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DOE/MC/16219-1179
(DE82013552)

TEST AND EVALUATION OF HOT GAS CLEANUP
DEVICES

Phase I & II (Task I)

Technical Progress Report for the Period
September 1—November 30, 1981

Work Performed Under Contract No. AC21-81MC16219

Curtiss-Wright Corporation
Wood-Ridge, New Jersey

TECHNICAL INFORMATION CENTER
UNITED STATES DEPARTMENT OF ENERGY

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DOE/MC/16219--1179

DE82 013552

DOE/MC/16219-1179

(CW-WR-81-024.2)

(DE82013552)

Distribution Category UC-90e

**TEST AND EVALUATION OF HOT GAS CLEANUP DEVICES
PHASE I & II (TASK 1)**

**TECHNICAL PROGRESS REPORT
FOR THE PERIOD
SEPTEMBER 1, 1981 - NOVEMBER 30, 1981**

**CURTISS-WRIGHT CORPORATION
POWER SYSTEMS DIVISION
WOOD-RIDGE, NEW JERSEY 07075**

**PREPARED FOR
THE UNITED STATES DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
UNDER CONTRACT DE-AC21-81MC16219**

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ABSTRACT

This report presents the status of the work performed on a program for test and evaluation of gas cleanup devices for PFBC combined cycle systems. The work was performed during the period September 1, 1981 through November 30, 1981. This is the second quarterly report since the start of the program. Work has continued to restore the pressurized fluidized bed (PFB) technology plant at Wood-Ridge, N.J. to an operational status. Preliminary designs to incorporate each of three advanced gas cleanup devices following a first stage low pressure drop inertial type separator were previously completed. The advanced devices provided by suppliers under a separate DOE contract include a ceramic bag filter, an electrostatic precipitator and an electrostatically enhanced inertial separator. The final design activity necessary to modify the facility for the test of the ceramic bag filter has been completed. Testing of each hot gas cleanup device concurrently with a DOE supplied advanced concept particle sampling system and an alkali metal content measurement system is planned to start in April 1982.

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Section 1.0 DESCRIPTION OF PROJECT

1.1 INTRODUCTION

The use of pressurized fluidized bed combustion of high sulfur coal in a combined cycle power system offers a unique opportunity for generation of clean, cost-competitive electric power. However, highly efficient removal of particulates exiting the PFB must be achieved in order to satisfy turbine protection and air quality criteria. Currently, a series of cyclone type inertial separators are used. These devices suffer from a), the high pressure drop required to improve efficiency, b) the reduced performance on the low micron size particulates and c) the reduced efficiency as cyclone size is scaled up to the commercial size hardware. Therefore, the DOE has sponsored a program to test and evaluate each of three gas cleanup devices under actual PFB conditions. The cleanup systems will be installed in the existing Pressurized Fluidized Bed Combustor/Small Gas Turbine (PFB/SGT) Technology Unit located at Curtiss-Wright's Wood-Ridge, N.J. facility. In addition, special on-line instruments to measure particulate and alkali metal (Na, K) content in the gas stream will be utilized in this evaluation. Under separate contracts the DOE has sponsored the design and development of several candidate concepts for these cleanup and system monitoring devices. The cleanup concepts include a ceramic pad filter, an electrostatic precipitator, and an electrostatically enhanced cyclone separator. These devices are being manufactured for testing in the Curtiss-Wright PFBC/SGT Technology Unit at a pressure of 95 psia and temperature of 1600°F with mass flow rates varying from 2.4 to 6.8 lbs per second. An on-line system for particulate measurement is being supplied by the Sandia Laboratory and an on-line alkali metal measurement system is being supplied by Ames Laboratory.

1.2 OBJECTIVES

The objective of the program is to evaluate the performance of alternative hot gas cleanup devices to provide low pressure drop, high efficiency particulate removal system which offer a) improved turbine protection and b) exhaust gas emissions which satisfy air quality requirements without the use of a stack

baghouse. As a secondary objective, instruments that perform on-line measurement of a) particulate concentration and size classification and b) trace element analysis of Na and K in the gaseous state will be evaluated.

