, if required. The staggered pattern allows for a sweeping action to eliminate any ash clinging, bridging, or rat-holing in the cone bottom, through the use of timed sequential operation of the cannon. Nitrogen will be used to operate the cannons, the additional requirement for which has been accounted for in the PCD utility specifications.

Westinghouse PCDs for Transport Gasifier and CPFBC

The schedule for the Westinghouse PCD's has been adjusted by SCS to provide delivery of FL0301 by February 13, 1995 and FL0352 by April 17, 1995. The program to deliver the PCDs has been organized in six main tasks. The revised schedule is shown in Figure 1 (page I-1).

Design basis, interface points and major equipment layout physical locations, DCS and utility requirements have been completed for both PCD 301 (FL0301) and PCD 352 (FL0352) and accepted by SCS and MWK for FL0301, and by FW for FL0352. Drawing 2D29758 (page I-2) shows the process flow diagram for FL0301 and drawing 2D29759 (page I-3) shows the same for FL0352. The design basis for both are summarized in Table 2-1.

Table 2-1**DESIGN BASIS FOR THE TWO WESTINGHOUSE PCDS FOR THE PSDF**

	FL0301	FL0352
Design Gas Temperature - °F	1800	1650
Design Gas Pressure - psig	350	300
Design Gas Flow - acfm	1000	6200
Pressure Vessel Design - for both	ASME Code Section VIII Div 1	
Design Gas ΔP (psi)	4 - 7	4 - 7
Design Gas ΔT (°F)	<40	<15
Process	MWK Transport Reactor	FW APFBC
Operational Mode	Gasifier/ Combustor	Combustor

The major interface to the processes are by flanged connections which are specified below:

For FL0301:

Connection	Connect to MWK Pipe #	Nozzle Specification	Bore Size
Ash Outlet	PMsP-003	30", 300 lb API 605	12", SS Liner
Gas In	PM-04	30", 300 lb API 605	9", SS Liner
Gas Out	PM-06	26", 300 lb API 605	9", SS Liner

For FL0352:

Connection	Connect to FW Pipe #	Nozzle Specification	Bore Size
Ash Outlet	LP1004	36", 300 lb, API 605	14", SS Liner
Gas In	LP1001	36", 300 lb, API 605	18", SS Liner
Gas Out	LP1002	36", 300 lb, API 605	16", SS Liner

The location of the filter vessel FL0301 and its back pulse and instrument skid FL0301-ME01 are shown on the plot plan drawing 2D29747 (page I-4) and the isometric plot plan drawing 7214C77 (page I-5). The plot plan drawings show the need for SCS to provide a wall extension at elevation 218 ft to prevent heat from the transport reactor from affecting the skid and also the need to provide various access platforms to service the inspection and instrumentation nozzles. The maintenance requirements for both PCDs require disconnection of the pulse pipes, removal of the access grating and the dome and the lifting of the tubesheet cluster assembly via the overhead crane. This is shown for FL0301 on drawing 7214C78 (page I-6).

The siting of FL0352, its back pulse skid (FL0352-ME01) and its instrument skid (FL0352-ME02) are shown on the plot plan drawing 2D29762 (page I-7) and the isometric 7214C95 (page I-8). The back pulse skid (-ME01) is located on a platform at elevation 248 ft. The instrument skid (-ME02) is located closer to the vessel at floor elevation 218 ft.

Additional platforms to access inspection nozzles have to be built and a drawing indicating their location will be supplied to SCS.

The detailed design of FL0301 is proceeding according to the schedule shown in Figure 3 (page I-9). The vessel design, and the back pulse and instrumentation P&IDs have been completed. Detailed design of the back pulse and instrument skid (FL0301) are in progress prior to vendor selection. The vessel drawings and specifications have been completed and Westinghouse is ready to begin the vendor selection process.

The detailed design of the PCD for the transport reactor - FL0301 - has incorporated within it all the changes and modifications detailed in the first quarterly report as well as issues raised at the 50% design review. The latter raised inspection and access issues which resulted in the addition of a row of inspection nozzles and increasing all instrumentation and inspection nozzles to a minimum 6" flange size. These changes will permit inspection and cleaning (if required) of the tops of the candles in each plenum

array and inspection and cleaning (if required) of the region between the dust cone on top of the lower plenum and the bottom of the top array of candles.

A dimensioned outline of the vessel is shown in drawing 1478E28 (page I-10) and a cross sectional view of the vessel showing insulation and liner are shown on drawing 1477E46 (page I-11). Nozzle identification and specification drawing 1477E45 (page I-12) shows the purpose to which the various nozzles will be put. Detailed panel, wiring and interconnect drawings are being prepared now and will be supplied to MWK/SCS.

Westinghouse is designing the internals for FL0301 to hold 80 candles and designing the hot metal structure to operate at 1800°F. Operation of the uncooled metal structures at 1800°F however, may be limited due to material creep properties. An estimate of the allowed hours at 1800°F combined with the three year's design life is currently in progress.

The detailed design of the PCD for the FW APFBC combustor, FL0352, was started after that for FL0301, and is on schedule as shown in Figure 4 (page I-13). The detailed design should be completed by July 1994. The detailed P&IDs have been completed and transmitted to SCS/FW for comment and approval. The design has been modified from that in the proposal to incorporate all of the lessons learned at AEP-Tidd and at Karhula as detailed in the last quarterly report, as well as the modifications suggested at the 50% design review. The vessel details and internal layout utilizing 270 candles are being prepared. The general process and instrumentation scheme is similar to that for FL0301. However, the back pulse arrangement is somewhat different being akin to the arrangement used successfully at AEP-Tidd and is more representative of larger installations. The design is based on pulsing with 3" solenoid valves as opposed to the 2" valves originally proposed by Westinghouse. The larger valves will provide more cleaning power. The ultimate choice of which valve to use will depend on the results of tests ongoing at STC on the 3" valve. That testing should be complete by June 1.

2.3.6 Task 2.8 - Experimental Test Plan

Project participants were requested to provide commissioning (shakedown and characterization) test plans, an overall test study plan (for implementation during normal operation), test rationale, test matrix and evaluation plans for their equipment and process. The information received from the participants was issued to DOE and EPRI for review prior to the 50% design status review meeting. Each participant presented the test plan for their equipment/process at the review meeting. These test plans are being used to develop an integrated test plan for the facility.

SRI began gathering PCD related information from various Clean Coal projects. The tests at the PSDF will be aimed to support such projects. The results of SRI's survey of

particulate cleanup conditions at Clean Coal projects was presented at the 50% design review meeting and was attached with the February monthly report. The parameters included in the survey were: the type of gasifier or pressurized fluidized-bed combustor; the type of coal; the number of cyclones ahead of the particulate control device (PCD); the PCD temperature, pressure, and face velocity; and the loading and mean particle size of dust entering the PCD. The survey revealed that the plans for most of the clean coal gasification projects called for operation of the PCDs at temperatures that were below the lowest PCD temperature planned for testing at the PSDF (i.e., below 1000°F). The range of particle loadings planned at the PSDF appeared to cover the range of loadings expected at the clean coal projects. The one exception was the relatively low particle loading produced by the Tidd PFBC before the cyclone performance was spoiled.

2.4 PHASE 3 - CONSTRUCTION, PROCUREMENT AND INSTALLATION

2.4.1 Task 3.1 - Procurement

Review of vendor engineering drawings has continued during the quarter. MWK has issued purchase orders for all major pieces of equipment. Drawings for vendor "buy-out" material (primarily instrument and electrical components) are beginning to arrive. Pre-inspection meetings with each of the vendors are being conducted to assure that all the Kellogg-required inspection hold points are identified; the vendor's obligations for documentation are understood; and there is full understanding by the fabricator as to the requirements of the purchase order. The equipment vendors have been released for material purchase and fabrication of equipment. Purchase orders for the transition pieces, PDV-384 and refractory lined pipe have not been issued. MWK Procurement Status Report is given in Appendix F.

SCS released FWUSA to proceed with procurement of the following equipment: Carbonizer RX0251, Combustor RX0252, FBHE PG0251, Topping Combustor BR0451, Gas Turbine GT0451, and Booster Air Compressor CO0251. Inquiries were issued for all equipment items and lined pipes, and bids received for a number of equipment items. The following bid tabulations were prepared by Foster Wheeler and issued to SCS for review and approval:

- 100 Carbonizer Cyclone CY0251
- 101 Flare BR0251
- 102 Baghouse Fan BL0251
- 103 Fugitive Dust Baghouse FL0253
- 104 Surge Hopper Vent Filters FL0254 and FL0255
- 105 Carbonizer and Combustor Burners AH252, AH253, and AH254

- 106 Drums DR0251, DR0252, DR0253, DR0254, DR0255, DR0256, DR0257, DR0260A, DR0260B, DR0264, and DR0265
- 107 Baghouse Bottoms Valve VL0258 and Coal Diverter Valves VL0259 and VL0260
- 108 Screw Cooler FD0256
- 109 Shell & Tube Heat Exchangers HX0251 and HX0256
- 111 Surge Hoppers HO0252 and HO0253

FW issued an estimate of the quantity and associated cost for "bulks" - piping and valves, instrument, and electrical. Job specifications were issued for induction motors, vendor piping for mechanical equipment, and packaging requirements for mechanical equipment. Additional inquiries issued by FWUSA were:

- 110 Screw Feeders FD0251, FD0252, and FD0253
- 112 Alkali Getters AG0253 and AG0254
- 113 Carbonizer RX0251, Carbonizer Drain Drum DR0258, and Char Cooler HX0255
- 114 Booster Air Compressor CO0251 and Transport Air Compressor CO0252
- 115 Bypass Valves VL0262, VL0451, VL0452, VL0263, and VL0264
- 116 Refractory Lined Pipe

An updated FW APFBC System Equipment Delivery Schedule is included in Appendix G. This was based on scheduling specification package issue, approval, inquiry package issue, bid evaluation, purchase order release, vendor drawing approval and expected fabrication time allowance.

2.4.2 Task 3.2 - Site Preparation

Site preparation was completed in December.

2.4.3 Task 3.3 - Construction and Installation

Russo Construction of Birmingham arrived on site to install the load test drilled pier. A 30" (nominal) diameter reinforced concrete drilled pier was installed 20' deep in the common bay area of the process structure. An Osterburg load cell was installed in the bottom of the test pier along with associated instrumentation. A report on the load test was received on 2/21/94. Information from the test report was incorporated into the design. The concrete cylinder breaks for the drilled pier load test were performed by Alabama Power Company (APCO), and averaged 4500 psi at 24 hours.

Meetings were held with MWK and FW to discuss the construction philosophy for modular construction of the PSDF. The sequence of construction was identified by bays and elevations. Since the equipment will have to be installed as the building is erected, the equipment delivery schedule will have to support the proposed construction schedule.

A joint constructability/project technical review was held with SCS, MWK and the site steel erection contractor, Steel City of Birmingham. Subsequently, a detailed review of the transport reactor erection procedure and sequence was conducted. As the review with MWK progressed, an outline construction plan for the entire structure was developed. This plan involves modular construction which allows the majority of assembly to be made at ground level, providing advantages in both construction and safety aspects. MWK equipment will be rough set to elevation 218 ft in the structure provided FW equipment is rough set at least to the 152 ft elevation. If FW equipment is not available at that time, equivalent ballast or dead load may be used temporarily. A step by step review of the MWK reactor loop erection procedure and sequence was also held during these meetings. An erection procedure and sequence plan for all refractory lined equipment in the gasifier train will be completed by MWK by early May. A preliminary draft plan is attached in Appendix H.

Action items from the FW constructability meeting included: 1) FW to provide to SCS any special field storage requirements/instructions for their equipment or refractory piping; 2) FW to provide the requirements for erection of the combustor in the field. It is planned for the combustor to be bolted together in the field. FW to review if the combustor can be bolted together on the ground and lifted into place as a unit; and 3) FW to rework J-valve piping to the combustor to allow the floor steel at elevation 208'-0" to be located normal to the FBHE rather than at 45 degrees.

Sunbelt Construction mobilized the week of March 17 to erect the Maintenance/Warehouse Building at the site. They began working on forms for the base slab, but will not start excavation for the concrete slab until April. The Coal Handling Structure structural steel drawings were issued 3/25/94. They will be sent to Qualico Steel Fabricators for shop drawings to be started.

A list of the most current equipment delivery dates from MWK, FW, SRI and PCD suppliers has been compiled for incorporation into the SCS construction schedule. An integrated construction schedule has been prepared. MWK provided a bulk material break down from the First Cost estimate to assist SCS in defining the construction scope.

2.4.4 Task 3.6 - Preparations for Operations

Wilsonville Interactive Learning System (WILS)

The WILS project is an extremely innovative interactive multimedia application for documenting the experience and knowledge gained at the PSDF through a vast storehouse of well organized visual, audio, and text-based information. When completed, WILS will contain a series of Technology Transfer Modules to provide highly usable, visually-based information on each technology at the Wilsonville facility. WILS will also contain a series of Interactive Video Training (IVT) modules on a variety of tasks. The Technology Transfer and Training modules are being developed concurrently with construction of the facility using 2D and 3D graphics and animation. Training modules will be completed prior to commissioning of each train to allow time for operator training, and revised and augmented with video following the shakedown period. The third and final component of WILS is a multimedia archive designed to document equipment modifications and the history of the PSDF, primarily through still photographs, live-action video, graphics and audio. WILS is being developed for delivery via a stand-alone, interactive CD ROM system.

During the 50% design review meeting, Nolan made presentations which provided a basic understanding of the WILS project and the interactive multimedia technology, the objectives and the role the WILS project will play at the PSDF, and the kind of materials needed to produce the multilayered interactive system. Because of developments in computer technology, programs like WILS will become an increasingly important means of preserving and conveying design and engineering information and operational experiences.

During the quarter, scripts for five of the seven Technology Transfer Modules were in preparation. The Real-time Monitors and Sampling Module provides far greater detail than previous scripts on the Advanced Gasifier and APFBC trains (dubbed "K-train" and "A-train" respectively for purposes of the WILS project). This new level of detail has set the example for all other Technology Transfer Modules. Based on new information in the 50% Design Documents, the script for the Transport Reactor module was written in significantly greater detail. The increased depth of information marks an important shift in emphasis for the WILS project; the program is becoming both an engineering and a training tool.

Scriptwriting for the Real-time Monitors and Sampling module were reviewed by SRI and SCS. The second draft incorporates all the comments received, and the restructuring presents information in a logical and orderly way. Graphics production was started on the Real-time Monitors and Sampling module. This included the production of graphs, charts and tables, where informational content could be easily altered at a later date.

A sample P&ID was added to the Introductory sections of the program for review by SCS. Both closer and wider views were saved as PICT files and linked to WILS via the multimedia authoring software (Director). The wider view allows the user to "see where he is" on the drawing before "zooming in" with a graphic magnifying glass for the more detailed view. Both drawings allow the user to navigate in any direction by using a graphic compass located in the upper left corner of the viewing area.

Allowing Nolan to accept electronic files in their native format directly from PSDF participants is the most economical and efficient way of incorporating CAD files into the WILS program. This requires Nolan to convert native CAD files into a format compatible with the WILS platform. It gives greater flexibility to Nolan in displaying appropriate solids model views. It also makes things easier for the various design teams supplying files, requires very little of their time, and ensures that Nolan will get the materials they need in a timely manner.

Data and Voice Communications

Voice and data communications requirements for the site were reviewed. A local area network will be established in the existing building at the site by early June 1994. This will provide data communication access to field construction management and engineering personnel. Voice communications (PBX) to the site will be established in the last quarter of 1994.

The interface issues involving local network, DCS, data acquisition system and transfer protocols were pursued with the DCS vendor. Computers on the local network with appropriate security will be capable of accessing both archived and real-time data. This will be helpful for all project participants to monitor operation and perform data analysis with their computers without the need for being present in the control room.

3.0 PLANS FOR FUTURE WORK

- 1. Orderly closure of the contract with EERC.**
- 2. MWK will continue with piping design and issue a requisition for refractory pipe and transition pieces. Also, the analyzer house inquiry requisition will be issued and issues resolved associated with sulfator start-up heater stack/main stack integration with SCS. MWK will continue to integrate the CPC PCD with the gasifier train as more information becomes available. MWK will continue to build an electronic model and develop major equipment erection plans and construction schedules with SCS. The pre-inspection meetings with equipment vendors will be continued into the next quarter and the remaining vendor drawings will be reviewed.**
- 3. FW will continue updating P&IDs, with an issue expected at the end of April, 1994 and review with SCS planned for the second week of May. Work will continue with respect to integration of the initial PCDs as well as SRI sampling equipment in design requirements. Also, work will continue on instrumentation, equipment inquiries and review of bids. Based on bid tabulations reviewed and approved by SCS, FW will place orders for equipment within the present budget period constraints.**
- 4. SCS will continue construction activities, including pouring foundations for the process and coal/limestone structures and erecting the warehouse/maintenance building. An integrated schedule of remaining design activities and construction has been developed, and the schedule will be updated as additional information becomes available. Process structural steel drawings will be issued and construction procedure and sequence plans will continue to be developed. Nitrogen requirements for all participants will be finalized and a nitrogen vendor will be chosen. The underground piping and utility drawings will be completed and issued for construction.**
- 5. To enhance the flexibility and value of the PSDF, it is necessary for the IF&P PCD currently assigned to the Foster Wheeler carbonizer and the Westinghouse PCD currently assigned to the MWK transport reactor to be interchangeable. SCS has requested FW and MWK to perform an initial assessment of the costs and modifications to the current design that will be required for the future relocation of these two PCDs to their respective trains. In the next reporting period, FW and MWK will conduct detail design necessary to provide for the switching of these two PCDs, including design of inlet and outlet nozzles, evaluation of pipe and equipment stresses, identification and modifications of structural support points for changes in load, consideration of auxiliary equipment (pulse skid, for example) size and**

weights, and supply of services such as power, instrumentation, nitrogen, and instrument air.

6. The results of the MWK design hazard review will be issued and reviewed by SCS and MWK for follow-up implementation, to assess whether the as-is design is acceptable or a corrective action is required to mitigate the risk. A corrective action plan for each item will be developed and implemented as required. An inquiry will be issued for the services of a qualified consultant to lead and document a process hazard review of the FW and BOP areas, and a vendor selected.
7. In the coming quarter, SRI will complete the revision of all P&IDs. Electrical wiring diagrams for the SRI sampling and monitoring systems will be prepared. SRI will also prepare a table providing the following information for all instrument loops: loop number, type of signal, scale factor, range, and functional description. SRI will work with MWK and with FW on the design of the metal port liners for SRI's sampling and monitoring nozzles and on the selection of spring hangers or spring cans to support the SRI batch sampling systems. The plastic model of the cyclone manifold will be sent out to foundries for quotes on casting.
8. Westinghouse will continue evaluation of alternate internals.
9. The mechanical design of the CPC refractory lined pipe and media valve will be completed. CPC loading diagrams and the electrical drawing package will be updated. The layout of CPC equipment in the process structure will be coordinated with both SCS and MWK.
10. IF&P will issue revised utility specifications including nitrogen. Data generated from in-house testing will be used to finalize design of filter vessel internals and the ceramic tubesheet fabrication process.
11. Continue preparation of an integrated test plan for components and system testing during shakedown, characterization and normal operation.
12. Continue characterization of char and ash samples from the Livingston pilot plant and explore spent solids disposal alternatives.
13. Nolan will continue development of Wilsonville Interactive Learning System modules along with instructional design activities.

- 14. FW will continue contract negotiations with Westinghouse and Allison regarding the topping combustor and gas turbine, respectively, and obtain subcontract agreements with Foster Wheeler Development Corporation (FWDC) and Foster Wheeler Energy Corporation (FWEC). Contract negotiations with FW subcontractors should be completed in the next quarter.**

APPENDIX A

**MWK TRANSPORT TRAIN:
DETAILED PROJECT SCHEDULE**

MASTER SCHEDULE				EARLY START	EARLY FINISH	PCT	1994									
							F	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	
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MASTER SCHEDULE				EARLY START	EARLY FINISH	PCT	1994									
							F	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	
PROCUREMENT - EQUIPMENT																
							SUC001, RELEASE TO FABRICATE									
SR0001 - TRANSPORT REACTOR				20SEP83A	23SEP84	37	SR0001, RELEASE TO FABRICATE									
DR0402 - STEAM DRUM				17MAY83A	20JUL84	40	DR0402, RELEASE TO FABRICATE									
DR0404 - FLARE SEAL DRUM				24SEP83A	20JUN84	50	DR0404, RELEASE TO FABRICATE									
DR0001 - HTF SYSTEM SURGE DRUM				24SEP83A	20JUN84	50	DR0001, RELEASE TO FABRICATE									
CY0001 - REACTOR PRIMARY CYCLONE				09MAR83A	21AUG84	40	CY0001, RELEASE TO FABRICATE									
CY0007 - DISCHARGER				09MAR83A	21AUG84	40	CY0007, RELEASE TO FABRICATE									
CO0001 - MAIN AIR COMPRESSOR				2JAN83A	20JUL84	43	CO0001, RELEASE TO FABRICATE									
CO0401 - RECYCLE GAS BOOSTER COMPR.				4JUN83A	8AUG84	41	CO0401, RELEASE TO FABRICATE									
CO0001 - SULFATOR AIR COMPRESSOR				20APR83A	17JUN84	50	CO0001, RELEASE TO FABRICATE									
BL0001 - THERMAL OXIDIZER BLOWER				1OCT83A	20JUN84	40	BL0001, RELEASE TO FABRICATE									
HE0001 - HEAT TRANSFER FLUID (HTF) SYSTEM				25JUN83A	17JUN84	50	HE0001, RELEASE TO FABRICATE									
FL0401 - RECYCLE GAS BOOSTER COMPR. FILTER				7OCT83A	22JUL84	30	FL0401, RELEASE TO FABRICATE									
SR0001 - SPENT SOLIDS SLO				20SEP83A	17JUN84	50	SR0001, RELEASE TO FABRICATE									
CY0001 - SULFATOR CYCLONE				0DEC83A	20MAY84	57	CY0001, RELEASE TO FABRICATE									
FD0001 - SPENT SOLIDS SCREW COOLER				10APR83A	1AUG84	44	FD0001, RELEASE TO FABRICATE									
FD0002 - FINES SCREW COOLER				10APR83A	1AUG84	44	FD0002, RELEASE TO FABRICATE									
FD0002 - SULFATOR SOLIDS SCREW COOLER				10APR83A	1AUG84	44	FD0002, RELEASE TO FABRICATE									
FD0010 - COAL FEEDER SYSTEM				23APR83A	10SEP84	41	FD0010, RELEASE TO FABRICATE									
FD0020 - LIMESTONE FEEDER SYSTEM				23APR83A	10SEP84	41	FD0020, RELEASE TO FABRICATE									
FD0010 - SPENT SOLIDS TRANSPORTER SYS.				23APR83A	10SEP84	41	FD0010, RELEASE TO FABRICATE									
FD0020 - FINES TRANSPORTER SYSTEM				23APR83A	10SEP84	41	FD0020, RELEASE TO FABRICATE									
FD0020 - SPENT SOLIDS FEEDER SYSTEM				23APR83A	10SEP84	41	FD0020, RELEASE TO FABRICATE									
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JACKETED TRANSITION PIECES				20OCT83A	20JUN84	21	JACKETED TRANSITION PIECES									
FDY-304				10APR84	7JUN84	0	FDY-304, RELEASE TO FABRICATE									
Plot Date Data Date Project Start Project Finish	4APR84 20MAR84 1SEP83 30DEC84	Activity Summary Dates Contract Start/Stop Program Start/Stop Manufacturing Activity		M. W. KELLOGG COMPANY, PROJECT 6704 POWER SYSTEMS DEVELOPMENT FACILITY MASTER SCHEDULE - SUMMARY												
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APPENDIX B

TIDD PLANT TRIP REPORT

TIDD PLANT TOUR

February 22, 1994

Attendees

AEP

**Steve Burge
Mario Marrocco
Mike Mudd**

Southern Company Services

**Jimmy Horton
King Knight
Lee McDonald
Darrell Moore
Tim Pinkston
Randall Rush**

Foster Wheeler

**John Cofone
Rich Curran
John DeBaise
Bob Froehlich
Al Malsbury
Jim McClung
Bill Proctor
Mike Quandt
Ed Shaffer**

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TIDD TRIP REPORT
February 22, 1994

Questions/Answers

1. Has TIDD experienced sorbent hydration during operation?

Yes, hydration was experienced early in the operations period until the effects of pressure and acid gas emissions were fully understood. Hydration was particularly prevalent during start-up which underscored the importance of defining a proper start-up procedure and adhering to the procedure.

2. What is the purpose of the auxiliary fans?

The auxiliary fan is used to prepressurize the pressure vessel/PFBC during start-up to prevent air from backflowing through the intercept valve (not a tight shut off) forcing bed material back through the air nozzle in reverse flow. The fan is a low-flow/high-head fan. A separate fan system is used to cool the PFBC and pressure vessel internals during shutdown or trip. (also see No. 104).

3. What is the start-up sequence for the auxiliary fans?

Writer's note: There is only one start-up fan as described in No. 2. It is started to prepressurize the combustor before the gas turbine is motored.

4. What is the concentration of Cl_2 in TIDD's fuel?

Tidd coal (Pittsburgh No. 8) is relatively low in chlorine content but has still caused problems, particularly in the retrofitted candle filter assembly [external to the pressure vessel] where SA-213, Type 321 expansion joints failed as a result of hydrochloric acid corrosion. Chloride concentration in the Tidd ash is about 1700 ppm. Chlorine in the coal, in addition to the SO_3 produced (see No. 5), exacerbated the corrosion attack in the high temperature piping and expansion joints.

5. How has Tidd protected their expansion joints and piping from corrosion attack?

The high temperature process gas piping was originally designed with an outer carbon steel A-53 pressure-retaining shell, an inner 310 stainless steel liner, and aluminasilica ceramic fiber blanket insulation between the liner and the shell. The inside of the carbon steel pipe shell was coated with Plastic 4300 for corrosion protection. Flue gas penetrating through the lining slip joints and migrating through the insulation condensed on the "cold" carbon steel surface and corroded through the carbon steel pipes causing failure within a few days. Upgrading of the piping included replacement of the ceramic fiber insulation with a cast refractory. The inner metal liner was retained to preclude the possibility of refractory spalling and being carried into the gas

turbine. To provide for expansion and cushioning, a 0.25-inch thick ceramic fiber roll board insulation was used between the stainless steel liner and the ID of the refractory. To further protect the outer carbon steel pipe all inside surfaces of piping and flanges were faced with 16-gauge thick Hastelloy C-22 cladding. Materials of construction of the expansion joints was also changed from SA-213, Type 321 (failed after 30 hours) to Hastelloy C-22.

Subsequent pinhole failure of the Hastelloy C-22 expansion joints (as a result of pitting corrosion due to hydrochloric acid) resulted in the decision to heat trace and insulate all expansion joints in the hot-gas piping system so as to maintain a minimum wall temperature of 400°F. In addition, extensive thermocouple instrumentation was added to monitor for hot spots on the outside wall of the bellows. The minimum wall temperature of 400°F. ensured that the wall temperature was always above the acid dew point of about 375°F (based on SO₃ = 25 ppm @ 12 bar resulting from 90 percent sulfur dioxide capture of 3 percent sulfur coal). SO₃ content is a function of SO₂ concentration and pressure and conversion of SO₂ to SO₃ is approximately 18 percent. The heat tracing is electrical (because it was a retrofit) and has been difficult to control because of limited temperature measurements (impractical to have numerous T/C's throughout the expansion joint). While AEP has no experience with high-flourine coal, they would not expect such coals to be more aggressive than coals containing chlorine.

To minimize failure/leakage, expansion joints should be located in straight pipe runs. Hot spots (which identify refractory breaching gas leakage) and cold spots (which provide condensation sites) can be very small and difficult to detect. To minimize problems, the expansion joint buyer should be very accurate and detailed in his specifications to the vendor. AEP recommends the number of expansion joints be minimized because they can require excessive maintenance. While heat tracing may have prevented corrosion of the SA-213, Type 321, Hastelloy C-22 is an added safety factor. AEP recommends all refractory be monolithic, rather than layered because of excessive cracking that has occurred at Tidd. The insulating layer was not dense enough and they did not allow for satisfactory drying of the refractory. Castle Block and AP Green refractory are not recommended. PSDF personnel should also witness the pouring and curing of the refractory.

Finally, Tidd Operations monitors all refractory-lined vessels and piping with an infrared camera once per shift to locate an hot spots that have developed.

SCS recommended action(s):

1. Minimize the number of expansion joints.
2. Foster Wheeler should review all expansion joint designs.
3. Maintain all expansion joints at 400°F temperature (minimum).
4. Purchase infrared cameras for monitoring piping and vessels.
5. Review refractory specifications to incorporate Tidd experience.

Writer's Note: Two papers are attached which summarize AEP's candle filter test results and the modifications made as described above.

6. How is the unit started up and shutdown to keep the unit from condensing the corrosive gases?

The bed is established at about 30 inches (cold). The deaerator is pegged and boiler feed water is circulated to warm the inbed tube bundle. The pressure vessel, internal ancillary components (PFBC, cyclones, ash reinjection vessels, etc.), and external candle filter assembly and associated piping are preheated using the air compressor heat of compression until all thermocouples are 50°F above the acid dew points. For Tidd, this normally takes about 12 hours. When all thermocouples are 50°F. above dew point, the bed preheater, firing No. 2 fuel oil, is lit off. The bed is preheated to greater than 1200°F. before coal is introduced. AEP later said they specified 1375°F. as the minimum bed preheat temperature to effectively and reliably ignite coal/water paste. Bed preheating normally takes about 5 hours. Sorbent is not added to increase the bed level until fuel firing is stable. Emissions are disregarded during start-up (AEP is allowed 2 hours for start-up) and the addition of sorbent is delayed as long as possible to increase sulfation of the bed and reduce elutriation. AEP does not use nor recommend electric start-up heaters due to their poor reliability.

7. Does TIDD still generate SO₃ gases, or have they found a way to eliminate this corrosive gas?

SO₃ is always produced under pressure conditions. SO₃ is a function of SO₂ concentration in the flue gas and system pressure, therefore, SO₃ yields are higher in PFBC than AFBC.

8. Is TIDD aware of any other units emitting corrosive gases?

All operating PFBC facilities have experienced corrosive acid gases.

9. Who manufactured the expansion joints?

Tidd expansion joints were double-walled (2-ply) joints manufactured by Badger. The inner ply is 0.038 inches thick and the outer ply is 0.062 inches thick. Failure is detected with local pressure gauges. AEP recommends that the specifications for the manufacture of expansion joints be specific and complete and that vendors are not relied upon to make assumptions about the application and suitability of expansion joints. As stated above, minimize the number of expansion joints and monitor temperature with thermocouples.

SCS recommended action(s):

6. In light of lessons learned at Tidd, have Foster Wheeler procure all expansion joints.
7. Review the use of T/C's for monitoring expansion joint temperature, and incorporate into PSDF, if warranted.

10. Explain the control of the two turbines and how they are controlled in relation to each other. Do both turbines generate load dependent upon the fuel input, with little or no biasing?

The steam turbine is a slave to (follows) the gas turbine, however, there is nothing sacred about this control philosophy. Understanding the gas and steam turbine cycle response time is critical to effect good control.

Writer's note: Three papers are attached which will help explain Tidd operation, start-up, shutdown, load following and how uncontrolled transients are handled. Suggested order of reading is (1) my paper first since it is the most general and lays the groundwork, (2) Krishna Pillai's paper next since it is somewhat more specific but not project specific, and (3) Denny McDonald's last since it is Tidd specific and concentrates more on the slave steam cycle.

11. Are the turbines put into any control such as boiler-follow, or turbine follow?

See No. 10.

12. Where are the emission monitoring taps located for control of the unit's O_2 and SO_2 ?

SO_2 taps are located downstream of the ESP; O_2 taps are located between the primary and secondary cycles. AEP has found it is difficult to keep the O_2 taps purged of dust to ensure accurate readings. Typically, the O_2 varies between 3 and 4.5 percent among the seven cyclone trains, however, when we toured the plants, there were readings as high as 16 percent. Maldistribution is also a problem, i.e., the end cyclone trains record the lowest O_2 readings while the cyclone trains in the middle record the highest.

Writers note: Teledyne oxygen analyzers were used early on but were trashed because of poor performance. AEP currently uses extractive-type Ametek oxygen analyzers.

13. What are the sequence of events after (1) turbine trip, (2) MTF, (3) high pressure trip and (4) any other trip situation unique to the PFBC?

