The U.S. Department of Energy – Federal Energy Technology Center

Climate Change Fuel Cell Program

The Richard Stockton College of New Jersey Fuel Cell Demonstration Project – One 200 kW Unit

Final Report

Reporting period start date – April 1, 2003

Reporting period end date – March 31, 2004

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ABSTRACT

A 200 kW, natural gas fired fuel cell was installed at the Richard Stockton College of New Jersey. The purpose of this project was to demonstrate the financial and operational suitability of retrofit fuel cell technology at a medium sized college. Target audience was design professionals and the wider community, with emphasis on use in higher education. “Waste” heat from the fuel cell was utilized to supplement boiler operations and provide domestic hot water. Instrumentation was installed in order to measure the effectiveness of heat utilization. It was determined that 26% of the available heat was captured during the first year of operation. The economics of the fuel cell is highly dependent on the prices of electricity and natural gas. Considering only fuel consumed and energy produced (adjusted for boiler efficiency), the fuel cell saved $54,000 in its first year of operation. However, taking into account the price of maintenance and the cost of financing over the short five-year life span, the fuel cell operated at a loss, despite generous subsidies. As an educational tool and market stimulus, the fuel cell attracted considerable attention, both from design professionals and the general public.

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EXECUTIVE SUMMARY

The Richard Stockton College of New Jersey is a medium sized, public liberal arts college located in the New Jersey Pinelands, a unique federally protected and state managed ecological reserve. The College has emphasized innovative energy technologies in its infrastructure decisions and also in its curriculum.

The objective of the Stockton College Fuel Cell Demonstration Project has been to stimulate commercialization of stationary fuel cell power plants and to reduce greenhouse gas emissions through the efficient use of natural gas.

The Project consisted of two phases. First was the installation of a fuel cell on the Stockton College campus in order to demonstrate its capabilities to a wide range of audiences. The fuel cell was installed as a retrofit to existing infrastructure, allowing a realistic evaluation of the circumstances many future users will face. The second phase of the Project was research on the economics and energy output of the fuel cell. This was done by enhancing the instrumentation of the fuel cell in order to determine effectiveness of heat recovery.

Construction began in September of 2002 and the 24-hour acceptance test was conducted March 26-27, 2003. This report covers the period from April 1, 2003 through March 31, 2004.

A public inauguration (ribbon cutting plus technical session) of the fuel cell was held on May 22, 2003, and attracted more than 100 participants: engineers, architects, scientists, Stockton faculty and students, and members of the public and press. Outreach and education activities continued through the reporting period. The demonstration activities associated with this project were served by the decision to locate the fuel cell, not with other utility equipment in an obscure location, but beside a walkway between the main parking lot and the student center. Graphics on the fuel cell outline the process by which it generates electricity.

The fuel cell selected was a PC25 ™ purchased from International Fuel Cells, a unit of United Technologies, and was installed by the South Jersey Energy Company in collaboration with Concord Atlantic Engineering and Broadley Mechanical. The PC25 ™ generates 200 kW of electricity and releases $9.49X\ 10^8$ joules (900,000 btu) per hour of usable heat. The PC25™ is fueled by natural gas.

The PC25 ™ has a predicted useful life span of approximately five years, after which the catalyst must be replaced, at a cost of about $350,000. See Reference 1. The fuel cell was operated at full power during the time of this Project.

In addition to the federal Department of Defense/Department of Energy Climate Change Fuel Cell Grant, financial support from outside the College was provided by the New Jersey Board of Public Utilities (though its Clean Energy Incentives Program) and the non-profit New Jersey Higher Education Partnership for Sustainability (through a group purchase arrangement).

The economic viability of a fuel cell depends on the recovery of “waste” heat and on the prices of natural gas and electricity at the time of study.

The major research goal of this project was to determine the operational heat recovery rate of the Stockton fuel cell. The fuel cell was placed close to significant building heat loads, namely two

gas fired boilers and a large cafeteria. The plumbing associated with heat recovery contributed substantially to the cost of the project.

Heat was recovered from the fuel cell at two temperatures. The high temperature loop experienced a temperature drop of about 5 degrees C and the low temperature loop less than 1 degree C. Heat recovery could be far more effective if the fuel cell and buildings were designed at the same time and with heat recovery as an engineering goal.

Temperatures were recorded at the locations where water left and returned to the fuel cell. The data collection interval was half an hour. Temperature differences were automatically converted to heat release expressed as BTU per hour. This was averaged for each month and compared to the design value listed above. Operational data on availability, average electrical efficiency and output, and natural gas consumption were provided quarterly by UTC. Equipment failures were reported on an annual basis.

Availability was high, above 98%. Average electrical efficiency showed the slight drop expected as the catalyst aged (41.98% efficiency initially, 40.74% at the end of the year). The heat recovery averaged 26% for the first year of operation, saving the College about $22,000 in gas costs.

Adding the value of the electricity generated, the cost benefit analysis indicates that the fuel cell saved the College about $54,000 in its first year of operation. This figure does not take into account maintenance cost and financing cost, the combination of which would eliminate the savings and render the project financially unfeasible.

