Los Angeles Department of Water and Power
Fuel Cell Demonstration Project

200 kW – Phosphoric Acid Fuel Cell Power Plant
Located at
1630 N. Main Street
Los Angeles, California

FINAL REPORT

DOE Award Number: DE-PS26-01NT41238

Reporting period: February 2002 – September 2004

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Los Angeles Department of Water and Power
111 North Hope Street
Los Angeles, CA 90012

Disclaimer

Abstract:

The Los Angeles Department of Water and Power (LADWP) is currently one of the most active electric utility companies in deploying fuel cell technology. Fuel cells offer many benefits and are now used as an alternative to traditional internal combustion engines in power generation. In continuing it's role as the leader in fuel cell deploying, LADWP installed a Phosphoric Acid Fuel Cell (PAFC) in February 2002 at its Main Street service center. The goal of this project is to evaluate the PAFC's performance and cost benefits. This will provide LADWP an insight for future deployment of fuel cell technology. The fuel cell ran smoothly through the first year of operation with very high efficiency and availability, and only with some minor setbacks. The Main street fuel cell project is funded by LADWP with partial grant funding from the Department of Defense's Climate Change Fuel Cell Buydown Program. The technical evaluation and the benefit-cost evaluation of the Main Street fuel cell are both examined in this report.

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Executive Summary:

The Los Angeles Department of Water and Power (LADWP) is a municipal electrical power company that has been delivering quality power to the greater Los Angeles city area for more than 100 years. Today LADWP provides electricity and water to more than 1.5 million of its' commercial and residential customers. LADWP utilizes many facilities strategically located throughout Los Angeles County to operate efficiently to cater to the needs of its customers. The Main Street service center, located on the outskirts of downtown Los Angeles, includes facilities that are used as testing laboratories, mechanical shops, transformer test and repair center, and an automotive shop.

A 200 kW Phosphoric Acid Fuel Cell Power Plant model PC25C was, originally made by ONSI Corporation, was installed in the Main Street facility in February 2002. ONSI Corporation is a sister organization of International Fuel Cells (IFC), IFC is a subsidiary of United Technologies Corporations (UTC). In 2001, UTC bought out ONSI and International Fuel Cells and changed its name to UTC. Although the company changed, the fuel cell remained the same.

The fuel cell helps supply an additional 200 kW of power into LADWP's power grid system. A more significant reason for the installation of this fuel cell is to continue the demonstration of fuel cell applications and to verify reliability under real world operating conditions. The fuel cell demonstration project would further advance FC technology by using independent performance test data over an extended period.

The total capital allocated for this project is approximately $1.1 million. The funding is made possible by LADWP's own budget and federal funding program from U.S Department of Defense Climate Change Buydown Program, administered by DOE. The PC25C fuel cell accumulated 6726 hours of operation during its one year of service, reaching an availability of more than 75%. The total energy output for the first year was 1,354MWhrs. The Main Street fuel cell plant only had four major forced shutdowns during the one-year operation. These shutdowns were due to faulty control system sensors.

The benefit to cost analysis shows the installation of the PC25C is not economically viable because of the initial high capital cost of the fuel cell. Forecasters predict with continuous growth in fuel cell application in the commercial sector, the cost will be driven down from $4000/kW to $1000/kW. For mass production of fuel cells to become a reality, fuel cell's cost, reliability, and efficiency must be improved. The fuel cell at the Main Street facility was installed after the installation of another type of fuel cell (Molten Carbonate Fuel Cell) at the John Ferraro Building. This fuel cell project further proves that fuel cells are a very reliable and efficient form of power generation. Fuel cell technology has very minimal NOx and SOx emissions, which make the fuel cell an environmentally friendly form of power generation. The achievement of this project contributed to the evaluation of fuel cell technology, providing technical and commercial data that will be valuable for further fuel cell technology development.

Introduction:

LADWP delivers water and electricity to more than 1.5 million commercial and residential customers. Being one of the leaders in the power generation industry, LADWP continuously strides to find a cleaner and more efficient method of power generation. With fuel cells being one of the cleanest and most efficient power generating technology today, LADWP has installed several fuel cells, including a Phosphoric Acid Fuel Cell (PAFC) in February 2002 at its Main Street power generating facility. The power generated from this fuel cell unit goes into LADWP's power grid.