In the event of a turbine trip: depressurize the system in a controlled manner, purge the combustor with nitrogen (a large supply is required) to displace the air and extinguish the combustion process, provide adequate cooling to the inbed tube bundle. The nitrogen is recycled to cool the bed with the auxiliary fans. The fans have an 8 psi discharge head but this is insufficient to fluidize a "full-load" bed after a trip.

In the event of a MFT: let the bed die out. No restart is attempted and the PFBC is drained to restart bed conditions.

If boiler feed water is lost, an emergency water tank (in the upper elevation) is placed into service. Emergency diesel pumps circulate water through the water wall and

inbed tube circuitry to prevent over temperature. The diesel pumps are also used in a "black-plant" trip.

In the event of a high pressure trip: an impossible occurrence.

SCS recommended action(s):

8. Specify Ametek oxygen analyzers, or consult AEP with respect to alternates.
9. Provide uninterruptible source of cooling for FBHE and other coolers where required.

14. What is the load following capability? How is it achieved?

Design load following rate is 2 percent per minute, but 4 percent is achievable. Load following is achieved by transferring bed material either to (for ramping load up) or from (for ramping load down) the PFBC to ash reinjection vessels. The ash reinjection vessels are partially evacuated to "suck" bed material from the PFBC. An L-valve is used to transfer bed from the ash reinjection vessels to the PFBC. The L-valve does not provide a seal ($P_{\text{storage}} \approx P_{\text{PFBC}}$); the pressure differential across L-valve is equal to the material head in ash reinjection vessel downcomer. Bed material flows easily. The ash reinjection vessel is on load cells to measure weight of bed material. The vessel is purged with nitrogen to keep bed ash from agglomerating (it is stored at 1540°F). The L-valve is aerated using nitrogen. At start-up, the bed height is 30 inches; at full load the bed height is about 120 inches. The operation of transferring bed back and forth to the ash reinjection vessels represents the slowest mass transfer unit operation in the plant.

15. How are the two flow paths protected from over pressurization, safety valves or bursting disks, and who makes them?

The PFBC uses a 30-inch, knife-gate-activated bursting disk. The pressure vessel uses a pressure relief valve. Both are uncooled.

While the PFBC and pressure vessel are protected against excessive pressure, it is impossible to overpressurize the system. A ruptured steamtube is the only way to overpressurize the system, and this is detected relatively quickly by an increase in the gas turbine output(or thermocouples if in the right location).

16. Where are the devices located in the piping, and what is the reason for the selection of these locations?

The pressure relief devices for the PFBC and pressure vessel are located above the pressure vessel and are vented to the roof.

17. What flow rates are these devices set/designed for?

Wasn't answered or recorded in notes.

18. What pressure are the devices set for in relation to the design operating pressures?

The B&W (USA) bubbling bed PFBC inside the pressure vessel was designed for a 10.5 psi pressure differential across the water walls (i.e., outside to inside). A rupture disk rated at 9 psi is used to protect against higher pressure differentials. The normal operating differential pressure across the water walls is approximately 7 psi. This safety disk has never ruptured due to overpressure of the system even though tube failure has occurred. However, the disc has experienced mechanical failures due to fatigue induced by overflexing in response to system pressure surges.

19. What pressure are the steam cycle pressure parts and the flue gas containment walls designed for?

Proprietary.

20. What is the pressure drop from the air compressor discharge to the gas turbine outlet?

Proprietary.

Writer's note: This information is available.

21. Have there been situations where a high differential pressure was experienced across the boiler water wall?

Wasn't answered or recorded in notes.

22. Have there been any tube leaks in the PFBC, and how did the system respond to it?

The first occurrence of PFBC tube leaks was two weeks prior to this visit. The breach was a localized occurrence and caused by erosion in a transition region between the lower refractory wall and upper water wall. The metallic transition piece warped and created an abnormal ash circulation flow pattern. The water wall sprang a leak which "jetted" to an adjacent inbed tube causing erosion and an additional leak (at approximately the "8 o'clock" position). Air nozzles in the vicinity of the leak plugged. This has been modified. AEP admitted that minor leaks were difficult, if not impossible, to detect. Major leaks are detected by an increase in turbine output. It took about 24 hours to get into the combustor. AEP recommends flue gas moisture detection to detect leaks, however again, "minor" leaks probably won't be detected.

SCS recommended action(s):

10. Review the need for flue gas moisture detection to detect PFBC tube leaks.

23. Is the fuel transport piping carbon steel or stainless steel?

The fuel transport piping was originally chrome-plated steel but has been replaced with stainless steel. Rubber piping joints isolate the paste feed pumps from the feed nozzles. The pH of the paste is about 3. Adding sorbent to the coal paste feed helps neutralize acidity (as well as producing a more pumpable paste).

24. Has the fuel feed system had pluggages, especially at low loads?

Not when the paste is mixed properly with attention to the proper particle size distribution. AEP currently uses a (crude) "slump" test for moisture content and paste quality, similar to the concrete industry's "slump" test. The sample is taken at the paste mixer discharge. After gaining some experience, AEP operators have become proficient in maintaining good quality paste using the crude test. An early method using a Moyno pump in a test loop to measure pressure drop as a means to evaluate paste moisture/quality failed after about a month. AEP does not consider the coal paste feed a good application for the Moyno pump.

AEP (and this writer) thinks paste feed is better than pneumatic (lower cost, more reliable, no inerting, no erosion). PSDF personnel should talk to Escatron operators who have had significant erosion of feed piping both in straight runs and bends. A recent catastrophic excursion occurred in the Escatron plant as a result of a complete breachment of the pneumatic transport feed line (coal and sorbent are fed together). Fortunately, no personnel was hurt. Pneumatic lines continually plug even though sorbent is added to the coal (which "conditions" the coal) and it only rains twice a year at the site. Fires within the lockhopper system is also a frequent occurrence during the summer months. AEP has no way of directly measuring paste feed rate other than measuring pump strokes (and even this is not repeatable).

SCS recommended action(s):

11. Discuss dry, pneumatic fuel feeding with Escatron operators.

25. What special equipment is utilized in fuel preparation to ensure the required preparation and moisture content? Could the originally installed equipment meet the specifications, or have modifications been made?

Tidd uses a Krupps Polysius double-roll crusher to crush coal, with a screen to divert reject (oversized) material back to the crusher. Size distribution is sensitive to coal properties (particularly moisture content, ash content and the ash constituents), and a single crushing step has been insufficient. AEP had to reface the Krupps Polysius rolls on one occasion. In an attempt to produce the proper amount of fines (without recycle), the adjustment on the rolls was set too tight and the center of the rolls wore excessively. A screw feeder force feeds the coal into the double rolls. Without the screw feeder the "wet" coal layed on top of the rolls and would not feed through. The Tidd coal is ground to a 1/8-in. topsize with oversized material recycled to ensure that 20 wt% of the coal is minus 325 mesh.

The coal water paste is 25% total moisture content (inherent plus surface) by weight. Water flow rate to the coal paste system is set based on the coal flow rate. Coal flow rate is monitored by means of a belt weigh feeder. The weigh belt feeder does not meter the coal; rather it quantifies how much is being fed. Crusher throughout meters coal to the mixer. This measurement, with proportional biasing based on assumed coal moisture, sets the control of water flow to the coal paste system. Coal moisture content is monitored by means of a microwave moisture analyzer, and biasing is reset accordingly. Quality of paste is critical to operation. Paste is usually stored about one hour (or less) prior to feeding the boiler. The paste feed tank capacity is 3 to 4 hours. Although ultimate mixing of the coal and water is not required, it is essential to keep the paste moving in the paste feed tanks. The feed tanks use helix agitators that scrape the walls and floor to avoid accumulation and deposits. The paste tank has no baffles. The agitator power is monitored as a measure of paste quality.

The sorbent is crushed in a hot air swept Williams Mill. The Mill has produced excessive fines which has caused plugging problems. AEP has experienced poor reliability with the Williams Mill in preparation of the dolomite feed. The Mill required rebuilding every 300 to 400 hours. Also, AEP had poor support from Williams. Installation of an upgraded (harder material) set of hammers has helped. AEP has found sorbent sizing is critical for effective sulfur capture. They would prefer a bimodal size distribution consisting of fine and coarse material. Even though the fine material has a short residence time in the PFBC, it has a very high sulfur capture rate due to its high surface area to volume ratio. The larger size particles are required to maintain a bed. Its sulfur utilization is also very high due to its long residence time and gradual attrition. Particles in the mid-size range are considered to be a problem due to short in-bed residence time and low surface to volume ratio which results in low sulfur capture and sorbent utilization.

AEP recommended that SCS ensure that the grinding system drying heaters are included in the permitting process. (They have been incorporated in the PSDF air permitting). AEP also recommended that the need for an explosion-suppression system be reviewed. AEP felt the coal would be better prepared using a hammermill (the sorbent crusher), and the limestone better prepared using the roll crusher. AEP's crushing/conveying system has an explosion compression system but it has never been used.

SCS recommended action(s):

12. SCS should review the need for an explosion-suppression system in the coal feed preparation area.

Writer's note: Although the preparation of paste is not an exact science, experience can be gained quickly. In spite of AEP's presumption that the number of precautions cited will ensure trouble-free operation with paste, the fact remains that Värtan has had little or no trouble and can start-up and shutdown their paste feed system with the "flick of a switch." The modifications made to the Tidd coal preparation and paste system are as follows:

1. Addition of the screw feeder to force coal into the crusher rolls.
2. "Roughing" the crusher roll surface to force coal into the rolls.
3. Addition of piping to recycle oversize material back to the crusher.

4. Installing a larger motor on the Krupps Polusius crusher.
5. Rebuilding the internals of the pug mixer using stainless steel.
6. Relocating the pug mixer outlet to the center of the paste feed tanks.
7. Rebuilding the sorbent Williams Mill hammers using harder material.

26. What special equipment is used to feed the fuel (and sorbent) into a pressurized combustor? What difference is there between this equipment and similar commercially available equipment? Could the originally installed equipment meet the specifications, or have modifications been made?

Tidd uses stainless steel and high-pressure rubber hose to transport fuel between the mixer, storage tanks, pumps and PFBC (also see No. 23). Paste injection nozzles have three-way valves to permit paste recirculation. Paste is recirculated in the event of a trip or prior to start-up to prevent paste from drying and plugging the line. In addition to the "quality" of the paste, the correct number of feed points and the amount of "splitting" (atomizing) air is important for proper operation using paste feed. Six paste feed nozzles and two sorbent nozzles are located on the side of the boiler. Each Putzmeister reciprocating pump has a dedicated feed nozzle. The six feed nozzles penetrate the pressure vessel and enter somewhat evenly along one side of the PFBC enclosure walls. AEP considers the non-uniform feeding of all of the paste to only one side of the PFBC is the primary cause for the maldistribution of gases which has resulted in post-bed combustion. Installation of steam nozzles in the free board area has reduced freeboard combustion. AEP thinks there are too few paste feed points (currently one per two square meters of bed area). They feel one feed point per one square meter of bed area may be required. Also, bottom feed (as opposed to side feed) may be more appropriate. Better feed distribution would also reduce the problems AEP is having in obtaining the desired level of SO₂ capture as a function of Ca/S ratio. Atomizing air is also critical. If droplets are too large, they have poor circulation, if too small, hot spots can occur (also see No. 100).

Dry sorbent is fed pneumatically using lockhoppers (on load cells) to two feed nozzles on the same side of the PFBC wall as the paste feed nozzles. The bifurcated feed line feeding the two nozzles does not distribute flow evenly. To minimize erosion, transport lines are lined with ceramic inserts and right turns are made using ceramic-lined tees with extended dead legs. Most sorbent is very erosive. The key to sorbent handling is to minimize moisture and eliminate moisture pickup after the sorbent has dried.

The Everlasting sliding disk valves used for lockhopper block valve service did not perform well when closing against solids due to solids packing in the valve body. Everlasting valves were also more expensive. AEP recommended using Neles ball valves for use in lockhopper service since they are designed to be effective in both cutting off the flow of solids and in sealing against a pressure differential

Writers note: Expanding further on AEP's comments that a paste feed system would again be their feed design of choice, B&W has indicated that coal/water pastes have been shown to burn more evenly and require fewer feed points than pneumatic feed systems. For first generation PFBC systems, the tradeoff is latent heat of vaporization of the water (an efficiency penalty) versus the added mass through the gas turbine (increased efficiency). This is why paste feeds are used rather than slurries, the break-

even point is about 22 percent moisture, however, a 22 percent moisture paste is very "stiff" and difficult to pump without drying out the feed lines. At 25 percent moisture (i.e., Tidd), the effect is a net cycle efficiency loss of a little less than a percentage point. For high ash fuels, the penalty is too great because of the amount of water that has to be added to effect a "good" paste.

For the Advanced PFBC, the situation is different. Paste feed has been shown to work in bubbling bed PFBC while gasification processes use coal/water slurries, and while some water is required in the carbonizer (steam has been used in varying amounts in the pilot plant) to effect good carbonization performance, a coal/water paste has not been tested at carbonizer conditions. This will be done in the pilot plant later this year.

The principal modifications made to the Tidd fuel feed system are as follows:

1. Rebuilding the Putzmeister pump internals (pistons and cylinders) using stainless steel (rather than chrome plate steel).
2. Modifications to the paste feed gun design.
3. Sorbent lines were ceramic lined where there was extensive erosion (although some bare pipe still exists in the feed lines).
4. The Neles ball and Everlasting sliding disk valve positions were swapped on the lockhoppers. The Everlasting valves were moved from the bottom to the top of the lockhoppers and vice versa for the Neles valves.

27. Why was the single vessel approach used for the plant instead of multiple vessels?

Fabricating vessel heads is more expensive than increasing vessel diameter. This lends itself to single vessel design. Also, the number of expansion joints are decreased.

Writers note: AEP's answer may be true up to a point. The P-800 (350 MWe) ABB module is still a single vessel design. A larger module may not be practical.

28. How is the PFBC supported inside the pressure vessel? Is it hung or bottom supported?

Top hung off the structural steel, and grows down. The structural steel is hung off the vessel walls (the walls act as vertical beams).

29. How are the vessels insulated?

Wasn't answered or recorded in notes.

30. Are the connections and access ports flanged or welded?

Flanged.

31. What was the cause of the gas turbine overhaul at TIDD?

High cycle fatigue failure (resonant frequency) of the LPT blading. This was turbine design, not PFBC related.

32. What was the cause of the gas turbine leakage at Escatron?

Proprietary.

Writers note: AEP was unaware that this problem has been published in the open literature. The problem is excessive leakage in the gas turbine intercept valve. While the valve was designed to leak, leakage was greater than desired. This has been fixed.

33. What amount of particles are getting to the gas turbine at TIDD?

About 400 ppm with a top size of about 7 to 8 microns and a D_{50} of less than 2 microns.

34. Has there been a study of the effects of the gas turbine inlet stop valve tripping closed during an emergency situation? Are shock waves propagated throughout the system?

Yes, modelling of the effects of tripping the stop valve (intercept valve) indicated the resultant shock waves would not be a problem. The voluntary tripping of the valve during plant operation confirmed this result.

35. Have the gas turbine inlet valves ever tripped closed?

Yes, when there has been a gas turbine trip. Gas turbine isolation has worked very well.

36. Who makes the gas turbine inlet stop valve?

The intercept valve is manufactured by ABB Stal, from their nuclear experience.

37. Does TIDD have a CaS discharge problem, or have they designed the problem out of the process?

The Tidd plant does not produce CaS.

38. Have the cyclones plugged during operation. (hydration, overloading, type of limestone, sizing of the recycle material)?

Yes, there has been "overloading" of some of the cyclones during start-up. Proper temperature measurements using thermocouples can help identify when plugging is occurring. Rapid temperature changes should be avoided in the cyclones to prevent plugging. Also, there has been a problem removing the flyash from the cyclone dip legs and getting it through the coolers and into the silos. The cyclone collection system must be properly preheated to avoid discharge problems. In addition to "overloading" the cyclones at start-up, there were other serious design problems in the cyclone flyash discharge system that required major rework. Eventually, the secondary cyclone flyash bypassed the ash silos and was discharged directly into the economizer (later into the ESP). The flyash depressurization subsystem is not a lockhopper and valve system; rather it is a long pipe (serpentine) over which pressure reduction is effected. The tradeoff is a (slightly) lower efficiency vs. maintenance on valves.

Värtan has not had to modify their systems and has not experienced the problems of Tidd. AEP attributes this mainly to the differences in feed coal properties. One major difference is the much lower sulfur content of the Polish coal fed at Värtan versus the greater than 3% sulfur content of the Pittsburgh No. 8 coal fed at Tidd. The higher sulfur content requires a significantly larger amount of sorbent feed. In addition, the Polish coal is a low-ash coal having approximately 1/2 the ash content of Pittsburgh No. 8. These factors in combination with the excessive amount of fines generated by the (sorbent) Williams Mill and the Krupp Polysius double-roll crusher resulted in a large amount of fines reporting to the flyash drain system. In the early stages of operation the flyash to bed ash split was in the ratio of 80/20. Currently, in runs closer to 50/50, similar to that at Värtan.

AEP modifications to the secondary cyclone blowdown system included deletion of ash cooling in the cyclone diplegs which caused plugging due to acid gas condensation. Flyash at high pressure must not be cooled below the acid dew point. A separate 3/4-inch line is not provided for each of the six secondary cyclones. Each pipe is provided with individual valving for block in and blowback of plugged material in the lines. The flowrate of blowdown gas from each cyclone is controlled by means of a restrictive device located at the terminus of the line. AEP employs intermittent grit injection in order to keep the lines clean. A gas blowback system is used for cleaning plugged cyclones if the plug is not too tight.

Because of the large quantity of flyash produced in the Escatron plant (the coal is lignite containing 36 percent ash and 7 percent sulfur requiring a high Ca/S), the cyclone system frequently plugs. Escatron contains nine pairs of cyclones (Tidd, seven pairs). The primary cyclone ash outlets are all individually piped to the ash silo (like Tidd eventually did on the secondary cyclone outlets). The secondary cyclone outlets are manifolded together (like Tidd originally was) and frequently plug, and as often as not, Escatron keeps on running. When the primaries occasionally plug, the secondaries could keep up until they plugged. This was the cause of the severe catastrophic erosion that occurred in the Escatron gas turbine on one occasion which forced a complete rebuild of the gas turbine.

Writers note: This will not affect Wilsonville. Our design is entirely different.

39. What is the particle size of the material that the primary cyclone and the secondary cyclone is collecting (efficiency)?

The primary cyclone collects flyash particles of about 80 to 100 microns in size. The top size exiting the primary cyclone is about 30 microns. The secondary cyclone collects flyash particles of about 2.5 microns in average size (top size in the range of 9 to 10 microns). AEP's experience with the two cyclones in series indicates that the secondary cyclone is not essential to meet turbine specifications. Escatron ignores secondary cyclone pluggages (see No. 38). No flyash from the cyclones is recycled to the bed.

At one point, AEP had to lower the inlet temperature to the candle filter to about 1400°F using "tempering" air. The theory was the very fine ash particles were "sticky" at temperatures greater than 1400°F and the tempering air cooled (froze) the particle surface and made it less sticky. AEP has little confidence that ceramic candle filters can operate effectively with very fine ash at temperatures greater than 1400°F. AEP recommends that provisions be made for bypassing airflow in front of the candle filter.

AEP achieved a significantly improved candle filter performance by "spoiling" the primary cyclone upstream of the candle filter. Spoiling of the cyclone is accomplished via the addition of air to the downcomer of the cyclone. Particulate loading to the candle filter (which replaces a secondary cyclone when in service) increases from 600 to 3500 ppm when spoiling is done. The 3500 ppm is accomplished at "maximum" spoiling, however, AEP does not vary the amount of spoiling gas in order to vary the particulate loading to the candle filter. Without spoiling, the mean particle size exiting the cyclone is 2 microns with a top size of about 9 to 10 microns. With spoiling, the mean particle size exiting the cyclone is 9 microns, with a top size of about 35 microns, which improves the performance of the candle filter. When the ash size was increased, the candle filter gas flow rate increased from the design 100,000 lb/hr to 135,000 lb/hr. The back pulsing takes place every 30-60 minutes with a 30-inch water differential pressure override. Each pulse takes two minutes, therefore, with nine filter clusters, the total pulse sequence takes about 18 minutes. AEP will share their experience in spoiling cyclones, including modeling. With the addition of coarser material to the candle filter, AEP believes the need to lower the inlet temperature to the filter may not be necessary.

SCS Recommended Action:

13. Foster Wheeler and SCS will review the need for obtaining spoiling design assistance from AEP.

Writer's Note: The flyash problem experienced at Tidd may not be as much a problem at Wilsonville because the ash mean particle size from the CPFBC cyclone is roughly an order of magnitude in size larger than the flyash at Tidd.

40. What are the cyclones made of, and how is the vortex finder hung?

Cyclones are made of carbon steel with 16-gauge Hastelloy C-22 (Sterling Boiler) lining. Sterling did an excellent job of "wallpapering" the dissimilar metals. This was also done at Grimethorpe but there were failures (not reported in the open literature). AEP has not experienced any erosion in their cyclones, however, Värtan has. AEP attributed this to the abrasiveness of the Polish coal ash compared to Pittsburgh No. 8 coal ash.

41. Are any J-Valves, L-Valves, or N-Valves used in the system?

There are L-valves at the bottom of the ash reinjection vessels to transport bed ash into the PFBC during start-up and load following. See No. 14.

42. How is the pressure vessel protected from over pressurization?

See No. 15.

43. How is (minimum) differential pressure maintained across the boiler wall during operation, and during upset conditions?

Wasn't answered or recorded in notes.

44. Provide upset condition experience, and solutions to protect both the boiler and the pressure vessel.

Wasn't answered or recorded in notes.

45. How are the penetrations for fuel, air, water, electrical, and flue gas made to the pressure vessel?

According to ASME Section 8, Division 1 code. The pressure vessel was fabricated in a B&W shop, hydrotested and the elliptical head cut off. The pressure vessel was then "stuffed" with the PFBC, cyclones, etc. and shipped to the site. Once at the site, the head was welded back on the vessel and the vessel code stamped as a "repaired" vessel.

46. What type of grid nozzles are being used?

Sparge ducts. Air from the air compressor enters and fills the pressure vessel and is routed to the air sparge ducts that serve as the floor of the bed. The sparge ducts distribute the air through nozzles located on top of the ducts. The sparge ducts are spaced to allow bed ash and small agglomerated material to fall and be collected in the boiler bottom.

- 47. What type of burners are used on the unit, where are they located, and what is their heat rating?**

Conventional combustion turbine can burners, slightly modified. A damper is used to divert combustion/fluidizing air to the preheater burner.

- 48. Who makes the start-up burners, and are they started under pressure?**

Combustion turbine can burners are manufactured by AB Stal and are started under pressure.

- 49. What is the inbed tube material?**

Proprietary.

Writers note: This information is available.

- 50. How are the inbed tubes supported?**

Proprietary.

Writers note: This information is available.

- 51. Has there been any inbed tube erosion? After what period of operation?**

Tidd has 5800 hours of coal firing experience and has not detected any appreciable erosion (other than localized polishing) of the inbed tube surface. Escatron, with 10,000 hours of coal firing, has seen no erosion (soft bed material). Värtan has experienced some localized erosion, particularly at the inbed tube bends.

Writers note: Värtan had at least one serious excursion that the writer knows of. It is recalled that it started at the waterwall; then, the leak caused a localized "jetting" action on an adjacent inbed tube. As a result of this, ABB covered their membrane water wall surface with refractory, a major departure from "business as usual."

Although Tidd has experienced no erosion on the inbed tubes, there were problems in the economizer, the writer believes due to bad welds. Leaks led to, again, localized "jetting", erosion and penetration of some of the tubing.

- 52. Have there been any problems withdrawing the ash from the unit or hoppers due to pressure or temperature?**

Bed ash is cooled in the boiler bottom (an inverted pyramidal bottom, two side by side), withdrawn and depressurized in two lockhopper trains in parallel. The lockhoppers discharge the 300°F ash onto a covered conveyor belt and transported to the bed ash silo (separate from the flyash silo). The bed ash is not too dusty, more

like sand. The system has worked well. Tidd has never operated with just a single lockhopper train. This would result in an uneven bed level. However, Tidd said a single lockhopper train has the capacity to keep up with the required bed removal rate. There is no provision for returning extracted bed material to the PFBC..

Flyash is depressurized in a "long pipe" (serpentine) and pneumatically transported to a flyash silo as discussed in No. 38.

Bed ash and flyash display distinctly different flow and erosion characteristics, and there are differences between primary and secondary cyclone flyashes as would be expected. SRI is investigating flyash flow properties as a function of temperature and chemical differences between coarse and fine flyash.

The primary cyclone flyash pneumatic transport system utilizes T-bends (like the sorbent pneumatic feed system) for erosion prevention and detection. The ash system piping is NASpipe in case the ash valve accidentally stays open and pressurizes the line. AEP recommends using ceramic-lined T-bends for erosion protection when conveying large material (coal and sorbent feed, PFBC bottom ash, primary cyclone flyash, etc.). For fine flyash, AEP's design of choice is long-radius els. Also see No. 59.

Writers note: As indicated in No. 38, flyash removal was very problematic early on. The ashes from the primary and secondary cyclones were combined after cooling for transport to the flyash silo. This never worked well. AEP eventually separated the two flows and sent the secondary ash to the economizer, and later to the ESP (when the economizer kept getting plugged). Cooling the bed ash was problematic early on also and modifications were made in the boiler bottom to cool the ash to the required temperature.

53. Is some of the flue gas used to transport the cyclone ash?

Yes. AEP estimates 2 percent PFBC flue gas bleed is used for pneumatic transport of flyash from the primary and secondary cyclone system. A system designed to handle high flyash loading and providing for transient flow peaks would require a significantly high bleed. Since PFBC flue gas bleed results in power loss from the system, pneumatic transport of cyclone flyash may not be appropriate for some design cases.

AEP noted that in the original design for Tidd, the primary cyclone flyash line size was larger than that provided for Värtan whereas the secondary cyclone flyash system used a smaller line size. The larger primary cyclone flyash line for Tidd was attributed to the significantly higher ash content of Pittsburgh No. 8 coal versus the Polish coal used at Värtan. The difference in secondary cyclone line sizing was attributed to a difference in operating philosophy. The larger line sizing at Värtan allows for the use of the secondary cyclones as backup to the primary cyclones in case of pluggage. Without this provision, Tidd is forced to shut down or else risk excessive wear of the turbine. Värtan, a commercial facility rather than a demonstration plant, considered the greater reliability worth the loss in efficiency.

54. Explain the modes of cooling the cyclone ash.

Primary and secondary cyclone flyash is cooled to below 800°F using the PFBC fluidizing air and internal coolers. The internal flyash (gas/gas) coolers were designed by ABB and are of proprietary design. An external ("external" to the pressure vessel) primary cyclone flyash cooler (water/gas) cools the primary flyash to about 300°F (higher temperatures are undesirable), and the ash is pneumatically conveyed to the flyash silo using flue gas as the transport medium. The secondary cyclone flyash was initially cooled in external (water/gas) coolers but the problems experienced with conveying the secondary flyash to the ash silo (see No. 38) forced AEP to bypass the external coolers and send the secondary ash (uncooled below 800°F) to the economizer (later the ESP). AEP did point out that there is a lot of heat to be recovered from the flyash, but that coolers may not be needed on the secondary cyclone flyash.

55. What is the ash system split (bottom ash and fly ash)?

About 50:50, depending on how the sorbent is fed (i.e., dry or with the paste). Värtan's split is also about 50:50. Escatron's split is about 60:40.

56. How many air compressors are required for the transport of the bed ash?

None, a belt conveyor is used (see No. 52). There are two schools of thought on bed ash, belts and pneumatic. AEP is indifferent to each.

57. Is the ash flow measured?

Not on a real time basis. When performance tests are done, it is measured using load cells on the ash reinjection vessel. AEP pointed out that lockhoppers and load cells may not work well for measuring solids flow rates if the weight of solids (like flyash) is low relative to the vessel weight and other forces. In addition, connection of the lockhoppers and load cells to structural steel can compromise accuracy (structural steel may deflect). AEP has installed a separate, bottom-supported structure for the sorbent feed hopper load cells to isolate the hoppers from the remainder of the structural steel.

AEP considered using weigh cells on the candle filter flyash but didn't use. They didn't say why.

SCS Recommended Action:

14. SCS and Foster Wheeler should review the design of load cells for the PSDF and incorporate the experiences of Tidd into the design.

58. Is there any problem with agglomeration because of high pressure?

Occasionally, "clumps" were found, but problems were not major.

59. What equipment is used to remove ash from the combustion system to the ash removal system, and what are the design considerations for erosion? Could the originally installed equipment meet the specification, or have modifications been made?

Tidd experience indicated that T-bends are helpful in preventing erosion, rather than long-radius els. AEP's secondary cyclone ash discharge piping is stainless steel using long-radius els (AEP's design choice for fine ash); AEP has had no problems with this line. Ensure that pneumatic piping is in perfect alignment; erosion will occur if piping is not in alignment.

SCS Recommended Action:

15. Identify where erosion is likely, and use ceramic-lined pipe, even if initial cost is higher.
60. Does the [candle filter] ash cooler have an overflow weir/baffle at its discharge?
- No.
61. What is the experience with the ash cooler's domed ends?
- The cooler's domed ends are a superior design, and experience has been good. The domed ends are maintained 5 psi higher than the screw section. This was the first time this design has been used in this application.
62. Does the ash cooler design incorporate any shaft seals, or just close clearance, between the domed section and the screw section? If seals are used, what is the type/configuration?
- Shaft seals are used between the domed ends and screw section. This design avoided the ash leakage experienced at Grimethorpe. The drive in DC, while the drive at Grimethorpe was hydraulic.
63. What is the ash cooler end dome air purge leakage rate into the screw section?
- Not available.
64. Does any ash find its way into the domed ends?
- No.

65. To maintain the desired ash exit temperature, does the screw speed vary inversely with ash flow rate?

The screw speed is variable (0-16 rpm), however, AEP found it was better to run the speed constant (typically 10 rpm).

66. Does the ash entering the ash cooler come in slugs that correspond to the pulse cleaning of the candle filter, and if yes, what effect does uneven feed have on the operation of the cooler?

Although the flyash comes to the cooler in slugs that correspond to backpulsing the candle filter, the uneven feed has no adverse effects on the operation of the cooler.

AEP said it was necessary to remove flyash continuously from the candle filter hopper and to avoid accumulating the fine ash in the hopper. Fine ash does not flow readily and has a very steep angle of repose (90°). If flyash builds up in the filter hopper, some flyash will stagnate along the walls and eventually bridge and plug the hopper outlet. Maintain movement of the ash at all times.

Writer's note: LLB (Deutsche Babcock) has said the same thing. "Keep the ash moving."

67. What is the more important reason for keeping the ash temperature at approximately 400°F to avoid acid gas condensation:

- Ash flowability, or
- Corrosion (It has been reported that the ash will adsorb and neutralize any condensation. Comments?)

Both reasons are equally important. To preclude the possibility of acid gas condensation, the cooling medium is maintained at a minimum inlet temperature of 320°F to 340°F. However, during an upset condition in which no flyash was removed for over 24 hours, acid gas condensation did occur resulting in caking of material within the screw cooler. Post test inspection showed no signs of corrosion. It is assumed that the corrosive condensate was neutralized by the flyash, although, AEP did not think the flyash would neutralize the acidic condensate.

68. Who designed and supplied the ash cooler lock hopper system?

The ash from the filter is discharged from a 12-inch nozzle into an 8-inch line to a Denver Hollow-Flight Screw Cooler, which is designed to cool 1000 lb/h of ash from 1670°F to 400°F. From the screw cooler, the ash discharges through an 8-inch line into an upper surge hopper through a 4-inch (10.2 cm) Everlasting sliding disk valve and into a lower lockhopper, which then discharges through a 4-inch Everlasting isolation valve and a 4-inch Everlasting ash flow regulation valve into the pneumatic flyash removal system which serves the Tidd electrostatic precipitator. The lockhopper valves are provided with purge air, and the anticipated flow rate of fines was 30 lb/h.

The candle filter ash screw cooler was supplied by Denver Equipment. The hydraulic drive and associated control package for the ash screw cooler were subcontracted by Denver. These did not function adequately until AEP became involved and assisted with the details of the modifications. The speed sensor was poor because there was only one magnetically generated pulse per revolution which was too infrequent at the cooler's relatively low speed of 8 to 10 rpm. This resulted in a false indication that shaft rotation had stopped.

