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TECHNICAL
REPORT

Demonstration of Tankless Water Heaters in Army Family Housing

by
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U.S. Army Engineering and Housing Support Center
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Tankless water heater technology is used widely throughout Europe and Japan to reduce the amount of energy required to produce a steady supply of hot water. Because this technology does not employ a water storage tank, standby heat losses are avoided, saving up to 25 percent of the energy consumed by conventional water heaters. The U.S. Army Construction Engineering Research Laboratories (USACERL) demonstrated two types of tankless water heaters in Army family housing at Fort Sill, OK, through the Facilities Engineering Applications Program (FEAP). U.S.-made gas and electric tankless water heaters were laboratory tested, and five units of each type were installed in 10 similar residences. Five new conventional gas water heaters and five new conventional electric units were installed in another 10 residences for comparison. All demonstration units were evaluated for (1) ability to provide a safe, steady supply of hot water and (2) energy costs.

The only U.S-made tankless gas water heater available for the demonstration was a unit designed for commercial applications. Initial results demonstrated that the unit tended to overheat water at low flow rates, making it unable to provide a safe supply of hot water. No further data on the unit were collected.

The tankless electric water heater provided a safe, sustained hot water supply, but the flow rate was lower than desirable. The average energy cost for the tankless unit was about 26 percent lower than for the conventional electric water heater. However, the tankless electric water heater required a costly electric service upgrade for each residence in which it was installed, and one unit malfunctioned early in the demonstration. The conventional gas water heater provided the most economical hot water of all units demonstrated, and no safety or performance problems were observed.

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FOREWORD

This research was performed for the U.S. Army Engineering and Housing Support Center (USAEHSC) under the Facilities Engineering Applications Program (FEAP) work unit "Tankless Water Heaters." The USAEHSC technical monitor was B. Wasserman, CEHSC-FU-M.

The work was performed by the Fuels and Power Systems Team (FEP) of the Energy and Utility Systems Division (FE), Infrastructure Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL). The team leader is Gary Schanche, CECER-FEP. Dr. David M. Joncich is Chief, CECER-FE. Dr. Michael J. O'Connor is Chief, CECER-FL. The USACERL technical editor was Gordon L. Cohen, Information Management Office.

Appreciation is expressed to Kevin Heyen and Daiva Tamulaitis for assistance in performing tests.

COL Daniel Waldo, Jr., is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

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DEMONSTRATION OF TANKLESS WATER HEATERS IN ARMY FAMILY HOUSING

1 INTRODUCTION

Background

Tankless water heater technology has been available for several years, and is used widely throughout Europe and Japan. Tankless water heaters do not use a water storage tank, as do conventional water heaters. Instead, they instantaneously heat water flowing through their coils to a desired delivery temperature. Tankless water heaters provide several advantages over conventional water heaters. Since tankless water heaters do not have a tank, they are more compact than conventional water heaters. Another benefit of tankless technology is that standby heat losses—the cooling of water standing in the storage tank—are avoided. Standby heat losses can account for up to 25 percent of the energy consumed by a conventional water heater (Herbert 1986). Such energy savings would be expected to result in corresponding dollar savings or utility bills.

Recognizing the energy-saving potential of tankless water heaters in Army family housing, the U.S. Army Engineering and Housing Support Center (USAEHSC) tasked the U.S. Army Construction Engineering Research Laboratories (USACERL) to demonstrate the technology. This demonstration, conducted through the Facilities Engineering Application Program (FEAP), required tankless water heaters capable of replacing 40-gallon* conventional water heaters. The tankless water heaters would have to be capable of providing a safe, dependable hot water supply that fully meets the needs of family housing occupants. The requirement to purchase products manufactured in the United States limited the number of options available to demonstrate, because most tankless water heaters are made in Europe or Japan.

Objective

The objective of this study was to determine the performance characteristics of tankless gas- and electric-powered water heaters in Army family housing.

Approach

Twenty family housing units at Fort Sill, OK, were selected for the demonstration. Tankless gas water heaters were installed in five units and tankless electric water heaters were installed in another five units. Conventional gas water heaters were installed in five units, and conventional electric units were installed in the remaining five housing units. All of the water heaters were new. Before the tankless water heaters were turned on in the test residences, one of each kind was installed in the laboratory and tested by USACERL.

The performance of all water heaters was monitored, and performance of the four types of water heaters was compared to determine which one provides the best service and economy.

* U.S. standard units of measure are used throughout this report. A table of metric conversion factors may be found on page 23.

Scope

This report covers the findings from the FEAP demonstration of tankless and conventional water heaters at Fort Sill, OK. Only equipment manufactured in the United States was used in the demonstration. The manufacturer of the tankless gas water heater originally selected for the demonstration went out of business before the equipment was acquired. The only other U.S.-made tankless gas unit available was designed for commercial applications. Testing of the unit uncovered a problem with its temperature controls that made it unsuitable for further consideration in a residential application. For this reason, no energy-use data for the tankless gas water heater were collected. Also, for reasons discussed in Chapter 4, test data were collected for a relatively short period of time between November 1991 and January 1992. Due to the short duration of the demonstration, therefore, this report does not cover aspects of the equipment's long-term reliability.

Mode of Technology Transfer

The findings of this research will be reported in the *DEH Digest*, and may be the subject of an informational flier or fact sheet distributed through the FEAP Information Center at USACERL. This research may also be reported in an issue of the *EIRS* Bulletin*. Additionally, it may be appropriate to publish an Engineer Technical Note on lessons learned through this research.

*Engineering Improvement Recommendation System.

2 DESCRIPTION OF WATER HEATERS USED IN DEMONSTRATION

Conventional Water Heaters

The conventional gas- and electric-powered tank water heaters used in this demonstration were high-efficiency units by Rheem Mfg. Co. The gas-powered model was the Rheemglas Fury 81GX40D, with a 40 gallon holding tank. The electric water heater was the Rheem Tri-Power Imperial 21V40-7, also with a 40 gallon holding tank. These two water heaters rely on thermostats to control the temperature of the water in the holding tank. If water temperature drops below the level set on the thermostat setpoint, the unit's heating system is switched on. When the water temperature reaches the setpoint, the main gas burner or electric elements are switched off. The Rheemglas Fury (gas) has an energy factor of 0.55 and a first-hour rating of 62 gallons. The Imperial (electric) has an energy factor of 0.96 and a first-hour rating of 49 gallons. The energy factor indicates the unit's overall efficiency, taking into account the model's recovery efficiency, energy input, and standby losses. The first-hour rating refers to the volume of heated water the unit can supply in its first hour of operation after a cold start, and is based on the model's tank size and heating rate. Both of these water heaters meet the criteria in American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90A - 1980, *Energy Conservation in New Building Design.*

The Hot Box Tankless Electric Water Heater

The tankless electric water heater used in this demonstration was the Hot Box, manufactured by HurriSystems, Inc. (see Figure 1). The Hot Box uses electric resistance elements to instantaneously heat water to a specified delivery temperature. A flow switch in the Hot Box turns on the heating elements when there is demand for hot water. When the user turns on the water, the Hot Box detects the flow and energizes the element to heat the water passing through the unit. The unit's heating elements are arranged in stages so the unit can change the water temperature as the flow rate changes.

