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RESEARCH ON COMPACT  
FUEL CELL POWER SUPPLIES

BY

AIRCRAFT ACCESSORY TURBINE DEPARTMENT  
FUEL CELL LABORATORY

PROGRESS REPORT NO. 5

MARCH 30, 1961 - MAY 30, 1961

FOR

U.S. ARMY

QUARTERMASTER RESEARCH AND ENGINEERING COMMAND  
NATICK, MASSACHUSETTS

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AIRCRAFT ACCESSORY TURBINE DEPARTMENT  
GENERAL ELECTRIC COMPANY  
LYNN, MASSACHUSETTS

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PROGRESS REPORT NUMBER 5

MARCH 30, 1961 - MAY 30, 1961

CONTRACT NUMBER DA 19-129-QM-1705 (01 5022)

The following statements are issued in accordance with the Statement of Work, Section B, Reports:

- a. An estimate of the percentage of the work completed to date - 75%.
- b. An estimate of the percentage of costs incurred to date - 48%.

As of this date, (May 30, 1961) to the contractor's best knowledge, the remaining unexpended funds are considered sufficient to complete the work called for by the contract.

General Electric Company  
Lynn, Massachusetts

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### INTRODUCTION

This is a technical progress report of a research program directed toward improvement of the Ion Exchange Membrane Fuel Cell concept. This work is conducted by the General Electric Company under contract No. DA-19-129-QM-1705 (OI 5022) with the U.S. Army Quartermaster Research and Engineering Command. The objective of this program is to:

"Initiate research studies to establish those factors which currently contribute the high energy losses of the ion exchange membrane and establish approaches for minimizing such losses to achieve substantially greater power densities per unit weight of cell."

In this series of reports, progress is reported on work directed toward the above objective. In addition, progress is reported on certain related work being conducted at the Aircraft Accessory Turbine Department. This is made possible by virtue of the similarity of the objective of this contract with that of other work being conducted concurrently. The Work Plan for the total work reported is given in section 0.4 of this report. Guidance and approval of the direction of the work under this contract is given by Mr. L. A. Spano - Chief Advanced Projects Office, Quartermaster Research and Engineering Command, Natick, Massachusetts.

These progress reports are issued on a bi-monthly basis and special summary reports will be issued as indicated. The reader should recognize that this is a progress report covering a particular period of time. The experiments reported are factual, but not necessarily complete, and any conclusions made must be considered tentative until a summary report is issued. Comments and suggestions on these reports are most welcome.

### SUMMARY

Work has been done in the following areas:

1. New ion exchange polymer. Preliminary tests have been made on fuel cells containing the new ion exchange polymer; The cells were run at current densities as high as 120 amps/ft<sup>2</sup>.
2. Polymer Reinforcements. Data is given on more ion exchange polymer reinforcement materials; thus concluding the work in this area for this contract.
3. Catalytic Electrodes. A cost comparison based on experimental data is included for various catalytic electrode systems at a current density of 50 amps/ft<sup>2</sup>.
4. Hydrogen Generation. The first half of the study of chemical hydrogen generation systems is presented including lithium hydride, sodium borohydride, and calcium hydride in water, basic, and acidic media;
5. Several low pressure (atmospheric) runs were made with the electrolyzer. The results were unsatisfactory because mixing of the gases occurred. During the next work-period, investigation will be made to determine the maximum current densities at which the electrolyzer can be operated.

### 0.3 STATEMENT OF WORK

#### A. SCOPE:

The Contractor shall, commencing on October 1960 and continuing through 2 October 1961 furnish necessary services, labor, materials, tools, equipment and supplies, and will furnish his best efforts to do what is deemed necessary to:

Initiate research studies to establish those factors which currently contribute the high energy losses of the ion exchange membrane and establish approaches to minimizing such losses to achieve substantially greater power densities per unit weight of cell. The principal effort under this contract should include but not be limited to a study of the factors that impede the conduction of electronic and ionic charges. Investigations of resins, membrane and catalyst formulations and their incorporation into a cell should be conducted to achieve maximum performance.

#### B. REPORTS:

Reports shall be submitted in accordance with the following:

1. The Contractor shall submit ten (10) copies of bi-monthly reports within fifteen (15) days following the end of each reporting period, indicating progress of work to date and significant developments. These quarterly reports shall include :
  - a. An estimate of the percentage of work completed to date.
  - b. An estimate of the percentage of costs incurred to date.
  - c. A statement that to the Contractor's best knowledge the funds remaining unexpended are sufficient to complete the work called for by the contract, or a revised estimate setting forth the costs required to complete the contract and the reason (s) for the contemplated excess.
2. Upon completion or termination of the contract, the Contractor shall furnish fifty (50) copies of a complete final report or summary report which shall consolidate all findings, notes, data, computations, test procedures, evaluation of all data, test results, principles and techniques relative to the objective indicated herein.

REPORTS (Cont'd)

The Contractor shall include specific conclusions and recommendations concerning work done and detailed information and recommendations relative to further work that may be required. All reports shall be identified with Project No. 7X8-01-New. The final report shall be submitted within thirty (30) days after the expiration or termination date of the contract. Reports shall be of a paper bound brochure type using commercially available bond paper. All reports shall be submitted to the responsible Project Officer, Chemicals and Plastics Division HQ QMR & E Center Natick, Massachusetts.

PRIORITY RATING:

DD C9E CERTIFIED UNDER DMS REGULATION #1 IS ASSIGNED TO THIS CONTRACT.

PLACE OF PERFORMANCE:

CONTRACTOR'S PLANT, WEST LYNN, MASSACHUSETTS

## 0.4 WORK PLAN

### REGULATED, COMPACT FUEL CELL POWER SUPPLIES

#### General Objective

Conduct a research and development program to achieve the capability of designing compact, lightweight and reliable, regulated fuel cell power supplies.

