Decoupled Sensible Cooling Systems

The advantages and disadvantages of radiant cooling panels, passive chilled beams, active chilled beams, and series fan boxes with sensible cooling.

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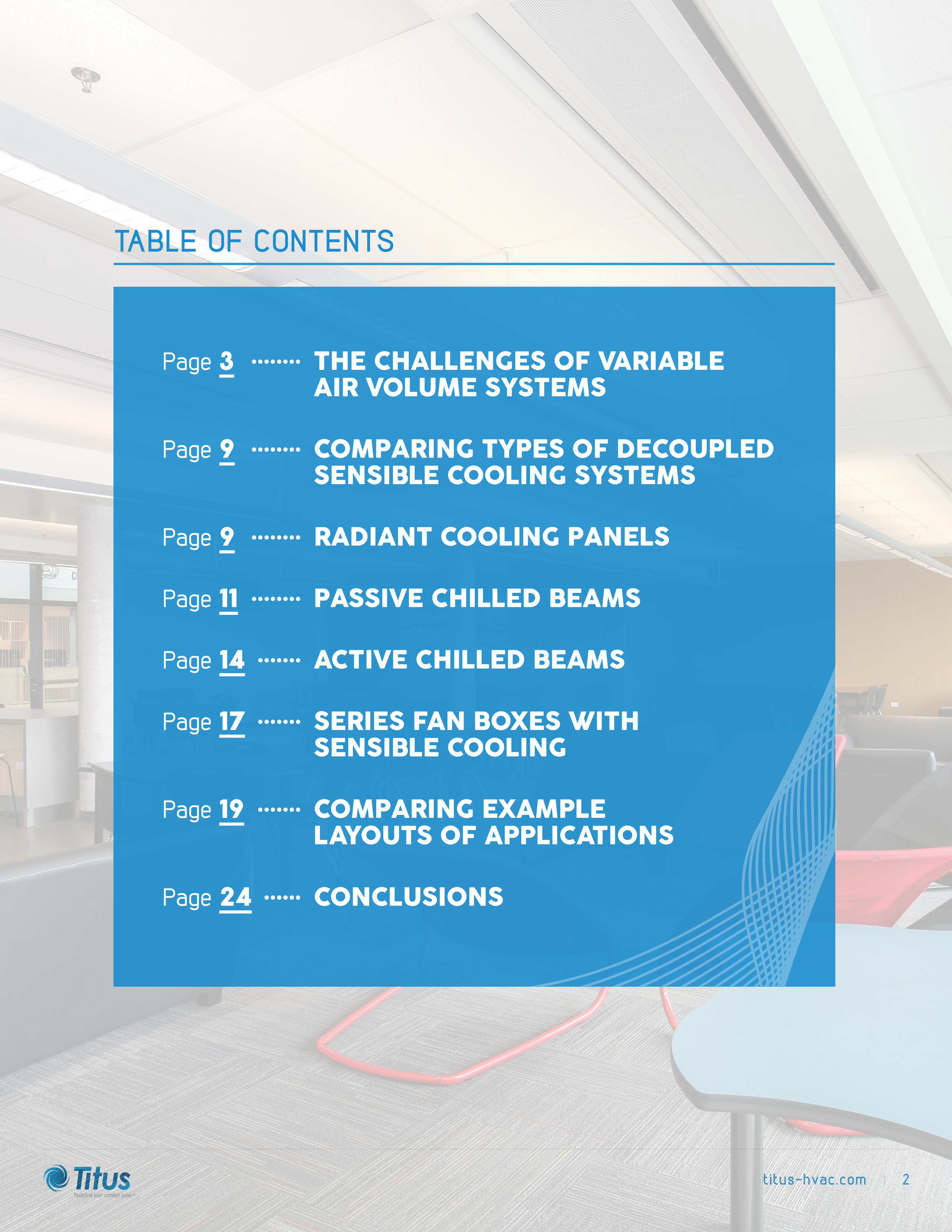

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THE CHALLENGES OF VARIABLE AIR VOLUME SYSTEMS

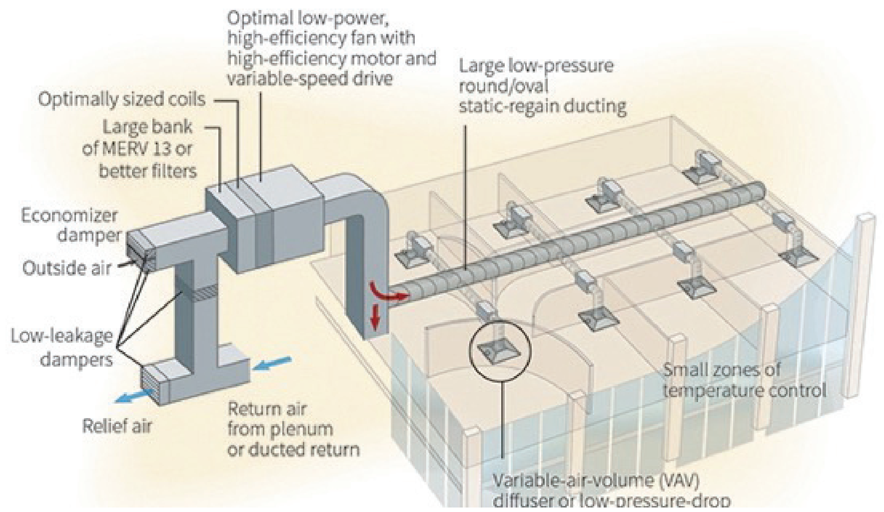
Variable Air Volume (VAV) HVAC systems have seen widespread use throughout North America for decades, with countless building owners satisfied with the system's performance; however, VAV is not without its issues, particularly when designing the system to comply with modern building ventilation standards.

The most frequently used standard for defining ventilation performance for acceptable indoor air quality (IAQ) in North American non-residential buildings is ASHRAE Standard 62.1. This standard is designed to provide IAQ acceptable to human occupants and minimize adverse health effects caused by excessive airborne contaminants.

Almost all "all air" VAV systems transport a mixture of recirculated and filtered outdoor air to the building via a ductwork distribution system fitted with VAV terminal units. The VAV units vary the quantity of mixed air sent to the space through grilles or diffusers in response to the space dry bulb temperature. The primary issue is that once this outdoor air is brought in to the building and mixed with return air at the air handling unit (AHU), it is difficult to determine exactly where this fresh air is distributed across the building. Distribution of the outdoor air is a function of space-sensible loads, local exhaust and exfiltration, interzonal air transfer, and VAV box minimum settings (Mumma, Lee, 1998). Due to these varying factors, it is virtually impossible to verify that the requirements of ASHRAE 62.1 are being met in all zones at all times.

How Traditional VAV Systems Work

Conventional Variable Air Volume (VAV) systems consist of a central air handler that mixes building return air with outdoor air. At the air handler, this mixed air is filtered, cooled, and distributed through a duct system to multiple temperature control zones. At each control zone, this air is supplied to a VAV terminal that handles room temperature control. Terminal units in perimeter zones usually include a reheat coil to compensate for exterior walls and glass exposures; in addition, they prevent overcooling during part-load conditions.



VAV image courtesy of *HPAC* magazine

Inherent Issues with VAV Systems

- Difficult to verify that ASHRAE Std 62.1 is being met
- Unpredictable ventilation performance with some areas over-ventilated and others under-ventilated
- Imprecise humidity control

Unpredictable Ventilation and Wasted Energy

When the ASHRAE 62.1 multispace equation is used, VAV system design can result in an over-ventilated building. The VAV box minimum settings for some spaces will be higher than what would be required for the minimum sensible cooling or heating settings to ensure that the outdoor air portion of the total supply mixture is enough to satisfy the minimum ventilation for the space. This practice results in wasted energy, as this high minimum box setting can result in excessive cooling of the space, forcing the terminal reheat coils to activate to keep the space temperature under control.

