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Construction Engineering
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Engineer Research and
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Site Evaluation for Application of Fuel Cell Technology

Naval Air Station Fallon, Fallon, NV

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Foreword

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).

This report documents work done at Naval Air Station Fallon, Fallon, NV. Special thanks is owed to the Naval Air Station Fallon points of contact (POCs) Greg Westmoreland and Jim Pellham for providing investigators with access to needed information for this work. 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 Michael J. Binder. Part of this work was performed by Science Applications International Corp. (SAIC), under Contract DACA88-94-D-0020, task orders 0002, 0006, 0007, 0010, and 0012. The technical editor was William J. Wolfe, Information Technology Laboratory. Larry M. Windingland is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Gary W. Schanche. The Acting Director of CERL is William D. Goran.

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

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Background

Fuel cells generate electricity through an electrochemical process that combines hydrogen and oxygen to generate direct current (DC) electricity. Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. Air emissions from fuel cells are so low that several Air Quality Management Districts in the United States have exempted fuel cells from requiring operating permits. Today's natural gas-fueled fuel cell power plants operate at electrical conversion efficiencies of 40 to 50 percent; these efficiencies are predicted to climb to 50 to 60 percent in the near future. In fact, if the heat from the fuel cell process is used in a cogeneration system, efficiencies can exceed 85 percent. By comparison, current conventional coal-based technologies operate at efficiencies of 33 to 35 percent.

Phosphoric Acid Fuel Cells (PAFCs) are in the initial stages of commercialization. While PAFCs are not now economically competitive with other more conventional energy production technologies, current cost projections predict that PAFC systems will become economically competitive within the next few years as market demand increases.

Fuel cell technology has been found suitable for a growing number of applications. The National Aeronautics and Space Administration (NASA) has used fuel cells for many years as the primary power source for space missions and currently uses fuel cells in the Space Shuttle program. Private corporations have recently been working on various approaches for developing fuel cells for stationary applications in the utility, industrial, and commercial markets. Researchers at the U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL) have actively participated in the development and application of advanced fuel cell technology since fiscal year 1993 (FY93), and have successfully executed several research and demonstration work units with a total funding of approximately $55M.

As of November 1997, 30 commercially available fuel cell power plants and their thermal interfaces have been installed at DoD locations. CERL managed 29 of these installations. As a consequence, the Department of Defense (DoD) is the owner of the largest fleet of fuel cells worldwide. CERL researchers have developed a methodology for selecting and evaluating application sites, have supervised the design and installation of fuel cells, and have actively monitored the operation and maintenance of fuel cells, and compiled "lessons learned" for feedback to manufacturers. This accumulated expertise and experience has enabled CERL to lead in the advancement of fuel cell technology through major efforts such as the DoD Fuel Cell Demonstration Program, the Climate Change Fuel Cell Program, research and development efforts aimed at fuel cell product improvement and cost reduction, and conferences and symposiums dedicated to the advancement of fuel cell technology and commercialization.

This report presents an overview of the information collected at Naval Air Station Fallon, Fallon, NV along with a conceptual fuel cell installation layout and description of potential benefits the technology can provide at that location. Similar summaries of the site evaluation surveys for the remaining 28 sites where CERL has managed and continues to monitor fuel cell installation and operation are available in the companion volumes to this report (see Table 1).

Objective

The objective of this work was to evaluate Naval Air Station Fallon as a potential location for a fuel cell application.

Approach

On 10 and 11 April 1996, representatives from CERL and Science Applications International Corporation (SAIC) visited the Naval Air Station Fallon (NAS Fallon) to investigate it as a potential location for a 200 kW phosphoric acid fuel cell power plant. This report presents a conceptual fuel cell installation layout, thermal interface schematics, preliminary economic evaluation, description of potential benefits, and an overview of information collected at the site. The Appendix to this report contains a copy of the site evaluation form filled out at the site.

Table 1. Companion ERDC/CERL site evaluation reports.

Location	Report No.
Pine Bluff Arsenal, AR	TR 00-15
Naval Oceanographic Office, John C. Stennis Space Center, MS	TR 01-3
Fort Bliss, TX	TR 01-13
Fort Huachuca, AZ	TR 01-14
Naval Air Station Fallon, NV	TR 01-15
Construction Battalion Center (CBC), Port Hueneme, CA	TR 01-16
Fort Eustis, VA	TR 01-17
Watervliet Arsenal, Albany, NY	TR 01-18
911th Airlift Wing, Pittsburgh, PA	TR 01-19
Westover Air Reserve Base (ARB), MA	TR 01-20
Naval Education Training Center, Newport, RI	TR 01-21
U.S. Naval Academy, Annapolis, MD	TR 01-22
Davis-Monthan AFB, AZ	TR 01-23
Picatinny Arsenal, NJ	TR 01-24
U.S. Military Academy, West Point, NY	TR 01-28
Barksdale Air Force Base (AFB), LA	TR 01-29
Naval Hospital, Naval Air Station Jacksonville, FL	TR 01-30
Nellis AFB, NV	TR 01-31
Naval Hospital, Marine Corps Air Ground Combat Center (MCAGCC), Twentynine Palms, CA	TR 01-32
National Defense Center for Environmental Excellence (NDCEE), Johnstown, PA	TR 01-33
934th Airlift Wing, Minneapolis, MN	TR 01-38
Laughlin AFB, TX	TR 01-41
Fort Richardson, AK	TR 01-42
Kirtland AFB, NM	TR 01-43
Subase New London, Groton, CT	TR 01-44
Edwards AFB, CA	TR 01-Draft
Little Rock AFB, AR	TR 01-Draft
Naval Hospital, Marine Corps Base Camp Pendleton, CA	TR 01-Draft
U.S. Army Soldier Systems Center, Natick, MA	TR 01-Draft

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

1 ft	=	0.305 m
1 mile	=	1.61 km
1 acre	=	0.405 ha
1 gal	=	3.78 L
°F	=	°C (X 1.8) + 32

2 Site Description

NAS Fallon is located adjacent to Fallon, NV, which is approximately 70 mi east of Reno. The ASHRAE design temperatures for the site are 96 and 8 °F. However, the extreme temperatures range from a high of 105 °F to a low of –28 °F. Fallon has 5,400 heating degree days and 2,500 cooling degree days. The elevation is approximately 4,000 ft and humidity is relatively low. Figure 1 shows an overall NAS Fallon site map.

