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DEVELOPMENT OF ADVANCED FUEL CELL SYSTEM (Phase IV)

SUMMARY REPORT

by

A. P. Meyer
W. F. Bell

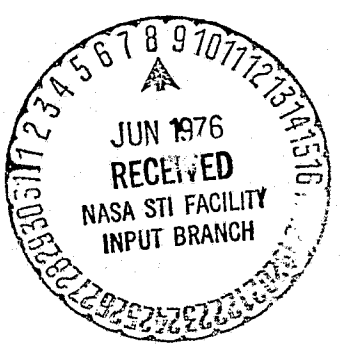
31 January 1976

UNITED TECHNOLOGIES CORPORATION
Power Systems Division

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA Lewis Research Center
Contract NAS3-15339
Dr. L. H. Thaller, Project Manager



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CONTRACT NAS3-15339

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FOREWORD

This report summarizes the several research and development tasks performed during Phase IV of an advanced fuel cell technology program.

The work was performed under a NASA Contract NAS3-15339 from 20 February 1975 through 31 December 1975. The NASA Program Manager for this contract was Dr. Lawrence H. Thaller. The contributions of Dr. Thaller and other members of the Direct Energy Conversion Laboratory staff at the NASA Lewis Research Center are gratefully acknowledged.

Principal Power Systems Division personnel who directed the tasks performed in this program were:

A. P. Meyer
W. F. Bell

ABSTRACT

A multiple-task research and development program was performed to improve the weight, life, and performance characteristics of hydrogen-oxygen alkaline fuel cells for advanced power systems. During Phase IV covered by this report, the lowest stabilized degradation rate observed in all the testing completed during four phases of the program, 1 μv/hour, was demonstrated. This test continues after 5000 hours of operation. The cell incorporates a PPF anode, a 90Au/10Pt cathode, a hybrid frame, and a Fybex matrix. These elements were developed under this program to extend cell life. The result demonstrated during Phase III, at the laboratory level, that the 80Au/20Pt cathode is as stable as a 90Au/10Pt cathode of twice the precious metal loading, was confirmed in full-scale cells during Phase IV. A hybrid frame two-cell plaque with dedicated flow fields and manifolds for all fluids was demonstrated to prevent the cell-to-cell electrolyte transfer that limited the endurance of multicell plaques during Phase I. At the conclusion of Phase IV, more than 90,900 hours of testing had been completed and twelve different cell designs had been evaluated. A technology base has been established which is ready for evaluation at the powerplant level.

I SUMMARY

This document reports the activity and results of Phase IV of a long-range research program to improve the life and performance and reduce the weight of alkaline fuel cells. The specific tasks are focused on meeting technology goals defined by the Engineering Model System (EMS), an advanced long-life, lightweight powerplant concept. The program is evolutionary in nature. Work has been carried out at the laboratory level, in subscale cells, and in full-scale cell assemblies. As fundamental improvements are defined in the laboratory; e.g., better catalysts and materials, they are committed to evaluation in the working environment of subscale fuel cells. If their merit is demonstrated at this level, they are committed to the full-scale cell tests for a final evaluation. The work completed during this phase of the program built on the accomplishments of the earlier phases. Each of the tasks and the results achieved are summarized below.

A. Materials Research

1.0 Electrodes

Task Description

This task focused on investigation and evaluation of electrode catalysts and structures. The overall task objective was to attain higher performance, lower catalyst loading, and improved long-term stability.

Results

During Phase IV, evaluation of the 80Au-20Pt cathode catalyst was continued. Results of laboratory testing during Phase III had shown that the endurance qualities of the 80Au-20Pt cathode were equal to those of "standard" 90Au-10Pt cathodes. Because of their higher specific area, the 80Au-20Pt alloy electrodes approached the activity levels of standard cathodes with only half the precious metal loading. Full size electrodes of this type were fabricated and tested in Cell Nos. 40 and 41 and in Two-Cell Plaque No. 1. Over 10,000 load hours were accumulated in these tests. A comparison of the cathode activity of Cell Nos. 40 and 41 with that of two representative 90Au-10Pt cathode cells is made in Figure 1. The initial activity of the 80Au-20Pt catalyst cells is slightly lower than the 90Au-10Pt cathodes, but with time the activity levels approach each other. Additional testing may show the 80Au-20Pt catalyst to be more stable than 90Au-10Pt catalyst and it may be preferred for extended operation. These tests conducted on full-scale strip cells with electrodes made using shop fabrication procedures showed that the change from laboratory manufacture to shop manufacture had no deleterious effect on their characteristics.

