

APPLICATIONS TESTS OF COMMERCIAL HEAT PUMP WATER HEATERS

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ABSTRACT

Field application tests have been conducted on three 4 to 6-ton commercial heat pump water heater systems in a restaurant, a coin-operated laundry, and an office building cafeteria in Atlanta. The units provide space cooling while rejecting heat to a water heating load. The tests, conducted for Georgia Power Company, examined both quantitative and qualitative aspects of the heat pumps and the overall water heating systems. The results provide valuable insight into the actual operating characteristics of heat pump water heaters and useful guidelines for system design and operation.

The capacity and efficiency of the units agreed with manufacturers' specifications. COP values ranged from 2.6 to 3.0 for water heating only, and from 4.1 to 5.0 when space cooling benefit was included. It was concluded that heat pump water heaters can provide economical water heating and space conditioning. However, application sites must be selected within certain constraints and a minimum level of operating control and maintenance must be observed.

Heat pump water heaters provide space cooling and dehumidification while rejecting heat to the domestic water heating load. Cooling efficiency compares to conventional air-conditioning systems, with water heating provided as a by-product.

Field application tests have been conducted on three commercial heat pump water heater systems in the Atlanta, Georgia area over the past two years. The tests, conducted by Abrams & Associates for Georgia Power Company, evaluated the thermal and economic performance of heat pump water heaters in typical commercial applications. The tests also provided insight into operation, installation, site selection, and maintenance considerations for heat pump water heaters. Hardware and test procedures were designed to provide basic information at low cost and with minimum complexity.

The study provides a unique examination of performance under field conditions. Real

world interactions with other systems, weather, and the human element are addressed. The results provide valuable insight into the actual operating characteristics of heat pump water heaters and useful guidelines for system design and operation.

TEST SITES AND SYSTEMS

The three sites chosen for the tests are described in the following paragraphs, figures, and tables.

STEAK & ALE RESTAURANT

The 6,900 sq. ft. restaurant serves 300 to 500 meals per day. The 4-ton heat pump and 105-gallon storage tank act as a preheater to a gas water heater. The heat pump is a Mueller QP-53 modified by Machine Ice Company (MIC) to include an air-cooled condenser for operation when there is no water heating load. The heat pump is controlled by a thermostat installed in the kitchen and operates whenever cooling is needed. An aquastat in the heat pump storage tank controls switching between the air-cooled and water-cooled condensers. The system was a retrofit installation; there was no previous cooling system installed in

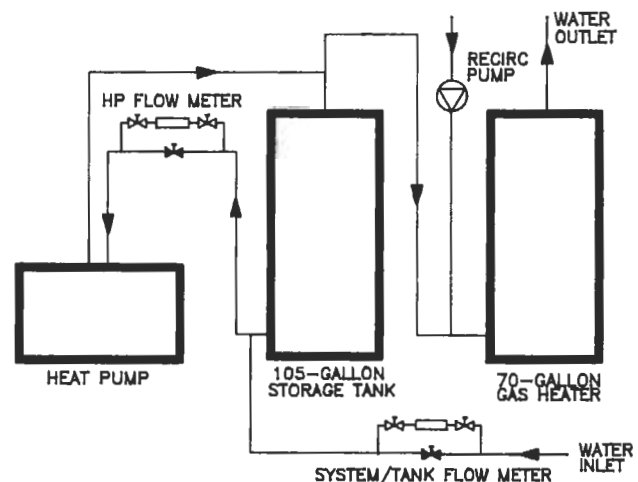


Fig. 1 Water Heating System Schematic, Steak & Ale Restaurant

MORNINGSIDE LAUNDRY

Morningside Laundry is a 2,300 sq. ft. laundry with 24 coin-operated washers and dryers. Two E-Tech model B413, 3-ton heat pumps and two 120-gallon storage tanks act as preheaters to the gas water heater. Cooling from the heat pumps supplements the existing 5-ton air conditioning system. System operation is controlled by a thermostat in the space and an aquastats in the heat pump storage tanks. The heat pumps operate only when both water heating and space cooling are needed; there is no air-cooled condenser. The heat pumps were added to the laundry to provide increased cooling capacity. The water heating system schematic is shown in Figure 2.

