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Review of the University of Florida Fuel Cell Bus Research, Demonstration and Education Program.

Daniel Betts, Timothy Simmons, Paul Erickson, and Vernon Roan
University of Florida Fuel Cell Research and Training Laboratory
University of Florida
Box 113172, Gainesville, Florida 32611
USA

Abstract

In the past decade fuel cell technology has had significant advances that have propelled it as one of the most important renewable energy technologies. In 1998 the University of Florida received the first of three methanol fueled, phosphoric acid fuel cell buses built under the direction of Georgetown University. Since then, the fuel cell bus has been repaired, refurbished, maintained and demonstrated by students of the University of Florida mechanical engineering department under the supervision of Dr. Vernon Roan. The bus was also used as an integral part of the research endeavors of the UF Fuel Cell Research and Training Laboratory. Some of the results from this research have been published and presented in various professional conferences and technical journals. The bus was also used as a teaching tool for the students of the University of Florida and the Gainesville community. For this purpose the bus has been featured in a number of local demonstrations where individuals have had the opportunity to learn and discuss about issues related to energy conservation and renewable energy technologies. This paper outlines the activities and results of the UF fuel cell bus demonstration and education program.

1. INTRODUCTION

The University of Florida Fuel Cell Bus (TBB-1) is one of a very small number of operational fuel cell vehicles in the world and it is probably no more than 3 or 4 operational fuel cell vehicles that use a liquid fuel. For this reason TBB-1 is an excellent education and research tool for teaching and evaluating the complexities and technical issues which are part of fully integrated fuel cell engines in vehicle applications.

TBB-1 was developed through funding from the US Department of Energy (DOE), the US Department of Transportation (DOT), and the California South Coast Air Quality Management District (SCAQMD). Georgetown University served as project manager, H-Power Inc was the primary vehicle developer, Booz Allen and Hamilton provided system integration support, and Argonne National Laboratory (ANL) acted as contract monitor. The University of Florida acted as a subcontractor to the project. The completed bus was delivered to DOE in 1994, nonetheless after a few demonstrations and performance/emissions evaluations the bus fell in disrepair and was therefore stored at ANL.

In 1998 the Florida Department of Community Affairs, Florida Energy Office, granted to the University of Florida a grant for transporting TBB-1 to the University of Florida main campus and start a demonstration and education program in fuel cell technology. As a result TBB-1 was repaired, refurbished and demonstrated to hundreds of interested residents of the state of Florida. In addition, TBB-1 quickly became a centerpiece of the University of Florida Fuel Cell Research and Training Laboratory's research endeavors.

Fuel cell technology offers presently the best alternative to internal combustion engines in vehicles. Fuel cell systems have been shown to operate at very high thermodynamic efficiencies and with reduced emission levels. Currently all major auto manufacturers, including Ford, GM, and Daimler-Chrysler, are involved in serious fuel cell engine research.

1.1. The UF Fuel Cell Bus (TBB-1)

TBB-1 represents one of a handful operational, liquid fueled, fuel cell vehicles in the world. The bus is 30ft long and was designed to carry 30 passengers. It is powered by a 60kW phosphoric acid fuel cell (PAFC) system, which uses a methanol deionized water mix as fuel. The fuel cell system uses steam reforming in order to process the methanol and water fuel mix into a hydrogen rich gas (reformate). The fuel cell stack's main reaction is the oxidation of the hydrogen in the reformate. After the fuel cell stack the depleted reformate gas is burned in order to provide energy for the steam reforming process before it is finally liberated into the atmosphere. Emission studies at the University of Florida have shown that the bus emissions consist mostly of carbon dioxide, and trace amounts of carbon monoxide. Figures 1 and 2 show simplified energy and fluid flows of the UF fuel cell bus.

