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Journal of Power Sources 137 (2004) 76–79

JOURNAL OF POWER SOURCES
www.elsevier.com/locate/jpowsour

Short communication

The US Army Foreign Comparative Test fuel cell program

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Received 26 April 2004; accepted 20 May 2004
Available online 30 July 2004

Abstract

The US Army RDECOM initiated a Foreign Comparative Test (FCT) Program to acquire lightweight, high-energy dense fuel cell systems from across the globe for evaluation as portable power sources in military applications. Five foreign companies, including NovArs, Smart Fuel Cell, Intelligent Energy, Ballard Power Systems, and Hydrogenics, Inc., were awarded competitive contracts under the RDECOM effort. This paper will report on the status of the program as well as the experimental results obtained from one of the units.

The US Army has interests in evaluating and deploying a variety of fuel cell systems, where these systems show added value when compared to current power sources in use. For low-power applications, fuel cells utilizing high-energy dense fuels offer significant weight savings over current battery technologies. This helps reduce the load a solider must carry for longer missions. For high-power applications, the low operating signatures (acoustic and thermal) of fuel cell systems make them ideal power generators in stealth operations.

Recent testing has been completed on the Smart Fuel Cell A25 system that was procured through the FCT program. The “A-25” is a direct methanol fuel cell hybrid and was evaluated as a potential candidate for soldier and sensor power applications.
Published by Elsevier B.V.

Keywords: Fuel cell; Direct methanol fuel cell; Soldier power; Power; Energy

1. US Army CERDEC

The Army’s Communications, Electronics Research Development and Engineering Center (CERDEC) Fuel Cell Technology team is currently testing a variety of fuel cell systems as possible candidates for eventual transition to the military. CERDEC develops and tests a variety of technologies in order to provide a power package with the greatest tactical capability to the soldier. CERDEC has identified three applications for fuel cell technology including soldier and sensor power (<100 W), standalone battery charging (100–500 W) and auxiliary power units (500 W–10 kW). These target areas represent the most practical near-term applications where fuel cell technology could transition into battlefield environments.

However, fuel cells are only a small part of the power solution. Future power sources will most likely be a hybrid of many power technologies in order to provide the greatest benefit and to compensate for the large gamut of military operating conditions and tactical capabilities. CERDEC has focused on direct methanol fuel cells (DMFCs) as the principal near-term technology solution for soldier and sensor power for several reasons. While there are many fuel cell technologies that utilize compressed hydrogen, this type of technology is not currently feasible in a battlefield environment. One of the major problems with fuel cell systems in the military is the choice of fuel. Current military regulations mandate that power sources over 500 W must utilize readily available logistics fuels such as JP8 or diesel. To date, there are no fuel cell systems that can operate effectively on either of these fuels, making integration into the military difficult. The low-power applications of direct methanol fuel cells (DMFCs) fall below this regulation. DMFCs use methanol to directly and efficiently provide power without a reforming process. The high-energy density, quick start capability, and technology maturity of DMFCs make this technology an attractive choice for low-power scenarios. Additionally, methanol can be prepackaged and has received limited DOT approval on airplanes and ground transportation making the logistics of deploying this technology safer and easier.

2. Foreign Comparative Test program

Foreign Comparative Test (FCT) programs are awarded through the Department of Defense and offer the opportunity to evaluate ‘near-production’ systems produced by foreign

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0378-7753/$ – see front matter Published by Elsevier B.V.
doi:10.1016/j.jpowsour.2004.05.049

Table 1
FCT Program units being tested

Vendor	Location	Technology
NovArs	Germany	670 W PEM, 3.8 kg
Smart Fuel Cell	Germany	25 W DMFC, 10 kg
Intelligent Energy	United Kingdom	2 kW PEM, 115 kg
Ballard Power/Idatech	Canada	1 kW methanol reforming, 87 kg
Hydrogenics	Canada	500 W sodium borohydride, 80 kg

vendors. These programs serve as a point of reference for cost and performance data of both foreign and domestic technology products. While other programs may focus on component evaluation and development, the focus of the CERDEC program is the evaluation of complete systems for rapid transition to the military. The systems range in size, weight, fuel, and type of fuel cell technology. All of the advanced prototype units have been received and are in the process of being tested. Table 1 provides detail on each unit received.

Each system underwent a series of tests to help determine the state of the technology. This included noting any shortcomings or operational discontinuities as well as the overall performance of the system. CERDEC has adopted a system of systems policy in fuel cell test and evaluation, and strives to convey the importance of reporting data on the total system level (including the stack, balance of plant components, fuel, etc.) This is an important distinction because on the battlefield, our soldiers will need to carry a total system and not just a subcomponent. Fuel consumption, efficiency, endurance, and environmental temperature tests were completed.

For low-power systems (<100 W) the goal was to compare the power quality, energy density, and overall performance to that of standard military batteries. Performance of the higher power systems was compared to against data for the tactically quiet generator sets (TQGs) used in the field today. These comparisons serve only to assess the added benefits that fuel cell systems may provide and not as a matter of replacing either batteries or generator sets.

