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Comparison of Heating Efficiency of a Heat Pump to Electric Heating Panels

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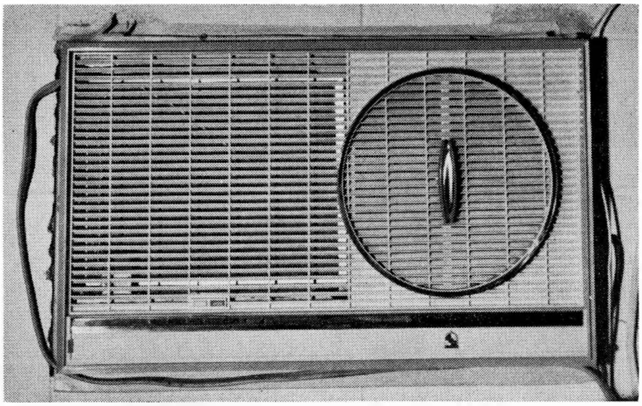
HEATS

COOLS

Comparison of Heating Efficiency of a

HEAT PUMP TO

ELECTRIC HEATING PANELS

AGRICULTURAL ENGINEERING DEPARTMENT
AGRICULTURAL EXPERIMENT STATION
SOUTH DAKOTA STATE COLLEGE, BROOKINGS

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Comparison of Heating Efficiency of a

HEAT PUMP

TO ELECTRIC HEATING PANELS

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and Dennis L. Moe, Head, Agricultural Engineering Department

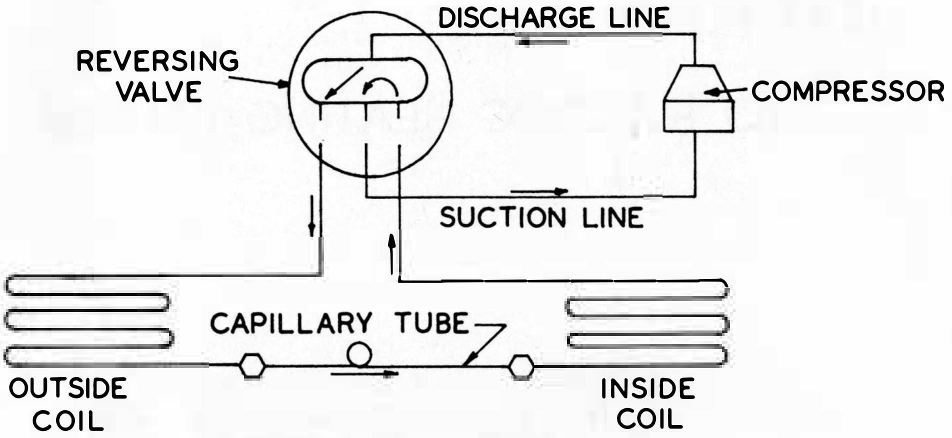
For many years engineers have known that heat exists in outdoor air down to approximately –460° F. and have attempted to devise a practical means to extract this energy for use indoors. Usually when an attempt has been made to extract this energy, the same basic mechanisms and devices have been utilized as those involved with present refrigeration; that is, a refrigerant liquid is made to boil by releasing the liquid from a high pressure to a lower pressure. As it boils the refrigerant absorbs the heat. The vaporized refrigerant is then compressed by a motor-driven compressor to a higher pressure and temperature, where it condenses back to a liquid. As it condenses, the refrigerant releases heat.

During the past few years several manufacturers have introduced to the market air conditioners which have the necessary controls to reverse the action to provide either heating or cooling. When controls are provided for either heating or cooling, the device is commonly called a heat pump.

A heat pump can provide more heat to the heated space than the electrical energy input under favorable operating conditions. The ratio of heat output to electrical energy input is commonly called the C.O.P. (coefficient of performance). For example, a C.O.P. of 1.5 means the heat output is 1.5 times the electrical input. The additional heat is extracted from outside air or other heat sources.

