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Engineer Research and
Development Center

Detailed Fuel Cell Demonstration Site Summary Report

Naval Hospital at Marine Corps Air Ground Combat Center – Twentynine Palms

J. Michael Torrey, John F. Westerman, William R. Taylor,
Franklin H. Holcomb, and Joseph Bush

June 2006



Detailed Fuel Cell Demonstration Site Summary Report

Naval Hospital at Marine Corps Air Ground Combat Center – Twentynine Palms

William R. Taylor, Franklin H. Holcomb, and Joseph Bush
Construction Engineering Research Laboratory (CERL)
U.S. Army Engineer Research and Development Center
2902 Newmark Dr.
Champaign, IL 61824

J. Michael Torrey and John F. Westerman
Science Applications International Corporation (SAIC)
San Diego, CA

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Abstract: Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. In fiscal year 1993 (FY93), the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) was assigned the mission of managing the DOD Fuel Cell Demonstration Program. Specific tasks included developing turnkey PAFC packages, devising site criteria, screening candidate DOD installation sites based on selection criteria, evaluating viable applications at each candidate site, coordinating fuel cell site designs, installation and acceptance of the PAFC power plants, and performance monitoring and reporting.

CERL selected and evaluated 30 application sites, supervised the design and installation of fuel cells, actively monitored the operation and maintenance of fuel cells, and compiled “lessons learned” for feedback to fuel cell manufacturers. At the conclusion of the demonstration period, each of the demonstration fuel cell sites was given the choice to either have the fuel cell removed or to keep the fuel cell power plant. This report presents a detailed review of a 200 kW fuel cell installed at the Marine Corps Air Ground Combat Center (MCAGCC) – Twentynine Palms and operated between June 1995 and May 2000.

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Preface

In fiscal years 93 and 94, Congress provided funds for natural gas utilization equipment, part of which was specifically designated for procurement of natural gas fuel cells for power generation at military installations. The purchase, installation, and ongoing monitoring of 30 fuel cells provided by these appropriations has come to be known as the “DOD Fuel Cell Demonstration Program.” Additional funding was provided by: the Office of the Deputy Under Secretary of Defense for Industrial Affairs & Installations, ODUSD (IA&I)/HE&E; the Strategic Environmental Research & Development Program (SERDP); the Assistant Chief of Staff for Installation Management (ACSIM); the U.S. Army Center for Public Works (CPW); the Naval Facilities Engineering Service Center (NFESC); and Headquarters (HQ), Air Force Civil Engineer Support Agency (AFCESA).

The work was performed by the Energy Branch (CF-E), of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Franklin H. Holcomb. Part of this work was done by Science Applications International Corporation (SAIC) under General Services Administration (GSA) contract No. 5TS5703C166. J. Michael Torrey and John F. Westerman are associated with SAIC. Dr. Thomas Hartranft is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Dr. Paul A. Howdyshell, CEERD-CVT. The Director of CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL James R. Rowan, and the Director of ERDC is Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
cubic inches	0.00001638706	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	$(5/9) \times (^{\circ}\text{F} - 32)$	degrees Celsius
degrees Fahrenheit	$(5/9) \times (^{\circ}\text{F} - 32) + 273.15$	kelvins
feet	0.3048	meters
gallons (U.S. liquid)	0.003785412	cubic meters
horsepower (550 ft-lb force per second)	745.6999	watts
inches	0.0254	meters
kips per square foot	47.88026	kilopascals
kips per square inch	6.894757	megapascals
miles (U.S. statute)	1.609347	kilometers
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square meters
square miles	2,589,998	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

1 Introduction

1.1 Background

In fiscal year 1993 (FY93), the U.S. Congress appropriated \$18 million to advance the use of phosphoric acid fuel cells (PAFCs) at Department of Defense (DOD) installations. An additional \$18.75 million was appropriated in FY94 to expand the program. The Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) was assigned the mission of managing the DOD Fuel Cell Demonstration Program. Specific tasks included developing turnkey PAFC packages, devising site criteria, screening candidate DOD installation sites based on selection criteria, evaluating viable applications at each candidate site, coordinating fuel cell site designs, installation and acceptance of the PAFC power plants, and performance monitoring and reporting.

Thirty DOD fuel cell sites were selected based on the following criteria:

1. Geographic diversity
2. Application diversity
3. Fuel cell utilization at site
4. Energy cost savings.

The first two criteria are related more to overall program goals; the last are typical criteria for most fuel cell evaluations. It was important for the DOD Fuel Cell Program sites to represent a cross section of both “base” (including climate) and “building” applications. It was also important to identify applications where a high percentage of the fuel cell thermal and electrical output could be used at the site to demonstrate the greatest possible benefits.

Energy savings were less important in this Program than is typical with commercial applications since fuel cells purchased by the DOD were given to the Program sites. The economic criteria for each application was to generate at least \$25,000 per year in energy savings, which would essentially cover annual maintenance costs. This would enable the fuel cell to pay for itself once the responsibility for maintenance was turned over to the base (after approximately 5 years).

The program followed a consistent approach for selecting sites, designing and reviewing installation plans, installing and maintaining the fuel cells, collecting fuel cell performance data and project decommissioning. This involved:

1. *Preliminary Screening.* Base energy data from the Defense Energy Information System (DEIS) was used to rank DOD sites by utility rates and potential fuel cell energy savings. DOD base personnel were contacted to identify their interest in hosting a fuel cell demonstration unit and to identify a preliminary list of potential building applications. The Navy and Air Force provided an initial list of candidate sites for consideration.
2. *Site Visits.* ERDC-CERL and Science Applications International Corporation (SAIC) representatives visited each base, evaluated potential fuel cell application sites and discussed possibilities with site personnel. Energy consumption and rates, hours of operation, availability of space, etc. and other information was collected during the site visit.
3. *Site Evaluation Reports.* SAIC prepared a site evaluation report* documenting site information, presenting conceptual fuel cell installation plans, estimation of electrical and thermal energy savings, and projected fuel cell energy savings. Based on the viability of the proposed fuel cell application, the base was accepted as a program site.
4. *Kick-off Meetings.* ERDC-CERL, SAIC, United Technologies Corp. (UTC) Fuel Cells (formerly ONSI Corp. and International Fuel Cells) and site personnel met to review the site evaluation report, discuss relevant issues, schedules, and any other concerns. UTC Fuel Cells collected site data for use in preparing the detailed site installation drawings.
5. *Design Review Meetings.* Detailed design drawings were submitted by UTC Fuel Cells for review by ERDC-CERL, SAIC, and site personnel. Specific issues related to the design were discussed and UTC Fuel Cells would incorporate changes to the drawings based on the input received.
6. *Acceptance Tests.* Installation of the fuel cells was the responsibility of UTC Fuel Cells. After the fuel cell installation was completed, a series of tests were performed to validate fuel cell performance. Upon successful completion, the fuel cell was turned over to the base, but operation and maintenance remained the responsibility of UTC Fuel Cells for approximately 5 years. Appendix A includes a copy of the acceptance test report.
7. *Dedication Ceremonies.* Many of the fuel cell sites held a fuel cell dedication ceremony as part of their program participation. Often, dignitaries such as Generals and State Governors were in attendance.

* Michael J. Binder, Franklin H. Holcomb, and William R. Taylor, ERDC/CERL Technical Report (TR) 01-32/ADA389308, paa, *Site Evaluation for Application of Fuel Cell Technology: Naval Hospital—Marine Corps Air Ground Combat Center Twentynine Palms, CA* (ERDC-CERL, Champaign, IL, March 2001)

8. *Fuel Cell Operations.* The fuel cells operated for 3 to 5 years. UTC Fuel Cells was responsible for maintenance of the power plant as well as collection of fuel cell performance data.
5. *Fuel Cell Decommissioning.* At the conclusion of the demonstration period, UTC Fuel Cells was responsible for removing the fuel cell and returning the site to the its condition before to the fuel cell installation. Each of the FY93 fuel cell sites, including MCAGCC Twentynine Palms, was given the opportunity to keep the fuel cell power plant at the end of the demonstration and take responsibility for all costs and issues related to operation, performance and decommissioning.

This report presents a detailed review of a 200 kW fuel cell installed at the Marine Corps Air Ground Combat Center (MCAGCC) – Twentynine Palms. The base is located in Twentynine Palms, CA, approximately 150 miles east of Los Angeles. The fuel cell was installed at the Naval Hospital as part of the DOD Fuel Cell Demonstration Program. The fuel cell operated between June 1995 and May 2000. This report also reflects follow-up investigation of operating information accomplished after 2001.

1.2 Objective

The overall objective of the Fuel Cell Demonstration Program was to:

- demonstrate fuel cell capabilities in real-world situations
- stimulate growth and economies of scale in the fuel cell industry
- determine the role of fuel cells in DOD's long-term energy strategy.

This specific objective of this part of the program was to give a detailed review of the PAFC fuel cell demonstration at the Marine Corps Air Ground Combat Center (MCAGCC) – Twentynine Palms, CA.

1.3 Approach

The review process involved:

1. Collecting data from the Fuel Cell Demonstration Project at MCAGCC
2. Analyzing the data in terms of the technology's capabilities, performance, and potential for a continuing role in the DOD's long-term energy strategy
3. Compiling lessons learned from the demonstration experience
4. Making recommendations for continued/improved use of the technology at DOD installation.

1.4 Mode of Technology Transfer

Results of this work will be forwarded directly to the funding sponsor and to the participating installation. This report will be made publicly accessible through the World Wide Web (WWW) at URL:

<http://www.cecer.army.mil>

<http://www.dodfuelcell.com>

2 Project Overview

This chapter reviews the timeline of events and the project participants involved in the fuel cell demonstration unit for the Naval Hospital at Marine Corps Air Ground Combat Center – Twentynine Palms.

2.1 Project Timeline

The first formal activity related to the fuel cell demonstration unit at the Naval Hospital was a site evaluation meeting held in December 1993. Between 20 June 1995 and 20 May 2000, the fuel cell operated for 21,889 hours and generated more than 3,500 MWh of electricity. The fuel cell had its last forced outage on 20 May 2000 and the fuel cell was removed in February 2001. (No fuel cell was in operation during this time.) Table 1 lists the major events and milestones for this fuel cell demonstration unit. Chapter 4 of this report gives a more detailed analysis of the fuel cell operation and performance history.

Table 1. Time line of major events and milestones for the fuel cell at the MCAGG Naval Hospital.

Date	Event
8-9 December 1993	Site evaluation meeting held at Twentynine Palms
8 March 1994	Site evaluation report submitted by SAIC
18 March 1994	Twentynine Palms selected as demonstration site
3 May 1994	Project kick-off Meeting held at Twentynine Palms
16 January 1995	Draft design drawings submitted by UTC Fuel Cells
14 February 1995	Fuel cell design review completed by SAIC
27 February 1995	ONSI submits revised drawings
2 March 1995	Fuel cell design review meeting held at Twentynine Palms
3 March 1995	Base authorizes commencement of site construction
13 March 1995	Start of construction
16-21 June 1995	Acceptance testing performed
23 June 1995	Acceptance Test Meeting; Form DD250 signed by Twentynine Palms
26 July 1995	1,000 hours of operation milestone
9 August 1995	Fuel Cell Dedication Ceremony
14 January 1996	Fuel cell shut down due to fleet-wide water issues
28 March 1996	Install new fuel cell stack
7 August 1996	SAIC monitoring system installed
9 August 1996	Reverse osmosis system installed; fuel cell restarted

14 July	1996	5,000 hours of operation milestone
10 March	1997	10,000 hours of operation milestone
30 January	1998	15,000 hours of operation milestone
11 May	1998	Replace heat exchangers
1 October	1999	20,000 hours of operation milestone
20 May	2000	Fuel cell shut down for final time
6 July	2000	Base requests to have fuel cell removed
February	2001	Fuel cell removed

The time between the initial site evaluation meeting and the fuel cell acceptance test time was approximately 18 months. It took approximately 3 ½ months to install the fuel cell following acceptance of the installation design. UTC Fuel Cells was responsible for the installation of all 30 fuel cells installed as part of this program. GBC Electrical Services installed the fuel cell as a sub-contractor to UTC Fuel Cells.

2.2 Project Participants

The successful demonstration of this fuel cell unit required the efforts of several organizations and individuals:

- ERDC-CERL had overall responsibility for the DOD Fuel Cell Demonstration Program unit installed at the Naval Hospital. ERDC-CERL was responsible for contracting with the fuel cell manufacturer, identifying all sites, managing all site evaluations, and overseeing all design, installation, operation, and maintenance activities.
- *UTC Fuel Cells* manufactured the PC25B and PC25C fuel cells used at the bases. They were responsible for manufacturing the fuel cell as well as the detailed design drawings, fuel cell installation, operation/maintenance and, if necessary, fuel cell removal.
- *SAIC* was responsible for evaluating potential building applications at each site, developing fuel cell conceptual designs, performing a preliminary economic analysis and submitting the site evaluation report for review by all parties. In addition, SAIC was involved in the detailed design reviews and participating in the design review meetings. For this demonstration unit, SAIC also conducted independent performance monitoring of the fuel cell.
- *GBC Electrical Services* was the installation contractor for this fuel cell. In addition, they performed the maintenance on the fuel cell and were involved in its removal.

- *The Naval Hospital* was directly involved in the review and approval of the fuel cell project as well as coordination of maintenance activities with GBC Electrical Services.
- *MCAGCC personnel* provided review and approval for various aspects of the project including fire and utilities interfaces.

Table 2 lists the individuals involved in this demonstration project at the Naval Hospital.

Table 2. Principal project participants at MCAGCC Twentynine Palms.

Organization	Name	Project Role
ERDC-CERL	Dr. Michael Binder Frank Holcomb William Taylor Gerald Cler	Manager, Fuel Cell Demonstration Program Fuel Cell Project Manager Fuel Cell Project Manager Fuel Cell Project Manager
UTC Fuel Cells	Joseph Staniunis Douglas Young Thomas Pompa	Installation Designer Technical Representative Installation/Maintenance Coordinator
Science Applications Int'l Corp.	Gerry Merten Mike Torrey	Principal Technical Manager Project Manager
Naval Hospital	Tiffany Monaco Patrick Dougherty C.J. Chitwood	Naval Hospital Point of Contact MCAGCC Utilities Engineer Naval Hospital
MCAGCC Twentynine Palms	Howard DeVore Stuart Hammons Luke Wren	Base Public Works Utilities Engineer Facilities Management
GBC Electrical Services	George Collard Ray Aselin	Installation/Maintenance Contractor Electrician

Appendix B lists the attendees lists for the Site Evaluation, Kick-off, Design Review, and Acceptance Testing meetings. No attendees list was created for the Dedication Ceremony.

2.3 Naval Hospital Interviews

Personnel from the Naval Hospital at Twentynine Palms were contacted to discuss their overall experience with the fuel cell demonstration. The original point of contact person, Ms. Tiffany Monaco, was involved with the project from the initial site evaluation through the early part of the fuel cell's operation. Since Ms. Monaco was not available for an interview, Mr. Patrick Dougherty, who took over as site point of contact, agreed to be interviewed.

Mr. Dougherty was responsible for facilities maintenance at the Naval Hospital. He was involved with the fuel cell demonstration from its inception and

attended the site evaluation meeting back in December 1993. Mr. Dougherty expressed his approval of the fuel cell technology, but stated that he “wished that it operated more than it did.” His view of the technology is generally positive and he is open to participating in another fuel cell demonstration, should the opportunity present itself.

The facility personnel conducted an analysis of costs associated with continued operation of the fuel cell, including replacement of the cell stack. The results of the analysis revealed that it would not be economically viable to continue to operate the fuel cell at the Naval Hospital. As a result, the Naval Hospital requested that the fuel cell be removed from the equipment pad following the demonstration period. Figure 1 shows the fuel cell installation. Figure 2 shows the fenced area where the fuel cell had been installed. The tall tank at the back left corner was for storing fuel cell thermal output. The area is now used for storage of miscellaneous items.



Figure 1. Fuel cell installation.



Figure 2. Fuel cell site after removal.

3 Fuel Cell Design and Installation

This Chapter reviews the basic fuel cell design and installation procedures used for the Naval Hospital fuel cell at Twentynine Palms.

3.1 Fuel Cell Building Application

The Naval Hospital building opened in early 1993, the same year that the site evaluation meeting was held. The hospital is a 190,000 sq ft facility with 39 patient beds and various specialty clinic facilities. The facility operates 24 hours per day. In addition to the hospital, a barracks was considered as a possible candidate site for the fuel cell. However, the barracks was eliminated from further consideration because it was scheduled to be torn down within a couple of years. ERDC-CERL TR 01-32 provides more details about the site evaluation.

3.2 Conceptual Installation Design

Based on the initial site evaluation meeting in December 1995, a preliminary conceptual design for the fuel cell installation was prepared. Figure 3 shows the layout of the hospital mechanical/electrical rooms, an outdoor equipment yard and an open space area between them.

The fuel cell was originally proposed to be located adjacent to the outdoor equipment yard that contained cooling towers, an electrical room, and three 1,000 kW backup generators. Because the open space between the equipment yard and the hospital building had a 5 to 10 percent grade, locating the fuel cell next to the mechanical rooms was deemed problematic. Subsequently, aesthetic and practical issues were resolved and the fuel cell was sited next to the mechanical rooms. This new location provided closer proximity to both the natural gas and thermal interface locations.

The main natural gas line enters the building just outside the boiler room. The gas line would be tapped into and run over the to fuel cell pad (approximately 50 ft).

The fuel cell electrical interface was originally to be tied into the low voltage side of the 12,000/480V transformers located in the equipment yard. Once the fuel cell location was moved, the point of electrical interface was moved to

the electrical panels located inside the hospital building. A dedicated load would later be identified for connecting to the grid-independent output interface of the fuel cell.

The thermal interface was to tie into the domestic hot water (DHW) system at the hospital. Figure 4 shows the proposed fuel cell thermal interface where water is pulled from the make-up line, heated up in the fuel cell, and then sent back to the DHW steam heaters. The tank size was reduced to 1,000 gal for the actual installation. The thermal piping distance was estimated at approximately 35 ft.

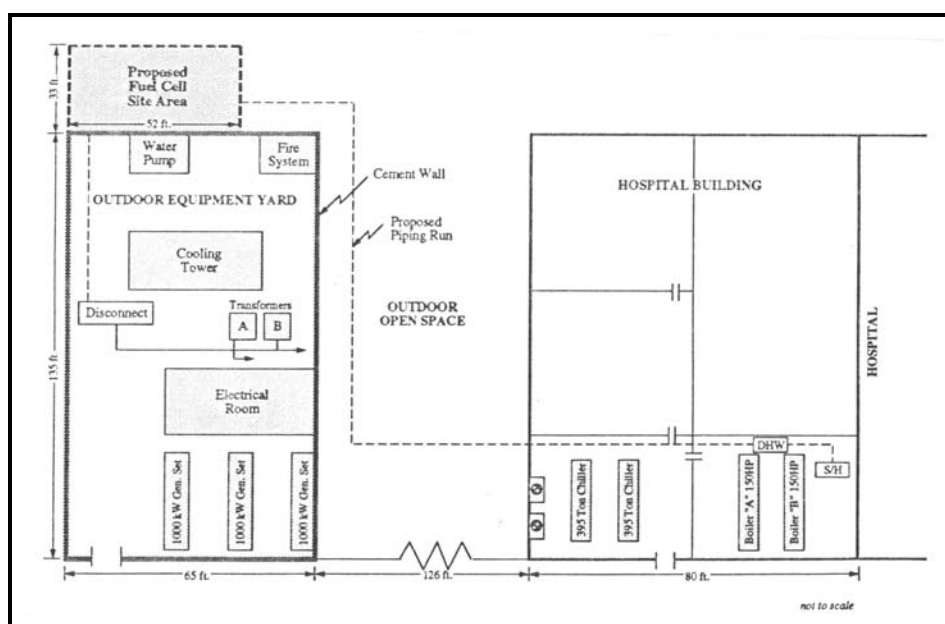


Figure 3. Original conceptual fuel cell location and interfaces (later changed).

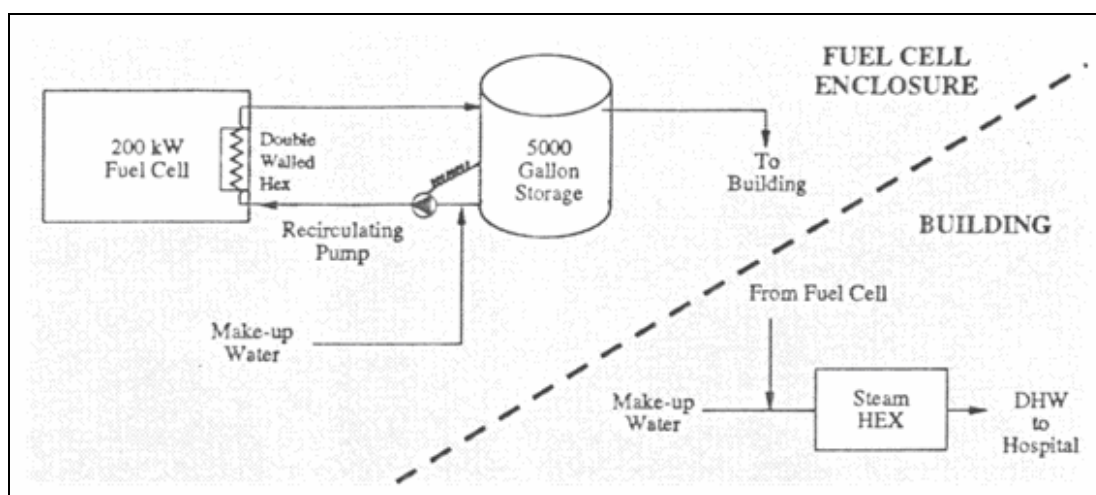


Figure 4. Original conceptual fuel cell thermal interface.

3.3 Detailed Design Drawings

UTC Fuel Cells submitted an original set of design drawings on 16 January 1995. The drawings were reviewed by base personnel, ERDC-CERL and SAIC. New drawings were made for the design review meeting held on 2 March 1995 at the Naval Hospital. Appendix B includes the attendees list.

The following drawings were submitted:

- S-1:** Foundation Layout Plan
- S-2:** Foundation Layout Plan / Side View A-A
- ME-1:** Site Layout Plan with Mechanical & Electrical Routing
- M-1:** Heat Recovery Piping & Instrumentation
- M-2:** Mechanical Piping Details
- E-1:** Electrical Wiring Diagram
- E-2:** Electrical Interface Details
- E-3:** Electrical Details

The most significant changes from the initial conceptual design involved moving the fuel cell from the equipment yard to a location with closer proximity to the mechanical building, reducing the size of the storage tank from 5,000 to 1,000 gal and adding a grid-independent interface with the hospital.

Reviewers submitted comments based on the initial drawings. Appendix C includes copies of these comments. Table 3 lists the changes made to the detailed site drawings, both before and after the design review meeting. Figures 5 through 12 show the final installation drawings.

Table 3. List of changes to design drawings based on comments.

Drawing	Changes
S-1	1. Equipment positioning adjustments made including nitrogen tank rack to back side of pad.
	2. Fence lengthened 1 ft. to 52 ft.
	3. Full concrete pad within fence.
	4. Add drainage accommodations at building end of pad.
S-2	1. Equipment position adjustments.
ME-1	1. DHW interface piping size changed from 2" to 3."
	2. Rerouted high pressure gas line up to fuel cell pad where low pressure regulator would be installed.
	3. Phone line conduit added to drawing.
	4. Typographical error corrected: gas pipe is 3," not 3'.
	5. Equipment position adjustments as on S-1.
	6. Spare conduit added (emergency power cord).
	7. Building wall penetrations noted.

Drawing	Changes
	8. Disconnect labels changed (reversed GC & GI).
M-1	1. Noted added that contractor would inspect water make-up line to insure that portable water system is isolated from city water system by an approved backflow prevention device in the existing system.
	2. Typographical error corrected: water tank diameter 4 ft, not 4 in.
	3. Mixing valves labeled.
	4. Closed valves illustrated
M-2	No changes.
E-1	1. Grounding illustration changed to correspond to E-3 drawing.
E-2	No Changes
E-3	1. Ground grid updated.

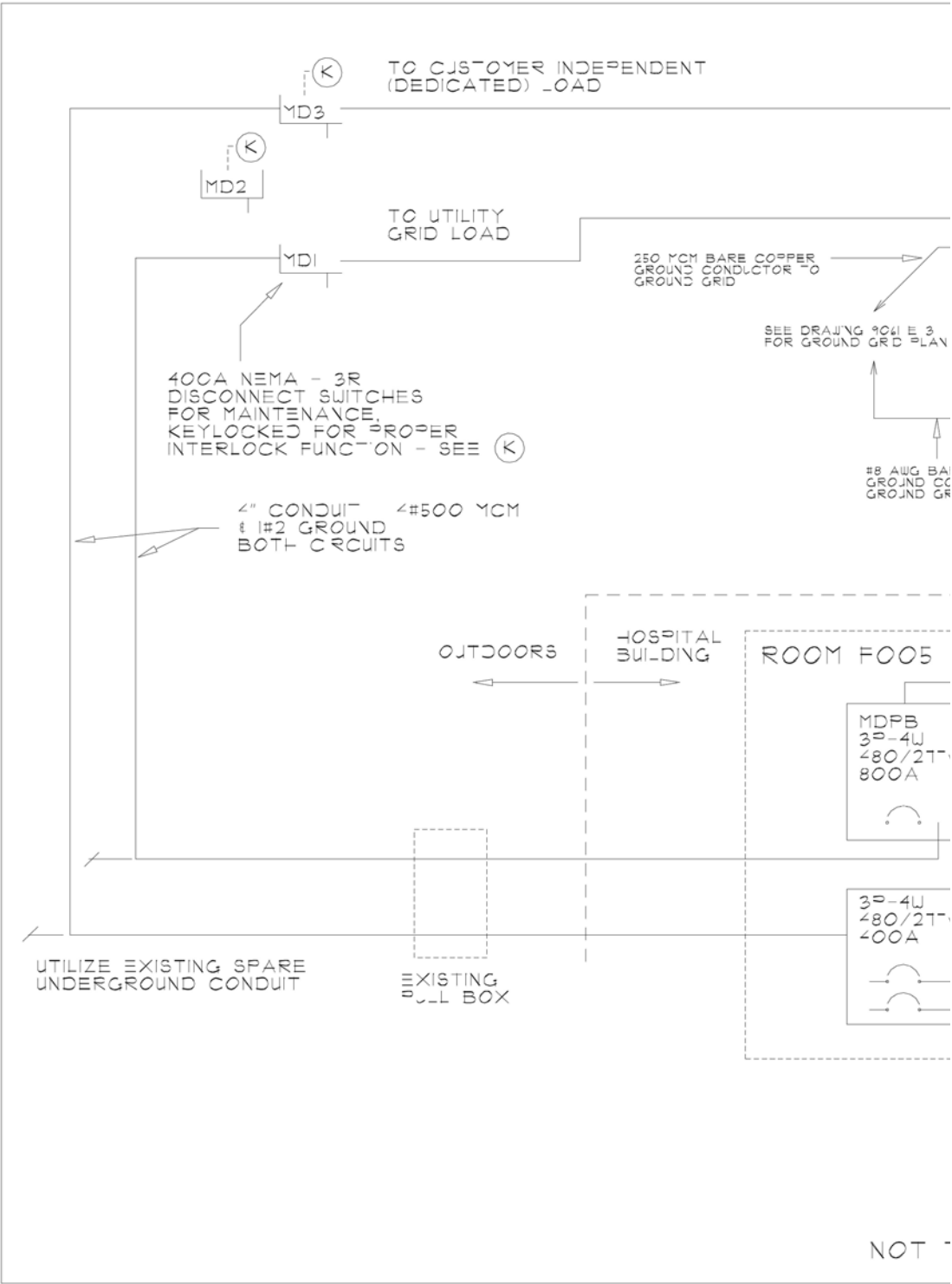
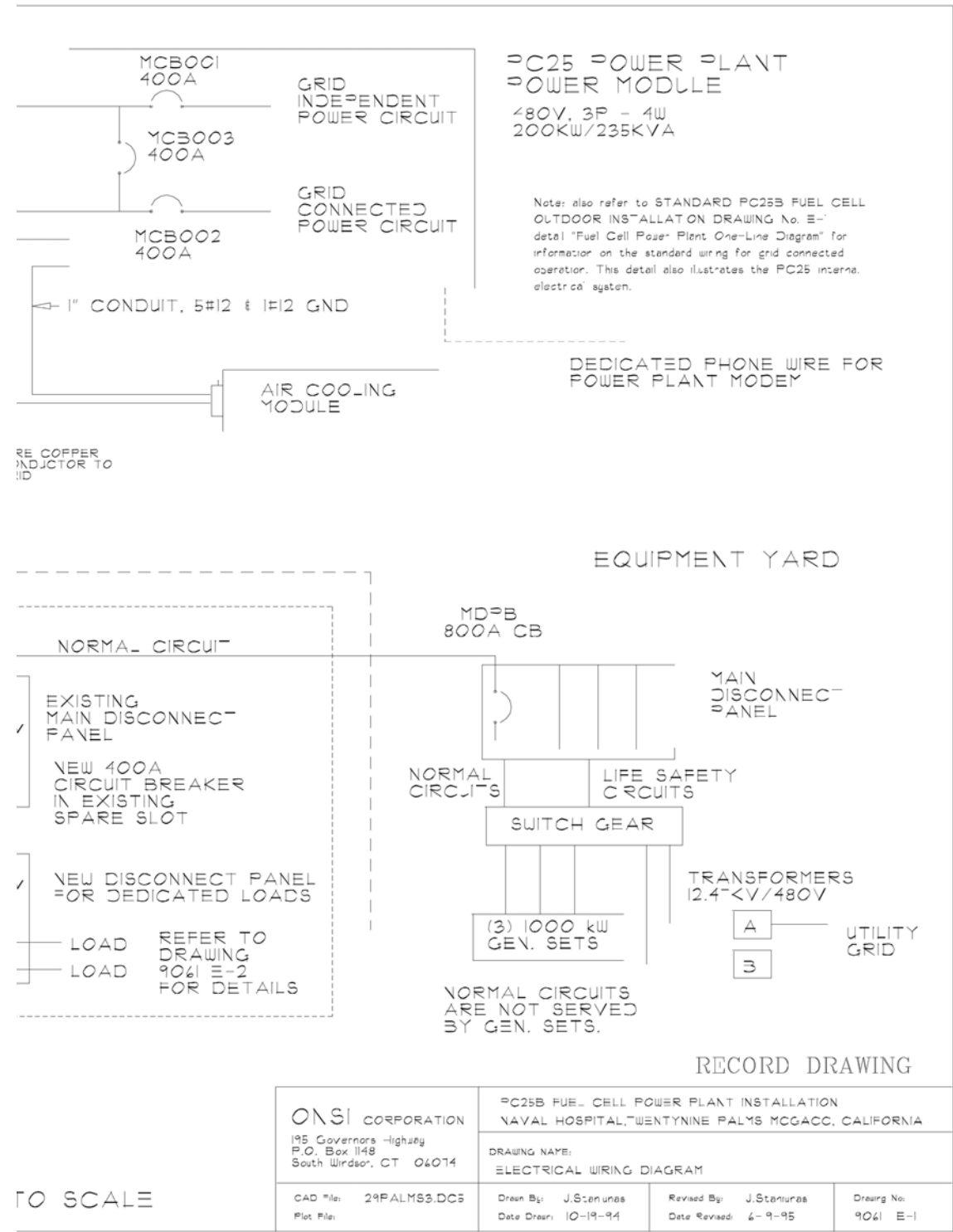


Figure 5. Final installation drawing – electrical wiring diagram.



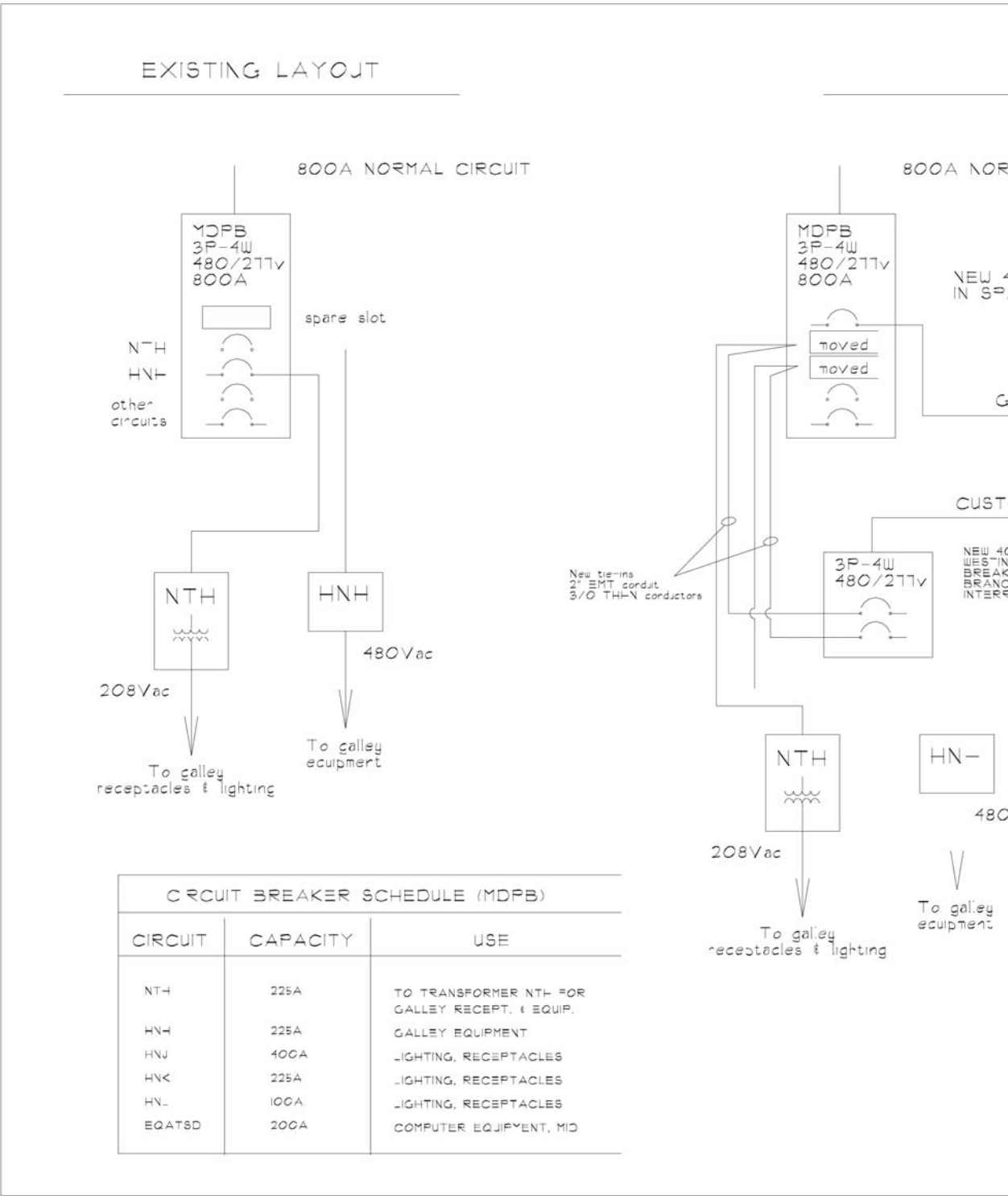


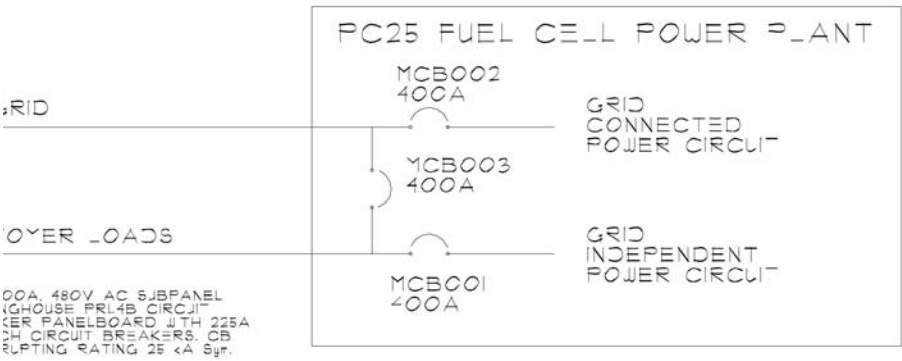
Figure 6. Final installation drawing – electrical interface details.

NEW LAYOUT

SMAL CIRCUIT

CUSTOMER LOAD MAY BE POWERED EITHER FROM THE POWER PLANT GRID CONNECT CIRCUIT (OPERATING IN PARALLEL WITH THE UTILITY GRID), OR THE POWER PLANT GRID INDEPENDENT CIRCUIT. IF THE POWER PLANT IS OFF - NE, THE CUSTOMER LOAD IS POWERED FROM THE UTILITY GRID VIA MCB003 (SEE CIRCUIT BREAKER TRUTH TABLE).

400A CIRCUIT BREAKER ARE S-LOT



2 Vac

PC25 OUTPUT CIRCUIT BREAKER TRUTH TABLE			
CIRCUIT BREAKER	POWER PLANT MODE		
	OFF	GRID CONN.	GRID INDEP.
MCB001	OPEN	OPEN	CLOSED
MCB002	OPEN	CLOSED	OPEN
MCB003	CLOSED	CLOSED	OPEN

RECORD DRAWING

ONSI CORPORATION 195 Governors Highway P.O. Box 1148 South Windsor, CT 06074	PC25B FUEL CELL POWER PLANT INSTALLATION NAVAL HOSPITAL, WENTYNINE PALMS MCGACC, CALIFORNIA		
	DRAWING NAME: ELECTRICAL INTERFACE DETAILS		
CAD File: 29FALMS3.DCS Plot File:	Drawn By: J.Stanunas Date Drawn: 10-19-94	Revised By: J.Stanunas Date Revised: 6-19-95	Drawing No: 9061 E-2

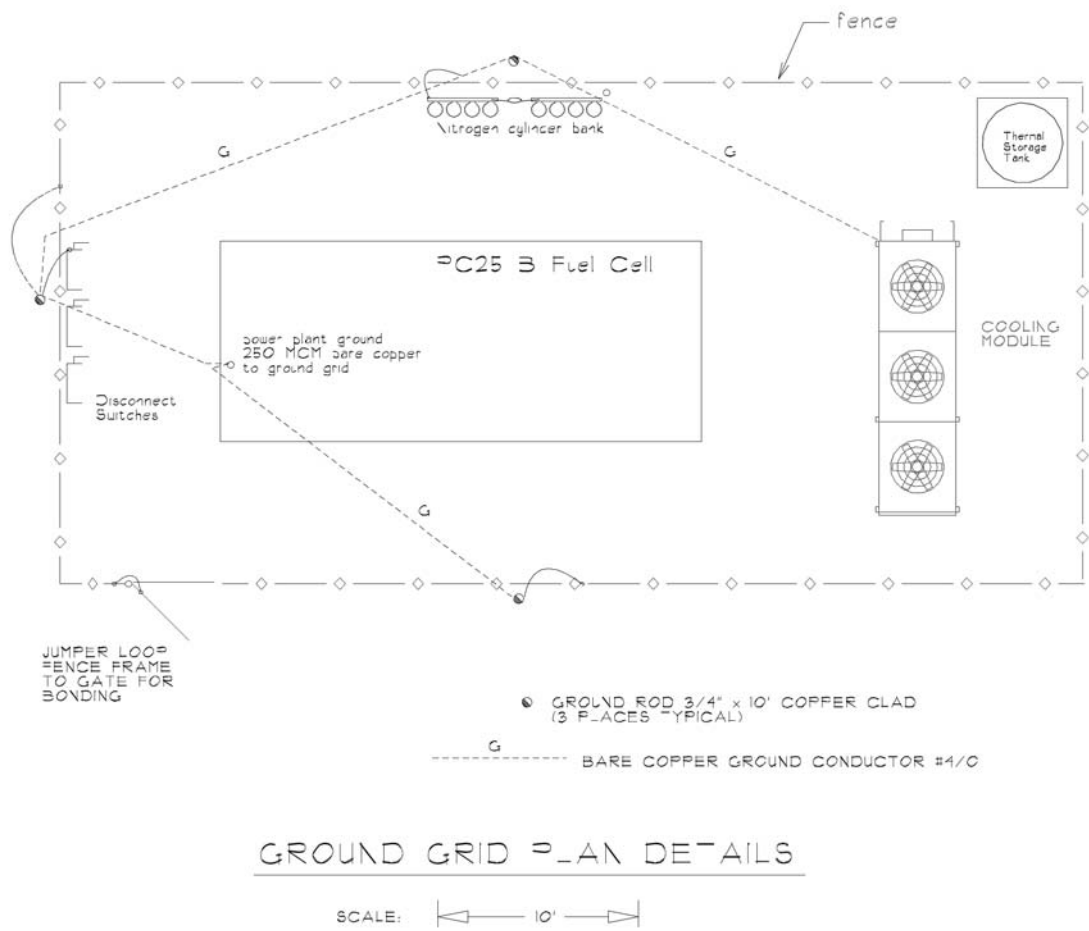
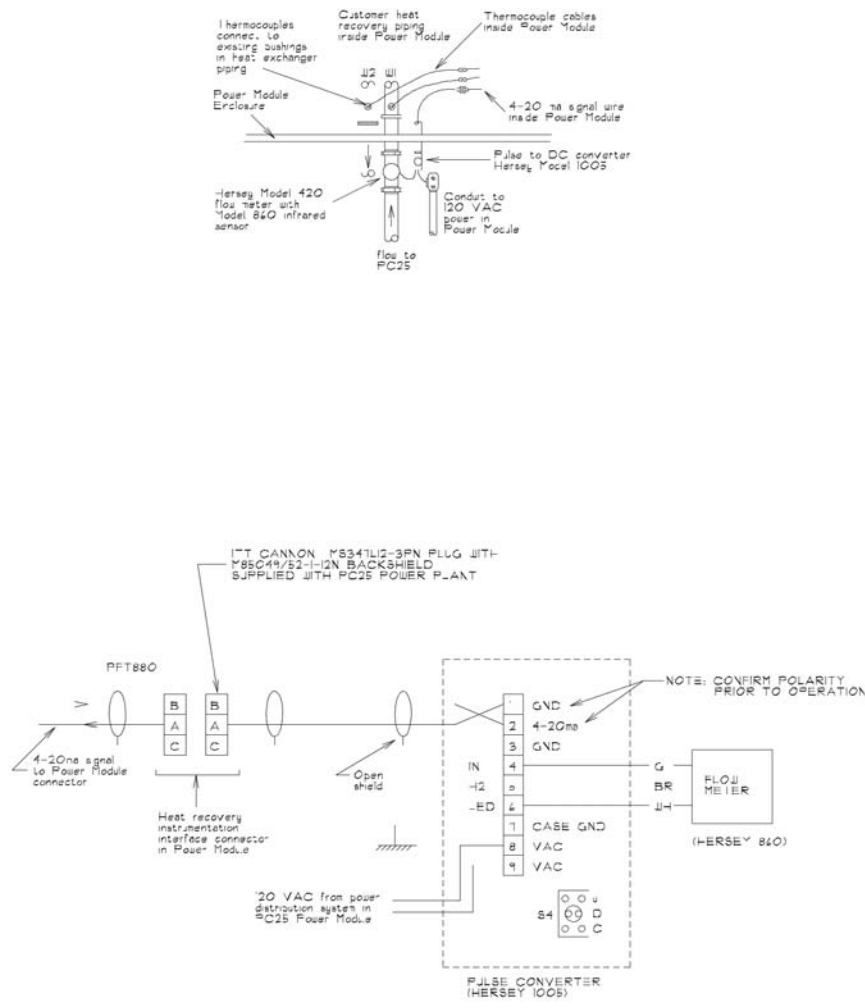


Figure 7. Final installation drawing – ground grid plan details.



