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FE-1765-13
Dist. Category UC-90h

MASTER

HIGH TEMPERATURE GAS TURBINE ENGINE
COMPONENT MATERIALS TESTING PROGRAM
TASK 1

Quarterly Technical Progress Report No. 3
Period: January 3 - April 4, 1976

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Date Published - April 15, 1976

PREPARED FOR THE UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

Under Contract No. E(49-18-1765)

Available from the National Technical Information Service (NTIS)
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Price: Paper Copy $________
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TABLE OF CONTENTS

Section		Page
	ABSTRACT	1
1	OBJECTIVE AND SCOPE OF WORK	2
	Objective	2
	Background	2
	Technical Requirements	4
2	SUMMARY OF PROGRESS TO DATE	11
3	DETAILED DESCRIPTIONS OF TECHNICAL PROGRESS	21
	Subtask 1 - Select Alloys, Coatings, Claddings, and Ceramics	21
	Work Accomplished	21
	Subtask 2 - Select Feedstock	21
	Work Accomplished	21
	Subtask 3 - Establish Test Conditions	21
	Work Accomplished	21
	Test Parameter Definition - Initial Coal-Derived Liquid Fuel Tests	21
	Establish Test Parameters - Initial Low-BTU Gas Tests	41
	Establish Test Parameters - Screening Tests	41
	Thermochemical Analyses	43
	Work Forecast	46
	Subtask 4 - Establish Test Facilities	46
	Work Accomplished	46
	Initial Coal-Derived Liquid Fuel Tests	46
	Initial Low-BTU Gas Tests	61
	Confirmation Tests	61
	Work Forecast	62
	Subtask 5 - Prepare Test Specimens	62
	Work Accomplished	62
	Initial tests	62
	Screening Tests	62
	Confirmation Tests	63
	Work Forecast	63

TABLE OF CONTENTS (Cont'd)

Section		Page
	Subtask 6 - Program Management	63
	Work Accomplished	63
	Work Forecast	65
	Subtask 7 - Conduct Tests	66
	Work Accomplished	66
	Work Forecast	68
4	CONCLUSIONS	70

LIST OF ILLUSTRATIONS

Figure	Title	Page
1	Fireside Corrosion Task 1 - Work Breakdown Structure and Master Schedule	12
2	Fuel Aromaticity	26
3	Dispersant Power For Synthoil Sludge of Several Oils	37
4	Synthoil Sludge Dispersed in Various Oils Particle Side Distribution	38
5	View From Above, Low BTU Gas Combustor and Turbine Simulator	50
6	Fuel-injection end - Turbine Simulator Assembly	51
7	Exhaust end - Turbine Simulator Assembly	52
8	Main combustor liner and simulator assembly	53
9	View upstream into the main combustor section before insertion of the Turbine Simulator Assembly	54
10	The Transition Piece attached to the Turbine Simulator Assembly; view from above	55
11	The Transition Piece attached to the Turbine Simulator Assembly; view from below	56
12	View looking downstream inside the Transition Piece	57
13	The Turbine Simulator mounted in the final assembly with exhaust duct removed; view from downstream	58
14	Two Nozzle Pins in Transition Piece after (a) Test 1 and (b) Test 2	69

LIST OF TABLES

Table	Title	Page
1	Report of Particle Study	23
2	FCC Slurry Oil (Mobile)	27
3	Cresote Oil (Allied)	28
4	#2 Oil/Synthoil Sludge	30
5	COED Oil/Synthoil Sludge Mix	31
6	FCC Slurry Oil/Synthoil Sludge	33
7	Creosote Oil/Synthoil Sludge	35
8	Synthoil Sludge #2	39
9	Coal Analysis	42
10	Na and K Levels Predicted by Analysis	45
11	GE Equipment sent to Morgantown	47

ABSTRACT

Efforts this quarter were highlighted by: (1) initiation of Initial Coal-Derived Fuel Testing; (2) initiation of Screening Tests; and (3) delivery of the turbine simulator skid to ERDA/MERC. Two turbine simulator tests were successfully performed at GE, using the Government-allocated COED fuel; the first test was performed with the fuel "as received" and the second test involved "doped" fuel, i.e., 3 ppm Sodium (Na) and 3 ppm Potassium (K) being added. Evaluation of test results indicated the presence of K- and Na-based corrosive species on test specimens. These probably formed during the second test. It is expected that hot corrosion attack would have occurred had the tests been run for an extended period of time (several thousand hours).

Investigations have indicated that the previously considered doping of No. 2 distillate fuel with chemicals and/or ash to simulate a coal-derived liquid fuel would not be feasible due to fundamental chemical differences between petroleum-based and coal-based fuels. A search for a coal-fuel base to develop a synthetic coal-derived liquid fuel was initiated, with three candidates fuel bases being identified. Samples of these candidates are currently being evaluated. Upon selection of an appropriate coal-fuel base, Initial Coal-Derived Liquid Fuel testing will be resumed. (GE's plans and approachs for developing synthetic fuels were reviewed with and approved by ERDA.)

Shakedown tests of the turbine simulator skid at the Morgantown test facility were initiated in March, and several areas in the test arrangements that needed minor modifications were uncovered. These are in the process of being incorporated. Actual testing is expected to start in April.

Materials screening tests were initiated in late February, using two test conditions established via thermochemical analysis. Two additional test conditions were developed in March.

Section 1

OBJECTIVE AND SCOPE OF WORK

OBJECTIVE

The objective of the program, "High-Temperature Gas Turbine Engine Component Materials Testing" is to provide the U.S. Energy Research and Development Administration (ERDA) with a firm engineering data base on the durability of selected gas turbine nozzle and bucket materials under test conditions selected to be representative of:

- Turbine inlet temperatures typical of projected duty in a gas turbine engine topping unit of a combined-cycle central station generating plant, simultaneously with
- Gas environments which would be expected from the combustion of coal-derived low-Btu gas and coal-derived fuel oil in such gas turbine engine topping units, and
- Nozzle and bucket internal cooling and associated design practice typical of high-temperature turbine operation.

It is realized that these data will be used by ERDA to help formulate decisions on other programs to improve the reliability of components and maintenance cost projections and to define firm developmental needs for improved component materials and coatings.

BACKGROUND

The work being carried out under this contract interfaces with and benefits from complementary programs planned by the General Electric Company but not forming any part of the work to be performed under this contract. In these complementary programs, General Electric Corporate Research and Development (CRD) plans to conduct cooperative tests (hereinafter referred to as the "Morgantown Test Program") with ERDA's Morgantown Energy Research Center (MERC) low-Btu gas facility to evaluate combustor characteristics and emission effects when burning low-Btu gas. As part of this Morgantown Test Program, a turbine simulator has been constructed and connected to the MERC gasifier. In addition, a modified combustor liner, a test specimen, and a bulkhead mounting fixture for these specimens (constructed and furnished by GE-CRD as part of this contract) was installed in the turbine-simulator and follow an Initial

Test conducted as described below:

1. Two Initial Tests, the first one using a high-sodium coal and the second a low-sodium coal, are planned. These tests will help to identify the effect of feedstock contaminant level on fouling, erosion, and corrosion of hot-gas path parts. Approximately 100 hours are anticipated for each test.

   During the tests, low-BTU gas fuel will be analyzed for major constituents and sulfur content. In addition, it is planned that isokinetic samples of entrained particulate matter in the low-BTU gas will be taken and analyzed for particle size and inorganic elements. Also, isokinetic samples of particulate matter in the gas stream entering the first-state turbine nozzle will be obtained and analyzed for particle size and chemical composition. The Nozzle Area Index Number (NAIN) will be monitored during the test in order to provide a basis for analysis of the particulate deposit rate.

   It is planned that the test data (including the operating condition data) taken during the Morgantown Test Program together with the tested specimens will be furnished to the General Electric Company's Gas Turbine Division (GTD) to enable General Electric to conduct analyses and evaluations under this contract.

2. General Electric Corporate Research and Development (GE-CR&D) is conducting a program for the Electric Power Research Institute (EPRI) under which a GEGAS-D low-BTU gasifier has been constructed at CRD's facility in Schenectady, N.Y. General Electric agreed to commit the output of this gasifier to the extent necessary for the Confirmation Tests to be conducted under this contract. The work under this contract will take priority over other work utilizing the output of this gasifier.

3. Further, the gas cleanup system available at CRD for use in cleaning up the low-BTU gas produced by the GEGAS-D gasifier, which simulates the gas composition expected for gas turbines in electric power applications, will be made available by CRD, on a priority basis as necessary, to complete the work under the present contract.

TECHNICAL REQUIREMENTS

This R&D project consists of ten interrelated subtasks, each of which will be performed over the 24 consecutive month duration of the program.

These subtasks are:

Subtask No.	Title
1	Select Alloys, Coatings, Claddings, and Ceramics
2	Select Feedstocks
3	Establish Test Conditions
4	Establish Test Facilities
5	Prepare Specimens
6	Program Management
7	Conduct Tests
8	Evaluate Test Results
10	Conduct Confirmation Tests
11	Documentation and Reporting

Descriptions of these subtasks are as follows:

Subtask No. 1 Select Alloys, Coatings, Claddings, and Ceramics

a. Materials to be tested under this program were selected by GTPD from those in current use as first-stage nozzles and buckets in the present generation of industrial gas turbines and from those in advanced materials development stages.

b. Anticipated material operating conditions were defined. Material surface stability requirements and cyclic and mechanical property requirements expected to satisfy the operating conditions were identified.

c. Available performance data for the candidate materials was reviewed. The selection of the candidate materials were based on a comparison of the known materials performance with the expected requirements.

Subtask No. 2 - Select Feedstocks

a. Two, coal feedstocks have been selected. The selection was on the basis of cost, geographical availability, and other factors. Candidate coals were identified and characteristics, particularly alkali metal content, pertinent to the durability of the gas turbine were defined.

b. Several typical low-Btu gasification and coal liquefaction processes were identified and characterized, based on published information and information supplied by ERDA with respect to such ERDA-sponsored programs. Characterization parameters included the effect of the selected coals' composition and impurity range on the gas turbine's ability to burn the fuel, and feedstock compatibility. Important impurity characteristics included sodium, potassium, vanadium, lead, chlorides, easily dissociated nitrogen such as ammonia, and sufur. The assumed cleanup is that normally ascribed to the process.

Subtask No. 3 Establish Test Conditions

a. Test conditions for the Initial Tests were established based on the temperature, velocity, and other design considerations representative of present and advanced generation open-cycle industrial gas turbines operating on a low-Btu gaseous fuel and a low-sulfur coal-derived oil. Combustion product contaminant levels were determined by the liquid fuels chosen and the cleanup system employed in the Morgantown Test Program.

b. Thermodynamic analysis was used to define the combustion product environment resulting from burning fuels derived from the selected coals. The composition of the condensates resulting from the passage of the combustion products over the nozzle and bucket surfaces at relevant temperatures and pressures were estimated.

c. The results of the Initial Tests (described under Subtask No. 7), in which coal-derived oil and low-Btu gas are to be burned, will be evaluated specifically for impact on the definition of the test conditions for the Screening Tests and Confirmation Tests. For example, contaminant levels and effects on materials, ash deposition and fouling, cooling hole plugging, and erosion are specific phenomena which will be evaluated.

d. Test parameters for the Screening Tests were specified by GTD based on characterization of the fuels derived from the selected feed-stocks, the results of the thermodynamic analysis, and the results of the Initial Tests. The major variable in these tests was the fuel impurity level.

e. Finally, test parameters for the Confirmation Tests will be defined by the General Electric Company based upon the results of all of the previous testing and will include preferred materials, cooling design, and representative fuel cleanup levels. Internal cleaning, and other gas turbine and fuel cleanup techniques currently available, may also be used.

Subtask No. 4 Establish Test Facilities

a. Initial Test facilities have been selected by GTD to provide early information on the real combustion environment with low-Btu gas and low-sulfur coal-derived liquid fuel, each at two impurity levels. General Electric's facility at Schenectady, New York, has been selected for the coal-derived oil tests and ERDA's MERC facility has been selected for the low-Btu gas tests.

b. Screening Test facilities will be the small burner test rigs located at the Gas Turbine Development Laboratory. It is planned to use four of these rigs; each rig can accommodate 21 specimens. The primary variable to be investigated will be the effect of contaminants, singularly and in combination, on corrosion.

c. Confirmation Test facilities have been selected to provide confirmation of the material and coating/cladding choices and to correlate the life predictions obtained from the Screening Tests data. General Electric's facility in Schenectady is being used for both the coal-derived oil and the low-Btu gas tests. The coal-derived oil test facility is the same as the one used in the Initial Tests. It is planned that the low-Btu gas test will use the GEGAS-D gasifier from the GE/EPRI-sponsored gasification program, and a simulated gas cleanup system will also be made available. Mating of the Turbine Simulator to the low-Btu gasifier will be accomplished under this program. These facilities will permit testing a representative advanced cooling design and may include fuel-cleanup and turbine-cleanup techniques for the liquid and gas fuels chosen. The Turbine Simulator at CRD will be modified to incorporate the preferred materials, a representative cooling design, and to operate on the chosen low-sulfur coal-derived liquid and gas fuels. For the latter tests, General Electric plans to connect the Turbine Simulator directly to the GEGAS-D gasifier. A combustor and transition piece will be incorporated into the Turbine Simulator for the low-Btu Confirmation Tests. It is planned that this combustor will have a dual fuel capability, i.e., oil and low-Btu gas to permit data comparisons.

Subtask No. 5 Prepare Specimens

a. Test specimens for the Initial, Screening, and Confirmation Tests are being designed and procured. The coal-derived fuel Initial Tests use a Turbine Simulator nozzle made of FSX-414 alloy. In addition, specimen tabs of IN-738 are welded to the trailing edge of the nozzle. The effect of the environment on the specimen tabs is expected to provide a basis for comparing the results from the Initial Tests to the background experience using crude and residual oils. Air-cooled cylindrical pin specimens of Hastelloy-X were designed and provided for use in the Initial Test program.

b. Small burner rig screening tests specimens are discs one inch in diameter, nominally 0.060 inch in thickness, with a tolerance of 0.0005 inch so that the two sides are as close to parallel as possible.

c. Depending upon the results of the Initial Tests, nozzle and bucket cascades with or without leading edge holes for air cooling will be prepared for use in the Confirmation Tests. The nozzle sector is planned to be an appropriately modified MS-3002 section of FSX-414 material. The preferred nozzle materials selected from the Screening Tests will be attached to the nozzle trailing edge with the nozzle instrumented as required. The bucket cascade will be fabricated from an alloy to be selected by General Electric. The preferred bucket materials selected from the Screening Tests will be attached to the bucket cascade trailing edge, and the cascade will be instrumented as required.

Subtask No. 6 - Program Management

General Electric conducts all of the necessary program management activities needed to direct, coordinate, and monitor the performance of this contract.

Subtask No. 7 - Conduct Tests

a. Initial Tests and Screening Tests are conducted under this subtask.

b. The objective of the Initial Tests as to define hot corrosion, erosion, fouling, and other potential problems as early in the program as possible. These tests are run using coal-derived liquid fuel in the Turbine Simulator at Schenectady, New York. This simulator duplicates conditions at the first-stage nozzle of a large central-station gas turbine. It is equipped with pin samples simulating nozzle and bucket leading edges to investigate the feasibility of cooling in the ash-laden environment caused by burning coal-derived fuels. Liquid fuels from two coal feedstocks have significantly different impurity levels are to be tested. Two tests will be conducted with a firing temperature of approximately 1950°F on a relatively clean COED oil. By using a nozzle sector and turbine inlet conditions similar to those used by General Electric in previous petroleum oil tests, it is expected that a correlation to prior experience can be established. A single test at approximately 1950°F will be conducted using a relatively high ash, high alkali contaminant level COED oil with the objective of identifying the fuel composition effects. A fourth and fifth test will be conducted at temperatures above 1950°F. The high and low contaminant level coal-derived oils used in the 1950°F tests will be used in tests 4 and 5. The test times will be approximately 100 hours for each of the above tests.

c. Liquid fuels are characterized by analysis prior to the tests and periodically during the tests. The fuels are analyzed for those elements known to be objectionable, i.e., alkali metals, vanadium, and lead, and the chlorine and sulfur content determined. Other inorganic elements are monitored in case the coal ash is significantly different from the oil ash.

d. Isokinetic samples of particulate matter in the low-Btu gas stream entering the first-stage turbine nozzle will be obtained and analyzed for particle size and chemical composition.

e. It is planned to investigate the low-Btu gas fuel by providing samples prepared in Subtask No. 5 to the Morgantown Test Program. Observers are provided during the period when the samples are being run on the coals specified in Subtask No. 4

f. Deposits from the hot-gas path parts for both the low-Btu gas and coal-derived oil tests are sampled and analyzed for crystal structure and chemical composition. Deposit rate in the coal oil test are determined by monitoring the Nozzle Area Index Number during the test.

g. Corrosion products on the alloy/coating samples will be analyzed for depth of penetration and chemical composition for both the coal oil and low-Btu gas tests.

h. Screening Tests for corrosion resistance in simulated environments are conducted in the small burner test rig. Approximately 20 selected materials are tested. Tests for most of the materials are run from 100 to 1000 hours each with the environment determined by the coal feedstock selection and test condition subtasks. Metal test temperatures in the range of

1700°F to 1900°F are anticipated. Test times for some selected materials that are more corrosion resistant may exceed 2000 to 3000 hours. After exposure, the specimens will be cross-sectioned and prepared by standard metallographic techniques. The cross section will then be examined microscopically and the corrosion penetration measured. Further studies of the corrosion products and distribution of the alloy elements and the contaminants in the scale and at the scale metal interface will be conducted, as required, to the extent determined by General Electric.