#### Research Approach

##### Task I

#### Studies of Contributions to and Efforts to Minimize Electronic and Ion Impedances

- A. Quantitative studies of contributions to electrical losses in present cells.
  1. Separate ohmic losses from electrochemical irreversibilities by use of an adaptation of the Kordesch-Marko bridge and other electronic techniques.
  2. Determine magnitude of various contributions to ohmic impedance by independent measurements of electrode-layer resistance, and electrolytic conductivity of the membranes. Establish apparent ohmic resistance attributable to the electrolytic conductivity of the membranes by other methods, including multi-frequency A.C. bridge measurements and driven-cell D.C. resistance with two hydrogen electrodes.
- B. Minimization of Electrolytic Conductance Losses
  1. Investigate ion exchange resin formulations with varying exchange capacities, ionization constants and water content with regard to their effect on cell performance.
  2. Investigate the effect on cell performance of membrane thickness along with varying the amount and distribution of resin and reinforcing material.



3. Evaluate various reinforcing materials from the standpoint of cell performance, strength, compatibility, and ease of membrane manufacture.

C. Minimization of Electronic Losses

1. Investigation of catalyst impregnated carbon electrodes to minimize electrode layer resistance.
2. Evaluate various carbon blacks with different catalyst loadings and physical properties with regard to cell performance and life.

Task II

Study of the Internal Generation and Storage of Hydrogen Fuel

- A. Studies at the Electronics Laboratory, HMEM, Syracuse, of palladium and other absorbents.
- B. Provision of data by the AAT Laboratory on the electrolysis characteristics of membrane fuel cells, including details of supplying the water required for such operation.

Task III

Study of the External Generation and Storage of Hydrogen and Oxygen

A. Electrolytic Methods:

Engineering work leading to the development of a prototype model of a small high pressure electrolyzer. The initial design concept is that of a compartmented vessel for simultaneous generation and containment of hydrogen and oxygen in quantities sufficient for operation of a fuel cell for a specified duty cycle. Included will be studies of pressure reduction methods including minimum weight regulators of conventional design.

B. Chemical Methods:

Studies of various chemical systems for minimum volume and cost hydrogen generators. The size will be set by the required duty cycle.

Chemical Methods (Cont'd)

Noxious reaction products are to be avoided. Feasibility of the process using the best of the chemical system (s) will be demonstrated by constructing a laboratory model generator including pressure regulators as required.

## 1.0 TASK IB - Minimization of Electrolytic Conductance Losses

- 1.1 A new ion exchange polymer is currently being developed by the AAT Fuel Cell Laboratory. This work is being done independently of this contract, but it is felt that data on these cells should be reported as part of the contract to give an indication of the possibilities of the new resin. Initial investigations show that the polymer resistivity may be as low as 4 ohm-cm as compared to 30 ohm-cm for the phenol sulfonic acid-formaldehyde resin.

A number of cells measuring about 3 x 7 inches, the size to be used for small 35 watt units, were tested to determine their performance and resistivity under running conditions. Figure 1 shows the results of testing Cell R-11 on the Kordesch-Marko Interruptor. The interrupted potential (No IR loss) shows a reasonably high value and little fall off with current density, and is comparable to the results obtained with good phenol cells. Note, however, that the operating range of current density was greatly extended (120 amps/ft.<sup>2</sup>) by the new polymer. The d.c. curve is somewhat erratic, since steady state running conditions were not entirely met, and the cell resistance was dropping during the run. The catalytic electrode used for these tests will be referred to as type A. One of the first cells operated with this type electrode was found to have a resistance of .05 ohms (per cell) which was relatively high. A section of the cell was cut out and checked for polymer resistivity on the parallel gold plates. The resistivity was found to be 7.5 ohm-cm, indicating that the cell resistance should have been .01 ohms instead of .05 ohms. The resistance due to catalytic electrode A, therefore, was 80% of the total cell resistance. On subsequent cells, catalytic electrodes of type B were used which alleviated the catalytic electrode resistance problem.

## 1.2 I-B 3. Reinforcing Materials

- 1.2.1 To complete the effort reported previously to find reinforcing materials for the phenol cells, fuel cells were made containing various cloths and porous glass materials. Table I shows the cloths investigated and the types of screening tests run, namely:

Fig. Performance (Short time) of new polymer cell.