POWER PLANT HEAT RECOVERY BTU METERING
(NOT TO SCALE)

RECORD DRAWING

REVISIONS		PC25B FUEL CELL POWER PLANT INSTALLATION		
Revision No. 1		NAVAL HOSPITAL, TWENTYNINE PALMS MCGACC, CALIFORNIA		
Description:		DRAWING NAME:		
1" draw line changed to 3".		ELECTRICAL DETAILS		
Descriptions regarding the		Drawn By: J. Stanlunas		
120V supply to flowmeter and		Date Drawn: 2-27-95		
the output power to Room		Revised By: J. Stanlunas		
PC05 clarified.		Date Revised: 6-19-95		
CAD File: 29PALMS3.DCS		Drawing No: 006 E-3		
Plot File:				

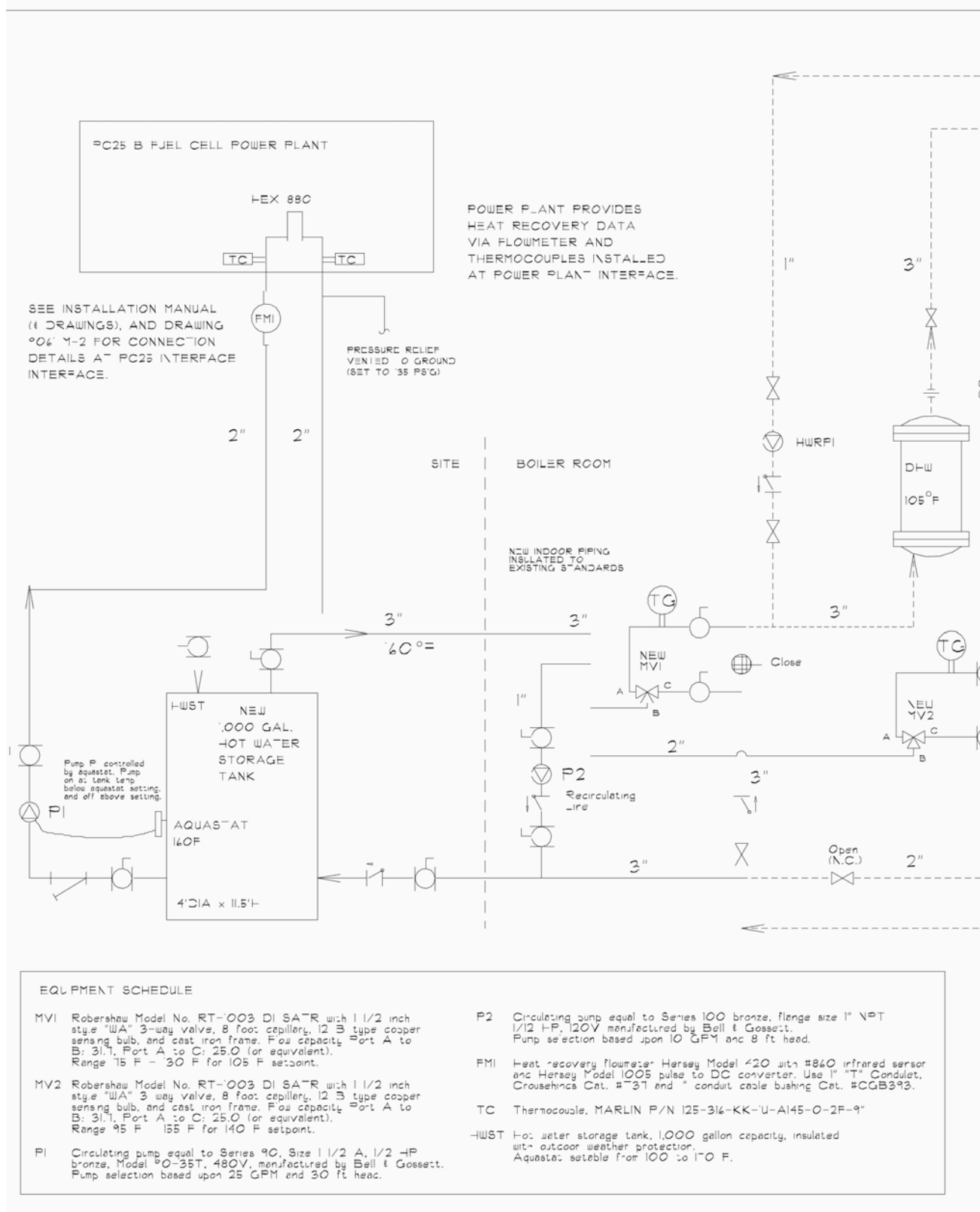
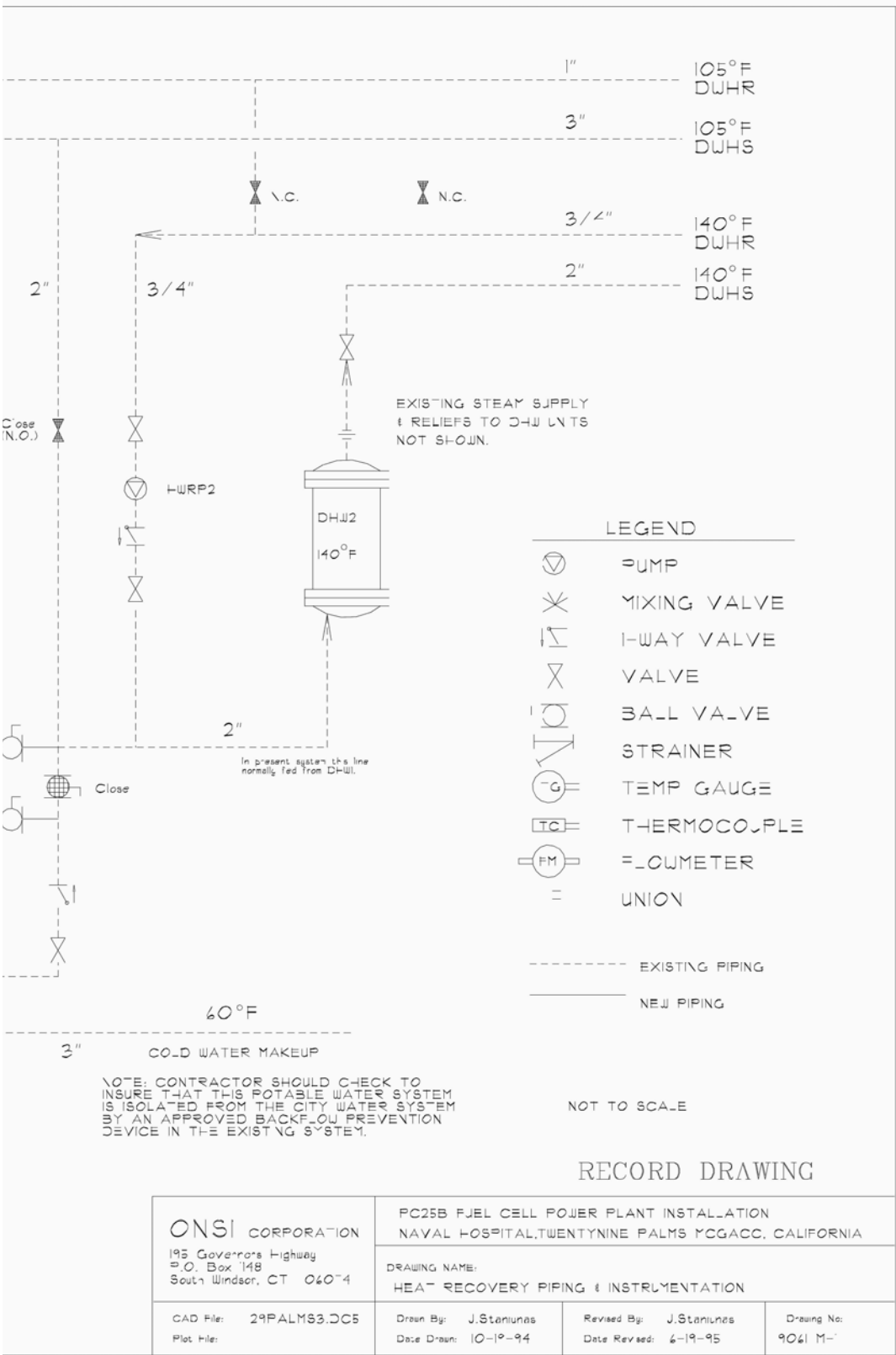


Figure 8. Final installation drawing – heat recovery piping and instrumentation.



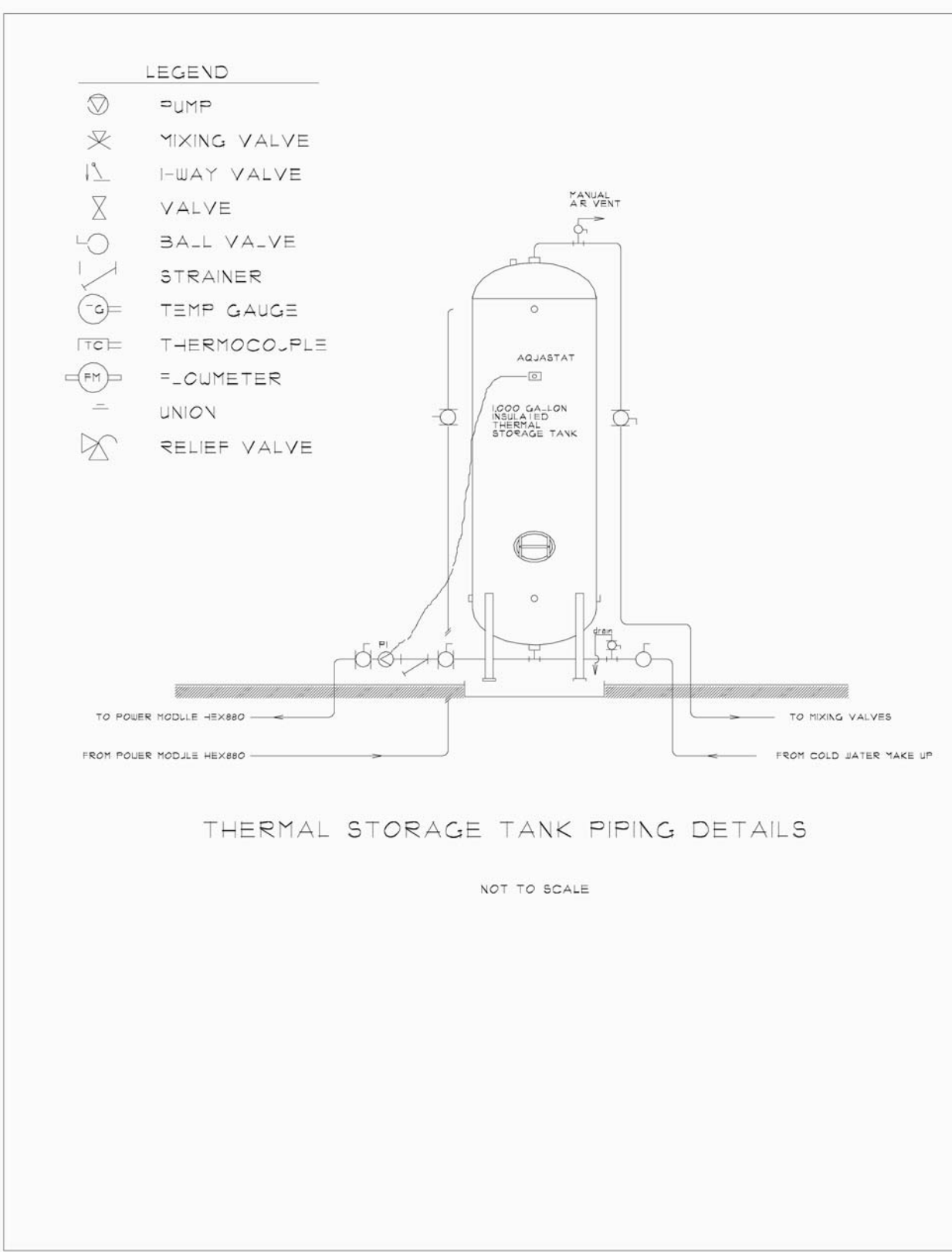
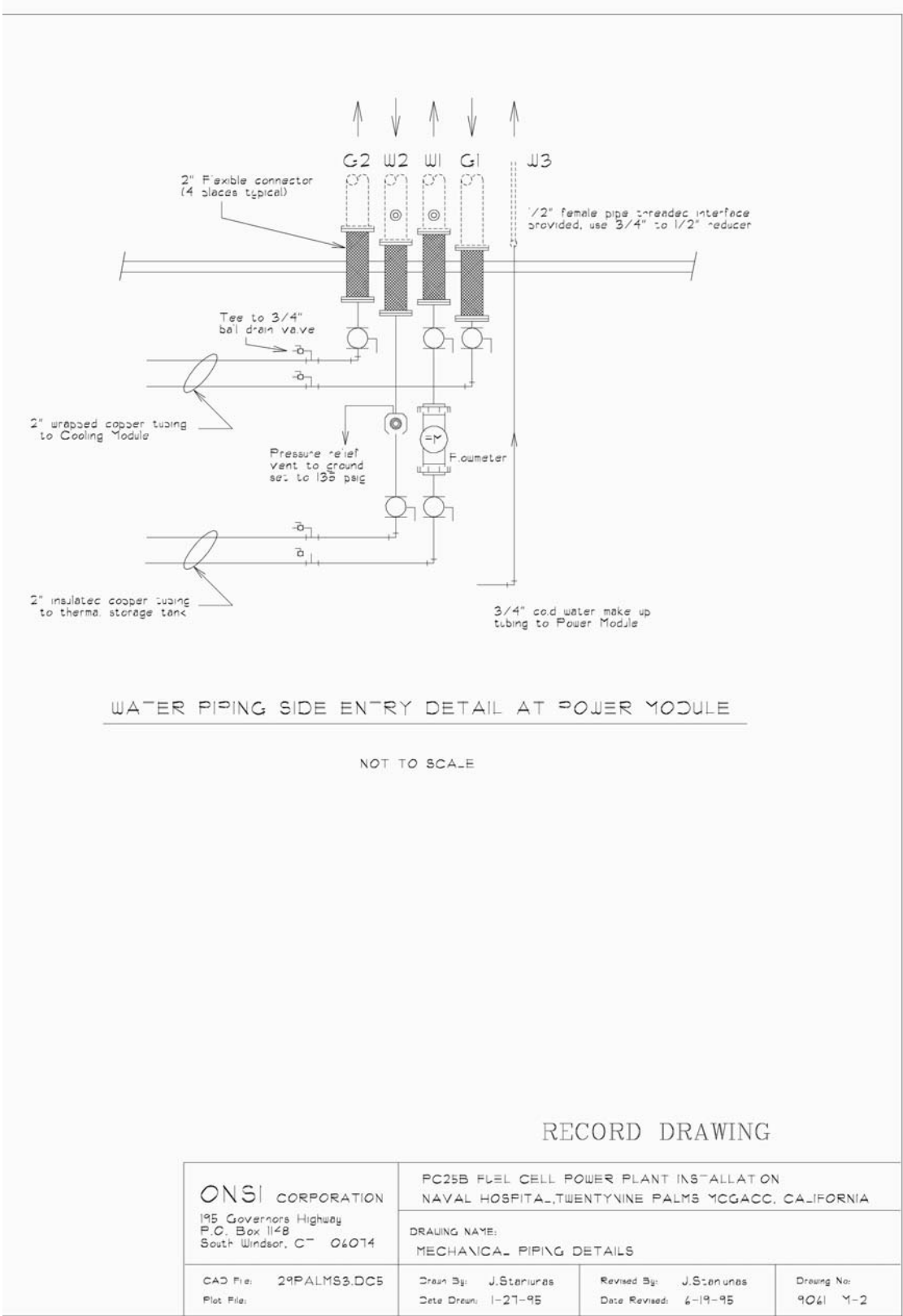


Figure 9. Final installation drawing – mechanical piping details.



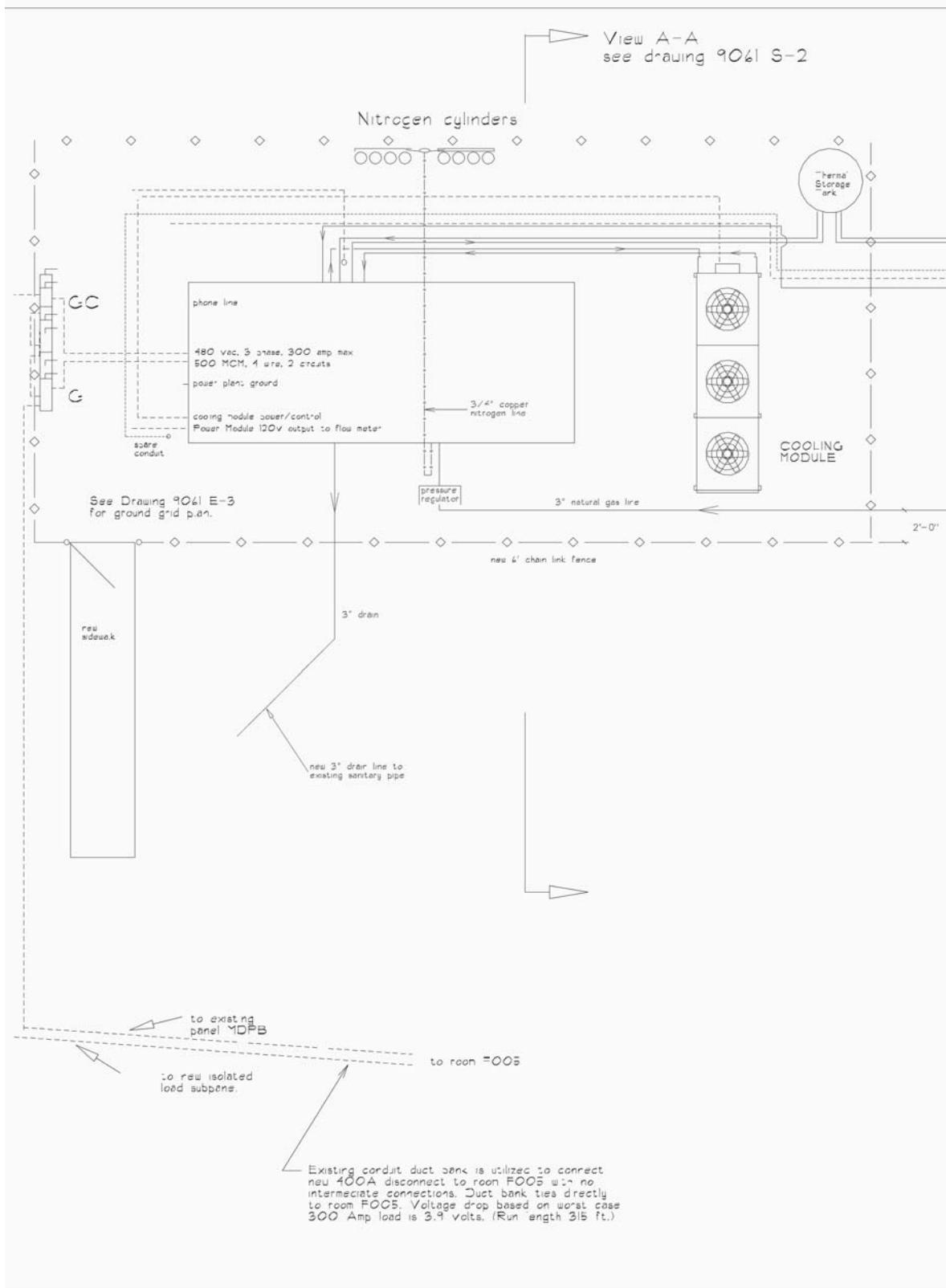
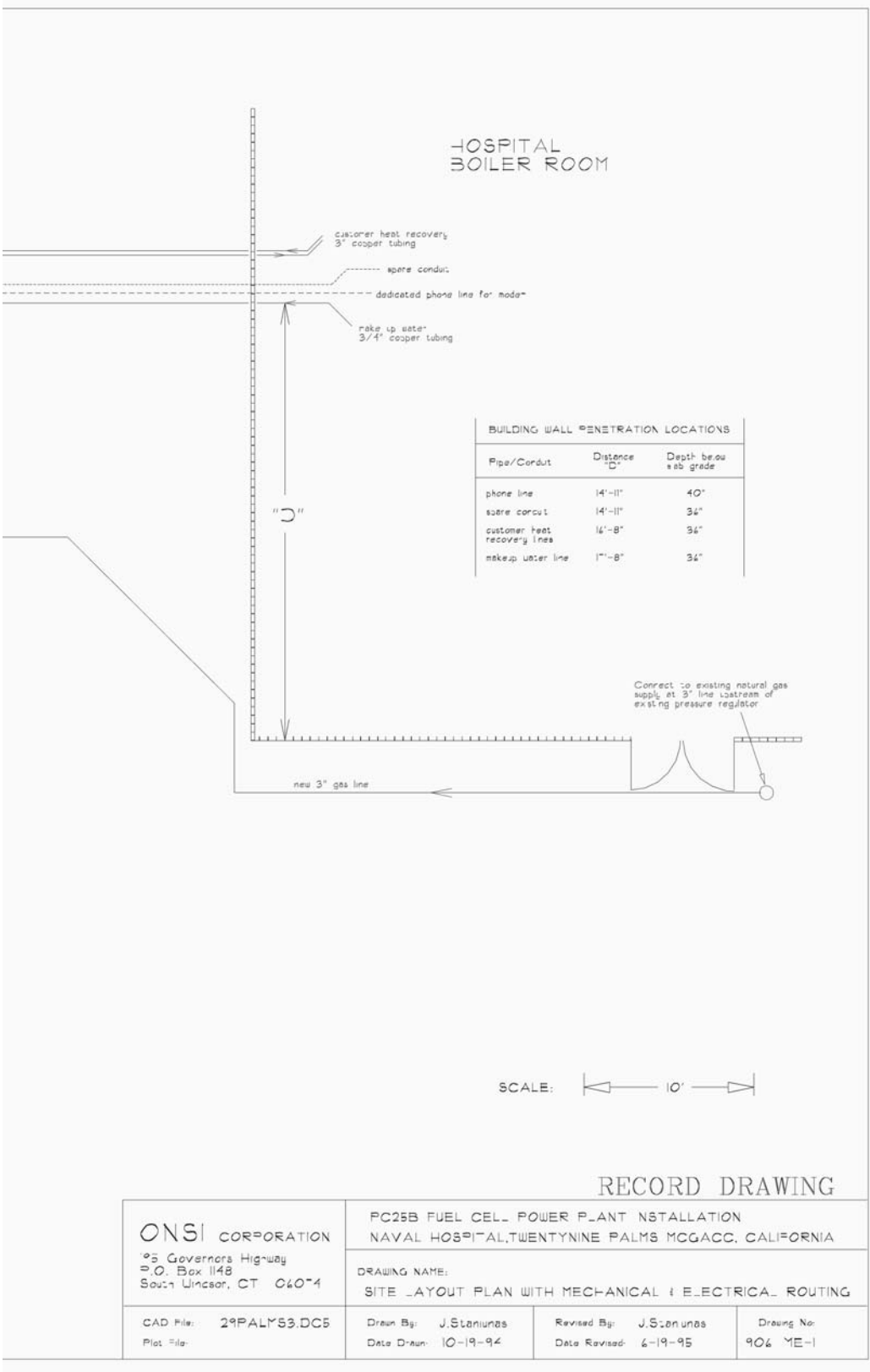


Figure 10. Final installation drawing – layout plan with mechanical and electrical routing.



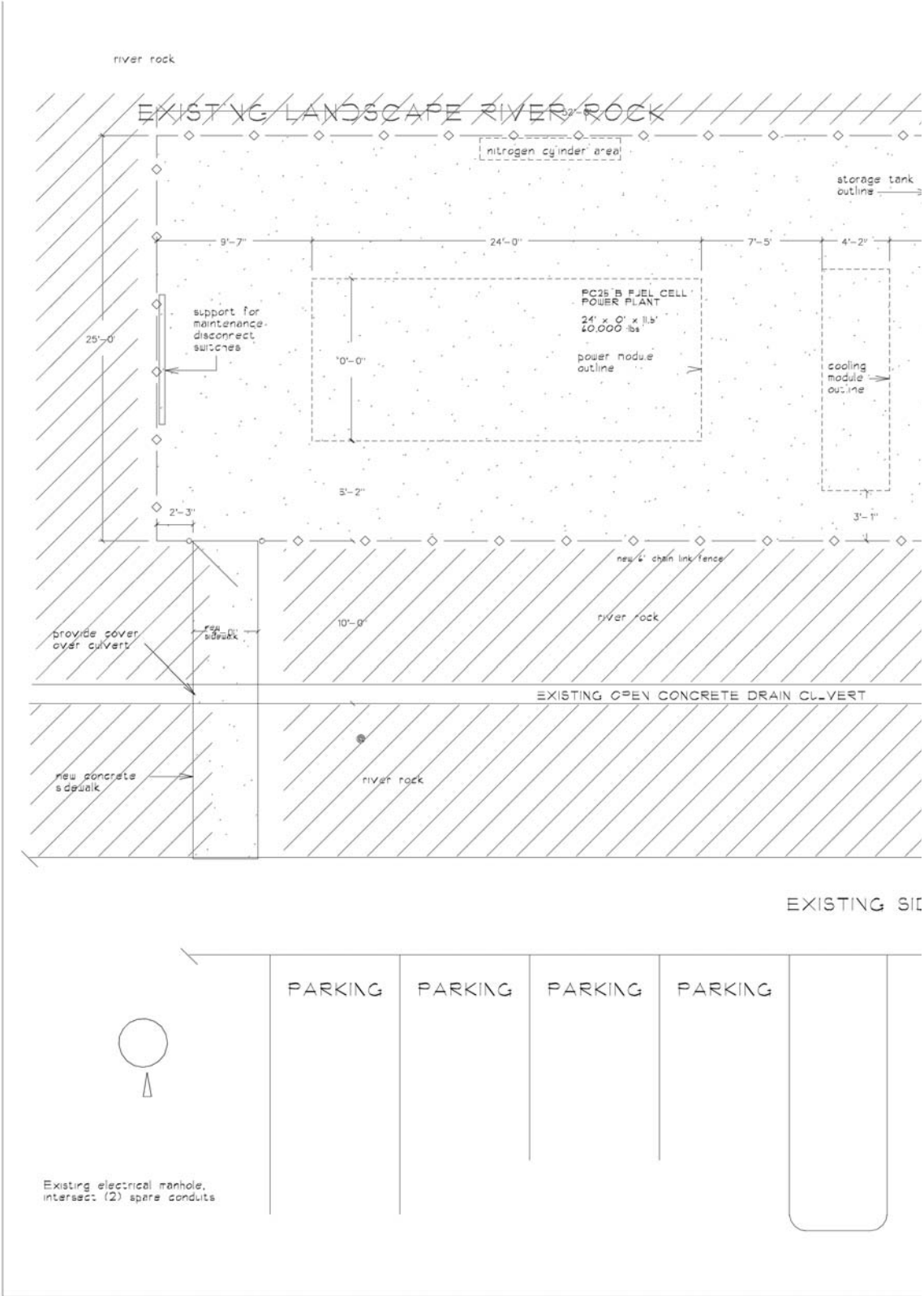
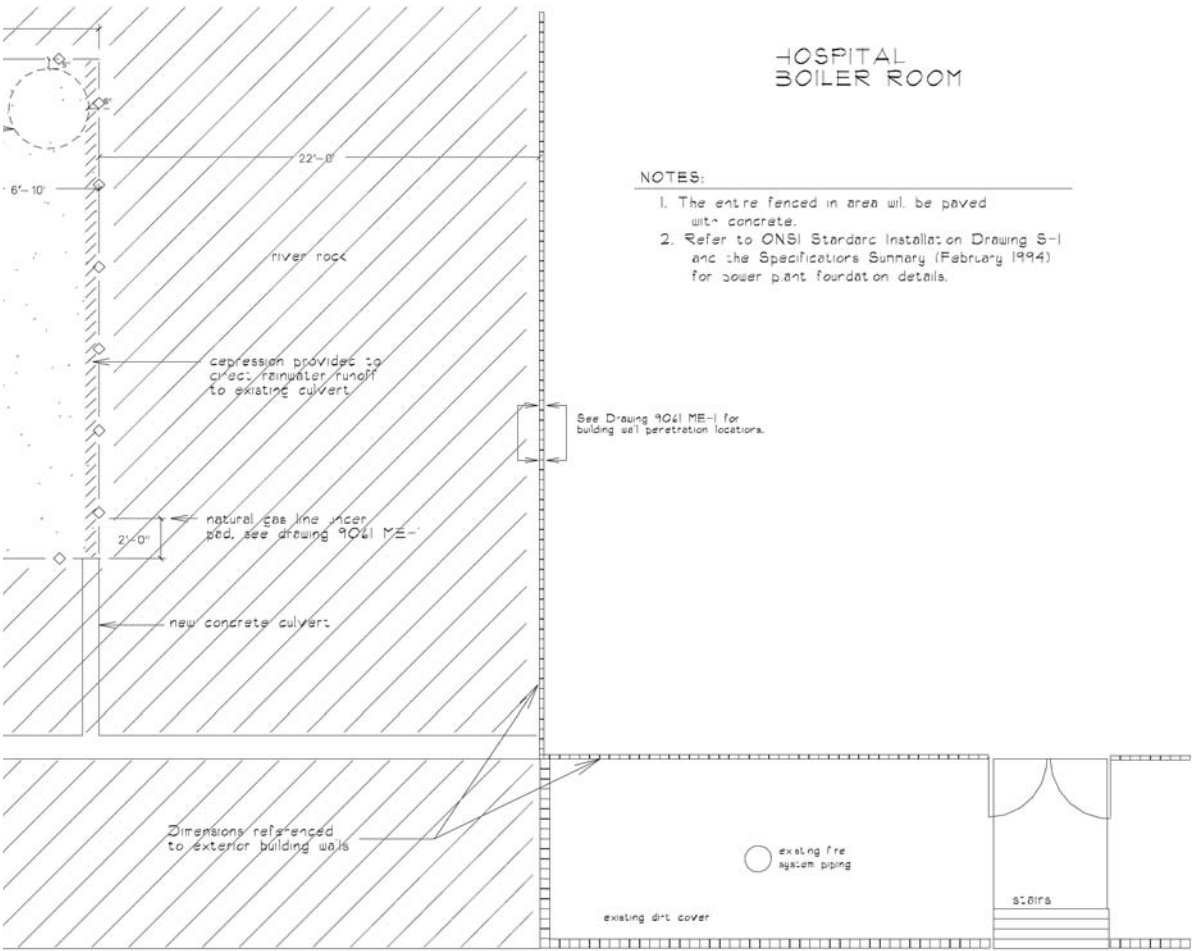


Figure 11. Final installation drawing – foundation layout plan.



HOSPITAL
BOILER ROOM

- NOTES:
- 1. The entire fenced in area will be paved with concrete.
 - 2. Refer to ONSI Standard Installation Drawing S-1 and the Specifications Summary (February 1994) for power plant foundation details.

DEWALK

EXISTING SIDEWALK

PAVED AREA FOR HOSPITAL
LOADING DOCKS

SCALE: 1" = 10'

RECORD DRAWING

ONSI CORPORATION 95 Governors Highway P.O. Box 1148 South Windsor, CT 06094		PC25B FUEL CELL POWER PLANT INSTALLATION NAVAL HOSPITAL, TWENTYNINE PALMS MCGACC, CALIFORNIA	
CAD File: 29PALMS3.DCS Plot File:		DRAWING NAME: FOUNDATION LAYOUT PLAN	
Drawn By: J. Stanunas	Revised By: J. Stanunas	Drawing No:	
Date Drawn: 10-19-94	Date Revised: 6-19-95	906 S-1	

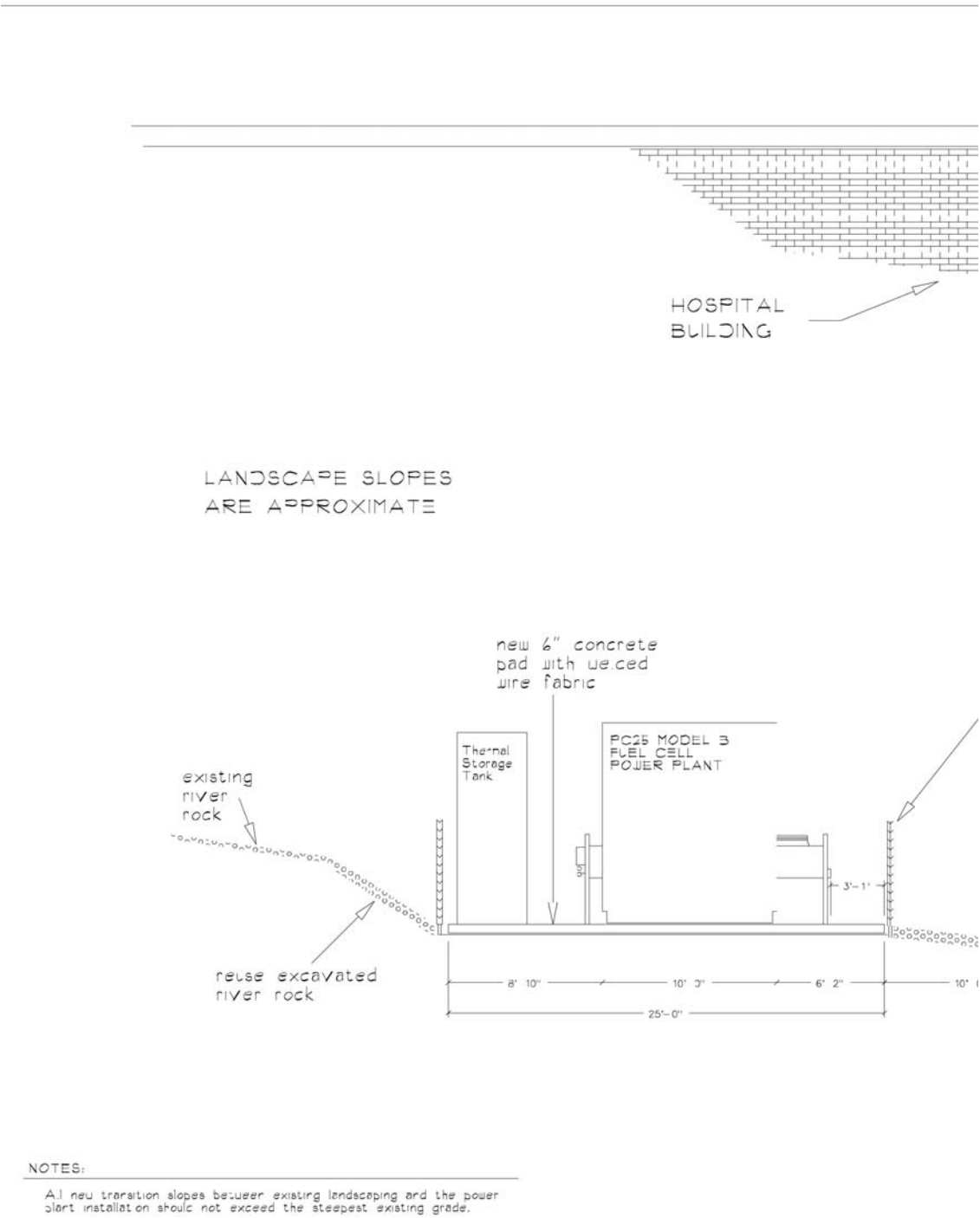
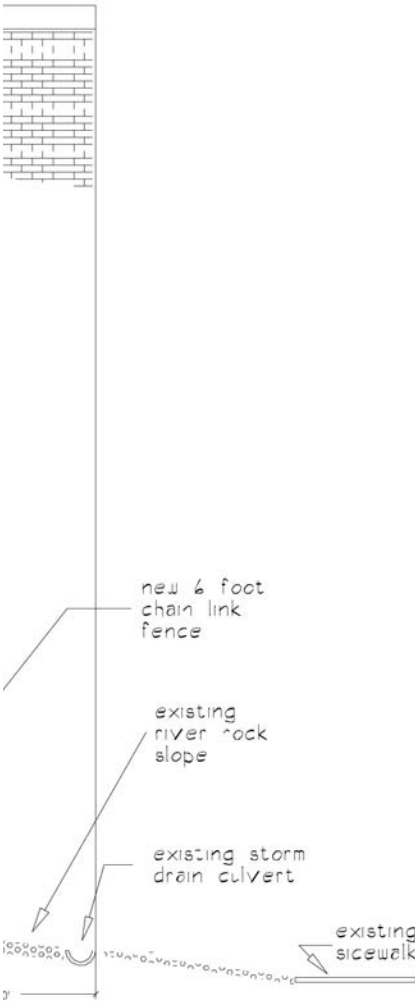


Figure 12. Final installation drawing – foundation layout plan side view.



VIEW A A

SCALE: 1" = 10'

RECORD DRAWING

ONSI CORPORATION 195 Governors Highway P.O. Box 148 South Windsor, CT 06094	FC25B FUEL CELL POWER PLANT INSTALLATION NAVAL HOSPITAL, TWENTYNINE PALMS MCGACC, CALIFORNIA		
CAD File: 29PALMS3.DC5 Plot File:	DRAWING NAME: FOUNDATION LAYOUT PLAN / SIDE VIEW A-A		Drawing No: 9061 S 2
	Drawn By: J.Staniunas Date Drawn: 10/9/94	Revised By: J.Staniunas Date Revised: 6/19/95	

4 Fuel Cell Performance

This Chapter summarizes fuel cell operating performance, outage history, and maintenance activities.

