PNL-10277
UC-350

Performance and Economic Evaluation of the Seahorse Natural Gas Hot Water Heater Conversion at Fort Stewart

Interim Report - 1994 Summer

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January 1995

Prepared for
the U.S. Department of Energy
Federal Energy Management Program
under Contract DE-AC06-76RLO 1830

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Preface

The federal government is the largest single energy consumer in the United States with consumption of nearly 1.5 quads/year of energy (1 quad = 10^{15} Btu) and cost valued at nearly $10 billion annually. The U.S. Department of Energy's (DOE) Federal Energy Management Program (FEMP) supports efforts to reduce energy use and associated expenses in the federal sector. One such effort, the New Technology Demonstration Program (NTDP), seeks to evaluate new energy-saving U.S. technologies and secure their more timely adoption by the U.S. government.

Pacific Northwest Laboratory (PNL)[a] is one of four DOE laboratories that participate in the New Technologies Demonstration Program, providing technical expertise and equipment to evaluate new, energy-saving technologies being studied under that program.

This interim report provides the results of a field evaluation that PNL conducted for DOE/FEMP and the U.S. Department of Defense (DoD) Strategic Environmental Research and Development Program (SERDP) to examine the performance of a candidate energy-saving technology—a hot water heater conversion system to convert electrically heated hot water tanks to natural gas fuel. The unit was installed at a single residence at Fort Stewart, a U.S. Army base in Georgia, and the performance was monitored under the NTDP. Participating in this effort under a Cooperative Research and Development Agreement (CRADA) were Gas Fired Products, developers of the technology; the Public Service Company of North Carolina; Atlanta Gas Light Company; the Army Corps of Engineers; Fort Stewart; and Pacific Northwest Laboratory.

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Executive Summary

Through a Cooperative Research and Development Agreement (CRADA), Pacific Northwest Laboratory (PNL), Gas Fired Products (GFP), Atlanta Gas Light Co. (AGLC), Public Service Company of North Carolina (PSC), the Army Corps of Engineers (COE), and Fort Stewart are all supporting and participating in the evaluation of a new U.S.-developed water heating technology that has been installed for the first time in a federal facility, at Fort Stewart, Georgia. This demonstration is being carried out under the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP) New Technology Demonstration Program (NTDP), with support from the U.S. Department of Defense (DoD) Strategic Environmental Research Development Program (SERDP).

The Seahorse natural gas-fired water heater conversion system selected for this demonstration is manufactured by Gas Fired Products. This system replaces the heating elements in a residential-size electric water heater with a hot water flow loop, the hot water being supplied by a tankless, gas-fired water heater located outside of the residence. Fuel switching from electric to natural gas water heating offers an opportunity for savings in energy cost and source energy[a] fuel use.

Field monitoring of the water heater conversion system from the time of installation in March 1994 through June 1994 allowed for a preliminary assessment of the efficiency and cost-effectiveness of the technology and brought to light several installation and operation issues. Based on the measured performance of the technology in the first seven weeks of monitoring, adoption of this technology at Fort Stewart would save the fort approximately $44 per residence in annual energy costs. It is expected that an additional $55 per residence would be saved in reduced demand charges, resulting in a net life-cycle energy cost savings of $939 (1994 dollars). However, this savings does not offset the initial installation cost for the hot water heater conversion system, estimated at $1,018. Detailed information on the technology, the installation, and the results of the technology test is provided in this report. A nomograph is also provided showing what combination of gas and electric energy costs are necessary for the system to be life-cycle cost-effective and illustrates this for several other DoD sites.

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[a] Source energy is defined as the energy input to the power plant in the case of electricity, or as the energy input to the regional gas transmission system in the case of natural gas, to provide a given amount of energy at the customer's site. Source energy, compared to site energy, includes generation losses as well as transmission and distribution losses, but does not include energy input required for fuel extraction, processing, and transportation of the fuel to the region.

Acknowledgments

The author wishes to acknowledge the participation, review, comments, and support provided to this project by the CRADA participants and others associated with the project. These include K. Dean Devine, FEMP; Randy Jones and Nate Adams, Fort Stewart; Robert Glass, GFP; Tony Chandler, AGLC; Tony Winslow, AGLC; and Robert Watkins, PSC. The author also wishes to thank all the PNL staff members who provided technical assistance on the project.

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1.0 Introduction

The purpose of the New Technology Demonstration Program is to accelerate the deployment of new, U.S. developed energy technologies through government and private sector partnerships that install and evaluate technology performance in the federal sector. Through the results of the program, federal agency decision makers have more hands-on information with which to validate a decision to utilize a new technology in their facilities. The New Technology Demonstration Program seeks to identify new energy-saving technologies, determine which have the broadest application in and benefit to the federal sector, and then shorten the deployment time for those technologies that prove beneficial to the federal market by providing a demonstration of the energy savings potential and the cost-effectiveness of these new technologies in the federal sector.

Fuel switching opportunities are considered in the New Technology Demonstration Program. Fuel switching from electricity to fossil fuel offers the benefit of lower energy costs for the end user while reducing source energy use. Adoption of fuel switching technologies can help in implementing Executive Order 12902, which states that all federal facilities will reduce their building energy use by 30% by the year 2005 based on energy consumption per-gross-square-foot. The interpretation of energy consumption has been based on the source energy use.

During the early stages of the New Technology Demonstration Program, the Public Service Company of North Carolina (PSC) contacted Pacific Northwest Laboratory (PNL) about the potential behind the Seahorse outdoor gas water heating system. PNL staff explained the New Technology Demonstration Program (at the time known as Test Beds) to PSC and suggested that the Seahorse could be a viable technology for demonstration if it met certain criteria for program acceptance. PSC encouraged Gas Fired Product (GFP), manufacturers of the Seahorse technology, to submit a letter of interest to the New Technology Demonstration Program.

A list of potential Department of Defense demonstration sites for the Seahorse technology and the local gas utilities at each of these sites was prepared. The site eventually chosen for demonstration was Fort Stewart, where natural gas is supplied by Atlanta Gas Light Company (AGLC). Once the demonstration site was chosen, both Fort Stewart and AGLC were asked to participate in the demonstration of the Seahorse technology. Army Forces Command (FORSCOM) suggested that the U.S. Army Corps of Engineers, Huntsville Division (COE), play a role in supporting the demonstration by providing technical review of the project. Thus, COE was also asked to participate in the Seahorse demonstration.

A draft Cooperative Research and Development Agreement (CRADA) and a Joint Statement of Work (JSOW) were prepared by PNL for consideration by each of the parties (see Appendix E). These documents formalize the partnership and outline the participation of each organization in the demonstration. The CRADA outlines the level of support to be provided by each organization and the rights to property and information generated by the project. The JSOW outlines the responsibilities of each CRADA member during the project. After review, and negotiation between members, these documents were finalized. The JSOW addresses the services that each member will bring to the project. Rather than DoD and DOE supporting the entire project, each organization contributed both monetary support and services to the project. This resulted in the cost and technical support of the project being shared by DoD, DOE and the other five participants. This type of cost sharing and leverage of public resources is an underlying feature of the New Technology Demonstration Program.

The Seahorse outdoor gas water heating system is a cost and energy saving strategy for residential water heating. At Fort Stewart, many residential housing units were initially outfitted with electric water heaters, either because natural gas was not available to these units or because electric water heaters represented the lowest first-cost alternative at the time. Over time, natural gas has become available to many of these residences. The Seahorse system allows conversion of an existing electric water heater to natural gas operation while avoiding purchase of a new gas fired hot water tank and minimizing installation costs associated with gas equipment venting. The Seahorse is a natural-gas-fired tankless water heater that is located outside of the residence. A hot water flow loop is used to move water heated by the Seahorse into the residence where the tank of the existing electric hot water is used for hot water storage.

The purpose of the Fort Stewart/Seahorse demonstration is to evaluate the performance and cost-effectiveness of the Seahorse outdoor gas water heating system in the federal sector. In this project, a Seahorse water heater was installed at a single residence at Fort Stewart in March 1994. A data acquisition system (DAS) was placed onsite to monitor the Seahorse water heater during the test period. The operating data were logged at 5-minute intervals and downloaded to a computer system at PNL for analysis.

This interim report presents information gathered during the first three months of testing at Fort Stewart. Background information on Fort Stewart and on the site chosen for the demonstration project is provided in Section 2. Section 3 describes the monitoring and data acquisition carried out during this project. Section 4 presents observations and analysis results for the monitored period. Section 5 examines the expected performance based on the analysis of the gathered data and provides a life-cycle cost analysis for the Fort Stewart location. Section 6 provides interim conclusions and recommendations from the Fort Stewart/Seahorse demonstration project. Reference used in the report are listed in Section 7. Several attached appendixes provide supplemental information on the Seahorse evaluation.

2.0 Background

2.1 Facility Description[a]

Fort Stewart is a 279,270-acre U.S. Army Forces Command (FORSCOM) facility in eastern Georgia. The main cantonment area is situated just north of Hinesville, Georgia, at 31.52°N latitude and 81.37°W longitude. Most of the facility (221,700 of the 279,270 acres) is unimproved.

The Fort mission is support of the 24th Infantry Division (Mechanized). Other tenants include the 92nd Engineer Battalion, 260th Quartermaster Battalion, and the 224th Military Intelligence Battalion. In addition, there is a large National Guard Training Center that occupies many of the buildings on what was the original Fort.

There are approximately 26,700 active military personnel assigned to the Fort, with approximately 21,500 military dependents. Of these, 8,570 military personnel and dependents live at the Fort.

2.1.1 Family Housing Characterization

There are 22 permanent on-post family housing areas containing a total of 2,440 family dwelling units with a total floor area of 3,323,618 ft^2. The residences range from single family to eight-unit rowhouse/townhouse structures. There is a variety of residential unit floor plans, ranging from two to four bedrooms and from 750 to 3,714 ft^2 in floor area. The family housing is broken down by area number. Each area number defines a separate group of residences that are similar in floor plan and age. These 22 housing areas use a mix of energy types for space and domestic water heating. Both gas and electric cooking appliances are used in these housing areas. Table 2.1 lists the family housing areas by area number and shows number of dwelling units, number of buildings, energy types used, and year of construction for each group area.

There are 629 residences listed in Table 2.1 that use natural gas for space heating, but use electricity for domestic hot water heating. There are an additional 808 residences that do not use natural gas in any form. The remaining 1,003 residences use gas for space heating as well as domestic hot water heating.

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[a]Background information on Fort Stewart was obtained primarily through the 1993 Integrated Resource Assessment (Keller et al. 1993) prepared by PNL for the FEMP.

There is also an 86-unit park for manufactured (mobile) homes that provides additional on-base military housing. Heat and hot water are provided by bottled propane for these residences. These homes are not being considered for conservation or fuel switching measures, however, because they are not owned or permanently situated at Fort Stewart.

Table 2.1 Fort Stewart Residential Housing Statistics

Housing Area	No. of Units	No. of Bldgs	Floor Area, ft^2	Energy Type[a]				Year Built
				Heating	Cooling	Stove	DHW	
5	68	34	113,152	G	E	E	E	1958
6	320	40	385,992	G	E	E	E	1958
3	63	32	90,779	G	E	E	E	1960
7	10	5	12,220	G	E	E	E	1960
1	16	8	24,296	G	E	G	G	1965
4	16	16	29,971	G	E	G	G	1965
8	100	30	123,040	G	E	G	G	1965
2	10	5	13,570	G	E	G	G	1970
9	109	33	128,877	G	E	G	G	1970
10	1	1	1,744	G	E	G	G	1970
11	168	42	228,940	G	E	E	E	1976
12	232	58	297,460	E	E	E	E	1976
13	5	5	14,396	G	E	G	G	1978
14	202	52	317,734	G	E	G	G	1978
15	224	58	348,264	G	E	G	G	1978
16	120	31	189,724	G	E	G	G	1978
17	200	100	379,954	G	E	G	G	1978
18	132	33	185,928	E	E	E	E	1980
19	64	14	54,400	E	E	E	E	1983
20	136	30	158,551	E	E	E	E	1983
22	101	20	97,824	E	E	E	E	1984
23	143	24	136,312	E	E	E	E	1985
Totals	2,440	671	3,323,618					

(a) E = Electricity; G = Natural Gas

2.1.2 Utility Services

Electrical service is provided by Georgia Power Company to a single substation at Fort Stewart. Primary electrical distribution voltage is 24.94 kVA. From the substation, seven electric feeders serve Fort Stewart. The residential housing areas are served predominantly by Feeder 1 and by Feeder 4. Annual electrical usage for 1990 resulted in a blended electrical cost of $0.0471/kWh for Fort Stewart. However, previous analysis of the electrical rate schedule and metered electrical consumption at Fort Stewart (Keller et al. 1993) suggests that the avoided cost electrical energy at Fort Stewart is $0.025/kWh. In addition, there is an $8.85/kW avoided demand charge for electrical usage. For the summer billing months of June through September, the billing demand is the greater of the current measured month demand, 95% of the measured demand occurring in any previous summer month, or 60% of the highest demand occurring in the previous occurring months of October through May. For the months of October through May, the billing demand is the higher of either 95% of the highest previous summer demand or 60% of the highest measured demand occurring in any previous October through May month, including the current month.

Natural gas is provided by Atlanta Gas and Light Company (AGLC) through a 4-inch, 300-psi pipeline to a pressure-reducing station located south of the Post Headquarters. There is also a propane-air station at this location. Gas is then delivered at 40 psi to 492 family housing buildings (1,437 residences) and 210 commercial buildings. The propane air station is used to provide an alternative or backup fuel for natural gas in the event of a natural gas shutdown. The station allows Fort Stewart to take advantage of lower-cost, interruptible gas rates. A full analysis of the avoided cost of natural gas at Fort Stewart (Stucky and Shankle 1993) showed an avoided cost of $0.30 per therm, assuming a total propane usage of 42,278 gallons annually.

2.2 Residence Demonstration Site Description

The site chosen for the Seahorse demonstration was the residence at # 9 Wheeler St. in housing area 5. This residence is one-half of a single-story duplex. The residence was a good candidate for the Seahorse system because natural gas was used for space heating prior to the demonstration project and electricity was used for heating domestic hot water. In addition, the utility room housing the electric water tank in this style of duplex is not adjacent to any external walls of the building. Installation of a conventional, gas-fired water heater would require penetrating the ceiling and roof above the utility room. The family occupying the residence consisted of two adults and two children, a typical occupancy for the residences at Fort Stewart. Finally, the site had already been examined during previous residential energy consumption tests at Fort Stewart, and the occupants had already expressed their willingness to take part in such tests.

The residence is a three-bedroom, two-bathroom unit, with approximately 1,300 ft^2 of floor area. Figure 2.1 shows a plan view of the residence. Hot water use is limited to three sinks, two tub/showers, a clothes washer, and a dishwasher.

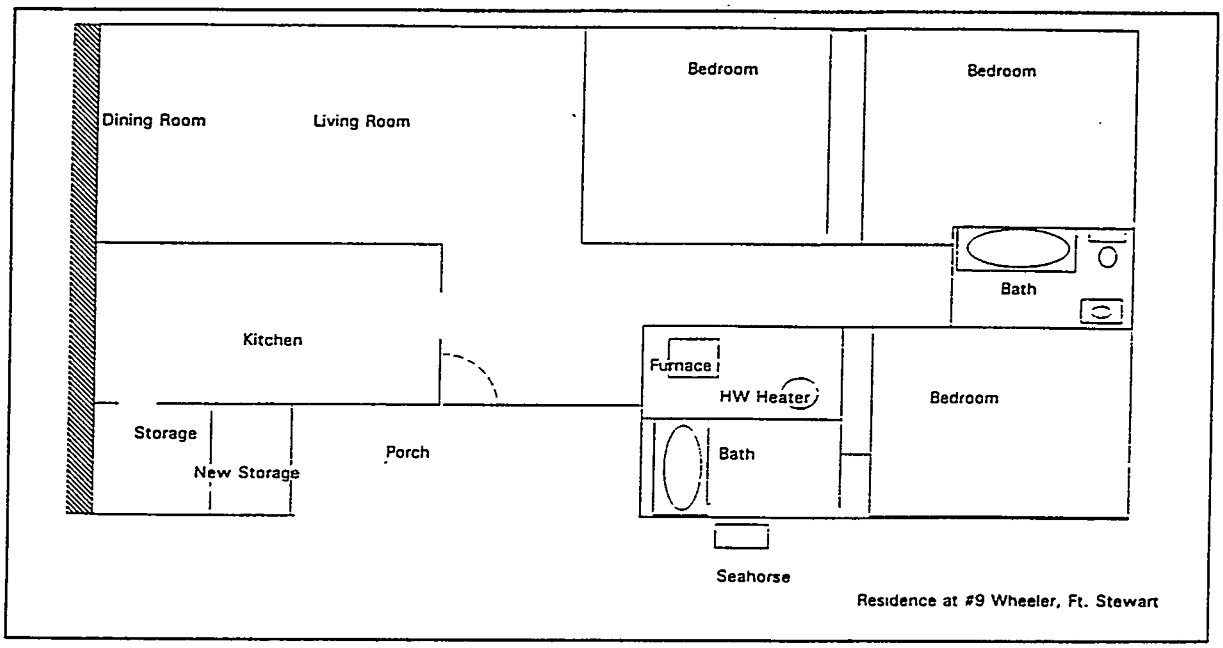

Figure 2.1 Plan View of Fort Stewart Residence Showing Seahorse Location

The existing hot water heater in the residence was a Rheem Glas Standard model electric water heater. The tank for this water heater has a 40-gallon water capacity, and both upper and lower electric elements are rated at 4500 watts. The elements cannot fire simultaneously, and the input heat capacity of the unit is 4500 watts. The original temperature settings for the upper and lower thermostats were 150°F.

2.3 Seahorse Gas Hot Water Conversion System

2.3.1 System Description

The Seahorse gas hot water conversion system consists of a natural-gas-fired tankless hot water heater and a small water pump, both housed in a 28 in. x 18 in. x 12 in. metal case. This heater is installed outside of the residence. The conversion system also includes adapters which allow plumbing the input and output water flows from the Seahorse to the existing electric hot water tank. For a two-element hot water tank, such as was used in this demonstration project, the upper electric element is removed from the tank and the hot water return tube from the Seahorse is installed in the upper element location. A new drain valve with an additional fitting is attached to the tank, and the water supply tube from the tank to the Seahorse is attached to this new drain valve. Once the Seahorse is installed, all electric power to the original electric hot water tank can be disconnected.

The Seahorse has a nominal gas input of 60,000 Btuh and is available in either propane or natural gas models. The gas inlet valve is a two-stage unit. The first stage opens for approximately 60 seconds at 50% capacity, after which it opens to 100% capacity. Ignition of the gas can be either by standing pilot light or by direct spark ignition (DSI). The unit supplied by GFP for this demonstration used DSI for the fuel ignition. The DSI uses a passive temperature sensor to determine if a gas flame exists. If a flame is not reported within 30 seconds, the gas valve is closed and the DSI is placed in a lockout mode. For the Seahorse to become energized again, the DSI must be reset by cutting the electrical power to the system for approximately 30 seconds.

The thermostat used to trigger operation of the Seahorse can be either the original tank thermostat (the lower thermostat is suggested by GFP) or a submersible thermostat (aquastat) that can be supplied by GFP. During the course of the test, operation of the Seahorse under both thermostat types was examined.

Figure 2.2 shows the installed Seahorse at Fort Stewart.

2.3.2 Operation

Operation strategy of the Seahorse is as follows. As the hot water storage tank cools, either through standby losses or hot water consumption, the normally open thermostat closes, calling for heat and triggering the operation of the Seahorse hot water circulating pump. This pump circulates water from the bottom of the hot water tank, through the Seahorse inlet flow pipe and to the heat exchanger located inside the Seahorse. As water is pumped through the heat exchanger, it activates a flow switch, opening the gas inlet valve to the Seahorse and triggering the gas ignition system. Water pumped through the Seahorse heat exchanger is heated and the hot water returned to the upper section of the hot water tank. When the water has been heated sufficiently, the thermostat contact opens and stops the gas flow and water flow to the Seahorse. Water flow rate through the unit is typically between 2.25 and 5.0 gpm. As a safety feature, a flow switch is installed in the water line at the Seahorse that will suspend operation of the Seahorse if the water flow rate is less than 2.25 gpm.

According to GFP, the rated thermal efficiency[a] of the Seahorse under laboratory, steady-state flow conditions has been measured at between 82% and 86% for flow rates of 2.25 and 5.0 gpm, respectively (see Appendix A). Measurement of the efficiency of the unit as installed in a residence and with typical residential water consumption patterns has not been recorded prior to this demonstration.

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[a]Thermal efficiency is defined as the thermal energy increase of the water flowing through the system divided by the fuel energy input to the heater. The fuel energy input is calculated using the higher heating value of the fuel.

2.3.3 Technology Assessment Methodology

The approach used in this project to assess the Seahorse technology was to measure the field performance of the Seahorse gas hot water conversion system, calculate the input energy needed to meet the hot water needs of the residence, and compare the cost to supply those needs with conventional electric and gas residential hot water heaters on a life-cycle cost basis.

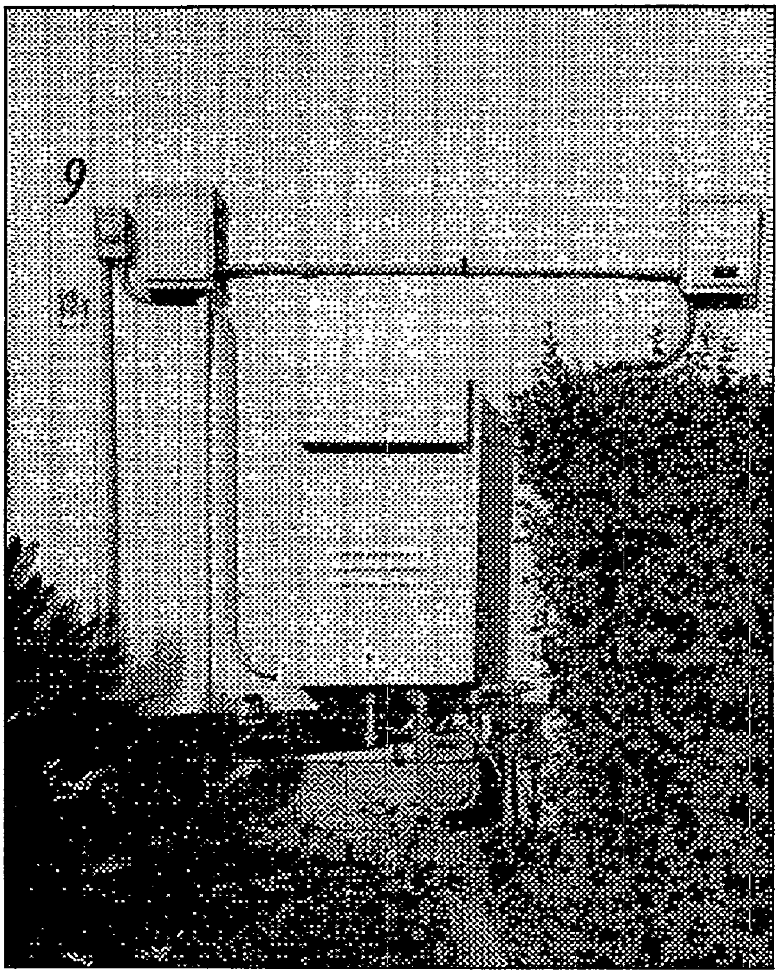

Figure 2.2 Seahorse hot water heater installed at Fort Stewart

To measure the field performance for the Seahorse, the Seahorse, the flow loop, and the hot water tanks were all instrumented with water flow, gas flow, and temperature sensors. A data acquisition system and dedicated phone line for uploading data were installed at the demonstration site. This is described in Section 3, Field Performance Monitoring.

To assess performance, the consumption of natural gas by the Seahorse technology and the amount of hot water energy supplied to the storage tank from the Seahorse were measured, along with the hot water volume and hot water energy supplied to the residence. From these, the efficiency of the Seahorse at supplying energy to the storage tank (the old electric water heater) and the efficiency of supplying hot water energy to the residence could both be calculated.

Two conventional water heating strategies are compared with the Seahorse system: 1) use of a conventional, tank-type, electric hot water heater, and 2) use of a conventional, tank-type, natural gas water heater. Comparison of energy cost of the Seahorse system with the electric water heater, the pre-retrofit condition, is straightforward. Since the storage tank is actually the original electric hot water tank in the residence, the cost of supplying the measured hot water energy input to the storage tank can be compared directly with the cost of supplying the same energy with electricity at electricity's 100% conversion efficiency. Any reduction in energy cost using the Seahorse must offset the purchase and installation cost of the Seahorse technology over the Seahorse life-cycle for the unit to be cost-effective.

Comparison of energy cost of the Seahorse technology with that of a conventional tank-type gas water heater requires estimating the delivery efficiency of hot water to the residence for a conventional gas water heater, estimating the installation cost of this type of water heater in a typical Fort Stewart residence, and comparing life-cycle cost of this water heating strategy with that of the Seahorse technology. Cost-effectiveness of the Seahorse technology is discussed in Section 5.

3.0 Field Performance Monitoring

Assessment of the performance of the Seahorse technology required extensive monitoring of the Seahorse and of the hot water storage tank. This section focuses on the design and installation of the data acquisition system.

3.1 Experimental Design and Measurements

Measurements taken during the course of the demonstration were used to evaluate the performance of the Seahorse technology and to diagnose operational problems within the system. Measurements taken fall into four major groups: those taken to determine natural gas and electrical energy input to the Seahorse, those taken to determine energy transferred from the Seahorse to the hot water tank, those taken to determine hot water energy transferred to the residence, and those taken to determine the operating conditions of the Seahorse technology.

Energy Input to the Seahorse: The primary energy input to the Seahorse water heater is natural gas. When the temperature of water in the tank (old electric water heater tank) drops below the thermostat setting, the Seahorse unit pumps water from the tank, heats it with the natural gas fired heater, and then returns it to the storage tank. The natural gas energy use is monitored by measuring the volumetric flow of natural gas, the entering gas temperature, and the barometric pressure. In addition, the manifold pressure of the supply gas to the burner was measured at installation to be 3.5 in. of water. The pressure in the residential gas line to the Seahorse was 7 in. of water. The absolute pressure of the gas passing through the gas flowmeter is calculated as the barometric pressure plus the additional 7 in. of water pressure in the residential gas line. The line gas pressure and the gas temperature measurements are used to convert the measured gas flow to the volumetric flow rate at standard temperature and pressure conditions. This gas flow is converted to an energy flow using the higher heating value of the gas (as reported by Atlanta Gas Light Company [AGLC]). In addition, the electrical energy use for the water pump inside the Seahorse is monitored using a standard watt-hour meter. Each of these measurement channels is sampled at 2-second intervals, and the samples integrated and recorded at 5-minute intervals by the data logger.