1.3 SCOPE OF WORK

The overall program to evaluate the devices is structured into three phases. Phase I is the redesign of structure and process pipe to separately accommodate each of the 3 hot gas cleanup (HGCU) vessels in the PFBC/SGT Technology Unit and the initial procurement of material. Phase I also includes the design and installation efforts necessary to incorporate the two test instruments into the system. An integral but distinct part of Phase I is the restoration of the PFBC/SGT Technology Unit. In 1979 the unit completed about 3000 hours of operation and was disassembled for inspection in 1980. The refurbishment of the unit is necessary to provide reliable and effective testing of the various devices in the current program. This phase started in May 1981 and will continue thru February of 1982. Phase II addresses to the installation of the 3 candidate HGCU vessels, for consecutive testing in Phase III. The complete program schedule is presented in Figure 1.1.

Phase I of the program is divided into six distinct tasks:

- I Program Management
- II Facility Restoration
- III Interface Design - Electrostatic Precipitation
- IV Interface Design - Electrocyclone
- V Interface Design - Ceramic Felt Bag
- VI Interface Design, Procurement and Installation - Instrumentation

Phase II of the program is divided into three separate tasks, the installation of each of the candidate hot gas cleanup devices. Similarly, Phase III consists of the testing of each device. The testing of the two instrumentation systems is included as part of the test of the HGCU devices. The HGCU devices and instruments will be supplied to Curtiss-Wright by various contractors selected by the DOE. The contractors supplying the devices are:

PFB/SGT - HOT GAS CLEAN-UP PROGRAM

OVERALL PROGRAM SCHEDULE

Figure 1.1
3

Research Cottrell	-	Electrostatic Precipitator
General Electric	-	Electrocyclone
Acurex	-	Ceramic Felt Bag
Sandia Laboratories	-	On-line particle measurement system
Ames	-	On-line trace element (Na, K) analysis

1.4 REPORT CONTENT

This Quarterly Progress Report summarizes the work performed on the Hot Gas Cleanup Test and Evaluation Program during the period September 1, 1981 thru November 30, 1981. The technical results of the design efforts are presented. The facility restoration plan is presented and progress reported. The Phase I design portion for the installation of the Acurex vessel is complete. The design of the Sandia support structure has also been completed.

1.5 DESCRIPTION OF PFBC/SGT PROCESS

A photograph of the PFBC Technology Test Plant is shown in Figure 1.2. Figure 1.3 is the flow schematic of the PFBC/Small Gas Turbine Technology Test Plant as it existed during the previous program. The current program will modify the hot gas cleanup system by replacing the 2nd stage Ducon unit with the candidate device. This is shown in the simplified flow schematic shown in Figure 1.4. A complete description of the systems operation and equipment was presented in the previous quarterly report.

PFBC TECHNOLOGY TEST PLANT

PFBC-III-474A

Figure 1 2

The diagram illustrates a complex industrial process for waste-to-energy conversion, centered around a Pressurized Fluidized Combustor (PFC). Key components and their functions include:

- Feed Systems:**
 - Coal Mill System:** Includes a coal mill, dust collector, heater, and air make-up system, feeding into a Milled Coal Silo.
 - Dolomite System:** Includes a Dolomite Silo, scalper, surge hopper, and dolomite injector, feeding into the PFC.
 - Air System:** Includes an air compressor and combust. air line feeding into the PFC.
- Combustion and Air Flow:**
 - Pressurized Fluidized Combustor (PFC):** The central reactor where combustion occurs. It has a cooling air inlet and outlet, and a sample port.
 - Air Flow:** Clean air from a PFB combustor heat exchanger is fed into the system. Air is also drawn from the stack for particulate sampling.
- Gas and Solid Handling:**
 - Flue Gas:** Flue gas carry-over is managed through a recycle cyclone and a recycle cyclone, feeding into a DYNATHERM unit.
 - Solids Handling:** Solids are moved through a DUCOM unit, a depressurizing & cooling hopper (3 units), and a surge hopper before entering the PFC.
 - Ash and Dust Collection:** Ash dust is collected and sent to a silencer and stack. Solids from all collectors are sent to a solids disposal unit.
- Energy Recovery and Emissions:**
 - Heat Recovery:** An existing gas-fired heater is used for preheating.
 - Emissions Control:** A cyclone removal bag house is used for particulate removal before the gas enters the stack.
 - Small Gas Turbine:** A small gas turbine is connected to a load bank, likely for power generation or process heating.

PFB-III-690A

Figure 1.3

SYSTEM MODIFICATIONS FOR CURRENT PROGRAM

Figure 1.4
7

Section 2.0

PHASE 1 - FACILITY INTERFACE DESIGN & RESTORATION

2.1 PROGRAM MANAGEMENT

The program has progressed essentially on schedule thru the first two quarters of the contract period. All of the procurement activity has been initiated. The various components necessary for the reassembly of the facility and the installation of the DOE contractor supplied equipment for the first test will be available for incorporation into the PFB/SGT Technology Unit during the next quarter. There has been some indication of two months slippage with regard to the expected delivery date of the Acurex filter. Half of that time may be recovered within the installation period.

Coordination efforts with all the various DOE program participants continued. In September a design review meeting was chaired by the DOE in Morgantown to review the G.E. program. As part of the meeting C-W and G.E. exchanged design interface drawings and exchanged correspondence on several questions on design details in follow-up letters. This meeting has resulted in the finalization of the mechanical design interfaces.

2.2 FACILITY RESTORATION

Operation of the PFBC/SGT Technology Unit was initiated in 1977 and it has accumulated over 3000 hours of operation. Some facility components required refurbishment due to the operating environment and the cyclic operation of the facility. To assure reliable operation during the current program and to have the facility available in a timely fashion, the restoration and maintenance program was started as part of the initial phase of the program. In addition, key components of the PFBC Technology Unit were disassembled for detailed inspection and evaluation. These components require servicing and reassembly. To facilitate the monitoring of the restoration progress this task was divided in ten sub-tasks viz:

- A Coal & Dolomite Handling System
- B Coal Grinding System
- C Coal & Dolomite Feed System
- D Filter, Dryers, Baghouses
- E Ash Hopper Systems
- F PFB Components
- G Gas Analysis System
- H Control System
- J Instrumentation
- K Exhaust System

The current status of this activity is presented below. The percent complete is based on the current status of the inspection and refurbishing effort of that particular sub-task.

Dynatherm Repair

The Dynatherm 1st stage cleanup system was reworked per Drawing ES 166266, (Figure 2.1). The outlet pipe braces were removed by cutting from the OD of the pipe and at the ID of the castables. A radial centering device was installed by drilling and reaming through the outer shell and castables a .750" diameter hole, 6 total. The first plane of three holes was located 1'10-1/2" from the outlet port, the second plane was 3" above the first plane. The .750" diameter holes are spaced 120° in both planes with the holes offset 60° between planes. With the riser pipe concentric with the ID of the castables, 6-1/2" diameter holes were drilled in the outlet pipe using the .750" diameter ream hole as the drill fixture. Six rods 6-1/2" long were custom machined for a push fit with the hole in the castables and plugged welded from the ID of the outlet pipe. The space between the end of the rod and the OD of the outer shell was filled with 16#/ft³ Kaowool. Six threadlets were welded to the outer shell and plugged with a 3/4" NPT pipe plug.

