Inside Insights

Chilled Beams:

Not your everyday weapon against heat

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Editor's Note: *"Inside Insights" is a column designed to address ongoing issues of interest to building owners, managers and operating engineers who use district energy services.*

The last few installments of this column have focused on heating terminal units and useful temperature ranges. So to be fair, in this edition we will discuss an emerging cooling technology that for the past 10 years or so has been receiving a great deal of attention from designers and consultants: chilled beams.

Although the name does create a vision of a large, exposed structural member filled with chilled water, in reality this is not so, since these beams have no structural value for supporting building elements. Neither are they some sort of *Star Trek energy beam used by Captain Kirk* and Scotty to put the Romulans 'on ice'; nor are they a new-fangled drink (Jim Beam on the rocks! Shaken, not stirred!).

So now that we know what they are not, what exactly are chilled beams? Chilled beams (CBs) are typically two-pipe cooling terminal units (some are three- and four-pipe configurations) that only provide sensible cooling to the space. By "sensible" I mean dry heat from lights, equipment, people, the building envelope, etc., since chilled beams do not directly remove latent heat or dehumidify.

Chilled-beam technology should not be confused with radiant cooling, although there are some similarities. Chilled beams rely mostly on convective and not radiant heat transfer. The convective cooling method 'turns over' the room air several times more than with a standard overhead air system.

Types of Chilled Beams

There are two major types of chilled beams: passive and active. Passive (aka "static") chilled beams (PCBs) consist of a finned coil in a housing that uses natural convection for cooling and is mounted below or flush with the ceiling. Warmer room air at the ceiling (or in the ceiling plenum) is induced into the unit by the cold air falling from the unit. Hybrid units also exist that incorporate a radiant panel for increased cooling output. Active (aka "ventilated") chilled beams (ACBs) are the same as passive but incorporate additional conditioned ventilation air introduced through high-velocity jets along the length of the unit. ACBs act as an induction unit (back to the future from the 1960s) to actively induce room air through the coil to be cooled.

There are many shapes and sizes of both types of chilled beams, from rectilinear slots to 24-inch squares and rectangles. There are also varieties of both passive and active chilled beams that incorporate other elements – e.g.,, lights, sprinklers, speakers, space occupancy sensors and smoke detectors – in a multi-service beam configuration. These can be surface-mounted, suspended or recessed in a lay-in ceiling. Common manufacturers are Frenger, Dadanco, Trox, Krantz, Carrier (ACB) and Halton.

Where Did They Come From?

Although the first actual uses of chilled beams were in Europe, they have similarities with the old high-pressure perimeter induction air systems introduced by Carrier in the late 1930s. With these, high-velocity streams of cold air induced room air circulation. The colder, high-pressure air systems enabled the air-handling units and ductwork to be smaller.

It is believed that the first radiating CBs were installed at the Volvo plant in Gothenburg, Sweden, in the late 1960s. In the early 1970s the Swedes used the first CBs with primary supply-air features. Those savvy Swedes – they are into everything! CBs have been a hot item for the past 15 or so years in Europe and Australia and are also becoming more frequently used and investigated in the U.S. They offer

Courtesy Dadanco.

This illustration of an active chilled beam indicates both the primary air connection (front center) as well as four-pipe water connections (right-hand side).

comfort advantages as well as the potential to save energy, which makes them attractive to the high-performance building and sustainable design professionals.

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How Do They Save Energy?