Imprecise Humidity Control

VAV system air is also tasked with controlling the building's humidity. Zone VAV boxes are typically only controlled by room dry bulb temperature sensors. So, while the space temperature will be tightly controlled, the space humidity may not. This often results in the building being overly dehumidified, particularly during peak summer, while some zones may become uncomfortably humid if occupant density increases when the perimeter sensible loads are still low. Precise humidity control is a problem with traditional VAV systems because the building humidity and zone dry bulb temperature are not controlled separately.

Dedicated Outdoor Air Systems Solve These Issues

Dedicated Outdoor Air Systems (DOAS) are designed to decouple temperature control from ventilation and humidity in order to control them separately and more precisely.

The Difference Between VAV and DOAS

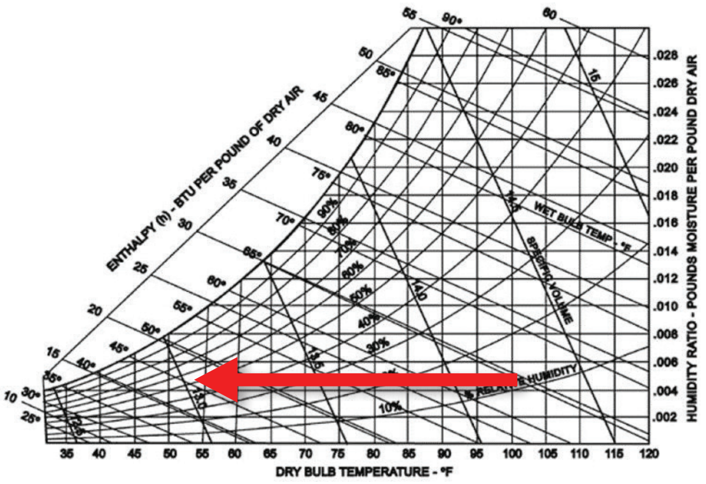
While a conventional **VAV** system primarily conditions building air and brings in only a fraction of its supply air from outdoors, a DOAS is primarily concerned with ventilation and has a large outdoor air intake to provide 100% outdoor air. It is designed to provide all of the necessary filtering, dehumidification, heating, and cooling necessary to make use of raw outdoor air. A DOAS typically provides improved filtration and better humidity control. All of this is necessary in order to allow the DOAS to deal with a wider range of entering air conditions.

DOAS units are air handlers that filter, heat or cool, dehumidify, and send 100% outdoor air to the building. With these systems, the supply air is tasked with only ventilating and dehumidifying, while the zone temperature control is handled by separate terminal units. These terminal units are available in various formats including variable refrigeration volume systems, fan coil units, radiant cooling panels, passive chilled beams, active chilled beams, and series fan boxes with sensible cooling.

This paper will compare the pros and cons of air/water sensible cooling systems, such as radiant cooling panels, passive chilled beams, active chilled beams, and series fan boxes with sensible cooling, and the applications these choices are best suited for.

What Is The Sensible Cooling Process?

Before we discuss these systems in detail, we should first define the sensible cooling process that makes them so efficient. Sensible cooling is the removal of heat from the air without changing the moisture content. On the psychrometric chart (right), the cooling process moves from right to left in a horizontal line. This process does not change the humidity ratio (W) or dew point (DP) temperature of the air. However, the wet bulb temperature (Twb), relative humidity (%RH), specific volume (v) and enthalpy (h) do change.



Psychrometric chart of the sensible cooling process

A key characteristic of zone sensible cooling is that as no moisture removal occurs, so the cooling coil operates in a dry condition. In order to accomplish this, the chilled water supplied to the coils must be held at or above the room dew point temperature. This is warmer than the chilled water used in traditional HVAC systems and is sometimes referred to as **medium temperature** chilled water.

The Advantages of Sensible Cooling Combined with DOAS

- Verifiable ventilation performance
- Reduced energy costs
- Reduced space requirements
- Reduced maintenance costs

Verifiable Ventilation Performance

Decoupled systems allow ventilation rates to be tightly controlled in all zones across the building. Compliance with the ASHRAE 62.1 ventilation standard can be verified simply by measuring the airflow leaving the diffuser or by taking an airflow reading in the duct serving the sensible cooling terminal unit. The outdoor air can be supplied at either constant volume (CAV) or variable air volume (VAV) to the space. VAV control is often used in spaces with variable occupancy, such as meeting or conference rooms, and is usually controlled by CO_2 sensors mounted on the wall or in the exhaust duct. The airflow is reduced when a lower ventilation demand situation occurs, often referred to as demand control ventilation (DCV).

Reduced Energy Costs

Space heating and cooling loads are dealt with separately by the terminal unit coils or radiant cooling panels. These coils are designed to operate dry at all times, so a humidity monitoring system must be employed to control the DOAS moisture content and chilled water system temperature. This prevents the dew point temperature from rising above supply chilled water temperature, which may otherwise cause condensation to form on the coils or panels.

A useful by-product of humidity monitoring is that the amount of dehumidification can be adjusted in response to the building and outdoor air conditions. This can reduce energy consumption as over-dehumidification of the outdoor air is less likely to occur. During warm but dry outside air conditions, the ventilation air only needs to be cooled down to just below a "room neutral" temperature, typically around 65–70°F. The zone sensible cooling terminal units provide supplementary heating or cooling as required.

Sensible cooling systems rely on water as the primary medium to transport cooling energy around the building. The use of water as a heat transfer medium offers considerable energy savings over air. A water pipe can transport the same amount of cooling energy as an air duct 250 times its cross-sectional area.

Water density is 800 times that of air.

Water heat transfer capacity is 3,500 times that of air on a mass basis.

1" diameter water pipe vs. 16" x 16" air duct

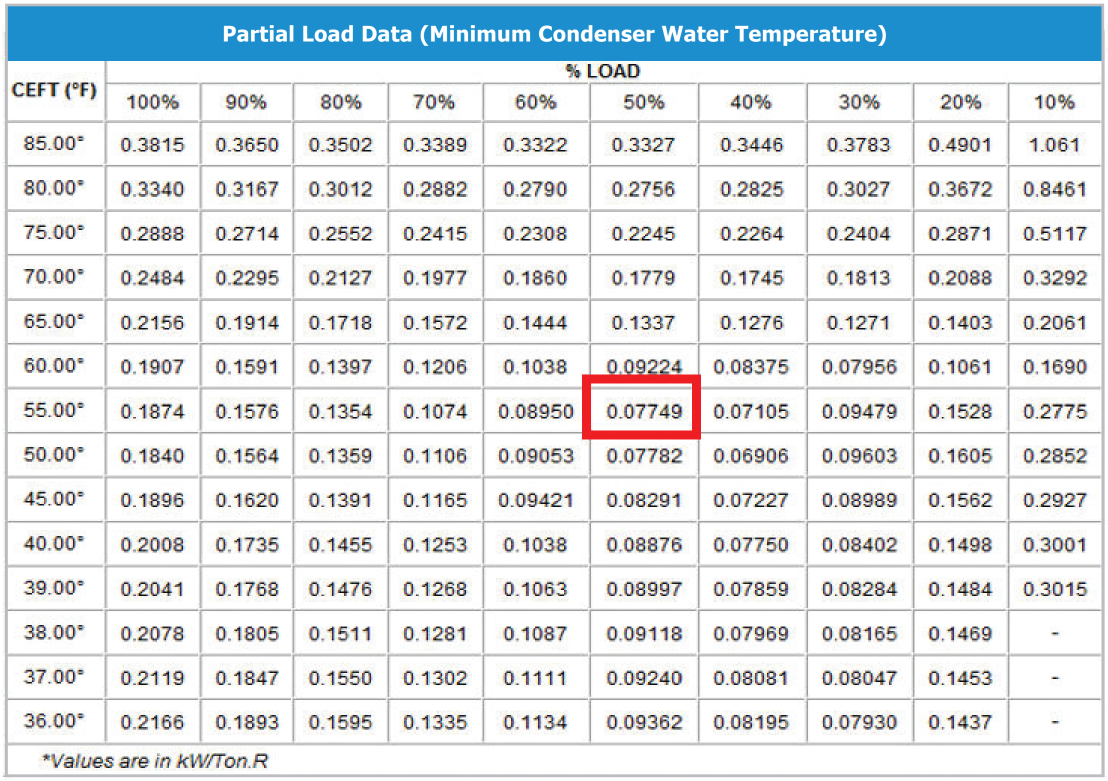
The Transport Characteristics of Water Versus Air

Due to its density (62.4 pounds per ft^3 versus air at 0.075 pounds per ft^3) and specific heat capacity (1.0 Btu/lb.-°F versus 0.24 Btu/lb.-°F for air), the heat transfer capacity of water is 3,500 times that of air on a mass basis.