The (PAFC) power plant was proposed to be installed at LADWP's Playa Vista Facility. However, due to problems involving title transfer and soil remediation, LADWP was unable to install the Fuel Cell Power Plant (FCPP) at this location in a timely manner. The FCPP was moved to Main Street in order to comply with the time constraints set forth by the grant requirements.

The (PAFC) was selected because it is believed to be the most mature fuel cell technology in terms of technology and commercialization activities, it has been under development for more than 20 years. Among the low temperature fuel cells, it is believed that the PAFC is the only technology that shows relative tolerances for reformed hydrocarbon fuels and thus provides for widespread applications.

LADWP selected United Technologies Corporations (UTC) to supply the phosphoric acid fuel cell. UTC was selected as a supplier for this project because of their expertise and experience in phosphoric acid fuel cell research and development. The fuel cell model PC25 (model C) remained the same as it was under ONSI and ITC, which delivers a maximum output of 200 kW.

The primary objective of this project is to gain experience with fuel cells, educate and collect field data for on year of operation. This experience will help LADWP make distributed generation using fuel cell technology a viable option for the future's growing power demands.

The fuel cell power plant has been in operation since February 5, 2002 and has achieved 1,354MWhrs hours during its first year.

Results and Discussion

The following paragraphs provide details about the first year of operation of the fuel cell at the Main Street facility in Los Angeles. Data is provided regarding power plant reliability, costs, expenses, efficiency and on operation and maintenance issues.

Installation

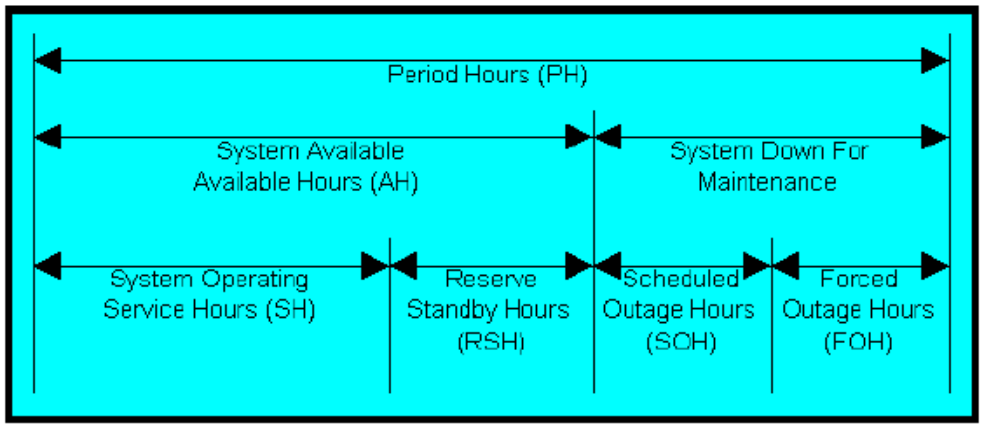
Project implementation began with a signed contract, that authorized expenditures of up to $1.1 million by LADWP. The contract led to the purchase of the unit on October 17, 2000. The purchase involved a 200 kW Phosphoric Acid Fuel Cell model PC25C manufactured by UTC, capable to operate independent of the utility grid. The power plant foundation was poured and the unit was delivered to the site for installation in September 2001. The delivery was a very smooth process with no problems encountered. The installation was delayed until February 2002, due to a lack of resources to install the unit.

Commissioning

The PC25C Fuel Cell power plant was commissioned on March 12, 2002 and commenced regular operation on February 5, 2002.

Reliability Analysis (MTBF)

To determine the reliability statistics, performance indices are used that are published by the Gas Technology institute (GTI) in Des Plaines, Illionois.



