Progress Made by Stationary Fuel cell Manufacturers: HARC's Fuel Cell Equipment Testing Experience

Introduction:

HARC is an independent, non-profit research organization and its research themes support sustainability solutions in ecosystems, water, air & climate, clean energy, the built environment, and environmental health. In 2000, HARC created the Center for Fuel Cell Research and Applications (CFCRA) to pursue research on a wide range of relevant fuel cell systems and applications. The Center studies the performance, efficiency and durability of fuel cell equipment to both evaluate the appropriateness of fuel cells in various residential, commercial, and industrial applications and to understand the economic, regulatory, and market barriers impacting deployment of the technology. Commercialization of stationary fuel cell systems will be driven by fuel cell performance rather than price because compelling performance will create opportunities that entice early adopters into action. The key to understanding the actual performance and application potential of fuel cell systems is to acquire and test actual hardware.

Test Methodology:

HARC's test methodology is to operate systems in a manner and environment consistent with those anticipated during actual use of the fuel cell in its intended operation. Through our testing, we compare actual performance to the manufacturer's performance claims and published specifications. In advance of system delivery, HARC develops a test plan with the system manufacturer. For example, HARC may focus on repetitive start-stop performance where a manufacturer's system design specifically enhances this type of performance. A standard test plan used by HARC includes a obtaining "performance snapshots" every 500/300 hours of operation. In between snapshots, the system is operated 24/7 at one half of its rated capacity. This test strategy is shown graphically in the Figure 1 below.

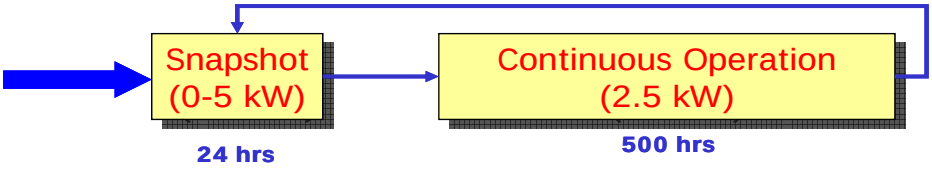

Figure 1: Standard test plan at HARC

Data and performance results important to HARC include system availability, electrical and total system efficiency, stack and system durability, maintenance issues, reasons for system failures, repair times, quality of manufacturer's technical support services, and other information important to potential technology adopters and distributors.

Through in-house and remote monitoring, HARC secures fuel cell performance data consistent with the ASME PTC-50 specification and delivers high quality reports summarizing the results. HARC engages in "black box" to highlight the performance of systems provided by fuel cell manufacturers and systems integrators. The equipment testing and evaluation program has discerned significant and measurable improvements in system performance and cost reduction. Manufacturers have put much more attention to the details and finish of their products, to ensure that the systems meet the requirements of their intended applications. Nagging problems like

deionized water usage, hydrogen consumption while in stand-by mode and unscheduled power interruptions are being minimized or eliminated. New products provide tangible performance enhancements reason for optimism that the technology will begin entering the market soon in secific niche markets.

S.No	Test Year	Fuel Cell System	Power (kW)	Total Operational Hours to failure(hrs)	Energy produced (kWh)	Test Duration (months)	Fuel	AC /DC	Major issues
1	2001	Avista labs SR-72 (PEM)	3	1361	587	17	H2	DC	Cartridges replaced twice during the test period
2	2001	DCH Enable (PEM)	5	240	300	9	H2	AC	No Manufacturer support
3	2002	Plug Power SU1(PEM)	5	7176	20342	10	Nat gas	AC	Stack changed at 816 hrs and 3607 hrs.Sulfur trap lifetime low (2 Canisters failed during the test). Stack degradation
4	2003	Avista Labs J32(PEM)	1	281	88	12	H2	DC	System was used prior to given to HARC
5	2003	Ballard Nexa RM(PEM)	4	7773	3812	17	H2	DC	Balance of plant component failure, stack degradation, etc
6	2004	Relion J48C(PEM)	1	2500	1103	6	H2	DC	Cartridge degradation
7	2004	Plug Power Gensys(PEM)	5	7800	14340	11	LPG	AC	Stack changed after 6000 hrs due to performance degradation
8	2004	Plug Power Gencore(PEM)	5	2500	4558	8	H2	DC	Cell failure in the stack
9	2005	Nuvera H2e(PEM)	5.5	1800	6560	4	H2	DC	Cell failure in the stack
10	2006	Acumentrics (SOFC)	5	406	610	12	Nat Gas	AC	Cell failure in the stack
11	2007	UTC(PEM)	5	1200 (Running)	2565	12	H2	DC	------

