European Technology Taking Hold in the U.S.

Chilled Beams

How active chilled beams are allowing designers to lower costs and improve the energy performance of buildings

By PETER RUMSEY, PE, CEM, FASHRAE, FRMI
Rumsey Engineers/Integral Group
Oakland, Calif.

The last five years have seen a steady increase in the rate of adoption of chilled beams in the United States, as designers and facility owners have become more aware of the many benefits this energy-efficient technology, popular in Europe, provides: improved indoor-air quality, low operating costs, thermal comfort, flexibility in unit design, ability to deliver multiple services with a single unit, low operating noise, adaptability where floor-to-slab height is minimal, reduced (by as much as 40 percent) outside-air-handler and ductwork size, and elimination of reheat, among others.

How Chilled Beams Work

Chilled beams, also known as induction diffusers, are fundamentally different than the all-air diffusers used in most U.S. buildings. There are two basic types: active and passive.

An active chilled beam receives outside air from an air-handling unit (AHU) and cold or hot water through a piping system with integral cooling coils. Primary airflow is introduced through small air jets built into the beam. These jets induce room airflow through the beam's coil (Figure 1). The induction process produces a forced-convection heat transfer with the coil.

A passive chilled beam relies on a room's natural convection and has no direct air supply. Warm room air rises to the beam's coil, which cools the air, causing it to fall into the occupied zone (Figure 2). Passive beams are best suited to cooling-only applications with low ventilation air requirements.

This article focuses on active chilled beams, referred to from this point simply as chilled beams.

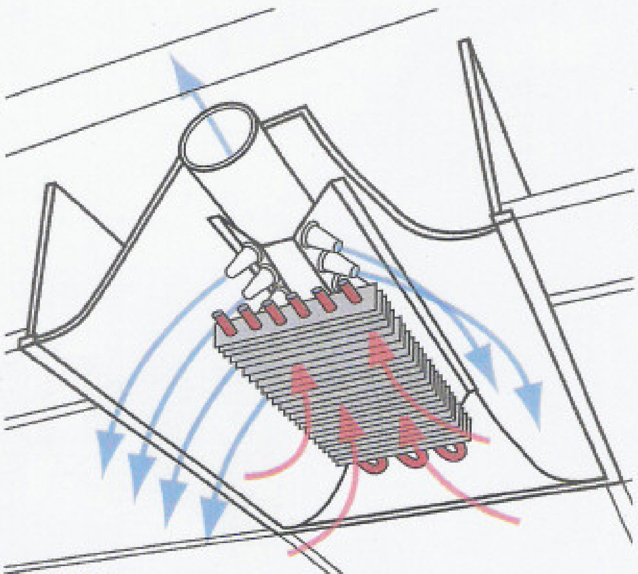


FIGURE 1. Active chilled beam.

