WHY HYDRONIC POWERED RADIANT HEATING AND COOLING ARE A PERFECT MATCH FOR GREEN BUILDING CONSTRUCTION

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INTRODUCTION

Hydronic heating and cooling systems are considered the most efficient, greenest technology known to man for the efficient distribution of warmth and cooling; in other words, the ideal human comfort experience. For people who may not know what hydronics are, here's the definition:

Hydronics: *A means of transferring the energy required for heating and cooling buildings utilizing water as the primary medium in an effort to maintain good human comfort and conserve energy resources.*

And while we are in definition mode, allow me to introduce a couple of other terms that are critically important.

Comfort: *My definition of comfort is being in a state of wellbeing, or not being aware of your surroundings. In this state, you are not hot, nor are you cold. Your sinuses are not too dry, nor is it too humid, and there is not a lot of noise in the background associated with the delivery of comfort. In short, if you have to think about your physical condition, you are probably not comfortable. Simply stated, if you are truly comfortable, you will not be thinking about it.*

Mean Radiant Temperature: *Mean radiant temperature, or MRT for short, is one of those things that cannot (normally) be seen by the bare human eye, but is the primary dictator of excellent human comfort. By definition, MRT is the temperature of those solid items surrounding your body. When the MRT is high, human comfort is achieved with a lower air temperature. When the air temperature is high, good human comfort is achieved with a lower MRT. MRT can be seen using an infrared camera, but most people do not have access to this wonderful technology.*

Before I go into my dissertation, I want to quickly dispel a myth. People have been taught over the years that "heat rises." This statement in and of itself is incorrect. Hot fluids rise. Hot air or hot water rise because of their differences in buoyancy compared to cooler surrounding fluids. Radiant energy travels in all directions, through the path of least resistance, including in a downward direction. The best explanation for comparison purposes is to think of being outside on a cool winter day when the sun is shining brightly and you are standing next to a dark colored wall. Your body can sense the radiant energy surrounding your body, and your body feels warmer than it really is due to this exposure to a higher MRT. Another prime example is sitting next to a

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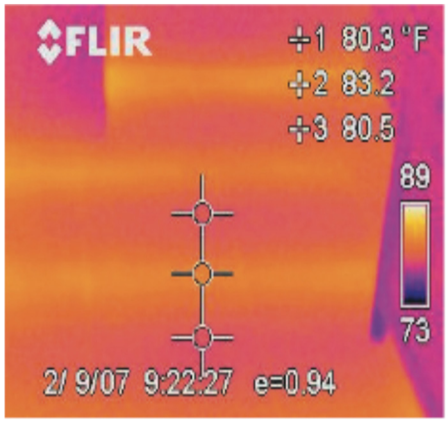
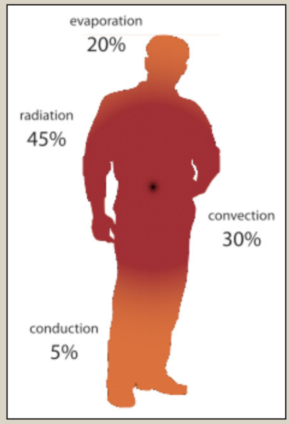


An infrared camera can be used to see the heat pattern created by the radiant floor. Temperatures are calabrated in colors, lighter colors being warmer than cooler colors. Note the chair on the right is much cooler than the floor.



campfire on a clear starlit night. Even though the ambient air temperature is low, your body can feel the radiation coming from the fire, and it feels warm and comforting on the side that is facing the fire. Your backside that is not facing the fire feels much cooler than the side that is facing the fire, so we rotate in an effort to even out this radiant exposure. If radiant energy only traveled upward, as in "heat rises," we would have to stand on top of the sun in order to realize any comfort due to radiant energy. As was already proved in our previous statement about MRT, such is not the case.

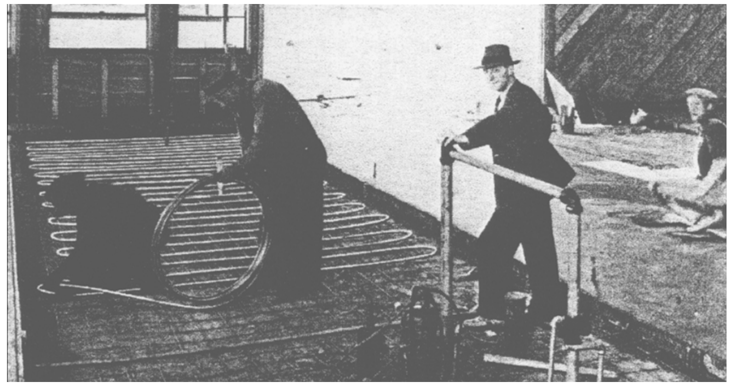
Controlling heat loss from our bodies by manipulating the MRT will guarantee that most people will be comfortable under all conditions. As can be seen from the above graphic, radiational losses account for nearly half of the human body's heat loss.