Table 1: Description of the fuel cell systems tested at HARC

Experience:

Since 2000, HARC has monitored, tested, and evaluated a total of eleven fuel cells and two fuel reformers. The CFCRA has tested fuel cells from Plug Power, Ballard Power Systems, ReliOn, Acumentrics, IdaTech, Nuvera and UTC Power. One of the first systems tested at HARC was a 5 kW PEM fuel cell from Enable Fuel Cell, Inc., which was retrofitted with a HyRadix Alpha 4 natural gas reformer. Ballard Nexa RM, the Plug Power GenCore, and the ReliOn Independence 1000 (Models J32 and J48C), which were tested earlier received attention as a battery replacement option in UPS and backup power applications. HARC tested three generations of Relion products from 2001 to 2004, wherein it has made improvements in their Independence 1000 product line. To achieve these results, ReliOn redesigned their power cartridge to improve output. As a result, the J48C model achieves the 1 kW rating with six cartridges, rather than the eight required in the J32. The upgrade was accomplished without increasing the size of the cartridges or the overall system.

The I-1000 J32 improves upon the predecessor SR-72 in both packaging and performance. The J32 also offered completely redesigned cartridge technology. Cartridges are much larger and heavier than the earlierSR-12 cartridges. The enhancements incorporated into the I-1000 J32 generation fuel cell unit at that time were considered to be in the right direction for the ReliOn. The performance of the I-1000 J32 system was not considered to be adequate for the UPS application and hence in December 2002, ReliOn discontinued production of the J32, replacing it with the Model J48C. The Center noticed a decent improvement in this version of J48C over the earlier Independence 1000 J32 and SR-72 units – in terms of power density, component reliability, maintenance, etc.

Similarly, Plug Power also made progress through its three generations of fuel cell systems tested at HARC. Compared to the older SU-1 system (vintage 2001), their follow-on GenSys Slide platform (vintage late 2003) is about 20 percent more efficient and offers significantly better stack durability. Compared to the SU-1 system tested at the Center, the system had improved system efficiency and stack durability. Also, the high availability achieved with the system indicated that Plug Power has resolved many of the problems that plagued the earlier SU-1, namely ATO/CPO failures, desulphurization canister failures, and inverter shutdowns.

A comparison of power densities for the recent PEM fuel cell systems tested at HARC are shown below .The bar on the left in each set shows the gravimetric power density and the improvements made by these systems through the years can be observed.