Tankless water heaters are rated on the basis of the temperature rise the unit is capable of producing. If a tankless water heater is capable of producing a 60 °F rise at 2 gallons per minute (gpm) and the inlet temperature is 55 °F, then the outlet temperature would be 115 °F.

At rates below the specified flow rate, the unit provides a larger temperature rise, while at higher flow rates, the unit provides a smaller temperature rise. Because the Hot Box is designed to provide a temperature rise of 60 degrees at 2 gpm, it can produce 120 gallons of hot water per hour (2 gpm x 60 minutes/hour). At the same time, the Hot Box is very compact, measuring only 19.5 in. x 14 in. x 4.5 in., and is designed to be wall mounted. The Hot Box cost $250 at the time of the demonstration.

The Hotomatic Tankless Gas Water Heater

The tankless gas water heater used in this demonstration was the Hotomatic #3, manufactured by Little Giant Mfg. Co. The Hotomatic, a cylinder measuring 41 in. tall and 14 in. in diameter (see Figure 2), is designed to provide a 60 °F temperature rise at 2.5 gpm, for 150 gallons per hour recovery. The Hotomatic uses a thermostat and temperature sensor to control water temperature. When the user turns on the hot water, cold water flows into the Hotomatic and cools the temperature sensor below the temperature set on the thermostat. This cooling triggers the thermostat to fire the main burner, which heats incoming cold water. However, when the user shuts off the hot water, the main burner continues to operate, rapidly heating water in the coils to the set-point temperature (even though the user no longer needs the hot water. When the set-point temperature is reached, the thermostat then shuts off the main burner. In this resp[illegible]e Hotomatic's design requires the main burner to cycle continuously to maintain water temperature, just as conventional water heaters do. (This design characteristic is related to system control difficulties reported in Chapter 4.)

The Hotomatic is approved by the International Gas Association, and retailed for $550 at the time of the demonstration.

Figure 1. The Hot Box Tankless Electric Water Heater.

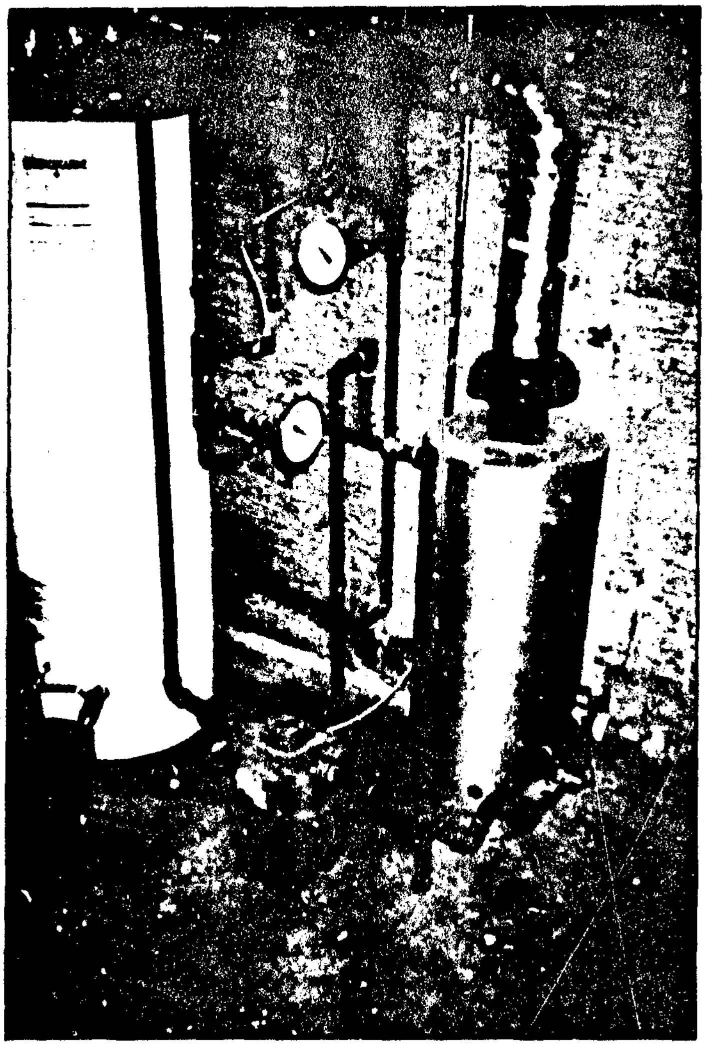

Figure 2. The Hotomatic Tankless Gas Water Heater.

3 INSTALLATION OF DEMONSTRATION UNITS

Laboratory Installation

One Hotomatic #3 and one Hot Box were installed at USACERL for testing under controlled conditions. The tankless water heaters are designed to provide a specified temperature rise at a specific flow rate, but the temperature rise changes as the flow rate changes. Laboratory testing was designed to measure the temperature rise over a wide range of flow rates.

Temperature sensors were placed on the inlet and the outlet of each tankless water heater to determine the temperature rise. A water meter was installed at the inlet of each water heater so the flow rate could be measured. In order to determine each water heater's energy consumption, gas and electricity usage were monitored. A gas meter was installed on the gas line to the Hotomatic, and current and potential transformers were installed in the circuit feeding the Hot Box to record the electrical demand and consumption. The laboratory test apparatus used a Synergistic Control Systems C-180 data logger to record data from the various sensors and meters. Figure 3 shows the laboratory setup for the electric tankless water heater. Figure 4 shows the laboratory setup for the tankless gas water heater, which required a pulsed-output gas meter. A temperature- and pressure-relief valve was installed on the outlet side of both water heaters. These valves were set at 150 pounds per square inch (psi) for pressure and 210 °F for temperature.

Field Installation

The family housing area at Fort Sill (the 2000 area) was selected for the demonstration because it includes many duplex housing units of similar layout and design (see Figure 5). Each duplex is divided into a north and a south residence. The water heaters for each residence is in the basement, next to the common wall. By running the sensor wires from south basement to the north one, a single data logger was used to monitor both sides. All of the demonstration water heaters, except the conventional gas-fueled ones, were plumbed in parallel with the existing water heaters.* Isolation valves were installed so the hot water supply in each residence could easily be switched from the old water heater to the demonstration unit. Thermowells for temperature sensors were installed on the inlet and outlet of each new water heater. A water meter with pulsed output was installed on the inlet side, and a temperature- and pressure relief valve was installed on the outlet side. Figure 6 shows the plumbing details for the new water heaters. The field installation also included 0 to 200 °F dial-reading temperature gauges on the inlet and outlet of each demonstration water heater. These gauges allowed visual verification of the water heater operation. New gas water heaters were installed with a gas meter on the gas line to measure the amount of gas used. Current transformers and potential transformers for measuring the amounts of electricity used were installed on the electrical circuits to the demonstration electric water heaters.

The residences in which a Hot Box was installed required extensive changes in electrical service to handle the new unit. The large electrical demand of the Hot Box—over 60 amps at 240 VAC (volts, alternating current)—dictated an upgrade of the existing 100 amp service to 200 amps. This required installation of a new panel, a new wire drop with an increase in size, and a new transformer. The required changes resulted in the Hot Box installations costing 20 to 30 times the installation cost of a conventional electric water heater. Although the cost of this upgrade was not documented, it is reasonable to assume that it was expensive enough to significantly diminish the appeal of the Hot Box as a cost-saving device.