The mission of NAS Fallon is "to maintain and operate facilities and provide services and materials to support operations of aviation activities and units of the operating forces of the Navy and other activities or units as designated by the Chief of Naval Operations." NAS Fallon is the home base of the Naval Strike Warfare Center and the future home of "Top Gun." Their primary mission is to provide quarters for aviators who are undergoing training. This results in a significant population fluctuation.

Site personnel had not selected a preferred location for the fuel cell prior to the site evaluation. Based on discussions with site personnel, the evaluation focused upon the galley (Bldg. 303), an indoor swimming pool (Bldg. 383), the bachelor officer quarters (BOQ, Bldgs. 468-472), and the bachelor enlisted quarters (BEQ, Bldg. 381). The BOQ and BEQ proved to have only limited need for thermal energy. The site evaluation focused further on the galley and swimming pool.

The facilities at NAS Fallon are served by both centralized and decentralized energy systems. The central energy plant provides 350 °F pressurized hot water. Sierra Pacific Power Company provides power to the air station from a 37.5 kV feeder. There are four or five electric meters for billing purposes. The air station electric services are both 12.5 kV or 4160 V. Site personnel indicated that power outages are not uncommon and they experience three or four extended outages per year. Southwest Gas presently supplies natural gas to the air station. Northwest Pipeline is completing a natural gas pipeline near NAS Fallon and would be an alternate supplier of gas in the future. Therefore, an adequate supply of natural gas exists and competition could drive the price down.

The water table at NAS Fallon is only 4 ft below the surface. If water is found during excavation, a dewatering permit will be needed for discharging the water.

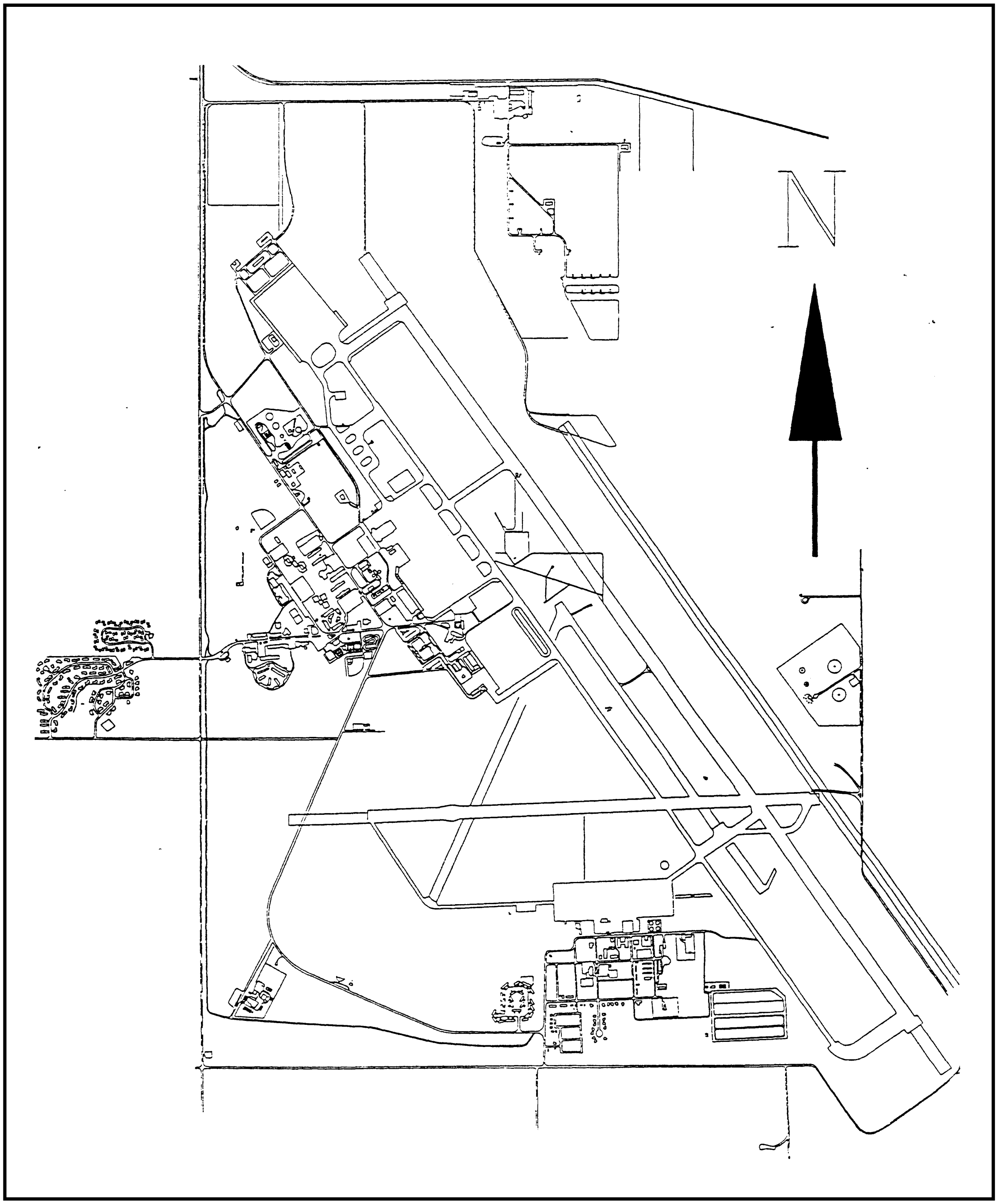

Figure 1. NAS Fallon site map.

Swimming Pool Site Description

The indoor swimming pool is housed in a building that also includes showers, changing rooms, small offices, and the mechanical room. The pool contains 250,000 gal of water and is equivalent to 1-1/2 Olympic size pools. The pool is

“L” shaped and varies in depth from 4 to 12 ft. It is heated to 82 to 84 °F year round. It is used for pilot rescue training and for recreational purposes. Approximately 50 people per day use the pool. Showers are required prior to use of the pool. Natural gas is available across the street from the pool. Make-up water for the fuel cell and telephone lines are available. More specific interface information for this site is provided in the Fuel Cell Interfaces section of this report.

Galley Site Description

The galley is centrally located at the air station. It serves three meals per day and operates from approximately 0430 until 0100 hours. There is an adequate natural gas line in the mechanical room. Make-up water and telephone lines are available. More specific interface information for this site is provided in the Fuel Cell Interfaces section of this report.

