FIFTH QUARTERLY REPORT
August 1, 1979 - October 30, 1979
Contract No. DE-AC03-78ET11300

D. Q. Hoover
Program Manager
November 1979

Prepared for:

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Washington, DC 20545

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CELL AND STACK DESIGN ALTERNATIVES

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TABLE OF CONTENTS

	Page
TASK 1: STUDY OF SYSTEM DESIGN ALTERNATIVES	1
1.2 Develop Computer Simulation of System	1
TASK 2: FUEL CELL DESIGN ALTERNATIVES	2
2.1 Fuel Cell Analysis	2
2.3 Stack Fabrication	2
2.4 Stack Testing	4
Stack No. 554	4
Stack No. 555	5
TASK 3: METHANE CONDITIONER STUDY	9
3.1 Technology Assessment	9
3.2 Mathematical Model	9
TASK 4: MANAGEMENT AND DOCUMENTATION	11
4.1 Supervision and Coordination	11
4.2 Documentation and Reporting	11
4.3 Planning	11

TASK 1: STUDY OF SYSTEM DESIGN ALTERNATIVES

1.2 Develop Computer Simulation of System

A decision to use an available executive program, TRNSYS, was made and verbal approval was given by the government technical manager after ascertaining that the program could be transmitted to the government. The use of this program will provide a convenient means for integrating the component and subsystem models into a variety of system configurations. The most recent version of TRNSYS was obtained from the Solar Energy Laboratory of the University of Wisconsin Engineering Experiment Station.

The development of subsystem and component models was completed during this period and the subroutines were written or modified to make them compatible with the TRNSYS program. The system model was assembled and initial attempts to exercise it were made. Debugging of the model is underway. The model will then be used to calculate the performance of the system for the hourly load profile developed earlier for the 48-unit apartment complex selected as an application.

TASK 2: FUEL CELL DESIGN ALTERNATIVES

2.1 Fuel Cell Analysis

A method for calculating current density and temperature distributions for the innovative cell geometry which will be used in the MK-2 stack of Phase II was developed. Preliminary designs of bipolar plates for these cells were developed to provide a basis for negotiations with machine shops to expedite the Phase II effort.

The procedure for calculating the pressure drop and split between process and cooling air streams was modified to include entrance and exit head loss effects. Although these effects were found to be significant, they did not fully account for the unexpectedly high pressure drops measured on stack No. 554. Subsequent inspection of the stack revealed that some channels in the cooling plates had deformed under stack compression and, therefore, the flow area available was less than that used in the calculations.

Correction factors for the effect of water vapor on orifice plate pressure drop were developed for use in calculating the mass flow rate in the 8 kW test loop. Relationships were developed to permit comparison of the makeup air flow rate measured by the orifice plate and that calculated from the oxygen gauge readings at the cell exit.

2.3 Stack Fabrication

All components, including the machined innovative cooling plates, were manufactured or procured for and the assembly and wicking of stack No. 556 was completed at ERC. Pretesting of this stack revealed some manifold leaks and these are being corrected. Pretesting of this stack will be completed and the stack will be shipped to Westinghouse in November. Figure 1 is a picture of stack 556 with manifolds removed. The wires on the tie rods are leads for strain gauges which insure that the correct forces are applied to the stack and that the tension in the tie rods is uniform.

Assembly and pretesting of stack No. 555 which contained conventional DIGAS cooling plates was completed and the stack was shipped to Westinghouse in September.

Figure 1 Stack No. 556 Assembled

2.4 Stack Testing

Stack 554

Stack 554, a 20 cell stack of 12.7 cm x 38.2 cm plates with DIGAS cooling in the 38.2 cm direction, was delivered to Westinghouse for testing. As described in the August monthly; tests were made to measure the temperature distributions under normal operating conditions, electrochemical performance of the cells under isothermal conditions and the air side pressure drops.

The measured temperature distributions of the cells averaged 1.2 times the temperature rise of the gas passing through the stack. The value of this parameter calculated by the detailed analytical model is 1.1.

The methods and results of the isothermal tests are described in the August monthly. These tests were made to determine if large temperature gradients in the cell were responsible for the relatively poor performance of this stack. The test results showed that cell performance is determined primarily by the average cell temperature and is independent of the temperature gradient. This confirms the predictions of the detailed mathematical model.

The air side pressure drops measured on stack 554 were 50 to 100 percent higher than calculated even after the calculation procedure was modified to include entrance and exit head loss effects. This was apparently due to a reduced flow area through the DIGAS cooling plates which resulted from structural failure and collapse of these plates under stack compression. In the future, strain gauges should be used on the stack tie bars to insure that the correct level of pressure is applied uniformly to the stack.

Testing of this stack was terminated in September due to an indicated gas crossover and to free the loop for installation of stack 555. The stack was returned to ERC where it was disassembled and examined. The examination indicated that the cells were in generally good condition but that the matrices were somewhat drier than normal.