Subtask No. 8 Evaluate Test Results

a. An existing proprietary General Electric model to predict the life of gas turbine buckets and nozzles will be used as the basis for extrapolation and interpolation of the data resulting from the materials Screening Tests, Initial Tests, and the Confirmation Tests with the objective of developing materials life curves for the selected nozzle and bucket test materials. These curves are intended to show materials life as a function of combustion product impurities and will cover a range of impurity contents representative of fuels derived from coal.

b. Initial Tests results will be evaluated with the objective of selecting the cooling design used for the Confirmation Tests. Recommendations of state-of-the-art corrosion inhibitors, ash modifiers, and internal cleaning procedures will be made. These inhibitors, modifiers, and procedures may be used in the Confirmation Tests, if required.

c. Consideration will also be given to trade-offs between gas cleanup versus gas turbine design and operating procedures alternatives from the standpoint of life improvement

Subtask No. 10 - Conduct Confirmation Tests

a. Confirmation Tests will be conducted at CRD's facility in Schenectady using a low-sulfur coal-derived oil and a low-Btu gas with the Turbine Simulator. It is planned that the Turbine Simulator will have the capability of burning low-Btu gas, conventional oil, and coal-derived oil. Samples prepared in Subtask No. 5 will be installed. It is planned that the Turbine Simulator will be connected to the GEGAS-D gasifier.

b. Four tests, each approximately 100 hours long, with coal-derived oil, and four tests, each approximately 100 hours long, with low-Btu gas will be conducted. Each series of tests will be stepped in four temperature increments from 1950°F to 2200°F.

c. Test specimens and fuels will be analyzed in the same manner as in the Initial Tests.

Subtask No. 11 - Documentation and Reporting

General Electric shall furnish reports in accordance with the requirements set forth in the contract.

Section 2

SUMMARY OF PROGRESS TO DATE

Work is being performed in Subtasks 3 through 7 as identified in the Master Program Schedule (Fig. 1). Work in three of the Subtasks is proceeding on or ahead of schedule, with schedule slips having been accrued in Subtasks 3 (Establish Test Conditions) and Subtask 7 (Conduct Initial and Screening Tests). These slips, initially produced a need to develop a synthetic coal-derived liquid fuel as a substitute for COED fuel (see previous quarterly reports, for background). However this quarter, investigations have indicated that the previously considered plan to dope No. 2 distillate fuel with chemicals or ash to simulate a coal-derived liquid fuel, would not be feasible due to fundamental chemical differences between coal-based and petroleum based fuels. A technically feasible alternate approach to come up with a synthetic fuel has been developed; candidate coal-fuel bases from which such a fuel can be synthesized have been identified and these bases are currently being evaluated.

The Screening Tests have been initiated using test conditions based on thermochemical analysis in lieu of Initial Test results. Summarized specifics are given below under the appropriate Subtask headings.

All of the efforts in Subtask 1 - Select Alloys, Coatings, Claddings and Ceramics were completed in October. A list of the materials, including those given in the proposal, was reviewed with regard to surface stability requirements, mechanical property requirements, and existing performance data. From this list 21 materials (alloys, coatings, claddings, and ceramics) have been selected. Certain materials were eliminated because of their uncertain availability or unsuitability as revealed by a more detailed investigation. Others were added because of their potential advantages to the test program. Full specifics are given in Quarterly Progress Report No. 1.

In Subtask 2 - Select Feedstocks, the coal feedstocks to be used for the Initial and Screening Tests involving low - BTU gas were selected in September: Illinois No. 6 coal (or equivalent) and North Dakota lignite or Montana Rosebud. The basis for their selection is provided in Quarterly Progress Report No. 1. These coal feedstocks have been ordered by ERDA for the forthcoming low-BTU gas tests at MERC. GTD requirements for advance samples of these coals to be used at MERC were published. Chemical analyses of these samples, received this quarter,

FIGURE I - FIRESIDE CORROSION TASK I - WORK BREAKDOWN STRUCTURE AND MASTER SCHEDULE (SHEET 1 OF 4)

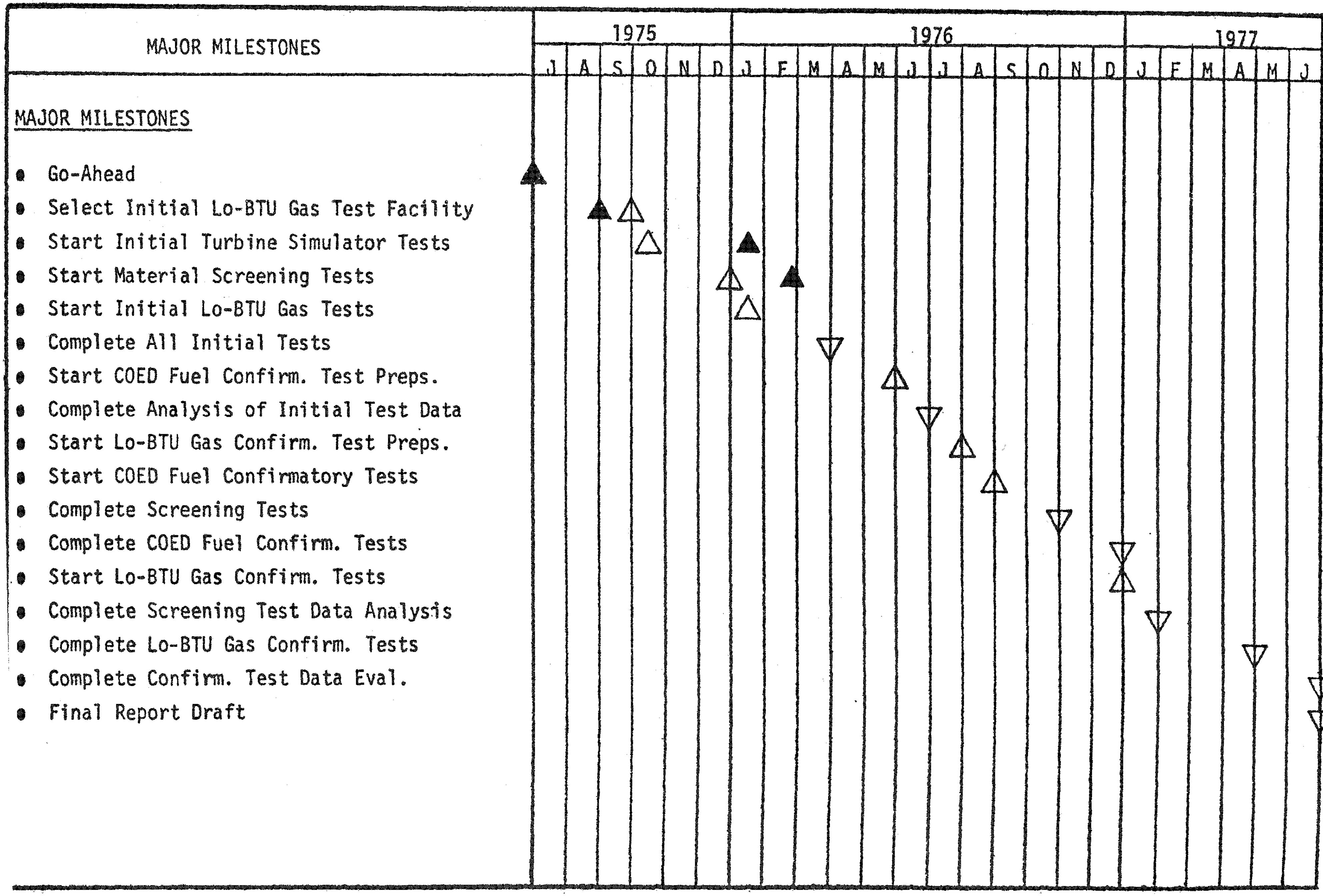


FIGURE I - FIRESIDE CORROSION TASK I - WORK BREAKDOWN STRUCTURE AND MASTER SCHEDULE (SHEET 2 OF 4)

WORK BREAKDOWN STRUCTURE

Subtask 1 - Select Alloys, Coatings, Clads, Ceramics

1. Define Materials Operating Conditions
   a. Define Mtls. Surface Stability Req.
   b. Define Mtls. Cycle & Mech. Property Req
2. Screen Candidate Materials
   a. Review Existing Performance Data
   b. Compare Known Performance to Expected Requirements

Subtask 2 - Select Feedstocks

1. Derive Candidate Coals Listings
   a. Define Economic Bases
   b. Define Coal Characteristics
2. Identify Processes and Characteristics
   a. Derive Candidate Listing
   b. Define Process Fuel Characteristics

Subtask 3 - Establish Test Conditions

1. Thermochemical Analysis
   a. Combustion Environment Definition
   b. Condensate Predictions
2. Initial Test Impact on Subsequent Tests
   a. Initial COED Fuel Test
   b. Initial Lo-BTU Gas Test
3. Define Test Parameters
   a. Initial Tests
   b. Screening Test
   c. Confirmation Tests

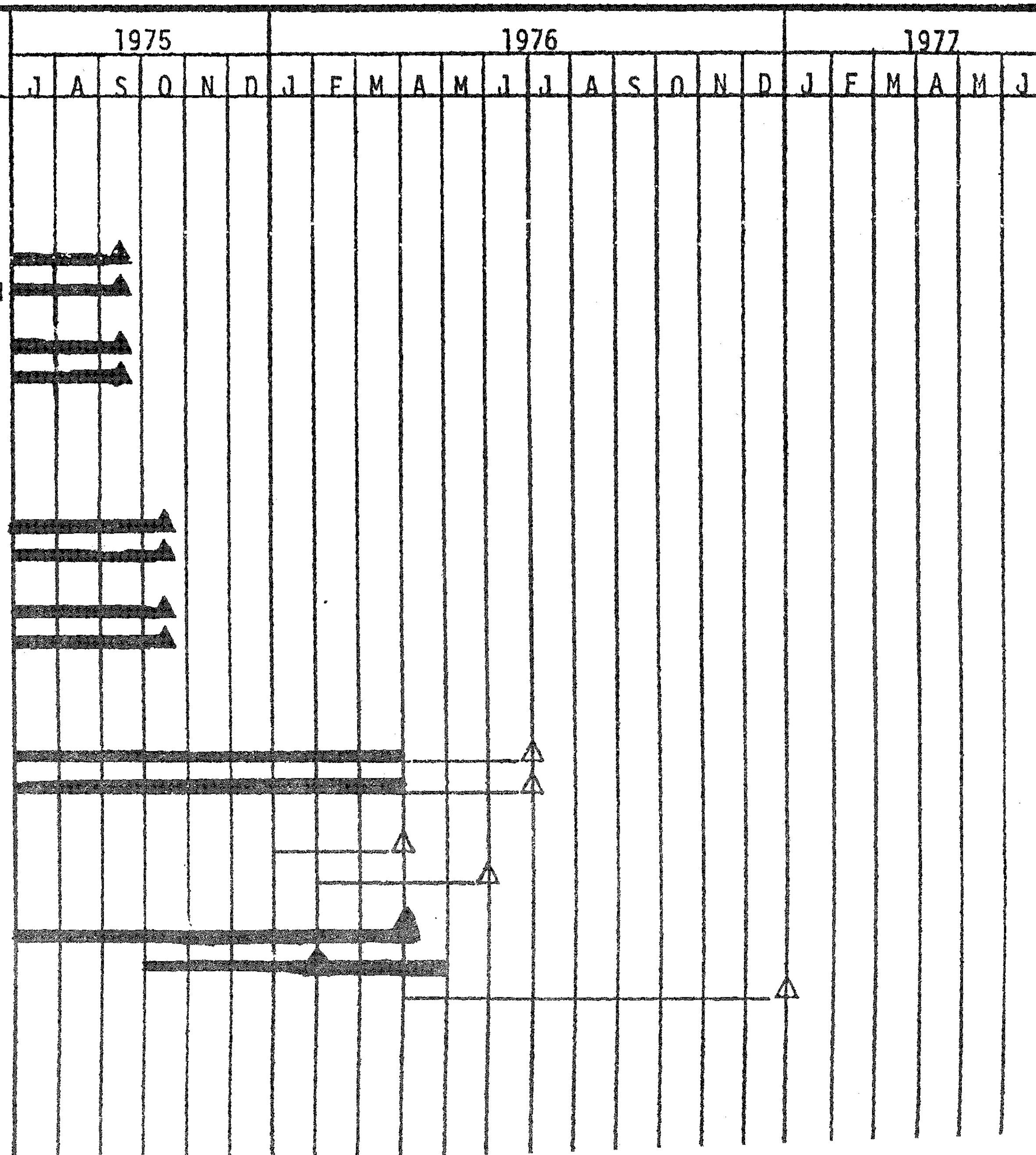


FIGURE I - FIRESIDE CORROSION TASK I - WORK BREAKDOWN STRUCTURE AND MASTER SCHEDULE (SHEET 3 OF 4)

WORK BREAKDOWN STRUCTURE	1975	1976	1977
	J A S O N D	J F M A M J J A S O N D	J F M A M J

<u>Subtask 4 - Establish Test Facilities</u>

1. Facilities Selection
   a. Identify Candidate Facilities and Characteristics
   b. Facility Adaption Estimates
2. Fuel Facility Modifications
   a. Morgantown Facility Availability
   b. Back-up GE Facility (Initial Test) — Not Needed
   c. Lo-BTU Gas Confirmation Test Facility
3. Turbine Simulator
   a. Initial Tests
   b. Confirmation Tests

<u>Subtask 5 - Prepare Test Specimens</u>

1. Initial Test Specimen Preparation
   a. Nozzle Cascade Preparation
   b. Nozzle Leading Edge Cooling Pin Specimen
   c. Bucket Leading Edge Cooling Pin Specimen
   d. Screen Test Corrosion Disc Procurement
2. Confirmation Test Piece Prep.
   a. Nozzle Cascade
   b. Bucket Cascade

FIGURE I - FIRESIDE CORROSION TASK I - WORK BREAKDOWN STRUCTURE AND MASTER SCHEDULE (SHEET 4 OF 4)

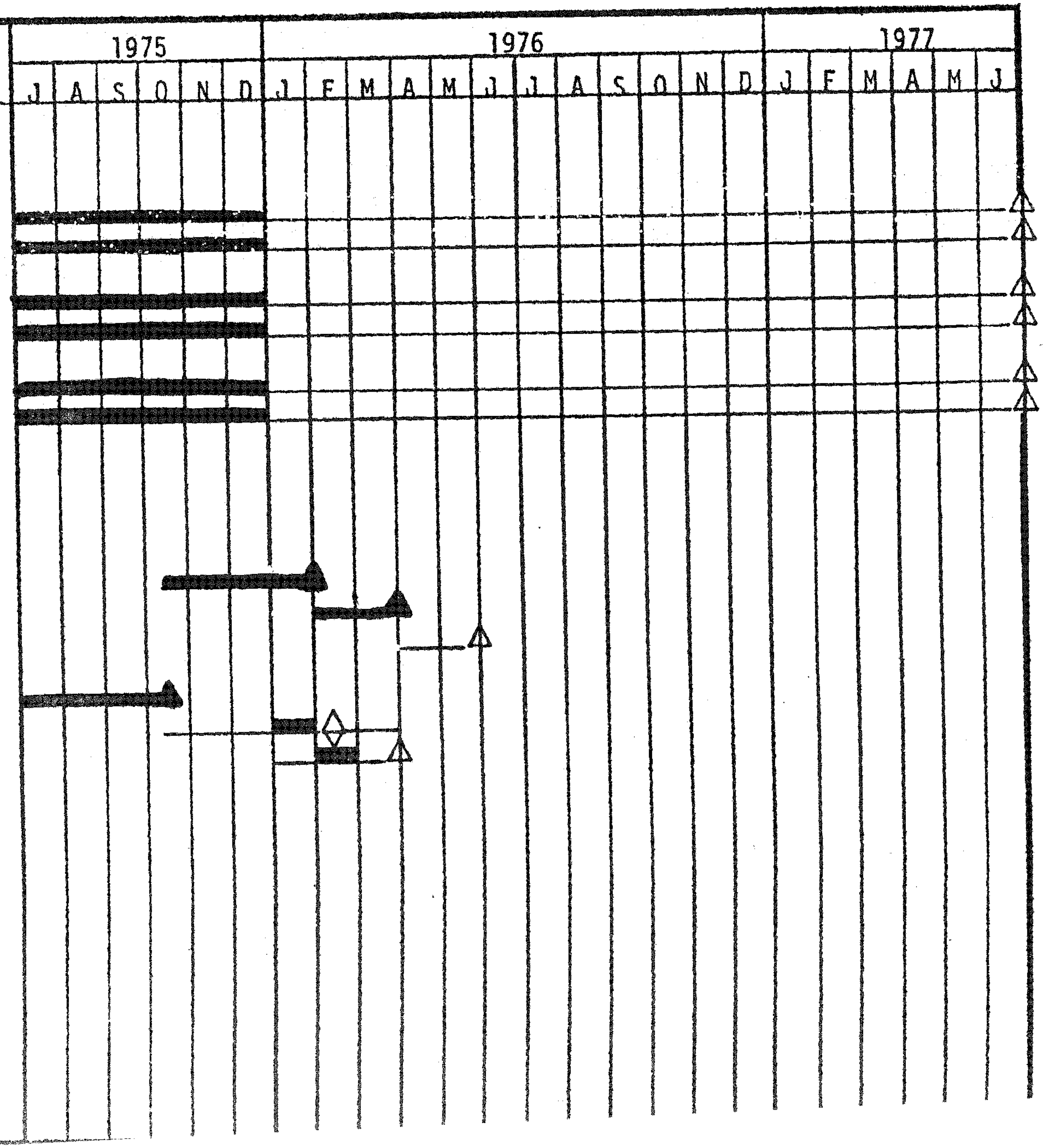
WORK BREAKDOWN STRUCTURE

Subtask 6 - Program Management

1. Program Direction
   a. Technical Direction
   b. Budget Control
2. Program Coordination
   a. Technical Coordination
   b. Budget Control
3. Program Monitoring
   a. Technical Progress
   b. Financial Monitoring
   c. Scheduling

Subtask 7 - Conduct Tests (Initial and Screening

1. Lo-BTU Gas Initial Test
   a. Test Set-Up and Pre-Test Analysis
   b. Conduct Test & Monitoring
   c. Post-Test Analysis
2. COED Fuel Initial Test
   a. Test Set-Up & Pre-Test Analysis
   b. Test Conduction and Monitoring
   c. Post-Test Analysis



fall into the province of Subtask 3 Establish Test Conditions.

