J. M. Calm, "Heat Pump Water Heaters," *Heat Pump Research and Applications* (New Orleans, LA, USA, February 1984), report EM-3797, Electric Power Research Institute (EPRI), Palo Alto, CA, USA, 14.1-14.9, November 1984

Seminar on Heat Pump Research and Applications
New Orleans, Louisiana, February 1984 EPRI REPORT EM-3797

Section 14

HEAT PUMP WATER HEATERS

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Water heating today accounts for approximately one-fifth of the energy used in a typical household, with 53 percent of in-place water heaters using natural gas and 45 percent using electric resistance heating. Propane, oil, and solar units account for most of the remaining 2 percent of the market, along with heat pump water heaters (HPWHs) -- about 23,000 of which are now in use.

HPWH TECHNOLOGY

The HPWH uses a vapor-compression (modified Rankine) cycle, the same cycle used by refrigerators and air conditioners. In service, heat pumps reverse the natural flow of energy from warmer to cooler substances; that is, they "pump" heat from cooler to warmer regions.

A typical heat pump uses a refrigerant to move heat from a source, most commonly air, to a higher-temperature use, which in water heating is water. This refrigerant circulates continuously in a closed cycle, picking up heat at the source via an evaporator and giving it up to the water (or air in space conditioning) via a condenser. At the evaporator, the refrigerant changes (evaporates or boils) from a liquid to a vapor by absorbing heat from the ambient air. An electric-motor-driven compressor then increases the refrigerant pressure to drive the cycle. The compressor also raises the refrigerant's temperature to provide the temperature differential fundamental for transferring heat to the water. This transfer, which occurs in the condenser, results in the refrigerant's return (by condensing) to a liquid state. The refrigerant then passes through an expansion device where its pressure and temperature are reduced, and it completes the cycle by returning to the evaporator.

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Two basic types of HPWHs, as illustrated in Figures 14-1 and 14-2, are commercially available: remote and integral. Remote units (sometimes called retrofit, without-tank, or add-on) use a separate heat pump package that connects to an existing water tank. Integral units combine the heat pump and the tank in one device. Remote units cost less ($600-$1,000 installed) than integral units ($1,100-$1,900) in residential applications, and because remote units are detachable, renters or families that move can take them along. In addition, the fact that remote units can use existing water tanks is an advantage.

Seventeen manufacturers, as listed in Table 14-1, currently offer HPWHs.

HPWH BENEFITS

The attractiveness of the HPWH stems from its high efficiency. As a heat pump, it does not simply produce heat per se. Rather, the majority of the heat is transferred from its immediate environment to the water to be heated. Consequently, it uses half or less than half the energy of a conventional electric resistance water heater and increasingly represents a cost-competitive alternative to use of natural gas. Solar water heaters show energy savings roughly equivalent to those of the HPWH, but the HPWH has the advantages of a higher degree of reliability and a significantly lower capital cost. Moreover, in comparison with electric resistance water heaters, which have relatively low load factors and high demands, HPWHs have a higher load factor and a more consistent demand pattern that is attractive to utilities.

HISTORY

The Hotpoint Company (now the Hotpoint Division of General Electric Company) developed the first HPWH designed for mass production in the 1950s, testing it in cooperation with the Tampa Electric Company. The device worked well, but falling electric rates reduced its appeal, and development was halted.

Interest in HPWHs was rekindled in the mid-1970s as energy prices began to rise and recognition of the potential of heat pumps to conserve energy grew. One of the first to take another look at the technology was the National Rural Electric Cooperative Association (NRECA). Because gas pipelines are costly to install, electric resistance water heating has predominated in sparsely populated rural regions.