* The conventional gas units were intended to remain in the test residence after the demonstration, so there was no reason to keep the existing unit installed and standing by.

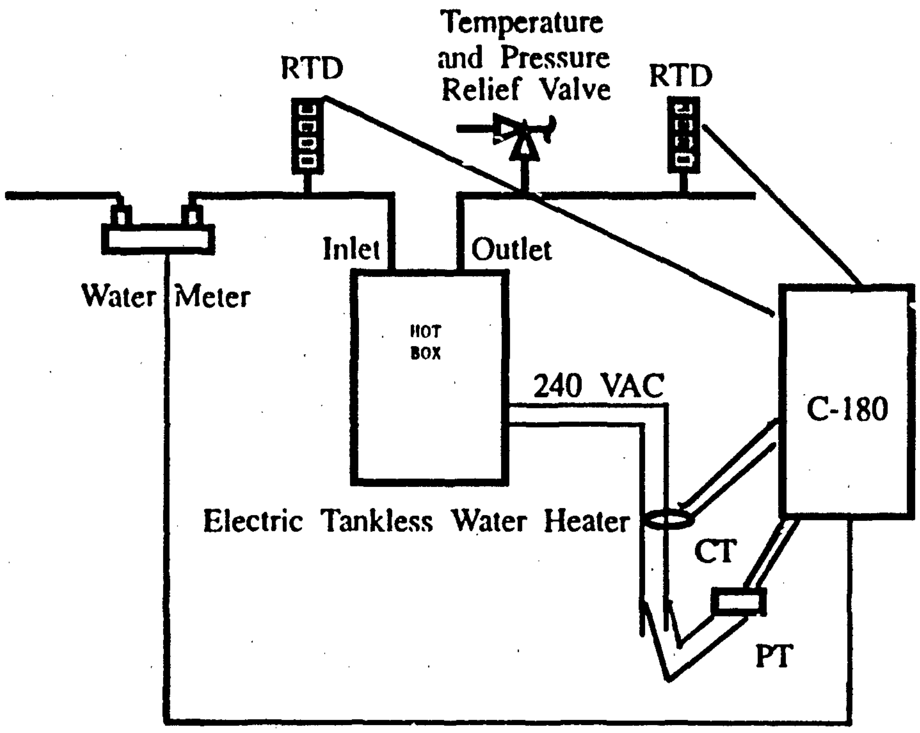

Figure 3. Laboratory Setup for Tankless Electric Water Heater.

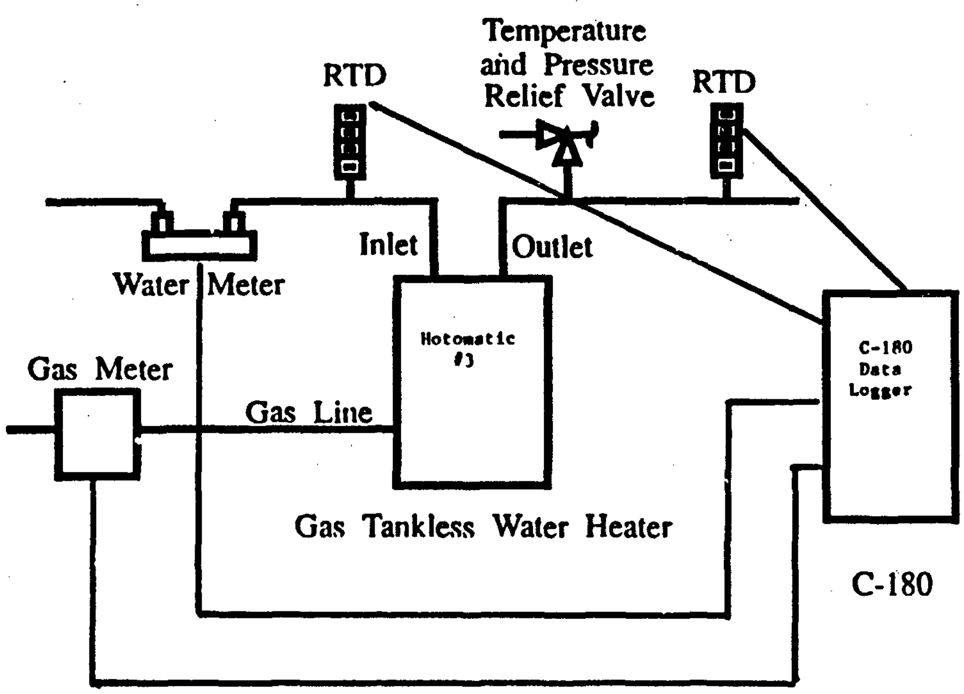

Figure 4. Laboratory Setup for Tankless Gas Water Heater.