Site Layout

Swimming Pool Site Layout

As Figure 2 shows, the mechanical room is located in the North corner of the pool facility. There is a chain link fence around the pool facility. The fuel cell could be located just outside the fence.

Galley Site Layout

The mechanical room is located at the back of the galley adjacent to the electrical room and the telephone room (Figure 3). The galley has a grassy area adjacent to the mechanical room that is adequate for siting the fuel cell. This appears to be a very good site for the fuel cell with ample space and short connections to all utilities.

Electrical System

Swimming Pool Electrical System

The swimming pool is fed through three 208/4160 V, 75 kVA transformers mounted on the utility pole about 50 ft from the pool facility.

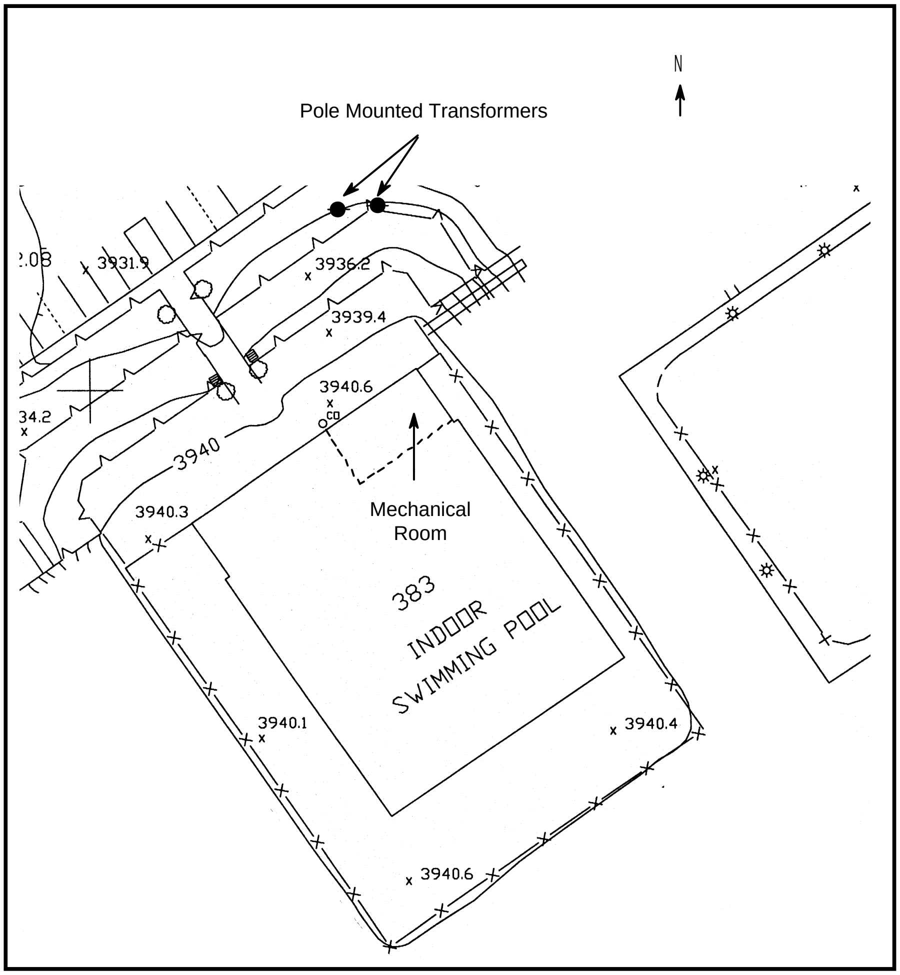

Figure 2. Pool facility layout.

Galley Electrical System

The galley is fed by a 208/4160 V, 300 kVA transformer located in the electric room adjacent to the mechanical room. The average electric demand is approximately 13 kW. The galley is not served by an emergency generator and site personnel indicated that using the fuel cell in an isolated emergency mode for the galley would provide additional benefits.

Steam/Hot Water System

Swimming Pool Steam/Hot Water System

A heat exchanger uses central hot water (350 °F) to produce 180 °F domestic hot water primarily for the showers. A mixing valve tempers the water before delivery to the showers. The pool facility has a gas-fired backup hot water heater.

