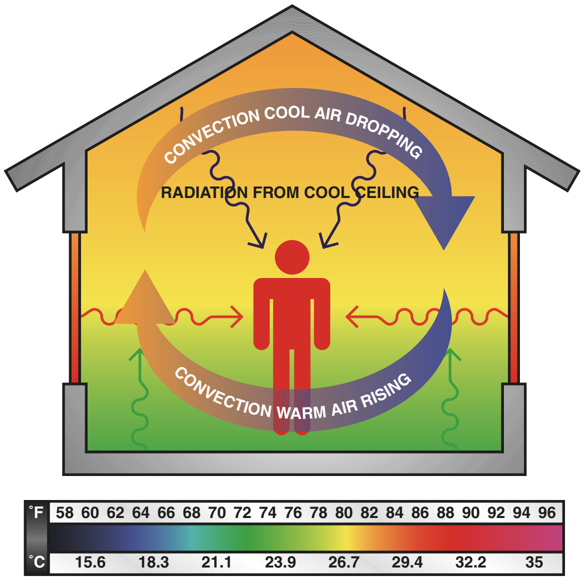
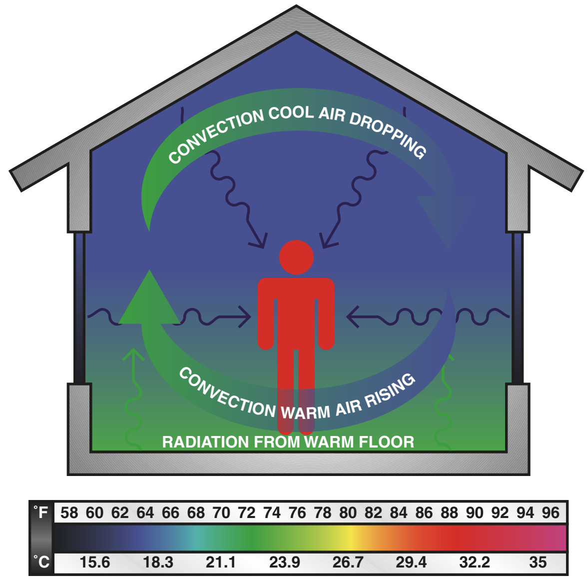
Summer Heat Conditions



Winter Heat Conditions



Most people equate comfort with air temperature and humidity level. In other words, they equate comfort with conditioned air. This can be a misconception. In fact, human comfort is affected by mean radiant temperature (MRT), air temperature, relative humidity, air movement, activity level, and clothing insulation. The first four are termed the environmental variables because they represent the surrounding environment that affects the body. The remaining two variables are directly controlled by the individual.

A number of occupant comfort studies find that human comfort factors are generally made up of: 50% radiation, 30% convection, and 20% evaporation. In other words, 50% of all thermal exchange between the environment and a human body is through a radiant heat transfer process. The human body is constantly exchanging radiant heat with all objects in view. The larger the view factor of the object, and the more intense the temperature difference between the human body's surface temperature and the object's temperature, the more profound the energy exchange. This can be easily understood when one is in direct view of the sun or a wood stove; one feels hot immediately. As well, the distance one is from the radiant source affects the intensity of this radiant heat exchange.

As referenced above, radiant energy exchange is conveniently gauged by the mean radiant temperature (MRT). The mean radiant temperature of a space is a measure of the combined effects of temperatures of surfaces in sight. It is actually the average temperature of all of the surfaces surrounding the person in question. In essence, all the surface temperatures of windows, walls, ceilings, floors, etc., are taken into consideration.

Mean radiant temperature also depends on one's position in the space. When a person moves closer to a warm window, the body's view angle of the warm window becomes larger, thus a higher MRT. Likewise, sitting near a large glass window that has a temperature of 60ºF, or lower, will lower the MRT significantly. Our body's surface (skin) temperature is about 90ºF to 92ºF, and radiates heat to cooler surfaces and receives heat from warmer surfaces. For maximum comfort, the body prefers to be surrounded with air and surface temperatures that average 74ºF. When air temperature and MRT are equal, our body loses as much of its excess heat through radiation to surrounding cooler surfaces, as it loses to surrounding air through convection. To maintain the same comfort level when MRT rises, the surrounding air must be cooler or vise versa.

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) has stated that MRT is equally as important as air temperature in providing comfort. In theory, with a change in MRT, there can be a corresponding change in air temperature in order to establish the same comfort. With all the other factors put aside, such as activity level, every 1ºF rise in MRT allows a decrement of 1.4ºF in air temperature for the same comfort level. However, it must be stated that not

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all people react to climatic and temperature conditions the same, and this is even more evident since not all people dress alike for warmth. Studies conducted by ASHRAE indicate that with radiant heating systems people can be comfortable at temperatures 6°F to 8°F lower than with forced-air and baseboard (convective) systems. Certainly one can argue that the same comfort can be provided by increasing the inside air temperature in an environment with a low MRT, but this is at the cost of using costly fuel to heat the air. With a thermally efficient building envelope, one can be assured of comfort, a high MRT in the occupied space, and low energy bills. Radiant floor heating can effectively raise the MRT in an enclosure.