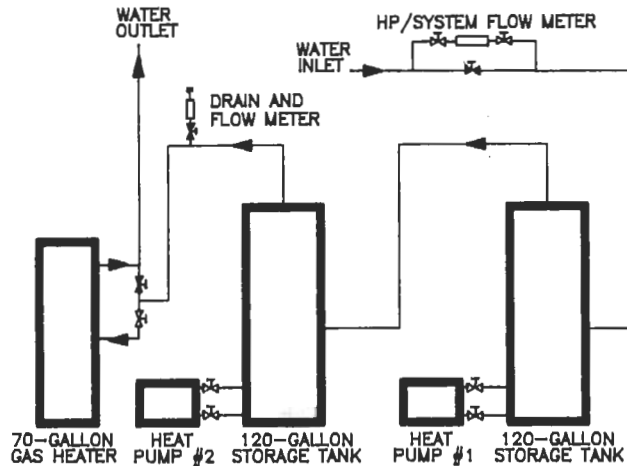


Fig. 2 Water Heating System Schematic, Morningside Laundry

C & S BANK SOUTHSIDE CENTER CAFETERIA

A 4-ton Mueller heat pump supplements a 150-kW, 800-gallon electric resistance water heater serving a cafeteria kitchen in a 300,000 sq. ft. office building. The heat pump is the same model as installed at the Steak & Ale site except that no air-cooled condenser was installed. The system is controlled only by an aquastat; it operates whenever there is a water heating load. Cooling is provided to the kitchen using the building's common return air system as a heat source. The heat pump was installed during construction of the building; however, the water heater was not down-sized. The water heating system schematic is shown in Figure 3.

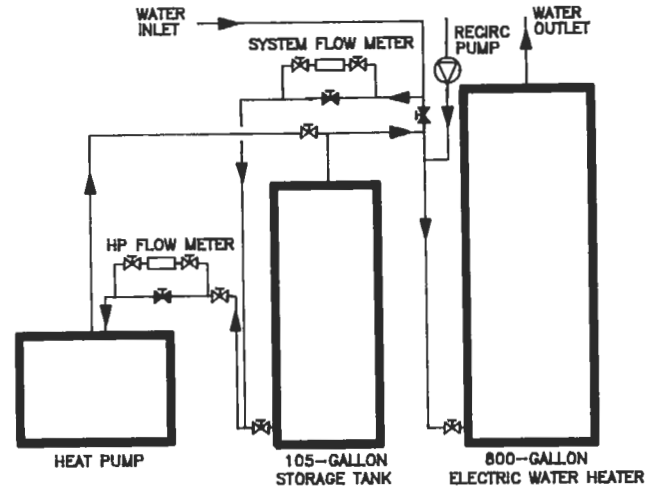


Fig. 3 Water Heating System Schematic, C & S Southside Center

Water heating system characteristics are summarized in Table 1.

	Restaurant	Laundry	Cafeteria
Hot water Use (gal/day)	3,000	2,325	790
Water heating load (MBtu/day)	2.6	1.1	0.53
Supply temp. (deg F)	180	130	150
Conventional water heater	Gas	Gas	Electric
Input (Btu/h)	500,000	300,000	150-kW
Volume (gal)	70	72	800
Recirculation water loop	Yes	No	Not used

Table 1 Water Heating System Characteristics

TEST METHODOLOGY

DATA ACQUISITION SYSTEM

The data collection systems were designed, assembled, and installed by Abrams & Associates. They consisted of Watt-hour meters, pulse counters, Btu meters, flow meters, natural gas meters, temperature measurement equipment, and run time meters. The systems provided accurate overall performance information with minimum cost and complexity. Data collection was accomplished by manual readings during weekly site visits. The site visits also provided an opportunity to make first hand observations of typical operating conditions and to detect problems in the water heating systems.

Monitoring equipment and data collected for the Steak & Ale Restaurant site are described below. The data acquisition systems installed at the other two test sites were similar.

- (4) Watt-hour meters: Power consumption of compressor and water pump, air-cooled condenser, and air handler, total building power consumption and demand.
- (2) Pulse counters: Power consumption of the compressor in the water heating/space cooling mode and the space cooling only mode.
- (3) Btu meters: Energy output from heat pump, heat pump tank, and total water heating system.
- (1) Water flow meter: Hot water consumption.
- (2) Gas meters: Natural gas consumption for water heating and the total building.
- (3) Run time meters: Run time of compressor, air-cooled condenser, and air handler.
- (1) Max/min thermometer: Kitchen air temperature extremes.
- (1) Temperature chart recorder: Kitchen air temperature, hot water supply temperature.