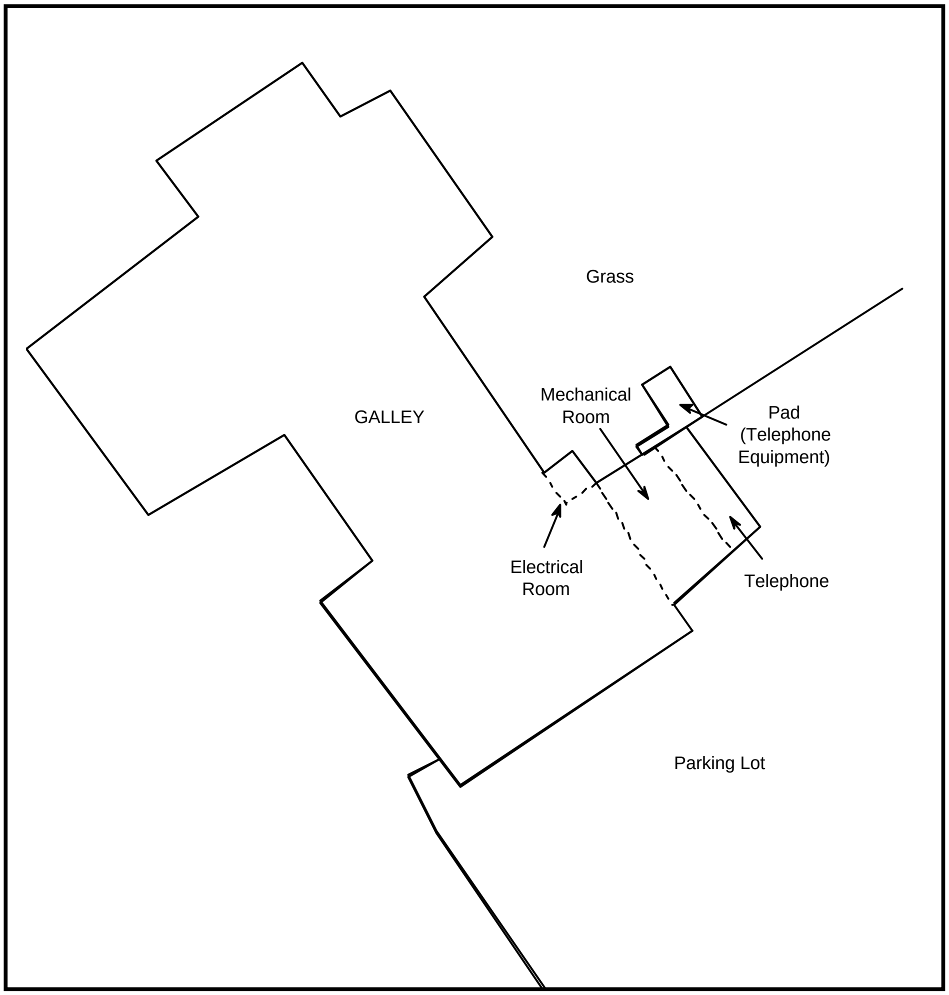

Figure 3. Galley layout.

Galley Steam/Hot Water System

High temperature (350 °F) hot water from the central plant produces saturated steam at 12 to 15 psi that produces 165 °F hot water through a heat exchanger in the galley. The mechanical room has a 2.5 MBtu/hr backup steam boiler.

Space Heating System

Swimming Pool Space Heating System

The pool enclosure has three overhead space heating air handling units. These units receive 180 to 200 °F hot water heated by a heat exchanger from 350 °F hot water supplied by a central plant.

Galley Space Heating System

High temperature (350 °F) hot water from the central plant produces saturated steam at 12 to 15 psi that is used in a heat exchanger to produce 180 to 200 °F hot water. A hydronic space heating system provides space heat to the galley. Space heating is also provided directly with steam in some areas of the galley. It is not practical for the fuel cell to produce steam, and in any case, the remaining hydronic space heating load would be less than 4 percent of the thermal output of the fuel cell on an annual basis. Therefore, it is recommended that the space heating load not be served.

Space Cooling System

Swimming Pool Space Cooling System

The pool enclosure has no mechanical cooling. The glass doors in the walls of the pool enclosure are opened during the summer and other times when cooling is required. The roof is designed to open, but is presently inoperative.

Galley Space Cooling System

The galley dining area is provided cooling from two 10,000 cfm evaporative coolers located in a mezzanine area. The kitchen area is not air-conditioned.

Fuel Cell Location

Swimming Pool Fuel Cell Location

Figure 4 shows the proposed location for the fuel cell at the swimming pool is adequate, but not as optimum as the galley. There is a sloping area adjacent to the mechanical room that is sufficient for siting the fuel cell. Grading and a retaining wall will be necessary. A new transformer will need to be installed near the fuel cell and a new electrical line (about 100 ft) from the 4160 V line adjacent to the pool facility will need to be installed. The thermal lines will be run approximately 40 ft to the mechanical room. The natural gas line can be connected to the main gas line, which is a piping run of approximately 375 ft.

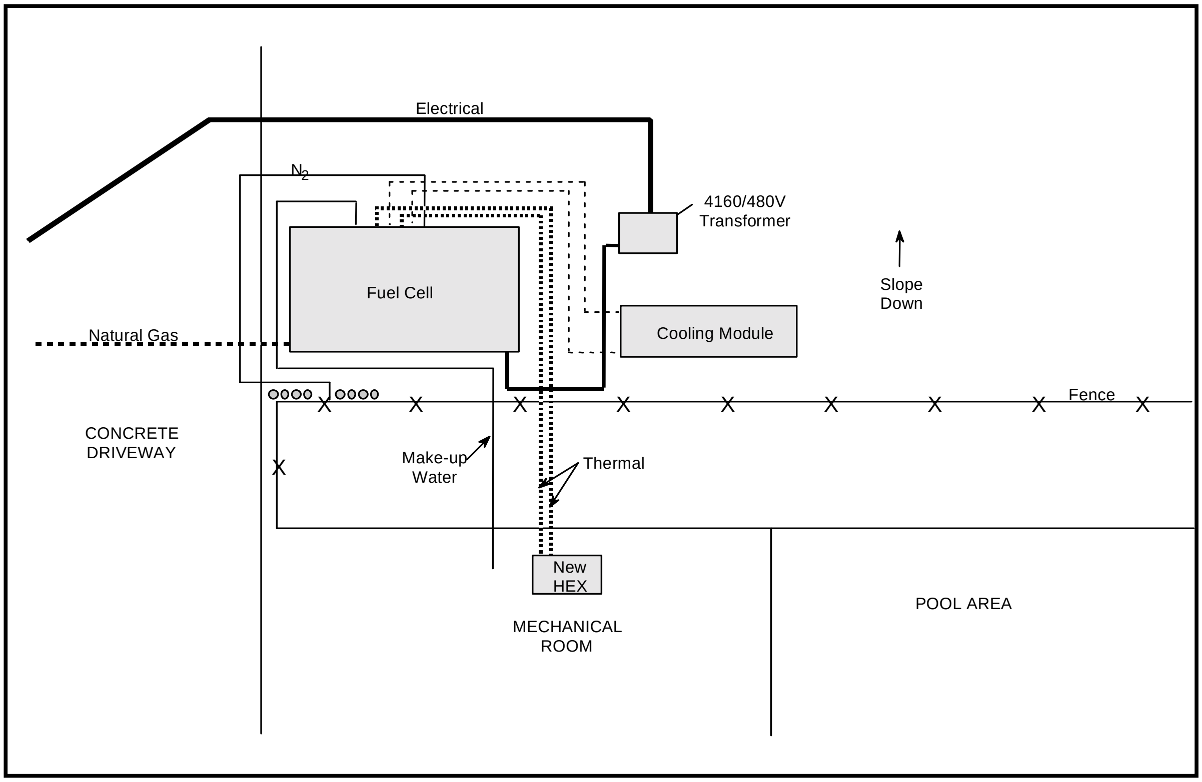

Figure 4. Fuel cell site layout — pool.

Galley Fuel Cell Location

The fuel cell is proposed to be located behind the mechanical room adjacent to the electrical room in a grassy area (Figure 5). There is adequate room around the fuel cell to maintain the 8-ft spacing required.

The electrical connection to a new transformer will be less than 20 ft. The thermal lines will be run approximately 40 ft to connect to the make-up water line feeding the steam heated domestic hot water tank. The natural gas line can be connected to the main gas line to the mechanical room, which is a piping run of approximately 50 ft.