10

Figure 2.1

At the outlet port the castable was reworked to obtain 1" clearance around the outlet tube. This clearance space was filled with 16#/cu ft Kaowool. The clearance is required since the outlet tube will expand .337 inches downward under steady-state operating conditions. Radial expansion of the outlet pipe is accommodated by the six radial centering pins.

Task No. IIA Coal and Dolomite Handling Systems

The raw coal handling system was refurbished and operated satisfactorily.

The refurbishment of the dolomite silo in areas of the bin vent filters, tubular conveyor and associated components were installed, completed and checked out.

Percent Complete: 100

Task No. IIB Coal Preparation System

The Williams impact mill modifications and refurbishment were completed and are awaiting check out. The oxygen analyzer was received and installed. The moisture determination tester is being evaluated for accuracy.

Percent Complete: 94

Task No. IIC Coal and Dolomite Feed Systems

The coal feed systems were completed and are ready for check out, flowing and utilizing the test vessel loop in conjunction with new coal feed lines and injector vessel mixing tees.

The improved dolomite mixing tee and feed line have been designed and detailed.

Percent Complete: 90

Task No. IID Filters, Dryers, Baghouses

The filter baghouse for the coal mill system, coal feed system and the individual silo filters have been completed and are awaiting check out.

The improved Pall Trinity transport air drying system has been completed and awaiting test vessel coal feed testing.

The preheaters are scheduled for service and maintenance upon completion of their present use on another program.

Percent Complete: 82

Task No. IIE Ash Hopper Systems

All components have been inspected and defective units are being repaired or replaced. New ash hopper stimulators are being installed and new or rebuilt Kamyr valves are scheduled for delivery by January 20, 1982.

Percent Complete: 69

Task No. IIF Facility Components

Refractory repairs of the heat exchanger tube assembly have been completed as well as the installation of the standby quench water pump. Other components such as orifices, ash system bellows and trickle valve have been inspected and found in satisfactory condition.

Percent Complete: 57

Task No. IIG Gas Analysis System

The Pace gas analysis system has been set up in the Control Room. Check out and calibration in progress.

Percent Complete: 60

Task No. IIH Control System

Check out, repair and calibration of all electrical control equipment, controls and computer peripheral equipment continues.

Percent Complete: 75

Task No. IIJ Instrumentation

Calibration of coal feed control instrumentation has been completed. Calibration continues on remaining process analog instrumentation.

Percent Complete: 70

Task No. IIK Exhaust System

All components of the exhaust system have been checked and items requiring new fabrication or repair are in work. Repair of the Fisher back pressure control valve with stellite coating is scheduled for February delivery.

Percent Complete: 75

Forecast

During the next quarter all restoration activity will be completed. Parts at vendors, such as Kamyr and Fisher valves, will be returned to the Technology Unit during the installation period for the Acurex vessel.

2.3 HOT GAS CLEANUP DEVICE INTERFACE DESIGNS

Task III, IV, V Facility Modification

The three (3) cleanup device installations were designed so that the same instrumentation spool assembly is used at both the inlet and outlet of the

test units. With this objective in mind the facility requires only one installation of the Sandia Real Time Particle Mass Monitor System, the Ames sampling probe, the C-W three element particulate sampling probe, a temperature probe and a pressure probe.

LS37083 SGT/PFB Facility Piping Layout for Acurex Bag Filter (Figure 2.2)

The outlet from the 1st Stage Cyclone to the vertical spool assembly 475421N2 (Figure 2.3) is common for all three installations. Spool assembly 475421N2 contains the following instrumentation ports:

- a. Sandia R.T. Mass Monitor Systems
- b. Ames Probe
- c. C-W Particulate Sampling Probe
- d. Temperature
- e. Pressure

The spool assembly also contains a Stairmand baffle for flow distribution. The outlet vertical spool assembly 475421N1 to the inlet of the 3rd Stage Cyclone is common for all three installations. Spool assembly 475421N1 is identical to 475421N2 except for the location of the male and female slip joints. The additional assemblies which are used for the Acurex installation are (1) a 90° elbow and pipe assembly, (2) an outlet spool assembly, and (3) an inlet spool assembly. During field fitup an identical assembly will be fabricated for use with the ESP installation and the Electro Cyclone installation. This orifice spool assembly will measure the particle laden airflow upstream of the dilution air. Provision is made in the Bag Filter installation to accommodate a dilution port and a bypass port for a pressurized water scrubber. These ports are used for the ESP and the Electro Cyclone installations.