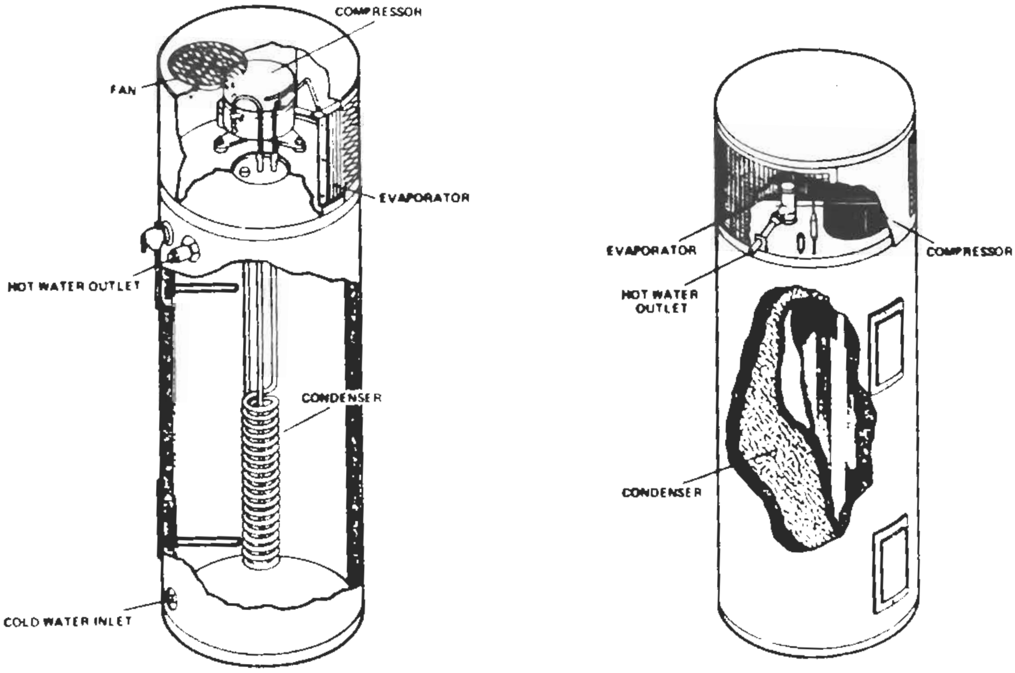

Figure 14-1. Integral HPWHs: Immersion (left) and External (right)

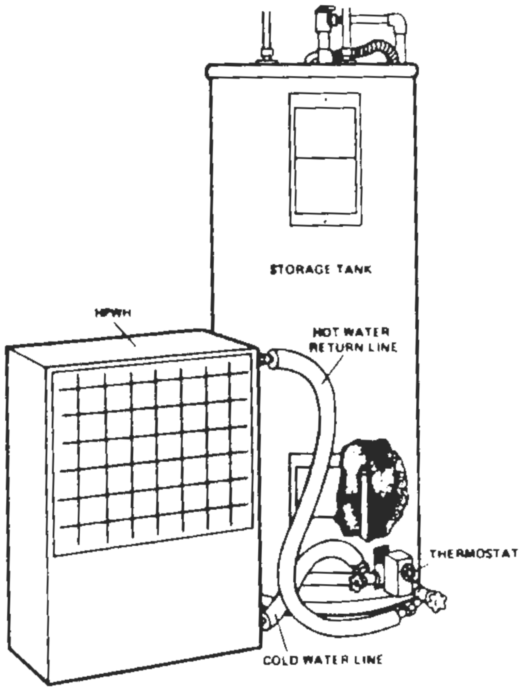

Figure 14-2. Remote HPWH

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Table 14-1

HPWH MANUFACTURERS*

Manufacturer	Trade Name
American Appliance Manufacturing Corporation	Ace, Agway, American Appliance, American Hardware, America's Best, Aqua Temp., Aqua Therm, Best, Best Deluxe, Buckeye, Canfield, Corona, Cozy, De-Limer, Dolphin, Duracrest, Dura-Hot, Eagle, The Earl's, Falcon, Fireglas, 500, Flame, G&L Plumbing Inc., Imperial, Galaxy, Gamble Artisan, Gimble, Globe, Golden Gate, Hotmaster, Hotstream, King-Kleen, King-Lane, Kleen-Glas, Limeout, McDonough Senior, Marine, Mermaid, Mor-Flo, Morris, Nationaline, Nautilus, Neptune, Niagara, Old Faithful, Plumbcraft, Premium, Prestige, Quaker, Queen-Line, Quick-Flo, Rapidac, Raywall, Redi-Hot, Reliance, Revere, Rexcel, Riviera, Sands, Sequoia, Silver Seal, Special, Special Deluxe, Super-Flo, Sure-Fire, Teter, Thoro-Clean, Tip-Top, Trophy, Unico, Val-Test, Webb, Yosemite, Collect-A-Ray
Borg-Warner Central Environmental Systems, Inc.	Fraser-Johnston, Luxaire, Moncrief, York
Carrier Air Conditioning Company	Carrier, Tempo-341
Craftmaster Water Heater Company	Craftmaster, H_2OT Pump
Daikin Industries, Ltd.	Daikin
DEC International Therma-Stor Products Group	Dari-Kool, Therma-Stor
Duo Therm Division, Motor Wheel Corporation	Duo Therm
E-Tech, Inc.	Efficiency II, E-Tech
Fedders	Fedders
Energy Utilization Systems, Inc.	EUS
Heat Controller, Inc.	Aqua therm
Lennox Industries, Inc.	Lennox
Mor-Flo Industries, Inc.	Mor-Flo, Heat Saver
Oregon Water Heater Company	Oregon
Reynolds Metals Company, Energy Products Group	Thermo-Tec I
Rheem Manufacturing Company, Water Heater Division	Rheem, Ruud
Sears Roebuck and Company, Inc.	Kenmore

