PLUG POWER FUEL CELL DEMONSTRATION PROJECT AT THE WATERVLIET ARSENAL

Interim Final Project Report
March 21, 2003

Prepared for

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1. Overview

This report shall serve as the Interim Final Report for the U.S. Army Corps of Engineers, Construction Engineering Research Laboratory (CERL) fuel cell demonstration program at the Watervliet Arsenal pursuant to contract number DACA42-01-C-0053. In accordance with the contractual change agreed to by both CERL, the Watervliet Arsenal and Plug Power on December 18, 2002 continued operation of the fleet beyond the one-year demonstration is authorized. This continued operation will be conducted by and at the expense of Plug Power. The number of systems and length of duration will be determined by Plug Power. Site decommissioning will be performed at those locations not used by Plug Power but complete site restoration will be completed at the end of the continued run but not to exceed December 31, 2003. After complete site restoration is completed, Plug Power will have 60 days in which to submit a Final Report to CERL. Included within this Interim Final Report is a complete account of the project consisting of material from the initial project description report, the midpoint project status report, complete fleet performance data, maintenance logs, and a conclusion section.

2. Background and Objectives of the Project

The installation and operation of Plug Power's PEM fuel cells at the Watervliet Arsenal, Watervliet, NY fulfilled objectives that further the missions of both the U.S. Army Corps of Engineers and Plug Power. The following points summarize the common high-level objectives that were met through this program:

- Continued assessment of fuel cells in supporting sustainable military installations;
- Increased the Army's ability to more efficiently construct, operate and maintain its installations;
- Assessed the role of PEM fuel cells in supporting the Army's training, readiness, mobilization, and sustainability missions;
- Provided a technology demonstration site for a military base market;
- Provided operational testing & validation of a fuel cell product to assess installation, grid interconnection, operation of systems in all seasonal conditions, and integration of units into an existing military base environment.

Furthermore, this program supported Plug Power's recognition of the Department of Defense as a potentially significant customer for fuel cells in the future, and provided the opportunity for an initial assessment of the use of PEM fuel cells supporting military base infrastructure.

3. Equipment

Plug Power designed, manufactured, installed and commissioned ten (10) Proton Exchange Membrane (PEM) fuel cell power systems at three separate sites within the Watervliet Arsenal facility. The fuel cell systems operated in electric-only, grid-parallel mode using natural gas as a fuel. Product specifications for the units are shown in Table 1.

Table 1: Product Specifications

Comment	Specification
Unit Size	Base Unit with integral skid: 84.5”L x 32”W x 68”H (excludes 22” exhaust stack)
Installation Location	Outdoor
Grid Parallel	Yes
Power Output/Set points	2.5kW, 4 kW, 5 kW
Remote monitoring capability	Via phone line
Output Voltage	120 / 240 VAC @ 60 Hz
Certification	Integrated System - CSA International Inverter - UL Listed
Power Quality	IEEE 519 or better
Emissions (steady-state)	NOx < 5 ppm Sox < 1 ppm CO < 50 ppm
Standard operating conditions	Temperature: O °F to 104 °F Elevation: up to 6,000 ft Noise: < 70 dBa @ 1 meter
Production Schedule	Systems were manufactured between June, 2001 and October, 2001

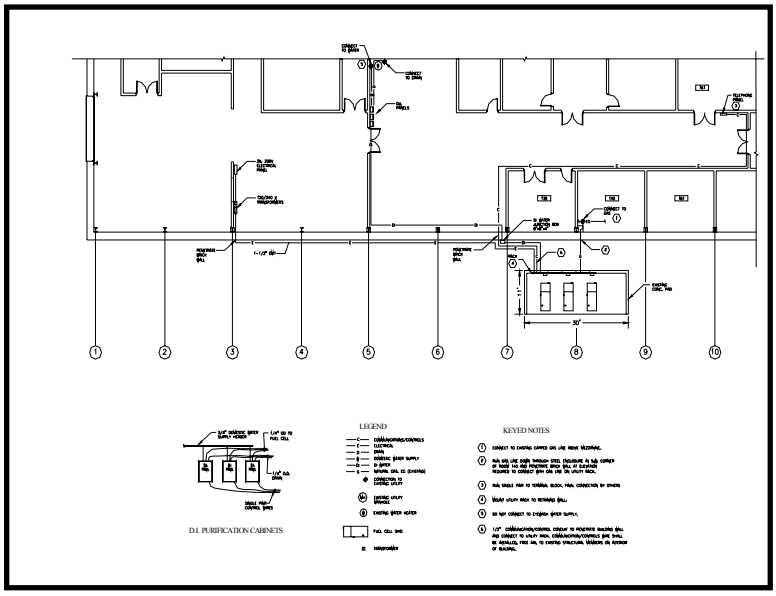
4. Site Information

The locations selected for installation support residential as well as operational facilities on the post. Plug Power worked with CERL and Watervliet Arsenal personnel to select the sites at the Arsenal. Each site was selected to match the power output of the systems to be installed. Plug Power provided the site preparation, the fuel cell systems, installation, operations and maintenance support for each of the fuel cells installed.

The first installation was in support of the destructive testing facility in Building 115. The fuel cell systems were located on the east side of the building on an existing 28’ x 10’ unused concrete pad as shown in Figure 1. Figure 2 shows the proposed installation schematic for the facility. Historical average demand for this facility has been approximately 5400 kW-hrs/month, which corresponds to a three system installation at an average fuel cell output of 2.5 kW.