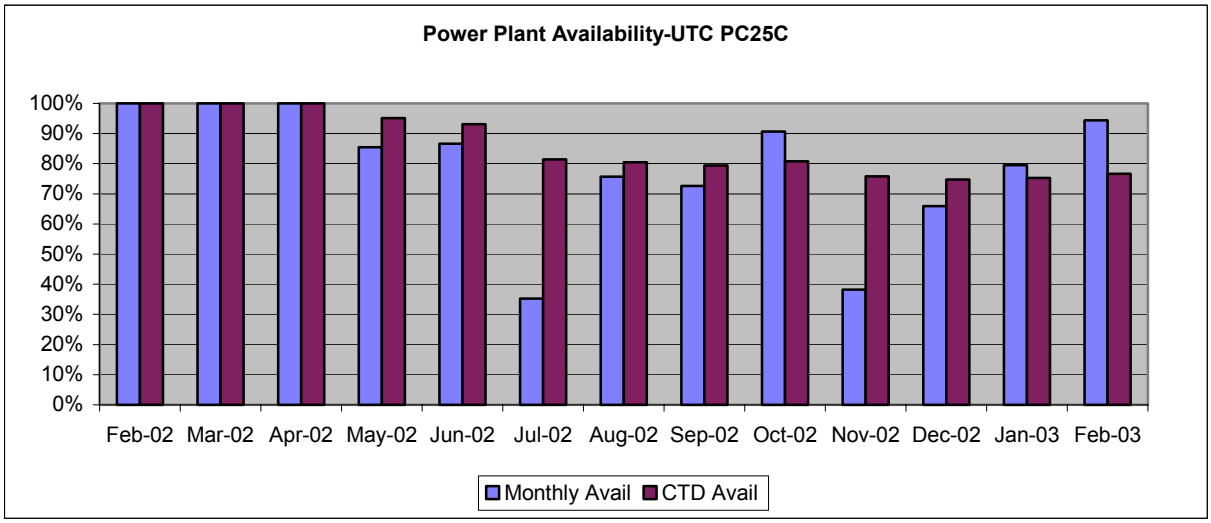
Reliability Performance Indices	Formula
Period of Demand (POD): *Measures the time the unit was planned to operate.*	$POD = PH - RSH - SOH$
Availability Factor (AF, %): *Measures, on a percent basis, the unit's "could run" capability. Impacted by planned and unplanned maintenance.*	$AF = \frac{(PH - SOH - FOH) \times 100}{PH}$
Forced Outage Rate (FOR, %): *Measures portion of downtime due to unplanned factors.*	$FOR = \frac{FOH \times 100}{SH + FOH}$
Scheduled Outage Factor (SOF, %): *Measures percent of time set aside for planned maintenance.*	$SOF = \frac{SOH \times 100}{PH}$
Service Factor (SF, %): *Percent of total period hours the unit is on-line – varies due to site-related or economic factors.*	$SF = \frac{SH \times 100}{PH}$
Mean Time Between Forced Outages (MTBFO): *Measures the nominal time between unscheduled forced outages.*	$MTBFO = \frac{SH}{\#\ ForcedOutages}$
Mean Down Time (MDT): *Measures the nominal duration the unit is down during maintenance events.*	$MDT = \frac{SOH + FOH}{\#\ ForcedOutages + \#\ PlannedOutages}$

(Source: http://www.gri.org/pub/solutions/dg/rel_metrics.html)

Reliability Performance Indices	
Period Hours, PH	8760hrs
Scheduled Outage Hours, SOH	1945hrs
Forced Outage Hours, FOH	89hrs
Reserve Standby Hours, RSH	0hrs
System Available – Available Hours, AH	6726hrs
System Operating Service Hours, SH	6726hrs
Period of Demand, POD	6815hrs
Availability Factor, AF	76.8%
Forced Outage Rate, FOR	1.3 %
Scheduled Outage Factor, SOF	20.9%
Service Factor, SF	76.8%
Mean Down Time, MDT	92hrs
Mean Time Between Failure (MTBF)	841hrs
System Total Use (kWh)	1,354,614kWh
System Peak Use (kW)	201kW
Total Fuel Cell Plant Capacity (kW)	200 kW
Heat Rate Ave Yr (BTU/kWh)	9,218BTU/kWh
Capacity Factor (% of Nameplate Rating)	77.3%
Thermal Output (Btu/yr), if byproduct used	N/A

Operating Hours / Availability:

The Main St Fuel Cell operated with an availability factor of 76.8% during the one-year period. The following chart shows the monthly availability and the cumulative to date availability for the one year of operation.