The flyash cooler lock hopper system was designed and supplied by United Conveyor Corporation. The depressuring of the ash from the screw cooler is done with two lock-hoppers in series. This approach was taken because at the time the design was developed, Tidd was having major problems with their cyclone ash pressure letdown system. Tidd said if they were to do it over, they would eliminate the screw cooler and lockhoppers and use the pipe/orifice pressure letdown and cooling technique that is used for the cyclone ash. The only change they would make is to route the secondary cyclone ash lines separately to the point of disposal.

Installation of the candle filter system included provision for a back-up cyclone in parallel with the filter. Isolation of the cyclone during normal operation of the filter was provided by means of an upstream gas tight wafer valve (Advanced Valve Design, NJ). Initially, this valve did not provide adequate sealing and had to be modified. Subsequently, the valve experienced mechanical failure and the line was blanked off because there was no real need for the back-up cyclone. There is sufficient capacity in the remaining six parallel secondary cyclones to handle the plant capacity if the filter becomes plugged. Pressure safety relief was not provided for on the inlet side of the filter due to the free gas path remaining through the parallel trains of cyclones. AEP has had good experience with vibrators for the removal of the fine ash from vessels. A specially designed vibrator connecting the liner cone liner with the outside cone wall has worked well.

69. Does the sorbent lockhopper system consist of two alternating drums in parallel, or two drums in series?

The lockhopper system consists of a common atmospheric storage vessel and two parallel, alternating feed drums.

70. Who designed and supplied the sorbent lock hopper system?

Babcock & Wilcox.

71. Are the lock hopper drums mounted on load cells, and if yes, at three or four support points?

Each lockhopper feed drum is supported at three points by Kistler Morese, link-type load cells. The lock hoppers are supported from a separate tubular structure that is isolated from surrounding platforms and structural steel. This was done because of concern that deflection of the general structural steel was adversely affecting the load cell accuracy.

Writers note: Foster Wheeler questions this requirement if the vessel and associated instrumentation and hardware is properly isolated.

- 72. What type of feeder is used to meter the sorbent from the lockhopper drum into the pneumatic conveying line?**

Variable speed rotary feeders meter the sorbent to the pneumatic feed line based on a sorbent demand signal. The rotary feeder has not been a issue.

- 73. Who is the manufacturer of the sorbent feeder, and what is the operating experience regarding availability, wear, and shaft seal performance?**

Beaumont Birch, they think? Experience has been good.

- 74. Is the sorbent feeder variable speed, and if yes, on what parameter(s) is speed controlled and what type motor driver is used?**

Yes, the feeder is variable speed. The motor is DC. See No. 72.

- 75. What are the sizes of the sorbent feeder outlet and the pneumatic conveying line, and did the transition between the two require special design and/or hardware? Has plugging been experienced at this transition point?**

There has been no plugging in the transition piping between the rotary feeder and the pneumatic feed line. However, there has been plugging in the bottom of the sorbent lockhoppers. Condensation can occur in the sorbent lockhoppers (warm, dried sorbent from the Williams Mill cooling off).

- 76. Has TIDD considered testing a direct to pressure feeder, e.g., plug forming screw, in place of the sorbent lock hopper?**

AEP has considered but not seriously.

- 77. What is the generic type of the coal paste mixer, and who is the manufacturer?**

The coal/water paste mixer is a "pug-type," paddle-shaft design in a horizontal tubular housing. The manufacturer is Loige from Germany.

- 78. What type devices are used to meter the coal and water into the coal paste mixer? Is water under automatic ratio control based on the coal feed rate?**

The coal flow rate into the mixer is measured by a weigh belt feeder running at constant speed. Water is metered into the mixer by a control valve and is under ratio control based on the coal feed rate with set point adjustment for inherent and surface

moisture (also see No. 25). A microwave moisture meter, located between the crusher and mixer, measures the surface moisture. Inherent moisture is assumed.

SCS recommended action:

16. Review the use of a microwave moisture meter for the PSDF, regardless of whether or not paste feed is used.

79. What is the primary reason for the split casing gas turbine configuration, and did thrust bearing life, (i.e., high differential pressure between turbine inlet and outlet, have any influence on using this configuration?

This was the design established by ABB Stal.

80. What recommendations, experiences, components, valves, vendors, procedures can be suggested with respect to solids handling and auxiliary systems?

THE KEY TO SUCCESSFUL PFBC TECHNOLOGY IS DEPENDENT ON SOLIDS HANDLING.

Answers to this question have been covered elsewhere. With respect to the Denver screw cooler, there were problems with the screw cooler picking up speed as a result of the slow response. Speed signals have been a problem, and AEP had a problem not knowing how fast the screw was turning. Tidd's cooling water system for the screw cooler is limited to 320°F (50°F below saturation), so, to prevent boiling of the cooling water, the system is a high pressure closed loop system. Keeping cooler warm improves ash flowability.

SCS Recommended Action:

17. Review the need for a high pressure, closed loop cooling water system for the screw coolers.

It is important to keep solids moving out of the hoppers, to prevent bridging. Vibrators (impact type, low-frequency with the shaft through the hopper walls and refractory to the hopper stainless steel liner), "strike" plates (for using a sledgehammer), and "blast" nozzles (high flow, high pressure gas) are used to keep solids from plugging in hoppers. Also see Nos. 66 and 68.

81. What operability problems have been experienced?

Covered elsewhere. AEP cautioned to exercise care in citing past experiences published in the open literature. Do not assume design and operating experience has been successful as published. Investigate the performance records of all equipment considered for use in PFBC systems.

82. Have there been any problems with dry feed systems, coal and limestone? Plugging/bridging in hoppers (how to prevent or remove?)? Are vibrators used or recommended for feed hoppers? What experience can be recommended concerning nitrogen "fluffing" or moisture prevention? Is condensation a problem in coal feed hoppers? What are the slope and material of construction of hopper cones? Are there problems transferring solids from pressurization hoppers to feed hoppers?

There have been problems with sorbent lockhopper vent valves. The original "Cooper" valves did not work well. Neles ball valves are now used. An orifice is installed downstream of the vent valves to effect the pressure drop.

A vibratory feeder is used at the coal inlet to the crusher.

It is important to keep the sorbent dry. There are no vibrators on the sorbent lockhoppers and the cones occasionally plugged. See No. 75.

The angle of the Tidd flyash hoppers is 18 degrees. [Foster Wheeler is designing for 20 degrees.] Air blasters in the hopper cones should point down, not up.

Tidd has the capability to introduce solids between the primary cyclone and the candle filter to increase solids loading to the candles, if necessary.

Upon shutdown, solids are removed from the system by several methods. Where there is a screw cooler, the discharge flange of the screw cooler is removed, and the solids are discharged into a hose to an evacuated truck. The screw cooler discharge nozzle is 12 inches. At other locations solids are removed via a vacuum hose/truck.

SCS Recommended Action:

18. Foster Wheeler and SCS should review the methods used by Tidd to remove solids from vessels, and incorporate Tidd's experience into the detailed design where appropriate.
83. What is the ash removal design? Is ash removal batchwise or continuous? If batch wise, what accumulation volume is needed upstream to the ash removal hoppers to provide ample time to remove solids from the ash hoppers? What instrumentation is used to control the ash removal process? Are there any inherent safety issues/procedures concerning removal of ash? How are ash discharge rates measured?

The early ash separator has silencers for bed ash and flyash. Bed ash is heated by heaters to maintain the temperature above 200°F. Bed ash and flyash are disposed of separately via trucks. 300°F ash can be loaded into trucks but ash is typically cooler than 300°F when loaded. Flyash is wetted upon discharge into the trucks because it is very fine. Bed ash is discharged directly into open top trucks. Both bed and flyash are transported a short distance (about 15 minutes) to an area where they are dumped and later removed by an ash utilization vendor. AEP perceives no problems combining bed ash and flyash. Separation of the ash was done to assess marketability of the ash.

84. Are these problems with solidification due to the removal of too much heat from the unit?

Yes, too much cooling under pressure can cause solidification. Again, the issue is acid gas dew point as a function of pressure. Hot air is used in the bottom of the flyash silos.

85. Is erosion of pneumatic feed lines a problem? How is this prevented? What schedule pipe, material of construction, or lining is used in solids transfer piping? For turns, are long radius "ells" preferred over dead-leg "tees"?

AEP's experience is that solids will build up on the I.D. of pneumatic transport piping. Since erosion and ash deposition can occur in the same pipe, sandblasting sand (Black Beauty) is thrown into transport gas intake valves once per shift to keep the piping clean.

The discharge of the Tidd ash depressurization hopper is NASpipe, with an integral check valve to protect against overpressurization of the system.

SCS Recommended Action:

19. Ensure that the ash removal system design pressure is high enough in the event of plugging or valve closing.

86. Describe start-up of the facility. What are the "critical path" activities during start-up which are important on ensuring successful start-up? What do you look for to indicate start-up is proceeding well or not?

See No. 6. It is important to get the cyclone dip legs and ash pipes above the acid dew point temperature before firing oil and coal.

87. Have there been stress failures caused by phases changes and hammering at start-up?

None, except for the vertical separator in early start-ups. (The vertical separator is the small drum which acts as a steam drum at low loads. At high loads, the steam system is once through and the vertical separator is dry).

88. What are the emissions during start-up?

There are problems with opacity during start-up. AEP has a two-hour grace period on emissions during start-up. (also see No. 6)

89. What are the ash characteristics at start-up?

AEP doesn't know.

90. What is the start-up bed material? What other start-up bed materials have been used?

Fresh sorbent was used early in the operation, however, the plant couldn't be started up because of excessive elutriation (a bed couldn't be established). Tidd imports sand (Minnesota glacier deposit) and uses for all cold start-ups. Spent bed material cannot be kept in the PFBC and used for start-up if it sits for a week or so, because it will hydrate and form lumps. Spent bed material can be used for hot start-ups (from the ash reinjection vessels), and may be suitable for cold start-ups if relatively "new" and crushed.

91. What are TIDD's experiences with turbine start-up? What is the gas turbine gas path reliability?

The large 42-inch coaxial pipe (a cross section of which is depicted below) routes compressor air to the pressure vessel and PFBC and flue gas from the PFBC and cyclones to the gas turbine. AEP acknowledged that the coaxial pipe has not exhibited any evidence of corrosion and appears to be a preferred way of handling high temperature combustion gases. There are no dead zones, and the coaxial piping is arranged so that dewpoint conditions cannot be reached.

- 92. What experience has TIDD had with ceramic liners inside the beds with respect to liner height vs. bed height?**

Tidd has had good experience with ceramic tile liners in the bed zone.

- 93. Have there been wear problems in the gas turbine due to solids "shaken loose", accumulating, and slugged into the turbine at start-up?**

None. The PSDF should have provisions, however, for removing solids, if necessary, to prevent "start-up" solids from entering the turbine.

SCS Recommended Action:

- 20. Review piping design to ensure no low spots where solids can accumulate at shutdown, and provide any necessary cleanout ports, etc.**

- 94. What experience does TIDD have with respect to the number of cyclones vs. efficiency? What experience has TIDD had with failure of cyclones at welds due to design of cyclone liners, particularly at lower velocities? Would lines down into the cone portion prevent such failures?**

Tidd has seven parallel strings of two (primary and secondary) cyclones in series. The cyclones are very efficient, and the plant can be operated with one string of cyclones out of service.

AEP feels that the cyclone pressure drop is high enough to force corrosive gases behind the refractory layer, condense and corrode the shell, whether the refractory is monolith or layered.

- 95. What are the start-up and availability problems associated with the secondary cyclone ash system?**

See No. 38.

- 96. Does TIDD have experience with respect to "spoiling" of the cyclones to obtain a range of particulates? What suggestions can be made concerning design of such spoiling (materials of construction, nozzles locations and orientation, flow measurement, repeatability, etc.)?**

See No. 39.

- 97. What overpressure protection system is used, including PCDs? What differential pressure protection is used for PCDs?**

There is no separate pressure protection for the candle filter.

98. What are the positive and negative experiences with sampling devices? What recommendations can be made for continuous sampling of solids (coal, limestone, ash, char), particulates, and gases? Are gas chromatographs or other sampling devices used for on-line monitoring?

For coal and sorbent, normal ASTM procedures are used. Sampling solids streams under pressure has been an engineering challenge and has not been successful at Tidd. AEP experienced erosion of the solids transfer piping around the vicinity of the sampling device. Also, sealing of the sampling device has been a problem. AEP suggests sampling in depressurized lines and vessels, where possible. They don't feel much accuracy is lost. Tidd ash samples are taken at atmospheric pressure. AEP uses the candle filter vent valve to sample the filter.

Tidd does not use a gas chromatograph because there is no gas produced other than products of combustion. For oxygen measurements, the gas must be conditioned. To supply representative samples for oxygen analyzers, AEP uses a high-flow extraction, off which a second extraction is pulled. The sample is filtered and pressure reduced through a ceramic orifice. The sample lines need heating at start-up, and cooling during operation. Also see No. 12.

On-line gas sampling is difficult, however, AEP has had good experience with annubar in-situ flow measuring devices in the hot pressurized flue gas stream at temperatures lower than 1600°F.

SCS Recommended Action:

21. Review the design of the entire Tidd system used for extracting and conditioning representative samples for their oxygen analyzers, and incorporate into PSDF design.

99. What is TIDD's experience with ash characterization and disposal?

Writer's note: AEP and ABB have conducted extensive studies to characterize the ashes and develop uses for the ash byproduct. Attached is an excerpt from an AB Quarterly newsletter that highlights some of this work. AEP indicated that requests for ash samples have been extensive.

100. How does TIDD respond to variations in feed (flow rates, coal/limestone ratio, air/solids ratio, etc.)? How important is control and adjustability of coal and sorbent feedstock sizing?

Coal size distribution is critical for "good" paste. Particle size distribution determines the moisture content of the paste. Moisture content is also very important. If the paste is too wet, carbon conversion is poor due to incomplete combustion. If the paste is too dry, hot spots occur in the PFBC causing ash agglomeration. If the paste is very "dry," the feed system will plug. Sorbent size appears to be important for sulfur capture. See Nos. 25 and 26.

- 101. Are start-up/maintenance procedures available, particularly for components which are similar to PSDF components (solids feed and storage systems, pneumatic conveying, ash removal system, ceramic filter operation and maintenance)?**

Yes, they are available but can't be released to SCS. It may be possible to work something out whereby SCS can review the procedures, or have AEP review PSDF procedures.

- 102. How is ash cooled and removed from the bed at shutdown? How is bed material returned to the bed? What is the design of the system? What are the controls and procedures for re-injecting bed material to prevent plugging and keep the system operational?**

Sorbent can be blown into the PFBC using pneumatic transport from bulk trucks.

- 103. What are recommendations for preheating of the bed? Ceramic filter? Other components or refractory lined piping?**

Covered elsewhere (Nos. 6, 86). AEP recommends electric preheaters not be used to preheat the PCDs. They are unreliable.

- 104. Why are start-up fans used instead of bypass air dampers to force air through the preheating burner?**

Writers note: I do not remember this being answered specifically, nor do I understand the question. If the question alludes to the use of F.D or I.D. fans (as in atmospheric FBC), the compressor replaces these components in PFBC. As discussed in No. 2, there is an auxiliary fan (in addition to the compressor) to prepressurize the pressure vessel and PFBC to about 7 to 8 psig to equalize differential pressure across the intercept valves.

- 105. What is the operation or experience with cyclone and ceramic filter solids removal? Recommendations?**

Covered elsewhere.

- 106. What are the reoccurring problems with operation and maintenance?**

Materials handling. Some assistance may be available from United Conveyors or Allen Sherman Hoff. Use equipment specifications rather than performance specifications. Share risk with vendor.

SCS Recommended Action:

22. Locate and utilize "experts" in the field of material handling.

107. What is the load following ability of TIDD.

See No. 14.

108. What are the positive and negative experiences with hot gas filters? What recommendations can be made for PSDF filter system design? What suggestions can be made for PSDF filter test plan consideration?

AEP believes that the piping system is critical from a stress perspective. Stresses on nozzles and flanges should be checked carefully, and the PSDF project team should be confident of assumed nozzle loads.

With respect to heating the backpulse gas (as recommended by the PCD vendor), AEP does not know if it is necessary since the gas cools quickly upon expansion anyway. Backpulse valves do not work well above 200°F. The PCD head and connecting piping is flanged together using inconel gaskets because of flue gas corrosion potential. The flanges have not leaked.

SCS Recommended Action:

23. Review nozzle loads to ensure design is OK.

26. Review backpulse gas temperatures with PCD vendors, with respect to the design temperature of the valves.

31. Specify that mufflers be included on the vents from the PCD backpulse valves.

109. What ash removal and filter cleaning techniques have been developed?

AEP recommends that an appropriately designed area for filter candle maintenance be provided.

SCS Recommended Action:

24. Review the needs of filter maintenance, and provide necessary support structure, accessibility, or utilities.

110. What system design or procedures have been incorporated to allow handling of agglomerated ash and "oversized" material?

Tidd has encountered sintering problems, and have tried to recirculate oversized materials using reinjection.

SCS Recommended Action:

25. Provide screening and/or a recirculation or reinjection system for oversized material where possible and appropriate.

- 111. Has TIDD operated with both limestone and dolomite? If so, what are the operational differences (examples might be plugging, ash characteristic, etc.)?**

Tidd typically uses Plum Run dolomite (has also used National Lime dolomite). AEP has tried to use limestone on three different occasions and each time the plant ran only a matter of hours before the formation of agglomerates and clinkers (in the PFBC bed) shut the plant down. AEP has not been able to determine the cause for in-bed agglomeration problems experienced using limestone. Escatron uses limestone, but at much finer particle sizes than Tidd. The industry has yet to develop a method of characterizing dolomite or limestone for PFBC use.

- 112. What are the instrumentation package requirements based on operational experiences, i.e., what are the instruments needed for operation and performance monitoring?**

Get the best package you can afford. The Tidd control system is Bailey Net 90. AEP does not have a separate, stand-alone safety interlock system, but it is incorporated in their DCS. Instrument installation details are very important; all instruments should be self draining. AEP recommended designing the PLC/DCS very carefully so that only data which is relevant and necessary to the plant operation is displayed to the operator. All irrelevant data can be logged on the DAS for retrieval and analysis as required.

- 113. What instrumentation has been added since start-up and why?**

Nuisance alarms and trips have been reduced by 50 percent. It is important to prioritize alarms. DON'T OVER CONTROL!

Tidd uses Annubar flow meters with C-22 fittings for hot gas flow measurement up to 1600°F. AEP indicated that 1800°F may be pushing it. See No. 27.

SCS Recommended Action:

27. Supply flow measurements for syngas and vitiated air. Review the use of Annubar flow measurement for these services.

- 114. What are critical control issues between the PFBC and gas turbine? Pressure drop? Air distribution control?**

Surge margin is a critical issue. It is important to understand the logic and operating limits of the gas turbine. AEP recommends that SCS develop the control logic for the gas turbine, not Allison, to allow for easier modifications later (one system to learn, not two). Currently, the PLC for the Wilsonville gas turbine is provided by Allen Bradley and is located at the turbine. The only independent PCL at Tidd is on the variable speed motors. Tidd has eight nodes and a spare in its DCS.

AEP expressed concern with respect to Wilsonville's planned use of the compressor serving a multitude of duties. Distributing compressed air to a variety of locations, each with its own demand and control characteristics, will make plant control difficult

and complex, at best. Pressurized air/gas should be treated as laminar (water) flow, i.e., dense and viscous.

SCS Recommended Action:

28. Revisit the issue of SCS having the ability to reconfigure the gas turbine control logic.

115. What control strategy issues have been learned?

Design the control loops well, pay attention to detail and document everything. Keep a programmer at the site.

116. Does TIDD have experience with view ports? How are plugging, leaking, and fogging prevented?

No. Tidd does have opacity meters downstream of the turbine, but not upstream.

117. What are critical safety procedures at start-up and shutdown?

Wasn't answered or recorded in notes.

Notes from the Plant Tour

- A Syntron vibrator is used on the screw cooler discharge piping.
- SCS Recommended Action:
 - 29. Confirm that space for the paste feed system is sufficient for the paste feed pumps and associated piping.
- The screen manufacturer is Morgensen.
- The "rejects" from the Krupps Polysius roll crusher is a larger quantity than originally indicated by the manufacturer resulting in more drum handling than originally anticipated.

SCS Recommended Action:

- 30. Ensure that ample space is provided at PSDF mills for drum handling, or review the design to allow some better way of removing solids that is not labor-intensive.
- A maintenance bay for candle filters is important, it allows accessibility and saves maintenance time.
- Backpulse valve actuators are manufactured by Apollo.
- Tidd seal welds the head of the PCD as a precautionary measure, in addition to using a gasket.
- Tidd will be glad to share the vibrator design which enters through the hopper walls and refractory, impacting on the stainless steel lining, and providing sealing of the shaft.

SCS Recommended Action:

- 31. Get this design from Tidd, and incorporate into PSDF design.
- The Norwalk air compressor has been problematic for AEP because it is unreliable. The compressor loads and unloads continually and the lubrication system cannot keep up. The compressor has been repaired dozens of times.
- SCS Recommended Action:
 - 32. Investigate the possibility of buying sorbent pre-ground/crushed, to save on capital costs. Compare incremental cost increase of sorbent to capital savings. Be sure to leave space and allow for other sorbent grinding design needs.
- Tidd is a non-attainment area for particulates.
- AEP has Tidd plant control monitors in the Columbus office.

References for the Tidd Trip Report

Question 5 references:

1. Mudd, M. J. and J. D. Hoffman; "Operating Data from the Tidd Hot Gas Clean Up Program".
2. Mudd, M. J., J. D. Hoffman, and R. A. Dennis; "Initial Operation of the Tidd PFBC Hot Gas Clean Up Filter".

Question 10 references:

1. McClung, J. D and D. F. Levstek; "Presurized Fluidized Bed Combustion Combined Cycle Enters the Commercial Age", presented at the Canadian Electrical Association's Thermal and Nuclear Power Section 1989 Spring Meeting, March 12-15, 1989.
2. Pillai, K. K. and A. G. Roberts; "Off-Design and Part-Load Behaviour of PFBC Combined Cycle Power Plant".
3. McDonald, D. K. P S. Weitzel; "The PfBC Boiler for AEP's Tidd Plant Design for Performance and Operation", presented at the 1988 EPRI Seminar on Fluidized Bed Combustion Technology for Utility Applications, May 3-5, 1988.

APPENDIX C

FW APFBC TRAIN: OVERALL PLANT CONTROL PHILOSOPHY

PERRYVILLE CORPORATE PARK

CLINTON, NJ 08809

OVERALL PLANT CONTROL
PHILOSOPHY

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4161-A-M50-D420

CUSTOMER:	SOUTHERN COMPANY SERVICES, INC.	REV	BY	DATE
LOCATION:	WILSONVILLE, ALABAMA	A	DL	12/8/93
PROJECT NO.:	15-4161	B1	JWH	2/1/94
PLANT:	POWER SYSTEMS DEVELOPMENT FACILITY	B2	JWH	3/11/94
SECTION:	APFBC SYSTEM	C		
AREA:	200B and 400B	D		

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1. SCOPE

Control of the APFBC plant is considered from the view point of the plant as a whole and the interactions between individual subsystems.

Control philosophies are developed for startup, normal operation (including load change), shutdown and trip conditions.

2. INTRODUCTION

The APFBC plant consists of a number of subsystems, which need to work together so that the plant is able to function as an integrated whole. Each of the subsystems has requirements which must be met and dynamics which must be matched appropriately to the other subsystems. In addition, the plant as a whole must conform to environmental constraints, which limit the options available for control.

3. REQUIREMENTS OF SUBSYSTEMS AND PRINCIPLES OF OPERATION

The APFBC is considered to consist of the following subsystems:

- Carbonizer system, consisting of the carbonizer coal feed system, sorbent feed system, startup heater, carbonizer, carbonizer cyclone, carbonizer PCD and carbonizer alkali getter.
- Char transfer system.
- Pressurized Fluidized Bed Combustor system, consisting of the coal feed systems circulating fluidized bed combustor, startup heaters, fluidized bed heat exchanger, combustor cyclone, combustor PCD and combustor alkali getter.
- Ash removal system.
- The topping combustor system, consisting of the topping combustor.
- Gas turbine system, consisting of the gas turbine engine, gearbox, and generator and the various process valves controlled by the gas turbine vendor's control panel.
- The topping combustor system, consisting of the topping combustor.
- The booster air compressor system.

The requirements, principles of operation and dynamics of relevant subsystems will be reviewed.

3.1 Carbonizer

The temperature at the exit from the carbonizer is to be maintained at a set point value, in the range 1400 to 1800°F, typically 1600°F during steady operation. This is accomplished by controlling the air and fuel admission rates as described below.

Rapid variation of the air flow rate to the carbonizer will cause a transient increase or decrease in the char flow rate to the PFBC. This is a consequence of voidage changes in the bed. Therefore major changes in air flow rate should be made slowly or in small increments with a ramp rate in air flow not exceeding 4% per minute of the design rate of 8000 lb/hr. The syngas demand signal from the gas turbine system's control panel is consequently filtered using an appropriate signal velocity limiter. This is discussed more fully in Section 4. (The ramp rate restriction would be overridden if necessary to avoid serious temperature excursion. The transient effect is discussed in more detail in Appendix 1).

There are two possible methods by which the outlet temperature from the carbonizer could be controlled and load changes affected. One method is to set the fuel rate and to adjust the air rate to give the required temperature. The alternative is to set the air rate and adjust fuel rate accordingly. In the Wilsonville plant configuration, both air rate and coal rate are capable of rapid response, consequently either method could be used. FWEC have stated a preference that the air rate on the CPFBC be reset and fuel rate be controlled to give the required vitiated air temperature. Consequently, coal rate to the carbonizer will be controlled from the temperature exit the CPFBC and air rate to the carbonizer will be used to control carbonizer exit temperature.

In startup from cold, the temperature rise must be limited to below 200°F per hour to avoid refractory damage. This imposes rather wide turndown requirements on the startup heaters.

During start up, the transition between oxidizing and reducing atmosphere must be effected without causing an overtemperature excursion.

3.2 Char Transfer

The char transfer system feeds char from the carbonizer, carbonizer cyclone and PCD into the combustor and must operate over a wide range of solids flowrates from each of these sources.

The char transfer system consists of a number of seal legs that function on hydrostatic principles. The primary requirement is that the pressure differential between the carbonizer and the combustor be within the capabilities of the seal legs. This range is reasonably wide (4 psi) but the range of variation in the pressure differential induced by PCD operation is wider (7.5 psi). Consequently, control of pressure differential, between the carbonizer and the PFBC, is required.

The char transfer system has no significant ability for solids accumulation and consequently provides no surge capacity between the carbonizer and the CPFBC. During steady operation, char is consequently fed to the CPFBC as fast as it flows from the carbonizer. The steady flow is upset for a few seconds during and after PCD regeneration as the height of char in each transfer leg readjusts itself to the changed pressure profile. The consequent upset to char flow to the CPFBC is of short duration and only a small amount of material is involved. The transient effect on CPFBC performance is insignificant due to the capacitance effect created by the large mass of recirculated solids in the CPFBC.

In order to protect equipment internals from overtemperature excursions during startup as well as normal operation, provision must be made to prevent the possibility of reverse flow of hot vitiated air from the CPFBC system into the syngas containing carbonizer overhead system.

3.3 Circulating Pressurized Fluid Bed Combustor

The vitiated air temperature exit the CPFBC must be maintained at a set point value of 1600°F. This temperature depends on the air flow rate, the char rate from the carbonizer, the coal rate to the CPFBC and the heat removed from the CPFBC. FWEC have stated a preference for setting the air flow rate and varying the fuel rate to give the required outlet temperature. This is accomplished by having the CPFBC air rate and CPFBC coal rate set (by the load management software) and controlling the coal feed rate to the carbonizer to give the desired temperature exit the CPFBC. A load change at 4% per minute can be accomplished without creating unacceptable transient conditions, see Appendix 1. The load management software will automatically feed coal the CPFBC directly as required under turndown conditions in order to maintain the vitiated air temperature.

The PFBC has a relatively high thermal inertia, by virtue of the inventory of circulating ash. Consequently if the fuel rate to the bed changes, either transiently or by load adjustment, the vitiated air temperature change will have a significant time lag.

In order to simulate the heat that would be removed by the steam boiler in a commercial plant, part of the heat in the circulating ash stream is removed into a condensate stream in the fluidized bed heat exchanger. There is provision to vary the amount of heat removed, but it will not be a tightly controlled variable in operation but rather steps will be taken to set heat removal within a desired range.

During startup from cold the rate of temperature increase must be limited to below 200°F per hour, which imposes turndown requirements on the heaters.

3.4 Gas Turbine

In steady operation, the gas turbine operates at a constant speed, dictated by the generator synchronous speed. The compressor is a multistage axial flow machine and as such is essentially a constant volume machine at pressures up to the surge point. As a consequence, the air mass flow varies almost entirely only due to inlet air density changes.

The expander of the gas turbine always operates with choked flow conditions exist at its inlet. This fixes the turbine inlet pressure for a given mass flow and temperature for a given mass flow and temperature and hence sets the pressure profile throughout the plant.

As a consequence of the above the useful power output (electrical load) and the turbine inlet temperature are directly, and almost linearly related for constant ambient conditions. As ambient temperature and pressure vary, the power output at a given expander inlet temperature changes again linearly. These effects are

shown graphically in Figure 1 comparing inlet temperatures of 60°F and 90°F by way of example.

The theoretical relationship between expander inlet pressure and temperature which follows from the choked flow condition and compressor performance is shown in Figure 2. This theoretical relationship is modified slightly in practice because part of the compressor discharge air is bled off for blade cooling and consequently bypasses the turbine inlet choke point. It is metered by orifices elsewhere in the engine.

FIGURE 1: POWER OUTPUT VERSUS CTIT **FIGURE 2: TURBINE INLET PRESS VS CTIT**

The normal operational range of the gas turbine is with an electrical output of between 1000 kW and the maximum power capability. The corresponding turbine inlet pressure is expected to be between 125 and 160 psia. The gas turbine inlet temperature lies between 1200°F and the maximum allowed by the manufacturer. This limit has been given as 1977°F burner outlet temperature, corresponding to a calculated turbine inlet temperature of 1895°F using Allison's standard exhaust gas thermocouple and control algorithm.

Conditions are given in Table 1 for four cases:

- i. Gas turbine design
- ii. Mass balance
- iii. Turndown to 50% for both vitiated air and syngas streams
- iv. Suction temperature higher (90°F)

Table 1: Gas Turbine Conditions Over Operational Range

	Gas Turbine Design	Mass Balance	Turndown	90°F Suction
Suction Temp (°F)	60	60	60	90
Suction Press (psia)	14.6	14.6	14.6	14.6
Syngas flow (lb/h)	10400	11048	5524	10805
Vitiated air (lb/h)	77400	73208	36640	71597
Dil air (FV 7223 - lb/h)	0	11713	5496	10740
Byp air (FV 7205 - lb/h)	28000	6287	55694	9160
Topping cooling (lb/h)	0	10000	10000	10000
Internal cooling (lb/h)	11000	11000	11000	11000
Expander flow (lb/h)	126800	123256	124318	123302
Expander P (psia)	155	150.6	128.7	150.7
Expander T (F)	1977	1977	1289	1977
Electric Power (kW)	3606	3357	1083	3046
Heat in vit. air (%)	43.1	40.5	41.8	38.6
Sens heat syngas (%)	7.3	7.6	7.4	7.8
Fuel heat syngas (%)	49.6	51.7	50.7	53.6
Fuel heat propane (%)	0	0	0	0

The dynamics of the gas turbine and generator are only relevant when speed change is possible, that is during startup and trip conditions. The turbine takes approximately 0.9 seconds to accelerate from 100% to 120% speed under full power.

3.5 Topping Combustor

The MASH topping combustor has a rich zone, which must be maintained at 2900°F followed by a lean zone. Lean zone operation at temperatures ranging up to 2350°F is to be demonstrated.

The rich zone temperature is determined by the position of a slide plate within the combustor. The lean zone temperature is determined by the amounts of vitiated air, syngas fuel and bypass air fed to the topping combustor.

It is intended to operate initially with air bypassed upstream of the topping combustor as a fixed fraction of air to the CPFBC. Some provision will additionally need to be made to override this method of determining air flowrate to provide enough air for combustion when propane is in use.

Propane, as a startup or supplementary fuel is fed to the MASH via a separate nozzle. Dilution of propane with steam may be required to avoid overtemperature in the rich zone, owing to its high calorific value relative to syngas.

3.6 Booster Air Compressor

The booster air compressor is a constant suction volume machine (reciprocating compressor at constant speed). Its discharge pressure is limited by use of spillback control.

