



A REASONABLE ALTERNATIVE TO CHILLED BEAMS

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The DOAS Fan Powered Terminal Unit

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ASHRAE is advocating that energy use in buildings be reduced 30% below that from employing the base system outlined in Standard 90.1. That base system is the traditional VAV, distributed by well mixed diffusers located in the ceiling. It follows that engineers are considering alternate systems for conditioning occupied spaces. This has led to the development and installation of Under Floor Air Distribution (UFAD), Displacement Ventilation (DV) and Chilled Beam (CB) systems.

Much has been written of late about Chilled Beams. This follows from the chilled ceilings seen in Europe a decade ago. In practice, both are a form of supplying sensible cooling at the ceiling in the form of radiation and convection devices. Increases in required quantities of outdoor air are causing engineers to consider the use of Dedicated Outdoor Air Systems (DOAS) to meet both ventilation and humidity requirements in buildings. With these systems, the quantity of outdoor air typically is kept at a minimum to control building energy consumption. Many of these DOAS concepts are also suggesting that Displacement Ventilation be the means of air delivery.

Displacement Ventilation (DV) is horizontally supplied air, at the floor level, which is drawn to localized heat loads by vertical convection. In most cases, the need for supplemental cooling arises from the limitations inherent in displacement ventilation systems. DV can be no colder than 65°F, or occupants complain of cold feet. Velocities cannot be too great, or they complain of drafts. As a result, air quantities at each outlet are limited. But ASHRAE Standard 62.1 recognizes that Displacement Ventilation often results in high levels of Air Change effectiveness, as it is injected into the breathing zone, reducing the probability of short circuiting back to a ceiling return. As a result, DV systems may use as much as 25% less outside air in meeting the minimum requirements of the standard.

The ASHRAE IAQ Standard (62.1 2007) also prescribes a building RH not greater than 65%, which is a wet bulb temperature of about 55°F. This means that the leaving air temperature of the cooling / dehumidifying coil in the outside air unit must be supplied at a temperature no warmer than 55°F. If one looks at the minimum ventilation rates of Standard 62.1, one can see that if delivered at about 55°F, these air quantities can handle both the latent and sensible loads of most office building occupants. However for comfort reasons, DV systems, cannot deliver air any cooler than 65°F. Instead return air is mixed with 55°F dry air, to raise the temperature to 65°F, resulting in mixed air quantities twice that required by the ventilation standard alone. There are also other design parameters to consider; additional space loads. While the additional space loads are getting lower all the time, they must be handled. With DV systems a means must often be created to handle any additional space loads.

If DOAS is added as a supplementary system, with 100% recirculated air provided by conventional systems, at the ceiling, the resulting conflict between two air distribution systems can result in drafts and poor temperature control in the space. Some systems which have been successfully employed in schools for adding ventilation air utilize downblow nozzles located along interior walls injecting room temperature ventilation towards the floor. This technique is probably not suitable for open plan offices, however.

Enter Chilled Beams:

A chilled beam is a device which provides sensible cooling at the ceiling. An active unit will use pressurized air from an air handler to induce air across a non-condensing cooling coil, which is then introduced into the room. Due to negative buoyancy, this air falls into the space. Some active beams may have sufficient velocity to achieve limited horizontal throw along a ceiling surface. Active beams employ air which typically comes from a DOAS air handler, and are designed to handle all latent loads. Active beams typically do not qualify for a reduction in ventilation air as DV systems do. A passive beam, however, relies on the convective effect of a cool surface to move air, and can seldom achieve a horizontal air pattern. Passive beams also require a second system to provide ventilation air and handle latent loads, which is typically provided by a DV system. Both systems must be located in the immediate vicinity of the load.

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The installation requires, at a minimum, cold water piping to every control zone. In a closed office space, this means every room. Some systems also have a heating coil, with either a three or 4 pipe system (note: heating with passive ceiling beams is not likely to be effective, and is questionable with most active beam designs). Some designs include lighting in the chilled beam device, requiring electrical connections as well.

