Chilled Beams
Getting a Warmer Reception

Gain an understanding of how chilled-beam technology works, the difference between active/passive chilled beams and potential applications for its use.

By Greg Cunniff, P.E.

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A new form of radiant cooling has entered the U.S. market: chilled beams. With these systems—long established in Europe and Asia—chilled water circulates through tubing embedded in a metal ceiling fixture to wick away heat. The technology features broad applicability for commercial structures and provides energy and thermal efficiency. A key advantage is that a chilled-beam system requires very little ceiling space and height or, in the parlance of commercial architects and designers, it conserves interior real estate.

Another key advantage, functionally and financially, is that water—the main transporter of thermal energy, and much denser than air—permits very high energy-carrying capacity and a smaller transport system: pipes. A forced-air system is, by its very nature, greatly less efficient because of the inherently low density of air and requires large ducts to transport Btu.

**Hydronics + Forced Air**

Because chilled beams are ceiling-mounted and do not use drain pans, the chilled-water supply temperatures must be above the ambient dew point. As a result dehumidification, or latent cooling, is handled by a separate 100% dedicated outdoor air system supplying dry, conditioned air to the space.

Passive chilled beams employ natural convection, while active chilled beams employ forced convection. Passive chilled-beam systems supply the DOAS air flow through a separate diffuser or grille in the room. An active chilled beam supplies the DOAS air flow through the chilled beam, thereby increasing the capacity of the cooling coil through forced convection. The amount of outside air required to operate a typical chilled-beam system is much less than that needed for a forced-air system. A chilled-beam system typically needs only one air change per hour, using outside air to pressurize the space to prevent the infiltration of outside air. With a forced-air system, that need grows to 8–10 air changes of recirculated (and fresh) air to cool a space.

Additional reductions also are seen in: the ceiling space typically required for ductwork; the amount of air circulated by the central system—often 80%–90% less than with conventional, all-air systems; and the horsepower to circulate air within interior spaces. The net result is lower energy consumption and operating costs. Studies have shown (in typical commercial buildings in the U.S.) that fan energy is often second only to lighting in the energy consumption. With active chilled-ceiling and chilled-beam systems, energy to operate fans is dramatically reduced due to the relatively small amount and low pressure of the primary air being circulated by the central system (see Figure 1).
Beam me up

Although the system sounds futuristic, many trade professionals are surprised to learn that chilled-beam technology is relatively simple and straight-forward. In a radiant chilled-ceiling system, about 50%–60% of the heat transfer from a chilled panel is radiant, and 40%–50% is convective (see Figure 2).

The chilled-water temperature must be above dew point to prevent condensation from forming on the underside of the panels. This is typically in the range of 55°F–60°F. The driving force or temperature difference between the chilled water and a room at 75°F is therefore reduced, falling within the range of 15°F–20°F, as opposed to a conventional chilled-water system using 40°F–45°F chilled water and a range of 30°F–35°F temperature difference.

As a result, higher chilled-water flow rates are required to achieve reasonable capacities. These flow rates are in the range of 4.5 gpm–6 gpm per ton using chilled-water ΔT of 4°F–5°F as opposed to conventional chilled water systems of 2 gpm–3 gpm per ton using ΔT of 8°F–12°F (also shown in Figure 2). The chilled-water flow rate for chilled panels and ceilings is therefore approximately double that of conventional chilled-water systems.

Even with higher flow rates, the capacity of radiant chilled panels and ceilings is relatively low, in the range of 20–40 Btuh/sq ft. While this is within the range of cooling loads for interior spaces, it may not be adequate for interior spaces with exterior walls. For the European experience in the 1980s, some cooling was better than none.

The Europeans discovered from their experience that by lowering the chilled panel below the ceiling, the convection cooling component of the individual panels could be increased; this satisfied the increased cooling loads from increased use of computers seen in the 1990s. Also, there was a desire to provide higher cooling capacities for exterior zones to provide better overall comfort.

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By lowering the panel below the ceiling and making it an open coil (see Figure 3), the capacity of the chilled panel can be increased to approximately 120–150 Btuh/sq ft. This configuration has been designated a "passive chilled beam" by the industry since the cooling component is natural convection.

With active chilled-beam systems—sometimes referred to as "induction diffusers"—a building's ventilation air is continuously supplied to the chilled-beam terminal units by a central air-handling system. Ventilation air is cooled or heated to partially handle temperature-driven sensible loads, while in the summer being sufficiently cooled and dehumidified to handle all of the internal moisture-driven latent loads. In active chilled beams, air from the chilled beam is introduced into the space through a slot diffuser, creating a Coandă effect (the tendency of a fluid jet to be attracted to a nearby surface or, in this case, the ceiling).