4. OUTLINE OF OPERATION OF CONTROL SCHEME

In the final analysis, the power produced by the AFPBC depends on the amount of coal and propane fuel fed to the unit. In developing the control scheme the dynamics of the various devices were considered in addition to the steady state conditions.

Fuel energy fed to the plant leaves the facility in the following major ways:

- Heat energy in the turbine exhaust.
- Power from the turbine/generator set.
- Heat rejection to the FBHE condensate coolant.
- Heat rejection to the atmosphere in the gas turbine exhaust.
- Heat losses.

Energy is stored in the plant in the following forms:

- The fuel value of the inventory of char in the carbonizer.
- Sensible heat of the CPFBC bed material inventory.

- Inventory of syngas and vitiated air.

Changes in the energy stored by these mechanisms affects the dynamics of startup, load change, PCD transients and trips. These will be discussed below.

There is a feasible range for steady state operation which is depicted (for the 15% bypass air case) in Figure 3, in terms of syngas and vitiated air flow rate.

FIGURE 3: FEASIBLE OPERATING DOMAIN 15% BYPASS CASE

The feasible range is bounded by the following:

- A downward sloping linear relationship between syngas flowrate and vitiated air flow rate corresponding to a turbine inlet temperature of 1895 deg. F. The topping combustor exit temperature and the amount of air voluntarily bypassing both reduce as vitiated air rate is increased along this line.
- A more steeply sloping line along which there is no bypass air downstream of the topping combustor and consequently air available to produce syngas rapidly decreases as air used to produce vitiated air increases. Power

output and topping combustor exit temperature both decrease as vitiated air increases along this line.

- A horizontal line corresponding to minimum turndown of the carbonizer (taken provisionally as 40% rate). Power output decreases while topping combustor exit temperature increases as vitiated air rate is decreased along this line.
- A vertical line corresponding to maximum turndown for the CPFBC (provisionally taken as 50% rate). Power and topping combustor exit temperature both increase as syngas flow is increased along this line.
- An upward sloping line corresponding to the maximum allowable topping combustor exit temperature of 2350°F. The power output increases as vitiated air rate increases along this line. The line intersects the first line discussed at a point where topping combustor exit temperature is 2350°F and simultaneously the power output is at a maximum.

The control system must be configured to permit operation at any point within the feasible range. Clearly it will be of interest to operate as close as possible to the maximum topping combustor temperature and maximum power lines.

The required functioning of the load management software is developed in Table 2 below together with a list of variables to be controlled and how to control is accomplished.

Table 2: Variables to be Controlled and Methodology Selected

Variable to be Controlled	Method by Which Variable is Controlled
Syngas exit temperature (to be maintained at 1600°F)	The carbonizer air rate is varied using a cascaded temperature signal to reset the flow rate set point. Ramp rate limit and range limits for the air flow should be incorporated.
Vitiated Air Flowrate	The required vitiated air rate is determined by the load management software and primary/secondary CPFBC air set points are calculated. The set points are fed to the air flowrate controllers after ramp rate and range limitations have been applied.
Vitiated air temperature (to be maintained at 1600°F)	The coal feed rate to the carbonizer is varied, using a cascaded control system from vitiated air temperature.
Electrical Load	The required electrical load is used to compute a CTIT setpoint. The actual load is allowed to fluctuate.

Gas Turbine Inlet Temperature	<p>These are considered together because an operating point within the feasible range may be defined in terms of the CTIT and the topping combustor exit temperature.</p> <p>These two inputs are used to calculate the required vitiated air flow rate and the required syngas flow rate. The required vitiated air flowrate is used as described above. The required syngas flow rate is used to compute an expected carboniser flow rate.</p> <p>The set point CTIT together with the FBHE heat load (calculated from condensate temperature increase) is used to calculate the total fuel requirement.</p> <p>The desired (set point) amount of propane firing is an operator input, carboniser coal expected flow rate is calculated as discussed above. CPFBC coal rate is determined by difference.</p> <p>There are two modes in which the plant will be capable of operating:</p> <ol style="list-style-type: none"> With actual propane firing at the set point value with gas turbine inlet temperature topping combustor exit temperature and load fluctuating about the desired operating point. With actual propane firing directly coupled to CTIT so that there is less fluctuation in load.
Flowrate of air bypassed upstream of topping combustor	<p>The intention is to operate with a fixed ratio between vitiated air flow rate and upstream bypass flowrate so that the air temperature to the topping combustor is essentially fixed. Initially 15% bypass is envisaged. This is accomplished by keeping the flowrate of bypass air in ratio to the air fed to the CPFBC. It is however also essential to ensure that sufficient air is fed to the combustor when propane is being fired as fuel. This is accomplished by calculating the amount of total air required for a topping combustor outlet temperature of 2350°F from total fuel requirements. The air fed to the carboniser and the CPFBC is then subtracted from the total and a second figure thereby obtained for the required bypass flowrate upstream of the topping combustor.</p> <p>The larger of the two alternative numbers is used as a set point for the flowrate of bypass air upstream of the topping combustor.</p>
Sorbent to Carbon ratio	<p>The amount of sorbent to be fed to the carboniser is computed from the total coal feed rate to carboniser and CPFBC.</p>
MASS rich zone exit temperature (to be held at 2900 °F)	<p>The slide plate within the MASS device is positioned to give the required temperature.</p>
FBHE Heat Load	<p>The FBHE heat load depends on, circulation rate of ash (hence performance of cyclone), amount of fluidisation air to FBHE, coils in service and which draw off point is used for ash.</p> <p>It will be operated by setting it up to give a heat load approximately as desired and thereafter will be left alone, is no on line control is anticipated.</p>

The functioning of the load management software discussed in Table 2 above is summarized in Figure 4.

Note that many of the signals pass through ramp limiting and range limiting filters, implemented in the software. This is to avoid the undesirable transients that could result from too rapid load change (or other movement between operating points).

FIGURE 4: LOAD MANAGEMENT SOFTWARE

The functions of individual valves and other devices in supporting the control methodology outlined in Table 2 are given in Table 3. Operation will be better understood by reference to Figure 5 which is an overall block flow diagram.

**FIGURE 5: BLOCK
FLOW DIAGRAM**

Table 3 : Control Devices, Functions and Control Methodology

Valve	Function	How Controlled
FV6225	Modulate air admission to carbonizer in order to maintain the desired syngas temperature of 1600°F.	<p>The air admission rate is flow controlled with a set point derived from the syngas temperature exiting the carbonizer.</p> <p>The air rate is not allowed to change faster than 320 lb/h/min in order to limit the magnitude of transient char flows caused by voidage changes. This feature may be overridden to prevent excessive temperature excursions.</p> <p>During startup operation, the flow controller is given a set point directly and there is no restriction on the air flow rate ramp rate.</p>
FD0252	Feed coal to carbonizer at a controlled rate to give required vitiated air temperature.	<p>As discussed in Table 2, the coal feed rate is varied to give the required vitiated air temperature exit to the CPFBC.</p> <p>The coal demand signal is converged into a feeder speed signal for final control which is corrected by measured weight changes of the lock hopper.</p>
FD0251	Feed coal to the PFBC when required.	<p>Combustor coal required is calculated by the load management system as discussed in Table 2.</p> <p>The combustor coal demand signal is converted to a feeder speed signal which is corrected with measured weight changes of lock hoppers.</p>
FV6360	Set the primary air admission rate to the PFBC in accordance with operating point requirements.	The required air rate is determined by the load management software. To avoid unacceptable transients, the ramp rate is limited to below 3000 lb/hr/min. (40/min.). In addition there is a minimum flowrate imposed to avoid slumping of the bed.
FV7222	<p>Two modes of operation:</p> <ol style="list-style-type: none"> 1. Modulate the propane admission rate to ensure that the required load is achieved. 2. Feed a fixed amount of propane 	<p>When used to achieve desired load, the admission of propane is controlled directly to give the desired calculated inlet turbine temperature (CTIT).</p> <p>The propane valve must have the ability to respond within a fraction of a second to changes in the CTIT.</p>
Slide Plate	To control the rich zone exit temperature of the MASH at 2900°F. This temperature is optimal from the view point of NOx emission reduction.	The temperature of the rich zone is measured directly by optical pyrometry and used directly to position the slide plate.
FV6356-9	Modulate secondary air flow to the PFBC.	<p>The secondary air flow rate at each level is controlled as a ratio to the primary rate.</p> <p>The required ratios will be determined with a view to minimizing NOx formation in the vitiated air.</p>
VL0452	<p>Keep the differential pressure across the char transfer system within required bounds, while the syngas flow and vitiated air flow are maintained as desired.</p> <p>In trip conditions, the valve must quickly stop flow of syngas to the topping combustor.</p>	<p>VL0452 is driven from PDI6350, to ensure that the differential is maintained within the required range.</p> <p>The differential is affected by the positioning of the air admission valves FV6360 and FV6225 as well as the operational pressure drop across the PCD's.</p> <p>In startup operation, the valve is kept at a minimal open position to ensure that the major startup airflow from the carbonizer proceeds via the char transfer system to the PFBC.</p> <p>In the case of a trip, the valve must shut quickly (within 0.6 seconds).</p>
FV6482-5	Admit fluidization air to FBHE	These valves are operated with a preset amount of air for desired FBHE operation. They consume only a small fraction of total air.

Valve	Function	How Controlled
XV6316	Isolation valve in char line between carbonizer and combustor.	<p>The valve is open during both startup and normal operation.</p> <p>It is closed as part of the trip event to prevent backflow of air into the syngas system.</p> <p>It may be closed deliberately during prolonged operation without the carbonizer.</p>
XV7219	Send syngas to flare when required.	<p>This valve is closed during normal operation.</p> <p>During start up, it is initially venting air rather than syngas. It is closed before syngas production starts.</p> <p>It is not pinched back for pressurization of the carbonizer but rather is shut completely when pressurization is to commence. (The vitiated air vent is used as the pinch back valve).</p> <p>In the event of a trip, it is required to open rather rapidly (within 1 second). It is sized and programmed for incremental operating so that the carbonizer is depressurized into the flare system at a reasonably controlled rate so as not to damage PCD and other sensitive equipment.</p>
VL0451	Isolation valve in the vitiated air line.	<p>The valve is open during normal operation and has a low pressure drop.</p> <p>It does not tightly shut off and consequently leaks back air during part of the startup.</p> <p>It is closed fairly quickly (of order 5 seconds to fully close) after a trip.</p>
XV7218	<p>In the case of a trip, vent vitiated air at an adequate rate to prevent gas turbine overspeed.</p> <p>In startup operation, pinch back to pressurize the PFBC and carbonizer.</p>	<p>The valve is closed during normal operation.</p> <p>In startup, it is pinched back gradually to pressurize the PFBC and carbonizer together. It is necessary to be able to pressurize to a pressure slightly above but as close as possible to the gas turbine inlet pressure prior to opening the vitiated air isolation valve, VL0451. (0 to 5 psi above the gas turbine inlet pressure is required).</p> <p>In the case of a trip, the valve must open rapidly (0.6 sec) initially and thereafter in a programmed incremental manner so that the CPFBC is depressurized in a controlled manner. The flowrate required initially has been estimated at 20,000 lb/hr.</p>
TV7207 FV7206	To provide cooling air for the MASH topping combustor.	In normal operation, the flow rate of cooling air required is set as a predetermined function of its temperature from Westinghouse requirements. During gas turbine startup, the cooling function is not critical as air to the topping combustor is comparatively cold (650 deg. F). It is preferable to override the flow control during startup so as not to upset gas turbine startup fuel scheduling unduly.
FV7223	To control the bypass air flow rate to upstream of the topping combustor	<p>The intention in normal operation is that bypass air rate be in a fixed ratio to vitiated air flow. However, in the event that propane is in use, it is important that enough air be admitted to the combustor for complete combustion.</p> <p>Accordingly, two alternative required air rates are calculated by the software and the larger value is used as a set point.</p>
FV7205	To bypass excess air while maintaining an acceptable differential pressure between gas turbine compressor and expander.	<p>The total amount of air delivered by the compressor is essentially fixed. The consumers of air described in this table are all flow controllers with the exception of this valve.</p> <p>Under these conditions, the air rate through FV7205 is fixed. The only remaining variable of concern on the gas turbine is pressure differential across the machine, which must be kept below 15 psi. FV7205 consequently performs as a differential pressure controller.</p> <p>The 15 psi maximum differential is only valid at 100% speed, and must be speed corrected to a lower value for start up. Alternatively FV7205 may be in its maximum open position for start up.</p>

Valve	Function	How Controlled
PV6613	To maintain a constant outlet pressure from booster compressor.	<p>It is advantageous for operation of the flow valves PV6225, PV6360, PV6356-9 and PV6482-5 to have a constant pressure exit the booster compressor.</p> <p>The mass flow in the recycle loop is fixed by other things and PV6613 operates to give the necessary pressure differential to give the required pressure exit the booster compressor.</p> <p>In order to avoid excessive outlet temperature, the set point for outlet pressure is over ridden by a value calculated from suction pressure and maximum permissible compression ratio in the event that the set point is too high.</p>

5. STARTUP

5.1 Alternative Strategies Considered

Two alternative methods to startup the facility were initially considered, namely the "gas turbine first" and the "all at once" strategies. The method chosen is an adaption of the "gas turbine first" method in which the startup of the gas turbine is decoupled from that of the rest of the plant. Startup activities however, commence earlier in the balance of the plant.

The perceived advantage of the "all at once" strategy was that there are no troublesome transient conditions to consider for the gas turbine. The disadvantages of the "all at once" strategy are that the capacitance effect of the volume of the plant interferes with the topping combustor fuel scheduling and may pose a difficult challenge as regards maintaining smooth continuity of the combustor and carbonizer warm up program. The turbine would need to run on propane for many hours while the PFBC and the carbonizer are gradually heated up and then pressurized.

The advantages of decoupling the gas turbine startup from that of the rest of the plant are that the conventional gas turbine startup hardware and software may be used and that less propane will be consumed during the startup period. Transient conditions during the startup (opening vitiated air isolation valve) have been considered and do not pose a problem (See Appendix 2).

5.2 Sequence of Events

The rate of the startup of the carbonizer and the PFBC are limited by refractory heating schedules, and the time taken to build the fluidized beds. The startup can be expected to take 12 to 24 hours (longer during initial startup, when refractory dry out will be necessary).

By contrast, the gas turbine startup takes of order 45 seconds.

The sequence adopted is:

1. Heat up the carbonizer and the PFBC at low pressure, with the gas turbine offline or motoring, using small mass flows of air. Air is drawn through the gas turbine which will slowly rotate accordingly (oil pumps must be on line).

FWEC require an air flowrate in the range 20000 to 30000 lb/hr for startup as heat transfer to the refractory is by convection only. Such flowrates are only attainable with the gas turbine rotating under starter motor power at the maximum speed possible. The booster air compressor is used for this purpose.

- ii. Cut back air flow to the carbonizer and the PFBC as far as possible and then start up the gas turbine, using propane. The topping combustor will achieve rich-quench-lean combustion from the start using an appropriate slide plate adjustment. The minimum air flow rate to the carbonizer and PFBC is determined by rangeability of the startup heaters. Turndown to approximately 5% or less of the normal flowrate is desired to avoid creating problems in fuel scheduling during the gas turbine start up.

The cranking motor power will also need to be reduced so that the speed drops to 2200 rpm, which is the normal light-off speed.

Bring the gas turbine to a normal running condition with a load point close to minimum, with the generator producing say 1000 kW of power. Steam injection will begin automatically when needed through valves controlled by Allison software in accordance with a Westinghouse supplied algorithm.

- iii. Pressurize the carbonizer and the PFBC by closing the valve XV7219 to the flare (first) then gradually pinching back the vitiated air vent valve XV7218.

Pressurization is mainly by forward flow of air through the booster air compressor and startup heaters with a small amount of back flow of air through the vitiated air isolation valve VL0451 and syngas trim valve, VL0452 which are not tight shutoff valves.

- iv. Allow the pressure in the PFBC to slightly overshoot (0 to 5 psi) the pressure at the gas turbine inlet (which is of order 113 psig at the 1000 kW load point). Then open the vitiated air isolation valve VL0451, gradually and completely. (The turbine power output transiently increases by 200 kW during the switchover, See Appendix 2). Once the vitiated air isolation valve VL0451 is fully open, close the vitiated air vent valve XV7218.

Open the trim valve VL0452 from the carbonizer to its minimum opening position so that a small hot air flow is established along this line to the topping combustor, but the major portion of air fed to the carbonizer flows via the char transfer system to the PFBC.

At this point, the carbonizer and PFBC act as conduits for hot air to the gas turbine. The load control automatically cuts back on fuel to the topping combustor to compensate for the heat contained in hot air fed to the topping combustor. However, most of the air flow to the topping combustor is still via the bypass valve FV7223.

- v. Increase the air flowrate to the PFBC into a range which is appropriate for building the fluidized bed. (The startup heaters will fire more propane to maintain the PFBC temperature and the topping combustor less propane to maintain gas turbine output). The topping combustor slide plate will, as at all other times, modulate to maintain 2900°F rich zone outlet temperature. Build the fluidized bed using sorbent, as per the startup procedure by Foster Wheeler Energy Corporation.

Once the bed is built, commence solid fuel feed, to the PFBC bring bed outlet temperature to 1600°F, reduce and finally eliminate start up heater propane. Bring the PFBC system fully on line, following the startup procedure by Foster Wheeler Energy Corporation.

At the end of this step the unit is functioning as a first generation PFBC power generator. The vitiated air rate being essentially constant and coal rate to the PFBC controlled to give the required exit temperature of 1600°F.

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- vi. Increase the air rate to the carbonizer to a suitable range to build a fluidized bed. (The startup heater will fire more fuel to maintain the temperature). Build the fluidized bed using sorbent, as per the startup procedure by Foster Wheeler Development Corporation.

Once the bed is built, ensure that the valve VL0452 in the syngas line to the topping combustor is positioned so that gas flow is from the carbonizer to the PFBC and not vice versa. This will be the case if the valve is nearly shut. Then commence solid fuel feed, bring outlet bed temperature to 1600°F.

During this operation, the char transfer system does not operate as a seal but rather in dilute phase pneumatic conveying mode. Initially sorbent fines and air are fed along this line to the PFBC.

The air rate to the PFBC may be increased at this point as char starts to come through into the PFBC. The air rate to the PFBC may be increased at this point as char starts to come through into the PFBC. At this stage of the startup, coal to the PFBC rather than coal to the carbonizer is used to control the vitiated air temperature. Before normal operation may commence, it is necessary to switch the coal rate to the PFBC to a preset rate and make the vitiated air temperature control the coal rate to the carbonizer.

The propane rate to the topping combustor automatically reduces to control the power output.

- vii. The final step in the startup is to put the char transfer system into normal operation. Up to this point, the syngas trim valve VL0452 has been restricted to induce a high gas flow rate between the carbonizer and the combustor. This serves to transfer the char and sorbent between the two devices in dilute phase. This is not acceptable for normal operation as the syngas flowrate to the topping combustor is too low for the required operation of the topping combustor.

The syngas trim valve VL0452 is gradually opened. The syngas flow to the topping combustor increases and that to the PFBC decreases until the velocity in the char transfer system is too low for dilute phase conveying through the upleg. A dense phase bed of char and sorbent rapidly builds up in the transfer system and normal operation commences.

At this stage, the plant is consuming coal in both the PFBC and the carbonizer. It is anticipated that the startup will be carried out at close to minimum turndown rate, under which conditions, such co-feeding is appropriate. Proportioning of coal feed between the carbonizer and the PFBC is an automatic control function as described above in Table 2. The coal fed to the PFBC is reduced and finally eliminated as the load is increased.

6. NORMAL OPERATION

6.1 Maintenance of Steady Conditions

The standard load/speed/firing temperature governor system employed by Allison in their gas turbines with conventional fuels works by varying firing rate to give the required CTIT (calculated turbine inlet temperature).

The APFBC facility employs the standard hardware and software as much as possible. The following adaptations are necessary:

- Software has to generate signals for the amount of coal to be fed to the carbonizer and the PFBC from the total fuel demand. It is envisaged that at low load, coal will be fed to both units and at high rates only to the carbonizer.
- Coal feed rate is not allowed to ramp too rapidly to prevent rapid inventory changes in the carbonizer, which would cause severe load point overshoot. Consequently, system responsiveness may be gained by using the CTIT to control the supplementary propane rate directly, rather than via a cascaded control.
- FWEC require an air lead, fuel follow strategy for the PFBC control. The consequences are explained in Table 2 above.

The envisaged software function is described in Table 2 and can be understood with reference to Figure 4, it will be briefly recapped so that the method by which a set point is maintained may be understood.

The required load and measured FBHE heat load is used to generate a total fuel demand signal. The required load and topping combustion firing temperature are used to generate signals for required vitiated air flow and required syngas flow. The expected carbonizer coal flow rate signal is generated from the syngas requirement. The desired propane firing rate is an operator input and the CPFBC coal rate is calculated by difference.

The CPFBC rate is controlled to equal the calculated set point value. The carbonizer coal rate is only indirectly controlled to give the required CPFBC exit temperature. The propane flowrate can either be directly controlled to give the required power output or else controlled to equal the set point value, at the operator's discretion.

The vitiated air rate is controlled to equal the calculated value. The syngas rate (carbonizer rate) is controlled to give the requisite carbonizer exit temperature of 1600°F.

The syngas rate will consequently fluctuate around the required value.

The calculations are in principle simple ones, involving linear simultaneous equations. The "constants" in those equations may need to be varied by the control system to correct an offset between the predicted load point and measured loadpoint. (This will be necessary to take account of such factors as minor variations in coal calorific value). Such a control strategy is within the capability of a DCS system.

6.2 Load changes

For any required load a range of syngas and vitiated air flows is possible as depicted in Figure 3. The new load point is uniquely defined if topping combustor exit temperature is specified in addition to the power.

Each operating point is defined by the following variables, which are under more or less direct control and consequently which may be altered for load change purposes:

- a. The required vitiated air rate.
- b. The setpoint value for propane flow.
- c. The coal rate to the CPFBC.

Load change must be accomplished so that the plant remains within the feasible region of operation, depicted on Figure 3, at all times. The path taken in load change will depend to some extent on where the initial and final operating points are located within the feasible range. Clearly it is unwise to effect load changes along a path that is unnecessarily close to the boundary of an infeasible region.

A typical load change path would be as follows:

- a. Begin to ramp air rates to the CPFBC at a controlled rate (4% of full range per minute maximum) towards the new control point. Vitiating air temperature control will cause the carbonizer coal rate to increase at a similar rate. The carbonizer exit temperature controller will cause carbonizer air rate and hence syngas rate to increase, generally at a lower rate than vitiating air flow.
- b. Simultaneously ramp CPFBC coal rate (4% per minute max.) towards the new control point.
- c. Simultaneously ramp propane flow to its new control point.

If the changes are carried out simultaneously and slowly as outlined above. Movement between operating points will be essentially along the straight line joining those points on Figure 3. A sequential load change strategy could of course be adopted instead and would be equally valid.

The need for a limit on the ramp rate for various variables (to 4% of load per minute) has been discussed above.

Appendix 3 illustrates the overshoot of setpoint that is anticipated when step changes are made to variables, using an increase in bypass rate as an example.

6.3 PCD Transients

The operation of the PCD's causes transient effects to the gas turbine system.

The first effect is that char transfer is either interrupted or increased for a few tens of seconds until the height of char in the transfer system down leg is appropriate for the new pressure conditions. (The amount of char involved in such events is approx 40 lb, equivalent to approx 0.14 MMBtu of vitiating air heat). This effect will be filtered out to a very large extent by the thermal inertia of the PFBC.

The second effect is that cold pulse gas is introduced into either the vitiating air or the syngas stream as the case may be. Each pulse of regeneration gas causes a transient upset to the pressure and composition of the syngas or air to the topping combustor. This in turn causes short lived transient spikes in the turbine power output.

The magnitude of the effect depends on the regeneration strategy that is chosen, being directly influenced by the amount of regeneration gas used per pulse. The effect can be reduced in severity by means of the following mitigating strategies:

- a. Use the minimum possible amount of regeneration gas per pulse episode, for example by increasing the number of banks of candles if necessary.
- b. Use air for regenerating the combustor PCD and a nitrogen/propane mixture for the carbonizer PCD.

The extent of the problem is currently being quantified. Appropriate steps to avoid PCD transient problems will be identified. This is targeted for inclusion in the 75% package.

7. TRIP CONDITION

The over-riding concern in a trip situation is to ensure that the gas turbine does not overspeed and become damaged.

The gas turbine is of the aero-derivative type and as such has a low rotational inertia. In the event of a breaker trip (consequently zero electrical load), the normal full load power output is enough to cause the machine to accelerate to 120% of normal speed in 0.9 of a second. The trip system is to ensure that such potentially damaging overspeed will not occur. It is desired to limit the overspeed to 110% in the event of a breaker trip.

At the start of a breaker trip event, the expander is producing more power than the compressor is consuming. When the trip occurs, initially that power goes into speeding up the machine. If the trip strategy is to be successful, it is necessary to rapidly come to a state where the compressor is consuming more power than the expander is delivering, so that the machine may begin to slow down.

In order to understand the working of the trip system, consider that approximately 45% of the heat to the engine comes from the vitiated air stream while 55% comes from the syngas stream. In addition, there is an inventory of hot, pressurized gas which is large compared to the acceleration time of the turbine. It is therefore clearly necessary to stop syngas flow as rapidly as possible, but by itself, this is not enough. The mass rate of vitiated air to the turbine would instantaneously increase, keeping the turbine inlet under choked flow conditions and the power output would remain positive. The following events happen in the case of a trip:

- i. The trip system takes 0.2 seconds to begin to shut valves.
- ii. The syngas valve VL0452 and propane valve FV7222 shut within 0.6 of a second. That is between 0.2 and 0.8 seconds from the start of the trip event.
- iii. The vitiated air vent valve XV7218 opens within 0.6 of a second. This occurs simultaneously.
- iv. The topping combustor upstream bypass air valve FV7223 and FV7205, the downstream bypass, are moved to the fully open position as quickly as possible (within 5 seconds would be adequate).
- v. The flare valve XV7219 opens within 1 second.
- vi. Vitiated air isolation valve VL0451 closes as quickly as possible (10 seconds would be adequate).
- vii. Coal and sorbent feed stops as quickly as possible, the feeders are expected to take about 5 seconds to run down. The transport gas to the carbonizer feeder should be switched from air to nitrogen and continue to flow for some seconds after the feeder has stopped (30 seconds would be adequate).
- viii. Char transfer valve XV6313 closes as soon as possible at worst, within 10 seconds.

- ix. Air admission valves to carbonizer FV6225 and combustor FV6360, FV6356-9, close as soon as possible, at worst within 10 seconds.
- x. Booster compressor kickback valve PV6613 opens automatically on pressure control.

The actuation of valves is initiated simultaneously after the initial 0.2 second induction period of the trip.

During the trip the turbine operates with vitiated air and bypass air to the expander with normal flow to the compressor. The reservoir of vitiated air is depressurized via the vent and expander. The overall effect is to reduce the power input to a small positive value within 0.8 seconds and to achieve a negative power output within a few seconds.

The effect is quantified in Appendix 4, for a vent valve sized for 20 000 lb/h and a bypass increased by 50 000 lb/h. The machine is expected to accelerate for 3 seconds to a maximum speed of 106% before beginning to slow down. This is satisfactory for the gas turbine.

The depressurization has to be carried out at a controlled rate. The first priority is to ensure that the gas turbine does not reach a damaging overspeed condition. Once that constraint is satisfied, it is important, if possible, to depressurize without either damaging filter elements or causing eduction of bed material. The constraints that these secondary requirements place on depressurization time and operation of the vent and flare valves is under study and is targeted for the 75% package.

The carbonizer and PFBC continue to depressurize at a controlled rate towards atmospheric pressure via the flare and the vitiated air vent.

In a commercial scale unit it is possible that in the event of a breaker trip that the unit would be kept on line at zero power output. This is difficult to implement in the Wilsonville case.

In less severe trip scenarios the generator breaker will not be opened until 0.5 seconds after the trip has been initiated. This will cause the machine to stay at constant speed until the shaft power has been greatly reduced.

In addition a fast path, hardwired loss of load detector circuit has been proposed to detect such events as breakage of shear pins and to initiate trip sequence without waiting for acceleration to trip speed.

8. SHUTDOWN

Voluntary plant shutdown is similar to trip, except that the problem of overspeed of the turbine does not arise.

9. CONCLUSIONS

A control philosophy has been outlined which is capable of dealing with startup, normal operation, trip and shutdown conditions.

More quantification of the PCD transient events and of depressurization of the plant after a trip is to be carried out for inclusion in the 75% design package.

10. APPENDICES**Appendix 1: Transient Response of Carbonizer**

A crude dynamic model of the carbonizer/CPFBC was used to assess what load change rate would be reasonable. This was done by contrasting a load change rate of 4% per minute to one of 20% per minute. The model was based on the following assumptions:

1. Carbonizer voidage was assumed to change by 5% between the minimum and maximum air rates. The volume of the bed was taken as 200 ft³ and the fluidized density 12 lb/ft³.
2. The ash inventory in the CPFBC was taken as 18000 lb/h.

The case where coal feed rate is ramped and the various temperatures and air rates follow was actually modelled. The control strategy currently envisaged is however to ramp the combustor air rate, to control the coal feed rate to maintain CPFBC outlet temperature and to control carbonizer air rate to maintain carbonizer exit temperature. This is a different strategy but the main conclusion, that is that a load change ramp rate of 4% per minute can be accomplished with no unacceptable transients, will not change.

The model has not yet been modified to reflect the strategy that will be employed.

Graphs are presented on the new four pages. Note the following:

1. In the case of a 20% per minute load change, the transient char rate to the CPFBC peaks at a value several times the steady value. In the 4% per minute case, there are minor "blips" on a steady ramp.
2. The upset in the CPFBC exit temperature is unacceptable in the 20% per minute case and reasonable in the 4% per minute case.

APPENDIX 1: GRAPHS

CARBONIZER: RESPONSE TO LOAD CHANGE
FAST: RAMP COAL FEED AT 20%/MIN

APPENDIX 1: GRAPHS

**COMBUSTOR: RESPONSE TO LOAD CHANGE
RAMP AT 20% PER MINUTE**

APPENDIX 1: GRAPHS

CARBONIZER: RESPONSE TO LOAD CHANGE
SLOW: RAMP COAL FEED AT 4%/MIN

APPENDIX 1: GRAPHS

**COMBUSTOR: RESPONSE TO LOAD CHANGE
RAMP AT 4% PER MINUTE**

Appendix 2: Transient effects during startup occasioned by the opening of the vitiated air isolation valve

A case was modelled where the gas turbine is initially operating on propane fuel, with air bypassing the CPFBC and the carbonizer. As part of the startup procedure, it is stated that the vitiated air isolation valve is opened with a minimal pressure differential across it. There will be a transient increase in power output as the CPFBC pressure equalizes with that into the turbine. The effect has been quantified for a differential of 5 psi and power output during the transient is as shown in the graph below:

TURBINE TRANSIENT STARTUPOPEN VIT AIR AT $t=0$, 5psi OVERPRESS

Appendix 3: Transient response: Example Case - Effect of increasing bypass flow by 50,000 lb/hr

The case where the air bypassing the CPFBC undergoes a step change was modelled as an example of the transient behaviour expected. Clearly, the steady state power output will drop when the bypass is opened as there will be less heat input to the turbine. However there is a transient power increase as the mass flow through the turbine increases until the pressure in the CPFBC settles out at the new (lower) steady value.

TURBINE TRANSIENT FOR VENT & BYPASS

CASE 1: 0 lb/h VENT, 50 000 BYPASS

TURBINE TRANSIENT FOR VENT & BYPASS

CASE 1: 0 lb/h VENT, 50 000 BYPASS

Appendix 4: Transient response: Trip Case

In the case of a breaker trip, shaft power which was previously taken out as electric power, can only go into accelerating the machine. Consequently it is important to drive the shaft power to a negative value as quickly as possible in the event of a breaker trip.

The strategy adopted to reduce shaft power is the following:

1. Shut off syngas flow as rapidly as possible.
2. Vent excess vitiated air.
3. Increase the bypass air rate, in order to limit the differential pressure across the scroll piece, to consume power by compressive braking and to reduce the turbine inlet temperature rapidly.

The model results, presented graphically are based on the following assumptions:

1. An induction time of 0.2 seconds, during which the machine accelerates at full power.
2. The syngas flow steadily decreases over a period of 0.6 seconds.
3. The vent flow steadily increases over a period of 0.6 seconds.
4. The rotational inertia of the machine is such that 0.9 seconds would be required to accelerate to 120% speed under full power.

