AN EVALUATION OF THERMAL COMFORT AND ENERGY CONSUMPTION FOR RADIANT PANEL HEATING SYSTEM

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EXECUTIVE SUMMARY

Heat can be transferred in three ways - by conduction, convection, and radiation. Most conventional heating systems in U.S. housing are convective systems - thermal comfort is delivered by heating the indoor air which then conveys heat to objects and occupants. Thermal comfort is, however, determined as much by the radiant temperature as the ambient air temperature. Interior spaces can be heated with a radiant source in much the same way as the sun heats the earth. With radiant heating systems such as the ceiling, surface-mounted Enerjoy system in this study, there is potential for significant savings by warming objects and occupants and only indirectly heating the air. With fast-acting, radiant panels and thermostat control in each room, heat is supplied to the home in a manner similar to lighting.

A review of the literature revealed little relevant, empirical evidence for energy savings and thermal comfort associated with ceiling, surface-mounted radiant heating systems. Empirical studies used to discuss the energy and thermal comfort performance of radiant heating systems made little or no distinction among the various types of radiant heating systems. Since ceiling, surface mounted radiant panels in contrast to other radiant systems are fast-acting and deliver a much higher proportion of their output as radiant heat, they can have substantial impact on both energy and thermal comfort performance. Additionally, many studies were performed in commercial or light industrial buildings. The dimensions, building materials and design, and heat loss characteristics of these buildings can be very different than residential structures. Computer models used to hypothesize energy or thermal comfort performance were not equipped to accurately characterize radiant systems or transient heating conditions. Clearly, testing the energy and thermal comfort performance in an occupied home could serve to expand the base of information on which discussions of various heating strategies are based.

To this end, a radiant heating system, an air-to-air heat pump system, and a monitoring data acquisition system were installed in an occupied research home. Information on thermal comfort and energy consumption for alternating operation of the two heating systems was collected for approximately one-half of a heating season. This allowed comparison of the radiant system and the more conventional, air-to-air heat pump system. Also, data on energy consumption from a zoned, electric baseboard heating system previously installed in the same house was available for comparison.

Fast-acting, radiant heating systems that can recover quickly from setback and target the delivery of heat to objects and occupants have a significantly reduced installed capacity in comparison to more conventional heating systems. In this study, for the same system operating and outdoor design conditions, the installed capacity of the radiant heating system was **2.5 times less** than the electric baseboard system and **two times** less than that of the heat pump system. Generally comparable levels of thermal comfort were provided by the radiant and heat pump systems. And the capacity of the installed radiant heating system was sufficient to meet outdoor design conditions. As a result, the significantly reduced installed capacity of the radiant heating system should be of particular interest to utilities whose capacities are stressed or whose territories are experiencing rapid growth and development.

Energy consumption savings of 33% were estimated for a typical record year in the Washington, DC area for the radiant system in comparison to the air-to air heat pump system and an estimated 52% energy savings in comparison to the electric baseboard system. The energy consumption data indicated that the radiant heating system would outperform both the heat pump and the electric baseboard systems regardless of climate. Because a portion of the energy savings with the radiant heating system was related to room by room setback and the specific number and routines of the research home occupants, savings for

other households may be different than those obtained by this study. The magnitude of the savings obtained for the working couple occupying the research home suggests that energy savings would be obtainable in a great portion of U.S. households.

The energy savings demonstrated by the radiant heating system were the combined result of reduced parasitic losses, room zoning, quick recovery from setback, and heating for comfort at a lower air temperature. Both heating systems were operated for energy conservation with day and night setback strategies; the major difference being that heat pump operation was determined by state-of-the-art, programmable thermostat and radiant panel operation was occupant-controlled based on actual room occupation. Occupants of the monitored research home set room thermostats forward 8°F upon entering a room and returned the thermostat to setback upon exiting. In this way, the radiant system was operated like a lighting system with ambient background lighting in each room at all times and higher levels only activated when occupancy required. Achievement of local thermal comfort conditions in approximately ten to fifteen minutes and room wide conditions in approximately 45 minutes was confirmed by data analysis and acceptable to the occupants. Although not used in this field study, light or motion-sensitive thermostats would reduce occupant involvement in system operation and programmable thermostats would eliminate any transition period between setback and recovery conditions for occupants preferring more immediate and automatic system operation. The occupants of the test home preferred the radiant heating system over the forced-air system.

Specific operating characteristics of the radiant system discussed in the literature were also addressed in the field study. Some thermal discomfort experienced due to panel cycling could be addressed with careful radiant panel location and distribution or an energy management system that modulates panel status. Vertical air temperature differences were well within standard comfort limits and less than differences experienced during operation of the forced air system.

The energy savings demonstrated in this study indicate that fast-acting radiant systems have a role to play in increasing the energy efficiency of U.S. housing. The operation of a ceiling, surface-mounted radiant system in conjunction with ductless cooling or a cooling system with the air handler with the air handler and all ducts inside the conditioned space may provide a more efficient combination heating and cooling system for areas of the U.S. where more than task cooling is required. Several areas of research that deserve further investigation are outlined in the final section of this report.

This study was conducted by the NAHB Research Center, Inc. jointly for the U.S. Department of Energy (DOE) and SSHC, Inc., Solid State Heating Division of Old Saybrook, Connecticut.

It is our hope and belief that the results of this study will broaden the understanding of home heating options available to the U.S. home owners and, in the process, contribute to the greater energy efficiency of the U.S.

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