# VRF Or Chilled Beam?

## Refrigerant- and water-based hydronic systems are very popular solutions for new and retrofit construction. Both systems offer notable benefits.

John Vastyan, Common Ground


In Chicago, 635 active chilled beams were installed at 250 S. Wacker Drive, a 15-story, multi-tenant office tower with retail space on the first floor. The chilled beams consume only 30% of the fan and pump power of a fan-powered VAV system.

One of the challenges faced when constructing or renovating a commercial facility is choosing how to heat and cool the interior spaces. After all, energy rates play an increasingly important role in determining the cost of building ownership. Also, if the building is to be leased, the HVAC solution must pass muster in terms of comfort and cost of operation.

Two of the most efficient methods of heating and cooling commercial facilities compete frequently: VRF (variable refrigerant flow) and hydronic (water-based) systems that include chilled beams. Each of the methods has its strengths and weaknesses.

With VRF technology, heat is transferred directly to and from interior spaces by circulating refrigerant between a remote condensing unit and interior evaporators. Wall-mounted ductless or fan-coil ducted units are located in or near occupied spaces. Multiple evaporators (wall-mounted or fan-coil) can be connected to the system, allowing optimal temperature control and zoning.

### VRF suited for many applications

VRF systems can serve a wide range of applications including multi-family units, hotels, nursing homes, restaurants, office buildings, condominiums, and schools where temperature-control zoning is needed. Depending on the manufacturer, capacities range from 2 to more than 30 tons of cooling/system, with the ability to connect as many as 48 indoor evaporators.

Space-temperature control in VRF systems is achieved by modulating the flow of refrigerant to each evaporator. Indoor-unit fan speed is determined by the difference between set point and control point (actual space temperature), according to Tim Young, PE, West Coast HVAC engineer for Fujitsu General America, Fairfield, NJ.

The heart of the system is a variable-speed compressor. The speed of the compressor—and thus the amount of refrigerant circulated—is varied to match the cooling loads of the indoor units. As zones are satisfied, compressor speed is reduced, thus saving energy and reducing noise. Also, compared with the operation and cycling of conventional, single-speed compressors, temperature control is vastly improved. Multiple thermistors in the indoor and outdoor units provide data to adjust and optimize compressor speed.

VRF systems, which can be coupled to dedicated outdoor air systems (DOAS), may be used to ensure air quality in conditioned spaces, according to Brendan Casey, commercial product manager for Fujitsu. High-performance filters, such as Apple-Catechin, ion deodorization, or MERV-13 help achieve high levels of IAQ.

"Most VRF indoor units can accept up to 10% fresh outside air directly to the indoor unit. Outside air is delivered by a booster fan that can be integrated with a $CO_2$ sensor and the indoor unit," he added. "By providing the precise amount of outside air required in each zone, VRF systems can contribute toward ensuring proper air quality in every zone."

