HYDROGEN-OXYGEN ELECTROLYTIC REGENERATIVE FUEL CELLS

Prepared for

National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland 35, Ohio
Attn: D. G. Soltis

Contract NAS 3-2781

EOS Report 4110-ML-12

10 October 1964

Prepared by

M. Klein

Approved by:

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Manager
Chemical and Fluid Systems

B. M. Wilner
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ELECTRO-OPTICAL SYSTEMS, INC.
Pasadena, California

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1. INTRODUCTION

This report reviews the progress made on development of a regenerative hydrogen-oxygen fuel cell (NAS Contract 3-2781) during the month of September, 1964. During the period covered, single cell tests of the type described in the previous monthly report were continued. These tests included variations in the electrode catalyst loading and asbestos mat type and electrolyte/asbestos weight ratio. Data is presented on the results of these tests including a continuous 50 hour cycling test. During this period, all of the components necessary for the 75 watt 6 cell unit were received, inspected, and found to be acceptable for use.

2. TECHNICAL DISCUSSION

2.1 Single Cell Tests

Single cell tests using the same test cell and instrumentation as described in the previous monthly report were continued in an attempt to arrive at the optimum electrode-mat-electrolyte arrangement. During the period, 10 single cells were assembled and subjected to cycling tests. Assembly details of these cells and results obtained from cycling are described in Table 1. The electrode back up plates used in the current series of tests were modified to include three radial grooves, 1/8" wide and 0.020" deep, to increase gas access to the backside of the electrodes.

Cell # 9 was cycled 7 times (35 minutes discharge, 65 minutes charge) and left on open circuit over a 3-day week-end at 0 psig and 70°C. After this stand period, two additional cycles showed that a considerable deterioration had occurred within the cell, i.e., the discharge voltage was low, and the cell exhibited a high charging voltage. It was reasoned that possible deteriorations had taken place with the asbestos mat. Therefore, Cell # 10 was assembled using a different grade of asbestos.

TABLE 1

SUMMARY OF SINGLE CELL TESTS

Cell #	O_2 O_2 Electrode No.	Catalyst	H_2 Electrode #		Mat Thickness and Grade	Mat Dry Wt. gms.	KOH Wt. 25.4% gms.	Comments	Results
9	6	10 mg Pt/cm^2	5	Catalyst 10 mg Pt/cm^2	.020-.020-.020 Electrolytic Grade	27	23.3	All following cells contained grooves in back-up plates.	Cycled 7 times, left on stand 3 days at temp. After stand exhibited low voltage on discharge.
10	4	"	3	"	Commercial Grade .035-.035	31	24.3		Cell test stopped due to excessive internal leakage
11	8	"	7	"	.035-.004-.035 Commercial Grade	34	28	.004 Mat layer was Visking celluosic membrane	Cell had excessive internal resistance
12	1	"	2	"	Electrolytic .020-.030-.020	31.8	23.5		Cycled 2 times left on stand at temp. 2 days. Gave degrated performance.
13	6	"	5	"	.020-.030-.020 Pure asbestos Fuel Cell Millboard	29.1	23.3	Added water to the cell by pressurizing and discharging.	Cycled 14 times. No deterioration noted but cell had low discharge voltage.
14	-	10 mg Pt/cm^2 + 10 mg Pd/cm^2	-	20 mg Pt/cm^2	Electrolytic .020-.030-.020	31	23.3		Gave improved initial discharge voltage but deteriorated after 7 cycles.
15	-	"	-	"	.020-.020-.020 Electrolytic	26.8	21.25	Following cells operated in horizontal position.	Cycled 7 times, showed deterioration with time.

TABLE 1 (con.)

16	-	"	-	"	.020-.020-.020 Electrolytic	26.8	21.25	Same electrodes as above without washing.	Shown initial good performance but deteriorated with cycling.
17	-	"	-	"	Pure .060	28.0	26.5	After 5th cycle added water remtly. to improve performance.	Cycled 10 times Cell had low discharge voltage
18	19	"	20	"	Pure .050	22	32		Cycled 32 times 50 hours continuous operation. Exhibited slow deterioration with cycli .

The mat used for Cell # 10 consisted of two layers of .035" thick commercial grade asbestos. In this configuration the cell exhibited considerable internal leakage and self-discharge. Therefore, the test was discontinued after a brief cycle period.