COED fuel was selected in September as the low-sulfur coal-derived liquid fuel for the Initial Tests. This selection was based primarily on the fact that COED fuels were the only known source of large quantities of liquid coal-derived fuels available for the Initial Test program. With but a limited amount (6,000 gallons) of COED fuel able to be allocated to the program by ERDA, it was decided to perform most of the Initial Testing using a synthetic COED fuel", i.e., a fuel base to which the contaminants found in the actual coal-derived fuel are chemically added. (This approach was successfully employed by GE on the MARAD Project, US Department of Commerce contract 0-35510, where "synthetic residual fuel oil", was developed.) COED oil derived from Pittsburgh coal was selected at that time, when it was found that it had the lowest purities of those COED oil samples tested.

This resulted in the successful completion of Subtask 2. Questions involving test conditions to be used for synthetic fuels, i.e., number and types of Turbine Simulator runs needed to establish the technical validity of deposition rates, corrosive species and ash morphology, fall into the province of Subtask 3-Establish Test Conditions.

As described in Quarterly Progress Report No. 2, work in Subtask 3-Establish Test Conditions has been impacted by the need to develop a synthetic coal-derived liquid fuel as a substitute for COED fuel. As indicated in the previous quarterly report, Subtask efforts had to be periodically reoriented during the last quarter of 1975. Initial plans had called for test conditions to be those established for Initial Tests in GE's proposal. However, circumstances necessitated reorienting subtask efforts to establish test parameters--and hence test conditions--on the basis of the nature and availability of fuels to be used for Initial Testing.

Following several iterations based on circumstances (See Quarterly Report No. 2), the following plan was established:

- Initial Test run #1: Thirty-five hour test involving COED fuel received" (Na+K<0.2ppm)
- Initial Test run #2: Thirty-five hour test involving COED fuel contaminant levels were chemically increased to reflect contaminant levels representative of liquid coal-derived fuels in general.

• Subsequent Initial Test runs: One hundred hour tests involving a fuel base to which contaminants (Na, K, etc) are chemically added.

While test runs 1 and 2 were performed this quarter, plans for subsequent test runs had to be altered when the previously considered plan to dope No. 2 distillate was found to be technically unfeasible. An alternate approach--to use an appropriate coal-oil base to which small amounts contaminant-bearing by-products (sludge) from either the Synthoil Process or some other coal liquefaction process is added--was established. Three suitable candidate commercially available coal-oil bases (FCC slurry oil, coal-tar distillate oil and anthracine oil) have been identified. Evaluations of these candidates, currently in process, involve chemical analysis of the fuel-oil base, the fuel-oil base sludge mixture, and testing the dispersability of sludge from the Synthoil Process within the fuel oil base. Results of these candidate bases are being compared with compatible data from similar tests initially made using COED fuel as a datum.

It should also be noted that the sludge would not disperse at all in No. 2 distillate fuel oil, thereby highlighting the fundamental differences in chemistry between coal-based and oil-based fuels.

Test conditions for the Screening Tests were established on the basis of thermochemical analysis, in lieu of initial test results. Two test conditions were established early this quarter, which permitted initiation of these tests in late February. Two additional test conditions were derived in March.

Test conditions for the Initial low-BTU Gas Testing at ERDA/MERC were discussed and agreed upon during the GE-ERDA interface meeting in November. Two test runs each of one hundred hours duration are involved; the two different coal feedstocks described under Subtask 2 are to be used. GE's analysis requirements for the coal feedstocks and low-BTU gas during these tests were furnished to ERDA following this meeting. Samples of the coal feedstacks to be used in these tests were received from ERDA/MERC, and subjected to chemical analyses. The results of these chemical analyses are being used to predict via thermochemical analysis the corrosive species that would be formed in the combustion products.

In Subtask 4-Establish Test Facilities, the test facilities to be used for the Initial, Screening and Confirmation Tests were selected in September on the basis of a systems analysis (see Quarterly Progress Report No. 1).

Modifications to the test facilities included the following:

- Initial Liquid Coal-Derived Fuel Tests

  Preparations included Turbine Simulator transition piece modifications to permit insertion of film-cooled "nozzle simulation pins", refurbishment of the turbine simulator's MS-3002 first stage nozzle segment and fabrication of a new exhaust duct arrangement to permit insertion of "bucket simulation" cooling pins and allow them to experience a flow having a Mach Number of approximately 0.5.

- Initial Low-BTU Gas Testing

  The Turbine Simulator Skid for Low-BTU Gas Initial Testing was completed and delivered to ERDA/MERC on February 9. This skid is very similar to the Schenectady turbine simulator. Modifications, however, were needed to reflect the unique ERDA/MERC facility, e.g., combustor pressure of two atmospheres absolute. This required modifications to the combustion system as well as ducting, downstream of the simulator, leading to the stack.

- Screening Tests

  No facility changes were needed in GE's small burner test rig to accommodate this program.

Confirmation Test preparations were initiated this quarter, with attention being focused on turbine simulator arrangements needed to accommodate these tests.

In Subtask 5-Prepare Test Specimens, all specimens for the Initial Tests and Screening tests were available by the end of 1975. These include:

- Initial Coal-Derived Fuel Tests

  (a) MS-3002 first-stage nozzle segment, a four-blade, full-sized standard hardware item made of FSX-414. This segment, used on earlier programs, was refurbished for use on this program.

  (b) Air-cooled cylindrical pins of Hastelloy-X, used to evaluate nozzle leading edge and bucket leading edge cooling. These pins are intended to provide early information about the effects of the combustion products on leading edge cooling holes and to evaluate air-film cooling. The results are intented to aid in fixing the design for the nozzle and bucket cascades to be used in the Confirmation Tests. Four nozzle pin designs and four bucket pin designs are being evaluated.

(c) One tab sample of IN-738 welded onto the trailing edge of the Turbine Simulator nozzle segment for evaluation during the test program.

- Initial Low-BTU Gas Tests

(a) MS-3002 first-stage nozzle segment identical to that in the Turbine Simulator at Schenectady.

(b) Cylindrical cooling pin simulations to evaluate nozzle leading-edge air-film cooling that are identical to those employed in the Turbine Simulator at Schenectady. The low (two atmosphere gas pressure) limitation inherent in the ERDA/MERC facility however precludes the acquisition of valid technical data from bucket simulation pins during the low-BTU gas tests; hence, these are only used in the Initial Tests in Schenectady.

- Screening Tests

Standard small burner corrosion test discs of the twenty-one different alloys, coating, claddings, and ceramics selected in Subtask 1, were prepared.

Design of the nozzle and bucket cassade specimens for Confirmation Testing was initiated this quarter. Two design candidates for these cascades are being evaluated.

Key program management-related events and results during the past quarter encompassed the following:

(a) Visit of the new ERDA Program Manager, Mr. Jack Smith to Schenectady on January 29 to review program background, discuss the status of work to date and tour test facilities being used to support technical efforts.

(b) Execution of a contract modification covering the transportation of COED fuel and development of "synthetic liquid coal-derived fuel."

(c) A technical review of the liquid coal-derived fuel situation described under Subtask 3 was held in Washington on March 1, 1976. GE gave presentations on test results to date and steps being taken to develop a coal-based "synthetic liquid coal-derived fuel."

As a result of the current schedule problems produced by the liquid coal-derived fuel-related matters discussed earlier, program schedules, availability of test facilities and resources, and various alternate program plans and options have been given considerable attention. An explicit revised schedule and program plan will be established as soon as they can be developed on the bases of factual data.

Efforts in Subtask 7-Conduct Initial and Screening Tests, were initiated this quarter in accordance with the revised plans described above under Subtask 3-Establish Test Conditions. Status and results to date are as follows:

- Initial Coal-Derived Liquid Fuel Tests

  Two test runs, each of thirty-hours duration, were performed at a firing temperature of 1950°F. These runs used up the 6000 gallons of Government-furnished COED fuel allocated to this program. The first test employed the fuel "as received", and the fuel use in the second run was doped to contain 3ppm Na and 3ppmK. Evaluations of test data indicated the presence of condensed potassium-based and sodium-based corrosive species on the test specimens; these probably formed during the second test run. It is expected that these would have caused hot corrosion attack to have taken place in a nickel-based alloy, had the test been run for an extended period of time, i.e., several thousand hours.

  Future test runs are being deferred, pending the selection of a suitable coal-oil base from which synthetic coal-derived liquid fuel can be synthesized.

- Initial Low-BTU Gas Testing

  Test arrangement shakedown tests, initiated in March, uncovered several areas in need of minor modifications. These are in process of being made, with actual testing expected to be initiated in April.

- Screening Tests

  Screening Tests were initiated in late February, employing two test conditions established by Thermochemical analysis. Two additional test conditions, derived in March, are in process of being implemented.

Section 3

DETAILED DESCRIPTIONS OF TECHNICAL PROGRESS

SUBTASK 1 SELECT ALLOYS, COATINGS, CLADDINGS AND CERAMICS

WORK ACCOMPLISHED

This work was completed during the third quarter of 1975 and reported in Quarterly Progress Report No. 1.

SUBTASK 2-SELECT FEEDSTOCKS

WORK ACCOMPLISHED

This work was completed during the fourth quarter of 1975 and reported in Quarterly Progress Report No. 2.

SUBTASK 3-ESTABLISH TEST CONDITIONS

(a) Test Parameter Definition Initial Coal-Derived Liquid Fuel Tests

As described in depth in Quarterly Technical Progress Report No. 2, the sodium (Na), potassium (K) and ash contents of the COED fuel as delivered were substantially lower than in the original sample of COED delivered from the manufacturer (FMC) in September 1976. As a result, the first Initial Coal-Derived Liquid Fuel Test run on the turbine simulator was performed with the clean COED as delivered (Na + K = 0.2 ppm) for 30 hours at a firing temperature of 1950^{o}F. Conditions for the second 30 hour test were the same except this COED fuel was doped with 3 ppm Na and 3 ppm K. Results of these tests are described in detail under Subtask 7 herein.

Because of the unavailability of a coal-derived fuel for the remaining Initial Tests, the synthesis of contaminated coal oil will be necessary to meet the objectives of the Initial Tests. The suggestion had been made in Quarterly Technical Progress Report No. 2 that doping of No. 2 fuel oil would provide a suitable synthetic coal oil. As the requirements for doping the No. 2 oil were studied in depth early in the past quarter, questions arose with regard to the feasibility of this approach due to the fundamental chemical differences between coal-derived oils and conventional petroleum products (No. 2 distillate). Consequently, it does not appear that doped No. 2 fuel oil can be considered as a simulator of a coal-derived liquid fuel.

Coal fuel simulation requires that the chemical composition, physical properties, and ash contaminants and amounts be similar to a coal-derived liquid fuel. Obviously, the most critical of these from a corrosion/deposition standpoint is the amount of ash and the ash chemistry.

By-product solids (sludge) from a coal liquefaction process should be representative of the ash composition in coal-derived liquids. Addition of a small amount of this sludge to a liquid oil similar to a coal oil should result in a good simulation, since the ash would then be in the same proportion and of the same type as in the original coal oil.

Consequently several pounds of sludge from the Synthoil Process were obtained from ERDA-Pittsburgh. Table 1 shows the compositon of the Synthoil sludge, a breakdown of the ash components, and the results of a particle study. The high ash content indicates that only small amounts of sludge would have to be added to give a coal oil with 0.1% ash by weight (1000 ppm).

The ideal liquid fuel matrix to be doped with the coal ash would be one that has the same characteristics as a typical coal-derived liquid fuel both in chemical composition and physical properties. However, a 100% simulation is probably not necessary for the corrosion and deposition study.

A liquid fuel matrix which has the same aromatic characteristics as a coal-derived fuel is the most desirable. The carbon content of the combustion ash, which affects hot corrosion, can depend on the aromaticity of the liquid fuel being burned. Aromatic liquids also have much greater solvent/dispersant power for the "dopants".

A parameter used to evaluate aromaticity is the hydrogen/carbon atom ratio (H/C). Highly aromatic liquids have an H/C ratio near 1.0. No. 2 Fuel Oil with an H/C ratio of 1.75 is paraffinic rather than aromatic. A comparison of different fuels is shown in Figure 2. The three liquids shown at the bottom of the chart are aromatic liquids which would simulate the aromaticity of typical coal-derived liquid fuels. The FCC (Fluid Cat Cracker) Decanted slurry Oil and the Creosote Oil (Coal Tar Distillate) are available in quantity and should be reasonable in cost. The latter is used as a startup coal solvent in the SRC process.

Some laboratory tests were carried out during the past quarter to dissolve or suspend the Synthoil sludge in No. 2 distillate oil, clean COED oil,

TABLE 1

Synthoil Sludge

%C	41.9	
% oil	17.9	(petroleum ether solubles)
% ash	40.8	

Ash Components (ppm)

V	600
Na	740
K	5400
Ca	770
Pb	20
Fe	~ 102000
Si	~ 102000
Al	~ 32640
Ti	~ 2440
Mg	~ 816
Cu	~ 163
Ba	~ 122
M_N	~ 82
B	~ 82
Cr	~ 33
Ni	~ 33
Mo	~ 12

TABLE 1 (Continued)

PARTICLE STUDY

Particle size microns	Number in 1 mg. of insoluble material	Remarks
1-5	7.6×10^6	Black opaque. Small number translucent: colorless, gray.
5-10	687,000	Most black opaque. Small fraction translucent: colorless, gray.
10-25	132,000	Most black opaque appeared to be agglomorates of particles < 10 µm. ~ 20% looked like discrete particles. < 10% were translucent colorless.
25-50	17,000	Most black opaque agglomorates of particles < 10 µm. ~ 10% looked like discrete black opaque particles. ~ 10% translucent colorless.
50-100	2500	Black opaque agglomorates having particles < 10 µm. < 10% translucent colorless.
100-250	560	Black opaque agglomorates having particles < 10 µm.

FCC slurry oil (Mobil) and Creosote oil. Analysis of the latter two oils as received are given in Tables 2 and 3 respectively. The FCC slurry oil is a heavy oil with very high viscosity, while the Creosote oil is much lighter. An excess of Synthoil sludge was added to these four fuel bases while the mixtures were heated to 150-175°F and stirred. The mixtures which resulted were allowed to stand for several days. The top portion of each mixture was then considered to be quasi-stable and was poured off and analyzed.