Note that the output power initially remains constant. Then it drops off rapidly to a small positive value as the valves move to the required positions. Thereafter, it drops to a negative value at a slower rate as the pressure in the CPFBC comes down as a consequence of the venting strategy.

The speed responds by accelerating rapidly initially, then at a slower rate, reaching a maximum of 110% before starting to drop.

TRIP: SYNGAS. VENT & BYPASS

CASE 1: 20 000 lb/h VENT, 50 000 BYPASS

TRIP: SYNGAS. VENT & BYPASS

CASE 1: 20 000 lb/h VENT, 50 000 BYPASS

APPENDIX D

FW APFBC TRAIN: NITROGEN FLOW REQUIREMENTS

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NITROGEN FLOW REQUIREMENTS

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SCOPE AND PURPOSE

This document considers the nitrogen requirements for the Foster Wheeler APFBC plant and associated equipment for a range of operational and upset conditions.

The plant is broken down into three different systems, namely:

1. Medium pressure (275 psig) users within the Foster Wheeler battery limit, including SRI's test instrumentation.
2. High pressure (1500 psig) nitrogen supplied to the Westinghouse particulate control devices (PCDs).
3. High pressure (1500 psig) nitrogen supplied to the Industrial Filter and Pump (IF&P) particulate control devices (PCDs).

A number of cases are considered which are intended to cover the range of possible variation in nitrogen flow. These include, inter alia, steady state, upset, startup, trip and shutdown cases. There are in principle two reasons for variability in nitrogen flowrates, which need to be understood. The first source of variability is that the demands will be different for different operational configurations and cases. The second source of variability arises from the lack of certain knowledge about how much nitrogen will be required for different devices. The nitrogen supply system must clearly be capable of supplying the range of demand anticipated at an acceptable efficiency.

The cases which are considered are as follows:

1. Three steady state cases, corresponding to different operational configurations. The design configuration (Second Generation APFBC) involves coal feed to the carbonizer alone. In addition, operation in the so-called First Generation mode with coal feed to the combustor alone is allowed for as a second case. The third case is that with simultaneous feed to the combustor and the carbonizer - this mode of operation will be used in start-up and at turndown to low rates.

Several sub-cases are considered for the design configuration to make allowance for the effects of the following:

- a. Alternate (Eagle Butte) coal.
- b. SRI's intended "future" instrumentation.
- c. Emergency "snuffing" of feed line fires.
- d. "Fluffing" of difficult materials to assist feeding.

2. The unsteady state cases considered are: offline, start-up, trip, shutdown and general power outage.

The purpose of the document is to enable the nitrogen supply system to be properly specified and nitrogen usages to be estimated. Accordingly, the following information is presented:

1. Summarized information for four cases, intended to bracket the range of possibility for nitrogen demand under steady state conditions. The summarized information consists of average, baseline and peak flowrates, peak duration and peak spacing. This information is given for each of the above three nitrogen systems as well as for the nitrogen system as a whole.
2. Similar information for start-up, which is the worst unsteady state case. In addition, the duration of the startup is given and is relevant because it may be desirable to use stored LIN to meet the excess demand of the startup.
3. Similar information pertaining to a general power outage scenario. This will enable equipment within the nitrogen system which must run from an emergency power supply to be identified.

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CONFIGURATION

FIGURE 1: CONFIGURATION OF NITROGEN SYSTEM

The configuration depicted in Figure 1 above is our current best understanding of SCS's intentions opposite the Nitrogen supply system. The system is described for the sake of clarity in later sections of this document:

It is intended to primarily supply nitrogen from an air separation unit. In order to gain some flexibility, the air separation unit is provided with two parallel air compressors, so that turndown to half rates is possible. The A.S.U. produces a gaseous and a liquid nitrogen product. The gaseous nitrogen is compressed first to 600 psig and then to 1500 psig and supplied to the various users. The LIN product is put into storage from whence it is pumped to 600 psig and gasified to supply nitrogen as required in parallel to the compressed gaseous nitrogen product. It is possible to import LIN if needed to augment the capacity of the system, for example for start-ups.

The battery limits between SCS, FW, Westinghouse and IF&P are shown on the diagram and the positions to which tabulated flow limits. This is because surge capacity is needed to convert the excessively spikey demands of the users into reasonable cyclic flows.

Note that Figure 1 shows propane addition to the nitrogen for the IF&P PCD. The reason why it is believed that propane addition will be necessary is that nitrogen introduced as pulses into the syngas stream will manifest itself downstream as dilution of fuel gas to the topping combustor. The flows, volumes and mass of pulse gas involved are such that serious downward spike excursions in the calorific value of the syngas are possible. This situation can be ameliorated by adding propane to the pulse gas to bring back the calorific value to a point where the topping combustor does not experience a serious excursion in exit temperature. It is envisaged that the amount of propane required for this purpose will not exceed 10% of the nitrogen flow to the PCD. It is envisaged that propane will be pumped as a liquid to 1500 psig and evaporated into the nitrogen stream (the mixed gas temperature needs to be at least 150 F). The flow of propane will be ratioed to nitrogen flow with the ratio controlled such that the calculated turbine inlet temperature does not experience either upward or downward excursions during regeneration. The propane addition system will be specified when better information on PCD transients has become available.

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NITROGEN FLOW REQUIREMENTS

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SUMMARY OF MEDIUM AND HIGH PRESSURE NITROGEN DEMAND

CASE (OPERATIONAL MODE)	NITROGEN FLOW RATES			TIME		REV NO
	AVE	BASELINE	INFLOW	PEAK	BETWEEN	
	(lb/h)	(lb/h)	PR % (lb/h)	DURATION (min)	PEAKS (min)	
STEADY STATE (NORMAL OPERATION) CASES:						B1
HIGHEST MP DEMAND, HIGHEST HP DEMAND						B1
MP NITROGEN	3679	3540	3748	66.0	32.5	B1
WESTINGHOUSE HP NITROGEN	1200	0	3600	2.5	5.0	B1
IF&P HP NITROGEN	4480	100	4480	7.5	0.0	B1
TOTAL	9359	3640	1828			B1
HIGHEST MP DEMAND, LOWEST HP DEMAND						B1
MP NITROGEN	3679	3540	3748	66.0	32.5	B1
WESTINGHOUSE HP NITROGEN	300	0	3600	2.5	27.5	B1
IF&P HP NITROGEN	427	100	2489	2.7	17.3	B1
TOTAL	4407	3640	9837			B1
LOWEST MP DEMAND, HIGHEST HP DEMAND						B1
MP NITROGEN	2223	2089	2387	33.0	40.5	B1
WESTINGHOUSE HP NITROGEN	1200	0	3600	2.5	5.0	B1
IF&P HP NITROGEN	4480	100	4480	7.5	0.0	B1
TOTAL	7903	2189	10467			B1
LOWEST MP DEMAND, LOWEST HP DEMAND						B1
MP NITROGEN	2223	2089	2387	33.0	40.5	B1
WESTINGHOUSE HP NITROGEN	300	0	3600	2.5	27.5	B1
IF&P HP NITROGEN	427	100	2489	2.7	17.3	B1
TOTAL	2950	2189	8476			B1
STARTUP CASE						B1
MP NITROGEN	4310	3822	4655	17.0	12.0	B1
WESTINGHOUSE HP NITROGEN	1200	0	3600	2.5	5.0	B1
IF&P HP NITROGEN	4480	100	4480	7.5	0.0	B1
TOTAL	9990	3922	12735			B1
GENERAL POWER OUTAGE (EMERGENCY POWER USERS):						B1
MP NITROGEN	2749	2739	2759			B1
WESTINGHOUSE HP NITROGEN	0	0	0			B1
IF&P HP NITROGEN	0	0	0			B1
TOTAL	2749	2739	2759			

NOTES:

1. THE SURGE CAPACITIES, SPECIFIED LATER ARE REQUIRED IN ORDER FOR THE ABOVE TABULATED PEAK FLOWS TO BE VALID.
2. THE RATIO BETWEEN THE SMALLEST AND LARGEST TOTAL; NITROGEN DEMANDS IS OVER 3:1. THIS IS LIKELY TO BE BEYOND THE ECONOMICAL TURNDOWN RANGE OF AN AIR SEPARATION UNIT.
3. THE START-UP CONDITION IS LIKELY TO BE REQUIRED FOR NO MORE THAN 4 HOURS AT A TIME. THE IF&P REQUIREMENTS FOR TRIPLE PULSING OF CANDLE FILTERS IS LIMITING. FOSTER WHEELER START-UP FLOWS CAN BE REDUCED AT THE EXPENSE OF REDUCING CATCH-UP CAPACITY IN THE LOCK HOPPER SYSTEM. THE SIZING OF LIQUID STORAGE DEPENDS ON THE START-UP FLOW REQUIREMENTS AND THE CHOSEN SIZE FOR THE NITROGEN SUPPLY SYSTEM.

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MEDIUM PRESSURE NITROGEN DEMAND

SUMMARY OF MEDIUM PRESSURE NITROGEN USAGE

CASE (OPERATIONAL MODE)	NITROGEN FLOW RATES [1.2]				REV
			OUTFLOW	INFLOW	
	AVE (lb/h)	BASELINE (lb/h)	PEAK (lb/h)	PEAK (lb/h)	NO
STEADY STATE CASES					
COAL TO CARBONIZER ONLY	2223	2089	4807	2387	B1
COAL TO PFBC AS WELL AS CARBONIZER	3679	3540	7630	3748	B1
COAL TO PFBC ONLY	1103	976	3008	1154	B1
COAL TO CARBONIZER ONLY: EAGLE BUTTE COAL	2648	2514	5232	2812	B1
COAL TO CARBONIZER ONLY: ALLOWANCE FOR FUTURE SRI INSTRUMENT	2855	2720	5438	3018	B1
COAL TO CARBONIZER ONLY: FEEDLINE FIRE SNUFFING	2483	2089	6107	2977	B1
COAL TO CARBONIZER ONLY: FLUFFING FOR DIFFICULT MATERIALS	2289	2089	4807	2502	B1
UNSTEADY STATE CASES					
OFFLINE	512	502	522	522	B1
START-UP	4309	3922	7912	4655	B1
TRIP OR SHUTDOWN	3126	3111	3795	3126	B1
GENERAL POWER OUTAGE (EMERGENCY POWER USERS)	2749	2739	2759	2749	B1
SURGE CAPACITY REQUIREMENTS:					
MAXIMUM SURGE CAPACITY REQUIRED (lb)	489				B1
DENSITY AT 600 PSIG; 125F (lb/ft3)	2.74				B1
DENSITY AT 290 PSIA AFTER ADIABATIC EXPANSION (lb/ft3)	1.59				B1
REQUIRED SURGE VESSEL VOLUME (ft3)	426				B1
INFLOW TO SURGE VESSEL					
MAXIMUM CYCLIC FLOW (lb/h)	4655				B1
BASELINE FLOW CORRESPONDING TO MAXIMUM (lb/h)	3822				B1

NOTES:

1. THE TERMS INFLOW AND OUTFLOW PEAK REFER TO FLOWS TO AND FROM A SURGE VESSEL WHICH IS ASSUMED TO EXIST BETWEEN THE SOURCE OF NITROGEN AND THE MEDIUM PRESSURE USERS. THE VESSEL OPERATES BETWEEN A PEAK PRESSURE OF 600 PSIG AND A MINIMUM OF 275 PSIG. EXPANSION WITHIN THE VESSEL IS ASSUMED TO BE ADIABATIC FOR THE PURPOSES OF SIZING OF THE SURGE VESSEL. THE SUPPLY OF NITROGEN TO THE SURGE VESSEL IS UNDER PRESSURE CONTROL, ATTEMPTING TO MAINTAIN THE SURGE DRUM AT 600 PSI, WHILE DRAWOFF FROM THE DRUM IS DONE SO THAT THE DOWNSTREAM PRESSURE IS MAINTAINED AT 275 PSIG. THE UPSTREAM NITROGEN SUPPLY SYSTEM (COMPRESSOR OR LIQUID PUMPS) MUST BE SIZED FOR THE MAXIMUM CYCLIC INFLOW REPORTED ABOVE. THE DOWNSTREAM VALVE MUST BE SIZED FOR THE MAXIMUM "OUTFLOW PEAK" REPORTED ABOVE.

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MEDIUM PRESSURE NITROGEN DEMAND

OPERATIONAL MODE: IN STEADY OPERATION WITH COAL TO BOTH PFBC AND CARBONIZER [1]

ITEM NO.	DESCRIPTION	NITROGEN FLOW RATES			PEAK		TIME BETWEEN PEAKS (min)	REV NO
		AVE (lb/h)	BASELINE (lb/h)	PEAK (lb/h)	DURATION (min)	PEAKS		
FL 0254	COAL SURGE HOPPER FILTER	10	0	20	1	1		A
NO 0252	COAL SURGE HOPPER	100	100	100	0	0		A
DR 0251	CARBONIZER COAL SURGE DRUM	55	0	1272	3	66		B1
DR 0252	CARBONIZER COAL FEED DRUM	152	151	251	1	66		B1
DR 0255	COMBUSTOR COAL SURGE DRUM	55	0	1272	3	66		B1
DR 0256	COMBUSTOR COAL FEED DRUM	152	151	251	1	66		B1
DR 0253	SORBENT SURGE DRUM	7	0	640	3	258		A
DR 0254	SORBENT FEED DRUM	31	31	31	1	258		A
RX 0255	CHAR COOLER	120	120	120	0	0		A
DR 0264	OVERSIZE CHAR DRUM	6	0	664	4	476		A
	55 GAL CHAR COLLECTION DRUM	3	0	22	60	420		A
LP 0613	CHAR TRANSFER: LEG RX0251 TO LP0615	30	30	30	0	0		B1
LP 0603	CHAR TRANSFER: LEG CY0251 TO LP0615	30	30	30	0	0		B1
LP 0606	CHAR TRANSFER: LEG FLO351 TO LP0615	30	30	30	0	0		B1
LP 0615	CHAR TRANSFER: UP FLOW LEG	278	278	278	0	0		B1
BR 0251	FLARE	70	70	70	0	0		A
	TOTAL PURGES	380	380	380	0	0		B1
	UTILITY STATIONS	0	0	0	0	0		A
FV 6080	CARBONIZER COAL FEED LINE	0	0	0	0	0		A
TV 6200	CARBONIZER COAL FEED LINE	0	0	0	0	0		A
FV 6132	PFBC COAL FEED LINE	1300	1300	1300	0	0		B1
FV 6183	SORBENT FEED LINE	0	0	0	0	0		A
RX 0251	CARBONIZER	0	0	0	0	0		A
RX 0252	COMBUSTOR	0	0	0	0	0		A
DR0265	ASH SURGE DRUM	0	0	0	0	0		A
SRI	TEST INSTRUMENTS (CARBONIZER)	434	434	434	0	0		B1
SRI	TEST INSTRUMENTS (PFBC)	434	434	434	0	0		B1
	TOTAL FLOW (scfm)	831	800	1,724				B1
	TOTAL FLOW, LB/HR	3,679	3,540	7,630				B1

SURGE CAPACITY AND COMPRESSOR REQUIREMENTS

SURGE STORAGE (lb)	229
CATCH-UP TIME (minutes)	66
COMPRESSOR REQD CAPACITY (lb/h)	3748

NOTES:

1. THIS MODE OF OPERATION IS AN ALTERNATE TO THE SECOND GENERATION APFBC MODE.

FOSTER WHEELER USA CORPORATION
PERRYVILLE CORPORATE PARK
CLINTON, NJ 08809

NITROGEN FLOW REQUIREMENTS

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CUSTOMER :	SOUTHERN COMPANY SERVICES, INC	REV	BY	DATE
LOCATION :	WILSONVILLE ALABAMA	A	JWH	12/22/93
PROJECT NO.:	15-4161	B1	JWH	03/24/94
PLANT:	PSD FACILITY	C		
SECTION:	APFBC SYSTEM	D		
AREA:	200 B - 400 B	E		

MEDIUM PRESSURE NITROGEN DEMAND

OPERATIONAL MODE: IN STEADY OPERATION WITH COAL TO CARBONIZER ONLY [1]

ITEM NO.	DESCRIPTION	NITROGEN FLOW RATES			PEAK		TIME BETWEEN PEAKS (min)	REV NO
		AVE (lb/h)	BASLINE (lb/h)	PEAK (lb/h)	DURATION (min)	PEAKS (min)		
FL 0254	COAL SURGE HOPPER FILTER	10	0	20	1	1	A	
HO 0252	COAL SURGE HOPPER	100	100	100	0	0	A	
DR 0251	CARBONIZER COAL SURGE DRUM	106	0	1272	3	33	B1	
DR 0252	CARBONIZER COAL FEED DRUM	154	151	251	1	33	B1	
DR 0255	COMBUSTOR COAL SURGE DRUM	0	0	0	0	0	B1	
DR 0256	COMBUSTOR COAL FEED DRUM	0	0	0	0	0	B1	
DR 0253	SORBENT SURGE DRUM	7	0	640	3	258	A	
DR 0254	SORBENT FEED DRUM	31	31	31	1	258	A	
RX 0255	CHAR COOLER	120	120	120	0	0	A	
DR 0264	OVERSIZE CHAR DRUM	6	0	664	4	476	A	
	55 GAL CHAR COLLECTION DRUM	3	0	22	60	420	A	
LP 0613	CHAR TRANSFER: LEG RX0251 TO LP0815	30	30	30	0	0	B1	
LP 0803	CHAR TRANSFER: LEG CY0251 TO LP0815	30	30	30	0	0	B1	
LP 0806	CHAR TRANSFER: LEG FL0351 TO LP0815	30	30	30	0	0	B1	
LP 0815	CHAR TRANSFER: UP FLOW LEG	278	278	278	0	0	B1	
SR 0251	FLARE	70	70	70	0	0	A	
	TOTAL PURGES	380	380	380	0	0	B1	
	UTILITY STATIONS	0	0	0	0	0	A	
FV 6080	CARBONIZER COAL FEED LINE	0	0	0	0	0	A	
TV 6200	CARBONIZER COAL FEED LINE	0	0	0	0	0	A	
FV 6132	PFBC COAL FEED LINE	0	0	0	0	0	B1	
FV 6183	SORBENT FEED LINE	0	0	0	0	0	A	
RX 0251	CARBONIZER	0	0	0	0	0	A	
RX 0252	COMBUSTOR	0	0	0	0	0	A	
DR0265	ASH SURGE DRUM	0	0	0	0	0	A	
SRI	TEST INSTRUMENTS (CARBONIZER)	434	434	434	0	0	B1	
SRI	TEST INSTRUMENTS (PFBC)	434	434	434	0	0	B1	
	TOTAL FLOW (scfm)	502	472	1,086			B1	
	TOTAL FLOW, LB/HR	2,223	2,089	4,807			B1	

SURGE CAPACITY AND COMPRESSOR REQUIREMENTS

SURGE STORAGE (lb)	164
CATCH-UP TIME (minutes)	33
COMPRESSOR REQD CAPACITY (lb/h)	2387

NOTES:

1. THIS IS THE DESIGN MODE OF OPERATION.

FOSTER WHEELER USA CORPORATION
PERRYVILLE CORPORATE PARK
CLINTON, NJ 08809

NITROGEN FLOW REQUIREMENTS

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CUSTOMER:	SOUTHERN COMPANY SERVICES, INC	REV	BY	DATE
LOCATION:	WILSONVILLE ALABAMA	A	JWH	12/22/93
PROJECT NO.:	15-4161	B1	JWH	03/24/94
PLANT:	PSD FACILITY	C		
SECTION:	APFBC SYSTEM	D		
AREA:	200 B - 400 B	E		

MEDIUM PRESSURE NITROGEN DEMAND

OPERATIONAL MODE: IN STEADY OPERATION WITH COAL TO PFBC ONLY [1]

ITEM NO.	DESCRIPTION	NITROGEN FLOW RATES			PEAK DURATION (min)	TIME BETWEEN PEAKS (min)	REV NO
		AVE (lb/h)	BASELINE (lb/h)	PEAK (lb/h)			
FL 0254	COAL SURGE HOPPER FILTER	10	0	20	1	1	A
HO 0252	COAL SURGE HOPPER	100	100	100	0	0	A
DR 0251	CARBONIZER COAL SURGE DRUM	0	0	0	0	0	B1
DR 0252	CARBONIZER COAL FEED DRUM	0	0	0	0	0	B1
DR 0253	COMBUSTOR COAL SURGE DRUM	106	0	1272	3	33	B1
DR 0256	COMBUSTOR COAL FEED DRUM	154	151	251	1	33	B1
DR 0253	SORBENT SURGE DRUM	7	0	640	3	258	B1
DR 0254	SORBENT FEED DRUM	31	31	31	1	258	B1
HE 0255	CHAR COOLER	0	0	0	0	0	B1
DR 0264	OVERSIZE CHAR DRUM	0	0	0	0	0	B1
	55 GAL CHAR COLLECTION DRUM	0	0	0	0	0	B1
LP 0613	CHAR TRANSFER: LEG R0251 TO LPO815	0	0	0	0	0	B1
LP 0803	CHAR TRANSFER: LEG CY0251 TO LPO815	0	0	0	0	0	B1
LP 0806	CHAR TRANSFER: LEG FLO351 TO LPO815	0	0	0	0	0	B1
LP 0815	CHAR TRANSFER: UP FLOW LEG	0	0	0	0	0	B1
BR 0251	FLARE	70	70	70	0	0	A
	TOTAL PURGES	190	190	190	0	0	B1
	UTILITY STATIONS	0	0	0	0	0	A
FV 6080	CARBONIZER COAL FEED LINE	0	0	0	0	0	A
TV 6200	CARBONIZER COAL FEED LINE	0	0	0	0	0	A
FV 6132	PFBC COAL FEED LINE	0	0	0	0	0	B1
FV 6183	SORBENT FEED LINE	0	0	0	0	0	A
RE 0251	CARBONIZER	0	0	0	0	0	A
RE 0252	COMBUSTOR	0	0	0	0	0	A
DR0265	ASH SURGE DRUM	0	0	0	0	0	A
SRI	TEST INSTRUMENTS (CARBONIZER)	0	0	0	0	0	B1
SRI	TEST INSTRUMENTS (PFBC)	434	434	434	0	0	B1
	TOTAL FLOW (scfm)	249	221	680			B1
	TOTAL FLOW, LB/HR	1,103	976	3,008			B1

SURGE CAPACITY AND COMPRESSOR REQUIREMENTS:

SURGE STORAGE REQD (lb)	98
CATCH-UP TIME (minutes)	33
COMPRESSOR REQD CAPACITY (lb/h)	1154

NOTES:

1. THIS IS THE "FIRST GENERATION" MODE OF OPERATION, WHICH WILL BE USED IN INITIAL SHAKEOUT.

FOSTER WHEELER USA CORPORATION
PERRYVILLE CORPORATE PARK
CLINTON, NJ 08809

NITROGEN FLOW REQUIREMENTS

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CUSTOMER:	SOUTHERN COMPANY SERVICES, INC	REV	BY	DATE
LOCATION:	WILSONVILLE ALABAMA	A	JWH	12/22/93
PROJECT NO.:	15-4161	B1	JWH	03/24/94
PLANT:	PSD FACILITY	C		
SECTION:	APFBC SYSTEM	D		
AREA:	200 B - 400 B	E		

MEDIUM PRESSURE NITROGEN DEMAND

OPERATIONAL MODE: IN STEADY OPERATION WITH COAL TO CARBONIZER ONLY [1]
USING EAGLE BUTTE COAL. [2]

ITEM NO.	DESCRIPTION	NITROGEN FLOW RATES			PEAK DURATION (min)	TIME BETWEEN PEAKS (min)	REV NO
		AVE (lb/h)	BASLINE (lb/h)	PEAK (lb/h)			
FL 0254	COAL SURGE HOPPER FILTER	10	0	20	1	1	A
HO 0252	COAL SURGE HOPPER	100	100	100	0	0	A
DR 0251	CARBONIZER COAL SURGE DRUM	106	0	1272	3	33	B1
DR 0252	CARBONIZER COAL FEED DRUM	154	151	251	1	33	B1
DR 0253	COMBUSTOR COAL SURGE DRUM	0	0	0	0	0	B1
DR 0256	COMBUSTOR COAL FEED DRUM	0	0	0	0	0	B1
DR 0253	SORBENT SURGE DRUM	7	0	640	3	258	A
DR 0254	SORBENT FEED DRUM	31	31	31	1	258	A
EX 0255	CHAR COOLER	120	120	120	0	0	A
DR 0264	OVERSIZE CHAR DRUM	6	0	664	4	476	A
	55 GAL CHAR COLLECTION DRUM	3	0	22	60	420	A
LP 0613	CHAR TRANSFER: LEG RX0251 TO LP0815	30	30	30	0	0	B1
LP 0803	CHAR TRANSFER: LEG CY0251 TO LP0815	30	30	30	0	0	B1
LP 0806	CHAR TRANSFER: LEG FLO351 TO LP0815	30	30	30	0	0	B1
LP 0815	CHAR TRANSFER: UP FLOW LEG [3]	703	703	703	0	0	B1
BR 0251	FLARE	70	70	70	0	0	A
	TOTAL PURGES	380	380	380	0	0	B1
	UTILITY STATIONS	0	0	0	0	0	A
FV 6080	CARBONIZER COAL FEED LINE	0	0	0	0	0	A
TV 6200	CARBONIZER COAL FEED LINE	0	0	0	0	0	A
FV 6132	PFBC COAL FEED LINE	0	0	0	0	0	B1
FV 6183	SORBENT FEED LINE	0	0	0	0	0	A
RE 0251	CARBONIZER	0	0	0	0	0	A
RE 0252	COMBUSTOR	0	0	0	0	0	A
DR0265	ASE SURGE DRUM	0	0	0	0	0	A
SRI	TEST INSTRUMENTS (CARBONIZER)	434	434	434	0	0	B1
SRI	TEST INSTRUMENTS (PFBC)	434	434	434	0	0	B1
	TOTAL FLOW (scfm)	598	568	1,182			B1
	TOTAL FLOW, LB/HR	2,648	2,514	5,232			B1

SURGE CAPACITY AND COMPRESSOR REQUIREMENTS:

SURGE STORAGE REQD (lb)	164
CATCH-UP TIME (minutes)	33
COMPRESSOR REQD CAPACITY (lb/h)	2812

NOTES:

1. THIS IS THE DESIGN MODE OF OPERATION.
2. ALTERNATE COAL.
3. THE RX0251 BED MATERIAL IS DENSER, CONSEQUENTLY LP0815 VELOCITY IS GREATER.

FOSTER WHEELER USA CORPORATION
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NITROGEN FLOW REQUIREMENTS

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CUSTOMER :	SOUTHERN COMPANY SERVICES, INC	REV	BY	DATE
LOCATION :	WILSONVILLE ALABAMA	A	JWH	12/22/93
PROJECT NO.:	15-4161	B1	JWH	03/24/94
PLANT:	PSD FACILITY	C		
SECTION:	APFBC SYSTEM	D		
AREA:	200 B - 400 B	E		

MEDIUM PRESSURE NITROGEN DEMAND

OPERATIONAL MODE: IN STEADY OPERATION WITH COAL TO CARBONIZER ONLY [1]
ALLOWING FOR FUTURE SRI INSTRUMENTATION.

ITEM NO.	DESCRIPTION	NITROGEN FLOW RATES			PEAK		REV
		AVE (lb/h)	BASELINE (lb/h)	PEAK (lb/h)	DURATION (min)	BETWEEN PEAKS (min)	
FL 0254	COAL SURGE HOPPER FILTER	10	0	20	1	1	A
HO 0252	COAL SURGE HOPPER	100	100	100	0	0	A
DR 0251	CARBONIZER COAL SURGE DRUM	106	0	1272	3	33	B1
DR 0252	CARBONIZER COAL FEED DRUM	154	151	251	1	33	B1
DR 0255	COMBUSTOR COAL SURGE DRUM	0	0	0	0	0	B1
DR 0256	COMBUSTOR COAL FEED DRUM	0	0	0	0	0	B1
DR 0253	SORBENT SURGE DRUM	7	0	640	3	258	A
DR 0254	SORBENT FEED DRUM	31	31	31	1	258	A
HE 0255	CHAR COOLER	120	120	120	0	0	A
DR 0264	OVERSIZE CHAR DRUM	6	0	664	4	476	A
	55 GAL CHAR COLLECTION DRUM	3	0	22	60	420	A
LP 0613	CHAR TRANSFER: LEG RX0251 TO LP0815	30	30	30	0	0	B1
LP 0803	CHAR TRANSFER: LEG CY0251 TO LP0815	30	30	30	0	0	B1
LP 0806	CHAR TRANSFER: LEG FLO351 TO LP0815	30	30	30	0	0	B1
LP 0815	CHAR TRANSFER: UP FLOW LEG	278	278	278	0	0	B1
BR 0251	FLARE	70	70	70	0	0	A
	TOTAL PURGES	380	380	380	0	0	B1
	UTILITY STATIONS	0	0	0	0	0	A
FV 6080	CARBONIZER COAL FEED LINE	0	0	0	0	0	A
TV 6200	CARBONIZER COAL FEED LINE	0	0	0	0	0	A
FV 6132	PFBC COAL FEED LINE	0	0	0	0	0	B1
FV 6183	SORBENT FEED LINE	0	0	0	0	0	A
RX 0251	CARBONIZER	0	0	0	0	0	A
RX 0252	COMBUSTOR	0	0	0	0	0	A
DR0265	ASH SURGE DRUM	0	0	0	0	0	A
SRI	TEST INSTRUMENTS (CARBONIZER) [2]	750	750	750	0	0	B1
SRI	TEST INSTRUMENTS (PFBC) [2]	750	750	750	0	0	B1
	TOTAL FLOW (scfm)	645	614	1,228			B1
	TOTAL FLOW, LB/HR	2,855	2,720	5,438			B1

SURGE CAPACITY AND COMPRESSOR REQUIREMENTS:

SURGE STORAGE REQD (lb)	164
CATCH-UP TIME (minutes)	33
COMPRESSOR REQD CAPACITY (lb/h)	3018

NOTES:

1. THIS IS THE DESIGN MODE OF OPERATION.
2. INSTRUMENTS MARKED AS "FUTURE" IN UN-NUMBERED LETTER OF 03-03-94 BY W J STEELE TO N FEINBERG.

FOSTER WHEELER USA CORPORATION
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NITROGEN FLOW REQUIREMENTS

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CUSTOMER:	SOUTHERN COMPANY SERVICES, INC	REV	BY	DATE
LOCATION:	WILSONVILLE ALABAMA	A	JWH	12/22/93
PROJECT NO.:	15-4161	B1	JWH	03/24/94
PLANT:	PSD FACILITY	C		
SECTION:	APFBC SYSTEM	D		
AREA:	200 B - 400 B	E		

MEDIUM PRESSURE NITROGEN DEMAND

OPERATIONAL MODE: OFFLINE

ITEM NO.	DESCRIPTION	NITROGEN FLOW RATES			PEAK DURATION (min)	TIME BETWEEN PEAKS (min)	REV NO
		AVE (lb/h)	BASELINE (lb/h)	PEAK (lb/h)			
FL 0254	COAL SURGE HOPPER FILTER	10	0	20	1	1	A
BO 0252	COAL SURGE HOPPER	100	100	100	0	0	A
DR 0251	CARBONIZER COAL SURGE DRUM	0	0	0	3	33	B1
DR 0252	CARBONIZER COAL FEED DRUM	0	0	0	1	33	B1
DR 0255	COMBUSTOR COAL SURGE DRUM	0	0	0	0	0	B1
DR 0256	COMBUSTOR COAL FEED DRUM	0	0	0	0	0	B1
DR 0253	SORBENT SURGE DRUM	0	0	0	3	258	A
DR 0254	SORBENT FEED DRUM	0	0	0	1	258	A
HX 0255	CHAR COOLER	0	0	0	0	0	A
DR 0264	OVERSIEE CHAR DRUM	0	0	0	4	476	A
	55 GAL CHAR COLLECTION DRUM	0	0	0	60	420	A
LP 0613	CHAR TRANSFER: LEG R10251 TO LP0815	0	0	0	0	0	B1
LP 0803	CHAR TRANSFER: LEG CY0251 TO LP0815	0	0	0	0	0	B1
LP 0806	CHAR TRANSFER: LEG FLO351 TO LP0815	0	0	0	0	0	B1
LP 0815	CHAR TRANSFER: UP FLOW LEG	0	0	0	0	0	B1
BR 0251	FLARE	70	70	70	0	0	A
	TOTAL PURGES	0	0	0	0	0	B1
	UTILITY STATIONS	332	332	332	0	0	A
FV 6080	CARBONIZER COAL FEED LINE	0	0	0	0	0	A
TV 6200	CARBONIZER COAL FEED LINE	0	0	0	0	0	A
FV 6132	PFBC COAL FEED LINE	0	0	0	0	0	B1
FV 6183	SORBENT FEED LINE	0	0	0	0	0	A
RX 0251	CARBONIZER	0	0	0	0	0	A
RX 0252	COMBUSTOR	0	0	0	0	0	A
DR0265	ASH SURGE DRUM	0	0	0	0	0	A
SRI	TEST INSTRUMENTS (CARBONIZER)	0	0	0	0	0	B1
SRI	TEST INSTRUMENTS (PFBC)	0	0	0	0	0	B1
	TOTAL FLOW (scfm)	116	113	118			B1
	TOTAL FLOW, LB/HR	512	502	522			B1

SURGE CAPACITY AND COMPRESSOR REQUIREMENTS:

SURGE STORAGE REQD (lb)	0
CATCH-UP TIME (minutes)	1
COMPRESSOR REQD CAPACITY (lb/h)	522

NOTES:

FOSTER WHEELER USA CORPORATION
PERRYVILLE CORPORATE PARK
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NITROGEN FLOW REQUIREMENTS

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CUSTOMER:	SOUTHERN COMPANY SERVICES, INC	REV	BY	DATE
LOCATION:	WILSONVILLE ALABAMA	A	JWH	12/22/93
PROJECT NO.:	15-4161	B1	JWH	03/24/94
PLANT:	PSD FACILITY	C		
SECTION:	APFBC SYSTEM	D		
AREA:	200 B - 400 B	E		

MEDIUM PRESSURE NITROGEN DEMAND

OPERATIONAL MODE: START-UP.