The PAFC stack produces electrical power from the oxidation of hydrogen. In TBB-1 this power is directed to a power conditioner, which distributes it between the bus' electric propulsion motor and 3 sets of Ni-Cad batteries. These batteries operate in parallel hybrid arrangement with the fuel cell engine. Due to the complexity of the fuel-processing step in the fuel cell engine, the fuel cell system exhibits sluggish transient behavior; therefore the batteries are designed to provide power during periods of bus acceleration and to recover excess electrical power from the fuel cell stack during decelerations.

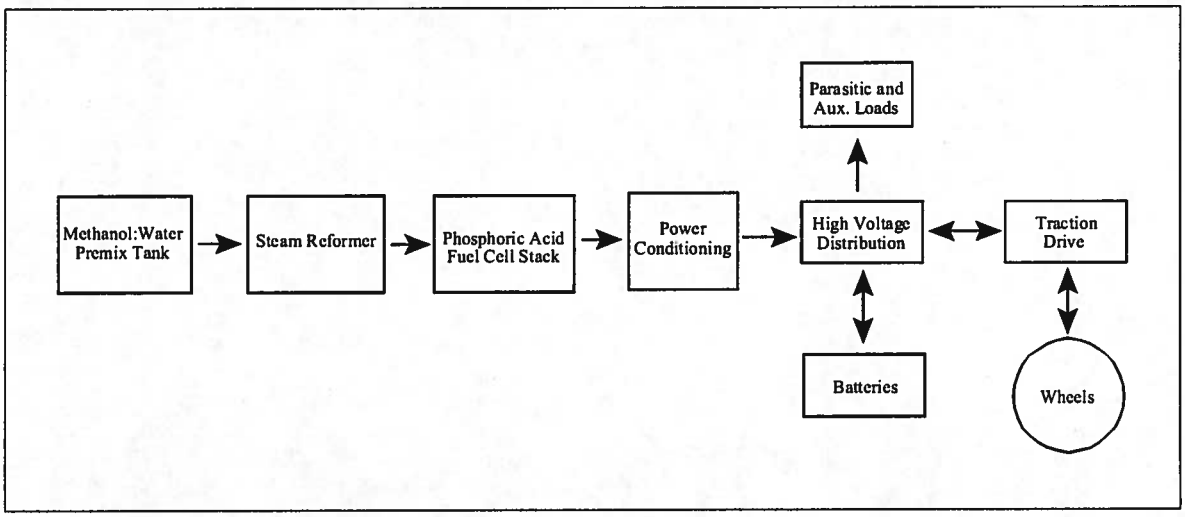

Figure 1. Simplified energy flow of UF fuel cell bus (TBB-1)

2. UF FUEL CELL BUS DEMONSTRATION, EDUCATION AND RESEARCH PROGRAM

The fuel cell bus arrived at the University of Florida in 1998 in a state of disrepair. Part of TBB-1's steam reformer catalyst bed had been damaged, the Ni-Cad batteries were unconditioned, and the burners had ignition problems, among other things. Graduate students of the UF Fuel Cell Research and Training Laboratory were given the responsibility of repairing and refurbishing TBB-1. This work was supervised and guided by Dr. Vernon Roan of the UF mechanical engineering department.