As such, the cooling amount transported by water flowing in a 1-inch diameter water pipe at 4 fps with a 6°F ΔT (between supply and return) is equivalent to the amount transportable by standard air at a 20°F ΔT traveling at 1,000 fpm through a 16"-square duct.

From this comparison, it is obvious that distributing cooling energy by water requires considerably less cross-sectional space than air. So, DOAS air handling units are considerably smaller than traditional VAV air handling units, resulting in a fan motor BHP reduction of 50–75%.

Chiller operating costs can also be significantly reduced if the chiller is configured to supply medium temperature chilled water instead of low temperature (44°F) water. Chiller efficiency increases by around 2–4% per degree increase of supply water temperature. The chiller performance table below illustrates just how efficiently a modern chiller can perform when producing 58°F chilled water.



Partial Load Data (Minimum Condenser Water Temperature)

CEFT (°F)	% LOAD									
	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%
85.00°	0.3815	0.3650	0.3502	0.3389	0.3322	0.3327	0.3446	0.3783	0.4901	1.061
80.00°	0.3340	0.3167	0.3012	0.2882	0.2790	0.2756	0.2825	0.3027	0.3672	0.8461
75.00°	0.2888	0.2714	0.2552	0.2415	0.2308	0.2245	0.2264	0.2404	0.2871	0.5117
70.00°	0.2484	0.2295	0.2127	0.1977	0.1860	0.1779	0.1745	0.1813	0.2088	0.3292
65.00°	0.2156	0.1914	0.1718	0.1572	0.1444	0.1337	0.1276	0.1271	0.1403	0.2061
60.00°	0.1907	0.1591	0.1397	0.1206	0.1038	0.09224	0.08375	0.07956	0.1061	0.1690
55.00°	0.1874	0.1576	0.1354	0.1074	0.08950	0.07749	0.07105	0.09479	0.1528	0.2775
50.00°	0.1840	0.1564	0.1359	0.1106	0.09053	0.07782	0.06906	0.09603	0.1605	0.2852
45.00°	0.1896	0.1620	0.1391	0.1165	0.09421	0.08291	0.07227	0.08989	0.1562	0.2927
40.00°	0.2008	0.1735	0.1455	0.1253	0.1038	0.08876	0.07750	0.08402	0.1498	0.3001
39.00°	0.2041	0.1768	0.1476	0.1268	0.1063	0.08997	0.07859	0.08284	0.1484	0.3015
38.00°	0.2078	0.1805	0.1511	0.1281	0.1087	0.09118	0.07969	0.08165	0.1469	-
37.00°	0.2119	0.1847	0.1550	0.1302	0.1111	0.09240	0.08081	0.08047	0.1453	-
36.00°	0.2166	0.1893	0.1595	0.1335	0.1134	0.09362	0.08195	0.07930	0.1437	-

**Values are in kW/Ton.R*

Evaporator leaving temperature 58°F. ECWT/LCWT: 85/94.3°F. Data courtesy of YORK®.

Given the Two Major Energy Consumers in a Traditional HVAC System, **the Savings Add Up.**

Air Handling Units Operating Costs

- Motor BHP typically reduced by 50–75%
- Annual fan/pump energy savings of 30–40%

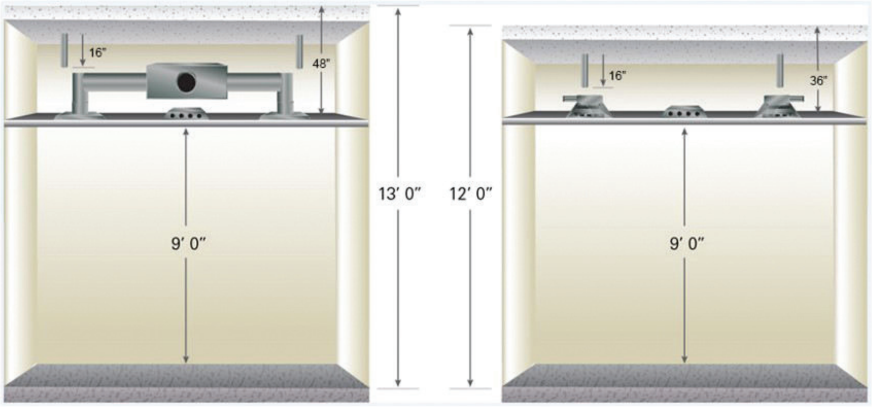
Chiller Operating Costs

- Higher supply water temperature increases efficiency by 2–4% per degree
- Chillers producing 58°F chilled water increase efficiency

Without the constraints of artificially high VAV minimum box settings to ensure the minimum ventilation rates are achieved, ventilation air can be supplied at a room neutral temperature. This enables parasitic reheat to be completely eliminated with DOAS decoupled systems.

Reduced Space Requirements

With smaller water pipes replacing large air ducts, significant space savings can be gained in both the ceiling interstitial and mechanical rooms. For example, an active chilled beam system can save around 12" of interstitial space per floor compared to “all air” VAV.



Typical slab-to-slab heights for VAV vs. typical slab-to-slab heights for active chilled beams

Reduced Maintenance Costs

Sensible cooling coils are operated dry, and since mold and bacteria are far less likely to grow on dry surfaces, the owner benefits from reduced maintenance and longer coil life. Dry coils also mean that a condensate drain system is not required, eliminating the need for condensate pumps and further reducing maintenance needs. Also, filters are not usually fitted to sensible cooling coils as most codes, including ASHRAE Standard 170, do not stipulate this as a requirement on coils not designed to condense water.

Most sensible cooling terminal units do not contain moving parts, so the maintenance-intensive components (fan, wet coils, and filters) are moved out of the occupied spaces and into the mechanical rooms where access is more convenient.

Sensible Cooling + DOAS

- Decoupling of sensible cooling from ventilation and dehumidification allows them to be controlled separately
- Guaranteed ventilation air delivery in all zones makes it easy to verify that ASHRAE 62.1 is met
- More precise humidity control for energy savings and better comfort
- Reduced cooling and heating transport costs
- Reduced main distribution ductwork size
- Reduced main air handling unit size

COMPARING TYPES OF DECOUPLED SENSIBLE COOLING SYSTEMS

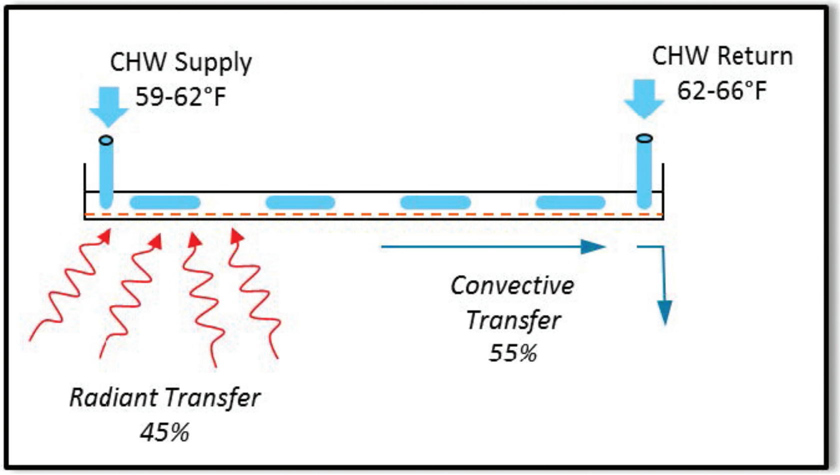
The following sections describe four types of decoupled sensible cooling systems: radiant cooling panels, passive chilled beams, active chilled beams, and series fan boxes with sensible cooling, with a comparison of the advantages and limitations of each and which applications they are best suited to.