ITEM NO.	DESCRIPTION		NITROGEN FLOW RATES			PEAK DURATION (min)	TIME BETWEEN PEAKS (min)	REV NO
			AVE (lb/h)	BASELINE (lb/h)	PEAK (lb/h)			
FL 0254	COAL SURGE HOPPER FILTER		10	0	20	1	1	A
EO 0252	COAL SURGE HOPPER		100	100	100	0	0	A
DR 0251	CARBONIZER COAL SURGE DRUM	(1)	196	0	1272	3	17	B1
DR 0252	CARBONIZER COAL FEED DRUM	(1)	157	151	251	1	17	B1
DR 0255	COMBUSTOR COAL SURGE DRUM	(1)	196	0	1272	3	17	B1
DR 0256	COMBUSTOR COAL FEED DRUM	(1)	157	151	251	1	17	B1
DR 0253	SORBENT SURGE DRUM	(1)	67	0	640	3	26	B1
DR 0254	SORBENT FEED DRUM	(1)	31	31	31	1	26	B1
EX 0255	CHAR COOLER		120	120	120	0	0	A
DR 0264	OVERSIZE CHAR DRUM		6	0	664	4	476	A
	55 GAL CHAR COLLECTION DRUM		3	0	22	60	420	A
LP 0613	CHAR TRANSFER: LEG RE0251 TO	(2)	50	50	50	0	0	B1
LP 0803	CHAR TRANSFER: LEG CY0251 TO	(2)	50	50	50	0	0	B1
LP 0806	CHAR TRANSFER: LEG FLO351 TO	(2)	50	50	50	0	0	B1
LP 0815	CHAR TRANSFER: UP FLOW LEG	(2)	500	500	500	0	0	B1
BR 0251	FLARE		70	70	70	0	0	A
	TOTAL PURGES		380	380	380	0	0	B1
	UTILITY STATIONS		0	0	0	0	0	A
FV 6080	CARBONIZER COAL FEED LINE		0	0	0	0	0	A
TV 6200	CARBONIZER COAL FEED LINE		0	0	0	0	0	A
FV 6132	PFBC COAL FEED LINE	(3)	1300	1300	1300	0	0	B1
FV 6183	SORBENT FEED LINE		0	0	0	0	0	A
RE 0251	CARBONIZER		0	0	0	0	0	A
RE 0252	COMBUSTOR		0	0	0	0	0	A
DR0265	ASH SURGE DRUM		0	0	0	0	0	A
SRI	TEST INSTRUMENTS (CARBONIZER)	(4)	434	434	434	0	0	B1
SRI	TEST INSTRUMENTS (PFBC)	(4)	434	434	434	0	0	B1
	TOTAL FLOW (scfm)		973	863	1,787			B1
	TOTAL FLOW, LB/HR		4,309	3,822	7,912			B1

SURGE CAPACITY AND COMPRESSOR REQUIREMENTS:

SURGE STORAGE REQUIRED (lb)	229
CATCH-UP TIME REQD (minutes)	17
COMPRESSOR REQD CAPACITY (lb/h)	4655

NOTES:

1. DURING START-UP, INITIALLY THE LOCK HOPPERS MAY OPERATE AT A HIGHER THAN NORMAL THROUGHPUT UNTIL INVENTORY IS BUILT UP. DESIGN MAXIMUM THROUGHPUT HAS BEEN USED. IN ADDITION, SOME NITROGEN WILL BE USED IN LOCK HOPPER PURGING. THE TABULATED FIGURES ARE CONSERVATIVE.
2. AN ABOVE NORMAL FLOWRATE HAS BEEN ALLOWED FOR IN THE START-UP MODE.
3. COAL IS CO-FED TO THE PFBC DURING THE START-UP.
4. THE NEED FOR THESE FLOWS DURING START-UP WAS CONFIRMED IN A TELECON WITH BILL STEELE OF SRI.

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NITROGEN FLOW REQUIREMENTS

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CUSTOMER :	SOUTHERN COMPANY SERVICES, INC	REV	BY	DATE
LOCATION :	WILSONVILLE ALABAMA	A	JWH	12/22/93
PROJECT NO.:	15-4161	B1	JWH	03/24/94
PLANT:	PSD FACILITY	C		
SECTION:	APFBC SYSTEM	D		
AREA:	200 B - 400 B	E		

MEDIUM PRESSURE NITROGEN DEMAND

OPERATIONAL MODE: PLANT TRIP OR SHUTDOWN.

ITEM NO.	DESCRIPTION	NITROGEN FLOW RATES			PEAK DURATION (min)	TIME BETWEEN PEAKS (min)	REV NO
		AVE (lb/h)	BASLINE (lb/h)	PEAK (lb/h)			
PL 0254	COAL SURGE HOPPER FILTER	10	0	20	1	1	A
NO 0252	COAL SURGE HOPPER	100	100	100	0	0	A
DR 0251	CARBONIZER COAL SURGE DRUM	0	0	0	0	0	B1
DR 0252	CARBONIZER COAL FEED DRUM	151	151	151	0	0	B1
DR 0255	COMBUSTOR COAL SURGE DRUM	0	0	0	0	0	B1
DR 0256	COMBUSTOR COAL FEED DRUM	0	0	0	0	0	B1
DR 0253	SORBENT SURGE DRUM	0	0	0	0	0	A
DR 0254	SORBENT FEED DRUM	31	31	31	0	0	A
EX 0255	CHAR COOLER	120	120	120	0	0	A
DR 0264	OVERSIZE CHAR DRUM	6	0	664	4	476	A
	55 GAL CHAR COLLECTION DRUM	0	0	0	0	0	A
LP 0613	CHAR TRANSFER: LEG RIG0251 TO LP0815	30	30	30	0	0	B1
LP 0803	CHAR TRANSFER: LEG CY0251 TO LP0815	30	30	30	0	0	B1
LP 0806	CHAR TRANSFER: LEG FLO351 TO LP0815	30	30	30	0	0	B1
LP 0815	CHAR TRANSFER: UP FLOW LEG	0	0	0	0	0	B1
BR 0251	FLARE	70	70	70	0	0	A
	TOTAL PURGES	380	380	380	0	0	B1
	UTILITY STATIONS	0	0	0	0	0	A
FV 6080	CARBONIZER COAL FEED LINE (1)	1300	1300	1300	0	0	A
TV 6200	CARBONIZER COAL FEED LINE	0	0	0	0	0	A
FV 6132	PFBC COAL FEED LINE	0	0	0	0	0	B1
FV 6183	SORBENT FEED LINE	0	0	0	0	0	A
RE 0251	CARBONIZER (2)	0	0	0	0	0	B1
RE 0252	COMBUSTOR	0	0	0	0	0	A
DR0265	ASH SURGE DRUM	0	0	0	0	0	A
SRI	TEST INSTRUMENTS (CARBONIZER) (3)	434	434	434	0	0	B1
SRI	TEST INSTRUMENTS (PFBC) (3)	434	434	434	0	0	B1
	TOTAL FLOW (scfm)	706	703	857			B1
	TOTAL FLOW, LB/HR	3,126	3,111	3,795			B1

SURGE CAPACITY AND COMPRESSOR REQUIREMENTS:

SURGE STORAGE REQD (lb)	45
CATCH-UP TIME (minutes)	476
COMPRESSOR REQD CAPACITY (lb/h)	3126

NOTES:

1. NITROGEN TO KEEP INLET CLEAR OF CHAR.
2. ADEQUATE PURGING TAKES PLACE VIA FV 6080.
3. PER TELECON WITH BILL STEELE, SRI BELIEVE IT TO BE NECESSARY TO MAINTAIN PURGE ON THESE INSTRUMENTS.

FOSTER WHEELER USA CORPORATION
PERRYVILLE CORPORATE PARK
CLINTON, NJ 08809

NITROGEN FLOW REQUIREMENTS

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CUSTOMER :	SOUTHERN COMPANY SERVICES, INC	REV	BY	DATE
LOCATION :	WILSONVILLE ALABAMA	A	JWH	12/22/93
PROJECT NO.:	15-4161	B1	JWH	03/24/94
PLANT:	PSD FACILITY	C		
SECTION:	APFBC SYSTEM	D		
AREA:	200 B - 400 B	E		

MEDIUM PRESSURE NITROGEN DEMAND

OPERATIONAL MODE: IN STEADY OPERATION WITH COAL TO CARBONIZER ONLY, EXTRA NITROGEN TO SNUFF A FEEDLINE FIRE.

ITEM NO.	DESCRIPTION	NITROGEN FLOW RATES			PEAK		TIME BETWEEN PEAKS (min)	REV NO
		AVE (lb/h)	BASLINE (lb/h)	PEAK (lb/h)	DURATION (min)	PEAKS		
FL 0254	COAL SURGE HOPPER FILTER	10	0	20	1	1	A	
HO 0252	COAL SURGE HOPPER	100	100	100	0	0	A	
DR 0251	CARBONIZER COAL SURGE DRUM	106	0	1272	3	33	B1	
DR 0252	CARBONIZER COAL FEED DRUM	154	151	251	1	33	B1	
DR 0255	COMBUSTOR COAL SURGE DRUM	0	0	0	0	0	B1	
DR 0256	COMBUSTOR COAL FEED DRUM	0	0	0	0	0	B1	
DR 0253	SORBENT SURGE DRUM	7	0	640	3	258	A	
DR 0254	SORBENT FEED DRUM	31	31	31	1	258	A	
EX 0255	CHAR COOLER	120	120	120	0	0	A	
DR 0264	OVERSIZE CHAR DRUM	6	0	664	4	476	A	
	55 GAL CHAR COLLECTION DRUM	3	0	22	60	420	A	
LP 0613	CHAR TRANSFER: LEG RE0251 TO LP0815	30	30	30	0	0	B1	
LP 0803	CHAR TRANSFER: LEG CY0251 TO LP0815	30	30	30	0	0	B1	
LP 0806	CHAR TRANSFER: LEG FLO351 TO LP0815	30	30	30	0	0	B1	
LP 0815	CHAR TRANSFER: UP FLOW LEG	278	278	278	0	0	B1	
BR 0251	FLARE	70	70	70	0	0	A	
	TOTAL PURGES	380	380	380	0	0	B1	
	UTILITY STATIONS	0	0	0	0	0	A	
FV 6080	CARBONIZER COAL FEED LINE (1)	260	0	1300	15	60	A	
TV 6200	CARBONIZER COAL FEED LINE	0	0	0	0	0	A	
FV 6132	PFBC COAL FEED LINE	0	0	0	0	0	B1	
FV 6183	SORBENT FEED LINE	0	0	0	0	0	A	
RE 0251	CARBONIZER	0	0	0	0	0	A	
RE 0252	COMBUSTOR	0	0	0	0	0	A	
DR0265	ASH SURGE DRUM	0	0	0	0	0	A	
SRI	TEST INSTRUMENTS (CARBONIZER)	434	434	434	0	0	B1	
SRI	TEST INSTRUMENTS (PFBC)	434	434	434	0	0	B1	
	TOTAL FLOW (scfm)	561	472	1,379			B1	
	TOTAL FLOW, LB/HR	2,483	2,089	6,107			B1	

SURGE CAPACITY AND COMPRESSOR REQUIREMENTS:

SURGE STORAGE REQD (lb)	489
CATCH-UP TIME (minutes)	33
COMPRESSOR REQD CAPACITY (lb/h)	2977

NOTES:

1. SWITCH FROM AIR TO NITROGEN AS TRANSPORT GAS FOR 15 MINUTES IN THE EVENT OF A HIGH TEMP TRIP.

FOSTER WHEELER USA CORPORATION
PERRYVILLE CORPORATE PARK
CLINTON, NJ 08809

NITROGEN FLOW REQUIREMENTS

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CUSTOMER :	SOUTHERN COMPANY SERVICES, INC	REV	BY	DATE
LOCATION :	WILSONVILLE ALABAMA	A	JWH	12/22/93
PROJECT NO.:	15-4161	B1	JWH	03/24/94
PLANT:	PSD FACILITY	C		
SECTION:	APFBC SYSTEM	D		
AREA:	200 B - 400 B	E		

MEDIUM PRESSURE NITROGEN DEMAND

OPERATIONAL MODE: IN STEADY OPERATION WITH COAL TO CARBONIZER ONLY, EXTRA NITROGEN REQUIRED TO ASSIST FLOW OF DIFFICULT MATERIALS IN SORBENT AND COAL HOPPERS.

ITEM NO.	DESCRIPTION	NITROGEN FLOW RATES			PEAK DURATION (min)	TIME BETWEEN PEAKS (min)	REV NO
		AVE (lb/h)	BASELINE (lb/h)	PEAK (lb/h)			
FL 0254	COAL SURGE HOPPER FILTER	10	0	20	1	1	A
HO 0252	COAL SURGE HOPPER	100	100	100	0	0	A
DR 0251	CARBONIZER COAL SURGE DRUM	167	0	1272	5	33	B1
DR 0252	CARBONIZER COAL FEED DRUM	154	151	251	1	33	B1
DR 0255	COMBUSTOR COAL SURGE DRUM	0	0	0	0	0	B1
DR 0256	COMBUSTOR COAL FEED DRUM	0	0	0	0	0	B1
DR 0253	SORBENT SURGE DRUM	12	0	640	5	258	B1
DR 0254	SORBENT FEED DRUM	31	31	31	1	258	A
RX 0255	CHAR COOLER	120	120	120	0	0	A
DR 0264	OVERSIZE CHAR DRUM	6	0	664	4	476	A
	55 GAL CHAR COLLECTION DRUM	3	0	22	60	420	A
LP 0613	CHAR TRANSFER: LEG RX0251 TO LP0815	30	30	30	0	0	B1
LP 0803	CHAR TRANSFER: LEG CY0251 TO LP0815	30	30	30	0	0	B1
LP 0806	CHAR TRANSFER: LEG FLO351 TO LP0815	30	30	30	0	0	B1
LP 0815	CHAR TRANSFER: UP FLOW LEG	278	278	278	0	0	B1
BR 0251	FLARE	70	70	70	0	0	A
	TOTAL PURGES	380	380	380	0	0	B1
	UTILITY STATIONS	0	0	0	0	0	A
FV 6080	CARBONIZER COAL FEED LINE	0	0	0	0	0	A
TV 6200	CARBONIZER COAL FEED LINE	0	0	0	0	0	A
FV 6132	PFBC COAL FEED LINE	0	0	0	0	0	B1
FV 6183	SORBENT FEED LINE	0	0	0	0	0	A
RX 0251	CARBONIZER	0	0	0	0	0	A
RX 0252	COMBUSTOR	0	0	0	0	0	A
DR0265	ASE SURGE DRUM	0	0	0	0	0	A
SRI	TEST INSTRUMENTS (CARBONIZER)	434	434	434	0	0	B1
SRI	TEST INSTRUMENTS (PFBC)	434	434	434	0	0	B1
	TOTAL FLOW (scfm)	517	472	1,086			B1
	TOTAL FLOW, LB/HR	2,289	2,089	4,807			B1

SURGE CAPACITY AND COMPRESSOR REQUIREMENTS:

SURGE STORAGE REQD (lb)	228
CATCH-UP TIME (minutes)	33
COMPRESSOR REQD CAPACITY (lb/h)	2502

NOTES:

1. SWITCH FROM AIR TO NITROGEN AS TRANSPORT GAS FOR 15 MINUTES IN THE EVENT OF A HIGH TEMP TRIP.

FOSTER WHEELER USA CORPORATION
PERRYVILLE CORPORATE PARK
CLINTON, NJ 08809

NITROGEN FLOW REQUIREMENTS

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CUSTOMER:	SOUTHERN COMPANY SERVICES, INC	REV	BY	DATE
LOCATION:	WILSONVILLE ALABAMA	A	JWH	12/22/93
PROJECT NO.:	15-4161	B1	JWH	03/24/94
PLANT:	PSD FACILITY	C		
SECTION:	APFBC SYSTEM	D		
AREA:	200 B - 400 B	E		

MEDIUM PRESSURE NITROGEN DEMAND

OPERATIONAL MODE: PLANT TRIP OR SHUTDOWN - EMERGENCY NITROGEN USERS.
FOR THE CASE THAT THERE IS AN ELECTRIC POWER OUTAGE

ITEM NO.	DESCRIPTION	NITROGEN FLOW RATES			TIME		REV
		AVE (lb/h)	BASELINE (lb/h)	PEAK (lb/h)	PEAK DURATION (min)	BETWEEN PEAKS (min)	
FL 0254	COAL SURGE HOPPER FILTER	10	0	20	1	1	A
HO 0252	COAL SURGE HOPPER	0	0	0	0	0	A
DR 0251	CARBONISER COAL SURGE DRUM	0	0	0	0	0	B1
DR 0252	CARBONISER COAL FEED DRUM	0	0	0	0	0	B1
DR 0255	COMBUSTOR COAL SURGE DRUM	0	0	0	0	0	B1
DR 0256	COMBUSTOR COAL FEED DRUM	0	0	0	0	0	B1
DR 0253	SORBENT SURGE DRUM	0	0	0	0	0	A
DR 0254	SORBENT FEED DRUM	0	0	0	0	0	A
EX 0255	CHAR COOLER	120	120	120	0	0	A
DR 0264	OVERSIZE CHAR DRUM	0	0	0	4	476	A
	55 GAL CHAR COLLECTION DRUM	0	0	0	0	0	A
LP 0613	CHAR TRANSFER: LEG RX0251 TO LP0815	0	0	0	0	0	B1
LP 0803	CHAR TRANSFER: LEG CY0251 TO LP0815	0	0	0	0	0	B1
LP 0806	CHAR TRANSFER: LEG FLO351 TO LP0815	0	0	0	0	0	B1
LP 0815	CHAR TRANSFER: UP FLOW LEG	0	0	0	0	0	B1
BR 0251	FLARE	70	70	70	0	0	A
	TOTAL PURGES	380	380	380	0	0	B1
	UTILITY STATIONS	0	0	0	0	0	A
FV 6080	CARBONISER COAL FEED LINE (1)	1300	1300	1300	0	0	A
TV 6200	CARBONISER COAL FEED LINE	0	0	0	0	0	A
FV 6132	PFBC COAL FEED LINE	0	0	0	0	0	B1
FV 6183	SORBENT FEED LINE	0	0	0	0	0	A
RX 0251	CARBONISER (2)	0	0	0	0	0	B1
RX 0252	COMBUSTOR	0	0	0	0	0	A
DR0265	ASH SURGE DRUM	0	0	0	0	0	A
SRI	TEST INSTRUMENTS (CARBONISER) (3)	434	434	434	0	0	B1
SRI	TEST INSTRUMENTS (PFBC) (3)	434	434	434	0	0	B1
	TOTAL FLOW (scfm)	621	619	623			B1
	TOTAL FLOW, LB/HR	2,749	2,739	2,759			B1

SURGE CAPACITY AND COMPRESSOR REQUIREMENTS:

SURGE STORAGE REQD (lb)	0
CATCH-UP TIME (minutes)	476
COMPRESSOR REQD CAPACITY (lb/h)	2749

NOTES:

1. NITROGEN TO KEEP INLET CLEAR OF CHAR.
2. ADEQUATE PURGING TAKES PLACE VIA FV 6080.
3. PER TELECON WITH BILL STEELE, SRI BELIEVE IT TO BE NECESSARY TO MAINTAIN PURGE ON THESE INSTRUMENTS.

APPENDIX E

FW APFBC TRAIN: DETAILED PROJECT SCHEDULE

E-4

ACT. ID	EARLY START	EARLY FINISH	ORIG DUR	1992												1993												1994												1995											
				OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG													
				PROCESS																																															
E1254	31DEC93A	26AUG94	170	<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></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ACT ID	EARLY START	EARLY FINISH	ORIG DUR	1992												1993												1994												1995																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
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P1755	14FEB94A	25MAR94A	15

ACT ID	EARLY START	EARLY FINISH	ORIG DUR	1992			1993												1994												1995													
				OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG						
				PROCUREMENT																																								
P1990	25NOV93A	25JAN94A	35																																		TRANSPORT AIR COMPRESSOR REQUISITION (C00252)							
P1991	25JAN94A	28JAN94A	15																																		ISSUE INQUIRY FOR TRANSPORT AIR COMPRI CY0252)							
P1992	17JAN94A	25FEB94A	20																																		REC QUOTES/VDR DWGS-TRANSPORT AIR COMPRI CY0252)							
P1993	4APR94	22APR94	15																																		BID EVAL/APPROVAL - TRANSPORT AIR COMPR (C00252)							
P1994	25APR94	6MAY94	10																																		ISSUE PURCH ORDER - TRANSPORT AIR COMPR (C00252)							
P1995	9MAY94	1JUL94	40																																		REC CERT VDR DWGS - TRANSPORT AIR COMPR (C00252)							
P1996	4JUL94	10FEB95	160																																		FAB AND DELIVER - TRANSPORT AIR COMPR (C00252)							
P1998	26NOV93A	24JAN94A	30																																		BOOSTER AIR COMPRESSOR (C00251) REQUISITION							
P2000	25JAN94A	28JAN94A	15																																		ISSUE INQUIRY FOR BOOSTER COMPRESSOR (C00251)							
P2005	17JAN94A	25FEB94A	20																																		REC QUOTES/VDR DWGS - BOOSTER AIR COMPR (C00251)							
P2010	4APR94	22APR94	15																																		BID EVAL/APPROVAL - BOOSTER AIR COMPR (C00251)							
P2015	25APR94	6MAY94	10																																		ISSUE PURCHASE ORDER - BOOSTER AIR COMPR(C00251)							
P2020	9MAY94	1JUL94	40																																		REC CERT VENDOR DWGS - BOOSTER AIR COMPR(C00251)							
P2025	4JUL94	10MAR95	180																																		FAB AND DELIVER - BOOSTER AIR COMPR (C00251)							
P2030	12NOV93A	6DEC93A	20																																		BAGHOUSE FAN (BLO251) REQUISITION							
P2031	10DEC93A	17DEC93A	10																																		ISSUE INQUIRY FOR BAGHOUSE FAN (BLO251)							
P2035	20DEC93A	14JAN94A	20																																		REC QUOTES/VDR DWGS - BAGHOUSE FAN (BLO251)							
P2040	15JAN94A	8APR94	15																																		BID EVALUATION/APPROVAL - BAGHOUSE FAN (BLO251)							
P2045	11APR94	15APR94	5																																		ISSUE PURCHASE ORDER - BAGHOUSE FAN (BLO251)							
P2050	18APR94	10JUN94	40																																		REC CERT VENDOR DWGS - BAGHOUSE FAN (BLO251)							
P2055	13JUN94	21OCT94	95																																		FABRICATE AND DELIVER - BAGHOUSE FAN (BLO251)							
P2085	25NOV93A	4JAN94A	30																																		SHELL AND TUBE EXCHANGER (HX0251,6) REQUISITION							
P2090	5JAN94A	7JAN94A	10																																		ISSUE INQUIRY FOR SHELL EXCHANGERS(HX0251,6)							
P2095	10JAN94A	25JAN94A	20																																		REC QUOTES/VDR DWGS - SHELL AND EXCH (HX0251,6)							
P2100	31JAN94A	8APR94	35																																		BID EVAL/APP L-SHELL & TUBE EXCHANGERS(HX0251,6)							
P2105	11APR94	22APR94	10																																		ISS PURCHASE ORDER-SHELL & TUBE EXCH (HX0251,6)							
P2106	25APR94	17JUN94	40																																		REC CERT VDR DWGS-SHELL & TUBE EXCH(HX0251,6)							
P2107	20JUN94	4NOV94	100																																		FAB AND DELIVER- SHELL & TUBE EXCH (HX0251,6)							
P2108	25NOV93A	24JAN94A	30																																		DOUBLE PIPE EXCHANGER (HX0255) REQUISITION							
P2109	25JAN94A	18MAR94A	10																																		ISSUE INQUIRY FOR DOUBLE PIPE EXCHANGER(HX0255)							
P2110	21MAR94A	15APR94	20																																		REC QUOTES/VDR DWGS-DOUBLE PIPE EXCH (HX0255)

ACT. ID	EARLY START	EARLY FINISH	ORIG DUR	PROCUREMENT											
				1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
P3065	28MAR94A	6MAY94	30												
P3066	9MAY94	24JUN94	35												
P3067	27JUN94	9OCT94	120												
P3068	24JUN94A	25MAR94A	45												
P3069	28MAR94A	6MAY94	30												
P3070	9MAY94	24JUN94	35												
P3071	27JUN94	9OCT94	120												
P3099	24JUN94A	22APR94	40												
P4000	25APR94	17JUN94	40												
P4005	20JUN94	15JUL94	20												
P4010	18JUL94	16OCT94	110												
P4014	4APR94	27MAY94	40												
P4015	30MAY94	22JUL94	40												
P4020	25JUL94	19AUG94	20												
P4025	22AUG94	20JAN95	110												
P4995	29JUL93A	4FEB94A	30												
P5000	7FEB94A	6MAY94	65												
P5010	9MAY94	1JUL94	40												
P5020	4JUL94	20JAN95	145												
P5025	29JUL93A	6OCT93A	30												
P5030	10OCT93A	15APR94	65												
P5040	18APR94	10JUN94	40												
P5050	13JUN94	21OCT94	95												
X2000		9JUN95	0												

APPENDIX F

MWK PROCUREMENT STATUS REPORT

SOUTHERN COMPANY SERVICES POWER SYSTEMS DEVELOPMENT FACILITY M.W. KELLOGG JOB NO. 6704										PROCUREMENT STATUS REPORT AS OF 25-MAR-94										04-Apr-94			
PURCHASE ORDER NUMBER TAG NUMBER, DESCRIPTION		REQUISITIONS COMPLETE		INQUIRIES ISSUED		QUOTES RECEIVED		TECH. EVAL. COMPLETED		COMMITMENTS (ENG ONLY)		P.O. ISSUED											
		PERIOD	TO DATE	PERIOD	TO DATE	PERIOD	TO DATE	PERIOD	TO DATE	PERIOD	TO DATE	PERIOD	TO DATE										
6704-3311001-8810-01 BR0201, STARTUP BURNER			1			1		1		1			1										
6704-3311001-8800-01 BR0401, THERMAL OXIDIZER/WASTE HEAT BOILER			1			1		1		1			1										
6704-3311001-8710-01 BR0402, FLARE TIP			1			1		1		1			1										
6704-3311001-8800-02 BR0602, SULFATOR STARTUP HEATER			1			1		1		1			1										
6704-3311001-8300-01 H00202, PRIMARY GAS COOLER			1			1		1		1			1										
6704-3311001-8300-02 H00402, SECONDARY GAS COOLER (REQQUOTE)			1			1		1		1			1										
6704-3311001-8300-03 H00501, SULFATOR HEAT RECOVERY EXCHANGER			1			1		1		1			1										
6704-3311001-8300-03 H00203, COMBUSTOR HEAT EXCHANGER			1			1		1		1			1										
6704-3311001-8300-01 H00204, TRANSPORT AIR COOLER			1			1		1		1			1										
6704-3311001-8300-02 H00405, COMPRESSOR FEED COOLER (REQQUOTE)			1			1		1		1			1										
6704-3311001-0650-01 CY0201, REACTOR PRIMARY CYCLONE			1			1		1		1			1										
6704-3311001-0650-01 CY0207, DISENGAGER			1			1		1		1			1										
6704-3311001-0411-01 DR0402, STEAM DRUM			1			1		1		1			1										
6704-3311001-0411-02 DR0404, FLARE SEAL DRUM			1			1		1		1			1										
6704-3311001-0413-01 DR0501, HTF SYSTEM SURGE DRUM			1			1		1		1			1										
6704-3311001-0310-01 FR0201, TRANSPORT REACTOR			1			1		1		1			1										
6704-3311001-0310-02 8L0501, SULFATOR			1			1		1		1			1										
6704-3311001-210-01 CO0201, MAIN AIR COMPRESSOR			1			1		1		1			1										
6704-3311001-1220-01 CO0401, RECYCLE GAS BOOSTER COMPRESSOR			1			1		1		1			1										
6704-3311001-1840-01 CO0601, SULFATOR AIR COMPRESSOR			1			1		1		1			1										
6704-3311001-1630-01 BL0401, THERMAL OXIDIZER BLOWER			1			1		1		1			1										
6704-3311001-1560-01 ME0540, HEAT TRANSFER FLUID (HTF) SYSTEM			1			1		1		1			1										
6704-3311001-1420-01 FL0401, RECYCLE GAS INLET FILTER			1			1		1		1			1										
6704-3311001-1611-01 CY0801, SULFATOR CYCLONE			1			1		1		1			1										
6704-3311001-1612-01 SH0802, SPENT SOLIDS SILO			1			1		1		1			1										
6704-3311001-1552-01 FD0204, SPENT SOLIDS SCREW COOLER			1			1		1		1			1										
6704-3311001-1552-01 FD0502, FINES SCREW COOLER			1			1		1		1			1										
6704-3311001-1552-01 FD0602, SULFATOR SOLIDS SCREW COOLER			1			1		1		1			1										
6704-3311001-1221-01 FD0210, COAL FEEDER SYSTEM			1			1		1		1			1										
6704-3311001-1221-01 FD0220, LIMESTONE FEEDER SYSTEM			1			1		1		1			1										
6704-3311001-1221-01 FD0510, SPENT SOLIDS TRANSPORTER SYSTEM			1			1		1		1			1										
6704-3311001-1221-01 FD0520, FINES TRANSPORTER SYSTEM			1			1		1		1			1										
6704-3311001-1221-01 FD0530, SPENT SOLIDS FEEDER SYSTEM			1			1		1		1			1										
6704-3311001-1221-01 FD0510, SULFATOR LIMESTONE FEEDER SYSTEM			1			1		1		1			1										
6704-3311001-1876-01 TRANSITION PIECES			1			1		1		1			1										
6704-3311002-1777-01 POV-384																							
6704-3311002-1777-01 REFRACTORY LINED PIPING																							
TOTAL EQUIPMENT ITEMS, 35 each		0	35	0	35	0	35	0	35	0	34	0	34										

APPENDIX G

TRANSPORT REACTOR TRAIN: ERECTION PROCEDURE AND SEQUENCE FOR REFRACTORY LINED EQUIPMENT & PIPING (A PRELIMINARY DRAFT PLAN)

**ERECTION PROCEDURE AND SEQUENCE
FOR REFRACTORY LINED EQUIPMENT & PIPING**

1.0 SCOPE OF DOCUMENT

The scope of this document is to define Kellogg's design premise and to clarify any special construction requirements for the refractory lined equipment and piping and to put forth a proposed sequence of erection.

2.0 INSPECTION OF EQUIPMENT

Upon equipment arriving at site a thorough inspection should be performed to insure no damage has occurred during shipment. The temporary closures should be removed and a visual inspection of internal refractory performed. Once the inspection is complete and the item is accepted, the temporary covers must be replaced to minimize moisture from standing on the internal refractory lining. The equipment item must be stored off the ground and out of the weather.