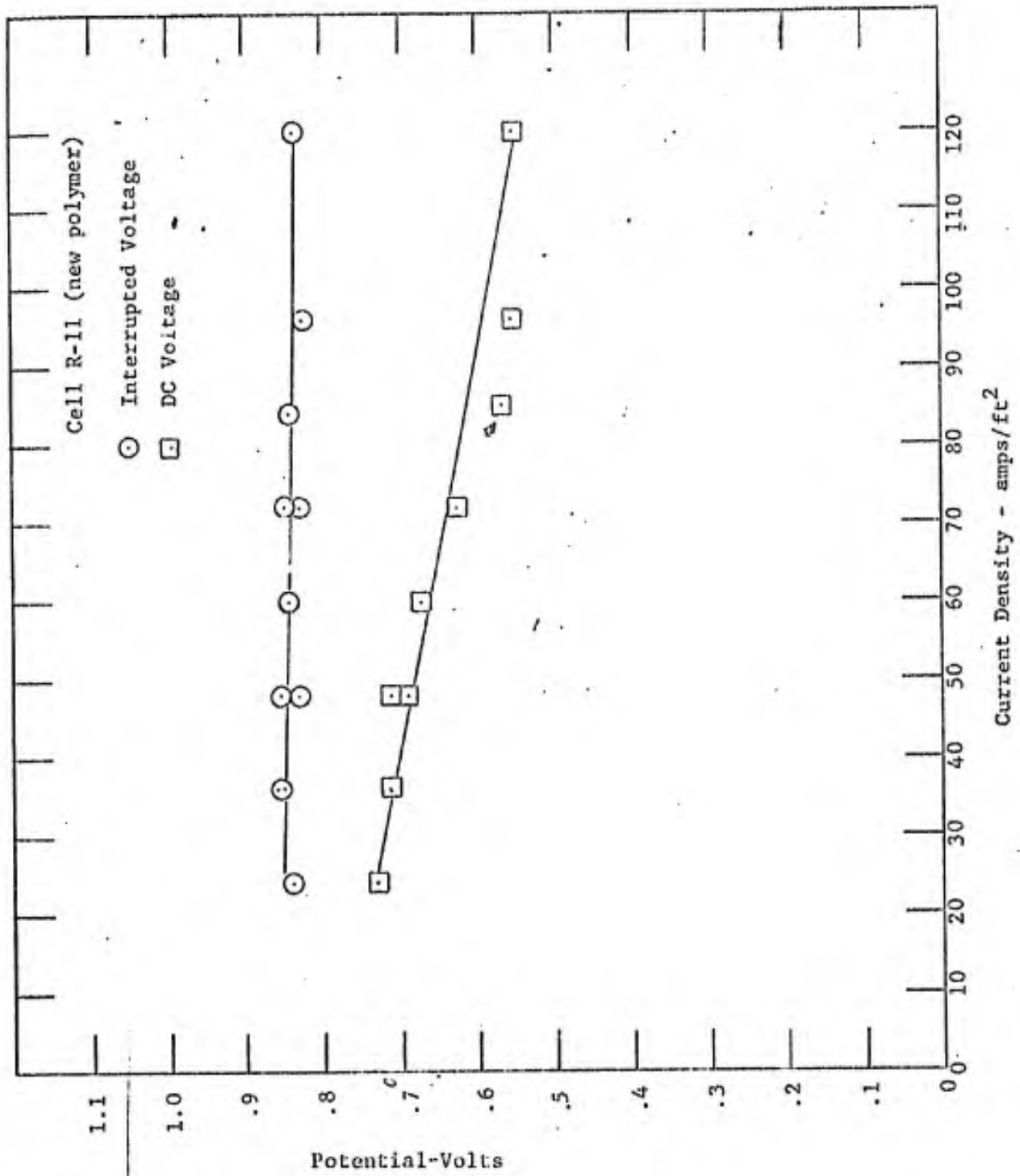


FIGURE 1

### 1.2.1 Cont'd

1. Dry out tests in ambient air on rigid frames.
2. Mullen Burst test (Hydraulic pressure on a section of cell).
3. Visual checks for structural integrity (mainly blister formation or delamination).

It can be seen that the cell made of three plies including 424/234/424 Dynel is still superior as far as dry out time is concerned. Also, it is apparent that "tissueglas" or porous glass is undesirable because of a drastic delamination problem when one tries to laminate the smooth surfaced material.

It is encouraging to note that the new ion exchange polymer currently under development will probably not have to be reinforced with cloth. This means that the present weight and cell resistance penalty will probably be reduced.

### 1.3 TASK I-C Minimization of Electronic Losses

#### 1.3.1 Cost Comparison of Various Catalyst Systems.

Various catalyst systems have been studied from the point-of view of overall cost of the catalyst on a cell for unit power density. The systems studied were made of mixtures of platinum, Stackpole Carbon, graphite, carbon cloth, and palladium. Polarization curves were obtained for various cells and a cost comparison for catalysts was made at a current density of 50 amps/ft.<sup>2</sup>.

Figure 1 shows a bar graph depicting the relative costs per kilowatt for various catalysts, taking into account the catalyst loading and the resistive power losses. The cost ranges from \$2500 per kilowatt for 0.11 g/in.<sup>2</sup> platinum to about \$240 per kilowatt for palladium mixed with Stackpole Carbon.