SGT/PFB FACILITY PIPING LAYOUT FOR ACUREX BAG FILTER

Figure 2.2

The image displays a set of architectural drawings for a building. The central feature is a large, detailed section of a building, likely a cross-section or a plan view, showing a complex layout of rooms, corridors, and structural elements. This main drawing is surrounded by several circular detail views, each labeled with a letter (A, B, C, D) and a corresponding title. These details provide close-up views of specific architectural features, such as door frames, window openings, and structural connections. The drawings are annotated with various dimensions, section lines, and descriptive text, providing a comprehensive technical representation of the building's design.

82-003

LS37082 - SGT/PFB Facility Piping Layout for Research Cottrell Electrostatic Precipitator (Figure 2.4)

This installation provides a dilution line which is the PFB combustor heat exchanger outlet flow. The flow is controlled with a 1600°F butterfly valve upstream of the mixing "Y". The flow is measured with a Bethlehem flow tube. These both exist in the existing SGT/PFB Technology Rig. This dilution line is common for both the ESP installation and the Electro Cyclone installation. The bypass port is fitted with a PL-1507-3 Emtrol Venturi Scrubber, size 6030, type W20. The eight inch outlet of the pressurized water scrubber is connected to the existing quench chamber which was reworked to receive the 8" line. Provision for a thermocouple was made to monitor the outlet temperature from the water scrubber. A 6" V ball control valve is provided in the 8" water scrubber outlet line.

Provision was made in the dilution line for a propane burner 475427 (Figure 2.5). The heated dilution air is monitored by three exposed junction thermocouples located 6" downstream of the propane burner, 12 feet downstream of the propane burner and the third thermocouple 28 feet downstream of the propane burner. The assemblies which are used only for the Electrostatic Precipitator installation are 475406N7, Horizontal Inlet Spool Assembly, 475406N6, Horizontal Outlet Spool Assembly, and 475401N1, Riser Outlet Elbow Pipe Assembly.

LS37084 - SGT/PFB Facility Piping Layout for G.E. Electro Static Cyclone (Figure 2.6)

This installation will follow the testing of the Electrostatic precipitator. The assemblies which are used only for the Electro Cyclone installation are 475413, Outlet Pipe, Elbow Pipe Assembly, 475412, Riser Elbow Pipe Assembly, 475406N8 Horizontal Inlet Spool Assembly, 475410N2, Riser Outlet Elbow Pipe Assembly.

SGT/PFB FACILITY PIPING LAYOUT FOR COTTRELL ELECTROSTATIC PRECIPITATOR

Figure 2.4

Figure 2.5

SGT/PFB FACILITY PIPING LAYOUT FOR G.E. ELECTROSTATIC CYCLONE

Figure 2.6

2.4 INSTRUMENTATION INSTALLATION - DESIGN AND PROCUREMENT

LS37085 (Figure 2.7) and LS37088 (Figure 2.8) - Sandia Real Time Particle Mass Monitor System Installation

The installation of the Sandia Real Time Particle Mass Monitor System installation is shown on LS37085 and the installation is common for all three tests. The mounting of the Sandia is shown on LS37088. The Sandia Vessel Frame is reworked by removing the 6 legs and providing bracket supports for four tie rods. The Sandia unit is mounted in the frame support assembly with a constant support spring hanger. Two hydraulic cylinders are used for retracting the probe assembly. Clamp stabilizers are used both front and rear of the vessel frame to accommodate the shift in c.g. when the Hi-Temperature Pressure Vessel is opened to inspect and clean the cyclone train. Safety rail stops are provided for the frame support assembly when the Hi-Temperature Pressure Vessel is opened.