When coupled with a DV system, sensible and latent loads can be managed, at low room velocities, and importantly, in schools, very low sound levels. A number of projects using both active and passive chilled beams are successfully operating in Europe, as well as a few in the US. An active beam typically uses about 40cfm of supply air, and delivers the equivalent of 100cfm of cooling. Chilled beams only handle sensible cooling loads, and are reported to be especially economical in laboratories.

Chilled beam installations can be expensive and somewhat inflexible. The first cost can approach \$1000 or even more (the higher cost if active and/or lighting is included), not including installation. With any chilled ceiling designs, however, great care must be taken to assure that the surfaces do not go below local dew point temperature, or condensation will result. This can be disastrous, if these surfaces are located over delicate / expensive electrical equipment. As a result, several layers of humidity protection are typically installed, typically including condensation sensors on the coils. Even so, should the controls fail, the result can be catastrophic, with water falling throughout an office space.

Some DV projects have been successfully implemented without the need for Chilled Beams/ceilings, due to the low loads seen in many today's buildings. DV systems by themselves likely cannot provide effective means of heating a space. Low velocity air rises by convection, and stratifies at the ceiling. Likewise, ceiling located coils may be ineffective for heating, due to resulting stratification. Some alternate means of treating morning warm-up and perimeter skin losses in winter is probably required. There are claims that active chilled beams can handle heating demand, but there is little actual data is available to back up those claims. It is unlikely that these systems will comply with the Table 6.2, Standard 62.1 requirements for overhead heating, without additional ventilation air. Building envelopes are getting better all the time, but are not yet, at least, zero energy transfer membranes. In most cases, supplementary perimeter systems must be supplied except in very temperate climates which can further raise the first cost.

A solution from the past:

Beginning in the late 30's, and continuing through today, one of the first means of controlling humidity, ventilation and sensible loads in buildings was the use of high pressure induction terminals. Pioneered by Carrier, the Series 36 "Weathermaster" induction units were typically installed under a window and used high pressure, very cold (and therefore dry) air to induce 2-3 times the supply quantity of air, and direct it into a room. To handle supplemental sensible loads, a non-condensing cooling coil was provided. Although the coil was kept above the building dew point, a catch pan was provided to catch the occasional condensation (typically seen early in the morning, before the building had stabilized). Heating coils were also implemented, to provide required perimeter heat in the days of single pane glass.

Millions of square feet of office were, and still are, conditioned by these systems. The high pressures and somewhat noisy units, however, were often compromised by well intentioned building owners/operators who decrease pressure and raise supply temperatures in an (ill conceived) attempt to save energy, resulting in loss of humidity control, poor induction ratios, and giving the systems a bad name. Remember, however, that the control systems of the time were less complicated, and few problems were reported when systems were operated as designed. The failure mode of these devices, however, is non-catastrophic. At worst, a wet floor or carpet results if the coils go below building dew point.

These devices, however, are best suited for applications in perimeter zones. They also require very high (by today's standards) system air pressure. We have recently seen hybrid solutions proposed that utilize an induction principle coupled with integral supply diffusers for use in interior spaces. These designs will require at least an inch of inlet supply air pressure (likely closer to 2") to get significant induction and still