Cell # 11 consisted of two layers of the same material with the inclusion of one layer of a celluosic membrane type material (Visking) in an attempt to reduce internal cell leakage. The addition of one layer of celluosic type separator material resulted in increasing the cell resistance considerably. Consequently, the cell performed very poorly on both charge and discharge. It was then decided to go back to the mat configuration of Cell # 7 which had given the best performance to date.

Cell # 12, using 3 layers of electrolytic grade asbestos, was cycled two times and left at temperature and 0 psig over a two day week-end. At the end of the period the cell exhibited degraded performance on both charge and discharge similiar to Run 9.

Cell # 13 was assembled using the same mat configuration as Cell # 12 except the grade of asbestos was changed to pure fuel cell millboard, manufactured by the Johns-Mansville Company. Initial cycling of this cell indicated that the mat was low in water content. Water was added to the cell by pressurizing the cell and discharging the hydrogen and oxygen to form water within the cell. By doing this, it was possible to bring the cell performance up, but the cell still operated below the desired level. After 14 cycles, the cell was disassembled.

In order to improve the discharge voltage characteristics of the cell, it was decided to increase the catalyst loading in the electrodes. For Cell # 14, an oxygen electrode containing 10 mg./cm^2 platinum catalyst, and 10 mg./cm^2 of palladium catalysts was used. The hydrogen electrode consisted of 20 mg./cm^2 of platinum. Initial performance of this cell was considerably better than all previous tests. Typical operating voltage on discharge with the original electrodes was approximately .7 of a volt. By increasing the catalyst

loading, the cell operated at approximately .8 of a volt on discharge at the same current level. However, after cycling 7-8 times, this cell also deteriorated in performance.

The next cell # 15, was assembled to evaluate the effect of cell orientation, and was assembled and placed in the horizontal position. In addition, matrix compression ratio was reduced from a 7/4 ratio to a 6/4 ratio while slightly increasing the electrolyte/asbestos weight ratio. This cell was also cycled 7 times. Performance again deteriorated on both charge and discharge over this period. In order to determine if the deterioration was being caused by contamination of the electrodes, Cell # 15 was rapidly disassembled and reassembled using the same electrodes without washing, but with a new asbestos matrix. This cell initially exhibited good performance, indicating that the electrodes had not been poisoned. After wet stand over night, without being cycled, this cell also exhibited deteriorated performance.

In Cell # 17, the grade of asbestos was changed to one layer of 0.060" fuel cell millboard. This cell was cycled 10 times and did not show any significant deterioration. However, the discharge performance was lower than some of the previous data obtained on initial cycling. Therefore, Cell # 18 was assembled containing a thinner (0.050") mat of the same type. The thickness was reduced in order to decrease the compression ratio. In addition, the quantity of electrolyte was increased. This cell was cycled two times then allowed to stand over night at temperature. It was then cycled continuously for 30 cycles over a 50 hour period. Typical performance is shown on Figure 1. During the period of testing, there was some degradation in discharge voltage, and increase in charge voltage as shown in Figure 2.

In order to determine the cause of deterioration, the test was stopped and the gas compartments were flushed, reasoning possibly that impurities or gas mixing might have been the cause of the deteriorated performance. The cell was then put on discharge. Flushing did not improve the performance of the cell. Next an attempt was made to add

