AN ALTERNATIVE/SUPPLEMENT TO CHILLED BEAMS

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The DOAS Fan Powered Terminal Unit

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 over a decade ago. In practice, a CB system is a form of supplying sensible cooling at the ceiling in the form of radiation and/or 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. Typically, 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. With passive beams, negative buoyancy causes air cooled by the coil to fall into the space. 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. Passive beams require a second system to provide ventilation air and handle latent loads, which is typically provided by a DV or UFAD system. Both systems must be located in the immediate vicinity of the load.

The installation requires, at a minimum, cool 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, but is possible with most active beam designs if the perimeter wall has low loading). 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 in the US. Chilled beams only handle sensible cooling loads, and are reported to be especially economical in laboratories (provided the laboratories are constant volume spaces).

Chilled beam installations can be expensive. 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, in addition to several layers of humidity protection including condensation sensors on the coils, the building must have excellent infiltration control construction.

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, however. 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. Active chilled beams can be designed to handle heating demand, provided the demand is low. 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 most designs and climates require supplementary perimeter systems which can further raise the first cost.

A solution from the past:

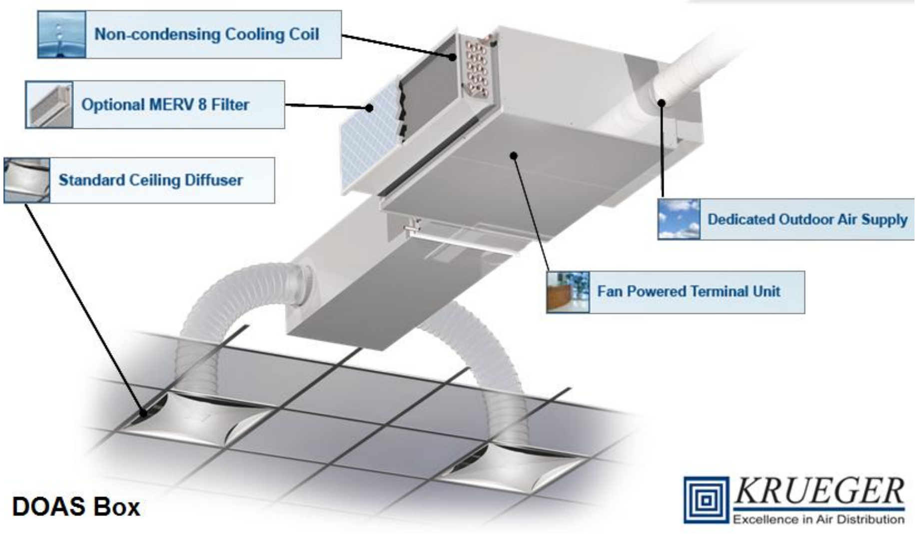
Beginning in the late 30's, and continuing through today, one of the first means of controlling humidity, ventilation and sensible loads in buildings was the use of high pressure induction terminals. Pioneered by Carrier, the Series 36 "Weathermaster" induction units were typically installed under a 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.