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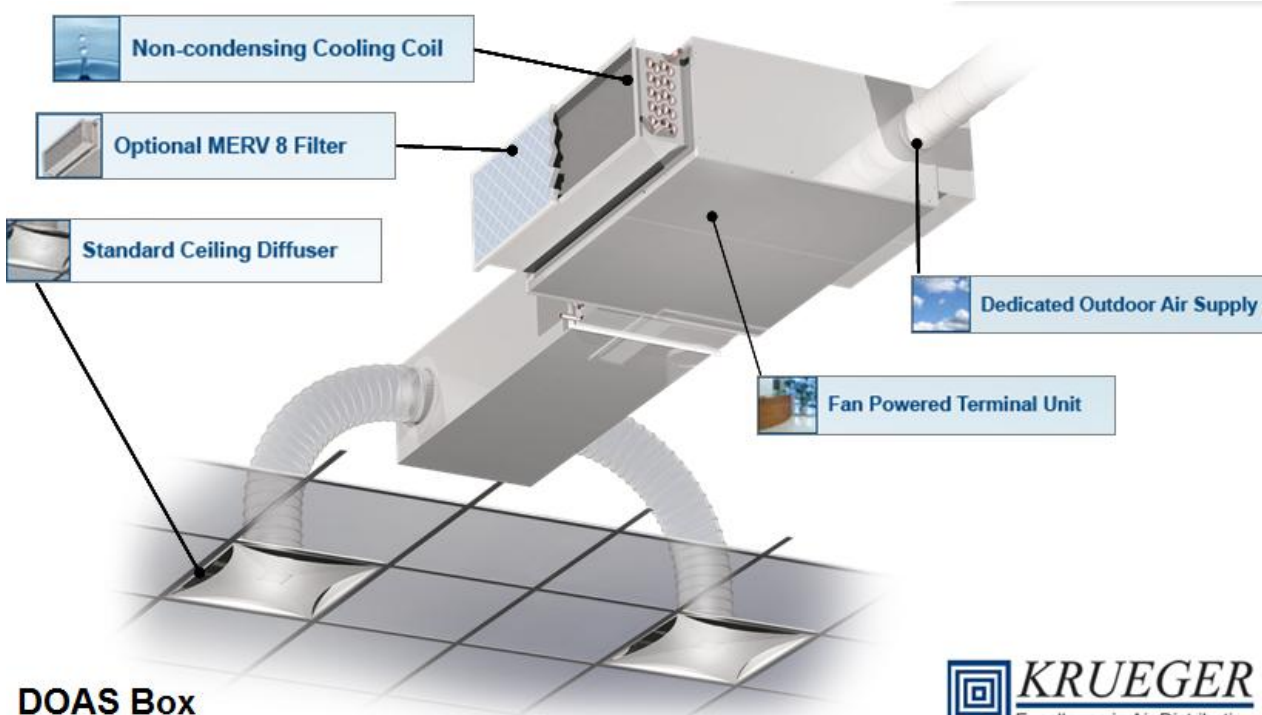
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overcome the outlet pressure of an integral slot diffuser. The same high static pressure issues that plagued the Carrier system will likely befall these systems, as owners reduce duct pressures to save energy without understanding the consequences.

Enter the DOAS Fan Powered Terminal Unit

It has been realized that the benefits of DOAS and the need for a non-condensing cooling coil to handle additional loads can be combined with modern systems of overhead air delivery. A properly sized non-condensing cooling coil, located on the induced inlet of a Fan Powered VAV Terminal Unit (either series or parallel type), with the primary air inlet sized for the zone ventilation requirements supplied from a DOAS unit, and with a heating coil in perimeter zones where required, can supply conditioned air at the required quantity, in a very flexible manner. Moreover, should there be a loss of humidity control in the building causing excessive condensation, the unit can be located in a non-critical area such as a hallway or closet and the failure mode will be non-catastrophic.

Air can be ducted by traditional means to several spaces from a single cold water / power / DOAS connection, greatly simplifying installation and flexibility (and thus providing for a more sustainable installation). The installing contractors and building maintenance personnel will be dealing with known technology. Conventional ceiling air distribution is then employed to distribute conditioned air to the space at a significantly lower zone cost, and with far greater flexibility.



DOAS Box

Options and Ideas

There are several design options to be considered to implement this system. Controls can be simplified through the use of a two position closed loop analog control for the primary (now ventilation) air valve. The "on" position will be tied to the fan relay in the unit, so it defaults to minimum ventilation settings whenever

the fan is activated. Additional optional ventilation settings can be activated by contact closures from the DDC system, a light switch, or other means. A standard DDC fan coil controller can be used to control the fan and cooling (and heating) water valves. It could also be used with electric heat. This allows a single unit to both heat and cool, and provide required ventilation air. Additionally, with the high capacity of the fan powered terminal unit, a single unit can feed several closed offices (which is not recommended, or even possible, with Active Chilled Beams).