Inducing warm room air to blow through the chilled coil substantially increases the capacity of the chilled beam. Active chilled-beam capacities are in the range of 350–600 Btuh/sq ft for the coil. Added to this is the capacity of the primary air from the DOAS. Depending on the temperature and quantity of this primary supply air, this can add up to 300 Btuh/sq ft of capacity. An active chilled beam can deliver from 500–900 Btuh/sq ft between the chilled coil and the primary air (see Figure 4).

Primary/ventilation air is introduced into the active chilled beam through a series of nozzles. This induces room air into the chilled beam and, in turn, through a water coil. Induced room air is cooled and/or heated by the water coil, then mixed with ventilation air and released, controlling room temperature. The technology works in tandem with a central air system, which is calibrated to circulate only the amount of air needed for ventilation and latent-load purposes. The chilled beams provide the additional air movement and sensible cooling and/or heating required through the induced room air and secondary water coil.

With an active beam, ventilation air is delivered to the beam by a central air system through ducts. The beam unit itself is not unlike an induction unit turned upside down, mounted to the ceiling. Ventilation air moves through ductwork, forcing room air to make contact with the cooling coil.

**Figure 3** By lowering the panel below the ceiling and making it an open coil, the capacity of the chilled panel can be increased. This configuration has been designated a "passive chilled beam" by the industry since the cooling component is natural convection.

**Figure 4** With active chilled-beam systems (shown here) a building's ventilation air is continuously supplied to the chilled-beam terminal units by a central air-handling system.
This air then mixes with the primary ventilation air and delivers it through linear diffusers.

Linear slot diffusers have been used for a number of years in VAV systems. Their primary advantage is that they do not “dump” cold air at low flow rates, making occupants uncomfortable. It is in this way that chilled beams transfer a huge portion of cooling (or heating) loads from the air-distribution system to the water-distribution system.
As more systems are installed in the U.S., chilled-beam technology has developed into an alternative to conventional VAV systems. Chilled beams are available in three variations: passive, active and integrated/multi-service beams. The difference between passive and active beams focuses on the way air flow and fresh air are brought into the space. Both of these systems are now enjoying significant attention here in the U.S. Integrated/multi-service beams are chilled beams with circulation systems that have been incorporated into lighting, sound, sprinkler and cable pathways—now an approach not uncommonly taken in Europe, though not yet explored here in the U.S.

**Injection mixing systems**

Radiant cooling and chilled beams help reduce fan electrical-energy demand/consumption up to 10 times from an all-air HVAC system, but the pump energy demand doubles. If the pump energy could be reduced, then this type of system could achieve significant energy savings.

Injection pumping has been used for a number of years in radiant heating systems by mixing-down the higher temperature boiler water (at 180°F) to that needed for a radiant floor panel (100°F–120°F). This same principal can be applied to a radiant cooling system, only in reverse—to mix up low-temperature chilled water (40°F–45°F) to that required by a chilled ceiling panel or beam (55°F to 60°F).

Figure 5 shows a schematic piping layout for a radiant-cooling/chilled-beam, low-flow/low-temperature injection piping system. In this system, instead of the primary chilled water flow being double that of a conventional chilled water system, it requires only one-quarter of the flow. This is the case since the primary chilled water system temperature difference is now 16°F instead of a radiant-cooling/chilled-beam system of 4°F and a conventional system of 8°F. This system reduces the electrical energy demand of an all-air system by almost 30% or more, thus reducing the transport energy to only 20% of the total HVAC system (see Figure 6).

**System benefits**

Some benefits of a radiant-cooling/chilled-beam system include the following:

- Radiant-cooling/chilled-beam systems circulate less air and do not create drafts or evaporative cooling on occupant’s skin.
- Quieter than all-air systems because they circulate less air.
- Lower energy consumption because fan use is minimized. It is far more efficient to pump water than to blow air.
- Floor-to-floor building height can be reduced and space can be maximized because chilled ceilings/chilled beams do not need large ductwork and fans.
- Lower first cost and additional space savings since only one pipe is required to serve multiple temperature requirements in either a chilled-water or heating-water system.

Greg Cunniff, P.E., is the Application Engineering Manager for Taco Inc., the HVAC and hydronic systems and components manufacturer based in Cranston, RI, with offices in Milton, ON. For more information, e-mail grecun@taco-hvac.com or visit www.taco-hvac.com.