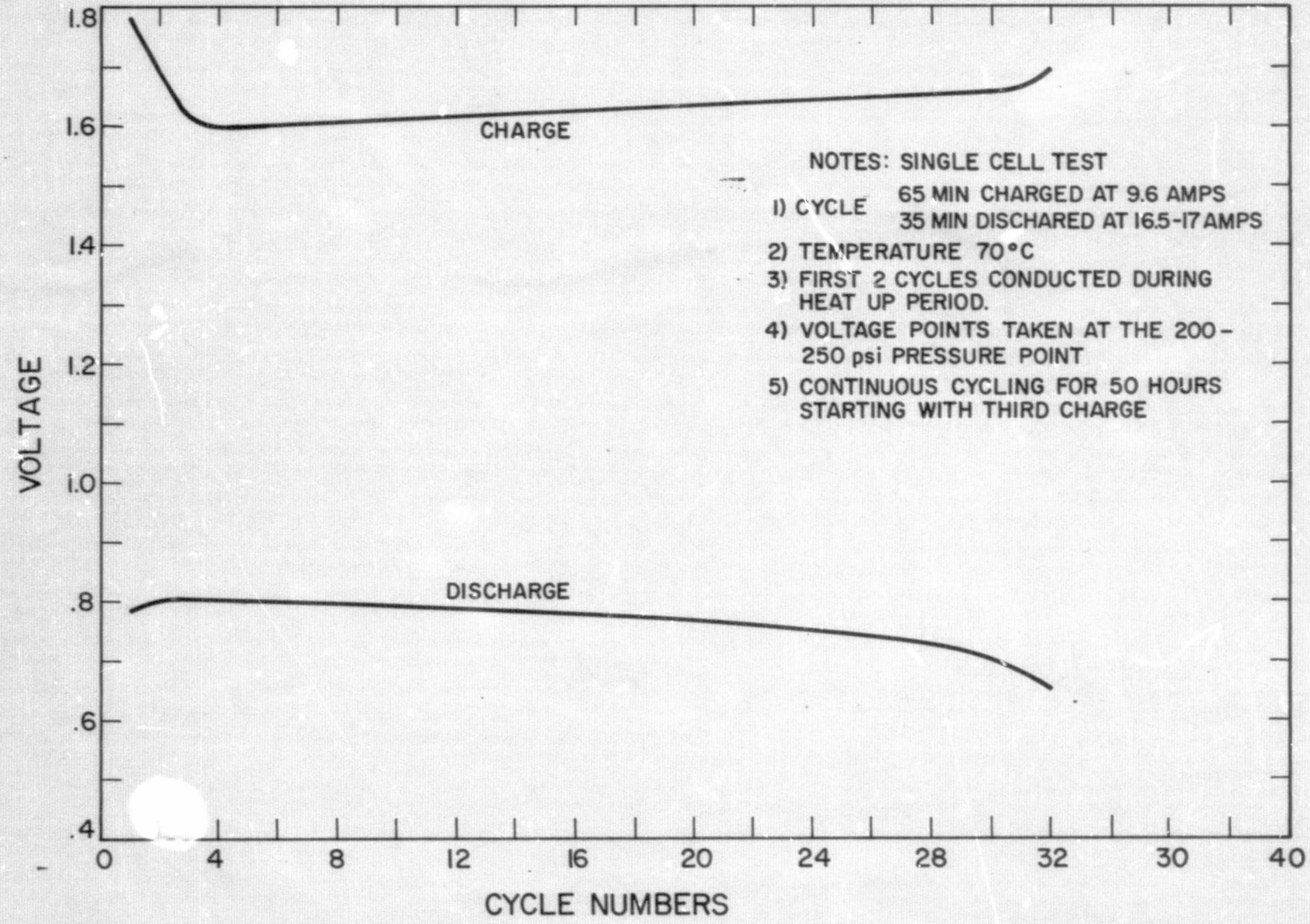

FIG. 1 EFFECT OF CYCLING ON CELL VOLTAGE

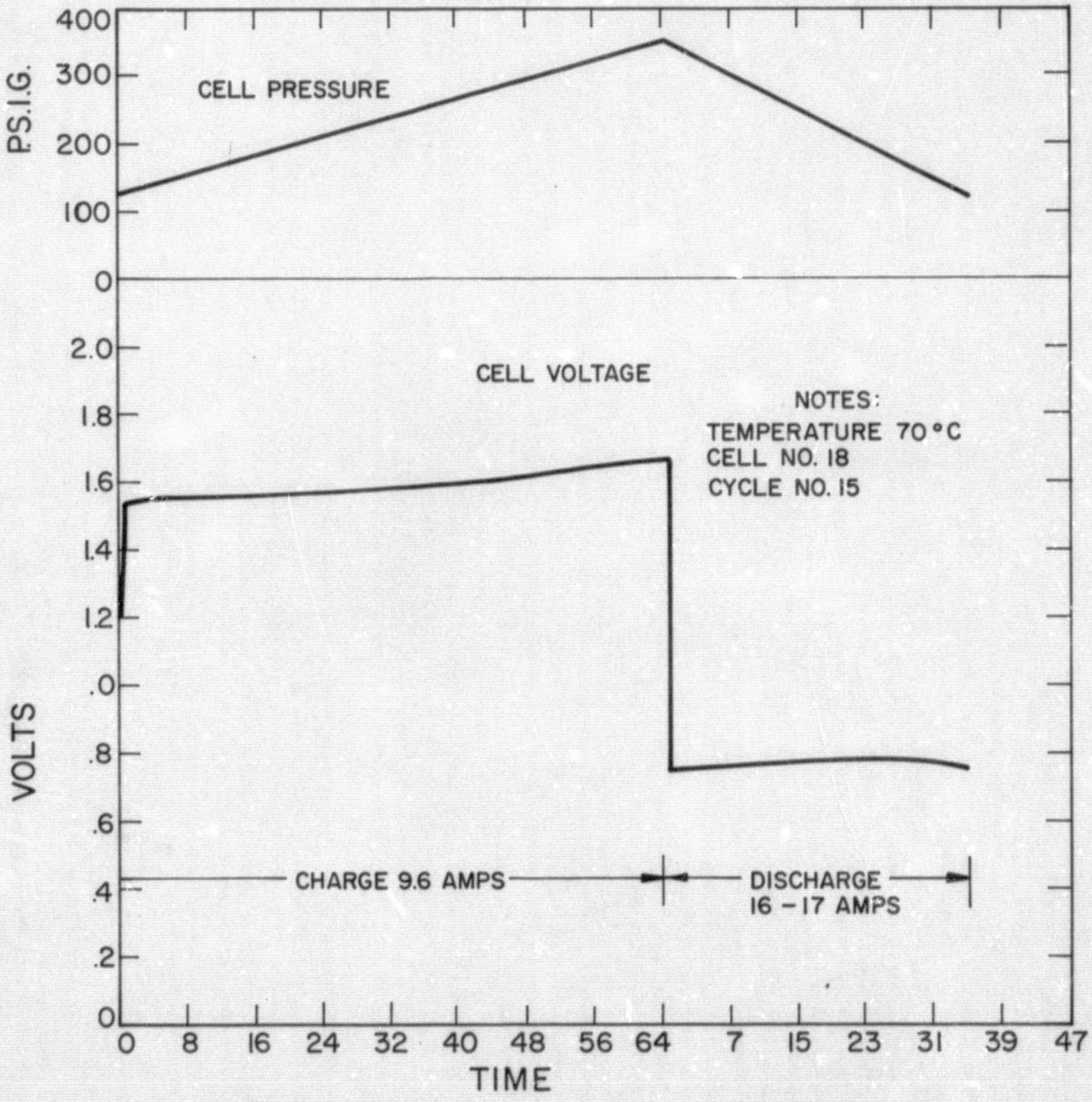

FIG. 2 CYCLING DATA HYDROGEN-OXYGEN ELECTROLYTIC REGENERATIVE FUEL CELL

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water to the cell by pressurizing the cell and discharging the added gas into the mat. An increase in water content did not improve the cell performance. The cell was then disassembled, and the mat examined. As in previous tests there was a discoloration of the mat adjacent to the hydrogen-electrode. Next, a sample of the mat was taken, and liquid KOH was squeezed out and titrated with 0.1 N HCl to determine the alkalinity content. This test showed that the liquid sample was approximately 10.5 percent KOH. Two separate samples titrated in the same manner gave the same result. (The cell had initially been assembled with 25.4 percent KOH.) Consumption of KOH such as was indicated, would explain the deteriorated performance. In order to check a possible direct chemical reaction with the asbestos mat, a sample of the fuel cell millboard asbestos was stored in KOH, over a period of 4 days, at elevated temperature. Analytical tests of this electrolyte sample showed essentially no decrease in the KOH content.

The question of KOH consumption is still unanswered. Apparently, the KOH is being consumed either by an impurity in the electrodes as a result of a reaction with some compound that is being formed during the cell charging process, or with some impurity we are adding during assembly. In the next tests increased KOH concentrations will be studied and additional peripheral tests will be made to determine the mode of KOH consumption.

2.2 Multi-Cell Components

During this period, all of the components necessary for the assembly of the 6-cell module were received and inspected. All components were found to be acceptable for use. The tanks were pressure checked, and all parts degreased and cleaned for assembly.

2.3 Test Facility

The new fuel cell test facility was completed during this period. All of the appropriate pneumatic and electrical connections were made which will enable remote hazard free testing of the 6 cell module during the next period.

3. PLANS FOR THE NEXT PERIOD

During the first phase of the next period, additional single cell tests will be conducted in order to analyze the effect of increased electrolyte concentration on cell performance. Additional tests will be conducted to determine the mode of KOH consumption as observed in the tests of this period. The 5 cell module will be assembled and subjected to a preliminary testing and debugging. If preliminary tests look satisfactory, a 48 hour multicell test will be initiated.

4. FINANCIAL STATEMENT

Manhours and dollar expenditure for the period August 30 through October 2, 1964 were as follows:

Direct Labor Hours	599.5
Direct Labor Dollars	$ 3,050.68
Purchases and Commitments	$ 3,485.08
Total Dollar Expenditure	$11,047.71