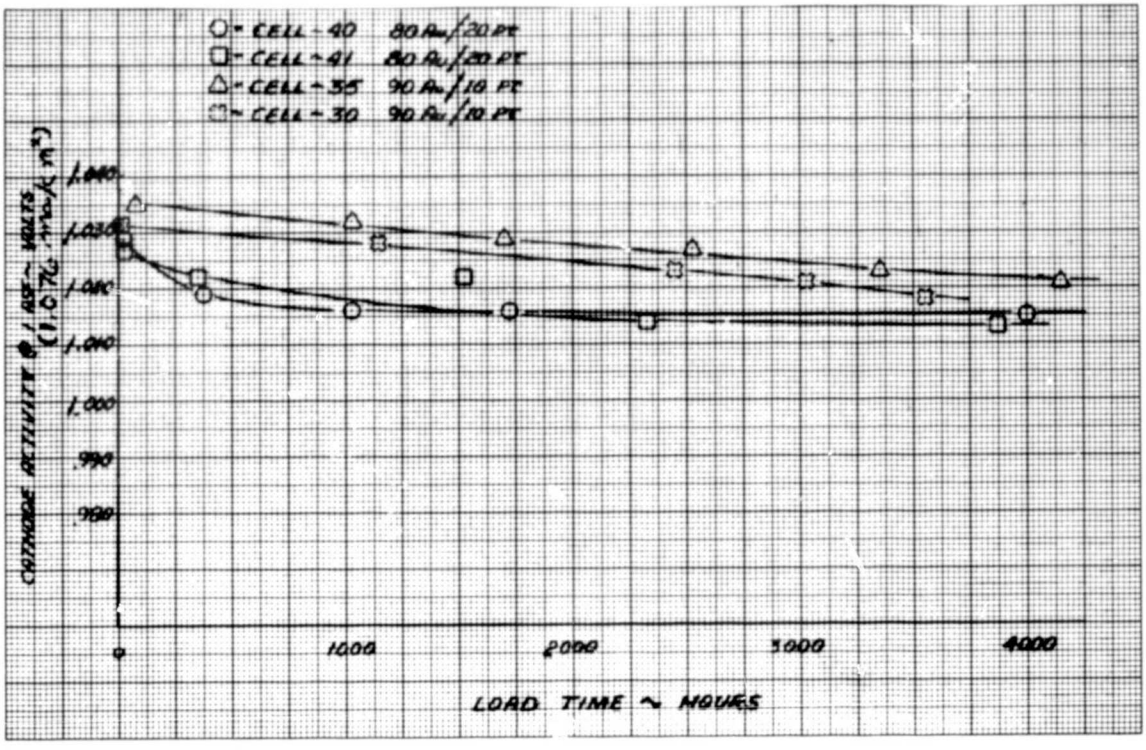

Figure 1 – Cathode Endurance Comparison

2.0 Matrices

Test Description

In the Phase III program, silicon-containing deposits on the anode were identified as a primary cause of anode flooding and increasing anode diffusion over long operating periods. The deposits were the product of corrosion of asbestos matrices. Fybex matrices, which contain no silicates, were tested in two 2 in. x 2 in. (5.08 cm x 5.08 cm) at 190° (87.8°C) and 250°F (121.1°C) for over 2300 hours. In both cases the decay attributable to anode diffusion was lower than that experienced in asbestos matrix cells.