KEYWORDS

radiant heating, radiant cooling, occupant comfort, system efficiency, radiant walls, radiant ceilings

HISTORY

Radiant heating and cooling are not new technologies. They have been around for thousands of years. The Romans had public bathhouses that utilized this technology for heating the floors and walls. They used a series of tunnels that caused the smoke and heat from a wood fire to waft through these channels in the floors and walls, thereby raising the surface temperatures and MRT within the space, delivering an excellent, comforting experience to those who visited the bathhouse. Radiant energy travels from a warm surface to a less-warm surface. Mother nature despises any imbalances in temperature, pressures, and humidity. She will do everything in her power to create a perfect state of equilibrium. In other words, if



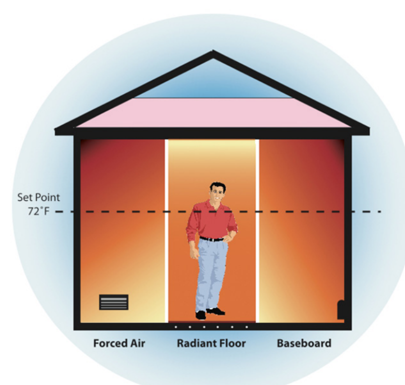
the ceiling is 85°F and the floor is 65°F, she wants to make these surfaces the average of 85 and 65, which is 75. This radiant energy will continue to bounce and reflect until she has achieved equilibrium.

The Koreans were one of the first societies to adopt this technology; it was known as Ondol and has been around for about 3,000 years according to Korean history. The first documented use of hydronics to provide this floor and wall warming experience was in late-1800s England using steam. It has been used in the United States since the early 1900s and, in fact, was incorporated into some housing projects on a major scale shortly after WWII by a builder who developed homes back east by the name of William J. Levitt.

World famous architect Frank Lloyd Wright was an early adopter of hydronic radiant heating systems. This is an example of one of his early homes that incorporated radiant floors using steel pipes into its design.

Shortly before the second World War broke out, most of our natural resources were dedicated to the war effort, and this is where forced air heating systems took position over hydronic-based systems. Sheet metal was readily available, but cast iron, steel, and copper—critical components in the construction of hydronic heating systems—were not, due to their being used to build the war machinery.

Here is a comparison of the temperatures associated with the two different types of systems.



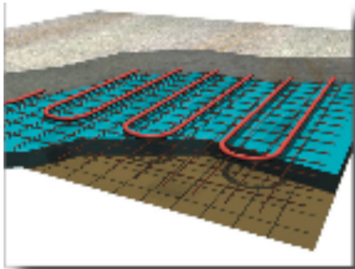
As you can see, with forced air and other convective (air-based) types of delivery systems, the hot air does rise, but with the radiant floor, very little air stratification occurs. This is due to the fact that radiant energy passes through air without heating it. It doesn't become sensible to us until it strikes a solid object, like our bodies, or surfaces surrounding our bodies.

There are numerous ways our bodies lose heat. We lose heat through convection, conduction, radiation, and evapotranspiration. Our skin temperature is roughly 85°F. The closer we can keep surrounding surface temperatures to our body temperature, the less heat our bodies give up through radiation, and the greater the comfort factor we achieve for a given circumstance. This is obviously governed by how much clothing we are wearing, the physical activity level being maintained, and the proximity of our bodies in relation to a cooler surface (think cold windows). These factors are all of the variables that we must control in order to deliver an excellent human comfort experience under all circumstances. Simply building a very energy efficient building does not guarantee a perfect comfort condition. It does go a long way toward achieving the goal of human comfort with minimal energy consumption, but it is still possible to have a very tight and energy efficient building with uncomfortable occupants inside. We need to learn how to build the buildings to satisfy the occupants inside based on MRT instead of satisfying the building itself to a particular temperature setting (68 to 72 degrees F). The only way to correctly manipulate and control the MRT within a space is by affecting large surface temperatures, not through the adjustment of air temperatures alone. This can be done with the use of hydronics, or through the use of electric heating cables and other electric heating (thin film and screen) elements. Obviously, electric cable systems will fall short when it comes to influencing the MRT during cooling demands.

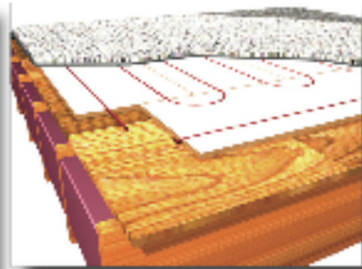
The piping materials that were used in the early applications of radiant floors were copper and steel. When properly and perfectly applied, these two materials have an unknown life expectancy. Unfortunately, these ideal conditions were rarely encountered in the construction environment and they subsequently failed at an early age.

As man moved forward in his effort to find a robust solution, the use of non-metallic pipes became apparent. Cross-linked polyethylene tubing, known as PEX, became the material of choice.

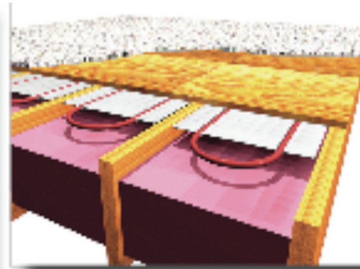
As can be seen in the accompanying picture, there are many different ways of applying radiant floors depending upon the method of construction being applied. I will explain each application, its features, benefits, and potential detractors.



