250
4/26/84
LB

①

DL#

2268.3

DOE/ET/14928-1541
(DE84005446)

EXPERIMENTAL EVALUATION OF THE STEADY STATE AND
DYNAMIC PERFORMANCE CHARACTERISTICS OF THE
INTERACTIVE UNITS OF A COAL GASIFICATION PROCESS

Quarterly Report for the Period December 27, 1982—April 3, 1983

By
J. C. Corman

May 1983

Work Performed Under Contract No. AC21-80ET14928

General Electric Company
Corporate Research and Development
Schenectady, New York

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

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A04
Microfiche A01

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issues of the following publications, which are generally available in most libraries: *Energy Research Abstracts (ERA)*; *Government Reports Announcements and Index (GRA and I)*; *Scientific and Technical Abstract Reports (STAR)*; and publication NTIS-PR-360 available from NTIS at the above address.

DOE/ET/14928-1541
(DE84005446)
Distribution Category UC-90c

EXPERIMENTAL EVALUATION OF THE STEADY STATE AND DYNAMIC PERFORMANCE
CHARACTERISTICS OF THE INTERACTIVE UNITS
OF A COAL GASIFICATION PROCESS

Quarterly Report

For The Period

27 December 1982 - 3 April 1983

GE Program Manager

J.C. Corman

May 1983

Work Performed

for

The Department of Energy

Contract No. DE-AC21-80ET14928

by

General Electric Company

Corporate Research and Development

Schenectady, NY 12301

Contributors to Quarterly Report

N.T. Cankurt

K.J. Daniel

M.H. Dawes

S.L. Kemner

R.G. Lavigne

D.M. Rib

D.P. Smith

B.F. Wheeler

TABLE OF CONTENTS

Section	Page
INTRODUCTION	vi
PROGRAM OBJECTIVE	vi
DESCRIPTION OF WORK ACTIVITIES	vii
SUMMARY OF PERIOD ACTIVITIES	ix
 1 TEST PROGRAM DEFINITION AND ANALYSIS	 1-1
SUMMARY OF TASK ACTIVITIES	1-1
1.2 TEST PLAN DEVELOPMENT	1-2
1.2.1 Objectives	1-2
1.2.2 Accomplishments	1-2
1.2.2.1 Testing Objectives	1-2
1.2.2.2 Discussion of Plan	1-5
System Characterization	1-7
IGCC Demonstrations	1-8
Component Dynamics	1-9
Environmental Compatibility	1-10
Supplementary Tests	1-11
1.2.2.3 Preliminary Test Schedule	1-12
1.2.3 Implications	1-13
1.3 TEST DATA ANALYSIS	1-14
1.3.1 Resaturation Impact on Combustor Stability	1-14
1.3.1.1 Objective	1-14
1.3.1.2 Accomplishments	1-15
Review of PEF Experimental Data	1-15
Review of Resaturator Design Parameters	1-17
Examination of Alternate Water Accumulation Mechanisms	1-18
1.3.1.3 Implications	1-20
1.3.2 Gasifier Gas Evolution Test	1-21
1.3.2.1 Objectives	1-21
1.3.2.2 Accomplishments	1-21
1.3.2.3 Implications	1-23
1.3.3 Evaluation of Heat Recovery Recycle Operation	1-24
1.4 REFERENCES	1-26
 2 FACILITY OPERATION	 2-1
2.1 OBJECTIVE	2-1
2.2 TECHNICAL APPROACH	2-1
2.3 DISCUSSION	2-1
 3 SYSTEM MODELING	 3-1
SUMMARY OF TASK ACTIVITIES	3-1

TABLE OF CONTENTS (Cont'd)

Section	Page
3.1 TASK DESCRIPTION AND OBJECTIVES	3-1
3.2 RESULTS AND DISCUSSION	3-2
3.2.1 Computer Control System	3-2
3.2.2 Control System Design	3-2
3.2.3 Operator Interface	3-3
3.2.4 Heating Value Calculation	3-4
3.2.5 Combined Cycle Simulation	3-4
3.2.6 Control Algorithm	3-4
3.2.7 Gasifier Simulation	3-8
3.2.7.1 Acid Gas Removal System	3-10
4 COMPONENT SUPPORT REQUIREMENTS	4-1
SUMMARY OF TASK ACTIVITIES	4-1
4.1 OBJECTIVES	4-1
4.2 APPROACH	4-1
4.3 DISCUSSION OF FACILITY SUPPORT	4-2
4.3.1 Gasifier System	4-2
4.3.2 Cleanup System	4-3
4.3.3 Sampling and Analysis System	4-4
4.3.4 Turbine Simulator	4-5
5 FUEL SYSTEM MODIFICATIONS	5-1
5.1 OBJECTIVE	5-1
5.2 DISCUSSION	5-2
6 PROGRAM MANAGEMENT	6-1
6.1 INTRODUCTION	6-1
6.2 PROGRESS SINCE LAST REPORTING PERIOD	6-2
APPENDIX A	A-1
RESATURATOR DESCRIPTION	A-1
REVIEW OF RESATURATOR DESIGN PARAMETERS	A-2
CONCLUSION	A-4
REFERENCE	A-4

LIST OF ILLUSTRATIONS

Figure		Page
1-1	Combustor Flameout After a Resaturator Transient	1-17
1-2	Isosymmetric Diagram of the PEF	1-20
1-3	Gasifier Response to Flow Stoppage	1-22
1-4	Composition Changes During Gas Evolution	1-23
1-5	Effect of Resaturator/Recirculation Flow on System Conditions	1-25
3-1	Flow Diagram for Control System Software	3-3
3-2	Gas Turbine Control Algorithm	3-6
3-3	Comparison of Coal Feed Test Transient Temperatures	3-9
3-4	Comparison of Coal Feed Test Transient CH ₄ Content	3-9
3-5	Periodic Feeding of Coal During Coal Feed Transient Test ..	3-10
3-6	Benfield H ₂ S Removal	3-11
3-7	Benfield H ₂ S Removal	3-11
3-8	Benfield H ₂ S Removal	3-12
3-9	Benfield CO ₂ Removal	3-13
A-1	Resaturator Schematic and Nominal Operation Data	A-1

LIST OF TABLES

Table		Page
1-1	Areas of Emphasis in 1983	1-3
1-2	Tests Planned for the 1983 PEF Operation	1-6
1-3	Resaturator Conditions and Combustor Flameouts	1-16

INTRODUCTION

PROGRAM OBJECTIVE

Coal gasification/gas cleanup fuels plants for synthetic fuel applications must be developed within two sets of constraints: one imposed by dynamic load response to variations in end-use demand, the other by the need to comply with environmental regulations. The overall objective of the program is to establish the technology base required to operate within those constraints. In order to establish that base, system and component performance of the fuels plant are being characterized in both steady state and dynamic operation; and the information required to establish system control logic is being developed.

An integrated coal gasification system composed of proven process units (i.e., a Process Evaluation Facility - PEF) at the Contractor's site is being used to perform tests for establishing an information base to:

- Establish performance parameters for each process unit
- Define dynamic interactions of process units operating under variable loads
- Characterize effluent flow streams from the process
- Develop an experimentally verified simulation model for integrated system operations

The combined experimental-analytical approach employed will yield empirically verified performance projections for full-scale systems.