Figure 1: Site at Bldg. 115

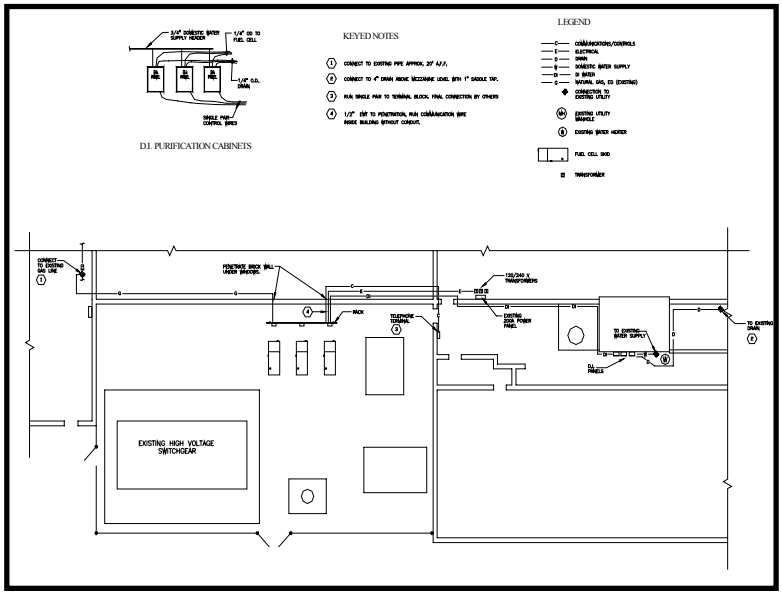
Figure 2: Bldg. 115 Installation Schematic



The second installation was in support of the Arsenal's telecommunication facility in Bldg. 110. The installation was located within the fenced area for substation 1A3 on the west-side exterior of the building shown in Figure 3. Figure 4 shows the installation schematic for the facility. Historical average demand for this facility has been approximately 5400 kW-hrs/month, which corresponds to a three system installation at an average fuel cell output of 2.5 kW.

Figure 3: Site at Bldg. 110

Figure 4: Bldg. 110 Installation Schematic

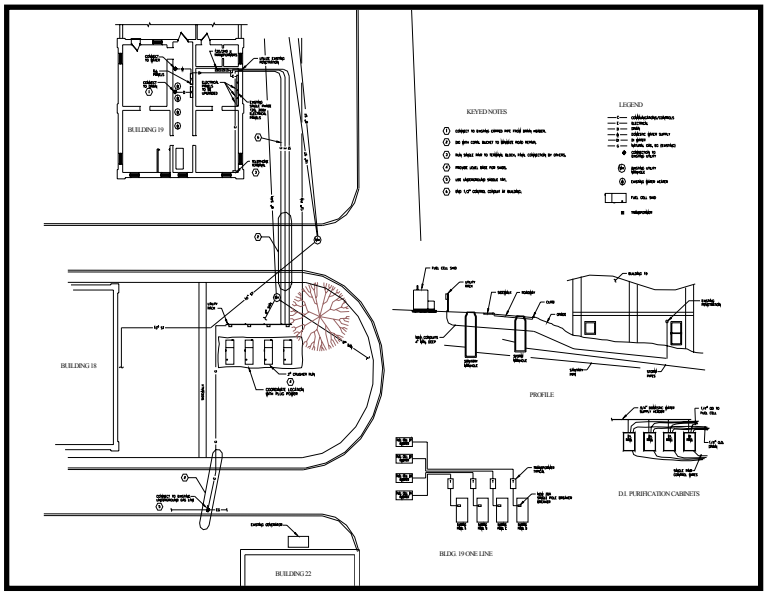


The third installation was in support of the Quarters 19 Officer Housing. Quarters 19 has 9,610 square feet of living space for 4 family units, with each unit individually metered. Power comes from Arsenal substation 2A4. Figure 5 shows the general vicinity of the installation and Figure 6

shows the proposed schematic. Historical average demand for this facility has been approximately 3400 kW-hrs/month, but the objective of demonstrating residential usage of fuel cell systems matched a single system to each housing unit. The four-system installation with at an average fuel cell output of 2.5 kW generated approximately 7200 kW-hrs per month. The local grid within the Arsenal consumed surplus electricity unused by the family units.

Figure 5: Vicinity Quarters 19

Figure 6: Q 19 Installation Schematic



5. Installation

With the site preparation complete, Plug Power was able to demonstrate a one-day turn around for fuel cell shipment, installation and commissioning – see Table 2 for details.

The following is a summary of the major installation activities:

- **December 17, 2001:** Site preparation began.
- **January 7, 2002:** Site preparation complete. This included all foundation work, gas piping, water system installation, electrical interconnection, communications wiring and other work necessary to prepare the sites for the installation and operation of the fuel cell systems.
- **January 15, 2002:** Four (4) systems for Quarters 19 were shipped, installed and commissioned (Figures 7 and 8).
- **January 16, 2002:** Three (3) systems for Building 110 were shipped, installed and commissioned (Figures 9 and 10).
- **January 17, 2002:** Three (3) systems for Building 115 were shipped, installed and commissioned (Figures 11 and 12).