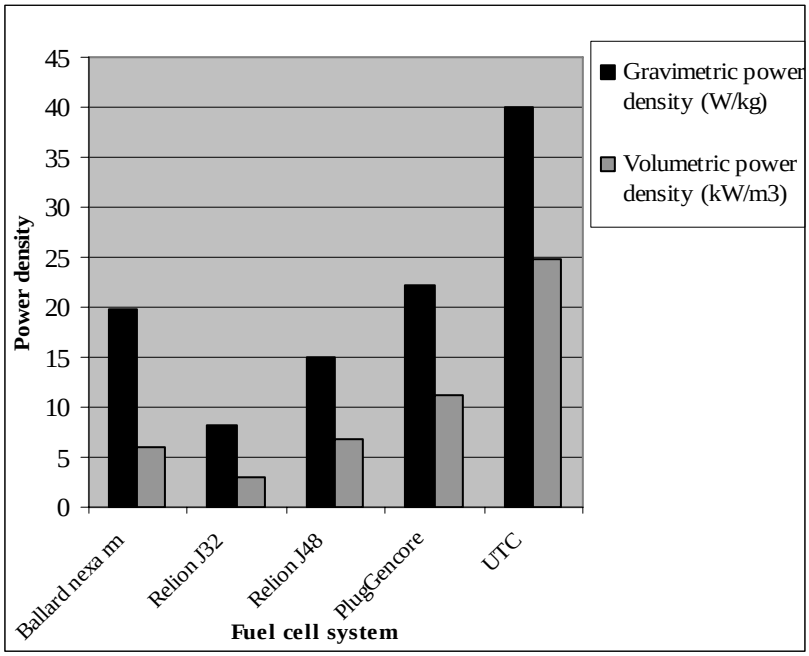

Figure 2: The above chart compares the PEM fuel cell systems run by Hydrogen gas

HARC's fuel cell testing and evaluation provides industry sponsors with the real story of fuel cell technology performance. From the very first fuel cell tested in 2001 to the present UTC fuel cell

system HARC has observed improvements in the fuel cell systems with respect to the performance, efficiencies, power densities, compactness and cost. The UTC 5kw PEM fuel cell that we are presently testing, which is applicable as a backup power source, is simple in operation and very compact in size when compared to previous fuel cell systems.

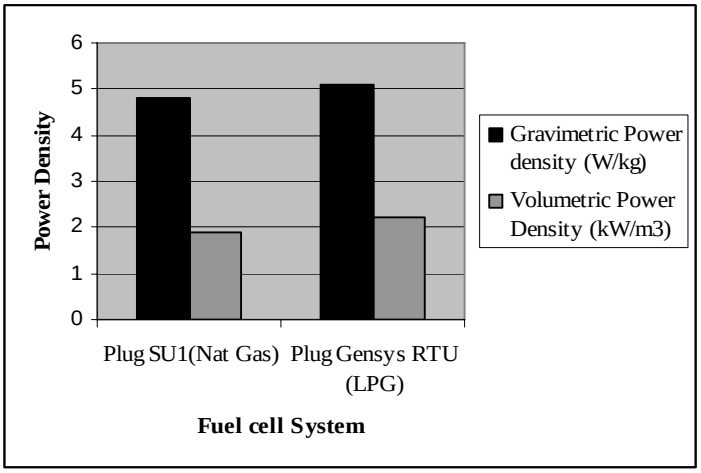

Figure 3: Power density comparisons of the Plug power systems run by Natural gas and LPG.

Much has been learned about how fuel cells will likely emerge in stationary applications, and much more will be learned as technology development continues. While fuel cells are not yet compelling options in most stationary applications, manufacturers are introducing equipment incorporating new features and better performance. Though there has been a very keen interest amongst different fuel cell and oil and gas companies on the fuel cell testing between the years 2002-2005, presently the companies seem to have lost interest as most of them believe that it is going to take longer for the fuel cell systems to commercialize in small stationary applications. In our annual Industry Assessment Report (IAR) research for the year 2006-2007 on the fuel cell Industry, we have observed that many fuel cell companies were either merged or acquired through 2006-2007.

Lessons learned from installing, operating and maintaining a fuel cell system are invaluable for making critical decisions about purchasing or investing in fuel cell technology, and in making the most cost-effective, lowest risk decisions about target applications. Industry participants still have much to learn from the testing and demonstration of stationary fuel cell systems, especially as new models and configurations are introduced into the marketplace.

Conclusions:

HARC's unique practical experience with the exciting technologies reveals that the adoption of fuel cell systems in stationary applications is still an unfolding story and the journey from the laboratory to the marketplace has not yet been realized. As this emergent technology evolves and matures, actual operating experience and practical understanding are critical to making good decisions on their opportunity and use.