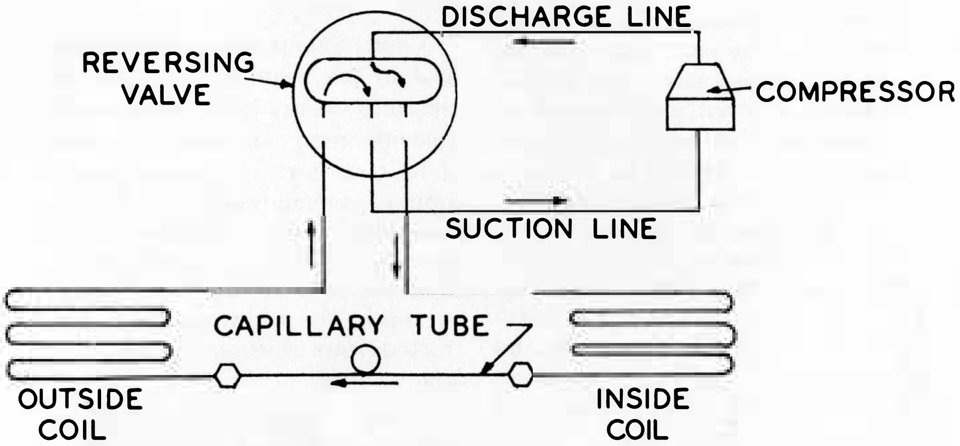
Figure 1 shows the path of the refrigerant through the reversing valve for the cooling cycle. Figure 2 shows the path of the refrigerant for the heating cycle. Built-in re-

HEAT PUMP



COOLING CYCLE

FIG. 1



HEATING CYCLE

FIG. 2

sistance heaters are commonly used to supply additional heat at colder outdoor temperatures.

Several questions may be raised about the practicability of the heating feature of a heat pump. Is the heat pump as economical to operate as the ordinary air conditioner and a separate heating system? What months during the year could the heat pump be operated to the best advantage? Could the heat pump supply all the heat requirements for South Dakota conditions?

Because there were so many unknown factors involved it was impossible to estimate the operating cost by calculation. Therefore, the purpose of this study was to compare the operating efficiency of a commercially available heat pump air conditioner (window model) with that of an electric heating panel under actual operating conditions in a single room.

PROCEDURE

Two methods of heating, heat pump and electric glass panel, were arranged through suitable controls and separate watt-hour meters to operate alternately, each for a 24-hour period. This gave approximately the same conditions for each method of heating during the period of this study. Switching from one heating method to the other was done each midnight, to correspond with official weather and temperature records.

Weather data were obtained from records kept by the Weather Engineering Station at South Dakota State College. The degree days used in this work were derived by taking the average of the high and low temperatures for the 24-hour period. A base of 65° F. was used to determine the heating degree days. Figure 3 shows the controls and separate meters used in the research.

Research was interrupted for the 1959-60 heating season. During the fall of 1959 the Agricultural Engineering Department moved to its new building. At this time the equipment being used for the heat pump research had to be moved from its original location to the new building.

Procedure for the 1960-61 heating season was generally the same as that for the 1958-59 work, except in 1960-61 the glass panel was used instead of the built-in resistance heaters in the pump.

DESCRIPTION OF EQUIPMENT

The electric heating panels were typical hard glass with the conducting element on the reverse side. In the first installation three 600-watt units were mounted on the outside wall under a window.

The heat pump air conditioner (window model) was typical in appearance and size. It was rated 1 horsepower with cooling capacity of approximately 9,100 BTU's at 40° F. outdoor temperature. Features differing from an ordinary air conditioner included:

(1) A reversing valve for the refrigerant, controlled by a thermostat in the unit, to switch from cooling to heating automatically.

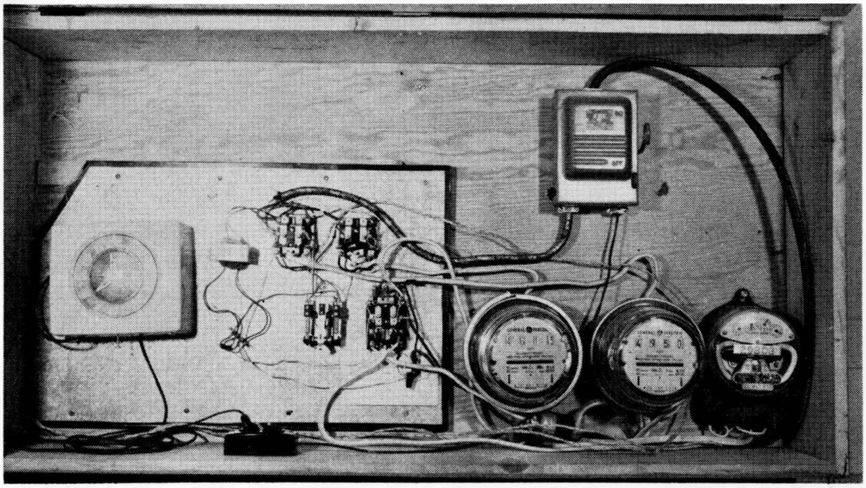


Figure 3. Control and watt-hour meters.

(2) A defrost control which automatically switched the unit to the air conditioning cycle temporarily to melt frost built up on the outdoor coil when the unit was heating.