Fuel Cell Interfaces

Four fuel cell applications were originally examined at NAS Fallon. They were the indoor swimming pool (#383), the BOQ (#468-472), the galley (#303), and the BEQ (#381). The BOQ and BEQ were rejected because the thermal load represented less than 4 percent use of the available fuel cell thermal output. The pool and the galley are viable candidate sites and are presented here.

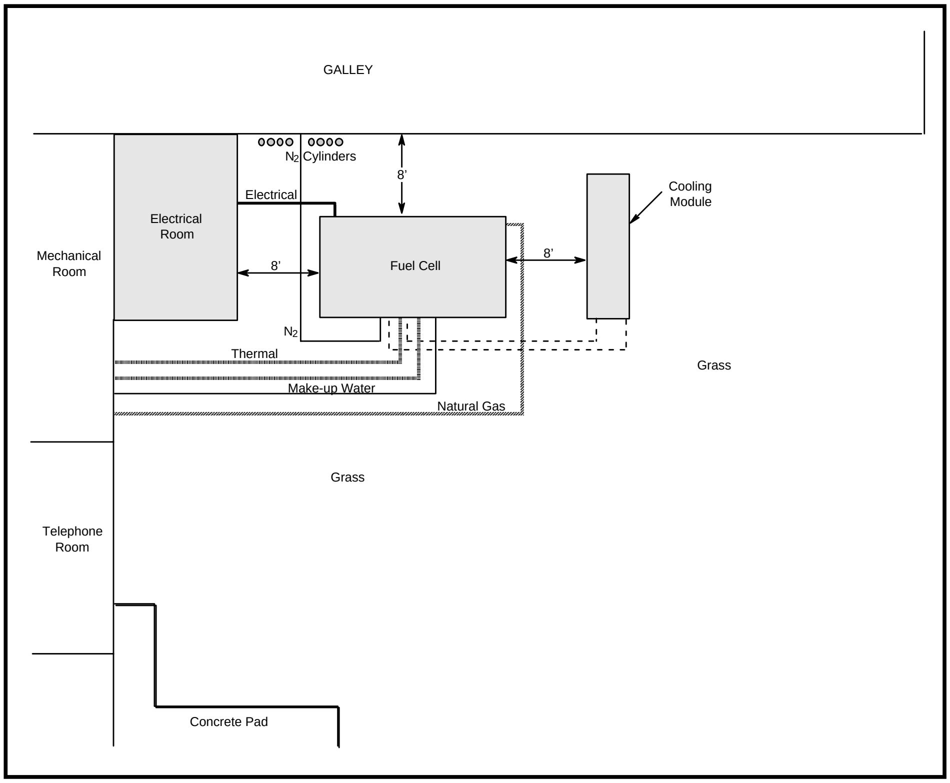

Figure 5. Fuel cell site layout — galley.

Indoor Swimming Pool (Building #383)

The pool facility uses 120/208 V power fed from three 75 kVA pole-mounted transformers. Feeding the fuel cell electrical output through these transformers is not an option since they are too small (300 kVA is required). Therefore, the fuel cell electrical output would be fed through a new 480/4160 V, 300 kVA transformer, into the base grid system.

The fuel cell thermal output would be used to heat the swimming pool. The pool heating load was calculated using the approach specified in the ASHRAE Applications Handbook. Table 2 lists the assumptions for this site.

The annual average load was calculated assuming 6 winter months and 6 summer months. The average pool heating load is:

(123 kBtu/hr) (4380 hrs/6 months) + (156 + 488 kBtu/hr) (4380hrs/6 months) =
383 kBtu/hr, 8760 hours/year

The average fuel cell thermal utilization is 55 percent (383 kBtu/hr/700 kBtu/hr).

Table 2. Assumptions for the site.

1. Temperature	**Summer**	**Winter**
Indoor Air Temperature (°F)	84	75
Indoor Relative Humidity (%)	80	60
Pool Water Temperature (°F)	84	84
2. The pool surface area is 5,170 sq ft		
3. Evaporative loss:		
Water evaporation = 0.1 (surface area) * (Water Vapor Pressure, pool surface – air)		
Summer: 0.1 (5,170 sq ft) (1.188 in Hg – 0.9503 in Hg) = 123 lb/hr		
heat load = 123 lb/hr * 1 kBtu/lb = 123 kBtu/hr		
Winter: 0.1 (5,170 sq ft) (1.188 in Hg – 0.886 in Hg) = 156 lb/hr		
Heat load = 156 lb/hr * 1 kBtu/lb = 156 kBtu/hr		
4. Convective/Radiation Loss:		
Heat Loss = 10.5 (Surface Area) (Pool Water Temperature – Air Temperature)		
Summer: 10.5 (5,170 sq ft) (84° – 84°) = 0 kBtu/hr		
Winter: 10.5 (5,170 sq ft) (84° – 75°) = 488 kBtu/hr		

Figure 6 shows how the fuel cell would be interfaced. An intermediate heat exchanger between the pool and the fuel cell is recommended to protect the fuel cell heat exchanger from the chlorinated pool water. Balancing valves can be used to direct the desired flow through the intermediate heat exchanger. The flow through the fuel cell will require a 25 gpm pump, which will operate whenever the fuel cell is operating and the water temperature to the heater is below the setpoint. The nearest gas line to the pool facility is across the parking lot and Churchill Street approximately 375 ft from the fuel cell site.

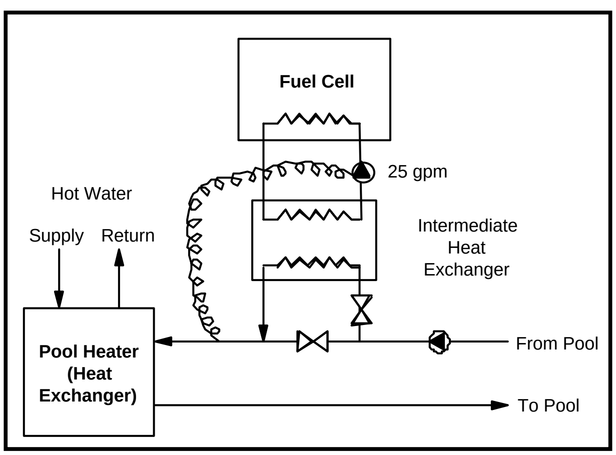

Figure 6. Fuel cell thermal interface — pool.

