# THE EVOLUTION OF VENTILATING HEAT PUMP WATER HEATER

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## ABSTRACT

With the development of "super-tight" housing, a market emerged for effective controlled ventilation systems. In response to this need, the Therma-Stor Products Group, Division of DEC International developed two products incorporating water heating, ventilation, space heating and space cooling in a single efficient unit.

The background of the company and the staff involved in developing commercial and residential water heating devices is in dairy refrigeration and stainless steel fabrication. This remains a major part of the parent company's business. Because of high requirements for hot water on dairy farms, refrigeration based water heating devices were conceived. This product line evolved into the most efficient water heating device in the United States-- The Therma-stor Heat Pump Water Heater.

The development of super tight housing and its accompanying need for controlled ventilation, led us to the development of incorporated heat recovery from exhaust air from the house, with water heating, space heating, and space cooling. These systems are of two styles:

1. A simple one direction air flow system--exhaust in the winter and intake in the summer, and

2. A semi-balanced air flow system for ultra tight homes (less than a natural 35 CFM exfiltration) or houses with open vented combustion devices.

Common features of both devices are that they:

1. Recover heat from exhaust air streams and use it to reduce water and space heating costs,

2. Deliver cool dry ventilation air in the cooling season,

3. Reduce water heating cost,

4. Provide consistent year around ventilation,

5. Provide dehumidification in the basement, if required.

In addition to the process and events leading to the development and marketing of these products, also discussed in this paper are the different control strategies for these devices.

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## 1. INTRODUCTION

### 1.1 Parent company

DEC International Inc. is a Madison,Wisconsin based privately owned international company. The company was established in the1940's as a dairy equipment manufacturer. DEC is the 11th largest privately owned corporation in Wisconsin.

### 1.2 Development of refrigerant water heating units.

In the mid 1950's a heat recovery water heating device was field tested. The performance was good, but acceptance was poor because of low energy cost. After the energy crisis, energy costs were high enough to cause interest in any energy saving equipment. A refrigerant heat recovery unit was marketed by DEC in Europe in 1974 and in the United States in 1976. The original concepts introduced have evolved into units that are very reliable, passive devices. The current concept was introduced by DEC in

1978. It is a glass lined storage tank encased in a waffle plate heat exchanger. This provides a massive heat exchange surface, through which the hot refrigerant gas from the milk cooler's compressor passes, transferring its heat to the water inside the tank. See Figure 1.

This concept accounts for 90% of the units sold to dairy farmers in the United States. There are 20,000+ units of this style operating today. Therma-stor Products Group was established in 1980 to market this concept to the non-agricultural market. Today this unit is standard equipment in most new and remodeled supermarkets, restaurants and ice arenas. Therma-stor has won numerous awards for design and energy conservation, including the State of Wisconsin Governor's award and Department of Energy's (DOE) Energy Product Award.

## 2.0 THE HISTORY OF HEAT PUMP WATER HEATERS (HPWH) AT DEC, INT'L

### 2.1 Development of HPWH.

From 1978 to 1981, reports from several research projects funded by DOE on the residential heat pump water heaters were published[1]. They showed that 50% of the energy used to heat water could be saved using a refrigeration cycle recovering waste heat from a house basement. Dehumidification was also a byproduct of the process.

Several problems were present. This was first generation design equipment, therefore reliability was poor, noise was also a problem, freeze-up in low temperature applications (garages in cold weather) occurred.

Although Therma-stor was not involved in the original concept, development or testing, we were looking for opportunities to apply our heat transfer technology to other areas. In 1980, after reviewing the DOE articles and some additional market research information, we decided to develop a residential heat pump water heater using our heat transfer concept. The result was the development of the most efficient water heater available (Figure 1). Tested according to the DOE electric water heater test, these units have a COP of 3.1 to 3.5, which reduces water heating cost 70%. Today, Therma-stor heat pump water heaters are the top rated units in the United States[2]. We have several thousand units in operation. The reliability and performance have been excellent, with the combined failure rate on major components less than 1% per year.

Originally there were 11 manufacturers. But today there are only three serious manufacturers left. Only 11,000 units are sold each year. Considering there are 6 million water heaters sold each year, this is poor sales performance. The total reported annual sales of heat pump water heaters are actually declining.

### 2.2 Current marketing problems of heat pumps

Cost of the unit was a larger problem than originally anticipated (because of low awareness of water heating cost). The consumer is over-aware of heating and cooling cost, but unaware of water heating cost. Typically they believe it may be $10 per month. In reality it is $20 to $50 per month. Because of low manufacturing volume, the economies of scale were never realized. Today the price of a heat pump water is $700 for an add-on and up to $1400 for a self-contained unit. On a replacement or new construction basis, a three year payback is common for a family of four.

