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Heat Pumps Without Supplemental Heat

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HEAT PUMPS WITHOUT SUPPLEMENTAL HEAT

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ABSTRACT

Through the past few years, fuel used to generate electricity has climbed steadily in cost resulting in a new and much higher level of acceptance for the air to air heat pump system. Manufacturers have improved the product tremendously and have established a level of reliability approaching that of the conventional air conditioner. The fact that heat pumps reduce the cost of heating by 30% to 50% over conventional electric resistance heating and that natural gas is not available in many parts of the country has resulted in more and more heat pumps being installed in homes. While the benefits to the user are sufficient to economically justify the added cost of installing the heat pump system, it can be a long term disaster for the electric utility. As long as a utility has a summer peak, any type of space heating load that occurs only during the winter months is welcome; but when the utility becomes a winter peak company, it changes the situation. An electrically heated home with conventional insulation has a winter peak contribution 3 to 4 times greater than the summer peak contributuion for air conditioning in the same home. The annual load factor for air conditioning in St. Louis, Missouri is about 11%. The annual load factor for electric resistance heating is about 13% and for the electric heat pump is 6% to 7%. It quickly becomes evident that if air conditioning caused a summer peak situation that was not manageable in todays high costs for generating plant and fuel, the problems associated with a future winter peak caused by todays' air to air heat pumps will be tremendously greater. One solution is the development of a heat pump system used in conjunction with thermal storage