Figure 2 - FUEL AROMATICITY

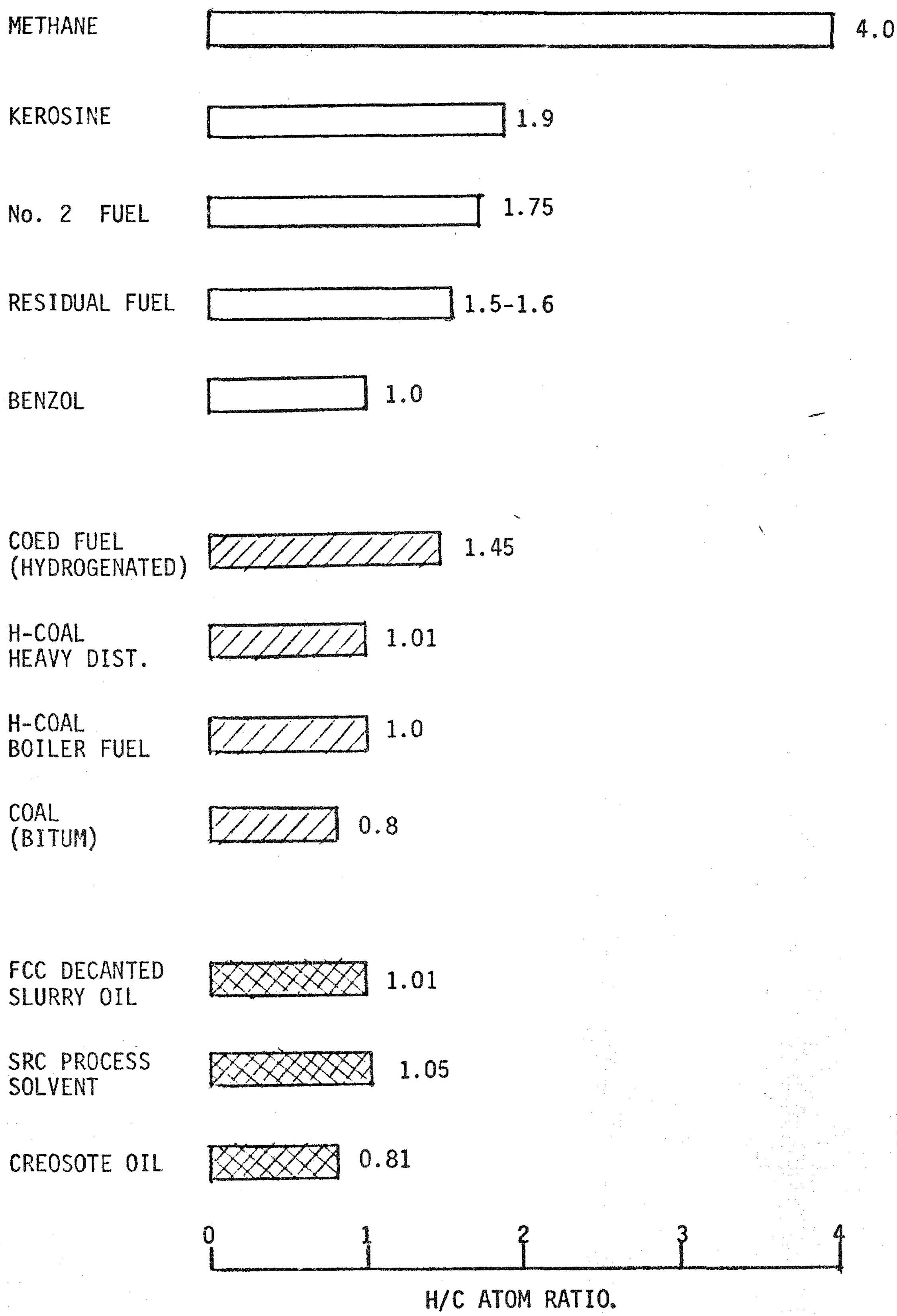


TABLE 2

FCC SLURRY OIL (MOBIL)

Viscosity, CS	
at 100°F	21.35
at 210°F	18.84
% ASH WT %	0.040

ASH COMPONENTS (ppm)

K	0.7
Na	2.3
V	< 0.5
Pb	0.1
Si	~ 81
Al	~ 81
Fe	~ 8
Mg	< 1
Mn	< 1
Cr	< 1
Sn	< 1
Ni	< 1
Ca	< 1
Cu	< 1
Ti	< 1

TABLE 3

CREOSOTE OIL (ALLIED)

VISCOSITY, CS	
at 70°F	13.50
at 100°F	7.01
% ASH WT %	0.0093

ASH COMPONENTS	(ppm)
K	0.4
Na	12.0

Tables 4 through 7 show the ash content and a breakdown of the ash components for the four oil/Synthoil sludge mixtures prepared in the laboratory. With the exception of the No. 2 distillate oil/sludge mixture (Table 4) results of particle studies for the oil/sludge mixtures are also given.

Results of the analyses indicate that:

(1) The coal type oils with lower H/C ratios (i.e. FCC slurry oil & creosote oil) have a much greater disperent power for the Synthoil sludge than No. 2 distillate or COED oil. This is illustrated in Figure 3 where the weight % of Synthoil sludge suspended in the oil matrices studies is plotted as a function of the H/C ratio of the oil. The COED oil, although it is a coal-derived oil, has been hydrogenated and has a H/C ratio approaching conventional petroleum oils.

(2) The ratios of the various ash components (Na & K most importantly) in the Synthoil sludge (See Table 1) and the oil Synthoil sludge mixtures (See Tables 4 through 7)) are roughly the same. This is desirable.

(3) The COED oil/sludge mixture and the Creosote oil/sludge mixture contain a greater proportion of smaller particles than the Synthoil sludge. The particle distribution in the FCC slurry oil/sludge mixture approximates that in the Synthoil sludge. This is due to the fact that the FCC slurry oil is very viscous (See Table 2) and, therefore, the larger particles do not readily settle out. Nevertheless the ash content of even the COED oil was increased from 10 ppm to 5300 ppm by addition of the sludge.

(4) Results of the particle studies are illustrated graphically in Figure 4.

Near the end of the past quarter a second sample of Synthoil sludge was forwarded to GE Schenectady for analysis. The results of this analysis are given in Table 8 and can be compared to the results for the first sample given in Table 1. Contaminant levels and particle size of this second sample were similar to the first sample. ERDA/PERC has indicated that they could supply one barrel (about 400 lbs) of this Synthoil sludge (typical of second sample) for doping with the selected oil base for use in the initial tests. This quantity of sludge would be adequate for doping about 5000 gallons of the selected matrix oil and result in approximately 50 hours of test time.

TABLE 4

#2 OIL/SYNTHOIL SLUDGE

% ASH	0.11

ASH COMPONENTS (ppm)

K	18
Na	1.9
Si	~ 450
Fe	~ 270
Al	~ 120
K	~ 40
Cu	~ 20
Ti	~ 9
Mg	~ 4
Na	~ 3
Ca	~ 1
Ba	~ 0.9
Mn, V	~ 0.5
B,Cr,Z+	~ 0.4
Ni	~ 0.2
Mo	~ 0.05

TABLE 5

COED Oil/Synthoil Sludge Mix

% ash 93

Ash Components (ppm)

K	93
Na	10
Si	~ 1300
Fe	~ 1300
Al	~ 500
Ti	~ 27
Mg	~ 16
Ni	~ 11
B, Ca,	~ 2.7
Cu, Ba	~ 2.7
M_N	~ 1
C_R	~ 0.3
Pb	~ 0.3
Mo	~ 0.2
V	~ 0.2

TABLE 5 (Continued)

PARTICLE STUDY

Particle size microns	Number in a 1 mg. sample	Remarks
1-5	1.7×10^7	Black opaque. Some translucent colorless.
5-10	491,000	Black opaque. Small fraction translucent colorless.
10-25	61,000	Most black opaque agglomorates having particles < 10 µm. ~ 20% looked like discrete particles. ~ 10% were translucent colorless.
25-50	6400	Black opaque agglomorates having particles < 10 µm. ~ 10% translucent colorless.
50-100	1800	Black agglomorates having particles < 10 µm. < 10% translucent: colorless, gray.
100-250	240	Black opaque agglomorates having particles < 10 µm.

TABLE 6

FCC Slurry Oil/Synthoil Sludge

% ASH 6.63

ASH COMPONENTS (ppm)

K		650
Na		81
Si	~	13000
Fe	~	7000
Al	~	4000
Ti	~	300
Mg	~	80
Ca	~	30
Cu	~	30
Ba	~	20
B	~	10
Zr	~	10
Mn	~	10
V	~	10
Cr	~	5
Ni	~	3
Pb	~	2
Mo	~	1

TABLE 6 (Continued)

PARTICLE STUDY

Particle size, microns	Number in a 1 mg. sample of particulate matter insoluble in hot solvent.	Remarks
1-5	8.6×10^6	Black opaque. Small number tanslucent.
5-10	515,000	Black opaque. ~ 10% translucent: colorless gray.
10-25	157,000	Most were black opaque agglomorates of particles < 10 µm. ~ 15% discrete black opaque particles. ~ 10% translucent: colorless, gray.
25-50	10,000	Black opaque agglomorates of particles < 10 µm. Small number shiny black flakes. ~ 20% translucent: colorless, gray.
50-100	1900	Black opaque agglomorates of particles < 10 µm. ~ 10% translucent colorless.
100-250	112	Black opaque agglomorates having particles < 10 µm.

TABLE 7

Creosote Oil/Synthoil Sludge

% ASH 3.38

ASH COMPONENTS (ppm)

K		380
Na		70
Si	~	8000
Fe	~	5000
Al	~	3000
Mg	~	80
Ti	~	50
Ca	~	30
Cu	~	20
V	~	10
Ba	~	10
B	~	10
Mn	~	8
Zr	~	5
Cr	~	4
Pb	~	3
Ni	~	2
Mo	~	2
Sn	~	1

TABLE 7 (Continued)

PARTICLE STUDY

Particle size, microns	Number in a 1 mg. sample of particulate matter insoluble in hot solvent	Remarks
1-5	1.15×10^7	Black opaque. Some translucent: colorless, gray.
5-10	418,000	Black opaque. Small fraction translucent colorless.
10-25	44,000	Black opaque agglomorates particles < 10 µm. ~ 40% Black opaque looked like discrete particles. ~ 10% translucent colorless.
25-50	6000	Black opaque agglomorates having particles < 10 µm. ~ 15% translucent colorless.
50-100	1700	Black opaque agglomorates having particles < 10 µm. ~ 20% translucent colorless.
100-250	208	Black opaque agglomorates having particles < 10 µm. ~ 5% translucent colorless

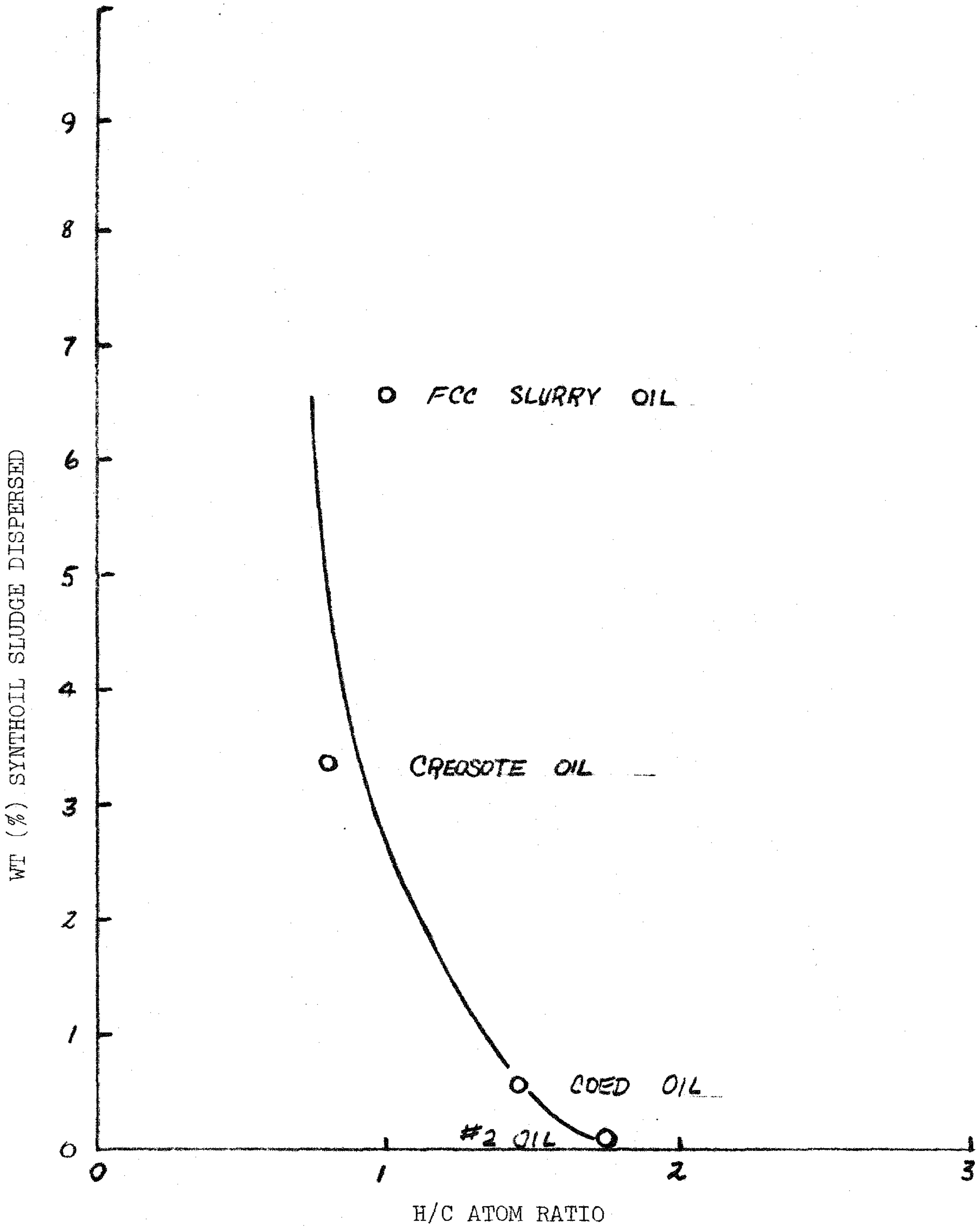


Figure 3 - DISPERSANT POWER FOR SYNTHOIL SLUDGE OF SEVERAL OILS

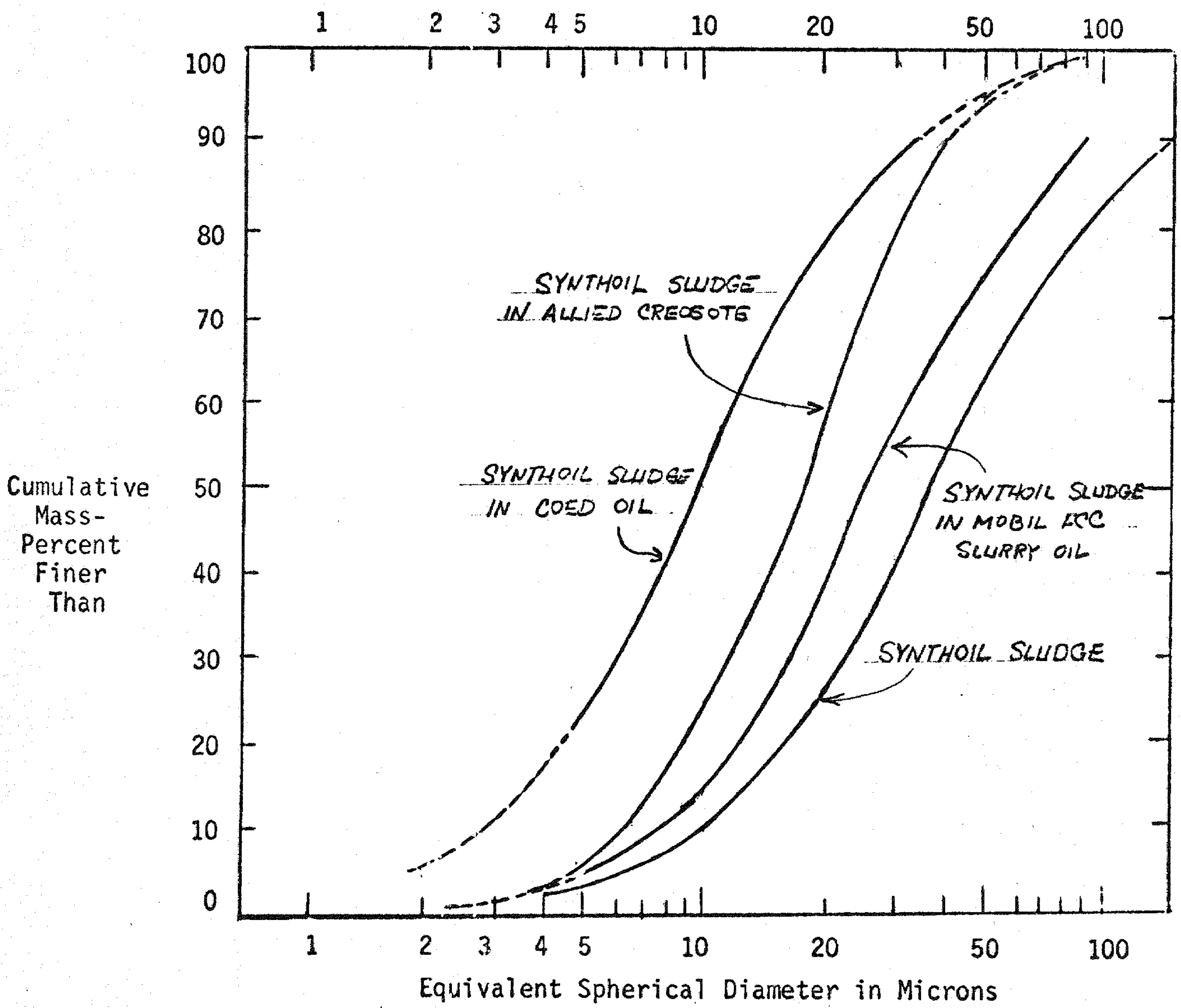


Figure 4 - SYNTHOIL SLUDGE DISPERSED OIL

PARTICLE SIZE DISTRIBUTION

TABLE 8

SYNTHOIL SLUDGE #2

% ASH 46.7

<u>ASH COMPONENTS (ppm)</u>

K		5200
Na		570
V		66
Pb		20
Si	~	140,000
Fe	~	80,000
Al	~	40,000
Ca	~	3,000
Ti	~	700
Mg	~	400
Cu,Mn,Ba	~	100
B	~	60
Ni,Ze	~	40
Cr	~	30
Mo	~	10

TABLE 8 (Continued)

PARTICLE STUDY

Particle size microns	Number in a 1 mg. sample of material insoluble in hot solvent.	Remarks
1-5	6.4×10^6	Black opaque. Translucent: colorless, gray.
5-10	393,000	Black opaque. Translucent: colorless, gray, amber.
10-25	93,000	~ 35% black opaque - looked like discrete particles. Black opaque - agglomorates having particles < 20 µm. ~ 25% translucent: colorless, tan, gray, amber.
25-50	15,000	Black opaque agglomorates having particles < 10 µm. ~ 25% black opaque looked like discrete particles. ~ 20% translucent colorless.
50-100	2600	Black opaque - both discrete and agglomorates having particles < 10 µm. ~ 15% translucent colorless.
100-250	96	Black opaque - agglomorates, particles < 10 µm. Most translucent: colorless, tan.