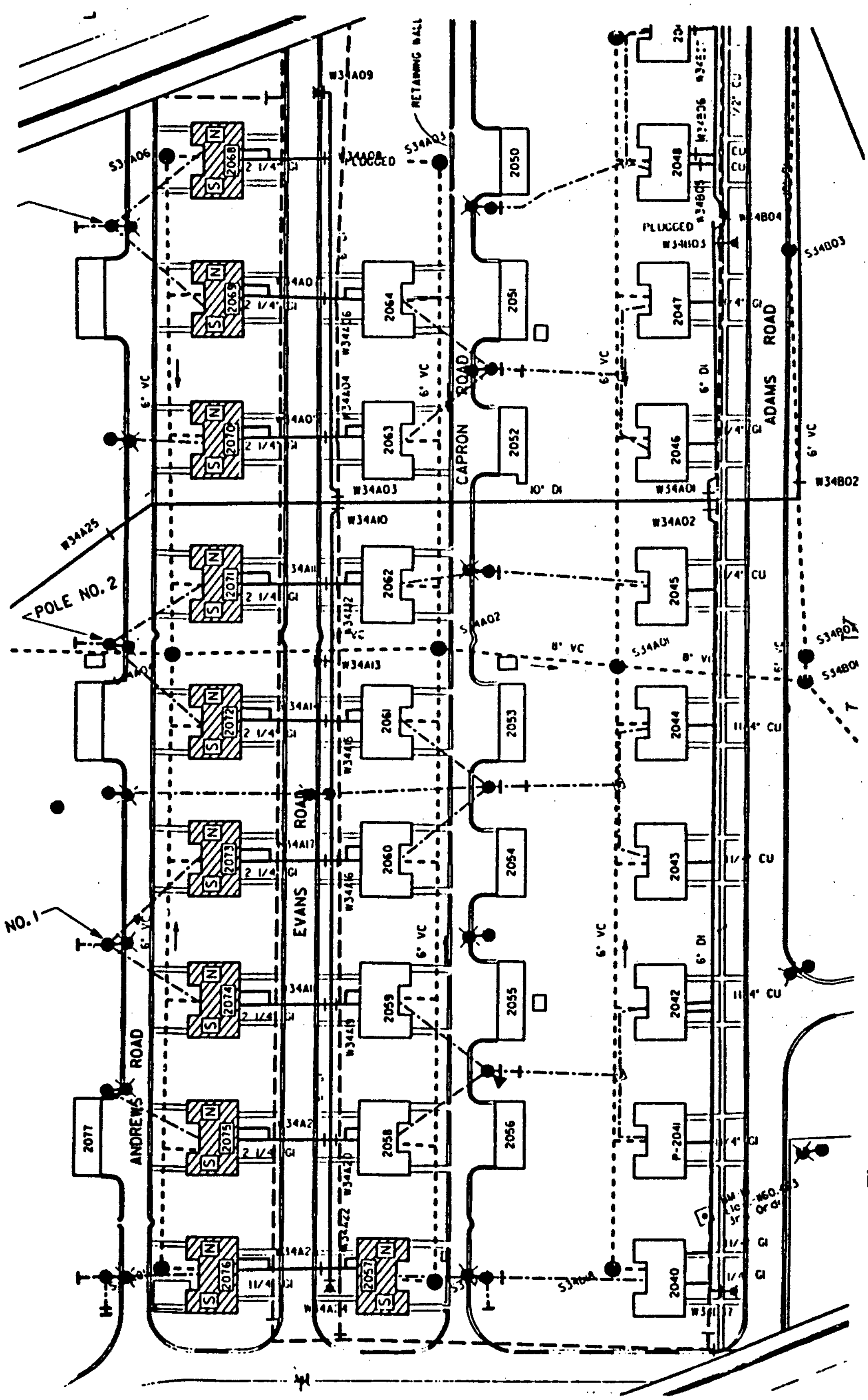

Figure 5. Family Housing Area at Fort Sill. Note: shaded buildings identify demonstration residences.

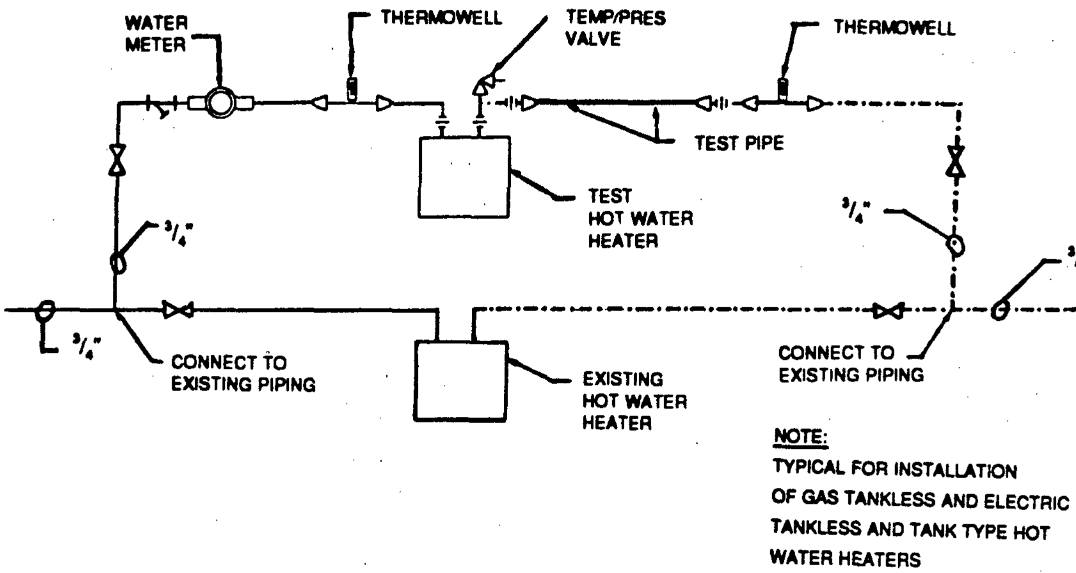

Figure 6. **Field Setup for Demonstration Water Heaters.** Note: for reasons explained in text, this setup was not used for the conventional gas water heaters in the demonstration.

4 WATER HEATER EVALUATION

Laboratory Testing

The tankless water heaters were tested at USACERL to evaluate the units under controlled conditions. Data were collected to determine the temperature rise versus flow rate for both tankless water heaters. Inlet and outlet temperatures were recorded over a wide range of flow rates.

The tankless electric water heater (Hot Box) was tested first. Inlet and outlet temperatures versus flow data are shown in Figure 7. At flow rates lower than 0.5 gpm, the water outlet temperatures range from 150 °F to 175 °F. The Hot Box is designed to restrict water flow, and is limited to a maximum flow rate of between 2.0 and 2.25 gpm. Figure 8 shows the power consumption versus flow rate for the same test, and reveals an increase in electrical demand as the hot water flow rate increases. At its maximum flow rate, the Hot Box required 16 kW (240 VAC) to heat the water. Such high demand could lead to increased demand charges on an Army installation if a large number of Hot Boxes were installed. For example, if 1000 units were installed, and only 10 percent of the units were operating during the period of peak demand, the Hot Boxes would add 1.6 MW to the installation's peak demand (1000 x 0.1 x 16 kW).

The tankless gas water heater (Hotomatic #3) was tested next. The temperature versus flow data are shown in Figure 9. Comparison of Figure 9 to Figure 7 shows that the Hotomatic unit provided hot water at higher flows than the Hot Box. Although the Hotomatic unit is capable of providing a 60 °F temperature rise at 2.5 gpm, as advertised in its specifications, this tankless gas water heater produced some alarming results. At flow rates between 0.25 and 0.75 gpm, the outlet temperature would inappropriately rise to 185 °F, activating the temperature-pressure relief valve. When activated, the valve releases hot water out a second pipe onto the floor or into a drain. When the temperature and pressure dropped to safe levels, the valve closed and the system returned to normal operation.

The reason for this problem appears to be related to a design characteristic of the unit. The Hotomatic uses a temperature sensor located near the inlet to prevent quantities of cold water from flowing out of the faucet before the unit is up to temperature. This design scheme may work correctly at high flow rates for large-scale applications like car washes, where the hot water is tapped off as fast as it is heated. In residential-scale flow rates of 0.25 to 0.75 gpm, however, the Hotomatic's powerful burner heats water faster than it can be used. At such low flow rates, the burner tended to overheat the water in the coils, which activated the relief valve.

Field Testing

As discussed earlier, the new water heaters used in this demonstration were plumbed in parallel with the original water heaters. This approach allowed for switching from the original water heater to the demonstration unit without interrupting the resident's hot water service. The power for the new water heater—gas or electric—was switched on, the unit was given time to warm up, the isolation valves were set to direct the hot water service from the old water heater to the demonstration unit, and then the old water heater was shut down by turning off its gas supply. The data logging equipment was checked to make sure it was collecting and recording data properly.

