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Final Report

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



December 1995

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

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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Final Report

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

D. W. Winiarski

December 1995

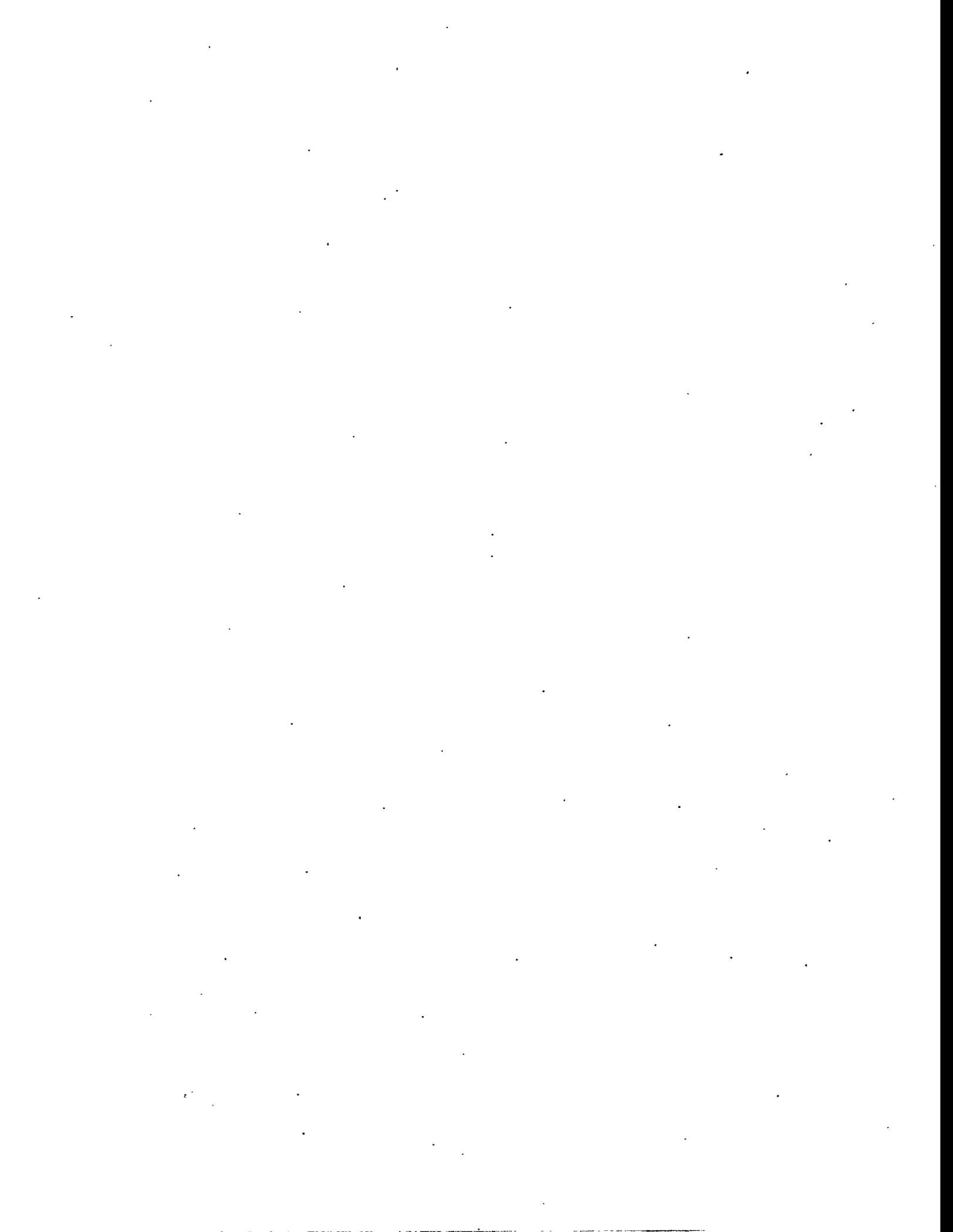
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Pacific Northwest Laboratory
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Preface

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 report provides the results of a field evaluation that PNL conducted for DOE/FEMP with funding support from 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 water heater conversion system to convert electrically powered water heaters 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.

^(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.



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 January 1995 allowed for an assessment of the technology's performance. It also allowed determination of the cost-effectiveness of the technology at Fort Stewart based on varying levels of residential hot water energy usage. In addition, the demonstration brought to light several installation and operation issues and suggested that there are simple improvements in design and installation of the technology that can help the Seahorse deliver better energy performance and make the system more cost-effective for the Federal sector. Gas Fired Products is currently incorporating related design improvements that will make newer Seahorse models more energy-efficient.

Based on the measured performance of the technology in the final 10 weeks of monitoring, replacement of existing residential electric water heaters with the Seahorse system is not recommended as a cost-effective alternative at Fort Stewart. Although the technology appears to be a cost-effective retrofit for Fort Stewart residences whose hot water energy consumption is close to the DOE's estimate for typical residential hot water energy consumption, the actual hot water energy consumption for the average Fort Stewart residence is expected to be less than the DOE estimate and for the average residence, the Seahorse does not appear to be cost-effective at Fort Stewart. Assuming an estimated hot water energy

^(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.

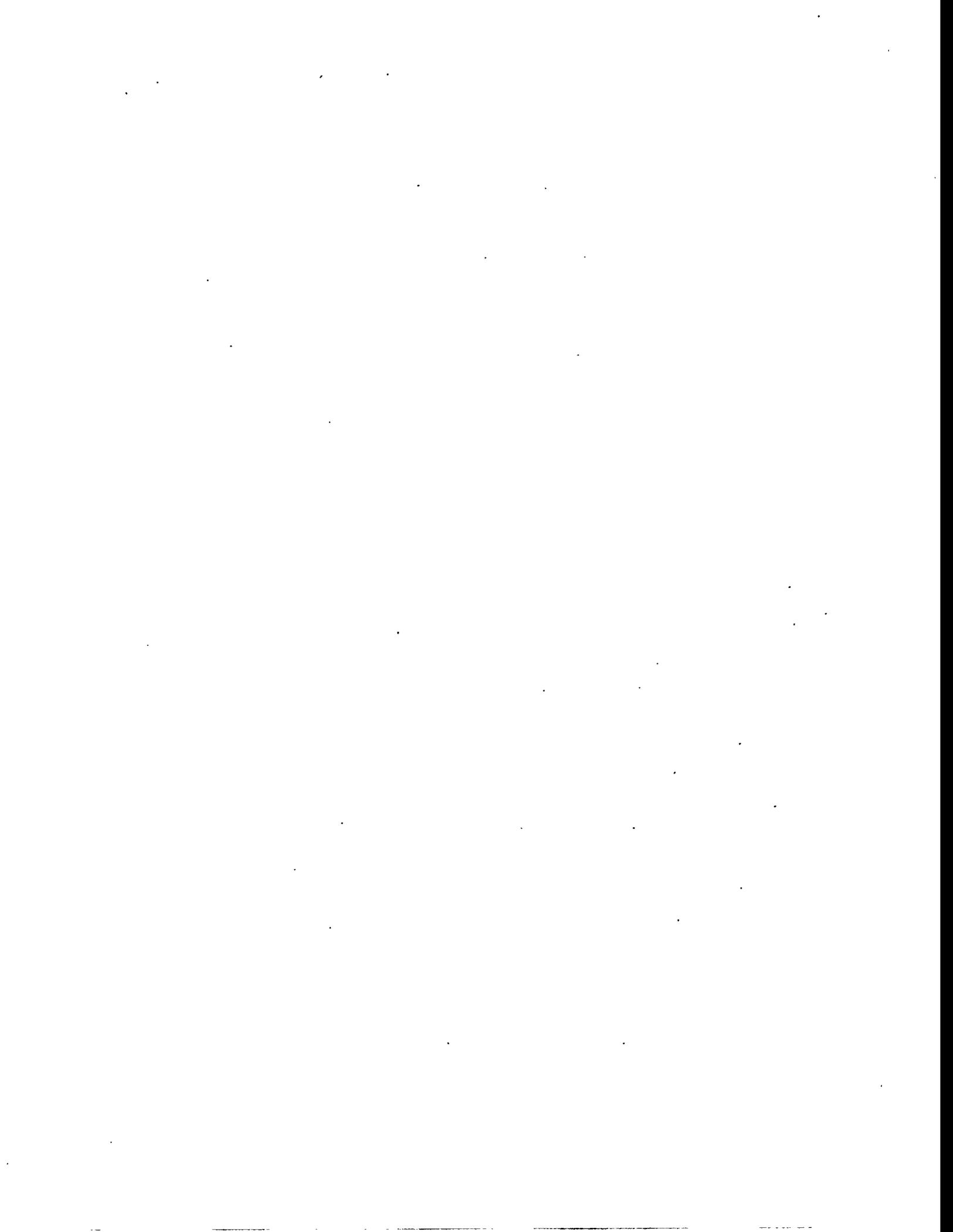
consumption based on the volumetric hot water consumption suggested by the DOE and Fort Stewart's residential supply water temperature, adoption of the demonstrated Seahorse technology at Fort Stewart to replace existing electric hot water heaters would save the Fort \$32/yr per residence in annual energy costs as well as \$48/yr per residence in reduced demand charges, resulting in a net life-cycle energy cost savings of \$778 (1995 dollars). The savings however do not offset the initial installation cost of the Seahorse of \$835. Marginally higher than average hot water energy consumption would make the Seahorse a cost-effective alternative to electric water heat at Fort Stewart, and the sensitivity of the cost-effectiveness of the Seahorse to residence hot water energy requirements is discussed at length. 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 for different levels of hot water consumption and illustrates this for several other DoD sites, showing examples where the Seahorse may be cost-effective.

Minor design and installation improvements will reduce standby losses and improve energy performance of the Seahorse, however, it is unknown if these improvements would make the Seahorse a cost-effective retrofit at Fort Stewart. It is strongly recommended that Gas Fired Products pursue rating the efficiency of the Seahorse/hot water tank combination using a standard test method to allow consumers to compare the efficiency of the whole system with other water heater products. This would also allow GFP to showcase improvements in the technology beyond the results of this demonstration.

The Seahorse appears to be a technology that shows potential for increased use in the Federal sector. It is recommended that sites that currently rely on electric resistance water heaters and that have natural gas or propane available, examine the discussed nomograph and determine if the Seahorse has the potential to be cost-effective based on the site's gas and electric energy costs and the DOE estimate for residential hot water consumption. If cost-effective using the DOE estimate, then a detailed look at the Seahorse and its advantages and disadvantages in relation to other water heating technologies is recommended. This report provides the type of detailed information on the technology necessary for this level of examination.

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.



Contents

Preface	iii
Executive Summary	v
Acknowledgments	vii
1.0 Introduction	1.1
2.0 Background	2.1
2.1 Facility Description	2.1
2.1.1 Family Housing Characteristics	2.1
2.1.2 Utility Services	2.3
2.2 Residence Demonstration Site Description	2.3
2.3 Seahorse Gas Hot Water Conversion System	2.4
2.3.1 System Description	2.4
2.3.2 Operation	2.5
2.3.3 Technology Assessment Methodology	2.6
3.0 Field Performance Monitoring	3.1
3.1 Experimental Design and Measurements	3.1
3.2 Data Acquisition System	3.4
4.0 Observed Performance and Operation	4.1
4.1 Seahorse and Data Acquisition System Installation	4.1
4.2 Observed Performance and Operation--April 2 to May 22, 1994	4.1
4.3 Observed Performance and Operation--May 27 to Aug 24, 1994	4.6
4.4 Observed Performance and Operation--Aug 26 to Sept 14, 1994	4.9
4.5 Observed Performance and Operation--Sept 20 to Nov 30, 1994	4.10
4.6 Comparison of the Performance During the Four Metering Periods	4.15
4.7 Household Energy Use Profile for the Seahorse Hot Water Heater	4.19
5.0 Preliminary Estimated Energy Savings and Life-Cycle Costs	5.1
5.1 Comparison of Annual Energy Performance - Electric Water Heater Versus Seahorse	5.1
5.2 Preliminary Life-Cycle Cost Comparison - Seahorse Versus Electric Water Heater	5.7
5.3 Comparison of Annual Energy Performance - Tank-Type Gas Water Heater Versus Seahorse	5.13
5.4 Life-Cycle Cost Comparison - Seahorse Versus Tank-Type Gas Water Heater	5.15
5.5 Seahorse Installation and the Effect on Performance and Cost-Effectiveness ..	5.16

6.0 Conclusions 6.1

7.0 References 6.3

Appendix A - Seahorse Operation and Installation Instructions A.1

Appendix B - Predicted Effect of System Cycle Time on Efficiency B.1

Appendix C - Collected Field Data - Daily Averages C.1

Appendix D - Estimate of Annual Cold Water Supply Temperature for Fort Stewart ... D.1

Appendix E - Potential Impact of Thermosiphoning on Seahorse Efficiency E.1

Appendix F - BLCC4 Economic Inputs and Life-cycle Cost Output F.1

Appendix G - Joint Statement of Work - Seahorse Demonstration G.1

Appendix H - Glossary of Terms and Abbreviations H.1

Figures

2.1	Plan View of Fort Stewart Residence Showing Seahorse Location	2.4
2.2	Seahorse Hot Water Heater Installed at Fort Stewart	2.6
3.1	Schematic of Seahorse/Hot Water Tank Instrumentation	3.4
3.2	Data Acquisition System for Seahorse at Fort Stewart	3.5
4.1	Daily Average Delivery-to-Tank Efficiency, April 2 to May 22	4.3
4.2	Loop Water Flow Versus Pump On-Time	4.5
4.3	Seahorse Operation, Pump On-Time and Average Tank Temperature -- 5-Minute Data	4.6
4.4	Seahorse Electric Power Consumption (5-minute data) June 15, 1994	4.8
4.5	Seahorse Electric Power Consumption (5-minute data) June 19, 1994	4.8
4.6	Seahorse Average Tank Temperature and Pump On-Time -- Oct 3	4.11
4.7	Average Daily Delivery-to-Tank Efficiency (Sept 20-Nov 30)	4.11
4.8	Seahorse Delivery-to-Tank Efficiency Versus Daily Hot Water Consumption (Sept 20-Nov 30)	4.12
4.9	Delivery-to-Residence Efficiency Versus Residence Hot Water Consumption (Sept 20-Nov 30)	4.14
4.10	Tank Efficiency Versus Residence Hot Water Consumption (gallons/day)	4.15
4.11	Gas Energy Consumption and Residential Hot Water Use Profiles Averaged over Periods 2, 3 and 4	4.20
5.1	Energy Costs and Net Present Value for Seahorse Retrofit	5.12
5.2	Present Value Cost for Seahorse and Tank-type Gas Water Heater Options	5.16
5.3	Standby Loss Recorded (Sept 20-Nov 30)	5.18
6.1	Energy Costs and Net Present Value for Seahorse Retrofit	6.2

Tables

2.1 Fort Stewart Residential Housing Statistics	2.2
3.1 Measuring Points: Seahorse Natural Gas Water Heater/Electric Tank System.	3.3
4.1 Monitored and Calculated Data for Seahorse: Test Periods 1 Through 4	4.16
4.2 Estimates of Actual Seahorse Delivery-to-Tank Efficiency for Period 2	4.18
5.1 Electric Water Heater Energy Consumption Studies	5.3
5.2 Annual Energy Consumption and Cost for Residential Water Heating Alternatives, Electric Water Heater and Seahorse/Hot Water Tank System	5.8
5.3 Installation Costs for Water Heater Alternatives	5.9
5.4 Comparison of Present-Value Costs for Water Heater Alternatives	5.11
5.5 Correlation Between Standby Loss and Other Measured System Parameters	5.19

1.0 Introduction

The purpose of the New Technology Demonstration Program (NTDP) 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 NTDP 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 NTDP. Fuel switching from electricity to fossil fuel can offer the benefit of lower energy costs for the end user while reducing source energy use.

During the early stages of the NTDP, 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 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 and information on the technology 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 the 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 invited 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 became responsible for certain project tasks.

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. The monitoring was completed in January 1995.

This report presents information gathered during the entire duration 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 each 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 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 ft². 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 ft² 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 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 water heating.

^(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.

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

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.

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 that is subject to a summer demand ratchet. 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 ft² 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.

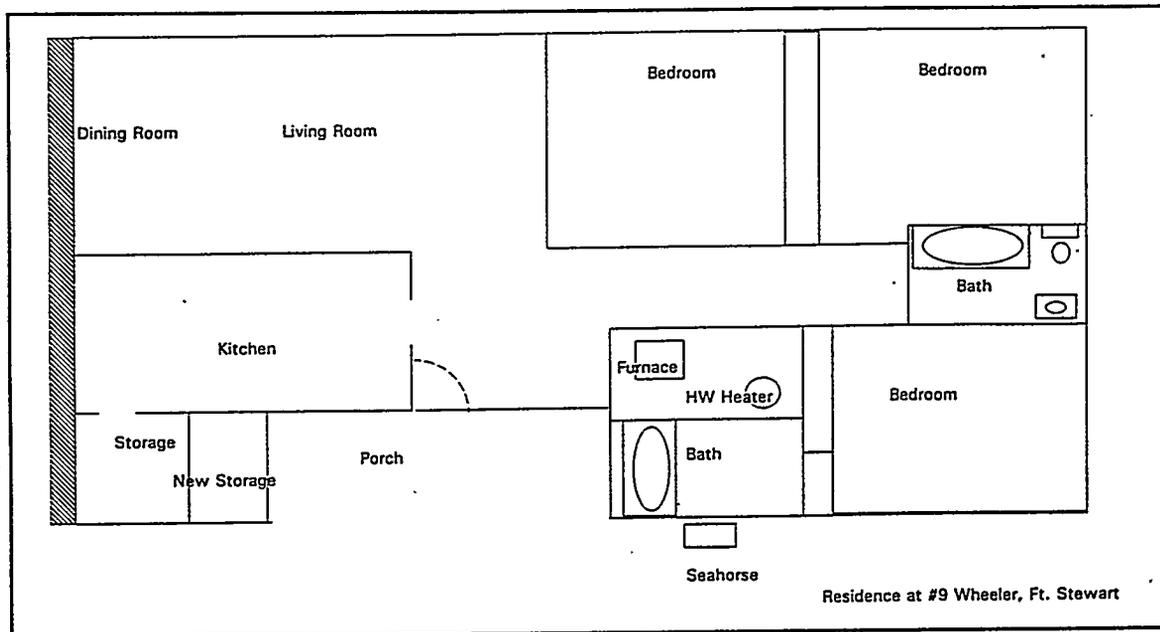


Figure 2.1. Plan View of Fort Stewart Residence Showing Seahorse Location

The existing 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 4,500 watts. The control of the elements was such that the elements cannot be powered simultaneously, and the maximum input heat capacity of the unit was 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 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 Btu/h 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.

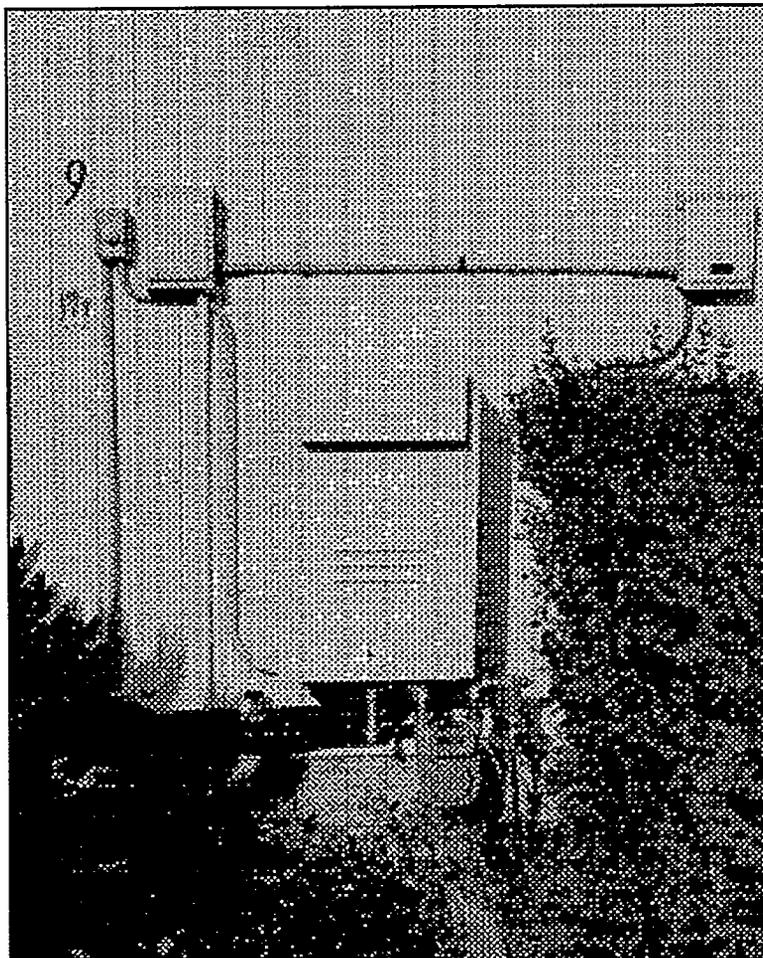
Figure 2.2 shows the installed Seahorse at Fort Stewart.

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, itself located on the building exterior. 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

^(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.



**Figure 2.2. Seahorse Hot Water Heater
Installed at Fort Stewart**

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 had not been recorded prior to this demonstration.

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.

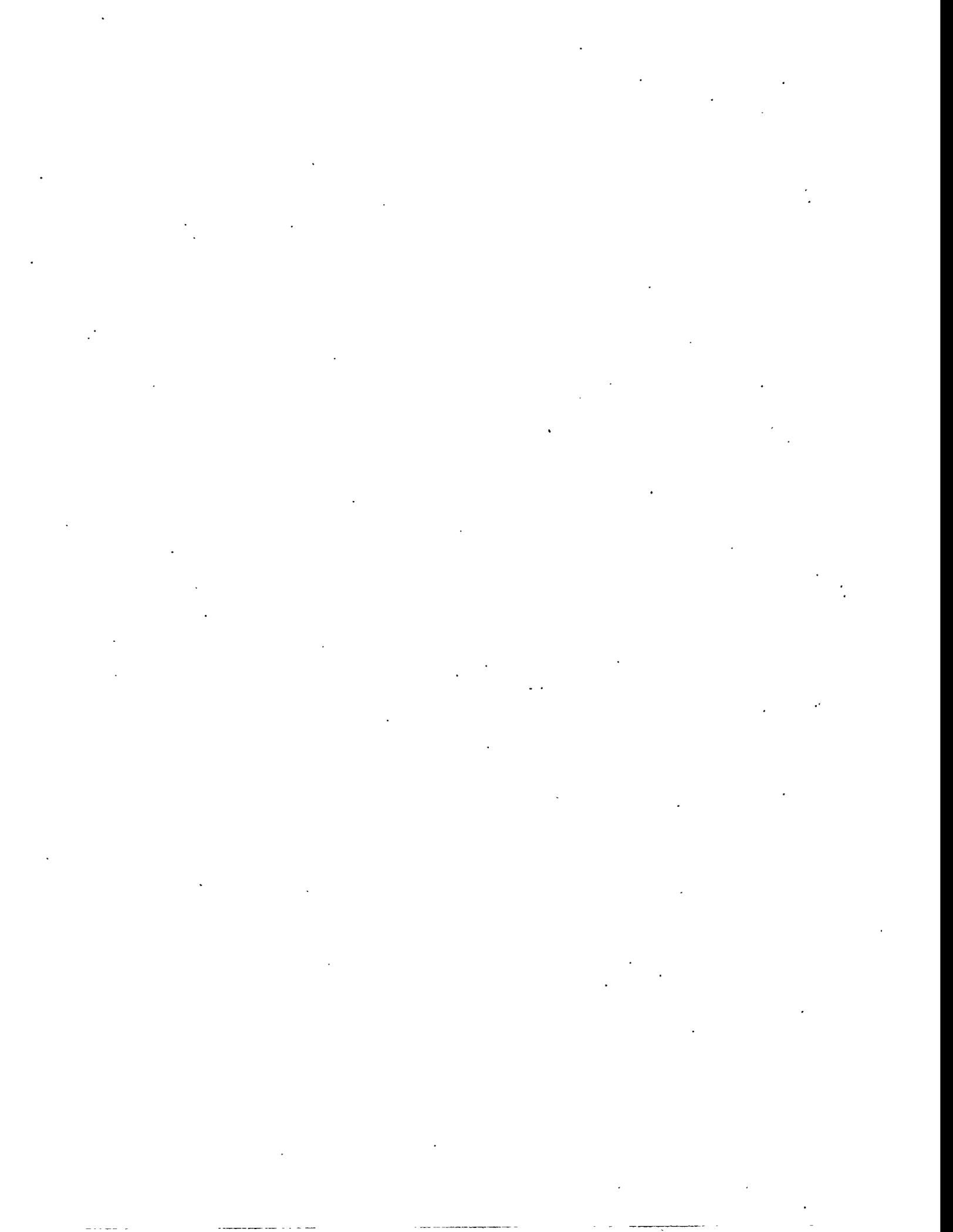
To measure the field performance for the Seahorse, the Seahorse, the flow loop, and the hot water tanks were all instrumented with water flow, gas flow, and temperature sensors. A

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 the energy cost of either water heating strategy with the Seahorse system involves determining the efficiency of delivering thermal energy to the hot water tank, determining the standby losses for the system, and using this information to predict the efficiency of the whole system at delivering hot water to the residence. The delivery-to-tank efficiency for electric resistance water heating is essentially 100%, which allows estimation of the standby losses for electric water heaters from available electric water heater test data. The delivery-to-residence efficiency can easily be calculated from the standby loss estimate and the expected residential hot water energy consumption. 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 for the expected residential hot water energy requirements from the available standby loss and delivery to residence efficiency data for this type water heater under the rated daily load conditions.

Once the energy cost requirements are ascertained, the life-cycle cost of either water heating strategy can be compared with that of the Seahorse technology by determining the lifecycle cost of the energy used by the water heater and the capital cost for purchase and installation of the water heater. For the Seahorse to be cost-effective when compared with an electric water heater, the assumed base case, any reduction in energy cost using the Seahorse must offset the purchase and installation cost of the Seahorse technology over the unit's life cycle. 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 was 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 was 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 were used to convert the measured gas flow to the volumetric flow rate at standard temperature and pressure conditions. This gas flow was 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 was monitored using a standard watt-hour meter. Each of these measurement channels was 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 was installed in this loop to monitor water flow. Differential temperature sensors placed close to the water tank were 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 was measured. This, in conjunction with the water flow measurement for the heat exchanger loop, was used to calculate the hot water energy the Seahorse unit provided to the hot water tank. A second set of differential temperature sensors were

installed at the inlet and outlet to the Seahorse unit, and the outlet water temperature at the Seahorse was also measured. All of the temperature and differential temperature measurements in this loop were 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 was measured to be above a threshold level, this was used as an indication that water was flowing in the loop and the differential and absolute water temperatures in the loop near the water tank were recorded. These measurements, in conjunction with the water flow measurement for the loop, were 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 were 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 was collected. This differential temperature measurement was gated to the inlet water flow meter so that temperature difference was only recorded during periods of residential hot water consumption. Additional temperature sensors, also gated to the flow meter, were used to measure the inlet cold water and exit residential hot water temperatures.

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 increase heat loss from the Seahorse unit as well as 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 were 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 with the location of each sensor point indicated. 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

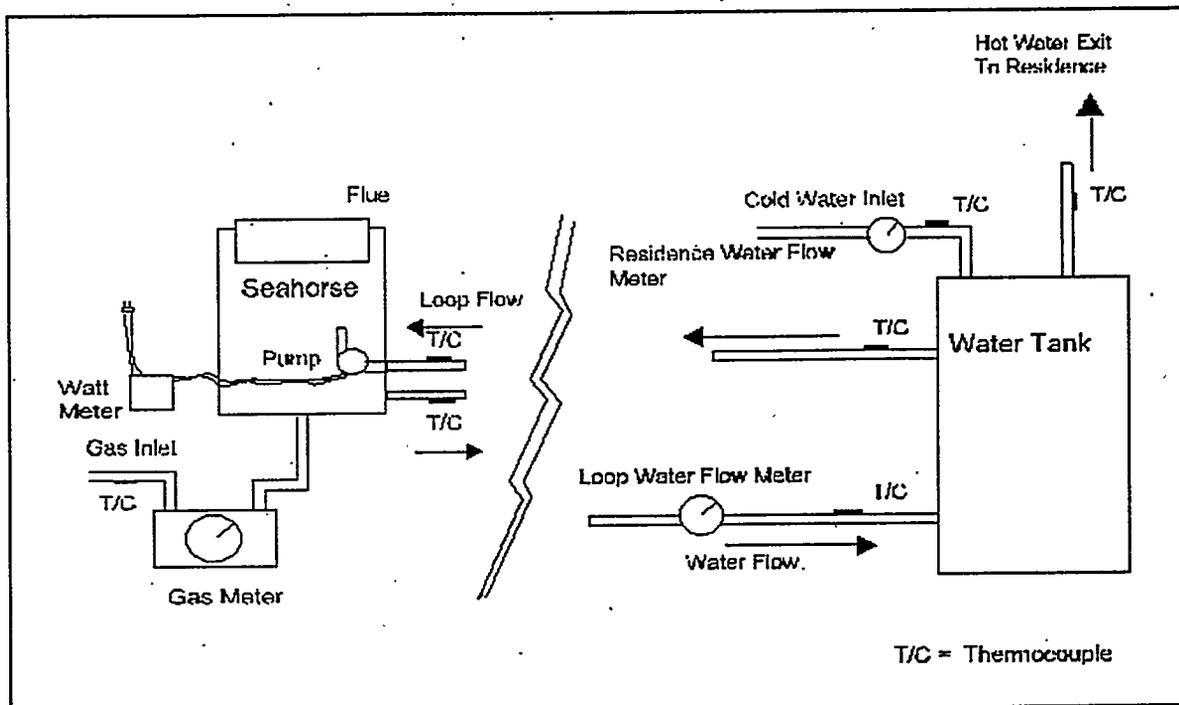


Figure 3.1. Schematic of Seahorse/Hot Water Tank Instrumentation

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 eight 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 ± 5 , ± 15 , ± 50 , ± 500 , or ± 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 six digital status inputs. The logger has 40 kilobytes 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.