Shutdown Summary:

UTC Fuel Cell's Model PC25C model fuel cell was delivered to the Main St Site in September 2001 and installed by LADWP. On February 5, 2002 the fuel cell began producing net power to the grid, which marked the beginning of the one-year running period. The plant continued to operate flawlessly for the first two months but then on May 4, 2002 the plant was shut down due to a control system sensor malfunction. On May 9, 2002 the fuel cell was restarted. The fuel cell plant was again shut down on June 22, 2002 due to an analog circuit card lockup. On June 25, 2002 the fuel cell was returned to normal service with a new power supply for the analog card. On October 30, 2002 the analog values on the analog card were high and the fuel cell was shut down. New hex 800 fan motors were replaced due to a manufacturers defect, and the plant was restarted on November 17, 2002. On January 16, 2002, during startup, a mishap occurred where the Power Control module had no output values. The same problem was seen on December 18, 2002, therefore new software, version 5.65, was installed to reset every cycle to correct the problem. The plant was restarted on January 23, 2003 with no complications.

During it's first year of operation, the fuel cell plant provided more than 1,300MWhs net AC to the grid. To insure proper maintenance, the fuel cell plant was monitored by UTC, in South Windsor, Connecticut through a secure data line throughout the one-year of operation. The following table shows a detailed timeline of the shutdowns at the Main St. fuel cell.

Description/Event	Date	Loadtime	Run Hours	System Down Hours
First Start-up Start of one year of operation	2/5/2002 12:00pm	0		
Shutdown due to bad sensor (RSD)	5/4/2002 1:00am	2101	2101	
Restart	5/8/2002 11:00pm	2101		118
Temporary shutdown to Hot Standby while repairing CJTS.	6/4/2002 7:00am	2733	632	
Restart	6/4/2002 8:00am	2733		1
Temporary shutdown to Hot Standby while replacing analog board	6/10/2002 2:00pm	2883	150	
Restart	6/10/2002 4:00pm	2883		2
Shutdown due to analog card lockup. Rebooted and replaced power supply and connector	6/22/2002 7:00am	3162	279	

Restart	6/25/2002 3:00pm	3162		80
Shutdown due to IP 200 low voltage..	7/3/2002 4:00pm	3355	193	
Restart with new PMPO400 and flow switch.	7/12/2002 11:00am	3355		211
Shutdown due to bad IDC sensor. Installed UPS and filter on logic power supply.	7/13/2002 3:00am	3371	16	
Restart	7/23/2002 12:00pm	3371		249
Shutdown due to bad IDC sensor.	7/29/2002 12:00am	3503	132	
Restart	7/30/2002 12:00pm	3503		36
Shutdown due to bad IDC sensor. Contractor on site to install recording device and new controller software.	8/3/2002 12:00pm	3599	96	
Restart	8/12/2002 12:00pm	3599		216
3706s FS400 OFF IN S40-S200 (SSD)	8/10/2002 12:00pm	3599	N/A	
Restart	8/12/2002 12:00pm	3599		N/A
Shutdown due to 4489S IP200 Inverter shutdown. Installed 5 volt supply for analog I/O & header on analog card.	9/14/02 7:00am	4386	787	
Restart	9/18/02 3:00pm	4386		
Shutdown due to a voltage transient on the 12V supply that locked up the analog signals.	9/19/2002 9:00am	4404	18	
Restart	9/23/2002 5:00pm	4404		104
Temporary shutdown due to analog values locked up low. Remote reboot got power plant into cool down.	10/15/2002 9:00am	4924	520	
Restart	10/15/2002 4:00pm	4924		7