*Omission of additional manufacturers and/or trade names is unintentional; no endorsement of any commercial product or manufacturer is implied.

In 1975 NRECA provided a grant to Energy Utilization Systems, Inc. (EUS), to develop a prototype HPWH as an alternative to electric resistance units. This effort was supplemented in 1977 by federal funding through the Department of Energy (DOE) (1). In the expanded study, EUS manufactured 100 integral units for testing by 20 electric utilities. Eighty-five of these were fully assembled HPWHs (including water tanks); 15 were heat pump kits for field conversion of existing electric resistance water heaters into integral units. The conversion HPWHs proved unsuccessful, but the 85 complete units were tested for 25 months or longer. Twenty of these units were disassembled for internal inspection, but most of the remainder are still in use.

These tests revealed an average HPWH operating-cost savings of 48 percent over electric resistance water heating (2,3). In addition, the tests showed an expected useful life of 10 or more years for the units (versus an average of 7-11 years for conventional gas and electric devices) and identified a number of improvements to increase efficiency, reliability, and service life (4). Simultaneously, a consumer attitude survey showed that the vast majority of users participating in the study were satisfied with the operation of their HPWHs, especially with the energy savings realized.

UTILITY FIELD TESTS

A number of electric utilities have independently undertaken programs in their service areas to evaluate HPWH performance and/or consumer attitudes toward the technology. A soon-to-be-published report sponsored by EPRI and conducted by Science Applications, Inc. (SAI), summarizes the results of 45 utility tests of 278 HPWHs (5). Most of tests consisted of installing a HPWH in parallel with a resistance water heater and alternating between them on a weekly basis. Other approaches included comparing HPWH test data to previous bills, to historical data, and to results from computer models. The major findings of the 45 utility tests include:

- The average annual performance factor (PF) of HPWHs was approximately 2.0.* This translates to a 50 percent energy savings compared to resistance units,
- There was no correlation between energy savings and climate, and
- There was insufficient data to quantitatively assess space conditioning impacts.

*These tests reflect older models; performance ratings of newer models are cited later in the paper.

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Few of the utilities surveyed had collected data on the load impacts of heat pump water heaters. Four utilities utilized time-of-use data acquisition systems in their field tests, while the other utilities surveyed either had not included load impacts in their field test objectives or had used simple analytic methods to approximate the load impact. Based on the results of these four utilities, HPWHs appear to offer improvements to utility load profiles. Equipment and performance data, guidelines for economic analysis, and data on experimental designs and instrumentation devices found to be most effective by the utilities are also contained in the report.

INSTALLATION AND OPERATION

To operate efficiently, HPWHs must be installed in carefully selected locations. The general requirements are:

- The ambient temperature should not ordinarily fall below 45°F (7°C),
- The air temperature should remain below the limit recommended by the manufacturer (95 to 120°F, 35-49°C),
- Sufficient air circulation (500 cfm, 236 litres/sec or more) is needed unless the space is of sufficient volume (1,000 cf, 28,300 litres, or more),
- Condensate drainage must be provided, and
- The HPWH should be located as close to the storage tank as possible.

Crawlspaces, garages, ventilated closets and utility rooms, and basements generally provide suitable locations for HPWHs. Several utilities are now examining the effect of location on HPWH operation. Bonneville Power Administration, for example, is sponsoring research by Pacific Power and Light Company involving HPWHs in up to six locations in 48 test homes.