RADIANT COOLING PANELS

Radiant cooling panels (sometimes referred to as chilled ceilings) remove space heat by both radiant and convective means. Convective heat transfer occurs as warm air passes across their cooled surface while additional heat is absorbed by radiation from occupants and other warm surfaces within the space.

A radiant cooling panel is a metallic ceiling tile that is fitted with chilled water copper meander bonded into the back of the tile, which is then dropped into an integrated ceiling support grid. Chilled water, supplied at a temperature 2–3°F warmer than the dew point temperature of the space it serves, is circuited through tubes attached to the back of the panel, cooling its surface.

The DOAS ventilation air is sized to handle all of the space latent loads and is introduced into the space via conventional ceiling diffusers or floor displacement outlets. Throwing the ventilation air across the ceiling will increase the convective heat transfer but at the cost of reduced radiant cooling panel surface area, which is lost to the ceiling diffuser.



Radiant cooling function

Radiant cooling systems offer one of the most comfortable occupant experiences of any HVAC system. The experience is similar to walking through a historic cathedral building on a warm day, where the cool masonry absorbs radiant heat emitted by the occupants. Radiant cooling has been used throughout Europe for decades and provides building owners with quiet, draft-free and energy-efficient cooling. Comfort can be enhanced further when combined with a displacement ventilation system.

Installation of radiant cooling panels. Note the high number of water connections required for the system.

There are however a number of drawbacks which have limited its widespread appeal in North America, including high cost and the cooling capacity being limited to around 25 BTU/h·ft^2 of surface area, which translates into an actual average cooling capacity of 18 BTU/h·ft^2 because other ceiling services such as sensors, sprinkler heads, and lighting reduce the cooling panel surface area to around 70% or less of the total ceiling.

Advantages of radiant cooling panels

- Very quiet, typically less than NC25
- Requires less than 8" interstitial height
- Very high comfort levels
- No moving parts apart from control valves
- Can also be used for heating

Limitations of radiant cooling panels

- Expensive
- Limited cooling capacity
- Extensive pipework with a high number of water connections
- Sound masking may be required for open office applications

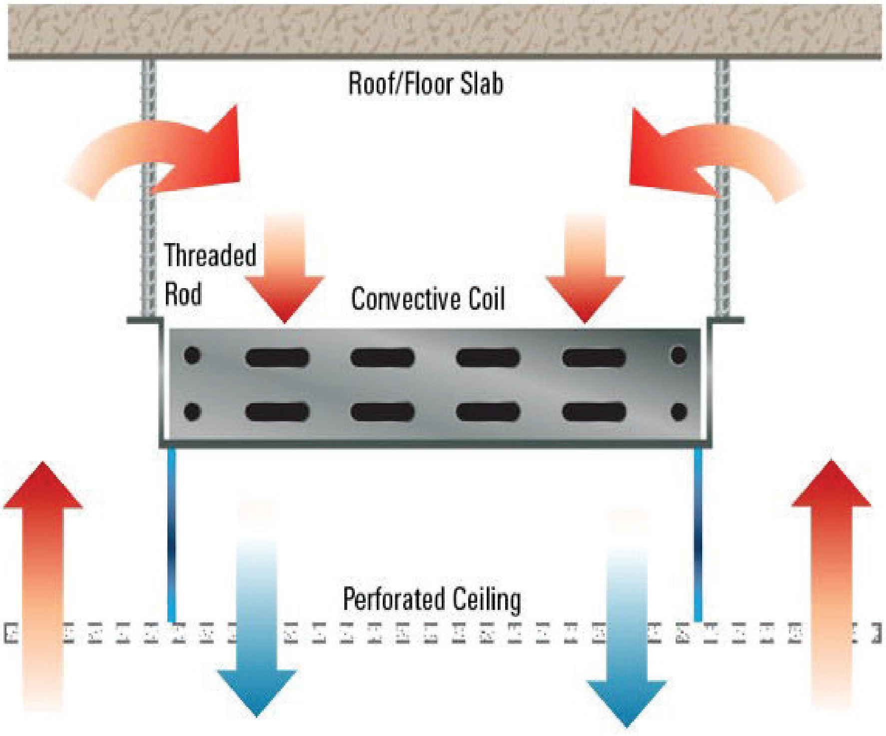
Best applications for radiant cooling panels

- Buildings with very low floor-to-slab heights
- Offices
- Hospital patient rooms
- Milder climates; system is rarely used in southern United States

PASSIVE CHILLED BEAMS

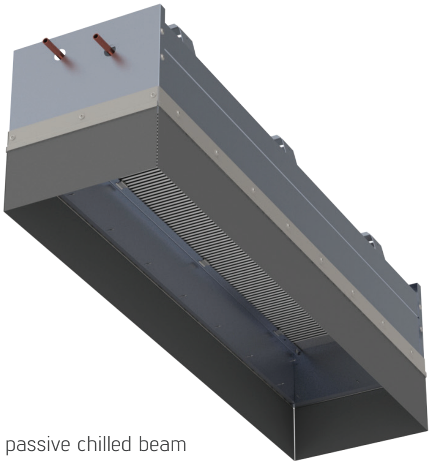
A passive chilled beam consists of a chilled water coil fitted into a metal enclosure. They are simple devices that cool the space with convection heat transfer by relying on the buoyancy of thermal currents to remove heat from the space. Warm natural convection currents deliver room air to the upper level of the space where the beams are located. The warm air is cooled upon contact with the coil and falls back into the space, creating a slight vacuum above the coil which draws additional warm air through the coil.

Passive chilled beams work in exactly the same manner as perimeter convective heating systems except turned upside down to drop cool air into the space. For that reason, passive chilled beams are not effective for heating, so a separate perimeter heating system must be used.



Passive chilled beam operational principle

Passive chilled beams generally incorporate coils with a fin spacing of four to six inches, much like that employed in hydronic fin tube heating. The wide fin spacing is important as the beam does not incorporate any mechanical means of moving air through it. They are typically supplied with chilled water at around 2°F above the room dew point temperature to ensure the coils operate dry at all times. Passive chilled beams are available in two configurations: recessed and exposed.



Recessed passive chilled beam

Recessed Passive Chilled Beams

Recessed models are designed for buildings with suspended ceilings. However, in order to ensure the transfer of convective air currents into the ceiling cavity, the ceiling tiles underneath and immediately adjacent to the beam must be perforated with a free area of no less than 40%.

Exposed Passive Chilled Beams

Exposed models are designed for buildings and spaces without suspended ceilings and are fitted with a decorative enclosure to conceal the coil.

Exposed passive chilled beam

Exposed passive chilled beams installed in a lounge area

As the cooling process is driven by convection currents, the cooling capacity of a passive chilled beam is affected by its proximity to the building structure and the ceiling type onto which it is installed. A clear distance of at least 25% of the passive chilled beam width is required above the top of the unit to allow the warm air to circulate through the beam. When recessed passive chilled beams are used, special care should be taken when selecting a ceiling tile. The tile should be perforated with a free area of at least 40%. The tiles should extend to either side of the beam to provide a surface area of at least the equivalent that is directly underneath the beam; so, for example, a 24"-wide beam should be installed above a 48" width of perforated tiles.

Passive chilled beams should not be located near exhaust/return ducts as they may create negative pressure high enough to draw room air upward through the chilled beam.

Passive chilled beams are best suited to exposed ceiling applications. Compared to an “all air” system, the smaller pipework can be easier to conceal than large ductwork and VAV boxes.

Outdoor air can be delivered through ceiling diffusers or floor outlets. Special care must be taken, however, to avoid throwing high velocity air across the face of the chilled beam when using ceiling diffusers, which may disturb the convective air currents.