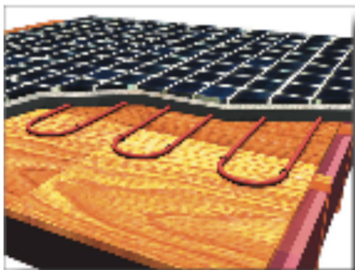
Slab-on-grade



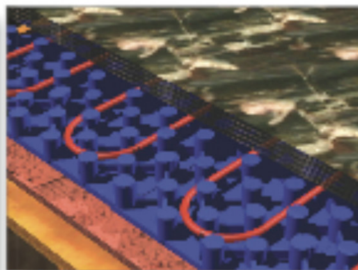
Floor panels



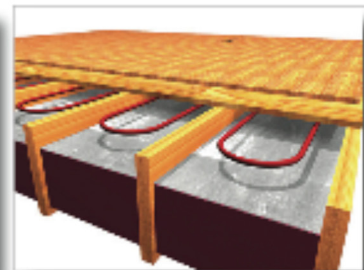
Staple-up plates



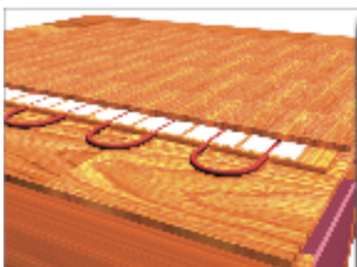
Thin-slab



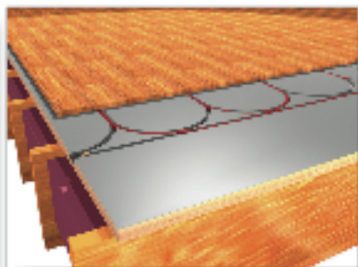
Grid panels



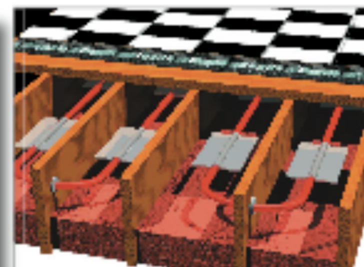
Staple-up or suspended



Sleepers with plates



Structural floor panel

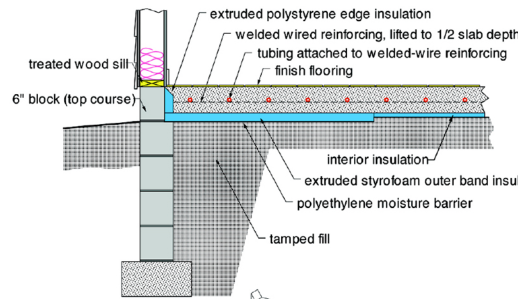


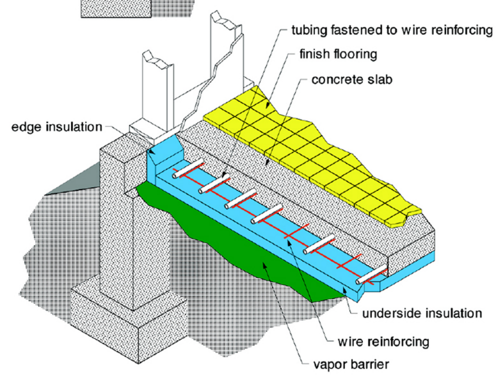
Convection fins

RADIANT FLOOR APPLICATIONS

Slab On Grade

This is the most cost-effective method of providing radiant floors because the only additional materials required are the wire reinforcement mesh used for holding the tubing in place, the PEX tubing, the distribution systems, and a heat source. Due to the use of concrete as the heat emitting surface, this system is very mass-intensive and has a tendency to be much more stable in temperature than some of the other less mass-intensive systems. This can be an advantage or a disadvantage depending upon the amount of anticipated solar gain. Some of the overshoot associated with solar gain can be accommodated with the use of sophisticated controls that monitor the potential of solar gains and adjust operating temperatures accordingly. The use of subfloor extruded polystyrene (XPS) insulation is a must in order to control the loss of energy into the soil below the slab, as well as controlling the side losses through the edges of the slab.





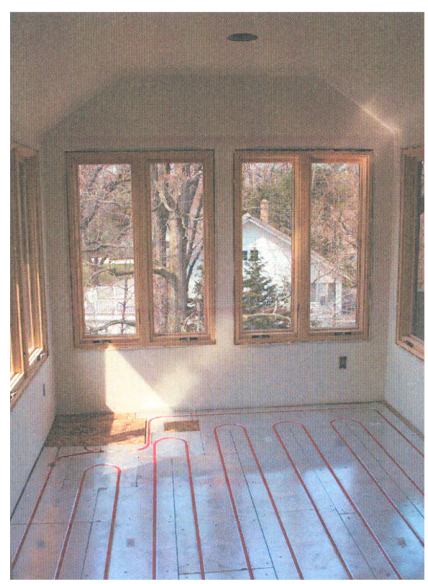
Advantages
Lowest first cost; lowest cost of operation due to the use of highly conductive cement; can be used for providing base cooling requirements; extremely stable temperatures due to flywheel mass effect of concrete; requires the lowest fluid temperatures to achieve excellent human comfort.

Disadvantage
Due to the inherent flywheel mass effect, if major solar gains or fluctuating internal (human or machines) gains are present (churches, office, and other places of quick assemblage), it may become difficult to control room temperature overshoot.

Detractor
High-mass systems are not conducive to deep set back temperatures and fast recovery periods. In a well-insulated home, the floors may not "feel" warm to the human touch, but will feel neutral. Cannot be retrofitted into existing slab applications. As with any radiant heating system, the use of properly placed and properly applied insulation is required to control the directional flow of heat, and avoid unwanted losses and or unwanted heat gains to adjoining spaces.

Floor Panel Systems
These systems are manufactured and engineered by numerous large tubing manufacturers. They can accommodate tube sizes from 3/8″ I.D. to 1/2″ I.D. They can be retrofitted into existing dwellings, and can also be incorporated into new construction.

Advantages
Can be retrofitted to existing dwellings; can also be applied to walls or ceilings when inadequate floor space is available; due to low mass, works well in areas with transient thermal gains.



Disadvantages
Will raise finished floor heights from 1 to 1½″, requiring adjustment to doors and stairs, as well as countertops; no significant thermal mass effect associated with their application.