Both Series and Parallel fan powered terminal unit designs can be considered. A series fan powered terminal unit has a minimum inlet pressure that is very low (about 0.1"), significantly lowering the primary (or DOAS) system pressure, compared to an induction system, and somewhat lower than a parallel box, which requires that the central system move air all the way through to the diffuser. ECM motors have the potential to further reduce fan energy. For this reason, a Series unit may be preferable to a Parallel unit.

Innovative control strategies can be employed to produce the best combination of air flows and discharge temperatures, with a broad array of diffuser styles to meet both comfort and aesthetic concerns. As mentioned before, a DDC Fan Coil controller and a self contained pressure independent DOAS air valve controller with up to 4 air flow settings (one would likely be 'off') set through contact closures and connection to the fan relay will provide an essentially off-the-shelf control package for this design. An analog input would allow any desired ventilation airflow setting, but likely adds control costs. Most importantly, with the emphasis on sustainable design, this concept provides a very flexible system which can be easily modified as space needs change. Finally, as VAV fan powered terminal units are in common use, both installation and maintenance will be familiar to all concerned.

While looking at the unit as an alternative to Active Chilled Beams, it may be also considered as a supplement to a chilled beam design, in perimeter zones. The ability to provide highly configurable heating coils and high velocity diffusers makes this a logical solution to the problems of heating with a chilled beam system.

Laboratory Systems

There have been a number of recent articles outlining the use of Active Chilled Beams in laboratories. In studying these applications, the advantages of the chilled beam include a decoupling of the pressure and load requirements in the laboratory. But there are shortcomings as well. At low flows, an induction nozzle will not induce very much air across a cooling coil. Additionally, it may be necessary to override the pressure needs to ensure adequate load control.

By locating a DOAS Fan terminal within the pressurized space (typically, having the room's walls extend above the ceiling to the deck above), it can easily provide the decoupled cooling and pressure control required in laboratories, without the issue of low induction at low pressure required flows.

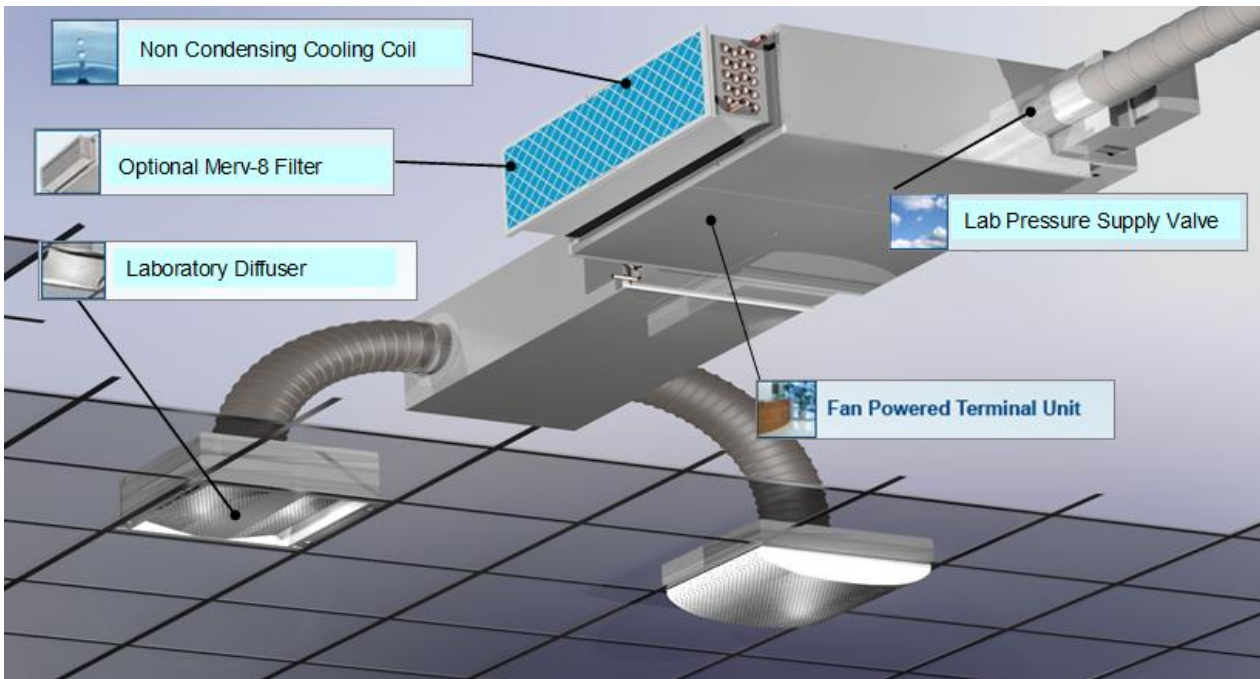
Additionally, the DOAS fan unit can be connected to proper laboratory-designed room air supply devices, such as the TAD and Radia-Flo. There is little data available to ensure that chilled beam units, when located in the proximity of a fume hood, will provide the safe air velocities or low room air currents needed to keep from entraining air from a hood. The DOAS terminal, fed with a laboratory pressure control air valve (such as Tec-Aire or Phoenix) attached to proper critical environment diffusers can safely supply the high air quantities often needed in laboratories.