Figure 7: Quarters 19

Figure 8: Quarters 19

Figure 9: Building 110

Figure 10: Building 110

Figure 11: Building 115

Figure 12: Building 115

Table 2: Acceptance Test Documentation

System Serial Num	Site Description	Delivery Date	Installation Date	Commission Date	Install Checklist	Commission Test	Installer Name
SU01B000000095	Building 19	1/15/02	1/15/02	1/16/02	Complete	Pass	Mike Mezz
SU01B000000096	Building 19	1/15/02	1/15/02	1/16/02	Complete	Pass	Bob Manning
SU01B000000097	Building 19	1/15/02	1/15/02	1/16/02	Complete	Pass	Jon Kinsey
SU01B000000098	Building 19	1/15/02	1/15/02	1/16/02	Complete	Pass	Jan Morawski
SU01B000000100	Building B110	1/16/02	1/16/02	1/17/02	Complete	Pass	Dave Seibert
SU01B000000102	Building B110	1/16/02	1/16/02	1/17/02	Complete	Pass	Vinny Cassala
SU01B000000103	Building B110	1/16/02	1/16/02	1/17/02	Complete	Pass	Mike Mezz
SU01B000000104	Building B115	1/17/02	1/17/02	1/18/02	Complete	Pass	Dave Seibert
SU01B000000105	Building B115	1/17/02	1/17/02	1/21/02	Complete	Pass	Jan Morawski
SU01B000000106	Building B115	1/17/02	1/17/02	1/18/02	Complete	Pass	Vinny Cassala

6. Operation

During this one-year demonstration, a significant amount of data and operational experience was garnered. Table 3 is a summary of the total fleet performance for the demonstration through January 21, 2003. For detailed system data, refer to Appendix A.

Table 3: Fleet Summary

Total Run Time (Hours)	Time Period (Hours)	Availability (%)	Total Energy Produced (kWe-hrs)	Average Output (kW)	Capcity Factor (%)	Total Natural Gas Usage (MMBTU's)	Electrical Efficiency (%)
83,007	**88,544**	**93.7%**	**214,555**	**2.58**	**51.7%**	**3,029.4**	**24.2%**

Figure 13: Fleet Availability

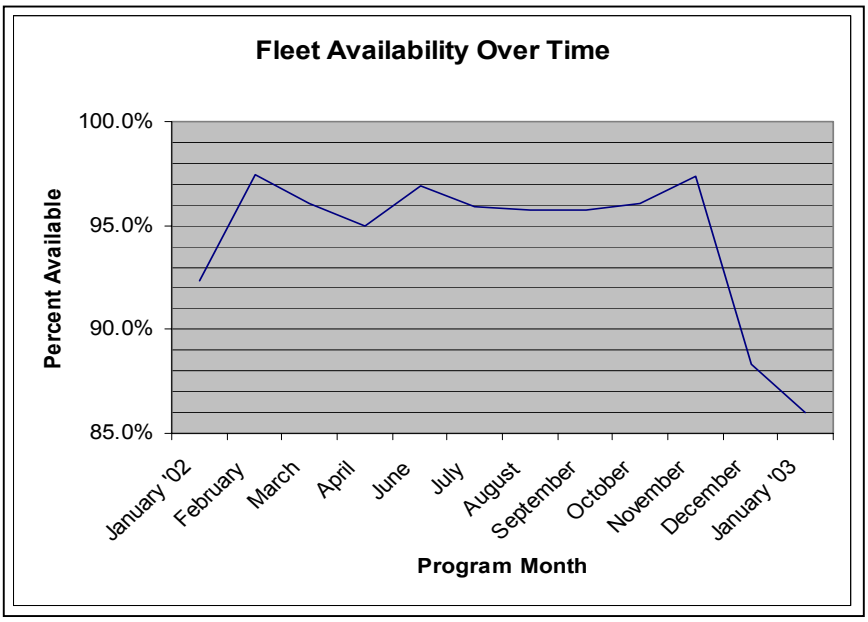
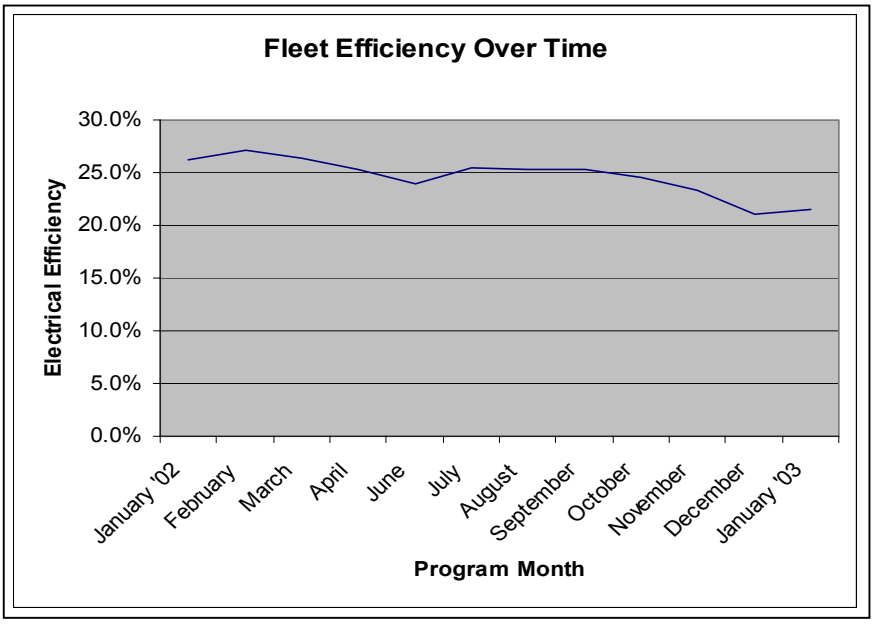