Energy Input to Hot Water Tank: The flow loop between the water tank and the Seahorse unit represents a potential source of energy loss in the system. A flow meter is installed in this loop to monitor water flow. Differential temperature sensors placed close to the water tank are used to measure the temperature difference between inlet and outlet at the tank during periods of water flow in the flow loop. The temperature of the water exiting the tank through this flow loop is measured. This, in conjunction with the water flow measurement for the heat exchanger loop, is used to calculate the hot water energy the Seahorse unit provides to the hot water tank. A second set of differential temperature sensors are installed at the inlet and outlet to the Seahorse unit, and the outlet water temperature at the Seahorse is also measured. All of the temperature and differential temperature measurements in this loop are gated to the electrical power draw of the Seahorse. The electrical power to the Seahorse is predominantly due to the Seahorse water pump. When the power draw is measured to be above a threshold level, water is flowing in the loop and the differential and absolute water temperatures in the loop near the water tank are recorded. These measurements, in conjunction with the water flow measurement for the loop, are used to calculate the hot water energy input to the water tank. The differential temperature measurements located near the Seahorse were installed to back up the previous differential temperature measurements, and to help determine energy losses in the flow loop.

Hot Water Energy to Residence: To calculate residential hot water energy consumption, temperature and flow measurements on the residence side of the water tank are made. A volumetric flow meter was installed on the cold water inlet to the tank and used to determine residential hot water consumption. A differential temperature measurement between the cold water inlet temperature and the hot water exit temperature of the hot water storage tank is collected. This differential temperature measurement is gated to the inlet water flow meter so that temperature difference is only recorded during periods of residential hot water consumption. Additional temperature sensors, also gated to the flow meter, are used to measure the inlet cold water and exit residential hot water temperature.

Operation and Environmental Parameters: Operating and environmental measurements include the outdoor temperature, the temperature of the utility room housing the hot water tank, and the average tank temperature. Cold outdoor air temperatures will reduce the thermal efficiency of the Seahorse unit as well as increase heat loss from the external piping. The temperature of the utility room will affect the heat loss from the tank and the internal piping. The average tank water temperature is also a factor in determining tank losses. Three thermocouples were placed on the tank body, underneath the tank insulation. These were placed at low, middle, and upper positions on the tank and are used to estimate the average temperature of the water in the tank.

Table 3.1 shows each metering point, the sensor type, and the output signal from each sensor. Figure 3.1 shows a schematic of the Seahorse/hot water tank system, showing the location of each sensor point. All instrumentation was installed by PNL during the initial installation of the Seahorse.

Table 3.1 Measuring Points: Seahorse Natural Gas Water Heater/Electric Tank System

Measuring Point	Sensor Type	Signal Type
Volumetric gas flow to Seahorse water heater	Volumetric gas flow sensor	Pulse
Gas line temperature	Thermocouple	Analog
Ambient barometric pressure	Barometer	Analog
Outside air temperature	Thermocouple	Analog
Power supplied to Seahorse pump	Watt Transducer	Analog
Water flow to water heater storage tank	Volumetric flow sensor for cold water	Pulse
Inlet water temperature to tank	Thermocouple	Analog
Exit water temperature from tank	Thermocouple	Analog
Differential water temperature about tank	Thermocouple Pair	Analog
Room temperature surrounding tank	Thermocouple	Analog
Tank Temperature	Thermocouple Series	Analog
Water flow in heat transfer loop	Volumetric flow sensor for hot water	Pulse
Differential water temperature in loop (next to tank)	Thermocouple Pair	Analog
Differential water temperature in loop (next to Seahorse)	Thermocouple Pair	Analog
Differential water temperature in hot water supply to house.	Thermocouple Pair	Analog
Total		Sensor Points: 3 Pulse 12 Analog

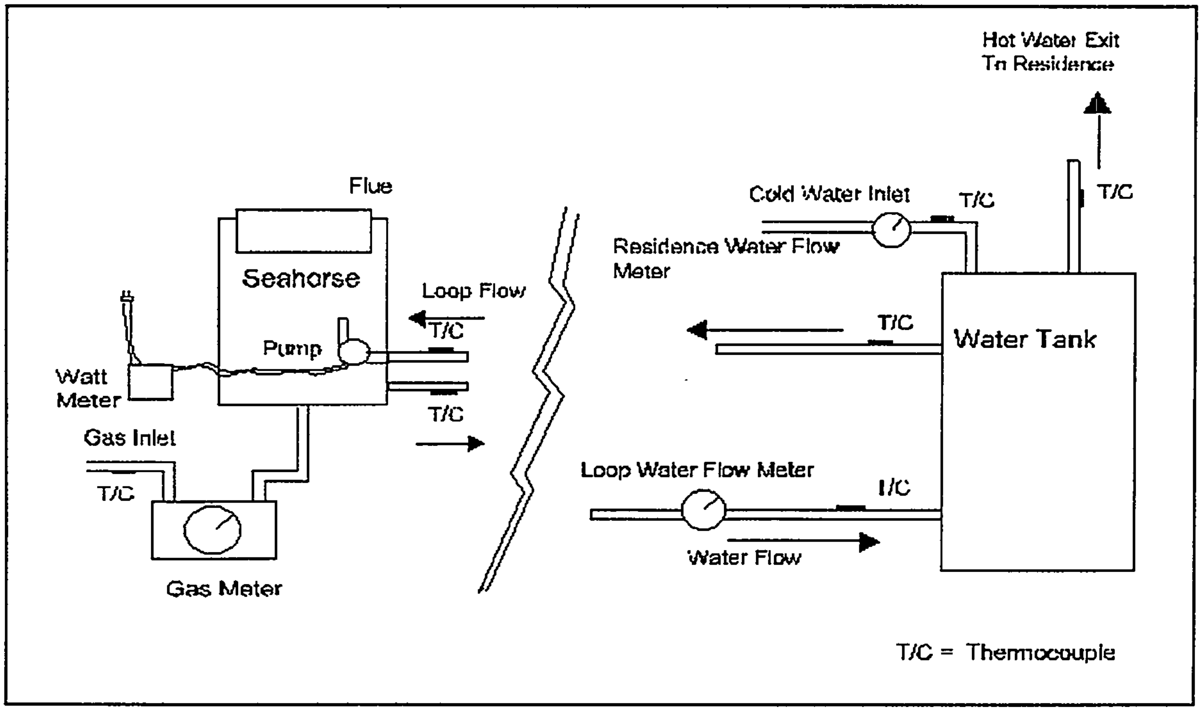

Figure 3.1 Schematic of Seahorse/Hot Water Tank Instrumentation

3.2 Data Acquisition System

A single, Campbell Scientific 21X micro datalogger serves as the data acquisition system (DAS) for the Seahorse/hot water tank system. This logger has 8 differential voltage channels for measuring analog inputs. Each differential voltage channel can also be configured as two single-ended voltage measurement channels, where the voltage is measured between the voltage input to the logger and ground. Differential and positive single ended voltage measurements are accurate to 0.05% of full-scale range when operated between 0°C and 40°C. Each channel can be configured for a voltage range of $\pm$5, $\pm$15, $\pm$50, $\pm$500, or $\pm$5000 mV. Resolution is 1 part in 15,000 for differential voltage measurements and 1 part in 7,500 for single ended voltage measurements. The logger has four pulse input channels, each capable of measuring pulse rates up to 2550 Hz. The logger also has 6 digital status inputs. The logger has 40 kbytes of on board memory. This memory must be allocated between input storage, program storage, system requirements, intermediate processing storage, and final storage. The final record storage is in a circular-ring memory format.

The data logging programs for the logger were developed by PNL. Measurements are taken every 2 seconds and integrated over 5-minute intervals. Data is recorded to the logger memory at these 5-minute intervals.

The logger is attached via RS232 serial port to a telephone modem and dedicated telephone line. Polling of the data logger from PNL is done automatically on a daily basis using a batch program for an IBM-compatible computer which calls Campbell Scientific remote data acquisition programs. The calling computer is dedicated to data collection activities and provides storage of the collected data.

Figure 3.2 shows a photo of the data acquisition system at Fort Stewart.

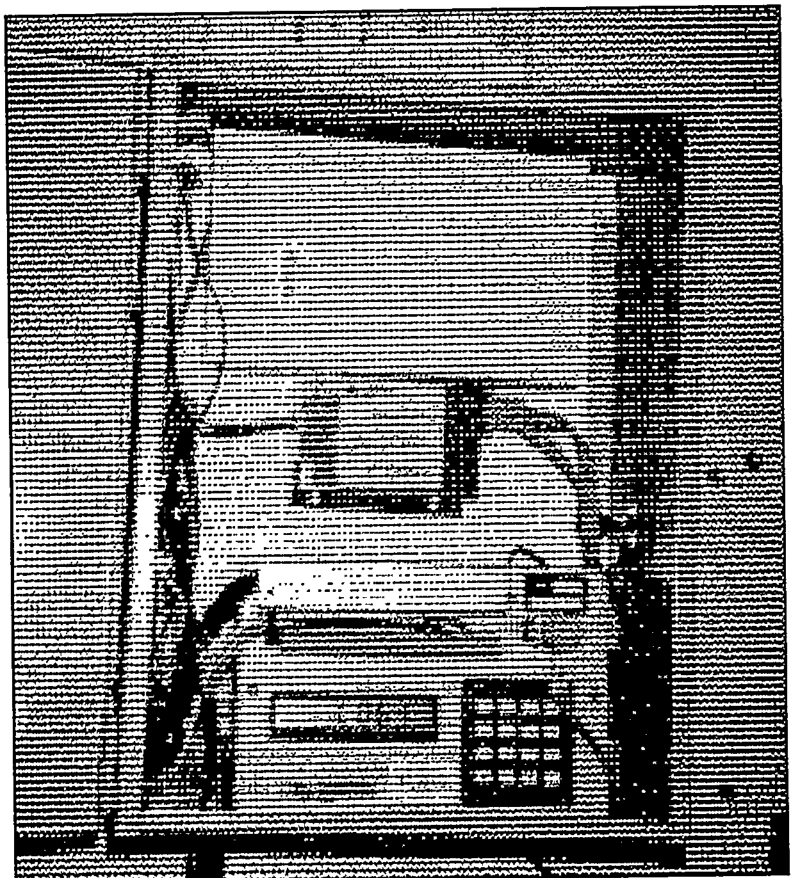

Figure 3.2 Data Acquisition System for Seahorse at Fort Stewart

4.0 Observed Performance and Operation

The Seahorse and DAS at Fort Stewart were installed between March 14 to 17, 1994. Continuous monitoring of the system began on April 2 and is scheduled to continue through September 1994. Analysis of the monitored data will be used to assess the performance of the Seahorse under varying load and environmental conditions. Monitoring of data collected in April 1994 suggested that there were metering difficulties with the residential hot water consumption. This was corrected during a site visit from May 22 to May 26. Water consumption data are not available for the period from installation to May 26. In addition, during the site visit the thermostat controlling the Seahorse was switched from the originally installed aquastat to the lower tank thermostat. For these reasons, this observed performance report is broken up into two periods, April 2 to May 22 and May 27 until June 29. The measured daily profiles from this study are shown in Appendix C, for both test periods.

4.1 Seahorse and Data Acquisition System Installation

Installation of the Seahorse and DAS was done over the period from March 14 to March 17, 1994. Plumbing and installation was accomplished by AGLC personnel under the direction of a GFP representative.

Installation and plumbing of the Seahorse took approximately 9 hours total. This was due primarily to having to re-solder joints in the copper plumbing between the water tank and the Seahorse. Installation of a Seahorse with two trained personnel (one plumber and one helper) is estimated by PNL to take approximately 3 hours.

The flow loop between the Seahorse and hot water tank consisted of 39 feet of a combination of 7/8-in. plastic and 3/4-in. copper tubing. All but 32 in. of this are insulated with 1/2-in. foam piping insulation.

During the initial installation of the Seahorse/hot water tank system, a submersible thermostat (aquastat), supplied by GFP, was installed to control the Seahorse heater. To install the aquastat, the lower thermostat element in the hot water tank was removed and the aquastat inserted in the original, lower element location. The aquastat has a variable differential control, and this control was left at the original factory setting of 5°F differential..

Installation of the monitoring sensors and DAS was completed over the next 2 days. Changes were made in the data acquisition program over the next 2 weeks. Continuous monitoring of the Seahorse did not begin until April 2.

4.2 Observed Performance and Operation--April 2 to May 22

Input Capacity--Seahorse The input capacity of the Seahorse is defined as the maximum gas energy input to the unit. During the period from April 2 to May 22, the maximum volume of gas use recorded during any 5-minute interval was 4.66 ft^3. This value was recorded during three different intervals. A value of 4.33 ft^3 was recorded 53 times during the same test period. Since one gas meter pulse corresponds to 0.33 ft^3, it is likely that the higher flow rate represents integration intervals where an extra pulse, corresponding to gas flow that occurred during the previous interval, is being counted. The actual peak flow rate is then somewhere between 4.33 ft^3 and 4.66 ft^3 per 5-minute interval, corresponding to a gas input rate of between 53,300 Btu/hr and 57,300 Btu/hr under standard temperature and pressure conditions. This is somewhat lower than the rated input capacity of the Seahorse (60,000 Btu/hr). The average daily higher heating value for the gas was 1,025 Btu/SCF (standard cubic feet), according to Atlanta Gas Light Company.

According to Gas Fired Products, the gas inlet valve on the Seahorse is a two-stage valve, opening for approximately 60 seconds at 50% capacity, and then opening to 100% capacity. There was some concern that the measured capacity might be lower than the nominal capacity because the first 60 seconds of operation was being included in the periods of peak operation. However, examination of the data shows that the peak gas input rates recorded during system operation typically occur after operation was recorded for more than 60 seconds in the previous interval. This suggests that the peak gas input rate for the Seahorse was measured at the 100% open valve condition.

Figure 4.1 shows the daily average profile of the gas input energy to the Seahorse for this period. The average hourly input energy is shown on the graph for reference.

Delivery-to-Tank Efficiency--Seahorse. The primary measure of Seahorse performance is the delivery efficiency of hot water energy from the Seahorse to the hot water storage tank. This delivery-to-tank efficiency is defined as the hot water energy provided by the Seahorse to the hot water storage tank divided by the gas energy input to the Seahorse. Energy to the storage tank is calculated as the mass flow of water in the heat transfer loop times the specific heat capacity of water multiplied by the temperature differential in the flow loop as measured at the tank. Natural gas energy input to the Seahorse is calculated as the volume of gas input to the Seahorse, calculated in standard cubic feet, multiplied by the higher heating value of the natural gas.

For the period from April 2 to May 22, 51 days, the Seahorse consumed a total of 4,133 standard cubic feet of natural gas, or approximately 4.23 MBtu. The total measured amount of hot water energy supplied to the storage tank by the hot water flow loop over this period was 2.80 MBtu, yielding an average delivery-to-tank efficiency of the Seahorse of 66.2%. Figure 4.2 shows the measured variation in Seahorse delivery-to-tank efficiency over this period.

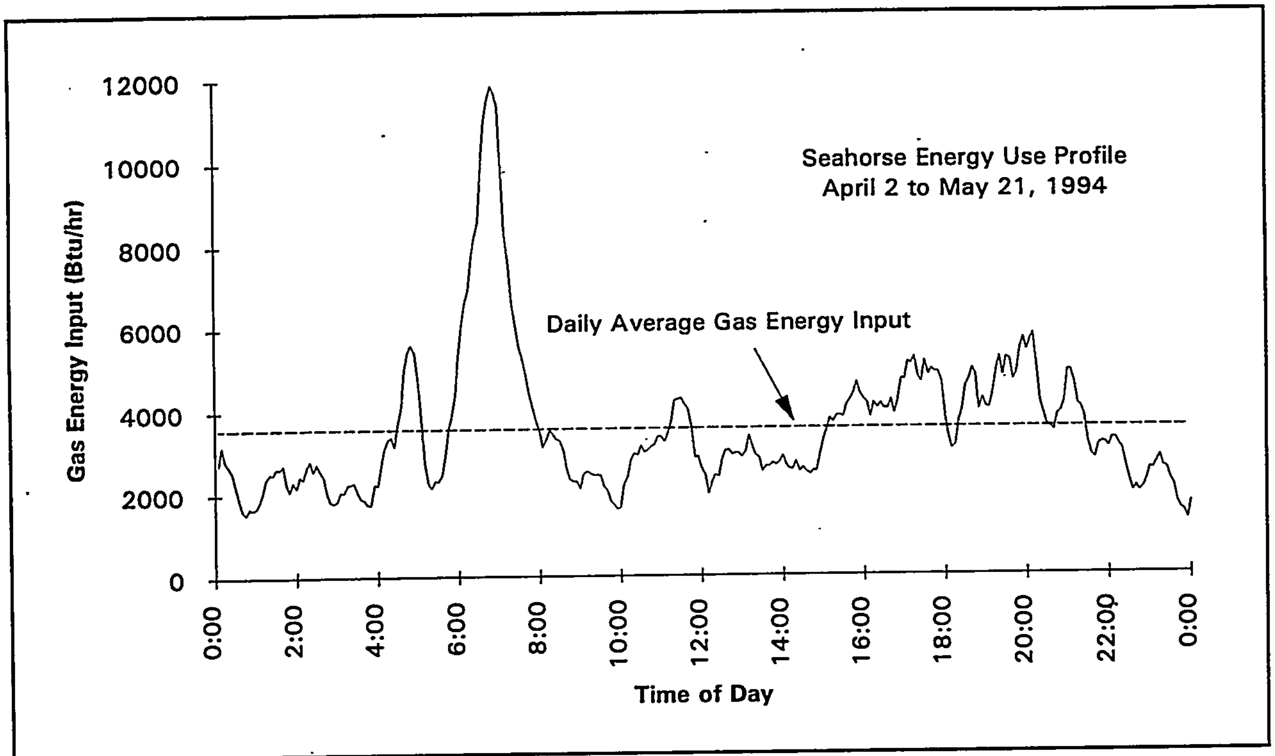

Figure 4.1 Average Daily Energy Consumption Profile, April 2 to May 22

Delivery-to-Residence Efficiency--Seahorse/hot water tank system. Measurement of hot water flow to the residence was hampered by pressure variations in the water distribution system on base. An expansion chamber, located in the walls of the residence, responded to these pressure variations by allowing back-and-forth movement of water through the hot water flow meter. This resulted in water flow measurement during periods of no actual hot water consumption. Instantaneous measurement of hot water flow during periods of actual consumption appeared to be accurate, but over each 5-minute integration period, the combination of periods with water consumption and periods without water consumption (but with the incorrect flow readings) exaggerated the actual water consumption. Because of this measurement difficulty, accurate determination of the residential hot water usage or the efficiency of the Seahorse/tank system at supplying water to the residence during this period could not be accomplished. This was corrected during the May 22 site visit.

Electrical Energy--Seahorse. Although small, pump power, electronic ignition and control system power all create electricity consumption for the Seahorse technology. Over the period from April 2 to May 22, the total Seahorse electric consumption measured for the Seahorse was 13.4 kWh. This corresponds to an average of 3.17 kWh/MBtu of gas consumed.

Electric power consumption by the Seahorse during operation was measured at the time of installation at 100 watts. Minimum power draw of the Seahorse was measured was at 4.0 watts. These peak high and low values remained constant throughout the test period. A

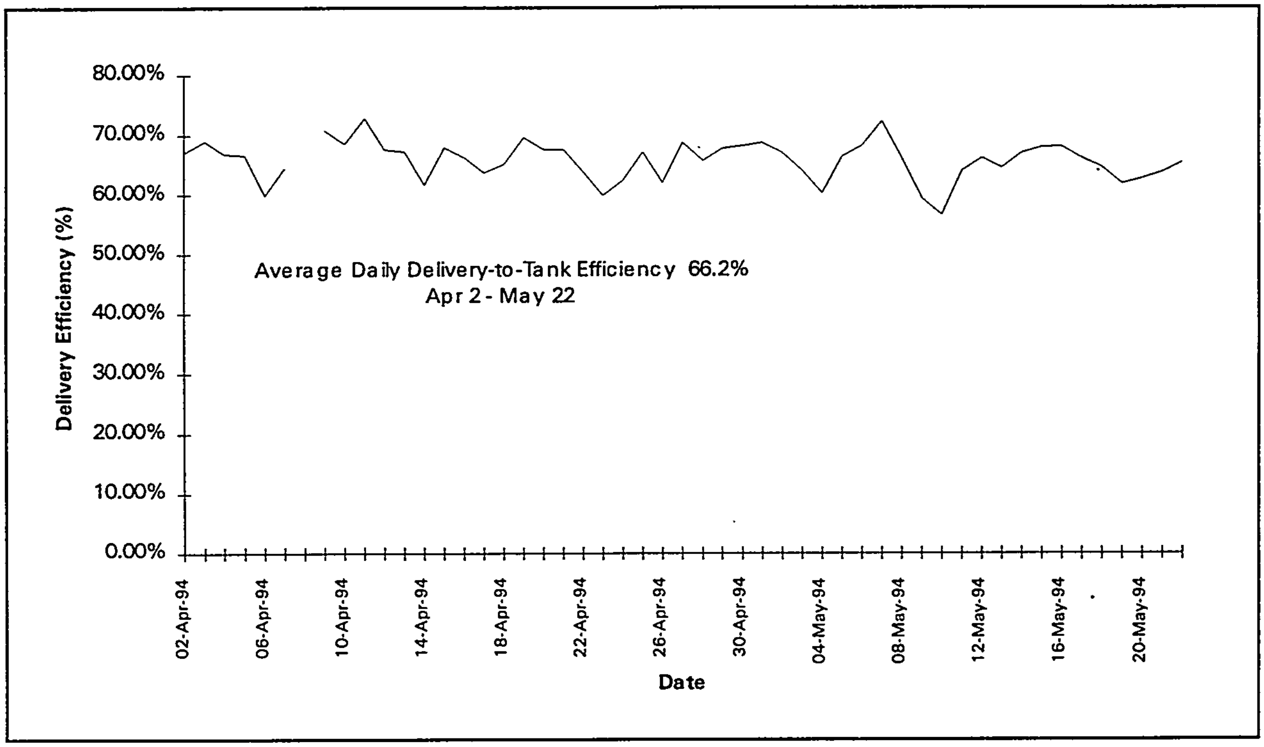

Figure 4.2 Daily Average Delivery-to-Tank Efficiency, April 2 to May 22

linear regression was used to correlate daily average electrical energy consumption with measured daily gas consumption. The correlation is excellent (R^2=0.99), yielding the following relation:

$$\textit{Electric Energy (kWh/day)} = 1.92\ \textit{kWh/(MBtu/day)}\ x\ \textit{Gas Consumption (MBtu/day)} + 0.099\ \textit{kWh/day} \quad (1)$$

Assuming the electrical current draw of the pump is constant, the fraction of pump on-time in any interval can be calculated as:

$$\textit{Fractional pump on-time} = \frac{\textit{(Interval average measured power} - \textit{Base power)}}{\textit{(Maximum power} - \textit{Base power)}} \quad (2)$$

or

$$\textit{Fractional pump on-time} = \frac{\textit{(Interval average measured power (watts)} - 4\ \textit{watts)}}{(100\ \textit{watts} - 4\ \textit{watts})} \quad (3)$$

An initial concern in the metering of the test setup was that the presence of the flow meter in the flow loop would reduce the flow rate of water in the loop and adversely affect the heat transfer in the Seahorse. By calculating the fractional pump on-time during each 5-minute interval and comparing this against measured flow, it is possible to determine the flow rate in the loop. A plot of pump on-time versus measured flow is shown in Figure 4.3. The flow rate appears staircased since the precision of the loop flow meter is 1 gallon. Regression of these two variables places the actual flow rate in the loop at 3.43 gpm. This flow rate is in the allowable flow range for the Seahorse (2.5 gpm to 5.0 gpm).

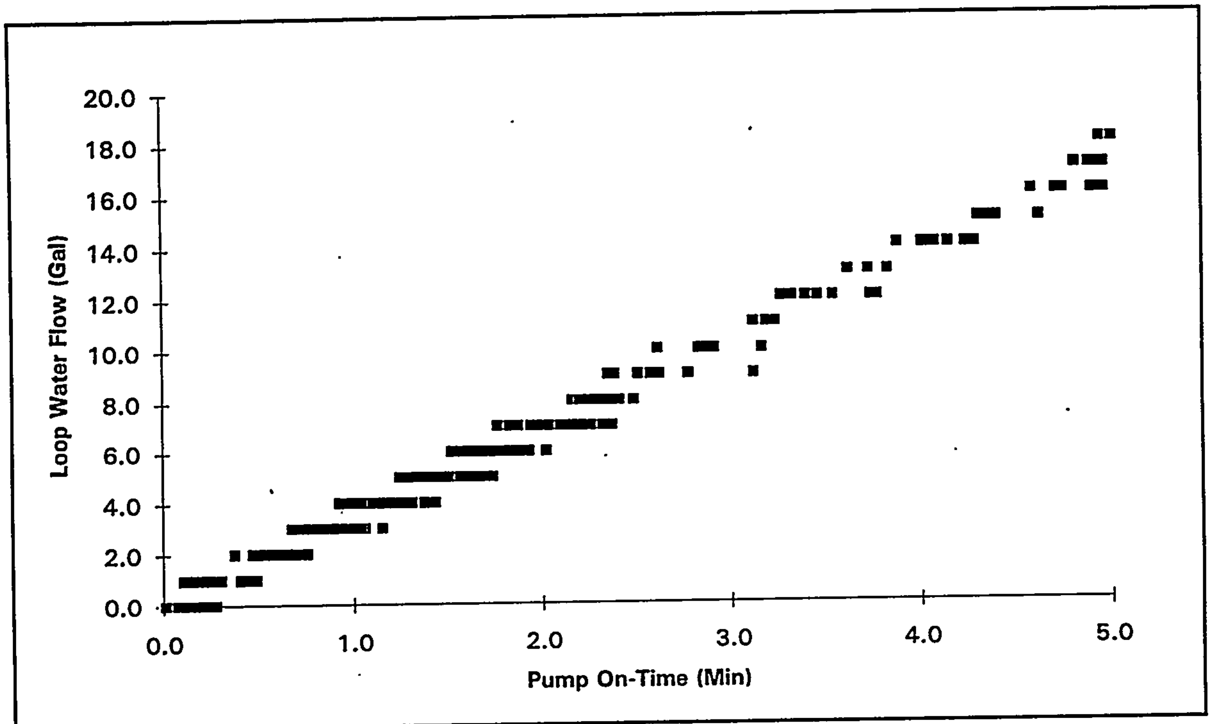

Figure 4.3 Loop Water Flow vs. Pump On-Time

Cycling Operation. An important issue in the Seahorse operation is the cycle time of the system. When the average temperature of the water in the tank drops sufficiently below the thermostat setpoint, the thermostat closes the control circuit, which is interpreted as a call for heat. At this signal, the Seahorse begins to pump water through the flow loop and ignites the gas burner. The circulating water is heated by the Seahorse and returned to the tank, gradually raising the hot water storage temperature. When the temperature has risen sufficiently above the setpoint of the thermostat, the thermostat contact is broken and the Seahorse pump and burner shut off. The temperature difference between the upper and lower thermostat temperatures that signal on and off operation is the differential of the thermostat.