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Summary

Active Chilled Beams are one option of providing either supplemental cooling when a DOAS/DV system doesn't handle the entire sensible load in a space, or active beams as the sole means of satisfying both sensible and latent loads. Active Chilled Beams, while providing a complete room cooling solution, tend to be complex and expensive. Neither the active nor passive Chilled Beam system is likely to provide heat in winter conditions without supplemental equipment. Active beams require significant supply air pressure to achieve significant room air induction.

But there is another way to achieve the same result in a much simpler and far less costly way. DOAS Series Fan Powered Terminals offer a real promise of sustainable, flexible year-round air delivery, at the lowest installed cost.

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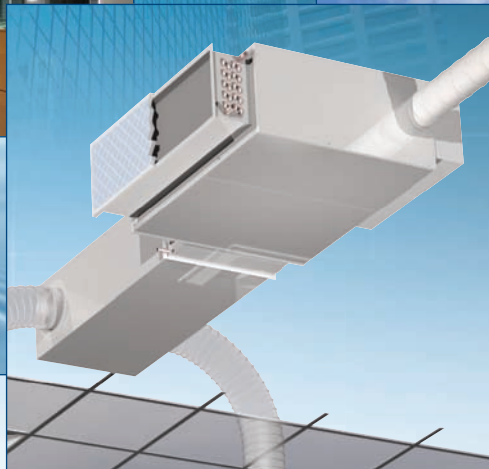
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Alternative Chilled Beam Solution DOAS VAV Terminal Unit