Results

During Phase IV, Fybex matrices were evaluated in full-scale cells. Cell Nos. 42, 43, and 44 were fabricated with filtered Fybex matrices. These cells accumulated a total of over 7000 hours of load time during the contract period. Figure 2 shows a comparison of the anode diffusion losses of two long-term asbestos-matrix cells, Nos. 30 and 35, and Cell Nos. 42 and 44. Consequently, replacement of asbestos as a matrix material can significantly reduce the degradation rate of cells over long periods of time. Fybex itself is not a good candidate for future cells since it is no longer commercially available. However, there are several other materials, including zirconia and ceria, which may be suitable replacements for asbestos. These materials should be evaluated in future work.

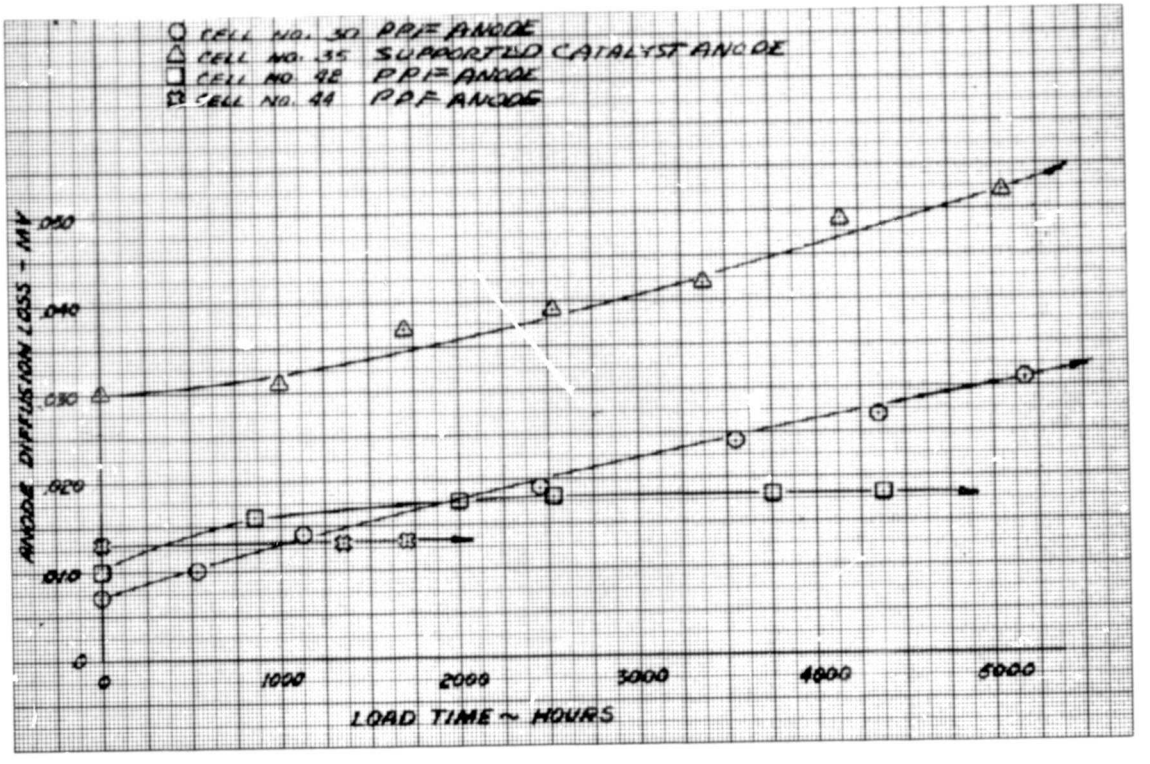

Figure 2 – Anode Diffusion Loss Comparison

B. Unitization Research

Task Description

Phase I plaque testing revealed electrolyte transfer from cell-to-cell could occur through the gas housings which are common to the plaque's six cells. To overcome this problem, development of a plaque design in which each cell had dedicated gas cavities and manifolds was undertaken.

Results

A two-cell plaque design was defined and developed in which all subassemblies, the unitized electrode assembly, the gas flow field frames, and the passive water removal assembly are bonded into an integral unit. Each cell is completely sealed from its neighbor. A set of subassemblies ready for bonding is shown in Figure 3.