The Btu meters determine energy delivery by measuring water flow and differential temperature in a piping system. The flow and temperature difference are integrated to obtain an energy value.

Observations of operating conditions and equipment status were made during weekly site visits. Included were inlet and outlet water temperature for the water heating system, wet-bulb and dry-bulb conditioned space temperature, and thermostat setpoints. Observations concerning occupant interaction with the systems were valuable in identifying operations problems and in resolving questions about performance, particularly heat pump run time.

The overall performance of the data collection systems was very good. The only major difficulty was a discrepancy between thermal output readings for the heat pump and the heat pump storage tank at Steak & Ale. Because of the plumbing configuration, only the heat pump tank Btu meter could be independently checked and calibrated. Therefore, readings from the heat pump Btu meter were disregarded and all heat pump performance values for Steak & Ale include the effects of heat loss from the heat pump storage tank. The performance of the heat pump itself, without the storage tank, would be slightly higher than the values presented here.

The test periods are described in Table 2. One year of testing was completed in October, 1986 at Steak & Ale Restaurant and

in April, 1987 at Morningside Laundry. Monthly data readings are continuing at both sites. Testing began in February, 1987 at the C & S Bank cafeteria site; therefore, only five months of data have been collected as of June, 1987.

Test Site	Test Period
Steak & Ale Restaurant	
Weekly data	Sep, 85 - Oct, 1986
Monthly data	Oct, 1986 - Pres.
Morningside Laundry	
Weekly data	Mar, 1986 - Apr, 1987
Monthly data	Apr, 1986 - Pres.
C & S Bank Cafeteria	
Weekly data	Feb, 1987 - Pres.

Table 2 Test Schedule

DATA MANAGEMENT AND ANALYSIS

Data was entered weekly into Lotus 1-2-3 spreadsheets developed by Abrams & Associates. The spreadsheets stored data, performed calculations, and generated graphs and tabular performance summaries. The ability to analyze results early in the test program and on a weekly basis made it possible to promptly identify and remedy problems with data collection and heat pump operation.

TEST RESULTS

The data system provided a variety of information on heat pump power consumption, thermal output, run time, and COP. The systems performed within manufacturers' published specifications. Preliminary results on the C & S site are presented where appropriate, since only three months of testing have been completed.

MEASURED PERFORMANCE VALUES

A summary of the annual test results is presented in Table 3.

HEAT PUMP RUN TIME

Run time for all three systems are illustrated in Figure 4. Heat pump run time varied greatly during the year at the restaurant and laundry sites, primarily because of variation in space cooling load. Average seasonal run time is summarized in Table 4. Note that the laundry heat pump run time values in Table 4 are the total for both heat pumps.

	Restaurant	Laundry
Hot water consumption (gallons)	1,080,000	843,145
Net water heating load (MBtu)	927	338
Heat pump heating output (MBtu)	157	188
Fraction of net load by heat pump	17%	56%
Building power consumption (kWh)	460,650	118,800
Heat pump power consumption (kWh)	24,760	21,165
Building actual peak demand (kW)	114	36
Heat pump demand, estimated (kW)	7.0	10.0
Building gas consumption (therms)	20,540	6,783
Water heat gas consumption (therms)	12,160	2,178
Heat pump space cooling (ton-hrs)	12,405	9,094
Heat pump run time, total (hours)	3,660	4,254
Summer (June - September)	2,355	2,622
Winter (October - May)	1,305	1,632
Fraction of heat pump run time in water heat/space cooling mode	70%	NA
Building electric power cost (\$/yr)	31,632	8,824
Building natural gas cost (\$/yr)	12,901	3,943

Notes: 1. Performance values include the effect of heat loss from the heat pump storage tank. Figures for the heat pump alone would be slightly more favorable. Thermal loads do not include the additional thermal load met by the electric booster heaters in the dishwashers.

2. Values of heat pump demand and space cooling output are estimates; the monitoring program did not include direct measurements of these quantities.