3.0 LIFTING

Temporary lugs shall not be welded on any areas of the equipment indicating a PWHT has been performed, these areas will be defined per MWK specification E40-1F-6704, par. 8.1.4. When using slings, timbers shall be placed between sling and equipment in order to avoid scarring the paint surface.

The lifting lugs on the equipment are only designed to lift each section of the line. The lugs are designed to be used in sets so that the load is distributed between lugs. If a different method is used, such as preassembling some of the lines on the ground, the method of lifting will also have to be changed (to possibly a sling).

See Attachment "A" for a guideline to lift the reactor loop equipment.

4.0 SETTING EQUIPMENT IN THE STRUCTURE

THIS SECTION TO BE FURNISHED LATER

5.0 FIELD TRIAL FIT OF REACTOR LOOP

- 5.1 The reactor system must be trial fit prior to any welding. The actual welding of the field joints is not as complicated as the fit-up. This is one of the most critical parts of installation.

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5.2 The basis of the Kellogg plan follows:

- 5.2.1** Secondary structural members in the vicinity of the reactor loop components which could inhibit maneuvering for trial and/or final fit-up should not be installed until after reactor loop components are final welded.
- 5.2.2** Field adjustment is not generally possible at flanged joints, so field welds have been located in each loop of the reactor for final field adjustment.
- 5.2.3** The sections of the reactor loop have been fabricated to close tolerances. However, a certain amount of adjustment will be required due to cumulative tolerances and the fact that we will be matching items from (4) separate scopes of supply; the reactor loop (RX0201), the cyclones (CY0201 & CY0207), the exchanger (HX0203) and the structure. Field joints are designed to accommodate angular misalignment or extension up to 1/2 inch without modifications, except that the weld and its root widen proportionally. A small reduction in length can be accomplished by grinding the refractory and backing ring on the male end of the joint.

Kellogg does not anticipate any significant fit-up problems. However, larger extensions and/or reductions in length at field joints that may occur shall be accounted for by careful rework of the joint. For instance, a large reduction in length may require cutting the hot face refractory to length with a diamond saw, chipping out an appropriate amount of back-up lining, cutting the shell to length and rebeveling, reinstalling the backing ring and repairing the back-up lining. A large extension may require that a short section of pipe be added. Spare pup pieces are being provided in case a large extension should be required.

NOTE: ANY MAJOR PROBLEMS AT FIELD JOINTS THAT CANNOT BE CORRECTED BY MINOR GRINDING OF THE REFRACTORY AND BACKING RING WILL REQUIRE A KELLOGG ENGINEERING REVIEW FOR RESOLUTION.

- 5.2.4** The field welds are provided with fit-up tie rod assemblies (see detail "B" on MWK dwg 499-D1). These tie rod assemblies are to be used for adjusting the root of the field weld to an approximate 1/8" gap.

NOTE: THE TIE ROD ASSEMBLIES ARE NOT ADEQUATE TO HANG CONNECTING EQUIPMENT FROM WITHOUT TEMPORARY SUPPORTS FROM THE STRUCTURE.

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5.3 The reactor loop must be assembled in a specific sequence.

- 5.3.1** The initial starting point for trial fit-up is to set "SP1" at elevation 192'-0". Install shim plates as required to establish the point of support (P.O.S.) at 192'-1". The shim packs are provided in various thicknesses in order to compensate for any imperfection in the structural beam elevation. The anchor bolts should be installed and tightened. (Note: anchor bolts and nuts are to be furnished by others, they will not be furnished with the reactor loop.)

This point is the bench mark of the system. This is the fixed point and everything else in the system will thermally expand from this point.

- 5.3.2** Place the disengager cyclone "CY0207" on top of "SP1". Install gasket, studs and nuts. Snug up bolting.
- 5.3.3** Set section "R2" on top of "CY0207". Install gasket, studs and nuts. At this stage the proper spacing between "R2" and "SP1" should be verified and all bolting snugged up. Install TFE slide bearing plates and shims as required to maintain a proper fit-up between "SP1, CY0207 and R2". (Note: this is a sliding support and no anchor bolts are required.)
- 5.3.4** Set section "DL1" at elevation 192'-0". Install TFE slide bearing plates and shims as required to maintain a 192'-1" P.O.S. (Note: this is a sliding support and no anchor bolts are required.)
- 5.3.5** Place the reactor primary cyclone "CY0201" on top of "DL1". Install gasket, studs and nuts. Snug up bolting.
- 5.3.6** Set "CO1" between "CY0201" and "CY0207". Install gaskets, studs and nuts. Snug up bolting. Verify spacings between "SP1, DL1 and R2". Shims at "DL1" may require adjustment to maintain proper fit-up between "CY0207", "CO1" and "CY0201".
- 5.3.7** "Caution" all (3) P.O.S. listed in steps 5.3.1, 5.3.4 & 5.3.6 have a theoretical P.O.S. of 192'-1", if this reference is substantially off, problems may be encountered when fitting up lower equipment. Contact M.W. Kellogg engineering for resolution.
- 5.3.8** Hang "R1" from "R2" using trunnions "PH1" to temporarily support "R1" from the structure. Install the fit-up tie rods and nuts. Adjust the root of the field weld to an approximate 1/8" gap.
- 5.3.9** Hang "DL2" from "DL1" using trunnions "PG2" to temporarily support "DL2" from the structure. Install the fit-up tie rods and nuts. Adjust the root of the field weld to an approximate 1/8" gap.

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- 5.3.10 Hang "MIX" from "R1" using the lifting trunnions to temporarily support "MIX" from the structure. Install gasket, studs and nuts. Snug up bolting.
- 5.3.11 Hang "SP2" from "SP1" using trunnions "PH2" to temporarily support "SP2" from the structure. Align flanges at "MIX" and "SP2", install the fit-up tie rods and nuts at field welds "SP1" to "SP2" and "DL2" to "SP2". Install gasket, studs and nuts at flanges "MIX" to "SP2". Snug up bolting. Adjust the root of the field welds for the optimum fit-up. In order to achieve the optimum fit-up at the field joints the root of the field welds in steps 5.3.8 and 5.3.9 may require adjustment.
- 5.3.12 Position exchanger "HX0203" while aligning spool piece "CO3" between "SP2" and "HX0203". Use lifting lugs to temporarily support "HX0203". Install gaskets, studs and nuts at flanges. Snug up bolting.
- 5.3.13 Hang "JL1A" from "HX0203" and install gasket, studs and nuts. Snug up bolting. "JL1A" is supported by flanged connection to "HX0203".
- 5.3.14 Hang "JL1B" from "JL1A" using a sling arrangement to temporarily support "JL1B" from the structure. Install the fit-up tie rods and nuts at the field weld. Adjust the root of the field weld to approximate 1/8" gap.
- 5.3.15 Assemble fit-up tie rods and nuts at field weld "JL2" to "JL3". Align "JL2" and "JL3" assembly with flanges at "MIX" and "JL1B". Install gaskets, studs and nuts. Snug up bolting. Adjust the root of the field weld for the optimum fit-up. Additional adjustment of field weld root in step 5.3.14 may be required to achieve optimum fit-up.
- 5.3.16 Check the entire reactor loop system and verify no equipment is in a bind. Make any final adjustments of field weld root gaps to optimize the fit-up.
- 5.3.17 Install spring supports at "HX0203" (leave pins in locked position) and remove temporary supports at "HX0203".
- 5.3.18 Match mark all adjacent components for correct orientation at final fit-up and welding.

In order to insure proper replacement of tie rods at final field welding, match mark all tie rods with fit-up rings for field weld location and tie rod to hole arrangement. Tack weld inner nuts on field tie rods.

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During final field fit-up and welding it is essential to insure each component is in correct location before welding. Considering one incorrect turn of a nut at the field weld tie rod assemblies could cause the lower end of the equipment to be out of position by one to two inches, measurements must be recorded at the lower end. For example, section "SP2" shall have measurements recorded between the equipment and the adjacent structural steel at elevation 132'-0". The measurements shall be taken in the North, South, East and West directions.

6.0 FINAL FIT-UP AND FIELD WELDING OF REACTOR LOOP

- 6.1** Once the trial fit-up is complete, final fit-up can begin. Final fit-up is also done in a very specific sequence. As each section is fit up, the flanges are bolted tight and/or field weld root pass made. This final fit up of each individual field joint (flanged or welded) must be completed in a very tight time frame, as there is an air hardening plastic refractory that is installed immediately prior to fit-up. If final fit-up is delayed after the plastic is installed, such that the plastic hardens, it can prevent pull-up of the joint. Scheduling must be such that once the plastic has been installed, final fit-up and bolting or root pass welding of that section must be completed without any work breaks.
- 6.2** Final field flanged joint assembly must be in accordance with details and procedure on MWK drawing 499-D2, detail "A".
- 6.3** Final field weld assembly must be in accordance with details and procedure on MWK drawing 499-D1, detail "B". Other requirements to consider are:
 - 6.3.1** The welding is Code and requires qualified welders per ASME B31.3.
 - 6.3.2** Caution needs to be observed by the personnel fitting up and welding the joints. The plastic refractory materials used to seal the refractory side of the joints contains phosphoric acid. If this material is allowed in or immediately adjacent to the prepared weld joint, it can cause weld porosity.
 - 6.3.3** The field joint will not be radiographed or hydrostatically tested. Because of this, the specified NDT is critical and includes Magnetic Particle Examination of the root and final weld, a 100% Ultrasonic Examination of the completed weld and a Pneumatic Pressure Test.
 - 6.3.4** It should be noted that after welding each joint, the fit-up of the remaining joints may change slightly due to weld shrinkage. All fit-ups must be rechecked after each weld is made.

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6.4 The reactor loop final fit-up and welding sequence.

- 6.4.1 Disassemble all bolted connections from trial fit-up above elevation 192'-0" and field weld connection at "R1" to "R2".
- 6.4.2 Prepare refractory surface per Kellogg procedure at "SP1" flange (See 6.2). Set service gasket in place. Place the disengager cyclone "CY0207" on top of "SP1". Install studs and nuts. Final tighten bolting.
- 6.4.3 Prepare refractory surface per Kellogg procedure at top flange of "CY0207" (See 6.2). Set service gasket in place. Set section "R2" on top of "CY0207". Install studs and nuts. At this stage the proper spacing between "R2" and "SP1" should be verified. Check TFE slide bearing plates and shims maintain a proper fit-up at support of "R2". (Note: this is a sliding support and no anchor bolts are required.) Final tighten bolting at "CY0207" and "R2".
- 6.4.4 Prepare refractory surface per Kellogg procedure at "DL1" flange (See 6.2). Set service gasket in place. Place the primary cyclone "CY0201" on top of "DL1". Install studs and nuts. Final tighten bolting.
- 6.4.5 Prepare refractory surfaces per Kellogg procedure at "CY0201" and "CY0207" flanges (See 6.2). Set "CO1" between "CY0201" and "CY0207". Install gaskets, studs and nuts. Verify spacings between "SP1, DL1 and R2". Check TFE slide bearing plates and shims maintain a proper fit-up at support of "DL1". (Note: this is a sliding support and no anchor bolts are required.) Final tighten bolting.
- 6.4.6 Remove pieces "CO3", "JL1A", "JL1B", "JL2" and "JL3" from trial fit-up assembly.
- 6.4.7 Disassemble bolted connections at "MIX" to "SP2" and "R1" to "MIX".
- 6.4.8 Disassemble field weld connections at "R1" to "R2", "SP2" to "DL2", "SP1" to "SP2" and "DL1" to "DL2". Keep tie rods in the upper fit-up ring, if possible, in order to insure proper assembly of joint for final fit-up and welding.
- 6.4.9 Lower "SP2" as far as possible. Be careful flanges at "SP2" and "HX0203" do not come in contact.
- 6.4.10 Lower "MIX" as far as possible. Be careful flanges at "MIX" and "SP2" do not make contact.
- 6.4.11 Lower "R1" as required and prepare refractory surface per Kellogg procedure at "R1" field joint. (See 6.3)

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- 6.4.12 Fit "R1" to "R2" and adjust the root of the field weld (using the preset tie rod assemblies) to the trial fit-up location. Confirm correct orientation. Make the root pass of the field weld (See 6.1). Complete welding and N.D.E. requirements. Temporary supports for "R1" may be removed at this point.
- 6.4.13 Lower "DL2" as required and prepare refractory surface per Kellogg procedure at "DL2" upper field joint. (See 6.3)
- 6.4.14 Fit "DL1" to "DL2" and adjust the root of the field weld (using the preset tie rod assemblies) to the trial fit-up location. Confirm correct orientation. Make the root pass of the field weld (See 6.1). Complete welding and N.D.E. requirements. Temporary supports at "DL2" should remain in place for lateral support.
- 6.4.15 Prepare refractory surface per Kellogg procedure at "MIX" top flange (See 6.2). Set service gasket in place. Fit "MIX" to "R1". Install studs and nuts. Confirm correct orientation. Final tighten bolting. Remove temporary supports at "MIX".
- 6.4.16 Prepare refractory surfaces per Kellogg procedures at field welded joints "SP1" to "SP2", "DL2" to "SP2" (See 6.3) and at flanged joint "MIX" to "SP2" (See 6.2) simultaneously. Set service gasket.
- 6.4.17 Fit field weld joints "SP2" to "DL2" and "SP2" to "SP1" while aligning flanges at "SP2" to "MIX". Install studs and nuts at flanges and tighten. Adjust the root of the field welds (using the preset tie rod assemblies) to the trial fit-up location. Confirm correct orientation. Make the root pass of the field welds (See 6.1). Complete welding and N.D.E. requirements. Temporary supports at "DL2" and "SP2" may be removed at this time.
- 6.4.18 Prepare refractory surfaces per Kellogg procedures (See 6.2) at flanged joints "SP2" to "CO3" and "CO3" to "HX0203". Set "CO3" between "SP2" and "HX0203". Install gasket, studs and nuts. Final tighten bolting.
- 6.4.19 Prepare refractory surfaces per Kellogg procedures (See 6.2) at flanged joint "HX0203" to "JL1A". Set service gasket in place. Fit "JL1A" to "HX0203" and install studs and nuts. Insure proper orientation. Final tighten bolting.
- 6.4.20 Prepare refractory surfaces per Kellogg procedures at field weld joint "JL1A" to "JL1B" (See 6.3). Hang "JL1B" from "JL1A" using a sling arrangement to temporarily support "JL1B" from the structure. Adjust the root of the field welds (using the preset tie rod assemblies) to the trial fit-up location. Confirm correct orientation. Make the root pass of the field welds (See 6.1). Complete welding and N.D.E. requirements. Temporary supports at "JL1B" may be removed at this time.

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- 6.4.21 Prepare refractory surfaces per Kellogg procedures at field weld joint "JL2" to "JL3" (See 6.3). Assemble field weld joint "JL2" to "JL3" and adjust the root of the field welds (using the preset tie rod assemblies) to the trial fit-up location. Confirm correct orientation. Prepare refractory surfaces per Kellogg procedures at flanged joints "JL1B" to "JL2" and "JL3" to "MIX" (See 6.2) simultaneously. Set service gasket. Align "JL2" and "JL3" assembly with flanges at "MIX" and "JL1B". Install studs and nuts. Final tighten bolting. Adjust the root of the field weld if necessary for optimum fit-up. Make the root pass of the field welds (See 6.1). Complete welding and N.D.E. requirements.
- 6.4.22 Prepare refractory surfaces per Kellogg procedures at flanged joint "CO1" to "BP3" (See 6.2). Set service gasket. Align "BP3" with "CO1" using slings to temporary support "BP3" from the structure. Install studs and nuts. Final tighten bolting.
- 6.4.23 Prepare refractory surfaces per Kellogg procedures at flanged joint "BP3" to control valve "PV384" (See 6.2). Set service gasket. Align "PV384" under "BP3" using sling to temporary support "PV384" from structure. Install studs and nuts. Insure proper orientation. Tighten bolting.
- 6.4.24 Prepare refractory surfaces per Kellogg procedures at flanged joint "BP2" to control valve "PV384" (See 6.2). Set service gasket. Position "BP2" under "PV384" using trunnion "PH3" to temporary support "BP2" from structure. Install studs and nuts. Insure proper orientation. Final tighten bolting.
- 6.4.25 Trial Fit-up "BP1" from "BP2" while aligning flanges at "HX0203". Use trunnion "PH4" to temporarily support "BP1" from the structure. Install the fit-up tie rods and nuts at field weld. Install gasket, studs and gasket at flanges "BP1" to "HX0203". Snug studs up. Adjust the root of the field weld to optimize fit-up. Mark all settings of inner nuts on field tie rods or tack weld inner nuts to tie rods.
- 6.4.26 Disassemble connections at "BP1" to "BP2" and "BP1" to "HX0203". Keep tie rods in the fit-up ring at "BP2", if possible, in order to insure proper assembly of joint for final fit-up and welding. Lower "BP1" out of position.
- 6.4.27 Prepare refractory surfaces per Kellogg procedures at field weld joint "BP1" to "BP2" (See 6.3) and prepare refractory surfaces per Kellogg procedures at flanged joint "BP1" to "HX0203" (See 6.2) simultaneously. Set service gasket. Position "BP1" to "BP2" while aligning flanges at "BP1" and "HX0203" and install studs and nuts. Final tighten bolting. Assemble field weld joint "BP1" to "BP2" and adjust the root of the field welds (using the preset tie rod assemblies) to the trial fit-up location. Make the root pass of the field weld (See 6.1). Complete welding and N.D.E. requirements.

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- 6.4.28 Remove temporary supports from "BP1", "PV384", "BP2" and "BP3".
- 6.4.29 Prepare refractory surfaces per Kellogg procedures at flanged joint "CO4" to "CY0201" (See 6.2). Set service gasket. Position "CO4" on top of "CY0201". Install studs and nuts. Insure proper orientation. Final tighten bolting.
- 6.4.30 Install spring hangers and set guides.
- 6.4.31 ???? Line to start-up heater later ?????

7.0 FIELD TRIAL FIT OF LINE TO PCD's

THIS SECTION TO BE FURNISHED LATER

8.0 FINAL CLOSURE WELDS OF LINE TO PCD's

THIS SECTION TO BE FURNISHED LATER

9.0 FIELD TRAIL FIT OF SULFATOR & SULFATOR CYCLONE LOOP

THIS SECTION TO BE FURNISHED LATER

10.0 FINAL CLOSURE WELDS OF SULFATOR & SULFATOR CYCLONE LOOP

THIS SECTION TO BE FURNISHED LATER

11.0 PNEUMATIC TEST OF REACTOR LOOP, LINE TO PCD's & LINE TO START-UP HEATER

THIS SECTION TO BE FURNISHED LATER

12.0 SULFATOR LINE PNEUMATIC TEST

THIS SECTION TO BE FURNISHED LATER

13.0 JACKETED TRANSITION PIECES PNEUMATIC TESTS

THIS SECTION TO BE FURNISHED LATER

14.0 PAINTING FIELDS JOINTS & TOUCH-UPS

THIS SECTION TO BE FURNISHED LATER

15.0 FIELD FABRICATION GENERAL GUIDELINES

- 15.1 All spring hangers (with pin in), guides and supports, unless otherwise noted, shall be installed as the piece of pipe they are connected to is installed. Spring hangers are to be installed in accordance with "VARIABLE AND CONSTANT TYPE SPRING SUPPORTS INSTALLATION" (see attached vendor procedures).
- 15.2 The final welding of all seams should not be completed until the entire line is fit up.
- 15.3 All equipment must be temporarily supported until the full loop is complete and enough welding has been completed to make the line self-supporting.
- 15.4 All lifting lugs must be removed, after erection of lines.
- 15.5 The lifting lugs on equipment are designed only to lift the individual equipment item. The lugs are designed to be used in sets so that the load is distributed between lugs. If a different method is used, such as preassembling some of the lines on the ground, the method of lifting will also have to be changed (to possibly a sling).
- 15.6 Variable type spring supports installation considerations.
 - 15.6.1 All springs shall arrive at the jobsite with the spring setting set for the "cold" load (non-operating pipe system) and locked in that position.
 - 15.6.2 All "base" type springs shall arrive at the jobsite with the height of the load column positioned to "fit" the support location. These type spring also have between 1" and 2" vertical adjustment by turning the load column while the spring is in the locked position.
 - 15.6.3 All "hanging" type springs that have rod hangers attached to them also have some measure of vertical adjustment by means of a turnbuckle.
 - 15.6.4 The supplied rods for the hanging type springs have been ordered to accommodate the "make-up" dimensions. Final adjustment, if required, can be made via the turnbuckles or trimming the rod lengths while the spring is in the cold set.
 - 15.6.5 If the actual cold loads do vary by more than 20% from the cold load settings, M. W. Kellogg Engineering should be informed.
 - 15.6.6 The cold load setting pins (locking devices) should only be released after all testing has been performed and the unit is read for start-up. The springs have been ordered with a means of storing the locking devices once released.

- 15.6.7 After the unit has started up and is running, all spring loadings should be checked and noted. Any actual hot loadings that vary by 20% over design load settings should be referred to M.W. Kellogg Engineering.
- 15.6.8 The spring vendors catalogues, literature, and representatives should be available for reference.

16.0 UNIT PUNCH LIST

Before unit start-up, a thorough engineering check needs to be made to insure that the construction meets with the design. The purpose of this section is not to list normal field quality assurance procedures but rather to list items that require special attention.

A final check of these items is necessary not only because of their importance in the proper function of the unit, but also because they are often overlooked and tend to be a problem on every unit. The check is basically for compliance with the drawings and to insure room for expansion.

When the unit is complete, someone familiar with the design criteria of the unit should make an item by item check of the actual construction against the drawings. In addition, the person doing the "walk through" should re-examine the design in view of his observations of the composite finished job to confirm the original basis.

- 16.1 All location and relative positions of equipment should be checked.
- 16.2 Check for operating and maintenance access.
- 16.3 Check for improper materials that may have been shipped to the field in error, etc.
- 16.4 Slide valves are one of the most complex, critical and least understood parts of the unit. For these reasons, they must be carefully checked.
 - 16.4.1 Installed position, flow direction, operator orientation, etc.
 - 16.4.2 Interferences considering both erection and operating.
 - 16.4.3 Supports, spring hangers, etc.
 - 16.4.4 A field check of disc clearances (this is critical) and a final refractory check.
 - 16.4.5 Flexibility in all connections to the valve sufficient to handle the thermal growth (instruments purge connections, etc.)
 - 16.4.6 Cold wall valve is NOT insulated.

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- 16.4.7 Purges should be checked for correct orifice plates and valve/piping arrangement.
- 16.4.8 Bonnet seal welded or service gasket installed.
- 16.4.9 Slide valve stems clean - many stems have been galled by stroking the valve with construction debris on the stem.
- 16.4.10 Instruments and hydraulics properly connected (stroke valve from the control room).
- 16.5 Spring hangers and cans are vital parts of the unit's design. They are often given less attention than required.
 - 16.5.1 Installed in proper location?
 - 16.5.2 Correct mark no. and model no.
 - 16.5.3 Installed and supported correctly - clevis, rod, etc.
 - 16.5.4 Load set correctly.
 - 16.5.5 Check type and installation against expected performance.
 - 16.5.6 Spring hangers free to move with system?
 - 16.5.7 Pins pulled?
 - 16.5.8 Install and check bench marks at the following times:
 - As installed (cold and no pressure)
 - At design temperature and pressure
 - After cold again (no pressure) check for design movements.
- 16.6 Guides, supports, etc.
 - 16.6.1 Installed correctly?
 - 16.6.2 Gaps (or no gaps) as required?
 - 16.6.3 Install and check bench marks at the following times:
 - As installed (cold and no pressure)
 - At design temperature and pressure
 - After cold again (no pressure) Check for design movements.
- 16.7 Refractory, Insulation, Paint and Fireproofing
 - 16.7.1 Check to see that the appropriate combination was used in each location.

- 16.7.2 Check terminations to see that locations and details are as specified.

Two particular locations where terminations should be checked are fireproofing terminations on refractory insulated vessels and external insulation terminations (where there is a corresponding insulating refractory termination). These are critical areas that are very often installed incorrectly.

16.8 Interferences and Check for Thermal Growth

- 16.8.1 A complete as built interference check.
- 16.8.2 Check flex hoses, instrument connections, etc. to see that they have enough room for thermal growth.
- 16.8.3 Check where all equipment (piping, vessels, nozzles, etc.) penetrates platforms or otherwise comes near the structure.
- 16.8.4 Check the flexibility of small diameter piping that is tied into other piping or equipment where that piping or equipment has large movements.

16.9 Miscellaneous

- 16.9.1 Is ceramic fiber installed in refractory lined manways and blinded nozzles?
- 16.9.2 Have manway plugs been checked for fit-up?
- 16.9.3 Are drain valves installed in required locations (not just as shown on drawings)?
- 16.9.4 Are there any projections into piping?
- 16.9.5 Trial fit thermowells in nozzles.
- 16.9.6 Have shipping bars been removed from nozzles projecting through skirts?
- 16.9.7 Check all purge connections to see that they have the correct orifice and piping arrangement (valves, by passes, etc.)

16.10 Mysterious Problems

Any problems that show up which cannot be readily explained should be referred to M.W. Kellogg engineering and be pursued until all of the questions are answered.

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ATTACHMENT "A"
EQUIPMENT LIFTING GUIDELINE

<u>Component</u>	<u>Approx. Weight</u>	<u>Approx. Over All Length</u>	<u>Lifting Arrangement</u>
Reactor Loop (RX0201)			
MIX	24,600 lbs	23'-10"	Lifting trunnions with 12 ton shackles and spreader beam. Tail with sling adjacent to bottom body flange. Remove lifting trunnions after erected.
R1	12,800 lbs	30'-6"	Sling below field fit-up rings and tail with sling below lower trunnion "PH1".
R2	17,700 lbs	29'-8"	Sling at crossover and tail with sling adjacent to bottom field fit-up rings.
SP1	17,000 lbs	32'-5"	Sling below standpipe support and tail with sling adjacent to bottom field fit-up rings
SP2	32,200 lbs	38'-4"	Sling from trunnions "PH2" and tail adjacent to bottom body flange.
SP3	2,000 lbs	4'-1"	Sling at body flange. Do not sling on jacket.
DL1	3,900 lbs	9'-10"	Sling at body flange support
DL2	13,600 lbs	26'-1"	Sling below field fit-up rings and tail with sling adjacent to trunnions "PG2".
JL1A	1,700 lbs	4'-0"	Sling at body flange.
JL1B	5,100 lbs	7'-10"	Sling below nozzles "TE32" and "A17".
JL2	2,700 lbs	6'-7"	Sling adjacent to field fit-up rings.
JL3	2,600 lbs	5'-0"	Use lifting eye through bolt hole on body flange. (furnished by construction contractor)

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CO1	6,000 lbs	5'-11"	Use (3) lifting lugs provided with equipment.
CO2	3,600 lbs	5'-11"	Use (2) lifting lugs provided with equipment.
CO3	2,700 lbs	1'-9"	Use (1) lifting lug provided with equipment.
CO4	5,700 lbs	8'-10"	Sling at 8" nozzle in head.
BP1	6,800 lbs	27'-3"	Sling adjacent to field fit-up ring and tail with sling at body flange.
BP2	5,000 lbs	20'-0"	Sling adjacent to body flange and tail with sling below trunnion "PG1".
BP3	5,800 lbs	See Detail	Sling as required.
Primary Cyclone (CY0201)	21,600 lbs	12'-2"	Sling between top flange and body flange. Tail with sling adjacent to dipleg flange.
Disengager Cyclone (CY0207)	18,000 lbs	13'-5"	Sling between top flange and body flange. Tail with sling adjacent to dipleg flange.
Exchanger (HX0203)	83,800 lbs	34'-9"	Use lifting lugs with ?? ton shackles and spreader beam. Tail lug provided. Remove lifting lugs tailing lug after erection.
Sulfator (SU0601)	121,000 lbs	42'-3"	Use lifting lugs with 50 ton shackles and spreader beam. Tail lug provided. Remove lifting lugs tailing lug after erection.
Sulfator Cyclone (CY0601)	9,500 lbs	11'-2"	Sling at top flange. Tail with sling adjacent to dipleg flange.