(b) Establish Test Parameters - Initial Low-BTU Gas Tests

The test envelope for these tests to be performed at ERDA/MERC (using the turbine simulator skid in conjunction with an ERDA gasifier) are as follows:

- Conditions - Nozzle Cascade

T_{out}	2200°F (max)
P_{in}	2.2 atm.
P_{out}	1.0 atm.

- Test Fuels and Test Runs

(1)	Low BTU Gas, water washed from Illinois #6 coal	1 - 100 hour test
(2)	Low BTU gas, water washed from Montana Rosebud coal	1 - 100 hour test

- Velocity/Cooling - MS 3002 impingement cooled nozzle operated at exit velocity of Mach 1.0
  Nozzle pin samples at Mach 0.1

Samples of the two feedstocks (Illinois #6 and Montana Rosebud Coals) which were received from ERDA/MERC were analyzed during the past month. The results are shown in Table 9.

The results of these chemical analyses will be used to predict via thermochemical analyses, the corrosive species that will form in the combustion products of the low BTU gas tests.

(c) Establish Test Parameters Screening Tests

Screening tests were initiated in February in the 1 atmosphere small burner test rigs (essentially flame tunnels having a hot gas velocity of 70 fps) at specimen metal temperatures of 1600°F and 1800°F. Specimens of the twenty-one materials selected in Task 1 will be tested for up to 1000 hours, with longer exposure times planned for selected materials.

All of these tests are run using No. 2 fuel oil doped with combinations of Na and K. The use of doped No. 2 fuel oil is justified in the materials Screening

TABLE 9

COAL ANALYSIS

ILLINOIS #6

% Ash	8.52
% S	3.46
ppm V	12
ppm Na	140
ppm K	550
ppm Pb	100

Approx ppm In Coal	
Si	20,000
Fe	20,000
Al	6,000
Tl	300
Ca	240
Mg	160
Nl	80
B	40
Ba, Cu Mg	20
Cr	7
Mo	6

MONTANA ROSEBUD

% Ash	9.07
% S	0.80
ppm V	4
ppm Na	283
ppm K	2,600

Approx ppm In Coal	
Si	27,000
Al	18,000
Fe	2,500
Mg	1,300
Ca	900
Tl	400
Mn	100
B	50
Pb	40
Ba	9
Cr	6
Mo	6

Tests, since the objective of these tests is to evaluate the effects of the important alkali trace metal contaminants, Na and K expected in coal-derived fuels, on the surface stability of the selected materials. It is, therefore, not necessary to simulate the other properties of a coal-derived fuel for corrosion tests in the small burner rigs.

After one week the tests had to be stopped because the amount and form of the salt condensate in the screening tests was unsatisfactory and the contaminant levels for these tests were re-evaluated. A table listing tenative new contaminant levels for the screening tests is given in Section (d) under this subtask together with documentation of the basis for the proposed levels. Before resuming the materials screening tests, tests involving placing a platinum disc in each of four small burner rigs currently operating at four of the newly specified test conditions were initiated. Conditions are: (a) 115 ppm Na, 34.6 ppm K, 1600°F; (b) 90.5 ppm Na, 86.5 ppm K, 1600°F; (c) 353 ppm Na, 265 ppm K, 1800°F (d) 299 ppm Na, 482 ppm K, 1800°F. After about 100 hours of operation the platinum discs will be removed and the amount and composition of the deposits will be checked to see how closely they match thermochemical predictions. Based on these results screening tests will be modified, if necessary, and re-initiated.

(d) Thermochemical Analysis

A decision was made to redefine the Screening Test conditions such that the corrosive effects of condensates formed from Na and K contamination of fuel could be compared directly to those observed for Na-containing condensates from the standard small burner rig test at 1600°F using 125 ppm Na as synthetic sea salt. The basis for specification of contaminant levels in the screening tests was to dope the fuel with Na and K to levels which give the same molar flux of alkali metals (Na + K) condensing as in the standard small burner rig test with 125 ppm Na as sea salt. Thermodynamic analysis has shown that at a test temperature of 1600°F in the standard small burner rig test with sea salt one atom out of every 2.5×10^5 atoms in the combustion products would condense if the combustion products in the small burner rig were brought to equilibrium. The actual amount of condensation in the small burner rig is less than the above amount since condensing atoms must diffuse through a boundary layer to specimen surfaces. The approach to evaluating the effects of Na + K in the screening test therefore, is to specify fuel contaminant levels that will result in a maximum (equilibrium) condensation of one atom out of every 2.5×10^5 in the combustion products at both 1600°F and 1800°F. The ratio of Na/K in the tests is fixed so that the condensate will be a liquid solution of Na and K sulfates (the lowest Na/K ratios would yield a solid deposit).

Thermochemical calculations were carried out during the past quarter and Table 10 which follows presents the Na and K levels obtained. These values are clearly non-linear with respect to the composition of the condensate as a result of differences in thermochemical properties and solution non-ideality. The results illustrate the requirement for a detailed calculation of test condition chemistry to compensate for variations on the standard small burner rig test with sea salt. All contaminant levels are experimentally obtainable and straight forward measurements of the K/Na ratio in condensate deposits should permit verification of the validity of the predictions. The contaminant levels in the fuel for the screening test are several orders of magnitude higher than what could be tolerated in the turbine because the test has to be accelerated by a factor of about 10 in order to get results in a reasonable period of time and because the small burner rig is run at one atmosphere where the turbine buckets operate at about seven atmospheres.

TABLE 10

SODIUM AND POTASSIUM LEVELS PREDICTED BY THERMOCHEMICAL ANALYSES

	$X_{K_2SO_4}$*	WT ppm in Fuel Na	K
	0.1	115	35
1600°F	0.2	103	62
	0.3	91	87
	0.4	79	108
	0.1	353	265
1800°F	0.2	328	386
	0.3	299	482
	0.4	295	579
	0.5	257	615
	0.6	246	633
	0.7	243	647

*mole fraction of K_2SO_4 in condensate.

WORK FORECAST

(a) Establish Test Conditions - Initial Coal-Derived Liquid Fuel Tests

- The components for a synthetic coal-derived fuel and the procedure for producing this fuel will be specified during the forthcoming quarter.
- Contaminant levels in the synthetic fuel for the remaining Initial Tests will be specified during the forthcoming quarter.

(b) Establish Test Conditions - Initial Low-BTU Gas Tests

- Work is complete

(c) Establish Test Conditions - Screening Tests

- Additional sets of test conditions will be established in April based on the results of work to date.

(d) Thermochemical Analyses

- Analyses will fix additional conditions for the screening tests.
- Analyses to predict condensate compositions from combustion of low BTU gas will be completed.

SUBTASK 4 - ESTABLISH TEST FACILITIES

(a) Initial Coal-Derived Liquid Fuel Tests

This work was completed in October, 1975 and the test facility checked out in December, 1975.

(b) Initial Low BTU Gas Tests

The combustor and Turbine Simulator assembly for the low BTU gas tests was shipped by truck from the GE Research and Development Center on February 6, 1976. It arrived without apparent damage at the ERDA - Morgantown Energy Research Center on February 9, 1976. The control panel and instrumentation racks were shipped at the same time. A listing of the combustor skid components and the instrumentation shipped to ERDA/MERC are given in Table 11. The combustor skid components identified in Table 11 are shown in Figure 5.

Description of Test Apparatus

The combustor and Turbine Simulator assembly is shown schematically in Fig. 4; the lettered components are identified in the attached list. Also, photographs of the assembly and selected components are shown in Figs. 6-13.

TABLE 11

GE EQUIPMENT SENT TO MORGANTOWN

I. Combustor Skid

A. Two outer casings; one with added hand holes and windows.

B. Two combustion liners; one modified to fit half size transition piece.

C. Two head-end cover plates.

D. Two pipe Tees; one 16" x 16" x 16", Other 16" x 16" x 10".

E. One inner liner - elbow.

F. Fuel nozzle for preheater.

G. Fuel nozzle for main chamber.

H. Four flanges; two with glass windows, one with quartz.

I. Two spark plug assemblies (pneumatically positioned).

J. Two ignition transformers with leads.

K. One flow sleeve for main combustor Tee.

L. One instrumented transition piece.

M. One turbine simulator with clamping plate and probe sleeve.

N. One cover plate for mounting turbine simulator.

O. One pipe reducer (16" to 10".)

P. One mounting skid.

Q. One Magnahelic ΔP gage; 2 psi.

R. One Ashcraft Bourdon test gage. 30 psig

S. One Honeywell Protectorelay RA890G with ultraviolet flame detector C7027A.

T. Two Asco solenoid air valves.

TABLE 11 (Cont'd)

II. Instrumentation

A. Inconel probe 3/8" OD x 36".

B. One Millipore filter holder, 90mm.

C. One FP Rotameter.

D. One sample-line water trap.

E. One control rack with Newport over-temperature controller.

F. One rack with Bendix Total Hydrocarbon analyzer, L + N recorder, calibration gas.

G. One rack with Beckman 865 Infrared Analyzer for CO, calibration gas, and Beckman E2 Oxygen analyzer.

H. One rack with Beckman 951 NO/NO_2 chemiluminescent analyzer with L + N recorder and calibration gas.

I. One rack with 12 point L + N thermocouple temperature recorder.

J. Water cooled probes.

K. One Thomas diaphragm pump 727CA39.

III. Miscellaneous

The outer carbon-steel casings have standard pipe flanges and are bolted together in the form of a letter H. The casing assembly is strapped to an I-beam skid measuring 7 ft by 10 ft which is equipped with hook eyes for lifting.

Metered air (about 18 psig) from a compressor (not shown) enters the preheater section and passes through the preheater combustor liner; this is a conventional liner and similar to the one shown in Fig. 8 except that the exit end is not tapered down. Natural gas is burned inside the liner to raise the air temperature to about 570°F which is a temperature typical of the compressed air in a conventional machine. In the process the O_2 concentration of the air falls from 21% to about 19% by volume. The hot vitiated air then passes through the reducer section (which forms the cross-over of the H) into the main combustor section. The temperature and gas composition are measured in the cross-over.

Inside the main combustor section, the vitiated air is forced to flow downstream around the end of the flow sleeve to cool the region around the turbine simulator. It then flows back upstream between the flow sleeve and the transition piece, through the Δp screen and on into the main combustor liner. The down-stream end of the flow sleeve and the Δp screen can be seen in Fig. 9. The Δp screen consists of two identical stainless steel annuli with 20 holes; they can be rotated relative to each other to vary the open area and hence the pressure drop in the air flow between the cooling pins and the main combustor. With no air flowing, the adjustment can be made through a hand hole in the main combustor casing.

The main combustor liner (Hastalloy X) is seen in Fig. 8. The cylindrical section is the same size as used in a commercial MS5000 machine. The tapered-down exit end has been added to slide inside the transition piece. (The transition piece is that duct which carries the hot products of combustion from the combustion liner to the turbine simulator.) The low-BTU-gas is injected into a swirling air flow at the head end of the liner to form the primary zone mixture; dilution air is added downstream to achieve a product gas temperature of 1950°F in the transition piece.

The transition piece carries the experimental cooling pins; it will be described under a separate heading.

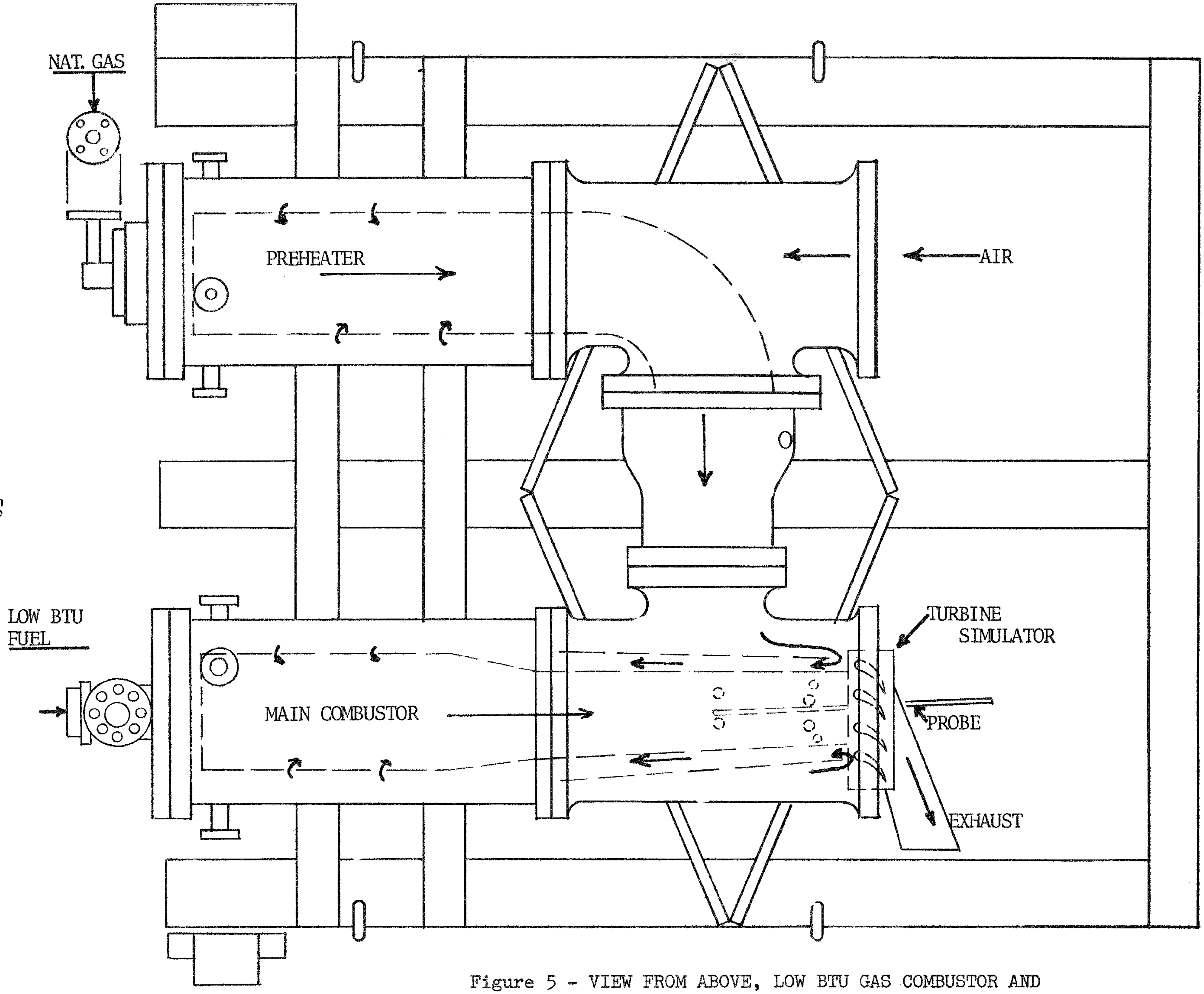


Figure 5 - VIEW FROM ABOVE, LOW BTU GAS COMBUSTOR AND TURBINE SIMULATOR

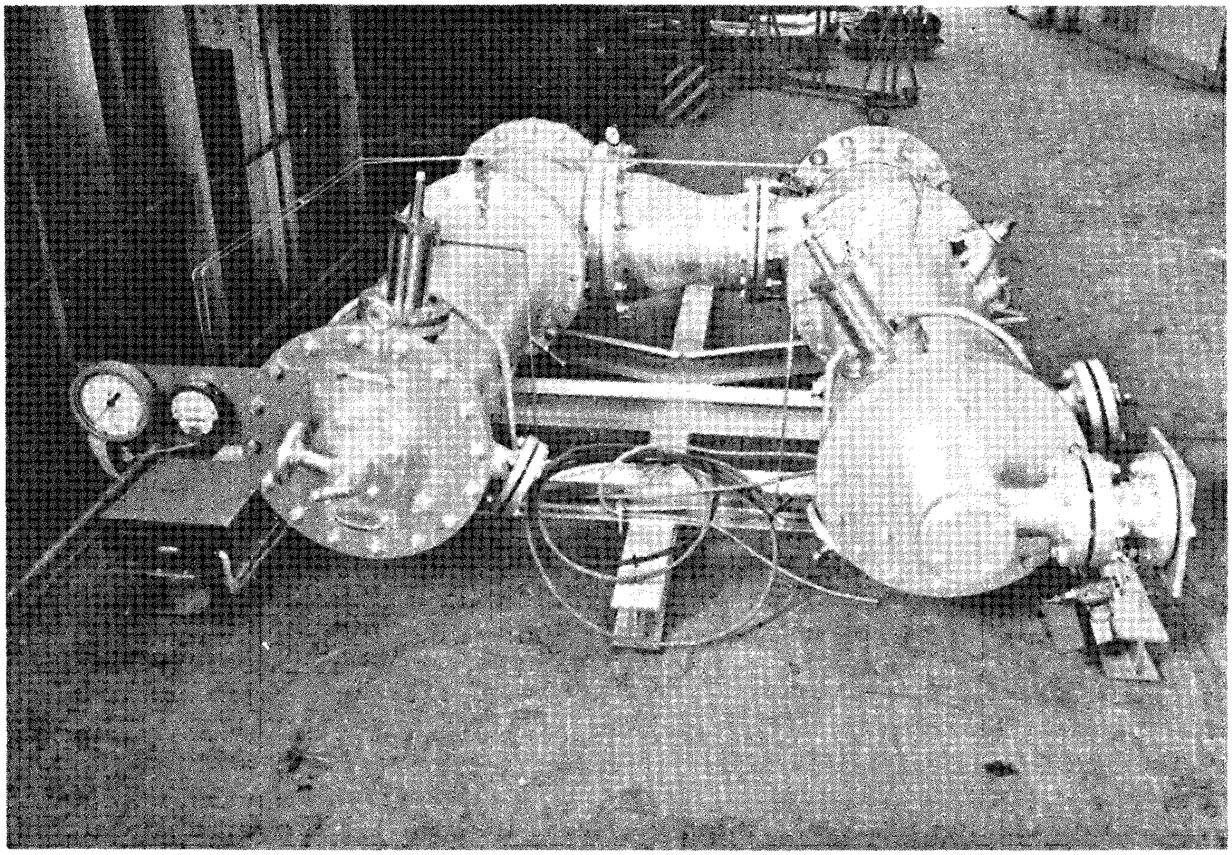


Figure 6 - Fuel-injection end. Preheater is to the left. Spark plug leads are not attached. The Protectorelay assembly which is normally mounted on the outer side of the I-beam has been slung inside for shipment.