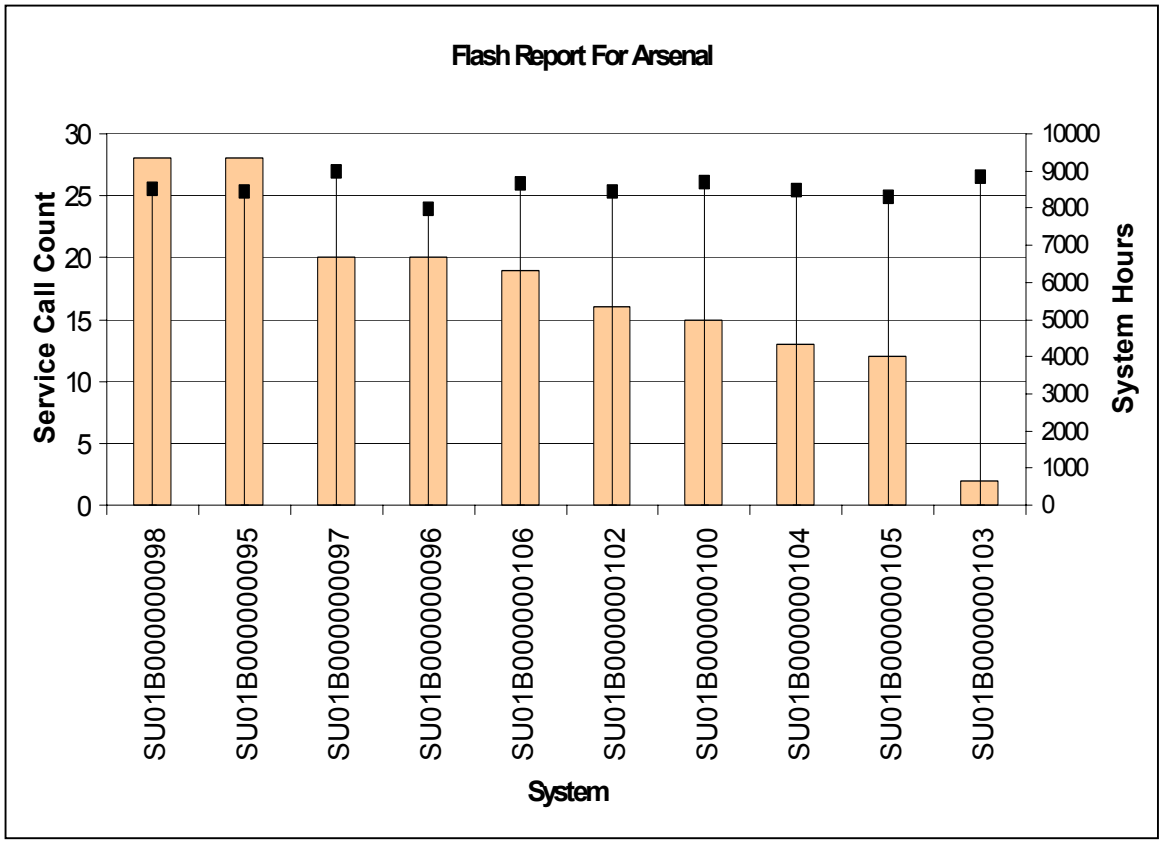
Figure 14: Fleet Efficiency



7. Maintenance

Chart 3 shows the service calls per system for the demonstration. Evident is the fact that certain system, such as B103 operated much more reliably than a system like B96. This sort of deviation should be expected within any given population. Data mining efforts are currently underway within Plug Power in order to determine what types of external factors (i.e. weather, air contaminants, facility load profile, etc.) may have impacted the results. This information is also being used to drive quality into future generation machines through smart component design and selection, simplification of design, improvement of site construction, etc.

Figure 15: Maintenance Summary



8. Decommissioning

As of this report, the sites at Buildings 110 and 115 have been decommissioned. A decommissioned site has all utilities locked and tagged out, all pipes/conduits terminated and protected against weather and damage, and otherwise put into a secure state pending re-population of restoration. Plug Power, CERL and the Watervliet Arsenal have entered into an agreement that will allow Plug Power to continue operation of all sites under Plug Power control and at Plug Power's expense through calendar year 2003. Quarters 19 has been selected for

continued operation and re-population of the two decommissioned sites is under consideration. Any action to repopulate decommissioned sites will occur only after prior approval is granted from the Watervliet Arsenal. Upon completion of the extended run or the end of calendar year 2003, whichever comes first, all three sites will be completely restored to their original condition. Subsequent to final site restoration, a Final Report will be generated that will highlight any major technological advances, lessons learned, significant findings and details of the restoration process.

9. Conclusion

This fuel cell demonstration was an invaluable learning experience for CERL, the Watervliet Arsenal and Plug Power. Each of the high level objectives presented in section 2 were satisfied and many program goals, such as the 90% availability target, were surpassed. This was an opportunity for Plug Power to expand the field experience that will result in a better product down the road yet reap immediate benefits in the systems of today. The Watervliet Arsenal installation was a benchmark for Plug Power and allowed for growth in every aspect of the business from manufacturing to field service.

The ability to produce ten identical fuel cell systems was a milestone within Plug Power. The transition from prototype to mass production is difficult during the best of times. This program presented the opportunity to prove the effectiveness and readiness of the Plug Power manufacturing tools, techniques and people.

The packaging and shipment of ten fuel cell systems was an opportunity for maturity as well. The logistics involved with preparing and packaging ten systems, loading them onto trucks and delivering them on site involved people from many groups both inside Plug Power and outside. From draining procedures to packaging materials, the support system that many mature companies take for granted had to be developed. For example, the fuel cell units are designed for rigging with a standard fork truck. Due to the location of the sites: elevated concrete pad, gravel bed behind substation transformers and a grassy hill, it was impractical to move the systems as designed. The easiest option for the arsenal was to move the systems using a crane. This required the engineering and manufacturing of lifting fixtures and the development of a new lifting procedure that has now allowed access to sites previously out of reach.