The issue of "Where does the heat come from in the winter?" still haunts people who are currently trying to market this concept. Research by a utility[3] has proven that if the unit is located in a non-heated area the additional heating load is negligible. The summer dehumidification and cooling benefit far outweighs the winter loss.

Reliability is still a problem for some manufactures, although most current equipment is adequate. This problem is mainly caused by reputation more than by current equipment being manufactured.

Up to 75% of all residential water heaters are purchased on price basis as opposed to a value basis. Most plumbers are unable to sell benefit well enough to justify the additional investment.

## 3.0 VENTILATING HEAT PUMP WATER HEATERS

### 3.1 Revitalization of the residential market.

After following the progress of the Swedish concept of residential heat recovery from exhaust air utilizing a heat pump water heater[4], we did some market research in the United States exploring the market potential of this concept. We considered the market to be tight home construction using air-to-air heat exchangers (AAX). Ninety-five percent of all the Wisconsin builders contacted expressed concern about potential air quality and moisture problems. It appeared that the interest and awareness of ventilation needs far exceeded the awareness of water heating cost. The decision was made to design a system containing cost effective ventilation and water heating.

### 3.2 Therma-stor's first ventilating heat pump water heater.

A project was initiated to develop an exhaust heat pump water heater (EHPWH). By modifying the current residential unit, a 52 gallon, 100 cfm prototype was developed (HPV-52). This unit was installed in Southern Wisconsin in a 7 month old home with four people. This unit has a one direction air flow of 110 CFM exhaust in the winter and induction in the summer. It replaced a similar heat pump water heater, which used basement waste heat as the heat source.

This unit operates when hot water is required, which is about 10 hours per day in the winter and about 8 hours per day in the summer. Heating degree days (degree days) were 6900 for the1984-85 heating season up to March1, 1985 and 7200 for the same period in 1985-86 heating season. Utility bills were 6% less for the time the HPV-52 was operating. The occupants thought the air in the house was fresher both in winter and in summer. This installation was not tested beyond review of the utility bills and a couple of air flow tests. On a warm day, it was impossible to detect a negative or positive pressure on the house with the operation in either mode or not operating at all. This house was loosely constructed compared to today's super insulated standards. The air flow was tested with a hot wire air flow meter. There was no provision to operate beyond the need for hot water. It is expected that the operation of the unit to heat water would provide adequate ventilation.

### 3.3 Reluctance to a simple concept

As this EHPWH concept was explained to local utilities and marketing organizations, the consensus was that the cost of heating the additional make up air was unacceptable and that customers would not accept the additional untempered cold air entering the house. We reviewed the cost of heating the additional make up air. This was done by multiplying the flowrate in CFM of air being removed from the structure by the heat content that needed to be added to heat the cold air up to 60°F. This estimate was treated as an incremental cost of utilizing the concept. At the condition of 8000 degree days, 106 CFM, and 10 hours per day, the power consumption calculated to be 2442 KWh at $.08 per KWh. The incremental cost of heating the cold air up to 68°F resulted in $195 for the year. This appeared to be an insurmountable objection.

It was also felt that 10 hours of ventilation per day was not adequate for all conditions. Operating beyond the need for hot water would appear to increase the incremental cost of ventilating. This was later found to be in error. But at that time we decided the EHPWH was a good unit for low degree day regions and to redesign the unit to deal with the objections in high degree day regions.

## 4.0 BALANCED AIR FLOW VENTILATING HEAT PUMP WATER HEATER

### 4.1 The Combination of AAX and HPWH

The concept evolved into a balanced air flow heat pump unit (HPX-80). The exhaust air flows countercurrent to the cold fresh air along the length of a conventional aluminum finned copper tube evaporator (figure 2 ). Heat transfer occurs between the warm, stale air and the refrigerant to the cold fresh air flowing through the other half of the evaporator. The refrigerant boils before it leaves the evaporator enroute to the compressor where it is compressed to a higher temperature and pressure and provides heat for water heating and space heating. In the summer, the fresh and stale air flows are reversed. The fresh incoming air is cooled and dried when water heating is required. The stale air flows through the heating side of the evaporator where it will remove heat from the fresh incoming air if it is cooler. Basement dehumidification can also be provided by routing the basement air through the heating side of the evaporator.