Advantages of passive chilled beams

- Lower cost than radiant cooling panels
- Less impact on ceiling design than radiant cooling panels
- Fewer water connections than radiant cooling panels
- Quiet system — less than NC25
- Smaller primary air system than active chilled beams
- No moving parts apart from control valves

Limitations of passive chilled beams

- Relatively expensive system
- Separate heating system required
- Requires a deeper interstitial space than a radiant system or active chilled beams
- Perforated ceiling tiles required underneath and adjacent to the chilled beam
- Cannot be installed up against the slab
- Room temperature not as tightly controlled as active chilled beams

Best applications for passive chilled beams

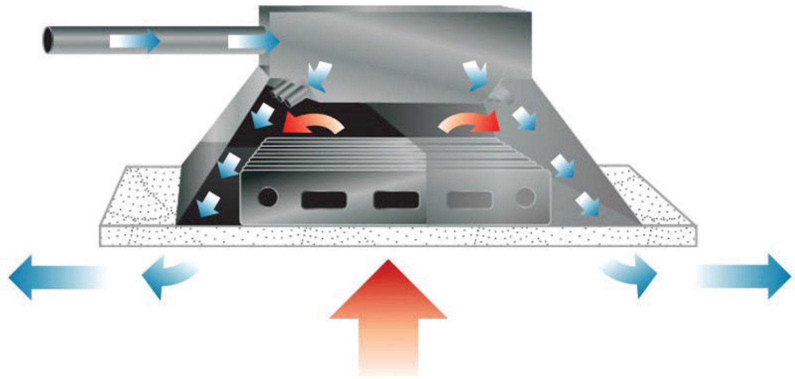
- Offices
- Call centers
- Buildings without suspended ceilings
- Perimeter applications with high sensible loads
- When combined with an underfloor air distribution system (UFAD), the UFAD airflow requirements can be reduced by more than half by moving most of the cooling load onto the passive chilled beams

ACTIVE CHILLED BEAMS

Active chilled beams use a combination of air and water to cool and heat the space. Air from a central air handling unit is ducted to the active chilled beams, which pressurizes a plenum fitted with aerodynamically designed discharge nozzles. High velocity air jets induce room air over the water coil integral to the unit and send the mixture of room and fresh air into the space through integral slots.

This forced induction dramatically improves the cooling capacity over passive chilled beams and radiant cooling panels, and also allows the coils to provide space heating in moderate climates.

Active chilled beams typically utilize a constant volume flow of air into the space while the water flow rate through the coil regulates the cooling or heating output. The primary air delivery can also be modulated in response to space occupancy when demand control ventilation (DCV) is used.



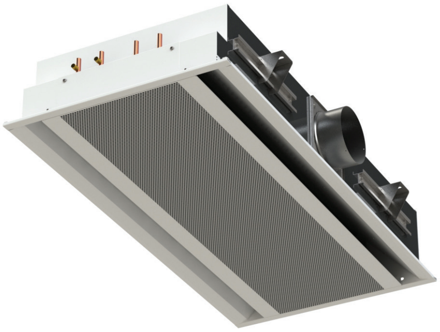
Active chilled beam operational principle. Room air is induced at a rate of around 3–4 parts for every 1 part of primary air.

Like radiant cooling panels and passive chilled beams, active chilled beams also utilize medium temperature chilled water but are significantly more resilient to condensation formation, so the chilled water temperature can be safely set at the room dew point temperature.

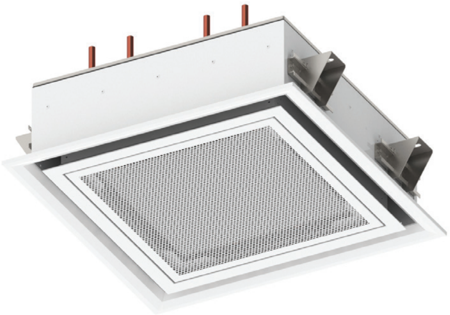
The fact that active chilled beams combine ventilation air delivery, cooling and heating in a single unit means their overall system install cost is lower than passive chilled beams and radiant cooling panels. Their cooling output is over double that of a passive chilled beam for a given length, so typically around half the number of units will be required on a project. They are also highly compact, so are ideal for renovating buildings that have low slab-to-slab heights and can be installed into ceiling interstitial spaces as small as 10–12" deep.

However, while active chilled beams offer several advantages, there are a few issues which should be considered. They may require more primary air than the ventilation and dehumidification airflow rates in the perimeter zones where the sensible loads are high. The primary air essentially “powers” the active chilled beam, so the flow rate adversely affects the heating and cooling capacity. It is not uncommon to see active chilled beams sized with around twice the ventilation airflow rate in perimeter locations. Engineers have addressed this issue by either designing the air handling units with a 50/50 mix of fresh/recirculated primary air or by using true DOAS units and delivering the primary air to the perimeter beams through one VAV box per façade, so the system controls can reduce the primary airflow rates during partial load conditions.

Active chilled beams are manufactured in several styles to suit various ceiling types and architectural tastes.



CBAL-24 linear active chilled beam, 24" wide



CBAM 4-way throw active chilled beam, 24" x 24"

CBAL-12 slimline linear active chilled beam, 12" wide

Integrated service beams incorporate lighting or other building services into their design, which cleans up the appearance of open ceiling applications.

VENTUS LUX integrated service beams with incorporated LED lighting

Floor-mounted active chilled beams deliver the supply air to the space in a displacement fashion at low velocity across the floor. IAQ is improved over ceiling-mounted active chilled beams as room air contaminants are allowed to rise out of the breathing zone instead of being mixed and diluted.

Floor-mounted active chilled beam

Titus CBAL-24 active chilled beams installed in Steinbach School, Manitoba

Advantages of active chilled beams

- Combined ventilation, heating, and cooling in a single unit
- High cooling and heating capacity
- Requires less ceiling interstitial space than passive chilled beams
- Lower first cost than radiant cooling panels and passive chilled beams
- No moving parts apart from control valves
- Fits into a standard suspended ceiling grid

Limitations of active chilled beams

- Perimeter zones may require more air than the latent and ventilation rate to drive room air induction across the coil
- Central air handlers must be run for night setback heating
- Difficult to relocate if the building layout changes and partition walls are moved

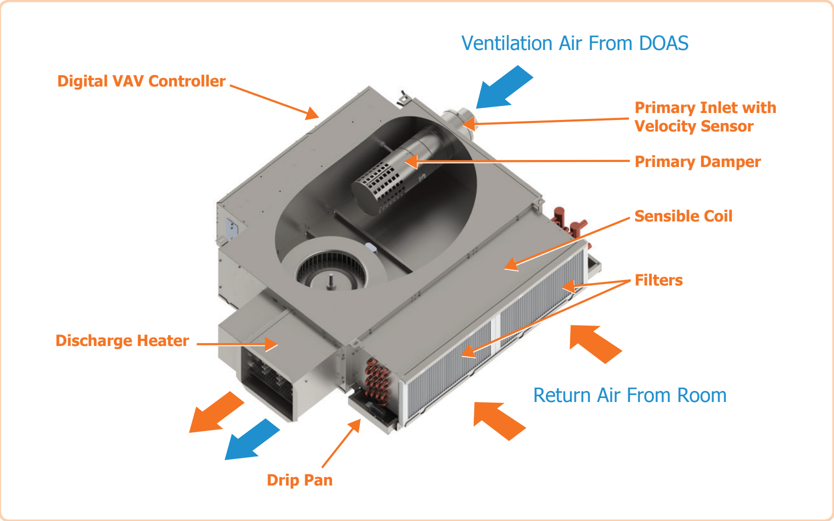
Best applications for active chilled beams

- Educational facilities
- Laboratories, especially those with high sensible loads
- Offices
- Buildings with low slab-to-slab heights
- Eliminates reheat in high ventilation applications such as hospitals

SERIES FAN BOXES WITH SENSIBLE COOLING

The basic concept behind series fan boxes with sensible cooling (SFSC) is not new. Sometimes referred to as DOAS boxes, they are a modified version of a standard series fan VAV terminal unit and have been used in buildings in North America for decades. Series fan boxes consist of a forward curved centrifugal fan, VAV air damper with cross-flow air sensor, a room air induction port and digital controls. The SFSC variant includes the addition of a large sensible cooling/heating coil fitted to the induction port. This sensible coil is supplied with chilled water at or above the room dew point temperature and is designed to operate dry. A drip tray can be installed underneath the coil to catch condensate that may occasionally form when the room humidity exceeds the design conditions due to open windows or other temporary uncontrolled infiltration situations.