4.1 Operating History

The fuel cell started operation in mid-June of 1995. Acceptance tests were performed between 16 and 21 June. Appendix A includes the Acceptance Test Report. Official data recording for the demonstration began on 20 June. The formal acceptance test meeting was held a few days later on 23 June, with title to the fuel cell transferred to the Naval Hospital using Form DD250. The power plant continued to operate (for 912 hours of continuous operation) until an event on 28 July 1995. A total of 36 power plant shut downs were recorded between 20 June 1995 with the final shut down occurring on 26 May 2000. There were 33 forced outages and 3 scheduled outages.

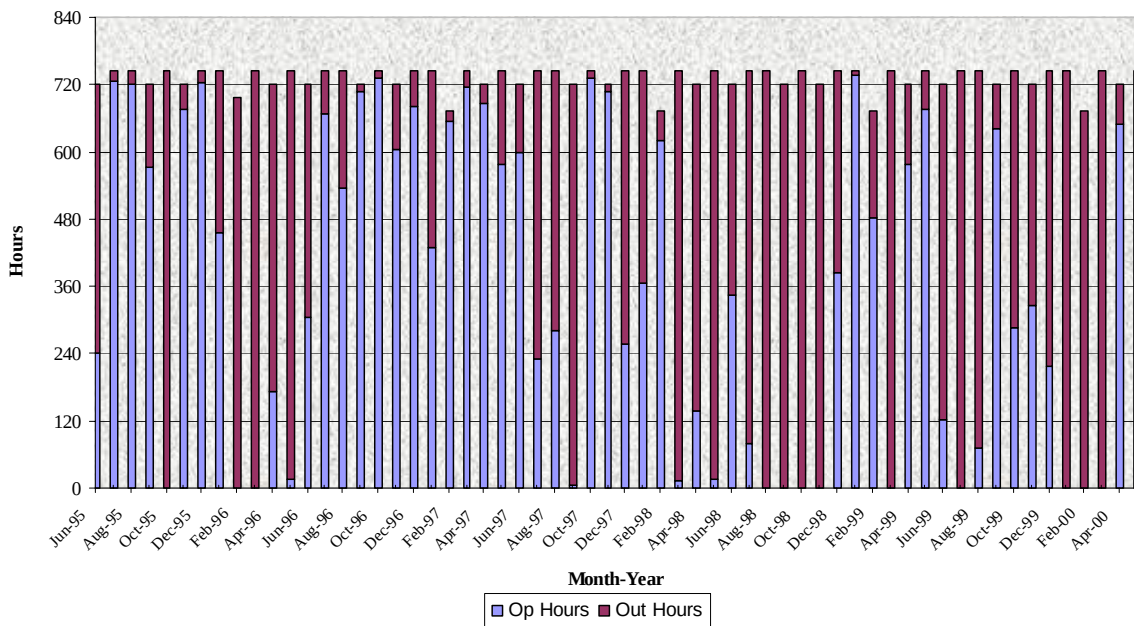
Performance data was collected via UTC Fuel Cells' RADAR data acquisition system. Using a modem and telephone line, the power plant was called routinely to retrieve a "snapshot" of the current status. Included in the metrics collected were cumulative totals for hot time, load time, MWHrs, input fuel, thermal output, etc. These data records were then used to generate the various performance parameters discussed in this report.

A total of 21,890 operating load hours were recorded for the Naval Hospital fuel cell. Of the 36 separate operating periods, eight of them had continuous fuel cell operating hours of more than 1,000 hours. The longest continuous operating period was 2,069 hours (~12 weeks) and occurred between 9 August and 3 November 1996. Table 4 lists the distribution of continuous periods of operation for this fuel cell.

Figure 13 shows the hours of operation and outages on a monthly basis for the entire demonstration period. Between 20 June 1995 and 20 May 2000 (43,094 hours), the fuel cell operated a total of 21,890 hours, which represents an availability of 50.8 percent.

Table 4. Distribution of continuous hours of operation.

Hours of Operation	Occurrences
Over 3,000 hours	0
2,001 – 3,000 hours	1
1,001 – 2,000 hours	7
751 – 1,000 hours	5
501 – 750 hours	5
250 – 500 hours	4
Less than 250 hours	14

**Figure 13. Fuel cell operating hours by month.**

The fuel cell generated over 3.5 million kWh of electricity for the Naval Hospital during the demonstration period. The data listed in Table 5 summarize annual fuel cell electrical performance at the Naval Hospital. The average electrical output of the fuel cell during operation was 161 kW over the 5+ year period. The data shows that the average annual rate of electrical output from the fuel cell through 1997 was 175 kW and decreased to an average low of 123 kW in 1999.

Table 5. Fuel cell electrical performance characteristics.

Year	Operating Hours	MWhrs	Avg. kW
1995	3,705	633.8	171
1996	4,836	838.8	173
1997	5,970	1,071.5	179
1998	1,989	315.8	159
1999	4,253	521.7	123
2000	1,136	140.8	124
Total/Avg.	21,890	3,522.4	161

The average rate of heat recovered and used by the Naval Hospital “thermal utilization” was only a fraction of the fuel cell’s 700,000 Btu/hour capacity. The site only used an average of 40,750 Btu/hour (<6 percent utilization). The data indicates that no heat was recovered in 2000. The level of heat recovery is important in that heat recovered from the fuel cell offsets the quantity of heat that must be produced (i.e., reduces natural gas consumption) by conventional heating systems at the facility thereby creating additional cost savings attributable to the fuel cell. Table 6 lists thermal output performance as well as natural gas consumption characteristics for the fuel cell. The fuel cell consumed natural gas at an average rate of 1,664.3 cu ft per hour during the course of the demonstration. The rate of natural gas consumption is fairly linear with the electric output at 10.5 cu ft/kW. The thermal efficiency component for the heat recovered from the fuel cell added approximately 2.38 percent to overall efficiency of the fuel cell.

Table 6. Fuel cell input fuel and thermal output characteristics.

Year	Input Fuel (cu ft)	Input Fuel (cu ft/hr)	Thermal Heat Recovery (therms)	Avg. Rate of Thermal Heat Recovery (kBtu/hr.)	Fuel Cell Thermal Efficiency (HHV) %*
1995	6,488,973.3	1,751.3	2,146.4	57.9	3.21
1996	8,339,251.1	1,724.3	3,118.1	64.5	3.63
1997	11,093,926.4	1,858.2	3,251.1	54.5	2.85
1998	3,419,098.2	1,718.7	226.2	11.2	0.63
1999	5,577,173.3	1,311.3	182.1	4.3	0.32
2000	1,514,140.0	1,333.1	0	0	0.00
Total/Avg.	36,432,562.3	1,664.3	8,923.9	40.8	2.38

* Higher Heating Value (HHV) is based on a natural gas heating value of 1,030 Btu/cubic foot.

Table 7 lists the fuel cell electrical efficiency based on higher heating value (HHV) for each year of operation. The average electrical efficiency for the demonstration was 32.0 percent (HHV).

Table 7. Fuel cell electric efficiency.

Year	MWhrs	Input Fuel (cu ft)	Electrical Efficiency (HHV)- %*
1995	633.8	6,488,973.3	32.4
1996	838.8	8,339,251.1	33.3
1997	1,071.5	11,093,926.4	32.0
1998	315.8	3,419,098.2	30.6
1999	521.7	5,577,173.3	31.0
2000	140.8	1,514,140.0	30.8
Total/Avg.	3,522.4	36,432,562.3	32.0
* Higher Heating Value (HHV) is based on a natural gas heating value of 1,030 Btu/cubic foot, calculated as: $\text{Efficiency} = ((\text{MWhrs} \times 1,000,000 \text{ Watt-hrs/MWhrs} \times 3.413 \text{ Btu/Watt}) / (\text{cu ft} \times 1,030 \text{ Btu/cubic foot})) \times 100$			

4.2 Fuel Cell Outage Summary

Between 20 June 1995 and 20 May 2000 (43,094 hours), the fuel cell had 36 outages resulting in 21,204 hours of downtime. The fuel cell's availability was 50.8 percent:

$$50.8\% = ((43,094 - 21,204) / (43,094)) \times 100$$

The outages were identified from the RADAR performance monitoring system data. Because data records are collected on average once per day, outage times occasionally had to be interpolated. Sometimes the modem did not respond or the phone line was down, which prevented a full complement of data records.

The longest outage was for 3,937 hours and occurred between 4 July and 15 December 1998. The next longest outage period occurred between 10 December 1999 and 3 April 2000 (2,746 hours). Table 8 lists the distribution of outage periods by hours of outage duration.

Table 9 lists the start and end dates/times (chronologically), the outage duration hours, and the outage type for the 36 individual events. Appendix D includes the complete list of outage codes for the PC25B fuel cell.

Table 8. Distribution of non-operational hours by duration.

Outage Hours	Occurrences
Over 3,000 hrs	1
2,001 – 3,000 hrs	2
1,001 – 2,000 hrs	1
751 – 1,000 hrs	1
501 – 750 hrs	0
250 – 500 hrs	10
Less than 250 hrs	27

Table 9. List of fuel cell outage periods.

No.	Off Date Stamp	On Date Stamp	Total Outage Hrs	Hours to Next Outage	Type	System	Part
		6/20/95 15:51		912.00			
1	7/28/95 15:51	7/28/95 16:24	0.55	823.10	F	APS	FT140
2	8/31/95 23:30	9/3/95 11:34	60.07	597.35	F	TMS	TCV400
3	9/28/95 08:55	11/2/95 09:11	840.27	1753.15	F	TMS	PMP400
4	1/14/96 10:20	4/17/96 14:02	2,259.70	173.85	F	OTR	SBSTK
5	4/24/96 19:53	5/4/96 18:40	238.78	15.55	F	CVS	CV500
6	5/5/96 10:13	6/14/96 13:20	963.12	5.00	F	ES	MCB001
7	6/14/96 18:20	6/18/96 22:55	100.58	968.08	F	ES	MCB002
8	7/29/96 07:00	8/9/96 15:30	272.50	2068.70	N		
9	11/3/96 20:12	11/6/96 10:19	62.12	693.02	F	TMS	FS400
10	12/5/96 07:20	12/7/96 10:50	51.50	947.87	F	OTR	
11	1/15/97 22:42	1/28/97 20:30	309.80	247.67	F	OTR	CRB
12	2/8/97 04:10	2/8/97 17:55	13.75	723.98	F	OTR	CRB
13	3/10/97 21:54	3/11/97 18:05	20.18	531.25	F	OTR	
14	4/2/97 21:20	4/3/97 20:01	22.68	1235.48	F	OTR	
15	5/25/97 07:30	6/5/97 23:25	279.92	659.68	F	FPS	
16	7/3/97 11:06	7/22/97 18:36	463.50	65.68	F	TMS	FT140
17	7/25/97 12:17	7/26/97 14:44	26.45	135.53	N		
18	8/1/97 06:16	8/13/97 16:56	298.67	120.07	F	OTR	PC
19	8/18/97 17:00	8/22/97 13:08	92.13	160.20	F	OTR	K001
20	8/29/97 05:20	9/30/97 19:28	782.13	1603.53	F	ES	UPS001
21	12/6/97 15:00	12/26/97 14:27	479.45	300.85	F	OTR	K002
22	1/8/98 03:18	1/23/98 13:50	370.53	851.75	F	OTR	FCV012
23	2/28/98 01:35	3/26/98 17:20	639.75	12.18	F	OTR	
24	3/27/98 05:31	4/18/98 11:50	534.32	137.00	F	ES	UPS001
25	4/24/98 04:50	5/11/98 19:00	422.17	17.32	F	ES	MCB003
26	5/12/98 12:19	6/16/98 16:32	844.22	429.87	F	OTR	CSA
27	7/4/98 14:24	12/15/98 16:05	3,937.68	1626.92	N	TMS	
28	2/21/99 11:00	4/6/99 21:00	1,066.00	1008.33	F	OTR	GRND

Table 9. List of fuel cell outage periods.

No.	Off Date Stamp	On Date Stamp	Total Outage Hrs	Hours to Next Outage	Type	System	Part
29	5/18/99 21:20	5/20/99 16:30	43.17	349.83	F	APS	FT140
30	6/4/99 06:20	8/20/99 13:48	1,855.47	122.18	F	OTR	
31	8/25/99 15:59	9/2/99 12:08	188.15	8.58	F	APS	FT140
32	9/2/99 20:43	9/3/99 17:12	20.48	1018.30	F	APS	FIL100
33	10/16/99 03:30	11/1/99 19:31	400.02	149.02	F	WTS	
34	11/8/99 00:32	11/23/99 13:06	372.57	408.60	F	OTR	INV
35	12/10/99 13:42	4/3/00 00:00	2,746.30	1134.00	F	TMS	FS400
36	5/20/00 06:00	Final Outage			F	PSS	VT310

Thirty-three of the outages were classified as “forced outages,” which contributed to a total of 16,420 hours of down time. Forced outages are broadly classified by the major fuel cell sub-systems listed in Table 10.

Table 10. Forced outage categories.

Category	Description
PSS	Power section system
APS	Air processing system
CVS	Cabinet ventilation system
ES	Electrical system
FPS	Fuel processing system
OTR	Other
TMS	Thermal management system
WTS	Water treatment system

Table 11 lists the forced outages by major system categories.

Table 11. Forced outage statistics.

Category	Number of Occurrences	Total Outage Time	Min. Outage Time per Occurrences	Max. Outage Time per Occurrences	Avg. Outage Time per Occurrence
APS	4	252.4	0.6	188.2	63.1
CVS	1	238.8	238.8	238.8	238.8
ES	5	2,802.3	100.6	963.1	560.5
FPS	1	279.9	279.9	279.9	279.9
OTR	14	7,852.2	13.8	2,259.7	560.9
PSS*	1	0.0	—	—	—
TMS	6	4,594.4	60.1	2,746.3	765.7
WTS	1	400.0	400.0	400.0	400.0
	33	16,420			497.6
*Final outage (no time associated)					

Fourteen of the thirty-three (42 percent) forced outages were classified as Other. The most frequent number of outages in the Other category were attributed to circuit breakers (CRB). In addition, circuit breakers K001 and K002 were attributed to 571.6 hours of total outages. The longest outage in the Other category was 2,259.7 hours (between January and April 1996) due to a problem with the cell stack. This occurred early on in the demonstration with 4,174 load hours on the fuel cell. At this time the cell stack was replaced. In July 1996, an external reverse osmosis water treatment unit was installed to address hard water problems that were having adverse affects on the fuel cell operation. Similar characteristics were also observed in other fuel cells installed in the southwestern region of the country, including Camp Pendleton, Edwards AFB, Davis-Monthan AFB, and Fort Huachuca. After significant analysis by UTC Fuel Cells, it was concluded that the hard water characteristics of the water supply was contributing to restrictions and blockages in the cooling system, which subsequently caused some of the fuel cell stacks to overheat and fail. Hard water is water that contains a high level of dissolved minerals, most notably calcium and magnesium. The degree of hardness increases with increased levels of calcium and magnesium. When hard water is heated, the dissolved minerals precipitate out of solution and attaches to plumbing and heat exchangers. To control the water chemistry of these systems, water treatment systems were installed.

The fewest number of forced outages by major system type (one occurrence each) were for the cabinet ventilation, fuel processing, and power section systems. The outage associated with the power section system was the final outage, which was not resolved.

Figure 14 shows a graph of forced outage occurrences.

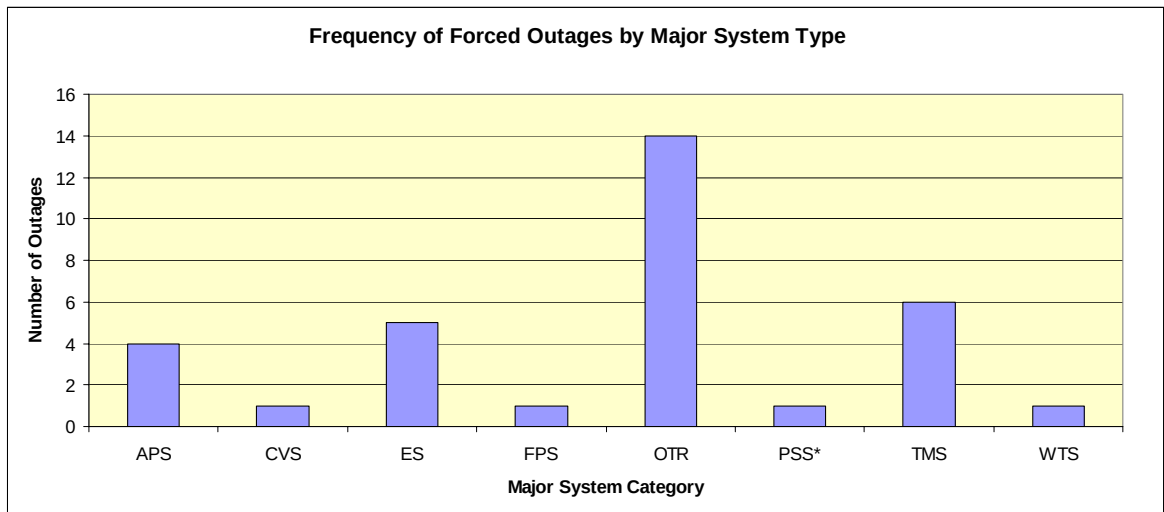


Figure 14. Forced outage occurrences by major system types.

Figure 15 shows the average duration of forced outage hours by major system category. The Thermal Management System (TMS) had the longest average duration at 765.7 hours per outage. The TMS accounted for 6 outages and a total of 4,594.4 hours. The shortest TMS outage was 60.1 hours (temperature control valve: TCV400) and the longest outage was 2,746.3 hours (flow switch: FS400).

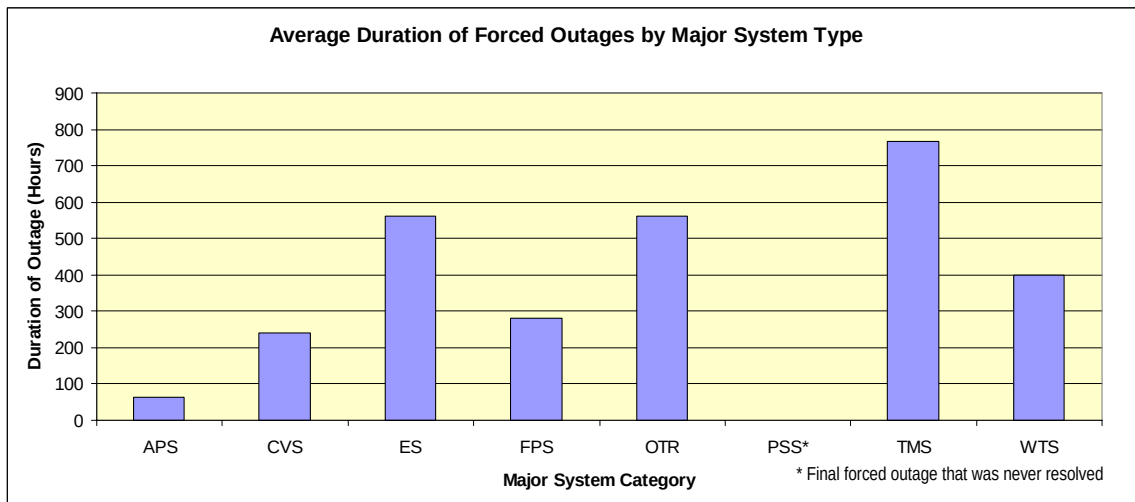


Figure 15. Average forced outage durations by major system types.

The outages that occurred most frequently for a specific fuel cell component were the motorized circuit breakers (MCB) and the air flow transmitter (FT140). During the demonstration, each of the three MCBs failed and accounted for a total of 1,485.9 hours of fuel cell outage. In addition, FT140 attributed to three forced outages for a combined duration of 695.4 hours.

These data show that forced outages have a significant impact on the availability of the fuel cell. The shortest outage lasted for 0.55 hours, and five outages lasted less than 24 hours. Of nine total outages with durations over 30 days, three lasted more than 90 days. Figure 16 shows the distribution of outages by their duration.

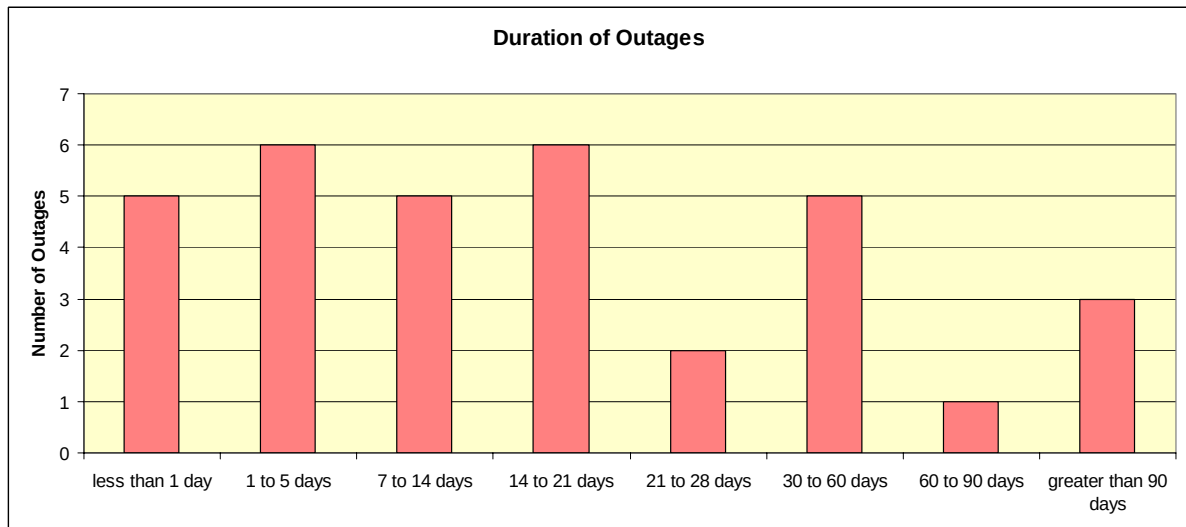


Figure 16. Number of forced outages by outage duration.

Figure 17 shows the total hours of forced outage based on the major system category with the OTR at 48 percent and TMS at 28 percent.

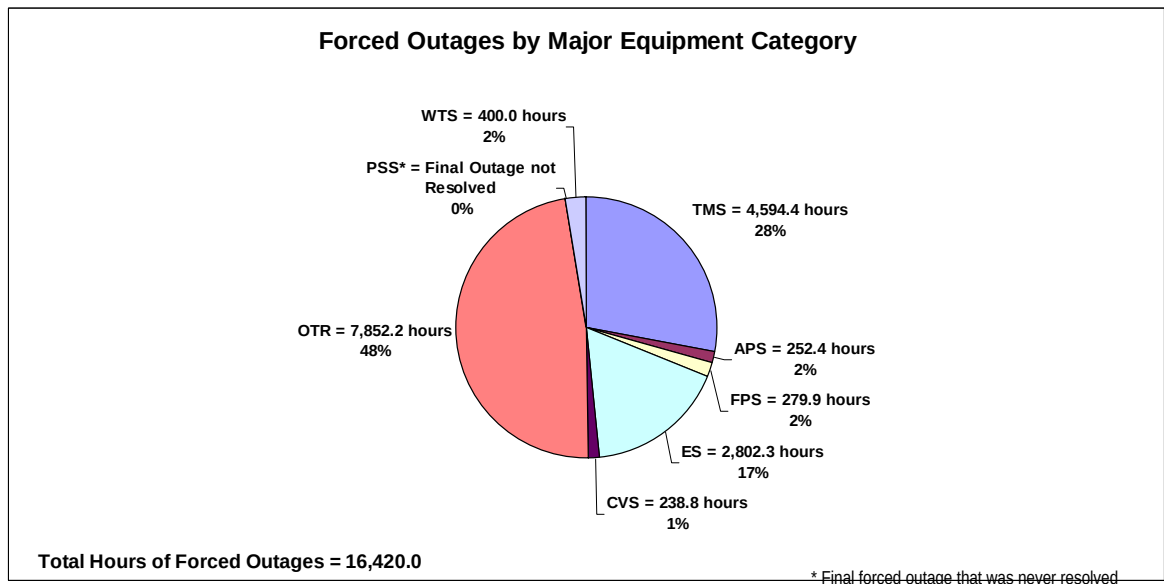


Figure 17. Total forced outage hours by major system types.

4.3 Fuel Cell Stack Degradation

The trend of the fuel cell electrical efficiency based on the lower heating value (LHV) of natural gas was analyzed based on the hours of fuel cell operation. The data was acquired through the UTC Fuel Cells' RADAR system. Data records are for fuel cell operation when the electrical output was greater than 50 kW in order to eliminate data from fuel cell testing and startup operation. Note that the data records were not recorded on regular intervals and 3,126 data points were used for this analysis. Figure 18 charts the individual data points with hours of operation in an X-Y plot. For this data set, the average LHV electrical efficiency is 36.0 percent.

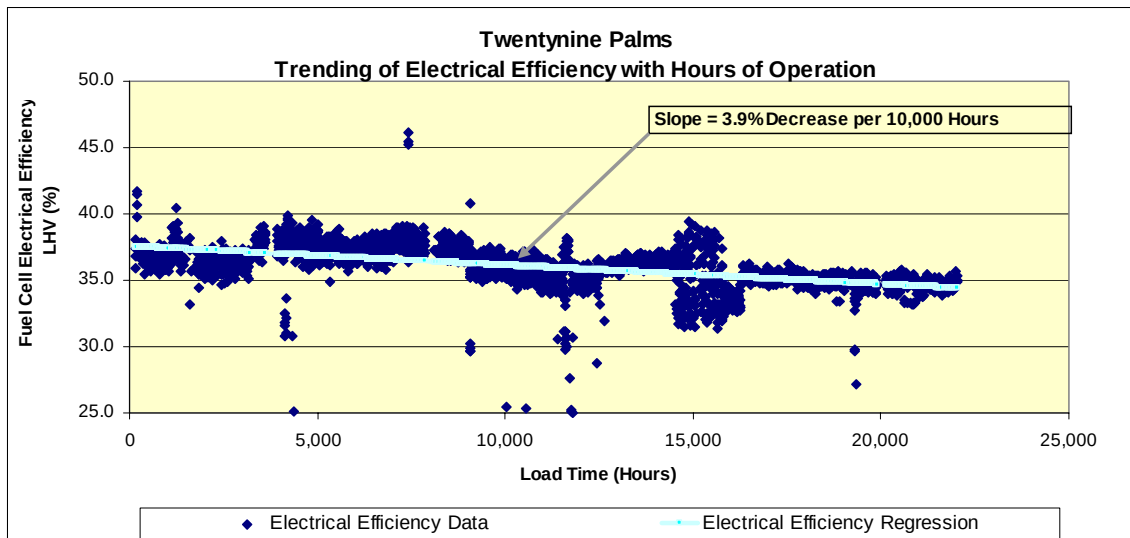


Figure 18. Fuel cell stack electrical efficiency degradation over time.

A linear regression was conducted on the data to characterize average efficiency trends for the fuel cell. The regression equation is:

$$\text{Electric Efficiency \% (LHV)} = ((\text{Load Hours}) \times (-1.42574 \times 10^{-4})) + 37.54944$$

The linear curve fit shows a trend of reduction in electrical efficiency with increasing hours of operation. Table 12 lists the resulting efficiencies at 5,000 load hour intervals.

Table 12. Trend of electrical efficiency with fuel cell load hours.

Load Hours	Electrical Efficiency LHV (%)
0	37.55
5,000	36.84
10,000	36.12
15,000	35.41
20,000	34.70
25,000	33.99

The data in Table 12 show that the fuel cell electrical efficiency decreased 1.42 basis points for every 10,000 hours of operation. The regression shows that the average initial electrical efficiency of the fuel cell was approximately 37.55 percent and it decreased at a rate of approximately 3.9 percent per 10,000 hours of operation. For example, the average decrease between 10,000 hours (36.12 percent) and 20,000 hours (34.70 percent) is:

$$3.9\% = ((36.12\% - 34.70\%) / 36.12\%)$$

The R Square statistic for the above regression is 0.21. This means that 21 percent of the variation seen in the trend of electrical efficiency can be attributed to load hours. Thus other factors in the system significantly affect the changes observed in electrical efficiency. The efficiency data shown in Figure 10 indicate that there are sub-trends in electrical efficiency within the life of the fuel cell's operation. Figure 19 shows the outages and identification of major system changes. Each of the 36 outages is represented as a circle on the 40 percent efficiency line. The figure identifies five major system changes that correspond to establishing a distinct electrical efficiency trend. The number identifier presented for the change corresponds to the outage number as listed in Table 9. The most significant changes were the installation of a new cell stack (#4), the installation of an external reverse osmosis (RO) water treatment system (#8), and the installation of a new fuel valve (#15). The six operational regions in Figure 11 were analyzed to determine the electrical efficiency trend by major system change. The trend in efficiency for each region was determined by a linear regression and the slope is reported in terms of percent change per 10,000 hours of operation. Note that the unit of percent change per 10,000 is presented for consistency and none of the regions evaluated consists of 10,000 hours of data. Table 13 lists the dates, fuel cell load hours, system changes and electric efficiency trends for each of the time frames.

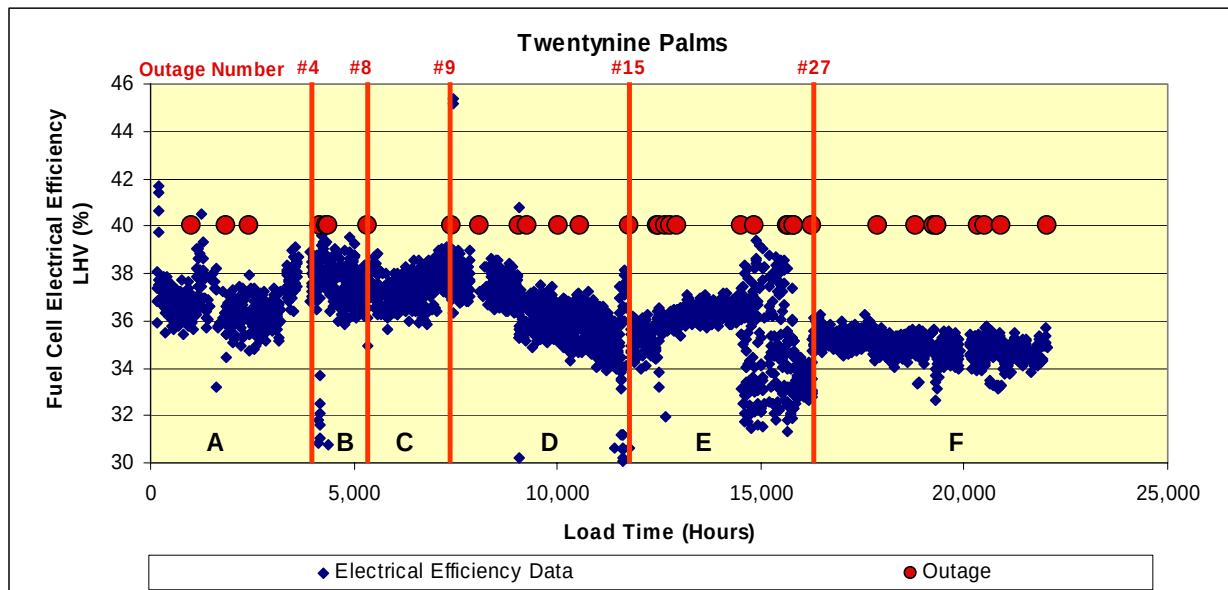


Figure 19. Electric efficiency trends with major system changes.

Table 13. Major system changes and electrical efficiency trends.

Range	Date	Fuel Cell Load hrs at End of Period	Change to System at Start of Period	Slope (% / 10000 hrs)
A	6/20/95 – 4/17/96	4,174	Initial System	No Trend
B	4/17/96 – 8/9/96	5,350	Install new cell stack	-1.8%
C	8/9/96 – 11/6/96	7,420	Install RO water treatment	12.7%
D	11/6/96 – 6/5/97	11,782	Repair coolant flow leak in TMS	-23.4%
E	6/5/97 – 12/15/98	16,262	Install new fuel valve	No Trend
F	12/15/98 – 5/20/00	22,033	Install new heat exchangers	-4.6%

Ranges A and E do not have a distinct electrical efficiency trend over the entire region and no major system changes occurred within the time range. The system changes that occurred around 15,000 hours in region E were mostly electrical system replacements including the UPS, circuit breakers, and a motorized circuit breaker. The average electrical efficiency in region B (37.4 percent), after the installation of the new cell stack, is greater than the average electrical efficiency in range A (36.6 percent). The trend in electrical efficiency in region C is an increase in efficiency over the range indicating that the installation of the external RO water treatment system had a positive impact on fuel cell performance by reducing and avoiding scaling within the thermal management system. Range D shows a strong decreasing trend of electrical efficiency after the repair of a coolant flow leak. It is not anticipated that this would result in an accelerated decrease in efficiency. The malfunctioning fuel valve that was replaced at outage #15 could possibly explain the trend. The trend in region F shows an anticipated gradual decrease in efficiency as the

hours of operation are increasing. Overall, with the data available it is difficult to make a definitive conclusion with respect to the trend of electrical efficiency with load hours.

The trend of the fuel cell stack cell voltage was analyzed based on the hours of fuel cell operation. The data is based on the same readings acquired through the UTC Fuel Cells' RADAR system as the electrical efficiency presented above. The individual data points are plotted with hours of operation in an X-Y plot (Figure 20). The average cell voltage for the data is 0.633 volts.

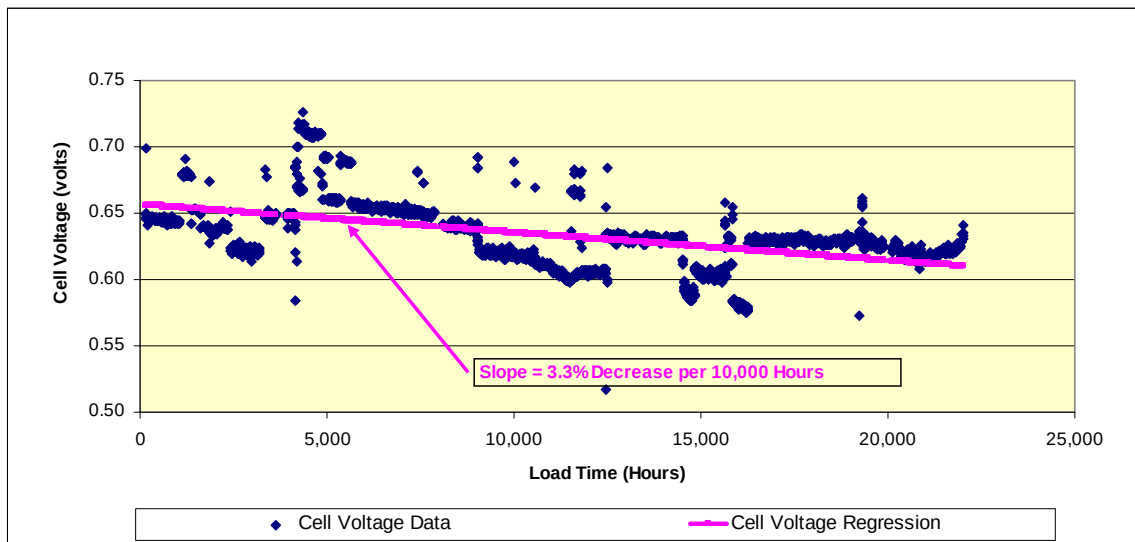


Figure 20. Fuel cell stack cell voltage degradation over time.

A linear regression was conducted on the data to characterize average cell voltage trends for the fuel cell. The resulting equation is:

$$\text{Cell Volts} = ((\text{Load Hours}) \times (-2.1071 \times 10^{-6})) + 0.656387 \quad \text{Eq. 1}$$

The regression shows a reduction in cell voltage with increased hours of operation. Table 14 lists the resulting cell voltages at 5,000 load hour intervals.

Table 14. Trend of cell voltage with fuel cell load hours.

Load Hours	Cell Voltage
0	0.656
5000	0.646
10,000	0.653
15,000	0.625
20,000	0.614
25,00	0.604

The fuel cell's cell voltage decreased at a rate of 0.021 volts per 10,000 hours of operation. The linear curve fit shows that the initial cell voltage was approximately 0.656 volts and that it decreased at an average rate of 3.3 percent per 10,000 hours of operation. For example, the average decrease between 10,000 hours (0.635) and 20,000 hours (0.614) is:

$$3.3\% = ((0.635 - 0.614) / 0.635)$$

The R Square statistic for the above regression is 0.27. This means that 27 percent of the variation seen in the trend of cell voltage can be attributed to load hours. Thus, other factors in the system are significantly affecting the changes observed in cell voltage. The cell voltage data (Figure 20) show that there are sub-trends in cell voltage during the life of the fuel cell's operation. Since the cell voltage is affected by the electrical output of the fuel cell, an additional analysis was conducted. The data was sorted by the fuel cell electric output for the most frequent operating levels of 200 kW, 175 kW, 150 kW and 125 kW. Then a linear regression was conducted for load hours greater than 5,000 hours (i.e., for the fuel cell after the stack was replaced). The results of the analysis are listed in Table 15.

Table 15. Cell voltage analysis by electrical output.

Fuel Cell Output	200 kW	175 kW	150 kW	125 kW
Data points	1075	126	336	823
R Square Statistic	0.80	0.53	0.45	0.88
Slope (%/10,000 hrs)	-13.9%	-12.3%	-5.2%	-6.2%

The analysis shows that the curve fit was very good for the 200 kW and 125 kW regressions with R Squared values of 0.8 and 0.88 respectively. This indicates that 80 to 88 percent of the decrease in cell voltage can be attributed to load hours for these data sets. The 175 kW and 150 kW regressions have R Squared values of approximately 0.50 indicating that approximately 50 per-

cent of the decline in the cell voltage can be attributed to the load hours for this data set. This is still an improved model of predictor to the original regression model. The slopes of the lines for the 200 kW and 175 kW power levels are significantly higher than the 150 kW and 125 kW levels. The reason for the difference cannot be explained by the lower number of data points at the 150 kW level since there are a significant number of data points at the 125 kW level. Figure 21 shows the regression lines of the analysis for each data set projected over the entire fuel cell operating range.

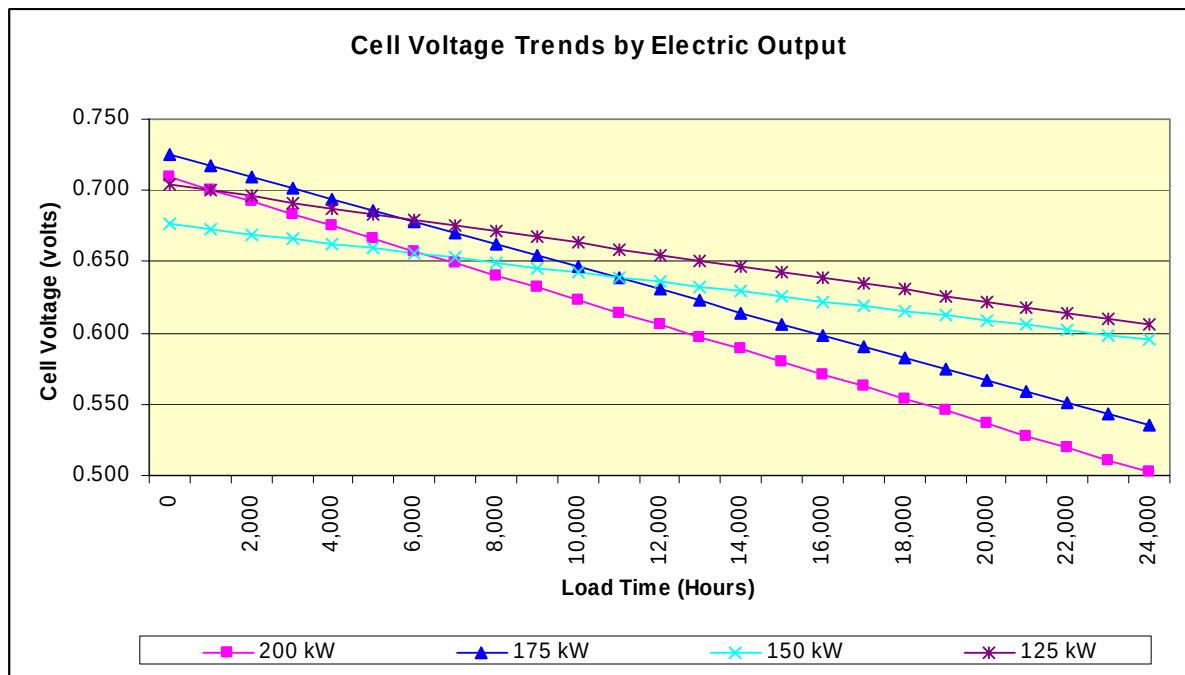


Figure 21. Cell voltage trends by electric output.