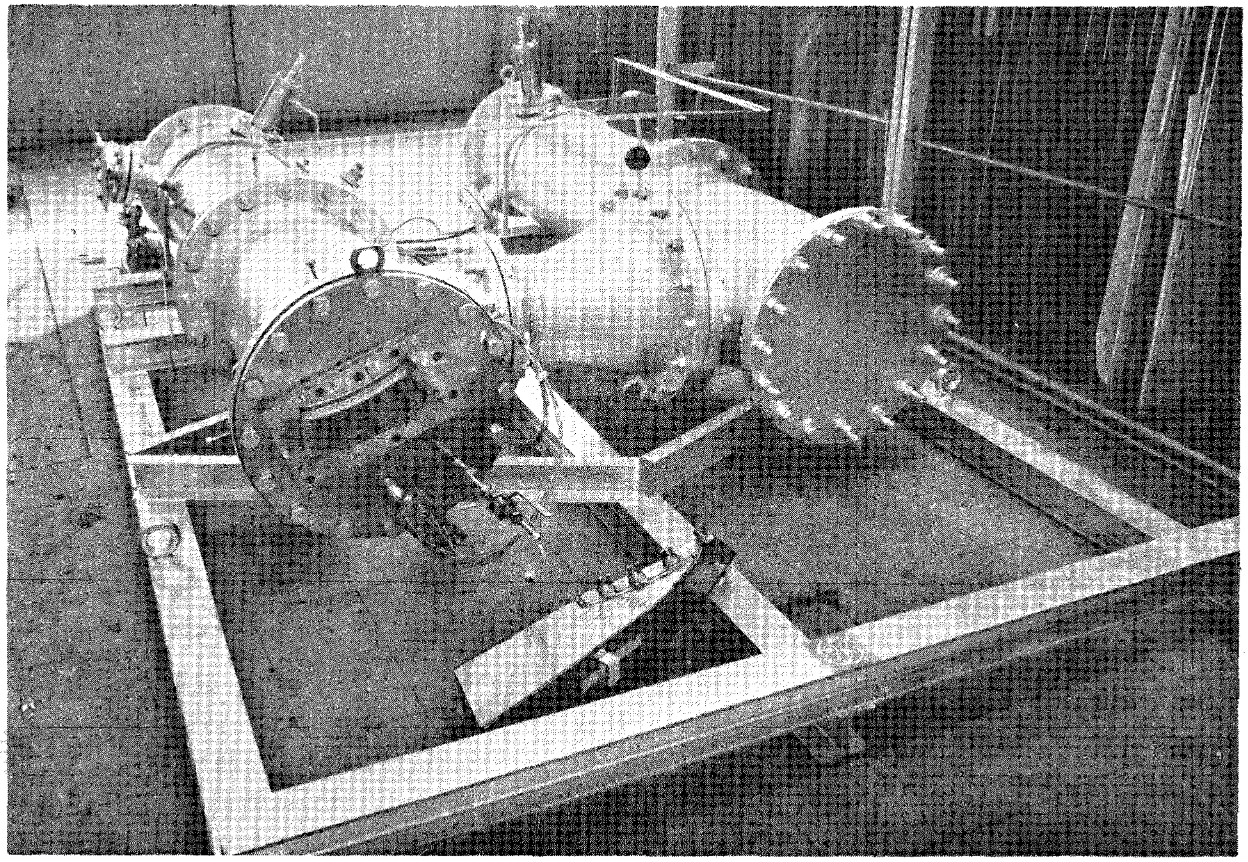


Figure 7 - Exhaust end. The Hastalloy X exhaust duct has been removed to expose the simulator nozzles. The air intake on the right is closed with a cover plate for shipment.

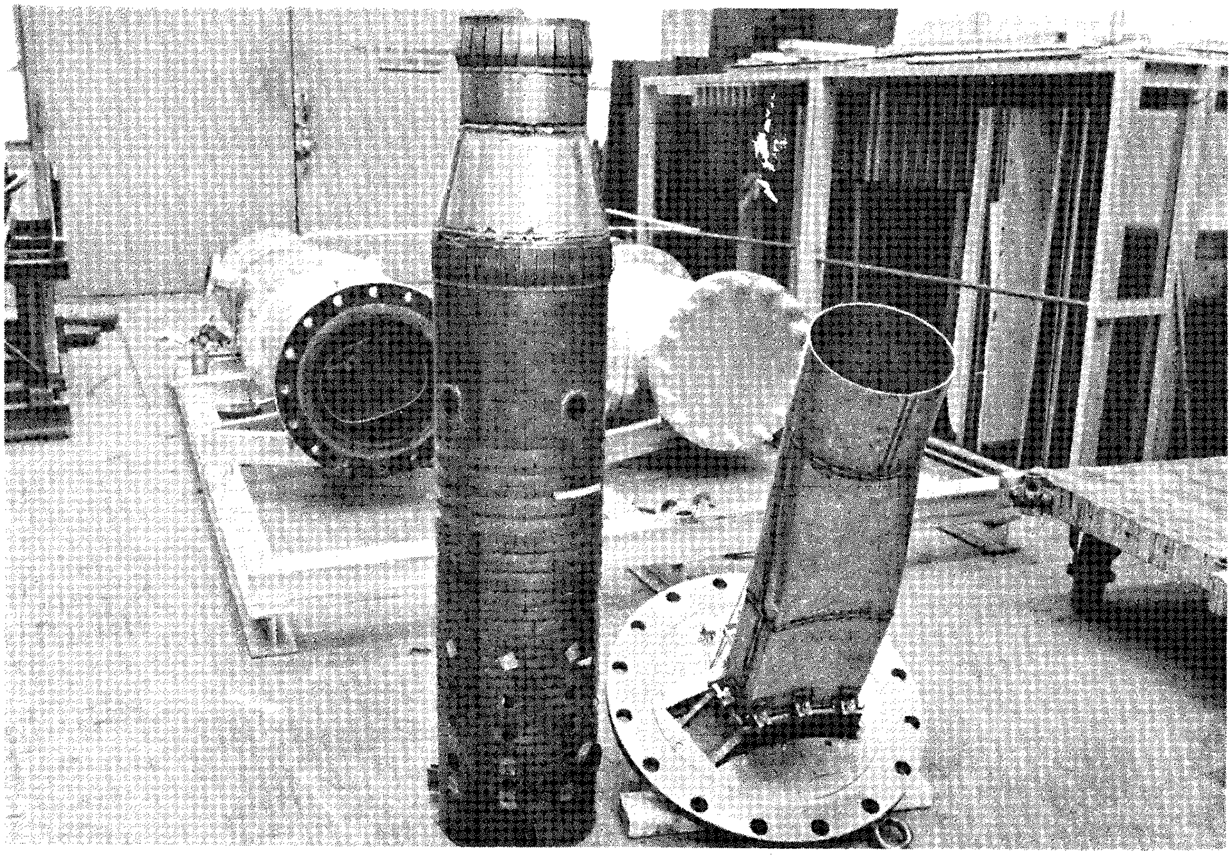


Figure 8 - Main combustor liner and simulator assembly with transition piece before insertion into flow sleeve.

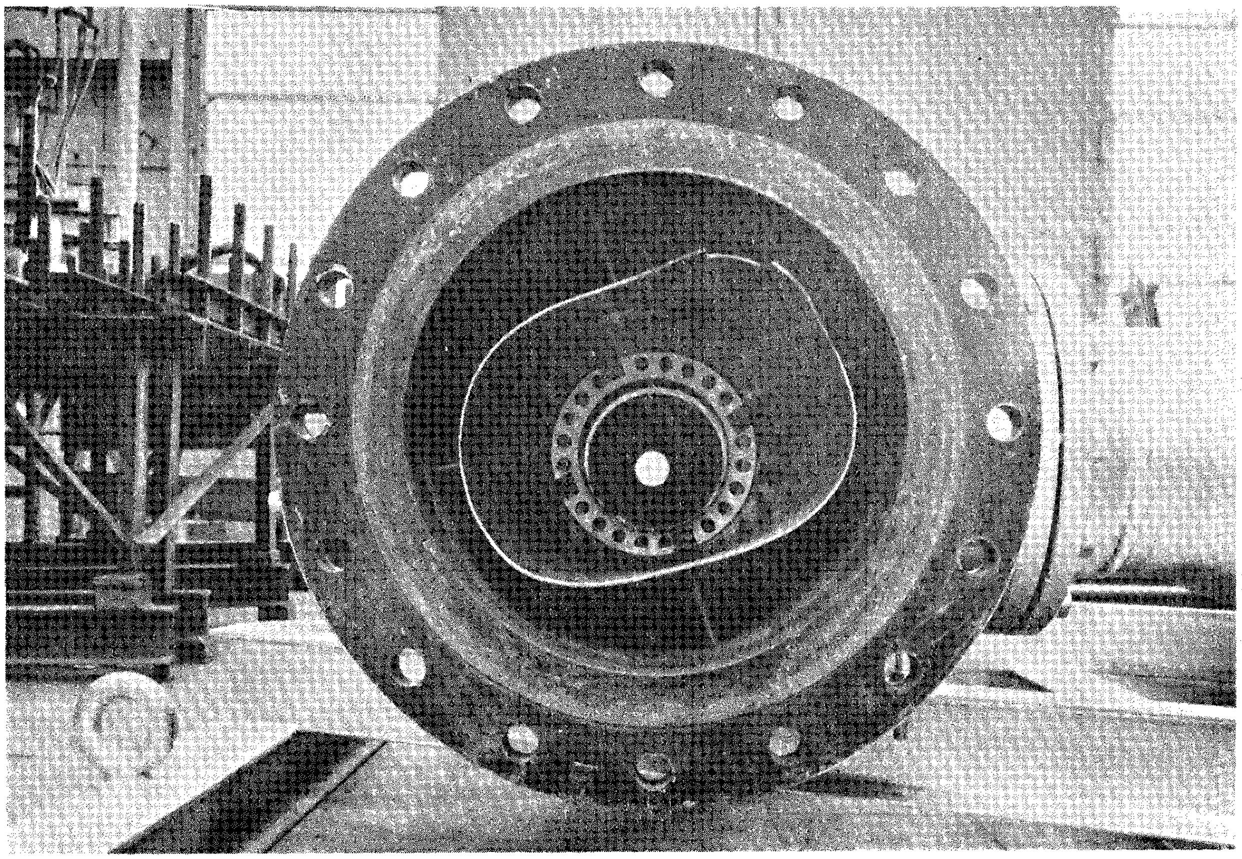


Figure 9 - View upstream into the main combustor section before insertion of the turbine simulator assembly. The oval cross-section of the flow sleeve is seen. Inside the flow sleeve the ΔP-screen is visible; it is the annular piece with 20 holes used to set the pressure drop in the vitiated air stream between the cooling pins and the combustor. Vitiated air from the preheater flows outward toward the viewer in the region between the flow sleeve and the outer casing. Between the flow sleeve and the transition piece (not in place), the air flows away from the viewer where it cools the transition piece.

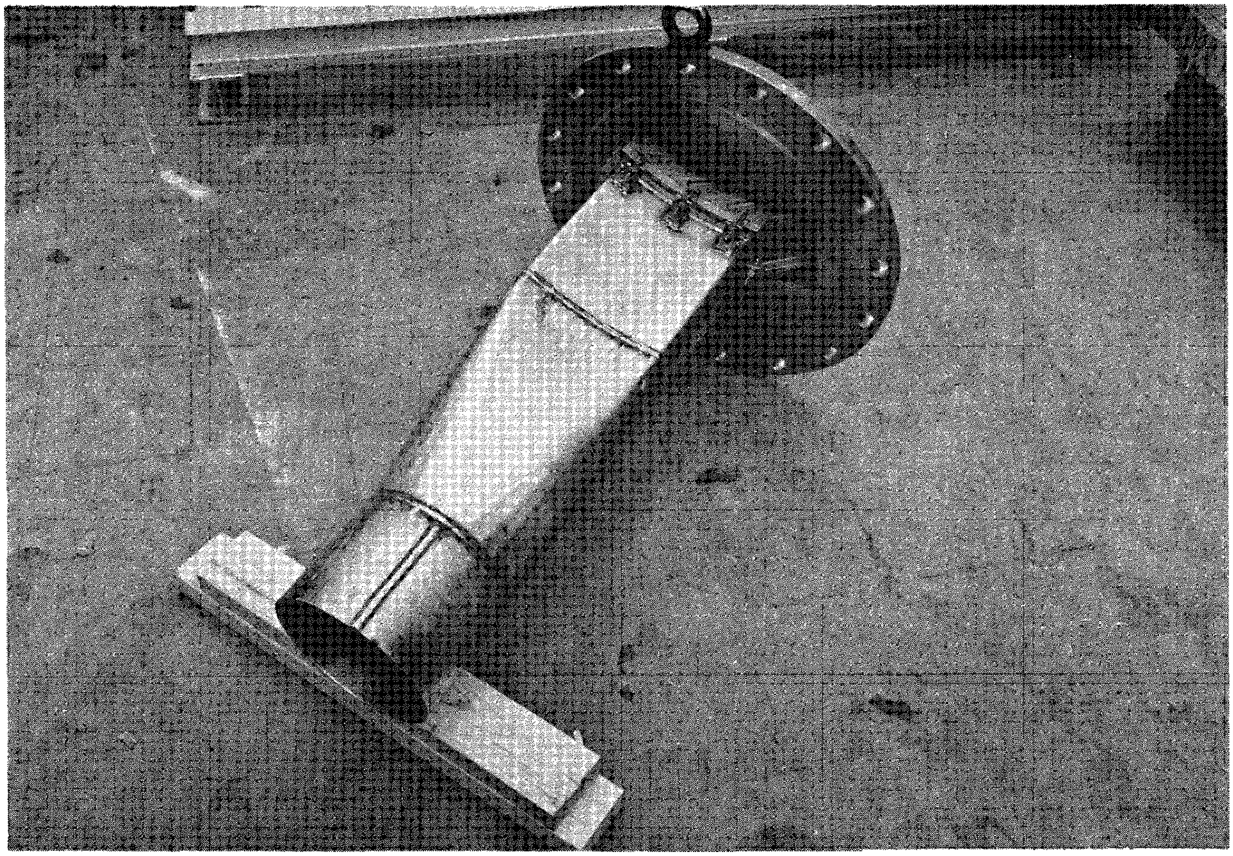


Figure 10 - The transition piece attached to the turbine simulator assembly; view from above. The hook eye is at the top in the final assembly. The duct has a circular cross section at the entrance (8 in. ID); the exit is a sector of an annulus. It is fabricated from 1/8 inch thick Hastalloy X. Stainless steel Swagelok fittings are welded to it.