Under periods of no hot water consumption, the hot water storage temperature will drop due to heat loss to the environment. The Seahorse will cycle on and off during these periods to maintain the hot water temperature near the thermostatic setpoint. Each time it cycles, it initially will remove hot water from the storage tank to the flow loop. It will replace that hot water with an equivalent amount of water from the flow loop--water that has been sitting in the flow loop since the last cycle. If the length of time between cycles is long enough, the water in the flow loop has cooled to the point where the initial start of the cycle is a net loss of energy from the tank. It is only after the slug of water that originally left the tank at the beginning of the cycle has been heated and returned to the tank that there is a net energy gain to the tank from the flow loop. At the end of the cycle, one-half of the flow loop is left filled with water directly from the hot water tank and one-half is left filled with water that has been heated by the Seahorse and is returning to the tank.

Only a certain amount of energy is required by the tank to offset the tank losses. If the thermostat differential is large, this energy can be supplied by a few system cycles of long duration. During these cycles, the energy lost in each cycle is a small part of the total energy delivered to the tank and the impact on efficiency is small. If the thermostat differential is small, however, many cycles will be necessary to make up the tank losses. The energy lost in each cycle will become a greater fraction of the total energy delivered to the tank and the efficiency of the Seahorse will be reduced.

Figure 4.4 shows a time series plot of average tank temperature and average pump on-time during a primarily unoccupied day period (April 3, 1994). Data points shown are the integrated averages over 5-minute intervals. The data show that the typical change in average tank temperature during a cycle is approximately 1.2°F, and that the average cycle time during this period was approximately 70 minutes. The average pump on-time during each cycle was calculated as 2.2 minutes and correlates to about 7.5 gallons of water flow per cycle. The calculated capacity of hot water left in the flow loop and Seahorse heat exchanger at the end of each cycle is 1.06 gallons, or 14.1% of the water flow in each cycle.

Independent calculations suggest as much as 35°F of cooling can be expected to occur in the water in the flow loop over the 70 minutes before the beginning of the next cycle resulting in an efficiency drop of 17% from the steady state flow condition. Detailed calculations showing the estimated effect on Seahorse delivery-to-tank efficiency during zero consumption periods are shown in Appendix B.

4.3 Observed Performance and Operation--May 27 to June 29

A site visit was made to Fort Stewart during the period from May 22 to May 26. The purpose of the visit was 1) to correct the residential hot water consumption measurement (by inserting a one-way flow valve in the cold water inlet to the tank), and 2) to examine the performance of the Seahorse when using the lower tank thermostat in place of the aquastat as the control for the Seahorse. The Seahorse installation manual suggests using this thermostat for the Seahorse control in place of the aquastat. In theory the differential of the tank thermostat would be considerably wider than the 1-2°F seen with the aquastat. It was

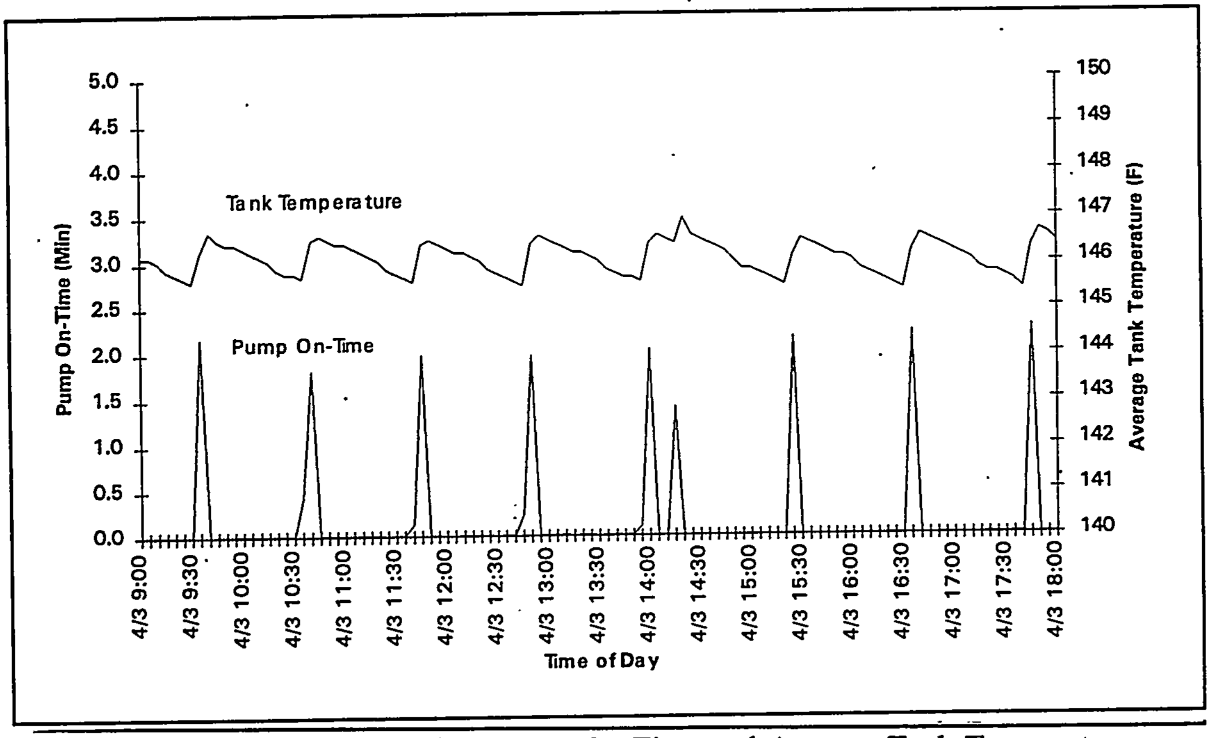

Figure 4.4 Seahorse Operation, Pump On-Time and Average Tank Temperature -- 5-Minute Data

believed that this would increase the time between system cycles and increase the delivery-to-tank efficiency of the Seahorse. For safety reasons, the temperature settings for the tank thermostat were reduced from the original 150°F to 140°F, as per the Seahorse installation instructions (Appendix A).

Delivery-to-Tank Efficiency--Seahorse For the period from May 27 to June 29, 33 days, the Seahorse consumed a total of 1,777 SCF of natural gas, or approximately 1.82 MBtu of gas energy. The total measured amount of hot water energy supplied to the storage tank by the hot water flow loop over this period was 0.954 MBtu, yielding an average deliver-to-tank efficiency of the Seahorse of 52.4%. Figure 4.5 shows the measured variation in Seahorse efficiency (delivery efficiency to the tank) over this period. The graph shows how for the first 8 days after the site visit, the Seahorse delivery-to-tank efficiency was approximately the same as before the site visit, averaging 67.8%. After June 3, the delivery-to-tank efficiency appears to jump around from 20% to 62%, averaging 46.3%. This unexpected behavior was significantly different than the behavior of the Seahorse when controlled by the aquastat, and is discussed under the section **Seahorse Control.**

Delivery-to-Residence Efficiency--Seahorse/hot water tank system Insertion of a one way flapper valve in the cold water inlet to the storage tank corrected the hot water consumption measurement problem caused by the expansion chamber noted earlier. Over the period from May 27 to June 29, the average daily hot water consumption was 37.8 gallons per day, with a maximum consumption of 94.2 gallons/day and a minimum consumption of 0.2 gallons/day.

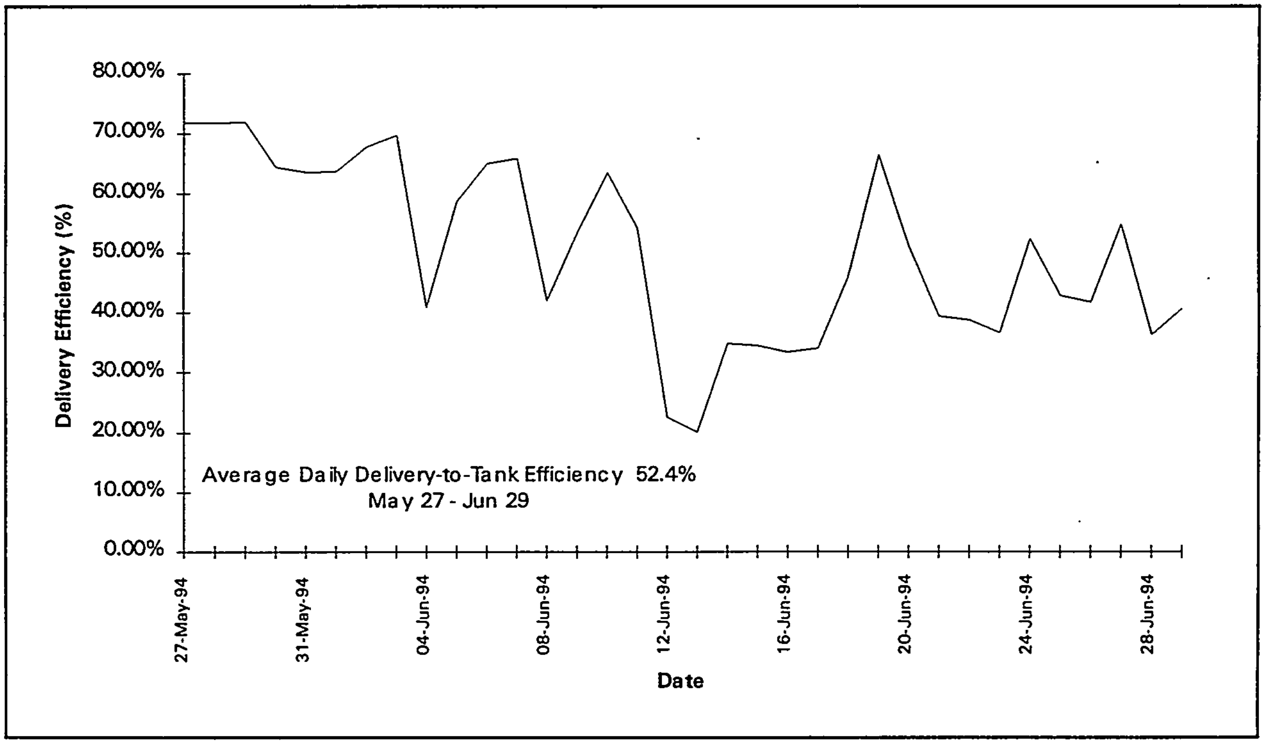

Figure 4.5 Average Daily Delivery-to-Tank Efficiency, May 27 to June 29

The average temperature of the residential hot water leaving the tank during this period was 126°F. The delivery-to-residence efficiency was made by dividing the hot water energy output from the tank by the gas energy input to the Seahorse. The average delivery-to-residence efficiency, calculated as described, was 33.6% over this period.

The delivery-to-residence efficiency is dependent on both the Seahorse delivery-to-tank efficiency and the residential hot water consumption. Higher hot water consumption means that a smaller fraction of the energy delivered to the tank is used to offset tank losses. By dividing the energy output to the residence by the energy input to the hot water tank one obtains the efficiency of the tank at converting input energy to energy output to the residence. Figure 4.6 shows the daily average tank efficiency as a function of daily hot water consumption for the period from May 27 to June 29. The curve shown on the graph represents the best fit (minimum R^2) to the data points using an equation of the form

$$Tank\ Efficiency = \left[1 + \frac{k}{consumption\ (gal)}\right]^{-1} \qquad (4)$$

Equation 4 is developed under the assumption of constant tank temperature and tank energy loss. The curve shows the non-linearity of the tank efficiency is with regard to residential consumption. The constant k represents the tank energy loss rate normalized to the energy required to raise 1 gallon of water to the residence hot water temperature.

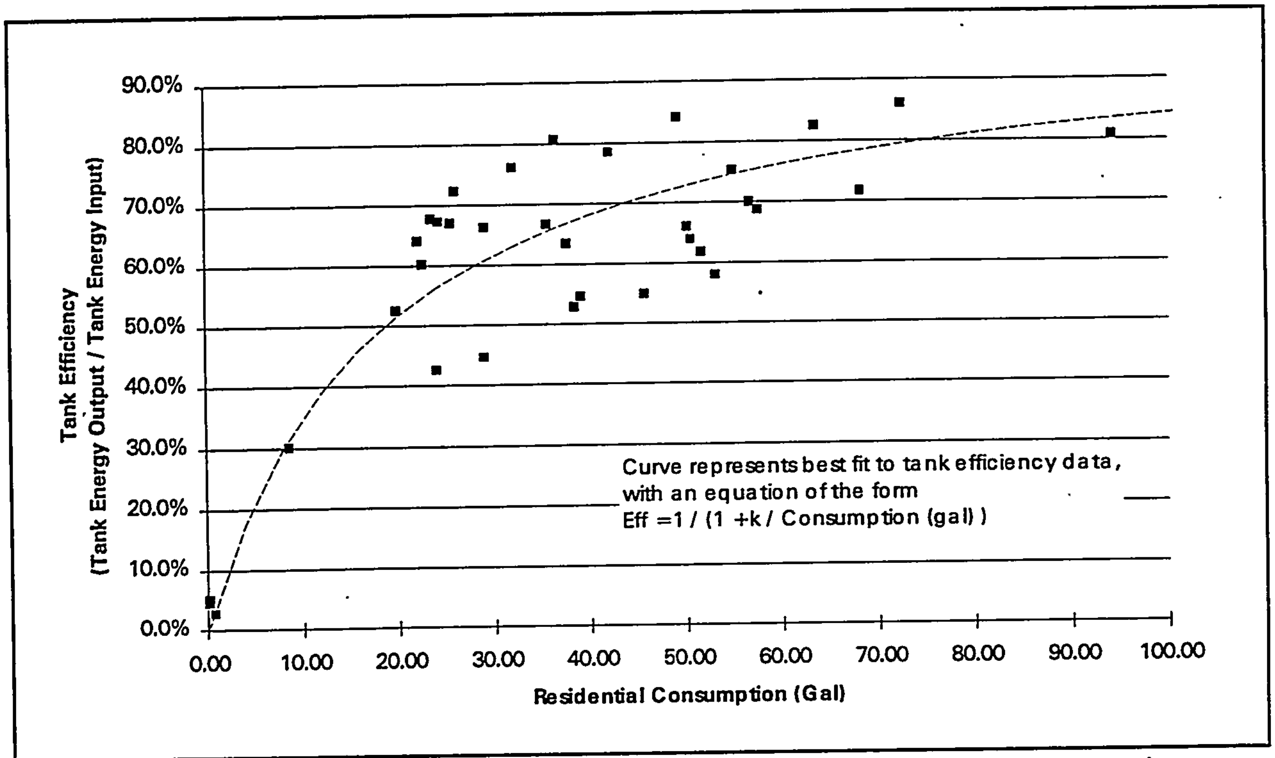

Figure 4.6 Tank Efficiency as a Function of Residential Hot Water Consumption

Seahorse Control. By examining the electric consumption data, it was possible to see how the thermostat caused the Seahorse to operate during days of low and of high delivery-to-tank efficiency. Problems with the Seahorse control are clearly evident from comparison of the measured electric power on June 15, a day with a calculated delivery-to-tank efficiency of 34.4%, with June 19, a day with a relatively high delivery-to-tank efficiency of 66.5%. The measured electric power for June 15 is seen in Figure 4.7. The measured electric power for June 19 is seen in Figure 4.8. The latter figure shows a characteristic time between cycles of approximately 80 minutes during the late evening and early morning periods. During these periods, in which there was little to no hot water consumption, the electric power spikes are separated by periods showing the base level (4.0 watt) electric power, representing no Seahorse pump activity.

Figure 4.7, however, shows pump power as many small power spikes occurring roughly every 10 minutes. The few large spikes on the graph correspond to periods of heavy water consumption. This fast cycling severely hurt the Seahorse efficiency. The average small spikes correspond to pump on-times, averaging between 25 and 50 seconds over each 10 minutes. Transitions between the long cycle time mode of operation to the short cycle time operation occur several times during the period from May 27 to June 29.

At the time of this writing, no definitive cause leading to this short cycle mode of operation has been uncovered.

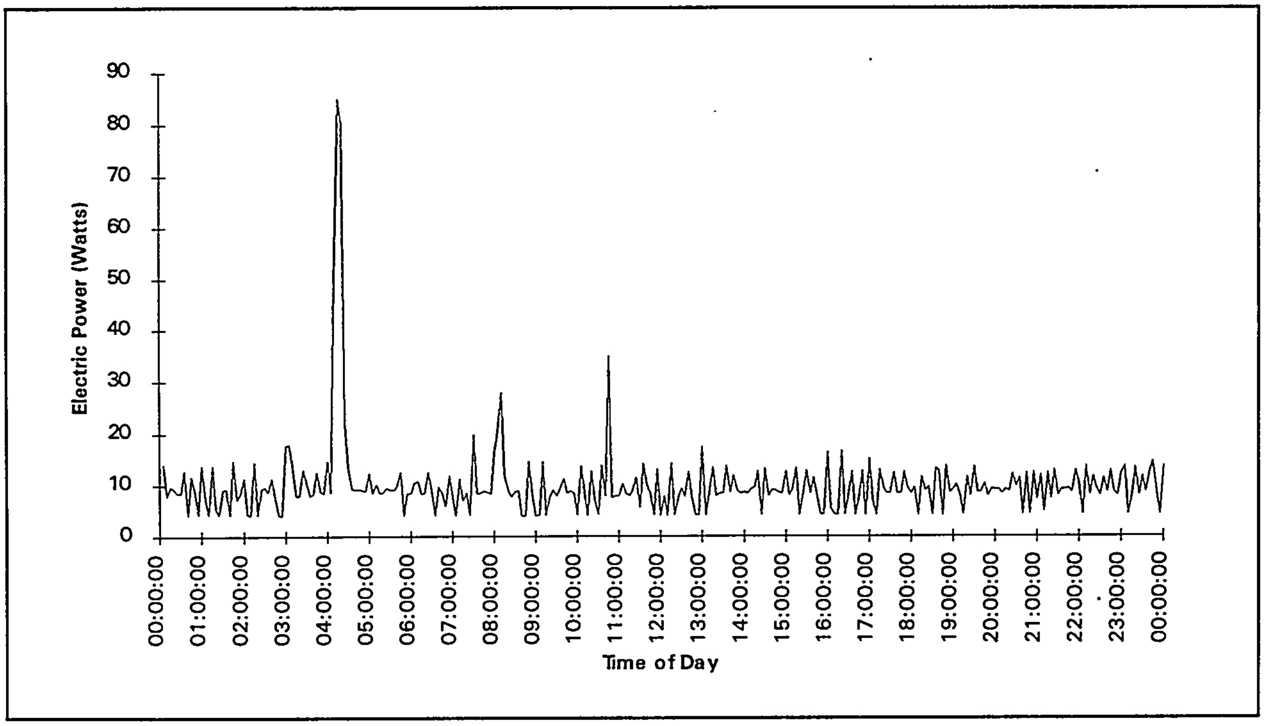

Figure 4.7 Seahorse Electric Power Consumption (5-minute data) June 15, 1994

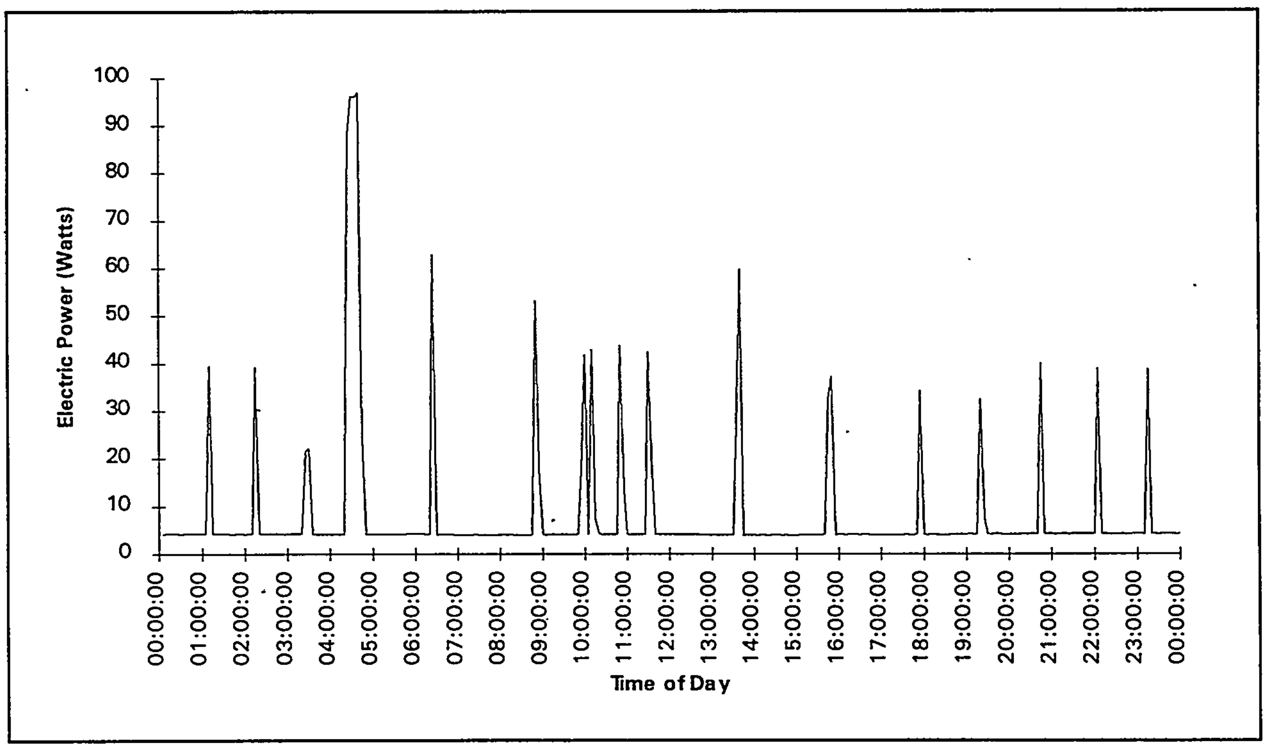

Figure 4.8 Seahorse Electric Power Consumption (5-minute data) June 19, 1994

Comparison of the Two Metering Periods Although the average delivery-to-tank efficiency for the Seahorse was higher during the first metering period, the average daily energy delivered to the tank during the second period (May 27 to June 29) was 48% less than the average energy delivered to the tank during the first period. This may be due to two causes. Since the average hot water delivery temperature to the residence is lower during the second period, appliances that use the same volume of hot water regardless of the water temperature (clothes and dishwashers) will use less hot water energy. Also, there appear to be a number of days of essentially zero hot water use during the second period, apparently time when the occupants were absent. It is unknown if there were days of zero occupancy during the first period. The low delivery-to-tank efficiency seen in the second period illustrates the need for proper control of the system to achieve efficient energy use.

5.0 Preliminary Estimated Energy Savings and Life-Cycle Costs

Preliminary energy and economic analysis for the Seahorse hot water heater is based on the results of the first test period, April 2 through May 21. The performance of the unit during this period represents the as-installed performance of the unit. The results showed that the as-installed delivery-to-tank efficiency of the unit during this period was approximately 65%. As the residential hot water load could not be measured during this period no correlation between efficiency of the unit and hot water load could be made.

5.1 Comparison of Annual Energy Performance with Electric Water Heater

There are no data on typical hot water usage in residences at Fort Stewart. However, typical electric hot water heater energy requirements for single-family residences in the Northwestern U.S. has been measured at approximately 4,800 kWh/yr (Taylor et al. 1991). Assuming electric resistance heating is 100% efficient, this corresponds to an annual heat input for a typical residential hot water tank of 16.4 MBtu (delivery energy to hot water tank).

To supply the same amount of energy to the tank using a Seahorse system operating at the 66.2% delivery efficiency measured, the gas energy input to the Seahorse would be 24.7 MBtu/yr, or 0.0678 MBtu/day on average. The electrical energy use of the Seahorse was estimated using equation (1), and is equal to 0.229 kWh/day, or 85.6 kWh/yr.

As discussed in Section 2, the avoided cost to supply electrical energy at Fort Stewart is $0.025/kWh and the avoided cost of electrical demand at the base is $8.85/kW-mo, where utility demand charge is based on the highest demand reading recorded during the current month or the previous 12 months. The marginal cost for natural gas at Fort Stewart is $3.00/MBtu.

Examination of monthly average demand at Fort Stewart (Keller et al. 1993) suggest that electrical monthly demand peaks at Fort Stewart occur between 3 pm to 5 pm daily for six months out of the year, the cooling season, and occur randomly sometime between 8 am and 10 pm during the other six months. However, the summer demand peak is up to 60% higher than the winter demand peak, and because of the demand "ratchet," demand charges are essentially based on the summer, afternoon peak. The avoided demand cost for the year can be estimated as:

$$\textit{Demand Cost (\$/kW-Mo)} = \frac{(8 \textit{ months} \times 95\% \times 8.85 \textit{ \$/kW-Mo}) + (4 \textit{ months} \times 100\% \times 8.85 \textit{ \$/kW-Mo})}{12 \textit{ Mo}} \quad (5)$$

$$= 8.56/kW\text{-}Mo)$$

Because of the number of residences on base and the measured water heater energy consumption profiles (Figure 4.1), electrical demand due to residential water heaters (electric heat or Seahorse) will be diversified during this summer peak electrical demand period. Examination of Figure 4.1 shows that although the peak electrical demand from the heater occurs in the morning, the average energy demand from the heater during the summer peak demand period is essentially equivalent to the average hourly energy demand from the water heater. For the typical residential electric water heater described above this would be 548 W. Because the pump power for the Seahorse was found to be constant during heating operation, it can be assumed to be proportional to the gas energy demand of the unit. The electrical power demand for the Seahorse will be equal to the average Seahorse electrical demand. Based on the calculated Seahorse electrical energy use, the average demand of the Seahorse is 9.5 W.

Calculation of source energy usage is used to compare the energy impact of conservation measures such as the Seahorse which result in a change of fuel source. Calculation of source energy use requires knowledge of the combined generation and distribution efficiency of the supply system. With natural gas supply, the combined generation and distribution efficiency is close to 99%. With electricity, a typical ratio of total fuel energy input to total electrical energy generated is 10,240 MBtu/kWh (OTA 1992), corresponding to a generation efficiency of 33%. Transmission losses are typically 6% of that or more, resulting in a combined generation and distribution efficiency of approximately 31%.

The results of comparison of Seahorse energy consumption with electric water heater energy consumption are shown in Table 5.1. This table also shows the electric and gas costs for each technology at the avoid rate, and the net annual operation cost savings.