Table 3 Summary of Annual Performance Results

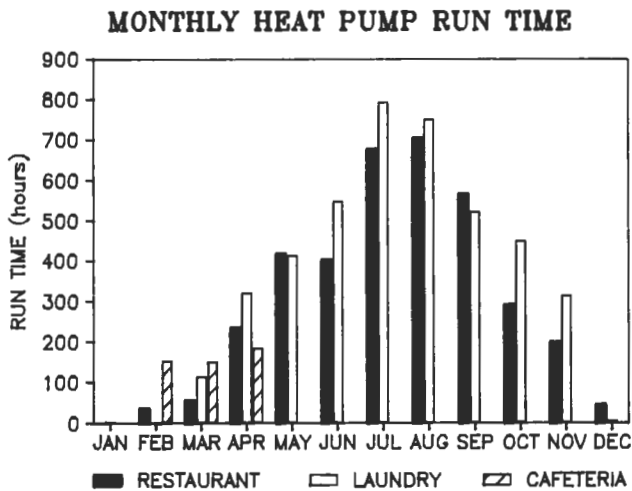


Fig. 4 Monthly Heat Pump Run Time

Season	Restaurant	Laundry	Cafeteria
Jun - Sep	18.3	29.1	NA
Dec - Mar	1.2	1.0	5.4
Apr, May, Oct, Nov	7.4	12.6	6.3

Table 4 Seasonal Heat Pump Run Time (hrs/day)

In projecting annual performance and economic return, it should be recognized that heat pump operation will be minimal in the winter months at most sites. Heat pump run time is less sensitive to ambient conditions at the cafeteria site because the conditioned space is located within a large office building and not strongly thermally coupled to the outdoors.

At the Steak & Ale Restaurant, heat pump run time was limited by poor thermostat management. Employees often adjusted thermostat settings. Kitchen temperatures of 89 F were recorded during weeks when the heat pump was not used for cooling. At the Morningside Laundry site, the setpoint on the conventional air conditioning system was often lower than the setpoint on the heat pump thermostat. This allowed the conventional system alone to meet small

cooling loads when the heat pump was available for operation, reducing heat pump run time. There is no space cooling thermostat on the heat pump at the C & S Bank site; the cooling load is large enough to ensure that the space is never overcooled by the heat pump. In general, system run time will be increased if the thermostat is not adjustable by the occupants.

SPACE-COOLING-ONLY VS. WATER HEATING/SPACE COOLING

The Mueller/MIC unit installed at the Steak & Ale restaurant is capable of operating in a space-cooling-only mode by rejecting heat to an outdoor air-cooled condenser. Neither of the other two heat pumps tested had this capability, although E-Tech and Mueller are now developing or manufacturing units that incorporate an auxiliary condenser.

The heat pump at the Steak & Ale Restaurant ran continuously for 16 weeks during the summer. 70 percent of run time was in the water heating/space cooling mode; 30 percent was in the space-cooling-only mode with heat rejected through the outdoor condenser. About 60 percent of the operation in the space-cooling-only mode occurred between the hours of 12 midnight and 8 a.m., when the kitchen was unoccupied. Heat pump operation during the unoccupied hours was almost entirely in the space-cooling-only mode, since the heat pump tank has storage capacity for only one hour of heat pump run time without hot water use. This has a significant detrimental effect on overall performance and economics. A simple time clock or setback thermostat could have prevented approximately 700 hours of unnecessary operation in the space-cooling-only mode during unoccupied hours. The overall COP would have been increased from 3.6 to approximately 3.9, and heat pump power consumption would have been reduced by approximately 4,835 kWh/year. The need for the auxiliary air-cooled condenser in this application is questionable. The water heating load is larger than the space cooling load, and continuous cooling capability was not of importance to the building owners. A larger heat pump storage volume would have shifted run time from the space-cooling-only mode to the water heating/space cooling mode.

The system installed at the Morningside Laundry did not have an auxiliary air-cooled condenser. The heat pumps did not always have an available water heating load when air conditioning was needed. In order to force the heat pumps to run and provide cooling to the building, water was often drained from the heat pump storage tanks. During the year of testing 352,000 gallons of water was drained from the system. This constitutes 16 percent of the annual water use. Some of the water use was unnecessary;

often water would be left on to drain through the night. In this application an air-cooled condenser was needed since space cooling was more important to the building owners than than savings in water heating cost.

POWER CONSUMPTION AND DEMAND

The monthly power consumption of the heat pump at the restaurant, laundry, and cafeteria are plotted in Figure 5. At the restaurant and laundry 66 percent and 62 percent, respectively, of the heat pump's power consumption took place during the utility's summer billing period (May through September).