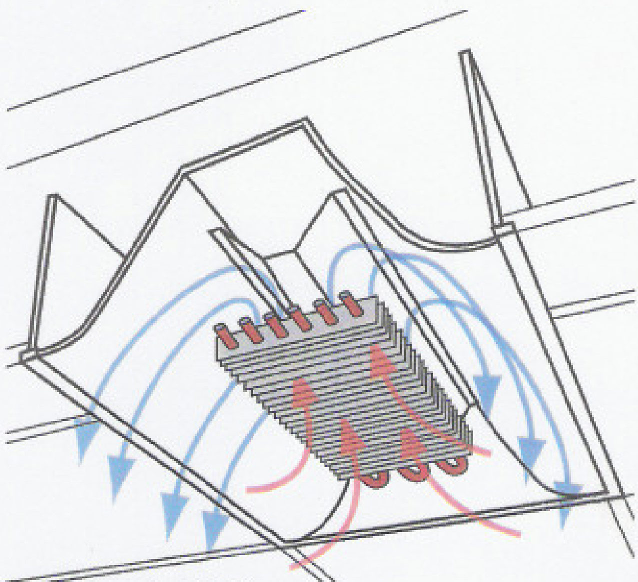
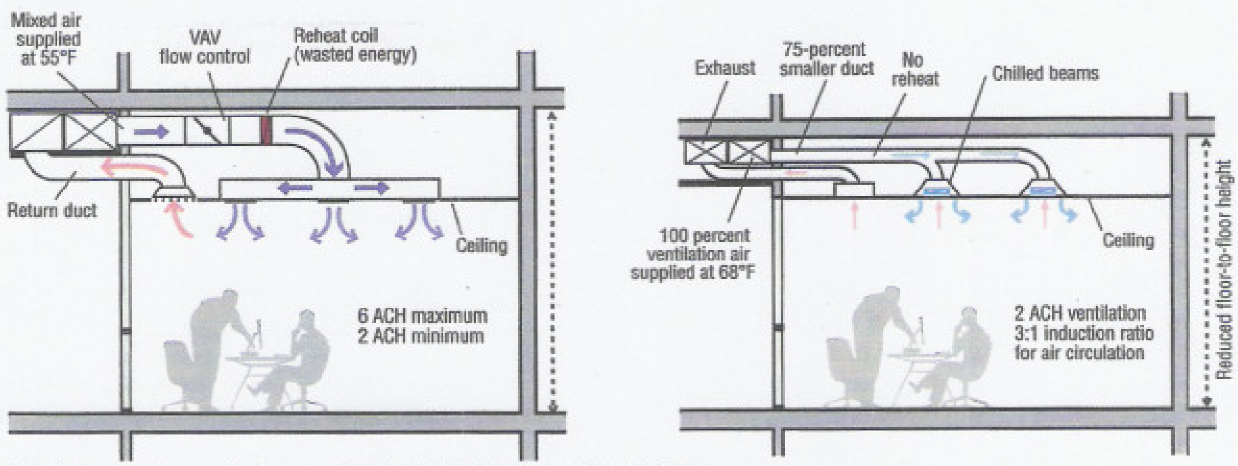


FIGURE 2. Passive chilled beam.

The founder and managing director of Rumsey Engineers (part of Integral Group), the first engineering firm in the United States with six Leadership in Energy and Environmental Design Platinum projects to its credit and the recipient of numerous local and national awards from the likes of The Association of Energy Engineers and The American Institute of Architects, Peter Rumsey, PE, CEM, FASHRAE, FRMI, has designed mechanical systems for data centers, cleanrooms, and laboratories that are among the most energy-efficient in the United States. He lectures at industry events, conferences, and colleges and universities, including the University of California at Berkeley and Stanford University.



Typical variable-air-volume reheat system (left) and chilled-beam system (right).

In properly designed environments, chilled beams provide sensible cooling only, while a central air-handling system provides ventilation and latent cooling. In this way, cooling is "decoupled" from ventilation. The ventilation air handler is set up as a 100-percent-outside-air unit that does not recirculate air. This commonly is referred to as a dedicated outside-air system (DOAS). A DOAS provides better air quality than a variable-air-volume (VAV) system and requires significantly smaller ducting and air handlers.

Chilled-water temperature and humidity level are critical considerations when designing with chilled beams. Chilled beams do not condense water when designed with warmer (55°F to 60°F) chilled water. Higher chilled-water temperatures open the door to more efficient chiller operation and longer hours of water-side economizing.

Design Practices

Chilled beams available in the United States generally have a 3:1 induction (room air to ventilation, or primary, air) ratio, are capable of 100 to 200 cfm of primary air per 6 ft of beam, and provide from 4,000 Btuh to 8,000 Btuh of sensible cooling per 6 ft of beam. Airflow, cooling, and sound performance vary considerably by manufacturer.

