Optimising radiant cooling applications

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Abstract

Radiant cooling refers to a temperature-controlled surface that cools indoor temperatures by removing sensible heat through thermal radiation, ensuring comfort for the users of the cooled space. This article looks at how radiant cooling works and how to configure a radiant cooling system and it gives an example of an optimal variable primary pumping radiant cooling system.

1. Introduction to radiant cooling

Radiant cooling systems are usually hydronic cooling using circulating water running in pipes in thermal contact with the surface. Water is a better heating and cooling transfer agent than air. Air requires a muchlarger volume to transport the same amount of heating and cooling capacity.

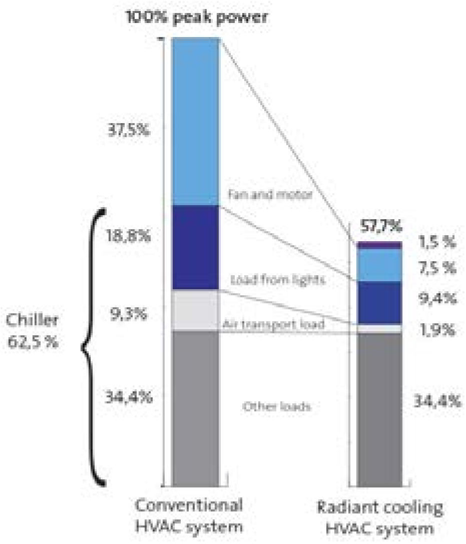
Chilled water which is just 2-4 °C (36–39 °F) below the desired indoor air temperature is circulated through pipes either buried under the floor or in the ceiling. Heat is then removed by the water flowing in hydronic circuit once the heat from different sources is absorbed by the actively cooled surfaces – ceiling, floor or walls.

The latent loads (humidity) from occupants, infiltration and processes generally need to be managed by an independent system.

2. Sensible cooling

Space cooling requires sensible and latent cooling. Sensible cooling involves reduction in temperature whereas latent cooling involves removal of humidity from the air.

Air	
Specific head capacity	1 kJ/kgK
Specific volume	1.25 Kg/m³
Heat transfer of one m³	**1.25 kJ/K**
Water	
Specific head capacity	4.2 kJ/kgK
Specific volume	1000 kg/m³
Heat transfer of one m³	**4200 kJ/K**



The figures above show the benefits of the cooling required to reduce the temperature of water without condensation. This shows two clear advantages of radiant cooling:

1. The chiller output can be 16 °C (61 °F) instead of the expected 7 °C (45 °F). This offers an immediate reduction in energy required.
2. Less energy is required to transport water than air.

3. How radiant heat transfer works

Heat will flow from objects, occupants, equipment and lights in an area to a cooled surface, as long as their temperatures are warmer than that of the cooled surface, and they are within the line of sight of the cooled surface.

The process of radiant exchange has a negligible effect on air temperature, but through the process of convection, the air temperature will be lowered when air comes in contact with the cooled surface.

Condensation caused by humidity is a limiting factor for the cooling capacity of a radiant cooling system; the surface temperature should not be equal to or below the dew point temperature in the chilled zone. For example, an air temperature of 26 °C (79 °F) at a relative humidity of 60 % would mean a dew point of 18 °C (64 °F).

Decreasing the surface temperature to below the dew point temperature for a short period of time may not cause condensation. Also, the use of an additional system, such as a dehumidifier, can limit humidity and allow increased cooling capacity.

4. Types of radiant systems

4.1 Chilled slabs

Chilled slabs are delivering cooling through the building structure, usually slabs, and are also known as thermally activated building systems (TABS). In TABS, water pipes are integrated into a concrete slab or a screed in the surface of a floor or a ceiling during construction. Water inlet temperature is usually around 14-18 °C (57-64 °F) and therefore the surface temperature is 17-21 °C (63-70 °F)

Cooling delivered through the floor makes the most sense when there is a high amount of solar gains from sun penetration, as the cool floor can more easily remove those loads than the ceiling. Chilled slabs, compared to panels, offer more significant thermal mass and therefore they can take better advantage of outside temperature swings. Chilled slabs cost less per unit of surface area, and are more integrated with the structure.

Laying of PEX chilled water pipes. Pipes are fastened to the steel reinforcement net before the concrete is casted.