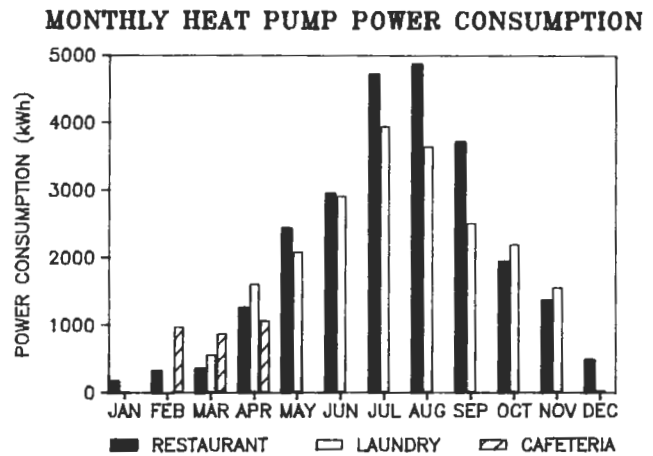


Fig. 5 Monthly Heat Pump Power Consumption

The average input power during run time for the heat pumps at Morningside Laundry was 5 kW each. The drainage caused the heat pumps to be used as air conditioners, and therefore they would be expected to add all of their input power requirement to the building's peak demand. If both heat pumps were operating at the time the building's peak demand was set, they would add approximately 10 kW. Similar analysis indicates that the heat pumps would add 7 kW at the restaurant. The heat pump at the cafeteria will lower the building's peak demand since it will displace the use of electric resistance water heating.

Typical values for annual hours of demand use (power consumption in kWh divided by demand in kW) for water heating and air conditioning and the values for the heat pumps are tabulated in Table 5. In this respect, the heat pump water heater is a highly desirable electrical load. However, as indicated earlier, the majority of the run time occurred during the summer billing period.

	Hours of Demand Use (hrs/yr)
Restaurant Heat Pump	3,540
Laundry Heat Pump	2,125
Typical Water Heating	1,500
Typical Air Conditioning	1,800

Table 5 Annual Hours of Billing Demand Use (1)

THERMAL OUTPUT

The heat pumps provided 17 percent, 56 percent, and 71 percent of the net water heating load at the restaurant, laundry, and cafeteria, respectively. Note that the heat pump did not operate for a significant portion of the winter at the restaurant and laundry; the space cooling load was insignificant.

Figure 6 illustrates the heat pumps' fractional contribution to the net water heating load and their maximum potential contribution. Heat pump output temperature is limited to 140 F; the water heater setpoint temperature was 180 F at the restaurant and 150 F at the cafeteria. At the Steak & Ale Restaurant, the heat pump provided 26 percent of its maximum potential output. The shortfall is a result of the limitations of cooling load, output capacity, thermostat control, water heating and space cooling load match, and storage capacity. Analysis of the data indicates that improved thermostat control could have increased the heat pump contribution to 46 percent of its maximum potential output.

HEAT PUMP FRACTIONAL CONTRIBUTION TO WATER HEATING LOAD

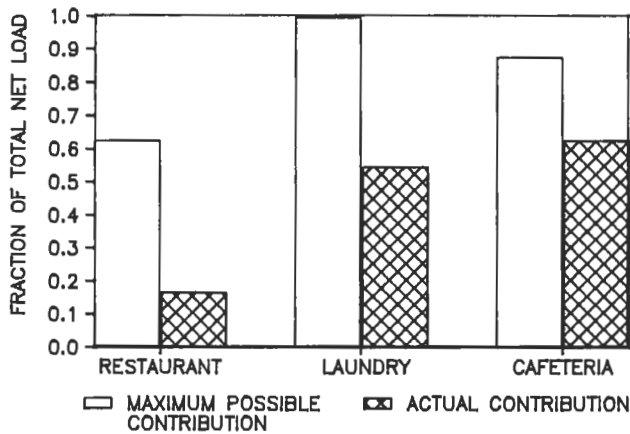


Fig. 6 Heat Pump Fractional Contribution to the Water Heating Load

Figure 7 plots measured weekly average capacity for the heat pump at the Steak & Ale site, and manufacturer's data at an outlet water temperature of 130 F and wet-bulb evaporator inlet air temperatures of 50, 65, and 80 F. The 130 F outlet water temperature is typical of operating conditions during the test. Although there is scatter due to varying temperatures, the graph indicates that the unit was operating within the manufacturer's specifications. Similar results were obtained at the other sites.