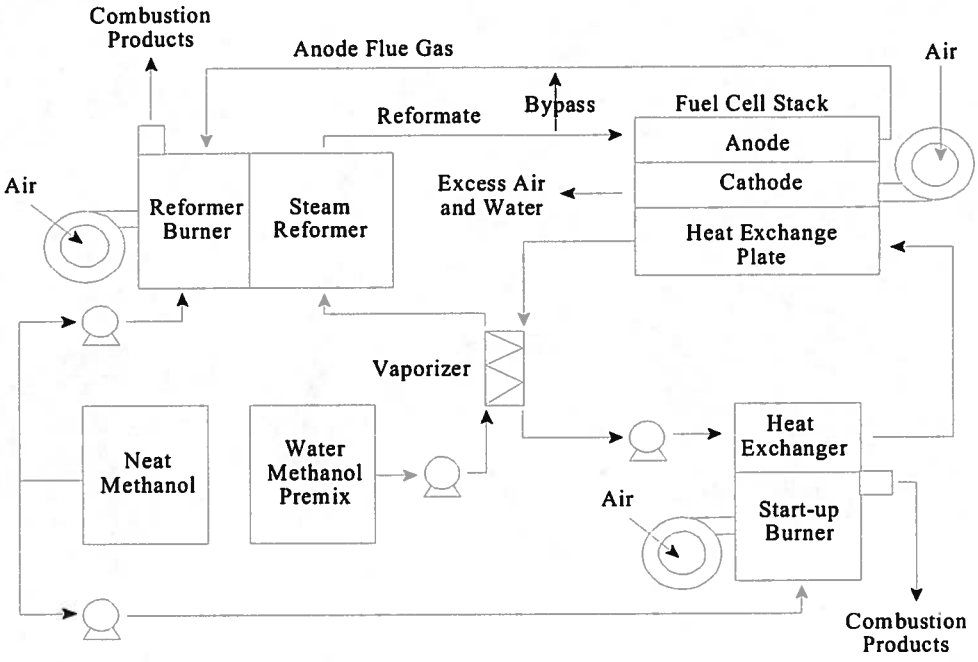

Figure 2. TBB-1 fuel cell system schematic.

Bus repairs were initiated by thoroughly inspecting and evaluating TBB-1's fuel cell system. For this a data acquisition system was installed in the bus in order to read the temperatures of the fuel cell stack coolant loop, reformer burner, start-up burner, and steam reformer catalyst bed temperatures. Secondly, the bus burner ignition problems were fixed through replacement of the burner igniters. The Ni-Cad batteries were then conditioned by refilling them with electrolyte, washing them, and subjecting them to controlled periods or charging and discharging. This process took place in a period of a year. The bus at this point was operational, however due to the damaged steam reformer, it could not operate during extended periods of time without overheating.

Upon evaluation of the damaged fuel processor it was decided that system reliability could be improved by implementing a new reformer burner fuel flow control scheme. Data analysis and implementation of a new control scheme resulted in improving the TBB-1's performance and reliability. The process of repairing and refurbishing TBB-1 was performed by 5 PhD students and 4 masters students.

Figure 3. Fuel Cell Research and Training Laboratory graduate students measuring bus emission levels.

Once repaired, TBB-1 was demonstrated by the graduate students who participated in its repair. During bus demonstrations, visitors were given handouts with information about fuel cell technology and were shown TBB-1's engine compartment. Graduate students gave general informative talks about the bus technology and were available to answer questions. Visitors were also treated to short bus rides.

A partnership was also developed with the Gainesville Regional Transit System in which students were given access to bus driving instruction and selected RTS personnel were taught about fuel cell technology and were allowed to drive TBB-1.

The reception of the public to the bus demonstrations was very positive. TBB-1 was featured in various news articles, radio shows, and local television news. The bus was made centerpiece of local museum open houses, earth day fairs, public transportation fairs, and special University of Florida events. The bus was also shown by UF to distinguished visitors to the university in various occasions.

UF's fuel cell bus has also been used as a research tool for the students of the University of Florida. Data obtained from TBB-1 has been published in two masters thesis, two doctoral dissertations, and 5 peer-reviewed papers presented at various international conferences.

2.1. Fuel Cell Bus Demonstrations

Below is a list of demonstrations of TBB-1 in chronological order

2.1.1. April – December 1998:

Throughout this period students of the University of Florida and local high-schools and middle schools were shown the bus and talked about fuel cell technology. In addition the Director of the Office of Energy Research DOE and the DOE Senior Policy Advisor were transported throughout the UF campus on the fuel cell bus. During this period the fuel cell bus program received publicity through UF's news and public affairs department. The publicity included newspaper articles and television segments.

2.1.2. January – March 1999

The fuel cell bus was used for transporting students participating in the National Society of Black Engineers (NSBE) Regional Conference held at the University of Florida. Participants at the conference were given lectures on fuel cell technology and allowed to ask questions about renewable energy. During this period individual and group demonstrations were also conducted at the University of Florida Energy Education Park.