DESCRIPTION OF WORK ACTIVITIES

The work activities for the first 3 years of this program are divided into six tasks:

Task 1 - Test Program Definition and Analysis

Task 2 - Facility Operation

Task 3 - System Modeling

Task 4 - Component Support Requirements

Task 5 - Fuel System Modifications

Task 6 - Program Management

Since the development of a technique to predict the operational performance of a commercial-size integrated coal conversion system is a primary objective, a key program activity is the projection of full-scale performance from PEF experimental results. The task of providing an analytical simulation of the full-scale and PEF-scale system is, therefore, critical to defining PEF dynamic experiments and interpreting results. System simulation models already available for analyzing integrated gasification gas turbine/steam turbine combined cycles are being modified to reflect the geometry and operational characteristics of the PEF-scale system. Results from the analytical system simulation model are used to define both system and component tests on the PEF system. The experimental results from these tests are then evaluated and used to modify the analytical system simulation model.

The first year's fired operation concentrated on steady state system and component performance. The second year's operation concentrated on characterizing the dynamic behavior of the system components and determining the environmental intrusion of the system.

The third year of the program is focused on characterization of integrated system dynamics and validation of the system dynamic model. By the end of the third year, a data base will have been established to ensure that the simulation model has been adequately verified experimentally. This data base and the understanding derived from the verified models, as well as the progress of other gasification/gas cleanup programs moving toward a demonstration phase, will serve as the basis for defining PEF simulation activities for future years of the program.

In each year of the program, the operating period is followed by an assessment of the PEF to determine facility additions, modifications, and maintenance required for the next operating period.

Throughout the course of the program, laboratory-scale experiments on critical components of the fuels plants are used to supplement the technical understanding of system performance developed by PEF results. Results of these laboratory-scale experiments are also used to determine the facility modifications required for PEF-scale evaluation of any new process concepts.

Program management includes preparation of reports and oral briefings directed at supplying critical data inputs for evaluating possible program direction and modification for support of new DOE activities.

SUMMARY OF PERIOD ACTIVITIES

A Test Plan Report has been prepared which details all the tests proposed for the 1983 operational season. One of these tests evaluates the thermal recycle mode which would be employed in a commercial configuration. In this mode, the condensate stream en route to the resaturator is passed back to the first gas cooler. The gas to liquid heat exchanger heats the condensate prior to resaturation. The analytical system simulation model, developed under this program, has been used to assess the operation of this mode and to select baseline conditions for the proposed test.

Analysis of the data and results from tests conducted during the 1982 season has continued. Under certain transient conditions in the resaturator, generally those that resulted in a rising exit gas temperature, flameout of the downstream combustor occurred. Since this would be undesirable in actual plant applications, further investigation of this phenomenon has been conducted. It appears that condensation of water on the pipe walls takes place as the pipe is being warmed. This condensed water then accumulates in a low place in the pipe run and is pushed as a "plug" through to the combustor. A test planned for 1983 will evaluate this hypothesis.

In specific application, particularly power generation, the need exists to accommodate unanticipated contingency conditions. The response of the gasifier to such an occurrence was tested in 1982. The blast and coal feeds, as well as the raw gas exit streams, were closed off simultaneously. This resulted in a condition which isolated and bottled up the gasifier. The resulting pressure rise and change in gas composition during this transient condition were modest. A control strategy is possible, therefore, where a

rapid loss of demand for gas can be met by bottling up the gasifier without flaring any gas. This has the potential advantages of rapid system restarts and ease in shutdown.

Validation of the component models for the gasifier and the acid gas removal system has continued. Several enhancements to the gasifier model in the devolatilization zone are being added to increase accuracy. Improvements in the representation of the CO₂ absorption rate in the acid gas removal system model are being incorporated.

A simplified combined cycle system model, integrated control system, and operator interface software modules are being installed on the PEF system data acquisition and control computers. This will permit system operation and model validation under a simulated end-use configuration.

TASK 1 - TEST PROGRAM DEFINITION AND ANALYSIS

SUMMARY OF TASK ACTIVITIES

Test plans have been written for the 1983 Process Evaluation Facility (PEF) operational season. Testing objectives, based on both the program objectives and the work completed in 1981 and 1982, were formulated and tests were then specified to meet these objectives. A test plan report, which describes each test in detail, has been completed and submitted to DOE for approval.

During dynamic testing of the resaturator, accumulation of water in the product gas was periodically observed. In some cases, the accumulation caused flameouts in the gas combustor. During this reporting period, this phenomenon was assessed because of its undesirable effect in an end-use application. Calculations were made which indicate that the problem was not due to flooding in the resaturator column, but rather to the collection of water in the pipes between the resaturator and the superheater. The data indicate that water apparently condensed on the pipe walls during transients when the gas temperature was rising, and collected in a low section of the pipe until a plug of liquid was pushed through to the combustor, causing a flameout.

A gas evolution test was run during the latter part of the 1982 test series, in which the flows into and out of the gasifier were simultaneously cut off. The vessel pressure increased by 25 psi. The results suggest that any control strategy involving the rapid termination of flow through the gasifier would be safe.

In a commercial configuration cycle, heat removed in the E-1 gas cooler would be recovered to heat the liquid recirculation loop in the resaturator. This configuration will be demonstrated in the 1983 test program. Meanwhile, the dynamic analytical system model developed under this program has been used to evaluate such operation. It has been shown that such operation should be stable, and suitable flowrates have been selected for demonstration.

1.2 TEST PLAN DEVELOPMENT

1.2.1 Objectives

Optimum use of resources during the testing phases of a highly integrated facility such as the PEF necessitates a comprehensive, logical test planning activity. This requires a balance between possible experimental tasks for generating technical information and the resource and facility constraints which are placed on the program. This balance is achieved by a careful, detailed study of program and testing objectives, and the requirements imposed by particular tests.

1.2.2 Accomplishments

1.2.2.1 Testing Objectives

The first step in the test planning process was to determine the areas for technical emphasis. The activities planned for 1983 have been chosen to both build on the results obtained in 1981 and 1982, and to complete the data base for the major program objectives. These activities are focused in the areas shown in Table 1-1.

Table 1-1
AREAS OF EMPHASIS IN 1983

- System dynamic characterization
- Verification of the dynamic analytical model
- Characterization of gaseous effluents
- Completion of component performance evaluations
- Completion of system performance evaluations

The emphasized areas were then further defined by the formulation of specific testing objectives, which provide a basis for planning suitable tests. These objectives are:

- Verification of the Dynamic System Model

During this year's operating period, the system dynamic model will be verified at the PEF scale by comparison of model predictions with data derived from system transient tests.

The usefulness of a gasification fuel plant model is governed by its ability to provide accurate performance predictions over the anticipated range of full-scale operation. In the first two years of the program, the models for individual PEF components were developed and verified by comparison with PEF test data. This verification was conducted for both steady state and dynamic conditions. The verified models were then concatenated into a dynamic system model.

- Assessment of System Dynamic Performance

An integrated gas turbine/steam turbine combined cycle power plant, operating in a utility environment, will be required to provide rapid and

smooth response to the varying demands placed upon it. Evaluation of the ability of such a plant to meet these demands will be made at the PEF system scale. A simulation of a gas turbine/steam turbine combined cycle plant and associated controls will be added to the PEF system control so that operation of the system fuels plant components in an Integrated Gasification Combined Cycle (IGCC) environment may be simulated.