4.2 Chilled ceilings

Chilled Ceilings are an alternative to Chilled Slabs and are typically used when:

- Ceiling cooling needs to be implemented in an existing building
- Cooling needs to be controlled by using zones

There are different ways chilled ceilings can be implemented. Pipes or mats can be embedded in gypsum plaster or cement plaster in the ceiling. Alternatively, they can be embedded in gypsum board ceilings. For better performance of chilled ceilings, thermally conductive boards are also available.

Example of a chilled gypsum board ceiling. Here chilled water pipes are fastened on the backside of the boards. The ceiling's surface temperature must not be lower than the air dew point in the room.

4.3 Cooling panel

Radiant cooling panels in commercial buildings are usually directly integrated with continuous dropped ceilings. Modular construction offers increased flexibility in terms of placement and integration with lighting or other electrical systems.

Chilled panels are also better suited to buildings with spaces who have a greater variance in cooling loads. Perforated panels also offer better acoustic dampening than chilled slabs. Ceiling panels are very suitable for retrofits as they can be attached to any ceiling. Chilled ceiling panels can easily be integrated with ventilation supplied from the ceiling. Ceiling panels tend to cost more per unit of surface area than chilled slabs.

A steel chilled ceiling panel seen from the backside. The chilled water pipes are glued directly onto the panel for ensuring conduction between pipe and panel. Copytight www. durlum.de

4.4 Chilled water distribution

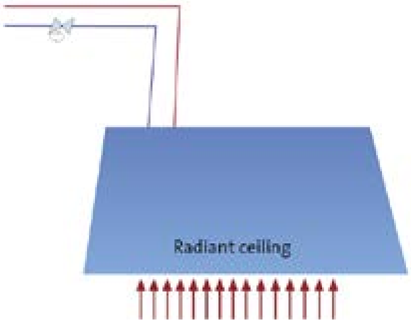
From chillers, branch headers are separated to feed individual building loops. Each individual floor plate or installation will be connected to manifolds which further distribute to the PEX pipes either buried or fitted on to the ceiling. Each pipe has fixed spacing between them to ensure proper heat transfer to the adjoining thermal mass. Temperature regulation of the supply of chilled water needs to be done as follows:

1. To avoid condensation on pipes and surfaces, the supply temperature should be maintained above the dew point temperature of the conditioned area.
2. In case of varying dew point temperature in the conditioned area, the chilled water temperature should also be variable in accordance with the dew point temperature with a temperature off-set of for example 2° C (4 °F).
3. In case of rapid and short dew point temperature changes (for example by undesired opening of a window), it is possible to shut off the chilled water supply.

4.5 Controlling water flow and temperature

2 port valve control

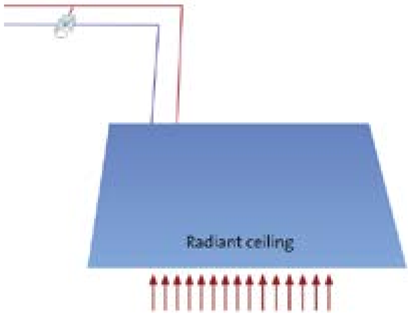
Traditionally, room air temperature is controlled by modulating the water flow rate using a 2 port valve with an on/off actuator. A 2 port valve allows a variable flow approach to the system, which will save on pumping costs. With a 2 port valve the water temperature has to be controlled by a central mixing loop, covering more zones, or by adjusting the chiller water leaving temperature. Water flow rates are adjusted using balancing valves in each zone and/or sub zone.



control is a poor control of the ceiling temperature and thereby also cooling performance.

3 port valve control

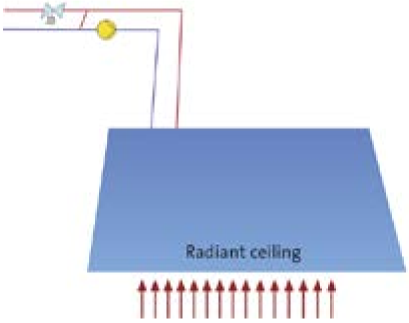
A more advanced system for controlling water flow rates is a 3 port control valve for each chilled ceiling loop. The benefits of this advanced system are better control of the system and reduced costs for commissioning. This is a typical approach in systems designed for constant flow on the primary side. A drawback is that this system does not allow primary pumping energy savings and nor can the flow temperature be adjusted locally.



A radiant ceiling controlled by a 3 port valve. This allows a variable flow in the radiant circuit ensuring improved and smoother performance. The drawback of this control is that water temperature cannot be controlled locally at the conditioned space and the primary side is a constant flow system.