Site preparation and construction was a significant challenge in and of itself. Grid interconnection issues, site selection, installation design, contractor bid packages, approvals and inspections, site access issues and project scheduling were all items that Plug Power had experience with but on a much smaller scale. Most of the techniques and processes used for the Watervliet installation are used by Plug Power to this day for installations from Japan to Brazil. The following are examples of site-preparation issues that were encountered and the steps taken to rectify them:

- Grid interconnection approval was an issue from early on in the installation planning. The local utility, Niagara Mohawk, required a lengthy and expensive review process before granting permission to interconnect power generation equipment to their grid. The expected application/review time of 8-12 weeks and cost of approximately $5000 per site were hurdles

that threatened the schedule and budget of the demonstration. Since the Watervliet Arsenal is a federal facility and has a primary metered service classification, where only the main feed to the complex is metered by the utility, the decision was made to forego the interconnection approval process. It was decided that Niagara Mohawk did not have jurisdiction within the Arsenal and the interconnection approval process was not applicable. Precedence was set by this action and the same argument/decision has been used at other subsequent government/military installations. A direct result of this experience is the continued efforts by Plug Power, Public Utility Commissions, the fuel cell industry and various other public and private entities to standardize, simplify and reduce the cost of interconnection activities. To reduce time and fees of detailed utility reviews, the equipment should be certified to a national interconnection standard by a nationally recognized testing laboratory such as Underwriters Laboratories. Once the equipment is certified, it can be listed by states such as CA, NY and TX that maintain certified interconnection listings. However, there are over 3000 utilities in the US, many with no simplified interconnection processes hindering the spread of distributed generation. Additionally, most utilities still will not pay for the free power they receive from distributed generation facilities. Recent improvements in the New York State Public Service Commission's System Interconnection Requirements allow for small inverter based systems to be interconnected in less than four weeks with no fees for interconnection outside of any necessary utility system modifications.

- The fuel cell systems installed at the Arsenal were equipped with a grid-parallel package designed to interconnect with the grid by means of tying into a circuit breaker in the end-user's service panel. Due to the age of the equipment found in the Arsenal, all three sites required either new electric service panels or sub-panels.
- The systems installed at the Arsenal require a supply of potable water, which is purified in a de-ionization process. Potable water provided by the local municipality via the Watervliet Arsenal presented two challenges: 1) The system's water filters is designed to last one year in a residential application. The hardness of the Arsenal's water would require changing the deionization filters twice a month. Plug Power installed cartridges that extended the life of the filters by six months. 2) Normal operating conditions require a minimum static pressure of 40 psi to completely process potable water into deionized water. The Arsenal, requires a back flow preventor at each building, significantly reducing the water pressure from the municipality. Booster pumps, similar to the kind found on residential wells, were installed. The low water pressure problem was solved but resulted in added installation costs.
- At the telecommunications facility (Bldg. 110), voltage levels of the electrical system fluctuated from +/- 5 to 10 volts rms. These fluctuations exceeded inverter anti-islanding set points. Subsequently, the inverters would detect these fluctuations, classify them as loss of grid or grid fault, detach themselves from the grid and enter into their anti-islanding sequence. After waiting a required five minutes, the inverters would again detect the grid (if voltage returned to within specifications) and reattach, entering into their power export sequence. The facility's fluctuations caused the fuel cell systems' inverters to cycle onto and off of the grid, a condition that prevents the units from exporting power to the grid. Arsenal personnel were able to re-tap the local transformer to provide a mean voltage within the normal operating range.

System installation and commissioning was traditionally a process that would take days and involve considerable last minute debugging. For the Watervliet Arsenal, Plug Power was able to

demonstrate a one-day turnaround and have the system landed and running within 24 hours. This is a considerable step in demonstrating that fuel cells can become user friendly and commercially viable.

The operation and maintenance of this ten-system fleet provided Plug Power with data from a sizeable sample that will add definition to it's ever increasing data pool. Of major importance were fleet availability and efficiency numbers.

Overall availability dropped during the final 3 months to approximately 86% and culminated in 93.7% for the demonstration. This is an important milestone for the fuel cell industry because it proves that fuel cell technology is real and can achieve the reliability levels needed to be commercially viable. The decreased availability toward the end of the program was directly related to the unusually severe winter conditions experienced in the Northeast in 2002. Plug Power anticipated an increased level of system shutdowns with this vintage system but the compounded affects of high snowfall totals and extreme low temperatures revealed a host of unanticipated issues. For example, one of the common shut down modes experienced was due to a design feature intended to protect the electronics compartment from extreme cold temperatures. An internal temperature switch was incorporated to shut the system down if it reached a temperature of -10°F. This temperature setting was identified as overly conservative and a change was made to allow operation below the initial setting. Furthermore, changes were made that allowed for improved drainage and more robust freeze damage protection.