EXPERIMENTAL

Materials and Equipment

The PC25 ™ generates 200 kW of electricity and releases 9.49×10^8 joules (900,000 btu) per hour of recoverable heat. It is fueled by natural gas (supplied by South Jersey Gas) that is catalytically "cracked" to provide hydrogen for the electrochemical reaction that generates electricity. Heat is a useful byproduct of this reaction.

To facilitate heat recovery, the fuel cell was placed close to significant building heat loads, namely two gas fired boilers utilizing heat delivered at about 71-82 degrees C (160-180 degrees F) to 82 degrees C and a large cafeteria utilizing heat delivered at 57 to 63 degrees C (135 to 155 degrees F) for domestic hot water.

Instrumentation

The utility-provided gas meter is a 16M-175 Rotary 500 Series type meter. The heat sensors are immersion type, 0-10 vdc, Trane part number 4190-1103 and 4190-1105.

Software

Customized software from Tracer-Trane was used to convert recorded temperature changes into heat recovery data.

Data collection

UTC recorded gas usage, hours of operation, electrical output, failures and causes (Reference 1).

RSC recorded temperatures at five (later four) locations in the low and high temperature heat recovery loops. Instantaneous temperature measurements were made at the described locations on a half hour interval.

RESULTS AND DISCUSSION

RESULTS

UTC Data - Data supplied by UTC (in its annual and quarterly reports) is included in Figures 1 - 4 and Tables 1-5 of the Appendix.

The UTC **annual report** consisted of four (4) Excel worksheets, entitled "charts", "shutdown data", "backup data" and "KWACNET".

The first excel worksheet included three (3) CHARTS of monthly and cumulative-to-date data, for (1) percentage availability, (2) output in kw-hrs, and (3) average electrical efficiency. These are shown in Figures 1-3.

The shutdown data (Table 1) listed date, time, shutdown type and cause for four (4) loss-of-power incidents, along with classification as to type of shutdown. Table 2 shows the associated mean time between failures calculation.

The backup data spread sheet included all the data from which the above information was derived (Table 3).

KWACNET is a remote monitoring system supplied by the manufacturer that records changes in fuel cell function, reporting electrical output as a function of clock time and operating (load) time. A reading is reported whenever the sensors identify a change in output, so the number of data points per day varies. The KWACNET report included 2327 instantaneous kW-hr output readings for the year of operation. Figure 4 is a graphical representation of the year's data. See Table 4 for a three-day sample.

Data provided by UTC in its **quarterly reports** included operating hours, availability and electrical output (all summarized in the annual report as indicated above) and, additionally, natural gas consumption. See Table 5 for complete quarterly report.

RSC Data - Data collected by **RSC** is illustrated in Tables 6 and 7.

Table 6 shows the site utility parameters for the year prior to the fuel cell installation and the first year of operation.

To determine efficiency of heat recovery, water temperatures were initially measured at five locations, one each at the beginning of the two heat recovery loops, at the return from the low temperature heat recovery loop and at the return from each of the two boilers served by the high temperature loop. Later it was determined that one temperature measurement was sufficient to determine heat recovery from the high temperature loop, as the two values did not vary significantly. See Table 7.

DISCUSSION

When possible, results will be compared with expectations based on two sources, information supplied by UTC during the planning stages of the project and the proposal provided by RSC's consultant, South Jersey Energy Company (Reference 2).

Discussion of data

Figures 1-3 indicate that the fuel cell operated efficiently and consistently in accordance with manufacturer's projections. The monthly availabilities of less than 95% for June '03 and March '04 (94.40% and 93.98% respectively – Figure 1) are cause for concern, though the yearly average availability of 98.87% of nameplate rated capacity (200 kW) is clearly acceptable.

Figure 2 shows the monthly and cumulative output of electricity. A total of 1.684×10^6 kW-hr of electricity was generated during the year under study. The slow drop of electrical efficiency from 41.98% to 40.74% over 12 months (Figure 3) is in line with the expectation of slow aging of the fuel cell.

Comparing measured to expected electrical output, the capacity factor of the fuel cell (versus nameplate rated capacity of 200 kW) for its first year of operation was 96.1%.

The shut down data (Table 1) indicated four (4) loss-of-power incidents. One was attributed to operator error. The other three were caused by an overheated inverter, a water leak and a stuck valve.

The mean time between failures (forced outages) was 2167 hours (Table 2), or about 90 days.

Table 3 includes supporting data for the UTC information cited above.

The KWACNET data was reported in two (2) formats, a graphical summary (Figure 4) and a chart (Table 4). These indicate that the fuel cell operated close to its rated value of 200 kW most of the time, going to zero in failure. The KWACNET data in Figure 4 reflects the four (4) reported shutdowns and additionally times when the operator intentionally lowered the fuel cell output.

The peak output of the fuel cell was 200.3 kW. Output showed little variation from the rated capacity of 200 kW.

As shown in Table 6 (Site Parameters), the fuel cell provides a small portion of the electricity used on the main meter which serves the campus academic complex, so the impact of the fuel cell appears to be minor. However, energy use on campus has been increasing yearly, due to increased year round building use, additionally scheduled classes and increasing enrollment. Therefore, the decline in demand (from 3796kW to3622kW) is noteworthy. Electrical use declined and gas consumption increased, as expected.