Galley (Building #303)

The galley uses 120/208 V power fed through a 208/4160 V 300 kVA transformer. Currently, the galley does not have any backup power supply. The site would like to use the fuel cell to supply power to the grid and to provide backup power in the event of a grid outage. To accomplish this, two additional transformers are required. The grid connect fuel cell output would be supplied through a new 480/4160 V, 300 kVA transformer to the high side of the existing 208/ 4160 V transformer. The grid independent fuel cell output would be fed through a new 208/480 V, 300 kVA transformer to the low side of the existing 208/ 4160 V transformer. The galley load must be disconnected from the current feed and be fed only from the fuel cell with a by-pass switch. Electric meter data from October 1994 to September 1995 shows the highest average demand to be 13.2 kW. It is almost assured that the peak demand for the galley will not exceed the 200 kW fuel cell capability.

The fuel cell thermal output will be used to preheat the domestic hot water (DHW) used in the galley. The DHW load was calculated using the number of meals served (Table 3) and an ASHRAE estimate of gallons of DHW required per meal.

The DHW load was calculated as follows.

DHW = (271,525 meals) (2.4 gal/meal) (8.35 lb/gal) (160 °F – 60°F) (.001 kBtu/ lb – °F) = 544,136 kBtu/yr or Avg 62 kBtu/hr

Table 3. Number of meals served in the NAS Fallon galley.

Month	Meals served
Oct 94	14,942
Nov 94	13,586
Dec 94	11,487
Jan 95	14,840
Feb 95	17,970
Mar 95	41,114
Apr 95	20,416
May 95	23,996
June 95	31,580
July 95	24,104
Aug 95	32,486
Sept 95	25,004
Total (meals/yr)	271,525

The fuel cell thermal utilization would be about 9 percent (62 kBtu/hr / 700 kBtu/hr).

The galley crew works from 0430 to 0100 hours, and DHW is used throughout this period. Therefore, the average DHW load when operating is 72 kBtu/hr (62 kBtu/hr * (24 hrs/20.5 hrs)). With this low average load, thermal storage is not required.

Figure 7 shows the thermal interface for the galley. Make-up water would be pulled from the make-up line heated in the fuel cell and returned to the top of the 190-gal steam heater tank. If the fuel cell does not fully heat the water to the desired galley temperature (165 °F), the existing steam heater will. A 25-gpm pump should be used to control the flow through the fuel cell. This will provide the desired fuel cell flow rate without restricting the make-up flow during periods of high demand. The pump should run when the fuel cell is operating and the tank temperature is below 165 °F. If there is no make-up water requirement, the fuel cell pump will pull water back from the tank, thus keeping the tank at temperature.

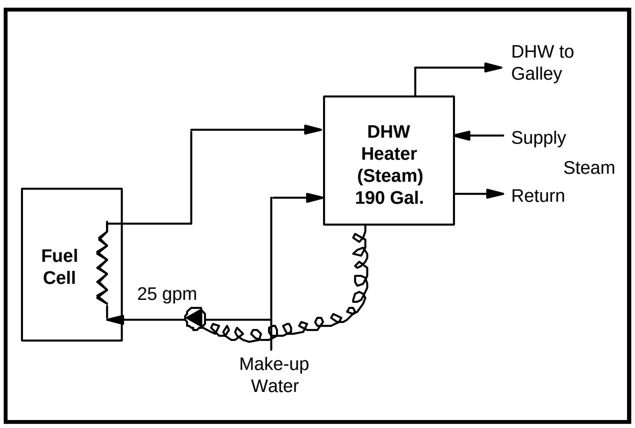

Figure 7. Fuel cell thermal interface — galley.

Table 4. Sierra Pacific Power Company GS-3 time-of-use rate schedule.

Demand Period	Energy Charge	Charge	Times
Winter - On-Peak:	4.522 cents/kWh	$7.30/kW	5:01 p.m. to 10:00 p.m. daily
Winter - Mid-Peak:	4.302 cents/kWh	$2.33/kW	7:00 a.m. to 5:00 p.m. daily
Winter - Off-Peak:	3.660 cents/kWh		All other hours.
Summer - On-Peak:	4.434 cents/kWh	$9.62/kW	10:01 a.m. to 10:00 p.m. daily
Summer - Off-Peak:	3.970 cents/kWh		All other hours.

Economic Analysis

NAS Fallon is located in Sierra Pacific Power Company's service territory and receives power under electric rate schedule GS-3, Large General Service. GS-3 is a time-of-use rate schedule. There are 8 winter months (October - May) and 4 summer months (June - September). Table 4 gives the rate schedule.

The site electricity consumption from its two main meters is shown in Table 5. The energy cost data provided by NAS Fallon was not consistent with the rate schedule due to overlap with late payments and mid-month season change, so it is not summarized here.

NAS Fallon is expected to begin purchasing natural gas from Southwest Gas under interruptible gas rate NT-1 in May 1996. Although it is an interruptible rate, this rate has a relatively high residential No. 2 priority for curtailment and is more than $3/MBtu less expensive than the current price of $5.57/Mbtu (Southwest Gas rate NG-22). NAS Fallon will pay $2.10/MBtu. Table 6 lists the calculated electric savings from the fuel cell. Electric savings from the fuel cell were calculated based on rate schedule GS-3 and the fuel cell operating 90 percent of the year:

Energy Savings = Hours/Day * Days/Year * $/kWh * 200 kW * 90% capacity factor **Eq. 1**

Demand Savings = 200 kW * $/kW * Months/Period **Eq. 2**

Total Electric Savings = $65,261 + $23,104 = $88,365.

Table 5. Electric savings from the fuel cell.

Period	Hours/Day	Days/Year	$/kWH	Energy Savings	$/kW	Demand Savings
Winter: (8 months)						
On-Peak	5	243	$0.04522	$9,890	$7.30	$11,680
Mid-Peak	10	243	$0.04302	$18,817	$2.33	$3,728
Off-Peak	9	243	$0.03660	$14,408		
Summer: (4months)						
On-Peak	12	122	$0.04434	$11,684	$9.62	$7,696
Off-Peak	12	122	$0.03970	$10,462		
Subtotals				$65,261		$23,104

Table 6. NAS Fallon electricity consumption.