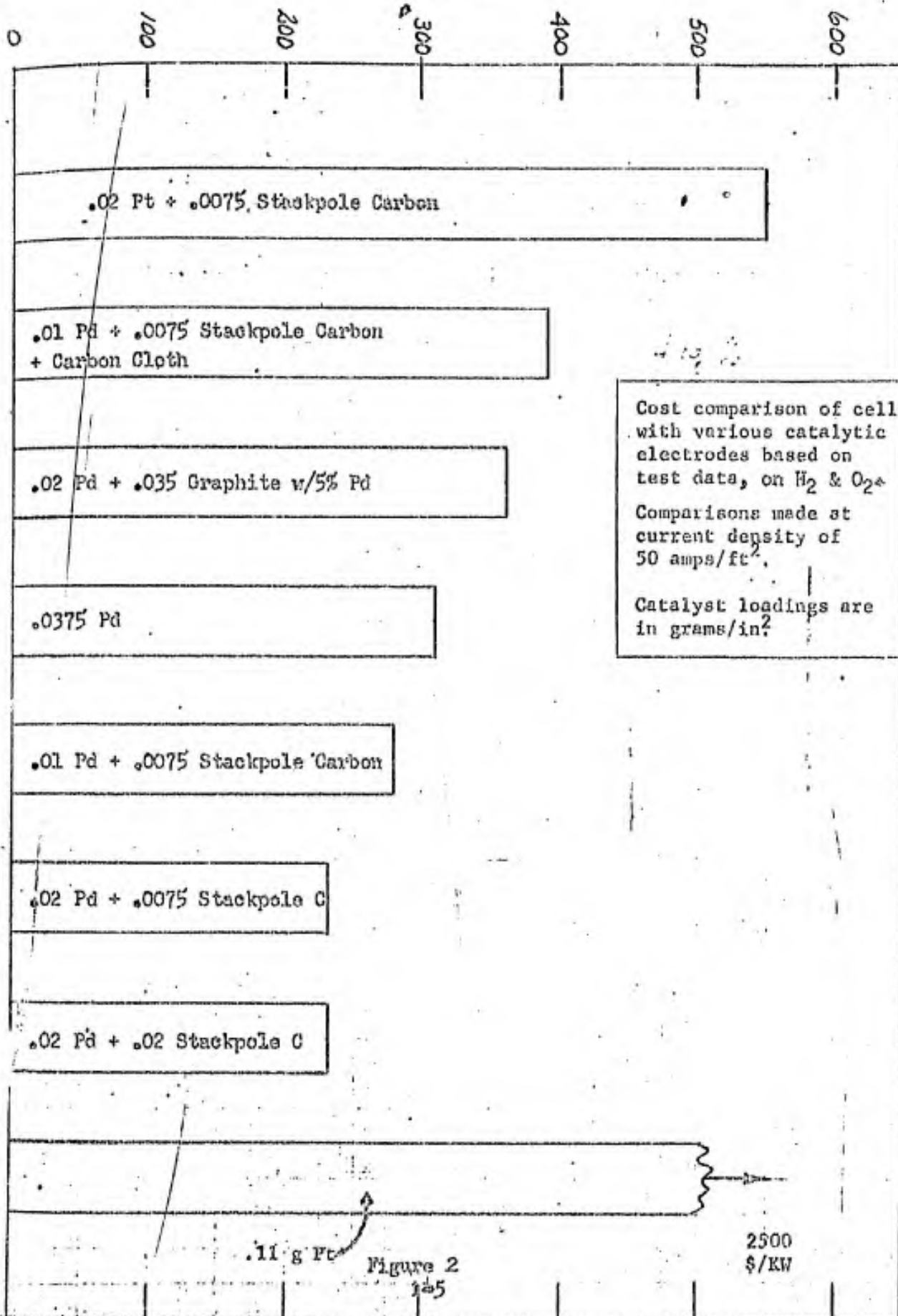
It is interesting to note that a titanium 0.290 palladium screen loaded with 0.11 g/in.<sup>2</sup> has a resistivity of 0.012 ohms per square versus about 0.5 ohms per square for just 0.11 g/in.<sup>2</sup> of platinum. It is beyond the scope of the present work to assess and solve the problems of mechanically loading various types of screens with reduced amounts of catalyst, and obtaining proper bonding of the electrodes to the cell surface without separation after long periods of operation.

POLYMER REINFORCEMENTS

Style #	Cloth Description	Wgt. 2 g/yd	Ply	Thickness (in.)	Dry Out Test-Min.	Mullen Burst Test (psi)	Resin Pickup. %	Blisters
Webril 234	Non-woven 100% Dynel	160	1	.025	24/25	135	62	
Webril 234	Non-woven 100% Dynel	75	2	.025	21/27	140	57/63	No
" 234	" "	75						
Webril 424	Compressed 100% Dynel	70	3	.025	55/60	195	51/57	Small
" 234	Non-woven " "							
" 424	Compressed " "							
Webril 234	Non-woven 100% Dynel	75	3	.025	41/44	335	51/57	Few
DNC	Woven							
Webril 234	Non-woven 100% Dynel	75						
Webril 261	Non-woven 100% Orlon	80	2	.025	2	90	58	Small
" 261	" "	80						
Webril 262	Non-woven 90% Dynel	75	2	.025	5	50	60	No
" 262	" " 10% Viscose	75						
Webril 263	Non-woven 90% Dynel	88	2	.025	5	90	52	No
" 263	" " 10% P.V.A.	88						
Webril 264	Non-woven 50% Dynel	63	2	.025	½	140	67	No
" 264	" " 50% Polypropylene	63						
Webril 234	Non-woven 100% Dynel	80	3	.025	Not Feasible (Blisters)	170	58	Many Large
Glass 108-38	Woven 100% Glass							
Webril 234	Non-woven 100% Dynel	80						
Webril 234	Non-woven 100% Dynel	80	3	.025	Not Feasible (Blisters)	120	47	Many Large
Glass 1238-38	Woven 100% Glass							
Webril 234	Non-woven 100% Dynel	80						
Webril 234	Non-woven 100% Dynel	80	3	.025	Not Feasible (Blisters)	150	-	Many Very Large
Glass 325-38	Woven 100% Glass							
Webril 234	Non-woven 100% Dynel	80						

TABLE I

DOLLARS/KILOWATT



Cost comparison of cells with various catalytic electrodes based on test data, on H<sub>2</sub> & O<sub>2</sub>. Comparisons made at current density of 50 amps/ft<sup>2</sup>. Catalyst loadings are in grams/in<sup>2</sup>.