Detractors
First cost is higher due to material and labor requirements; fluid temperatures may be mid-range depending upon final floor finish resistance values; may have some noise associated with heat up and cool down if no outdoor temperature compensating controls are used.

Staple Up Plates

Again, many respected tubing manufacturers provide this methodology of application. It is performed from below the finished floor, in the floor joist cavities. The tubing is installed, typically at an 8″ center to the bottom of the plywood subfloor. Then an aluminum heat transfer plate is placed over the tubing and stapled or screwed tight to the side of the tubing to create as much conductivity as possible to enhance the transfer of thermal energy from the insides of the plastic tubing, through the subfloor materials and eventually to the top side of the finished floors.

Advantages

Can be retrofitted to existing homes; does not require changes in floor elevations; can also be applied to walls and ceiling applications; due to low mass consideration, works well in areas with transient thermal gains.

Disadvantages

Higher first cost due to extra materials, increased tube center density, extra labor required for proper placement and securing of light aluminum heat transmission plates; can be extremely noisy if no outdoor reset control is used, or if allowances are not made for tubing expansion and contraction; requires a higher water temperature than some other methods in order to overcome the resistance values associated with the subfloor and finish floor materials and goods.

Detractors

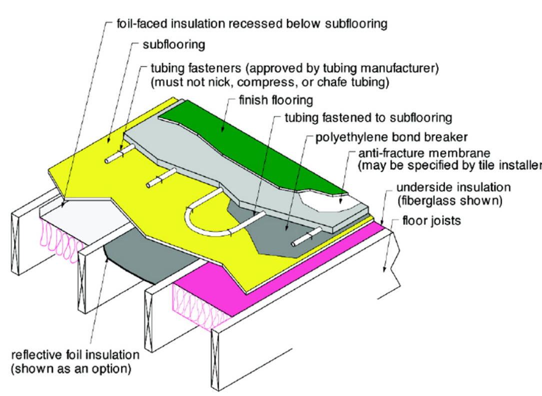
Requires a greater amount of labor in a difficult situation of access, thereby becoming more expensive than alternative methods of application; can be rather noisy if water temperatures are not well controlled using reset technologies; exposes potable water lines and other plumbing lines to a higher intensity of heat, causing evaporation of trap seals, and requiring a lot of water to be wasted in order to get a glass of cold water.

Thin Slab

Thin slab applications include the use of cementitious compounds that include a mixture of gypsum and cement (gypcrete) and lightweight (small aggregate) concrete compounds. While this method works best in new construction, where proper structural engineering can take into consideration the additional dead loads associated with the applications of the cementitious materials, in certain situations it can be applied to retrofit considerations.

Advantages

Is considered a medium-mass application, with most all of the advantages previously described for high-mass applications; also provides a good degree of noise and fire resistance to the construction assembly.



Disadvantages

Requires a second sole plate on all framed walls to compensate for the elevation changes associated with adding 1-1/2″ to 2″ of height to the floor; structural engineering must accommodate 12 to 15 pounds of additional dead load to the floor structure, requiring either deeper floor joists, shorter spans between support structures, or both.

Detractors

Sand, a major component of gypcrete, is not readily available in all geographic areas; shipping adds cost to the job if sand is not readily available; lightweight concrete requires the application of a bond breaker sheet to the subfloor before pouring, and also requires the use of expansion control joints to control and avoid cracking of the final finished flooring; both materials will require a crack isolation shield to be applied if hard tile goods are to be applied; depending upon the application, it can have some temperature overshoot issues due to the flywheel mass effect caused by transient solar and other thermal gains.

Grid Panels

Grid panels are a foam or plastic structure that accommodates the placement and securing of the plastic tubing on top of the floor. It is applied on top of the plywood or concrete subfloor, and requires placement of a hard surface over it to receive the final finished goods. There are some foam grid plate materials for applications in concrete-poured floor applications.

Advantages

Facilitates tubing placement and securing; in the case of concrete applications, also acts as the required insulation barrier to control the directional flow of energy.

Disadvantages

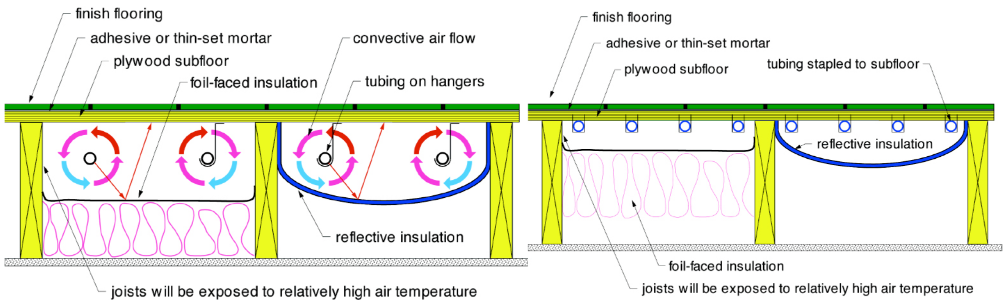
Will raise the finished floor height between 1″ and 2″ depending upon the application of finished goods; in retrofit, this will require adjustment of doors, counter tops and stair treads; the installation can be noisy if fluid temperatures are not controlled with outdoor reset; is difficult to apply hardwood floors due to lack of anchoring capabilities.

Detractors

Higher initial costs than some alternate methods.

Staple Up or Suspended Tube

This method of application requires the tubing to be installed below the plywood subfloor, typically at 8″ on center, or less depending up the energy needs of the building. In all of the previous methodologies, the application of insulation is pushed tight against the tubing. In this application, the insulation must be installed to maintain a consistent minimum 2″ air gap between the face of the insulation and the face of the sub floor to guarantee that the tubing has space to create convective currents, and a path for radiant heat transfer. This methodology depends on the three means of heat transfer in order to achieve its goal—conductive, convective, and radiant. If any one of these heat transfer methods is interrupted due to poor insulation placement, it would have a significant negative impact on the floor’s output.