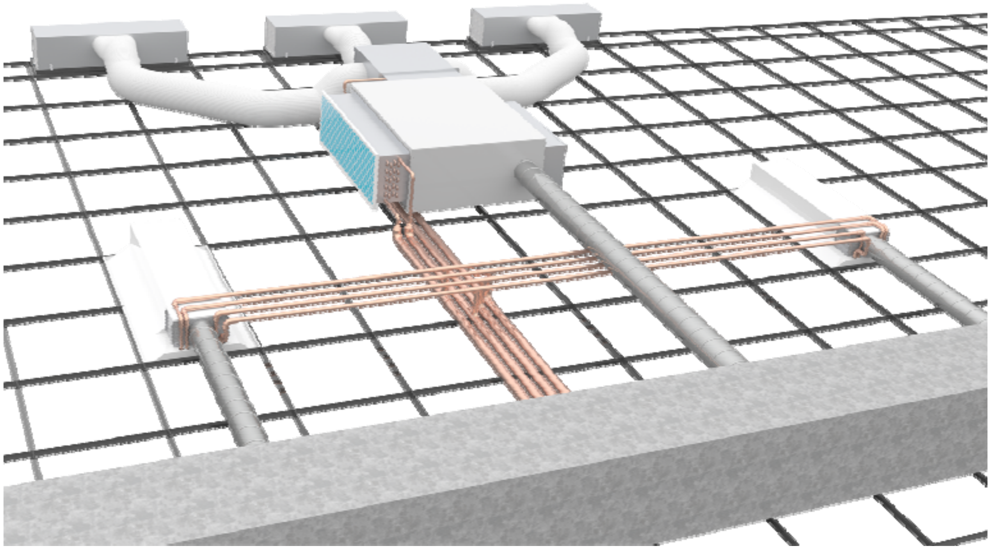
These devices, however, are best suited, and typically installed, for applications in perimeter zones. They also require very high (by today's standards) system air pressure. We have recently seen hybrid solutions proposed that utilize an induction principle coupled with integral supply diffusers for 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 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.



Perimeter zones in colder climates are a challenge to the external pressure limitations inherent in a chilled beam, but easily managed with a fan terminal:



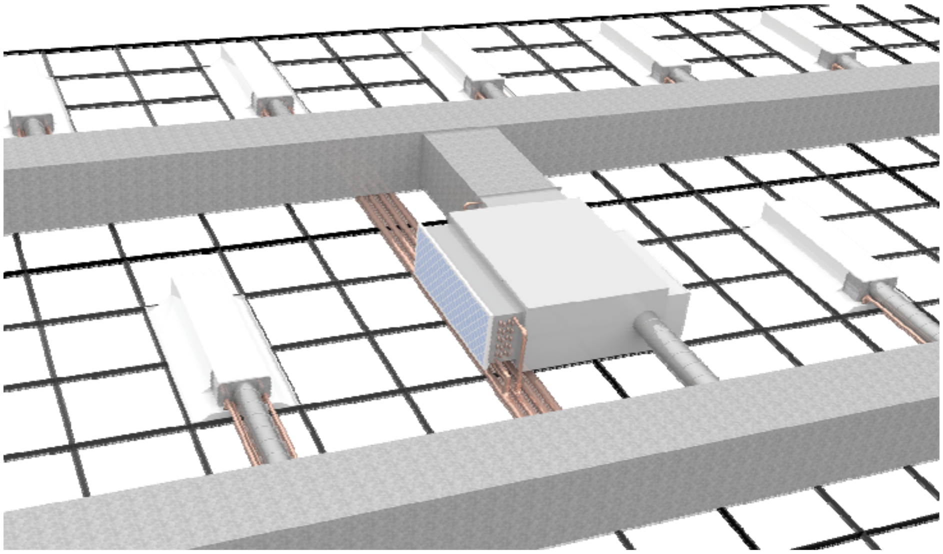
Air can be ducted by traditional means to several spaces from a single cold water / power / DOAS connection, greatly simplifying installation and flexibility (and thus providing for a more sustainable installation). The installing contractors and building maintenance personnel will be dealing with known 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.

Options and Ideas

There are several design options to be considered to implement this system. Control is simplified through the use of a two (or more) position pressure independent analog control for the primary (now ventilation) air valve. The "on" position is 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 is used to control the fan and cooling (and heating) water valves. It can 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.

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 (except in laboratories – see below).

On the other hand it may be practical to use a parallel Fan Box to supply a few chilled beams. This would allow the chilled beams in a small area to be operated when the main air handler is off. During normal operation, the parallel fan would be inoperative and the system air would pass through the unit to the beams.