Figure 2  
1-5

2500  
\$/KW

CELL CONSUMPTION FOR FERRONITRILE CELLS AT VARIOUS CURRENT DENSITIES FOR VARIOUS CATALYSTS

Cell Number & Dimensions	Oxygen Catalytic Electrode Loading (g/cm <sup>2</sup> )	Hydrogen Catalytic Electrode Loading (g/cm <sup>2</sup> )	Cell Resistivity (Ohm-cm)	Cell Resistivity Calculated (Ohm-cm <sup>2</sup> )	Current Density (A/cm <sup>2</sup> )	Inter-plate Voltage (to 11 drop) Volts	Inter-plate Power Watts/cm <sup>2</sup>	Resistance Power Loss Watts/cm <sup>2</sup>	Net Power (W)	Cost of Cell per Watt \$/Watt
008-10 23x (.025)	.11 Pt	.11 Pt	1.88	2.03 x 10 <sup>-3</sup>	30	.85	27.1	1.82	23.5	1.82
008-8 23x (.025)	.0075 Pt	.0075 Pt	2.03	2.19 x 10 <sup>-3</sup>	30	.82	25.0	2.0	23.0	.17
008-12 23x (.025)	.01 Stachpole Carbon + .0075 Pt	.01 Stachpole Carbon + .0075 Pt	9.65		30	.80	11.0	5.5	35.5	.21
008-11A 23x (.025)	.007 Stachpole Carbon + .02 Pt	.007 Stachpole Carbon + .02 Pt	3.07	3.30 x 10 <sup>-3</sup>	30	.80	8.0	.3	7.7	2.24
008-13 23x (.025)	.0075 Stachpole Carbon + .02 Pt	.0075 Stachpole Carbon + .02 Pt	6.76	7.3 x 10 <sup>-3</sup>	30	.79	13.5	6.5	5.9	.17
008-15 23x (.025)	.0075 Stachpole Carbon + .02 Pt	.0075 Stachpole Carbon + .02 Pt	1.23	1.56 x 10 <sup>-3</sup>	30	.695	23.5	18.2	20.3	.28
008-17 23x (.025)	.02 Stachpole Carbon + .02 Pt	.02 Stachpole Carbon + .02 Pt	1.53	1.88 x 10 <sup>-3</sup>	30	.769	8.2	1.1	7.1	.75
008-16 23x (.025)	.025 Graphite W/S Pt + .02 Pt	.025 Graphite W/S Pt + .02 Pt	1.53	1.88 x 10 <sup>-3</sup>	30	.750	23.1	1.1	19.0	.30
008-7 23x (.025)	.0075 Stachpole Carbon + .02 Pt	.0075 Stachpole Carbon + .02 Pt	2.31	2.57 x 10 <sup>-3</sup>	30	.752	16.3	11.3	25.9	.23
					50	.752	7.6	.5	7.1	.21
					30	.752	23.5	1.1	19.0	.30
					50	.752	16.3	11.3	25.9	.23
					30	.752	23.5	1.1	19.0	.30
					50	.752	16.3	11.3	25.9	.23
					30	.752	23.5	1.1	19.0	.30
					50	.752	16.3	11.3	25.9	.23

TABLE II

\* Interpolation

WOULD BE WITH AT HIGH C.D.



## 2.0 TASK III-B Chemical Methods of Hydrogen Generation

2.1 For these studies the following systems were chosen to be compared experimentally:

1. Calcium hydride and water.
2. Calcium hydride and 35% sulfuric acid.
3. Sodium borohydride and 35% sulfuric acid.
4. Sodium borohydride in water solution of 10% sodium hydroxide with cobalt sulfate as the catalyst.
5. Lithium hydride.

The aluminum-sulfuric acid system described in Report #3 was not considered, because of the high volume required and the necessity of making a proper amalgam for reaction.

Tests were run in a small volume glassware system as sketched in Figure 3. Solids are held in a 125 cc flask fitted with a thermometer to measure reaction temperature. Liquids are held in a glass separatory-funnel which has pressure equalization to maintain itself at reaction vessel pressure. Gases are led through a cold trap to any one of three gas burets made of 3/4 inch plexiglass tubing about four feet tall. Any buret can be quickly emptied of reaction gas while the others are filling, so that the capacity of the system can be increased.

The tests on the  $\text{CaH}_2$  + water system showed that about three times the stoichiometric water is necessary to get 95% utilization of the solid reactant (see figure 4), and that reaction temperatures were  $100^\circ\text{C}$ , as would be expected in such a system with excess water.

Another feasible system for hydrogen generation, providing that low temperature storage is not needed, is the  $\text{NaBH}_4$  +  $\text{H}_2\text{O}$  +  $\text{NaOH}$  with  $\text{CoSO}_4$  added to activate the reaction. Referring to Table IV, one sees that the system produces good yields, but a definite foaming problem is associated with the reaction, which could prove troublesome to delicate controls needed on a large scale generator. It was found that the best way to operate was to glue the  $\text{CoSO}_4$  to a fiberglass mat to prevent the catalyst from breaking up and causing the reaction to "bump" downstream into gas exhaust lines.