4.6 Mixing loop control

A mixing loop is the superior approach for control of radiant ceilings. Here flow rate and temperature can be adjusted according to the desired performance of the radiant ceiling. Also mixing loops allows for variable flow on both the primary and secondary side, which ensures reduced pumping costs.



A radiant ceiling zone supplied from a mixing loop. With a mixing loop both water temperature and flow can be adjusted according to the actual need.

5. How to serve latent loads in a radiant cooling system

Radiant cooling systems can only cater to sensible cooling loads in the conditioned area. To ensure comfort for occupants, both sensible and latent loads have to be satisfied. For this, Dedicated Outdoor Air Systems (DOAS) are installed in parallel to Thermally Active Building Systems (TABS) or Radiant Ceiling panels.

A dedicated outdoor air system uses a separate unit to condition all of the outdoor air brought into the building for ventilation. Then it is delivered directly to each occupied space or to the individual local units or air handlers serving those spaces.

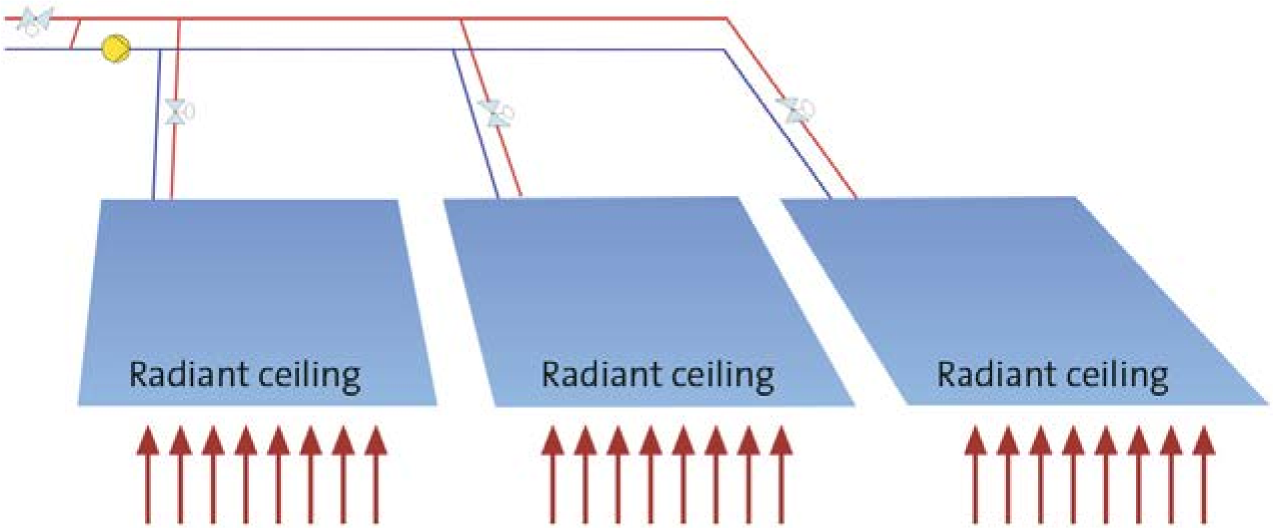
6. How does doas work?

Outdoor air (OA) is preconditioned with an enthalpy wheel, using room return air (RA) cooling the outdoor air. The heat recovery and dehumidification efficiency of an enthalpy wheel can be as high as 90 %. If further air cooling or dehumidification is needed, a cooling coil is used. The supply air temperature leaving the cooling coil is controlled. The cold and dry 100 % outdoor ventilation supply air is delivered to the space via high induction overhead diffusers.

The dew-point temperature for the area is maintained low enough for the radiant panel to never form condensation when radiant cooling is used to meet the balance of the space sensible cooling load.

A 3-way control valve is modulated as necessary to meet the space dry bulb temperature set point, limited by space dew point temperature. The room return air temperature (RA) and relative humidity are used to compute the space dew point temperature.

7. Advantages of zoning

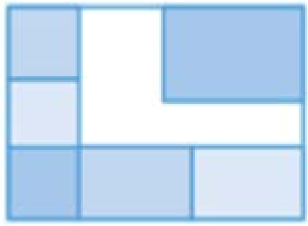


A radiant cooling system with three zones covering areas where there are different requirements to temperature or where the internal load from occupants is different. As occupant load is variable and hence moisture load is variable, each zone should be provided with an enthalpy sensor for monitoring air moisture level in to avoid condensation on the ceilings.