Temperature data from Table 7 was converted to BTU data using a program supplied by Trane. See Table 8. Tables 7 and 8 illustrate this data collection and conversion using a twelve (12) hour sample. Table 9 summarizes the thermal output recovered by month.

Results of monitoring the low temperature loop suggest that very little heat was exchanged to the target domestic hot water system. In some cases, water came back warmer than when it left the fuel cell, resulting in reports of negative heat recovery. The low temperature loop contributed less than 10% of the total heat recovered. The demand for hot water was irregular and heat was lost while water stood in the piping. Installation of a circulating pump to remedy this was considered, but not implemented.

Discussion of cost and benefits for first year of operation – Table 10

The price of gas at the time of this study was $8.6 per Mbtu ($0.86 per therm). The price of electricity was $0.096 per kWatt-hr.

The thermal output (recovered heat) totaled $2.0559x10^4$ btu/year. A multiplier of 1.3 was used to adjust for the 75% efficiency of the boilers supplemented by the recovered heat, yielding the equivalent of $2.6726x10^4$ btu/year.

The heat rate was calculated to be 1221 btu/kW-hr, or 1587 btu/kW-hr (adjusted).

Heat recovery efficiency was determined to be 26.4% of that potentially available.

Allocation of operating cost into fixed and variable costs is problematic. Financing would constitute a fixed cost. The manufacturer charged no maintenance cost in the first year of operation, but the maintenance contract cost has increased each year thereafter. The gas cost and electrical cost during the first year of operation were fixed by contract (in the case of gas) and NJ BPU regulation (in the case of electricity). Cost of staff time has not been estimated.

The savings for the first year of operation was $54,375 ($39,375 if maintenance had been charged) and not taking finance charges into account.

In Table 10, results are shown by month, averaged and summed for the year. The electricity price used is as actually experienced during the time period in question (9.6 cents per kW-hr), rather than the design value of 11 cents.

The fuel cell cost benefit analysis generated during the pre-installation planning projected 100% heat recovery and a total annual savings of $96,383 (Reference 2.) While this was unrealistic, the measured heat recovery value of 26% was disappointing.

Several contributory factors can be identified: (1) A retrofit project poses inherent difficulties because the fuel cell should be located as close as possible to existing, major, consistent heat loads, (2) The College's decision to use a highly visible location (between parking lots and the main academic complex) limited the locations considered, (3) The low temperature loop was not designed to keep the water in motion, (see "discussion of data" above), and (4) steam was not being utilized so the temperatures of heat transfer were lower than the system can potentially produce, 121 degrees C (250 degrees F) according to manufacturer.

Careful engineering design to optimize heat recovery is essential to the economics of fuel cell use. If the heat recovery had been doubled to 52%, the first year savings would have been $77,358 (not including maintenance or financing).

The cost benefit analysis reported here did not include two major costs, maintenance and financing. Maintenance charges were waived by the manufacturer for the first year of operation. Thereafter, maintenance has cost from $15,000 to $35,000 annually. As of 2006, the maintenance contract does not include supplies (compressed gases and chemicals), and penalties are levied for activities outside of normal working hours.

One benefit not explicitly included here was reduced maintenance cost on the boiler being supplemented by the high temperature heat loop. A rough value of $1000 per year was suggested in the original Proposal (Reference 2).

Additionally, the fuel cell's 200 kW of power reduced the summer peak for 2003 from 3600 kW to 3400 kW, slightly dropping the demand portion of some of the subsequent bills. (In the PJM-AE supply district, demand penalties eventuate only when demand drops below 80% of annual peak.) The fuel cell contributed 5.5% of the College's demand. Because of its steady operation, it contributed roughly 10% of total electricity use in kW-hrs.

The installed cost of this 200 kiloWatt fuel cell was $1,300,000, including design, purchase, installation, commissioning and training of operator. Three agencies provided subsidies totaling $995,000, leaving Richard Stockton College to pay $305,000. If $305,000 were borrowed at 5% for 5 years (estimated fuel cell life) the annual payment would total $69,000. Viewed from this perspective, the project lost money from its inception, despite the generous subsidies.

Discussion of environmental impact

Environmental impact is best evaluated by estimating carbon dioxide reduction. The manufacturer states that the fuel cell releases 46% of the carbon dioxide per kw-hr from the average US fossil fueled generating plant. New Jersey, however, generates only 60% of consumed energy from coal (Reference 3), so the fuel cell reduces carbon dioxide output by 28% relative to the average electricity generated within New Jersey.

The fuel cell emits negligible quantities of the oxides of nitrogen and sulfur and almost no particulate material.

The noise rating of the fuel cell is 60dBa (decibels adjusted) at 30 feet. This is negligible in an outdoor setting and there have been no complaints.

Discussion of market stimulation

The fuel cell at Stockton has attracted considerable attention from the time of its installation. The inaugural event was one of the largest technical sessions (100+ participants) ever held on the campus, and included participants from out of state. Richard Stockton College classes in a variety of subject areas have "toured" the fuel cell. Additionally, Stockton representatives have discussed it at meetings of the statewide organization NJ HEPS (Higher Education Partnership for Sustainability). Fuel cell technology is now very expensive, but many potential users are watching for the time when it will be within reach.