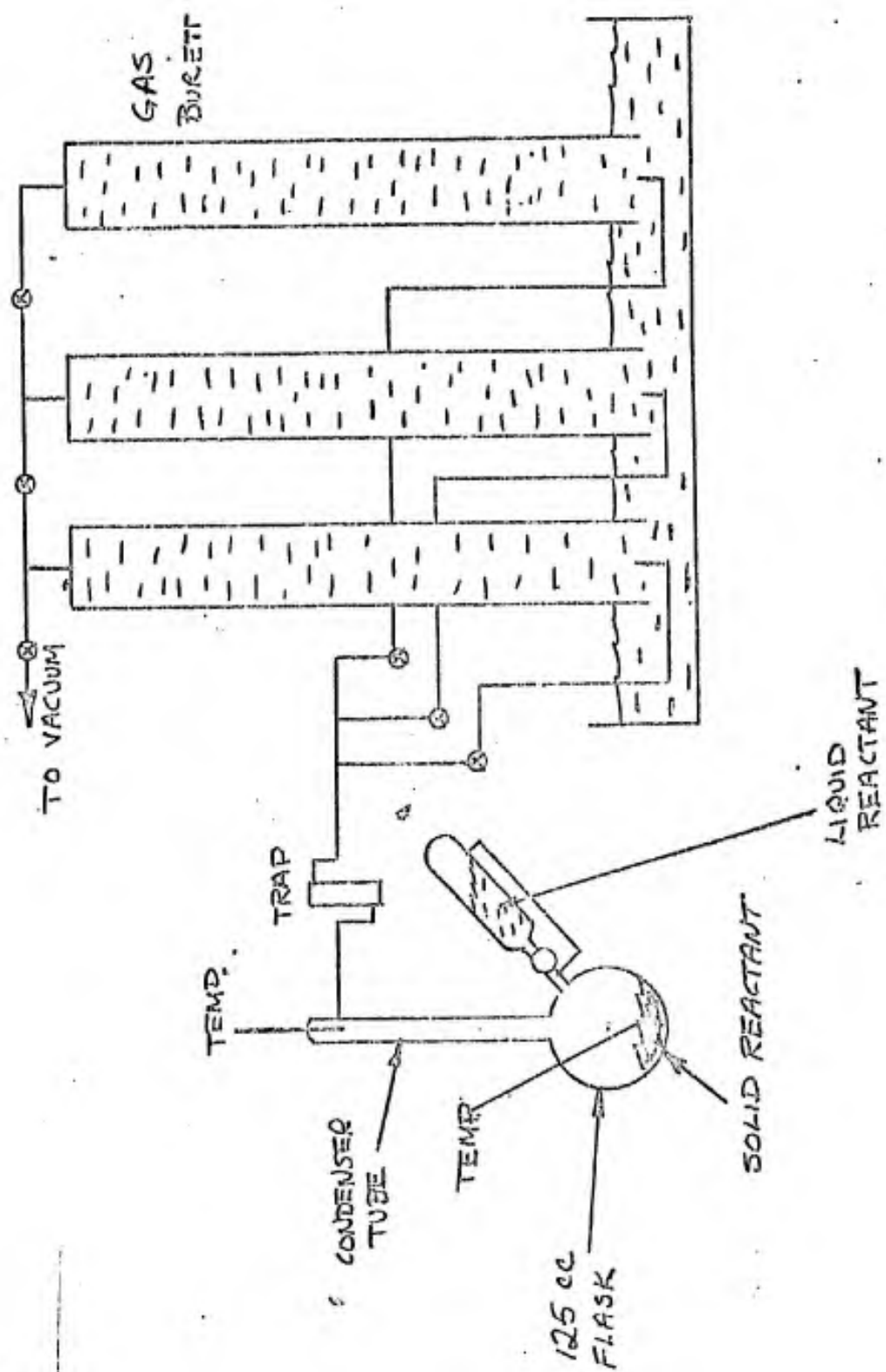


FIG 2. GAS GENERATION APPARATUS SCHEMATIC

UTILIZATION OF METAL HYDRIDES  
IN A 125 cc SPHERICAL REACTOR

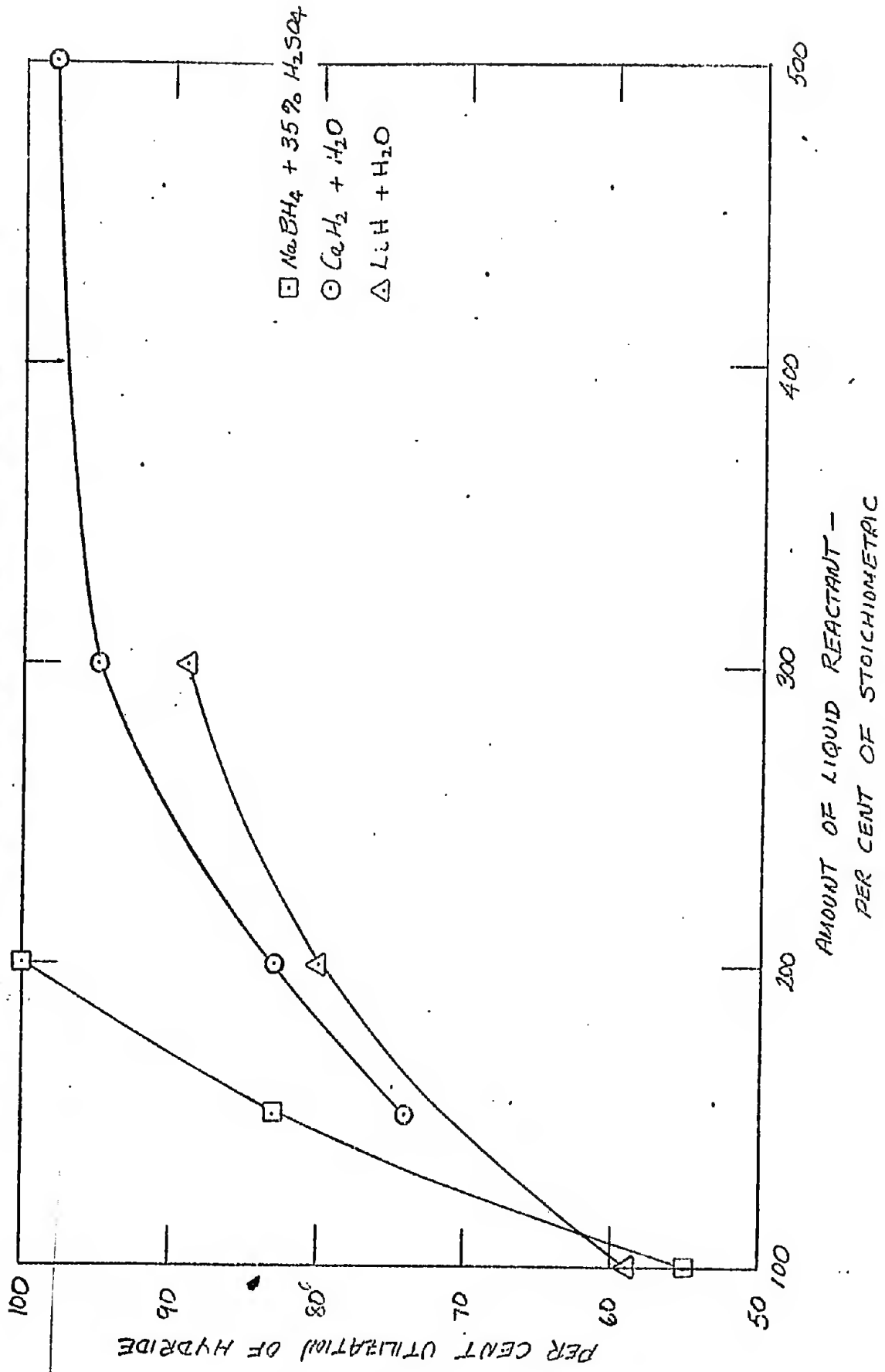


Figure 4

## 2.1 Cont'd

Solid  $\text{NaBH}_4$  with 35%  $\text{H}_2\text{SO}_4$  (Table V) was a well-behaved system, giving 100% yield with 2 "stoich" sulfuric acid, and was free from physical defects, except of course, the corrosion problem associated with storage of 35%  $\text{H}_2\text{SO}_4$ .

