CBS Newsletter
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Hydronic Radiant Cooling Systems

Cooling nonresidential buildings in the U.S. contributes significantly to electrical power consumption and peak power demand. Part of the electrical energy used to cool buildings is drawn by fans transporting cool air through the ducts. The typical thermal cooling peak load component for California office buildings can be divided as follows: 31% for lighting, 13% for people, 14% for air transport, and 6% for equipment (in the graph below, these account for 62.5% of the electrical peak load, labeled "chiller"). Approximately 37% of the electrical peak power is required for air transport, and the remainder is necessary to operate the compressor.

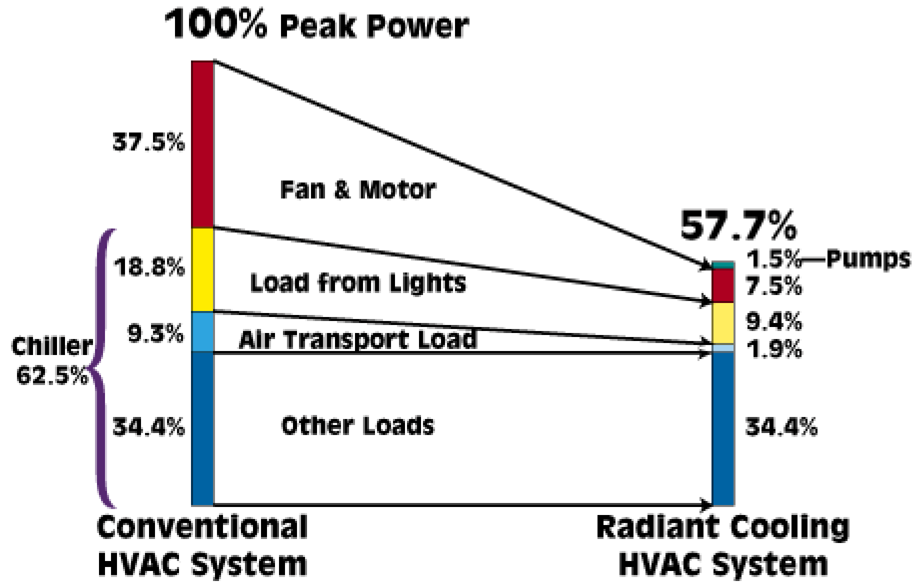
DOE-2 simulations for different California climates using the California Energy Commission base case office building show that, at peak load, only about 10% to 20% of the supply air is outside air. Only this fraction of the supply air is necessary to ventilate the buildings sufficiently to maintain a high level of indoor air quality. For conventional HVAC systems, the difference in volume between supply air and outside air is made up by recirculated air. The additional recirculated air, however, often causes drafts and indoor air quality problems by distributing pollutants throughout the building. This is the problem motivating our study of a building cooling technology called hydronic radiant systems which use less recirculated air, and in the process, could save energy.

Our efforts have taken the form of projects to characterize the technology and to develop a computer model. In order to be able to design radiant cooling systems and to simulate their thermal performance, we have developed a thermal building simulation model which operates in the SPARK environment, an easy-to-use graphical interface. The model is based on the finite differences method and covers both active and passive building elements. The aim is to integrate this model into PowerDOE, the successor of the DOE-2 thermal building simulation model (CBS News, Summer 1994).