### 4.2 Performance Specifications of the HPX-80

This unit provides hot water at a COP of 2.3 at 8000 degree days, 68°F ambient, 55°F supply water temperature, 125°F hot water delivery temperature, and a balanced air flow (150+ CFM on each side), continuous winter operation with the extra heat being added to fresh air entering the house. The heat exchanger is about 75% efficient while heating water. The HPX-80 can be operated in an extended operating time mode. This mode allows some of the condensing heat to be used to heat the fresh air leaving the heat exchanger. It slows the water heating rate by 50%. Operating in the extended mode, yields 80°F fresh air to the house at a 10°F outside ambient. The extra heat is about 3500 Btu per hour. This unit also has a hot gas defrost for winter operation. An additional benefit is that the unit dehumidifies fresh air if its dew point is above 32°F. In the summer mode, 8000 Btu of air conditioning are available when water is being heated. Figure 4 has the performance specifications at various typical conditions.

Approximately 20 HPS-80 installations have been operating one winter in various locations in the northern U.S. Cold weather tests showed more air entering the unit than leaving, even with the balanced system. The question was: Where does the extra air go? It appeared the lower house was under significant negative pressure with significant quanitties of air entering low in the structure. Equal amounds of air were leaving high in the structure which was subjected to positive pressure.

After reviewing research done at Berkeley Laboratory[5] and subsequent conversations with Bob Mowris[6] and Dennis Dietz[7], we acccepted the conclusion that every house has a positive pressure high in the structure and a negative pressure low in the structure. The infiltration and exfiltration rate depends on the tightness of the house, the temperature difference between inside and outside of the house and the wind velocity. Most researchers have known this but we had not considered the effect in evaluating the EHPWH. We realized that a balanced flow system had no way of recovering the heat that was exiting high in the structure (Figure 2).

Other difficulties were encountered because of improper duct installations. Because of their complexity, we had a new appreciation for a knowledgable AAX installer.

## 5.0 EXHAUST HEAT PUMP WATER HEATERS

### 5.1 EHPWH Is Better Than Original Estimates.

What is the impact of the EHPWH on a house with a natural air flow (cold air entering and heated air exiting)? If a 2000 sq. ft. house has a .2 natural air change per hour(ACH) which is 53 CFM entering and 53 CFM leaving, what happens when an EHPWH removes 106 CFM of air from this house? (Figure 3).

1. The air flow entering the house is raised to a minimum of 106 CFM . This is .4 ACH, which is independent of outside temperature. Although the same amount of air is penetrating the house, this causes a slight increase in negative pressure on the lower house and eliminates the positive pressure higher in the structure, which moves the balance point to the ceiling.

2. Virtually all the air leaving the house is routed through the EHPWH. This allows heat recovery from the original exfiltrating 53 CFM of air, which was impossible with the balanced air flow system.

3. Exhausting 106 CFM of air caused an additional 53 CFM of air to enter the structure which must be heated. This is half of original heat load anticipated. Under most conditions the heat recovered was more than that required to heat the 106 CFM of fresh air entering the house.

4. Any open chimney now has the potential to become a fresh air inlet and may require power venting or an independent fresh air supply.

An EHPWH can be used in houses that have high infiltration rates. EHPWH will reduce the amount of heat leaving the structure in extremely cold weather. This would provide consistent ventilation throughout the entire year.

Figure 5 lists: the total BTUs required to heat all fresh air entering the house at various degree days and length of heating season. The BTUs of supplemental heat from the EHPWH. The kwh to operate the EHPWH continuously for the heating season and heat the water the balance of the year. "Saved KWh" is the KWh saved if supplemental space heating is provided by the unit then compared to electric resistance. The annual Kwh saved using the EHPWH to heat 64 gallons of wtaer per day for the entire year. More heat is recovered than needed to heat the total make up air in the lower degree days. To calculate the dollar savings per year: Add the two appropriate "KWh saved" columns and multiply by your cost per Kwh.

If the system cost $1500 more than an electric water heater and mechanical exhaust ventilation system, a 3 to 5 year-pay back is usually achieved. We have not estimated the cooling benefit, which would be less than any of the other benefits. All of these costs are rough estimates. Further testing is being conducted to verify the estimates.

### 5.2 Improvements made to the original HPV-52

Realizing the potential of the EHPWH for northern climates, we decided to update the unit with additional features:

1. The fan capacity was increased and made adjustable from 80 CFM to 240 CFM at .4" water gauge pressure to accommodate the ventilation rates of the various size houses and codes.

2. The refrigeration system was improved. Figure 6 and Figure 7 show specific water and space heating performance specifications at various air flows and hot water consumptions.