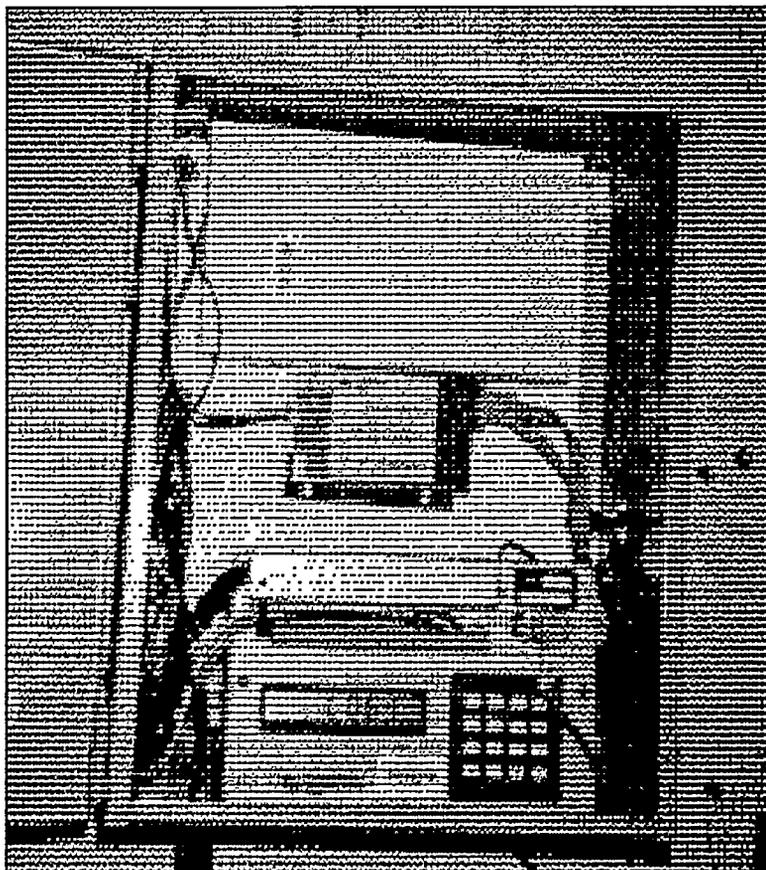
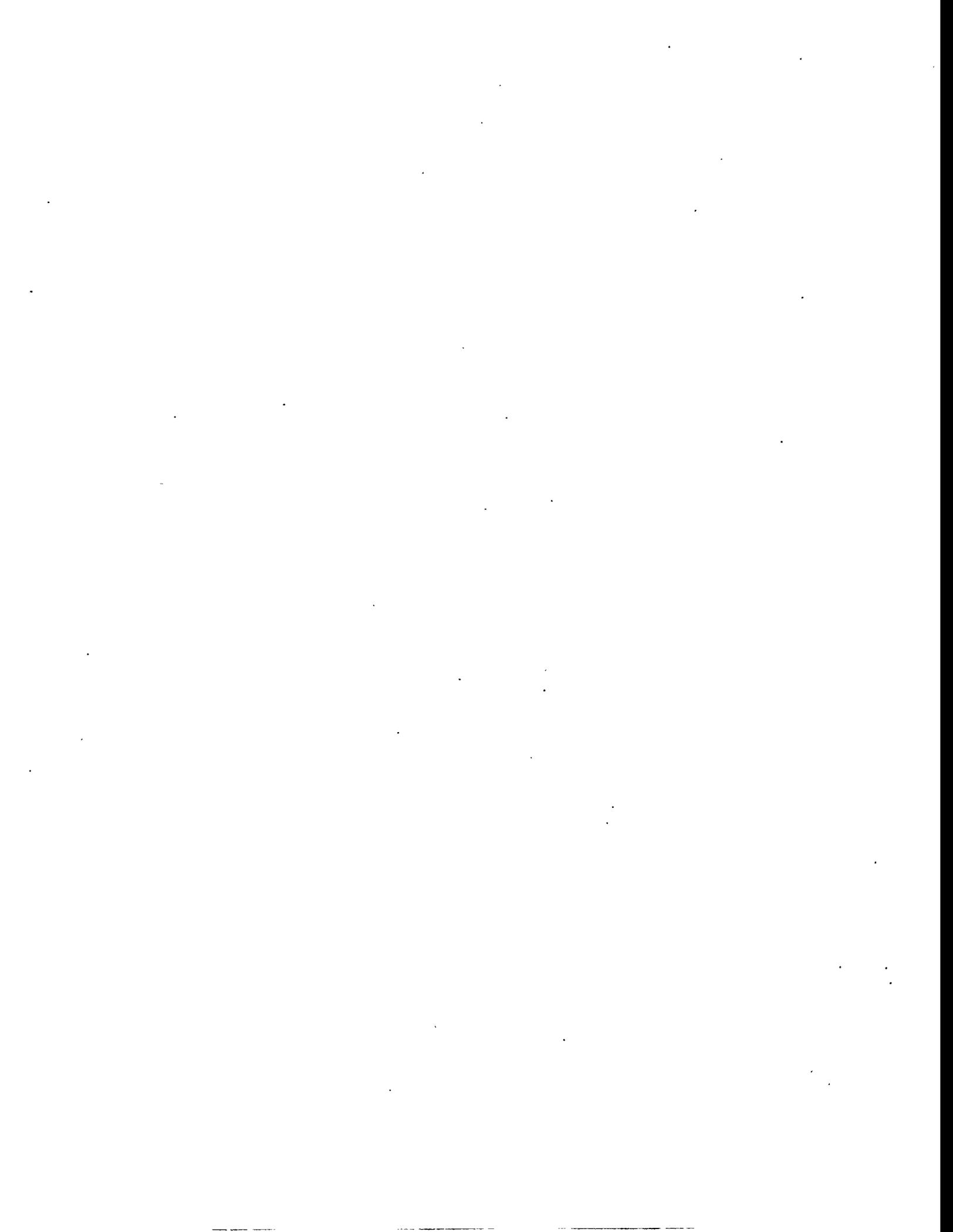


Figure 3.2. Data Acquisition System for Seahorse at Fort Stewart



4.0 Observed Performance and Operation

The Seahorse and DAS at Fort Stewart were installed between March 14 to March 17, 1994. Continuous monitoring of the system began on April 2, 1994, and continued through November 30, 1994. Analysis of the monitored data was used to assess the performance of the Seahorse under varying load and environmental conditions. Between April 2, 1994, and January 31, 1995, changes were made on three specific dates to either the Seahorse controls or to the metering apparatus. Because of these changes, the monitoring of data is broken up into four distinct periods. The energy performance of the Seahorse/hot water tank system is described here separately for each of these four 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 leaking joints in the copper plumbing between the water tank and the Seahorse. Installation of a Seahorse with two experienced 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 was 39 feet in total length and consisted predominantly of 7/8-in. plastic hose with some 3/4-in. copper tubing used near the entrance to the water heater. All but 32 in. was 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 had a variable differential control and temperature setting. The cut-out temperature of the aquastat was set to 145°F and the differential control was set to a 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, 1994

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 ft³. This value was recorded during three different intervals. A value of 4.33 ft³ was recorded 53 times during the same test period. Since one gas meter pulse corresponds to 0.33 ft³, 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 ft³ and 4.66 ft³ 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.

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 4.1 shows the measured variation in Seahorse delivery-to-tank efficiency over this period.

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

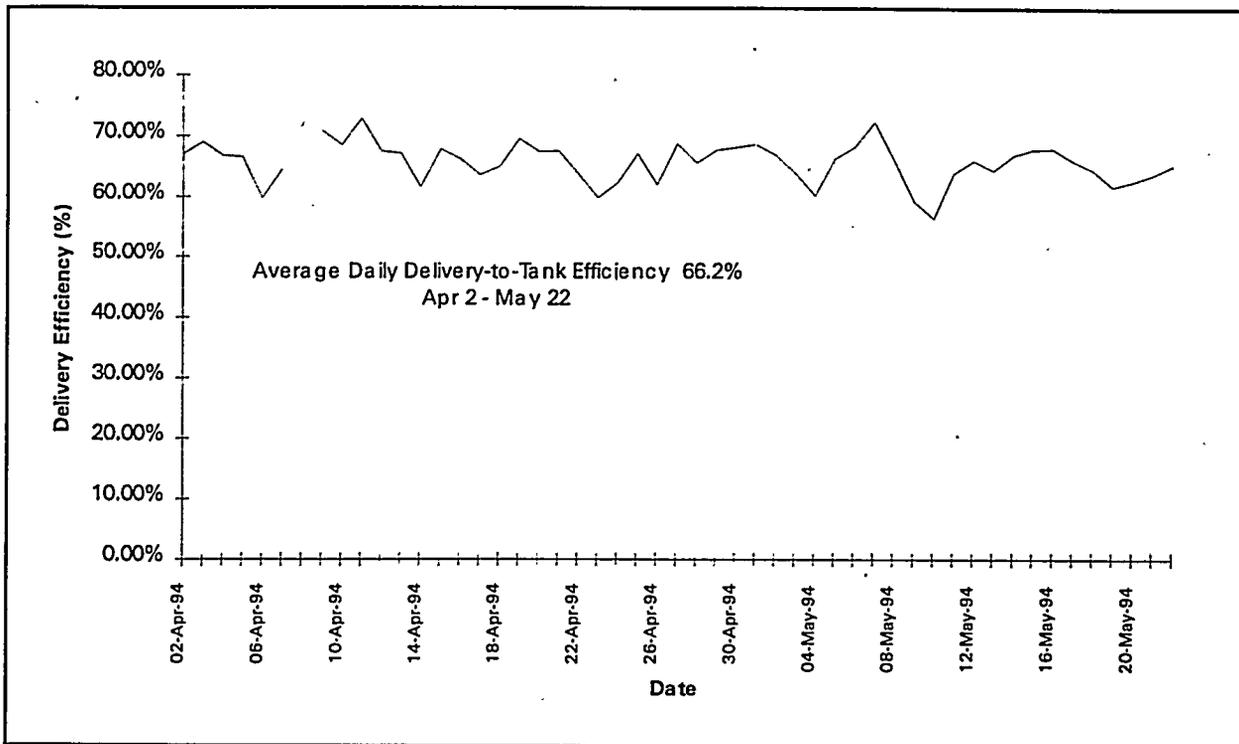


Figure 4.1. Daily Average Delivery-to-Tank Efficiency, April 2 to May 22

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 a site visit on May 22.

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

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

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

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

or

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

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 4.2. 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).

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 temperature of the stored hot water 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

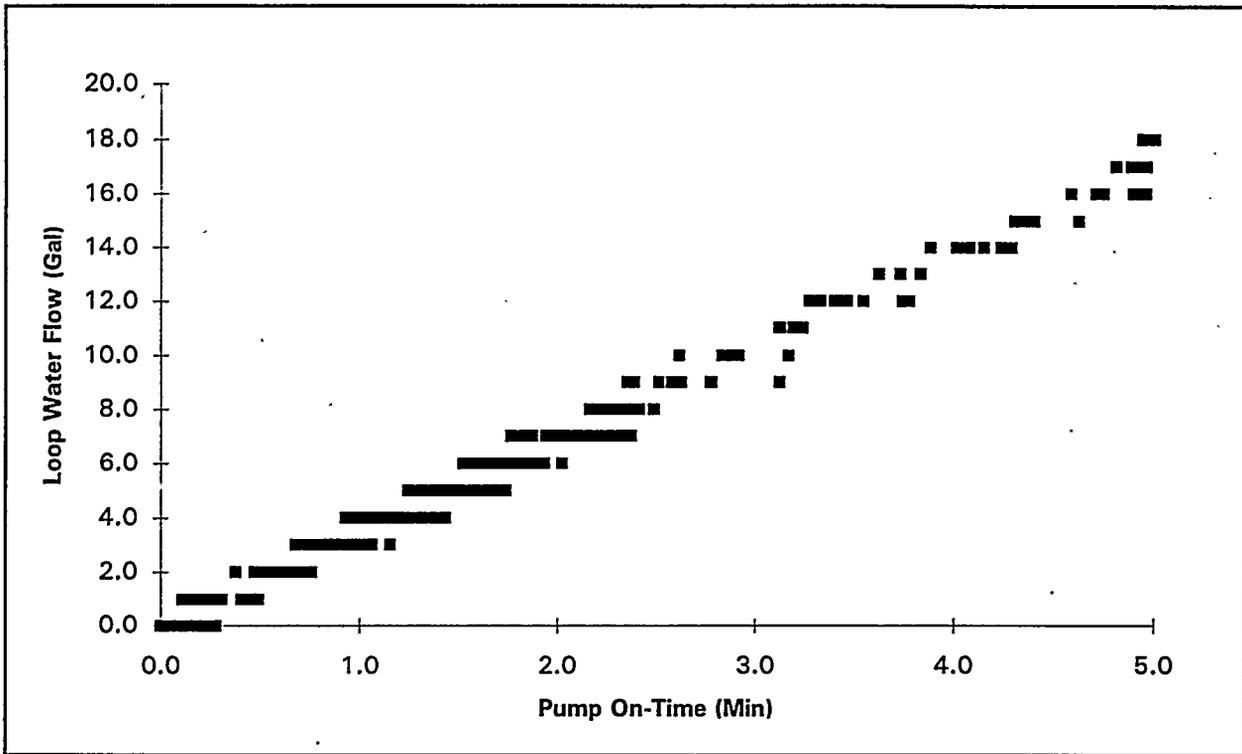


Figure 4.2. Loop Water Flow Versus Pump On-Time

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 4.3 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.

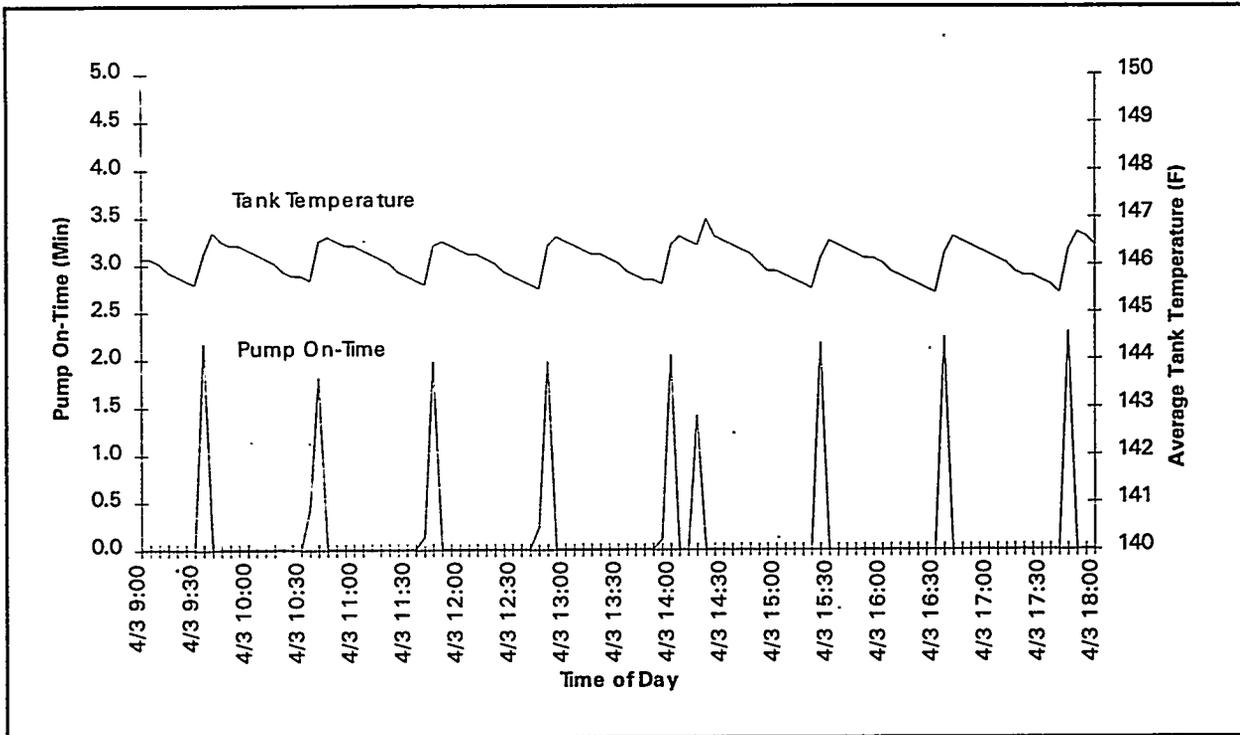


Figure 4.3. Seahorse Operation, Pump On-Time and Average Tank Temperature -- 5-Minute Data

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 Aug 24, 1994

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 use of this thermostat for the Seahorse control when an aquastat has not been installed. It was desired to test this suggestion while at the same time determine if the original tank thermostat, expected to have a larger thermostat differential, would improve the performance of the Seahorse/hot water tank system. Standard thermostats used for residential hot water tanks have differentials in the 10-20°F range as compared to the aquastat differential setting of 5°F used in operation period 1. It was believed that the larger differential 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 90 day period from May 27 to Aug 24, period 2, the Seahorse consumed a total of 4,993 SCF of natural gas, or approximately 5.12 MBtu of gas energy. The measured amount of hot water energy supplied to the storage tank by the hot water flow loop over this period was 2.71 MBtu, which indicated an average delivery-to-tank efficiency of the Seahorse of 53.0%. The value for the first 33 days of the test period suggested a delivery-to-tank efficiency of 53.4%, as reported in the interim report for this project (Winiarski 1995). A review of the performance of the Seahorse/hot water tank system in two subsequent test periods suggested that both these delivery-to-tank efficiency estimates are below the actual delivery-to-tank efficiency for this test period. It is believed that during this period, difficulties with the Seahorse control resulted in an inability of the installed metering apparatus to accurately record the energy transferred to the tank. Over this metering period, the measured delivery-to-tank thermal efficiency varied from 20% to a high of 74%. Analysis of the periodic operation of the Seahorse pump during this period [see interim report] showed that for most of the metering period, the Seahorse was operating in a mode of sporadic cycling. During these periods, the Seahorse would cycle roughly every 10 minutes, with operation times of between 25 and 50 seconds during each of these short cycles. Figure 4.4 shows the Seahorse electrical power consumption on June 15, a period of sporadic cycling. Figure 4.5 shows the Seahorse electrical power consumption on June 19, a period of proper cycling operation. During this period a characteristic cycle time of approximately 80 minutes is easily seen. The measured delivery-to-tank efficiency for June 15 was 34.4%. The measured delivery-to-tank efficiency for June 19 was 66.5%.

The delivery-to-tank efficiency calculation involves measuring the temperature difference between the water entering and leaving the tank through the flow loop and multiplying this by the water flow rate every two seconds during which water is flowing in the flow loop. The electrical energy to the pump was used to trigger these flow and temperature measurements. The thermocouples used to measure the inlet and outlet water temperature from the tank at the flow loop are initially exposed to a rapidly changing water temperature, and it takes several seconds for the thermocouples to respond to the temperature change. During the other test periods the differential of the aquastat thermostat used to control the Seahorse was such that the pump would operate for between 2 and 5 minutes per cycle just to account for tank energy loss. During these time periods, the time for the thermocouples to respond to the temperature change was small compared to the time water flowed in the loop and any error introduced is small. However, during period 2, the pump would often cycle on for time periods of less than 30 seconds. During these short operation periods, the time required for the thermocouples to respond became significant. An attempt to estimate the actual delivery-to-tank efficiency for this period is discussed in Section 4.6.

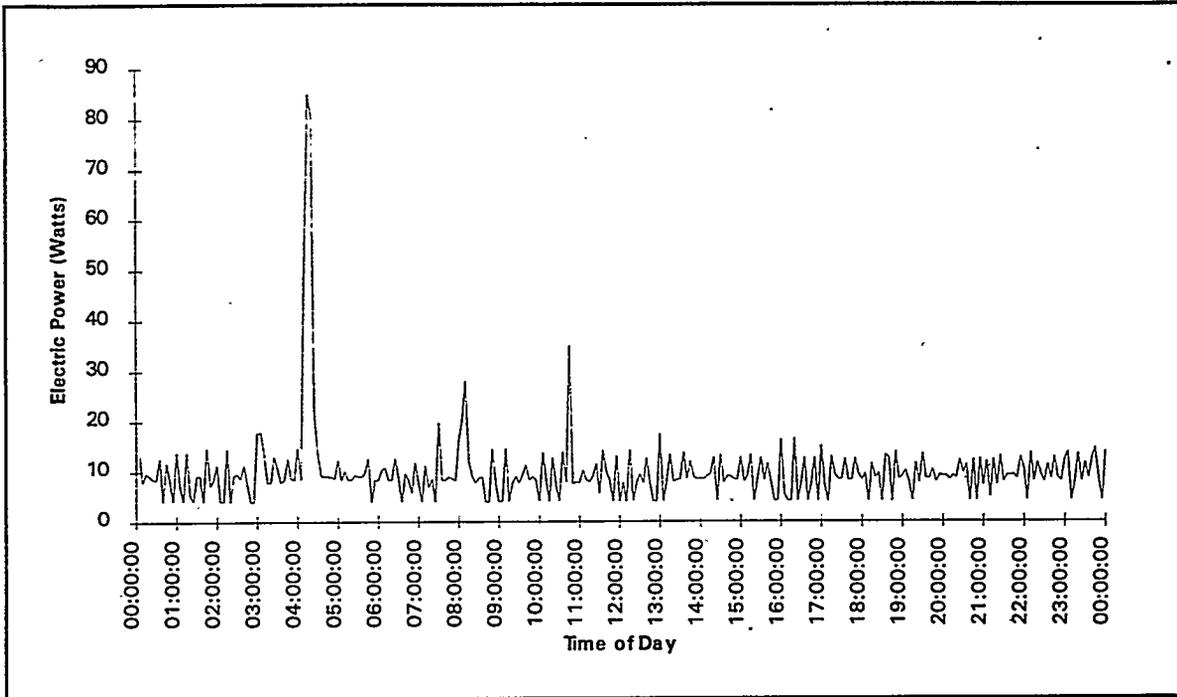


Figure 4.4. Seahorse Electric Power Consumption (5-minute data) June 15, 1994

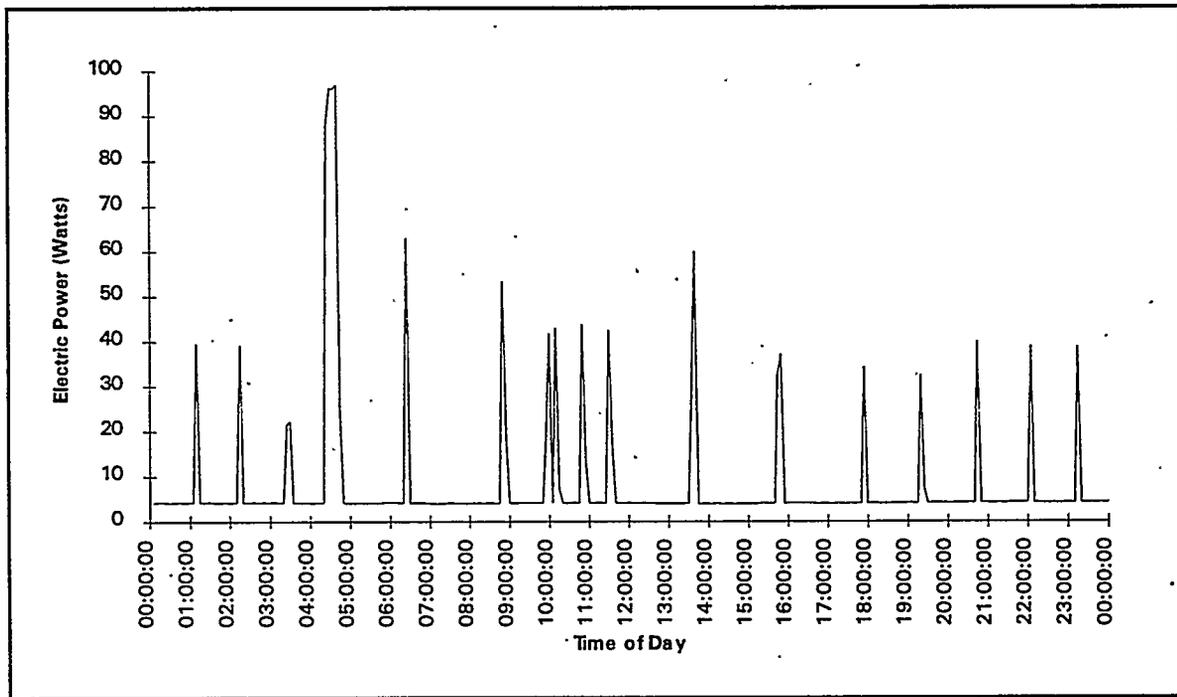


Figure 4.5. Seahorse Electric Power Consumption (5-minute data) June 19, 1994

Delivery-to-Residence Efficiency--Seahorse/Hot Water Tank System: Insertion of a one way valve in the cold water inlet to the storage tank corrected the hot water consumption measurement problem seen in period 1. Over the period from May 27 to August 24, the average daily hot water consumption was 43.2 gallons per day, with a maximum consumption of 155.6 gallons/day and a minimum consumption of 0.2 gallons/day. The average temperature of the residential hot water leaving the tank during this period was 134°F. The delivery-to-residence efficiency was calculated by dividing the hot water energy output from the tank by the gas energy input to the Seahorse. The average measured delivery-to-residence efficiency, calculated as described, was 35.6% over this period.

Electrical Energy--Seahorse: The electrical energy use of the Seahorse increased with increased gas consumption, however, the correlation between the electrical and gas energy use was considerably poorer than the correlation calculated for period 1. During period 2, the total electrical energy usage was 20.8 kWh. The daily electrical energy usage was regressed against the gas energy use resulting in the following equation:

$$\text{Electric Energy (kWh/day)} = 1.74 \text{ kWh/(MBtu/day)} \times \text{Gas Consumption (MBtu/day)} + 0.13 \text{ kWh/day} \quad (4)$$

The R² calculated for this regression was 0.583. It is believed that the poor correlation is the result of the short cycling times that occurred during this metering period. During periods when the cycle time of the Seahorse was approximately 10 minutes, the on-time of the Seahorse during each cycle was typically less than a 60 seconds. During these cycles, the two-stage gas valve would only allow the Seahorse to consume gas at the first stage rate, approximately 50% of the second stage rate. Power draw of the pump during the cycle remained constant during the entire cycle period. During periods when the cycle time was longer, more of the Seahorse operation time would be spent at the high rate of gas flow than at the low rate of gas flow as compared with periods of short cycle time. Thus the ratio of electrical usage to gas usage for the Seahorse differed between the two operating modes .

4.4 Observed Performance and Operation--Aug 26 to Sept 14, 1994

On August 25, representatives from AGL disconnected the control wires from the tank thermostat and reconnected the aquastat. This was done to fix the short cycling of the system that occurred in period 2. The settings of the aquastat were left as they were in period 1, and the unit operated similarly to as it had during period 1. Monitoring period 3 extended from Aug 26, 1994 to Sept 14, 1994 (20 days). The differential of the aquastat during this period was 5°F with a 140°F low temperature cut in and 145°F high temperature cut out. The average temperature of the water delivered to the residence during period 3 was 145°F. During this period, the typical variation in measured average tank temperature was 1.1°F, cycling between 143.7 and 144.8 degrees (more or less) with approximately 80 minutes between cycles under conditions of no residential hot water use.

Delivery-to-Tank Efficiency--Seahorse: During Period 3, the total gas consumed by the Seahorse was 1,611 SCF or 1.65 MBtu of gas energy. The total heat delivered to the tank was 1.16 MBtu for a delivery-to-tank efficiency of 70.3%.

Delivery-to-Residence Efficiency--Seahorse/Hot Water Tank System: From Aug 26 to Sept 14, the average daily hot water consumption was 50.0 gallons with a maximum of 310.5 gallons/day and a minimum of 0.2 gallons/day. The average hot water temperature delivered to the residence was 145°F, resulting in 0.579 MBtu of hot water energy delivered to the residence during this period. The calculated delivery-to-residence efficiency for this period was 40.0%.

Electrical Energy--Seahorse: The electrical energy use of the Seahorse varied linearly with the gas consumption. Over this 20 day metering period, the total electrical energy usage was 4.6 kWh. The daily electrical energy usage was regressed against the gas energy use resulting in the following equation:

$$\text{Electric Energy (kWh/day)} = 1.79 \text{ kWh/(MBtu/day)} \times \text{Gas Consumption (MBtu/day)} + 0.100 \text{ kWh/day} \quad (5)$$

The R² calculated for this regression was 0.998.

4.5 Observed Performance and Operation--Sept 20 to Nov 30, 1994

On September 15, a representative from GFP visited Fort Stewart. During this site visit, the controls of the aquastat were set to a 100°F cut-in temperature and a 130°F cut-out temperature, corresponding to a 30°F differential. By increasing the thermostat differential, an improvement in performance of the Seahorse/hot water tank system was anticipated. During the period from September 20 to November 30 (monitoring period 4), the measured average tank temperature varied from 123°F to 127°F during periods of no residential hot water consumption, with typical time between cycles of between 3 and 4 hours (see Figure 4.6) during periods of no hot water consumption. The average temperature of hot water delivered to the residence during this period was 128°F.

Delivery-to-Tank Efficiency--Seahorse: During the period from Sept 20 - Nov 30 the total gas consumed by the Seahorse was 4,199 SCF or 4.30 MBtu of gas energy. The total hot water energy delivered to the tank during this period was 3.33 MBtu for a delivery-to-tank efficiency of 77.4%. The daily delivery-to-tank efficiency, shown in Figure 4.7, is relatively constant over the monitoring period. The delivery-to-tank efficiency was somewhat affected by the hot water energy requirements of the household. Figure 4.8 shows the daily delivery-

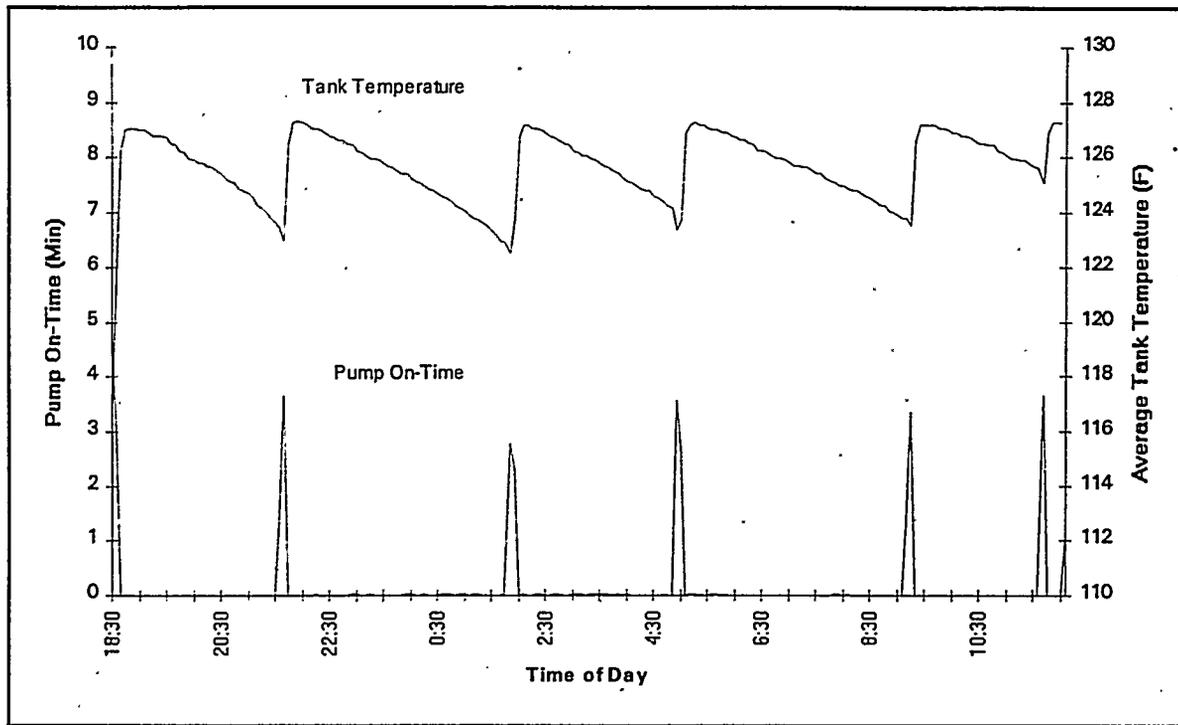


Figure 4.6. Seahorse Average Tank Temperature and Pump On-Time -- Oct 3

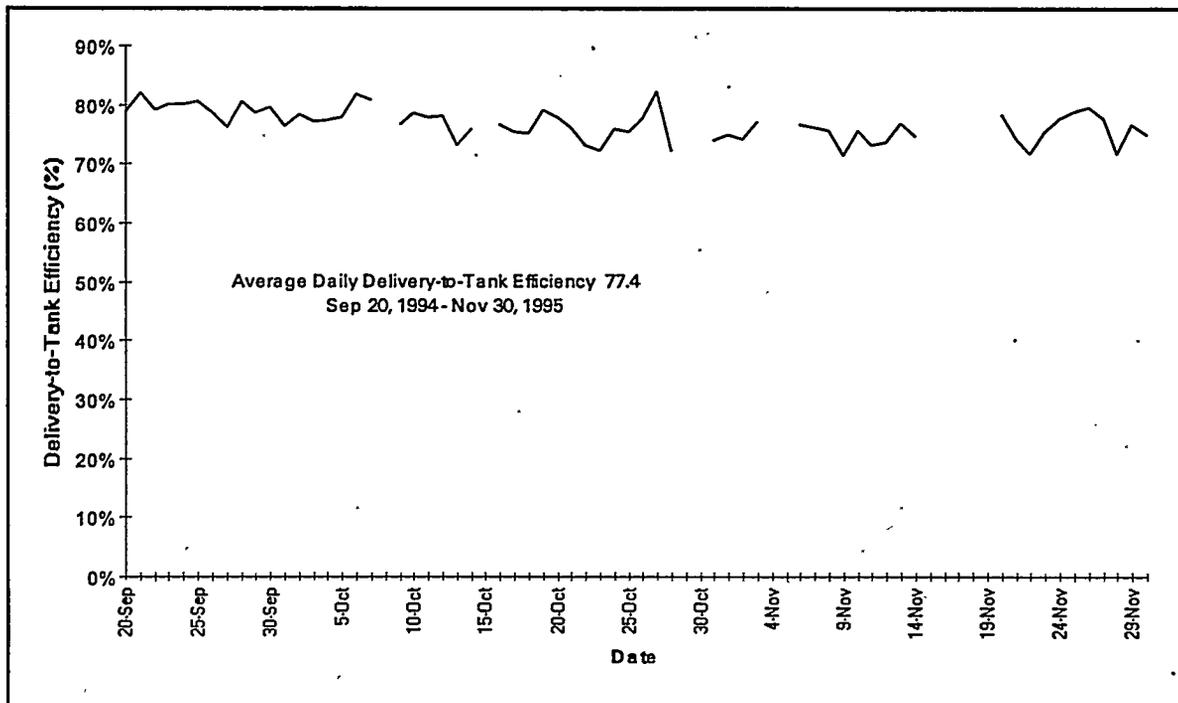


Figure 4.7. Average Daily Delivery-to-Tank Efficiency (Sept 20-Nov 30)

to-tank efficiency as a function of the residential hot water consumption in gallons per day. During this test period, each gallon of hot water delivered to the residence provided an average 463 Btu of hot water energy. Since the Seahorse only cycled on every few hours, there was significant scatter in the daily data depending on whether a cycle to recover energy lost during the day occurred at 11:00 at night or 1:00 the next morning. To produce Figure 4.8, the daily delivery-to-tank efficiency was smoothed using a rolling 3-day average of the hot water consumption and of the delivery-to-tank efficiency. Figure 4.8 plots the results of this averaged delivery-to-tank efficiency against the averaged daily hot water consumption.