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Intelligent Design



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Energy Efficient



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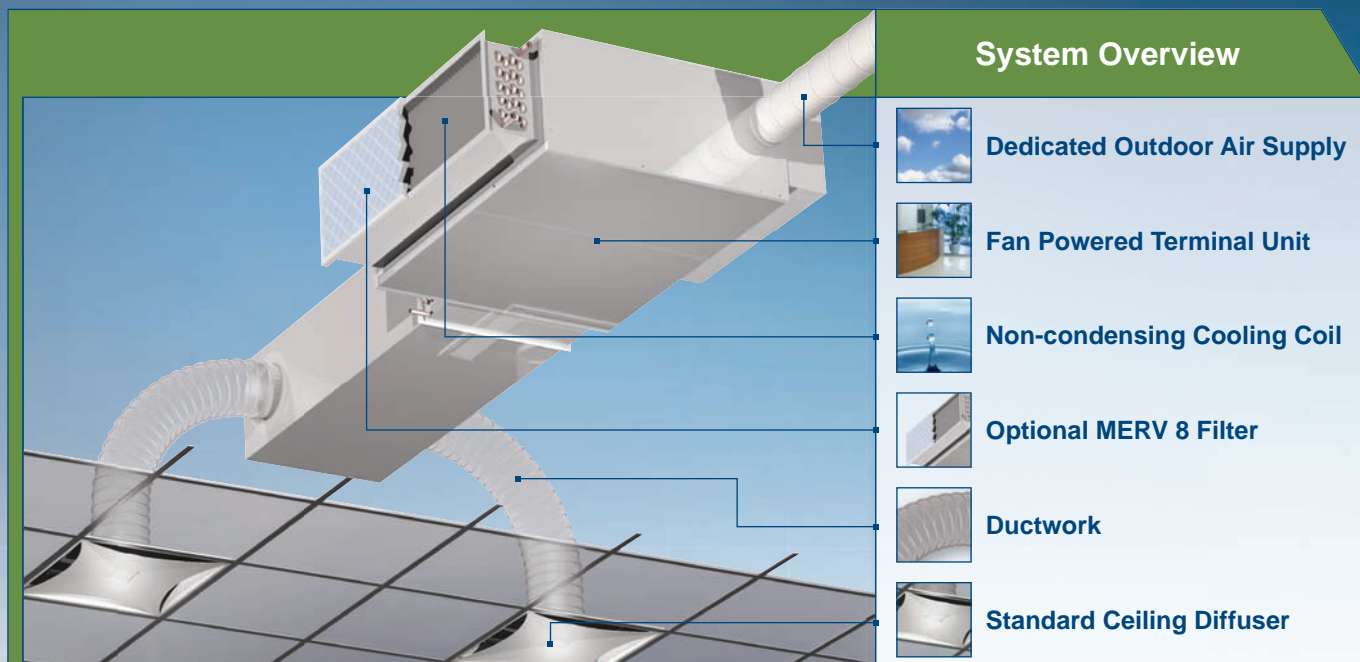
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Why to Consider DOAS

Most commercial buildings today utilize VAV systems. They are designed around a base air supply rate of 1 cfm/ft², at about 30% outdoor (ventilation) air, to meet ASHRAE IAQ Standard (62.1 2007). Analysis of actual loads, however, shows that the required air supply rate to meet space loads is far less, often approaching 0.4 cfm/ft². This combined with the air handler keeping the ventilation rate (outside air quantity) constant; the air supply rates are approaching 100% outside air.

The effective occupant ventilation rate is usually around 17 cfm/person. At a typical supply temperature of 55°F, this is often more cooling than required by a sedentary occupant. With reduced lighting and equipment loads in today's offices, the excess cooling capacity contained in the minimum ventilation air is often sufficient to supply much of the additional space loads. Therefore, it is not uncommon to see dedicated outdoor air handling systems (DOAS) being designed into many new buildings.

Krueger's DOAS Fan Powered Terminal Unit

The benefits of a DOAS air handler can be combined with a traditional system of overhead air delivery by adding a cooling coil to a series fan powered VAV terminal to provide the most cost effective, flexible design that still meets all the building requirements for conditioned air. When 100% outside air is employed, all return air is exhausted, including waste heat from lighting, further reducing the load required by the building's HVAC system.

The Krueger DOAS fan powered terminal unit uses a non-condensing cooling coil that is located on the induced air inlet of a series fan powered VAV terminal unit, with the primary air inlet sized for the zone ventilation requirements supplied from the DOAS unit. Air can be ducted by traditional means to several spaces from a single cold water / power / DOAS connection. This design not only offers lower zone costs and simplifies installation, but it adapts well to any build-

ing changes that may occur. If required, an optional heating coil can be added in perimeter zones.

An added benefit to Krueger's DOAS fan powered terminal unit is that both contractors and building maintenance personnel will experience comfort by working with known technology, such as terminal units, standard ducting, and conventional overhead air distribution.

In summary, Krueger's DOAS fan powered terminal unit offers the lowest total cost, most flexible solution that provides both ventilation and comfort to the modern building applications.