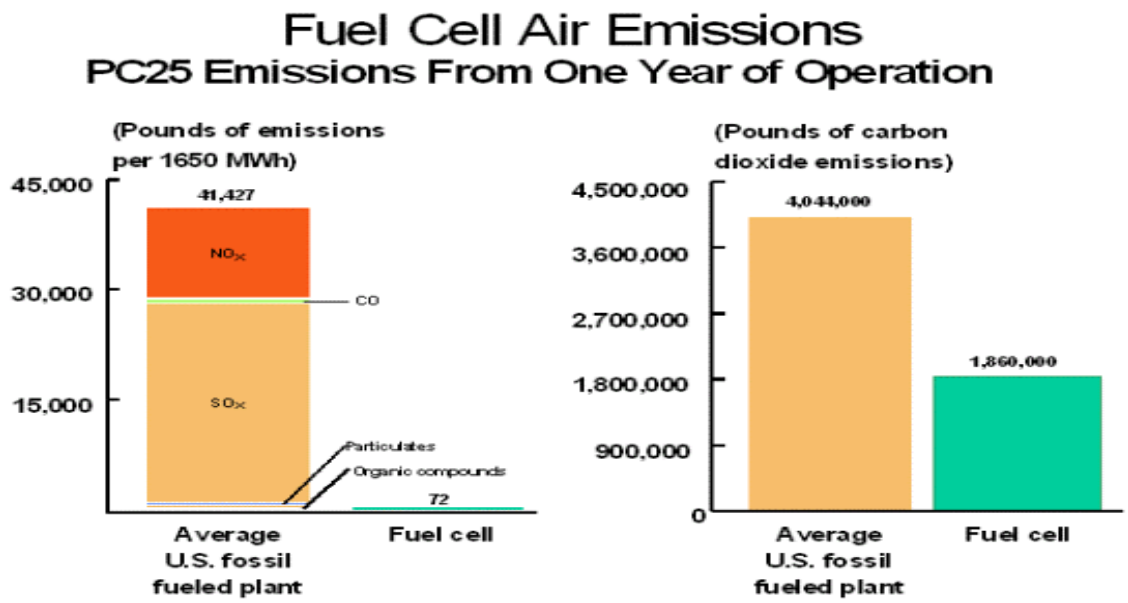
Temporary shutdown in fix software program by setting update times back to 5 seconds from 0.1.	10/17/2002 8:00am	4964	40	
Restart	10/18/2002 3:00pm	4964		31
Temporary shutdown while attempting to go to load.	10/25/2002 9:00am	5126	162	
Restart	10/25/2002 2:00pm	5126		5
Shutdown due analog signal lockup. Software changed to allow PP to cool down if analog values all went high and locked up.	10/27/2002 11:00pm	5183	57	
Restart	10/28/2002 3:00pm	5183		16
Shutdown due to analog values locked up. Replaced hex 800 fan motors due to manufacturing defect	10/30/2002 10:00pm	5238	55	
Restart	11/16/2002 2:00pm	5238		400
Shutdown due to bad IDC sensor	11/24/2002 7:00am	5423	185	
Restart	11/27/2002 12:00pm	5423		77
Temporary Shutdown due to loss in communication via modem. Manual shutdown to replace modem.	11/30/2002 4:00pm	5499	76	
Restart	11/30/2002 5:00pm	5499		1
Temporary shutdown due to LOR being tripped.	12/4/2002 7:00am	5585	86	
Restart	12/5/2002 10:00pm	5585		39
Shutdown due to analog card locked up with all values high.	12/9/2002 1:00am	5660	75	
Restart	12/11/2002 5:00pm	5660		64

Temporary shutdown due to TC's shields being reconfigured.	12/13/2002 10:00am	5701	41	
Restart	12/13/2002 1:00pm	5701		3
Shutdown due to the digital card locking up the signals going to the PC10.	12/18/2002 10:00am	5818	117	
Restart with new digital card and switch cables.	12/23/2002 10:00am	5818		120
Shutdown due to controller problem. Software version 5.65 installed to reset every cycle.	1/16/2003 10:00pm	6406	588	
Restart	1/23/2003 4:00am	6406		150
End of one year operation	2/5/2003 12:00pm	6726	320	
		Total	**6726**	**2034**

Emissions

Measures to improve the air quality in the city of Los Angeles Are very important to LADWP. By installing a 200 kW phosphoric acid fuel cell (PAFC), LADWP is reducing the amount of harmful air pollutants in the air such as NOx or SOx. Compared with traditional combustion power plants, PAFC's eliminate 40,000 pounds of acid rain and smog-causing emissions from the environment every year. From this table, it can be seen that the amount of NOx produced is negligible along with the other harmful emissions, thus confirming the use of fuel cell technology as a virtually pollution free source of energy.