	Date	Billing Days	Summer OffPeak kWh	Summer OnPeak kWh	Summer OnPeak kW	Winter OffPeak kWh	Winter MidPeak kWh	Winter MidPeak kW	Winter OnPeak kWh	Winter OnPeak kW	Total kWh
12.5kV	4/6/95	29				368,400	522,000	2,652	247,200	2,376	1,137,600
	5/8/95	30				361,200	511,200	2,556	231,600	2,256	1,104,000
	6/8/95	32	86,400	87,600	2,376	334,800	471,600	2,748	226,800	2,616	1,207,200
	7/7/95	30	543,600	644,400	2,808						1,188,000
	7/7/95	0	758,400								758,400
	8/7/95	29	555,600	694,800	2,892						1,250,400
	9/7/95	33	633,600	775,200	2,676						1,408,800
	10/9/95	29	501,600	618,000	3,084	57,600	76,800	2,760	31,200	2,724	1,285,200
	11/7/95	30				421,200	573,600	2,856	273,600	2,604	1,268,400
	12/7/95	32				430,800	589,200	2,664	274,800	2,472	1,294,800
	1/8/96	30				404,400	506,400	2,544	243,600	2,292	1,154,400
	2/6/96	29				428,400	559,200	2,568	265,200	2,376	1,252,800
	3/8/96	32				458,400	594,000	2,472	280,800	2,412	1,333,200
Ave. kW					2,767			2,647		2,459	
4160V	4/6/95	29				310,400	420,800	1,728	203,200	1,632	934,400
	5/8/95	30				283,200	390,400	1,680	180,800	1,536	854,400
	6/7/95	32	57,600	62,400	1,552	206,400	300,800	1,520	142,400	1,344	769,600
	7/7/95	30	363,200	446,400	1,824						809,600
	7/7/95	30	417,600								417,600
	8/7/95	29	443,200	572,800	2,080						1,016,000
	9/7/95	33	512,000	670,400	2,128						1,182,400
	10/6/95	29	361,600	472,000	1,952	38,400	56,000	1,776	22,400	1,680	950,400
	11/21/95	30				289,600	393,600	1,616	187,200	1,520	870,400
	1/8/96	30				322,800	420,000	1,728	211,200	1,584	954,000
	2/6/96	29				333,600	450,000	1,908	223,200	1,908	1,006,800
	3/7/96	32				348,000	466,800	1,848	229,200	1,716	1,044,000
Ave. kW					1,907			1,726		1,615	
Total kWh/Average kW			5,234,400	5,044,000	4,674	5,397,600	7,302,400	4,372	3,474,400	4,074	26,452,800

Thermal energy savings for the indoor swimming pool were estimated based on an average annual usage of 384 kBtu/hr, a 70 percent displaced boiler efficiency and a natural gas rate of $2.10/MBtu. Total thermal savings were calculated as:

4,324 MBtu/year = (0.384 MBtu/hr / 70% boiler eff.) * 8,760 hrs/yr * 90% cap. factor

Thermal cost savings would be $9,082 (4,324 MBtu * $2.10/MBtu) for the indoor pool.

Thermal savings for the galley were estimated based on an average annual usage of 62 kBtu/hour, a 70 percent boiler efficiency and a natural gas rate of $2.10/MBtu. Thermal energy savings for the galley are calculated as:

698 MBtu/year = (0.062 MBtu/hr / 70% boiler eff.) * 8,760 hrs/yr * 90% cap. factor

Thermal cost savings would be $1,466 (698 MBtu * $2.10/MBtu) for the galley. The cost for the input natural gas to the fuel cell was based on a fuel cell consumption of 14,949 MBtu/year assuming a 36 percent electric conversion efficiency (Higher Heating Value – HHV). Input fuel costs were estimated at $31,393. Table 7 summarizes the net savings from the fuel cell for both the indoor pool and the galley. The net savings for the indoor pool is estimated at $66,054. For the Galley, the net savings was estimated at $58,438.

This analysis is a general overview of the potential savings from the fuel cell. For the first 3 years, ONSI will be responsible for the fuel cell maintenance. Maintenance costs are not reflected in this analysis, but could represent a significant impact on net energy savings. Since detailed load energy profiles were not available, net energy savings could vary depending on actual thermal and electrical utilization.

Table 7. Economic savings of fuel cell design alternatives.

Case	ECF	TU	Displaced kWh	Displaced Gas (MBtu)	Electrical Savings	Thermal Savings	Nat. Gas Cost	Net Savings
A - Max. Thermal	90%	100%	1,576,800	7,884	$88,365	$16,556	$31,393	$73,528
A - Base Case- Indoor Pool	90%	55%	1,576,800	4,324	$88,365	$9,082	$31,393	$66,054
A - Base Case- Galley	90%	9%	1,576,800	698	$88,365	$1,466	$31,393	$58,438
B - Max. Thermal	90%	100%	1,576,800	7,884	$76,813	$16,556	$31,393	$61,976
B - Base Case - Indoor Pool	90%	55%	1,576,800	4,324	$76,813	$9,082	$31,393	$54,502
B - Base Case-Galley	90%	9%	1,576,800	698	$76,813	$1,466	$31,393	$46,886
C - Max. Thermal	90%	100%	1,576,800	7,884	$65,261	$16,556	$31,393	$50,424
C - Base Case- Indoor Pool	90%	55%	1,576,800	4,324	$65,261	$9,082	$31,393	$42,950
C - Base Case - Galley	90%	9%	1,576,800	698	$65,261	$1,466	$31,393	$35,334

Assumptions:

Input Natural Gas Rate:	$2.10 /MBtu
Displaced Thermal Gas Rate:	$2.10 /MBtu
Fuel Cell Thermal Output:	700,000 Btu/hour
Fuel Cell Electrical Efficiency:	36%
Seasonal Boiler Efficiency:	70%

CASE A: full fuel cell demand savings
CASE B: 50% of full fuel cell demand savings
CASE C: zero fuel cell demand savings

ECF = Fuel cell electric capacity factor
TU = Thermal utilization

3 Conclusions and Recommendations

This study concludes that the galley (Bldg 303) represents a good application for a 200 kW phosphoric acid fuel cell. The net energy bill savings are expected to be $58,000/year with the full demand savings. The fuel cell installation at the galley is straightforward with minimum piping and wiring runs.