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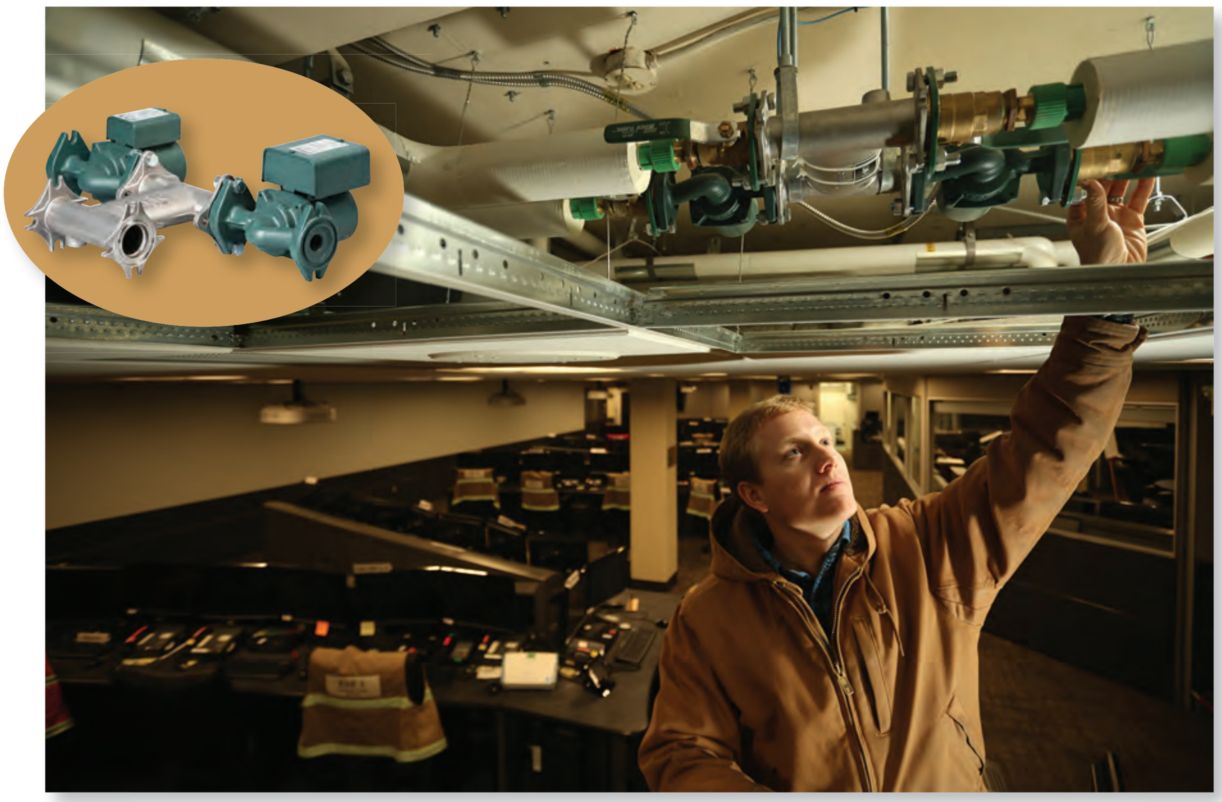
**Chilled beams with injection-mixing technology were installed at the Penn Foundation mental health facility near Allentown, PA. Btus are removed from or delivered to enclosed spaces through the chilled beams, which have a capacity approaching 400 Btuh/sq. ft.**

**Different water temperatures are readily available for a variety of terminal units throughout the Penn Foundation facility from a single-pipe system because injection-mixing blocks blend supply and return water temperatures.**



**A technician inspects a Taco LOFlo mixing block installation at the Emergency Operations Center (EOC) on Joint Base Elmendorf-Richardson Air Force Base near Anchorage.**
**(Inset) The mixing block installation, which consists of a variable-speed injection circulator and constant-speed zone circulator, results in pump energy savings for the chilled-beam system.**

Ductless indoor units eliminate risks associated with the build up of dust, mold, and allergens inside long duct runs. With VRF technology, even ducted units, which can be hidden in mechanical spaces or above suspended ceiling tiles, use significantly less duct than a standard central system, allowing easy cleaning and maintenance while preserving IAQ.

According to Barbara McCrary, PE, LEED AP BD+C, an associate with HHB Engineers based in Prattville, AL, VRF's ease of zoning also plays into another strength: the systems offer a wide variety of options for indoor air handling, such as ceiling cassettes, wall units, floor-mounted air handlers, and ducted units—all playing into an interior designer's ability to match equipment to space aesthetics.

## Not in the sweet spot

On the other hand, experts agree VRF systems aren't well suited for surgical suite, lab, or clean-room applications where 100% outside air may be required, or those that may have high filtration requirements.

Process-cooling use or large gymnasiums and sports arenas would not be in the VRF sweet spot, either, because of the technology's lack of compatibility for use with high latent loads (humidity).

Detractors also point to refrigerant management concerns. As it is with all larger refrigerant-based systems, there's the need to be vigilant about containing toxic refrigerants. Refrigerants such as R-410a are hermetically sealed within a VRF system's compressor, refrigerant lines, and

## Chilly in Chicago

In Chicago, 635 active chilled beams were installed at 250 S. Wacker Drive, a 15-story, multi-tenant office tower with retail space on the first floor. The first and top floors had dedicated HVAC systems, separate from systems serving the 2nd through 14th floors. The intermediate floors had a floor-mounted induction perimeter system and a constant-volume/variable-temperature interior system. Each of the floors has about 14,300 sq. ft. of rentable floor area (215,000 sq. ft. total).

A major renovation of the building included removal of the building's exterior walls and glass and gutting the structure to bare concrete. Building owners concluded that the existing induction units would have to be replaced.

The building's three-year renovation involved a change to 100%, low-e exterior glass, which significantly reduced the building's heating and cooling loads. Heat losses along the perimeter were reduced to less than 200 Btu/lineal foot, which made it possible to provide comfort conditioning of interior spaces with active chilled beams.