- Establish System Environmental Performance Impacts

A major advantage of a gasification and gas cleanup fuel plant is the ability to meet stringent emissions limitations. It is, therefore, necessary to fully understand the emissions from the plant and the factors which influence them.

The combustion exhaust and other gaseous effluents will be analyzed to determine emissions levels. The operation of the turbine simulator during system transients provides an opportunity to evaluate emissions under several conditions. Liquid effluent characterization will be continued to supplement the data base which relates discharge rate to composition.

- Supplement Stream Composition Data Base

In order to establish individual process unit performance parameters, a data base is being developed which characterizes the compositions and conditions of the gas and liquid streams at each major location in the system. The emphasis is on completion of hydrocarbon and chloride balances, and on the determination of physical properties of process condensates.

1.2.2.2 Discussion of Plan

A test plan has been developed for the 1983 operating season which addresses the test objectives described above. Table 1-2 lists the planned tests for each of those objectives. Also included is a group of supplementary tests. These tests have been assigned a lower priority in terms of their objectives and, therefore, will only be attempted on a time-available basis.

A test plan report has been written in which each of the planned tests are described in detail. These test descriptions include summary sheets which outline the objectives, procedures, and key variables. The summary sheets are followed by sampling and data acquisition requirements, comments pertinent to the facility operation, and, where necessary, tables of test conditions to further define the tests. The test plan report has been forwarded to DOE program management. The discussion which follows gives a brief summary of the objectives and descriptions of the individual tests.

Table 1-2
TESTS PLANNED FOR THE 1983 PEF OPERATION

Test Group	Planned Tests
System Characterization:	System Load Ramps Composition and Temperature Transients Steady State System Operation Combustion Characteristics Cleanup System Capacity Condensate Heat Recovery Operation
IGCC Demonstrations:	IGCC Control Mode Demonstration Load Trip and Resynchronization Frequency Regulation System Emergency Shutdown
Component Dynamics:	E-1 Gas Cooler Dynamic Response E-11 Superheater Dynamic Response Gasifier Steam/Air Transients Pipe Temperature Transients Pipe Condensation Impact on Combustor Stability
Environmental Compatibility:	Stream Composition Determination Gaseous Emissions Assessment Particulate Scrubber Efficiency Component Particulate Removal System Liquid Effluent Characterization
Supplementary Tests:	Resaturator Liquid Holdup Benfield Regenerator Dynamic Response Reduced Flow Operation Temperature Impacts on Material Distribution

System Characterization

The PEF system performance is evaluated for varying gas flowrates, varying gas composition, and operating in a heat recovery configuration.

The System Load Ramps test evaluates the system response to changes in the gas flow at several ramp rates. This test is designed to expose the component interactions under realistic system transient conditions and to provide a data base for system model verification.

In the Composition and Temperature Transients test, the steam/air ratio of the gasifier blast is changed in a step from 0.4 to 0.6, and the propagation of the change in gas composition through the system is observed.

The Steady State System Operation test defines the baseline condition for the steady state tests; i.e., Illinois No.6 coal fuel, blast air flow of 1.2 lbm/sec, steam flow of 0.48 lbm/sec, system pressure of approximately 300 psig, and temperatures and recirculation rates at design levels. This is also the starting condition for most of the imposed transients. Evaluations made during these conditions will verify that the 1983 baseline is comparable to conditions in past test periods.

The Combustion Characteristics test permits evaluation of the turbine simulator combustor during steady and transient conditions. Combustion stability and dynamic pressure oscillations will be monitored.

In the Cleanup System Capacity test, the gas production is slowly increased to determine the operating limits of each of the components, so that capacity-limiting factors for each component can be identified.

For the Condensate Heat Recovery Operation test, the liquids in the resaturator recirculation are routed through the shell of the E-1 gas cooler. The objective is to simulate a heat recovery configuration that would be employed in a commercial condensate design.

IGCC Demonstrations

In order to impose realistic transients on the PEF gasification/gas cleanup fuel plant, a computer simulation of an IGCC in utility operation will be utilized as a forcing function. Computer software control operating parameters will be used to guide the PEF through simulated load changes and system contingencies. Computer models predict the performance of a combined cycle power generation system based on the conditions at the PEF turbine simulator. The result is a demonstration of the response of the gasification/gas cleanup fuel plant to a realistic set of operational transients.

The IGCC Control Mode Demonstration test evaluates two strategies for power plant control: turbine lead and gasifier lead. Load changes are imposed in both modes, and the differences in stability and response capability are assessed. The control scheme which shows better performance is used for the remaining demonstration tests.

The Load Trip and Resynchronization test simulates a situation which occurs frequently in power plants. When the load is suddenly lost, the turbines begin to overspeed, so gas production must be decreased quickly. The turbines are again brought on-line and the gas flow is then ramped back up to quickly return the turbines to normal operating conditions.

The Frequency Regulation test simulates a utility-imposed frequency regu-

lation transient, which would result from changes on a utility grid involving multiple power plants and a varying load. This requires the individual plants to make small, but rapid changes in power generation. Simulation of this situation involves modest, but rapid, changes in the coal gas production rate.

The final IGCC demonstration test is the System Emergency Shutdown. If, for example, a mechanical failure occurs in a turbine, the gas production must be quickly and automatically halted, and the system brought to a warm bank condition which would be maintained while the turbine is serviced. An objective of this demonstration is to minimize the amount of gas which is flared while bringing the PEF to a stable warm bank.

Component Dynamics

The component dynamics tests provide data for completion of the component model validations and assess the participation of the system piping in system transients.

Component dynamic response tests are performed on two heat exchangers; the E-1 Gas Cooler and the E-11 Superheater. In each case, the coolant or steam flow to the shell side is changed in steps. The resulting transient responses in the gas exit temperatures are compared to computer model predictions.

The Gasifier Steam/Air Transients test provides transient data about the gasifier bed conditions and raw gas characteristics resulting from step changes in the ratio of steam-to-air in the blast stream.

The pipes in the gasification fuel plant represent a fairly large thermal mass which should be considered in the system transients. When the gas tem-

perature within a section of pipe is increased, heat is drawn from the gas to raise the temperature of the pipe. If the inlet gas is saturated with water vapor, condensation provides the heat to the pipe walls. The Pipe Temperature Transients test is designed to observe this effect by monitoring gas temperatures along a pipe length after a large increase in the inlet temperature. In the Pipe Condensation Impact on Combustor Stability test, the water condensed from the resaturator exit gas stream is measured. Results from 1982 resaturator tests suggest that water which condenses following temperature transients collects in a low spot in the pipe until a plug of water is pushed through, causing the combustor to flameout.

Environmental Compatibility

The purpose of the environmental compatibility tests is to complete the characterization of effluent streams. The major source of gaseous emissions is the combustor exhaust, and this stream is analyzed during steady and transient conditions. Earlier testing has focused on solid and liquid effluent streams, as well as internal material distributions, and this work is continued in the 1983 tests.

The Stream Composition Determination test is designed to complete the data base of stream composition profiles and material distributions. Samples will be collected to complete the hydrocarbon and chloride balances, and condensate samples will be analyzed to determine their physical properties.