Hotomatic Results

Echoing the results of the laboratory investigation discussed earlier, the tankless gas water heaters proved to be the most troublesome. The Hotomatic unit at residence 2057S was started and tested with a short-duration, low flow rate load. The load was repeated every few minutes while the dial temperature gauge on the water heater's outlet was monitored. During each load the temperature would climb 10 to

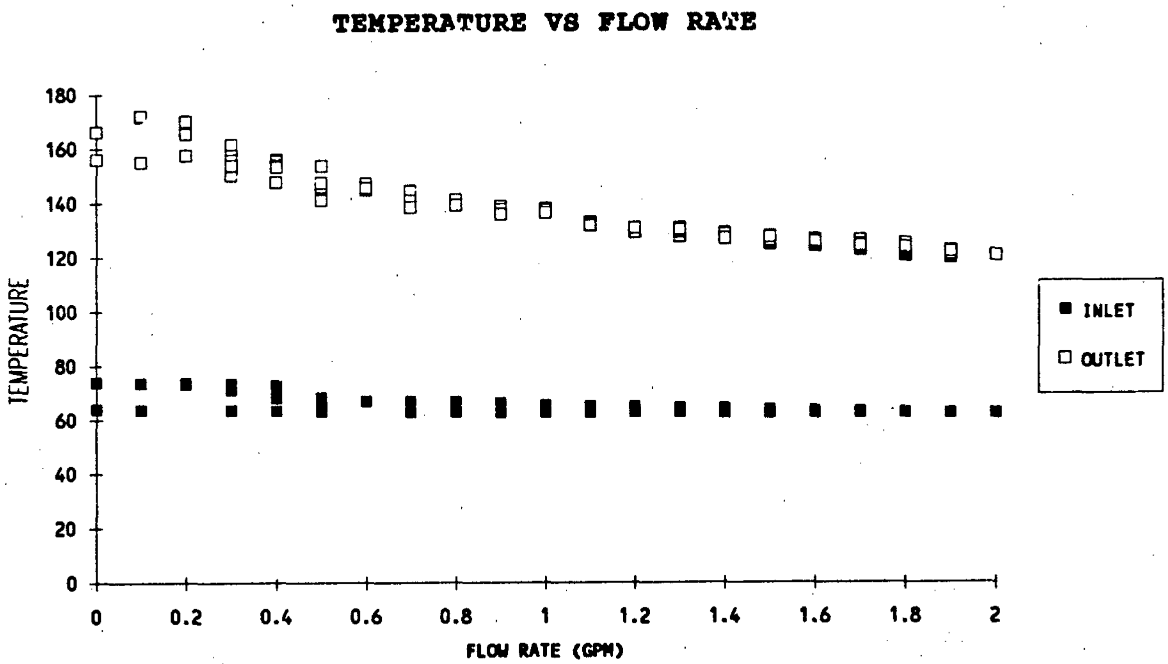

Figure 7. Water Temperature versus Flow Rate for Laboratory Test of Hot Box.

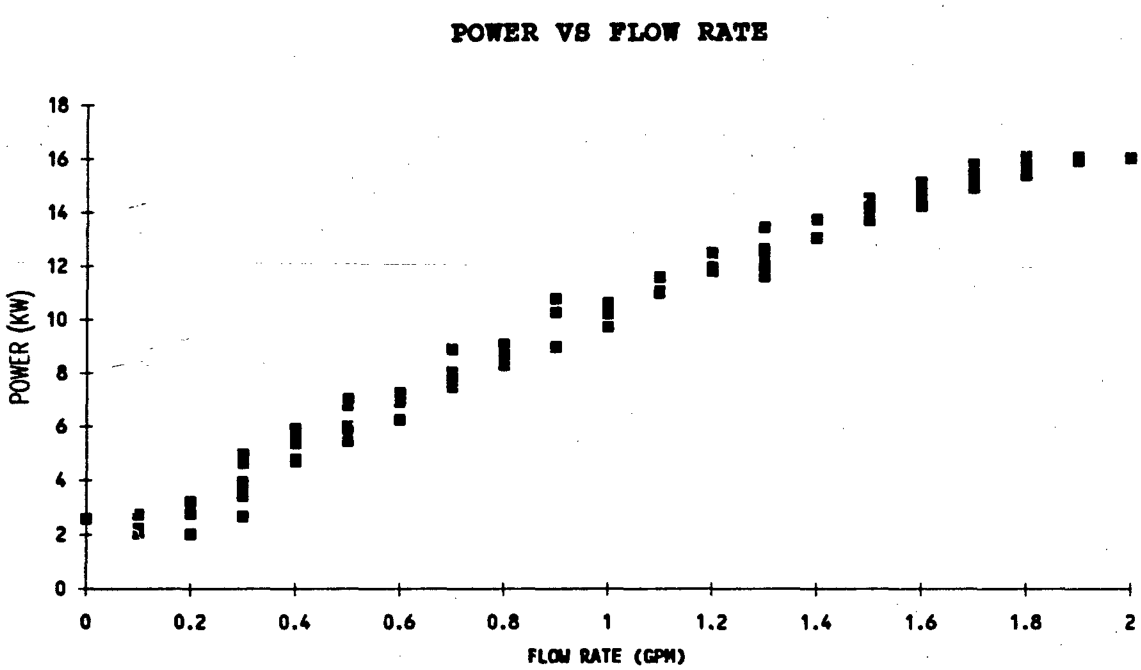

Figure 8. Power Consumption versus Flow Rate for Laboratory Test of Hot Box.

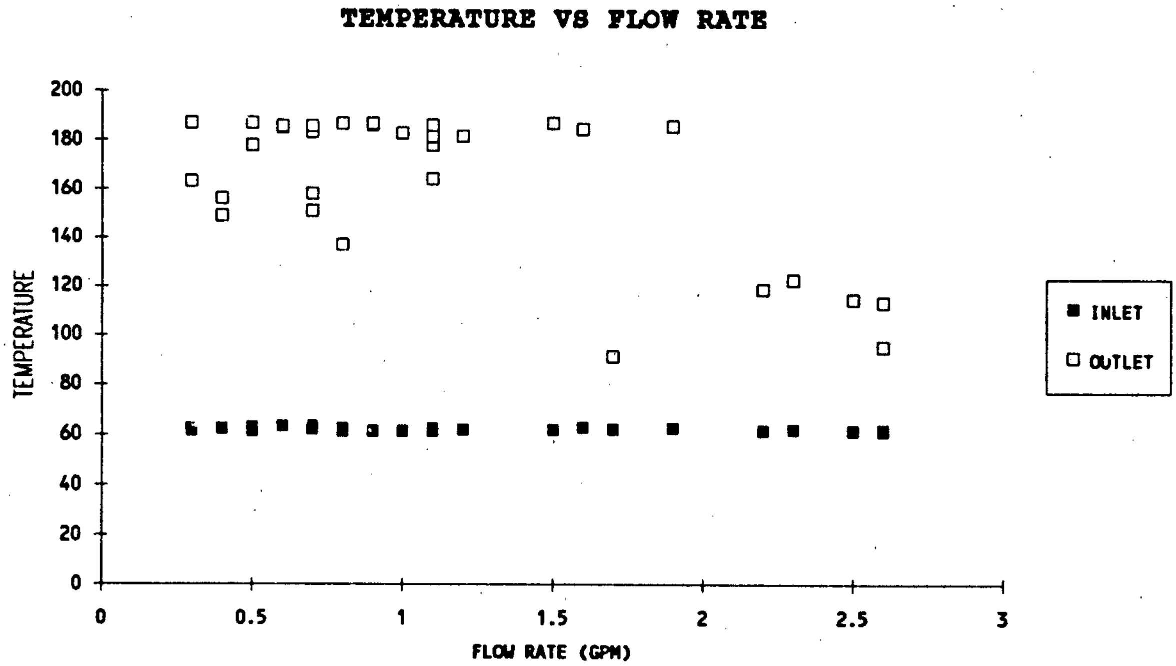

Figure 9. Water Temperature versus Flow Rate for Laboratory Test of Hotomatic #3.