Radiant versus Convective System

Forced-air and baseboard (whether electric or hot-water) heating systems are convective systems because they use air as the primary heat-transfer medium. Typically, heating outlets or baseboards are placed on outside walls, and the system is designed to fill the area with warm air until the preset temperature on the thermostat is reached. The warm air rises to the ceiling until it cools, falling to the floor for return to the furnace or to fill the convective vacuum created by a baseboard heater. Air stratification and heat loss to the ceiling are significant with convective heat. When super-heated air from a furnace or baseboard heater flows against relatively cold exterior walls, the increased temperature differential results in a stack effect that draws cold air into the house through any cracks. Air infiltration and exfiltration increase as the difference between inside and outside temperature (ΔT) becomes larger.

Hot air heating systems do not distribute heat where the body needs it most. Radiant heat does not heat air, it heat only objects (people and furnishings) to a comfortable temperature. With radiant systems, air-infiltration heat loss is reduced as air is only warmed to the temperature of the thermostat setting (which is usually lower to start with), so the temperature differential at the outside wall is less, thereby reducing air infiltration.

Although the radiant system only deals with sensible heat and not humidity control, humidification is usually unnecessary because radiant heat does not alter air moisture content, which is generally adequate if the air isn't dried out by combustion or by increased infiltration of cold, dry outside air.

Glass, particularly low-e glass, reflects long-wave radiance produced by radiant heating systems. This greenhouse effect serves to contain radiant energy within the heated building cavity, reducing heat loss.

Radiant Floor Heating Design considerations

A radiant floor heating system turns the entire floor surface into a low temperature radiator. Heat is provided by all three modes of heat transfer: conduction from direct contact with the floor, radiation from the floor and from other objects that re-radiate heat, and convection from air passing over the floor surface.

Install a separate zone for each room where temperature regulation is needed. Try to keep the amount of piping about the same for each zone. Since water in the piping will be warmest at the beginning and coolest toward the end of each zone, run the piping to the coldest part of the room first (usually along the window wall) to heat the space most efficiently.

When the piping is in the floor, the required temperature of the running water inside the piping depends on:

1. how well constructed the building is (i.e. the heat loss),
2. what the floor is made of (i.e. floor covering and material),
3. how close together the pipes are (i.e. pipe spacing), and
4. how deeply buried the piping is (i.e. pipe depth).

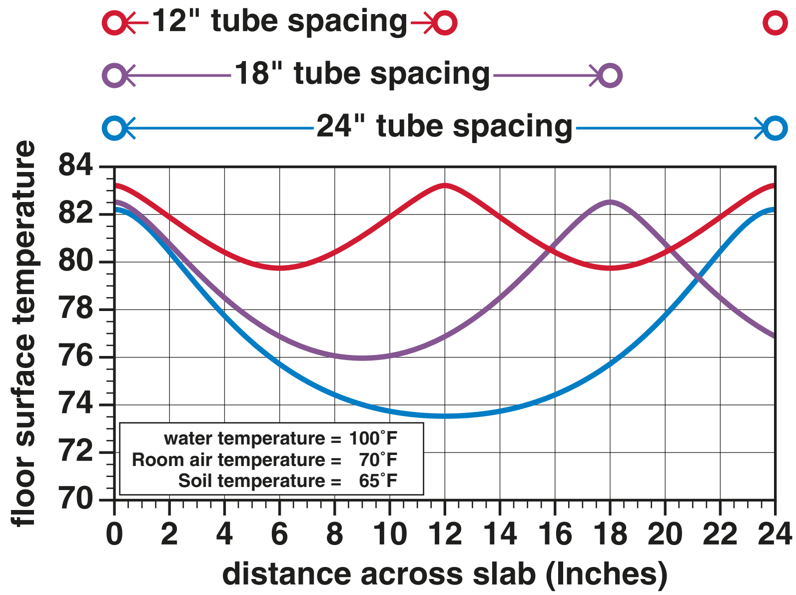
Radiant floor heating is a low temperature application. The water temperature running through the pipes is typically between 100°F and 150°F depending largely on whether the piping is in a slab or stapled under a wood floor, and whether or not the floor is covered with carpet or other insulating material. Floor surface temperatures are designed to remain at or below 88°F. Floor surface temperatures more than 88°F may be too warm for bare feet.