CERTIFICATION

The Richard Stockton College of New Jersey certifies that the FUEL CELL has been in operation for more than one year and that the activity required under the agreement with DOE is complete.

CONCLUSIONS

Stockton's experience with the fuel cell has been mixed. It produces electricity reliably both in terms of availability (98.9 %) and mean time between forced outages (90 days). It saved about $54,000 in its first year of operation, but maintenance and financing costs were not included in that calculation. Deducting maintenance cost, the first year savings would have been $39,000. Heat recovery averaged 26%. Iff heat recovery had been double that achieved, savings would rise by $23,000. If the project were financed over the short five-year life of the fuel cell, it would operate at a loss.

It can be seen in the cost benefit analysis that, in addition to depending on heat recovery, the economics of a fuel cell project depends heavily on the costs of natural gas and electricity. These are difficult to predict. The future rebuild of the fuel cell catalyst stack at the five to six year point is prohibitively expensive. Based on Stockton's experience, a retrofit stationary fuel cell is not presently an economically viable option for a medium sized college campus.

REFERENCES

1. All descriptions of the fuel cell and its technical specifications provided by United Technologies Corporation, (South Windsor, Connecticut) a subsidiary of International Fuels Cells
2. "Proposal for Fuel Cell System" May 30, 2002 by South Jersey Energy Company, Folsom, New Jersey.
3. NJ BPU 2004, electric supplier environmental disclosure website http://www.bpu.state.nj.us/home/supplierpage

LIST OF ACRONYMS AND ABBREVIATIONS

BEG	beginning
DHW	domestic hot water
CTD	cumulative to date
KWACNET	kiloWatts alternating current, remotely monitored
MTBF	mean time between failures
NJ BPU	New Jersey Board of Public Utilities
PJM/AE	Penn-Jersey-Maryland Regional Transmission Organization/Atlantic Electric district (southern New Jersey)
RSC	The Richard Stockton College, aka “the College”, aka “Stockton”
SJE	South Jersey Energy (engineering services)
UTC	United Technologies Corporation (fuel cell manufacturer), a subsidiary of International Fuel Cells, aka “manufacturer”