5.2 Preliminary Life-Cycle Cost Comparison

Preliminary life-cycle cost analysis of a Seahorse water heater and of a typical residential electric water heater was performed using the FEMP analysis program BLCC (Peterson 1993). The chief economic parameters used in the analysis were as follows:

Analysis Basis:	Federal Analysis--Energy Conservation Projects
Study Period:	15 years (1994 through 2008)
Discount Rate:	3.1% Real (exclusive of general inflation)
Avoided Electrical Energy Cost:	$0.025/kWh
Avoided Electrical Demand Cost:	$8.85/kW-Month
Avoided Gas Energy Cost:	$3.00/MBtu

Table 5.1 Comparison of Energy Usage and Cost for Electric Water Heaters and the Seahorse

Parameter	Electric Hot Water Heater	Seahorse	Savings
Annual Electric Energy Consumption (kWh/yr)	4800	86	4714
Annual Electric Demand (kW-mo.)*	6.6	0.1	6.5
Gas Energy Consumption (MBtu/yr)	0	24.7	-24.7
Source Energy Consumption (MBtu/yr)	52.8	24.7	28.1
Annual Electric Cost ($/yr)	120	2	118
Annual Demand Cost ($/yr)	56	1	55
Annual Gas Cost ($/yr)	0	74	-74
Annual Total Operation ($/yr)	176	77	99

*Demand savings for a single Seahorse water heater installation are too small to be recorded at the main Fort Stewart electric meter. The demand savings estimate is the savings per unit assuming installation of many Seahorse units.

The alternatives analyzed were 1) the use of the original electric water heater for 5 years until the end of its useful service life, after which it is replaced with an identical unit every 10 years, and 2) immediate installation of a Seahorse conversion kit, which is used to the end of its useful service life, after which it is replaced with an identical unit. Because the Seahorse is a retrofit application and its use requires an insulated hot water storage tank, comparison of the life-cycle cost for the Seahorse technology includes the cost of replacing the storage tank at the same schedule as for the electric heater. Zero dollar salvage values were assumed for the water heater and for the Seahorse unit to be replaced.

Because it is a new product, no typical system lifetime is known for the Seahorse. A GFP estimate of 15 years was assumed for economic evaluation. The estimated lifetime of the electric hot water tank was 10 years (DOE 1993).

A breakdown of the estimated installation costs for the electric water heater and for a Seahorse water heater with storage tank is provided in Table 5.2

Table 5.2 Installation Costs for Water Heater Alternatives

Installation Costs - Electric Water Heater	
Item Cost	
40 Gal Electric Water Heater	$220
Installation of electric water heater	
(4 man-hours @ $18.20/hr)	$73
Overhead and Profit (25%)	
Total	**$366**

Installation costs - Seahorse	
Item Cost	
Seahorse conversion kit	
(cost to dealer)	$627
40 ft. 7/8" Plastic Hot Water	
Tubing (@ $0.45/ft.)	$18
Aquastat submersible thermostat	$60
Installation of Seahorse conversion kit	
including cost to run gas piping	
(6 man-hours @ $18.20/hr)	$109
Overhead and Profit (25%)	
Total	**$1018**

Costs and installation labor for electric hot water heater were obtained from Means (Means 1992). Cost to dealer for the Seahorse represents a GFP discount to dealers of 30% off the retail price of the Seahorse of $895. Cost for plastic hot water tubing and aquastat are approximate costs to dealers for these products. Labor costs for Seahorse installation are PNL estimates.

In replacing the electric heater used with the Seahorse with a second storage tank, the tank procurred should deliver the same thermal storage performance as the electric water and have the same number of fittings for connecting to the Seahorse and to the residence. As the cost of the electric elements in a typical tank are small, the likely choice for replacement would be an identical electric water heater. It is this replacement that is used in the Seahorse analysis.

Due to lack of maintenance data for the Seahorse, maintenance costs were assumed to be negligible over the life span of both the Seahorse and the electric water heaters analyzed.

Table 5.3 shows a comparison of present value, as calculated by BLCC (see Appendix D), for the two alternatives.

Table 5.3 Comparison of Present-Value Costs for Water Heater Alternatives

	Electric Water Heater	Seahorse/Storage Tank	Savings from Electric Heater
Initial Investment ($)	0	1,018	-1,018
Energy and Maintenance Costs ($)	2,066	1,127	939
Additional Capital Investment ($)	314	314	0
Total Costs ($)	2,380	2,459	-79

Net present value (NPV) for the Seahorse conversion as a function of natural gas and electric energy costs, assuming the capital investment costs shown in Table 5.2, is illustrated in Figure 5.1. The nomograph is divided into two areas, energy costs that lead to a negative NPV for the Seahorse conversion and energy costs that lead to a positive NPV for the Seahorse conversion. The avoided blended electrical cost shown on the x-axis is calculated as:

$$\textit{Blended energy cost } (\$/kWh) = \textit{avoided energy cost } (\$/kWh) + (\textit{avoided demand cost } (\$/kW\text{-}Mo) \div 760\ hr/Mo) \qquad (6)$$

The nomograph maps the avoided energy costs of Fort Stewart, as well as several other federal sites, to show locations where the analysis suggests the Seahorse would be cost-effective. The median industrial gas and electric energy costs for the U.S. (Energy User News 1994a and 1994b) and the average residential gas and electric energy costs for the U.S. (DOE/EIA 1994) are also shown on the nomograph. Although these are not avoided costs, they serve as a useful reference.

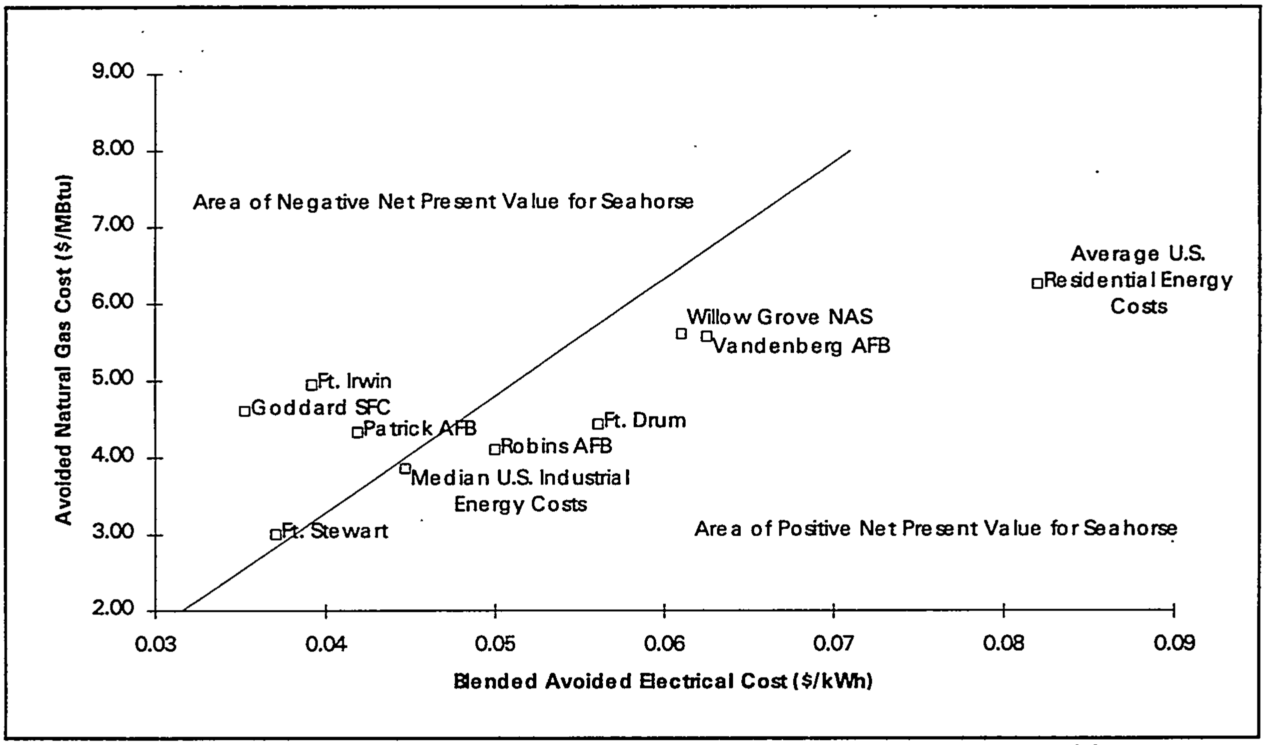

Figure 5.1 Energy Costs and Net Present Value for Seahorse Retrofit (A positive net present value represents cost-effectiveness of the technology)

6.0 Preliminary Conclusions

Initial testing of the Seahorse suggests a delivery-to-tank efficiency of approximately 66% as originally installed at the Fort Stewart residence and with that residence's hot water consumption. Observation of the unit suggests that this efficiency could likely be improved with better control systems, more pipe insulation in the water flow loop, and shorter distances between the hot water tank and Seahorse unit. Thermal modeling of the system using typical residential hot water consumption is recommended to determine the optimum values for control thermostat differential settings and pipe insulation levels.

During the first observation period, no maintenance issues developed when the installed Seahorse used the aquastat control. Because of the efficiency penalty and short-cycling operation that occurred when the tank thermostat was used for control, preliminary recommendations are that an aquastat be used for any new Seahorse installations until proper operation using the original tank thermostat can be shown under a wide variety of hot water loads and temperature settings.

Based on the preliminary results of the demonstration and the life-cycle cost analysis, the Seahorse appears to not be cost-effective when compared against an electric water heater at Fort Stewart. A life-cycle cost comparison with gas-fired, tank-type water heaters was not made for this preliminary report, as that calculation will depend heavily on the installation costs for these units in each residence type.

A nomogram showing the electrical and natural gas costs leading to a positive net present value for the Seahorse conversion was demonstrated. This nomogram suggests that the Seahorse could be a cost-effective retrofit strategy for other federal facilities. Improvements in the as-installed efficiency of the unit, either by better control strategies, reduction of standby losses in the Seahorse and piping system, and possibly strict installation protocols like set thermostat differential settings, would improve the cost-effectiveness of the unit for the federal sector.

It must be emphasized that the energy calculations and economic results outlined in this report are preliminary, based on less than 2 months of monitored system operation. The extrapolation of these results to other potential Seahorse installations should be done cautiously until such time as further monitoring data corroborate the reported results.

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Appendix A

Seahorse Operation and Installation Instructions

OWNER / INSTALLER
FOR YOUR SAFETY
THIS MANUAL MUST BE CAREFULLY READ BEFORE INSTALLING, OPERATING OR SERVICING THIS HEATER.

Seahorse®

OUTDOOR GAS WATER HEATING SYSTEM

OUTDOOR INSTALLATION ONLY

INSTALLATION AND OPERATING INSTRUCTIONS

MODEL Nos. WH60 - (N,L) 5 and WHT60 - (N,L) 5

WARNING: If the information in these instructions is not followed exactly, a fire or explosion may result causing property damage, personal injury or death.

- **Do not store or use gasoline or other flammable vapors and liquids in the vicinity of this or any other appliance.**

- **WHAT TO DO IF YOU SMELL GAS**

  - **Do not try to light any appliance.**
  - **Do not touch any electrical switch; do not use any phone in your building.**
  - **Immediately call your gas supplier from a neighbor's phone. Follow the gas supplier's instructions.**
  - **If you cannot reach your gas supplier, call the fire department.**

Installation and service must be performed by a qualified installer, service agency or the gas supplier.

WARNING: Improper installation, adjustment, alteration, service or maintenance can cause injury, property damage or death. Refer to this manual. For assistance or additional information, consult a qualified installer, service agency or the gas supplier.

SAVE FOR FUTURE REFERENCE

FORM 4341205 12/93

Patent Nos. 5020721 and 5203500

CONTENTS

Manufactured by: Seahorse Division
Gas Fired Products, Inc.
P.O. Box 36485
Charlotte, NC 28236
(704) 372-3485

WARNINGS

IMPORTANT: Read these Installation and Operating Instructions carefully and completely before attempting to install, operate or service this heater. Experience has shown that improper installation or system design, rather than faulty equipment, is the cause of most operating problems. Improper use of this heater can result in serious bodily injury or death due to hazards of fire, explosion, or electrical shock. Make sure that you have read and fully understand all Warnings. Retain this manual for future reference.

1. This heater is designed for use with one type of gas (L.P.G. or Natural). Make sure that the type of gas supplied to this heater matches that shown on the rating plate.
2. DO NOT install indoors! This heater is designed for installation outside the dwelling ONLY!
3. This heater must be connected to a storage tank. An existing electric storage type water heater can be used as the storage tank for this heater if the electric elements are permanently disconnected from the electrical supply system. This must be done by a licensed electrician.
4. The storage tank must contain a listed 210F/150PSIG temperature and pressure or 150PSIG pressure relief valve which meets the ANSI Z21.22 (latest edition) - Standard for Relief Valves and Automatic Gas Shut-off Devices for Hot Water Supply Systems.
5. Installation and repair should be done by a qualified service person. This heater should be inspected before use and at least annually by a professional service person. Always turn off the gas and electrical supply when servicing this heater. It is imperative that the control compartment and burner be kept clean.
6. WARNING: Any change to this heater or its controls can be dangerous.
7. LPG-Containers (Propane tanks) must be located at least 10 feet away from this heater.
8. DO NOT place flammable materials on or near this heater.
9. Any safety screen or guard removed for servicing this heater must be replaced prior to operating.
10. Children and adults should be alerted to the hazard of high surface temperature around the vent and should stay away to avoid burns or clothing ignition.
11. Keep the area within 3 ft. of the heater free from combustible materials, gasoline, or other flammable vapors and liquids.
12. NEVER attempt to service this heater while it is plugged in, operating or hot.
13. Should overheating occur or the gas supply fail to shut off, turn off the manual gas control valve to the heater.
14. Water temperatures above 120°F can cause severe burns instantly or death from scalds. Children, disabled and elderly are at the highest risk of being scalded. Feel water prior to bathing or showering.
15. The manufacturer of this heater will not be liable for any damages caused by failure to comply with the installation and operating instructions outlined on the following pages. These instructions are a guide for the correct installation of your heater.
16. DO NOT use this appliance if any part has been under water. Immediately call a qualified service technician to inspect and replace any part of the control system and any gas control which has been under water.
17. DO NOT use any valves or fittings that are not completely compatible with potable water applications.
18. DO NOT use valves that may cause excessive restriction to water flow. Use full flow Ball or Gate valves only.
19. If this heater is to be used in conjunction with a hydronic space heating system requiring water temperatures in excess of 120°F, an anti-scald or mixing valve must be installed in the domestic hot (potable) water supply to reduce the risk of scalding and must be set to a maximum of 120°F.
20. Some local codes may require a backflow preventer in the incoming cold water line to the storage tank. This will create a closed water system whereby the water in the pipe, inside your dwelling cannot get back out into the supply main. During the heating cycle of the heater, the water expands, creating a pressure build-up in the water system inside your dwelling. In such cases, the temperature and pressure relief valve may weep or relieve due to expansion of the heated water. A diaphragm-type expansion tank (such as TACO or EXTROL) will normally eliminate this weeping condition. This generally applies to new construction applications. For every 50 U.S. gallons of stored water, the expansion tank must have a minimum capacity of 1.5 U.S. gallons. Please read and follow the manufacturer's instructions for installation of such tanks.
21. Strain relief of the 115V and 24V supply wiring to the heater must be field supplied to prevent damage to this wiring.
22. DO NOT use this heater in areas where the ambient outdoor temperature can drop lower than -40°F.

SAFETY REQUIREMENTS

23. This heater has an exterior finish which is suitable for outdoor installations. However, the cabinet can be repainted to match the color of the dwelling. NOTE: DO NOT PAINT OVER ANY OF THE LABELS THAT ARE LOCATED ON THIS HEATER. **CAUTION: Turn the gas supply to the heater off before attempting to paint it.** An explosion or fire can result from ignition of paint fumes if this is not done. Follow the Lighting Instructions inside the heater after the paint has dried completely.
24. If this heater is located in an area where vehicles could possibly run into it, posts or permanent barricades must be installed to protect the heater and gas lines.
25. DO NOT store or use flammable liquids (such as gasoline, solvent, liquified propane or butane, etc.) or other substances (such as adhesives, etc.) near or adjacent the newly converted storage tank or any other spark producing appliance. All of these emit flammable vapors, which because of natural air movement in a room or other enclosed space, can be carried some distance from where the liquids are being stored or used. The storage tank thermostat contacts can arc and ignite such vapors. The resulting flashback and fire can cause death or serious burns to anyone in the area, as well as property damage. For these reasons the storage tank must not be installed in an area where there are flammable vapors.
26. HYDROGEN GAS can be produced in a hot water system that has not been used for an extended period of time (generally two weeks or more). HYDROGEN GAS IS EXTREMELY FLAMMABLE. To prevent the possibility of injury under these circumstances, it is recommended that the hot water faucet be opened for several minutes at the kitchen sink before you use any electrical appliance which is connected to the hot water system. DO NOT light a cigarette, cigar, or pipe. DO NOT smoke. If hydrogen is present, there will probably be an unusual sound such as air escaping through the faucet as the hot water begins to flow. There should be no smoking or open flame near the faucet at the time it is opened.
27. The WH60 and WHT60 models have a high limit switch designed to shut off the gas flow to the burner if the water temperature exceeds 190°F and 200°F respectively. This higher temperature limit may be desirable for those applications where higher water temperatures are necessary. We recommend the use of an anti-scald mixing valve anytime the WH60 or WHT60 models are used for systems operating at temperatures above 140°F to prevent scald potential.
28. Installation on Manufactured Homes (Mobile Homes) may require the use of 24" on center spacing mounting brackets. Please order Part No. 4347400 from your dealer or call the factory if you need these wider mounting brackets. The standard brackets shipped with every heater have 16" on center spacing.

SPECIFICATIONS

MODEL	WH 60 - N5	WH 60 - L5
B.T.U. Input	60,000	60,000
Type Gas	Natural Gas	LP Gas
Ignition Type	Direct Spark	Direct Spark
Control Voltage	24 Volts	24 Volts
Supply Voltage	115 Volts/60 Hz/1 Phase	115 Volts/60 Hz/1 Phase
Amperage	1.5 Amps	1.5 Amps
Burner Orifice Size	1.05mm	0.65mm
Gas Connection	1/2" NPT	1/2" NPT
Inlet Gas Pressure		
Maximum	14.0" W.C.	14.0" W.C.
Minimum	4.5" W.C.	11.0" W.C.
Manifold Pressure	3.5" W.C.	10.0" W.C.
Maximum Working Pressure (H_2O)	150 PSIG	150 PSIG
Dimensions (H x W x D) - Heater	28" x 18" x 12"	28" x 18" x 12"
- Carton	30" x 20" x 14"	30" x 20" x 14"
Weight - Heater	72.0 lbs.	72.0 lbs.
- Shipping	77.0 lbs.	77.0 lbs.

LOCAL CODES

Please read these instructions carefully and check all state and local codes before installing this heater. This will help avoid needless service costs that result from causes beyond our control and therefore not covered in the warranty. The installation of this heater must conform to state and local codes. In the absence of these codes, the installation must conform with the National Fuel Gas Code ANSI Z223.1 (latest edition) also known as NFPA 54 or with CGA B149 Installation Codes (latest edition). All electrical wiring must be in accordance with state and local codes or, in the absence of these codes, with the National Electrical Code ANSI/NFPA No. 70 (latest edition). This heater must be electrically grounded in accordance with these codes. The Manufactured Home Construction and Safety Standard, Title 24 CRF, Part 3280 may be applicable for Manufactured Home installations. These codes are available from the American National Standards Institute Inc., 1430 Broadway, New York, NY 10018, the National Fire Protection Association Inc., Batterymarch Park, Quincy, MA 02269 or the Canadian Gas Association, 55 Scarsdale Road, Toronto, Ontario M3B 2R3, Canada.

UNPACKING THE HEATER

1. Remove the heater from its carton. (The vent and tank connections are shipped in a separate box).
2. Locate and retain the Instruction Manual, Warranty Card, and Scald Warning Label Instruction Sheet.
3. Check the heater for shipping damage. If any damage is found, immediately contact the dealer from whom the heater was purchased.

   WARNING: Do not leave small children unattended with the packaging from this water heater because ingestion of styrofoam could result in suffocation.

INSTALLATION OF HEATER

IMPORTANT: Installation should be done by a qualified service person in accordance with state and local codes.

I. CHECK GAS TYPE

Use only the type gas indicated on the heater rating place located inside the cabinet. If you observe that your gas supply is different than what is specified on the heater; do not install the heater. Call your dealer for the proper heater.

II. LOCATING THE HEATER

The following points should be considered when determining the location of the heater:

1. This heater is certified for OUTDOOR INSTALLATION ONLY!

2. The heater should be located such that it is as close to the location of the water storage tank as possible. This will ensure the shortest possible runs of pipe and the lowest installation cost.

3. The storage tank can be located as far as 50 feet away from the heater (50 equivalent ft. to heater and 50 equivalent ft. back to tank) and as much as 10 feet above or below the heater for proper operation. Consult the factory for any installations in excess of these distances.

4. This heater should be located with respect to building construction and other equipment to allow easy access to it. Installer shall use good installation practices when locating the heater and must give consideration to service accessibility.

5. The heater should be located such that branches of trees or shrubs will not interfere with the vent or air intake louvers to this heater. Maintain the minimum clearances to combustible materials shown on the next page.

6. The vent on the heater must be located at least 4 feet below, 4 feet horizontally from, or 1 foot above any door, window or gravity air inlet into the dwelling.

7. The heater is designed for mounting to the exterior wall of the dwelling. The heater should be mounted as close to the ground (min. 12") as possible such that sufficient room is available underneath the heater for the water, gas and electrical connections and ease of entry through the dwelling wall or foundation. Aesthetic considerations should be taken into account when identifying the best location for the heater. In areas where snow accumulation or drifting is likely, the heater should be located on a wall away from prevailing winds and high enough off the ground such that the air inlet louvers on the side of the heater cabinet will not become blocked by drifting snow.

8. If the heater is to be located near an outside corner of the dwelling, it is recommended that it be located at least 24" away from the corner to reduce the possibility of any adverse effects of swirling winds around the corner.

9. If the heater is to be located near an air conditioning condensing unit, it is recommended that it be located at least 24" away from the condensing unit.

10. The following minimum clearances to combustible materials must be maintained:

Minimum and Recommended clearances from combustible construction:

	Minimum Clearances	Recommended Clearances
Sides	1"	12"+
Top	30"	30"+
Back*	0"	0"
Front	----	24"+
Bottom	12"	12"+

* The back clearance utilizes the mounting brackets supplied with the heater.

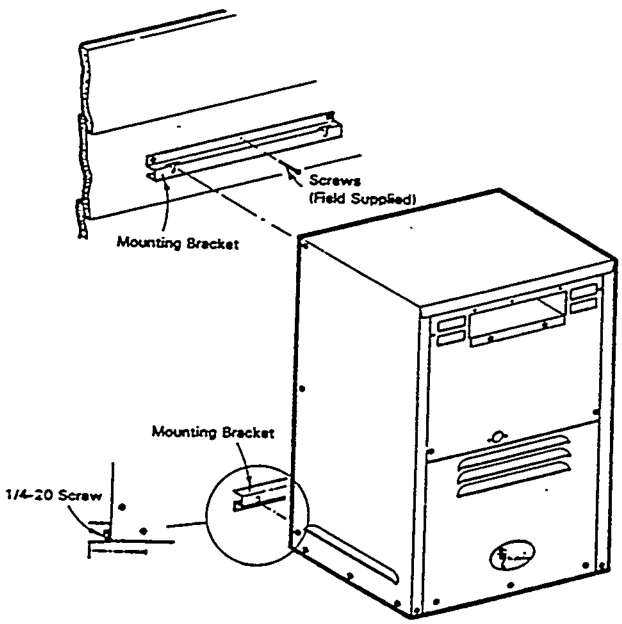


Figure 1. - Mounting the Heater

III. MOUNTING THE HEATER

1. After a suitable location is found for the heater, secure one mounting bracket to the wall of the dwelling at a height equal to the desired mounting height of the heater. Make sure that the bracket is level. See Figure 1.

2. Secure the other mounting bracket to the lower portion of the back panel of the heater using the two 1/4-20 screws attached to the rear of the heater. The flange of the bracket should extend below the bottom of the heater by approximately 1 inch. See Figure 1.

3. Loosen the two 1/4-20 screws located about 2 inches from the top of the back panel of the heater.

4. Lift the heater into position on the wall so that the heads of the two upper 1/4-20 screws on the back of the heater fit into the slots of the upper bracket which is secured to the exterior wall.

5. Lower the heater very carefully until you are sure that the heater is being properly supported by the bracket. Tighten the two upper 1/4-20 screws through the slots in the bracket.

6. Secure the lower bracket to the wall with screws that will permit removal without damage to the building structure. This is necessary if the heater must ever be removed for service or repair.

7. Attach the draft diverter assembly to the face of the heater as shown in Figure 2. Attach the vent/cabinet trim piece to the draft diverter assembly as shown. Place the flue outlet shield over the draft diverter assembly and secure with the sheet metal screws provided. The holes are offset to prevent incorrect alignment of these vent components on the heater.

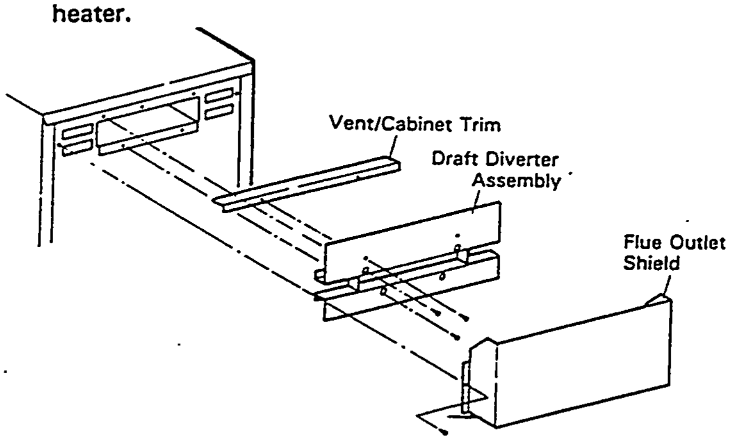


Figure 2. - Vent Installation

IV. WATER CONNECTIONS

1. Remove the front panel of the heater giving you access to the internal components. Make sure that you know where the supply and return water connections in the heater are located. The pump is connected in the supply line to the heater. Each connection is marked on the bottom of the heater.

DO NOT use galvanized piping. The system should be installed only with new piping that is suitable for hot, potable water, such as copper, QEST (Polybutylene) or CPVC. DO NOT use PVC piping.

DO NOT use any valves or fittings that are not completely compatible with hot potable water. DO NOT use a lead-based solder on potable water pipe connections.

INSTALLATION OF HEATER

2. Connect the inlet water supply piping (3/4" NPT minimum) to the fitting marked "INLET WATER CONNECTION", and the hot water return piping (3/4" NPT minimum) to the fitting marked "OUTLET WATER CONNECTION". Larger pipe sizes may be required for longer runs.