There are three streams characterized in the Gaseous Emissions Assessment test. The major point for gas emission is the combustor exhaust. This effluent stream is analyzed by on-line equipment for sulfur and nitrogen compounds, as well as the major gas components. A second gas effluent is the

acid gas from the sulfur removal system; samples of the acid gas are collected and analyzed. In the liquid recycle scheme, liquid blowdowns from the system are depressurized, and the vapors rising from the liquid surface make up the remaining gaseous effluent stream. Pressurized samples from the liquid recirculation loop are degassed, and the vapors are analyzed.

One of the components of the gaseous emissions is particulate matter. Two tests are included to assess the particulate removal in the gas cleanup system. The Particulate Scrubber Efficiency test investigates the effect of varying the liquid recirculation rate in the venturi scrubber. In the Component Particulate Removal test, particulate samples are collected at the exit of each cleanup component to determine the contributions to the overall particulate removal. For both tests, the particulate samples collected are analyzed for potassium and sodium to determine the alkali content of the gas streams.

The analysis results of the system liquid discharge from the 1982 PEF operation indicated that predictions of steady state composition could be made by modeling transient composition data. A low discharge rate is maintained through two test runs for the Liquid Effluent Characterization test. The analyses of discharge samples, which are to be taken every four hours, will contribute to the development of the composition modeling technique.

Supplementary Tests

The Resaturator Liquid Holdup test provides data for determination of the amount of liquid in the packing. Temperature transients are imposed by changing the temperature of the liquid entering the resaturator, and the resulting temperature profiles in the packed section are monitored. These profiles are

compared to predictions of the computer model, and the liquid holdup value is varied to yield the best match. The result is a method of determining the liquid holdup for any resaturator condition.

The Acid Gas Removal System Regenerator Dynamic Response test completes the characterization of the H_2S removal system. Samples of the regenerated solution streams are taken following step changes in the solution flowrates and in the heat input to the regenerator. These samples are analyzed for sulfide and carbonate concentration to determine the regeneration during the transients.

The Reduced Flow Operation is an alternate steady state condition for system characterization and for component testing. The gas flow for this test is approximately 30% of the baseline flowrate. Data is collected to determine the water and hydrocarbon distributions for this condition.

For the Temperature Impacts on Material Distributions, the exit gas temperatures from the E-1 gas cooler and from the resaturator are varied and the effects are determined. During each off-design temperature condition, the gas and liquid streams are sampled for hydrocarbons, ammonia, and phenols.

1.2.2.3 Preliminary Test Schedule

The remaining steps in the test planning procedure are the finalization of a test schedule and the preparation of an operational plan. The operational plans for each of the tests include detailed instructions for implementing the conditions and data acquisition requirements. This operational plan is presently being compiled. The test schedule must efficiently utilize the available facilities and manpower to complete the planned tests. The specific

manpower, equipment, and time requirements of each test will be more clearly defined in the operational plan; however, a preliminary schedule has been projected, based on the details in the test plans.

The testing season will consist of three test runs. The first test run will include the Environmental Compatibility tests and the System Characterization tests which require steady state operation. The System Characterization tests which involve transient conditions and the Component Dynamics tests will be run in the second test run. The IGCC Demonstrations will occur in the third test run. This preliminary schedule will be optimized to ensure the most effective use of the facility and manpower.

1.2.3 Implications

The evaluation of the overall program objectives and the work items already accomplished enabled the formulation of testing objectives to complete the program data base. The process of forming objectives, writing test plans, then writing operational plans, insures that the facility operation personnel will have adequate understanding of the data necessary to meet the objectives.

1.3 TEST DATA ANALYSIS

1.3.1 Resaturation Impact on Combustor Stability

Liquid in the product gas stream was first observed during the 1981 PEF test period. Most of the product gas was being burned in the flare since few of the tests conducted that season required use of the turbine simulator. On several occasions, a "plug" of water went through the flare. More than once, the water plug was sufficient to cause a flameout.

During dynamic testing of the resaturator in the 1982 PEF testing period, the product coal gas was utilized in the turbine simulator to observe the effects of the resaturator transients on combustion characteristics. The same type of incidents occurred, but because the resaturator dynamics were being tested and more carefully instrumented, the circumstances which accompanied these upsets were better defined. A series of tests were run in which the recirculation rate and the temperature of the liquid in the resaturator were changed. The turbine simulator (pressurized combustor system) was on-line during most of these tests to observe any changes in the product gas quality or combustibility. The combustor experienced a number of flameouts; the results from these tests have provided an opportunity to review the system conditions leading up to flameouts.

1.3.1.1 Objective

Such instability in a combined cycle power plant could cause operational problems; therefore the objective of this test was to investigate the available data to determine the cause of this instability.

1.3.1.2 Accomplishments

The resaturator carryover investigation has been made in three areas. First, the available experimental data from PEF operation was examined. Second, some of the resaturator column design parameters were reviewed to be sure that no carryover can be expected due to flooding. The third area of investigation has been the exploration of alternate water accumulation mechanisms because carryover has been observed even though the resaturator design should prevent carryover.

Review of PEF Experimental Data

A list of the relevant experimental data is shown in Table 1-3. It appears that flameouts generally follow a rise in the resaturator gas exit temperature. (There is one instance where a flameout followed a temperature decrease, and a few occurred when there was no change.) The delay between temperature increases and flameouts ranges from 3 to 16 minutes. It is possible that flameouts occurring 30 or 60 minutes later may have been caused by the same transient.

There are two types of transients represented in Table 1-3. The first is an increase in the resaturator liquid recirculation flow, which raised the gas temperature through improved heat transfer. The temperature increases were small and resulted in few flameouts. The other type of transient is an increase in the temperature of the liquid entering the top of the resaturator. These tests produced more dramatic temperature transients, and a greater number of flameouts.

Table 1-3
RESATURATOR CONDITIONS AND COMBUSTOR FLAMEOUTS
(July 1982)

Step Change Time	Resaturator Recirc Flow (gpm)	Resaturator Exit Temp(°F)	Combustor Flameout Time
(7-26-82)			
06:35	65→100	324→329	06:38
06:46	38→100	315→328	-
06:55	14→100	280→330	-
13:44	65→105	316→323	-
18:38	60→105	322→328	18:46
-	105	326	19:07
(7-27-82)			
14:42	105	290→330	14:50
-	105	330	15:19
16:50	105	250→335	17:06
-	105	335	17:33
17:40	105→78	320→290	18:03
18:42	78→105	323→332	-

One of the liquid temperature transient tests is represented in the plot in Figure 1-1. The steam supply to the liquid heater was increased, which raised the temperature of the liquid entering the resaturator and caused the rise in the gas temperature. The recirculation rate was constant throughout the test. The combustor exhaust temperature remained stable for about 8 minutes; then a flameout occurred. The combustor was brought back up and a second flameout occurred 30 minutes after the first one.

The effects of resaturator transients on the clean gas superheater (E-11) performance were checked by looking at the superheater gas exit temperature. The steam valve for the superheater was at a constant position throughout the tests. The exit gas temperature dropped sharply at the same time as the resaturator exit temperature increased. This resulted from the rise in mass flow due to the increase in water vapor content. The superheater returned to nor-

mal conditions within 2 minutes, and no other effects were seen. The cause of the flameouts either does not affect the superheater, or the effects were too short-lived to be detected by the data scan cycle of 20 seconds.

Figure 1-1. Combustor Flameout after a Resaturator Transient

Review of Resaturator Design Parameters

One possible cause of liquid accumulation in the resaturator product gas is carryover or excessive entrainment from the resaturator column due to either a non-conservative design or fouling in the column.