3. An optional remote refrigerant condenser with a high efficiency particulate arresting filter (HEPA) to remove dust from the house in the winter is available. It is located inside the house and has a 7" duct to and from the open living area, and will operate after the domestic water is heated. Operation of this unit can be extended and the exhaust air flow to match the ventilation needs. Figure 7 shows the capacity at various air flows. By recovering heat from the exhaust air using the EHPWH, cost of heating makeup air can be reduced by 64% compared to resistance electric. In some cases this extra heat, combined with other natural heat gains, may be adequate to heat the house through much of the heating season. Conversely when the ambient is below 17°F the heat required to heat the ventilation air is greater than the heat produced by the EHPWH and must be made up by the house's heating system. At 4000 degree days, we believe the total heat produced by the remote condenser equals the total heat required to heat the ventilation air. See figure 5 for specific information on BTU recovered compared to BTU required to heat infiltrating fresh air.

4. A convenient air reversing valve is provided to change the air flow direction in the air conditioning season.

5. Also incorporated in the EHPWH'S evaporater is HEPA filter to keep pollen and dust out of the house in the summer. During the air conditioning season filtered cool dry air is blown into the house (Figure 3).

6. An optional control package can be added that deals with making the control of the unit, beyond water heating, automatic.

7. The size of the water tank was increased to 80 gallons to deal with the larger water users and provide more flexibility in applying the unit. The model designation is HPV-80.

## 6.0 CONTROL STRATEGIES FOR EPWH

EHPWH provides hot water on demand in a manner similar to conventional water heaters. EHPWH uses a conventional adjustable thermostat (110°F-140°F) to control the water heating. All other tasks are interrupted to meet the water heater needs. The backup element is located in the top of the storage tank and only operates when the tank is depleted of hot water. The backup thermostat is adjustable from 65°F to 120°F.

EHPWH provides an adjustable 80 CFM to 240 CFM of ventilation. Air flow is adjusted at the time of installation to provide the amount required. Using the optional inside condenser in the winter mode allows the heat pump to operate on a continuous basis or the remote condenser can be controlled by dehumidistat and (or) a thermastat. The exhaust fan is also controlled by a 24 hour timer which will provide a minimum ventilation independent of hot water usage or heating requirements.

Table II. DHW retrofit savings in five public housing complexes in Trenton, New Jersey (MBtu/apt-yr)

| BUILDING | PRE-RETROFIT: 7/84-6/85 $E_{hd}$ | 365a | $365a_s$ | COOKING | POST-RETROFIT: 1985-86 $E_h$ | $E_d$ | $E_{ds}$ | $E_{hd}$ | SAVINGS | %SAVINGS | SAVINGS ($/apt-yr) 11/85 | 4/86 | INST. COST $/apt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lincoln | 115(3) | 29( 6) | 30 | N/A | 102( 4) | 30(1) | 29 | 132( 4) | -17( 4) | -15( 4) | -137 | -157 | 313 |
| Donnelly | 138(3) | 35( 7) | 36 | N/A | 84( 4) | 46(2) | 44 | 130( 4) | 8( 4) | 6( 4) | 6 | -62 | 187 |
| Kerney | 138(5) | 9(25) | 29 | 8(0) | 97( 3) | 31(1) | 28 | 128( 3) | 10( 3) | 7( 4) | 5 | -54 | 322 |
| Campbell | 167(5) | 41(12) | 47 | 10(0) | 136( 8) | 37(2) | 33 | 172( 8) | -5( 8) | -3( 6) | -85 | -131 | 337 |
| Wilson | 157(5) | 28(13) | 38 | N/A | 97(16) | 47(2) | 40 | 145(17) | 12(17) | 8(11) | 31 | -45 | 187 |

Notes: Standard errors are shown in parentheses. Savings calculated using the following fuel prices in $/MBtu. Oil-5.32, Gas-6.06 and 6.87 (11/85); Oil-3.96, Gas-5.95 and 6.96 (4/86).

Table III. Sensitivity of post-retrofit heating energy consumption and energy savings to boiler-on period for five public housing complexes in Trenton, New Jersey (MBtu/apt-yr).

| BUILDING | UNITS | BOILER ON | $E_h$ | $E_{hd}$ | SAVINGS | %SAVINGS |
|---|---|---|---|---|---|---|
| Lincoln | 118 | 10/ 15 to 5/ 1 | 101( 3) | 131( 4) | -16( 5) | -14( 4) |
| | | 10/ 1 to 5/ 31 | 103( 4) | 133( 5) | -18( 5) | -16( 5) |
| Donnelly | 376 | 10/ 15 to 5/ 1 | 81( 3) | 128( 4) | 10( 5) | 7( 3) |
| | | 10/ 1 to 5/ 31 | 89( 5) | 135( 5) | 3( 6) | 2( 5) |
| Kerney | 102 | 10/ 15 to 5/ 1 | 94( 2) | 126( 3) | 13( 5) | 9( 4) |
| | | 10/ 1 to 5/ 31 | 101( 3) | 132( 3) | 6( 4) | 4( 4) |
| Campbell | 81 | 10/ 15 to 5/ 1 | 131( 7) | 168( 8) | -1( 9) | 0( 6) |
| | | 10/ 1 to 5/ 31 | 145(10) | 181(10) | -14(10) | -9( 7) |
| Wilson | 219 | 10/ 15 to 5/ 1 | 96(14) | 144(14) | 14(15) | 9( 9) |
| | | 10/ 1 to 5/ 31 | 99(23) | 147(24) | 11(23) | 7(15) |

Note: Standard errors are shown in parentheses.