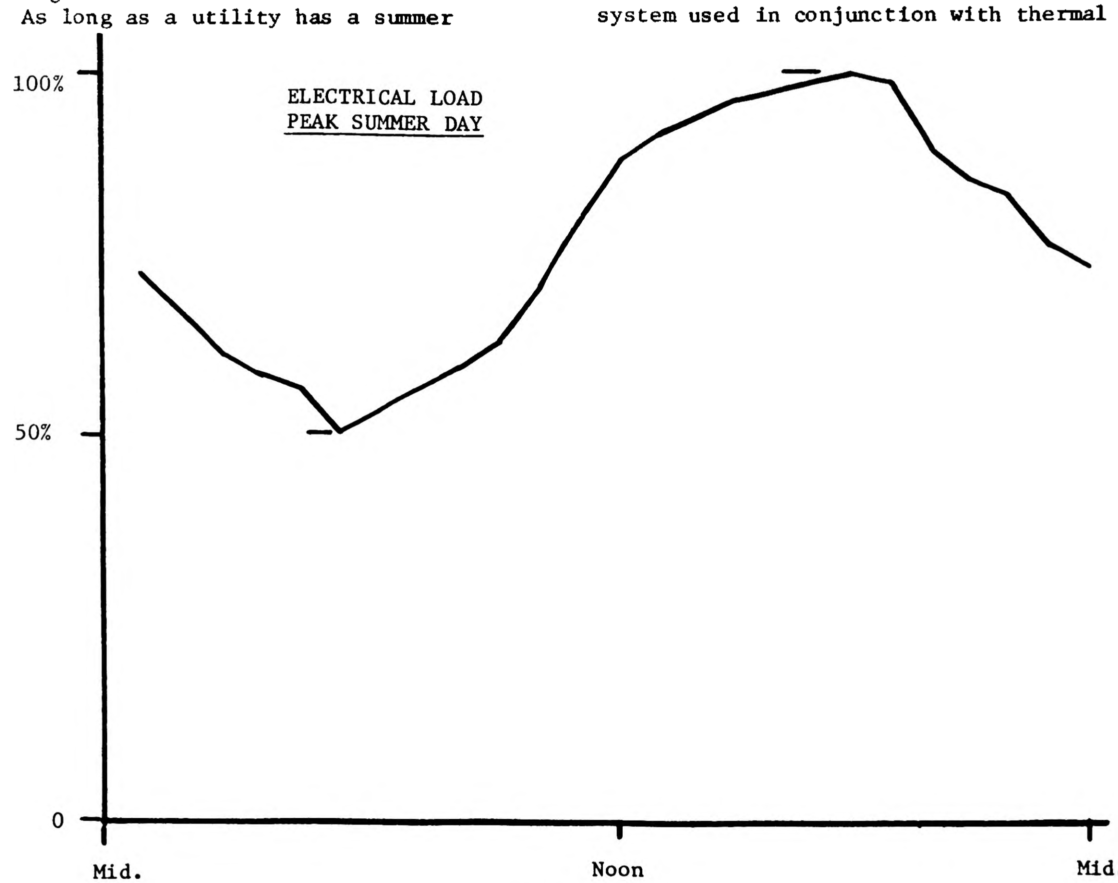

FIGURE 1

that will limit the demand for electricity during periods of extremely cold weather to the requirements of the heat pump only. There would be no supplemental electric heating installed in the system. Such a system would provide an ideal solution for both the home owner and the utility.

INTRODUCTION

The daily load curve is of great importance to a utilities' ability to manage load effectively. The summer daily load curve for Union Electric Company is shown in Figure 1. As can be seen, there is a great difference between the peak load on the system at 6:00 P.M. versus the minimum load during the same day occuring at 5:00 A.M. The ratio of peak to valley is 2:1. This is because the air conditioning peak is caused by the sun and occurs during the day which is also coincident with the office building loads, the industrial plant loads, etc. At night, both the solar load and the lighting and power load on the utilities' system diminish. This means that a utility can use load mangement systems in which they disconnect customer devices during the peak hours (ripple control, etc.) and make up the energy during the valley portion of the daily load cycle. This same principle cannot be applied to space heating loads.