Calculations have been made to evaluate whether flooding in the resaturator might be expected due to the column design, and they show that the resaturator operating conditions yield gas velocities which are less than 50% of the flooding level. Also, it does not appear that the liquid distribution tray causes flow problems. (See Appendix B.)

Examination of Alternate Water Accumulation Mechanisms

Liquid accumulation in the resaturator product gas could also be caused by the effects of tars and oils, or by condensed water collecting in the low section of the pipe. This water may be the result of condensation on the pipe walls or fog formation in the gas stream exiting the resaturator. Each of these alternates will be discussed further.

Effects of Tars and Oils When the PEF resaturator was first operated, there was concern about the possible effects of the tars and oils in the liquid. If the packing were to become fouled, the heat transfer efficiency would be reduced and flooding tendencies would be increased. If foaming occurred on the liquid surface, the foam would tend to be carried over in the exit gas stream.

A bench-scale model of the resaturator was constructed in order to study these possibilities.⁽¹⁾ The model was operated at the PEF pressure and temperatures, and condensates from the PEF operation were used as the liquid feed in laboratory operation. As a result of this test, no indications of carry-over were observed. None of the materials showed hydrophobic tendencies, and there were no significant buildups of hydrocarbons on the packing or other column internals. A visual inspection of the PEF resaturator revealed negligible fouling of the packing and distribution tray.

Fogging Fogging is a condition that may occur when moisture is added to a saturated gas. In the case of the resaturator, this could be a problem at the exit when there is a significant difference between the temperature of the exit gas and liquid input temperature. Under this condition, the water vapor pressure is higher at the gas-liquid interface than in the bulk gas stream; if the gas stream is already saturated, then fogging will occur.

An existing computer model of the resaturator⁽²⁾ was used to evaluate the possibility of fogging. The model predicts that, under design conditions, the gas exiting the resaturator is about 99% saturated. The predicted degree of saturation declines as either the liquid flowrate or the liquid entrance temperature is decreased. For example, at one quarter of the design flowrate, the exit gas is predicted to be about 90% saturated.

The reason for the undersaturation is the relative rates of the heat and mass transfer. In the upper region of the resaturator packing, the temperature of the gas rises fast, relative to the rate of water vapor diffusion into the gas. The gas temperature becomes higher than its saturation temperature. In lower portions of the packing, the relative driving forces for heat and mass transfer are reversed so that fogging is predicted for all operating conditions. However, this fog vaporizes as it enters the upper region so it does not affect the exit gas stream.

Thus the computer model predicts undersaturated conditions in the resaturator exit gas stream. Fogging is not likely to occur unless the ratio of the mass transfer coefficient to the heat transfer coefficient is increased by a factor of 2.

Condensation Another mechanism for water deposition in the pipe is condensation. Water could be condensed out of the gas and onto the pipe walls during a transient when the temperature is increased. There are approximately 70 foot of 4-inch schedule 40 pipe between the resaturator and superheater, (See Figure 1-2). This insulated pipe requires heat input to match the gas temperature increases. Condensation of about one-half pound of water from the gas stream is required to increase the pipe temperature by 5°F. There is

electrical heat tracing on the pipe; however, the response of the heat tracing is much too slow to participate in process transients.

Condensation of water on the pipes during temperature rises appears to be at least a partial source of liquid in the product gas line. This conclusion is supported by the experimental data showing flameouts following large temperature increases. However, only about a gallon of water is predicted to condense during the most severe transient. This amount could not significantly block the low section of pipe. However, if water was already in the pipe before the transient, then the additional water could caused a plug in the gas stream.

Figure 1-2. Isosymmetric Diagram of the PEF

1.3.1.3 Implications

While the review of the resaturator design shows that flooding and carry-over are not expected, the experimental observation is that water is occasion-

ally carried through the product gas lines. Future PEF testing will include a closer look at the conditions under which water collects in the product gas lines and at the conditions which accompany combustor flameouts. These tests should verify or correct the conclusions reached in this investigation.

Careful design of a resaturation system is important. Future designs should locate the superheater as closely as possible to the resaturator, and eliminate low points in the piping between the two components. The resaturator column design should be conservative to preclude any possibility of flooding or excessive entrainment. Also, ramps in gas flow or temperature should be at minimum rates to avoid large temperature gradients in the resaturation system.

1.3.2 Gasifier Gas Evolution Test

In many end-use applications, a gasifier will be subjected to a number of severe transients which require a rapid decline in the coal gas production. A major concern related to the gasifier dynamic response to such conditions is that gasification reactions would continue after the blast flow is stopped, and the evolved gases would cause a large rise in system pressure.

1.3.2.1 Objectives

In order to assess this phenomenon, a Gas Evolution test was run in which the flows into and out of the gasifier were simultaneously cut off.

1.3.2.2 Accomplishments

The gasifier was subjected to the Gas Evolution test during the latter part of the 1982 test series. The response of the gasifier to this sudden

isolation is represented in Figure 1-3. The observed pressure increase was a modest 25 psi.

Figure 1-3. Gasifier Response to Flow Stoppage

The heating value of the gas increased rapidly when the flow was halted. This was caused mainly by a dramatic rise in methane, due to the continuing devolatilization of coal near the top of the gasifier bed. Within about 7 minutes of the flow termination, the methane content had risen from just under 5% to a concentration greater than the 10% calibration limit of the mass spectrometer being used for gas analysis. The gas heating value for the remainder of the test was determined from gas calorimeter measurements. The heating value began to decline 8 to 10 minutes after the flow termination, indicating that the gasification reactions and devolatilization were subsiding.

The methane concentration and three other major gas components are shown in Figure 1-4. The change in methane content is dramatic, but there were also

initial increases in the hydrogen and carbon monoxide concentrations. These increases are due to the preceding reactions in the gasification zone. There was some decrease in the CO_2 content, but this probably only reflects the increases in the other components.

Figure 1-4. Composition Changes During Gas Evolution

1.3.2.3 Implications

The results of the gas evolution test suggest that any control strategy involving the rapid termination of flow through the gasifier is safe. The pressure rise is small, and the temporary rise in gas heating value diminishes within a matter of minutes. These conditions permit an extended "bottle-up" period before any further action must be taken.

1.3.3 Evaluation of Heat Recovery Recycle Operation

The dynamic component analytical models generated under this program have been coupled to create an overall fuels plant system model. This has permitted evaluation of a particular system configuration which has yet been untested in the experimental facility. Specifically, the condensate liquid recirculation loop around the resaturator has been routed to the E-1 gas cooler/condenser. In a commercial configuration of this cycle, such a thermal coupling of these two components would be an essential part of efficient cycle design. It permits the heat removed in cooling the gas for H₂S removal to be directly returned to the cleaned gas stream.

Evaluation of this mode of operation is planned for the 1983 test program. The integrated system model is being used to evaluate possible operating conditions and to select initial flowrates and temperatures for this test.

The model has been operated in the mode with no heat input from steam heater E-8 for the recirculation liquid. Steady state values of the various gas and liquid temperatures and flows have been obtained for a range of recirculation at rated and partial gas flows. The resulting gas temperatures for the saturator and E-1 are within reasonable ranges. These characteristic curves, along with others to be run, will be used in evaluating this mode of operation prior to test operation.

As yet, no conditions or situations are apparent that should lead to operation problems in this mode. All gas temperatures, while different than the standard baseline, are within reasonable ranges.