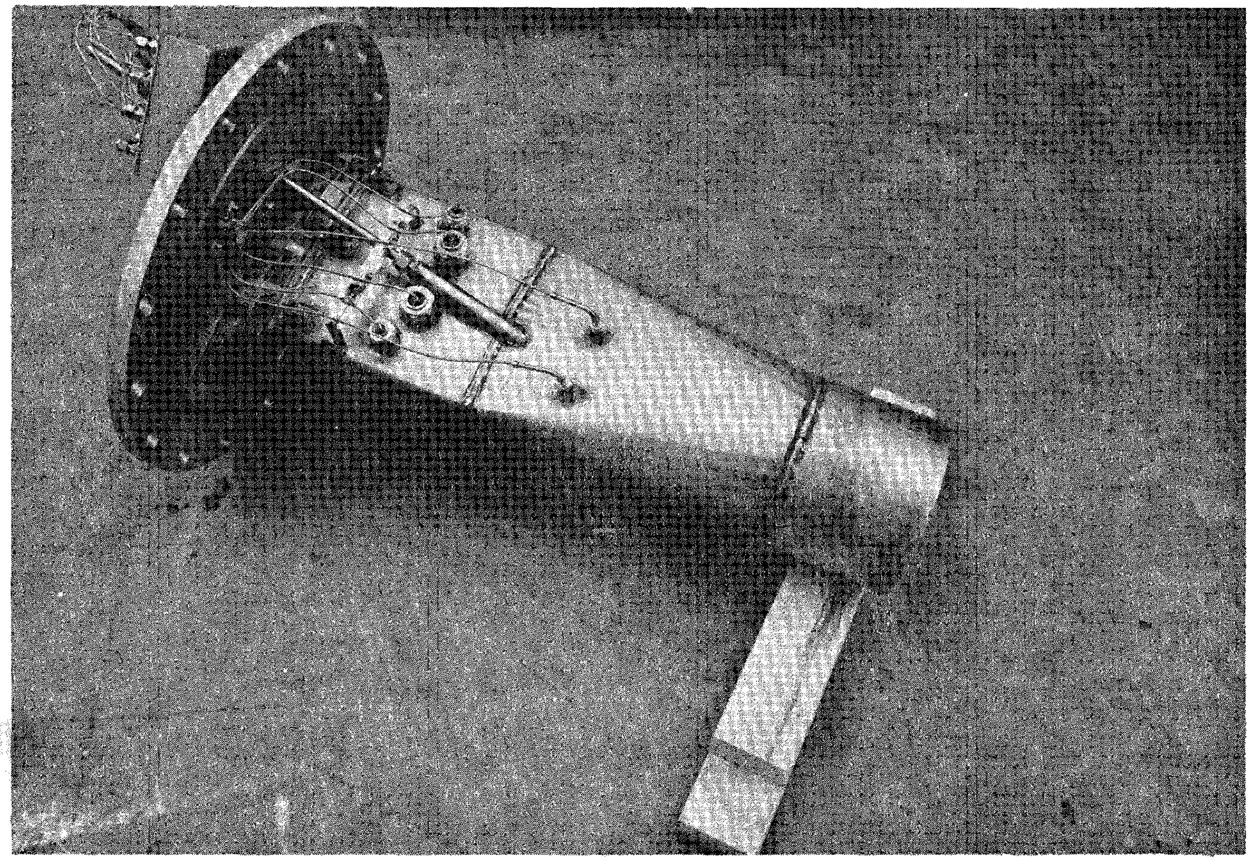


Figure 11 - The transition piece attached to the turbine simulator assembly; view from below. The first two fittings downstream from the circular entrance carry heavy shielded thermocouples. The set of four fittings across the sector section further downstream hold the cooling pins; the larger pins (1.0 in OD) have two thermocouples each to measure surface metal temperatures on the cooling pins. The smaller pins (0.56 in OD) have one each. Thermocouple leads are encased in rigid Inconel tubing (1/8 in O.D., .010 in wall) to support them in the high velocity stream of cooling air. The Inconel conduits are welded to spider structures at the open end of the cooling pins. At the other end they are welded to a common manifold. The sheathed .040 inch leads come out through the junction box seen on the outer surface of the end cover. The tube passing obliquely through the cover plate and into the transition piece is the sleeve through which the sample probes are inserted.

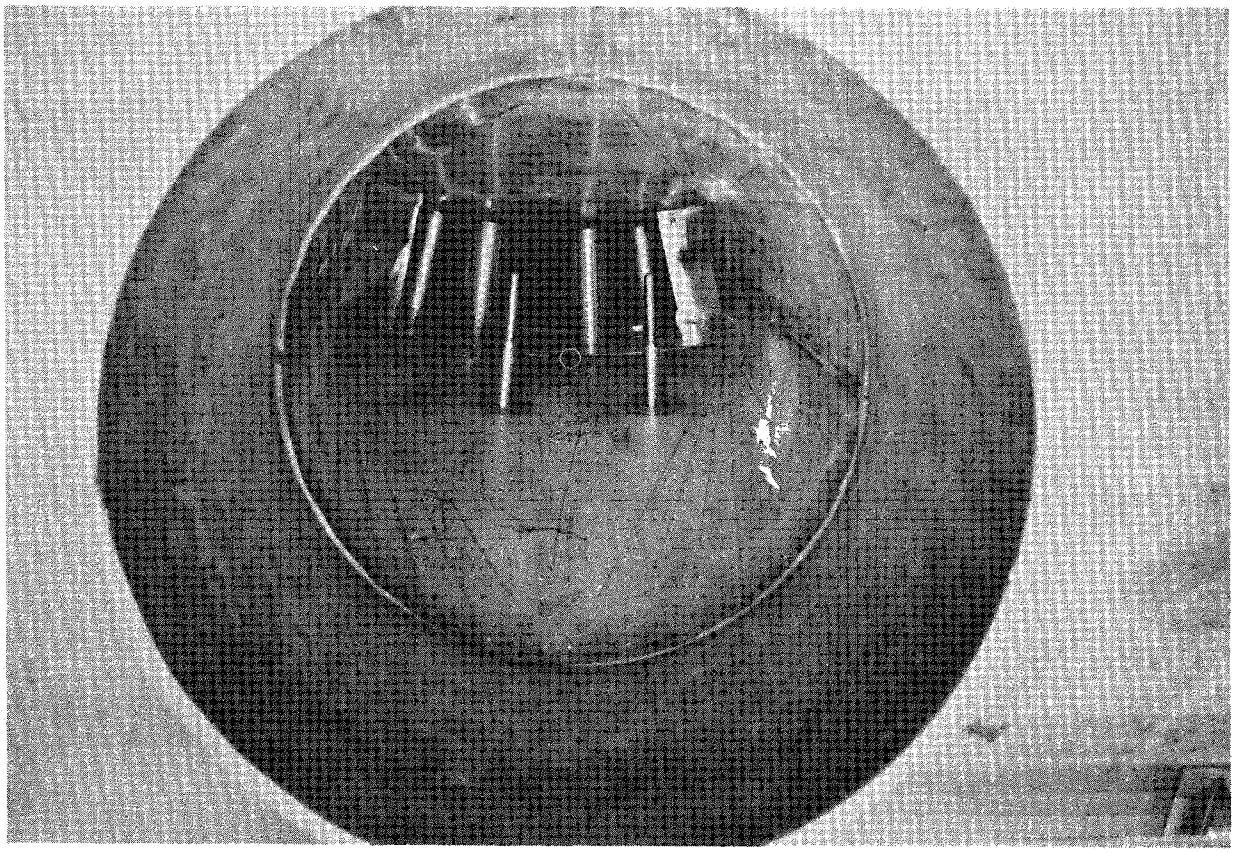


Figure 12 - View looking downstream inside the transition piece. The two shielded thermocouples projecting into the duct to measure gas temperatures appear first, they are located 14" upstream of the entrance to the turbine simulator. Behind them may be seen the four cooling pins arranged nearly in a straight line across the duct about 6 in. upstream of the entrance to the nozzle section. The pattern of cooling-air holes on the pins is visible. Also, the entrance of the round probe sleeve into the duct can be seen.

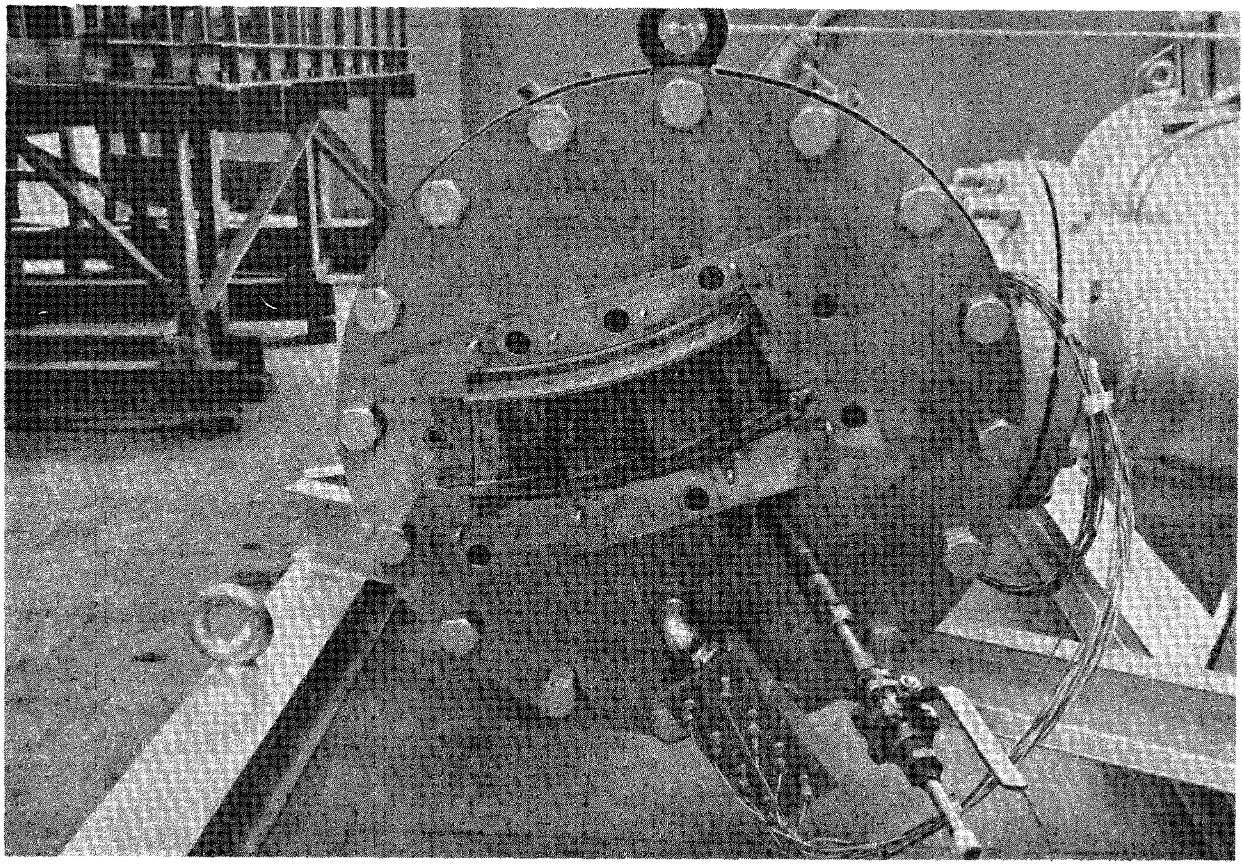


Figure 13 - The turbine simulator mounted in the final assembly with exhaust duct removed; view from downstream. The 3-nozzle sector was machined from a commercial MS3000 machine sector. A test specimen (IN738) welded onto the suction-side trailing edge of the middle nozzle is seen. The Inconel probe (3/8 in. OD with paper tape wrapped on the end) is mounted in the probe sleeve. At the hot-gas entrance the probe I.D. is 0.125 in.

The hot product gases pass through the transition piece and out through the 3 passage nozzle turbine simulator which will be running choked. It is shown in Fig. 13. The simulator, like the cooling pins, is cooled by the vitiated preburner products. A small test specimen of IN738 is welded onto the suction-side trailing edge of one nozzle segment for corrosion evaluation.

Finally, the hot product gases leave the turbine simulator at an angle of 75^{o} from the axis of the combustor. They pass through a short duct of Hastalloy X which is designed to reduce radiation from the turbine simulator; then go into the exhaust stack. The coupling into the stack is open to the atmosphere to provide entrained air to help cool the stack. The primary stack coolant will be water.

The Transition Piece

Views of the transition piece with associated thermocouples, probe sleeve and cooling pins are shown in Figs. 10, 11, 12. The sector-shaped cross section of the exit is held constant for a distance of 10 inches upstream from the simulator. The 4 cylindrical "film-cooled nozzle simulation" pins are mounted across this constant section of the duct about 6 in. upstream of entrance to the turbine simulator. These pins are identical to those described in Monthly Progress Report No. 4 as far as the portion exposed to the hot gas stream is concerned. However, the pins are here mounted in straight-through Swagelok fittings and cut back to the fitting height. The fitting end of the tube is open to the preheater air flowing back toward the main combustor between the transition piece and the flow sleeve; thus all cooling air comes directly from the simulated compressor outlet as is the case for a real machine. The pins extend into the hot gas stream for a distance of about 3 3/8 in. with the air hole pattern facing upstream. The depth of the duct at this point is 3 1/2 in.

Each cooling pin has one or more Inconel sheathed (.040 in.) chromel-alumel thermocouples inserted through the pin wall from the inside and welded into the wall at the outer surface to measure metal temperature there. One thermocouple is mounted diametrically behind the center pattern of cooling holes on each pin. In addition the two larger pins (1.0 in. OD, 0.109 in wall) mounted closer to the center of the duct have an additional thermocouple mounted at right angles to the first and at the same distance down the pin. Two pins (one large and one small) have the cooling-air holes drilled at an angle of 45 degrees with an element of the cylinder; the other two have the holes at 25 degrees.

The two heavy (.25 in OD) sheathed thermocouples located 14 in. upstream of the simulator entrance are used to estimate gas temperatures. They protrude 2-7/8 in. into the gas stream which is 4-7/8 in. in depth at this point. A sizable radiation correction must be applied to the recorded reading. The reading of one of these thermocouples will be continuously displayed and will be used for control purposes and to actuate the over-temperature shut-down.

The probe tip reaches the approximate centerline-line of the cylindrical entrance at a point just upstream of the two thermocouples.

The thermocouple wires pass back along the under side of the transition piece to a junction box mounted outside the end cover and below the Turbine Simulator exhaust duct. A radiation shield (not shown in Fig. 13) has been mounted between the exhaust duct and the junction box. The region through which the wires must pass (i.e., between the transition piece and the flow sleeve) is one of high air velocity and the wires must be supported all the way. This is accomplished by pulling them through rigid conduits of 1/8 in. OD Inconel tubing (wall thickness = 0.010 in.) The conduits are welded to a manifold piece at the junction box end. At the cooling pins the conduits are centered at the axis of the pins by a welded spider which allows full air flow into the pins.

The fabrication of this instrumentation arrangement was extremely difficult and required considerable ingenuity and skill on the part of the technician involved.

Following delivery of the turbine simulator to ERDA/MERC GE personnel during March checked out thermocouples, analytical instrument, start-up and control circuits, and advised in the installation of the probe lines. The cooperation and assistance of MERC personnel was excellent.

The thermocouples and analytical instruments were found to function normally.

When a start-up was simulated with no flow through the apparatus, it was found that the fuel shut-down valve cycled between the open and partially-closed positions in an abnormal manner. This happened because the UV flame sensor was actuated by light from the ignition spark. The problem was eliminated by placing a collinator between the sensor and the viewing port to prevent spark light from reaching the sensor. The start-up and shut-down system then worked as designed.

Air from the MERC compressor (A Spiraxial Roots blower) was first run through the apparatus on March 16. At flows greater that about 1/4 of that required, the compressor pulsations excited a strong resonance within the preheater sections. The resulting oscillations were too strong to permit operation of the equipment and consequently MERC has lengthened the air supply lines and installed a large surge tank to attempt to dampen out the compressor pulsations. GE has designed and MERC has fabricated and installed a baffle at the point where the 4 in. air supply line enters the preheater. The baffle should provide a pressure drop of about 1.5 psi, give an improved air flow within the preheater and help isolate it from supply-line pulsations.

After the air pulsations problems are corrected, the preheater will be operated with natural gas as the fuel to ensure that stable operation can be maintained. Following that, full operations on producer gas will be initiated.

(c) Screening Tests

No test facility modifications were necessary.

(d) Confirmation Tests

Overall system thermodynamic, flow and physical requirements have been analyzed. Detail design of the components will begin shortly and minor adjustments in system parameters will be incorporated into the Status Design as they are identified.

The design will attempt to simulate flow rates, operating pressures and Mach numbers of a production gas turbine. The system is being sized such that these conditions will be realized using the existing air compressors at CR&D. The throat area of the bucket cascade will be altered from the existing MS7001 STG1-B hardware to appropriately reduce the throat area. A water-cooled variable orifice is specified for downstream of the bucket cascade to provide flexibility in achieving the proper bucket inlet Mach number while minimizing the likelihood of shock occurring at the nozzle exit. The ducting connecting the nozzle and bucket cascades will require no internal blockages, but will require external water cooling. The exhaust gases will be cooled by water injection.

