GEORGETOWN UNIVERSITY

3700 O Street N.W.
Washington D.C. 20057

File
12.2 File
rlh
8-20-90
DOE/NV/10649--T4

QUARTERLY REPORT

Period: January 1, 1990 to March 31, 1990

CONTRACT DE - AC08 - 87NV10649

RESEARCH DEVELOPMENT and DEMONSTRATION

of a

FUEL CELL/BATTERY POWERED BUS SYSTEM

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Prepared For : Department of Energy,
Office of Transportation Systems,
Electric & Hybrid Propulsion Division

Prepared by : S. Romano
J.R. Thelmo

MASTER

May 8, 1990

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED_{W/W}

QUARTERLY REPORT

Covering period, January 1, 1990 to March 31, 1990

I. INTRODUCTION

This contract covers the Georgetown University technical support effort to the Argonne National Laboratory (ANL) in the technical management of the Research and Development being conducted on the Fuel Cell/Battery Powered Bus System Program. It also includes the contract coordination, planning and monitoring of the Systems Design and Integration Contract being carried out under this program.

II. TECHNICAL PROGRESS SUMMARY

During this period work was concerned with reviewing the final efforts of the two systems integration contractors for the Phase I Program. Coordination meetings were held with ANL personnel to outline the requirements for the Phase II Program. The following items were addressed.

- Evaluation of Phase I Final Reports
- Evaluation of Brassboard Test Results
- Program Management Team Meetings
- Technology Transfer Activities
- Vehicle Design Studies
- Vehicle Simulation Documentation

Task I - Vehicle Design and Applications Analysis and Technical Support

o Vehicle Design Studies

The requirement for a baseline diesel powered vehicle to be used as a reference for evaluating the performance of the fuel cell/battery bus was established. A specification, was prepared and submitted to DOE. The baseline vehicle will be operated over the Georgetown Arlington route with typical passenger loads and data identifying speed, distance traveled passenger loads, stop times, fuel consumption and complete maintenance and service requirements will be recorded for comparison with the operation of the fuel cell buses when they are introduced. The basic specification for the baseline bus is shown in Attachment I.

o Vehicle Performance Modeling

The basic vehicle computer simulation program was completed during this period and work continued on the documentation. The basic program models the fuel cell and reformer as steady state devices. The transient modeling has been completed however, the computer program must be modified to simplify the mechanization so that the run time is reasonable. This program will use a different mechanization than the basic program. It is expected that

the documentation for the basic program will be completed during the next report period and the program will be released. Organizations working on the modeling and computer simulation include:

University of Florida - Fuel cell modeling

Opsearch - Programming and simulation

Pavlics Engineering - Vehicle modeling and program evaluation

- o Vehicle Selection

Bus Manufacturing Inc. has been preparing typical designs for a heavy duty low floor transit bus to be used with the fuel cell/battery power and propulsion system. The design for a bus that meets Georgetown requirements has been established. The bus has a 15 inch floor height and is 27 feet long. The specification is similar to the Attachment I specification.

Other manufacturers were visited or contacted during this period to determine their interest in participating in the program as bus suppliers. Specifically a visit was made to Ontario Bus Industries Inc. in Ontario Canada and Transportation Manufacturing Corporation, Roswell, NM. Both were interested in keeping abreast of program developments. Gillig Corporation, Hayward, CA was contacted and also indicated interest.

Task 2 - Technology Transfer and Assessment

- o Technical Presentations

During this period a technical paper on "Installing a Fuel Cell in a Transit Bus" was presented at the Electric Vehicle Systems session of the 1990 Society of Automotive Engineers (SAE), International Congress and Exposition in Detroit, MI on February 26, 1990. In response to invitations, papers were also prepared and accepted for the 25th Intersociety Energy Conversion Engineering Conference (IECEC) and the annual meeting of the Electrochemical Society. The papers are titled "The DOE/DOT Fuel Cell Bus Program and its Application to Transit Missions" and "Development of a Fuel Cell Bus for Transportation" respectively.

- o California Energy Commission

A presentation was made to the California Energy Commission (CEC) of the state of California describing the fuel cell bus program and inviting their participation. CEC has a wide range of energy related projects underway and planned.

- o Industry Contacts

- XL Inc, Costa Mesa, CA

- During this period several organizations reputed to be working on fast methanol reformers were contacted. The XLInc company has work underway at Chemical Energy Specialists of Costa Mesa, CA. A test reformer has been operating for some time and has demonstrated significant changes in product gas output in fractions of a second. Further discussions are planned to better evaluate the performance.

- Fuel Cell Systems, Laguna Hills, CA

- Discussions were also held with principals of Fuel Cell Systems of Laguna Hills, CA. They have been proposing a "Hot Spot Reformer" based on work done by Johnson-Mathey of London, England. A small reformer used to produce hydrogen to supplement the fuel for an ICE powered generator has been tested. This system is only indirectly related to the type reformer used with fuel cells.

- Soleq Inc, Chicago, IL

- Soleq has been supplying propulsion systems for many years. They produced the propulsion system for the Santa Barbara inductively coupled bus system developed for the state of California and have developed electric drives for a variety of electric vehicles. A visit was made to Soleq to determine their present capability and to review the propulsion system developed for the Chrysler heavy duty van.

- o Canadian Program

- A visit to Ballard Power Systems, Vancouver, B.C. was made to discuss their fuel cell bus program proposed for the province of British Columbia. Ballard plans to use a proton exchange membrane fuel cell (PEM) and will consider a battery hybrid system in their initial studies, but have not made the decision to proceed along this path. The use of hydrogen directly will give the system a satisfactory response and the exceptional PEM power density will allow packaging a full power system in the small bus. The only considerations that may suggest a battery hybrid system are economic and the ability to take advantage of regenerative braking.