3. Smart Fuel Cell

Under the FCT Program, two SFC A25 units were leased from Smart Fuel Cell (SFC) AG based in Brunnthal-Nord, Germany, and arrived at Fort Belvoir in August 2003. From August 2003 to January 2004 all planned testing was completed. The A25 is a direct methanol fuel cell-battery hybrid system that uses a 25 W PEM fuel cell stack and a 12 V lead acid battery linked in series.

Under this configuration, the fuel cell is used to trickle charge the lead acid battery, which then powers the load. Consequently, all data collected is influenced by the condition of the lead acid battery.

Fig. 1. SFC A25.

The SFC A25 system, shown in Fig. 1, weighs 22 lbs and measures 18.25 in. × 6.5 in. × 12.25 in. The current size and weight of this system does not make this version practical for near-term military adaptation. Reducing the weight and logistics burden on the soldier is a common goal shared across all research and development areas within the military. The SFC A25 is fueled by "neat" methanol that is prepackaged in 2500 mL containers.

The primary goal of testing the system was to determine the operational capabilities of the system in different environmental conditions. The first part of the testing was completed under ambient conditions ($T = 20$–$25\,^{\circ}$C, RH $= 50$–75%). Fuel consumption tests provided system efficiencies at various power outputs. The performance tests at ambient conditions were used as a baseline for the tests executed at high and low temperatures. In addition to the performance tests, a continuous fuel consumption test was completed to determine the actual total runtime per fuel cartridge at different loads. A hot swap test and fuel consumption test, using methanol from Fort Belvoir instead of the prepackaged SFC fuel, were also completed.

At a load of 20 and 25 W the system was run for a full day (∼8 h) on three different occasions. Table 2 shows the average fuel consumptions and system efficiency values from this series of tests.

The efficiency was calculated using the lower heating value of methanol, measurements of the weight of the fuel, and the density of 'neat' methanol. Additionally, Fig. 2 shows how the efficiency fluctuated over the duration of the test with measurements being taken every 30 min.

During the continuous fuel consumption test the unit was run at a load of 25 W until the 2500 mL fuel container of methanol was empty. CERDEC data show a total runtime of ∼56 h at 25 W. Manufacturer data report 100+ h of operation under the same conditions. At present, there is no clear explanation for the discrepancy between the manufac-

Table 2
Fuel consumption and efficiency averages

Load	Fuel consumption (kg/h)	Fuel consumption (L/h)	Efficiency
25 W	0.034	0.043	13.1%
20 W	0.032	0.040	11.4%

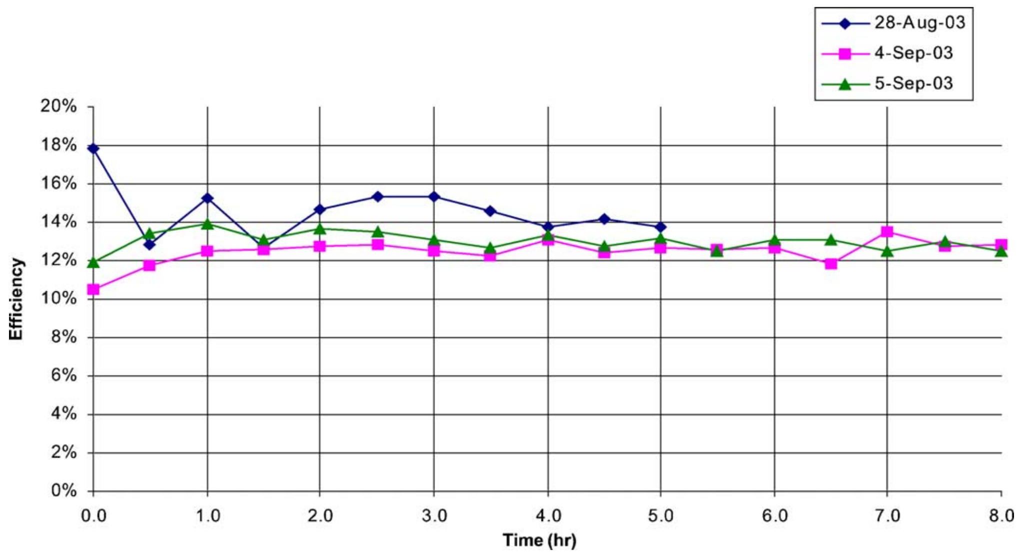

Fig. 2. SFC A25 #0003 fuel efficiency over time at 25 W load.

turer and RDECOM test results. Such a large discrepancy presents a problem in assessing the actual capabilities of the system. All charts and data reported in this paper incorporate only those values observed by CERDEC and not those quoted by the manufacturer.

Prior to environmental testing, one of the units was damaged and was therefore not included in any further testing. The damaged unit began to leak methanol from the base and would not carry a load. It was determined that this failure resulted from the unit not being operated in a perfectly upright position. Several other groups testing the A25 also experienced this problem. This unit had to be returned to SFC for repair.

