FUEL CELL

RESEARCH & DEVELOPMENT

RESEARCH ON COMPACT
FUEL CELL POWER SUPPLIES

PROGRESS REPORT NUMBER 4

JANUARY 30, 1961 - MARCH 30, 1961

CONTRACT NO. DA19-129-QM-1705 (OI 5022)

U.S. ARMY

QUARTERMASTER RESEARCH AND ENGINEERING COMMAND

NATICK, MASSACHUSETTS

AIRCRAFT ACCESSORY TURBINE DEPARTMENT

GENERAL ELECTRIC

18

ADDENDUM

TO

QUARTERMASTER CORPS

PROGRESS REPORT NUMBER 4

JANUARY 30, 1961 - MARCH 30, 1961

The following two statements, a and b, are issued in accordance with Statement of Work, Section B - Reports:

a. Estimate of the percentage of work completed to date (March 30, 1961) 50%.

b. Estimate of the percentage of costs incurred to March 30, 1961) 44%.

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

RESEARCH ON COMPACT FUEL CELL POWER SUPPLIES

BY

AIRCRAFT ACCESSORY TURBINE DEPARTMENT

FUEL CELL LABORATORY

PROGRESS REPORT NO. 4

JANUARY 30, 1961 - MARCH 30, 1961

FOR

U.S. ARMY

QUARTERMASTER RESEARCH AND ENGINEERING COMMAND

NATICK, MASSACHUSETTS

AIRCRAFT ACCESSORY TURBINE DEPARTMENT

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 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

An outline of the work accomplished on the various Experimental Studies through March, 1961, is submitted at this time because of the rearrangement in the work schedule during the past reporting period. A temporary cessation of work was agreed to by the Project Officer, but will be resumed during the ensuing report period.

The next report will include further details of the total work covered during the past two reporting periods.

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. 7X80-01-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 & 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 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, HMED, 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 avioded. 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 IA Quantitative Studies of Electrical Losses in Present Cells

1.1 New Ion-Exchange Polymers

Various polymer systems for fuel cells have been tested. The effects on performance of catalyst loading are being examined. Thus far, cells have been operated in the 35 watt experimental current collectors at current densities up to 120 amps/ft^2 on hydrogen and oxygen.

1.2 Ion Exchange Polymer Reinforcement

Various materials were used in fuel cell constructions to determine their effect on:

a. Mechanical strength of the cell.
b. Drying out and pinholing properties of the materials.
c. Proper lamination of the reinforcements with the ion-exchange polymer.

1.3 Catalyst Optimization Studies

Various loadings of Platinum Palladium and Carbon were used on fuel cells to determine performance versus various catalyst systems. Cost comparisons for various catalyst systems at high current densities were made.

1.4 Laboratory Evaluation Model

A laboratory model 35 Watt Fuel Cell has been designed and partially built to evaluate the results of this Research Program. Multi-cell stacks have been tested to determine the feasibility of the current collector design. Bi-metallic current collectors have been built to alleviate the heat transfer problem of a closed multi-cell stack.

2.0 TASK II - Internal Generation and Storage of Hydrogen Fuel

2.1 TASK IIA - Palladium and Other Absorbents for Hydrogen

This work will be accomplished by the General Electric Heavy Military Electronics Department at Syracuse, New York and will be reported under separate cover by the above department.

2.2 TASK IIB - Electrolysis by Ion Membrane Fuel Cells

Work to be initiated at a later date.

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

3.1 TASK IIIA - Electrolytic Methods

Continued examination of the literature has contributed little information to aid in the development of a small high pressure electrolytic hydrogen-oxygen generator, therefore, the design approach to this unit must be from the fundamentals of water electrolysis. In our continued search, no new methods of separating the electrodes could be found. The M.G. Treadwell 3,000 psi electrolytic oxygen generator utilized asbestos cloth as the separating membrane. However, the Treadwell unit is sufficiently large (750 Amperes) so that a rather complicated external method of pressure control is justified*. By measuring and transmitting the differential in pressure between the two gases to a pneumatic controller which positions a control valve, the difference in gas pressures is controlled to 0 ± 0.2 inch W.C.