While the efficiency remains relatively constant along the various fuel cell power levels, power plant cell voltages tend to increase at lower electric output levels. This is most evident for fuel cell operation greater than 11,000 load hours. There is no data to indicate why the slope of the data varies at the different power levels.

4.4 Fuel Cell Maintenance Activities

UTC Fuel Cells had overall responsibility for maintenance on the fuel cell during the 5-year demonstration period. GBC Electrical Services, as the maintenance contractor, performed most maintenance activities under the guidance of UTC Fuel Cells.

Invoices from GBC Electrical Services were obtained to assess maintenance activity levels. GBC Electrical Services is actually located in Twentynine Palms which meant that there was no extensive travel required for maintenance activities. Table 16 lists the number of maintenance days at the site and total labor hours by year.

Table 16. Maintenance days and labor hours by year.

Year	Days at Site	Labor Hrs.
1995	6	22.5
1996	60	605.0
1997	35	249.5
1998	58	401.5
1999	45	293.0
2000	13	76.5
Total	217	1,648

Tables 17 through 22 list the date, labor hours and a brief description of the maintenance activities that were billed between the years 1995 and 2000.

Table 17. Maintenance activities in 1995.

1995	Labor Hrs	Description of Activity
2-Nov	7.0	Started fuel cell using catalyst reduction procedure
8-Nov	1.0	Performed water conductivity test at HV-453 and HV-431
16-Nov	1.0	Performed water conductivity test at HV-453, HV-452 and HV-431
11-Dec	10.0	Performed water conductivity test at HV-453, HV-452 and HV-431; recharged resin bottles
13-Dec	2.5	Performed voltage test using sub stack voltage measurement box (150 kW & 200 kW)
28-Dec	1.0	Performed water conductivity test at HV-453 and HV-431

Table 18. Maintenance activities in 1996.

1996	Labor Hrs	Description of Activity
13-Jan	2.0	Checked fuses and replaced one blown fuse; checked amps on each phase
14-Jan	2.0	Problem with stack voltage; power level reduced to 100 kW and then shut down fuel cell
26-Jan	5.0	Preparation for steam cleaner
29-Jan	8.5	Preparation for steam cleaner
30-Jan	10.0	Preparation for steam cleaner
31-Jan	10.5	Preparation for steam cleaner
2-Feb	11.0	Preparation for removal of fuel cell stack
3-Feb	10.0	Continued with cell stack wet-up procedures in preparation for removal
5-Feb	9.0	Continued with cell stack wet-up procedures in preparation for removal
6-Feb	18.0	Continued with cell stack wet-up procedures in preparation for removal
8-Feb	26.0	Fuel cell stack removed and secured in shipping crate
21-Mar	8.0	Preparation for Water Treatment System (WTS) cleaning

1996	Labor Hrs	Description of Activity
22-Mar	10.0	Flush fuel cell Water Treatment System
23-Mar	10.0	Continue with Water Treatment System cleaning
25-Mar	10.0	Continue with Water Treatment System cleaning
26-Mar	89.0	Continue with Water Treatment System cleaning
27-Mar	9.0	Continue with Water Treatment System cleaning; prepare for arrival of new fuel cell stack
28-Mar	23.0	Receive and install new fuel cell stack
29-Mar	8.0	Continue with Water Treatment System cleaning
1-Apr	9.0	Continue with Water Treatment System cleaning
2-Apr	17.0	Continue with Water Treatment System cleaning
3-Apr	14.0	Complete flushing of Water Treatment System
9-Apr	9.5	Install <i>retrofits</i> with UTC Fuel Cells
10-Apr	10.0	Install <i>retrofits</i> with UTC Fuel Cells
11-Apr	14.0	Install <i>retrofits</i> with UTC Fuel Cells
12-Apr	10.0	Install <i>retrofits</i> with UTC Fuel Cells
15-Apr	7.5	Start-up fuel cell
16-Apr	6.0	Repair heater 400
17-Apr	10.0	Start fuel cell with reduction process
18-Apr	12.0	Finish details and adjust new valve 400
19-Apr	12.5	Final setting on valve 400
20-Apr	3.0	Testing of grid-independent capability during site outages; ramp up fuel cell to 200 kW
27-Apr	6.5	Attempted to restart fuel cell several times and conducted water sampling; reformer burner (BE030) malfunctioning
3-May	8.5	Repair process steam control valve (CV500) and start fuel cell
4-May	3.5	Attempted to restart fuel cell
13-May	4.0	Worked on electrical systems
12-Jun	4.5	Prepared to install reverse osmosis unit
13-Jun	6.0	Modifications made to Water Treatment System
14-Jun	8.5	Start-up fuel cell
17-Jun	6.5	Replace circuit breaker and relay
18-Jun	5.0	Start fuel cell
19-Jun	6.5	Conduct water testing
8-Jul	9.0	Water recovery testing
9-Jul	9.0	Water recovery testing
10-Jul	9.0	Water recovery testing
11-Jul	8.0	Install reverse osmosis unit
12-Jul	7.0	Install reverse osmosis unit
16-Jul	7.5	Install reverse osmosis unit
17-Jul	9.0	Install reverse osmosis unit electrical
18-Jul	14.0	Install reverse osmosis unit enclosure
19-Jul	7.0	Install reverse osmosis unit and initiate operation
9-Aug	9.5	Start fuel cell
22-Aug	6.0	Increase power level to 200 kW and perform water testing

1996	Labor Hrs	Description of Activity
4-Nov	4.0	Troubleshooting
6-Nov	8.0	Replace module and start
7-Nov	2.0	Increase power level and conduct water testing
12-Nov	8.0	Change out resin and charcoal
13-Nov	1.0	Conduct water testing
3-Dec	6.0	Restart power plant
7-Dec	8.0	Restart power plant

Table 19. Maintenance activities in 1997.

1997	Labor Hrs	Description of Activity
17-Jan	9.0	Troubleshoot circuit breaker K002
18-Jan	7.0	Changed relay K2, cleaned fire eye and attempted to start fuel cell
21-Jan	11.5	Attempted to start fuel cell
22-Jan	12.0	Attempted to start fuel cell
23-Jan	8.0	Trouble shooting system
24-Jan	6.0	Trouble shooting system and replace fire eye
27-Jan	1.0	Change out Water Treatment System bottles
28-Jan	10.0	Changed pump 451 and started fuel cell
8-Feb	7.5	Restart fuel cell
11-Mar	9.0	Quarterly maintenance and change our resin
12-Mar	7.0	Restart fuel cell
3-Apr	10.0	Worked on leaks and restarted fuel cell
1-May	3.5	Attempted to fix leak on discharge side of pump 451
29-May	2.0	Trouble shot flow control valve (FCV012)
5-Jun	36.0	Perform annual maintenance and install new fuel valve
7-Jul	5.0	Changed out pump 451 and checked valve 541
8-Jul	5.0	Attempted to start fuel cell (FCV140 stuck)
9-Jul	7.0	Replace FCV140 and attempted to start fuel cell unsuccessfully
10-Jul	2.0	Tested FT140 and identified that part failed
11-Jul	5.0	Replaced FT140 and attempted to start fuel cell unsuccessfully
12-Jul	7.0	Cleaned fire eye and restarted power plant
24-Jul	4.0	Worked with UTC Fuel Cells personnel at site
4-Aug	4.0	Worked with UTC Fuel Cells personnel at site
5-Aug	8.0	Worked with UTC Fuel Cells personnel at site
6-Aug	6.0	Changed union F0420
12-Aug	5.0	Worked with UTC Fuel Cells personnel at site
13-Aug	8.0	Worked with UTC Fuel Cells personnel at site
15-Aug	4.5	Worked with UTC Fuel Cells personnel at site
2-Sep	1.0	Put power plant back in water conditioning mode
16-Sep	7.5	Removed old batteries from UPS and found that the replacements were wrong
18-Sep	7.5	Changed batteries in UPS and changed nitrogen bottles

1997	Labor Hrs	Description of Activity
23-Sep	8.0	Drained water from fuel cell; removed and reinstalled pump 451 and put power plant in water conditioning
24-Sep	7.5	Attempted to start fuel cell unsuccessfully and troubleshot failure
30-Sep	4.0	Cleaned fire eye and restarted power plant
26-Dec	4.0	Attempted to start the fuel cell

Table 20. Maintenance activities in 1998.

1998	Labor Hrs	Description of Activity
5-Jan	3.0	Troubleshoot circuit breaker CB002
20-Jan	17.0	Remove and replace pump 820
22-Jan	7.0	Installed motor controller and started power plant
23-Jan	11.0	Troubleshoot shutdown, replaced FCV012 and started power plant
27-Feb	8.0	Changed resin and charcoal bottles
16-Mar	6.0	Drained the system; put new O-rings in FCU400 and refilled the system
17-Mar	8.5	Started fuel cell
18-Mar	1.0	Attempted to restart power plant
24-Mar	6.0	Replaced circuit breaker mechanisms and restarted power plant
26-Mar	13.0	Checked wiring in CB K001, K002 & K003 and replaced I/O modules and relays
6-Apr	2.0	Troubleshoot UPS problem
9-Apr	16.0	Removed and replaced UPS and started power plant
14-Apr	3.0	Removed and replaced panels from fuel cell
16-Apr	5.5	Installed PC7 ribbon cable; started power plant; changed out nitrogen bottles
20-Apr	3.0	Worked with UTC Fuel Cells on phone as they could not communicate directly with fuel cell
8-May	4.0	Troubleshoot communications problem
11-May	12.0	Changed out MCB003; started power plant; conducted cell stack tests at idle, 100 kW and 150 kW
12-May	4.0	Worked with UTC Fuel Cells on phone; took cell stack readings
18-May	10.0	Took out J pipes and put in bypass pipes; took out BP440 and put in bypass
19-May	16.0	Started steam cleaning and conducted water testing
20-May	19.0	Steam cleaning and water testing
21-May	2.0	Steam cleaning and water testing
22-May	10.0	Steam cleaning and water testing
26-May	6.0	Cleaned cell stack assembly (CSA)
27-May	12.0	Cleaned cell stack assembly (CSA)
28-May	9.0	Cleaned cell stack assembly (CSA)
29-May	10.0	Cleaned cell stack assembly (CSA)
2-Jun	6.0	Cleaned and greased fittings
3-Jun	8.0	Changed SAC metals
4-Jun	12.0	Cleaned wire box, etc.
5-Jun	7.0	Put fuel cell back together
8-Jun	8.0	Worked with UTC Fuel Cells personnel at site
9-Jun	13.0	Worked with UTC Fuel Cells personnel at site
10-Jun	7.0	Worked with UTC Fuel Cells personnel at site

1998	Labor Hrs	Description of Activity
11-Jun	8.5	Worked with UTC Fuel Cells personnel at site
12-Jun	4.0	Worked with UTC Fuel Cells personnel at site
16-Jun	8.0	Worked with UTC Fuel Cells personnel at site
17-Jun	5.0	Worked with UTC Fuel Cells personnel at site
18-Jun	2.0	Worked with UTC Fuel Cells personnel at site
19-Jun	4.0	Worked with UTC Fuel Cells personnel at site
23-Jun	12.0	Ran chemicals through reverse osmosis unit to clean in place; replaced final pressure gauge
24-Jun	5.5	Started reverse osmosis unit and replaced filter
2-Jul	2.0	Conducted grid connect/grid-independent test
31-Jul	2.0	Conducted grid connect/grid-independent test
28-Aug	2.0	Conducted grid connect/grid-independent test
15-Sep	1.0	Checked to make sure cooling fans were on and working
16-Sep	2.0	Reset logic so cooling fans would cool stack; flushed reverse osmosis unit for 15 minutes
28-Sep	2.0	Put fuel cell back into water conditioning; flushed reverse osmosis system
30-Sep	4.5	Worked with UTC Fuel Cells personnel at site
1-Oct	9.5	Worked with UTC Fuel Cells personnel at site; install two heat exchangers
2-Oct	9.0	Worked with UTC Fuel Cells personnel at site; install two heat exchangers
3-Oct	4.5	Worked with UTC Fuel Cells personnel at site
23-Oct	2.0	Conducted grid connect/grid-independent test
5-Nov	2.0	Install modem cable
6-Nov	2.0	Troubleshoot lockout relay
14-Dec	4.5	Changed flow meter and attempted to start power plant
15-Dec	10.5	Turned gas on and cleaned fire eye; started power plant and did two shift reducing tests
16-Dec	8.0	Tuned power plant; restarted power plant after gas outage

Table 21. Maintenance activities in 1999.

1999	Labor Hrs	Description of Activity
22-Feb	4.0	Checked bottom of cell stack looking for acid residue
23-Feb	6.0	Checked bottom of cell stack looking for acid residue
25-Feb	17.0	Prepared fuel cell for megohmmeter test; repaired water leak at reverse osmosis unit
26-Feb	7.0	Isolated cell stack and tested with megohmmeter
9-Mar	10.0	Troubleshoot short in cell stack assembly
10-Mar	9.0	Continued looking for leak in CSA manifold and cleaned area
11-Mar	4.0	Retested CSA for short
12-Mar	2.0	Retested CSA for short; placed a space heater in CSA area to dry water from cleaning
16-Mar	11.0	Had CSA patch modified to fit; installed patch and retested CSA
5-Apr	4.0	Worked on CSA base insulators
6-Apr	18.0	Installed base insulators; reassembled CSA and cabinet; started power plant
19-May	1.0	Troubleshoot hot shut down; put power plant in cool down
20-May	12.0	Troubleshoot FT140 shutdown; repaired leaks in water treatment system; started power plant
21-May	3.5	Changed water treatment system bottles

4-Jun	7.0	Troubleshoot FT140 and attempted to fix leak on FO420 union; left power plant in P15
8-Jun	2.0	Replaced FT140 and took apart FO420
9-Jun	3.0	Worked with welder
10-Jun	6.0	Attempted to start power plant
11-Jun	8.0	Attempted to start power plant
14-Jun	9.0	Attempted to start power plant
15-Jun	6.5	Troubleshoot TCV400
16-Jun	7.5	Rebuilt TCV400
18-Jun	13.0	Attempted to start power plant; replaced TCV400.
17-Jul	1.0	Put power plant back in water conditioning
21-Jul	2.0	Replaced PC19 card; put power plant back in water conditioning
10-Aug	8.0	Troubleshoot FT140
11-Aug	12.0	Attempted to start power plant
12-Aug	9.0	Cleaned fire eye and attempted to start power plant
13-Aug	5.5	Attempted to start power plant
20-Aug	8.0	Attempted to start power plant; worked with UTC Fuel Cells on phone
24-Aug	7.0	Attempted to start power plant; worked with UTC Fuel Cells on phone
25-Aug	8.0	Attempted to start power plant; worked with UTC Fuel Cells on phone
26-Aug	10.0	Attempted to start power plant; worked with UTC Fuel Cells on phone
27-Aug	5.0	Attempted to start power plant; found bad valve FCV140
31-Aug	13.0	Attempted to start power plant; changed brakes on FCV110; worked with UTC Fuel Cells on phone
1-Sep	4.0	Attempted to start power plant
2-Sep	8.0	Changed Filter 100; started power plant and left at 125 kW
9-Sep	3.0	Changed out water treatment system bottles
14-Oct	2.0	Analyzed the modem and made sure it was operating properly
15-Oct	2.0	Worked with UTC Fuel Cells on phone
17-Oct	1.0	Put power plant back in water conditioning
18-Oct	2.0	Attempted to start power plant; leak detected and shut down power plant
1-Nov	9.0	Repaired pump 450 water leak; started power plant
3-Dec	2.0	Rerouted conductivity sensor for DMN450 bottles
12-Dec	1.0	Troubleshoot pump 400

Table 22. Maintenance activities in 2000.

2000	Labor Hrs	Description of Activity
6-Jan	1.0	Removed old 50 amp breaker
18-Jan	1.0	Installed 50 amp breaker for heater 400
19-Jan	6.0	Changed heater 400
20-Jan	8.5	Flushed system
21-Jan	8.0	Attempted to start power plant; troubleshoot failed start
24-Jan	9.5	Troubleshoot FO400 and attempted to start power plant
27-Jan	8.0	Rebuilt CV500 and attempted to start power plant

2000	Labor Hrs	Description of Activity
28-Jan	5.0	Worked with UTC Fuel Cells on phone; checked FO420, flow orifices and leak down on water tank
10-Feb	7.0	Changed out FS400 and FO420/440
11-Feb	6.0	Started power plant and power plant shutdown
15-Feb	5.0	Troubleshoot FS400 problem
31-Mar	3.0	Changed out FS400
3-Apr	8.5	Started power plant

4.5 Fuel Cell Retrofits

As part of the fuel cell demonstration and overall fuel cell development, UTC Fuel Cells refined the fuel cell design based on operational experience gained through the operation of the fleet of fuel cells. These improvements and modifications were classified as retrofits. Once a retrofit was developed, it would be incorporated into the production of new fuel cells or retrofit in the field for installed fuel cells. The details of the retrofits are considered proprietary information by UTC Fuel Cells and are not available for this report. The data in Tables 17 through 22 show that the only retrofit that was added to the fuel cell in the field was during 9 –12 April 1996. At this time there was a modification to the Thermal Management System to modify piping and a flow control valve. The objective of the retrofit was to increase the rate of heat transfer off the stack so the appropriate stack temperature could be maintained when the level of heat generated by the stack increases toward the end of the stack life.

4.6 Fuel Cell Operation and Outage Summary

Appendix E shows the operational and outage periods for each hour within the 60 months that the fuel cell was active (June 1995 to May 2000). The outage times are highlighted in gray along with a listing of the outage number, duration in hours and minutes, and a brief description of the shutdown. Days where on-site maintenance was performed is shown graphically by an 8-hour box. GBC Electrical Services, the maintenance contractor, provided maintenance activity records.

5 Fuel Cell Economics

5.1 Hospital Energy Costs

The Naval Hospital, as a tenant at MCAGCC Twentynine Palms, pays the Base for its electricity usage. The Base purchases electricity from Southern California Edison (SCE) under a time of use rate schedule, TOU-8. This rate has a summer and winter season consisting of on-peak, mid-peak and off-peak time periods. Table 23 lists the structure of the TOU-8 tariff. The difference between the facility-related demand charge and the time-related demand charges are the method of calculation. The facility-related demand charge is the highest demand over any 15-minute period during the billing period. The time-related demand charge is determined as the highest demand over any 15-minute period for the time periods defined (on-peak, mid-peak and off-peak). Typically, the on-peak demand charge is the highest cost of all the demand charges and the off-peak demand charge is zero.

Table 23. SCE TOU-8 rate structure.

	Summer	Winter
Months	June – September	October – May
On Peak Period	Noon – 6:00 pm	None
Mid-Peak Period	8:00 am – Noon 6:00 pm – 11:00 pm	8:00 am – 9:00 pm
Off-Peak Period	All other hours and holidays	All other hours and holidays
Charges	Facility Charge (\$/meter) Energy Charge (\$/kWh) Facility-Related Demand Charge (\$/kW) Time-Related Demand Charge (\$/kW) Excess Transformer Capacity (\$/kVA) Power Factor Adjustment (\$/kVA)	Facility Charge (\$/meter) Energy Charge (\$/kWh) Demand Charge (\$/kW) Excess Transformer Capacity (\$/kVA) Power Factor Adjustment (\$/kVA)

The Base purchases natural gas from two sources, a contracted commodity purchase through a gas provider for the central plant and Southern California Gas Company (SoCalGas). The costs that are passed on to the Hospital are the SoCalGas costs, which are billed under tariff GN-20.

Records of the Hospital electric and natural gas consumption were collected from the Base for the period of October 1997 through 2001. Data for the period of June 1995 through September 1997 were not available. Tables 24 through 27 list the data for the periods of FY 98 through FY01 respectively.

Table 24. Hospital energy bills for FY98.

Month	ELECTRICITY			NATURAL GAS		
	Consumption kWh	Costs \$	Average Cost \$/kWh	Consumption Therms	Costs \$	Average Cost \$/Therm
October 1997	299,240.00	\$31,120.96	\$0.1040	16,426.00	\$9,527.08	\$0.5800
November 1997	226,400.00	\$23,545.60	\$0.1040	17,097.00	\$9,916.26	\$0.5800
December 1997	223,749.00	\$23,269.90	\$0.1040	15,964.00	\$9,259.12	\$0.5800
January 1998	230,189.00	\$23,939.66	\$0.1040	4,964.00	\$2,879.12	\$0.5800
February 1998	215,949.00	\$22,458.70	\$0.1040	19,574.00	\$11,352.92	\$0.5800
March 1998	496,120.00	\$50,455.40	\$0.1017	8,936.00	\$3,642.49	\$0.4076
April 1998	576,360.00	\$58,615.81	\$0.1017	12,754.00	\$5,198.79	\$0.4076
May 1998	531,384.00	\$54,041.75	\$0.1017	11,891.00	\$4,847.01	\$0.4076
June 1998	534,800.00	\$54,389.16	\$0.1017	4,884.00	\$1,990.82	\$0.4076
July 1998	729,840.00	\$74,224.73	\$0.1017	3,789.00	\$1,544.47	\$0.4076
August 1998	602,368.00	\$61,260.83	\$0.1017	3,392.00	\$1,382.65	\$0.4076
September 1998	738,360.00	\$75,091.21	\$0.1017	3,506.00	\$1,429.12	\$0.4076
Total	5,404,759.00	\$552,413.71	\$0.1022	123,177.00	\$62,969.85	\$0.5112

Table 25. Hospital energy bills for FY99.

Month	ELECTRICITY			NATURAL GAS		
	Consumption kWh	Costs \$	Average Cost \$/kWh	Consumption Therms	Costs \$	Average Cost \$/Therm
October 1998	738,360.00	\$75,091.21	\$0.1017	3,506.00	\$1,429.12	\$0.4076
November 1998	390,320.00	\$39,695.54	\$0.1017	6,489.00	\$2,645.05	\$0.4076
December 1998	403,040.00	\$40,989.17	\$0.1017	11,868.00	\$4,837.63	\$0.4076
January 1999	440,384.00	\$44,787.05	\$0.1017	12,710.00	\$5,180.85	\$0.4076
February 1999	601,480.00	\$61,170.52	\$0.1017	10,960.00	\$4,467.52	\$0.4076
March 1999	474,056.00	\$48,211.50	\$0.1017	6,784.00	\$2,765.29	\$0.4076
April 1999	401,744.00	\$40,857.36	\$0.1017	8,963.00	\$3,653.50	\$0.4076
May 1999	731,272.00	\$74,370.36	\$0.1017	10,906.00	\$4,445.50	\$0.4076
June 1999	268,488.00	\$27,305.23	\$0.1017	2,321.00	\$946.09	\$0.4076
July 1999	739,904.00	\$75,248.24	\$0.1017	5,399.00	\$2,200.74	\$0.4076
August 1999	765,336.00	\$77,834.67	\$0.1017	1,361.00	\$554.77	\$0.4076
September 1999	626,250.00	\$63,689.63	\$0.1017	4,997.00	\$2,036.88	\$0.4076
Total	6,580,634.00	\$669,250.48	\$0.1017	86,264.00	\$35,162.94	\$0.4076

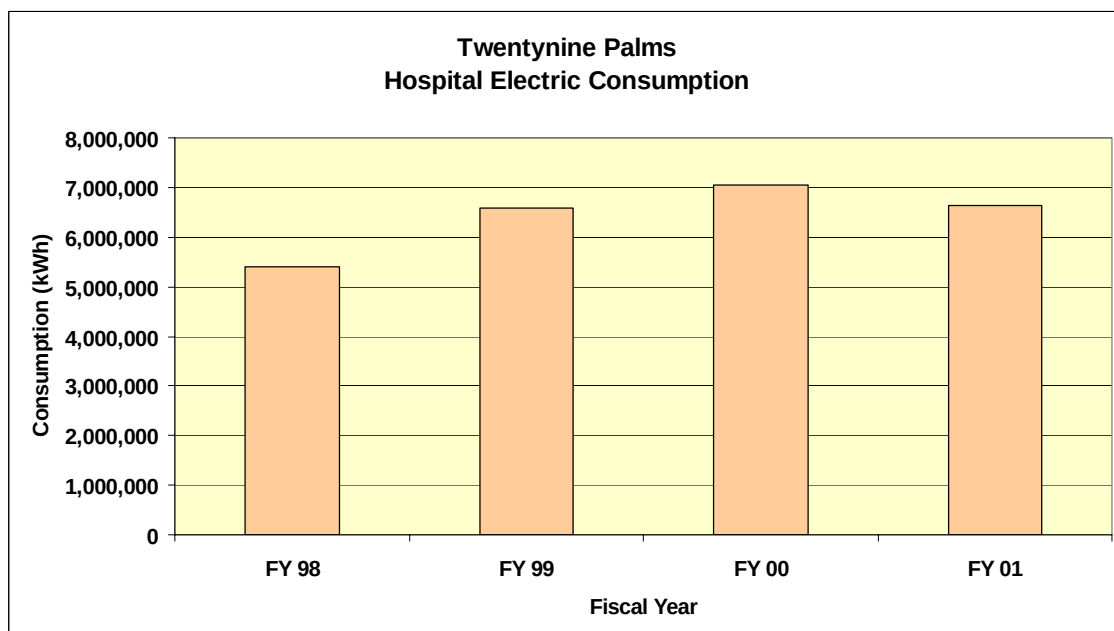
Table 26. Hospital energy bills for FY00.

Month	ELECTRICITY			NATURAL GAS		
	Consumption kWh	Costs \$	Average Cost \$/kWh	Consumption Therms	Costs \$	Average Cost \$/Therm
October 1999	635,480.00	\$64,628.32	\$0.1017	10,005.00	\$4,078.24	\$0.4076
November 1999	528,448.00	\$53,743.16	\$0.1017	9,963.00	\$4,061.12	\$0.4076
December 1999	628,096.00	\$63,877.36	\$0.1017	10,983.00	\$4,476.89	\$0.4076
January 2000	531,176.00	\$54,020.60	\$0.1017	10,080.00	\$4,108.81	\$0.4076
February 2000	569,184.00	\$57,886.01	\$0.1017	11,500.00	\$4,687.63	\$0.4076
March 2000	503,752.00	\$51,231.58	\$0.1017	7,500.00	\$3,057.15	\$0.4076
April 2000	455,672.00	\$46,341.84	\$0.1017	7,000.00	\$2,853.34	\$0.4076
May 2000	648,536.00	\$65,956.11	\$0.1017	6,500.00	\$2,649.53	\$0.4076
June 2000	666,224.00	\$67,754.98	\$0.1017	3,000.00	\$1,222.86	\$0.4076
July 2000	574,560.00	\$58,432.75	\$0.1017	3,000.00	\$1,222.86	\$0.4076
August 2000	622,968.00	\$63,355.85	\$0.1017	4,500.00	\$1,834.29	\$0.4076
September 2000	682,305.00	\$69,390.42	\$0.1017	4,252.00	\$1,733.20	\$0.4076
Total	7,046,401.00	\$716,618.98	\$0.1017	88,283.00	\$35,985.92	\$0.4076

Table 27. Hospital energy bills for FY01.

Month	ELECTRICITY			NATURAL GAS		
	Consumption kWh	Costs \$	Average Cost \$/kWh	Consumption Therms	Costs \$	Average Cost \$/Therm
October 2000	620,440.00	\$63,098.75	\$0.1017	6,931.00	\$4,851.70	\$0.7000
November 2000	509,856.00	\$51,852.36	\$0.1017	3,573.00	\$2,501.10	\$0.7000
December 2000	622,712.00	\$63,329.81	\$0.1017	10,550.00	\$7,385.00	\$0.7000
January 2001	538,968.00	\$54,813.05	\$0.1017	5,256.00	\$3,679.20	\$0.7000
February 2001	480,480.00	\$48,864.82	\$0.1017	11,500.00	\$8,050.00	\$0.7000
March 2001	515,000.00	\$52,375.50	\$0.1017	11,500.00	\$8,050.00	\$0.7000
April 2001	524,000.00	\$78,600.00	\$0.1500	8,000.00	\$7,600.00	\$0.9500
May 2001	581,936.00	\$87,290.40	\$0.1500	8,000.00	\$7,600.00	\$0.9500
June 2001	581,672.00	\$87,250.80	\$0.1500	8,000.00	\$7,600.00	\$0.9500
July 2001	620,984.00	\$93,147.60	\$0.1500	8,000.00	\$7,600.00	\$0.9500
August 2001	489,488.00	\$73,423.20	\$0.1500	8,000.00	\$7,600.00	\$0.9500
September 2001	553,231.00	\$82,984.65	\$0.1500	8,000.00	\$7,600.00	\$0.9500
Total	6,638,767.00	\$837,030.94	\$0.1261	97,310.00	\$80,117.00	\$0.8233

Figure 14 shows the annual trend in Hospital electric consumption and Figure 15 shows the annual trend in Hospital natural gas consumption.

**Figure 22. Annual hospital electric consumption.**

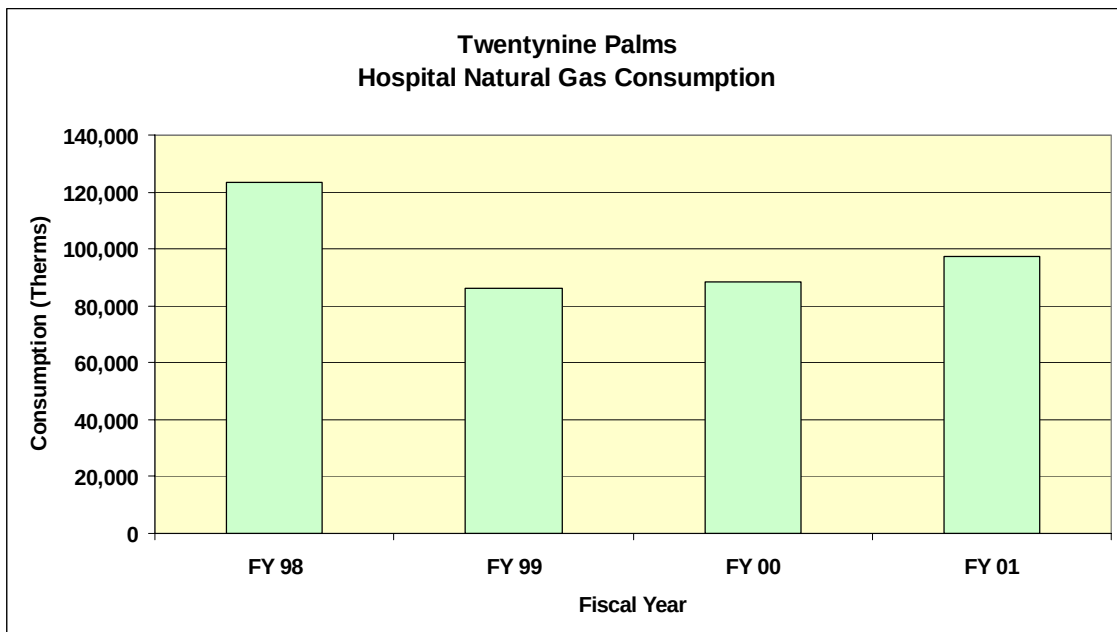


Figure 23. Annual hospital natural gas consumption.

5.2 Fuel Cell Maintenance Costs

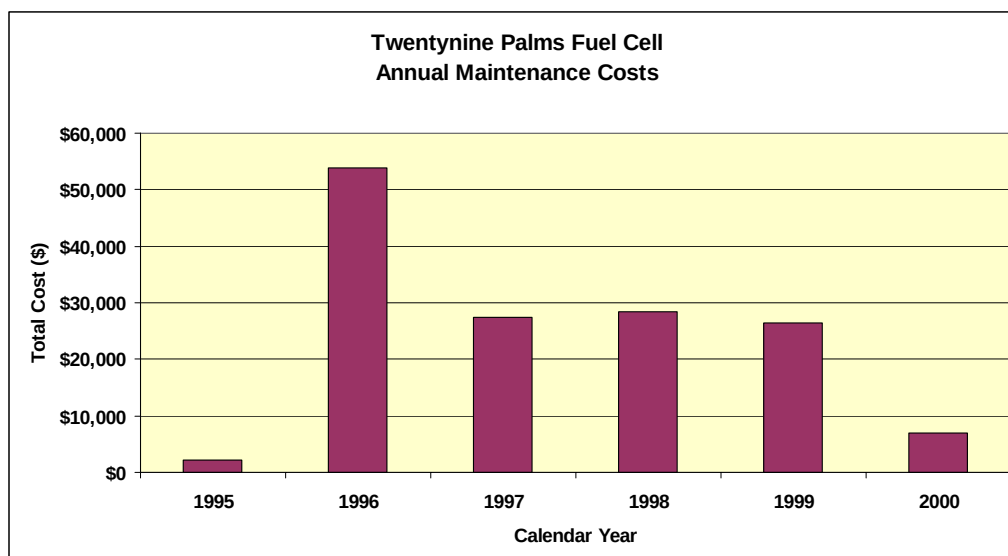
Table 28 lists the maintenance costs for services provided by GBC Electrical Services between 1995 through the end of the demonstration project. Labor was the highest cost category at \$76,969. Labor hours averaged 330 work-hours per 12 months. The highest number of work-hours in a calendar year was 605 in 1996. Nitrogen costs totaled \$21,472. Spread across the 36 outages that occurred, this averages \$596 per outage. While charcoal used in the water treatment system was a relatively minor cost (~\$500/year), resin was a significant program cost totaling nearly \$25,000. A bed of ion-exchange resin is used to soften the water in the water treatment system. The softening process exchanges calcium and magnesium ions in the water for sodium ions in the resin. Resin costs work out to approximately \$1,120 per one thousand operating hours. Appendix F presents maintenance costs by Invoice date.

Table 28. Summary of fuel cell maintenance costs.

CATEGORY	1995	1996	1997	1998	1999	2000	TOTALS
Labor Hours	22.5	605	249.5	401.5	293	76.5	1,648
Labor Costs	\$968	\$24,598	\$12,475	\$18,925	\$15,772	\$4,233	\$76,969
Nitrogen Costs	\$1,188	\$6,459	\$6,422	\$3,100	\$3,285	\$1,018	\$21,472
Charcoal (cu. ft.)	0	4	4	4	4	0	16
Charcoal Costs	\$0	\$372	\$372	\$372	\$392	\$0	\$1,508
Resin (cu. ft.)	0	41	27	18	16	0	102
Resin Costs	\$0	\$10,395	\$6,102	\$4,068	\$4,240	\$0	\$24,805
Other Costs	\$32	\$11,877	\$1,485	\$1,716	\$2,627	\$1,746	\$19,484
Travel Costs	\$0	\$0	\$0	\$0	\$154	\$33	\$187
Shipping Costs	\$34	\$122	\$572	\$304	\$0	\$0	\$1,031
TOTALS	\$2,222	\$53,823	\$27,428	\$28,485	\$26,470	\$7,029	\$145,457

The cost of maintenance over the entire operating period as shown above was \$145,457. This corresponds to an average maintenance cost of approximately 4.12 cents/kWh ($\$145,457 / 3,533,735 \text{ kWh}$) for all the electricity supplied to the Naval Hospital. This represents \$29,091/year over the 5-year demonstration period. ***Note that the maintenance costs presented do not include the cost of any parts or equipment provided by UTC Fuel Cells to repair or modify the fuel cell.***

Figure 24 shows the trend in annual maintenance costs for the fuel cell. Note that the costs presented for 1995 and 2000 are for approximately 6 months each as the fuel cell started operation on 20 June 1995 and concluded operation on 26 May 2000. The high costs on 1996 are attributed to the hard water problems and the resulting water treatment system installation.

**Figure 24. Annual trend in fuel cell maintenance costs.**

Fuel cell maintenance costs for the 5-year demonstration period were included in the original purchase contract with the fuel cell manufacturer. First year maintenance costs were included in the original fuel cell purchase price. For the final 4 years of contract maintenance, UTC Fuel Cells was paid \$137,200 (\$34,300 per year).

5.3 Fuel Cell Energy Savings

Energy savings from the fuel cell were calculated based the Naval Hospital's monthly electric and natural gas energy bills. Average monthly rates were applied to monthly fuel cell electrical and thermal output as well as the input fuel. For periods where electricity and natural gas bills were not available, costs were interpolated. Table 29 lists the annual energy savings delivered by the fuel cell. Net energy savings for this site over the entire program were \$131,761.

Table 29. Annual energy savings at naval hospital.

	1995	1996	1997	1998	1999	2000	Total
Electric Savings	\$44,369	\$67,106	\$96,435	\$32,278	\$53,055	\$14,318	\$307,560
Thermal Savings	\$1,341	\$1,949	\$2,032	\$142	\$93	\$50	\$5,557
Total Savings	\$45,710	\$69,054	\$98,467	\$32,420	\$53,148	\$14,318	\$313,118
Natural Gas Costs	\$33,418	\$42,947	\$57,134	\$18,003	\$23,415	\$6,357	\$181,273
Net Savings	\$12,292	\$26,107	\$41,333	\$14,417	\$29,733	\$7,961	\$131,844

Overall electric savings were \$307,560 with a maximum annual savings of \$96,435 occurring in 1997. The modest level of thermal heat recovery from the fuel cell and used by the Hospital resulted in a total natural gas savings of \$5,557. The value of the recovered heat was greatest in 1997 with savings of \$2,032. The cost of natural gas to operate the fuel cell totaled \$181,273 over the course of the demonstration. This amount corresponds to a fuel cost for electric generation of \$0.0515/kWh (\$181,273/3,522,400 kWh). Figure 25 shows the trend in annual energy savings.

5.4 Fuel Cell Lifecycle Costs

The fuel cell lifecycle cost analysis is presented for the operational life of the fuel cell at MCAGCC Twentynine Palms. At the end of the demonstration, the fuel cell was removed. Therefore, the costs and operation in this report cover the entire life of the fuel cell (20 June 1995 — 20 May 2000). Note that the cost of fuel cell removal is not included in the analysis.

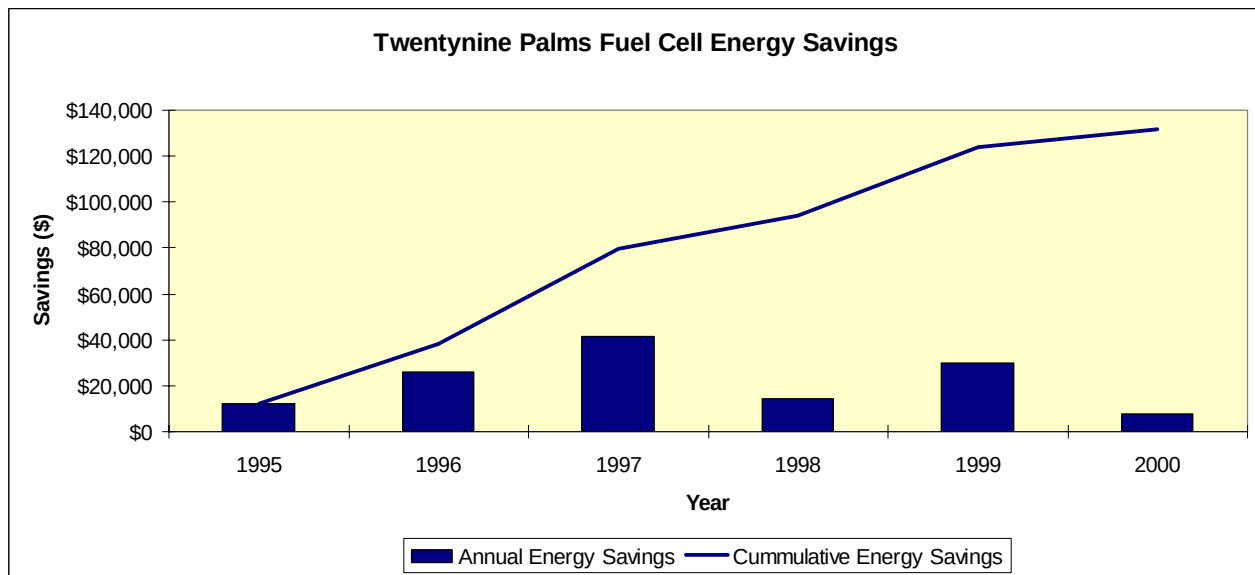


Figure 25. Annual fuel cell energy savings.