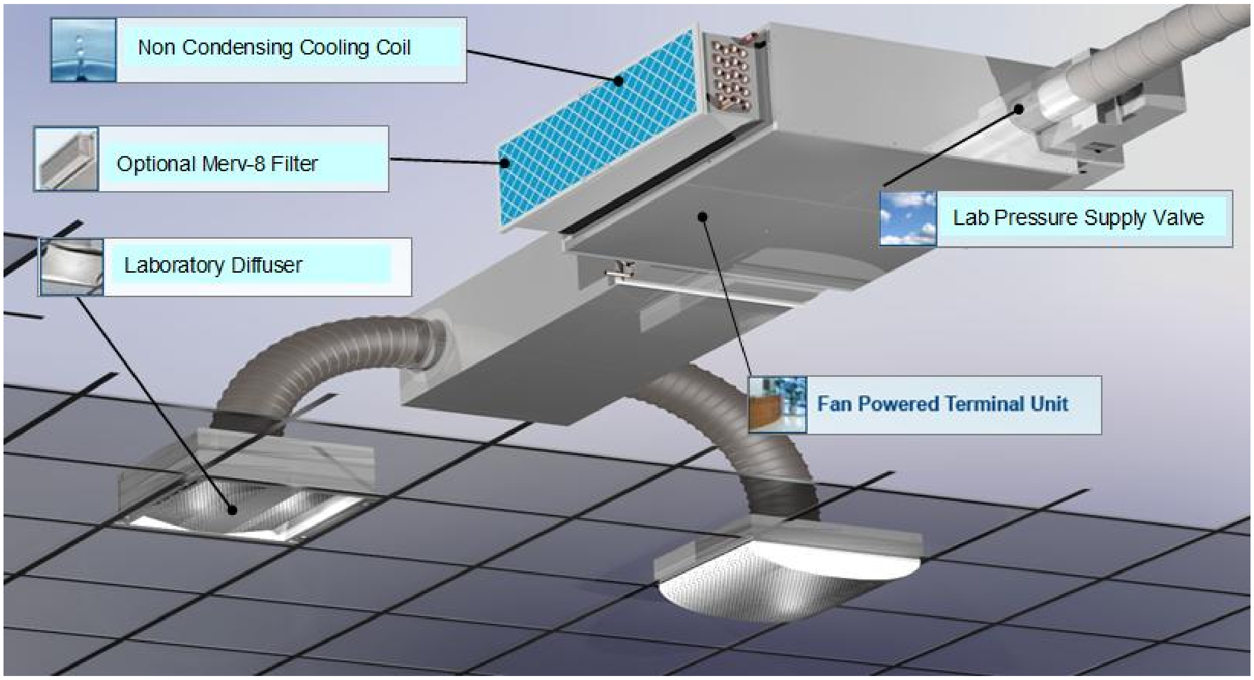
Innovative control strategies can be employed to produce the best combination of air flows and discharge temperatures, with a broad array of diffuser styles to meet both comfort and aesthetic concerns, especially in perimeter areas. As mentioned before, a DDC Fan Coil controller and a self contained 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.

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. Chilled Beams cannot, however, be expected to operate well with the VAV airflow required in fume hood laboratories. In addition, the horizontal air patterns provided by chilled beams may create excessive air velocities at the face of fume hoods.

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.

A Parallel DOAS fan terminal design, with the ECM Fan motor programmed to operate only when additional cooling is required, has been considered as a more efficient alternative, and will be available soon as a standard design option for the DOAS unit.



Most importantly, the DOAS fan unit can be connected to proper laboratory-designed room air supply devices, such as the TAD and Radia-Flo. 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 equipped with VAV fume hoods.

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. Neither the active nor passive Chilled Beam system is likely to provide heat in winter conditions without supplemental heating equipment at the perimeter. A DOAS Fan terminal, used in conjunction with Chilled beams in the interior, will provide a full solution to ventilation and comfort control in a properly designed building.

It may be possible to get all the advantages of both non-condensing cooling coils and high ventilation rates without the use of chilled beams at all. The DOAS Series Fan Powered Terminal offers a promise of sustainable, flexible year-round air delivery, at the lowest installed cost.

With either alternative, the use of a DOAS Fan terminal can provide yet another solution to the complex design decisions facing the engineer today.