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Being Radiant



Planning in-slab hydronic heating and cooling

by Ryan Westlund

Photo © Tim Griffith

HYDRONIC RADIANT HEATING AND COOLING SYSTEMS SIGNIFICANTLY REDUCE ENERGY CONSUMPTION IN THE BUILT ENVIRONMENT. MANY OF THE WORLD'S MOST EFFICIENT COMMERCIAL BUILDINGS RELY ON THE COUPLING OF RADIANT AND FORCED AIR SYSTEMS TO ACHIEVE ENERGY PERFORMANCE TARGETS.

In-slab hydronic radiant assemblies, along with downsized forced-air systems, are gaining popularity as a means of optimizing thermal comfort while lowering energy use. Typically designed in conjunction, radiant cooling systems circulate colder water through the same network of pipes where

warmer water circulates during the heating season. This network of pipes can turn the floors, walls, and ceilings of a conditioned space into cooled surfaces that evenly absorb heat energy.

Radiant systems are ideally suited to a broad range of commercial applications and achieve best results when combined with other energy-efficient solutions in tight building structures. While radiant heating-only systems have a long history in conditioning both commercial and residential structures, radiant cooling is fairly new to North America. Early adopters of these systems were located primarily in arid regions. Mainstream acceptance required the development of more advanced controls, coupled with compelling evidence of reduced energy



Specifiers integrated the engineering functionality of an exposed concrete radiant-cooled ceiling with the architectural vision of exposed ductwork and drop lighting to provide a collaborative feel within the interior space at Earth Rangers Centre (ERC) in Woodbridge, Ontario.

Photo courtesy Klimatrol Environmental Systems

consumption for the built environment.

A recent study by the New Buildings Institute found nearly half of the zero-energy buildings in the United States incorporate radiant systems to meet their energy goals.¹ The study also notes the radiant systems in these buildings are integrated with ground-source heat pumps (GSHPs) to achieve zero energy as part of a cost-effective package.

Radiant systems operate at a relatively low temperature in heating mode, and are able to run in some of the most efficient ranges of a GSHP. Likewise in cooling, the moderately cooled water is a far cry from chiller temperatures, further saving energy when heating and cooling a space.

Real-world coordination trumps simulations

There is a school of thought that recommends in-depth building simulations in order to design an effective radiant project. However, one should be wary of these recommendations. In contrast, radiant professionals have learned from practical experience radiant systems are highly forgiving and robust in nature.

Although oversimplification of radiant design may be equally dangerous, shying away from a technology because an EnergyPlus building simulation model is not being performed may be too rash. Of all things specifiers and designers can bring to the table when incorporating a radiant system into a project, a thorough simulation may be the least important. Understanding how differ-

ent trades can work together to plan and implement a successful radiant slab project is much more crucial. This coordination can go much further in propelling a successful design.

There are numerous manufacturers in the radiant industry that can help move projects forward. They offer design services for the radiant piping layouts, engineering consultation, and training for designers and installers. While radiant may not become as simple as specifying a rooftop unit any time soon, there are some project basics that, if discussed early in the process, can go a long way toward keeping a project on track in terms of timing and performance.

A reasonable estimate of achievable capacity

Questions to ask regarding the capacity achievable in heating and cooling modes include how much is required, and whether the space needs 75 W/m^2 (23.8 Btu/h/sf) or twice that?

Radiant systems have finite capacities based on other parameters such as floor construction and covering, so it is important to have a conversation with manufacturers early on to ensure expectations are reasonable. It is useful to understand radiant floor heating systems typically have two to three times more capacity in heating mode than in cooling mode and can be more forgiving with a wider range of possible fluid temperatures.

Desired floor coverings and the impact on system capacity

Floorcoverings are an important design element to architects and owners. A radiant designer's 'perfect' polished concrete floor covering may not be suited for the aesthetics of the space. This can be especially true for residential projects where architectural trends have often included coverings with high thermal resistances, such as carpet pads or hardwood. Even in commercial spaces, specifiers should be wary as thin commercial-grade carpet can reduce a system's capacities by as much as 30 percent.