15 °F. After several repeated tests, the temperature-pressure relief valve was activated, spraying hot water on the floor (Figure 10) before the gas was shut off. The outlet temperature reached 190 °F, as observed on the outlet temperature gauge.

Next, the Hotomatic in residence 2068N was started. After the new hot water system was turned on, the resident was asked to run some hot water. The outlet temperature was monitored on the large-dial gauges. After running for a few minutes, the water temperature climbed to 185 °F, the level at which the temperature-pressure relief valve should have activated. The gas was shut off but the temperature continued to climb for a few seconds, finally reaching 197 °F. The temperature-pressure relief valve failed to activate. At this point, the researchers determined that the low-flow operating characteristics of the Hotomatic unit made it unsafe for use in family housing. The Hotomatic unit in residence 2068N was shut down, and all other Hotomatic units installed for this demonstration at Fort Sill were left off line. All of these residences continued to use their original water heating systems.

Hot Box Results

The tankless electric water heater (Hot Box) performed somewhat better than the Hotomatic, but significant problems were reported nevertheless. Two residents reported that they had no hot water the day after the switchover. At residence 2073N, the two valves used to isolate the original water heater from the demonstration system were not closing off the water flow as intended. Instead of drawing water through the Hot Box, the system was pulling water from the cold tank of the original water heater. When the system was switched over the evening before, it had not been obvious that the hot water was still being drawn from the tank of the original heater. The residence was switched back to its original water heater until the faulty isolation valve could be replaced.

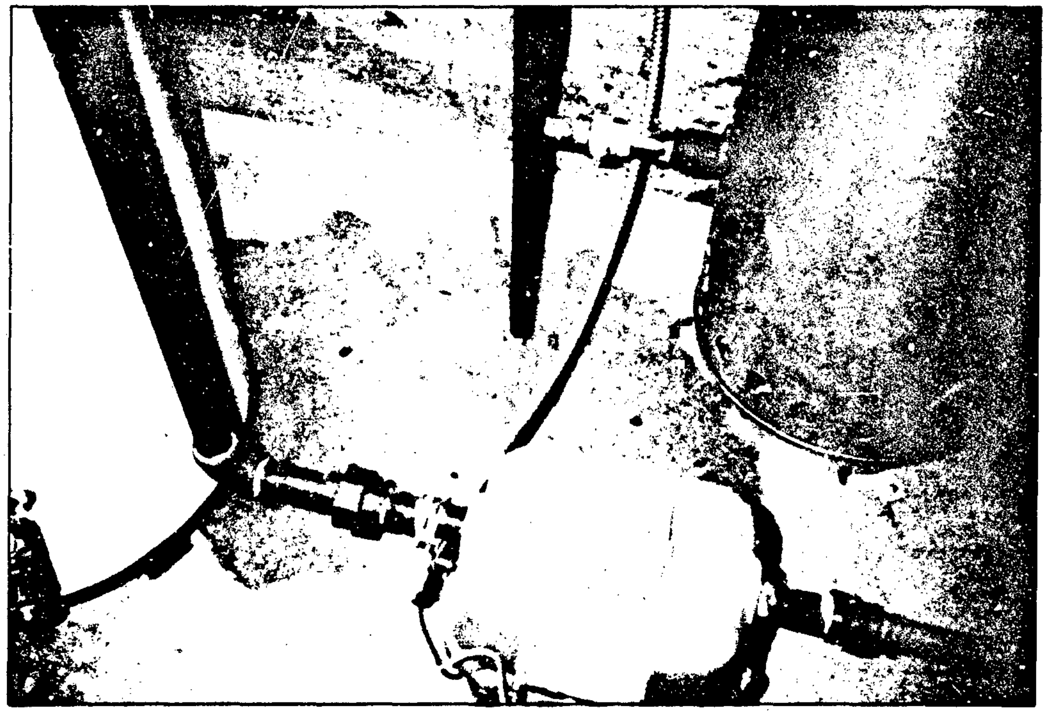

Figure 10. Discharge from Hotomatic Temperature-Pressure Relief Valve.

The residents at 2072N also reported insufficient hot water early in the demonstration. The residence had hot water, but the flow rate in the upstairs shower was much lower than it had been under the old system. Figure 11 shows the original flow of the shower and Figure 12 shows how the Hot Box reduced the flow. This reduction of flow was apparently due to the smaller diameter pipe used inside the Hot Box to reduce the maximum flow rate to about 2.5 gpm. To address the resident's complaint about the low flow rate, the hot water service was switched back to the original system.

During a second site visit by the researcher to collect data in January 1992, the residents of 2071N reported problems with the Hot Box. Several weeks after the Hot Box had been switched on, the residents noticed a burning smell in the basement. The residents were unable to contact anyone at Family Housing, so they called the base fire department. The residents did not know what the fire department did to resolve the problem, but when the system was examined it was found that the Hot Box had been switched off and the conventional gas water heater was operating once again. When the cover of the Hot Box was opened, burned insulation was found on several wires. Insulation on the two wires supplying power from the circuit panel had melted 2 to 3 in. from the Hot Box terminal, and insulation on the wire that carries the power from that same terminal to the interior of the Hot Box had melted back 4 to 6 in. Figure 13 shows the damaged wires from several angles. Investigation of the problem and speculation on its cause are beyond the scope of this research. However, any future use of the Hot Box should be conditional on investigation of the unit's failure and correction of the cause by the manufacturer.

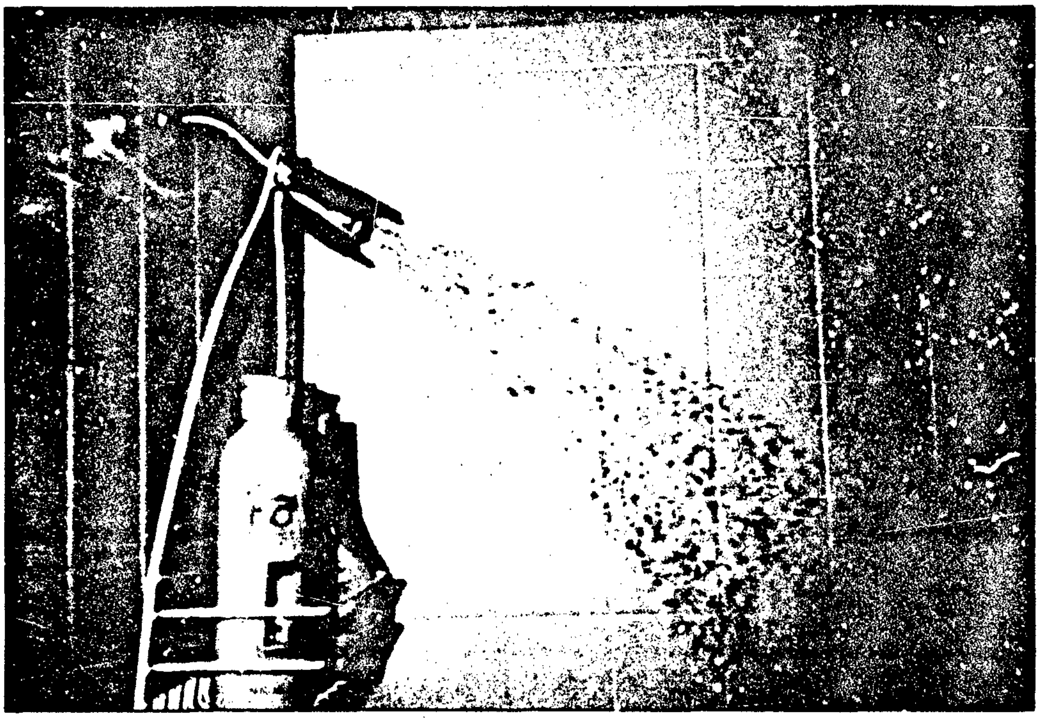

Figure 11. Original Flow in Upstairs Shower, Residence 2072N.