Figure 2 shows the daily load curve for a

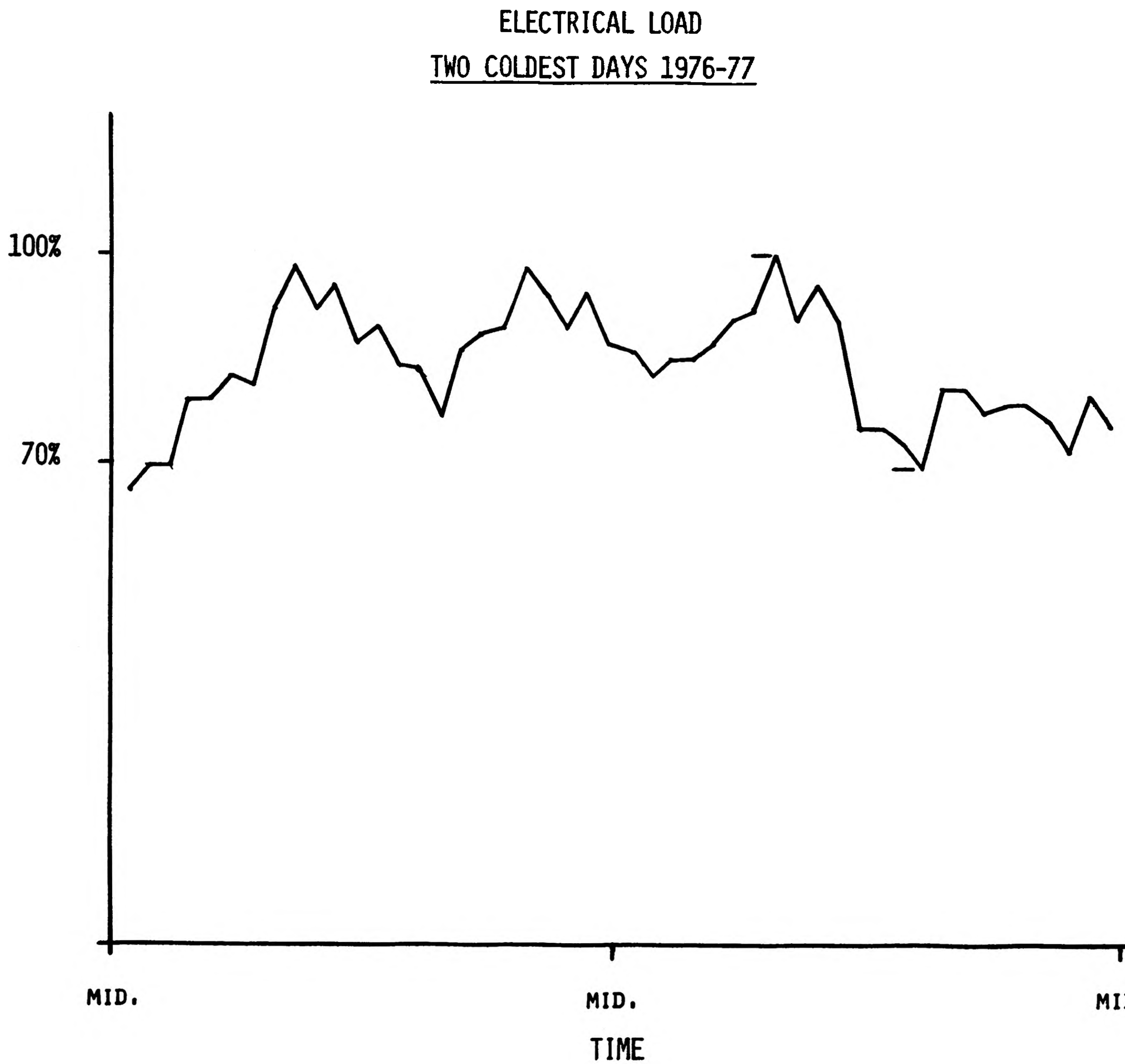

FIGURE 2

winter peaking area with high space heating concentration in Union Electric's system extending for 2 days during the coldest part of the winter in January, 1977. It's readily apparent that the ratio of peak to valley is greatly reduced, being :1 in the case shown. This is because there is diversity between the peak heating system requirement and the lighting and power demands on the utility system. The maximum heating load occurs at about 6 A.M. in the morning and the minimum heating load is during the afternoon hours which is exactly opposite to the lighting and power loads which peak during the day and are minimum at night. This results in far less flexibility for the utility in attempting to institute load management through conventional means. Due to the magnitude of the problem in Kw load and the flatness of the daily load cycle, current load management principles as applied to air conditioning will not suffice. The only logical solution to the problem is the development of a system that will result in an electrically heated home being no greater a winter heating load than the same home is a summer air conditioning load. It's the only solution that will permit the utility to remain financially sound and permit the customer to have energy available for heating at a reasonable cost. We cannot afford the luxury of rebuilding our electrical utility systems to provide space heating if natural gas, oil and propane fuels become unavailable in the future.

BUILDING INSULATION

Homes built during the last few years have had relatively high levels of insulation installed when compared to homes constructed a decade or more ago. Even though the last few years have shown considerable improvement in thermal characteristics of houses, this will not be sufficient for the future. Table 1 shows the heating and cooling loads for a sample 2220 square foot home (with equal sized basement) insulated to the accepted level of 2 or 3 years ago compared with what many would refer to as a "super insulated" home of today.