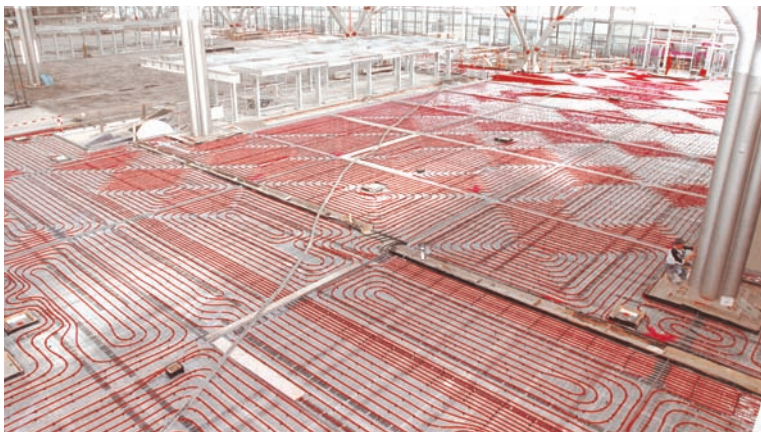
Beyond high R-values, some floorcoverings pose additional risks. It is necessary to review research demonstrating under what conditions, if any, a particular finish may be used with radiant cooling slabs. Radiant cooling is neither typically recommended with hardwood flooring, nor compatible with radiant floor panels.

Especially with dry panel systems and floating floors, there is a lack of research to prove beyond a reasonable doubt highly concentrated localized pockets of humid air cannot be trapped below the



These images show the radiant pipe layout at the Stuttgart Airport

Photos courtesy REHAU



floor. The combination of moisture, wood, and darkness is a recipe insurance brokers would probably advise against.

A well-formulated radiant schedule will clearly call out the thermal resistance of each area's floorcovering. Thermal resistances of different flooring materials can be referenced from the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) *Fundamentals Handbook* and the Radiant Professionals Alliance (RPA).

The radiant schedule should have input from everyone who will be involved in realizing the project—from the installer to the architect. The various aspects of a radiant design will have different levels of significance to each member of the design team. Having the input of multiple trades will help avoid last-minute scrambling when it is time to pour the concrete.

Specified air setpoint temperatures

It is important to keep in mind radiant systems should be operated with higher space setpoint temperatures in cooling mode and lower in heating mode than traditionally conditioned spaces (*i.e.* 100 percent forced-air systems). Since radiant systems directly manipulate the mean radiant

temperature, air setpoints should be adjusted to compensate and maintain the same thermal comfort.

This means in cooling mode, air setpoints should be no less than 24 C (75 F); in heating mode, they should typically be at 20 C (68 F). While these ranges deviate from standard forced-air design practice, the addition of a radiant system maintains thermal comfort.²

Realistic locations for manifolds

In a radiant design, it is important for specifiers to agree on suitable manifold locations to balance the distribution of fluid to the various zones being served. Concerns from architects may include the visibility, or in some cases, accessibility (*i.e.* classrooms with access at a student's level), of the cabinets. Concurrently, engineers are tasked with providing distribution piping and pumping schematics to provide adequate flow to these manifolds. The essential question, 'Is the number of manifolds sufficient for the space?', is often neglected until the project reaches the desk of the designer tasked with drawing circuit layouts.

Radiant circuits in a typical heating-only project are spaced 152 to 305 mm (6 to 12 in.), resulting in typical maximum circuit lengths covering no more than 14 to 28 m² (150 to 300 sf). Radiant cooling systems are almost always spaced at 150 mm, and therefore yield radiant areas closer to 14 m² (150 sf).