Reduced Air Transport

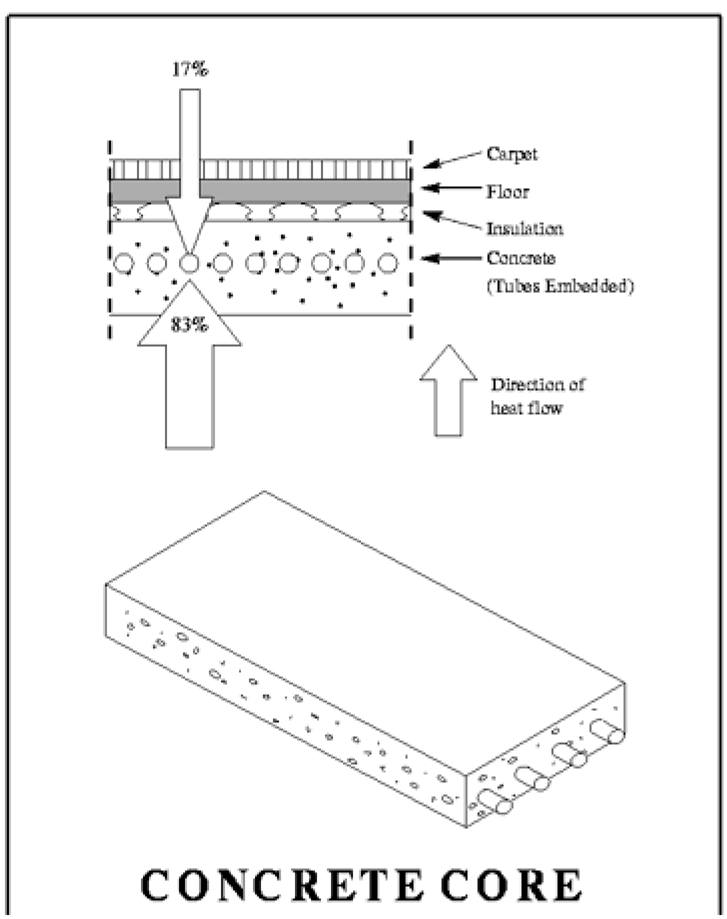
Traditionally, HVAC systems are designed as all-air systems. Hydronic radiant systems are air-and-water systems that separate the tasks of ventilation and thermal space conditioning by using the primary air distribution to fulfill the ventilation requirements, and the secondary water distribution system to thermally condition the space. These systems reduce the amount of air transported through buildings significantly, because the ventilation is provided by outside air systems without affecting the recirculating air fraction.

Radiation provides most of the cooling, using water as the transport medium. Thanks to the physical properties of water, hydronic radiant cooling systems can remove a given amount of thermal energy using less than 5% of the fan energy that would otherwise be necessary. (Energy savings relative to conventional systems are shown in the chart below.) The separation of cooling and ventilation tasks not only improves comfort conditions, it also improves indoor air quality as well as the control and zoning of the system. Hydronic cooling systems combine mechanisms to control the temperature of room surfaces with central air handling systems.



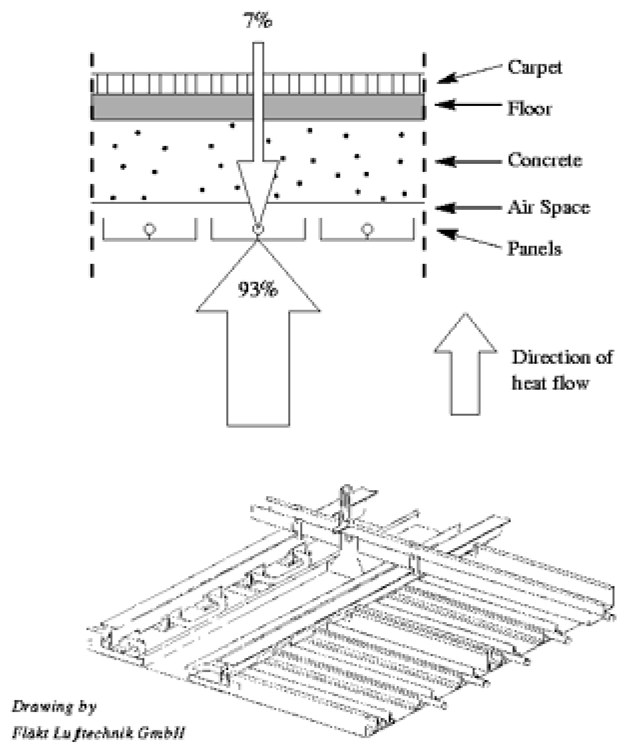
Comparison of electrical peak power load for conventional systems and radiant cooling systems (percentages are relative to overall peak power for the conventional system).