Advantages

Lower perceived first cost due to menial (non-skilled) labor skill set required to perform installation.

Disadvantage

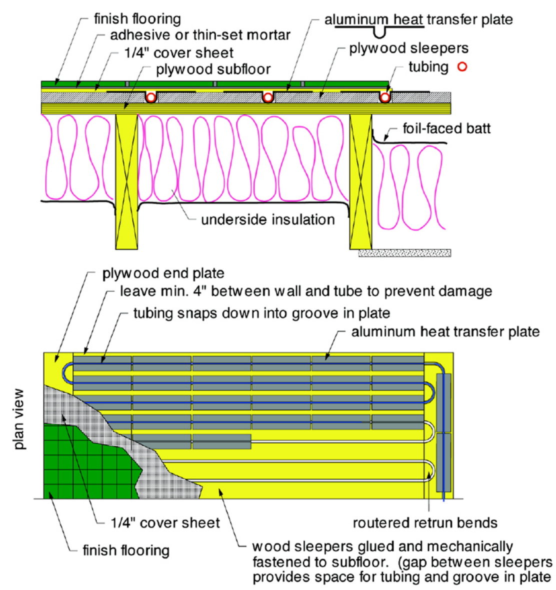
Requires highest fluid temperature in order to achieve comfort in conditions where heat load is high, and resistance values placed over the top of the floor are also high; can be extremely noisy due to high co-efficient of thermal expansion of unbound plastic tubing; requires exacting placement of insulation in order for it to perform correctly.

Detractors

This methodology is not usually compatible with water temperatures associated with alternative energy sources that are typically available at lower temperatures than other energy sources.

Sleepers with Plates

This method is mostly used in retrofit considerations, and is placed over the top of an existing floor. Tubing centers are dictated by the demand for energy and energy availability. Tubes can be installed anywhere between 6″ on center and 12″ on center. It is performed by placing 1-by wood planks on the floor, leaving approximately 1″ of space between the sides of the boards to allow for the placement of aluminum heat transmission plates and then tubing into these receivers. The heat transmission plates can be either the light aluminum flashing type, or the more conductive extruded aluminum type of plates. The heavier the heat transmission plate, the lower the required fluid temperature and the better the overall performance of the floor. A thin wood cover can then be placed over this assembly, and final finish flooring goods applied.



Advantages

It is conducive to retrofit considerations, or can be employed in new construction; is considered a low-mass, high-recovery rate system in applications with transient solar and other heat gain considerations; labor required for sleeper placement does not have to be skilled labor; can be used with lower temperature water than some other methods of application.

Disadvantages
Can be noisy if outdoor reset controls are not used; will raise finished floor height between 1 and 2 inches depending upon finished materials applied in retrofit applications.

Detractors
This is a labor- and material-intensive application, depending upon final finished flooring goods, and it may require higher water operating temperatures than other methods.

Structural Floor Panels

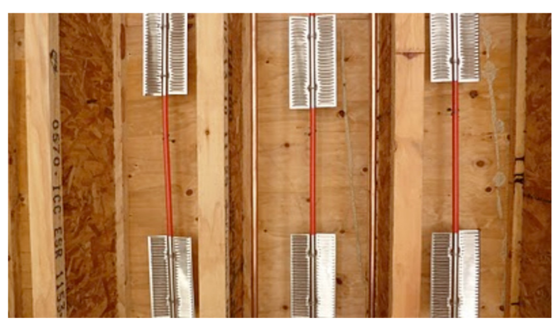
In this application, the materials are most conducive to new construction applications. The material is a 1⅛″ thick tongue and groove plywood with grooves routed into the wood at 12″ centers, and .025 aluminum glued and rolled into the preformed grooves. Tubing is then snapped into the grooves and covered with a thin board or finished flooring goods, depending upon the application. This system is considered a fast response system and is very conducive to quick recovery and or quick shut down for fast moving transient load conditions.

Advantages
The heat emitter is also the subfloor assembly; has the highest conductivity heat transfer characteristics of other wood flooring systems, meaning that it is perfectly compatible with alternative energy heating systems that typically have low fluid temperatures available at design conditions.

Disadvantages
Considered more expensive than other alternatives.

Detractors
Perceived first cost when compared to other cementitious suspended floor applications; when all other variables are taken into consideration, the net additional costs of this system are mitigated due to the much lower required water temperatures and associated efficiency of operation; minimal contribution to the advantageous flywheel mass effect.

Convection Fins



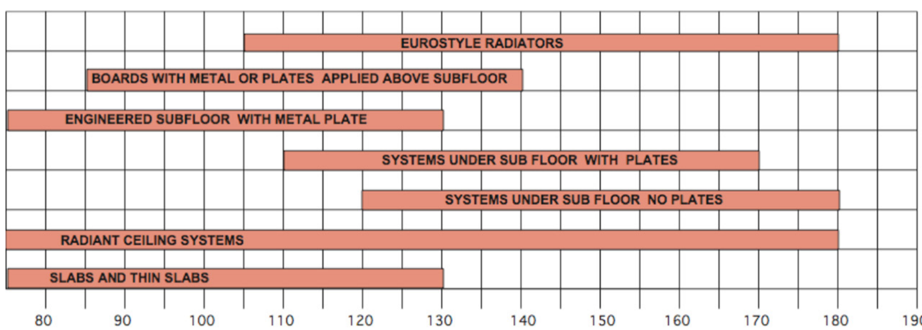
This is a system that is similar to the suspended tube or staple up installation except that it has aluminum fins placed over the fluid-conveying pipes to enhance the convective circulation patterns occurring within the floor joist bays. Like the suspended or staple up tubing application, its performance is very dependent upon a properly applied, properly installed (required consistent air gap) insulation. This system can be considered a fast recovery type of system; however, if it is needed in that capacity it will require a control logic that can be overridden if it is in a reset mode and the home needs recovered quickly.