The installed cost of the fuel cell was \$1,200,000. The lifecycle cost analysis uses the utility rates presented in section 5.1, the maintenance costs presented in section 5.2 and the savings presented in section 5.3. Note that the analysis is based on the average cost of electricity that the Hospital is charged. That is to say that demand savings are not calculated separately in the analysis. A review of the data shows that demand savings would have been realized in only ten of the 59 full months of operation and that the average demand reduction for the 10 months would have been 170.1 kW. The criterion for determining demand savings is that the fuel cell was operational during all hours of the peak period hours for the calendar month. In two cases the fuel cell was down during the month, but the entire outage occurred during non-peak time periods. Table 30 lists the months in which the facility demand savings could have been attributed to the fuel cell and the average output of the fuel cell during the month. Note that for the SCE TOU-8 tariff that the peak demand is applicable during the months of June through September. The data in Table 30 show that the peak demand savings would have occurred on only three of the months, July 1995, August 1995, and September 1996.

Table 30. Fuel cell demand savings.

Month of Demand Savings		Fuel Cell Demand Savings
July	1995	200
August	1995	143
December	1995	158
September	1996	200
October	1996	200
February	1997	200
October	1997	150
November	1997	150
February	1998	175
January	1999	125
Number of Months		10
Average Demand		170

Data in Table 31 represent the lifecycle cost analysis. The analysis allocates the capital cost of the fuel cell in the 1995 calendar year. In addition, values are actual costs and are not adjusted to a base year. The analysis shows that the operational costs exceeded the savings in 1996 and 1998 and that the cumulative operational savings were negative at the end of the period of analysis.

Table 31. Lifecycle cost analysis.

Year	1995	1996	1997	1998	1999	2000
Hours of Operation						
Operation Hours/Yr.	3,705	4,836	5,970	1,989	4,253	1,136
Total Operation Hours	3,705	8,542	14,512	16,501	20,755	21,890
Hours Since Overhaul	3,705	8,542	14,512	16,501	20,755	21,890
Operation Values						
Electrical Eff (%)	32.4%	33.3%	32.0%	30.6%	31.0%	30.8%
Thermal Eff (%)	3.2%	3.6%	2.9%	0.6%	0.3%	0.0%
Demand Disp. (kW)	501	400	500	175	125	-
Electric Output (MWh)	633.8	838.8	1071.5	315.8	521.7	140.8
Thermal Displ. (MMBTU)	268.25	389.75	406.38	27.88	22.75	0.00
Fuel Input (MMBTU)	6683.6	8589.4	11426.7	3521.7	5744.5	1559.6
Average Energy Rates						
Demand Rate (\$/kW):	-	-	-	-	-	-
Electric Rate (\$/kWh):	0.0700	0.0800	0.0900	0.1022	0.1017	0.1017
Facility Gas Rate (\$/MMBTU):	5.00	5.00	5.00	5.11	4.08	4.08
Generator Gas Rate (\$/MMBTU):	5.00	5.00	5.00	5.11	4.08	4.08
GENERATOR SAVINGS						
Energy Savings (\$):						
Demand:	-	-	-	-	-	-
Energy:	\$44,366	\$67,104	\$96,435	\$32,275	\$53,057	\$14,319
Displaced Fuel:	\$1,341	\$1,949	\$2,032	\$142	\$93	\$0
Subtotal (\$):	\$45,707	\$69,053	\$98,467	\$32,417	\$53,150	\$14,319
Costs (\$):						
Fuel Cost:	\$33,418	\$42,947	\$57,134	\$18,003	\$23,415	\$6,357
Maintenance:	\$2,222	\$53,823	\$27,428	\$28,485	\$26,470	\$7,029
Generator Overhaul:	\$0	\$0	\$0	\$0	\$0	\$0
Subtotal (\$):	\$35,640	\$96,770	\$84,562	\$46,488	\$49,885	\$13,386
Annual Savings:	\$10,067	(\$27,717)	\$13,905	(\$14,071)	\$3,265	\$933
Cumulative Savings:	\$10,067	(\$17,650)	(\$3,745)	(\$17,815)	(\$14,550)	(\$13,617)
Installed Cost	\$1,200,000					
Net Cash Flow	(\$1,189,933)	(\$27,717)	\$13,905	(\$14,071)	\$3,265	\$933
Cumulative Cash Flow	(\$1,189,933)	(\$1,217,650)	(\$1,203,745)	(\$1,217,815)	(\$1,214,550)	(\$1,213,617)

6 Summary, Conclusions, and Recommendations

6.1 Review of Fuel Cell Demonstration at MCAGCC Twentynine Palms

The 200 kW phosphoric acid fuel cell operated for 21,890 hours which corresponds to an availability of 50.8 percent. The fuel cell generated approximately 3,522 MWh of electricity at an average rate of 160.9 kW. The fuel cell electrical efficiency averaged 32.0 percent (HHV) over the course of the demonstration. The thermal utilization of 40,600 BTU/hr was only 6 percent of the fuel cell's capability of 700,000 BTU/hr. Data in Table 32 summarize the performance of the fuel cell operation.

Table 32. Summary of fuel cell performance.

	1995	1996	1997	1998	1999	2000	Totals
Fuel Cell Operation							
Hours in the Period	4,664.2	8,784.0	8,760.0	8,760.0	8,760.0	3,366.0	43,094.2
Fuel Cell Operation Hours	3,705.3	4,836.4	5,970.3	1,989.3	4,253.3	1,135.8	21,890.5
Fuel Cell Outage Hours	958.9	3,947.6	2,789.7	6,770.7	4,506.7	2,230.2	21,203.7
Availability	79.4%	55.1%	68.2%	22.7%	48.6%	33.7%	50.8%
Electric Generation							
Total Generation (MWh)	633.8	838.8	1,071.5	315.8	521.7	140.8	3,522.5
Average Rate of Generation (kW)	171.1	173.4	179.5	158.8	122.7	124.0	160.9
Natural Gas Consumption							
Total Consumption (Ft ³)	6,488,973.3	8,339,251.1	11,093,926.4	3,419,098.2	5,577,173.3	1,514,140.0	36,432,562.3
Average Rate of Consumption Ft ³ /hr	1,751.3	1,724.3	1,858.2	1,718.7	1,311.3	1,333.1	1,664.3
Heat Recovery							
Total Heat Recovered (MMBTU)	214.64	311.81	325.11	22.26	18.21	0.00	892.0
Average Rate of Recovery (kBTU/Hr)	57.93	64.47	54.45	11.19	4.28	0.00	40.75
Efficiencies							
Electrical (%)	32.4%	33.3%	32.0%	30.6%	31.0%	30.8%	32.0%
PURPA (%)	34.0%	35.1%	33.4%	30.9%	31.2%	30.8%	33.2%

The longest continuous period of operation was just under 2,100 hours, or about 3 months and the longest forced outage was 2,260 hours, or about 3 months. The fuel cell stack had to be replaced once during the demonstration period and an external water treatment system had to be retrofit to the fuel cell due to high conductivity of the water. A total of 36 outages were recorded with 33 outages classified as a forced outage.

At the completion of the demonstration, the fuel cell was not functional and the Base opted not to invest its own money in repairing, operating and maintaining the fuel cell. In accordance with the demonstration agreement, the fuel cell was removed at the request of the Base.

6.2 Lessons Learned

The experience of installing, operating and finally decommissioning the fuel cell, resulted in the following lessons learned:

- High conductivity of water, particularly due to the hardness of the water in the Southwest region of the United States, must be addressed to prevent negatively impacting the performance of the fuel cell stack.
- Installation of the fuel cell was a relatively straight forward process with no major concerns at this site. The installation took 3 ½ months.
- The level of energy savings was less than anticipated due to:
 - the average fuel cell electrical output, which was only 161 kW and not the anticipated 200 kW.
 - the fuel cell availability, which was only 50.8%, not the anticipated 95%.
 - the level of heat recovery, which averaged approximately 6% instead of the anticipated 60%.
 - the fuel cell's potential to reduce the demand of the Hospital in only 10 of the 59 months of the demonstration.
- Most of the forced outages were categorized as "Other," which accounted for a total of 7,852 hours, or 48% of the forced outage down time.
- The average duration of a forced outage was 497.6 hours, or approximately 21 days.
- The maintenance costs averaged \$29,100/year, which represents an average cost of 4.12 cents/kWh. This does not include the equipment cost of the replacement cell stack or the reverse osmosis unit.
- The average fuel cost to generate electricity was 5.2 cents/kWh (\$181,273 / 3,522,500 kWh).
- The average operating and maintenance costs to generate electricity was 9.3 cents/kWh (5.2 cents/kWh [fuel cost] + 4.12 cents/kWh [O&M costs]). Note that this does not include the value of the heat recovered from the fuel cell. Over the same period of time, the cost of electricity purchased from SCE averaged 9.2 cents/kWh.

6.3 Recommendations

The review and analysis of the 200 kW phosphoric acid fuel cell installed at MCAGCC Twentynine Palms resulted in several recommendations:

- **Water Quality Requirements.** UTC Fuel Cells has identified through the demonstration that the hardness of the water impacts the fuel cell operation. The Twentynine Palms fuel cell required the installation of a reverse osmosis water treatment system. It is recommended that further re-

search be done to determine the hardness level at which the fuel cell will require an RO system

- **Fuel Cell Electrical Efficiency Trends.** The analysis of the electrical efficiency trends showed that, in addition to the number of load hours, other factors affect the efficiency degradation. The secondary analysis that was conducted based on evaluating the trends between major system changes did not substantially improve on the ability to better quantify the electrical efficiency degradation. It is recommended that further evaluation be done to qualify the trends of other demonstration fuel cells might provide more insight.
- **Cell Voltage Trends.** The analysis of the cell voltage trends showed that the rate of cell voltage reduction was greater at the higher electric output levels (200 kW and 175 kW) than at lower electric output levels (125 kW and 150 kW) as the fuel cell load hours increase. It is recommended that these trends be further analyzed to see if this consistent with other fuel cells.
- **System Design Improvements.** As part of the fuel cell demonstration and overall fuel cell development, UTC Fuel Cells refined the fuel cell design based on operational experience gained through the operation of the fleet of fuel cells. These improvements and modifications were classified as retrofits. The details of the retrofits are considered proprietary information by UTC Fuel Cells and are not available for this report. Investigation of maintenance activities for a larger number of B type fuel cells is recommended to provide greater insight into the modifications to the fuel cell design that can be attributed to the demonstration program.

Appendix A: Fuel Cell Acceptance Test Report

ONSI CORPORATION

ON SITE ACCEPTANCE TEST REPORT

POWER PLANT :

LOCATION :

TEST DATES :

S/N 9061

NAVAL HOSPITAL MCAGCC

TWENTY NINE PALMS, CALIFORNIA

JUNE 16 THROUGH JUNE 21, 1995

ONSI CORPORATION

01/23/95

DoD ACCEPTANCE TEST OF PC25™ POWER PLANT INSTALLATION

- Following a normal power plant start-up, operate at IDLE for one hour. At the completion of the one hour, obtain prints of the following five (5) display screens.
 - KEY PARAMETERS (screen 09)
 - REACTANT SUPPLY SYSTEM (screen 10)
 - STACK LOOP, ANC LOOP, & WTS (screen 11)
 - ELECTRICAL OVERVIEW (screen 14)
 - POWER CONDITIONER SYSTEM (screen 25)
 - In the grid connect mode with unity power factor and no heat recovery, operate at each of the following powers for one hour. After one hour obtain prints of the five (5) screen displays outlined above. Also perform the additional demonstrations at 100 KW and 200 KW listed below which are accomplished after the one hour hold. The required display screen prints for verification are shown in brackets {}.
- * 50 KW
 - * 100 KW
 - demonstrate leading and lagging power factor for 5 minutes
 - * max leading power factor up to 0.85 within limitations imposed by the grid {screen 14}
 - * 0.85 lagging power factor {screen 14}
 - * 150 KW
 - * 200 KW (Rated Power)
 - demonstrate < 3% harmonic distortion [using THD meter across the output power breaker]
 - demonstrate 60 Hz $\pm$ 3 Hz frequency [using a Fluke Model 87 True RMS Multimeter or equivalent]
 - demonstrate leading and lagging power factors for 5 minutes
 - * max leading power factor up to 0.85 within limitations imposed by the grid {screen 14}
 - * 0.85 lagging power factor {screen 14}
 - demonstrate minimum of 2 hours of heat recovery at time of normal site heat usage and consistent with site design
 - * {screen 09 at beginning and end of demonstration plus screen 11 at beginning and every hour until heat recovery demonstration completed}
 - * confirmation of 1900 SCFH $\pm$ 100 SCFH natural gas consumption during this two hour hold
 - Grid Independent operation will be demonstrated at those sites where such capability is installed, at power conditions consistent with normal site demand. After one hour of grid independent operation, each of the five (5) screens displays noted above shall be printed as verification.
 - demonstrate 60 Hz $\pm$ 3 Hz frequency [using a Fluke Model 87 True RMS Multimeter or equivalent]
 - demonstrate 480 volts $\pm$ 3%

STACK LOOP, ANC LOOP, & WTS
 06/16/95 IDC= 239.2 VDC= 237 KWACNET= 2 VT310DEL= -0.91 EVENTS 0
 0656:41 FT012ACT= 21.2 TS400FT= 370.1 TE012FT= 1495.0 OVERRIDE 0
 P/P 9061 P 150 R 160 S 60 W 20 A 30 N 40 C 30 L 10 26

TS400	SEPARATOR TEMP (PRIMARY)	370.2	DEGF	SETPOINT:	370.0
TS400R	SEPARATOR TEMP (BACKUP)	369.8	DEGF	SEP TEMP FACTOR(DEGF)	1.0
TS400DEL	SEP TEMP DELTA	0.4	DEGF		
LS450	WATER TANK LEVEL SWITCH	On		STK FLOW SW (FS400)	On
TS431	POLISHER TEMP	75.7	DEGF	F/W TEMP SW (TS451)	On
TE810	CONDENSOR EXIT TEMP	138.8	DEGF		
TS820	CUST HEX HOT IN TEMP	153.3	DEGF	CUMHEATREC(MMBTU)	0.689
TE880	CUST HEX COLD IN TEMP	90.0	DEGF	FT880 FLOW (PPH)	21940
TE881	CUST HEX COLD EX TEMP	102.3	DEGF	HEAT REC (MBTU/HR)	270
TE401	STACK COOLANT INLET TEMP	361.2	DEGF		
LT400	SEPARATOR LEVEL	11.2	IN		

PMP451	WTS FEEDWATER PUMP	Off		ON TIME, MIN.(PWPUMP):	0
STARTTEMP	TEMP FOR REF HEATUP	350.0	DEGF		
IDCNET	NET DC CURRENT	-42.6	AMPS		

HTR400	ELEMENT "A"	On		ELEMENT "C"	On
	ELEMENT "B"	On		ELEMENT "D"	Off

KEY PARAMETERS (ENGLISH UNITS)

P/P 9061	06/16/95	0653:37	EVENTS: C	OVERRIDE: C
P 150 R 160 S 60 W 20 A 30 N 40 C 30 L 10	26			
POWER OUTPUT (NET)	2.5	KWAC	OPERATING TIME	66.7 HRS
POWER OUTPUT (GROSS)	56.3	KWAC	POWER FACTOR	0.90
STACK CURRENT	339.1	AMPS	CUMULATIVE POWER	0.839 MWHR
STACK VOLTAGE	227.4	VOLTS	HALF STACK VOLTAGE	-0.09 VOLTS
VOLUMETRIC FUEL FLOW	461.2	SCFH	FUEL FLOW SETPOINT	457.6 SCFH
ACTUAL FUEL FLOW	20.7	PPH		
TE010 EJECTOR POSITION	18.9	%	TE010 SETPOINT	19.1 %
PHI MONITOR	1.02		TOTAL FUEL CONS	32622 SCF
FT140 BURNER AIR FLOW	206.7	PPH	FT140 SETPOINT	210.0 PPH
TE012 REFORMER TEMP	1492.7	DEGF	TE112 POSITION	41.9 %
TE012R BACKUP REF TEMP	1436.1	DEGF	TE012 SETPOINT	1495.0 DEGF
TE002 HDS TEMP	499.7	DEGF	TE350 ANODE INLET TEMP	395.6 DEGF
TS400FT STEAM SEP TEMP	371.8	DEGF	TE400 SETPOINT	370.0 DEGF
TE881 TEMP TO CUST	102.3	DEGF	RECOVERED HEAT	289 MBTU/HR
			TE431 POLISHER TEMP	75.7 DEGF
LT400 SEPARATOR LEVEL	10.5	IN	TE810 GLYCOL TEMP	140.8 DEGF
PMP451 STATUS	Off		TE160 MOTOR COMP AIR	68.7 DEGF
			TE150 MCT COMP AIR IN	62.7 DEGF
ELECTRICAL EFFICIENCY	2.0	%	press <NEXT PAGE> key to view RM data	

REACTANT SUPPLY SYSTEM

06/16/95 IDC= 243.5 VDC= 237 KWACNET= 2 VT310DEL= -0.91 EVENTS 0
 0655:38 FT012ACT= 21.4 TS400FT= 370 TS012FT= 1494 OVERRIDE 0
 P/P 9061 P 150 R 160 S 60 W 20 A 30 N 40 C 30 L 10 1 26

TE012	REF TUBE TEMP (PRIMARY)	1494.4	DEGF	SETPOINT:	1497.3
TE012R	REF TUBE TEMP (BACKUP)	1487.4	DEGF	REF/FUEL CONT OUTPUT:	1.13
TE012DEL	REF TUBE TEMP DELTA	7.0	DEGF		
FT012ACT	ACTUAL MASS FUEL FLOW	21.4	PPH	SETPOINT:	21.0
FT012	UNCORR. MASS FUEL FLOW	22.6	PPH	TE011 FUEL TEMP(DEGF)	56.9
SCFH	ACTUAL VOLUME FUEL FLOW	475.9	CFH	SETPOINT:	468.0
FUELTOT	TOTAL FUEL CONSUMED	22637	SCF	PT012 VENTURI(Psia)	7.88
ZE010	EJECTOR POSITION	19.0	%	SETPOINT:	18.3
PHIMON	PHI MONITOR	1.02		STEAM FLOW S.P.(PPH):	105.0
TE000	ANODE INLET TEMP	397.5	DEGF		
TE002	ODE BED TEMP	499.3	DEGF	HT002 STATUS:	On
EFFREF	REFORMER EFFICIENCY	77.6	%		

ELECTRICAL OVERVIEW

06/16/95 IDC= 239 VDC= 237 KWACNET= 2.5 VT310DEL= -0.91 EVENTS 0
 0657:53 FT012ACT= 21.1 TS400FT= 369 TS012FT= 1498 OVERRIDES 0
 P/P 9061 P 150 R 160 S 60 W 20 A 30 N 40 C 30 L 10 1 26

LOADTIME	TOTAL LOAD TIME	66	HR		
HOTTIME	TOTAL HOT TIME	120	HR		
CELV	AVG VOLTS PER CELL	1.741	V/C		
ASF	CURRENT DENSITY	42	ASF		
KWDC	DC KILOWATTS	56.7	KW		
VT310DEL	DELTA HALF STK VOLT	-0.91	V	VT310 HALF STK VOLT	-0.08
	INSTANTANEOUS STK AMPS	239	A		
EFFINV	INVERTER EFFICIENCY	99.3	%	CELL EFFICIENCY (%)	59.3
EFFMECH	MECHANICAL EFFICIENCY	4.4	%	REF EFFICIENCY (%)	75.5
EFFELEC	ELECTRICAL EFFICIENCY	1.9	%	HEAT RATE (BTU/KWHR)	190563
KWACNET	NET AC POWER	2.5	KWAC	DISPATCHED POWER:	0.0
PFACT	ACTUAL POWER FACTOR	0.90	-	DISPATCHED P.F.:	1.00
KVARNET	NET KVAR	1.1	KVAR	DISPATCHED KVAR:	0.0
KVANET	NET KVA	2.7	KVA		
PARPOWER	PARASITE POWER	53.7	KW		
KWACGROS	GROSS AC POWER	56.3	KW		
MWRSGR	GROSS AC MW HRS	2.369	MWHR		
MWHSNET	NET AC MW HOURS	0.840	MWHR		

POWER CONDITIONER SYSTEM

06/16/95 IDC= 239 VDC= 237 KWACNET= 2.5 VT310DEL= -0.92 EVENTS 0
 0658:49 PT012ACT= 21.1 TE400FT= 370.0 TE012FT= 1503.6 OVERRIDE 0
 P/P 9061 P 150 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 26

PT001A	INV AC VOLTAGE, PHASE A	482.7	V		
PT001B	INV AC VOLTAGE, PHASE B	480.6	V		
PT001C	INV AC VOLTAGE, PHASE C	478.5	V		
CT001A	INV AC CURRENT, PHASE A	0.5	A		
CT001B	INV AC CURRENT, PHASE B	0.0	A		
CT001C	INV AC CURRENT, PHASE C	0.1	A	CURRENT UNBAL (%)	0.0
PT003A	NET AC VOLTAGE, PHASE A	494.5	V		
PT003B	NET AC VOLTAGE, PHASE B	492.0	V		
PT003C	NET AC VOLTAGE, PHASE C	489.2	V	VOLTAGE UNBAL (%)	1.0
LINKVDC	LINK VOLTAGE	600.3	V		
PERCFUND	PERCENT FUNDAMENTAL	83.8	%		
PSREQ	PHASE SHIFT REQUEST	2.0	DEG		
MCB001	G/I BREAKER STATUS	Off			
MCB002	G/C BREAKER STATUS	Off			
MCB003	INTER-TIE BREAKER STAT	On			
INTCOUNT	INTERRUPT COUNT	0			

KEY PARAMETERS (ENGLISH UNITS)

P/P 9061 06/16/95 0837:02 EVENTS: 0 OVERRIDE: 0
 P 150 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

POWER OUTPUT (NET)	50.7	KWAC	OPERATING TIME	68.4	HRS
POWER OUTPUT (GROSS)	102.6	KWAC	POWER FACTOR	-1.00	
STACK CURRENT	459.8	AMPS	CUMULATIVE POWER	0.915	MWHR
STACK VOLTAGE	223.0	VOLTS	HALF STACK VOLTAGE	0.05	VOLTS
VOLUMETRIC FUEL FLOW	900.9	SCFH	FUEL FLOW SETPOINT	250.7	SCFH
ACTUAL FUEL FLOW	40.5	PPH			
ZE010 EJECTOR POSITION	24.7	%	ZE010 SETPOINT	23.7	%
PHI MONITOR	0.98		TOTAL FUEL CONS	14035	SCF
FT140 BURNER AIR FLOW	282.3	PPH	FT140 SETPOINT	283.1	PPH
TE012 REFORMER TEMP	1523.4	DEGF	ZT110 POSITION	45.7	%
TE012R BACKUP REF TEMP	1522.1	DEGF	TE012 SETPOINT	1514.4	DEGF
TE002 HDS TEMP	500.1	DEGF	TE350 ANODE INLET TEMP	195.4	DEGF
TE400FT STEAM SEP TEMP	357.7	DEGF	TE400 SETPOINT	360.6	DEGF
TE881 TEMP TO CURT	129.8	DEGF	RECOVERED HEAT	0	MBTU/HR
LE400 SEPARATOR LEVEL	11.4	IN	TE421 POLISHER TEMP	74.8	DEGF
PMP451 STATUS	Off		TE813 GLYCOL TEMP	139.3	DEGF
			TE150 MOTOR COMP AIR	64.9	DEGF
			TE150 HOT COMP AIR IN	67.6	DEGF
ELECTRICAL EFFICIENCY	20.5	%			

press <NEXT PAGE> key to view RM data

REACTANT SUPPLY SYSTEM

06/16/95 IDC= 457.6 VDC= 226 KWACNET= 48 VT310DEL= -0.58 EVENTS 0
 0839:24 FT012ACT= 38.3 TE400FT= 358 TE012FT= 1524 OVERRIDE 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

TE012 REF TUBE TEMP (PRIMARY) 1524.3 DEGF SETPOINT: 1514.4
 TR012R REF TUBE TEMP (BACKUP) 1522.5 DEGF REF/FUEL CONT OUTPUT: 1.05
 TE012DEL REF TUBE TEMP DELTA 1.7 DEGF
 FT012ACT ACTUAL MASS FUEL FLOW 38.3 PPH SETPOINT: 37.0
 FT012 UNCORR. MASS FUEL FLOW 42.0 PPH TE011 FUEL TEMP(DEGF) 71.1
 SCFH ACTUAL VOLUME FUEL FLOW 551.7 CFH SETPOINT: 900.4
 FUELTOT TOTAL FUEL CONSUMED 24064 SCF PT012 VENTURI(Psia) 7.29

ETC10 EJECTOR POSITION 24.5 % SETPOINT: 23.3
 PHIMON PHI MONITOR 1.13 STEAM FLOW S.F.(PPH): 143.8
 TE350 ANODE INLET TEMP 396.6 DEGF

TEC02 HDS BSD TEMP 500.1 DEGF HTR002 STATUS: On

3PPREF REFORMER EFFICIENCY 80.7 %

STACK LOOP, ANG LOOP, & WTS

06/16/95 IDC= 459.9 VDC= 223 KWACNET= 48 VT310DEL= -0.78 EVENTS 0
 0849:06 PT012ACT= 41.2 TE400FT= 359.9 TE012FT= 1511 OVERRIDE 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

TE400 SEPARATOR TEMP (PRIMARY) 359.9 DEGF SETPOINT: 358.3
 TE400R SEPARATOR TEMP (BACKUP) 359.5 DEGF SEP TEMP FACTOR(DEGF) 1.0
 TE400DEL SEP TEMP DELTA 0.4 DEGF
 LS450 WATER TANK LEVEL SWITCH On STK FLOW SW (FS400) On
 TE431 POLISHER TEMP 74.6 DEGF P/W TEMP SW (TS451) On
 TE810 CONDENSOR EXIT TEMP 139.9 DEGF
 TE820 CUST HEX HOT IN TEMP 173.8 DEGF CUMHEATREC(MMBTU) 1.056
 TE880 CUST HEX COLD IN TEMP 172.9 DEGF FT880 FLOW (PPH) 0
 TE881 CUST HEX COLD EX TEMP 123.6 DEGF HEAT REC (MBTU/HR) 0 0
 TE401 STACK COOLANT INLET TEMP 339.0 DEGF
 LT400 SEPARATOR LEVEL 11.2 IN

PMP451 WTS FEEDWATER PUMP Off ON TIME, MIN.(FWPUMP): 0
 STARTTEMP TEMP FOR REF HEATUP 350.0 DEGF
 IDCNET NET DC CURRENT 224.3 AMPS

HTR400 ELEMENT "A" Off ELEMENT "C" On
 ELEMENT "B" On ELEMENT "D" Off

ELECTRICAL OVERVIEW

06/15/95 IDC= 473 VDC= 224 KWACNET= 50.2 VT310DEL= -0.85 EVENTS 0
 0946:35 FT012ACT= 37.7 TE400FT= 161 TE012FT= 1507 OVERRIDES 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

LOADTIME	TOTAL LOAD TIME	68	HR		
HOTTIME	TOTAL HOT TIME	122	HR		
CELV	AVG VOLTS PER CELL	1.700	V/C		
ASF	CURRENT DENSITY	84	ASF		
KWDC	DC KILOWATTS	106.2	KW		
VT310DEL	DELTA HALF STK VOLT	-0.85	V	VT310 HALF STK VOLT	-0.01
	INSTANTANEOUS STK AMPS	465	A		
EFFINV	INVERTER EFFICIENCY	99.0	%	CELL EFFICIENCY (%)	56.0
EFFMECH	MECHANICAL EFFICIENCY	48.0	%	REF EFFICIENCY (%)	86.6
EFFELSC	ELECTRICAL EFFICIENCY	23.0	%	HEAT RATE (BTU/KWHR)	16506
KWACNET	NET AC POWER	50.2	KWAC	DISPATCHED POWER:	50.0
PFACT	ACTUAL POWER FACTOR	-1.00	-	DISPATCHED P.F.:	1.00
KVARNET	NET KVAR	-1.1	KVAR	DISPATCHED KVAR:	0.0
KVANET	NET KVA	49.7	KVA		
PARPOWER	PARASITE POWER	55.0	KW		
KWACGROS	GROSS AC POWER	105.2	KW		
MWHRSGR	GROSS AC MW HRS	2.549	MWHR		
MWHRSNBT	NET AC MW HOURS	0.922	MWHR		

POWER CONDITIONER SYSTEM

06/15/95 IDC= 462 VDC= 224 KWACNET= 49.9 VT310DEL= -0.80 EVENTS 0
 0846:35 FT012ACT= 40.4 TE400FT= 161.5 TE012FT= 1511.1 OVERRIDES 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 20 L 10 I 50

PT001A	INV AC VOLTAGE, PHASE A	497.5	V		
PT001B	INV AC VOLTAGE, PHASE B	494.2	V		
PT001C	INV AC VOLTAGE, PHASE C	493.2	V		
CT001A	INV AC CURRENT, PHASE A	53.7	A		
CT001B	INV AC CURRENT, PHASE B	56.9	A		
CT001C	INV AC CURRENT, PHASE C	58.2	A	CURRENT UNBAL (%)	7.5
PT003A	NET AC VOLTAGE, PHASE A	497.6	V		
PT003B	NET AC VOLTAGE, PHASE B	495.2	V		
PT003C	NET AC VOLTAGE, PHASE C	492.3	V	VOLTAGE UNBAL (%)	1.0
LINKVDC	LINK VOLTAGE	599.7	V		
PERCFUND	PERCENT FUNDAMENTAL	86.5	%		
PSREQ	PHASE SHIFT REQUEST	4.8	DEG		
MCB001	G/C BREAKER STATUS	Off			
MCB002	G/C BREAKER STATUS	On			
MCB003	INTER-TIE BREAKER STAT	On			
INTCOUNT	INTERRUPT COUNT	0			

KEY PARAMETERS (ENGLISH UNITS):

P/P 9061 06/16/95 1027:37 EVENTS: 0 OVERRIDE: 0
 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

POWER OUTPUT (NET)	101.0	KWAC	OPERATING TIME	70.3	HRS
POWER OUTPUT (GROSS)	117.7	KWAC	POWER FACTOR	0.99	
STACK CURRENT	539.5	AMPS	CUMULATIVE POWER	1.084	MWHR
STACK VOLTAGE	220.9	VOLTS	HALF STACK VOLTAGE	0.03	VOLTS
VOLUMETRIC FUEL FLOW	993.2	SCFH	FUEL FLOW SETPOINT	1002.8	SCFH
ACTUAL FUEL FLOW	44.7	PPH			
ZT010 EJECTOR POSITION	26.9	%	ZT010 SETPOINT	25.9	%
PHI MONITOR	1.05		TOTAL FUEL CONS	35819	SCF
FT140 BURNER AIR FLOW	315.1	PPH	FT140 SETPOINT	319.3	PPH
TE012 REFORMER TEMP	1521.2	DEGF	ZT110 POSITION	48.7	%
TE012R BACKUP REF TEMP	1519.0	DEGF	TE012 SETPOINT	1520.5	DEGF
TR002 HDS TEMP	510.7	DEGF	TE350 ANODE INLET TEMP	397.3	DEGF
TE400FT STEAM SEP TEMP	356.8	DEGF	TE400 SETPOINT	356.8	DEGF
TE881 TEMP TO CUST	102.5	DEGF	RECOVERED HEAT	0.0	MBTU/HR
LT400 SEPARATOR LEVEL	11.1	IN	TE431 POLISHER TEMP	82.3	DEGF
PMP451 STATUS	Off		TE810 GLYCOL TEMP	140.6	DEGF
			TE160 MOTOR COMP AIR	74.4	DEGF
			TE150 MOT COMP AIR IN	69.8	DEGF
ELECTRICAL EFFICIENCY	37.3	%	press <NEXT PAGE> key to view RM data		

REACTANT SUPPLY SYSTEM

06/16/95 IDC= 521.3 VDC= 222 KWACNET= 101 VT310DEL= -0.80 EVENTS 0
 1028:43 FTO12ACT= 44.4 TE400FT= 357 TE012FT= 1522 OVERRIDE 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

TE012	REF TUBE TEMP (PRIMARY)	1522.1	DEGF	SETPOINT:	1519.6
TE012R	REF TUBE TEMP (BACKUP)	1520.4	DEGF	REF/FUEL CONT OUTPUT:	1.09
TE012DEL	REF TUBE TEMP DELTA	1.7	DEGF		
FT012ACT	ACTUAL MASS FUEL FLOW	44.4	PPH	SETPOINT:	43.5
FT012	UNCORR. MASS FUEL FLOW	50.7	PPH	TE011 FUEL TEMP (DEGF)	75.0
SCFH	ACTUAL VOLUME FUEL FLOW	986.9	CFH	SETPOINT:	957.6
FUELTOT	TOTAL FUEL CONSUMED	35836	SCF	PT012 VENTURI (PSIA)	6.85
ET010	EJECTOR POSITION	26.3	%	SETPOINT:	25.3
PHIMON	PHI MONITOR	1.02		STEAM FLOW S.P. (PPH):	161.8
TE350	ANODE INLET TEMP	398.2	DEGF		
TE002	HDS BED TEMP	510.2	DEGF	HTR002 STATUS:	On
EFFREF	REFORMER EFFICIENCY	78.9	%		

STACK LOOP, ANC LOOP, & WTS
 06/16/95 IDC= 542.1 VDC= 221 KWACNET= 99.1 VT310DEL= -0.81 EVENTS 0
 1029:49 FT012ACT= 44.6 TE400FT= 356.9 TE012FT= 1524 OVERRIDES 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

TE400	SEPARATOR TEMP (PRIMARY)	357.3	DEGF	SETPOINT:	356.7
TE400R	SEPARATOR TEMP (BACKUP)	357.3	DEGF	SEP TEMP FACTOR(DEGF)	1.0
TE400DEL	SEP TEMP DELTA	0.0	DEGF		
LS450	WATER TANK LEVEL SWITCH	On		STK FLOW SW (TS400)	On
TS431	POLISHER TEMP	81.8	DEGF	F/W TEMP SW (TS451)	On
TE310	CONDENSOR EXIT TEMP	139.9	DEGF		
TE820	CUST HEX HOT IN TEMP	160.6	DEGF	CUMHEATREC(MMBTU)	1.055
TE880	CUST HEX COLD IN TEMP	150.0	DEGF	TE880 FLOW (PPH)	0
TE881	CUST HEX COLD EX TEMP	103.4	DEGF	HEAT REC (MBTU/HR)	0 0
TE401	STACK COOLANT INLET TEMP	329.1	DEGF		
LT400	SEPARATOR LEVEL	10.8	IN		
PMP451	WTS FEEDWATER PUMP	On		ON TIME, MIN.(FWPUMP):	0
STARTTEMP	TEMP FOR REF HEATUP	350.0	DEGF		
IDCNET	NET DC CURRENT	544.5	AMPS		
HTR400	ELEMENT "A"	Off		ELEMENT "C"	Off
	ELEMENT "B"	Off		ELEMENT "D"	Off

ELECTRICAL OVERVIEW
 06/16/95 IDC= 535 VDC= 222 KWACNET= 99.1 VT310DEL= -0.84 EVENTS 0
 1031:21 FT312ACT= 44.4 TE400FT= 356 TE012FT= 1524 OVERRIDES 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

LOADTIME	TOTAL LOAD TIME	70	HR		
HOTTIME	TOTAL HOT TIME	123	HR		
CELV	AVG VOLTS PER CELL	1.695	V/C		
ASF	CURRENT DENSITY	96	ASF		
KWDC	DC KILOWATTS	119.3	KW		
VT310DEL	DELTA HALF STK VOLT	-0.84	V	VT310 HALF STK VOLT	-0.01
	INSTANTANEOUS STK AMPS	539	A		
EFFINV	INVERTER EFFICIENCY	98.0	%	CELL EFFICIENCY (%)	55.5
EFFMECH	MECHANICAL EFFICIENCY	86.9	%	REF EFFICIENCY (%)	79.6
EFFELRC	ELECTRICAL EFFICIENCY	37.5	%	HEAT RATE (BTU/KWHR)	10093
KWACNET	NET AC POWER	100.3	KWAC	DISPATCHED POWER:	100.0
FFACT	ACTUAL POWER FACTOR	-1.00	-	DISPATCHED P.F.:	1.00
KVARNET	NET KVAR	-0.5	KVAR	DISPATCHED KVAR:	0.0
KVANET	NET KVA	100.4	KVA		
PARPOWER	PARASITE POWER	16.3	KW		
KWACGROS	GROSS AC POWER	116.5	KW		
MWHRSGR	GROSS AC MW HRS	2.754	MWHR		
MWHRNET	NET AC MW HOURS	1.091	MWHR		

POWER CONDITIONER SYSTEM

06/16/95 IDC= 539 VDC= 221 KWACNET= 100.2 VT310DEL= -0.80 EVENTS 0
 1032:46 FT012ACT= 44.5 TE400FT= 356.8 FT012FT= 1523.9 OVERRIDE 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

PT001A	INV AC VOLTAGE, PHASE A	492.8	V		
PT001B	INV AC VOLTAGE, PHASE B	490.1	V		
PT001C	INV AC VOLTAGE, PHASE C	490.5	V		
CT001A	INV AC CURRENT, PHASE A	108.0	A		
CT001B	INV AC CURRENT, PHASE B	116.2	A		
CT001C	INV AC CURRENT, PHASE C	121.3	A	CURRENT UNBAL (%)	12.3
PT003A	NET AC VOLTAGE, PHASE A	493.1	V		
PT003B	NET AC VOLTAGE, PHASE B	490.8	V		
PT003C	NET AC VOLTAGE, PHASE C	488.4	V	VOLTAGE UNBAL (%)	1.0
LINKVDC	LINK VOLTAGE	599.8	V		
PERCFUND	PERCENT FUNDAMENTAL	86.3	%		
PSREQ	PHASE SHIFT REQUEST	6.5	DSG		
MCB001	G/I BREAKER STATUS	Off			
MCB002	G/C BREAKER STATUS	On			
MCB003	INTER-TIE BREAKER STAT	On			
INTCOUNT	INTERRUPT COUNT	0			

ELECTRICAL OVERVIEW

06/16/95 IDC= 546 VDC= 221 KWACNET= 100.1 VT310DEL= -0.80 EVENTS 0
 1041:36 FT012ACT= 45.0 TE400FT= 356 FT012FT= 1529 OVERRIDES 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

LOADTIME	TOTAL LOAD TIME	70	HR		
HOTTIME	TOTAL HOT TIME	124	HR		
CELV	AVG VOLTS PER CELL	.591	V/C		
ASF	CURRENT DENSITY	98	ASF		
KWDC	DC KILOWATTS	121.1	KW		
VT310DEL	DELTA HALF STK VOLT	-0.80	V	VT310 HALF STK VOLT	0.02
	INSTANTANEOUS STK AMPS	542	A		
EFFINV	INVERTER EFFICIENCY	97.9	%	CELL EFFICIENCY (%)	55.4
EFFMECH	MECHANICAL EFFICIENCY	84.8	%	REF EFFICIENCY (%)	77.5
EFFELEC	ELECTRICAL EFFICIENCY	35.5	%	HEAT RATE (BTU/KWHR)	10669
KWACNET	NET AC POWER	100.1	KW	DISPATCHED POWER:	100.0
PFACT	ACTUAL POWER FACTOR	0.90	-	DISPATCHED P.F.:	0.85
KVARNET	NET KVAR	45.9	KVAR	DISPATCHED KVAR:	61.9
KVANET	NET KVA	110.6	KVA		
PARPOWER	PARASITE POWER	18.3	KW		
KWACGROS	GROSS AC POWER	118.4	KW		
MWHRSGR	GROSS AC MW HRS	2.773	MWHR		
MWHRNET	NET AC MW HOURS	1.107	MWHR		

ELECTRICAL OVERVIEW

05/16/95 IDC= 542 VDC= 221 KWACNET= 100.9 VT310DEL= -0.80 EVENTS 0
 1051:11 TE012ACT= 45.8 TE400FT= 356 TE012PT= 1531 OVERRIDES 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

LOADTIME	TOTAL LOAD TIME	70	HR		
HOTTIME	TOTAL HOT TIME	124	HR		
CELV	AVG VOLTS PER CELL	.690	V/C		
ASF	CURRENT DENSITY	97	ASF		
KWDC	DC KILOWATTS	120.1	KW		
VT310DEL	DELTA HALF STK VOLT	-0.80	V	VT310 HALF STK VOLT	0.02
	INSTANTANEOUS STK AMPS	544	A		
EFFINV	INVERTER EFFICIENCY	97.7	%	CELL EFFICIENCY (%)	55.3
EFFMECH	MECHANICAL EFFICIENCY	85.3	%	REF EFFICIENCY (%)	78.5
EFFELEC	ELECTRICAL EFFICIENCY	36.3	%	HEAT RATE (BTU/KWHR)	10415