Because large surfaces are available for heat exchange in hydronic radiant cooling systems (usually almost the whole ceiling or floor), the coolant temperature is only slightly lower than the room temperature. Since the coolant can be maintained at a high temperature level, the use of heat pumps with high coefficient-of-performance values, cooling towers, night cooling, or some combination of these can reduce electric power requirements further. At the same time, hydronic radiant cooling systems reduce problems caused by duct leakage, since they use significantly less ventilation air and since the air is conditioned only to meet room-temperature rather than cooling-supply air temperature conditions.



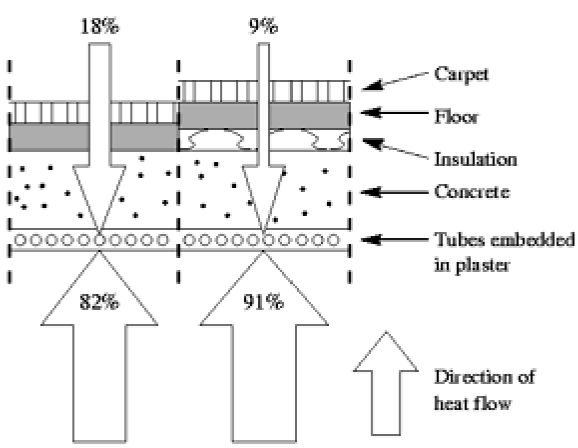
SYSTEM

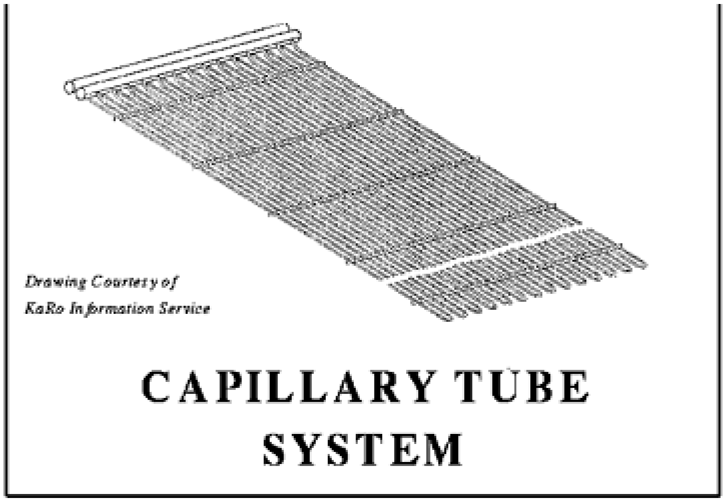
A **core-cooled** ceiling is the cooling equivalent of a floor heating system. In this system, water is circulated through plastic tubes embedded in the core of a concrete ceiling. This layout allows the system to take advantage of the storage capacity of the concrete, and provides the opportunity to shift the building peak load away from the utility grid peak. (As shown by the arrows most of the cooling effect occurs on the ceiling side of radiant panels.)



SUSPENDED CEILING PANEL SYSTEM

The most used system is the **panel system**. It is usually built from aluminum panels, with metal tubes connected to the rear of the panel. An alternative is to build a "sandwich system," in which the water flow paths are included between two aluminum panels. The use of a highly conductive material in the panel construction provides the basis for a fast response of the system to changes in room loads.





Cooling grids made of **capillary tubes** placed close to each other, can be imbedded in plaster, gypsum board, or mounted on ceiling panels. This system provides an even surface temperature distribution. Due to the flexibility of the plastic tubes, cooling grids might represent the best choice for retrofit applications.

Another benefit is that the ventilation systems and their duct work need only about 20% of the space requirements of conventional HVAC systems, reducing cost. A hydronic radiant cooling system combined with the sprinkler system might reduce the initial cost even further. Because of the hydronic energy transport, this cooling system has a potential to interact with thermal energy storage systems and looped heat pump systems.

Hydronic radiant cooling has been applied in the U.S., but it never reached significant market penetration. In Europe too, hydronic cooling was more or less abandoned after some application in the late 1930s and the 50s. However, user complaints about all-air systems changed the designers' attitude towards the technology, which led to new hydronic system designs with better control. Together with efficient ventilation systems and humidity control, the hydronic radiant cooling system provides advantages over conventional HVAC systems that are worth considering during building design.

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