Advantages
Lower perceived first cost due to menial (non-skilled) labor skill set required to perform installation.

Disadvantage
Requires highest fluid temperature in order to achieve comfort in conditions where heat load is high and resistance values placed over the top of the floor are also higher; can be extremely noisy due to high co-efficient of thermal expansion of unbound plastic tubing; requires exacting placement of insulation in order for it to perform correctly.

Detractors
This methodology is not compatible with alternative energy sources that are typically available at lower temperatures than other energy sources due to its higher required fluid operating temperatures (140 to 180°F).

Each of the above methods of applications has a required fluid operating temperature that runs between 85 and 180°F. The lower the required fluid operating temperature, the more efficient the heat source will be and the more compatible the system will be with alternative energy sources like solar thermal, ground source heat pumps, and air source heat pumps. The charts below show the various applications and their associated ranges of fluid temperature operation. This may limit your choices as it pertains to the selection of the radiant panel heating system.



TYPICAL SUPPLY WATER TEMPERATURE RANGE FOR DIFFERENT HYDRONIC RADIANT SYSTEMS.
NOTES:
Electric cable systems often operate in the same temperature range where applicable. These are typical operating ranges of these systems and intended for conceptual overview only. There are many possible exceptions! Hydronic ceiling systems with tubing typically operate in the lower range of temperatures shown for ceilings.

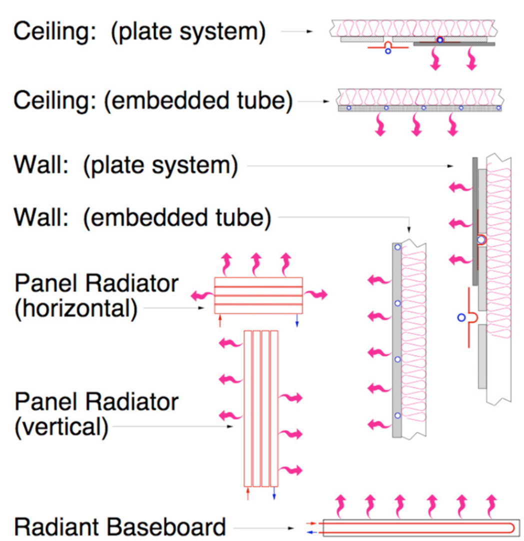
ENTER RADIANT WALLS AND CEILINGS . . .

It should be noted here that although radiant floors are in fact some of the most comfortable systems in the world, primarily due to the fact that our feet are in contact with the heat emitting surfaces, they also represent the most expensive method of heat delivery to maintain good human comfort. The truth of the matter is that radiant ceilings and radiant walls were more prevalent in new construction during the early 1900s than were radiant floors. In fact, in many cases, prior to the early 1900s, large, voluminous upright cast iron radiators manipulated the MRT. The placement of these radiators directly in front of windows was done in an effort to try and cancel the cold, heat robbing effect of the single pane glass windows. With the advent of high efficiency windows, the need for radiators directly in front was negated; and with the introduction of electrical-powered circulators, it became possible to have invisible radiators built into the ceilings and walls of the structure due to the use of small diameter tubes.

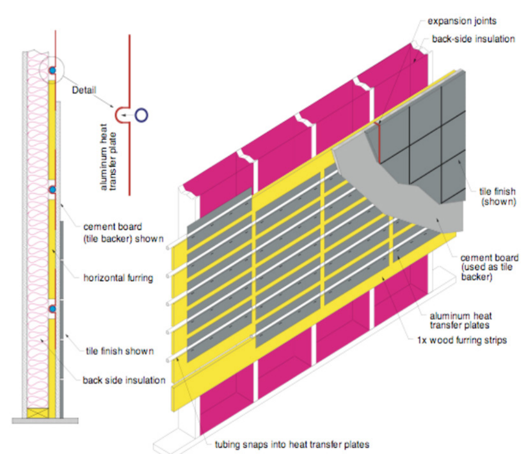
One distinct advantage of radiant walls and ceilings compared to radiant floors is the ability of ceilings and floors to put out more Btu per square foot than radiant floors can provide. Although this is a moot point when considered for use in low energy impact homes, it can provide more heat in highly glazed areas where floors are the primary source of heat. Radiant floors are limited to a maximum surface operating temperature of 85°F. That number should sound familiar because it is the typical skin temperature of an adult human being. This surface temperature limitation is not a physical limitation, but rather a human physiology limitation. If we have skin in contact with a surface greater than 85°F, our bodies think our core is going to overheat, and it quickly goes into the cooling mode known as evapotranspiration, or sweating.

With ceilings and walls, due to the fact that we are not in physical contact, they are capable of delivering more Btu per square foot than a typical radiant floor. Remember, thermal energy flows from warm to cool in an effort to average out the surface temperatures. This means that a radiant wall will warm both the ceiling and the floor in Mother Nature's effort to balance out all surface temperatures. In the case of radiant walls and ceilings, it is not necessary to cover every square foot of the ceiling or wall surface with heat-emitting panels; only the square footage required to counter the heat loss requirements of the space to keep the occupants comfortable and the MRT under control. This square footage is dependent upon the energy demand and supply temperature availability. The lower the demand, the lower the required supply water temperature.