DO NOT apply heat to any of these fittings. If sweat connections are used, sweat tubing to the adaptor before fitting adaptor to the threaded inlet and outlet water connections. When making these connections, always use a pipe joint compound good for potable water applications and be sure that all joints are drawn up tight. Hold the heater fittings in position with a wrench to prevent possible damage or misalignment of piping inside the heater.

NOTE: All outside pipe external to the heater should be insulated with appropriate insulation for the piping system used.

3. The water in the indoor storage tank must be completely drained before proceeding.

4. Partially fill the tank with water and drain it again to flush any collected sediment and particulates out of the storage tank. Continue to flush the tank until the water is clear and free from sediment.

5. Once the storage tank has been flushed and drained, unscrew the drain valve from the storage tank. If possible, scrape any collected sediment out of the bottom of the storage tank through the drain valve opening.

6. Screw the new supply tube assembly into the drain valve opening. Once the nipple in this assembly is tightly secured, align the notch on the supply tube so that it is vertical as shown in Figure 3. Tap the end of the supply tube into the nipple to lock the supply tube in place. Carefully screw the new drain valve onto this nipple. NOTE: Hold the nipple in place with a pipe wrench to ensure that the supply tube assembly is oriented correctly when tightening the drain valve onto the nipple.

NOTE: The use of manual shut-off valves in the supply and return water lines between the storage tank and heater is required. These are needed to isolate the heater during servicing of the appliance. These must be field supplied and must be compatible with hot, potable water.

7. Attach the pipe connected to the "Inlet Water Connection" to the side fitting of the new drain valve installed in the storage tank in Step #6. This is the water supply connection to the outdoor heater.

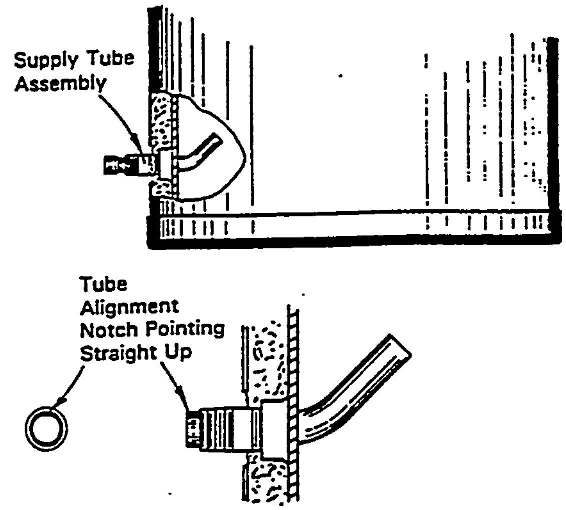


Figure 3. - Supply Tube Assembly Installation

8. The hot water return to the storage tank can be made at any convenient inlet into the tank. The penetrations into the tank where the electric elements are located in an electric storage tank are ideal locations for the hot water return to the storage tank.

WARNING: If the electric element penetration into the storage tank is to be used, the electric supply must be permanently disconnected at the breaker or fuse box by a licensed electrician.

9. If the storage tank contains 2 screw type electric elements, remove the top electric element using a 1-1/2" socket wrench and turning counterclockwise and discard it. Install the return tube assembly into the upper penetration as shown in Figure 4.

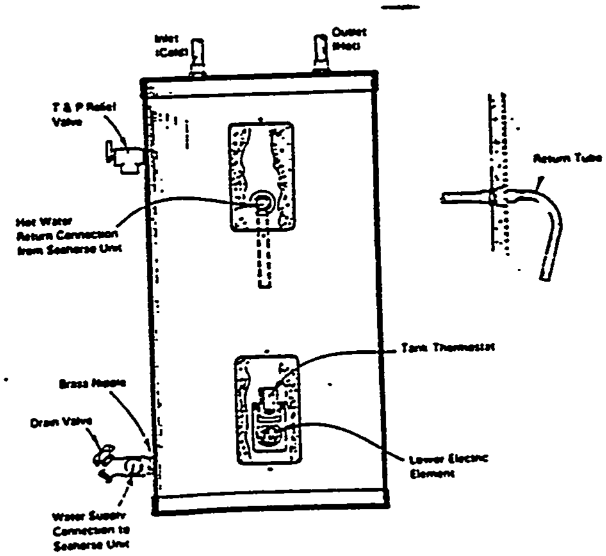


Figure 4. - Return Tube Assembly Installation
2 - Element Storage Tank

10. If the storage tank contains only one screw type electric element, use a 1-1/2" socket wrench and turn counterclockwise to remove it, then discard it. Install the return tube assembly into this penetration as shown in Figure 5. NOTE: Make sure that the return tube assembly is facing upward as shown in Figure 5.

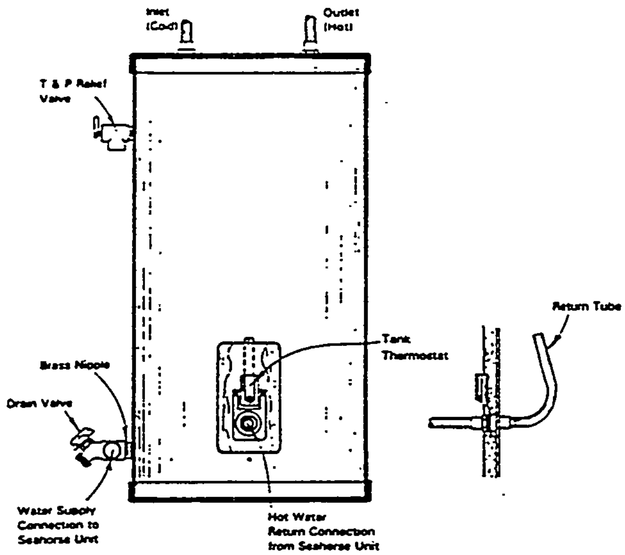


Figure 5. - Return Tube Assembly Installation
Single Element Storage Tank

NOTE: If the electric element penetration to be used is located in the upper 1/2 of the storage tank, the return tube assembly should be installed facing downwards. If the electric element penetration is in the lower 1/2 of the storage tank, the return tube assembly should be installed facing upwards. The return tube will swivel for easy attachment once it is positioned properly inside the storage tank.

11. If the storage tank has flange-type electric elements, remove the electric elements and clean the tank surface of any residual gasket material. Use the Seahorse Flange Kit which is available as an accessory (Part No. 4344300). Attach the new flange to the water storage tank with the appropriate gasket in place using the longer bolts supplied with the kit. Follow the procedures outlined in items 9 or 10 above.

WARNING: If you find an application that does not fit into any of the situations outlined below, contact your local dealer or the factory for advice.

12. Attach the pipe connected to the "Outlet Water Connection" on the heater to the return tube assembly installed in the storage tank in Steps 9, 10 or 11. This is the water return connection to the heater.

13. Attach the Scald Warning Label, which was enclosed in the Information Package, to the storage tank at the location on the tank jacket close to the thermostat that will be used (lowest in the tank). Clean or wipe the jacket surface before attaching the label for the best results. This label is intended to warn the occupants about the scald potential if the thermostat is adjusted above 120°F.

V. ELECTRICAL CONNECTIONS

1. A grounded 115 VAC, 1 Phase, 60 Hz, less than 2 amps, electrical service is required at the heater.

WARNING: The heater must be electrically grounded in accordance with state and local codes, or in the absence of these codes, with the National Electric Code ANSI/NFPA 70 (latest edition).

CAUTION: All internal electrical components have been wired at the factory. No attempt should be made to connect electric wires to any other location except the terminal block located inside the junction box on the inside of the heater cabinet.

2. Strain relief must be field supplied on the 115V supply wiring entering the heater as well as the low voltage thermostat wiring from the storage tank to the heater. The connections should be made on the terminal block located inside the junction box. The appropriate terminals for 115V and 24V supply wiring are indicated by a label next to the terminal block inside the junction box.

WARNING: DO NOT turn on the electric supply until the entire installation is complete, the tank has been filled with water and the new heater system has been properly primed.

3. Connect suitable "low voltage" thermostat wire to the terminals #7 and #8 on the terminal block located inside the junction box.

4. Connect the other end of the thermostat wire directly to the lowest thermostat already located in/on the storage tank. Refer to the Wiring Diagram shown in Figure 8 on Page 8.

NOTE: The thermostat in the storage tank controls the operation of the heater. Any desired changes in the water temperature should be made on the thermostat located in/on the storage tank. DO NOT UNDER ANY CIRCUMSTANCES set the thermostat at a point above 120°F without the use of an anti-scald or mixing valve.

NOTE: Always use the thermostat located in the lowest portion of the storage tank for proper operation. For improved reaction time and operation, an Aquastat (Part No. 3046700) may be used.

It is recommended that a wall mounted on-off service switch be installed in the electrical service in accordance with the National Electric Code.

VI. GAS SUPPLY AND PIPING

1. A gas pipe of sufficient size should be run to the heater. Refer to the National Fuel Gas Code (NFPA 54) for proper pipe size. Make sure that the type of gas supplied is the same as listed on the heater rating plate. Gas supply and manifold pressure requirements are listed on Page 2 of these instructions.

WARNING: It is important to guard against gas control fouling from contaminants in the gas pipe. Before attaching the gas pipe, be sure that it is clean on the inside. Such fouling of gas control can result in improper operation, fire or explosion. Apply pipe thread sealing compound (which is suitable for LP gas) to the male threads only.

2. Install a readily accessible manual shut-off valve in the gas supply line servicing the heater. **NOTE TO INSTALLER: Show the home owner the location and operation of this manual shut-off valve before leaving the installation.**

3. Install a drip-leg in the gas pipe serving this heater in accordance with state and local codes and the NFPA 54. This is meant to prevent dirt and foreign materials from entering the gas control. See Figure 6.

4. A ground joint union should be installed between the manual shut-off valve and the heater to permit servicing of the unit.

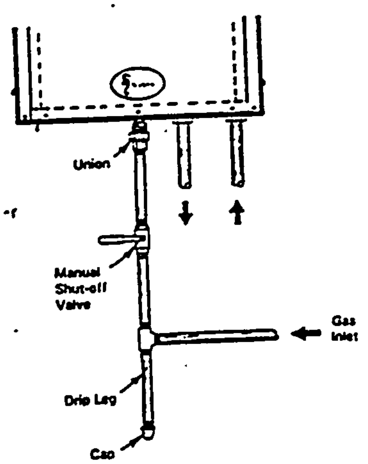


Figure 6. - Gas Piping Connection

NOTE: When measuring or setting the gas pressure, use a water manometer. Gauges which measure in oz. per square inch or pounds per square inch are not accurate enough to measure or set the pressure.

LEAK TESTING:

5. If the codes require that the heater be tested at a gas pressure exceeding the design of the gas control valve (1/2 psig), the heater and its individual manual gas shut-off valve must be disconnected from the gas supply piping system and the line capped.

The heater must be isolated from the gas supply piping system by closing its individual manual gas shut-off valve during any pressure testing of the gas supply system at test pressures equal to or less than 1/2 psig. The maximum allowable gas inlet pressure to the heater is 1/2 psig, which equals 14"W.C.

6. The heater gas connections must be leak tested before operation. Leak test all gas connections with a heavy soap and water solution. Bubbles will indicate a leak that must be fixed. Retest with the soap and water solution until no leaks are found.

WARNING: Never use a match or other open flame to test for gas leaks. A fire or explosion could result.

PRIMING THE SYSTEM

NOTE: All water, gas and electrical connections must be made before proceeding with this next section.

1. Fill the storage tank with water. Check for water leaks around the new drain and the return tube assembly. Open a bathtub or shower hot water faucet inside the dwelling to bleed air out of the water lines. Once all the air is bled out of the dwelling water lines, proceed to Step #2. The cold water supply to the storage tank should be wide open.

2. Lift the lever of the T&P relief valve which is located to the right of the gas control valve inside the heater cabinet. See Figure 7. Water and air will come out of the T&P relief valve onto the ground. Continue to drain water until a steady stream of water is coming out of the T&P relief valve without any air.

3. Release the lever of the T&P relief valve and make sure that it closes properly. Once it closes, there should not be any water leaking from the relief valve. Check all water connections for leaks.

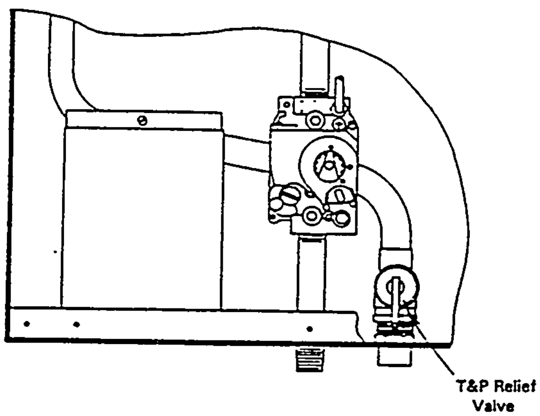


Figure 7. - T&P Relief Valve Location

4. Turn on the 115V electric supply to the heater. If the storage tank thermostat is set at or above 100°F, the pump in the heater should be operating. Place your hand on the pump motor housing. You will be able to feel if it is operating. If you do not feel the pump operating, refer to the Troubleshooting section of these instructions starting on page 12.

5. Light the heater following the procedure outlined on the appliance Lighting Instructions labels located on the back of the lower access panel and on Page 10 of these instructions.

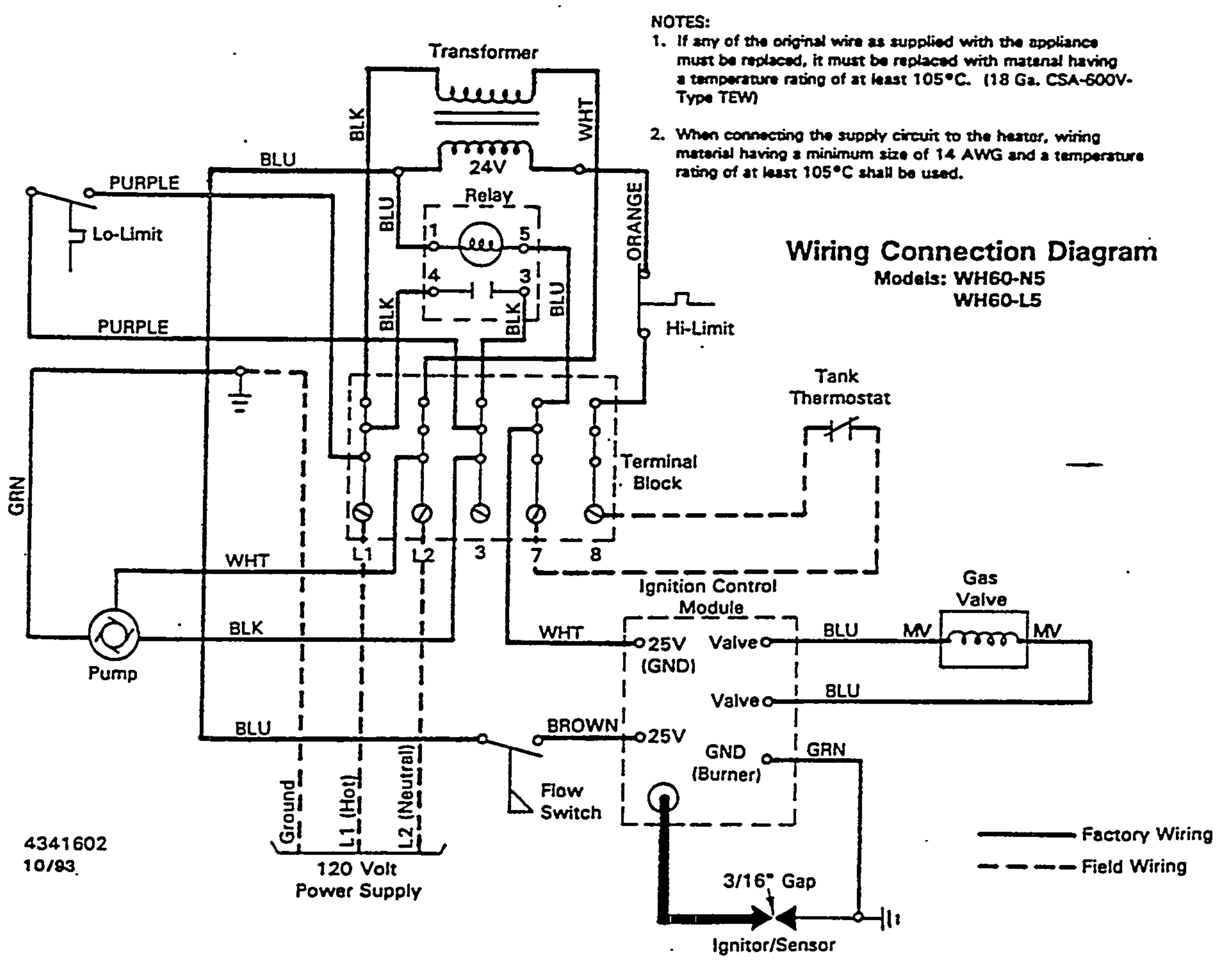
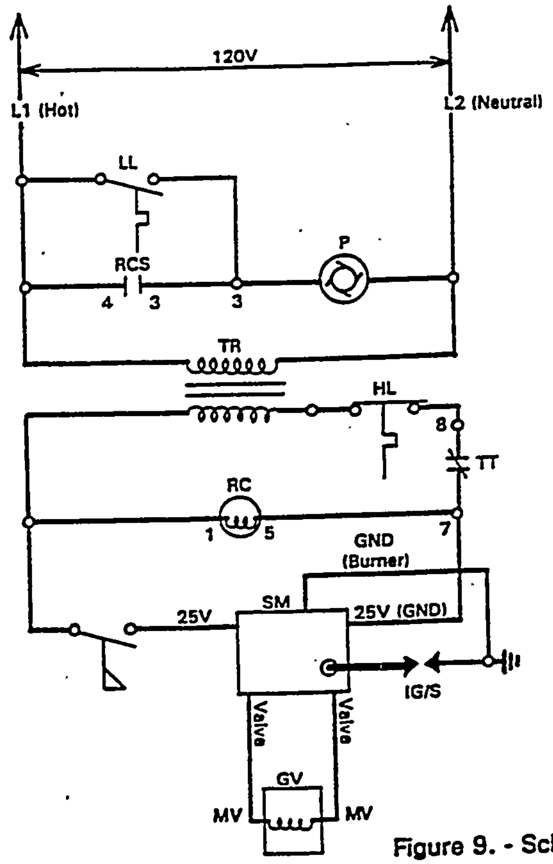


Figure 8. - Wiring Connection Diagram



SCHEMATIC WIRING DIAGRAM

LEGEND:

- LL — Lo-Limit Thermostat (Closes on Temperature Fall)
- RCS — Relay Contact
- P — Pump
- TR — Transformer - 120/24V
- TT — Tank Thermostat
- RC — Relay Coil
- GV — Gas Valve
- FS — Flow Switch (Closes on Water Flow)
- HL — Hi-Limit Thermostat (Opens on Temperature Rise)
- SM — Spark Module
- IG/S — Ignitor/Sensor
- IC — Ignition Cable

Figure 9. - Schematic Wiring Diagram

TEMPERATURE & PRESSURE RELIEF VALVE

For protection against excessive pressure and/or temperature, a Temperature and Pressure (T&P) relief valve is installed in this heater. This is a listed 210/150 PSIG temperature and pressure relief valve which meets the ANSI Z21.22 - (latest edition) - Standard for Relief Valves and Automatic Gas Shutoff Devices for Hot Water Supply Systems.

A separate relief valve is required in the storage tank for proper operation and safety. This relief valve can be either a Pressure relief valve or a Temperature and Pressure relief valve which meets the ANSI Z21.22 - (latest edition) - Standard for Relief Valves and Automatic Gas Shutoff Devices for Hot Water Supply Systems.

Relief piping from the storage tank valve must terminate 6 inches above a floor drain or external to the building. DO NOT thread, cap or plug the end of the discharge line. The function of the Temperature and Pressure relief valve is to discharge water in large quantities should circumstances demand. If the discharge pipe is not directed to a drain or other suitable means, the water flow may cause property damage.

WARNING: DO NOT locate anything directly below the heater as the T&P valve discharge could result in scalding or property damage. If this concern exists, install drain piping from the heater T&P valve outlet to the ground.

WARNING: The Temperature and Pressure relief valve must not have any valve between the relief valve and the storage tank or between the relief valve and the end of the discharge line. The discharge line must not be smaller than the pipe size of the relief valve and it must be made of a material capable of withstanding 210°F water without distortion.

The operation of all relief valves should be checked at least once per year. Standing clear of the outlet (CAUTION: Discharge water may be hot), lift and release the lever handle on the relief valve to make the valve operates freely. The relief valve should reset once the lever is released. If the relief valve does not reset, replace the relief valve.

If the relief valve in the storage tank discharges periodically, this may be due to thermal expansion in a closed water system. Contact the water supplier, local plumbing inspector, or plumber on how to correct this situation. DO NOT plug the relief valve.

FOR YOUR SAFETY READ BEFORE LIGHTING

> WARNING: If you do not follow these instructions exactly, a fire or explosion may result causing property damage, personal injury or loss of life.

A. This heater does not have a pilot. It is equipped with an electronic device which automatically lights the burner. DO NOT try to light the burner by hand.

B. BEFORE LIGHTING smell all around the heater area for gas. Be sure to smell next to the ground because some gas is heavier than air and will settle on the ground.

WHAT TO DO IF YOU SMELL GAS
- Do not try to light any appliance.
- Do not touch any electric switch; do not use any phone in your building.
- Immediately call your gas supplier from a neighbor's phone. Follow the gas supplier's instructions.
- If you can't reach your gas supplier, call the fire department.

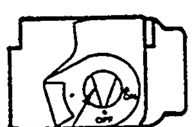
C. Use only your hand to turn the gas control knob. Never use tools. If the knob will not operate by hand, don't try to repair it, call a qualified service technician. Force or attempted repair may result in a fire or explosion.

D. Do not use this heater if any part has been under water. Immediately call a qualified service technician to inspect the heater and to replace any part of the control system and any gas control which has been under water.

OPERATING INSTRUCTIONS

1. STOP! Read the safety information above on this page.
2. Turn off all electrical power to the heater.
3. This heater is equipped with an ignition device which automatically lights the burner. DO NOT try to light the burner by hand.
4. Remove the lower control access panel.
5. Turn gas control knob clockwise to "OFF".

CONTROL KNOB SHOWN IN "OFF" POSITION



GAS CONTROL KNOB AND POSITION INDICATOR

6. Wait five (5) minutes to clear out any gas. If you then smell gas, STOP! Follow "B" in the safety information above on this page. If you don't smell gas, go to the next step.
7. Turn gas control knob counterclockwise to "ON".
8. Replace lower control access panel.
9. Turn on all electrical power to the heater.
10. If the heater will not operate, follow the instructions "To Turn Off Gas To Heater" and call your service technician or gas supplier.

TO TURN OFF GAS TO THE HEATER

1. Turn off all electrical power to the heater if service is to be performed.
2. Remove the lower control access panel.
3. Turn gas control knob clockwise to "OFF". DO NOT force.
4. Replace the lower control access panel.

THERMOSTAT SETTING

The temperature of the water in the storage tank can be adjusted by the setting of the storage tank thermostat dial. The thermostat dial on your storage tank may have numbers identifying the different temperatures or it may have "LOW" and "HIGH" marked on the dial. Adjust the storage tank thermostat for energy efficient operation at the minimum water temperature consistent with the dwelling occupants' needs.

WARNING: The 120°F setting is the highest recommended setting for simple water heating. Adjusting the thermostat past this recommended setting will increase the risk of scald injury. IF TEMPERATURES ABOVE 120°F ARE NECESSARY, AS FOR COMFORT HYDRONIC HEATING, A MIXING OR ANTI-SCALD VALVE MUST BE USED. SET THE MIXING OR ANTI-SCALD VALVE TO 120°F MAXIMUM. A mixing valve (Part No. 3046301) and anti-scald valve (Part No. 3046300) are available as accessories. Contact your dealer or the factory for pricing and availability.

WARNING: HOT WATER CAN PRODUCE THIRD DEGREE BURNS
- IN 6 SECONDS AT 140°F (60°C)
- IN 30 SECONDS AT 130°F (54°C)

NOTE: Households with small children, disabled or elderly may require a lower temperature setting than 120°F.

FREEZE PROTECTION

The heater is equipped with a freeze protection device (freezestat) that will activate the pump and circulate water through the system if the water temperature approaches freezing. This heater has been satisfactorily tested at temperatures as low as -40°F. However, a potential for freezing exists when the electricity goes out and the temperatures are below freezing. To protect the heater under these circumstances, a Freeze Protection Valve is available as an accessory (Part No. 3044600) and should be used in those areas where severe freezing temperatures, in conjunction with extended electrical outages, are possible. A check valve must be installed in the hot water return piping at the storage tank whenever the Freeze Protection Valve is utilized. Please refer to the Installation Instructions packaged with the Freeze Protection Valve for complete details.

NOTE: If water is supplied from a well and the electricity is off, the heater must be manually drained in severe freezing weather to protect the heat exchanger and water piping from damage.

NOTE: If this heater is used in a cabin or other vacation home which is used only occasionally, we recommend that the heater be drained before leaving for extended periods of time.

MAINTENANCE

WARNING: Before performing any maintenance or service work on this heater, make sure that the electrical power supply is turned "OFF". The gas supply should be turned off when removing any components in the gas control system.

1. Keep all foliage or obstructions clear of the vent area at all times. The Minimum Clearances to Combustibles noted on Page 4 of these instructions must be maintained at all times. It is recommended that all limbs, branches or shrubs that are within 30 inches of the heater be trimmed.

2. The burner should not require maintenance during normal operation of this heater. However, the main burner flame should be observed for proper operation every 12 months. Refer to Figure 10 for correct burner flame characteristics. If the flames have any appearance other than that shown, contact a qualified service person to clean the burner and controls.

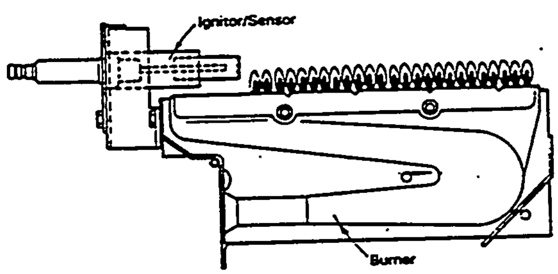


Figure 10. - Correct Burner Flame Pattern

3. The relief valves should be tested every 12 months. If they do not function properly, they must be replaced by a qualified service technician.

4. The air intake louvers located in the cabinet must be kept clear and open at all times.

NOTE: There are no moving parts which require lubrication in this heater.

NOTE: After replacement or service, the system must be properly primed as stated earlier in these instructions.