Another frequently overlooked question is whether the manifolds are centrally located within the space, or isolated, for example, at the end of a long hallway. If the number of circuits is chosen solely on the zone's area, there may be issues with the supply and return to the furthest extent of a zone. In other words, the radiant designer will run into difficulties reaching the end of the hall and returning to the manifold if the distance is greater than 46 to 61 m (150 to 200 ft).

A tell-tale sign of this problem is final shop drawings with a maximum loop pressure differential substantially greater than other circuits. Although this design can be achieved



Although designs of two of the latest buildings on Infosys' campus near Hyderabad, India may look the same, one has a leg up in energy efficiency with its radiant heating and cooling system. Integrated early into the project's design, radiant cooling helps the building maintain increased thermal comfort with a one-third reduction in energy consumption.

Photo courtesy Infosys Limited

with a sufficient pipe diameter and reasonable temperature drop (or gain when operated in cooling mode), these situations tend to result in frustrating discussions and unexpected costs, since the circulating pumps may be sized for a lower head loss.

One of the many reasons radiant systems are increasingly specified is the flexibility many hydronic manifolds have to serve multiple zones. Unfortunately, if manifold locations are not coordinated with realistic understanding of the path where the circuit tails need to be routed, there can be issues.

Many times, based on structural walls, the most effective way to route tails to circuits filling an exterior zone is back to a manifold centrally located in a hallway. In this case, as shown in Figure 1, the interior hallway has lost its original intention of being a separate zone. Revisions to this design were likely needed to rectify the situation, resulting in added manifold locations, distribution piping, and possibly even pumping selection.

A strategy for mitigating condensation risk
Condensation is a fairly straightforward phenomenon. If a surface is colder than the dewpoint temperature, water condenses on the cool surface. Although this is desirable for a fan-coil when trying to remove latent energy from the space, it is not so desirable on a radiant manifold—and even worse on a radiant slab.

In most commercial buildings, protecting against the risk of condensation can be quite simple. The coolest point in the fluid's path through the radiant circuit is, by definition, the entering water temperature at the supply header of a radiant cooling manifold. Therefore, it makes the most sense to monitor and control the system from this point. Ensuring the entering water temperature is never lower than 1.6 C (3 F) above dewpoint effectively mitigates condensation.

Typically, a 23.9 C (75 F) space temperature will be maintained to no

▶ ADDITIONAL INFORMATION

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Abstract

In-slab hydronic radiant heating and cooling systems, along with downsized forced-air systems, are gaining popularity as a means

of optimizing thermal comfort while reducing energy consumption. Typically designed in conjunction with radiant heating, radiant cooling systems circulate cooled water through the same network of pipes where warm water circulates during the heating season. This network of pipes can turn the floors, walls, and ceilings of a conditioned space into cooled surfaces that evenly absorb heat energy.