2.1.3. April – June 1999

TBB-1 was highlighted in a presentation given at the Renewable Energy and Advanced Energy Systems for the 21st Century Conference in Lahiana, Hawaii by a UF Fuel Cell Research and Training Laboratory graduate student. During this period group and individual demonstrations also took place.

2.1.4. July – September 1999

The repair of TBB-1 was almost complete by this period. For this reason a greater number of demonstrations took place during this quarter.

The Gainesville Regional Transit System (RTS) showcased TBB-1 in downtown Gainesville on August 12. This demonstration attracted a large number of curious individuals who were eager to ask questions to UF graduate students. In addition, local TV channel 20 covered the event and an interview regarding fuel cell technology with a UF graduate student was featured in the local news.

Due to the success of the August 12th demonstration, RTS again made TBB-1 a centerpiece of their Hike, Bike, Ride Week Fair held on September 17th in downtown Gainesville. A large number of individuals from the community were informed about fuel cell technology and renewable energy during this demonstration.

During the period of September 23rd to the 25th TBB-1 was shown at the Florida Natural History Museum in Gainesville during their EarthQuest exhibit. During this demonstration reporters covering the event were allowed to ride the bus and ask questions about fuel cell technology and renewable energy issues. In addition, bus rides were scheduled through the three day event for children and parents visiting the EarthQuest exhibition.

Figure 4. UF graduate student provides visitors with explanation about fuel cell technology and the fuel cell bus at the Florida Natural History Museum in Gainesville, FL.

2.1.5. October – December 1999

During this period the fuel cell bus was transported to Tallahassee in order to participate at the National Environmental Trust (NET) Pollution Solutions Tour, held at the state capitol building on November 5. The bus was showcased alongside other fuel efficient vehicles and technologies, and the local community and law makers were taught about fuel cell technology. During this demonstration National Public Radio interviewed a UF Fuel Cell Research and Training Laboratory student.

On November 8th the bus was again shown as part of NET's Pollution Solution Tour at the Florida Museum of Natural History in Gainesville, FL. Pictures of the bus during this demonstrations were printed in the Gainesville Sun newspaper and the UF Alligator newspaper.

2.1.6. January – March 2000

The fuel cell bus was shown to visitors to the mechanical engineering department throughout this quarter. In addition, high school students participating in the 37th Annual Junior Science, Engineering and Humanities Symposium (JSEHS) at UF were given rides on TBB-1 and received a short lecture on fuel cell technology by UF graduate students.

2.1.7. April – June 2000

TBB-1 was demonstrated as the centerpiece of the University of Florida Energy Research and Education Park Earth Day Open House on April 22nd. Visitors to the park heard lectures about renewable energy issues and technology while being driven aboard TBB-1. During this event UF faculty, students, and officials were transported in TBB-1. Pictures of the bus and coverage of this event was published in the "The Solar Touch" newsletter.

UF students taking Air Pollution Control and Design class, taught through the Environmental Engineering Department, were treated to a ride on TBB-1, following a lecture on fuel cell technology by graduate students working at the UF Fuel Cell Research and Training Laboratory on April 27th.

Also during this period, the UF fuel cell bus was shown as part of the Sensational Science exhibit at the Florida Museum of Natural History in Gainesville. UF graduate students throughout the day gave bus rides and lectures to visitors of the museum.

3. CONCLUSIONS:

The UF fuel cell bus program has become an integral part of the renewable energy education program at the University of Florida and the Gainesville community. The fuel cell bus has served as a research and education tool at all levels. Educationally, first graduate students at UF were taught, through hands on approach, about fuel cell technology. Then these graduate students were trained to relay the information learned through their experiences to the general community and to groups of disparate educational levels. Finally, high-level research conducted on TBB-1 provided insight on fuel cell technology issues and solutions. This research was presented to the scientific community by means of peer-reviewed papers authored by UF graduate students and presented at international conferences.