Features & Benefits

Easily Applied to a Chilled Beam Specification

Krueger's DOAS fan powered terminal unit uses the same primary pipes and ducting as a Chilled Beam system.

Minimum Static Pressure (Ps) Requirements

Active Chilled beams use induction nozzles to move air across the cooling coils, often requiring 1" Ps or more. The DOAS fan powered terminal unit has minimal inlet pressure requirements, less than 0.1" Ps.

Assures Minimum Ventilation Rates

By providing up to 4 settings of ventilation air utilizing a self contained pressure independent air volume controller, The DOAS fan powered terminal unit assures the proper amount of ventilation air at all times.

Earn "Green"/LEED Points

Using Krueger's DOAS unit will earn you "green" points by its flexible design. Whether the occupant space expands or changes, the system can easily adapt.

Optional MERV 8 Filter

Earn a LEED point for providing the optional MERV 8 filter on the non-condensing cooling coil.

Lower First-Cost Compared to Chilled Beams

A Chilled Beam unit is installed over every occupied space, often costing several times what a ducted DOAS fan powered terminal unit will cost, with a single unit supplying several areas.

Energy Efficiency

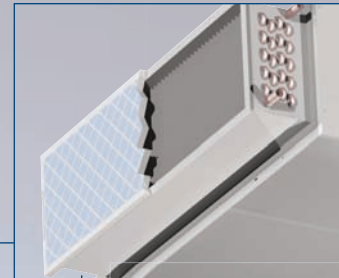
ECM motors are available for optimum energy use and control.

Optional Reheat Capabilities

Optional hot water or electric heating allows for effective standard overhead heating eliminating the need for a secondary system.

Conventional Installation

Using standard diffusers, contractors will be able to install the complete system with no training or difficulty.



Energy Savings

ASHRAE advocates reducing energy use in buildings 30% below the base system currently outlined in Standard 90.1. This base system is a traditional VAV system distributed by well mixed diffusers located in the ceiling. To meet this potential new standard, engineers are considering alternate systems for conditioning occupied spaces. This has led to the development and installation of Under Floor Air Distribution (UFAD), Displacement Ventilation (DV) and Chilled Beam (CB) systems. The DOAS fan powered terminal unit has characteristics that may make it a better solution than these other systems. Krueger's DOAS fan powered terminal unit features an ECM motor which has the potential to reduce fan energy. Even better, it also has a minimum inlet pressure that is very low (about 0.1"). These mentioned features will significantly lower the DOAS total system pressure and provide more savings for the building owner when compared to other existing technologies.

DOAS vs. Chilled Beams

There are two types of chilled beams, active and passive, both of which are designed to provide sensible cooling at the ceiling. An active unit will use ventilation air from an air handler (usually a DOAS unit) to induce air across a non-condensing cooling coil, which is then introduced into the room. A passive beam, however, relies on the convective effect of a cool surface to move air, and can seldom achieve a horizontal air pattern. Passive beams require a second system to provide ventilation air and handle latent loads, typically provided by a DV system. Both must be located in the immediate vicinity of the load.

Chilled Beam installations can be expensive, and somewhat inflexible. The first cost is somewhere between \$1000 and \$1600 per unit (the higher cost if active and/or lighting is included), not including installation, for about 300 square feet. The units have to be installed in specific locations to maximize capacity. Krue-

ger's DOAS fan powered terminal unit, at a much lower cost, will handle several times the square area. It can be installed in multiple locations and is easily reconfigured by simply relocating diffusers.

With claims that active chilled beams can handle heating demand, there is little supporting data. It is unlikely that these systems will comply with the Table 6.2, Standard 62.1 requirements for overhead heating without additional ventilation air. In most cases, supplementary perimeter systems must exist, except in temperate climates along with active chilled beam systems.

Krueger's DOAS fan powered terminal unit, however, can easily be configured to handle any type of perimeter load while fully complying with the ASHRAE overhead heating requirements; without the need for a secondary system.

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