The Plug Power Field Support Team was the beneficiary of a large portion of the learning from this project. More efficient processes, procedures and equipment were required to maintain system operation. For example, the design and implementation of a heater panel was necessary in order to thaw systems that froze while shut down. More effective trouble shooting methods were also developed in order to expeditiously identify and rectify issues keeping systems off-line. A comprehensive engineering support network and incident report (IR) database was initiated in order to drive issues to closure and track component failures, software deficiencies, stack replacements, etc. Improvements in component selection and design for serviceability were two of the more significant deliverables from this exercise. Some examples of improvement were:

- The development of a pump retrofit kit implemented to replace a previous model of coolant pump that experienced numerous failures. The new pumps have a much more robust design and reduced the number of repeat shutdowns and replacements due to an inadequate component.
- Water filter/deionized water assembly upgrades. Water issues were responsible for a number of repeat shutdowns throughout the demonstration. In addition to more comprehensive water testing, a systematic, scheduled filter replacement regimen was initiated to proactively monitor and replace filters before they caused a shutdown. Also, a more robust filter design was put in place that includes the use of sediment pre-filters and scale inhibiting cartridges.
- Outfitting and dispatching technicians became more efficient and waste was reduced by eliminating redundant or unnecessary equipment/parts from the technician's toolbox and vehicle.
- Customer training improved dramatically because of the real world experience the Field Technicians were able to bring back to the classroom.

- Shipping and rigging of the fuel cell units was improved through the design of lifting fixtures.

Fleet efficiency experienced two periods of decreased performance in the June and November timeframes. These dips represent the cumulative affect of stack degradation and subsequent replacements. Plug Power requires stack replacement when the system electrical efficiency drops to 20%. As a stack ages, you should expect to see this type of drop in efficiency. The reason for the more pronounced drop starting in November is attributable to the efforts involved around stack end-of-life testing. In order to maximize learning, Plug Power and CERL agreed to allow select systems to degrade past the 20% efficiency barrier. Of particular interest were the two unusually long-lived stacks in systems B98 and B104. The stack in B98 totaled 7056 hours of run time while B104 stack accumulated 6742. Both of these milestones represent the longest-lived stacks in Plug Power history. In an effort to maximize the life of these and the other system stacks, when the system efficiencies started to drop below the 20% mark, the units were put into a recovery mode. During this recovery mode, the systems would increase their power output to 4.0 kWe. This would serve two purposes; first, it would prove that the stack still had some life left and could reach elevated setpoints. Second, the increased flow rates of fuel and air would help to blow out any excess product water that may have accumulated within the stack. The results of this testing will become evident in future generation stacks that can benefit from the learning done at Watervliet.

10. Points of Contact

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APPENDIX A

Monthly Fleet Data – Quarters 19

System #	Site Name	Commission Date	Month of Operation (2002)	Total Run Time (Hours)	Time Period (Hours)	Availability (%)	Total Energy Produced (kWe-hrs)	Average Output (kW)	Capcity Factor (%)	Total Natural Gas Usage (MMBTU's)	Electrical Efficiency (%)
B95	Quarters 19	1/16/02	January '02	276	374	73.8%	679	2.46	49.2%	9.4	24.7%
			February	672	672	100.0%	1697	2.53	50.5%	21.9	26.4%
			March	699	744	94.0%	1656	2.37	47.4%	22.6	25.0%
			April	701	720	97.4%	1737	2.48	49.6%	24.7	24.0%
			May	718	744	96.5%	1789	2.49	49.8%	25.0	24.4%
			June	716	720	99.4%	1643	2.29	45.9%	28.9	19.4%
			July	733	744	98.5%	1781	2.43	48.6%	26.7	22.8%
			August	703	744	94.5%	1760	2.50	50.1%	26.0	23.1%
			September	617	720	85.7%	1547	2.51	50.1%	25.3	20.9%
			October	710	744	95.4%	1765	2.49	49.7%	27.9	21.6%
			November	563	720	78.2%	1351	2.40	48.0%	24.8	18.6%
			December	431	744	58.0%	993	2.30	46.1%	12.5	27.1%
			January '03	493	504	97.9%	1179	2.39	47.8%	17.8	22.6%
			Program Total	8033	8894	90.3%	19578	2.44	48.7%	293.5	22.8%
B96	Quarters 19	1/16/02	January '02	377	391	96.4%	954	2.53	50.6%	12.0	27.1%
			February	662	672	98.5%	1718	2.60	51.9%	21.8	26.9%
			March	639	744	85.9%	1577	2.47	49.4%	20.8	25.9%
			April	699	720	97.1%	1734	2.48	49.6%	24.1	24.6%
			May	724	744	97.3%	1869	2.58	51.6%	28.6	22.3%
			June	707	720	98.2%	1787	2.53	50.6%	24.7	24.7%
			July	710	744	95.4%	2157	3.04	60.8%	27.1	27.2%
			August	744	744	100.0%	1877	2.52	50.5%	24.4	26.2%
			September	658	720	91.4%	1661	2.52	50.5%	23.6	24.0%
			October	689	744	92.6%	1566	2.27	45.5%	26.2	20.4%
			November	434	720	60.3%	859	1.98	39.6%	16.8	17.5%
			December	564	744	75.8%	1389	2.46	49.3%	25.6	18.5%
			January '03	339	504	67.2%	613	1.81	36.2%	11.6	18.0%
			Program Total	7946	8911	89.2%	19761.13	2.49	49.7%	287.428	23.5%
B97	Quarters 19	1/16/02	January '02	323	325	99.4%	827	2.56	51.2%	10.5	26.9%
			February	662	672	98.5%	1674	2.53	50.6%	22.8	25.0%
			March	688	744	92.5%	1727	2.51	50.2%	24.4	24.2%
			April	660	720	91.7%	1663	2.52	50.4%	23.0	24.7%
			May	721	744	96.9%	1827	2.53	50.7%	25.6	24.4%
			June	686	720	95.3%	1731	2.52	50.5%	27.1	21.8%
			July	712	744	95.7%	1707	2.40	47.9%	21.5	27.1%
			August	629	744	84.5%	1569	2.49	49.9%	22.3	24.0%
			September	720	720	100.0%	1815	2.52	50.4%	23.5	26.4%
			October	744	744	100.0%	1873	2.52	50.3%	24.9	25.7%
			November	720	720	100.0%	2160	3.00	60.0%	39.8	18.5%
			December	643	744	86.5%	1478	2.30	45.9%	27.2	18.5%
			January '03	504	504	100.0%	1356	2.69	53.8%	17.0	27.2%
			Program Total	8412	8845	95.1%	21406.99	2.54	50.9%	309.675	23.6%
B98	Quarters 19	1/16/02	January '02	354	368	96.2%	886	2.50	50.1%	11.3	26.8%
			February	595	672	88.5%	1530	2.57	51.4%	19.1	27.3%
			March	715	744	96.1%	1788	2.50	50.0%	22.6	27.0%
			April	717	720	99.6%	1814	2.53	50.6%	23.0	26.9%
			May	727	744	97.7%	1855	2.55	51.0%	24.0	26.4%
			June	720	720	100.0%	1901	2.64	52.8%	26.5	24.5%
			July	644	744	86.6%	1667	2.59	51.8%	24.8	22.9%
			August	710	744	95.4%	1794	2.53	50.5%	26.7	22.9%
			September	707	720	98.2%	1922	2.72	54.4%	29.4	22.3%
			October	728	744	97.8%	2548	3.50	70.0%	45.0	19.3%
			November	610	720	84.7%	1208	1.98	39.6%	21.3	19.3%
			December	652	744	87.7%	1239	1.90	38.0%	21.3	19.8%
			January '03	224	504	44.5%	465	2.07	41.5%	6.2	25.7%
			Program Total	8103	8888	91.2%	20616.65	2.54	50.9%	301.21	23.4%