APPENDIX

FIGURES

Figure 1. Availability Data

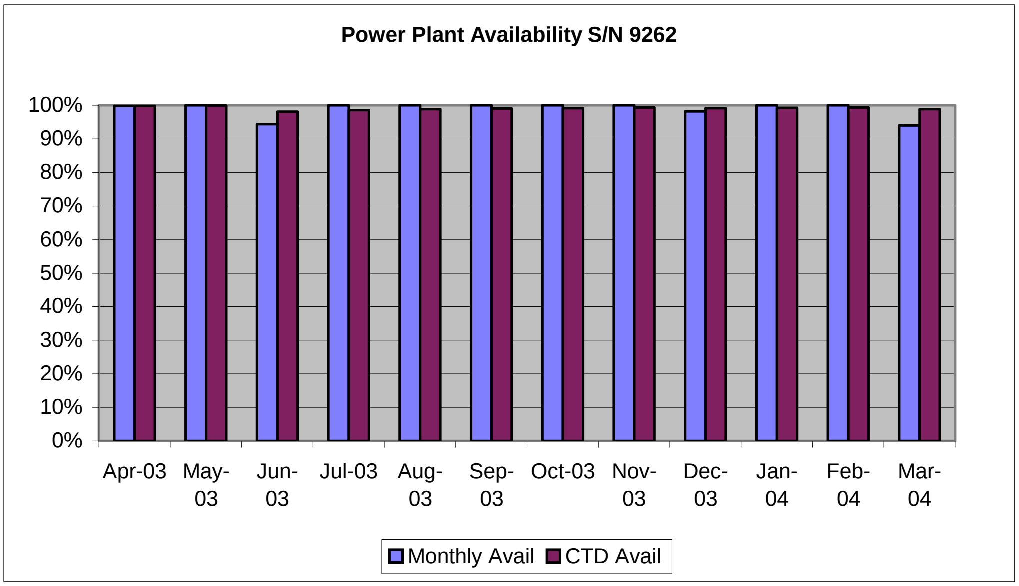


Figure 2. Output of Electricity

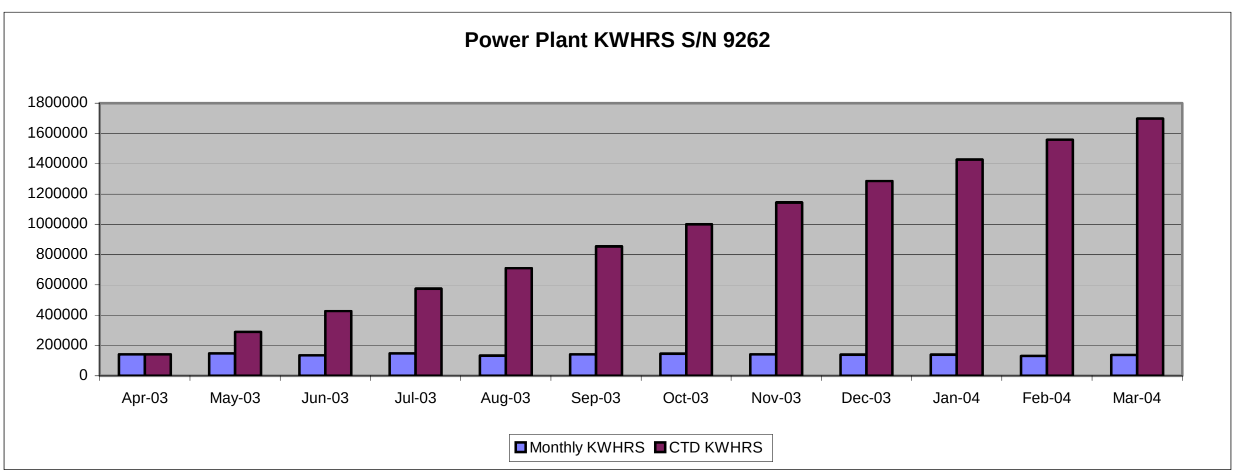


Figure 3. Average Electrical Efficiency

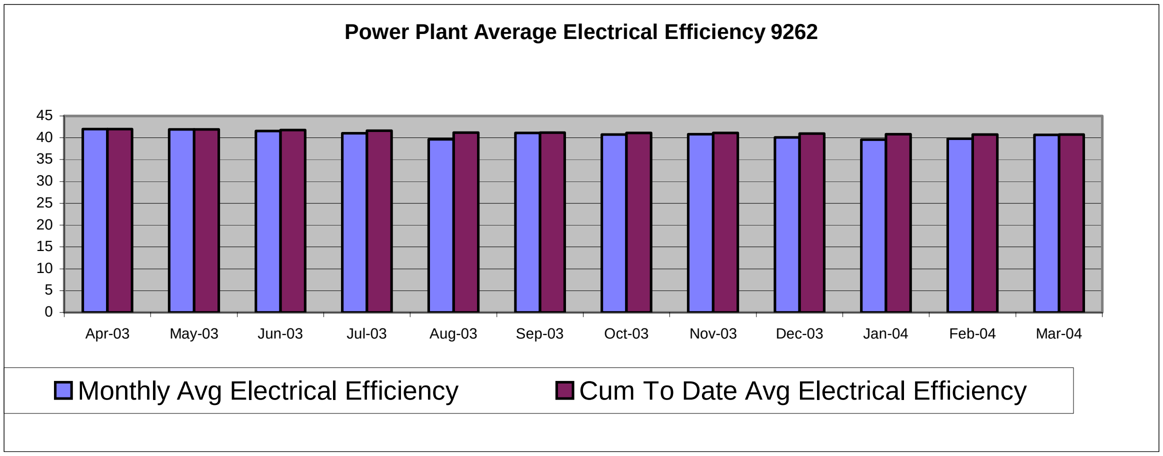
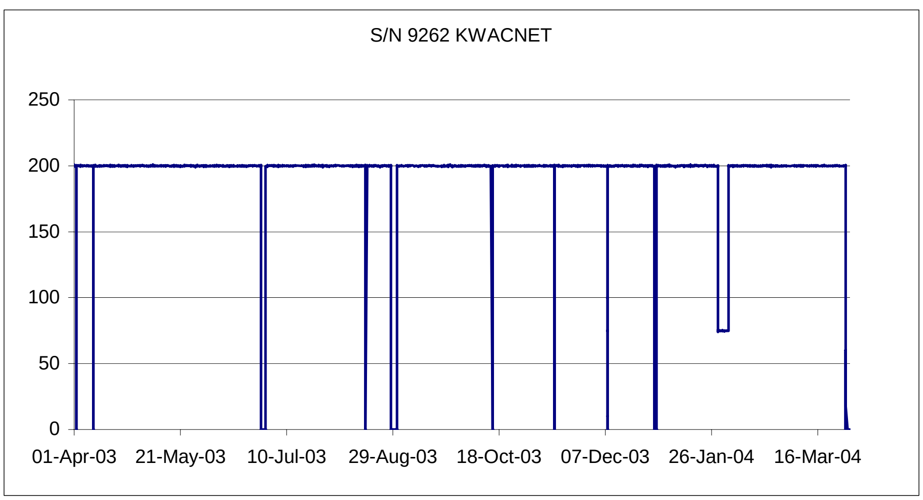


Figure 4. KWACNET Summary



TABLES

Table 1. Shutdown Data

Date & Time	Run hours	Cum hours	Restart	Shutdown type		Diagnosis	
4/10/03 12:28	359	386	10-Apr-03	386S IP200 Inverter Shutdown		Operator Error	Shutdown while adjusting inverter gains. Operator error
6/28/03 21:04	1904	2290	30-Jun-03	2290S IP200 Inverter Shutdown		VSD800	inverter overtemp
12/8/03 6:25	3857	6147	08-Dec-03	6147S LT400 low (SSD)		TMS/WTS Leakage	FIL451 housing cracked causing water leak
3/29/04 15:30	2684	8831		8831S TE012FT high for 10s (RSD)		FCV012	Stuck FCV012. Will also do annual maintenance

Table 2. Mean Time Between Failures

PP_ID	Load Time	#F	MTBFO	Cal T ime	Avail
9262	8669.897	4	2167.474	8769.267	98.87%