## 7.0 BASEMENT DEHUMIDIFICATION

If summer basement dehumidification is desirable in the house with an EHPWH, the fresh air from the EHPWH is blown into the basement and allowed to force its way up through the house. Because the air leaving the EHPWH is 40°F 90%RH, entering a 65°F basement is going to have a drying effect and provide some air conditioning for the whole house as the air exfiltrates the upper structure.

## 8.0 MAJOR LIMITATIONS OF EHPWH

The conditions where an EHPWH should not be considered are:

1. The house does not have a minimum natural air exfiltration of 30 CFM at the design temperature. A balanced ventilation system may be a better choice in ultra tight housing.

2. Open flame devices with chimneys are used without power venting or sealed combustion with dedicated fresh air supplies.

## 9.0 SUMMARY -- A cost effective solution to the two major problems left in energy efficient housing: Ventilating and Water Heating

The balanced flow unit (HPX-80) is recommended for houses that have less than 35 CFM of natural air infiltration at design temperature and more than 6000 degree days or in any situation where open combustion takes place that requires a natural draw chimney to function. The AAX efficiency is 85% and the water heating COP is 2.0. When the unit is operated beyond the need for hot water, the unit provides extra heat to the house.

The EHPWH (HPV-80) is recommended for houses with more than 35 CFM of natural air infiltration at design temperature and no open flame combustion that requires a chimney. This unit can be used at any degree day condition. The water heating COP is 2.5 if the exhaust air flow is 100 CFM at 68°F 45% RH and the hot water temperature is 125°F. The unit can be operated beyond the need for hot water by using the optional remote indoor condenser, which produces 6105 Btu of heat at a COP of 2.8 under the above conditions. More air flow results in a higher COP.

Both units dehumidify and cool the fresh air coming into the house in the summer. If you are committed to ventilating a house on a year around basis and you use 64 gallons of hot water per year, both units have three to five year paybacks when compared to electric resistance space and water heating.

## REFERENCES

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[2] GAMA's Consumers' directory of Certified Water Heater Efficiency Ratings January 1986.

[3] "A Limited Investigation of the Energy and Demand Management Potential for the Temcor/Energy Utilization Systems Heat Pump Water Heater" Final Report. Research and Technical Services, Pennsylvania Power & Light, August 1981.

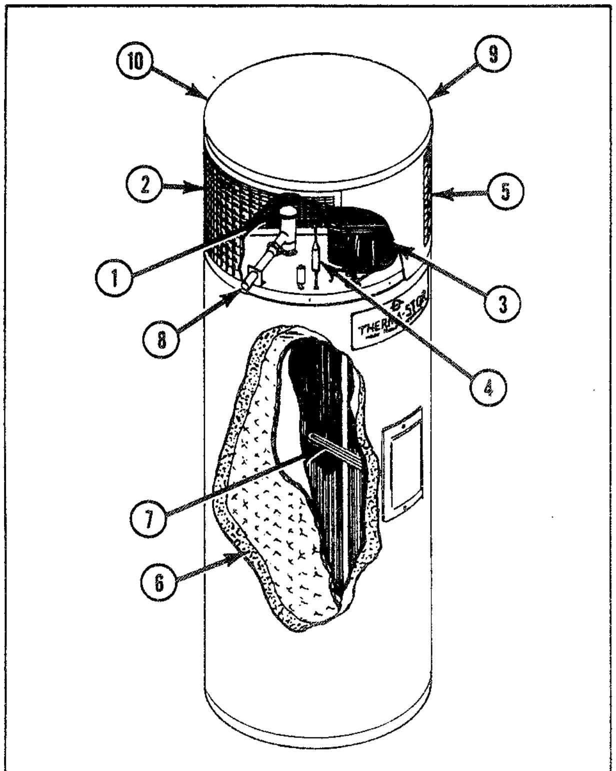
[4] Lars-Goran Mansson, Swedish Council for Building Research, Sankt Goransgatan 66,S-112 33 Stockholm, Sweden. "Airtight new wall construction in prefabricated Swedish single family houses",1984.