Although there is still scatter in the daily efficiency, there is a steady increase seen in the delivery-to-tank efficiency over the range of daily consumption examined. A linear regression of delivery-to-tank efficiency as a function of residential hot water consumption suggests that over the range of daily consumption seen, the delivery-to-tank efficiency over this period can be modeled as

$$\text{delivery-to-tank (\%)} = 0.0739 \times \text{daily hot water consumption (gal/day)} + 72.6 \quad (6)$$

The R^2 (goodness of fit) for this regression was 0.64. For average consumption rates higher than are seen in Figure 4.8, the delivery-to-tank efficiency would be expected to flatten out, asymptotically approaching the steady-state efficiency of the Seahorse at close to 84% to 86%. This would occur because the losses between the Seahorse and the tank are

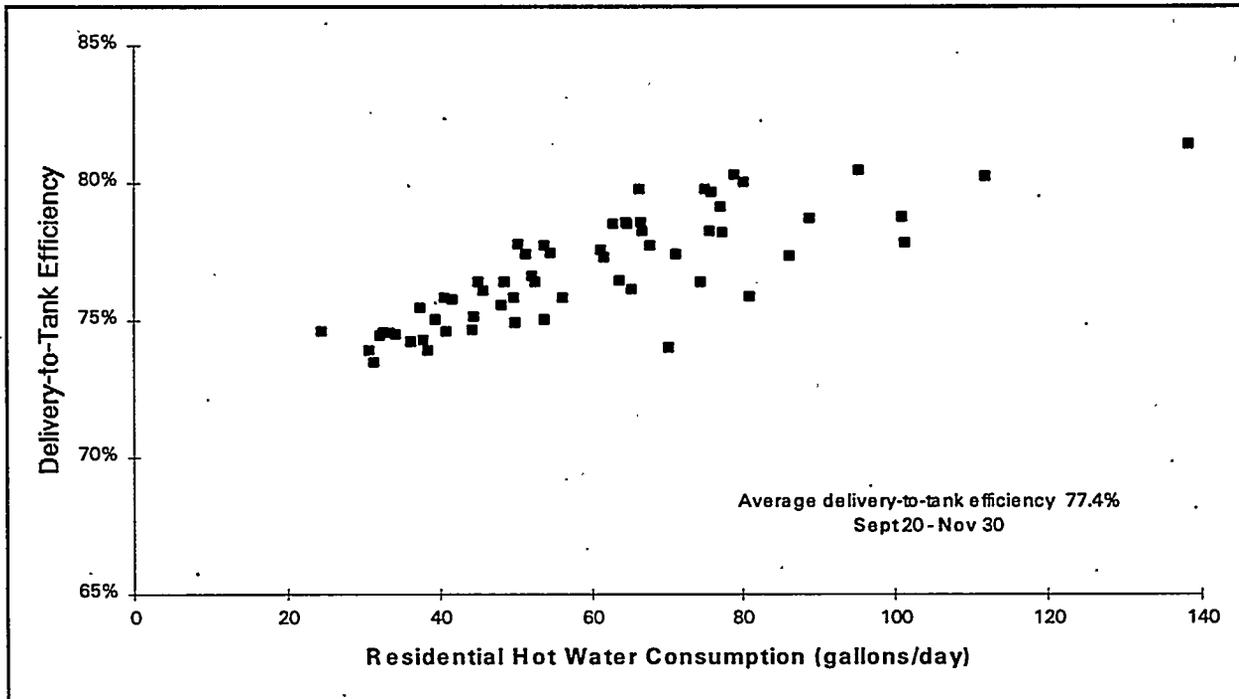


Figure 4.8. Seahorse Delivery-to-Tank Efficiency Versus Daily Hot Water Consumption (Sept 20 - Nov 30)

relatively constant and become a smaller fraction of the energy delivered to the tank at high flow rates.

The delivery-to-tank efficiency of the Seahorse is primarily related to two parameters, the energy required from the unit, which determines how long the unit is operating as compared with how long the unit is in a standby mode, and the outdoor air temperature, which determines the heat loss rate from the Seahorse and outdoor piping to the surroundings as well as the temperature of the entering combustion air. For a given installation inside a home, the indoor temperature is relatively constant and will not greatly influence the delivery-to-tank efficiency.

A multiple linear regression was made of the 3-day-average delivery-to-tank efficiency against the hot water energy delivered to the tank and the outdoor air temperature. The resulting regression equation was

$$\text{delivery-to-tank (\%)} = 62.01 + 0.1295 \times \text{Outdoor Air Temperature (F)} + 138.4 \times \text{Energy to Tank (MBtu/day)} \quad (7)$$

The R² for this regression was 0.77. The range of daily energy delivered from the Seahorse over which this regression was done and is valid is between 28,800 and 82,100 Btu/day. Above 82,100 Btu/day, the delivery-to-tank efficiency would be expected to flatten out, asymptotically approaching the steady-state efficiency of the Seahorse at close to 84-86%

Delivery-to-Residence Efficiency--Seahorse/Hot Water Tank System: From Sept 20 - Nov 30, the average daily hot water consumption was 60.7 gallons with a maximum consumption of 170.6 gallons/day and a minimum of 10.3 gallons/day. The delivery-to-residence efficiency over the monitored period was calculated to be 46.8%. Figure 4.9 shows the variation of daily delivery-to-residence efficiency as a function of daily residential hot water consumption. This graph demonstrates the dependence of the delivery-to-residence efficiency on residential hot water use. The delivery-to-residence efficiency is expected to start from a value of zero, for zero residential hot water consumption, and asymptotically approach a maximum value approaching the steady-state efficiency of the Seahorse at high hot water consumption rates. This is because at higher hot water consumption rates, a smaller fraction of the energy delivered to the tank is used to offset storage 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 the tank to useful energy output to the residence. Figure 4.10 shows this daily average tank efficiency as a function of daily hot water consumption for the period from Sept 20 to Nov 30. The curve shown on the graph represents the best fit (minimum R²) to the data points using an equation of the form

$$\text{Tank Efficiency} = \left[1 + \frac{k}{\text{consumption (gal)}} \right]^{-1} \quad (8)$$

Equation (8) was developed under the assumption of constant tank temperature and constant tank energy loss. The curve shows the nonlinearity of the tank efficiency with regard to residential consumption. The constant k in Equation (8) represents the tank energy loss rate normalized to the energy required to raise 1 gallon of water to the residence hot water temperature. The fit of the data to the equation form was very good, resulting in a goodness of fit parameter, R^2 , of 0.96 using a value for k of 39.2 gallons/day.

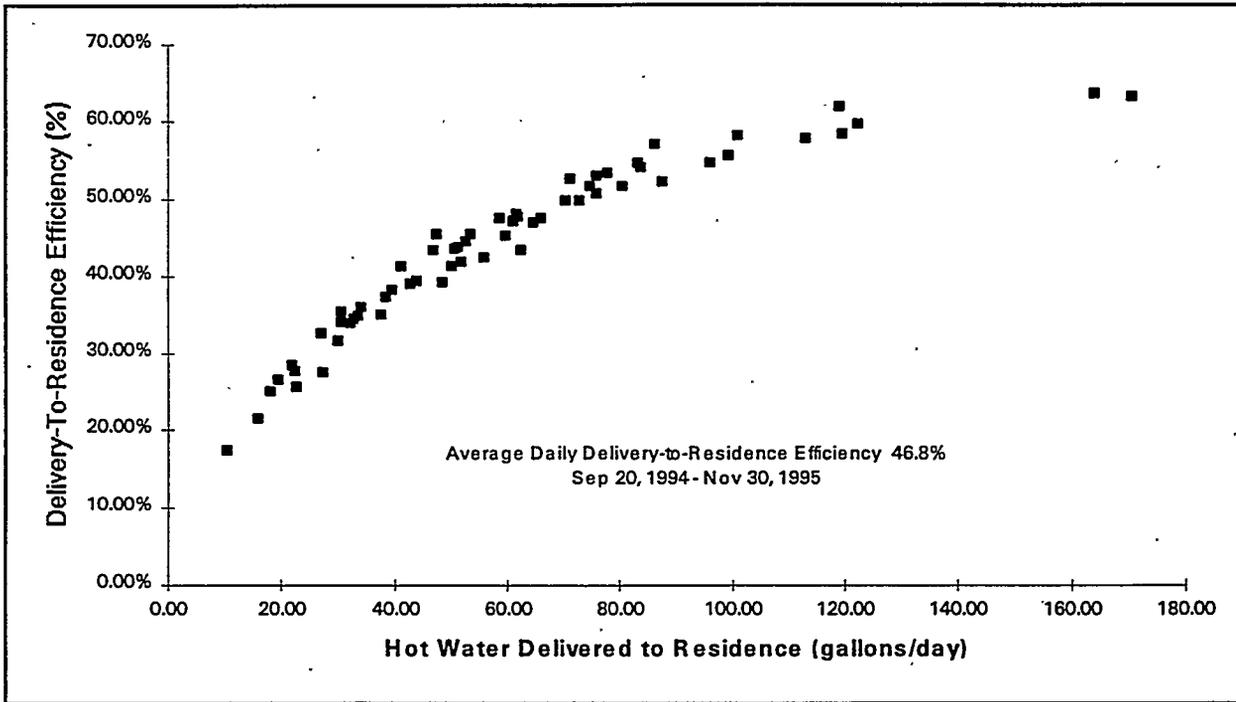


Figure 4.9. Delivery-to-Residence Efficiency Versus Residence Hot Water Consumption (Sept 20-Nov 30)

Electrical Energy--Seahorse: The electrical energy use of the Seahorse varied linearly with the gas consumption. Over this 72-day metering period, the total electrical energy usage was 30.6 kWh. The daily electrical energy usage was regressed against the gas energy use resulting in the following equation:

$$\begin{aligned} \text{Electric Energy (kWh/day)} &= 1.78 \text{ kWh/(MBtu/day)} \times \text{Gas Consumption (MBtu/day)} \\ &+ 0.101 \text{ kWh/day} \end{aligned} \quad (9)$$

The R^2 calculated for this regression was 0.995.

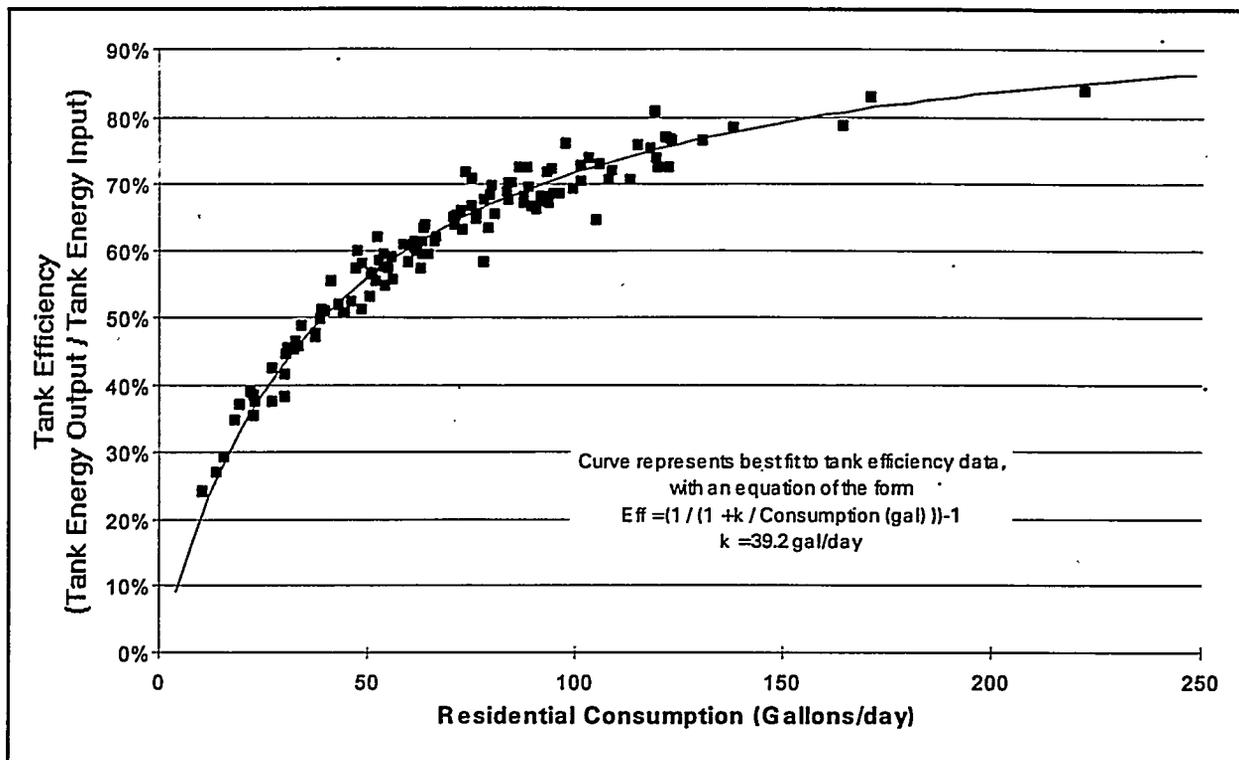


Figure 4.10. Tank Efficiency Versus Residence Hot Water Consumption (gallons/day)

4.6 Comparison of the Performance During the Four Metering Periods

Table 4.1 shows the energy use and performance of the Seahorse and Seahorse/hot water tank system as well as other measured parameters for each of the four monitoring periods. Three issues are of primary concern in determining the performance of the Seahorse/hot water tank system, delivery-to-tank efficiency, delivery-to-residence efficiency, and whether the Seahorse/hot water tank system served the hot water requirements of the residence. These issues are addressed in this section.

Energy Performance - Period 1 and Period 3: Monitoring periods 1 and 3 represent the Seahorse/hot water tank system's performance as originally set up during this test. The calculated delivery-to-tank efficiency for both these periods is very similar at 66.2% in period 1 and 68.7% in period 3. The delivery-to-residence efficiency could not be determined in metering period 1, but because the set up of the Seahorse/hot water tank system was similar to that seen in period 3, it is expected that the delivery-to-residence efficiency would also be similar to that seen in period 3.

Energy Performance - Period 2: The measured data from monitoring period 2 shows poor Seahorse/hot water tank efficiency. However, comparison of the results from period 2 with

Table 4.1. Monitored and Calculated Data for Seahorse: Test Periods 1 Through 4

Monitoring Period	1	2	3	4
Date	Apr 2-May 22	May 27-Aug 24	Aug 26-Sep 14	Sept 20-Nov 30
No. of Days	51	90	20	72
Gas Use (SCF)	4133	4993	1424	4199
Gas Energy (MBtu)	4.23	5.12	1.46	4.30
Energy To Tank (MBtu)	2.80	2.71 ^b	1.00	3.33
Energy to Residence (MBtu)	N.A.	1.83	0.579	2.02
Electrical Energy (kWh)	13.4 (8.5 pump ^a)	20.8 (9.1 pump ^a)	4.63 (2.63 pump ^a)	15.0 (7.7 pump ^a)
Delivery to Tank Eff	66.2%	53.0% ^b	68.7%	77.4%
Delivery to Residence EFF	N.A.	35.5%	40.0%	46.8%
Water To Residence (gal)	N.A.	3887	1001	4367
Average Tank Temperature (F)	144	132	144	126
Room Temperature (F)	77	77	77	74
Ambient Temperature (F)	74	81	80	70
Water to Residence Temperature (F)	N.A., but estimated at 145 F based on period 3 data	134	145	128
Cold Water Inlet Temperature (F)	N.A.	80	80	74
Daily Water Consumption (gal/day)	N.A.	43.2	50.0	60.7
a) The value in parenthesis refers to calculated electrical energy consumed solely by the Seahorse pump. b) Some of the metered data from which this value was calculated appears to be in error. N.A. means that this value could not be determined based on the metered data from this period				

period 4 suggests that the performance of the Seahorse alone during period 2 may have been better than what was calculated based on the measured data.

Comparison of the gas energy delivered to the Seahorse during period 2 is within 3% of the total gas usage measured for the residence (4,830 SCF) measured using the existing residential gas meter. A correlation of daily gas usage measured at the Seahorse and total gas usage measured for the residence during period 2 had a goodness of fit measure of $R^2 = 0.998$. As this period was in the summer, no space heating likely occurred, and the data suggests that no measurement problems occurred during this time period with the gas input into the Seahorse. However, the previously mentioned difficulty with the temperature sensors on the flow loop not being able to react fast enough during these short cycling times suggested that a second estimate of the delivery-to-tank efficiency should be made for this period.

The actual delivery-to-tank efficiency of the Seahorse during period 2 was estimated using the calculated values for the tank efficiency from period 4. As discussed previously, using the metered data from period 4, a curve of was fit to the daily average tank efficiency calculations using Equation (8) shown in Section 4.5. The best fit line resulted from a value k equal to 39.2 gallons/day, with a goodness of fit parameter, R^2 of 0.96. When a similar regression was made with the measured data from period 2, the best fit to the equation model resulted in an R^2 of 0.40, with a k value of 18.7 gallons/day. The poor fit to the equation and the low estimate for k , were further indications that the period 2 flow loop measurements did not accurately record the energy delivered to the tank.

As described in Section 4.5, k is a measure of the tank energy loss rate normalized by the energy required to raise 1 gallon of water to the residence hot water temperature. Hot water tanks lose energy through the insulated tank wall surface as well as through connected piping, which act as fins for heat transfer. The tank energy loss rate will be a function of the tank-to-room temperature difference modified primarily by heat transfer to the uninsulated cold water inlet pipe. The tank-to-room temperature difference was 55°F in period 2 and 52°F in period 4. Heat transfer to the cold water pipe is a function of the difference in temperature of the cold water pipe and the top of the hot water tank to which the pipe connects. The difference in temperature between the top of the water tank (here assumed equal to the temperature of water exiting at the top of the hot water tank) and the measured cold water inlet temperature was 54°F in both period 2 and period 4. Since the temperature difference is the same, it is expected that the heat loss to the cold water piping would also be similar between period 2 and period 4. This suggests that, at most, the ratio of tank heat loss between period 2 and period 4 will be proportional to the temperature difference between the room temperature and the tank temperature in each period. In actual practice it will be somewhat less since the tank loss rate also depends on the tank-to-cold water pipe temperature difference, which did not change between period 2 and period 4.

The energy required to raise 1 gallon of water to the residence hot water temperature is proportional to difference between cold water inlet and hot water exit temperatures for the tank. The difference between average inlet and outlet temperatures for the tank is 54°F in both period 2 and period 4. By multiplying the k for period 4 by the ratio of room-to-tank temperature differences and dividing the result by the ratio of inlet-to-outlet temperature

differences, one can estimate a maximum (assuming all energy lost through tank shell) value for k for period 2 (k_2). This is shown in Equation (10).

$$k_2 = k_4 \times \frac{(T_{\text{tank,per2}} - T_{\text{room,per2}})}{(T_{\text{tank,per4}} - T_{\text{room,per4}})} \div \frac{(T_{\text{outlet,per2}} - T_{\text{inlet,per2}})}{(T_{\text{outlet,per4}} - T_{\text{inlet,per4}})} \quad (10)$$

Plugging in the temperature values from Table 4.1, one estimates a maximum k_2 value of

$$\begin{aligned} k_2 &= 39.2 \text{ gal/day} \times \frac{(132F - 77F)}{(126F - 74F)} \div \frac{(134F - 80F)}{(128F - 74F)} \\ &= 41.6 \end{aligned} \quad (11)$$

k_2 is likely to be somewhere between the value determined for period 4, 39.2, and the value determined above, 41.6. Using a estimated value for k_2 the tank efficiency can be estimated for each day of the metering period from k_2 and Equation (4). By dividing the hot water energy supplied to the residence each day by the estimated tank efficiency for each day, a calculation was made for the thermal energy delivered to the tank for each day during period 2. The estimated hot water energy delivered to the tank for all of period 2 was the sum of the daily energy delivered for all days in period 2. Table 4.2 shows the measured thermal energy to the residence and the calculated thermal energy delivered to the tank during period 2 as well as the resulting delivery-to-residence efficiency estimates based on the two different values for k_2 . The result of this analysis suggests that the actual delivery-to-tank efficiency for period 2 was between 68.2% and 70.1%. Although this still represents a loss in efficiency over that seen in period 4 when the unit was functioning correctly, it is a considerably higher efficiency estimate than the 53% calculated based on the flow loop measurements for period 2. This estimate for delivery-to-tank efficiency is also more in line with the 66% figure that was predicted analytically based on a simplified model of the Seahorse/hot water tank system (see Appendix B).

Table 4.2. Estimates of Actual Seahorse Delivery-to-Tank Efficiency for Period 2

k estimate	Gas energy delivered to Seahorse (MBtu)	Estimated energy delivered to tank (MBtu)	Estimated delivery-to-tank efficiency
39.2	5.12	3.59	70.1%
41.6	5.12	3.49	68.2%

Period 4: Period 4 represents operation of the Seahorse under proper control conditions. As a result, the measured thermal efficiency of the Seahorse in period 4, at 77.4%, was significantly higher than that seen in the other periods. It is important to note that the increased differential and subsequent cooler average tank temperatures did not affect the ability of the Seahorse to meet the hot water demands of the residence. By increasing the thermostat differential to 30°F, the Seahorse turned on infrequently unless there was a hot water draw on the tank. However, because of the location of the aquastat, when there was a significant hot water draw of several gallons or more, cool inlet water entering the lower half of the water tank quickly triggered the thermostat and activated the Seahorse hot water heater. The heater then removes cooler, mixed water from the lower half of the tank (at approximately the cut-in setpoint of 100°F), and supplies it to the top of the tank at approximately 21 degrees higher temperature. Since the flow loop operated at a measured rate of approximately 3.4 gallons per minute, it was able to supply hot water as fast as the residence consumed it during this period. The high Seahorse recovery rate allowed the hot water tank to consistently supply water at 124 degrees or higher even during the heaviest consumption periods recorded in monitoring period 4 (25 to 45 gallons of hot water per hour).

The results of the period 4 monitoring as compared with the other monitoring periods suggest that future Seahorse installations should include an aquastat to be used for accurate control, and that for maximum efficiency the aquastat should be set to operate with a large temperature differential, on the order of 30°F. From the metered data, it did not appear that the broader thermostat differential and subsequent low cut-in temperature of the Seahorse reduced the ability of the Seahorse to provide hot water at an appropriate temperature and volume to meet typical residential hot water loads during test period 4.

4.7 Household Energy Use Profile for the Seahorse Hot Water Heater

The average gas energy use profile for the Seahorse hot water heater was seen to track the residential hot water consumption during the three monitoring periods where residential water consumption was available with the exception that, during periods of low water consumption such as at night, some gas use was still required to make up for standby heat loss from the hot water tank.

Figure 4.11 shows the average gas use and hot water consumption profile over monitoring periods 2, 3, and 4. Period 1 is not included since the water consumption data were not available. The average hourly gas consumption for all three monitoring periods was 2,472 Btu/h and is shown by a horizontal line in Figure 4.11. As can be seen, minimal hot water usage was recorded between midnight to 4:00 a.m. The rate of gas usage by the Seahorse is correspondingly low during this period and the unit fired primarily to compensate for tank losses. A morning peak hot water load occurred around 7:00 a.m. that corresponded with the peak energy use of the Seahorse water heater. A gentle rise in water consumption also occurred around noon corresponding with lunch, and then a second rise about 6:30 p.m. corresponding to the evening meal. However, the measured hot water load

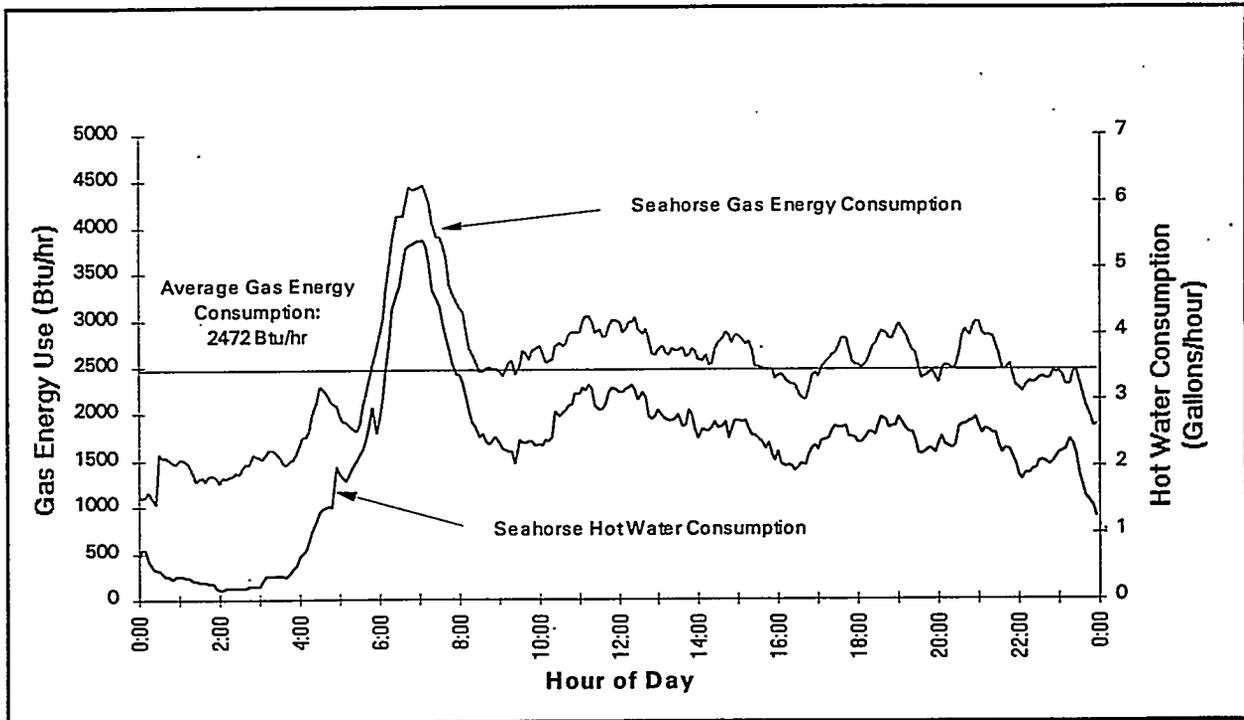


Figure 4.11. Gas Energy Consumption and Residential Hot Water Use Profiles Averaged over Periods 2, 3, and 4

between 10:00 a.m. to 10:00 p.m. was relatively flat compared to the morning peak and the average gas energy usage during the period from 10:00 a.m. to 10:00 p.m. was 2,667 Btu/hr or 108% of the average gas energy usage for the day.

5.0 Estimated Energy Savings and Life-Cycle Costs

The energy and economic analyses for the Seahorse hot water heater described in this section are based on the results of the fourth test period, September 20 through November 30, 1994. The level of performance measured during this period should be easily achievable with a similar installation. The metering results from this test showed a delivery-to-tank efficiency of the unit during operation of 77.4%. A correlation was shown in Section 4 relating the delivery-to-tank efficiency and the residential hot water consumption measured during this period. The correlation allowed the delivery-to-tank efficiency to be determined as a linear function of outdoor air temperature and daily residential energy requirements for the hot water tank. This correlation was valid over a broad range of typical daily hot water loads.

5.1 Comparison of Annual Energy Performance - Electric Water Heater Versus Seahorse

There are no available statistical data on typical hot water energy usage in residences at Fort Stewart. Residential hot water energy consumption will vary depending on volumetric hot water consumption, hot water delivery temperature, and cold water inlet temperature. A number of studies of typical electric hot water heater energy requirements have been made over the past 15 years, primarily for electric utilities, but also by different government agencies. These studies have focused on the electric energy requirements for electric hot water heaters, so the energy use reported represents the sum of the energy in the hot water consumed and the energy lost during storage.

The analysis method for the interim Seahorse report (Winiarski 1995) examined only the energy delivered from the Seahorse and assumed that the standby losses would be equivalent to the losses from the existing electric storage tank. Further review of the available data on the Seahorse/hot water tank system performance suggests that this analysis method is misleading. In a water heater, the standby loss is the difference between the energy delivered to the tank during heating and the hot water energy delivered to the residence. A review of the Seahorse energy consumption data suggests that the standby losses in this installation were higher than what would be expected from the original electric hot water tank. For this reason, the analysis discussed here will focus on the measured efficiency for the entire Seahorse/hot water tank system.

Comparisons of the energy use and cost-effectiveness of the Seahorse system with an electric water heater serving the same household load were calculated based on three different levels of hot water energy use. These were the DOE's figure for typical residential hot water energy usage (10 CFR 430), annual energy use based on the DOE's figure for hot water consumption and the annual inlet water temperature for Fort Stewart, and the measured hot water energy usage from the Fort Stewart demonstration.

Since residential-sized tank-type water heaters are tested in accordance with the DOE's residential hot water rating test procedure, analysis based on the DOE energy use figure will allow quick comparison with readily available energy usage and energy cost estimates for existing water heaters.

Base Case Electric Water Heater Energy Use: Determining typical water heating energy use requirements is one of the most difficult steps in the analysis of the cost-effectiveness of residential water heating equipment. Estimates of hot water energy requirements vary widely. A recent report done for the Gas Appliance Manufacturers Association (GAMA) (Arthur D. Little, Inc. 1994) listed the average electrical energy (in kWh/yr) required for electric water heating by single-family residences as determined for 25 different end-use metering studies done at different locations around the United States. Table 5.1 lists the results of those studies. The average annual electric energy use for all the studies is 3,582 kWh/yr. The highest level reported for all the studies was 4,820 kWh/yr, and the low was 2,126 kWh/yr. The average for moderate climate states (where Georgia would be included) was 3,638 kWh/yr. A factor of greater than two difference can be seen between the lowest and highest energy consumption reported for all the studies.

In an tank-type electric resistance water heater, the efficiency for conversion of electric energy into hot water energy is essentially 100%. However, a portion of the energy transferred to the hot water is continuously lost as heat is convected away from the storage tank to the surrounding air. The electric energy requirements of this type of water heater account not only for the energy used to supply hot water to a residence but also for this "standby loss." Standby loss rates vary with hot water and surrounding air temperatures as well as with electric water tank construction. For the highest annual energy requirements reported in Table 5.1, storage losses would typically represent between 8% and 15% of the actual energy use.

For this analysis, three separate levels of residence hot water energy requirements were examined. In the first case, the hot water consumption assumed was equivalent to the DOE estimate for typical daily hot water energy consumption as is used in the DOE rating procedure for residential water heating equipment (10 CFR 430). The DOE estimate suggests that 64.3 gallons of 135°F hot water are required to serve the hot water needs of a typical residence (based on an assumed four-person family). The DOE estimate assumes an average cold water inlet supply temperature of 58°F resulting in a 77°F temperature rise and corresponding to 41,000 Btu/day of hot water energy delivered to the residence. Determining the water heater energy use at this level of hot water energy consumption allows the Seahorse to be compared with other water heaters for which an annual energy consumption estimate has already been determined through the DOE rating procedure.

In reality, a residence is not concerned with the temperature rise for the hot water, but rather with the ability to supply a certain quantity of water at a certain delivery temperature. Thus, hot water energy requirements will generally be less in climates where the inlet supply water temperature is warm and more in climates where the inlet supply water

Table 5.1. Electric Water Heater Energy Consumption Studies

Source	Area Served	Year of Study	Avg No. of Persons/Home	Site Energy Consumption (KWh/yr)
Bangor Hydroelectric Company	Maine	1988-1989	2.5	2700
Massachusetts Joint Utility End use Metering	Massachusetts	1987-1988	2.86	3552
North East utilities	Connecticut, Massachusetts	1991-1992	2.9	4820
OtterTail Power electric space heat	Minnesota, North and South Dakota	1993-1994	representative	3336
OtterTail Power non-electric space heat	Minnesota, North and South Dakota	1993-1994	representative	3205
Central Hudson Gas and Electric	New York	1987-1988	3.5	4476
ELCAP	Pacific Northwest	1986-1992	3.1	4675
PG&E	Northern California	1985-1986	unknown	4012
Baltimore Gas and Electric	Maryland	1988	unknown	3141
Indianapolis Power and Light	Indiana	--	--	4023
Midwest Power	Iowa	1991	unknown	3481
Kentucky utilities	Kentucky	--	--	4040
Potomac Electric power	Maryland, Washington D.C.	1994	unknown	3855
Potomac Electric power	Maryland, Washington D.C.	1994	unknown	2984
Atlantic Electric	Ohio, W. VA., KY	1984-1986	unknown	4023
Carolina Power and Light	North Carolina	1986-1987	3	3600
Virginia Power	Virginia & North Carolina	1989-1992	3-4	3767
American Electric Power Service Co.	Ohio, West Virginia, Kentucky	--	2.6	3100
El Paso Electric Co.	Texas	--	representative	2910
Tennessee Valley Authority	Tennessee, Alabama	1980-1981	3	4535
Florida Solar Energy Center	Florida	1982-1983	unknown	2916
Central Power and Light	Corpus Christi, Texas	1986-1987	unknown	2782
Houston Lighting and Power	Texas	1991	3	3960
Alabama Power	Alabama	1992-1993	2.87	3544
Florida Power	St. Petersburg, Florida	1986-1989	unknown	2126

temperature is cold. During the Fort Stewart demonstration, the average inlet water temperature was extrapolated from the hourly metered data. The estimated annual average inlet temperature was determined to be approximately 71.3°F (Appendix D). The hot water energy use can be estimated as the product of the volumetric hot water usage, the heat capacity of water (8.28 Btu/gal-°F), and the average expected temperature rise of 63.7°F (135°F - 71.3°F). This procedure gives estimated hot water energy requirements of 33,900 Btu/day or 83% of the DOE estimated hot water energy consumption.