Monthly Fleet Data – Building 110

System #	Site Name	Commission Date	Month of Operation (2002)	Total Run Time (Hours)	Time Period (Hours)	Availability (%)	Total Energy Produced (kWe-hrs)	Average Output (kW)	Capcity Factor (%)	Total Natural Gas Usage (MMBTU's)	Electrical Efficiency (%)
B104	Bldg. 110	1/18/02	January '02	314	324	96.9%	795	2.53	50.6%	10.1	26.9%
			February	672	672	100.0%	1705	2.54	50.7%	21.3	27.3%
			March	744	744	100.0%	1882	2.53	50.6%	24.0	26.8%
			April	707	720	98.2%	1784	2.52	50.5%	22.9	26.6%
			May	723	744	97.2%	1813	2.51	50.2%	24.4	25.4%
			June	720	720	100.0%	1785	2.48	49.6%	23.6	25.8%
			July	732	744	98.4%	1845	2.52	50.4%	25.4	24.8%
			August	699	744	94.0%	1758	2.52	50.3%	26.4	22.7%
			September	679	720	94.3%	1761	2.59	51.9%	28.1	21.4%
			October	720	744	96.8%	2648	3.68	73.6%	45.9	19.7%
			November	634	720	88.1%	748	1.18	23.6%	10.5	24.2%
			December	586	744	78.8%	1790	3.05	61.1%	26.2	23.3%
			January '03	452	504	89.7%	1252	2.77	55.4%	22.7	18.8%
			Program Total	8382	8844	94.8%	21566.03	2.57	51.5%	311.566	23.6%
B105	Bldg. 110	1/21/02	January '02	235	249	94.4%	625	2.66	53.2%	7.9	26.9%
			February	672	672	100.0%	1791	2.67	53.3%	22.3	27.4%
			March	684	744	91.9%	1785	2.61	52.2%	23.3	26.1%
			April	720	720	100.0%	1869	2.60	51.9%	24.9	25.6%
			May	744	744	100.0%	1953	2.63	52.5%	28.5	23.4%
			June	652	720	90.6%	1903	2.92	58.4%	27.8	23.4%
			July	675	744	90.7%	1568	2.32	46.5%	19.3	27.7%
			August	710	744	95.4%	1746	2.46	49.2%	21.8	27.3%
			September	720	720	100.0%	1830	2.54	50.8%	23.9	26.1%
			October	720	744	96.8%	1786	2.48	49.6%	23.9	25.5%
			November	600	720	83.3%	1902	3.17	63.4%	31.8	20.4%
			December	631	744	84.8%	1624	2.57	51.5%	24.8	22.3%
			January '03	431	504	85.5%	1067	2.48	49.5%	14.8	24.6%
			Program Total	8194	8769	93.4%	21448.73	2.62	52.4%	295.045	24.8%
B106	Bldg. 110	1/18/02	January '02	317	336	94.3%	729	2.30	46.0%	9.9	25.0%
			February	650	672	96.7%	1643	2.53	50.6%	20.7	27.0%
			March	744	744	100.0%	1875	2.52	50.4%	24.7	25.9%
			April	694	720	96.4%	1776	2.56	51.2%	25.0	24.2%
			May	689	744	92.6%	1773	2.57	51.5%	24.6	24.6%
			June	654	720	90.8%	1869	2.86	57.2%	26.7	23.9%
			July	718	744	96.5%	1823	2.54	50.8%	23.3	26.7%
			August	744	744	100.0%	1880	2.53	50.5%	24.2	26.5%
			September	720	720	100.0%	1822	2.53	50.6%	24.4	25.5%
			October	719	744	96.6%	1825	2.54	50.8%	26.7	23.3%
			November	691	720	96.0%	2025	2.93	58.6%	33.9	20.4%
			December	736	744	99.0%	1855	2.52	50.4%	33.1	19.1%
			January '03	444	504	88.1%	1098	2.47	49.4%	16.8	22.4%
			Program Total	8520	8856	96.2%	21992.45	2.58	51.6%	314.019	23.9%