HEAT PUMP WATER HEATING CAPACITY TEST POINTS AND MANUFACTURER'S DATA

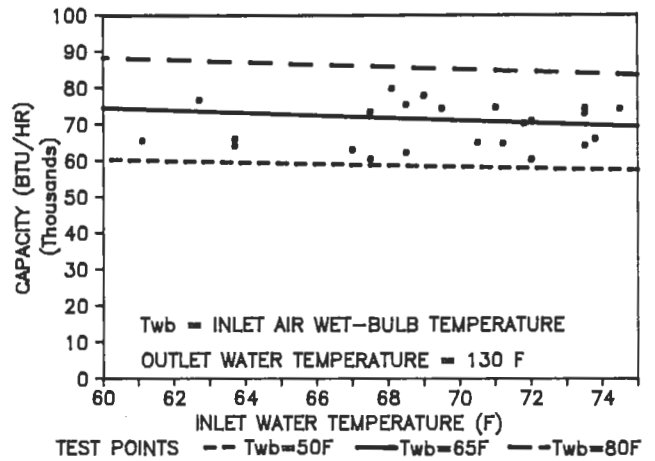


Fig. 7 Heat Pump Water Heating Capacity; Test Points and Manufacturer's Data

HEAT PUMP COP AND WATER HEATING EFFICIENCY

Several different COP values are required to describe the various evaluation perspectives and to accommodate the two operating modes for the systems. Performance values at the restaurant and laundry are for the installed heat pump system with storage tanks, not for only the heat pump. The effects of heat loss from the heat pump storage tank are included.

Abbreviations:

- WHSC - Water heat/space cooling mode of operation; the heat pump provides simultaneous water heating and space cooling. This is the only mode of operation for the laundry and cafeteria systems.
- SCO - Space-cooling-only mode of operation; the heat pump rejects heat to the outdoor condenser while providing cooling. This mode is available only for units with outdoor condenser.
- WH - Water heating.
- WH&C - Water heating and space cooling.

$$\text{WH Mode COP} = \frac{\text{(WH\&C thermal output in WHSC)}}{\text{(power input in WHSC)}}$$

The water heating mode COP describes the efficiency of the heat pump system when operating in the water heat/space cooling mode. Credit is given for space cooling and water heating benefits.

$$\text{WH Mode COP} = \frac{\text{(WH thermal output in WHSC)}}{\text{(power input in WHSC)}}$$

W/O cooling

This value also describes the water heating efficiency for the heat pump system in the water heat/space cooling mode; however, it gives no credit for cooling effects. Heat pump manufacturers usually report this value in their literature.

$$\text{Overall COP} = \frac{\text{(WH\&C thermal output in WHSC + cooling output in SCO)}}{\text{(power input WHSC + power input in SCO)}}$$

The overall COP value is calculated only for the restaurant site, where the system is able to operate in a space-cooling-only mode. It describes the efficiency of the heat pump system as a combined water heating and space cooling device. It gives credit for both water heating and space cooling output and includes power consumption in both operating modes.

Total water heating system efficiency is defined as the total water heating thermal output of both the heat pump and the conventional water heater divided by the total input energy. All recirculation and standby heat loss is included, but no credit is given to space cooling output. The total system efficiency varies greatly with both hot water use and heat pump run time.

Measured performance values are summarized in Table 6.

	Restaurant	Laundry	Cafeteria
WH Mode COP	5.0	4.1	4.6
WH Mode COP, W/O cooling	3.0	2.6	2.7
Overall COP	3.6	NA	NA
Overall System Efficiency	0.71	1.2	1.3

Table 6 Annual Performance Figures

SYSTEM RELIABILITY

There were several service problems with the heat pumps. At the restaurant,

during the first week of testing, the heat pump controls were found to be operating improperly. The condenser fan operated when the unit was in the water heating/space cooling mode. The manufacturer corrected an installation error in the control wiring, and the unit operated properly. A leak in the liquid line receiver reduced run time and capacity for two weeks prior to its repair. Service personnel then had difficulty in attaining the correct refrigerant charge in the unit, causing reduced capacity and efficiency for four weeks after the leak repair. A manufacturer's representative was contacted to assist the servicemen. Charging instructions and refrigerant capacity information were not included with the heat pump.

At both the laundry and the cafeteria sites, the heat pumps were very sensitive to the 140 F maximum outlet water temperature limit. Exceeding the maximum output temperature caused the units to trip out on high pressure, requiring a manual reset. Setting the system control to produce 135 F water would reduce these nuisance trips.

Regular air handler filter changes are necessary. On one occasion, dirty filters at the restaurant restricted air flow to the point that the return gas line froze, and the unit was manually switched off to protect the compressor.