Finally, a third estimate comes from the metered data taken during this study. During the period from May 27 to November 30, the average hot water energy consumption for the residence amounted to 25,040 Btu/day. The flow-averaged tank inlet temperature recorded for this period was 77.6°F, and the flow-averaged delivery temperature was 133.3°F. To supply the same amount of hot water energy at a nominal 135°F delivery temperature would have required supplying the residence with 52.7 gallons of 135°F hot water per day. Using the estimate for the average cold water inlet supply temperature for the entire year of 71.3°F and assuming daily delivery of 52.7 gallons of 135°F water suggests an average daily hot water energy requirement of 28,000 Btu/day for this residence or 68.3% of the DOE suggested hot water energy requirements.

Residential electric water heaters sold in the United States and tested using the DOE test procedure are given an energy factor rating. The energy factor is the ratio of hot water energy supplied by the electric water heater during the DOE test to the total electric energy input to the water heater. The difference between hot water energy supplied and electrical input energy is the standby loss during the test. Since in the DOE test, the total hot water energy output from the tank is a fixed 41,000 Btu/day and the conversion efficiency from electricity to heat is 100% for the electric resistance elements, the standby loss during the test can be calculated for an electric water heater as

$$\text{Standby loss (Btu/hr)} = \frac{(1.0 - EF)}{24 \text{ hr}} \times \frac{41,000 \text{ Btu/day}}{EF} \quad (12)$$

The energy factor for residential water heaters is subject to Federal regulation. All residential electric water heaters purchased after January 1, 1990, were required to have an energy factor of 0.88 (10 CFR 430). Since the service life of electric water heaters is roughly 10 years (DOE 1993), approximately 50% of existing electric water heater stock are likely to have energy factors of at least 0.88. Most of the additional electric water heaters in use are from sales during the 1980s and will have energy factors of at least 0.82 but likely 0.84 or higher (Koomey 1994). For simplicity, this analysis assumes that all water heaters are presently in the middle of their service life and will need to be replaced within 5 years on average. The average energy factor over the life of the analysis is assumed to be 0.88. This corresponds to a daily average electrical energy input to the water heater of 46,600 Btu/day (4,980 kWh/yr) based on DOE's typical residential hot water usage. Thus, the DOE hot water load corresponds to an annual electric energy use slightly higher than the maximum energy use reported in the studies listed in Table 5.1.

An energy factor of 0.88 corresponds to a standby loss of approximately 232 Btu/hr at the DOE test conditions (135°F water from the tank and a room temperature of 67.5°F). Although the room temperature measured at Fort Stewart was 5°F to 10°F higher than the nominal 67.5°F room temperature used in the DOE test conditions, the original temperature setting of the electrically heated hot water tank before the Seahorse installation was also approximately 10°F higher than 135°F. For the purpose of this analysis, it is assumed that

the standby losses from the electric storage tank will thus be approximately the same as during the DOE test conditions, or 232 Btu/hr. The combination of the hot water load of 28,000 Btu/day with shell losses of 232 Btu/hr gives a corresponding annual input energy requirement of 33,570 Btu/day or 3590 kWh/yr, or an annual electric energy requirement in the middle of the range of energy requirements reported in Table 5.1.

Similarly, using the DOE's estimated hot water consumption in conjunction with the estimated annual inlet water temperature for Fort Stewart, and the same level of standby losses (232 Btu/hr) would result in 4170 kWh/yr of electric usage.

Estimated Annual Seahorse Water Heater Energy Use: During Period 4, the Seahorse/hot water tank system delivered 2.02 MBtu of hot water to the residence in a 72-day period. The total hot water energy delivered to the tank by the Seahorse flow loop was 3.33 MBtu. The difference between these two values represents the standby losses from the storage tank system, corresponding to an average rate of energy loss from the tank of 758 Btu/hr. The average temperature of hot water delivered to the residence during this period was 128°F.

The total gas energy required during this period was 4.30 MBtu of energy, corresponding to 59,720 Btu/day of gas energy. The measured delivery-to-tank efficiency was 77.4%. The delivery-to-residence efficiency for this period was 46.9%.

The delivery-to-tank efficiency of the Seahorse under different conditions can be estimated using Equation (7). Since this equation expresses the measured delivery-to-tank efficiency as a linear function of the energy delivered to the tank and the outdoor air temperature, annual average values for those two variables can be used to determine the annual average delivery-to-tank efficiency for the Seahorse. The annual average air temperature at nearby Hunter Army Air Field is 65.6°F (U.S. Air Force et al. 1978). The energy that needs to be supplied to the tank is the hot water energy requirement for the residence plus the standby losses. The DOE estimate of 41,000 Btu/day of hot water to the residence in conjunction with 758 Btu/hr of standby losses requires that 59,190 Btu/day of heat energy be supplied to the tank. Using this figure in Equation (7) along with the average temperature at Ft. Stewart suggests a delivery-to-tank efficiency of 78.7%. Dividing the energy supplied to the tank by the above delivery-to-tank efficiency gives a net gas energy input to the Seahorse of 75,200 Btu/day of gas energy. The net delivery-to-residence efficiency of the Seahorse/hot water tank system is calculated to be 54.5% for the DOE level of estimated hot water energy consumption. The resulting Seahorse electrical energy use can be calculated from Equation (9) to be 85.7 kWh/yr.

Similarly, using the DOE's estimated hot water consumption, the estimated annual inlet water temperature for Fort Stewart, and the same level of standby losses (758 Btu/hr) would require that 52,100 Btu/day of energy be supplied to the tank for a Fort Stewart residence. Using Equation (7) again, this corresponds to 77.7% delivery-to-tank efficiency and a resulting 67,050 Btu/day of gas energy use for an average delivery-to-residence efficiency of

50.6%. The resulting Seahorse electrical energy use is calculated from Equation (9) to be 80.4 kWh/yr.

Using the measured level of hot water energy use at Fort Stewart (28,000 Btu/day) and the same level of standby losses (758 Btu/hr) would require 46,200 Btu/day of energy be supplied to the tank. This corresponds to 76.9% delivery-to-tank efficiency and a resulting 60,100 Btu/day of gas energy use for an average delivery-to-residence efficiency of 46.6%. The resulting Seahorse electrical energy use is 75.9 kWh/yr.

Estimating Annual Hot Water Heater Demand Cost: As discussed in Section 2, the avoided cost to supply electrical energy at Fort Stewart is \$0.025/kWh. The avoided cost of electrical demand at the base is \$8.85/kW-mo, where the utility demand charge is based on the monthly demand reading modified by the demand ratchet as described in Section 2.1.2. 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) suggests that electrical monthly demand peaks at Fort Stewart occur between 3 p.m. to 5 p.m. daily for six months out of the year (the cooling season) and occur randomly sometime between 8 a.m. and 10 p.m. 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 heavily influenced based on the summer afternoon peak. The average avoided demand cost for the year can be estimated as

$$\begin{aligned} \text{Demand Cost } (\$/kW-Mo) &= \frac{(8 \text{ months} \times 95\% \times 8.85 \text{ } \$/kW-Mo) + (4 \text{ months} \times 100\% \times 8.85 \text{ } \$/kW-Mo)}{12 \text{ Mo}} \quad (13) \\ &= 8.56/kW-Mo \end{aligned}$$

Because of the number of residences on base and the measured water heater energy consumption profiles (Figure 4.11), electrical demand due to residential water heaters (electric heat or Seahorse) is expected to be evenly diversified during this summer peak electrical demand period. Examination of Figure 4.11 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 example, for a typical residential electric water heater consuming 4,980 kWh/yr (at the DOE level of hot water energy use), the average electrical demand would be 4980 kWh/yr divided by 8760 hr/yr or equal to 568 W. The average electrical demand from the Seahorse unit can be similarly estimated by averaging the annual electric load over 8,760 hours in the year. At the DOE level of hot water energy use, the average electrical demand for the Seahorse is 9.79 W. The annual electrical demand cost is then calculated by multiplying the average electrical demand by 12 billing months and by the demand cost in \$/kW-mo.

Source Energy Use: Calculation of source energy usage is helpful in comparing the environmental impact of conservation measures such as the Seahorse that 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 (Office of Technology Assessment 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%.

Total Energy Costs: Table 5.2 shows the annual energy consumption and associated annual energy costs for the Seahorse/hot water tank system and for a standard electric hot water tank based on the DOE's estimated hot water energy consumption, the estimated energy consumption based on DOE's hot water consumption and Fort Stewart's inlet water temperature, and the measured hot water energy consumption from the Fort Stewart demonstration.

5.2 Preliminary Life-Cycle Cost Comparison - Seahorse Versus Electric Water Heater

Life-cycle cost analysis of a Seahorse water heater and of a typical residential electric water heater was performed using the National Institute of Standards and Technology (NIST) analysis program BLCC (Peterson 1993) for the three different levels of hot water energy consumption. The chief economic parameters used in the analysis were as follows:

Analysis Basis:	Federal Analysis--Energy Conservation Projects
Study Period:	15 years (Sept 1995 through Sept 2009)
Discount Rate:	3.1% Real (exclusive of general inflation)
Avoided Electrical Energy Cost:	\$0.025/kWh
Avoided Electrical Demand Cost:	\$8.56 kW-month
Avoided Gas Energy Cost:	\$3.00/MBtu

The two 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 during the lifetime of the Seahorse unit. Zero dollar salvage values were assumed for the water heater and for the Seahorse unit to be replaced.

Table 5.2. Annual Energy Consumption and Cost for Residential Water Heating Alternatives, Electric Water Heater and Seahorse/Hot Water Tank System

System	Electric Water Heater			Seahorse/Hot Water Tank System		
	DOE Estimated HW Energy Consumption	DOE Hot Water Consumption	Measured Hot Water Consumption	DOE Estimated HW Energy Consumption	DOE Hot Water Consumption	Measured Hot Water Consumption
Equivalent Hot Water Energy Use (Btu/day)	41,000	33,900	28,000	41,000	33,900	28,000
Annual Electric Energy Consumption (kWh/yr)	4,980	4,225	3,590	85.7	80.4	75.9
Annual Electric Demand (kW-mo)	6.8	5.8	4.9	0.1	0.1	0.1
Gas Energy Consumption (MBtu/yr)	0.0	0.0	0.0	27.5	24.5	21.9
Source Energy Consumption (MBtu/yr)	54.9	46.5	39.5	28.4	25.4	22.8
Annual Electric Cost (\$/yr)	\$125	\$106	\$90	\$2	\$2	\$2
Annual Demand Cost (\$/yr)	\$58	\$49	\$42	\$1	\$1	\$1
Annual Gas Cost (\$/yr)	\$0	\$0	\$0	\$83	\$73	\$66
Annual Total Operating Cost (\$/yr)	\$183	\$155	\$132	\$86	\$76	\$69

Because it is a new product, no typical system lifetime is known for the Seahorse. A GFP estimate of 15 years was assumed for this 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 5.3.

Costs and installation labor for electric hot water heater were obtained from *Means Repair and Remodeling Cost Data 1993* (R. S. Means Company, Inc. 1992). The estimated Seahorse cost used in this analysis represents a 45% discount off the retail price of \$895 that GFP offers to gas utilities. It is assumed that the local gas utility would purchase the units and sell them at cost to the installing contractor. 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 procured should deliver the same thermal storage performance as the electric water heater and have the same number of fittings for connecting to the Seahorse and to the

Table 5.3. Installation Costs for Water Heater Alternatives

Installation Costs - Electric Water Heater

<u>Item</u>	<u>Cost</u>
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

<u>Item</u>	<u>Cost</u>
Seahorse conversion kit (cost to local gas utility)	\$492
40 ft. 7/8" Plastic Hot Water Tubing (@ \$0.45/ft.)	\$18
Aquastat submersible thermostat	\$49
Installation of Seahorse conversion kit including cost to run gas piping (6 man-hours @ \$18.20/hr)	\$109
Overhead and Profit (25%)	
Total	\$835

the residence. As the cost of the electric elements in a typical tank are small, the likely choice for replacement would be a similar electric water heater. It is this replacement that was assumed in the Seahorse analysis. An additional half-hour of labor above and beyond the cost to install the replacement electric water heater was assumed to account for reconnection of the Seahorse system and checking for leaks in the flow loop connections to the hot water tank.

The Seahorse represents a more complicated technology than either electric resistance water heaters or tank-type gas water heaters. Because of this, maintenance is expected to be somewhat higher.

The Seahorse warranty covers replacement of all parts for 1 year after purchase, pumps are warranted up to 3 years after purchase, and heat exchangers for up to 5 years after purchase. In addition, Seahorse will honor the electric hot water tank manufacturer's warranty if the tank manufacturer refuses to honor it after a Seahorse has been installed.

Because the Seahorse has been in production only since 1992, failure rates and repair and maintenance costs are largely unknown. According to GFP, there have been few cases of installed Seahorse systems requiring parts replacements. In instantaneous gas hot water heaters, which share many design similarities with the Seahorse, fatigue problems induced by

scaling and thermal expansion often result in relatively short heat exchanger life spans of around 10 years (DOE 1993). Because the temperature increase of water in the Seahorse heat exchanger is relatively low (approximately 20°F compared to around 50°F in many instantaneous gas water heaters) these problems are expected to be significantly reduced in comparison with instantaneous gas hot water heaters, and the Seahorse's heat exchangers are expected to last the life of the product.

Other maintenance issues that affect instantaneous gas water heaters and that could potentially affect the Seahorse include component failures, particularly in pumps, gas valves, and ignition modules, as well as leakage through gaskets (DOE 1993). Components that fail through improper installation or poor manufacture will often do so within the first year warranty period. Any failure after this will likely result in a service call whose cost would be borne by Fort Stewart.

An additional issue with all gas water heaters is the potential for nuisance maintenance calls, caused predominantly by a failure of a gas flame to ignite or stay lit. This concern is exacerbated with the Seahorse since it is designed to be an outside unit and thus exposed to windier conditions than would exist in a residence. To alleviate this problem, new Seahorse models are equipped with a spark-pilot ignition system. With this system, the Seahorse, on a call for heat, opens a gas valve for a small pilot light and, at the same time, uses an electronic ignition system to light the pilot. The electronic ignition system will continually try to light the pilot until a temperature sensor determines that the pilot light is lit or approximately 20 seconds pass. If the sensor determines that the pilot light was lit, the first stage of the main gas valve will open and the gas burner will be lit by the pilot light. If the temperature sensor does not sense the ignition of the pilot during the ignition period, the Seahorse will go into lockout mode for approximately 5 minutes. After the lockout period is over, a re-ignition sequence is begun. This ignition system design is intended to minimize nuisance maintenance requirements due to ignition difficulties while at the same time maintaining a high degree of safety by not allowing large quantities of unignited natural gas to develop in the area surrounding the Seahorse. It should be noted that, even with the simpler DSI system used in the Seahorse demonstrated at Fort Stewart, there were no such maintenance or nuisance calls during the demonstration period.

For the purpose of this analysis and based on discussions with GFP, it is assumed here that service calls on Seahorse units requiring repair will be expected for 1% of all installed units each year through the end of the expected service life (15 years) and that the average cost per service call will be approximately \$150.

Regular maintenance requirements recommended by GFP for the Seahorse are an annual examination of the gas burner flame and annual check of the temperature and pressure (T&P) valve. This minimal level of maintenance is similar to the annual check recommended for other residential water heaters types and realistically, there is expected to be no higher regular maintenance costs for the Seahorse/hot water tank system than for existing tank-type water heaters.

Because of manufacturers' experience and the inherent simplicity of the technology, repair and maintenance costs for new electric water heaters are typically low. To a large degree, maintenance problems that do exist are related to leaking storage tanks. Since these same tanks would be used with the Seahorse, maintenance costs due to tanks were assumed to be identical and were not included in the economic analysis for either system. Because of this, repair costs for electric water heaters are shown as zero in this analysis.

Table 5.4 shows a comparison of present value costs (1995 dollars), as calculated by BLCC (see Appendix F), for the electric water heater and for the Seahorse assuming either the DOE's estimated hot water energy consumption, the estimated energy consumption based on DOE's hot water consumption and Fort Stewart's inlet water temperature, or the measured hot water energy consumption from the Fort Stewart demonstration. Based on this analysis, the Seahorse was cost-effective only for the DOE equivalent energy consumption. Further analysis revealed that the hot water energy consumption necessary to make the Seahorse a cost-effective retrofit was 94% of the DOE equivalent energy consumption or 39,480 Btu/day of hot water energy usage.

Table 5.4. Comparison of Present-Value Costs for Water Heater Alternatives

	Electric Water Heater			Seahorse/Hot Water Tank System		
	DOE Estimated HW Energy Consumption	DOE Hot Water Consumption	Measured Hot Water Consumption	DOE Estimated HW Energy Consumption	DOE Hot Water Consumption	Measured Hot Water Consumption
Initial Investment (\$)	\$0	\$0	\$0	\$835	\$835	\$835
Energy Costs (\$)	\$2,174	\$1,842	\$1,569	\$1,191	\$1,064	\$953
Repair/Maintenance Costs (\$)	\$0	\$0	\$0	\$27	\$27	\$27
Additional Capital Investment (\$)	\$314	\$314	\$314	\$314	\$314	\$314
Total Costs (\$)	\$2,489	\$2,156	\$1,884	\$2,366	\$2,239	\$2,128

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 5.3, is illustrated in Figure 5.1 for two levels of hot water energy use. In this figure, a positive net present value means that the Seahorse is a cost-effective alternative to an electric water heater. Two lines are shown. The upper line represents hot water use equivalent to the DOE energy use estimate, the lower line represents the measured hot water energy requirements during the Fort Stewart demonstration. A third line (not shown) representing hot water energy use as calculated from the DOE estimated water consumption and the estimated Fort Stewart cold water inlet temperatures would fall midway between the two lines shown.

In this nomograph, combinations of gas and electric energy costs that appear below a given line lead to a positive NPV for the Seahorse for the hot water energy consumption

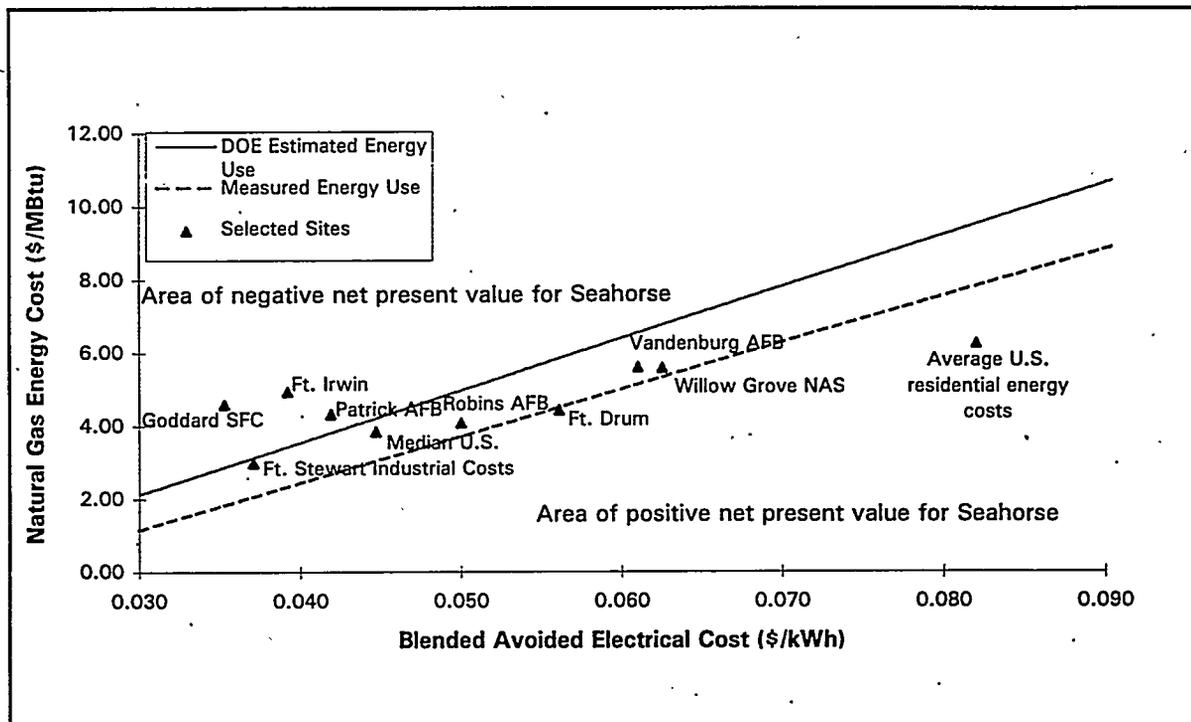


Figure 5.1. Energy Costs and Net Present Value for Seahorse Retrofit

level indicated by that line. The avoided blended electrical cost shown on the x-axis of Figure 5.1 was calculated as

$$\text{Blended energy cost (\$/kWh)} = \text{avoided energy cost (\$/kWh)} + (\text{avoided demand cost (\$/kW-Mo)} \div 730 \text{ hr/Mo}) \quad (14)$$

The nomograph maps the avoided energy costs of Fort Stewart, as well as several other Federal sites, to give an idea of the cost-effectiveness of the Seahorse system in other locations. Note that the actual hot water energy requirements for these sites would vary with cold water inlet temperature and that Federal sites interested in the Seahorse can use their own estimates of typical residential hot water energy use in their area to interpolate the cost-effectiveness of the Seahorse at their site. The median industrial gas and electric energy costs for the United States (*Energy User News* 1994a, 1994b) and the average residential gas and electric energy costs for the United States (Energy Information Administration 1994) are also shown on the nomograph for reference. Based on the national average residential electrical energy cost of \$0.082/kWh and gas energy cost of \$6.25/MBtu and DOE's estimated annual hot water energy usage, the Seahorse would be expected to save \$230/yr in energy cost.

The results of the analysis suggest that the measured Seahorse performance would make the Seahorse a cost-effective retrofit at Fort Stewart for residences whose hot water energy requirements were similar to that predicted by the DOE on a national average basis. However, the average hot water energy use for a typical Fort Stewart residence may be

significantly less than the DOE estimate, based on the metered results from Fort Stewart, various utility studies, and from the DOE's own hot water consumption estimate coupled with the cold water inlet temperature for the site.

5.3 Comparison of Annual Energy Performance - Tank-Type Gas Water Heater Versus Seahorse

The performance of the Seahorse/hot water tank system, as measured during monitoring period 4, was approximately equivalent to what would be expected of a base model tank-type gas water heater. This conclusion is based on comparison of the annual delivery-to-tank efficiency and tank loss rate for the Seahorse that is estimated from the data obtained during the fourth monitoring period.

According to the Federal regulations (10 CFR 430), the minimum allowed energy factor rating for gas water heaters less than 75 gallons in storage capacity is calculated as a function of storage volume using Equation (15) below.

$$EF = 0.62 - 0.0019 \times Vol(\text{gallons}) \quad (15)$$

A typical 40-gallon water heater would thus have a minimum energy factor of 0.544.

Data from 97 gas-fired tank-type water heaters listed in the California Energy Commission Home Appliance database (California Energy Commission 1995) with energy factors of 0.54 to 0.56 were examined. The reported recovery efficiencies were typically 76% to 77%. Based on the measured data, the Seahorse, operating at the same hot water load and air temperature used for the DOE 24-hour test, would be expected to have a comparable delivery-to-tank efficiency of 78.7%. The average tank heat loss rate reported for the 97 units varied from 3.5% to 4.5%, averaging 3.8%. This means that 3.8% of the stored energy will leave the tank in any 1-hour period. The stored energy is based on the temperature difference between the hot water and the 67.5°F ambient room temperature used during the DOE 24-hour test procedure. However, since the stored energy is based on the hot water-room temperature difference, and the tank heat loss is roughly proportional to the hot water-room temperature difference, reporting the average loss rate as the percentage of the stored energy makes it roughly constant with hot water temperature.

During test period 4, the 40-gallon hot water tank was maintained at an average tank temperature of 126°F. The room temperature was maintained at 74°F. The average level of hot water energy stored in the tank was calculated to be 17,200 Btu. The average loss rate of 758 Btu/hr corresponds to an average hourly loss of 4.4% of the stored energy in the tank each hour, a loss rate at the high end of the standby energy loss rates listed in the California database.

The electricity use by the Seahorse is minimal. The steady power draw for the direct spark ignition device will likely be similar to that for new gas water heaters with electronic ignition devices. Pilot lights would typically be more expensive to operate than either electronic device. Net energy requirements to operate the Seahorse pump alone are estimated to be less than 25 kWh/yr, with an annual cost of less than \$1.

The origin of the combustion air plays some role in the total energy cost of the water heater. Placing the combustion unit inside the residence, as would likely be the case with a tank-type water heater, requires bringing in outside air to the residence during firing. It may also require opening a hole in the residence roof for a new flue, which would increase residence infiltration and space heating/cooling energy use. In some instances, an existing furnace flue may also be used for the water heater. This minimizes the additional infiltration. However, a nominal amount will always exist because the installed water heater will draw combustion air from the residence. The Seahorse, being an outside unit, requires that only two small openings be made for the water flow loop piping and, once sealed, these openings are not anticipated to increase house infiltration. The additional energy cost due to infiltration induced by a tank-type gas water heater is small, but will exist in all climates.

Assuming that the DOE estimate of 41,000 Btu/day is accurate for Fort Stewart, the additional infiltration necessary to make up combustion air can be easily estimated. This level of hot water energy consumption corresponds to a total gas usage of 27.7 million Btu/yr, which at a typical energy factor of 0.54, corresponds to 27,000 SCF of natural gas (at 1,025 Btu/SCF). Assuming an excess air ratio of 25% for combustion of natural gas results in an air/fuel ratio of approximately 21.5 to 1 (mass basis) and results in the use of 321,900 SCF/year (36.7 SCF/hr) of air. If it is assumed that heating is required at temperatures of below 65°F and cooling at temperatures above 80°F, then a residence at Fort Stewart has 3,728 hours requiring space heating per year and 1,481 hours requiring space cooling per year (U.S. Air Force et al. 1978). The average outdoor temperature is 51.3°F during these heating hours and the average outdoor temperature is 85.2°F during cooling hours. The cost to heat combustion makeup air can be calculated as the product of the average air flow rate induced by the water heater combustion, the number of conditioning hours per year (heating or cooling respectively), the heat capacity of air, the average indoor outdoor temperature difference during heating or cooling respectively, and the energy cost divided by the efficiency to produce that energy. For example, for heating,

$$\text{Cost to heat combustion air} = \text{Hourly Makeup-air} \times \text{Heating hours/yr} \times C_{p_{air}} \times \quad (16)$$

$$(\text{T}_{in_{heating}} - \text{T}_{out_{heating}}) \times \text{Fuel Cost} / \text{Eff}_{heating}$$

where

$\text{T}_{in_{heating}}$ = the average indoor temperature during heating (assumed 72°F)
 $\text{T}_{out_{heating}}$ = the average outdoor temperature during heating (51.3°F)

Eff_{heating} = the heating system efficiency (assumed 77% for gas furnace)
 Cp_{air} = heat capacity of air (0.0184 Btu/SCF-°F).

The average electricity cost in this example includes the demand cost and is estimated using Equation (14) to be \$0.037/kWh at Fort Stewart. For Fort Stewart, the average cost to heat makeup air for this example is \$0.20/yr. Similarly, the cost for sensible (temperature reduction only) cooling of combustion makeup air can be calculated to be \$0.04/yr. Even if this is doubled to account for the latent load on the system, the total cost for space conditioning of combustion air is very small, approximately \$0.28/yr.

In all, the measured performance of the Seahorse/hot water tank system installed in this demonstration was roughly equivalent to a tank-type gas water heater meeting the minimum performance specifications for installation at a Federal facility. It is important to note that there is presently no test procedure established for gas water heaters in the same category as the Seahorse and thus no mechanism for a consumer to directly compare the Seahorse with other gas water heater types.

5.4 Life-Cycle Cost Comparison - Seahorse Versus Tank-Type Gas Water Heater

Because the measured performance was similar to that of a base-efficiency level, tank-type gas water heater, the decision to purchase a Seahorse or tank-type gas water heater should be based primarily on the differential capital cost for each water heater type, the cost for installation, and also on any additional labor and material costs through the life of either system. Two alternatives present themselves for water heater replacement: immediate replacement of the existing electric water heater, with a second gas water heater installed after 10 years have elapsed (the estimated tank lifetime), or replacement of the existing water heater on failure at the estimated 5-year mark. As most major housing retrofits at Fort Stewart are contracted out to third parties, systematic replacement of all water heaters at once (the first case) would be the most likely scenario and was chosen for analysis.

The unit cost for a 40-gallon, base efficiency gas water heater with a life span of 10 years (DOE 1993) is estimated at approximately \$300 based on the R. S. Means Company residential cost data for 1995 (Means 1995). Labor to install and plumb the gas water heater will be approximately \$80 not including installation of a flue vent (Means 1992). The installation cost for venting will vary widely depending on the desired location of the water heater and, in particular, whether or not an existing furnace vent may be used.

Figure 5.2 shows the estimated present value costs at Fort Stewart of the Seahorse and of a tank-type gas water heater with an energy factor of 0.54 based on the DOE equivalent hot water energy usage and the energy costs at Fort Stewart. The present value cost for the Seahorse is from Section 5.3. The present value cost for the tank-type gas water heater is shown as a function of the cost to install venting for that unit. For this level of hot

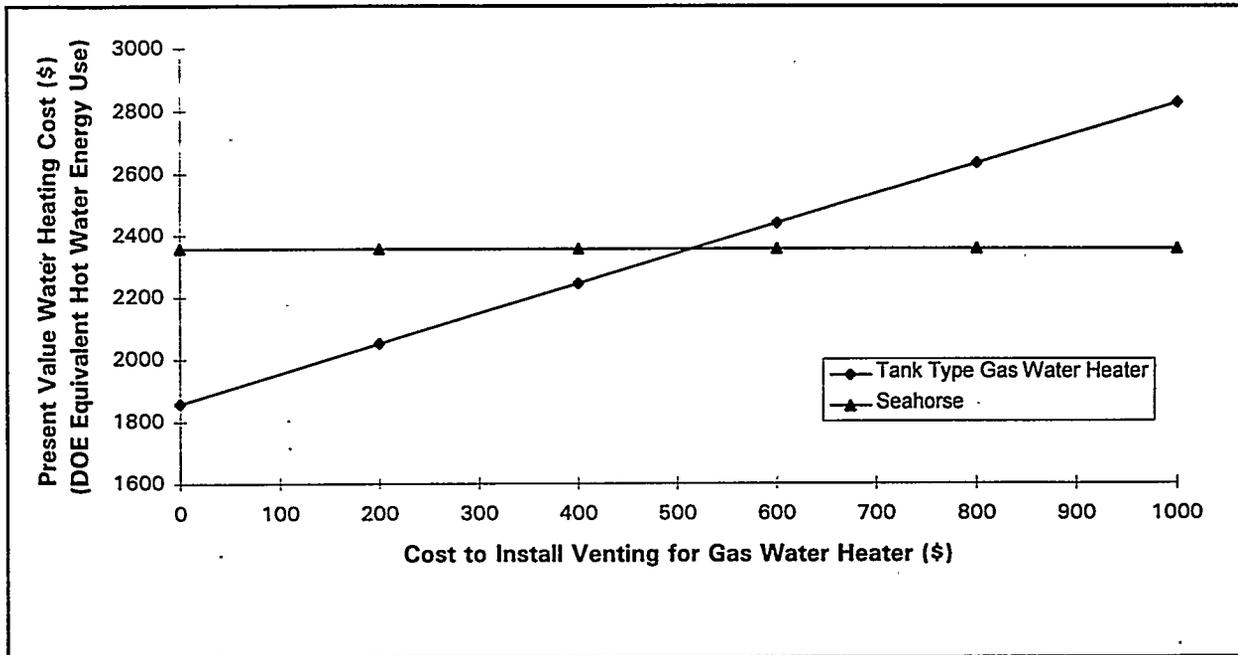


Figure 5.2. Present Value Cost for Seahorse and Tank-Type Gas Water Heater Options (assuming DOE's level of estimated residential hot water energy use)

water energy usage, the Seahorse does not become cost-competitive until the cost to install venting for the tank-type gas water heater is approximately \$525. This is due primarily to the higher installation costs assumed for the Seahorse as well as the need for a separate storage tank with the Seahorse.

For the residence used for the test, the furnace and existing water heater are in the same room and could likely use the same external vent. In this application, it is estimated that the material and labor cost to vent the gas water heater would be less than \$150 and that immediate installation of a tank-type gas water heater would be the most cost-effective water heating strategy.