TROUBLESHOOTING GUIDE

TROUBLE	CAUSE	SOLUTION
1. No spark at burner.	- Ignition module is in lockout.	- Turn power "OFF" and then "ON" again after approx. 60 seconds.
	- No power to heater.	- Make sure that 115VAC is supplied to heater.
	- Transformer defective.	- Check for 24VAC at secondary side of transformer, if not, replace.
	- Hi-limit switch tripped.	- Make sure that hi-limit switch reset button is pushed in and holds.
	- No water flow.	- Feel pump housing for flow - check for water by lifting lever on T&P relief valve.
	- Low water flow - flow switch contacts won't close.	- Too much line restriction, use larger I.D. water tubing and long radius elbows in installation.. - Check for clogging of the pump impeller or the flow switch caused by sediment and debris from the storage tank.
	- Flow switch not working.	- Check continuity through flow switch. If switch contacts are open, confirm that pump is moving water, then replace flow switch.
	- Defective thermostat in storage tank.	- Check continuity through thermostat and replace if necessary.
	- Broken low voltage wire.	- Replace wiring.
	- Defective components in spark system.	- See next section.
	- Ignition module fuse blown.	- Check fuse and if blown, replace. If fuse is o.k., replace ignition module.
2. Spark only exists when ignition lead is pulled and placed next to metal object.	- Poor or incorrect ground.	- Check to make sure heater is properly grounded.
	- Ceramic insulator of electrode cracked or broken.	- Check and replace as necessary.
	- Electrode gap incorrect.	- Check for 3/16" gap and correct as necessary.
	- Ignition cable defective.	- Check boot of the ignition cable for signs of melting or buckling and replace as necessary.
3. Main burner does not light.	- Manual shut-off valves closed.	- Open valves.
	- Gas control knob not in "ON" position.	- Put gas control knob into "ON" position.
	- Air in gas line.	- Repeat ignition procedure until air is eliminated.

TROUBLE	CAUSE	SOLUTION
3. Main burner does not light - cont'd.	- No voltage at gas valve. - Gas control valve will not open.	- Check for 24VAC across valve and valve terminals on ignition module. If no voltage, replace ignition module. - Replace valve if 24VAC exists across valve terminals.
4. Spark does not stop when burner is lit.	- Defective ignition/sensor cable and/or ground wire. - Electrode not positioned in burner flame properly.	- Check continuity of ignition/sensor and ground wires. If either is broken, replace. - Check to be sure that burner flame fully covers tip of electrode. If electrode position looks good, replace ignition module.
5. System shuts off prior to end of call for heat.	- Defective ignition/sensor cable and/or ground wire. - Excessive heat at sensor insulator boot (temperatures above 1000°F cause short to ground).	- Check continuity of ignition/sensor and ground wires. If either is broken, replace. NOTE: If ground is poor or erratic, shutdowns may occur occasionally even though operation is normal at time of checkout. - Check boot for signs of melting or buckling. If checks are o.k., replace ignition module.
6. No hot water available.	- Ignition module is in lockout. - Tank thermostat set too low. - Tank thermostat wires not connected properly. - Defective tank thermostat. - Broken low voltage wiring. - Pump not working. - No water pressure. - Vapor lock in system. - Flow switch not working.	- Turn power "OFF" and then "ON" again after approx. 60 seconds. - Set thermostat at 120°F or temperature consistent with dwelling needs. - Make sure lowest thermostat is used as the control. - Connect thermostat wires to #7 and #8 on the terminal block in the heater junction box. - Replace tank thermostat. - Replace wiring. - See following sections. - Check to see if water has been shut off. - Open T&P relief valve until a steady stream of water is present. - Replace flow switch.
7. Runs out of hot water quickly.	- Using upper tank thermostat.	- Use lowest thermostat in storage tank.

TROUBLESHOOTING GUIDE

TROUBLE	CAUSE	SOLUTION
8. Pump is not working.	- No power at pump.	- Make sure thermostat is calling for heat. - Make sure Hi-Limit switch is not tripped. - Check electrical connections and voltage at pump. There should be 115V at the pump.
	- Pump motor defective/burnt.	- Replace pump.
	- Pump impeller defective or broken.	- Replace pump cartridge.
9. Pump runs all the time.	- Freezestat contacts are closed.	- Check continuity through switch, if closed, raise switch temperature about 90°F for 5 minutes. Switch should open, if not, replace freezestat.
	- Tank thermostat is defective.	- Replace tank thermostat.

SEQUENCE OF OPERATION

1. When hot water is used, it is automatically replaced in the storage tank by cold water which enters the storage tank near the bottom.

2. If the temperature of the water in the storage tank falls below the thermostat setting, the normally open contacts in the thermostat close, which activates the pump in the heater.

3. Tempered water is pulled through the supply tube assembly in the bottom drain outlet of the storage tank and pumped through the outdoor heaters' heat exchanger.

4. As water flows through the heat exchanger, it activates a flow switch that is set to prevent the operation of the main burner until a minimum flow of 2.5 gpm of water through the heat exchanger is reached. Once the minimum flow level is reached, the normally open contacts of the flow switch close; and the direct spark ignition module is energized which opens the gas valve and the gas is ignited by the electrode on the burner surface.

5. The water flowing through the heat exchanger is heated by the efficient combination of conduction and radiant heat from the burner; and then is returned to the storage tank using the return tube assembly via a convenient upper inlet into the tank.

6. When a sufficient amount of hot water has been returned to the storage tank to satisfy the demands of the thermostat, the contacts in the thermostat open. This turns the pump and the main burner off.

7. If the water in the heat exchanger gets too hot (approximately 190°F [205°F on WHT60 models]), a high limit switch (normally closed contacts) will sense this and the contacts will open. If this occurs, it is indicative of a problem that should be addressed by a qualified service person. The Hi-Limit switch must be manually reset before the heater will operate again.

8. The heater is equipped with a freezestat that will activate the pump and circulate hot water from the storage tank through the heat exchanger when the water temperature drops to 43°F. This will run only long enough for the water temperature to rise and for the freezestat to reset (approximately 20-90 seconds depending on the temperature of the water in the storage tank). This is done to prevent the water from freezing and potentially causing damage to the heat exchanger and/or the water piping. The heat exchanger is also enclosed in an insulated cabinet for protection during freezing temperatures.

9. As heat is extracted from the hot water in the storage tank, the temperature in the storage tank may fall below the storage tank thermostat setting. When this occurs, the pump is activated in the outdoor heater and the Seahorse heater begins to replenish the hot water supply immediately.

HYDROHEAT GENERAL INFORMATION

Should comfort hydronic heating be desired, a separate circulation system must be installed with its own individual pump electrically connected to the household thermostat. This separate circulation system must include a hot water coil that can be installed in the air handling system or an entire air handling system (or other suitable heat transfer device like radiators) that is designed for operation with hot potable water. In addition, the supply and return water lines from the storage tank must be insulated. When the household thermostat calls for heat, this separate circulating pump will draw hot water out of the storage tank and circulate it through the efficient heat exchanger which will transfer this energy into the air that is being circulated through the house. The cooler water is then pumped back to the storage tank.

The heater is capable of producing a large quantity of hot water than can satisfy normal water heating needs and can also be used for hydronic heating. While we do not manufacture auxiliary heating coils or air handling systems, these are commonly available from your local plumbing/heating contractors.

The following information represents some generic information concerning hydroheat systems that should be read and understood before the installation of any hydroheat system. If any questions arise, they should be directed to the hydroheat equipment manufacturer.

Gas Fired Products, Inc. does not assume any responsibility for hydroheat installations. Our Seahorse Outdoor Gas Water Heating System is simply the device used to put hot water into a storage tank for multiple uses.

DO adhere strictly to all local and national code requirements pertaining to the installation of potable water hydroheat systems.

DO NOT use with baseboard radiation or any other system that has been served by non-potable water such as boiler water or any other possible non-potable water source.

DO NOT use in conjunction with new finned tube baseboard radiators or convectors until you have properly determined the capacity of those units with the temperature of the water available.

DO NOT use with piping that has been treated with chromates, boiler seal or other chemicals.

DO NOT add boiler treatment or any chemicals to any piping, since the piping contains potable water.

DO NOT use with ferrous piping. The system should be installed only with new piping that is suitable for potable water, such as .copper or QEST (polybutylene). DO NOT use with PVC piping.

DO NOT use any pumps, valves, or fittings that are not completely compatible with hot, potable water.

DO use an isolation check valve in the cold water supply line to the storage tank.

DO NOT use valves that may cause excessive restriction to water flow. Use Full Flow Ball or Gate Valves ONLY!

DO NOT turn the thermostat on the storage tank all the way to "HIGH". Properly applied hydroheat systems are designed to provide adequate heat with water temperatures set at "MEDIUM" (135°F - 140°F). If conditions do require a water temperature setting above 120°F, an approved mixing or anti-scald valve must be installed for domestic water use with a setting of 120°F maximum. Read the instructions included with the mixing or anti-scald valve to assure proper installation.

DO flush all supply and return water lines between the hydroheat unit and the water storage tank after installation and before start-up to eliminate flux, metal chips, sand, or other particulate matter just as you would with any new plumbing system.

DO NOT use 50/50 solder on any potable water piping system. Use only solders permitted by your local plumbing code.

DO use a minimum of 3/4 inch nominal (7/8 O.D.) piping between the water storage tank and the hydroheat system.

DO adequately insulate all piping to reduce unnecessary heat loss. Consider the use of freeze protection devices for any piping which runs through unheated spaces subjected to freezing temperatures.

DO NOT utilize piping in excess of 200 total feet of length for installation of a hydroheat system.

DO connect the hydroheat system to the water lines through the horizontal connection of "T" fittings in the vertical hot and cold water supply lines at the water storage tank. This ensures that any air in the storage tank or lines will bypass the heating loop and then be purged each time the hot water is used in the dwelling. If this piping procedure is not followed, the pump may "air-lock" and fail to pump hot water through the hydroheat system upon demand.

DO use manual shut-off valves to allow the isolation of the hydroheat system from the storage tank for service or repair.

DO use long radius elbow fittings whenever possible to reduce friction losses and to help insure proper operation.

Some water storage tanks come with a normally closed, spring-loaded check valve factory installed. Since the circulating pump in the hydroheat system may not be able to open this valve in addition to recommended check valves, this valve should be removed before installation.

PARTS DIAGRAM AND REPAIR PARTS LIST

ITEM NO.	PART NO.	DESCRIPTION
1	3041403	High Limit Switch - Models WH60 only
2	3041404	High Limit Switch - Models WHT60 only
3	3041402	Freezestat (Purple Leads)
4	4336100	Coil Housing Sub-Assembly (Less Flue Hood)
5	4342400	Tradename Plate (included with Item 10)
6	4337600	Flue Hood Assembly
7	4336498	Panel, Heater Cabinet
8	4336599	Panel, Base Mounting
9	4336699	Panel, Upper Front
10	4336798	Panel, Lower Access
11	3041300	Flow Switch
12	4338098	Adapter Sub-Assembly
13	4338099	Pump Sub-Assembly
14	3041296	O Ring Gasket
15	3041298	Capacitor, Replacement Pump
16	3041299	Cartridge, Replacement Pump
16a	3041295	Plate
17	0333310	Nipple, 1/2 x 3 Galv.
21	3033307	Valve, VR8205P-2408 - Nat @ 3.5" W.C.
22	3033308	Valve, VR8205P-2416 - LP @ 10.0" W.C.
23	3044201	Union Nut 1/2" FPT
24	3044202	Union Half 1/2" FPT
26	4275701	Nipple, Restrainer 4"
28	3014800	Bushing, Insulation
29	3027900	Transformer
30	3037500	Terminal Block - ELD5020
31	3038300	Relay - 24V Coil SPST NO
32	4338400	Panel, Electric Mounting
33	4338798	Cover Panel Assembly
34	4338900	Shield, Burner
35	4339001	Burner Mounting Bracket - R.H.
36	4339002	Burner Mounting Bracket - L.H.
37	4339100	Bracket, Burner Support
38	4339200	Bracket, Flue Hood
39	4339300	Plate, Pump Mounting
40	4339400	Bracket, Pump Mounting
41	3042619	Adapter, 3/4" OD x 3/4" MPT
42	3045200	Valve, T&P Relief
43	4339799	Return Tube Sub-Assembly
44	4339900	Bracket, Return Tube
45	4340000	Clamp, Return Tube
48	4341602	Label, Wire Connection - (Not Shown)
49	3042000	Main Burner
50	3042100	Main Burner Manifold
51	3042201	Main Burner Orifice (1.05mm) - Nat (12 ea)
52	3042202	Main Burner Orifice (0.65mm) - LP (12 ea)
53	3044203	Union Half 1/2" FPT
54	4346000	Shield, Flue Outlet
55	4346900	Bracket, Heater Wall
56	4345900	Trim, Vent/Cabinet
57	4345500	Draft Diverter Assembly
58	3041600	Valve, Water Drain
59	4339501	Supply Tube Assembly (Water Tank Outlet)
60	4339500	Return Tube Assembly (Water Tank Inlet)
61	4341205	Instruction Manual (Not Shown)
62	3023503	Spark Ignition Module - S87A-1018
63	3029500	Ignitor/Sensor (Electrode)
64	3031412	Ignition Cable - 14" Long
65	4344000	Bracket, Spark Module
66	4344100	Bracket, Ignitor/Sensor

MODEL NUMBER SUFFIXES

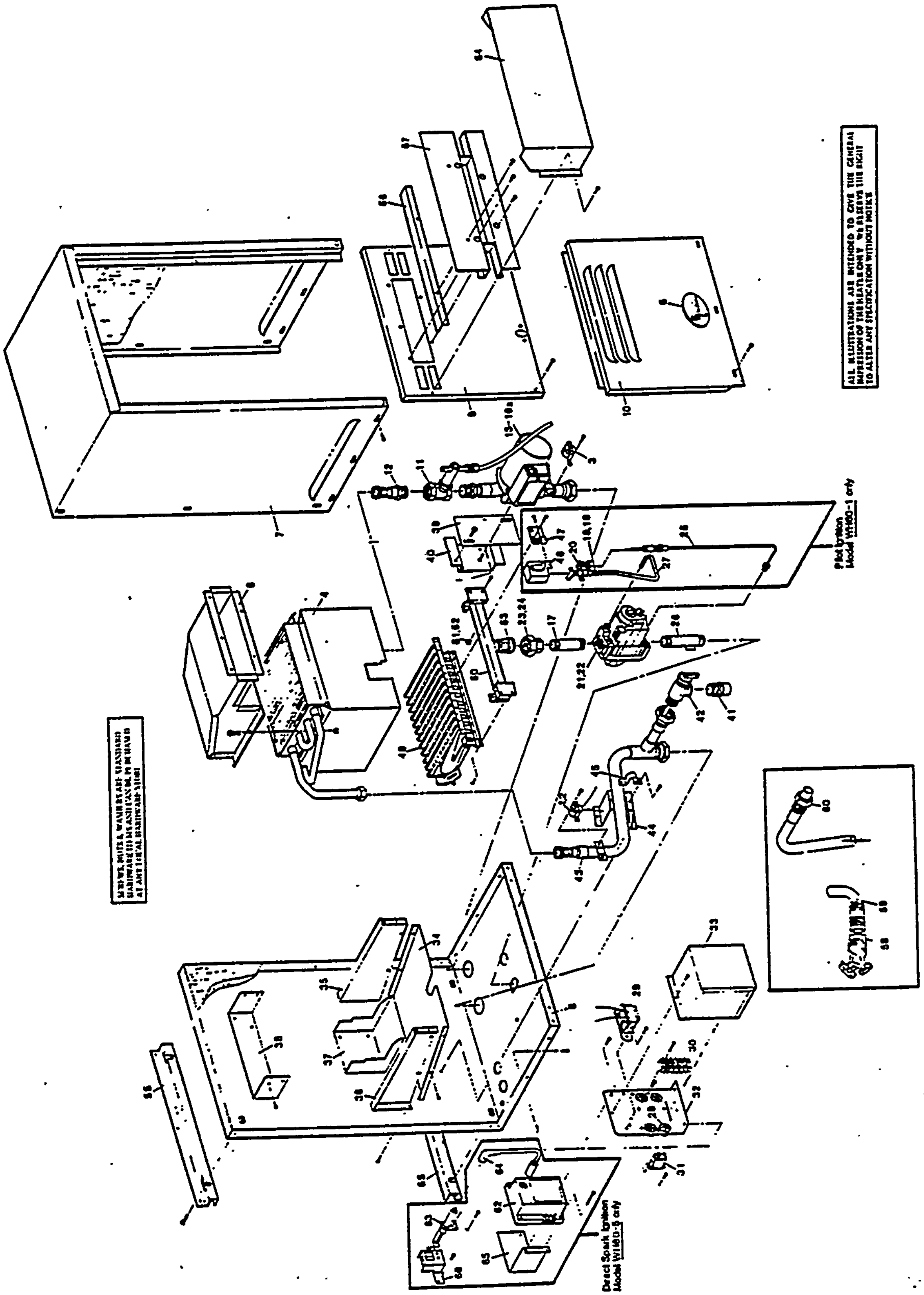
N - Natural Gas
L - Propane Gas

5 - Direct Spark Ignition

IMPORTANT

PLEASE ORDER BY PART NUMBER - NOT BY ITEM NUMBER.
ALSO REFER TO COMPLETE MODEL NUMBER WHEN ORDERING.

ALL REPLACEMENT PART PRICES AVAILABLE WHEN ORDERING.



HOT WATER CONTROL
Adjustable Differential

This control, designed for use on hot water heating systems, has a coiled element that is immersed directly into the boiler water. This feature gives unusual speed of response to rapid changes of water temperature thereby preventing thermal lag.

It has open on rise contact action. This control may be used as a high limit or as a low limit control.

These controls have special contacts which are suitable for use on low voltage and millivolt (thermocouple generator type) circuits as well as line voltage gas valve and motor loads.

INSTALLATION

If the boiler manufacturer recommends a control location, then follow such recommendations. If none are offered the following information shows suggested locations.

For high limit service, the control should be located in the hottest part of the boiler. This is usually near the top of the boiler. A high limit control should not be in the same section of the boiler that contains the heater or the pipes that heat domestic hot water.

For low limit or operating service, the control should be so located, that it responds to the temperature of that section of the boiler that heats domestic hot water.

When tightening the control into the boiler, care should be taken to apply all leverage on the hexagonal nut so as not to injure the diaphragm or control mechanisms.

WIRING

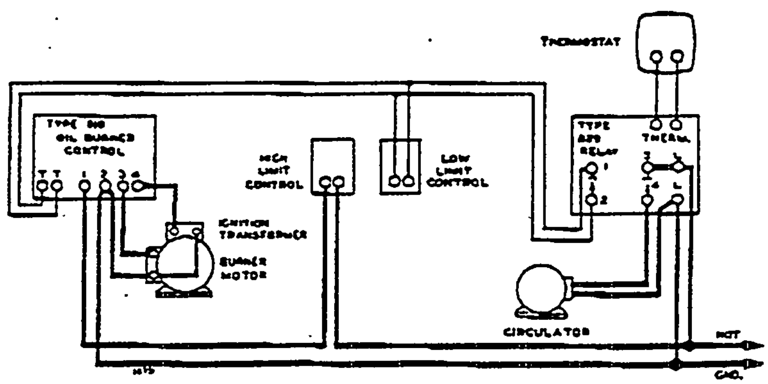
All wiring should be done according to local and national electrical codes.

If the boiler manufacturer recommends a wiring diagram, then follow such recommendations. If none is offered, this diagram shows a suggested circuit.

LOW LIMIT APPLICATION — This diagram shows a common circuit on an oil fired heating system that also heats domestic hot water which is stored in a tank.

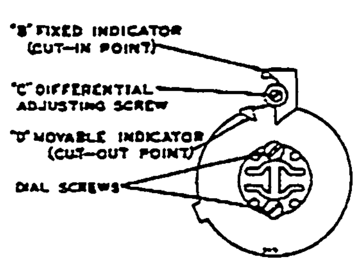
Low limit control maintains domestic hot water temperature all year around.

When thermostat calls for heat, burner and circulator operate.



SETTING

1. Insert screwdriver in the center slot and turn the dial until the fixed indicator "B" points to the temperature at which the contacts should close.
2. Then turn the differential adjusting screw "C" until the movable indicator "D" points to the temperature at which contacts are to open.



Appendix B

Predicted Effect of System Cycle Time on Efficiency

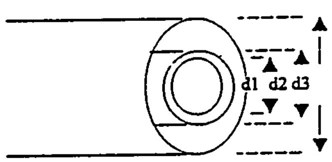
Predicted Effect of System Cycle Time On Efficiency

The efficiency variation of the Seahorse with cycle time was estimated using a spreadsheet thermodynamic model of the system. In this model, the heat loss from the insulated flow loop pipe was estimated using one dimensional heat transfer relationships for conduction through cylindrical pipe and pipe insulation and standard convection and radiation heat transfer out to the environment, resulting in a single equation for pipe heat loss per unit length

$$\frac{q}{l}=\frac{2(\pi)(T_{water}-T_{ambient})}{\frac{1}{k_{insul}}\ln(\frac{r3}{r2})+\frac{1}{k_{pipe}}\ln(\frac{r2}{r1})+\frac{1}{h_{out}r3}}$$

An average ambient temperature of 80°F was assumed for this analysis. An average water temperature for the flow loop after the Seahorse heater shuts off was assumed to be 136°F. The coefficients used in this calculation are seen in Table B-1.

Table B-1 Heat Loss Data for Seahorse Flow Loop



d3	1.875 inch	{diameter at insulation surface}
d2	0.875 inch	{diameter at outer pipe surface}
d1	0.716 inch	{diameter at inner pipe surface}
k insul	0.17 Btu/in-hr-ft^2-F	
k pipe	2.0 Btu/in-hr-ft^2-F	
h_out	1.3 Btu/hr-ft^2-F	
vol/ft	0.002796 ft^3	

Water left in pipe after cycle (gal)	1.06
Temperature rise during Seahorse operation (F)	22
Temperature of water in tank (F)	125
Average temp in loop at Seahorse shutdown (F)	136
Tank loss rate (Btu/hr/F)	18.18

A exponential correlation of the total temperature drop of the water in the flow loop as a function of time from the Seahorse shut down was obtained using the least squares method. This correlation was then used to estimate the total heat loss rate from the piping for a time duration t after the Seahorse shut down. In addition, the typical heat loss rate for the tank during standby conditions was estimated from measured data to be approximately 18.2 Btu/hr per degree temperature difference between the water in the tank and the tank environment. Figure B.1 shows the estimated temperature drop in the flow loop over time.

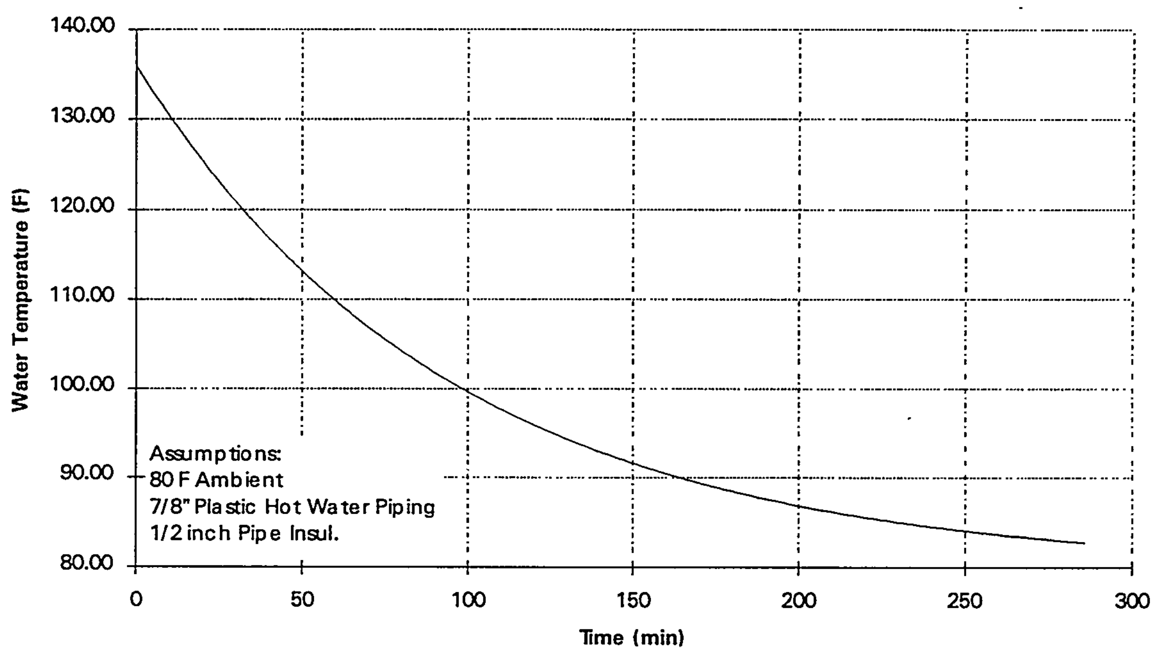


Figure B.1 Temperature Decay for Hot Water in Seahorse Flow Loop

The cycle time for the Seahorse is defined as the time between the start of the Seahorse flow loop pump, through the period of Seahorse shut down and tank standby up to the time the Seahorse pump starts again. It is primarily of interest for periods of no residential hot water consumption. During these periods, the cycle time is primarily a function of the heat loss from the tank and the thermostat differential. By using the estimated tank heat loss rate is was possible to determine the total heat needed by the tank over a given cycle time. The delivery-to-tank efficiency during periods of no hot water consumption can be estimated for a given cycle time as

$$\textit{Seahorse-Tank Delivery Efficiency} = \frac{(\textit{Tank Heat Loss})}{(\textit{Tank Heat Loss} + \textit{Flow Loop Heat Loss}) \div \textit{Seahorse Thermal Efficiency}}$$

where tank heat loss and flow loop heat loss are calculated over the length of the cycle period.

Figure B.2 shows the estimated delivery to tank efficiency as a function of cycle time for periods of no hot water consumption. As can be seen, short cycle periods can have a significant negative affect on the system efficiency.

The simple methodology shown here results in rough estimates for the Seahorse technology. Since it assumes a completely insulated flow loop and does not separately identify the loss rates from the external, uninsulated heat exchanger, it probably underestimates the degradation in efficiency with cycle time. It does however, give an idea of the effect of cycle time on Seahorse efficiency for a set-up similar to the Fort Stewart demonstration.