Detailed Engineering discussions began during the last quarter with the Sandia Project staff. This included reviews and comments on: their process flow diagram, interconnecting wiring diagrams, and the physical connections between the Sandia control panel, its computer, field devices, and the CWC computer for data logging and subsequent analysis.

Tests of the TEOM unit in operation are scheduled to be observed by CWC at Sandia shortly and any outstanding problems resolved. A complete writeup of the controls system for the Sandia equipment is being sent to CWC for review. Preparation of other interfacing equipment and services required at the CWC test site has begun.

LS31700 - Ames Trace Element Probe Assembly

The Trace Element Probe Assembly is in work and is 75% complete. The Probe Assembly is shown on LS37100. The high temperature 10 micron filter will be designed by Curtiss-Wright using Nichrome V-Cb mesh material electron beam welded to a cylindrical cage. The flow area through the mesh is 30 times the

SANDIA - REAL TIME PARTICLE MASS MONITOR SYSTEM INSTALLATION

Figure 2.7

SANDIA - REAL TIME PARTICLE MASS MONITOR SYSTEM ASSEMBLY

Figure 2.8

required flow area. A preliminary sketch of the filter is shown on SK121781WH, (Figure 2.9).

LS37101 - Particulate Grab Sample Skid Assembly

The layout is 75% complete. The present sampling system configuration includes threaded pipe, tees, etc., which can trap sample particulate and possibly cause false readings. The design will utilize stainless tubing without fittings. The lines are straight and the filter orientation is vertical. To obtain satisfactory samples the sample line temperature must be maintained above the dewpoint. The lines will be insulated, weather sealed, heat trace sample tubing furnished by Technical Heaters. The sample line will have a Heat/Line Temperature Controller Model 10450. The heat trace lines below the particulate sample shutoff valve will use a Fenwall Series 550 Thermocouple Sensing Temperature Controller. The flow control needle valve which is subjected to sonic pressure drops is located after the moisture trap to eliminate erosion due to cavitation.

As the sample gas cools after the sample particulate is removed in the filter, condensation accumulates in the flow control rotometer causing errors in maintaining isokinetic flow. To correct this problem a liquid trap is provided ahead of the rotometer. The thermocouple for measuring air temperature was located close to the rotometer to improve the accuracy of maintaining isokinetic sampling conditions.

To demonstrate that the stream conditions at the Sandia Probe (with the upstream mixing baffle) provide a true representation of the conditions in the process pipe, a three element Particulate Sampling Probe part number 475430, (Figure 2.10) was designed. This three element probe will be used at both the inlet and outlets of the test units.

1600°F FILTER

Figure 2.10

Section 3.0
PHASE II - DEVICE INSTALLATION

3.1 INSTALLATION OF THE ACUREX FILTER

The refractory piping details defined by layout drawing in Figure 2.2 have been placed on order and delivery is scheduled for mid January. The modifications to the structural steel which supports the ceramic filter have been designed and incorporated into the facility. After erection of the ceramic filter on the facility steelwork the refractory piping that requires field fit-up can be erected. The balance of the field piping work will proceed in accordance with the schedule presented in Figure 3.1. This schedule is predicated on the delivery of the ceramic filter in early January to allow the field fit-up to start in mid January when the piping is available.

1981

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Section 4.0
WORK FORECAST

Restoration

- . All test facility restoration activity will be completed during the next quarter.

Design

- . The facility piping designs will be completed. The structural designs will be completed.

Installation

- . The ceramic filter will be assembled and installed.
- . The Sandia and Ames instruments will be installed.
- . Prefabricated refractory pipe will be installed.
- . Field fit - refractory pipe will be fit-up and returned to the supplier for final fabrication.