According to Jim Wilson, Windy City Representatives, Oak Brook, IL, manufacturers' representative for commercial HVAC products, there were many advantages, beginning with unobstructed visibility through the floor-to-ceiling windows along exterior walls. Also, there are no down drafts, floor space is gained, and the cost of custom enclosures for floor-mount units was avoided. Also, fan energy and noise levels were greatly reduced.

The developer approved installation of 635 active chilled beams, which now consume only 30% of the fan and pump power of a fan-powered VAV system (assuming that the average cooling loads are 70% of the full design cooling load).

The building's chilled beams have proven successful in operation. Many visits to the site by professionals keenly interested in studying system function have been conducted. One trip to the building took place when ambient temperatures were at –12 F, yet visitors were comfortable sitting next to exterior windows with no hint of down draft.

## A Good Mix In Pennsylvania

Chilled beams with Taco Inc.'s, Cranston, RI, LOFlo injection-mixing technology were installed at the Penn Foundation mental health facility near Allentown, PA. "I don't know that you'll find a smarter, more efficient mechanical system than the one installed at the new Penn Foundation building," said Glenn Snyder, PE, vice president, Lederach Associates, Lederach, PA.

The facility is a 36,000-sq.-ft., two-story addition to the foundation's mental-health facility. The building uses a total of 98 mixing blocks, 88 of which are coupled to chilled beams in the 1,000- to 6,000-Btu size range.

"Geothermal systems were installed," added Snyder. "But the real uniqueness of this job is the way Btus are removed from or delivered to enclosed spaces through chilled beams, technology with a capacity approaching 400 Btuh/sq. ft.

"Different water temperatures are readily available for a variety of terminal units throughout the facility from a single-pipe system because we're using the injection-mixing blocks that blend supply and return water temperatures," he said.

According to Lederach engineers, Penn Foundation will see a return on additional investment of the geothermal and chilled-beam system—compared with operation of conventional heat pumps—within 16 months.

**With VRF technology, heat is transferred directly to and from interior spaces by circulating refrigerant between a remote condensing unit (shown here) and interior evaporators. Wall-mounted ductless or fan-coil ducted units are located in or near occupied spaces.**

within the condensing unit and indoor units. Great care is taken to test for leaks during installation and routine maintenance check-ups.

McCrary also points to a final VRF design consideration. "VRF isn't well suited for facilities that will require modification to the system in the future," she said. "If a tenant plans to do interior remodeling, or if they anticipate growth that could lead to modifications of interior spaces, then VRF may not be the best option. Because of the way refrigerant lines are installed, the systems serve their purpose best when designed specifically to meet a building's existing needs.

### Beam me up

An alternative to VRF systems is hydronic chilled-beam technology. First devised in Europe as a cooling retrofit for older, non-ducted structures, chilled beams achieve high energy efficiencies and superior comfort levels by combining forced convection with radiation. The systems are sure to grow in popularity now that ideally matched use of 100% dedicated outdoor air systems (DOAS) is better understood.

The use of chilled beams with injection pumping, using a single-pipe system, makes hydronics more competitive, from a first-cost basis, due to the reduced piping. Such a system is also self-balancing because its primary/secondary piping arrangement efficiently distributes Btus.

"With a chilled-water system it's easier and less costly to provide multiple zones of temperature control, particularly in larger buildings because multiple terminal units [chilled beams, heat pumps, fan coils] are linked to one set of central generation equipment with one piping distribution system," explained Greg Cunniff, PE, application engineering manager for Taco Inc., Cranston, RI.

A perennial challenge with HVAC systems is how to deal with humidity. Hydronic and refrigerant coils (such as with VRF systems) handle dehumidification differently. The biggest challenge with dehumidification is to remove moisture continuously for optimal comfort and also to reduce the risk of condensate formation where it's not wanted, such as in ceilings or behind walls where mold might grow.

Humidity problems can be mitigated by smart selection and positioning of cooling coils (best when facing airflow velocity). This can be difficult in DX or VRF systems where refrigerant-coil configuration and sizes are limited. This is not the case for hydronic coils employed for passive or direct dehumidification.

Chilled beams separate the functions of ventilation and dehumidification. The business end of chilled-beam systems is made of copper tubing bonded to aluminum fins. The "beam" is housed in a sheet-metal enclosure that's typically placed at ceiling level.

### Little space required

"What makes this technology so interesting is its broad applicability for commercial structures and extreme energy and thermal efficiency," said Cunniff. "A key advantage is that a chilled-beam system requires very little ceiling space and height."