Table 3: Backup Data

MONTH	BEGINING TIME	BEG LOAD TIME	BEG MWHRS NET TIME	END TIME	END LOAD TIME	END MWHRS NET TIME	TOTAL LOAD	CAL TIME	% AVAIL 9261	KW-HRS	FUEL TOT	AVE ELEC EFF
Apr-03	01-Apr-03	160.78	30.63	30-Apr-03	873.32	172.70	712.53	714.20	99.77%	142,078.3	1,240,431.7	41.98
CTD	01-Apr-03	160.78	30.63	30-Apr-03	873.32	172.70	712.53	714.20	99.77%	142,078.3	1,240,431.7	41.98
May-03	01-May-03	879.32	173.90	31-May-03	1,616.13	321.24	736.82	736.83	100.00%	147,337.9	1,289,235.0	41.89
CTD	01-Apr-03	160.78	30.63	31-May-03	1,616.13	321.24	1,455.35	1,457.03	99.88%	290,616.1	2,540,129.7	41.93
Jun-03	01-Jun-03	1,623.07	322.61	30-Jun-03	2,296.43	457.22	673.36	713.32	94.40%	134,614.6	1,188,034.0	41.53
CTD	01-Apr-03	160.78	30.63	30-Jun-03	2,296.43	457.22	2,135.65	2,177.27	98.09%	426,597.1	3,740,491.7	41.80
Jul-03	01-Jul-03	2,303.03	458.56	31-Jul-03	3,040.25	605.95	737.22	737.21	100.00%	147,390.1	1,316,654.0	41.03
CTD	01-Apr-03	160.78	30.63	31-Jul-03	3,040.25	605.95	2,879.47	2,921.09	98.58%	575,320.2	5,068,681.7	41.60
Aug-03	01-Aug-03	3,046.51	607.21	31-Aug-03	3,784.07	740.93	737.55	737.54	100.00%	133,718.1	1,235,703.0	39.66
CTD	01-Apr-03	160.78	30.63	31-Aug-03	3,784.07	740.93	3,623.28	3,664.90	98.86%	710,304.6	6,315,388.7	41.22
Sep-03	01-Sep-03	3,790.48	742.20	30-Sep-03	4,503.88	884.81	713.40	713.40	100.00%	142,610.2	1,271,554.0	41.11
CTD	01-Apr-03	160.78	30.63	30-Sep-03	4,503.88	884.81	4,343.10	4,384.73	99.05%	854,181.2	7,598,499.7	41.20
Oct-03	01-Oct-03	4,510.56	886.14	31-Oct-03	5,249.71	1,031.62	739.15	739.15	100.00%	145,482.4	1,309,416.0	40.72
CTD	01-Apr-03	160.78	30.63	31-Oct-03	5,249.71	1,031.62	5,088.93	5,130.55	99.19%	1,000,996.6	8,919,764.7	41.13
Nov-03	01-Nov-03	5,255.70	1,032.82	30-Nov-03	5,968.53	1,175.08	712.83	712.83	100.00%	142,261.0	1,276,790.0	40.84
CTD	01-Apr-03	160.78	30.63	30-Nov-03	5,968.53	1,175.08	5,807.75	5,849.38	99.29%	1,144,457.6	10,207,237.7	41.09
Dec-03	01-Dec-03	5,975.46	1,176.45	31-Dec-03	6,698.66	1,317.06	723.20	736.89	98.14%	140,606.0	1,285,950.0	40.07
CTD	01-Apr-03	160.78	30.63	31-Dec-03	6,698.66	1,317.06	6,537.88	6,593.20	99.16%	1,286,429.6	11,505,727.7	40.98
Jan-04	01-Jan-04	6,705.58	1,318.42	31-Jan-04	7,443.48	1,458.70	737.90	737.90	100.00%	140,282.0	1,299,470.0	39.57
CTD	01-Apr-03	160.78	30.63	31-Jan-04	7,443.48	1,458.70	7,282.70	7,338.03	99.25%	1,428,077.6	12,817,347.7	40.84
Feb-04	01-Feb-04	7,449.53	1,459.15	29-Feb-04	8,137.33	1,589.95	687.80	687.79	100.00%	130,796.0	1,204,290.0	39.81
CTD	01-Apr-03	160.78	30.63	29-Feb-04	8,137.33	1,589.95	7,976.55	8,031.87	99.31%	1,559,321.6	14,027,227.7	40.74
Mar-04	01-Mar-04	8,143.33	1,591.15	31-Mar-04	8,830.68	1,728.56	687.35	731.40	93.98%	137,409.0	1,237,780.0	40.69
CTD	01-Apr-03	160.78	30.63	31-Mar-04	8,830.68	1,728.56	8,669.90	8,769.26	98.87%	1,697,930.6	15,275,757.7	40.74

Table 4. KWACNET Data Sample

Date	Time	Load Time	Output in KW
03-Apr-03	0217:48	208.800	200.3174
03-Apr-03	0314:39	209.750	200.0244
03-Apr-03	0814:35	214.750	200.2441
03-Apr-03	1414:29	220.750	199.9512
03-Apr-03	2014:24	226.750	200.0488
04-Apr-03	0214:18	232.750	199.5117
04-Apr-03	0217:56	232.800	200.1465
04-Apr-03	0714:15	237.750	200.5615
04-Apr-03	1314:11	243.750	199.5361
04-Apr-03	1914:05	249.750	199.8291
05-Apr-03	0213:03	256.733	200.1953
05-Apr-03	0214:00	256.750	199.6582
05-Apr-03	0713:56	261.733	200.1709
05-Apr-03	1313:50	267.733	200.0244
05-Apr-03	1913:45	273.733	200.2197

Note: This is a sample reflecting three days of operation.