[5] M.H. Sherman and D.T. Grimsrud, July 1982, A Comparison of Alternate Ventilation Strategies, Lawrence Berkeley Laboratory, U of Ca.,Berkeley, CA. 94720, Pages 9-22 Lawrence Berkeley Lab. Report No. LBL-13678.

[6] Telephone conversations with Robert J. Mowris, Building Systems Engineering,Department of Civil and Architectural Engineering, University of Colorado, Boulder,Co..

[7] Discussion with Dennis Dietz,Ph.D.,Consultant to American Aldes Corporation,4539 Northgate Court, Sarasota, FL.

# Model HP-80 Specifications




1. Aluminum-finned, copper tube evaporator for corrosion-free long life.
2. Suction line accumulator protects the compressor from refrigerant slugging.
3. Hermetically sealed 3/4 Hp compressor.
4. Filter-dryer removes moisture and minute particles from the refrigerant system for years of trouble-free service.
5. Air conditioning capacity of 8,000 BTU's per hour of operation.
6. Two inch, R-15 urethane insulation.
7. 2500 watt electric heating element as back-up heat source, adjustable from 65°F to 120°F.
8. 7/8 inch copper tube hot water outlet.
9. 1550 RPM fan motor gives quiet, efficient operation (on 80-HR model, 1050 RPM on 80 model).
10. Insulated refrigerant line to minimize heat loss.

**Therma-Stor® plate design, provides rapid, free-flowing paths for refrigerant gas — promoting excellent waste heat transfer throughout the tank.**

## Limited Warranty

DEC International, Inc., Therma-Stor® Group, warrants the storage tank, heat exchanger and compressor for five years, when used in a normal single family installation. For complete details, request a warranty statement from your dealer or DEC International, Inc., Madison, WI.

| Model | Capacity (Gallons) | Height (Inches) | Diameter (Inches) | Electrical Specifications | Recovery Rate* (Gallons/Hour) @80°F Rise | Recovery Rate* (Gallons/Hour) @60°F Rise | First Hour Rating* (Gallons) | Energy Efficiency Factor (C.O.P.) | U.L. Approval | GAMA Cert. | Shipping Weight (Pounds) | Refrig. Charge | Part Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TS-HP-80 | 80 | 73.0 | 24.0 | 208-230V, 60 Hz, 1-Ph 20A Circuit | 16.0 | 21.0 | 74 | 3.50 | Yes | Yes | 400 | R-22 34 Oz. | 4017000 |
| TS-HP-80 HR | 80 | 72.0 | 24.0 | 208-230V, 60 Hz, 1-Ph 20A Circuit | 16.0 | 21.0 | 74 | 3.50 | Yes | Yes | 400 | R-22 32 Oz. | 4017600 |

*Test data is from the GAMA Test for Certification of Heat Pump water heater efficiency.

FIGURE 1.

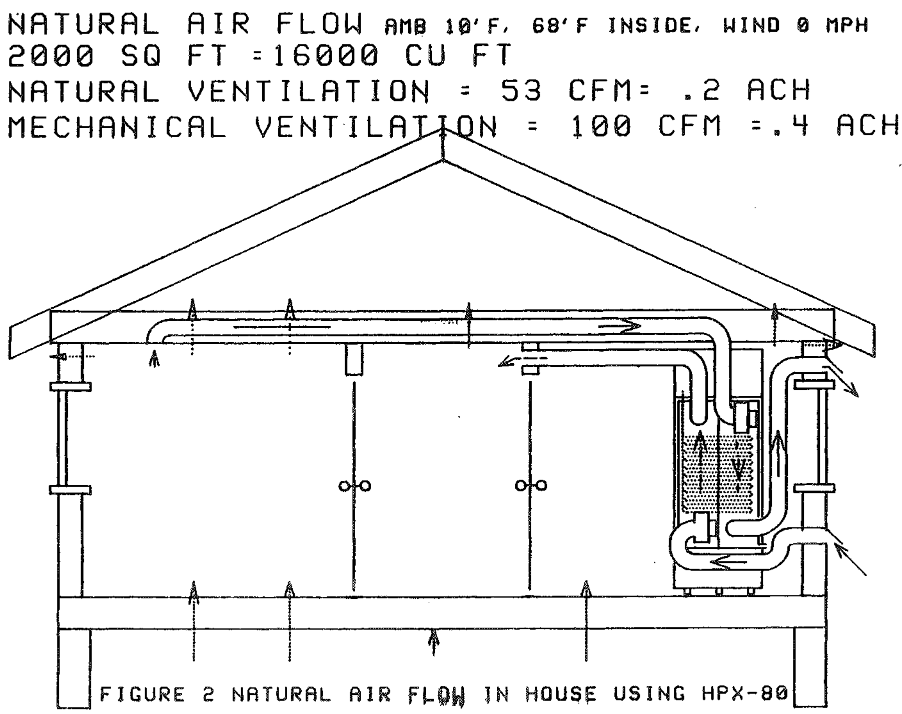



FIGURE 2.