CONVENTIONAL INSULATION

Ceiling	- 4" insulation
Walls	- Brick veneer with 2" insulation batts
Bsmt Walls	- No insulation
Glazing	- Storm sash

SUPER INSULATION

Ceilings	- 10" to 12" insulation with thermal resistance R = 30.
Walls	- 2" x 6" construction with 6" batts, R = 19.
Basmt Walls	- Furred with 2" x 2" and 2" insulation batts, R = 7.4.
Glazing	- Storm sash

BTU/HR COMPARISON OF HEATING AND COOLING LOADS

	Heat Loss (Btu/Hr)	Heat Gain (Btu/Hr)	Ratio Ht. Loss: Ht. Gain
Conventional Insul.	89,985	56,116	1.6 to 1
Super Insulation	52,207	43,150	1.2 to 1

KW UTILITY LOAD COMPARISON OF HEATING AND COOLING LOADS

	Heating Load (Kw)	Cooling Load (Kw)	Ratio Ht. Load: Cool. Load
Conventional Insul.	26.4	7.0	3.8 to 1
Super Insulation	15.3	5.4	2.8 to 1

TABLE 1

The improvement in insulation reduces the maximum calculated heat loss of the home by approximately 42% which is extremely important when considering total heat requirement of the home. It does not solve the winter-summer inbalance of the utility load relationship, however. While the Btu/Hr comparison for heating load to cooling load is close to unity for the super insulated home; when one factors in the C.O.P. of the refrigeration system serving the house, the Kw load relationship is still near 3 to 1. For the same reasons cited previously regarding present day utility economics of purchasing electrical capacity, the simple solution of added insulation is not enough to relieve the major problem of winter/summer inbalance.

THERMAL STORAGE

Based on the conclusion that insulation alone cannot realistically balance the winter/summer load relationship in a home, the next area to investigate is thermal storage to make up the difference between what can be obtained from the heat pump and the requirements of the house. Conditions that existed on Union Electric Companys' system during the extremely cold weather of January, 1977 dictate that any storage system must have the capability of carrying the house through 4 days of near outdoor design weather conditions with no replenishment of that storage. The first task is to define the heating requirement of the sample home through such a period. This was done by using the Automated Proceedures for Engineering Consultants, Inc. (APEC) HCC-III Heating/Cooling Load Computer Program. A run was made for every hour of a design day profile of temperature which defined net heating requirements of the home on an hourly basis. Figure 3 shows the hourly net heating requirements of the home derived from the APEC HCC-III Computer Program. The peak heating requirement of the home is 44,400 Btu/Hr occuring at 5:00 A.M.