Table 5: Quarterly Report

2003

1st Quarter 1/1/03 - 3/31/03		*2nd Quarter 4/1/03 - 6/30/03*	
Operating Hours	127.77	Operating Hours	2,135.65
Available Hours	277.60	Available Hours	2,177.27
Availability	46.03%	Availability	98.09%
Electrical Output	24,906.40	Electrical Output	426,597.10
Natural Gas Consumption	219,966.22	Natural Gas Consumption	3,740,491.70

3rd Quarter 7/1/03 - 9/30/03		*4th Quarter 10/1/03 - 12/31/03*	
Operating Hours	2,200.85	Operating Hours	2,188.10
Available Hours	2,200.85	Available Hours	2,201.80
Availability	100.00%	Availability	99.38%
Electrical Output	426,251.10	Electrical Output	430,915.40
Natural Gas Consumption	3,846,472.00	Natural Gas Consumption	3,895,379.00

2004

1st Quarter 1/1/04 - 3/31/04	
Operating Hours	2,125.10
Available Hours	2,169.13
Availability	97.97%
Electrical Output	410,135.0
Natural Gas Consumption	3,757,880.0

Notes: This data is as provided by manufacturer. Electrical output is expressed in kilowatt hours. Natural gas consumption is expressed in ccf (hundred cubic feet).

Table 6: Site Parameters (RSC)

Before fuel cell installation

Month	Demand peak (kW)	**mW-hours**	gas in Mmbtu
Jan 02	2626	1,192	5,192.5
Feb	3052	1,447	4,964.0
Mar	2857	1,420	3,292.1
Apr	3777	1,584	4,874.6
May	2920	1,112	4,874.6
Jun	3596	1,235	4,874.6
Jul	3486	1,893	642.9
Aug	3579	1,390	2,711.3
Sep	**3796**	1,552	1,934.6
Oct	3789	1,550	3,770.8
Nov	2939	1,265	8,535.1
Dec	2728	1,313	0.0
		16,953	45,667.1

After fuel cell installation

	Demand peak (kW)	**mW-hours**	gas in Mmbtu
Jan 04	2460	1,151	9,372.6
Feb	2676	1,437	11,098.7
Mar	2619	1,231	6,776.9
Apr 03	3202	1,239	4,353.8
May	3102	990	2,884.1
Jun	3459	1,150	2,083.8
Jul	**3622**	1,411	2,211.6
Aug	3344	1,551	2,581.7
Sep	3597	1,700	10,214.7
Oct	3369	1,326	5,078.2
Nov	3371	1,265	7,668.9
Dec	2805	1,271	10,169.9
		15,722	74,494.9

Notes: Electrical demand peaks are in bold type. Due to billing complications, only 12 month total for gas usage can be considered accurate.

Table 7: Temperature Data

	high temp loop			low temp loop	
Time	Boiler **supply** water	Boiler **return** water	Boiler **return** water	DHW **supply** water	DHW **return** water
1/8/04 23:30	82.94	68.67	69.11	67.06	66.11
1/8/04 23:00	80.61	66.89	67.44	63.89	64.22
1/8/04 22:30	80.83	66.11	66.67	66.28	65.72
1/8/04 22:00	75.50	65.39	65.50	67.44	67.28
1/8/04 21:30	79.67	68.06	68.89	64.61	63.89
1/8/04 21:00	75.50	67.11	67.67	67.28	66.11
1/8/04 20:30	81.22	67.28	67.89	63.17	63.17
1/8/04 20:00	81.00	65.22	65.89	65.72	65.33
1/8/04 19:30	74.56	65.56	65.89	66.28	66.50
1/8/04 19:00	81.00	65.72	66.50	64.22	63.17
1/8/04 18:30	75.72	67.89	68.89	66.28	65.11
1/8/04 18:00	77.28	67.50	68.50	62.11	62.11
1/8/04 17:30	78.44	66.72	67.44	64.94	64.22
1/8/04 17:00	75.72	65.22	65.50	67.44	66.50
1/8/04 16:30	81.22	65.72	66.28	62.94	63.17
1/8/04 16:00	82.17	66.72	67.28	66.11	65.72
1/8/04 15:30	72.78	64.44	64.94	67.89	65.33
1/8/04 15:00	78.22	65.56	66.50	57.39	55.72
1/8/04 14:30	81.39	67.28	67.67	63.17	61.89
1/8/04 14:00	81.22	67.50	68.11	63.89	48.83
1/8/04 13:30	80.06	66.11	67.06	62.11	60.22
1/8/04 13:00	79.67	67.28	68.28	66.50	63.17
1/8/04 12:30	77.28	68.06	68.67	66.11	65.11
1/8/04 12:00	82.39	69.83	70.39	65.50	56.00

Notes: Table 7 reflects a 12-hour sample. Temperatures are recorded in degrees Celsius.