Emissions	**Main St FC Emissions (15% O_2)**
NOx	1ppm
SOx	Negligible
NO_2	Negligible
SO_2	2 ppmv
CO	5 ppmv
Particulates	Negligible
Smoke	None
Hydrocarbons	6ppm



Cost Parameter
The following table provides the economic data from the first year of operation.

Specification	Data
Total Fuel Cell Plant Cost ($)	$864,000
Fixed Operating Cost	50mills/kWh
Variable Operating Costs	37 mills/kWh
Local Area Electricity Price (cents/kWh)	5 cents/kWh for generation 9 cents/kWh for delivered
*Fuel Price ($/MBTU)	$5.50/MBTU

*Year Average from February 2002 to February 2003

Cost-Benefit Evaluation

Activity	Cost
Investment	
Total Fuel Cell Plant Cost	$864,000
Installation Cost	$150,000
Shipping	$30,000
Sales Tax (8.0%)	$83,000
Total Investment	**$1,127,000**
Funding	
U.S. DOE	$250,000
Total Funding	**$250,000**
Total Costs	
Fuel Cost	$68,700
Operation and Maintenance Cost	$50,400
Total Costs	**$119,100**

Electrical Consumption of the Main St. Site

Main St. Prior to Installation

Date	Electrical Use (kWh)	Peak Electrical Use (kW)
Feb-01	1,222,794	2,458.9
Mar-01	1,332,794	2,701.3
Apr-01	927,137	2,501.7
May-01	782,468	2,438.2
Jun-01	921,508	2,488.6
Jul-01	918,690	2,479.0
Aug-01	872,057	2,463.1
Sep-01	953,675	2,476.2
Oct-01	893,662	2,557.7
Nov-01	935,799	1,311.6
Dec-01	1,093,002	2,592.8
Jan-02	1,078,323	2,611.7
Feb-02	1,022,221	2,642.9

Main St. During Operation

Date	Electrical Use (kWh)	Peak Electrical Use (kW)
Feb-02	1,022,221	2,642.9
Mar-02	648,355	2,140.5
Apr-02	610,379	2,149.9
May-02	675,433	2,349.1
Jun-02	703,427	2,339.5
Jul-02	777,252	2,346.5
Aug-02	730,453	2,340.5
Sep-02	712,282	2,354.6
Oct-02	735,807	2,347.0
Nov-02	1,324,285	2,544.5
Dec-02	939,578	2,624.4
Jan-03	732,858	2,362.3
Feb-03	663,574	2,039.8

Due to the fuel cell being small in comparison to the entire site, the decline in electrical use prior to installation, and after installation, is not dependant on the fuel cell. The 200kW PAFC is connected to LADWP's power grid instead of the Main St. Facility therefore the electric demand of the Main St. Site will not be affected.