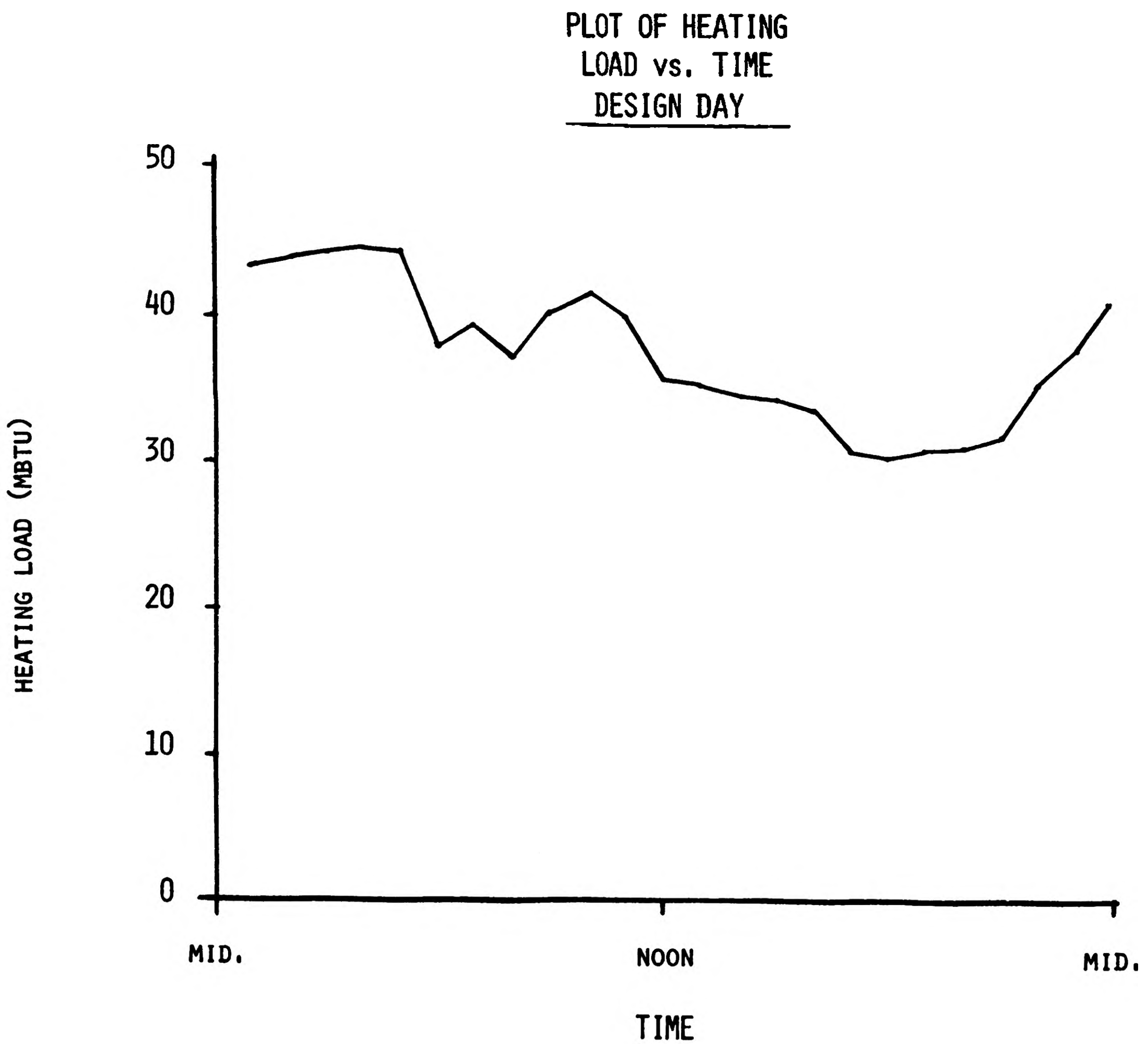

FIGURE 3

There are two ways of utilizing thermal storage with the heat pump. One is to utilize the heat pump in the conventional manner and supplement the output of the heat pump with heat energy from the storage system. This has the drawback of requiring a high temperature as the lower limit of the storage medium because 130°F would probably be the lowest acceptable temperature to maintain 75F. under design conditions. If water were used as the storage medium, this would limit the useful working temperature range of the storage to about 40°F. (170°F. to 130°F) and thus require a large storage tank to provide a 4 day carryover.

The other alternative is to use the water storage to increase the air temperature to the outdoor coil of the heat pump and let the pump raise the temperature to a useable level. In this way, the lower bound for the storage medium temperature becomes the point at which the heat pump can supply the home at design conditions. Figure 4 shows a capacity curve for a 3 1/2 ton heat pump (sized to meet the cooling load of the sample house) and locates the minimum operating temperature for the storage system. At 50°F outdoor coil conditions, the heat pump can supply the maximum heating requirements for the house with an input of 5.7 Kw. Therefore if the second method for supplementing the heat pump is chosen and water is again used as the storage medium, the working range of the storage can be expanded to 110°F. (170°F to 60°F) assuming a 10°F. approach temperature for the outdoor coil. Figures 5 and 6 show schematics of the energy flows for such a system. Above the balance point, the system would function as a conventional air to air heat pump shown in figure 5 extracting all