(3) An outdoor thermostat which turned the compressor off when the outdoor temperature reached approximately 15° F. At the same time the thermostat turned on an 1,800-watt resistance heat unit which supplied heat as required by the room thermostat.

(4) A smaller 1,000-watt resistance heat unit, controlled by a fixed temperature thermostat that came on whenever room temperature fell below 70° F. The thermostat automatically disconnected the 1,000-watt heater when the room temperature rose above 74° F.

Later models by the same manufacturer omit the outdoor thermostat to turn off the compressormotor. They also omit the fixed temperature thermostat and 1,000-watt heater, but substitute one larger resistance heater which is allowed to come on if the heat pump does not maintain the temperature setting of the thermostat when the outdoor temperature is below 45° F.

Water produced in defrosting the outdoor coil is directed to the indoor side where a 200-watt resistance heater evaporates the water into the room. This has the effect of humidifying the indoor air. The amount evaporated into the room is least when outdoor temperatures are coldest and the need for humidification is greatest.

For purposes of the experiment, control of both types of heating was accomplished by a wall-mounted thermostat. This was partly to produce the same room temperature by both heating methods and partly to eliminate the continuous operation of the blower on the heat pump. Intermittent operation of the blower was not nearly as objectionable to the people in the room as continuous operation.

Equipment used during the 1960-61 heating season was the same as that used during the 1958-59 heating season except for a single 3,000-watt glass panel unit instead of the three 600-watt glass panels. Figure 4 shows the heat pump and glass panel used. For the 1960-61 season the resistance heating elements in the heat pump were disconnected. An outdoor thermostat switched operation from the heat pump to the glass panel at temperatures below 15° F.

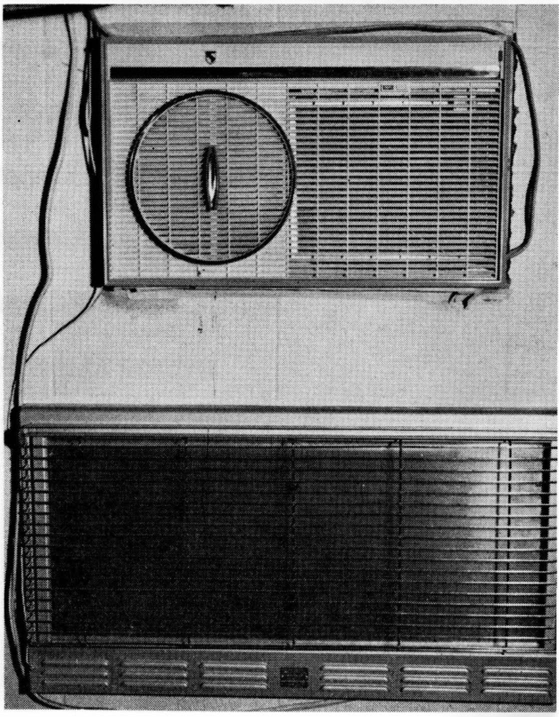
RESULTS

During the heating season for 1958-59 the two heating methods were able to produce comfortable living conditions in a single room at all times, even though the building (a relocated barracks building) was poorly constructed and not well insulated. The graph in figure 5 gives the average consumption in kilowatt-hours per degree day from the first part of March until November.

The graph in figure 6 gives the results of the research for the 1960-61 heating season. It shows the average consumption in kilowatt-hours per degree day to compare the two heating methods. In this graph you will note that for the heat pump method part of the bar indicates the amount of kilowatt-hours per degree day the heat pump used, and the other part the amount in kilowatt-hours per degree day the heat panel used to maintain the room temperature. The total of the two represents the kilowatt-hours used in comparison to those used by the glass panel alone.

The heat pump unit provided the heating requirements with less kilowatt-hours per degree day for March, April, and May. The glass panel alone was more efficient during the colder months of November, December, January, and February.

Figure 4. Heat pump (upper half) and electric glass panel (lower half).