High-temperature testing was conducted on the remaining functional unit. SFC specs for temperature operation are −20 to 40 °C. The high-temperature testing began at 26.6 °C. At 35 °C there were repeated shutdowns and the system dropped the load. This happened more frequently with increasing temperature. At 40 °C the system would not carry a load at all. Cold temperature testing was also largely unsuccessful. The system did not start or operate at +15 °C. The system was rebooted under ambient conditions but could no longer carry a load. CERDEC concluded that severe degradation to the system occurred during the environmental testing. This unit was also returned to SFC for repair.

In order to accurately assess the advantages and disadvantages of this system to the soldier, the SFC A25 was compared to current battery technology in terms of weight. Fig. 3 shows the weight advantage of the A25 for longer mission lengths.

Fig. 3 represents the trend seen in most fuel cell technologies. After a longer mission duration, it becomes advantageous in terms of weight to use fuel cell power instead of battery power. At a mission length of 2 days, A25 provides a weight advantage over current rechargeable batteries and at 4 days, the A25 proves to be lighter than primary batteries. There is also a logistics benefit. For a mission of 2 days, the solider carries one A25 unit and one fuel container ver-

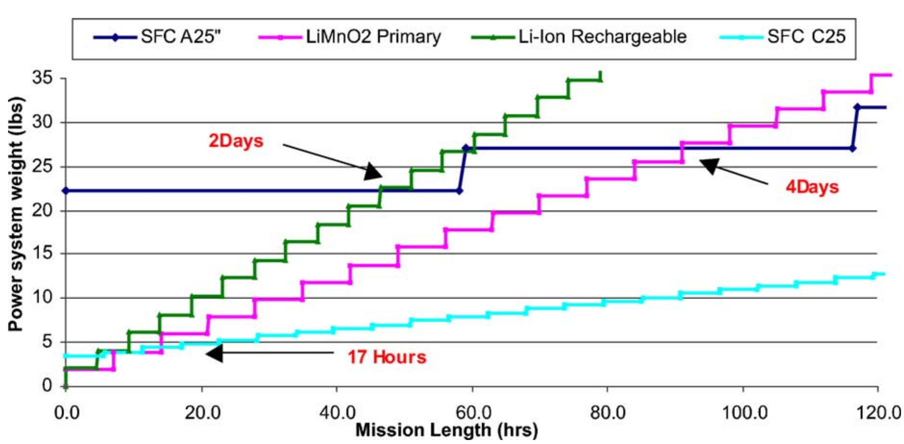

Fig. 3. SFC A25 and C25 vs. battery power; weight comparison for 25 W continuous load profile.

Fig. 4. SFC C25 prototype 25 W DMFC.

sus 8–11 batteries. Although the weight is equal, the ability to carry one fully fueled A25 is more realistic than carrying 11 batteries. However, for any mission less than 2 days batteries are currently the best available option.

One of the primary drawbacks of the A25 unit is the initial system weight of 22 lbs. In order to reduce the size and weight footprints of the existing A25 unit, SFC was able to develop a smaller second-generation 25 W DMFC called the C25. CERDEC is currently awaiting delivery of two of these prototype C25 units. Figure 4 illustrates the SFC C25.

The C25 provides the same 25 W continuous power output as the A25, but weighs only 1.4 kg with a 0.2 kg fuel cartridge. SFC quotes this fuel cartridge will provide power for approximately 7 h at 20 W, offering 140 W h of energy. This system has clear advantages for use as soldier power. Data on the C25 is also included above in Fig. 3. After only 17 h the C25 begins to offer weight advantages over current battery technologies for low-power applications. The size of this system is comparable to the BA5590 military battery making integration into the field more realistic. SFC has also taken into account the problem experienced with the A25 in terms of orientation during operation as shown in Fig. 5.

Fig. 5. Orientation-independent operation.

4. Conclusions

The Foreign Comparative Test Program provides the opportunity to assess the state of fuel cell technology worldwide. Ultimately this program serves as a point of reference for all subsequent fuel cell test and evaluation within CERDEC. Fuel cells for use in military applications may provide additional tactical capabilities in terms of size, weight, and mission scenario. However, current fuel cell technology has not advanced to a point where effective and reliable operation in military environments and conditions is feasible. With continued research and development fuel cells may help to bridge the gap between current and future power technologies in the military.

The Smart Fuel Cell A25 operates well under limited conditions. Environmental factors remain an issue in the fuel cell arena and are evident in the results of this testing. Current military efforts are focused in areas of both extreme hot and cold temperatures that exceed the environmental capabilities of the A25. System orientation and methanol leaks were two of the other major problems encountered during CERDEC testing. In battlefield environments, the system will almost never be operating on a flat surface and perfectly upright. The SFC A25 needs to be ruggedized and upgraded to be applicable in military applications and provide added benefit over current power technologies.

The durability and reliability of military power sources is a strict requirement and to date there are no fuel cell technologies that can handle the harsh environments and conditions of the battlefield. In order for fuel cell technology to make real strides in commercialization and substantial use in the military, the focus must be placed on developing ruggedized complete systems that operate consistently and reliably on the battlefield.