It must be noted that several of the problems were found and corrected only as a result of the test program. If the heat pump sites had not been visited weekly, run time would have been further reduced because of service problems. A maintenance and inspection schedule must be followed in order to ensure optimum heat pump performance.

ECONOMIC ANALYSIS

Using the test results, an economic comparison was made between the heat pump and conventional systems using applicable local utility rates. Performance differences between the heat pumps and the conventional systems were considered in calculating operating costs.

Steak & Ale Restaurant normally installs conventional air conditioning units with rated cooling capacity of 6-tons in their kitchens. The Morningside Laundry would also have installed a conventional 6-ton air conditioner if the heat pump had not been installed.

OPERATING COSTS

Water heating and air conditioning costs were calculated for three systems: 1) gas water heating with conventional air conditioning, 2) electric resistance water

heating with conventional air conditioning, and 3) the heat pump water heater with conventional gas water heating. Annual operating cost values are shown in Table 7. The loads used were the gross water heating load at the site and the cooling output provided by the heat pump. Present incremental power costs are \$0.0278/kWh and \$175.87/kW/year. Incremental gas cost is \$0.605/therm. Sales tax rate is 5 percent.

	Restaurant (\$/yr)	Laundry (\$/yr)
Heat Pump Water Heater	9,185	3,665
Gas and Conventional AC 65% efficiency	10,755	-
70% efficiency	-	4,786
Electric Resistance and Conventional AC	19,335	9,183

Table 7 Annual Water Heat and Air Conditioning Costs

The heat pump provides significant savings over the alternatives. The heat pump reduced annual operating cost by \$1,565 at the restaurant and \$1,121 at the laundry. This does not include the cost of drained water at the laundry.

To be cost effective compared with gas water heating, the heat pump must be installed in applications where the space cooling is assigned a value and would have been supplied by other means. The heat pump offers a very attractive alternative to electric resistance water heating, even with no value assigned to the cooling.

SIMPLE PAYBACK

The simple payback period for the heat pump compared with gas water heating and conventional air conditioning, and with electric resistance water heating and conventional air conditioning is provided in Table 8. The incremental cost of the heat pump over a conventional system was \$4,000 at the restaurant and \$5,650 at the laundry.

	Restaurant (yrs)	Laundry (yrs)
Gas and Conventional AC 65% efficiency	2.6	-
70% efficiency	-	5.0
Electric Resistance and Conventional AC	0.4	1.0

Table 8 Simple Payback Period

If the extra cost associated with the drained water at the laundry is considered, the heat pump is not an economical alternative to gas water heating.

RECOMMENDATIONS AND GUIDELINES

While heat pump water heaters are technically sound and economically cost effective, they are not as simple as conventional electric and gas water heating equipment and cannot be universally applied. In marketing and installing heat pump water heaters, it is suggested that the inherent advantages and limitations of the devices be considered carefully.

SYSTEM CONTROLS AND INTERACTION WITH OCCUPANTS

The three test sites employed three different control strategies. The heat pump at the restaurant operated whenever air conditioning was needed, the laundry heat pump operated whenever air conditioning and water heating were needed simultaneously, and the cafeteria heat pump operated whenever water heating was needed. The most consistent and economic heat pump operation is achieved in installations such as the office building cafeteria, where a large space cooling load is available. This eliminates the need for a space conditioning thermostat, thereby eliminating occupant interference with system operation. This type of application, however, is rare in small commercial settings.

Most importantly heat pumps must be intelligently integrated with existing space conditioning systems and controls. The heat pump should be used to meet the cooling and water heating loads whenever possible since it is the most economical system to operate. The heat pump should not be allowed to operate when the building's conventional system is providing heat to the space.

OUTDOOR CONDENSER

Heat pump water heaters are available with only the standard water-cooled condenser and with both a water-cooled and an outdoor air-cooled condenser. A unit with only a water-cooled condenser offers minimum equipment cost and operates only in the higher efficiency space cooling/water heating mode. The outdoor condenser adds equipment cost and operating cost, but allows operation for space cooling when there is no need for further water heating. The appropriate choice of units is influenced by the customer's objectives, his real and perceived needs, the relative size and timing of the water heating and air-conditioning loads, the relative efficiency for each function, and storage capacity.

Suggested Guidelines:

- * If the customer desires space cooling on demand, install an outdoor condenser in all cases except where the water heating load is always very large with respect to the space cooling load.