5.5 Seahorse Installation and the Effect on Performance and Cost-Effectiveness

The performance of the Seahorse in this demonstration suggested a slightly lower delivery-to-tank efficiency than was originally expected for the gas-fired Seahorse technology. In addition, the ratio of the measured energy output for the system to the energy input to the tank suggested that standby loss rates from the installed system were considerably higher than would be typical of an electric water heater storage tank operating under similar conditions.

Any hot water heating system in which the heating device and the storage tank are separated with a flow loop will suffer from standby losses in the piping. For this reason, the

distance separating the Seahorse and the hot water tank should be minimized in any installation. During standby periods, the Seahorse will also lose much of the hot water energy stored in the hot water left in the Seahorse heat exchanger after each operating cycle. However, that energy loss is fixed by the temperature of water in the heat exchanger and the volume of the heat exchanger.

To alleviate the energy loss stemming from the hot water left in the heat exchanger, the newest versions of the Seahorse continue to run the pump for a short time after the burner has shut off. This "purge cycle" removes any water in the Seahorse heat exchanger and flow loop that was heated at the end of an operation cycle but was not yet pumped into the tank. It replaces that hot water with tank water that would typically be 10 to 15 degrees cooler than the average water temperature in the flow loop. For an installation similar to Fort Stewart's where the water stored in the flow loop and heat exchanger is approximately 1 gallon, this new design could be expected to save approximately 100 Btu/cycle (1 gal x 8.28 Btu/gal-F x 12.5°F = 103.5 Btu).

In the case of the installed Seahorse system, there is a significant possibility for thermosiphoning in the flow loop. This may explain the significantly higher rate of heat loss reported during standby than would be typical of a standard electric water tank.

As the water in the flow loop cools, both through losses in the flow loop piping and losses through the Seahorse heat exchanger, the water in the flow loop becomes more dense than the water in the tank. The dense, cooler water will sink through the flow loop system while less dense hot water from the tank will fill the upper flow loop section. If, as in this installation, the bottom of the Seahorse is at the same level as the bottom of the tank, the cooler water from the lower loop section will flow into the bottom of the storage tank, moving in a direction counter to the direction of flow during Seahorse operation. Discussions with GFP have indicated that the Seahorse has no built in mechanism to stop this thermosiphoning. Typical fluid metering devices such as those used in the flow loop for this demonstration are not capable of measuring the type of low flow rates that would be typical of thermosiphoning while at the same time measuring the much higher flow rates that occur during Seahorse operation. Thus, in this demonstration, any energy loss due to thermosiphoning appears only as nonspecific standby losses.

However, engineering calculations (see Appendix E) suggest that water flow rates of 1-2 gal/hr (less than 1/100th of the flow during pump operation) could easily result from such thermosiphoning. A 1 gal/hr flow with 128°F water leaving the tank and 80°F water entering the bottom of the tank (due to losses in the flow loop and heat exchanger over the approximately 1 hour transit time) would correspond to 397 Btu/hr of heat loss in the piping, which, in conjunction with the heat losses from the tank, would account for the majority of standby losses in this demonstration. Higher temperature drops or higher flow rates would result in higher losses due to thermosiphoning.

A further clue pointing to the existence of thermosiphoning losses is found by examining the variation of daily standby loss with the environmental and system parameters. For the period from Sept 20-Nov 30, the daily standby loss was calculated by subtracting the energy delivered to the residence from the energy delivered to the hot water tank by the Seahorse. A graph of the standby loss during this period is shown in Figure 5.3. As can be seen there is a significant amount of scatter in this parameter about an average standby loss rate of 18,240 Btu/day.

Linear regressions were made comparing the daily standby loss against a number of the important system parameters. The goodness-of-fit parameter R-squared (maximum possible correlation at $R^2 = 1.0$) for these regressions is shown in Table 5.5 for several of these parameters.

All the correlation coefficients are small, indicating that the standby heat loss from the tank cannot be completely categorized by any single measured parameter. However, it is noted that there is almost no correlation between the daily hot water consumption in gallons or daily hot water energy use and the standby loss. A higher correlation with these parameters would be expected if the high standby loss recorded was the result of a consistent bias in the recording of hot water consumption.

The correlation of standby loss with daily average outdoor temperature is the strongest correlation of the parameters examined. This is consistent with the theory that most of the recorded standby loss occurs because of thermosiphoning. In a thermosiphoning system the greatest heat losses will occur in the outdoor piping and, more importantly, through the heat exchanger outside the house. The rate of loss will vary with the

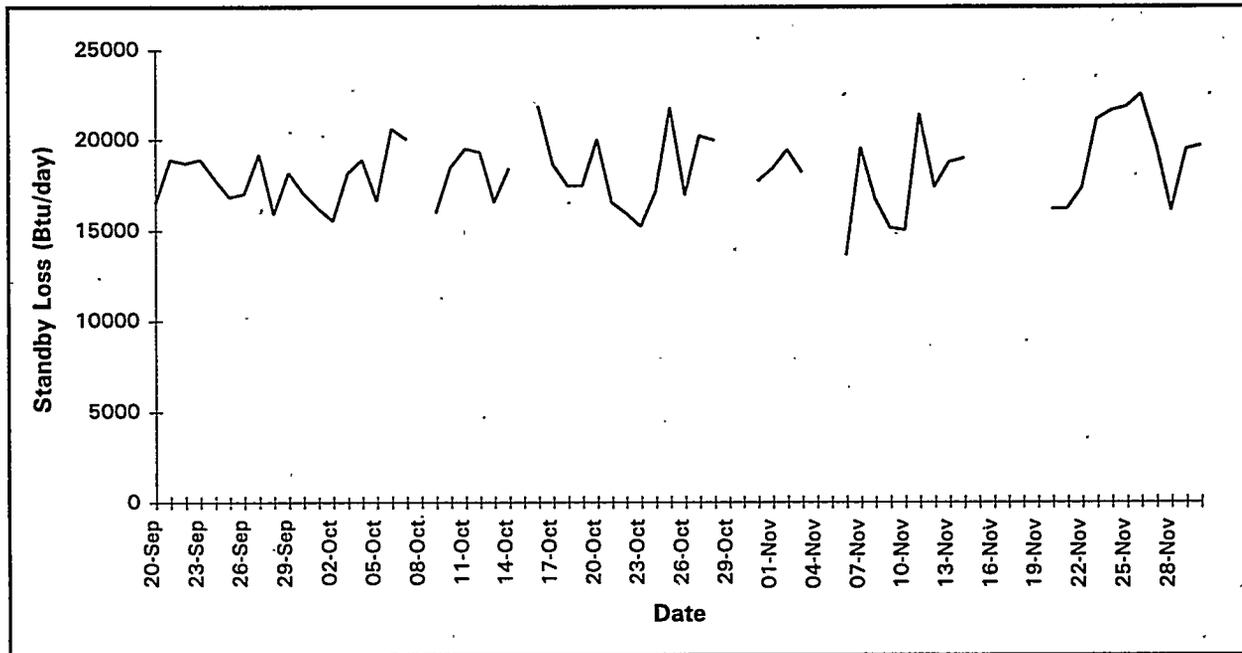


Figure 5.3. Standby Loss Recorded (Sept 20- Nov 30)

Table 5.5. Correlation Between Standby Loss and Other Measured System Parameters

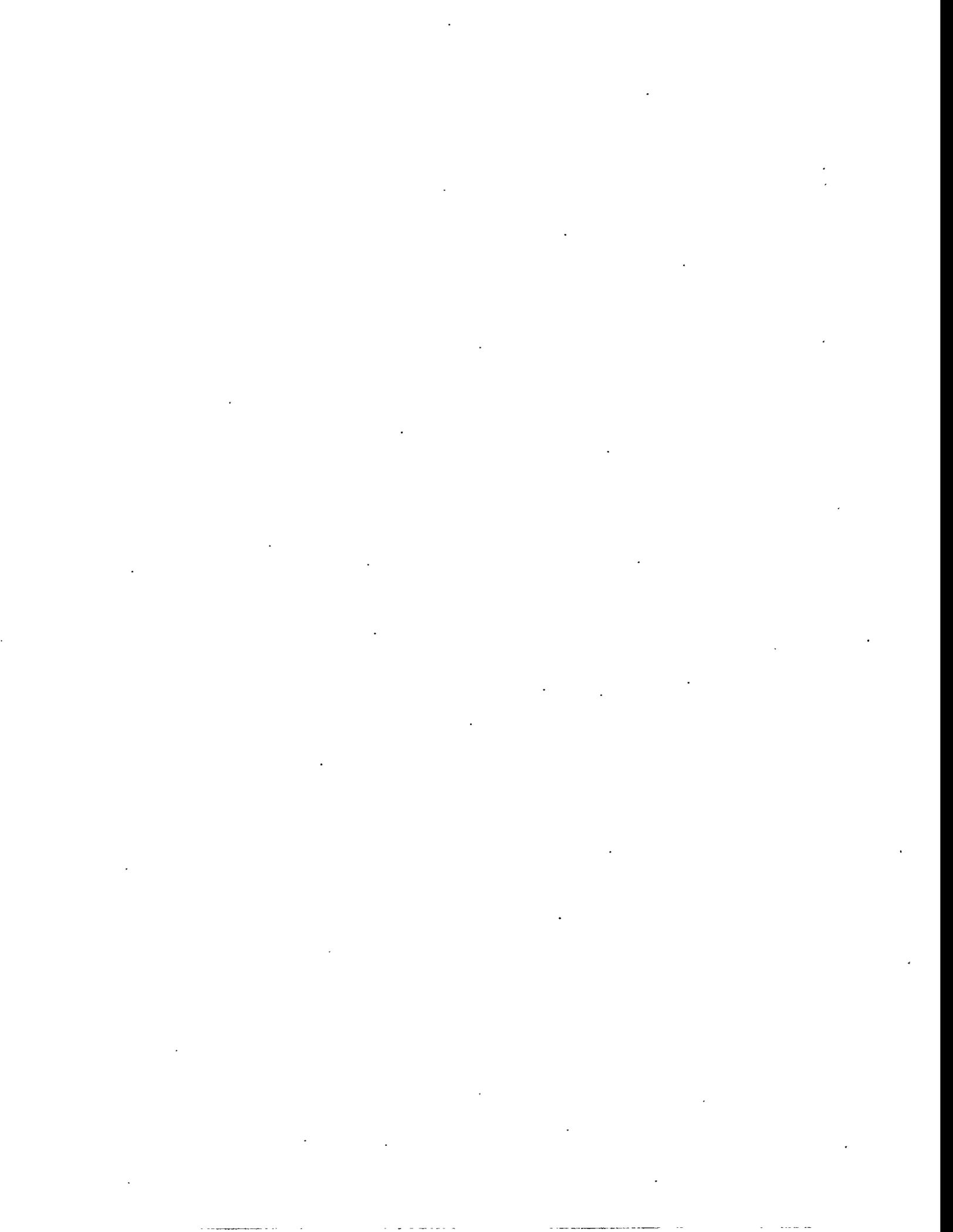
System Parameter	R ²
Daily hot water consumption (gal)	0.03
Daily hot water energy use (Btu/day)	0.04
Daily gas energy use (Btu/day)	0.10
Daily Energy delivered to tank	0.11
Daily average room temperature (F)	0.08
Daily average outdoor temperature (F)	0.39
Daily average tank temperature (F)	0.09

temperature difference between the water in the loop and the outside temperature, and some degree of correlation between the loss rate and the outdoor temperature is expected. Note that the correlations of standby losses with average room temperature and average tank temperature are also significantly less than the correlation with outdoor temperature, indicating the low relative importance of these parameters as compared with the outdoor temperature.

The correlations with daily gas energy use and daily energy delivered to tank are also considerably less than the correlation with outdoor air temperature. Again, any over-estimates of standby losses due to poor temperature or flow measurement would be strongly linked with these parameters. As this is not the case, any experimentally induced over-estimates of standby loss are likely small compared to the influence of the outdoor air on the tank/flow-loop system.

Since there are indications that thermosiphoning in the flow loop is a significant issue with the system, it is suggested that a simple, low-cost check valve, placed in the flow loop, would significantly improve the Seahorse performance. The valve would be placed so flow could proceed in the direction of the pump flow, but would close to prevent flow in the reverse direction. Such valve are commonly in use to prevent thermosiphoning in solar hot water systems that rely on flow loops to move hot water from solar collectors to separate storage tanks. Costs of such valves through retailers are in the \$10 to \$20 range.

Installations in residences with larger families and proportionally higher hot water energy consumption would make the Seahorse more cost-effective. In addition, plumbing of a single Seahorse to two separate hot water tanks located in adjacent residences (as is possible in duplex-style housing) may represent a very cost-effective use of the technology and, according to GFP, is being done in the private sector. Based on the measured performance, the heating capacity of the Seahorse appears to be adequate for this type of installation.



6.0 Conclusions

On-site testing of the Seahorse as installed in a single residence at Ft. Stewart suggested that a delivery-to-tank efficiency of 75-79% can be expected during operation based on typical, single-family, residential hot water loads. Observation of the demonstrated unit suggests that attaining this efficiency level requires proper setting of the Seahorse temperature control during installation. It was seen that larger thermostat differentials reduce the cycling of the Seahorse unit and provide higher efficiency. A differential setting of 30°F provided the above performance while still able to meet the residence requirements for temperature and volume of hot water. Because of the efficiency penalty and short-cycling operation that occurred when the tank thermostat was used for control, it is suggested that an underwater thermostat (aquastat) be used for any new Seahorse installations. The measured efficiency of the Seahorse/hot water tank system at delivering hot water to the residence was on the order of 50-55% over the same range of hot water requirements. Improvements in control strategies available in more recent Seahorse models will raise this system efficiency. The use of one way valves in the flow loop between the Seahorse and hot water tank is also expected to raise the system efficiency, however this was not tested in this demonstration.

Determination of the cost-effectiveness of the Seahorse depends on the hot water requirements for the residence. Based on the data gathered during this demonstration and Fort Stewart energy costs, the Seahorse would be a cost-effective retrofit compared to the existing electric hot water heater for residences whose daily hot water energy consumption was similar to, or greater than, the DOE's estimate for average residential hot water energy consumption. However, for reasons discussed in this report, typical residential hot water energy consumption for Fort Stewart could be significantly less than the DOE estimate. At marginally lower levels of hot water consumption (94% of the DOE figure or less), the Seahorse was determined not to be a cost-effective retrofit for Fort Stewart.

A nomograph showing the electrical and natural gas costs leading to a positive net present value for the Seahorse conversion was developed from this demonstration and is repeated in Figure 6.1. This nomograph suggests that the Seahorse could be a cost-effective retrofit strategy for Federal facilities with higher energy costs or greater cost differentials between gas and electric energy costs than were seen at Fort Stewart. It is recommended that Federal facilities with gas and electric energy costs that lead to a positive net present value in Figure 6.1 (as compared with the DOE Estimated HW Energy use) consider use of the Seahorse in residential applications presently served by electric water heaters. Improvements in the as-installed efficiency of the unit, as mentioned above, or reductions in price as more units are ordered and sold; will likely improve the cost-effectiveness of the Seahorse in the Federal sector.

A comparison of the Seahorse performance with more typical tank-type gas water heaters suggested that the installed Seahorse/hot water tank system at Fort Stewart performed

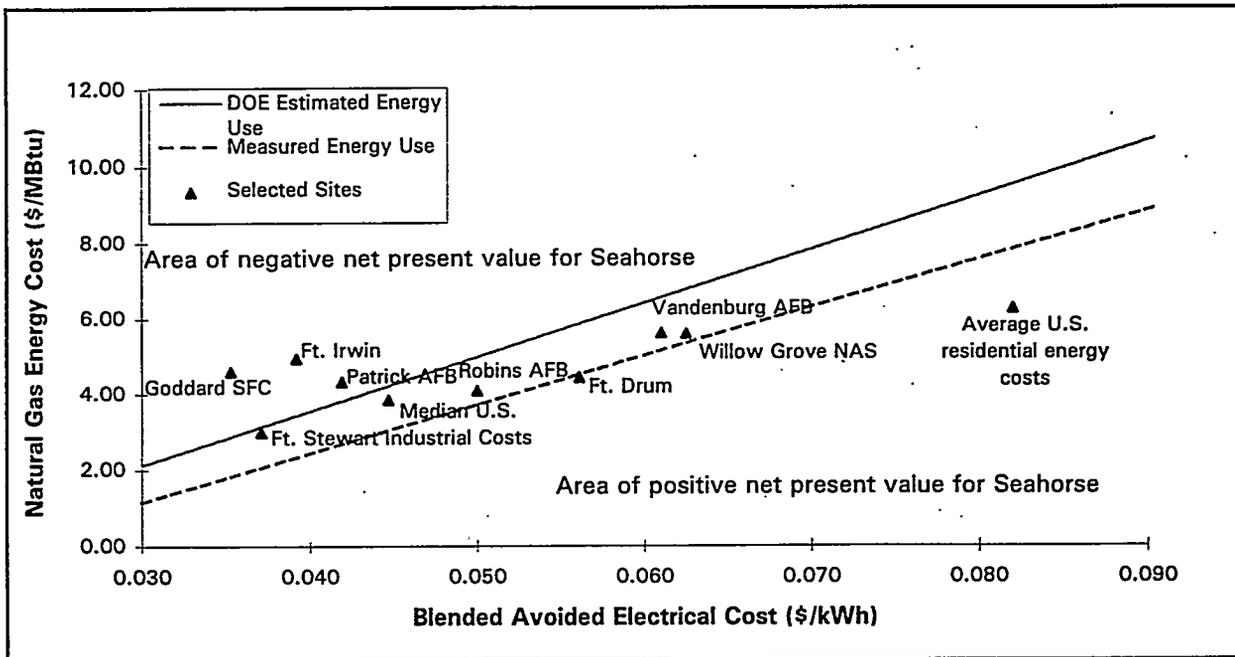


Figure 6.1. Energy Costs and Net Present Value for Seahorse Retrofit

at roughly the same level of efficiency as a typical 40 gallon gas water heater with an energy factor of 0.54, the minimum efficiency level allowed for installation at a Federal site. Again, improvements in system design in the present generation of Seahorse units may make new Seahorse models more efficient than base tank-type gas water heater. In addition, installation of a check-valve in the Seahorse flow loop would also improve the Seahorse efficiency beyond what was measured in this installation. Similar levels of improvements are also available in residential tank-type gas water heaters but often at higher costs. However, based on the measured data, it is recommended that the decision to purchase a Seahorse versus a tank-type gas water heater be based primarily on capital and installation cost consideration. A life-cycle cost comparison with gas-fired, tank-type water heaters will depend heavily on the installation costs for the tank-type gas water heaters, particularly the cost of providing an exhaust flue for ventilation of the gas water heater. A second nomograph is provided in this report which illustrates which gas water heater type would be more cost effective based on the cost to provide a flue system for the tank-type water heater.

In conclusion, the Seahorse appears to be a robust technology for which there are cost-effective applications in the Federal sector. Federal energy managers supervising areas with the right combination of energy costs (as shown in Figure 6.1) should consider the Seahorse as an alternative to electric resistance water heaters for residences that have natural gas or propane gas available to them. Based on the measured performance, the decision to use the Seahorse instead of a more conventional, tank-type gas water heater should be based primarily on capital cost, installation cost, and additional maintenance considerations as outlined in this report.

Because the as-operated efficiency of the Seahorse/tank system is significantly different from the thermal efficiency of the Seahorse alone, it is strongly recommended that GFP pursue rating the Seahorse using a test procedure that includes the use of the hot water storage tank. This will make efficiency comparison between the Seahorse and other water heating technologies easier for the consumer and will allow GFP to showcase efficiency improvements that have been made to more recent Seahorse models.



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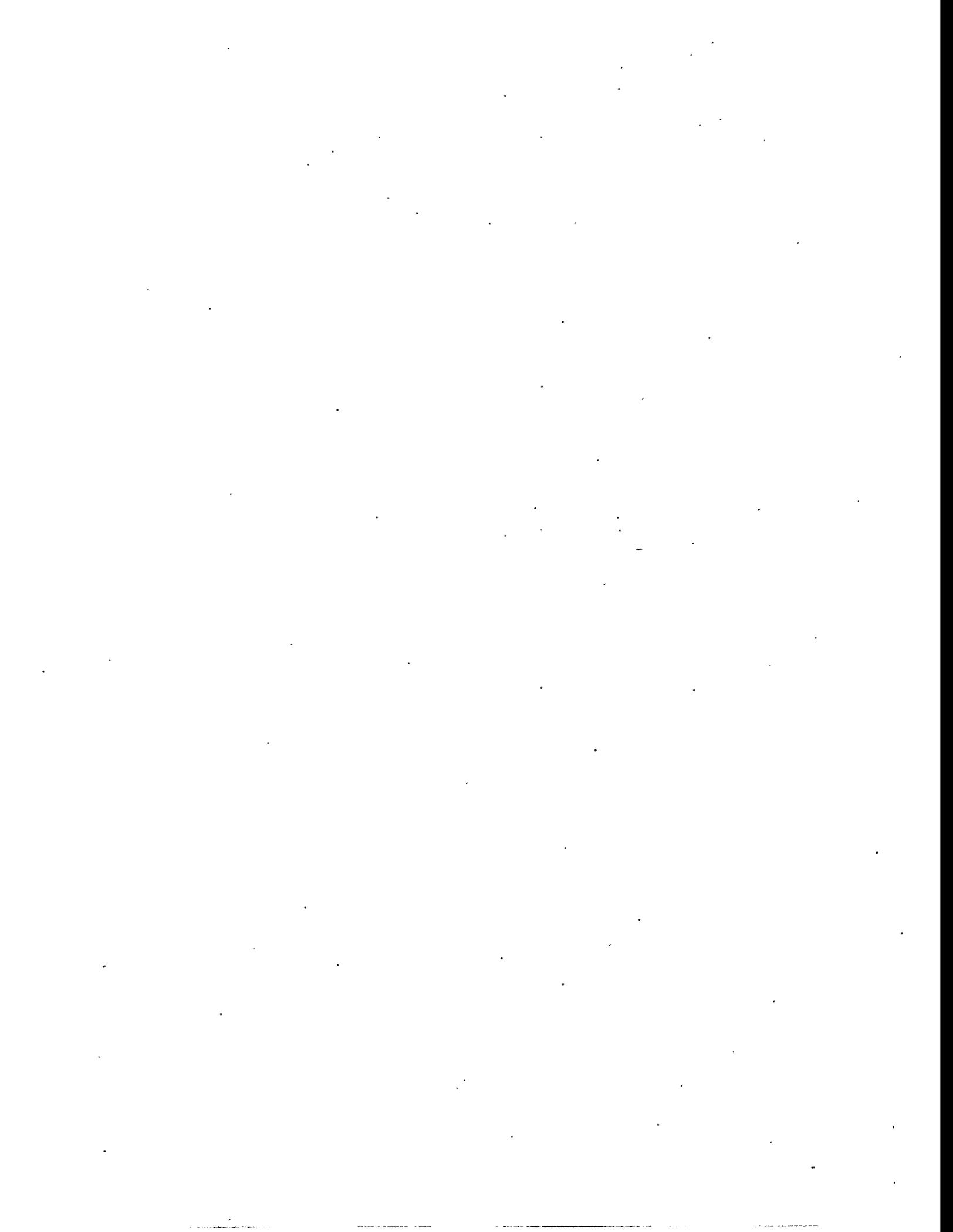
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Appendix A

Seahorse Operation and Installation Instructions





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



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

CONTENTS

<u>SECTION</u>	<u>PAGE</u>
Safety Requirement	A.3
Specifications	A.4
Local Codes	A.5
Unpacking the Heater	A.5
Installation of Heater	A.5
Check Gas Type	A.5
Locating the Heater	A.6
Mounting the Heater	A.6
Water Connections	A.8
Electrical Connections	A.9
Gas Supply and Piping	A.9
Priming the System	A.10
Wiring Diagrams	A.11
Temperature & Pressure Relief Valve	A.12
Lighting and Operating Instructions	A.13
Thermostat Setting	A.13
Freeze Protection	A.13
Maintenance	A.13
Troubleshooting Guide	A.14
Sequence of Operation	A.16
Hydroheat General Information	A.16
Parts Diagram and Repair Parts List	A.18

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

SAFETY REQUIREMENTS

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.

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 plate 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.

INSTALLATION OF HEATER

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.

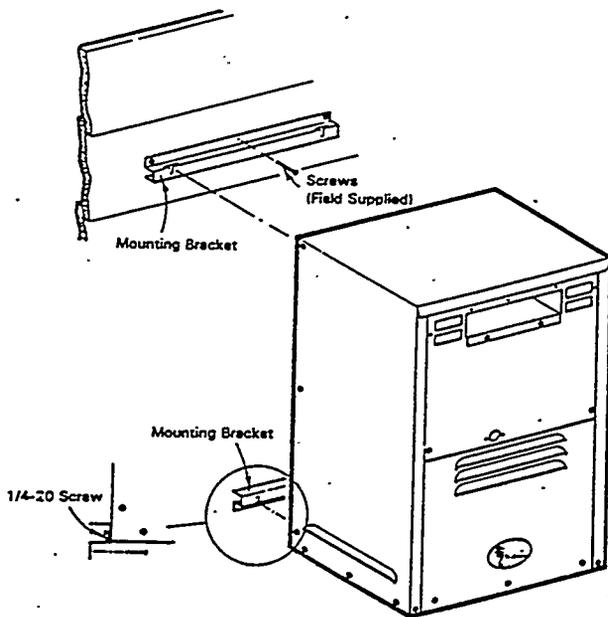


Figure 1. - Mounting the Heater

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.

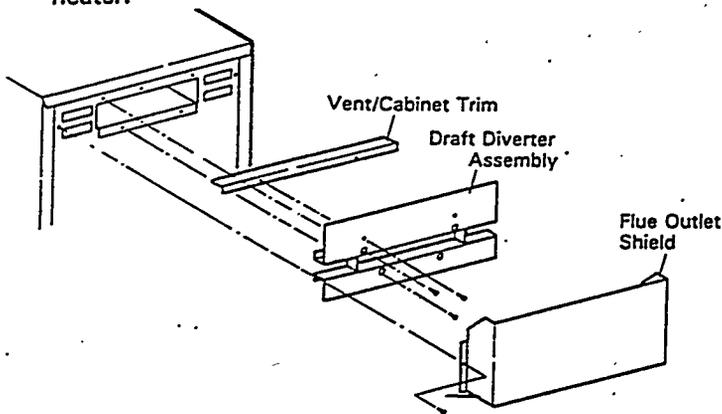


Figure 2. - Vent Installation

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.

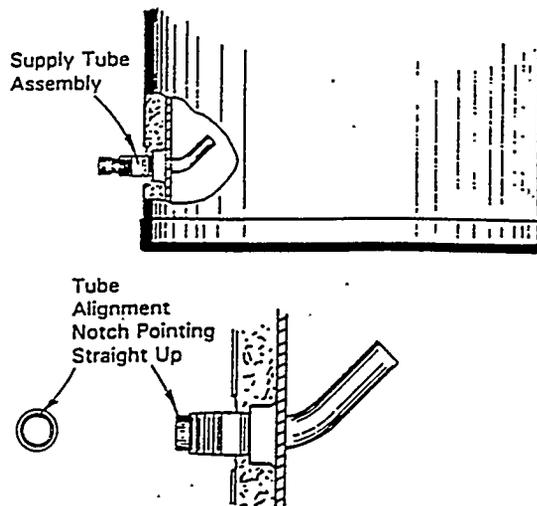


Figure 3. - Supply Tube Assembly Installation

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.

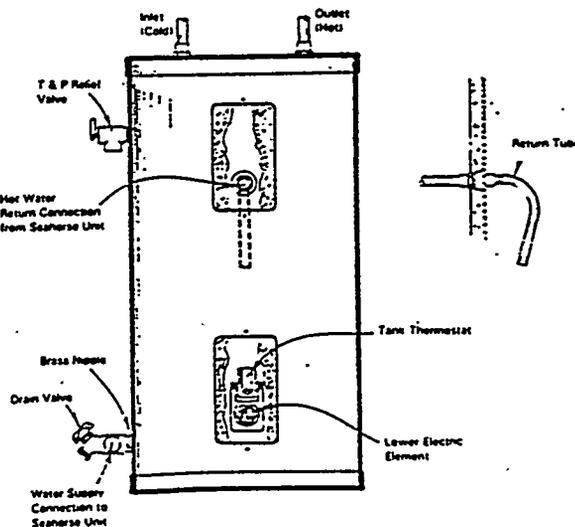


Figure 4. - Return Tube Assembly Installation
2 - Element Storage Tank

INSTALLATION OF HEATER

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.

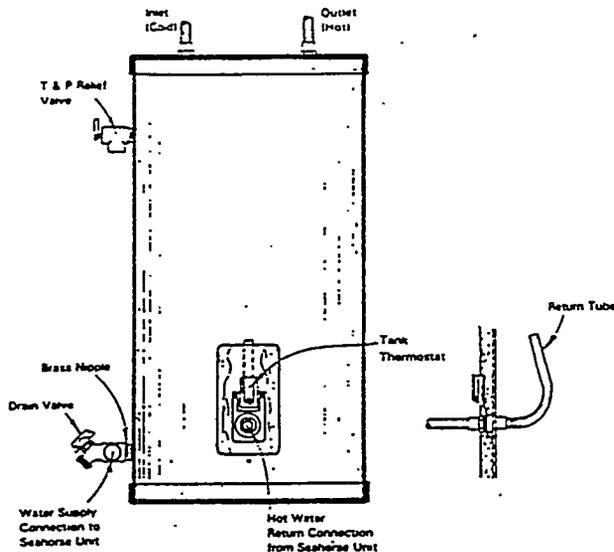


Figure 5. - Return Tube Assembly Installation
Single Element Storage Tank

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.

INSTALLATION OF HEATER

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.

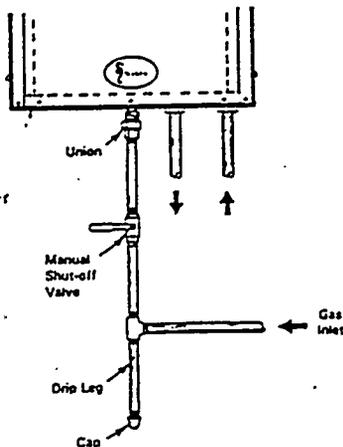


Figure 6. - Gas Piping Connection

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.

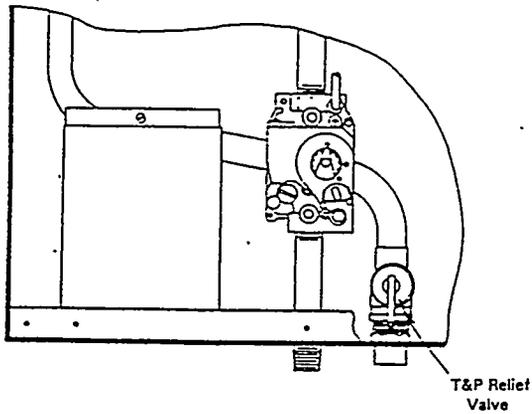


Figure 7. - T&P Relief Valve Location

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.