Unlike parallel VAV fan boxes, a series fan box will run the fan continuously when the space is occupied, varying the speed in response to space heating, cooling, and ventilation demands. Room air is drawn through the induction port and mixed with primary air ducted from the central air handling units before being delivered to the space via conventional ceiling diffusers. Since the integral fans are powered by electrically commutated (EC) motors, SFSC boxes are particularly efficient at low fan speeds where the box will operate most of the time.



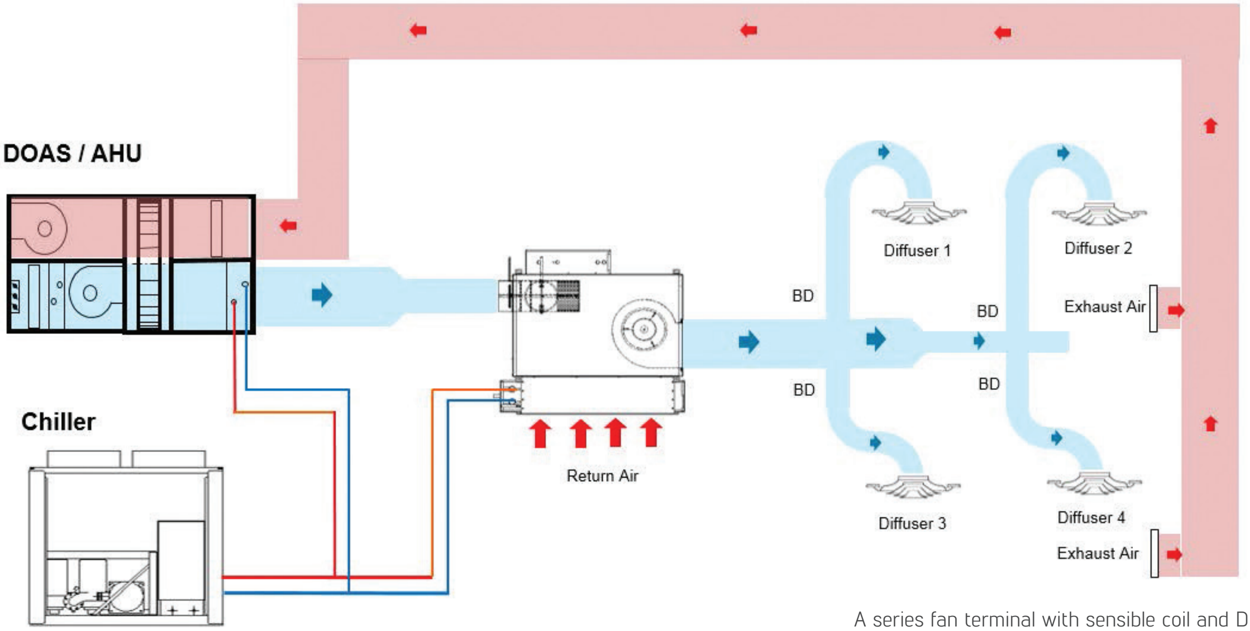
Cutaway illustration showing the main components of a series fan box with sensible cooling system

The primary air system is sized for the ventilation and building latent loads only, while the space heating and cooling loads are handled by the SFSC terminal unit. The SFSC system can be thought of as a hybrid of a fan-powered VAV and active chilled beam system, taking the best features of both; however, there are some disadvantages over other decoupled cooling systems, including increased noise, added zone fan energy, and additional maintenance due to fans being installed above the ceiling.

Variable occupancy zones such as meeting or conference rooms which are designed with demand control ventilation are ideal applications for SFSC due to the integral primary air VAV controller. Controlled by CO_2 sensors, the VAV unit can precisely ventilate the space independently of the space cooling and heating loads.

SFSC can also be used in a chilled beam system for zones that may experience occasional uncontrolled infiltration, such as atria and lobbies, where beams may not be suitable due to potential condensation issues.

Overall, an SFSC has certain advantages over chilled beams and few drawbacks. It is ideally suited to office buildings, particularly for perimeter zones as slightly less primary air is required than active chilled beams. For owners who do not want chilled beams due to concerns about condensation or appearance, SFSC can be a viable alternative.



A series fan terminal with sensible coil and DOAS

Advantages of series fan boxes with sensible cooling

- Night setback heating and cooling possible without DOAS operation
- Electric heat option available
- Potentially reduced pipework compared to chilled beams
- Requires less ceiling surface space than chilled beams
- Air is delivered through diffusers, so more aesthetic choices are available
- Office applications may require less primary air than active chilled beams
- Easy to relocate diffusers if office partition layout changes

Limitations of series fan boxes with sensible cooling

- Ceiling tiles must be removed for fan maintenance access
- System requires more interstitial depth than active chilled beams or radiant cooling panels
- Higher noise levels than chilled beams or radiant cooling panels, although this can provide sound masking for open-plan office spaces
- Unsuitable for applications where return air ceiling plenums are not viable
- Expensive for buildings where every space requires thermal control; e.g., small perimeter offices each with a thermostat
- Large ductwork downstream of SFSC box
- System requires custom controls

Best applications for series fan boxes with sensible cooling

- Offices
- Complements interior zone active chilled beams in perimeter spaces where the air handling unit is to remain off during nights and weekends
- Atria
- Lobbies

COMPARING EXAMPLE LAYOUTS OF APPLICATIONS

Using a simplified floor plate of an open-plan office building, the unit quantity, primary airflow, and water flow rate requirements can be compared for each system.

When comparing these example layouts, it should be noted that the actual thermal zoning and floor plan layout of a space will ultimately dictate the quantity of chilled beams or terminal units required for each system.

These layouts can be used as an approximate guide to compare the performance and potential cost of each system.

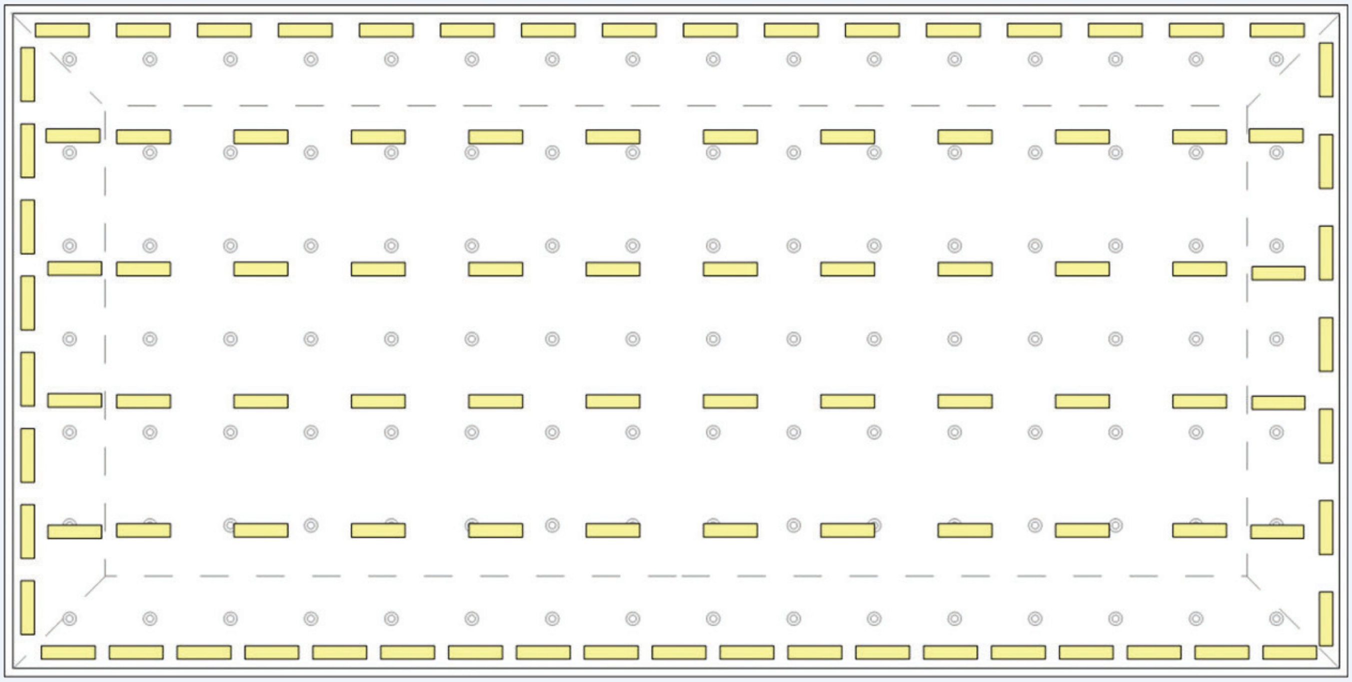
Radiant cooling has been excluded from this comparison since its low cooling capacity precludes it from consideration for most mainstream applications.