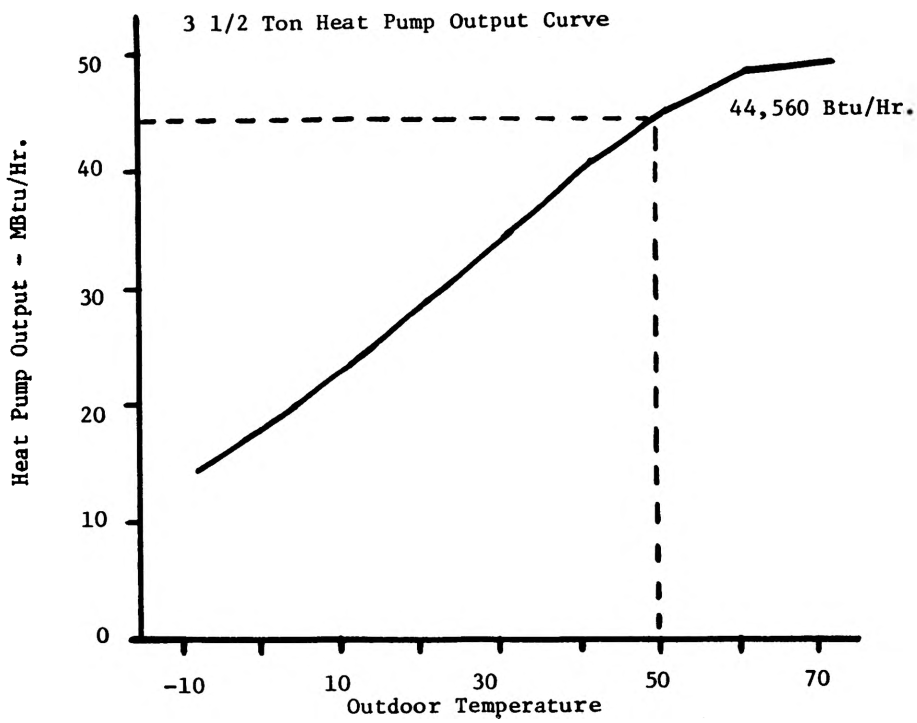

FIGURE 4

ABOVE BALANCE POINT SYSTEM DIAGRAM

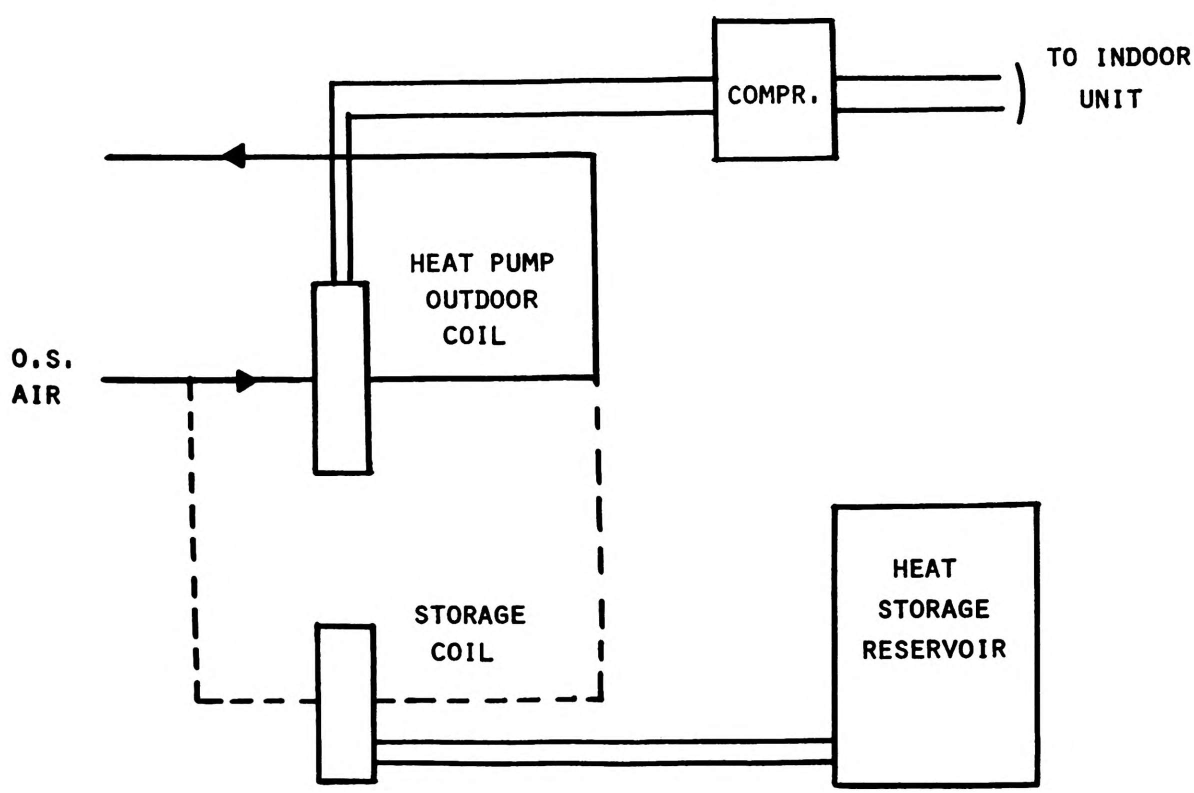

FIGURE 5

heating requirements from the outdoor air. When the temperature falls below the balance point, outdoor air would be shut off and the outdoor coil would receive constant 50°F. air from a closed-loop system with heat being supplied from the storage reservoir. This mode is shown in figure 6.

Since the heat pump is operating at an artificially fixed outdoor operating condition sized to meet the peak daily demand of the house, there will be some cycling of the unit. The actual daily load factor of the heat pump calculates to be 84% in this example which means that some direct replenishment of heat storage could be done during the day to furthur extend the capability of the storage.

STORAGE CAPACITY

Initially, one of the requirements established was the capability to function through a 4 day period of design weather conditions. Everything to this point has been on a daily basis so a multiplication factor of 4 must be added when sizing storage capability. Storage requirements can be calculated as follows:

Heat requirement/day	896.4 Mbtu
Heat from heat pump input	
5.7 Kw x 3410 Btu/Kw x 24 hrs x .84 div.	391.8 MBtu
Net required from storage/day	504.6 MBtu
Requirement for 4 days	2018.4 MBtu

This does not consider any replenishment of energy from those periods when the heat pump is off and resistance heat could be rebuilding heat storage. Again assuming water as the storage medium, the quantity of water requried for 4 days storage would be:

Temperature range of storage

170°F to 60°F = 110°F working range

BELOW BALANCE POINT

SYSTEM DIAGRAM

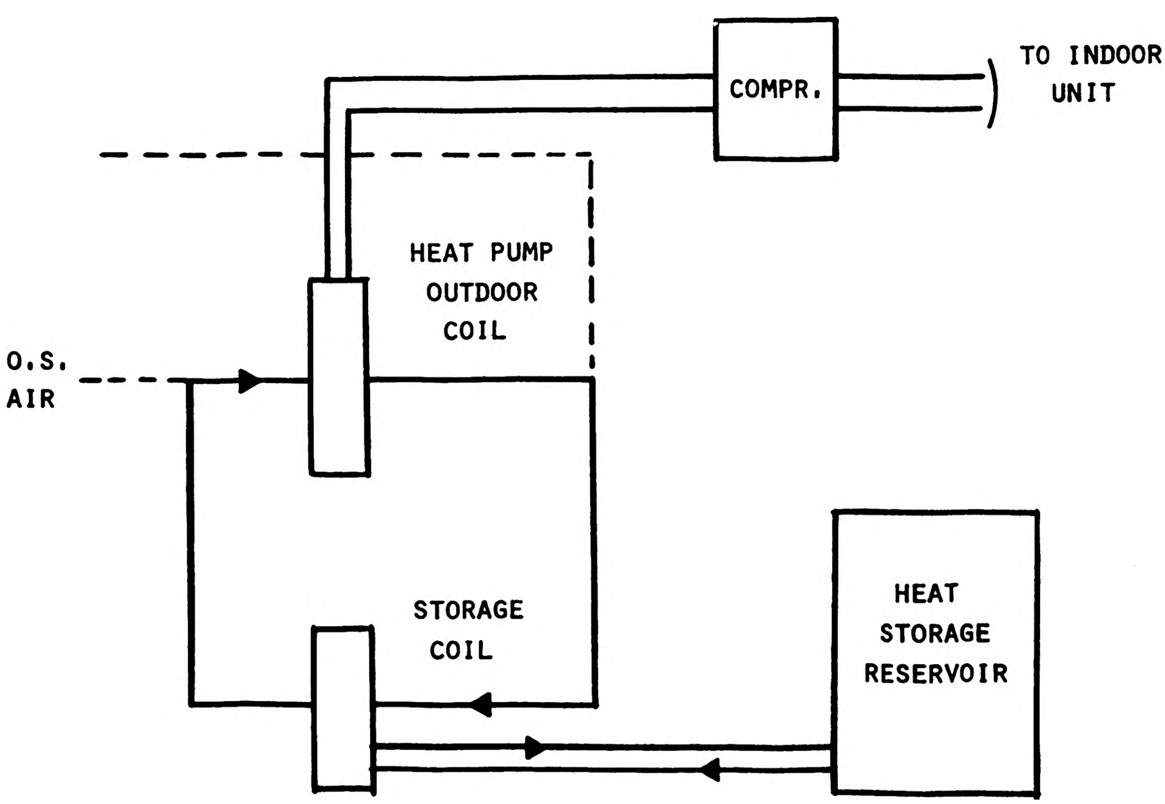

FIGURE 6

Storage per gallon

8.33#/gal x 110 Btu/# = 916.3 Btu/gal.

Total storage required

$$\frac{2018.4 \text{ MBtu} \times 10^3}{916.3 \text{ Btu/gal}} = 2200 \text{ gallons}$$

This quantity of water is not excessive in terms of volume required. It requires a space slightly larger than 6' x 6' x 8' to put such a storage tank in place.

CONCLUSIONS

All the foregoing is to illustrate the feasibility of such a system, and by no means does this paper explore all the avenues that such a system opens up. The question of what to supply the energy in the storage system is left open. If water is used as the storage medium, solar energy could be easily adapted to be the heat source. If solar energy were used as the source, then during mild periods of weather the complete heating of the house could be done with solar and furthur conserve energy. Solar along with resistance heat working into the storage tank controlled by a simple logic controller to look ahead at predicted temperatures could manage such a system to enable it to be used directly for heating in mild weather but build up the storage system for a predicted cold spell. All of these possibilities go beyond the intended scope of this paper.

At the outset, the possible problems associated with mass conversion to electric heating were discussed from a utility standpoint. If the petroleum based fuels become virtually extinct, these problems will arise and the only solution is an investment in money to solve that problem. The investment can be made by the electric utility in the form of added electrical generating equipment and larger power distribution systems or it can be made by the customer in a form such as described here where he purchases such a storage system. In the end, the objective is the same -- to provide heat capability for the homes in which we live. The end cost will also be borne by the same individual regardless of who makes the investment --- the cost will be paid by the ultimate user. It would appear that the lower over-all cost lies with the user investment.

Conclusions that can be drawn form the discussion contained within this paper are:

1. Increased levels of thermal insulation are re-required to make such a system as this feasible. In fact, high levels of insulation are necessary for any type of heating system.

2. The system described herein is possible with present day equipment.

3. The system described herein is applicable to be retro-fitted into existing heat pumps.

4. This system offers a viable way to work solar energy into a scheme whereby everyone can embrace it as economically sound including the electric utility. Using solar as a base heating system and supplementing with electric resistance as most solar concepts presently do are a financial disaster for the electric utility.