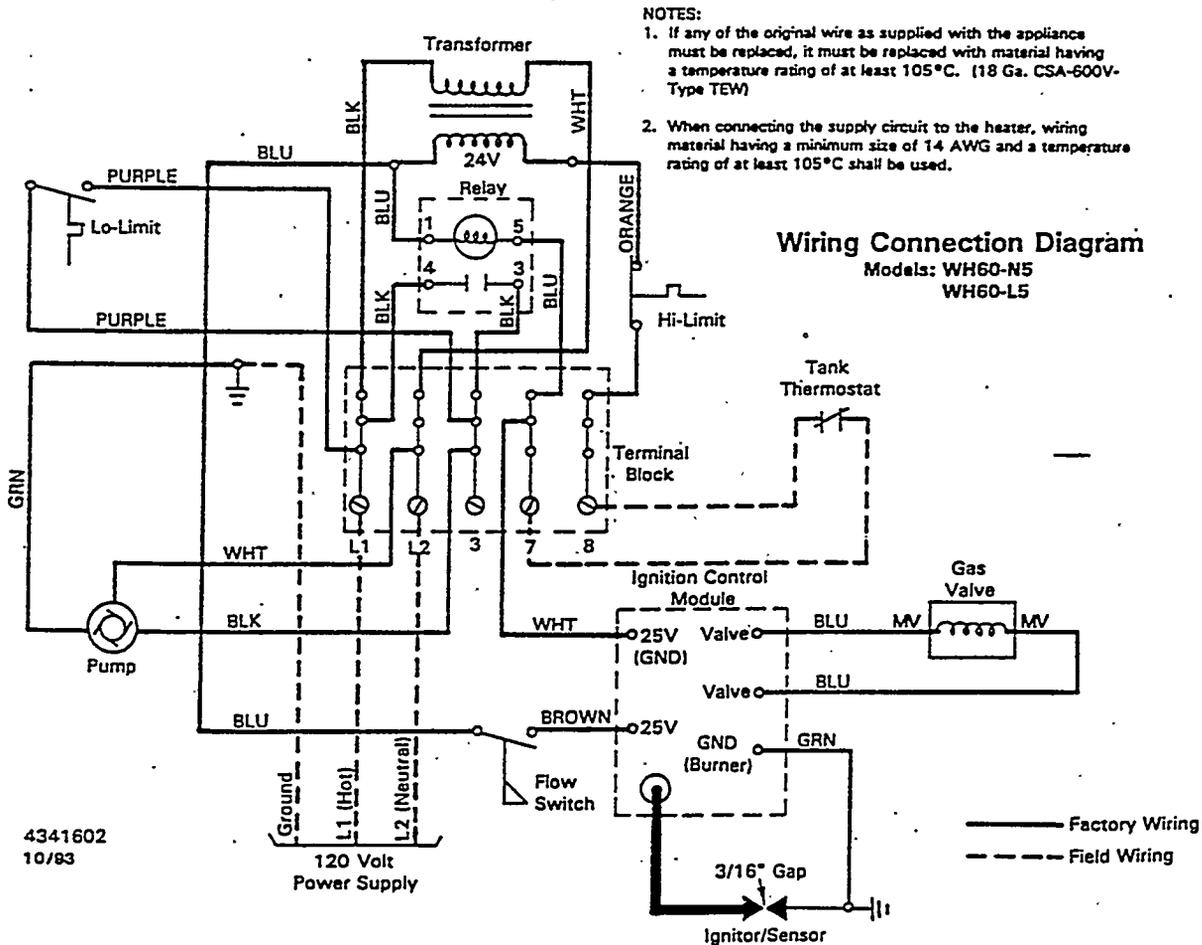


Figure 8. - Wiring Connection Diagram

SCHEMATIC WIRING DIAGRAM

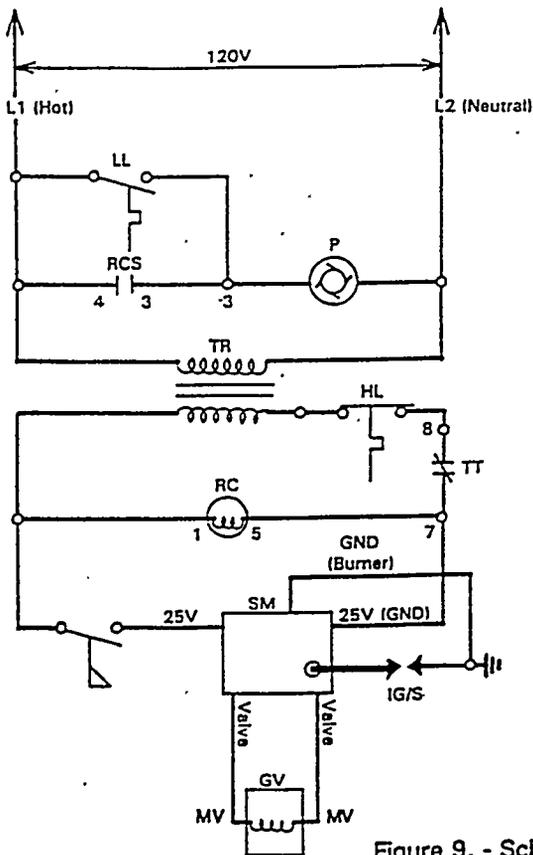


Figure 9. - Schematic Wiring Diagram

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

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".
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.

CONTROL
KNOB
SHOWN IN
"OFF" POSITION



GAS CONTROL KNOB
AND POSITION INDICATOR

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.

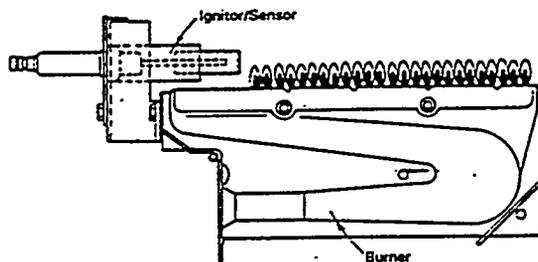


Figure 10. - Correct Burner Flame Pattern

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
<p>1. No spark at burner.</p>	<ul style="list-style-type: none"> - Ignition module is in lockout. - No power to heater. - Transformer defective. - Hi-limit switch tripped. - No water flow. - Low water flow - flow switch contacts won't close. - Flow switch not working. - Defective thermostat in storage tank. - Broken low voltage wire. - Defective components in spark system. - Ignition module fuse blown. 	<ul style="list-style-type: none"> - Turn power "OFF" and then "ON" again after approx. 60 seconds. - Make sure that 115VAC is supplied to heater. - Check for 24VAC at secondary side of transformer, if not, replace. - Make sure that hi-limit switch reset button is pushed in and holds. - Feel pump housing for flow - check for water by lifting lever on T&P relief valve. - 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. - Check continuity through flow switch. If switch contacts are open, confirm that pump is moving water, then replace flow switch. - Check continuity through thermostat and replace if necessary. - Replace wiring. - See next section. - Check fuse and if blown, replace. If fuse is o.k., replace ignition module.
<p>2. Spark only exists when ignition lead is pulled and placed next to metal object.</p>	<ul style="list-style-type: none"> - Poor or incorrect ground. - Ceramic insulator of electrode cracked or broken. - Electrode gap incorrect. - Ignition cable defective. 	<ul style="list-style-type: none"> - Check to make sure heater is properly grounded. - Check and replace as necessary. - Check for 3/16" gap and correct as necessary. - Check boot of the ignition cable for signs of melting or buckling and replace as necessary.
<p>3. Main burner does not light.</p>	<ul style="list-style-type: none"> - Manual shut-off valves closed. - Gas control knob not in "ON" position. - Air in gas line. 	<ul style="list-style-type: none"> - Open valves. - Put gas control knob into "ON" position. - Repeat ignition procedure until air is eliminated.

TROUBLESHOOTING GUIDE

TROUBLE	CAUSE	SOLUTION
3. Main burner does not light - cont'd.	<ul style="list-style-type: none"> - No voltage at gas valve. - Gas control valve will not open. 	<ul style="list-style-type: none"> - 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.	<ul style="list-style-type: none"> - Defective ignition/sensor cable and/or ground wire. - Electrode not positioned in burner flame properly. 	<ul style="list-style-type: none"> - 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.	<ul style="list-style-type: none"> - Defective ignition/sensor cable and/or ground wire. - Excessive heat at sensor insulator boot (temperatures above 1000°F cause short to ground). 	<ul style="list-style-type: none"> - 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.	<ul style="list-style-type: none"> - 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. 	<ul style="list-style-type: none"> - 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.	<ul style="list-style-type: none"> - Using upper tank thermostat. 	<ul style="list-style-type: none"> - Use lowest thermostat in storage tank.

TROUBLESHOOTING GUIDE

TROUBLE	CAUSE	SOLUTION
8. Pump is not working.	<ul style="list-style-type: none"> - No power at pump. - Pump motor defective/burnt. - Pump impeller defective or broken. 	<ul style="list-style-type: none"> - 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. - Replace pump. - Replace pump cartridge.
9. Pump runs all the time.	<ul style="list-style-type: none"> - Freezestat contacts are closed. - Tank thermostat is defective. 	<ul style="list-style-type: none"> - Check continuity through switch, if closed, raise switch temperature about 90°F for 5 minutes. Switch should open, if not, replace freezestat. - 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

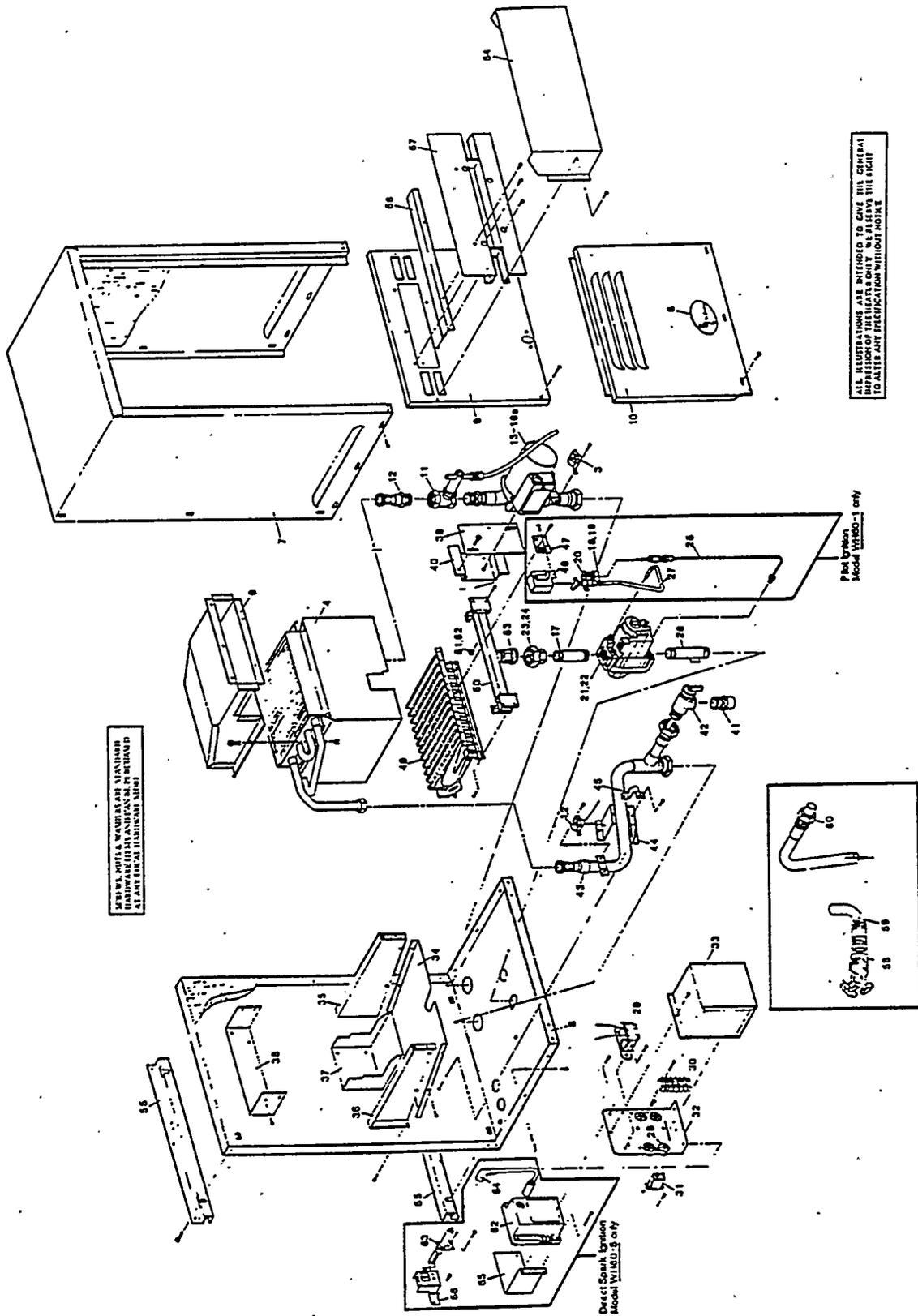
ITEM NO.	PART NO.	DESCRIPTION
1	3041403	High Limit Switch - Models WH60 only
2	3041404	High Limit Switch - Models WHT60 only
3	3041402	Freezestat (Purple Leads)
4	4336100	Coil Housing Sub-Assembly (Less Flue Hood)
5	4342400	Tradename Plate (included with Item 10)
6	4337600	Flue Hood Assembly
7	4336498	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 5 - Direct Spark Ignition
L - Propane Gas

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.



REMOVE THESE SCREWS AND ASSEMBLY HARDWARE IN REVERSE ORDER AT ANY TIME. TURN HANDLE UPWARD.

ALL ILLUSTRATIONS ARE INTENDED TO GIVE THE GENERAL CONCEPT OF THE OPERATION OF THE SYSTEM. THEY DO NOT ATTEMPT TO SHOW THE EXACT LOCATION OF ALL PARTS OR THE EXACT POSITION OF ALL PARTS.

WR

WHITE ROEGERS

3046-701
Direct Limit
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.

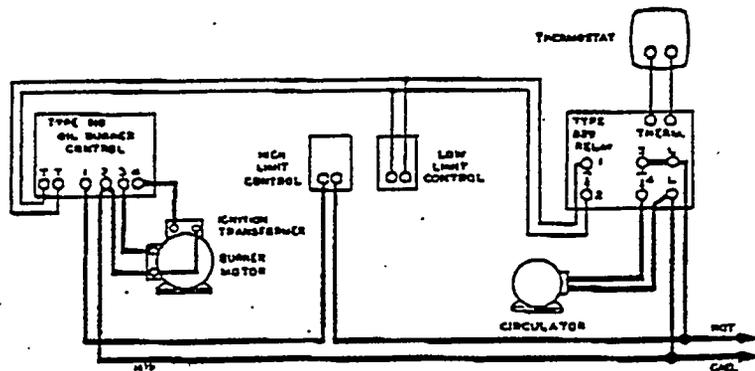
If the boiler manufacturer recommends a wiring diagram, then follow such recommendations. If none is

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

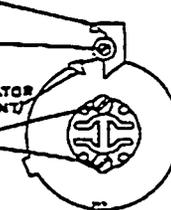
1. Insert screwdriver in the center slot and turn the dial until the fixed indicator "B" points to the temperature at which the contacts should close.
2. Then turn the differential adjusting screw "C" until the movable indicator "D" points to the temperature at which contacts are to open.

"B" FIXED INDICATOR
(CUT-IN POINT)

"C" DIFFERENTIAL
ADJUSTING SCREW

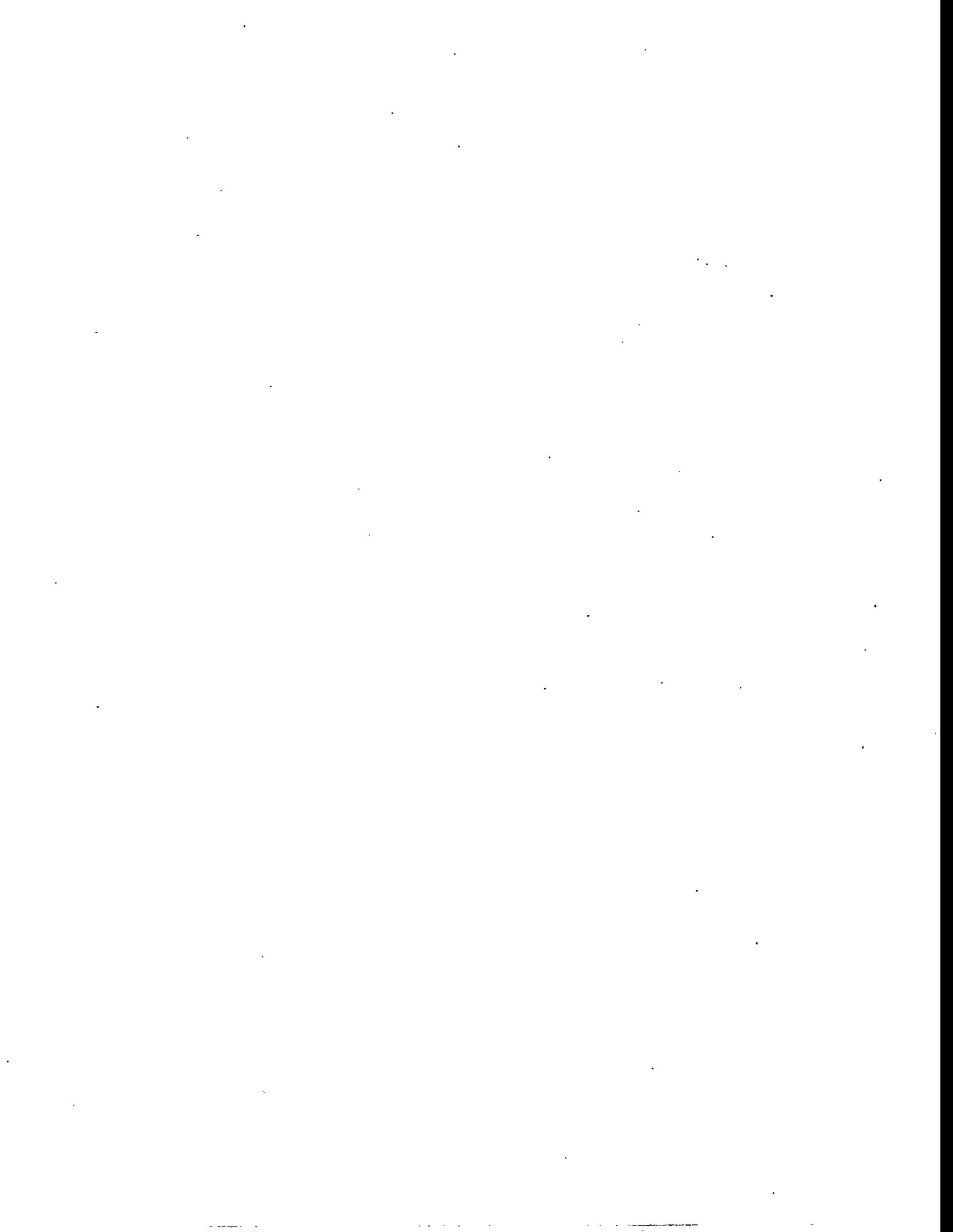
"D" MOVABLE INDICATOR
(CUT-OUT POINT)

DIAL SCREWS



Appendix B

Predicted Effect of System Cycle Time on Efficiency



Appendix B

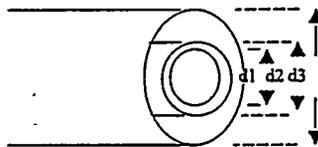
Predicted Effect of System Cycle Time On Efficiency

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

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

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

An 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.

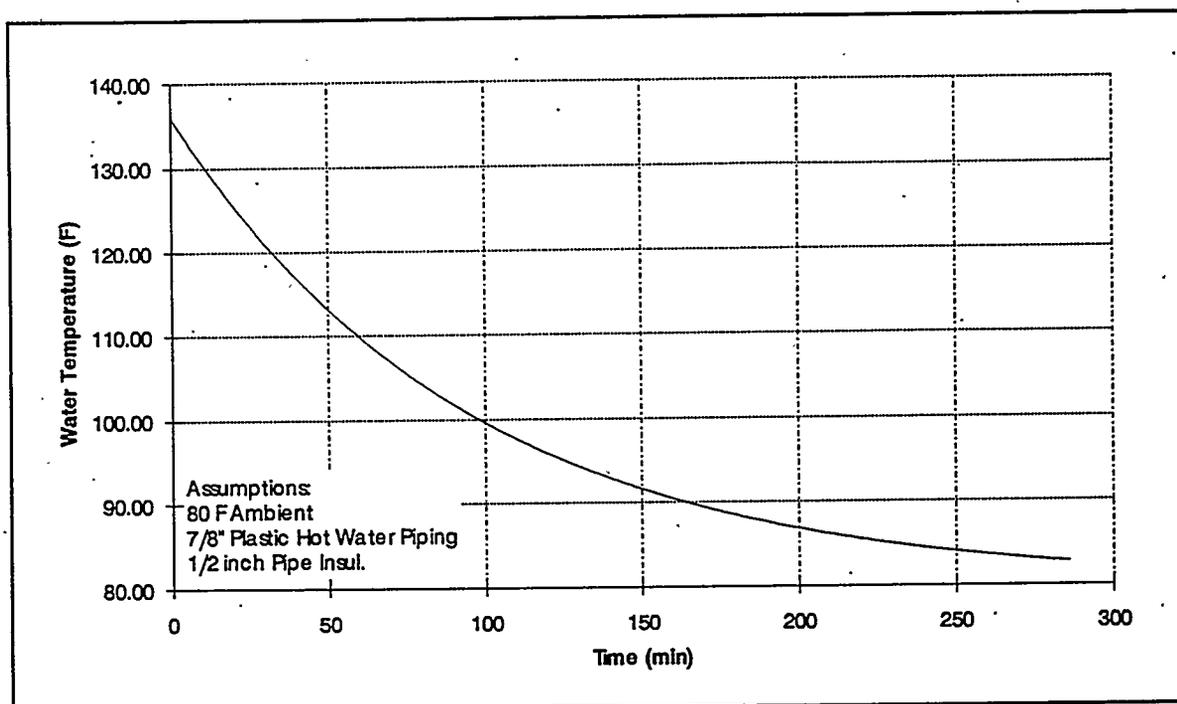


Figure B.1. Temperature Decay for Hot Water in Seahorse Flow Loop

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 it 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

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

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 effect 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 setup similar to the Fort Stewart demonstration.

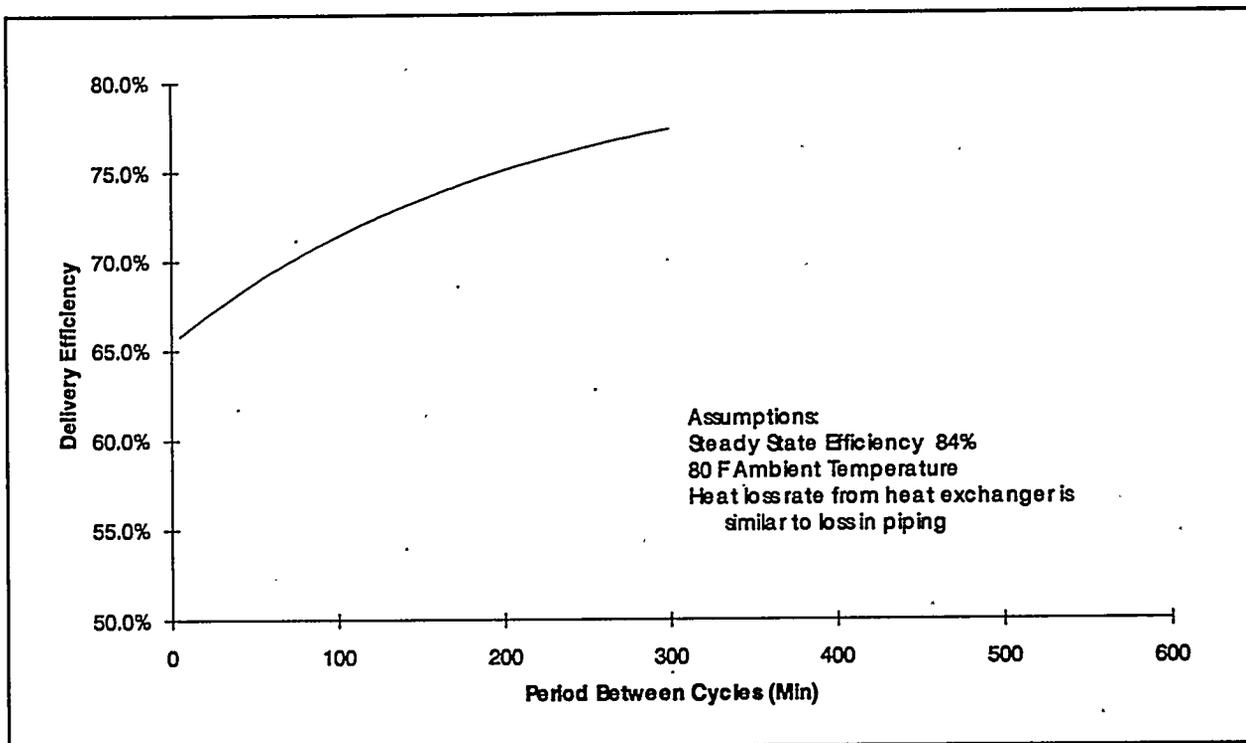
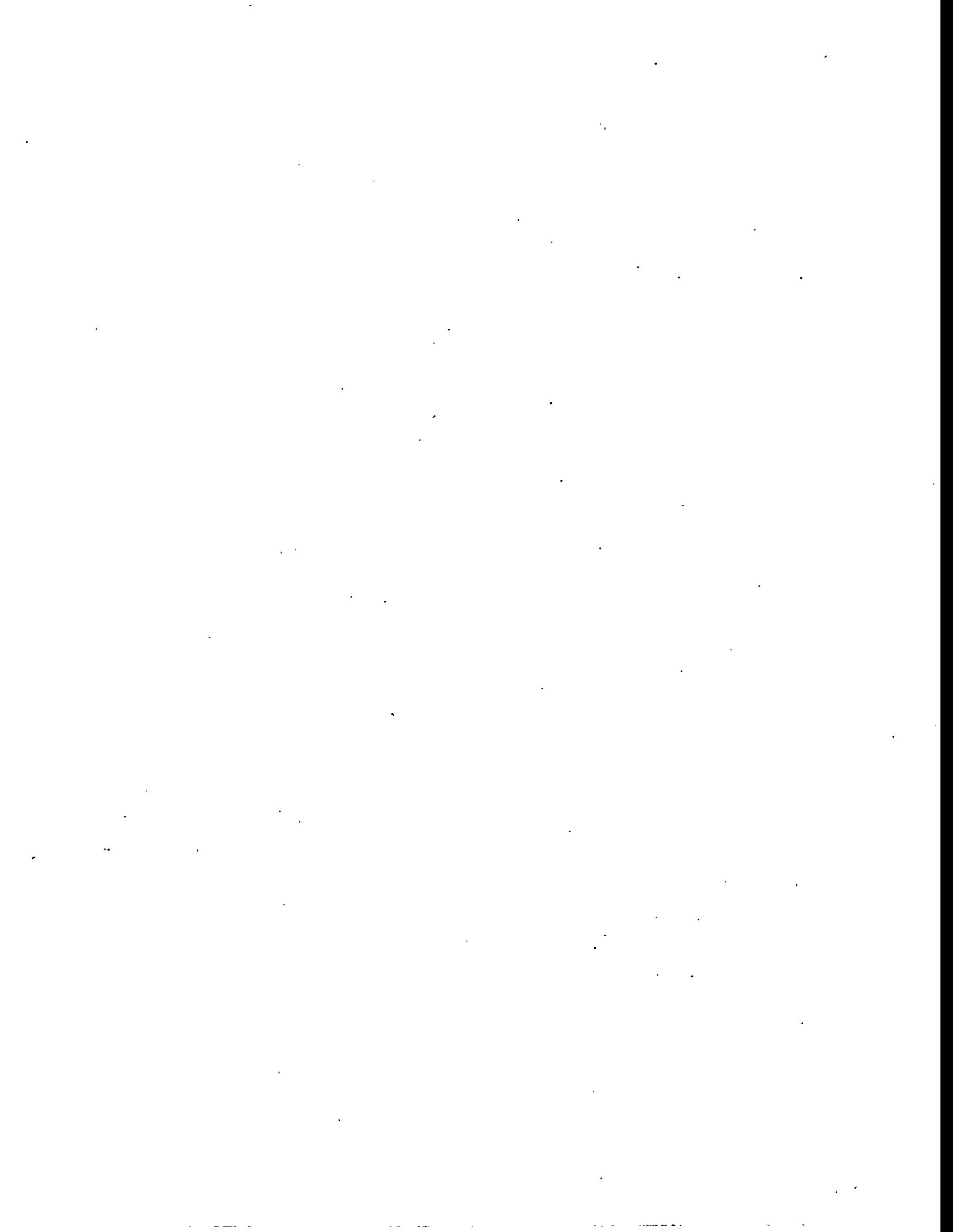


Figure B.2. Estimated Seahorse Delivery-to-Tank Efficiency Versus Cycle Time -- No Residential Hot Water Consumption



Appendix C

Collected Field Data - Daily Averages



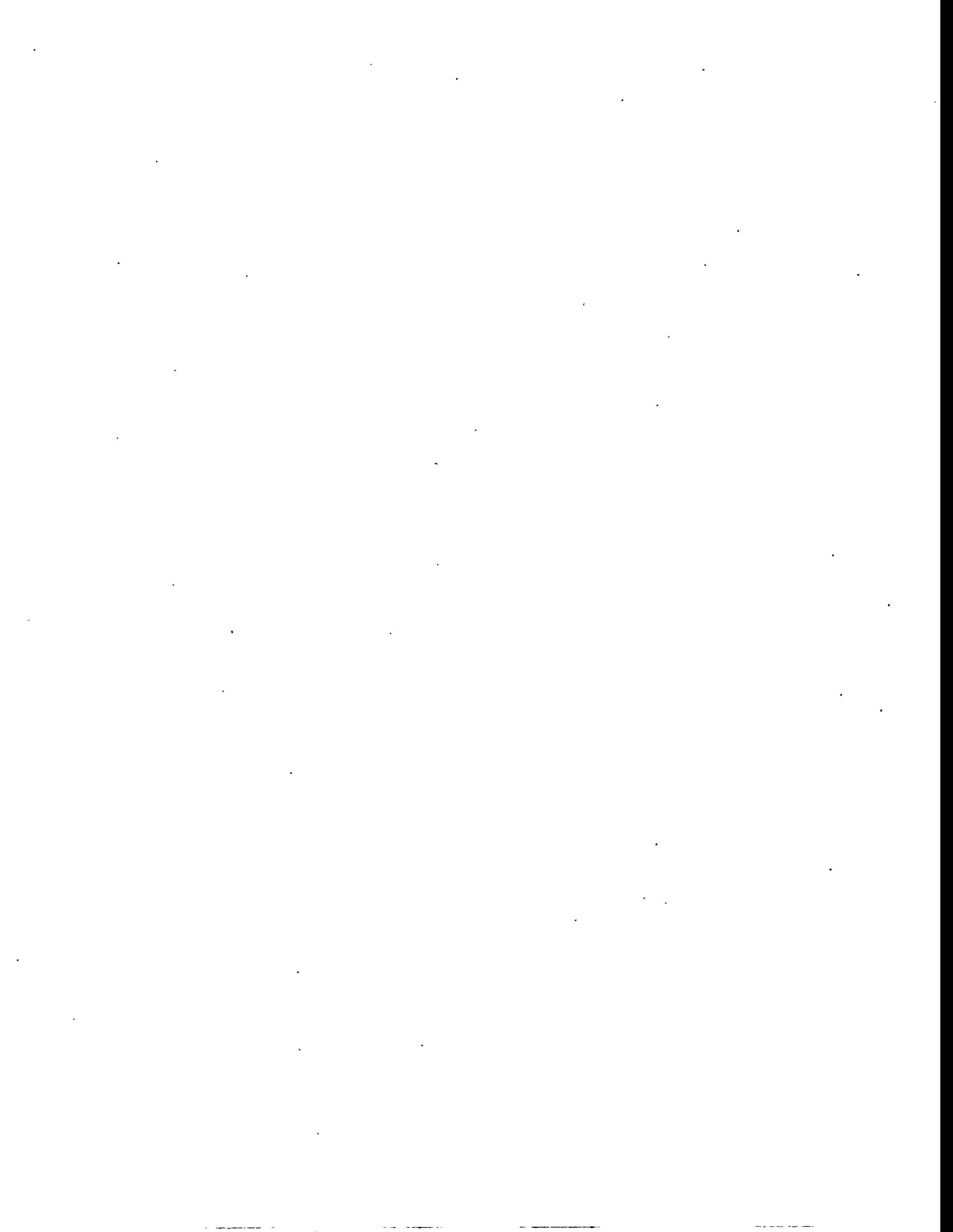
24-May-94	000000	240	310	122	246	138	757	751	769	1357	149	33	88	1646	226	1419	317	152	0.53	0.00	0.16	767	1327	841	0.31	0.20	323
25-May-94	000000	265	316	141	257	150	783	716	715	1356	149	33	91	1645	229	1417	218	1622	0.52	0.96	0.18	748	1365	811	0.31	0.20	327
30-May-94	000000	505	331	181	282	158	810	749	763	1349	149	33	94	1625	190	1409	217	1693	0.49	1.00	0.24	743	1365	811	0.31	0.20	318
31-May-94	000000	261	244	134	261	158	816	797	745	1321	149	33	84	1609	181	1465	217	1485	0.49	1.00	0.24	743	1365	811	0.31	0.20	313
01-Jun-94	000000	401	474	264	273	158	812	792	717	1327	149	33	83	1609	218	1366	259	1509	0.51	0.84	0.25	754	1351	817	0.34	0.20	337
02-Jun-94	000000	224	182	103	259	158	812	782	770	1356	149	33	78	1649	229	1421	217	1509	0.51	0.64	0.25	762	1366	818	0.34	0.20	331
03-Jun-94	000000	175	115	63	253	158	814	784	791	1326	149	33	73	1649	229	1421	217	1509	0.51	0.64	0.25	762	1366	818	0.34	0.20	331
04-Jun-94	000000	162	63	37	217	158	789	762	751	1314	149	33	106	1488	233	1362	123	1211	0.29	1.17	0.18	764	1255	842	0.14	0.21	174
05-Jun-94	000000	237	232	136	256	159	769	712	757	1347	149	33	94	1616	227	1400	214	1588	0.32	0.92	0.20	763	1273	840	0.14	0.21	176
06-Jun-94	000000	281	312	64	259	158	779	768	760	1351	149	33	76	1631	227	1401	214	1588	0.32	0.92	0.20	763	1273	840	0.14	0.21	176
07-Jun-94	000000	166	91	53	259	159	834	806	763	1315	149	33	100	1486	236	1360	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
08-Jun-94	000000	234	177	103	263	158	807	781	772	1316	149	33	87	1646	236	1361	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
09-Jun-94	000000	242	235	134	259	159	812	787	758	1323	149	33	63	1646	236	1361	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
10-Jun-94	000000	118	06	03	253	159	823	792	756	1311	149	33	33	1646	236	1361	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
11-Jun-94	000000	143	01	01	257	159	810	780	757	1304	149	33	83	1646	236	1361	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
12-Jun-94	000000	143	01	01	257	159	810	780	757	1304	149	33	83	1646	236	1361	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
13-Jun-94	000000	143	01	01	257	159	810	780	757	1304	149	33	83	1646	236	1361	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
14-Jun-94	000000	143	01	01	257	159	810	780	757	1304	149	33	83	1646	236	1361	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
15-Jun-94	000000	143	01	01	257	159	810	780	757	1304	149	33	83	1646	236	1361	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
16-Jun-94	000000	143	01	01	257	159	810	780	757	1304	149	33	83	1646	236	1361	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
17-Jun-94	000000	197	111	66	266	158	804	713	713	1304	149	33	98	1646	236	1361	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
18-Jun-94	000000	197	111	66	266	158	804	713	713	1304	149	33	98	1646	236	1361	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
19-Jun-94	000000	197	111	66	266	158	804	713	713	1304	149	33	98	1646	236	1361	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
20-Jun-94	000000	199	119	71	274	158	799	749	749	1306	149	33	102	1490	240	1351	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
21-Jun-94	000000	224	164	97	267	158	769	761	713	1313	149	33	100	1472	240	1351	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
22-Jun-94	000000	224	164	97	267	158	769	761	713	1313	149	33	100	1472	240	1351	158	1033	0.32	0.64	0.08	767	1273	840	0.14	0.21	166
23-Jun-94	000000	278	294	172	263	158	842	802	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
24-Jun-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
25-Jun-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
26-Jun-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
27-Jun-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
28-Jun-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
29-Jun-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
30-Jun-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
01-Jul-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
02-Jul-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
03-Jul-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
04-Jul-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
05-Jul-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
06-Jul-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
07-Jul-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
08-Jul-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
09-Jul-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
10-Jul-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
11-Aug-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220
12-Aug-94	000000	209	182	107	265	158	719	767	712	1326	149	33	110	1612	223	1394	203	1140	0.31	0.74	0.14	718	1267	845	0.18	0.17	220