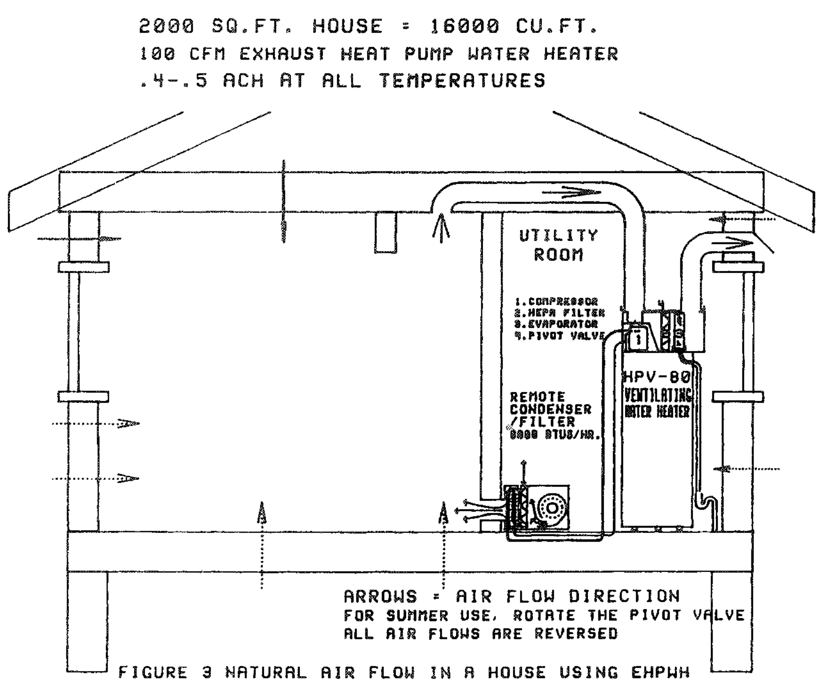



FIGURE 3.

PERFORMANCE SPECIFICATIONS
HPX-80

| Outside Air Temp | Outside Air %RH | Stale Air Temp | Stale Air %RH | Fresh Air Temp | Fresh Air %RH | +/- BTUs/Hr | Hot $H_2O$ Gals/Hr | KWh/Hr | Dehum #/Hr | COP W.H. | A-AX %/EF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 80 | 68 | 40 | 58 | 15 | +10,080 | 5 | .64 | 0.0 | 1.5 | 85 |
| 30 | 80 | 68 | 50 | 63 | 25 | + 6,300 | 7.5 | .68 | 0.0 | 2.1 | 86 |
| 60 | 70 | 68 | 60 | 68 | 40 | + 2,000 | 10 | .73 | 1.5 | 2.7 | 100 |
| 70 | 70 | 74 | 65 | 72 | 55 | - 1,400 | 11 | .81 | 1.7 | 3.0 | 0 |
| Recommend changing to A/C mode | | | | | | | | | | | |
| 60 | 90 | 68 | 65 | 52 | 90 | - 5,000 | 11 | .73 | 1.6 | 2.9 | 0 |
| 70 | 70 | 74 | 65 | 54 | 90 | - 7,000 | 11 | .81 | 2.1 | 3.0 | 0 |
| 80 | 70 | 76 | 65 | 61 | 90 | - 8,000 | 12 | .84 | 3.2 | 3.3 | 0 |

125°F thermostat setting, 55°F cold supply water

**FIGURE 4.**

SAVED KWH PER YEAR USING EHPWH ON 2000 SQ.FT. HOUSE EXHAUSTING 106 CFM (.4 ACH)
24 HOURS ON HEATING DAYS COMPARED TO MECHANICAL EXHAUST VENTILATION WITH NO
HEAT RECOVERY AND ONLY OPERATING UNIT TO HEAT WATER REST OF YEAR