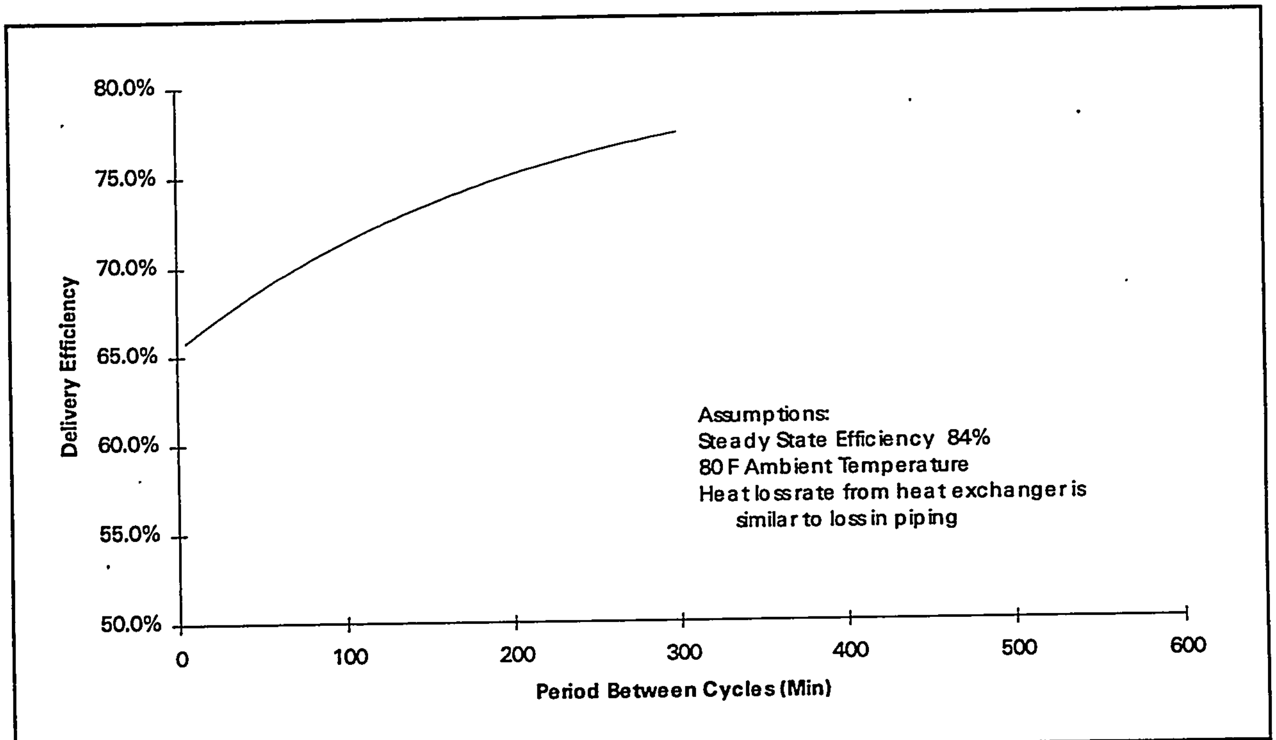


Figure B.2 Estimated Seahorse Delivery-to-Tank Efficiency vs. Cycle Time -- No Residential Hot Water Consumption

Appendix C

Collected Field Data - Daily Averages

DAY Julian Date	TIME HH/MM/SS	21X_T(C) C	BATVOLT Volts	OAT F	GAS_T F	ROOM_T F	TANK_T F	BAR_P PSI	DIFF_P PSI	PUMP_W Watts	TOUT_SH F	DT_SH F	TOUT_ TANK TO SH F	DT_TANK F	BTU TO TANK Btu	DT_LOOP F	LOOP FLOW Gal	RESFLOW Gal	TIN TANK F	TOUT TANK TO RES F	BTU2RES Btu	GAS_SH Cubic Ft.	GAS_RES Cubic Ft.	DT_LOOP F
01-Apr-94	00:00:00																							
02-Apr-94	00:00:00	24.483	13.887	64.686	65.208	72.812	145.971	15.006	3.305	11.887	172.306	22.902	149.484	21.467	229.017	0.526	1.372	0.368	69.063	142.095	225.706	0.329	0.313	22.962
03-Apr-94	00:00:00	26.159	13.842	68.536	68.602	76.097	145.880	14.928	3.266	10.970	172.379	22.921	149.603	21.472	204.978	0.527	1.202	0.290	72.797	138.205	180.447	0.289	0.497	22.910
04-Apr-94	00:00:00	27.701	13.805	69.277	69.086	79.623	146.245	14.882	3.231	13.389	172.045	22.683	149.488	21.284	264.935	0.521	1.608	0.422	73.351	142.580	269.836	0.387	0.802	22.624
05-Apr-94	00:00:00	25.168	13.870	70.637	70.651	74.596	146.096	14.868	3.289	12.755	172.002	22.522	149.614	21.034	247.306	0.515	1.516	0.364	71.883	142.661	238.011	0.364	0.351	22.483
06-Apr-94	00:00:00	27.688	13.807	72.446	71.412	78.719	146.282	14.857	3.231	11.837	171.738	22.119	149.707	20.676	194.995	0.506	1.334	0.288	72.557	147.938	186.519	0.321	0.312	21.986
07-Apr-94	00:00:00	26.277	13.842	67.764	70.057	75.505	146.253	14.952	3.263	14.276	171.841	22.478	149.470	21.118	280.721	0.516	1.733	0.436	71.493	146.808	284.913	0.424	0.406	22.469
08-Apr-94	00:00:00																							
09-Apr-94	00:00:00	26.851	13.830	70.979	71.082	76.965	144.737	15.025	3.251	11.314	172.071	22.760	149.434	21.392	220.831	0.524	1.295	0.335	72.314	139.452	170.740	0.303	0.295	22.774
10-Apr-94	00:00:00	26.970	13.827	74.573	74:407	77.226	143.699	14.992	3.249	10.063	172.198	22.528	149.690	21.181	175.417	0.519	1.073	0.243		139.016	100.326	0.251	0.243	22.527
11-Apr-94	00:00:00	26.221	13.843	76.065	75.947	75.919	143.671	15.000	3.265	13.582	169.787	22.394	147.486	21.043	299.290	0.515	1.730	0.454		143.325	225.403	0.404	0.389	22.403
12-Apr-94	00:00:00	27.094	13.824	75.225	74.051	77.594	143.745	14.978	3.245	10.918	172.206	22.626	149.632	21.364	200.838	0.524	1.233	0.307		142.620	136.870	0.291	0.281	22.726
13-Apr-94	00:00:00	27.747	13.805	71.169	71.330	78.481	143.723	14.888	3.228	10.372	171.997	22.565	149.523	21.230	181.534	0.520	1.129	0.288		141.381	118.343	0.265	0.257	22.548
14-Apr-94	00:00:00	26.963	13.829	75.788	75.712	77.163	143.700	14.914	3.247	8.542	172.383	22.589	149.892	21.223	118.607	0.518	0.795	0.180		140.399	58.367	0.190	0.181	22.548
15-Apr-94	00:00:00	27.155	13.825	80.107	79.178	77.717	143.763	14.907	3.243	10.378	172.088	22.471	149.622	21.205	186.493	0.518	1.139	0.291		140.955	123.469	0.273	0.264	22.520
16-Apr-94	00:00:00	26.827	13.830	74.593	76.000	76.926	143.651	14.929	3.250	11.309	172.030	22.546	149.545	21.255	209.210	0.520	1.285	0.309		143.092	147.141	0.311	0.299	22.593
17-Apr-94	00:00:00	26.504	13.837	70.580	71.945	76.365	143.434	14.979	3.260	11.763	172.215	23.019	149.312	21.795	212.970	0.532	1.243	0.313		141.606	156.802	0.326	0.320	23.145
18-Apr-94	00:00:00	26.650	13.836	74.009	74.542	76.626	143.654	14.978	3.257	10.453	172.159	22.570	149.616	21.309	178.035	0.521	1.132	0.259		142.357	118.858	0.269	0.260	22.661
19-Apr-94	00:00:00	27.066	13.825	76.271	76.752	77.393	143.624	14.961	3.247	11.023	171.952	22.491	149.491	21.170	208.088	0.518	1.250	0.282		137.999	132.422	0.295	0.285	22.515
20-Apr-94	00:00:00	27.319	13.820	79.421	79.392	77.994	143.649	14.919	3.241	11.068	171.931	22.373	149.599	21.037	204.287	0.514	1.268	0.295		146.088	147.487	0.301	0.288	22.310
21-Apr-94	00:00:00	27.450	13.816	77.363	76.621	78.251	143.648	14.886	3.238	9.991	172.014	22.469	149:585	21:157	172.664	0.517	1.094	0.248		143.481	108.023	0.253	0.246	22.458
22-Apr-94	00:00:00	27.489	13.813	73.245	73.304	78.294	143.630	14.847	3.236	8.734	172.304	22.501	149.871	21.106	127.253	0.516	0.837	0.176		142.236	63.075	0.197	0.191	22.399
23-Apr-94	00:00:00	26.806	13.832	66.812	68.442	76.648	143.555	14.918	3.253	8.616	172.417	22.694	149.826	21.340	116.678	0.522	0.785	0.158		141.919	51.196	0.190	0.180	22.708
24-Apr-94	00:00:00	26.304	13.843	72.018	72.315	75.979	143.515	14.920	3.264	9.067	172.285	22.491	149.815	21.199	134.023	0.518	0.865	0.169		141.474	65.987	0.211	0.205	22.522
25-Apr-94	00:00:00	27.116	13.825	75.732	75.178	77.584	143.627	14.894	3.246	9.023	172.110	22.436	149.729	21.095	165.224	0.515	1.021	0.231		141.829	98.619	0.243	0.236	22.395
26-Apr-94	00:00:00	27.318	13.817	76.335	75.215	78.169	143.797	14.913	3.242	9.364	172.021	22.328	149.737	21.009	141.124	0.513	0.927	0.248		138.305	82.862	0.225	0.215	22.299
27-Apr-94	00:00:00	27.978	13.800	78.278	77.561	78.654	143.676	14.945	3.226	10.838	172.136	22.667	149.542	21.349	202.711	0.522	1.205	0.306		138.770	132.308	0.292	0.281	22.631
28-Apr-94	00:00:00	26.713	13.833	78.202	78.071	76.905	143.661	14.980	3.256	10.155	172.187	22.505	149.770	21.091	172.294	0.515	1.080	0.280		137.303	107.974	0.259	0.250	22.415
29-Apr-94	00:00:00	27.021	13.828	76.868	76.741	77.459	143.803	14.986	3.249	12.478	171.815	22.471	149.448	21.042	245.775	0.514	1.493	0.419		139.540	181.510	0.358	0.346	22.336
30-Apr-94	00:00:00	26.930	13.827	76.995	76.336	77.209	143.417	14.931	3.251	10.813	171.843	22.539	149.371	21.209	200.250	0.518	1.177	0.342		133.245	131.697	0.291	0.278	22.494
01-May-94	00:00:00	28.255	13.793	80.154	79.158	79.542	143.732	14.881	3.220	11.563	171.769	22.489	149.379	21.053	221.578	0.514	1.320	0.369		134.892	155.893	0.322	0.313	22.329
02-May-94	00:00:00	26.815	13.831	73.571	73.579	76.861	143.718	14.910	3.254	11.067	172.181	22.617	149.673	21.219	201.570	0.519	1.247	0.350		137.930	135.749	0.296	0.288	22.546
03-May-94	00:00:00	26.691	13.836	73.427	73.444	76.700	143.538	14.886	3.256	9.193	172.320	22.687	149.668	21.386	141.214	0.523	0.896	0.285		134.255	75.219	0.218	0.208	22.731
04-May-94	00:00:00	26.978	13.827	65.888	67.483	77.196	143.721	14.844	3.249	9.837	171.877	22.419	149.654	20.993	145.469	0.512	0.983	0.294		138.440	84.911	0.236	0.229	22.280
05-May-94	00:00:00	26.064	13.849	69.512	70.325	75.087	143.548	14.912	3.270	10.393	172.207	22.648	149.681	21.330	182.936	0.521	1.118	0.302		139.201	115.360	0.270	0.264	22.685
06-May-94	00:00:00	25.918	13.851	73.400	72.745	75.555	143.564	14.933	3.274	11.346	172.128	22.527	149.626	21.220	213.832	0.519	1.288	0.320		143.497	152.227	0.308	0.295	22.607
07-May-94	00:00:00	26.524	13.842	75.734	72.214	76.388	143.313	14.873	3.260	12.913	171.734	22.771	149.024	21.502	282.920	0.525	1.604	0.418		142.765	215.678	0.386	0.379	22.850
08-May-94	00:00:00	26.415	13.841	75.674	74.818	76.038	143.430	14.821	3.263	11.517	171.750	22.332	149.441	20.994	212.793	0.513	1.323	0.308		142.370	146.866	0.320	0.312	22.327
09-May-94	00:00:00	26.480	13.838	75.148	72.825	76.650	143.789	14.881	3.262	11.515	171.598	21.828	149.838	20.374	186.616	0.498	1.320	0.246		147.825	127.634	0.310	0.302	21.661
10-May-94	00:00:00	26.598	13.840	73.497	73.153	76.551	143.704	14.906	3.260	10.782	171.655	21.993	149.789	20.577	162.954	0.503	1.160	0.241		147.560	120.347	0.284	0.274	21.875
11-May-94	00:00:00	26.643	13.837	77.826	75.158	76.698	143.529	14.915	3.259	11.007	171.837	22.210	149.678	20.882	191.990	0.510	1.230	0.281		145.622	141.742	0.296	0.288	22.191
12-May-94	00:00:00	26.686	13.837	80.037	77.980	76.728	143.581	14.852	3.258	10.331	171.859	22.200	149.725	20.887	179.646	0.510	1.118	0.274		143.537	122.768	0.271	0.264	22.188
13-May-94	00:00:00	26.501	13.836	76.424	74.798	76.498	143.492	14.878	3.262	10.329	171.924	22.205	149.700	20.970	173.528	0.513	1.101	0.259		144.665	119.433	0.266	0.257	22.296
14-May-94	00:00:00	26.846	13.832	79.233	77.509	77.312	143.566	14.900	3.253	10.930	172.026	22.482	149.551	21.233	202.243	0.519	1.229	0.307		141.943	142.649	0.300	0.285	22.551
15-May-94	00:00:00	27.272	13.820	77.751	75.863	77.542	143.585	14.883	3.263	11.086	171.693	22.206	149.503	20.894	207.698	0.511	1.243	0.323		139.746	147.400	0.303	0.295	22.177
16-May-94	00:00:00	26.026	13.849	81.218	79.000	75.548	143.532	14.840	3.272	11.460	172.100	22.420	149.649	21.230	232.139	0.519	1.320	0.360		138.055	159.397	0.326	0.316	22.601
17-May-94	00:00:00	26.178	13.846	78.856	77.043	75.753	143.566	14.838	3.269	10.254	172.178	22.389	149.745	21.171	178.050	0.517	1.097	0.275		141.406	119.540	0.268	0.260	22.509
18-May-94	00:00:00	26.140	13.847	74.729	73.363	76.173	143.463	14.827	3.270	9.572	172.149	22.506	149.707	21.266	153.307	0.521	0.962	0.209		141.160	91.720	0.235	0.229	22.668
19-May-94	00:00:00	26.673	13.833	65.011	66.691	76.627	143.532	14.824	3.258	10.934	171.834	22.367	149.658	20.965	180.587	0.513	1.174	0.273		144.128	122.701	0.286	0.320	22.279
20-May-94	00:00:00	25.830	13.853	66.250	66.266	74.899	143.254	14.855	3.278	10.590	172.023	22.533	149.603	21.253	177.070	0.520	1.108	0.259		143.464	117.711	0.276	0.266	22.648
21-May-94	00:00:00	25.884	13.851	67.969	67.085	75.393	143.352	14.882	3.277	11.212	171.976	22.513	149.565	21.156	199.160	0.517	1.226	0.293		142.841	141.470	0.304	0.295	22.527
22-May-94	00:00:00	26.232	13.844	74.009	72.850	75.506	143.460	14.881	3.269	10.978	171.947	22.389	149.566	21.155	196.492	0.517	1.209	0.278		142.509	135.180	0.296	0.285	22.504
23-May-94	00:00:00	25.849	13.856	79.998	77.516	75.352	143.383	14.876	3.278	9.039	172.258	22.339	149.817	21.144	135.517	0.520	0.886	0.169		143.492	74.994	0.219	0.212	22.611
24-May-94	00:00:00	26.149	13.840	81.765	78.463	76.859	129.971	14.854	3.271	11.149	170.527	21.319	149.327	19.788	242.399	0.491	1.278	0.359		140.583	201.061	0.310	0.302	21.330
25-May-94	00:00:00	26.178	13.844	82.048	79.353	76.540	127.454	13.668	3.264	10.890	178.141	24.402	153.375	23.452	235.004	0.503	1.171	0.434	76.126	134.328	188.882	0.311	0.300	25.226
26-May-94	00:00:00	26.162	13.842	80.617	78.317	76.603	132.564	14.805	3.270	12.864	166.203	22.770	141.439	21.903	295.513	0.526	1.629	0.464	76.554	128.970	225.429	0.396	0.378	22.895
27-May-94	00:00:00	27.084	13.822	78.532	78.147	78.149	134.955	14.835	3.249	8.916	163.163	22.781	140.465	21.577	155.686	0.514	0.924	0.179	77.332	128.651	96.236	0.216	0.208	22.375
28-May-94	00:00:00	26.417	13.840	75.539	74.937	76.697	135.775	14.900	3.264	8.786	164.698	22.667	141.892	21.787	153.101	0.520	0.899	0.159	76.597	128.581	83.979	0.211	0.201	22.660
29-May-94	00:00:00	25.667	13.853	78.474	77.561	75.550	135.514	14.948	3.282	9.283	164.431	22.902	141.619	21.775	168.981	0.521	1.007	0.184	75.828	128.195	98.004	0.233	0.222	22.660
30-May-94	00:00:00	26.118	13.845	72.862	72.981	76.090	133.357	14.920	3.270	10.560	157.207	19.062	138.880	17.735	168.976	0.430	1.226	0.237	76.108	129.162	120.932	0.258	0.246	10.713
31-May-94	00:00:00	26.418	13.840	81.442	79.202	77.538	134.299	14.896	3.263	10.284	159.665	20.125	139.993	18.309	148.028	0.444	1.164	0.197	75.287	133.357	103.567	0.232	0.226	19.346
01-Jun-94	00:00:00	27.239	13.820	81.692	79.766	78.449	132.789	14.893	3.244	13.290	153.178	16.160	137.804	14.910	205.441	0.359	1.705	0.327	75.853	134.587	165.852	0.321	0.309	15.643
02-Jun-94	00:00:00	26.759	13.835	80.789	78.707	77.499	133.794	14.892	3.256	8.291	161.063	21.749	139.716	20.861	130.081	0.507	0.836	0.133	77.394	128.018	68.655	0.191	0.184	22.024
03-Jun-94	00:00:00	26.426	13.839	81.800	78.655	77.352	135.467	14.892	3.262	7.798	164.613	22.892	141.866	21.655	119.977	0.524	0.740	0.100	76.422	130.874	53.393	0.171	0.163	22.794
04-Jun-94	00:00:00	27.487	13.814	78.527	76.543	78.606	131.968	14.890	3.237	7.760	152.416	16.210	136.742	14.910	49.790	0.353	0.674	0.030	78.136	126.547	14.988	0.121	0.118	15.375
05-Jun-94	00:00:00	25.430	13.863	77.778	76.410	74.980	132.081	14.899	3.285	10.362	151.695	15.214	137.179	14.131	131.823	0.337	1.153	0.176	75.906	125.985	84.227	0.222	0.215	14.694
06-Jun-94	00:00:00	25.732	13.854	78.817	77.135	75.905	134.655	14.870	3.277	9.117	162.581	22.754	139.938	21.491	149.219	0.523	0.875	0.200	76.591	127.537	102.412	0.228	0.219	22.743
07-Jun-94	00:00:00	25.789	13.852	78.140	76.930	75.643	134.919	14.832	3.275	7.485	163.450	22.659	140.813	21.483	99.457	0.524	0.622	0.083	76.102	127.785	42.230	0.150	0.146	22.794
08-Jun-94	00:00:00	26.146	13.849	83.667	80.799	77.013	131.073	14.827	3.267	8.457	148.681	14.344	135.331	13.976	64.009	0.335	0.761	0.069	76.329	127.554	33.579	0.153	0.145	16.636
09-Jun-94	00:00:00	26.352	13.841	80.018	77.631	76.772	132.046	14.866	3.261	9.503	150.879	15.144	136.663	13.961	101.697	0.337	0.949	0.131	77.079	127.346	64.511	0.190	0.184	14.671
10-Jun-94	00:00:00	25.740	13.855	81.722	79.113	75.744	132.072	14.867	3.277	8.762	157.918	21.046	136.979	20.461	133.472	0.492	0.668	0.174	76.489	127.129	88.030	0.209	0.201	21.446
11-Jun-94	00:00:00	25.597	13.858	82.372	79.276	75.670	131.115	14.881	3.282	6.467	158.490	22.143	136.538	20.654	57.830	0.494	0.448	0.002	75.833	123.853	1.630	0.106	0.101	21.548
12-Jun-94	00:00:00	25.686	13.855	80.552	77.631	75.684	130.406	14.908	3.279	8.532	143.871	10.329	134.684	9.068	27.767	0.203	0.761	0.001	75.957	122.778	1.269	0.122	0.121	8.898
13-Jun-94	00:00:00	25.716	13.854	81.935	79.364	75.803	130.407	14.922	3.278	8.688	142.612	9.213	134.689	8.062	24.701	0.182	0.779	0.001	76.139	122.680	1.262	0.122	0.118	7.958
14-Jun-94	00:00:00	26.109	13.847	83.161	79.656	76.627	130.535	14.927	3.270	9.179	143.682	10.412	135.354	9.227	55.656	0.224	0.876	0.077	76.983	123.970	35.670	0.159	0.156	9.798
15-Jun-94	00:00:00	26.583	13.836	79.987	77.070	77.327	130.425	14.950	3.257	9.985	142.991	9.487	135.133	7.166	58.488	0.173	1.008	0.084	77.731	124.794	39.299	0.168	0.166	7.577

16-Jun-94	00:00:00	26.756	13.834	78.136	76.461	77.619	130.386	14.935	3.252	10.354	142.150	8.556	134.961	5.780	56.336	0.137	1.071	0.082	77.856	124.734	38.174	0.167	0.163	6.000
17-Jun-94	00:00:00	27.469	13.814	79.975	79.015	78.916	130.633	14.902	3.234	10.085	143.261	9.713	135.108	7.403	57.884	0.176	1.022	0.090	78.037	127.306	41.794	0.169	0.166	7.705
18-Jun-94	00:00:00	26.614	13.837	76.653	75.889	77.042	131.472	14.895	3.255	9.633	148.633	13.650	136.509	11.639	86.026	0.284	0.932	0.123	77.514	124.953	57.311	0.185	0.180	12.414
19-Jun-94	00:00:00	26.528	13.837	78.000	76.763	77.093	133.412	14.897	3.257	8.013	161.256	22.355	139.378	20.662	117.914	0.509	0.736	0.136	77.274	127.893	64.234	0.176	0.170	22.100
20-Jun-94	00:00:00	26.349	13.842	84.694	80.471	76.958	130.464	14.884	3.261	11.303	145.051	11.320	135.105	9.781	124.951	0.235	1.286	0.220	77.183	125.987	103.054	0.244	0.232	10.266
21-Jun-94	00:00:00	27.183	13.822	85.012	81.375	78.809	130.628	14.854	3.243	10.292	143.382	9.823	135.167	8.079	73.415	0.195	1.078	0.126	78.472	125.038	59.191	0.187	0.184	8.524
22-Jun-94	00:00:00	27.391	13.817	85.956	82.838	78.932	130.668	14.839	3.238	9.817	144.235	10.698	135.214	9.010	68.253	0.216	0.987	0.111	79.286	123.929	51.945	0.178	0.173	9.445
23-Jun-94	00:00:00	26.695	13.836	81.832	80.064	77.503	130.656	14.840	3.255	9.169	145.124	11.763	135.367	11.110	60.867	0.268	0.931	0.089	78.413	122.706	40.746	0.166	0.163	11.709
24-Jun-94	00:00:00	27.067	13.825	80.174	78.005	78.380	130.906	14.824	3.245	11.555	146.317	12.537	135.352	10.819	135.170	0.262	1.338	0.252	79.369	124.531	116.267	0.258	0.253	11.450
25-Jun-94	00:00:00	26.424	13.841	77.084	75.749	76.856	130.486	14.874	3.262	11.147	144.220	10.747	135.221	8.966	92.641	0.216	1.244	0.171	77.945	123.237	77.874	0.215	0.208	9.458
26-Jun-94	00:00:00	26.166	13.848	77.941	76.411	76.332	130.493	14.908	3.268	10.824	143.649	10.067	135.295	7.686	85.288	0.187	1.157	0.146	77.137	122.396	67.017	0.202	0.196	8.192
27-Jun-94	00:00:00	26.197	13.846	83.783	80.416	77.119	131.588	14.872	3.265	10.153	150.284	15.111	136.559	13.690	119.407	0.335	1.077	0.191	77.608	124.786	89.778	0.218	0.212	14.588
28-Jun-94	00:00:00	26.830	13.830	81.224	78.830	77.639	130.639	14.887	3.251	9.513	145.380	11.435	135.453	9.108	60.147	0.223	0.928	0.078	78.068	122.202	36.193	0.165	0.163	9.719
29-Jun-94	00:00:00	26.654	13.834	79.953	78.380	77.781	130.879	14.870	3.255	9.553	145.822	11.935	135.501	10.101	69.952	0.246	0.949	0.101	78.127	123.121	46.307	0.171	0.166	10.743