Figure 1-5 shows the calculated temperatures for the various gas and

liquid flows at the saturator and E-1 at 100% gas flow, as the saturator recirculation liquid flow is varied. The maximum saturator gas temperature ($\sim 311^{\circ}\text{F}$) is reached at a flow of 5 lbm/sec, well within the capability of the plant design. For higher recirculation flows, the liquid/gas temperature decreases, but the gas exit temperature also decreases slightly. The E-1 gas exit temperature is also within the range of operation for the PEF at $\sim 300^{\circ}\text{F}$.

Figure 1-5. Effect of Resaturator/Recirculation Flow on System Conditions
(Heat Recovery Configuration, No. E-8 Heat Input)

1.4 REFERENCES

- [1] House, K.L., "Laboratory Studies of the Condensate Resaturator in an IGCC Coal Gas Cleanup System", GE CRD Technical Information Series Report No. 81CRD020, 1981.
- [2] Daniel, K.J., Crapo, A.W., "Transient Saturator Performance," To be presented at the 21st National Heat Transfer Conference, July, 1983.

TASK 2 - FACILITY OPERATION

2.1 OBJECTIVE

The objective of this task is to provide experimental operational data on the steady state and dynamic performance characteristics of the Process Evaluation Facility (PEF) for evaluation under Tasks 1 and 4.

2.2 TECHNICAL APPROACH

The Process Evaluation Facility operates at conditions specified by engineering test requirements to achieve specific component and system objectives.

2.3 DISCUSSION

Illinois No.6 coal, required for the 1983 operating season, was ordered.

The facility was not operated during the reporting period.

TASK 3 - SYSTEM MODELING

SUMMARY OF TASK ACTIVITIES

Activities have focussed on preparing for the verification of the integrated system during the 1983 test runs and continuing the validation and improvement of individual component models.

The component models have been concatenated in a system model, and a simplified integrated combined cycle representation has been added to simulate a complete power generation application. This combined cycle model has been added to the PEF control and data acquisition computer system with an integrated system control algorithm. This will permit the PEF system to be operated and evaluated as though it were participating in a typical end-use application. Work on the necessary software modules has been begun; this task will be completed in the next period.

Enhancements are being added to the gasifier model devolatilization zone and the acid gas removal system model in the area of CO₂ absorption rate representation.

3.1 TASK DESCRIPTION AND OBJECTIVES

The purpose of this task is to correlate the dynamic predictions of analytical/simulation models with experimental data and, using these models, determine forcing function inputs for transient process evaluation facility operation. Primary emphasis is on providing input to the development of an experimentally verified predictive model. Such a model permits evaluation of component performance and end-use subsystem interaction, leading to the effi-

cient design of control systems to maximize plant performance within the required emission control constraints.

3.2 RESULTS AND DISCUSSION

3.2.1 Computer Control System

Significant progress was made on the development of the computer control system hardware and software, which will be used to simulate utility/fuel plant interactions. The software is divided into seven sections: data input and output (I/O), low-speed data logging, high-speed data logging, user interface, heating value calculations, control algorithms, and gas turbine/steam turbine combined cycle simulation. The overall design of the system and the development of the latter four sections of software are being addressed within Task 3. The overall design was developed during this period and work on the individual sections has begun.

3.2.2 Control System Design

A preliminary information flow diagram for the control system software is shown in Figure 3-1. The seven sections of software are identified by boxes. An HP 2250 computer will collect the data from the Process Evaluation Facility (PEF) and convert it to engineering units. It will also convert the output variables from engineering units to process units and send the required signal to the process equipment. The actual control algorithms, combined cycle simulation, and user interface will reside on an HP A600 computer, and will interface to the process through the HP 2250. It will also interface with the gasifier HP 1000 computer, which is responsible for the on-line display of data. The HP 1000 computer will also provide the low speed data collection

and logging. This will allow a means for consistent recording of both data and simulation results on a single tape. For the turbine trip and frequency regulation tests, this method of data logging will be too slow. Consequently, during these tests the HP A600 computer will store the data directly in its memory and, following the test, will place the results in a disk file. This software will reside on the HP A600 computer and will output to a directly connected disk.

Figure 3-1. Flow Diagram for Control System Software

3.2.3 Operator Interface

The primary function of the user interface will be to recognize terminal commands and communicate the desired actions to the controls/simulation software. Through this software, specific tests will be started and variables such as tuning parameters can be changed, while the controls/simulation pro-

gram is running. Interlocks are incorporated in the interface software to prevent the operator from inputting erroneous combinations of inputs.

3.2.4 Heating Value Calculation

The heating value calculations uses the data from the fuel gas combustor and the saturator exit gas temperature to infer an instantaneous gas composition, required input for the gas turbine simulation. This software has been developed and results have compared well to experimental data taken in 1982.

3.2.5 Combined Cycle Simulation

The computer simulation of the combined cycle power plant, previously developed under this program, was transferred to the HP A600 computer and exercised. This was done to determine the amount of elapsed real time the simulation would require. Preliminary timings of the code indicate that it will run in approximately 20% of real time. This will leave sufficient time for processing the remaining sections of the software.

3.2.6 Control Algorithm

The controls algorithm was designed during this reporting period. The algorithm is based on the actual method used in the control of combined cycle plants. Discussions were held with personnel with experience in combined cycle plant control to provide guidance during the development activity.

The steam turbine control is built into the models for the steam valve and Heat Recovery Steam Generator (HRSG), (Quarterly Report for the period 28 December 1981 - 28 March 1982). The control objective for this bottoming cycle is to utilize as much of the exhaust heat as possible. The control of

the bottoming cycle has no impact on fuel demand and is only slightly affected by the requirements of the fuel plant. Since the objective of this program is to evaluate the effect of typical end-use on the fuel plant, the steam generator and the steam turbine and its control can be eliminated during the two short-time scale tests (turbine trip and resynchronization and frequency regulation) where end-use impact on the fuel plant is negligible. The removal of this subsystem will eliminate the need for steam turbine controls implementation. This subsystem would be required when simulating changes to the air boost compressor.

The gas turbine control algorithm is shown in Figure 3-2. The control manipulates the fuel flow, blast flows, and compressor inlet guide vanes (IGV) opening to maintain the desired power output, fuel plant pressure, turbine speed, turbine combustor temperature, and turbine exit temperature. The inlet guide vanes control the amount of air entering the compressor. This control is valuable in the control strategy at load points near full load. At these points the amount of power output can be decreased by reducing the amount of flow through the machine while maintaining normal exhaust temperatures. This allows the steam turbine bottoming cycle to operate at its maximum efficiency at part load.

The control algorithm uses three PI controllers. These are shown in the center of Figure 3-2. The lower one manipulates the IGV position between 57 and 77°. Depending on the operating conditions, its input is determined by either the turbine exhaust temperature or the turbine exit temperature. Either can be limiting. Note that the IGV control input is biased by 10° F. This is to prevent interactions with the emergency temperature control that provides an input to the fuel flow PI control when the IGV encounters a limit.

