Chilled Beam Cooling

By Kurt Roth, Ph.D., Associate Member ASHRAE; **John Dieckmann,** Member ASHRAE; **Robert Zogg,** Member ASHRAE; and **James Brodrick, Ph.D.,** Member ASHRAE

Most U.S. commercial buildings cool spaces by delivering air that is cooled before it flows into different spaces. In contrast, chilled beam systems use chilled water pipes in modular units mounted to ceilings. They differ from radiant chilled ceilings in that they transfer heat primarily via convection instead of radiation. Similar to radiant chilled ceilings, to date, chilled beams have been used primarily in Europe and, to some extent, Australia.[1,2,3] Chilled beams come in two distinct architectures: passive and active.

Passive chilled beams consist of a cooling coil with fins and housing that is suspended from the ceiling (*Figure 1*). Chilled water passes through the coil at temperatures typically from 55°F to 63°F (13°C to 17°C),[3,4,5] cooling the air around the chilled beam and causing it to descend toward floor level. Passive systems have design sensible cooling capacities of approximately 5.6 W/ft^2 to 6.5W/ft^2 (60 W/m^2 to 70 W/m^2) of ceiling area covered by chilled beam units.[1]

Active chilled beams, also known as induction diffusers,[3] are more complex than passive chilled beams (*Figure 2*). In addition to a finned cooling coil, they have an integral air supply designed to meet minimum outdoor air (OA) requirements (e.g., ANSI/ASHRAE Standard 62-2001, *Ventilation for Acceptable Indoor Air Quality*). In this way they differ from fan-coil units, which blow indoor air over cooling coils located in the conditioned space and rely upon a separate system to meet OA requirements. The supply air passes through nozzles, inducing additional airflow from the conditioned space through the cooling coil and down to the conditioned space. Due to forced convection, active chilled beams achieve cooling densities about twice (e.g., 12 W/ft^2 to 14.8 W/ft^2 [130 W/m^2 to 160 W/m^2][1]) those of passive chilled beams. The low cooling density of passive chilled beams limits their ability to cool many buildings in many U.S. climates. For this reason, we focus on active chilled beam systems.

Although they use higher chilled water supply temperatures than conventional chilled water systems, chilled beams require attention to building and HVAC system design to avoid condensation of moisture on the chilled water supply pipes and cooling coils. In most commercial buildings, the strategy for avoiding condensation on chilled beams is straightforward: manage indoor moisture levels such that the dew point of the indoor air is lower than the chilled water temperature.[1,3,5,6] In most building types and climates, ventilation outdoor air (OA) and infiltration are the main sources of humidity. Consequently, chilled beam systems in most climates usually require dedicated outdoor air systems (DOAS) and tight building envelopes to manage humidity. The DOAS handles the OA humidity loads prior to introduction to the space, with enough additional humidity removed to cover internal moisture generation.

Chilled beams are often well-suited for laboratories in applications where heat generated by laboratory and process equipment drives cooling loads and supply airflow levels. In such cases, using chilled beams to meet internal heat loads can appreciably reduce (often halving) required supply airflows and the associated energy consumption. In laboratories where safety requirements govern minimum airflow requirements, however, chilled beams cannot reduce supply airflow.[3] Conversely, chilled beams are not recommended for buildings with high indoor latent loads, such as restaurants, health clubs or theaters.[1,6]

Energy Savings Potential

Chilled beams can save energy in several ways. First, they deliver sensible cooling directly to spaces, decoupling maximum air delivery from the cooling load and reducing ventilation fan energy consumption. With sensible cooling separated from ventilation, OA can be provided as needed to satisfy OA requirements, greatly reducing the ventilation energy consumed to deliver cooling (e.g., 0.25 to 0.5 inches of water [62 Pa to 124 Pa] versus 3 to 8 inches of water [746 Pa to 1990 Pa] for central air systems[3]). Second, the combination chilled beam and DOAS can meet Standard 62-2001 ventilation requirements with less ventilation airflow due to the inherent precision of the DOAS in delivering required ventilation flows in the aggregate and to the individual zones in the building. This reduces the quantity of OA to be conditioned and, hence, the energy consumed to condition the OA.[6] Third, because chilled beams use higher chilled water temperatures than conventional air-conditioning systems (55°F to 63°F [13°C to 17°C] versus 39°F to 45°F [4°C to 7°C]), a chiller dedicated for chilled beam cooling has a lower temperature lift and operates at a 15% to 20% higher efficiency than for an conventional system (for cooling loads independent of ventilation).[3,6] Fourth, the combination of higher chilled water system temperatures and the fact that active chilled beams entrain large quantities of room air greatly reduces or eliminates the need for energy-consuming reheat of the cooled air.[3,5]