Another advantage is that water, the main transporter of thermal energy in a chilled-beam system, permits very high energy carrying capacity through pipes—a big advantage over larger, less efficient, forced-air conveyance. A forced-air system is, by its very nature, less efficient because of the inherent low density of air and the requirement of large ducts to transport Btus.

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

"The amount of outside air required to operate a typical chilled-beam system is much less than that needed for a forced-air system," added Cunniff. "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 eight to ten air changes of recirculated (and fresh) air to cool a space."

According to Cunniff, any system using air as its means of delivering sensible cooling in a space will create evaporative cooling from the increased air volumes and velocities in the space. With chilled-beam technology, however, reduced air flow means greater comfort since evaporative cooling is virtually eliminated.

Also reduced is the ceiling space typically required for ductwork. The amount of air circulated by the central system is also dramatically reduced, often 80% to 90% less than with conventional, all-air systems. The net result is lower energy consumption and operating costs.

### Injection-mixing systems

Although radiant cooling and chilled beams reduce fan electrical-energy demand and con-

sumption as much as 10 times, when compared with traditional forced-air systems, pump energy demand doubles.

To address this, Taco designers devised an injection-mixing system to reduce pump energy. Coupled with chilled beams, significant energy savings are achieved by the company's LOFlo system. Low-temperature chilled water (40 to 45 F) is "mixed-up" to that required by a chilled ceiling panel or beam (55 to 60 F) for cooling.

"With the mixing system, circulation to and from chilled beams—instead of double that of conventional chilled-water systems—requires only one-quarter of the flow," explained Cunniff.

Compared with an all-air system, a chilled-beam/injection-mixing system reduces electrical-energy demand by 35% or more, thus reducing the transport energy to only 20% of the total HVAC system.

Depending on the application, VRF and chilled-beam technologies offer a variety of solutions to enhance energy efficiency and occupant comfort. Carefully weighing the options will ensure optimum results. cbp

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## VRF, Chilled Beam: Pros And Cons

**VRF Pros**

- Versatile: They heat and cool simultaneously.
- As zones are satisfied, compressor speed is reduced, saving energy and making these a green technology.
- Precise temperature control.
- Excellent results for buildings with multiple temperature-control zones.
- Well suited for retrofit applications where ductwork isn't feasible.
- Separate indoor air handling units help reduce the transfer of bacteria and germs within health-care facilities.
- Easy, inexpensive cleaning and maintenance.
- Wide variety of indoor units: wall mount, cassette, compact duct, floor/ceiling mounted, and high-static-pressure duct.
- Very high efficiency during shoulder season, part-load operation.
- Single-source supplier for condensing unit, air handlers, and integral DDC control.
- Quiet operation.
- Small footprint.

**VRF Cons**

- Not for surgical suite, lab, or clean-room applications where 100% outside air is required.
- Not best for buildings with high filtration requirements or for process cooling.
- Large gymnasiums and sports arenas aren't a good fit for VRF because of high latent loads (humidity).
- Refrigerants are toxic. System designers must take into account limitations set by ASHRAE Standard 15.
- Smaller zones limit the maximum size of condensing units.
- Not well suited for buildings that will require later modification.
- Higher initial cost compared with traditional HVAC (but lower cost of ownership).

**Chilled Beam Pros**

- Versatile: They heat, and cool simultaneously.
- Superb energy efficiency (especially with injection mixing). Water, the main transporter of thermal energy, permits very high energy-carrying capacity.
- High-efficiency, variable-speed chillers and geothermal heat pumps can be easily combined with chilled beams.
- Hydronic systems can take advantage of lower-cost gas heat in middle to northern latitudes of the U.S.
- Single-pipe systems with injection mixing make them competitive from a first-cost basis.
- With primary/secondary piping, systems are essentially self-balancing. Additional zones can be added easily in the future without having to rebalance the entire system.
- Ideally suited for multiple zones of temperature control, particularly in larger buildings.
- Superior temperature control. Hydronic chilled-beam systems take advantage of the thermal inertia of water vs. other systems that require air as the final Btu delivery medium.
- Systems require very little ceiling space and height.
- No down drafts. Extremely comfortable because chilled beams circulate less air and do not create drafts or evaporative cooling on occupants' skin.
- Super-quiet, essentially no sound.
- Lower maintenance. Older components can always be replaced with newer, more efficient units from multiple vendors.
- Very reliable. Highly skilled, certified technicians are not required.

**Chilled Beam Cons**

- The risk of condensate moisture must be dealt with continuously and definitively.
- Interconnected hydronic systems tend to be more complex and involved.
- Higher initial cost when compared to traditional HVAC (but lower cost of ownership).