Both gas cross-pressure tests prior to operation and operating tests showed that effective sealing of the cells one from another had been achieved. In a test in which one cell was filled with potassium hydroxide electrolyte and the other with sodium hydroxide, analysis of the electrolytes after testing showed only small quantities of sodium in the potassium hydroxide. This small quantity of sodium had no effect on the operation of either cell. This design is suitable for construction of multicell plaques in the future.

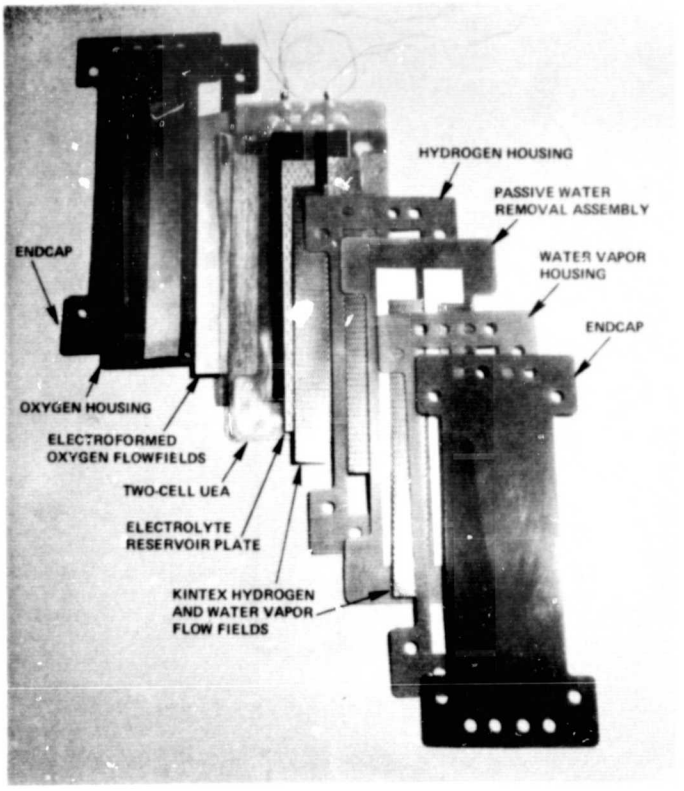

Figure 3 – Components of a Two-Cell Plaque Assembly (WCN-3666)

A second unitization task was fabrication of the first hybrid frame unitized electrode assemblies with a particulate matrix. The processes used were developed based on the methods with which reconstituted asbestos matrices are unitized. The primary difference was the addition of an extra laminate layer about the edge and which penetrates slightly into the matrix. This modification ensures a positive high-cross-pressure seal at the matrix-frame bond even if the particulate matrices do not absorb the frame resin during the heat-bonding step in fabrication. Three cells, Nos. 42, 43 and 44, were fabricated using this method and were successfully tested. No problems with cross leakage at the matrix frame occurred.

C. Cell and Plaque Testing

Task Description

The single cell and plaque tasks provide the means for evaluating the performance and endurance characteristics of evolutionary EMS fuel cell designs. The investigations performed in this area are: evaluation of alternative cell designs, testing to determine the compatibility of alternative cell frame materials and construction techniques in the actual cell environment, and development of cell fabrication procedures to translate the most compatible materials available into practical cell configurations.

Results

Four different NASA-approved single cell designs and two different NASA-approved two-cell plaque configurations were evaluated by test during Phase IV. More than 90,900 hours of cell testing have now been accomplished under the program. The longest cell test at 100 ASF (107.6 ma/cm^2) is 10,020 hours in duration and the longest test at 200 ASF (215.2 ma/cm^2) is 6680 hours in duration. These long term tests were accomplished in earlier phases of the program.

During this phase, the lowest performance degradation rate demonstrated at any time in this program was exhibited by Cell No. 42. The overall average degradation rate is less than 5μ V/hour, with a rate of approximately 1μ V/hour after the first 1000 hours of test. This cell incorporates a 90Au/10Pt cathode, a Fybex matrix and a hybrid frame. Each of these components was specifically developed during the program to extend cell endurance capability. Figure 4 presents a comparison of the degradation rate of Cell Nos. 42 and 44, both of this configuration, with that of Cell Nos. 30 and 35 which had previously been among the cells with the lowest degradation rate. The low degradation rate is attributed primarily to the Fybex matrix which does not increasing anode diffusion loss in tests of long duration.