Stack No. 555

Pretesting of stack 555, a DIGAS cooled stack of 23 - 30.5 cm x 43.2 cm cells, was completed at ERC and the stack was shipped to Westinghouse in September. Figure 2 gives polarization curves for this stack taken prior to (8/27/79) and subsequent to a rewicking operation. The performance of the stack was satisfactory (580 mV at 100 mA/cm²) and reproducible.

Polarization and temperature profiles for these stacks were measured at Westinghouse and some typical results for operation with no recirculation are presented in Figures 3 and 4.

The points represented by squares in Figure 3 were taken at nearly isothermal conditions. This was accomplished by operating the stack at 28 amps until a steady state was reached and then stepping the current to higher values and reading the corresponding voltages before the temperatures could respond to the changed condition. The triangular points of Figure 4 are the measured temperatures for these tests.

The points represented by circles in Figure 3 were taken by rapidly changing the current from a base value of 114 amps. The temperature distribution for these tests is given by the circular points in Figure 4.

The solid line in Figure 3 is the result of pretests at ERC under similar conditions to those measured at Westinghouse. The difference is apparently largely due to the poor performance of four cells at the bottom of the stack. The Westinghouse tests were terminated when crossover was indicated and the stack will be returned to ERC for examination.

The temperature profile given in Figure 4 for operation at 114 amps with an air temperature rise of 53.5°C shows a cell temperature differential of 63°C. This provides excellent confirmation of the detailed analytical model which predicted a 63°C cell temperature differential for an air temperature rise of 55.5°C.

Fig. 2 — Polarization for stack 555

Curve 719618-A

Fig. 3 — Performance of stack 555

Curve 719620-A

Fig. 4 — Temperature profiles for stack 555

TASK 3: METHANE CONDITIONER STUDY

3.1 Technology Assessment

A set of documents entitled "Fuel Cell Component Specifications" were received from the government technical manager. Considerable effort was devoted to reviewing and analysing these documents.

The information gleaned from these documents, particularly transient temperature and flow rate information, will be extremely valuable in our Phase II work. However, our review of these documents revealed some discrepancies. These are probably a result of the fact that the system specification is still evolving. Clarification of these points was requested from the government technical manager.

Based on the heat exchanger specifications in the "Fuel Cell Component Specifications" inquiries were sent to more than 30 manufacturers to establish sources for Phase II. Several positive responses have been received and Harrison Division of GMC has indicated an interest in working closely with us on developing appropriate exchanger designs.

This effort is now complete and documentation for the Phase I final report is underway.

3.2 Mathematical Model

In August, work was completed on the derivation of a computer model incorporating kinetics and heat transfer into the methane/steam reformer model. This model uses the reformer material and energy balances with heat transfer and physical property correlations to calculate the temperature profile and reaction conversions stepwise through a reformer tube. Input data includes flow rates and compositions of the reforming and combustion gases, initial temperatures, pertinent reformer tube dimensions, pressure, and the initial feed conversions. Calculated output values are the equilibrium constants, heat transfer coefficients, mole fractions, mass fractions, and the molar flow rates anywhere in the reformer, as well as the reactant conversions and temperatures.

A tabulation of results from computer runs using the model was presented in the August "Technical Status Report." A card deck, sample printouts and a description of the use of the program have been prepared for the Phase I final report. The program will be used to obtain estimates of reformer size during Phase II.

TASK 4: MANAGEMENT AND DOCUMENTATION

4.1 Supervision and Coordination

An extension of the period of performance of this contract to December 31, 1979, was requested by Westinghouse and approved by DOE. This extension will permit the testing of a stack with an advanced cooling plate geometry which, due to limited availability of sophisticated machining equipment, was delivered to ERC on September 28. The decision to request this extension was arrived at jointly with the government technical manager at a review meeting held at the Westinghouse R&D Center on August 3.

4.2 Documentation and Reporting

The Fourth Quarterly Report was submitted for patent approval, the required modifications were made and the report is being reproduced for distribution, according to a new list provided by the government technical manager, very early in the next quarter.

Patent approval for the June monthly report was received and the report was distributed to the specified addresses.

The August and September "Monthly Status Reports" were prepared and submitted for patent approval and the management reports for July, August and September were submitted.

A program review meeting was held at the Westinghouse R&D Center on August 3.

A presentation of the significant achievements of Phase I (to date) was made to Dr. Momtaz Mansour, recently appointed fuel cell branch chief at an ERC meeting on October 23. A presentation was also made to a group headed by Dr. E. Leavins, Director of the Fossil Fuel Utilization Division, on August 9 at the Westinghouse R&D Center.

4.3 Planning

The Phase II contract was received and executed with an effective date of October 1, 1979.

Several meetings were held with ERC and the government technical manager to develop a schedule and plan for the fuel cell module development efforts of Phase II. Two drafts of the work statement for the ERC subcontract were submitted to the government technical manager for review and comment, and steps were taken to initiate drawing up of the anticipated subcontract.

Some effort was devoted to preliminary work on Phase II (e.g. design of the MK-II bipolar plate) to eliminate some bottlenecks that otherwise would have occurred.

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