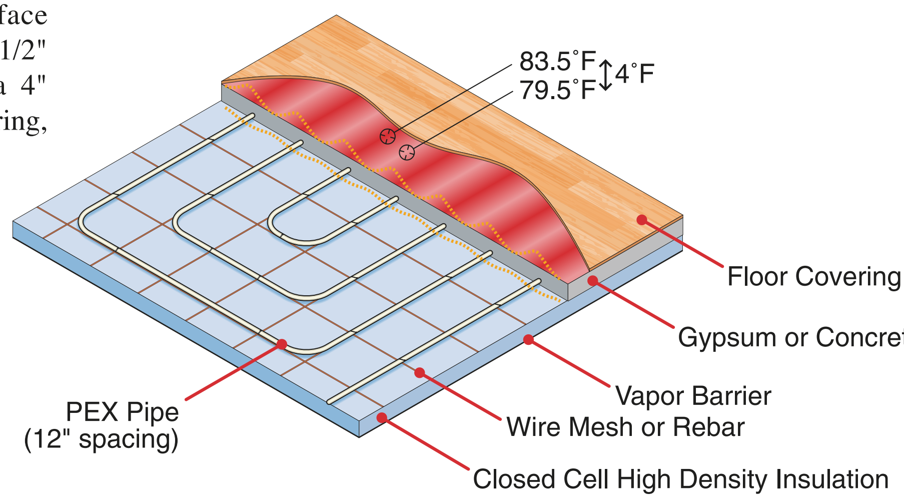
In general, the more the flooring material surrounds the piping, the lower the water temperature can be. In other words, if piping is buried in concrete, there will be more piping-to-floor contact than there will be if the piping is stapled to the underside of a wood floor. The result is that the water temperature can be lower when the piping is in concrete.

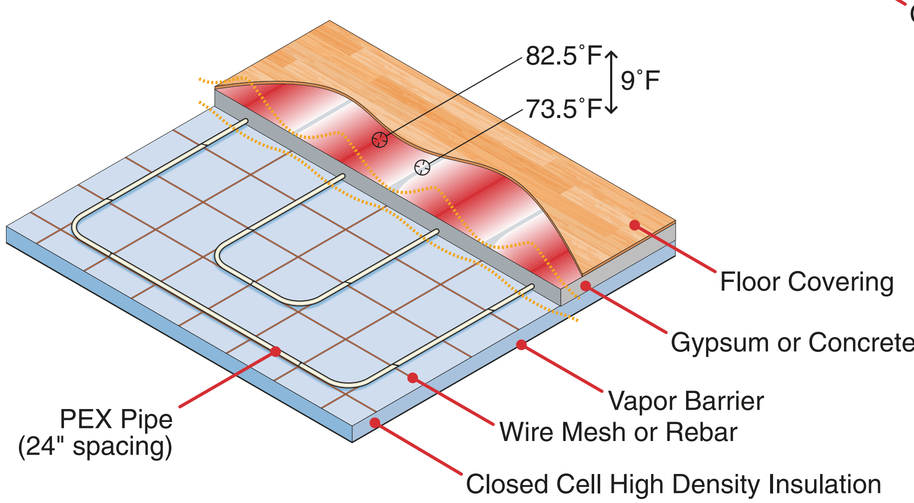
Floor covering (i.e. its thermal resistance R-Value) has direct impact on water temperature. Low R-Value floor coverings can conduct more heat than those of high R-Value. For a given heat loss, the smaller the R-Value of the floor covering, the lower the water temperature is necessary.

Pipe spacing depends on several factors, including the rate that heat must be released from the floor, average water temperature of the heating system, and the type of floor covering installed over the floor. It is worth noting that average floor surface temperature is inversely proportional to pipe spacing. The floor surface temperature difference between maximum and minimum is proportional to the pipe spacing.

Shown on right is the floor surface temperature profile for an array of 1/2" heating pipes, at 12" spacing, in a 4" concrete slab, covered with 3/8" flooring, and a 1" extruded polystyrene underside insulation. The soil temperature under the insulation was set at 65ºF. Room temperature was set at 70ºF.







Typical spacings for slab-on-grade jobs are 6" and 12" corresponding nicely to the 6" grid pattern of welded-wire reinforcing mesh. Closer 6" spacing is common near the edges of the slab where heat losses are greater, or in areas with lesser-thermal-resistance (R-Value) floor coverings, such as vinyl, hardwood or tile. For higher-thermal-resistance covering, such as carpet, 12" spacing is suggested. Other spacings, though possible, can complicate fastening the tubing to standard reinforcing wire. Combinations of spacing can sometimes be utilized within the same room. For instance, the beginning of the circuit may use 3" or 6" spacing (pending pipe size) near an exterior wall with a large area of windows, and then make a transition to 12" spacing after it has progressed 3' in from the wall.

In general,

- The closer the pipe spacing, the lower the water temperature required to offset a given heat loss.
- Floor coverings of small R-Value require closer pipe spacing directly above the piping to avoid noticeably warmer floors (e.g. tile as opposed to carpet).
- Pipe spacing can be used to change the average floor surface temperature by decreasing or increasing the spacing in the design phase.

The thermal output of a slab-on-grade radiant floor heating system depends on the depth of the piping within the slab. The deeper the piping is in the slab, the greater the upward resistance between the piping and the floor surface. The higher resistance increases the water temperature necessary for a given rate of heat output. In addition, the closer the piping is to the bottom of the slab—the greater the underside losses, both with and without underslab insulation. Furthermore, the further away the piping is from the surface of the slab, the bigger the thermal mass above it. The result is that the warm-up time in response to a call for heat is longer, as is the cooling time after the heat input is interrupted by system control.

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