Logged Data for Seahorse Study

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00:00:00	14-Aug-94	2:07	17:6	107	15:6	25:6	80:7	75:5	130:3	14:9	3:3	8:4	133:0	18:3	134:8	18:2	107:2	0:44	0:80	0:12	76:9	131:4	131:4	0:12	17:9
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00:00:00	16-Aug-94	2:11	17:0	10:1	13:9	71:8	76:9	74:7	131:5	14:9	3:3	8:3	135:1	20:4	136:5	17:4	110:6	0:47	0:41	0:11	76:2	131:9	131:9	0:18	20:5
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00:00:00	03-Sep-94	2:86	23:4	14:1	13:8	82:4	82:6	76:5	144:1	14:9	3:3	9:3	139:3	21:9	130:3	20:5	82:4	0:31	1:03	0:63	78:0	131:7	131:7	0:16	31:4
00:00:00	05-Sep-94	3:78	41:2	22:6	13:8	83:4	81:5	76:3	144:1	14:9	3:3	11:1	139:3	21:9	130:3	20:5	82:4	0:31	1:03	0:63	78:0	131:7	131:7	0:16	31:4
00:00:00	08-Sep-94	2:97	26:1	14:4	13:8	82:8	82:8	77:7	144:1	14:9	3:3	11:1	139:3	21:9	130:3	20:5	82:4	0:31	1:03	0:63	78:0	131:7	131:7	0:16	31:4
00:00:00	10-Sep-94	3:08	28:6	15:8	13:8	82:7	80:3	78:1	144:2	14:9	3:3	9:8	139:3	21:9	130:3	20:5	82:4	0:31	1:03	0:63	78:0	131:7	131:7	0:16	31:4
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00:00:00	06-Oct-94	3:24	30:9	16:7	13:8	71:5	76:7	76:4	144:0	14:9	3:3	10:2	139:3	21:9	130:3	20:5	82:4	0:31	1:03	0:63	78:0	131:7	131:7	0:16	31:4
00:00:00	08-Oct-94	4:23	48:5	26:2	13:8	81:3	79:3	76:8	144:0	14:9	3:3	11:8	139:3	21:9	130:3	20:5	82:4	0:31	1:03	0:63	78:0	131:7	131:7	0:16	31:4
00:00:00	09-Oct-94	2:91	24:4	13:1	13:8	78:9	77:1	77:0	144:1	14:9	3:3	9:5	139:3	21:9	130:3	20:5	82:4	0:31	1:03	0:63	78:0	131:7	131:7	0:16	31:4
00:00:00	11-Oct-94	4:84	37:7	31:4	13:8	79:3	78:2	76:5	144:0	14:9	3:3	13:1	139:3	21:9	130:3	20:5	82:4	0:31	1:03	0:63	78:0	131:7	131:7	0:16	31:4
00:00:00	12-Oct-94	3:26	30:0	16:2	13:8	79:2	78:0	75:6	144:0	14:9	3:3	10:1	139:3	21:9	130:3	20:5	82:4	0:31	1:03	0:63	78:0	131:7	131:7	0:16	31:4
00:00:00	14-Oct-94	3:05	24:0	13:0	13:8	79:2	77:8	75:1	144:0	14:9	3:3	10:1	139:3	21:9	130:3	20:5	82:4	0:31	1:03	0:63	78:0	131:7	131:7	0:16	31:4
00:00:00	15-Oct-94	3:47	31:0	17:1	13:8	78:0	77:1	74:3	144:1	14:9	3:3	10:6	139:3	21:9	130:3	20:5	82:4	0:31	1:03	0:63	78:0	131:7	131:7	0:16	31:4
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00:00:00	17-Oct-94						66:7	76:9	140:6		1:3														
00:00:00	18-Oct-94						31:0	73:6	135:7																
00:00:00	19-Oct-94						71:3	75:1	135:5	14:9	3:3	7:9	135:2	23:3	135:1	21:2	134:4	0:54	0:76	0:19	74:7	131:4	131:4	0:16	32:7
00:00:00	20-Oct-94	3:41	54:1	33:4	13:9	75:7	75:1	72:0	135:6	14:9	3:3	10:4	134:7	23:0	135:0	21:8	230:5	0:35	1:31	0:42	75:2	131:3	131:3	0:18	32:3
00:00:00	21-Oct-94	3:17	28:5	17:5	13:9	74:5	72:2	73:6	135:6	14:9	3:3	9:9	134:9	23:0	135:2	21:9	109:0	0:34	0:39	0:18	74:8	131:3	131:3	0:20	32:5
00:00:00	22-Oct-94	3:12	44:5	37:1	13:9	74:2	73:8	73:1	135:6	14:9	3:3	9:9	134:7	22:9	135:3	21:9	134:5	0:35	0:46	0:21	75:0	131:4	131:4	0:19	32:6
00:00:00	24-Oct-94	2:26	37:6	16:8	13:9	79:0	77:2	73:7	135:6	14:9	3:3	8:7	135:0	22:9	135:3	21:9	134:5	0:35	0:46	0:21	75:0	131:4	131:4	0:19	32:6
00:00:00	25-Oct-94	2:47	33:9	20:6	13:9	75:7	74:4	74:2	135:8	14:9	3:3	8:7	135:0	22:9	135:3	21:9	134:5	0:35	0:46	0:21	75:0	131:4	131:4	0:19	32:6
00:00:00	26-Oct-94	2:24	37:6	16:8	13:9	75:8	75:6	73:8	135:9	14:9	3:3	8:3	135:0	22:9	135:3	21:9	134:5	0:35	0:46	0:21	75:0	131:4	131:4	0:19	32:6
00:00:00	28-Oct-94	2:30	24:9	15:1	13:9	75:6	72:2	73:6	135:6	14:9	3:3	8:4	135:2	23:0	135:4	21:7	134:5	0:35	0:46	0:21	75:0	131:4	131:4	0:19	32:6
00:00:00	30-Oct-94	2:31	31:5	19:3	13:9	75:2	74:4	73:1	135:1	14:9	3:3	8:8	134:8	23:0	135:4	21:7	134:5	0:35	0:46	0:21	75:0	131:4	131:4	0:19	32:6
00:00:00	01-Nov-94	2:71	37:6	21:8	13:9	79:7	78:7	74:0	135:1	14:9	3:3	9:1	135:1	23:2	135:3	21:7	134:5	0:35	0:46	0:21	75:0	131:4	131:4	0:19	32:6
00:00:00	02-Nov-94	2:48	31:5	19:0	13:9	77:3	76:7	73:3	135:6	14:9	3:3	8:7	135:1	23:2	135:3	21:7	134:5	0:35	0:46	0:21	75:0	131:4	131:4	0:19	32:6
00:00:00	03-Nov-94	2:50	34:5	21:1	13:9	75:1	74:2	74:5	135:6	14:9	3:3	8:7	135:1	23:2	135:3	21:7	134:5	0:35	0:46	0:21	75:0	131:4	131:4	0:19	32:6
00:00:00	04-Nov-94	2:48	29:6	17:8	13:9	75:3	72:2	74:7	135:8	14:9	3:3	8:7	134:8	23:2	135:3	21:6	134:5	0:34	0:46	0:21	75:0	131:4	131:4	0:19	32:6
00:00:00	05-Nov-94	2:38	26:5	15:9	13:9	75:1	73:9	73:9	135:7	14:9	3:3	8:6	134:8	23:2	135:0	21:0	134:8	0:34	0:46	0:21	75:0	131:4	131:4	0:19	32:6
00:00:00	06-Nov-94	2:23	26:1	15:3	13:9	75:1	73:9	73:9	135:7	14:9	3:3	8:6	134:8	23:2	135:0	21:0	134:8	0:34	0:46	0:21	75:0	131:4	131:4	0:19	32:6
00:00:00	07-Nov-94	3:49	50:2	29:7	13:9	71:6	71:4	72:4	135:5	14:9	3:3	10:6	135:0	23:4	131:9	21:2	244:1	0:54	1:31	0:57	73:8	131:6	131:6	0:38	33:7
00:00:00	08-Nov-94	4:72	73:3	43:3	13:9	70:8	70:1	72:6	135:7	15:0	3:3	13:9	134:4	23:3	131:4	21:2	306:1	0:54	1:31	0:57	74:7	131:6	131:6	0:38	33:7
00:00:00	09-Nov-94	1:48	13:0	7:1	13:9	76:8	75:1	74:4	135:6	14:9	3:3	6:9	135:2	23:2	133:3	21:0	98:8	0:56	0:69	0:29	74:7	131:8	131:8	0:13	33:4
00:00:00	10-Nov-94	2:77	31:7	21:2	13:9	72:4	71:2	74:9	135:8	14:9	3:3	8:2	134:6	23:0	131:9	21:9	136:4	0:54	1:05	0:28	75:2	131:7	131:7	0:13	33:4
00:00:00	11-Nov-94	2:07	19:7	11:4	13:9	74:4																			

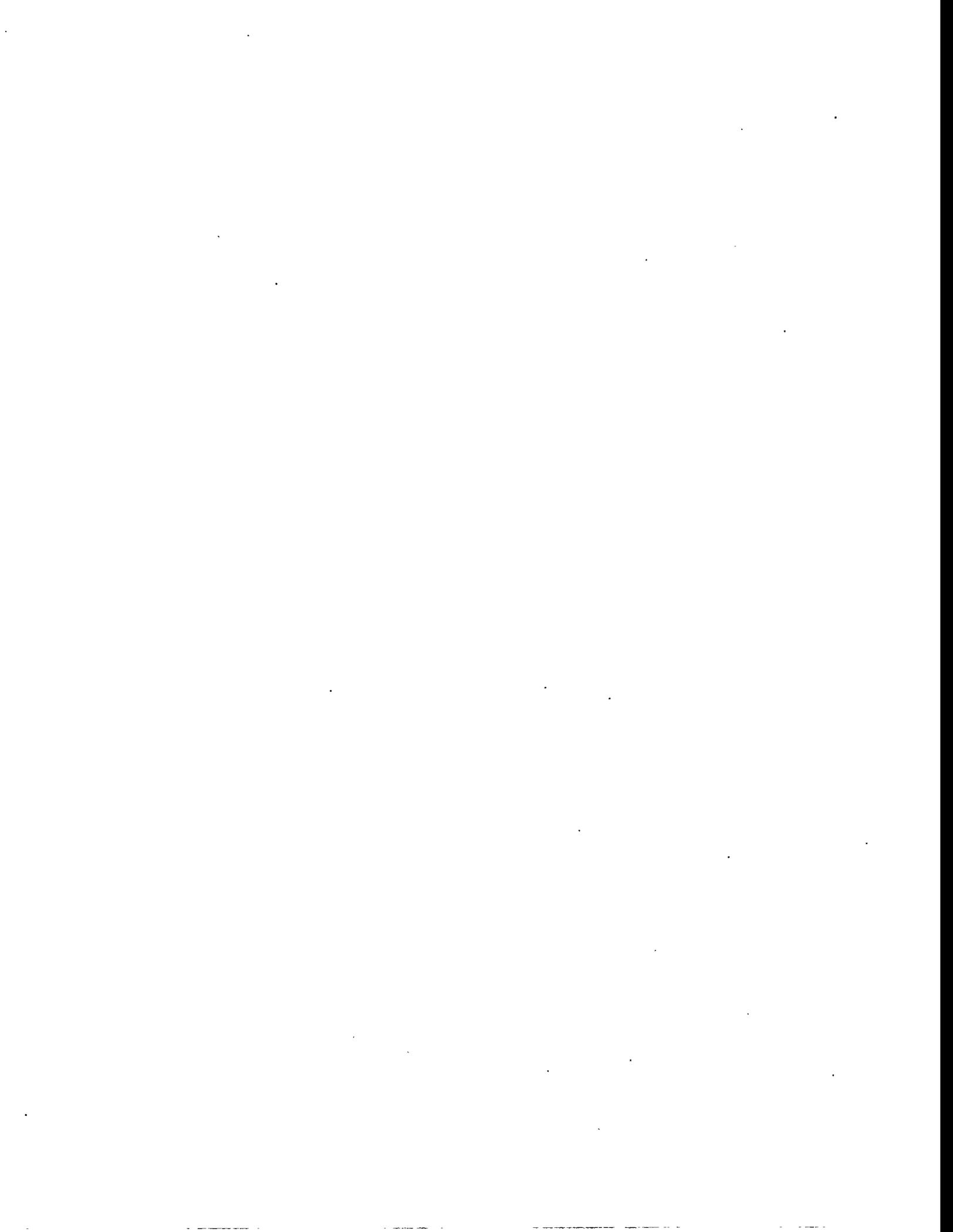
Logged Data for Seahorse Study

29-Oct-94	000000	182	146	83	249	139	733	718	744	1358	148	33	75	1531	210	1325	217	1153	0.53	0.67	0.11	715	1233	337	015	015	232
30-Oct-94	000000	183	144	82	250	139	616	695	739	1358	148	33	76	1531	211	1324	219	1172	0.53	0.67	0.11	731	1244	331	015	021	233
01-Nov-94	000000	202	165	93	259	139	613	628	699	1325	150	33	79	1536	214	1325	220	1284	0.54	0.73	0.13	692	1241	607	017	016	235
02-Nov-94	000000	200	336	183	218	139	648	647	704	1327	150	34	96	1533	214	1321	222	1912	0.54	1.07	0.26	661	1238	1278	024	024	238
03-Nov-94	000000																										
04-Nov-94	000000																										
05-Nov-94	000000	377	334	296	253	139	747	732	749	1358	149	33	111	1545	216	1319	217	2467	0.53	1.39	0.41	726	1263	1991	032	031	231
06-Nov-94	000000	179	133	76	263	138	720	713	766	1358	150	33	73	1550	212	1323	219	1166	0.54	0.66	0.10	753	1195	486	015	015	232
07-Nov-94	000000	211	211	118	245	139	699	701	728	1358	150	33	81	1552	213	1321	221	1365	0.54	0.77	0.16	723	1219	783	018	017	234
08-Nov-94	000000	137	86	49	257	139	732	734	756	1359	149	33	67	1552	213	1323	220	840	0.53	0.50	0.07	744	1230	312	012	011	232
09-Nov-94	000000	201	212	119	249	139	749	732	743	1360	149	33	79	1551	213	1319	223	1304	0.54	0.74	0.16	738	1234	782	017	017	235
10-Nov-94	000000	191	120	68	237	139	547	604	718	1361	149	33	78	1553	214	1324	220	1196	0.54	0.70	0.09	707	1228	450	016	040	235
11-Nov-94	000000	188	153	84	232	139	603	619	702	1359	150	33	77	1557	215	1327	219	1184	0.54	0.69	0.12	692	1237	379	016	015	234
12-Nov-94	000000	237	272	150	232	139	676	671	713	1359	150	33	90	1550	213	1319	221	1687	0.53	0.95	0.21	696	1235	1034	021	033	233
13-Nov-94	000000	206	172	95	244	139	702	692	729	1359	150	33	80	1554	215	1325	222	1317	0.54	0.76	0.13	713	1243	657	017	017	236
14-Nov-94	000000																										
15-Nov-94	000000																										
16-Nov-94	000000																										
17-Nov-94	000000																										
18-Nov-94	000000																										
19-Nov-94	000000	308	387	211	241	139	649	654	722	1359	149	33	99	1549	212	1322	219	2063	0.54	1.14	0.30	707	1243	1500	026	025	235
20-Nov-94	000000	169	184	101	254	139	718	723	751	1360	149	33	78	1551	218	1323	219	1265	0.54	0.73	0.14	725	1270	702	017	021	234
21-Nov-94	000000	160	100	53	247	139	699	691	732	1364	149	33	72	1552	212	1326	218	953	0.53	0.58	0.08	717	1270	380	013	013	233
22-Nov-94	000000	156	234	123	216	139	604	614	717	1358	150	33	89	1553	212	1325	220	1649	0.54	0.93	0.18	692	1272	914	021	020	235
23-Nov-94	000000	344	392	230	222	139	507	536	698	1365	151	34	106	1555	216	1320	217	2185	0.55	1.35	0.30	668	1283	1533	028	028	240
24-Nov-94	000000	433	338	233	253	139	573	582	770	1363	150	33	121	1548	214	1312	217	2013	0.55	1.33	0.41	684	1287	2153	035	031	241
25-Nov-94	000000	368	429	226	240	138	541	571	793	1359	150	33	110	1550	214	1313	218	2093	0.56	1.33	0.33	684	1284	1719	020	017	242
26-Nov-94	000000	237	226	121	245	139	681	688	728	1360	149	33	86	1552	212	1317	217	1571	0.55	0.86	0.18	698	1266	885	020	019	240
27-Nov-94	000000	120	45	23	230	139	713	690	743	1358	149	33	64	1553	210	1321	214	740	0.54	0.44	0.04	721	1239	179	010	010	234
28-Nov-94	000000	239	225	122	252	139	677	666	743	1358	149	33	86	1552	214	1316	217	1564	0.54	0.86	0.18	721	1241	886	020	019	237
29-Nov-94	000000	218	178	94	230	139	593	604	752	1361	150	33	83	1553	214	1318	216	1396	0.54	0.79	0.14	699	1251	712	018	040	237



Appendix D

Estimate of Annual Cold Water Supply Temperature for Fort Stewart



Appendix D

Estimate of Annual Cold Water Supply Temperature for Fort Stewart

The cold water supply temperature to the storage tank was monitored at Fort Stewart from May 27, 1994, to February 1, 1995. Figure D.1 shows the measured water temperature during this period. As can be seen, there is significant variance in the recorded temperature during the year. Because supply water is brought to residences by underground water pipes, the water temperature supplied to each residence is a function of shallow ground temperature and is thus influenced by the regional climate patterns. As can be seen from the data in Figure D.1, supply water temperatures rise in the spring and peak in the summer at around 81.5°F. They decrease after that. The monitored data stops before the coldest temperatures are reached in the winter.

To estimate typical water temperatures for the site, the recorded inlet water temperatures was curve-fitted to a sinusoidal function based on day of the year. Each measured daily average water temperature was then compared with the predicted value from the sinusoidal function, and coefficients were chosen to minimize the squared error between the known temperatures and the estimated temperatures. With this in mind, the following equation for inlet water temperature was developed:

$$\text{Cold Water Supply Temperature } T(^{\circ}\text{F}) = 71.3^{\circ}\text{F} + 10.3^{\circ}\text{F} \times \text{COS}\left[\frac{(n+266)}{365} \times 2\pi\right]$$

where n is the day of year (Jan 1 =1).

The estimated temperatures for the year are shown plotted with the measured data in Figure D.1. Because of the sinusoidal nature of the above equation, the average temperature predicted for the year is 71.3°F. For comparison, the Electric Power Research Institute (EPRI) reports an average cold water supply temperature of 68.1°F for Savannah, Georgia (EPRI 1993).

Reference

Electric Power Research Institute. 1993. *HOTCALC 2.0 Commercial Water Heating Performance Simulation Tool - User's Guide*. EPRI CM-100211 R1, Palo Alto, California.

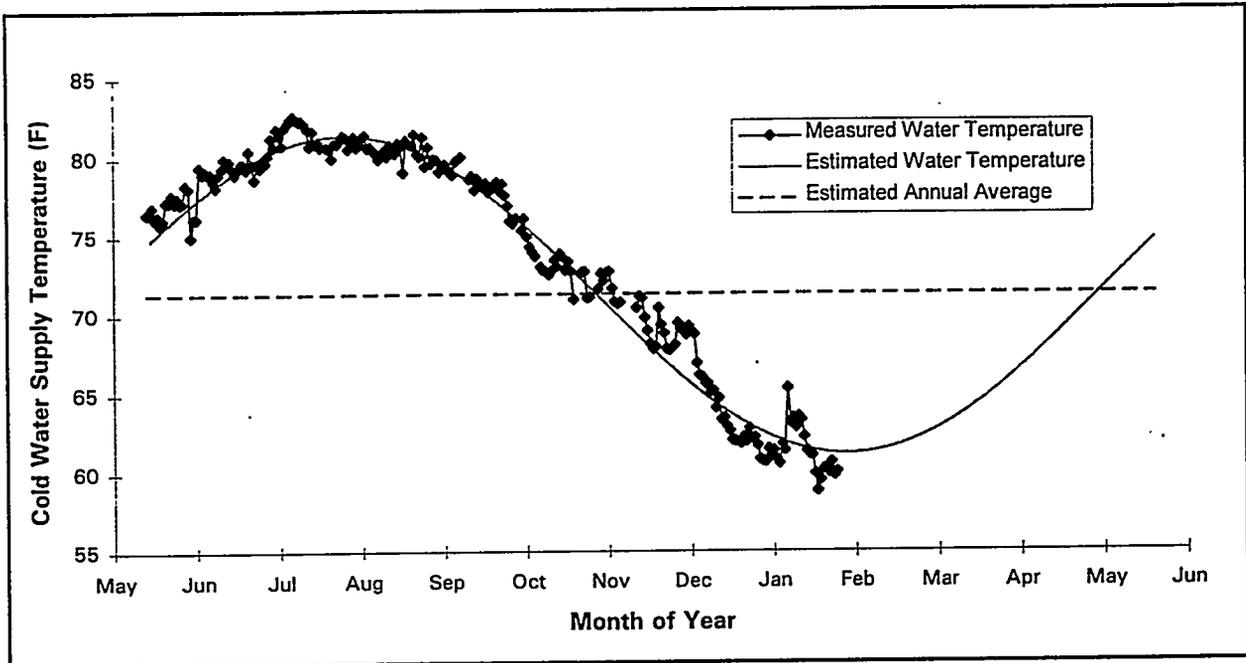
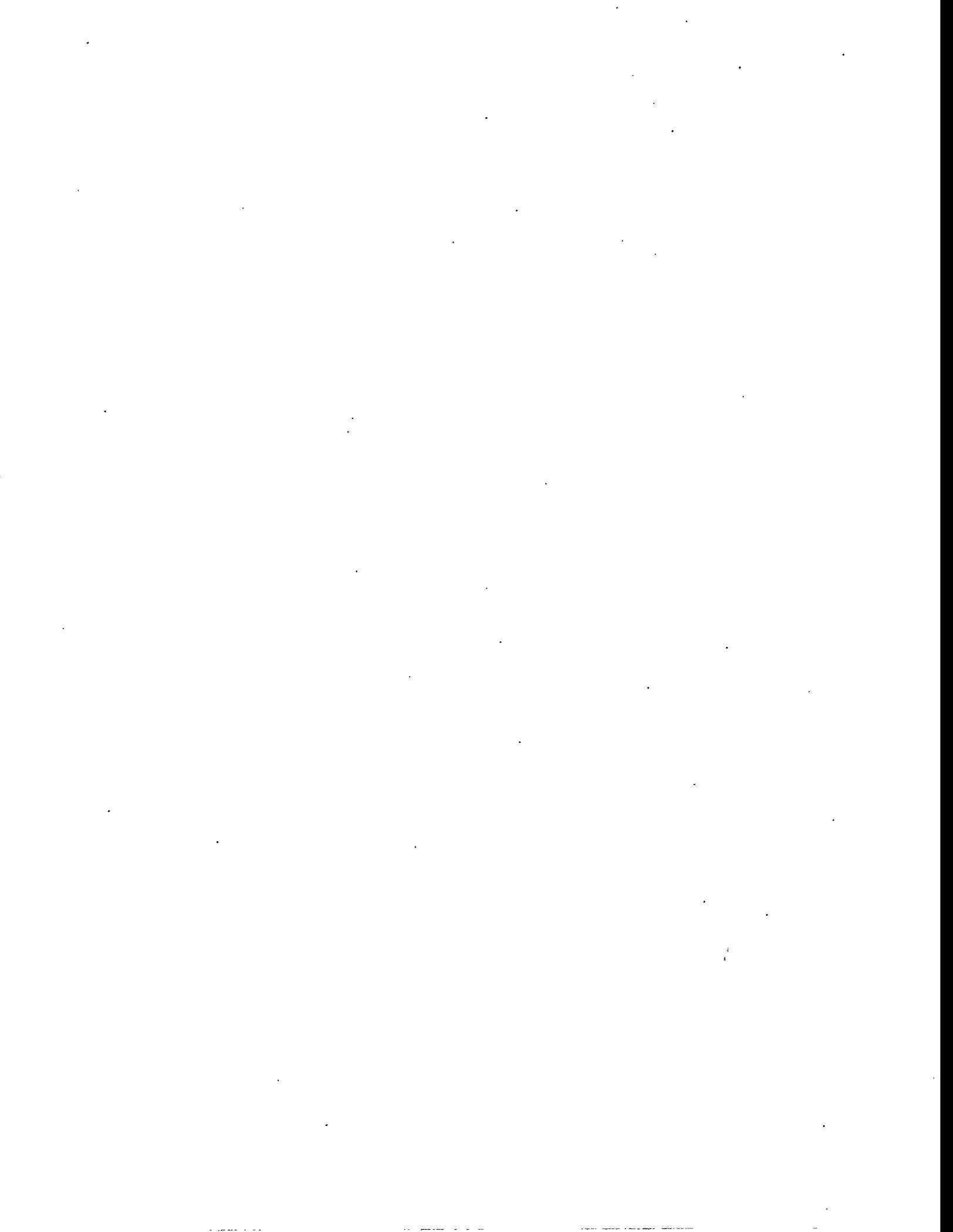


Figure D.1. Annual Cold Water Supply Temperature for Fort Stewart

Appendix E

Potential Impact of Thermosiphoning on Seahorse Efficiency



Appendix E

Potential Impact of Thermosiphoning on Seahorse Efficiency

In the installation of the Seahorse retrofit demonstrated at Fort Stewart, thermosiphoning of hot water through the flow loop may account for significant standby losses in the system. After the Seahorse finishes a heating cycle and the pump and burner turn off, the average temperature of water in the upper section of the flow loop (the hot water return to the tank) is higher than the average temperature of water in the tank or in the lower flow loop section. The water in the lower flow loop (water supply from the tank to the Seahorse) is at the same temperature as the water in the lower section of the tank. However, since the heat exchanger is not insulated from the ambient air, and since the surface-to-volume ratio of the insulated pipe is relatively large, the water contained in the flow loop and heat exchanger cools faster than water contained in the storage tank. In a short period of time, the average water temperature in the flow loop will become cooler than the average water temperature inside the tank. Once this happens, the column of water in the flow loop becomes denser than the average density of a similar column of fluid in the storage tank. The denser fluid in the flow loop will then begin to sink in the flow loop, with the hot water from the tank filling the upper tube section and cold water from the lower section of the flow loop entering the lower section of the tank. The hot water moving into the upper flow loop section will, in turn, also cool and, once started, this process will continue until either the Seahorse cycles on again or the average tank temperature in the flow loop and the tank are both equal to the ambient temperature.

A rough engineering estimate for the magnitude of the flow can be calculated by solving simultaneously the equation for pipe heat loss and the thermal/density induced flow through the flow loop system.

The following outlines a methodology to estimate the magnitude of heat losses that might be expected from thermosiphoning in the Seahorse system.

Calculation of Fluid Flow in Loop

The flow in the pipe is governed by

$$H = \frac{2 F_f L}{D V^2 g}$$

where

H is the head loss through the piping system (ft H₂O)

F_f is the Fanning friction factor

L is the equivalent length of pipe (ft)

D is the diameter of the pipe (ft)

V is the velocity of fluid flow in the system (ft/s)

g is the gravitational constant (32 f/s²).

If laminar flow is assumed in the piping, the Fanning friction factor is equal to 16 divided by the Reynolds number for flow in the pipe (Welty et al. 1984). The Reynolds number, expressed as a function of fluid velocity and pipe diameter, is $Re = vD/\nu$ where ν is the kinematic viscosity of the fluid and equals the viscosity of the fluid divided by the fluid density. Using the laminar flow assumption allows the above pipe flow equation to be rewritten as

$$H = \frac{32 \nu V L}{g D^2}$$

For the Seahorse and flow loop system, the equivalent length of pipe is equal to the actual length of the flow loop, plus equivalent lengths of piping that would give similar pressure loss factors as the Seahorse fittings and heat exchanger. The pressure head that is developed is determined by the difference in weight between the two imaginary columns of water, one inside the tank and one in the flow loop system. As the density of the water is a known function of water temperature, the pressure head then becomes a function of the difference in average temperature of the two water columns.

$$H = gh(\rho_{\text{tank}} - \rho_{\text{loop}})$$

where ρ_{tank} and ρ_{loop} refer to the average density of the two different imaginary water columns and are each a known function of the average water temperature in each column. Since ρ_{tank} depends on the temperature of fluid in the tank, it is known at the outset. ρ_{loop} is a known function of the temperature of water entering and leaving the flow loop.

Calculation of Heat Loss in Flow Loop

A conservative estimate of the heat loss in the flow loop can be made by considering only the heat loss in the flow loop piping and ignoring the heat loss in the heat exchanger. Calculation of the overall heat loss coefficient (UA) of the piping was shown in Appendix B. Since the rate of fluid flow is estimated to be very low, there will be a significant temperature drop through the flow loop during thermosiphoning. The water entering the flow loop at the top of the tank will be at the maximum tank water temperature. The total heat loss from the flow loop piping can be calculated using the concept of the log-mean temperature difference (Welty et al. 1984).

$$q = UA \frac{(T_{hot} - T_{amb}) - (T_{cool} - T_{amb})}{\ln \frac{(T_{hot} - T_{amb})}{(T_{cool} - T_{amb})}}$$

where

q is the total rate of heat loss from the piping

T_{hot} is the known temperature of water entering the pipe at the upper flow loop connection

T_{cool} is the temperature of water entering the pipe at the lower flow loop connection

T_{amb} is the ambient air temperature.

The rate of heat loss q can also shown as the temperature drop of the fluid from one end of the other times the fluid heat capacity or

$$q = \rho_{loop} V A C_p (T_{hot} - T_{cool})$$

where

V is the velocity of the fluid

A is the cross-sectional area of fluid flow

C_p is the heat capacity of the fluid.

There are thus four equations and four unknowns, H , T_{cool} , and q , V with some additional known functions relating water density and temperature. Thus, these equations can be solved simultaneously. The attached spreadsheet illustrates the solution of the thermosiphoning energy loss for the no-heat-exchanger case and also provides a graph showing how the thermosiphoning energy loss is expected to vary with increases in the overall heat loss coefficient (UA) of the flow loop and heat exchanger.

Reference

Welty, J.R., C.E. Wicks, R.E. Wilson. 1984. *Fundamentals of Momentum, Heat, and Mass Transfer*. John Wiley & Sons, New York, New York.

Seahorse Thermosiphon Energy Loss Calculations

Ft Stew/Seahorse Thermosiphon Calculations.

Because the heat flow in the loop is triggered with the pump, thermosiphon losses are not attributed to the Seahorse. But rather are accounted for in the general tank losses.