Providing emergency power to the galley with the fuel cell would provide added benefit to the base. If the emergency power option is selected, a PC25B model should be considered. Two additional transformers would be required, 480/4160 V and a 208/480 V for emergency power.

The indoor pool facility also offers a good application for the 200 kW phosphoric acid fuel cell. The net energy bill savings for the pool facilities are higher than those at the galley (at $66,000/year). The higher savings are due to higher thermal recovery. Longer piping and wire runs would be required up to 375 ft for the gas piping. An intermediate heat exchanger is recommended to keep chlorinated pool water away from the fuel cell. An additional 480/4160 V transformer would be required.

Appendix: Fuel Cell Site Evaluation Form

Site Name: **Naval Air Station Fallon**

Contacts: **Greg Westmoreland**
702 426-2410

Location: **Fallon, NV**

1. Electric Utility: **Sierra Pacific Power**
   Contact: **N/A**
   Rate Schedule: **GS-3**

2. Gas Utility: **Southwest Gas**
   Contact: **N/A**
   Rate Schedule: **New interruptible**
   Rate: **Residential Priority 2**

3. Available Fuels: **Natural Gas, Fuel Oil**
   Capacity Rate:

4. Hours of Use and Percent Occupied:
   Hours listed are for galley
   Pool is heated 24 hr/day

   Weekdays __**5**__ Hrs.__**21**__
   Saturday __**1**__ Hrs.__**21**__
   Sunday __**1**__ Hrs.__**21**__

5. Outdoor Temperature Range: **ASHRAE design - 96°F high, 8°F low**
   Extremes – **105 °F high, -28 °F low.**

6. Environmental Issues: **Water table is 4'. If water is found upon excavation, dewatering permit is required for water discharge.**

7 Backup Power Need/Requirement: **Naval Strike Warfare Center (three 400 kW gen. sets existing) and galley could benefit from being served as an isolated load. Some outages do occur.**

8. Utility Interconnect/Power Quality Issues: **None**

9. On-site Personnel Capabilities: **Most station maintenance is performed by a contractor, Dyn Corp.**

10. Access for Fuel Cell Installation: **Good for both pool and galley.**

11. Daily Load Profile Availability: **No load data is available. See Fuel Cell Interfaces section of report for galley meals and pool showers data.**

12. Security: **Only at Naval Strike Warfare Center.**

Site Layout

Facility Type: **Indoor pool** Age: **23 years**

Construction: **Aluminum and glass walls and ceiling**

Square Feet: **14,170**

Facility Type: **Galley** Age: **39 years**

Construction: **Concrete block with cast concrete roof**

Square Feet: **20, 814**

See Figures 1,2,3

Show:

electrical/thermal/gas/water interfaces and length of runs
drainage
building/fuel cell site dimensions
ground obstructions

Electrical System

Pool

Service Rating: **4,160 volt service to building, 120/208 volt service in building**

Electrically Sensitive Equipment: **N/A**

Largest Motors (hp, usage): **10 HP pool pump**

Grid Independent Operation?: **No**

Galley

Service Rating: **4,160 volt service to building, 120/208 volt service in building**

Electrically Sensitive Equipment: **N/A**

Largest Motors (hp, usage): **N/A**

Grid Independent Operation?: **Yes, it would be beneficial but not required**.

Steam/Hot Water System

Pool

Description: **High temperature hot water (350°F) provided by central plant heats pool water through a heat exchanger to 82 - 84°F.**

System Specifications:

Fuel Type: **Natural Gas**

Max Fuel Rate:

Storage Capacity/Type: **250,000 gal. pool.**

Interface Pipe Size/Description: **1-½ in.**

End Use Description/Profile: **High temperature hot water used for pool heating, DHW, and space heating.**

Galley

Description: **High temperature hot water (350°F) provided by central plant with 2.5 MBtu/hr back up boiler in galley mechanical room. High temperature water produces saturated steam at 12 - 15 psi in the galley mechanical room which then produces domestic hot water at 165 °F.**

System Specifications:

Fuel Type: **Natural Gas**

Max Fuel Rate:

Storage Capacity/Type: **190-gal DHW tank**

Interface Pipe Size/Description: **3-in.**

End Use Description/Profile: **High temperature hot water produces steam used for DHW and space heating.**

Space Cooling System

Pool

Description: **No mechanical cooling. Roof and sliding glass doors open for cooling.**

Air Conditioning Configuration:
Type:
Rating:
Make/Model:
Seasonality Profile:

Galley

Description: **Two evaporative cooling units (10,000 cfm ea.) located in mezzanine. Kitchen is not cooled.**

Air Conditioning Configuration:
Type:
Rating:
Make/Model:

Seasonality Profile:

Space Heating System

Pool

Description: **High temperature hot water (350°F) from the central plant is provided to heat exchangers that produce hot water at 180 - 200°F that is distributed to three air handlers in the pool enclosure.**

Fuel: **Natural Gas**

Rating:

Water supply Temp: **180 °F to 200 °F**

Water Return Temp:

Make/Model:

Thermal Storage (space?):

Seasonality Profile: Winter space heating: October - May

Galley

Description: **High temperature hot water (350°F) provided by central plant . High temperature water produces saturated steam at 12 - 15 psi in the galley mechanical room which then produces hot water at 180°- 200°F for hydronic space heating system. Steam is also directly used for space heating in the galley.**

Fuel: **Natural Gas**

Rating:

Water supply Temp: **180 °F to 200 °F**

Water Return Temp:

Make/Model:

Thermal Storage (space?):

Seasonality Profile: **Winter space heating: October - May**

Billing Data Summary

ELECTRICITY

	Period	kWh	kW	Cost
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10				
11.				
12.				

NATURAL GAS

	Period	Consumption	Cost
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			

OTHER

	Period	Consumption	Cost
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10			
11.			
12.			

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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. Researchers at the U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL) have actively participated in the development and application of advanced fuel cell technology since fiscal year 1993 (FY93). CERL has selected and evaluated 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 manufacturers for 29 of 30 commercially available fuel cell power plants and their thermal interfaces installed at Department of Defense (DoD) locations.

This report presents an overview of the information collected at Naval Air Station Fallon, Fallon, NV, along with a conceptual fuel cell installation layout and description of potential benefits the technology can provide at that location. Similar summaries of the site evaluation surveys for the remaining 28 sites where CERL has managed and continues to monitor fuel cell installation and operation are available in the companion volumes to this report.

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