Table 8: Calculated Heat Recovery

Time	BTU from low temp loop	BTU from high temp loop	Total BTU
1/8/04 23:30	12,600	327,670	340,270
1/8/04 23:00	-12,600	327,670	315,070
1/8/04 22:30	12,600	327,670	340,270
1/8/04 22:00	19,800	285,000	304,800
1/8/04 21:30	14,400	327,670	342,070
1/8/04 21:00	12,600	327,670	340,270
1/8/04 20:30	-14,400	291,000	276,600
1/8/04 20:00	12,600	327,670	340,270
1/8/04 19:30	9,900	259,500	269,400
1/8/04 19:00	9,000	327,670	336,670
1/8/04 18:30	15,300	327,670	342,970
1/8/04 18:00	-18,000	268,500	250,500
1/8/04 17:30	11,700	312,000	323,700
1/8/04 17:00	18,900	327,670	346,570
1/8/04 16:30	-14,400	327,670	313,270
1/8/04 16:00	6,300	327,670	333,970
1/8/04 15:30	25,200	279,000	304,200
1/8/04 15:00	23,400	327,670	351,070
1/8/04 14:30	23,400	327,670	351,070
1/8/04 14:00	327,670	195,000	522,670
1/8/04 13:30	30,600	327,670	358,270
1/8/04 13:00	27,000	327,670	354,670
1/8/04 12:30	49,500	117,000	166,500
1/8/04 12:00	115,200	261,000	376,200

Note: Table 8 reflects a 12-hour sample

Table 9: Thermal Output

	Monthly averages	BTU per HOUR
Year 2003	April	121,406.2
	May	254,659.8
	June	181,818.1
	July	202,704.9
	August	231,359.7
	September	231,539.6
	October	202,249.2
	November	284,322.0
	December	287,732.4
Year 2004	January	327,670.0
	February	290,004.0
	March	237,773.0

Table 10: Cost Benefit Analysis

Month	average btu/hr	load hours	therms saved	adjusted therms saved	potential therms saved	recovery percent	heat savings (dollars)
Apr-03	121,406.15	704	854.9	1,111.4	6,337.5	13.49	$955.78
May	254,659.77	728	1,854.4	2,410.7	6,553.6	28.30	$2,073.18
June	181,818.06	704	1,280.3	1,664.4	6,337.5	20.20	$1,431.38
July	202,704.94	741	1,502.4	1,953.1	6,670.6	22.52	$1,679.68
Aug	231,359.74	741	1,714.8	2,229.2	6,670.6	25.71	$1,917.13
Sept	231,539.58	717	1,660.5	2,158.7	6,454.5	25.73	$1,856.48
Oct	202,249.20	737	1,490.9	1,938.2	6,634.6	22.47	$1,666.86
Nov	284,322.01	714	2,030.5	2,639.7	6,427.5	31.59	$2,270.15
Dec	287,732.39	737	2,121.1	2,757.4	6,634.6	31.97	$2,371.38
Jan-04	327,670.00	731	2,395.8	3,114.6	6,580.6	36.41	$2,678.55
Feb	290,044.00	660	1,914.7	2,489.2	5,941.4	32.23	$2,140.69
March	237,773.26	731	1,738.5	2,260.1	6,580.6	26.42	$1,943.68
Average	237,773.26	720.42	1,713.2	2,227.2	6,459.0	26.42	$1,915.41
Total	2,853,279.10	8645	20,559.0	26,726.7	77,823.5		$22,984.94

(continued…)

Month	electricity KW-hr/month	electric savings	total savings	natural gas therms/month	fuel monthly cost	**SAVINGS**
Apr-03	142,078.3	$13,639.52	$14,595.30	12,404	$10,667.44	**$3,927.86**
May	147,337.9	$14,144.44	$16,217.62	12,892	$11,087.12	**$5,130.50**
June	134,614.6	$12,923.00	$14,354.38	11,880	$10,216.80	**$4,137.58**
July	147,390.1	$14,149.45	$15,829.13	13,166	$11,322.76	**$4,506.37**
Aug	133,718.1	$12,836.94	$14,754.07	12,357	$10,627.02	**$4,127.05**
Sept	142,610.2	$13,690.58	$15,547.06	12,715	$10,934.90	**$4,612.16**
Oct	145,482.4	$13,966.31	$15,633.17	13,094	$11,260.84	**$4,372.33**
Nov	142,261.0	$13,657.06	$15,927.20	12,767	$10,979.62	**$4,947.58**
Dec	140,606.0	$13,498.18	$15,869.56	12,859	$11,058.74	**$4,810.82**
Jan-04	140,282.0	$13,467.07	$16,145.62	12,994	$11,174.84	**$4,970.78**
Feb	130,796.0	$12,556.42	$14,697.10	12,042	$10,356.12	**$4,340.98**
March	137,409.0	$13,191.26	$15,134.95	12,377	$10,644.22	**$4,490.73**
Average	140,382.1	$13,476.68	$15,392.10	12,629	$10,860.87	**$4,531.23**
Total	1,684,585.6	$161,720.22	$184,705.15	151,547	$130,330.42	**$54,374.73**

Photograph: Fuel Cell, The Richard Stockton College of New Jersey, April 2003.