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APPENDIX H

FW APFBC SYSTEM EQUIPMENT DELIVERY SCHEDULE

COMPONENT SCHEDULE

FOSTER WHEELER USA CORP Report EADC1.R2R Page 1
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ITEM ITEM DESCRIPTION	CPM Ref	REQ	INO	PO	ISSUE SPEC/ REQ	CLIENT APPROVE SPEC/ REQ	ISSUE INQUIRY/ RFQ	RECEIVE BIDS/ QUOTES	COMPLETE BID TABS	CLIENT APPROVE BID TABS	RELEASE PURCHASE ORDERS	RECEIVE VENDOR DRAWINGS	SHIP F.O.B.	DELIVERY TO SITE/ SHOP	FIELD/ SHOP NEED SLACK (in wks)
EQUIPMENT LIST CLASS EXCHANGERS															
HX0251 Process Air Cooler	2085	1211A	109		P 1/03/94 A/F 1/04/94A	1/17/94 1/06/94A	1/31/94 1/07/94A	2/28/94 1/25/94A	3/14/94 2/25/94A	3/28/94 4/08/94	4/11/94 4/22/94	6/06/94 6/17/94	9/19/94 10/21/94	10/03/94 11/04/94	9/06/94 9/06/94
HX0255 Char Cooler === RE-BID ===	2108	1221A	113		P 1/03/94 A/F 1/24/94A	1/17/94 1/25/94A	1/31/94 3/18/94A	2/16/94 4/15/94	3/02/94 4/29/94	3/16/94 5/13/94	3/30/94 5/27/94	5/25/94 7/22/94	9/07/94 11/25/94	9/21/94 12/09/94	2/13/95 2/13/95
HX0256 Air Heater	2085	1211E	109		P 1/03/94 A/F 1/04/94A	1/17/94 1/06/94A	1/31/94 1/07/94A	2/28/94 1/25/94A	3/14/94 2/25/94A	3/28/94 4/08/94	4/11/94 4/22/94	6/06/94 6/17/94	9/19/94 10/14/94	10/03/94 10/28/94	9/06/94 9/06/94
EQUIPMENT LIST CLASS FBHE PACKAGE															
CY0252 Combustor Cyclone By FWEC	1799	1291A			P 1/03/94 A/F 1/31/94A	1/17/94 2/04/94A	1/24/94 2/11/94A	2/21/94 2/25/94A	3/07/94 3/25/94A	3/21/94 4/08/94	4/04/94 4/22/94	5/30/94 6/17/94	1/09/95 1/06/95	1/23/95 1/20/95	4/17/95 4/17/95
HX0253 Fluidized Bottom Ash Cooler By FWEC	1775	1291A			P 1/03/94 A/F 1/31/94A	1/17/94 2/04/94A	1/31/94 2/11/94A	2/28/94 2/25/94A	3/14/94 3/25/94A	3/28/94 4/08/94	4/11/94 4/22/94	6/06/94 6/03/94	9/19/94 1/13/95	10/03/94 1/27/95	9/15/94 9/15/94
PG0251 Fluid Bed Heat Exchanger By FWEC	1810	1291A			P 12/24/93 A/F 1/31/94A	12/31/93 2/04/94A	1/14/94 2/11/94A	2/11/94 2/25/94A	2/25/94 3/25/94A	3/11/94 4/08/94	3/25/94 4/22/94	5/20/94 6/17/94	2/14/95 3/17/95	2/28/95 3/31/95	3/02/95 3/02/95
RX0252 Combustor By FWEC	1742	1291A			P 12/24/93 A/F 1/31/94A	1/07/94 2/04/94A	1/21/94 2/11/94A	2/18/94 2/25/94A	3/04/94 3/25/94A	3/18/94 4/08/94	4/01/94 4/22/94	5/27/94 6/17/94	2/21/95 2/17/95	3/07/95 3/03/95	4/17/95 4/17/95
VL0261 Combustor Cyclone J Valve By FWEC	4995	1291A			P 1/03/94 A/F 2/08/94A	1/17/94 2/08/94A	1/31/94 2/18/94A	2/28/94 3/25/94A	3/14/94 4/08/94	3/28/94 4/22/94	4/11/94 5/06/94	6/06/94 7/01/94	1/16/95 1/06/95	1/30/95 1/20/95	4/17/95 4/17/95
EQUIPMENT LIST CLASS MECHANICAL EQUIPMENT															
FL0351 Carbonizer PCD Filter By I.F.P.	2206				P A/F						3/25/94 4/08/94	5/20/94 6/03/94	10/14/94 2/27/95	10/28/94 3/13/95	4/17/95 4/17/95
FL0352 Combustor PCD Filter By Westinghouse.	3020				P A/F						3/25/94 4/08/94	5/20/94 6/03/94	10/14/94 4/03/95	10/28/94 4/17/95	4/17/95 4/17/95

COMPONENT SCHEDULE

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ITEM ITEM DESCRIPTION	CPM Ref	REQ	INQ	PO	ISSUE SPEC/ REQ	CLIENT APPROVE SPEC/ REQ	ISSUE INQUIRY/ RFQ	RECEIVE BIDS/ QUOTES	COMPLETE BID TABS	CLIENT APPROVE BID TABS	RELEASE PURCHASE ORDERS	RECEIVE VENDOR DRAWINGS	SHIP F.O.B.	DELIVERY TO SITE/ SHOP	FIELD/ SHOP NEED SLACK (in wks)	
EQUIPMENT LIST CLASS MECHANICAL - ALLISON																
CO0451 Main Air Compressor By Allison	1700	1379A			P A/F						1/10/94 4/08/94	5/30/94 7/15/94	4/10/95 5/26/95	4/24/95 6/09/95		
G80451 Gear Box By Allison	0	1332A			P A/F						1/10/94 4/08/94	5/30/94 7/15/94	4/10/95 5/26/95	4/24/95 6/09/95		
GNO451 Electric Generator By Allison	0	1332A			P A/F						1/10/94 4/08/94	5/30/94 7/15/94	4/10/95 5/26/95	4/24/95 6/09/95		
GT0451 Gas Turbine By Allison	0	1332A			P A/F						1/10/94 4/08/94	5/30/94 7/15/94	4/10/95 5/26/95	4/24/95 6/09/95		
SLO451 Air Filter Silencer By Allison	0	1332A			P A/F						1/10/94 4/08/94	5/30/94 7/15/94	4/10/95 5/26/95	4/24/95 6/09/95		
VL0453 Diverter Valve By Allison	5025	1332A			P A/F						1/10/94 4/08/94	5/30/94 7/15/94	4/10/95 5/26/95	4/24/95 6/09/95		
EQUIPMENT LIST CLASS MECHANICAL - MATERIAL HANDLING																
FL0254 Coal Surge Hopper Filter	1965	1356B	104		P A/F	12/06/93 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 1/18/94A	2/14/94 3/18/94A	2/28/94 4/08/94	3/14/94 4/15/94	5/09/94 6/03/94	8/29/94 10/07/94	9/12/94 10/21/94	4/17/95 4/17/95
FL0255 Sorbent Surge Hopper Filter	1965	1356B	104		P A/F	12/06/93 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 1/18/94A	2/14/94 3/18/94A	2/28/94 4/08/94	3/14/94 4/15/94	5/09/94 6/03/94	8/29/94 10/07/94	9/12/94 10/21/94	2/13/95 2/13/95
VL0258 Baghouse Bottoms Valve	5025	1361J	107		P A/F	12/06/93 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 1/17/94A	2/14/94 2/18/94A	2/28/94 4/08/94	3/14/94 4/15/94	5/09/94 6/03/94	9/26/94 10/07/94	10/10/94 10/21/94	
VL0259 Coal Diverter Valve	5025	1347A	107		P A/F	12/06/93 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 1/17/94A	2/14/94 2/18/94A	2/28/94 4/08/94	3/14/94 4/15/94	5/09/94 6/03/94	9/26/94 10/07/94	10/10/94 10/21/94	
VL0260 Dry Coal Diverter Valve	5025	1347A	107		P A/F	12/06/93 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 1/17/94A	2/14/94 2/18/94A	2/28/94 4/08/94	3/14/94 4/15/94	5/09/94 6/03/94	9/26/94 10/07/94	10/10/94 10/21/94	
EQUIPMENT LIST CLASS																

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ITEM ITEM DESCRIPTION	CPM Ref	REQ	ING	PO	ISSUE SPEC/ REQ	CLIENT APPROVE SPEC/ REQ	ISSUE INQUIRY/ RFO	RECEIVE BIDS/ QUOTES	COMPLETE BID TABS	CLIENT APPROVE BID TABS	RELEASE PURCHASE ORDERS	RECEIVE VENDOR DRAWINGS	SHIP F.O.B.	DELIVERY TO SITE/ SHOP	FIELD/ SHOP NEED SLACK (in wks)
MECHANICAL - MATERIAL HANDLING															
FD0251 Sorbent Feeder === REDESIGN ===	1939	1361E	110		P 12/17/93 A/F 12/17/94A	12/31/93 1/06/94A	1/14/94 1/11/94A	2/11/94 2/11/94A	2/25/94 4/08/94	3/11/94 4/15/94	3/25/94 4/29/94	5/20/94 6/24/94	10/14/94 11/25/94	10/28/94 12/09/94	9/06/94 9/06/94
FD0252 Carbonizer Coal Feeder === REDESIGN ===	1939	1361E	110		P 12/17/93 A/F 12/17/94A	12/31/93 1/06/94A	1/14/94 1/11/94A	2/11/94 2/11/94A	2/25/94 4/08/94	3/11/94 4/15/94	3/25/94 4/29/94	5/20/94 6/24/94	9/30/94 11/25/94	10/14/94 12/09/94	9/06/94 9/06/94
FD0253 Combustor Coal Feeder === REDESIGN ===	1939	1361F	110		P 12/17/93 A/F 12/17/93A	12/31/93 1/10/94A	1/14/94 1/11/94A	2/11/94 2/11/94A	2/25/94 4/08/94	3/11/94 4/15/94	3/25/94 4/29/94	5/20/94 6/24/94	9/30/94 11/25/94	10/14/94 12/09/94	9/06/94 9/06/94
FD0256 Fines Cooling Screw Feeder	1939	1379B	108		P 12/17/93 A/F 12/17/93A	12/31/93 12/23/93A	1/14/94 12/24/93A	2/11/94 2/04/94A	2/25/94 4/01/94A	3/11/94 4/15/94	3/25/94 4/29/94	5/20/94 6/24/94	9/30/94 11/25/94	10/14/94 12/09/94	1/23/95 1/23/95
FL0253 Fugitive Dust Bag House Filter	1965	1356A	103		P 12/06/93 A/F 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 2/04/94A	2/14/94 3/11/94A	2/28/94 4/08/94	3/14/94 4/15/94	5/09/94 6/10/94	8/29/94 10/07/94	9/12/94 10/21/94	3/23/95 3/23/95

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EQUIPMENT LIST CLASS MECHANICAL - WESTINGHOUSE															
AG0253 Carbonizer Alkali Getter By Westinghouse	1710	1123A	112		P A/F							1/14/94 4/08/94	3/18/94 6/03/94	9/02/94 10/09/95	9/15/94 10/23/95
AG0254 Combustor Alkali Getter By Westinghouse	1710	1124A	112		P A/F							1/14/94 4/08/94	3/18/94 5/06/94	9/02/94 9/18/95	9/15/94 10/02/95
BR0451 Topping Combustor By Westinghouse	1672	1379A			P A/F							1/10/94 4/08/94	6/13/94 7/15/94	12/22/94 1/23/95	1/05/95 2/06/95
IG0456 Ignitor Power Supply By Westinghouse	0	1379A			P A/F							1/10/94 4/08/94	6/13/94 9/09/94	8/01/95 10/28/95	8/15/95 11/11/95
ME0455 Combustor Skid Assembly By Westinghouse	0	1379A			P A/F							1/10/94 4/08/94	6/13/94 9/09/94	8/01/95 10/28/95	8/15/95 11/11/95

EQUIPMENT LIST CLASS
MECHANICAL EQUIPMENT

COMPONENT SCHEDULE

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ITEM ITEM DESCRIPTION	CPM Ref	REQ	INQ	PO	ISSUE SPEC/ REQ	CLIENT APPROVE SPEC/ REQ	ISSUE INQUIRY/ RFQ	RECEIVE BIDS/ QUOTES	COMPLETE BID TABS	CLIENT APPROVE BID TABS	RELEASE PURCHASE ORDERS	RECEIVE VENDOR DRAWINGS	SHIP F.O.B.	DELIVERY TO SITE/ SHOP	FIELD/ SHOP NEED SLACK (in wks)
BL0251 Baghouse Fan	2030	1325A	102		P 12/06/93 A/F 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 1/14/94A	2/14/94 2/18/94A	2/28/94 4/08/94	3/14/94 4/15/94	5/09/94 6/10/94	9/05/94 10/07/94	9/19/94 10/21/94	4/17/95 4/17/95
CO0251 Booster Air Compressor	1998	1322A	114		P 1/03/94 A/F 1/25/94A	1/17/94 1/28/94A	1/31/94 1/28/94A	2/28/94 2/25/94A	3/14/94 4/08/94	3/28/94 4/22/94	4/11/94 5/06/94	6/06/94 7/01/94	1/27/95 3/03/95	2/10/95 3/17/95	9/06/94 9/06/94
CO0252 Transport Air Compressor	1990	1322B	114		P 1/14/94 A/F 1/25/84A	1/28/94 1/28/94A	2/11/94 1/28/94A	3/11/94 2/25/94A	3/25/94 4/08/94	4/08/94 4/22/94	4/22/94 5/06/94	6/17/94 7/01/94	1/03/95 1/27/95	1/17/95 2/10/95	
EQUIPMENT LIST CLASS MISCELLANEOUS															
AH0252 Carbonizer Air Preheater	1845	1244A	105		P 12/06/93 A/F 12/06/93A	12/20/93 12/09/94A	1/03/94 12/17/93A	1/31/94 1/17/94A	2/14/94 2/25/94A	2/28/94 4/08/94	3/14/94 4/22/94	5/09/94 6/17/94	10/03/94 11/11/94	10/17/94 11/25/94	2/13/95 2/13/95
AH0253 Combustor Air Preheater	1845	1244B	105		P 12/06/93 A/F 12/06/93A	12/20/93 12/09/94A	1/03/94 12/17/93A	1/31/94 1/17/94A	2/14/94 2/25/94A	2/28/94 4/08/94	3/14/94 4/22/94	5/09/94 6/17/94	10/03/94 9/16/94	10/17/94 9/30/94	9/06/94 9/06/94
AH0254 Combustor Above Grid Air Preheater	1845	1244C	105		P 12/06/93 A/F 12/06/93A	12/20/93 12/09/94A	1/03/94 12/17/93A	1/31/94 1/17/94A	2/14/94 2/25/94A	2/28/94 4/08/94	3/14/94 4/22/94	5/09/94 6/17/94	10/03/94 11/11/94	10/17/94 11/25/94	1/23/95 1/23/95
BR0251 Flare	1906	1928A	101		P 12/06/93 A/F 12/06/93A	12/20/93 12/09/94A	1/03/94 12/17/93A	1/31/94 1/19/94A	2/14/94 2/25/94A	2/28/94 4/08/94	3/14/94 4/22/94	5/09/94 6/17/94	10/24/94 12/02/94	11/07/94 12/16/94	4/17/95 4/17/95
CY0251 Carbonizer Cyclone	1876	1353A	100		P 12/06/93 A/F 12/06/93A	12/20/93 12/09/94A	1/03/94 12/17/93A	1/31/94 1/18/94A	2/14/94 2/11/94A	2/28/94 4/08/94	3/14/94 4/22/94	5/09/94 6/17/94	11/28/94 1/20/95	12/12/94 2/03/95	4/17/95 4/17/95
EQUIPMENT LIST CLASS REFRACTORY LINED PIPE															
LP0601 Carbonizer Overhead	3064	1161A	116		P 1/21/94 A/F 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94	
LP0612 Carbonizer Hot Start-up Air	3064	1161A	116		P 1/21/94 A/F 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94	
LP0613 Carbonizer Char	3064	1161A	116		P 1/21/94 A/F 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94	

COMPONENT SCHEDULE

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ITEM ITEM DESCRIPTION	CPM Ref	REQ	INO	PO	ISSUE SPEC/ REQ	CLIENT APPROVE SPEC/ REQ	ISSUE INQUIRY/ RFQ	RECEIVE BIDS/ QUOTES	COMPLETE BID TABS	CLIENT APPROVE BID TABS	RELEASE PURCHASE ORDERS	RECEIVE VENDOR DRAWINGS	SHIP F.O.B.	DELIVERY TO SITE/ SHOP	FIELD/ SHOP NEED SLACK (in wks)
LP0801 Carbonizer Cyclone Overhead	3064	1161A	116		P A/F	1/21/94 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94
LP0802 Carbonizer PCD Overhead	3064	1161A	116		P A/F	1/21/94 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94
LP0803 Carbonizer Cyclone Bottoms	3064	1161A	116		P A/F	1/21/94 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94
LP0804 Carbonizer Char to Combustor	3064	1161A	116		P A/F	1/21/94 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94
LP0806 Carbonizer PCD Bottoms	3064	1161A	116		P A/F	1/21/94 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94
LP0910 Combustor Primary Hot Start-up air	3064	1161A	116		P A/F	1/21/94 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94
LP0913 Combustor Above Grid Start-up air	3064	1161A	116		P A/F	1/21/94 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94
LP1001 Combustor Cyclone Overhead	3064	1161A	116		P A/F	1/21/94 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94
LP1002 Combustor PCD Overhead	3064	1161A	116		P A/F	1/21/94 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94
LP1004 Combustor PCD Bottoms	3064	1161A	116		P A/F	1/21/94 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94
LP1401 Carbonizer Alkali Getter Outlet	3064	1161A	116		P A/F	1/21/94 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94
LP1402 Combustor Alkali Getter Outlet	3064	1161A	116		P A/F	1/21/94 1/21/94A	2/04/94 2/04/94A	2/18/94 2/18/94A	3/18/94 3/25/94A	4/01/94 4/08/94	4/15/94 4/22/94	4/29/94 5/06/94	6/24/94 7/01/94	11/18/94 11/25/94	12/02/94 12/09/94
LP2501 Fuel Gas Bypass DELETED DI 50-011 (dated 3/8/94)	3064	1161A	116		P A/F										

COMPONENT SCHEDULE

FOSTER WHEELER USA CORP Report EADC1.R2R Page 6
File EAD.R2D 4/15/94
FWUSA Project Sort ELCLASS/ITEM

Actuals thru: 1-Apr-94

ITEM ITEM DESCRIPTION	CPM Ref	REQ	INQ	PO	ISSUE SPEC/ REQ	CLIENT APPROVE SPEC/ REQ	ISSUE INQUIRY/ RFO	RECEIVE BIDS/ QUOTES	COMPLETE BID TABS	CLIENT APPROVE BID TABS	RELEASE PURCHASE ORDERS	RECEIVE VENDOR DRAWINGS	SHIP F.O.B.	DELIVERY TO SITE/ SHOP	FIELD/ SHOP NEED SLACK (in wks)
LP2502 Vitiated Air Bypass DELETED DI 50-011 (dated 3/8/94)	3064	1161A	116		P A/F										
EQUIPMENT LIST CLASS VALVES															
VL0262 Char Valve === RE-BID ===	5025	1162A	115		P A/F	1/24/94 1/24/94A	2/07/94 1/27/94A	2/21/94 4/01/94A	3/21/94 4/29/94	4/04/94 5/13/94	4/18/94 6/24/94	5/02/94 7/01/94	6/27/94 8/26/94	12/09/94 2/10/95	12/23/94 2/24/95
VL0263 Vitiated Air Bypass Valve DELETED DI 50-011 (dated 3/8/94)	5025	1629C	115		P A/F										
VL0264 Fuel Gas Bypass Valve DELETED DI 50-011 (dated 3/8/94)	5025	1629D	115		P A/F										
VL0451 Vitiated Air Valves === RE-BID ===	5025	1511A	115		P A/F	1/24/94 1/24/94A	2/07/94 1/27/94A	2/21/94 4/01/94A	3/21/94 4/29/94	4/04/94 5/13/94	4/18/94 6/24/94	5/02/94 7/01/94	6/27/94 8/26/94	12/09/94 2/10/95	12/23/94 2/24/95
VL0452 Fuel Gas Valve === RE-BID ===	5025	1511B	115		P A/F	1/24/94 1/24/94A	2/07/94 1/27/94A	2/21/94 4/01/94A	3/21/94 4/29/94	4/04/94 5/13/94	4/18/94 6/24/94	5/02/94 7/01/94	6/27/94 8/26/94	12/09/94 2/10/95	12/23/94 2/24/95
EQUIPMENT LIST CLASS VESSELS - DRUMS															
DR0251 Carbonizer Coal Surge Drum	2119	1131A	106		P A/F	12/06/93 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 1/18/94A	2/14/94 2/25/94A	2/28/94 4/08/94	3/14/94 4/22/94	5/09/94 6/17/94	10/03/94 8/13/94	10/17/94 8/27/94
DR0252 Carbonizer Coal Feed Drum	2119	1131B	106		P A/F	12/06/93 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 1/18/94A	2/14/94 2/25/94A	2/28/94 4/08/94	3/14/94 4/22/94	5/09/94 6/17/94	10/03/94 8/13/94	10/17/94 8/27/94
DR0253 Sorbent Surge Drum	2119	1131C	106		P A/F	12/06/93 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 1/18/94A	2/14/94 2/25/94A	2/28/94 4/08/94	3/14/94 4/22/94	5/09/94 6/17/94	10/03/94 8/13/94	10/17/94 8/27/94
DR0254 Sorbent Feed Drum	2119	1131D	106		P A/F	12/06/93 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 1/18/94A	2/14/94 2/25/94A	2/28/94 4/08/94	3/14/94 4/22/94	5/09/94 6/17/94	10/03/94 8/13/94	10/17/94 8/27/94
DR0255 Combustor Coal Surge Drum	2119	1131E	106		P A/F	12/06/93 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 1/18/94A	2/14/94 2/25/94A	2/28/94 4/08/94	3/14/94 4/22/94	5/09/94 6/17/94	10/03/94 8/13/94	10/17/94 8/27/94

COMPONENT SCHEDULE

FOSTER WHEELER USA CORP Report EADC1.R2R Page 7
 File EAD.R2D 4/15/94
 FWUSA Project Sort ELCLASS/ITEM

Actuals thru: 1-Apr-94

ITEM ITEM DESCRIPTION	CPM Ref	REQ	INO	PO	ISSUE SPEC/ REQ	CLIENT APPROVE SPEC/ REQ	ISSUE INQUIRY/ RFQ	RECEIVE BIDS/ QUOTES	COMPLETE BID TABS	CLIENT APPROVE BID TABS	RELEASE PURCHASE ORDERS	RECEIVE VENDOR DRAWINGS	SHIP F.O.B.	DELIVERY TO SITE/ SHOP	FIELD/ SHOP NEED SLACK (in wks)
DR0256 Combustor Coal Feed Drum	2119	1131F	106		P 12/06/93 A/F 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 1/18/94A	2/14/94 2/25/94A	2/28/94 4/08/94	3/14/94 4/22/94	5/09/94 6/17/94	10/03/94 8/13/94	10/17/94 8/27/94	9/15/94 9/15/94
DR0257 Moisture Separator Drum	2146	1131G	106		P 1/03/94 A/F 1/19/94A	1/17/94 1/19/94A	1/31/94 1/28/94A	2/14/94 2/11/94A	3/14/94 3/25/94A	3/28/94 4/08/94	4/11/94 4/22/94	6/06/94 6/17/94	10/31/94 11/25/94	11/14/94 12/09/94	9/06/94 9/06/94
DR0258 Carbonizer Cyclone Drain Drum === RE-BID ===	2146	1131H	113		P 1/03/94 A/F 1/24/94A	1/17/94 1/25/94A	1/31/94 3/18/94A	2/28/94 4/15/94	3/14/94 5/06/94	3/28/94 5/20/94	4/11/94 6/24/94	6/06/94 8/19/94	10/31/94 2/03/95	11/14/94 2/17/95	1/23/95 1/23/95
DR0260 A/B Ash Depressurization Drums	2119	1131K	106		P 12/06/93 A/F 12/06/93A	12/20/93 12/13/93A	1/03/94 12/17/93A	1/31/94 1/18/94A	2/14/94 2/25/94A	2/28/94 4/08/94	3/14/94 5/13/94	5/09/94 7/08/94	10/03/94 9/03/94	10/17/94 9/17/94	9/06/94 9/06/94
DR0264 Oversize Char Drum	2146	1131L	106		P 1/03/94 A/F 1/19/94A	1/17/94 1/20/94A	1/31/94 1/20/94A	2/28/94 2/11/94A	3/14/94 3/25/94A	3/28/94 4/08/94	4/11/94 5/13/94	6/06/94 7/08/94	10/31/94 9/03/94	11/14/94 9/17/94	9/26/94 9/26/94
DR0265 Ash Surge Drum	2146	1131M	106		P 1/03/94 A/F 1/19/94A	1/17/94 1/19/94A	1/31/94 1/20/94A	2/28/94 2/11/94A	3/14/94 3/25/94A	3/28/94 4/08/94	4/11/94 5/13/94	6/06/94 7/08/94	10/31/94 9/03/94	11/14/94 9/17/94	9/26/94 9/26/94
EQUIPMENT LIST CLASS VESSELS - HOPPERS															
H00252 Coal Surge Hopper	2231	1143A	111		P 1/03/94 A/F 1/05/94A	1/17/94 1/13/94A	1/31/94 1/14/94A	2/28/94 1/28/94A	3/14/94 3/04/94A	3/28/94 4/15/94	4/11/94 5/13/94	6/06/94 7/08/94	10/31/94 12/23/94	11/14/94 1/06/95	4/17/95 4/17/95
H00253 Sorbent Surge Hopper	2231	1143B	111		P 1/03/94 A/F 1/05/94A	1/17/94 1/13/94A	1/31/94 1/14/94A	2/28/94 1/28/94A	3/14/94 3/04/94A	3/28/94 4/15/94	4/11/94 5/13/94	6/06/94 7/08/94	10/31/94 12/23/94	11/14/94 1/06/95	2/13/95 2/13/95
EQUIPMENT LIST CLASS VESSELS - REACTORS															
RX0251 Carbonizer === RE-BID ===	1719	1121A	113		P 1/03/94 A/F 1/24/94A	1/17/94 1/25/94A	1/31/94 3/18/94A	2/28/94 4/15/94	3/14/94 4/29/94	3/28/94 5/13/94	4/11/94 5/27/94	6/06/94 7/22/94	2/06/95 3/31/95	2/20/95 4/14/95	4/17/95 4/17/95

APPENDIX I

WESTINGHOUSE

OVERALL SCHEDULE FOR DELIVERY OF PCDs TO PSDF, WILSONVILLE, ALABAMA (Revised)

Figure 1

I-2

FLOW STREAM NUMBER	1	2	3	4
MEDIUM	REACTOR GAS	HIGH PRESSURE N ₂	CLEAN GAS	ASH DISCHARGE
FROM	PRIMARY CYCLONE	SCS SUPPLY	FLO301	FLO301
TO	FLO301	FLO301-ME01	GAS COOLER	ASH REMOVAL SYSTEM
ASH FLOW LB/HR	75 MIN 300 MAX	---	<.1	75 MIN 300 MAX
GAS FLOW LB/HR	18000 TO 25000		18500 TO 25500	---
PRESSURE PSIA	189-300		184-293	189-300
TEMPERATURE °F	1000 TO 1800		980 TO 1780	1000 TO 1800

SOUTHERN COMPANY SERVICES INC 708 DEPARTMENT OF ENERGY POWER SYSTEMS DEVELOPMENT FACILITY WILKINSONVILLE, GA WESTINGHOUSE CONTRACT NO. C-83-001833 WORK REF. NO. 8704-211001-1-100-2 ITEM NO. FLO301 - PARTICULATE CONTROL DEV.	
DATE 2-7-91	SCALE 2.5" = 1'-0"
DESIGNED BY DOE/SCS, PWR. SYS. DEV. FACILI.	
FLO301 PROCESS FLOW DIAGRAM	
SIZE 0 01269	DATE 2029758

I-3

FLOW STREAM NUMBER	1	2	3	4
MEDIUM	CPFBC GAS	HIGH PRESSURE N ₂	CLEAN GAS	ASH DISCHARGE
FROM	PRIMARY CYCLONE	SCS SUPPLY	FLO352	FLO352
TO	FLO352	FLO352-ME01	ALKALI GETTER	ASH REMOVAL SYSTEM
ASH FLOW LB/HR	1130	---	< 0.2	1130
GAS FLOW LB/HR	75235		76400	---
PRESSURE PSIA	150		145	150
TEMPERATURE °F	1600		1585	1600

COMMENT
PRINT

SOUTHERN COMPANY SERVICES INC FOR DEPARTMENT OF ENERGY POWER SYSTEMS DEVELOPMENT FACILITY BILLOWSVILLE, MISSISSIPPI WESTINGHOUSE CONTRACT NO. C-83-001853 PS JOB NO. 15-1181 ITEM NO. FLO352 - PARTICULATE CONTROL DEVICE	
BY KDPES 2-7-91	8 WESTINGHOUSE ELECTRIC CORPORATION PITTSBURGH, PENNSYLVANIA 15224 USA
CHK	TITLE DOE/SCS, PMR. SYS. DEV. FACILITY
APP	FLO352 PROCESS FLOW DIAGRAM
APP	REVISIONS REV 0 0269
APP	DATE 12/29/90
APP	NO. 2029759

PLAN AT ELEVATION 218'-0"

WESTINGHOUSE ELECTRIC CORPORATION 480 WESTINGHOUSE AVENUE PITTSBURGH, PA 15222-4100 TEL: (412) 582-2000 FAX: (412) 582-2001 WWW: WWW.WESTINGHOUSE.COM	
PROJECT NO. 2029747 DRAWING NO. 0269 SHEET NO. 1 OF 1	PROJECT NAME PROJECT LOCATION PROJECT DESCRIPTION PROJECT STATUS

DATE	2-2-95
BY	ZSP/PMR 3-9-95
CHECKED	
APPROVED	
REVISIONS	

REVISED
WEEK 3-9-95

SOUTHERN COMPANY SERVICES INC
FOR DEPARTMENT OF ENERGY
POWER SYSTEMS DEVELOPMENT FACILITY
WILSONVILLE, AL
WESTINGHOUSE CONTRACT NO. C-93-001853
MARK REF. NO. 6704-331001-490-01
ITEM NO. FLO301 - PARTICULATE CONTROL DEVICE

WESTINGHOUSE ELECTRIC CORPORATION
MAINTENANCE ISOMETRIC
SIZE 1/2 IN
ITEM NO 7244C78
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REVISIONS IN INCHES
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6'-0"

11'-0"

25'-0"

FLO352

INST. SKID
AT 218'-0"
FLO352-ME02

4'-0"

6'-0"

BACKPULSE SKID
AT 248'-0"
FLO352-ME01

6'-0"

21'-0"

3'-0"

6.00 REF

6.00 REF

N 1075'-0"

N 1080'-0"

E 1000'-0"

20'-0"

25'-0"

A B C

4 5 6

N

**COMMENT
PRINT**

NORTHROP COMPANY SERVICES INC SUBPARTNER OF NORTHROP CORPORATION POWER SYSTEMS DEVELOPMENT FACILITY 2101 KENYON AVE ST. LOUIS, MO 63114 15700000 CONTRACT NO. C-83-004083 15700000 15-1041 ITEM NO. F1.03.02 - PARTICULATE CONTROL SERVICE			
BIDDING & NEGOTIATION PERIOD 10/1/83 - 10/15/83			
WESTINGHOUSE ELECTRIC CORPORATION PARTICULATE CONTROL SERVICE			
TITLE DOE/SCS, PHWR, SYS. DEV. FACILITY F1.03.02-MEDIA/ME2 PLOT PLAN (VESSEL & SHED)			
SPECIFICATIONS BOOKS			
NO 15	ITEM NO 01269	BIDDING NO 2029762	REV 1

REF	REFES 2-11-9
Out	
REF	
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TASK 3a : SCHEDULE FOR DETAIL DESIGN OF FL0301

Figure 3

I-10

PROCESS CONDITIONS

DESIGN GAS TEMPERATURE 1800° F
DESIGN GAS PRESSURE 200 PSIA

NOTE

ALL FLANGES 24.00 DIA AND SMALLER ARE
ANSI B16.5 CLASS 300
ALL FLANGES 30.00 DIA AND LARGER ARE
API 605 CLASS 300

MATERIAL: SA508 GR70

BOTTOM
MANWAY

SOUTHERN COMPANY SERVICES INC
204 DEPARTMENTS OF ENERGY
POWER SYSTEMS DEVELOPMENT FACILITY
RELAYVILLE, ALA
DESIGN CONTRACT NO. E-93-00-853
ITEM NO. E-93-00-853-1, 400-01
ITEM NO. E-93-00-853-1, 400-01
ITEM NO. E-93-00-853-1, 400-01

DATE	BY	CHKD	APP'D
10/1/83	J. R. SMITH	J. R. SMITH	J. R. SMITH
VESSEL DATA SHEET			
VESSEL NO.		478E28

NOTE: FLANGES MAY NOT BE SHOWN IN CORRECT ORIENTATION FOR CLARITY. FOR CORRECT POSITION AND NUMBER SEE 1477E46

SOUTHERN COMPANY SERVICES INC
FOR DEPARTMENT OF ENERGY
POWER SYSTEMS DEVELOPMENT FACILITY
WINSTON-SALEM, NC
CONTRACT NO. C-93-001653
WSP REF. NO. 1704-221001-4-90-01
ITEM NO. FL0201 - PARTICULATE CONTROL DEVICE

CHANGES TO MINIMUM
CHANGES ALLOWED

NO.	DATE	DESCRIPTION
1	10/1/83	ISSUED FOR CONSTRUCTION
2	10/1/83	REVISIONS
3	10/1/83	REVISIONS
4	10/1/83	REVISIONS
5	10/1/83	REVISIONS
6	10/1/83	REVISIONS
7	10/1/83	REVISIONS
8	10/1/83	REVISIONS
9	10/1/83	REVISIONS
10	10/1/83	REVISIONS

DESIGNED BY	DATE
CHECKED BY	DATE
APPROVED BY	DATE
INFORMATION DETAIL	
1477E46	

NOZZLE NO.	PURPOSE	CONNECT TO	NOZZLE SPECIFICATION	NOZZLE LOCATION
1	ART. OUTLET	UPPER PUMP-005	3/4" 300-400 S.G.S	BOTTOM
2A,B	TEMP. & PRESS. AND TEMP. SENSORS	PULSE SKID	3/4" 300-400 S.G.S	24", 26", 28"
3A,B	INSPECTION	---	3/4" 300-400 S.G.S	24", 26"
4	MANWAY	---	3/4" 300-400 S.G.S	24"
5	MANWAY	EXHAUST (UP REAR)	3/4" 300-400 S.G.S	24"
6A,B	TEMP. & PRESSURE	PULSE SKID	3/4" 300-400 S.G.S	24", 26", 28"
7	GAS IN	UPPER PUMP-04	3/4" 300-400 S.G.S	24"
7A	TEMP. & PRESSURE	PULSE SKID	3/4" 300-400 S.G.S	24" 26" SKIT
8A,B	INSPECTION	PULSE SKID	3/4" 300-400 S.G.S	24", 26", 28"
9A,B	TEMP. & PRESSURE	PULSE SKID	3/4" 300-400 S.G.S	24", 26", 28"
10	GAS OUT	UPPER PUMP-08	3/4" 300-400 S.G.S	24"
10A	TEMP. & PRESSURE	PULSE SKID	3/4" 300-400 S.G.S	24" SKIT
11	MANWAY	---	3/4" 300-400 S.G.S	24"
12A, 12C	TEMP. & PRESSURE	PULSE SKID	3/4" 300-400 S.G.S	24", 26"
12B	INSTRUMENTATION OR PRESSURE RELIEF	SPARE	3/4" 300-400 S.G.S	24"
13	BACK PULSE	---	3/4" 300-400 S.G.S	24" TOP
13A,B	BACK PULSE PIPES	PULSE SKID	3/4" 300-400 S.G.S	24" TOP

NOTE: PULSE SKID IS ITEM NO. FLO301-ME01

SOUTHERN COMPANY SERVICES INC.
FOR DEPARTMENT OF ENERGY
POWER SYSTEMS DEVELOPMENT FACILITY
MILBORVILLE, AL
TEST HOUSE CONTRACT NO. C-93-001853
UPPER REF. NO. 6704-221001-L490-01
ITEM NO. FLO301 - PARTICULATE CONTROL DEVICE

CHANGES 000-0000
CHANGES ALLOWED

DATE: 11-1-83
DRAWN: J. G. M.
CHECKED: J. G. M.
APPROVED: J. G. M.
NOZZLE IDENTIFICATION
1477E45
11-1-83

TASK 3b : SCHEDULE FOR DETAIL DESIGN OF FL0352

Figure 4

DATE

FILMED

8/4/94

END