KWACNET	NET AC POWER	100.9	KWAC	DISPATCHED POWER:	100.9
PFACT	ACTUAL POWER FACTOR	-0.85	-	DISPATCHED P.F.:	-0.85
KVARNET	NET KVAR	-59.0	KVAR	DISPATCHED KVAR:	-61.9
KVANET	NET KVA	116.8	KVA		
PARPOWER	PARASITE POWER	18.1	KW		
KWACGROS	GROSS AC POWER	119.0	KW		
MWHRSGR	GROSS AC MW HRS	2.793	MWHR		
MWHRNET	NET AC MW HOURS	1.124	MWHR		

KEY PARAMETERS (ENGLISH UNITS)

P/P 9061 06/16/95 1201:57 EVENTS: 0 OVERRIDE: 0
 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

POWER OUTPUT (NET)	150.1	KWAC	OPERATING TIME	71.9	HRS
POWER OUTPUT (GROSS)	166.0	KWAC	POWER FACTOR	-1.00	
STACK CURRENT	802.5	AMPS	CUMULATIVE POWER	1.295	MWHR
STACK VOLTAGE	212.1	VOLTS	HALF STACK VOLTAGE	0.16	VOLTS
VOLUMETRIC FUEL FLOW	1457.4	SCFH	FUEL FLOW SETPOINT	1456.7	SCFH
ACTUAL FUEL FLOW	65.6	PPH			
TE010 EJECTOR POSITION	43.2	%	TE010 SETPOINT	42.1	%
PHI MONITOR	1.25		TOTAL FUEL CONS	37925	SCF
TE140 BURNER AIR FLOW	438.9	PPH	TE140 SETPOINT	435.2	PPH
TE012 REFORMER TEMP	1587.6	DEGF	TE110 POSITION	63.1	%
TE012R BACKUP REF TEMP	1592.0	DEGF	TE012 SETPOINT	1596.6	DEGF
TE302 HRS TEMP	537.1	DEGF	TE350 ANODE INLET TEMP	399.5	DEGF
TE400FT STEAM SEP TEMP	343.1	DEGF	TE400 SETPOINT	348.4	DEGF
TE88L TEMP TO CUST	94.6	DEGF	RECOVERED HEAT	0.0	MBTU/HR
TE400 SEPARATOR LEVEL	11.3	IN	TE431 POLISHER TEMP	86.5	DEGF
PMP451 STATUS	051		TE810 GLYCOL TEMP	155.5	DEGF
			TE160 MOTOR COMP AIR	74.2	DEGF
			TE150 MOT COMP AIR IN	73.5	DEGF
ELECTRICAL EFFICIENCY	36.3	%	press <NEXT PAGE> key to view RM data		

REACTANT SUPPLY SYSTEM
 06/16/95 IDC= 800.6 VDC= 212 KWACNET= 150 VT310DEL= -0.67 EVENTS 0
 1203:45 FT012ACT= 96.5 TE400FT= 349 TE012FT= 1599 OVERRIDE 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 52

TE012	REF TUBE TEMP (PRIMARY)	1599.9	DEGF	SETPOINT:	1597.1
TE012R	REF TUBE TEMP (BACKUP)	1505.6	DEGF	REF/FUEL CONT OUTPUT:	1.07
TE012DEL	REF TUBE TEMP DELTA	5.7	DEGF		
FT012ACT	ACTUAL MASS FUEL FLOW	66.5	PPH	SETPOINT:	65.6
FT012	UNCORR. MASS FUEL FLOW	71.1	PPH	TE011 FUEL TEMP(DEGF)	76.8
SV01	ACTUAL VOLUME FUEL FLOW	1477.0	CFH	SETPOINT:	1460.1
FUSLIC1	TOTAL FUEL CONSUMED	37950	SCF	PT012 VENTURI(PSIA)	7.85

ETC10	EJECTOR POSITION	42.1	%	SETPOINT:	41.2
PEIMON	PHI MONITOR	1.01		STEAM FLOW S.P.(PPH):	242.2
CE350	ANODE INLET TEMP	399.3	DEGF		

IS002	HDS BED TEMP	527.9	DEGF	HTR002 STATUS:	Off
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EFFR3EF	REFORMER EFFICIENCY	80.6	%		
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STACK LOOP, ANC LOOP, & WTS
 06/16/95 IDC= 806.7 VDC= 212 KWACNET= 151 VT310DEL= -0.67 EVENTS 0
 1205:01 FT012ACT= 66.2 TE400FT= 349.0 TE012FT= 1606 OVERRIDE 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

TE400	SEPARATOR TEMP (PRIMARY)	348.6	DEGF	SETPOINT:	348.5
TE400R	SEPARATOR TEMP (BACKUP)	348.7	DEGF	SEP TEMP FACTOR(DEGF)	0.9
TE400DEL	SEP TEMP DELTA	0.6	DEGF		
LS450	WATER TANK LEVEL SWITCH	On		STK FLOW SW (PS400)	On
TE431	POLISHER TEMP	84.5	DEGF	F/W TEMP SW (TS431)	On
TE810	CONDENSOR EXIT TEMP	157.5	DEGF		
TE820	CUST HEX HOT IN TEMP	189.8	DEGF	CUMHEATREC(MMBTU)	1.055
TE880	CUST HEX COLD IN TEMP	156.8	DEGF	FTS80 FLOW (PPH)	0
TE881	CUST HEX COLD EX TEMP	95.0	DEGF	HEAT REC (MBTU/HR)	0.0
TE401	STACK COOLANT INLET TEMP	308.0	DEGF		
LT400	SEPARATOR LEVEL	10.8	IN		

PMP451	WTS FEEDWATER PUMP	On		ON TIME, MIN.(FWPUMP):	0
STARTTEMP	TEMP FOR REF HEATUP	350.0	DEGF		
IDCNET	NET DC CURRENT	809.4	AMPS		

HTR400	ELEMENT "A"	Off		ELEMENT "C"	Off
	ELEMENT "B"	Off		ELEMENT "D"	Off

ELECTRICAL OVERVIEW

06/15/95 IDC= 797 VDC= 212 KWACNET= 148.8 VT310DEL= -0.65 EVENTS 0
 1206:00 PTC12ACT= 64.1 TE4COFT= 350 TE012FT= 1607 OVERRIDES 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

LOADTIME	TOTAL LOAD TIME	71	HR		
HOTTIME	TOTAL HOT TIME	125	HR		
CELV	AVG VOLTS PER CELL	.664	V/C		
ASF	CURRENT DENSITY	142	ASF		
KWDC	DC KILOWATTS	168.9	KW		
VT310DEL	DELTA HALF STK VOLT	-0.65	V	VT310 HALF STK VOLT	0.18
	INSTANTANEOUS STK AMPS	802	A		
EFFINV	INVERTER EFFICIENCY	97.6	%	CELL EFFICIENCY (%)	53.1
EFFMECH	MECHANICAL EFFICIENCY	90.1	%	REF EFFICIENCY (%)	82.0
EFFELEC	ELECTRICAL EFFICIENCY	38.2	%	HEAT RATE (BTU/KWHR)	9919
KWACNET	NET AC POWER	148.8	KWAC	DISPATCHED POWER:	150.0
PFAC	ACTUAL POWER FACTOR	-1.00	-	DISPATCHED P.F.:	1.00
KVARNET	NET KVAR	-1.3	KVAR	DISPATCHED KVAR:	0.0
KVANET	NET KVA	149.3	KVA		
PASPOWER	PARASITE POWER	15.8	KW		
KWACGROS	GROSS AC POWER	164.7	KW		
MWHRSGR	GROSS AC MW HRS	2.996	MWHR		
MWHRNET	NET AC MW HOURS	1.307	MWHR		

POWER CONDITIONER SYSTEM

06/15/95 IDC= 801 VDC= 212 KWACNET= 150.1 VT310DEL= -0.65 EVENTS 0
 1206:59 PTC12ACT= 64.0 TE4COFT= 348.5 TE012FT= 1599.5 OVERRIDE 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

PT001A	INV AC VOLTAGE, PHASE A	498.2	V		
PT001B	INV AC VOLTAGE, PHASE B	496.3	V		
PT001C	INV AC VOLTAGE, PHASE C	496.5	V		
CT001A	INV AC CURRENT, PHASE A	164.0	A		
CT001B	INV AC CURRENT, PHASE B	176.0	A		
CT001C	INV AC CURRENT, PHASE C	179.5	A	CURRENT UNBAL (%)	9.1
PT003A	NET AC VOLTAGE, PHASE A	497.1	V		
PT003B	NET AC VOLTAGE, PHASE B	495.8	V		
PT003C	NET AC VOLTAGE, PHASE C	491.9	V	VOLTAGE UNBAL (%)	1.0
LINKVDC	LINK VOLTAGE	539.6	V		
PERCFUND	PERCENT FUNDAMENTAL	88.8	%		
PSREQ	PHASE SHIFT REQUEST	6.9	DEG		
MCB001	G/I BREAKER STATUS	Off			
MCB002	G/C BREAKER STATUS	On			
MCB003	INTER-TIE BREAKER STAT	On			
INTCOUNT	INTERRUPT COUNT	0			

KEY PARAMETERS (ENGLISH UNITS)

/P 9061 06/20/95 1746:14 EVENTS: 0 OVERRIDE: 0
 150 R 160 S 50 W 20 A 30 N 40 C 30 L 10 I 50

POWER OUTPUT (NET)	193.8	KWAC	OPERATING TIME	150.1	HRS
POWER OUTPUT (GROSS)	216.1	KWAC	POWER FACTOR	-1.00	
TACK CURRENT	1084.4	AMPS	CUMULATIVE POWER	11.584	MWHR
TACK VOLTAGE	207.0	VOLTS	HALF STACK VOLTAGE	0.49	VOLTS
VOLUMETRIC FUEL FLOW	1975.1	SCFH	FUEL FLOW SETPOINT	1992.6	SCFH
ACTUAL FUEL FLOW	88.3	PPH			
TE010 EJECTOR POSITION	66.7	%	TE010 SETPOINT	66.2	%
PHI MONITOR	1.00		TOTAL FUEL CONS	139496	SCF
TE140 BURNER AIR FLOW	555.9	PPH	TE140 SETPOINT	533.3	PPH
TE012 REFORMER TEMP	1663.2	DEGF	TE110 POSITION	84.0	%
TE012R BACKUP REF TEMP	1676.0	DEGF	TE012 SETPOINT	1655.6	DEGF
TE002 HDS TEMP	581.9	DEGF	TE350 ANODE INLET TEMP	407.8	DEGF
TE400FT STEAM SEP TEMP	350.8	DEGF	TE400 SETPOINT	350.1	DEGF
TE381 TEMP TO CUST	177.1	DEGF	RECOVERED HEAT	254	MBTU/HR
TE400 SEPARATOR LEVEL	11.2	IN	TE431 POLISHER TEMP	119.0	DEGF
MP451 STATUS	Off		TE810 GLYCOL TEMP	153.3	DEGF
ELECTRICAL EFFICIENCY	36.2	%	TE160 MOTOR COMP AIR	113.1	DEGF
			TE150 MOT COMP AIR IN	99.2	DEGF

press <NEXT PAGE> key to view RM data

REACTANT SUPPLY SYSTEM

06/20/95 IDC= 1085.5 VDC= 207 KWACNET= 200 VT310DEL= -0.36 EVENTS 0
 1746:55 TE012ACT= 88.3 TE400FT= 351 TE012FT= 1656 OVERRIDE 0
 P/P 9061 P 150 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

TE012	REF TUBE TEMP (PRIMARY)	1657.1	DEGF	SETPOINT:	1655.2
TE012R	REF TUBE TEMP (BACKUP)	1670.2	DEGF	REF/FUEL CONT OUTPUT:	1.08
TE012DEL	REF TUBE TEMP DELTA	14.5	DEGF		
FT012ACT	ACTUAL MASS FUEL FLOW	88.3	PPH	SETPOINT:	89.8
FT012	UNCORR. MASS FUEL FLOW	91.7	PPH	TE011 FUEL TEMP(DEGF)	99.0
SCFH	ACTUAL VOLUME FUEL FLOW	1962.2	CFH	SETPOINT:	1996.0
FUELTOT	TOTAL FUEL CONSUMED	139496	SCF	TE012 VENTURI(Psia)	8.70
TE010	EJECTOR POSITION	65.8	%	SETPOINT:	65.7
PHIMON	PHI MONITOR	1.02		STEAM FLOW S.P.(PPH):	322.3
TE350	ANODE INLET TEMP	407.4	DEGF		
TE002	HDS BED TEMP	582.8	DEGF	HT002 STATUS:	Off
EFFREF	REFORMER EFFICIENCY	81.2	%		

STACK LOOP, ANC LOOP, & WTS

06/20/95 IDC= 1089.6 VDC= 207 KWACNET= 200 VT310DEL= -0.37 EVENTS 0
 1747:41 FT012ACT= 90.8 TS400FT= 351.5 TE012FT= 1651 OVERRIDE 0
 P/P 9061 P 150 R 160 S 60 W 20 A 30 N 40 C 30 L 10 1 50

TE400	SEPARATOR TEMP (PRIMARY)	351.1	DEGF	SETPOINT:	350.4
TE400R	SEPARATOR TEMP (BACKUP)	350.7	DEGF	SEP TEMP FACTOR(DEGF)	0.9
TE400DEL	SEP TEMP DELTA	0.4	DEGF		
LS450	WATER TANK LEVEL SWITCH	On		STK FLOW SW (FS400)	On
TE431	POLISHER TEMP	119.0	DEGF	F/W TEMP SW (TS451)	On
TE310	CONDENSOR EXIT TEMP	153.3	DEGF		
TE820	CUST HEX HOT IN TEMP	177.5	DEGF	CUMHEATREC(MMBTU)	1.210
TE880	CUST HEX COLD IN TEMP	105.4	DEGF	FT880 FLOW (PPH)	2762
TE881	CUST HEX COLD EX TEMP	178.8	DEGF	HEAT REC (MBTU/HR)	202
TE401	STACK COOLANT INLET TEMP	316.6	DEGF		
LT400	SEPARATOR LEVEL	10.8	IN		
PMP451	WTS FEEDWATER PUMP	On		ON TIME, MIN.(FWPUMP):	0
STARTTEMP	TEMP FOR REF HEATUP	350.0	DEGF		
IDCNET	NET DC CURRENT	1092.8	AMPS		
HTR400	ELEMENT "A"	Off		ELEMENT "C"	Off
	ELEMENT "B"	Off		ELEMENT "D"	Off

ELECTRICAL OVERVIEW

06/20/95 IDC= 1092 VDC= 207 KWACNET= 199.7 VT310DEL= -0.36 EVENTS 0
 1748:44 FT012ACT= 92.6 TS400FT= 351 TE012FT= 1658 OVERRIDES 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 1 50

LOADTIME	TOTAL LOAD TIME	150	HR		
HOTTIME	TOTAL HOT TIME	210	HR		
CELV	AVG VOLTS PER CELL	1.646	V/C		
ASF	CURRENT DENSITY	194	ASF		
KWDC	DC KILOWATTS	224.5	KW		
VT310DEL	DELTA HALF STK VOLT	-0.36	V	VT310 HALF STK VOLT	0.46
	INSTANTANEOUS STK AMPS	1078	A		
EFFINV	INVERTER EFFICIENCY	96.0	%	CELL EFFICIENCY (%)	51.7
EFFMECH	MECHANICAL EFFICIENCY	92.4	%	REF EFFICIENCY (%)	79.2
EFFELSC	ELECTRICAL EFFICIENCY	36.3	%	HEAT RATE (BTU/KWHR)	10435
KWACNET	NET AC POWER	199.9	KWAC	DISPATCHED POWER:	200.0
PFACT	ACTUAL POWER FACTOR	-1.00	-	DISPATCHED P.F.:	1.00
KVARNET	NET KVAR	-0.7	KVAR	DISPATCHED KVAR:	0.0
KVANET	NET KVA	200.2	KVA		
PARPOWER	PARASITE POWER	16.8	KW		
KWACGROS	GROSS AC POWER	216.2	KW		
MWHRSGR	GROSS AC MW HRS	14.718	MWHR		
MWHRNET	NET AC MW HOURS	11.591	MWHR		

POWER CONDITIONER SYSTEM

06/20/95 IDC= 1086 VDC= 207 KWACNET= 199.3 VT310DEL= -0.35 EVENTS 0
 1749:30 FT012ACT= 89.7 TE400PT= 351.2 TE012PT= 1659.3 OVERRIDE 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

PT001A	INV AC VOLTAGE, PHASE A	491.2	V		
PT001B	INV AC VOLTAGE, PHASE B	489.9	V		
PT001C	INV AC VOLTAGE, PHASE C	489.8	V		
CT001A	INV AC CURRENT, PHASE A	225.1	A		
CT001B	INV AC CURRENT, PHASE B	242.1	A		
CT001C	INV AC CURRENT, PHASE C	239.5	A	CURRENT UNBAL (%)	7.1
PT003A	NET AC VOLTAGE, PHASE A	489.5	V		
PT003B	NET AC VOLTAGE, PHASE B	486.3	V		
PT003C	NET AC VOLTAGE, PHASE C	484.2	V	VOLTAGE UNBAL (%)	1.1
LINKVDC	LINK VOLTAGE	599.9	V		
PERCFUND	PERCENT FUNDAMENTAL	88.8	%		
PSR2Q	PHASE SHIFT REQUEST	8.8	DEG		
MCB001	G/I BREAKER STATUS	Off			
MCB002	G/C BREAKER STATUS	On			
MCB003	INTER-TIE BREAKER STAT	On			
INTCOUNT	INTERRUPT COUNT	0			

ONSI CORPORATION

TOTAL HARMONIC DISTORTION

DEMONSTRATED: 1.27 %
 REQUIRED: < 3.00 %
 RESULT: PASS

06/28/95 13:04:46

VOLTS = 483.7
 AMPS = 0.04
 WATTS = 17
 P.F. = +1.00

HARM PWR = 2
 Approx TDF = 0.95

VOLTS AMPS

TIF	8	77
THD	1.27%	17.39%
F	474.30	0.04A
2	0.46%	13.04%
3	0.40%	4.35%
4	0.06%	4.35%
5	0.04%	4.35%
6	0.04%	0.00%
7	0.32%	4.35%
8	0.04%	0.00%
9	0.06%	0.00%
10	0.08%	4.35%
11	0.48%	4.35%
12	0.02%	0.00%
13	0.38%	4.35%
14	0.02%	0.00%
15	0.02%	0.00%
16	0.02%	0.00%
17	0.04%	0.00%
18	0.02%	0.00%
19	0.02%	0.00%
20	0.02%	0.00%
21	0.00%	0.00%
22	0.02%	0.00%
23	0.04%	4.35%
24	0.00%	0.00%
25	0.00%	0.00%

ONSI CORPORATION

OUTPUT FREQUENCY (GRID CONNECT)

DEMONSTRATED: 60.00 HZ
 REQUIRED: 60±3 HZ
 RESULT: PASS

ELECTRICAL OVERVIEW

06/20/95 IDC= 1093 VDC= 207 KWACNET= 200.1 VT310DEL= -0.40 EVENTS 0
 1922:17 PT012ACT= 90.1 TE400FT= 351 TRED12PT= 1661 OVERRIDES 0
 2/2 9061 F 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

LOADTIME	TOTAL LOAD TIME	150	HR		
HOTTIME	TOTAL HOT TIME	211	HR		
CELV	AVG VOLTS PER CELL	.646	V/C		
ASF	CURRENT DENSITY	196	ASF		
KWDC	DC KILOWATTS	226.7	KW		
VT310DEL	DELTA HALF STK VOLT	-0.40	V	VT310 HALF STK VOLT	0.43
	INSTANTANEOUS STK AMPS	1091	A		
3FFINV	INVERTER EFFICIENCY	95.6	%	CELL EFFICIENCY (%)	51.7
EFFMECH	MECHANICAL EFFICIENCY	92.2	%	REF EFFICIENCY (%)	81.1
EFFELEC	ELECTRICAL EFFICIENCY	36.5	%	HEAT RATE (BTU/KWHR)	10268

KWACNET	NET AC POWER	200.2	KWAC	DISPATCHED POWER:	200.0
PFACT	ACTUAL POWER FACTOR	0.99	-	DISPATCHED P.F.:	0.85
KVARNET	NET KVAR	25.1	KVAR	DISPATCHED KVAR:	123.9
KVANET	NET KVA	202.0	KVA		
PARPOWER	PARASITE POWER	16.1	KW		
KWACGROS	GROSS AC POWER	216.4	KW		
MWHRSGR	GROSS AC MW.HRS	14.841	MWHR		
MWHRNET	NET AC MW HOURS	11.704	MWHR		

ELECTRICAL OVERVIEW

06/20/95 IDC= 1110 VDC= 206 KWACNET= 200.2 VT310DSL= -0.39 EVENTS 0
 1829:02 FT012ACT= 88.8 TE400CFT= 351 TE012FT= 1656 OVERRIDES 0
 P/P 9061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

LOADTIME	TOTAL LOAD TIME	150	HR		
NOTTIME	TOTAL NOT TIME	211	HR		
CRLV	AVG VOLTS PER CELL	.645	V/C		
ASF	CURRENT DENSITY	198	ASF		
KWDC	DC KILOWATTS	229.1	KW		
VT310DEL	DELTA HALF STK VOLT	-0.39	V	VT310 HALF STK VOLT	0.43
	INSTANTANEOUS STK AMPS	1113	A		
EFFINV	INVERTER EFFICIENCY	95.2	%	CELL EFFICIENCY (%)	51.6
EFFMECH	MECHANICAL EFFICIENCY	92.4	%	REF EFFICIENCY (%)	82.0
EFFELEC	ELECTRICAL EFFICIENCY	37.1	%	HEAT RATE (BTU/KWHR)	10198

KWACNET	NET AC POWER	199.7	KWAC	DISPATCHED POWER:	200.0
PFAC	ACTUAL POWER FACTOR	-0.85	-	DISPATCHED P.F.:	-0.85
KVARNET	NET KVAR	-122.6	KVAR	DISPATCHED KVAR:	-123.9
KVANET	NET KVA	234.8	KVA		
PARPOWER	PARASITE POWER	17.4	KW		
KWACGROS	GROSS AC POWER	217.2	KW		
MWHRSGR	GROSS AC MW HRS	14.866	MWHR		
MWHRNET	NET AC MW HOURS	11.724	MWHR		

KEY PARAMETERS (ENGLISH UNITS)

P/P 9061 06/20/95 1834:08 EVENTS: 0 OVERRIDE: 0
 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

POWER OUTPUT (NET)	200.2	KWAC	OPERATING TIME	150.9	HRS
POWER OUTPUT (GROSS)	214.3	KWAC	POWER FACTOR	-1.00	
STACK CURRENT	1077.0	AMPS	CUMULATIVE POWER	11.744	MWHR
STACK VOLTAGE	207.2	VOLTS	HALF STACK VOLTAGE	0.44	VOLTS
VOLUMETRIC FUEL FLOW	1943.4	SCFH	FUEL FLOW SETPOINT	1963.9	SCFH
ACTUAL FUEL FLOW	87.5	PPH			
ZT010 EJECTOR POSITION	64.3	%	ZT010 SETPOINT	64.3	%
PHI MONITOR	1.02		TOTAL FUEL CONS	1411.0	SCF
FT140 BURNER AIR FLOW	536.8	PPH	FT140 SETPOINT	519.6	PPH
TE012 REFORMER TEMP	1660.1	DEGF	ZT110 POSITION	84.4	%
TE012R BACKUP REF TEMP	1672.9	DEGF	TE012 SETPOINT	1656.3	DEGF
TE002 HDS TEMP	595.5	DEGF	TE350 ANODE INLET TEMP	409.8	DEGF
TE400FT STEAM SEP TEMP	351.1	DEGF	TE400 SETPOINT	350.2	DEGF
TE881 TEMP TO CUST	134.0	DEGF	RECOVERED HEAT	912	MBTU/HR
LT400 SEPARATOR LEVEL	11.0	IN	TE431 POLISHER TEMP	119.0	DEGF
PMP451 STATUS	On		TE810 GLYCOL TEMP	150.2	DEGF
ELECTRICAL EFFICIENCY	37.4	%	TE160 MOTOR COMP AIR	119.0	DEGF
			TE150 MOT COMP AIR IN	101.9	DEGF

press <NEXT PAGE> key to view RM data

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STACK LOOP, ANC LOOP, & WTS
 06/20/95 IDC= 1068.4 VDC= 208 KWACNET= 199 VT310DEL= -0.37 EVENTS 0
 1834:53 FT012ACT= 27.5 TE400FT= 350.7 TE012FT= 1656 OVERRIDE 0
 P/P 3061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

TE400	SEPARATOR TEMP (PRIMARY)	350.7	DEGF	SETPOINT:	350.2
TE400R	SEPARATOR TEMP (BACKUP)	350.0	DEGF	SEP TEMP FACTOR(DEGF)	0.9
TE400DEL	SEP TEMP DELTA	0.2	DEGF		
LS45C	WATER TANK LEVEL SWITCH	On		STK FLOW SW (FS400)	On
TE431	POLISHER TEMP	119.0	DEGF	F/W TEMP SW (TS451)	On
TE810	CONDENSOR EXIT TEMP	149.4	DEGF		
TE820	CUST HEX HOT IN TEMP	176.6	DEGF	CUMHEATREC(MMBTU)	1.350
TE880	CUST HEX COLD IN TEMP	92.6	DEGF	FT880 FLOW (PPH)	22075
TE881	CUST HEX COLD EX TEMP	130.2	DEGF	HEAT REC (MBTU/HR)	840
TE401	STACK COOLANT INLET TEMP	299.7	DEGF		
LT400	SEPARATOR LEVEL	11.2	IN		
PMP451	WTS FEEDWATER PUMP	Off		ON TIME, MIN.(FWPUMP):	0
STARTTEMP	TEMP FOR REF HEATUP	350.0	DEGF		
IDCNST	NET DC CURRENT	1064.1	AMPS		
HTR400	ELEMENT "A"	Off		ELEMENT "C"	Off
	ELEMENT "B"	Off		ELEMENT "D"	Off

STACK LOOP, ANC LOOP, & WTS
 06/20/95 IDC= 1088.1 VDC= 207 KWACNET= 200 VT310DEL= -0.45 EVENTS 0
 1934:51 FT012ACT= 91.6 TE400FT= 351.0 TE012FT= 1651 OVERRIDE 0
 P/P 3061 P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

TE400	SEPARATOR TEMP (PRIMARY)	351.1	DEGF	SETPOINT:	350.4
TE400R	SEPARATOR TEMP (BACKUP)	350.0	DEGF	SEP TEMP FACTOR(DEGF)	0.9
TE400DEL	SEP TEMP DELTA	0.0	DEGF		
LS45C	WATER TANK LEVEL SWITCH	On		STK FLOW SW (FS400)	On
TE431	POLISHER TEMP	119.5	DEGF	F/W TEMP SW (TS451)	On
TE810	CONDENSOR EXIT TEMP	152.2	DEGF		
TE820	CUST HEX HOT IN TEMP	180.6	DEGF	CUMHEATREC(MMBTU)	1.942
TE880	CUST HEX COLD IN TEMP	146.1	DEGF	FT880 FLOW (PPH)	0
TE881	CUST HEX COLD EX TEMP	179.9	DEGF	HEAT REC (MBTU/HR)	0
TE401	STACK COOLANT INLET TEMP	303.4	DEGF		
LT400	SEPARATOR LEVEL	10.8	IN		
PMP451	WTS FEEDWATER PUMP	On		ON TIME, MIN.(FWPUMP):	0
STARTTEMP	TEMP FOR REF HEATUP	350.0	DEGF		
IDCNST	NET DC CURRENT	1087.2	AMPS		
HTR400	ELEMENT "A"	Off		ELEMENT "C"	Off
	ELEMENT "B"	Off		ELEMENT "D"	Off

KEY PARAMETERS (ENGLISH UNITS)

P/P 9061 06/20/95 2034:51 EVENTS: 0 OVERRIDE: 0

P 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 50

POWER OUTPUT (NET)	200.2	KWAC	OPERATING TIME	152.9	HRS
POWER OUTPUT (GROSS)	215.7	KWAC	POWER FACTOR	1.00	
STACK CURRENT	1086.0	AMPS	CUMULATIVE POWER	12.144	MWHR
STACK VOLTAGE	206.7	VOLTS	HALF STACK VOLTAGE	0.39	VOLTS
VOLUMETRIC FUEL FLOW	1994.2	SCFH	FUEL FLOW SETPOINT	1997.0	SCFH
ACTUAL FUEL FLOW	89.8	PPH			
ZT010 EJECTOR POSITION	66.9	%	ZT010 SETPOINT	66.2	%
PHI MONITOR	1.01		TOTAL FUEL CONS	145056	SCF
FT140 BURNER AIR FLOW	517.7	PPH	PT140 SETPOINT	517.8	PPH
TE012 REFORMER TEMP	1652.2	DEGF	ZT110 POSITION	85.2	%
TE012R BACKUP REF TEMP	1661.9	DEGF	TE012 SETPOINT	1657.1	DEGF
TE002 HDS TEMP	603.9	DEGF	TE350 ANODE INLET TEMP	409.8	DEGF
TE400FT STEAM SEP TEMP	350.9	DEGF	TE400 SETPOINT	350.2	DEGF
TE881 TEMP TO CUST	180.4	DEGF	RECOVERED HEAT	101	MBTU/HR
TE400 SEPARATOR LEVEL	11.0	IN	TE431 POLISHER TEMP	121.9	DEGF
PMP451 STATUS	Off		TE810 GLYCOL TEMP	153.3	DEGF
ELECTRICAL EFFICIENCY	27.4	%	TE160 MOTOR COMP AIR	107.6	DEGF
			TE150 MOT COMP AIR IN	93.1	DEGF

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ONSI CORPORATION

FUEL CONSUMPTION

TIME
1834:08
2034:51

ELAPSED TIME:
INCREMENTAL FUEL CONSUMED:
AVG. VOLUMETRIC FUEL FLOW RATE:
REQUIRED FUEL FLOW RATE:

RESULT:

CUMULATIVE FUEL CONSUMED
141,110 SCF
145,086 SCF

2.012 HRS
3976 SCF
1976 SCFH
1900 ± 100 SCFH

PASS

STACK LOOP, ANC LOOP, & WTS

06/20/95 IDC= 1086.1 VDC= 207 KWACNET= 139 VT310DEL= -0.44 EVENTS 0
 2035:32 PT012ACT= 89.9 TE400FT= 350.8 TEC12FT= 1655 OVERRIDE 0
 P/P 9061 F 160 R 160 S 60 W 20 A 30 N 40 C 30 L 10 150

TE400	SEPARATOR TEMP (PRIMARY)	350.9	DEGF	SETPOINT:	350.1
TE400R	SEPARATOR TEMP (BACKUP)	350.9	DEGF	SEP TEMP FACTOR(DEGF)	0.9
TE400DEL	SEP TEMP DELTA	0.0	DEGF		
LS450	WATER TANK LEVEL SWITCH	On		STK FLOW SW (FS400)	On
TE431	POLISHER TEMP	121.9	DEGF	E/W TEMP SW (TS451)	On
TE810	CONDENSOR EXIT TEMP	154.0	DEGF		
TE820	CUST HEX HOT IN TEMP	188.0	DEGF	CUMHEATREC(MMBTU)	1.997
TE880	CUST HEX COLD IN TEMP	150.7	DEGF	PT880 FLOW (PPH)	2591
TE881	CUST HEX COLD EX TEMP	182.0	DEGF	HEAT REC (MMTU/HR)	83
TE401	STACK COOLANT INLET TEMP	316.8	DEGF		
LT400	SEPARATOR LEVEL	10.8	IN		
PMP451	WTS FEEDWATER PUMP	Off		ON TIME, MIN.(FWPUMP):	0
STARTTEMP	TEMP FOR REF HEATUP	350.0	DEGF		
IDCNET	NET DC CURRENT	1081.8	AMPS		
HTR400	ELEMENT "A"	Off		ELEMENT "C"	Off
	ELEMENT "B"	Off		ELEMENT "D"	Off

ONSI CORPORATION

HEAT RECOVERY

TIME
 1834:50
 2035:32

CUMULATIVE HEAT RECOVERY
 1,350,000 BTU
 1,997,000 BTU

ELAPSED TIME:
 INCREMENTAL HEAT RECOVERY:
 AVERAGE RATE OF HEAT RECOVERY:

2.012 HRS
 647,000 BTU
 321,570 BTU/HR.

KEY PARAMETERS (ENGLISH UNITS)

P/P 9061 06/21/95 0935:15 EVENTS: 0 OVERRIDE: 0

P 161 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 80

POWER OUTPUT (NET)	38.1	KWAC	OPERATING TIME	166.0	HRS
POWER OUTPUT (GROSS)	90.3	KWAC	POWER FACTOR	0.95	
STACK CURRENT	410.4	AMPS	CUMULATIVE POWER	14.561	MWHR
STACK VOLTAGE	227.9	VOLTS	HALF STACK VOLTAGE	-0.00	VOLTS
VOLUMETRIC FUEL FLOW	711.9	SCFH	FUEL FLOW SETPOINT	717.6	SCFH
ACTUAL FUEL FLOW	32.0	PPH			
ZT010 EJECTOR POSITION	23.2	%	ZT010 SETPOINT	21.8	%
PHI MONITOR	1.07		TOTAL FUEL CONS	169280	SCF
FT140 BURNER AIR FLOW	250.4	PPH	FT140 SETPOINT	253.7	PPH
TE012 REFORMER TEMP	1515.5	DEGF	ZT110 POSITION	45.5	%
TE012R BACKUP REF TEMP	1513.2	DEGF	TE012 SETPOINT	1527.3	DEGF
TE002 HDS TEMP	603.0	DEGF	TE350 ANODE INLET TEMP	406.7	DEGF
TE400PT STEAM SEP TEMP	364.0	DEGF	TE400 SETPOINT	363.4	DEGF
TE881 TEMP TO CUST	162.1	DEGF	RECOVERED HEAT	237	MBTU/HR
LT400 SEPARATOR LEVEL	10.9	IN	TE431 POLISHER TEMP	105.2	DEGF
PMP451 STATUS	On		TE810 GLYCOL TEMP	151.3	DEGF
ELECTRICAL EFFICIENCY	18.4	%	TE160 MOTOR COMP AIR	100.8	DEGF
			TE150 MOT COMP AIR IN	84.0	DEGF

press <NEXT PAGE> key to view RM data

REACTANT SUPPLY SYSTEM

06/21/95 IDC= 398.5 VDC= 229 KWACNET= 31 VT310DEL= -0.83 EVENTS 0

0936:14 FT012ACT= 32.3 TS400PT= 363 TE012PT= 1518 OVERRIDE 0

P/P 9061 P 161 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 80

TE012	REF TUBE TEMP (PRIMARY)	1518.2	DEGF	SETPOINT:	1526.8
TE012R	REF TUBE TEMP (BACKUP)	1513.6	DEGF	REF/FUEL CONT OUTPUT:	1.04
TE012DEL	REF TUBE TEMP DELTA	6.5	DEGF		
FT012ACT	ACTUAL MASS FUEL FLOW	32.0	PPH	SETPOINT:	31.7
FT012	UNCORR. MASS FUEL FLOW	36.1	PPH	TE011 FUEL TEMP (DEGF)	85.4
SCFH	ACTUAL VOLUME FUEL FLOW	710.9	CFH	SETPOINT:	700.5
FUELTOT	TOTAL FUEL CONSUMED	169292	SCF	PT012 VENTURI (PSIA)	7.15
ZT010	EJECTOR POSITION	22.9	%	SETPOINT:	21.6
PHIMON	PHI MONITOR	1.04		STEAM FLOW S.P. (PPH):	134.4
TE350	ANODE INLET TEMP	406.7	DEGF		
TE002	HDS BED TEMP	602.1	DEGF	HTR002 STATUS:	Off
EFFREF	REFORMER EFFICIENCY	83.7	%		

STACK LOOP, ANC LOOP, & WTS

06/21/95 IDC= 490.8 VDC= 222 KWACNET= 54 VT310DEL= -0.80 EVENTS 0
 0937:07 FT012ACT= 40.4 TE400FT= 362.5 TE012FT= 1520 OVERRIDE 0
 P/P 9061 P 161 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 80

TE400	SEPARATOR TEMP (PRIMARY)	362.5	DEGF	SETPOINT:	358.8
TE400R	SEPARATOR TEMP (BACKUP)	362.1	DEGF	SEP TEMP FACTOR(DEGF)	1.0
TE400DEL	SEP TEMP DELTA	0.4	DEGF		
TS450	WATER TANK LEVEL SWITCH	On		STK FLOW SW (FS400)	On
TE431	POLISHER TEMP	105.2	DEGF	F/W TEMP SW (TS451)	On
TE810	CONDENSOR EXIT TEMP	153.3	DEGF		
TE820	CUST HEX HOT IN TEMP	186.1	DEGF	CUMHEATREC(MBTHU)	3.231
TE880	CUST HEX COLD IN TEMP	150.5	DEGF	FT880 FLOW (PPH)	22247
TE881	CUST HEX COLD EX TEMP	160.6	DEGF	HEAT REC (MBTU/HR)	224
TE401	STACK COOLANT INLET TEMP	346.1	DEGF		
LT400	SEPARATOR LEVEL	11.3	IN		
PMP451	WTS FEEDWATER PUMP	Off		ON TIME, MIN.(FWPUMP):	0
STARTTEMP	TEMP FOR REF HEATUP	350.0	DEGF		
IDCNET	NET DC CURRENT	209.3	AMPS		
ETR400	ELEMENT "A"	On		ELEMENT "C"	On
	ELEMENT "B"	On		ELEMENT "D"	Off

ELECTRICAL OVERVIEW

06/21/95 IDC= 452 VDC= 225 KWACNET= 44.5 VT310DEL= -0.85 EVENTS 0
 0938:12 FT012ACT= 35.0 TE400FT= 361 TE012FT= 1528 OVERRIDES 0
 P/P 9061 P 161 R 160 S 60 W 20 A 30 N 40 C 30 L 10 I 80

LOADTIME	TOTAL LOAD TIME	166	HR		
HOTTIME	TOTAL HOT TIME	225	HR		
CELV	AVG VOLTS PER CELL	1.704	V/C		
ASF	CURRENT DENSITY	81	ASF		
KWDC	DC KILOWATTS	102.1	KW		
VT310DEL	DELTA HALF STK VOLT	-0.85	V	VT310 HALF STK VOLT	-0.02
	INSTANTANEOUS STK AMPS	452	A		
EFFINV	INVERTER EFFICIENCY	97.4	%	CELL EFFICIENCY (%)	56.1
EFFMECH	MECHANICAL EFFICIENCY	50.1	%	REF EFFICIENCY (%)	88.4
EFFELEC	ELECTRICAL EFFICIENCY	23.8	%	HEAT RATE (BTU/KWHR)	16152
KWACNET	NET AC POWER	44.5	KWAC	DISPATCHED POWER:	0.0
PFAC	ACTUAL POWER FACTOR	0.95	-	DISPATCHED P.F.:	1.00
KVARNET	NET KVAR	14.5	KVAR	DISPATCHED KVAR:	0.0
KVANET	NET KVA	46.8	KVA		
PARPOWER	PARASITE POWER	54.6	KW		
KWACGROS	GROSS AC POWER	99.1	KW		
MWHRSGR	GROSS AC MW HRS	17.986	MWHR		
MWHRNET	NET AC MW HOURS	14.563	MWHR		

POWER CONDITIONER SYSTEM

06/21/95 IDC= 427 VDC= 227 KWACNET= 42.6 VTE10DEL= -0.81 EVENTS 0
 0939:11 FT012ACT= 35.6 TE400FT= 361.9 TE012FT= 1525.2 OVERRIDE 0
 P/P 9061 P 161 R 160 S 60 W 20 A 3G N 40 C 30 L 10 I 80

PT001A	INV AC VOLTAGE, PHASE A	482.9	V		
PT001B	INV AC VOLTAGE, PHASE B	480.0	V		
PT001C	INV AC VOLTAGE, PHASE C	478.9	V		
CT001A	INV AC CURRENT, PHASE A	52.3	A		
CT001B	INV AC CURRENT, PHASE B	54.9	A		
CT001C	INV AC CURRENT, PHASE C	47.5	A	CURRENT UNBAL (%)	14.3
PT002A	NET AC VOLTAGE, PHASE A	485.4	V		
PT002B	NET AC VOLTAGE, PHASE B	482.7	V		
PT002C	NET AC VOLTAGE, PHASE C	480.7	V	VOLTAGE UNBAL (%)	1.0
LINKVDC	LINK VOLTAGE	599.9	V		
PERCFUND	PERCENT FUNDAMENTAL	85.4	%		
PSREQ	PHASE SHIFT REQUEST	2.0	DEG		
MCB001	G/I BREAKER STATUS	On			
MCB002	G/C BREAKER STATUS	Off			
MCB005	INTER-TIE BREAKER STAT	Off			
INTCOUNT	INTERRUPT COUNT	0			

DEMONSTRATED OUTPUT VOLTAGE:
 REQUIRED OUTPUT VOLTAGE:

478.9 TO 482.9 VAC
 480 ± 2% VAC

RESULT:

PASS

ONSI CORPORATION

OUTPUT FREQUENCY
(GRID INDEPENDENT)

DEMONSTRATED:	59.99 HZ
REQUIRED:	60 ± 3 HZ
RESULT:	<u>PASS</u>

Appendix B: MCAGCC Twentynine Palms – Naval Hospital, Project Meeting Attendees

Site Evaluation, 8-9 December 1993

Attendees	Organization
Mike Binder	USACERL
T. Monaco	Naval Hospital
M.J. Roman	Naval Hospital
Lt. C.R. Miranda	Naval Hospital
Patrick Dougherty	Naval Hospital
LCDR Brannman	Naval Hospital
E.P. Thompson	Naval Hospital
S.D. Hammons	MCAGCC
Gerry Merten	SAIC
Mike Torrey	SAIC

Kick-off Meeting, 03 May 1994

Attendees	Organization
Gerald Cler	USACERL
T. Monaco	Naval Hospital
K.J. Kouser	Naval Hospital
C.J. Chitwood	Naval Hospital
S.D. Hammons	MCAGCC
Howard DeVore	Public Works
Wayne Hofeldt	Southern California Edison
Mike Torrey	SAIC
Douglas Young	United Technologies/ONSI

Design Review, 02 March 1995

Attendees	Organization
Mike Binder	USACERL
Gerald Cler	USACERL
Bill Taylor	USACERL
T. Monaco	Naval Hospital
S.D. Hammons	MCAGCC
Howard DeVore	Public Works
Andrew Dufour	MCAGCC
George Collard	GBC Electrical Services
Ray Aselin	GBC Electrical Services
Gerry Merten	SAIC
Douglas Young	United Technologies/ONSI

Acceptance Test, 23 June 1995

Attendees	Organization
Mike Binder	USACERL
Frank Holcomb	USACERL
T. Monaco	Naval Hospital
Luke Wren	Facilities Management
Douglas Young	United Technologies/ONSI
George Collard	GBC Electrical Services

Appendix C: Review Letters for Original Design Drawings



February 14, 1995

Dr. Mike Binder
USACERL
Energy and Utilities Systems Division
2902 Newmark Drive
Champaign, IL 61821-1076

Subject: Twenty-Nine Palms Final Design Review

Dear Mike:

SAIC and our licensed mechanical and electrical subcontractors have reviewed the fuel cell installation design drawings for the Twenty-Nine Palms Marine Corps. Base. Our comments are presented below.

