PRICIPLES OF RADIANT HOME HEATING

Understanding the differences between conduction, radiation and convection heat transfer is relatively easy. Understanding how they relate to each other in a radiant home heating situation is much more complex. To some degree conduction, radiation and convection exist in all types of home heating systems; however the proportions of each can be quite different from system to system. This difference in proportions will affect the comfort within the home and the efficiency (cost) for heating the home.

TYPES OF HEAT TRANSFER

Radiant heat is transmitted from a warm object to a cooler object through infrared radiation. The distance between objects, their surface area and their temperature difference affect the rate of the radiant heat exchange. A good example of radiant heat transfer is the way in which the sun warms the surface of planets in the solar system. Another example would be the way a radiant heater warms the surfaces inside a home.

When the distance between two solid objects of differing temperatures goes to zero and they come into direct contact, the heat exchange between them is then called conduction. Conduction between solid objects results in a faster rate of heat exchange than that of radiation. A good example of this difference is the amount of heat one would feel holding their hand just above a hot stove (radiation) versus actually touching the stove (conduction).

Heat transfer within solid objects is accomplished through conduction. The amount of heat applied to the surface of the object, the amount of mass (weight) the object has and the density of the mass (weight per unit volume) affect the rate of conduction within the solid object. For example, the higher density of soapstone allows it to absorb and radiate more heat per unit volume than common brick of a lower density.

Heat transfer within gases is quite different from heat transfer within solids. Gases have relatively little mass (weight) and very little density (weight per unit volume) when compared to solids. Unlike solids gases can dramatically expand or contract their density. Their density expands when they are heated and contracts when they are cooled. Warm gases that are expanded are lighter than cool gases that are contracted. The difference in weight causes warmer gases to rise and cool gases to fall creating movement within

the body of gas. This movement is called convection. The speed of the convection (movement) is largely determined by the how much and how quickly heat is introduced into the body of gas. For example, a 600 degree wood stove causes much more convection (air movement) than a 200 degree masonry heater in the same living area.

RELATIONSHIPS BETWEEN TYPES OF HEAT TRANSFER

Home heating systems employ some type of heated surface which is used to transfer heat into the home. The heated surface may take different forms and be in different locations.
For example:

1) Forced Air Furnace - located outside the primary living area with a heat exchanger that heats air which is then circulated via ducts to rooms in the primary living area. The air enters the primary living area from the duct work under pressure and is forced to return to the furnace through another set of ducts.
2) Hot Water Baseboard Furnace – located outside the primary living area with a heat exchanger that heats water which is then circulated via pipes to rooms in the primary living area. In the primary living area the heated water runs through a baseboard heat exchanger warming room air which then circulates by natural convection.
3) Electric Baseboard Heat – located in the primary living area with a heat exchanger that heats air which then circulates by natural convection.
4) Hot Water Radiator Furnace - located outside the primary living area with a heat exchanger that heats water which is then circulated via pipes to rooms in the primary living area. In the primary living area the heated water runs through a radiator. The radiator must have enough mass to store the heat from the incoming water. The heat in the radiator dissipates into the room through a combination of natural radiation and convection. The proportion of radiation versus convection is dependant on the size, design and location of the radiator in the room.
5) Hot Water Radiant Floor Furnace - located outside the primary living area with a heat exchanger that heats water which is then circulated via pipes to rooms in the primary living area. In the living area the heated water runs through a network of pipes imbedded in the floor giving up its heat to the mass of the floor. The floor gives up its heat

to the room largely through natural radiation and some conduction to the objects in direct contact with the floor. Convection from the floor is minimal in comparison to heat transfer by radiation and conduction.

6) Electric Radiant Floor Elements – located in the primary living area with heating elements embedded in the mass of the floor. The floor gives up its heat to the room largely through natural radiation and some conduction to the objects in direct contact with the floor. Convection from the floor is minimal in comparison to heat transfer by radiation and conduction.
7) Wood Stove – located in the primary living area a heat exchanger (firebox) heating relatively little thermal mass. The heat dissipates into the room mostly through natural convection and some through radiation. The proportion of radiation versus convection is dependant largely on the temperature which the stove is operated.
8) Masonry Heater – located in the primary living area with a heat exchanger (firebox) that heats its substantial thermal mass. The heat stored in the thermal mass dissipates into the room mostly through natural radiation and some through convection. The proportion of radiation versus convection is dependant on the size, design and location of the masonry heater in the room.

In the descriptions of home heating systems enumerated above I have given some general indication as to the proportions of the various heat transfer types for each system. I would now like to group these systems in some general proportional categories.

1) Convection - Forced Air Furnace, Hot Water Baseboard and Electric Baseboard heat predominately by convection.
2) Convection/Radiation – Wood Stoves heat predominately by convection with radiation accounting for a smaller amount.
3) Radiation – Hot Water Radiant Floors and Electric Radiant Floor Elements heat predominately by radiation with a small amount by convection and very little by convection.
4) Radiation/Convection – Hot Water Radiators and Masonry Heaters heat predominately by radiation with convection accounting for a smaller amount.

The common element that is present in category 3 and 4 heat systems and is missing in those of category 1 and 2 is the presence of significant thermal mass for heat storage. The thermal mass present in large radiators, floors and masonry heaters significantly lowers the temperature of the heated

surface area that transfers heat into the home. When these surface area temperatures stay in the 75 to 150 °F range heat transfer by radiation will predominate. Between 150 to 300 °F range heat transfer by radiation and convection will even out. Above 300 °F heat transfer by convection will predominate.

Next Article: The layered approach to radiant home heating.