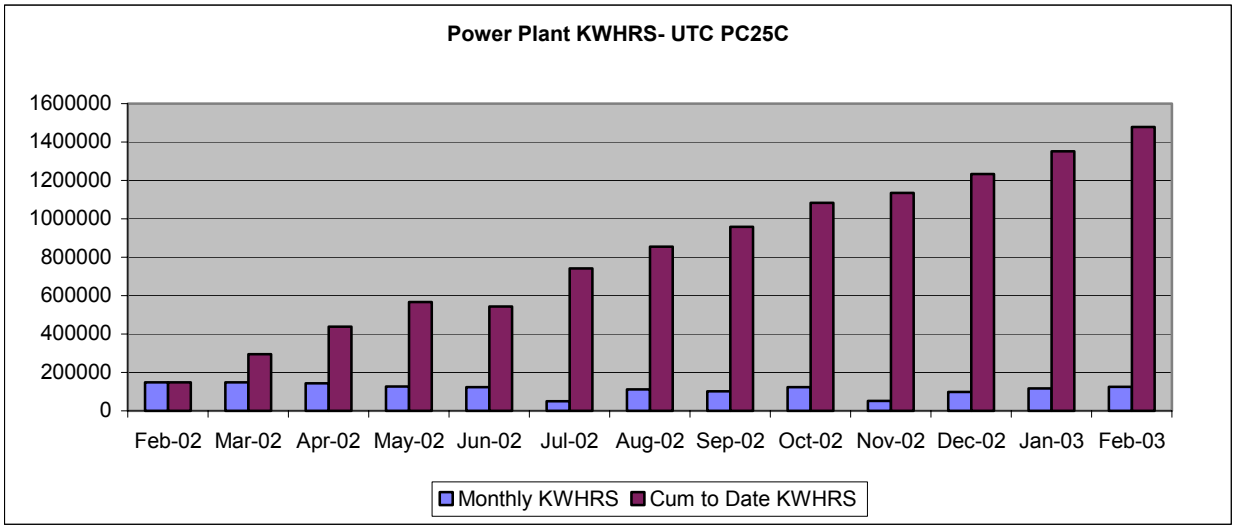
Fuel Consumption of the Main St. Site

Date	Gas Use (MMBtu)	Peak Gas Use MMBtu/dy
Feb-01	2,113	105.7
Mar-01	1,511	75.5
Apr-01	1,151	57.5
May-01	698	34.9
Jun-01	180	9.0
Jul-01	32	1.6
Aug-01	27	1.4
Sep-01	38	1.9
Oct-01	44	2.2
Nov-01	268	13.4
Dec-01	1,155	57.8
Jan-02	1,099	54.9
Feb-02	1,503	75.1

Date	Gas Use (MMBtu)	Peak Gas Use MMBtu/dy
Feb-02	1,503	75.1
Mar-02	2,584	129.2
Apr-02	2,236	111.8
May-02	2,552	127.6
Jun-02	1,994	99.7
Jul-02	1,020	51.0
Aug-02	1,419	71.0
Sep-02	1,904	95.2
Oct-02	1,734	86.7
Nov-02	1,000	50.0
Dec-02	1,679	84.0
Jan-03	2,715	135.8
Feb-03	2,393	119.7

Fuel Cell Electric Output

Date	Energy Output (kWh)	Max. Electric Output (kW)
February-02	135,007	200.9033
March-02	147,685	200.9033
April-02	142,729	201.1963
May-02	126,339	201.001
June-02	122,822	200.8789
July-02	50,586	200.8057
August-02	111,656	201.123
September-02	102,154	201.123
October-02	124,038	200.7568
November-02	52,477	200.5859
December-02	97,985	200.8789
January-03	117,058	201.2207
February-03	24,079	200.6592
Total	1,354,614.62	



The 200kW PAFC produced a total of 1,354MWh within its first year of operation. The fuel cell performed well its first year and helped relieve the LADWP power grid.

Conclusion

The UTC Model PC25 fuel cell power plant at the Main St. Facility in Los Angeles, California successfully completed its first year of operation. Operating data shows that the power plant is reliable and its electrical performance complies with premium power supply requirements. In terms of efficiency, the power plant performs better than single stage conventional combustion technologies. During the year the PC25C supplied a total of 1,354MWh into the Los Angeles Department of Water and Power (LADWP) Grid. It also provided valuable technical and operational data, which will help LADWP for future fuel cell installations.

The Los Angeles Department of Water and Power has taken a leadership role in fuel cell research in order to commercialize fuel cells and drop the high equipment costs. Fuel cells are highly efficient and environmentally friendly but due to the high initial costs of fuel cells many companies are unable to afford them. Along with the purchase of the PC25C at the JFB, LADWP also purchased three additional fuel cells for other LADWP sites, which will help promote fuel cell technology.

With the purchase of the PC25C, LADWP is not only providing electricity to the grid but is also cleaning up the air in Los Angeles. Fuel cell power plants are becoming attractive in combined systems where its heat output can be utilized. By using fuel cell power plants to generate power, LADWP is able to reduce the amount of harmful pollutants in the air such as NOx and SOx.

With the Department of Energy's help to fund the purchase of the PC25C fuel cell, LADWP is able to promote fuel cells and eventually reduce the equipment costs of fuel cells. This will allow more companies to install fuel cells and further promote the maturing concept of distributed generation.

Photo Gallery

Site Overview

Fuel Cell Cooling Module

Fuel Cell Operating

PC25C fuel cell power plant at the Main St. Facility in full load operation

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