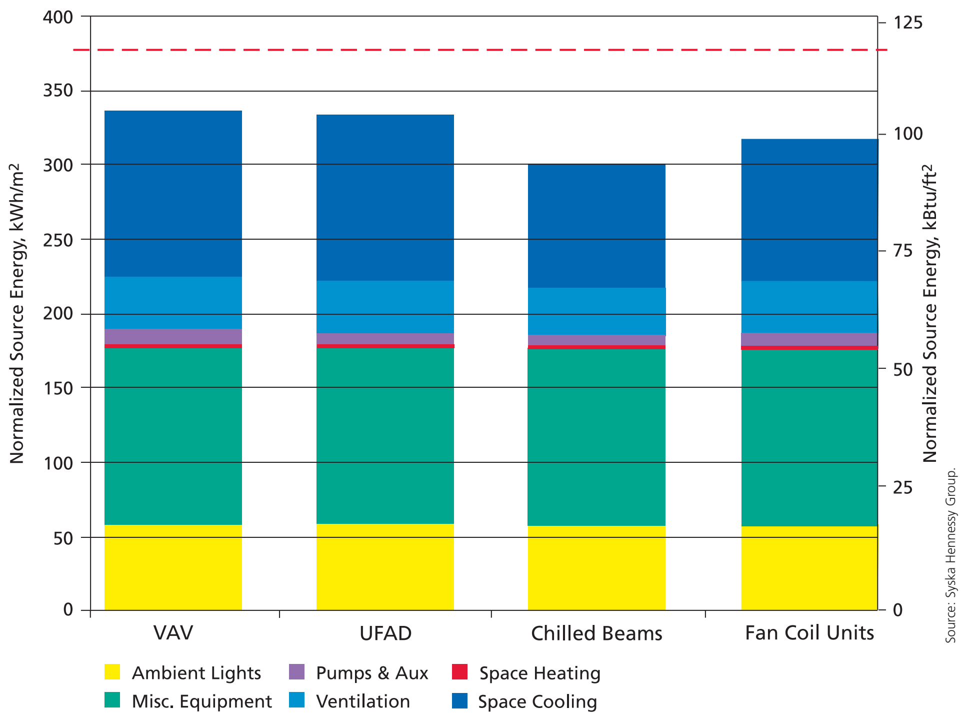
The green aspects of CBs are attractive to building owners and design professionals due to the simple fact that water is a more efficient means of conveying cooling energy than air is (volumetric heat capacity or specific heat) and thus reduces the fan energy required. While primary air is still delivered to the CBs, the majority of the space cooling is handled with pipes and pumps, not ducts and fans. For example, a 1-inch pipe can carry amounts of thermal energy similar to an 18-inch-by-18-inch duct.

As stated earlier, chilled beams can only remove the sensible heat in the space; therefore, the latent heat load is typically handled by a dedicated outside air system (DOAS), which wrings most of the moisture out of the primary air stream. Since the DOAS only handles about twice the ventilation air required for occupancy, they are inherently smaller than traditional air-handling units by 25 percent to 35 percent.

Not only are the DOAS air-handling units smaller in physical size, but so are the associated primary air ductwork and fan motors. These size reductions translate not only to the air-side cost savings but also fan energy savings. The energy savings of CBs help consulting engineers as well as building owners meet future energy codes that are requiring a reduction in building energy usage by 30 percent over standard ASHRAE 90.1-compliant buildings.

To illustrate the energy-saving potential of chilled-beam technology, it can be helpful to compare the energy usage of traditional HVAC systems to systems using CBs. Figure 1, created using the DOE-2-driven energy modeling software eQuest®, shows that CBs do use less overall energy when compared to the following systems: fan-powered variable air volume (VAV), under-floor air distribution (UFAD) and ceiling-mounted fan coil units (FCU).

Figure 1. HVAC System Annual Energy Usage Summary Comparison.



Note that chilled beams require less energy for space cooling (fan and latent cooling energy) as well as for pumps and auxiliary equipment. Furthermore, energy is saved because warmer chilled water must be used to prevent condensation from forming on the chilled-beam heat transfer surfaces and dripping (raining) on the occupants. The success of the CB requires that the space humidity be controlled; hence the chilled-water entering temperature must be 3-4 degrees F above the room design dew point, which results in supply temperatures of 55-60 F.