1. HEAT REJECTION LOOP (COOLING MODULE)

- a. Assumed 30 gpm flow rate.
- b. Total equivalent piping length of 335 feet.
- c. Pressure drop - 30 gpm in 2" pipe = 2'/100'.
- d. Fluid cooler pressure drop - 12' at 30 gpm.
- e. Total pressure drop external to fuel cell is $(3.35' \times 2') + 12' = 18.7'$

Pipe sizing and velocity are adequate at 2". Discharge head for circulating pump located in fuel cell power module should include the 18.7' piping loop pressure drop.

2. HEAT RECOVERY PIPING - CUSTOMER SIDE

- a. Flow rate - 50 gpm.
- b. Total equivalent piping length - 318 feet.
- c. Pipe size - 3"
- d. Pressure drop - 25 gpm in 3" pipe = 0.8/100'.
- e. Piping pressure loss = $3.18 \times 0.8 = 2.8'$
- f. Pressure drop through HEX880 (in power module) = 15' ±
- g. Total pump head required = $2.8' + 15' = 17.7'$

Piping sizing and velocity are adequate at 3"; however, as the velocity is low at 2.3 feet per second, some savings could be realized by utilizing 2" pipe versus 3". A check valve is recommended at the discharge of Recirculating Pump P-2.



3. HEAT RECOVERY PIPING - FUEL CELL SIDE (HEX880 TO STORAGE TANK LOOP W/P-1)

- a. Flow rate - 25 gpm
- b. Pipe size - assume 2"
- c. Total equivalent piping length - 221'
- d. Pressure drop - 25 gpm in 2" pipe = 1.5'/100'
- e. Piping pressure loss = $2.21 \times 1.5 = 3.3'$
- f. Pressure drop through HEX880 = 15' ±
- g. Total pump head required = $3.3' + 15' = 18.3'$

Piping sizing and velocity are adequate at 2". The B&G Series 90, size 1-1/2A, 1/2 H.P. pump is adequate.

4. CITY WATER TO FUEL CELL POWER MODULE

- a. Flow rate - assume 10 gpm ±
- b. Water pressure - assume 50 psig ±
- c. Total equivalent piping length - 156'
- d. Pressure drop - 10 gpm in 3/4" pipe = 10 psig/100'
- e. Pressure drop through HEX880 - assume 15'
- f. Total pressure drop then is $(1.56 \times 10) + (15 \times .43) = 22$ psig. The 3/4" pipe size is adequate assuming that about 28 psig at the fuel cell inlet is satisfactory.

Should the City water supply not be isolated from the potable system elsewhere in the plant, an approved backflow prevention device should be provided.

5. NATURAL GAS

- a. Connected load - 1,900 CFH.
- b. Pipe size - 3"
- c. Pressure at point-of-connection - assume under 14" W.C.
- b. Total equivalent piping length - 180'.
- c. Maximum delivery capacity of 0.60 specific gravity natural gas per hour with pressure drop of 0.5 inch water column in 3" pipe is 2,257 CFH. Pipe sizing at 3" is adequate.

6. NITROGEN

- a. Required flow rate - could not be determined from data provided.
- b. Pipe size - 3/4"
- b. Total equivalent piping length = 60'.

Assuming a required delivery pressure of 50 psig at the fuel cell power module connection, capacity of a 3/4" pipe is in excess of 1,600 liters per minute. This pipe size should be adequate depending on ONSI's maximum anticipated flow rate



5. ELECTRICAL

- a. The plans should be stamped by a registered electrical engineer.
- b. More details should be given for the new 400A subpanel; i.e., mounting AIC, breaker sizes, etc.
- c. The sizes of conduits and conductors from new sub-panel to "NTH" and "HNH" should be given.
- d. The 120V power source to the fuel cell power module should be shown.
- e. Show ground grid around fuel cell enclosure and all termination points.
- f. Show routing to room F005 along with feeder length and voltage drop.

Based on the 105°F and 140°F supply temperatures for the domestic hot water loops, the 1,000 gallon storage tank appears adequate. The detailed electrical and thermal designs are sufficient. With consideration of the above comments, we believe that the site design is adequate to proceed with construction.

Sincerely,

A handwritten signature in black ink, appearing to read "Gerry", is positioned above the printed name.

Gerry Merten
Division Manager,
Advanced Energy Systems

29 PALMS "RECORD DRAWING" CHANGES

6/19/95
J. STANWORTH

DRAWING

CHANGE

S-1

Equipment positioning adjustments including
nitrogen racks to back side of pad
Fence lengthened 1 ft to 52 ft
Full concrete pad within fence
Drainage accommodations at building end of pad

S-2

Equipment position adjustments

ME-1

Equipment repositioned as on S-1
Gas line repositioned
Spare conduit added (emergency power cord)
Building wall penetrations noted
Disconnect labels changed (reversed GC & GE)

M-1

Storage tank dimension typo corrected
Mixing valves labeled (inlets S+G, outlet A)
Closed valves illustrated

M-2

No changes

E-1

Grounding illustration changed to correspond
to ground grid on 9061 E-3 drawing

E-2

No changes

E-3

Ground grid updated.

Appendix D: PC25B Fuel Cell Forced Outage Description Codes

Fleet Log Model B				page1			
FORCED OUTAGE ORIGIN BY POWER PLANT				CHANGE IN STATE	FORCED OUTAGE/ UNFORCED OUTAGE		
DESCRIPTION	CODE1	CODE2	CODE3	DESCRIPTION	CODE	DESCRIPTION	CODE
POWER SECTION SYSTEM	PSS			POWER UP	PU	FORCED	F
FREEZE PREVENTION HEATER A			HTR310A	POWER DOWN	PD	UNFORCED	U
FREEZE PREVENTION HEATER B			HTR310B	IDLE UP	IU		
GROUND FAULT DETECTOR			GFD-001	IDLE DOWN	ID		
HALF-STACK VOLTAGE MONITOR			VT310	SHUTDOWN	S		
FUEL PROCESSING SYSTEM	FPS			NONE	N		
SHUTOFF VALVE			CV000				
SHUTOFF VALVE			CHV100				
CHECK VALVE			CV100				
FLOW CONTROL VALVE			FCV012				
EJECTOR			EJT010				
REFORMER			REF300				
LOW TEMP SHIFT CONVERTER			SC300				
AIR PRE-HEATER			HEX910				
BURNER CONTROL			BSC001				
INTEGRATED LOW TEMP SYSTEM		ILS					
AIR PROCESSING SYSTEM	APS						
FILTER			FIL100				
PROCESS AIR BLOWER			BLO100				
CATHODE			FCV100				
CATHODE AIR VALVE			FCV110				
REFORMER BURNER			FCV140				
VALVE POSITION INDICATOR			ZT110				
AIR FLOW TRANSMITTER			FT140				
HAND ORIFICE			HO135				
FIXED ORIFICE			FO130				
REFORMER BURNER SENSOR			BE030				
THERMAL MANAGEMENT SYSTEM	TMS						
FLOW SWITCH			FS400				
THERMAL TEMP MANAGEMENT CONTROL			TE400				
THERMAL TEMP MANAGEMENT CONTROL			TE431				
CELL STACK COOLING H2O SUB-SYSTEM		CSCW					
COOLANT ACCUMULATOR			ACC400				
COOLANT PUMP			PMP400				
THERMAL CONTROL HEAT EXCHANGER			HEX400				
FLOW ORIFICE			FO400				
FLOW ORIFICE			FO420				
BLOWDOWN COOLER			HEX310				
BLOWDOWN VALVE			FCV430				
MIXED RESIN DEMINERALIZER BED			DMN440				
ELECTRIC HEATER			HTR400				
MOTORIZED VALVE			TCV400				
ANCILLARY COOLANT SUB-SYSTEM		ACS					
PUMP			PMP830				
BLOWDOWN COOLER			HEX431				
CONDENSER			HEX920				
CUSTOMER HEAT EXCHANGER			HEX880				
FORCED CONVECTION COOLING MODULE			HEX800				
SELF-ACTUATED FLOW CONTROL VALVE			TCV800				
MOTORIZED VALVE			TCV830				
HAND ORIFICE			HO840				
WATER TREATMENT SYSTEM	WTS						
WTS PUMP			PMP450				
ORGANIC FILTER			ORG450				
MIXED RESIN DEMINERALIZER BED			DMN450A				
MIXED RESIN DEMINERALIZER BED			DMN450B				
MIXED RESIN DEMINERALIZER BED			DMN450C				
MIXED RESIN DEMINERALIZER BED			DMN450D				

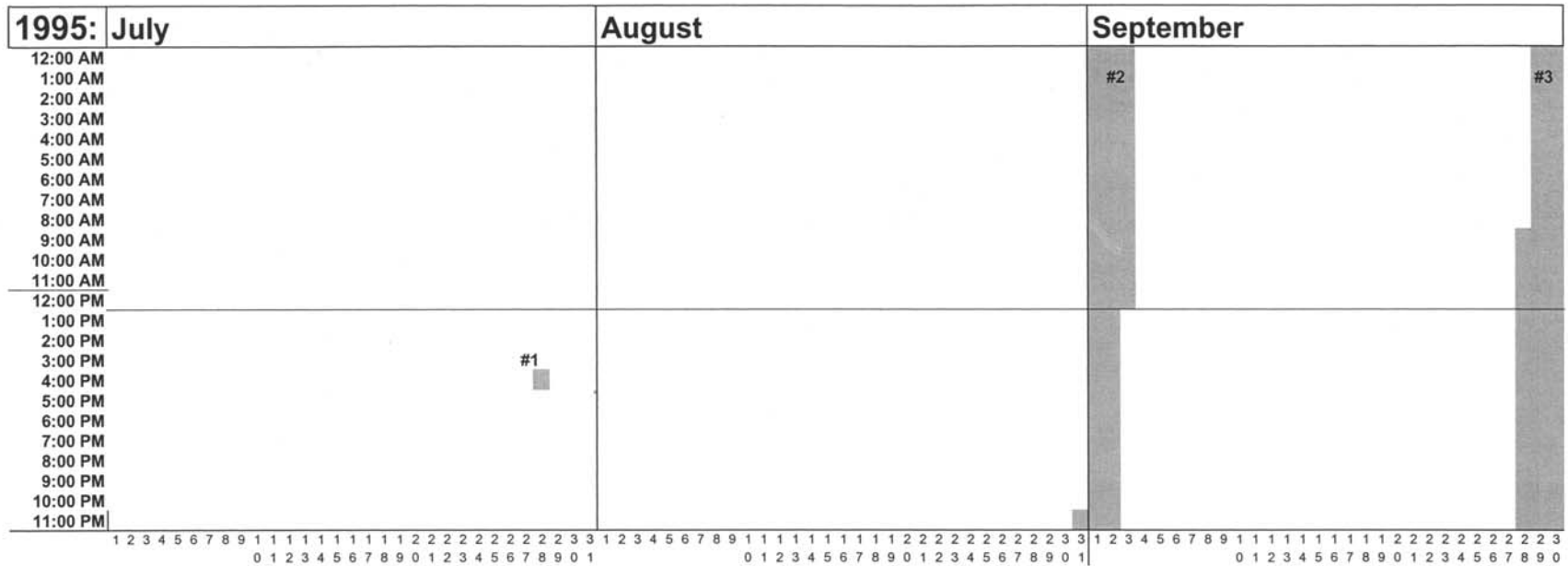
			Fleet Log Model B
FEEDWATER PUMP			PMP451
ISOLATION HAND VALVE			HV450A
ISOLATION HAND VALVE			HV450B
WATER TANK LEVEL TRANSMITTER			LS450
WATER TANK LEVEL TRANSMITTER			LS451
WATER TANK LEVEL TRANSMITTER			LT450
WATER LEVEL CONTROL VALVE			LCV451
CHECK VALVE			CHV451
NITROGEN PURGE SYSTEM	NPS		
OPEN SOLENOID VALVE			CV720
OPEN SOLENOID VALVE			CV710
FLOW ORIFICE			FO720
AIR EJECTOR			EJT710
CABINET VENTILATION SYSTEM	CVS		
VENTILATION FAN			FAN165
VENTILATION FAN			FAN150
FLOW SWITCH			FS165
FILTER			FIL150
FLOW CONTROL DAMPER			FCD150
EXIT FLOW RATE CONTROL			TE150B
TO PROCESSED STEAM SHUTOFF VALVE			CV500
ELECTRICAL SYSTEM	ES		
POWER CONDITIONING SYSTEM		PCS	
MOTORIZED AC CURCUIT BREAKER			MCB001
MOTORIZED AC CURCUIT BREAKER			MCB002
MOTORIZED AC CURCUIT BREAKER			MCB003
POWER DISTRIBUTION SYSTEM		PDS	
AUXILIARY TRANSFORMER			T005
UNINTERRUPTABLE POWER SUPPLY			UPS001
POWER PLANT CONTROL		PPC	
LOCAL OPERATING INTERFACE			LOI
LOCAL DIAGNOSTIC TERMINAL			LDT
ELECTICAL CONTROL SYSYEM		ECS	
OTHER	OTR		
OTHER ELECTRICAL		OTRE	
K001			K001
K002			K002
INVERTER			INV
CSA			CSA
PC CARD			PC
BOOST REGULATOR			BSRG
FUSE			FUSE
POLE FAULT			POLE
BRIDGE FAULT			BRDG
QUAD POWER SUPPLY			QUAD
DUAL POWER SUPPLY			DUAL
RELAY TRIP			RELAY
GROUND FAULT			GRND
CIRCUIT BREAKER			CRB
CONTROLLER			CRL
SUBSTACK			SBSTK
GRID DISTIRBANCE			GRID
OTHER GAS		OTRG	
OTHER WATER		OTRW	

Appendix E: Operational and Outage Periods

Detailed Fuel Cell Demonstration Site Summary Report
MCAGCC Twentynine Palms

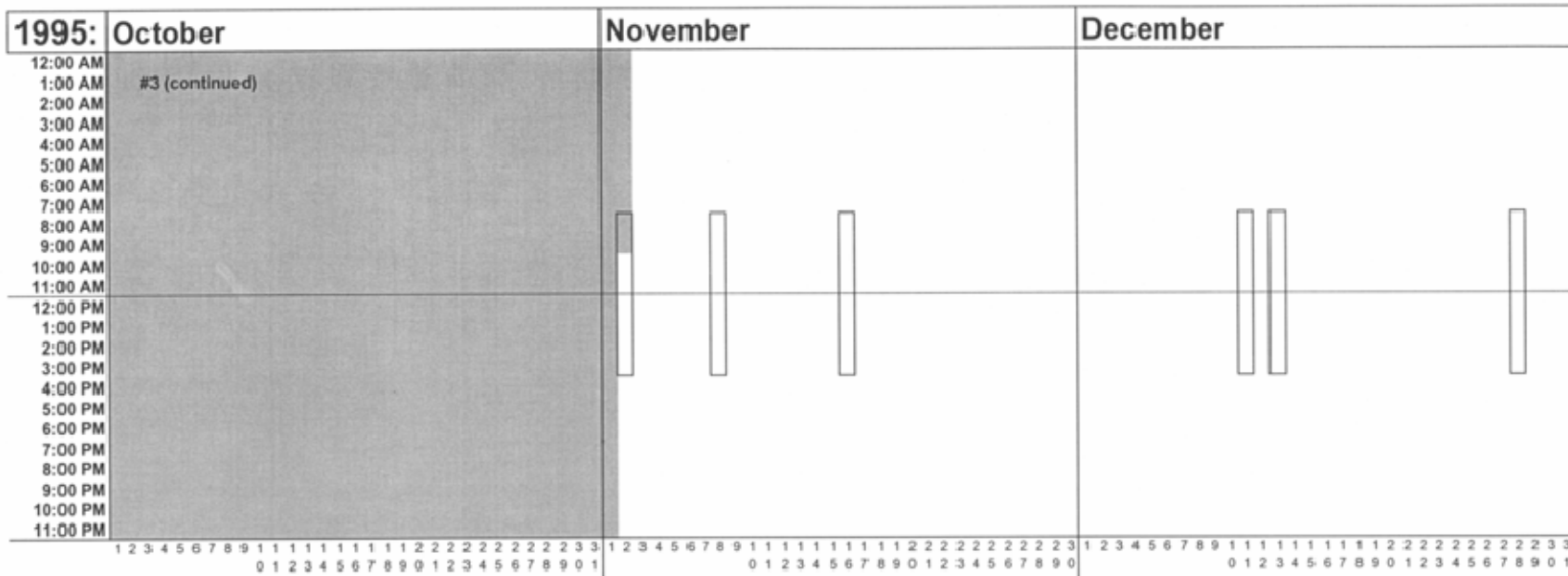
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2:00 AM		
3:00 AM		
4:00 AM		
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7:00 AM		
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0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0	0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1	0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

Outage #	Duration	Description
		Acceptance Test performed between June 16th through June 21st.



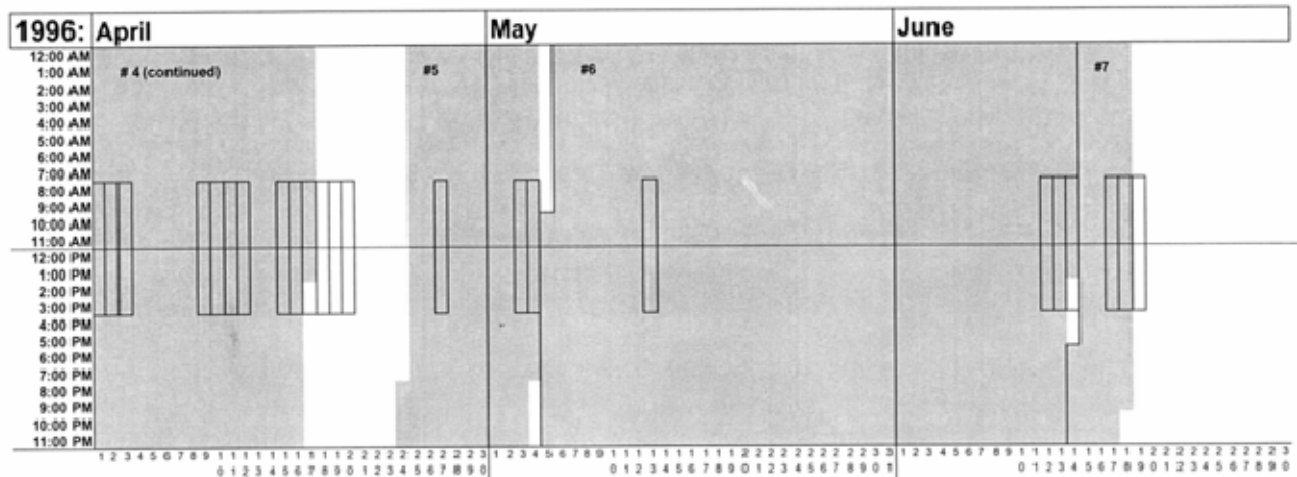
Outage #	Duration	Description
1	00:33	APS: FT140 low in R80-R160 shutdown (while adjusting electro-mechanical brake to prevent unstable FCV1140 operation)
2	60:12	TMS/CSW: Loss of separator control (SEPDEL high for 10min in S60) restarted raised power slowly.
3	840:20	TMS/CSW: Low HDS bed temperature (TE002 low for 60sec in R110-R160). Completed 2000 hour maintenance. Replaced FCV503. Replaced FO002 orifice with 1.1" size. Replaced PMP400 with high flow pump to improve TE401. Replaced PC7 controller card.

Detailed Fuel Cell Demonstration Site Summary Report
 MCAGCC Twentynine Palms

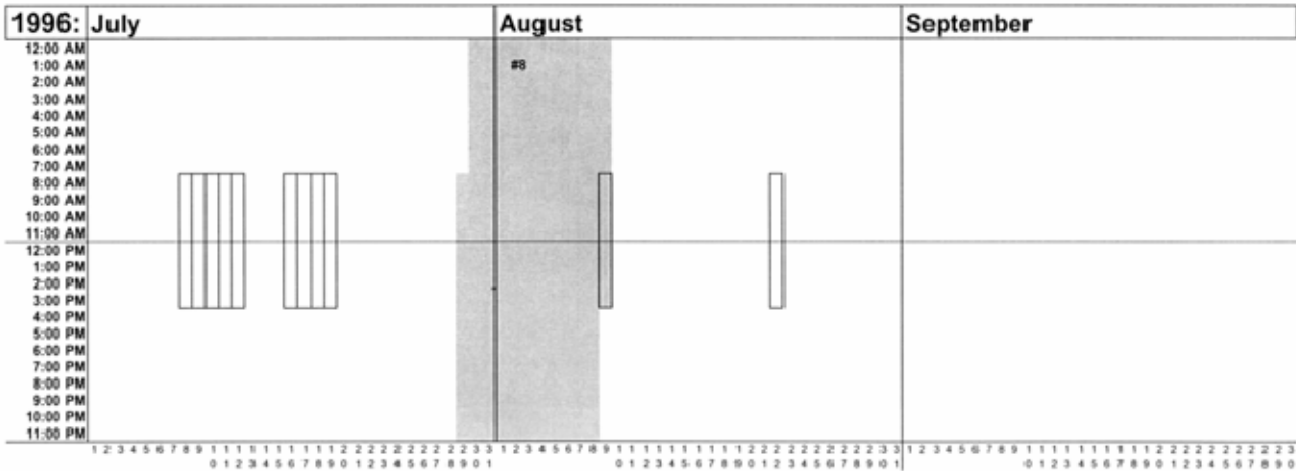


Outage #	Duration	Description
3	840:20	See previous page.

Detailed Fuel Cell Demonstration Site Summary Report
MCAGCC Twentynine Palms

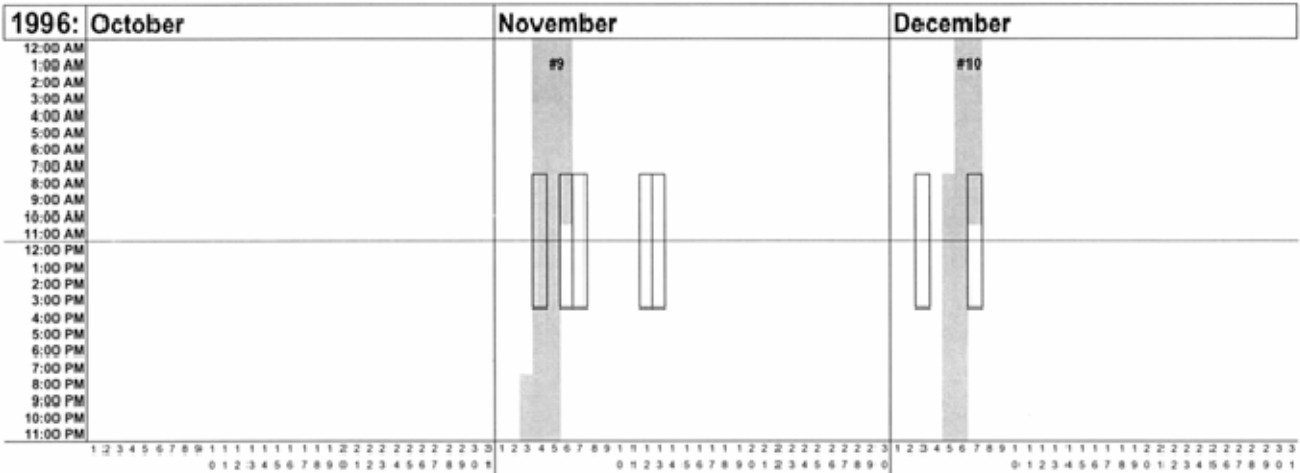


Detailed Fuel Cell Demonstration Site Summary Report
MCAGCC Twentynine Palms



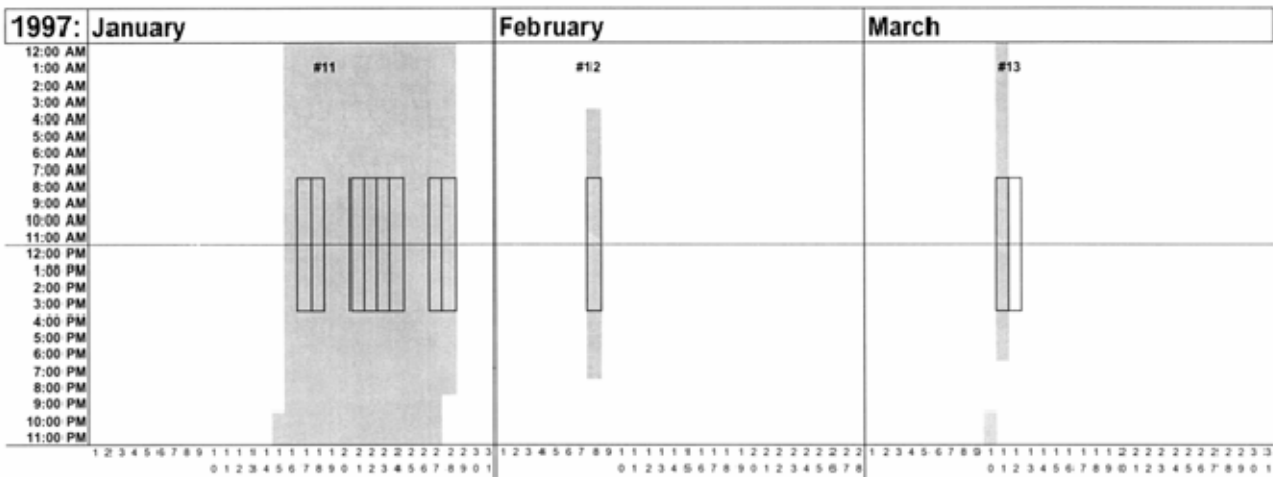
Outage #	Duration	Description
8	272:30	Power plant manually shutdown. Install SAIC instrumentation per direction from CERL. PMP400 and FAN150 motor starters failed. Parts shipped

Detailed Fuel Cell Demonstration Site Summary Report
 MCAGCC Twentynine Palms



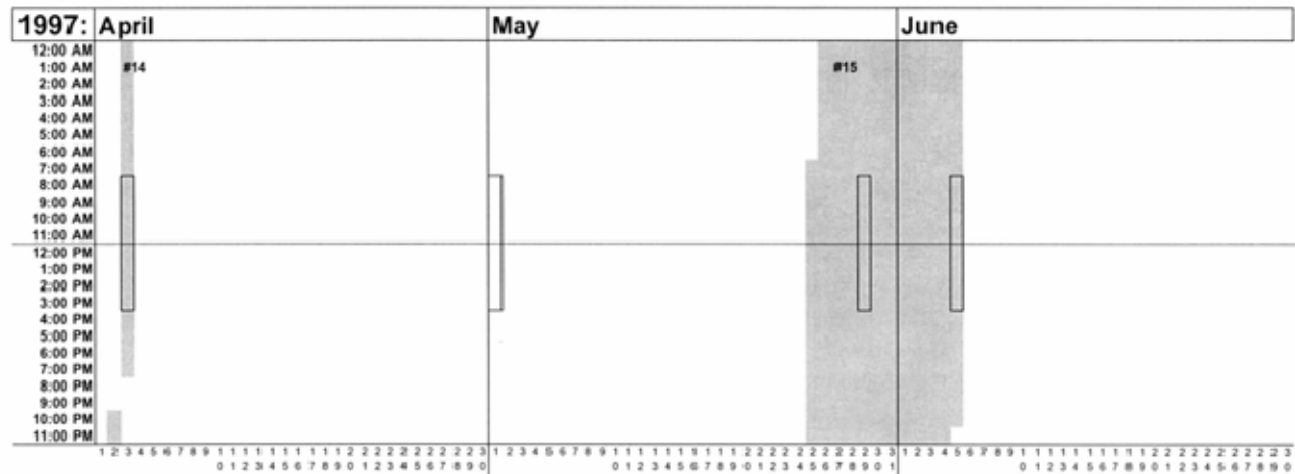
Outage #	Duration	Description
9	62:07	TMS: Power plant shutdown due to an indicated low coolant flow (FS400)
10	51:30	OTR: Power plant shutdown due to an interruption in gas supply

Detailed Fuel Cell Demonstration Site Summary Report
MCAGCC Twentynine Palms



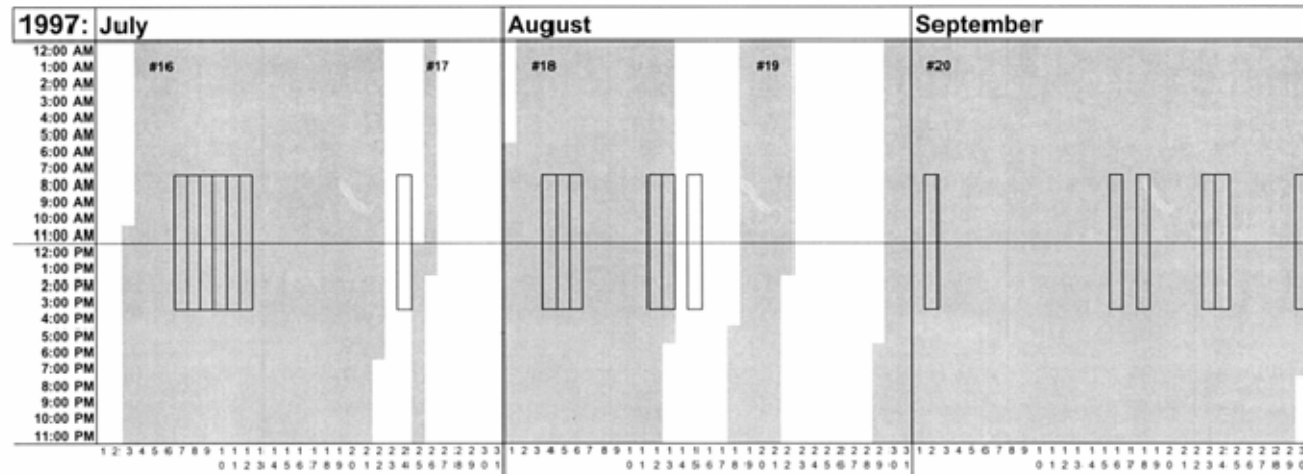
Outage #	Duration	Description
11	309:48	OTR: Power plant shutdown due to circuit breaker sequence error during grid event. Relay replaced.
12	13:45	OTR: P/P shutdown due to circuit breaker sequence error at time of grid disturbance.
13	20:12	OTR: P/P shutdown due to a plugged filter in the R/O unit.

Detailed Fuel Cell Demonstration Site Summary Report
MCAGCC Twentynine Palms



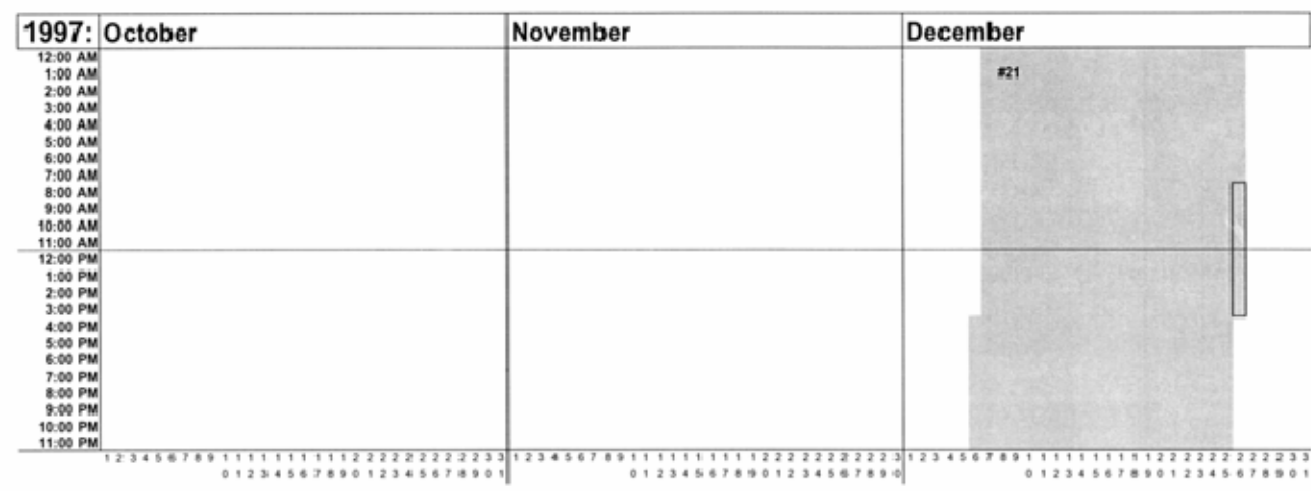
Outage #	Duration	Description
14	22:42	OTR: P/P manually shutdown to repair a water leak.
15	279:56	FPS: P/P shutdown due to a sticking fuel valve. Annual maintenance completed.

Detailed Fuel Cell Demonstration Site Summary Report
MCAGCC Twentynine Palms



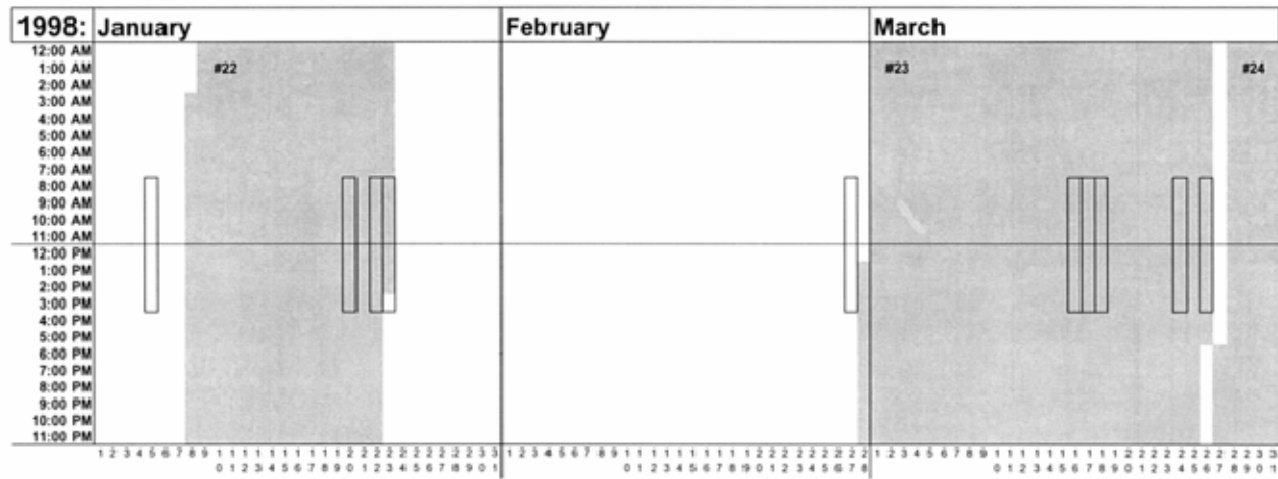
Outage #	Duration	Description
16	463:30	TMS: P/P shutdown due to high feed water temperature caused by back flow from the TMS. The shut-off valve, check valve, feed water pump, FT140, burner air valve and flow transmitter were replaced.
17	26:26	P/P manually shutdown to repair a site gas leak
18	298:40	OTR: P/P shutdown due to a logic card cage fan failure. Replaced PC5.
19	92:08	OTR: P/P shutdown due to a circuit breaker sequence error (K001).
20	782:08	ES: P/P shutdown due to a UPS failure. UPS batteries were replaced; PMP451 rebuilt.

Detailed Fuel Cell Demonstration Site Summary Report
MCAGCC Twentynine Palms



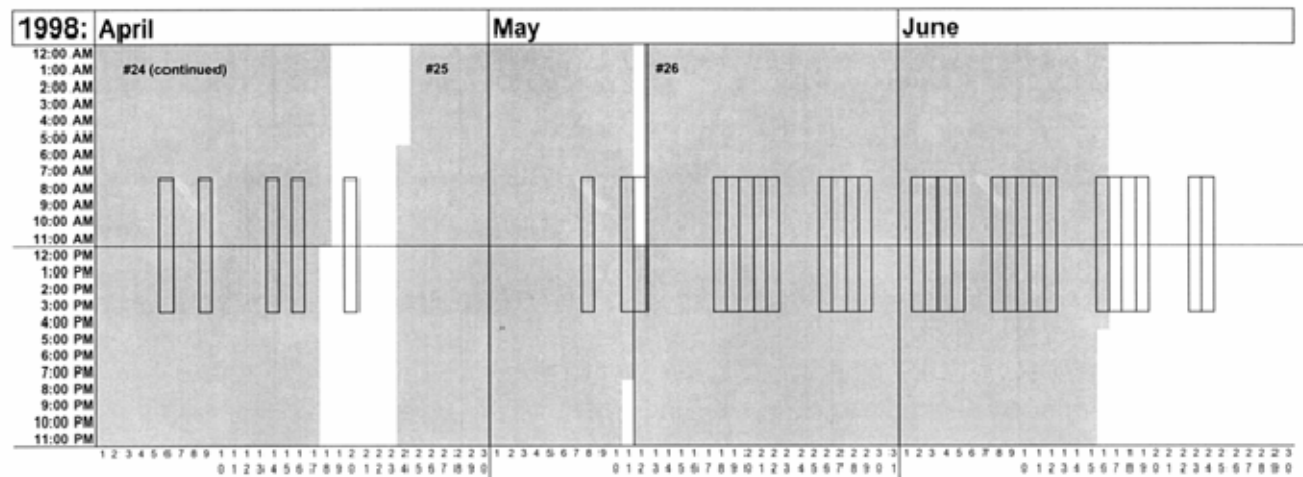
Outage #	Duration	Description
21	479:27	OTR: P/P shutdown due to a K002 sequencing error. Motorized circuit breaker adjusted.