The nozzles through which primary air is supplied can produce noise. Thus, sound levels must be balanced with unit cooling capacity. Too much air can result in higher nozzle noise, but increased cooling capacity. Integration into the ceiling grid and coordination with lighting, piping, and other above-ceiling systems also are required.

The sizing of a chilled-beam system can be divided into four major steps:

1) Determine the load for the zone being served.

2) Decide on the preferred ventilation (primary) air, chilled-water, and hot-water supply temperatures and the maximum allowable pressure drop and noise at the induction nozzles.

3) Select the size and number of chilled beams for the zone.

4) If the number of chilled beams needs to be increased or decreased, revise the temperatures in Step 2 and repeat Step 3.

Dehumidification

Chilled-beam systems are appropriate in humid climates. The DOAS coupled with chilled beams are responsible for latent loads. In most cases, outside air is the largest latent load. The DOAS dehumidify outside air before it enters the building. If additional latent loads from the space need treatment, ventilation air that is dryer than the target space humidity can be delivered into the building.

To realize the energy-efficiency benefits of higher chilled-water temperatures in chilled beams, a direct-expansion compressor often is used in DOAS air handlers. Rumsey Engineers has found that over 80 percent of annual loads are sensible-cooling, not latent, loads.

The runaround coil is one strategy for reducing and even eliminating reheat energy in ventilation air and ultimately an entire chilled-beam system. This type of system puts a coil before and after the dehumidification coil in a DOAS air handler. In this configuration, some free precooling is harvested, and free reheat is realized.

Costs and Cost Models

Chilled-beam systems can be installed for the same cost as or less cost than the less-efficient VAV reheat systems typically found in buildings. With three or four products now manufactured in North America, the cost of chilled-beam units has come down significantly. Although chilled beams cost more than traditional diffusers, the cost is more than offset by significant reductions in ducting, shafts, and air-handler capacity. With first cost between chilled-beam and standard VAV-reheat systems being equal, operating costs make a compelling case for chilled beams, representing immediate energy savings of 50 to 60 percent.

Two recent office projects Rumsey Engineers designed verify the cost parity with VAV systems. In a new 80,000-sq-ft building in Palo Alto, Calif., chilled-beam costs were in line with VAV costs despite the chilled-beam design including thermostats in each room. In the design/build renovation of a 600,000-sq-ft building in Denver, the chilled-beam system was equal to a VAV system, but resulted in the elimination of two air handlers on each floor. The net present value of 20 years of leasing the space is $9.2 million.

In laboratories, the cost results are equally compelling. In a comparison of the first costs of a chilled-beam system and a standard VAV system for a 14,100-sq-ft laboratory, active chilled beams were shown to cost 84 percent of a standard VAV system, while active chilled beams with built-in lights were shown to cost 96 percent.

Table 1 compares the approximate costs of a chilled-beam system and a standard system for the Tahoe Center for Environmental Sciences at Sierra Nevada College.

	Standard system	Active chilled beam
Outside-air handler	27,000 cfm	18,000 cfm
Ductwork	37,500 lb	30,000 lb
Exhaust-fan capacity	27,000 cfm	18,000 cfm
Cooling-system capacity	35 tons	20 tons
Floor-to-ceiling height[1]	9 ft	10 ft
Mechanical-system cost[2]	$741,000	$722,000

1) Floor-to-floor height kept constant. Active-chilled-beam design allowed ceiling to be raised 1 ft.
2) Laboratory portion of the building is 10,000 sq ft, or 25 percent of the building. HVAC costs include laboratory systems only.

TABLE 1. Comparison of a chilled-beam system and a standard system for the Tahoe Center for Environmental Sciences.

Contractors, Constructability, and Coordination

Few mechanical contractors are familiar with chilled-beam technology. Thus, it is important to keep an eye on installation costs and methods. In one case, estimated installation costs were suspiciously high; further investigation revealed contractors had estimated three to four times the actual time required for unit installation, largely because they were unfamiliar with the technology.