The use of warmer chilled water also saves a great deal of energy since many times chilled-water return from the DOAS cooling coils can be used as CB supply water. (This is referred to as a chilled-water cascade effect). For example, if the chilled-water entering temperature for the DOAS unit is 44 F, with a 16 F delta T, then the 60 F leaving water can be run to the chilled-beam water system and potentially returned back to the source at 67 F using standard temperature drops – a 23 F delta T. That is just far out! This enables a larger delta T for the chilled-water system, which we all know uses smaller pipes and pumps. This also has a beneficial effect back at the central plant or the energy transfer station.

Where Can Chilled Beams Be Used?

Can chilled beams be used everywhere? Not really. We still haven't found the perfect HVAC system yet. That is why there are consultants! CBs are mostly used in commercial office buildings and K-12 schools, and they are also being used in laboratories with high sensible loads. But due to the warmer chilled-water supply temperature requirement, CBs cannot be used in spaces with high latent loads, spaces exposed to humid conditions or large quantities of unconditioned outside air, such as lobbies, vestibules, atriums, theaters, restaurants, kitchens, pools, gyms and airport jet ways. Spaces that have high ceilings (higher than 14 ft) are also not appropriate, since the characteristics of induced room air flow are lost.

Since chilled beams are not the panacea for the HVAC world, their advantages must be weighed against their disadvantages. The key points are summarized in table 1.

As with any technology used correctly – and like Scotty you don't try to change the laws of physics – chilled beams can be an extremely effective cooling solution and offer a reduced energy footprint to your building. So whether you enjoy *Star Trek*

Table 1. Advantages and Disadvantages of Chilled Beams.

	Advantages	Disadvantages
Air Side	• Air-handling units can only be downsized based on reduced air (DOAS) requirements and not full cooling requirements, resulting in: • 25 percent to 50 percent less air than VAV system must deliver at peak load • smaller air handlers and ductwork • lower fan energy • elimination of reheat piping • potential reduction in overall building costs since floor-to-floor heights and shaft dimensions may be compressed due to smaller duct sizes	• Building must have very good external envelope with no leaks and good building humidity control • Beams have less capacity output than standard air diffusers • Beams take up more ceiling space for potential conflict with other ceiling-mounted devices if not integrated – lights, speakers, sprinklers, etc. • Dimensions may impact ceiling grid layout and require special installation details • Space humidity and condensation sensors required for better humidity control
Water Side	• Uses warmer chilled-water temperatures and can extend free-cooling operating range, enabling large chilled-water delta T's for smaller pipes and pumps • Water is more efficient way of conveying cooling than air (volumetric heat capacity or specific heat), reducing air-side costs • Similar to benefits of water source heat pumps, warmer chilled-water temperatures may not require vapor barrier, and some designers even use thick-wall plastic piping to provide insulating effect so pipe insulation not required	Installation costs are higher because • chilled-water piping routed to each beam and each room • actual cost of beam high compared to other terminal units (cost discrepancy may reduce as technology is applied more)
Operation	• Quiet as long as unit is selected properly and too much primary air is not used • Provide good thermal comfort and potentially more air circulation	• Not appropriate for highly latent load spaces or ceilings higher than 14 ft • Not as appropriate for rooms dependent on high heat gain or air change (labs) • Respond more slowly to varying cooling loads
Other	• Have reduced maintenance requirements compared to HVAC terminal units that have moving air-side parts and dampers	• Typically come with two position on-off control valves that are used since modulating valves may create a laminar condition

or *This Old House*, you always need the right tool for the right job. CBs, while having no structural properties, are the one beam and tool that can build a bridge to new technologies and lower energy usage, costs and ultimately, carbon dioxide emissions. And who doesn't want that? So (chilled) 'beam' me up, Scotty! I am ready for some chilling action.

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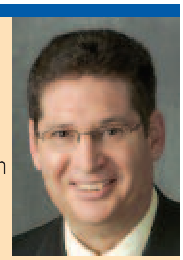

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