Figure 12. Reduced Flow in Upstairs Shower Due to Hot Box, Residence 2072N.

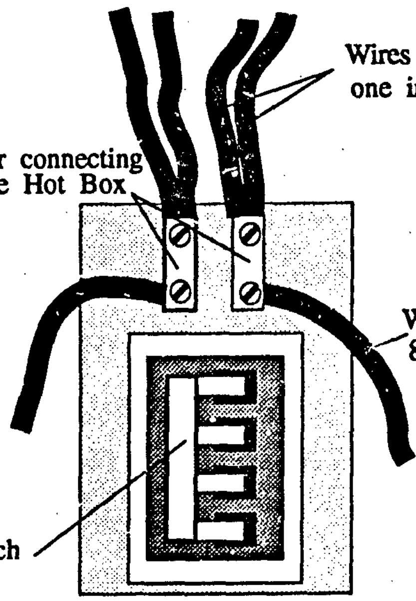

Figure 13. Damaged Wires on Hot Box Installed at Residence 2071N.

Data Collection and Analysis

Data were collected for the field test over 2 months, from November 1991 to January 1992. The total amount of hot water consumed and the total amount of energy required to heat that water were recorded. Table 1 summarizes the data. The table lists the residence number, type of water heater, amount of energy consumption, total hot water consumption, average daily hot water consumption, and the cost of heating 100 gallons of water.

As indicated previously, technical problems prevented the collection of a complete data set for all water heaters installed for this demonstration. There are no field data for the Hotomatic units because they were judged too unsafe to use. Also, the data logger at residence 2072N malfunctioned, providing only readings of "0." This was the residence where the original hot water service was restored after occupants complained of insufficient hot water flow in the upstairs shower the day after the Hot Box was switched on. There are also incomplete data for: residence 2073N, where faulty isolation valves prevented testing of the Hot Box during the demonstration period; residence 2074N, which was vacant during most of the demonstration period; and residence 2071N, where the Hot Box was shut down in late November after insulation on the unit's wiring began to melt. The calculation of average daily hot water consumption was based on data collected over 79 days from all properly functioning demonstration water heaters (except residence 2071N, whose tankless water heater operated for only 22 days).

The average daily amount of hot water used by the residences with conventional water heaters ranged from 38 to 138 gallons, with an overall average of 82 gallons per day. The cost for 100 gallons of hot water was based on Fort Sill's costs of $ .00584 per kiloWatt-hour for electricity and $ 0.216 per hundred cubic freet (ccf) for gas.

Table 1

Hot Water Consumption and Energy Data for 20 Fort Sill Residences, November 1991 to January 1992

Residence	Water Heater	Gas Start	Gas End	Gas Total	Water Start	Water End	Water Total	Daily Avg.	KWH Usage	Cost per 100 gals
1057N	Gas	54810	64560	9750	56973.2	66447.5	9474.3	120	N/A	$0.22
2057S	Hotomatic	0	10	10	0	10	10	N/A	N/A	$0.22
2068N	Hotomatic	0	0	0	2.5	10.2	7.7	N/A	N/A	N/A
2068S	Gas	71400	78630	7230	70307.6	76062.2	5754.6	73	N/A	$0.27
2069N	Hot Box	N/A	N/A	N/A	4	2843	2839	36	619.89	$0.13
2069S	Electric	N/A	N/A	N/A	40.5	6585	6544.5	83	1741	$0.16
2070N	Hotomatic	0	0	0	0	0	0	N/A	N/A	N/A
2070S	Gas	54610	62585	7975	56672	62852.2	6180.2	78	N/A	$0.28
2071N	Hot Box	N/A	N/A	N/A	0	2164.5	2164.5	98	411.77	$0.11
2071S	Electric	N/A	N/A	N/A	20.4	6090.8	6070.4	77	1984.4	$0.19
2072N	Hot Box	N/A	N/A	N/A	51	150	99	N/A	No Data	N/A
2072S	Electric	N/A	N/A	N/A	42	5184	5142	65	No Data	N/A
2073N	Hot Box	N/A	N/A	N/A	0	0	0	N/A	0	N/A
2073S	Electric	N/A	N/A	N/A	48.5	3018	2969.5	38	852.92	$0.17
2074N	Hot Box	N/A	N/A	N/A	0.8	0.8	0	N/A	0	N/A
2074S	Electric	N/A	N/A	N/A	0	10922.4	10922.4	138	2573.67	$0.14
2075N	Hotomatic	0	0	0	0	0	0	N/A	N/A	N/A
2075S	Gas	46150	51770	5620	39194.3	43562	4367.7	55	N/A	$0.28
2076N	Hotomatic	0	0	0	0	0	0	N/A	N/A	N/A
2076S	Gas	50290	58380	8090	46377.2	53418.2	7041	89	N/A	$0.25

The cost of heating 100 gallons of water using the conventional gas water heater ranged from $ 0.22 to $ 0.28, with an average of $ 0.26. For the reasons previously discussed, no costs could be calculated for the tankless gas water heater technology.

The cost for the conventional electric water heaters to heat 100 gallons varied from $0.14 to $0.19, with an average of $0.16. The cost of heating 100 gallons of water with the Hot Box ranged from $0.11 to $0.13,* with an average of $0.12 (Table 2). Therefore, the average cost for heating water using the Hot Box was 26 percent lower than with conventional electric water heaters.

Figures 14 and 15 show the relative costs of heating water with gas and electricity at Fort Sill. Figure 14 includes no data for tankless gas technology because testing was canceled due to safety considerations, as previously discussed. Figure 15 shows the relative savings possible by using the Hot Box in place of conventional electric water heater technology. Note that the savings increase as the cost per kiloWatt-hour increases.

In regions where electricity is less expensive than gas for heating water, the Hot Box could save money compared to conventional electric water heaters.

Table 2

Costs of Heating 100 Gallons of Water

Heater Type	Low	High	Average
Conventional Gas	$0.22	$0.28	$0.26
Tankless Gas	n/a	n/a	n/a
Conventional Electric	$0.14	$0.19	$0.16
Tankless Electric	$0.11	$0.13	$0.12

* This was the cost for the unit at residence 2071N, for which data were gathered over only 22 days.