Chilled beams present relatively few constructability issues and generally do not require extensive structural support. Also, they can be effective in instances of tight spacing.

Most manufacturers recommend mounting a chilled beam in a T-bar ceiling and supporting the weight with wires or threaded rods, one at each corner of the beam. In seismic zones, additional guide wires often are required. To be lined up in a ceiling grid, chilled beams need to be adjusted in all three dimensions. Chilled beams need to move up and down so they can be leveled upon installation and made flush with the ceiling. Because chilled beams and their supply ductwork often are much shallower than conventional VAV boxes, they can save on the required floor-to-floor height of a building.

Commissioning, Operations, and Maintenance Issues

Commissioning chilled beams is similar to commissioning standard supply diffusers or duct heating and cooling coils. A chilled-beam water loop must be purged of air pockets during startup and throughout the life of the system. The lower flow through each beam's chilled-water coil can make purging air at startup difficult, so care must be taken to ensure each zone is purged. Experience with installed systems has shown that manual air vents are more reliable for purging air than automatic air vents. Special attention must be paid when manual vents are placed at high points in a chilled-water piping network.

Chilled-beam systems are less expensive to maintain than traditional VAV-reheat systems because of fewer moving parts. Higher chilled-water temperatures for noncondensing operation are more energy-efficient and allow more options in providing chilled water (e.g., expanded water-side free cooling and thermal-energy storage from nighttime free cooling). No fans or electrical connections are required, and a single room can be controlled with one valve and temperature sensor.

Chilled-beam coils require periodic cleaning, the frequency depending on the filter used at the AHU and the amount of dust in the space. Maintenance should include vacuuming the face of beam coils at least every three years. When designing a system, space beams far enough apart to allow easy access by maintenance personnel. Maintenance personnel need to be able to access beams from a ladder.

Sourcing

Historically, the leading manufacturers of chilled beams have been European or Australian. More manufacturers, however, are producing chilled beams in North America, which is resulting in cost reductions, better availability, and contractors becoming more comfortable with the technology.

Successful Installations

The Rumsey Engineers-designed Leadership in Energy and Environmental Design (LEED) Platinum Tahoe Center for Environmental Sciences was the first laboratory in the United States to use chilled beams. Other Rumsey Engineers projects incorporating chilled beams include the biomedical-sciences building at the University of California, Santa Cruz; the Cal Poly Center for Sciences; and the headquarters of The David and Lucile Packard Foundation in Los Altos, Calif.

Set to open in 2010, Constitution Center in Washington, D.C., features the largest chilled-beam system of its kind in the United States. The renovated 1.4-million-sq-ft, 10-story building, which is targeting LEED Gold certification, employs active chilled beams and DOAS heat-recovery units to accommodate limited ceiling space. According to SmithGroup, the project architects, modeling of the Constitution Center indicated the chilled beams provide a 54-percent reduction in required cooling energy.

Featuring an active-chilled-beam system, the $118 million, 166,000-sq-ft Jerry Yang and Akiko Yamazaki Environment and Energy (Y2E2) Building at Stanford University uses 50-percent less energy than a building adhering to ANSI/ASHRAE/IESNA Standard 90.1-2004, *Energy Standard for Buildings Except Low-Rise Residential Buildings*. Designed by Boora Architects and ARUP, the Y2E2 Building breaks new ground as a Beyond LEED facility, cutting energy consumption in half and reducing potable-water consumption by 90 percent.

Summary

Chilled beams are efficient because they decouple ventilation from conditioning, saving energy while improving ventilation and air quality.

While a chilled-beam system may cost more than regular VAV diffusers on the component level, the difference is made up in reduced ducting and piping costs.

U.S. designers and facility owners are becoming better informed about the benefits of chilled beams, and builders are becoming more familiar with the technology and how to integrate it into projects. Consequently, the cost of the technology is dropping, and barriers to the technology's adoption are falling.

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