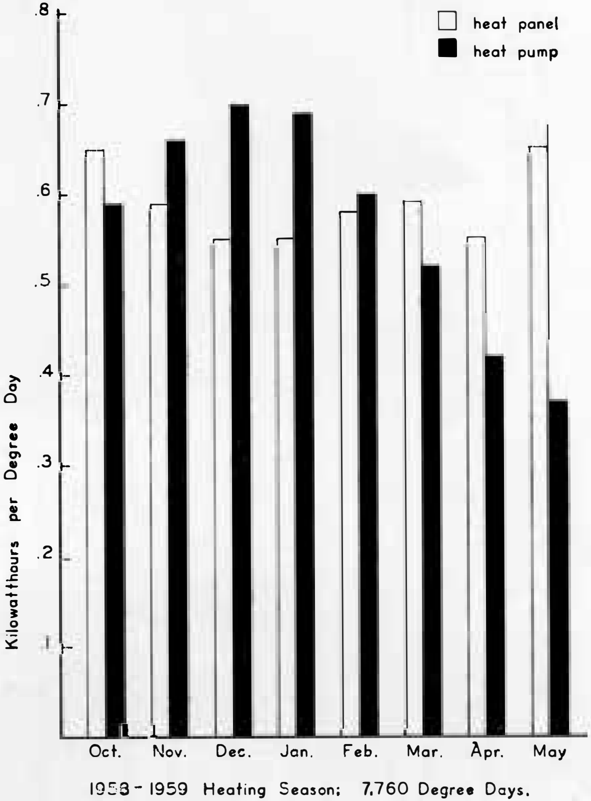


Figure 5. Efficiency comparison of heat pump and electric glass panels.

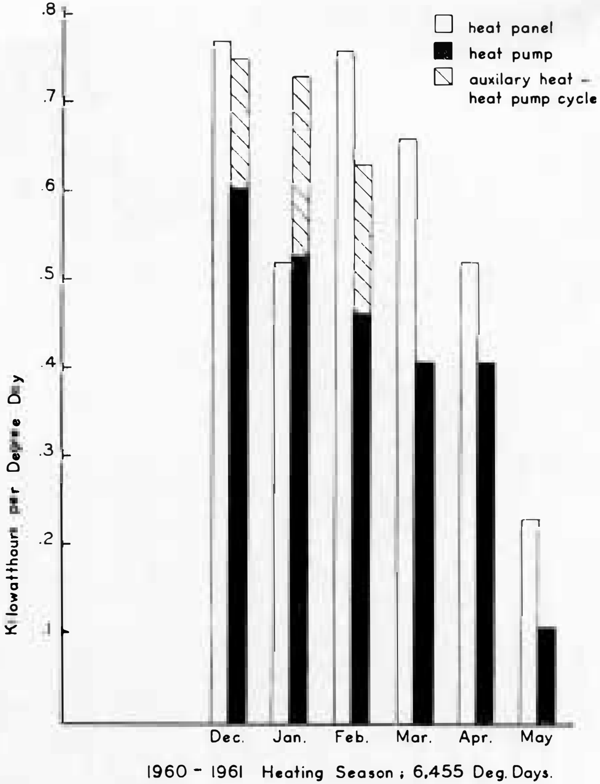


Figure 6. Efficiency comparison of heat pump and electric glass panels.

DISCUSSION

Results show that the heat pump is not as efficient as the electrical panel heating method during the cold winter season. This inefficiency would partly be explained by the fact that the blower and compressor motors on the heat pump are mounted in the outdoor air stream and the energy input to these motors is largely wasted. Also the coefficient of performance of the heat pump (amount of heat transferred per watt input) decreases as the temperature drops.

The heat pump was shut off at 15° F. when its coefficient of performance was theoretically equal to that for resistance heating. Data would seem to indicate that its coefficient of performance between the approximate temperature of 35° and 15° F. was poorer than that for the glass panel.

Results indicate a possible application of the heat pump unit in conjunction with another heating system—that is, either where resistance electric heating is already in use (using the heat pump on milder days) or where it is desired to shut down the central heating plant for a longer time during spring and fall. It would be expected that the only place where most persons would justify the cost would be where heating as well as cooling is desired. The heat pump model costs approximately 20 to 30% more than the model that does only cooling.

Heating as well as cooling may be desired during the months when hot days are followed by cool evenings. The heat pump is particularly convenient during the spring and fall when it is desirable to remove the chill without starting the central heating system. It can be used in summer cottages or cabins without any other source of heat. It can be used for added-on rooms, basement and attic rooms, and offices which cannot be fully accommodated or controlled accurately with existing heating systems.

CONCLUSIONS

(1) The glass heating panel was more efficient than the heat pump during the coldest months even though on milder days, above 15° F., it proved to be less efficient. For the two heating seasons studied the heat pump proved more efficient than the glass panels during the spring and fall.

(2) The heat pump unit used in this study proved to be quite dependable in operation and performed well according to its design and purpose. It appears that control by a wall-mounted thermostat may be desirable in some locations to eliminate the objection to the otherwise continuous blower noise.

(3) The heat pump air conditioner may find application in multiple occupancy buildings such as offices and apartments where central heating systems do not supply the varying temperatures desired in individual rooms.

(4) It can serve as a supplemental heat source in homes that have a central heating system.