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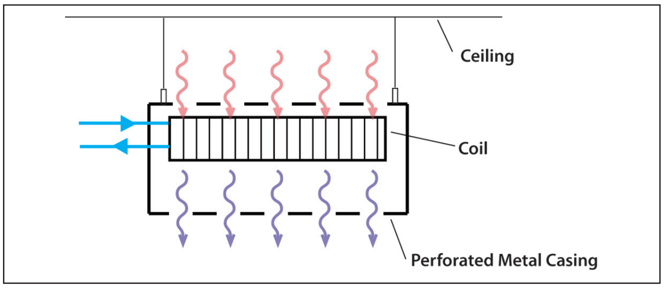

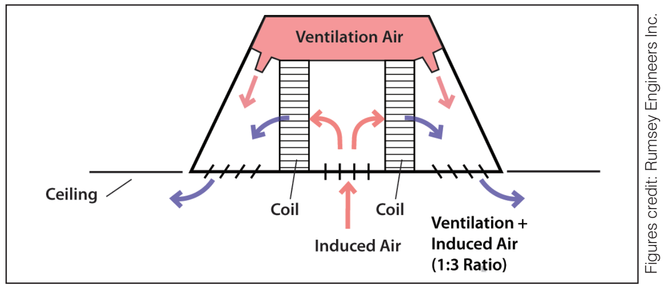

Figure 1 (left): Passive chilled beam. Figure 2 (right): Active chilled beam.[3]

On the other hand, the lower supply airflow volumes limit the extent of outdoor air economizing possible[1] unless this capability is designed in separately.[3]

There are limited data available for the energy savings potential of active chilled beam systems. One comparison of the energy performance of active chilled beams with a variable-air-volume (VAV) system for an office building in cooling-dominated Sydney, Australia, found similar energy performance for the two systems. During summer months, the chilled beam system consumed less energy than the VAV system, but it consumed more during the moderate (average daily temperature ~54°F [12°C]) winter months because the reduced quantity of supply air precluded extensive use of airside economizing. Simulations of other buildings in Australia found that the energy impact varied appreciably depending on the specifics of a given project, but illustrated that HVAC energy savings as large as 10% to 20% per year can be achieved.[1] This is similar to another estimate for the average U.S. energy savings of radiant ceilings and chilled beams deployed with DOAS. Extrapolated to the population of commercial buildings in the U.S., chilled beams could reduce commercial building energy consumption by approximately 0.6 quad (0.64 EJ).[6]

Market Factors

Although relatively common in parts of Europe, chilled beams have achieved limited market penetration in the U.S. Thus, most contractors have not worked with chilled beams, increasing both their first and installed costs. At present and considered independently of other building systems, chilled beam systems cost more than VAV systems, e.g., comparative evaluations of active chilled beam and VAV systems in major Australian projects found that chilled beam systems cost about \$8/ft^2 (\$80/m^2).[1] This does not, however, consider savings possible from reduced building height and space requirements for air handlers afforded by the smaller supply air requirements for active chilled beam systems. For example, chilled beams can reduce per-story building height by 0.33 ft to more than 1.3 ft (0.1 m to 0.4 m)[1,3] and the size of air-handling systems in offices by 20% to 30%.[3]

On the other hand, chilled beam systems have limited heating capacities and often require a separate perimeter heating system.[5] This increases the total cost of the HVAC system. In some buildings, envelope and interior cooling loads would require a density of chilled beams that exceeds the manufacturers' installation recommendations to avoid flow restrictions that compromise system performance.[1,3] Unless a supplemental cooling system is added (at additional expense), this precludes the use of chilled beams in these applications.

In some instances, architects and end users may not like the aesthetics of chilled beams. Specifically, chilled beams usually cover 50% or less of the ceiling, in which cases occupants can see the building services near the ceiling.[1] To overcome these aesthetic challenges, integrated service beams have come to market that incorporate additional services, such as lighting; cabling; and conduits for power, voice and data services; openings for sprinklers, smoke detectors, and public address system speakers; lighting control sensors; and closed-circuit television cameras.[4,5] Alternatively, the ceiling and in-ceiling services are sometimes painted black to reduce their visibility.[1]

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Robert Zogg, P.E., and Kurt Roth, Ph.D., are associate principals; and John Dieckmann is a principal with TIAX LLC, Cambridge, Mass. James Brodrick, Ph.D., is a project manager with the Building Technologies Program, U.S. Department of Energy, Washington, D.C.