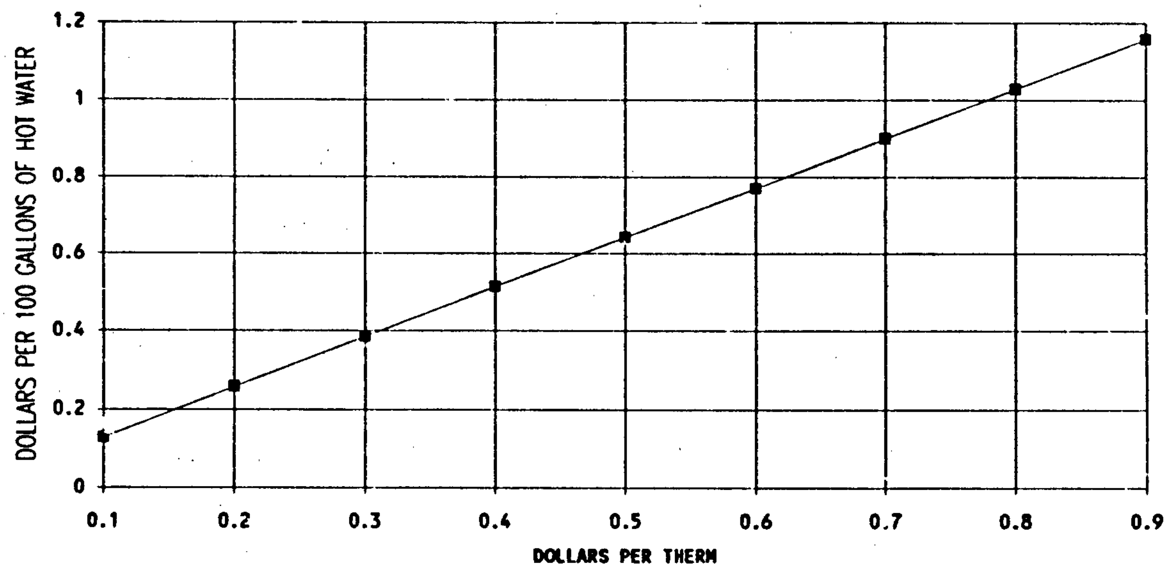

Figure 14. Effect of Changing Gas Prices on Cost of Heating 100 Gallons of Water With Standard Gas Water Heaters at Fort Sill.

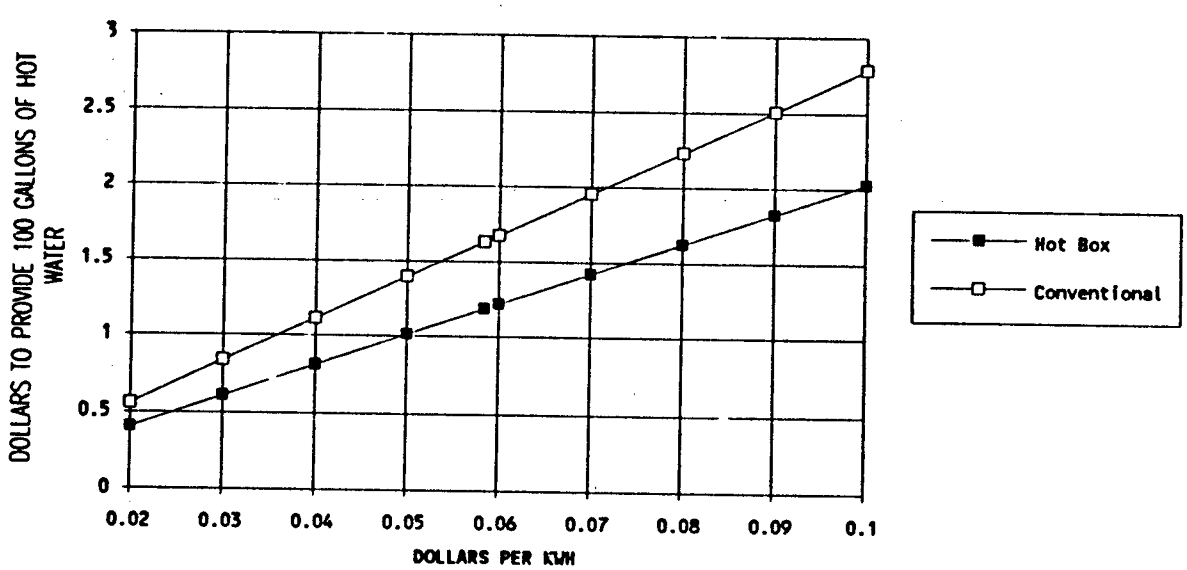

Figure 15. Effect of Changing Electricity Prices on Cost of Heating 100 Gallons of Water With Conventional and Tankless Electric Water Heaters at Fort Sill.

5 SUMMARY

In this FEAP demonstration, tankless gas- and electric-powered water heaters were to be tested and compared with conventional gas- and electric-powered water heaters in terms of performance and economy. Due to problems related to the design of the temperature controls on the Hotomatic #3 tankless gas water heater early in the project, however, it was determined that the Hotomatic could not provide a safe source of hot water at low flow rates. Therefore, only the tankless electric unit—the Hot Box—operated long enough to provide data for comparing tankless and conventional water heating technologies.

The Hot Box reduced the amount of electricity needed to provide hot water as compared to the new conventional electric water heaters tested in the demonstration. In areas where electricity is more economical than gas, the Hot Box could provide dollar savings on energy costs when replacing a conventional electric water heater. The Hot Box's small size and wall-mounted design provided for a compact installation that did not use any floor space in the residents' basements. The Hot Box performed adequately in the field except for two problems:

- The lower flow rate was the subject of complaints by some residents
- One unit—the Hot Box installed at residence 2071N—malfunctioned, melting the insulation on some of its wires.

The costs of installing a Hot Box in many of the Army's older family housing units, such as the ones in the Fort Sill demonstration, would be prohibitively high wherever it was necessary to upgrade the 240 VAC electrical service from 100 amp to 200 amp. Also, it could be counterproductive to install a large number of Hot Boxes on any Army installation that is attempting to reduce electrical demand and the associated charges.

As noted above, the Hotomatic tankless gas water heater failed to provide safe hot water service for the residences in which it was installed. As currently designed, the Hotomatic would require extensive plumbing modifications to make it safe for residential use. However, it should be remembered that the Hotomatic was designed for commercial-scale application by users who do not depend on the unit's performance at low flow rates. Therefore, it should not be concluded that there is something inherently unsafe about the unit, just that its current design is not appropriate for low-flow residential applications.

The conventional gas and electric water heaters installed for this demonstration both successfully provided residents hot water service. The residents with these water heaters used an average 82 gallons of hot water per day. The cost to heat 100 gallons of water using the electric units averaged \$0.16 while heating the same quantity of water with the gas units averaged \$0.26. The conventional electric water heater would have to be the choice to use at Fort Sill, due to its lower operating cost. The cost of heating 100 gallons of water with the hot box was lower than the cost of heating water with the conventional electric water heater: \$0.12 versus \$0.16, respectively. The Hot Box also cost more to install than the electric water heater due to the requirement for a new panel, new wire drop, and new transformer to upgrade the existing electrical service.

METRIC CONVERSION FACTORS

1 in.	=	25.4 mm
1 cu ft	=	0.002832 m^3
1 psi	=	6.89 kPa
1 lb	=	0.453 kg
1 gal	=	3.78 l
°F	=	(°C + 17.78) × 1.8

ABBREVIATIONS AND ACRONYMS

AC	alternating current
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ccf	hundred cubic feet
FEAP	Facilities Engineering Applications Program
gpm	gallons per minute
psi	pounds per square inch
USACERL	U.S. Army Construction Engineering Research Laboratories
USAEHSC	U.S. Army Engineering and Housing Support Center
VAC	volts, alternating current

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