Detailed Fuel Cell Demonstration Site Summary Report
MCAGCC Twentynine Palms



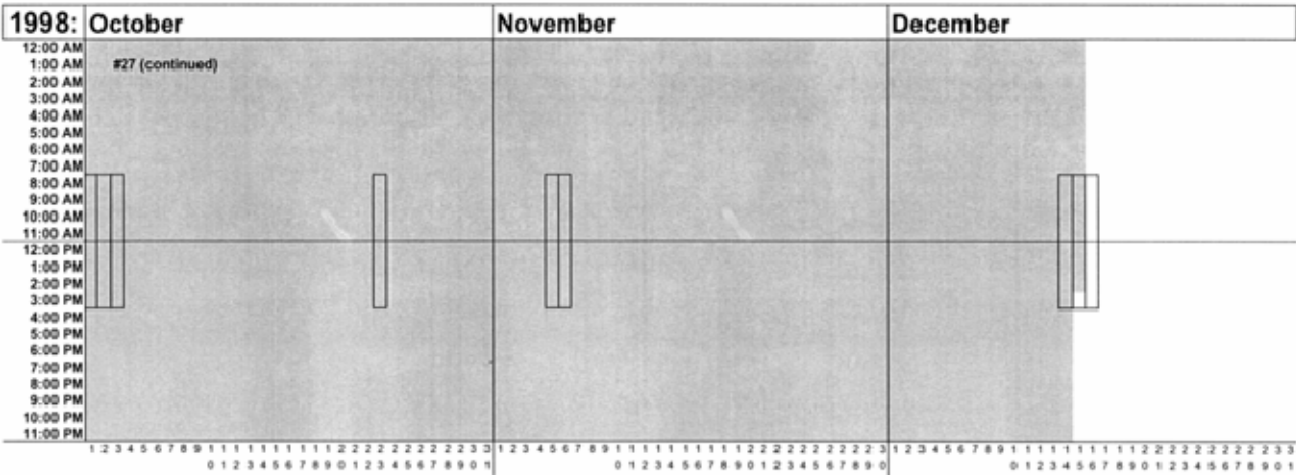
Outage #	Duration	Description
22	370:32	OTR: P/P shutdown due to low DC voltage. FCV012 replaced.
23	639:45	OTR: Maintenance activities involved circuit breakers K001, K002, and K003.
24	534:20	ES: Maintenance activities involved UPS replacement.

Detailed Fuel Cell Demonstration Site Summary Report
MCAGCC Twentynine Palms



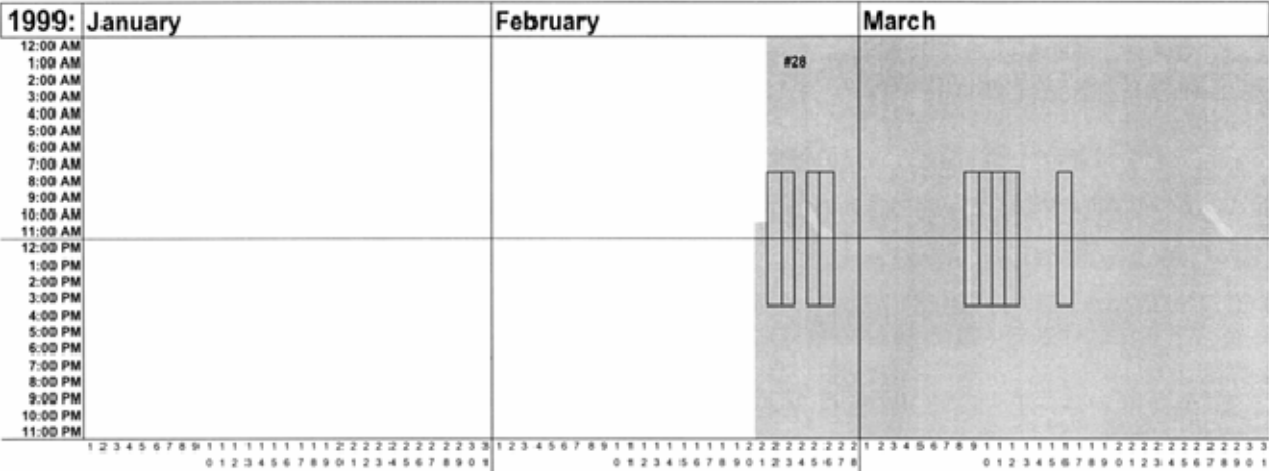
Outage #	Duration	Description
24	534:20	See previous page
25	422:10	TMS: Shutdown waiting to replace Hex's; replacement heat recovery flow meter on back order 6/5; replacement HEX430 & HEX431 ordered.
26	844:12	ES: P/P shutdown due to MCB002 error. Completed physical check of all wiring in motorized circuit breaker circuit. Fuel cell stack assembly was cleaned.

Detailed Fuel Cell Demonstration Site Summary Report
 MCAGCC Twentynine Palms



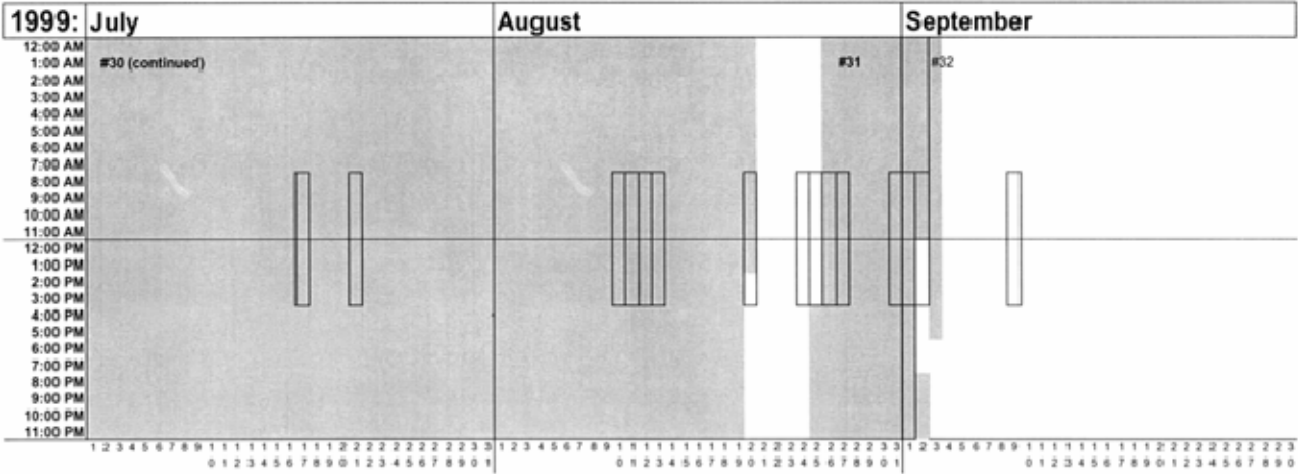
Outage #	Duration	Description
27	3,937:40	See previous page.

Detailed Fuel Cell Demonstration Site Summary Report
 MCAGCC Twentynine Palms.



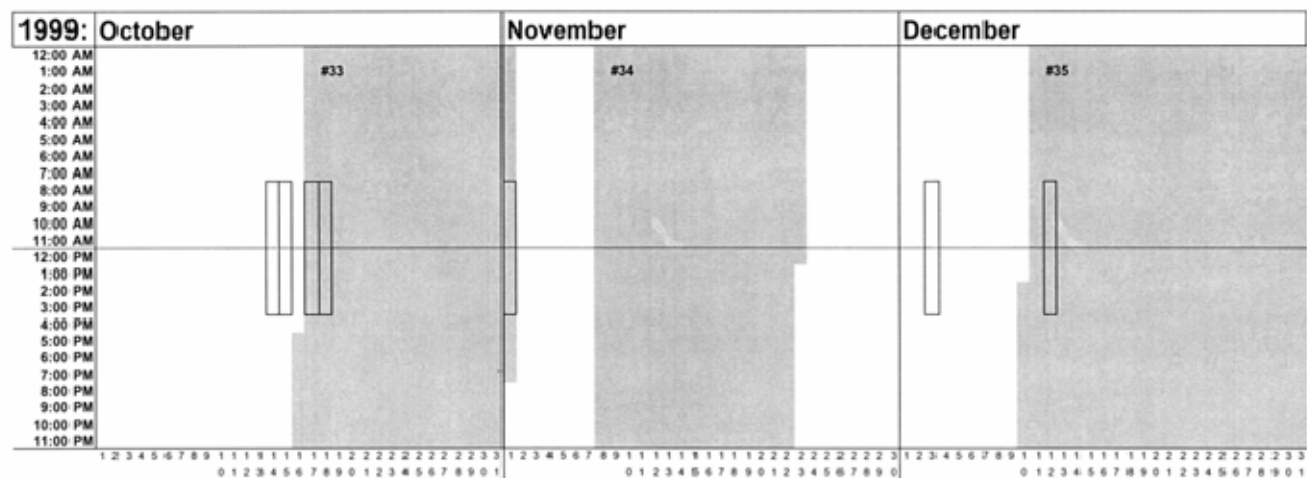
Outage #	Duration	Description
28	1,066:00	OTR: Shutdown on ground fault fuse.

Detailed Fuel Cell Demonstration Site Summary Report
 MCAGCC Twentynine Palms



Outage #	Duration	Description
30	1,855:30	See previous page
31	188:09	APS: Shutdown on FT 140 low.
32	20:30	APS: Minimal information about outage, but probably same as outage #31.

Detailed Fuel Cell Demonstration Site Summary Report
MCAGCC Twentynine Palms



Outage #	Duration	Description
33	400:00	WTS: Shutdown on loss of WTS water, FS450 off.
34	372:34	OTR: Shutdown on inverter sequence error.
35	514:18	TMS: Shutdown on FS400 off. Failed pump 400. Replacement sent.

Appendix F: Summary of Maintenance Invoices by Year

Twentynine Palms Fuel Cell

Invoice Date	Labor Hours	\$	Nitrogen Cubic Feet	\$	Charcoal Cubic Feet	\$	Resin Cubic Feet	\$	Other Equipment Part #	\$	Travel \$	Shipping \$
2-Nov-95	7.0	\$315.00										
8-Nov-95	1.0	\$45.00										
16-Nov-95	1.0	\$45.00	2432	\$494.43					Shipping Cylinder Rental	\$12.97		\$34.00
11-Dec-95	1.0	\$45.00										
11-Dec-95	9.0	\$405.00										
13-Dec-95	2.5	\$112.50										
28-Dec-95	1.0		2432	\$693.24					Cylinder Rental	\$19.41		
Totals	22.5	\$967.50	4,864	\$1,187.67	0	\$0.00	0	\$0.00		\$32.38	\$0.00	\$34.00

Total Cost \$2,221.55

Maintenance Summary

Year #1: 1995

Twenty-nine Palms Fuel Cell

Invoice Date	Labor Hours	Labor \$	Nitrogen Cubic Feet	Nitrogen \$	Charcoal Cubic Feet	Charcoal \$	Resin Cubic Feet	Resin \$	Other Equipment Part #	Other Equipment \$	Travel \$	Shipping \$
Jan 13, 1996	2.0	\$135.00							Misc.	\$3.12		
Jan 14, 1996	2.0	\$135.00										
Jan 26, 1996	5.0	\$225.00										
Jan 29, 1996	8.5	\$382.50							W.W. Grainger	\$2,742.91		
Jan 30, 1996	10.0	\$450.00							Misc.	\$37.32		
Jan 31, 1996	10.5	\$472.50							Diesel Fuel	\$11.62		
Feb 02, 1996	11.0	\$495.00							Diesel Fuel	\$12.00		
Feb 03, 1996	10.0	\$675.00							Misc.	\$488.18		\$116.05
Feb 05, 1996	9.0	\$405.00							Cylinder Rental	\$12.94		
Feb 06, 1996	18.0	\$810.00							Crane Service	\$1,275.00		
Feb 08, 1996	26.0	\$1,170.00	4864	\$1,703.58								
Mar 21, 1996	8.0	\$360.00										
Mar 22, 1996	10.0	\$450.00										
Mar 23, 1996	10.0	\$675.00										
Mar 25, 1996	10.0	\$450.00							Misc.	\$264.30		
Mar 26, 1996	89.0	\$360.00										
Mar 27, 1996	9.0	\$405.00							Crane Service	\$1,275.00		
Mar 28, 1996	23.0	\$1,035.00										
Mar 29, 1996	8.0	\$360.00										
Apr 01, 1996	9.0	\$405.00							Misc.	\$937.59		
Apr 02, 1996	17.0	\$765.00										
Apr 03, 1996	14.0	\$630.00										
Apr 09, 1996	9.5	\$427.50										
Apr 10, 1996	10.0	\$450.00										
Apr 11, 1996	14.0	\$630.00										
Apr 12, 1996	10.0	\$450.00										
Apr 15, 1996	7.5	\$337.50										
Apr 16, 1996	6.0	\$270.00										
Apr 17, 1996	10.0	\$450.00							Welding	\$135.00		
Apr 18, 1996	12.0	\$540.00										
Apr 19, 1996	12.5	\$562.50							Misc.	\$378.93		
Apr 20, 1996	3.0	\$202.50										
Apr 27, 1996	6.5	\$438.75							Misc.	\$315.37		
May 03, 1996	8.5	\$382.50	3648	\$343.92								
May 04, 1996	3.5	\$236.25	3640	\$222.22								
May 13, 1996	4.0	\$180.00										
Jun 12, 1996	4.5	\$202.50	3648	\$278.02								
Jun 13, 1996	6.0	\$270.00							Misc.	\$163.24		
Jun 14, 1996	8.5	\$382.50							Misc.	\$126.47		
Jun 17, 1996	6.5	\$292.50										
Jun 18, 1996	5.0	\$225.00							Misc.	\$1,560.60		
Jun 19, 1996	6.5	\$292.50										
Jul 08, 1996	9.0	\$405.00										
Jul 09, 1996	9.0	\$405.00										
Jul 10, 1996	9.0	\$405.00							Misc.	\$309.61		
Jul 11, 1996	8.0	\$360.00							Cell Phone	\$199.28		
Jul 12, 1996	7.0	\$315.00										
Jul 16, 1996	7.5	\$337.50										
Jul 17, 1996	9.0	\$405.00							Cylinder Rental	\$6.47		
Jul 18, 1996	14.0	\$630.00							Misc.	\$1,015.65		
Jul 19, 1996	7.0	\$315.00	1216	\$250.22								
Aug 09, 1996	9.5	\$427.50							Misc.	\$224.77		\$5.89
Aug 22, 1996	6.0	\$270.00							Misc.	\$147.85		
Sept. 1996									Misc.	\$65.94		
Nov 04, 1996	4.0	\$200.00										
Nov 06, 1996	8.0	\$400.00										
Nov 07, 1996	2.0	\$100.00										
Nov 12, 1996	8.0	\$400.00										
Nov 13, 1996	1.0	\$50.00							Cell Phone	\$75.00		
Dec 03, 1996	6.0	\$300.00							Cell Phone	\$72.90		
Dec 07, 1996	8.0	\$400.00							Misc.	\$269.41		
Totals	605.0	\$24,597.50	17016	\$6,439.33	4	\$372.00	41	\$10,395.00		\$11,877.26	\$0.00	\$121.94

Total Cost \$53,823.93

Twentynine Palms Fuel Cell

Invoice Date	Labor Hours	\$	Nitrogen Cubic Feet	\$	Charcoal Cubic Feet	\$	Resin Cubic Feet	\$	Other Equipment Part #	\$	Travel \$	Shipping \$
Jan 17, 1997	9.0	\$450.00										
Jan 18, 1997	7.0	\$350.00										
Jan 21, 1997	11.5	\$575.00										
Jan 22, 1997	12.0	\$600.00										
Jan 23, 1997	8.0	\$400.00										
Jan 24, 1997	6.0	\$300.00										
Jan 27, 1997	1.0	\$50.00										
Jan 28, 1997	10.0	\$500.00										
Feb 08, 1997	7.5	\$375.00	\$306.00						Cylinder Rental	\$19.41		
Mar 11, 1997	9.0	\$450.00			2	\$186.00	16	\$3,616.00				
Mar 12, 1997	7.0	\$350.00	\$600.54									
Apr 03, 1997	10.0	\$500.00	\$804.96						Misc.	\$69.17		
May 01, 1997	3.5	\$175.00	\$403.00									\$165.75
May 29, 1997	2.0	\$100.00	\$848.84						Cylinder Rental	\$6.47		
Jun 05, 1997	36.0	\$1,800.00	\$737.30		2	\$186.00	11	\$2,486.00	Misc.	\$271.16		\$41.71
Jul 07, 1997	5.0	\$250.00										
Jul 08, 1997	5.0	\$250.00										
Jul 09, 1997	7.0	\$350.00										
Jul 10, 1997	2.0	\$100.00										
Jul 11, 1997	5.0	\$250.00										
Jul 12, 1997	7.0	\$350.00										\$30.00
Jul 24, 1997	4.0	\$200.00										
Aug 04, 1997	4.0	\$200.00										
Aug 05, 1997	8.0	\$400.00	\$620.96									
Aug 06, 1997	6.0	\$300.00							Welding	\$100.00		
Aug 12, 1997	5.0	\$250.00							Cylinder Rental	\$25.88		
Aug 13, 1997	8.0	\$400.00							Misc.	\$110.00		
Aug 15, 1997	4.5	\$225.00	\$549.34						Misc.	\$76.71		\$50.79
Sep 02, 1997	1.0	\$50.00							Misc.	\$59.66		\$177.00
Sep 16, 1997	7.5	\$375.00										
Sep 18, 1997	7.5	\$375.00										
Sep 23, 1997	8.0	\$400.00										
Sep 24, 1997	7.5	\$375.00	\$752.82						Cell Phone	\$248.00		
Sep 30, 1997	4.0	\$200.00	\$399.75									
Nov 1997									Batteries	\$498.94		\$106.41
Dec 26, 1997	4.0	\$200.00	\$398.03									
Totals	249.5	\$12,475.00	0	\$6,421.54	4	\$372.00	27	\$6,102.00		\$1,485.40	\$0.00	\$571.66

Total Cost \$27,427.60

Maintenance Summary

Year #3: 1997

Twenty-nine Palms Fuel Cell

Invoice Date	Labor Hours	\$	Nitrogen Cubic Feet	\$	Charcoal Cubic Feet	\$	Resin Cubic Feet	\$	Other Equipment Part #	\$	Travel \$	Shipping \$
Jan 05, 1998	3.0	\$150.00		\$240.55								
Jan 20, 1998	17.0	\$850.00										
Jan 22, 1998	7.0	\$350.00							Cylinder Rental	\$6.47		\$20.88
Jan 23, 1998	11.0	\$550.00										
Feb 27, 1998	8.0	\$400.00			2	\$186.00	8	\$1,808.00	Cylinder Rental	\$12.94		
Mar 16, 1998	6.0	\$300.00										
Mar 17, 1998	8.5	\$425.00		\$339.95								\$42.90
Mar 18, 1998	1.0	\$50.00							Cylinder Rental	\$6.47		
Mar 24, 1998	6.0	\$300.00							Misc.	\$1.33		
Mar 26, 1998	13.0	\$650.00										
Apr 06, 1998	2.0	\$100.00										
Apr 09, 1998	16.0	\$800.00										\$70.70
Apr 14, 1998	3.0	\$150.00										
Apr 16, 1998	5.5	\$275.00		\$471.31					Misc.	\$16.99		
Apr 20, 1998	3.0	\$150.00		\$314.65			2	\$452.00	Cylinder Rental	\$6.47		
May 08, 1998	4.0	\$200.00										
May 11, 1998	12.0	\$600.00							Misc.	\$62.29		
May 12, 1998	4.0	\$200.00		\$142.39								
May 18, 1998	10.0	\$500.00										
May 19, 1998	16.0	\$800.00										
May 20, 1998	19.0	\$950.00										
May 21, 1998	2.0	\$100.00										
May 22, 1998	10.0	\$500.00		\$215.85					Misc.	\$10.80		
May 26, 1998	6.0	\$300.00										
May 27, 1998	12.0	\$600.00							Cylinder Rental	\$6.47		
May 28, 1998	9.0	\$450.00							Misc.	\$29.62		
May 29, 1998	10.0	\$500.00										
Jun 02, 1998	6.0	\$300.00										
Jun 03, 1998	8.0	\$400.00							Welder	\$75.00		
Jun 04, 1998	12.0	\$600.00		\$136.79					Misc.	\$48.67		
Jun 05, 1998	7.0	\$350.00										
Jun 08, 1998	8.0	\$400.00										
Jun 09, 1998	13.0	\$650.00							Misc.	\$34.25		
Jun 10, 1998	7.0	\$350.00										
Jun 11, 1998	8.5	\$425.00										
Jun 12, 1998	4.0	\$200.00										
Jun 16, 1998	8.0	\$400.00										
Jun 17, 1998	5.0	\$250.00										
Jun 18, 1998	2.0	\$100.00										
Jun 19, 1998	4.0	\$200.00			2	\$186.00	8	\$1,808.00				
Jun 23, 1998	12.0	\$600.00		\$244.20					Misc.	\$138.48		
Jun 24, 1998	5.5	\$275.00		\$215.85								
Jul 02, 1998	2.0	\$100.00		\$133.35					Cylinder Rental	\$6.47		
Jul 31, 1998	2.0	\$100.00										\$72.40
Aug 28, 1998	2.0	\$100.00		\$299.18					Misc.	\$197.94		\$28.00
Sep 15, 1998	1.0	\$50.00										
Sep 16, 1998	2.0	\$100.00										
Sep 28, 1998	2.0	\$100.00										
Sep 30, 1998	4.5	\$225.00										
Oct 01, 1998	9.5	\$475.00							Cylinder Rental	\$12.94		
Oct 02, 1998	9.0	\$450.00							Misc.	\$158.93		
Oct 03, 1998	4.5	\$225.00		\$207.15					Welder	\$850.00		
Oct 23, 1998	2.0	\$100.00										
Nov 05, 1998	2.0	\$100.00										
Nov 06, 1998	2.0	\$100.00							Cylinder Rental	\$6.47		
Dec 14, 1998	4.5	\$225.00										
Dec 15, 1998	10.5	\$525.00		\$139.20								
Dec 16, 1998	8.0	\$400.00							Cylinder Rental	\$6.47		\$60.00
Totals	401.5	\$20,075.00	0	\$3,100.42	4	\$372.00	18	\$4,068.00		\$1,715.67	\$0.00	\$303.88

Total Cost \$29,634.97

Year #: 1998

Twenty-nine Palms Fuel Cell

Invoice Date	Hours	Labor \$	Nitrogen Cubic Feet \$	Charcoal Cubic Feet \$	Resin Cubic Feet \$	Other Equipment Part # \$	Travel \$	Shipping \$
Jan 1999			\$143.84			Cylinder Rental	\$6.47	
Feb 1999			\$233.85			Cylinder Rental	\$6.47	
Feb 22, 1999	4.0	\$200.00						
Feb 23, 1999	6.0	\$300.00						
Feb 25, 1999	11.0	\$550.00				Misc.	\$29.43	
Feb 25, 1999	6.0	\$300.00						
Feb 26, 1999	7.0	\$350.00						
Mar 09, 1999	10.0	\$500.00						
Mar 10, 1999	9.0	\$450.00						
Mar 11, 1999	4.0	\$200.00						
Mar 12, 1999	2.0	\$100.00				Cylinder Rental	\$6.47	
Mar 16, 1999	11.0	\$550.00	\$129.92			Misc.	\$81.13	
Apr 05, 1999	4.0	\$200.00				Cylinder Rental	\$6.47	
Apr 06, 1999	18.0	\$900.00	\$238.55			Misc.	\$179.39	
May 19, 1999	1.0	\$55.00						
May 20, 1999	12.0	\$705.00	\$139.20			Cylinder Rental	\$12.94	
May 21, 1999	3.5	\$192.50		2	\$186.00	Misc.	\$61.53	
Jun 02, 1999			\$238.55		8	\$2,080.00	Misc.	\$1,131.94
Jun 04, 1999	7.0	\$385.00						
Jun 08, 1999	2.0	\$110.00						
Jun 09, 1999	3.0	\$165.00				Welding	\$125.00	
Jun 10, 1999	6.0	\$330.00						
Jun 11, 1999	8.0	\$440.00						
Jun 14, 1999	9.0	\$495.00				Cell Phone	\$60.98	
Jun 15, 1999	6.5	\$357.50						
Jun 16, 1999	7.5	\$412.50						
Jun 18, 1999	13.0	\$752.50						
Jul 17, 1999	1.0	\$55.00	\$374.97			Cell Phone	\$57.48	
Jul 21, 1999	2.0	\$110.00	\$304.00			Cylinder Rental	\$6.47	
Aug 10, 1999	8.0	\$440.00				Cylinder Rental	\$157.81	
Aug 11, 1999	12.0	\$660.00						
Aug 12, 1999	9.0	\$495.00						
Aug 13, 1999	5.5	\$302.00						
Aug 20, 1999	8.0	\$440.00	\$553.89				\$42.34	
Aug 24, 1999	7.0	\$385.00						
Aug 25, 1999	8.0	\$440.00						
Aug 26, 1999	10.0	\$550.00						
Aug 27, 1999	5.0	\$275.00						
Aug 31, 1999	13.0	\$715.00	\$514.05					
Sep 01, 1999	4.0	\$220.00				Cylinder Rental	\$6.47	
Sep 02, 1999	8.0	\$440.00				Misc.	\$11.05	\$91.59
Sep 09, 1999	3.0	\$165.00		2	\$206.00			
Oct 14, 1999	2.0	\$110.00			8	\$2,160.00		
Oct 15, 1999	2.0	\$110.00						
Oct 17, 1999	1.0	\$55.00				Misc.	\$13.20	
Oct 18, 1999	2.0	\$110.00	\$414.62			Cylinder Rental	\$304.51	
Nov 01, 1999	9.0	\$495.00				Cylinder Rental	\$6.47	\$20.07
Dec 03, 1999	2.0	\$110.00				Misc.	\$124.19	
Dec 12, 1999	1.0	\$55.00				Cylinder Rental	\$231.38	
Totals	293.0	\$15,771.50	0	\$3,285.44	4	\$392.00	16	\$4,248.80
							\$2,627.25	\$154.00
							\$0.00	\$0.00

Total Cost \$26,470.19

Year #5: 1999

Maintenance Summary

Twenty-nine Palms Fuel Cell

Invoice Date	Hours	Labor \$	Nitrogen Cubic Feet \$	Charcoal Cubic Feet \$	Resin Cubic Feet \$	Other Equipment Part # \$	Travel \$	Shipping \$
Jan 06, 2000	1.0	\$55.00	\$330.72			Cell Phone	\$17.21	
Jan 18, 2000	1.0	\$55.00						
Jan 19, 2000	6.0	\$330.00						
Jan 20, 1999	8.5	\$467.50				Misc.	\$44.29	
Jan 21, 2000	8.0	\$440.00				Cylinder Rental	\$6.47	
Jan 24, 2000	9.5	\$522.50						
Jan 27, 2000	8.0	\$440.00				Misc.	\$22.33	
Jan 28, 2000	5.0	\$275.00				Cylinder Rental	\$142.06	
Feb 10, 2000	7.0	\$385.00						
Feb 11, 2000	6.0	\$330.00	\$546.28			Misc.	\$12.21	
Feb 15, 2000	5.0	\$300.00	\$140.90			Cylinder Rental	\$6.47	\$32.95
Mar 31, 2000	3.0	\$165.00				Cylinder Rental	\$167.48	
Apr 03, 2000	8.5	\$467.50				Cylinder Rental	\$218.00	
May 2000						Cylinder Rental	\$188.08	
Jun 2000						Cylinder Rental	\$194.03	
Jul 2000						Cylinder Rental	\$212.95	
Jul 2000						Misc.	\$28.85	
Aug 2000						Cylinder Rental	\$168.16	
Sep 2000						Cylinder Rental	\$231.81	
Oct 2000						Cylinder Rental	\$85.92	
Totals	76.5	\$4,232.50	0	\$1,017.90	0	\$0.00	0	\$0.00
							\$1,746.12	\$32.95
							\$0.00	\$0.00

Total Cost \$7,029.47

Year #6: 2000

Maintenance Summary

Appendix G: Project Meeting Notes

VARRYL MATSUI
GEN'S CRANK
STU HAMMONS
LUKE WREN

PAT DOUGHERTY
HOSPITAL FACILITY MANAGER
08 DEC 93
29 PALMS

Robotics Construction
HOFELD - MILITARY BASE
369-5425
(Yuma Valley)
DSSC - CAMERON STATION

ELEC - So CAL EDISON (WAYNE HOFELD)
GAS - So CAL GAS (ALSO SOME ~~DSSC~~ - CAMERON STATION)
↳ TOU & RATE
So CAL GAS POC (TERRANCE MACK).

DIESEL FUEL OIL IS ONLY OTHER FUEL ALLOWED BY
CALIFORNIA LAW - IT IS BACK UP FUEL FOR HOSPITAL
(EMERGENCY GENERATOR USE #2 DIESEL).

CENTRIFUGAL CHILLERS IN HOSPITAL.

HOSPITAL WAS SUPPOSED TO GO ON LINE IN NOVEMBER 1992
BUT WASN'T OCCURED UNTIL AROUND MARCH 1993.

3 - 1000 kW Diesel Generators

ENSIGN TIFFANY MONACO
Naval Hospital, 29 Palms
(619) 830-2395

PRIMARY POC
FOR HOSPITAL
(MAINTENANCE OFFICER)

Scott: NRE. ext. 5624
Major. Des. HQ Mgt. Dist
Victorville, Ca.

Richard Wales.

Air Qual. Engr.

#(619) 245-5402

(Chris Collins)

29 Palms - Kick off meeting

03 MAY 94

1/

EMERGENCY GENERATOR TIE IN ?

WEEKLY/MONTHLY TESTS ON GENERATORS REQUIRED.
FUEL CELL MAY HAVE TO BE INCLUDED IN TEST.

IF GRID LOST - Generators come on. FUEL CELL
DOES NOT RECONNECT UNTIL Grid is up - Requires
Manual restart (9 sec. delay on emergency generators).

* Follow up on Anaheim Hospital fuel cell visit.

ONSI's COMMENTS:

(1) MAJOR COST OF INSTALLATION $\Rightarrow$ PIPING
($\&$ THERMAL LOSSES)

Doug Young - How DATA MONITORING WORKS.

TOU STANDBY RATE - WAYNE WILL SEND TO ME.

HOSPITAL Expansion (Ensign to check w/ Jim Jensen / NAVFAC - SWOIR)

ONSITE Review Meeting - Get SW involved - If not,
Public Works would do review (HOWARD Devore).

Could hook into Gallery for emergency backup without
interfacing with generators (Extra manhole access conduits).

ROSTER FOR 09 DEC 93 MEETING ON "FUEL CELL"

<u>NAME</u>	<u>POSITION</u>	<u>AGENCY</u>
T. MONACO	FACILITIES OFFICER	NHTP
M. J. Roman	X O	NHTP
S. D. HAMMONS	FAC. MAINT. UTIL. ENGR.	MCAGCC
JEFF MERTEN	Div. mgr	SAIC
MIKE BINDER	PRINCIPAL INVESTIGATOR	USACERL (CECER-FEP)
T. C. R. MIRANDA	FACILITIES (MCLO) PRO TEN	NAVITO-PTP.
Patrick Dougherty	FAC. MAINT off.	NHTP
DR Brannan	DXA	NHTP
E. P. THOMPSON	ASST FOR MAINT C	NHTP

29 PAMS MCB DESIGN REVIEW 02 MAR 95

LT. DuFour - POIC COORDINATOR FOR PROJECT

DRAWING REVISIONS GIVEN TO BASE/HOSPITAL
FROM USARMC/SAIC REVIEW

GENERAL TIME FRAME/PROCEDURES FROM HERE
TO RIBBON CUTTING,
PRESENTATION OF DESIGN - DOWNEYING (ONST)

DRAWINGS: (1st Go-Through - Original design
2nd Go-Through - Modifications per our
Comments [revised drawings])

S1 - FOUNDATION LAYOUT

S2 -

ME1 - Rev 1

M1 - REV 1 (105°F & 140°F DHW Supply)

M2 - NEW DRAWING

E-1 - ELECTRICAL WIRING

(500-520 V Common AT HOSPITAL-BASE
TO INSTALL VOLTAGE REGULATION IN SAMMER-
FUEL CELL WITH DROPOFF GRID AT 515V)

- GALLEY IS ON GRID INDEPENDENT
(DEDICATED LOAD) TERMINALS

- DESCRIPTION OF MONITORING/COMMUNICATION
FOR OEM OF FCELL

E-2 Rev 1

E-3

M114 MARKUP OF HOSPITAL DRAWING

M122 - MAKEUP OF HOISTING DRAWING

ACTION ITEM - Make 125°F to 140°F

SEE LETTER
OF RESOLUTION
FROM WNSJ

Recirc lines to just after P2 to increase thermal recovery - Didn't do originally ~~but~~ because of long pipe runs but with new fuel cell location it looks pretty short.

⇒ JOE STANUNAS TO LOOK AT THIS - IF WE DECIDE THAT, THE P3-BUILTS WILL REFLECT THIS,

SEE ACCEPTANCE
TEST NOTES

TAKE ANOTHER POWER MEASUREMENT TO DETERMINE IF WATHE GALLEY can run on FCFF (< 200 kW), Then Note ON E-1 ABOUT Selected Normal Circuits to be powered will be removed.

⇒ Put recorder on GalleY circuit to verify peak loads.
George will Supply Recorder and Coordinate with Base Personnel,

DISCUSSION OF CERL/SAIC COMMENTS & How Revisions Address Them.

Drawing E-1 2" } Piping from Storage
M-1 3" } Tank
ME-1 2" }

⇒ Check and correct discrepancy

⇒ (Also 4" DIA on M-1 should be 4' dia Storage tank). Correct on drawing
(also possibly on another drawing
a) well - Check*)

SAIC Comment #4 - Note to deal for backflow added to M-1 Rev 1 (Stu ⇒ probably won't need one). CHECK TO MAKE SURE.

SAIC Comment 5 Electrical (Actually 2).

a. No PE Electrical Available in high desert area. ⇒ Base will not require stamp

b } E-2 Rev 1 handles
c }

d } ME-1 handles

ME-1 Rev1 Can move connection to existing
gas supply to left (close to fuel
cell) to cut down on piping. Check on
this. [Also change 3" line to 3" line
on ME-1 Rev-1.] Regulator needed in
either case to drop pressure down to FCF
requirements.

SALC ELECT COMMENTS

- (e) Drawing E-3 handle
- (f) ME-1 Rev1 handles

ENGIN MARRAS:

S-2 & S-1 Grade slopes toward hospital
as well as $\perp$ to hospital - Drain
required on hospital side of concrete slab.

⇒ BASE NEEDS TO CONTACT BASE THREE to get
2 Pair Phone line connection (Request to be done
by Engr. Marras).

Authorization to proceed as per results of fire
construction meeting (to ONSI)

ONSI Comments to me by next Thursday morning. I
can draft letter to ONSI. Public Works & Draft Letter
to desk.

PRE Construction Meeting on Weds 08 MAR
with George & Hqs. to Base personnel
Time 0900.

Construction Starts Monday 13 MAR (subject
to results of preconstruction meeting)

Spot Gas vs. Solcal Gas (22.10 MBTU
vs. ~ 46.0 MBTU). Check with SW DIV on
whether line could be run for spot gas.

⇒ Check with Dave Winn or Max Sheh.

Does Solcal Gas have Capex rate? (Terrence
Mach is POE at Solcal)?

Base to take photographs during construction.

NOTE: DHW MARKUP IS THE ONLY THERMAL INTERFACE
THAT WILL BE USED.

29 PALMS MCB - ACCEPTANCE TEST 23 JUN 95

- I. INTRO - PURPOSE OF MEETING (ACCEPTANCE TEST REPORT, INSTALLATION VS DESIGN, ACCURACY OF AS-BUILTS, SITE WALK THROUGH, DO FORM 250, DEDICATION ~~SCHEDULE~~ ^{TRAINING} CEREMONY DISCUSSION, CONSTRUCTION PICTURES/INTERNAL NOTES)
- II. ACCEPTANCE TEST REPORT - Doug Young
 - OVERVIEW OF ACCEPTANCE ^{TEST} PROCEDURE
 - DISCUSSION OF ACTUAL SCREEN DISPLAYS (IDLE STATE) - VERY DETAILED DESCRIPTION OF EACH DATA ITEM.
 - REVIEW OF ALL OTHER SETS POINTS DATA SCREENS.
 - GRID DEPENDENT
 - GRID INDEPENDENT
- III. AS-BUILT DRAWINGS ^{OFF FUEL CELL} (RECORD DRAWINGS) - ^{Date} Young
 - LIST OF CHANGES FROM DESIGN DRAWINGS.
 - [NOTE: ENTIRE GALLEY IS POWERED BY FUEL CELL - NOTE ON E-1 ABOUT SELECTED CIRCUITS TO BE REMOVED FROM AS-BUILTS.]
- IV. MARKED UP HOSPITAL DRAWINGS - GEORGE GUARD
- V. ACTION ITEMS
 - FIX NOTE ON DRAWING E-1
 - PHYSICALLY POSITION COLD WATER FEEDLINE TO POSITION AS SHOWN ON M-1

-2-

- CHANGE HOSPITAL MARKUP DRAWINGS TO REFLECT CHANGE OF COLD WATER INLET LOCATION (PER PREV NOTE.)
- KIRK-KEY SYSTEM TO BE DELIVERED BY SQUARE D
- KEY TO FENCE CHAIN & LOCK KEYPED TO MR3.
- EXTENSIVE CALLS MADE DURING START UP - BILL TO BE PAID BY ONSI
- ONSI WILL REPLACE STOLEN NOTEBOOK COMPUTER
- ~~SH~~ SHUT METAL KILNS TO BE CUT IN PENETRATIONS.

NOTES:

- IF UTILITY LOST, GOES TO IDLE 1 SECOND, THEN TO GRID INDEPENDENT.
- IF GRID COMES BACK FOR 15 SEC, GRID CONNECT MODE REESTABLISHED
- IF GRID OUT FOR MORE THAN 3200 SECONDS, Manual ReConnect is required (Fuel cell won't automatically reconnect).
- DURING GENERATOR TESTS, FUEL CELL WILL PARTICIPATE IN TEST (GRID SHUT OFF AUTOMATICALLY)
- TRAINING COMPLETE
- CONSTRUCTION PHOTOS - LT MONACO
- CONSTRUCTION NOTES - George + Prosside

- 3 -

~~WEEK OF 17 JUL~~

- THURSDAY 20 JUL for DEDICATION
CEREMONY (9:00 am) (Lt Monica to confirm)

*

- CONTACT DANA ABOUT 95%
Electric Power + ABOUT PRESS
COVERAGE

*

- CALL & INVITE DICK WALSH TO
ATTEND.

*/

- QUESTION ABOUT PROJECT NEPA
DOCUMENTATION. (CHECK WITH BILL -
IF ONE EXISTS & Palmi would like one
on file).

Appendix H: Fuel Cell Photographs



DSCF0102.JPG



DSCF0103.JPG



DSCF0104.JPG



DSCF0105.JPG





DSCF0108.JPG



DSCF0109.JPG



DSCF0110.JPG



DSCF0111.JPG



DSCF0112.JPG



DSCF0113.JPG



DSCF0114.JPG



DSCF0115.JPG



DSCF0116.JPG



DSCF0117.JPG



DSCF0118.JPG



DSCF0119.JPG



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DSCF0121.JPG

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				5b. GRANT NUMBER	
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14. ABSTRACT Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. In fiscal year 1993 (FY93), the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) was assigned the mission of managing the DOD Fuel Cell Demonstration Program. Specific tasks included developing turnkey PAFC packages, devising site criteria, screening candidate DOD installation sites based on selection criteria, evaluating viable applications at each candidate site, coordinating fuel cell site designs, installation and acceptance of the PAFC power plants, and performance monitoring and reporting. CERL selected and evaluated 30 application sites, supervised the design and installation of fuel cells, actively monitored the operation and maintenance of fuel cells, and compiled “lessons learned” for feedback to fuel cell manufacturers. At the conclusion of the demonstration period, each of the demonstration fuel cell sites was given the choice to either have the fuel cell removed or to keep the fuel cell power plant. This report presents a detailed review of a 200 kW fuel cell installed at the Marine Corps Air Ground Combat Center (MCAGCC) – Twentynine Palms and operated between June 1995 and May 2000.					
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