A first attempt at designing a small high pressure electrolytic hydrogen-oxygen generator has been made. (See Figure 1, Page 3-2.) In this design, the electrolyzer unit consists of three sections:

1) A single electrolytic cell

2) A pressure equalizer or gas accumulator

3) An electrolyte storage vessel

* High Pressure Electrolytic Oxygen Generator for Submarine Service - Robert Sptizer. Presented on May 5, 1959 at the Philadelphia Meeting of the Electrochemical Society.

ELECTROLYTIC GENERATOR ASSEMBLY

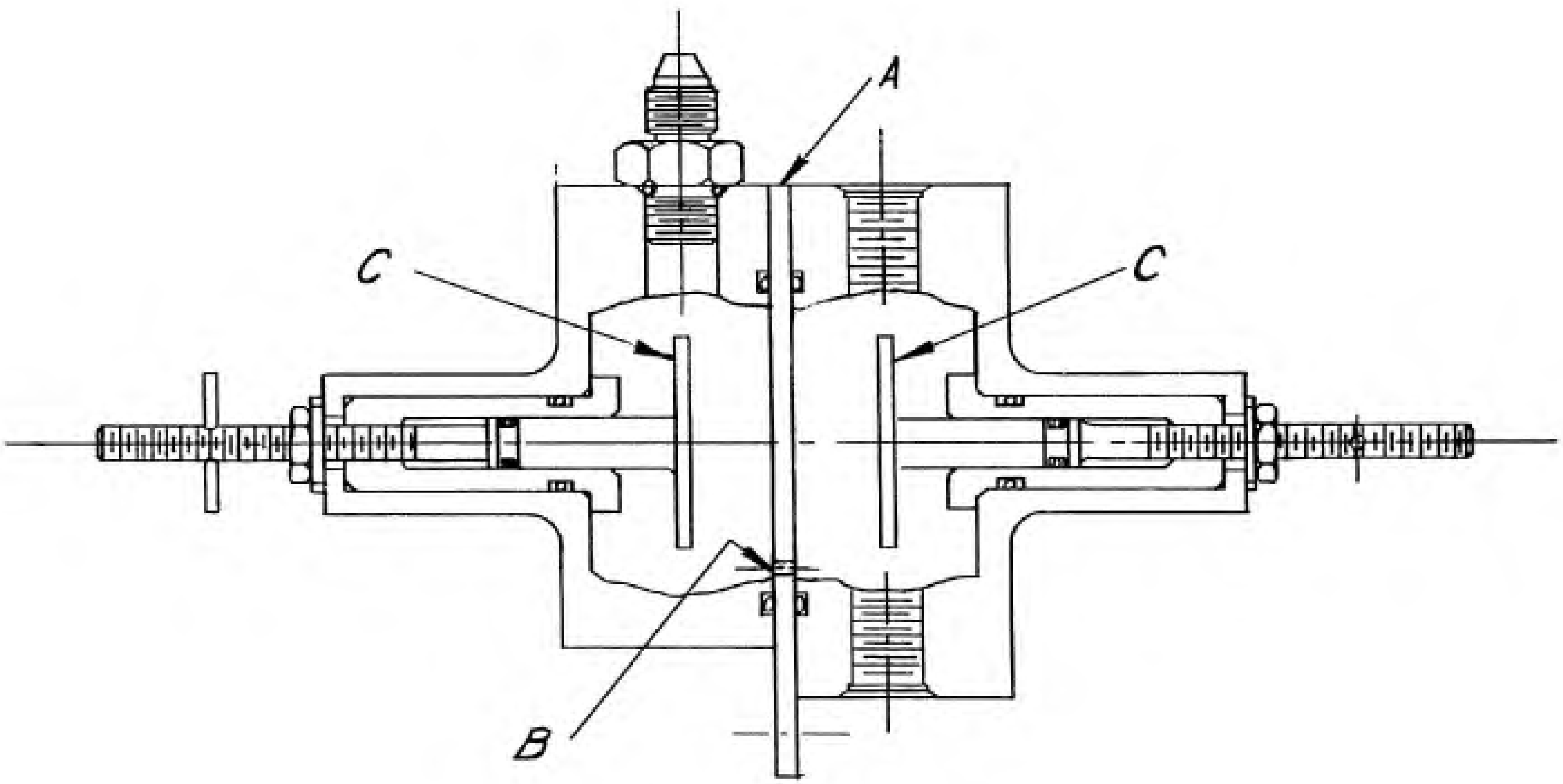
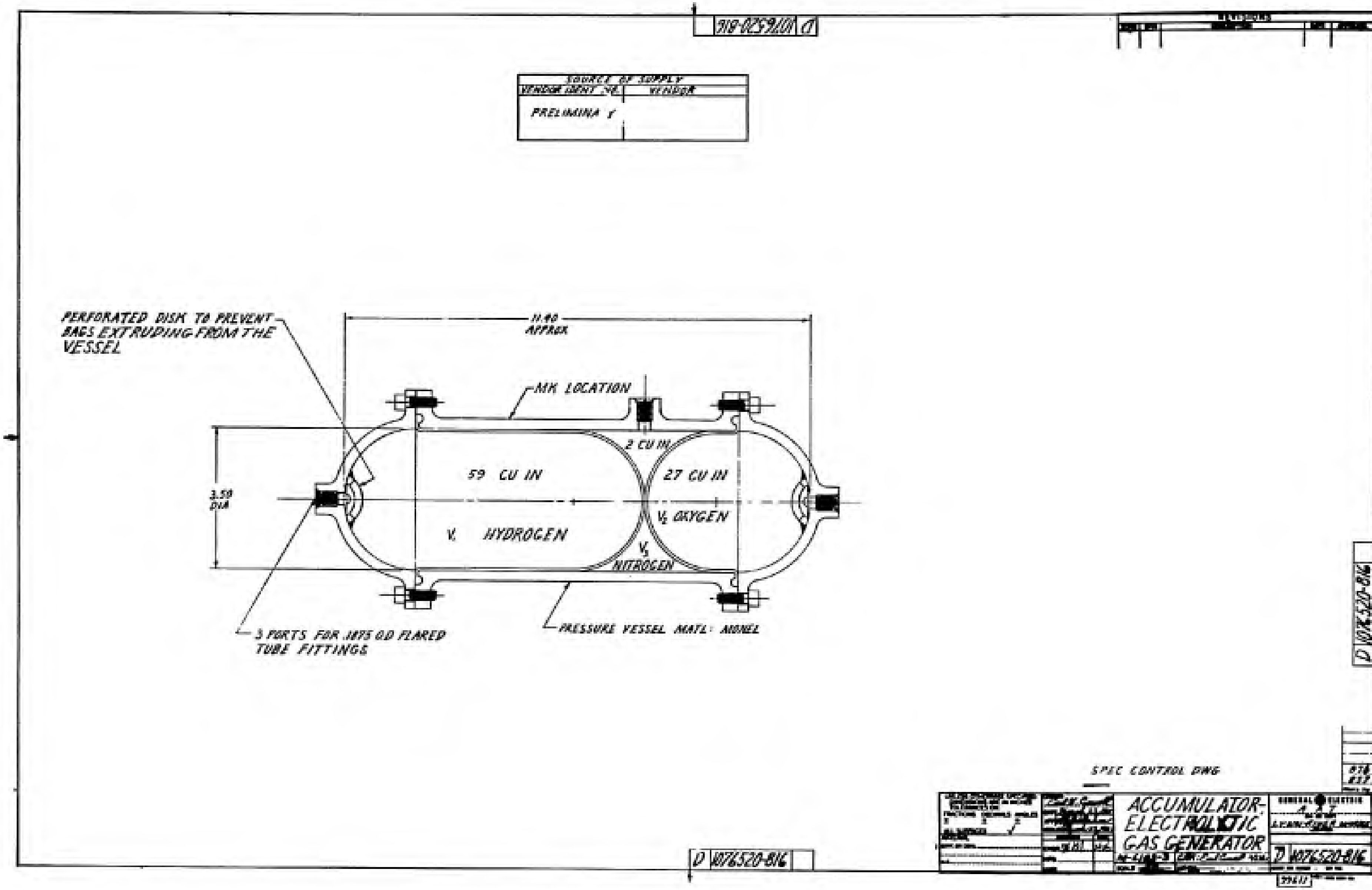