Figure 3-2. Gas Turbine Control Algorithm

The control algorithm will operate either in turbine lead or gasifier lead control mode. In turbine lead mode the power output is controlled primarily by the fuel flow PI controller and the fuel plant pressure is controlled by the blast flow PI controller. In the gasifier lead control mode, the power output is controlled indirectly by the the blast PI controller, and the fuel plant pressure is controlled by the fuel valve PI controller. For instance, when more power is required, the blast valves open and pressure in the fuel plant rises. The fuel valve senses the rise in pressure and allows more fuel to go to the gas turbine. In the simulated control system, the MW error signal and the pressure error signal are switched between the fuel flow

PI controller and the blast flow PI controller depending on the control mode selected.

Input to the fuel flow PI controller can also come from the emergency temperature control or the speed. The turbine speed is critical in two cases: turbine trip and frequency regulation, both fast transients. In the first case, the control system must respond quickly to a sudden decrease in load demand. If not, the turbine speed will increase to high levels. In the second case, the control system must respond to relatively small, but fast variations in speed to match utility load demand with utility generation. In both control modes, the error signal affects the turbine fuel flow PI controller directly.

The blast flow controller simultaneously manipulates the steam and air flow as shown. The air flow demand is a direct output of the PI control and the steam flow is proportioned from this. In order to allow for a smooth transition from manual to computer control, the control system has a tracking mode option where the computer will track the actual values of flow. Upon activation of the computer control system, there will be no abrupt change in the controlled variables.

The computer control system does not control the flow valves directly. The control outputs from the computer are converted to analog set-points which are fed to existing analog flow controllers controlling orifice pressure difference. All flow demand signals are converted to the desired orifice pressure difference. These values are then used as remote set-points for the analog controllers.

3.2.7 Gasifier Simulation

During this period, work has begun on the comparison of data with predictions of the gasifier model. Initial comparisons of model predicted dynamics with 1982 experimental results were poor; however, several improvements have been made in the methodology incorporated in the the model. A recent comparison is shown in Figure 3-3 and 3-4. The exit gas temperature is shown in Figure 3-3 and the raw gas methane content is shown in Figure 3-4, during a transient where coal was fed periodically instead of continuously. The periodic feeding (Figure 3-5) allowed the devolatilization zone of the gasifier to become depleted of moisture and volatile products. This caused large variations in the exit temperature and methane content. While the model predictions compare well with the data, there is still considerable discrepancy. Originally the model used only a single time lag to model the effects of the devolatilization zone. This proved to be inadequate. The model now includes a time lag for the drying of the coal and another for the devolatilization of the coal. A further modification will be made to add simplified kinetics for this devolatilization. This should result in an improved comparison.

Figure 3-3. Comparison of Coal Feed Test Transient Temperatures

Figure 3-4. Comparison of Coal Feed Test Transient CH₄ Content

Figure 3-5. Periodic Feeding of Coal During Coal Feed Transient Test

3.2.7.1 Acid Gas Removal System

During this reporting period the absorber model predictions were compared to the experimental data. Good agreement was found for the comparisons of H_2S absorption for transients in the lean (Figure 3-6) and semi-lean solution flowrate (Figure 3-7). On the other hand, poor agreement was found for comparisons of the H_2S absorption for reboiler steam flow transients (Figure 3-8). The discrepancy is partially due to uncertainties in the transient concentrations of bicarbonate and bisulfide in the absorption solutions. In addition, there is some question in the absorption measurement during this transient period. The data seems to indicate that the measurement devices calibration changed during the transient test. The resulting discontinuities were smoothed to obtain the data shown in the figure.

Figure 3-6. Benfield H₂S Removal

Figure 3-7. Benfield H₂S Removal

Figure 3-8. Benfield H_2S Removal

The model predicts CO_2 transient response well, but is in error in the absolute value of absorption (Figure 3-9). The cause for the error is the simplification in the method used to predict the rate of absorption. The model assumes that the absorption is irreversible. However, in reality, the absorption process approaches equilibrium near the bottom of the absorber. The model must be modified to include this phenomenon.

Figure 3-9. Benfield CO₂ Removal

TASK 4 - COMPONENT SUPPORT REQUIREMENTS

SUMMARY OF TASK ACTIVITIES

Engineering assessment of the status of the Process Evaluation Facility following 1982 operations has been completed. All systems and subsystems have been evaluated for operational readiness and problem areas have been identified. Procurement action has been initiated for repair parts and equipment as well as for equipment identified as necessary in preliminary test planning. Generation of the operations plan based upon the test plan is on-going.

4.1 OBJECTIVES

It is the objective of Task 4 to identify those items which significantly increase the effectiveness of operation of the Process Evaluation Facility (PEF), improve the quality of the technical data obtained, install new hardware, and modify the PEF to improve the reliability and operational acceptability of existing components.

4.2 APPROACH

An engineering assessment is made of any potential operational problem areas in the PEF facility and plans are implemented to correct them. Procurement action is initiated on major hardware items identified.

4.3 DISCUSSION OF FACILITY SUPPORT

4.3.1 Gasifier System

At the conclusion of the 1982 operational period, a hot spot was discovered in the lower midsection of the gasifier vessel. This section was disassembled and the cause of the hot spot was attributed to a void in the refractory lining. This caused the hot gas to shunt around the refractory and overheat a section of the pressure vessel wall. The refractory was completely removed from the entire midsection and shipped to the vendor for mechanical repairs. The damaged section of the wall was repaired by cutting out approximately a 70° section, and welding in a new section.

Once the new section of material was welded in place, the welds were checked by X-ray and the entire midsection hydro-tested to assure reliability of the complete assembly. An external water-cooling jacket was added to this section of the pressure vessel as a precautionary measure against metal over temperature. At the conclusion of all mechanical repairs, the midsection was sent to a vendor for installation of a refractory lining.

The refractory-lined section in the grate area has been inspected and found to contain cracks and voids. This section was replaced. A new section of 3/8-inch plate steel was rolled to fit inside the pressure shell and then this section was relined with refractory materials.

Repairs and modifications to the quench blowdown control system are essentially completed. This includes installation of a new control station suitable for outdoor service and revamping of the wiring logic. A Programmable Controller (PC) is being incorporated; this added control capability will

increase the lockhopper cycle efficiency and eliminate the chance of operator error during the valve cycling of this blowdown process.

Critical areas of the ash lockhopper vent piping have been replaced. The vent valves and piping are exposed to a highly erosive environment and require inspection and replacement at regular intervals to insure reliable performance for the entire test period. Similarly, the piping associated with the quench blowdown has been modified to allow for a quicker and easier startup of the sludge removal system. The valving will now be actuated from within the control room and will allow for a much quicker and safer transition from the startup vessel to the sludge blowdown vessel. This modification will also provide the operator with a safe control mode in the event of a problem with the Sludge Blowdown Vessel (BDV).

Routine inspection of all process pumps and recirculation systems has been completed. The mechanical seals located in both the primary and backup quench recirculation pumps required replacement. These pumps provide the water to the quench spray nozzle, and reliable operation is essential to maintaining thermal and particulate loading stability to the remainder of the system. The makeup water pumps to the quench recirculation were also inspected and cleaned.

4.3.2 Cleanup System

The isolation valves used in the scrubber recirculation loop were inspected and found to be severely worn. The replacement and rebuilding of these valves have been completed. The filter baskets were inspected and rebuilt, where necessary; one filter housing was found to contain a stress crack and a replacement housing was ordered and installed. A backup system, which

will allow more time between filter changes and provide added system reliability of the scrubber recirculation flow, has also been installed.