- The Ballard/BC Phase I program is expected to start in July of this year and will result in a test bus in approximately two years. Their program is 29 months long. The next phase will use reformed methanol and they are expecting to use a fast response reformer to keep the battery size to a minimum. Ballard has talked to the same reformer developers mentioned in the above paragraphs. Ballard/BC would like to take advantage of the work we have done in designing the low floor electric bus for our phosphoric acid fuel cell system.

Task 3 - Coordination and Monitoring of the System Design and Integration Contracts

During this period the brassboard test programs of the two contractors were completed. Visits were made to both contractor sites for a first hand review of the system performance and evaluation of test results. Both systems performed well after the normal test set-up shakedown.

The draft final reports of the two contractors were reviewed and together with the Argonne National Laboratory (ANL) comments were sent to the contractors for consideration. The final reports were submitted during this period and accepted.

Work started on the preparation of the technical requirements for the Phase II program. Bus specifications were prepared for both the small and the full sized (40 ft.) transit buses. The power and propulsion system requirements were defined for both buses. The request for proposal for Phase II is planned for release during the next report period.

III CURRENT PROBLEMS

There are no current problems to report.

IV WORK PLANNED

During the next period the technical requirements for the Phase II program will be completed. Technical support to ANL for release of the Phase II RFP will continue.

The computer simulation program for the steady state FC model will be released together with the documentation. Work on the transient modeling of the fuel cell/reformer will continue with the University of Florida and Opsearch. The basic program will also be configured to accommodate a battery only power system and a fuel cell only system. In addition other battery types where test data is available, will be modeled.

A program plan for the fuel cell and diesel bus comparison testing activity will be started. The program should get underway this program year to allow enough time to acquire the buses and permit a test program of sufficient duration to be meaningful.

V. SCHEDULE AND COST REPORT

The Schedule and Milestone Chart has been updated and is attached. The Manpower and Cost report is also attached.

Date: 10-08-87

Revision: 04-30-90

GEORGETOWN UNIVERSITY
FUEL CELL / BATTERY POWERED BUS PROGRAM
MANPOWER PLAN (HRS)

GEORGETOWN UNIVERSITY

DATE: 10-08-87

REVISION: 04-30-90

FUEL CELL / BATTERY POWERED BUS PROGRAM

COST PLAN (\$)

GEORGETOWN UNIVERSITY

FUEL CELL/BATTERY BUS PROGRAM

SCHEDULE & MILESTONE CHART

DATE: 10-8-87
REVISION: 4-30-90

GEORGETOWN UNIVERSITY

FUEL CELL/BATTERY BUS PROGRAM

SCHEDULE & MILESTONE CHART

DATE: 10-08-87
REVISION: 04-30-90

March 21, 1990

ATTACHMENT 1

BUS SPECIFICATIONS

1.0 INTRODUCTION

The purpose of this specification is to define the general requirements for a small, heavy duty transit bus to be operated over a test route for evaluation of the fuel cell/battery bus under development by the U.S. Departments of Energy and Transportation. The initial configuration of the bus is to be diesel powered. The bus is to be capable of being retrofitted with the fuel cell/battery electric power and propulsion system after an initial test period. All standard requirements for transit buses listed in the "Baseline Advanced Design Transit Coach Specifications" (DOT White Book) are applicable except as modified in this specification.

2.0 REQUIREMENTS

2.1 Mission

The bus is to operate on the Georgetown Arlington route as described in Appendix A. This document defines the route, the stops and dwell times, the speed for each segment and the elevations along the route. The bus is required to negotiate this route for a minimum of 15 hours a day from 6:30 am to 9:30 pm. The headway during the peak hours from 6:30 to 8:30 and 3:30 to 7:30 is 40 minutes. The headway during off peak periods is 60 minutes.

3.0 PERFORMANCE REQUIREMENTS

3.1 Power requirements

The propulsion system and drive train shall provide power to enable the bus to meet the required acceleration, top speed, and gradability. Sufficient excess power shall be available to operate all accessories.

3.1.1 Acceleration

An average acceleration rate of at least 0.06g shall be achieved with a full complement of seated passengers (or 3,000 lb load). Maximum times to accelerate are:

0 to 10 mph	6.0 sec
0 to 20 mph	12 sec
0 to 30 mph	24 sec
0 to 40 mph	46 sec

3.1.2 Top Speed

The bus shall be capable of a top speed of at least 50 mph with a full seated load (or 3,000 lb load) on a straight level road.

3.1.3 Gradability

Gradability requirements shall be met on grades with a surface friction coefficient of 0.3 and above at full seated load and all accessories operating. The minimum requirements are to maintain a speed of 34 mph on a 2-1/2 % grade and 7 mph on a 12 % grade.

3.1.4 Jerk Rate

Jerk, the rate of change of acceleration, shall be minimized through the acceleration/deceleration and shall be no greater than 0.3 g/sec.

4.0 GENERAL CHARACTERISTICS

The vehicle shall be designed as a high quality, heavy duty transit bus utilizing an integral body - chassis construction. The bus must meet all applicable Federal Motor Vehicle Safety Standard (FMVSS).

Vehicle Curb Weight	 18,000 lbs (maximum)
Seated passengers	 20 (minimum)
Standing Passengers	 13
Length (max.)	 27 ft
Width	 91 in
Height	 110 in
Floor Height	 13.5 in (at door opening)
Floor Height	 15 in (bus centerline)
Speed	 50 mph (min top speed)
Turning Radius	 28 ft (wall to wall)
Angle of Approach	 10 deg
Angle of Departure	 10 deg
Suspension (fr & r)	 Air spring
Brakes	 Two circuit air type
Front Door	 30 in (min)
Rear door	 40 in (min)