Testing of two two-cell plaques demonstrated a sealed, fully-bonded plaque design will prevent the cell-to-cell electrolyte transfer that limited the endurance of multicell plaque tests during Phase I. This design fabricated in a hybrid-frame unitized plaque assembly was evaluated with both standard PPF and 90Au/10Pt electrodes and the advanced supported catalyst anode and 80Au/20Pt cathode. This configuration is a suitable basis for the design and construction of an advanced powerplant power section. Although the electrolyte transfer problem has been overcome, both plaques exhibited higher than normal decay rate in both cells, loss of dry-side tolerance in Cell No. 1 and initially higher decay rate and increasing internal resistance in Cell No. 1. Specific causes for these effects were not identified and will require investigation in future programs.

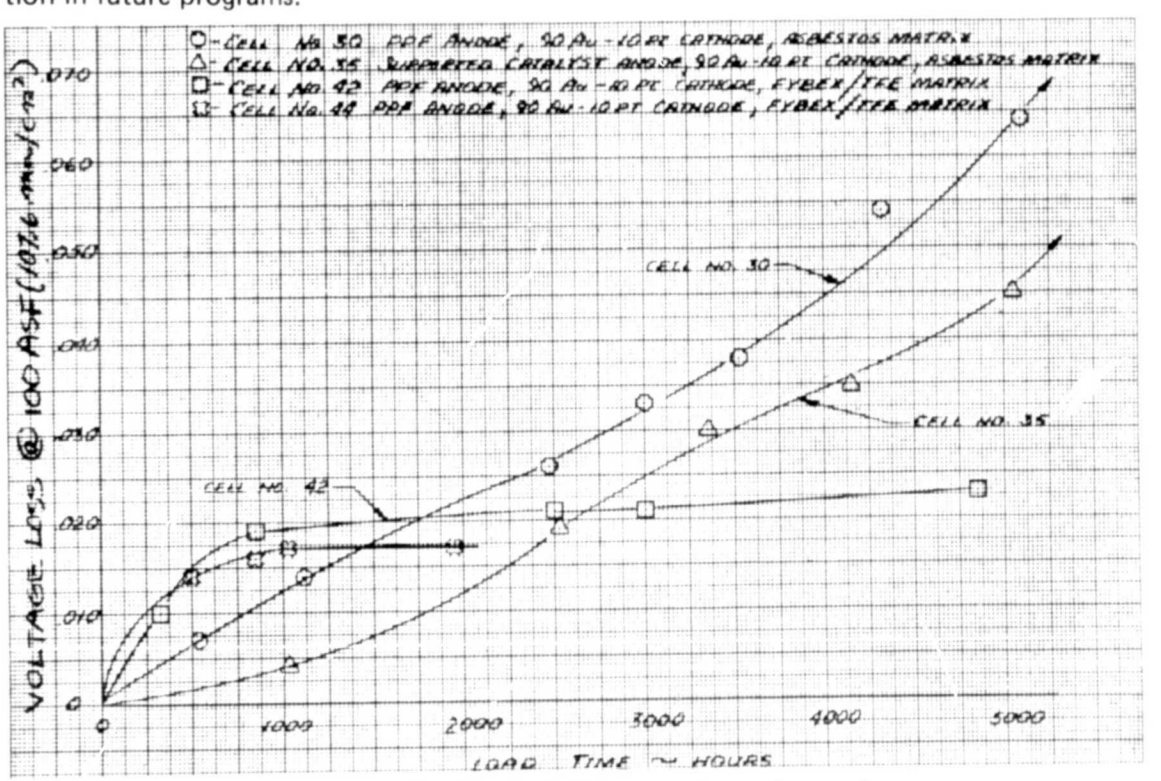

Figure 4 – Single Cell Voltage Loss Comparison