Zoning is recommended when there is:

- Different occupancy patterns
- Different temperature requirements
- Different activities in the space
- More than one floor (particularly when top floor is poorly insulated)

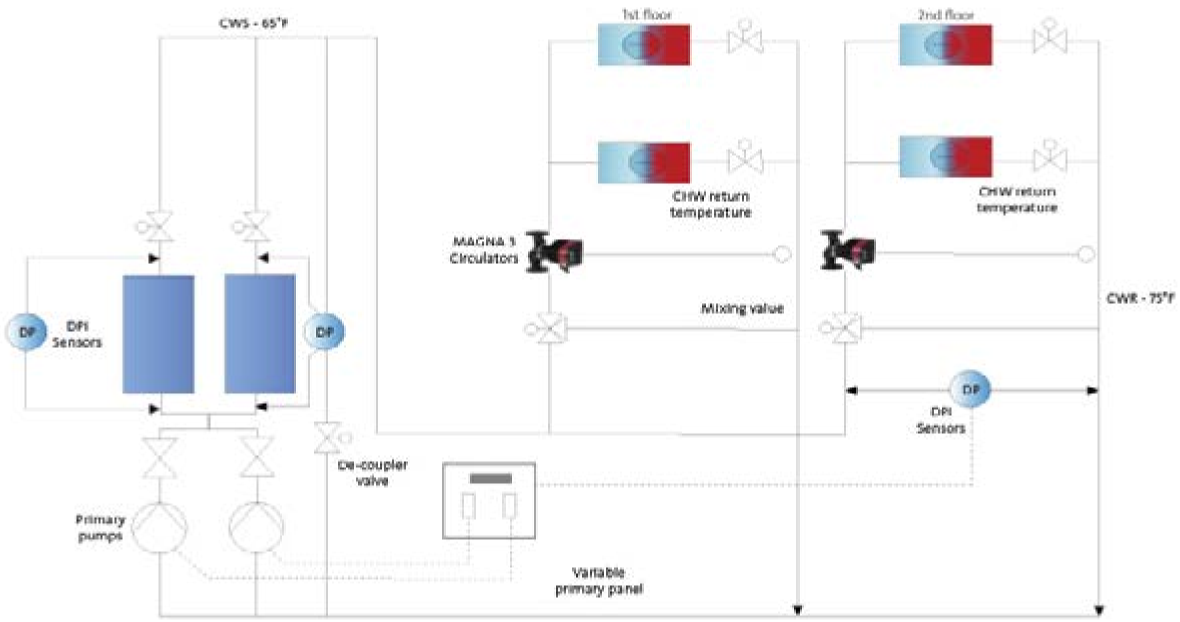
Additional investment in zoning can be recouped over time through energy savings. However, the most obvious improvement is increased staff comfort.



Multi-storey buildings can be zoned floor by floor

Multi-tenanted buildings provide an ideal opportunity to zone on the basis of tenants requirements

8. Using variable primary pumping scheme in radiant cooling system



8.1 Variable Primary Pumping (VPF) system

Variable primary flow systems coupled with mixing loop control at radiant cooling zones offer a higher degree of control and comfort.

Primary pumps vary the flow through evaporator coils as commanded by field Differential Pressure (DP) Sensors. When 3-way valves modulate to recirculate the zone return supply temperature back to the space area, the differential pressure across the riser shaft increases, resulting in the speeding down of the primary pumps.

DP sensors across the chillers ensure that pumps do not drop below the safe minimum flow as recommended by chiller manufacturer. Also when the load demands a flow rate much less than the safe minimum flow, VPF controller ensures the excess flow is recirculated back to the plant by opening of 2-way valve in a de-coupler line.

8.2 Mixing loop control

When the return chilled water from the radiant cooling panels is less than the design, 3 way valves are modulated to recirculate the chilled water to the space areas.

Similarly, when the supply temperature for any reason drops below the dew point temperature, chilled water supply from the main plant is cut off and the MAGNA3 pump is stopped immediately to avoid condensation.

8.3 Zone circulation pumps

MAGNA3 pumps operating at constant temperature mode ensure the right supply temperature to radiant cooling panels. With the return temperature sensor in the zone connected to the MAGNA3 pump, BTU spent on the zone can be monitored in the MAGNA3 itself without any additional instrument.

With soft communication to the Building Management System through Modbus/BACnet, the MAGNA3 pump can run from an external reference, which can be based on realistic weather data, so the flow is controlled in such a way to maintain space temperature which is based on relative humidity and dew point of the installation.

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