HPWHs also cool their surroundings as they pump ambient heat into the water tank. This effect can help cool and dehumidify indoor air if the units are indoors. During winter months, however, this cooling may, depending on the HPWH location in the home, increase space-heating loads, partially offsetting the HPWH's energy savings. Various tests to assess this characteristic have been undertaken. One such test, conducted by Pennsylvania Power and Light Company, indicates that units located in basements (and presumably other unconditioned or partially conditioned spaces) do not materially affect space-heating loads (6). Per unit of power, the

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recovery rate (i.e., the rate at which cold water is heated after hot water is drawn from the tank) of HPWHs exceeds that of conventional water heaters. However, lower output capabilities are generally selected for HPWHs to decrease equipment costs. Although this results in more continuous operation -- thus increasing load management benefits -- it also lowers the net recovery rate. Use of a larger storage tank or of supplemental electric resist- ance heat can overcome the lower recovery rate during periods of very high hot water demand. However, supplemental electric resistance heating reduces (but does not eliminate) the HPWH's energy saving and load management benefits.

Noise can be a problem if HPWHs are improperly located. Fan and compressor operation typically produce a sound level of approximately 65 decibels five feet from the unit -- about the same as an average room air conditioner. Placement of the unit in normally unoccupied areas, as recommended, should eliminate any concern.

CONSUMER ACCEPTANCE

Lack of consumer familiarity with heat pump technology and concepts and the high initial cost of HPWH units (ranging two to four times as high as that of conventional water-heating devices) are important reasons for the relatively small number of units sold to date. But repeated analyses show that they pay for themselves in a relatively short period of time -- usually well under four years -- depending on energy prices. Many consumers are unaware of the amount of energy used for water heating.

To address these concerns, some utilities are now conducting promotional campaigns to familiarize the general public with the benefits of HPWHs and their potential for energy and cost savings. In addition, rebates and zero or low-interest loans are being offered to customers to encourage purchase of the devices.

In one recent demonstration, Puget Sound Power and Light Company installed HPWHs in the homes of 50 of its employees (7). A subsequent survey of these individuals and families showed that the units were generally well accepted, especially when the extent of the energy savings was realized.

Two states have also given a boost to the technology: California, where a new building code promotes HPWH use in new buildings using electricity for water heating, and Oregon, where beginning in 1984 the state's energy conservation tax credit will extend to HPWHs.

PERFORMANCE RATINGS

The Air-Conditioning and Refrigeration Institute (ARI), the Gas Appliance Manufacturers Association (GAMA), and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) have each been involved in drafting rating standards for HPWHs. The ASHRAE standard is likely to be adopted within a year and become the consensus standard unless preempted by a government mandated procedure. For the present, a directory of water heater efficiency ratings is available from GAMA with listings of HPWH performance data based on GAMA's proposed test procedures (8). ARI has terminated its effort in this area.

Listed HPWH performance factor ratings in the most recent GAMA directory range from 2.3 to 3.5 for integral models and 2.0 to 2.9 for remote models.

OUTLOOK

At least 50 utilities are now evaluating HPWHs in their service areas, and over 15 space conditioning and water heater equipment manufacturers are actively marketing such products.

Future acceptance of HPWHs will depend on four key factors:

- Energy prices,
- Equipment cost reductions,
- Efficiency improvement, and
- Consumer awareness and understanding of this option.

High-efficiency HPWHs are already cost-competitive with gas-fired units in many regions of the country, and projected increases in energy prices should make them even more competitive. Compared to electric resistance water heating, HPWHs already offer energy cost savings exceeding 50 percent.

Equipment costs are the most limiting factor at present. Further research and development is likely to reduce such costs as will the economies associated with increased production levels. When compared to window air conditioner, or similar consumer products, a price reduction of 20-25 percent is expected in a competitive high-volume market. A key consideration will be assurance of HPWH reliability as costs are reduced, but experienice with related technologies indicates that proper engineering can avoid this concern.

Efficiency is likely to improve, but is closely linked to the equipment cost issue. More recently introduced HPWHs offer considerably greater energy savings than the earlier models; this trend is likely to continue. Integration with space-conditioning heat pumps offers both efficiency and equipment cost benefits. Several such products are in development and one was announced by its manufacturer this year.

Increased consumer awareness and understanding of the HPWH's potential to conserve energy and reduce costs is needed. Both manufacturers and utilities are active in this area.

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