Elevation	Area	Sensible Cooling Load	Latent Cooling Load	Heating Load	Occupancy	Minimum Ventilation
North	2760 ft^2	25 BTU/h·ft^2	3 BTU/h·ft^2	9 BTU/h·ft^2	22	276 CFM
East	1260 ft^2	35 BTU/h·ft^2	3 BTU/h·ft^2	12 BTU/h·ft^2	10	126 CFM
South	2760 ft^2	30 BTU/h·ft^2	3 BTU/h·ft^2	11 BTU/h·ft^2	22	276 CFM
West	1260 ft^2	40 BTU/h·ft^2	3 BTU/h·ft^2	10 BTU/h·ft^2	10	126 CFM
Interior	11900 ft^2	12 BTU/h·ft^2	2 BTU/h·ft^2	N/A	95	1189 CFM

Size of example floor plan used in all comparisons

Passive Chilled Beams + Underfloor Air Distribution

Passive chilled beams combined with an underfloor air distribution (UFAD) system are a good solution for open-plan offices and call centers. This system can easily be reconfigured when the office layout is changed. Partition walls can be repositioned anywhere, even directly under the passive chilled beams. Floor outlets are also easily moved or added by simply relocating floor tiles. In this example, the heating load is addressed with the use of a UFAD perimeter diffuser incorporating finned tube heating coils.

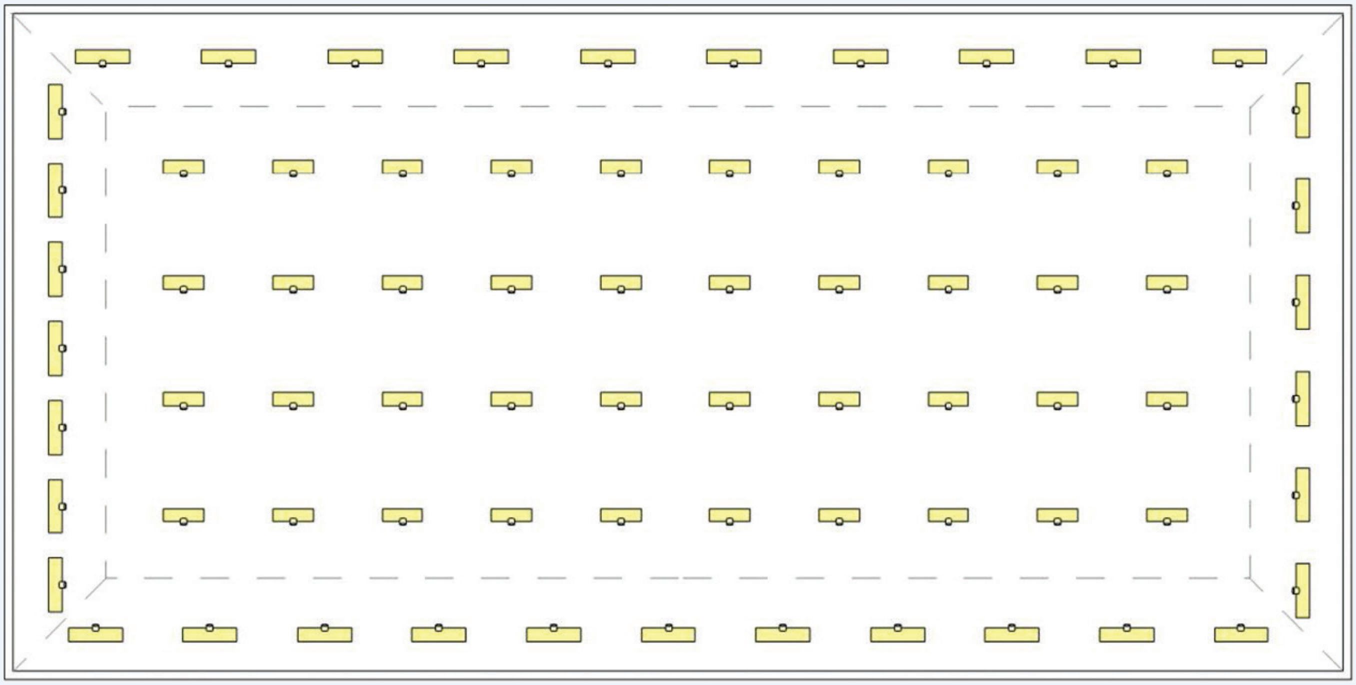


Summary

- 98 chilled beams
- 2574 CFM primary air
- 147 GPM chilled water
- 21 GPM hot water

Active Chilled Beams

The interior zone chilled beam density is being dictated by air distribution requirement. The active chilled beams also serve as diffusers, so to ensure the ventilation air is thrown far enough into the space a minimum density of around one active chilled beam per 300 ft^2 is recommended. The perimeter zone beams are selected based on load, so the beam count is around half of the passive chilled beam layout. Note that this design requires more than the ventilation and dehumidification airflow rates to drive induction through the beam coils. All of this additional air is being supplied to the perimeter beams.