FIG 1

The electrolytic cell, Figure I, (A), uses a 0.10 inch monel sheet as the electrode separator rather than a porous membrane. The holes, (B) (0.094" D), drilled in the separator below the electrodes allow a passage for the electrolyte. The use of this metallic separator will eliminate the need for a porous membrane such as the asbestos cloth. The solid monel separator has the advantage over the porous membrane in that, should the electrolyte drop below its normal level, the gases will not diffuse through the separator. This normally would occur with a porous type separation. Both the cathode and anode will be 0.10 inch monel metal and will be electrically insulated from the body of the cell by Teflon. The cell is so designed that the electrode spacing is adjustable in order that optimum spacing can be determined.

Since one requirement is that the electrolyzer be of a small size, the usual method (pneumatic controllers, etc.) used in controlling differential pressure certainly are not applicable in this instance. Several other methods of pressure equalization have been investigated with the method decided upon illustrated in Figure II, Page 3-4. The pressure equalizer or accumulator is a pressure vessel containing two expansible bags, one each for the oxygen and hydrogen and capable of dilating and contracting as differences in pressure demand. The volume between the bags is filled with an inert gas pre-pressurized to approximately 1 to 3 psi. A specification control drawing has been issued in order that bags of the proper sizes and materials may be obtained.

The electrolyte storage vessel, described here as a separate component of the electrolyzer unit, will be used only in testing and will not be included in a final design. It is believed that sufficient electrolyte will be carried in the electrolytic cell to operate the unit for the prescribed duty cycle.



D 1076520-816
SOURCE OF SUPPLY
VENDOR IDENT. NO.
VENDOR
PRELIMINARY
PERFORATED DISK TO PREVENT BAGS EXTRUDING FROM THE VESSEL
11.40 APPROX
MK LOCATION
2 CU IN
59 CU IN
27 CU IN
3.50 DIA
V₁ HYDROGEN
V₂ OXYGEN
V₃ NITROGEN
3 PORTS FOR .1875 O.D FLARED TUBE FITTINGS
PRESSURE VESSEL MATL: MONEL
SPEC CONTROL DWG
ACCUMULATOR-ELECTROLYTIC GAS GENERATOR
GENERAL ELECTRIC
D 1076520-816

In the first design we have limited the operating pressure of the electrolyzer unit to 1,000 psig. However, should the design of the cell and pressure equalizer prove to be practical, a re-design would involve a change of pressures to 3,000 and 4,000 psi in order to decrease the volume of the equalizer. The final design of the electrolyzer will not necessarily by limited to a single cell. The number of cells must be determined by:

1) Maximum amperage which the cell can tolerate.

2) Minimum regeneration rate acceptance.

In the present design it is estimated that the cell will tolerate a minimum of six amperes without difficulty. At six amperes the regeneration rate for the hydrogen will be 0.09 SCF/hr.

3.2 TASK IIIB - Hydrogen Generation Studies

Various chemical systems were sized for a 20 minute duty cycle for a 35 watt fuel cell. Experiments in small volume glassware systems were run on CaH_2, $NaBH_4$, and LiH systems to determine feasibility. A small volume hydrogen generator has been built and is to be tested. An uncomplicated hydrogen generation system has been devised and will be proof tested.