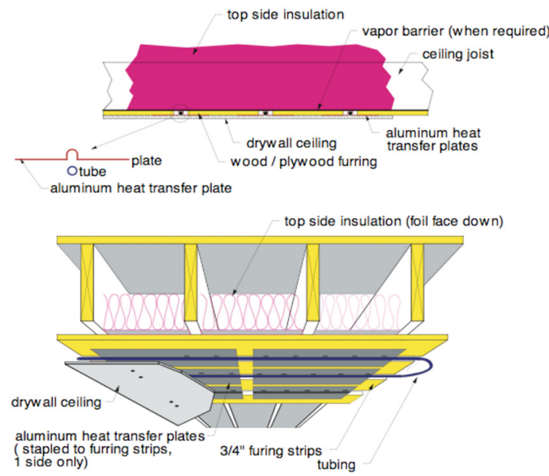
Here is a group photo of some of the possible alternatives to radiant floor heating applications.



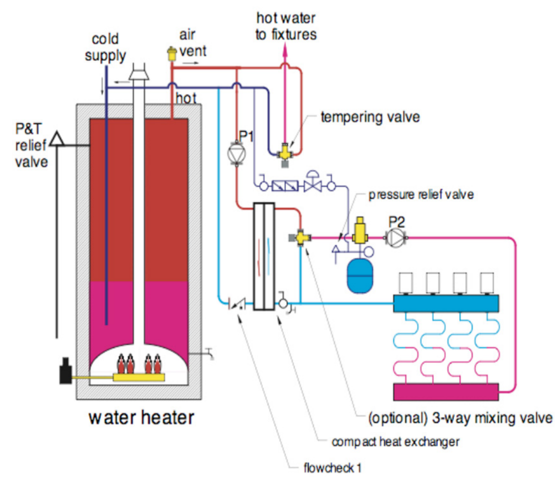
Below is a detailed example of a radiant wall warming application. These walls are typically only installed below the 4-foot level to avoid the possibility of a tube puncture due to a misplaced nail or screw for hanging a picture.



On the next page is a detailed picture of a radiant ceiling heating and cooling system. Radiant cooling has been effectively placed in radiant floors, but common sense again tells us that we can maintain a lower surface temperature from a ceiling with which we are not in contact than we can a floor with which we are in contact. In all cases, the cooling surface temperature must be controlled to keep it well above the dew point of the atmosphere for a given scenario. Also, it is virtually impossible for a radiant cooling system to address the need for humidity control, so a small air handling system for dehumidification will always be necessary; its size and the volume of air movement needed, however, will be significantly less than a cooling system that depends strictly upon an air moving system to deliver good comfort conditions. It should be noted that radiant cooling works exactly like radiant heating does, except on the opposite end of the comfort scale. As previously noted, by affecting the MRT, humans are more comfortable at a different air temperature than they are used to when using an air moving system. In heating, 68° air temperatures with a higher MRT "feels like" 72°F. Conversely, when controlling the MRT in the cooling mode, a corresponding air temperature of 76°F "feels like" 72°F, provided that good humidity controls are in place.



With many of the newer homes having extremely low natural air exchange rates, it becomes necessary to provide mechanically induced infiltration and exhaust from kitchen and bathrooms in order to maintain good comfort conditions. Comfort isn't only about heating and cooling. It's also about maintaining good indoor environmental air quality, and today's hydronic systems can handle these energy needs, as well as the largest energy demand imparted upon the home—domestic hot water (DHW). In fact, with today's low energy demand houses, it is entirely possible to set one high-efficiency combination heat source that will efficiently satisfy the family's DHW needs, as well and their hydronic radiant heating needs, and conditioning (warming and humidifying) of the incoming air for the required air-to-air energy recovery or heat recovery system. Here is a simple schematic showing how a DHW heater can do both DHW heating and space heating.



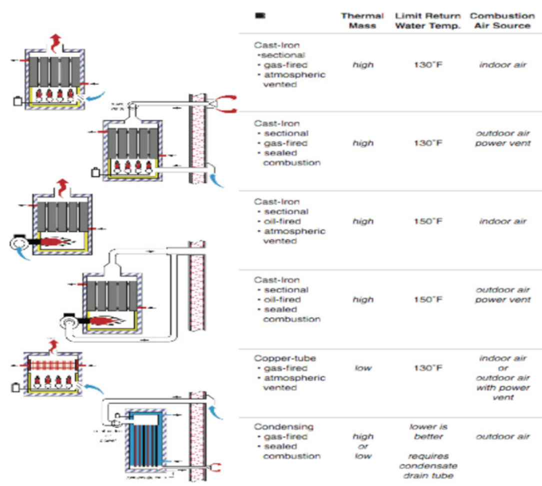
The efficiency of the heat source can be as high as 95 percent for both DHW and space heating needs. If the home has a substantially-sized solar photovoltaic array, the space heating, space cooling, and DHW preheating needs could be satisfied through the use of an electric-powered air source heat pump.