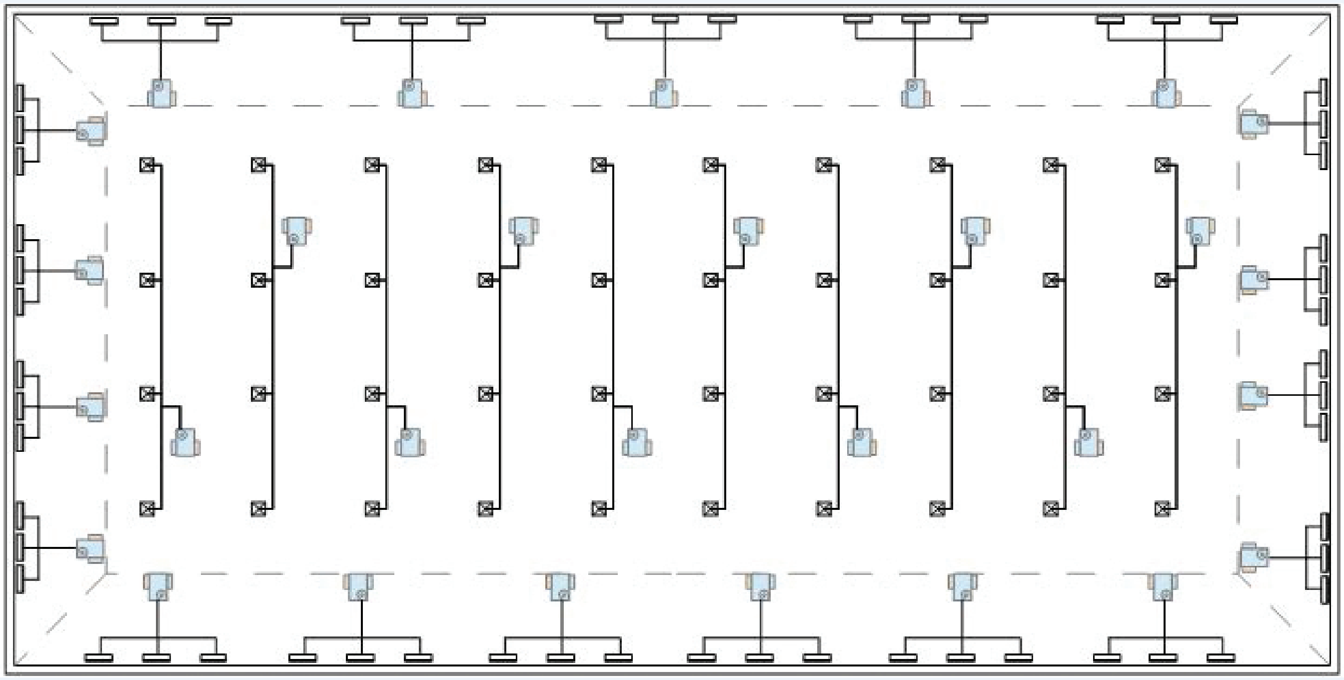


Summary

- 74 chilled beams
- 4070 CFM primary air
- 119 GPM chilled water
- 17 GPM hot water

Series Fan Boxes with Sensible Cooling

The SFSC box quantity is based on cooling/heating loads and acceptable noise levels. The SFSC boxes for this layout were selected for a maximum noise level of NC35. Although this layout requires considerably less pipework than either of the chilled beam options, each fan terminal requires a high voltage power connection, diffusers and additional ductwork downstream of the boxes, so overall first cost may be higher than the active chilled beam layout.

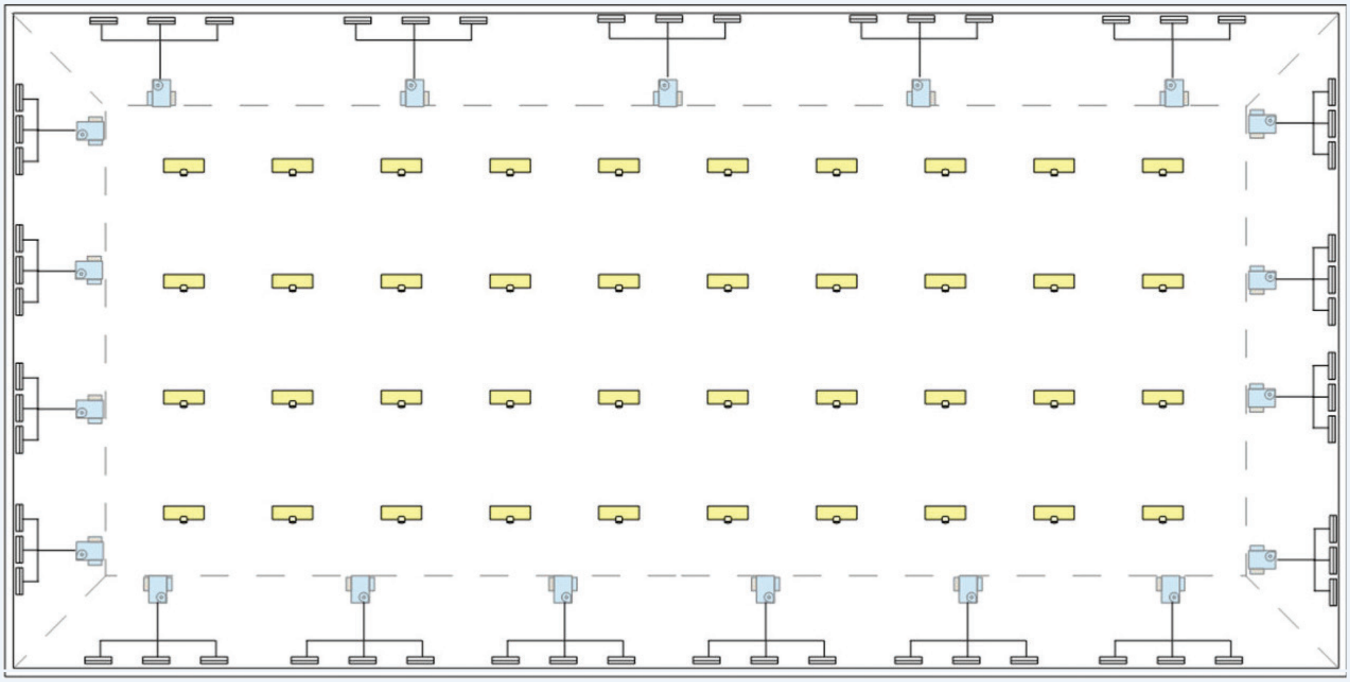


Summary

- 29 fan terminals
- 2574 CFM primary air
- 116 GPM chilled water
- 9.5 GPM hot water

Active Chilled Beams and Series Fan Boxes with Sensible Cooling Hybrid

This hybrid layout utilizes active chilled beams in the interior zone and series fan boxes with sensible cooling for the perimeter. Due to the low sensible loads, the interior chilled beams can be selected with small high-induction nozzles that will provide enough sensible cooling when supplied only with the ventilation and dehumidification airflow rates. The SFSC boxes on the perimeter allow the DOAS unit to be shut down when the building is unoccupied for setback heating and cooling.



Summary

- 40 chilled beams
- 19 fan terminals
- 2636 CFM primary air
- 116 GPM chilled water
- 9.5 GPM hot water

CONCLUSIONS

All of these decoupled sensible cooling systems are viable HVAC solutions for applications in many buildings in North America. Each has their own unique advantages for different building types, applications, and climates.

Radiant Cooling Panels

While radiant cooling offers unparalleled thermal comfort and exceptional energy performance, its high cost, limited cooling capacity, and ceiling service coordination challenges have limited its use in buildings in warmer climates. However, a number of large-scale installations have proven successful.

Passive Chilled Beams

Product pricing has been significantly reduced in recent years, as more vendors are manufacturing passive chilled beams domestically versus importing them from European suppliers. Installation costs have also dropped as contractors have gained more experience. However, not all applications are suitable for passive chilled beams, since they require a relatively deep ceiling interstitial and separate perimeter heating system. Plus, the building owner must accept that zone temperature may not be as tightly controlled as other systems.

Active Chilled Beams

This is the most commonly used decoupled sensible cooling system in North America today, and for good reasons. Active chilled beams have the lowest installation cost, highest cooling/heating capacity, and are quite compact. They can cope with variations in room humidity that may occasionally occur in rooms with operable windows or in entrance lobbies. There is also the option to specify drip trays in situations when limited condensation may be a concern for these types of applications.

The most notable drawbacks for active chilled beams are architectural ceiling impact and comparatively high primary airflow rates on the perimeter. With that being said, active chilled beams still have fewer drawbacks compared to other systems.

Series Fan Boxes with Sensible Cooling

Since series fan boxes with sensible cooling is the newest of the decoupled sensible cooling options, there are few case studies comparing its energy performance to other systems. However, most SFSC boxes employ fans with EC motors which are proven to be energy efficient, so when combined with a chiller dedicated to producing tempered chilled water, an SFSC system should offer improved energy performance over traditional VAV reheat.

Series fan boxes with sensible cooling offers some advantages over chilled beams in office applications, especially those with frequent churn, as it is far easier to relocate the diffusers. For many applications, however, the first cost is likely to be higher than chilled beams, especially for buildings where the owner requires user-accessible thermal controls in every room.

Better Options for Your Next Project

Whether your application calls for radiant cooling panels, passive chilled beams, active chilled beams, or series fan boxes with sensible cooling, any of these decoupled sensible cooling systems, when combined with a dedicated outdoor air system, can be a more efficient choice than traditional VAV systems.