Appendix D

BLCC4 Economic Inputs and Life-Cycle Cost Output

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***********************************************************************
*        N I S T   B L C C 4.0   I N P U T   D A T A   L I S T I N G     *
***********************************************************************
```

FILE NAME: SEAH001
FILE LAST MODIFIED ON 07-29-1994/13:31:25
PROJECT ALTERNATIVE: Seahorse
COMMENT: Seahorse Water Heater/1:Seahorse

GENERAL DATA:

ANALYSIS TYPE: Federal Analysis--Energy Conservation Projects
BASE DATE FOR LCC ANALYSIS: JUL 1994
STUDY PERIOD: 15 YEARS, 0 MONTHS
SERVICE DATE: JUL 1994
DISCOUNT AND INTEREST RATES ARE Real (exclusive of general inflation)
DISCOUNT RATE: 3.1%
Escalation rates do not include general inflation

CAPITAL ASSET COST DATA:

INITIAL COST (BASE YEAR $)	1,018
EXPECTED ASSET LIFE (YRS/MTHS)	15/0
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	1

REPLACEMENTS TO CAPITAL ASSETS:

REPLACEMENT NUMBER	1
YEARS/MONTHS FROM SERVICE DATE	5/0
INITIAL COST (BASE YEAR $)	366
EXPECTED REPL. LIFE (YRS/MTHS)	10/0
RESALE VALUE FACTOR	0.00%

OPERATING, MAINTENANCE, AND REPAIR COST DATA:

ANNUAL RECUR OM&R COST ($): 0

No non-annually-recurring OM&R costs reported.

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2
DOE energy price escalation rates filename: ENCOST94
DOE region (state code): 3 (GA)
DOE rate schedule type: Industrial
Underlying gen. inflation rate used with DOE rates: 0.00%

	TYPE 1	TYPE 2
ENERGY TYPE:	Electricity	Natural Gas
BASE ANNUAL CONSUMPTION:	86	25
UNITS:	kWh	MBtu
PRICE PER UNIT ($):	0.025	3.000
ANNUAL DEMAND CHARGE ($):	1.00	0.00
ESCALATION RATE METHOD:	DOE rates	DOE rates
1994	0.39	3.38
1995	0.24	1.98
1996	0.38	3.16
1997	0.59	4.11
1998	1.24	4.75
1999	1.12	5.03

2000	0.67	5.22
2001	1.00	5.69
2002	1.09	4.99
2003	0.62	3.47
2004	0.29	2.23
2005	0.29	1.94
2006	0.36	2.02
2007	-0.03	0.94
2008	0.00	0.35

* *
*   NIST BLCC 4.0: DETAILED LCC ANALYSIS   *
* *

PART I - INITIAL ASSUMPTIONS AND COST DATA

Project alternative: Seahorse
Run date: 07-29-1994 13:33:51
Run type: Federal Analysis--Energy Conservation Projects
Comment: Seahorse Water Heater/1:Seahorse
Input data file: SEAH001.DAT, last modified: 07-29-1994/13:31:25
LCC output file: SEAH001.LCC, created: 07-29-1994/13:31:32
Base Date of Study: JUL 1994
Service Date: JUL 1994
Study period: 15.00 years (JUL 1994 through JUN 2009)
Discount rate: 3.1% Real (exclusive of general inflation)
End-of-year discounting convention

INITIAL CAPITAL ASSET COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL INITIAL CAPITAL ASSET COSTS	$1,018

ENERGY-RELATED COSTS

ENERGY TYPE	UNITS	UNITS/ YEAR	PRICE ($/UNIT)	AN. DEMAND COST	TOTAL P.V. COST
Electricity	kWh	86	$0.025	$1	$37
Natural Gas	MBtu	25	$3.000	$0	$1,090

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* *

PART II - LIFE-CYCLE COST ANALYSIS
DISCOUNT RATE = 3.1% Real (exclusive of general inflation)

PROJECT ALTERNATIVE: Seahorse RUN DATE: 07-29-1994/13:33:51

	PRESENT VALUE (1995 DOLLARS)	ANNUAL VALUE (1995 DOLLARS)
CASH REQUIREMENTS AS OF SERVICE DATE	$1,018	$86
OPERATING, MAINTENANCE & REPAIR COSTS:		
SUBTOTAL	$0	$0
ENERGY COSTS	$1,127	$95
REPLACEMENTS TO CAPITAL COMPONENTS	$314	$27
RESALE VALUE OF ORIG CAPITAL COMPONENTS	$0	$0
RESALE VALUE OF CAPITAL REPLACEMENTS	$0	$0

TOTAL LIFE-CYCLE PROJECT COST	$2,459	$207

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*        N I S T  B L C C 4.0  I N P U T  D A T A  L I S T I N G     *
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FILE NAME: ELECH001
FILE LAST MODIFIED ON 07-14-1994/22:19:09
PROJECT ALTERNATIVE: Elec Heat
COMMENT: Seahorse Water Heater/2:Elec Heat

GENERAL DATA:

ANALYSIS TYPE: Federal Analysis--Energy Conservation Projects
BASE DATE FOR LCC ANALYSIS: JUL 1994
STUDY PERIOD: 15 YEARS, 0 MONTHS
SERVICE DATE: JUL 1994
DISCOUNT AND INTEREST RATES ARE Real (exclusive of general inflation)
DISCOUNT RATE: 3.1%
Escalation rates do not include general inflation

CAPITAL ASSET COST DATA:

INITIAL COST (BASE YEAR $)	0
EXPECTED ASSET LIFE (YRS/MTHS)	5/0
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	1

REPLACEMENTS TO CAPITAL ASSETS:

REPLACEMENT NUMBER	1
YEARS/MONTHS FROM SERVICE DATE	5/0
INITIAL COST (BASE YEAR $)	366
EXPECTED REPL. LIFE (YRS/MTHS)	10/0
RESALE VALUE FACTOR	0.00%

OPERATING, MAINTENANCE, AND REPAIR COST DATA:

ANNUAL RECUR OM&R COST ($): 0

No non-annually-recurring OM&R costs reported.

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2
DOE energy price escalation rates filename: ENCOST94
DOE region (state code): 3 (GA)
DOE rate schedule type: Industrial
Underlying gen. inflation rate used with DOE rates: 0.00%

	TYPE 1	TYPE 2
ENERGY TYPE:	Electricity	Natural Gas
BASE ANNUAL CONSUMPTION:	4800	0
UNITS:	kWh	MBtu
PRICE PER UNIT ($):	0.025	3.000
ANNUAL DEMAND CHARGE ($):	56.00	0.00
ESCALATION RATE METHOD:	DOE rates	DOE rates
1994	0.39	3.38
1995	0.24	1.98
1996	0.38	3.16
1997	0.59	4.11
1998	1.24	4.75
1999	1.12	5.03

2000	0.67	5.22
2001	1.00	5.69
2002	1.09	4.99
2003	0.62	3.47
2004	0.29	2.23
2005	0.29	1.94
2006	0.36	2.02
2007	-0.03	0.94
2008	0.00	0.35

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*                  NIST BLCC 4.0: DETAILED LCC ANALYSIS                         *
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PART I - INITIAL ASSUMPTIONS AND COST DATA

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Project alternative: Elec Heat
Run date: 07-15-1994 10:02:14
Run type: Federal Analysis--Energy Conservation Projects
Comment: Seahorse Water Heater/2:Elec Heat
Input data file: ELECH001.DAT, last modified: 07-14-1994/22:19:09
LCC output file: ELECH001.LCC, created: 07-14-1994/22:19:12
Base Date of Study:   JUL 1994
Service Date:         JUL 1994
Study period:         15.00 years (JUL 1994 through JUN 2009)
Discount rate:         3.1%  Real (exclusive of general inflation)
End-of-year discounting convention
```

INITIAL CAPITAL ASSET COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL INITIAL CAPITAL ASSET COSTS'	$0

ENERGY-RELATED COSTS

ENERGY TYPE	UNITS	UNITS/ YEAR	PRICE ($/UNIT)	AN. DEMAND COST	TOTAL P.V. COST
Electricity	kWh	4,800	$0.025	$56	$2,066
Natural Gas	MBtu	0	$3.000	$0	$0

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PART II - LIFE-CYCLE COST ANALYSIS
DISCOUNT RATE = 3.1% Real (exclusive of general inflation)

PROJECT ALTERNATIVE: Elec Heat — RUN DATE: 07-15-1994/10:02:14

	PRESENT VALUE (1995 DOLLARS)	ANNUAL VALUE (1995 DOLLARS)
CASH REQUIREMENTS AS OF SERVICE DATE	$0	$0
OPERATING, MAINTENANCE & REPAIR COSTS:		
SUBTOTAL	$0	$0
ENERGY COSTS	$2,066	$174
REPLACEMENTS TO CAPITAL COMPONENTS	$314	$27
RESALE VALUE OF ORIG CAPITAL COMPONENTS	$0	$0
RESALE VALUE OF CAPITAL REPLACEMENTS	$0	$0

TOTAL LIFE-CYCLE PROJECT COST	$2,380	$201

* *

Appendix E

Joint Statement of Work - Seahorse Demonstration

JOINT STATEMENT OF WORK (JSOW)
TEST BED DEMONSTRATION PROJECT

FT. STEWART

DOMESTIC ELECTRIC WATER HEATER NATURAL GAS CONVERSION TEST BED

1.0 BACKGROUND

The Federal government is the largest single consumer of energy in the United States. Although energy use is decreasing, there are opportunities for further reduction. Through its Office of Federal Energy Management Program (FEMP), the U.S. Department of Energy (DOE) has been providing technical and administrative support to Federal agency programs directed at reducing energy consumption and cost in Federal buildings and facilities. One such program is the Test Beds Demonstration Program (TBDP), or test bed.

A test bed is a demonstration of a U.S. energy-related technology at a Federal site. Through a partnership with a Federal site, the utility serving the Federal site, a manufacturer of an energy-related technology, Pacific Northwest Laboratory (PNL), and other organizations associated with these interests, new technologies can be evaluated. The partnership of these interests is secured through a Cooperative Research and Development Agreement (CRADA).

The goals of the Test Bed Demonstration Program are:

- To deploy a new U.S. technology in the Federal sector.
- To improve the energy efficiency of the Federal sector.
- To reduce life cycle costs and improve reliability of Federal installations.
- To stimulate widespread commercialization of U.S. technology.
- To document ways in which Federal facility management can affect change.
- To show that government and industry can work together toward common goals.

2.0 OVERALL PURPOSE AND OBJECTIVES

The purpose of this CRADA is to install, operate, monitor, evaluate and make known the results of the demonstration of a domestic outdoor natural gas conversion kit for an electric water heater installed at Ft. Stewart, Georgia. This JSOW forms part of the Domestic Electric Water Heater Natural Gas Conversion Test Bed CRADA which has as a major objective the rapid and widespread application of this new U.S. technology by the Federal sector.

Gas-Fired Products, Inc. (GFP) and the Public Service Company of North Carolina, Inc. (PSC) objectives are to further document the capability of this technology by installing units in the Federal building environment and having the performance monitored. Atlanta Gas Light's (AGLC's) objectives are to demonstrate the source energy savings and cost effectiveness of retrofitting existing electric water heaters to operate on natural gas. Ft. Stewart's objectives are to reduce energy consumption and cost associated with their operations. The objectives of the United States Army Engineer Division, Huntsville (COE) are to verify the performance of the technology and determine its applicability to additional U.S. Army family housing units world-wide. The secondary objective is to take greater advantage of existing collaborations between product development organizations, the Federal sector, utilities, and associated organizations.

3.0 TECHNICAL OBJECTIVES

The technical objectives of this collaboration are derived from the requirements within the FEMP and present technology deployment and energy conservation efforts within the heating, ventilating, and air conditioning industry and utility sector. These objectives will be met by work to be done by PNL staff, GFP, Ft. Stewart, AGLC, COE, and PSC and their joint efforts. The results of this collaboration will include a high-level data reporting, analysis, and management system to support the deployment efforts associated with the technology. The technical objectives are:

- Successfully install, commission, operate, maintain, and document the performance of the Seahorse domestic outdoor natural gas conversion kit for an electric water heater.
- Determine the life-cycle cost savings that can be achieved by using the Seahorse outdoor natural gas water heater, based on the documented installed cost and operating and maintenance costs.
- Determine if any specific improvements are required in the Seahorse outdoor natural gas water heater before it can be successfully deployed in the Federal sector.
- Determine the most effective way to facilitate the widespread and rapid deployment of the domestic outdoor natural gas water conversion kit for an electric water heater in the Federal sector and to clearly define any barriers to deployment.

4.0 INDIVIDUAL RESPONSIBILITIES

The approach to achieving the objectives stated above involves extensive collaboration between the PNL, the GFP, Ft. Stewart, COE, AGLC, and the PSC. Each party has roles and responsibilities. Through a synergistic effort a significant advancement in deployment of this technology, necessary to support the increased use of this U.S. technology and reduce Federal energy use, will occur. The overall responsibilities are defined here. Detailed responsibilities are defined in subsequent sections of the JSOW.

PNL will have two primary responsibilities in this collaboration. First PNL will provide overall project management and reporting. Second, PNL will oversee monitoring of the equipment and analysis of the operating data.

GFP will provide the domestic outdoor natural gas conversion kit for the electric water heater and support its maintenance during the demonstration project.

AGLC will provide customer support and energy to Ft. Stewart and the equipment necessary to evaluate the technology and, along with PSC, assist with data acquisition and assessment.

Ft. Stewart will provide facility access and support all efforts to install, operate, and monitor the technology demonstration.

COE will assist with data acquisition and assessment.

PSC will support outreach efforts to communicate the results of the project within the Federal sector.

5.0 DESCRIPTION OF THE OVERALL PROJECT

To demonstrate a new technology, it must be installed, maintained, operated, and monitored. In addition, the results of the installation must be effectively communicated to those in the public and private sectors. The natural gas water heater test bed covered by this JSOW has four distinct areas for activity: planning, execution, documentation, and decommissioning. Within each area numerous tasks are contemplated.

The objective of planning is to ensure that the technology installation at the site can be effectively implemented and that necessary and appropriate data to evaluate the technology will be obtained. This includes tasks related to site preparation, technology procurement and delivery, identification of a methodology to evaluate technology performance, the design of the data acquisition system, and the monitoring and reporting process.

The objective of execution is to obtain the data necessary to serve as a basis for an evaluation of the technology. This includes installing the technology in a single family residence, operating the building and its systems, monitoring the acquisition of data, and maintaining the technology throughout the length of the project.

The objective of documentation is to record and present the results of the project and make them available. This includes data analysis, preparation of final results, and participation in activities to communicate the results of the project in support of technology deployment.

The objective of decommissioning is to remove the technology, if so desired, and the monitoring equipment. This is a return of the installation to its original, or some other agreed upon, condition. The effort described herein anticipates that the technology will perform as expected by the manufacturer. If the technology cannot complete the test, decommissioning will supersede all tasks remaining, except for publication of the final report on the project.

A description of each of the tasks to be performed to meet these objectives is provided in Sections 6.0, 7.0, 8.0, and 9.0. The partners having primary and secondary responsibility are specified for each task. The anticipated deliverable for each task is also stated.

PNL will have the lead responsibility for project management, monthly progress reports, and, with assistance provided by all test bed partners as appropriate (based on who has lead responsibility for the task), all specific reports specified herein.

A composite task-by-task schedule for the project is provided in Section 10.0.

6.0 PLANNING

The planning effort includes those activities necessary to design the project so that the installation of the domestic outdoor natural gas conversion kit for an electric water heater can be made at Ft. Stewart, necessary operating data can be obtained from the test home and the formal technology demonstration can be ended. It includes any activity up to the point where full operation and data acquisition begins in addition to the consideration of what to do when the test is completed.

6.1 Site Selection

Agreement will be reached between PNL and Ft. Stewart in developing a list of candidate houses. This will include agreement as to which week PNL will enter the housing units for instrumentation installation. PNL will provide an estimate of the time needed in a housing unit for doing this work. PNL will provide a descriptive letter for the base housing office to supply to the occupants that explains the nature of the test. The base shall work from the list of candidate houses to designate a house with occupants who have expressed a willingness to participate. The base ensures that PNL staff will have access to the housing unit during the designated installation week. If the occupants are not present during the designated installation week, the base will provide means to enter the unit and complete the installation work. If necessary, this would include an MP escort for PNL staff during the installation work.

Primary responsibility: Ft. Stewart and PNL.

Deliverable: Identification of candidate housing units which provide the necessary access for the completion of this test bed demonstration.

Planned Start: 1/94 Planned Completion: 2/94

6.2 Site Evaluation

Obtain a description of candidate single family homes, their present occupant load conditions related to water heating, and available information about past operation, maintenance, and control of the energy systems that will be replaced or modified. This must include necessary schematics, energy and water consumption and billing information, maintenance records, and photographs, as well as other information necessary to portray the building and its water heating system as it currently exists. This information must emphasize and detail those parts of the building and energy systems that will be changed pursuant to the project and which will impact the validity of any tests associated with the technology.

Primary responsibility: Ft. Stewart.

Secondary responsibility: PNL.

Deliverable: A report detailing the "before" condition of the home and its domestic hot water system that focuses on those aspects of the building and energy systems to which the new technology will apply and reduce energy use and cost.

Planned Start: 1/94 Planned Completion: 2/94

6.3 Equipment Specification and Delivery

Based on the description of the existing building and domestic hot water system installation and operating history, provide the necessary drawings, operations and maintenance manuals, specifications, and instructions for the modification of the existing water heater and installation and commissioning of the domestic outdoor natural gas conversion kit for an electric water heater. This will include those items that must be modified on site to accommodate the technology, as well as equipment and accessories that must be delivered. Deliver to the site the domestic outdoor natural gas conversion kit for an electric water heater and any necessary accessories (such as tools, fixtures, materials, and consumables) required to install, maintain, and commission the technology. Representatives of AGLC shall be provided training in the operation and maintenance of this technology. Although Federal facility staff are not to be responsible for any service and maintenance, they too must be provided training to understand the operation and maintenance of the technology. Also provide a baseline operating specification and a statement of technology goals in terms of fuel consumption, reduction, availability and reliability, service and maintenance.

Primary responsibility: GFP and PSC.

Secondary responsibility: Ft. Stewart and PNL.

Deliverables: The domestic outdoor natural gas conversion kit for an electric water heater, drawings, operations and maintenance manuals, specifications, replacement parts, and instructions that will ensure the proper installation, maintenance, and commissioning of the technology; and any accessories necessary to facilitate technology installation and commissioning.

Planned Start: 1/94 Planned Completion: 2/94

6.4 Technology Monitoring Design and Delivery

Design a monitoring approach for the project based on the description of the homes outlined in Section 6.2, the domestic outdoor natural gas conversion kit for an electric water heater, the installation instructions, the report on the "before" condition of the building, and information that will be needed to evaluate the technology. This will include defining what is to be measured and logged, the method of measurement, the increment at which measurement should be taken, the method of data acquisition and reporting, and the necessary report formats, forms, and log sheets to be used. In addition, provide the monitoring equipment and necessary installation, operation, and maintenance instructions for the test home. Also develop and define the quality assurance program for the acquisition of the performance and the operations and maintenance data.

Primary responsibility: PNL.

Secondary responsibility: GFP, PSC, COE and AGLC.

Deliverable: A plan for technology monitoring, installation, operating and maintenance instructions for the data acquisition equipment, and delivery of the necessary equipment to implement the technology monitoring plan.

Planned Start: 1/94 Planned Completion: 2/94

6.5 Technology and Monitoring Installation

Install the technology and the data acquisition equipment based on the instructions and plan prepared pursuant to Sections 6.3 and 6.4 above. Where necessary, conduct testing and field verification work to further establish both the "before" conditions for the test and baseline upon which the technology will be evaluated. The energy required to operate the domestic outdoor natural gas conversion kit for an electric water heater must be provided, as well as any associated natural gas piping and connections necessary to facilitate the installation. Subsequent to installation, commission the technology and the data acquisition equipment and conduct a test to verify that it will properly function; that all necessary data are being obtained and can be secured according to the technology monitoring plan.

Primary responsibility for technology side: GFP.

Secondary responsibility for technology side: Ft. Stewart.

Primary responsibility for monitoring side: PNL.

Secondary responsibility for monitoring side: AGLC and COE.

Primary responsibility for gas supply and piping: AGLC

Secondary responsibility for gas supply and piping: Fort Stewart

Deliverable: A report documenting the installation process, documenting that the installation is functioning properly, and that it is being properly monitored.

Planned Start: 1/94 Planned Completion: 2/94

6.6 Technology Decommissioning

To provide for the completion of the test and possible removal or continuation of the operation, a plan for responsibilities under technology and removal scenarios must be prepared. This plan must also include a contingency plan to address the early forced removal of the technology due to failure of the technology or catastrophic events which could adversely impact the specific site or Ft. Stewart.

Primary responsibility: PNL.

Secondary responsibility: Ft. Stewart.

Deliverable: A plan for unscheduled and scheduled decommissioning of the technology.

Planned Start: 3/94 Planned Completion: 3/94

7.0 EXECUTION

The execution effort includes those activities necessary to operate, maintain, monitor, and document the performance of the domestic outdoor natural gas conversion kit for an electric water heater throughout the project and to ensure that information on the progress and results associated with the project is made available to those associated with the project.

7.1 Performance Monitoring and Data Acquisition

Monitor the operation of the domestic outdoor natural gas conversion kit for an electric water heater and other building and system functions pursuant to Section 6.4. This includes acquisition of all data (at specified intervals) that are defined as critical to technology performance monitoring, and conduct of data validation tests to ensure that accurate data are being obtained. Carry out calibration of any automated data acquisition equipment throughout the test, as required. Implement all quality assurance program tasks associated with performance and operations and maintenance data acquisition.

Primary responsibility: PNL.

Secondary responsibility: AGLC and COE.

Deliverable: Monthly reports on the status of the test and data acquisition effort.

Planned Start: 2/94 Planned Completion: 8/94

7.2 Operation and Maintenance

Operate and maintain the domestic outdoor natural gas conversion kit for an electric water heater as defined by the operations and maintenance manual and training provided by the manufacturer, commensurate with the building use, the intended purpose of the gas water heater, and other requirements of the managers of the facility. Data must be logged with sufficient accuracy to permit detailed cost and reliability analyses to be carried out. This includes maintaining a log of all O&M activities, parts and materials usage and cost, labor cost, and downtime associated with maintenance of the technology.

Primary responsibility: ALGC and GFP.

Secondary responsibility: Ft. Stewart.

Deliverable: Monthly reports on technology maintenance activities and expenses.

Planned Start: 2/94 Planned Completion: 8/94

7.3 Data Analysis

Analyze the performance and operation and maintenance data to determine the performance, energy use, operating costs, and life-cycle cost, associated with the domestic outdoor natural gas conversion kit for an electric water heater, as well as the reliability, safety, and serviceability aspects of the installation.

Primary responsibility: PNL.

Secondary responsibility: AGLC and COE.

Deliverable: A preliminary report midway through the test period on the results of the data analysis and a final report containing the results of the data analysis for the entire test period.

Planned Start: 2/94 Planned Completion: 9/94

8.0 DOCUMENTATION

Documentation includes those efforts necessary to record the project activities, evaluate the project, determine the level of success of the project, and present the results of the project.

8.1 Preparation of Test Bed Report

The data acquired pursuant to Section 7.1 and 7.2 and the analysis conducted on the data pursuant to Section 7.3 will make it possible to report on the results of the domestic outdoor natural gas conversion kit for an electric water heater installation. Prepare a report detailing if and to what degree the domestic outdoor natural gas conversion kit for an electric water heater will benefit the Federal sector. In preparing this report the information obtained in Section 6.2 to describe the "before" condition of the building and the data acquired pursuant to the test of the new technology must be used. This must include performance, energy use, operating costs, maintenance costs, reliability, quality of service, and other factors considered important for evaluation.

Primary responsibility: PNL.

Secondary responsibility: AGLC, PSC, GFP, COE and Ft. Stewart.

Deliverable: A detailed report that contains the results of the data acquisition and analysis effort, the expected benefits of the technology in the Federal sector, a description of any necessary improvements required in the gas water heater before its widespread deployment in the Federal sector, and a description of any factors limiting deployment.

Planned Start: 9/94 Planned Completion: 12/94

8.2 Development of Project Presentation and Media

Commensurate with the success of the project, develop necessary materials to communicate the results of the project and identify those in the Federal sector, policy makers, utilities, and others involved in impacting technology use in the Federal sector. In addition, identify the most effective media for making these materials and the results of the project available. This could include a press release, video, printed matter, conference, or workshop.

Primary responsibility: PNL.

Secondary responsibility: AGLC, GFP, COE and PSC.

Deliverable: A communication package on the results of the project targeted to different key audiences.

Planned Start: 12/94 Planned Completion: 2/95

8.3 Implementation of Presentation

Implement the most beneficial presentation through the most effective media based on the efforts of Section 8.2. The purpose of this presentation will be to communicate the results of the project to those in the Federal sector who could specify increased use of the domestic outdoor natural gas conversion kit for an electric water heater in the Federal sector and who would support the test bed concept. In addition communication must also focus on those in the private sector who would advocate the use of the gas water heater and the test bed concept.

Primary responsibility: PSC.

Secondary responsibility: GFP, AGLC, Ft. Stewart, COE, and PNL.

Deliverable: A copy of the presentation and a report on its implementation, distribution, and reception.

Planned Start: 2/95 Planned Completion: 3/95

9.0 DECOMMISSIONING

The decommissioning effort includes those activities necessary to remove the technology (if it is determined that it is to be removed) as well as the monitoring equipment.

9.1 Technology Removal

If it is determined that the technology is to be removed pursuant to the plan developed under Section 6.6, or due to a failure in the technology, the building is to be returned to its previous condition or to some other condition agreed upon in advance by Ft. Stewart, GFP, and AGLC. The equipment that was installed to monitor the technology installation and any accessory equipment associated with the monitoring installation must also be removed.

Primary responsibility for equipment: GFP.

Secondary responsibility for equipment: Ft. Stewart.

Primary responsibility for monitoring: PNL.

Secondary responsibility for monitoring: AGLC.

Deliverable: A report on the disposition of the technology and the monitoring equipment, and the return of the installation to the Federal site in an acceptable manner.

10.0 PROJECT SCHEDULE AND RESPONSIBILITIES

The following schedule shows each of the tasks in Sections 6.0 through 9.0 and the starting point, ending point, and duration of each task. It also shows critical events (milestones). The primary and secondary responsibility for each task is shown as well as the critical path for the project.

```
      Jan   Feb    Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec
1994|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|

6.0   Planning
    <----------------->
6.1   Site Selection
      <-->
6.2   Site Evaluation
      <--->
6.3   Water Heater Specification and Delivery
       <----->
6.4   Water Heater Monitoring Design and Delivery
       <----->
6.5   Technology and Monitoring Installation
       <------>
6.6   Technology Decommissioning
                <-->
7.0   Execution
7.1   Performance Monitoring and Data Acquisition
7.2   Operation and Maintenance
7.3   Data Analysis
              <----------------------------------------->
8.0   Documentation
                                                         <--------------------
8.1   Preparation of Test Bed Report
                                                         <-------------------->
9.0   Technology Removal (if necessary)
                                                                  <---->

      Jan   Feb    Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec
1995|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|

8.0   Documentation
    -------------------->
8.2   Development of TBDP Presentation and Media
    <------------->
8.3   Implementation of Presentation
                  <---->
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Appendix F

Glossary of Terms and Abbreviations

Appendix F

Glossary of Terms and Abbreviations

AGLC	Atlanta Gas Light Company
BLCC	Building Life-Cycle Cost
Btu	British thermal unit
COE	Corps of Engineers
CRADA	Cooperative Research and Development Agreement
DAS	data acquisition system
DoD	Department of Defense
DOE	Department of Energy
DSI	direct spark ignition
FEMP	Federal Energy Management Program
FORSCOM	Forces Command
gal	gallon
GFP	Gas Fired Products
gpm	gallons per minute
h and hr	hour
in.	inch
JSOW	Joint Statement of Work
k	thermal conductivity
k	constant
kVA	kilovolt-ampere
kWh	kilowatt-hour
MBtu	Million British thermal units
NIST	National Institute for Standards and Technology
NPV	net present value
PNL	Pacific Northwest Laboratory
PSC	Public Service Company of North Carolina
psi	pounds per square inch
quad	quadrillion British thermal units
SCF	standard cubic foot
SERDP	Strategic Environmental Research and Development Program

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