Without an outdoor condenser, the operation of the heat pump for space cooling is limited by the water heating load. The lack of anticipated cooling capacity is obvious to the building occupants and certain to cause dissatisfaction.

- * If energy conservation and cost reduction are the customer's primary objectives and space cooling is not essential, avoid use of an outdoor condenser.
- * If an outdoor condenser is installed, ensure that the control system precludes operation during unoccupied periods. This is easily accomplished with a setback thermostat or a time clock.
- * In system design, simple comparisons of water heating and space cooling loads or capacities are not necessarily appropriate. The relative capacity of the heat pump for each function must be considered. For example, for the models tested the hourly water heating thermal output exceeds the hourly space cooling output by approximately one third. Thus a balanced condition would exist when typical water heating load = 1.33 x typical space cooling load. Even though typical water heating and space cooling loads may be balanced, performance will be adversely affected if the two loads are significantly out of phase.

THEMAL AND ECONOMIC PERFORMANCE PREDICTIONS

Caution must be used to assure that performance projection methods are sufficiently rigorous. Performance estimates must consider the interaction of the water heating and space cooling loads. It cannot be assumed that the full capacity of the heat pump is always available to meet either load. This inevitably leads to unrealistic expectations and disappointment. A heat pump without an outdoor condenser can provide cooling only when a water heating load exists. Similarly, both types of heat pump water heaters provide water heating only when the building can accept the space cooling output. If the heat pump is not available, loads will be met by more expensive alternatives.

In most small commercial applications, there is no space cooling load during cold weather. Annual estimates of water heating performance must be reduced accordingly. Power consumption estimates must include a reasonable assessment of the hours of operation in the space-cooling-only mode.

INSTALLATION, OPERATION, MAINTENANCE, POTENTIAL PROBLEMS, AND OPPORTUNITIES FOR PERFORMANCE IMPROVEMENTS

High quality heat pump water heaters are now available from several manufacturers. However, there are concerns regarding the installation, operation, and maintenance of the products. Most seem to result from a lack of familiarity with the equipment and concepts, inadequate documentation or procedural guidelines, or a view of the heat pump as an isolated device rather than as a component in the overall water heating and space conditioning system. Problems may be often sufficient to preclude the effective operation of the heat pump. The situation is compounded by the fact that a fault or failure in the heat pump is not always readily apparent to the occupants of the building. Hot water is still available from the conventional system.

In addition, there are also several areas where a general lack of information makes it difficult to make informed design and operation decisions.

- * Selection of optimum heat pump storage volume.
- * Space cooling thermostat control strategies for lowest total space cooling and water energy heating cost. There is a poor understanding of the costs in the various operating modes, making informed operating decisions difficult.
- * Guidelines for estimating annual availability of water heating capacity as a function of space cooling load characteristics, and vice versa.

CONCLUSION

The test programs was successful in providing information on the thermal and economic performance of the heat pumps. The heat pumps operated within manufacturers' specifications of performance and capacity. Annual COP values ranged from 2.6 to 3.0 for water heating, and 4.1 to 5.0 with space cooling benefits included.

These test programs indicate heat pump water heaters can be effectively and economically utilized in commercial restaurants, laundries, kitchens, and similar operations. However, the units cannot be universally applied, and appropriate recognition should be given to certain inherent limitations, notably the lack of winter operation. To avoid undesirable installations, site selection should be accomplished with care. Particular concerns include:

- * Customer's priorities for cooling vs. water heating cost reduction.
- * The balance between cooling and water heating loads (magnitude of loads and schedule).

- * Match between loads and heat pump output and storage.
- * Controls and user interactions.
- * Proper installation, startup, and maintenance.
- * Presenting the customer with reasonable economic performance projections.

It is suggested that the growth of the industry could be facilitated by the resolution of certain system design issues and the development of simple applications information, with particular emphasis on site selection, realistic performance prediction, and problem avoidance in installation. A heat pump could be easily combined with other energy conservation opportunities which would reduce the overall payback of installation.

Heat pump water heaters function best where a source of excess heat and humidity are available. Thus, typically overheated spaces with coincident water heating loads, such as kitchens and laundries, are ideal. Of particular interest is the potential to provide space conditioning to spaces in which conventional air-conditioning systems are not traditionally installed. Cooling systems can be more easily justified because of the water heating feature of the heat pump water heater.

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REFERENCES

1. DeMonbreun, R. C., "Hour Use-kW Revenue Sheet", Georgia Power Company, Atlanta, GA, 1986.