Note, immediately after the Seahorse cycles off, the water in the upper flow loop is originally at a temperature higher than the average tank average tank temperature, however, as the water in the flow loop and the seahorse heat exchanger cools, its temperature drops below the average tank temperature and it becomes denser than the water in the tank. It thus begins to flow in the direction opposite to the flow during operation, with the hot water from the tank filling the upper tube section and cooler water in the loop sinking in the flow loop and flowing into the bottom of the tank. Once started, this process will continue for the complete standby period.

An rough engineering estimate for the magnitude of the flow can be calculated by solving simultaneously the equation for pipe heat loss and the flow through the pipe based on the pressure differential caused by the different densities for water in the flow loop and in the tank

Heat loss from pipe $Q = UA \times (\log \text{ mean temperature difference between water and ambient})$
 Flow in pipe $\text{Head loss} = 2 Ff L/D V^2/g$ (Laminar flow in pipe)
 where Ff is the Fanning friction factor, L is the equivalent pipe length, D is the pipe diameter, V is the velocity of the fluid, and g is the gravitational constant.
 Since the flow will be laminar, $Ff = 16/Re$ (Reynold's number)
 or $\text{Headloss} = 32 u V L/(g p D^2)$
 where u is the viscosity of water and p is the density of water

This spreadsheet solves iteratively the equations for pressure head and water flow based on 40 feet of insulated piping loop. It does not take into account the Seahorse heat exchanger which will dramatically increase the heat loss in the pipe and thus the buoyancy driven flow in the loop.

Buoyancy Driven flow section			
	Water Temperature (F)	Water Density (lb/ft ³)	Calculated
Water at top of tank	128.00	61.59	
Water at lower pipe	109.61	61.86	
Water at lower tank	125.00	61.64	
Average in pipe	118.80	61.73	
Note, think of this as a loop insulated flow loop with an average water inside temperature inside and 75 F ambient conditions and with 32 inches of height			
	Base of Column (lb/ft ²)	Base of Loop column (lb/ft ²)	delta Pressure (lb/ft ²)
Pressure = pgh	164.30	164.62	0.32
Pipe flow is calculated as $\text{head loss} = 2 Ff L/D v^2/g$ Where Ff is fanning friction Factor = $16/Re$ or $\text{headloss} = 32 u v L/(g p D^2)$			
The difference in pressure head drives the flow. In this case if we assume a low flow rate (laminar flow)			
Head loss (feet)	0.00497493 ft H2O		
Kinematic Viscosity	0.0000108 ft ² /s		
gravitational constant	32 ft/s ²		
pipe ID	0.05967 ft		
Length of pipe	40 ft		
Equivalent Length (with Loss Coefficients)	100 ft		(Estimate taking into account pressure drops for elbows and centrifugal pump).
Velocity	0.02 ft/sec		
Transit Time	2439.12 sec		
Re	90.60		
f	0.71		
Flow rate	1.23 gal/hr		

Seahorse Thermosiphon Energy Loss Calculations

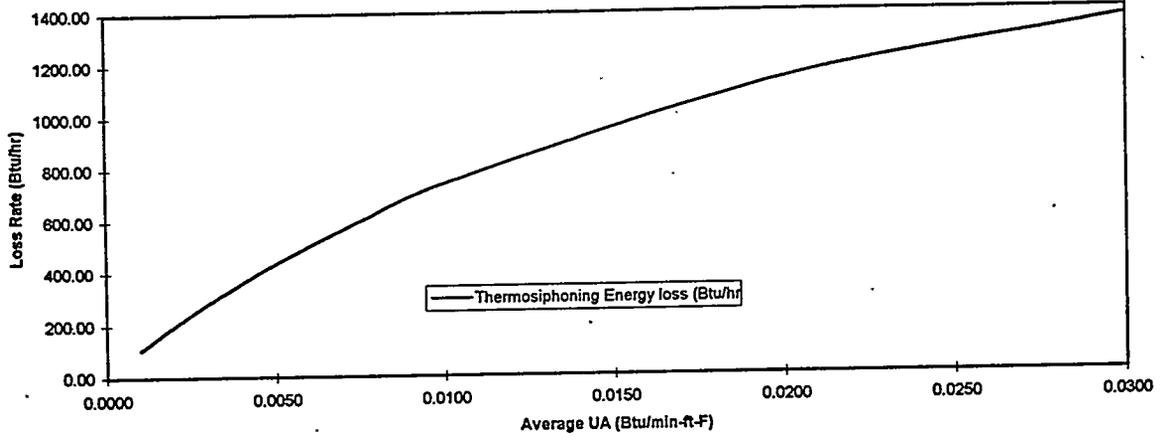
Heat Transfer Section			
UA pipe	0.00188	Btu/min-F-ft	
loss by end of pipe	3.29	Btu/ft	
Avg Amb	75.00	F	
Log mean temp difference			
(fluid in pipe - amb)	43.15	F	
Tempdrop of fluid in pipe	18.39	F	
Relevant data for heat transfer from the storage loop			
d3	1.875	inch	{diameter at insulation surface}
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	
Heat loss due to thermosiphoning			
	188	Btu/hr	

Heat Loss with Heat Exchanger

Incorporating the Seahorse heat exchanger in these calculations would increase the average heat transfer coefficient from the loop significantly while providing only a minor increase in pressure drop in the flow loop. Temperature drop through the loop would increase significantly, increasing total flow and significantly increasing the heat loss. The graph shown below shows the expected loss rate as a function of the average UA of the loop (including the heat exchanger). If it is assumed that the heat exchanger UA is equal to the piping UA, the resulting loss rate would be approximately 340 Btu/hr

Loop UA (Average Btu/ft ² -min- F)	Water Temp at bottom of flow loop	Flow (Gal/hour)	Thermosiphoning Energy loss (Btu/hr)
0.00100	113.85	0.90	105.83
0.00188	109.59	1.24	188.41
0.00200	109.11	1.27	199.13
0.00250	107.28	1.41	242.66
0.00300	105.66	1.54	284.44
0.00376	103.51	1.70	344.95
0.00500	100.55	1.92	436.91
0.00750	95.91	2.26	601.10
0.01000	92.38	2.52	742.12
0.02000	83.77	3.12	1142.00
0.03000	79.48	3.41	1369.95

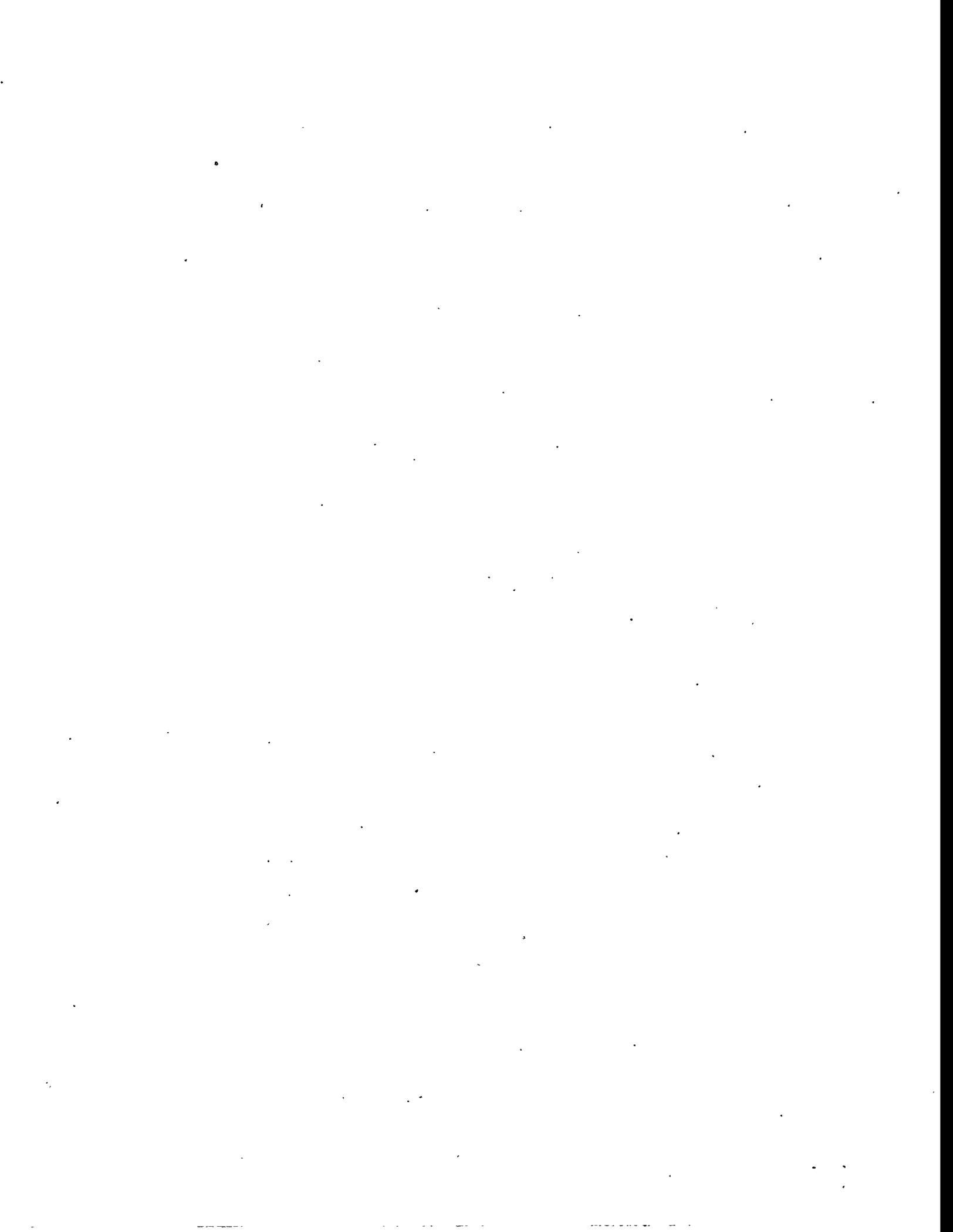
Seahorse Thermosiphon Energy Loss Calculations



Thermosiphoning Energy Loss as a function of average UA for Seahorse flow loop

Appendix F

BLCC4 Economic Inputs and Life-Cycle Cost Output



BLCC COMPARATIVE OUTPUT BASED ON DOE ESTIMATED RESIDENTIAL HOT WATER ENERGY CONSUMPTION

NIST BLCC: COMPARATIVE ECONOMIC ANALYSIS (version 4.20-95)

BASE CASE: Elec Heat
ALTERNATIVE: Seahorse

PRINCIPAL STUDY PARAMETERS:

ANALYSIS TYPE: Federal Analysis--Energy Conservation Projects
STUDY PERIOD: 15.00 YEARS (SEP 1995 THROUGH AUG 2010)
DISCOUNT RATE: 3.1% Real (exclusive of general inflation)
BASE CASE LCC FILE: ELECDOE.LCC
ALTERNATIVE LCC FILE: SEADOE.LCC

COMPARISON OF PRESENT-VALUE COSTS

	BASE CASE: Elec Heat	ALTERNATIVE: Seahorse	SAVINGS FROM ALT.
INITIAL INVESTMENT ITEM(S):			
CASH REQUIREMENTS AS OF SERVICE DATE	\$0	\$835	-\$835
SUBTOTAL	\$0	\$835	-\$835
FUTURE COST ITEMS:			
ANNUAL AND NON-AN. RECURRING COSTS	\$0	\$26	-\$26
ENERGY-RELATED COSTS	\$2,174	\$1,191	\$983
REPLACEMENTS TO CAPITAL	\$314	\$314	\$0
SUBTOTAL	\$2,488	\$1,531	\$957
TOTAL P.V. LIFE-CYCLE COST	\$2,488	\$2,366	\$122

NET SAVINGS FROM ALTERNATIVE Seahorse COMPARED TO ALTERNATIVE Elec Heat

Net Savings	=	P.V. of non-investment savings	\$957
	-	Increased total investment	\$835
		Net Savings:	\$122

Note: the SIR and AIRR computations include differential initial costs, capital replacement costs, and resale value (if any) as investment costs, per NIST Handbook 135 (Federal and MILCON analyses only).

SAVINGS-TO-INVESTMENT RATIO (SIR)
FOR ALTERNATIVE Seahorse COMPARED TO ALTERNATIVE Elec Heat

$$\text{SIR} = \frac{\text{P.V. of non-investment savings}}{\text{Increased total investment}} = 1.15$$

ADJUSTED INTERNAL RATE OF RETURN (AIRR)
FOR ALTERNATIVE Seahorse COMPARED TO ALTERNATIVE Elec Heat
(Reinvestment rate = 3.10%; Study period = 15 years).

AIRR = 4.04%

ESTIMATED YEARS TO PAYBACK

Simple Payback occurs in year 10
Discounted Payback occurs in year 13

ENERGY SAVINGS SUMMARY

Energy type	Units	Annual Consumption			Life-Cycle Savings
		Base Case	Alternative	Savings	
Electricity	kWh	4,980	86	4,894	73,413
Natural Gas	MBtu	0	28	-28	-413

EMISSIONS REDUCTION SUMMARY

Energy type	Annual Emissions		Annual Reduction	Life-Cycle Reduction
	Base Case	Alternative		
Electricity:				
CO2 (Kg):	2,892.8	49.8	2,843.0	42,644.7
SOx (Kg):	24.3	0.4	23.9	204.5
NOx (Kg):	12.4	0.2	12.2	182.9
Natural Gas:				
CO2 (Kg):	0.0	1,452.3	-1,452.3	-21,784.1
SOx (Kg):	0.0	0.0	-0.0	0.0

NOx (Kg):	0.0	1.1	-1.1	-16.5
Total:				
CO2 (Kg):	2,892.8	1,502.1	1,390.7	20,860.6
SOx (Kg):	24.3	0.4	23.9	204.5
NOx (Kg):	12.4	1.3	11.1	166.4

BLCC COMPARATIVE OUTPUT BASED ON DOE ESTIMATED RESIDENTIAL HOT WATER CONSUMPTION AND FORT STEWART COLD WATER SUPPLY TEMPERATURES

NIST BLCC: COMPARATIVE ECONOMIC ANALYSIS (version 4.20-95)

BASE CASE: Elec Heat
ALTERNATIVE: Seahorse

PRINCIPAL STUDY PARAMETERS:

ANALYSIS TYPE: Federal Analysis--Energy Conservation Projects
STUDY PERIOD: 15.00 YEARS (SEP 1995 THROUGH AUG 2010)
DISCOUNT RATE: 3.1% Real (exclusive of general inflation)
BASE CASE LCC FILE: ELECDOW.LCC
ALTERNATIVE LCC FILE: SEADOW.LCC

COMPARISON OF PRESENT-VALUE COSTS

	BASE CASE: Elec Heat	ALTERNATIVE: Seahorse	SAVINGS FROM ALT.
INITIAL INVESTMENT ITEM(S):			
CASH REQUIREMENTS AS OF SERVICE DATE	\$0	\$835	-\$835
SUBTOTAL	\$0	\$835	-\$835
FUTURE COST ITEMS:			
ANNUAL AND NON-AN. RECURRING COSTS	\$0	\$26	-\$26
ENERGY-RELATED COSTS	\$1,842	\$1,064	\$778
REPLACEMENTS TO CAPITAL	\$314	\$314	\$0
SUBTOTAL	\$2,156	\$1,404	\$752
TOTAL P.V. LIFE-CYCLE COST	\$2,156	\$2,239	-\$83

NET SAVINGS FROM ALTERNATIVE Seahorse COMPARED TO ALTERNATIVE Elec Heat

Net Savings = P.V. of non-investment savings	\$752
- Increased total investment	\$835
Net Savings:	-\$83

Note: the SIR and AIRR computations include differential initial costs, capital replacement costs, and resale value (if any) as investment costs, per NIST Handbook 135 (Federal and MILCON analyses only).

SAVINGS-TO-INVESTMENT RATIO (SIR)
FOR ALTERNATIVE Seahorse COMPARED TO ALTERNATIVE Elec Heat

$$\text{SIR} = \frac{\text{P.V. of non-investment savings}}{\text{Increased total investment}} = 0.90$$

ADJUSTED INTERNAL RATE OF RETURN (AIRR)
FOR ALTERNATIVE Seahorse COMPARED TO ALTERNATIVE Elec Heat
(Reinvestment rate = 3.10%; Study period = 15 years)

AIRR = 2.39%

ESTIMATED YEARS TO PAYBACK

Simple Payback occurs in year 13
Discounted Payback never reached during study period.

ENERGY SAVINGS SUMMARY

Energy type	Units	Annual Consumption			Life-Cycle Savings
		Base Case	Alternative	Savings	
Electricity	kWh	4,225	80	4,145	62,168
Natural Gas	MBtu	0	25	-25	-368

EMISSIONS REDUCTION SUMMARY

Energy type	Annual Emissions		Annual Reduction	Life-Cycle Reduction
	Base Case	Alternative		
Electricity:				
CO2 (Kg):	2,454.2	46.8	2,407.5	36,112.3
SOx (Kg):	20.6	0.4	20.2	173.1
NOx (Kg):	10.5	0.2	10.3	154.9
Natural Gas:				
CO2 (Kg):	0.0	1,293.8	-1,293.8	-19,407.7
SOx (Kg):	0.0	0.0	-0.0	0.0

NOx (Kg):	0.0	1.0	-1.0	-14.7
Total:				
CO2 (Kg):	2,454.2	1,340.6	1,113.6	16,704.6
SOx (Kg):	20.6	0.4	20.2	173.1
NOx (Kg):	10.5	1.2	9.3	140.2

BLCC COMPARATIVE OUTPUT BASED ON MEASURED HOT WATER ENERGY USE AT FORT STEWART

NIST BLCC: COMPARATIVE ECONOMIC ANALYSIS (version 4.20-95)

BASE CASE: Elec Heat
ALTERNATIVE: Seahorse

PRINCIPAL STUDY PARAMETERS:

ANALYSIS TYPE: Federal Analysis--Energy Conservation Projects
STUDY PERIOD: 15.00 YEARS (SEP 1995 THROUGH AUG 2010)
DISCOUNT RATE: 3.1% Real (exclusive of general inflation)
BASE CASE LCC FILE: ELECNAT.LCC
ALTERNATIVE LCC FILE: SEANAT.LCC

COMPARISON OF PRESENT-VALUE COSTS

	BASE CASE: Elec Heat	ALTERNATIVE: Seahorse	SAVINGS FROM ALT.
INITIAL INVESTMENT ITEM(S):			
CASH REQUIREMENTS AS OF SERVICE DATE	\$0	\$835	-\$835
SUBTOTAL	\$0	\$835	-\$835
FUTURE COST ITEMS:			
ANNUAL AND NON-AN. RECURRING COSTS	\$0	\$26	-\$26
ENERGY-RELATED COSTS	\$1,569	\$953	\$616
REPLACEMENTS TO CAPITAL	\$314	\$314	\$0
SUBTOTAL	\$1,884	\$1,293	\$590
TOTAL P.V. LIFE-CYCLE COST	\$1,884	\$2,128	-\$245

NET SAVINGS FROM ALTERNATIVE Seahorse COMPARED TO ALTERNATIVE Elec Heat

Net Savings	= P.V. of non-investment savings	\$590
	- Increased total investment	\$835
Net Savings:		-\$245

Note: the SIR and AIRR computations include differential initial costs, capital replacement costs, and resale value (if any) as investment costs, per NIST Handbook 135 (Federal and MILCON analyses only).

SAVINGS-TO-INVESTMENT RATIO (SIR)
FOR ALTERNATIVE Seahorse COMPARED TO ALTERNATIVE Elec Heat

$$\text{SIR} = \frac{\text{P.V. of non-investment savings}}{\text{Increased total investment}} = 0.71$$

ADJUSTED INTERNAL RATE OF RETURN (AIRR)
FOR ALTERNATIVE Seahorse COMPARED TO ALTERNATIVE Elec Heat
(Reinvestment rate = 3.10%; Study period = 15 years)

$$\text{AIRR} = 0.75\%$$

ESTIMATED YEARS TO PAYBACK

Simple Payback never reached during study period
Discounted Payback never reached during study period

ENERGY SAVINGS SUMMARY

Energy type	Units	Annual Consumption			Life-Cycle Savings
		Base Case	Alternative	Savings	
Electricity	kWh	3,590	76	3,514	52,710
Natural Gas	MBtu	0	22	-22	-329

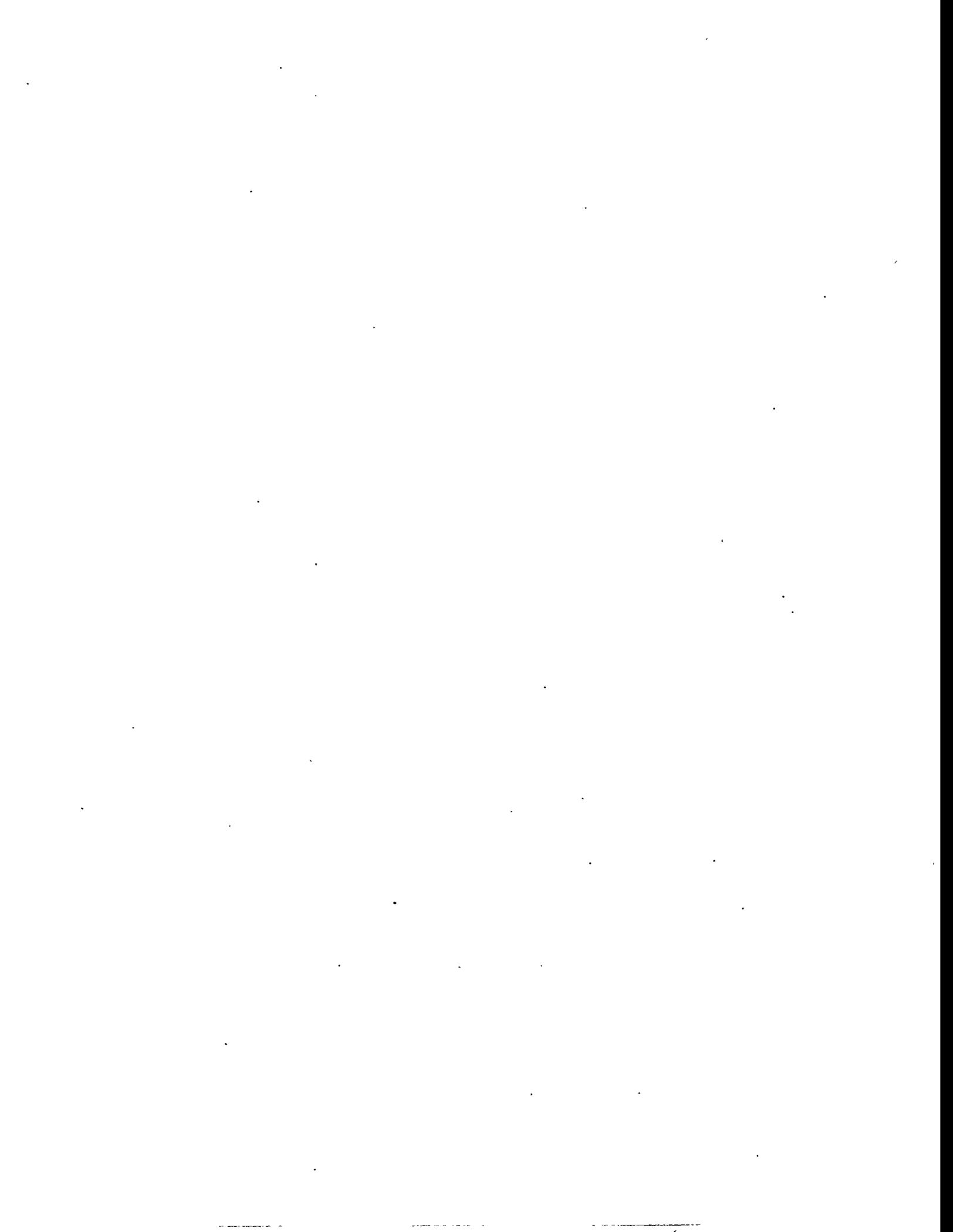
EMISSIONS REDUCTION SUMMARY

Energy type	Annual Emissions		Annual Reduction	Life-Cycle Reduction
	Base Case	Alternative		
Electricity:				
CO2 (Kg):	2,085.4	44.1	2,041.2	30,618.6
SOx (Kg):	17.5	0.4	17.2	146.8
NOx (Kg):	8.9	0.2	8.8	131.3
Natural Gas:				
CO2 (Kg):	0.0	1,156.5	-1,156.5	-17,348.1
SOx (Kg):	0.0	0.0	-0.0	0.0

NOx (Kg) :	0.0	0.9	-0.9	-13.1
Total:				
CO2 (Kg) :	2,085.4	1,200.7	884.7	13,270.5
SOx (Kg) :	17.5	0.4	17.1	146.8
NOx (Kg) :	8.9	1.1	7.9	118.2

Appendix G

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,

Ft. Stewart
DMH 1/27/94

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

Ft. Stewart
DMH 1/27/94

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

Ft. Stewart
DMH 1/27/94

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,

Ft. Stewart
DMH 1/27/94

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.

Ft. Stewart
DMH 1/27/94

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

Planned Start: 3/94

Planned Completion: 3/94

Ft. Stewart
DMH 1/27/94

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.

Ft. Stewart
DMH 1/27/94

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

Ft. Stewart
DMH 1/27/94

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

Ft. Stewart
DMH 1/27/94

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.

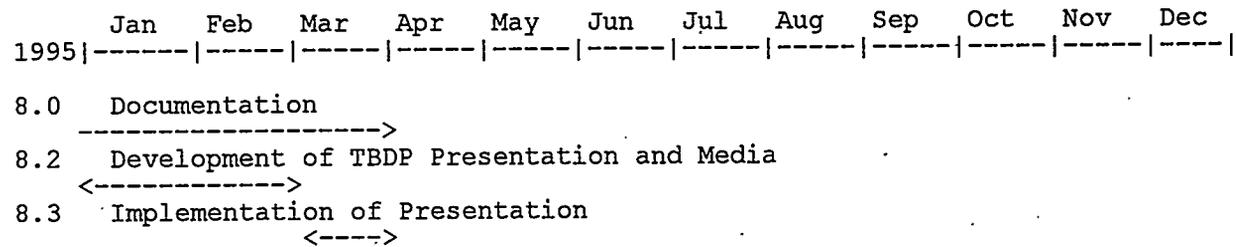
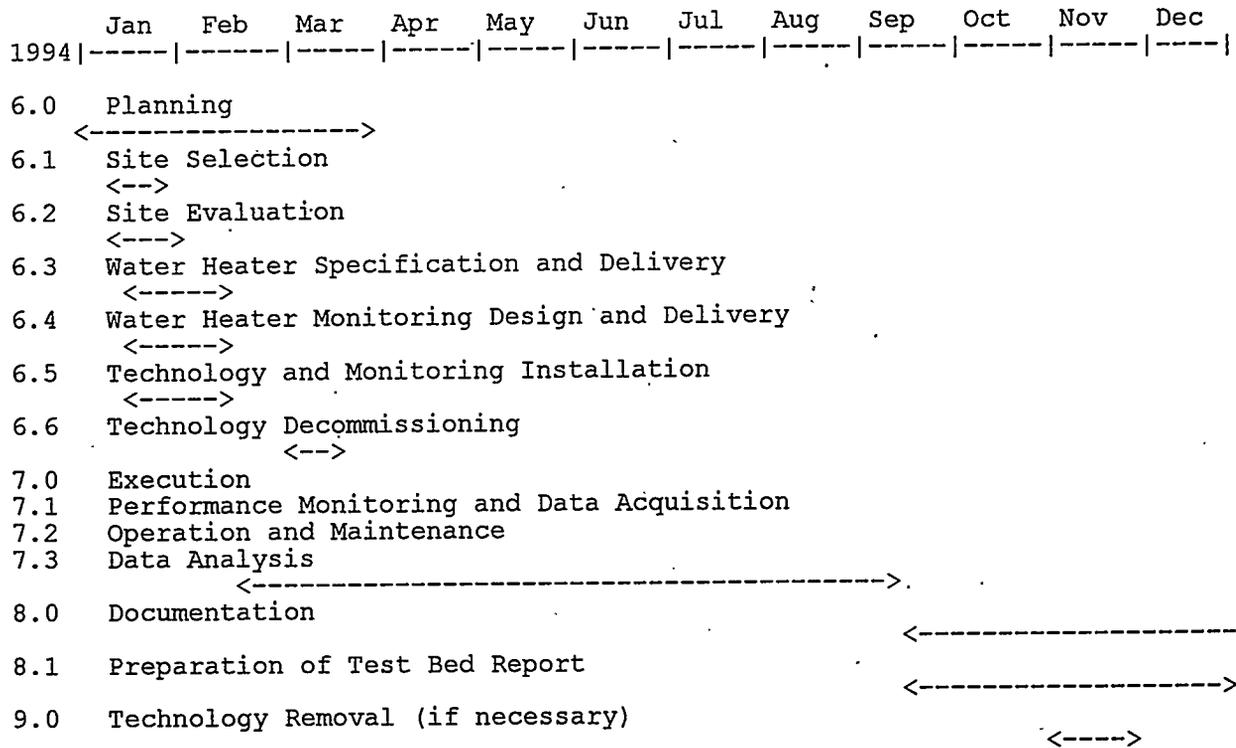
Primary responsibility for monitoring: PNL.

Secondary responsibility for monitoring: AGLC.

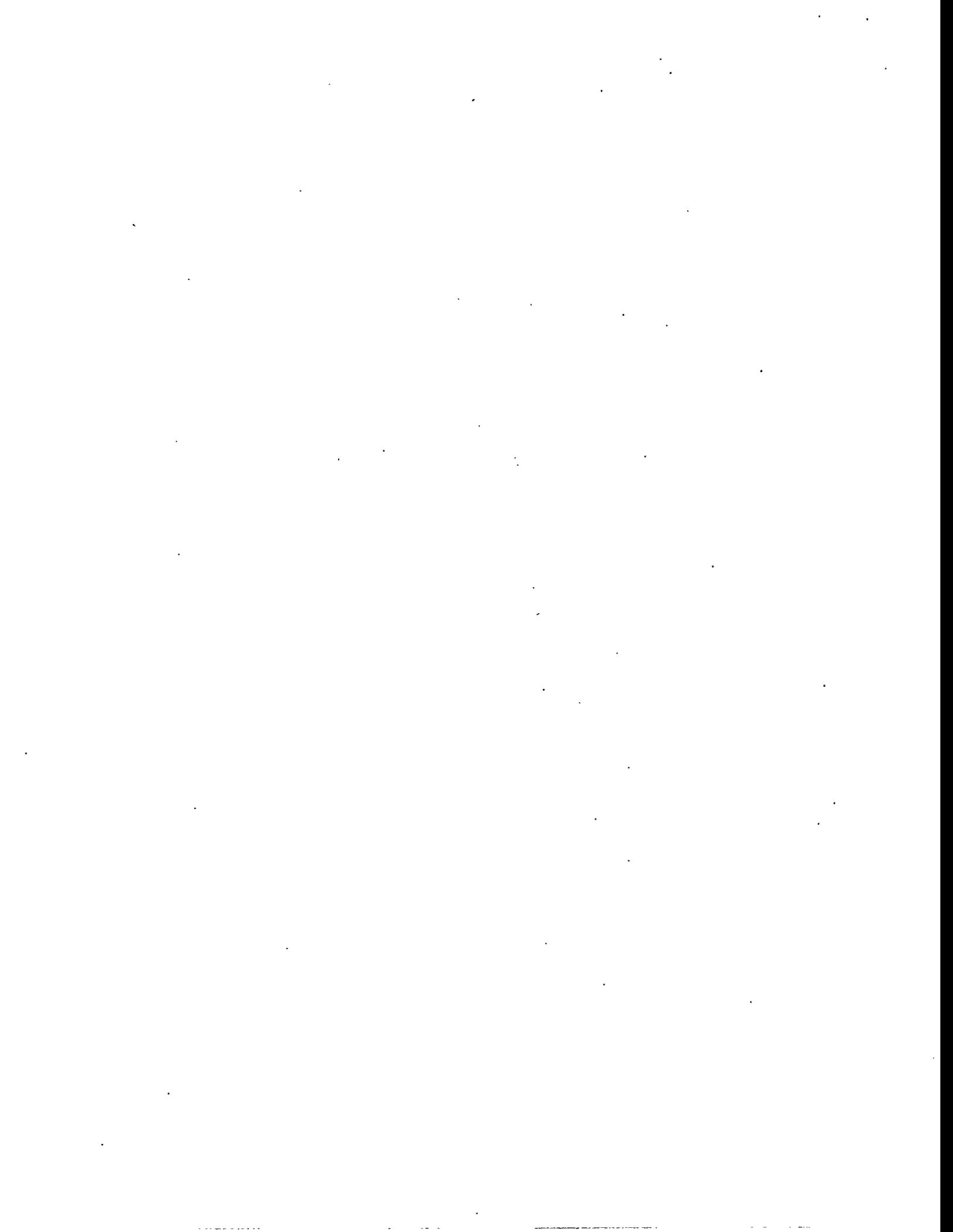
Deliverable: A report on the disposition of the technology and the monitoring equipment, and the return of the installation to the Federal site in an acceptable manner.

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.



Appendix H
Glossary of Terms and Abbreviations



Appendix H

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 of 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