Lithium hydride (Table VI) and water indicated a very severe bumping and foaming problem. The reaction would proceed slowly at first, and then gain speed, throwing reactants into the gas exhaust lines. This behavior, and the high volume system associated with  $\text{LiH}$ , are sufficient reason to discourage its further use.

After these systems were initially screened, a different reactor for the hydrogen generation experiments was designed and built to more closely simulate actual generator geometry. The generator was designed particularly for a laboratory fuel cell demonstrator of 35 watt size, probably using  $\text{CaH}_2$  and water, since the system is safe to operate and lacks the corrosion problem of  $\text{H}_2\text{SO}_4$ .

The generator is sketched in Figure 5. It was designed primarily for simplicity without controls and fitted with a balloon to accept all the hydrogen generated from a 12 watt hour reaction. The generator consists of an upper and lower half which are separated by a frangible diaphragm. Solids are placed in the lower half, liquid reactants in the upper half, and the reaction is started by puncturing the diaphragm with the plunger. The reaction is therefore allowed to proceed in its entirety, and the exhaust gases are caught in the balloon, to be used as needed in the fuel cell.

The apparatus has been tested on  $\text{CaH}_2$  and water and is safe to operate. The  $\text{CaH}_2$  utilization is about 80% after 20 minutes, using 2 "stoich" water (100% excess water). More studies will be made comparing:

1.  $\text{CaH}_2 + \text{H}_2\text{O}$
2.  $\text{CaH}_2 + \text{H}_2\text{SO}_4$
3.  $\text{NaBH}_4 + \text{H}_2\text{SO}_4$

with slow additions of the liquid reactants to determine the effect on packing of the reaction products and probable masking of the reactive solids by the reaction products.

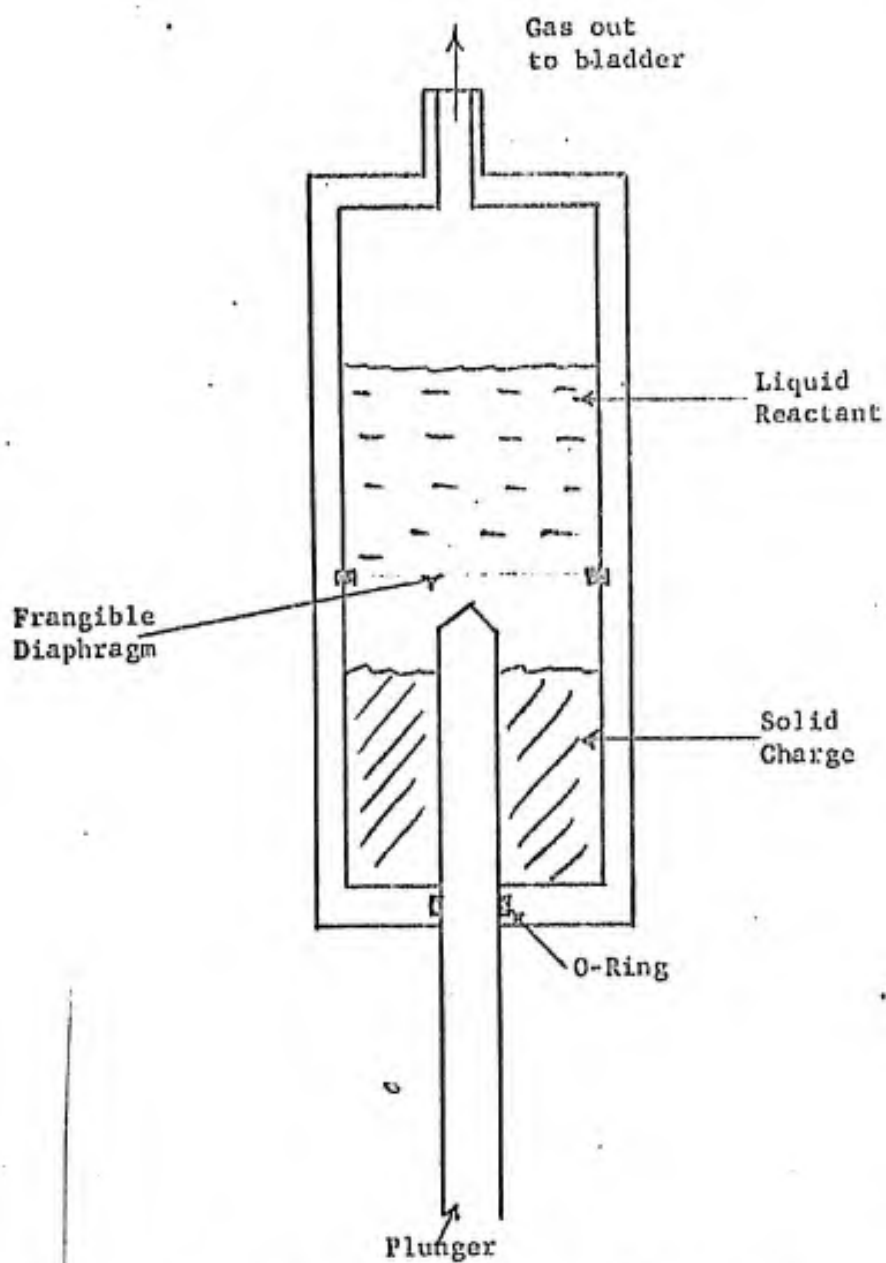


FIG 5. SKETCH - BATCH  $H_2$  GENERATOR  
2-5

TABLE III Results of Hydrogen Generation Testing

System:  $\text{CaH}_2$   
 $\text{H}_2\text{O}$  in 125 cc Spherical Reactor.