In addition to this basic heating and cooling source device, you would also need to install a DHW preheat tank, an electric DHW auxiliary heater, and possibly a solar thermal DHW preheat storage tank and collectors. There is a critical need to keep your final DHW storage tank temperatures above 130°F in order to avoid the possibility of creating a condition that will keep water borne bacteria (Legionelosis, or Legionaires disease) from amplifying and causing potential health issues related to these deadly diseases. One disadvantage of the air source heat pump is that when it gets extremely cold outside, the availability of energy from the air decreases and the efficiency of the heat pump also decreases to the point that it becomes uneconomical to operate. If this condition occurs, depending upon your location, it may be necessary to have an augmentation heat source, like a direct resistance water heating boiler to pick up where the heat pump leaves off. If you are in a conducive electrical metering application, the kilowatt hours used during the winter will be significantly offset during the summer months when solar PV production is the greatest, possibly allowing the consumer to achieve a net zero configuration.

HEATING AND COOLING SOURCES

In heating-only applications, gas-fired boilers can be provided that can create the temperatures necessary for any and all methods of distribution previously covered. Seasonal efficiencies (AFUE) vary between 84 and 96 percent, depending upon whether or not the appliance is extracting the latent heat from the flue gasses leaving the appliance, and the fluid temperature of operation at design condition.

There are also some combined heat and power units (CHP) that generate electricity as well as thermal energy. Some of these units are gas-powered reciprocating engine types, as well as hydrogen fuel cell generators. In order to maximize the output of these CHP units, the system needs to be configured such that both the thermal capacity and the electrical capacity are utilized, otherwise the heat source system efficiency will suffer significant reductions in performance.



	Thermal Mass	Limit Return Water Temp.	Combustion Air Source
Cast-Iron •sectional • gas-fired • atmospheric vented	high	130°F	indoor air
Cast-Iron • sectional • gas-fired • sealed combustion	high	130°F	outdoor air power vent
Cast-Iron • sectional • oil-fired • atmospheric vented	high	150°F	indoor air
Cast-Iron • sectional • oil-fired • sealed combustion	high	150°F	outdoor air power vent
Copper-tube • gas-fired • atmospheric vented	low	130°F	indoor air or outdoor air with power vent
Condensing • gas-fired • sealed combustion	high or low	lower is better requires condensate drain tube	outdoor air

There are some more expensive technologies that have proven themselves to be reliable over time. The most efficient method that uses conventional electricity is the ground source heat pump (GSHP).

These systems, when properly installed and configured, have electrical efficiencies approaching 200 to 300 percent. For each watt of electricity consumed, they can move 2 to 3 watts of low-grade earth energy to the surface for heating and cooling, hence the 200 to 300 percent efficiency claim. As previously noted, these units can provide DHW preheat, space heating needs as well as space cooling needs from one unit. These units are typically sized to the greatest connected thermal load, and are connected to a buffer tank to avoid short cycling during marginal calls for heating and or cooling. This buffer tank can also act as the DHW preheat tank, thereby saving floor space in the mechanical room.

These GSHP heating and cooling devices can be connected to open wells, closed-loop vertical bore holes, closed-loop horizontal loop fields, closed-loop large pits or mounds, closed-loop heat exchangers immersed in flowing lakes or ponds, and even streams, rivers, and oceans. Their cooling performance is usually quite high because they have a significantly large and efficient heat dump (Mother Earth). Ideally, the heating demand should closely match the cooling demand so that the source is always being discharged and recharged to avoid the possibility of exhausting either resource.

Recent advances have been made in the technology of air-to-water source heat pumps (ASHP), allowing them to be applied to these hydronic-based distribution systems. Unfortunately, due to the fact that they are using air as their energy source, their seasonal performance is not as high as a GSHP system, but the trade-off is one of initial costs.

The cost of drilling bore holes or other alternative methods for sourcing the energy for a GSHP system is not inexpensive. The seasonal efficiency of the ASHP typically runs a coefficient of performance of between 1.5:1 to 2.5:1, making them 150 to 250 percent efficient. Again, due to the fact that they are extracting heat from potentially extremely cold air during the heating demands, and pushing heat into potentially hot air during cooling mode, their efficiencies during peak load conditions may suffer. As previously mentioned, with the appropriate solar PV application, the electrical energy used during the heating season may be significantly offset with electricity produced during the summer months.

As you can see from this presentation, there are many choices to be made in the process of developing a good comfort delivery system for any given application. As with many products, there is a good, better, and best option, and if the consumer is looking for the ultimate ultra-high efficiency radiant heating system, it will have a higher installed cost than some of the lesser alternatives—but will also have the lowest operating cost of a lesser expensive system. It is possible to come up with a combination of systems, placing radiant floors in those spaces that really demand it (bathrooms, dressing rooms, highly glazed areas, etc.) and a combination of other radiant heat-emitting surfaces being used in other spaces (radiant ceilings in a bedroom, for example). A good consumer is an educated consumer. When the consumer understands his options, he can make better-informed decisions about what type of system he wants installed.

Although the installation of radiant heating surfaces can be done by anyone with a high degree of construction skills, it is extremely important that the system be properly designed from the beginning. This requires that a heating and cooling loss calculation be performed. Once that has been performed and a decision has been made in regard to the final finish goods to be placed on the radiant heat emitting surfaces, as well as what the heat source is going to be, the tube center density can then be determined, along with the fluid temperature and required flow rate in order to guarantee proper performance when the comfort delivery system is exposed to "design conditions." This will require the use of a qualified system designer. If you choose to use one of the Internet providers of these services, make certain that you do a good job of due diligence, checking their references and making certain that they really do know what they are doing.

The Radiant Professionals Alliance is in the process of developing a Designer/Installers Certification program that will have American National Standards Institute (ANSI) approval. Members of the RPA have many years of experience in designing and installing all of these excellent comfort delivery systems. We also offer many courses for designers and installers for people who are considering going the "Do It Yourself" route. For more information, contact us at www.radiantprofessionalsalliance.org