Monthly Fleet Data – Building 115

System #	Site Name	Commission Date	Month of Operation (2002)	Total Run Time (Hours)	Time Period (Hours)	Availability (%)	Total Energy Produced (kWe-hrs)	Average Output (kW)	Capcity Factor (%)	Total Natural Gas Usage (MMBTU's)	Electrical Efficiency (%)
B100	Bldg. 115	1/17/02	January '02	254	317	80.1%	553	2.18	43.5%	7.6	24.7%
			February	672	672	100.0%	1712	2.55	51.0%	20.6	28.4%
			March	744	744	100.0%	1867	2.51	50.2%	22.6	28.2%
			April	582	720	80.8%	1417	2.43	48.7%	19.8	24.4%
			May	681	744	91.5%	1690	2.48	49.6%	21.7	26.6%
			June	712	720	98.9%	2300	3.23	64.6%	30.5	25.7%
			July	718	744	96.5%	2395	3.34	66.7%	37.2	22.0%
			August	715	744	96.1%	1805	2.52	50.5%	23.1	26.7%
			September	720	720	100.0%	1820	2.53	50.6%	22.7	27.4%
			October	728	744	97.8%	1843	2.53	50.6%	24.2	26.0%
			November	715	720	99.3%	1909	2.67	53.4%	30.0	21.7%
			December	722	744	97.0%	1803	2.50	49.9%	29.4	20.9%
			January '03	504	504	100.0%	1332	2.64	52.8%	20.3	22.4%
			Program Total	8467	8837	95.8%	22445.66	2.65	53.0%	309.713	24.7%
B102	Bldg. 115	1/17/02	January '02	334	336	99.4%	857	2.57	51.3%	11.0	26.5%
			February	662	672	98.5%	1691	2.55	51.1%	21.1	27.4%
			March	744	744	100.0%	1875	2.52	50.4%	24.1	26.5%
			April	656	720	91.1%	1638	2.50	49.9%	21.8	25.6%
			May	655	744	88.0%	1636	2.50	50.0%	23.0	24.3%
			June	695	720	96.5%	2336	3.36	67.2%	31.5	25.3%
			July	740	744	99.5%	2462	3.33	66.5%	36.1	23.3%
			August	726	744	97.6%	1820	2.51	50.1%	22.9	27.1%
			September	655	720	91.0%	1641	2.51	50.1%	21.5	26.0%
			October	740	744	99.5%	1867	2.52	50.5%	24.9	25.6%
			November	671	720	93.2%	1678	2.50	50.0%	23.7	24.2%
			December	720	744	96.8%	1803	2.50	50.1%	29.5	20.8%
			January '03	285	504	56.6%	714	2.50	50.0%	9.8	24.9%
			Program Total	8283	8856	93.5%	22017.49	2.66	53.2%	300.875	25.0%
B103	Bldg. 115	1/17/02	January '02	299	324	92.3%	759	2.54	50.8%	9.6	26.9%
			February	631	672	93.9%	1635	2.59	51.8%	20.4	27.4%
			March	744	744	100.0%	1867	2.51	50.2%	22.4	28.4%
			April	700	720	97.2%	1758	2.51	50.2%	22.5	26.7%
			May	744	744	100.0%	1879	2.53	50.5%	23.0	27.9%
			June	716	720	99.4%	2545	3.55	71.1%	35.2	24.7%
			July	743	744	99.9%	2647	3.56	71.3%	31.7	28.5%
			August	744	744	100.0%	1933	2.60	52.0%	25.0	26.4%
			September	720	720	100.0%	1868	2.59	51.9%	24.4	26.1%
			October	744	744	100.0%	1922	2.58	51.7%	25.4	25.8%
			November	720	720	100.0%	1858	2.58	51.6%	24.9	25.5%
			December	716	744	96.2%	1862	2.60	52.0%	26.1	24.3%
			January '03	446	504	88.5%	1190	2.67	53.3%	15.8	25.7%
			Program Total	8667	8844	98.0%	23722.23	2.74	54.7%	306.345	26.4%

APPENDIX B

Program Economic Analysis

This program consisted of the planning, installation, and operation of ten (10) Plug Power fuel cell systems at various locations supporting operations at the Watervliet Arsenal. The Niagara Mohawk Power Corporation supplies the Watervliet Arsenal's electricity and natural gas. The Watervliet Arsenal Facilities Engineering Department (Vanessa Duenas) supplied the following rates as average cost estimates for the 12 months prior to system commissioning in January 2002:

- Electrical = $0.077/kW-hr
- Natural Gas = $3.50/decatherm

The total system gas consumption for the demonstration was:

- Fleet natural gas usage = 3,029.4 MM BTUs
  = 30,294 Therms

The total program cost of natural gas is calculated by multiplying the number of therms consumed by the cost per therm:

- NG cost = 30,294 therms X $0.35/therm = $10,602.90

The equivalent cost of the fuel cell energy if purchased from Niagara Mohawk is based on the number of kilowatt-hours produced by the systems multiplied by Niagara Mohawk's charge per kW-hr.

- Total energy produced by fleet = 214,555 kW-hrs
- Electrical savings = 214,555 kW-hrs. X $0.077/kW-hr = $16,520.74

The total electrical savings for the program by using system-generated electricity instead of purchasing the power from Niagara Mohawk is:

- Avoided cost = $16,520.74 – 10,602.90 = $5,917.84