| Htg Days | Deg. Days | BTU to Heat Makeup Air For Yr | Space Heat Provided By EHPWH BTU/Year | KWh to Operate EHPWH | Saved Kwh Resist. Space Heat | Saved KWh Heat/w EHPWH vs. Elect Resis |
|---|---|---|---|---|---|---|
| 90 | 2000 | 6,762,960 | 9,340,650 | 2,324 | 2,736 | 2,508 |
| 100 | 3000 | 9,393,600 | 10,378,500 | 2,443 | 3,040 | 2,633 |
| 110 | 4000 | 12,262,800 | 11,416,350 | 2,562 | 3,344 | 2,717 |
| 120 | 5000 | 15,773,760 | 12,454,200 | 2,682 | 3,648 | 2,842 |
| 130 | 6000 | 18,308,160 | 13,492,050 | 2,801 | 3,952 | 2,926 |
| 140 | 7000 | 21,359,520 | 14,529,900 | 2,921 | 4,256 | 3,051 |
| 150 | 8000 | 24,274,800 | 15,567,750 | 3,040 | 4,560 | 3,260 |
| 160 | 9000 | 26,288,640 | 16,605,600 | 3,159 | 4,864 | 3,469 |

**FIGURE 5.**

EHPWH WATER HEATING PERFORMANCE SPECIFICATIONS AT DIFFERENT AIR FLOWS AND 7000 DD (AVERAGE 140 DAYS, 15°F @ $.06/KWH)

| | | | | | | |
|---|---|---|---|---|---|---|
| Stale Air Exhaust CFM 68°F 45% RH | 70 | 100 | 130 | 160 | 190 | 220 |
| KWh Heat Pump | 0.65 | 0.66 | 0.67 | 0.68 | 0.69 | 0.70 |
| BTU/Hr | 5,250 | 5,550 | 5,800 | 6,250 | 6,650 | 7,000 |
| Gals Hot $H^2O$/Hr | 8.4 | 8.9 | 9.3 | 10.0 | 10.7 | 11.2 |
| COP of Heat Pump | 2.37 | 2.46 | 2.54 | 2.69 | 2.82 | 2.93 |
| Gals of Hot H2O/Day | 60 | 65 | 70 | 75 | 80 | 85 |
| Hrs to Heat Water | 7.83 | 7.95 | 8.16 | 8.07 | 8.05 | 8.09 |
| $H_2O$ Heating KWh/Yr | 1,857 | 1,918 | 1,995 | 2,002 | 2,027 | 2,068 |
| $/Yr @ $.06/KWh | $ 111 | $ 115 | $ 120 | $ 120 | $ 122 | $ 124 |
| Conv El WH KWh/Yr | 4,393 | 4,725 | 5,058 | 5,391 | 5,724 | 6,056 |
| $/Yr @ $.06/KWh | $ 264 | $ 284 | $ 303 | $ 323 | $ 343 | $ 363 |
| Reduction KWh/Yr | 2,536 | 2,807 | 3,063 | 3,388 | 3,696 | 3,989 |
| Savings $/Yr | $ 152 | $ 168 | $ 184 | $ 203 | $ 222 | $ 239 |
| Avg Exhaust Temp °F | 39.00 | 42.00 | 44.00 | 45.00 | 46.00 | 47.00 |

FIGURE 6.

EHPWH SPACE HEATING PERFORMANCE SPECIFICATIONS AT DIFFERENT AIR FLOWS AND 7000 DD (AVERAGE 140 DAYS, 15°F @ $.06/KWH)

| | | | | | | |
|---|---|---|---|---|---|---|
| Stale Air Exhaust CFM 68°F 45% RH | 70 | 100 | 130 | 160 | 190 | 220 |
| KWh Heat Pump | 0.63 | 0.64 | 0.65 | 0.66 | 0.67 | 0.68 |
| BTU/Hr | 5,775 | 6,105 | 6,380 | 6,875 | 7,315 | 7,700 |
| COP of Heat Pump | 2.68 | 2.79 | 2.88 | 3.05 | 3.20 | 3.32 |
| Hrs Space Heat/Day | 16.17 | 16.04 | 15.84 | 15.93 | 15.95 | 15.91 |
| Space Heat KWh/Yr | 1,428 | 1,437 | 1,442 | 1,471 | 1,495 | 1,512 |
| $/Yr @ $.06/KWh | $ 86 | $ 86 | $ 86 | $ 88 | $ 90 | $ 91 |
| Resist Heat KWh/Yr | 3,830 | 4,015 | 4,145 | 4,492 | 4,784 | 5,023 |
| $/Yr @ $.06/KWh | $ 230 | $ 241 | $ 249 | $ 270 | $ 287 | $ 301 |
| Reduction KWh/Yr | 2,403 | 2,577 | 2,704 | 3,021 | 3,290 | 3,511 |
| Savings $/Yr | $ 144 | $ 155 | $ 162 | $ 181 | $ 197 | $ 211 |
| Avg Exhaust Temp °F | 36 | 40 | 43 | 44 | 45 | 46 |

FIGURE 7.