Test No.	Wgt. $\text{CaH}_2$ (gm)	Volume $\text{H}_2\text{O}$ (cc)	% of "stoich" $\text{H}_2\text{O}$	Theoretical Volume $\text{H}_2$ ft. <sup>3</sup>	Actual Volume $\text{H}_2$ in. 20 min. (ft. <sup>3</sup> )	% Utilization $\text{CaH}_2$	Watt Hrs. Generated watt-hr.	Remarks
11	3.00	7.65	300%	.124	.119	96%	5.3	None
13	8.5	11	150%	.350	.261	74%	11.6	None
14	8.6	15	200%	.354	.293	83%	13.1	None

TABLE IV

System: 30% NaBH<sub>4</sub>  
 10% NaOH  
 60% H<sub>2</sub>O by weight.

Test No.	Volume of Charge (cc)	Weight of Catalyst (gm)	Theoretical H <sub>2</sub> Yield (ft <sup>3</sup> )	Actual H <sub>2</sub> Yield (ft <sup>3</sup> ) (per 20 min.)	% Yield in 20 min.	Watt Hrs Generated (20 min.)	Remarks
20	14.1	.1g CoSO <sub>4</sub> .7 H <sub>2</sub> O	.389	.390	100%	17.3	Foaming
21	13.7	.065 CoSO <sub>4</sub> .7 H <sub>2</sub> O	.377	.355	94%	15.8	Foaming
22	14.7	.049	.405	.324	80%	14.4	Foaming after 15 minutes.
23	13.7	.1	.377	.358	95%	15.9	Foaming
28	13.7	Cemented small amt of powder on Fiberglas	.377	.352	93%	15.7	Foaming not as violent (No foaming out of reactor)

TABLE V

System:  $\text{NaBH}_4$  (98% by weight) (Solid)  
 $35\% \text{H}_2\text{SO}_4$  in 125 cc Spherical Reactor

Exp. No.	Weight $\text{NaBH}_4$ (grams)	Volume $35\% \text{H}_2\text{SO}_4$ (cc)	% of "Stoich" of $35\% \text{H}_2\text{SO}_4$	Theoretical Volume of $\text{H}_2$ ( $\text{ft}^3$ )	Actual Volume of $\text{H}_2$ (20 min.) ( $\text{ft}^3$ )	% Utilization $\text{NaBH}_4$	Watt Hrs. Generated watt-hr.	Remarks
32	4.471	6.5%	100%	.379	.208	55%	9.26	Reaction quick but no foaming
33	4.456	13.0	200%	.377	.394	100+ %	17.5	No foaming
34	4.426	9.7	150%	.374	.311	83%	13.8	No foaming



TABLE VI

System:  $\text{LiH} + \text{H}_2\text{O}$ 

Test No.	Weight LiH (grams)	Volume $\text{H}_2\text{O}$ (cc)	% of "Stoich" for $\text{H}_2\text{O}$	Theoretical Volume $\text{H}_2$ (ft <sup>3</sup> )	Actual Volume $\text{H}_2$ in 20 min. (ft <sup>3</sup> )	% Utilization of LiH %	Watt-Hrs generated watt-hr	Remarks
41	3.75	8.5	100%	.377	.217	59%	9.7	No foaming
42	3.74	17.0	200%	.377	.302	80%	13.4	Bumped into upper portion of reactor clogged gas line
43	3.74	25.5	300%	.377	.333	89%	14.8	Very vigorous bumping

### 3.0 TASK III -- External Generation and Storage of Hydrogen and Oxygen

#### 3.1 TASK IIIA -- Electrolytic Methods

Several low pressure (atmospheric) runs were made with the electrolyzer whose design was described in Progress Report #4.

At the beginning of each run, the electrolyzer was filled with the electrolyte, an aqueous solution of 25 wt. percent potassium hydroxide, and the gases generated were then collected in glass tubes for volume measurements. The results of these first runs were rather unsatisfactory because mixing of the gases occurred; that is, hydrogen and oxygen were collected as mixtures from both electrode compartments. In Run #1 the ratio of the volume of hydrogen to the volume of oxygen varied from 1.1 to 1.2 with a change in current density from 450 ma/cm<sup>2</sup> to 76. ma/cm<sup>2</sup>. For Run #4 a piece of porous polyethylene was placed over the holes in the separating monel plate. With the polyethylene in place and with an electrode separation of 1 inch, the ratio of the volume of hydrogen to the volume of oxygen varied from 1.3 to 1.9 with a change in current density of 132 ma/cm<sup>2</sup> to 37 ma/cm<sup>2</sup>. It becomes apparent, although data is somewhat limited, that increasing agitation, sufficient to cause mixing, occurs with increasing density. During the next work-period we propose to fully investigate the maximum current density at which the electrolyzer can be operated without mixing the gases, as well as the design changes necessary to increase the current density.

Two vendors have been contacted who are capable and willing to supply us with the expansible bags, at reasonable cost, for our pressure equalizer or accumulator. Working drawings have been completed, and it is expected that the accumulator will be fully evaluated during this next work-period.