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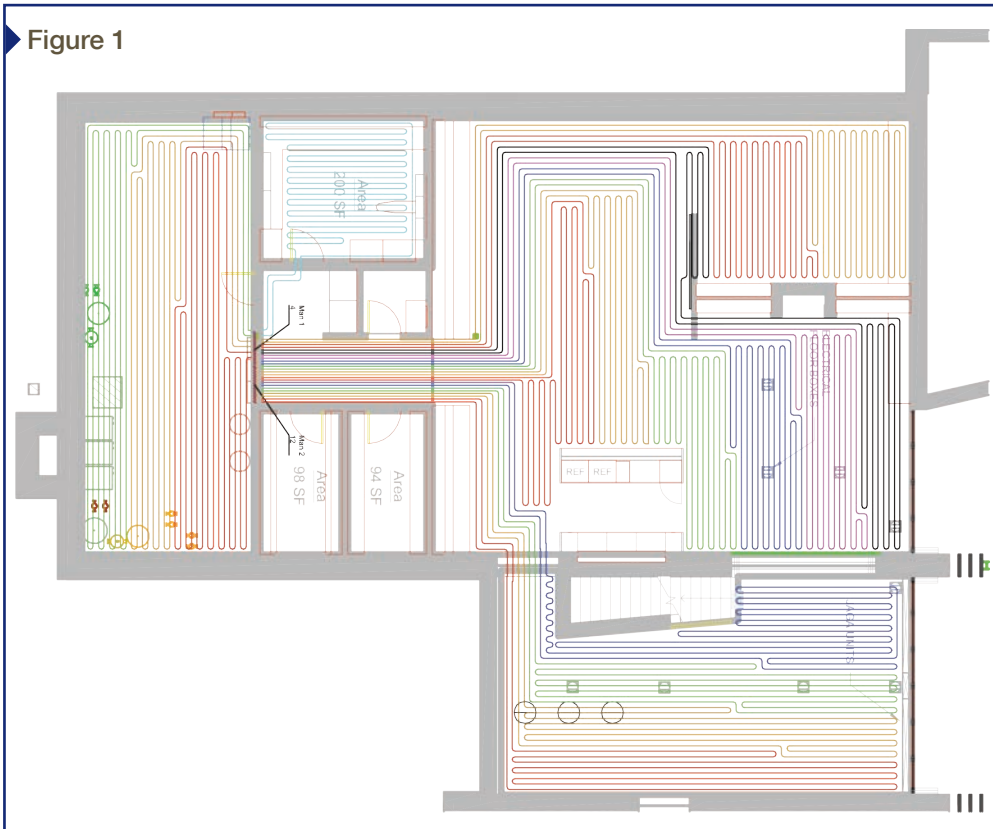
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Key words

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Cooling

In-slab hydronic radiant assemblies
Thermal comfort

Figure 1



In this diagram, there is a clear design flaw in that nearly all of the project tails are required to funnel through one small hallway. Not only has the ability to zone this hallway separately been lost, but also the chance of overheating this interior space is greatly increased because external zones will call for heat first.

Image courtesy REHAU

greater than 50 percent relative humidity (RH), yielding a 12.8 C (55 F) dewpoint temperature. Therefore, the most common supply water temperature to maximize a system's capacity is 14.4 C (58 F). Before the system circulates fluid, controls within the system should always check to make sure the dewpoint is sufficiently reduced. Some systems also make use of trending data to minimize air swings and the need for rapid dehumidification when dewpoint rises to its threshold.

While humidity is relatively easy to control in high-performance buildings with a curtain wall or fixed windows, buildings designed with operable windows pose challenges for radiant system control. There are successfully commissioned projects with these openings, but more engineering work may be needed to ensure the radiant systems do not run the risk of operating when windows are open—this is most important in humid climates.

Relays can be installed to detect whether a window or door is left open, but it is hard to guarantee the thermal mass 'charged with cooling' combined with humid air flowing into the space will always operate outside of dangerous condensation risk.

Conclusion

Only 15 years ago, a radiant system capable of cooling was nearly unheard of in North America. Today, with hundreds of reference projects in nearly all climatic zones throughout the region pushing the high-performance building industry, the question is less, 'why?' than 'how to get there efficiently?' By considering some of the above design attributes, specifiers will provide better direction to the HVAC and radiant system designers and minimize design iterations. Concurrently, it will help in achieving a successful and robust hybrid radiant system. While it is always easier to continue specifying the status quo, hydronic radiant systems are definitely an option for paving the way to net-zero building construction.

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Notes

¹ For more, see "Getting to Zero 2012 Status Update: A First Look at the Costs and Features of Zero Energy Commercial Buildings" at newbuildings.org/sites/default/files/GettingtoZeroReport_0.pdf.

² For more information see this author's "What Does the Thermostat Say? Why Air Temperature is Just Part of the Comfort Equation," at <http://www.rehau.com/us-en/company/blog/air-temperature-in-the-comfort-equation/868410>.