WORK FORECAST

(a) Initial Coal-Derived Liquid Fuel Tests

All work has been completed.

(b) Initial Low BTU Gas Tests

All work has been completed

(c) Confirmation Tests

Design for modifications of the Turbine Simulator will be completed and modification will begin during the forthcoming quarter.

SUBTASK 5 - PREPARE SPECIMENS

(a) Initial Coal Derived Liquid Fuel Testing

All specimens were available in Mid-October, as indicated in Quarterly Progress Report No. 2.

(b) Initial Low-BTU Gas Testing

Modifications to the MS-3002 first-stage nozzle segment to fit the turbine simulator skid, was completed during the past quarter. The IN-738 tab specimen was welded to the nozzle segment trailing edge.

(c) Screening Tests

All small burner rig corrosion specimens were available by the end of December as indicated in Quarterly Progress Report No. 2.

(d) Confirmation Tests

(i) Nozzle Cascade Design

Studies under this program have indicated that cooling of the nozzle is feasible without leading edge cooling. Consequently design of a nozzle without leading edge cooling was begun during the past quarters and is now 50% completed.

The design uses the existing production form of the MS3002 STG-IN airfoil, core and core plug, although trailing edge thickness may have to be increased to allow for cooling holes. The design incorporates normal internal air impingement from a single chamber core plug, and suction and pressure side film cooling holes. Cooling flow is to be established based on a percentage of total air flow similar to that utilized in a production design. The sidewalls will also require impingement and film cooling.

Cooling flow is expected to be approximately 5-6% of compressor discharge per throat. Coolant will be supplied at 8.3 atmospheres pressure, and 650°F.

(ii) Bucket Cascade Design

Studies have also indicated that cooling of the bucket is feasible without leading edge cooling. Consequently design of a bucket without leading edge cooling was begun during the past quarter and is now 75% completed.

A film-cooled leading edge design has been started as well, however as a back up design.

The design uses the production MS7001 STG-1B airfoil with several major modifications. These include cutting of an internal core, addition of a new core plug, blunting the leading edge, and radial truncation of the blades. This last modification, along with the sandwiching of the truncated blades between specially-designed sidewalls, will provide the desired throat area for the cascade. The design incorporates normal internal air impingement from a single chamber core plug, and suction and pressure side film cooling holes. The sidewalls will be film cooled as well.

Cooling flow is expected to be approximately 2.5 of compressor discharge per throat. Coolant will be supplied at 6 atmospheres pressure and 650°F.

WORK FORECAST

Confirmation Tests

- Design of the nozzle and bucket cascades will be completed during the next quarter.
- Fabrication of the nozzle and bucket cascades will be initiated during the next quarter.

SUBTASK 6 - PROGRAM MANAGEMENT

WORK ACCOMPLISHED

Program management efforts this quarter consisted of: (1) periodic meetings with project contributors in all Subtask areas directed at identification of critical areas and insuring attainment of milestones on schedule; (2) continuous liason with the ERDA program manager and contracting officer regarding program progress and administrative/programmatic matters; and (3) monitoring closely the Initial Coal-Derived Liquid Fuel Testing described under Subtasks 3 and 7.

Following receipt of ERDA's written directive regarding implementation of Administrative orders 3 and 4 for this program, the first two quarterly reports were reproduced and disseminated. The annual report is currently in reproduction.

In addition to these reports, a summary of the Fireside Corrosion Task 1 Program was prepared at the request of Dr. G. Alex Mills, Director of ERDA Fossil Energy Research.

An advance copy of a forthcoming ERDA Administrative Order covering monthly financial reports was received and reviewed.

Program management attention was also given to the Initial Coal-Derived Liquid Fuel Program. To facilitate GE's efforts to establish test conditions that would generate the proper turbine ash during future runs, the ERDA Program Manager arranged in January to have ERDA/Pittsburgh Energy Center transmit a sample of contaminant-bearing ash from the Synthoil Process to GE for analysis and consideration for use in these test runs. Also arranged were direct communications between GE and ERDA/Pittsburgh Research Center fuel chemists regarding specifics of this sample (see Subtask 3).

The results of the first two test runs (see Subtasks 3 and 7) plus the technical problems involving development of synthetic coal-derived liquid fuels from petroleum-based distillate fuel (see same two subtasks) were brought to the attention of the ERDA Program Manager during his January 29 visit to Schenectady. At GE's request, ERDA set up a technical meeting between GE and ERDA fuel experts to review this situation.

At this meeting, held in Washington on March 1, GE gave presentations on test results to date and steps being taken to develop a coal-based "synthetic coal-derived liquid fuel." The outcome of this meeting was:

(a) ERDA approved GE's plans and approaches for coming up with coal-based liquid fuels for future program testing.

(b) The choice of the coal-fuel base will be left up to GE.

(c) ERDA provided the following:

(i) ERDA/Pittsburgh Energy-Center is reserving one drum (500 lb.) of contaminant-bearing "sludge" from the Synthoil Process for GE's use (in adding contaminants to coal-oil base); a gallon sample forwarded to GE for chemical analysis has been received.

(ii) ERDA determined that "Sludge" from the H-coal process is not available. (see Subtask 3)

(iii) ERDA/Pittsburgh Energy-Center provided information and a contract for "antracine oil", for consideration as a possible coal-fuel base. (see Subtask 3)

As a result of current schedule conflicts brought about first by the limited availability of COED fuel (see Quarterly Report No. 2) and then by the technical problems associated with the development of a synthetic coal-derived liquid fuel for Initial Testing, program schedules, availability of test facilities and resources, and various alternate program plans and options have been given considerable review. An explicit revised schedule and program plan will be established as soon as they can be developed on the basis of factual data. In the interim, the schedule given in Figure 1 is being used with slips as noted until such time that it can be properly updated.

In the interim, GE is providing the leadership necessary to resolve these difficulties as rapidly and expediently as possible.

Project Funding Authorizations (PFA's), an internal GE-GTD program management means for issuing funds for and controlling efforts being performed by functional groups on development programs, were prepared and issued for calendar year 1976.

Meetings with project contributors in all subtask areas continue to be held. These are directed at identification of critical areas and insuring attainment of milestones. A key integration meeting was held on January 27 to go over plans for the design, development and fabrication of both test specimens and test facility modifications for Confirmation Tests to be run later this year.

WORK FORECAST

This forecast consists of the following:

- Establishment of a revised program schedule and PERT network that reflects delays accrued by the liquid coal-derived fuel problems.
- Close liason with the ERDA program manager with regard to the selection of the coal-base to be used to develop a synthetic coal-derived liquid

fuel, plans for the balance of Initial Coal-Derived Liquid Testing, and the program replan described above. This will consist of keeping ERDA fully appraised of test results and GE's technical and programmatic recommendations.

- Continued implementation of program management systems to insure that potential situations in key areas are rapidly resolved before they become problems, and to insure that program milestones are met on schedule and within assigned costs.

SUBTASK 7 - CONDUCT TESTS

(a) Initial Coal-Derived Liquid Fuel Tests

The first two test runs on coal-derived liquid fuel were performed during the past quarter at a 1950°F firing temperature using COED oil derived from Pittsburgh coal. The first test was run using approximately 3,000 gallons of COED oil "as received" (see Quarterly Progress Report No. 2 for details of its chemical composition).

The first test ran for about 30 hours, following which the test specimens were visually examined. There was no evidence of the plugging of cooling holes in either the nozzle or bucket cooling pin specimens. One nozzle pin specimen was burned badly; this is attributed to blockage in the flow metering circuit which caused a subsequent reduction in cooling air to this pin. No evidence of corrosion was visible after the first test.

In the process of performing this test run, it was learned that the COED fuel must be heated moderately (80-120°F) in order to properly pump, control, and atomize it. Since this first run was performed with unheated fuel (the pour point having been fixed at 20°F), some difficulties were experienced in maintaining the firing temperature at 1950°F, i.e., periodic excursions above 1950°F occurred.

The second test was run using the final 3,000 gallons of the COED fuel allocated to the program at a firing temperature of 1950°F. For this test the COED fuel was chemically doped with 3 ppm Na and 3 ppm K. The test run was for about 30 hours. As was the case with the first test, post-test visual examinations yielded no evidence of either plugging of cooling holes or corrosion.

For this test run, the COED oil was heated to 80-120°F before being fed into the turbine simulator. This eliminated the fuel forwarding problems encountered with the unheated oil in the first test run. The test consequently ran much smoother.

One question that the Initial Tests should have answered was whether the clean COED fuel (which is representative of almost any clean coal-derived oil) was an acceptable turbine fuel from a corrosion and deposit point of view. Because of the short test time and the fact that the second batch of fuel was doped with 6 ppm alkali (this contaminant level is unacceptable with the materials utilized in current production machines) an unequivocal answer to this question is not possible. If the alkali content of the coal-derived fuel is below 1 ppm as it was in test run No. 1 there is good reason for optimism based upon the visual observation of specimens after the tests.

A post test analysis of specimens exposed in these Tests was performed. The IN-738 specimen tab was cut from the trailing edge of the nozzle sector, sectioned, mounted and polished, and examined metallographically. The specimen was covered with a thin protective oxide, but there was no evidence of hot corrosion.

The nozzle sector was removed from the turbine simulator and taken to the analytical laboratory. The nozzle was first washed with a solvent. A qualitative flame test showed the presence of Na (K not checked). The nozzle was next washed with distilled water for an hour. At the end of the washing period the rate of removal of Na had only slightly diminished. This was an indication that only a portion of the alkali which had deposited was removed. (Recall that test #2 was doped with 3 ppm Na and 3 ppm K.) The solvent washing affluent was added to the water washing affluent and the entire solution was analyzed for Na and K. 94 mg of sodium and 32 mg of potassium were measured which indicates that the surface material contained more than 94 mg of Na and more than 32 mg of K. The amount of alkali condensed was far in excess of that which could have condensed during the five minute shutdown at the end of the test, indicating that condensation of the alkali sulfate was occurring during the test. The level of alkali present on the nozzle suggests that hot corrosion would have occurred on a nickel base alloy operating in the test environment after several thousand hours, even though this was not evident on the IN-738 tab after only 35 hours.

Figure 14 shows two of the nozzle pins located in the transition piece just in front of the nozzle after (a) test number 1 and (b) test number 2. The pins were rotated 180° before photographing so that the cooling holes could be observed. Note that the cooling holes were not plugged with ash after either test and that there is a dark carbonaceous deposit on the parts which is heaviest after the second test. The high C/H ratio of the coal based fuel is the cause of these deposits. Carbonaceous deposits of this type have not been observed in the past during operation of the turbine simulator on #2 distillate oil and could serve to accelerate hot corrosion with this oil.

Present indications are that the selection of a suitable procedure for synthesizing the coal oil will be made shortly and that resumption of the Initial Coal Oil Tests will take place during May. As indicated under Subtask 3 of this report the one barrel of Synthoil sludge to be supplied by ERDA/PRC would only permit approximately 50 hours of additional testing. Obviously additional by-product ash or sludge will have to be obtained from alternate sources to complete the full duration of testing.

(b) Initial Low BTU Gas Testing

Integration of the GE furnished Turbine Simulator skid with the ERDA/MERC test facility was completed during the past quarter. As a result of shakedown testing some modifications to the system were required. These are described under Subtask 3 of this report. It is now anticipated that the first test run on Illinois #6 coal in the gasifier will be conducted during early April.

(c) Screening Tests

These tests were initiated in late February 1976. Test conditions for these tests have required redefinition (see Subtask 3). Presently new condensates for each of four test conditions is being collected on platinum discs. The condensates will be analyzed to insure correspondence with thermochemical predictions before the tests are resumed.

WORK FORECAST

(a) Initial Coal-Derived Liquid Fuel Tests

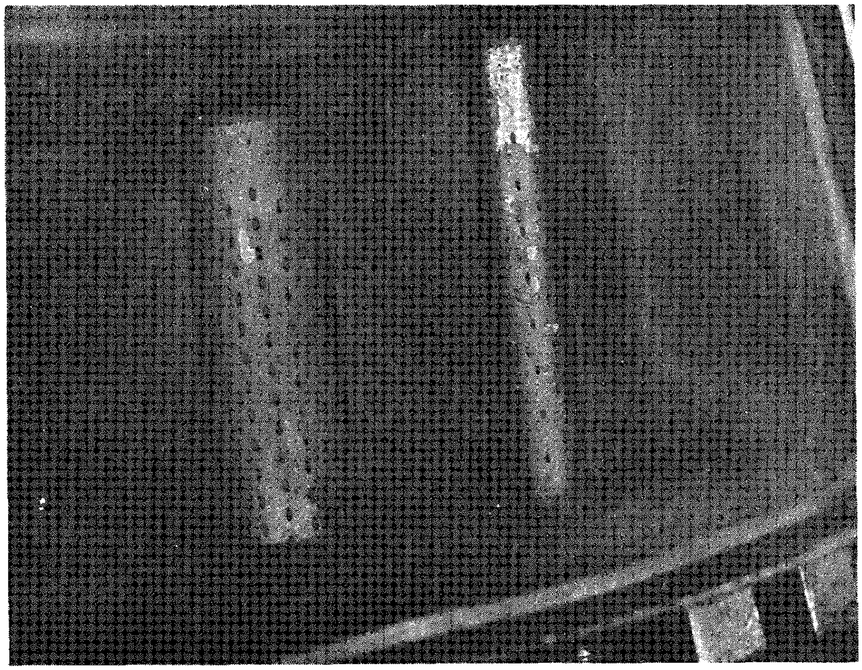
- Testing will be resumed and should be completed before the end of the next quarter.

(b) Initial Low BTU Gas Testing

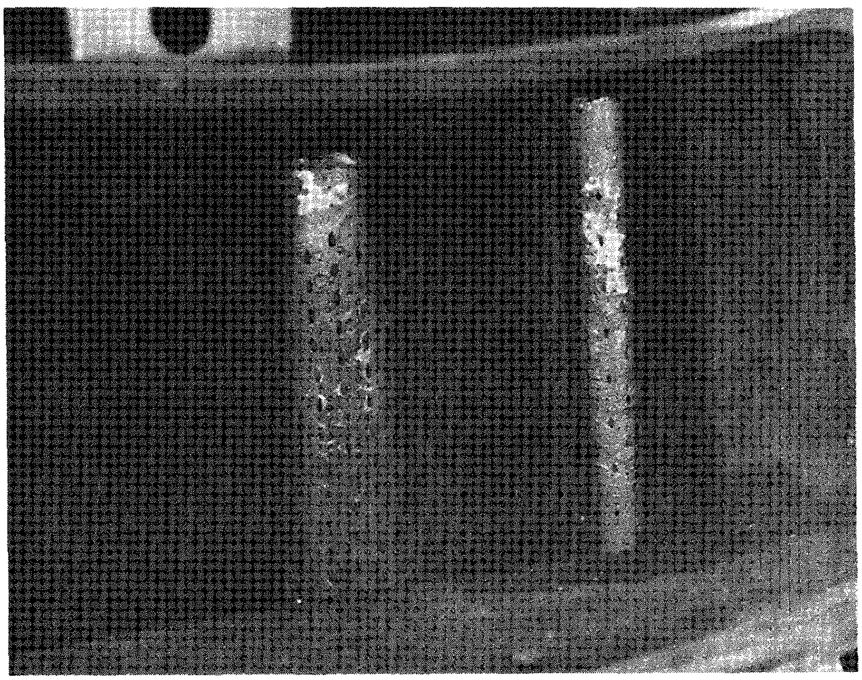
- Testing will be initiated and should be completed before the end of the next quarter.

(c) Screening Tests

- Testing will continue during the next quarter.



(a)



(b)

FIGURE 14 - Two Nozzle Pins in Transition Piece after
(a) Test 1 and (b) Test 2

SECTION 4

CONCLUSIONS

(1) The coal type matrix oils such as the FCC Slurry Oil and Creosote oil have a very high dispersant power for the Synthoil sludge. Tentatively, a creosote oil/sludge mixture appears to be the best simulation of a coal-derived oil for use in the remaining Initial Tests and the Confirmation Tests.

(2) Fabrication of the Turbine Simulator for the low BTU gas tests was completed and the assembly was shipped to ERDA/MERC on February 6, 1976.

(3) The Turbine Simulator has been coupled with the ERDA/MERC gasifier and full scale testing is about to begin.

(4) Two tests were run during the past quarter in the GE Turbine Simulator at a 1950^{o}F firing temperature burning COED oil derived from Pittsburgh Coal. The first test was run for 30 hours using 3000 gallons of COED oil in the "as received" (clean) condition. The second test used a similar amount of fuel which was doped with 3 ppm Na and 3 ppm K.

(5) Because of the short test time an unequivocal answer as to whether the "clean" COED fuel (1st Test) was acceptable from a corrosion and deposition standpoint is not possible. The results do allow good reason for optimism.

(6) A post test analysis of the nozzle sector following the second test (fuel doped with 3 ppm Na and 3 ppm K) revealed that Na and K were deposited on the nozzle. The level of alkali present suggests that hot corrosion would have occurred on a nickel base alloy operating in a similar environment after several thousand hours. Further testing over longer time periods will be required however to substantiate this hypothesis. Use of the coal-based Creosote doped with Synthoil or H-Coal sludge appears to be the best fuel for substantiation of this hypothesis.