A point-source nuclear level device was ordered for the scrubber. The new control design will allow for both automatic and manual control of the scrubber sump level and will insure accurate level control. Attempts to use capacitance measurement of the recirculation liquor or inert gas purges in conjunction with differential pressure transducers have not been successful. During the last operational period it was necessary to manually observe and maintain the level in the scrubber via a sight glass.

Installation of new thermocouples (TC) or the retrofit of existing thermocouples in areas of the process stream that require quicker response is now being completed. Some of the tests planned for 1983 require a quicker response time than the conventional industrial quality TCs provide. The process gas line at both the immediate inlet and exit of E-11, the final gas heater, and a few other sections of the process piping will receive new thermocouples.

4.3.3 Sampling and Analysis System

All sampling and analysis equipment has been inspected and prepared for operation. Final calibration and data link loop checks will be performed just prior to operations. Calibration gases have been inventoried and replacement calibration gases have been ordered. A sample conditioning system is being installed in the area of the turbine simulator to perform the exhaust gas analysis as planned in the 1983 preliminary test planning. All heat-traced sample lines have been checked for operability and replacement sample lines ordered to replace any found to be defective.

4.3.4 Turbine Simulator

An inspection of the turbine simulator and associated instrumentation was performed. The combustion liner was found to contain some cracks and was replaced with a new one, which had previously been reserved as a spare. All of the instrumentation and process piping is in good condition and required very little maintenance. Final calibration and loop checking will be performed just prior to the operational period.

TASK 5 - FUEL SYSTEM MODIFICATIONS

5.1 OBJECTIVE

The objective of this task is to provide an alternate gasifier system to be evaluated on the existing process evaluation facility. Direct comparison information will be developed on the steady state and dynamic performance characteristics between the existing advanced fixed-bed gasifier and other gasification technologies for the integrated coal gasification process.

5.2 DISCUSSION

No activity was conducted on this task during the reporting period.

TASK 6 - PROGRAM MANAGEMENT

6.1 INTRODUCTION

The program is under the direction of the Program Manager. A Program Director and Program Administrator report directly to the Program Manager.

As a result of participation in numerous government programs, GE-CRD has established contract support organizations. These organizations support the program manager in contract administration, legal consultations, and patent-related activities.

The Program Director coordinates the activities of four teams. The facility operation team is responsible for the functional operation of the facility in order to accomplish the specified engineering objectives. The system engineering team defines the experimental program objectives, analyzes the system and component performance results, and develops the technology data base required for system simulation. The system simulation team is responsible for modeling the full-scale fuel plant predictive techniques. The system support team is responsible for facility modification and maintenance.

The technical success of this program depends upon the development of an experimental data base, the utilization of this information to enable evaluation of full-scale systems, and the development of modeling tasks. This interaction is under the direct control of the Program Director.

The specific technical direction of each year's experimental program is presented to the DOE Project Manager in an oral report. After this review, the recommended test plan for the year is documented. The planning cycle for

each year's program has sufficient flexibility to permit redirection of activity to achieve near-term DOE program needs for specific information.

6.2 PROGRESS SINCE LAST REPORTING PERIOD

The following reports have been submitted:

- Cost Management Report (3)
- Manpower Management Report (3)
- Milestone Management Report (3)
- Contract Management Summary Report (3)

APPENDIX A

This section describes the evaluations which were made of the resaturator column design to determine whether or not flooding or excessive entrainment is expected.

RESATURATOR DESCRIPTION

A schematic diagram of the PEF resaturator is shown in Figure A-1. The total height of the vessel is 34 feet, with an inner diameter of 22.75 inches. An 18-foot section near the top of the column is packed with 2-inch carbon steel Pall rings. There is a demister element in the gas exit port at the top of the column, which consists of a 4-inch thick wire mesh pad.

Figure A-1. Resaturator Schematic and Nominal Operation Data

Clean coal gas exiting the sulfur scrubber is heated in an indirect steam preheater, then enters the resaturator about 3 feet below the packing. As the gas contacts the liquid, heat and water vapor are transferred to the gas phase. The gas exits the top of the resaturator at a temperature which is a few degrees below the inlet liquid temperature. The vapor content of the product gas is within 1% of saturated conditions; the saturation may be lower at off-design conditions.

The recirculating liquids are heated in an indirect steam heat exchanger before entering the resaturator column over a distribution plate just above the packing. At the bottom of the packing, the liquid drops from the packing support to the sump at the bottom of the column. The sump drains directly to the recirculation pump. Condensates from the decanting vessels join the recirculation flow before the liquid is heated for introduction at the top of the resaturator. A blowdown stream is taken near the discharge of the recirculation pump. The blowdown flowrate is controlled by a level sensor on the column sump, so that the liquid level is maintained approximately 4 to 5 feet below the packing.

REVIEW OF RESATURATOR DESIGN PARAMETERS

The packed section of a column is usually checked first when flooding is suspected. Flooding occurs if the gas phase pressure drop through the packed section is increased to the point where the liquid holdup is greater than the available volume. This pressure drop depends on the liquid and gas mass flow velocities, the physical characteristics of the two streams, and the characteristics of the packing. It is common practice to design a packed section so that the gas flow is 60% of the calculated flooding velocity. A flooding cal-

ulation was made using a standard method,⁽¹⁾ and the gas velocity was found to be only about 40% of the flooding velocity. Even the most severe conditions which the resaturator experiences, result in less than 50% of flooding velocity.

Flooding could also occur on the liquid distribution tray, which is just above the packing. This tray contains 72 holes (11/32-inch diameter) for the liquid flow. For the gas flow, there are four risers extending 8 inches above the tray with a combined area of 69 in². The liquid level on the tray should be 1-2 inches or more to assure even distribution. If the liquid flow area is too small, either by design or due to fouling, the liquid height may increase to the top of the gas risers and restrict the gas flow area.

The characteristics of the distribution tray were visually inspected after the 1982 PEF operational season. Only a few of the holes were covered by fouling and this did not appear to significantly affect its operation. The liquid flow was observed in the absence of gas flow, and the liquid height on the tray was in the desired range. A calculation of the gas flow pressure drop across the tray showed that there is a negligible effect on the liquid height. This result was expected since the nominal gas velocity in the resaturator column is only about 1 ft/sec.

When the liquid flow on the distribution tray was observed, it was noted that it was misdirected by the liquid inlet pipe. This pipe extends over the middle of the tray, between two of the gas risers, with a series of holes on the underside of the pipe to direct liquid to the tray. Since the pipe had been installed with a 30° rotation, some of the liquid was falling into a gas riser. This situation has been corrected. Although this may have caused some

maldistribution, the gas pressure drop would not be significantly altered. There is a possibility of some entrainment from this situation; however, the gas velocity is fairly low, the liquid droplets are large, and any entrained large droplets should easily be removed in the demister pad at the top of the column.

The only other possible cause of flooding in the column could be the packing support plate. This plate must have adequate restraints to hold the packing without restricting the gas and liquid flows. This plate has not been fully inspected recently. Moreover, it is assumed from evaluation of design drawings that the plate is unlikely to be the cause of liquid entrainment.

CONCLUSION

The review of the resaturator column has not revealed any explanation for the occasional presence of liquid in the product gas stream. The design of the column is apparently sufficiently conservative to prevent any flooding over the entire range of operating conditions.

REFERENCE

- [1] Treybal, R.E., 'Mass Transfer Operations,' published by McGraw Hill, Inc., 1968, pages 160-164.